AIR PHOTO INTERPRETATION OF WETLANDS, NORTHERN CLAY SECTION, ONTARIO

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ABSTRACT

The hierarchical classification of Ontario wetlands proposed by Jeglum et al. (1974) is evaluated for the interpretability of the classification units from black and white air photos at the scale of 1:15,840. This evaluation is based on intensive field sampling, and air photo interpretation for 16 locations in the Northern Clay Section. It is suggested that the classification, based on vegetational physiognomy and dominance, is well suited to air photo interpretation, as the choice of the level to which interpretation will be carried can be adapted to the scale and type of photos available as well as the time and resources available for ground truthing. Interpretation to the level of formations and subformations is easiest. With minimal ground truthing it is possible to map to the next level--physiognomic groups--and with more intensive ground truthing to the levels of dominance or site type. It is recommended that wetland units at the level of formation and subformation--OPEN and TREED BOG, OPEN and TREED FEN, MARSH and SWAMP--be adopted and mapped in provincial forest inventory mapping programs.

RÉSUMÉ

La classification hiérarchique des terrains mouillés (marécageux) de l'Ontario proposée par Jeglum et coll. (1974) est évaluée quant à la façon d'interpréter les classes à partir de photos aériennes en noir et blanc selon l'échelle 1:15,840. Cette évaluation est fondée sur un échantillonnage intensif au sol et sur l'interprétation de photos aériennes en 16 endroits de la section des Argiles du Nord. Les auteurs suggèrent que la classification, fondée sur la physionomie végétative et la dominance, convient très bien à l'interprétation des photos aériennes, puisque le choix du niveau d'interprétation peut être adapté à l'échelle et au type de photos disponibles ainsi qu'au temps et aux ressources disponibles pour la vérification au sol. L'interprétation au niveau des formations et sous-formations est la plus facile. Moyennant une vérification minimale au sol, il est possible de cartographier jusqu'au niveau suivant--les groupes physionomiques--et moyennant une vérification au sol plus intensive, jusqu'aux niveaux de dominance ou du type de station. Les auteurs recommandent que les classes marécageuses au niveau de la formation et de la sous-formation--les TOURBIÈRES DÉNUDÉES ou BOISÉES, les FAINGS DÉNUDÉS ou BOISÉS, les PRAIRIES MARÉCAGEUSES, les MARAIS ARBORÉS--soient adoptés et cartographiés dans les programmes provinciaux de cartographie des inventaires forestiers.

ACKNOWLEDGMENTS

We wish to thank Messrs. P. Copis and N. Hurdman for aid in preparing the figures, and Mr. V.F. Haavisto for carefully reviewing the manuscript and making constructive suggestions on the organization and contents of the report.

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INTRODUCTION

A hierarchical classification of Ontario wetlands has been proposed (Jeglum et al. 1974) in which it is demonstrated how the classification framework could be applied to wetland types in the Northern Clay Section of Ontario (Rowe 1972). The levels in the hierarchy, from most generalized to most specific, are formations, subformations, physiognomic groups, dominance types, and site types. A hierarchical approach was used so that the classification could be applied at different levels of generalization, depending upon the level of detail desired and/or the scale of available photo imagery. Vegetational physiognomy and dominance were stressed for two reasons--these features best reflect the resultant of all the interactions of the biotic and abiotic features of wetland ecosystems, and they are the most readily observable features of wetlands both in the field and on air photos.

The main objectives of this study are: i) to ascertain which of the five levels of the classification of Northern Clay Section wetlands can be recognized on black and white air photos of the scale of 1:15,840 (photos of the Ontario Forest Resources Inventory), and ii) to provide aids for the recognition of those wetland types which are interpretable.

To provide the necessary background for this report, the complete classification of Jeglum et al. (1974) is included in Appendix A. For clarity in distinguishing the various levels of the classification, the present report uses the same typefaces as those used in Jeglum (1974). Further, letter symbols--usually the first letters of the type names--are used as shorthand representations of the various types in the figures and tables. These symbols are presented in Appendix B. Finally, a glossary of selected terms used in wetland and peatland science, and those used in air photo interpretation in this report, are presented in Appendix C.

STUDY AREA

The Northern Clay Section is underlain largely by varved clays deposited in freshwater glacial Lake Barlow-Ojibway, some parts of which were subsequently overridden by a glacial readvance (Boissonneau 1966). The relief is predominantly gently undulating to level, and the lower parts of the landscape are overlain by shallow to deep deposits of peat. The average annual precipitation at Cochrane is 810 mm; mean annual water deficiency is 0 cm and mean annual water surplus is 33 cm. The mean daily temperature is 17°C for July, -18°C for January, and 0.5°C for the year (Chapman and Thomas 1968).

The Ontario Land Inventory has maps and tabular information on soils for the Northern Clay Section. As determined from the tabular data for the Cochrane and Kapuskasing Land Classification Maps as well

as that part of the Timmins Map included in the Northern Clay Section, 36% of the land area is peatland and 54% is peatland plus wet sites on mineral soil. However, Ketcheson and Jeglum (1972), using information from the Forest Resource Inventory (Dixon 1963), estimated that 51% of the Northern Clay Section is peatland. The difference in estimates of peatland area is due to differences in where the interpreters draw the line between upland and peatland (see definition in Appendix B). Regardless of these differences, it is clear that peatlands and wetlands are abundant in the Northern Clay Section.

Further breakdowns of the types of wetlands recognized in the Forest Resource Inventory, and their approximate equivalents to the wetland units of Jeglum et al. (1974), are given in Table 1. SWAMP, in which *BLACK SPRUCE* CONIFER SWAMP is the most common dominance type, comprises 71% of the wetlands. The next most common formation is BOG, estimated at 22% of the wetlands. TREED BOG is more common than OPEN BOG in the Northern Clay Section. The remaining 7% consists of MARSH and FEN.

METHODS

An ecological survey of wetlands, consisting of detailed vegetational and habitat measurements for 153 plots, was conducted in the Northern Clay Section. The wetland type was determined for each plot using the classification framework presented in Appendix B.

Sixteen areas in which transects or clusters of plots were located were selected to determine if the wetland types established by Jeglum et al. (1974) could be interpreted from air photos using features such as vegetational appearance, location in the landscape (in relation to drainage, and surface and basin morphology), and photo image (tone, texture, pattern, and shape). The 16 areas were within 72 km of Cochrane, Ontario (Fig. 1).

The locations of the plots were marked on black and white photos (scale 1:15,840). Stereoscopic pairs of the photos were then studied to determine if differences in wetland types recognized in the field could be detected. Photos of the 16 areas in Figure 1 are reproduced in this report as Figures 2 to 19. As well, detailed ground information for the transects of plots shown in Figures 6, 8, 9, 11, 13 and 16 is given in Appendix D.

The areas were chosen to include all four wetland formations--BOG, FEN, MARSH, and SWAMP. Mineral soil uplands were often included in these areas as well. The photos were interpreted only to the level of the classification at which determinations could be made with reasonable accuracy. On the air photos, we separated the four formations and

Table 1. Estimates of peatland and wetland areas in the Northern Clay Section

Ontario Forest Resource Inventory Units (Ketcheson and Jeglum 1972)	Equivalent Units in the Wetland Classification for Ontario (Jeglum et al. 1974)	Area ('000 ha)	Percentage of Wet-land	Percentage of Total land
	Wooded wetlands			
Pure productive black spruce	*BLACK SPRUCE* SWAMP	1,716	64	33
Cedar-dominated (productive)	*WHITE CEDAR* SWAMP	31	1	+
Larch-dominated (productive)	*TAMARACK* SWAMP (probably includes some TREED FEN)	6	+	+
Brush, alder and flooded	THICKET SWAMP (flooded, probably includes some MARSH)	162	6	3
Treed muskeg	TREED BOG (probably includes some TREED FEN)	396	15	8
Stagnant stands (values given for sections further north)	TREED FEN (probably includes some TREED BOG and *BLACK SPRUCE* SWAMP)	0	0	0
	Open wetlands			
Open muskeg	MARSH plus OPEN FEN plus OPEN BOG	378	14	7
Bogs (values given only for sections further north)	MARSH plus OPEN FEN plus OPEN BOG	0	0	0
	Total wetland	2,689	100	51
	Summary by formations			
	SWAMP	1,915	71	36
	BOG (treed muskeg and half of open muskeg)	585	22	11
	MARSH plus FEN (half of open muskeg)	189	7	4

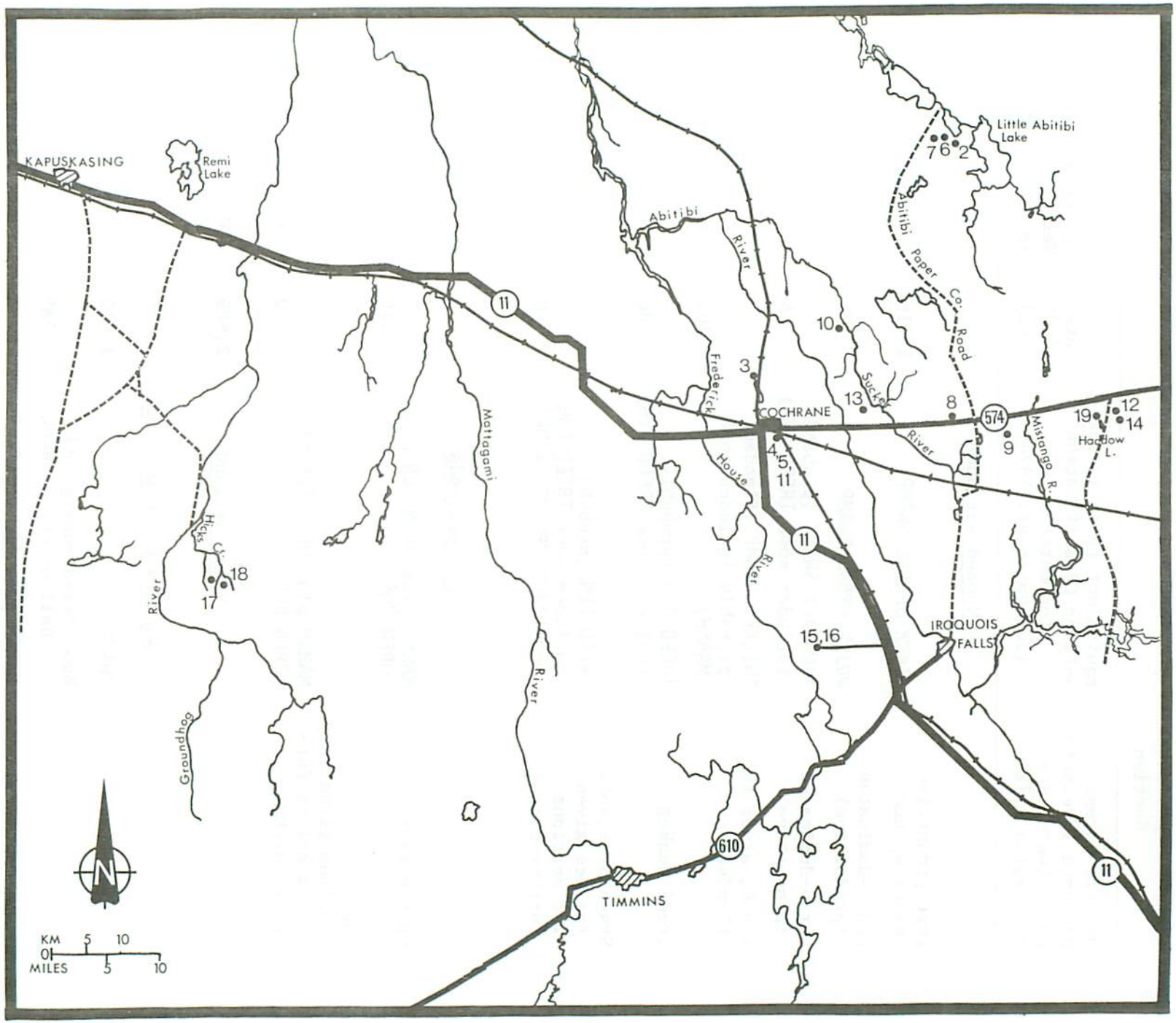

Figure 1. Location of the study sites in the Cochrane area. Site numbers correspond to figure numbers for Figures 2 to 19.

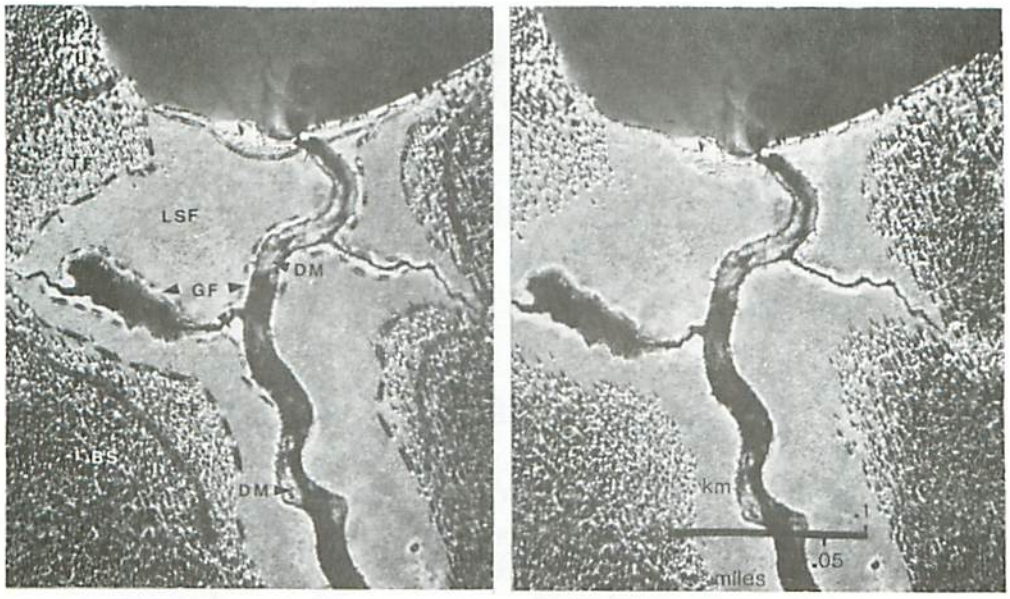

Figure 2. The outlet at the south end of Williston Lake. Scale ca. 1:4,000. Note how GRAMINOID FEN is next to LOW SHRUB FEN. U = upland; DM = DEEP MARSH; GF = GRAMINOID FEN; LSF = LOW SHRUB FEN; TF = TREED FEN.

In this and subsequent air photos (Fig. 3-19) we separate the four formations and uplands with solid lines, and subformations and physiognomic groups within formations with dashed lines. We also indicate locations and plot numbers for the ecological survey done by the senior author.

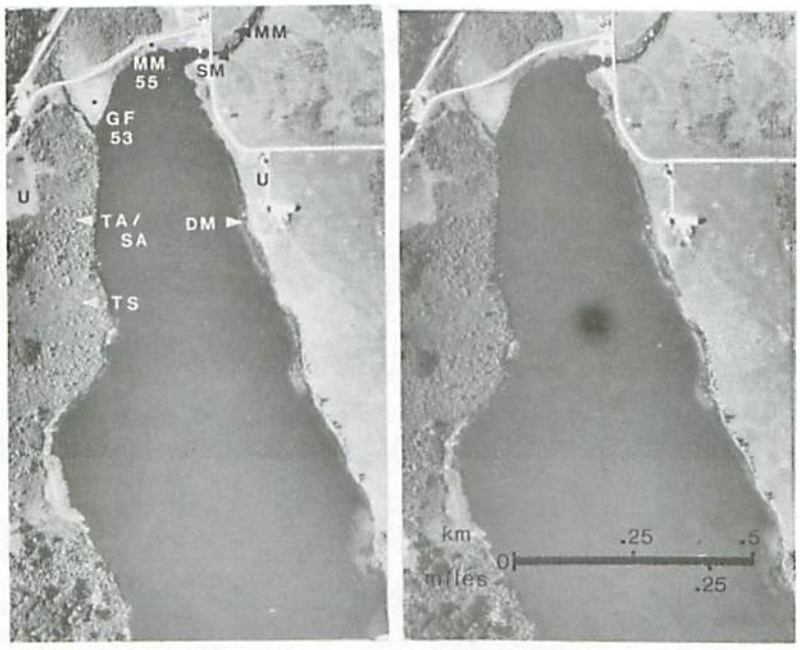

Figure 3. The outlet at the north end of Lillabelle Lake. Scale 1:15,840. Note how the MEADOW MARSH (55) is next to THICKET, and GRAMINOID FEN (53) occurs just back of MEADOW MARSH at the lake margin, and grades into LOW SHRUB FEN (separated by the road). U = uplands; DM = DEEP MARSH; SM = SHALLOW MARSH; MM = MEADOW MARSH; GF = GRAMINOID FEN; TS = THICKET SWAMP; TA/SA = *Tamarack/Speckled Alder*.

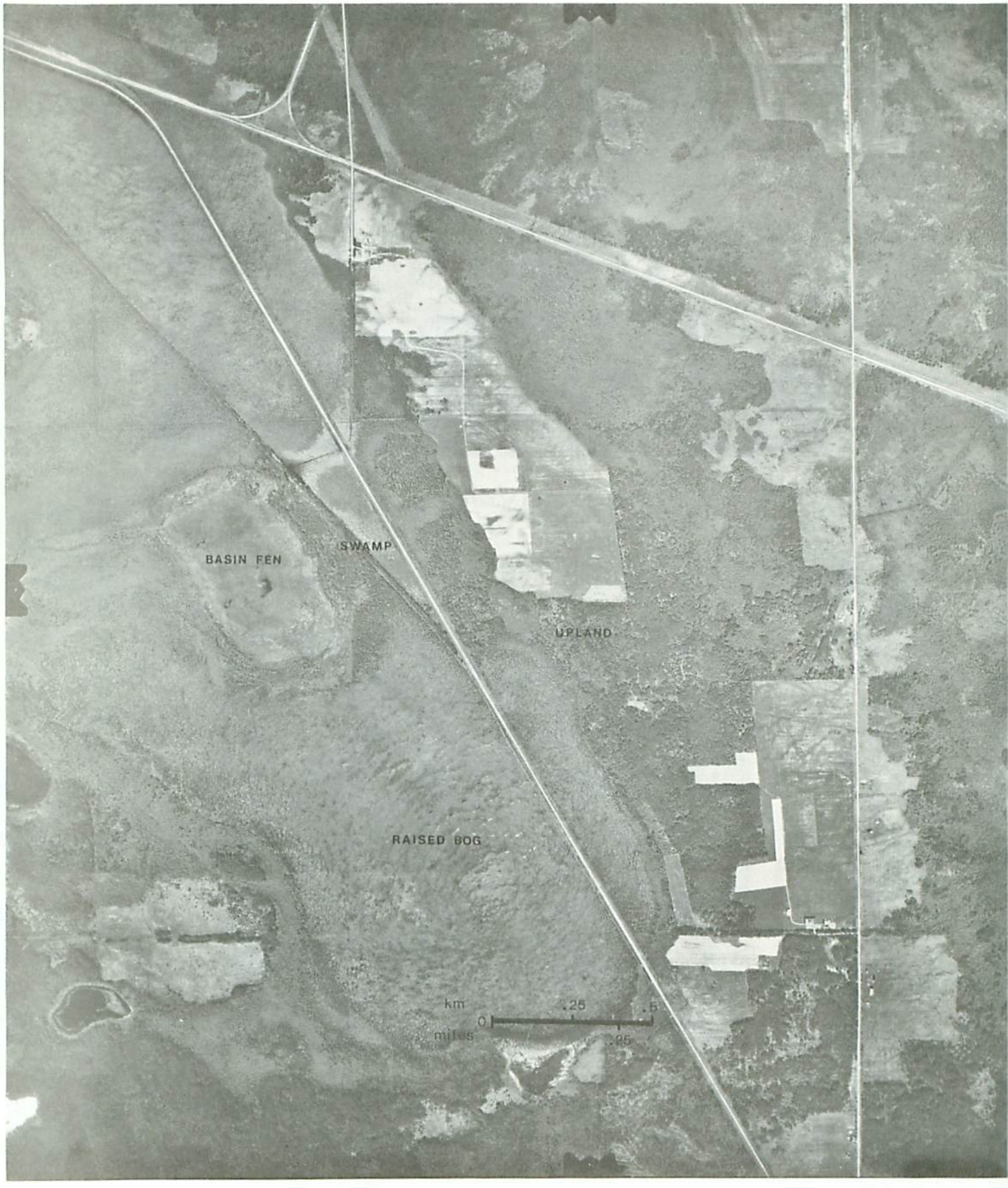

Figure 4. A basin FEN (above) and a centre-wet raised BOG (below) near Cochrane. Scale 1:15,840. SWAMP occurs between the FEN and upland, and between the BOG and upland. (More details are given in Figures 5 and 11.)

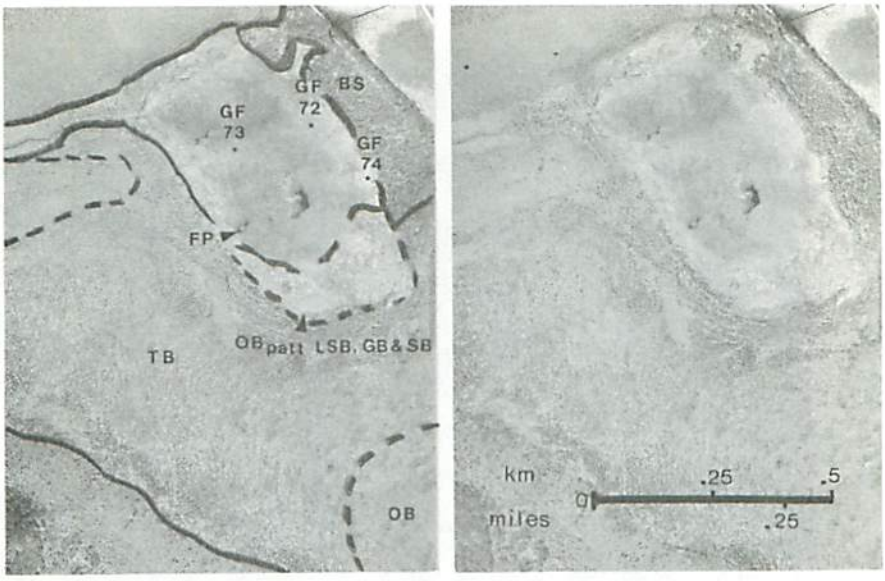

Figure 5. A basin FEN near Cochrane (see also Fig. 4). Scale 1:15,840. The BOG at the margin of the FEN shows a blotchy pattern. FP = FEN POOL; GB = GRAMINOID BOG; GF = GRAMINOID FEN; BS = *BLACK SPRUCE* CONIFER SWAMP; OB = OPEN BOG; OB_{patt} = patterned OPEN BOG; SB = SPHAGNUM BOG; LSB = LOW SHRUB BOG; TB = TREED BOG.

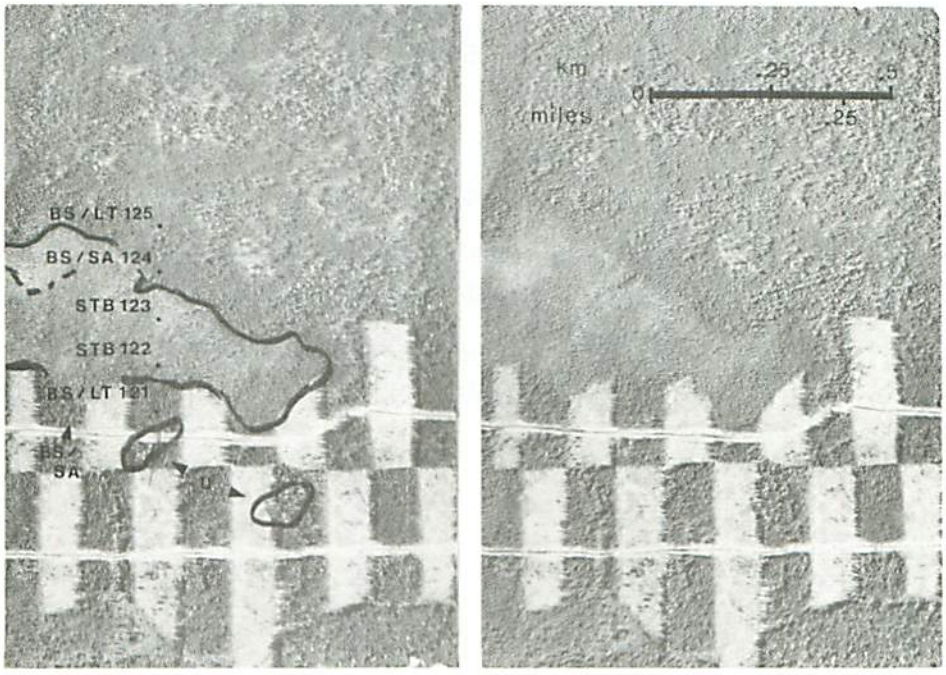

Figure 6. An area with upland, SWAMP and BOG near Williston Lake. U = upland; BS/LT = *Black Spruce/Labrador-tea;* BS/SA = *Black Spruce/Speckled Alder*; STB = SHRUB-RICH TREED BOG. (See Fig. 6a and 6b in Appendix D, for detailed ground information.)

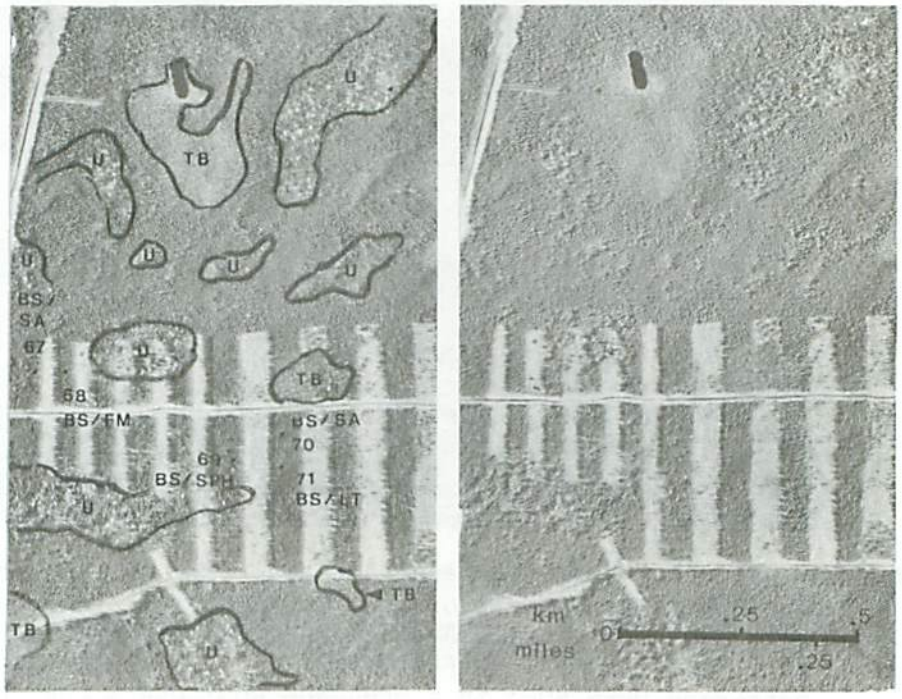

Figure 7

An area with upland, SWAMP, and BOG near Williston Lake. Scale 1:15,840. The BOG areas are basin BOGS.

U = upland

BS/FM = *Black Spruce/Feather Moss*

BS/LT = *Black Spruce/Labrador-tea*

BS/SA = *Black Spruce/Speckled Alder*

BS/SPH = *Black Spruce/Sphagnum*

TB = TREED BOG

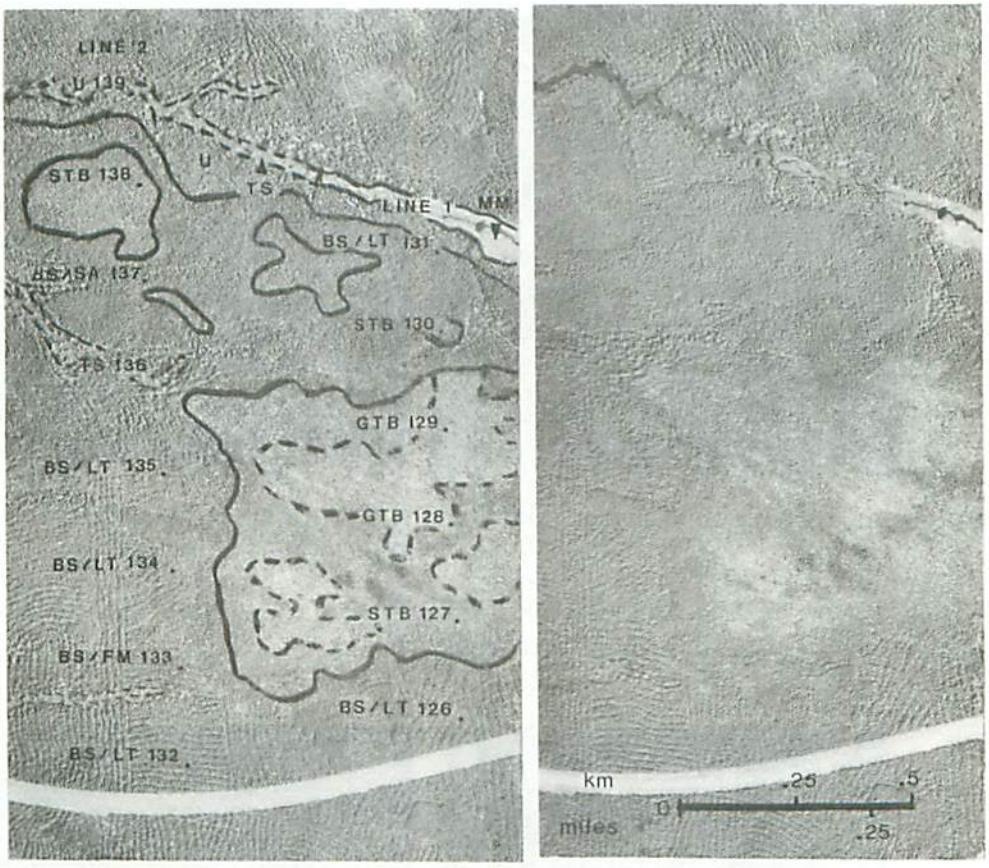

Figure 8

An area with upland, SWAMP, and BOG near Wade Lake (Wally Creek). Scale 1:15,840. The BOG areas are basin BOGS. Note how the terrace along the stream is occupied by MEADOW MARSH near the "beaver meadow", and grades into THICKET further downstream.

U = upland

MM = MEADOW MARSH

TS = THICKET SWAMP

BS/FM = *Black Spruce/Feather Moss*

BS/LT = *Black Spruce/Labrador-tea*

BS/SA = *Black Spruce/Speckled Alder*

GTB = GRAMINOID-RICH TREED BOG

STB = SHRUB-RICH TREED BOG

(See Fig. 8a, 8b, 8c, and 8d in Appendix D, for detailed ground information.)

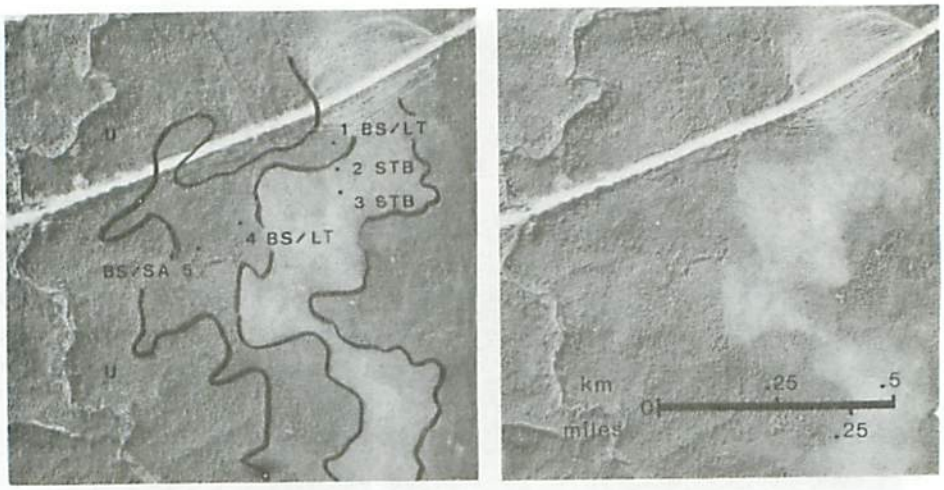

Figure 9. An area with upland, SWAMP, and BOG near Wade Lake (West Mistango Creek). Scale 1:15,840. The BOG area is basin BOG. U = upland; BS/LT = *Black Spruce/Labrador-tea*; BS/SA = *Black Spruce/Speckled Alder*; STB = SHRUB-RICH TREED BOG. (See Fig. 8a and 8b, Appendix D, for detailed ground information.)

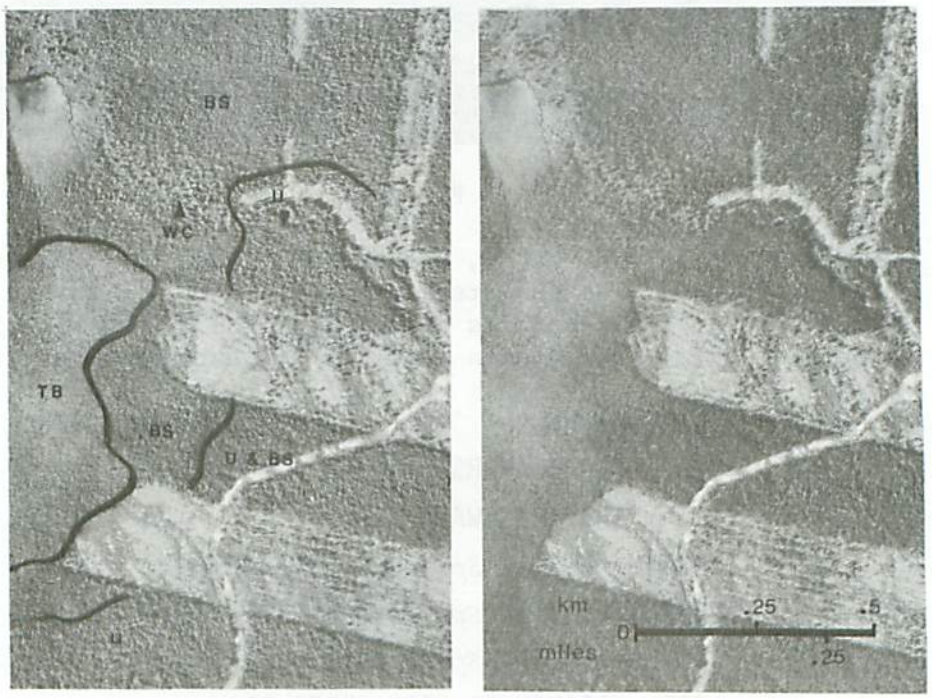

Figure 10. An area with upland, SWAMP, and BOG near the Sucker River (Kennedy Township Study Area, CFS). Scale 1:15,840. The BOG area is a basin BOG. Note the distinct lines of speckled alder following drainageways across the cut and uncut areas. U = upland; BS = *BLACK SPRUCE* CONIFER SWAMP; WC = *WHITE CEDAR* CONIFER SWAMP; TB = TREED BOG.

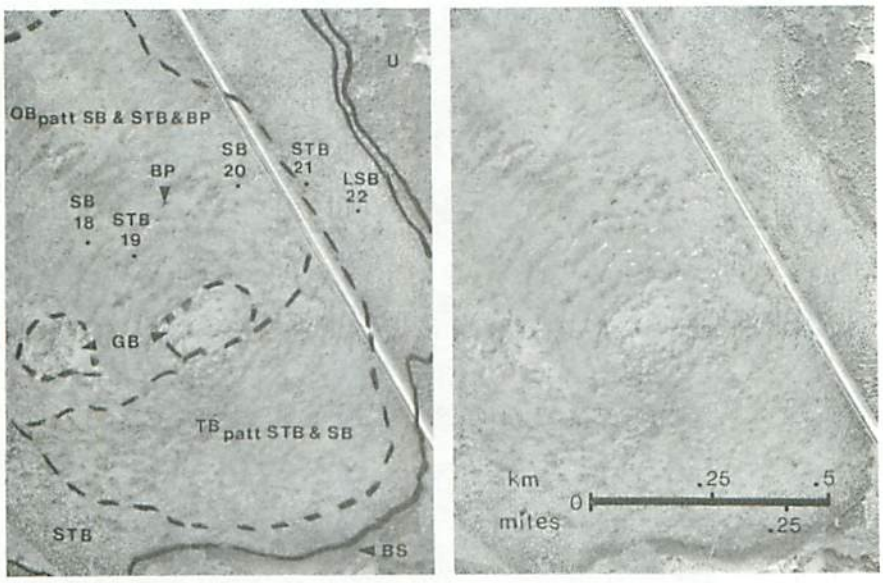

Figure 11. A centre-wet, raised BOG near Cochrane (see also Figure 4). Scale 1:15,840. The BOG has ridge and swale patterns, with short ridge and reticulate subtypes present. There tends to be a concentric arrangement of the short ridge and reticulate ridge patterns. U = upland; BS = *BLACK SPRUCE* CONIFER SWAMP; OB_{patt} = OPEN BOG, patterned; SB = SPHAGNUM BOG; GB = GRAMINOID BOG; LSB = LOW SHRUB BOG; TB_{patt} = TREED BOG, patterned; STB = SHRUB-RICH TREED BOG. (See Fig. 11a and 11b in Appendix D, for detailed ground information.)

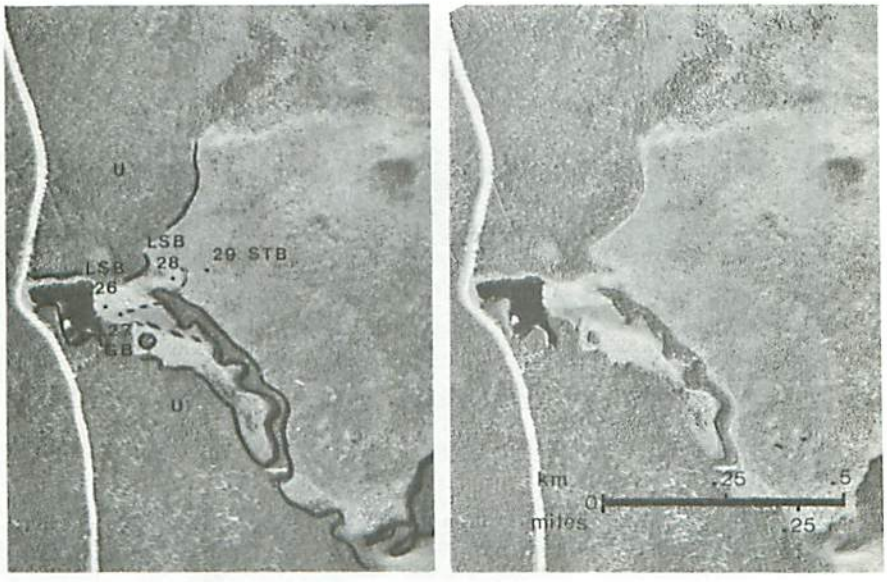

Figure 12. An area with upland and a centre-dry, raised BOG, probably flat, near Haddow Lake (ca. 50 km east of Cochrane). Scale 1:15,840. U = upland; GB = GRAMINOID BOG; LSB = LOW SHRUB BOG; STB = SHRUB-RICH TREED BOG.

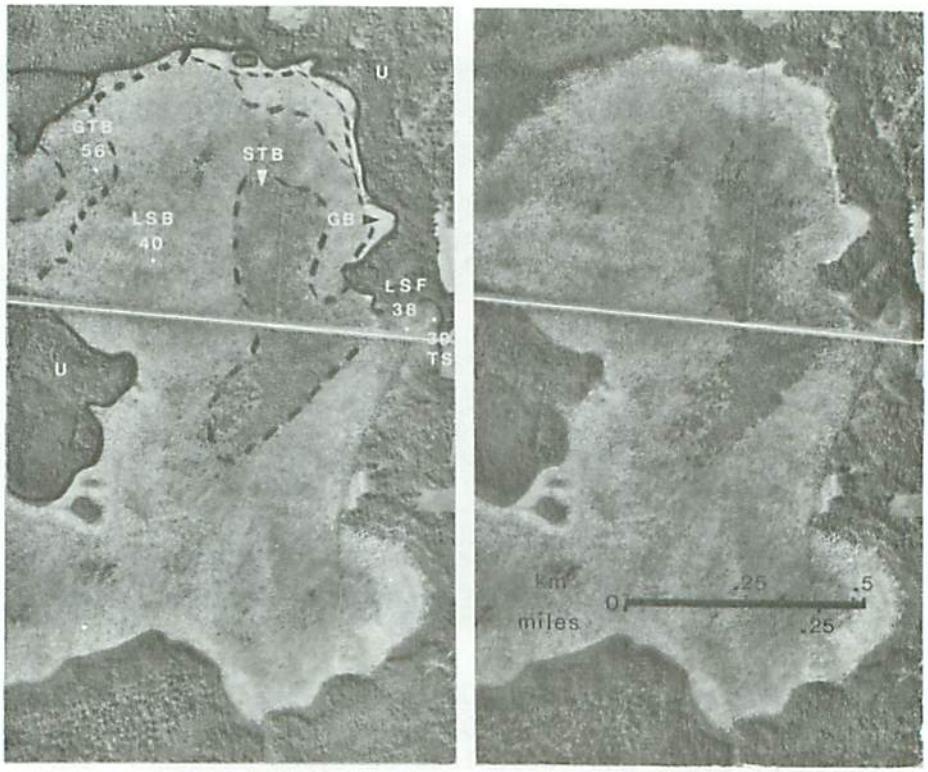

Figure 13. An area with upland and a centre-dry, raised BOG, probably flat, near the Abitibi River (Kennedy Township, east of Cochrane). Scale 1:15,840. The LOW SHRUB BOG may well have developed following burning as there is abundant regeneration of black spruce at present. U = upland; LSF = LOW SHRUB FEN; TS = THICKET SWAMP; GB = GRAMINOID BOG; LSB = LOW SHRUB BOG; GTB = GRAMINOID-RICH TREED BOG; STB = SHRUB-RICH TREED BOG. (See Fig. 13a and 13b in Appendix D, for detailed ground information.)

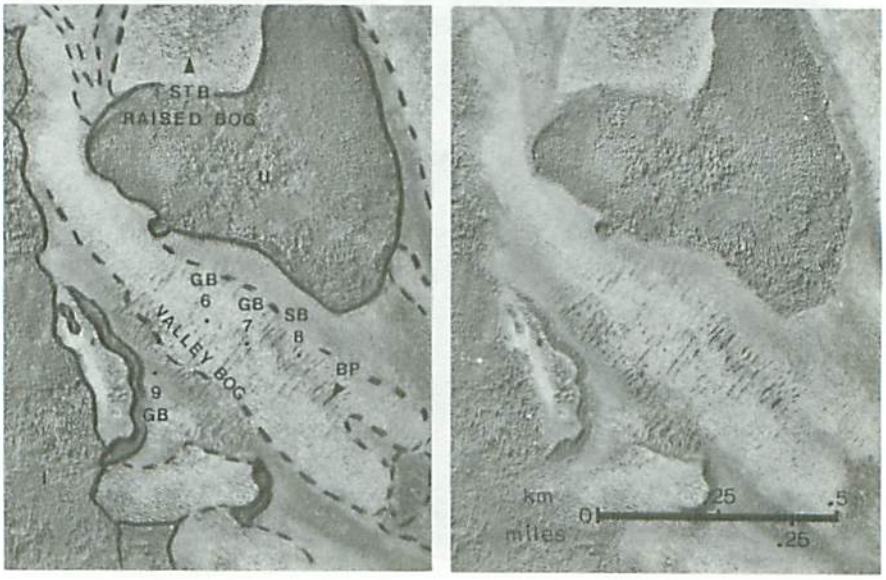

Figure 14. An area with upland, a centre-dry, raised BOG, probably domed, and a valley BOG, near Haddow Lake (ca. 50 km east of Cochrane). Scale 1:15,840. The valley BOG has ridges and swales of the ribbed subtype. OPEN BOG types are on both ridges and in swales, and some swales contain BOG POOLS. The valley BOG is a wet, OPEN BOG with BOG POOLS oriented crosswise to the movement of water from the lower right to the upper left. U = upland; BP = BOG POOL; SB = SPHAGNUM BOG; GB = GRAMINOID BOG; STB = SHRUB-RICH TREED BOG.

Figure 15. A valley BOG, possibly transitional to raised BOG, near Nellie Lake. Scale 1:15,840. There are drainageways with distinct channels on either side of the BOG. Water movement is from top to bottom in the photo and fans outward from the central axis, as shown by the dark, mineral soil streaks from the road across the BOG, and the arcuate arrangement of TREED BOG ridges. (More details are given in Fig. 16.)

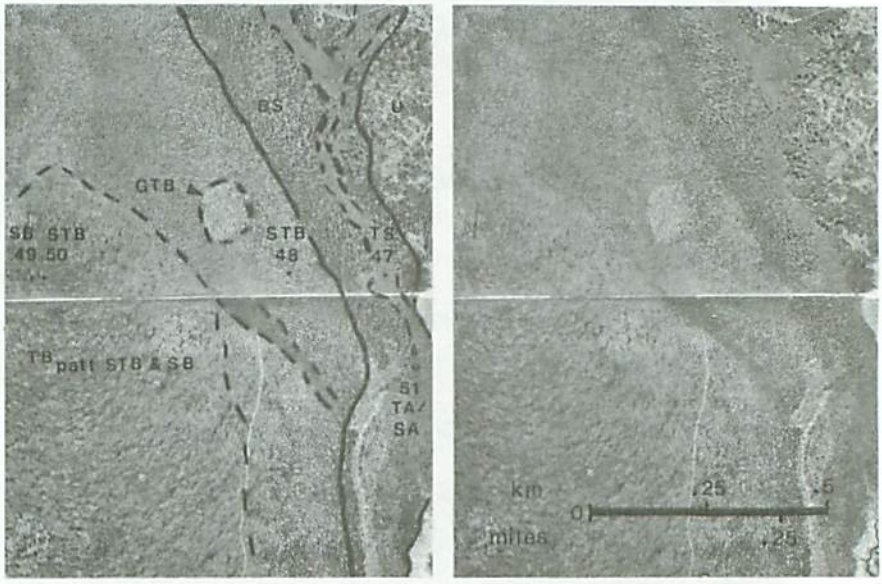

Figure 16. A valley BOG, possibly transitional to raised BOG (see also Fig. 15). Scale 1:15,840. The BOG has ridge and swale patterns of the short ridge subtype. Note the conspicuous "sedge ring" in the margin of the BOG body. U = upland; TS = THICKET SWAMP; TA/SA = *Tamarack/Speckled Alder*; BS = *BLACK SPRUCE* CONIFER SWAMP; SB = SPHAGNUM BOG; TB_{patt} = TREED BOG, patterned; GTB = GRAMINOID-RICH TREED BOG; STB = SHRUB-RICH TREED BOG. (See Fig. 16a and 16b in Appendix D, for detailed ground information.)

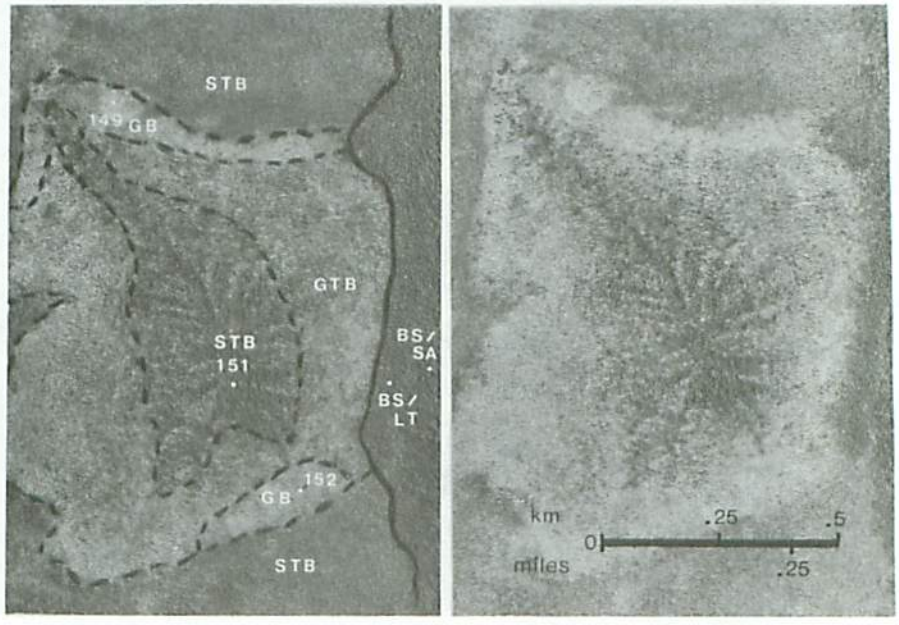

Figure 17. A centre-dry, raised BOG, probably domed, located in Hicks Township ca. 72 km NW of Timmins. Scale 1:15,840. Note the "sedge ring" (plot 149), and the lines of treed and open areas radiating outwards from the presumed dome of the raised BOG. BS/LT = *Black Spruce/Labrador-tea*; BS/SA = *Black Spruce/Speckled Alder*; GB = GRAMINOID BOG; GTB = GRAMINOID-RICH TREED BOG; STB = SHRUB-RICH TREED BOG.

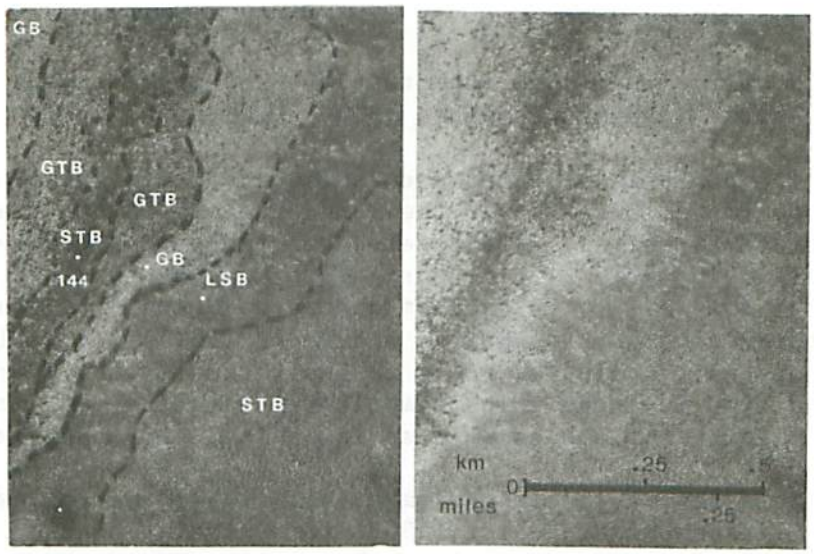

Figure 18. A valley BOG located in Hicks Township ca. 72 km NW of Timmins. Scale 1:15,840. Note the linear orientation of zones along the length of the BOG, and particularly the raised BOG crest, with SHRUB-RICH TREED BOG, in the centre of the valley BOG. GB = GRAMINOID BOG; GTB = GRAMINOID-RICH TREED BOG; STB = SHRUB-RICH TREED BOG.

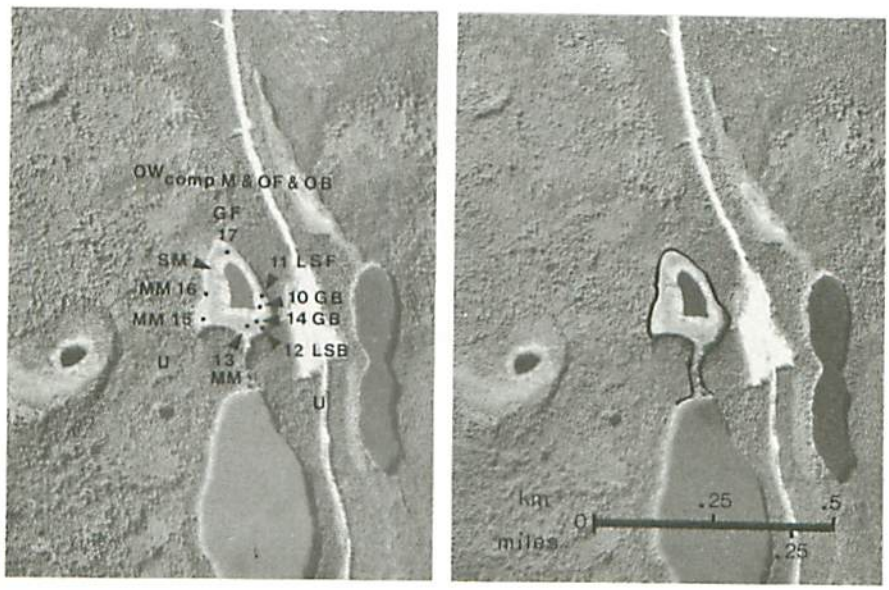

Figure 19. A wetland complex in a poorly-drained basin near Haddow Lake ca. 50 km east of Cochrane. Scale 1:15,840. The GRAMINOID BOGS are examples of zonal development of a basin BOG between a FEN lake and a lagg containing FEN and MARSH vegetation. The LOW SHRUB BOG is an example of a terraced raised BOG abutting the upland on the margin of the basin. U = upland; W_{comp} = WETLAND complex; SM = SHALLOW MARSH; MM = MEADOW MARSH; GF = GRAMINOID FEN; LSF = LOW SHRUB FEN; GB = GRAMINOID BOG; LSB = LOW SHRUB BOG.

uplands with solid lines, and subformations and physiognomic groups within formations with dashed lines (Fig. 2-19).

To aid photo interpreters we tabulated descriptions of the vegetational appearance, location in the landscape, and photo image features for the wetland types that were observed on the photos (Table 2). From the information in Table 2 we constructed a key for interpreting the wetland types (Table 3). In developing tables 2 and 3 we found the air photo interpretation work of Morris and Meyer (1954) for wetlands in Minnesota especially helpful. Both tables refer to the figures in which each wetland type is found. The symbols representing the wetland types are in the figure captions as well as in Table 2 and Appendix B.

In this report, as in Jeglum et al. (1974), we follow the nomenclature of Gleason and Cronquist (1963) for vascular plants, and of Nyholm (1954-1969) for moss species. Scientific names are not given in the body of the report.

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type.

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
1 WATER		Lakes, ponds, pools, rivers, streams.	Black to medium gray, very smooth, flat, sometimes flecked with white (waves), or completely white owing to reflection of sun.	Many of the figures have water bodies--lakes, streams, ponds, pools.
1 MARSH	Tall reeds, grasses, rushes, and sedges, either uniformly dispersed or in clumps. Pools, channels, and open water may be present. Either the vegetation or the water may be continuous phase, but when emergent vegetation has less than 25% cover, one is in "shallow open water" (Zoltai et al. 1975).	In small patches and zones at margins of lakes, ponds, rivers, streams, and small basins. Active flow usually occurs, with moderate to high seasonal water level fluctuations, and flooding by silt-enriched waters.	Very light to medium gray, depending on species composition and how much water shows under and between the canopy. Vegetation appears smooth, clumped, or patchy. Beaver channels may be present as dark lines.	M--Figures 2, 3, 8, 19.
3 DEEP MARSH (OPEN MARSH)	Tall reeds, grasses, and rushes with relatively open canopies and standing water below. Abundant pools and channels.	Usually adjacent to open water; also in roadside ditches and borrow pits.	Light to medium gray. Patchy or blotchy. Canopy cover 25 to 75%, beneath canopy or between clumps is standing water and/or mud flats.	DM--Figures 2, 3.
3 SHALLOW MARSH (CLOSED MARSH)	Tall to medium height reeds, grasses, rushes, and sedges, with relatively closed canopies. Pools and channels common.	Zones landward from DEEP MARSH as well as adjacent to open water; also in roadside ditches and borrow pits.	Light to medium gray. Canopy closed and bumpy to open and patchy or blotchy. Often with beaver channels and small pools. Canopy cover 75 to 100%, beneath canopy or between clumps is standing water and/or mud flats.	SM--Figures 3, 19.

(continued)

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type. (continued)

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
3 MEADOW (MEADOW MARSH)	Medium height sedges and grasses, with relatively closed canopies. Sedges usually broad-leaved. Occasional pools and channels. Sometimes with scattered clumps of tall shrubs.	Zones landward from SHALLOW MARSH. THICKETS may occur adjacent and landward. Often in old beaver empoundments ("beaver meadows"), on floodplains adjacent to flowage lakes and streams, and in shallow-peated, drained basins.	Light to medium gray. Usually smooth texture, but may have round bumps which are clumps of tall shrubs.	MM--Figures 3, 8, 19.
1 FEN	Medium to low sedges and grasses in the field layer. Sedges usually narrow-leaved. With or without low shrubs, with or without tamarack. May have small pools within graminoid matrix. Water may be below surface, or shallowly covering the surface. Sphagnum generally unimportant, or in less abundance than the brown mosses.	In peatlands separated from the influence of extreme seasonal flooding by flowage lakes and streams, but still influenced by soil-derived nutrients usually via lateral movement of mineral soil water through or across them. Root mats become spongy and float upwards with high water levels; less mineral content in organic soils than for MARSH. Occurs (i) in the margins of, or completely filling, poorly drained basins, (ii) in laggs between raised BOG and upland, and (iii) along slow flowing streams with low seasonal water level fluctuation and no extreme flooding.	See subtypes below	F--Figures 2-5, 13, 19.

(continued)

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type. (continued)

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
2 OPEN FEN	With less than 10% cover of tamarack.	See subtypes below.	See subtypes below.	OF--Figures 2-5, 13, 19.
3 FEN POOL	Small water body in FEN.	Found in FEN.	See WATER.	FP--Figures 4-5.
3 GRAMINOID FEN	Dominated by medium to low sedges, often with brown mosses, less than 25% shrub cover.	Often in wet conditions, with groundwater close beneath or shallowly covering the ground surface. Often occurs as floating sedge mats adjacent to open water.	Very light gray to medium gray, depending on the dominant sedge species, and on how much water and/or floating brown moss shows beneath the sedge canopy. Smooth, fuzzy or velvety; sometimes mottled or blotchy with patches of light gray in medium gray, or medium gray in light gray. Medium gray tones may be caused by brown mosses, water surfaces, certain sedge dominants, or low shrubs; light gray tones are caused by certain sedge dominants.	GF--Figures 2-5, 19
3 LOW SHRUB FEN	With 25% or more cover of low shrubs, usually with sedges and brown mosses.	In slightly drier conditions, further away from water bodies, and with less surface water, than GRAMINOID FEN. Mats more consolidated, but may still be floating.	Medium gray, usually mottled or blotchy, with small patches of light gray indicating shrubless, sedge-dominated areas.	LSF--Figures 2, 13, 19.

(continued)

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type. (continued)

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
2 TREED FEN	Tamarack the dominant tree, with 10% or more cover of trees; trees short, usually not over 10 m; usually an important component of sedges in field layer, and with or without low shrubs. (No development of tall shrubs; if so it is *Tamarack/Speckled Alder* SWAMP.)	In slightly drier conditions than, and landward from, OPEN FEN. Downslope from and in wetter conditions than SWAMP. In less well drained, and poorer, sites than *Tamarack/Speckled Alder* SWAMP, often associated with broad expanses of open peatland.	Tree crown light to very light gray (leaves light green in summer, yellow in autumn), sometimes almost white on sun side. Heights generally uniform. Narrowly to ovally conical, to oval small crowns. Crown cover from 10% to moderately closed. Openings in canopy either medium gray (low shrubs) or light gray (sedges). Separation of *Tamarack/Speckled Alder* from *BLACK SPRUCE* CONIFER SWAMP may be difficult.	TF--Figure 2.
1 SWAMP	Forested or thicketed wetland, closed canopies without, or with little of, the understory visible. Trees large and usually of merchantable size.	Along streams not having drastic flooding, in drainageways, on gentle slopes and lowland flats, downslope from mineral soil upland sites, upslope from MARSH, FEN, or BOG. (Sometimes downslope from raised BOG.) Groundwater is minerotrophic.	See subtypes below.	S--Figures 2-11, 13, 15-17.
3 THICKET (THICKET SWAMP)	Wetlands dominated by tall shrubs (over breast height), with more than 25% cover of tall shrubs, and less than 25% cover trees. Primarily *SPECKLED ALDER (ALNUS RUGOSA)* but also *WILLOW (SALIX)* THICKET SWAMP.	Naturally occurring on stream banks, on margins of flowage lakes, in drainageways between upland and peatland, in linear and dendritic drainageways through *BLACK SPRUCE* CONIFER SWAMP; often adjacent to MARSH, and associated with beaver empoundments. Also developing following cutovers of the *Black Spruce/Speckled Alder* SWAMP site type.	Very light to medium gray. Bumpy or granular appearance. Crowns round or crenated; usually closed (densely packed) canopies, sometimes open or scattered. Natural stand crowns with irregular sizes and spacing; crowns of cutover THICKETS more regular and canopy not as distinctly bumpy, sometimes fuzzy. Often some scattered bumps (trees) stand above shrub canopy.	TS--Figures 3, 8, 13, 16.

(continued)

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Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
3 CONIFER SWAMP[a]	Treed wetlands, excluding TREED BOG and TREED FEN; tree cover ≥ 25%.	See subtypes below.	See subtypes below.	CS--See subtypes below.
4 *TAMARACK (LARIX LARICINA)*	Tamarack-dominated swamp.	See subtype *Tamarack/Speckled Alder*.	See subtype *Tamarack/Speckled Alder*.	TA--See subtype TA/SA.
5 *Tamarack/ Speckled Alder*	A mixture of tamarack overstory with ≥ 25% cover, and speckled alder with ≥ 25% cover. Often with some black spruce present.	On floodplains and in drainageways, often associated with THICKET SWAMP and slightly downslope from *BLACK SPRUCE* CONIFER SWAMP. In better drained, richer sites than TREED FEN. May be natural or develop following cutovers.	Crowns very light to light gray (leaves light green in summer, yellow in autumn), sometimes almost white on sun side. Closed to open canopies with taller trees than in TREED FEN, usually over 10 m. Stand pattern usually irregular, crowns narrowly to ovally conical. Openings in canopy often show medium gray, clumped canopies of speckled alder. Separation from TREED FEN and *BLACK SPRUCE* CONIFER SWAMP may be difficult.	TA/SA--Figures 3, 16.
4 *BLACK SPRUCE (PICEA MARIANA)*	Black spruce-dominated SWAMP. Medium to tall forests, closed to open canopies. Usually pure stands, sometimes balsam fir or tamarack mixed in. Usually merchantable.	On gentle slopes and flats in lower positions in the landscape. Downslope from mineral soil uplands, upslope from or adjacent to TREED BOG.	Crowns medium to dark gray (may be light if angle of sun is right), small, sharply outlined, round or slightly jagged from top. Shadows small, pointed cylindrical to narrowly conical, often with compact, oval clusters of branches known as a 'club-tops'. Canopy closed to open, often with regular stand pattern and uniform heights.	BS--Figures 2, 5, 10, 11, 16; also see subtypes below.

[a] HARDWOOD SWAMP is not included since it is uncommon in the Northern Clay Section.

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type. (continued)

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
5 *Black Spruce/ Feather Moss*	Total shrub cover ≤ 25%. Feather mosses are dominant.	Just downslope from mineral soil upland. Slopes often detectable on ground. Other *BLACK SPRUCE* types downslope from this one.	Canopy usually closed. Trees variable height, merchantable.	BS/FM--Figures 7, 8.
5 *Black Spruce/ Labrador-tea*	Total shrub cover ≥ 25%. Labrador-tea is the dominant shrub. Sphagnum moss is usually the dominant moss, and a sphagnum peat moss horizon is developing.	In poorly drained sites and undrained depressions. Slopes often detectable on ground. Other *BLACK SPRUCE* site types may be upslope, and TREED BOG may be downslope.	Canopy moderately to very open. Trees medium height and merchantable, to short, small diameter, and unmerchantable.	BS/LT--Figures 6-9, 17.
5 *Black Spruce/ Speckled Alder*	Total shrub cover ≥ 25%. Speckled alder is the dominant shrub. Ground surface irregular with pits, channels, and mounds. Sphagnums and feather mosses are present.	Often in linear paths indicating drainage and seepageways. Along THICKET SWAMP in drainageways, or upper branches of a dendritic drainage network.	Canopies moderately open. Trees variable in height, merchantable. Openings in canopy may reveal medium gray, rounded crowns of speckled alder.	BS/SA--Figures 6-9, 17.
5 *Black Spruce/ Sphagnum*	Total shrub cover ≤ 25%. Sphagnum mosses are dominant.	In poorly drained sites. Slopes often not detectable on ground. *Black Spruce/ Speckled Alder* may be adjacent in drainageways. *Black Spruce/Feather Moss* may be upslope in less wet conditions. *Black Spruce/Labrador-tea* may be adjacent.	Canopy closed, sometimes overstocked. Trees medium height and merchantable to short and unmerchantable.	BS/SPH--Figure 7.

(continued)

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Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
4 *EASTERN WHITE CEDAR (THUJA OCCIDENTALIS)*	White cedar-dominated SWAMP.	In drainageways, areas with springs, along streams, and at lake margins where subsurface drainage and nutrient supply are good, and above-surface flooding does not occur. Adjacent to THICKET SWAMP and *BLACK SPRUCE* CONIFER SWAMP.	Crowns medium gray, squatty and shorter than other conifers, sometimes leaning, variable in height and width, ovally conical to oval to pointed cylindrical. Canopy open and ragged (with erratic changes in height) often mixed with other taller conifers that have slender conical crowns, and occasional round crowns of hardwoods. Can be confused with small black spruce.	WC--Figure 10.
1 BOG	Sphagnum-dominated ground layer, underlain by a relatively continuous layer of sphagnum peat moss, with or without graminoids, low shrubs and stunted black spruce.	Virtually isolated from influshing of mineral soil waters, but may have residual influence of minerotrophy from previous minerotrophic system over which the BOG has developed. Occur as valley BOGS with slightly concave or flat surfaces and unilateral drainage, often weakly minerotrophic; as basin BOGS which are slightly concave or flat, often weakly minerotrophic; and as raised BOGS which are flat or slightly convex, mostly ombrotrophic.	See subtypes below.	B--Figures 4-19; valley BOGS, Figures 14-16, 18, 19; basin BOGS, Figures 6-10, 19; and raised BOGS, Figures 4-5, 11-16, 17-19.

(continued)

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type. (continued)

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
2 OPEN BOG	Black spruce over breast height < 10% cover.	See subtypes below.	See subtypes below	OB--Figures 5, 11-14, 17-19; also 15 and 16 as the open phase in ridge and swale patterns in TREED BOG.
3 BOG POOL	A pool in BOG, sometimes being encroached upon by aquatic sphagnum.	In large raised BOGS with distinct radial outflow of water, and in valley BOGS with definite unilateral movement of water.	See WATER. Often with linear configuration alternating with linear ridges, both of which are oriented crosswise to the movement of water.	BP--Figures 11, 14.
3 SPHAGNUM BOG	Sphagnum provides main visual impact, sedges <25% cover and shrubs <25% cover.	As the predominant phase of large, raised and valley BOGS which have wet OPEN BOG centres and less wet TREED BOG margins. As zones in basins (basin BOGS) adjacent to ponds which are slowly drained or undrained. As floating mats filling BOG POOLS.	*SPHAGNUM RUBELLUM* BOG is medium gray. Mottled or dappled appearance may be present owing to lighter gray patches of GRAMINOID BOG. *SPHAGNUM CUSPIDATUM* BOG, filling what were previously BOG POOLS, usually light gray (yellow green to bright green).	SB--Figures 5, 11, 14, 16 (as the open phase in ridge and swale patterns in TREED BOG).

(continued)

Table 2. Vegetational appearance, location in landscape, and photo image on black and white air photos at 1:15,840 scale, for wetland types in the Northern Clay Section, Ontario. The complete wetland classification of Jeglum et al. (1974) is given in Appendix A. Numerals preceding the types indicate their levels in the classification hierarchy: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, and 5 - site type. (continued).

Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
3 GRAMINOID BOG	Sedges dominate field layer with ≥ 25% cover.	*CAREX LIMOSA* GRAMINOID BOG is probably the richest and transitional from FEN. *CAREX OLIGOSPERMA* GRAMINOID BOG is often associated with *Sphagnum fallax*, and is often slightly minerotrophic. Both of the aforementioned types can be found in basin or valley BOGS. *CAREX PAUCIFLORA* GRAMINOID BOG is the poorest type, often located in the open phases of raised BOGS which are mainly treed.	*CAREX LIMOSA* is medium gray, often in linear dark streaks suggesting flush of mineral soil water. Sometimes there are patches of light gray *Carex oligosperma*, plus *Sphagnum fallax* included, and other darker gray tones of LOW SHRUB BOG. *CAREX OLIGOSPERMA* is light to very light gray. Sometimes this type occurs as a 'sedge-ring' in a matrix of GRAMINOID-RICH TREED BOG (e.g., Fig. 17). *CAREX PAUCIFLORA* is light to very light gray and difficult to distinguish from the previous type. In these last two types, patches of medium gray LOW SHRUB BOG may be present.	GB--Figures 5, 11-14, 17-19.
3 LOW SHRUB BOG	Low, ericaceous shrubs dominate field layer with ≥ 25% cover.	In valley, basin, or raised BOGS; it develops in the 'driest' OPEN BOGS; sometimes it is the result of burning of SHRUB-RICH TREED BOG (e.g., Fig. 13).	Medium gray (shrubs); may be blotchy or patchy, with mixtures of light gray (sedges), and medium gray (shrubs). Black spruce may be present as scattered individuals appearing as dark stipplings on the images.	LSB--Figures 5, 11-13, 19.

(continued)

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Wetland type	Vegetational appearance	Location in landscape	Photo image (tone, texture, pattern, shape)	Symbols used in figures
2 TREED BOG	Black spruce ≥ 10% cover, up to as much as 40 to 50%. Trees short, usually < 10 m.	For valley and basin BOGS, there is sometimes a distinct line between SWAMP which occurs on sloping ground, and TREED BOG which occurs on an adjacent, virtually flat, waterlogged peatland. In other cases there is a continuum from SWAMP on subtle slopes into TREED BOG on flats, with no distinct line of demarcation. For raised BOG there may be a distinct abrupt rise in the ground surface from SWAMP onto the raised BOG surface. Often the TREED BOG grades into the OPEN BOG toward the centre of the BOG body, but the opposite is true for centre-dry, raised BOGS.	Trees medium to dark gray, canopies closed to open or scattered. Trees and shadows pointed linear, with club-tops. Understory between trees may be light (sedges and light-toned sphagnum, e.g., *S. fallax*) to medium (low shrubs and dark-toned sphagnum, e.g., *S. fuscum*) to dark gray (abundant low growing black spruce).	TB--Figures 4-18.
3 GRAMINOID-RICH TREED BOG	Understory dominated by sedges, over *Sphagnum fallax* (yellow green yields light gray) and *S. magellanicum* (red yields medium gray). Trees often on slightly raised mounds or islands, on which shrub cover may exceed that of sedges.	Similar to GRAMINOID BOG, but with trees. May be adjacent to raised BOG in slightly minerotrophic locations. Usually in basin and valley BOGS.	Light to very light gray between trees. Tree island phase may be randomly scattered where water movement is not strong, or the islands may have elongated forms that are oriented crosswise to the movement of water. Sometimes this type occurs as a 'sedge ring' in a matrix of SHRUB-RICH TREED BOG (e.g., Fig. 16).	GTB--Figures 8, 13, 16-18.
3 SHRUB-RICH TREED BOG	Understory dominated by low shrubs, mainly leatherleaf over *Sphagnum fuscum*.	Similar to LOW SHRUB BOG, but with trees. As centres of centre-dry raised BOGS, and on the margins of centre-wet raised, valley, and basin BOGS. In the latter marginal locations, occurs between centrally located OPEN BOG, and SWAMP on the margin of the BOG.	Trees dark gray, stippled texture, usually randomly scattered, with no or little concentration on islands. Understory medium (low shrubs) to dark gray (dense low black spruce).	STB--Figures 6, 8, 9, 11-14, 16-18.

Table 3. Key for air photo interpretation of wetland types in the Northern Clay Section from black and white air photos at 1:15,840 scale. The wetland types follow the classification of Jeglum et al. (1974) (see Appendix A).

1a Hilltops, steep to moderate slopes, well-drained sand flats, levees, and steep banks along streams. Stands dominated by trembling aspen, white birch, balsam fir, jack pine, or white spruce, and stands dominated by black spruce with some content of the aforementioned species . . . . . MINERAL SOIL UPLANDS (Fig. 2-4, 6-16, 19)

1b Basins and depressions, flat and slightly sloping areas in low parts of the landscape, gentle lower slopes with restricted drainage, drainageways, wet floodplains and terraces along streams and lakes. Occupied by BOG, FEN, MARSH, and SWAMP. Stands dominated exclusively by black spruce, white cedar, tamarack, speckled alder, and willow, or mixtures thereof, are usually wetlands . . . . . WETLANDS (Fig. 2-19).... 2

2a Sphagnum-dominated ground layer, underlain by a continuous horizon of poorly decomposed sphagnum peat $\geq$ 30 cm thick, with or without graminoids, low shrubs, and stunted black spruce; the latter, if present, with open canopies and short trees, usually < 10 m. In basins and valleys, virtually isolated from the influshing of mineral soil water. Tone variable, very light to dark gray. Texture and pattern variable: (i) fine-textured and uniform; (ii) mottled owing to patches of different-toned sphagnums, sedges, low shrubs, or black spruce; (iii) with parallel ridge and swale patterns that are ribbed or reticulate; and (iv) with seepage areas radiating out from the BOG centre like wheel spokes . . . . . BOG (Fig. 4-19).... 3

2b Without sphagnum-dominated ground layer, or, if with abundant sphagnum, not underlain by a continuous horizon of poorly decomposed sphagnum peat $\geq$ 30 cm thick. Site clearly influenced by inflowing or residual mineral soil water . . . . . MARSH, FEN, and SWAMP 8

3a Black spruce < 10% cover . . . . . OPEN BOG (Fig. 5, 11-19).... 4

3b Black spruce $\geq$ 10% to ca 50% cover . . TREED BOG (Fig. 5-18).... 7

(continued)

Table 3. Key for air photo interpretation of wetland types in the Northern Clay Section from black and white air photos at 1:15,840 scale. The wetland types follow the classification of Jeglum et al. (1974) (see Appendix A). (continued)

4a Water bodies occurring within BOG, often with linear forms oriented crosswise to water movement . . . . . BOG POOL (Fig. 11, 14)

4b Firm BOG terrain, above water most of the time..... 5

5a Sphagnum provides main visual impact. Light to medium gray depending on dominant species. Uniform texture, or slightly mottled or blotchy owing to patches of different-toned sphagnums or sedges . . . . SPHAGNUM BOG (Fig. 5, 11, 14, 16)

5b Visual impact influenced by definite field layers developed over the sphagnum 6

6a Sedges over a sphagnum ground layer provide main visual impact. Tone very light to medium gray depending on dominant species; medium mottlings or blotches represent mounds with low shrubs and sometimes scattered black spruce . . . . . GRAMINOID BOG (Fig. 5, 11-14, 17-19)

6b Low shrubs over a sphagnum ground cover provide main visual impact. Tone medium gray, usually with light mottlings or blotches (lows with sphagnums and sedges) and scattered dark stipplings (black spruce) . . . . . LOW SHRUB BOG (Fig. 5, 11-13, 19)

7a For the ground between the tree crowns, sedges over sphagnum provide main visual impact. Tone very light to light gray. Trees may be randomly scattered, or aggregated on slightly elevated mounds. Mounds, if present, in roundish islands, or in elliptic or crescentic ridges oriented crosswise to water movement . GRAMINOID-RICH TREED BOG (Fig. 8, 13, 16-18)

7b For the ground between the tree crowns, low shrubs over sphagnum provide main visual impact. Tone medium gray (low shrubs) to dark gray (dense low black spruce). Trees distributed as in 7a . . . . . SHRUB-RICH TREED BOG (Fig. 6, 8-9, 11-14, 16-18)

(continued)

Table 3. Key for air photo interpretation of wetland types in the Northern Clay Section from black and white air photos at 1:15,840 scale. The wetland types follow the classification of Jeglum et al. (1974) (see Appendix A). (continued)

8a Open, minerotrophic wetlands (not including OPEN BOG, see 2a, 3a), with < 25% cover of tall shrubs and < 25% cover of trees taller than breast height. (The trees in some *TAMARACK* TREED FENS may exceed 25% cover, but these are usually short, and have sedges or low shrubs as understory, in contrast to *Tamarack/Speckled Alder* SWAMP which has taller trees and tall shrubs in the understory.) . . . . . FEN and MARSH.... 9

8b Wooded, minerotrophic wetlands (not including TREED BOG, see 2a, 3b), with ≥ 25% canopy cover of tall shrubs or trees taller than breast height . . . . . SWAMP (Fig. 2-11, 13, 15-17)... 15

9a Tall to medium graminoid vegetation. Canopy often clumped or patchy, sometimes smooth or fuzzy. Usually adjacent or close to open water of open drainage systems (lakes, streams, distinct channels) with high water level fluctuations. Also in drained basins, roadside ditches, and borrow pits. Frequently with standing water visible between vegetation clumps or beneath canopy. Firm floating mats uncommon . . . . . MARSH (Fig. 2, 3, 8, 19)... 10

9b Medium to short graminoid, low shrub, or stunted tamarack vegetation. Located in peatland expanses or margins without distinct channels. Usually removed spatially from open water and from open drainage systems. May or may not have pools and/or shallow water covering the peat surface. Firm floating or spongy root mats common . FEN (Fig. 2-5, 13, 19)... 12

10a Emergent vegetation in or adjacent to open water, pools or channels commonly interspersed with clumps of vegetation, or water beneath the graminoid canopies..... 11

10b Closed graminoid vegetation behind zones of emergents, and on wet floodplains or terraces adjacent to open drainage systems. Usually seasonally flooded, or flooded in recent past (e.g., beaver empoundments) . . . . . MEADOW (MEADOW MARSH) (Fig. 3, 8, 19)

(continued)

Table 3. Key for air photo interpretation of wetland types in the Northern Clay Section from black and white air photos at 1:15,840 scale. The wetland types follow the classification of Jeglum et al. (1974) (see Appendix A). (continued)

11a Canopy cover 25-75%; standing water and/or mud flats beneath canopy or between clumps . . DEEP MARSH (Fig. 2, 3)

11b Canopy cover 75-100%; standing water and/or mud flats beneath canopy or between clumps . . . . . SHALLOW MARSH (Fig. 3, 19)

12a Tamarack < 10% cover . . . OPEN FEN (Fig. 2-5, 13, 19)... 13

12b Tamarack ≥ 10 to ca 50% cover . . . TREED FEN (Fig. 2)

13a Water bodies occurring within FEN . . . FEN POOL (Fig. 4, 5)

13b Firm, vegetated FEN terrain 14

14a Graminoid vegetation, < 25% cover of low shrubs . . . . . GRAMINOID FEN (Fig. 2-5, 19)

14b With ≥ 25% cover low shrubs (lower than breast height), can still be a significant component of graminoids . . . . . LOW SHRUB FEN (Fig. 2, 13, 19)

15a With ≥ 25% cover of tall shrubs (taller than breast height), and less than 25% cover of trees . . . . . THICKET (THICKET SWAMP) (Fig. 3, 8, 13, 16)

15b With ≥ 25% cover of conifer trees . . . . . CONIFER SWAMP[a] (Fig. 2, 3, 5-11, 16, 17)... 16

16a Dominated by tamarack with speckled alder in the understory. Crowns very light to light gray. Closed to open canopies with good growth trees. Stand pattern usually irregular, crowns narrowly to ovally conical. Openings in canopy may reveal rounded crowns of speckled alder. In drainageways and along streams and flowage lakes . . . . . *Tamarack/Speckled Alder* SWAMP (Fig. 3, 16)

16b Not as above 17

[a] HARDWOOD SWAMP is not included in the key since it is so uncommon in the Northern Clay Section.

(continued)

Table 3. Key for air photo interpretation of wetland types in the Northern Clay Section from black and white air photos at 1:15,840 scale. The wetland types follow the classification of Jeglum et al. (1974) (see Appendix A). (concluded)

17a Dominated by white cedar. Crowns medium gray, squatty and shorter than other conifers, sometimes leaning, variable in height and width, ovally conical, to pointed cylindrical. Canopy open and ragged (with erratic changes in height), often mixed with other taller conifers that have slender conical crowns, and occasional hardwoods. In drainageways through *BLACK SPRUCE* CONIFER SWAMP, along streams, and at lake margins where water movement is distinct but above surface flooding does not occur . . . . . *EASTERN WHITE CEDAR (THUJA OCCIDENTALIS)* SWAMP (Fig. 10)

17b Dominated by black spruce. Crowns medium to dark gray, small, sharply outlined, round or slightly angular from top. Shadows small, pointed cylindrical to narrowly conical, often with compact, oval clusters of branches known as 'club-tops'. Canopy closed to open, often with regular stand pattern and uniform heights . . . . . *BLACK SPRUCE (PICEA MARIANA)* SWAMP (Fig. 2, 5-11, 16)... 18

18a Canopy closed, uniform height and crown size, sometimes overstocked (very densely growing) 19

18b Canopy moderately to very open, often with irregular heights and crown sizes 20

19a Good growth merchantable forests, located immediately downslope from upland, the latter indicated by some content of upland-preferring trees (see 1a). Slopes may be reflected in canopy slopes . . . . . *Black Spruce/Feather Moss* SWAMP (Fig. 7, 8)

19b Moderate to poor growth forests, often in poorly drained wet flats and depressions. Sometimes adjacent to *Black Spruce/Speckled Alder* drainageways, somewhat removed from the active drainage line . . . . . *Black Spruce/Sphagnum* SWAMP (Fig. 7)

20a Usually good growth forests, often in linear paths indicating drainage and seepage paths. Openings in canopy may reveal medium gray, rounded crowns of speckled alder . . . . . *Black Spruce/Speckled Alder* SWAMP (Fig. 6-9, 17)

20b Usually poor growth forests, merchantable to non-merchantable. In poorly drained sites and undrained depressions, sometimes adjacent to and grading into TREED BOG . . . . . *Black Spruce/Labrador-tea* SWAMP (Fig. 6-9, 17)

RESULTS

In the following paragraphs we discuss the interpretability of the formations, the subformations, and the units within each of the formations. We conclude with sections on BOG patterns, and the problem of mapping patterns and complexes.

Distinguishing between Formations and Subformations

The main units of wetlands are not all equally distinct. The sequence of formations and subformations, from most easily to least easily interpreted, is SWAMP, TREED BOG, OPEN BOG, MARSH, TREED FEN, and OPEN FEN.

SWAMP is the most easily distinguished formation owing to the distinctness of its vegetation: it consists of forested and thicketed wetlands. SWAMP is generally distinguished from upland by the flatness of the terrain, and the overwhelming predominance in it of pure stands of black spruce, with occasional stands of tamarack, white cedar, and mixtures of these species. Pure black spruce stands sometimes continue from SWAMP onto mineral soil uplands, particularly where there has been a severe fire. However, the uplands usually have detectable slopes, which distinguish uplands from the level, or level-appearing, surfaces of the SWAMP.

In work done by Ketcheson and Jeglum (1972), pure black spruce stands, plus stands of black spruce with lesser amounts of tamarack and/or white cedar, were considered "black spruce on peatland", whereas black spruce stands with some content of other species that are usually found on upland--e.g., trembling aspen, white birch, balsam fir, white spruce, and jack pine--were considered mineral soil upland sites (i.e., those with less than 30 cm peat). This assumption is not always valid, as both pure and mixed (with upland species) black spruce cover types may occur on either peatland or mineral soil upland. However, for the degree of precision required for estimating areal extent and regional distribution, this assumption is probably reasonable. Hence, we suggest for interpretive purposes that where black spruce stands have any content of broad-leaved species, balsam fir, or white spruce, such a site be regarded as mineral soil upland.

BOG is the next most easily distinguished formation after SWAMP. Difficulties may be encountered in separating *BLACK SPRUCE* CONIFER SWAMP from TREED BOG, especially when there is a gradual transition between them. However, frequently a physiographic discontinuity exists, which may correspond to an abrupt change in ground slope or in the character of the underlying peat type, which in turn is reflected in an abrupt change in tree height, canopy cover, and density. These differences have already been used by forest inventory interpreters to differentiate

between merchantable black spruce stands and treed muskeg, the former being more or less equivalent to *BLACK SPRUCE* CONIFER SWAMP, the latter to TREED BOG.

OPEN BOG is not easily distinguishable from MARSH or FEN on the basis of tone because all three units are highly variable in tonal character (Table 2). One aid in distinguishing OPEN BOG from MARSH and FEN is the location in the landscape of the wetland unit relative to the influence of mineral soil waters. BOGS are isolated, completely or almost so, from the influence of mineral soil waters. This isolation occurs especially in the centres of large peatland expanses that are well removed from upland margins and from drainage systems with distinct channels. Most larger areas of treeless peatland will be OPEN BOGS; this interpretation is even more certain if there are scattered, stunted black spruce on this peatland, or if it is bordered by TREED BOG (which is almost always dominated by black spruce). MARSHES and FENS, on the other hand, are distinctly influenced by mineral soil waters, and are found near mineral soil uplands and near the channels of active drainage systems.

Patterns are also useful in recognizing BOGS; these are dealt with in a later section on bog patterns.

MARSH is judged intermediate with respect to ease of interpretation. It has a distinct position at the margins of streams and lakes which usually have seasonally fluctuating water levels. MARSH is also frequently adjacent to THICKET. Differentiation between MARSH and OPEN FEN is difficult, as both are quite variable in tone, and both have graminoid-dominated vegetation (Table 2). MARSH and OPEN FEN are regarded as part of a continuum responding primarily to a fertility gradient. MARSH usually occurs on sites that are more nutrient-rich than FEN (Jeglum 1972, 1973). In mapping vegetation at 1:15,840 or smaller scales, it may be necessary to combine MARSH and OPEN FEN in one category. This is particularly applicable to the Northern Clay Section since the area of both types is estimated to comprise only 4% of the total area (Table 1). In other areas where MARSH and OPEN FEN are more common, and where they are oriented in zones parallel to shorelines (e.g., the Hudson Bay Lowland), they may be separated with additional ground truthing.

FENS are judged the most difficult formation to distinguish, mainly because their location in the landscape is difficult to describe, and because they usually occur as small areas in the Northern Clay Section. They are in locations influenced by mineral soil water, usually via lateral movement of water through or across them, but separated from the influence of seasonal flooding by streams and flowage lakes. FENS occur in the centres of poorly drained basins, in laggs, and along slow-flowing streams or lakes that have relatively low seasonal water level fluctuations.

The differentiation of TREED FEN from SWAMP is determined primarily by the leading dominant, tamarack in the former, black spruce in the latter. TREED FEN is relatively uncommon in the Northern Clay Section, and in the Ontario Forest Inventory cover type maps it often may have been overlooked and lumped with *BLACK SPRUCE* SWAMP. On good quality air photos, however, tamarack is readily distinguishable from black spruce because of its lighter tone (Zsilinszky 1966).

As tamarack occurs in SWAMP as well as TREED FEN, it may be difficult to distinguish between *TAMARACK* SWAMP and *TAMARACK* TREED FEN. However, the former has taller trees with tall shrubs in the understory (*Tamarack/Speckled Alder*), and is often next to *SPECKLED ALDER* THICKET in distinct drainageways. The TREED FEN has shorter trees, usually less than 10 m, with sedges and/or low shrubs in the understory, and is often next to OPEN FEN in less well-drained, but still minerotrophic, wetlands.

The distinction of TREED and OPEN subformations of BOG and FEN is based on an arbitrary choice of 10% canopy cover by trees. This level of cover is judged to be where the aspect of the vegetation, as viewed by a person standing on the ground, changes from an open to a treed condition. Field observations have shown that depths to groundwater are usually less in OPEN BOGS and FENS than in TREED BOGS and FENS; hence wetter, more saturated, and less well-aerated peats occur in the open types. TREED FEN and TREED BOG frequently occur on the margins of OPEN FEN and OPEN BOG, respectively, the treed sites having slightly higher ground surfaces and/or greater surface slopes relative to the open areas. However, in centre-dry, raised BOG, TREED BOG occupies the central position and OPEN BOG occupies the margins. The central peat dome has deeper groundwaters, and hence better aeration for tree growth, than does the margin of this type of BOG.

Distinguishing Physiognomic Groups within MARSH

The physiognomic groups DEEP and SHALLOW MARSH are obviously named on the basis of depth of standing water. Unfortunately, depth of water cannot be interpreted on conventional air photos. In addition, we cannot discern any strong floristic distinctions between these two types.

On photos, the degree of closure of the canopy and the reciprocally related cover of open water are the most useful discernible features for delimiting physiognomic groups within the MARSH formation. (In the case of low water levels it is the degree of exposure of ground surface rather than open water cover.) Since degree of canopy closure is related to the stage of development of the MARSH as well as to the depth of water, it would be more suitable to define MARSH physiognomic groups on the basis of canopy closure rather than water depth. Hence, for the air photo interpreter we propose that OPEN MARSH (roughly equivalent to DEEP MARSH) be defined as MARSH with 25% to 75% canopy cover

of all emergents. CLOSED MARSH (roughly equivalent to SHALLOW MARSH) is MARSH with $\geq$ 75% canopy cover of all emergents. (Note that canopy cover less than 25% classes a zone or site as 'shallow open water' (Zoltai et al. 1975).

One clear distinction between DEEP and SHALLOW MARSH, and MEADOW MARSH, is a decrease in height of dominants from the tall emergents in the former to shorter sedges or grasses in the latter. One can observe this height difference in Figure 3 where, at the end of the lake, a narrow zone of *CAT-TAIL* SHALLOW MARSH separates the open water from MEADOW. This distinction would be more apparent on photos of larger scale than 1:15,840. Tonal differences between MARSH and MEADOW are apparent in some instances but not in others (Fig. 3).

In some cases zones of DEEP or SHALLOW MARSH are succeeded in the landward direction by GRAMINOID FEN rather than MEADOW. An example of this is seen in Figure 3 where a floating mat with FEN dominants occurs behind a lakeside zone of MARSH. Where water fluctuation is minimal, a floating mat with FEN dominants often occurs adjacent to open water (Fig. 2).

Unfortunately, tone does not aid in differentiating MEADOW from GRAMINOID FEN, as both vary from very light to medium gray. Differences in location in the landscape may allow the separation of these two types (see Table 2). Another aid is found in the bordering shrub type. If THICKET SWAMP occurs next to and grades into the graminoid zone, the latter is probably MEADOW (e.g., Fig. 3 and 8); if LOW SHRUB FEN occurs next to the graminoid zone, the latter is probably GRAMINOID FEN (e.g., Fig. 2 and 3).

Distinguishing Physiognomic Groups within FEN

The physiognomic groups of OPEN FEN are usually distinguishable. GRAMINOID FEN generally has very light to light gray tones which are often smooth-textured, fuzzy or velvety (Fig. 2, 3, and 5). LOW SHRUB FEN, on the other hand, has medium gray tones, may be somewhat patchy or blotchy, and a distinct shrub layer may be discernible (e.g., Fig. 13). GRAMINOID FEN may also have a medium gray tone (Fig. 4 and 5), but the usually smooth texture serves to separate it from LOW SHRUB FEN.

An additional physiognomic group should be added to TREED FEN in the Jeglum et al. (1974) classification (Appendix A), viz., SHRUB-RICH TREED FEN, as this type does occur in the area (Fig. 2). This would parallel the LOW SHRUB FEN subdivision of OPEN FEN. The type of TREED FEN may be interpreted from the tone of the openings between the tree crowns--light gray for sedge-dominated and medium gray for low shrub-dominated. In addition, understory of a particular TREED FEN may be inferred from the type of adjacent OPEN FEN. For example, the fact that LOW SHRUB FEN is next to the TREED FEN in Figure 2 suggests that the latter is SHRUB-RICH TREED FEN. It should be added, however, that

interpretation below the level of TREED FEN is not important in the Northern Clay Section since its occurrence is minimal (Table 1).

SPHAGNUM-RICH TREED FEN, although an intergrade between TREED FEN and TREED BOG, is placed in TREED FEN because of the dominance of tamarack. This physiognomic group is not distinguishable from the GRAMINOID-RICH TREED FEN on the photos.

Distinguishing Physiognomic Groups, Dominance Types, and Site Types within SWAMP

The differentiation of physiognomic groups, THICKET and CONIFER SWAMP, is easy (Tables 2 and 3)[2]. THICKET is dominated mainly by *SPECKLED ALDER* but it also includes some *WILLOW* dominance types. *SPECKLED ALDER* occurs in well-drained locations and cutovers where minimal water level fluctuations occur, whereas *WILLOW* occurs in locations with poorer drainage and greater water level fluctuations. Separation of *ALDER* THICKET and *WILLOW* THICKET was not attempted. THICKET also develops on moist to wet abandoned fields and pastures, and on clearcut SWAMPS as a pioneer seral stage. Separation of upland from wetland THICKET is made on the basis of topographic positioning (see separation of uplands and wetlands in Table 3).

Separation of SWAMP according to dominance by *BLACK SPRUCE*, *WHITE CEDAR*, and *TAMARACK* has been dealt with in detail by Zsilinszky (1966), and the main distinguishing features are summarized in Tables 2 and 3. Black spruce has dark to medium gray tones; canopies which vary from closed to open, usually uniform in height, and often regular in pattern; and crowns that are small and round or slightly jagged. Tamarack is distinguished mainly by its very light gray tones, much lighter than those of other conifers. White cedar is variable in tone, but usually has medium gray tones intermediate between those of tamarack and black spruce. It has canopies which are closed to open, usually shorter than those of the other two species, highly irregular and variable in crown shape, and sometimes with scattered, overtopping conifers or hardwoods.

The vegetational appearance, location in the landscape, and photo image characteristics of site types of *BLACK SPRUCE* SWAMP are summarized in Tables 2 and 3. In our judgment these site types are not distinguishable with sufficient accuracy in air photos with a scale of 1:15,840, for two reasons. First, the canopy characteristics and physiography of the site types are not distinct enough, and these features intergrade and overlap among the site types, which have been classified on the basis of the dominant species of the understory (shrubs or ground cover vegetation). Second, in many areas the mixing of site types is so

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[2] Although *BLACK ASH* HARDWOOD SWAMPS are found in the Northern Clay Section, their occurrence is so limited that a consideration of their distinguishing characteristics is not warranted.

intricate that it is impractical to interpret specific site types. In some areas, however, physiographic conditions are sufficiently uniform over broad areas that individual site types can be interpreted and mapped if one has good ground truthing for the area.

It may, however, be possible to recognize two general site types: i) *Black Spruce/Speckled Alder*, and ii) a combined unit including *Black Spruce/Feather Moss*, *Black Spruce/Labrador-tea*, and *Black Spruce/Sphagnum*. *Black Spruce/Speckled Alder* is the most distinct of the four site types, owing to its occurrence in drainageways or seepageways, and its tall but moderately open tree canopies (Fig. 6-9, 17). The other site types (Fig. 6-9, 17) are less readily distinguished and could be combined.

Distinguishing Physiognomic Groups within BOG

SPHAGNUM BOG and GRAMINOID BOG are difficult to differentiate because they are both so variable in tone, ranging from very light to medium gray, and have no tall vegetation to aid the interpreter in recognizing them (Fig. 11, 14, 16-19). At times the two groups can be readily differentiated (e.g., Fig. 11). At other times it is not clear even on the ground which of the two groups the site belongs to; determining the degree of graminoid cover separating the two groups, and even obtaining a good estimate of graminoid cover, are problems that have not been resolved. Indeed, a great deal of vegetational and ecological variability is included in both these groups and the use of physiognomy may not be the best basis for subdivision of OPEN BOG, especially the SPHAGNUM and GRAMINOID BOG groups.

LOW SHRUB BOG is usually medium gray, has light gray blotches, and often contains scattered black spruce seedlings or stunted trees (e.g., Fig. 11-13). This seems to be a more homogeneous group in terms of physiognomy and ecological characteristics, but here, too, intermediate sites between LOW SHRUB and GRAMINOID BOG are found that are difficult to classify even on the ground. For example, the *Leather-leaf/Carex limosa/Sphagnum* LOW SHRUB BOG might be better combined, in terms of ecological status, with all sites that are rich in *Carex limosa*, rather than with the *Leather-leaf/Sphagnum fuscum* LOW SHRUB BOG.

The physiognomic groups within TREED BOG are differentiated by the tones of the understory appearing between the tree crowns. The sedges dominant in GRAMINOID-RICH TREED BOG are very light to light gray (mainly *Carex oligosperma*, *C. exilis*, and *C. pauciflora*) (Fig. 8, 13, and 16). Medium to dark gray tones indicate SHRUB-RICH TREED BOG (Fig. 6, 8, 11, 13, 14, and 16). The dark tones are contributed by leather-leaf and *Sphagnum fuscum*. Although the tonal qualities of *Leather-leaf/Carex limosa* LOW SHRUB BOG, and *CAREX LIMOSA* GRAMINOID BOG, are similar to SHRUB-RICH TREED BOG, these units are readily distinguished by the nil to scant tree cover for the LOW SHRUB and GRAMINOID BOGS, and the 10%-40% tree cover for the SHRUB-RICH TREED BOG.

Bog Patterns

The photo images for both OPEN and TREED BOGS contain patterns that may aid in identifying them. Patterns in BOGS can reflect various combinations of all the physiognomic groups, including BOG POOLS.

There are three distinct types of patterns in BOGS: ridge and swale patterns, with ribbed and reticulate subtypes, oriented crosswise to the lateral movement of water (Fig. 11, 14, and 16); patchy or blotchy patterns, comprised of hummocks and hollows with different-toned dominants (Fig. 5, 8, 9, 12, 13, and 18); and radiating patterns, comprised of treed ridges and sparsely treed or open seepages radiating outwards from a raised bog cupola or crest, like spokes of a wheel, or like palmate or pinnate venation of leaves (Fig. 17). The ribbed subtype of the ridge and swale pattern can be further described as having either long continuous ridges (Fig. 14), or short ridges with elliptic and crescentic shapes, often arranged concentrically in raised BOGS (Fig. 11 and 16). Long continuous ridges seem to be found in relatively narrow drainageways and valleys where lateral surface and subsurface water movement is distinct; short ridges and reticulate patterns are found in broad valleys and raised BOGS where lateral water movement is less distinct; and patchy and blotchy patterns are found in basins and flat-surfaced raised BOGS where lateral water movement is very weak or nil.

In the Northern Clay Section, patterns do not occur in FENS as they do in more northerly regions of Ontario (e.g., Sjörs 1959, 1963). In addition, patchy or blotchy patterns seem more distinct in BOGS than in FENS or MARSHES (e.g., Fig. 5). However, it should be noted here that the term BOG as used in this report includes weakly minerotrophic, transitional BOGS, regarded as "poor fen" by Sjörs (1959, 1963). If we use Sjörs' concepts, then some of the patterns, viz., the long ridges and swales (Fig. 14) and the blotchy patterns (Fig. 5), do occur in poor fen.

A good example of the mottled or blotchy pattern is shown in Figure 5. The wetland basin in the photo is occupied mainly by GRAMINOID FEN, but it also has a zone of OPEN BOG on its southern margin. This margin receives nutrient-poor, acidic water that is draining from the adjacent raised BOG into the basin. The process here is invasion of BOG over the FEN. The BOG zone consists of a complex mixture of the three physiognomic groups--LOW SHRUB, GRAMINOID, and SPHAGNUM BOG, in descending order of areal coverage. The medium gray tones characterize LOW SHRUB BOG (leather-leaf and *Sphagnum fuscum* are dominants and both yield medium gray tones), and some patches of *CAREX LIMOSA* GRAMINOID BOG. The light gray patches are *Carex oligosperma/Sphagnum fallax* GRAMINOID BOG and *SPHAGNUM CUSPIDATUM* SPHAGNUM BOG.

Another example of the patchy or blotchy pattern in BOGS is one of the BOG types reported on by Boissonneau and Jeglum (1976) and shown

as LOW SHRUB BOG in Figure 18. Its medium gray tone reflects the main dominants--leather-leaf and *Carex limosa*. Small pockets of *Sphagnum majus* and *Drepanocladus* species also contribute to the medium tones. (The presence of these latter species definitely suggests that this zone is weakly minerotrophic.) Light gray patches in this zone were caused by *Carex oligosperma* and *Sphagnum fallax*. Hence, although the type is judged to be a LOW SHRUB BOG, it also has an important component of GRAMINOID BOG types.

The vegetation in the example above is similar to that found for a *CAREX LIMOSA* GRAMINOID BOG on the margins of the valley BOG with ridges and swales in Figure 14 (Plot No. 9). The medium gray tone in this latter site was caused by the *Carex limosa*, small amounts of leather-leaf, and sphagnum which seemed to have been stained, perhaps by dissolved minerals or silt carried in the groundwater at the margins of the drainageway. A similar medium-to-dark gray tone is seen in Figures 15 and 16 as streaks below the road which crosses the BOG. These streaks suggest that water moves unilaterally in this BOG. The darker gray tones of the streaks may be explained by increased growth of species such as *Carex limosa* and leather-leaf, and also by staining of the sphagnum by the minerals derived from the road fill (soil spread onto a corduroy log road).

Circular features were observed in several of the BOG areas (Fig. 15-17). These were relatively distinct features, but other less distinct circular features also occur in the photos. Usik (1966) briefly reported on circular features in the Moose River District of Ontario, noting that the lighter toned circular features were dominated by tamarack, whereas the darker toned areas surrounding these were black spruce dominated. In our observations, the light tones are caused mainly by field layer vegetation, and are areas richer in sedges, particularly *Carex oligosperma*, than the surrounding areas which are richer in darker toned species such as leather-leaf and *Carex limosa*. The classification of these sedge-rich rings is either GRAMINOID BOG (Fig. 17) or GRAMINOID-RICH TREED BOG (Fig. 16), depending on the amount of tree cover.

[The cause of these 'sedge rings' is not known. It is possible that they are vigorous colonies of a dominant, such as *Carex oligosperma*, which occur at random with no particular relation to environmental causes. This may account for some of the indistinct rings, but others seem too distinct to be explained in this way. Other possible explanations are as follows: i) they are the vegetational expression of an underlying ore body, which gives rise to a localized ionic diffusion halo (Usik 1966); ii) they are slight depressions in the ground surface that are wetter and possibly slightly more nutrient-rich than the surrounding area, and hence have more lush sedge development; iii) they are relict thaw features from an earlier, colder, post-glacial period, such as collapsed palsas or small pockets of thaw in permafrost.]

Mapping of Patterns and Complexes

Mapping units will sometimes have to consist of combinations of wetland units, because it is impractical to map the smallest units distinguishable. In map units with more than one constituent element, it should be indicated whether the elements are arranged as a pattern or as a complex. It is suggested that for wetland mapping, a pattern is a regular or irregular combination of wetland units, usually within one formation; a complex is a regular or irregular arrangement of wetland units with two or more formations (cf. 'mire complex' Sjörs 1948) (see definitions, Appendix C).

When a map unit consists of a pattern within a formation, the predominant subformation or formation should be used to name it, and it should be subscripted with "patt" followed by the component physiognomic groups in order of decreasing cover. For example, the central upper part of the raised BOG in Figures 4 and 11 is OPEN BOG $_{patt}$ SPHAGNUM BOG + SHRUB-RICH TREED BOG + BOG POOL (OB_{patt} SB + STB + BP). The central part of the BOG in Figures 15 and 16 is TREED BOG $_{patt}$ SHRUB-RICH TREED BOG + SPHAGNUM BOG (TB_{patt} STB + SB). Figure 5 demonstrates OPEN BOG $_{patt}$ LOW SHRUB BOG + GRAMINOID BOG + SPHAGNUM BOG (OB_{patt} LSB + GB + SB).

If there is more than one formation in a unit the next higher unit of OPEN or TREED WETLAND, or simply WETLAND, may be used, followed by "comp" and the constituent formations or subformations. For example, the basin complex in Figure 19 is OPEN WETLAND comp MARSH + OPEN FEN + OPEN BOG (OW_{comp} M + OF + OB).

In both cases of patterns and complexes it may be useful to give estimates of percentages of cover of the constituent units.

DISCUSSION

From this study we conclude that the emphasis of the wetland classification (Jeglum et al. 1974) on physiognomy and dominance is well suited to the original requirement for the units to be interpretable from air photos. Black and white photos of the Forest Resource Inventory (scale 1:15,840) can be interpreted, with little additional ground truthing, to the levels of formation and subformation for BOG, FEN, MARSH, and SWAMP. With some minimal ground truthing, interpretation can easily be done to the level of physiognomic groups.

If the initial mapping and interpretation are followed by more intensive field checks and subsequent refinement of map units, the interpreter can undoubtedly interpret to lower, more detailed levels of the wetland classification. For example, a study of wetland mapping by

Boissonneau and Jeglum (1976) for an area located 72 km northwest of Timmins, in the Northern Clay Section (Fig. 17 and 18 in this study), concluded that for BOG types it is possible to map to the most detailed level of the classification, namely the site type level, from black and white photos at the scale of 1:15,840. This study included one day of intensive helicopter ground truthing, which allowed for detailed classification of the mapped units.

For SWAMP, interpretation is already being carried down to the dominance type (cover type) level, and even to subunits (stands) within these, on the basis of similar tree density and height features (Jenns 1965). An additional distinction that we feel should be made more definite in mapping programs is that between SWAMP (WETLANDS) and mineral soil uplands. These are treated quite differently operationally (winter versus summer cut), and have quite different silvicultural problems (e.g., Fraser et al. 1976). Hence, it is very important that attempts be made to separate them in mapping.

It is doubtful that site types of *BLACK SPRUCE* CONIFER SWAMP can be consistently identified and mapped at the 1:15,840 scale. At larger scales it would be possible to map finer site types, but at the level of forest management presently practised, it is probably impractical to map such detail in pre-cut mapping. It is more realistic to use the present forest inventory stands that are mapped at 1:15,840, and to treat them according to their constituent site types. The manager could classify, and possibly subdivide the mapped stands, according to the site types proposed in our classification. The stand could then be treated according to the predominant site type, or even differentially according to constituent types, in reforestation and silvicultural programs.

The formations and subformations are not equally distinguishable. The most difficult to separate are MARSH and OPEN FEN. In this regard it may be necessary in mapping to establish a combined MARSH-FEN main unit. The physiognomic groups of such a unit could be OPEN MARSH, CLOSED MARSH, SEDGE MEADOWS and FENS, LOW SHRUB FEN, and TREED FEN.

A three-part division of wetlands is suggested in other literature for boreal regions (e.g., Dansereau and Segadas-Vianna 1952; Jeglum 1972), and a recent study on peat nutrient contents for units of this classification (Stanek et al. 1977) suggests that FEN and MARSH are the most closely related of the four formations.

On the other hand, FEN and MARSH units are more distinct in areas of extensive zonations of graminoid-dominated wetlands, such as the Hudson Bay Lowland and around large lakes. In addition, MARSH is the prevailing graminoid type in prairie and deciduous forest regions, whereas FEN prevails in boreal regions. Hence, for the present we advocate maintaining MARSH and FEN as formations, at least until such time as more studies on wetland mapping are done.

Within formations there will be patterns of vegetation types which could be combined into units of a higher order of classification based on surface morphology, basin morphology, and location in the landscape (Zoltai et al. 1975). For example, there are a number of morphological BOG types such as raised BOG, basin BOG, and valley BOG (see Appendix C). However, a discussion of these types is not within the scope of this report, which is limited to the interpretability of the vegetationally defined units of the classification by Jeglum et al. (1974).

CONCLUSIONS

Forest managers are becoming increasingly involved in planning other uses for forest lands in their jurisdictions, e.g., recreation, wildlife, peat deposits, etc. Since the Ontario Forest Resource Inventory is the only detailed operational mapping program for forest lands, it seems logical that the wetlands should be classified in the most useful way possible for resource managers.

The present system of classifying wetlands used by the Forest Resource Inventory provides only the broadest of units (Table 1) and a number of these have limited ecological meaning. Our classification provides a vegetationally based approach for classifying wetlands that is compatible with the Forest Resource Inventory approach of mapping forest cover types on the basis of dominant tree species. What is more important, our classification provides the resource manager with easily recognized and ecologically meaningful units.

In our opinion, this classification has been sufficiently developed and tested to allow the Forest Resource Inventory to incorporate some parts of it into their current photo interpretation and mapping program in Ontario. As a minimum we recommend the recognition and mapping to the formation and subformation levels. The conversion to and adoption of our system would require a period of orientation for photo interpreters, but this could be accomplished fairly easily and quickly.

In some cases mapping to the physiognomic group may be found to be useful. For forest sections other than the Northern Clay Section, where our intensive field surveys were done, some additional field work and ground truthing will be required. Undoubtedly it will become necessary for others in different areas to recognize new physiognomic groups, patterns and complexes, permafrost features, etc. However, we believe our classification will provide a useful foundation for developing units appropriate to these areas.

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APPENDICES

APPENDIX A

Outline of wetland vegetation in the Northern Clay Section, from Jeglum et al. (1974). Key to hierarchical levels: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, 5 - site type

1 MARSH

3 DEEP MARSH

4 *ELEOCHARIS PALUSTRIS (MARSH SPIKE-RUSH)*
4 *EQUISETUM FLUVIATILE (WATER HORSETAIL)*
4 *GLYCERIA BOREALIS (SMALL FLOATING MANNA-GRASS)*
4 *PHRAGMITES COMMUNIS (REED)*
4 *SCIRPUS ACUTUS (HARD-STEM BULRUSH)*
4 *SCIRPUS RUBROTINCTUS (RED-SHEATHED BULRUSH)*
4 *TYPHA LATIFOLIA (BROAD-LEAVED CAT-TAIL)*

3 SHALLOW MARSH

4 See dominance types for DEEP MARSH

3 MEADOW (MEADOW MARSH)

4 *CALAMAGROSTIS CANADENSIS (BLUE-JOINT)*
4 *CAREX AQUATILIS (AQUATIC SEDGE)*
4 *CAREX LACUSTRIS (LAKE SEDGE)*
4 *CAREX ROSTRATA (BEAKED SEDGE)*
4 *CAREX STRICTA (TUSSOCK SEDGE)*
4 *CAREX VESICARIA (INFLATED SEDGE)*
4 *SCIRPUS CYPERINUS (COMMON WOOL-GRASS)*

1 FEN

2 OPEN FEN

3 GRAMINOID FEN

4 *CAREX FLAVA (YELLOW SEDGE)*
4 *CAREX LASIOCARPA (VILLOSE SEDGE)*
4 *RHYNCHOSPORA ALBA (WHITE BEAK-RUSH)*
4 *SCIRPUS HUDSONIANUS (HUDSONIAN CLUB-RUSH)*

3 LOW SHRUB FEN

4 *BETULA GLANDULOSA var. GLANDULIFERA (GLANDULAR BIRCH)*
4 *CHAMAEDAPHNE CALYCULATA (LEATHER-LEAF)*
4 *MYRICA GALE (SWEET GALE)*
4 *SPIRAEA ALBA (WHITE MEADOW-SWEET)*

(continued)

Outline of wetland vegetation in the Northern Clay Section, from Jeglum et al. (1974). Key to hierarchical levels: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, 5 - site type

2 TREED FEN

3 GRAMINOID-RICH TREED FEN

4 *LARIX LARICINA (TAMARACK)*

5 *Tamarack/Aquatic Sedge*
5 *Tamarack/Villose Sedge*

3 SPHAGNUM-RICH TREED FEN

4 *LARIX LARICINA (TAMARACK)*

5 *Tamarack/Sphagnum*

1 SWAMP

3 THICKET (THICKET SWAMP)

4 *CORNUS STOLONIFERA (RED-OSIER DOGWOOD)*
4 *ALNUS RUGOSA (SPECKLED ALDER)*
4 *BETULA GLANDULOSA var. GLANDULIFERA (GLANDULAR BIRCH)*
4 *SALIX BEBBIANA (BEAKED WILLOW)*
4 *SALIX PLANIFOLIA (FLAT-LEAVED WILLOW)*
4 *SALIX PYRIFOLIA (BALSAM-WILLOW)*

3 HARDWOOD SWAMP

4 *FRAXINUS NIGRA (BLACK ASH)*
4 *POPULUS BALSAMIFERA (BALSAM POPLAR)*
4 *POPULUS TREMULOIDES (TREMBLING ASPEN)*
4 *ULMUS AMERICANA (AMERICAN ELM)*

3 CONIFER SWAMP

4 *LARIX LARICINA (TAMARACK)*

5 *Tamarack/Speckled Alder*

4 *PICEA MARIANA (BLACK SPRUCE)*

5 *Black Spruce/Speckled Alder*
5 *Black Spruce/Feather Moss*
5 *Black Spruce/Labrador-tea*
5 *Black Spruce/Sphagnum*

(continued)

APPENDIX A (concluded)

Outline of wetland vegetation in the Northern Clay Section, from Jeglum et al. (1974). Key to hierarchical levels: 1 - formation, 2 - subformation, 3 - physiognomic group, 4 - dominance type, 5 - site type

4 *THUJA OCCIDENTALIS (EASTERN WHITE CEDAR)*

1 BOG

2 OPEN BOG

3 SPHAGNUM BOG

4 *SPHAGNUM CUSPIDATUM*
4 *SPHAGNUM FALLAX*
4 *SPHAGNUM MAGELLANICUM*
4 *SPHAGNUM PALUSTRE*
4 *SPHAGNUM RUBELLUM*

3 GRAMINOID BOG

4 *CAREX EXILIS (STARVED SEDGE)*
4 *CAREX LIMOSA (MUD SEDGE)*
4 *CAREX OLIGOSPERMA (FEW-SEEDED SEDGE)*
4 *CAREX PAUCIFLORA (PAUCIFLOROUS SEDGE)*
4 *CAREX PAUPERCULA (STUNTED SEDGE)*
4 *ERIOPHORUM SPISSUM (DENSE COTTON-GRASS)*
4 *SCHEUCHZERIA PALUSTRIS (SCHEUCHZERIA)*

3 LOW SHRUB BOG

4 *CHAMAEDAPHNE CALYCULATA (LEATHER-LEAF)*
4 *LEDUM GROENLANDICUM (LABRADOR-TEA)*

2 TREED BOG

3 GRAMINOID-RICH TREED BOG

4 *PICEA MARIANA (BLACK SPRUCE)*

5 *Black Spruce/Few-seeded Sedge*
5 *Black Spruce/Dense Cotton-grass*

3 SHRUB-RICH TREED BOG

4 *PICEA MARIANA (BLACK SPRUCE)*

5 *Black Spruce/Leather-leaf*

APPENDIX B

Alphabetical list of symbols and the wetland types which they represent (see Tables 2 and 3; Figures 2-19)

B--BOG

BP--BOG POOL

BS--*BLACK SPRUCE (PICEA MARIANA)*

BS/FM--*Black Spruce/Feather Moss*

BS/LT--*Black Spruce/Labrador-tea*

BS/SA--*Black Spruce/Speckled Alder*

BS/SPH--*Black Spruce/Sphagnum*

CS--CONIFER SWAMP

DM--DEEP MARSH

F--FEN

FP--FEN POOL

GB--GRAMINOID BOG

GF--GRAMINOID FEN

GTB--GRAMINOID-RICH TREED BOG

LSB--LOW SHRUB BOG

LSF--LOW SHRUB FEN

M--MARSH

MM--MEADOW (MEADOW MARSH)

OB--OPEN BOG

OF--OPEN FEN

OW-OPEN WETLAND

S--SWAMP

SB--SPHAGNUM BOG

SM--SHALLOW MARSH

STB--SHRUB-RICH TREED BOG

TA--*TAMARACK (LARIX LARICINA)*

TA/SA--*Tamarack/Speckled Alder*

TB--TREED BOG

TF--TREED FEN

TS--THICKET (THICKET SWAMP)

U--UPLAND

WC--*WHITE CEDAR (THUJA OCCIDENTALIS)*

APPENDIX C

Glossary of selected terms

Basin BOG: A BOG occurring in a depression, having a concave or flat surface and hydrotopography, with slight water movement toward the centre of the basin, or virtually no lateral movement. May occur filling the central area of the basin, or as a ring-shaped mat around a centrally located lake. Weakly minerotrophic or ombrotrophic (e.g., see Fig. 19).

Basin FEN: A FEN occurring in a basin, having a concave or flat surface and hydrotopography, with water movement toward the centre of the basin or virtually no lateral water movement. Minerotrophic (e.g., see Fig. 5).

Beaver channel: A linear, water-filled canal, usually less than 1 m wide, excavated by beavers through peatland or wetland. It is probably built as a route for safe travel, as well as for transporting their wood materials.

Beaver meadow: Open wetland type that occurs around an active beaver pond, or that has invaded an area once occupied by a beaver pond. Usually of the MEADOW MARSH physiognomic group (e.g., see Fig. 8).

Blotchy: Having or marked with blotches, which are spots or marks differing in tone from the surrounding area, especially when large or irregular (Anon. 1971). Similar to patchy. This pattern is best developed in BOG, but is also found in FEN and MARSH (see Table 2, also Fig. 5, OB_{patt}).

Bumpy: Having or exhibiting raised protuberances (Anon. 1971); closely packed, raised, more or less rounded objects, such as the appearance conveyed by a surface of pebbles (e.g., see Fig. 2, 3).

BOG: "Bogs are peat-covered areas or peat-filled depressions with a high water table and a surface carpet of mosses, chiefly *Sphagnum*. The water table is at or near the surface in the spring, and slightly below during the remainder of the year. The mosses often form raised hummocks, separated by low, wet interstices. The bog surface is often raised, or if flat or level with the surrounding wetlands, it is virtually isolated from mineral soil waters. Hence the surface bog waters and peat are strongly acid and upper peat layers are extremely deficient in mineral nutrients. Peat is usually formed in situ under closed drainage, and oxygen saturation is very low. Although bogs are usually covered with *Sphagnum*, sedges may grow on them. They may be treed or treeless, and they are frequently characterized by a layer of Ericaceous shrubs." (Zoltai et al. 1975.)

(continued)

Brown mosses: An ecological group of species that are nutrient-demanding, occur in FENS, and are often brown in color. Includes such species as *Aulacomnium palustre*, *Campylium stellatum*, *Drepanocladus exannulatus*, *D. revolvens*, *Tomenthypnum nitens*, *Scorpidium scorpioides*, *Paludella squarrosa*, and *Calliergon giganteum*, and some of the more nutrient-demanding *Sphagnum* species such as *S. subsecundum*, *S. teres*, and *S. warnstorfii* (references cited in Jeglum et al. 1974).

Canopy closure (Zsilinszky 1966):

closed crown
(crowns touching)

open crown

scattered crown

Clumped: Consisting of groups of things clustered together, compact masses, closely compact groups or lumps (Anon. 1971). Often used in reference to alder or willow shrubs, often consisting of a number of clustered stems (e.g., see Fig. 2, 3).

Complex: Sjörs (1948) describes "mire [peatland] complex" as a combination of FEN and BOG types. For this report we extend the meaning to include any unit consisting of two or more of our four formations, BOG, FEN, MARSH, and SWAMP (e.g., see Fig. 19).

Crescentic: Resembling or suggesting a crescent, which is the shape or figure defined by a convex or a concave edge (Anon. 1971) (e.g., see Fig. 11, 16).

Crown shape: The shape of the crowns of trees and tall shrubs. The terms used in this paper (adapted from Zsilinszky 1966) are as follows:

Side or Oblique Views

conical or
pyramidal

convex
conical

concave
conical

pointed
cylindrical

(continued)

Side or Oblique Views (cont'd)

pointed oval | oval | spherical

Top Views

jagged | round | crenated

Ericaceous: Plant species belonging to the family Ericaceae, a family of low shrubs, often with leathery, evergreen leaves (Anon. 1971).

FEN: "Fens are peatlands characterized by surface layers of poorly to moderately decomposed peat, often with well decomposed peat near the base. They are covered by a dominant component of sedges, although grasses and reeds may be associated in local pools. *Sphagnum* is usually subordinate or absent, with the more exacting shrub cover mosses being common. Often there is much low to medium height shrub cover and sometimes a sparse layer of trees. The waters and peats are less acid than in bogs of the same area, and sometimes show somewhat alkaline reactions. Fens usually develop in restricted drainage situations where oxygen saturation is relatively low and mineral supply is restricted. Usually very slow internal drainage occurs through seepage down very low gradient slopes, although sheet surface flow may occur during spring melt or periods of heavy precipitation." (Zoltai et al. 1975).

Fuzzy: Having a furry or downy appearance; lacking in clarity or definition; indistinct in outline, not in focus, blurred (Anon. 1971). Similar to smooth and velvety (e.g., GF, fig. 2, 3).

Graminoid: Resembling or relating to grasses; with grassy appearance (Anon. 1971); includes grasses, reeds, rushes, sedges and horsetails.

Lagg: "A Swedish term denoting the zone where the water collects at the margin of a peatland near the mineral ground of the surrounding upland. The water is relatively rich in bases and supports a eutrophic type of vegetation, with the communities resembling those of a fen." (Stanek 1977).

MARSH: "Marshes are grassy wet areas, periodically inundated up to a depth of 2 meters or less with standing or slowly moving water. Surface water levels may fluctuate seasonally, with declining levels exposing drawdown zones of matted vegetation or mud flats. Marshes are subject to a gravitational water table but water remains within the rooting zone of plants during at least part of the growing season. The substratum usually consists of mineral or organic soils with a high mineral content, but there is little peat accumulation. Waters are usually circumneutral to alkaline, and there is a relatively high oxygen saturation. Marshes characteristically show zonal or mosaic surface patterns of vegetation, comprised of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent nonwoody plants such as rushes, reeds, reedgrasses and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish." (Zoltai et al. 1975).

Mineral soil water: Water that has percolated through or over mineral soil, and has dissolved in it varying quantities of mineral ions derived from the mineral soil (Sjörs 1948).

Minerotrophic: Nourished by mineral soil. Receiving varying quantities of water and nutrients from the mineral soils surrounding or underlying the peatland. In percolating through or over the mineral soil, mineral ions are dissolved in and carried on by the water (Sjörs 1959).

Mottled: Marked with spots of different tones; dappled, spotted (Anon. 1971). Similar to stippled. This pattern is best developed in BOG having scattered black spruce (e.g., see Fig. 18).

Ombrotrophic: Rain-nourished. Receiving water and nutrients only from precipitation. The scarcity of metal ions in the water of precipitation, and the fact that acids are always formed in peats, leads to strongly acid and very nutrient poor conditions, both of the water and of the peat, in most ombrotrophic peatlands (Sjörs 1959).

Patchy: Having patches, which are circumscribed regions differing in tone from the surrounding area (Anon. 1971). Similar to blotchy. This pattern is best developed in BOG, but is also found in FEN and MARSH (see Table 2, also Fig. 5, OB_{patt}).

(continued)

Pattern: "In a photo image, the regularity and characteristic placement of tones or textures. Some descriptive adjectives for patterns are *regular, irregular, random, concentric, radial,* and *rectangular*" (Anon. 1960). We also have used the adjectives *blotchy* (q.v.), *patchy* (q.v.), *crescentric* (q.v.), *linear, parallel, reticulate* (q.v.) and *ribbed* (q.v.), and the nouns *ring* (q.v.), *streak* (q.v.), *ridge* and *swale* (q.v.) to describe patterns. For purposes of clarity, we suggest using the term pattern for regular or irregular variation within one of our four formations--BOG, FEN, MARSH, or SWAMP (see Complex).

Peat: "A layer of the Earth's crust, consisting largely of organic residues, originating under more or less water-saturated conditions through the incomplete decomposition of plant and animal constituents due to anaerobic conditions, low temperatures, or other complex causes" (Heinselman 1963). See Peatland.

Peatland: "Generic term including all classes of peat-covered terrain. Many peatlands are in fact a complex of swamps, bogs and fens. Equivalent to Sjörs 'mire complex'" (Heinselman 1963). "In the north an arbitrary depth limit (of 8 to 12 in.) often must be invoked to separate peat from raw humus" (ibid.). In Europe, 40 cm (16 in.) has also been used to separate peatland from non-peatland (Sjörs 1948). See Peat.

Raised BOG: A BOG occurring in a valley or basin having its surface and hydrotopography raised in relation to surrounding minerotrophic wetlands, with radial water movement out of the BOG. The surface of the raised BOG may be distinctly domed, flat, or slightly centre-depressed (in relation to its margins). Ombrotrophic (e.g., see Fig. 7).

Reticulate: The type of ridge and swale patterns in which the ridges are netlike in pattern, circumscribing swales which are still somewhat elongated or diamond-shaped and oriented crosswise to the direction of water movement. Usually found where unilateral water movements are weak, or where two water tracks are converging into one (e.g., see Fig. 11, 16).

Ribbed: The type of ridge and swale pattern which has relatively long parallel ridges and swales. Usually found where unilateral water movements are more distinct (e.g., see Fig. 14).

Ridge and swale pattern: Elongated raised ridges alternating with depressed swales. Similar to "Strangmoor" (string peatlands) and "Aapamoor" of European authors. Have also been called "ripplemark patterns", "patterned fen", and "string bog" by various North American authors. Consists of ribbed (q.v.) or reticulate (q.v.) variants.

(continued)

Ring pattern: A circular feature. The example in this report is the "sedge ring" patterns in BOG (e.g., Fig. 15-17).

Smooth: Having a continuously even surface, without roughness, points, bumps, or ridges; regarding a reflective surface, having surface irregularities small compared with the wavelength of the reflected radiation (Anon. 1971). Similar to fuzzy and velvety (e.g., GF, Fig. 2, 3).

Stippled: Dotted, spotted, speckled (Anon. 1971). Similar to mottled. This pattern is best developed in BOG having scattered black spruce (e.g., see Fig. 18).

Streak: An irregular strip or line of contrasting tone and/or texture differing from and usually darker than the surrounding area (Anon. 1971) (e.g., see Fig. 14, 16).

SWAMP: "Swamps are wooded wetlands where standing to gently flowing waters occur seasonally or persist for long periods on the surface. Frequently there is an abundance of pools and channels indicating subsurface water flow. The substrate is usually continually water-logged. Waters are circumneutral to moderately acid in reaction, and show little deficiency in oxygen or in mineral nutrients. The substrate consists of mixtures of transported mineral and organic sediments, or peat deposited in situ. The vegetation cover may consist of coniferous or deciduous trees, tall shrubs, herbs and mosses. In some regions *Sphagnum* may be abundant" (Zoltai et al. 1975).

Texture: "In a photo image, the frequency of change and arrangement of tones. Some descriptive adjectives for textures are *fine*, *medium* or *coarse*, and *stippled* [q.v.] or *mottled* [q.v.]" (Anon. 1960). Zsilinszki (1966) used descriptive terms such as *smooth* (q.v.), *fuzzy* (q.v.), *fluffy* and *soft blanket-like*; and Morris and Meyer (1954) used *velvety* (q.v.). Texture grades into pattern as the constituent elements of an image become larger than dots, spots, or grains.

Tone: "Each distinguishable shade variation from black to white" (Anon. 1960). We use the descriptive terms, *black*, *dark gray*, *medium gray*, *light gray*, *very light gray*, and *white*.

Valley BOG: A BOG occurring in a valley, having a concave or flat surface and hydrotopography across its width, with water movement unilateral along its length (as well as toward its centre from the margins when it is concave). Weakly minerotrophic or ombrotrophic (e.g., see Fig. 14).

(continued)

Velvety: Having the character of velvet; soft and smooth (to the sight in this case) (Anon. 1971). Similar to fuzzy and smooth (e.g. GF, Fig. 2 and 3).

Wetland: Land in which the groundwater level is close to the surface (Sjörs 1948) during much of the growing season. Depth to groundwater usually 50 cm or less, but during droughty periods may be much deeper. Peat tends to accumulate in wetlands, owing to incomplete decomposition in these wet, poorly aerated sites. Wetland is a broader concept than peatland, including wet sites that have not as yet accumulated enough peat to be regarded as peatland. All boreal peatlands are regarded as wetlands.

APPENDIX D

Vegetation and habitat data sampled along transects

For plots sampled along transects in the ecological survey by the senior author, we present actual ground data for comparison with the air photo images. This will be useful to the wetland expert in assessing the characteristics of the classification units used in this report. To facilitate comparisons we have assigned the same figure numbers to the air photos and their corresponding ground transect diagrams, with letters to distinguish the latter, as follows:

Air photo	Ground transect diagrams
Figure 6	Figure 6a. Vegetation. Figure 6b. Habitat.
Figure 8	Figure 8a. Vegetation, Line 1. Figure 8b. Habitat, Line 1.
Figure 8	Figure 8c. Vegetation, Line 2. Figure 8d. Habitat, Line 2.
Figure 9	Figure 9a. Vegetation. Figure 9b. Habitat.
Figure 11	Figure 11a. Vegetation. Figure 11b. Habitat.
Figure 13	Figure 13a. Vegetation. Figure 13b. Habitat.
Figure 16	Figure 16a. Vegetation. Figure 16b. Habitat.

In the transect diagrams for vegetation, only those species achieving 10% cover or more in one plot are included. Chemical and electrochemical data are for water samples collected at the time of sampling from natural pools or shallowly dug pits in the plots.

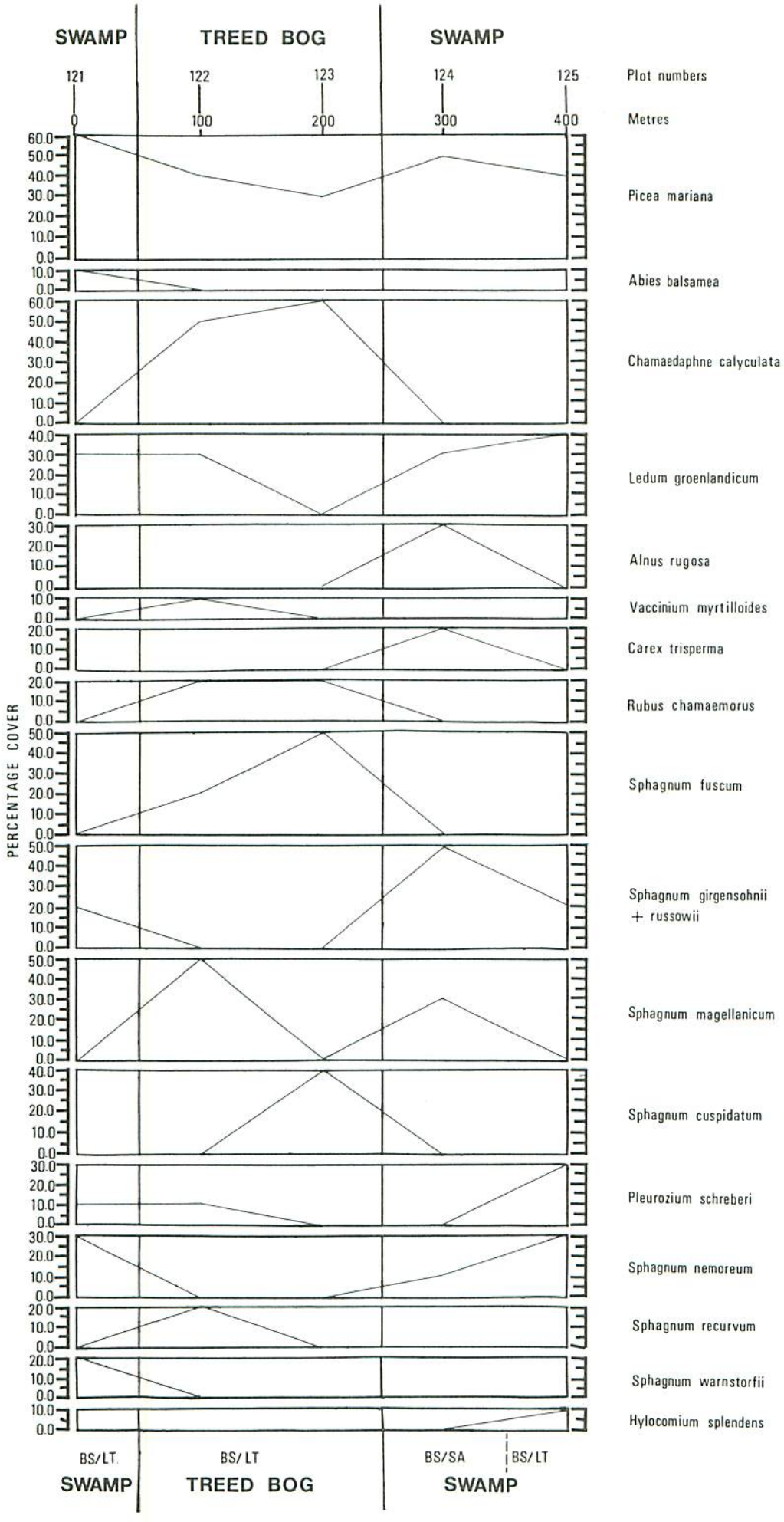
SWAMP
TREED BOG
SWAMP
121
122
123
124
125
Plot numbers
0
100
200
300
400
Metres
PERCENTAGE COVER
Picea mariana
Abies balsamea
Chamaedaphne calyculata
Ledum groenlandicum
Alnus rugosa
Vaccinium myrtilloides
Carex trisperma
Rubus chamaemorus
Sphagnum fuscum
Sphagnum girgensohnii + russowii
Sphagnum magellanicum
Sphagnum cuspidatum
Pleurozium schreberi
Sphagnum nemoreum
Sphagnum recurvum
Sphagnum warnstorfii
Hylocomium splendens
BS/LT
BS/LT
BS/SA
BS/LT
SWAMP
TREED BOG
SWAMP

Figure 6a

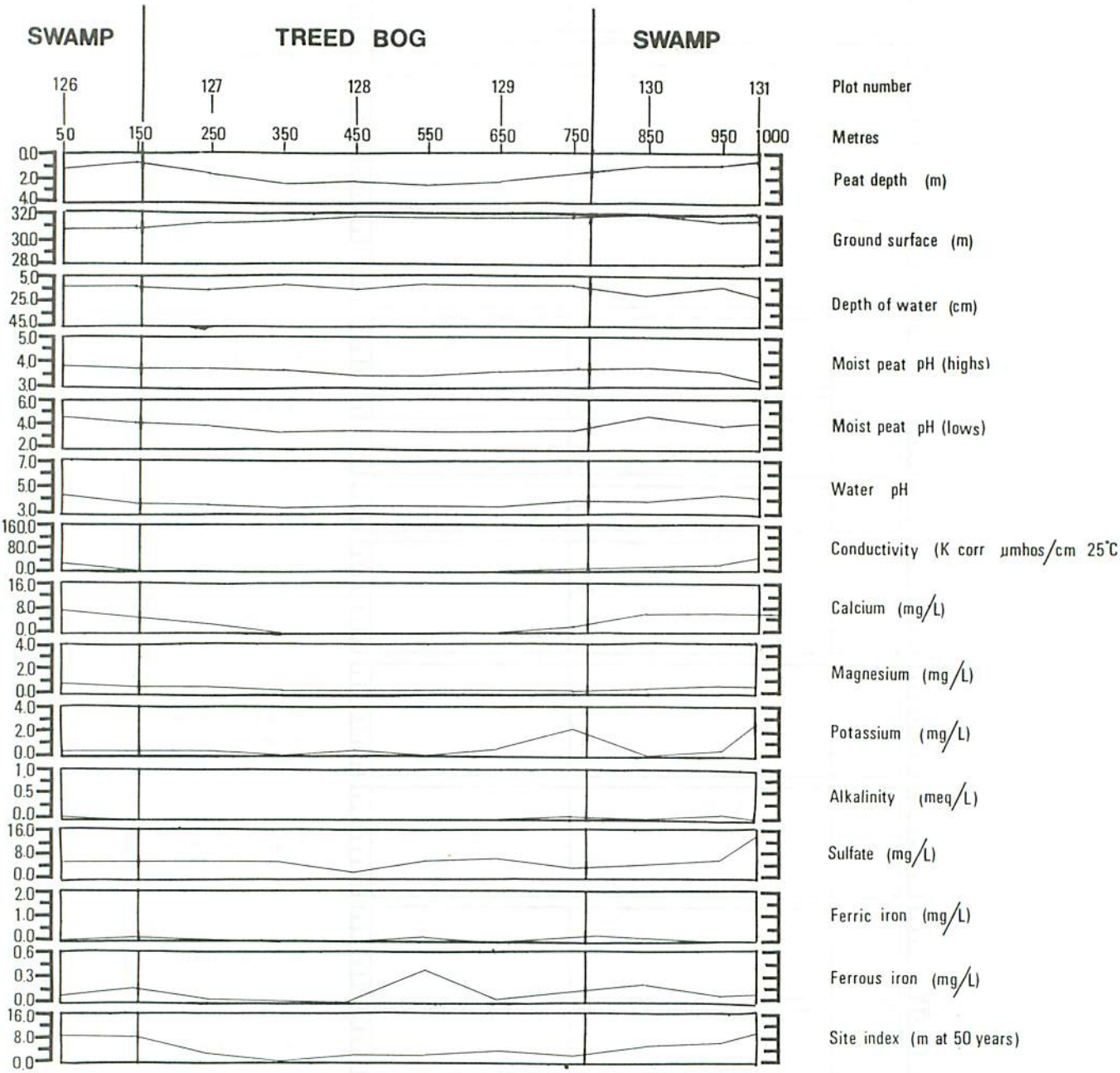
SWAMP
TREED BOG
SWAMP
126
127
128
129
130
131
Plot number
50
150
250
350
450
550
650
750
850
950
1000
Metres
0.0
2.0
4.0
Peat depth (m)
32.0
30.0
28.0
Ground surface (m)
5.0
25.0
45.0
Depth of water (cm)
5.0
4.0
3.0
Moist peat pH (highs)
6.0
4.0
2.0
Moist peat pH (lows)
7.0
5.0
3.0
Water pH
160.0
80.0
0.0
Conductivity (K corr µmhos/cm 25°C)
16.0
8.0
0.0
Calcium (mg/L)
4.0
2.0
0.0
Magnesium (mg/L)
4.0
2.0
0.0
Potassium (mg/L)
1.0
0.5
0.0
Alkalinity (meq/L)
16.0
8.0
0.0
Sulfate (mg/L)
2.0
1.0
0.0
Ferric iron (mg/L)
0.6
0.3
0.0
Ferrous iron (mg/L)
16.0
8.0
0.0
Site index (m at 50 years)

Figure 6b

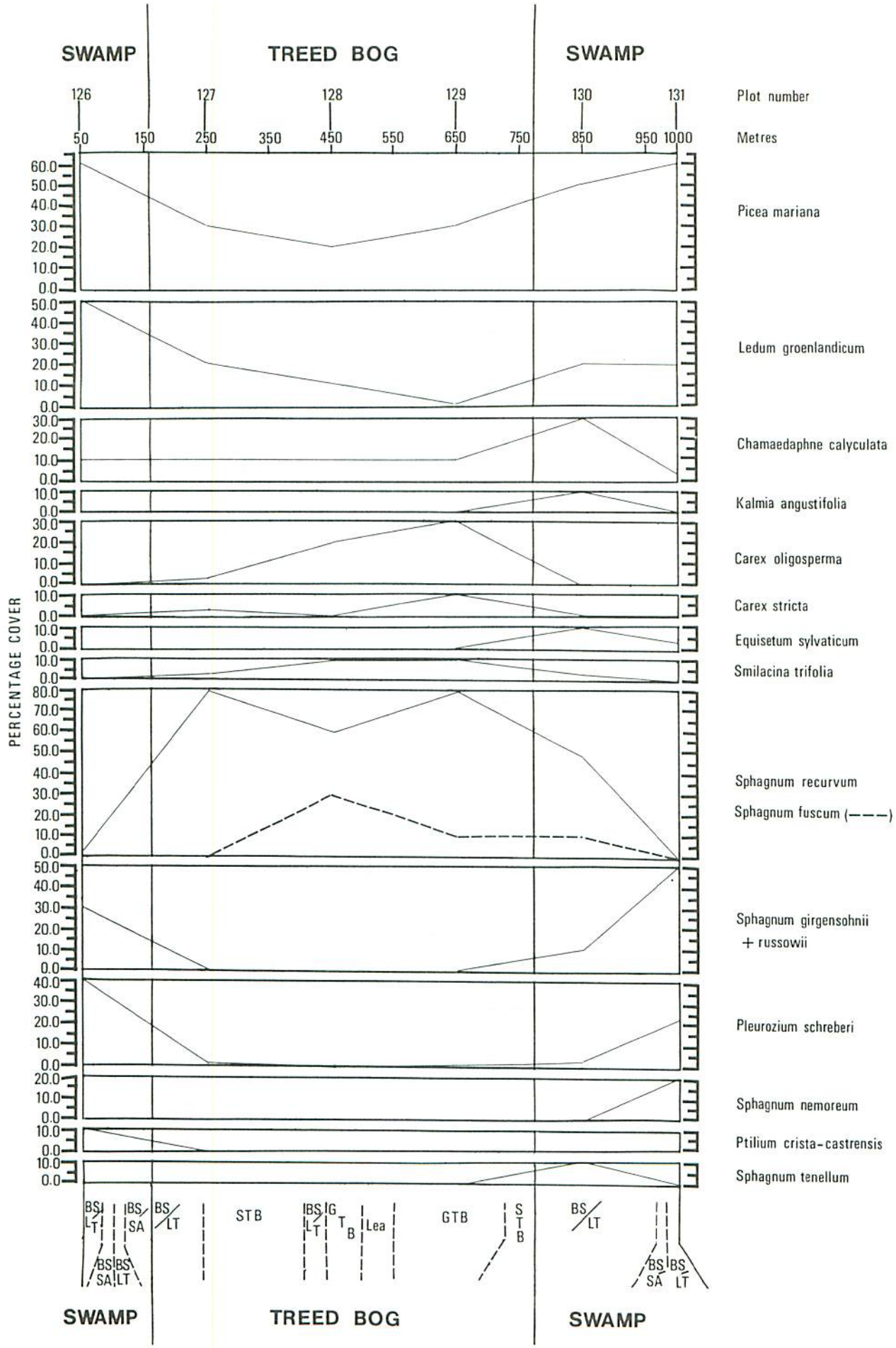
SWAMP
TREED BOG
SWAMP
126
127
128
129
130
131
Plot number
50
150
250
350
450
550
650
750
850
950
1000
Metres
PERCENTAGE COVER
Picea mariana
Ledum groenlandicum
Chamaedaphne calyculata
Kalmia angustifolia
Carex oligosperma
Carex stricta
Equisetum sylvaticum
Smilacina trifolia
Sphagnum recurvum
Sphagnum fuscum (---)
Sphagnum girgensohnii + russowii
Pleurozium schreberi
Sphagnum nemoreum
Ptilium crista-castrensis
Sphagnum tenellum
BS/LT
BS/SA
STB
GTB
SWAMP
TREED BOG
SWAMP

Figure 8a

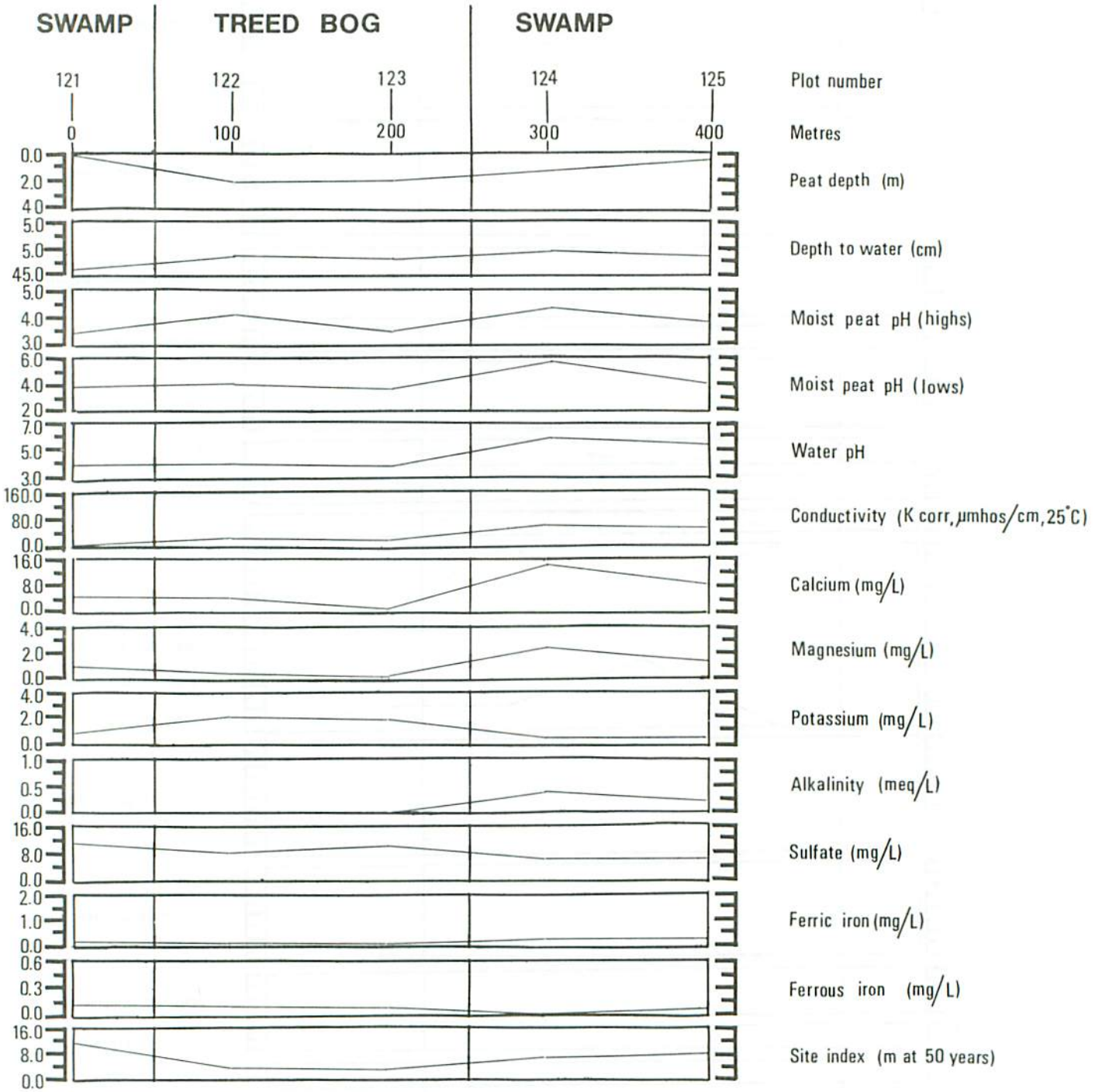
SWAMP
TREED BOG
SWAMP
121
122
123
124
125
Plot number
0
100
200
300
400
Metres
0.0
2.0
4.0
Peat depth (m)
5.0
5.0
45.0
Depth to water (cm)
5.0
4.0
3.0
Moist peat pH (highs)
6.0
4.0
2.0
Moist peat pH (lows)
7.0
5.0
3.0
Water pH
160.0
80.0
0.0
Conductivity (K corr, µmhos/cm, 25°C)
16.0
8.0
0.0
Calcium (mg/L)
4.0
2.0
0.0
Magnesium (mg/L)
4.0
2.0
0.0
Potassium (mg/L)
1.0
0.5
0.0
Alkalinity (meq/L)
16.0
8.0
0.0
Sulfate (mg/L)
2.0
1.0
0.0
Ferric iron (mg/L)
0.6
0.3
0.0
Ferrous iron (mg/L)
16.0
8.0
0.0
Site index (m at 50 years)

Figure 8b

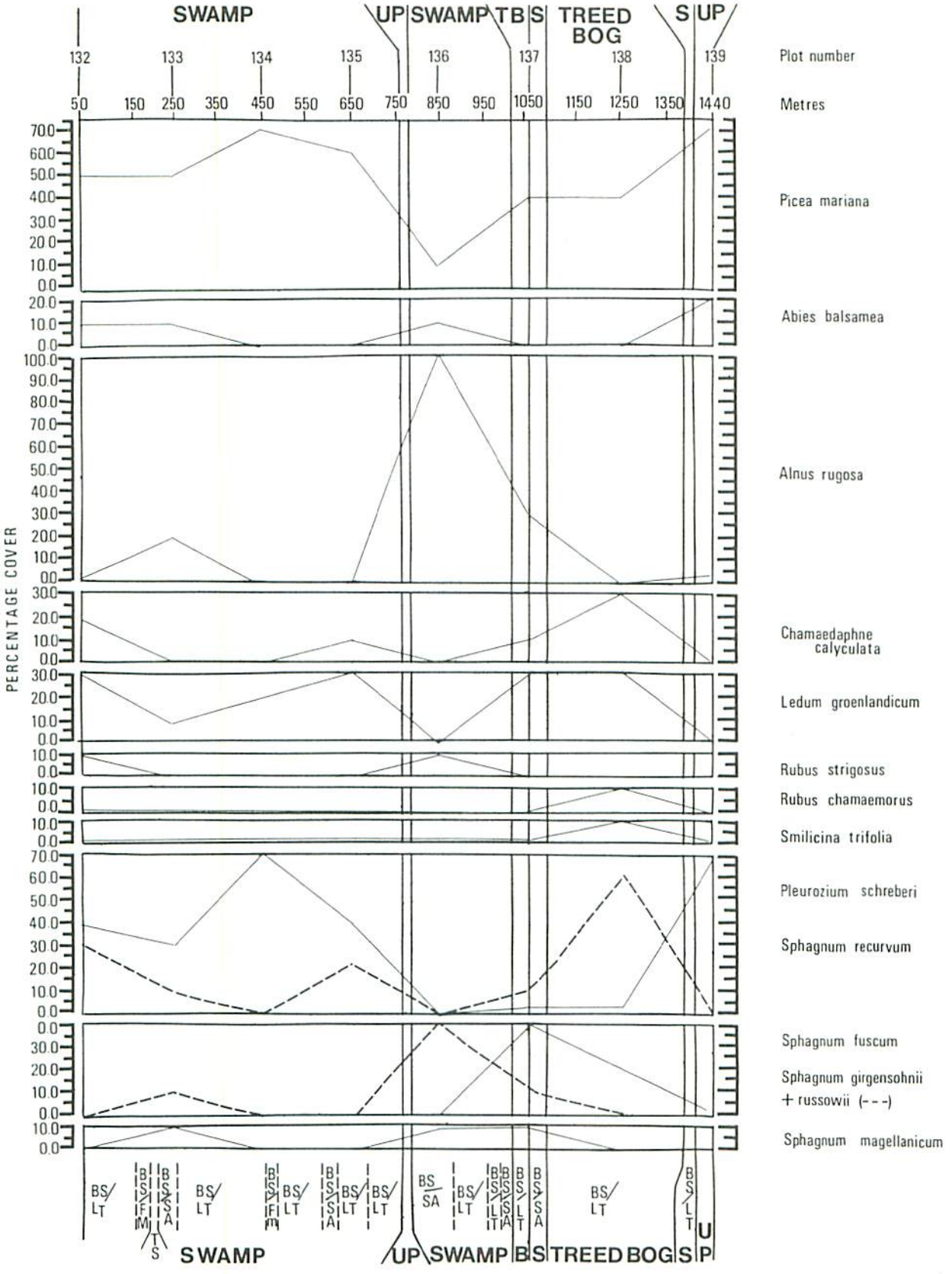
SWAMP
UP
SWAMP
TB
S
TREED BOG
S
UP
Plot number
Metres
PERCENTAGE COVER
Picea mariana
Abies balsamea
Alnus rugosa
Chamaedaphne calyculata
Ledum groenlandicum
Rubus strigosus
Rubus chamaemorus
Smilicina trifolia
Pleurozium schreberi
Sphagnum recurvum
Sphagnum fuscum
Sphagnum girgensohnii + russowii (- - -)
Sphagnum magellanicum
SWAMP
UP
SWAMP
TREED BOG

Figure 8c

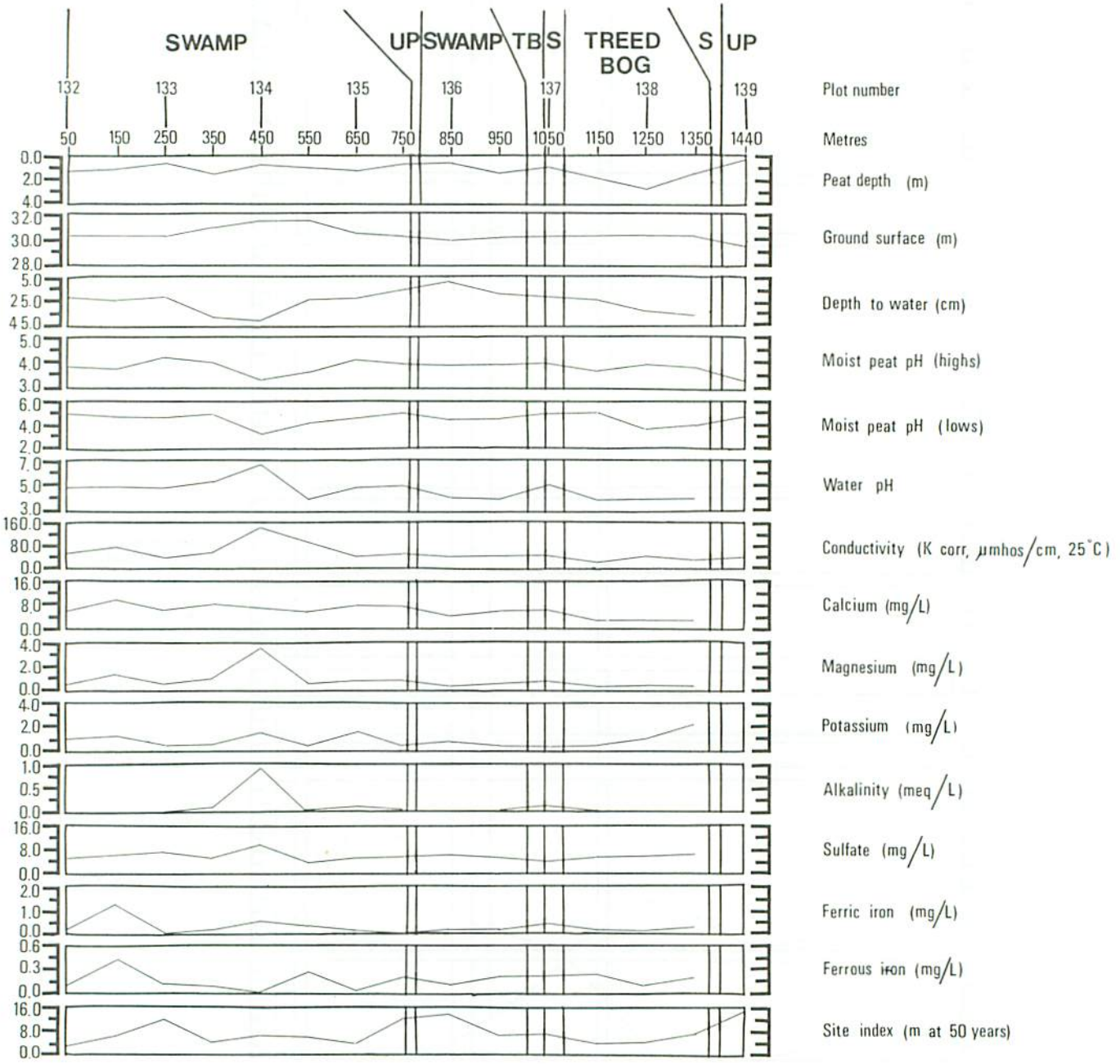
SWAMP
UP
SWAMP
TB
S
TREED BOG
S
UP
132
133
134
135
136
137
138
139
Plot number
50 150 250 350 450 550 650 750 850 950 1050 1150 1250 1350 1440
Metres
0.0 2.0 4.0
Peat depth (m)
32.0 30.0 28.0
Ground surface (m)
5.0 25.0 45.0
Depth to water (cm)
5.0 4.0 3.0
Moist peat pH (highs)
6.0 4.0 2.0
Moist peat pH (lows)
7.0 5.0 3.0
Water pH
160.0 80.0 0.0
Conductivity (K corr, µmhos/cm, 25°C)
16.0 8.0 0.0
Calcium (mg/L)
4.0 2.0 0.0
Magnesium (mg/L)
4.0 2.0 0.0
Potassium (mg/L)
1.0 0.5 0.0
Alkalinity (meq/L)
16.0 8.0 0.0
Sulfate (mg/L)
2.0 1.0 0.0
Ferric iron (mg/L)
0.6 0.3 0.0
Ferrous iron (mg/L)
16.0 8.0 0.0
Site index (m at 50 years)

Figure 8d

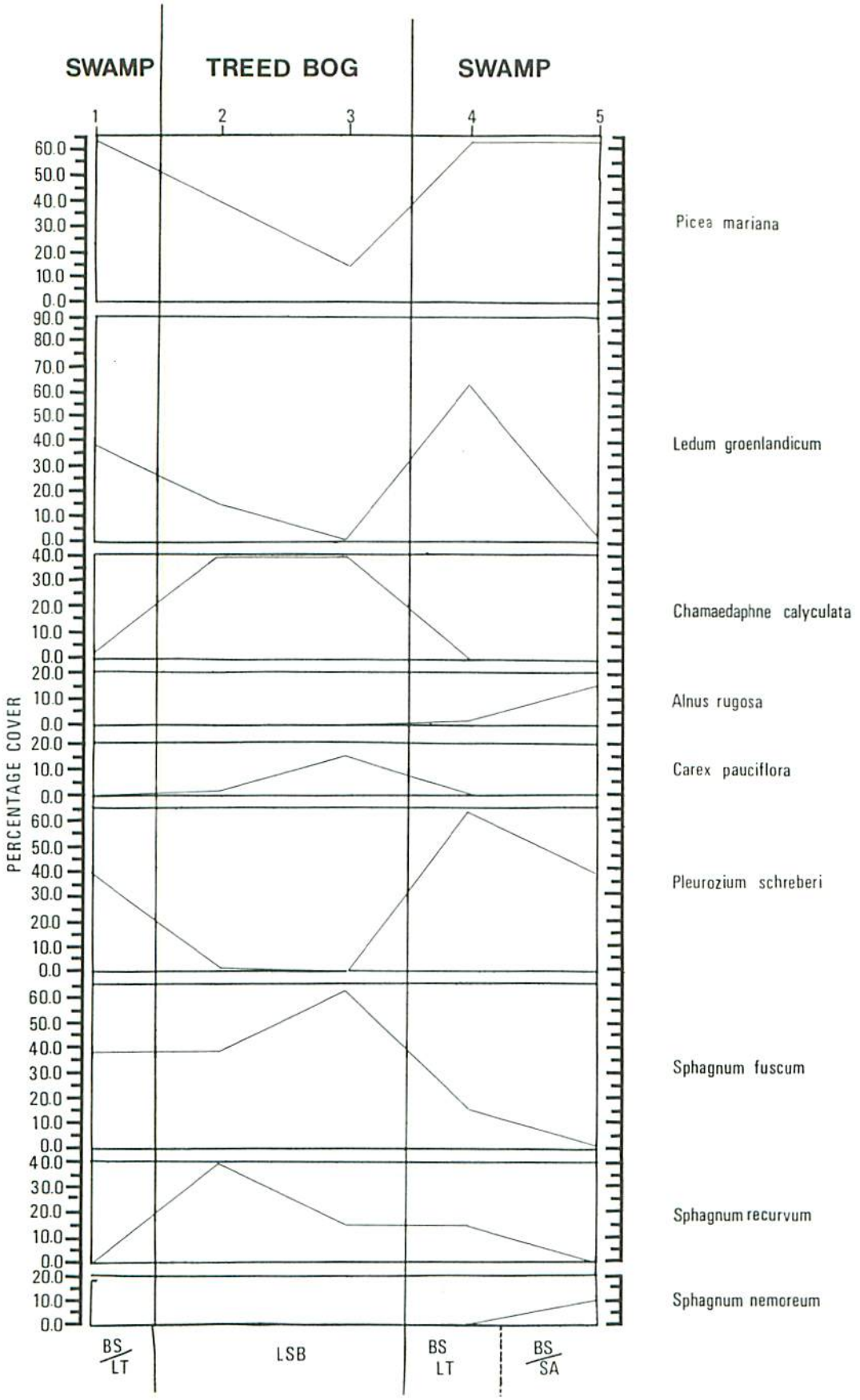
SWAMP
TREED BOG
SWAMP
1
2
3
4
5
PERCENTAGE COVER
Picea mariana
Ledum groenlandicum
Chamaedaphne calyculata
Alnus rugosa
Carex pauciflora
Pleurozium schreberi
Sphagnum fuscum
Sphagnum recurvum
Sphagnum nemoreum
BS/LT
LSB
BS
LT
BS/SA

Figure 9a

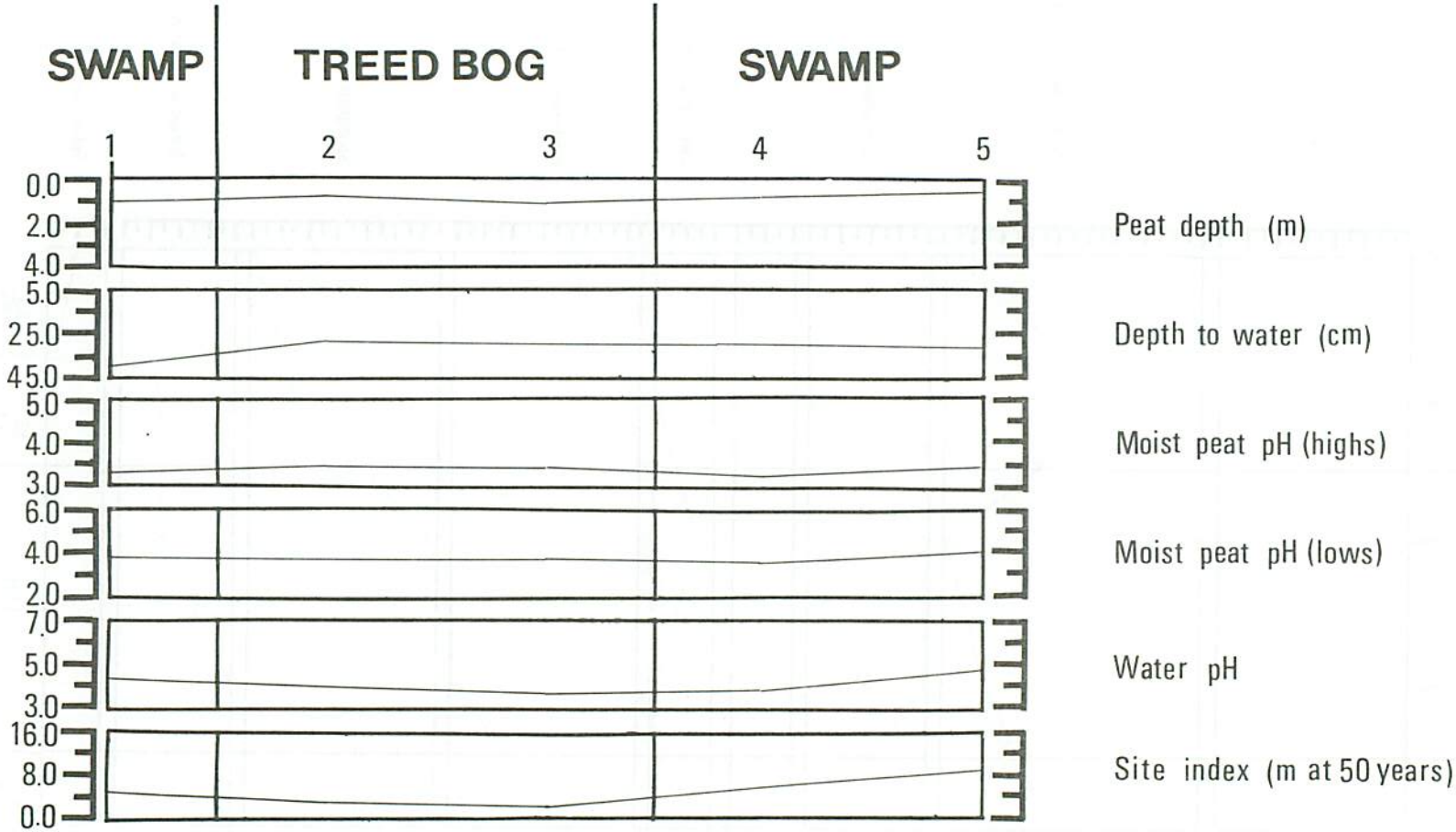
SWAMP
TREED BOG
SWAMP
1
2
3
4
5
0.0
2.0
4.0
5.0
25.0
45.0
5.0
4.0
3.0
6.0
4.0
2.0
7.0
5.0
3.0
16.0
8.0
0.0
Peat depth (m)
Depth to water (cm)
Moist peat pH (highs)
Moist peat pH (lows)
Water pH
Site index (m at 50 years)

Figure 9b

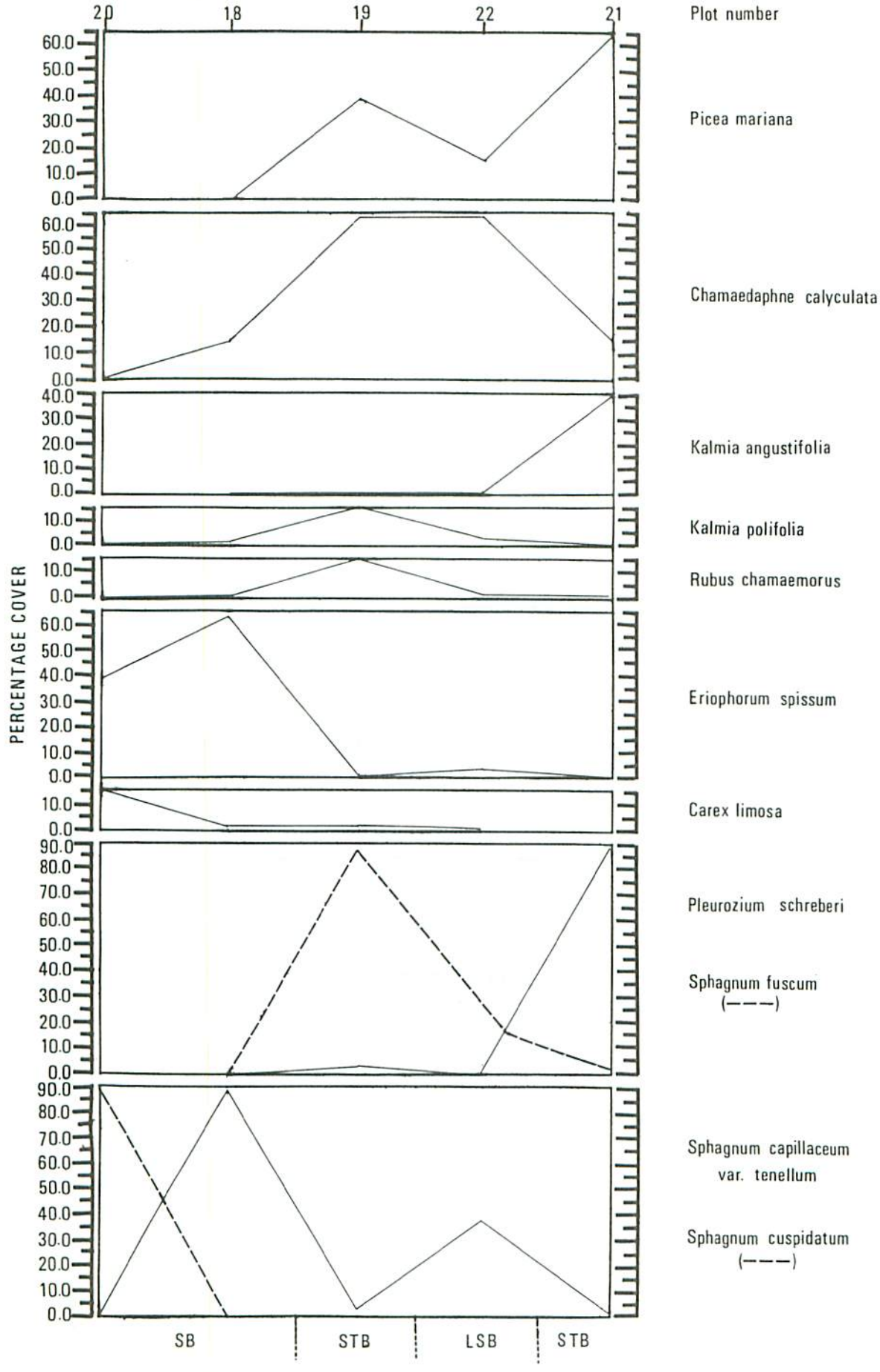
20
18
19
22
21
Plot number
PERCENTAGE COVER
Picea mariana
Chamaedaphne calyculata
Kalmia angustifolia
Kalmia polifolia
Rubus chamaemorus
Eriophorum spissum
Carex limosa
Pleurozium schreberi
Sphagnum fuscum
(———)
Sphagnum capillaceum
var. tenellum
Sphagnum cuspidatum
(———)
SB
STB
LSB
STB

Figure 11a

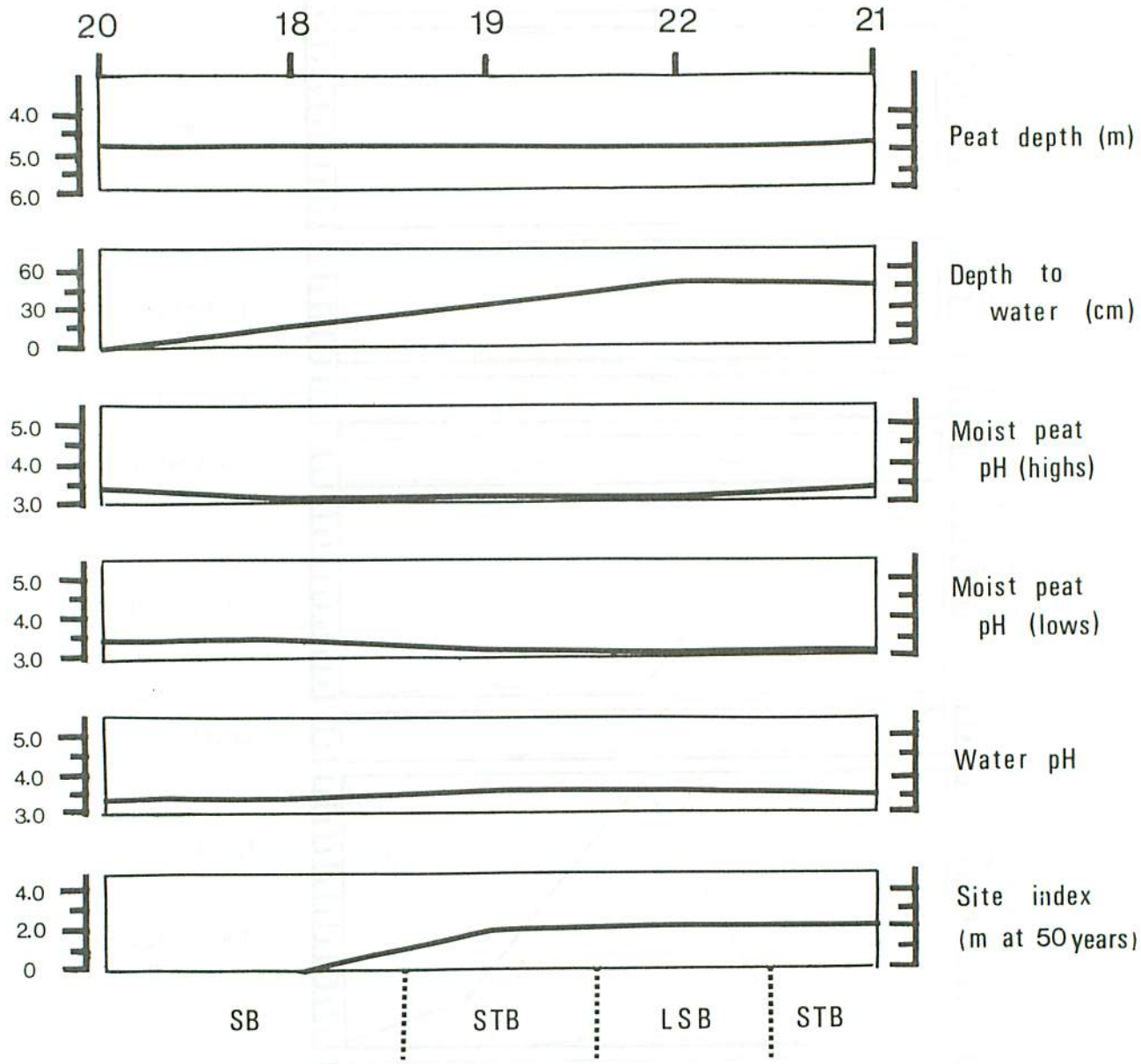
20
18
19
22
21
4.0
5.0
6.0
Peat depth (m)
60
30
0
Depth to water (cm)
5.0
4.0
3.0
Moist peat pH (highs)
5.0
4.0
3.0
Moist peat pH (lows)
5.0
4.0
3.0
Water pH
4.0
2.0
0
Site index (m at 50 years)
SB
STB
LSB
STB

Figure 11b

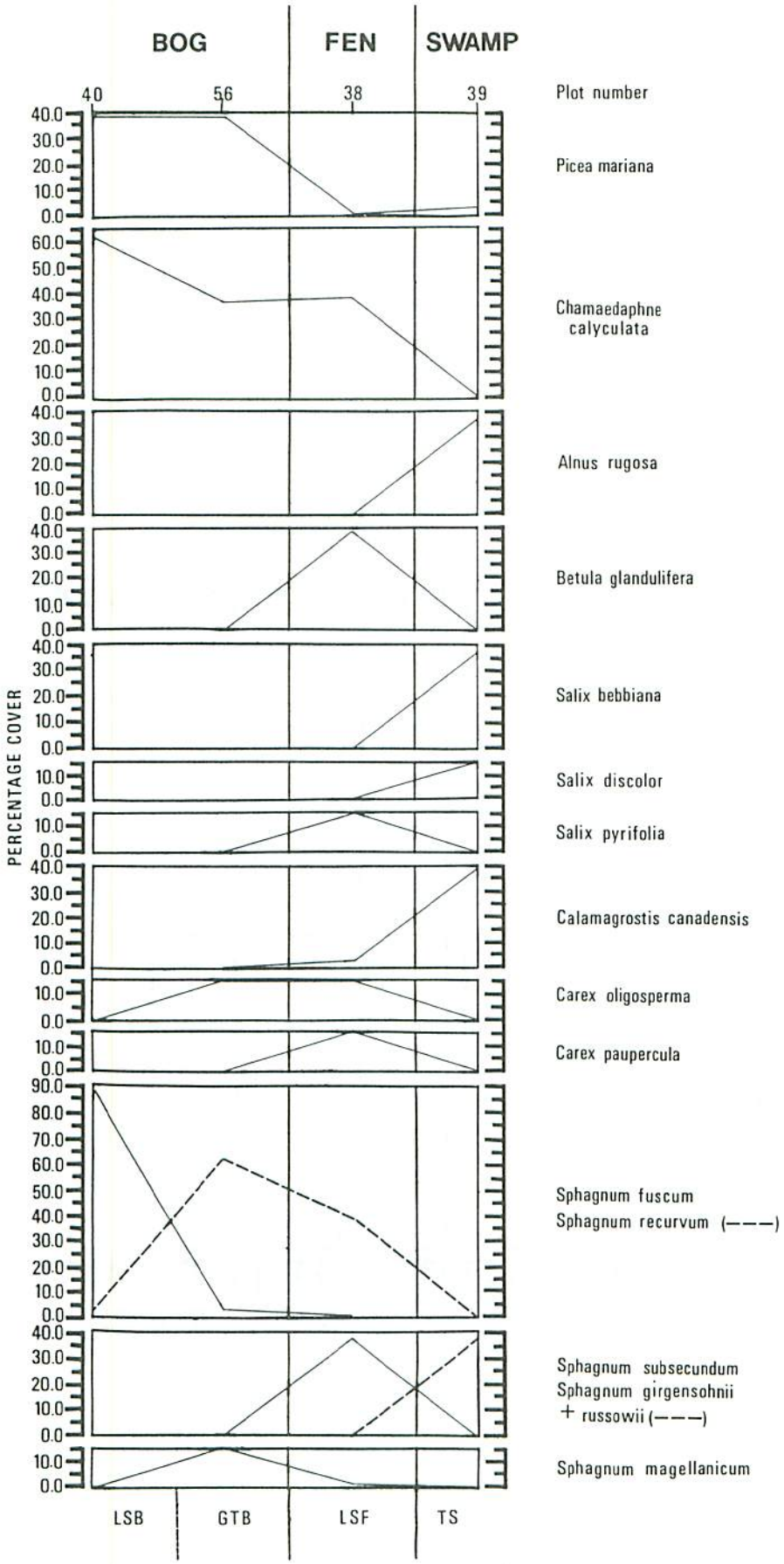
BOG
FEN
SWAMP
40
56
38
39
Plot number
PERCENTAGE COVER
Picea mariana
Chamaedaphne calyculata
Alnus rugosa
Betula glandulifera
Salix bebbiana
Salix discolor
Salix pyrifolia
Calamagrostis canadensis
Carex oligosperma
Carex paupercula
Sphagnum fuscum
Sphagnum recurvum (---)
Sphagnum subsecundum
Sphagnum girgensohnii + russowii (---)
Sphagnum magellanicum
LSB
GTB
LSF
TS

Figure 13a

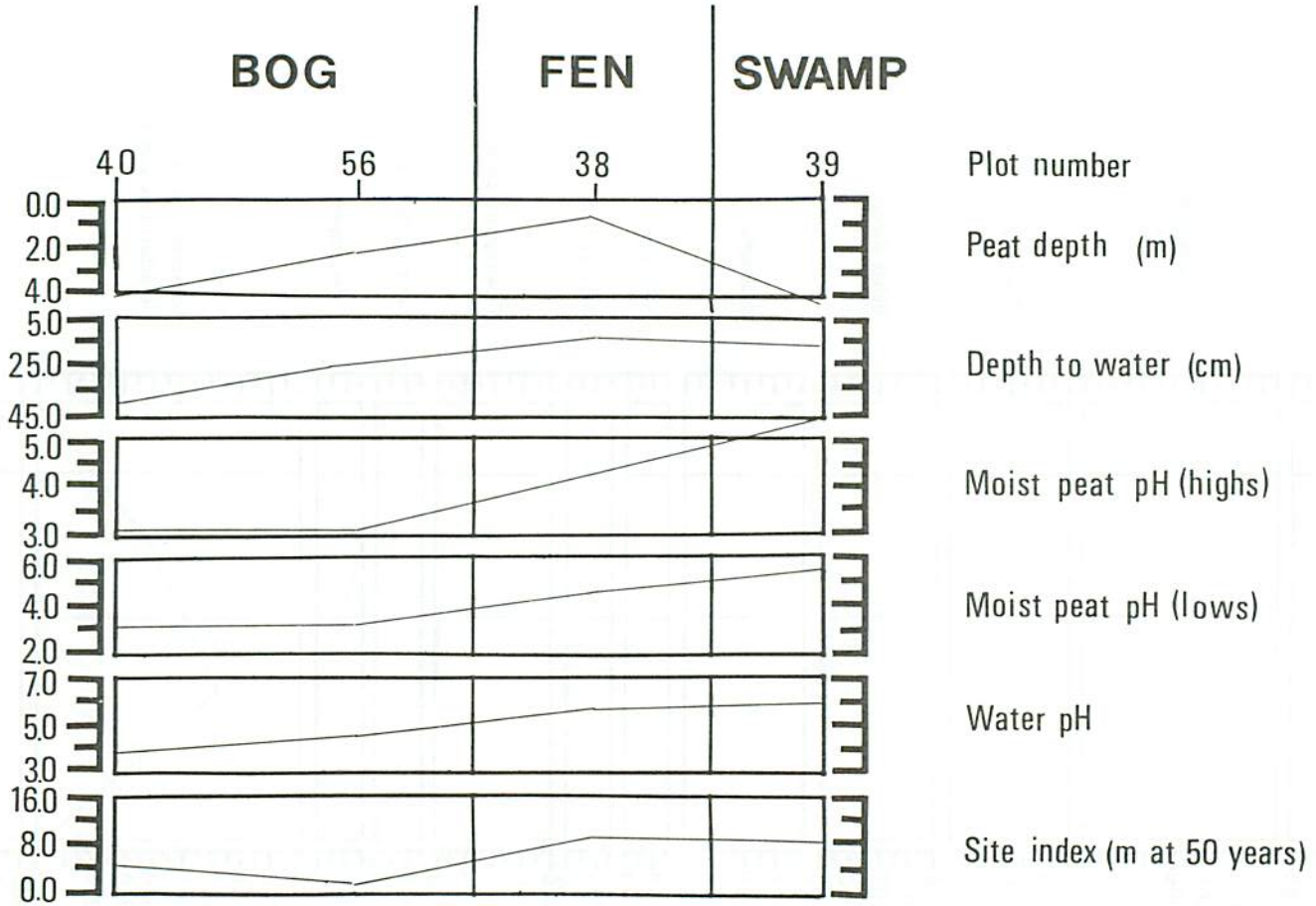
BOG
FEN
SWAMP
40
56
38
39
Plot number
0.0
2.0
4.0
Peat depth (m)
5.0
25.0
45.0
Depth to water (cm)
5.0
4.0
3.0
Moist peat pH (highs)
6.0
4.0
2.0
Moist peat pH (lows)
7.0
5.0
3.0
Water pH
16.0
8.0
0.0
Site index (m at 50 years)

Figure 13b

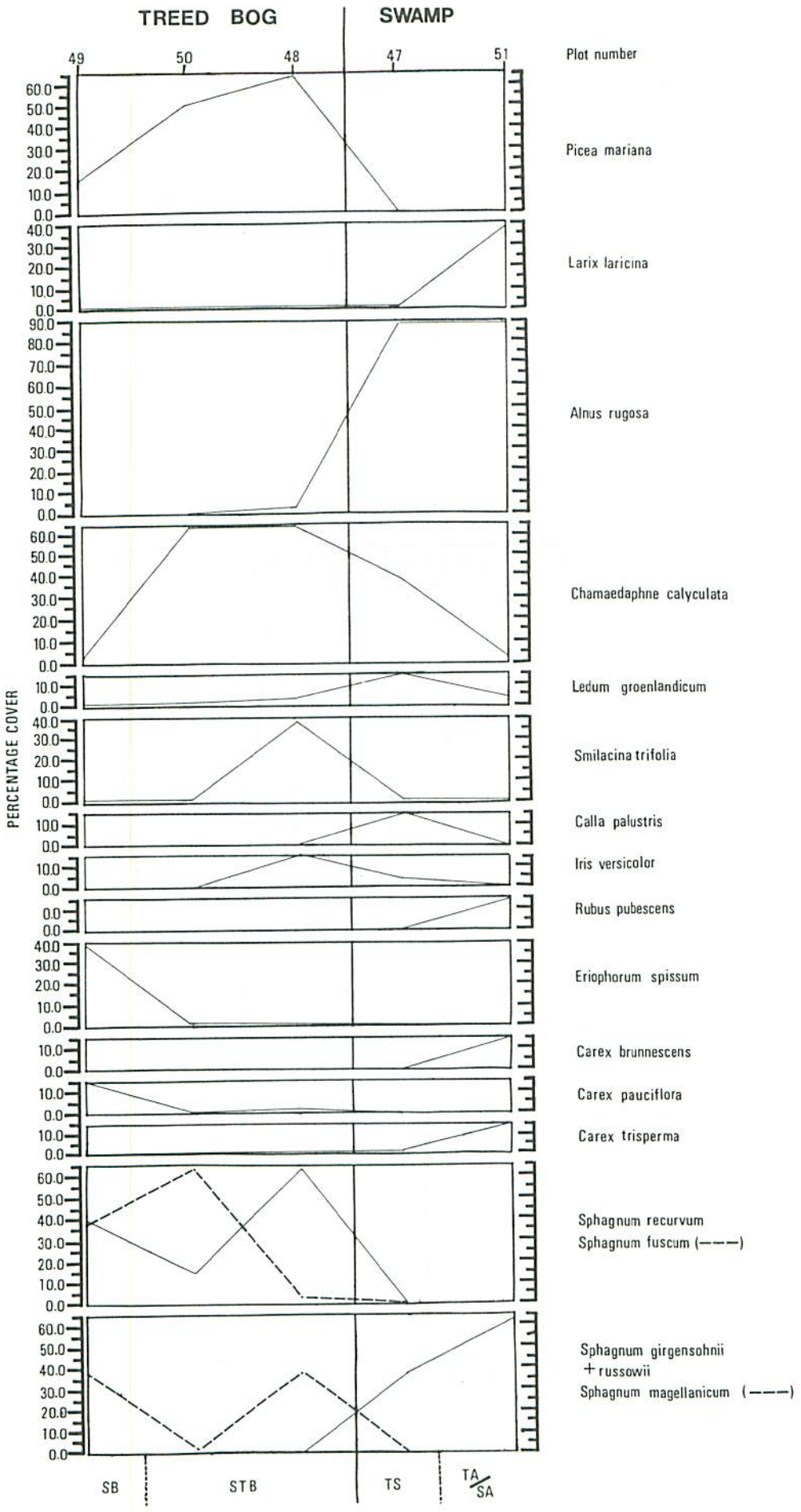
TREED BOG
SWAMP
Plot number
49
50
48
47
51
PERCENTAGE COVER
Picea mariana
Larix laricina
Alnus rugosa
Chamaedaphne calyculata
Ledum groenlandicum
Smilacina trifolia
Calla palustris
Iris versicolor
Rubus pubescens
Eriophorum spissum
Carex brunnescens
Carex pauciflora
Carex trisperma
Sphagnum recurvum
Sphagnum fuscum (———)
Sphagnum girgensohnii
+ russowii
Sphagnum magellanicum (———)
SB
STB
TS
TA/SA

Figure 16a

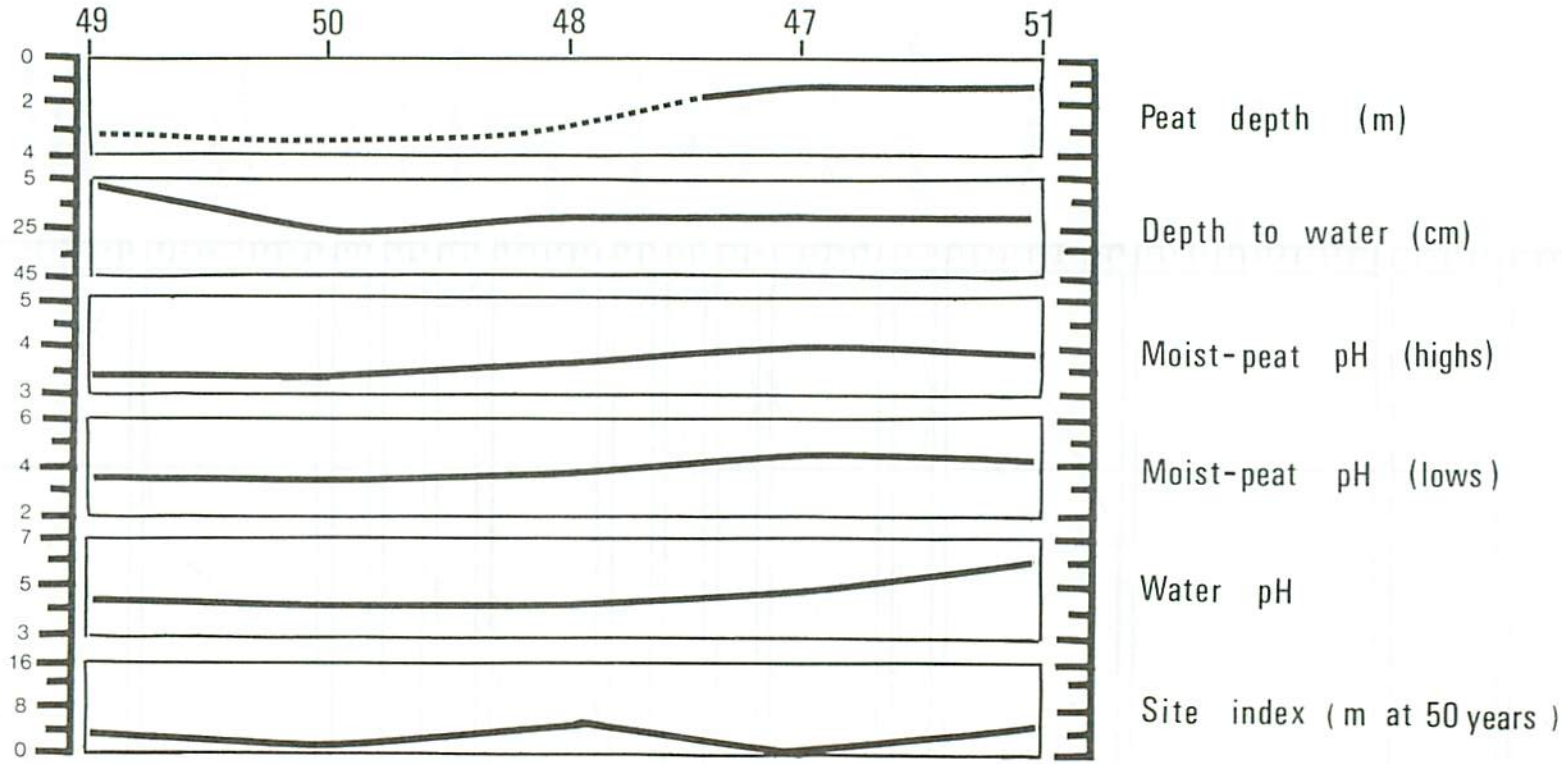
49
50
48
47
51
0
2
4
5
25
45
5
4
3
6
4
2
7
5
3
16
8
0
Peat depth (m)
Depth to water (cm)
Moist-peat pH (highs)
Moist-peat pH (lows)
Water pH
Site index (m at 50 years)

Figure 16b