A PRELIMINARY VEGETATION SURVEY OF THE ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM STUDY AREA

by

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for

VEGETATION TECHNICAL RESEARCH COMMITTEE
ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Sub-project VE 2.2
November 1976

LETTER OF TRANSMITTAL

The Hon. D. J. Russell
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

and

The Hon. R. Le Blanc
Minister of Fisheries and Environment
Parliament Buildings
Ottawa, Ontario.

Sirs:

Enclosed herein is the report on "A Preliminary Vegetation Survey of the AOSERP Study Area".

This report was prepared as a result of field studies in Fall 1975, which were initiated by the Vegetation Technical Research Committee of the Alberta Oil Sands Environmental Research Program, under the Alberta-Canada Agreement of 28 February 1975.

Respectfully,

W. Solodzuk, P.Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

for J. S. Tener, Ph.D.
Member, Steering Committee, AOSERP
Assistant Deputy Minister,
Environmental Management Service
Environment Canada.

Research Sub-project VE 2.2:

A Preliminary Vegetation Survey of the Alberta Oil Sands Area

DESCRIPTIVE SUMMARY

Abstract:

Limited time and access constraints restricted this preliminary vegetation survey to Townships 85-103, Ranges 6-12, west of the 4th meridian. This area centres on sites of maximum development north of Fort McMurray (i.e. the GCOS and Syncrude leases).

Eighty-four stands were chosen as representative of all the major vegetation types in the study area. These stands were all sampled between August 18 and September 3, 1975. The structure and species composition of each stand was described by assigning each understory species a cover-abundance value, measuring strata heights, and by obtaining quantitative data on the tree stratum where appropriate.

The stands were classifed by means of a cluster analysis method which grouped closely related stands on the basis of overall species similarity. The ten distinct vegetation types defined by cluster analysis are:

(i) Fen
(ii) Sandbar Willow Scrub
(iii) Tall River Alder-Willow Scrub
(iv) Tall Willow Scrub
(v) Bottomland Balsam Poplar Forest
(vi) Upland White Spruce-Aspen Forest
(vii) Black Spruce Bog Forest
(viii) Semi-open Black Spruce Tamarack Bog Forest and Muskeg
(ix) Lightly Forested Tamarack and Open Muskeg
(x) Jack Pine Forest

Each type is discussed in terms of the vascular plant species. The more prominent bryophytes and lichens were also included in the stand descriptions. Correlations with forest cover types, generally accepted successional

trends (succession after fire, riverine succession, succession from fen and succession in bogs), and photo-interpretive characteristics as related to the area under consideration are discussed.

BACKGROUND

The primary objective of this study was to obtain exploratory data on the vegetation of the Alberta Oil Sands Study Area to provide an information base to aid in designing a full-scale vegetation inventory program. Secondary objectives were to: 1) describe the main structural and compositional features of the major plant communities in the study area (especially wetland and non-forest vegetation), 2) delineate feasible plant community mapping units and criteria for identifying these units at a scale of 1:25,000, 3) supply a set of photographs of the principal plant community types, and 4) assess normal duration of field season for vegetation surveys and aerial photography.

Despite the very limited time available for field work (August 18 to September 3, 1975) when this study was approved, there are a number of recommendations made which pertain to a large scale vegetation inventory.

Those recommendations are:

a) Photo-interpretation must be accompanied by extensive ground truth studies if more than broad, physiognomic mapping is desired.
b) Existing black and white imagery is of limited use for wetland and herbaceous vegetation, being more useful for obtaining rapid mapping of major topographic features and broadly defined vegetation types.
c) Colour and false-colour infra-red photographs used together are much more useful in distinquishing vegetation types, especially herbaceous ones.
d) Vegetation mapping should be carried out only after the dynamics and environmental relationships of the communities have been determined as far as possible, particularly in wetlands. The field studies should be in conjunction with a detailed analysis of the physical environment such as soils and water.
e) Since most plants in the area are in flower between late July and late August, it is essential that future studies maximize the use of this limited season.

f) Vegetation mapping of the area might follow the photo-interpretive method of Dabbs (1971). Existing information could be pooled to prepare a preliminary map at a scale of 1:15,000 or larger, designating major land units, and representative sub-areas within them could be selected for more detailed studies as a basis of mapping at a scale of 1:7,000 - 1:12,000 (requiring new, large-scale colour and false colour infra-red photographs and intensive field studies).

ASSESSMENT

The Vegetation Technical Research Committee (TRC) has reviewed and accepted the report, "A preliminary vegetation survey of the Alberta Oil Sands Area", prepared by Dr. Paul W. Stringer of Intraverda Plant Systems Ltd. The Committee has taken the recommendations of Dr. Stringer under advisement and where feasible they will be incorporated into the final vegetation-soils inventory.

The report is well written and gives a good preliminary account of the flora in the study area. It also presents a preliminary grouping of vegetation types and forms a solid stepping stone for the next phase of the vegetation inventory.

In light of the information in the document, the Vegetation TRC in agreement with the Oil Sands Environmental Study Group recommend that the report be made public and available to the AOSERP researchers.

F.W. McDougall, Chairman
Vegetation Technical Research Committee

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Alberta ENVIRONMENT

Environment Canada Environnement Canada

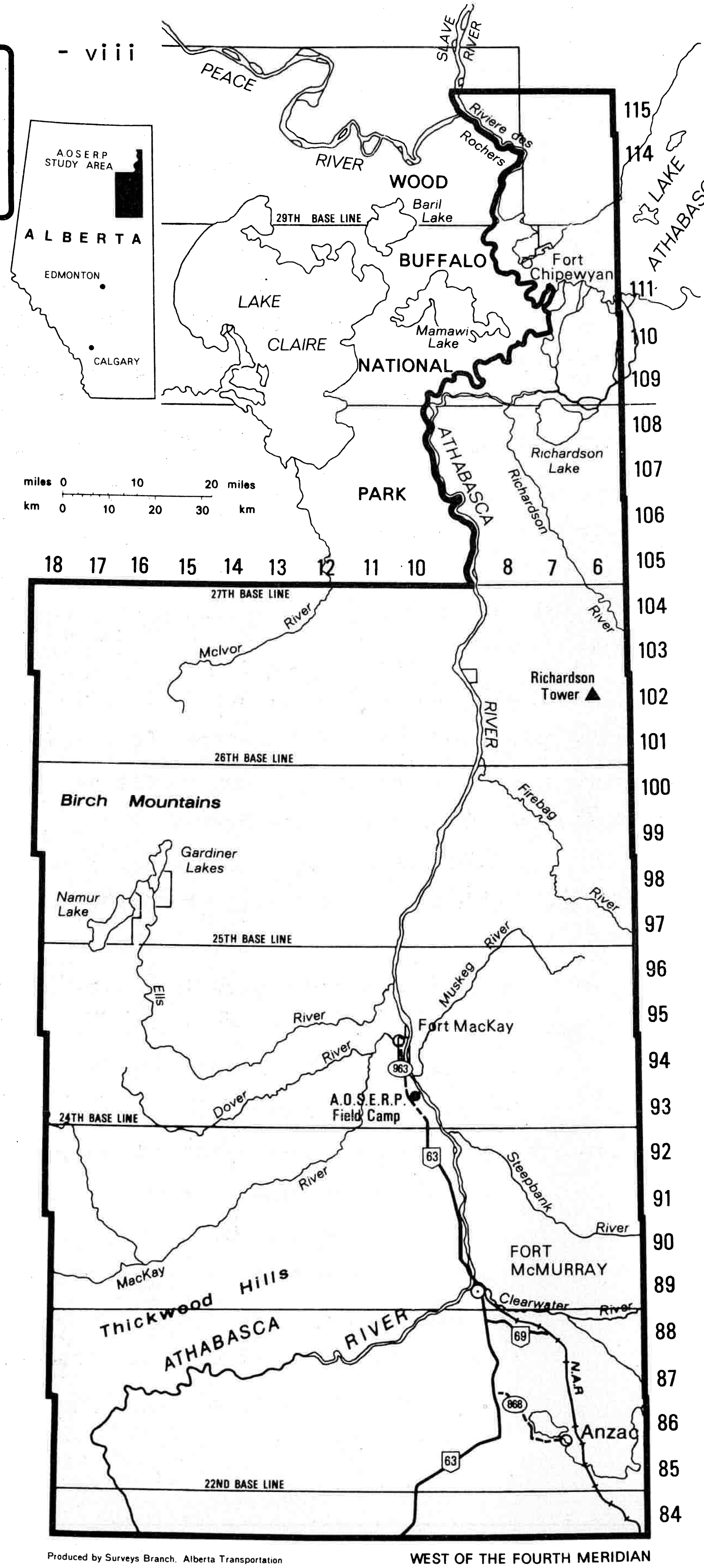

FIGURE 1. Location of the AOSERP study area.

ABSTRACT

Between August 18 and September 3, 1975, 84 homogeneous stands chosen as representative of the major vegetation types were sampled in the Alberta Oil Sands Environmental Research Program (AOSERP) study area (56^o 21' - 58^o 00' N and 110^o 50' - 112^o 00' W). The structure and species composition of each was described by assigning to each understory species a cover-abundance value, measuring strata heights, and by obtaining, where appropriate, quantitative data on the tree stratum.

The 84 stands were classified on the basis of overall species similarity by means of cluster analysis. The clusters resulting from the analysis were readily identifiable as distinct vegetation types and were therefore distinguished on the basis of general species composition rather than by the more usual weighting of the tree stratum.

Ten vegetation types were identified: Fen; Sandbar Willow Scrub; Tall River Alder-Willow Scrub; Tall Willow Scrub; Bottomland Balsam Poplar Forest; Upland White Spruce-Aspen Forest; Black Spruce Bog Forest; Semi-open Black Spruce-Tamarack Bog Forest and Muskeg; Lightly Forested Tamarack and Open Muskeg; Jack Pine Forest.

There were also a number of ill-defined clusters and several consisting of a few stands only. This suggests that probably more, as yet inadequately sampled, vegetation types exist. The findings of this study correlate well with the vegetation units indicated on the most recent forest cover maps.

Bryophytes and lichens were important components of many of the vegetation types. They often formed the bulk of the terrestrial plant biomass and were sometimes quantitatively more important than the vascular species, especially in mesic, closed-canopy coniferous forest, xeric jack pine forests, fens and muskegs. Many of the terrestrial species are sensitive indicators of the total environment and as such can be important in community classification.

Many lichens and bryophytes, especially corticolous species, are also sensitive indicators of air pollutants such as sulphur dioxide.

In future studies on mapping the AOSERP study area the following points should be noted. First, if anything more than a broad, physiognomically based mapping is to be attained, photointerpretation must be

accompanied by extensive ground truth surveys.

Existing black and white imagery is of limited use for wetland and herbaceous vegetation. It is most useful for obtaining a rapid mapping of the major topographic features and of physiognomically defined vegetation types. Color and color infrared (false color) photographs used in conjunction are much more useful, enabling additional vegetation types, especially herbaceous ones, to be distinguished. A combination of true and infrared color aerial photography supplemented by the limited ground surveying possible may be the only feasible way of obtaining sufficient data on the extensive areas of wetland vegetation.

Ideally mapping of the vegetation should be done only after the dynamics of the communities and their relationship to the physical environment have been determined as far as possible, particularly in wetlands.

Finally, since most plants in the area are in flower between late July and late August, it is essential that future studies make maximum use of this very limited season.

OBJECTIVES

OVERALL OBJECTIVE

To obtain exploratory data on the vegetation and flora of the AOSERP study area. This data is intended to:

(1) provide an information base for the designing of a full-scale vegetation survey-mapping program commencing in 1976; and

(2) provide basic vegetation information for use not only by the AOSERP Vegetation Committee but also by other committees, notably Terrestrial Fauna and Land Use.

PRIMARY OBJECTIVES

In order to achieve the overall objective of the 1975 survey, the following specific major objectives were set:

1. describe the main structural and compositional features of the principal plant communities of the AOSERP study area with special emphasis on the wetland and non-forest vegetation.
2. delineate feasible plant community mapping units for the AOSERP at a scale of 1:25,000 and establish criteria for identifying these units;
3. supply a set of photographs of the principal plant community types, including, where possible, both lateral (ground) and oblique and vertical (air) views;
4. assess the probable normal duration of the season suitable for field vegetation surveys and during which conditions for aerial photography are optimal.

SECONDARY OBJECTIVES

Since time for the 1975 study was short, the following objectives were of necessity ranked as secondary:

1. compile an ecologically annotated list of the principal plant species of the AOSERP area as a useful precursor to the compilation of the flora of the area;
2. prepare a complete set of plant voucher specimens suitable for deposit in the herbarium of the University of Alberta;
3. develop alternative vegetation survey, classification, and mapping systems for AOSERP and to determine suitable aerial photographic scales, films, and filters for identification of plant communities.

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1. INTRODUCTION

The Alberta Oil Sands Environmental Research Program study area surveyed is located in northeastern Alberta adjacent to the Canadian Shield and includes a large proportion of the lower watersheds of two major rivers, the Athabasca and the Clearwater.

Due to the limited time available for this study (August 11 - November 14), and especially the brevity of the field season remaining, it was decided to restrict the area of study to the oil sands area proper and to omit for the time being adjacent areas that may ultimately be affected by oil sands development. The largest area thus omitted was the Peace-Athabasca Delta to the north. This area, however, has already been thoroughly studied (Dabbs, 1971; Dirschl, 1970a, 1970b, 1971, 1972, 1973; Dirschl and Dabbs, 1972; Dirschl, Dabbs, and Gentle, 1972; Raup, 1935, 1946). Further difficulty of access would have been a major problem in attempting to include this region.

Because of time and access constraints, the boundaries for the preliminary study were set at approximately 56°21' to 58°00'N and 110°50' to 112°00'W, that is Townships 85 - 103, Ranges 6 - 12, west of the 4th meridian. This area centers on the sites of present maximum development north of Fort McMurray, namely the Great Canadian Oil Sands Ltd. (GCOS) and Syncrude Canada Ltd. leases.

2. STUDY AREA

2.1 TOPOGRAPHY AND SURFICIAL DEPOSITS

The main drainage of the oil sands area is provided by the Athabasca-Clearwater River system, the valleys of which lie about 700-800 feet above sea level and cut into the broad, muskeg-covered interior plain to depths of 200-300 feet (Figure 1). Recent sandy alluvium covers the Athabasca and Clearwater River valleys, both of which are U-shaped with steep walls. However, the two valleys are different: the Clearwater meanders through a floodplain valley whereas the larger Athabasca cuts its way through a more or less straight and sometimes narrower valley.

The tributaries of this system originate in the highland areas (Figure 1): the Birch Mountains to the west of the Athabasca River which rise to about 2700 feet, Stony Mountain south of Fort McMurray which reaches an elevation of 2500 feet, and Muskeg Mountain to the east of the Athabasca River which rises gradually to 1900 feet. To the southwest of the area, between the Birch Mountains and Stony Mountain and north of the eastward flowing Athabasca River, rise the Thickwood Hills, a subdued highland area with gentle slopes. All four of these highland areas are covered with deposits of glacial till of varying thickness, and have extensive cover of their slopes by alluvial fans and colluvium.

The remaining areas between these four highland areas and the valley floodplains are occupied by flat to undulating plateaus covered with glacio-fluvial outwash and glacio-lacustrine deposits varying in texture from gravelly sand to silty clay. In some areas there are post-glacial aeolian sand dunes that have been stabilized by vegetation. In many places this plain is dissected by streams with steep banks and much evidence of slumping. However, much of this plain is depressional, poorly drained and covered in fen, muskeg, and bog forest. McClelland Lake, the largest in the area north of Fort McMurray, is within an area of internal drainage.

A number of shallow lakes are located on the top of the Birch Mountains and form an interconnected chain draining into the Ells River. The only other sizeable water body is Gregoire Lake, south of Fort McMurray. This lake is the focus of a developing recreational area (Gregoire Lake Provincial Park) and drains freely into a tributary of the

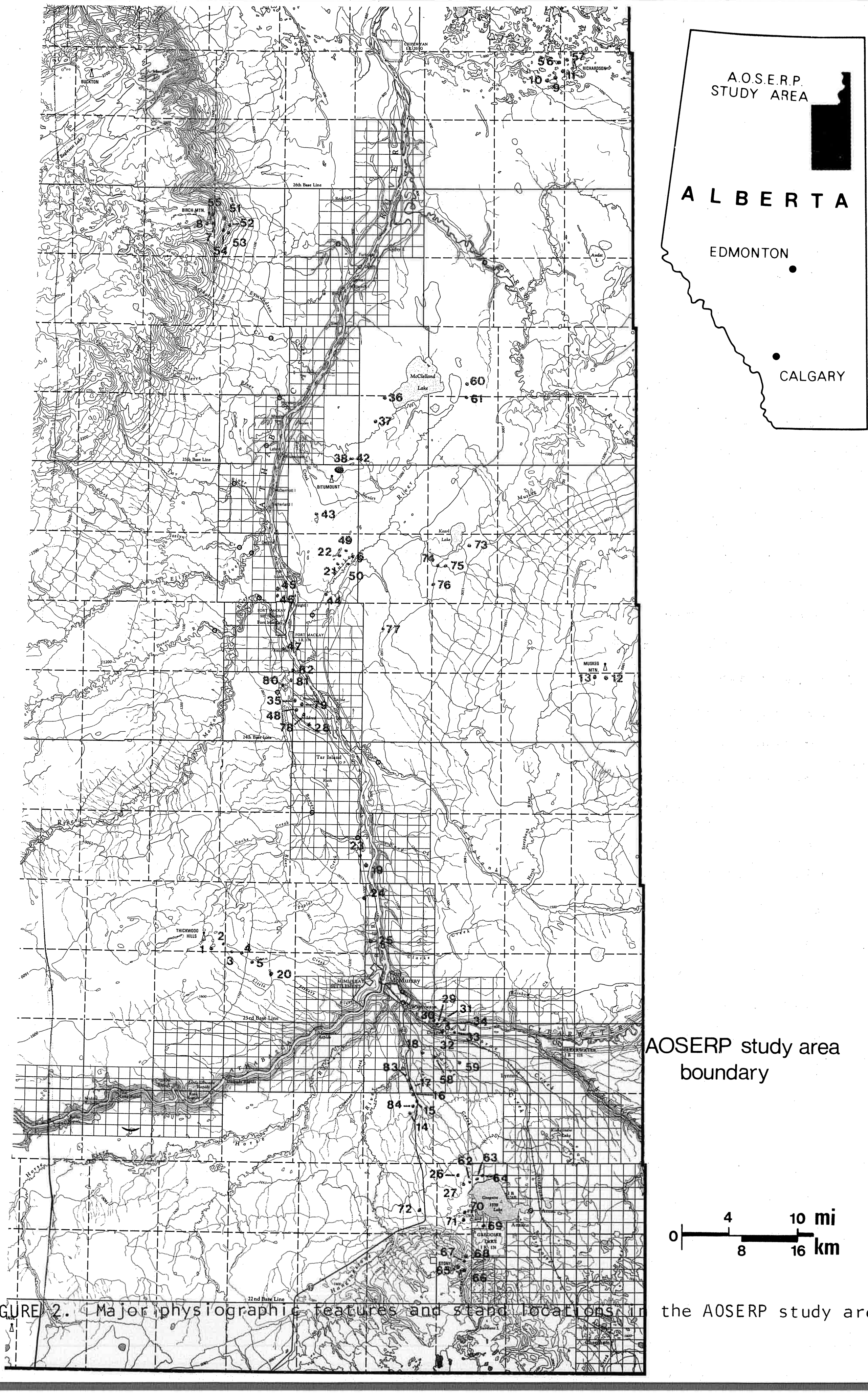

FIGURE 2. Major physiographic features and stand locations in the AOSERP study area.

Clearwater River.

Published information on the surficial geology and topography of this area is incomplete and generally inadequate but the Bitumount area map (Bayrock, 1971) is excellent and other useful information can be found in Lindsay, et al. (1957, 1961, 1962), Carrigy (1973), Lombard North (1974) and Hanley (1973).

2.2 SOILS

Soils information on the AOSERP study area is scanty. The only detailed soils survey report is that of Crown and Twardy (1970) which encompasses 400 square miles in the vicinity of Fort McMurray. Information on other soils is to be found in the Alberta Research Council's (ARC) Exploratory Soil Surveys (Lindsay et al., 1957, 1961, 1962) and less detailed accounts in Hanley (1973), Syncrude (1973) and Lombard North (1974).

The AOSERP study area is situated in the Grey Wooded soil zone of Alberta. On well to moderately well drained upland sites that are usually occupied by mixedwood or aspen forest, Grey Luvisols have developed on the glacial till, glacio-lacustrine, and glacial outwash deposits. They are characterized by a thin leaf and humus mat at the surface, beneath which is found a light-colored layer from which clay and soluble materials have been leached. Those which are moderately well drained are Orthic Grey Luvisols, while imperfectly drained profiles, characterized by some mottling, are Gleyed Grey Luvisols.

However, very large inland areas occupied by fen, muskeg, and bog forest have gleysolic and organic soils. These soils have developed thick layers of sphagnum and other mosses and sedge peat under reducing conditions caused by poor drainage and consequent water saturation. This peat is strongly to moderately acid and has a very high water holding capacity. The Gleysols (less than 24 inches of peat) and Organic soils (more than 24 inches of peat) are usually closely associated with each other and very often have a climafrost or permafrost layer 18-24 inches below the surface.

Although the soils listed above are the major types in the area, several others are also prominent, namely Regosols, Eutric and Dystric Brunisols, and Ferrohumic Podzols.

Regosolic soils with little or no profile development predominate on the alluvium in the main valleys. They are often cumulic with buried organic horizons caused by regular floodplain sand and silt deposition. They may also be imperfectly drained (Gleyed Cumulic Regosols).

Eutric Brunisols are found on well to imperfectly drained outwash sands and gravel as well as alluvium on terraces above the present floodplain level. Dystric Brunisols are found on acidic outwash sands and gravels on upland sites, most often occupied by jack pine forests. Both Brunisols may be either orthic (well drained), gleyed (imperfectly drained) or degraded (thin leached layer present).

Ferrohumic Podzols also occur principally on acidic outwash sands and gravels. However, they have strongly defined ash-grey leached A horizons and orange to reddish-brown B horizons due to strong ferralization.

2.3 LITERATURE REVIEW OF VEGETATION

There are very few specific accounts of the vegetation of the AOSERP study area. However, the following publications contained information pertinent to this study.

Lewis, Dowding and Moss (1928) give detailed but geographically non-specific descriptions of swamp, moor and bog forest, and Moss provides (1955) a similar treatment of all the principal vegetation types throughout the boreal forest in Alberta.

La Roi (1967a) gives a general description of the vegetation of the boreal forest in Alberta, and also gives a detailed analysis of the boreal spruce-fire forests across North America (1967b).

Raup (1946) includes a brief, historical account of botanical explorations along the Clearwater and Athabasca Rivers and describes the major vegetation types as part of a much larger study area, the Athabasca-Slave Lake Region.

Lindsay et al. (1957, 1961, 1962) present a brief description of the major vegetation types in relation to the soils, surficial deposits, and topography in areas covered by the 74 D, E, L and 84 A, H, and I map sheets.

Syncrude (1973) give a fairly detailed account of 12 basic habitat types on the Syncrude lease. The major emphasis is on a browse survey with no coverage of non-woody plants. This report also includes a comparative description for aspen- and spruce-dominated mixedwood forest.

Lombard North (1974) presents brief descriptions of the eleven principal plant communities on the Amoco lease. The descriptions include non-woody understory species.

Rowe's (1972) brief but very useful geographical description of the forests in the Boreal Forest Region in Alberta places much of the AOSERP study area in the Mixedwood Section. The Athabasca River valley north of Fort MacKay is placed in the Upper Mackenzie Section and the northeastern part of the area is included in the Athabasca Section of the Boreal Forest Region.

Several other authors give accounts of vegetation types in adjacent areas which are directly comparable with the AOSERP study area. Moss (1932) and Duffy (1964, 1965) give detailed accounts of the vegetation of the Mixedwood Section of the Boreal Forest Region to the south of the AOSERP study area with Duffy employing a forest land classification approach.

Other pertinent references are those of Moss (1953a) on the forest communities of northwestern Alberta, Moss (1953B) on the marsh and bog vegetation of northwestern Alberta, and Dix and Swan (1971) and Jeglum (1968) on the upland boreal forest and wetlands respectively of an area in north central Saskatchewan.

Finally, Dabbs (1971), Dirschl (1973) and Dirschl , Dabbs and Gentle (1974) give excellent and detailed accounts of the vegetation of the Peace-Athabasca Delta area immediately to the north of the area where many of the wetland types so described are directly comparable to communities in the AOSERP study area.

As bryophytes and lichens form an important component of the vegetation of the area, a special mention should be made of literature pertaining to them. However, although a search of the literature reveals that there are no accounts of the bryophytes or lichens of this area per se much useful information is contained in descriptions of vegetation types in areas similar to or adjacent to the study area. For example, La Roi and Stringer (1976) give an analysis of the bryophyte flora of the boreal spruce-fir forests of the North American taiga. Also, the habitats of the principal bryophytes and lichens are described for forest communities in northeastern Alberta (Moss, 1953a), for marshes and bogs in central Alberta (Moss, 1953b), for bryophytes of the Edmonton region (Moss and Turner, 1961), and for poplar forests of central Alberta (Moss, 1932). Bird and his associates have published many invaluable accounts of the whole bryophyte and lichen flora of the three prairie provinces, but principally of Alberta, the most pertinent of which are Bird (1962, 1968, 1969, 1970, 1972, 1973).

Many studies of plant communities and vegetation types in areas adjacent to the AOSERP study area at best mention only a few of the largest, most conspicuous or most easily identified moss and lichen species and are, therefore, of limited use, e.g. Dirschl (1970a, 1973), Dirschl, Dabbs and Gentle (1974), Duffy (1964, 1965), Lewis and Dowding (1926), Lewis, Dowding and Moss (1928), Moss (1955), Raup (1946) and Swan and Dix (1971).

Several other publications are pertinent to this study although they deal with study sites outside Alberta. These include Argus (1964, 1966, 1968) on the bryophytes of boreal Saskatchewan, Heinselman (1963, 1970) on the peatland ecology of mosses and lichens in Minnesota, Jesberger and Sheard (1973) on corticolous lichen communities in the boreal forest of Saskatchewan, Jonescu (1970) on lichens on aspen in west-central Canada, and Looman (1964) on bryophytes and lichen communities in Saskatchewan.

3. FIELD METHODS

Eighty-four stands (plots) chosen as representative of all the major vegetation types in the area were sampled between August 18 and September 3, 1975 (Numbers 1-84, Figure 1).

The stands (plots) varied in size from 25 x 25 feet to 100 x 100 feet depending upon the type of vegetation, and were chosen as representatives of the vegetation types in which they were situated. For example, a 25 x 25 foot area was considered adequate to sample sedge marsh or dense small-statured black spruce bog forest, whereas 100 x 100 feet was thought necessary to sample adequately semi-open jack pine forest or mature bottomland balsam poplar forest.

The only selection criteria used were that the stand be homogeneous, representative of a clearly-defined vegetation type, and undisturbed by man. Ease of accessibility also placed limitations on the selections possible.

The extremely short field survey period necessitated somewhat abbreviated survey methods. Only the very minimum that would allow a plant community description was possible in the time available. Thus no subsampling of the stands to obtain statistically more useful results was attempted and certain normally basic field survey methods had to be omitted.

Within each non-forested stand, and for the understory of forested stands, the average maximum height of each woody species was estimated and a semi-quantitative, visual estimate was made of the cover-abundance value of each terrestrial plant species by means of a modified Braun-Blanquet (1964) scale as follows:

R = rare, usually a single plant only
+ = common but cover <1%
1 = abundant, cover 1-5%
2 = abundant, cover 5-25%
3 = abundant, cover 25-50%
4 = abundant, cover 50-75%
5 = abundant, cover 75-100%

The more prominent terrestrial bryophytes and lichens were included as well as all vascular plants. All unknowns were collected for later identification. Inconspicuous, low-cover terricolous, corticolous, saxicolous, and lignicolous bryophytes and lichens were collected en masse as time permitted. Several samples were taken from each of the principal substrate types having bryophyte and lichen populations, e.g. rotting logs, tree bases, litter and humus, exposed mineral soil. These samples which generally consisted of species mixtures were dried and stored for later confirmation or identification.

There was no attempt made at the time to make a comprehensive collection of all bryophyte and lichen species in the whole area or even in the communities themselves. A number of minor vegetation types and other possibly species-rich habitats were not sampled at all, e.g. roadsides, wasteground, ditches, most riverine habitats, steep banks, rock outcrops, aquatic habitats. Minute crustose lichens were almost completely omitted, and species growing on the bark of living trees (corticolous species) were neglected.

Thus this collection provides by no means a comprehensive list of the species in the area. It does, however, indicate the more frequent species in the major vegetation types, their habitat preferences and community relationships.

In forested stands, the tree stratum was sampled by recording the diameter and species of each tree (≥3" diameter at 1.5 m height) and sapling (1-3" diameter at 1.5 m height) within the defined stand area, and measuring the heights of several of the larger trees with a clinometer and tape. Increment boring of trees for age unfortunately had to be omitted due to the time factor. Notes on topography, tree regeneration, stand health, signs of disturbance, etc., were made to round out a stand description.

On the basis of the data collected, the structure and composition of each stand of vegetation was described together with its exact location on both an aerial photograph and a forest cover map to allow later photo-interpretive study.

In most stands, a soil corer was used to obtain a quick visual estimate of soil type.

4. STAND CLASSIFICATION

4.1 METHODS

In order to classify the stands objectively into distinctive vegetation types based on the total species composition, the Cluster Analysis method was applied to the data from the 84 stands.

The method of Carmichael (George and Carmichael, 1966; Carmichael, George and Julius, 1968) was suitable for this purpose. It is an agglomerative method of classification. Given a set of points (stands) located in space by their relative proximities, this method finds those subsets (groups) of points which are sufficiently isolated from the other subsets to be recognized as discrete clusters. A rank-ordered list of the interpoint similarities is searched to find clusters of very close points. These clusters are then added to and combined at successively lower levels of similarity.

The value used to represent the similarity between each pair of points (stands) was that of Gleason (1920), as follows:

Coefficient of Similarity = $2w/(a+b)$

where: a = sum of values of all species in one stand

b = sum of values of all species in another stand

and w = sum of values of species the two stands have in common.

The quantitative values for each stand used in the equation were derived from the cover-abundance values of all species except the trees themselves and all uncommon or rare species, that is, those present in four stands or less and having no cover-abundance values greater than 1. Omission of the tree data from this Cluster Analysis allows the results to be compared with forestry classifications based on tree data alone, and will show how closely the understory and overstory are correlated.

The Coefficient of Similarity was then calculated for each pair of stands using the cover-abundance values directly and using the values 0.5 and 0.1 to replace "+" and "R" respectively.

Cluster Analysis followed the method of Carmichael, George and Julius (1968) precisely, except that the value "BEGIN" (the minimum level of interpoint similarity necessary to start a cluster) was set at 0.3000 instead of the recommended value (set automatically at 10% down the list of similarities and in this case 0.4000).

The configuration of stands at all 12 levels of resolution was represented in the form of dendrogram (Figure 2), and decisions as to which levels of resolution would give the most meaningful clustering were then made by comparison of configurations at all levels.

4.2 RESULTS

The 84 stands were clearly divided into a number of distinct clusters between which few linkages existed. Such linkages are formed by stands of intermediate position.

By consideration of both cluster amalgamations and linkage between clusters, it was possible to arrange the stands in a linear sequence (Appendix 2). However, it should be noted that the true relationships between the stands are not linear as no single environmental influence is of overriding importance. Most of this linear sequence appears to represent a simple moisture gradient from open fen to dry sandy pine forest but anomalies in the sequence show that other conflicting environmental factors are also strongly operative, and that the true spatial relationships are multidimensional.

There were comparatively few changes in clustering from the highest level of resolution (Level 1 = 14 clusters) to the lowest (Level 12 = 11 clusters).

Most of the smaller clusters tended to remain independent. Thus the 13 clusters have been labelled from A-M (Figure 2), and their relationship at various levels of resolution are as follows:

Changes in relationship between Stands 40, 44, 10, 37, 60, 36, and 1 with Satellites[1] 38 and 43 at different levels of resolution show that these stands form a single linear cluster (A) of nine, which remains quite distinctive from other clusters throughout.

Clusters B, C, D and E are small clusters that remain independent (Figure 2). Clusters C, D and E, however, have strong links with each other or the large central Cluster H.

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[1] A satellite is a stand that is associated with a cluster by reason of a strong similarity link with at least one member of an existing cluster. It is not however close enough overall to be taken into that cluster.

Clusters F, G, H, I and J form a large central complex that changes its configuration several times from Levels 1 to 12. These clusters gradually amalgamate to form, along with Cluster L, two large clusters (F-G-H-L and I-J) at Level 4, linked by Stands 5, 47 and 80. The F-G-H-L cluster then breaks up at Level 9 to reform the F, G and H clusters, transfer Stands 5, 47 and 80 to the I-J cluster and join L to M.

Cluster K remains quite independent except for a linkage to Cluster L through Stand 49.

Clusters L and M amalgamate to form one large cluster at Level 9, indicative of a close relationship between them. Cluster L also has a close relationship to Cluster F-G-H as it is joined to that cluster from Levels 4 to 9.

Consideration of the cluster configuration at one level only gives a false impression of the relationships involved and therefore definition of the final recognized clusters involves configurations at all levels, and somewhat subjective decisions on the most logical groupings.

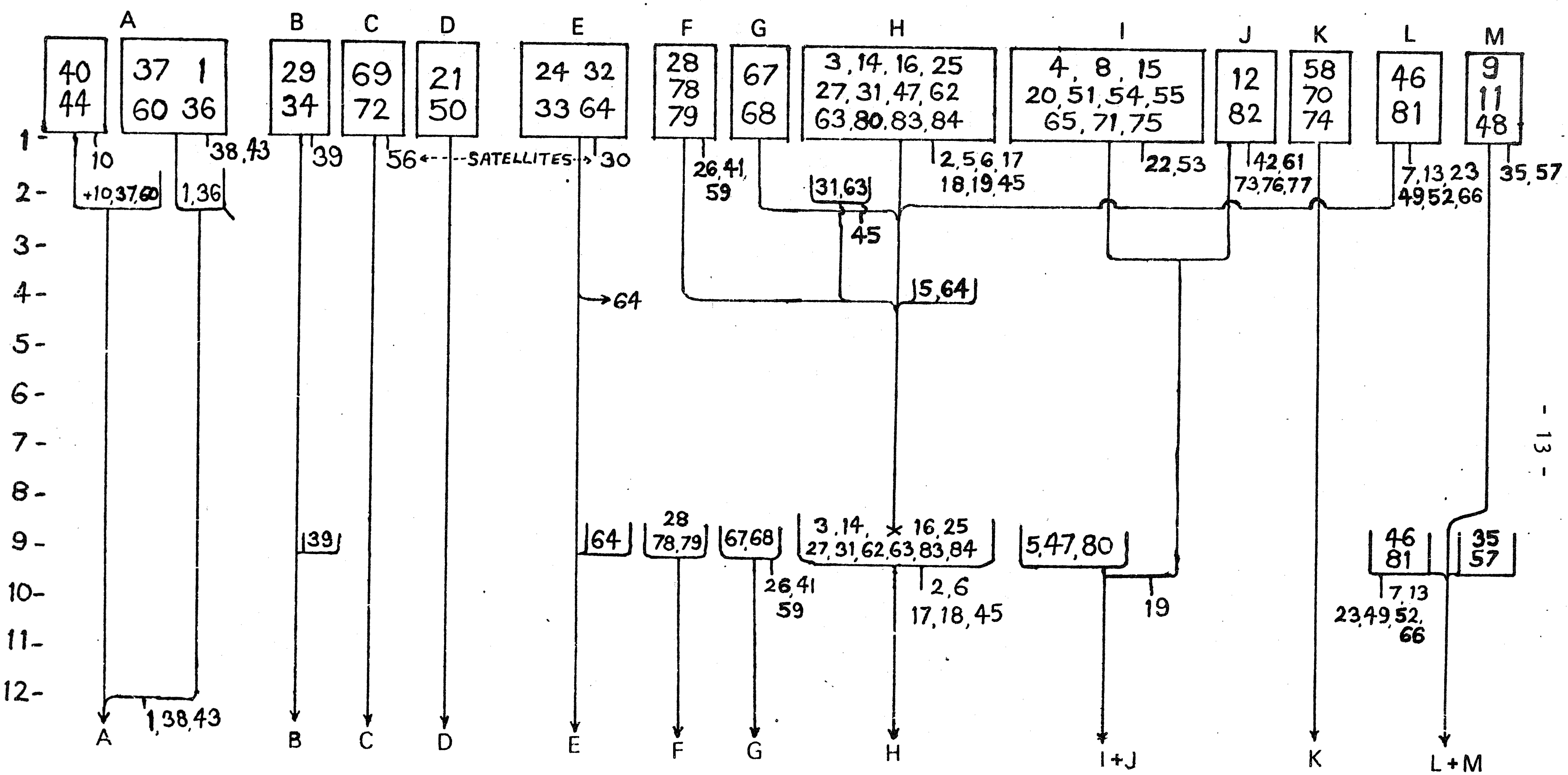

FIGURE 3. Dendrogram, showing clustering of 84 stands at 12 levels of resolution. The degree of similarity between the stands forming each cluster decreases uniformly with increasing level of resolution.

5. VEGETATION TYPES

5.1 STRUCTURE AND COMPOSITION

Appendix 2 shows the linear sequence and clustering of stands defined principally at Level 1 of the cluster analysis, together with species compositions and abundance, and forest type information. This enables the dominant and characteristic species of the clusters to be determined and correlations between understory vegetation and forest types to be shown.

5.1.1 Fen.

Cluster A is composed of fen stands on very wet upland sites, that is, away from the major valleys or rivers. The shrub stratum, intermittent or sometimes absent, is composed principally of *Betula pumila* var. *glandulifera* (Swamp birch) 1-5 feet high. The dominant herb stratum consists almost entirely of a thick unstable, seemingly floating mat of sedges. Stands 10, 37, 38, 40, 44 and 60 are dominated principally by the broad-leaved sedges *Carex aquatilis* and *C. lasiocarpa*, whereas Stands 1, 36 and 43 are dominated by the fine-leaved sedges *Carex diandra* and *C. disperma*. A number of semiaquatic forbs are also present, for example, *Menyanthes trifoliata* (Buck-bean), and *Potentilla palustris* (Marsh cinquefoil), often accompanied by *Triglochin maritima* (Arrow grass), *Scutellaria galericulata* (Skullcap), *Rumex occidentalis* (Western dock), and *Polygonum amphibium* (Water smartweed). Among the lower stems and roots of these vascular plants is a dense, almost continuous, thick, spongy, waterlogged mat of semiaquatic mosses principally *Drepanocladus revolvens* var. *intermedius* and *D. aduncus* var. *polycarpus*. These two mosses together with *Carex diandra, C. disperma, C. lasiocarpa, Menyanthes trifoliata,* and *Potentilla palustris* were far more abundant than elsewhere and can be considered as differential species to this community type.

Other bryophyte species were relatively unimportant: *Brachythecium nelsonii, Campylium stellatum, Meesia triquetra* and *Meesia longiseta* were occasionally to be found within the *Drepanocladus* mat, probably in the slightly drier microsites. Conspicuous hammocks of *Aulacomnium palustre* and *Tomenthypnum nitens* were occasionally found, especially toward the margins of the fens. *Sphagnum* species were rare.

Liverworts were generally absent. However, six small liverworts were found in Stand 38 on slightly raised hummocks formed by the bases of low willows and dead wood *(Lophocolea heterophylla, Lophozia ventricosa, Riccardia latifrons, Cephalozia pleniceps, Cephaloziella hampeana,* and *Scapania irrigua)*. The latter three species were not found elsewhere in this study.

Lichens were infrequent and were found usually on the bark of shrubs, principally low willows. The most common was the bright yellow *Cetraria pinastri*.

5.1.2 Sandbar Willow Scrub.

Cluster B consists of three stands of willow scrub 10-18 feet high, which usually borders rivers and watercourses but is also present in some wet depressions. The stands were completely dominated by willows, principally *Salix interior* (Sandbar willow) and less frequently *Salix pseudomonticola*. These willows are exclusive to this community type. The annual deposition of alluvial soil, and the dense shade cast by the willows permits few other species to grow. The only prominent herbs were *Equisetum arvense* (Field horsetail) and *Calamagrostis canadensis* (Marsh reed grass). The small mosses *Dicranella varia, Barbula fallax* and *Polia wahlenbergii*, and the thallose liverwort *Blasia pusilla*, formed an intermittent and sparse bryophyte ground stratum. The few other bryophyte and lichen species present were found as small, scattered patches on shrub bases and dead wood above the ground surface. These appear to represent partially, communities more typical of nearby forest habitats.

5.1.3 Tall Willow-River Alder Scrub

Cluster C is composed of three stands of tall willow-river alder scrub 15 - 18 ft. high completely dominated by a closed canopy of the willows *Salix bebbiana, S. lasiandra,* and *Alnus tenuifolia* (River alder). *Cornus stolonifera* (Dogwood), 5 feet high, was prominent in Stand 72.

The herb stratum was varied and sparse in stands of Cluster C with only *Calamagrostis canadensis* (Marsh reed grass) being consistently prominent. Among the wide diversity of accompanying herbs, the more common were

Epilobium angustifolium (Fireweed), *Equisetum arvense, Galium triflorum* (Sweet scented bedstraw), *Mertensia paniculata* (Lungwort), *Mitella nuda* (Mitrewort), *Rubus acaulis* (Dwarf raspberry), and *R. pubescens* (Dewberry). Habitat conditions in this vegetation type are very similar to those in sandbar willow scrub. However, flooding disturbance on these sites may be somewhat less because of their greater distance from surface water. Thus, the dense shade and generally low moisture availability at the ground surface excluded all but a few species. Lichens and liverworts were virtually absent. Mosses were found mainly on shrub bases and dead wood, and were poorly-developed specimens of species more characteristic of nearby forest habitats. The only common nonvascular species occuring on the ground were two small hummock-forming turf mosses, *Aulacomnium palustre* and *Tomenthypnum nitens*.

5.1.4 Tall Willow Scrub.

Cluster D is composed of tall willow scrub stands 15-20 feet high, differing from Cluster C in the notable absence of *Alnus tenuifolia* and *Salix lasiandra* from the tall shrub stratum and *Aulacomnium* and *Tomenthypnum* from the bryophyte stratum, and from Cluster B in the extra height and differing willow species. Thus, the tall shrub stratum was completely dominated by *Salix bebbiana* and the bryophyte stratum by a prominent turf of *Climacium dendroides*. The shrub *Cornus stolonifera* formed conspicuous clumps 6 - 9 feet high beneath the *Salix* stratum. The herb stratum was again sparse and varied, being dominated by *Anemone canadensis* (Canada anemone), *Calamagrostis canadensis, Equisetum arvense, E. pratense, Galium boreale* (Northern bedstraw), and *Rubus pubescens*.

Clusters C and D are representative of large areas of tall scrub bordering rivers, and occupying wet but freely-drained depressions throughout the AOSERP area. The sandbar willow scrub stands of Cluster B occur most frequently as a narrow band between stands of the C and D clusters and the major rivers.

5.1.5 Bottomland Balsam Poplar Forest.

Within Cluster E, the central core of Stands 24, 32 and 33 is representative of balsam poplar *(Populus balsamifera)* forest found in the bottomland along the Clearwater River, parts of the Athabasca River, and probably present as small patches along some of the major tributaries. Stands 30 and 64 are, respectively, white birch forest and river alder scrub immediately adjacent to poplar stands and they therefore contain many of the same understory species.

The balsam poplar trees are generally of large size being up to 26 inches in diameter and 80-95 feet in height. Occasionally, medium-large white spruce *(Picea glauca)* and aspen *(Populus tremuloides)* were present. Regeneration of the tree species was sparse or absent entirely.

The understory was composed of a medium-dense tall shrub stratum of *Alnus tenuifolia* (15-20 feet), an intermittent medium shrub stratum of *Cornus stolonifera* (6-9 feet), a medium-dense low shrub stratum 1½-6 feet high, principally composed of *Virburnum edule* (Low bush cranberry), *Ribes oxyacanthoides* (Wild gooseberry), *R. triste* (Wild red currant), *Rosa acicularis* (Prickly rose), and *Rubus strigosus* (Wild red raspberry), and finally a medium-dense herb stratum consisting of *Calamagrostis canadensis, Equisetum pratense, Galium triflorum, Rubus pubescens* and many other less prominent species. The principal nonvascular species were mosses that are more usually found in upland mixedwood and aspen forests. Thus, *Pylaisiella polyantha* was the dominant species on bark toward the bases of trees, while further down the trunk and on the humus and litter at the tree base, *Eurhynchium pulchellum, Plagiomnium cuspidatum,* and *Brachythecium salebrosum* formed a continuous "stocking". Several species were frequent but not prominent on litter, twigs, fragmented wood, and dead logs on the forest floor. The principal species in this group were *Brachythecium rutabulum, Brachythecium salebrosum, Amblystegium juratzkanum, Campylium hispidulum, Drepanocladus uncinatus, Haplocladium microphyllum,* and *Oncophorus wahlenbergii.*

Hypnum pratense and *Timmia megapolitana* were found only in this vegetation type. They occurred on thin humus over mineral soil. Liverworts were rare and lichens appeared to be absent from this vegetation type.

Cluster E stands usually form the belt of vegetation on the side of tall scrub stands of Clusters C and D away from the major rivers.

5.1.6 Upland Mixedwood and Deciduous Forest.

Clusters F and G are two small closely related clusters which represent closed canopy, upland forest of mixed composition. The principal tree species are aspen, white spruce, white birch *(Betula papyrifera)* with some jack pine *(Pinus banksiana)*. The mature white spruce are generally largest (up to 17 inches in diameter and up to 110 feet in height), the aspen intermediate (up to 8 inches in diameter and up to 60 feet in height), and the white birch smallest (up to 8 inches in diameter and up to 70 feet high). Tree regeneration was poor in all these stands and the species composition often quite different from the major canopy species. For example, black spruce *(Picea mariana)* reproduction was abundant in Stands 67 and 68, balsam fir *(Abies balsamea)* in Stand 68, and white spruce in Stand 26. Thus, all the stands of these two clusters seem to be successional stages on upland sites and probably do not form a natural grouping.

Many of the most prominent understory species were common to stands of both clusters, namely a medium-dense, tall shrub stratum dominated by *Alnus crispa* (Green alder) 10-15 feet high, a dense herb-dwarf shrub stratum dominated by *Vaccinium myrtilloides* (Blueberry), *Vaccinium vitis-idaea* (Bog cranberry), *Cornus canadensis* (Bunchberry), *Aralia nudicaulis* (Wild sarsaparilla), *Linnaea borealis* (Twin-flower), *Schizachne purpurascens* and *Lycopodium complanatum* (Ground cedar), and an intermittent bryophyte and lichen stratum dominated by the feathermosses *Pleurozium schreberi* and *Hylocomium splendens*, the turf mosses *Polytrichum juniperinum* and *Dicranum polysetum*, and the foliose lichen *Cladina arbuscula*.

However, significant differences in species composition did exist between these two clusters of stands; *Lycopodium annotinum* (Stiff club moss) was confined to Cluster G whereas the shrubs *Rosa acicularis* and *Amelanchier alnifolia* (Saskatoon berry), the grasses *Elymus innovatus* (Canada wild rye), and *Oryzopsis pungens* and the dwarf shrub *Arctostaphylos uva-ursi* (Common bearberry), were confined to Cluster F.

The varied tree canopies together with the diverse understory of the stands of Clusters F and G makes their validity as distinct stand groupings and their relationship within the overall community classification obscure. This especially applies to the two satellite Stands 41 (dense tamarack bog forest) and 58 (dense black spruce bog forest) whose position seems to be completely anomalous.

5.1.7 Upland White Spruce-Aspen Forest.

Cluster H is a very large group of stands of closed canopy, upland forest composed principally of white spruce and aspen, together with occasional black spruce, balsam poplar, and balsam fir. Many stands have significant regeneration of both the principal tree species and sometimes other species not represented in the canopy, for example, balsam poplar reproduction in Stand 25, black spruce in 62, balsam fir in 27,31, 47, and white birch in 47 and 62. Clearly, most stands in this cluster are of a successional nature.

In the five stands dominated by white spruce, the spruce have reached heights up to 105 feet and diameters of up to 22 inches whereas the aspen are invariably smaller and seem to have been surpassed by the spruce (maximum height 75 feet, diameter 16 inches). The nine stands dominated by aspen usually had aspens of high density with heights which reached up to 65 feet and diameters up to 16 inches but which were usually a good deal lower. Tree reproduction, if present, usually was species other than aspen and usually consisted of white spruce.

Thus, most of the stands of Cluster H appear to be successional stages of a sere culminating in a climax of white spruce with perhaps balsam fir. The individual stands represent a variety of stages of succession from pure fire-initiated stands of young aspen (Stand b) to mature white spruce-balsam fir forests which may be very close to the climax state (Stand 63).

The Cluster H stands have a very distinctive understory. An intermittent tall shrub stratum of *Alnus crispa,* 9-15 feet high, is present in several stands. Medium and low shrubs constitute a well developed stratum 1-6 feet high, dominated by *Ribes triste, Rosa acicularis,* and *Viburnum edule* (Low bush cranberry), and sometimes accompanied by *Ledum groenlandicum* (Labrador tea) and *Vaccinium* *myrtilloides*. The well-developed, dense dwarf shrub-herb stratum has a high species diversity and is dominated by *Aralia nudicaulis, Cornus canadensis, Linnaea borealis, Petasites palmatus* (Coltsfoot), *Rubus pubescens,* and *Vaccinium vitis-idaea*. Only slightly less abundant are *Aster ciloilatus* (Lindley's aster), *Calamagrostis canadensis, Elymus innovatus, Epilobium angustifolium, Equisetum sylvaticum* (Woodland horsetail), *Fragaria virginiana* var. *glauca* (Wild strawberry), *Galium triflorum, Lathyrus ochroleucus* (Pea vine), *Lycopodium annotinum, Maianthemum canadense* (Wild lily-of-the-valley), *Mertensia paniculata, Mitella nuda, Pyrola asarifolia* (a Wintergreen), *P. secunda* (a Wintergreen), *Schizachne purpurascens, Vaccinium vitis-idaea,* and *Viola renifolia* (Kidney-leaved violet).

The bryophyte and lichen component of these forests varied widely. The species and their abundance at any one site apparently depended upon the availability of various substrates as most of the species seemed to be substrate-specific. Forests with a large proportion of coniferous trees generally had a high species diversity because of greater range of substrates available and less chance of smothering by deciduous leaf fall.

In aspen and other hardwood forests, bryophytes and lichens were confined to substrates above the forest floor, i.e. to those sites which are not smothered by leaf fall, e.g. tree bases, stumps, logs.

Continuous mats of *Pylaisiella polyantha* covered the bases of trees such as aspen, poplar, and white birch. Below the *Pylaisiella,* other mosses, principally *Brachythecium salebrosum, Plagiomnium cuspidatum, Eurhynchium pulchellum* and *Haplocladium microphyllum* occurred at the tree base where some humus had collected. Mature white birch and most coniferous trees carried a variety of epiphytic lichens chiefly *Evernia mesomorpha, Ramalina farinacea, Usnea subfloridana, Hypogymnia physodes,* and *Parmelia sulcata*. In these forests, aspen and balsam poplar rarely bore epiphytes, although moss species of the genus *Orthotrichum,* e.g. *Orthotrichum obtusifolium,* were often present as small dark-green patches on poplar as well as coniferous tree bark.

On rotting deadfall on the forest floor there were a large number of species. These form a complex series of successional communities as the wood rots and additional humus accumulates. The most frequent colonizers of this deadfall were the mosses *Amblystegium juratzkanum, Campylium hispidulum, Dicranum flagellare, D. fragilifolium, D. fuscescens, Herzogiella turfacea, Oncophorus wahlenbergii, Pohlia nutans,* and *Tetraphis pellucida;* the liverworts *Isopaches hellerianus, Jamesoniella autumnalis, Lophozia longidens, Ptilidium pulcherrimum* and *Tritomaria exsectiformis;* and the small yellow lichen *Cetraria pinastri.* As humus accumulates on the rotting wood these colonizers are replaced by other more vigorous species, e.g. *Brachythecium salebrosum, B. velutinum, B. rutabulum, Climacium dendroides, Drepanocladus uncinatus, Plagiomnium cuspidatum, P. drummondii.* In forests with a high proportion of coniferous trees, these successional species are, in their turn, eventually overgrown by a thick continuous feathermoss carpet dominated by *Hylocomium splendens* and *Pleurozium schreberi.*

On the forest floor as a whole, a brophyte-lichen carpet occurred only where there was a high proportion of coniferous trees in the canopy. In such forests the smothering effect of leaf fall from deciduous trees and shrubs was slight.

Thus, in mature, closed-canopy white spruce forests, there was a continuous carpet of the feathermosses *Pleurozium schreberi* and *Hylocomium splendens,* occasionally with scattered plants of the mosses *Ptilium crista-castrensis* and *Rhytidiadelphus triquetrus,* and the large lichens *Cladina arbuscula, Peltigera aphthosa* var. *variolosa, P. canina* var. *rufescens* and *P. polydactyla.*

5.1.8 Black Spruce Bog Forest and Muskeg.

Cluster I was a group of 12 stands of black spruce bog forest and muskeg on organic soils composed of peat usually in excess of three feet in depth. The black spruce vary from sparse to medium dense, are small in diameter (0-4 inches) and low in height (up to 30 feet but usually much less). The only other tree species, tamarack *(Larix laricina)*, was present in two stands only and was of about the same size as the spruce. However, two stands, 51 and 54, had abundant reproduction of white birch.

No tall shrubs were present. The intermittent shrub stratum was dominated by *Ledum groenlandicum* (1-3 feet high) and *Vaccinium* *myrtilloides* (0.3-1 foot) with a scattered representation of *Betula glandulosa* (Dwarf birch), *Chamaedaphne calyculata* (Leather-leaf), *Salix glauca*, and *S. myrtillifolia*. The dwarf shrub-herb stratum was sparse, the only prominent species being *Equisetum sylvaticum, Oxycoccus microcarpus* (Bog cranberry), *Rubus chamaemorus* (Cloudberry) and *Vaccinium vitis-idaea* with *Eriophorum vaginatum* (Cottongrass) and *Smilacina trifolia* (Three-leaved Solomon's seal) somewhat less common.

5.1.9 Semi-Open Black Spruce-Tamarack Bog Forest and Muskeg (Cluster J).

These stands are low, semi-open black spruce-tamarack bog forest and muskeg, very similar to those in Cluster I. There is however, a higher proportion of open muskeg, and tamarack is more frequent.

The black spruce and tamarack are of sparse to medium density, the spruce being up to 30 feet high and 7 inches in diameter but usually much less. The tamarack, which generally appear to be more vigorous, are about the same diameter but can be up to 35 feet high. Tree regeneration is usually completely absent except for some layering by the spruce.

The prominent medium to low shrub stratum is completely dominated by *Ledum groenlandicum* (1-3 feet) although in open muskeg *Betula pumila* var. *glandulifera* (2-4 feet), *Chamaedaphne calyculata, Kalmia polyfolia* (Mountain laurel), *Andromeda polyfolia* (Bog rosemary), and *Salix pedicellaris* var. *hypoglauca* (0.7-1.5 feet) become prominent also. Dwarf shrubs and herbs are scattered and sparse with only *Vaccinium vitis-idaea* and *Rubus chamaemorus* being prominent in the bog forest stands. In open muskeg, cover and diversity of this latter stratum increase to include *Carex aquatilis, C. gynocrates, C. paupercula, C. tenuiflora, Oxycoccus microcarpus, Potentilla palustris,* and *Smilacina trifolia*.

5.1.10 Lightly-Forested Tamarack and Open Muskeg (Cluster K).

These stands are generally of open muskeg but may have a few scattered trees present. The one forested stand (69) has scattered tamarack 12-15 feet high and more frequent but smaller and less vigorous black spruce only 3-6 feet high.

A prominent shrub stratum is dominated by *Salix lasiandra* and *Salix bebbiana* (2-6 feet), *Betula glandulosa* (2-4 feet) and *Ledum groenlandicum* (1-2 feet). The herb stratum is dominated by *Carex aquatilis, C. gynocrates, Equisetum scirpoides, E. sylvaticum, Oxycoccus* *micranthus* and *Parnassia palustris* (Grass of Parnassus).

The stands of Clusters I, J, and K represent large areas of poorly-drained uplands in the AOSERP study area completely covered with thick peat deposits derived from sphagnum and other bog mosses. Here, only two tree species - black spruce and tamarack - can thrive. In these areas there is a complete gradient from dense mature bog forest at the mesic extreme in Cluster I through lightly treed black spruce-tamarack muskeg to open muskeg at the hydric extreme in Cluster K. These open muskegs are poorly-drained and acid, and differ markedly from the open fens which are freely drained though water-saturated and neutral to alkaline. In both fens and muskegs, a thick, spongy, continuous surface layer of mosses is characteristic, but the species involved are quite different. *Drepanocladus* species are characteristic of fens while muskegs usually have thick, peat-forming hummocks composed of *Sphagnum* species, with *Aulacomnium palustre* and *Tomenthypnum nitens*. To call these muskegs "*Sphagnum* bogs" may be a misnomer as *Aulacomnium* and *Tomenthypnum* may often be more important.

Of the five principal *Sphagnums* found, *S. capillaceum* was more prominent in the drier bog forests whereas *S. fuscum* and *S. warnstorfii*, and to a lesser extent, *S. magellanicum* and *S. recuruum* var. *tenue* were most prominent in the open muskeg. *Aulacomnium palustre* and *Tomenthypnum nitens* were also prominent in the open muskegs.

Growing within and on the surface of the *Sphagnum* - *Aulacomnium* - *Tomenthypnum* hummocks were a number of inconspicuous but characteristic liverworts. The more important of these were *Mylia anomala, Calypogeia sphagnicola, Lophozia obtusa, Cephalozia media* and *Cephaloziella rubella*.

Two prominent turf-forming mosses *Polytrichum juniperinum* and *Dicranum undulatum,* were frequently found as small cushions among the larger *Sphagnum* hummocks, and several other mosses, e.g. *Hypnum lindbergii, Drepanocladus revolvens,* and *Calliergon* species often occupied moister, muck-filled hollows.

On the tops and sides of old, disintegrating *Sphagnum* hummocks, several fruticose lichens formed a conspicuous crust. These were invariably species of *Cladonia* and *Cladina*, especially *Cladonia deformis* and *Cladina mitis*. Most dead and rotting wood on the ground especially in semi-open areas, also bore several *Cladonia* species, e.g. *Cladonia gracilis*, c.f. the liverworts and moss communities on deadfall in forests.

The bark of trees, again especially in semi-open areas, often bore colonies of other lichens profusely, the most abundant of which were *Parmelia sulcata, Hypogymnia physodes, Evernia mesomorpha, Alectoria glabra, Usnea subfloridana* and several other species of *Usnea* and *Alectoria*.

In denser bog forests, all the foregoing species occurred besides many species more typical of mesic upland coniferous forest. Thus, *Sphagnum* hummocks were often found alternating with sheets of *Peltigera aphthosa* var. *variolosa*, and mats of the feathermosses *Hylocomium splendens, Pleurozium schreberi, Ptilium crista-castrensis*, with *Plagiomnium rugicum* sometimes prominent in wet, shady hollows.

5.1.11 Upland Mixedwood and Coniferous Forest.

Cluster L is a heterogeneous group of mixedwood and coniferous forest stands on upland, sandy sites. The principal tree species are jack pine, black spruce and white birch, but white spruce, balsam fir and aspen also occur. Jack pine reach 11 inches diameter and 50 feet in height, and black spruce 8 inches diameter and 40 feet in height but both are usually considerably smaller. In stands where both species occur together, black spruce seems to be succeeding the larger jack pine; in every stand but one, black spruce is the only species reproducing. The white birch never exceeds 3 inches in diameter and 30 feet in height. As in Clusters F and G, the diverse composition of the tree stratum precludes any correlation between understory composition and the forest type.

The understory strata are more consistent in composition. A tall shrub stratum is either absent or consists of scattered *Salix bebbiana* and *Alnus crispa*. A well developed and prominent shrub stratum is dominated almost entirely by *Ledum groenlandicum* (1-2 feet) and *Vaccinium myrtilloides* (0.3-1 foot). The dwarf shrub-herb stratum is variable with only *Vaccinium vitis-idaea* prominent and constant. However, the bryophyte-lichen stratum forms an almost complete ground cover, the principal species being *Pleurozium schreberi, Hylocomium splendens, Dicranum polysetum, Cladina mitis*, and *C. alpestris*. Also common are

Polytrichum juniperinum, Peltigera malacea, Cetraria nivalis, Cladina rangiferina, and *C. arbuscula.*

5.1.12 Upland Jack Pine Forest.

Cluster M is a group of five closely related stands of jack pine forest (or openings in that forest) on dry, well drained sites formed of aeolian sand. Jack pine, the only tree species present, is up to 10 inches in diameter and up to 45 feet in height but no reproduction is present. However, considerable numbers of aspen saplings were present in Stands 35 and 48, indicating a possible eventual succession to aspen.

The understory of these stands is very distinctive. There are no tall or medium shrubs present. A prominent but often sparse low shrub stratum is composed entirely of *Vaccinium myrtilloides* (0.3-1 foot high). The sparse dwarf shrub stratum is dominated by *Arctostaphylos uva-ursi,* and *Oryzopsis pungens* with a scattered representation of *Campanula rotundifolia* (Bluebell), *Galium boreale, Vaccinium vitis-idaea, Comandra pallida* (Bastard toad-flax), *Solidago nemoralis* var. *decemflora, Melampyrum lineare* (Cow-wheat), and *Apocynum androsaemifolium* (Spreading dogbane). Most of these species are strongly differential to this community, particularly the latter three species, and so form a very distinctive stratum.

Although terrestrial bryophytes are absent, fruticose lichens do form a prominent and often nearly continuous lichen stratum. By far the most important of these was *Cladina mitis,* but *C. arbuscula, C. rangiferina, C. alpestris, Cladonia uncialis, C. cornuta, C. gracilis, C. phyllophora* and *Cetraria nivalis* were also common. Occasionally, sheets of *Peltigera* species, principally *Peltigera malacea* were also prominent. The only noticeable bryophytes were the mosses *Polytrichum junipernum* and *P. piliferum* which occurred as occasional tufts.

The following lichens were the principal colonizers of deadfall: *Cetraria halei, Parmeliopsis ambigua, Cetraria pinastri,* and *Cladonia coccifera.* Corticolous lichens were rare or absent. *Evernia mesomorpha* was the only common species.

5.2 PRINCIPAL VEGETATION TYPES

The principal vegetation types defined by cluster analysis as having distinctive species compositions follow.

5.2.1 Fen.

Fen (Cluster A) is dominated by broad-leaved sedges (Stands 10, 37, 38, 40, 44, 60) or by fine-leaved sedges (Stands 1, 36, 43) and occupies large areas generally away from the larger rivers, either bordering lakes or following the major upland drainage channels as string bog and patterned fen.

5.2.2 Sandbar Willow Scrub.

Sandbar willow scrub (Cluster B) reaches 10-18 feet high and is dominated by *Salix interior* with some *S. pseudomonticola* usually forming a narrow zone along the aggrading shores of the larger rivers, but also borders lakes and sloughs.

5.2.3 Tall Willow-River Alder Scrub.

Within Cluster C tall willow-river alder scrub grows 15-18 feet high. Dominated by *Salix bebbiana, S. lasiandra,* and *Alnus tenuifolia,* it occupies wet depressions inland and forms a zone immediately behind the sandbar willow scrub along the major rivers.

5.2.4 Tall Willow Scrub.

The tall willow scrub of Cluster D which is 15-20 feet high and dominated by *Salix bebbiana*, is found in wet depressions.

5.2.5 Bottomland Balsam Poplar Forest.

Cluster E, of bottomland balsam poplar forest, is dominated by a very tall, often pure population of balsam poplar and forms a wide zone behind the willow scrub zones on the floodplains of the major rivers.

5.2.6 Upland White Spruce-Aspen Forest.

Upland white spruce-aspen forest (Cluster H) with some balsam fir, appears to be the principal mature forest type on well to moderately drained upland sites throughout the Alberta oil sands area, the aspen-dominated sites being successional in the development toward a mature spruce-fir forest.

5.2.7 Black Spruce Bog Forest.

This type (Cluster I), developed on thick deposits of sphagnum moss, occupies very large, poorly-drained upland sites and grades imperceptibly into the next two types.

5.2.8 Semi-Open Black Spruce-Tamarack Bog Forest and Muskeg.

This type (Cluster J) developed on thick deposits of sphagnum and other bog mosses.

5.2.9 Lightly-Forested Tamarack and Open Muskeg.

The type indicated by Cluster K developed on poorly-drained upland sites similar to those on which the two previous vegetation types occurred.

5.2.10 Jack Pine Forest.

This type, (Cluster M) growing on upland, sandy and well- to very well-drained sites, is the most xerophytic vegetation type represented. It is the dominant type on large areas of aeolian sand in the northeastern and southwestern parts of the oil sands area.

The remaining three clusters (F, G and L) are forest stands whose tree canopy is too varied for them to be clearly defined as vegetation types. These three indefinable clusters, together with the very small numbers of stands in the types represented by Clusters B, C, D, and K, suggest that many more vegetation types exist. Clearly it was quite impossible to cover adequately the total range of vegetation types within the AOSERP area in the time permitted.

Therefore, these 10 vegetation types should be looked upon as the first tentative steps toward a vegetation classification, and should be used only as a guide to more definitive studies. Perusal of the literature supports the suggestion that the vegetation of the area is considerably more complex than this preliminary study indicates.

On an area of much smaller size but similar overall vegetation and topography in north-central Saskatchewan, Jeglum (1968) defined nine distinct categories of wetland vegetation--emergent fen (reedswamp), broad-leaved sedge fen, narrow-leaved sedge fen, tall shrub fen, low shrub fen, wooded (tamarack) fen, intermediate fen bog, treed bog (muskeg) and moist forest. He further divides these categories to give a total of 36 dominance types. The range of vegetation covered by these 36 dominance types is equivalent to only about 50 of the stands in this study.

Dabbs (1971) on the photogrammetrically-based classification of the Peace-Athabasca Delta in northeastern Alberta defined eight terrestrial--coniferous forest, deciduous forest, tall shrub (10-20 feet), low shrub (less than 10 feet), fen, immature fen on mudflats, forest and grassland on Precambrian rock outcrops--and 13 aquatic vegetation types at a scale of 1:37,000. At a scale of 1:7,000 and using black and white, color, and color infrared imagery together with ground-truth surveys, Dabbs was able to define 35 land-facet vegetation types similar to Jeglum's Dominance Types.

Detailed comparison of the 84 stands in the AOSERP study area with the vegetation types as defined by Dabbs and Jeglum shows that many of the clusters are probably composites of several types, especially the loosely-defined Clusters F, G, and L, the fen Cluster A and the large central Cluster H.

This illustrates the complexity of the vegetation and thus the necessity for more extensive studies in order to determine the full range of vegetation types.

5.3 CORRELATION WITH FOREST COVER TYPES

As the only existing vegetation maps of the AOSERP study area are Alberta Energy and Natural Resources Forest Cover Maps, it is necessary to determine how much these maps can contribute to a vegetation map of the area.

The whole study area is detailed on forest cover maps presented at scales of 1:63,360 (blue-lined) and 1:126,720 (lithography). These maps were compiled from broad-inventory interpretations of aerial black and white photography flown between 1950-1954. They designate forest height, density, sub-type (lodgepole or jack pine, black or white spruce, balsam fir, tamarack, deciduous, and combinations of these), and a certain number of non-forested types (potentially productive, burned over, marsh, bog or muskeg, grassland, hay meadow, treed muskeg, scrub, windfall, rock barren, barren above timberline).

Another series of forest cover maps at a scale of 1:63,360, published in 1951-1955 from the same aerial photography cover only 74D

(6, 11, 13, 14) and 74E (3, 4) map sheet areas, and give exactly the same information as the previous series.

Drawbacks in using these map series for a detailed study are:

(A) white birch, aspen, balsam poplar and perhaps even tall willow and alder scrub are all included under the same designation "deciduous". Admittedly it is very difficult to distinguish these species from each other on aerial photographs even with today's improved technology;

(B) all low stature wetland vegetation is included in one overall cover type, designated as "marsh, bog or open muskeg";

(C) the designation "scrub" includes a wide range of low woody vegetation--tall alder and willow scrub, forest on very low quality sites, and low-height bog forest.

Even allowing for the small map scale used, the 20-25 years growth since the aerial photographs were taken, and the less sophisticated technology of the early 1950s, there is too much disparity between these maps and the existing vegetation patterns to make them any more than marginally useful, and then only for the forested component of the vegetation.

Another series of forest cover maps has been published by Alberta Energy and Natural Resources at a scale of 1:31,680 from photographs taken in 1972 and 1974. However, since they cover only approximately Townships 88-100, Ranges 7-14, West of the 4th Meridian, they include only 48 of the 84 stands sampled. Nevertheless, they do present a great deal more information than the previous maps. Forest height and density are given in more detail, extra information is presented on commercial status of coniferous forests, condition and disturbance, date of origin, and site index. Three extra cover categories are included: deciduous scrub, coniferous scrub, and sand and unconsolidated deposits. There is no extra information on composition and so the three drawbacks listed for the previous two series still apply.

However, crosschecking indicated that a close correlation occurs between the most recent forest cover maps (1972, et. seq., 1:31,680) and existing vegetation. They should prove extremely useful in preparing the detailed AOSERP study area vegetation map. Limitations on their usefulness are imposed by the differing interpretive objectives involved, that is, the emphasis having been placed primarily on forestry rather than the vegetation overall.

Nonforested vegetation is much more difficult to interpret than forest. For example, with the scale and type of aerial photography used in preparing these maps, it is very difficult if not impossible to distinguish between open muskeg, fen, and low forest regenerating after fire.

Correspondence between stand clusters and forest cover map designations is as follows:

Cluster and Vegetation Type	Forest Cover Map Type (1:31,680)
A fen	muskeg (marsh, bog and open muskeg)
B sandbar willow scrub C tall willow-river alder scrub D tall willow scrub	scrub-deciduous
E bottomland balsam poplar forest	deciduous forest
F & G upland mixedwood and deciduous forest (combinations of aspen, white spruce, white birch)	deciduous and mixedwood forest
H upland white spruce-aspen forest	deciduous, mixedwood and coniferous forest
I black spruce bog forest and muskeg	black spruce forest of low site quality and volume, scrub-coniferous, treed muskeg and muskeg
J semiopen black spruce-tamarack bog forest and muskeg	scrub-coniferous, treed muskeg, muskeg and possibly scrub-deciduous
K lightly-forested tamarack and open muskeg	treed muskeg, muskeg and possibly scrub-deciduous
L upland, mixedwood and coniferous forest (combinations of jack pine, black spruce and white birch	mixedwood and coniferous forest
M upland jack pine forest	pine forest and possibly (if observed) pine forest with deciduous understory

5.4 SUCCESSION

No attempt can be made at this stage to discuss in detail the climax status of vegetation or successional trends involving the various vegetation types.

References that provide detailed analysis and discussion of successional trends which are highly pertinent to the AOSERP area are found in Dabbs (1971), Dirschl (1973), Dirschl, Dabbs and Gentle (1974), Dix and Swan (1971), Jeffrey (1961), Jeglum (1968), La Roi (1967a and b), Lewis and Dowding (1926), Lewis, Dowding and Moss (1928), Moss (1932, 1953a and b, 1955), Raup (1935, 1946), and Sjörs (1961).

However, even at this early stage, several generally accepted successional trends can be recognized.

5.4.1 Succession After Fire.

Vast areas, especially on well-drained upland sites, are in the early stages of regeneration after fire. These areas have not been sampled in this study as emphasis was put primarily on more mature vegetation. Young aspen occupies most of this area with jack pine on dry sandy sites. The aspen forest will eventually be replaced by aspen-white spruce mixedwood and then coniferous forest of white spruce with possibly some balsam fir. This sequence is well documented for other similar areas by Dix and Swan (1971), Moss (1932, 1953a and b, 1955) and Raup (1946). The nature of fire-free forest is largely a matter of conjecture. There are many stands dominated by aspen, jack pine, and white and black spruce beneath which there is little or no reproduction and therefore no evidence of succession. The area has probably undergone many fire disturbances followed in each instance by vegetational readjustments. Indeed, Rowe (1961) has described the western boreal forest as a disturbance forest. Thus any attempt to fit the vegetation into the mold of a climax concept would be premature.

5.4.2 Riverine Succession.

On aggrading meanders in the major river valleys, especially the Clearwater River, succession occurs from zones of willow scrub and alder to balsam poplar bottomland forest and possibly eventually to balsam poplar-white spruce mixedwood forest. Dabbs (1971), Dirschl (1973) and

and Moss (1932) document similar successions.

Succession on lakeshores away from river valleys has a similar hydrarch succession.

5.4.3 Succession from Fen.

Dabbs (1971), Dirschl (1973), Jeglum (1968), Lewis, Dowding and Moss (1928), Moss (1953a and b) and Sjörs (1961) all give examples of succession from fen, continuing through intermediate stages of lightly forested muskeg, semiopen tamarack-black spruce bog forest, and seemingly terminating at nearly closed canopy black spruce bog forest; but it seems equally possible that it represents merely an environmental moisture gradient and not succession at all.

5.4.4 Succession in Bogs.

There are many examples of succession on peatlands associated with peat accumulation and accompanying nutrient deficiency [Jeglum (1968), Moss (1953a and b), Lewis, Dowding and Moss (1928), Sjörs (1961)]. This type of succession is represented in the study area by sequence from fen through open muskeg to bog forest. However, there has been considerable debate on the direction of this type of successional sequence.

Originally, succession was thought to operate by tree invasion from fen and open bog to bog forest. However, more recently it has been shown that this succession is more usually retrogressive, that is, from bog forest to open muskeg and bog as moss peat accumulates with concomitant rise in the water table, decline in nutrient availability and stunting of tree growth (Lewis and Dowding, 1926; Jeglum, 1968; Sjörs 1961).

However, few sites on wetlands can be regarded as part of a single successional process and each site should be examined individually for changes that have taken place. And, obviously, not enough stands have been sampled in this vast oil sands area and not enough information on soils and topography accumulated to permit more than speculation on the successional sequences involved.

5.5 IMPORTANCE OF THE BRYOPHYTE-LICHEN COMMUNITY COMPONENT

Bryophytes and lichens are important components of plant communities in three respects: as sensitive indicators of the total environment they are of considerable use in plant community classification; they also constitute a significant proportion of the non-woody plant biomass in many communities; and finally, many species, particularly lichens, are sensitive indicators of air pollution.

Because of their sensitivity to environmental factors, many bryophytes and lichens are characteristic of the vegetation type in which they occur. This is particularly true of those occurring on the ground surface, i.e. on litter, humus, and bare mineral soil, where minor differences in moisture regime, humidity and the pH and mineral nutrient regime of the soil in physiogramically similar ecosystems are reflected in marked differences in the bryophyte and lichen floras (Stringer and Stringer, 1973, 1974a). In the stands studied in this project for example, *Dicranella varia* is characteristic of bare, disturbed, calcareous and fine-textured soil, *Drepanocladus vernicosus* and *D. aduncus* var. *polycarpus* of calcareous fens, *Barbula fallax* of moist calcareous soil, and *Polytrichum piliferum* of dry, sandy or gravelly mineral soil in open situations (Crum, 1973).

Thus, terrestrial bryophyte and lichen species in particular can be and often are just as important as vascular plants in community classification (Stringer and Stringer, 1974a; LaRoi and Stringer, 1976). Their use for this purpose in forestry in conjunction with vascular understory species has been advocated by Rowe (1956).

However, most non-terrestrial species are more specific to substrate type than vegetation type and therefore are of much less use in community classification; bryophyte-lichen communities in rotten logs, tree bases, and tree bark tend to be similar across a range of vegetation types. For example, in this study, rotten wood in mesic habitats was colonized by a very specific group of species, the most prominent of which were the small turf mosses *Pohlia nutans, Tetraphis pellucida, Oncophorus wahlenbergii, Dicranum flagellare, D. fragilifolium, D. fuscescens,* and the liverworts *Ptilidium pulcherrimum, Jamesoniella autumnalis* and *Lophozia longidens*. Most tree bases, but especially hardwoods, had a "stocking" of mosses principally *Brachythecium salebrosum, Plagiomnium cuspidatum* and *Eurhynchium pulchellum* with *Pylaisiella polyantha* usually forming a continuous band just above them. Most tree species had a distinctive community of epiphytic, corticolous lichens on their bark often regardless of tree species, principally *Evernia mesomorpha, Ramalina farinacea, Hypogymnia physodes, Parmelia sulcata* and *Usnea subfloridana.*

Several of the terrestrial bryophyte and lichen species played a very prominent quantitative role in many plant communities often forming the bulk of the terrestrial plant biomass. A number of species were sometimes quantitatively more important than the vascular species, e.g. *Sphagnum* species, *Aulacomnium palustre* and *Tomenthypnum nitens* in muskegs, *Drepanocladus* species in fens, *Pleurozium schreberi* and *Hylocomium splendens* in mesic, closed-canopy coniferous forests, and *Cladina* species in xeric jack pine forests.

Finally, many lichens and bryophytes are known to be sensitive indicators of air pollution (Stringer and Stringer, 1974b; LeBlanc and De Sloover, 1970), and the large corticolous foliose and fruticose lichens just mentioned are particularly sensitive, particularly to sulphur dioxide. Their presence on or absence from selected tree trunks around the GCOS, Syncrude and other future plants could be used to monitor air pollution levels in the Alberta oil sands area. Physiological changes in the lichen colonies would be readily apparent and their disintegration and death could be correlated with the results of specifically located air pollution instrumentation to give an accurate picture of pollution dispersion patterns, as has been done from Winnipeg (Stringer and Stringer, 1974b), Montreal (Le Blanc and De Sloover, 1970), Sudbury, Ontario (Le Blanc, Rao and Comeau, 1972), Wawa, Ontario (Gordon and Gorham, 1963), and Tyne Valley, England (Gilbert, 1965, 1968).

Small foliose and crustose lichens which are often less sensitive have not been adequately sampled in this study and any future work using lichens as pollution indicators will necessitate that this should be done.

In conclusion, not only are lichens and bryophytes often very important members of the communities in which they occur, but also some of the less quantitatively important species may be potentially important in other respects. They may be used as sensitive indicators of specific environmental factors so that subtle changes in those factors will be quickly reflected in detectable changes in the lichen-bryophyte populations. Thus, increasing air pollution will certainly be reflected in various obvious changes in the corticolous lichen population before pollution affects the less sensitive vascular plants of the community. Visual monitoring will show that most lichen species will decline and eventually die, although a few tolerant species may actually increase for some time.

Similarly, subtle changes in groundwater regime caused by disturbance will be reflected in visual changes in the terrestrial bryophyte populations even at considerable distance from the source of disturbance.

Therefore, it is as vitally important to know the bryophyte-lichen component of plant communities as it is to know the vascular species.

A knowledge of the lichens and bryophytes, often neglected in many studies, should be an integral part of any comprehensive vegetation survey of the AOSERP study area.

5.6 PHOTOINTERPRETIVE CHARACTERISTICS

It is not the intent of this report to cover the technical aspects of imagery formation, or to discuss the merits and usefulness of all the film types and photographic techniques involved, but to state which of the vegetation types in the study area can be distinguished on aerial photographs and under what conditions.

The problems of the photointerpretation of vegetation are well covered in many publications. The two most useful for this report are those of Dabbs (1971) on landscape classification in the Peace-Athabasca Delta, and Syncrude (1974) on the application of remote sensing to the Alberta oil sands with special regard to the Syncrude lease.

Of particular relevance is the methodology adopted by Dabbs (1971), together with his photointerpretative data on vegetation types very similar to those in this study.

All the existing 9 x 9 inch block photography of the study area is black and white from Panchromatic or infrared film, (see Appendix 5).

It has been reported that infrared black and white film has considerable advantages over black and white films, in that all water bodies appear black (all infrared radiation is absorbed), the differing soil moisture levels are more clearly shown and the contrast between coniferous and deciduous trees is stronger. Conversely Panchromatic allows better resolution of detail particularily with regard to shadow penetration, observation of stand structure and tree shape, and penetration of water.

It was found impossible to compare directly Panchromatic and infrared black and white imagery due to the practice of using the former film in April or May before the deciduous canopy has developed leaves and the latter in July or August when the canopy is in full leaf. As most of the study area is covered by the infrared black and white imagery, it was decided to use this type for all further interpretation in this study. Interpretation of black and white aerial photographs depends upon the tonal values of the black and white imagery. The nine-step Munsell Neutral Value Scale is one of several that can be used for the determination of gray tone values. However, as Dabbs (1971) points out the gray tone of the image is subject to a number of variables which may negate results which fail to take this into account: (1) type of film emulsion, (2) developers, time, and temperature for processing the film, (3) surface and contrast grade of print paper, (4) exposure time and light intensity while printing, and (5) position on the photo. For these reasons, tonal values should be reported as a range.

Regardless of these limitations, the Munsell Neutral Value Scale may be used, in conjunction with defined textural classes and stereoscopic form characteristics, to give some objectivity to the photointerpretation of vegetation types.

Thus, the Munsell Neutral Value Scale is divided into nine tonal classes as follows:

Tonal value	Shade description
9	white
8 - 7	grayish-white
6 - 4	gray
3	dark gray
2 - 1	black

Textural classes, following Dabbs (1971) are defined as follows:

1. Dappled - spotted appearance of large nonuniform light and dark tones.
2. Stippled - mixture of light and dark tones as a pattern of dots of uniform size (fine, medium and coarse).
3. Mottled - blotches of irregular configurations with grading tonal values.
4. Uniform.

Dabbs (1971) defines stereoscopic form as the three dimensional relief characteristics displayed by the vegetation when two photographs are viewed stereoscopically.

Thus, by means of tonal values, textural classes and stereoscopic form, the photointerpretive characteristics of each of the vegetation types can be defined on black and white infrared film. Table 1 shows the photointerpretive characteristics of stands selected as representatives of the principal vegetation types.

It should be noted that photointerpretation must be carried out in conjunction with representative ground surveys, and is only an aid to vegetation mapping rather than a method of mapping per se.

Black and white imagery is of most use in obtaining a rapid interpretation of major physical features of the landscape and interpretation and mapping of major physiognomically-defined vegetation types. Thus, it is of limited use for wetlands and herbaceous vegetation as quite different vegetation types can have exactly the same tone and texture. Due to these equivalent effects and also lack of stereoscopic structure, interpretation of fen, bog, meadow, marsh and grassland vegetation in black and white imagery is, therefore, usually difficult and sometimes impossible.

However, these problems can be partially overcome by the use of color and color infrared (false color) photography. The thousands of combinations of hue, value and chroma possible on color films provide varied stimuli to aid in interpretation. The color infrared is often even more useful than true color as subtle differences in reflectance of herbaceous vegetation types enable additional distinctions to be made, for example, between *Calamagrostis* and *Carex* dominated fen.

Table 1. Characteristics of selected stands on black and white infrared aerial photographs at a scale of 1:21,120

Stand	Cluster	Vegetation Type	Tone	Texture	Stereoscopic Form	
					Height	Configuration
37	A	broad-leaved sedge fen	8 + 9	mottled	none	smooth
36	A	fine-leaved sedge-swamp birch fen	7 + 8.5	mottled	none	smooth
1	A	fine-leaved sedge fen	8.5	uniform	none	smooth
29	B	sandbar willow-scrub	6 + 9	fine stippled	uniform	granular
21	D	tall willow scrub	6 + 8	medium stippled	irregular	foamy
30	E	tall willow-river alder scrub	5 + 9	medium stippled	irregular	foamy
32	E	bottomland balsam poplar forest D4Pb(Aw)*	5 + 8	coarse stippled	very irregular	coarsely foamy
78	F	mixedwood forest, B1PjAw*	4 + 8	medium stippled	slightly irregular	dark narrow and light granular crowns
79	F	deciduous forest C2AwBw	5 + 8	medium stippled	slightly irregular	granular
45	H	aspen forest, D2Aw	6 + 7	fine stippled	uniform	very finely flocculent
6	H	aspen forest, spruce understory D1Aw(Sw)	6.5 + 7.5	fine stippled	uniform	very finely flocculent
3	H	mixedwood forest D4SwAw	2 + 4 + 7	coarse stippled	irregular	dark conical spruce and light granular aspen crowns
80	H	white spruce forest D5Sw(Sb,Aw)	3 + 7	coarse stippled	irregular	dark conical spruce with a few light granular aspen crowns

*Forest cover types are the author's field application of Alberta Forest Service Phase 3 Forest Cover Type symbols. These symbols have been applied to tree cover on all sites regardless of growth quality. It is recognized that in forestry use these symbols are used only for "productive forest" considered to be capable of producing a commercial timber yield, and that sites of very low potential productivity are designated as scrub, treed muskeg, etc.

Aw = aspen, Bw = white birch, Pb = balsam poplar, Sw = white spruce, Sb = black spruce, Pj = jack pine, Lt = tamarack

Stand	Cluster	Vegetation Type	Tone		Texture	Stereoscopic Form	
						Height	Configuration
25	H	mixed spruce forest B4Sb(Sw)	3	+ 5	medium stippled	uniform	densely bristly with needle-pointed crowns
5	H	black spruce bog forest D1Sb	3	+ 5	medium stippled	uniform	densely bristly with needle-pointed crowns
4	I	black spruce bog forest D1Sb	4	+ 6	medium stippled	slightly irregular	densely bristly with needle-pointed crowns
82	J	black spruce-tamarack bog forest C1SbLt	4	+ 7	medium stippled	irregular	dense needle-pointed crowns of two tones
73	K	lightly forested sphagnum muskeg A0Sb(Lt)	5	+ 7	fine stippled	irregular	finely and sparsely bristly with needle-pointed crowns
77	K	low scrub-sphagnum muskeg	6	+ 8	mottled	slightly irregular	slightly roughened
46	L	jack pine-black spruce forest B2PjSb	3	+ 5	medium stippled	irregular	dark sharp and lighter blunt crowns
48	M	jack pine forest A2Pj	4	+ 6	medium stippled	uniform	medium dark blunt crowns with light ground showing
35	M	jack pine forest B2Pj	4	+ 7	medium stippled	uniform	medium dark blunt crowns with light ground showing

*Forest cover types are the author's field application of Alberta Forest Service Phase 3 Forest Cover Type symbols. These symbols have been applied to tree cover on all sites regardless of growth quality. It is recognized that in forestry use these symbols are used only for "productive forest" considered to be capable of producing a commercial timber yield, and that sites of very low potential productivity are designated as scrub, treed muskeg, etc.

Aw = aspen, Bw = white birch, Pb = balsam poplar, Sw = white spruce, Sb = black spruce, Pj = jack pine, Lt = tamarack

Dabbs (1971) recommends that, if possible, more than one camera should be used, using several films in sensing in various portions of the electromagnetic spectrum and so utilizing a multispectral approach and obtaining a maximum amount of information. Synchronized cameras loaded with three film types would provide complementary photographs of more use than any one film. For example, color infrared film is of most use when it is used in conjunction with true color. If true color alone is used it should be processed to negatives so that either black and white or color prints can be made.

6. CONCLUSIONS AND RECOMMENDATIONS

This preliminary study has resulted in the description of the following principal plant communities in the Alberta oil sands area:

(i) Fen of broad-leaved sedges *(Carex aquatilis, C. lasiocarpa)*, and fine-leaved sedges *(Carex diandra, C. disperma)*.

(ii) Sandbar willow scrub *(Salix interior* with *S. pseudomonticola*.

(iii) Tall willow-river alder scrub *(Salix bebbiana, S. lasiandra, Alnus tenuifolia)*.

(iv) Tall willow scrub *(Salix bebbiana)*.

(v) Bottomland balsam poplar forest.

(vi) Upland white spruce-aspen forest.

(vii) Black spruce bog forest.

(viii) Semiopen black spruce-tamarack bog forest and muskeg.

(ix) Lightly-forested tamarack and open muskeg.

(x) Jack pine forest.

Several other, more tentative vegetation types have not been as readily defined.

By sampling only 84 stands, it is quite impossible to cover the whole range of vegetation within the AOSERP study area sufficiently for detailed classification purposes. Thus this report describes the major vegetation types and indicates some of the minor ones.

There are very few sharp vegetational discontinuities and therefore much of the total land area is covered by ecotonal communities representing intermediate positions on gradual environmental gradients. Also very large areas are occupied by young, successional tree growth after fire.

The major problem then, is the definition of the distinctive vegetational units required for mapping purposes. As vegetation is often continuous, fixing any boundaries for mapping purposes has a large element of subjectivity in it and depends on the objectives behind the mapping process. Simply trying to map the vegetation that is there, without

classif. vs. mapping

considering causal and environmental relationships is of very little practical use. It is essential to have a clear understanding of the dynamics and environmental relationship of ecosystems involved. This will then provide a clear basis for land use decisions, and enable predictions to be made as to probable response to disturbance.

A meaningful vegetation classification has to be based on all relevant environmental information, on topography, hydrology, soil types, surficial geology, etc., as well as the structure, composition and dynamics of the communities themselves. This additional information is especially essential with regard to wetland vegetation which is at present poorly understood in Alberta.

Jeglum (1968) emphasized water conductivity, nutrient status and acidity as controlling influences on the wetland vegetation of the Candle Lake area in north central Saskatchewan.

Dabbs (1971), Dirschl (1973), Dirschl, Dabbs and Gentle (1974) emphasize the importance of seasonal changes in water regime and small variations in land elevation in determining vegetational patterning and successional trends in the Peace-Athabasca Delta area. Heinselman (1963, 1970) related the vegetation of peatlands within the Lake Agassiz Peatlands Natural Area in Minnesota to topography waterflow patterns, water chemistry, and the evolution of the landscape as recorded by peat stratigraphy. He found that vegetation types often had sharp boundaries related to changes in water properties, peat surface configuration and paths of waterflow.

The studies of these authors stress not only the complexity of boreal wetland vegetation but also the absolute necessity for detailed physical environmental analysis to accompany the field vegetation studies.

Therefore, every effort should be made to conduct further field studies in conjunction with soil and water sampling, topographic analysis and even surficial deposit analysis if possible, in order to develop a functional and useful vegetation classification.

Emphasis should also be placed on elucidatory successional relationships. The large areas of young spruce, aspen and pine representing regeneration after fire should not simply be designated as potentially productive or coniferous and deciduous scrub but integrated into the whole pattern of successional relationships.

Another important consideration in planning field sampling of vegetation is the restricted season length. Many vascular plant species cannot be identified accurately except during the period late June - late August. Even middle and late August may be too late for many early flowering liliaceous species and some grasses and sedges. On the other hand, early and mid July is far too early to try to identify many late flowering species such as the bulk of the composites. Many dominant species of muskegs, bogs and coniferous forests are evergreen and identifiable vegetationally. This gives a superficial impression of adequacy to any species list compiled outside this recommended time period. However, many important species which may be highly characteristic of these communities may be difficult to identify or even missed entirely.

Therefore, adequate preparations should be made to make maximum use of the very restricted period when plant community assessment can be carried out efficiently to prevent wastage of a great deal of valuable field time, especially by taxonomically inexperienced personnel.

A particular problem in wetland studies is that traditional ground sampling methods are slow at best due to inaccessibility of the sites and a sole dependence on these techniques severely limits detailed vegetation mapping. In such cases, Dabbs (1971) recommends the use of large scale color and color infrared aerial photography to supplement traditional ground sampling techniques.

Existing aerial photographic coverage of most of the study area is black and white (Panchromatic and infrared at a scale of 1:21,120 and taken in 1972. Various other minor coverages exist at a wide range of scales from 1:12,000 and up. This existing photography is adequate to map at a scale of 1:25,000 only the major physiognomically-distinctive vegetation types, that is, fen, tall scrub, upland coniferous, mixedwood or deciduous forest, coniferous bog forest, pure populations of tree species, etc. The distinguishing of the many herbaceous and low scrub vegetation types is impossible, and of mixed tree populations very difficult.

A very feasible approach would be to adopt the methodology of

Dabbs (1971) to the AOSERP study area. By using the existing photography and with few or no ground truth surveys, a preliminary map could be prepared delineating major landforms, physiognomically distinct vegetation types, major forest cover types, and water systems; that is, an overview map. Dabbs (1971) mapped the Peace-Athabasca Delta at a scale of 1:37,000 in this way and delineated eight ecosystems: coniferous forest, deciduous forest, tall shrub, low shrub, fen, immature fen on newly colonized mud-flats, forest and grassland on Precambrian rock. Detectable ecosystems would be somewhat different in the AOSERP area. A map prepared on this basis from existing aerial photographs, the most recent forest cover maps, and the existing ground survey information would be invaluable as a basis for more detailed further studies. Major land units could be designated and a representative area from each studied by more intensive methodology such as improved aerial photography and intensive ground truth surveys accompanied by environmental analyses. Those areas representative of land units could then be mapped in detail in the same way as those of Dabbs (1971) at 1:7,000, and this information extended to apply to the whole AOSERP study area.

Additional necessary aerial photography should follow the recommendations of Dabbs (1971), who stated that the interpretation of low herbaceous vegetation types has been proven to be extremely difficult or often impossible on black and white photographs. Color infrared, however, showed the differences between the plant species components of the fen and lakeshore areas very clearly. Dabbs further stated that, because the imagery of vegetation found on color infrared is in unnatural shades grading from pink to magenta, it was necessary in many cases to examine the true color Ektachrome film to make accurate identifications. Working combinations of the two color films proved extremely effective in mapping the low herbaceous vegetation.

Thus, selected areas representative of the major land units, or if possible the whole AOSERP study area should be photographed using both true and infrared color photography at a scale of 1:7,000-12,000, preferably flown during June or July to obtain deciduous vegetation in fresh and full leaf. However, there is probably no "perfect" time of the year for aerial photography of vegetation. For example, white birch was clearly detectable at 1:12,000 when leafless (May photography) because of its distinctive branching and very white trunks, whereas it was indistinguishable from aspen when in full leaf. Also, coniferous trees in mixedwood are much better identifiable to species when the deciduous trees are leafless.

A great deal of emphasis has been placed on the methodology of Dabbs (1971), as it is apparent that this work together with the subsequent publications by Dabbs and his associates (Dirschl, 1973; Dirschl, Dabbs and Gentle, 1974 and others) is of great use in planning further progress in mapping the vegetation of the Alberta oil sands.

However, another very important publication should be mentioned as having great potential use for landscape classification and mapping: A progress report based on results of Biophysical Land Classification pilot projects and discussions of Subcommittee on Biophysical Land Classification National Committee on Forest Land (Lacate, 1969). This report presents a physical land classification, of a reconnaissance nature, that will provide an ecologically-sound base from which lands can be classified as to their use for forestry, agriculture, recreation, wildlife, and water yields. Emphasis is placed throughout on land patterns and the grouping of characteristics for broad planning. It aims at differentiating and classifying ecologically significant segments of land surface rapidly and at a small scale in order to satisfy the need for an initial overview. This method relies on the use of aerial photographs combined with supporting field checks.

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8. ACKNOWLEDGEMENTS

The author expresses his thanks to Ms. Madelaine Dumais, Botany Department, University of Alberta for confirmation of certain vascular plant species, to Mr. Wilbur Peterson, Botany Department, University of Alberta for confirmation of certain *Dicranum* species, to Dr. Dale H. Vitt, Botany Department, University of Alberta for confirmation of *Sphagnum* species, and especially to Dr. Muriel H.L. Stringer for editing this manuscript.

Appendix I

Location of stands and vegetation types

Stand No.	Location: Latitude (West)	Longitude (North)	Forest cover type *	Non-forested vegetation type
1	111° 46.8'	56° 47.5'		fine-leaved sedge fen
2	111° 46.1'	56° 47.7'	C3Aw(Sb)	
3	111° 45.5'	56° 47.4'	D4SwAw	
4	111° 44.7'	56° 47.3'	D1Sb	
5	111° 44.0'	56° 46.9'	D1Sb	
6	111° 28.7'	57° 15.6'	D1Aw(Sw)	
7	111° 50.2'	57° 41.7'	D0Pj	
8	111° 50.7'	57° 41.7'	B0Sb	
9	111° 1.8'	57° 52.9'	C1Pj	
10	111° 2.3'	57° 52.9'		broad-leaved sedge fen
11	111° 1.3'	57° 53.0'	C1Pj	
12	110° 53.2'	57° 7.8'	C1Sb	
13	110° 53.5'	57° 7.8'	C2Pj(Bw)	
14	111° 19.0'	56° 34.5'	D4AwSw	
15	111° 18.8'	56° 35.1'	B1Sb	
16	111° 19.3'	56° 35.9'	D1Aw(Sb)	
17	111° 19.4'	56° 36.5'	D3Aw(PbSw)	
18	111° 19.3'	56° 39.4'	D3SbSw	
19	111° 27.0'	56° 53.6'	D2Aw	
20	111° 42.4'	56° 45.8'	B0Sb	
21	111° 29.3'	57° 15.4'		tall willow scrub
22	111° 29.3'	57° 15.4'	C0Sb(Lt)	
23	111° 27.3'	56° 54.0'	C3SwSb	
24	111° 26.5'	56° 51.3'	B4Pb	
25	111° 25.7'	56° 46.4'	B4Sb(Sw)	

* Forest cover types are the author's field application of Alberta Forest Service Phase 3 Forest Cover Type symbols. These symbols have been applied to tree cover on all sites regardless of growth quality. It is recognized that in forestry use these symbols are used only for "productive forest" considered to be capable of producing a commercial timber yield, and that sites of very low potential productivity are designated as scrub, treed muskeg, etc.

Crown Density (%)	Height (feet)	Composition	
A = 6 - 30	0 = 1 - 20	Aw = aspen	Sw = white spruce
B = 31 - 50	1 = 21 - 40	Pb = balsam poplar	Sb = black spruce
C = 51 - 70	2 = 41 - 60	Bw = white birch	Fb = balsam fir
D = 71 - 100	3 = 61 - 80	Lt = tamarack	Pj = Jack pine
	4 = 81 - 100		
	5 =101+		

Stand No.	Location: Latitude (West)	Longitude (North	Forest cover type *	Non-forested vegetation type
26	111° 13.4'	56° 29.8'	D2Bw	
27	111° 12.1'	56° 28.8'	D3Aw(Pb)	
28	111° 34.5'	57° 3.1'	B4Sw(Aw)	
29	111° 15.8'	56° 40.8'		sandbar willow scrub
30	111° 15.8'	56° 40.8'		tall willow-river alder scrub
31	111° 15.2'	56° 41.2'	D4Sw(Aw)	
32	111° 15.0'	56° 40.9'	D4Pb(Aw)	
33	111° 13.7'	56° 40.7'	C4Pb	
34	111° 14.7'	56° 40.9'		sandbar willow scrub
35	111° 36.9'	57° 5.6'	B2Pj	
36	111° 25.0'	57° 28.4'		fine-leaved sedge fen
37	111° 27.5'	57° 26.6'		broad-leaved sedge fen
38	111° 29.3'	57° 22.9'		broad-leaved sedge fen
39	111° 29.3'	57° 22.9'		sandbar willow scrub
40	111° 29.3'	57° 22.9'		broad-leaved sedge fen
41	111° 29.3'	57° 22.9'	D1Lt	
42	111° 29.3'	57° 22.9'	A0Lt	
43	111° 30.3'	57° 19.0'		fine-leaved sedge fen
44	111° 32.6'	57° 13.1'		broad-leaved sedge fen
45	111° 39.0'	57° 12.8'	D2Aw	
46	111° 38.5'	57° 12.2'	B2PjSb	
47	111° 38.5'	57° 10.1'	C5Sw	
48	111° 36.4'	57° 5.2'	A2Pj	
49	111° 29.0'	57° 15.6'	B1Pj(Sb)	
50	111° 28.7'	57° 15.6'		tall willow scrub
51	111° 49.3'	57° 41.5'	C0Sb	
52	111° 49.0'	57° 41.3'	D0BwPj	
53	111° 49.4'	57° 41.1'		open muskeg
54	111° 49.4'	57° 41.1'	A0Sb	
55	111° 49.8'	57° 42.0'		open muskeg
56	111° 1.6'	57° 53.3'		tall willow-river alder scrub
57	111° 1.0'	57° 53.5'		clearing in Jack pine forest
58	111° 17.1'	56° 39.3'	A0Lt(Sb)	
59	111° 14.1'	56° 39.1'	D0Sb	
60	111° 12.2'	57° 27.8'		broad-leaved sedge fen
61	111° 12.8'	57° 25.9'		open muskeg
62	111° 11.8'	56° 28.9'	D3Aw	
63	111° 11.3'	56° 29.0'	D3SwFb(Pb)	
64	111° 11.0'	56° 29.0'	C2Bw	
65	111° 12.9'	56° 22.7'	C1Sb	
66	111° 12.8'	56° 22.7'	D1Sb(Fb)	
67	111° 12.7'	56° 22.9'	C2BwAw	
68	111° 12.5'	56° 23.1'	C3Aw(Sw)	
69	111° 9.8'	56° 26.0'		tall willow-river alder scrub
70	111° 11.0'	56° 26.7'		open muskeg

Stand No.	Location: Latitude (West)	Location: Longitude (North)	Forest cover type I	Non-forested vegetation type
71	111° 11.0'	56° 26.6'	A0Sb	
72	111° 17.8'	56° 26.7'		tall willow-river alder scrub
73	111° 13.1'	57° 17.0'	A0Sb(Lt)	
74	111° 17.7'	57° 14.3'		open muskeg
75	111° 17.7'	57° 14.3'	B0Sb	
76	111° 18.3'	57° 12.9'		open muskeg
77	111° 26.2'	57° 9.8'		open muskeg
78	111° 36.0'	57° 4.8'	B1PjAw	
79	111° 36.4'	57° 5.4'	C2AwBw	
80	111° 38.4'	57° 7.2'	D5Sw(SbAw)	
81	111° 37.7'	57° 7.5'	C2Sb	
82	111° 37.4'	57° 7.9'	C1SbLt	
83	111° 19.8'	56° 37.1'	D4Sw	
84	111° 19.0'	56° 34.7'	D4Sw	

Other vascular plant species recorded (with stand representation in brackets) were as follows:

Tall shrubs

Viburnum trilobum (24, 47)

Medium-low shrubs

Myrica gale (10, 74)
Ribes americanum (24, 41)
Ribes glandulosum (2, 26, 64, 72)
Ribes hudsonianum (72)
Ribes lacustre (47)
Salix candida (10, 61)
Salix discolor (40, 77, 78)
Vaccinium caespitosum (16)

Herbs and dwarf shrubs

Achillea millefolium (14, 28, 58, 69)
Actaea rubra (24, 63, 83)
Agropyron repens (34)
Agropyron trachycaulum (14, 17, 58, 83)
Anemone multiflora (35)

Aster conspicuus (25, 31, 45)
Aster hesperius (34)
Aster junciformis (43)
Astragalus sp. (80)
Caltha palustris (58, 61, 64)

Cardamine pensylvanica (64)
Carex concinna (23, 46)
Carex grawfordii (40)
Carex limosa (1, 60)
Carex vaginata (17, 22)

Cicuta bulbifera (1, 38)
Cicuta douglasii (34)
Cinna latifolia (27, 32)
Circaea alpina (24, 33)
Deschampsia caespitosa (58, 74)

Drosera rotundifolia (1, 20, 61)
Dryopteris spinulosa (26, 62, 64, 72)
Elymus canadensis (29)
Empetrum nigrum (7, 8)
Epilobium leptophyllum (1, 38, 73, 77)

Equisetum fluviatile (1, 38, 76, 77)
Eriophorum angustifolium (38, 53)
Eriophorum gracile (36, 73)
Erysimum cheiranthoides (44)
Fragraria vesca var. *americana* (32)

Galium labradoricum (60, 61, 76)
Galium trifidum (38, 40, 43)
Gaultheria hispidula (65, 66)
Geocaulon lividum (18, 20, 52)
Geum allepicum var. *strictum* (44)

Geum macrophyllum var. *perincisum* (38, 40,
Glyceria grandis (40)
Gymnocarpium dryopteris (26, 27, 63, 64)
Habenaria orbiculata (14, 23, 67, 68)
Halenia deflexa (17)

Hieracium umbellatum (35, 48)
Hudsonia tomentosa (9, 48)
Juncus balticus (58)
Juncus vaseyi (74)
Lilium philadelphicum var. *andinum* (6, 35)

Luzula parviflora (69)
Lycopus asper (34, 44)
Matteuchia struthiopteris (29, 30, 34)
Mentha arvensis var. *villosa* (30)
Moneses uniflora (12, 22)

Oryzopsis asperifolia (6, 16)
Pedicularis labradorica (20)
Petasites sagittatus (76, 82)
Petasites vitifolius (18, 22, 50)
Poa sp. (68, 74)

Potentilla tridentata (35)
Pyrola minor (22, 56)
Pyrola virens (23)
Ranunculus lapponicus (22)
Sarracenia purpurea (37)

Scheuchzeria palustris var. *americana* (37)
Scirpus microcarpus (34)
Senecio indecorus (41)
Senecio pauperculus (17)
Solidago lepida (35, 50)

Solidago multiradiata (5, 23)
Spiranthes romanzoffiana (22)
Stellaria longifolia (40, 73)
Stellaria longipes (20, 70)
Streptopus amplexifolius (26)

Taraxum officinale (29)
Thalictrum sparsiflorum (30)
Thalictrum venulosum (32, 44, 50)
Urtica gracile (21, 30, 44)
Vicia americana (25, 33, 69)
Viola adunca (17)
Viola rugolosa (31).

Appendix 2

Principal vegetation types in the Alberta oil sands area as represented by 84 stands arranged in clusters, and showing the composition of the tree canopy and cover-abundance values of principal understory species by strata.

LEGEND

D – principal tree species

d – secondary tree species

* – vigorous reproduction in understory

Cover-abundance values

5 –	75-100% cover
4 –	50- 75%
3 –	25- 50%
2 –	5- 25%
1 –	1- 5 %
+ –	less than 1% but common
R –	rare

VEGETATION TYPE	EMI-OPEN BLACK SPRUCE- AMARACK OG FOREST								LIGHTLY-FORESTED TAMARACK AND OPEN MUSKEG			UPLAND MIXEDWOOD AND CONIFEROUS FOREST								UPLAND JACK PINE FOREST				
CLUSTERS	J								K			L								M				
STANDS	40	44	2	42	73	76	77	61	58	74	70	49	23	66	81	46	52	13	7	9	11	48	35	57
TREES																								
BALSAM POPLAR																								
WHITE BIRCH				*					*								D	d						
ASPEN									*								d					*	*	
WHITE SPRUCE													D											
BLACK SPRUCE			D		*				d*			d*	D*	D*	D*	D*	*	d*						
TAMARACK			D	d*	*				D															
JACK PINE												D				D	D	D	D*	D	D	D	D*	
BALSAM FIR														d										
TALL SHRUBS -10 FT. OR MORE IN HEIGH																								
SALIX INTERIOR																								
SALIX PSEUDOMONTICOLA																								
SALIX LASIANDRA										+	2													
SALIX BEBBIANA									2	2	3	1				1			R					
ALNUS TENUIFOLIA										+														
ALNUS CRISPA														+			2							
PRUNUS PENSYLVANICA																						+	+	
MEDIUM-LOW SHRUBS -UPRIGHT AND 9 IN,																								
BETULA PUMILA						3	1	3																
RIBES HIRTELLUM									+															
CORNUS STOLONIFERA																								
RUBUS STRIGOSUS																								
RIBES OXYACANTHOIDES																								
RIBES TRISTE			R																					
AMELANCHIER ALNIFOLIA																						+	+	
LONICERA INVOLUCRATA																								
VIBURNUM EDULE																								
ROSA ACICULARIS									R			R	1			+							R	
SHEPHERDIA CANADENSIS									+			1	+										+	
SYMPHORICARPOS ALBUS									+															
LONICERA DIOICA																								
LONICERA VILLOSA										1														
SALIX MYRTILLIFOLIA																								
SALIX GLAUCA					1	1																		
CHAMAEDAPHNE CALYCULATA				4	3		4																	
KALMIA POLYFOLIA				2	1																			
ANDROMEDA POLYFOLIA				1			2	1																
SALIX PEDICELLARIS				1		2	3																	
SALIX MACCALLIANA											2													
BETULA GLANDULOSA										2	2													
LEDUM GROENLANDICUM			[illegible]		2	2	2	1	2	2	+	2		1	2	2	3	3	3					
VACCINIUM MYRTILLOIDES									1			2		+	2	1	+	4	5	+	2	2	2	1
ARCTOSTAPHYLOS RUBRA									+				R			R								
POTENTILLA FRUTICOSA									+			R	R											

	J								K			L								M				
	40	44	10	2	73	76	77	61	58	74	70	49	23	66	81	46	52	13	7	9	11	48	35	57
HERBS AND DWARF SHRUBS (PROSTRATE)																								
CAREX DIANDRA					1	+				+														
CAREX LASIOCARPA	4	3	2					1																
CAREX ROSTRATA	1					2										+								
MENYANTHES TRIFOLIATA								1																
POTENTILLA NORVEGICA	1																							
POTENTILLA PALUSTRIS			+		+	+	+																	
POLYGONUM AMPHIBIUM	1		+																					
RUMEX OCCIDENTALIS	+	+				R																		
SCUTELLARIA GALERICULATA	+		+																					
TRIGLOCHIN MARITIMA								+																
AGROSTIS SCABRA					+															R				
EQUISETUM ARVENSE									R	+														
ACHILLEA SIBIRICA																								
ASTER FOLIACEUS																								
BROMUS CILIATUS																								
RUBUS ACAULIS											R													
CALAMAGROSTIS CANADENSIS							+				+	R	R											
ANEMONE CANADENSIS																								
RUBUS PUBESCENS																								
EQUISETUM PRATENSE																								
GALIUM TRIFLORUM																								
SCHIZACHNE PURPURASCENS																								
LYCOPODIUM COMPLANATUM																								+
LYCOPODIUM OBSCURUM																								
LYCOPODIUM ANNOTINUM																	2							
GOODYERA REPENS																								
MITELLA NUDA																								
ELYMUS INNOVATUS									+			1	+			1	1							
CORNUS CANADENSIS												3			+	+								
GALIUM BOREALE									+			R	+			R							R	
MAIANTHEMUM CANADENSE					2							+									R	1	+	
LINNAEA BOREALIS													1											
MERTENSIA PANICULATA																								
PYROLA ASARIFOLIA																								
PYROLA SECUNDA																								
ARALIA NUDICAULIS																							R	
ASTER CILIOLATUS									+			R												+
EPILOBIUM ANGUSTIFOLIUM								+	+			R				R	+							
FRAGARIA VESCA									1	+		R	R											
LATHYRUS OCHROLEUCUS																								

	A								K			L								M				
	40	44	10	37	60	76	77	61	58	74	70	49	23	66	81	46	52	13	7	9	11	48	35	57
PETASITES PALMATUS												+				R								
CAREX BRUNNESCENS																								
TRIENTALIS BOREALIS													R											
VIOLA RENIFOLIA																								
VACCINIUM VITIS-IDAEA						1				+		2	+	+	1	2	3	3	3			2	1	+
EQUISETUM SYLVATICUM									2			+		R				R						+
RUBUS CHAMAEMORUS						+																		
SMILACINA TRIFOLIA						+	+	1			R													
ERIOPHORUM VAGINATUM							+		+	+														
OXYCOCCUS MICROCARPUS						+	1	1		1	+													
HABENARIA HYPERBOREA								+	+															
CAREX PAUPERCULA						+	+																	
CAREX AQUATILIS	2	3	4	3	1	2	1	+	2	1	2	+												
CAREX DISPERMA					1	+				+														
CAREX GYNOCRATES							2	1	1	1	+													
CAREX TENUIFLORA						+	1																	
EQUISETUM SCIRPOIDES									1	1		+				R								
PARNASSIA PALUSTRIS									1	+	+	R												
ARCTOSTAPHYLOS UVA-URSI									1				+							1	1	3	3	3
ORYZOPSIS PUNGENS												1								+	+	+	1	1
CAMPANULA ROTUNDIFOLIA													+							+	+	+	+	R
COMANDRA PALLIDA													1									1	+	
APOCYNUM ANDROSAEMIFOLIUM																				+	1	+	R	R
MELAMPYRUM LINEARE																						+	+	R
SOLIDAGO NEMORALIS																R				R	+	+		+
<u>BRYOPHYTES AND LICHENS</u>																								
BRACHYTHECIUM NELSONII				1	+																			
DREPANOCLADUS REVOLVENS				5	3																			
DREPANOCLADUS ADUNCUS	1															+								
CLIMACIUM DENDROIDES																								
DICRANUM POLYSETUM													2	+	+	+		+						
PTILIDIUM PULCHERRIMUM																								
BRACHYTHECIUM RUTABULUM																								
MNIUM RUGICUM																								
POLYTRICHUM COMMUNE											+			2					1					
RHYTIDIADELPHUS TRIQUETRUS																								
BRACHYTHECIUM SALEBROSUM																								
DREPANOCLADUS UNCINATUS								+																
PELTIGERA CANINA																			+					
PTILIUM CRISTA-CASTRENSIS														1				+						
EURHYNCHIUM PULCHELLUM																								
HYLOCOMIUM SPLENDENS												R	1	+	+	1			+					
PLEUROZIUM SCHREBERI													4	5	4	4	+	1	+					
PELTIGERA APHTHOSA							R		+	R		1	1	+	1	+		1	+					
POLYTRICHUM JUNIPERINUM						+	+		R	1		+		+			R	+	1					
SPHAGNUM CAPILLACEUM														1										
SPHAGNUM MAGELLANICUM																								
SPHAGNUM RECURVUM						3																		
DICRANUM UNDULATUM										+							+	+						
TOMENTHYPNUM NITENS						3	+	2		2	2													
SPHAGNUM FUSCUM							2	2	+	+	3													
SPHAGNUM WARNSTORFII						3	2				3							+						
AULACOMNIUM PALUSTRE							3		2	2	1	1							+					
PELTIGERA POLYDACTYLA													+	1		+								
CLADINA RANGIFERINA															+	+								
CLADINA ARBUSCULA										3			1	+					2				3	
CLADINA MITIS									+			3			3	5		1	3	5	5	5	3	
CLADINA ALPESTRIS									+			+	+		2	+						+	+	
CETRARIA NIVALIS															+	+				+			+	
PELTIGERA MALACEA															+	+		+					+	
CLADONIA UNCIALIS																					+	+	1	2

Appendix 3A

Preliminary species list of the AOSERP study area: Vascular plants.

This listing of vascular plants is alphabetical, with nomenclature following Moss (1959), Flora of Alberta. It should be noted that this list is very incomplete because the sampling was carried out late in the growing season, and several vegetation types were not sampled at all; for example, roadside verges, waste ground, emergent and submerged aquatics.

Abies balsamea (L.) Mill.	(Balsam fir)
Achillea millefolium L.	(Common yarrow)
Achillea sibirica Ledeb.	
Actaea rubra (Ait.) Willd.	(Baneberry)
Agropyron repens (L.) Beauv.	(Quack grass)
Agropyron trachycaulum (Link) Malte	(Slender wheat grass)
Agrostis scabra Willd.	(Hair grass)
Alnus crispa (Ait.) Pursh	(Green alder)
Alnus tenuifolia Nutt.	(River alder)
Amelanchier alnifolia Nutt.	(Saskatoon-berry)
Andromeda polifolia L.	(Bog rosemary)
Anemone canadensis L.	(Canada anemone)
Anemone multifida Poir.	(Cut-leaved anemone)
Apocynum androsaemifolium L.	(Spreading dogbane)
Aralia nudicaulis L.	(Wild sarsaparilla)
Arctostaphylos rubra (Rehder & Wils.) Fern.	(Alpine bearberry)
Arctostaphylos uva-ursi (L.) Spreng.	(Common bearberry)
Aster ciliolatus Lindl.	(Lindley's aster)
Aster conspicuus Lindl.	(Showy aster)
Aster foliaceus Lindl.	
Aster hesperius A. Gray	(Western willow aster)
Aster junciformis Rydb.	
Aster laevis L. var. *geyeri* A. Gray	(Smooth aster)
Astragalus sp.	(Milk vetch)
Betula glandulosa Michx.	(Dwarf birch)
Betula papyrifera Marsh.	(White or paper birch)
Betula pumila L. var. *glandulifera* Regel	(Swamp birch)
Bromus ciliatus L.	(Fringed brome)
Calamagrostis canadensis (Michx.) Beauv.	(Marsh reed grass)
Caltha palustris L.	(Marsh marigold)

Campanula rotundifolia L.	(Bluebell)
Cardamine pensylvanica Muhl.	(Bitter cress)
Carex aquatilis Wahlenb.	
Carex brunnescens (Pers.) Poir.	
Carex concinna R. Br.	
Carex crawfordii Fern.	
Carex diandra Schrank	
Carex disperma Dewey	
Carex gynocrates Wormsk.	
Carex lasiocarpa Ehrh.	
Carex limosa L.	
Carex paupercula Michx.	
Carex rostrata Stokes	
Carex tenuiflora Wahlenb.	
Carex vaginata Tausch	
Chamaedaphne calyculata (L.) Moench	(Leather-leaf)
Cicuta bulbifera L.	(Water hemlock)
Cicuta douglasii (DC.) Coult. & Rose	(Water hemlock)
Cinna latifolia (Trev.) Griseb.	(Drooping wood reed)
Circaea alpina L.	(Enchanter's nightshade)
Comandra pallida A. DC.	(Bastard toad-flax)
Cornus canadensis L.	(Bunchberry)
Cornus stolonifera Michx.	(Dogwood)
Deschampsia caespitosa (L.) Beauv.	(Tufted hair grass)
Drosera rotundifolia L.	(Sundew)
Dryopteris spinulosa (Muell.) Watt	(Shield fern)
Elymus canadensis L.	(Canada wild rye)
Elymus innovatus Beal	(Hairy wild rye)
Empetrum nigrum L.	(Crowberry)
Epilobium angustifolium L.	(Fireweed)
Epilobium leptophyllum Raf.	
Equisetum arvense L.	(Field horsetail)
Equisetum fluviatile L.	
Equisetum pratense Ehrh.	
Equisetum scirpoides Michx.	

Equisetum sylvaticum L.	(Woodland horsetail)
Eriophorum angustifolium Honckeny	(Cotton grass)
Eriophorum gracile Koch	(Cotton grass)
Eriophorum vaginatum L.	(Cotton grass)
Erysimum cheiranthoides L.	(Wormseed mustard)
Fragaria vesca L. var. *americana* Porter	(Woodland strawberry)
Fragaria virginiana Duchesne var. *glauca* S. Wats.	(Wild strawberry)
Galium boreale L.	(Northern bedstraw)
Galium labradoricum Wieg.	
Galium trifidum L.	(Small bedstraw)
Galium triflorum Michx.	(Sweet-scented bedstraw)
Gaultheria hispidula (L.) Bigel.	(Creeping snowberry)
Geocaulon lividum (Richards.) Fern.	(Bastard toad-flax)
Geum allepicum Jacq. var. *strictum* (Ait.) Fern.	(Yellow avens)
Geum macrophyllum Willd. var. *perincisum* (Rydb.) Raup	(Yellow avens)
Glyceria grandis S. Wats.	
Goodyera repens (L.) R. Br.	(Rattlesnake plantain)
Gymnocarpium dryopteris (L.) Newm.	(Oak fern)
Habenaria hyperborea (L.) R. Br.	(Northern green orchid)
Habenaria orbiculata (Pursh) Torr.	(Round-leaved orchid)
Halenia deflexa (Sm.) Griseb.	(Spurred gentian)
Hieracium umbellatum L.	(Narrow-leaved hawkweed)
Hudsonia tomentosa Nutt.	(Sand heather)
Juncus balticus Willd.	(Wire rush)
Juncus vaseyi Engelm.	
Kalmia polifolia (Wang.) var. *microphylla* (Hook.) Rehd.	(Mountain laurel)
Larix laricina (Du Roi) K. Koch	(Tamarack)
Lathyrus ochroleucus Hook.	(Pea vine)
Ledum groenlandicum Oeder	(Common Labrador tea)
Lilium philadelphicum L. var. *andinum* (Nutt.) Ker	(Western wood lily)
Linnaea borealis L. var. *americana* (Forbes) Rehd.	(Twin-flower)
Lonicera dioica L. var. *glaucescens* (Rydb.) Butters	(Twining honeysuckle)
Lonicera involucrata (Richards.) Banks	(Bracted honeysuckle)
Lonicera villosa (Michx.) R & S.	(Fly honeysuckle)
Luzula parviflora (Ehrh.) Desv.	(Wood rush)

Lycopodium annotinum L.	(Stiff club-moss)
Lycopodium complanatum L.	(Ground cedar)
Lycopodium obscurum L.	(Tree club-moss)
Lycopus asper Greene	(Water horehound)
Maianthemum canadense Desf. var. *interius* Fern.	(Wild lily-of-the-valley)
Matteuccia struthiopteris (L.) Todaro	(Ostrich fern)
Melampyrum lineare Desr.	(Cow-wheat)
Mentha arvensis L. var. *villosa* (Benth.) S.R. Stewart	(Wild mint)
Menyanthes trifoliata L.	(Buck-bean)
Mertensia paniculata (Ait.) G. Don	(Tall mertensia)
Mitella nuda L.	(Mitrewort)
Moneses uniflora (L.) A. Gray	
Myrica gale L.	(Sweet gale)
Oryzopsis asperifolia Michx.	
Oryzopsis pungens (Torr.) Hitchc.	
Osycoccus microcarpus Turcz.	(Small bog cranberry)
Parnassia palustris L. var. *neogaea* Fern.	(Grass-of-Parnassus)
Pedicularis labradorica Wirsing	
Petasites palmatus (Ait.) A. Gray	(Palmate-leaved coltsfoot)
Petasites sagittatus (Pursh) A. Gray	(Arrow-leaved coltsfoot)
Petasites vitifolius Greene	(Vine-leaved coltsfoot)
Picea glauca (Moench) Voss var. *albertiana* (S. Brown) Sarg.	(White spruce)
Picea mariana (Mill.) BSP.	(Black spruce)
Pinus banksiana Lamb.	(Jack pine)
Poa sp.	(Bluegrass)
Polygonum amphibium L. var. *stipulaceum* (Coleman) Fern.	(Water smartweed)
Populus balsamifera L.	(Balsam poplar)
Populus tremuloides Michx.	(Aspen)
Potentilla fruticosa L.	(Shrubby cinquefoil)
Potentilla norvegica L.	(Rough cinquefoil)
Potentilla palustris (L.) Scop.	(Marsh cinquefoil)
Potentilla tridentata Ait.	(Three-toothed cinquefoil)
Prunus pensylvanica L.f.	(Pin cherry)

Pyrola asarifolia Michx.	(Common pink wintergreen)
Pyrola minor L.	(Lesser wintergreen)
Pyrola secunda L.	(One-sided wintergreen)
Pyrola virens Schweigg.	(Greenish-flowered wintergreen)
Ranunculus lapponicus L.	(Buttercup)
Ribes americanum Mill.	(Wild black currant)
Ribes glandulosum Grauer	(Skunk currant)
Ribes hirtellum Michx.	(Wild gooseberry)
Ribes hudsonianum Richards.	(Wild black currant)
Ribes lacustre (Pers.) Poir.	(Bristly black currant)
Ribes oxyacanthoides L.	(Wild gooseberry)
Ribes triste Pall.	(Wild red currant)
Rosa acicularis Lindl.	(Prickly rose)
Rubus acaulis Michx.	(Dwarf raspberry)
Rubus chamaemorus L.	(Cloudberry)
Rubus pubescens Raf.	(Dewberry)
Rubus strigosus Michx.	(Wild red raspberry)
Rumex occidentalis S. Wats.var. *Fenestratus* (Greene) Le Page	(Western dock)
Salix bebbiana Sarg.	(Beaked willow)
Salix candida Fluegge	(Hoary willow)
Salix discolor Muhl.	(Pussy willow)
Salix glauca L.	
Salix interior Rowlee	(Sandbar willow)
Salix lasiandra Benthe.	
Salix maccalliana Rowlee	
Salix myrtillifolia Anderss.	
Salix pedicellaris Pursh var.*hypoglauca* Fern.	(Bog willow)
Salix pseudomonticola Ball	
Sarracenia purpurea L.	(Pitcher-plant)
Scheuchzeria palustris L. var. *americana* Fern.	
Schizachne purpurascens (Torr.) Swallen	(False melic)
Scirpus microcarpus Presl	(Small-fruited bullrush)
Scutellaria galericulata L.	(Common skullcap)
Senecio indecorus Greene	

Senecio pauperculus Michx.	
Shepherdia canadensis (L.) Nutt.	(Canadian buffalo-berry)
Smilacina trifolia (L.) Desf.	(Three-leaved Solomon's seal)
Solidago lepida DC.	
Solidago multiradiata Ait.	
Solidago nemoralis Ait. var. *decemflora* (DC.) Fern.	
Spiranthes romanzoffiana Cham. & Schl.	(Ladies'-tresses)
Stellaria longifolia Muhl.	(Long-leaved chickweed)
Stellaria longipes Goldie	(Long-stalked chickweed)
Streptopus amplexifolius (L.) DC.	(Twisted-stalk)
Symphoricarpos albus (L.) Blake	(Snowberry)
Taraxacum officinale Weber	(Common dandelion)
Thalictrum sparsiflorum Turcz.	(Flat-fruited meadow rue)
Thalictrum venulosum Trel.	(Veiny meadow rue)
Trientalis borealis Raf.	(Star-flower)
Triglochin maritima L.	(Arrow-grass)
Urtica gracilis Ait.	(Common nettle)
Vaccinium caespitosum Michx.	(Dwarf bilberry)
Vaccinium myrtilloides Michx.	(Blueberry)
Vaccinium vitis-idaea L. var. *minus* Lodd.	(Bog cranberry)
Viburnum edule (Michx.) Raf.	(Low-bush cranberry)
Viburnum trilobum Marsh	(High-bush cranberry)
Vicia americana Muhl.	(Wild vetch)
Viola adunca J.E. Smith	(arly blue violet)
Viola renifolia A. Gray	(Kidney-leaved violet)
Viola rugulosa Greene	(Western Canada violet)

Appendix 3B

Preliminary species list of the AOSERP study area: Bryophytes and lichens.

BRYOPHYTES AND LICHENS

The lists of lichens, liverworts, and mosses which follow are arranged alphabetically. Species with names preceded by a question mark are in difficult groups. Identifications of these were tentative because of lack of fruiting plants or sufficient material. The numbers in the second column following the species names refer to the sites described in Appendix 2. The symbols in the third column indicate the usual substrate type on which the species occurred, as follows:

m = mineral soil, sometimes with a very thin humus-litter layer

h = loose humus and litter

w = dead wood, with or without bark

b = live bark of shrubs and trees

t = on or in thick moss turf and humus which may or may not be of that species

LICHENS. Nomenclature follows Bird (1972).

	Site Number	Substrate Type
Alectoria glabra Mot.	(8,15,73,81,82)	b.
Alectoria nadvornikiana Gyeln.	(81)	b.
Cetraria ericetorum Opiz	(9)	m, h.
Cetraria halei W. Culb. & C. Culb.	(2,8,9,11,35,73,66,80)	b, w.
Cetraria merrillii Du Rietz	(77)	b.
Cetraria nivalis (L.) Ach.	(4,9,35,46,81)	m, h.
Cetraria pinastri (Scop.) S. Gray	(2,6,9,11,13,15,26,35, 40,43,75,76,79)	b.
Cetraria sepincola (Ehrh.) Ach.	(13,75)	b.
Cladina alpestris (L.) Harm.	(20,23,35,46,48,49,75, 81)	m, h.
Cladina arbuscula (Wallr.) Rabenh.	(7,23,28,35,65,66,74, 78,79)	m, h.
Cladina mitis (Sandst.) Hale & W. Culb.	(4,5,7,9,11,13,15,20, 46,48,49,51,71,75,80,81)	m, h.
Cladina rangiferina (L.) Harm.	(46,81)	m, h.
Cladonia chlorophaea	(14,71)	h, w.
Cladonia coccifera (L.) Willd.	(9,11)	m, h, w.

	Site Number	Substrate Type
Cladonia coniocraea (Flörke) Spreng.	(14,25,51,62)	w.
Cladonia cornuta (L.) Hoffm.	(4,7,13,14,22,52,75)	h, m.
Cladonia crispata (Ach.) Flot.	(7)	h.
Cladonia cristatella Tuck.	(71)	h.
Cladonia deformis (L.) Hoffm.	(4,13,51,55,75)	h.
Cladonia ecmocyna (Ach.) Nyl.	(22)	w.
Cladonia fimbriata (L.) Fr.	(2,71)	h.
Cladonia gracilis (L.) Willd. var. *dilatata* (Hoffm.) Schaer.	(4,7,13,14,15,22,25,45, 51,52,55,58,75,79)	h, m, w.
Cladonia phyllophora Hoffm.	(11,52)	h, m.
Cladonia pyxidata (L.) Hoffm.	(46)	h, m.
Cladonia uncialis (L.) Wigg.	(9,11,13,35,48,57)	m, h.
Cladonia verticillata (Hoffm.)Schaer.	(20,45)	m, h.
Evernia mesomorpha Nyl.	(2,11,14,15,18,26,35, 66,67,73,79,81,82,83)	b.
Hypogymnia physodes (L.) Nyl.	(2,6,11,15,18,23,25, 26,28,40,47,66,75,79, 80,82,83,84)	b.
Hypogymnia vittata (Ach.) Gas.	(77)	b, w.
Icmadophila ericetorum (L.) Zahlbr.	(15,55,75)	h (over mosses).
Nephroma resupinatun (L.) Ach.	(27)	h.
Pannaria microphylla (Sw.) Mass.	(72)	b, w.
Parmelia elegantula (Zahlbr.) Szat.	(3,47)	b.
Parmelia flaventior Stirt.	(3)	b.
Parmelia olivacea (L.) Ach.	(14)	b.
Parmelia subolivacea Nyl.	(26)	b.
Parmelia sulcata Tayl.	(2,3,8,14,15,16,18,26, 47,66,67,79,80,82,83,84)	b.
Parmeliopsis aleurites (Ach.) Nyl.	(8)	w, b.
Parmeliopsis ambigua (Wulf.) Nyl.	(2,8,9,11,13,35,75)	w, b.
Parmeliopsis hyperopta (Ach.) Arn.	(11,13,18,65)	w, b.
Peltigera aphthosa (L.) Willd.	(7,13,17,23,46,66)	h, m.
Peltigera aphthosa (L.) Willd. var. *varioloso* (Mass.) Thoms.	(2,5,6,12,16,20,22,23, 25,27,28,47,49,58,62, 63,72,74,77,80,81,84)	h, m.
Peltigera canina (L.) Willd.	(14,45)	h, m.

	Site Number	Substrate Type
Peltigera canina (L.) Willd. var. *rufescens* (Weiss) Mudd.	(2,3,5,6,17,27,45, 47,63,79,80)	h, m.
Peltigera canina (L.) Willd. var. *spongiosa* Tuck.	(7,65)	h, m.
Peltigera canina (L.) Willd. var. *spuria* (Ach.) Schaer.	(42)	h, m.
Peltigera canina (L.) Willd. var. *ulorriza* (Flörke) Schaer.	(62)	h, m.
Peltigera horizontalis (Huds.) Baumg.	(25,83)	h, m.
Peltigera malacea (Ach.) Funck	(13,23,35,46,81)	h, m.
Peltigera polydactyla (Neck.) Hoffm.	(7,16,22,28,47,62)	h, m.
Ramalina farinacea (L.) Ach.	(2,3,47,84)	b.
Usnea cavernosa Tuck.	(47)	b.
Usnea dasypoga (Ach.) Röhl.	(2,8,14,80)	b.
Usnea glabrata (Ach.) Vain.	(47)	b.
Usnea scabrata Nyl. var. *nylanderi* Mot.	(82)	b.
Usnea subfloridana Stirt.	(2,3,8,14,15,26,47,63, 66,67,68,73,82,83,84)	b.

<u>LIVERWORTS</u> *(Hepaticae)*. Nomenclature follows Bird (1973).

Blasia pusilla (L.) Micheli	(29,30,34)	m.
Blepharostoma trichophylla (L.) Dum.	(12,26,42)	w.
Calypogeia muelleriana (Schiffn.) K. Müll.	(75)	t. (Sphagnum and bog mosses).
Calypogeia sphagnicola (Arn. and Pers.) Warnst. and Loesk.	(15,20,71,74,82)	t. (Sphagnum and bog mosses).
Cephalozia media Lindb.	(20,64,71,73,74,75, 77)	t. (Sphagnum and bog mosses).
Cephalozia pleniceps (Aust.) Lindb.	(38)	h.
Cephaloziella hampeana (Nees) Schiffn.	(38)	h.
Cephaloziella rubella (Nees) Warnst.	(20,42,77,80,81)	t. (moss turf).
Chiloscyphus pallescens (Ehrh.) Dum.	(33)	t. (moss turf).
Isopaches hellerianus (Nees) Buch	(14,28,62,80)	w.
Jamesoniella autumnalis (Cand.) Steph.	(3,14,26,27,28,31,47, 62,63,64,78,80,83)	w.
Lepidozia reptans (L.) Dum.	(64,82)	t. (Sphagnum and bog mosses).

	Site Number	Substrate Type
Lophocolea heterophylla (Schrad.) Dum.	(17,24,38,42,58,72)	h, w.
Lophozia longidens (Lindb.) Macoun	(24,27,80,83)	w.
Lophozia obtusa (Lindb.) Evans	(15,22)	t. (Sphagnum hummocks).
Lophozia porphyroleuca (Nees) Schiffn.	(28)	w.
Lophozia ventricosa (Dicks.) Dum.	(12,38)	h.
Marchantia polymorpha L.	(46)	t. (moss turf).
Mylia anomala (Hook.) S.F. Gray	(8,13,15,20,24,51,54,55, 65,71,74,75)	t. (Sphagnum and bog mosses).
Orthocaulis kunzeanus (Hueb.) Buch	(42)	t. (moss turf).
Plagiochila asplenioides (L.) Dum.	(42,76)	t. (moss turf).
Ptilidium ciliare (L.) Hampe	(7,23,47)	h.
Ptilidium pulcherrimum (Web.) Hampe	(2,6,13,14,18,25,26,28, 45,47,59,64,67,78,79, 80,83)	w, h, b.
Riccardia latifrons Lindb.	(38,74)	t. (moss turf).
Scapania irrigua (Nees) Dum.	(38)	w.
Scapania paludicola Loesk. and K. Müll.	(42)	t. (moss turf).
Tritomaria exsectiformis (Breidl.) Schiffn.	(14,28)	w.

MOSSES *(Musci)*. Nomenclature follows Bird (1973).

Amblystegium juratzkanum Schimp.	(6,17,24,33,50,58,63, 72,79)	h, w, b.
Amblystegium serpens (Hedw.) B.S.G.	(63)	w.
Aulacomnium palustre (Hedw.) Schwegr.	(1,5,6,7,8,12,16,17,20, 22,26,36,38,41,43,49, 56,58,63,64,66,67,69, 70,73,74,77,82)	t.
Barbula fallax Hedw.	(29,30,34)	m.
Brachythecium curtum (Lindb.) Limpr.	(7,62)	h.
Brachythecium nelsonii (Grout)	(36,40,60)	h. *(Drepanocladus* mat.).

	Site Number	Substrate Type
Brachythecium rutabulum (Hedw.) B.S.G.	(3,6,21,26,32,46,58,64)	h, w.
Brachythecium salebrosum (Web. and Mohr) B.S.G.	(2,6,17,24,27,28,31,32, 33,37,39,45,50,58,62, 63,72,79,83)	h, w, b.
Brachythecium velutinum (Hedw.) B.S.G.	(2,28,31,63,67,79,80)	h.
Bryum creberrimum Tayl.	(74)	h.
Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer and Scherb.	(2,14)	h, t.
Calliergon cordifolium (Hedw.) Kindb.	(64)	t.
Calliergon richardsonii (Mitt.) Kindb. ex Warnst.	(12)	t.
Calliergon stramineum (Brid.) Kindb.	(42,77)	t.
Campylium hispidulum (Brid.) Mitt.	(e,6,17,24,27,32,33,62, 63,67,72,80,83)	h, w.
Campylium polygamum (B.S.G.) C. Jens.	(33)	w.
Campylium stellatum (Hedw.) C. Jens.	(12,17,37,43,59)	h, t.
Ceratodon purpureus (Hedw.) Brid.	(15,33,47,79)	h, w.
Climacium dendroides (Hedw.) Web. and Mohr	(17,21,22,26,27,50,72)	h.
Dicranella schreberiana (Hedw.) Schimp. var. *robusta* Schimp. ex. Braithw.	(12)	h.
Dicranella varia (Hedw.) Schimp	(29,30,34)	m.
Dicranum acutifolium (Lindb. and H. Arnell) C. Jens. ex Weinm.	(5,26,31,62,63,64,71,75)	t.
Dicranum flagellare Hedw.	(26,27,28,31,62,63,64, 78)	w.
Dicranum fragilifolium Lindb.	(25,26,47,63,79)	w, t.
Dicranum fuscescens Turn.	(23,26,28)	w, t.
Dicranum polysetum Sw.	(2,3,5,6,13,16,18,19, 23,25,26,28,31,46,64, 66,67,73,78,79,80,81)	t.
Dicranum undulatum Brid.	(4,12,13,15,20,22,25,26, 27,51,52,55,61,64,65,73, 74,75,78,79,82)	t.

	Site Number	Substrate Type
Ditrichum flexicaule (Schwaegr.) Hampe	(23)	h.
Drepanocladus aduncus (Hedw.) Warnst. var. *polycarpus* (Bland. ex Voit) Roth	(36,37,38,39,43,46)	t.
Drepanocladus revolvens (Sw.) Warnst.	(12,73)	t.
Drepanocladus uncinatus (Hedw.) Warnst.	(7,16,17,18,22,33,42,45, 47,50,62,63,64,77,78,79, 82,84)	h, w.
Drepanocladus vernicosus (Lindb. ex. C. Hartm.) Warnst.	(1,36,37,38,60)	t.
Eurhynchium pulchellum (Hedw.) Jenn.	(2,3,6,14,17,18,24,27,31, 32,47,62,63,64,68,80,83, 84)	h, b.
Funaria hygrometrica Hedw.	(29)	m.
Haplocladium microphyllum (Hedw.) Broth.	(6,17,24,27,32,33,34,62, 63,72)	h, w.
Helodium blandowii (Web. and Mohr) Warnst.	(42,59,69,76)	t.
Herzogiella turfacea (Lindb.) Lindb.	(62,63)	w.
Hylocomium splendens (Hedw.) B.S.G.	(2,3,5,6,7,12,14,16,17, 18,20,22,23,25,26,27,28, 31,42,46,47,49,59,62,63, 64,66,68,69,77,78,79,80, 81,82,83,84)	h.
Hypnum callichroum Funck ex Brid.	(25)	h.
Hypnum lindbergii Mitt.	(21,26,50,64,69,73,76, 77,82)	h, t.
Hypnum pallescens (Hedw.) P. Beauv.	(62)	b.
Hypnum pratense Koch ex Brid.	(32,33)	h, m.
Leptobryum pyriforme (Hedw.) Wils.	(2)	w.
Leptodictyum trichopodium (Schultz) Warnst.	(34)	m.
Meesia longiseta Hedw.	(38)	t.
Meesia triquetra (Richt.) Ongstr.	(37)	t.
Mnium spinulosum B.S.G.	(63)	h.

	Site Number	Substrate Type
Myurella julacea (Schwaegr.) B.S.G.	(72)	h.
Oncophorus wahlenbergii Brid.	(3,6,14,17,24,26,27,31, 33,62,63,78,80,83)	w.
Orthotrichum obtusifolium Brid.	(2,14)	b.
Plagiomnium cuspidatum (Hedw.) Kop.	(2,6,24,27,32,33,50,58, 62,63,67,72,83,84)	h, w, b.
Plagiomnium drummondii (Bruch and Schimp.) Kop.	(27,63)	h, w.
Plagiomnium medium (B.S.G.) Kop.	(3)	h.
Plagiomnium rugicum (Laur.) Kop.	(3,12,17,39,41,47,59, 64,82)	h.
Platygyrium repens (Brid.) B.S.G.	(26,62,63)	w, b.
Pleurozium schreberi (Brid.) Mitt.	(2,3,4,5,6,7,8,12,13,14, 15,16,17,18,19,20,22,23, 25,26,27,28,42,46,47,51, 52,62,64,65,66,67,73,78, 79,80,81,82,83,84)	h.
Pohlia nutans (Hedw.) Lindb.	(5,7,8,14,25,26,31,45,62, 63,67,69,78,80,81)	h, w.
Pohlia wahlenbergii (Web. and Mohr) Andr.	(29,30,34)	m.
Polytrichum commune Hedw.	(2,7,8,49,55,62,65,66,67)	t.
Polytrichum juniperinum Hedw.	(1,2,7,13,15,20,26,28,45, 47,49,50,51,52,53,54,55, 56,58,62,65,66,69,71,73, 74,75,77,79,82)	t, m, h.
Polytrichum piliferum Hedw.	(9,11)	m, h.
Ptilium crista-castrensis (Hedw.) De Not.	(2,3,4,6,12,13,16,18,19, 26,27,28,31,47,59,62,63, 64,66,67,80,83,84)	h.
Pylaisiella polyantha (Hedw.) Grout	(2,6,14,18,24,27,28,32,33, 45,47,50,63,83)	b.
Rhytidiadelphus triquetrus (Hedw.) Warnst.	(31,63)	h.
Sphagnum capillaceum (Weiss) Schrank	(4,13,15,20,22,51,53,54, 65,66,71,75,80)	t.
Sphagnum fuscum (Schimp.) Klinggr.	(1,4,8,12,15,20,42,51,55, 58,61,65,70,71,74,75,77)	t.
Sphagnum magellanicum Brid.	(4,8,53,73)	t.

	Site Number	Substrate Type
Sphagnum recurvum P. Beauv. var. Tenue Klinggr.	(8,54,58,73,76,82)	t.
Sphagnum squarrosum Crome	(38,42)	t.
Sphagnum warnstorfii Russ.	(8,12,65,69,70,73,76, 77,82)	t.
Tetraphis pellucida Hedw.	(31,62,64)	w.
Tetraplodon angustatus (Hedw.) B.S.G.	(15)	h. (dung).
Thuidium recognitum (Hedw.) Lindb.	(5,22,82)	h.
Timmia megapolitana Hedw.	(32,33)	h, m.
Tomenthypnum nitens (Hedw.) Loeske	(5,12,16,20,22,36,42,43, 56,58,61,69,70,72,73,74, 76,77,82)	t.
Tomenthypnum nitens (Hedw.) Loeske var. *falcifolium* (Ren. ex. Nich.) Podp.	(77)	t.

Appendix 4

Some taxonomic problems

Sampling plant communities in late August presented many taxonomic problems, an explanation of which may be of some use to other plant ecologists working in the Alberta oil sands area:

1. It is possible that certain closely related and similar-appearing species may have been confused in the field to the point that populations labelled as one species may have been mixture of two. Thus, there could have been confusion between the two field horsetails *Equisetum arvense* and *E. pratense,* the dwarf birches *Betula glandulosa* and *B. pumila* var. *glandulifera,* the bush cranberries *Viburnum edule* and *V. trilobum* and the black currant-gooseberries *Ribes oxyacanthoides, R. hirtellum* and *R. lacustre*. The *Ribes* species were a particular problem as many species seemed intermediate in characteristics and were usually lacking in reproductive structures making definite identification occasionally impossible.

2. Small species of goldenrod (*Solidago* sp.), although of little quantitative importance, were often depauperate and even flowering specimens seemed intermediate in characteristics, that is, *Solidago multiradiata* and *S. nemoralis* var. *decemflora* could have been confused with each other.

3. Many sedges (*Carex* species) and even some grasses could have been missed, as many populations, although recognizable to genus in the case of the sedges by their vegetative characteristics, had no flowering culms at all. They were therefore virtually impossible to identify and have been labelled simply as *Carex* sp.

4. The most confusion occurred with the willows (*Salix* sp.). The identities of the specimens of *Salix glauca* and *S. discolor* are tentative and confusion may have occurred between some of these and specimens of the principal willow, *Salix bebbiana*. To add to the difficulty, the latter species had a very wide morphological variation and together with the complete absence of any catkins made sure identification impossible of this whole group of willows.

5. Several species which occur prominently or even as dominants in communities in adjacent areas apparently did not occur at all in this study. Some of these are species in notoriously difficult genera, and so may have been missed inadvertently in sampling or confused with closely related species. This comment applies particularily to *Salix planifolia,* a dominant willow of tall scrub in the Peace-Athabasca Delta (Dabbs, 1971), and wetlands

of north-central Saskatchewan (Jeglum, 1968), and to *Calamagrostis inexpansa*, an important grass of many of Alberta's wetland communities.

Appendix 5

Aerial photographic coverage of the Alberta oil sands area

All of the following black and white photography has been flown by the Aerial Surveys Section of Alberta Energy and Natural Resources. Undoubtedly other pertinent photography exists which is unknown to the author.

Project	Map Sheet	Job No.	Roll	Photo Nos.	Film	Date Flown	Scale
Most of Alberta oil sands	74 D, E, 84 A, H	6706-26	AS 961 to AS 968	1743 photographs	Pan	Aug. 27-30 and Sept. 14, 1967	1:31,680
Most of Alberta oil sands	74 E4, 5, 84 H1, 2, 7, 8	AS 174	AS 1028	1-189	Pan XX	1969?	1:31,680
Embarras	74 L5, 6, 11, 12	AS 223	AS 1045	120-201	Pan	July 2, 1969	1:24,000
A7-Q1-CB≠3	74 E11, 12	AS 50	AS 1044	1-59	IR	July 30, 1969	1:15,840
Fire DA 2-7 (70)	74 E1, 8	?	AS 1011	146-172	IR	July 30, 1969	1:15,840
A3-L3	74 D6	AS 64	AS 1042	222-251	IR	July 31, 1969	1:15,840
A2-L1	74 D10, 11	AS 68	AS 1042	184-221	IR	July 31, 1969	1:15,840
Richardson Tower	74 E14	70-177	AS 1068	121-131	IR	Aug. 2, 1970	1:15,840
Muskeg Tower	74 E2	70-199	AS 1046	204-206	IR	Aug. 2, 1970	1:12,000
Grande Tower	84 A8	70-212	AS 1046	194-198	IR	Aug. 2, 1970	1:12,000
Stony Mtn. Tower	74 D6	70-213	AS 1046	184-186	IR	Aug. 2, 1970	1:12,000
Anzac	74 D6	70-214	AS 1046	181-183	IR	Aug. 2, 1970	1:12,000
Fort Chipewyan	74 L11	70-197	AS 1046	177-180	IR	Aug. 2, 1970	1:12,000
Fort Chip D.O.T.	74 L14	70-198	AS 1046	173-176	IR	Aug. 2, 1970	1:12,000

Project	Map Sheet	Job No.	Roll	Photo Nos.	Film	Date Flown	Scale
Embarras	74 L3	70-195	AS 1046	164-167	IR	Aug. 2, 1970	1:12,000
Bitumount airstrip	74 E5	70-194	AS 1046	191-193	IR	Aug. 2, 1970	1:12,000
Bitumount	74 E5	70-193	AS 1046	171-172	IR	Aug. 2, 1970	1:12,000
Fort MacKay	74 E4	70-192	AS 1046	168-170	IR	Aug. 2, 1970	1:12,000
Fire DA 2-4 (70)	74 D14	70-172	AS 1068	73-82	IR	Aug. 2, 1970	1:15,840
Fire DA 2-7 (70)	74 D15	70-173	AS 1068	83-90	IR	Aug. 2, 1970	1:15,840
Fire DA 3-4 (70)	74 E11	70-176	AS 1068	118-120	IR	Aug. 2, 1970	1:15,840
Fire DA 4-2	74 E14	70-177	AS 1068	121-131	IR	Aug. 2, 1970	1:15,840
Twp 88-89, Rge 9, W4	74 D11	71-42	AS 1093	268-306	IR	June 12, 1971	1:21,120
Gregoire Lake	74 D6	71-110	AS 1109	94-127	IR	Oct. 10, 1971	1:12,000
Fort McMurray	74 D11, 12, 13, 14	71-319	AS 1147	1-280	IR	Oct. 8, 1971	1:12,000
Ft. McMurray Holding Camp	74 D11	72-100	AS 1046	253-254	IR	March 28, 1972	1:7,380
SR 963 Ft. McMurray to Ft. MacKay	74 E4, 5, 74 D11, 13, 14	72-201	AS 1295	84-232	Estar XX Pan	May 17 and May 27, 1972	1:12,000
Gregoire Lake Park	74 D6	72-208	AS 1296	87-115	Estar XX Pan	May 27, 1972	1:12,000
E & N R Div. Hdqts. and Alta. Voc. Training Centre	74 D11	72-34	AS 1191	1-17	IR	June 26, 1972	1:6,000

Project	Map Sheet	Job No.	Roll	Photo Nos.	Film	Date Flown	Scale
Most of Alberta oil sands	74 D, E, 84 A, H	72-133 & 72-137 (duplicates)	AS 1200 to AS 1205	1685 photographs	IR	Aug. 15, 22, 23 & Oct. 2, 1972	1:21,120
Hwy 63, Jct Hwy 46 to Ft. McMurray	74 D5-7, 11, 14	73-148	AS 1275	185-232	Estar XX Pan	April 26, 1973	1:24,000
Gregoire Lake	74 D6, 11	73-42	AS 1242	208-249	IR	May 13, 1973	1:12,000
Ft. McMurray	74 D11-14	74-43	AS 1300	1-130	Pan	May 22, 1974	1:12,000
West of Ft. McMurray	74 D11-14 84 A9, 16	74-4	AS 1299	122-317	Pan	May 23, 1974	1:21,120
Firebag River	74 E11	74-75	AS 1362	166-175	Pan	Oct. 21, 1974	1:6,000
S.E. Birch Mtns.	74 E5, 12, 84 H3	74-36	AS 1362	1-138	Pan	Oct. 22, 1974	1:21,120
E. Birch Mtns. area	74 E5	74-74	AS 1362	156-165	Pan	Oct. 28, 1974	1:6,000
Tar River area	74 E5	74-73	AS 1362	149-155	Pan	Oct. 28, 1974	1:6,000
Ells River area	74 E4, 5	74-72	AS 1362	143-148	Pan	Oct. 28, 1974	1:6,000
Steepbank Creek area	74 E3	74-71	AS 1362	133-142	Pan	Oct. 28, 1974	1:6,000

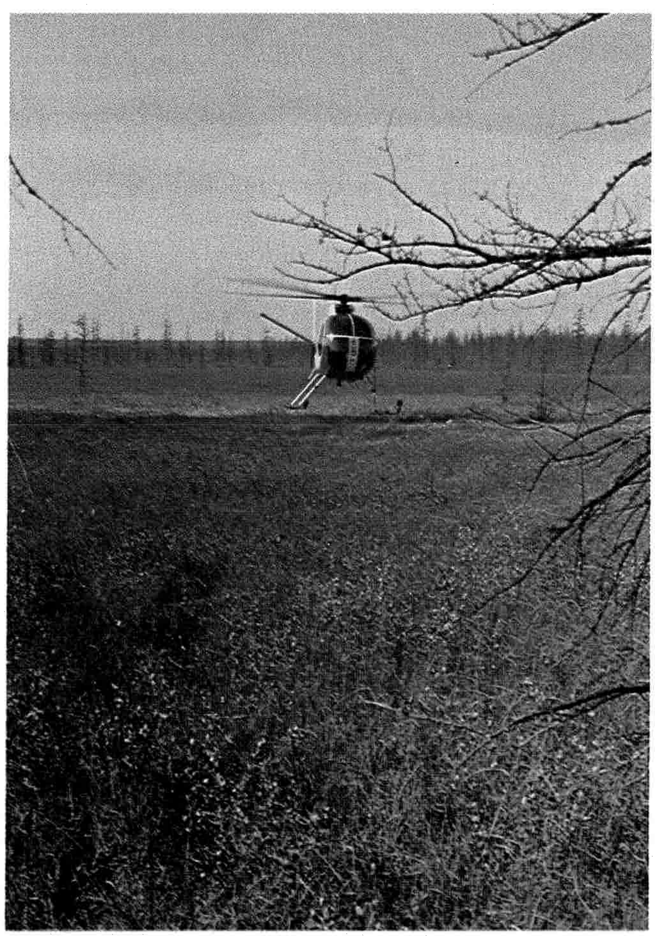
Also note the following multispectral imagery:

Ft. McMurray up the Athabasca River to Firebag River, E-W strip 80 miles wide (74 D NW, and 74 E SW, NW, and NE), photographed by (1) Color IR, (2) Color (natural), (3) B. and W., filter in red, (4) B. and W., filter in green, (5) B. and W. IR, on July 29, 1973, at a scale of 1:720,000; Master roll number 30784; Job Number 73/75; 98 photographs. Alberta Remote Sensing Centre, Edmonton.

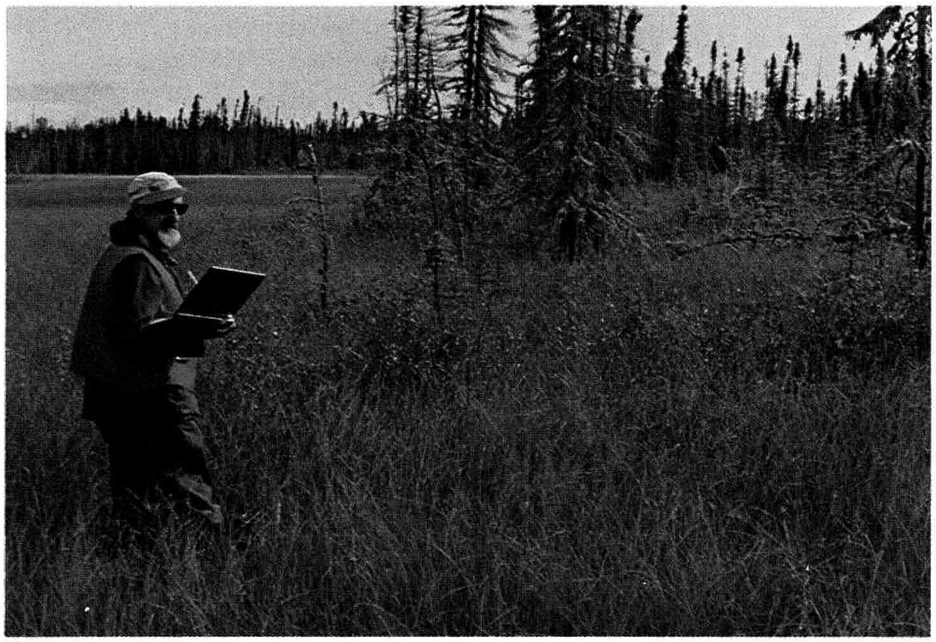
Appendix 6

Photographs illustrative of the principal vegetation types of the AOSERP study area.

PHOTOGRAPH 1. Fine-leaved sedge fen (Stand 36). Aerial view of a patterned fen southwest of McClelland Lake; patches of tamarack on ridges alternate with fen.

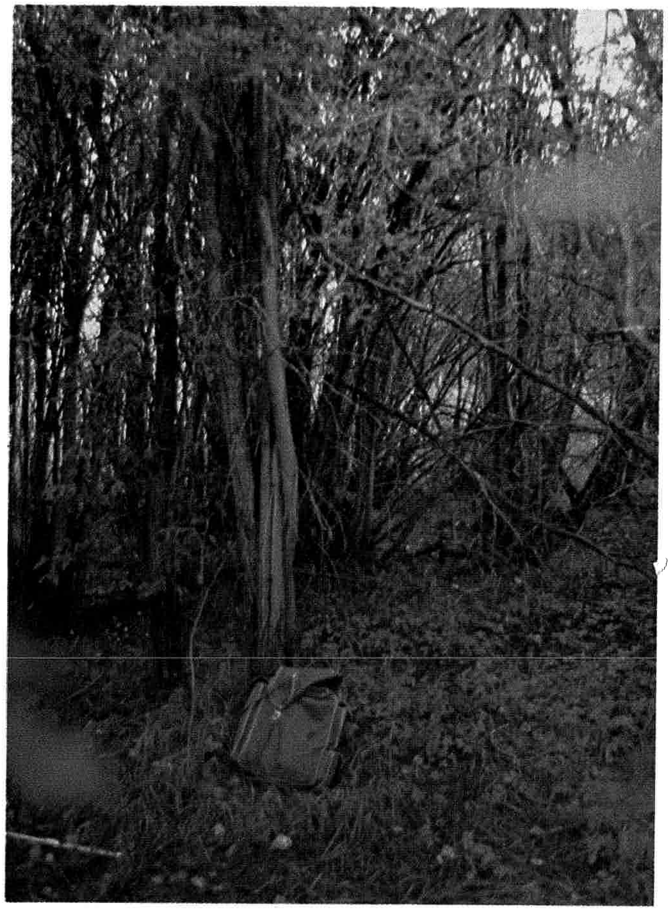


PHOTOGRAPH 2. Broad-leaved sedge fen (Stand 37). Treeless fen, 2 mi south of site in Photograph 1; ground is much too soft for the helicopter to land.

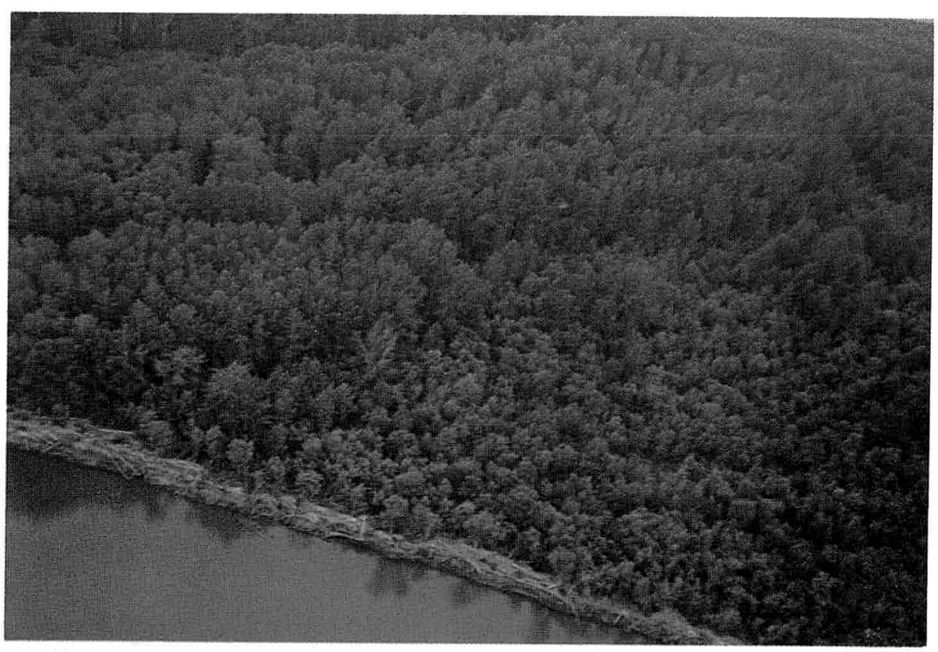


PHOTOGRAPH 3. Fine-leaved sedge fen (Stand 1). At the edge of a small lake (off left) and gradually merging into a sparse black spruce bog forest (right background).

PHOTOGRAPH 4. Fine-leaved sedge fen (Stand 40) in the foreground; sandbar willow scrub (Stand 39) in the background, backed by mixed-wood forest.

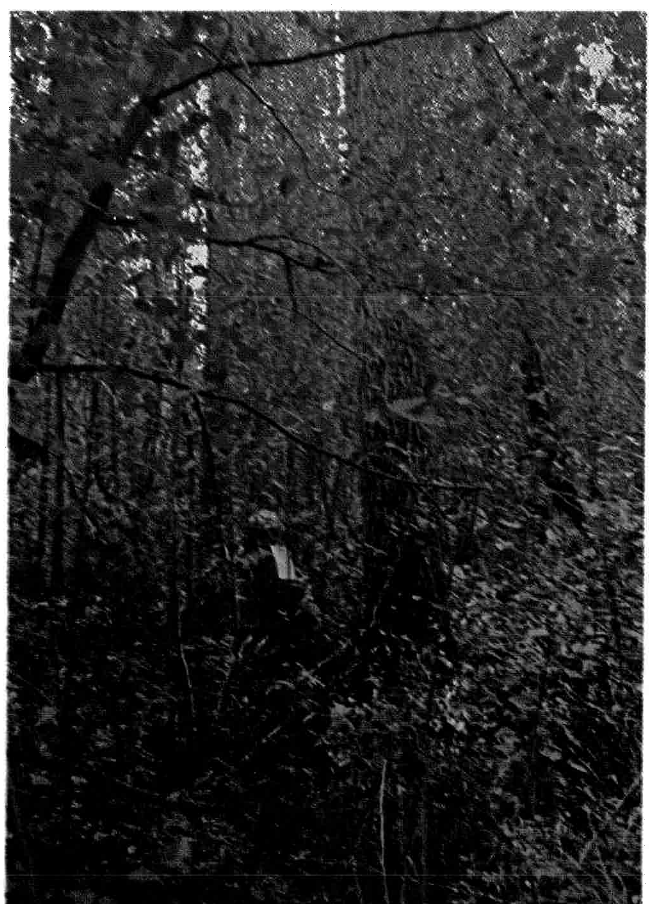


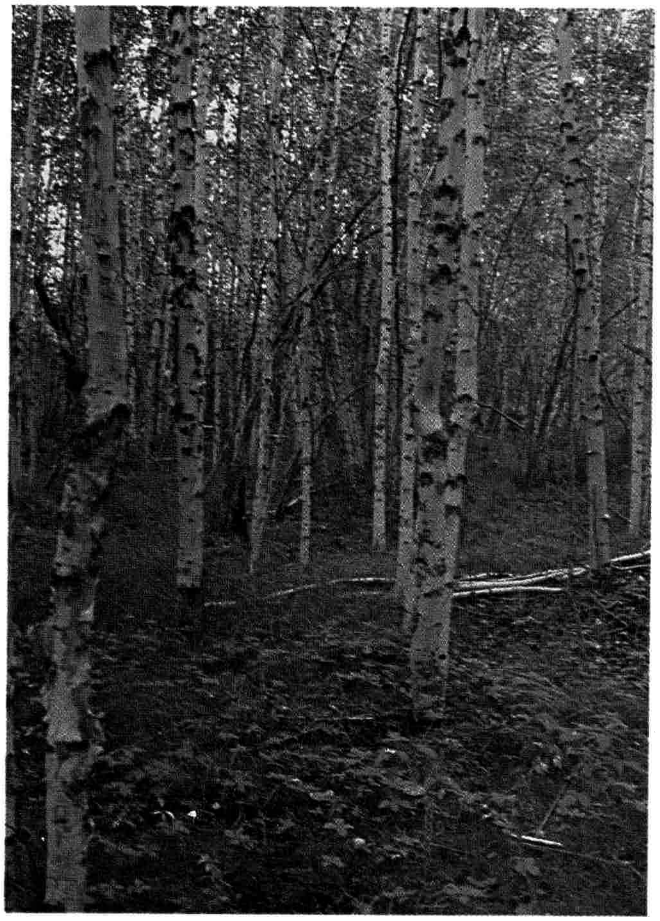
PHOTOGRAPH 5. Tall willow scrub (Stand 21). Note the sparse herb stratum under the dense shrub canopy.

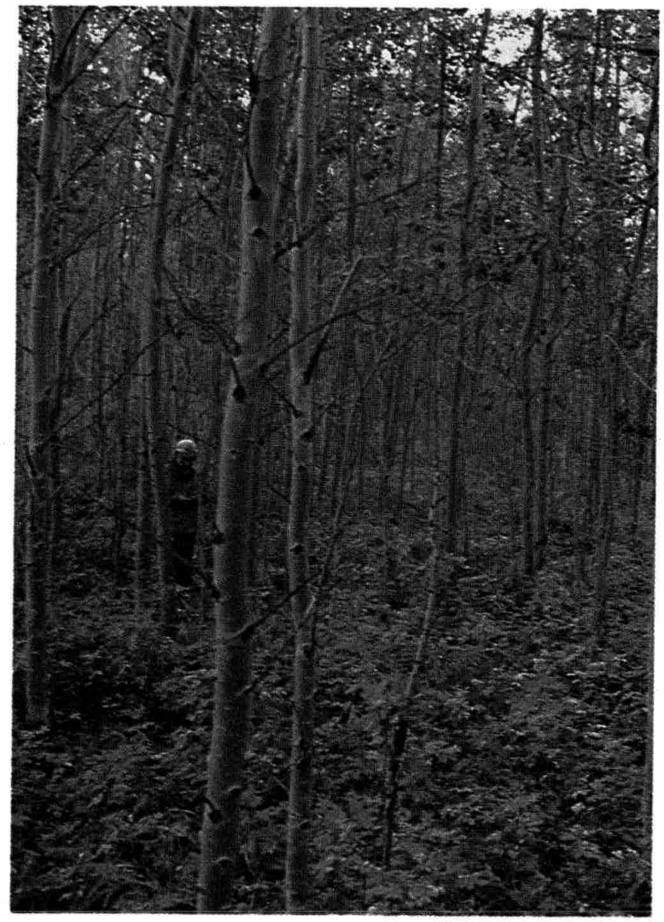


PHOTOGRAPH 6. Tall willow scrub (lower right) and bottomland balsam poplar forest (center and left) along the Athabasca River, near the junction of the Firebag River.

PHOTOGRAPHS 7 and 8. Bottomland balsam poplar forest (Stand 33, Photograph 7; and Stand 24, Photograph 8), with a dense high shrub stratum of *Alnus tenuifolia*.

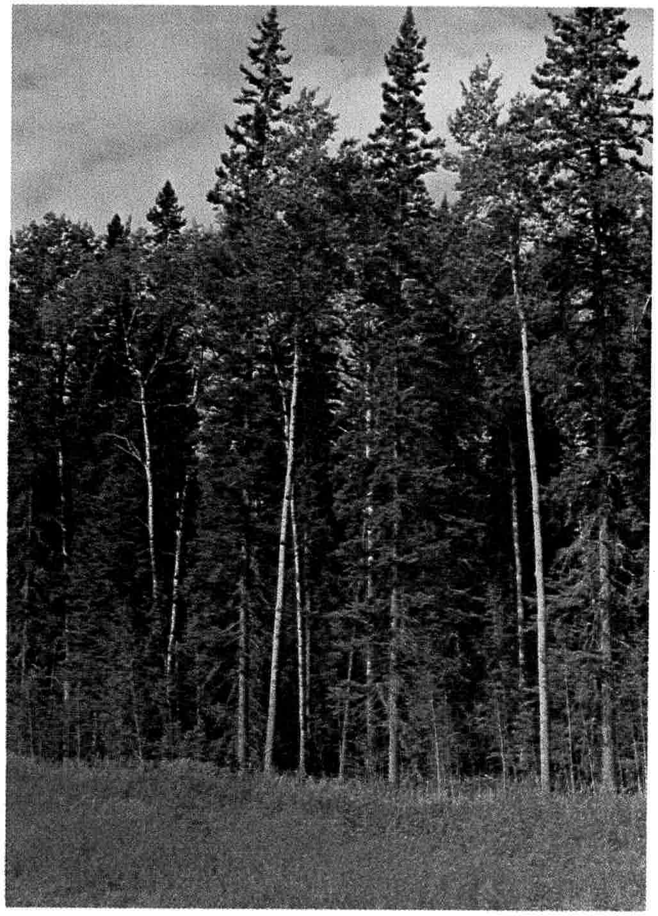




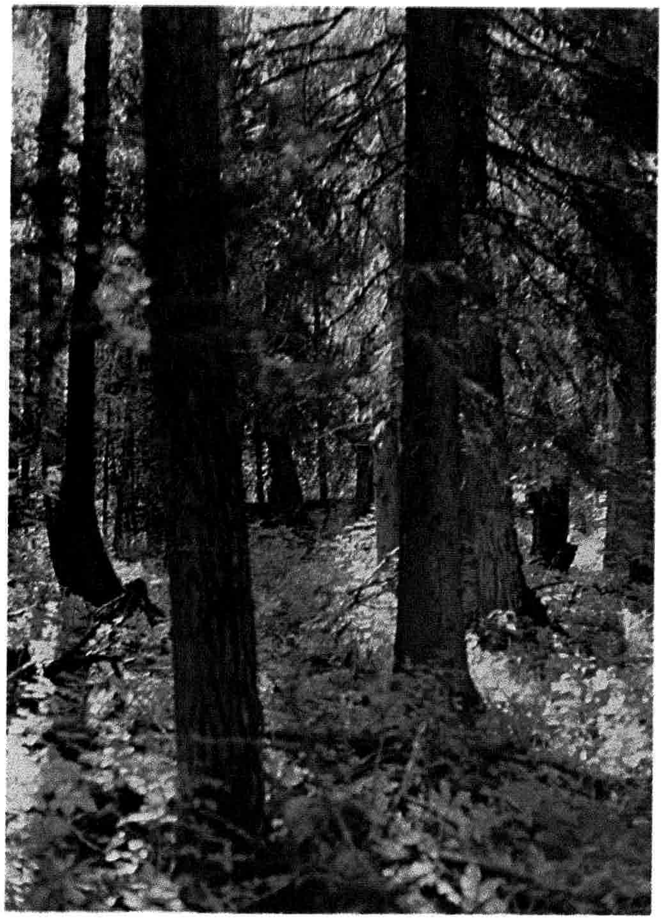


PHOTOGRAPH 9. White birch forest (Stand 26) with no shrub stratum, but a prominent herb stratum dominated by *Calamagrostis canadensis* and *Cornus canadensis*.

PHOTOGRAPH 10. Young aspen forest (Stand 6) with dense and diverse shrub and herb strata developed under a light tree canopy.

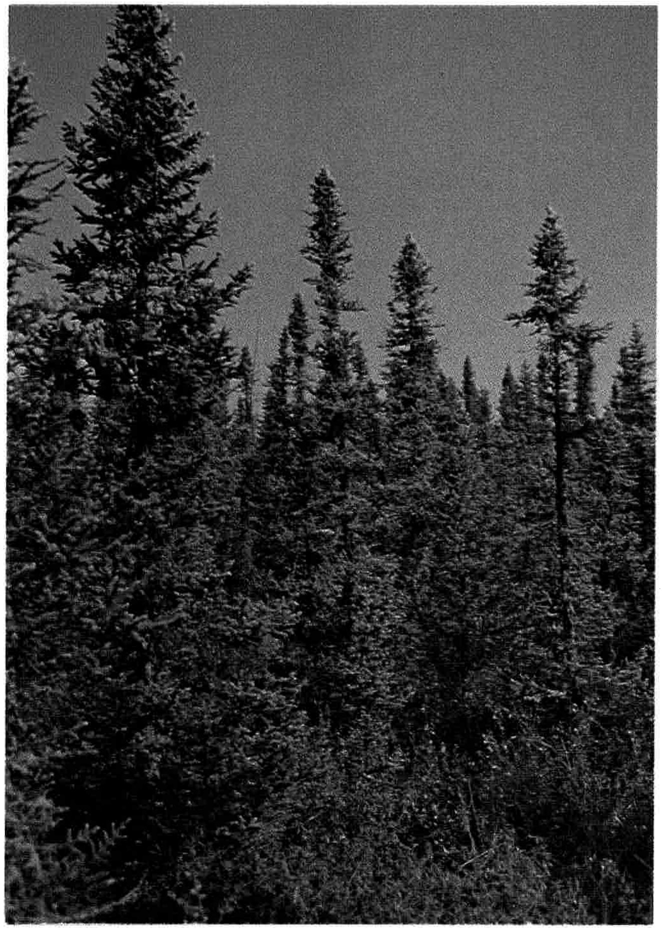


PHOTOGRAPHS 11 and 12. Upland mixedwood forest (Stand 14) of aspen and white spruce with a diverse understory of many grasses and forbs, but only a sparse shrub stratum.

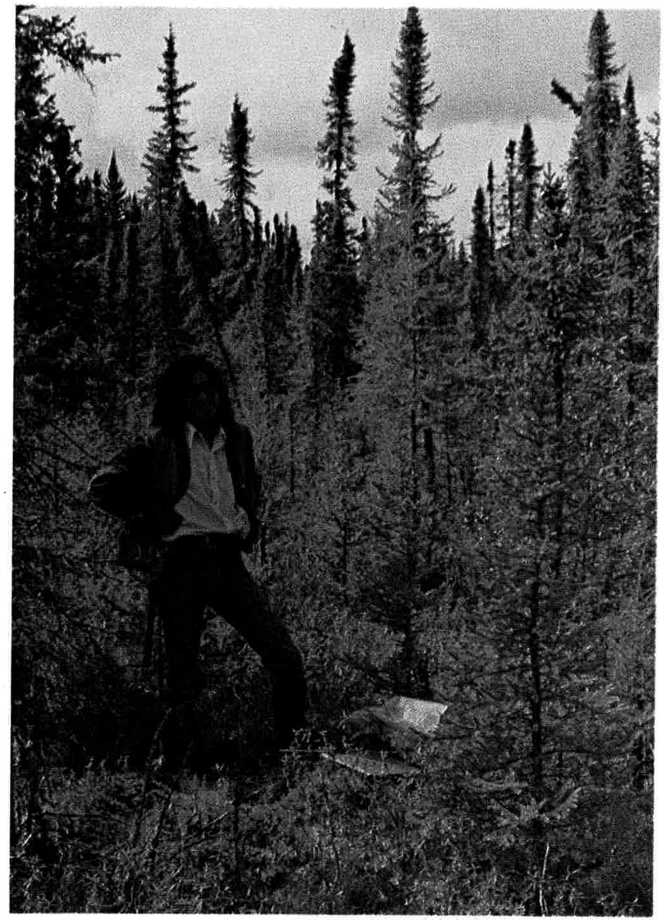


PHOTOGRAPH 13. Upland coniferous forest (Stand 63) of white spruce and balsam fir with a diverse but sparse herb stratum underlain by a discontinuous spongy feathermoss carpet dominated by *Hylocomium splendens*.

PHOTOGRAPH 14. Very dense coniferous forest (Stand 18) of black and white spruce with a ground cover almost entirely composed of a continuous and thick feathermoss carpet of *Hylocomium splendens*, *Pleurozium schreberi* and *Ptilium crista-castrensis*.



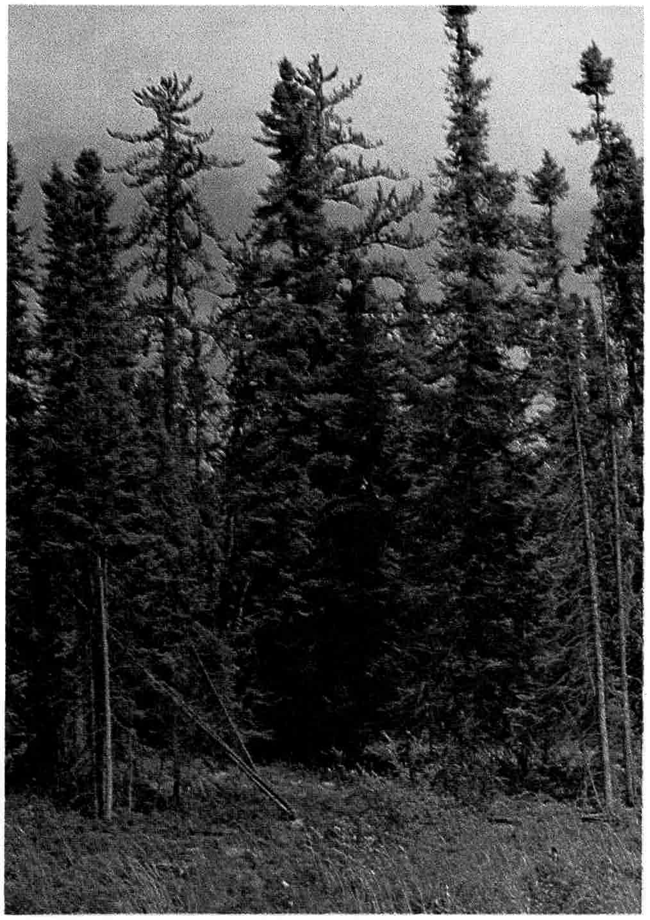
PHOTOGRAPHS 15 and 16. Black spruce bog forest (Stand 8) with a prominent shrub stratum dominated by *Ledum groenlandicum*. The ground cover photograph shows a *Sphagnum recurvum* hummock covered with the typical bog species *Ledum groenlandicum*, *Rubus chamaemorus* and *Vaccinium vitis-idaea*.

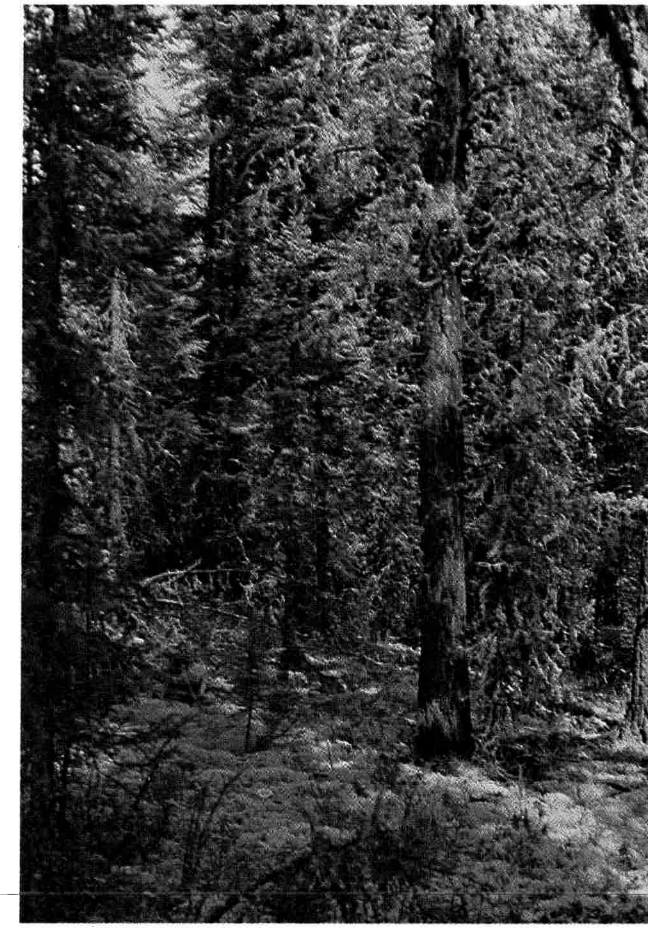


PHOTOGRAPH 17. Black spruce-tamarack bog forest (Stand 20) with an understory of *Ledum groenlandicum* and other bog species growing on conspicuous hummocks of *Sphagnum fuscum* and *S. capillaceum*.

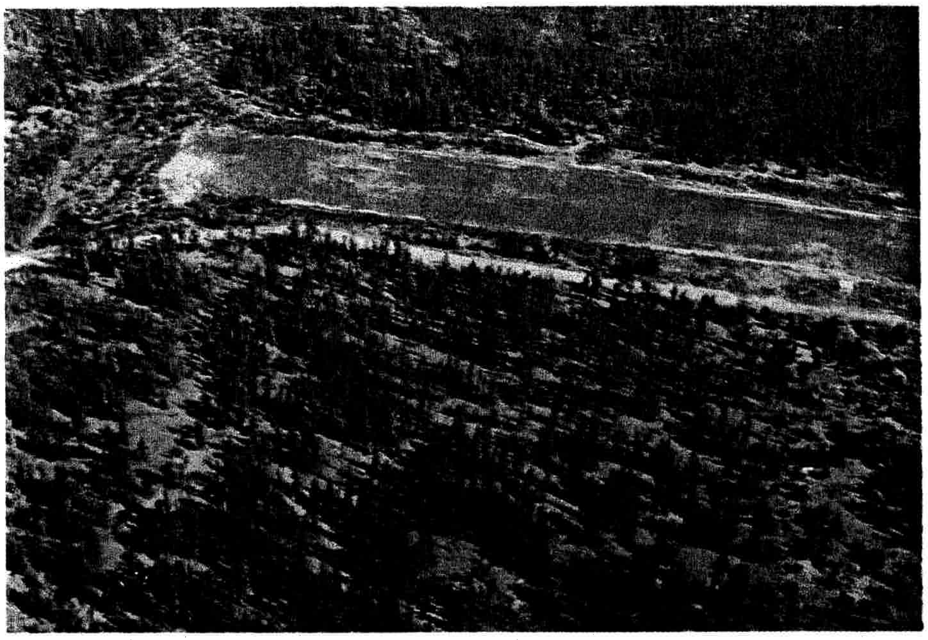
PHOTOGRAPH 18. Lightly treed tamarack muskeg (Stand 42) with a prominent low shrub stratum of *Chamaedaphne calyculata* and *Kalmia polyfolia* on a thick bog moss carpet principally of *Tomenthypnum nitens*.

PHOTOGRAPHS 19 and 20. Open muskeg (Stand 77) merging gradually into black spruce bog forest in the distance; the ground cover photograph shows *Ledum groenlandicum, Salix pedicellaris, Chamaedaphne calyculata* and *Carex* spp. on hummocks of *Sphagnum fuscum*.

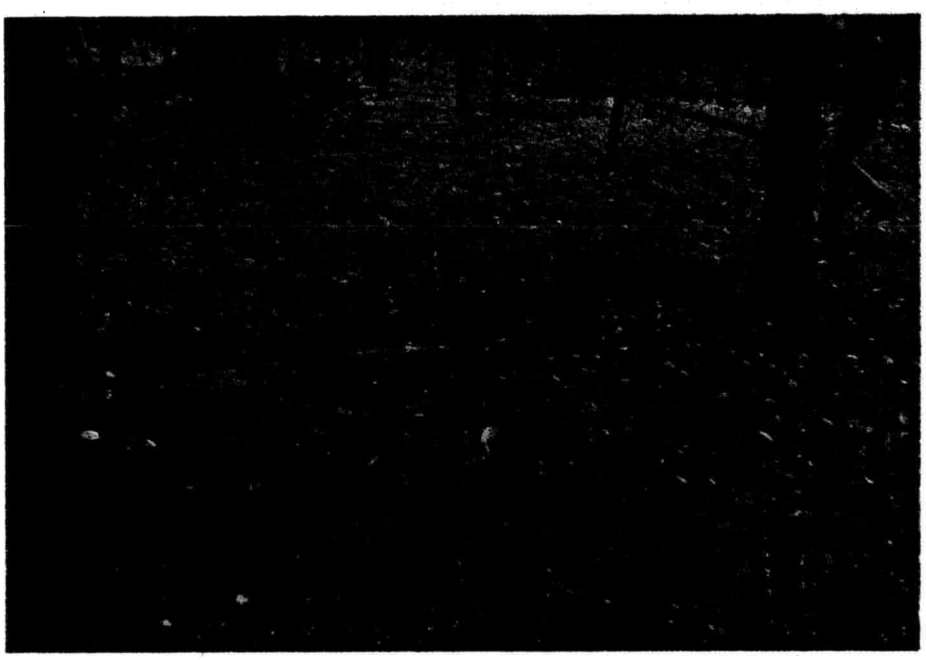




PHOTOGRAPHS 21 and 22. Upland black spruce-jack pine forest (Stand 46) with an understory composed principally of dense cushions of *Cladina mitis* and only scattered vascula plants (*Vaccinium vitis-idaea*, *Vaccinium myrtilloides*, *Ledum groenlandicum*).



PHOTOGRAPH 23. An aerial view of extensive upland jack pine forest on aeolian sand. Stand 9 is located in the center of the photograph, which also shows the Richardson Tower airstrip. The light-colored ground surface is accentuated because of a discontinuous cover of terrestrial lichens of the genera *Cladina*, *Cladonia* and *Cetraria*.



PHOTOGRAPH 24. Upland jack pine forest (Stand 35) on aeolian sand; the sparse understory is principally *Arctostaphylos uva-ursi* with *Vaccinium vitis-idaea*, *V. myrtilloides*, *Oryzopsis pungens*, and extensive cushions of the lichens *Cladina mitis* and *C. arbuscula*.