Not for publication

DEVELOPMENT OF BURNING INDEX TABLES FOR WHITE SPRUCE-ALPINE FIR AND LODGEPOLE PINE FOREST COVERTYPES IN THE PRINCE GEORGE FOREST DISTRICT

(An Establishment and Progress Report)

by
R. N. Russell and Gy. Péch

FOREST RESEARCH LABORATORY
VICTORIA, BRITISH COLUMBIA
INTERNAL REPORT BC-8

CANADA
DEPARTMENT OF FORESTRY
AND RURAL DEVELOPMENT

FORESTRY BRANCH
MAY, 1968

DEVELOPMENT OF BURNING INDEX TABLES
FOR WHITE SPRUCE-ALPINE FIR AND LODGEPOLE PINE FOREST COVERTYPES
IN THE PRINCE GEORGE FOREST DISTRICT
(AN ESTABLISHMENT AND PROGRESS REPORT)

by

R.N. Russell and Gy. Péch

Forest Research Laboratory
Victoria, British Columbia

Internal Report BC-8

Department of Forestry and Rural Development
May 1968

TABLE OF CONTENTS

DEVELOPMENT OF BURNING INDEX TABLES FOR WHITE SPRUCE-ALPINE FIR AND LODGEPOLE PINE FOREST COVERTYPES IN THE PRINCE GEORGE FOREST DISTRICT

An Establishment and Progress Report on Project B.C. 609

for 1966 and 1967

by

R.N. Russell and Gy. Péch

INTRODUCTION

Recent expansion of the pulp industry in the Prince George Forest District, and the resulting increase of traffic in the woods, necessitate the derivation of an improved local fire danger table. In the past, the Protection Division of the British Columbia Forest Service has attempted to adapt the British Columbia Cariboo and the Alberta East Slope Fire Danger Tables in the Prince George Forest District without satisfactory results. The diversity of stand and fuel characteristics, of topography, and of the regional climate preclude the universal application of these tables. After several years' use the Drought Index component of these tables has received much criticism while other parts have caused some minor dissatisfaction. These criticisms present obstacles to promoting the use of the tables, and indicate the need for revising the fire danger rating system. To answer this need, Project B.C. 609 was initiated in 1966.

The project has two objectives. The first is to develop burning index for white spruce[1/]-alpine fir and lodgepole pine stands in the

---

[1/] See Appendix I for Latin names of tree species.

Prince George Forest District. This is to be achieved through the ignition and observation of two-minute test fires which will be set under various weather conditions during different periods of the day and night. A subsequent analysis of these data will be undertaken to derive the tables. Since the field procedure has been described in the Project Plan (Péch 1966b), only modifications, effected during the 1966, 1967 field seasons, and future plans are detailed in this report. The method of collecting and compiling the information is also described.

The second objective is to assist in the revision of the fire danger rating system. The data collected in the field is particularly suitable for work on revisions to the Rainfall Code and Drying Code Tables. This report describes the field procedures and the subsequent compilation of the data in detail.

The completion time of the project will depend largely upon the weather. Cool and wet field seasons could prolong the work over four years, but a mixture of dry and wet field seasons should permit completion by 1968.

PROCEDURE

FIELD LOCATION

Early in the summer of 1966, four experimental sites were selected. The four sites chosen represent a moderately dry and a moist white spruce-alpine fir stand plus a dry and moderately moist lodgepole pine stand. One main fire weather station and two auxiliary fire weather stations were established and instrumented near the experimental sites (Fig. 1). Details regarding site and instrumentation of each station follows:

Main Climatological Station

The Main Climatological Station (W. 122° 38' long, N. 54° 22' lat., elevation 2300 ft. M.S.L.) was located on an extensive flat area, about 800 feet west of the John Hart Highway, 36 miles north of Prince George. Aluvial deposits covered the ground. Vegetation consisted of moss, annual herbs and sparsely distributed yet dense willow-aspen bush communities 1 to 4 feet high. At the station site, the top four inches of rocks were removed from a 30 by 30 ft. area and replaced with topsoil. A mixture of grass and clover seed was sown. By mid-August of 1966, the turf was regularly trimmed to a height of one inch. Certain patches, notably the north-western quadrant of the site, became bare due to continued tramping around the fuel samples. These patches were returfed in 1967 to conform to World Meteorological Organization specifications.

Meteorological Instruments

The following instruments were in operation during the summer months of 1966 and 1967.

(a) In 1966 two Fuess hygrothermographs (Model No. 79r) equipped with drums which rotate once every 24 hours, were placed 4 - 5 ft. above the ground in a portable Stevenson (Day 1965) and a plastic (Muraro 1962) screen. The property number of each instrument was marked on all charts because the hygrothermographs were frequently interchanged between the two screens. The plastic screen was used merely to collect information on its performance in the open (Péch 1966); however, the presence of the second hygrothermograph proved valuable for the following reasons. There were a few instances when the hygrothermograph under the Stevenson screen did not function properly. On two occasions the observer neglected to re-engage the pens after servicing the instrument, resulting in a loss of records for approximately 24 hours. During long periods of rainfall, the hygroscopic ink in the pens occasionally became overly diluted and when observers failed to clean and refill the pens the diluted ink trace on the chart often became illegible. Missing information was obtained from records on the second hygrothermograph in such cases. In 1967 these two instruments were again used but they were both housed in portable Stevenson screens.

The portable Stevenson screen was preferred to the Meteorological Service of Canada (M.S.C.) screen, because the latter required the lifting of the hygrothermograph out of the screen for servicing each day, a practice detrimental to its accuracy. With the former screen, the sides and the roof of the shelter were filled while the instrument remained on the platform. To shield the sensors from direct solar radiation, an aluminum tally board was placed beside the hygrothermograph during the servicing period.

(b) A Negretti-Zembra sunshine recorder, Jordan type, was installed on a four ft. high platform, levelled with a circular spirit level, oriented true north, and the chart drum inclined at 54.5 degrees of latitude.

The flux density of solar radiation was recorded with a bimetallic actinograph (Belfort Instrument Co.). The clock drum was geared for 1 revolution in 24 hours. The purpose of using the relatively fast drum rotation was twofold: the fast chart movement helped reduce pen friction, thereby increasing the sensitivity of the instrument. The resolution of the trace was also expanded allowing planimetric evaluation of the radiant flux record for every half hour.

(c) Precipitation was measured to .01 in. accuracy with a syphon-type Casella rainfall recorder (Model No. 5372) geared for 1 revolution in 24 hours.

(d) Wind speed and direction was measured 33 feet above ground with a three-cup anemometer and wind vane assembly (Science Associated Inc.), and recorded on an analog-event recorder. The wind vane operated on 12 volt D.C. battery supply, while the recorder had a spring wound chart drive (Model 471 SW). A standard, triangular, three section M.S.C. mast, was used for mounting the cups and the wind vane. The two Radar-Lite batteries and the recorder chart were replaced once every six to seven weeks.

(e) Two Potvin-type dew gauges were exposed but the records were almost negligible as dew collection seemed to occur only in the late spring and early fall.

(f) In 1966, two sets of standard Meteorological Service of Canada mercury-in-glass maximum thermometers and spirit-type minimum thermometers were exposed 4-5 ft. above ground in a portable Stevenson and a plastic screen. For this type of measurement the M.S.C. type Stevenson screen with the hinged wall would have been preferable to either screens used. This type reduces the slight jolts and vibrations to the thermometers which are frequently unavoidable when lifting and lowering the portable Stevenson and plastic screens. In 1967 one hinged screen was used to house a minimum and maximum thermometer.

During the first year, the minimum thermometers were reset at 1630 Pacific Standard Time to ensure the indication of the true minimum air temperature on the following morning. This practise was discontinued in 1967, lest the opening of the screen interfere with the accuracy of the current maximum temperature record. Instead, the minimum thermometer was read at 0800 P.S.T. to establish the minimum temperature and reset at 1100 hours for the next minimum reading. The maximum temperature for the previous day was also recorded at 0800 hr. In the future, the 1967 schedule will continue to be used.

Inside the screen the horizontally mounted minimum thermometer was placed about 6 inches from the roof and the maximum thermometer a further 3 inches lower; the latter was mounted in a slanted position with the mercury reservoir about 1 inch lower.

Special care must be exercised when the maximum thermometer is reset. The mercury reservoir should always be lower than the rest of the stem during the light shaking procedure. Failure to follow this procedure could result in shattering of the thermometer at the constriction or separation of the mercury column.

No unusual difficulties were experienced at the main climatological station in respect to the maintenance of the instruments, or the performance of duties. All records, both on the main meteorological site and at the test sites were recorded according to Pacific Standard Time.

The field work on the revision of the Rainfall and Drying Code Tables (Anon. 1961) was confined to the exposure and regular weighing of various fuel samples at the main climatological station. The objectives of this work and the routine procedure adopted in 1966 and 1967 are discussed in a separate section of this report.

Station Layout

Figure two represents a plan view of the met. site in 1966. Alterations in the layout were found necessary as the fuel sample measurements were influenced by some shade effects during the early morning and evening. In 1967 the site was rearranged (Fig. 3) to eliminate all possible chances of shading caused by the anemometer mast, guy lines and pole fence. This re-arrangement proved suitable in all respects.

Auxiliary Fire Weather Stations

Both auxiliary stations were established in clearings with a diameter at least four times the height of the surrounding trees. Auxiliary Station North (Fig. 1) was placed in a 400 ft. wide high voltage transmission line right-of-way. The amount and duration of precipitation recorded at this station was assumed representative of the dry pine experimental site one-quarter mile away. A two foot high enclosure was built around the recorder to protect the highly polished brass instrument from vandalism. The log enclosure did not protrude above the top of the instrument and as a result did not affect the catchment.

The other auxiliary climatological station was located approximately 800 feet from moderately dry white spruce-alpine fir stand and 3000 feet from the wet spruce site (Fig. 1 Auxiliary Station South) in a clearing formerly used as a loading site for timber. The precipitation records for this station were assumed representative for the amount and duration of rain over both white spruce-alpine fir stands. A syphon-type Casella rain gauge (Model 5372) equipped with weekly gears was placed at each of the stations, and serviced every Monday.

Experimental Sites

One 10-acre experimental site was selected on level ground within each of the four stands (Fig. 1). Stand descriptions, soil profiles, and vegetation characteristics are described in Appendix I. Each site was divided in half, one subsite serving for fuel moisture studies and the other for conducting two-minute test fires. Details of these experiments follow.

Fuel Moisture Study Site

The procedures followed and equipment used in the fuel moisture studies were identical at each subsite.

Within each 5-acre subsite, twenty 2 x 2 ft. sampling areas were marked with aluminum stakes and string in a grid pattern with rows twenty feet apart. A small amount of fine surface fuel was gathered within each of the twenty squares. The composite sample was placed into two 16 oz. air tight fuel tins. A collection was made each time test firing was undertaken, or once a day when no tests were attempted. The necessity of persistent supervision in this work cannot be over-emphasized. Materials collected from below the required uppermost surface fuels must be avoided. The sampling areas should be relocated as often as deemed necessary to ensure representative sampling of fine surface fuels.

Five trays were located under a variety of crown closures within 50 ft. of a weighing platform. Changes in the moisture content of the full organic layer was determined by weighing each tray once a day using a triple beam balance (Ohaus Scale Corp., Capacity = 2610g. accuracy = .05g.). To reduce wind error and protect the scales from rain, the wood platform was shielded with plastic sheeting.

In 1966, heavy fuel moisture content was measured by suspending and weighing a 6-10 ft. long log daily. A single beam balance (capacity = 300 lbs., accuracy = ½ lb.) was used on each of three sites, and a spring balance (capacity = 500 lb., accuracy = 5 lbs.) on the moist white spruce-alpine fir site. Both ends of the log were simultaneously held by a cable which, in turn, was attached to the balance. The log was supported approximately 2 inches above the ground by two small logs. When weighing the log, the supports were removed and the weighing procedure initiated.

On the wet spruce site a "come along" pulley was necessary to raise the spring balance and the log off the ground.

In 1967, three 10-15 lb. log rafts were placed under a variety of canopy closures at each site to eliminate the unrepresentative shading one large log experiences when suspended between two trees.

A Fuess hygrothermograph (Model No. 79r) was placed near the weighing platform under an average canopy closure. The instrument was equipped with a one revolution per week drum, and was operated 4-5 ft. above the litter in a plastic screen. In 1967, portable Stevenson screens were used in the pine sites only, but the spruce sites will be similarly equipped in 1968.

Test Fire Site

At each of the four test fire subsites, sixty-four 18-inch long aluminum stakes were driven into the ground in a grid pattern of 20 x 20 foot spacing. The stakes were subsequently numbered and a map of the outlay was enclosed in the aluminum folder containing the test fire recording forms for the site.

As a precaution against fire, a two-foot-wide fire guard was constructed around the two pine test fire subsites. In addition, a 45 gallon water tank and two Indian back-pack pumps, together with several pulaskies and shovels, were kept at each of the four sites. A fire pump and ample hose were retained at the main meteorological site for any possible fire escapes on the spruce sites.

Prior to the start of the field season the crew spent several days learning and practising the procedure of igniting, observing and rating two-minute test fires. The various columns of the Fire Hazard Studies Inflammability Test Form (McLeod 1948 p. 29, Figs. a and b) were discussed, and the rating guides memorized. For match fires or campfires that spread to the surrounding litter, the "Depth of Ash" column was changed to "Depth of Burn". For campfires that did not spread, the percentage of the initially assembled fuels consumed by the fire was noted under the column "Area of Burn".

A group of either 2 or 3 men were assigned to each test fire site. Each day the groups rotated, those who worked in the two pine stands one day worked in the spruce stands the next.

Before each test fire, a stake number was selected at random and checked off on the site sketch map. The stake was located and a back-pack pump was positioned near it. A sensitive cup anemometer (Casella make, old model with a totalizing dial) was placed 4 feet above the ground on a tripod and positioned at about 20 feet upwind from the stake. One observer estimated the percentage of the different fuel classes in a 4-9 sq. ft. area around the stake and the depth of fuel that felt dry to the touch of the fingers. Immediately prior to the ignition, air temperature and relative humidity were measured at 4 inches above the point of ignition with a Bendix psychrometer.

All test fires were lit 4 inches away from the apex of the vertical stake. With this rule of thumb, subjectivity as to the type of surface fuel to be ignited and the point of ignition was eliminated. A maximum of three matches were used per fire. The stop watch and the anemometer dial were started when the flame of the first match touched the fuel. If the fuel failed to ignite a second match was lit and the same fuel was touched again with the flame. If at the end of two minutes the fuels were burning with small flames on one or more fronts, and the fire was likely to go out by itself, only the anemometer dial was read and mentally recorded, and the fire was allowed to burn for another 3-4 minutes. This helped the observers determine the degree of fire vigour.

If all three matches failed to ignite the fuels, a nil report was made. Twigs and litter were then gathered in the vicinity of the test site and a 12-inch diameter, pyramid-shaped campfire was built by the assistant. The stop watch and anemometer were started when the flame of the first match touched the fuels. A total of five matches were allowed to ignite the campfire.

During the test fires flame heights were periodically measured with a metal tape. Unusual occurrences, such as gusts of wind, concentrations of fuels especially conducive to the spread of fire, abrupt changes in cloud cover or approaching storms, were noted under "Remarks".

Some of the campfires were allowed to burn as long as 45 minutes in the pine stands to obtain information on the rate of spread of the established surface fires.

When the selected area was completely burned a new gridwork of stakes was relocated on the subsite. During the 1966 field season the gridwork was moved once in the spruce stands and twice in the pine stands. On this basis the five-acre subplots were judged to be sufficiently large enough to accommodate two-minute test fires for five field seasons.

PROPOSED REVISIONS TO THE RAINFALL AND DRYING CODE TABLES

An accurate estimate of fire danger is indispensible to the intelligent control and use of fire. It is becoming more and more evident that fire danger estimates are needed at various times of the day.

The revision is directed towards devising a method of estimating fire danger anytime of the day. The first major step is to evaluate the separate influences of weather and characteristics of fuels on fire danger. Initially the effect of weather and of fuel characteristics on fire danger should be evaluated separately as a basis for evaluating the more complex inter-relationships between the 3 parameters. One of the proposed means of separation [1/] envisions the simultaneous estimation of a Fire Weather Index and a Burning Index. The Fire Weather Index would reveal the influence of weather on a fast drying fuel model and a slow drying fuel model while the Burning Index would relate some parameters of fire behaviour in various fuel types to the drying rates of the fuel model.

The Fire Weather Index is to be calculated from the fine fuel moisture. Two separate fine fuel moisture tables will be necessary for estimating the 6 A.M. and the 4 P.M. starting moisture contents. A Rainfall Correction Table will provide the means of computing the fine fuel moisture after the cessation of rain. These tables will replace the Rainfall and Drying Code tables (Anon. 1961) but the components of the new and old tables should be similar. The fine fuel moisture will not be coded but derived from actual moisture content measurements of the three-week-old western white pine (*Pinus monticola*, Douglas) mats (Péch 1967). These measurements will be correlated with temperature, relative humidity and wind speed as a function of the initial moisture content. In addition to sampling white pine mat moisture content, intensive sampling of the fine surface fuels in the dry pine site will be undertaken in 1968. Development of drying code tables based on natural fuel moisture contents is anticipated.

In 1966, five trays of white pine match splints, five B.C. indicator sticks and one set of white pine mats were exposed and weighed regularly at the main climatological station (Fig. 2) for ten weeks during July, August

---

[1/] S.J. Muraro 1966, Personal Communication.

and early September. The fuel moisture indicators were measured systematically every hour between 0100 hrs. P.S.T. and 2100 P.S.T. daily and at half hour intervals around sunrise and sunset. The match splint trays (12 x 12 x ½ inch) and white pine mats (10 x 17 x 1/8 inch) were placed 1 inch above standardized pine needle fuel beds (Péch 1967), and the Indicator Sticks 10 inches above the short cut grass, on wire brackets, with their long axis orientated true east-west. On Monday mornings one white pine mat was soaked for an hour and placed on the appropriate sector of the pine needle bed (Fig. 2). The mats already on the site were advanced and the raft entering the fourth week of weathering was replaced and ovendried (Péch 1967).

In 1967, three white pine mats were systematically weighed using the same technique of establishment and weighing schedule used in 1966. One splint tray containing 120 grams of match splints and two B.C. hazard sticks were exposed in a manner similar to those established the previous year. The locations of these samples are indicated in Figure 3.

Fuel samples were weighed with an Ohaus triple beam balance (capacity = 2610 g., accuracy = .05 g., magnetic damping type) in a wooden hut adjacent to the seeded area (Fig. 2). No difficulties were encountered with either the western white pine sample or the B.C. Indicator Sticks but experience with the match splints confirmed earlier contentions (Péch 1967) that additional moisture is collected by the trays, that the splints align themselves in groups in certain directions following rain thereby displaying unique drying curves, and that at times some splints are blown out of the tray and lost, thus changing the ovendry weight of the tray's contents. Among the five trays set out the first year, two contained weathered match splints that had been exposed for two previous summers and twice ovendried.

These splints showed no further sign of weathering, and the moisture regimes of the two trays of splints were identical throughout the ten-week period. The unweathered and untreated match splints in the remaining three trays showed visible signs of weathering, and displayed differences in wetting and drying characteristics even after eight weeks of exposure.

PRELIMINARY RESULTS AND OBSERVATIONS

The summer of 1966 north of Prince George was cooler and wetter than the 30-year average (Table 1). From the beginning of the field season (June 20th) it rained frequently at all four experimental areas. The longest rainless period, following 1.77 inches of rain in six days, lasted ten days [(August 15-25) Table 1B].

In contrast, the 1967 field season was one of the driest on record. The summer started with a virtually rainless period of 26 days. Only scattered rains, normally less than .3 inches, fell till the end of August. During the first week of September 1.2 inches of rain was recorded. The rain caused slower and less vigorous burns for the remainder of the season. Figures 4 and 5 show the rainfall distribution for 1966 and 1967 respectively. Further weather summaries are given in Tables 1A and 1B.

In the first year, 424 match fires and campfires were attempted. The frequent rains and long project establishment period limited test firing that year. In 1967, fires were attempted in the four stands on 1150 occasions. Tables 2, 3, 4 and 5 give the summaries of the test fire data for B.C. 609 over the past two field seasons.

Throughout most of the 1966 and 1967 field season the estimated danger index in the two spruce stands was less than four. This may have been caused by the high fuel moisture content (especially in 1966), by the compactness of the litter preventing ignition and hindering combustion, or by a combination of both. Abundant minor vegetation also shaded the litter from direct solar radiation and reduced the ventilation above the litter.

RECOMMENDATIONS

Based on the knowledge gained during 1966 and 1967, it may be concluded that matches are unsuitable as a fire brand for ignition in the spruce stands. Experience with test fires suggests that nearly all future work in these stands should be confined to lighting campfires and observing their behaviour for at least 15 minutes. The fuels gathered for these campfires should contain about 40% litter and 60% dry twigs and lichen collected from the nearby trees. Such a proportion of natural fuels ensures the ignition of the campfire and moderates the behaviour of the fire according to moisture content of the litter. Although these refinements were carried out last year, further adjustments in the test firing pattern are required. In the wet spruce stand, ignition should be limited to those areas in close proximity to standing timber. A ten foot radius around any given tree stem would be considered maximum. Reduced variability in herbaceous cover and degree of compaction should give a more consistent fire danger rating on any given day. When instituted, the research team will not be faced with attempting to set fires in the more open canopies where the annual herbaceous cover is often excessive. These exuberant shrubs and herbs do not represent a hazardous medium except in the early spring or late fall and, as a result, do not give a clear indication of summer buildup patterns.

A new campfire behavior rating should be evolved for estimating the index between nil (0) and the mid-point of high (10) in stands with very compact and often moist litter. Emphasis in the classification of fire behavior could be placed on rate of spread, vigour and smouldering outside the campfire. Should the litter ignite using only one to three matches, and the fire continue to spread vigorously at the end of two minutes, the index would likely be close to the top of the high (11-12), or be in the extreme class (13-16).

The data in Tables 2, 3, 4 and 5 are averages that represent a wide range of fuel moisture contents at various times of the day. Quantitative deductions are not yet warranted as the research staff has not obtained enough actual fine fuel moisture data. When the revision of the National Danger System is complete, the original test fire records will be classified according to the fine fuel moisture content class (Drying Code) and the current Drought Index. This stratified test fire information will form the basis of Burning Index Tables for white spruce-alpine fir and lodgepole pine stands in the Prince George Forest District.

REFERENCES

Anon. 1961. Forest fire danger tables -- British Columbia, Cariboo; British Columbia, Coast. Canada Dept. For., For. Res. Branch, Ottawa.

Day, R.J. 1965. A portable standard instrument shelter. Canada Dept. For. Mimeo. 65-A-8.

Farstad, L. and C.C. Kelly. 1946. Soil Survey of the Prince George Area of British Columbia. B.C. Dept. Agriculture, Soil Survey No. 2.

__________ and D.G. Laird. 1954. Soil Survey of the Quesnel, Nechaco, Francois Lake and Bulkley-Terrace Areas in the Central Interior of British Columbia. B.C. Dept. Agriculture, Soil Survey No. 4.

Illingworth, K. and J.W.C. Arlidge. 1960. Interim Report on Some Forest Site Types in Lodgepole Pine and Spruce-Alpine Fir Stands. B.C.F.S. Res. Notes No. 35.

Macleod, J.C. 1948. The effect of night weather on forest fire danger. Canada Dept. Mines Resources, Dom. For. Serv., For. Fire Res. Note No. 14, pp.29.

Muraro, S.J. 1962. Preliminary report on a pilot model of a versalite instrument shelter. Canada Dept. For., Mimeo B.C. 1962 Febr.

Paul, P.M. 1964. Field practices in forest fire danger rating. Canada Dept. For., Mimeo.64-M-4.

Péch, Gy. 1966a Limitations of a plastic hygrothermograph shelter. Canada Dept. For., Internal Report BC-3, pp. 4.

__________ 1966b. Burning Index Tables for White Spruce-Alpine Fir and Lodgepole Pine Forest Covertypes in the Prince George Forest District. Project Plan BC-609. Mimeo., pp. 11.

Péch, Gy. 1967. The association between atmospheric humidity and fuel moisture. Special paper prepared for the Congress of the Internat. Union of For. Res. Organizations, Munich, Germany, Sept. 1967.

Rowe, J.S. 1959. Forest Regions of Canada. Canada Dept. Northern Aff's. Nat'l. Res., Bull. 123.

APPENDIX I

CHARACTERISTICS OF STANDS AND SOILS AT THE EXPERIMENTAL SITES

Vegetation Cover Type

The Prince George forest cover type lies within the M-4 (Montane Transition) section of the Montane Forest Region of Canada (Rowe 1959). At the test sites, a transition to the subalpine region is apparent, as there is considerable spruce (*Picea glauca*, *Picea Engelmanni* and their intergrades) and alpine fir (*Abies lasiocarpa*). Blue Douglas fir (*Pseudotsuga menziesii* var. *glauca*) is scattered throughout the region. In the past, parts of the widely distributed spruce-fir forests were killed by fires, resulting in an expansion of associations, one of which is lodgepole pine (*Pinus contorta* var. *latifolia*).

Topography and Soils

The north-central plateau of B.C. consists of large, rolling uplands separated by broad valleys. Elevations vary from 1500 to 2500 feet above sea level in the valleys and 3000 to 4000 feet above sea level in the uplands. All the four experimental areas were located at an elevation of approximately 2500 feet above mean sea level.

As a result of glaciation, with subsequent weathering and erosion, the landforms are varied. A drumlinized till plain predominates, but alluvial terraces and plains are also found in the river valleys (Farstad and Kelly 1946). The experimental areas are located on both geological formations.

Site and Stand Description

(a) The Dry Lodgepole Pine Stand

The ten-acre plot is located approximately two miles north of the Main Climatological Station.

The soil type for this stand is Orthic Grey Wooded with some indication of podzolization. The profile forms one of the dominant upland soil groups of the interior plateau. The soil generally has inferior physical properties and is often low in natural fertility (Farstad and Liard 1954). Baker [1/] examined and obtained the following measurements from a representative soil profile on the dry pine site:

Layer	Depth	Notes
A1	0 - 1/2"	
Af	1/2 - 1"	
Ah	1 - 1 1/4"	well decomposed
Ae	1 1/4 - 2 3/4"	leach, grey, fine sand
A-B	2 3/4 - 3 3/4"	transition zone, loamy sand
Bt	3 3/4 - 11"	loamy sand
C	11"	coarse gravel

Oven dry weights, expressed in pounds per square foot, for full organic layer samples collected from this stand and the other three experimental sites, are given in Table 6.

In the cool, moist regimes of the Northern Montane transition zones, changes in vegetation association are gradual. The dry pine site most closely resembles the Arctostaphylos - Lichen Type (Bearberry-Reindeer Moss) (Illingworth and Arlidge 1960). This type is associated with dry sandy soils and is indicative of low site productivity with a Site Index of 40-55. The shrub layer is generally open with only scattered regeneration of pine. The herb layer is characterized by an extensive cover of Arctostaphylos uva-ursi especially in the gravelly areas. The mosses,

---

[1/] Dr. J. Baker, Research Scientist, Forest Research Laboratory, Canada Department of Forestry and Rural Development, Victoria, B.C.

Calliergonella schreberi and Dicranum spp., are abundant. The lichen layer is moderately developed and is comprised of several species of Cladonia.

A ten percent cruise of the experimental area produced the following results:

Species	Diameter Class (in.)	No. of Trees/Acre	Volume (cu. ft./ac.)
Lodgepole pine	4	308	739.2
	6	283	1415.0
	8	76	781.8
	10	8	103.2
		Total	3039.2 cu. ft./acre

The mean tree height is 54 ft. and the stand is 120 years old. The site is moderately dense and uniform.

(b) The Moderately Wet (Fresh) Lodgepole Pine Stand

The ten-acre plot in a moderately wet pine stand is established less than a half mile from the Main Climatological Station.

The soil group of this site appears to belong to the Orthic Grey Wooded type. The soil constituents are coarser and much less sorted than those under the dry pine stand.

Layers	Depth	Notes
Al	0 - 1 1/2"	
Af Ah	1 1/2 - 2"	Hardly discernable
Ae	2 - 4"	Grey sand, clay content is slightly higher than the alluvial layer in the dry pine stand.
C	4" +	Unsorted glacial deposit without stratification.

The wet pine site most closely resembles the Vaccinium scoparium site type (Blueberry) (Illingworth and Arlidge 1960). The shrub layer is light to moderate mostly with Vaccinium scoparium and Vaccinium conadense. Calliergonella schreberi and Dicranum mosses are general with Cladonia spp. more scattered.

The site is of medium productivity but it has several understocked areas. The overstory is composed of 65 foot, 80-year-old lodgepole pine with some 75 foot, 140-year-old Douglas fir. The gross volume for lodgepole pine and Douglas fir is 1453 cu. ft./ac. and 385 cu. ft./ac. respectively. White spruce and alpine fir have a limited distribution, accounting for only a total of 80 cu. ft./ac. Appreciable numbers of young lodgepole pine, trembling aspen and, more rarely, white spruce and alpine fir are growing in the understocked areas.

(c) The Moderately Dry White Spruce-Alpine Fir Stand

The experimental area is located a mile south of the Main Climatological Station.

A well-developed podzolic profile is present on this site. The Orthic Grey Brown Podzol has the following profile:

Layers	Depth	Notes
A1	0 - 1/2"	
Af	1/2" - 1 1/2"	
Ah	1 1/2" - 2"	Charcoal noted
Ae	2" - 10"	
Bf	10" - 14"	Iron deposition, loamy sand
B_2	14" +	Mottling near the 30" depth also gley

The ground vegetation has a great variety of species. The dry spruce site most closely resembles the Aralia-Dryopteris site (Sarsaparilla-

Oakfern) (Illingworth and Arlidge 1960). Dryopteris is the characteristic plant of this site. When the understory is moderate to light in density Vaccinium membranaceum, Vaccinium ovalifolium, Lonicera envolucrata, Viburnum pauciflorum, Rubus parviflorus, Cornus stolonifera, Alnus tenuifolia, Sorbus sitchensis, and Oplopanax horridum are found. When the understory of trees is moderate to heavy, the following species are present: Dryopteris austriaca, Aralia nudicaulis, Smilacina racemosa, Tiarella unifoliata, Cornus canadensis, Rubus pedatus, Striptopus roseus, Lycopodium annotinum, and Veratrum eschocholtzii. The mosses are patchy, and include Ptilium crista-castrensis, Calliergonella schreberi and Mnium spp.

On the dry spruce site the overstory varies from dense to moderate with alpine fir being the most numerous. Spruce and some scattered birch and Douglas fir form the remainder of the canopy. For white spruce the co-dominant tree height was 75 ft. at 175 years of age, with a diameter of 10 inches. A dominant spruce, 185 years old, 23 inches in diameter, was 114 ft. tall. Alpine fir averaged 70 ft. tall and 180 years of age. The basal area volume for white spruce and alpine fir was 2870 cu. ft./ac. and 680 cu. ft./ac. respectively.

(d) The Moist White Spruce-Alpine Fir Stand

The moist spruce site is located approximately two miles south of the Main Climatological Station.

The soils of this site, especially in the low lying areas, are intrazonal in character. Poor drainage has prevented maximum development of the profile. The moist spruce soil type, as a result, belongs to the gleysolic order. The gley horizon is sticky, compact, and structureless. No noticeable illuviation or elluviation is seen indicating a stable water table level.

Layers	Depth	Notes
Al	0 - 1/4"	
Af	Trace	
Ah	1/4 - 2 1/4"	
B	2 1/4 - 30"	Gley horizon
C	30" +	

As to lesser vegetation, the moist spruce site most closely resembles the Oplopanax site type (Illingworth and Arlidge 1960). An extensive cover of Oplopanax horridus (Devil's Club) and large, widely spaced trees are characteristic in this site. Other shrubs found are Rubus parviflorus, Vaccinium ovalifolium, Vaccinium membranaceum, Alnus sinuata and Cornus stolonifera. The herb layer contains a number of plant species. Dryopteris austriaca, Streptopus omplexifolius, Cornus canadensis, Rubus pedatus, Aralia nudicaulis, Smilacina racemosa and Veratrum eschocholtzii are the most prolific. The mosses are very patchy with the Brachythecium and Mnium spp. present. Ptilium crista-castrensis is conspicuous by its dense cover on old, rotting wood.

Widely-spaced, large spruce and alpine fir trees form the tree canopy. For white spruce the co-dominant tree height was 94 ft. for a 180-year-old, 18-inch diameter tree. Alpine fir growth averaged 70 ft. in the 8-inch diameter class. The 10% cruise indicated a volume of 3875 cu. ft./ac. for the white spruce and 955 cu. ft./ac. for the alpine fir.

FIGURE 1

LOCATION OF THE FOUR EXPERIMENTAL SITES, THE MAIN AND THE TWO AUXILIARY METEOROLOGICAL STATIONS.

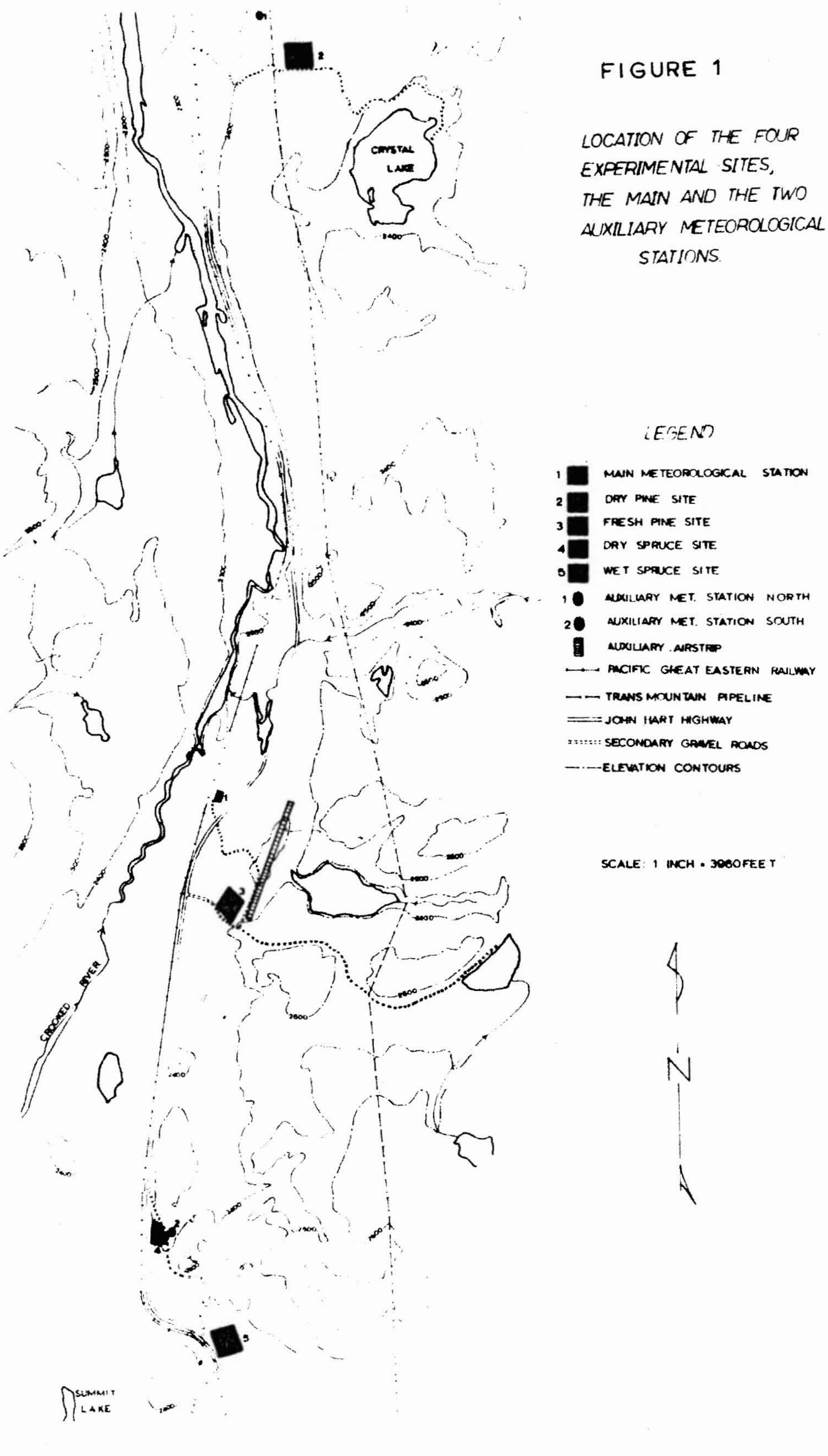
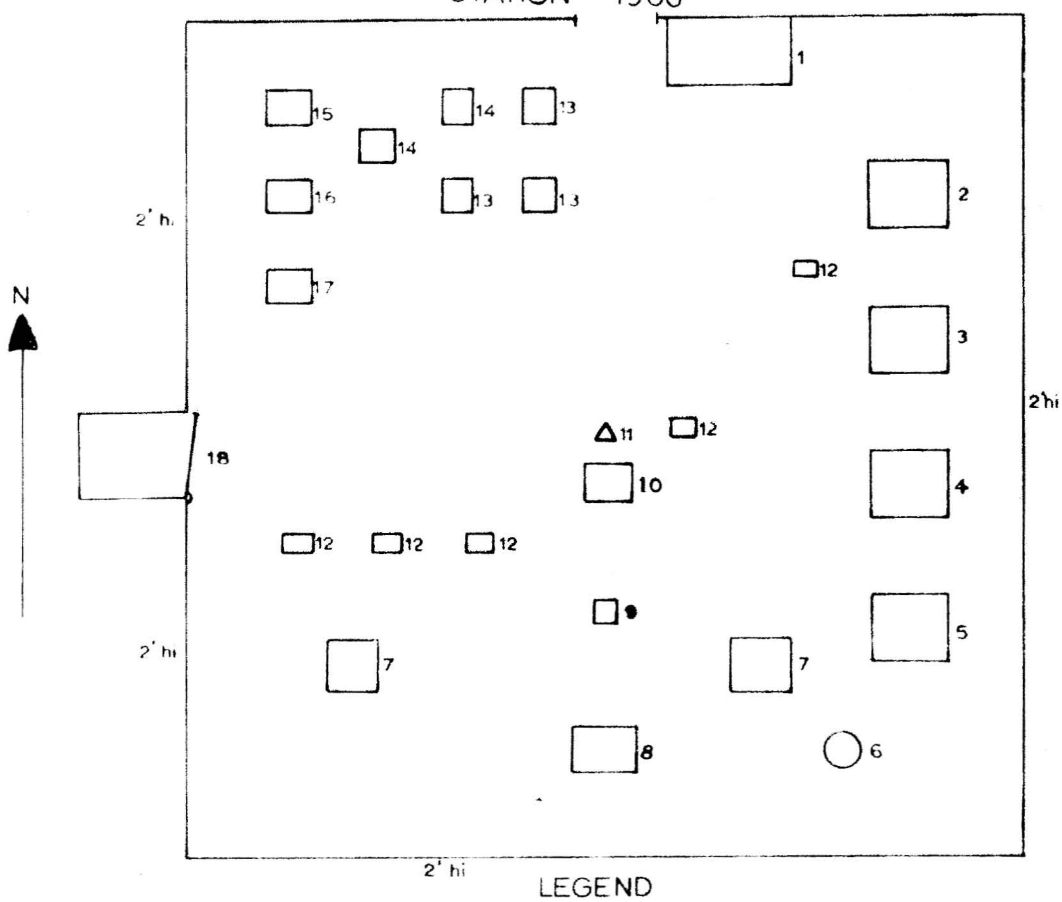


FIGURE 2

A PLAN VIEW OF THE MAIN METEOROLOGICAL STATION 1966

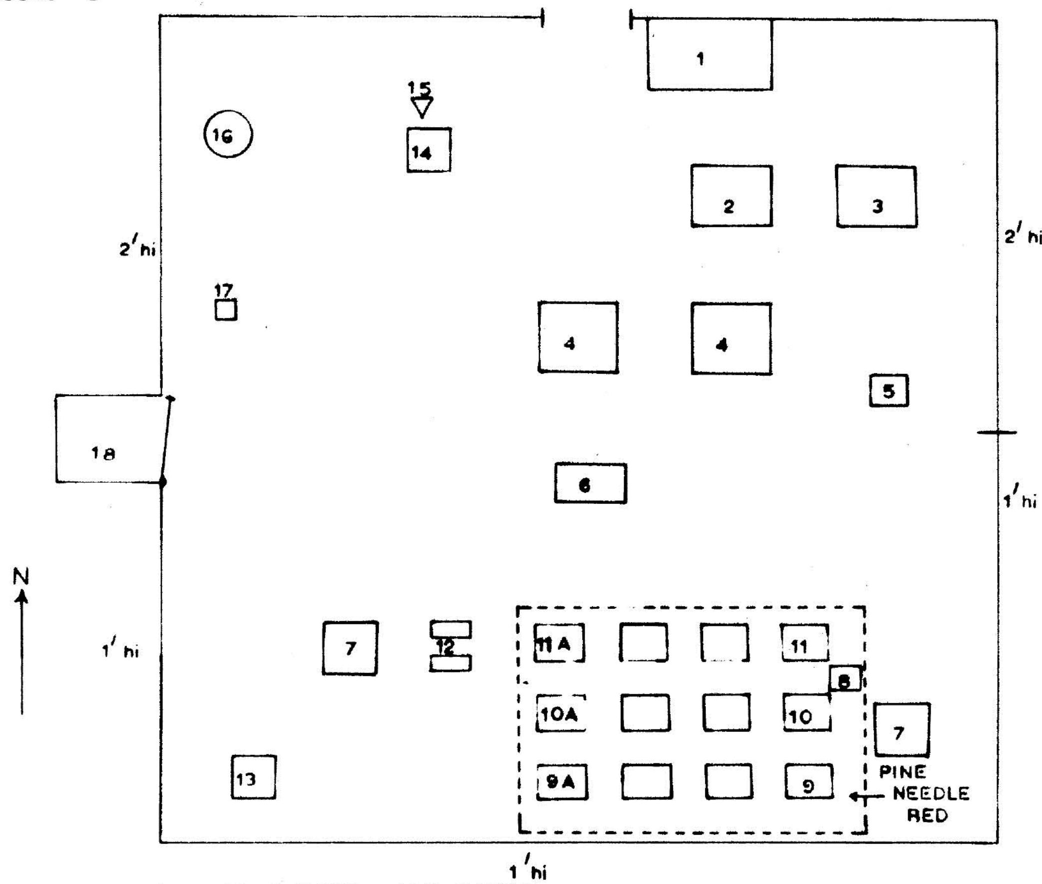


LEGEND

1 - SHELTER FOR INSTRUMENT CHARTS, INK AND FUEL MOISTURE SHEETS
2 - STEVENSON SCREEN - HYGROTHERMOGRAPH
3 - PLASTIC SCREEN - HYGROTHERMOGRAPH
4 - STEVENSON SCREEN - MAX. AND MIN. THERMOMETERS
5 - PLASTIC SCREEN - MAX AND MIN. THERMOMETERS
6 - RECORDING RAIN GAUGE
7 - POTVIN DEW GAUGES
8 - ACTINOGRAPH
9 - JORDAN SUNSHINE RECORDER
10 - RECORDING ANEMOMETER
11 - ANEMOMETER MAST
12 - B.C. HAZARD STICKS
13 - NEW MATCH SPLINTS
14 - WEATHERED MATCH SPLINTS
15 - ONE WEEK WHITE PINE MAT
16 - TWO WEEK WHITE PINE MAT
17 - THREE WEEK WHITE PINE MAT
18 - WEIGHING SHELTER FOR FUEL MOISTURE DETERMINATION

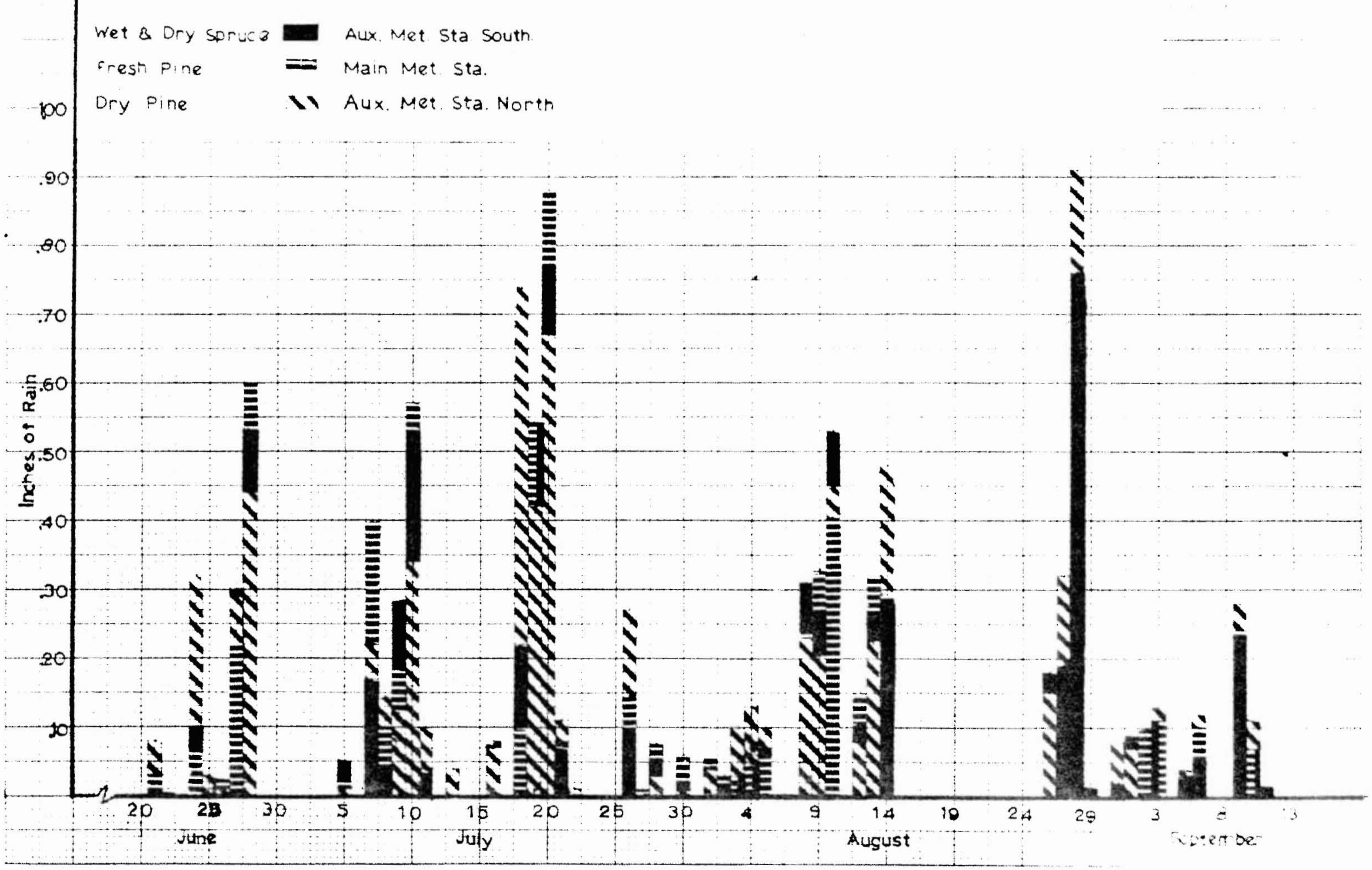
A PLAN VIEW OF THE MAIN METEOROLOGICAL STATION 1967

FIGURE 3



1	STORAGE SHELTER (INK, CHARTS)		
2	STEVENSON SCREEN - ASPIRATED PSYCHROMETER		
3	STEVENSON SCREEN - MAX.& MIN. THERMOMETERS		
4	STEVENSON SCREEN - HYGROTHERMOGRAPHS		
5	JORDAN SUNSHINE RECORDER		
6	ACTINOGRAPH		
7	POTVIN DEW GAUGES		
8	MATCH SPLINTS		
9	ONE WEEK WHITE PINE MATS	9A	DOUBLE WHITE PINE MAT
10	TWO WEEK WHITE PINE MATS	10A	DOUBLE WHITE PINE MAT
11	THREE WEEK WHITE PINE MATS	11 A	DOUBLE WHITE PINE MAT
12	B.C. HAZARD STICKS		
13	HILTNER DEW RECORDER		
14	RECORDING ANEMOMETER		
15	ANEMOMETER MAST		
16	RECORDING RAIN GAUGE		
17	STANDARD RAIN GAUGE		
18	WEIGHING SHELTER FOR FUEL MOISTURE DETERMINATION		

FIGURE 4 1966 RAINFALL DISTRIBUTION — PROJECT 609



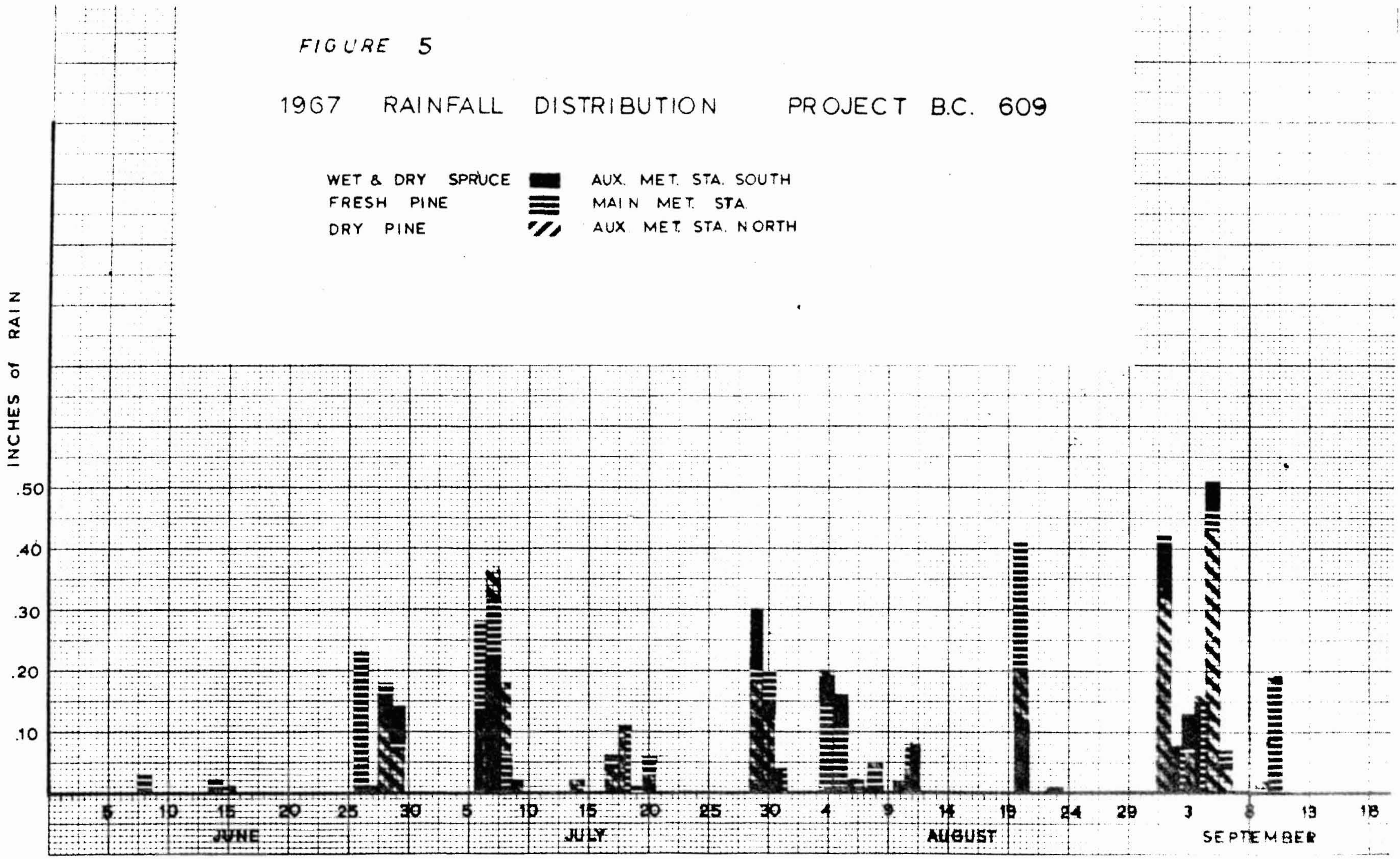


FIGURE 5
1967 RAINFALL DISTRIBUTION PROJECT B.C. 609
WET & DRY SPRUCE
AUX. MET. STA. SOUTH
FRESH PINE
MAIN MET. STA.
DRY PINE
AUX. MET. STA. NORTH
INCHES of RAIN
.50
.40
.30
.20
.10
5 10 15 20 25 30 5 10 15 20 25 30 4 9 14 19 24 29 3 8 13 18
JUNE
JULY
AUGUST
SEPTEMBER

TABLE 1A

Relative Humidity and Air Temperature on Rainless Days between 1300 and 1600 hours, four inches above the litter, during the 1966, 1967 Field Seasons

	1966 Relative Humidity		1967 Relative Humidity		1966 Temperature		1967 Temperature	
	MEAN	MIN.	MEAN	MIN.	MEAN	MAX.	MEAN	MAX.
Dry Pine Site	33%	26% Aug. 21 & July 13	31%	17% Aug. 18	76°F	87°F July 13	77°F	92°F Aug. 31
Wet Pine Site	39	18 Aug. 23	36	17 Aug. 17	77	85 July 15	76	91 Aug. 17
Dry Spruce Site	50	38 July 4	39	25 Aug. 18	72	78.5 July 14	76	83 Aug. 29
Wet Spruce Site	58	48 July 6	50	28 July 25	71	76 July 14	73	82 Aug. 31

TABLE 1B

A Comparison of the 1966, 1967 Field Season Precipitation Records with the 30 Year Average for the Prince George Airport

	June	July	August	September	Total for Full Months of July-August
30 year average	2.44	2.53	2.56	2.19	5.09
1966 Field Records	.95* From June 20	2.96	3.15	.58* To Sept. 12	6.11
1967 Field Records	.56	1.36	.81	1.46* To Sept. 19	2.17

Table 2

Summary of Test Fire Results in the Dry Lodgepole Pine Stand

For the 1966–1967 Field Seasons.

	1966	1967	1966		1967		1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
Fire Brand 1/	M	M	M	M	M	M	M	M	M	M	M	M	CF	CF	CF	CF
Estimated Index (16 point scale)	0	0	1-3	4	1-3	4	5-8	5-8	9-12	9-12	13-16	13-16	0	0	1-4	1-4
No. of Fires lit or attempted	32	54	3	11	62	9	73	132	8	51	1	3	7	5	35	92
Average Vigour (5 point scale)	0	0	1.0	1.1	1.1	1.0	2.23	2.47	3.5	3.96	5.0	5.0	-	-	-	-
Average Smouldering (5 point scale)	0	.3	1.0	1.0	1.1	1.1	1.96	2.41	2.5	3.27	5.0	4.0	0	0	2.0	1.51
Average Area Burnt (sq. ft.)	0	0	Spot	.03	Spot	.05	.31	.40	1.31	1.88	1.4	2.8	0	0	5.23	4.36
Maximum Area Burnt (sq. ft.)	0	0	Spot	.05(4)	Spot	.05	1.0(8)	1.0(8)	20(10)	6.1(12)	1.4(13)	3.8(13)	0	0	60.0(4)	53.0(4)
Average linear Rate of Spread (in./min.)	-	0	-	-	-	3.34	-	2.29	-	4.37	-	5.13	-	0	-	1.25
Maximum linear Rate of Spread (in./min.) (Average)	-	0	-	-	-	1.68	-	3.67	-	6.48	-	8.97	-	0	-	2.25
Perimeter Rate of Spread (in./min.)	0	0	-	1.00	-	3.58	3.0	3.53	7.53	7.97	7.10	9.81	0	0	1.59	2.38

1/ M = 1-3 matches. C.F. = 12 x 12 x 5/8 inch campfire lit with 1-5 matches.

Table 3 Summary of Test Fire Results in the Moderately <u>Wet</u> Lodgepole Pine Stand

For the 1966-1967 Field Seasons.

	1966	1967	1966		1967		1966	1967	1966	1967	1966	1967	1966	1967	1966	1967
Fire Brand 1/	M	M	M	M	M	M	M	M	M	M	M	M	CF	CF	CF	CF
Estimated Index (16 point scale)	0	0	1-3	4	1-3	4	5-8	5-8	9-12	9-12	13-16	13-16	0	0	1-4	1-4
No. of Fires lit or attempted	50	51	6	3	72	14	39	104	2	29	-	3	4	4	51	89
Average Vigour (5 point scale)	0	0	.70	1.0	86	1.1	2.0	2.27	4.0	3.7	-	5.0	-	-	-	-
Average Smouldering (5 point scale)	0	0	.70	.30	1.3	1.8	2.2	2.48	4.0	3.4	-	4.3	0	0	2.05	2.3
Average Area Burnt (sq. ft.)	0	0	Spot	.04	Spot	.035	.25	.32	1.05	2.06	-	6.0	0	0	1.82	4.13
Maximum Area Burnt (sq. ft.)	0	0	Spot	.05	Spot	.05(4)	1.0(8)	1.00(8)	1.10(12)	5.40(12)	-	8.0(14)	0	0	22.5(4)	32.0(4)
Average linear Rate of Spread (in./min.)	-	0	-	-	-	.54	-	2.15	-	5.10	-	12.0	-	0	-	1.18
Maximum linear Rate of Spread (in./min.)	-	0	-	-	-	.79	-	3.30	-	6.88	-	18.24	-	0	-	2.40
Perimeter Rate of Spread (in./min.)	0	0	-	1.10	-	1.09	2.86	3.18	6.14	8.36	-	14.14	0	0	1.70	2.70

1/ M = 1-3 matches. C.F. = 12 x 12 x 5/8 in. campfires lit with 1-5 matches.

Table 4 **Summary of Test Fire Results in the Moderately Dry White Spruce - Alpine Fir Stands**

For the 1966-1967 Field Seasons

	1966	1967	1966		1967		1966	1967	1966	1967	1966	1967
Fire Brand 1/	M	M	M	M	M	M	M	M	CF	CF	CF	CF
Estimated Index (16 point scale)	0	0	1-3	4	1-3	4	5-8	5-8	0	0	1-4	1-4
No. of **Fires** lit or attempted	27	80	2	-	23	-	-	3	13	9	16	93
Average Vigour (5 point scale)	0	0	50	-	.87	-	-	1.3	-	-	-	-
Average Smouldering (5 point scale)	0	0	1.0	-	1.22	-	-	2.0	0	0	1.4	2.3
Average Area Burnt (sq. ft.)	0	0	.01	-	Spot	-	-	.10(5)	0	0	.60	2.02
Maximum Area Burnt (sq. ft.)	0	0	.01	-	Spot	-	-	.10	0	0	3.0	21.0
Average linear Rate of Spread (in./min.)	0	0	-	-	-	-	-	-	0	0	-	.90
Maximum linear Rate of Spread (in./min.)	0	0	-	-	-	-	-	-	0	0	-	2.58
Perimeter Rate of Spread (in./min.)	0	0	-	-	-	-	-	1.90	0	0	1.08	1.96

1/ M = 1-3 matches. C.F. = 12 x 12 x 5/8 inch campfire lit with 1-5 matches.

Table 5 Summary of Test Fire Results in the Wet Spruce Alpine Fir Stands

For the 1966-1967 Field Seasons

Fire Brand 1/	1966 M	1967 M	1966 M	M	1967 M	M	1966 M	1967 M	1966 CF	1967 CF	1966 CF	1967 CF
Estimated Index	0	0	1-3	4	1-3	4	5-8	5-8	0	0	1-4	1-4
No. of Fires lit or attempted	19	71	-	-	6	2	-	2	17	4	5	83
Average Vigour	-	-	-	-	.67	1.0	-	2.0	-	-	-	-
Average Smouldering	-	-	-	-	1.33	2.0	-	3.0	-	-	2.6	2.0
Average Area Burnt	-	-	-	-	Spot	.05	-	.08	-	-	1.18	1.3
Maximum Area Burnt	-	Spot	-	-	Spot	.05	-	.10	-	Spot	2.0(2)	8.2(4)
Average linear Rate of Spread	-	-	-	-	-	.36	-	-	-	-	-	.96
Maximum linear Rate of Spread	-	-	-	-	-	1.20	-	-	-	-	-	1.92
Perimeter Rate of Spread	-	-	-	-	-	1.34	-	1.62	-	-	1.55	2.00

1/ M = 1-3 matches. C.F. = 12 x 12 x 5/8 inch campfire lit with 1-5 matches.

Table 6 **Oven Dry Weights in pounds per square foot for Full Organic Samples taken from the Four Experimental Sites in B. C. 609**

Site	1 A 1/	1 B 2/	2 A 1/	2 B 2/	3 A 1/	3 B 2/	4 A 1/	4 B 2/	5 A 1/	5 B 2/	6 A 1/	6 B 2/	Average
Dry Pine	.8	-	.4	-	.4	-	.4	-	.5	-	.4	-	.5 lbs/ ft ^{2}
Wet Pine	.6	-	.5	-	1.2	-	2.9	-	2.7	-	2.2	-	1.7 lbs/ ft ^{2}
Dry Spruce	.96	.44	.90	.21	.84	.22	2.39	.17	.94	.14	1.1	.04	1.39 lbs/ ft ^{2}
Total	1.4		1.11		1.06		2.56		1.08		1.14		
Wet Spruce	2.12	.20	2.8	.09	1.6	.01	3.1	.18	3.9	.60	2.34	-	2.82 lbs/ ft ^{2}
Total	2.32		2.89		1.61		3.28		4.5		2.34		

1/ Full Organic Layer without large roots

2/ Large Roots