FIELD PRACTICES

IN

FOREST FIRE DANGER RATING

by

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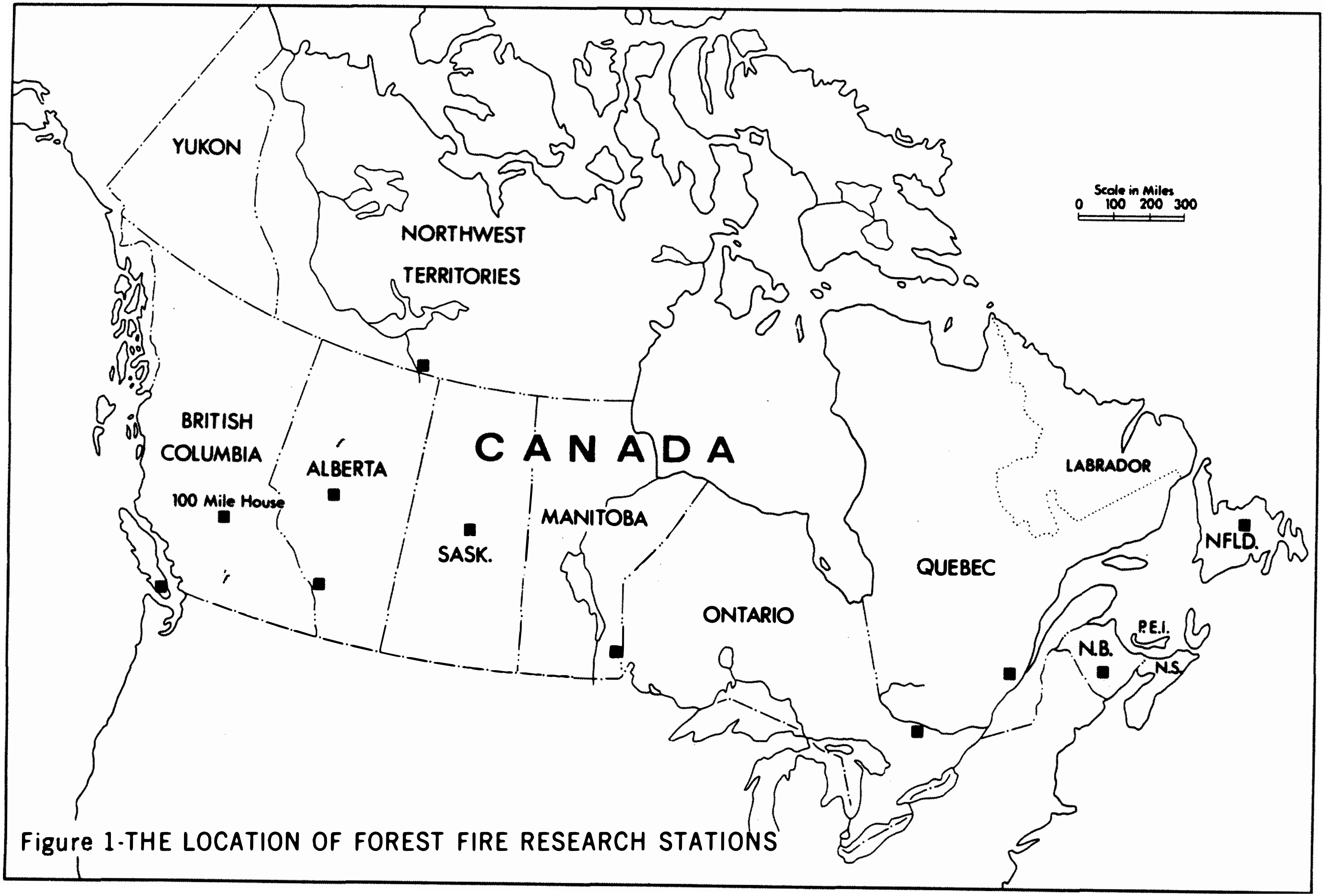

Figure 1-THE LOCATION OF FOREST FIRE RESEARCH STATIONS

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ABSTRACT

Developments in the Canadian fire danger rating system are traced chronologically from their beginnings in the late 1920's to the publishing, in 1967, of a set of Forest Fire Danger Tables for forecasting purposes in Quebec. This paper is, however, mainly concerned with describing the factors required to obtain the basic field data needed for the danger rating system. Due to an extensive revision of the system, the first fruits of which can be seen with the publishing, in provisional form in 1969, of a new Canadian Fire Weather Index, the expression used throughout this paper, *Forest Fire Danger Tables*, is certain to become obsolete in a few years. But despite this fact, the basis for this new system, as with the earlier Danger Tables, is still the basic field data gathered at forest fire research stations throughout Canada. Examples in the appendices and references in the text are to one such station, *100 Mile House, British Columbia*, to more clearly illustrate the field practices.

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INTRODUCTION

Forest fire danger ratings provide a numerical expression of the possibility of fires occurring, and the probable rate of spread and difficulty of control of those that do. A reliable and consistent method of evaluating fire danger is needed in all four phases into which fire control is normally divided -- prevention, detection, presuppression and suppression. It is needed as much by the foreman on a fireline as by the fire control supervisor in the office and, faced with fighting fires with today's costly and complex tools, it is inadvisable to leave decisions solely to personal judgment. "Experience and general observation alone are not sufficiently accurate, specific, consistent, and transferable from one person to another" and, moreover, "important changes in current fire danger are often not detectable through general observation" (Davis, 1959). But whether the decision has to do with determining the state of preparedness that must be maintained, with regulating slash burning, with closing down industrial operations, or with revoking camp-fire and travel permits[2], a reliable and unbiased system of rating fire danger is required.

The influence of weather upon forest fire behaviour was first considered before World War I (Beals, 1914) although serious attempts to measure fire danger were not undertaken until the mid 1920's. Most of the early investigations were under the supervision of H. T. Gisborne in the United States and J. G. Wright in Canada. Progressing independently, it is scarcely surprising that, while there were striking similarities in the two approaches to the problem, there were also significant differences.

Wright's investigation of the relationship between weather and fire behaviour was initiated at the Petawawa Forest Experiment Station, near Chalk River, Ontario, in 1929. His study resulted in the publication of a set of Forest Fire Hazard Tables[3] for the mixed red and white pine types of eastern Ontario and western Quebec (Wright, 1933). To allow for the effects of differences in fuels, topography, and climate, and with close cooperation from provincial

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[2] *For the many ways in which fire danger ratings can be used, see pages 22 - 24 in the Forest Fire Danger Manual (Williams, 1963).*

[3] *The name was changed to Forest Fire Danger Tables in 1946 and it is frequently shortened to Danger Tables. A distinction is made in this paper between Tables spelled with a capital "T" which refers to a publication containing a series of tables (e.g. New Brunswick Danger Tables) and with a small "t" referring to an individual table within the booklet (e.g. grass hazard table).*

forestry organizations, similar studies were started in other areas. Work was concentrated in eastern Quebec and New Brunswick before World War II and in Newfoundland and western Canada in the post-war years. The early Tables embraced large areas and provided for many different forest types but, from 1956 to 1962 emphasis was on preparing separate Tables for individual provinces, or regions within a province.

FIELD PROCEDURES

To obtain the field data needed to prepare Danger Tables for the different regions of Canada, 11 *forest fire research stations* have been established for periods up to five fire seasons (Figure 1). Certain innovations in field practice gradually evolved over the years and variations due to local influences have always been present but, whether the work was done in Newfoundland or on Vancouver Island, the basic procedures did not differ greatly. Fire behaviour is largely dependent on fuel moisture content and it, in turn, is influenced by past and present weather conditions. Since fire danger measurement is essentially a determination of the correlations among the variables of weather, fuel moisture, and fire behaviour, most of the field work falls logically into one of three broad categories.

(1) Acquiring Meteorological Data
(2) Measuring Fuel Moisture Content
(3) Observing Test Fire Behaviour.

While treated as separate and distinct entities in this paper, all three studies are carried on concurrently at a research station and all three are closely related.

Field practices are easier to grasp if frequent reference is made to the normal procedures at a typical field station and, therefore, a field station familiar to the author was selected for illustrative purposes. It was operated for three seasons near 100 Mile House, British Columbia. (See Appendices II, III, and IV.)

ESTABLISHING THE FIELD STATION

Provincial forestry officials usually propose the general area for a research station because of their intimate knowledge of the main forest types within their borders. For instance, a location on the Cariboo Plateau was recommended by Forest Service personnel for the Interior British Columbia Station. This plateau lies in the Central Douglas Fir Section of the Montane Forest Region (Rowe, 1959) and occupies a large part of the interior uplands of that province. The main tree species is blue Douglas fir[4] although lodgepole pine and aspen are frequently encountered. Rich pine grass is present under nearly all forest stands and in large meadows common throughout the rolling, hilly uplands.

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[4] *For the list of common and scientific names of plant species used in the paper, see Appendix I.*

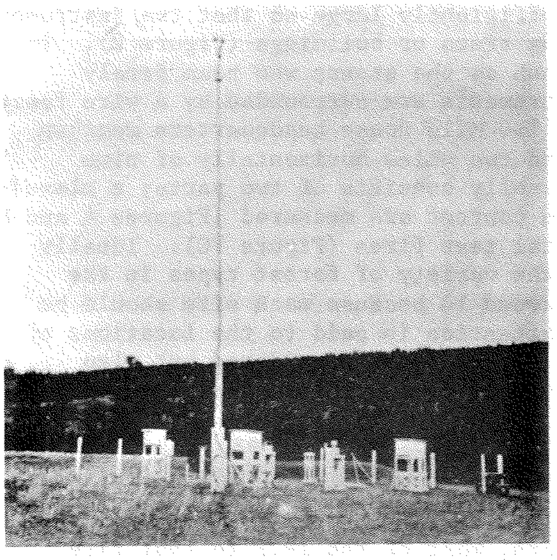

Figure 2. Headquarters weather station.

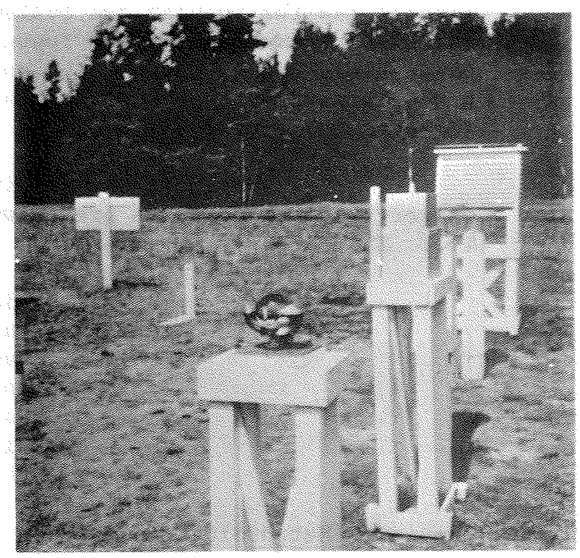

Figure 3. Close up of the weather enclosure.

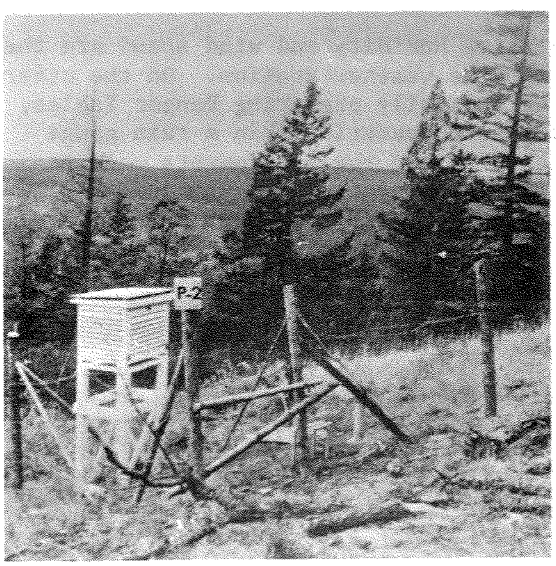

Figure 4. Field site enclosure.

Upon the completion of living and working quarters for a three to five man party, a climatological station is set up on level, grassy terrain in a nearby clearing. The clearing should be sufficiently large so that the instruments will not be unduly influenced by surrounding trees or buildings (Figure 2). To prevent interference from large animals, such as the steers who roam freely through the Cariboo range country, the instruments are surrounded by a wire fence. Situated at an elevation of 3050 feet, the 100 Mile House headquarters *weather enclosure* was within 800 feet vertically and two miles horizontally of nine *field sites* (Appendix II). A field site usually consists of two parts; a closed-off area in which weather and fuel moisture content are measured (Figures 4 and 9) and an adjacent burning area for experimental test fires (Figure 7C). Ideally the number of field sites is dependent on the variety of forest types in the region but seldom does the actual number exceed 10 because each site should be visited both morning and afternoon. Much attention is paid to the locations of field sites and not only is the variety of forest types considered but also factors such as the amount, arrangement, type of combustible material as well as aspect, slope and elevation.

RECORDING FIELD DATA

Apart from the World War II years, most of the 1929 to 1961 fire seasons saw the regular and systematic collection of field data at one or more of the 11 above-mentioned fire research stations (Figure 1). Initially recorded on basic field forms, observation on nearly 15,000 small-scale experimental fires and a large amount of supplementary data have been transferred to I.B.M. cards (Fraser and Joly, 1961, 1962 and 1965).

A sample of the original measurements for days of *high* and *low* fire danger at 100 Mile House are shown on the seven most widely used forms (Appendix IV). They are:

Table 1. Miscellaneous Weather Data
Table 2. Rainfall Record
Table 3. Oven-Drying of Samples
Table 4. Moisture Content of Match Splints
Table 5. Moisture Content of Hazard Sticks
Table 6. Flammability Tests
Table 7. Phenological Observation

Acquiring Meteorological Data

Temperature, precipitation, relative humidity and wind speed are the parameters actually needed at an operational fire weather station. On the other hand, in order to collect the basic data for initially preparing Danger Tables, a fire research station needs more complete instrumentation than a rain gauge and a simple hygrometer. The parameters measured and the instruments used to measure them (Figure 5) are listed on the following page.

WEATHER PARAMETER	INSTRUMENT
1. Temperature and Relative Humidity	Hygrothermograph & Psychrometer
2. Wind Velocity and Direction	Anemometer (Anemovane & Anemograph)
3. Precipitation	Rain Gauge
4. Maximum and Minimum Temperatures	Max. & Min. Thermometers
5. Sunshine	Sunshine Recorder
5. Cloud Cover	Ocular Estimate
7. Pressure	Barograph
8. Dew	Potvin Dew Gauge
9. Evaporation	Wright Evaporimeter

With the exception of the "Potvin" dew gauge and the "Wright" evaporimeter, all are standard weather instruments. Because they are fully described in the Forest Fire Danger Manual (Williams, 1963) as well as in many meteorological textbooks, only a brief mention of their role at a fire research station is given here.

A hygrothermograph (Figure 5A) is set up in an instrument shelter to continuously record *Temperature and Relative Humidity*. Three times daily the readings are spot checked with a sling psychrometer (Table 1).

The anemovane measures *Wind Velocity and Direction* at approximately 10 feet above tree top level (Figure 2) and, by the transmission of electrical impulses through an underground cable, records on an anemograph (Figure 5C) in the office (Table 1).

Precipitation is collected in a standard rain gauge (Figure 5D), and also recorded on a tipping-bucket gauge of the type shown in Figure 5E. The chief advantage of the latter is that it registers duration and intensity as well as amount (Table 2).

Daily Maximum and Minimum Temperatures are recorded primarily for monthly climatological record purposes (Figure 5B) although in mountainous or very hilly country, a second minimum thermometer is also installed in the instrument shelter. With its bulb moistened by a wick immersed in water, it is used to determine the low overnight relative humidity -- essential information for applying a correction to the danger index. This suggested method of H. W. Beall's works well except in freezing weather (Macleod, 1948; Williams, 1963) and does away with having to resort to delicate and expensive instruments (Table 1).

By focusing the sun's rays through a glass ball (Figure 5G), the duration of *Sunshine* is determined by measuring the length of the lines burnt on a graduated card held behind the ball.

Cloud Cover is ocularly estimated in tenths at three daily observation times (Table 1).

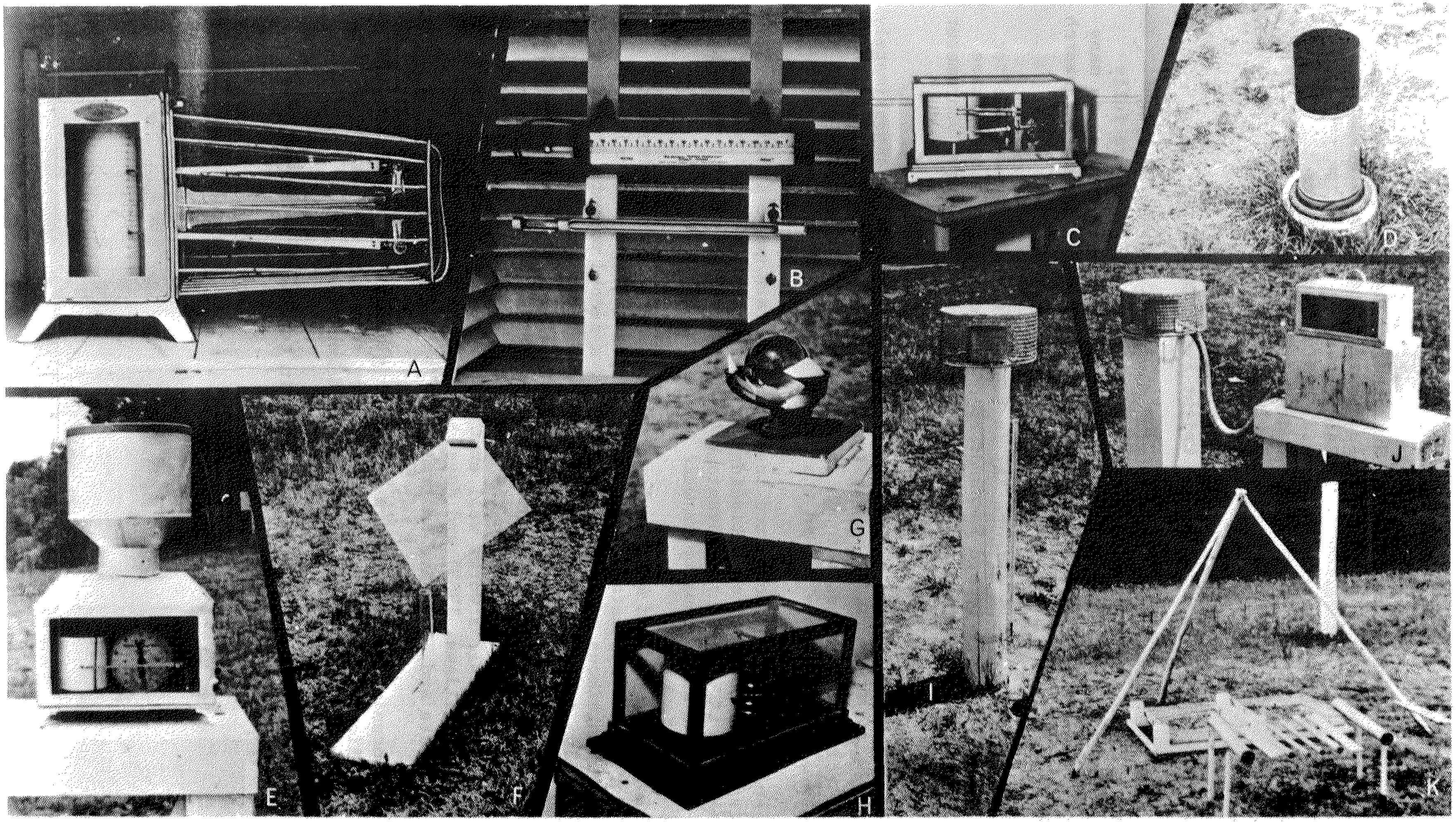

Figure 5. Weather instruments and fuel moisture indicators.

(A) Hygrothermograph; (B) Maximum and Minimum thermometers; (C) Anemograph; (D) Standard Rain Gauge; (E) Recording Rain Gauge; (F) Dew Gauge; (G) Sunshine Recorder; (H) Barograph; (I) Pan Evaporimeter; (J) Recording Evaporimeter; (K) Hazard Sticks and Match Splint Trays.

Pressure changes may indicate the coming of a storm or herald the approach of fair weather. In the days when official fire weather forecasts were not readily available (Paul, 1964), the barograph (Figure 5H) was one of the more dependable aids used to forecast forthcoming weather locally and, thereby, enable the observer to predict tomorrow's fire danger at his station (Beall, 1948b).

By increasing the moisture content of the forest fuels *Dew* retards fire spread until finally dissipated by the warmth of the morning sun. Since 1948 it has been measured at field stations by simple gauge (Figure 5F) designed by Potvin (1949) and consisting of a one-foot square sheet of glass set at an angle of 45^0. On clear nights dew may collect on the glass plate and drip into a graduate beneath.

Evaporation has always been considered an important phenomenon in fire danger investigations and believing it to be "the greatest single measurable factor controlling the rate of drying of forest fuels", Wright (1932) designed his own instrument to measure it (Figures 5I and 5J). The Wright evaporimeter was initially required for calculating fire danger but, because the readings from the instrument were often erratic due to wind or exposure, it was decided in 1946 to use only ordinary meteorological instruments. This, however, does not detract from the importance of the instrument for fire studies and, since it is inexpensive, able to withstand freezing temperatures, easy to operate and keep in repair, it is frequently used by ecologists and others as well. The original pan was made from one-half of a five-pound baking powder tin (improvisation was necessary in the 1930's when money was scarce for forest research purposes!) and was correlated with a standard Livingston atmometer. Using a burette in the manner shown in Figure 7A, the pan is filled each day to a predetermined height (Table 1).

In addition to the extensive use of automatic recording instruments and three daily readings at headquarters, a thorough weather record is also built up for the field sites (Appendix II). Hygrothermographs are set out at sites where the elevation and/or aspect differ significantly from headquarters and temperature and relative humidity are also determined with a sling psychrometer whenever fuel moisture content is measured. The wind velocity is either estimated or measured with a hand-held anemometer whenever test fires are ignited. Because the precipitation pattern can sometimes vary appreciably in relatively short distances, rain is measured in clearings near the field sites.

Measuring Fuel Moisture Content

Knowledge of the moisture content of forest fuels is indispenable to an investigator studying the behaviour of fire under changing weather conditions. He is interested in the light and medium-sized fuels in which fires usually break out. He is also concerned with the heavy fuels which may play an insignificant role in starting fires, but often exert a tremendous influence on the ease by which fires, once started, are extinguished. To obtain a reliable measure of the moisture content of a variety of forest fuels, direct and indirect sampling techniques are employed.

FUEL MOISTURE INDICATORS

1. Fuel Samples
2. Match Splints
3. Moss and Cladonia
4. Hazard Sticks
5. Log Boring Samples
6. Electric Moisture Meters
7. Weigh-Beam Logs
8. Water Level Recorders

The most straight-forward method of determining moisture content is to collect, oven-dry, and weigh representative *Fuel Samples* (Table 3).

Oven-dried *Match Splints* are scattered on wire-framed, nylon-covered trays and set out in the open in the headquarters and field site enclosures (Figures 5K and 6A). In sufficient numbers these untreated western white pine match splints -- resembling wooden matches without heads -- are as sensitive to changes in relative humidity as the light surface fuels themselves. In fact, except for moss and cladonia, the splints are actually to be preferred as a measure of moisture content because most natural fuels "are unsuitable, owing to lack of uniformity, rapid decomposition, and the difficulty of separating newly fallen material from the original sample" (Beall, 1947). Moreover the splints are less subject to the random sampling error that is especially noticeable with natural fuels after light rain (Table 4).

Cleaned and oven-dry *Moss and Cladonia* are set out in trays in the same manner as the splints wherever these fuels constitute a major component of the ground vegetation.

For many of the reasons that splints replace the light fuels, *Hazard Sticks* (Figure 7B) are substituted for twigs, broken branches and other medium fuels. The hazard sticks are round, square, flat, one-quarter to two inches thick and about 18 inches long (Figure 5K). At 100 Mile House, dowelled "B.C. Hazard Sticks" were also used (Table 5).

Collecting *Log Boring Samples* is a good method of estimating the moisture content of heavy fuels. An auger is bored into a windfallen log and the resulting wood shavings are removed at depths of one-quarter, one-half, one, two, three or more inches. The chips are placed in sample tins and oven-dried in the same manner as the fuel samples (Table 3).

Figure 6A. Match splint tray.

Figure 6B. Weigh-beam log.

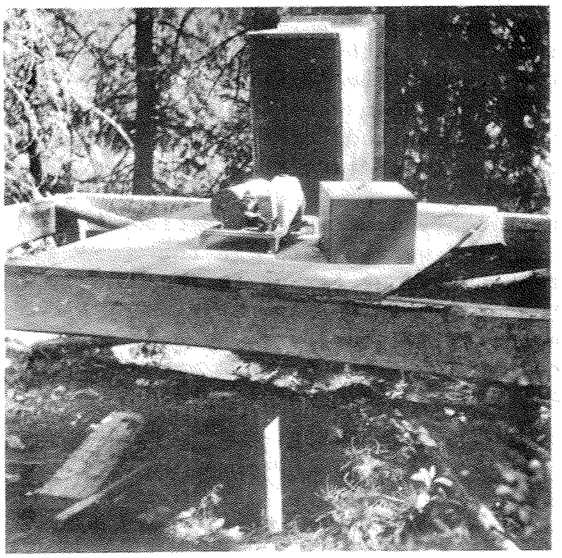

Figure 6C. Water level recorder.

Figure 6. Equipment at field sites.

Electric Moisture Meters may be used to check the moisture content of the log at the different depths. This is done by inserting the prongs of the meter into the wood. Although this practice was discontinued at the field research stations because of its unreliability outside a fairly narrow band, it could be revived now that better moisture meters are on the market.

Large *Weigh-Beam Logs* are set out at field sites with one end suspended while the other rests on a knife edge (Figure 6B). The average oven-dry per cent moisture content, determined from cross-sections initially cut from the two ends, is considered to be representative of the log as a whole at the time the weigh-beam is set up (Table 5).

Water Level Recorders are installed over "seepage pits" dug in undrained swamps or stagnant ponds (Figure 6C). Recorded on the graphs are fluctuations in the water table level which can be related to the moisture content of heavy fuels and to the long-term drought factor (Williams, 1954).

The number and the location of the fuel moisture indicators set out at 100 Mile House are shown in Appendix II.

Observing Test Fire Behaviour

While fire control officers would be the first to agree that forest fires break out far too frequently, they do not occur often enough in the immediate vicinity of the field station to enable the fire investigator to rely solely on them for information on fire behaviour. Wildfires are, of course, studied at every opportunity but the principal method of gathering the data needed to prepare Danger Tables is to observe and record the behaviour of small experimental fires. The unquestionable advantage of *test fires* lies in the fact that they -- along with the simultaneous measurement of weather and fuel moisture content parameters -- can be observed regularly in a variety of forest types over the whole range of danger conditions from *low* to *extreme*. While the degree of danger cannot be controlled on any particular day, over the course of one or more fire seasons a representative sample of all the danger class days is likely to be encountered. Through the years good success has been achieved in correlating test fires with actual fire behaviour. In most fuel types the tests "provide a reliable indication of large-fire behaviour" and in many others "are indicative of susceptibility to ignition from standard fire-brands" (Beall, 1947). The lighting of test fires is usually confined to the afternoon when the degree of danger is near or at its peak, although, at the high latitude of Fort Smith in the Northwest Territories, it was also feasible to attempt morning fires.

The test fire procedure has been thoroughly described by Macleod (1949) but, in essence, it involves placing a lighted wooden match in the appropriate fuel and observing the ensuing fire's behaviour for up to two minutes (Figure 7C). Each fire is rated as shown in Table 6. In rating a fire the most weight is given to average flame height, vigour, area burned, degree of smouldering, and ease of suppression. At least two persons are always present whenever a fire is attempted and, at all times, rigid safety precautions

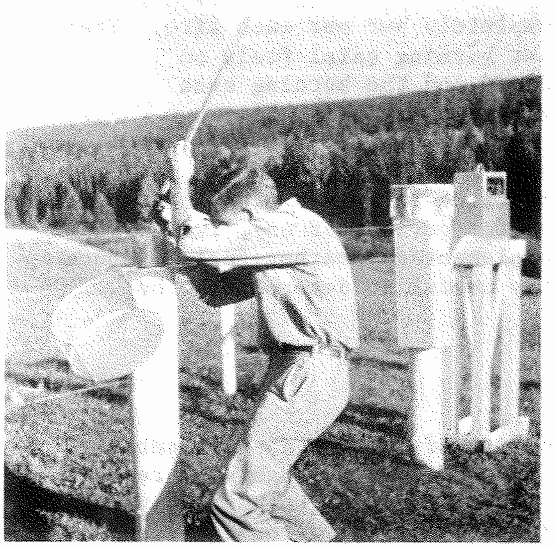

Figure 7A. Acquiring meteorological data. (Filling the evaporimeter.)

Figure 7B. Measuring fuel moisture content. (Weighing a hazard stick.)

Figure 7C. Observing test fire behaviour.

are enforced. The fireguard is continually kept clear of debris and back-pack pumps and hand tools are used to quickly and completely put out each fire. Even more stringent measures were adopted for the fast burning salal fuels on Vancouver Island. There, fireguards were bulldozed and the burning area patrolled for upwards of two hours after each fire was extinguished.

During periods of prolonged dry weather, and in the absence of lightning or man-made fires, a series of continuity test fires are undertaken at a fast drying site. At intervals of three hours for periods of one, two, or even three days, test fires are attempted and the supplementary weather-fuel moisture data collected. This information is particularly useful in determining the diurnal effect of fire danger[5].

Obtaining Miscellaneous Data

While it is evident that the main duties of the field party entail measuring weather elements, weighing fuel moisture indicators, observing test fires, and regularly noting phenological development (Table 7), other activities must also be carried out. At the outset they include setting up headquarters and field site enclosures, building instrument stands, and digging fireguards Some tasks must be repeated each year. The oven-dried weights of the match splints and hazard sticks are determined at the start of the season and again at the end. The instruments are calibrated before being set out in the spring and are dismantled and packed for winter storage in the fall. Moreover, the equipment must be serviced regularly and other miscellaneous chores, such as the preparation of site descriptions (Appendix III), performed from time to time.

DEVELOPMENT OF THE FIRE DANGER RATING SYSTEM

In the late 1920's and early 1930's most of the procedures and techniques in fire danger rating described in this paper were tried at the Petawawa Forest Experiment Station. Many of the practices first introduced at Petawawa have been employed at all subsequent field stations although sometimes in a modified form. The most important of these was the small-scale experimental "test fire". It was the really distinctive feature of the Wright system and, coupled with the data on weather and fuel moisture content, it is the chief means of evaluating fire danger. Test fires were essential when Wright developed the first set of Tables for the mixed red and white pine types of eastern Ontario and western Quebec in 1933 and they were just as important in preparing the Canadian Fire Weather Index in 1969.

The 1933 Tables consisted of rapid and slow drying hazard tables. The first was representative of extreme conditions under open canopy; the second of average conditions under nearly full canopy. The hazard in these fuel types was determined from measurement of rainfall and late afternoon relative humidity and evaporation.

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[5] *See page 21 of the Forest Fire Danger Manual (Williams, 1963).*

In 1938 the Tables were broadened in scope to include the hazard for tolerant hardwoods, mixed woods, an oak ridge, and six pine types. Correction factors for wind velocity and seasonal variation were added and a new unit of measurement[6] adopted. In the 1940 reprinting of the Tables (Wright and Beall), a large supplement was appended. There were many improvements in the 1940 edition but the most important was the inclusion of an index to balance the fire danger in more hazardous fuels against that present in the less susceptible ones. Called an administrative hazard index at first, this awkward phrase was replaced by the term *danger index*[7] in 1946.

Applicable to the forests of Canada east from the Rocky Mountains, the 1946 edition and the subsequent revision (Beall, 1948a) included separate fire danger tables -- "Eastern", "Midwest" and "East Slope" -- for three distinct areas. The number and complexity of hazard tables was reduced and, more significantly, the mid-afternoon peak fire danger period could now be calculated from noon weather observations using only a simple and inexpensive hygrometer and rain gauge. (Evaporation readings were no longer needed.) Wind velocity measurements were still required but, by using the "Intermountain Scale of Wind Velocity", it could be satisfactorily estimated. The 1948 revision also included J. C. Macleod's important correction for the influence of unusually low overnight relative humidities on fire danger. Such temperature and humidity inversions are a rare phenonenon in the midwest and eastern Canada but are frequently encountered at higher elevations in mountainous country. The Tables were widely acclaimed at home and also became a model for foreign investigators. They were, for example, recommended for adoption in Argentina (Castellanos and Papara, 1956) and adapted to *Pinus pinaster* under Portuguese conditions (Dias, 1958).

In 1956 new provincial Danger Tables were planned and, in the next three year period, individual Tables were published for Newfoundland, New Brunswick, Ontario, Manitoba, Saskatchewan, Alberta, and Alberta East Slope (Anon. 1957 and 1959). The preface to the "1956 edition" explained why this step was deemed necessary. "Derived in large measure from those of the 1948 edition, and retain(ing) their characteristic basic principles, modifications were made in some of them as a result of several years' research in areas for which field data had not previously been obtained." There was another important reason for this decision. The 1948 edition contained no fewer than 73 pages and, while it was not difficult to calculate the danger index, it looked like a formidable task to the uninitiated. Now, knowing the noon relative humidity, wind, and the previous 24-hour precipitation, the danger index could be quickly determined by consulting four basic tables[8] on two facing pages or alternately by spinning the dial of a pocket-size meter (Paul, 1962). The earlier Tables gave prominence to the most

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6 *The numerical scale adopted at this time is as follows: NIL - 0; LOW - 1-4; MODERATE - 5-8; HIGH - 9-12; EXTREME - 13-16.*

7 *The DANGER INDEX really represents the average fire danger prevailing in the region as a whole. The HAZARD INDEX applied specifically to one type of fuel, usually a particularly troublesome fuel to control.*

8 *Drought Index (table 1); Rainfall table 2); Relative Humidity and Wind (table 3); Fire Danger (table 4). Table 4 may be divided into the Spring, Summer and Fall periods.*

potentially dangerous fuels and this feature was retained in the 1956 edition by including hazard tables for slash, grass, fast drying litter and, if an important constituent of the forest floor, cladonia.

With the publication of two sets of Danger Tables for British Columbia (Anon. 1961), the format was altered to more precisely rate fire danger in the diversified forest types of that province. Although there has been some criticism that these Tables are too complicated, those who actually work out the danger index do not find them difficult (Howard, 1963). The Tables for the District of Mackenzie, Northwest Territories, (Anon. 1962), which appeared the following year, more closely resemble the 1956 than the 1961 edition. One worthwhile innovation was the separation of the coniferous and broad-leaved species in the summer fire danger period.

No new fire research stations have been established since 1961 and no new Danger Tables have been prepared since 1962, but in 1967 Danger Tables were published in Quebec to be used in conjunction with the inauguration of fire weather forecasting at the Montreal International Airport (L. Pouliot, 1967, 1968). These Tables superseded a system based on a modification of Beall's 1946 edition (Villeneuve, 1948).

For a number of years there had been more emphasis paid to research relating to other phases of fire control, such as fuel type classification, prescribed burning, and fire damage appraisal, but there is now a definitely renewed interest on the part of fire control officers for further concentrated investigations in fire danger rating. A new system was envisaged and this resulted in the recent publication in provisional form of the Canadian Fire Weather Index, (Anon., 1969). Further refinements and clearer explanations and instructions are needed but the approach, still based on basic field data, is readily seen. It is not expected that the calculations will be any more difficult than in the past but there are more steps. This is much less of a problem now than it used to be because rapid speed computers can and will be utilized.

SUMMARY

Forest Fire Danger Tables have a multiplicity of uses but, by providing a reliable, consistent, and unbiased estimate of the degree of fire danger in the forest, they fulfil the main function of enabling a protection staff to effectively and efficiently plan its work load. The preparation of a danger rating system for the major forested regions of Canada received a great deal of attention by federal forest fire research investigators from 1929 to 1961; and it is doing so again.

The development of Danger Tables for a region was necessarily a long-term undertaking. Three to five years of investigations at a field station were usually required to obtain sufficient data to make an accurate and realistic analysis of the complex relationships of weather, fuel moisture content, and fire behaviour. Apart from the infrequent study of wildfire behaviour, the field work was primarily concerned with igniting and observing test fires over a lengthy period of time under widely varying weather and fuel moisture conditions in a variety of forest types.

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APPENDIX I

LIST OF COMMON AND SCIENTIFIC NAMES

EVERGREEN TREES

Douglas-fir, blue	*Pseudotsuga menziesii* (Mirb.) Franco var. *glauca* (Beissn.) Franco
Pine, jack	*Pinus banksiana* Lamb.
Pine, lodgepole	*Pinus contorta* Doug. var. *latifolia* Engelm.
Pine, maritime	*Pinus pinaster* Ait.
Pine, red	*Pinus resinosa* Ait.
Pine, eastern white	*Pinus strobus* L.
Pine, western white	*Pinus monticola* Dougl.
Spruce, Engelmann	*Picea engelmannii* Parry

DECIDUOUS TREES

Aspen, trembling	*Populus tremuloides* Michx.
Birch, western white	*Betula papyrifera* Marsh. var. *commutata* (Regel) Fern.

SHRUBS

Buffalo-berry	*Shepherdia canadensis* (L.) Nutt.
Hazelnut	*Corylus cornuta* Marsh.
Serviceberry	*Amelanchier* spp.
Wild Rose	*Rose acicularis* Lindl.
Willow	*Salix* spp.

HERBACEOUS VEGETATION

Aster	*Aster* spp.
Bedstraw, northern	*Galium boreale* L.
Clematis, blue	*Clematis columbiana* (Nutt.) T. & G.
Dewberry	*Rubus pedatus* Smith
Fairybells, Oregon	*Disporum oreganum* (S. Wats.) B. & H.
Fireweed	*Epilobium angustifolium* L.
Snowberry	*Symphoricarpos albus* (L.) Blake
Strawberry	*Fragaria glauca* (S. Wats.) Rydb.
Sunflower	*Compositae* spp.
Wild pea	*Lathyrus ochroleucus* Hook

GROUND VEGETATION

Bearberry	*Archtostaphylos uva-ursi* (L.) Spreng.
Grass	*Gramineae* spp.
Moss	*Sphagnum* spp. *Hypnum crista-castrensis* Hedw. *Polytrichum commune* Hedw.
Reindeer-moss	*Cladonia rangiferina* (L.) Web.

APPENDIX II

FIELD SITE SUMMARY

Site/Cover Type	Hygrothermographs	Rain Gauges	Fuel Samples	Match Splint Trays	Hazard Sticks	Weigh-Beam Logs
HQ (G)	1	2	0	2	9	0
P-1	0	0	4	4	10	0
A/AP[1]	0	1	6	6	9	0
G	1	1	1	1	5	0
D-3 (SA)	1	1	8	3	11	1
D-1	1	1	4	4	11	1
D-4	0	1	3	3	9	0
D-5	1	1	1	2	11	0
P-2 (D)	1	1	1	1	6	0
TOTAL	6	9	28	26	81	2

[1] *These two sites share a common enclosure.*

Weather instruments, number of fuel samples collected and fuel moisture indicators measured at 100 Mile House, B.C. field sites.

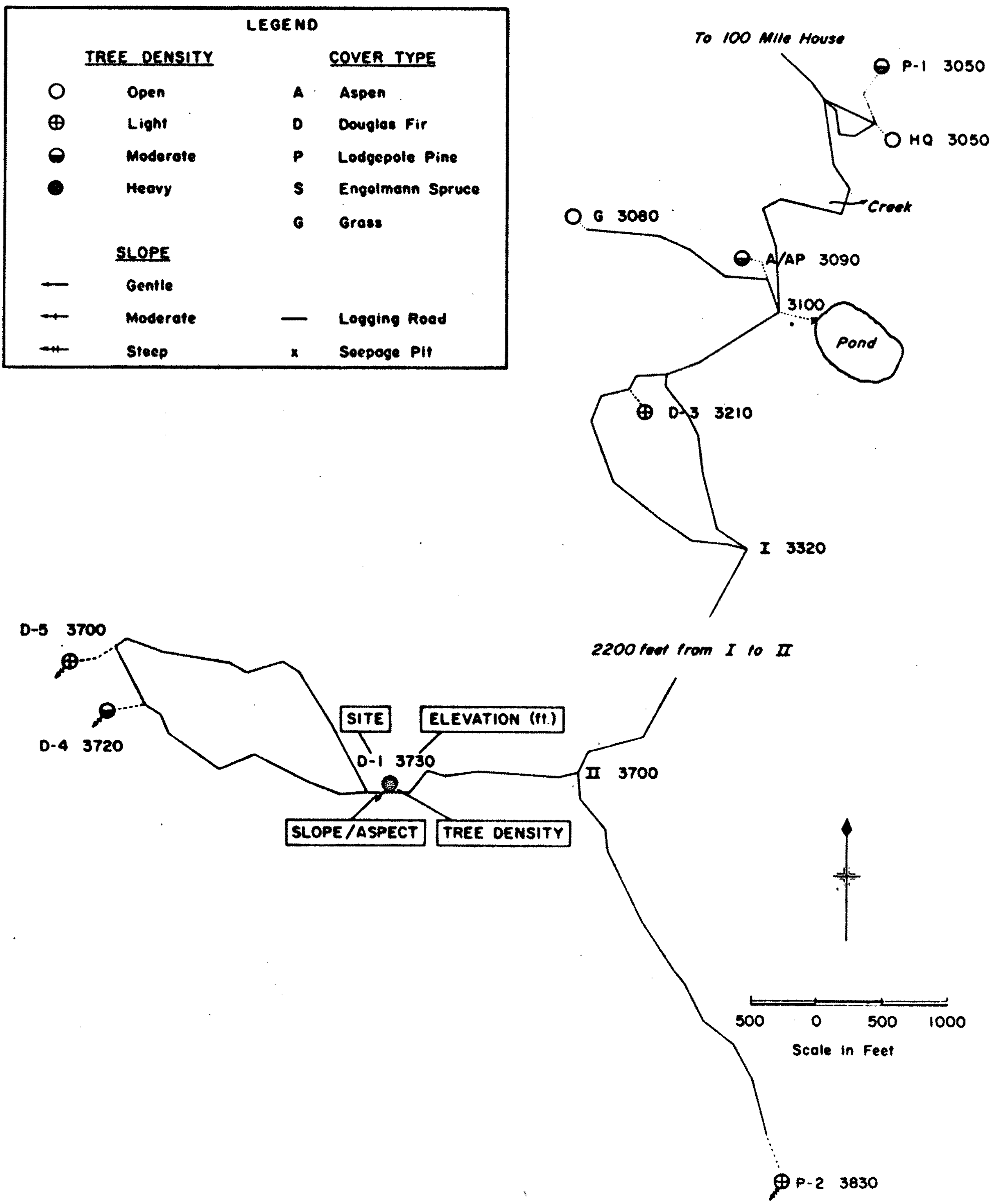

Figure 8. Map of 100 Mile House, B.C. Field Sites

APPENDIX III

FIELD SITE DESCRIPTION

for

100 Mile House, B.C. field site D-1

STAND

Site D-1 is primarily a well stocked stand of mature to overmature blue Douglas fir, ranging in height from 65 to 90 feet, and in diameter, from 15 to 27 inches (Figure 6A). Most of the overmature trees exhibit a pronounced lean and many are dead or dying. Moss and lichen cover their branches to within 15 feet of the ground. Immature fir is firmly established and regeneration, while abundant, is mainly clustered in stand openings. These openings are due to the logging of a few large trees and their removal has reduced what would otherwise have been almost complete canopy closure to about 60 per cent. While there are also a number of immature lodgepole pine, few pine seedlings are present.

In general the ground slopes gently to the southwest although there is a more abrupt drop within the enclosure itself. To the south and east, cutting has been heavy and, as a result, the stand is exposed to winds from those directions. Moreover, there is evidence to suggest that a light ground fire swept through the stand about 1945.

GROUND VEGETATION

The shrubs, mosses and herbs that are present in the enclosure are as follows:

Very Abundant	Abundant	Frequent	Sparse
Grass	Wild Rose	Buffalo-berry	Willow
Aster	Strawberry	Wild pea	Northern Bedstraw
	Mosses	Bearberry	Blue Clematis
			Oregon Fairybells

LITTER

Three large windfallen logs, in an advanced state of decay, were present in the enclosure (Figure 9) but, except for duff, twigs and cones concentrated under the trees, litter was sparse. The "Top Layer Duff" was analysed as follows:

1. Five one-foot square samples were randomly selected.
2. The samples were thoroughly mixed.
3. Their oven-dry weight was determined (432.2 gms.).
4. Approximately one-half the sample was thrown away.
5. Step 4 was repeated to provide a manageable amount (77.5 gms.).
6. The components were mechanically separated.

Site D-1 Elevation - 3730 feet

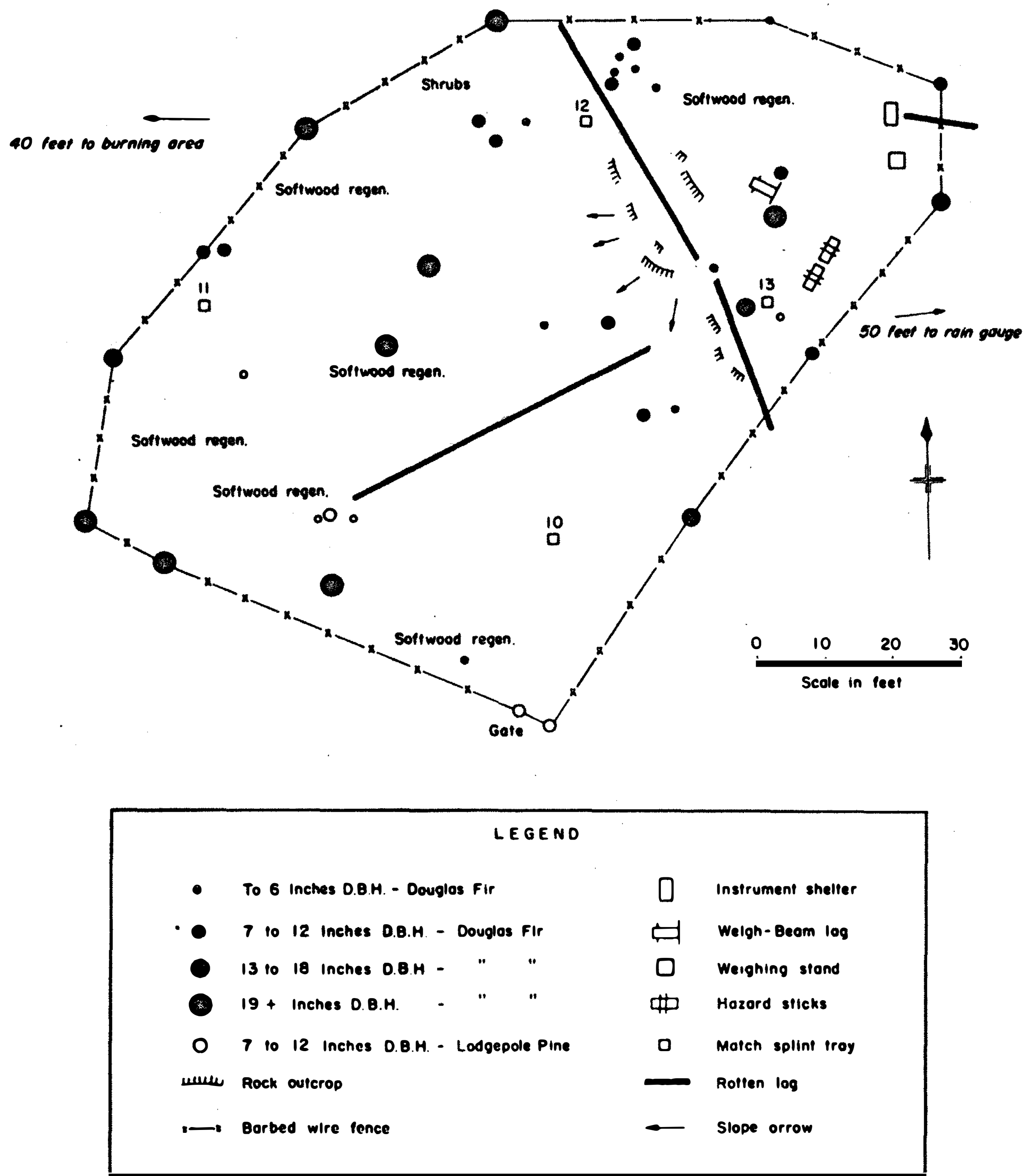

Figure 9. Enclosure at 100 Mile House, B C field site D - I.

	Twigs	Fir Needles	Bark	Cones	Grass	Pine Needles	TOTAL
Weight of Sample:	29.1	23.4	12.7	9.4	2.2	0.7	77.5
Per Cent by Weight:	37.6	30.2	16.4	12.1	2.8	0.9	100.0

SOIL

The 100 Mile House region is predominantly made up of rock outcrop soils or lithosols. At high elevations bedrock occurs at a shallow depth and barren outcrops of rock are not uncommon. Glacial deposits are found in the form of unassorted till. The soils are young, as evidenced by their shallow profiles and the coarseness of soil particles, and they generally show podzolic characteristics as illustrated by the following description:

	Horizon	Depth (Inches)	Description
	L	½	Litter
Organic Horizons	F	½	Fermented Layer
	H	Tr.	Humus
	A_e	0-3	Fine sand; strongly leached; ashy-grey colour
Mineral Horizons	B	3-8	Sandy loam; light to dark brown; interspersed basaltic rock fragments
(Roots are present throughout the soil profile to 12 inches)	C	8	Sandy clay loam; increase in size of rock fragments from "B"
		12	Bedrock - dark red basalt

APPENDIX IV

RECORDED FIELD DATA

(100 Mile House, B.C. - June 8 & 11, 1959)

TABLE 1. MISCELLANEOUS WEATHER DATA

Hour - Readings are taken every day of the fire season at 8:00 a.m., sun noon, and 6:00 p.m., local standard time. The time the sun crosses the meridian at 100 Mile House is 12:05 p.m., P.S.T.

Wind - The wind, shown as blowing from the southeast at 12 miles per hour at noon on June 11, was actually registered on the anemograph chart as the average for the previous hour.

Psychrometer - On June 11 the noon dry-bulb temperature was 58° F. and the wet-bulb temperature was 49°F. These temperatures were obtained by whirling the psychrometer in the shade until the lowest readings were reached. By looking up the appropriate psychrometric table, the relative humidity was found to be 51 per cent.

Hygrothermograph - A temperature of 59° F. and a relative humidity of 49 per cent were read from the hygrothermograph chart at precisely 12:05 p.m. on June 11.

Air Temperature - The minimum temperature of 30°F. was the lowest reached during the early hours of June 11 whereas 62° F. was the highest temperature during the day.

Clouds - On June 11 the sky was 10-tenths covered (completely over-cast) in the morning, 5-tenths (partly cloudy) by noon, and 3-tenths (mostly clear) in the early evening. The low lying stratus and nimbostratus clouds produced only .01" of rain during the morning (see Table 2) and, by noon, had given way to the fair weather cumulus.

Evaporation - The small differences between the pan and recording evaporimeter readings can mostly be attributed to the difficulty of filling the pans to the proper level (Figure 7A). On June 11 evaporation for the 14 hours from 6:00 p.m. until 8:00 a.m. was slight compared to the 10 hours between 8:00 a.m. and 6:00 p.m.

Average 2-Hour Minimum Relative Humidity - The value of 38 per cent on June 11 was determined from the pen tracing on the hygrothermograph chart.

MISCELLANEOUS WEATHER DATA

SITE: H. Q. DATE: June 1959

DATE	HOUR	WIND		PSYCHROMETER				HYGROTH 'H		AIR TEMP.		CLOUDS		EVAPORATION		AV. 2-HR MIN. R.H.
		DIR.	VEL.	DRY	WET	DIFF.	R.H.	TEM.	R.H.	MIN.	MAX.	AMT.	TYPE	PAN.	REC.	
8	08.00	SE	8	54	44	10	45	53	44	27	59	10	St	25.4	25.2	
	12.05	SE	10	63	47	16	28	63	27			4	Cu			
	18.00	W	4	58	46.5	11.5	42	58	39	52	63	9	Ci Cu	56.3	55.7	25
														81.7	80.9	
11	08.00	E	9	52	44	8	53	52	50	30	53	10	Ns St	6.4	6.1	
	12.05	SE	12	58	49	9	51	59	49			5	Cu			
	18.00	E	12	59	50	9	54	60	51	51	62	3	Cu	50.4	49.9	38
														56.8	56.0	

TABLE 2. RAINFALL RECORD

For fire danger determination purposes, the precipitation on June 9 was treated as a single rain. (To qualify as two separate rains, there must be an interval of more than five hours between the time the first rain ended and the second started.)

RAINFALL RECORD

SITE: H. Q. DATE: June 1959

DATE	HOUR	INCHES RAIN	TIME OF RAINFALL				REMARKS
			START	STOP	START	STOP	
7	18.00	TR.					
8							
9	12.05	.12	11.00	12.00			A single rain of .37"
	18.00	.25			12.30	14.30	
10	18.00	.33	01.00	15.00			
11	12.05	.01	08.45	09.15			

TABLE 3. MOISTURE CONTENT OF FUEL SAMPLES

Fuel samples were collected whenever a test fire was attempted and at Site D-1 four fuels were regularly gathered. They were grass, moss, "top layer duff" (in this case Douglas fir needles), and "twigs on the ground".

Tare is the oven-dry weight of the sample tin. Gross Wet is the weight of the fuel sample and the tin before being put in the oven. Gross Dry is the weight of the fuel and the tin after being oven-dried at a temperature of 212°F. with its lid removed. The light fuels are dried overnight; the heavier fuels until there is no further loss in weight. A simple slide rule calculation is all that is now needed to calculate the Per Cent Moisture.

The moisture content of all fuels increased appreciably as a result of the heavy rains of June 9 and 10* although the moss gained the most moisture because of its remarkable water holding capacity.

* The total two-day precipitation recorded in a clearing near Site D-1 was 0.66 inches compared to 0.70 inches at headquarters. The field site was 1.5 miles from headquarters and at a 680 foot higher elevation.

MOISTURE CONTENT OF FUEL SAMPLES

SITE: D-1 DATE: June 1959

DATE	HOUR	FUEL	TIN No.	TARE	GROSS WET	GROSS DRY	NET DRY	GMS. MOIST.	% MOIST.	REMARKS
8	14.55	Grass	9	76.51	81.02	80.55	4.04	0.47	11.6	
		T. L. D.	10	77.99	92.57	91.78	13.79	1.19	8.6	
		T. O. 6.	11	75.49	102.90	100.62	25.13	2.28	9.1	
		MOSS	12	76.14	81.51	81.01	4.87	0.50	10.2	
.11	15.15	Grass	9	76.51	84.26	82.78	6.27	1.48	23.6	
		T. L. D.	10	77.99	94.13	87.60	9.61	6.53	67.9	
		T. O. 6.	11	75.49	94.31	88.92	13.43	5.39	40.1	
		MOSS	12	76.14	98.00	83.84	7.70	14.16	183.8	

TABLE 4. MOISTURE CONTENT OF MATCH SPLINTS

Data from two of four trays set out at Site D-1 are shown. To simplify the calculations, the trays were brought initially to uniform weights of 600 gms. and the oven-dried splints to 300 gms. Since the Gross Weight of tray 12 at 2.55 p.m. on June 8 was 912 gms., the moisture content of the splints was 4 per cent (i.e. 12/300 x 100 = 4%). Two days of heavy rain raised it to nearly 21 per cent. However, trays 10 and 11, located under more open canopy in the enclosure (Figure 9), must have gained much more moisture because the average for all four trays is 27 per cent. At the end of each season an entry is made in the column headed Correct Per Cent to adjust for deterioration due to the inevitable weathering of the splints.

MOISTURE CONTENT OF MATCH SPLINTS

SITE: D-1 DATE: June 1959

DATE	HOUR	No. 12 GROSS WT.	No. 12 UNCORR. %	No. 12 CORR. %	No. 13 GROSS WT.	No. 13 UNCORR. %	No. 13 CORR. %	AVERAGE 10.11.12.13 UNCORR %	AVERAGE 10.11.12.13 CORR. %	REMARKS
8	09.55	914	4.7		923	7.7				
	14.55	912	4.0		911	3.7		5.0		
11	AM									raining
	15.15	962	20.7		964	21.3		27.0		

TABLE 5. MOISTURE CONTENT OF HAZARD STICKS

It is impractical to bring hazard sticks to the same initial weight and, instead, moisture content graphs were prepared for each stick individually. It should be noted that, while none of the hazard sticks gained as much moisture after rain as did the splints or fuel samples, neither are they likely to lose their moisture as rapidly as do the finer fuels. The large weigh-beam log gains (and loses) moisture very slowly.

MOISTURE CONTENT OF HAZARD STICKS

SITE: D-1 DATE: June 1959

DATE	HOUR	No. 3 (2" Rd.)			No. 9 (2" flat)			No. 9 (3/4" Rd.)			No. 2 (Weigh-Beam Log)		
		GROSS WT.	UNCORR %	CORR. %	GROSS WT.	UNCORR. %	CORR. %	GROSS WT.	UNCORR %	CORR. %	GROSS WT.	UNCORR %	CORR. %
8	09.55	443.3	8.4		77.3	11.1		64.5	10.8		88.0	12.9	
	14.55	442.1	8.1		75.5	8.5		63.7	8.8		88.0	12.9	
11	AM	raining											
	15.15	489.3	19.5		82.4	18.4		73.2	24.9		89.2	14.4	

TABLE 6. FLAMMABILITY TESTS

Test fires were attempted at all 100 Mile House field sites except D-3 (Figures 6B and 7B) where the high concentration of slash made the risk too great.

Canopy, Vigour and Smouldering are easily deciphered by referring to the codes shown below the data. The meaning of the Estimated Index is also clear and the other columns are self-explanatory. (Wind is measured or estimated at a height of four feet.) With the high moisture content of the fuels on June 11 -- (Table 3) -- it is scarcely surprising that test fires would not burn.

INDEX

0 Nil	Fire will not keep on spreading from a campfire 12 inches in diameter (may spread 2 ft. or more but goes out by itself within 15 minutes). For match test only, Vigour 0.
1 to 4 Low	Fire will not spread from match but continues to spread from a 12-ins. campfire. (Observations should last 5 to 15 minutes after start of campfire depending on fire behaviour). For match test only, Vigour 1 or 2.
5 to 8 Moderate	Fire will continue to spread from at least 1 out of 3 matches but rate of spread does not exceed 1 sq. ft. in 2 min. for softwood duff or moss, or 2 sq. ft. in 2 mins. for hardwood duff. (Observations should last at least 2 min.; more if fire nearly out at that time.)
9 to 12 High	Fire will continue to spread from match, and burns more than area specified for "moderate", but flames can be stamped out without difficulty after 2 min.
13 to 16 Extreme	Fire continues to spread from match, and flames are stamped out with difficulty or other means are needed to extinguish after 2 min.

The above classification is intended only as a general guide and the index assigned to the test fire should take the following additional factors into account.

Rate of spread
Height of flame
Depth of ash
Size of twigs burned
Persistence of smouldering after flames are extinguished.

Smouldering should be observed for several minutes, if necessary, after flames are stamped out, before water is applied.

FLAMMABILITY TESTS

SITE: D-1 DATE: June 1959

DATE	TIME	FIRE BRAND	FUEL	CANOPY	DEPTH DRY INS.	WIND	FLAMES MAX INS.	FLAMES AVG. INS.	VIGOUR	TIME SECS.	AREA SQ.FT.	ASH INS.	SM'G	EST. INDEX	REMARKS
8	14.35	1m	Moss Grass Twigs Herbs	3	1	3	14	6	3	120	2.6	3/8	3	10	} 11
	14.45	1m	Grass Twigs Duff	2	1½	2½	22	7	4	120	3.1	½	4	11	
11	15.10	3m	Grass Moss Twigs											0	Too wet to burn

CANOPY

0. No cover whatsoever and well away from overhanging branches.
1. High slight cover in one quadrant only.
2. High slight cover in two or three quandrants only.
3. High general cover fairly complete, or low (below 8 ft.) dense cover in two quadrants.
4. Low cover on more than two quadrants, excluding all (or practically all) sun on fire site.
5. Very dense cover or a combination of Nos. 3 or 4 with cover of leafy shrubs.

VIGOUR (Match-set fires)

0. Fire goes out before two minutes.
1. At two minutes fire is burning very weakly on one front only and goes out by itself.
2. At 2 minutes fire is burning slowly and poorly on two or more fronts and seems likely to go out on its own accord rather than continue indefinitely.
3. At two minutes no sign of fire going out by itself, burning fairly briskly, but not on all fronts.
4. Fire burning briskly at two minutes on all fronts with tendency to become progressively stronger, but no difficulty in putting it out with the feet.
5. As for No. 4 but difficult or impossible to put out fire with feet after two minutes.

SMOULDERING (Sm'g)

0. Sparks go out within a few seconds of flames going out and smoke ceases.
1. Light smoke continues to rise for about one minute after fire is out.
2. Sparks observed glowing in several places, but do not persist for more than one minute.
3. More persistent glowing than No. 2, but cannot be made to burst into flame by strong continued blowing by mouth.
4. Smouldering strong and will burst into flame by strong continued blowing.
5. Smouldering highly persistent; has a tendency to burst into flame by itself and will do so with light blowing or in moderate breeze.

TABLE 7. PHENOLOGICAL OBSERVATIONS

Plant species do not develop at the same rate from year to year and this is largely attributable to the complex inter-relationships of weather factors. Yet, because phenological development influences fire behaviour, the stage of the vegetation serves as a guide in deciding when the change from the spring to summer and summer to fall portions of the Danger Tables.

Seasonal differences can be compared by examining individual tree species, shrubs and the lesser vegetation indigenous to the region. At representative open sites these indicators are observed weekly or at more frequent intervals in the spring and autumn when leaf development or leaf fall are taking place rapidly.

PHENOLOGICAL OBSERVATIONS

SITE: D-3 DATE: June 8, 1959

EVERGREEN TREES

SPECIES	% GREEN	TERMINAL GROWTH IN PROGRESS	REMARKS	SPECIES	% GREEN	TERMINAL GROWTH IN PROGRESS	REMARKS
Lodgep. Pine	95	yes	(95)				
Engel. Spruce	90	yes	(90)				
Douglas Fir	95	yes	(95)				

DECIDUOUS TREES / SHRUBS

	SPECIES	SPRING	SUMMER & AUTUMN				REMARKS
		% DEVELOPED	% GREEN	% YELLOW OR RED	% BROWN	% REMAINING	
DECIDUOUS TREES	Tr. Aspen	80					(40)
	White Birch	80					(50)
SHRUBS	Willow	30					(20)
	Hazelnut	75					(40)
	Service berry	75					(50)
	Wild Rose	35					(30)
	Buffalo-berry	80					(30)
	Cranberry	70					(25)

GENERAL SUMMARY

EVERGREENS

DECIDUOUS TREES Trembling Aspen turning Silvery

SHRUBS Saskatoon flowering

BRACKEN

GRASS

OTHER VEGETATION Strawberry flowering

WEATHER SINCE LAST OBSERVATION moderate to moderately cool; gradually cloudy; .04" of rain

HERBACEOUS VEGETATION

SPECIES	SPRING	SUMMER & AUTUMN			REMARKS	SPECIES	% GREEN	REMARKS
	% DEVELOPED	% GREEN	% BROWN	% CRISP				
Fireweed	40				(30)	Grasses	35	(30)
Honeysuckle	80				—	Bearberry	70	(70)
Aster	65				—	Moss	60	(60)
Sunflower	85				(85)			
Snowberry	70				—			
Dewberry	85				(40)			
Strawberry	85				(30)			

N.B. Numbers in brackets in remarks column denote '% green' or '% developed' as of June 1.