CANADA

DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

Technical Memoranda

THE DROUGHT INDEX AS A FIRE WEATHER FORECAST TOOL

BY

A.W. JACKSON

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THE DROUGHT INDEX CHART AS A FIRE WEATHER FORECAST TOOL

by

A. W. Jackson

ABSTRACT

The determination of the drought index (in the U.S., the build-up index) for many weather stations is a routine part of fire weather analysis. Maintaining these values from day to day for a number of stations enables one to draw lines of equal drought index in order to gain a continuing picture of drought conditions.

"Normal" drought index charts may be prepared, and graphical subtraction of values on this chart from those on the current one gives a picture of the above-normal and below-normal drought areas.

Graphical addition of conditions of humitity and wind to the drought picture may be done to obtain a chart of fire weather index, from which fire danger may be deduced.

The same procedure may be used to obtain a forecast chart of the index.

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UTILISATION DE LA CARTE DE L'INDICE DE SÉCHERESSE POUR LA PRÉVISION DU TEMPS À INCENDIE

par

A. W. Jackson

RÉSUMÉ

La détermination de l'indice de sécheresse (aux É.-U., "build-up index" ou indice d'accumulation) fait habituellement partie de l'analyse des conditions favorables aux incendies pour plusieurs stations météorologiques. En gardant ces valeurs quotidiennes pour un certain nombre de stations, on peut tracer des lignes d'indice de sécheresse égale afin d'obtenir une représentation continue des conditions de sécheresse.

On peut préparer des cartes d'indice de sécheresse "normale", et la soustraction graphique des valeurs inscrites sur cette carte de celles qui sont inscrites sur la carte courante donne une représentation des régions de sécheresse au-dessus et au-dessous de la normale.

L'addition graphique des conditions d'humidité et de vent à la représentation de la sécheresse peut être effectuée pour obtenir une carte de l'indice du temps à incendie dont peut être déduite l'existence d'un danger d'incendie.

La même méthode peut servir à obtenir une carte de prévision de l'indice.

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1. Introduction.

Forest fire danger indices are frequently derived by combining a factor which integrates past weather (the drought or build-up) with recent and present weather. (Davis, 1959 and MacTavish, 1965). This paper deals mainly with methods which may be used to prepare charts of drought index or build-up index and describes the use to which such charts may be put.

2. The Calculation of Drought Index.

The integration of the effects of past weather for fire danger purposes has been accomplished in several ways, but the consensus today lies with a method which assigns a drying factor to each day; accumulates these as drought progresses, and reduces the sum so obtained by varying amounts when rain occurs. The result is called the Drought Index, or, in the United States, the Build-up Index.

The preamble to the Canadian Fire Danger Tables contains the statement that "The drought index is a cumulative index of the moisture content of a moderately deep full organic layer."

The National Fire Danger Rating System of the U.S. (Nelson, 1964) holds that "The build-up index reflects the dryness or wetness of fuels (other than fine flashy fuels) which have a pronounced effect on fire behaviour".

Neither of the above descriptions of the type of fuel to which the index applies is very precise, but the conglomerate is probably similar, for they arrive at approximately the same measure of cumulative drying.

Figure 1 shows the history of both indices for an industry station on southern Vancouver Island last year. The similarity of the two measures is obvious.

The question as to how well the index we are using reflects actual heavy fuel moisture is not part of this discussion. Suffice it to say that inadequacies are recognized and are being investigated. When the index is improved the chart should be that much more valuable.

3. Chart preparation.

The data plotted around each fire weather station contains the temperature, humidity and wind information necessary to arrive at the drying factor for the day. This factor is added to the index plotted on the previous chart at that station in order to arrive at the index for the current day. This is in turn plotted on the current chart. If rain has occurred, the amount which has fallen between chart times is used to reduce the

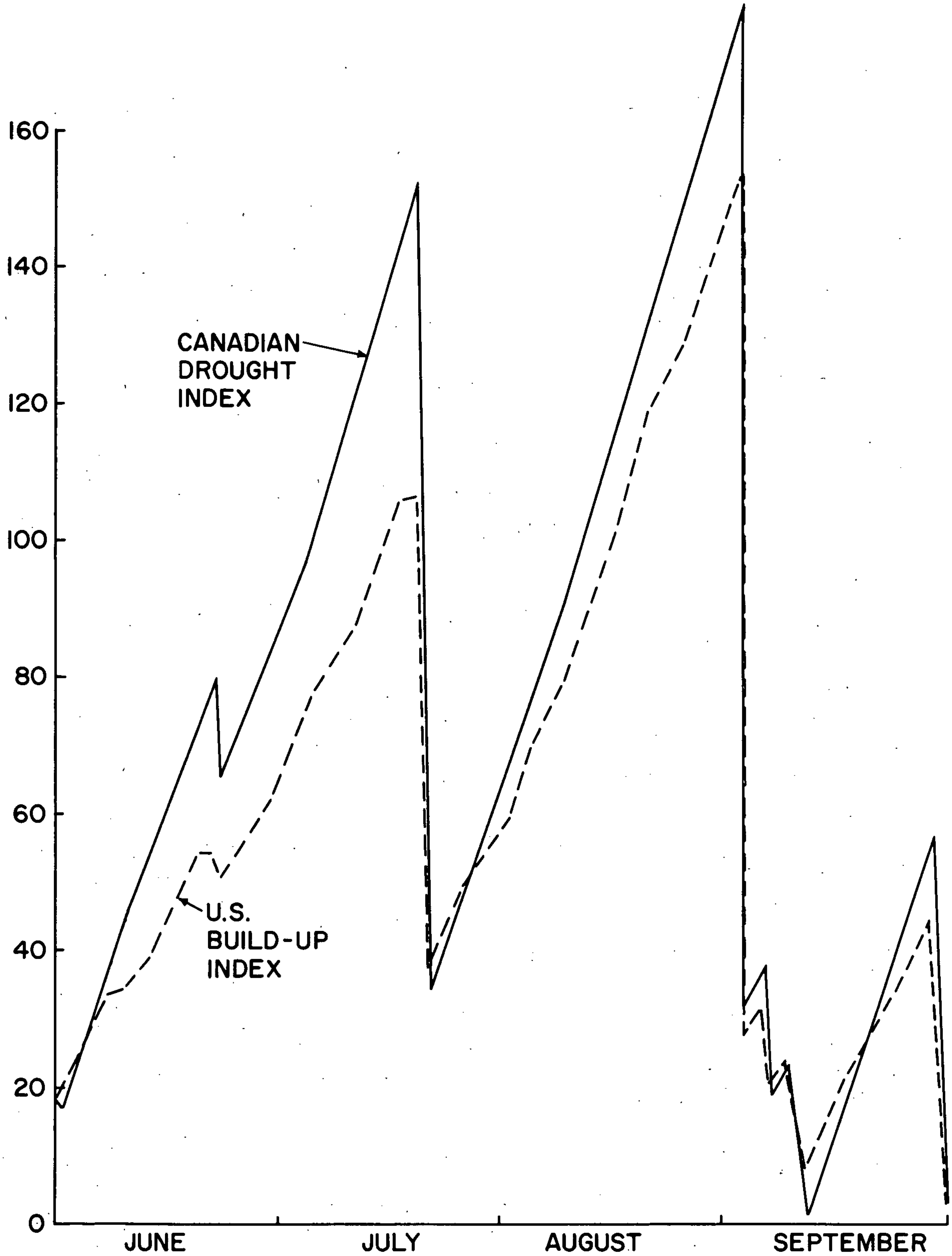
160
140
120
100
80
60
40
20
0
CANADIAN
DROUGHT
INDEX
U.S.
BUILD-UP
INDEX
JUNE
JULY
AUGUST
SEPTEMBER

Figure 1

the drought index as indicated by the tables. After the values have been plotted, lines of equal drought index are drawn, and a chart similar to figure 2 results. This is the drought index chart for the southern two-thirds of B.C. on August 15 last year.

Information from about 120 stations is available for preparation of the chart, but not all stations are equally useful for this purpose. On the coast, many stations are at sea level and do not reflect drying conditions a few miles away at an altitude 1500 to 3000 feet higher. Since the latter is the altitude range of most of the forest, care has to be taken to assess the drought index by reference to stations at the best altitude.

In the interior altitudes vary widely, and this is reflected in the complicated rainfall pattern, which is largely governed by terrain. Subjective estimates of the pattern of rainfall and consequently of the pattern of drought index must be made to allow for topography using the methods of synoptic climatology. Fortunately, we have at least one comprehensive study on which to base a rational method for such adjustment. (Walker, 1961)

Errors in assessing the pattern of rainfall in the interior may also be due to the showery nature of summer rain. This makes it difficult to get an accurate picture of drought conditions, for a heavy local shower at one of the reporting stations may distort the pattern badly.

Here again resort is made to subjective corrections, this time with the aid of rangers and lookout men in the district. Reports from the regularly reporting stations on the airways are examined to determine whether shower activity has been isolated or general, and if it appears that a misconception of actual conditions may be possible, the ranger is asked for his opinion as to the rainfall distribution in his district. He and his staff normally cover a considerable area in their daily travel, and they have many contacts who can assist in providing rainfall information. On this basis the drought index depletion by rainfall is adjusted. Some problems exist due to altitude in consideration of the daily drying factor too, because this factor depends on temperature humidity and wind, each of which varies with altitude. However, the differences here are minor when compared to rainfall discrepancies, and are disregarded.

Snow on the ground complicates things at the beginning of the fire season. The drought index is considered to be zero where snow is still on the ground, but snow may be on the ground in the forest and not at the lower elevation of the weather station. It would be very convenient to have all of our stations at the forest altitude, but the fact is that they are not, and allowance has to be made for this. Again the assistance of the ranger is asked in order that we be kept informed of the height of the snow line. Snow course reports of the Provincial Water Board are also for this purpose. In the far northern reaches of the province the receding snowline may be followed in satellite pictures, although care must be taken to compare several days in succession in order to minimize errors due to variations in contrast from day to day.

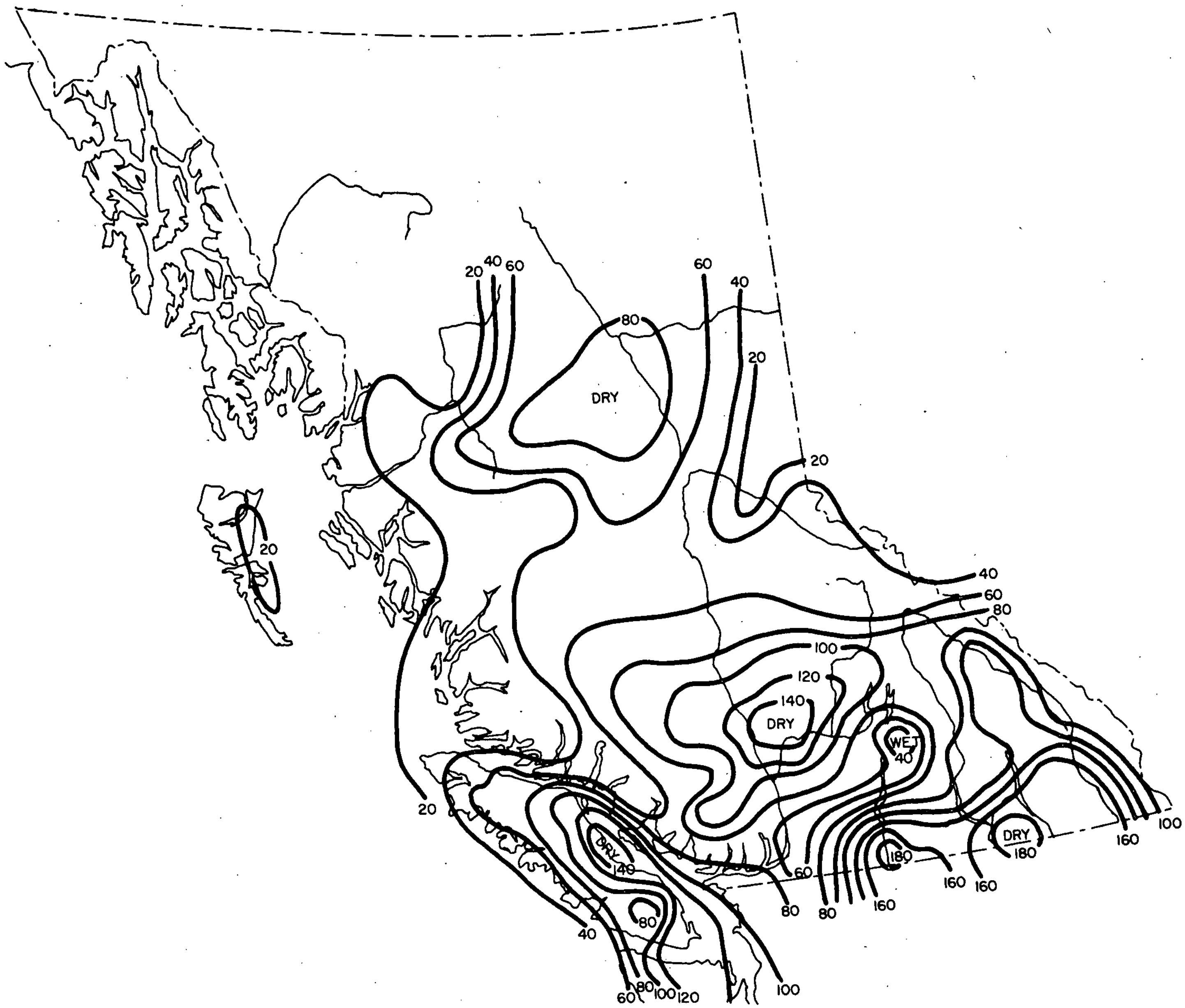

Figure 2
Drought Index Chart
for August 15, 1967

4. Chart Interpretation.

The chart gives an areal view of the distribution of drought index, and consequently a continuing daily picture of the effect that rainfall (or lack of it) is having on the heavier forest fuels.

However, the chart itself is not very meaningful unless it is compared with a chart of normal drought conditions for that time of year. Fire control officers must continually estimate potential fire load, and this can be assisted by a knowledge of how far drought conditions depart from normal.

Examination of climatological records will provide the necessary information on rainfall, temperature, humidity and wind that is required to compute normal values of the drought index for each month of the fire season. The normal chart for the end of July following a 7-day drought is shown in figure 3.

Graphical subtraction of the normal from the actual for August 15, 1967, gives the chart shown in figure 4. The method is the usual one of placing one chart above the other over a light table and drawing difference lines through the intersections. The result shows the distribution of above-normal and below-normal areas of drought index. Given normal conditions otherwise, this chart shows the departure from normal of the potential fire load.

However, it does not show the degree of departure from normal, and it may be advantageous to show the departure as a fraction of that normal. The result may provide a better perspective.

Figure 5 is a percentage departure chart, separating areas of below-normal drought index from those above normal. It also delineates those areas which are more than 50% above normal and more than double normal. To obtain it, successive subtractions of the current chart are made from charts of normal, 150% of normal and 200% of normal for the zero difference line only. Each additional percentage variation would require another "fraction of normal" chart and another subtraction.

5. Preparation of a chart of fire danger.

As indicated earlier, fire danger indices are frequently computed by combining an index of the moisture in the heavy fuels with another factor which measures the fine fuel moisture.

In the provisional Canadian system which is in use in the Vancouver fire weather office, the fine fuel moisture is expressed as a "drying code number", and the combination of this with the drought index provides what is called the "fire weather index". This combination may also be accomplished graphically, but the result is only an approximation because of the non-linearity of the sums. The basic technique used for the charts already described is adapted to make an addition instead of a subtraction.

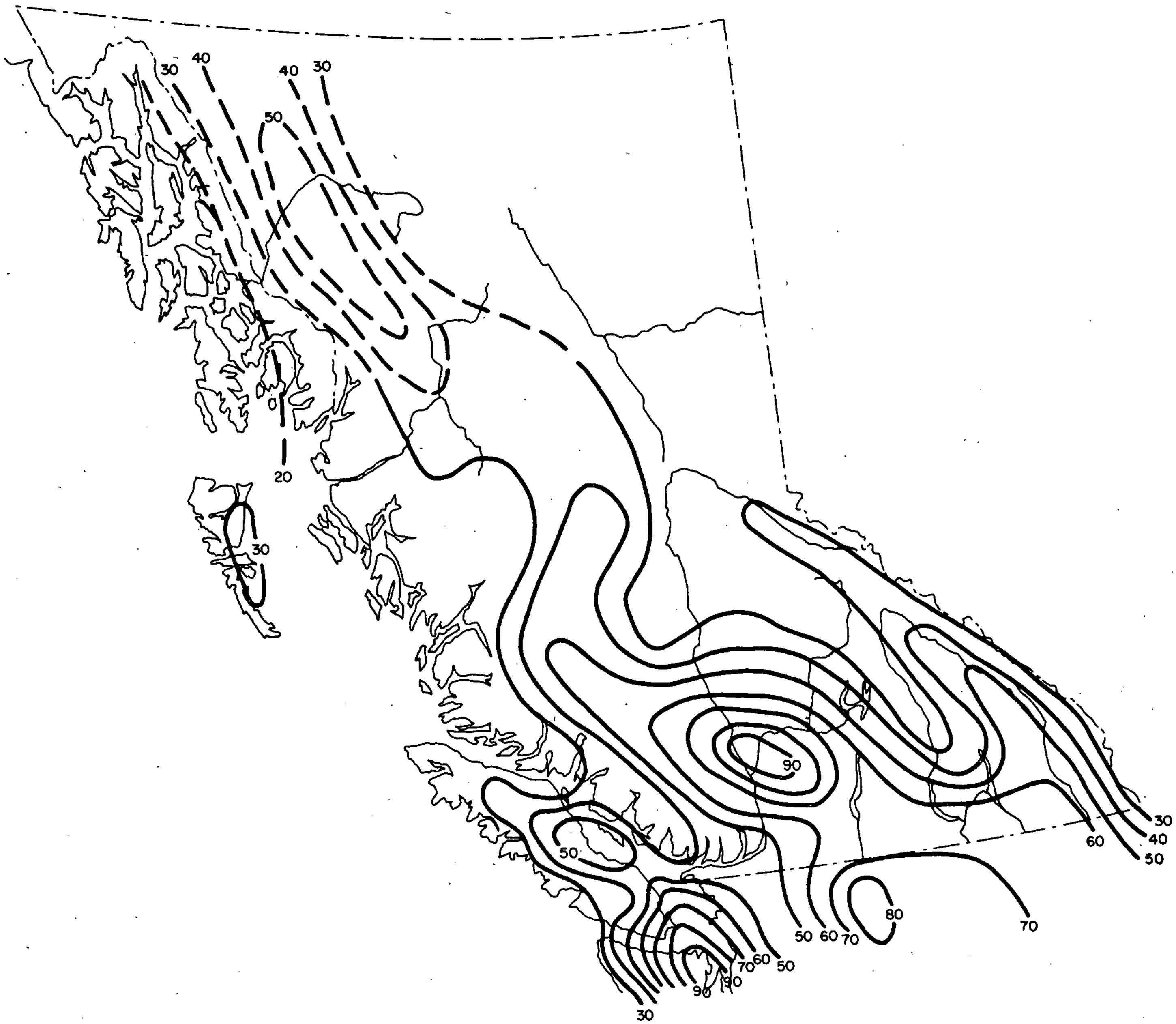

Figure 3
Normal Drought Index
for End of July After
a Seven-Day Drought

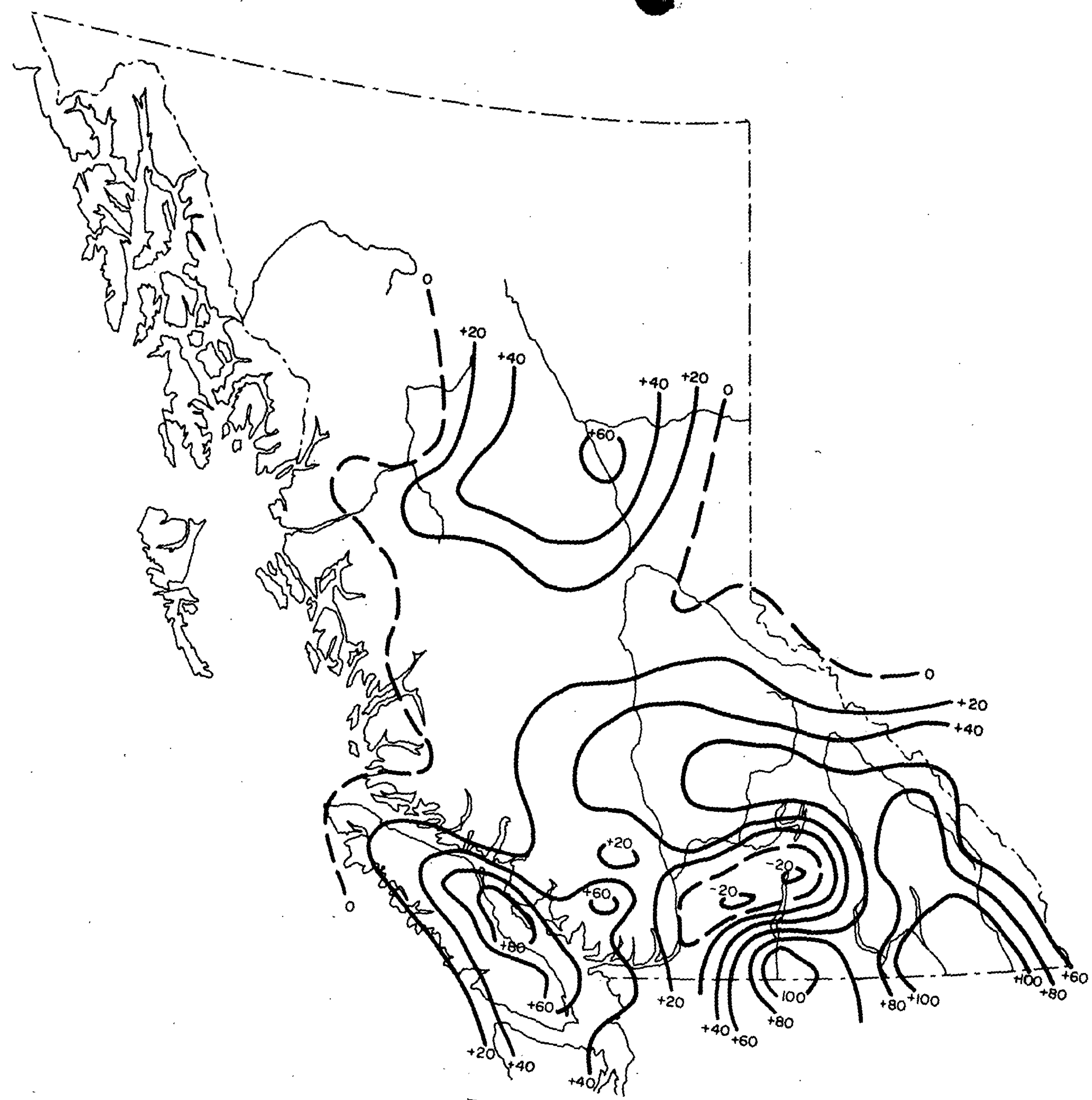

Figure 4
Departure of Drought
Index from Normal
August 15, 1967

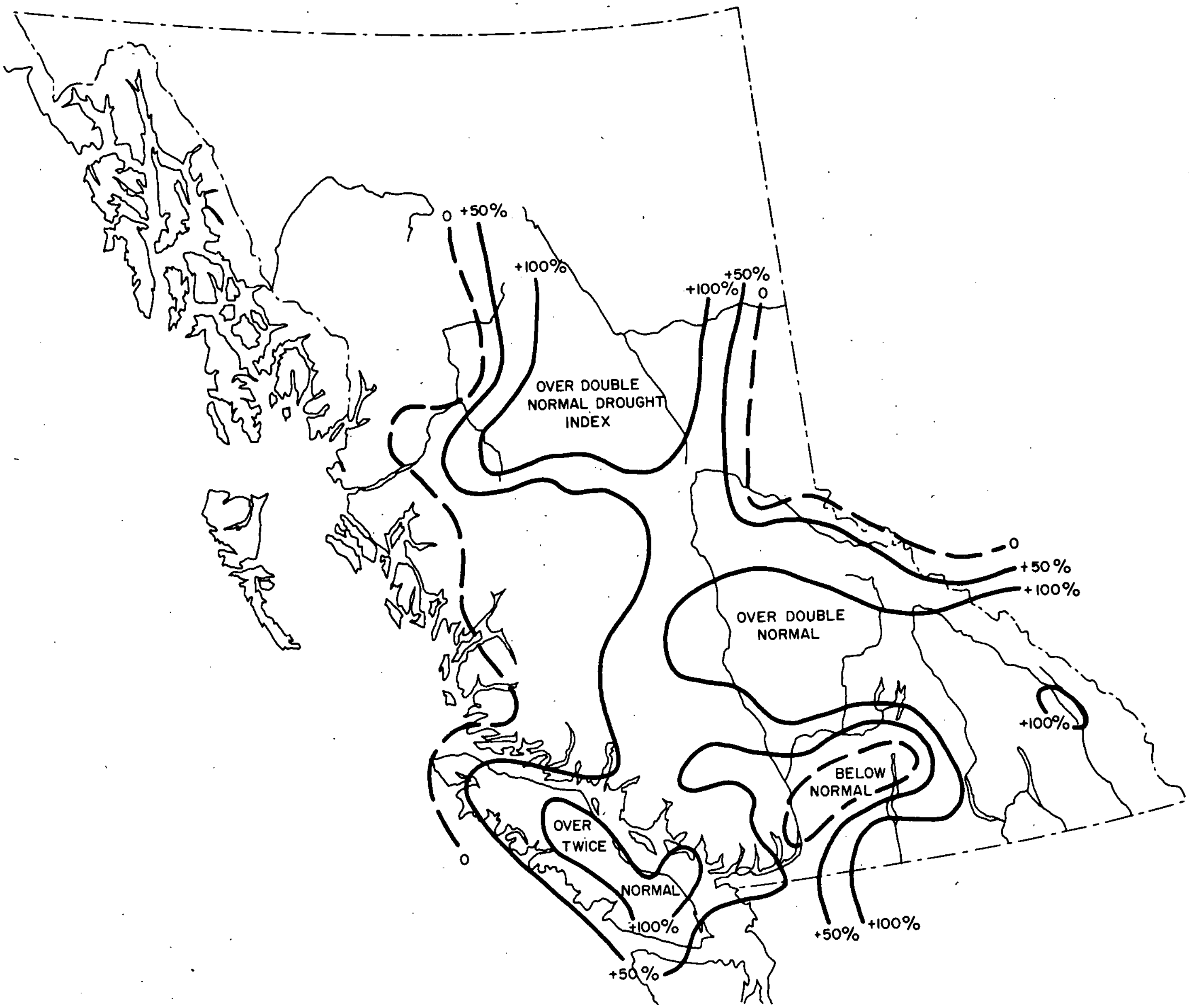

Figure 5
Percentage Departure
of Drought Index from
Normal, August 15, 1967

Figure 6 shows the pattern of fine fuel moisture in solid lines and the result of the combination of these values with the drought index pattern of figure 2 is shown in dotted lines. Both patterns must be interpolated at suitable values in order that the graphical combination may be accomplished. In this case the drying code number values were 81, 84, 88, 92 and 97, and the drought index values were 17, 20, 30, 43, 60 and 90. The combination provides preliminary values of the fire weather index, in the range from zero to 60. Another 40 points on this index (which has a range from zero to 100) is assigned to a wind correction, for which a table must be consulted. (See table 4, Appendix) The total is designed to be proportional to the potential fire load at any point.

In practice it is not found to be profitable to perform this combination. The interpolation requirement, the coarseness of the result at the higher values of fire weather index, the large wind correction, and the fact that this kind of combination makes no allowance for varying the weight put on the drought index as fuels vary all add up to a questionable return for time and effort spent.

Finally, it is possible to produce in like manner a forecast chart of fire weather index, but again the ratio of benefit obtained to effort expended is small. One must first produce a forecast of rainfall humidity and wind at a sufficient number of points that the pattern of change of drought index and fine fuel moisture may be forecast. Then it is necessary to draw prognostic charts of the two and combine them to arrive at a chart of forecast fire weather index uncorrected for wind. One might just as well forecast the fire weather index at each point.

6. Summary

Drought index charts have been prepared as fire weather office routine, and they have proven useful in showing the areal distribution of the effects of drought. Showery rainfall decreases their validity because of non-representativeness of the measured rainfall.

The distribution of drought index may be viewed as departure from normal by preparing normal charts of drought index and making a graphical subtraction of the normal from the actual. The departure may also be viewed as a percentage departure from normal by an extention of this technique.

The fine fuel moisture pattern may be added to the drought index pattern to achieve a preliminary picture of the fire weather index which must be corrected for wind. The same procedure may be used to obtain a forecast picture of this distribution, but the benefit likely to accrue from either of these procedures is small.

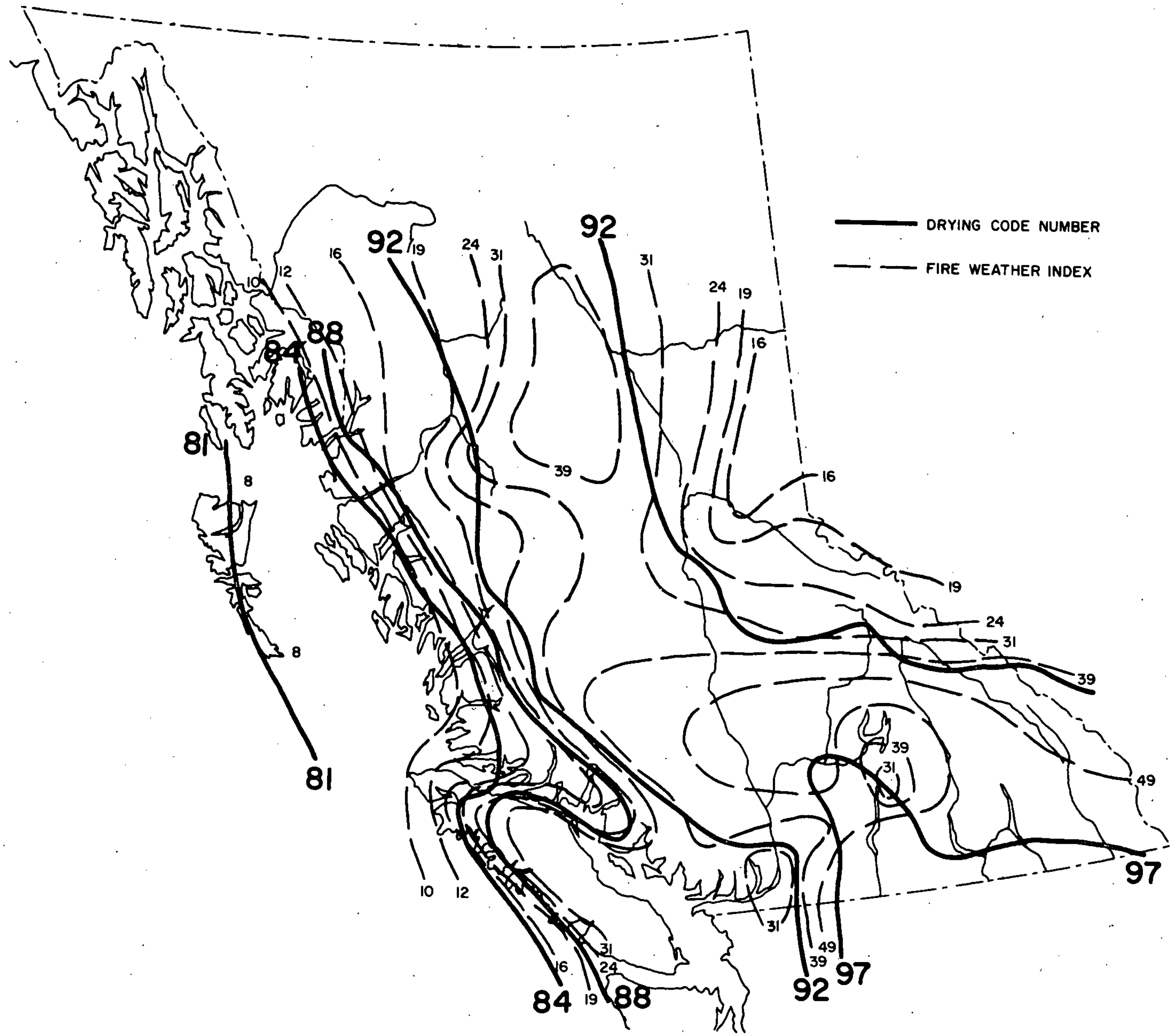

Figure 6
August 15, 1967
(The Difference Between the
Drying Code Number and 100
is the Fine Fuel Moisture)

The tables used for calculation of the drought index and the fire weather index are included in the Appendix. They are part of suggestions which have been made to provide a basis for research by the Canadian Forest Fire Research Institute.

APPROVED,

J.R.H. Noble,
Director,
Meteorological Branch.

7. References

(1) Davis, Kenneth P., 1959. Forest Fire Control and Use. McGraw-Hill Book Co., Inc.

(2) MacTavish, J.S., 1965. Forest Fire Danger Table (B.C. Coast) Canadian Department of Forestry, Ottawa, Ontario. Publication No. 1099.

(3) Nelson, R.M., 1964. The national fire danger rating system: Derivation of spread index for eastern and southern states. U.S. Forest Service Research Paper SE-13, Southeastern Forest Experiment Station.

(4) Walker, E.R., 1961. A Synoptic Climatology for Parts of the Western Cordillera. Scientific Report No. 8. Arctic Meteorology Research Group, McGill University, Montreal, Canada.

APPENDIX

Table 1.

DRYING FACTOR TABLE

R.H. %	Wind MPH	Temp. < 70	R.H. %	Wind MPH	Temp. 70+
<15	0-4 5+	3 4		all	4
16 to 35	0-10 11+	3 4		0-4 5+	3 4
36 to 65	0-4 5+	2 3	36 to 45	0-10 11+	3 4
66 to 75	0-10 11+	2 3	46 to 75	0-4 5+	2 3
76+	all	2		all	2

Table 2.

DROUGHT INDEX DEPLETION TABLE

	Drought index before rain																									
	0	3	10	17	24	31	38	45	52	59	66	73	82	91	100	109	118	127	138	149	162	175	188	201	214	227
to	2	9	16	23	30	37	44	51	58	65	72	81	90	99	108	117	126	137	148	161	174	187	200	213	226	239
Rainfall (inches)																										
.02 – .05	to account for the effect of .02 – .05 inches of rain subtract 1 from the Drying Factor.																									
.06 – .10	0	4	10	17	23	30	36	43	49	55	61	68	75	82	89	95	101	107	113	119	125	130	135	141	143	143
.11 – .15	0	2	9	15	21	28	34	40	45	51	57	63	69	75	81	86	91	97	100	106	110	114	117	119	121	123
.16 – .20	0	1	7	13	20	25	31	37	42	47	53	58	64	69	74	79	83	88	91	95	99	102	104	106	107	108
.21 – .30	0	0	5	11	17	22	28	33	38	43	47	52	57	62	67	71	74	78	81	84	86	89	90	91	92	93
.31 – .40	0	0	2	8	13	18	23	28	33	37	41	45	50	54	57	60	63	66	68	71	73	75	76	77	78	78
.41 – .50	0	0	0	5	10	15	19	24	28	32	35	39	43	46	49	52	54	57	59	61	62	64	65	65	66	66
.51 – .60	0	0	0	2	7	11	16	19	23	27	30	33	37	40	42	45	47	48	51	52	54	55	55	56	57	57
.61 – .80	0	0	0	0	3	9	11	14	17	20	23	26	29	32	34	36	37	39	41	42	43	44	45	45	46	46
.81 –1.00	0	0	0	0	0	1	4	7	10	13	15	18	21	23	24	26	27	29	30	31	32	32	33	33	34	34
1.01 –1.20	0	0	0	0	0	0	0	2	4	7	9	11	13	15	16	18	19	20	21	22	23	23	24	24	24	24
1.21 –1.50	0	0	0	0	0	0	0	0	0	0	2	3	5	7	8	9	10	11	12	13	13	14	14	14	15	15
1.51+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2

Table 3

FIRE WEATHER INDEX TABLE

Today's Drought Index	Today's Drying Code Number																																	
	50	55	60	65	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
	Uncorrected fire weather index																																	
0 - 2	0	0	0	0	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	4	4	4	5	5	6	6	7	7	8	8	9	10
3 - 5	0	0	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	7	7	8	8	9	10	10	11	12
6 - 8	0	1	1	1	1	2	2	2	2	3	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	8	9	9	10	11	11	12	13	14
9 -12	1	1	1	1	2	3	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7	8	9	9	9	10	11	12	12	13	14	15	16	17
13 -18	1	1	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	8	8	9	9	9	10	10	11	12	13	14	15	16	17	18	19	20
19 -24	1	2	2	2	3	4	4	5	5	5	6	6	7	7	8	8	9	9	10	10	11	12	12	13	14	15	16	17	18	19	20	21	23	24
25 -32	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	10	10	11	12	13	13	14	15	16	17	18	19	20	21	22	23	25	26	28
33 -40	2	3	3	3	4	5	5	6	6	7	8	8	9	9	10	11	12	13	14	15	15	16	17	18	19	20	21	23	24	26	27	29	30	32
41 -50	2	3	3	3	5	5	6	6	7	8	9	9	10	11	12	13	14	15	16	17	18	19	20	21	22	24	25	27	28	30	31	33	35	37
51 -60	2	2	3	3	5	6	7	7	8	9	10	10	11	12	13	15	16	17	18	19	21	22	23	25	26	28	30	31	33	35	36	38	40	42
61 -80	3	3	3	4	7	7	8	8	9	10	11	12	13	14	16	17	18	20	21	23	24	25	26	29	30	32	34	36	38	40	42	44	46	48
81 -99	3	3	4	5	8	9	9	10	11	12	13	14	15	16	18	19	21	22	24	26	27	29	30	32	34	36	38	41	43	45	47	49	51	54
100+	3	4	5	6	9	10	11	12	13	14	15	16	18	19	20	22	24	25	27	29	31	33	35	37	39	41	43	46	48	50	53	55	58	60

Table 4.
WIND CORRECTION TABLE

Wind m.p.h.	Today's uncorrected index																			
	0 to 3	4 6	7 9	10 12	13 15	16 18	19 21	22 24	25 27	28 30	31 33	34 36	37 39	40 42	43 45	46 48	49 51	52 54	55 57	58 60
	Addition to uncorrected index																			
0-3	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2
4-6	0	1	2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5	6	6
7-9	0	2	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	12	13
10-12	1	3	5	6	7	8	9	9	10	11	11	12	13	13	14	15	15	16	18	19
13-15	2	4	7	8	9	10	11	12	13	14	14	16	17	17	18	19	20	21	23	24
16-18	3	5	9	9	11	13	14	15	16	17	18	19	21	21	23	24	25	26	29	30
19-21	3	6	10	11	13	14	16	17	18	19	20	22	23	24	26	27	28	30	33	34
22-30	4	7	11	12	15	15	17	18	20	21	22	24	25	26	28	30	31	33	36	38
31+	4	7	12	12	15	16	18	19	21	22	23	25	27	28	30	31	32	34	38	40

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