

SUMMER CLIMATE OF THE HINTON-EDSON  
AREA, WEST-CENTRAL ALBERTA, 1961-1970

BY

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# *ABSTRACT*

The summer climate (May to September) is described for an area of west-central Alberta lying between latitude 52°50'N and 54°15'N and longitude 115°30'W and 119°05'W. The analysis is based on daily temperature and precipitation data for the decade 1961-1970 from 20 stations. Comparison of the 1961-1970 data from 3 long-term stations with data from two 3-year normal periods shows that the summer climate for the study period was generally representative. Seasonal and monthly values for the months May to September are given for the mean daily temperature, total precipitation, frequency of days with a mean temperature above -2.2°C, and water deficiency assuming a spring storage level of 100 mm. These variables, along with latitude, longitude, and elevation were used as input for a factor analysis. The factor scores were then used in a hierarchical grouping procedure, followed by discriminant analysis to give statistically stable groups. The most statistically significant variables were also used to aid in the positioning of climatic boundaries. Six macroclimate groupings were represented in the area; the mean and range of the 15 most important discriminating variables are given for each of these groups. The advantages of this classification of the area are compared with earlier published maps.

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# RÉSUMÉ

Les auteurs décrivent le climat estival (mai à septembre) d'une région du centre-ouest de l'Alberta sise entre 52°50' et 54°15' de latitude nord, et 115°30' et 119°05' de longitude ouest. Ils fondent leur analyse sur les températures et les précipitations journalières durant la décade 1961-1970 dans 20 stations météorologiques. En comparant les données de 1961-1970 à celles des décades précédentes observées dans 3 stations à long terme, s'échelonnent sur deux périodes normales de 30 ans, les auteurs concluent que le climat estival de 1961-1970 était généralement représentatif. Cet article fournit des données saisonnières et mensuelles de température moyenne journalière, précipitation totale, fréquence des jours à température moyenne supérieure à -2.2°C, et manque d'eau, assumant que le niveau printanier d'emmagasinement soit 100 mm. Ces variables, outre la latitude, la longitude et l'altitude, servirent à des analyses factorielles. Puis les auteurs utilisèrent les comptes factoriels pour produire un groupement hiérarchique, suivi d'une analyse des discriminants pour donner des groupes statistiquement stables. Les variables les plus (statistiquement) significatives aidèrent aussi à tracer les limites climatiques. Dans cette région, six macroclimats existent; pour chacun d'entre eux, les auteurs donnent la moyenne et la variation des 15 variables discriminatoires les plus importantes. Ils comparent les avantages, sur les cartes antérieurement publiées, de cette classification de la région.

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*INTRODUCTION*

Whether based on annual or summer data, existing climatic classifications of west-central Alberta generally divide the area into only one or two classes. The most widely accepted system is Köppen's, based on annual data, which classifies the whole area as a Sub-Arctic or Cold "snowy forest" climate (Longley 1970). Longley's map was based on temperature and precipitation data from the 1931-1960 period; however, an earlier map using 1921-1950 data (Canada Department of Mines and Technical Surveys 1957) shows the mountain area, excluding Jasper, as part of the Tundra zone where the mean temperature of the warmest month is below 10°C. Other maps such as Rheumer's (1953) have modified Köppen's classification by subdividing the area, especially parallel to the mountain ranges. Chapman and Brown's (1966) agriculturally oriented climatic zones, based on summer data, also separate the mountain fringe from the rest of the study area. The agro-climatic areas of Bowser (1967) divide the area into two zones by separating the north-eastern fringe from the balance of the area.

These earlier classifications are quite broad and yield little information on the local scale. They were also often based on predetermined class limits or were discipline-oriented, for example, for agriculture. As a result these classifications are inadequate for assessing forest land use productivity or for conducting or applying forestry research in this basically forested portion of Alberta. This study was therefore undertaken as background for an ongoing study of the climate of clear-cut forest areas and for other forest research studies on the pulpwood lease of the North Western Pulp and Power Company Limited, Hinton.

Selected climatic variables are discussed and a factor analysis approach is used to establish the homogeneous summer climatic zones or groupings present in the area. The factorial analysis approach provides a more rational statistical process of analyzing climatic data and more efficiently delimits climatic groupings and their boundaries than the classical or traditional a priori climatic classifications of Köppen and Thornthwaite.

The only long-term year-round stations in the area are Entrance, Jasper, and Whitecourt in the Athabasca River Valley and Edson in the McLeod River Valley. A few other stations have recorded year-round data for a few years only. Fortunately the Alberta Forest Service has maintained a dense network of summer fire weather stations in the area since the early 1960's which have taken daily observations of both precipitation and temperature. For this reason the present study was restricted to an analysis of climate during the months May to September inclusive for the years 1961-1970. Data from three of the long-term stations (Edson, Entrance, Jasper) for the 1961-1970 period are compared with data from two 30-yr normal periods to establish the representativeness of the summer climate for the 10-yr study period.

Although trees are perennial and have to survive the whole year, this 5-mon summer period is particularly important because it includes the whole of the growing season. Analysis of this summer climate information should therefore prove useful for forest growth and other forestry-related studies.

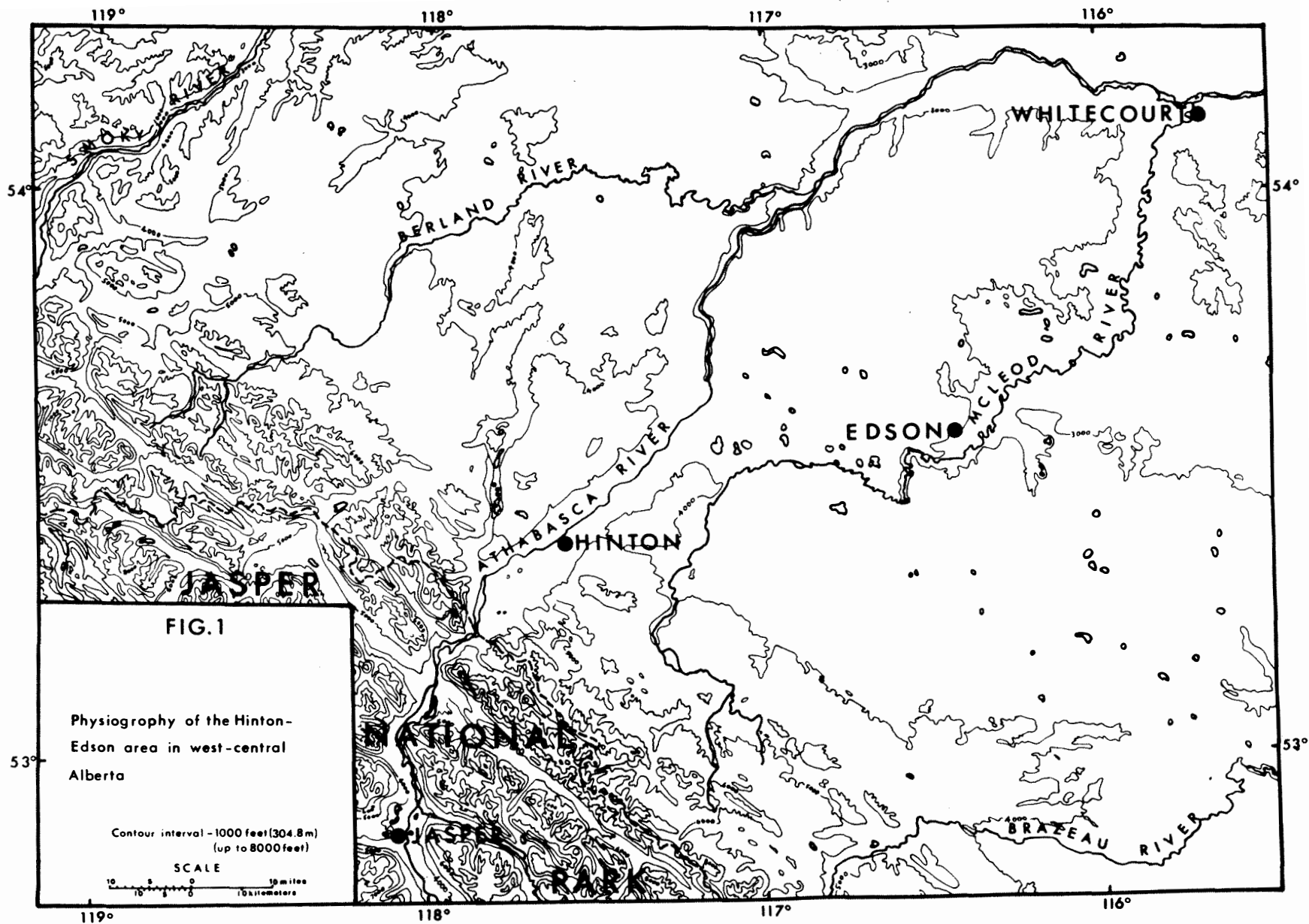
*METHODS AND MATERIALS*

The study area included that portion of west-central Alberta lying between latitude 52°50'N and 54°15'N and longitude 115°30'W and 119°05'W, centered on the lease area of the North Western Pulp and Power Company. The area includes the southeast to northwest trending ranges of the Rocky Mountains in the southwest and portions of the Upper and Lower Foothills Regions. The Athabasca River flows through the area from the southwest to the northeast. Figure 1 shows the physiography of the area with elevations above sea level shown at 305-mm (1000-ft) intervals. The lowest land lies to the east of Edson and around Whitecourt in the northeast. Most of the lease area lies between 918 m (3000 ft) and 1524 m (5000 ft). In the southwest the ranges of the Rocky Mountains rise to 3000 m in Jasper National Park. Most of the lease area falls within the Lower Foothills (B 19a) and Upper Foothills (B 19c) sections of the Boreal Forest Region (Rowe 1972). A small portion centered near Jasper lies within the Douglas-fir and lodgepole pine section (M.5) of the Montane Forest Region, while most of the mountain ranges lie within the East Slope Rockies section of the Subalpine Forest Region.

Figure 2 shows the boundary of the pulpwood lease area and the location of all climatological stations in the area that have recorded precipitation and temperature data at any time up to the end of 1969 (Canada Department of Transport 1970). Table 1 lists all the stations by latitude, longitude, and elevation, and gives the years during which precipitation and temperature data were collected up to 1970 (Canada Department of Transport 1970).

For the study only stations with a minimum of 6 yr of precipitation and temperature data during the decade 1961-1970 were





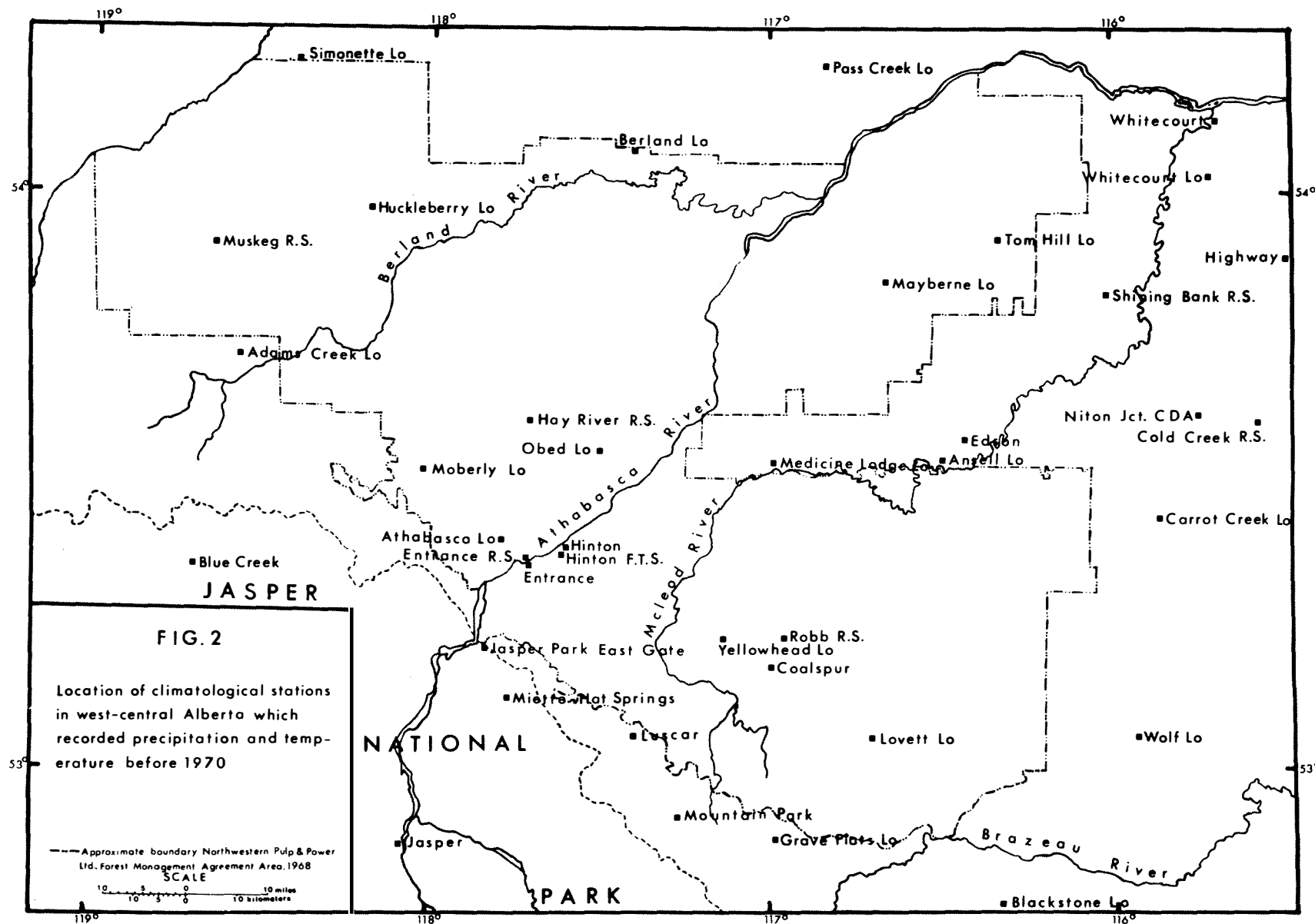


TABLE 1. Climate stations within the study area and the years they have reported temperature and precipitation records up to 1970

Station Name	Lat. °N	Long. °W	Elev. m	Temperature	Precipitation
*ADAMS CREEK LOOKOUT	53 43	118 34	2210	1962-3, 65-70	1962-70
ANSELL LO.	53 31	116 21	957	1962-70	1960-70
*ATHABASCA LO.	53 25	117 47	1631	1965-70	1954, 1956-70
*BERLAND LO.	54 05	117 24	1219	1966-70	1958-70
BLUE CREEK	53 19	118 47	-	-	1941-44
COALSPUR	53 11	117 00	1173	1913-4, 1922-38	1913-4, 1922-38
*COLD CREEK R.S.	53 37	115 35	792	1962-67, 69-70	1962-67, 69-70
*CARROT CREEK LO.	53 27	115 52	1043	1939-56, 65-70	1939-70
EDSON	53 35	116 25	923	1914, 16-27, 29-60	1914, 16-27, 29-60
*EDSON	53 35	116 25	925	1960-70	1960-70
*ENTRANCE	53 22	117 42	1006	1917-27, 29-70	1917-27, 29-70
ENTRANCE R.S.	53 22	117 43	983	1968-70	1968-70
*GRAVE FLATS LO.	52 51	117 00	2074	1963-70	1960-70
HAY RIVER R.S.	53 37	117 42	1158	1964-5	1964-5
HIGHWAY	53 55	115 32	823	-	1969-70
HINTON	53 24	117 33	1013	1956, 58-68, 70	1956, 58-68, 70
HINTON FTS	53 24	117 35	1021	1963-70	1963-70
*HUCKLEBERRY LO.	53 59	118 11	1429	1965-70	1958-70
JASPER	52 53	118 09	1058	1914-27, 29-31	1914-27, 29-31
*JASPER	52 53	118 04	1061	1926-70	1926-70
JASPER PARK EAST GATE	53 14	117 58	-	-	1940
*LOVETT LO.	53 05	116 41	1445	1965-70	1939-70
LUSCAR	53 02	117 20	-	-	1923-25
*MAYBERNE LO.	53 52	116 40	1490	1962-70	1939-70
*MEDICINE LODGE LO.	53 33	117 00	945	1962-70	1962-70
MIETTE HOT SPRINGS	53 07	117 46	-	-	1940
MOBERLY LO.	53 33	118 02	1647	1967-70	1967-70
MOUNTAIN PARK	52 56	117 17	1186	1915-17, 19-24	1915-17, 19-24
*MUSKEG R.S.	53 55	118 39	1226	1962-70	1962-70
NITON JUNCTION CDA EPT	53 37	115 42	838	1967-70	1967-70
*OBED LO.	53 34	117 30	1585	1963-70	1958-70
*PASS CREEK LO.	54 14	116 50	1135	1966-70	1953-70
*ROBB R.S.	53 14	116 58	1130	1965-70	1965-70
SHINING BANK R.S.	53 48	116 17	914	1967-70	1967-70
*SIMONETTE LO.	54 14	118 25	1274	1966-70	1956-70
TOM HILL LO.	53 56	116 20	1295	1966-70	1966-70
*WHITECOURT	54 08	115 40	741	1942-70	1942-70
*WHITECOURT LO.	54 02	115 43	1201	1939-42, 44-70	1939-43, 44-70
*WOLF LO.	53 09	115 54	1098	1962-70	1956-70
*YELLOWHEAD LO.	53 14	117 09	1483	1965-70	1957-70

\* Stations used in the analysis

Data source: Canada Department of Transport 1970.

considered for selection. In addition a few stations (e.g. Ansell Lookout, Hinton, and Hinton FTS) were not included if a nearby station had a more complete record for the period. Initially 22 stations were considered and these are indicated by a asterisk in Table 1. Daily climatological data were obtained on magnetic tape from the Atmospheric Environment Service, Environment Canada for each station for the period 1961-1970, except that the 1970 data from the forestry stations was obtained separately on tape from the Alberta Forest Service.

The World Meteorological Organization recommends the use of a 30-yr period for establishing standard climatological normals ending with the last year of the previous decade, e.g. 1941-1970. Landsberg and Jacobs (1951) suggested that a 25-yr period for temperature and a 50-yr period for precipitation amounts was generally required in mountainous terrain to obtain a stable frequency distribution, and a shorter period (15 and 40 yr respectively) on more level terrain. Court (1968), however, has shown that a 10- to 15-yr period gives reliable results for most climatic parameters in most areas. In a companion study using stations throughout the Prairie Provinces, long-term stations such as Calgary and Edmonton were used to check that the selected data period (1961-1970) attained the degree of stability inherent in 30-yr normals and did not differ significantly from the long-term normal value. This was done by calculating the cumulative mean temperature and cumulative totals of precipitation for each of the months May to September, and their standard deviations over the period 1941-70, beginning with 1970. It was assumed that the minimum data period required is indicated when the accumulated mean approaches the 30-yr mean value and secondly when the standard

deviation about the mean is at a minimum. The analysis showed that a data period of 10 yr or less for both temperature and precipitation for the tested stations is sufficient. The selection of a 10-yr period for this study was therefore considered satisfactory, and allowed for a greater density of stations to be considered.

The statistical analysis procedures used for the macroclimate grouping require complete sets of daily observations for each station for the period 1961-70 from May to September inclusive. Stations with missing data must either be eliminated from further statistical analysis or an attempt must be made to generate the missing data. The latter approach was followed, and it was necessary to generate missing data for several of the forest fire weather stations, especially for portions of May and September when they are often closed. A paired station method was used, comparing data from a neighbouring climatic station with complete data to a station with incomplete data. A curvilinear regression equation was calculated based upon the comparable data points and this relationship was used to generate data for the incomplete station. A subsequent analysis of variance test verified the significance of the regression equation. A third order polynomial regression was used to generate missing values for temperature, precipitation, and frequency of days  $>-2.2^{\circ}\text{C}$ . The stations of Carrot Creek Lookout and Medicine Lodge Lookout were eliminated from further analysis because the generated precipitation data failed to satisfy the F ratio requirements at the 95% confidence level. Muskeg Ranger Station also showed only fair correlation for the generated frequency of days  $>-2.2^{\circ}\text{C}$  for May and September but was

retained in the analysis.

The macroclimatic grouping analysis formed part of a larger companion study involving over 300 stations covering the forested areas of the three Prairie Provinces. A full report on the overall study is presently under preparation. Earlier phases of this study have been briefly reported in other publications (Powell and MacIver 1975a,b). A preliminary factorial analysis of summer climate, but using different programs in the final stages, and including the present area of interest for the years 1954-1968 has also been reported (MacIver 1970; MacIver et al. 1972). Further details of the methods employed for the complete analysis can be found in these publications. Briefly, an R-mode factor analysis, having as input the 22 climatic variables for each station, identifies the significant factors which account for a large percentage of the total variance. The coefficients generated in the rotated factor matrix, in combination with the input variables for each station, yield weighted indices per station in the form of factor scores. These independent normalized factor scores are then used as input into a hierarchical grouping program. This program indicates the optimal number of groups for delineating climatic regions and also shows the linkage of stations in successive stages of the hierarchy. Finally, Wilk's Lambda test is used in the discriminant analysis program for significance testing of the classification scheme and identification of the major discriminating variables between climatic groups, which are then used to aid in the positioning of group boundaries.

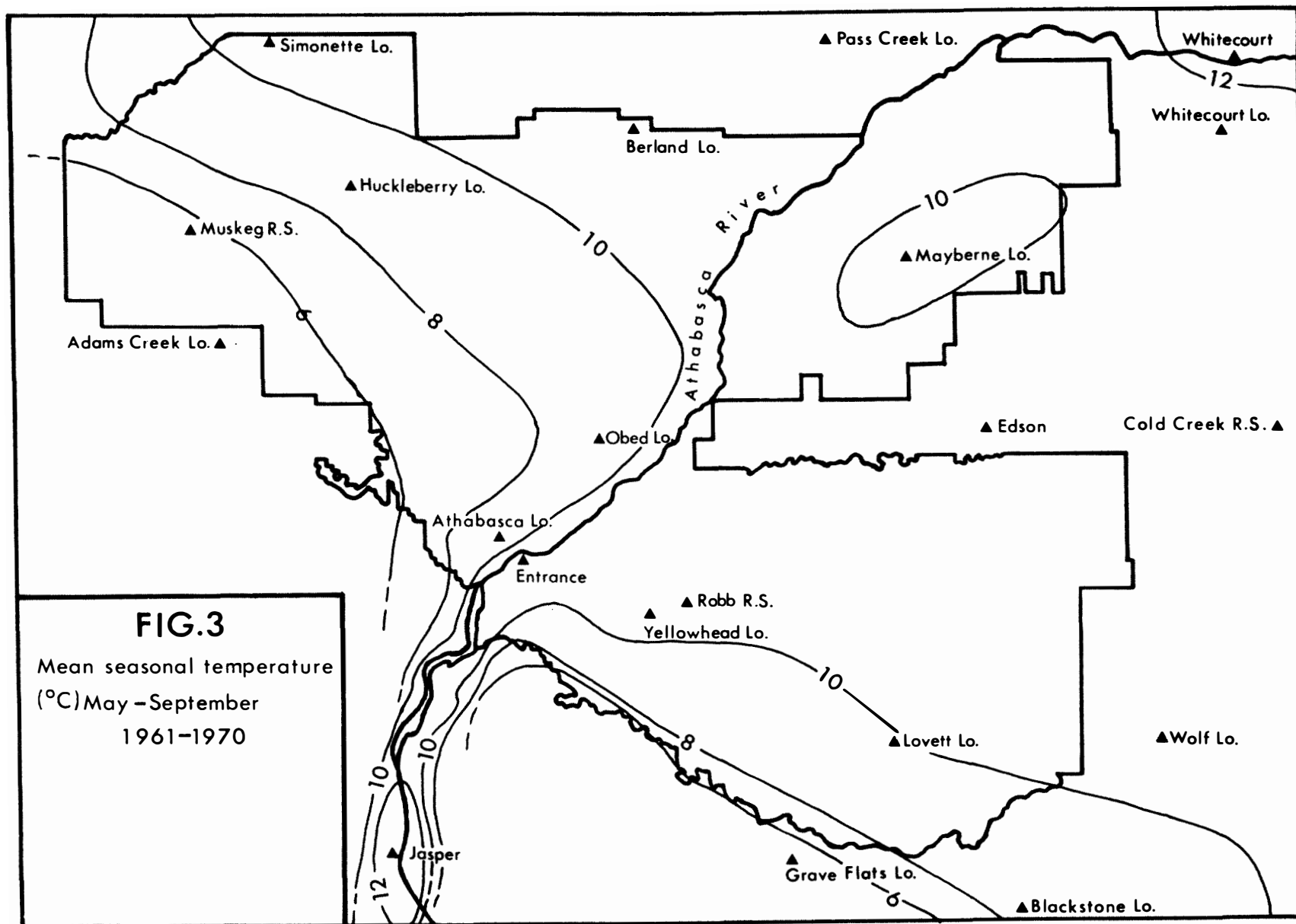
In previous studies using factor analysis (Powell and MacIver 1975a,b) it was found that monthly values for four climatic variables, plus those of elevation, latitude, and longitude, were the most statisti-

cally significant variables for defining and characterizing the climate of an area. Values for the mean daily temperature for the months May to September, total precipitation for the months May to September, frequency of days with a mean temperature above  $-2.2^{\circ}\text{C}$  ( $28^{\circ}\text{F}$ ) for the months May to September, and water deficiency for the months June to September were therefore obtained for this study. The variables of temperature and precipitation (the raw data for the analysis) provided the general and traditional variables utilized in most classification models to represent and define the climate of a region. The two additional variables of frequency of days  $>-2.2^{\circ}\text{C}$  and water deficiency values represent limiting climatic factors allowing for a stratification of climatic variations within a region. The  $-2.2^{\circ}\text{C}$  ( $28^{\circ}\text{F}$ ) mean temperature was chosen because values below it are considered to be killing frosts for most sensitive vegetation. Water deficiency values were calculated using Thornthwaite's Water Balance technique but adjusted for a 7-mon period from April to October assuming a soil moisture storage level of 100 mm (4 in.) per year by the end of March for each of the stations.

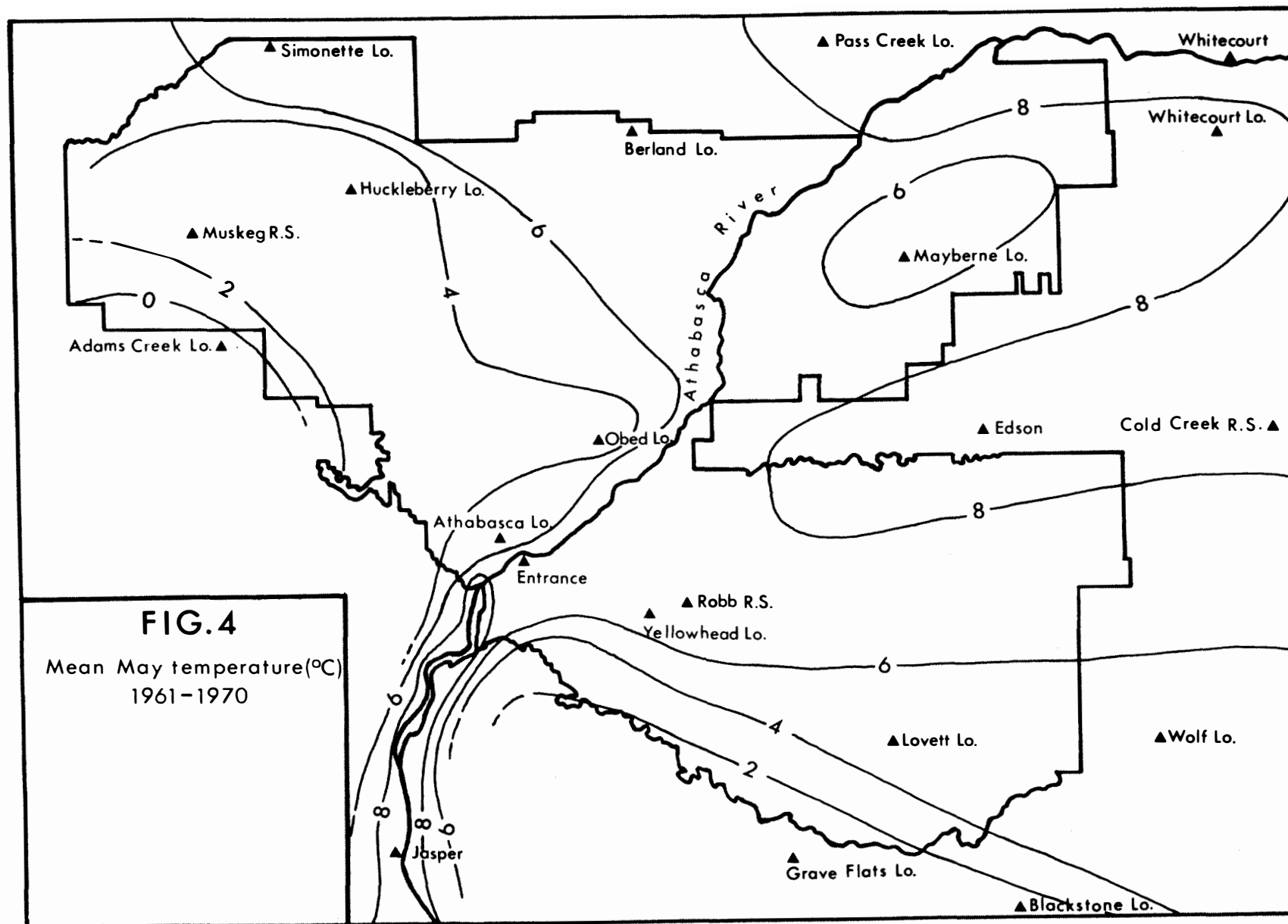
## *RESULTS AND DISCUSSION*

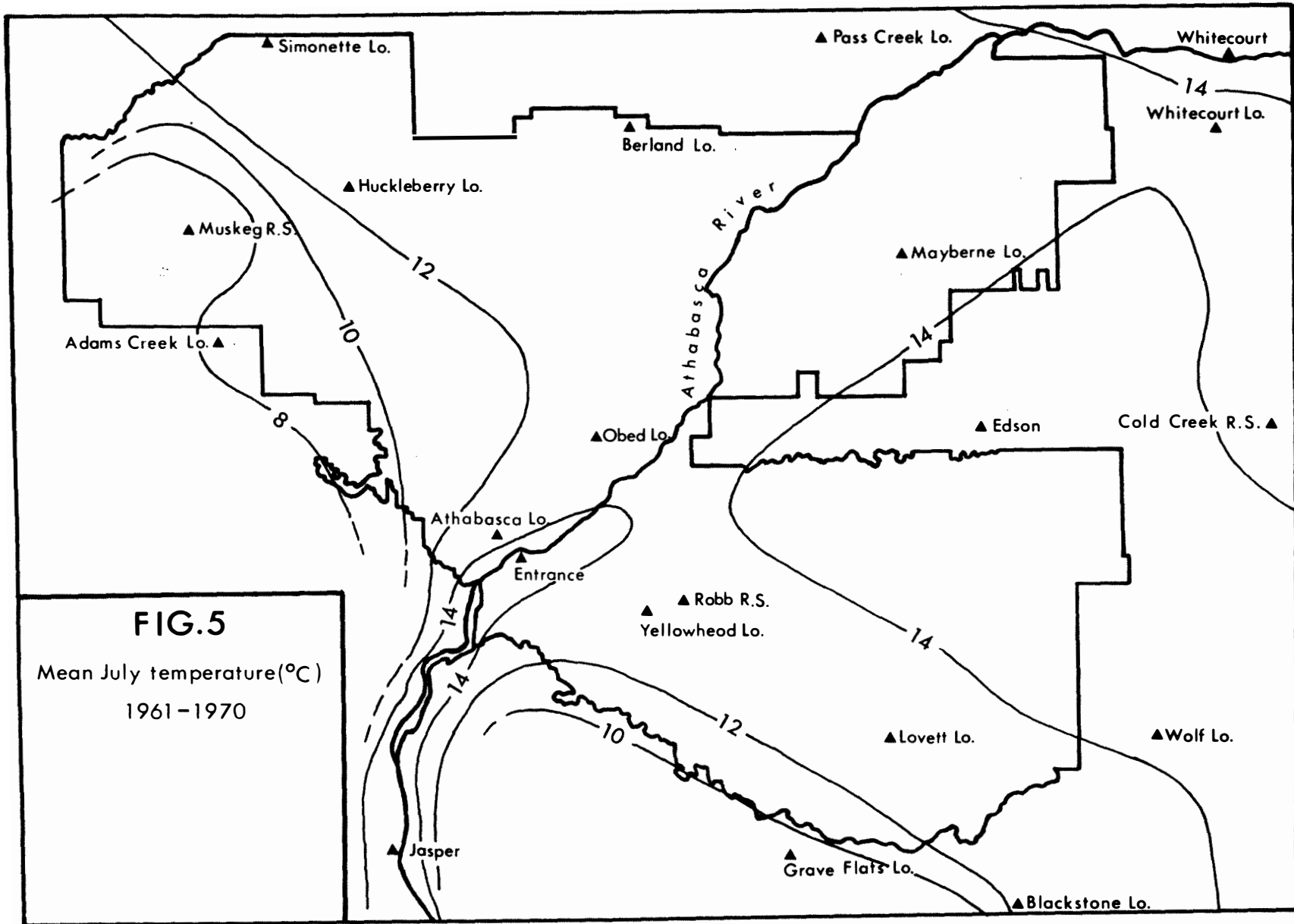
### TEMPERATURE

Seasonal daily mean temperatures for the period May to September inclusive are shown in Fig. 3. The warmest station in the area is Jasper, closely followed by Whitecourt; both stations are located in a major river valley. As would be expected the coolest stations are at the higher elevations in the foothills or front ranges of the Rocky Mountains at Adams Creek ( $4.2^{\circ}\text{C}$ ), Grave Flats ( $5.9$ ), and Muskeg R.S. ( $5.3$ ). Generally most of the study area has summer seasonal temperatures between









**FIG.5**

Mean July temperature(°C)  
1961-1970

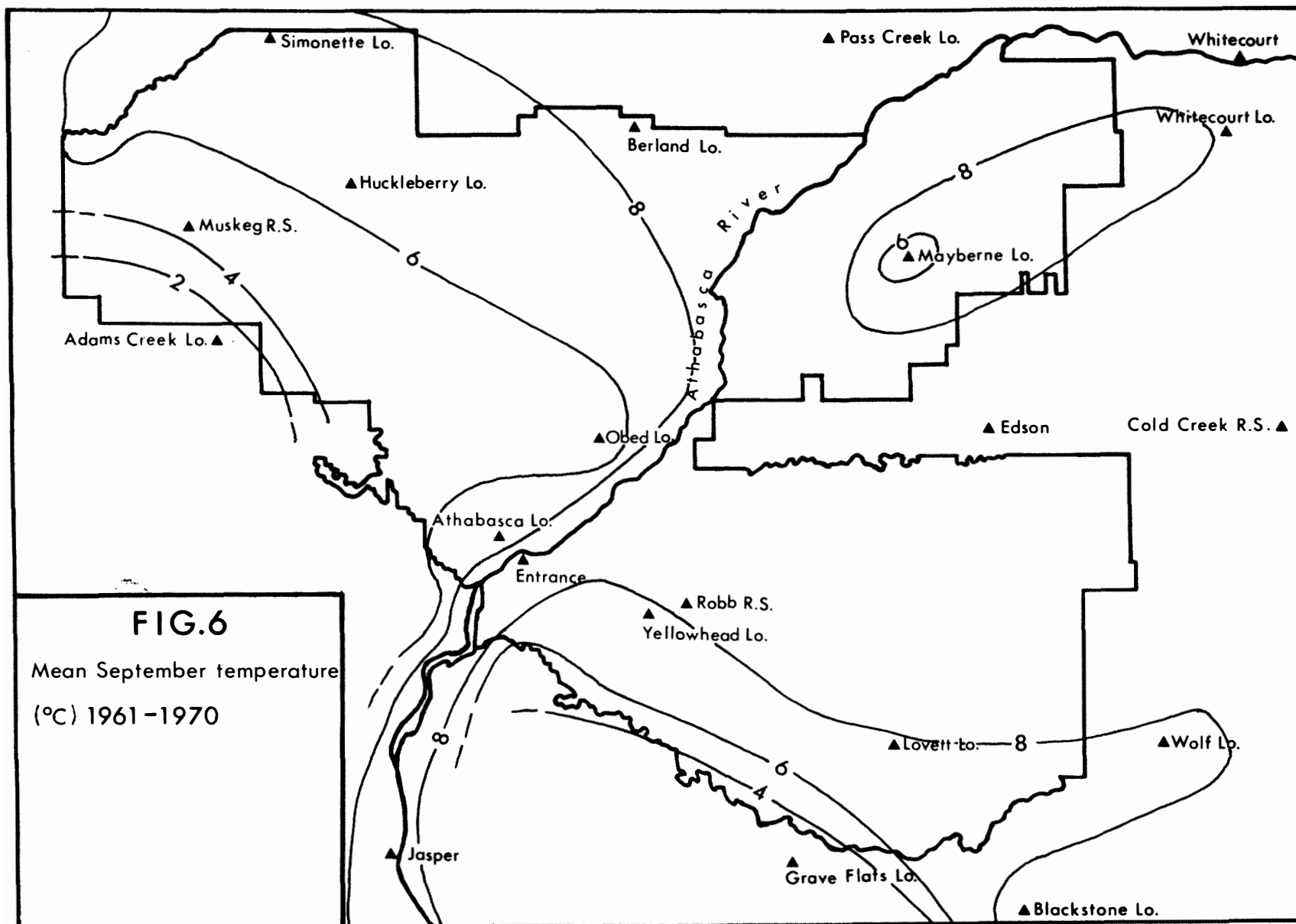
8 and 12°C.

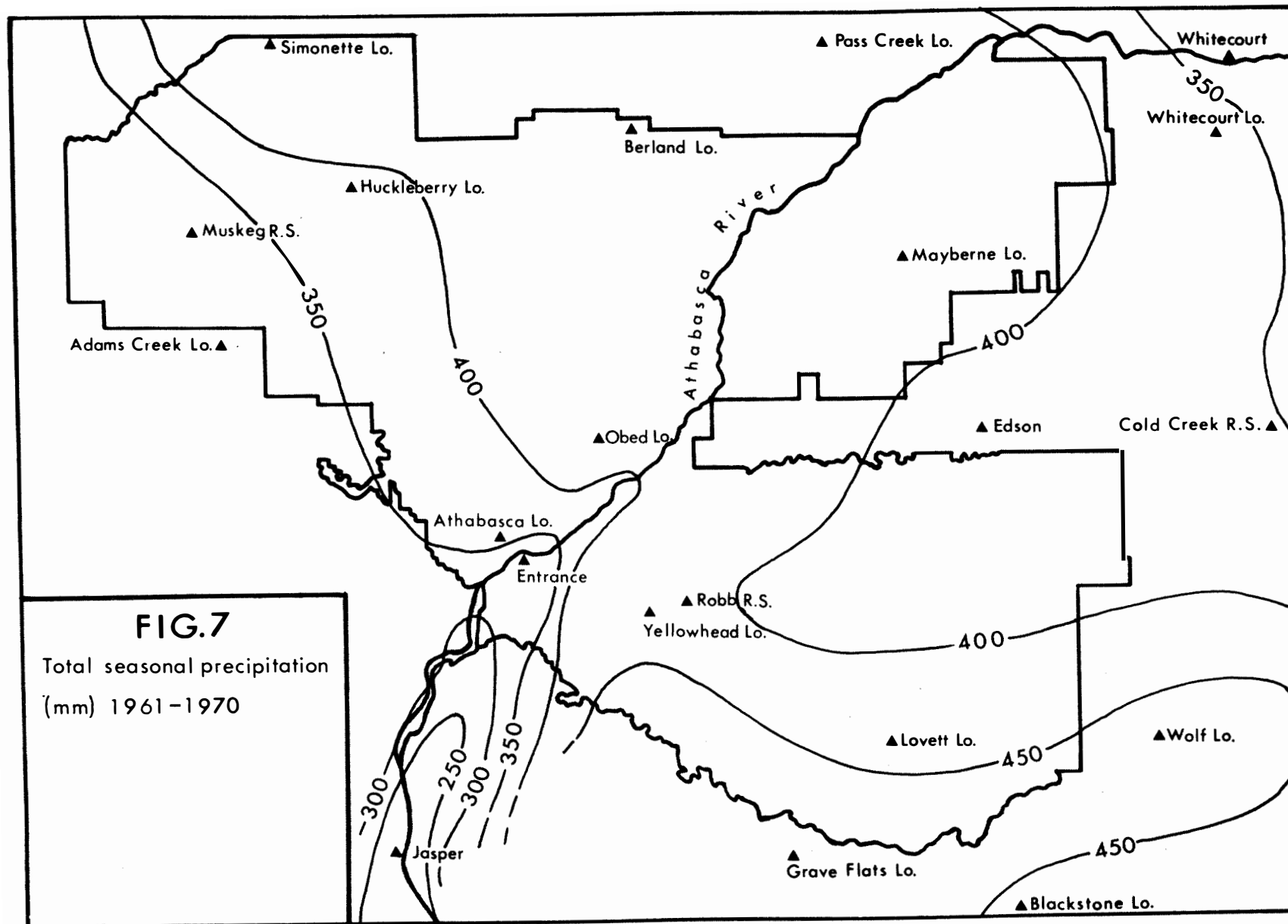
Similar temperature patterns over the area are experienced in the individual summer months (Figs. 4, 5, 6). In May there is a considerable temperature gradient from the Foothills northeastwards (Fig. 4). Temperatures remain fairly cool at the higher lookout stations because of snow cover for much of the month. The mean temperature at Adams Creek is still below 0°C. June temperatures at almost all stations are 4-6° higher than in May. Exceptions to this are found at Cold Creek R.S. and Muskeg R.S. where increases are respectively 1.7 and 2.7°. Maximum daily mean temperatures occur in July (Fig. 5) at all stations, except Muskeg R.S. which has a maximum in August. Jasper and Whitecourt are the warmest, with mean temperatures of 15.2°C. Most of the July mean temperatures on the lease area range between 12 and 14°C. Temperatures in September (Fig. 6) are 3-7° cooler than those in August, with the larger decreases occurring at the higher lookout stations such as Adams Creek, Obed, and Mayberne, where snow is often present by the end of the month.

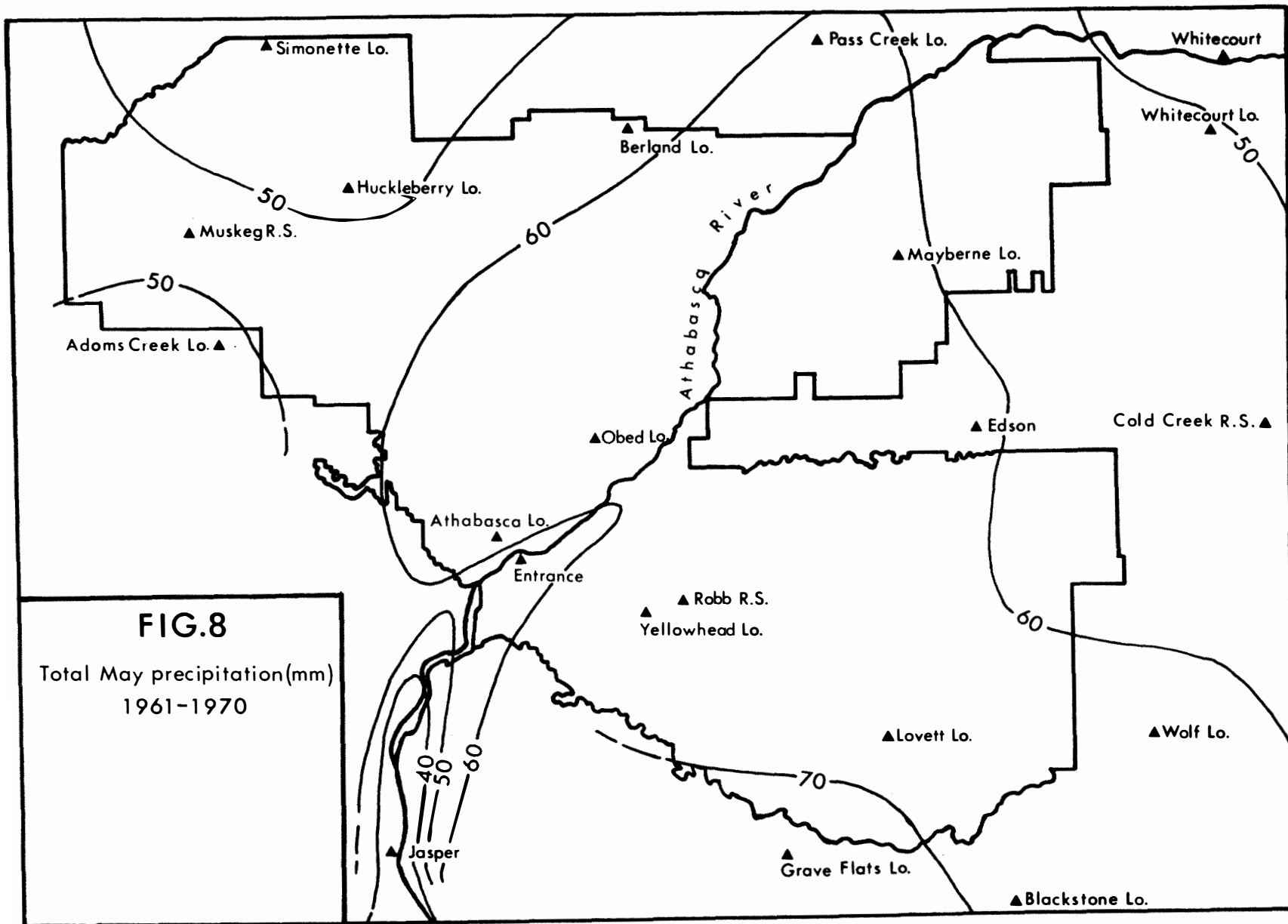
Because of the absence of climate stations in the mountains east and northwest of Jasper isolines for temperature and other climatic variables for these portions of the study area are missing or tentative.

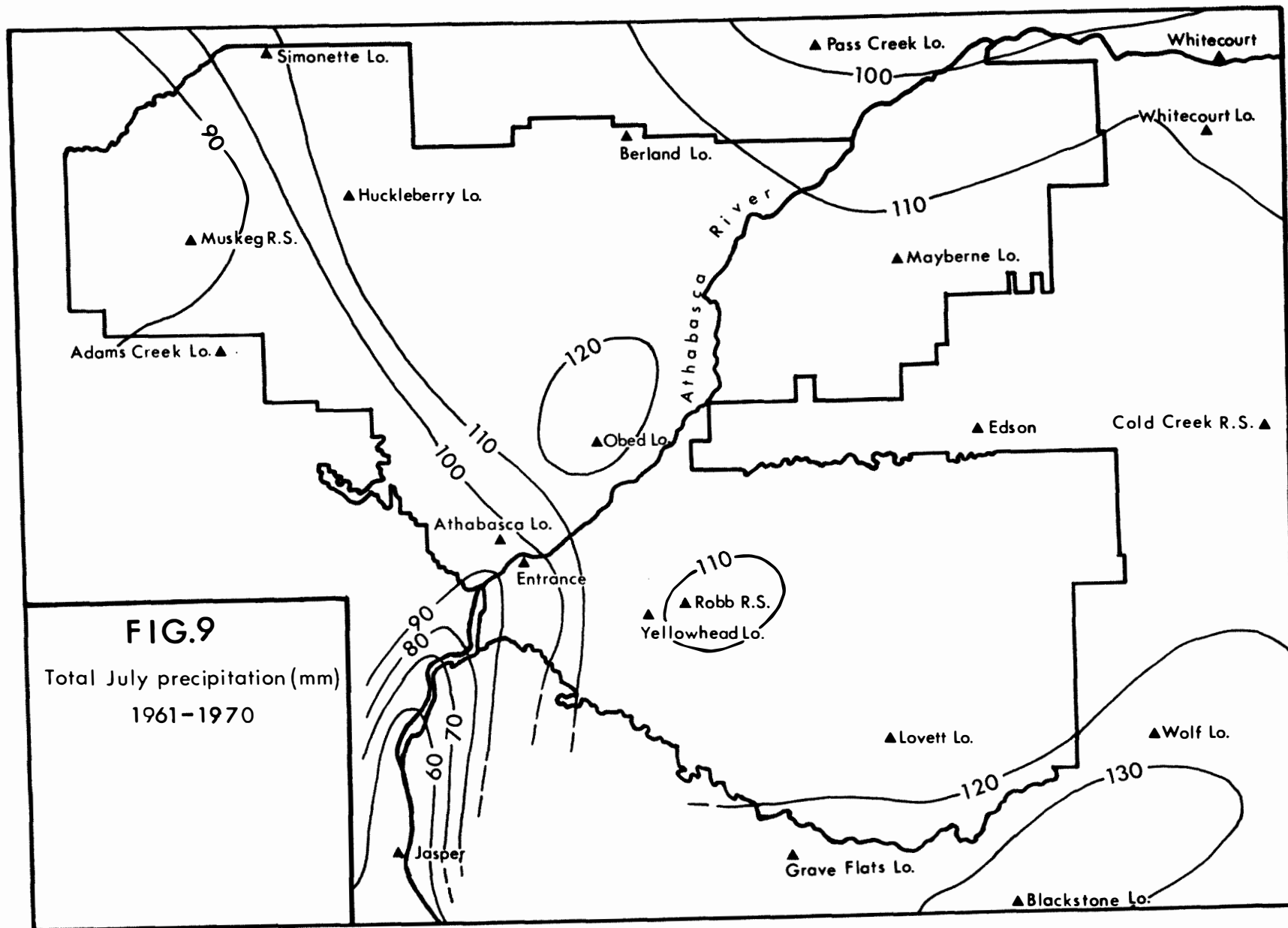
#### PRECIPITATION

The seasonal total precipitation for the period May to September varies from a low of 200 mm at Jasper to over 465 mm at Grave Flats and Wolf Lookouts (Fig. 7). North of the Athabasca River there is an increasing gradient from 325 to over 430 mm, but in the southeastern part of the area the gradient of precipitation decreases from over 470 to 350 mm at Cold Creek. Total summer precipitation over most of the lease area ranges between 380 and 430 mm. Jasper appears to be in a marked rain shadow location since in all summer months it has the lowest precipitation total.









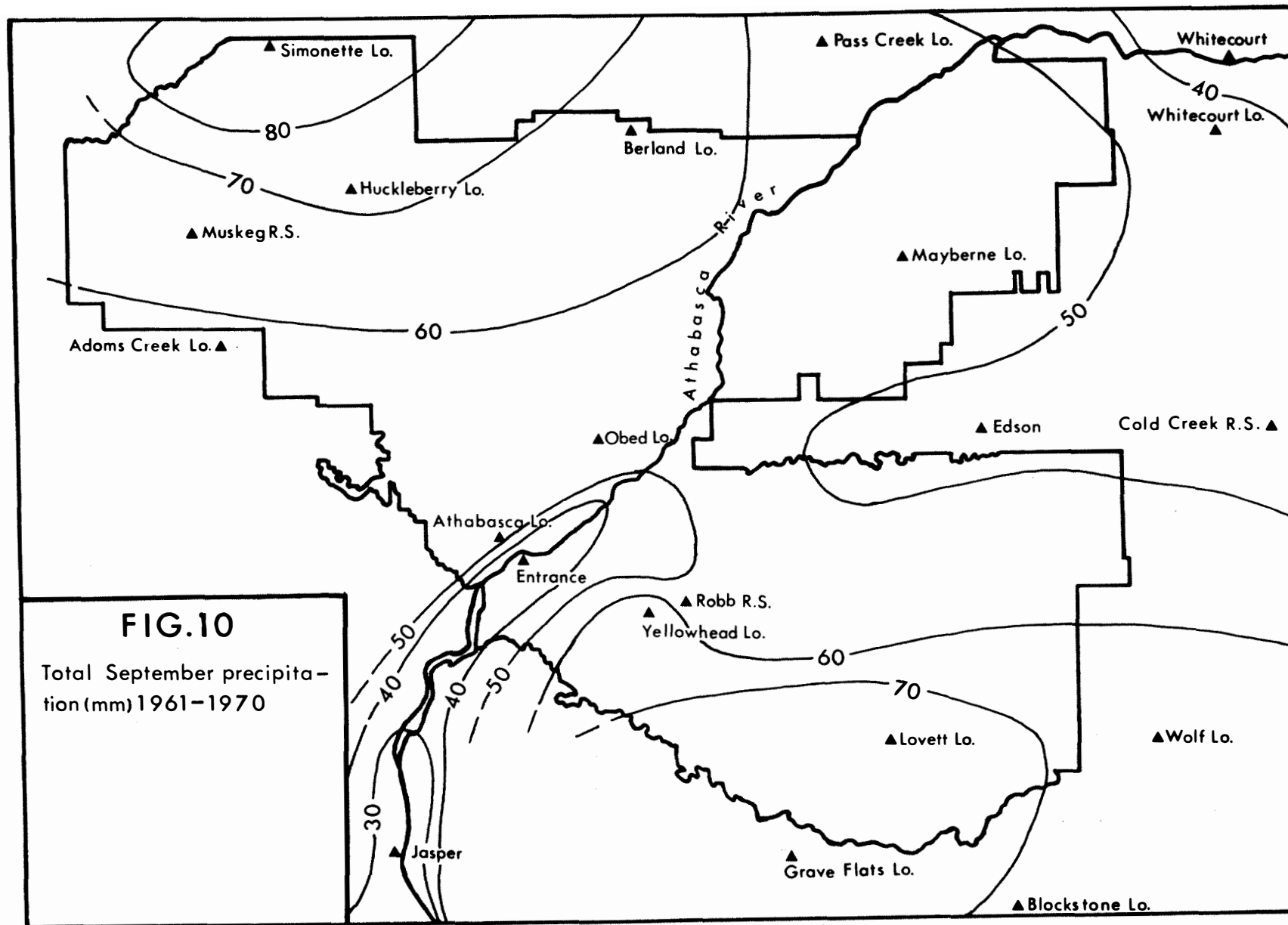
July is the wettest month. Most of the area receives 100-130 mm, with the exception of the western portion which at Jasper receives less than 60 mm (Fig. 9). August is the second wettest month, with all of the area receiving 70-110 mm except Jasper. May (Fig. 8) and September (Fig. 10) are the driest summer months, with few stations having more than 70 mm. Some areas are drier in one of these months than the other. In May the stations west and north of the Athabasca River with the exception of Pass Creek have lower totals than in September, but in September stations such as Cold Creek, Entrance, Edson, Robb, and Whitecourt have lower totals than in May. The other stations have very similar totals in the two months. Totals in June are usually intermediate between the two drier and two wetter months. June totals at Cold Creek, Grave Flats and Wolf, however, were slightly higher than August totals.

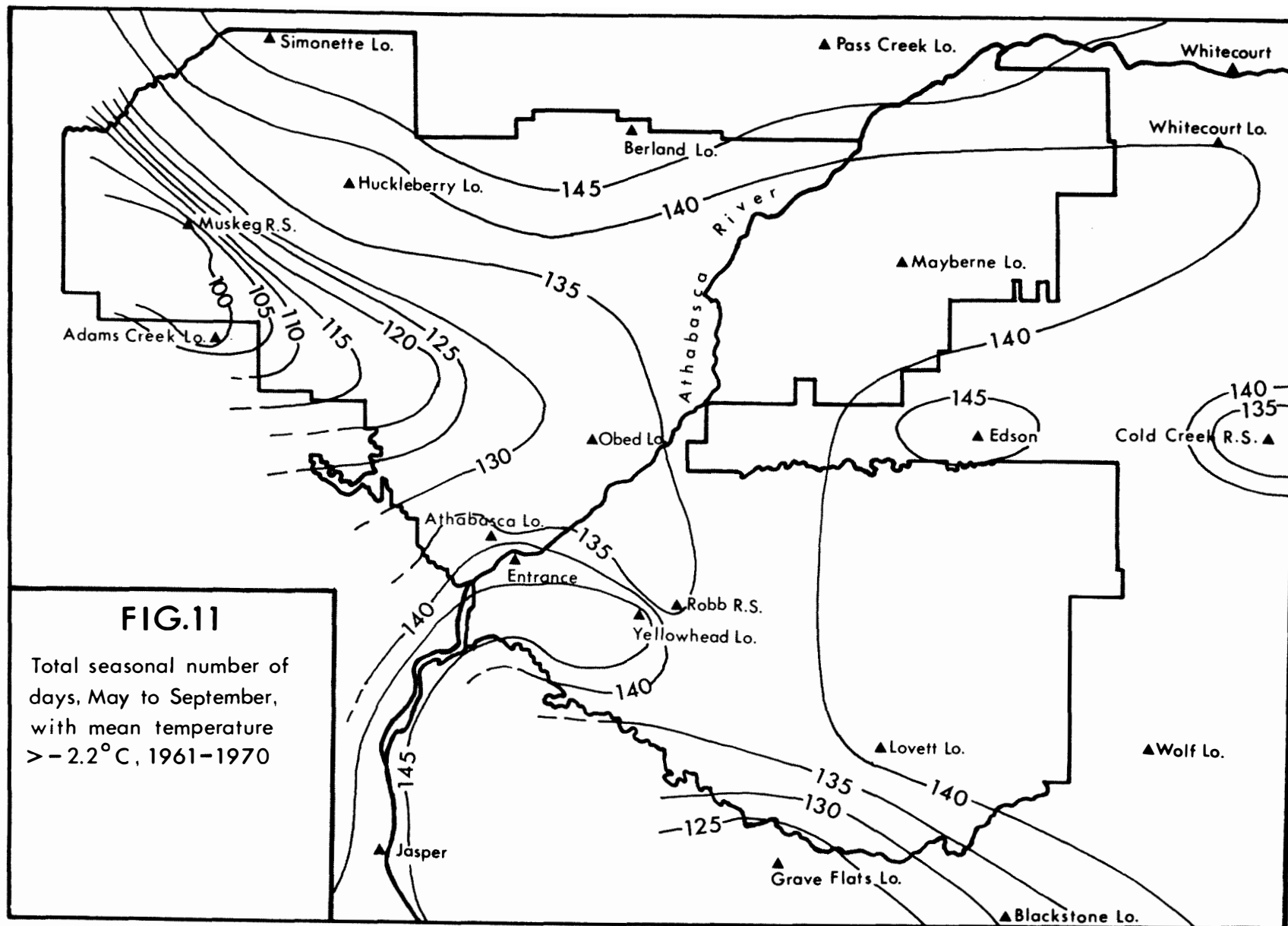
#### FREQUENCY OF DAYS WITH MEAN TEMPERATURES HIGHER THAN $-2.2^{\circ}\text{C}$

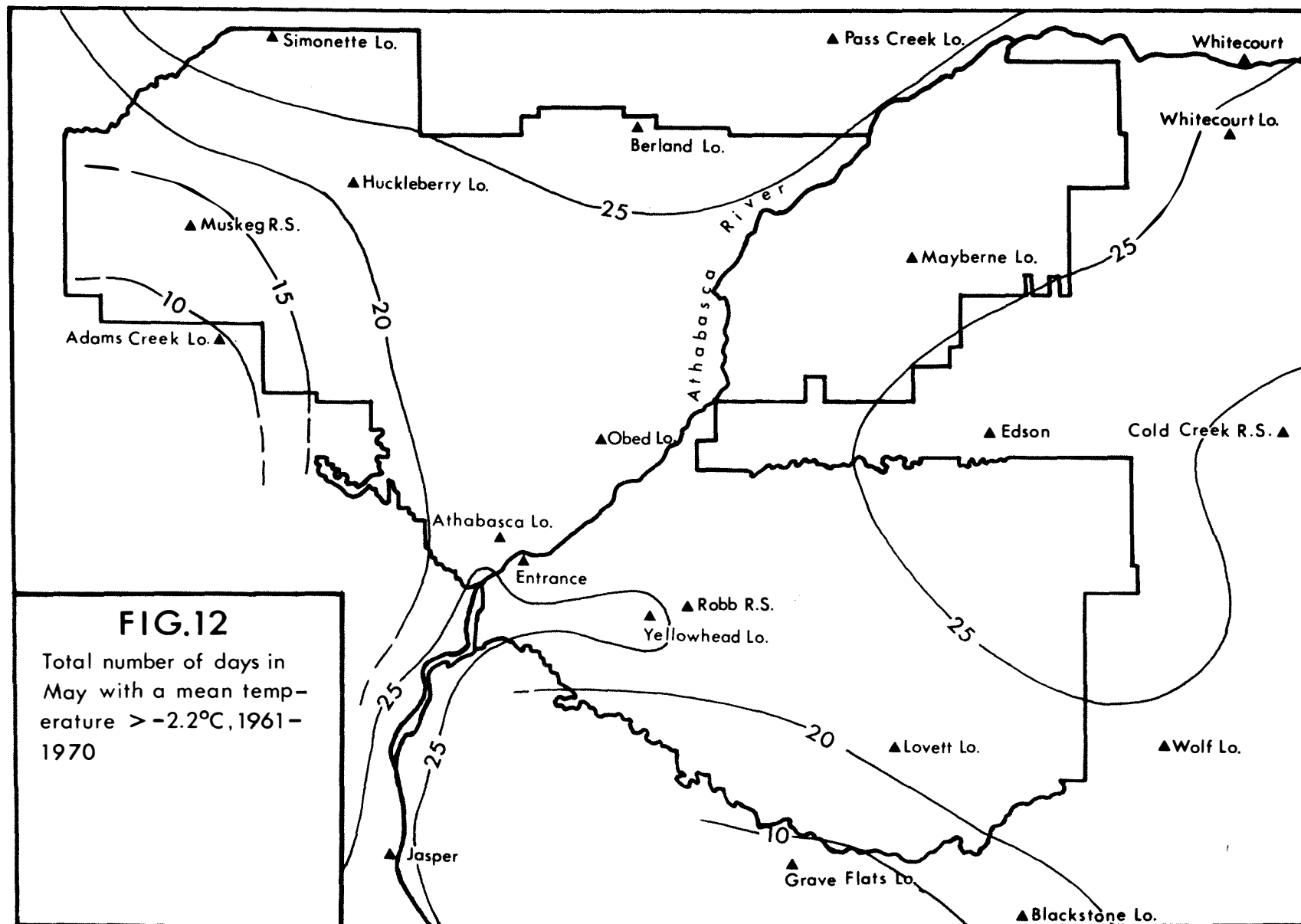
Seasonally most of the lease area has over 130 days with mean temperatures above  $-2.2^{\circ}\text{C}$  (Fig. 11). Exceptions occur at the higher elevations of Grave Flats (121), Adams Creek (100), and Muskeg (99). The northern stations of Simonette, Berland, and Pass Creek, along with Jasper and Yellowhead, have totals above 145.

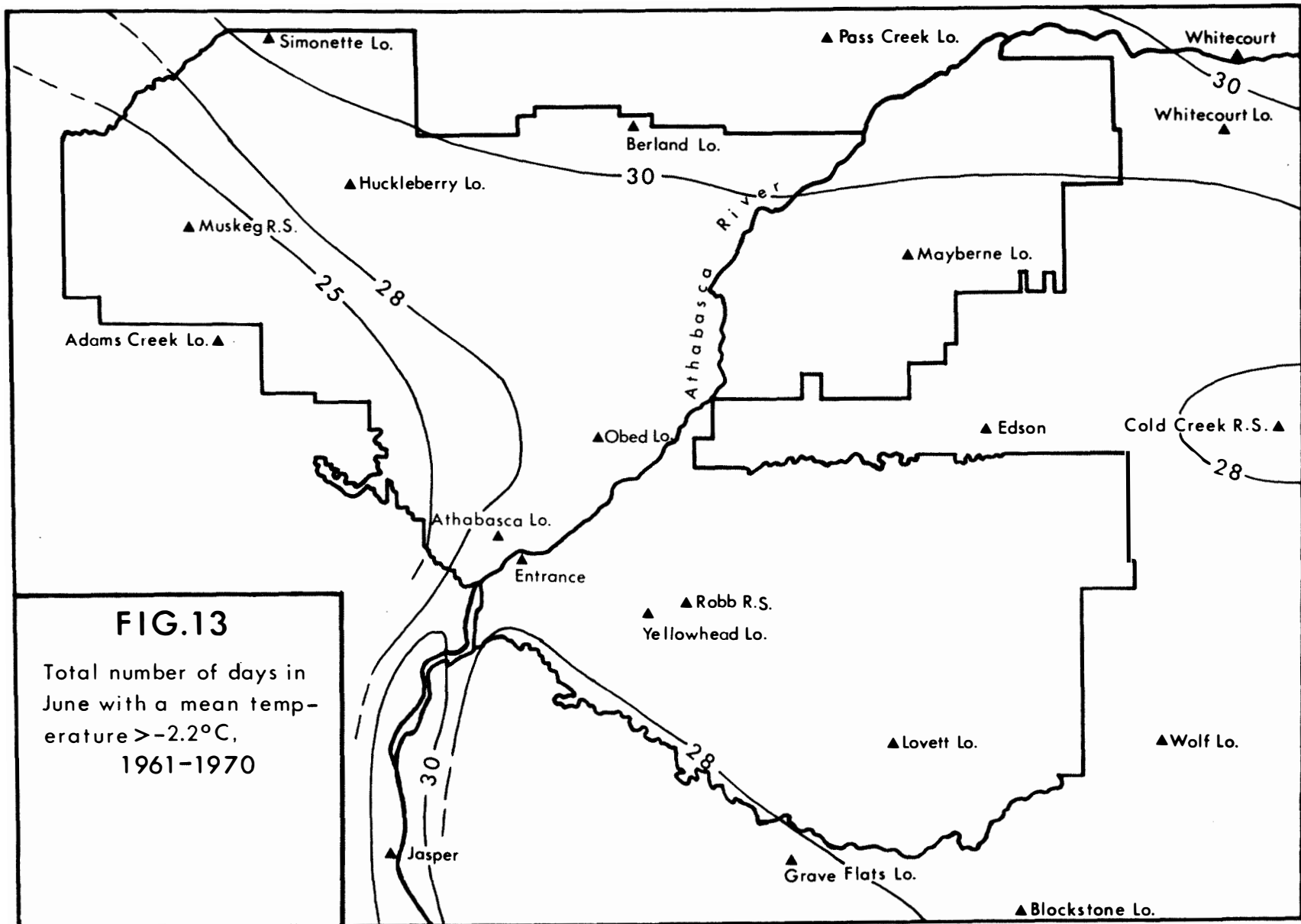
The 25-day contour for May includes the northern stations and Edson, Jasper, Whitecourt Lookout, and Yellowhead (Fig. 12). The other stations fall within the 20-24.9-day area with the exception of Muskeg, Grave Flats, and Adams Creek which have fewer than 20 days with a mean temperature higher than  $-2.2^{\circ}\text{C}$  in May. Adams Creek has fewer than 10 days. In June most stations have between 28 and 30 days, with the notable exceptions of Muskeg and Adams Creek with 20 and 21 days respectively (Fig. 13). In July the same two stations have the lowest frequency (25 and 29 respectively), but all other stations have 30-31 days (Fig. 14). Values











for all stations are very similar in August, but by September (Fig. 15) the pattern of frequency values is similar to that occurring in May. The northern stations all have more than 25 days with a mean temperature higher than  $-2.2^{\circ}\text{C}$  as does a band of stations from Jasper to Wolf Lookout and Edson, but Grave Flats, Muskeg, and Adams Creek are all below 20 and the latter two below 15 days.

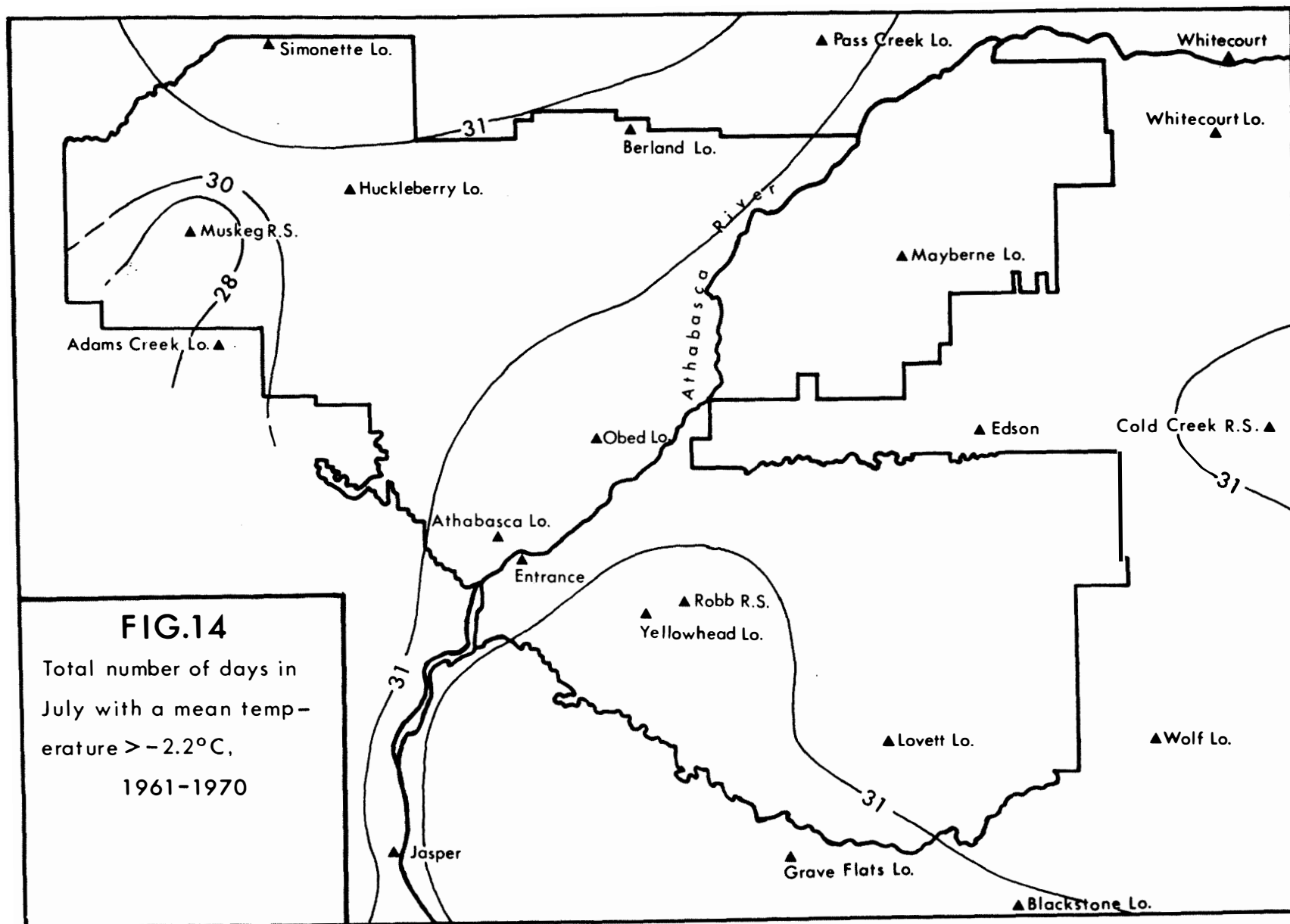
#### WATER DEFICIENCY

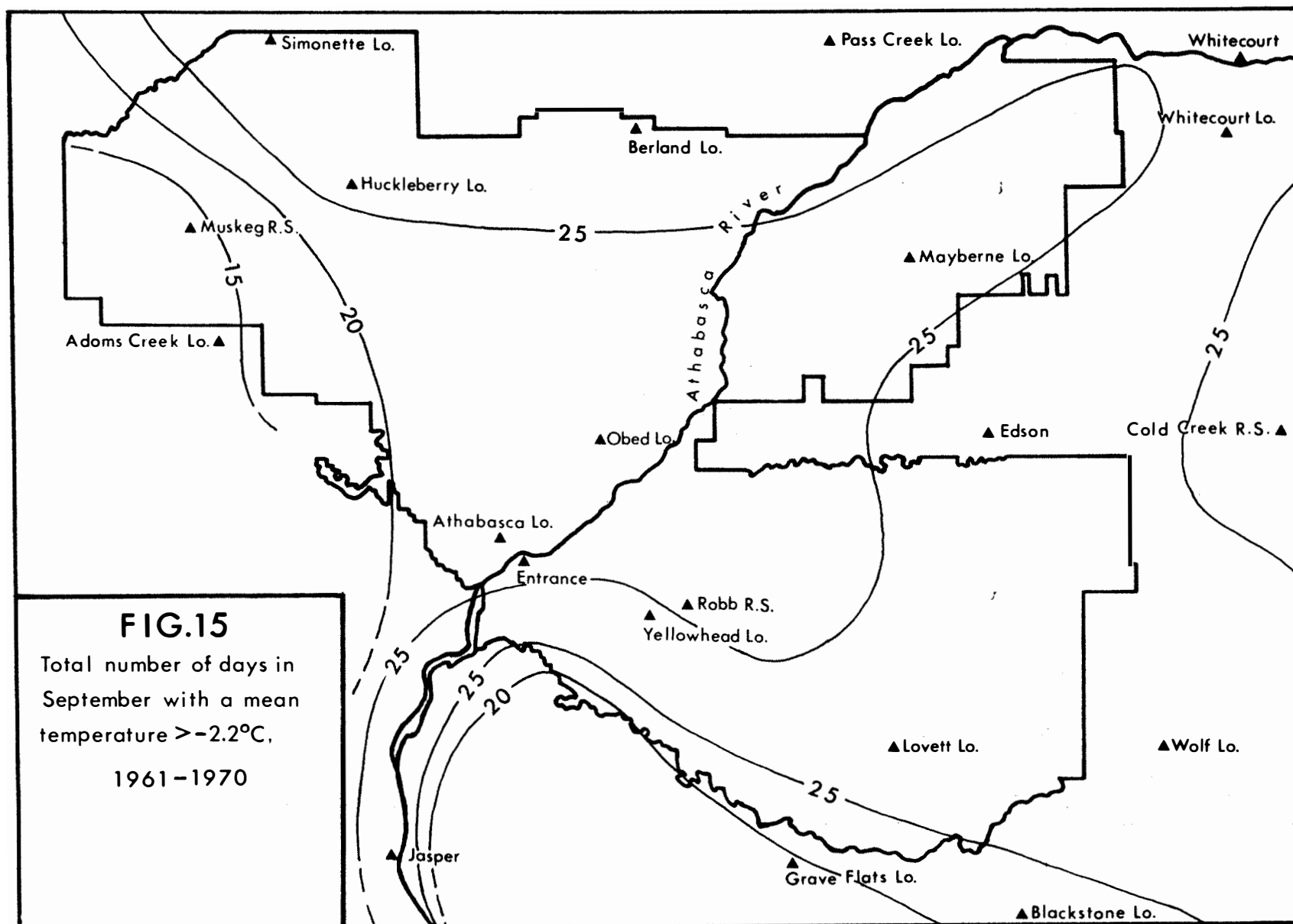
The seasonal water deficiency total, assuming a spring storage level of 100 mm, is highest at Jasper (150 mm), closely followed by Edson (137 mm) (Fig. 16). Entrance, Whitecourt, and Whitecourt Lookout have seasonal total deficiencies between 43 and 61 mm, and only four other stations--Mayberne, Simonette, Wolf, and Yellowhead--experience any water deficiency (between 8 and 20 mm).

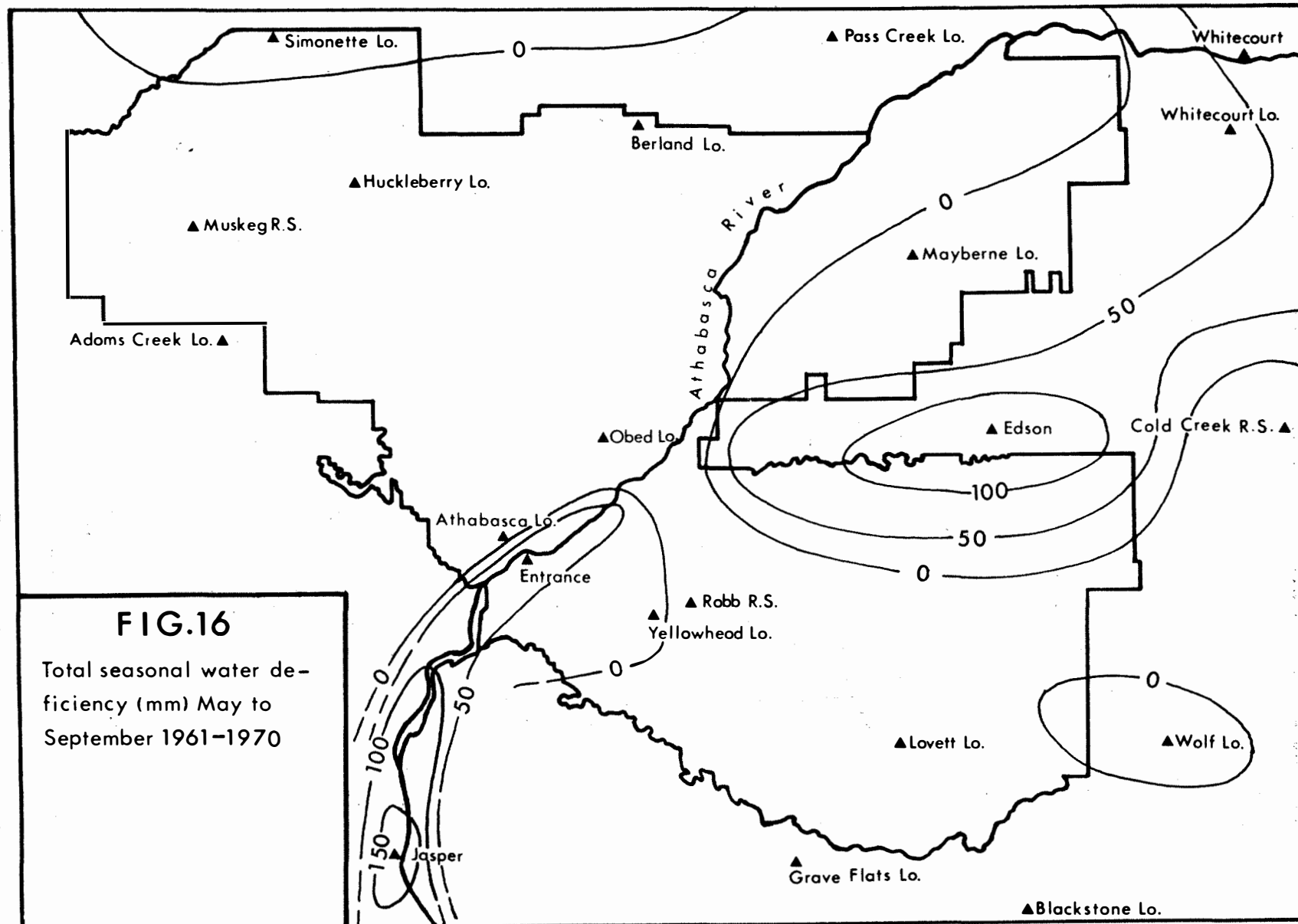
None of the stations experiences a water deficiency in May. Four stations, those having the greatest seasonal deficiency, show a deficiency in June. Whitecourt Lookout and Yellowhead first show a deficiency in July, Wolf and Mayberne in August, but Simonette not until September. Only Jasper has a monthly water deficiency of 50 mm or more, in July and August. Edson records a deficiency of over 25 mm in 4 mon.

#### THE 1961-70 PERIOD COMPARED WITH 30-YEAR "NORMAL" PERIODS

Table 2 shows the monthly and seasonal (May to September) mean temperature, and monthly and seasonal total precipitation for Edson, Entrance, and Jasper for the normal periods 1931-60 and 1941-70 and for the study period 1961-70. For the study period, temperatures in May were slightly









cooler and in August slightly warmer at all three stations. There was also a tendency for June temperatures to be warmer, especially at Edson and Jasper. July and September temperatures were cooler at Entrance, but similar at Edson and Jasper to those for the normal periods. The seasonal values for 1961-70 were slightly higher at Edson and Jasper, but lower at Entrance than for the normal periods.

For the study period precipitation totals were lower in June and August but higher in July than in the normal periods. Values in May were similar to the normal periods. In September totals at Edson were slightly higher, but lower at Entrance and Jasper. The seasonal totals at Entrance and Jasper were slightly lower than during the normal periods but at Edson fell between the values for the two normal periods.

Generally it can be said that the values for the 1961-70 study period are representative of the two normal periods and show only minor fluctuations in certain months; the seasonal values are similar. The greatest seasonal variation occurred in the precipitation total at Jasper which was respectively 14.2 mm and 24.1 mm lower than the 1941-70 and 1931-60 averages.

#### MACROCLIMATE CLASSIFICATION

Factor analysis compressed large numbers of input climatic variables, which included the monthly climatic parameters discussed above along with the latitude, longitude, and elevation of each station, into composite factors of only the most significant variables based upon the degree of statistical correlation within the original group of input variables. In this way a smaller number of variables is required to delineate homogeneous climatic groupings. The hierarchical grouping program

TABLE 2. Monthly and seasonal (May to September) mean temperature (°C) and monthly and seasonal total precipitation (mm) for Edson, Entrance, and Jasper for the normal periods 1931-60 and 1941-70 and for the study period 1961-70.

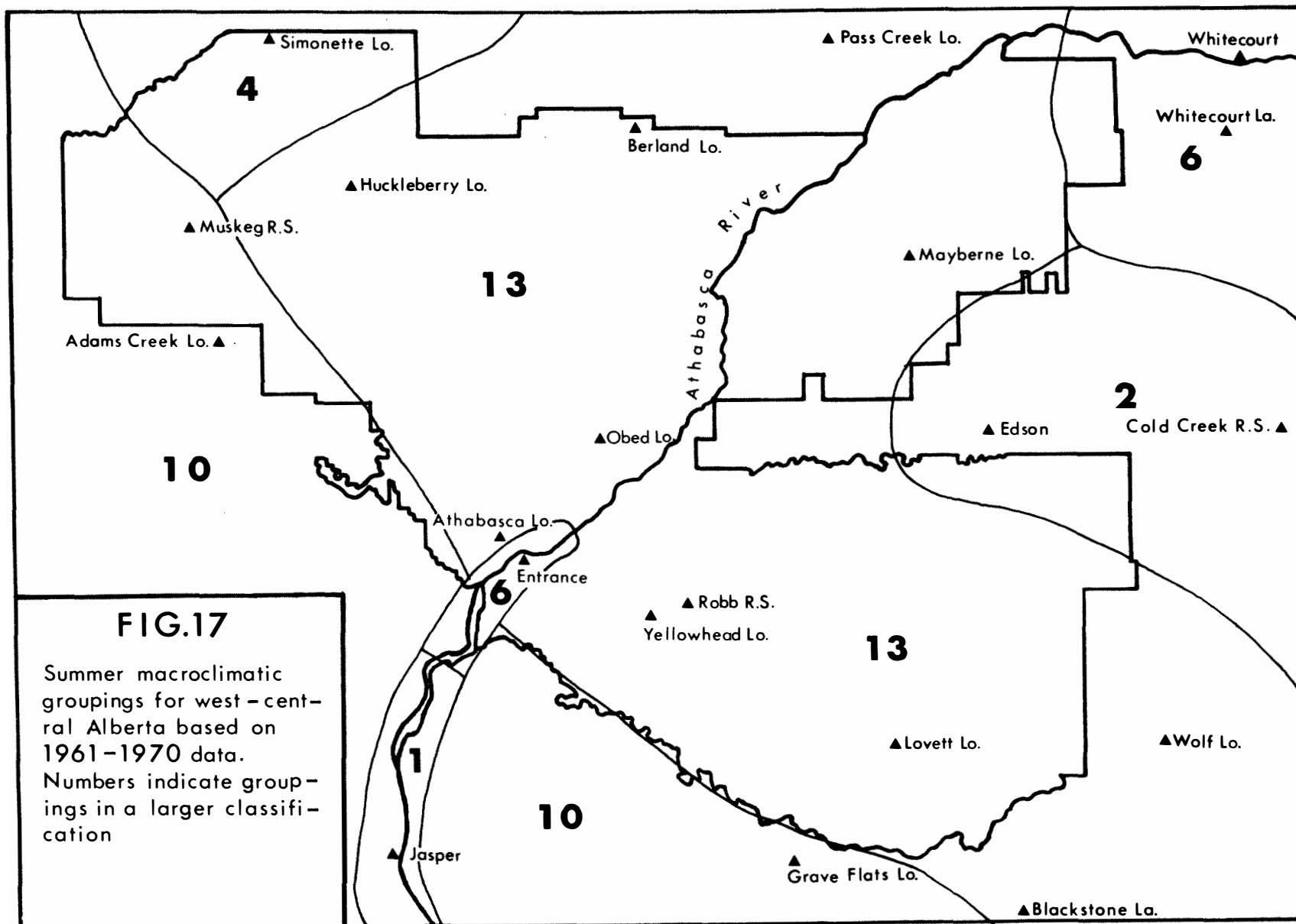
		May	Jun	Jul	Aug	Sep	May-Sep
TEMPERATURE							
Edson	1931-60 <sup>1</sup>	9.0	12.2	14.8	13.4	9.3	11.8
	1941-70 <sup>2</sup>	8.6	12.3	14.9	13.5	9.1	11.7
	1961-70	8.4	12.7	14.9	14.2	9.2	11.9
Entrance	1931-60 <sup>1</sup>	8.7	11.9	14.8	13.7	9.6	11.7
	1941-70 <sup>2</sup>	8.3	12.1	14.6	13.3	9.1	11.4
	1961-70	7.8	12.1	14.0	13.4	8.2	11.1
Jasper	1931-60 <sup>1</sup>	8.9	12.3	15.2	13.8	10.2	12.1
	1941-70 <sup>2</sup>	8.7	12.5	15.2	14.1	9.9	12.1
	1961-70	8.4	13.0	15.2	14.6	10.0	12.2
PRECIPITATION							
Edson	1931-60 <sup>1</sup>	52.1	91.2	92.9	80.2	41.4	357.9
	1941-70 <sup>2</sup>	59.2	84.3	104.1	77.5	45.5	371.1
	1961-70	61.0	63.5	116.8	73.7	48.3	363.2
Entrance	1931-60 <sup>1</sup>	53.3	91.2	69.1	78.7	46.0	338.3
	1941-70 <sup>2</sup>	55.1	84.8	75.2	79.2	38.6	333.0
	1961-70	55.9	66.0	94.0	76.2	35.6	327.7
Jasper	1931-60 <sup>1</sup>	33.3	54.6	49.8	51.1	35.6	224.8
	1941-70 <sup>2</sup>	34.8	49.8	47.5	48.0	34.8	214.9
	1961-70	33.0	40.6	53.3	43.2	30.5	200.7

<sup>1</sup> Source: Canada Department of Transport 1967

<sup>2</sup> Source: Canada Department of the Environment [1973]

statistically groups the various stations and shows the linkage of stations in successive stages. An error value is calculated for each successive step in the grouping. A plot of the minimum accumulated-error-loss indicates the points of change or discontinuity in the slope of the curve which allow one to select the optimal number of groups. The 20 stations of the present study were employed as part of a larger 300-station sample for the whole Prairie Region. The program indicated that there are six macroclimate groupings in the area (Fig. 17). The numbers on the map indicate the groupings from the larger total sample and are retained here to aid future comparisons. Most of the study area falls into climatic group 13 which centers on the lease area with extensions to the northeast in the Swan Hills and to the southeast to include Blackstone and Wolf Lookouts. Simonette is in group 4 located to the north and northeast to include the Smoky River Basin. Entrance is in the same group 6 as Whitecourt and Whitecourt Lookout. Adams Creek and Grave Flats fall into group 10 of high-elevation mountain stations, while Jasper is a mountain valley outlier of group 1 centered on the Peace River country. Edson and Cold Creek are the western extension of group 2 that extends to Athabasca and Wabasca in the north with other outliers in east-central Alberta and west-central Saskatchewan. Muskeg Ranger Station gave some atypical results because of the confidence level of some of the generated data, but further analysis indicated it to be close to group 10, and it was therefore placed in this zone on the map rather than established as a separate group.

Values were obtained for the mean, range, variance, standard deviation, and number of stations in each grouping. The statistically



significant climatic variables and the mean and range values that distinguish each climatic grouping are given in Table 3. Several groups appear similar in some variables (e.g. July temperature for groups 1 and 2, or groups 4 and 6) but it is the degree of statistical difference between the other variables that delimits the final groupings. Thus the most significant variable distinguishing group 4 from group 6 was September precipitation (see also Appendix A). It should be noted again that these values are based on a larger sample of stations than occur in the study area. The 15 significant variables in Table 3 are listed in the approximate order that they characterize the climate. Thus the first three (May frequency of days with mean temperature  $>-2.2^{\circ}\text{C}$ , May mean temperature and June number of days  $>-2.2^{\circ}\text{C}$ ), which form the first factor score, are the most important; and August frequency of days  $>-2.2^{\circ}\text{C}$  is the least important major discriminating variable. The sixteenth variable, not shown in Table 3 and not a major discriminating variable, was June precipitation. The other six variables used as input (June, August, September mean temperature; September frequency of days  $>-2.2^{\circ}\text{C}$ ; July and September water deficiency) were not important discriminating climatic variables in this analysis. Table 3 therefore provides both a general idea of the summer climate to be found within each group and an indication of the variability to be found between groups.

These values (Table 3) were used to discriminate statistically between adjacent climatic groups and to aid in the positioning of climatic grouping boundaries between two stations in adjacent groups.

TABLE 3. The six climatic groups represented in the area, with the mean value and range of values of the climatic significant variables for each group.

Group No.	May	May	June	Long. <sup>1</sup>	Elev. <sup>1</sup>	July	July	Aug.	Aug.	Lat. <sup>1</sup>	May	June	Sept	July	Aug.
Mean & Range	>-2.2°C (Days)	Temp. <sup>1</sup> (°C)	>-2.2°C (Days)	(Min. Sec.)	a.s.l. (m)	Temp. <sup>1</sup> (°C)	Ppt. <sup>1</sup> (mm)	Ppt. <sup>1</sup> (mm)	Def. <sup>1</sup> (mm)	(Min. Sec.)	Ppt. <sup>1</sup> (mm)	Def. <sup>1</sup> (mm)	Ppt. <sup>1</sup> (mm)	>-2.2°C (Days)	>-2.2°C (Days)
(1)															
Mean	27.5	9.3	29.4	118.17	588	15.7	65.3	49.8	51.8	56.22	33.5	17.3	43.2	30.8	30.8
Range	23.2-29.8	8.7-9.7	26.9-30.0	115.26-122.35	279-1093	14.4-16.7	50.8-86.4	38.1-66.0	43.2-63.0	55.11-58.50	20.3-48.3	7.4-36.1	33.0-68.6	30.0-31.0	30.2-31.0
(2)															
Mean	25.7	8.9	29.1	111.87	639	15.6	81.3	59.4	31.0	54.21	38.9	4.6	37.6	30.8	30.8
Range	23.3-29.1	4.9-10.5	26.6-30.0	107.46-115.35	483-792	13.2-16.9	53.3-114.3	33.0-71.1	0.0-57.2	53.08-56.37	22.9-50.8	0.0-15.0	27.9-43.2	30.0-31.0	29.9-31.0
(4)															
Mean	28.0	7.8	29.8	117.86	1014	14.1	93.2	87.1	15.8	54.52	53.6	2.8	67.3	30.9	30.9
Range	22.1-29.8	6.2-9.2	28.5-30.0	115.37-119.24	762-1274	12.1-15.1	71.1-116.8	68.6-104.1	0.0-29.0	54.14-55.13	43.2-63.5	0.0-7.6	45.7-86.4	30.4-31.0	30.0-31.0
(6)															
Mean	26.4	8.4	29.7	115.05	875	14.2	91.4	79.0	19.8	54.22	43.9	6.1	38.4	30.8	30.8
Range	24.4-29.1	7.2-9.2	29.1-30.0	111.43-118.04	610-1272	12.4-15.2	63.5-116.8	66.0-94.0	7.8-37.9	53.11-55.04	30.5-53.3	0.3-14.0	33.0-48.3	30.1-31.0	29.6-31.0
(10)															
Mean	12.7	0.1	25.4	117.47	1768	10.1	95.3	72.9	10.4	52.94	48.5	1.5	56.4	30.1	29.4
Range	7.8-17.1	9.4-5.7	21.4-27.9	115.57-119.53	1326-2210	8.5-12.1	68.6-127.0	40.6-104.1	0.0-34.3	51.15-55.04	35.6-76.2	0.0-10.2	40.6-83.8	28.9-30.5	27.5-30.8
(13)															
Mean	23.7	5.6	29.5	116.63	1320	13.4	115.1	98.6	3.1	53.63	63.0	0.3	62.2	30.9	30.8
Range	17.7-28.7	1.3-8.1	28.4-30.0	115.09-118.11	1036-1631	12.3-14.4	99.1-132.1	71.1-124.5	0.0-19.3	52.47-54.55	48.3-68.6	0.0-0.3	50.8-73.7	30.5-31.0	30.3-31.0

<sup>1</sup> Abbreviations used: Long.= Longitude; Lat.= Latitude; Elev.a.s.l.= Elevation above sea level; Temp.= Temperature; Ppt.= Precipitation; Def.= Water deficiency

As the station groupings were derived from the intercorrelation of the most statistically significant climatic variables it was logical to use these same statistically important variables for positioning climatic boundaries between stations. To do this the significant climatic variables with the most dissimilar values between adjacent climatic groups were tested for statistical differences by means of the Student t-test at the 95% confidence level. The statistically significant between group variables together with mean and standard deviation values used are given in Appendix A. When more than one variable was important in delimiting the boundary between two climatic groups, multiple variables and their combined weighted influence were used to arrive at a more accurate location for the boundaries.

#### COMPARISON OF PRESENT STUDY WITH OTHER RECENT STUDIES

The earlier preliminary summer macroclimatic classifications which included the area (MacIver 1970, MacIver et al. 1972; Powell and MacIver 1975a) were based on a different final step(s) in the analysis and a different number of variables. Even the more recent preliminary map (Powell and MacIver 1975b) is based on an extra variable (water deficiency for the month of May, which was later dropped because it was negligible at all stations), and a slightly different data base and therefore a different number of groupings. In the first classification (MacIver 1970, MacIver et al. 1972) only seven stations were used for our present study area, and only two climatic groups were indicated. That classification included 75 input variables compared with the 22 of the present study; as well, an algorithmic grouping procedure was used instead of the present hierarchical grouping, and no discriminant analysis was used to test whether the groups were significantly different. The pre-

liminary classification of Alberta (Powell and MacIver 1975a) did not include discriminant analysis, and the number of stations covering our area of interest was fewer although the same input variables were used. In this classification the area was divided into six classes in a 15-grouping and seven classes in a 28-grouping. The main lease area, however, fell into two or three classes.

The classification of the present study is therefore based on a larger geographical area; a denser number of stations; 22 largely independent variables rather than 75, many of which showed a high dependence on other variables; and a statistically stable and mutually exclusive climatic grouping. The boundaries of the climatic groupings have also been positioned through the use of the most statistically significant variables. However, it should be remembered that the final selected climatic groupings vary in response to first, the type of variables selected to characterize the climate; secondly, the accuracy of the data reported by the climatic stations; and thirdly, the representativeness of the stations.

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## REFERENCES

- Bowser, W.E. 1967. Agro-climatic areas of Alberta. Can. Dep. Energy, Mines Resour., Surv. Mapping Br. Ottawa.  
1 map with text.
- Canada Department of the Environment. [1973]. Temperature and precipitation 1941-1970. Means for the period 1941-1970 and extremes up to 1970. Prairie Provinces. Atmos. Environ. Serv. Downsview, Ont. 159 pp.
- Canada Department of Mines and Technical Surveys. 1957. Atlas of Canada. Geographical Br. Ottawa. Plate 30: Climatic Regions.
- Canada Department of Transport. 1967. Temperature and precipitation tables for Prairie Provinces. Meteorol. Br. Toronto. Vol. III. 56 pp.
- Canada Department of Transport. 1970. Climatological station data catalogue--the Prairie Provinces. Meteorol. Br. Toronto. CLI 4-70. 126 pp.
- Chapman, L.J. and D.M. Brown. 1966. The climates of Canada for agriculture. Can. Dep. For. Rural Develop., Can. Land Inventory. Rep. No. 3. 24 pp.
- Court, A. 1968. Climatic normals as predictors. San Fernando Valley St. College, Dep. Meteorol., Climatol. Sect. Climatol. Rep. Nos. 68-82-1,2,3,4,5.
- Landsberg, H.E. and W.C. Jacobs. 1951. Applied climatology. pp. 976-992 In Malone, T.F. (Ed.). Compendium of meteorology. Am. Meteorol. Soc. Boston, Mass. 1334 pp.

- Longley, R.W. 1970. Climatic classification for Alberta forestry. pp. 147-153 In Powell, J.M. and C.F. Nolasco (Eds.). Proceedings of the Third Forest Microclimate Symposium. Kananaskis Forest Experimental Station. Seebe, Alta., Sept. 23-26, 1969. Can. Dep. Fish. For., Can. For. Serv., For. Res. Lab. Calgary, Alberta.
- MacIver, D.C. 1970. Macroclimatic zonation in northern Alberta. Univ. Alberta. Unpubl. M.Sc. thesis. 187 pp.
- MacIver, D.C., W.D. Holland and J.M. Powell. 1972. Delineation of similar summer climatic regimes in central Alberta. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alta. Inf. Rep. NOR-X-30. 32 pp.
- Powell, J.M. and D.C. MacIver. 1975a. Climatic classifications of the Prairie Provinces: a new preliminary classification for the forested area of Alberta. pp. 99-111 In B.M. Barr (Ed.). Western Canadian research in geography: The Lethbridge papers. B.C. Geogr. Ser. No. 21. Occas. Pap. Geogr. Can. Assoc. Geogr., West. Div. 124 pp.
- Powell, J.M. and D.C. MacIver. 1975b. A factor analytic climatic classification of the forested areas of the Prairie Provinces. 12th Agric. For. Meteorol. Conf., Am. Meteorol. Soc. Tucson, Ariz., April 14-16, 1975. Preprint Vol. pp 65-66. (Also Abstract in Bull. Am. Meteorol. Soc. 56:119, 1975).
- Rheumer, G.A. 1953. Climate and climatic regions of western Canada. Univ. Illinois. Unpubl. Ph.D. thesis. 185 pp.
- Rowe, J.S. 1972. Forest regions of Canada. Environ. Can., Can. For. Serv. Publ. No. 1300. 172 pp.

## APPENDIX A

Comparative climatic boundary groups and associated significant variables with means and standard deviation values. (Significance of between-group variables was determined by Student t-test and established at the 95% confidence level.)

Groups	Variables	Means	Standard Deviations
1 and 6	Elevation <sup>1</sup>	588/875	198/271
	July Temp. <sup>2</sup>	15.7/14.2	1.1/1.1
	Aug. Ppt. <sup>3</sup>	49.8/79.0	8.8/11.4
	Aug. Def. <sup>4</sup>	51.8/19.8	6.7/10.2
2 and 6	Elevation <sup>1</sup>	638/875	91/271
	July Temp. <sup>2</sup>	15.6/14.2	0.8/1.0
2 and 13	May Temp. <sup>2</sup>	8.9/5.6	1.4/2.0
	Elevation <sup>1</sup>	638/1320	91/214
	Aug. Ppt. <sup>3</sup>	59.2/98.6	10.2/11.9
	Aug. Def. <sup>4</sup>	31.0/3.1	17.5/5.6
4 and 6	Sept. Ppt. <sup>3</sup>	67.3/38.4	11.9/5.6
4 and 10	May >-2.2 <sup>5</sup>	28.0/12.7	2.2/3.2
	May Temp. <sup>2</sup>	7.8/0.1	1.1/4.7
	Elevation <sup>1</sup>	1014/1768	172/317
	July Temp. <sup>2</sup>	14.1/10.1	0.9/1.5
4 and 13	May >-2.2 <sup>5</sup>	28.0/23.7	2.2/3.2
	May Temp. <sup>2</sup>	7.8/5.6	1.1/2.0
	Elevation <sup>1</sup>	1014/1320	172/214
	July Ppt. <sup>3</sup>	93.2/115.1	15.9/10.5
6 and 13	May Temp. <sup>2</sup>	8.3/5.6	0.8/2.0
	Elevation <sup>1</sup>	875/1320	271/214
	Aug. Def. <sup>4</sup>	20.1/3.1	10.2/5.6
10 and 13	May >-2.2 <sup>5</sup>	12.7/23.7	3.2/3.2
	May Temp. <sup>2</sup>	0.1/5.6	4.7/2.0
	June >-2.2 <sup>5</sup>	25.4/29.5	1.9/0.5
	Elevation <sup>1</sup>	1768/1320	317/214
	July Temp. <sup>2</sup>	10.1/13.4	1.5/0.7
	July Ppt. <sup>3</sup>	95.3/115.1	21.6/10.4
	Aug. Ppt. <sup>3</sup>	72.9/98.6	20.3/11.9

<sup>1</sup> Elevation above sea level (m)

<sup>2</sup> Mean Temperature (°C)

<sup>3</sup> Total Precipitation (mm)

<sup>4</sup> Water Deficiency (mm)

<sup>5</sup> Number of days with mean temperature greater than -2.2°C