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Maps of selected climatic parameters for the Prairie Provinces, May to September, 1961-1970

J.M. Powell and D.C. MacIver

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J.M. POWELL AND D.C. MACIVER

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ABSTRACT

Maps of mean daily temperature, precipitation, number of days with a minimum temperature of -2.2°C or below, and water deficiency assuming a soil moisture storage level of 100 mm are presented for the individual summer months May to September and for the summer season (May to September). The study used data from 360 stations for the months May to September for the years 1961-1970 and included all stations in the forested areas of the Prairie Provinces with an adequate record during the same period, but only selected stations in the southern agricultural area. It was necessary to generate missing daily values for many of the forest-fire weather stations, especially in May and September, to provide complete sets of data to estimate mean values for the period.

RESUME

Les auteurs ont dressé des cartes indiquant la température moyenne quotidienne, les précipitations, le nombre de jours où la température minimale était de -2.2°C ou moins, et la déficience hydrique (en supposant que la teneur en humidité du sol fût de 100 mm) pour chacun des mois de mai à septembre ainsi que pour toute la saison estivale (mai à septembre). Leur étude s'étayait sur les données provenant de 360 stations pour les mois de mai à septembre des années 1961 à 1970, et incluait toutes les stations situées dans les régions boisées des Prairies ayant une fiche adéquate durant la période étudiée, mais seulement quelques stations choisies parmi les régions agricoles du Sud. Pour se procurer des ensembles complets de données permettant d'estimer les valeurs moyennes concernant la période étudiée, il leur a fallu générer les valeurs quotidiennes qui manquaient pour plusieurs stations forêt-météo, particulièrement en mai et septembre.

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INTRODUCTION

A large volume of climatological data was generated during the development of a factorial summer climatic classification of the forested regions of the Prairie Provinces (Powell and MacIver 1977). That study used data from 303 stations for the individual months May to September for the years 1961-1970. Daily temperature and precipitation values were employed to provide mean monthly daily temperatures, monthly precipitation totals, frequency of days with a minimum temperature >-2.2°C, and water deficiency values for the months May to September for each of the stations used in the analysis. In a further study briefly reported by Powell (*in press*), 24 stations were added to the earlier study to represent the southern predominantly agricultural area of the Prairie Provinces, and Churchill was added to represent northern Manitoba. Mean monthly daily temperature, monthly precipitation totals, and frequency of days with a minimum temperature of -2.2°C or below were obtained for these additional stations and for a further 32 stations in the agricultural area, including Cypress Hills Park, for the months May to September for the same period (1961-1970).

Most of the above data, with the addition of locational data for each station, were used to develop maps of summer climatological zones for the area (Powell *in press*; Powell and MacIver 1977). However, these publications do not provide information about the individual climatic variables used in the analysis, other than to show which are the most significant variables and to give zonal means and ranges for them. In order to make this information available, seasonal and monthly (May to September) maps have been drawn of mean daily temperature, precipitation, frequency of days with a minimum temperature of -2.2°C or below, and water deficiency assuming a soil moisture storage level of 100 mm at the beginning of the season.

METHODS AND MATERIALS

All climatological stations in the predominantly forested area and fringe agricultural areas of the Prairie Provinces with 6 or more years of daily temperature and precipitation data during the months May to September inclusive in the 1961-1970 period were considered for use in this study. A few stations in the adjacent portions of British Columbia, Ontario, and the Northwest Territories were included to aid in the placement of isolines. Most of the raw climatic data was purchased from the Atmospheric Environment Service, Environment Canada, Downsview, Ontario. The study was restricted to the summer months, as data are available for these months only from the majority of the forest-fire weather stations in Alberta. Unfortunately, comparable data were not available from forest-fire weather stations in Manitoba and Saskatchewan. Data from 57 selected stations from the southern agricultural regions were added to cover the nonforested portions of the Prairie Provinces. The density of stations for the nonforested portion of the study area is therefore sometimes less than for the forested areas, where all stations meeting the selection criteria were included. In the maps the 360 (Figs. 1-18) or 303 (Figs. 19-23) stations used for the study are shown by dots. Powell and MacIver (1977) mentioned that a few stations appeared to have inconsistent data. Data from these suspect stations were checked in the *Monthly Record* (Canada Department of Transport 1961-1971); in most cases the earlier data proved to be inconsistent and were therefore adjusted for use in this report. Adjustments included derived data for the number of days with a minimum temperature of -2.2°C or below, but water deficiency data were not recalculated using adjusted data.

The factor analytic procedure used for the macroclimate grouping required complete sets of daily observations for each station for the period 1961-1970 from May to September inclusive. It was therefore necessary to generate missing daily values for many of the forest-fire weather stations, especially for portions of May and September when they were often closed. The estimation procedure involved curvilinear regression analysis, using available data from an incomplete station as the dependent variable, with corresponding data from a nearby complete station as the independent variable. If the F-ratio was significant at the 95% confidence level, the regression equations were used to estimate values for the missing data from the data for the complete station. If the regressions were not significant, the stations were eliminated from further analysis. Water deficiency values were calculated using Thornthwaite's water balance technique (Thornthwaite and Mather 1955) adjusted for a 7-month period from April to October, assuming a soil moisture storage level of 100 mm (4 in. equivalent) per year by the end of March. The -2.2° C (28° F) minimum temperature was selected because values below it are considered to be killing frosts for most sensitive vegetation. Further details on the method of generating data, the selection of stations and variables, the study period, and study area are given by Powell and MacIver (1977).

RESULTS

Temperature

Seasonal (May to September) mean daily temperatures are shown in Fig. 1. Mean temperatures range from 5.6° C at Adams Creek Lookout to 16.4° C at Medicine Hat. Seasonal mean daily temperatures are >15° C in portions of southern Alberta, Saskatchewan, and Manitoba. For much of the rest of the agricultural area they range from 12.5 to 15° C, although a few locations have means below 12.5°, including some in the Peace River area and in the area north of North Battleford in Saskatchewan. In the Rocky Mountains and Foothills area of Alberta there is a considerable gradient in means from <6.0° to >10° C. Most of the lower Foothills and the Swan Hills have values between 10 and 12.5° C. Areas of higher elevation in northwestern Alberta and around the Birch Mountains have mean temperatures close to 10° C, but most of the boreal forest area in Alberta has values between 11 and 12° C.

There is considerable range in the mean May temperature in the area (Fig. 2). The southern area, including most of the grasslands, has mean May temperatures >10° C, but some of the lookout stations in the Rocky Mountains have mean May temperatures close to 0° C. The isolines of the means tend to form almost uniform bands stretching from northwest to southeast. Thus, the 10° C isotherm is south of Winnipeg in Manitoba, but north of Edmonton in Alberta. Isotherm bands are also found parallel to the mountains, although stations in the major passes have higher temperatures. Certain local uplands, such as the Swan Hills and Birch Mountains in Alberta and Riding Mountain in Manitoba, have noticeably cooler temperatures. Mean May temperatures are generally <5° C in northern Manitoba and northeastern Saskatchewan.

By June most of the agricultural area has mean temperatures >15° C (Fig. 3). The highest mean temperatures for June are recorded at Emerson (17.5° C) and Morris (17.1° C) in the Red River valley, and at Medicine Hat (17.0° C) in southeastern Alberta. Several other stations record mean temperatures >16° C in southern Manitoba and Saskatchewan. A few lookout stations in the Rocky Mountains still record mean temperatures close to 5° C, and several others <10° C, but most stations in the study area have mean temperatures >10° C. In the Peace River area mean temperatures range between 12.5° C and 14.7° C, the latter occurring at Fort Vermilion. A few of the extreme northern stations have mean temperatures <12.5° C, as do stations in the Birch Mountains and northwestern Alberta, while the mean June temperature at Churchill is only 6.4° C.

Mean July temperatures (Fig. 4) reflect almost the same pattern as mean June temperatures, although southern stations are considerably warmer than in the earlier month. Several stations in the extreme south have mean temperatures >20° C, and much of the agricultural area has temperatures >17.5° C. A few stations at higher elevations in the Rocky Mountains still have temperatures <10° C. Most of the remainder of the study area has mean temperatures >15° C, although there are notable exceptions. These include stations in the Alberta Foothills and some to the east of these in the Swan Hills and the area north of Lesser Slave Lake. Other areas with mean temperatures <15° C include the Birch Mountains, northwestern and east-central Alberta, northeastern Saskatchewan, and northern Manitoba.

The pattern of mean August temperatures (Fig. 5) is very similar to July except that temperatures are slightly cooler. Mean temperatures in southeastern Alberta and

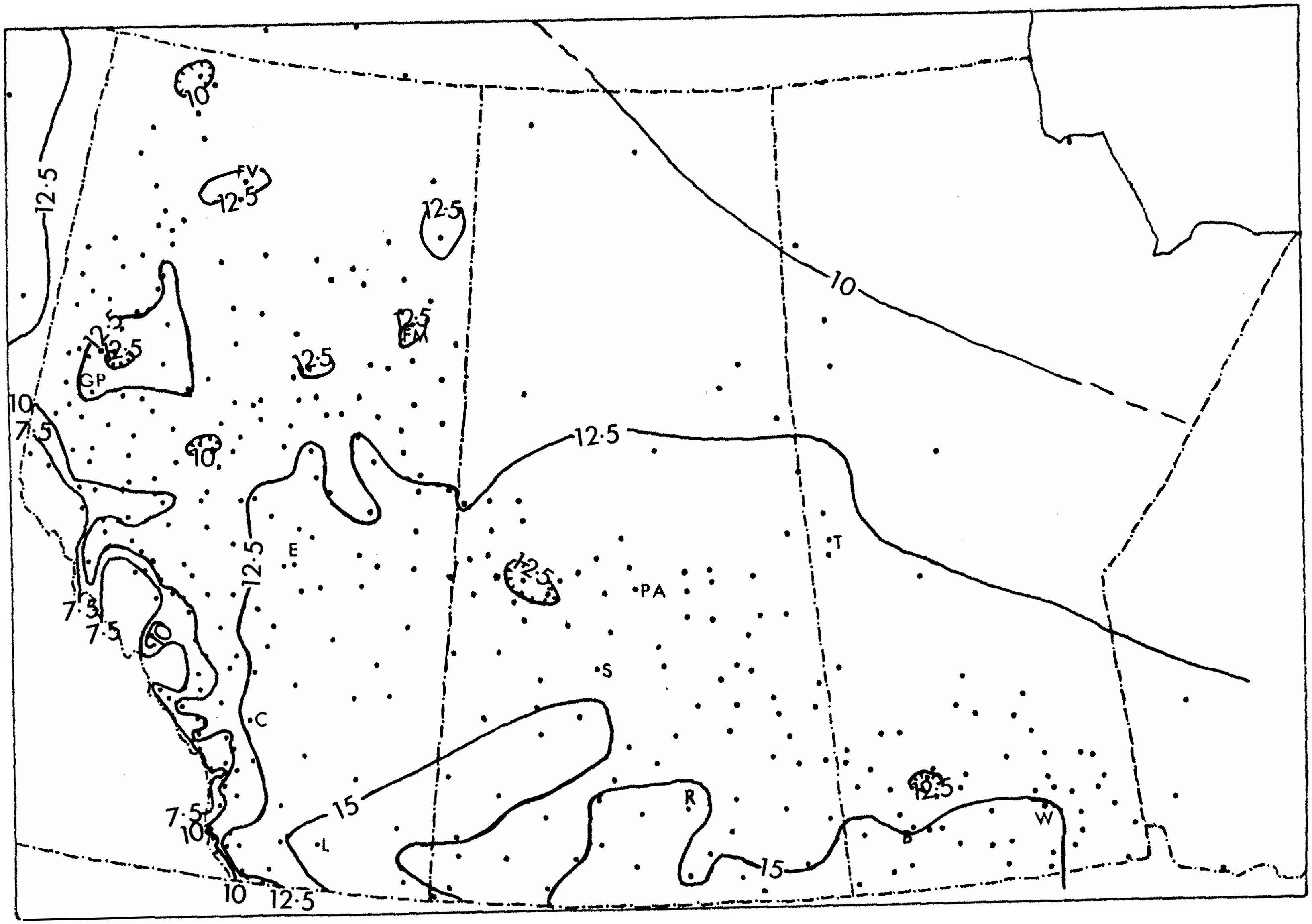

Fig. 1. Mean May to September temperature (°C); 1961-1970. Dots represent stations used in the analysis. B-Brandon; C-Calgary; E-Edmonton; FM-Fort McMurray; FV-Fort Vermilion; GP-Grande Prairie; L-Lethbridge; PA-Prince Albert; R-Regina; S-Saskatoon; T-The Pas; W-Winnipeg.

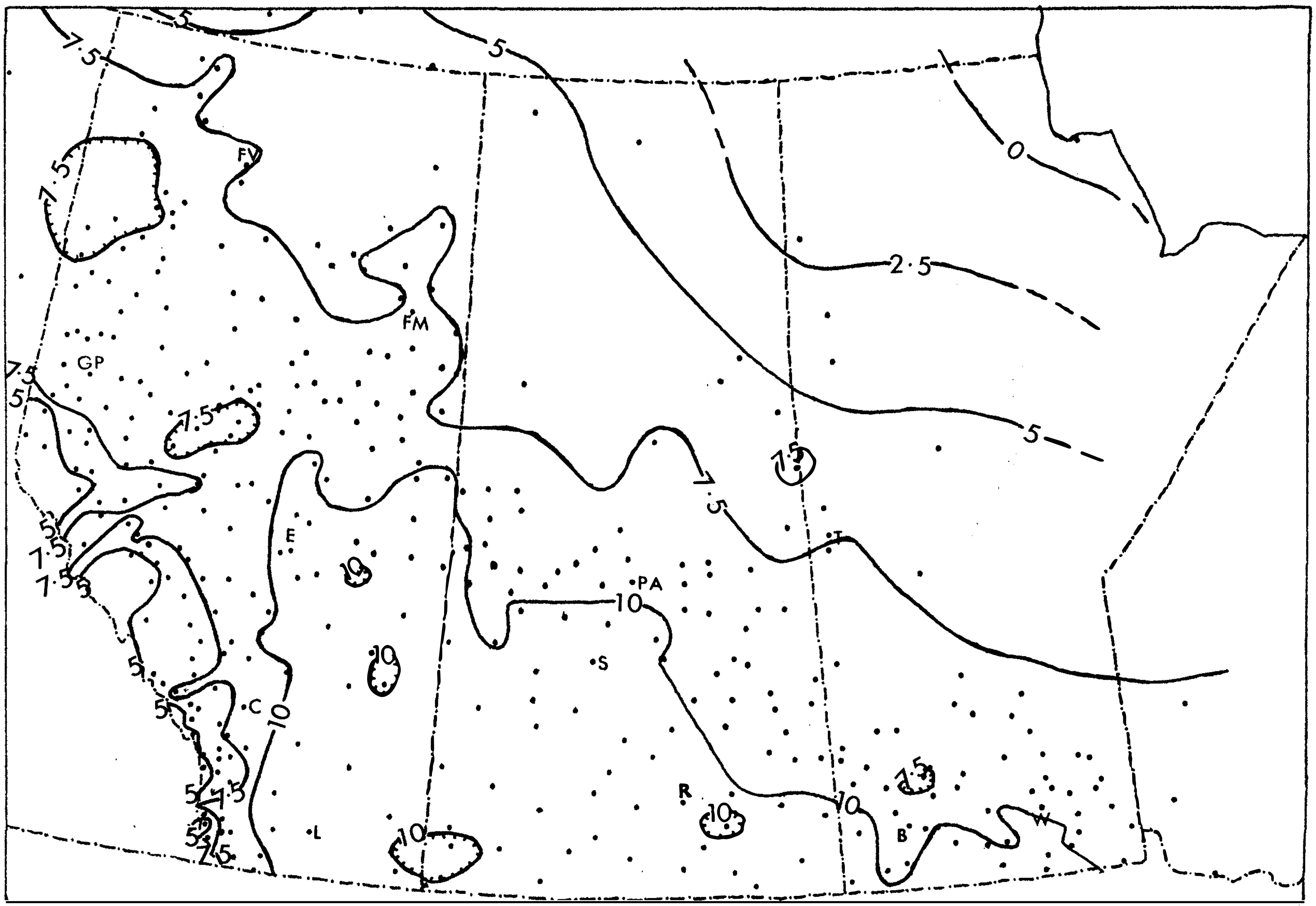

Fig. 2. Mean May temperature (°C), 1961-1970.

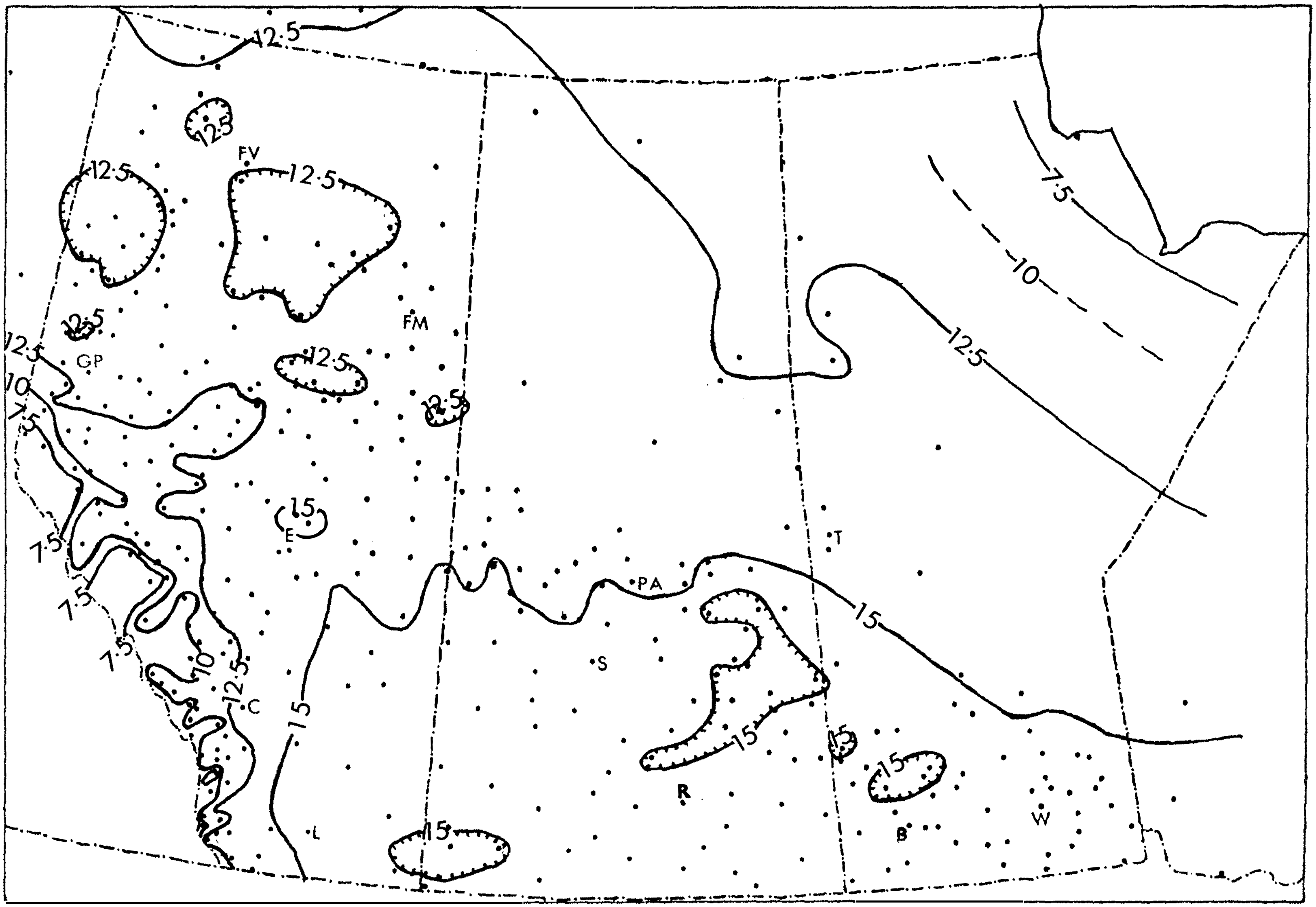

Fig. 3. Mean June temperature (°C), 1961-1970.

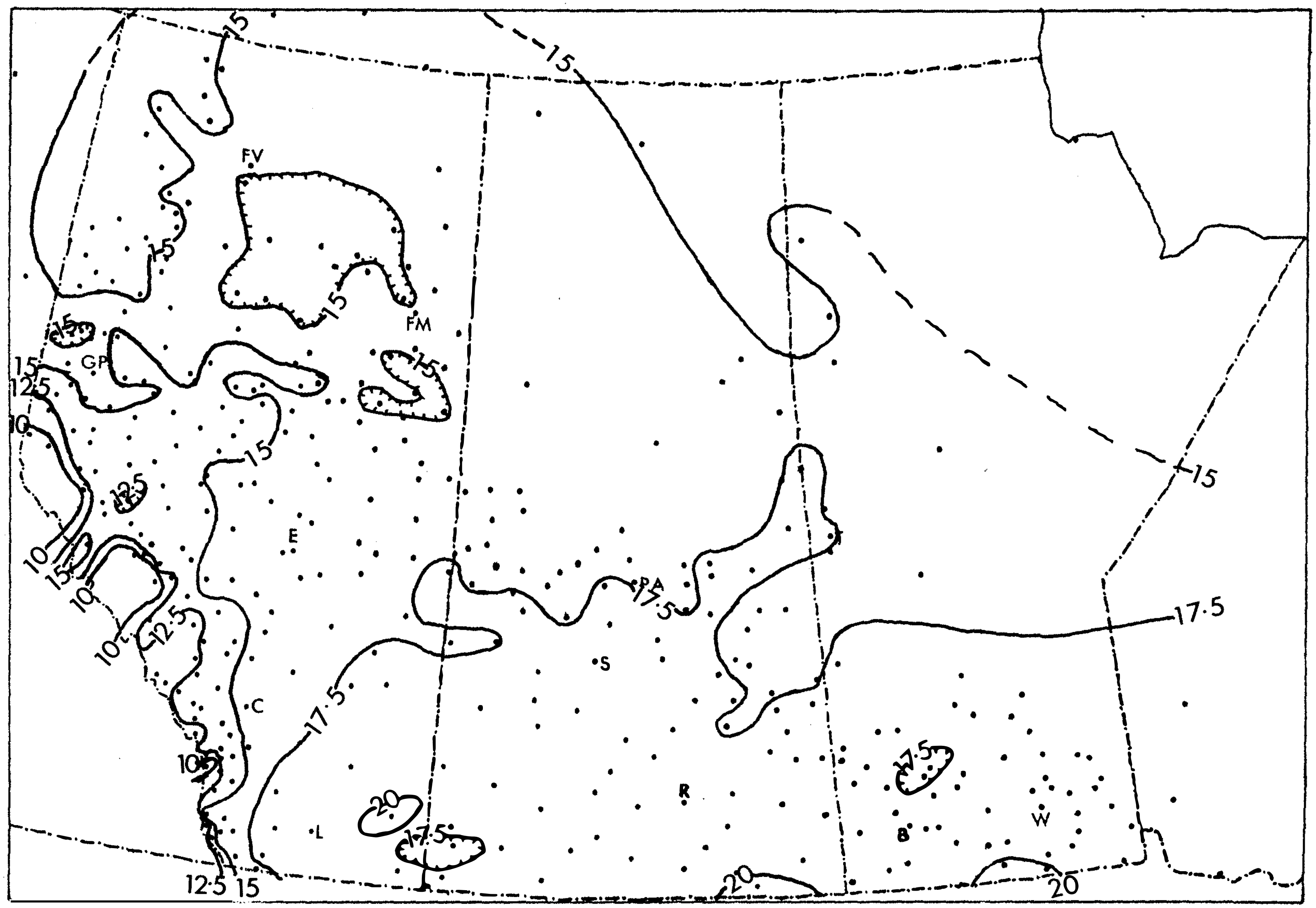

Fig. 4. Mean July temperature (°C), 1961-1970.

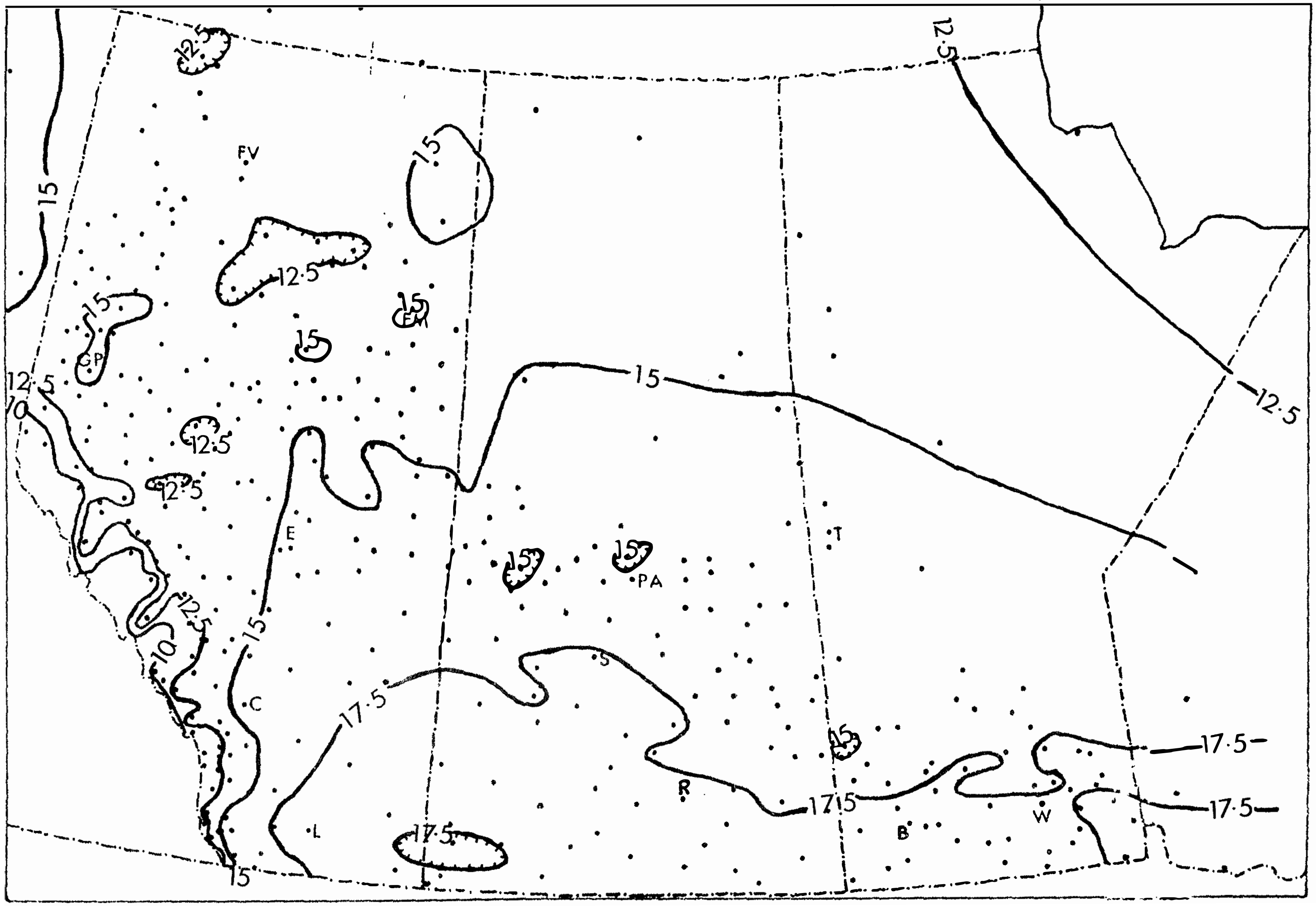

Fig. 5. Mean August temperature (°C), 1961-1970.

southern Manitoba are still >19°C, and a considerable area of the southern prairies has means >17.5°C. A few stations in the Rocky Mountains have mean temperatures <10°C, but all others have higher temperatures. Most of the forested zone in Alberta has mean temperatures <15°C, but in Saskatchewan and Manitoba the southern boreal forest zone has mean temperatures ranging from 15°C to as high as 17.5°C in southeastern Manitoba, where elements of the Great Lakes Forest Region are found. Only a portion of the Peace River area has mean temperatures >15°C.

Considerable cooling has occurred by September (Fig. 6). Only a few southern stations have mean temperatures >12.5°C; Medicine Hat (13.3°C) and Morden (13.2°C) record the highest values. Much of the northern fringe of the agricultural zone has mean temperatures >10°C, but only a few locations in the Peace River area do. Several areas in Alberta, generally at higher elevations, have mean temperatures close to 5°C, although in Saskatchewan and Manitoba only the extreme northern stations have temperatures <7.5°C, and none have a mean temperature <5.7°C (Churchill).

Precipitation

The seasonal (May to September) map of precipitation (Fig. 7) shows values ranging from around 150 mm on the south shores of Great Slave Lake to 483 mm at Emo, Ontario. In Alberta there are several areas in the Foothills with total precipitation >450 mm, and the Swan Hills and Marten Mountain-Stoney Mountain areas have >400 mm. Most of the agricultural belt in Saskatchewan and Alberta, including the Peace River area, receives between 200 and 300 mm, although <200 mm occurs in parts of southeastern Alberta and southwestern Saskatchewan. Southern Manitoba generally receives more precipitation, from 260 mm to >400 mm in the extreme southeastern area and at Riding Mountain Park. Much of the boreal forest zone receives >300 mm, although totals are less in the northern area.

For the most part, May is the driest of the five summer months, with most of the area having precipitation values between 25 and 50 mm (Fig. 8). The Alberta Foothills area extending out to the Swan Hills, and southeastern Saskatchewan and southern Manitoba have precipitation totals >50 mm. In the extreme south of Manitoba and in two areas of southwestern Alberta totals are >75 mm. In the main plains area there are four small areas with >50 mm and three with <25 mm, including southwestern Saskatchewan. The extreme northern stations all have precipitation totals <25 mm, and values at several stations in the Rocky Mountains are <50 mm.

As precipitation reaches the maximum level for the year in June and July, the pattern of rainfall distribution changes radically from May's. In June several areas in the southern Alberta Foothills have precipitation totals >125 mm, and generally much of the southern Foothills receives >100 mm (Fig. 9). The northern Foothills have <100 mm, some of the stations in the interior valleys of the Rocky Mountains receive <75 mm, and Jasper receives <50 mm. Several high-elevation stations in the Swan Hills and northeast of Lesser Slave Lake have totals >100 mm. Throughout the agricultural belt of the Prairies, including much of the Peace River area, totals generally range between 50 and 75 mm, with localized areas in west-central Saskatchewan and southeastern Manitoba receiving more. The extreme northern stations, including stations in the Lower and Upper Peace River area, have totals close to or <50 mm. In July (Fig. 10) the highest precipitation totals occur in southeastern Manitoba and adjacent Ontario, and in a zone in central Alberta. Precipitation totals >100 mm also occur in northern Alberta. Most of central and northern Saskatchewan has <75 mm, exceptions being portions of the eastern and western provincial boundary areas. In Alberta the southwest, the valley-bottom stations in the Rocky Mountains, the Peace River region, and some of the northern areas all have <75 mm. The lowest precipitation totals (<50 mm) occur in southern Alberta from the Porcupine Hills south to the border with Montana, and throughout southwestern Saskatchewan. The lowest July precipitation occurs at Manyberries (27.2 mm) in southeastern Alberta.

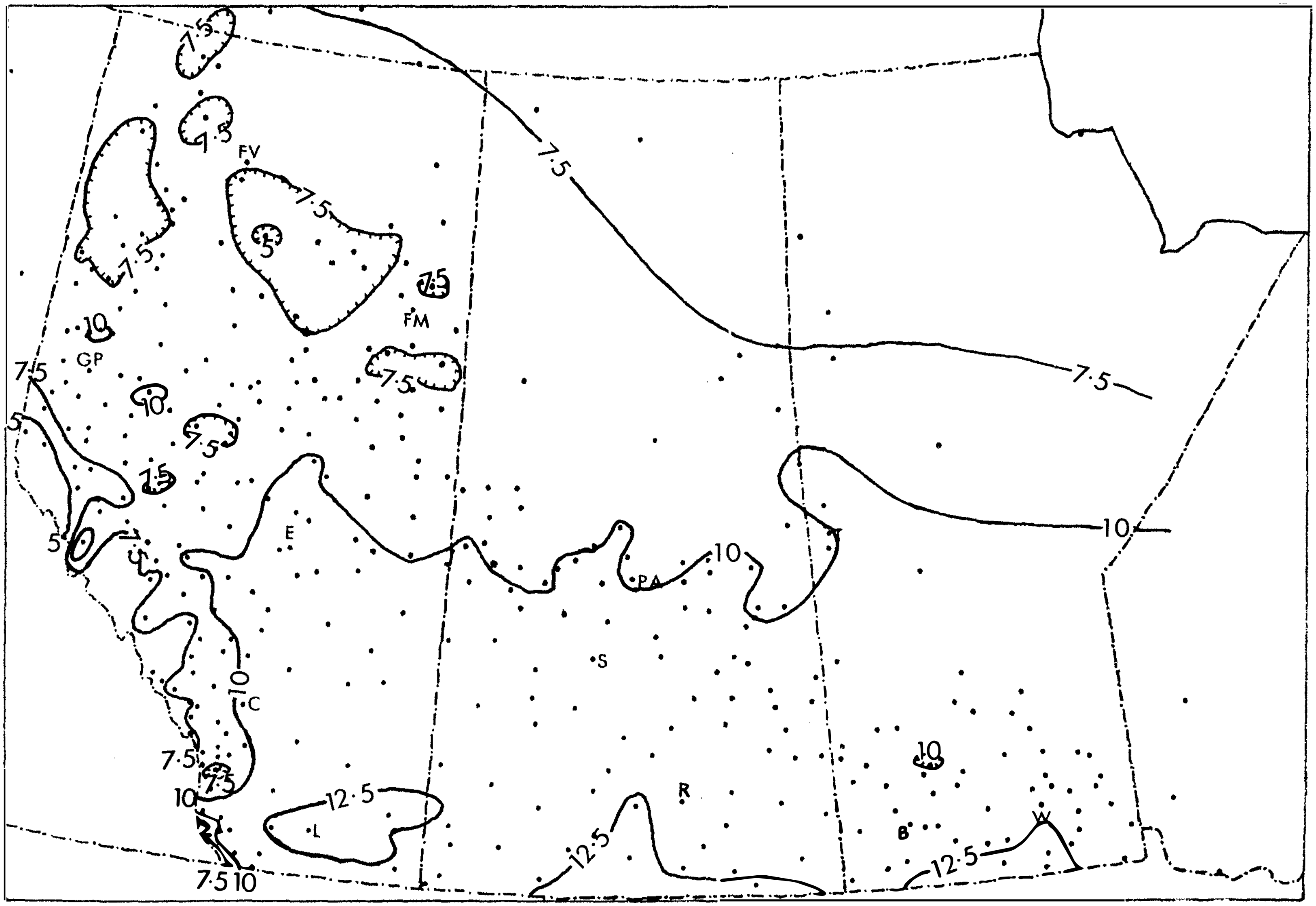

Fig. 6. Mean September temperature (°C), 1961-1970.

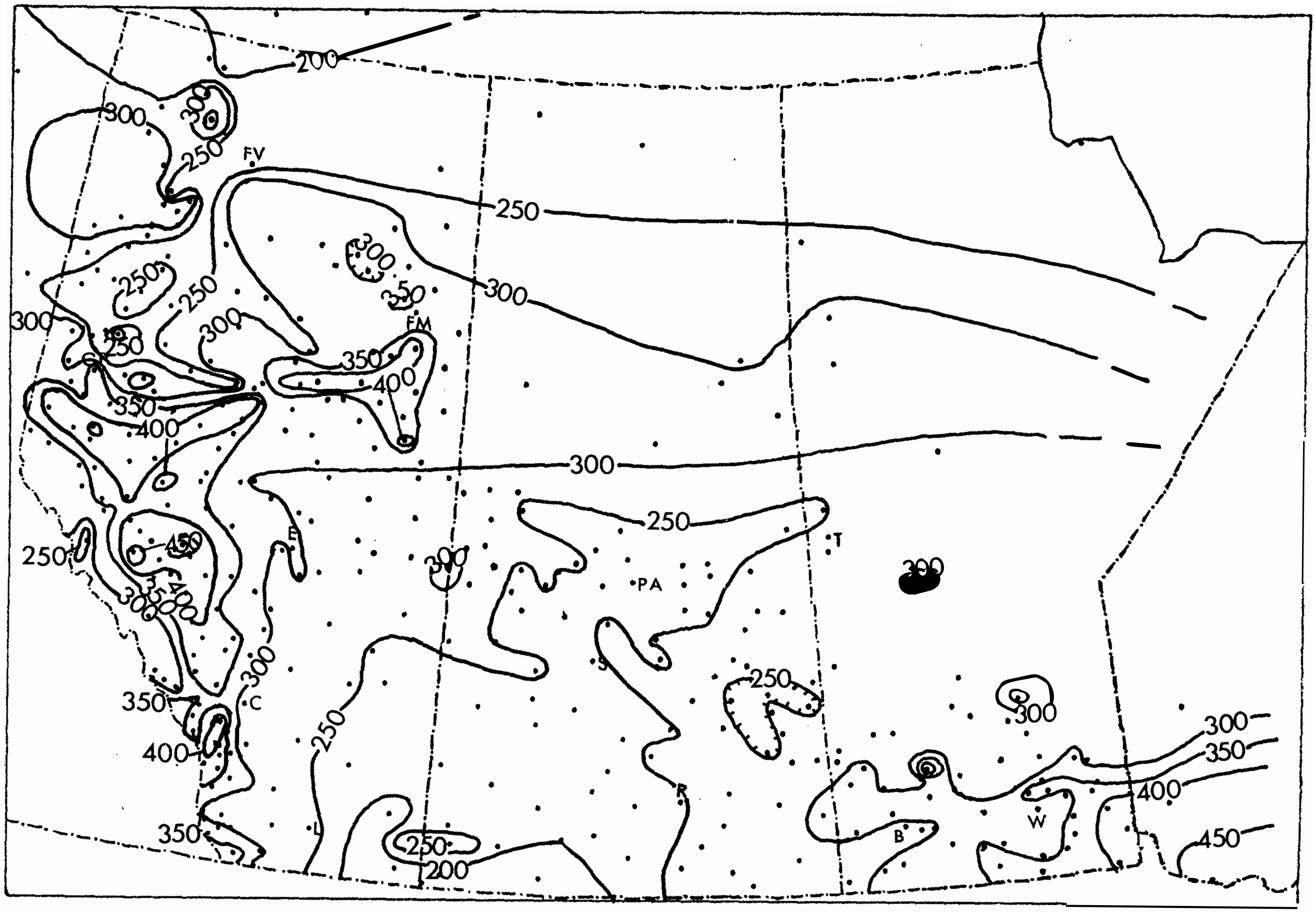

Fig. 7. Mean May to September precipitation (mm), 1961-1970.

Fig. 8. Mean May precipitation (mm), 1961-1970.

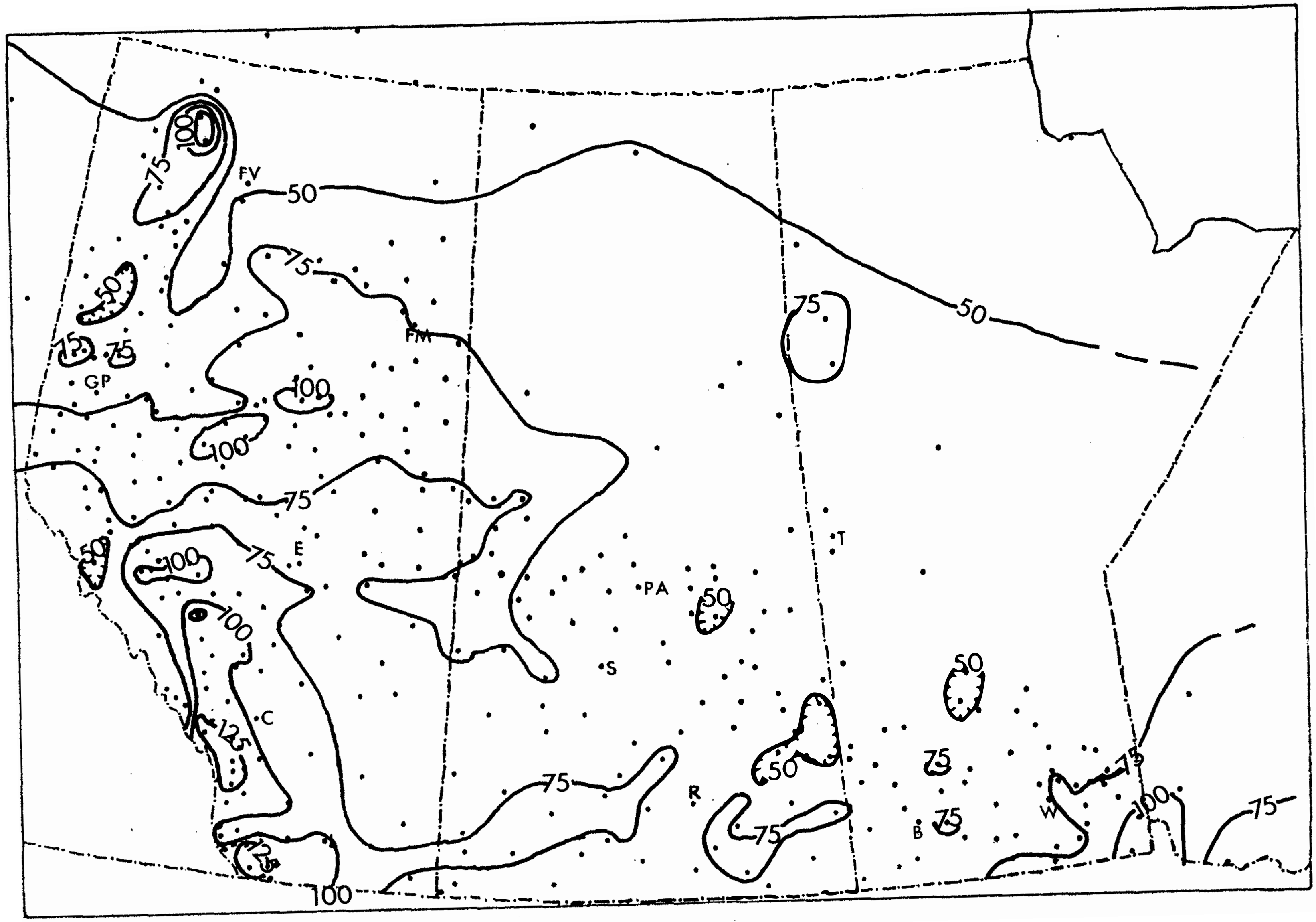

Fig. 9. Mean June precipitation (mm), 1961-1970.

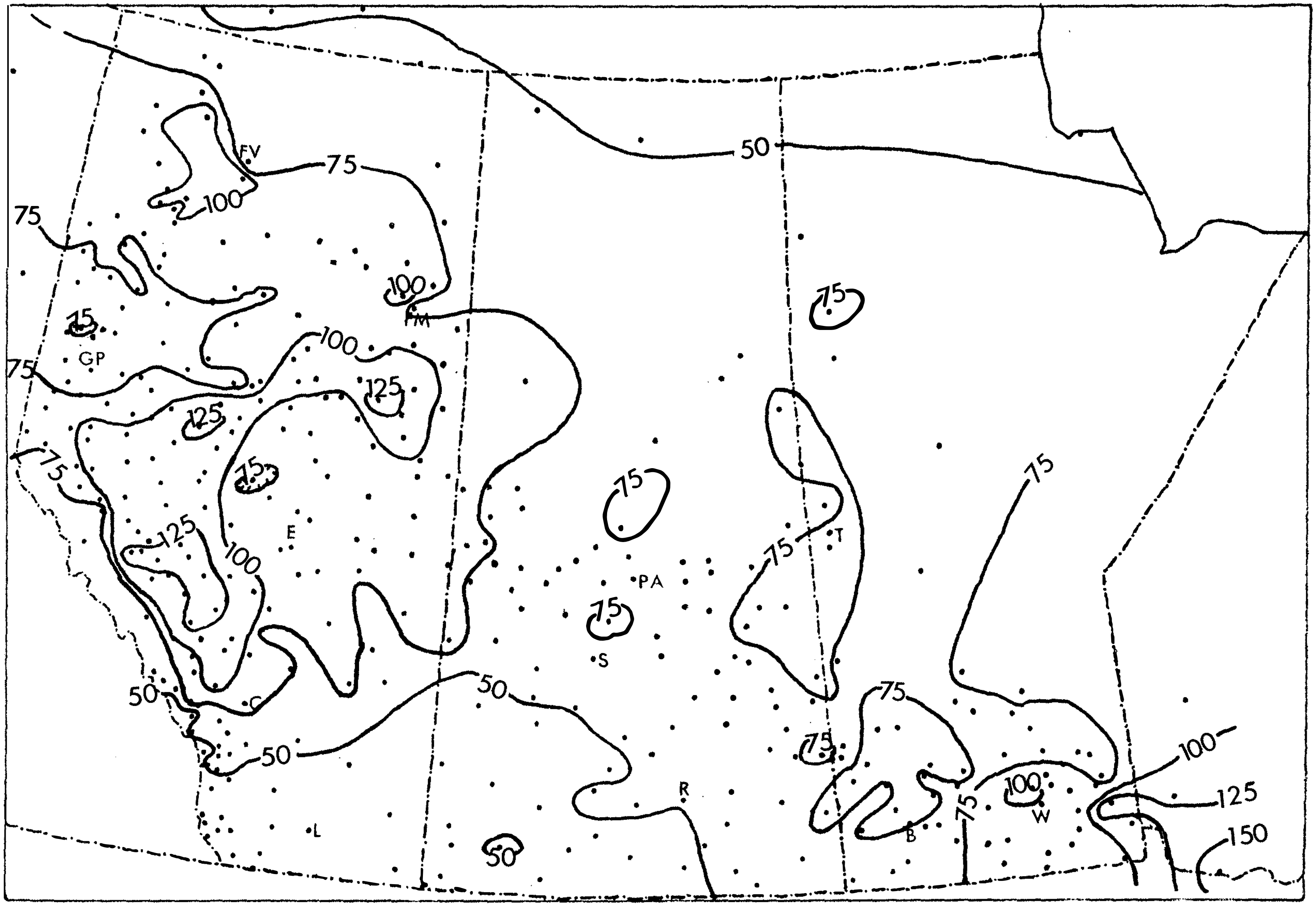

Fig. 10. Mean July precipitation (mm), 1961-1970.

The August precipitation pattern is roughly the same as July's, but totals are generally lower; most of the area receives between 50 and 75 mm of precipitation (Fig. 11). Central and southern Saskatchewan, southern Alberta including stations in the Rocky Mountains, the Peace River region, and northern Alberta and adjacent Northwest Territories all receive <50 mm. Southeastern Manitoba and a triangle in west-central Alberta all receive >75 mm, with the highest values (124.5 mm at Goose Mountain) in the Swan Hills. The lowest August precipitation occurs at Medicine Hat (19.1 mm) and Carway (22.9 mm) in southern Alberta and at Val Marie (22.6 mm) in southwestern Saskatchewan.

By September total precipitation is generally much lower (Fig. 12), although more falls in portions of southwestern Alberta during this month than in July or August, generally the wettest months throughout the area. Precipitation ranges between 25 and 50 mm in a broad band through southern Manitoba, central and southern Saskatchewan, and southern, central, and northern Alberta. The lowest total occurs at Nashlyn (21.6 mm) in southwestern Saskatchewan. Other low totals (25-30 mm) occur in a small area west and northwest of Saskatoon, and at four isolated stations in Alberta. Several areas have >50 mm, including the triangle of west-central Alberta that had some of the higher precipitation totals in earlier months, two areas in southwestern Alberta, and a broad band running from southeastern Manitoba through northern Manitoba, north-central Saskatchewan, and Alberta. Only a few small areas receive >75 mm (highest, 94 mm at Stoney Lookout in northeastern Alberta).

Frequency of Days with a Minimum Temperature of -2.2°C or Below

The seasonal map (Fig. 13) of days with a minimum temperature of -2.2°C or below shows the greatest range in the Rocky Mountains and Foothills area of Alberta, with frequencies ranging from <10 to over 35 days. Elsewhere, frequencies tend to range from 3 to 20 days, with those in the agricultural area generally with a frequency of <10 days. Most northern stations have frequencies over 15 days, except for some in the northwestern portion of the study area.

The frequency of days with a minimum temperature of -2.2°C or below in May ranged from over 15 at stations in the Rocky Mountains to <2 in several areas (Fig. 14). The latter stations were concentrated in the Peace River region, where 10 of the stations had frequency values between 1 and 2 days. Thirteen stations in central and southern Alberta also had values of <2, but only five in Saskatchewan and none in Manitoba. The isolines of 6, 10, 15, 20, and 25 days generally trend from the northwest to the southeast. The greater convoluting of the 6-day isoline is probably due to the larger density of stations upon which to position the line. Isolines are also found parallel to the Rocky Mountains, with a major indentation following the Athabasca River through the mountains, where Jasper has a value of 4 days. The topographic effect of the Rocky Mountains is shown by the very rapid gradients in short distances in the number of days with minimum temperatures of -2.2°C or below.

By June (Fig. 15) only a few areas in the Rocky Mountains have >5 days with a minimum temperature of -2.2°C or below; none have more than 10 days. Many areas have no days with a killing frost, and most other areas have <1 day. Nearly all of the Peace River region, including an area northward to Bassett and Naylor Hills, has no June killing frosts. Other areas at scattered locations in central and southern Alberta, as well as in discontinuous bands across Saskatchewan, and in Manitoba also have no June killing frosts.

In July (Fig. 16) a large part of the area has no killing frosts. Very few stations have a frequency of >1 day; these occur at isolated lookout stations in the Rocky Mountains.

In August (Fig. 17), many stations are still without days with a minimum temperature of -2.2°C or below. These occur throughout the area. A few stations in the Rocky Mountains or high Foothills have >1 day with a killing frost, with the highest frequencies occurring at Muskeg Ranger Station (3.3) and at Adams Creek Lookout (3.5).

By September there are considerable changes. A few areas in the Rocky Mountains have >10 days with a minimum temperature of -2.2°C or below (Fig. 18), and most of the

Fig. 11. Mean August precipitation (mm), 1961-1970

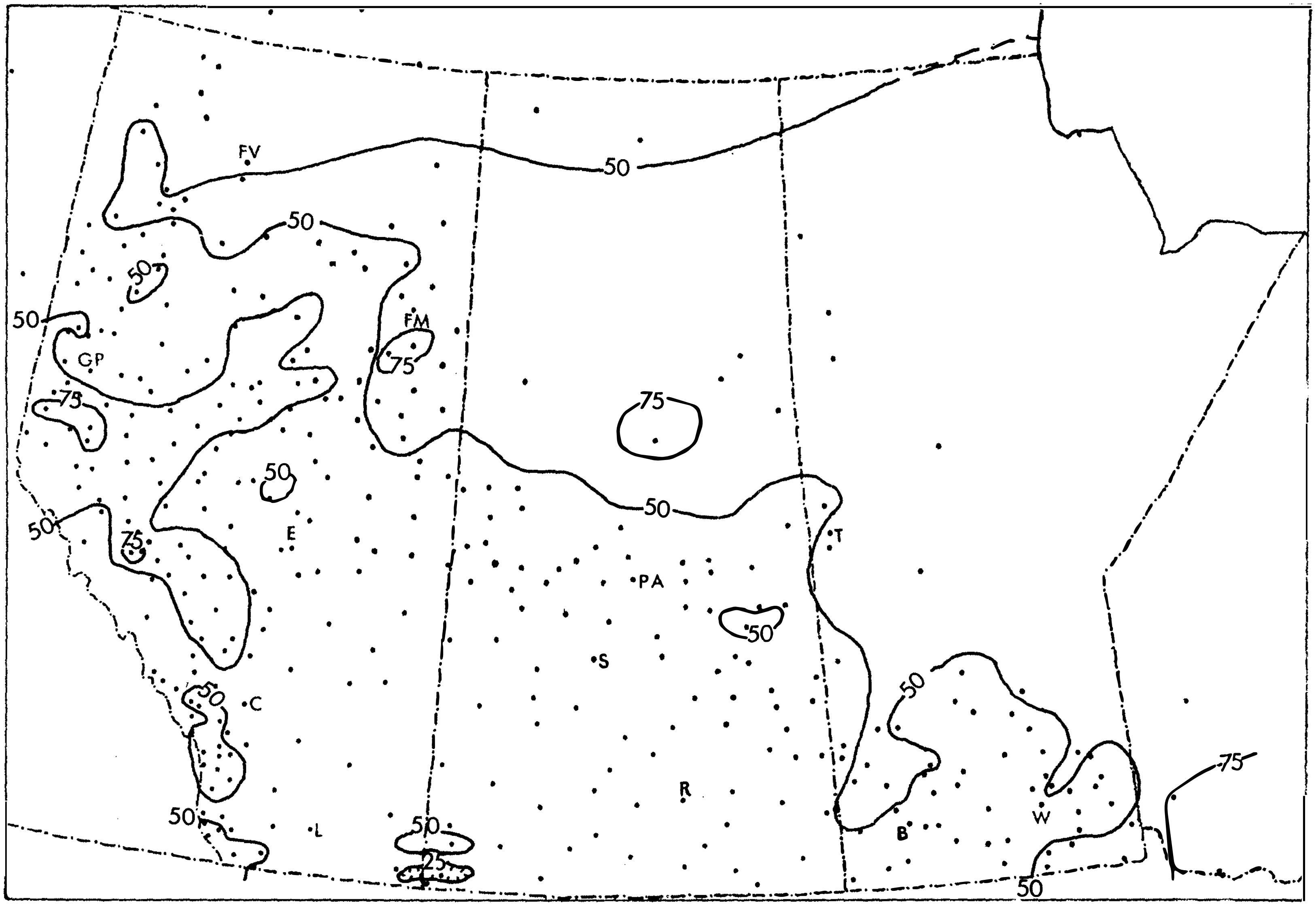

Fig. 12. Mean September precipitation (mm), 1961-1970.

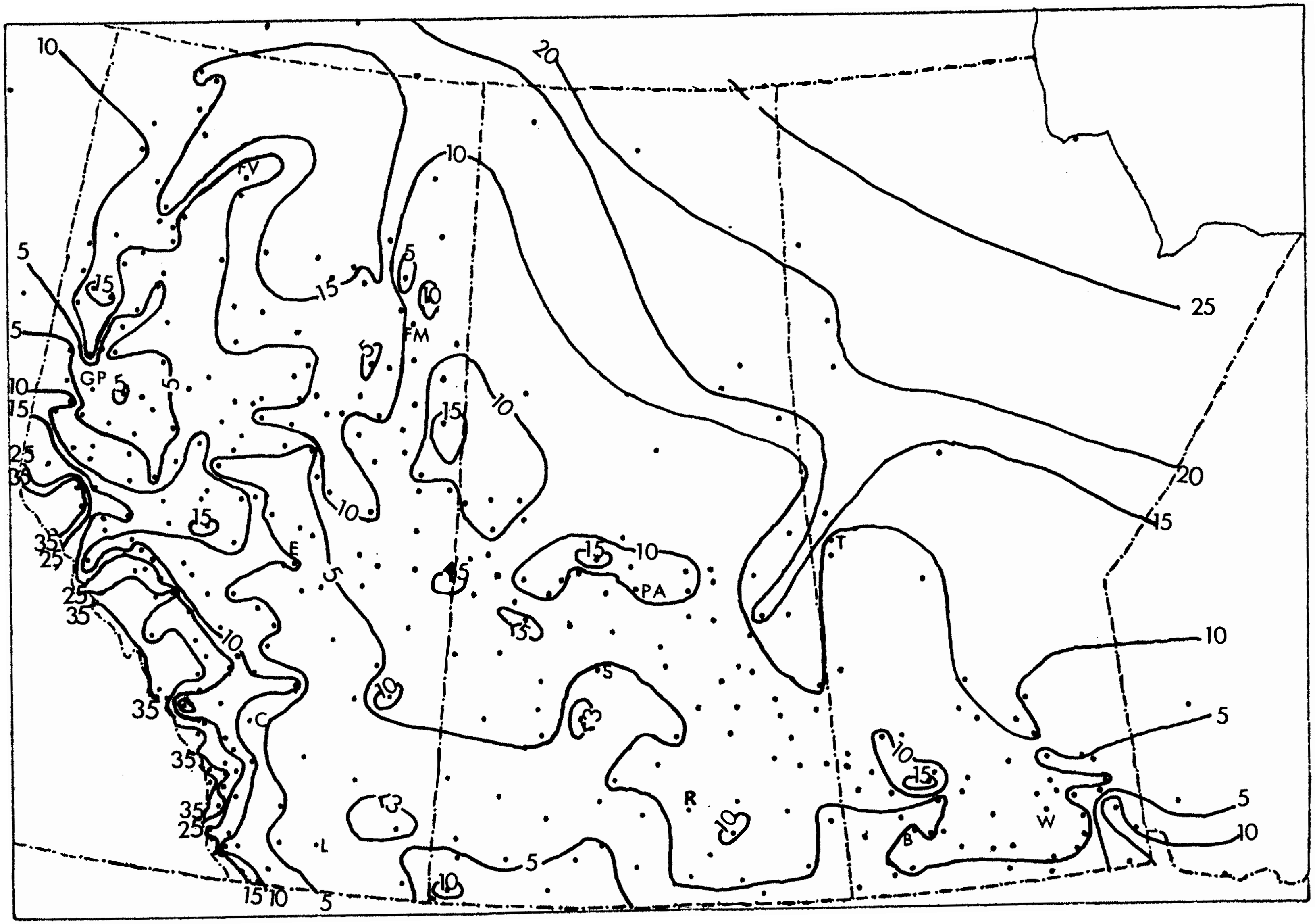

Fig. 13. Mean number of days during May to September with a minimum temperatures of -2.2°C or below, 1961-1970.

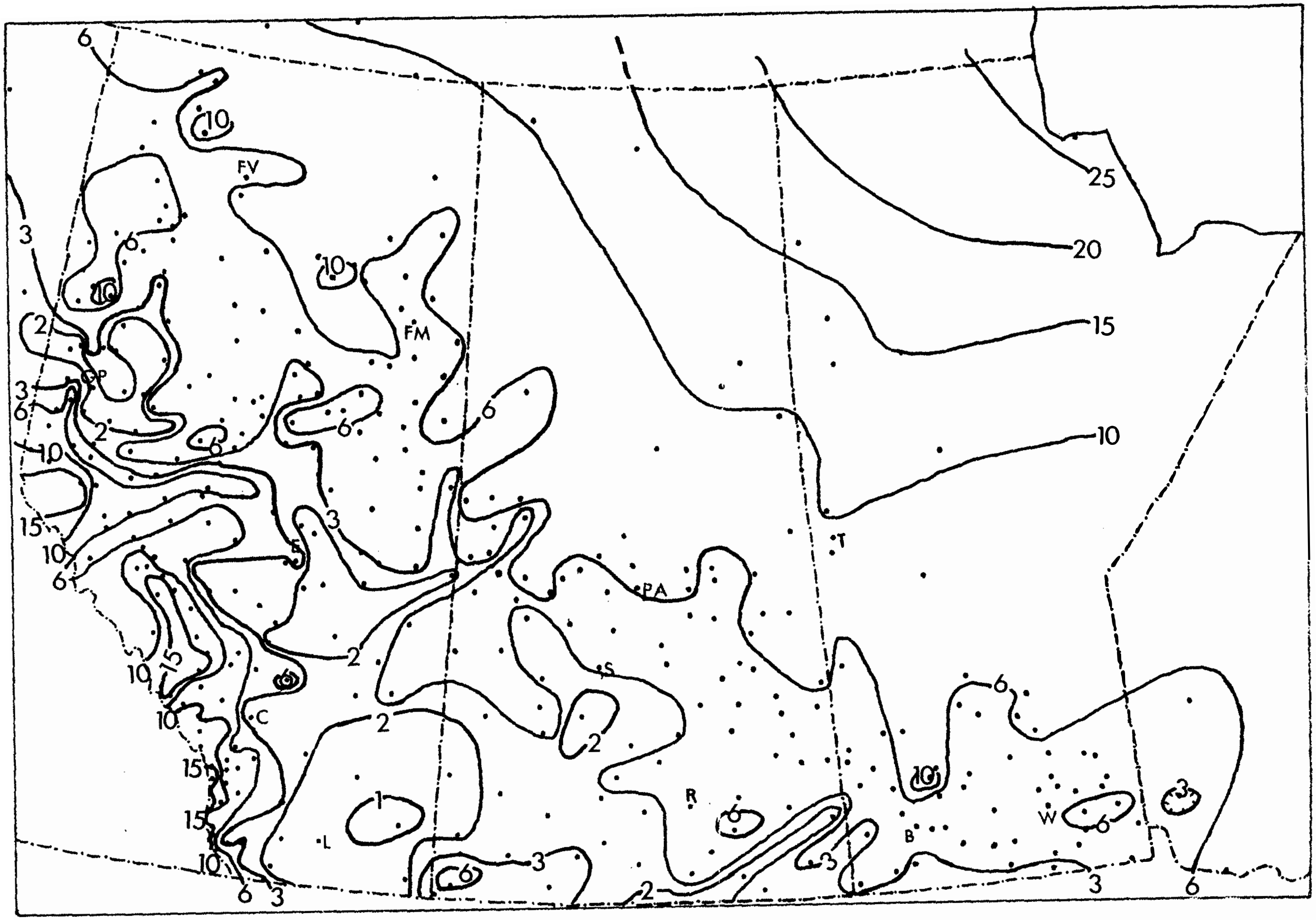

Fig. 14. Mean number of days in May with a minimum temperature of -2.2°C or below, 1961-1970.

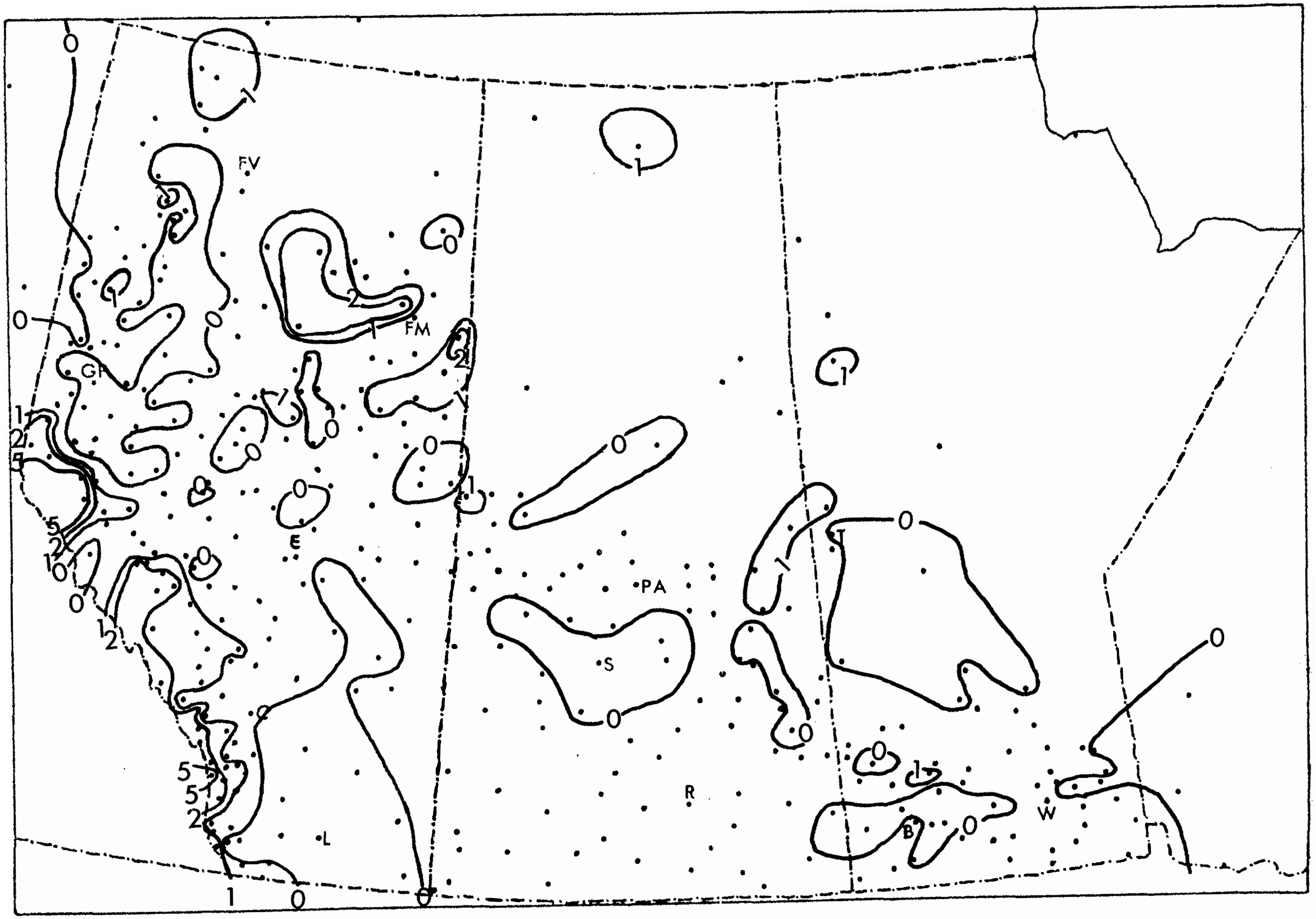

Fig. 15. Mean number of days in June with a minimum temperature of -2.2°C or below, 1961-1970.

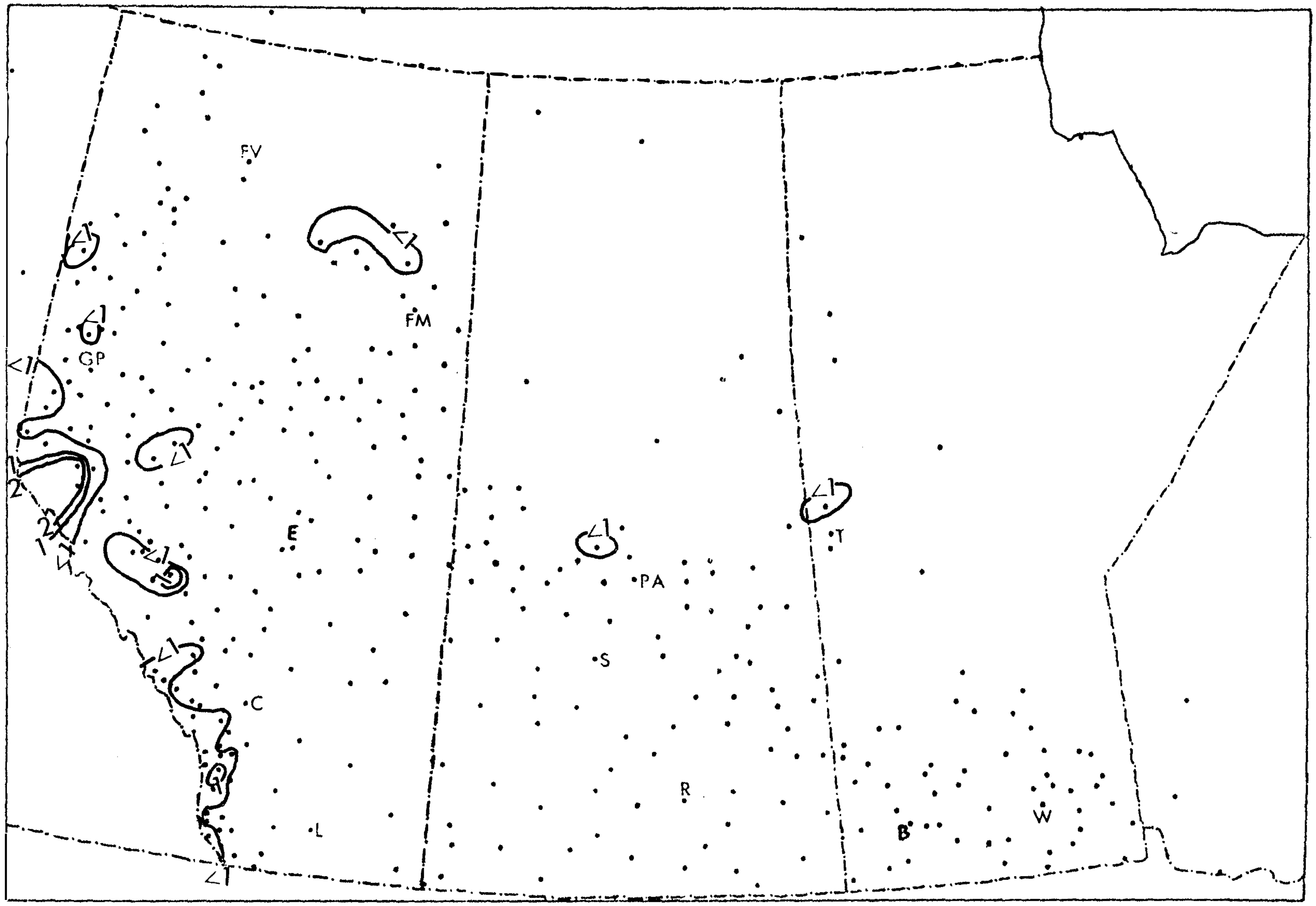

Fig. 16. Mean number of days in July with a minimum temperature of -2.2° C or below, 1961-1970.

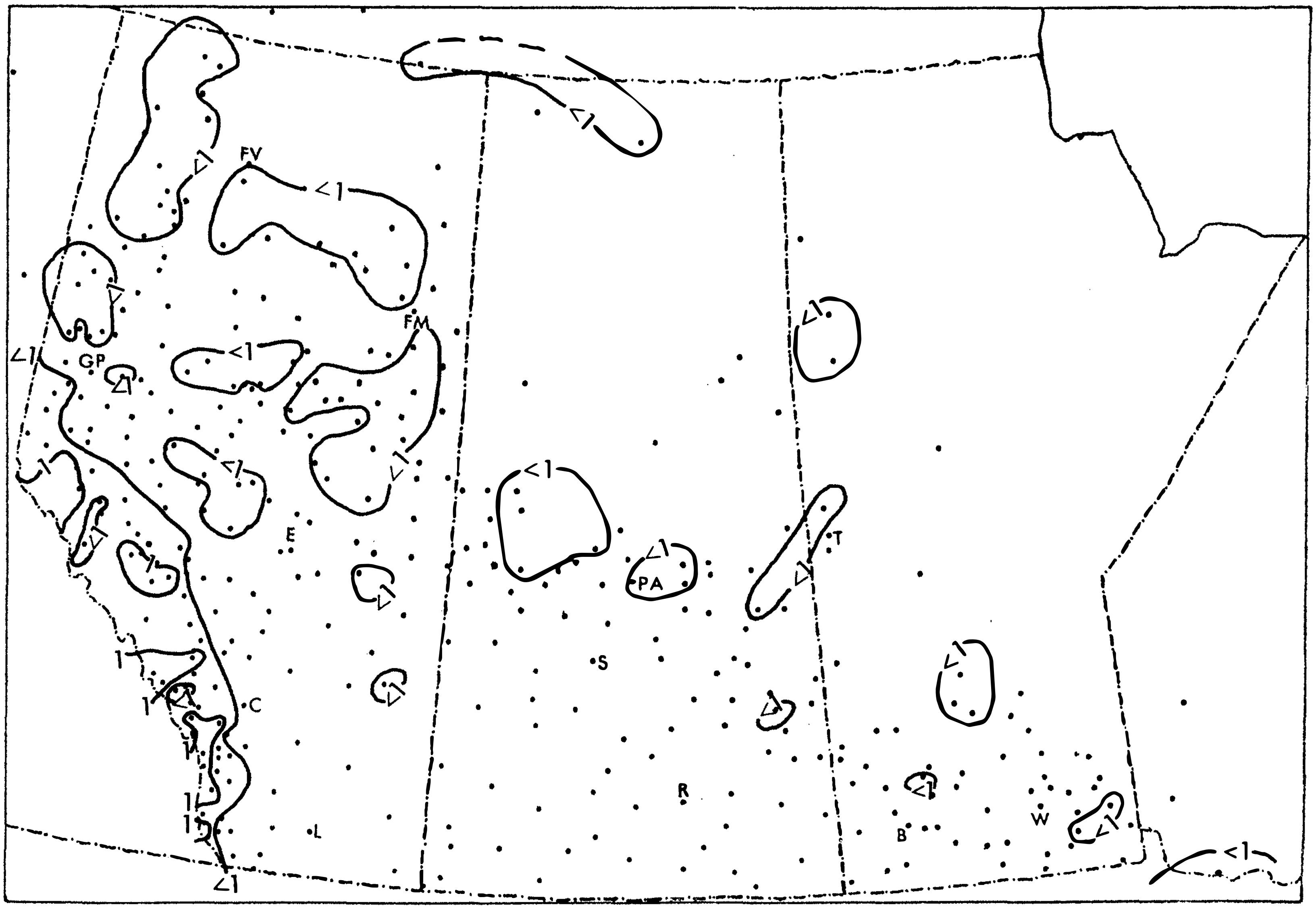

Fig. 17. Mean number of days in August with a minimum temperature of -2.2° C or below, 1961-1970.

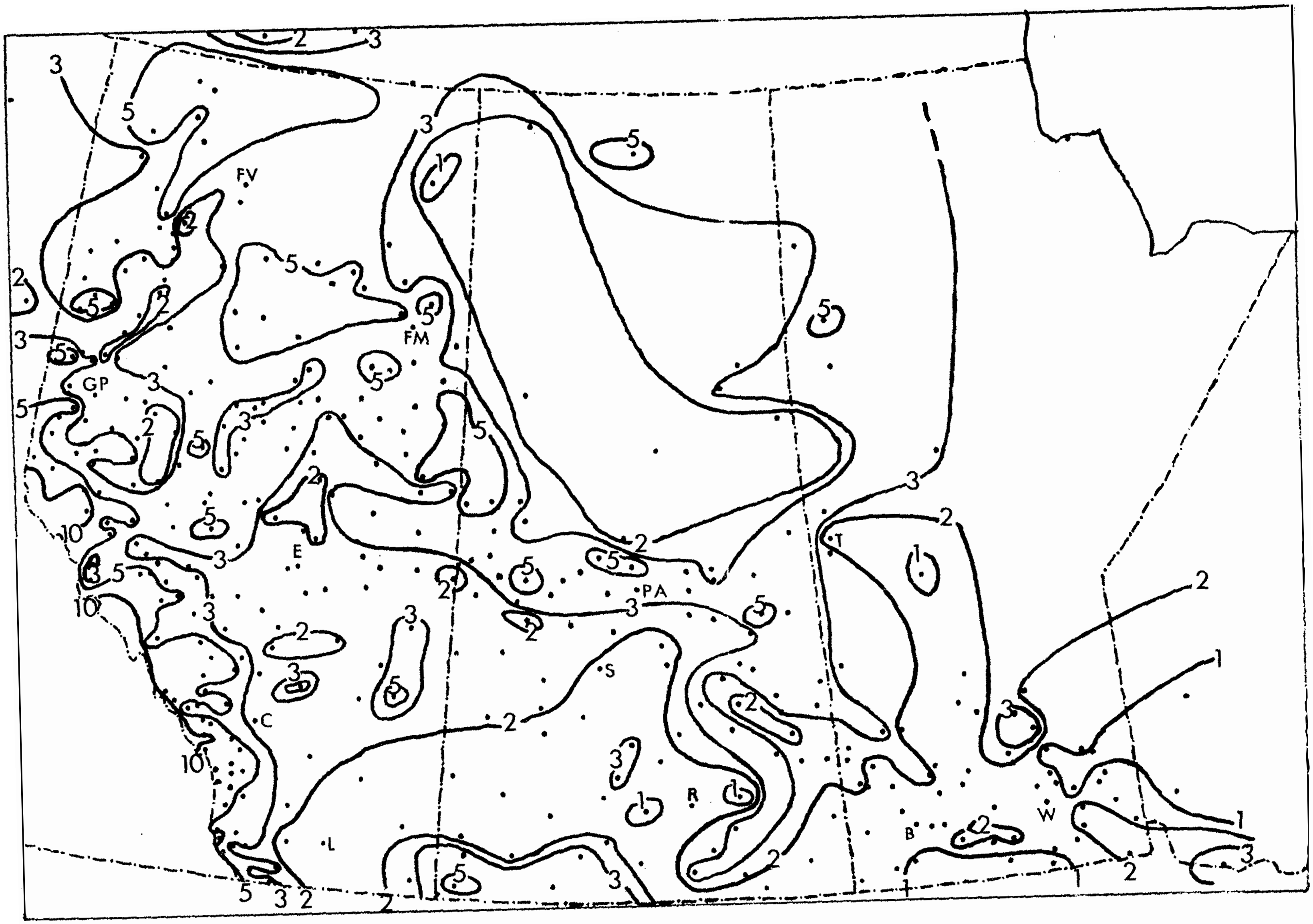

Fig. 18. Mean number of days in September with a minimum temperature of -2.2° C or below, 1961-1970.

agricultural fringe area now has values from 1 to 5 days, with isolated locations having >5 days. The lowest frequencies (<1 day) occur in southern Saskatchewan and Manitoba and adjacent northwestern Ontario. Several stations close to large water bodies such as Lake Athabasca, Great Slave Lake, and Lake Winnipeg retain relatively low frequencies of killing frosts through September.

Water Deficiency

The water deficiency of stations in the southern agricultural zone was not analyzed. In the forested and fringe agricultural zone some areas have no seasonal (May to September) water deficiency (Fig. 19). These areas occur largely in the Rocky Mountains (excluding the major river valley locations) and Foothills, with a few stations also in the area south of Fort McMurray. Highest water deficiencies (>150 mm) occur in northern Alberta and adjacent Northwest Territories, and in central Saskatchewan around North Battleford-Saskatoon-Lost River. Most of the agricultural fringe areas, including the Peace River region, have water deficiencies >100 mm, although areas in southern Manitoba and west and east-central Saskatchewan have deficiencies between 75 and 100 mm. In the zone of the outer Alberta Foothills there is a rapid gradient of increasing water deficiency eastward from 0, or <25 mm, to >100 mm.

In May the only station to record a small water deficiency was Emo (5 mm) in northwestern Ontario.

The June water deficiency pattern (Fig. 20) illustrates that precipitation for the year is at or near its maximum during this month. A broad band in western Alberta and much of the northwestern and northeastern areas of the province experiences no water deficit in June. In Saskatchewan the areas with no water deficiency are more discontinuous, and only three exist in Manitoba, including the far north. The highest water deficiency areas (>25 mm) occur close to Edmonton and in a band from Rosthern to Tisdale in Saskatchewan. The rest of the area, including the Peace River region and much of the contiguous northern grain-growing lands in Alberta, Saskatchewan, and Manitoba, shows only small water deficiencies.

By July there is a general increase in the area experiencing a water deficiency (Fig. 21). In Saskatchewan all stations experienced some deficit, with the highest amounts recorded at Melville (58 mm) and Uranium City (53 mm). In Manitoba, only small areas near The Pas and in the southeast recorded no water deficit; highest deficits were recorded at Moosehorn (64 mm) and Steeprock (61 mm). In Alberta, water deficiencies >50 mm occurred at several stations in extreme northern Alberta and in the Peace River area, and at Jasper, but much of the Foothills had no water deficit.

The August water deficiency pattern (Fig. 22) is similar to the July pattern. Areas of zero deficiency are those that receive the greatest amount of rainfall in midsummer and are now few and found only in Alberta. They include areas in west-central Alberta in the High and Low Foothills north of the Bow River, an area in the Foothills of southwestern Alberta, and several scattered areas in northern Alberta. Portions of southwestern Alberta, the Peace River region, the Alberta-NWT border, and a band across central Saskatchewan and south-central Manitoba have a water deficiency >50 mm. Four stations had the maximum August water deficiency of 76.2 mm (Carway, Hay River, Fort Resolution, and Notikewin Lookout). In Manitoba, the lowest August water deficiencies occur in the southeast (<25 mm), continuing into adjacent Ontario.

Water deficiencies in September (Fig. 23) are less than in August. Most of the agricultural area has deficits of between 20 and 40 mm, while most stations in the forested area have deficits of 0 to 20 mm. The highest water deficit in September occurred at North Battleford (40 mm).

DISCUSSION

Maps of mean annual temperature and precipitation are provided in most atlases covering the three Prairie Provinces, often along with maps for selected seasons or months (Canada Department of Energy, Mines and Resources 1973; Canada Department of Mines and Technical Surveys 1957; Government of Alberta and University of Alberta 1969; Richards and Fung 1969; Weir 1960; Weir and

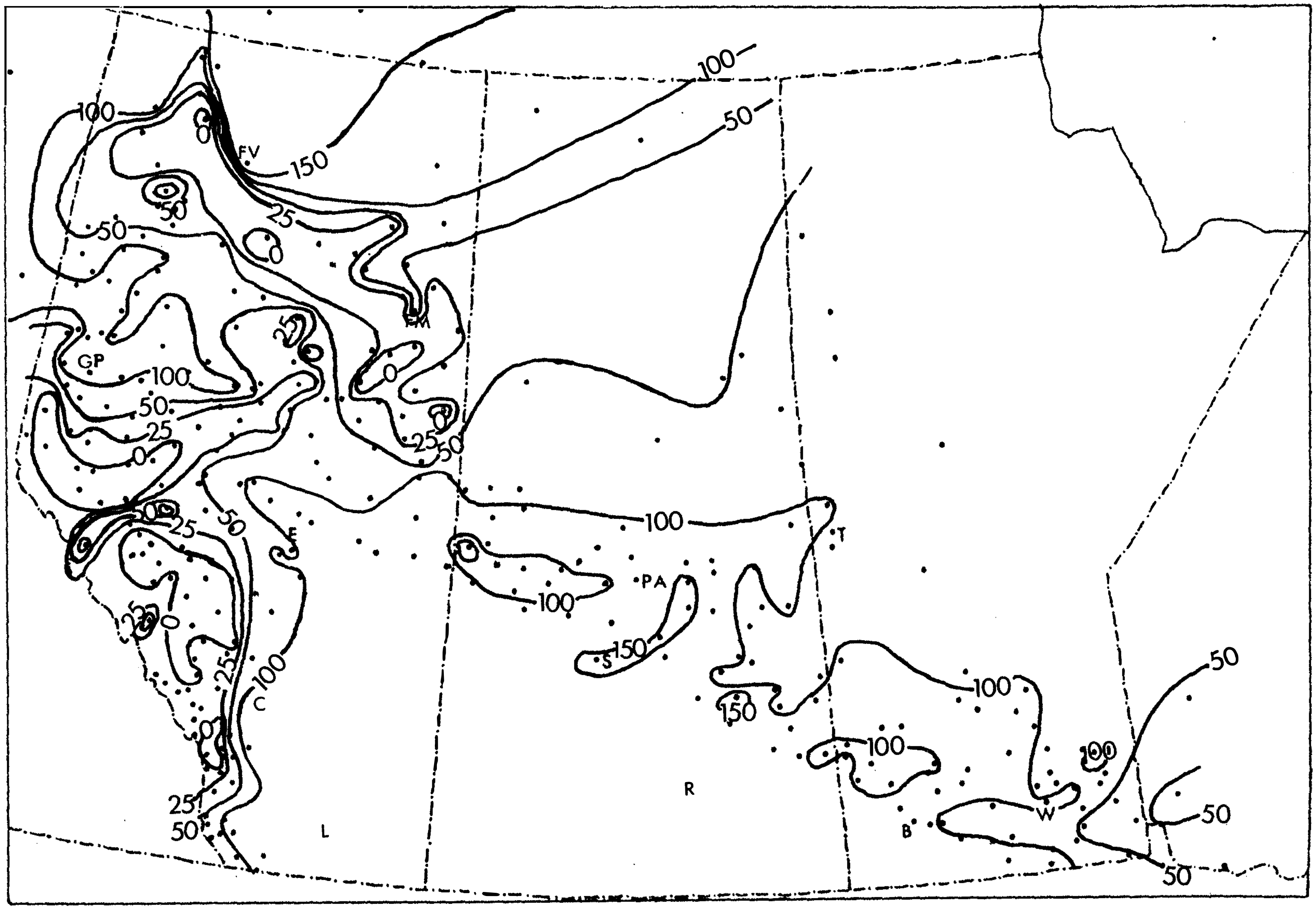

Fig. 19. Mean May to September water deficiency (mm), 1961-1970.

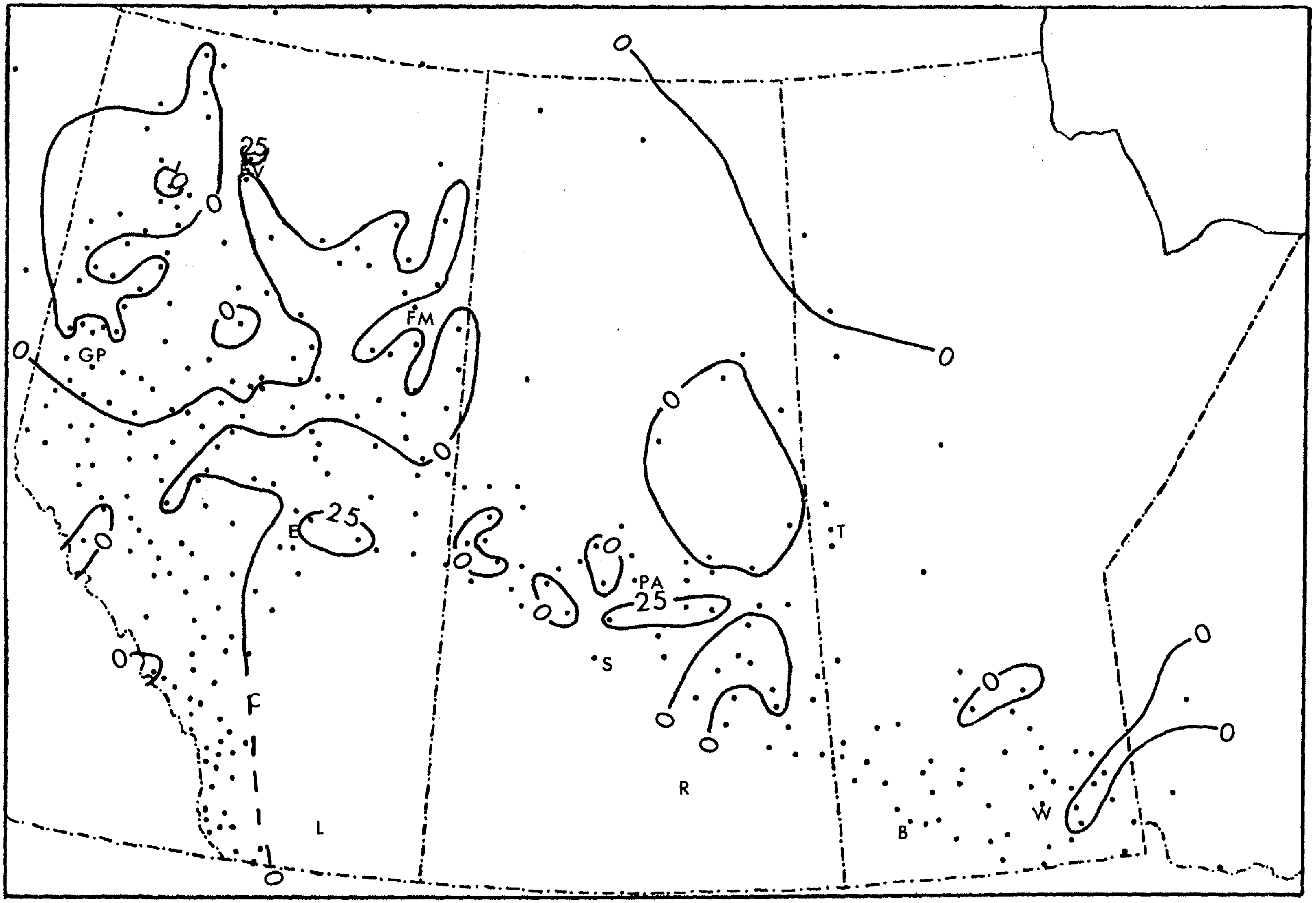

Fig. 20. Mean June water deficiency (mm), 1961-1970.

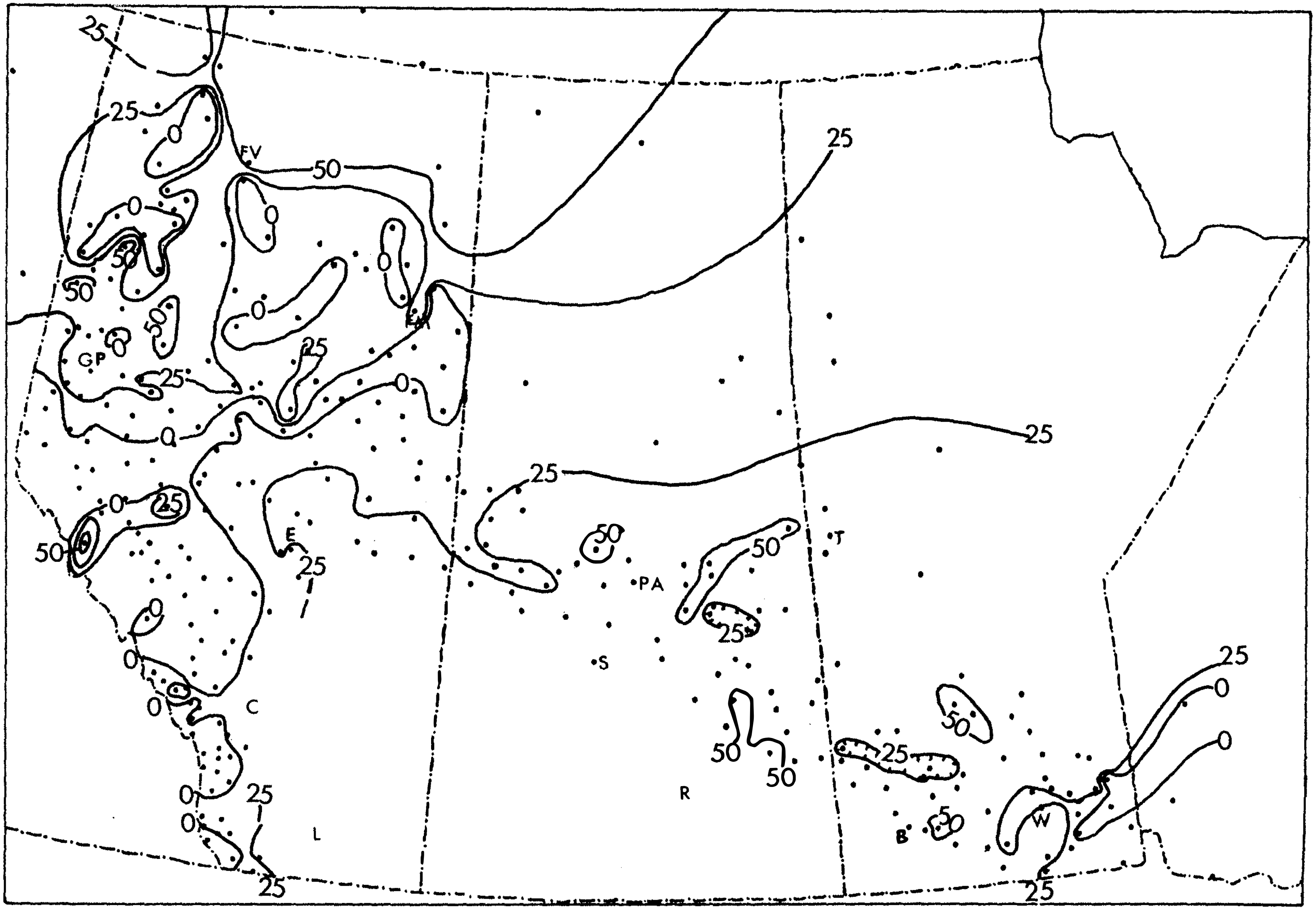

Fig. 21. Mean July water deficiency (mm), 1961-1970.

Fig. 22. Mean August water deficiency (mm), 1961-1970.

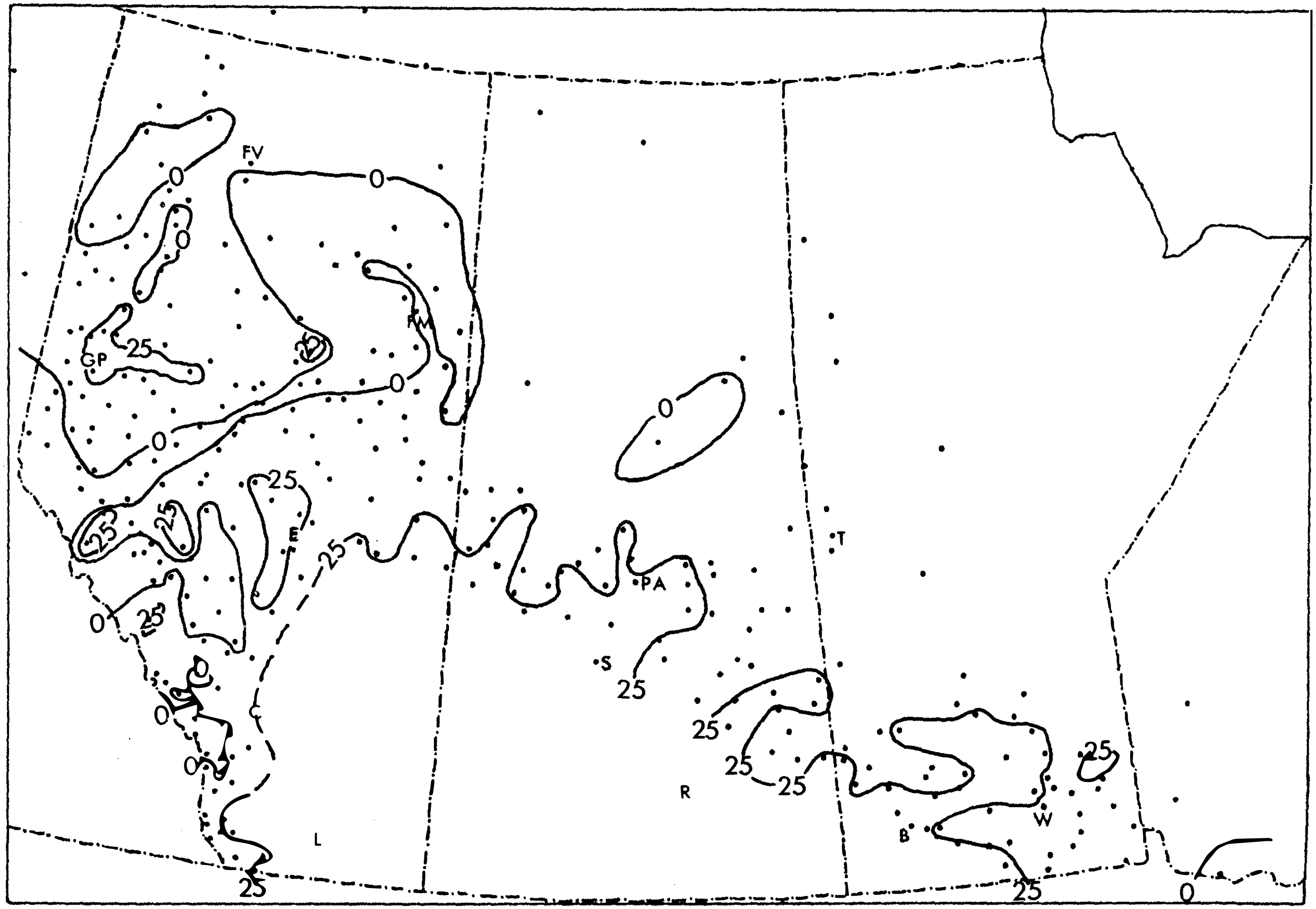

Fig. 23. Mean September water deficiency (mm), 1961-1970.

Matthews 1971). However, generally these maps are based on 30-year periods of data from only first-order meteorological and year-round climatological stations; the density of stations is therefore relatively sparse. Because the forested areas of the Prairie Provinces have generally been represented on such maps by only a few nonrepresentative valley or lakeside stations, detailed information on them is lacking. Longley (1972) has used records from some of the short-term summer lookout stations in Alberta, but isolines for the Rocky Mountains have been omitted, although some actual values have been inserted on the maps for the longer-term valley stations. Most atlas maps that use stations in mountain valley locations show below-average precipitation and above-average temperature values for these regions unless topography is taken into account. A few studies have made adequate allowances for topography and used hydrological data from other sources in preparing maps (Laycock 1957, 1967). Even away from the mountains, stations in deep valleys receive less precipitation than the neighbouring plains and hilly areas (Laycock 1967; Longley 1973). Some precipitation maps have been based on all available data, such as that by Laycock (1967) for average annual precipitation, 1921-1950, or recent ones by Powell (1977) of annual, winter, and summer precipitation for the Eastern Slopes of the Rocky Mountains and adjacent areas of Alberta.

There are no comparable seasonal maps of mean summer temperature (May to September), although Weir and Matthews (1971) give one for April to July 1931-1960. McKay (1965) gives monthly maps for the months May to September based on 1921-1950 data, and many sources provide a map of mean daily July temperatures based on 1921-1950 or 1931-1960 data, but only Longley (1972) gives a map based on 1941-1970 data and a denser network of stations.

McKay (1965) and Longley (1972) provide a seasonal precipitation map for the period May to September inclusive, and Shaykewich (1974) gives a similar map for southern Manitoba. Others have precipitation maps for the April-September period (Canada Department of Energy, Mines and Resources 1973); April-August (Government of Alberta and University of Alberta 1969), April-July, August-October (Weir and Matthews 1971), or for shorter seasonal periods (Canada Department of Mines and Technical Surveys 1957; Longley 1972; Weir 1960). *The National Atlas of Canada* (Canada Department of Energy, Mines and Resources 1973) provides monthly precipitation maps, and for Alberta some monthly maps are given by Stashko (1971) and the *Atlas of Alberta* (Government of Alberta and University of Alberta 1969). The maps by Stashko include data for the forested area based on forest-fire lookout data for the period 1963-1970.

The *Agroclimatic Atlas* (Canada Agriculture 1977) uses the base of -2°C (28°F) to show the number of days of the average freeze-free period between the spring and fall killing frosts and provides similar values to those of the present study, which gives number of days with a minimum temperature of -2.2°C (28°F) or below in the period May to September inclusive. Shaykewich (1974) also shows the average length of the killing frost-free period for southern Manitoba, based on a network of 32 stations.

Several sources show the seasonal or annual water deficit based on a soil storage of 100 mm of water at the beginning of March (Canada Agriculture 1977; Canada Department of Energy, Mines and Resources 1973; Government of Alberta and University of Alberta 1969; Laycock 1967; Longley 1972; Shaykewich 1974; Weir 1960). The amount of assumed soil moisture recharge in March of 100 mm is an average value for a loam soil with a cereal cover with moderate root development, and is therefore a generalization. For a loam soil with a mature forest cover a storage capacity of 300 mm is generally assumed, and obviously if the soil is a sand or clay, or is shallow over bedrock other storage capacities should be used. Or again, if an area has a high natural water table the calculation of a water deficit based on climatic data is often meaningless. Most water balance calculations are based on monthly values, but in the present study daily values are used to calculate the monthly and seasonal totals. Pierpoint and Farrar (1962) used daily values and showed that a water storage of only 25 mm was a more reasonable assumption for very shallow soils over bedrock in a forested area of Ontario. Satterlund (1959) has also shown that forest vegetation can store an appreciable quantity of water. This is additional to the water stored in the soil and is particularly effective in areas of shallow soils. Because much of the northern areas of Saskatchewan and Manitoba has shallow soils over bedrock these two points should be considered in any detailed water balance studies of a forested area.

With the exception of the maps prepared by Longley (1972), Powell (1977), Shaykewich (1974), and Stashko (1971), all the others referred to above are based on 1921-1950 or 1931-1960 data, rather than the 1941-1970 normal period or recent shorter periods. However, in the foreword to the *Agroclimatic Atlas* (Canada Agriculture 1977) W. Baier mentions "that the normals for 1941-70 do not significantly differ from those for 1931-60"; thus, data from these two normal periods should be comparable.

With a few exceptions the station density in Alberta used in the study is good (Powell and MacIver 1977). It could be improved in extreme northern Alberta and at higher levels in Banff and Jasper national parks where summer climatological stations were generally lacking prior to the mid-1960's. Some recent data are now available for these areas and could be used in future studies to fill gaps, although daily temperature and precipitation data are still largely missing for higher elevations in the national parks (Janz and Storr 1977). In northern Saskatchewan and Manitoba there is a general lack of stations, especially in the forested area. Kabzems *et al.* (1976) also note the lack of meteorological data in the forested areas of Saskatchewan in their ecological study of the Mixedwood Section and recommend the establishment of additional stations on a year-round basis. Most of the fire lookout stations in Manitoba and Saskatchewan could be instrumented and operated to take daily climatological records of temperature and precipitation for the growing season. At present some lookouts or ranger stations take fire weather records at irregular intervals with the emphasis on precipitation and midday weather conditions, which are of little value to the climatologist and are not maintained by the forecasting services beyond the fire season for which they were obtained. If meaningful climatic data or derived data are going to be available for the forested areas of Manitoba and Saskatchewan, a program must be initiated to upgrade the climatological input from forestry stations and to establish new stations in areas presently lacking data.

In using the maps it must be remembered that they represent mean values; the range in values one can expect will depend upon the particular climatic parameter and month. Many of the stations used in the present report are situated in valleys, on lakeshores, or on hill-tops in the case of fire weather lookouts; therefore, caution should be used in identifying them as representative of the surrounding area. Some of the station values used in the present maps included estimated values for missing days, months, or years that was necessary to prepare complete sets of data for factor analysis for the associated study (Powell and MacIver 1977). Stations with short-term records that do not fit the complete study period will always be a problem for any analysis. However, records have accumulated for many of these stations since the cutoff year of 1970, and thus more accurate values could be developed based on a longer period of record independently of other nearby stations. The maps presented in this report could be refined by adding new stations to the network or by using longer-term records for recently established stations. Greater emphasis could also be given to making topographic allowances in the drawing of isolines, especially in mountainous or hilly terrain where variations in both temperature and precipitation and their derived climatic parameters can be quite large. To do this adequately would require a larger map scale and, most importantly, sufficient information, now largely lacking, to quantitatively describe such effects.

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REFERENCES

Canada Agriculture. 1977. Agroclimatic atlas. Res. Br., Chem. Biol. Res. Inst., Agrometeorol. Res. Serv. Sect. Ottawa. 19 pp.

Canada Department of Energy, Mines and Resources. 1973. The national atlas of Canada. 4th Ed. Surv. Mapp. Br. Ottawa.

Canada Department of Mines and Technical Surveys. 1957. Atlas of Canada. Geogr. Br. Ottawa.

Canada Department of Transport. 1961-1971. Monthly record. Meteorological observations in Canada. Meteorol. Br. Toronto.

Government of Alberta and University of Alberta. 1969. Atlas of Alberta. Univ. Alberta Press. Edmonton. 162 pp.

Janz, B. and D. Storr. 1977. The climate of the contiguous mountain parks: Banff-Jasper-Yoho-Kootenay. Environ. Can., Atmos. Environ. Serv., Meteorol. Appl. Br., Appl. Consult. Div. Proj. Rep. No. 30. 324 pp + map (unpubl. manuscript).

Kabzems, A., A.L. Kosowan, and W.C. Harris. 1976. Mixedwood Section in an ecological perspective, Saskatchewan. Sask. Dep. Tourism Renewable Resour., For. Br. Tech. Bull. No. 8. i-vi, 118 pp. + map.

Laycock, A.H. 1957. Precipitation and streamflow in the mountain and foothills regions of the Saskatchewan River Basin. Prairie Prov. Water Board. Rep. No. 6. 47 pp.

———. 1967. Water deficiency and surplus patterns in the Prairie Provinces. Prairie Prov. Water Board. Rep. No. 13. 185 pp.

Longley, R.W. 1972. The climate of the Prairie Provinces. Environ. Can., Atmos. Environ. Serv. Climatol. Stud. No. 13. 79 pp.

———. 1973. Note on the effects of valleys on precipitation. Environ. Can., Atmos. Environ. Serv. CLI 3-73. 4 pp.

McKay, G.A. 1965. Climatic maps of the Prairie Provinces for agriculture. Can. Dep. Transp., Meteorol. Br. Climatol. Stud. No. 1. 18 pp.

Pierpoint, G. and J.L. Farrar. 1962. The water balance of the University of Toronto forest. Univ. Toronto, Fac. For. Tech. Rep. No. 3. 48 pp.

Powell, J.M. 1977. Precipitation climatology of the Eastern Slopes area of Alberta. Pages 187-204 *in* R.H. Swanson and P.A. Logan (Compilers). Alberta Watershed Research Program Symposium Proceedings, 1977. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-176. 342 pp.

———. Climatic classification of the Prairie Provinces of Canada. *In* Essays of meteorology and climatology: In honor of Richmond W. Longley. Univ. Alberta, Dep. Geogr. (in press).

Powell, J.M. and D.C. MacIver. 1977. A summer climate classification for the forested area of the Prairie Provinces using factor analysis. Fish. Environ. Can., Can. For. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-177. 51 pp.

Richards, J.H. and K.I. Fung. 1969. Atlas of Saskatchewan. Univ. Sask., Saskatoon. Modern Press. Saskatoon. 236 pp.

Shaykewich, C.F. 1974. Climate of southern Manitoba as it relates to agriculture. Manit. Dep. Agric. Publ. No. 546. 24 pp.

Stashko, E.V. 1971. Precipitation means, Alberta Forestry Stations, May to September 1963-1970. Alberta Dep. Lands For., Alberta For. Serv. 32 pp.

Satterlund, D.R. 1959. Vegetation storage on the watershed. J. For. 57:12-14.

Thornthwaite, C.W. and J.R. Mather. 1955. The water balance. John Hopkins Univ., Lab. Climatol. Publ. Climatol. 8(1):104 pp.

Weir, T.R. (Ed.). 1960. Economic atlas of Manitoba. Manit. Dep. Ind. Commer. 81 pp.

Weir, T.R. and G. Matthews. 1971. Atlas of the Prairie Provinces. Oxford Univ. Press. Toronto. 34 pp.