THE SEASONAL DISTRIBUTION OF PRECIPITATION AND ITS FREQUENCY AND INTENSITY IN THE UNITED STATES.

By JOSEPH BURTON KINCER, Meteorologist.

[Dated: Weather Bureau, Washington, Oct. 11, 1919.]

SYNOPSIS.—Much has been written on the subject of precipitation in the United States, and a number of charts have been prepared and published showing its geographic distribution. Most of these, however, have represented the average annual amount, the only other available chart, where more than a very limited number of records were used, being that for the summer-half year.

The need for a series of charts based on all available records, showing the seasonal distribution of precipitation in this country has long been recognized, and the accompanying series is presented to meet this need. Those here shown consist of 12 monthly charts, and 1 for each of the 4 seasons, together with auxiliary maps for the seasons showing the percentage of the annual precipitation that occurs in each. The monthly and seasonal charts are based on all available records of sufficient length for such use, about 3,600 in number, reduced to a uniform 20-year period.

There are, in addition, a number of graphs showing for selected stations representing various rainfall types, the total precipitation in each season for each of the 20 years on which the maps are based. These show the relative variations in amount that may be expected from year to year in different sections of the country, and also give an indication of the dependability of the averages. In localities where the dispersions about the mean value are small, the latter is more indicative of the amount likely to be received in a particular year than in those where wide variations are shown by the graphs.

Departures from year to year from the average precipitation vary in magnitude inversely with the length of the season considered. The relative variations from the mean for the annual, the summer-half year, each of the 4 seasons, and for each of the 12 months, are graphically shown in figure 1, in such manner as to admit of direct comparison, as the scales are drawn on a comparable basis.

In addition to an indication of the variations from the mean precipitation that are likely to occur, it is important in considering the representations of precipitation charts to take into account the frequency with which significant amounts occur, the intensity of falls, and the subnormal frequency and duration. Auxiliary charts for use in this connection are presented as follows: Showing the average number of days annually with precipitation from 0.01 inch to 0.25 inch in 24 hours; the average number of days annually with 0.26 to 1 inch; the average annual number with more than 2 inches; the average annual number with more than 1 inch in an hour, and the maximum precipitation in 24 hours for the entire 20-year period. Also, the percentage of years east of the Rocky Mountains with 30 consecutive days or more, without 0.25 inch of rainfall in 24 hours from March to September, inclusive, and the greatest number of consecutive days without 0.25 inch in 24 hours for the same months. These auxiliary charts are based on the records of all regular reporting stations for the 20-year period from 1895 to 1914.

INTRODUCTION—RELATIVE UTILITY OF RAINFALL CHARTS.

Existing charts of the average precipitation for the United States are mostly for the year. Seasonal and monthly charts have been published, but these have been based on a limited number of stations and the isohyets drawn with little regard for topography. (See Weather Bureau Bulletins C, 1894, and D, 1897; also, Climatic Charts, edition of 1904.) The annual chart, however, is more frequently consulted, notwithstanding that seasonal amounts of precipitation are of great significance, especially in all sections where agricultural operations are conducted by ordinary farming methods. The principal difficulty in the application of statistics of annual precipitation arises from the fact that there is always a possibility, because of the long period covered, that large deficiencies in some portions of the year may be offset by excesses in others, and a disastrous drought during the season of critical plant development may thus be obscured in the annual total. Furthermore, the latter gives no indication of the seasonal distribution, which, agriculturally at least, is of great importance. For example, the average annual precipitation in the eastern portion of South Dakota is between 20 and 25 inches. This amount of precipitation may, or may not, be sufficient for successful agriculture as ordinarily practiced, depending wholly on the seasonal distribution and the locality as regards the amount of evaporation, soil texture and other factors. It is sufficient in eastern South Dakota, but in a locality with a more uniform seasonal distribution and more rapid evaporation it would be inadequate.

Monthly charts, also, are not entirely satisfactory for many purposes, because of the relatively large fluctuation in amounts from year to year in so short a period, and from the further fact that the means are sometimes unduly magnified by the occurrence of a few very heavy rainfalls which have little agricultural value. Seasonal charts are less subject to the limitations mentioned for annuals and monthlies and are, therefore, better representations of precipitation in its relation to agriculture; consequently their importance can hardly be overemphasized.

The accompanying series of charts includes a map showing the average amount of precipitation for the different sections of the country for each month of the year, Charts I to XII, and one for each of the four seasons, Charts XIII to XVI, each based on 3,600 records. There are also presented four charts, each based on 1,350 records, showing the percentage of the annual amount occurring in each of the seasons, figures 1–4, as well as graphs indicating for selected stations the variations from year to year in the annual, seasonal, and monthly totals. In addition, a few charts indicating the relative intensity of rainfall in different sections of the country, and the frequency and duration of certain features of subnormal rainfall for the warmer season of the year, are presented, as these factors have an important bearing on the significance of the averages for a series of years.

RECORDS REDUCED TO UNIFORM 20-YEAR PERIOD.

The records on which the monthly and seasonal charts are based were made at well-distributed points throughout the country, and have been reduced to the uniform period of 20 years from 1895 to 1914, inclusive. Of these, about 1,600 represent actual averages for the period

named, with short breaks interpolated, and the other 2,000 have been reduced to this uniform period by the method described in the MONTHLY WEATHER REVIEW, May, 1917, **45**, 333–335. The isohyets were drawn on bases showing, by hachures, the topographic features of the United States, and in accordance with the principles outlined in the paper referred to. The latest chart of annual precipitation in the United States constructed on these principles appeared in the MONTHLY WEATHER REVIEW for July, 1917, **45**, with comment by Prof. R. deC. Ward (pp. 338–345; reviewed, Science, July 19, 1918 pp. 69–71).

and monthly, the annual has the smallest variations and the monthlies the largest, with the seasonal holding an intermediate position.

These dispersions about the mean are shown graphically in their relation to one another in figure 1. The records of four representative stations are shown in this graph: Augusta, Ga.; Columbus, Ohio; Omaha, Nebr.; and Miles City, Mont. To visualize comparability, the scales for the respective periods are proportioned to their length—that is, the scale for the summer-half year is twice as large as the annual, the seasonal twice as large as the summer-half year, and the monthly, in turn,

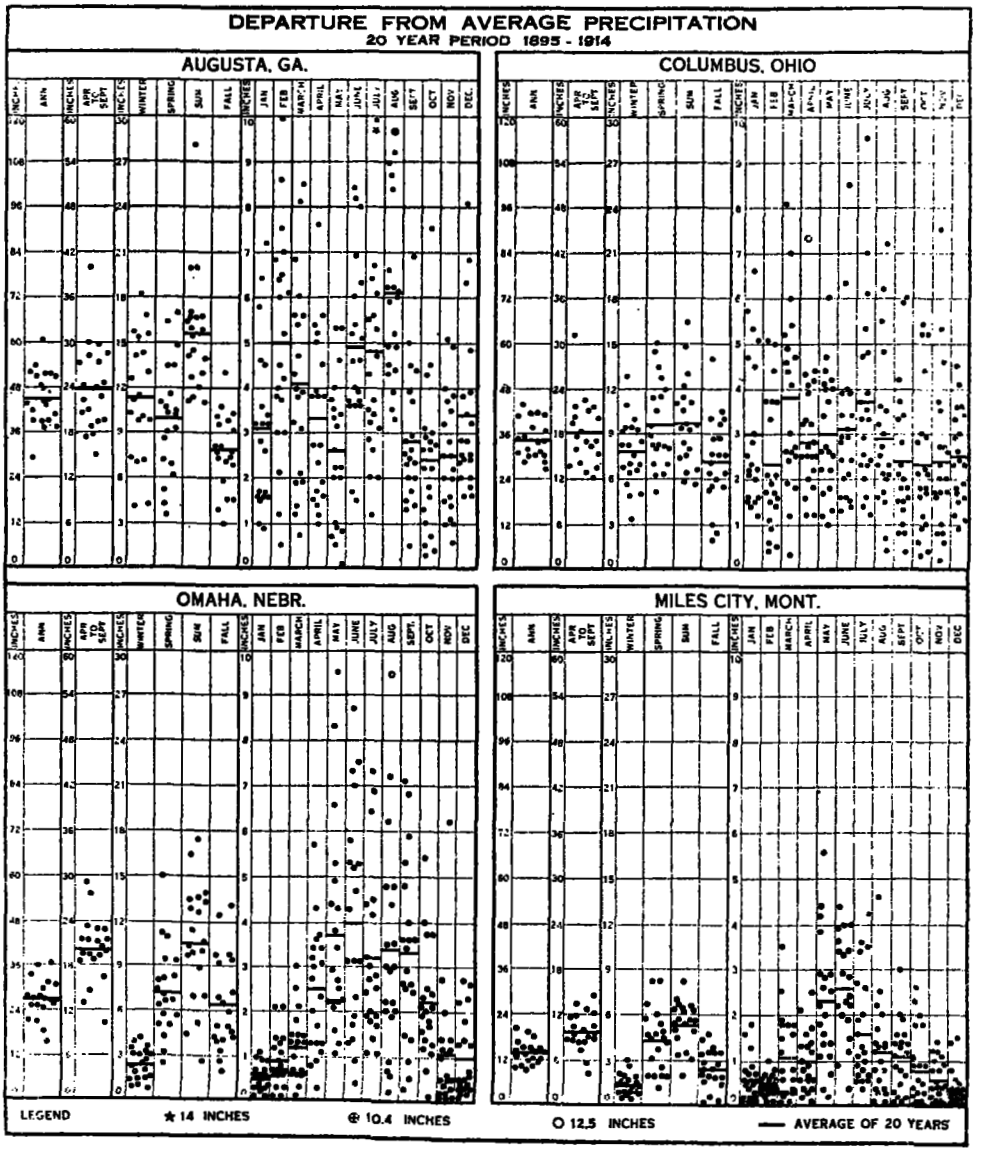


FIG. 1.

VARIATIONS FROM AVERAGE RAINFALL.

Owing to the fact that the significance that attaches to an average made up of variables of different magnitudes depends on the nature of the dispersions of the variables about the average, in considering precipitation charts based on an average for a series of years, the variation from year to year should be taken into account. These are not similar in the different sections of the country nor in different periods of the year, and they also vary with the length of the season represented. For the three classes of charts under consideration, annual, seasonal, three times as large as the seasonal. This affords a direct comparison of dispersions about the mean for the respective periods and indicates the amplitude of variation, which have an important bearing on the relative dependability of averages for different seasonal lengths. It will be seen from this graph that the annual amounts are grouped closely about the mean and that the individual totals from year to year have rather uniformly increasing and comparatively pronounced larger variations through the half year, quarter year, and monthly representations.

RAINFALL TYPES.

Omitting, for lack of space, a discussion of the indications of the individual monthly maps, Charts I to XII, we shall briefly consider, in a general way, the seasonal distribution of precipitation as indicated by these and the four seasonal charts combined. A number of distinctive types of distribution in the United States are well known, which in some cases, at least, are comparatively uniform over large areas. Prof. A. J. Henry has recognized 11 more or less distinct types (see Weather Bureau Bulletin D, p. 11), while Prof. Ward has pointed out 14 types, made composite curves and discussed each (see Geogr. Review, vol. 4, 1917, pp. 131–144; reviewed, Science, July, 19, 1918, pp. 71–72). From an agricultural standpoint, and for the purpose of this brief discussion, we may consider only six principal types, as a number of the others are lacking in distinctive features

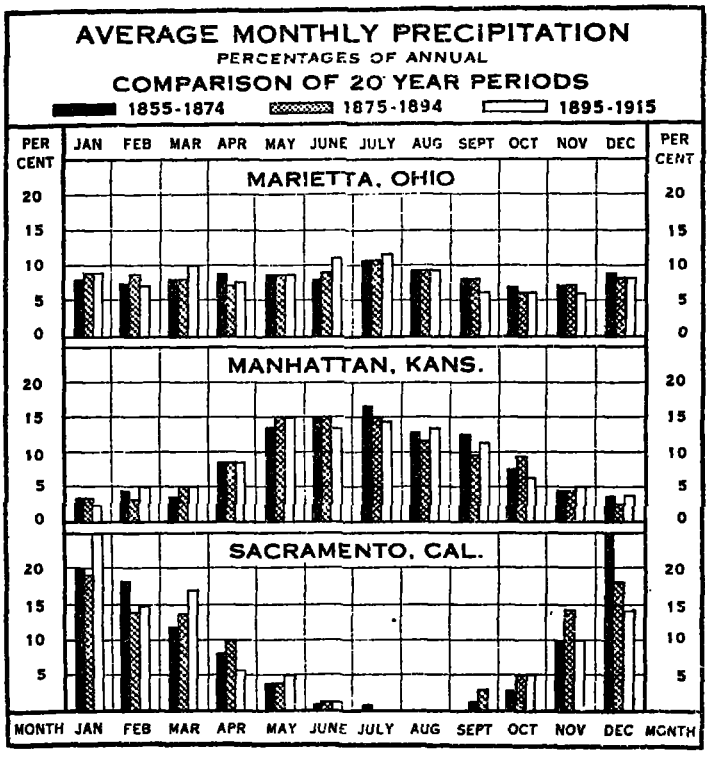


FIG. 2.

to make them of special importance, although relevant in a technical discussion of rainfall phenomena. The types considered are Florida, Eastern, Plains, Arizona, Sub-Pacific, and Pacific. The Eastern type includes the originally forested eastern section of the United States, excepting the Florida Peninsula where the seasonal distribution of rainfall is so distinct as to become a separate type; the Plains type includes the prairie and plains region extending from the Great Lakes and the central Mississippi Valley westward to the crest of the Rocky Mountains and southward to Missouri and Oklahoma; the Arizona type includes western Texas, New Mexico, and Arizona, as well as portions of southern Utah and Nevada, although it is not well marked in the latter localities; the sub-Pacific type occupies the central and northern portions of the Plateau region between the Rockies and the Sierra Nevada and Cascade ranges, and the Pacific type extends from these ranges westward to the Pacific Ocean.

In this connection it is of interest to inquire as to the permanency of these various types of precipitation; that is, as to whether they would show material alteration by the adoption of a different series of years. If the precipitation of the year were equally distributed through the several months, each would receive substantially one-twelfth of the annual amount. Figure 2 presents data for Marietta, Ohio; Manhattan, Kans.; and Sacramento, Calif.; representing, respectively, the Eastern, Plains, and Pacific types of precipitation, indicating the percentage variations of the annual amount occurring from month to month for three consecutive 20-year periods, 1855 to 1874, 1875 to 1894, and 1895 to 1914. The variations for the different periods indicated for each of these types are about in proportion to the respective fluctuations occurring from year to year in the individual monthly amounts; that is, the Eastern and Plains types are more constant in the relative monthly distribution than is the Pacific type, which is also true for the monthly amount of rainfall from year to year. It will be seen that the typical distribution is maintained to a rather remarkable degree in the respective types in each of the three periods. The graphs indicate, however, that caution should be exercised in pointing out less distinctive types of rainfall from data based on a period as short as 20 years. For example, in the case of Marietta, the first period, 1855 to 1874, indicates that rainfall in May is greater than in June, but the other periods do not show this, while for Manhattan, the first shows more rain in June than in May, but the others indicate differently.

Florida type.—Important seasonal variations in precipitation are found in the Florida Peninsula. Here rainfall is comparatively light from November to May, inclusive, only from 2 to 3 inches occurring on the average in each month. During the other 5 months it is usually heavy, particularly on the west coast during July and August and on the east coast during September and October. The maximum averages in these months reach more than 10 inches. The heavy rainfall on the west coast is due to thunderstorms, while tropical storms which occasionally visit the east coast during this season are responsible for the large averages there. The heavy late summer rainfall, characteristic of the Florida type, extends northward along the Atlantic and westward along the Gulf coasts, gradually merging into the more uniform distribution of the Eastern type.

Eastern type.—This type is characterized by a comparatively uniform distribution of precipitation throughout the year, particularly in the central and northern districts. The rainfall is, in general, however, lighter during the fall months than in any other season. The areas having the maximum average rainfall, as shown on the accompanying charts, for the several months of the year east of the Rocky Mountains, indicate, in general, amounts from about 5 to somewhat more than 6 inches, except that from June to September they are 8 to more than 10 inches. Excluding a few restricted localities, the monthly charts show this area to be located as follows: In January, it occupies the lower Mississippi Valley; by February, it is farther east and overlies the southern portions of Mississippi and Alabama; in March, it includes the northern portions of these States with extensions into northern Georgia, western North Carolina, and eastern Tennessee; in April, it again appears in the lower Mississippi Valley, while in May it occupies western Arkansas and eastern Oklahoma. From June to October, inclusive, it is found in the Florida Peninsula, but in November, the only month with averages less than 5 inches, it occupies the Mississippi Valley from western Tennessee

southward, while in December it is restricted to limited areas in northern Mississippi and parts of Louisiana (see Charts I to XII). It will be noted by referring to figures 3–6, that the percentage of the annual precipitation occurring in each of the four seasons in the area covered by the Eastern type is comparatively uniform.

Plains type.—This is a very important type agriculturally, covering, as it does, much of the great interior wheat and corn belt. It is characterized by generous rains in the late spring and summer months and very light late-fall and winter precipitation. In portions of Montana and over small areas in the Dakotas and in eastern Colorado the total precipitation for the three winter months averages less than one inch, Chart XIII, while over the remaining area between the Rocky Mountains and a line extending from the Panhandle of Texas northeastward through central Minnesota, it is less than 2 inches. With the advent of warmer weather, however, the precipitation of this type increases rapidly. It will be noted by reference to the monthly charts that a large area immediately to the westward of the Mississippi River receives on the average more than 4 inches of rainfall during each of the months of May, June, and

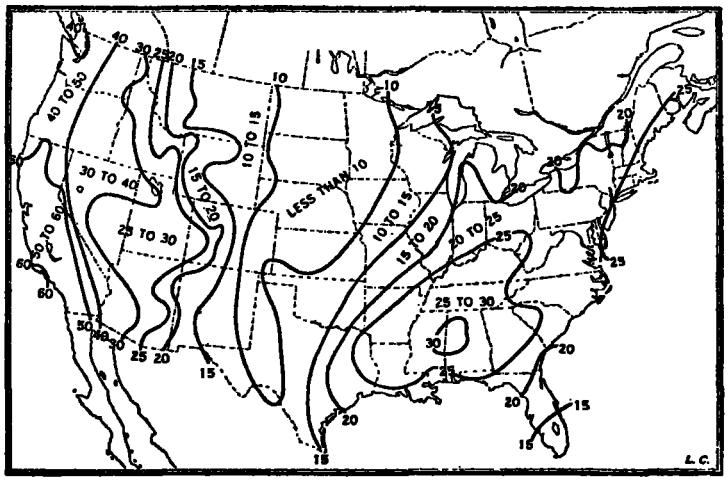


FIG. 3.—Percentage of annual precipitation occurring during the winter months, December-February.

July, Charts V, VI and VII. The seasonal distribution in percentage of the annual in much of the Plains is about as follows: Winter, less than 10 per cent; spring, 25 to 30 per cent; summer, 40 to 50 per cent; autumn, 15 to 20 per cent. The amount of stored soil moisture at the beginning of the growing season in much of the great grain-producing Plains region is not large, owing to the scanty winter precipitation, and here successful crop production depends largely on the amount of rainfall received during the period of actual growth. This is largely the reverse of conditions in the area covered by the Pacific type of precipitation.

Arizona type.—The distinctive feature of this type is heavy rainfall in July and August, when about 35 per cent of the annual amount of precipitation occurs. April, May, and June are usually the months of least rainfall, and during the other months the distribution is quite uniform. Summer rains in this area are due largely to thunderstorms during the warmer part of the day, while the amount and distribution of winter rains depend mostly on the frequency and position in latitude of cyclonic disturbances entering the United States from the Pacific Ocean. The Arizona type differs from the Plains type in that the heavier rains cover a shorter period of the year, and also, in that precipitation occurs more frequently in the afternoon, while in the Great Plains it is of more frequent occurrence at night.[1]

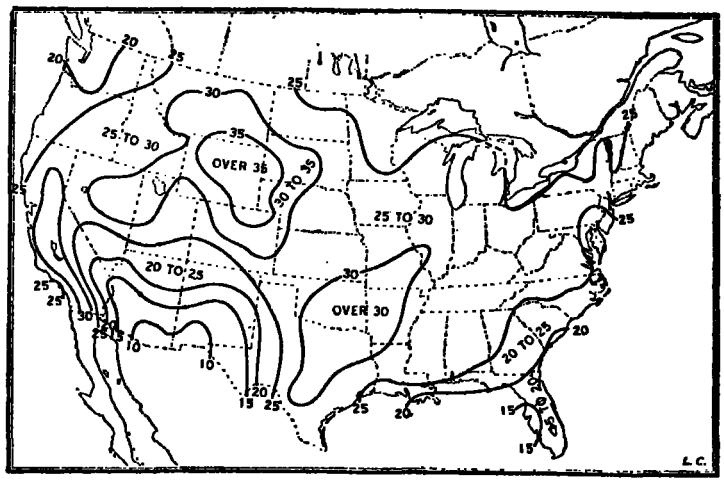


FIG. 4.—Percentage of annual precipitation occurring during the spring months, March-May.

Sub-Pacific type.—This designation has been given to the type of precipitation occurring in the eastern portions of Washington and Oregon and in Idaho, Nevada, and Utah. It differs from the Pacific type in the absence of a marked winter concentration and, generally speaking, may be considered of fairly uniform distribution through the year, except for the summer months when it is very light and in large areas negligible. In portions of Nevada and Utah more rain usually falls during the spring months than in any other season. The sub-Pacific is a transitional type between the Pacific type and that found in the northern Rocky Mountains and eastern foot-hills, which culminates farther east in the Plains type proper. The relation between these types is graphically illustrated by figures 3–5. For the winter season the highest percentages of the annual amount appear on the Pacific Coast, figure 3; in spring, this area comprises the northern Rocky Moun-

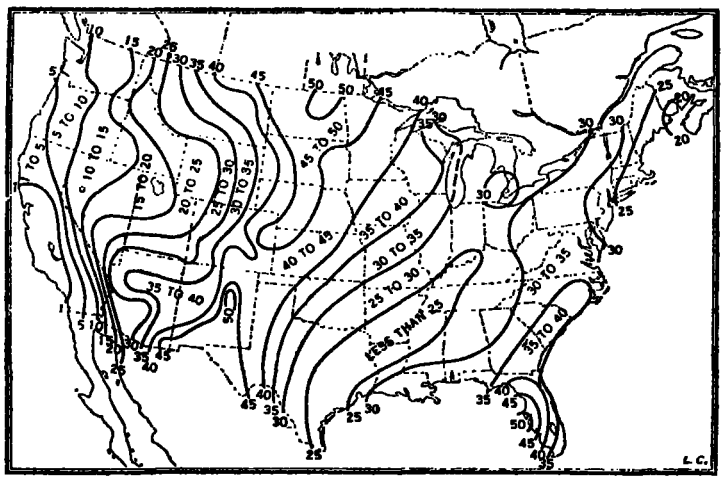


FIG. 5.—Percentage of annual precipitation occurring during the summer months· June-August.

tains and eastern foot-hill region, but high percentages extend westward into Idaho and Nevada and eastward well into the Plains, figure 4; while in the summer the

[1] See "Daytime and nighttime precipitation and their economic significance," J. B. Kincer, MONTHLY WEATHER REVIEW, November 1916, 44: 628–633.

area appears still farther east and occupies the Plains proper, figure 5. Thus as the season progresses the area of relatively heaviest precipitation occupies successive localities from the Pacific coast to the interior Great

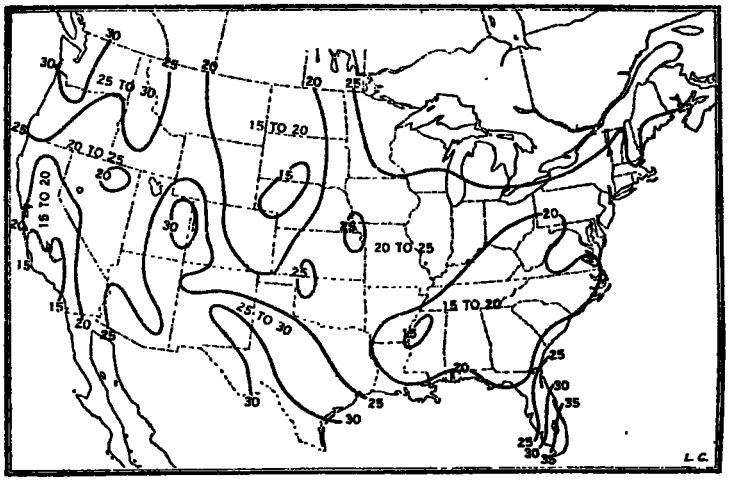


FIG. 6.—Percentage of annual precipitation occurring during the autumn months, September-November.

Plains. In the area covered by the sub-Pacific type of precipitation the actual amount is scanty throughout the year, except in the higher elevations of the more northern States, with agricultural operations depending largely on irrigation or dry-farming methods.

Pacific type.—This type is characterized by a marked winter concentration of precipitation and by a summer

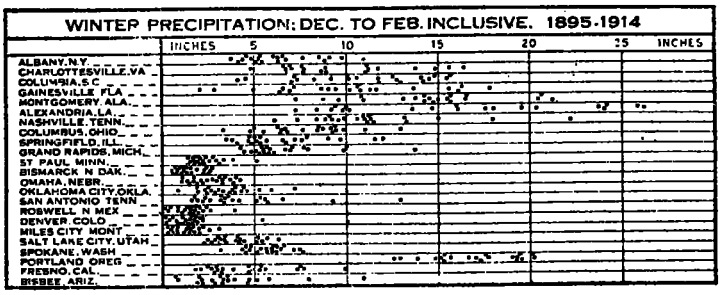


FIG. 7.

dryness. In the western portions of Washington and Oregon, from 40 to 50 per cent of the annual precipitation occurs, on the average, during the winter months, December–February, while in the southern portion of the area from 50 to 60 per cent of the annual is received

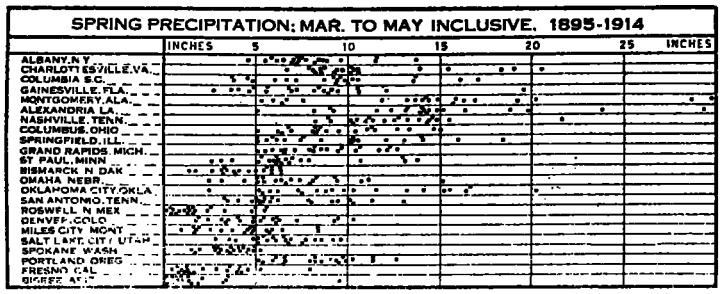


FIG. 8.

during this period, figure 3. The average total for the winter season ranges from more than 50 inches on the western slope of the Olympic Mountains in Washington to less than 4 inches in the southern end of the great valley of California (Chart XIII). For the three spring months, chart XIV, the amounts usually average about half as large as for the winter, except that in the Cascades they are about two-thirds as great. The proportion of the annual amount received during the summer months, June to August, figure 5 ranges from about 1 per cent in most

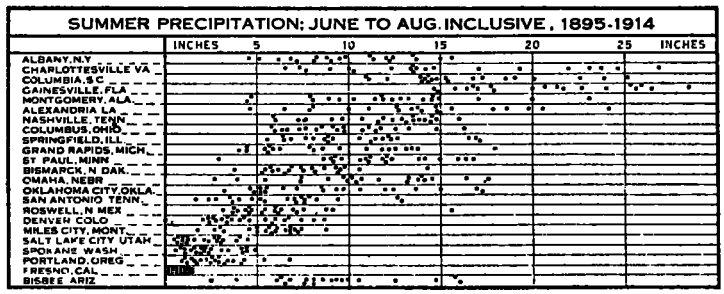


FIG. 9.

of California to 10 per cent in the vicinity of the Puget Sound. The rainy season sets in over the northern portion earlier than over the southern, the rainfall in November, Chart XI, becoming heavy in portions of Washington and Oregon, this being, in fact, the month of the

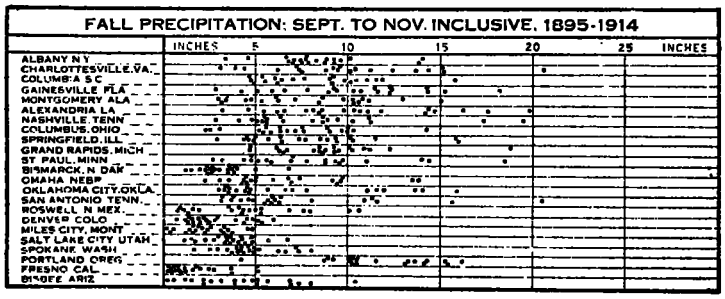


FIG. 10.

maximum rainfall in some localities of that section. The precipitation in fall ranges from 30 per cent of the annual amount in the northern portion to 15 per cent in the south, figure 6. In the area covered by the Pacific type of precipitation, fall-sown grain under the influence

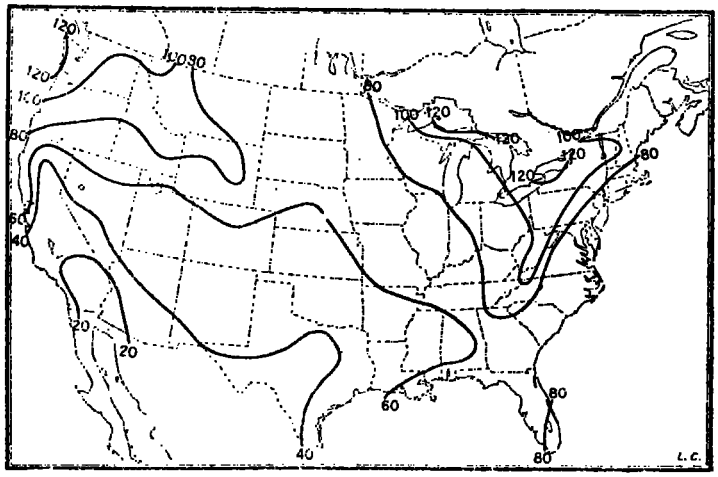


FIG. 11.—Average annual number of days with precipitation 0.01 to 0.25 inch.

of comparatively mild temperatures and ample moisutre, grows steadily during the winter season and matures after the cessation of rain, largely utilizing the moisture stored in the soil during the wet winter months.

Figures 7 to 10 show for a number of representative localities, geographically arranged, the seasonal precipitation for each of the 20 years on which the four seasonal charts are based. On these graphs, the amount for the season in each year is represented by a dot. These show for different localities the variations in the seasonal amount that may be expected to occur from year to year.

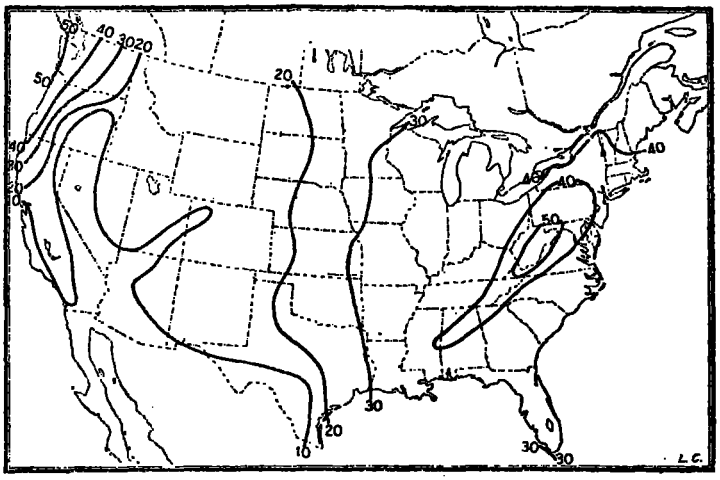


FIG. 12.—Average annual number of days with precipitation 0.26 to 1.00 inch.

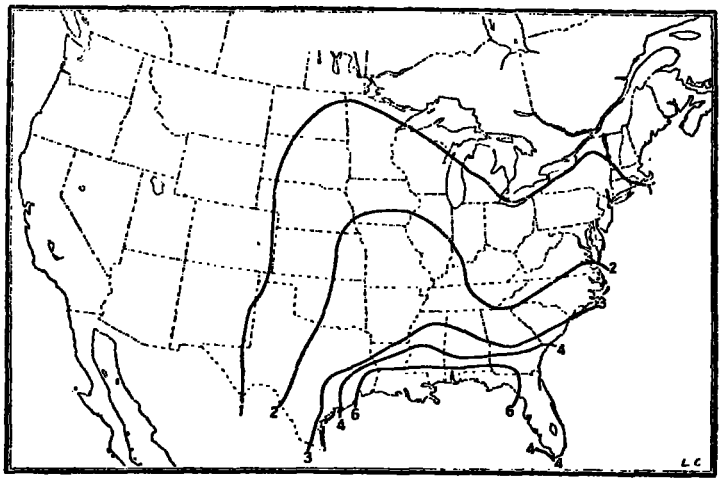


FIG. 14.—Average annual number of days with precipitation more than 1.00 inch in an hour.

RAINFALL FREQUENCY AND INTENSITY.

In studying the relation of precipitation to plant development the question of frequency of occurrence and intensity of falls should be considered. In regions of abundant rain there is a greater tendency to excessive amount and, consequently, a much greater loss by run-off which cannot be utilized for plant growth. On the other hand, the average precipitation in a given locality may be considerably less than in some other, but the rains may be better distributed as to frequency of occurrence, and may be less torrential in character for short periods, thus largely offsetting the difference in actual amount. For example, the average amounts of precipitation over the eastern section of the United Sates increase from the northern districts southward to the Gulf region, but the frequency of occurrence of moderate rains often increases in the opposite direction, this condition being especially marked during the spring months. It will be seen from figure 11 that the average annual number of days with rainfall between 0.01 and 0.25 inch varies from 60 to 70 days in the east Gulf section to 120 days in portions of the Lake region. It will also be noted from figures 13 and 14 that excessive falls are much more frequent in the Gulf section than in the central and northern districts. These conditions, together with the difference in the amount of evaporation, largely offset the difference between the actual amount of rainfall in the southern, and the central and northern districts.

Figures 11 to 15 show, respectively, the average annual number of days with precipitation between 0.01 and 0.25 inch; 0.26 to 1.00 inch; with more than 2 inches in 24 hours; with more than 1 inch in an hour, and the maximum precipitation in 24 hours for the entire period from 1895 to 1914. These charts indicate the relative frequency of precipitation of varying amounts in different sections. They are based on 200 regular reporting stations.

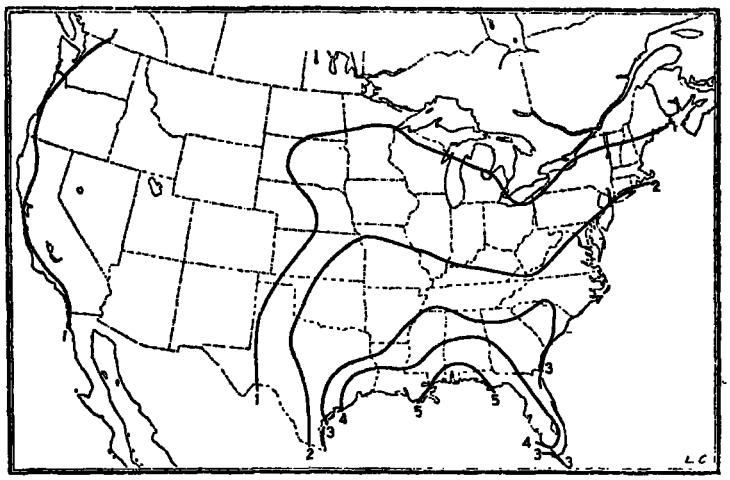


FIG. 13.—Average annual number of days with precipitation over 2.00 inches.

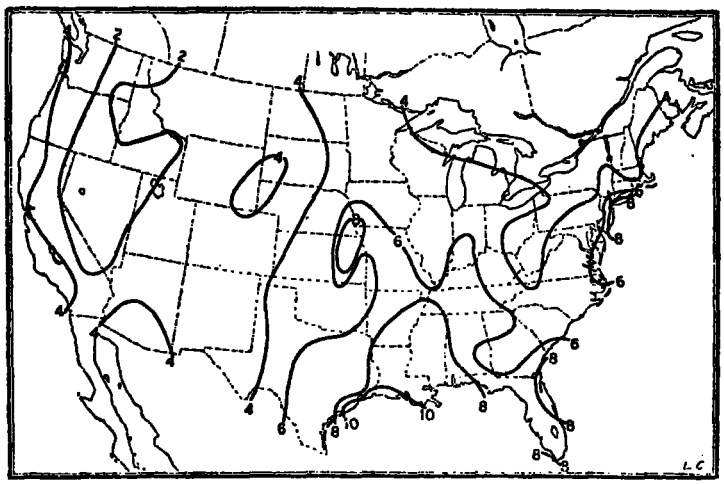


FIG. 15.—Maximum precipitation in 24 hours.

In some isolated cases, much heavier rainfall than is indicated on figure 15 has been recorded for 24 hours at substations of the Weather Bureau, particularly where topographic features of the immediate locality are such as to facilitate condensation and precipitation under favorable meteorological conditions. However, the chart affords a general picture of the maximum precipitation in 24 hours during the period covered, as it is drawn to the records of all regular reporting stations.

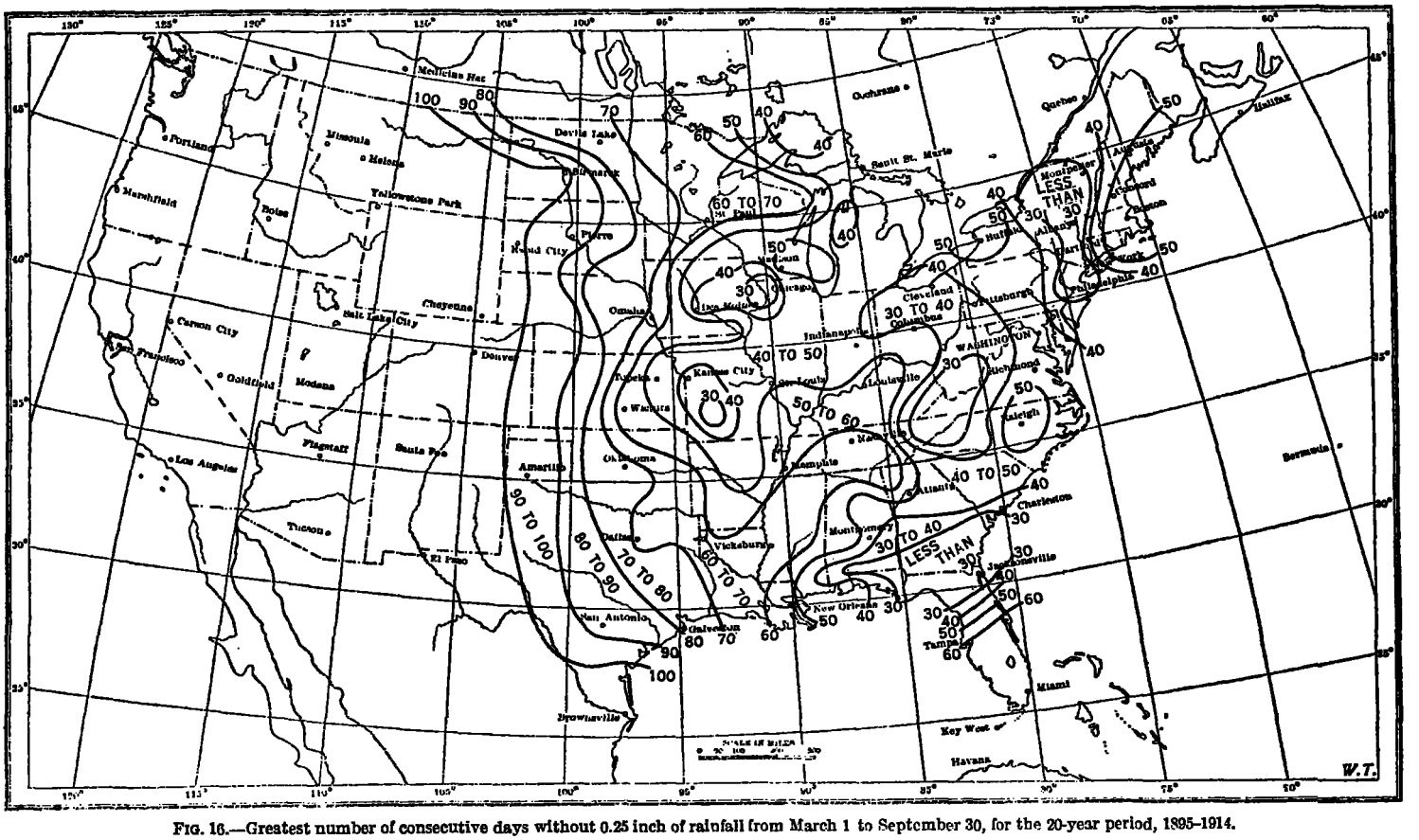


FIG. 16.—Greatest number of consecutive days without 0.25 inch of rainfall from March 1 to September 30, for the 20-year period, 1895–1914.

SUBNORMAL RAINFALL.

In addition to the frequency and intensity of rainfall, it is important in considering charts of average precipitation to take into account the frequency of subnormal rainfall, or droughts, in different sections of the country, especially those occurring during the warm or growing season in areas where rainfall is usually adequate for vegetation. Figures 16 and 17 show some interesting phases of subnormal rainfall for the country east of the Rocky Mountains. The first named indicates the percentage of years with 30 consecutive days, or more, without 0.25 inch of rainfall in 24 hours for the period from March to September, inclusive, and the other shows the longest period in 20 years with similar conditions prevailing. It will be noted from figure 16 that from the central Appalachian Mountain district northward to Lake Erie droughts of this character occur on the average only about 1 year in 3, which is also the case in portions of the Northeast and Southeast, and in limited areas in the lower Missouri and upper Mississippi Valleys. The percentages increase, as a rule, from the Mississippi Valley westward, reaching 75 per cent in the central plains and 100 per cent in the extreme western portion of that area. The longest period in 20 years of consecutive days without 0.25 inch of rainfall in 24 hours ranges from a maximum of about 80 days in the western Great Plains to 40 in the upper Ohio Valley and central Appalachian Mountain districts.

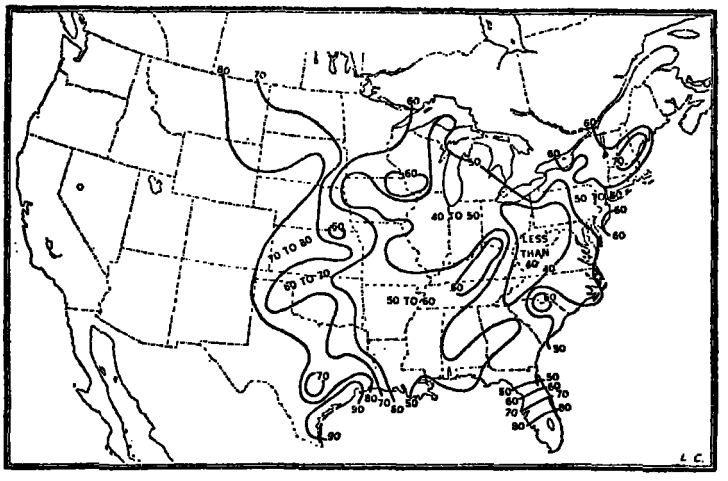


FIG. 17.—Percentage of years with 30 consecutive days or more without 0.25 inch of rainfall in 24 hours from March 1 to September 30, for the 20-year period, 1895–1914.

RAINFALL REQUIRED FOR CROP PRODUCTION.

The amount of precipitation required under favorable distribution for the successful production of crops in much of the country east of the Rocky Mountains is considerably less than the average annual amount. It is usually considered that between 15 and 20 inches of annual precipitation, broadly speaking, determines the dividing line between areas where farming operations can be successfully conducted by ordinary methods and those where irrigation or other special methods are necessary; no hard and fast rule can be laid down in this connection, however. There are, in some northwestern States, important grain areas which receive, on the average, less than 15 inches of precipitation annually; in fact, wheat is grown in some places in that area where the average annual amount is only about 9 inches, but in such cases special care is given to conservation of moisture.

Again, amounts of precipitation as large as those shown on average precipitation charts occur usually in less than half of the years, particularly in the case of monthly values; the amounts in 25 per cent of the years for the several months of the growing season in some of the principal agricultural regions are only about half as large as the 20-year average.

SUMMARY.

In conclusion it may be emphasized that, considering the areas covered and their climatic importance, there are three major types of seasonal distribution of precipitation in the United States. These are the Pacific type, with a marked winter concentration; the Plains type, with relatively heavy rainfall in the late spring and early summer; and the Eastern type, with comparatively uniform distribution throughout the year. The Arizona and Florida types are pronounced in character, but the areas covered are comparatively small and consequently their climatic significance is less important. The Sub-Pacific type is not only less marked in distinguishing features than most of the major types mentioned, but precipitation is scanty throughout the year in much of the area covered by it, which, in considerable sections, precludes extensive crop growth without the employment of special methods of conservation of soil moisture or the artificial application of water to growing vegetation.

SOME CHARACTERISTICS OF THE RAINFALL OF THE UNITED STATES.

By Prof. ROBERT DEC. WARD, Harvard University.

(Abstract from the Scientific Monthly, September, 1919, vol. 9, pp. 210-223.)

Prof. Ward in this interesting and valuable bibliographic paper discusses in considerable detail various phases of rainfall phenomena in the United States. Included in these are the annual and monthly variability; the maximum duration of rainy periods (consecutive days with rain) and of dry periods (consecutive days without rain); droughts; hourly frequency of rainfall; excessive falls; and secular variations in the amount of precipitation.

The importance of a knowledge of the probable limit in the variations from year to year from the average rainfall is emphasized, especially from the standpoint of the farmer and the engineer. It is pointed out that the percentage variations from the mean are larger where the annual amounts are smaller. The following table is presented to show in a general way the ratios of the wettest and driest years to the mean fall:

Mean fall.	Average of wettest year.	Average of driest year.
Inches.	*Per cent.*	*Per cent.*
50-60	142	70
40-50	143	64
30-40	154	64
5-30	178	55

The mean annual variability of rainfall at New York is only 9 per cent, while at San Francisco it is 25 per cent. In addition to the annual variability, Prof. Ward discusses monthly variations and cites some pronounced cases.

The maximum number of consecutive days recorded during the period of record with and without precipitation is a matter of considerable general interest. This, of course, refers to the extreme for the entire period of record and not to the annual occurrences. Over most of the country the longest period of consecutive days with rain ranges from 10 to 20. These conditions are characteristic of most districts east of the Rockies, except in the extreme southern Great Plains. Along the north Pacific coast more than 30 consecutive days with rain have been recorded. From 15 to 30 days have elapsed without precipitation over most of the eastern district and from 30 to 60 days in much of the Great Plains and in the northern plateau and north Pacific Provinces. In the arid southwest over five months have been experienced without precipitation.

Excessive rainfall may result either from short, heavy downpours, or from lighter, but longer continued rainfall. In general, rains of the former type do the most damage, although disastrous floods occasionally result from rainfall of the latter type, particularly when a heavy, warm rain with wind occurs when a deep snow cover is on the ground

As regards the maximum limit of excessive falls, an examination of available data shows that 30 inches of rainfall in a month is not often exceeded, although a maximum of over 70 inches was recorded in a single month at Helen mine, California. The maximum daily fall of record in the United States is 22.22 inches, at Altapass, Mitchell County, N. C., on July 14–15, 1916. Very intensive rainfall, but of short duration, is sometimes experienced. In a record "cloud-burst" at Campo, Calif., August 12, 1891, 11.50 inches of rain fell in 80 minutes, or at the rate of about 8.50 inches in an hour. In some "cloud-bursts" the rate has actually been as high as 16 to 18 inches in an hour, but such intense falls continued for very short periods only.[1]

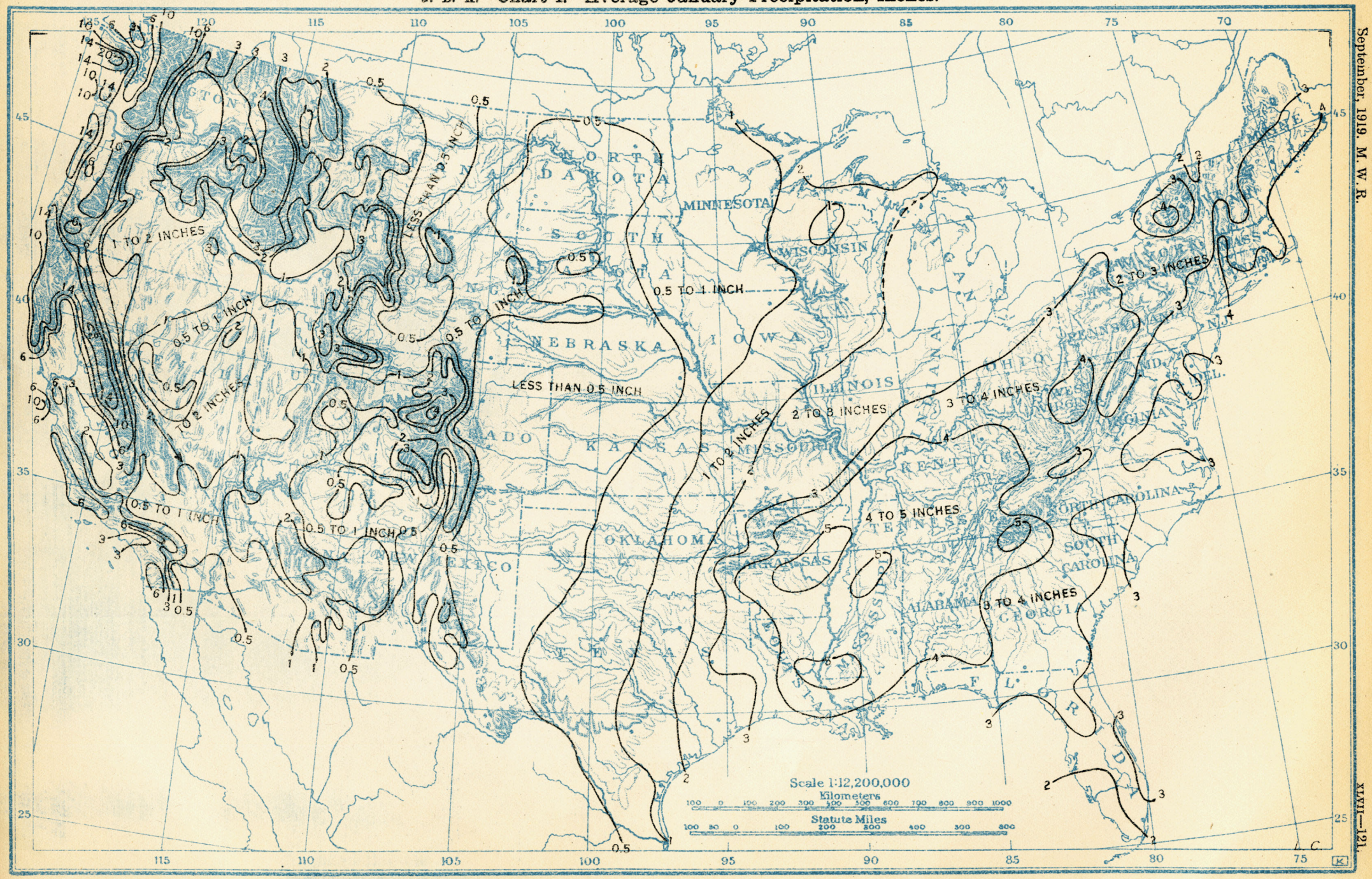
Popular belief in a "change" of climate goes back to the early decades of the settlement of the United States and frequent mention of the subject occurs in literature. Prof. Ward reviews at some length the available literature dealing with various investigations and conclusions drawn therefrom relative to long-period fluctuations in rainfall, based on both instrumental records and noninstrumental evidence. Actual rainfall records available in this country are too short to give any definite indication of secular variations. The longest cover a period of only about 100 years and few stations have records of more than 50 years in length. While a study of these shows more or less definite and recognizable long-period fluctuations, they appear to be largely localized and no definite conclusions can be drawn for extended areas.

In the case of noninstrumental evidence, such as the measurement of the thickness of the rings of trees of great age, as was recently done by Profs. A. E. Douglass and Ellsworth Huntington, Prof. Ward points out that climatologists agree that such evidence is in a wholly different category from that of actual rain-gage records, in that the former can not possibly be subjected to the same rigid analysis and scrutiny as in the case of the latter. After reviewing the attitude of climatologists regarding noninstrumental evidence of climatic changes, he concludes that the conservative climatologist may well remain open minded on the whole question.

Reviewer's note.—To give some indication of long-period fluctuation in this country, as evidenced by actual gage records, the accompanying graph, figure 1, is pre-

[1] See tables, MONTHLY WEATHER REVIEW, May, 1919, 47.

Chart I.—Average January Precipitation, Inches.



September, 1919. M. W. R.

J. B. K. **Chart II.—Average February Precipitation, Inches.**

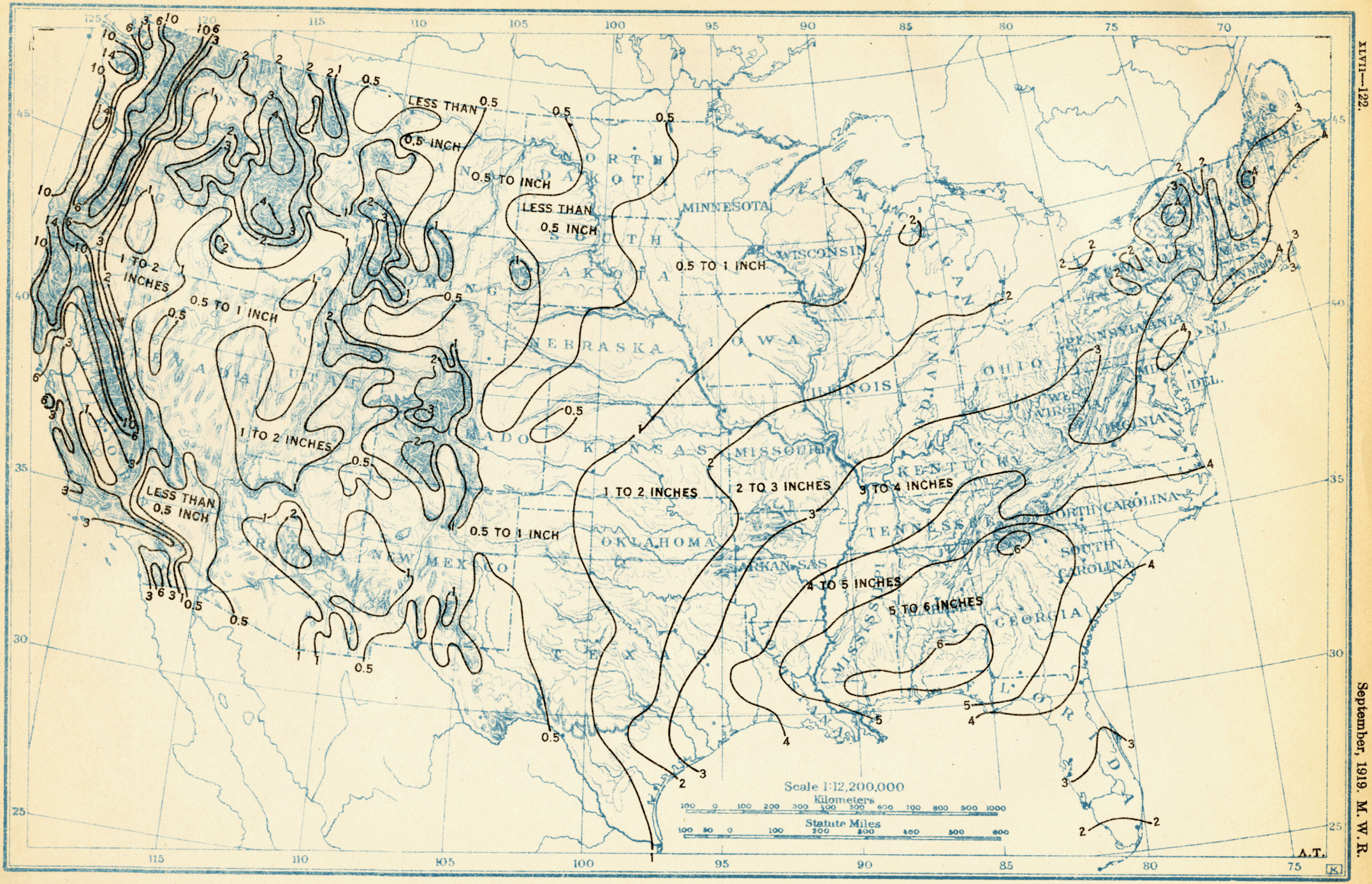
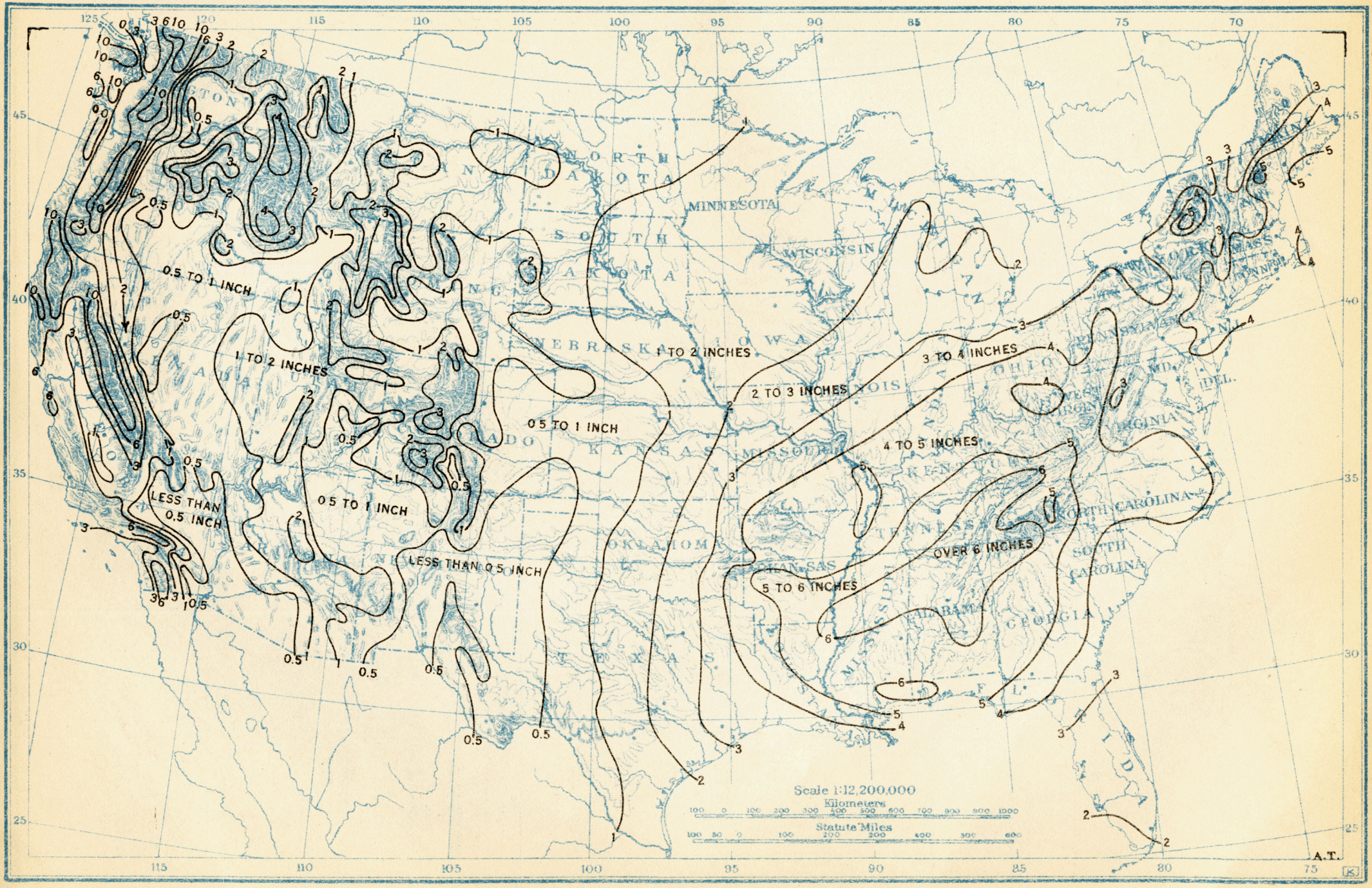
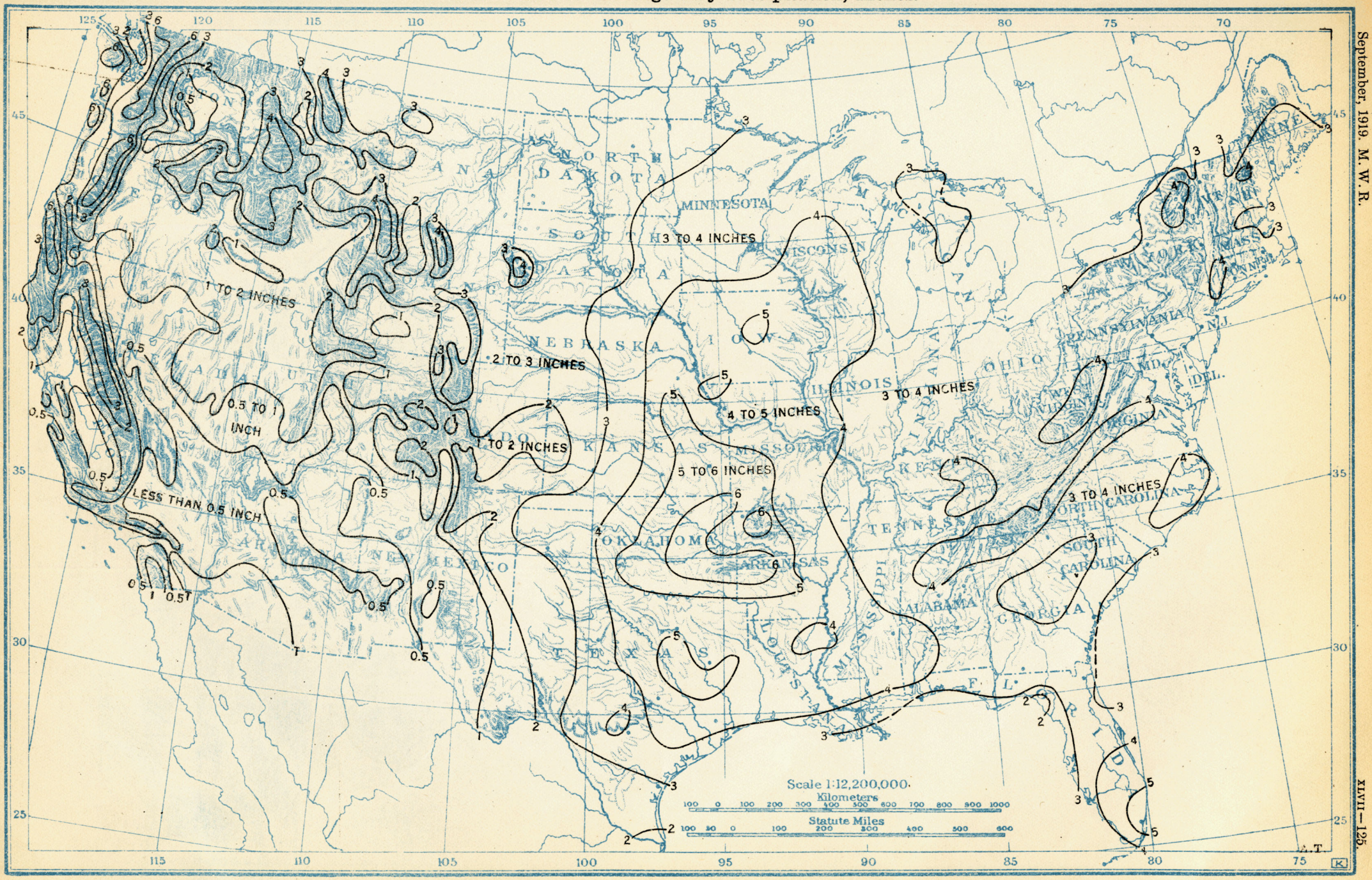


Chart III.—Average March Precipitation, Inches.



J. B. K. **Chart IV.—Average April Precipitation, Inches.**

J. B. K. **Chart V.—Average May Precipitation, Inches.**



J. B. K. **Chart VI.—Average June Precipitation, Inches.**

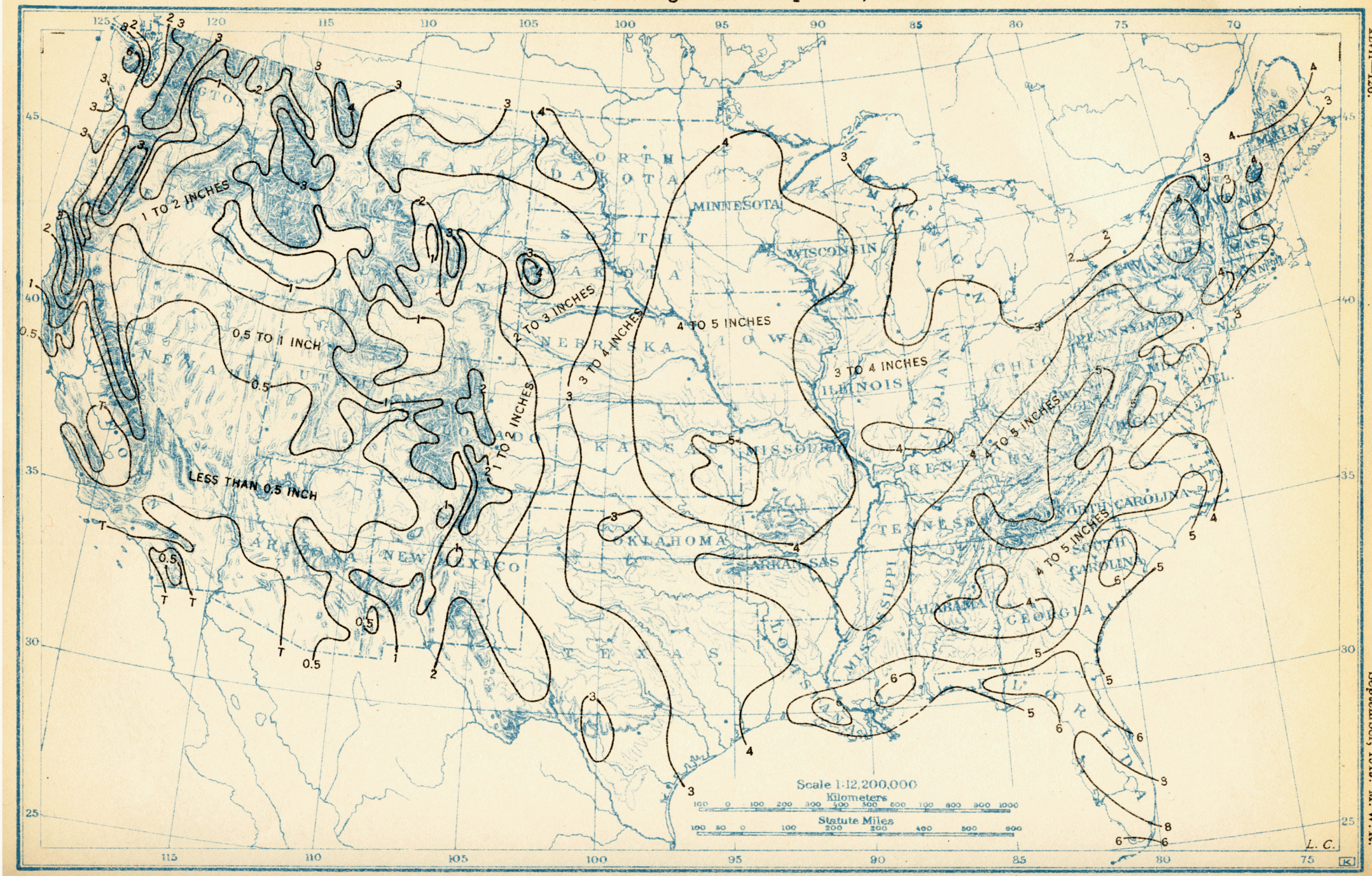
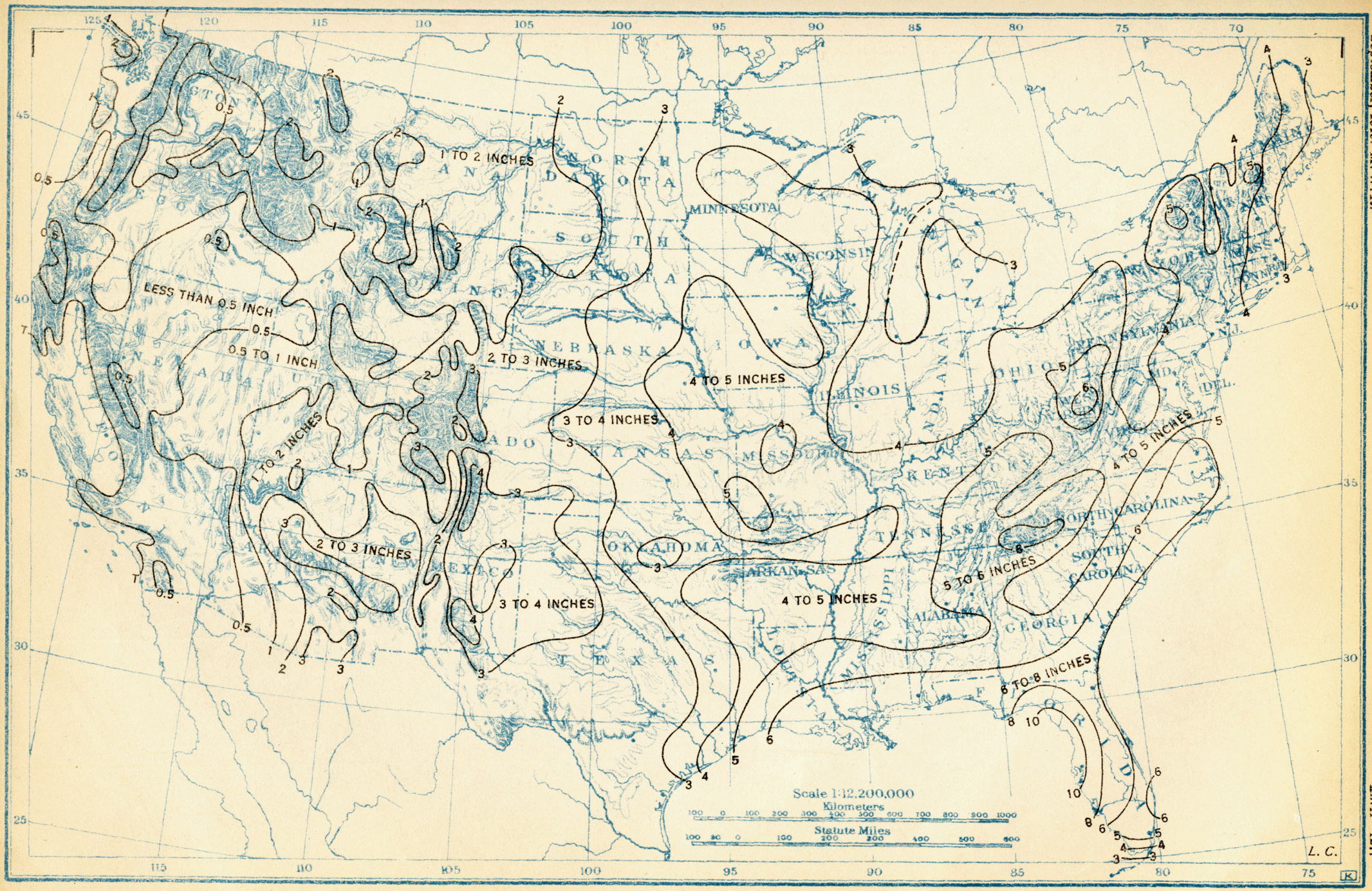


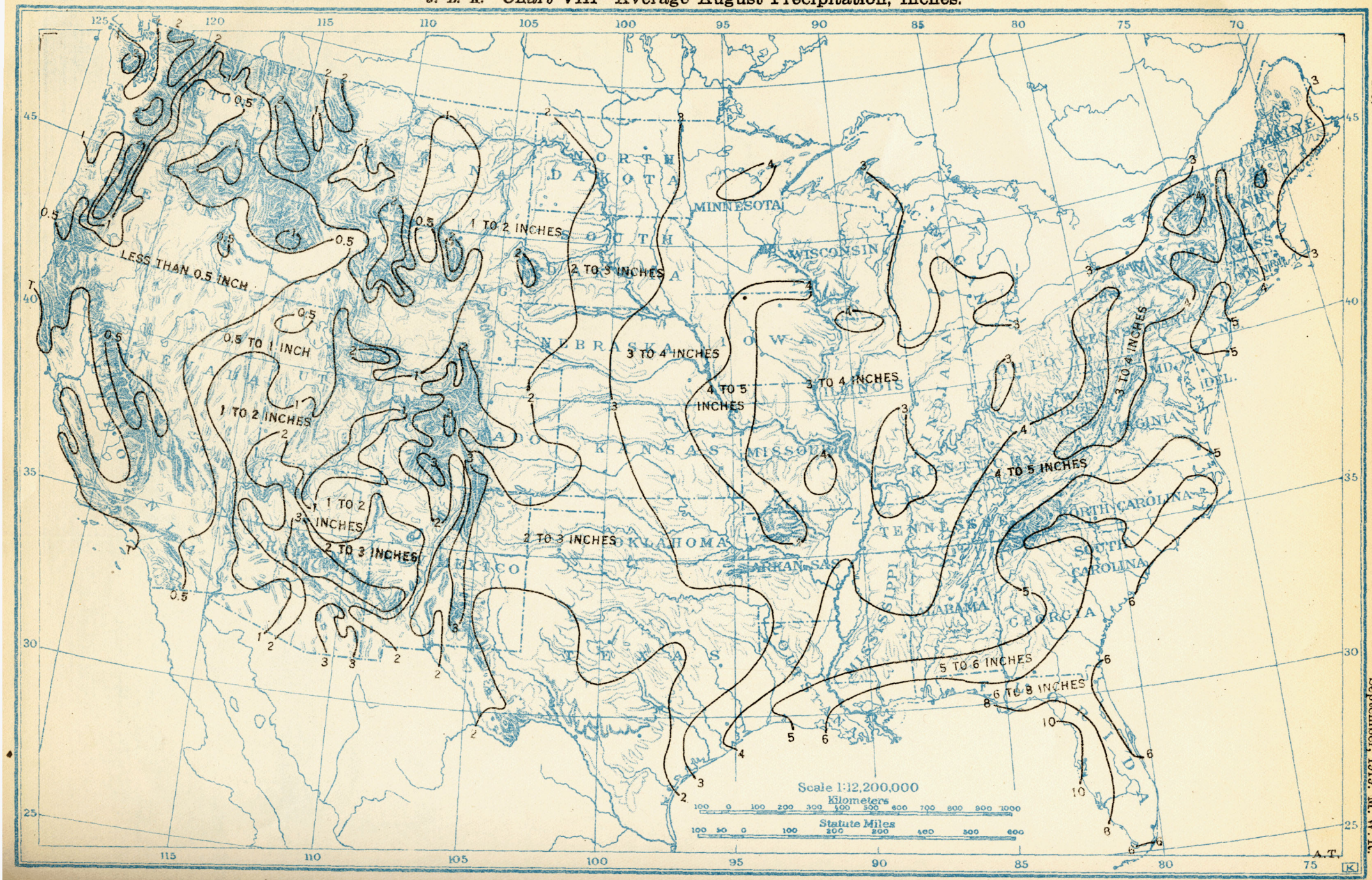
Chart VII.—Average July Precipitation, Inches.



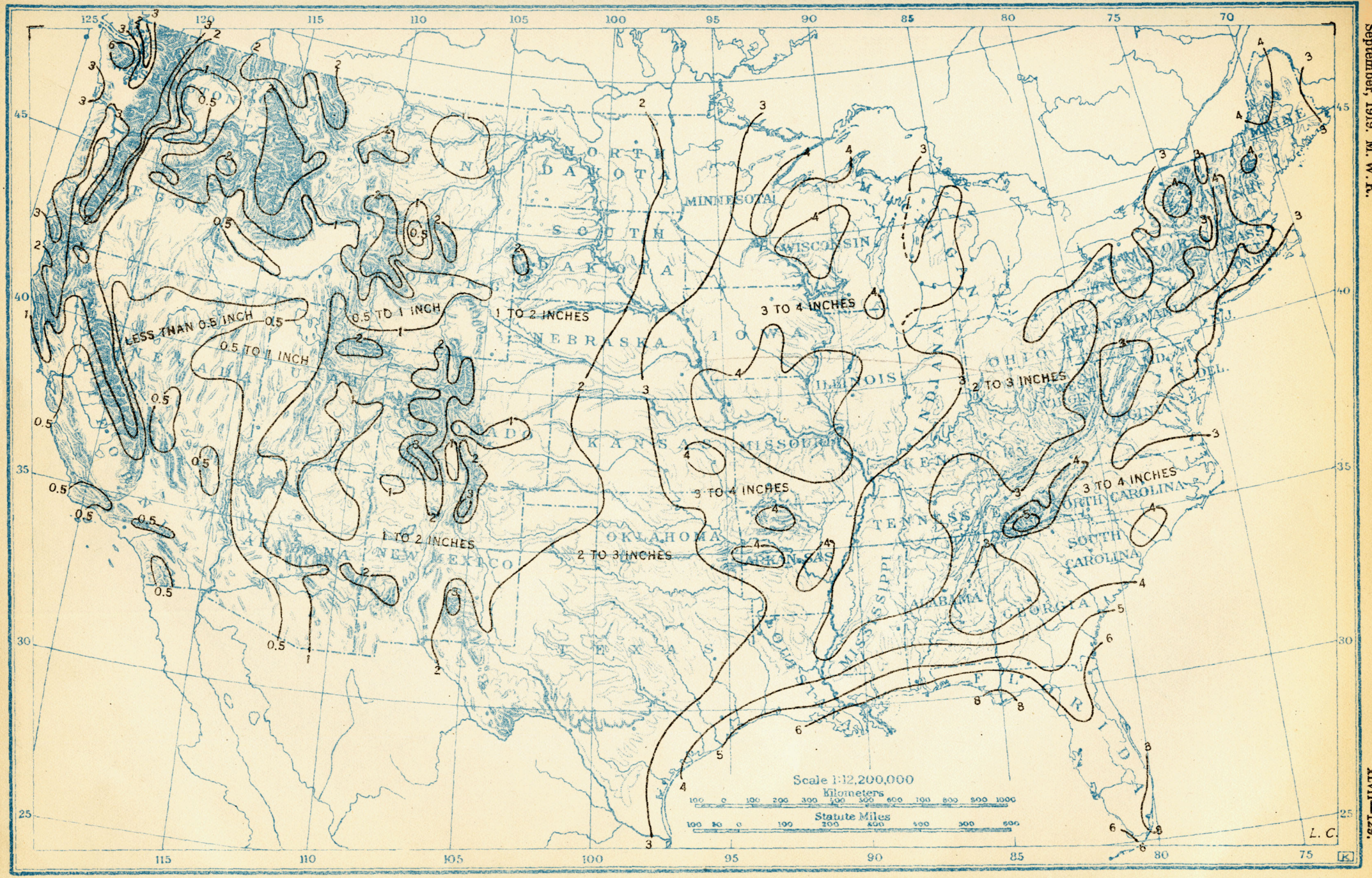
September, 1919. M. W. R.

XLVII—127.

J. B. K. **Chart VIII—Average August Precipitation, Inches.**



J. B. K. **Chart IX.—Average September Precipitation, Inches.**



J. B. K. **Chart X.—Average October Precipitation, Inches.**

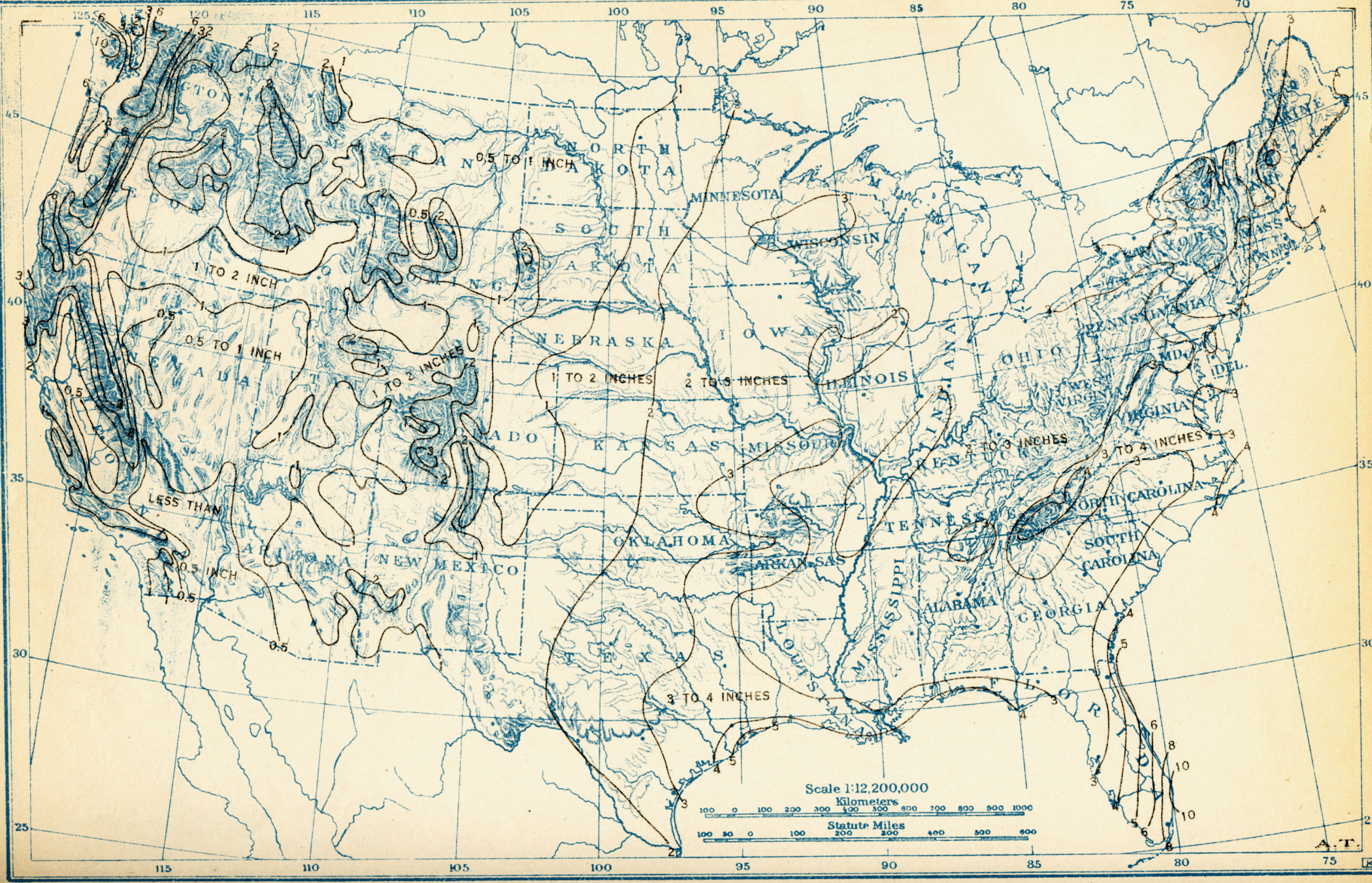
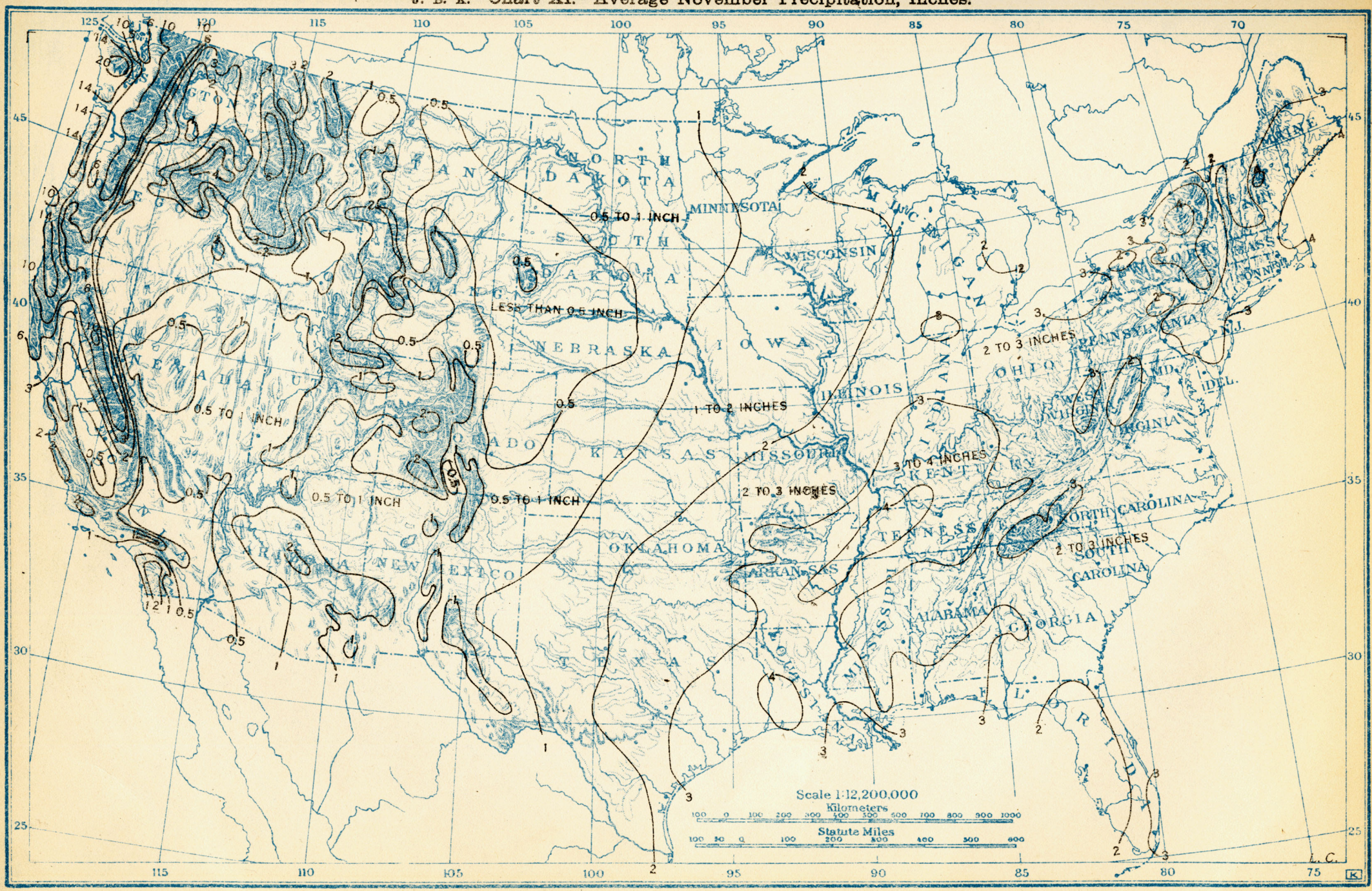
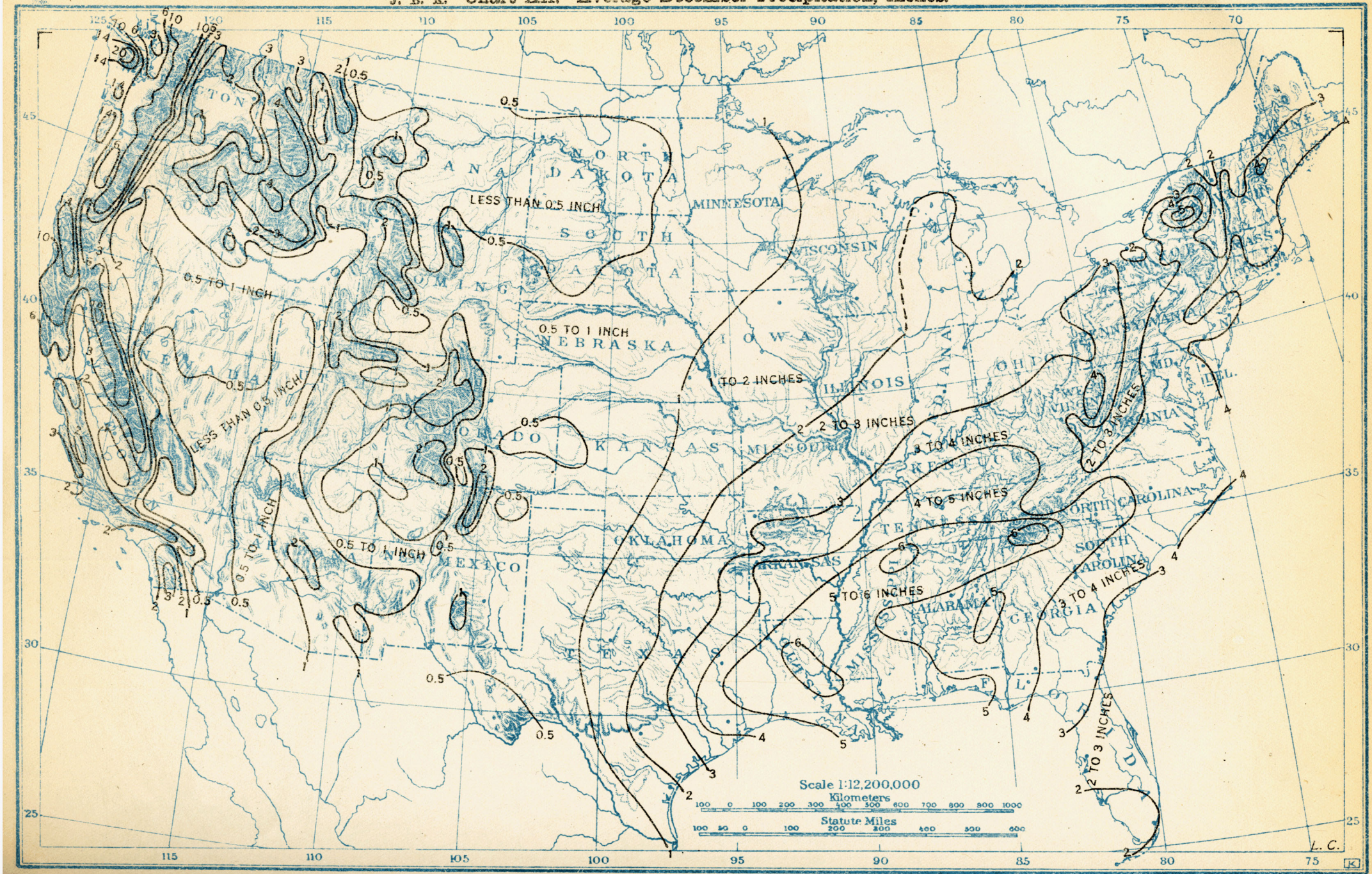


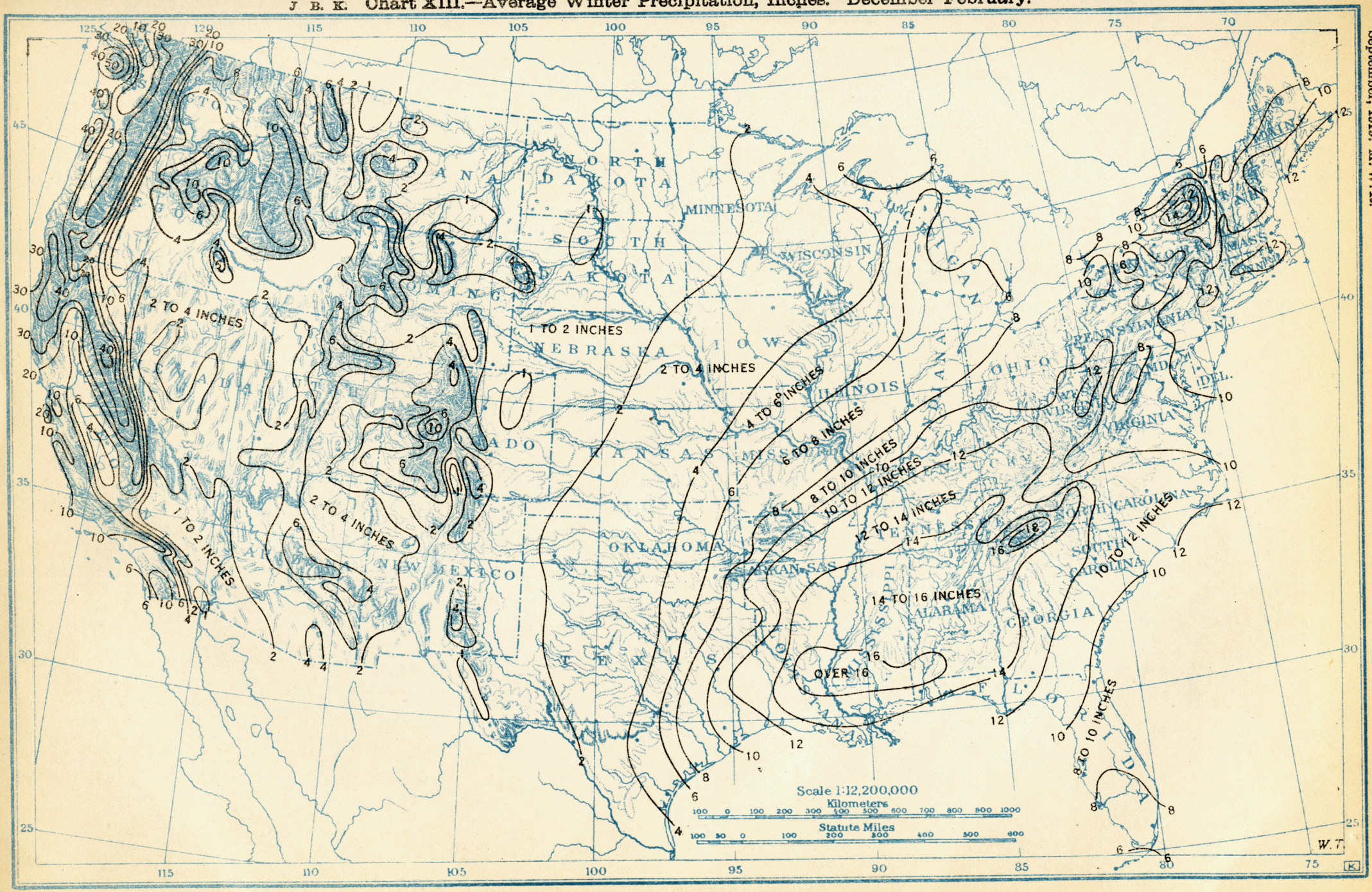
Chart XI.—Average November Precipitation, Inches.



J. B. K. **Chart XII.—Average December Precipitation, Inches.**

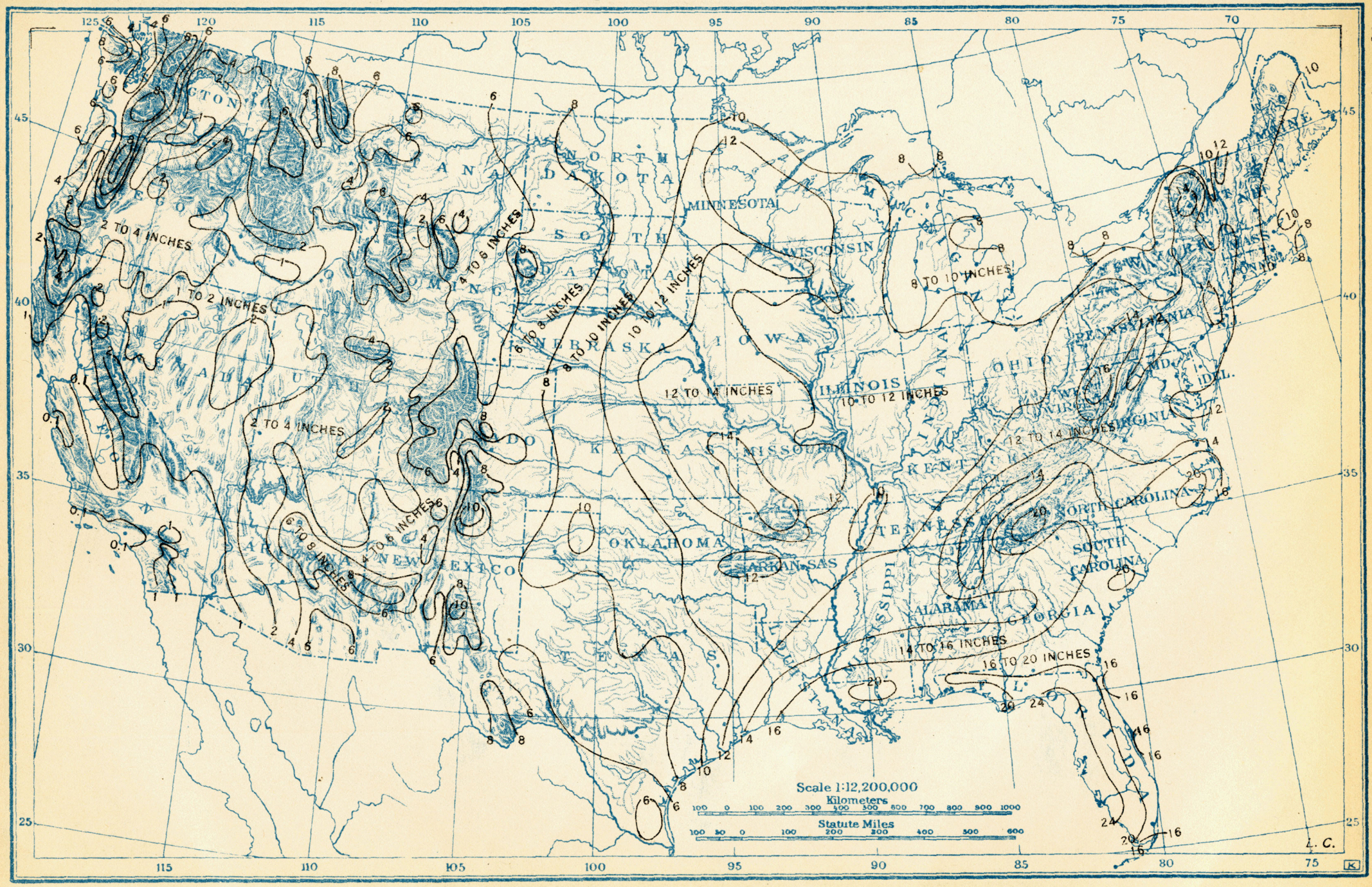


J. B. K. **Chart XIII.—Average Winter Precipitation, Inches. December–February.**



J. B. K. **Chart XIV.—Average Spring Precipitation, Inches. March-May.**

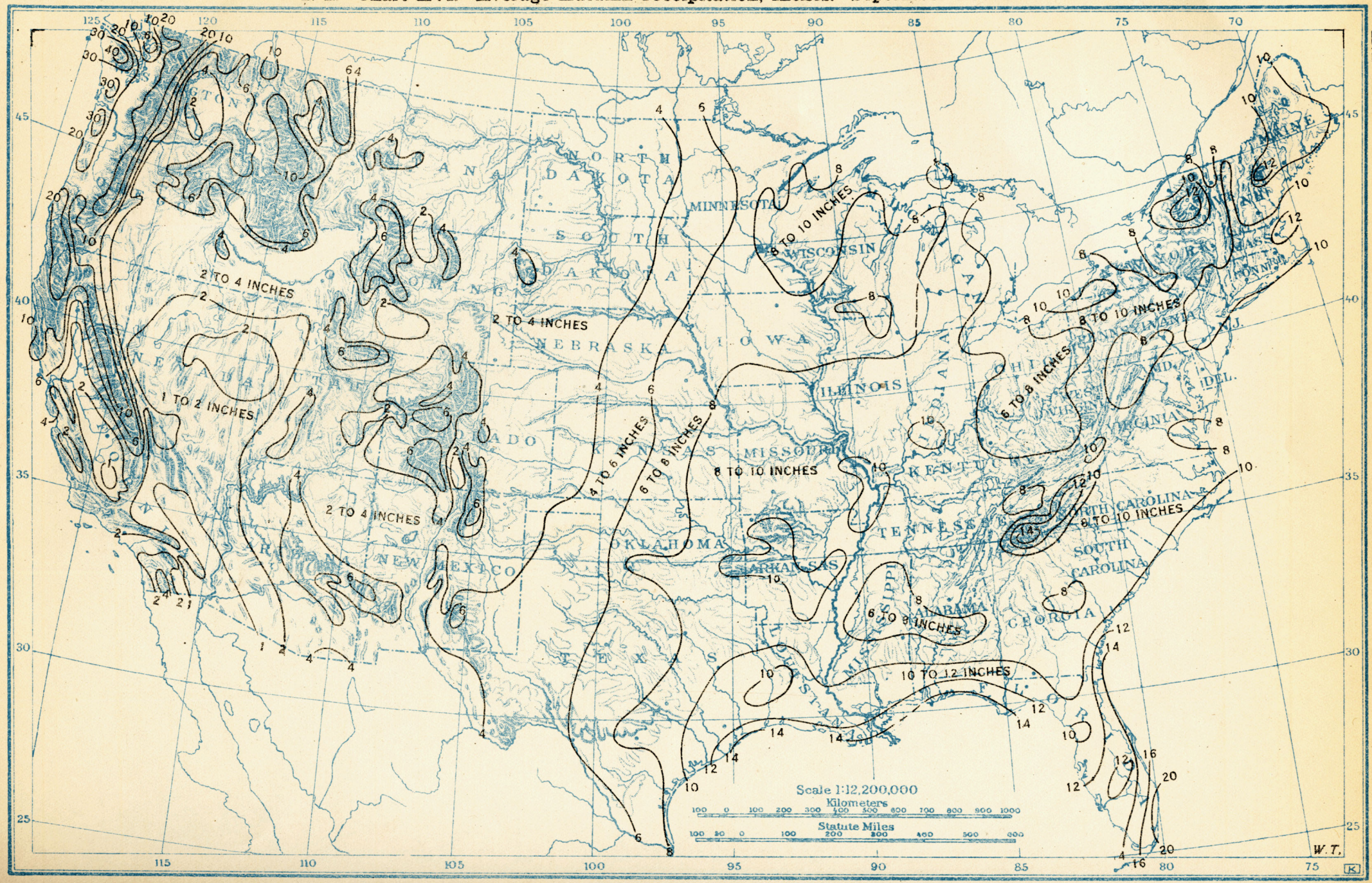
Chart XV.—Average Summer Precipitation, Inches. June–August.

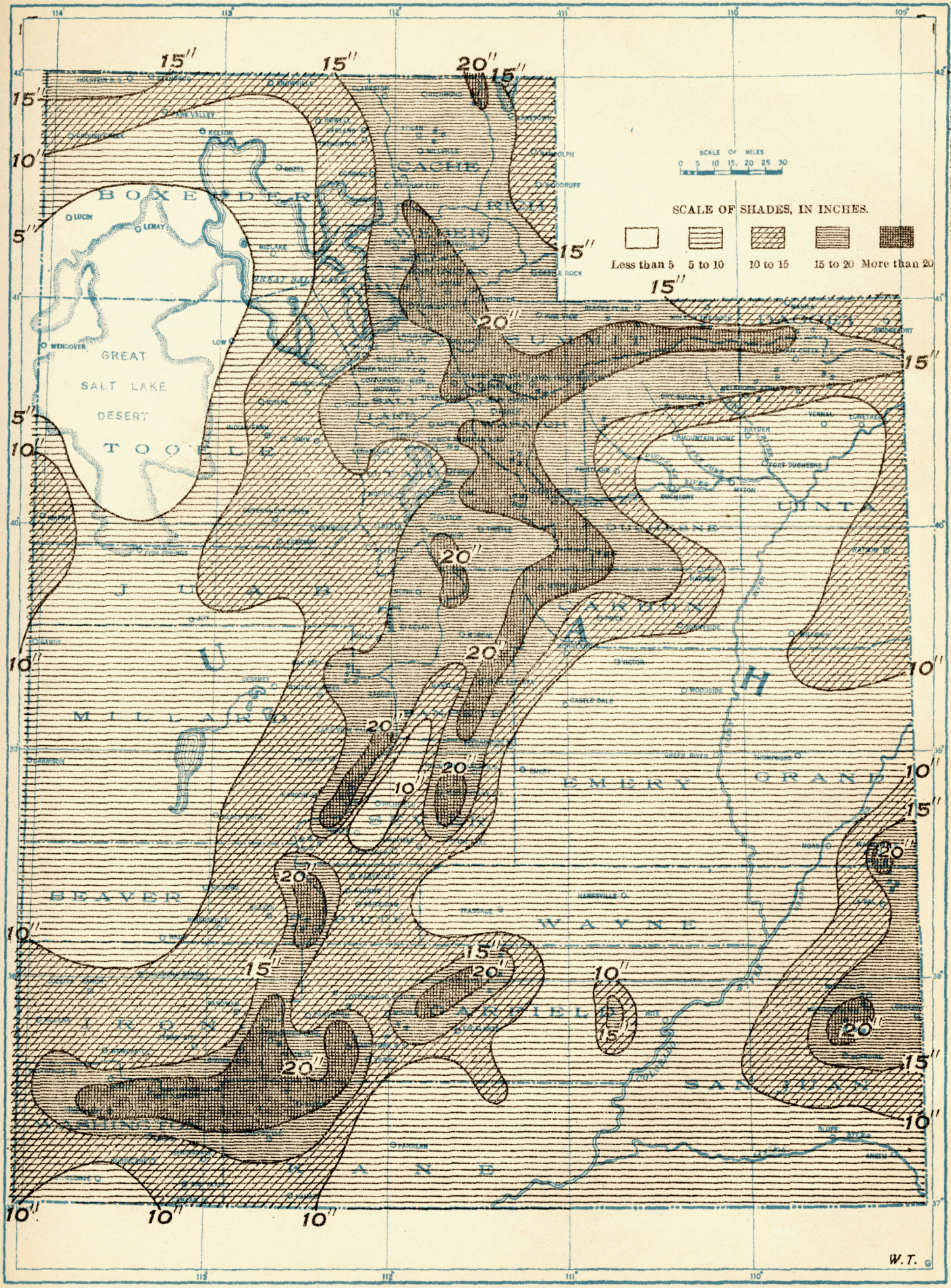


September, 1919. M. W. R.

XLVII—185.

J. B. K. **Chart XVI.—Average Autumn Precipitation, Inches. September–November.**





W. T. G.

September, 1919. M. W. R.