U. S. DEPARTMENT OF COMMERCE
SINCLAIR WEEKS, *Secretary*

WEATHER BUREAU
F. W. REICHELDERFER, *Chief*

TECHNICAL PAPER NO. 28

Rainfall Intensities for Local Drainage Design in Western United States

20
For Durations of [redacted] Minutes to 24 Hours and 1- to 100-Year Return Periods

Prepared by
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
U. S. WEATHER BUREAU
for
SOIL CONSERVATION SERVICE
U. S. DEPARTMENT OF AGRICULTURE

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PREFACE

This expansion of Technical Paper No. 24, Parts I and II[1], is part of a Weather Bureau project sponsored by the Soil Conservation Service (authorization: Watershed Protection and Flood Prevention Act, P. L. 566) to portray the rainfall intensity-duration-frequency regime of the United States. Technical Paper No. 24 had been prepared for the Airfields Branch, Engineering Division, Military Construction, Office of the Chief of Engineers, to provide rainfall intensity-frequency data for design criteria in estimating capacities of drainage systems for various types of military installations.

The Soil Conservation Service requires rainfall data for longer durations and a wider range of return periods than are given in Technical Paper No. 24, extending to 24 hours and 1 to 100 years, respectively. Insofar as practicable, the results of Technical Paper No. 24 were preserved, but at the same time the present technical paper is complete in itself, requiring no reference to the earlier paper.

The investigation was conducted under the direction of D. M. Hershfield, project leader, in the Cooperative Studies Section (W. T. Wilson, Chief), of Hydrologic Services Division (W. E. Hiatt, Chief). Technical assistance was furnished by L. L. Weiss; collection and processing of data were preformed by W. H. Bartlett, Mrs. E. C. I'Anson, S. P. Kerr III, Mrs. L. L. Langdon, Miss E. E. Marlowe, T. P. O'Connell, S. Otlin, and J. G. Wangler, Jr.; typing was by S. P. Kerr III, and drafting by C. W. Gardner. Coordination with the Soil Conservation Service, Department of Agriculture, was maintained through H. O. Ogrosky, Staff Hydrologist of the Engineering Division. W. C. Ackerman, until recently Chief of the Watershed Studies Section of the Agriculture Research Service; M. A. Kohler, Chief Research Hydrologist, and A. L. Shands, Assistant Chief, Hydrologic Services Division, acted as consultants. Mrs. L. Rubin of the Hydrometeorological Section edited the text.

BASIC DATA

The partial-duration series, which is an array of all the high-ranking data without regard to year of occurrence, was analyzed for Technical Paper No. 24. For this paper the annual series, which consists of the maximum value for each year, was also used insofar as practicable because it is less laborious to process than the partial-duration series.

Table 1 shows the number of stations used for this study (including those previously processed for Technical Paper No. 24), the type of series, and the source of data. The short-record 6-hr amounts were estimated from the relationship $\frac{\text{1-hr} + \text{24-hr}}{2.0}$, which was developed from the 200 long-record Weather Bureau stations. The results obtained from this relationship show an average error of 3%.

Table 1
Precipitation Data, Number of Stations, Type of Series, and Sources of Data

	ANNUAL SERIES			PARTIAL-DURATION SERIES			
Duration	No. of Stations	Av. length of Rec(Yrs)	Source §	No. of Stations	Av. length of Rec(Yrs)	Source §	Total No. of Stations
All durations (20 min to 24 hrs)	200§§	40	2	50 (1&24hr only)	40	3	200
Hourly Precip	___	___	___	750	10	4&5	750
6-Hourly Precip	___	___	___	750	10	4&5	750
Daily Precip	1500	13§§§	4&5	1000	10§§§	4&5	2500
Daily Precip	120	40	4&5	___	___	___	120

§ The numbers in the "Source" columns of this table refer to items in the Bibliography at the end of the report.

§§ Only 50 of these stations are in the area covered by this study.

§§§ In some instances, less than the total record was used.

Only about half the recording-gage and nonrecording-gage records examined were considered suitable for evaluation and analysis. Reasons for rejection were: (1) length of record less than 8 years, making it too unreliable for estimating the required return periods, (2) significant changes in the location of the gage during the period of record, and (3) large published rainfall amounts which could not be verified from the original records.

Diagram A, INTENSITY OR DEPTH OF RAINFALL FOR DURATIONS LESS THAN 6 HOURS

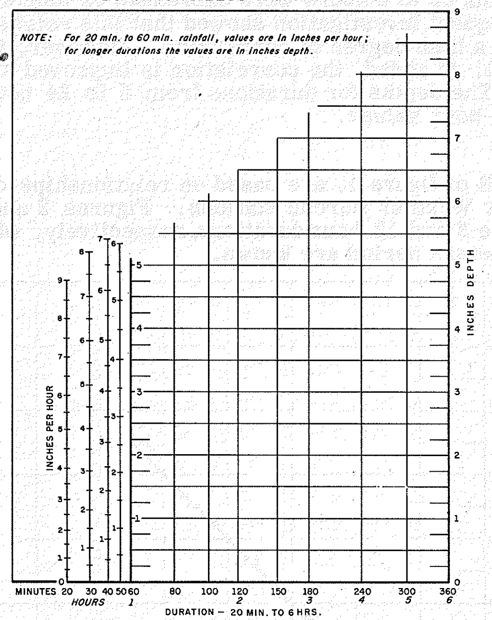


Diagram B, DEPTH OF RAINFALL FOR DURATIONS OF 6 TO 24 HOURS

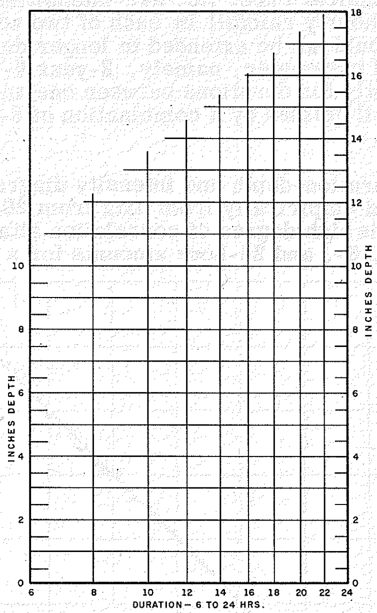
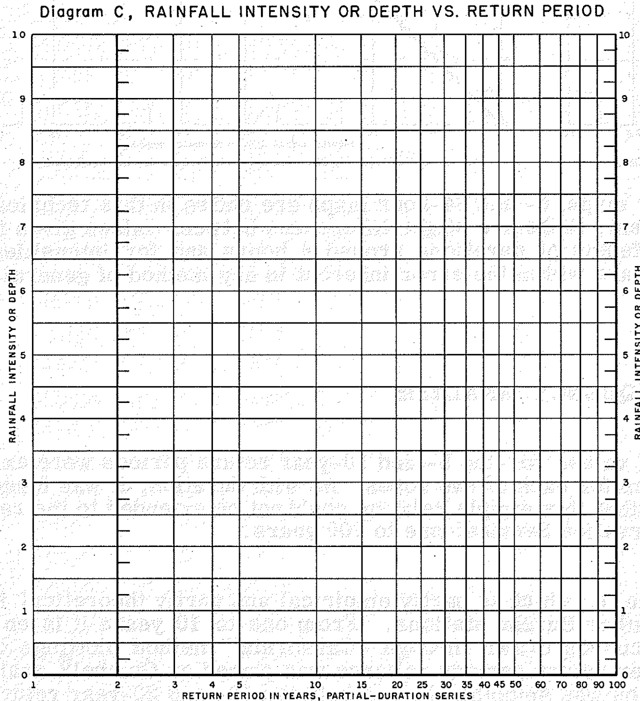


Diagram C, RAINFALL INTENSITY OR DEPTH VS. RETURN PERIOD



NOTE: To use this diagram for values greater than 10, a factor of 10 may be used, as with a slide rule, with proper attention to the decimal point. If more convenient, other factors such as 2 or 5 may be used.

TABLE 3, with three examples, outlines the steps in the order they should be carried through in solving for the required rainfall intensities or depths.

TABLE 3

	Example 1	Example 2	Example 3
1. Location	46° 00' N 121° 00' W	36° 00' N 119° 00' W	40° 00' N 108° 00' W
2. Required Int (Depth)-Dur-Freq.	25-Yr 3-Hr Rainfall(In)	1-Yr 12-Hr Rainfall(In)	50-Yr 30-Min Int(In/Hr)
3. 2-Year 1-Hour Rainfall. Fig. 6-11	0.4 In.	——	0.6 In.
4. 2-Year 6-Hour Rainfall. Fig. 12-17	1.0 In.	0.9 In.	0.9 In.
5. 2-Year 24-Hour Precip. Fig. 18-23	——	1.4 In.	——
6. Straightedge connecting (3) and (4) or (4) and (5) intersects required duration. Diagrams A or B	(2-Yr 3-Hr) 0.7 In.	(2-Yr 12-Hr) 1.1 In.	(2-Yr 30-Min) 0.9 In/Hr.
7. 100-Yr 1-Hr Rainfall / 2-Yr 1-Hr Fig. 24-29	3.2	——	2.5
8. 100-Yr 6-Hr Rainfall / 2-Yr 6-Hr Fig. 30-35	2.1	2.7	2.1
9. 100-Yr 24-Hr Precip. / 2-Yr 24-Hr Fig. 36-41	——	2.5	——
10. (7) x (3)	(100-Yr 1-Hr) 1.3 In.	——	(100-Yr 1-Hr) 1.5 In.
11. (8) x (4)	(100-Yr 6-Hr) 2.1 In.	(100-Yr 6-Hr) 2.4 In.	(100-Yr 6-Hr) 1.9 In.
12. (9) x (5)	——	(100-Yr 24-Hr) 3.5 In.	——
13. Straightedge connecting (10) and (11) or (11) and (12) intersects required duration. Diagrams A or B	(100-Yr 3-Hr) 1.7 In.	(100-Yr 12-Hr) 2.9 In.	(100-Yr 30 Min) 2.5 In/Hr.
14. Straightedge connecting (6) and (13) gives (2). Diagram C	1.3 In.	0.8 In.	2.2 In/Hr.

FIGURE 1. DURATION AND FREQUENCY DIAGRAMS AND EXAMPLES OF COMPUTATION FOR WEATHER BUREAU TECHNICAL PAPER NO. 28 (PREPARED JUNE, 1956)

DURATION ANALYSIS

In Technical Paper No. 24, intensities for durations up to 4 hours were expressed as functions of the hourly rainfall in each of two zones. Subsequent investigation showed that this relationship could not be extended to longer durations with a high degree of correlation. However, if a second parameter, namely, 2-year 6-hour rainfall, is added, the correlation is improved significantly for durations between one and 6 hours. The depths for durations from 6 to 24 hours are well defined by a combination of 6-hour and 24-hour values.

The duration-depth and intensity diagrams, A and B of figure 1, are based on relationships developed empirically from data from 200 first-order Weather Bureau stations. Figures 2 and 3 show the high degree of correlation attainable for the 3 and 12-hour durations, respectively, when the 1-, 6-, and 24-hour amounts for a particular return period are known.

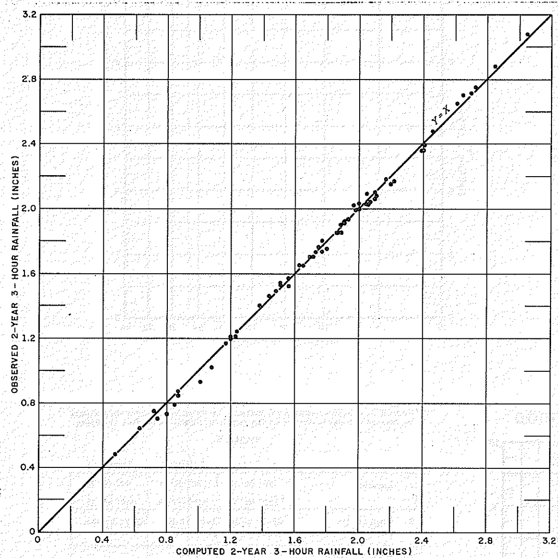


FIGURE 2. CORRELATION OF COMPUTED WITH OBSERVED 2-YEAR 3-HOUR RAINFALL.

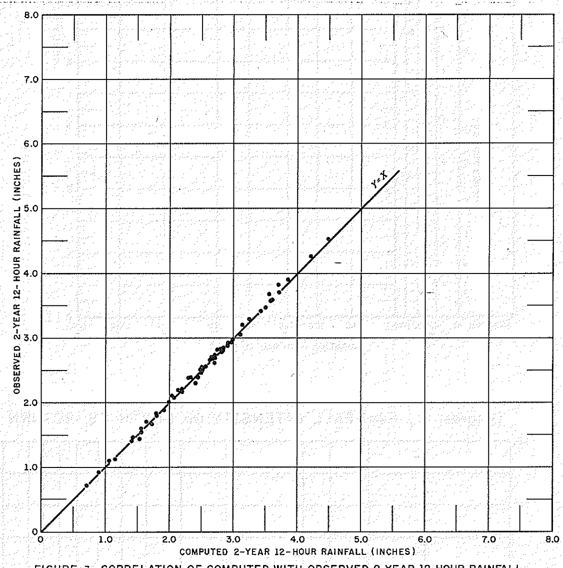


FIGURE 3. CORRELATION OF COMPUTED WITH OBSERVED 2-YEAR 12-HOUR RAINFALL.

Accordingly, in addition to the one-hour maps, 6- and 24-hour maps are shown in this technical paper. Because of the different treatment, there are slight differences between values given in the two technical papers for rainfall depths of durations around 4 hours and for intensities around 20 minutes. These differences are within the error inherent in any method of generalizing presently available data.

FREQUENCY ANALYSIS

In Technical Paper No. 24, the rainfall values for the 5- and 10-year return periods were expressed as functions of the 2-year values for each of two zones. As with duration, it was found in preparing the present technical paper that this simple relation could not be extended to the return periods required by the Soil Conservation Service: one to 100 years.

The return-period diagram, C of figure 1, which is partly empirical and partly theoretical is based on data from the long-record Weather Bureau stations. From one to 10 years it is entirely empirical, based on free-hand curves drawn through "California" method plottings of partial-duration series data. For longer return periods reliance was placed on Gumbel[6] analysis of annual series data. The transition was smoothed by eye between 10- and 20-year return periods. If values between 2 and 100 years are taken from the return-period diagram, then converted to annual series values and plotted on either Gumbel or log-normal paper, the points will very nearly define a straight line.

Table 2
Empirical Factors for Converting the Partial-Duration Series to the Annual Series

2-year return period	0.88
5-year return period	0.96
10-year return period	0.99

For example, if the 2-, 5-, and 10-year partial-duration series values estimated from the return-period diagram are 3.00, 3.75, and 4.21 inches, respectively, the annual series values are 2.64, 3.60, and 4.17 inches after multiplying by the conversion factors in Table 2.

The two intercepts needed for the frequency curve are the 2-year values obtained from the 2-year maps, and 100-year values obtained by multiplying the 2-year values by those given on the 100-year to 2-year ratio maps. Thus, given the rainfall values for both the 2- and 100-year return periods, values for other return periods are functionally related and may be determined from diagram C which is entered with the 2- and 100-year values. The 100-year values for the first-order stations were taken from Gumbel analysis of the annual series (Technical Paper No. 25[7]).

The 2-year values for the short-record recorder stations were obtained from the "California" method of plotting partial-duration series data on log-log paper, and correspond to those used in Technical Paper No. 24. Where the data formed a relatively smooth curve, records as short as 8 years were used in regions of sparse data.

As reported in Technical Paper No. 24, there was no apparent secular trend for the short-duration data. Figures 4 and 5, which are based on 158 widely scattered Weather Bureau stations, illustrate that there was no positive or negative change over a long period of time for the 24-hour data. These figures also compare the 10- and 100-year values estimated from 10- and 45-year records. The average differences of 15 and 20% give some indication of the precision that can be achieved from the short record.

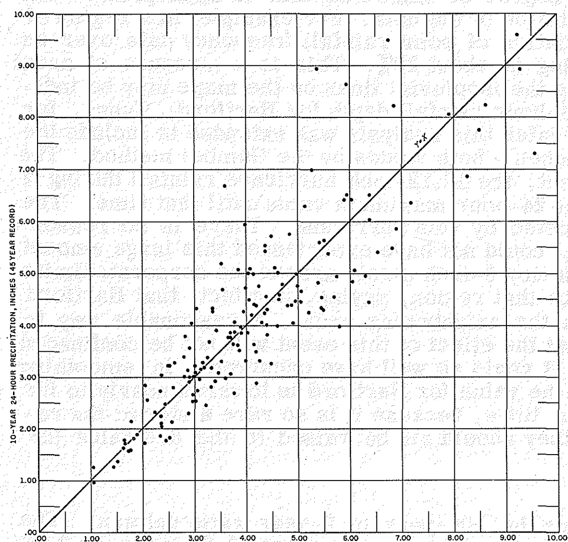


FIGURE 4. COMPARISON OF 10-YEAR 24-HOUR PRECIPITATION BASED ON 10 YEAR AND 45 YEAR RECORDS. AVERAGE DIFFERENCE IS APPROXIMATELY 15%

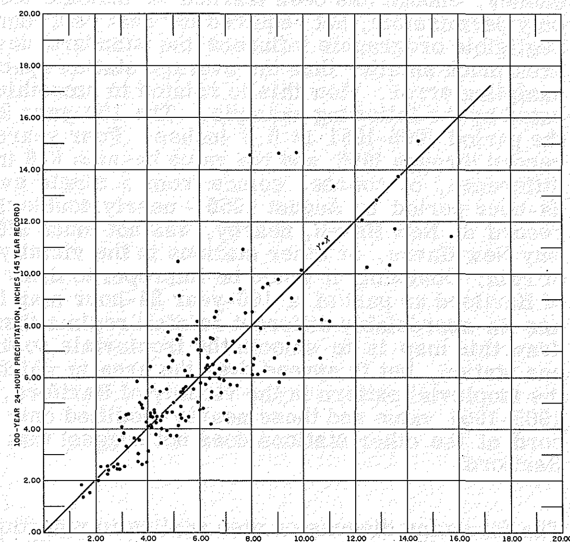


FIGURE 5. COMPARISON OF 100-YEAR 24-HOUR PRECIPITATION BASED ON 10 YEAR AND 45 YEAR RECORDS. AVERAGE DIFFERENCE IS APPROXIMATELY 20%

Slight differences exist between Technical Paper No. 24 and this paper with respect to values for the 5- and 10-year return periods because of the difference in the method of generalizing. These differences are within the range of error of processing and expressing the rainfall data on a frequency basis.

The directions for using the diagrams appear on figure 1, with examples. Large working diagrams are available and have been put in the pocket attached to the back cover of this paper.

MAPS

The 2-year one-hour maps are identical with those in Technical Paper No. 24. The 2-year 24-hour maps are based on a much larger number of stations and therefore are considered to be more reliable. Even so, the maps are rather flat because of the sparsity of data and because the evaluation of detailed topographic effects on the rainfall regime cannot as yet be generalized over large regions. The 2-year 6-hour maps are based on observed data from the long-record stations and data estimated from the relationship established with hourly and daily rainfall for a particular return period.

In lieu of 100-year maps, a set of 100-year to 2-year ratio maps has been presented which can be used in conjunction with the 2-year maps to obtain the 100-year value. Even though an extra step is required to estimate the 100-year value - multiplication of the 2-year amounts by the 100-year to 2-year ratios - more precise values are obtained by interpolating between the lines on the relatively flat ratio maps than on a set of steep gradient 100-year maps. The average dispersion of 15% in comparing the 100-year to 2-year ratios from 10- and 45-year records was considered in smoothing the pattern on the ratio maps.

The 2-year one- to 24-hour ratio map shown in Part II of Technical Paper No. 24 was based on a small number of recorder stations and was used to estimate additional hourly amounts from the nonrecorder data. A similar map can be constructed from the 2-year one-hour and 2-year 24-hour maps of this paper which will show a slightly different pattern. The difference is due largely to additional nonrecorder data used to analyze the 24-hour map.

DISCUSSION

While not enough work has yet been done to define the area-depth characteristics of rainfall frequency, enough has been learned to indicate the degree of smoothing that is appropriate - not only permissible, but required for best representation of the data. For example, in a region of negligible orographic influence the standard deviation of point rainfall frequency data over an area much smaller than the average station spacing is about 20%. This is a measure of areal sampling error. How this is related to smoothing the isopluvial lines on the maps may be indicated by the following example. The 100-year 24-hour rainfall depth for Hartford, Conn., for the period 1905-1951 is 6.3 inches. Four years later this analysis was extended to include the record through 1955, and the value became 8.6 inches - both values by the Gumbel method. The difference, of course, comes from a single event, the 12.12-inch hurricane rainfall during a 24-hour period in August 1955 - nearly double the 24-hour maximum value until that time. The record at New Haven, nearby, was not much affected by this hurricane. There is no reason why New Haven, or other stations in the vicinity, could not have experienced this large amount of rain. Obviously it would be improper to draw a tiny 8-inch circle around the corporate limits of Hartford as part of a 100-year 24-hour map for that region, saying, in effect, that Hartford has an appreciably different rainfall regime than the neighboring area. A reasonable way to draw this map is to smooth the isopluvials so that the effect of this event will not be confined to one station, but is spread over the area in which it could as well have occurred. In smoothing the isopluvial pattern in the vicinity of Hartford, the value for Hartford is lowered nearly to its 1905-1951 value and those nearby modified only a little, because it is so rare a storm: the record at the other stations does not suggest that they should all be raised to the 8.6 value for Hartford.

The foregoing discussion also applies to smoothing the 100-year to 2-year ratio pattern. The addition of the 1955 value increased the Hartford 2-year 24-hour value from 2.80 inches to 2.87 inches and the 100-year value from 6.30 inches to 8.60 inches. This in turn increased the 100-year to 2-year ratio from 2.25 to 3.00, which must be smoothed in the same manner as that discussed for the isopluvial pattern. This example has been cited because it is of recent knowledge and dramatically shows the effect of a single event on the sensitive frequency relationship.

In the region covered by this technical paper, particularly where orographic influences are important (which is not true of Hartford and New Haven), perhaps the best anomaly is Mt. Tamalpais vs. Kentfield, Calif. Here, one station, practically in the shadow of the other, has twice the rainfall values for nearly all durations and return periods. To ask which one is 'right' is inappropriate because each may well be right for its particular site. The rainfall record of a single gage may not, and often cannot, 'represent' the rainfall regime of an appreciable area. All it may represent is the regime at a site having the combination of exposure and physiographic parameters which exist where it is observed. It may be possible, by severely restricting the size of region, to find a unique relation between rainfall intensity-frequency and parameters such as elevation, orientation, concavity or convexity of local site, distance from ridge, local slope, etc. This has been done, with various degrees of subjectivity, by various agencies and enhances the maps they have been able to draw. Los Angeles County Flood Control District[8] and the State Bulletin on "California Culvert Practice"[9] have maps of much greater detail than is possible in this technical paper, which must cover a large region. Where orographic influences are important, and where local agencies have prepared maps of detail scale, users are urged to refer to these and other available maps and diagrams.

No attempt was made to examine station exposures and to standardize them by double-mass or other methods, which would be a way of distinguishing between large-scale topographic parameters that affect the production of rain and the smaller-scale parameters that merely affect gage performance. While such analyses have been fruitful for mean annual and mean seasonal rainfall, considerable investigation with very short-duration rainfall has not as yet disclosed any generally applicable method for interpreting terrain features affecting gage catch. In effect, it is assumed that the generalizing and smoothing of sampling and other error includes variability of exposure - both within and among station records.

There is little doubt that the precipitation values for short durations and long return periods are rain - even in the Rockies. But the arrays of data which were analyzed certainly have a number of snow events for, say, the lesser 24-hour depths. Using both annual series and partial-duration series, and comparing arrays of all ranking precipitation events with those known to have only rain, has shown trivial differences for several high-elevation stations tested.

Since the results of this study contain the estimated 100-year values, which are considered to be rare events, a logical question that might be asked, is, how do these values compare with the probable maximum values given in reports in the area covered by this paper. Cooperative Studies Report No. 12, "Probable Maximum Precipitation on Sierra Slopes of the Central Valley of California"[10] is the only probable maximum study where comparability is possible because the area diagram actually extends to "zero" area or what might be considered a point. A systematic comparision of the values from both studies revealed that in a few instances the 100-year values in this paper are larger than the estimated probable maxima. Although these results appear inconsistent with the concept of probable maximum precipitation, comparability is limited because of the definitions and the procedures used to determine these estimates.

As may be seen from the analysis outlined in this paper, the procedure is statistical. A small sample of point rainfall, subject to large errors due to sampling variability, is mechanically projected to the 100-year return period. In the probable maximum method, a combination of statistical and meteorological principles are used to envelop and adjust storm data over an area to their climatological potential. Also, there is no suggestion of the probability corresponding to any of the probable maximum values. In the light of these considerations, it is not surprising that some of the 100-year values exceed the probable maxima.

GLOSSARY

Annual series

A series made up of the annual maximum events for a particular duration. For example, the annual maximum daily rainfall is the largest of the 365 observations of daily rainfall.

California method

The analysis of partial-duration series data on logarithmic paper. The data are ranked according to increasing magnitude and the corresponding points are plotted versus $\frac{m_i}{n}$ where m is the rank and i goes from one to n; n is the number of years of record. A curve is then fitted by eye and the amount of precipitation associated with a particular return period is read off the variate coordinate.

Double-mass analysis

An analysis used to determine if the time trends in the precipitation data at a station are due to changes in the gage location. The accumulated annual precipitation at the station to be tested is compared with the concurrent accumulated amounts of mean precipitation for a fixed group of stations. A significant change in the slope of the double-mass curve generally indicates a change in the precipitation regime.

Gumbel method

A method of analyzing extreme values which was introduced by Fisher and Tippett[11] and applied to hydrologic data by Gumbel. The probability of occurrence of a value in the annual series equal to or less than x is given by:

$$F(x) = \exp(-e^{-y}) \quad \text{where } y = a(x-u)$$

For a long record, a and u may be estimated with the help of:

$$1/a = s\sqrt{6}/\pi, \quad u = \bar{x} - 0.45005s$$

$\bar{x}$ is the sample mean and s is the sample standard deviation.

Gumbel paper

Special probability paper constructed for the analysis of extreme values. If the data plots close to a straight line, the Gumbel theoretical solution is considered applicable.

Isopleth

A line connecting equal values on a chart.

Isopluvial line

A line on rainfall charts connecting points having the same rainfall values.

Log-normal method

The logarithms of the observed data are fitted to the normal probability curve or distribution:

$$y = n/s\sqrt{2\pi}\; e^{-\frac{1/2\,(x-\bar{x})^2}{s^2}}$$

where n is the size of the sample, $\bar{x}$ is the sample mean, and s is the sample standard deviation.

Log-normal paper

Probability paper for determining quickly if the extreme values follow the log-normal distribution. This paper has a logarithmic scale in the vertical direction and a probability scale in the horizontal direction. If the data plots close to a straight line, the log-normal distribution is considered applicable.

Partial-duration series

A series formed by the highest n values in n years of observation. Year of occurrence is not considered in this series.

Return period

The interval of time, in years, within which the magnitude of the rainfall event will be equaled or exceeded once, on the average. For example, if we say the 50-year 24-hour rainfall at a station is 5.00 inches, the return period is 50 years.

Standard deviation

For any frequency distribution, the standard deviation is the root-mean-square of the deviations of the values of the variables from their arithmetic means.

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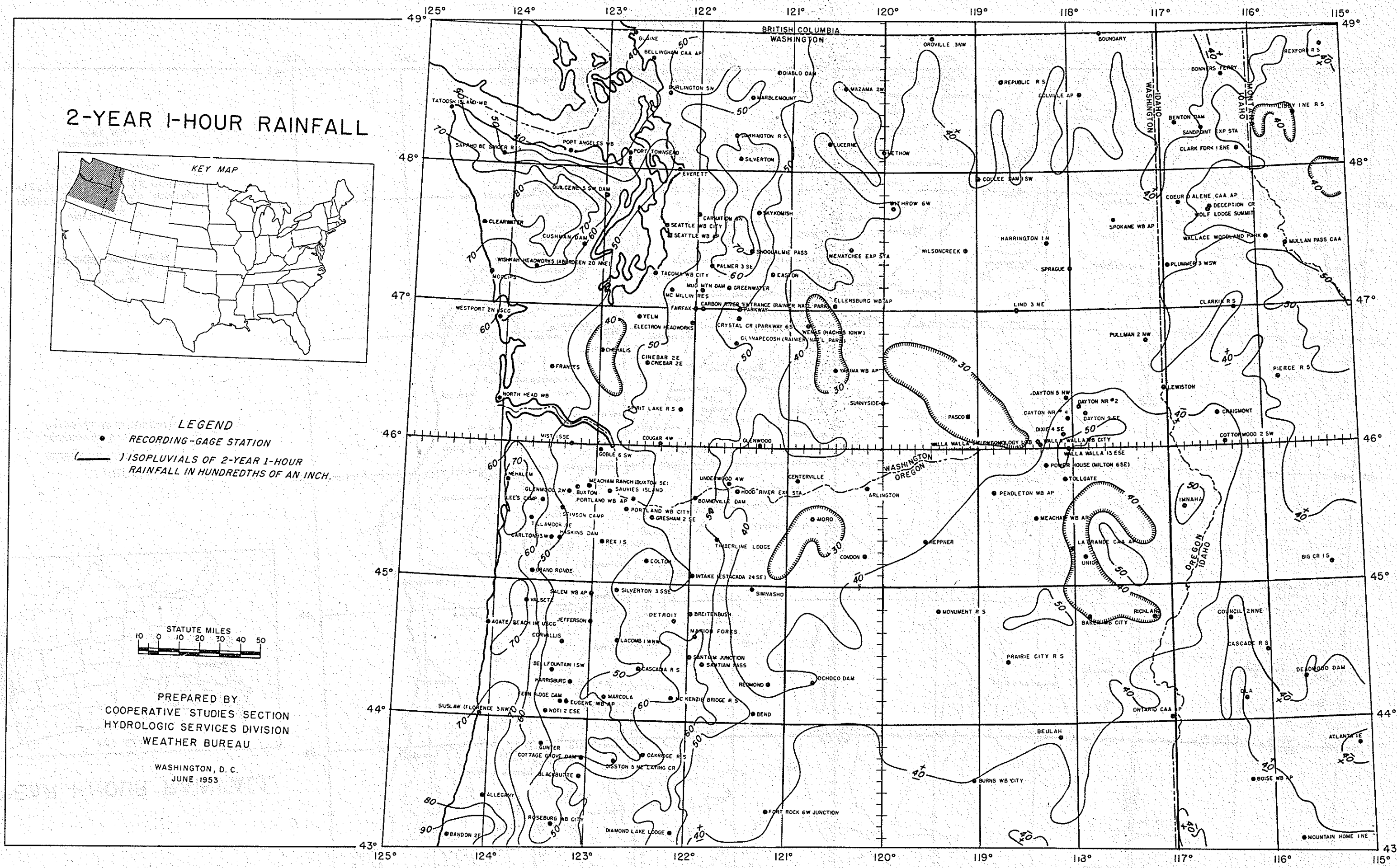
2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
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ISOPLUVIALS OF 2-YEAR 1-HOUR RAINFALL IN HUNDREDTHS OF AN INCH.
STATUTE MILES
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
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WASHINGTON, D. C.
JUNE 1953
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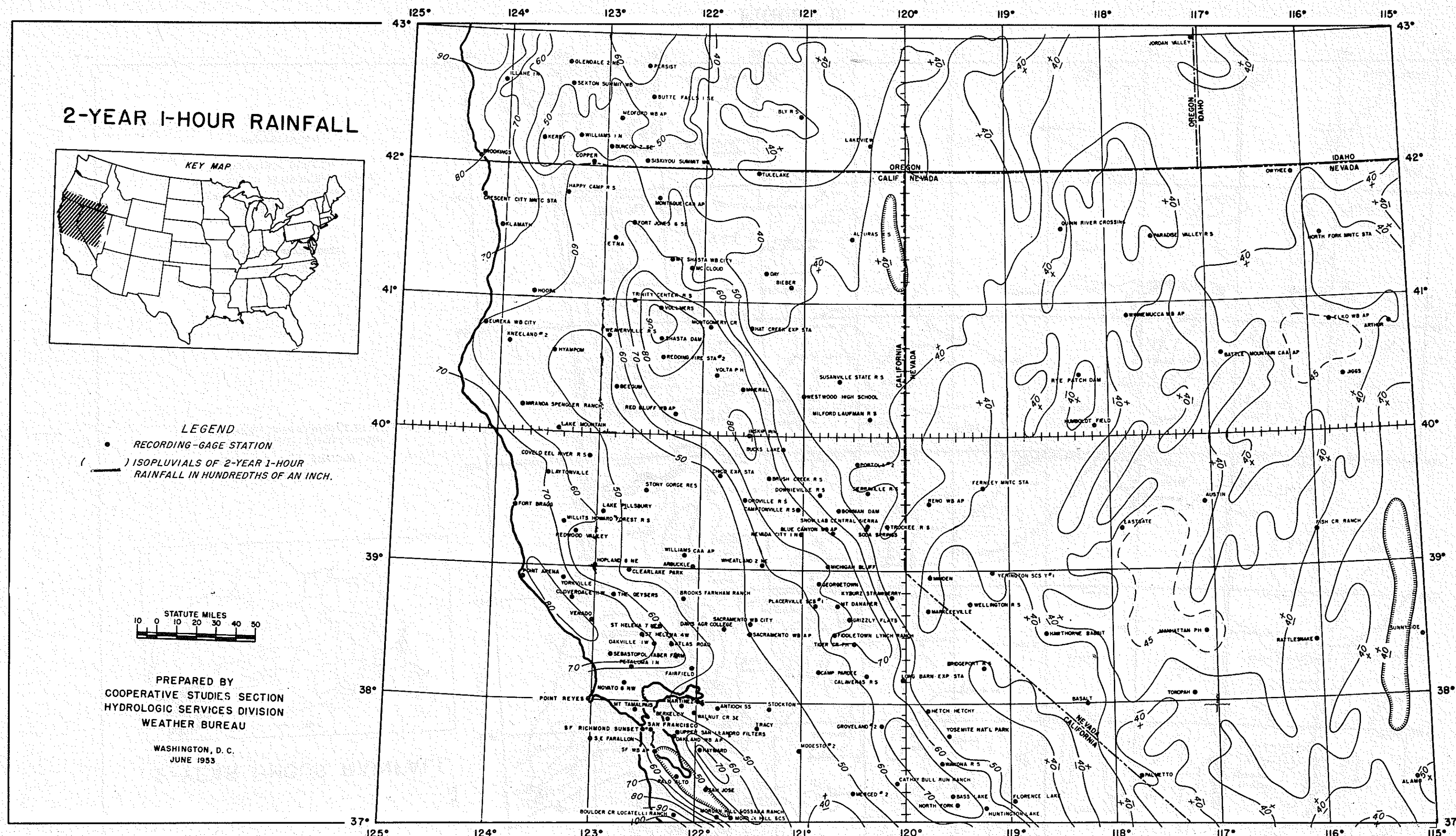
WASHINGTON
OREGON
IDAHO
MONTANA

FIGURE 6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NEVADA
IDAHO
CALIFORNIA
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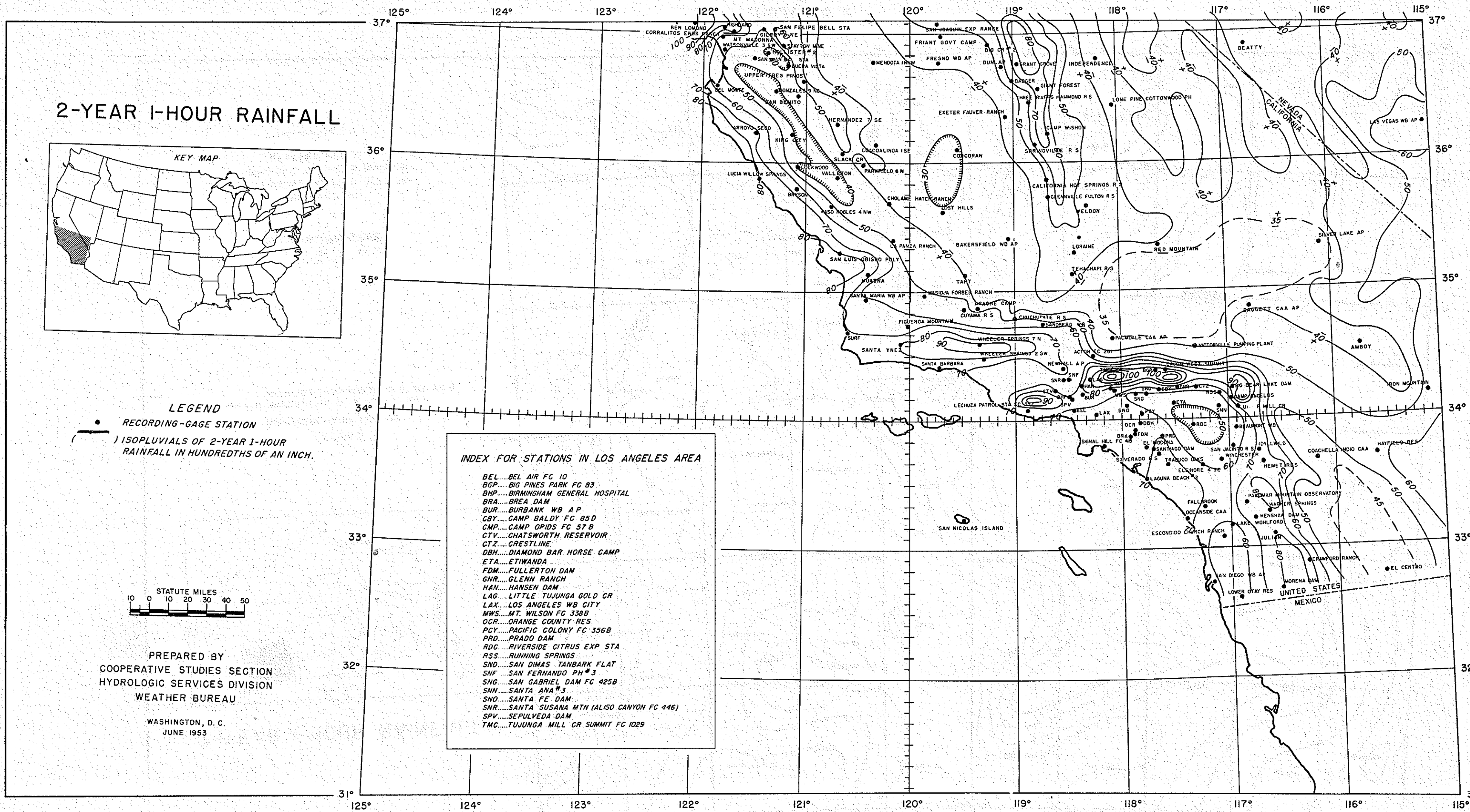
43° 42° 41° 40° 39° 38° 37°

FIGURE 7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WASHINGTON, D. C.
JUNE 1953
INDEX FOR STATIONS IN LOS ANGELES AREA
BEL....BEL AIR FC 10
BGP....BIG PINES PARK FC 83
BHP....BIRMINGHAM GENERAL HOSPITAL
BRA....BREA DAM
BUR....BURBANK WB AP
CBY....CAMP BALDY FC 85D
CMP....CAMP OPIDS FC 57 B
CTY....CHATSWORTH RESERVOIR
CTZ....CRESTLINE
DBH....DIAMOND BAR HORSE CAMP
ETA....ETIWANDA
FDM....FULLERTON DAM
GNR....GLENN RANCH
HAN....HANSEN DAM
LAG....LITTLE TUJUNGA GOLD CR
LAX....LOS ANGELES WB CITY
MWS....MT. WILSON FC 338B
OCR....ORANGE COUNTY RES
PCY....PACIFIC COLONY FC 356B
PRD....PRADO DAM
RDC....RIVERSIDE CITRUS EXP. STA
RSS....RUNNING SPRINGS
SND....SAN DIMAS TANBARK FLAT
SNF....SAN FERNANDO PH #3
SNG....SAN GABRIEL DAM FC 425B
SNN....SANTA ANA #3
SNO....SANTA FE DAM
SNR....SANTA SUSANA MTN (ALISO CANYON FC 446)
SPV....SEPULVEDA DAM
TMC....TUJUNGA MILL CR SUMMIT FC 1029
NEVADA
CALIFORNIA
UNITED STATES
MEXICO
SAN NICOLAS ISLAND

FIGURE 8

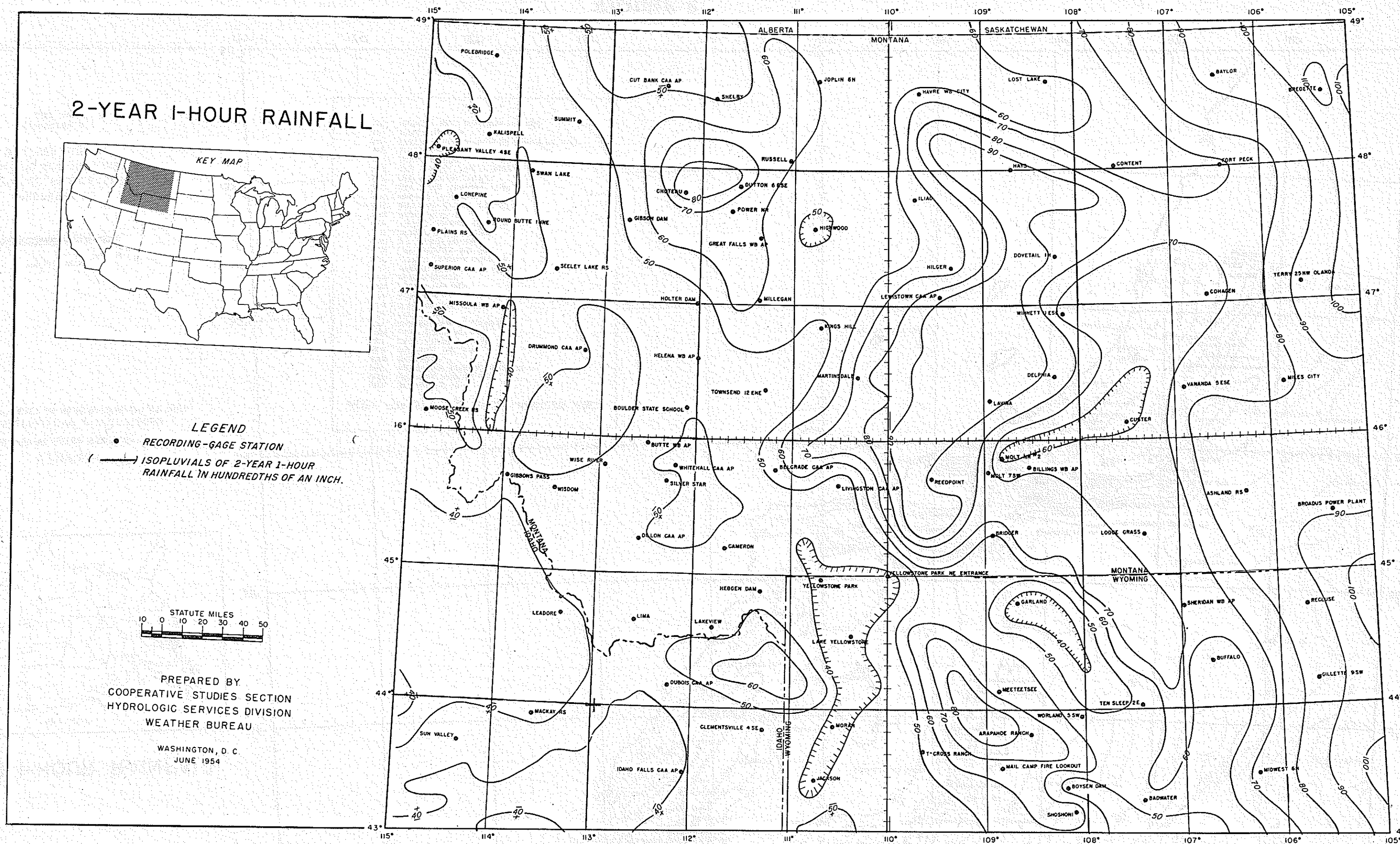
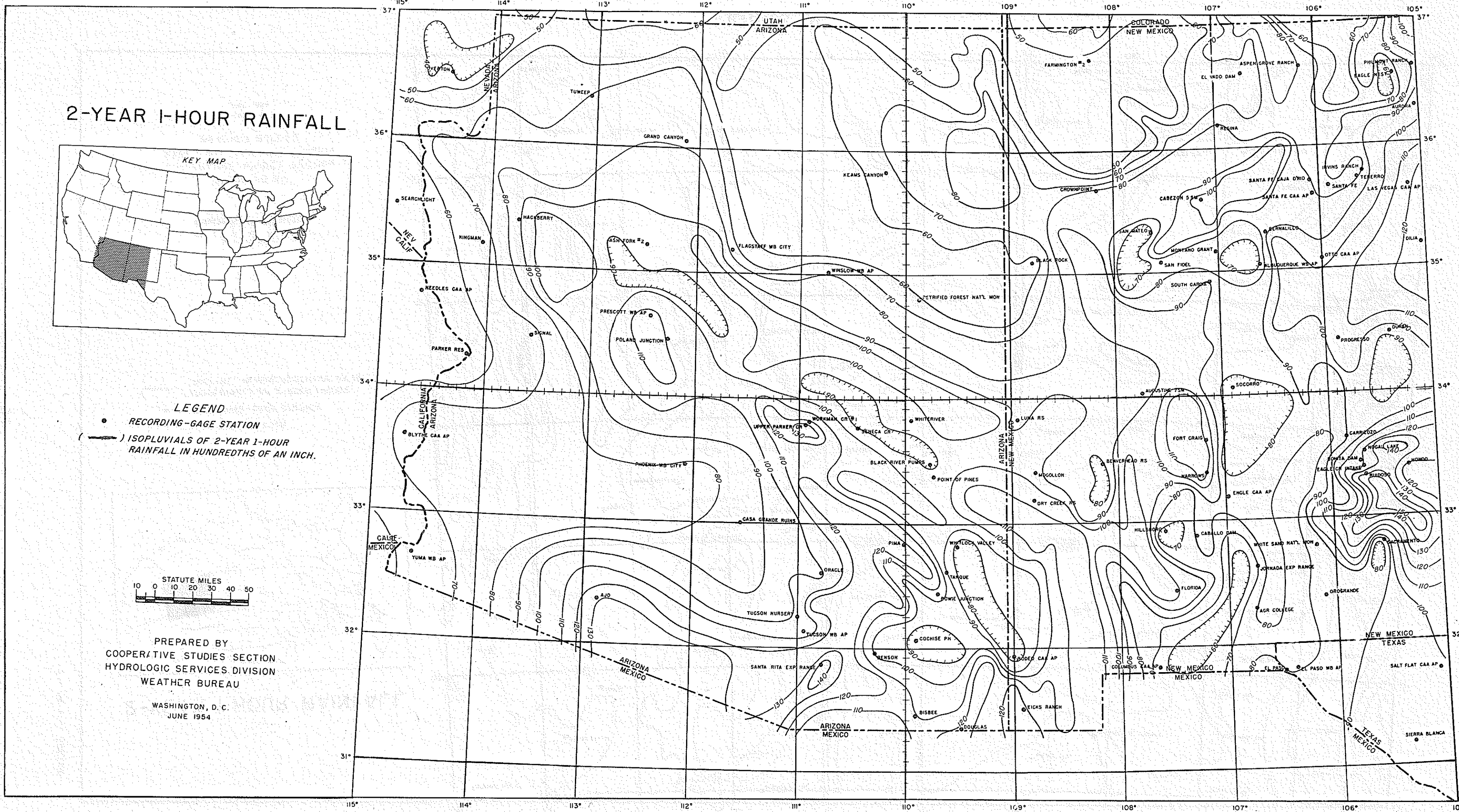

2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLUVIALS OF 2-YEAR 1-HOUR RAINFALL IN HUNDREDTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1954
ALBERTA
SASKATCHEWAN
MONTANA
IDAHO
WYOMING
MONTANA
WYOMING
YELLOWSTONE PARK
115° 114° 113° 112° 111° 110° 109° 108° 107° 106° 105°
49° 48° 47° 46° 45° 44° 43°

FIGURE 9

407359 O - 56 - 2

FIGURE 10



2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLUVIALS OF 2-YEAR 1-HOUR RAINFALL IN HUNDREDTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1954
UTAH
ARIZONA
COLORADO
NEW MEXICO
NEVADA
CALIFORNIA
ARIZONA
MEXICO
TEXAS

FIGURE 11

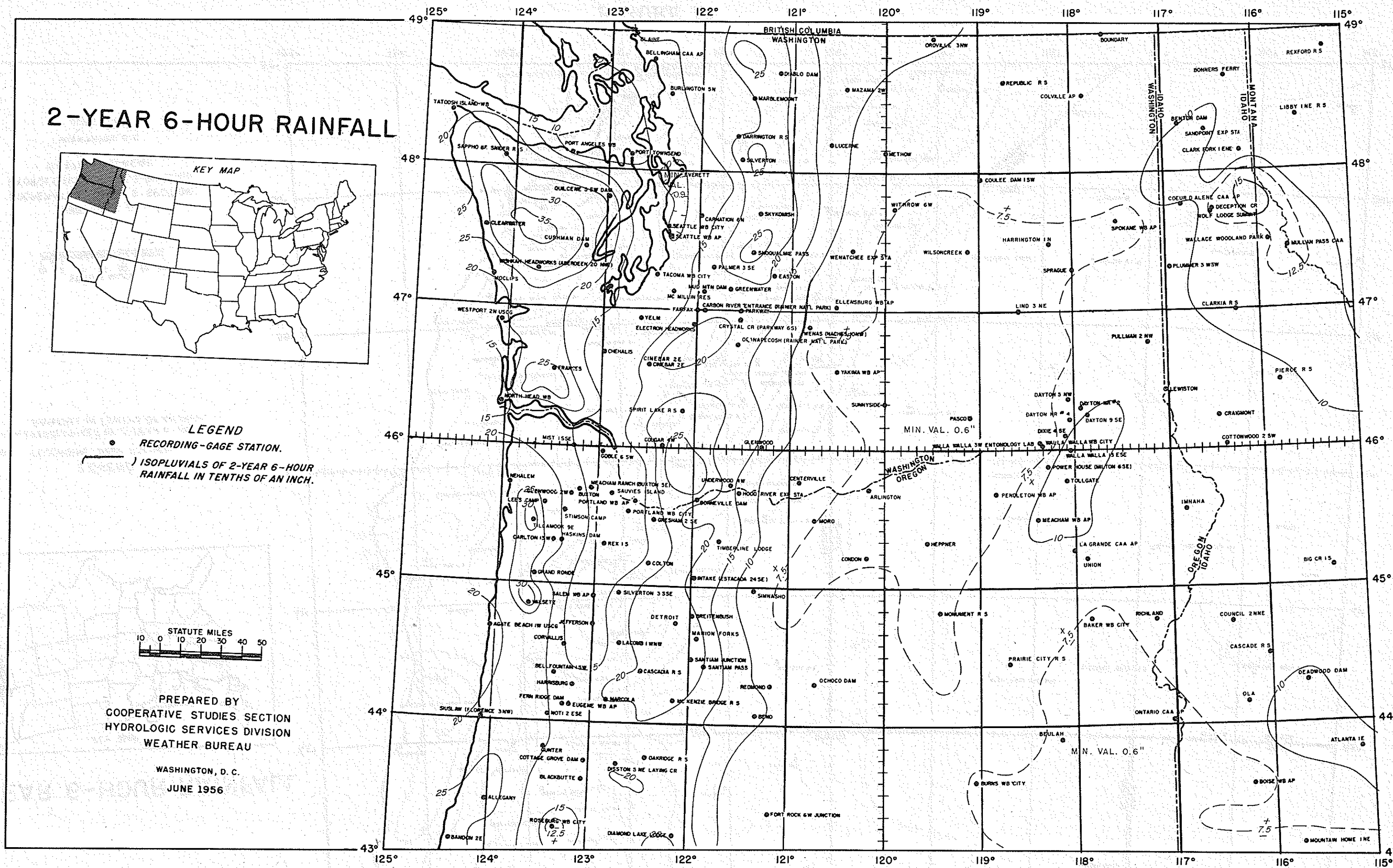

2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION.
ISOPLUVIALS OF 2-YEAR 6-HOUR RAINFALL IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
BRITISH COLUMBIA
WASHINGTON
OREGON
IDAHO
MONTANA
MIN. VAL. 0.6"
MIN. VAL. 0.6"

FIGURE 12

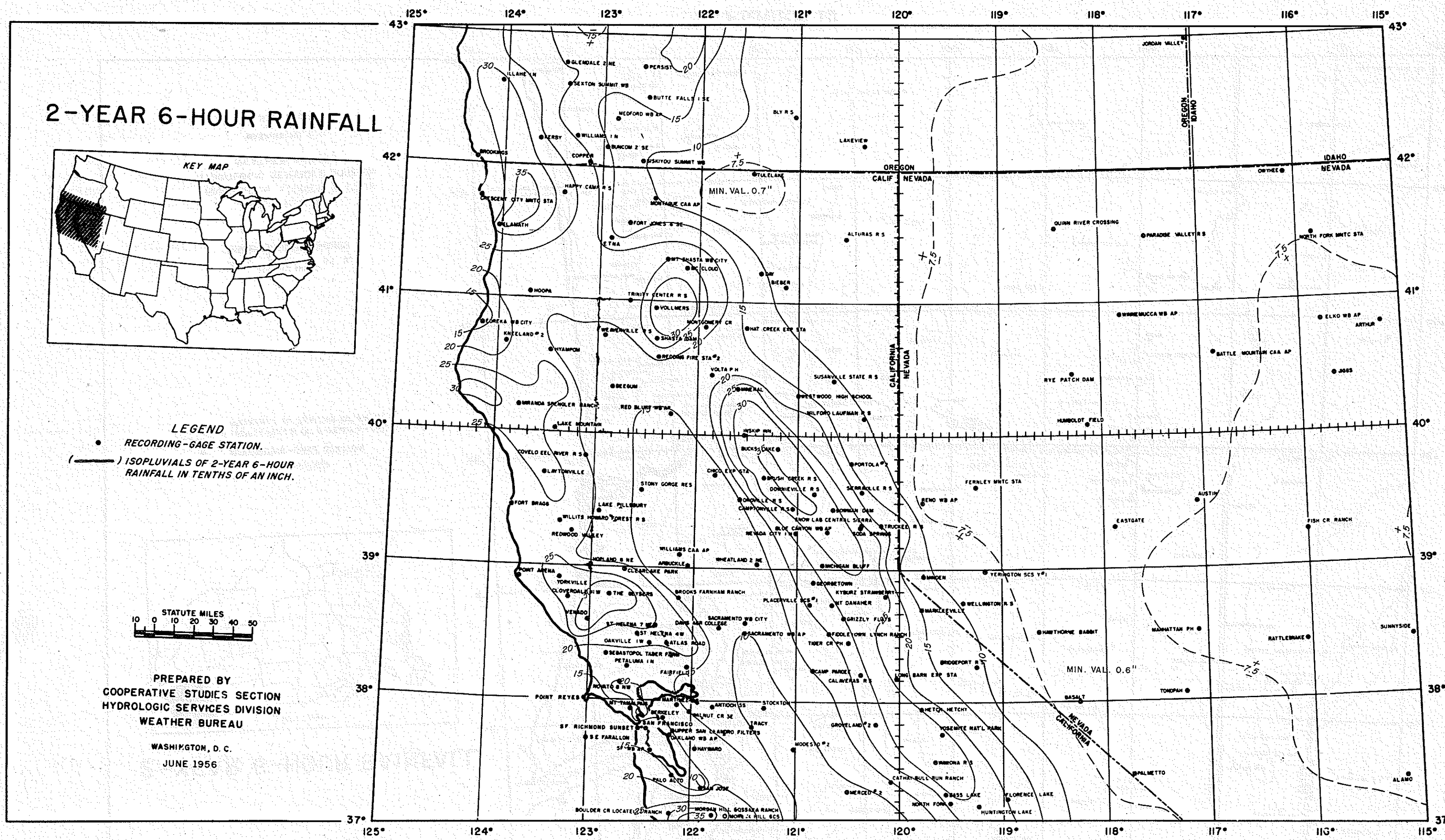

2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION.
ISOPLUVIALS OF 2-YEAR 6-HOUR RAINFALL IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
43° 42° 41° 40° 39° 38° 37°
OREGON
CALIF
NEVADA
IDAHO
CALIFORNIA
MIN. VAL. 0.7"
MIN. VAL. 0.6"

FIGURE 13

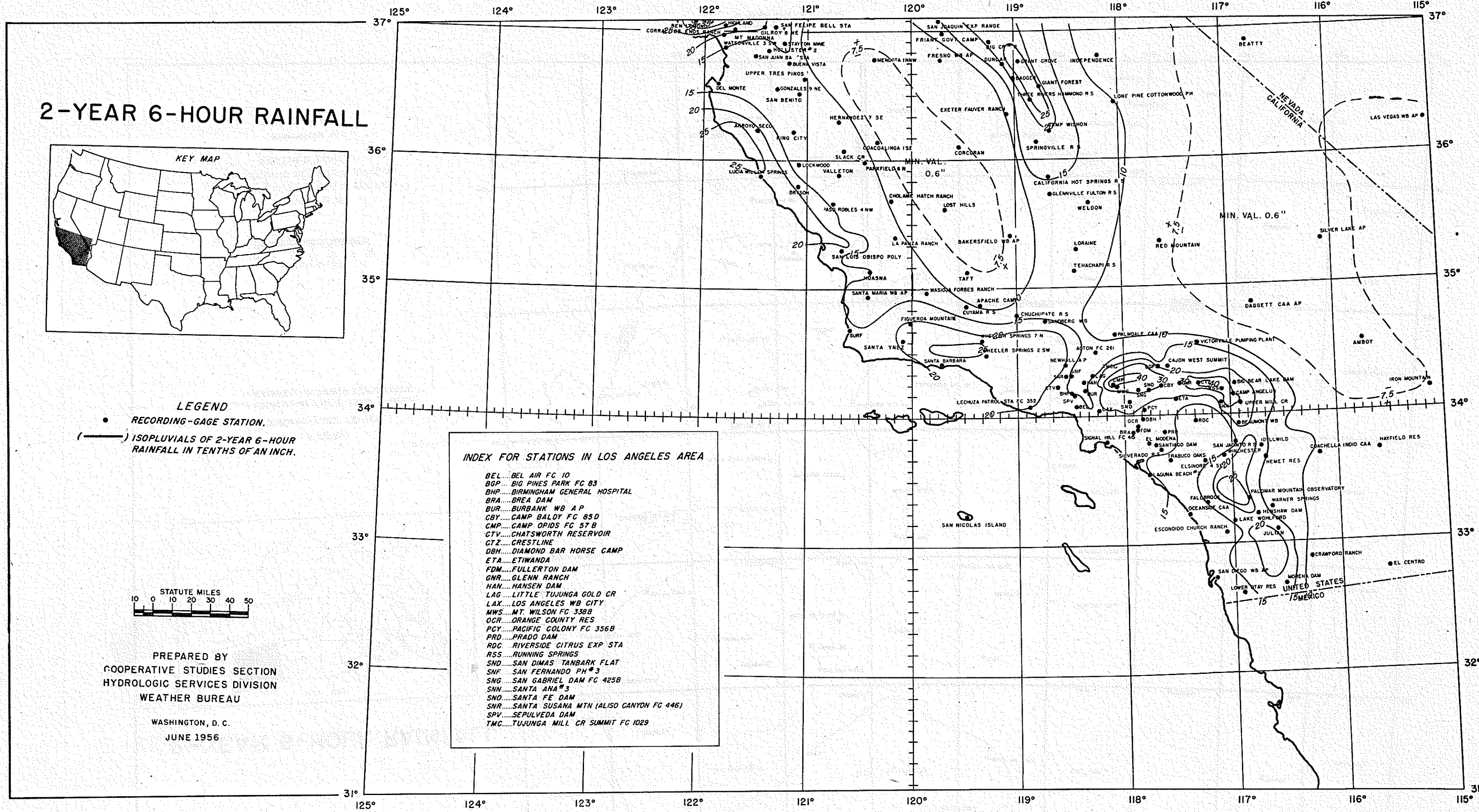
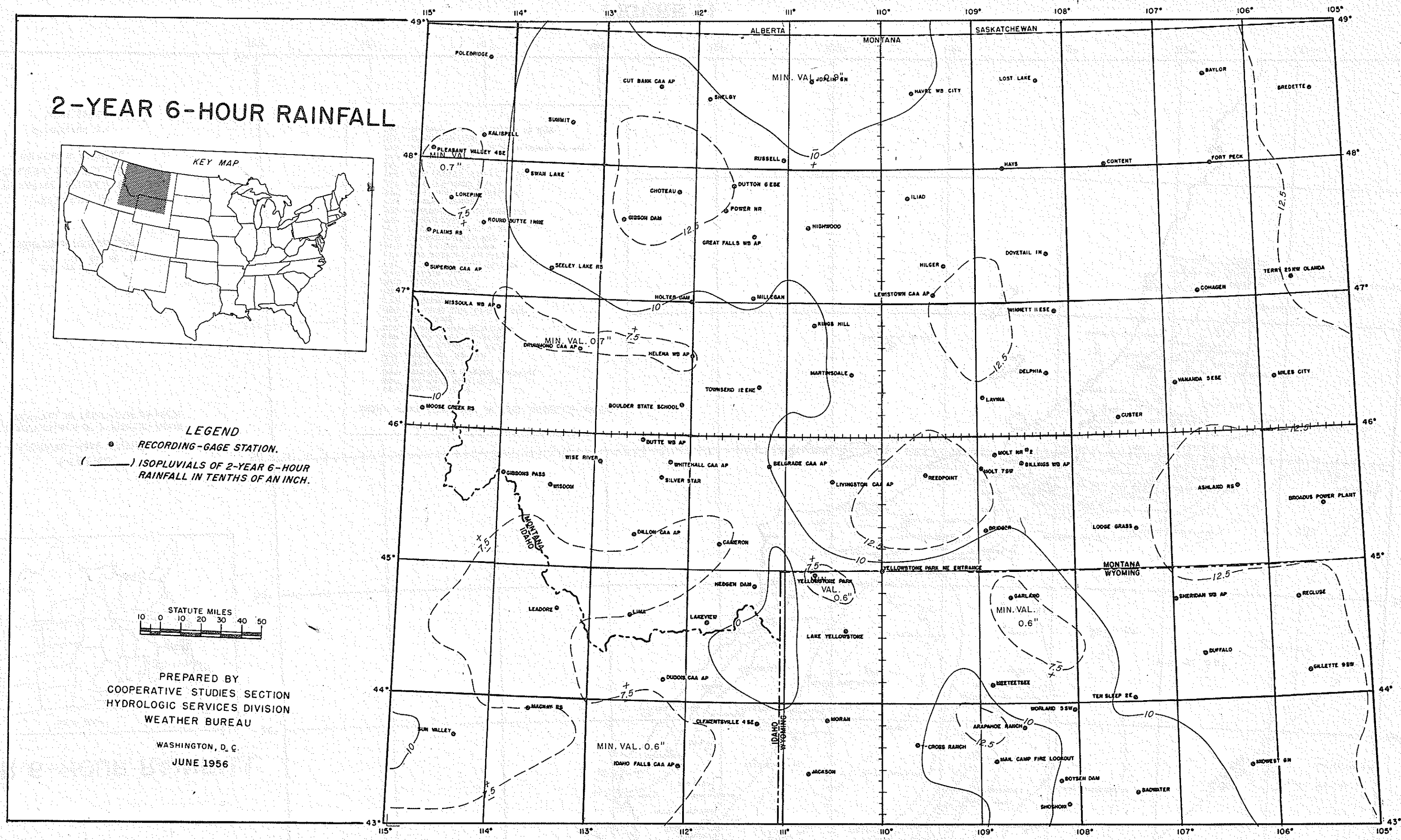

2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION.
ISOPLUVIALS OF 2-YEAR 6-HOUR RAINFALL IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
INDEX FOR STATIONS IN LOS ANGELES AREA
BEL....BEL AIR FC 10
BGP....BIG PINES PARK FC 83
BHP....BIRMINGHAM GENERAL HOSPITAL
BRA....BREA DAM
BUR....BURBANK WB AP
CBY....CAMP BALDY FC 85D
CMP....CAMP OPIDS FC 57B
CTV....CHATSWORTH RESERVOIR
CTZ....CRESTLINE
DBH....DIAMOND BAR HORSE CAMP
ETA....ETIWANDA
FDM....FULLERTON DAM
GNR....GLENN RANCH
HAN....HANSEN DAM
LAG....LITTLE TUJUNGA GOLD CR
LAX....LOS ANGELES WB CITY
MWS....MT. WILSON FC 338B
OCR....ORANGE COUNTY RES
PCY....PACIFIC COLONY FC 356B
PRD....PRADO DAM
RDC....RIVERSIDE CITRUS EXP STA
RSS....RUNNING SPRINGS
SHD....SAN DIMAS TANBARK FLAT
SNF....SAN FERNANDO PH #3
SNG....SAN GABRIEL DAM FC 425B
SNN....SANTA ANA #3
SNO....SANTA FE DAM
SNR....SANTA SUSANA MTN (ALISO CANYON FC 446)
SPV....SEPULVEDA DAM
TMC....TUJUNGA MILL CR SUMMIT FC 1029
MIN. VAL. 0.6"
MIN. VAL. 0.6"
NEVADA
CALIFORNIA
UNITED STATES
MEXICO

FIGURE 14



2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
• RECORDING-GAGE STATION.
(———) ISOPLUVIALS OF 2-YEAR 6-HOUR RAINFALL IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
ALBERTA
SASKATCHEWAN
MONTANA
IDAHO
WYOMING
MIN. VAL. 0.7"
MIN. VAL. 0.6"

FIGURE 15

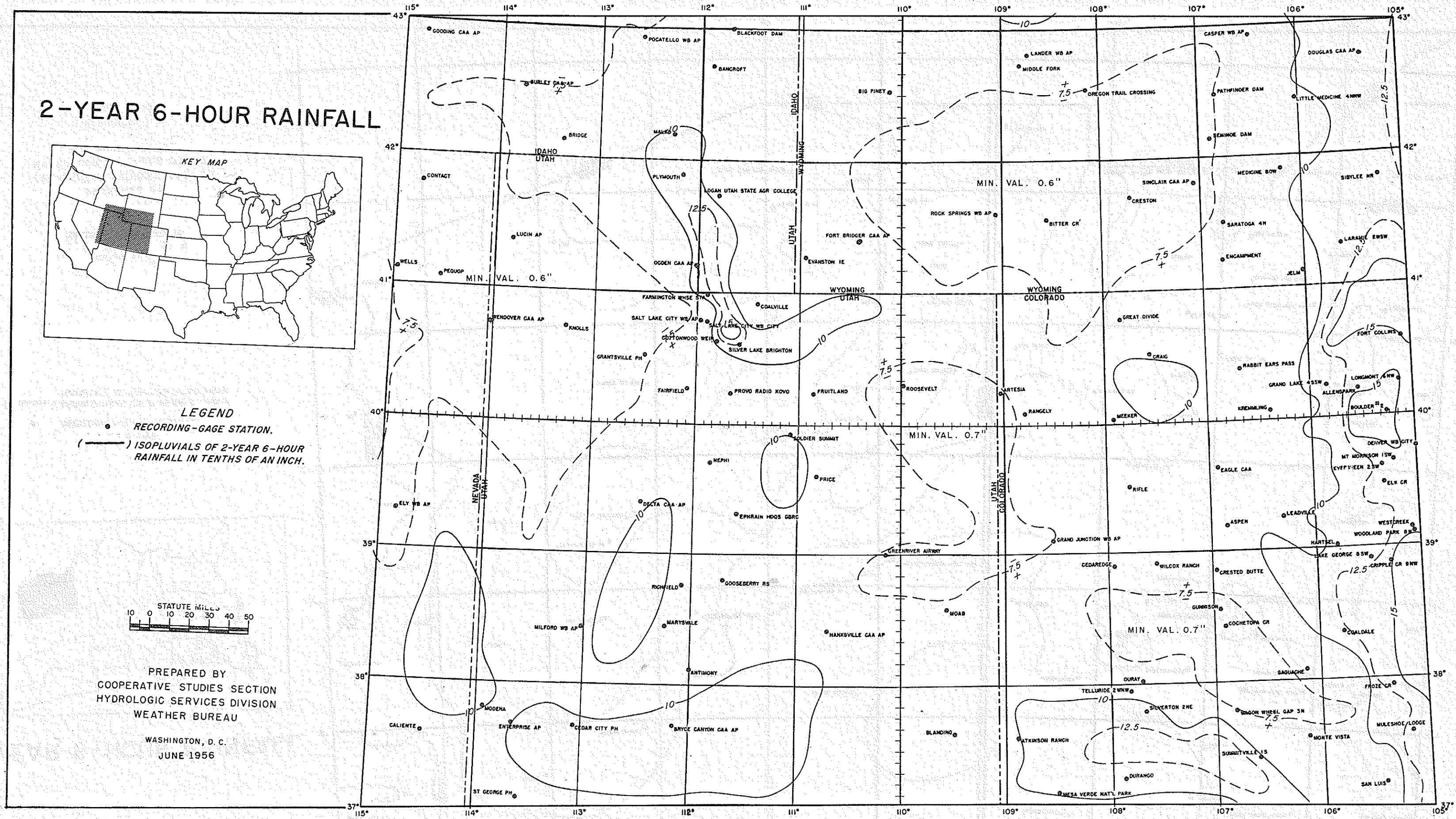

2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION.
(———) ISOPLUVIALS OF 2-YEAR 6-HOUR RAINFALL IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
MIN. VAL. 0.6"
MIN. VAL. 0.6"
MIN. VAL. 0.7"
MIN. VAL. 0.7"
IDAHO
UTAH
WYOMING
COLORADO
NEVADA
115°
114°
113°
112°
111°
110°
109°
108°
107°
106°
105°
43°
42°
41°
40°
39°
38°
37°

FIGURE 16

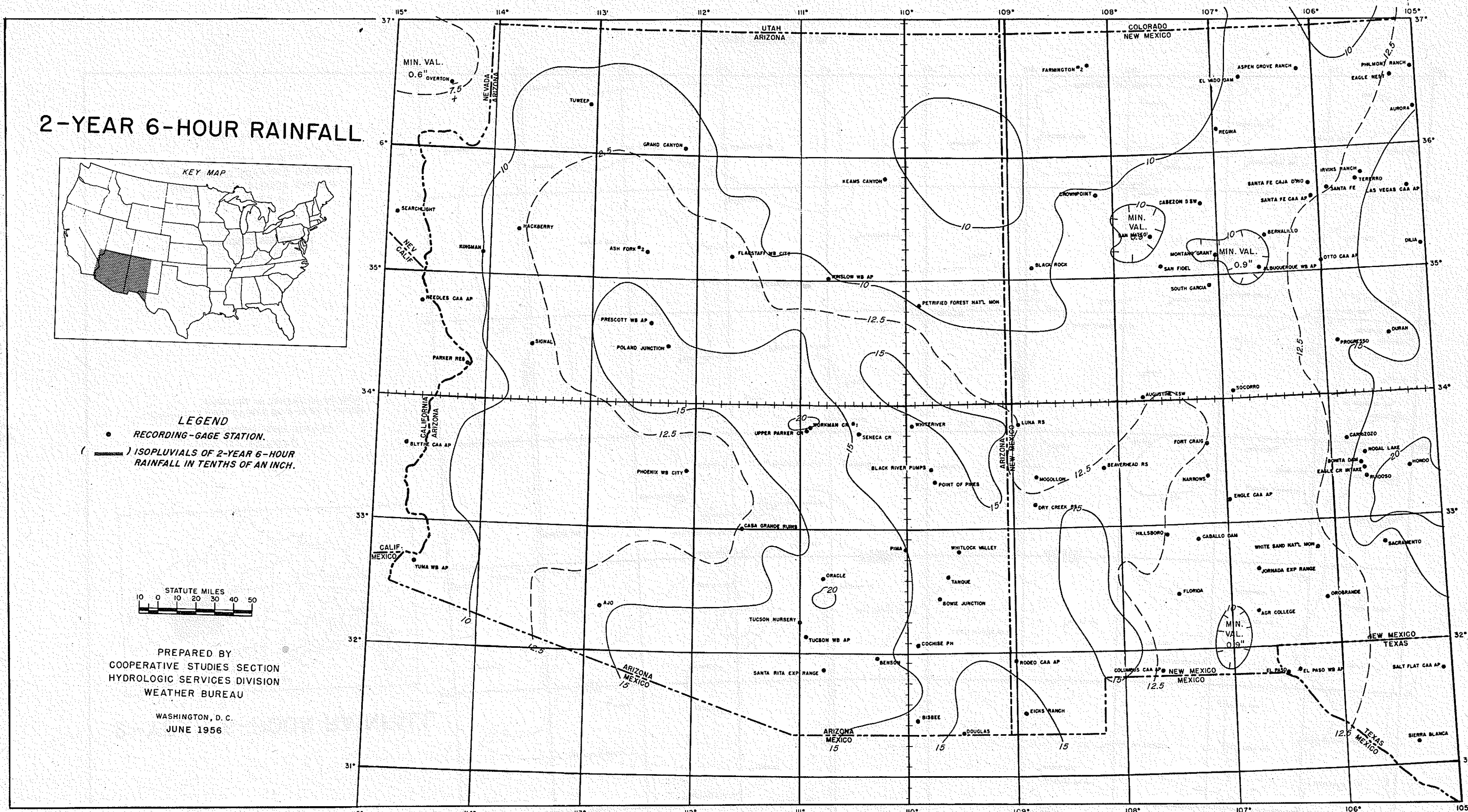
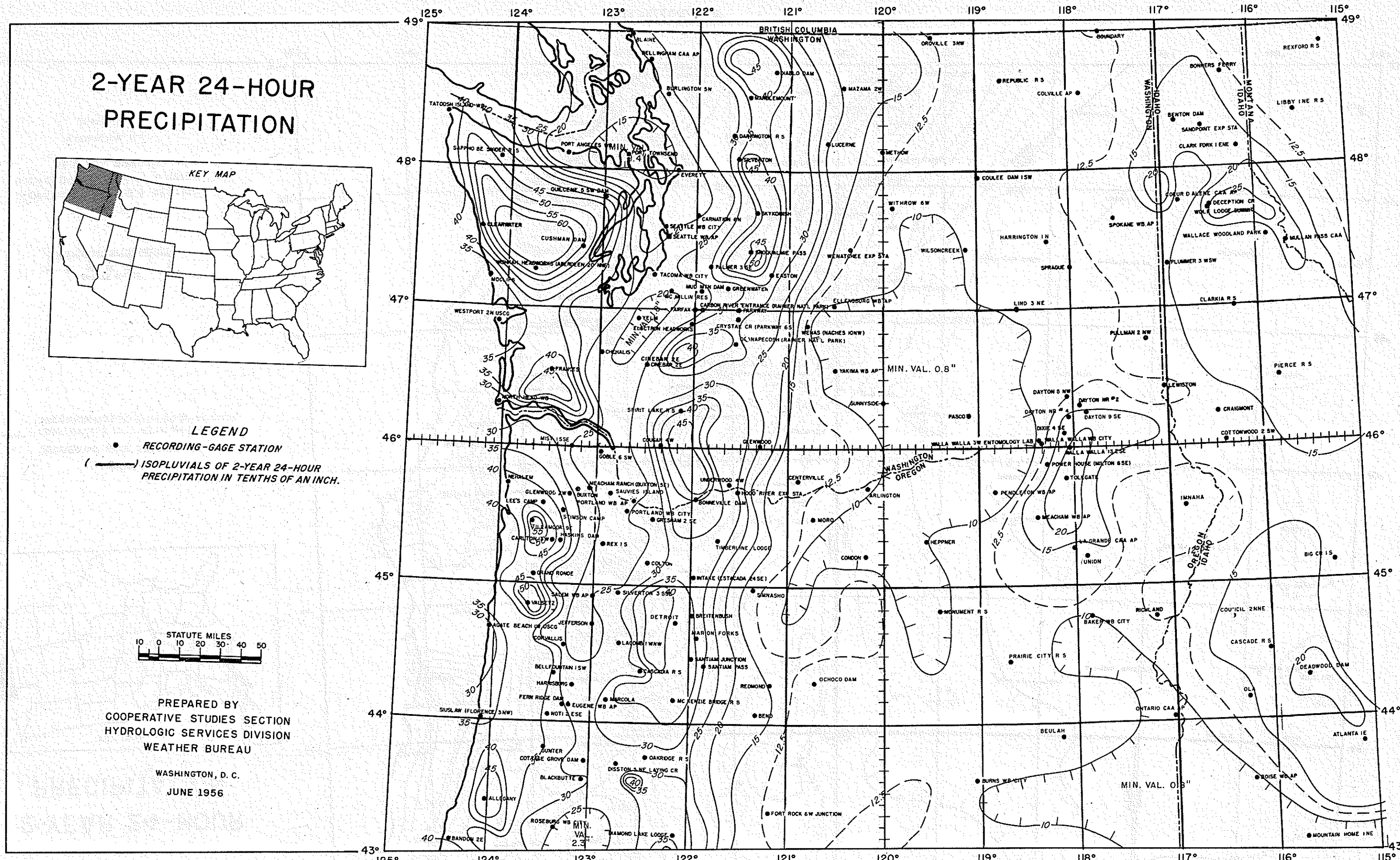

2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
• RECORDING-GAGE STATION.
( ) ISOPLUVIALS OF 2-YEAR 6-HOUR RAINFALL IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
UTAH
ARIZONA
COLORADO
NEW MEXICO
NEVADA
ARIZONA
NEV
CALIF
CALIFORNIA
ARIZONA
CALIF.
MEXICO
ARIZONA
MEXICO
NEW MEXICO
TEXAS
TEXAS
MEXICO
MIN. VAL.
0.6"
MIN. VAL.
0.9"
MIN. VAL.
0.9"

FIGURE 17



2-YEAR 24-HOUR PRECIPITATION
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
BRITISH COLUMBIA
WASHINGTON
OREGON
IDAHO
MONTANA
MIN. VAL. 0.8"
MIN. VAL. 2.3"
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
49° 48° 47° 46° 45° 44° 43°

FIGURE 18

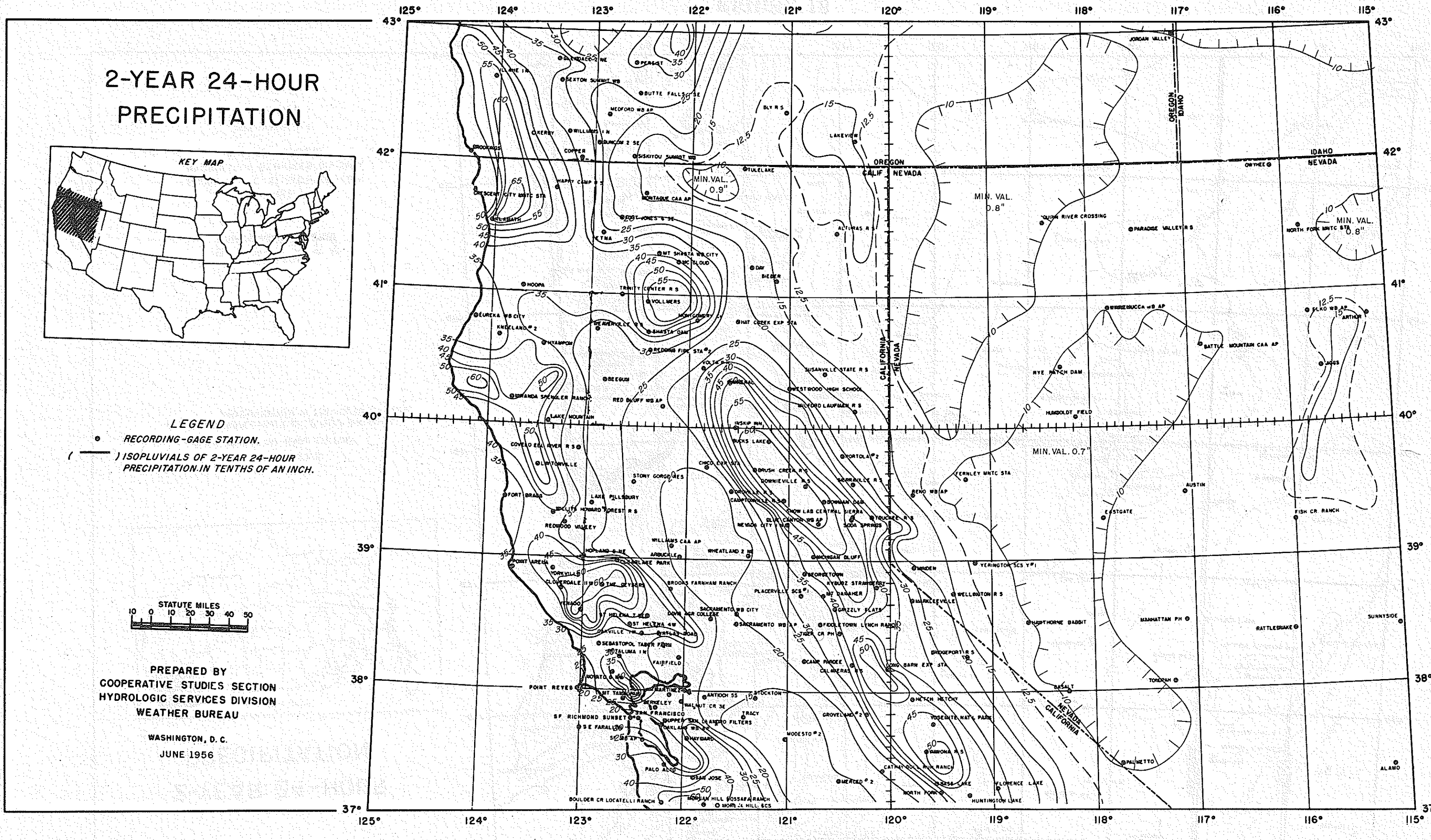
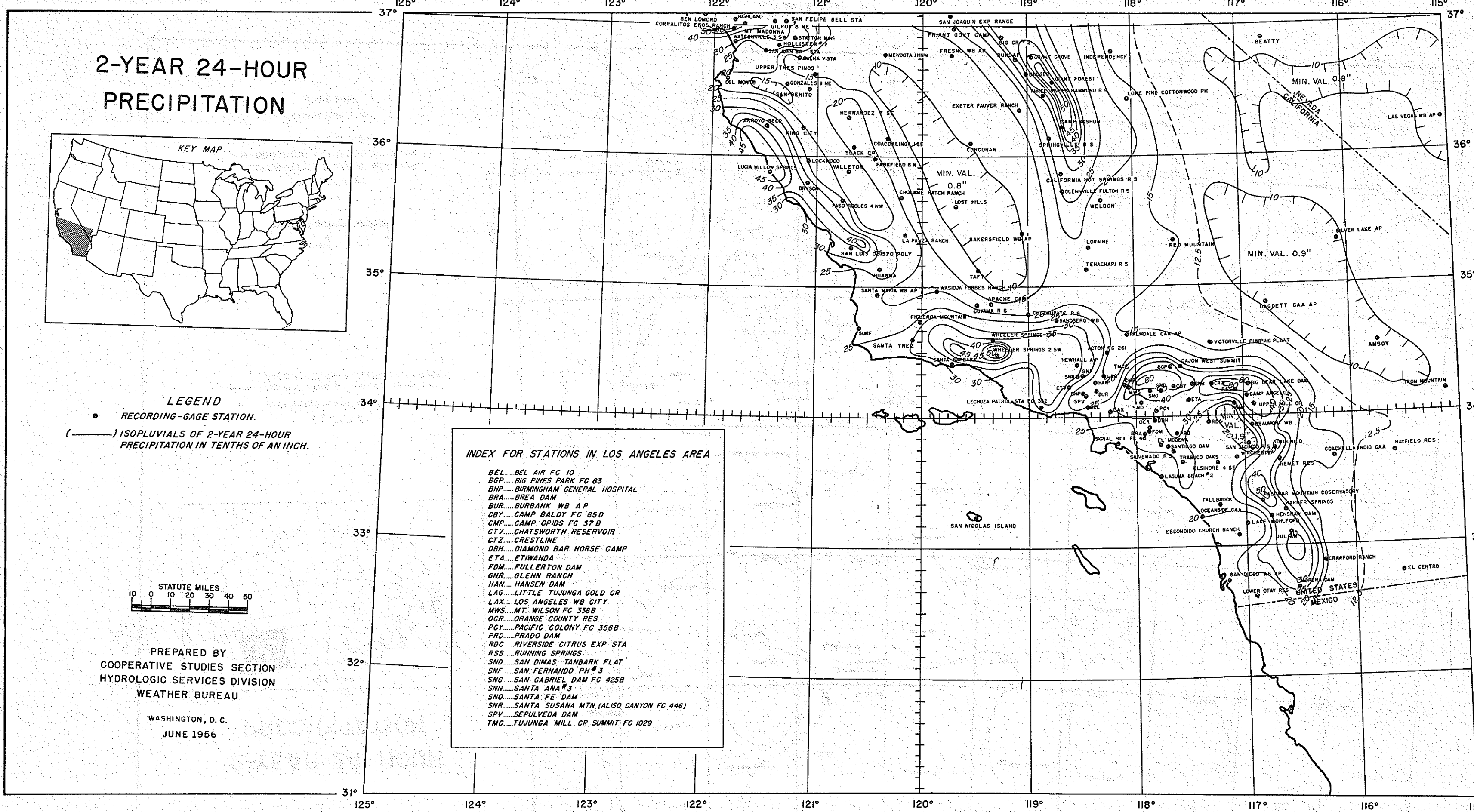

2-YEAR 24-HOUR PRECIPITATION
KEY MAP
LEGEND
RECORDING-GAGE STATION.
ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
43° 42° 41° 40° 39° 38° 37°
OREGON
CALIF.
NEVADA
IDAHO
CALIFORNIA
MIN. VAL. 0.9"
MIN. VAL. 0.8"
MIN. VAL. 0.7"
POINT REYES
SAN FRANCISCO
PALO ALTO
SAN JOSE
STOCKTON
TRACY
FAIRFIELD
PARADISE VALLEY R S
BATTLE MOUNTAIN CAA AP
AUSTIN
EASTGATE
TONOPAH
SUNNYSIDE
ALAMO
FISH CR RANCH
RATTLESNAKE
MANHATTAN PH
PALMETTO
HUMBOLDT FIELD
RYE PATCH DAM
WINNEMUCCA WB AP
ELKO WB AP
JORDAN VALLEY
LAKEVIEW
ALTURAS R S
TULELAKE
MEDFORD WB AP
BUTTE FALLS
HOOPA
EUREKA WB CITY
STONY GORGE RES
WILLIAMS CAA AP
WHEATLAND
TRUCKEE R S
RENO WB AP
MINDEN
YOSEMITE NAT'L PARK
HUNTINGTON LAKE
FLORENCE LAKE
MERCED
MODESTO
GROVELAND

FIGURE 19


2-YEAR 24-HOUR
PRECIPITATION
KEY MAP
LEGEND
• RECORDING-GAGE STATION.
(———) ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
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HYDROLOGIC SERVICES DIVISION
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WASHINGTON, D. C.
JUNE 1956
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MIN. VAL. 0.8"
MIN. VAL. 0.9"
NEVADA
CALIFORNIA
UNITED STATES
MEXICO
SAN NICOLAS ISLAND
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
37° 36° 35° 34° 33° 32° 31°

FIGURE 20

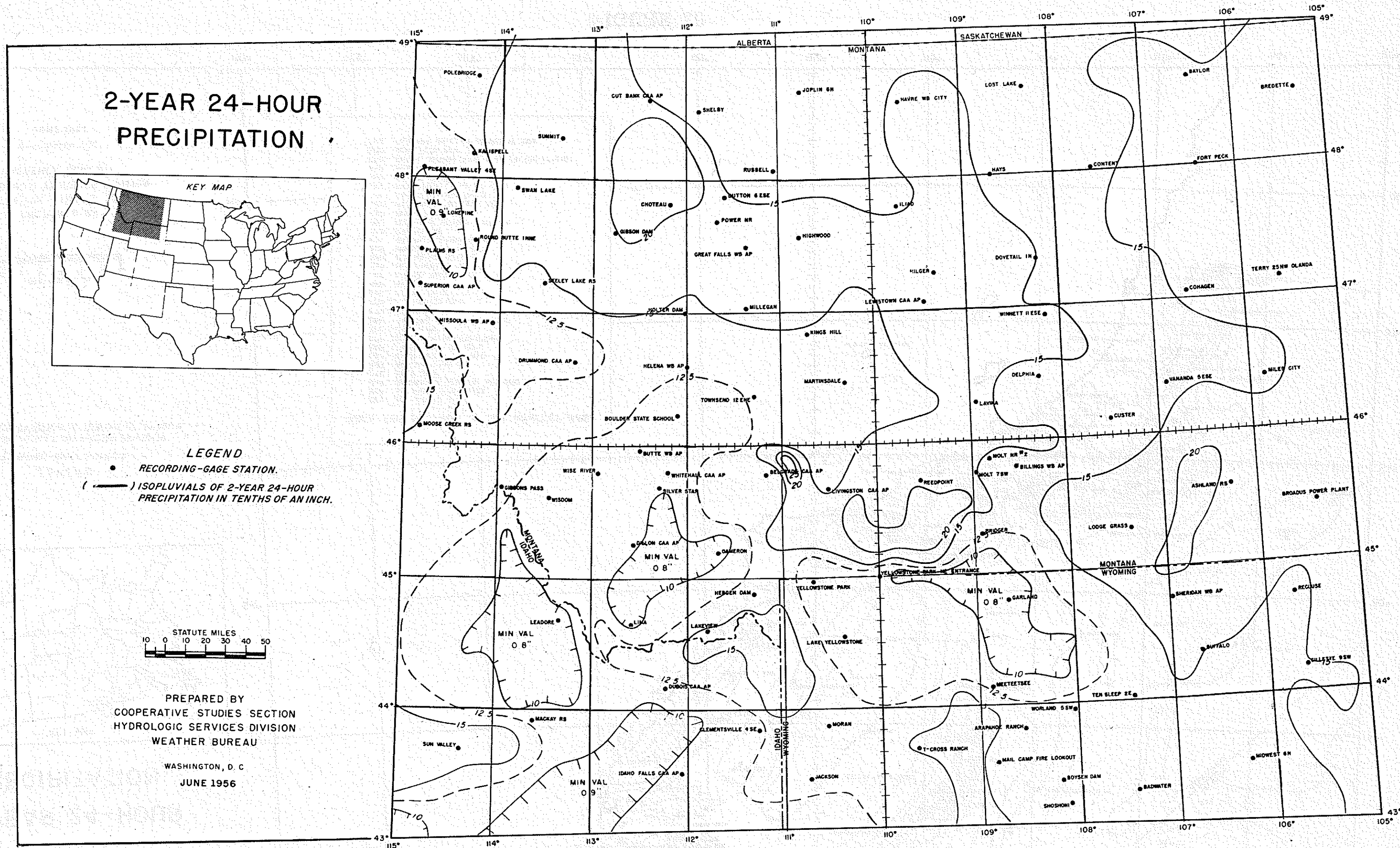

2-YEAR 24-HOUR
PRECIPITATION
KEY MAP
LEGEND
RECORDING-GAGE STATION.
ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
ALBERTA
SASKATCHEWAN
MONTANA
WYOMING
IDAHO
MIN VAL 0.9"
MIN VAL 0.8"
MIN VAL 0.8"
MIN VAL 0.8"
MIN VAL 0.9"

FIGURE 21

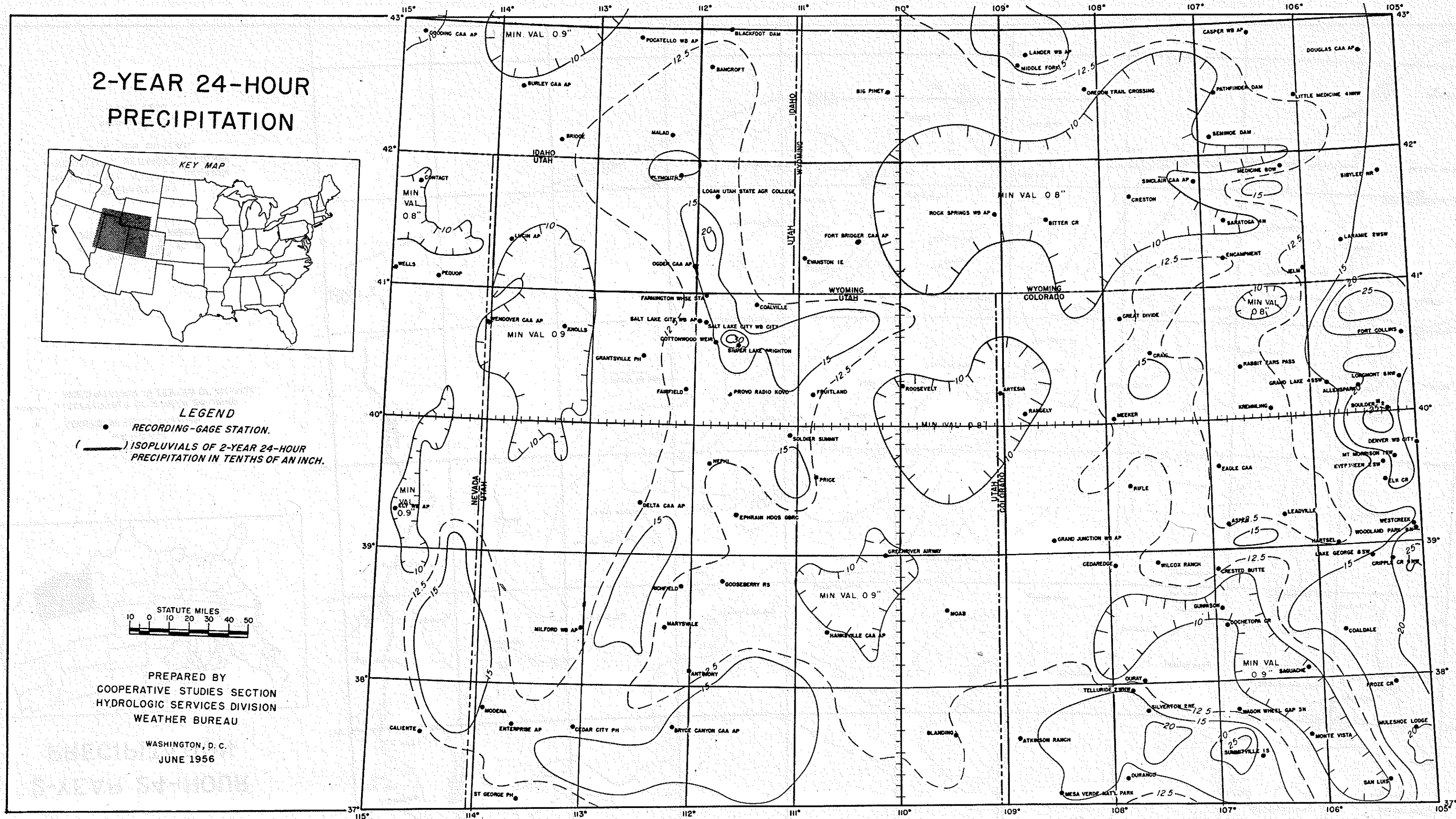

2-YEAR 24-HOUR PRECIPITATION
KEY MAP
LEGEND
RECORDING-GAGE STATION.
ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
IDAHO
UTAH
WYOMING
COLORADO
NEVADA
MIN VAL 0.9"
MIN VAL 0.8"

FIGURE 22

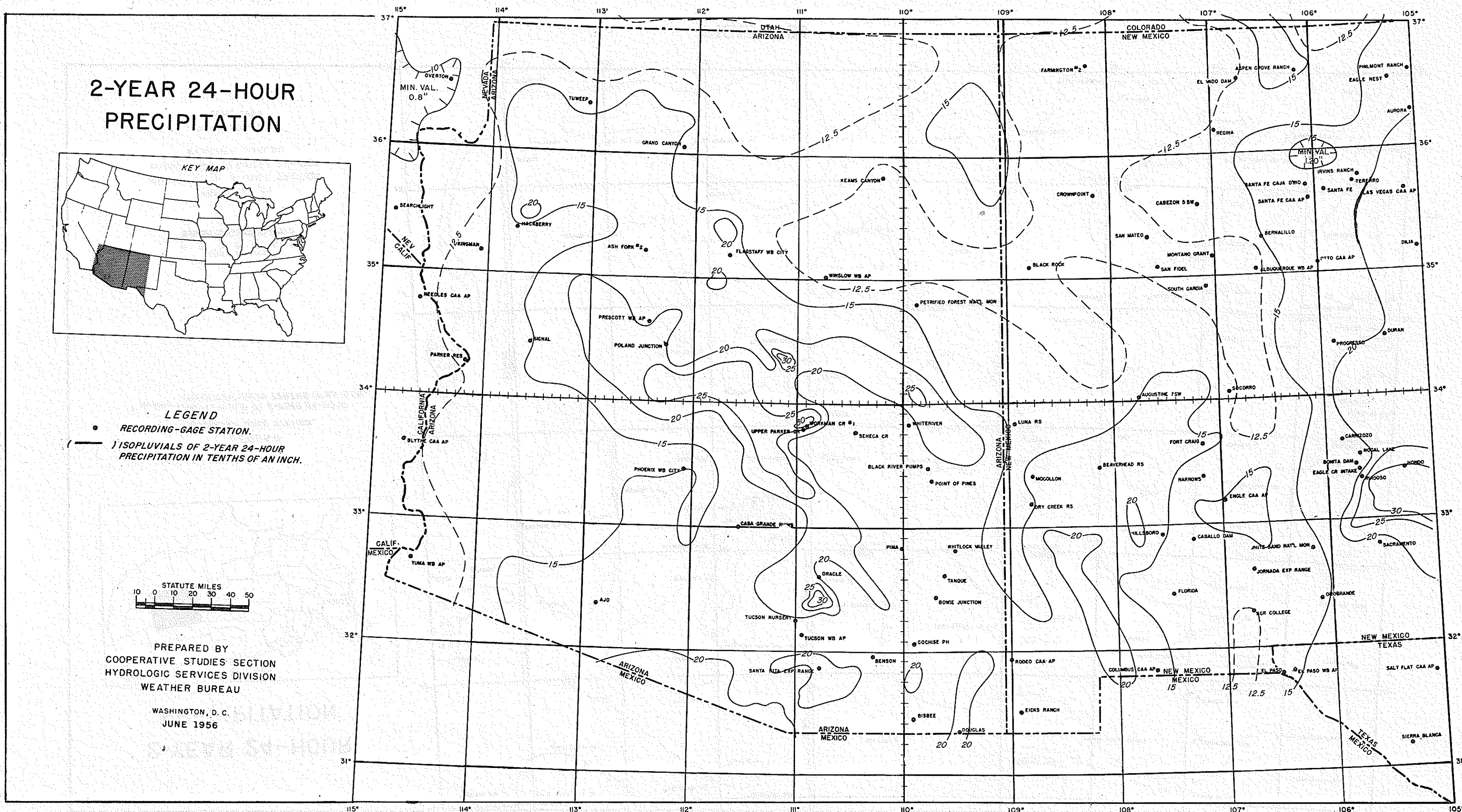

2-YEAR 24-HOUR PRECIPITATION
KEY MAP
LEGEND
• RECORDING-GAGE STATION.
(——) ISOPLUVIALS OF 2-YEAR 24-HOUR PRECIPITATION IN TENTHS OF AN INCH.
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
MIN. VAL. 0.8"
MIN. VAL. 1.20"
UTAH
ARIZONA
COLORADO
NEW MEXICO
NEVADA
CALIFORNIA
MEXICO
TEXAS

FIGURE 23

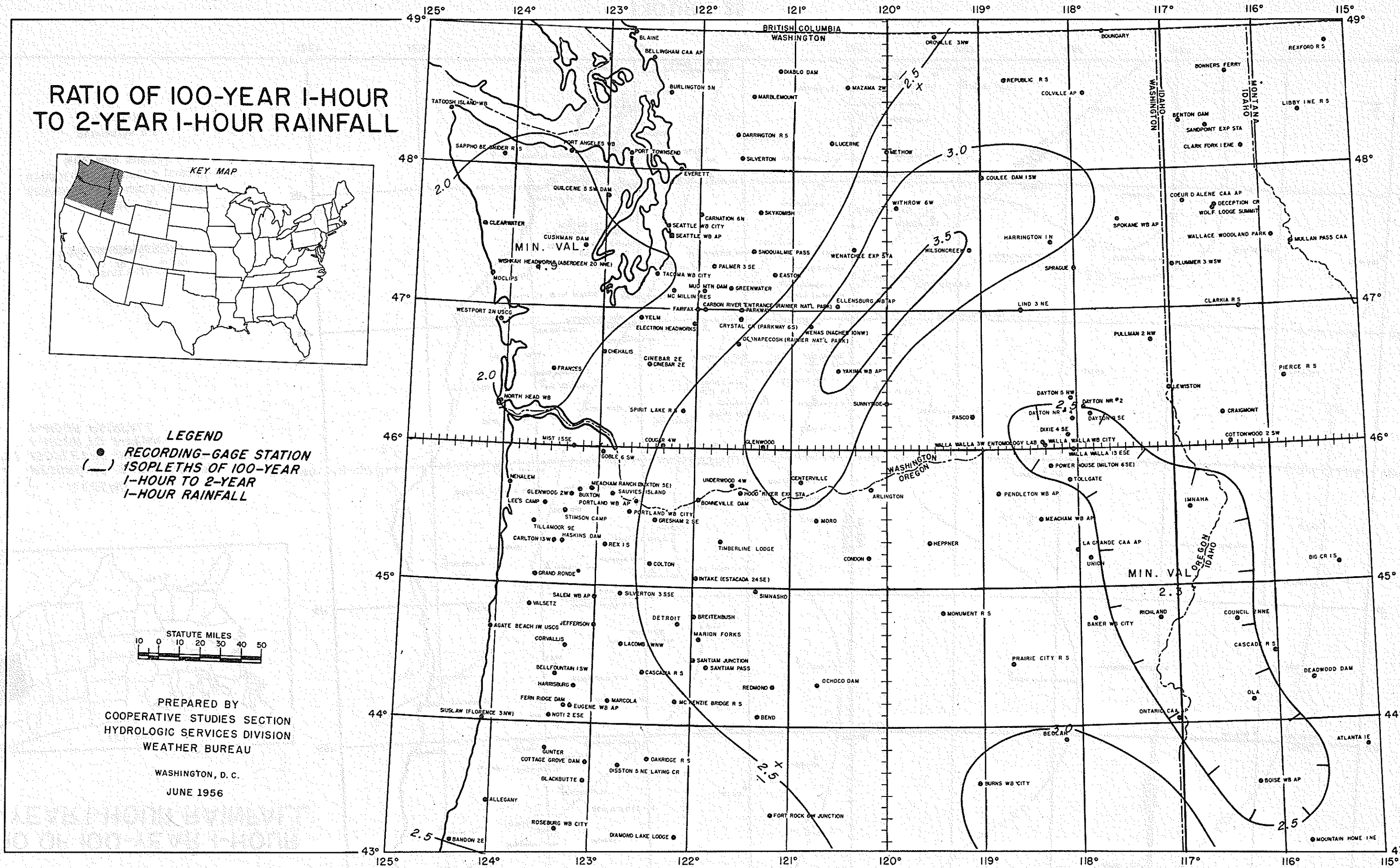

RATIO OF 100-YEAR 1-HOUR
TO 2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 1-HOUR TO 2-YEAR 1-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
BRITISH COLUMBIA
WASHINGTON
OREGON
IDAHO
MONTANA
MIN. VAL.
2.0
2.5
3.0
3.5
125°
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
49°
48°
47°
46°
45°
44°
43°

FIGURE 24

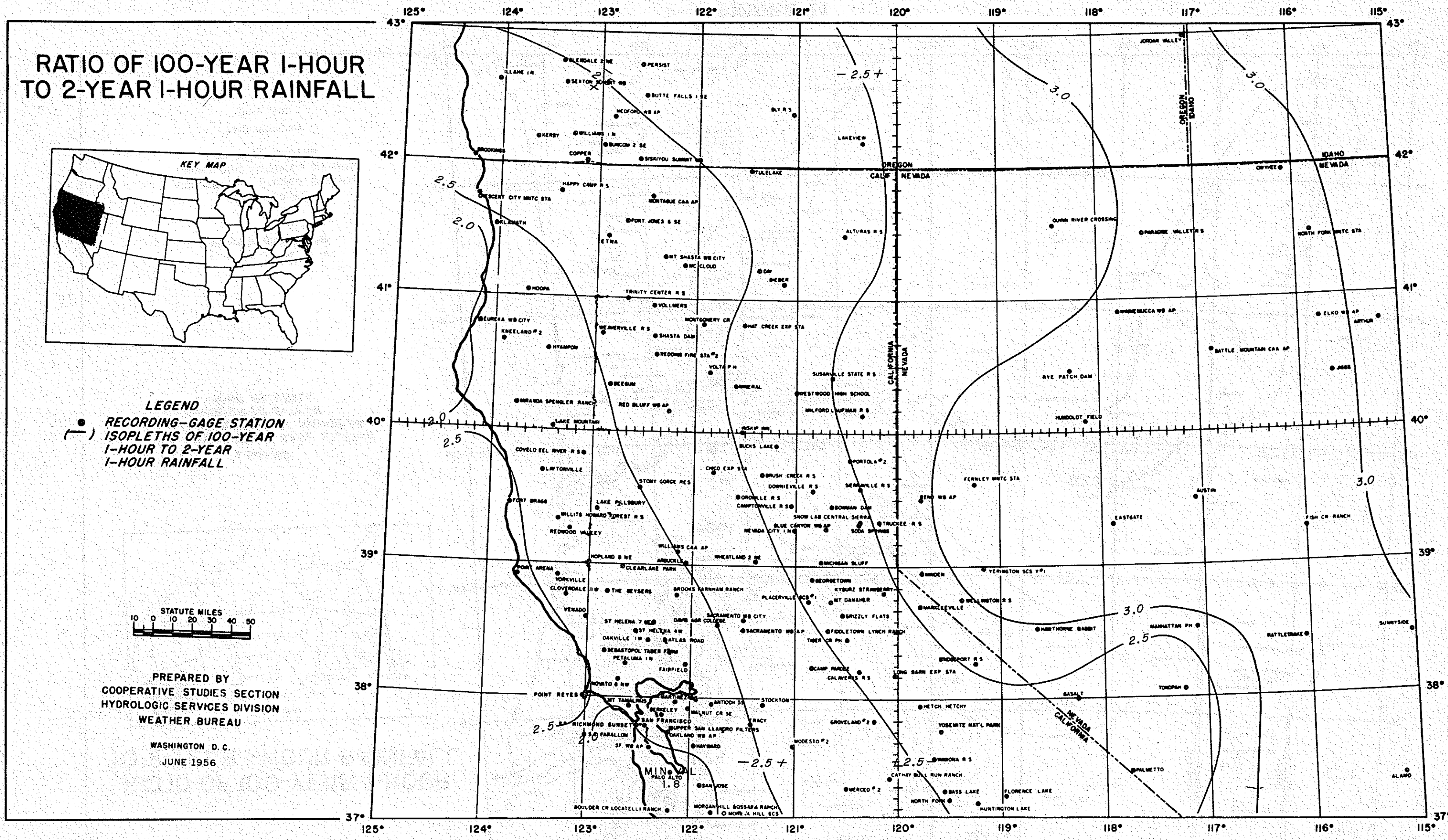

RATIO OF 100-YEAR 1-HOUR
TO 2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 1-HOUR TO 2-YEAR 1-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON D.C.
JUNE 1956
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
43° 42° 41° 40° 39° 38° 37°
OREGON
CALIF
NEVADA
IDAHO
CALIFORNIA
MIN VAL. 1.8
3.0
2.5
2.0

FIGURE 25

407359 O - 56 - 3

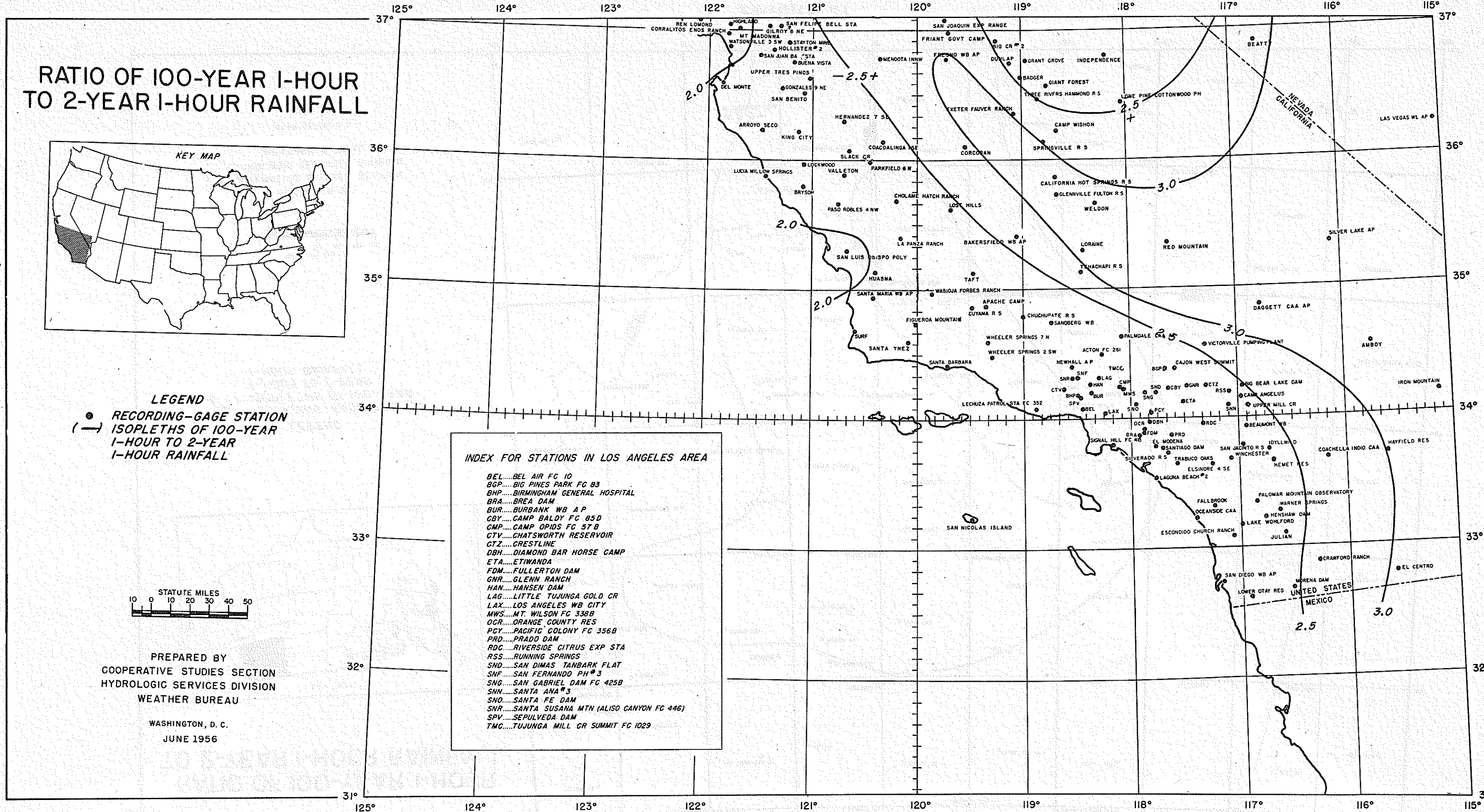


FIGURE 26

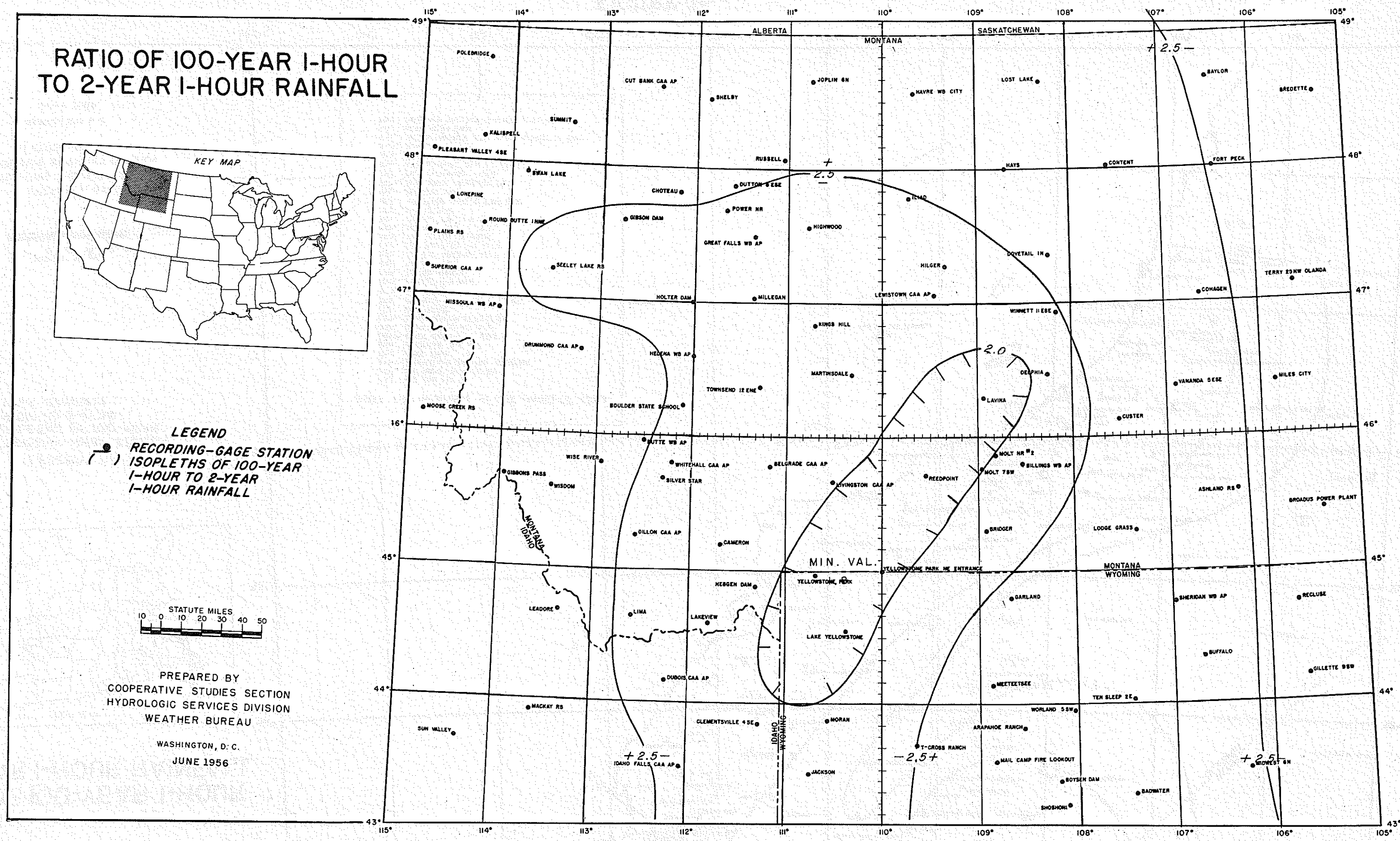
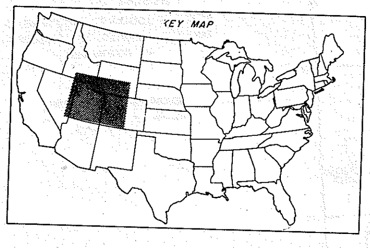

RATIO OF 100-YEAR 1-HOUR
TO 2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 1-HOUR TO 2-YEAR 1-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
ALBERTA
SASKATCHEWAN
MONTANA
WYOMING
IDAHO
MIN. VAL.
2.0
2.5

FIGURE 27

RATIO OF 100-YEAR 1-HOUR TO 2-YEAR 1-HOUR RAINFALL



LEGEND

● RECORDING-GAGE STATION

( ) ISOPLETHS OF 100-YEAR 1-HOUR TO 2-YEAR 1-HOUR RAINFALL

STATUTE MILES

10 0 10 20 30 40 50

PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU

WASHINGTON, D. C.
JUNE 1956

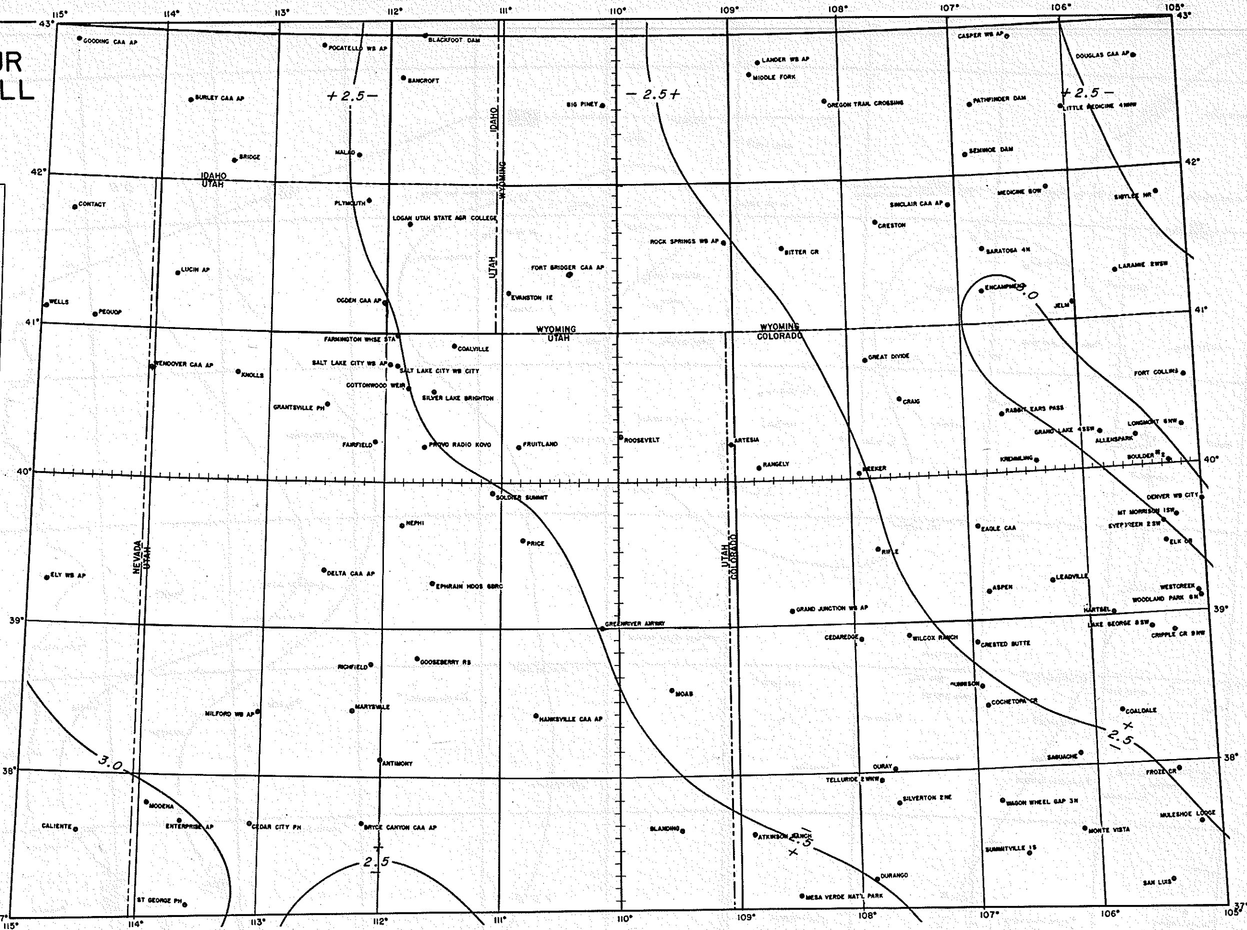


FIGURE 28

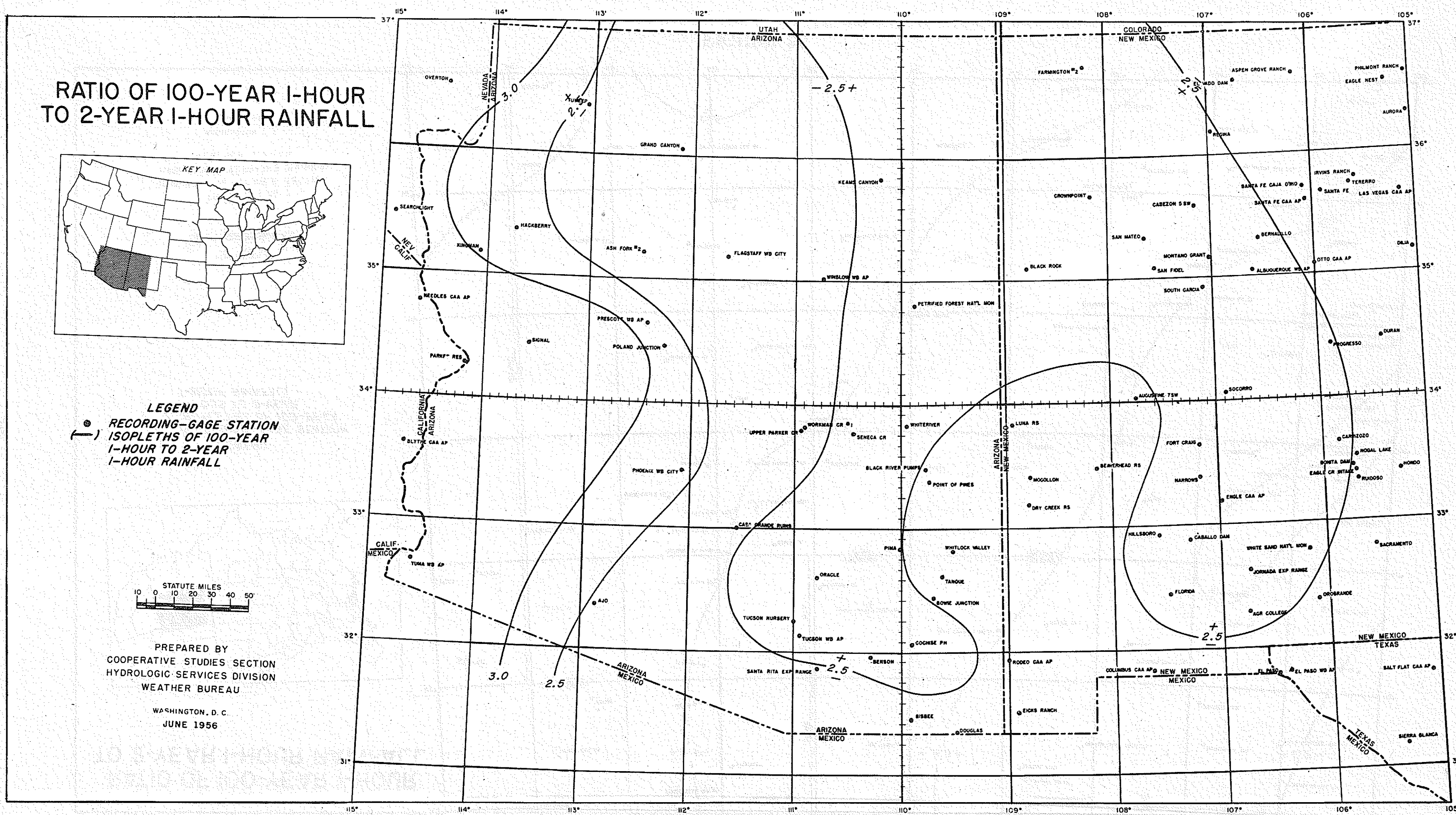
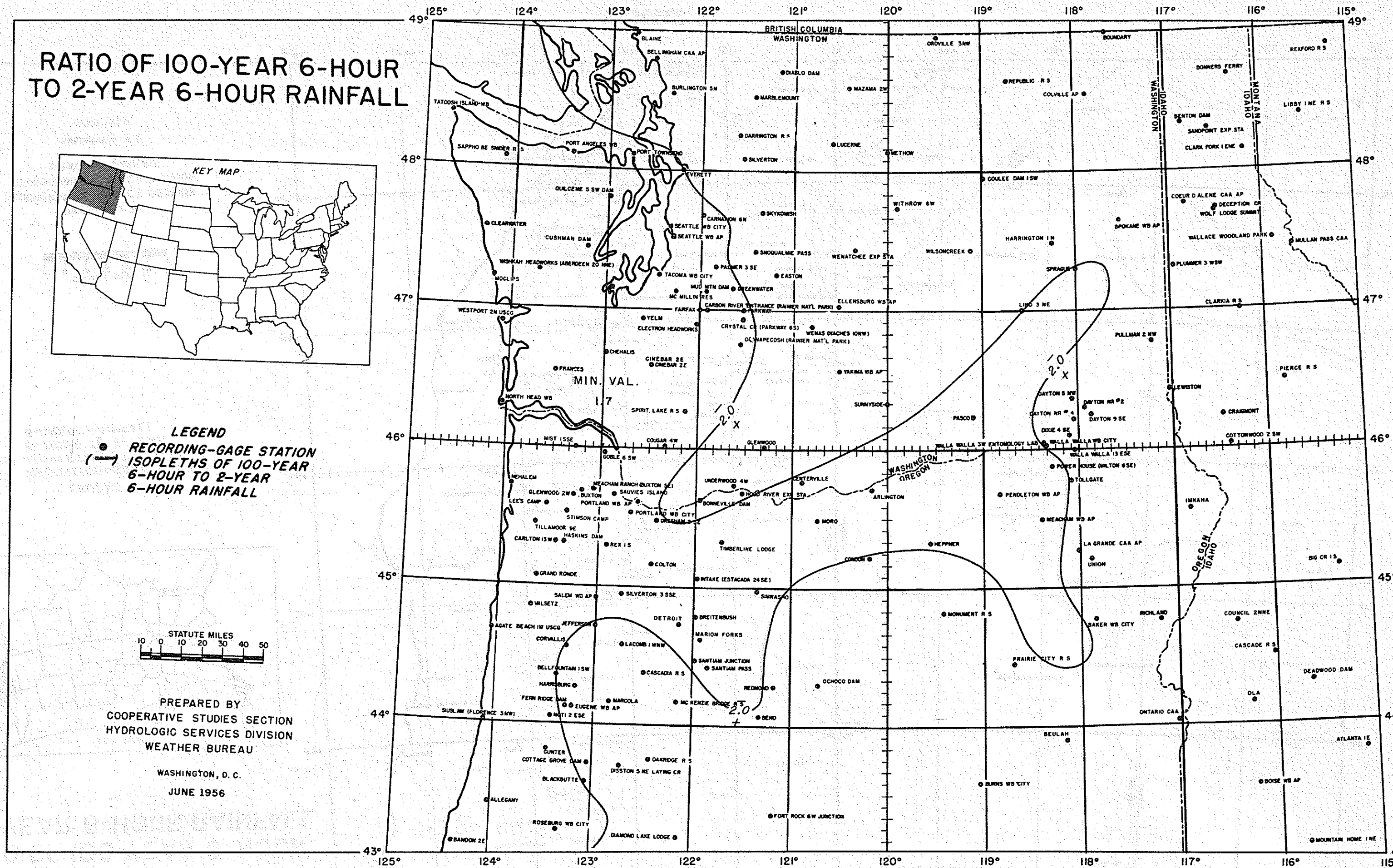

RATIO OF 100-YEAR 1-HOUR
TO 2-YEAR 1-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 1-HOUR TO 2-YEAR 1-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
3.0
2.5

FIGURE 29



RATIO OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
BRITISH COLUMBIA
WASHINGTON
OREGON
IDAHO
MONTANA
MIN. VAL.
1.7
2.0
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
49° 48° 47° 46° 45° 44° 43°

FIGURE 30

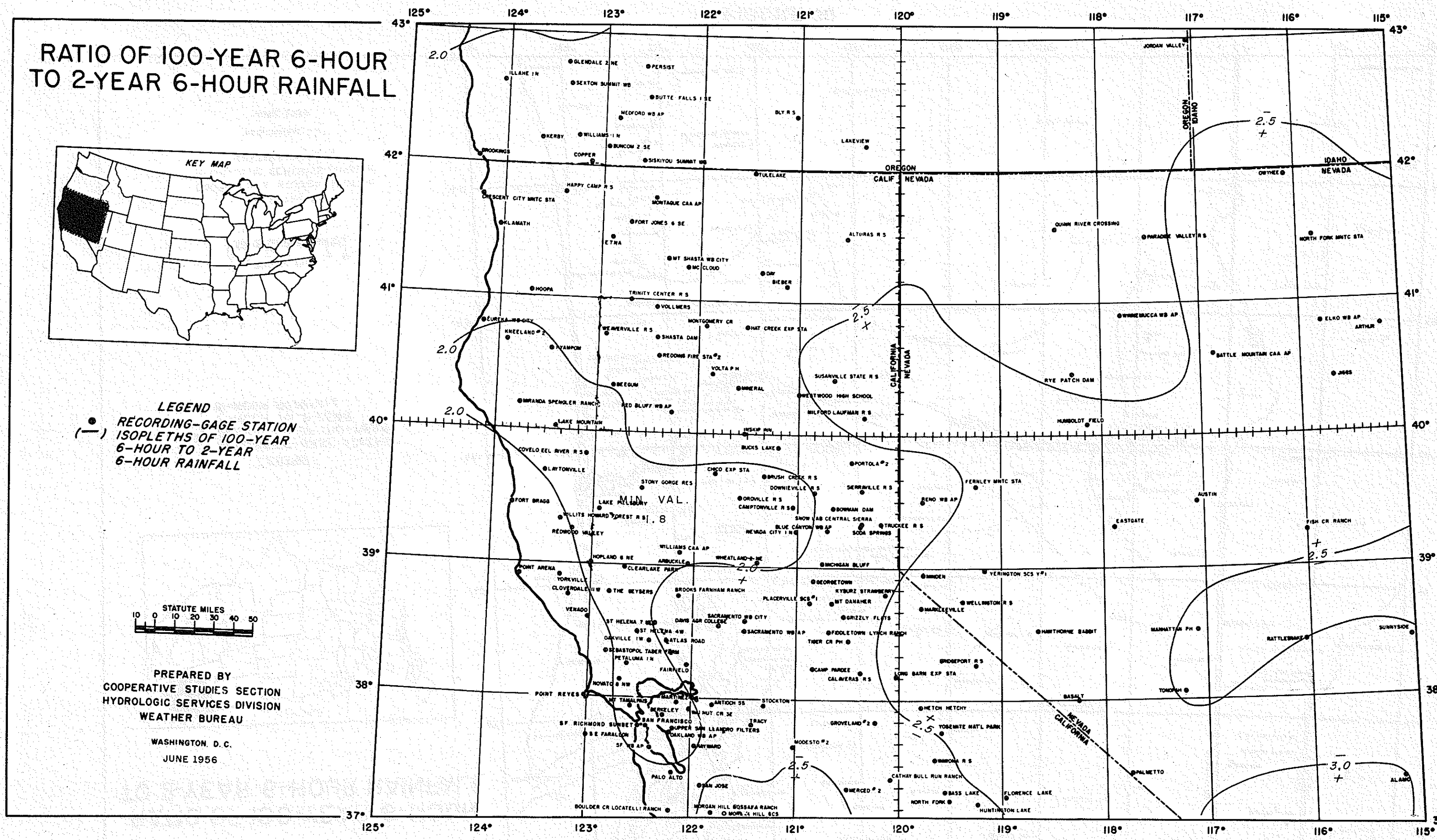

RATIO OF 100-YEAR 6-HOUR
TO 2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
125°
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
43°
42°
41°
40°
39°
38°
37°
OREGON
CALIF
NEVADA
IDAHO
CALIFORNIA
MIN. VAL.
1.8
2.0
2.5
3.0

FIGURE 31

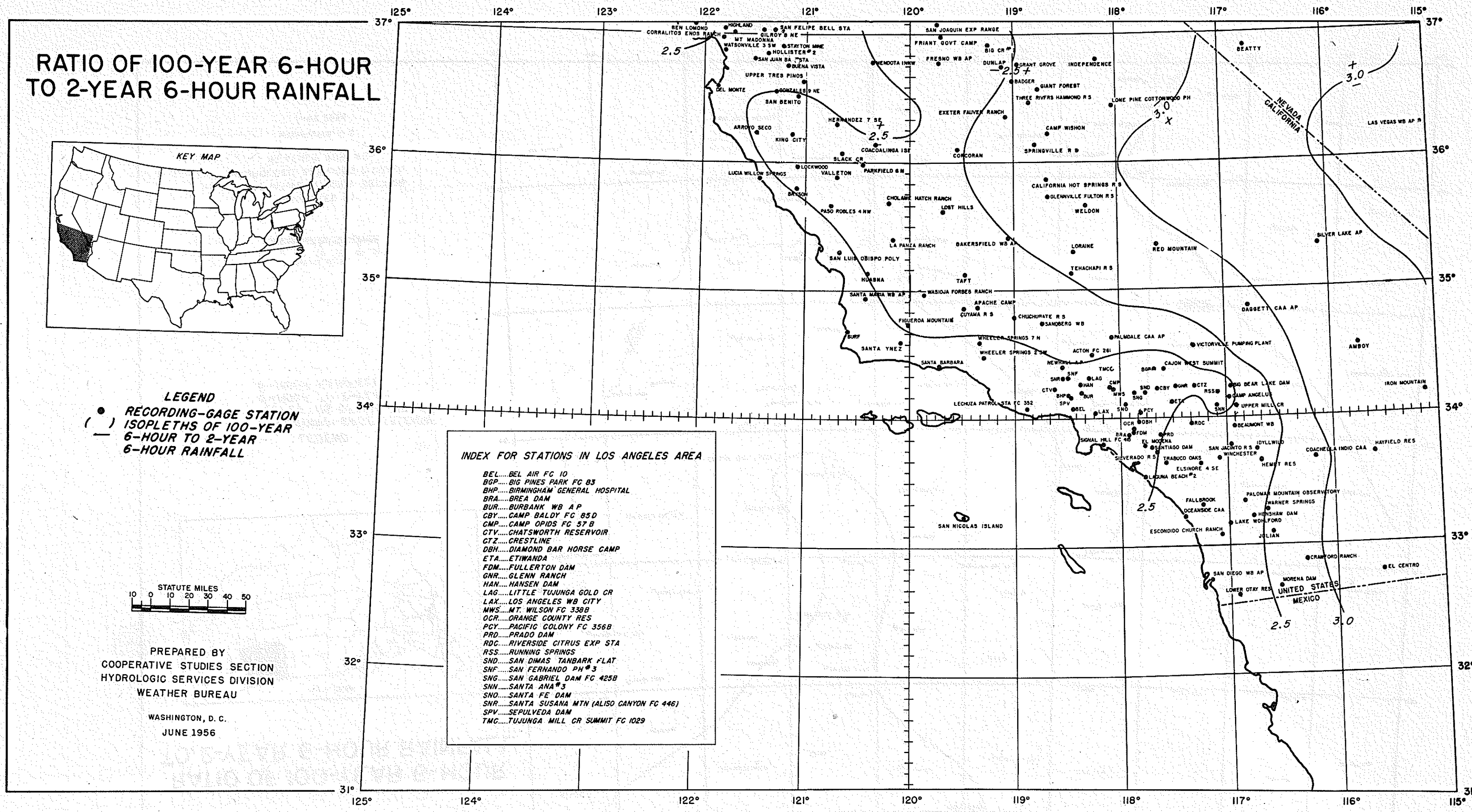

RATIO OF 100-YEAR 6-HOUR
TO 2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
INDEX FOR STATIONS IN LOS ANGELES AREA
BEL.....BEL AIR FC 10
BGP.....BIG PINES PARK FC 83
BHP.....BIRMINGHAM GENERAL HOSPITAL
BRA.....BREA DAM
BUR.....BURBANK WB A P
CBY.....CAMP BALDY FC 85D
CMP.....CAMP OPIDS FC 57 B
CTV.....CHATSWORTH RESERVOIR
CTZ.....CRESTLINE
DBH.....DIAMOND BAR HORSE CAMP
ETA.....ETIWANDA
FDM.....FULLERTON DAM
GNR.....GLENN RANCH
HAN.....HANSEN DAM
LAG.....LITTLE TUJUNGA GOLD CR
LAX.....LOS ANGELES WB CITY
MWS.....MT. WILSON FC 338B
OCR.....ORANGE COUNTY RES
PCY.....PACIFIC COLONY FC 356B
PRD.....PRADO DAM
RDC.....RIVERSIDE CITRUS EXP STA
RSS.....RUNNING SPRINGS
SND.....SAN DIMAS TANBARK FLAT
SNF.....SAN FERNANDO PH #3
SNG.....SAN GABRIEL DAM FC 425B
SNN.....SANTA ANA #3
SNO.....SANTA FE DAM
SNR.....SANTA SUSANA MTN (ALISO CANYON FC 446)
SPV.....SEPULVEDA DAM
TMC.....TUJUNGA MILL CR SUMMIT FC 1029
NEVADA
CALIFORNIA
UNITED STATES
MEXICO
2.5
3.0

FIGURE 32

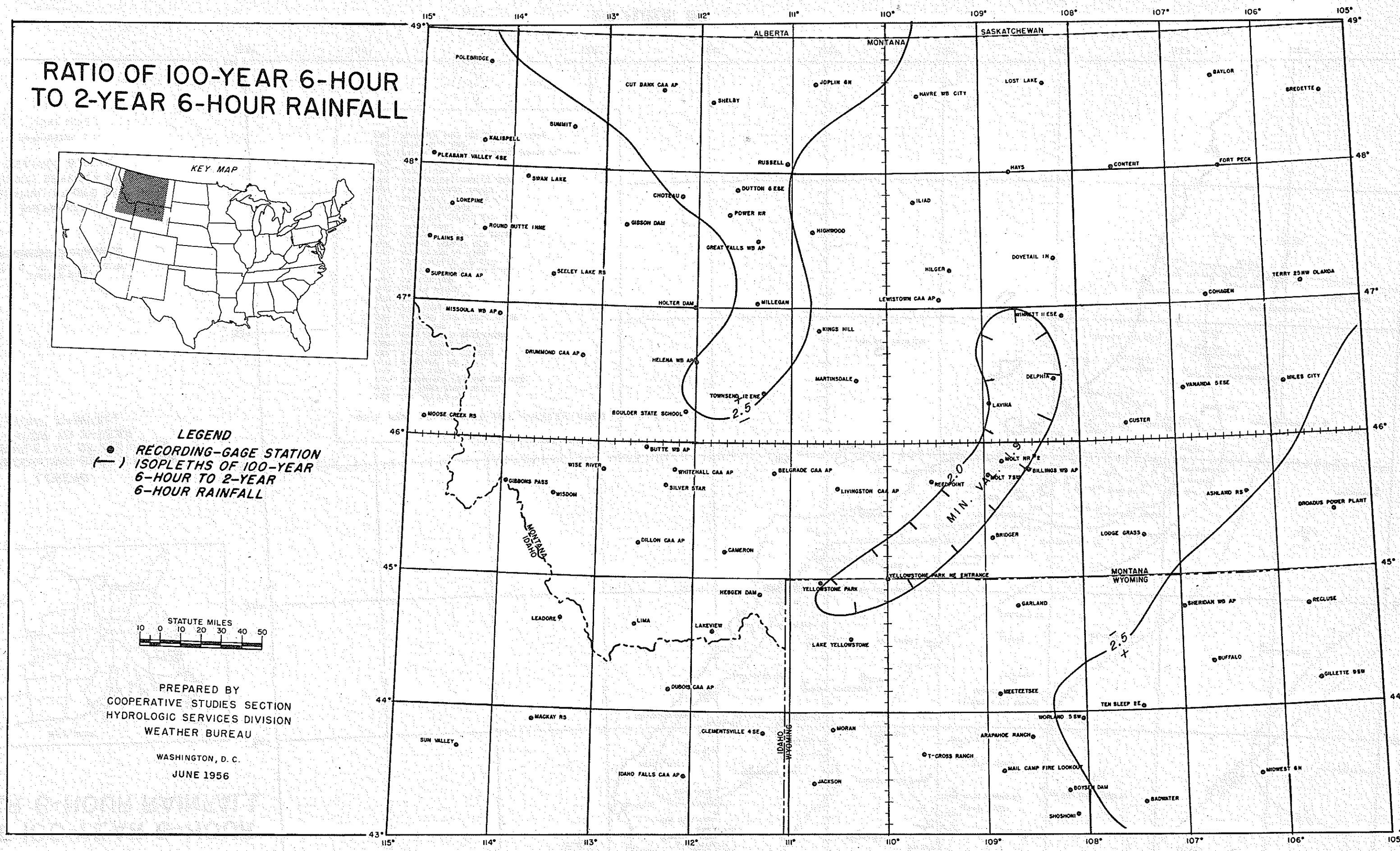

RATIO OF 100-YEAR 6-HOUR
TO 2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
ALBERTA
SASKATCHEWAN
MONTANA
MONTANA
IDAHO
MONTANA
WYOMING
IDAHO
WYOMING
2.5
2.0
MIN. VAL. 1.5
2.5
115°
114°
113°
112°
111°
110°
109°
108°
107°
106°
105°
49°
48°
47°
46°
45°
44°
43°

FIGURE 33

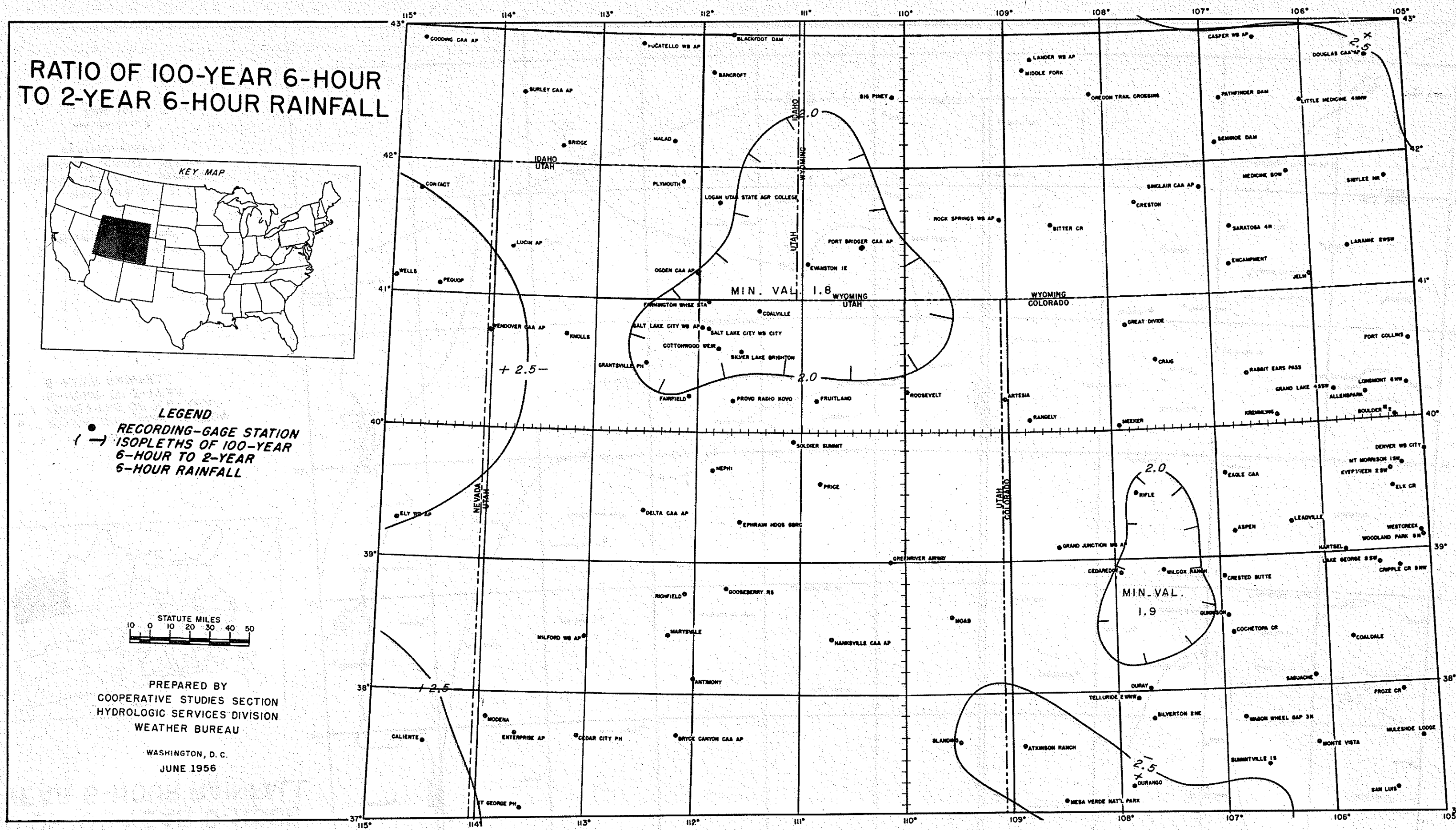
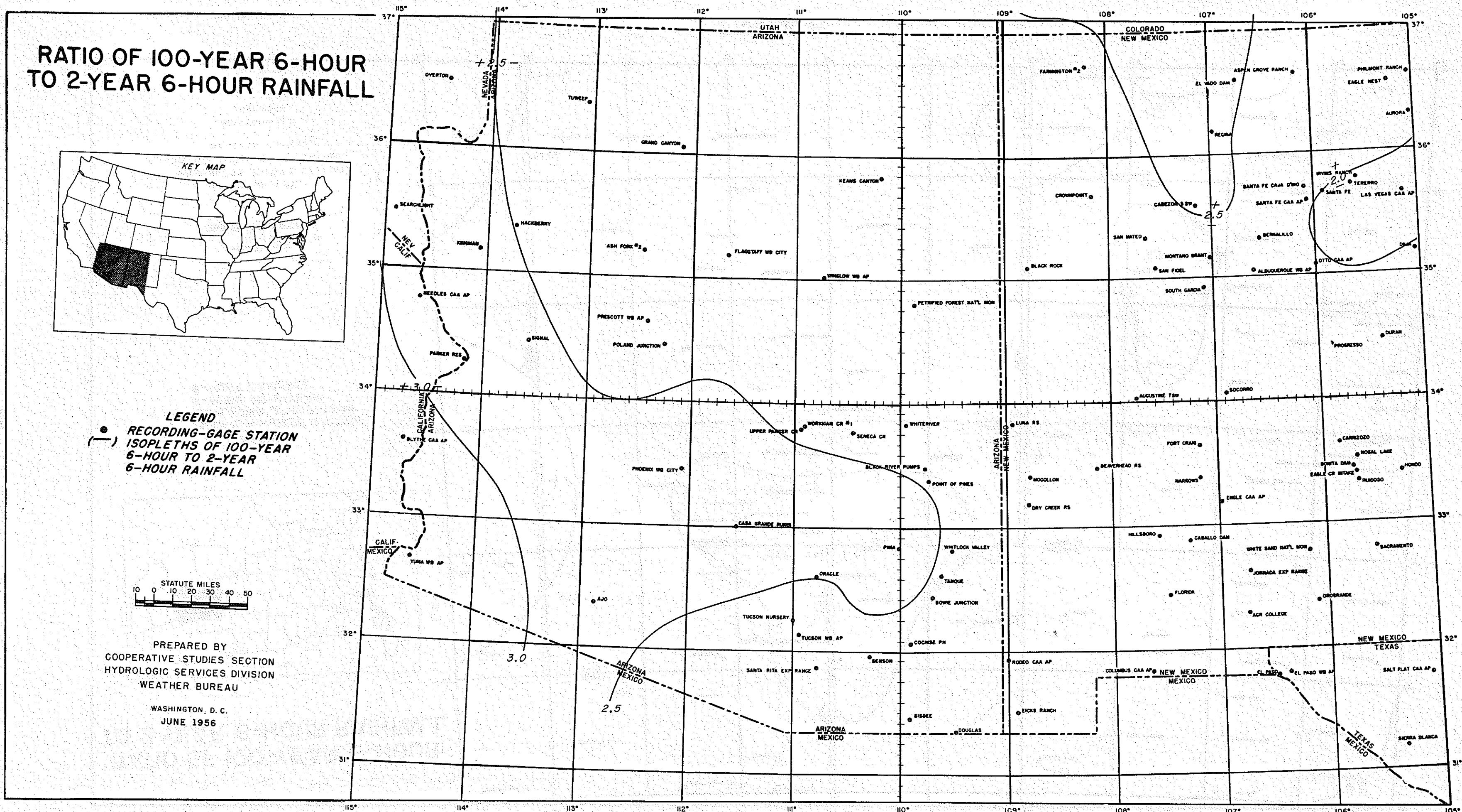

RATIO OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
COOPERATIVE STUDIES SECTION
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
IDAHO
UTAH
WYOMING
COLORADO
NEVADA
MIN. VAL. 1.8
MIN. VAL. 1.9
2.0
2.5
115°
114°
113°
112°
111°
110°
109°
108°
107°
106°
105°
43°
42°
41°
40°
39°
38°
37°

FIGURE 34


RATIO OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 6-HOUR TO 2-YEAR 6-HOUR RAINFALL
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
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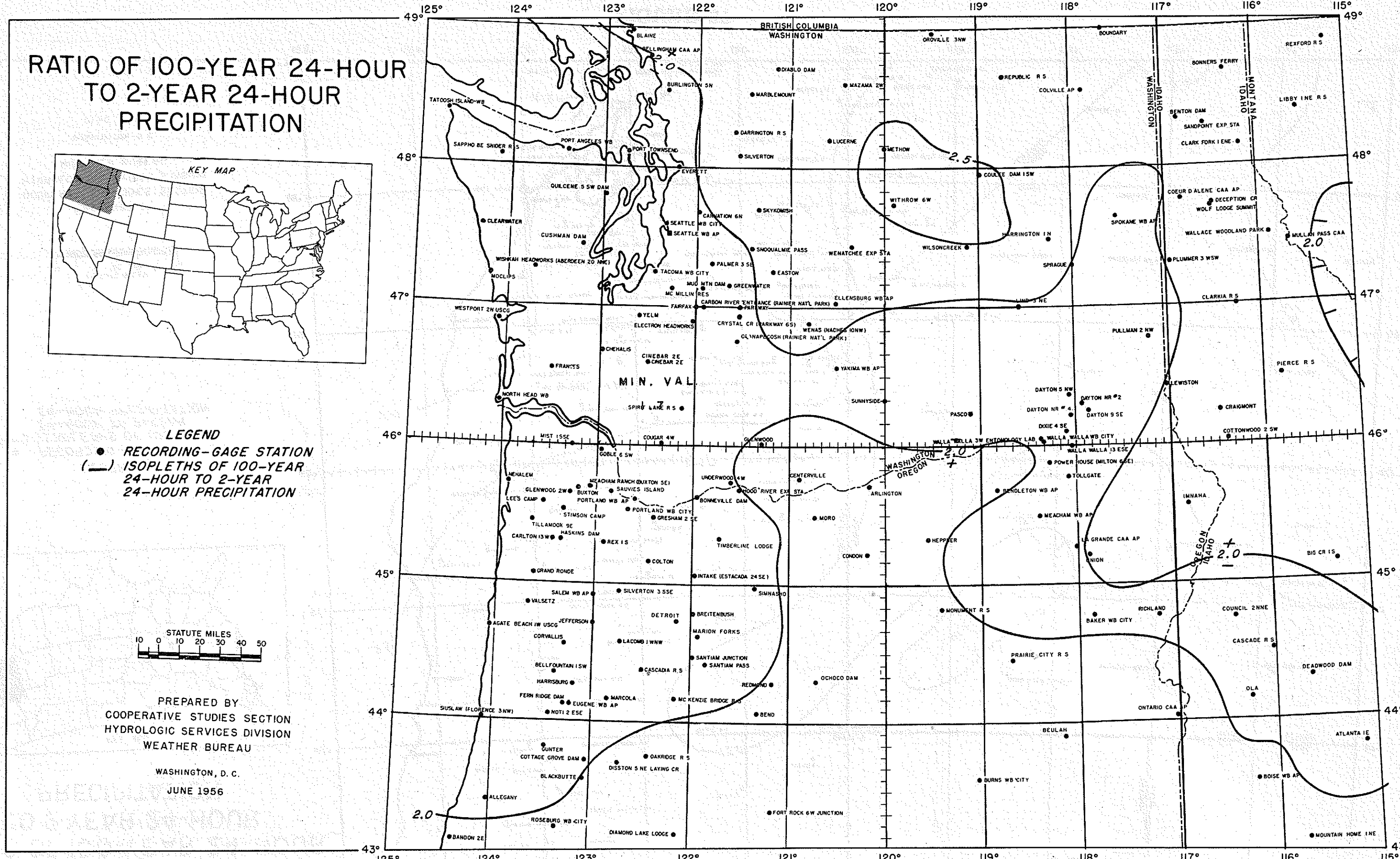
HYDROLOGIC SERVICES DIVISION
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
UTAH
ARIZONA
COLORADO
NEW MEXICO
NEVADA
ARIZONA
NEV
CALIF
CALIFORNIA
ARIZONA
CALIF-
MEXICO
ARIZONA
MEXICO
NEW MEXICO
TEXAS
TEXAS
MEXICO
3.0
2.5
2.0
115°
114°
113°
112°
111°
110°
109°
108°
107°
106°
105°
37°
36°
35°
34°
33°
32°
31°

FIGURE 35


RATIO OF 100-YEAR 24-HOUR TO 2-YEAR 24-HOUR PRECIPITATION
KEY MAP
LEGEND
• RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 24-HOUR TO 2-YEAR 24-HOUR PRECIPITATION
STATUTE MILES
10 0 10 20 30 40 50
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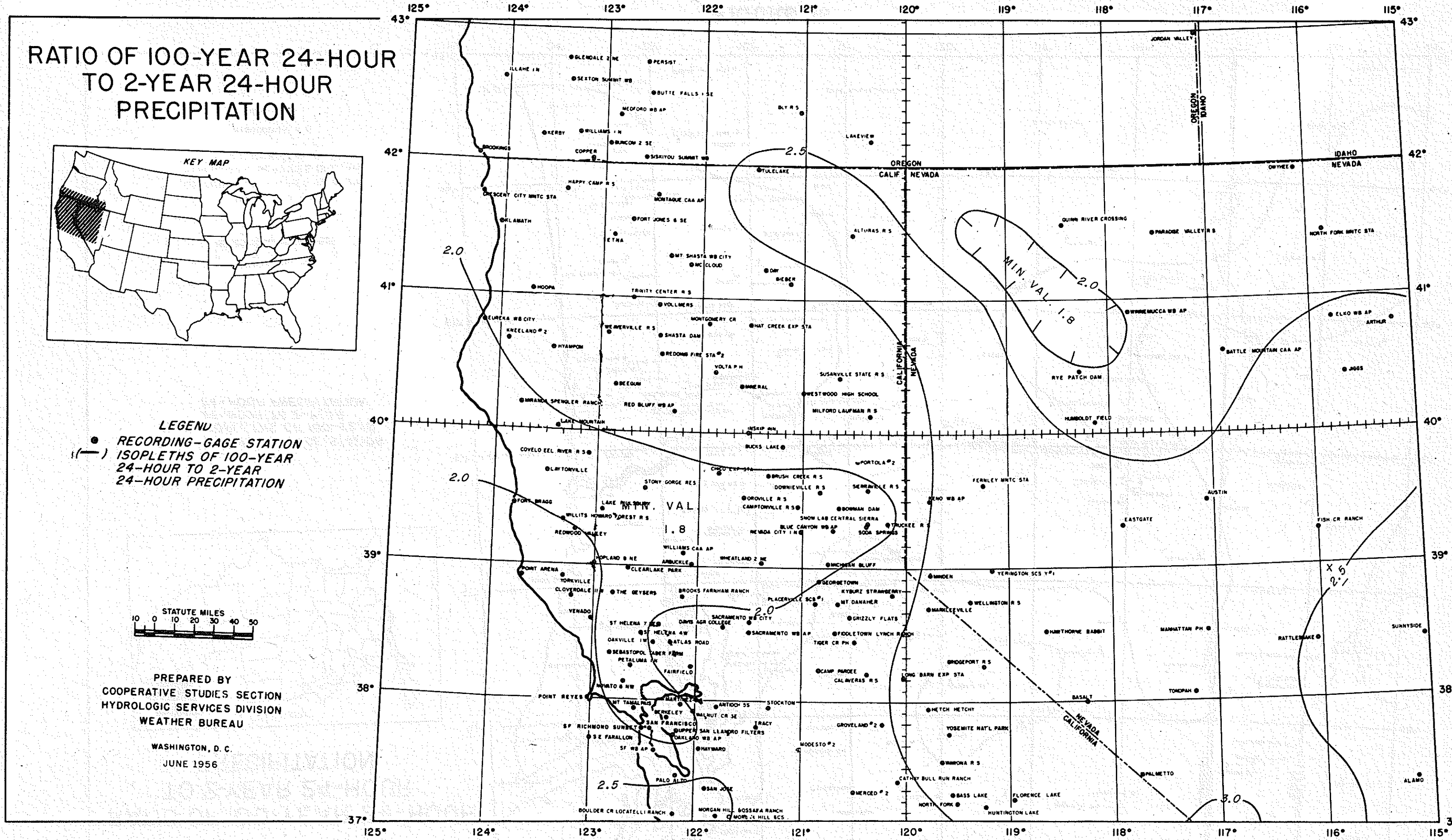
WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
BRITISH COLUMBIA
WASHINGTON
OREGON
IDAHO
MONTANA
MIN. VAL.
2.0
2.5
125° 124° 123° 122° 121° 120° 119° 118° 117° 116° 115°
49° 48° 47° 46° 45° 44° 43°

FIGURE 36


RATIO OF 100-YEAR 24-HOUR
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PRECIPITATION
KEY MAP
LEGEND
RECORDING-GAGE STATION
ISOPLETHS OF 100-YEAR 24-HOUR TO 2-YEAR 24-HOUR PRECIPITATION
STATUTE MILES
10 0 10 20 30 40 50
PREPARED BY
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WEATHER BUREAU
WASHINGTON, D. C.
JUNE 1956
OREGON
CALIF
NEVADA
IDAHO
CALIFORNIA
MIN. VAL. 1.8
MTN. VAL. 1.8
2.0
2.5
3.0
125°
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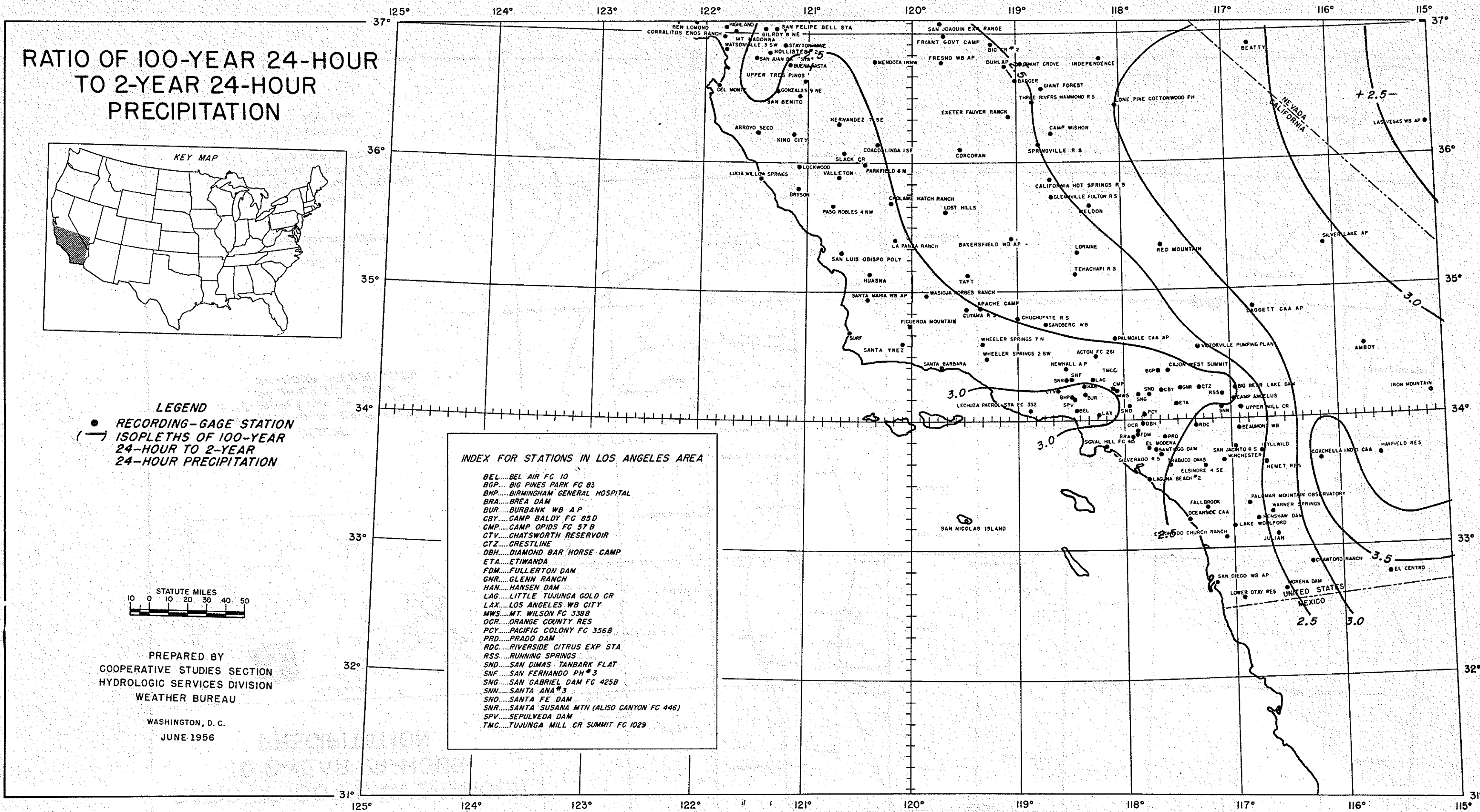
123°
122°
121°
120°
119°
118°
117°
116°
115°
43°
42°
41°
40°
39°
38°
37°

FIGURE 37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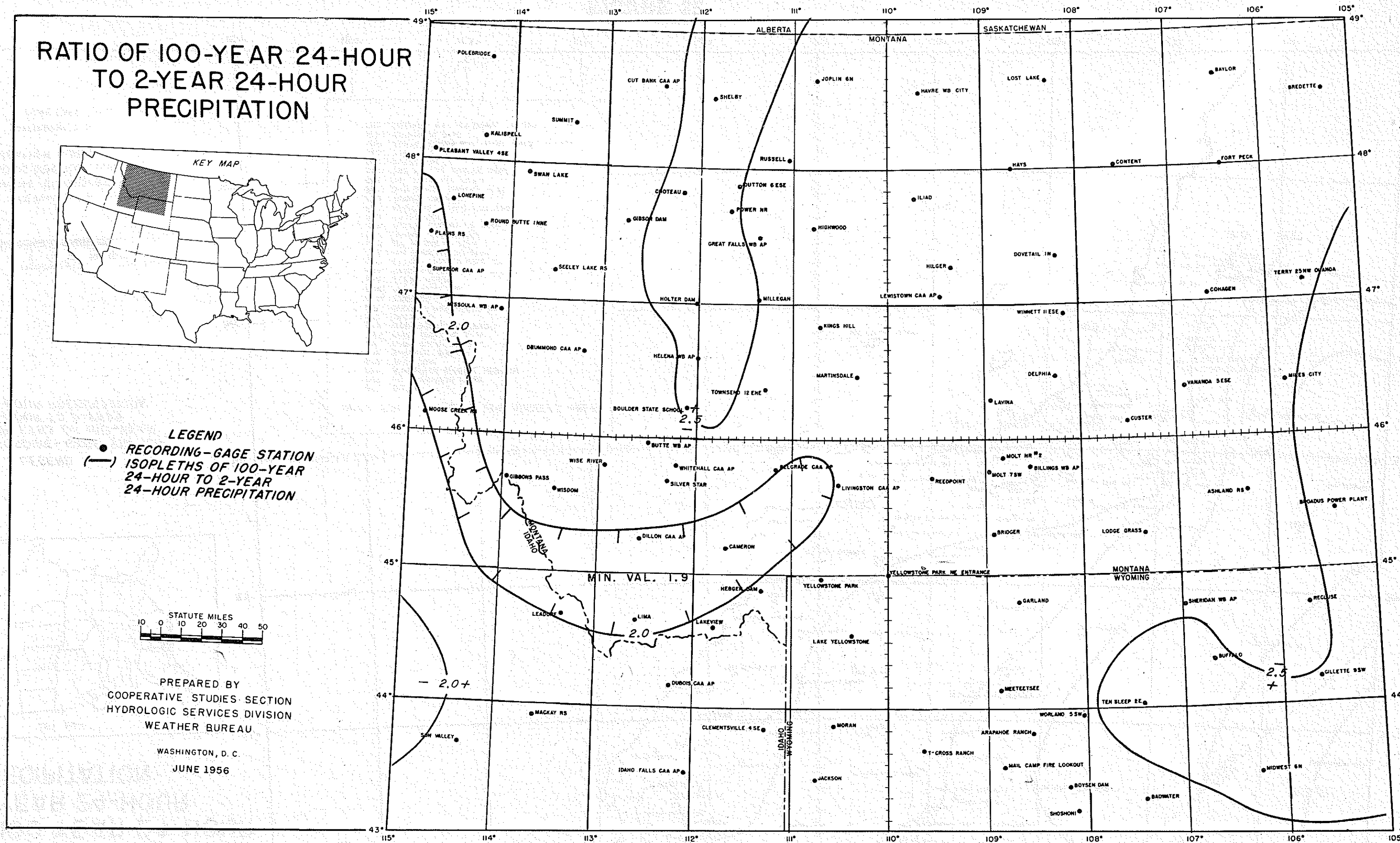
NEVADA
CALIFORNIA
UNITED STATES
MEXICO
SAN NICOLAS ISLAND
2.5
3.0
3.5

FIGURE 38



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KEY MAP
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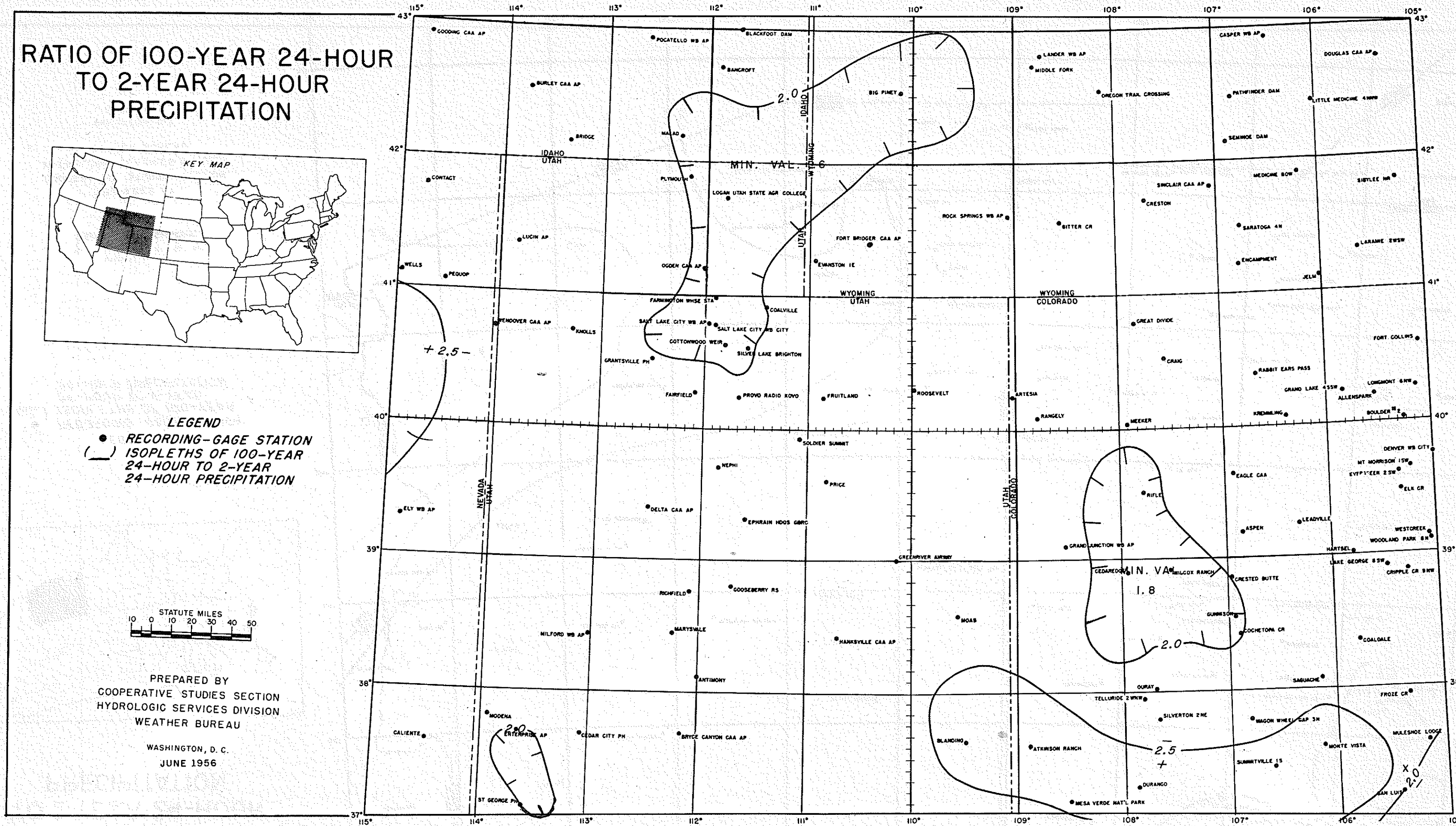
SASKATCHEWAN
MONTANA
MONTANA
IDAHO
MONTANA
WYOMING
IDAHO
WYOMING
MIN. VAL. 1.9
2.0
2.5
2.0+

FIGURE 39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IDAHO
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NEVADA
MIN. VAL. 1.6
MIN. VAL. 1.8
2.0
2.5
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FIGURE 40

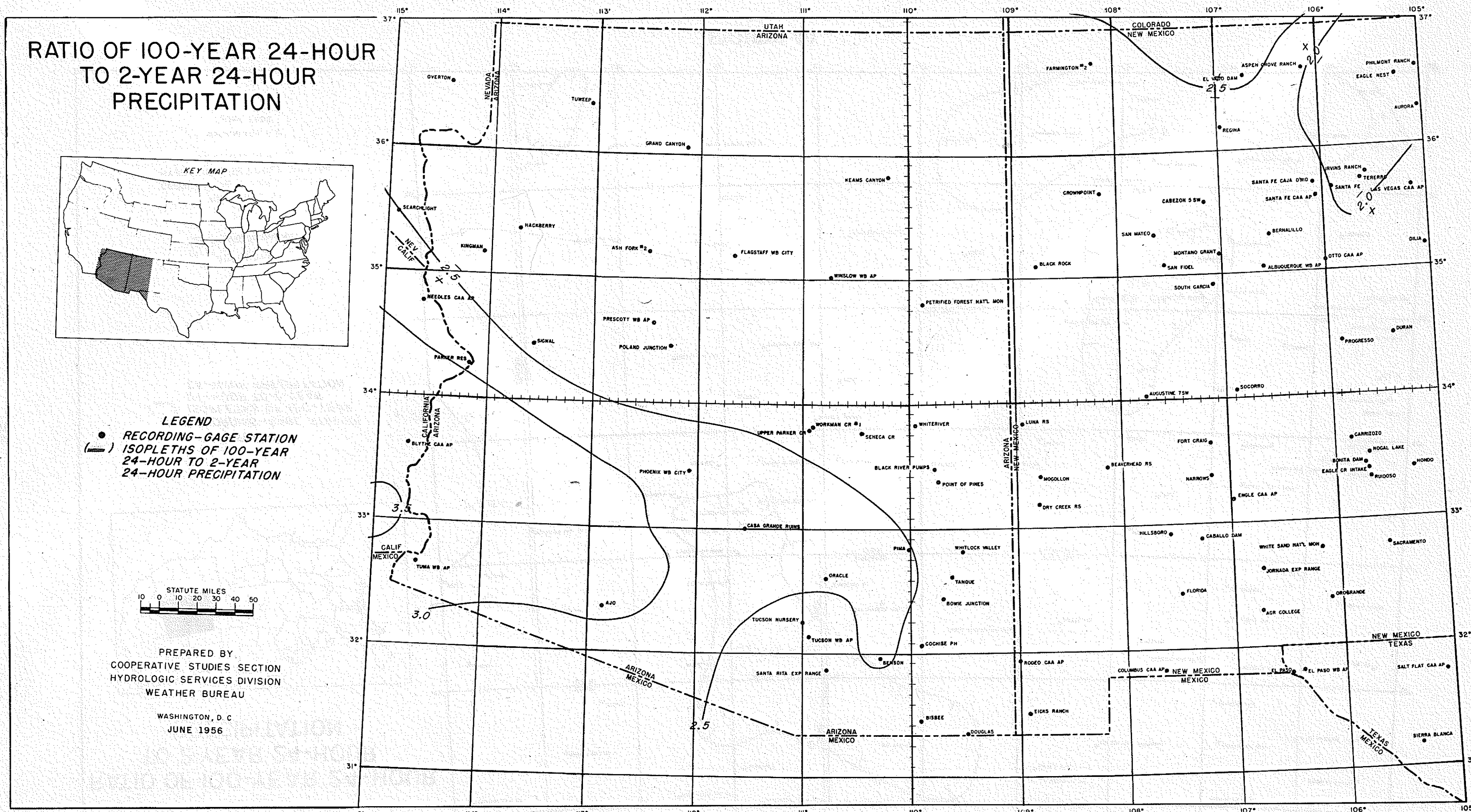

FIGURE 41

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