UNITED STATES DEPARTMENT OF THE INTERIOR

FLOODS IN COLORADO

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UNITED STATES DEPARTMENT OF THE INTERIOR
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FLOODS IN COLORADO

BY

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FLOODS IN COLORADO

By Robert Follansbee and Leon R. Sawyer

ABSTRACT

The first records of floods in Colorado antedated the settlement of the State by about 30 years. These were records of floods on the Arkansas and Republican Rivers in 1826. Other floods noted by traders, hunters and emigrants, some of whom were on their way to the Far West, occurred in 1844 on the Arkansas River, and by inference on the South Platte River. Other early floods were those on the Purgatoire, the Lower Arkansas, and the San Juan Rivers about 1859.

The most serious flood since settlement began was that on the Arkansas River during June 1921, which caused the loss of about 100 lives and an estimated property loss of $19,000,000. Many floods of lesser magnitude have occurred, and some of these have caused loss of life and very considerable property damage.

Topography is the chief factor in determining the location of storms and resulting floods. These occur most frequently on the eastern slope of the Front Range. In the mountains farther west precipitation is insufficient to cause floods except during periods of melting snow, in June. In the southwestern part of the State, where precipitation during periods of melting snow is insufficient to cause floods, the severest floods yet experienced resulted from heavy rains in September 1909 and October 1911.

In the eastern foothills region, usually below an altitude of about 7,500 feet and extending for a distance of about 50 miles east of the mountains, is a zone subject to rainfalls of great intensity known as cloudbursts. These cloudbursts are of short duration and are confined to very small areas. At times the intensity is so great as to make breathing difficult for those exposed to a storm. The areas of intense rainfall are so small that Weather Bureau precipitation stations have not been located in them. Local residents, being cloudburst conscious, frequently measure the rainfall in receptacles in their yards, and such records constitute the only source of information regarding the intensity.

A flood resulting from a cloudburst rises so quickly that it is usually described as a "wall of water." It has a peak duration of only a few minutes, followed by a rapid subsidence. Nearly 90 cloudburst floods in Colorado are described in varying detail in this report. The earliest recorded cloudburst—called at that time a waterspout—occurred in Golden Gate Gulch, July 14, 1872. The "wall of water" was described as a "perpendicular breast of 10 or 12 feet." A cloudburst flood on Kiowa Creek in May 1878 caused the loss of a standard-gage locomotive, and although search was made by means of long metallic rods, the locomotive was never recovered, as bedrock was about 50 feet below the creek bed.

All available information relative to floods in Colorado, beginning with the flood of 1826 on the Arkansas River, is presented in this report, although for many of the earlier floods estimates of discharge are lacking.

Floods throughout a large part of the State have occurred in 1844, June 1864, June 1884, May 1894, and June 1921. The highest floods of record were on the

larger streams and occurred as follows: South Platte River, June 1921; Rio Grande, June 1927; Colorado River, June and July 1884; San Juan River, October 1911.

The greatest floods on the plains streams occurred during May and June 1935 and were caused by cloudbursts. Ranchers living in the vicinity noted rainfalls as high as 24 inches in a 13-hour period, measurements being made in a stock tank.

The effect of settlement on channel capacities can be clearly traced. When settlement began, and with it the beginning of the livestock industry, the plains were thickly covered with a luxuriant growth of grasses. With the development of the livestock industry the grass cover was grazed so closely that it afforded little protection against erosion during the violent rains and resulting floods. The intensive grazing packed the soil so hard as to increase greatly the percentage of rainfall that entered the streams. This condition was noted during the Arkansas River flood of October 1908, when an estimated two-thirds of the 6-inch rainfall appeared almost immediately in the nearby streams.

The development of flood protection was of slow growth and progressed through four stages: (1) Removal of buildings to higher ground; (2) improvement of river channel capacity but without definite objective, owing to lack of knowledge of flood flows to be accommodated; (3) increase of channel capacity to equal measured peak flow of recent outstanding floods; and (4) construction of storage or detention reservoirs to hold back the greatest probable flood. These stages succeeded each other as losses from flood became greater and as the accumulation of meteorologic and hydrologic data permitted a more rational solution of the flood problem.

INTRODUCTION

In July 1938 the Federal Emergency Administration of Public Works made an allotment to the Geological Survey, United States Department of the Interior, for flood and drought studies. In Colorado the studies were devoted to a compilation of all available data regarding past floods. Not only were the newspaper files searched and all pertinent records obtained from the State engineer and other public officials, but all available writings of early travelers through Colorado before permanent settlement took place, including those of the Spanish explorers and padres, were examined. Information regarding some later floods was obtained through field studies. As a necessary part of flood study, meteorological data, so far as available, were compiled for the major floods.

ACKNOWLEDGMENTS

The United States Weather Bureau furnished data on storms in Colorado. Search was made in the National Archives for material regarding storms in early years. The Bureau of Reclamation furnished newspaper clippings from the Gunnison Press Review regarding snowfall and high water during the spring of 1884 and a report on the Wilson Creek flood. L. T. Burgess, chief hydrographer in the office of the State engineer of Colorado furnished all available flood records. Acknowledgment of specific information is made at appropriate places in the report. Valuable assistance was given by Mrs. Mildred Rex,

librarian of the State historical society in Denver; by newspaper publishers throughout the State, who allowed access to their files; and by many residents who furnished data regarding floods in their localities. Leon R. Sawyer collected most of the flood data, Lawrence F. Hanks devoted considerable time to field examinations of specific floods, J. H. Baily made many of the computations, and Robert Follansbee prepared the report.

PREVIOUS FLOOD INVESTIGATIONS

Unusual floods, whether on large or small streams, have attracted the attention of the Geological Survey for many years, and whenever possible this bureau has made investigations of them and has published reports embodying its findings. Likewise, the State engineer of Colorado has investigated certain floods; for some of these his findings have been published, and for others unpublished reports are on file in his office. A few floods have been investigated by municipal agencies, which have published reports. In the preparation of this paper, these various reports have been drawn upon for pertinent facts, credit for which is given in connection with the discussion of the specific floods. A list of the reports follows:

GEOLOGICAL SURVEY

HINDERLIDER, M. C., and assistants, Floods in the Denver district, in Murphy, E. C., and others, Destructive floods in the United States in 1904: U. S. Geological Survey Water-Supply Paper 147, pp. 150–171, 1905. Includes the following: Flood on Cache la Poudre River [from reports of J. A. Armstrong], pp. 155–156; Purgatory River flood, by R. I. Meeker, pp. 158–169; La Plata River flood [from report of Theo Tobish], pp. 169–171.

FREEMAN, W. B., Flood in the Arkansas Valley, Colo., October 1908, in Surface Water Supply of the United States, 1907–08, part 7, Lower Mississippi River Basin: U. S. Geological Survey Water-Supply Paper 247, pp. 33–40, 1910.

FREEMAN, W. B., Flood in San Juan Valley, September 5 and 6, 1909, in Surface Water Supply of the United States, 1909, part 9, Colorado River Basin: U. S. Geological Survey Water-Supply Paper 269, pp. 187–191, 1911.

RUSSELL, G. H., and GRAY, G. A., Flood of October 1911 in the region of the San Juan, San Miguel, and La Plata Mountains, in Surface Water Supply of the United States, 1911, part 9, Colorado River Basin: U. S. Geological Survey Water-Supply Paper 309, pp. 246–249, 1914.

FOLLANSBEE, ROBERT, and JONES, E. E., The Arkansas River Flood of June 3–5, 1921: U. S. Geological Survey Water-Supply Paper 487, 44 pp., 1922.

FOLLANSBEE, ROBERT, and HODGES, P. V., Some Floods in the Rocky Mountain Region, in Contributions to the Hydrology of the United States, 1923–24: U. S. Geological Survey Water-Supply Paper 520, pp. 105–129, 1925. Includes, under the heading "Cloudburst floods," reports on the following localities: Templeton Gap near Colorado Springs, Colo., p. 121; Cherry Creek near Parker, Colo., pp. 122–123; Buckhorn Creek near Loveland, Colo., pp. 123–124.

FOLLANSBEE, ROBERT, Upper Colorado River and Its Utilization: U. S. Geological Survey Water-Supply Paper 617, 394 pp. 1929. Contains a section on floods, pp. 151–154.

FOLLANSBEE, ROBERT, and SPIEGEL, J. B., Flood on Republican and Kansas Rivers, May and June 1935: U. S. Geological Survey Water-Supply Paper 795–B, pp. 51–52, 1937.

STATE ENGINEER OF COLORADO

Published reports

6th Biennial Report [for the years 1891 and 1892]. 1893. Includes a brief report, by L. R. Hope, of the flood on Cache La Poudre River, June 9, 1891, due to the failure of the Chambers Lake Dam (p. 19), and the figures of peak discharge during that flood (p. 22).

8th Biennial Report [for the years 1895 and 1896]. 1897. Contains a description of the gaging station on Bear Creek at Morrison, and an estimate of the discharge at that station during the flood of July 24, 1896 (p. 454).

15th Biennial Report [for the years 1909 and 1910]. 1911. Includes reports on the failure of the Middle and Trout Lakes reservoir dams, in the early part of September 1909, due to a flood on Lake Fork of San Miguel River (pp. 113–116).

28th Biennial Report [for the years 1935 and 1936]. 1939. Includes a paper by L. T. Burgess, entitled "Disastrous floods in 1933–1934–1935" (pp. 38–43), in which he describes briefly floods on the following streams: Purgatoire River, Sept. 15, 1934; Horse Creek, Aug. 28, 1935; Granada Creek, July 11–12, 1935; Monument Creek at Colorado Springs, May 30, 1935; Cherry Creek, Aug. 2–3, 1933; Arikaree River, May 30, 1935; South Fork of Republican River, May 30, 1935; Bijou Creek, May 30, 1935; and Kiowa Creek, May 30, 1935.

Unpublished reports, on file in the Office of the State Engineer

HINDERLIDER, M. C., Report of the Horse Creek flood, Aug. 28, 1935, and the failure of the Horse Creek Dam, 1935.

BURGESS, L. T., Report on Purgatoire River flood at Ninemile Dam, Sept. 15, 1934.

BURGESS, L. T., Report of floods in Granada and Wolf Creeks, July 11 and 12, 1935.

BURGESS, L. T., Report of flood, Sept. 9–10, 1933, in the South Platte River at Denver.

CITY OF DENVER

Report of the Cherry Creek Flood Commission, May 1913, Denver.

OCCURRENCE OF FLOODS

Colorado was settled in the late 1850's, but before that time traders, hunters, and emigrants on the long trek to the Far West recorded floods, the earliest being those on the Arkansas and Republican Rivers in 1826. The next, which is believed to have been widespread, occurred in 1844 on the Arkansas River, and by inference on the South Platte River, also. Severe floods occurred on the Colorado River in 1853 and on the Purgatoire River and San Juan River about 1859.

Since the settlement of Colorado the most disastrous flood occurred

on the Arkansas River in June 1921. This flood caused the loss of about 100 lives in Pueblo, and an estimated property loss of $19,000,000 in the Arkansas Valley, of which the greater part was also sustained by Pueblo. This may not have been the greatest flood from the standpoint of volume, however, as some of the early floods apparently reached higher stages.

Single floods inundating large areas and causing heavy loss of life are rare in Colorado, but many floods of considerable magnitude have occurred, some of which caused loss of life and great property damage. Many of the areas flooded are shown in figure 1.

TOPOGRAPHIC ZONES

Colorado may be roughly divided from east to west into three zones: The eastern three-sevenths of the State, which occupies the western edge of the high plains and has a rolling topography; the central two-sevenths, made up of parallel ranges of the Rocky Mountains that attain their highest elevation in Colorado, and between which are high, relatively level areas known as mountain parks; and the western two-sevenths, made up in the northern part, of rolling hills, and in the central and southern parts, of the deeply eroded high plateaus that characterize much of the Colorado River Basin. This topography, because of its wide range, exerts a marked influence on the occurrence of floods.

INFLUENCE OF TOPOGRAPHY ON PRECIPITATION

During the spring and summer storms the chief source of moisture is the Gulf of Mexico.[1] The warm, moisture-laden air from the Gulf, being deflected upward by the Front Range, is cooled and precipitates its moisture not only on the Front Range but also on the adjacent plains area. Although the storms may continue westward, the remaining moisture is insufficient to produce heavy precipitation west of the Front Range, and does not cause floods on the streams in the mountain area. Very rarely, as in September 1909 and October 1911, late summer and early fall storms bring in moisture-laden air from the Pacific Ocean, which being deflected upward by the mountain mass bordering the high plateau in the western part of the State, causes heavy rainfall in the southwestern part of the State and lesser amounts farther east.

During the winter the moisture comes chiefly from the Pacific Ocean; it is deflected upward by the western mountain chains and is precipitated in the form of snow, usually heaviest on the western slopes of the highest ranges and decreasing eastward. Along the

[1] Holzman, Benjamin, Sources of moisture for precipitation in the United States: U. S. Dept. Agr. Tech. Bull. 589, p. 24, 1937.

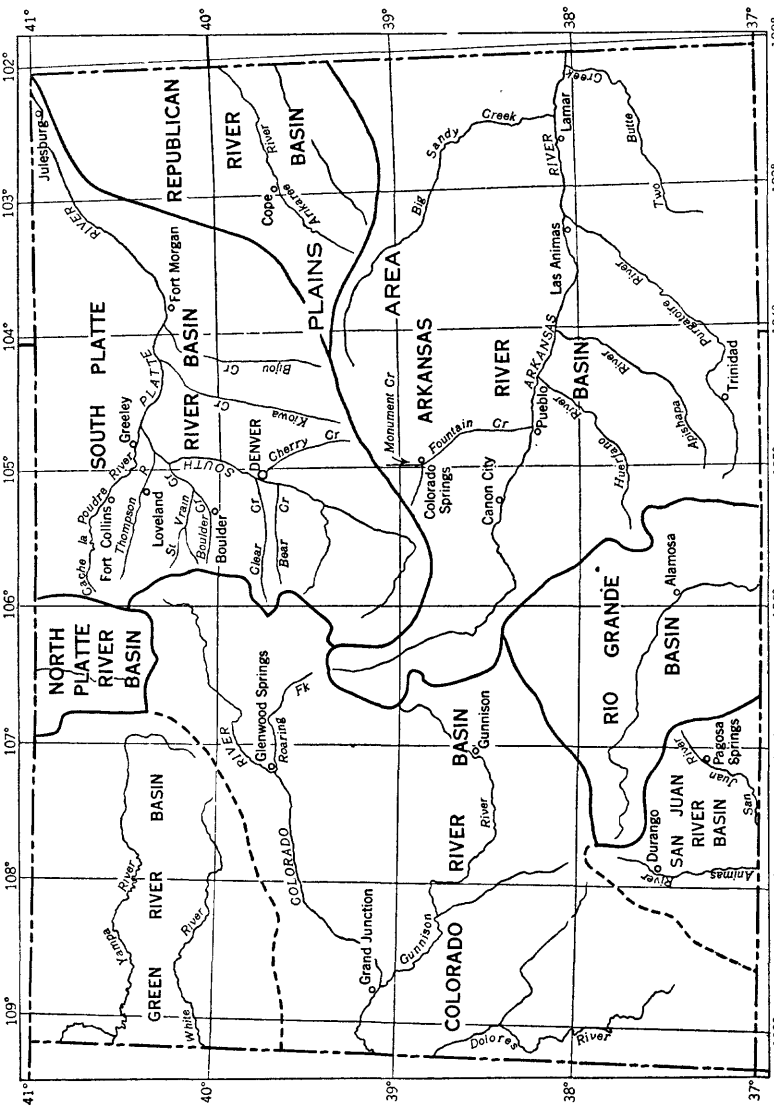


FIGURE 1.—Map of Colorado showing principal river systems and cities mentioned in the text.

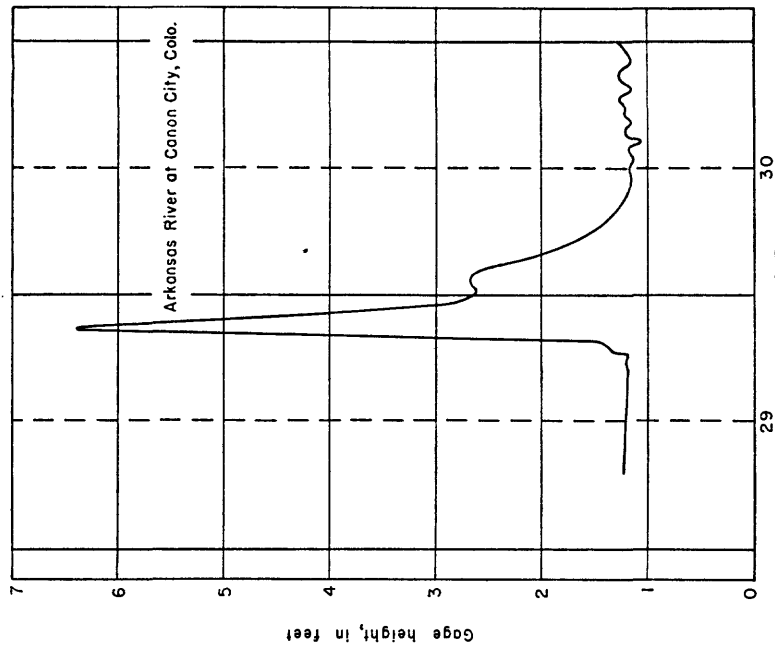
Front Range some precipitation, even in winter is caused by moisture from the Gulf. In general, however, the snowfall is heaviest on the western ranges, and its melting in June has a greater effect on the flow of the streams in that region than the melting of the snow over the eastern ranges has upon the streams draining the Front Range. In late spring, precipitation not only along the Front Range but also farther west sometimes augments the melting snow sufficiently to cause floods.

Precipitation in the plateau region is so light during the summer that floods rarely occur. East of the Front Range general precipitation is rarely sufficient to cause floods.

AREAS SUBJECT TO FLOODS

From observation of the effect of topography on precipitation it is evident that floods occur most frequently on the eastern slope of the Front Range both in the South Platte and the Arkansas River Basins. In the mountains farther west precipitation is insufficient to cause floods, except during the period of melting snow in June. At that time the severity of the resulting floods is dependent not only on the rainfall but also, and to a greater degree, on the depth of snow cover and the rate of the seasonal rise in temperature. Hence, only floods caused by rainfall on melting mountain snow occur simultaneously throughout the greater part of the State. The most severe floods of record on the Rio Grande, South Platte, Colorado, and Gunnison Rivers have resulted from this cause, as have the outstanding floods that occurred before gaging-station records began. During the storm of June 2–7, 1921, the combination of melting snow and rainfall caused severe floods on all the major rivers except the Arkansas. Over the Arkansas River Basin the storm, influenced by the topography, was concentrated in a series of cloudbursts in the foothills just east of Canon City. These cloudbursts caused the most severe flood on the Arkansas River ever recorded, and at a time when the water from melting snow from the higher areas was insignificant in amount.

The tributary streams in the South Platte and Arkansas River Basins are subject to heavy rains of cloudburst intensity which cause the cloudburst type of flood, the peak discharge of which is greater than that caused by rainfall during the period of melting snow. Whenever heavy rain occurs along the Front Range, particularly in the lower foothills, it is usually concentrated in cloudbursts at various points. The cloudburst flood flow is of such short duration, the peak lasting only a few minutes, and the total quantity of water during the flood is so small, that when it reaches a larger stream, channel storage quickly reduces it to a stage which is not a serious flood. This is well illustrated by the typical stage hydrographs shown in figure 2.



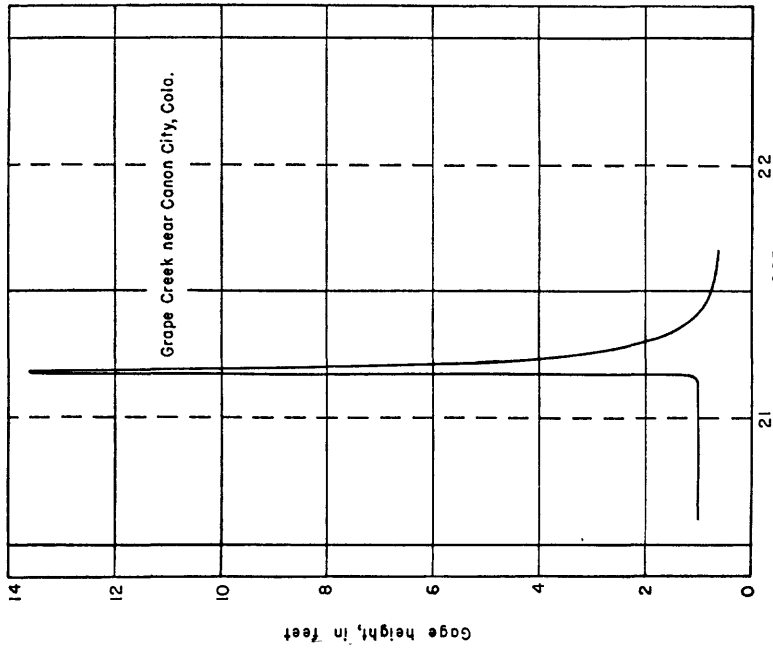


FIGURE 2.—Typical stage hydrographs of cloudburst floods.

In the southwestern part of the State the severest floods, and the only ones of record, have resulted from the storms of September 1909 and October 1911. Precipitation during melting snow in June has been insufficient to cause floods as severe, except during June 1927 when the resulting flood on the Animas River was more severe than that during September 1909.

In the North Platte River Basin the slight precipitation is not sufficient to cause floods. This basin includes North Park, a high, level area surrounded by mountain ranges, except at the lower end where rolling hills displace the mountains.

The Green River Basin in Colorado, in the northwestern part of the State, lies on the western slope of the Continental Divide, and is made up of rolling hills and some comparatively level country. The Yampa and White Rivers are the principal tributaries of the Green River. Here, as in the North Platte River Basin, the precipitation is insufficient to cause floods. The greatest flood of record in this part of Colorado was that of 1884, which was caused by rain at the time the very heavy snow cover was melting.

METHODS OF MEASURING FLOODS

For most of the earlier floods it has not been possible to estimate the actual discharge; the facilities and technique for making such estimates either had not been developed at the time these floods occurred or were not available for application.

Most of the later floods described have either been of such short duration as to make measurement of them impossible, or if of longer duration, as on the larger streams, they have destroyed the approaches to bridges and other means whereby they might have been measured. Few dams exist suitable for use as weirs in computing flood discharges, and the same is true of bridges suitable for use in computing the discharge by the contracted-opening method. Discharges for the major floods of longer duration that have occurred since the establishment of gaging stations have usually been estimated from the extension of the rating curves. However, some of these floods reached stages so far above stages of current-meter measurements that it was necessary to obtain slope-area measurements of the peak discharges in order to extend the rating curves. This was particularly true of the Arkansas River flood of June 1921, which overflowed large areas.

The only means by which most peak discharges could be measured for most of the floods described in this paper was by the slope-area method, which has been in use in Colorado since the early nineties. The procedure generally followed is to visit the stream soon after the flood, while the high-water marks are still visible, and select a straight, uniform reach as long as possible, up to 1,000 feet on the larger streams.

The high-water slopes on both banks through the reach of river selected are measured, and the average of the two is taken as the slope during the flood peak. Cross sections of the channel to the high-water line are run at each end of the reach, and if the reach is long, a cross section between the two end sections is also run; the average of the cross sections is used to compute the discharge by the Chezy formula, $V=C\sqrt{RS}$. The coefficients of roughness used in the computations are based both on judgment and on experiments made to determine them. If there is considerable difference in the areas of the upstream and downstream cross sections, it is necessary to consider the velocity head and to correct the slope of the water surface to the energy gradient.

METEOROLOGIC CONDITIONS CAUSING MAJOR FLOODS

Meteorologic conditions preceding the floods of the late spring of 1844, and of June 1864, May 1876, June 1884, May 30, 1894, and June 1921, the last named of which was the most widespread on record, are set forth in this report, as are also those of frequent occurrence that produced the floods of September 1909 and October 1911, which affected more than one large drainage area. Precipitation records of floods in any one basin are presented in connection with the description of those floods.

1844

The belief that floods were widespread during the spring of 1844 as a result of heavy rains falling on a deep snow cover rests chiefly on circumstantial evidence. Settlers came to Pueblo and the upper Arkansas Valley in 1859, and reports were common among them concerning an Indian legend of a flood in which the water "reached from bluff to bluff"—an expression commonly used in connection with legends about floods on western rivers. This circumstantial evidence was reinforced by the statement of Rockafellow,[2] in his history of Fremont County, that a French trader named Maurice, who lived near the mouth of Adobe Creek, told the pioneers that 4 feet of snow fell all over the valley in 1844 and lay there three "moons," from all of which it is surmised that the flood of Indian legend was in 1844, the year of the great flood at St. Louis. In that year the lower Arkansas River at Little Rock reached a stage of 32.6 feet, as compared with 34.6 feet in 1833, and 33.0 feet in 1927.[3] Furthermore, a high-water mark of this flood at Pueblo was reputedly 12 feet higher than the high-water mark of the flood of 1921, the greatest flood of record there.[4]

[2] Rockafellow, B. F., History of Arkansas Valley, O. L. Baskin & Co., Chicago, 1881.

[3] Arkansas River and tributaries: 74th Cong., 1st sess., H. Doc. 308, vol. 1, p. 56, 1936.

[4] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3–5, 1921: U. S. Geological Survey Water-Supply Paper 487, pp. 35–36, 1922.

The evidence of a flood in the South Platte River Basin the same year rests on the diaries of Clyman,[5] who left Independence Mo., on May 14, 1844, on his way to Oregon. He records almost daily rains and floods from that time until July 10, when the party crossed the Divide from the Kansas River to the Platte River near the present site of Grand Island, Nebr. The latter stream was "as high or higher than the Kansas," which he had previously described as being very high. The Kansas River had its highest flood of record during the spring of 1844, the stage at Topeka being about 2 feet higher than that reached in 1903.[6] More specific data regarding the flood in the South Platte River Basin is contained in a letter written by Antoine Janis, a French trapper on the Cache la Poudre River near the present site of Laporte. Ansel Watrous,[7] an early historian of Larimer County, quotes from this letter as follows:

> On the first day of June 1844, I stuck my stake on a claim in the valley. * * * At that time the streams were all very high.

Further data, also indirect in character, refer to a great flood in the vicinity of Denver. Albert B. Sanford, curator of the State Historical Society Museum, in an article in the Colorado Magazine, May 1927, quotes a statement made in 1864 by the editor of the Rocky Mountain News:

> Mr. Byers told the writer of an old Indian who * * * solemnly warned of "heap big water" such as he had seen cover the whole bottom lands "so," and he held his hands above his head.

In further confirmation of the flood of Indian legend, an unsigned article in the Denver Commonwealth, June 22, 1864, reads in part:

> In the summer of 1861 we were one of Lieut. Berthoud's exploring party to and from Salt Lake City. Major James Bridger, one of the most thorough practical explorers in the West, was guide on that trip. * * * He proceeded to tell us that many years ago while on a journey from Fort Laramie to some other point, he found the entire bottoms of Cherry Creek and [South] Platte River covered between the extreme bluffs of the two, which compelled him to remain on the opposite bank from [the present site of] this city 9 days before he was able to effect a crossing.

As the article quoted described Bridger as an old man in 1861, he would have been active in 1844, and as no other reference is known concerning a great flood in the South Platte River Basin prior to 1844, it is believed Bridger's reference was to the flood of that year.

The references to deep snow in the Arkansas River Valley and to continuous rain in the Platte River Basin lead to the conclusion that

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[5] James Clyman's diaries and memoranda of a journey through the far West, 1844 to 1846, Book I, California Hist. Soc., 1928.

[6] Kansas River, Colo., Nebr., and Kans.: 73d Cong., 2d sess., H. Doc. 195, pp. 38-39, 1934.

[7] Watrous, Ansel, History of Larimer County, Conner Printing & Publishing Co., Fort Collins, Colo., 1911.

the winter of 1843–44 was one of heavy snowfall and that rain occurred during the period of melting snow, thus causing severe floods in Colorado. The absence of white settlers in other sections of Colorado accounts for the lack of references to high water in those sections. It is probable that the heavy snow cover was widespread and that high water occurred on most of the mountain streams.

JUNE 1864

The evidence of severe floods in June 1864 rests on more complete information, as permanent settlements had then been made in the South Platte and Arkansas River Basins.

In his history of Colorado, Gen. Frank Hall [8] records the following:

> The summer of 1863 was marked by a protracted drought which dried up the streams, and prevented the growth of crops in the limited area then cultivated. * * * Earlier than usual, about the middle of October, one of the severest winters ever known in this latitude set in, with frequent heavy snows, and very cold weather. Those who had stock on the range lost it; supply trains were blockaded and many abandoned. * * *
>
> In the following spring the great masses of snow melted, flooded rivers, and expelled the miners. Rains succeeding, torrents poured down the mountain slopes upon the hapless residents, sweeping in some cases, their homes from their foundations, and filling others with mud and debris. In the valleys many ranches were overwhelmed, covered with sand and well-nigh destroyed.

Watrous [9] in his history of Larimer County, stated:

> A great body of snow fell in the winter of 1863–64, filling the gulches and ravines to a depth of several feet and the snow was from 4 to 6 feet deep in the timber on the hillsides. From the barren mountain tops above timberline the snow had blown off into the timber, gulches, and ravines where it became packed and hard as an ice bed, almost. The foothills near the plains held the snow in place, preventing it from drifting, so that back in the hills there was a great quantity of water-making material.

Watrous wrote particularly of Larimer County and of the Cache la Poudre River, describing the high water caused by melting snow augmented by "an extraordinary rainstorm" in the mountainous part of the basin, June 9, 1864. He said further:

> The storm which brought on the flood was general in the northern part of the Territory, and Denver, the Boulder, St. Vrain, and Big Thompson valleys suffered severely from its effects.

The Central City Daily Miners Register, May 10, 1864, stated:

> Just 8 months [ago] fell the snow which marked out the beginning of the present winter season. From that time until today the [snow] storms have taken the lead on the general make-up of the winter's character. This is the most extraordinary epoch known in the history of Colorado's climate.

The Register of May 18, refers to the rainstorm of the "past few days" and the melting snow on the higher hilltops.

[8] Hall, Frank, History of the State of Colorado, vol. 1, p. 306, Blakely Printing Co., Chicago, 1889.
[9] Watrous, Ansel, op. cit. p., 212.

In the Arkansas River Basin a severe flood occurred on June 11, 1864. The meager information at hand indicates that heavy rain fell just before that date, and although the heavy snow cover was melting, it is possible that the flood was due primarily to cloudbursts, as was the flood of 1921.

MAY 21–23, 1876

The storm of May 21–23, 1876, caused floods in the South Platte River Basin and on Fountain Creek, which drains the foothills region from Pikes Peak to the Arkansas River. The storm extended as far north as the Cache la Poudre River. The Greeley Tribune of May 24, 1876, reported:

> The rainstorm which began on Sunday night [May 21] and continued with but little intermission till late on Monday night, was the severest since the settlement of the valley—at least 4 inches of water fell during the 24 hours, and three-fourths of an inch in 2 hours on Monday evening after dark.
>
> Hail fell at Fort Collins during the recent heavy rains, to a depth in places of a foot.

Precipitation during this storm was recorded at nine stations in Colorado as shown in the following table.

Precipitation, in inches, in the South Platte River Basin, May 21–23, 1876

Station	Altitude (feet)	May 21	May 22	May 23	Total
Denver	5,283	0.03	[1] 6.50	0.20	6.73
Golden	5,799	1.33	1.37	1.80	4.50
Pikes Peak	14,111	----------	3.19	Tr.	3.19
Colorado Springs	6,098	----------	2.62	----------	2.62
Las Animas	3,899	----------	----------	----------	[2] 2.74
Fort Lyon	3,910	----------	----------	.32	.32
Fort Garland	7,996	----------	----------	----------	[2] 2.16
Silverton	9,400	----------	----------	----------	.00
Hermosa	6,633	----------	----------	----------	.00

[1] Greatest 24-hour precipitation recorded at Denver.
[2] Total for month.

From the meager information available it appears that the storm was heaviest in Denver and the Pikes Peak region. The weather maps show that a deep low (29.2 inches) developed over the southeastern part of Colorado and the northeastern part of New Mexico, and a high (30.4 inches) just north of the Great Lakes. Probably associated with this low was a mass of moist air from the Gulf which was forced upward by the Front Range, causing heavy precipitation. As the precipitation was partly in the form of snow, especially on Pikes Peak, the resulting floods were less severe than they would have been had the heavy precipitation occurred later in the year when higher temperatures prevailed.

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JUNE 1884

By 1884, settlements had been made in all parts of Colorado, and references to the deep snow cover, heavy rain and high discharge of streams in different parts of the State are more numerous than in 1864.

In the South Platte River Basin the record at the recently established gaging station on the Cache la Poudre River shows that the discharge during 1884 was far above average, indicating run-off from deep snow cover. Precipitation records at Denver and Fort Collins, both in the South Platte Valley, show that precipitation for the period October 1, 1883, to April 30, 1884, was nearly 60 percent above normal.

The Georgetown Courier, May 1, 1884, reported:

> People who have resided in this section for 20 years say that the past winter and spring months have been the worst in their recollection.

And in its issue of May 15, 1884, the Courier stated:

> The road to Middle Park over Berthoud Pass [head of Clear Creek] will be opened for travel soon. * * * It will be quite a job, for the snow now lies, in places, to the depth of 30 or 40 feet.

In the Arkansas River Basin, the Canon City Record of May 3, 1884, in describing the trip of a signal-service employee from Pikes Peak to Colorado Springs, says that he "plodded his way through snow 20 and 30 feet deep." It was reported that the snow on the trail was the deepest known since the establishment of the weather station on Pikes Peak in 1873.

The Pueblo Commercial Standard of June 28, 1884, stated:

> The Fountain at Pueblo was wide, swift, and deep on Thursday [June 26] and swept away both the wagon bridges on Fifth Street and the Denver and Rio Grande Railroad bridge.

Although no reference to the cause of this flood is made, its occurrence coincides within a few days with that of the flood peak caused by the rain and melting snow in other basins. At Pueblo, east of the foothills, the precipitation from January 1 to April 30, 1884, was 62 percent above normal.

In the Rio Grande Basin numerous references to high water appeared in the Del Norte San Juan Prospector, but no statements were made regarding the actual snow cover. W. D. Carroll of Alamosa, states that on Cumbres Pass, a region of heavy snowfall, the snow cover during the winter of 1883–84 reached to the wires on the telegraph poles, which were from 20 to 25 feet high. The San Juan Prospector, June 21, 1884, states that on June 14, 1884, heavy rain fell in the mountains for 12 to 20 hours.

In the Colorado River Basin, references to snow cover are more numerous. The Gunnison Press Review stated that on May 7, 1884,

the mining camp Frisco, on the headwaters of the Blue River, was still snowbound. At Kokomo, at a higher altitude in the same basin, it was reported that 80 feet of snow fell during the winter, measurements having been made after each storm. Judge John L. Noonan, of Colorado Springs, crossing Independence Pass at the head of Roaring Fork early in July 1884, found drifts 12 to 15 feet deep.[10] The Gunnison Press Review on May 9, 1884, referred to the "unprecedented snowfall and the late spring," stating that in the valley near Crested Butte the snow was 2 to 2½ feet deep, and in the streets at Gothic it was 5 feet deep. The Gothic Record referred to the "unheard of snows of the present spring," and stated that the mountains were covered with 10 to 15 feet of snow. At Evans sawmill, the exact location of which is unknown, the snow was 10 to 12 feet deep. From old settlers interviewed in connection with a previous study of the upper Colorado River [11] it was learned that the early snowfall had been unusually heavy, and that this was followed in April by a snow which was 1½ feet deep in the valley near Delta. Stockmen were unable to take their cattle to the summer range in the mountains until July.

The Colorado Springs Gazette of June 28, 1884, contained the following item from Crested Butte:

> On the night of June 12 we had a severe rainstorm which, on top of the warm weather, converted the mountain streams into torrents of water and sent them booming down the streams.

The San Juan Prospector reported that Rico, in the San Juan region, had suffered greatly from the heavy snows of the past winter, and that 64 feet of snow had fallen at the Sunbright Cabin on Mount Wilson. The only record of precipitation in southwestern Colorado during the winter of 1883–84 was at Fort Lewis, in a valley in the San Juan River Basin. That record showed a total precipitation for the period October 1, 1883, to April 30, 1884, 40 percent above normal.

No reference has been found to the snow cover in the White and Little Snake River Basins, but settlers in both basins have stated that those rivers reached their highest known stage during June 1884 and remained at high stages nearly all summer.

MAY 29–JUNE 1, 1894

The storm of May 29–June 1, 1894, which caused widespread floods in the South Platte and Arkansas River Basins, is the earliest flood-producing storm for which more than a few rainfall records are available. It was associated with a large area of low pressure (29.4 inches)

[10] Follansbee, Robert, Upper Colorado River and its utilization: U. S. Geol. Survey, Water-Supply Paper 617, p. 152, 1929.

[11] Idem.

over Nevada, and an area of high pressure (30.1 inches) over northern Minnesota and the western edge of the Great Lakes. The following table shows the precipitation at stations in these basins, listed from north to south, for the period May 29 to June 1, 1894.

Rainfall, in inches, along the foothills and Front Range, May 29 to June 1, 1894

Station	Altitude (feet)	May 29	May 30	May 31	June 1	Total
South Platte River Basin:						
Laporte	5,053	0.27	0.50			0.77
Fort Collins	4,985	.04	.07			.11
Loveland	5,000	.17	.30			.47
Moraine	7,775			3.30		3.30
Sugarloaf	9,300			5.00		5.00
Ward district	9,300		4.50	2.30	1.74	8.54
Sunnyside	9,300		4.65	1.06	.12	5.83
Gold Hill	8,630	.50	2.75	2.50		5.75
Dumont	7,955		2.40	2.65		5.05
Denver	5,283		.62	.88		1.50
Castle Rock	6,201		2.84			2.84
Alma (South Park)	10,228			2.15	.04	2.19
Como (South Park)	9,785	Tr.	1.34	.68		2.02
Arkansas River Basin:						
Divide Experiment Station	6,960	.02	1.65	.82		2.49
Pikes Peak	14,111	.75	4.57	1.33	.01	6.66
Husted	6,540	.08	1.17	.84	.32	2.41
Glen Eyrie	6,500		3.13	1.58	.15	4.86
Lake Moraine	10,265		5.50	2.00		7.50
Colorado Springs	6,098	.08	2.95	1.44	.50	4.97
Canon City	5,343	.75	4.31			5.06
Pueblo	4,685		1.38	1.64	.16	3.18
North Lake	8,700	.50	.30	.40		1.20

The only station at which precipitation was recorded farther west in the Arkansas River Basin was Twin Lakes (altitude 9,200 feet), which had a total precipitation of 1.44 inches for the period.

In the storm of 1894 there were two areas of heavy precipitation—the Pikes Peak region and the eastern slope of the Front Range west of Boulder. The Front Range here forms the Continental Divide, and the area of heaviest recorded precipitation was about 10 miles east of the Divide, where the mountains rise more steeply both on their eastern and western slopes than elsewhere, and the topography is somewhat analogous to the abrupt slopes of the Pikes Peak region.

West of the Front Range the rainfall was very much less, being less than 1 inch at every station except Climax, near the Continental Divide, which rises abruptly from the western end of South Park, a comparatively level expanse that extends eastward to the Front Range.

Melting snow was a less important factor in causing high water in this flood than in 1921, as the snow cover was slightly less than normal.

SEPTEMBER 3–6, 1909

The storm of September 3–6, 1909, like that of October 4–6, 1911, affected chiefly the southwestern part of the State and was similar in character. It was less severe than the storm of October 1911 in the

San Juan region but more severe in the other parts of the State, probably as a result of a mass of moisture-laden air deflected upward by the Front Range, where the heaviest precipitation outside the San Juan region occurred. Depth of precipitation at the four stations outside the San Juan region at which it was greatest was as follows:

	Inches
Boulder	3. 97
Hawthorne	3. 41
Colorado Springs	2. 66
Santa Clara	5. 25

Rainfall was general throughout the State, but was much less in amount at other stations than at those just listed. The following table gives the amounts at stations in the San Juan region.

Rainfall, in inches, in the San Juan region, Sept. 3–6, 1909

Station	Altitude (feet)	Sept. 3	Sept. 4	Sept. 5	Sept. 6	Total
Mancos	7,035	0.29	0.04	0.99	0.42	1.74
Fort Lewis	7,610	.15	.04	1.99	.67	2.85
Durango	6,589	.04	.37	1.64	.82	2.87
Tacoma	7,200	.30	.15	2.52	.64	3.61
Cascade	8,900	.23	.34	2.90	.85	4.32
Terminal Dam	8,300	.10	.08	2.48	.84	3.50
Silverton	9,400	.13	.17	2.00	.65	2.95
Gladstone	10,400	.35	.18	1.81	.42	2.76
Pagosa Springs	7,108	.18	.30	1.40	.47	2.35
Ignacio	6,425	Tr.	.04	.50	.37	.91
Eureka	10,000	.13	.19	.11	.17	.60
Dolores	6,942	----------	.10	.41	.48	.99
Chromo	7,500	.27	.18	.79	.37	1.61

OCTOBER 4–6, 1911

The severest flood of record in the southwestern part of the State was caused by the storm of October 4–6, 1911, which followed a summer during which the precipitation was above normal. The daily weather maps show that on October 4 a low of 29.7 inches developed over western Nevada, and moved with increasing intensity over central Arizona, reaching 29.45 inches on October 5. At that time a high of 30.3 inches had developed over the Great Lakes. As the season was early fall, the moist winds from the Pacific had high temperatures. These winds were deflected upward by the mountain masses in the southwestern part of the State, causing intense precipitation. By October 6, the low had moved northwestward over Iowa, passing over the southeastern part of Colorado, and precipitation had practically ceased in Colorado.

The following table indicates the influence of the mountains on precipitation in the San Juan region.

Precipitation, in inches, in the San Juan region, Sept. 22 to Oct. 2 and Oct. 4–6, 1911

Station	Altitude (feet)	Total Sept. 22–Oct. 2	Oct. 4	Oct. 5	Oct. 6	Total Oct. 4–6
Exposed to southwest:						
Fort Lewis	7,610	-------	-------	2.30	0.58	2.88
Durango	6,589	1.75	1.16	2.26	-------	3.42
Terminal Dam	8,300	3.60	.72	2.80	-------	3.52
Cascade	8,900	5.36	.19	2.40	.13	2.72
Silverton	9,400	3.80	.20	4.05	-------	4.25
Gladstone	10,400	5.04	.11	8.05	Tr.	8.16
Pagosa Springs	7,108	2.04	.15	3.67	-------	3.82
Cumbres	10,015	4.15	3.08	1.26	.49	4.83
Sheltered from southwest:						
Mancos	7,035	3.99	.08	1.54	-------	1.62
Eureka	10,000	1.11	-------	.47	-------	.47
Rico	8,824	2.03	.37	1.71	.15	2.23
Telluride	8,756	3.26	.02	1.57	.20	1.79
Chromo	7,500	3.69	.50	2.00	.01	2.51
Ironton	9,800	2.55	.21	2.16	.08	2.45
Northeastern slope of San Juan Mountains:						
Wagon Wheel Gap Experiment Station	9,610	.99	.71	1.94	-------	2.65
Platoro	9,800	1.78	.05	3.25	.04	3.34

The San Juan Mountains in southwestern Colorado are much higher than any mountains southwest of them, hence the moist air was deflected upward and, on cooling, deposited much of its moisture in that region. The amount of precipitation was influenced not only by altitude but by the degree of exposure to the storm. Mancos is sheltered by Mesa Verde; and Eureka, although on the south slope of the San Juan Mountains, is in a deep, narrow valley cut off by high mountains.

North and east of the San Juan Mountains the precipitation was much less, averaging about 1.5 inches for October 4–6, except along the Sangre de Cristo Mountains, which form the eastern boundary of the San Luis Valley. The part of the San Juan Mountains forming the western boundary of the valley is not as wide as the northern part in the Silverton region and caused less loss of moisture from the air crossing that part. Consequently, when the air currents reached the Sangre de Cristo Mountains and were deflected upward, heavy precipitation resulted. Although no rainfall records for the western slope are available, there is evidence of severe floods on all streams draining that slope, indicating heavy rainfall. At Hermit Lake, at an altitude of 10,000 feet on the eastern slope just below the crest, the precipitation October 4–6 was 3.68 inches. At La Veta Pass it was 2.01 inches.

The only other record of precipitation in the State that exceeded 2 inches for the period October 4–6, 1911, was 2.35 inches at Marble, at an altitude of 7,950 feet on the north slope of the Elk Mountains, a high mountain mass somewhat west of the central part of the State.

JUNE 2–7, 1921

The general storm of June 2–7, 1921, was the only storm of record that caused severe floods and unusually high water in nearly all parts of Colorado. The daily weather maps for the first week in June 1921 show that an area of high pressure exceeding 30.5 inches appeared June 1 over the Province of Alberta. By June 2 it had displaced a low pressure area over the upper Missouri Valley, and on June 3 it was over Manitoba and the northern part of North Dakota. Between June 3 and 4 the movement of the high pressure area was very slow, and it advanced only as far as northeastern Minnesota. By June 5 it had reached a point over the Great Lakes.

During this period an area of low pressure, 29.7 inches, had developed over western Arizona and remained over the southern Rocky Mountain plateau for several days.[12] Warm, moist air from the southern States and the Gulf of Mexico was drawn into the low-pressure area. When this moist air met the cold front from the north it was forced upward, and being cooled, its moisture was released as precipitation. The effect of the cold front was increased by the foothills, especially in the vicinity of Pikes Peak, which is a semi-detached mountain mass rising abruptly from the plains.

The following table shows the rainfall during the period June 2–7 along the foothills and the Pikes Peak region. Stations are listed from north to south.

Rainfall, in inches, along foothills and Pikes Peak region in South Platte and Arkansas River Basins, June 2–7, 1921

Station	Altitude (feet)	June						Total
		2	3	4	5	6	7	
South Platte River Basin:								
La Porte	5,053	0.66	0.47	1.88	0.47	0.26	------	3.74
Fort Collins	4,985	.24	1.07	1.46	.25	.02	0.60	3.64
Waterdale	5,206	.07	1.56	1.88	.52	.24	.61	4.88
Longmont	4,950	------	4.40	.45	.44	.48	.05	5.82
Boulder	5,347	.31	.14	1.19	.71	.61	.40	3.36
Hawthorne	6,000	.01	.56	.50	.20	.30	.17	1.74
Edgewater	5,450	------	2.15	.45	.48	.60	.05	3.73
Morrison	6,120	.23	.40	1.98	1.60	.40	.37	4.98
Kassler	5,492	.14	.17	3.51	.52	.36	.15	4.85
Elk Creek	8,140	.23	1.20	2.15	.95	.58	.47	5.58
Castle Rock	6,201	.06	2.78	.50	Tr.	.18	.75	4.27
Cheesman	6,890	.34	.10	2.22	1.07	.49	.20	4.42
Aldhurst	8,500	------	1.10	.80	.10	.90	.20	3.10
Arkansas River Basin:								
Monument	7,200	.06	------	2.90	.82	.05	.40	4.23
Lake Moraine	10,265	------	.65	3.68	1.40	.18	Tr.	5.91
Fremont Experiment Station	8,836	------	2.53	2.61	1.43	.48	.03	7.08
Victor	10,100	------	.03	2.08	1.55	.37	.01	4.04
Colorado Springs [1]	6,098	.16	2.23	2.00	------	------	------	4.39
Pueblo	4,685	1.94	1.64	1.12	.09	.01	.15	4.95
Canon City	5,343	------	.30	2.35	.75	.40	------	3.80
Trinidad	5,994	------	.20	.55	.30	Tr.	.27	1.32

[1] Corrected record.

[12] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3-5, 1921: U. S. Geol. Survey, Water-Supply Paper 487, pp. 11–12, 1922.

Along the Front Range back of the foothills the precipitation was generally less, except at Silver Lake where a total of 10.88 inches was reported. The following table shows the precipitation in that area.

Rainfall, in inches, along the Front Range back of the foothills, June 2–7, 1921

Station	Altitude (feet)	June						Total
		2	3	4	5	6	7	
South Platte River Basin:								
Frys Ranch	7,500	------	0.67	0.04	0.20	0.10	0.70	1.71
Estes Park	8,000	0.20	.28	1.12	.45	.20	.20	2.45
Near Longs Peak	8,956	.50	.25	1.55	1.00	.35	.30	3.95
Silver Lake	10,200	.40	.18	1.30	------	2.00	3.00	[1] 6.88
Georgetown	8,550	------	.55	.60	------	.76	------	1.91
Idaho Springs	7,543	.14	.20	1.16	.59	.32	.20	2.61
Arkansas River Basin:								
La Veta Pass	9,242	------	.98	.89	------	.20	------	2.07
Cuchara Camps	8,200	------	------	.86	.21	.12	.42	1.61
North Lake	8,700	------	2.00	.55	.18	------	.53	3.26
Madrid	6,364	------	.23	.64	.54	.10	.25	1.76

[1] Rainfall, June 8, 1921, 4 inches reported, making a total of 10.88 inches for the storm period.

The Pikes Peak uplift not only was responsible for the highest recorded precipitation, but by its practically isolated position it deflected the moist air currents into the upper basin of the Arkansas River east of Canon City, where the storm took the form of a series of cloudbursts in a small area. These cloudbursts were the sole cause of the flood of June 3–5, 1921, on the Arkansas River,[13] as the river above Canon City was not at high stage, and the foothill region did not contain any appreciable amount of snow.

A few days later the highest flood of record on the upper South Platte River occurred, with floods on its principal mountain tributaries. These floods were caused not only by the heavy precipitation of the storm, but also by the melting of the mountain snows. During April the snowfall had been unusually heavy, about three times its normal depth for that month, and this late snow, being loose, melted rapidly under the influence of the rain and the high temperature that prevailed after the storm. Temperature records are not available for points at the higher altitudes, but the temperature, although cooler, varies generally with that on the plains. The temperature records at Denver are shown in the following table.

Maximum and minimum temperatures at Denver, June 1–13, 1921

June	Maximum (° F.)	Minimum (° F.)	June	Maximum (° F.)	Minimum (° F.)
1	76	54	8	73	54
2	65	53	9	77	56
3	73	53	10	81	58
4	64	47	11	86	61
5	64	53	12	80	61
6	59	53	13	85	61
7	66	54			

[13] Follansbee, Robert, and Jones, E. E., op. cit., p. 12.

Although precipitation was general throughout the State, it was much less in the Rio Grande and Colorado River Basins, as shown in the following table.

Rainfall, in inches, in the Rio Grande, Colorado River, and Gunnison River Basins, June 3–7, 1921

Station	Altitude (feet)	Total rainfall	Station	Altitude (feet)	Total rainfall
Rio Grande Basin:			Colorado River Basin—Con.		
Garnett	7,576	1.51	Collbran	6,000	0.95
Manassa	7,700	1.16	Palisade	4,729	.79
Del Norte	7,868	1.18	Grand Junction	4,602	.39
Platoro	9,800	1.13	Fruita	4,590	.59
Cumbres	10,115	.20	Gunnison River Basin:		
Hermit	8,912	.16	Pitkin	9,180	1.72
Wagon Wheel Gap Experiment Station	9,610	1.21	Gunnison	7,670	1.47
Colorado River Basin:			Cathedral	8,925	1.05
Fraser	8,671	1.02	Crested Butte	8,867	1.20
Dillon	8,800	.43	Sapinero	9,350	1.63
Nast	8,800	1.23	Columbine Ranch	6,925	2.04
Ashcroft	9,483	2.50	Paonia	5,694	1.16
Shoshone	6,120	1.21	Crawford	6,600	.65
Glenwood Springs	5,823	1.31	Montrose	5,811	1.04
Rifle	5,310	.99	Cedaredge	6,175	1.12
			Delta	5,025	1.02

In the San Juan region the rainfall was about 1.5 inches. This slight increase over the rainfall in the Rio Grande and Colorado River Basins was doubtless due to moisture from the Pacific Ocean drawn in by the low-pressure area over Arizona. In the northwestern part of the State the recorded rainfall ranged from 0.19 inch at Yampa, in the mountains, near the head of the Yampa River Basin, to 1.60 inches at Lay, farther west in the plateau region.

Immediately west of the Continental Divide on the north and the Sangre de Cristo Range on the south, the April precipitation was more than twice the normal, but the snowfall decreased westward, being normal or slightly below normal in the western part of the State. In the San Juan region, however, the April snowfall was about 150 percent of normal, except at Telluride, where it was 250 percent. Therefore, the floods resulting from the precipitation, snow cover, and rise in temperature (the latter being similar to that at Denver), were not so severe as those in the South Platte and Arkansas River Basins, and should be termed more correctly unusually high "June rises." The causes of the floods in June 1921 have been described at length, as they typify the various factors that in combination cause a majority of the floods in Colorado.

It will be noted that the general storms causing floods have occurred most frequently during the later part of May and the early part of June. According to meteorologists of the Weather Bureau, this is due principally to the fact that it is during that season over the great interior of the North American continent that the temperature con-

trast between the surface air and the upper air is the greatest. The upper air is still very cold to the north, but the surface air has begun to heat up rapidly toward the south. This maximum contrast in temperature causes the heaviest general precipitation.

CLOUDBURSTS

A type of storm confined chiefly to the eastern foothills region below an altitude of about 7,500 feet and extending eastward from the mountains for a distance of about 50 miles, is the so-called cloudburst, which is a rainfall of great intensity confined to a very small area and lasting usually a very short time. The intensity of cloudbursts is indicated by two incidents reported on reliable authority. The first occurred during the cloudburst that caused the Bear Creek flood of July 25, 1896. The daughter of a rancher was riding on Green Mountain, looking after the stock, when the storm started. By the time she reached the barn she was practically unconscious on her horse. and had to be revived by means used for resuscitating victims of drowning, as the intensity of the rain made it almost impossible for her to breathe. The other incident occurred during the series of cloudbursts that caused the Arkansas River flood of June 3, 1921; a horse was drowned in an open field.

Cloudbursts occur only where there is a marked range in temperature within a relatively small area. This condition exists chiefly in the foothills, where the warm air from the plains drifts toward the mountains, is deflected upward, and cools rapidly at the higher altitudes near the heads of the canyons. For this reason cloudbursts generally occur in the afternoon or early evening of an unusually warm day. On rare occasions rainfall of cloudburst intensity occurs as far east as the eastern edge of the State. An outstanding example was the storm of May 30–31, 1935, which took the form of a series of cloudbursts along the path extending from the Pikes Peak region to the Colorado-Nebraska State line in the Republican River Basin. At the higher altitudes the differences in temperature are usually insufficient and the mass of warm air too small to cause cloudbursts,[14] although on rare occasions they have occurred at high altitudes during unusually warm weather.

PRECIPITATION RECORDS

Cloudbursts cover such small areas that only rarely have they occurred where the rainfall could be measured at a Weather Bureau station; moreover, within these small areas the depth of precipitation

[14] Follansbee, Robert, and Hodges, P. V., Some floods in the Rocky Mountain region: U. S. Geol. Survey Water-Supply Paper 520, p. 107, 1925.

varies greatly within short distances. Fortunately, the local residents are "cloudburst-conscious," and frequently measure the precipitation of cloudburst storms by means of various receptacles standing on their premises. Although many such records may not have a high degree of accuracy, they are of value in that they constitute the only record of the intense rainfall that causes the cloudburst floods. A field search in connection with investigations of floods frequently brings such records to light. An experience of the senior author indicates the wide variations in rainfall within a comparatively short distance. On August 11, 1936, the Weather Bureau station in Denver recorded 1.35 inches of rainfall. Three miles distant, at the author's residence, a bucket in an open space was nearly filled during that storm, indicating a rainfall of at least 6½ inches after allowance was made for the slightly flaring sides. Other evidence showed that the precipitation was much greater in that vicinity than at the Weather Bureau station.

MAJOR FLOODS

SOUTH PLATTE RIVER

The headwaters of the South Platte River have their sources in the mountainous region surrounding the large basin near the center of the State, known as South Park, and in the long eastern slopes of the high mountains forming the Continental Divide. The general course of the stream is eastward to Lake George, thence through Platte Canyon northward to its junction with the Cache la Poudre River near Greeley, and thence eastward again to its junction with the North Platte River at North Platte, Nebr.

Beyond Platte Canyon the South Platte River emerges from the foothills and flows across the plains in a shallow valley for a distance of 190 miles to the Colorado-Nebraska State line. Through the canyon the river has an average fall of 55 feet to the mile, but across the plains the fall decreases from 15 to 7 feet per mile. The South Platte River is rarely subject to floods above the canyon section, although the general storm of June 2–7, 1921, caused a flood that did serious damage. Below the canyon the river is subject to floods, caused chiefly by the tributary streams draining the Front Range, and rarely by the tributaries from the plains area.

The floods in the South Platte River Basin described in this report were on tributaries that drain the eastern slope of the Front Range of the Rocky Mountains, with the exception of Cherry, Kiowa, and Bijou Creeks, which are plains streams.

Gaging stations have been maintained at the following points on the South Platte River in the areas subject to floods:

Gaging stations on South Platte River

Station	Drainage area (square miles)	Period of record
South Platte	2,550	March 1902 to date.
Waterton	2,620	May 1926 to date.
Denver	3,840	May 1895 to date.
Henderson	4,740	May 1926 to date.
Fort Lupton	5,070	May to September 1906; April 1929 to date.
Kersey	9,500	April 1901 to October 1903; March 1905 to date.
Sublette	12,900	April 1926 to date.
Balzac	17,700	January 1917 to date.
Julesburg	20,600	April 1902 to November 1906; May 1908 to date.

1844

The earliest flood for which circumstantial evidence is available occurred in 1844, at which time the bottom lands in the vicinity of Denver were covered with water from bluff to bluff.

1864

The first direct mention in written reports or articles concerning floods on the South Platte River relates to the floods of 1864. Three separate floods occurred during May and June of that year. The first, originating in the Cherry Creek and Plum Creek Basins, occurred during the nights of May 19–20 and was caused primarily by a cloudburst in the upper part of those basins. It was the severest flood of record on Cherry Creek, but the newspapers at that time did not mention the flood on the South Platte River itself. The Cherry Creek Flood Commission in its report [15] states:

> This storm extended over the water shed of Plum Creek also, which discharged into the South Platte River [above Denver], making an unprecedented height. The two floods came together in Denver on the morning of the 20th, covering the lower portions of the city with water to a depth of from 1 to 5 feet leaving great deposits of sand and gravel. * * * At that time a large portion of the city was constructed directly within and near the bed of Cherry Creek and the South Platte River bottoms.

The only reference to the flood below Denver is contained in an unpublished article written in 1925 by Lyman E. Bishop, of Denver, which states that an old resident of Platteville, who was living on the bank of the river near Platteville during that flood, told him that the May flood covered his barnyard to a depth of 8 feet and that no subsequent flood had even reached the barnyard.

The Denver Weekly Commonwealth of June 1, 1864, stated that the heavy rains of May 26 and 27 caused the South Platte River to overflow both banks. Severe rains again fell on June 9 and 10, and the Commonwealth of June 10 stated:

> The [South] Platte contains at the present time an immense body of water which spreads from bluff to bluff either way. Numerous * * * ranches,

[15] Report of Cherry Creek Flood Commission, Denver, 1913.

indeed every one along the river, so far as heard from, are entirely out of sight * * * the great deluge has come and destroyed nearly all except the buildings above.

Above Denver the South Platte River overflowed its banks and covered the adjacent low-lying lands. This rise was caused by the heavy rains and melting snow in the mountains.

The rain was particularly severe in the South Platte River Basin above the mouth of the canyon, some 20 miles southwest of Denver. No direct references to a flood at this time on the South Platte River below Denver have been found, probably because settlement was very sparse along the river; but a number of references to floods in tributary streams have been recorded. It is evident that the flood at Denver was augmented through its later course by floods on tributary streams, at least as far as the mouth of the Cache la Poudre River, the lowest mountain tributary, and probably by floods on the plains tributaries farther east, as the rainstorm was apparently general. So far as known, however, no estimate of the discharge of any of the floods of 1864 in the South Platte River Basin has ever been made.

1867

The Rocky Mountain News, Denver, May 20, 1867, stated that both Cherry Creek and the South Platte River were in flood, and that it was estimated that the South Platte was carrying more water than during the flood of 1864. The flood of 1864 had so increased the channel capacity of the South Platte River that the flood of 1867 did not overflow its banks.

1876

The next flood noted was that of May 22–23, 1876, which resulted from precipitation on mountain snow. The Rocky Mountain News of May 23, 1876, describing this flood, stated:

The [South] Platte appeared to get the start of "Old Cherry" [Cherry Creek] and by the middle of the afternoon was sloshing around the cottonwoods in the bottoms. * * * The [South] Platte has never since the memorable freshet of 1864 run so high and wide as on yesterday. It was higher to be sure—several feet higher perhaps in 1864—but it was not able to work such destruction at that time as now. There wasn't so much town here in 1864 as now, nor as many bridges.

1894

Concerning the flood caused by the storm of May 29 to June 1, 1894 the Denver Republican of June 2, 1894, stated:

At 7 o'clock yesterday morning the [South] Platte River at the canyon station of the Citizens Water Works was 5 feet above the ordinary mark. The river continued at this height for 5 hours and at 12 o'clock it began to fall, * * * At 9 o'clock last night it had gone down 3 inches.

The diversion dam of the Highline Canal, located in the canyon section, was in substantially the same condition during the flood of

1894 that it is at present. H. L. Potts, engineer of the Denver Water Board, computed the flow over this dam under a head of 5 feet as about 4,500 second-feet. Taking this as the peak flow, the mean for the 24-hour period is estimated at about 3,500 second-feet. At Denver, the Rocky Mountain News, June 1 and 2, 1894, stated that the South Platte River rose 4 feet on May 31 and was fully 10 feet above low water at the Sixteenth Street Bridge in Denver. In 1895 a gaging station was established at the Fifteenth Street Bridge, where conditions were similar to those at the Sixteenth Street Bridge. From the extension of a rating curve developed subsequently, it is estimated that the peak flow for a stage 10 feet above low water was about 14,000 second-feet. As the river remained near that stage for nearly 24 hours, the mean for the day was probably about 13,000 second-feet. If the river rose 4 feet to a 10-foot stage on May 31, it had reached a stage of 6 feet on May 30, which indicates a discharge of nearly 8,000 second feet on that date. As Cherry Creek had its normal small flow, practically all this water came from the upper South Platte River.

A dispatch to the Rocky Mountain News, May 31, 1894, stated that at Brighton, 20 miles below Denver, the situation was becoming alarming, and that hundreds of acres of crops in the bottoms were utterly ruined. Old timers were reported as saying that no such flood on the South Platte River had occurred since 1876. The following day, June 1, it was reported that the river had gradually risen all day and was from 1 foot to 6 feet deep over the lower lands. Clear Creek enters the South Platte River between Denver and Brighton, and as the creek was also in flood the flow of the South Platte River was doubtless greater at Brighton than at Denver. This increase in discharge of the South Platte must have become materially greater as far north as the mouth of St. Vrain Creek, near Platteville, as Boulder and St. Vrain Creeks both had heavy floods. The effect of this increased volume of the South Platte River was noted near Brush, Colo., and reported in the Rocky Mountain News, June 3, 1894:

> Brush, Colo., June 2. The [South] Platte River commenced raising at noon today and at this [not stated] hour it has raised 8 feet and is still coming up * * *. The water was within 1 foot of the bridge at 6 o'clock * * *. The water from the river is running out over the bottoms and the river is fully 2 miles wide.

A rough comparison of the height of the flood of 1894 and that of 1921 has been made at Fort Morgan. The Fort Morgan Times,

June 8, 1894, stated that for 24 hours on June 2 the flood touched the caps on the top of the bridge piling. According to a local resident the crest of the flood of 1921 reached nearly to the top of the piling, which still had the same elevation as in 1894. Thus the maximum stage and presumably the maximum discharge of both floods were nearly the same. No information is available regarding the flood below Brush, but it is probable that channel storage flattened it out increasingly as it proceeded downstream.

1921

The severest flood of record on South Platte River occurred during June 1921 and was caused by heavy rains widespread throughout the State, June 2–7. The rainfall extended east of the mountains for considerable distance, and the plains tributaries as well as those in the mountains contributed to the flow in the South Platte River. No gaging stations were being maintained at the mouths of the tributaries, and it is impossible to determine the discharge entering the river from tributary streams.

At South Platte, in the canyon section, the flood reached a stage of about 9 feet and washed out the narrow-gage track of the Colorado & Southern Railroad in the canyon. From the mouth of the canyon to Denver, a distance of 43 miles, farms in the bottom lands were inundated by the overflow, which varied in width from ½ to 1½ miles. Several families were driven from their homes. Bridges were rendered impassable, and several were destroyed. The South Platte River rose about 7 feet in Denver; the local press estimated that about 500 houses were inundated and many families forced to seek higher ground. Three large packing plants and practically all the lower feeding pens at the Denver Union Stock Yards were flooded.[16] Ten acres of railroad yards were flooded to a depth of 1 foot.[17] The bottom lands in the valley below Denver were flooded, the general overflow being as much as 4 miles wide near Sterling. Between Brighton and Orchard, a distance of 30 miles, the wooden bridges were impassable; 2 were destroyed, and the approaches to the others were destroyed for a distance of several hundred yards. At Fort Morgan the water surface was within a foot of the bridge level near the Union Pacific Railroad station.

The following table shows the daily discharge of the South Platte River at the various gaging stations.

[16] Rocky Mountain News, Denver, Colo., June 7, 1921.
[17] Idem, June 9, 1921.

Daily discharge, in second-feet, of South Platte River, during flood of June 1921

June	South Platte (drainage area 2,550 square miles)	Denver [1] (drainage area 3,840 square miles)	Kersey [1] (drainage area 9,500 square miles)	Balzac [1] (drainage area 17,700 square miles)	Julesburg [1] (drainage area 20,600 square miles)
1	1,250	1,270	808	311	110
2	1,250	1,320	832	630	103
3	1,410	1,460	912	1,030	101
4	2,340	4,010	1,800	1,350	127
5	3,040	5,540	10,500	1,760	273
6	4,650	7,010	18,300	5,900	938
7	5,860	8,250	31,000	12,000	1,130
8	[2] 6,070	8,500	30,000	17,100	2,350
9	5,360	8,290	30,000	18,300	15,000
10	4,920	7,350	29,000	30,400	16,600
11	4,650	6,530	26,000	31,200	22,300
12	4,470	5,600	23,300	27,500	25,800
13	4,300	5,140	19,900	25,600	24,200
14	4,180	4,600	19,900	23,600	25,700
15	4,200	4,720	18,300	20,900	30,200
16	4,030	4,840	16,800	21,800	30,800
17	3,750	4,760	15,400	21,500	22,000
18	3,140	4,040	12,800	20,300	14,400
19	2,690	3,150	11,000	19,100	14,900
20	2,470	2,890	9,000	14,600	13,500
21	2,260	2,540	9,500	12,600	10,900
22	2,070	2,180	5,200	10,900	10,300
23	1,880	1,960	3,690	7,680	8,180
24	1,890	1,740	3,240	5,030	6,470
25	1,840	1,540	2,800	3,540	5,630
26	1,860	1,440	2,500	2,700	4,350
27	1,670	1,340	2,380	2,170	3,780
28	1,490	1,250	1,860	2,000	3,240
29	1,450	1,030	1,460	2,000	2,760
30	1,400	781	1,130	1,920	2,380

[1] Data from reports of Colorado State Engineer.

[2] Peak discharge, 6,320 second-feet.

1933

The flood on the South Platte River in the vicinity of Denver with the highest recorded discharge at that point occurred during the night, September 9–10, 1933. It was caused by heavy rain on the divide separating Cherry Creek from Plum, Big Dry, and Little Dry Creeks, which enter the South Platte River between the mouth of the canyon and Denver. The flow of South Platte River at Denver increased from 410 second-feet at 8 p. m., September 9, to 22,000 second-feet at 1:30 a. m., September 10, remained nearly steady until 3 a. m., then receded to 5,810 second-feet at noon. The average discharge for the 24-hour period ending at noon, September 10, was 6,700 second-feet. At Waterton, near the mouth of the canyon, the peak discharge was 1,360 second-feet. At Henderson, about 12 miles below Denver, the peak discharge of 22,000 second-feet was reduced by channel storage to 5,600 second-feet. In an investigation of this flood the Office of the State Engineer made a slope-area determination of the peak flow in Plum Creek and found it to be 5,500 second-feet. Big Dry Creek and Little Dry Creek were the chief contributors to the South Platte flood, their combined total being estimated at 10,800 second-feet.[18]

[18] Burgess, L. T., Report on flood of September 9–10, 1933, in the South Platte River at Denver. Unpublished.

The second largest recorded flood on the South Platte River occurred early in June 1935. This was due to rains of cloudburst intensity, May 30–31, on the headwaters of the plains tributaries to the South Platte, following the wettest May in the 48-year climatic record in Colorado. The chief sources of the flood were Kiowa and Bijou Creeks, which enter the South Platte River below the Sublette gaging station. The mountain tributaries from the west were not in flood.

Kiowa Creek enters the South Platte River 18 miles above Fort Morgan and Bijou Creek enters 3½ miles above. Further than the fact that a severe flood occurred on Kiowa Creek, little is known concerning its flow. On Bijou Creek, however, a rise occurred about 11:30 p. m., May 30, and about 3:30 a. m., May 31, and according to J. M. Dille, manager of the Bijou Irrigation Co., a veritable "wall of water" appeared at a point 4 miles above the mouth. This crest lasted for 20 minutes and then dropped rapidly, according to a rancher living on the stream, who timed it. The crest reached Fort Morgan about 5:30 a. m., May 31, and was about 10 feet above normal stage; by 7 a. m. it had receded about half a foot and continued to recede rapidly; and on the morning of June 2 the stage was again normal. Some days later, L. T. Burgess, chief hydrographer of the State of Colorado, made a slope-area measurement of the peak flow a mile above Fort Morgan and found it to be 84,300 second-feet. As the Bijou Creek flood debouched into the channel of the South Platte River, the waters flowed upstream, downstream, and across the lowlands, and thus the peak was materially reduced. Owing to the short time that the South Platte River was at peak stage at Fort Morgan, the mean discharge for the maximum 24-hour period was much less than 84,300 second-feet, but no real estimate of this mean can be made.

The flood reached a higher stage near Fort Morgan than at any other point on the river, as little or no additional flow entered the South Platte River below Bijou Creek, and channel storage reduced the peak flow as it progressed toward the Colorado-Nebraska State line. Near Sterling, little or no overflow occurred, but near Crook, 25 miles downstream, a break occurred in the Union Pacific Railroad grade which allowed the river to form a lake half a mile wide north of the highway.[19]

The following table shows the daily discharge at gaging stations of the South Platte River. The short duration of the flood period shows the cloudburst character of the storm that caused it.

[19] Sterling Advocate, Sterling, Colo., June 3, 1935.

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Daily discharge of South Platte River, in second-feet, during flood of June 1935

Date	Denver, 3,840 square miles	Kersey, 9,500 square miles	Sublette, 12,900 square miles	Julesburg, 20,600 square miles
May 30	788	2,390	1,450	4,850
31	2,900	5,700	1,720	3,310
June 1	860	4,120	3,620	6,810
2	719	2,390	2,080	[1] 24,000
3	640	1,360	917	15,900
4	500	1,060	520	7,510
5	450	880	407	4,580
6	425	660	336	3,320
7	411	717	291	2,580
8	390	890	263	2,130

[1] Peak discharge, 31,300 second-feet.

BEAR CREEK

Bear Creek, which drains the eastern slope of the Front Range, emerges from the foothills near Morrison and flows through a shallow valley for a distance of 10 miles to its junction with the South Platte River. Between Idledale and Morrison the fall is 173 feet per mile, and across the plains it is 44 feet per mile.

Gaging stations on Bear Creek

Station	Drainage area (square miles)	Period of record
Idledale (Starbuck)	111	October 1919 to September 1934.
Morrison	165	April 1888 to September 1891; May 1895 to March 1902; October 1934 to date.
Sheridan Junction at mouth of Bear Creek.	265	April to November 1914; February 1927 to date.

From available references Bear Creek appears to be subject to more frequent cloudburst floods than any other tributary of the South Platte River. This may be partly due to its proximity to Denver and to the fact that many residents of Denver have summer homes in that area, thus focusing attention on this stream. The highway was formerly only a few feet higher than the creek, and considerable loss of life occurred when travelers were trapped in vehicles on the highway during floods. Of the 15 floods to which references have been found, the 5 larger ones are described in this report.

The storm of May 21–23, 1876, which took the form of snow over the upper part of Bear Creek Basin, caused the flood reported in the Denver Tribune of June 5, 1876.

* * * informs us that he has never seen such destruction in the region as resulted from the late storm. He spent some days in the valleys [of] Soda and Bear Creeks and their tributaries and found new gulches worn to the depth of 20 feet in the action of the raging torrents.

The widespread storm of May 29–June 1, 1894, resulted in one of the few recorded floods caused by general rains. The Colorado Transcript,

June 6, 1894, mentioned the destruction caused in various parts of the State, and stated that in the vicinity of Morrison the flood caused the loss of bridges, railroad tracks, and houses, and destroyed the highway in the canyon.

During July 1896 rainfall was recorded at frequent intervals at practically every Weather Bureau station in Colorado, and although the amounts recorded for each storm were not great, the total for the month ranged from 1 inch to 5 inches. No outstanding floods occurred except in the adjacent basins of Bear Creek and Clear Creek, and precipitation records are not available for these. The flood on Bear Creek was the severest recorded for that area, and caused the loss of several lives, and much property damage. Unlike the other floods on Bear Creek, which originated below Evergreen in the vicinity of Cold Spring Gulch, the flood of July 24, 1896, originated on Cub Creek, above Evergreen. A resident of Evergreen says that a 24-hour rain terminated in a cloudburst on Cub Creek that washed out a small mill dam on that stream.

The Colorado Transcript, August 5, 1896, reported:

> Commencing at the origin of the flood which is at the head of Cub Creek, about 8 miles southwest of Evergreen, there is nothing but ruin and desolation in its wake.

The Rocky Mountain News, July 25, 1896, stated:

> Without a moment's warning the largest flood that ever came down Bear Creek struck Morrison about 8 o'clock tonight [July 24], sweeping everything in its path. * * * The terror was added to by a report that a flood that would wipe out the entire town was coming down Mount Vernon Gulch * * * but, although the water came down through the town nearly 3 feet deep in the main street, the buildings in the business section all withstood it.

The peak flow at the Morrison gaging station above the mouth of Mount Vernon Creek was computed by the slope-area method as 8,600 second-feet.[20] According to the newspaper reports, the area of heavy rainfall extended to the head of Cub Creek and probably was about 50 square miles, which indicates a unit runoff of 172 second-feet per square mile.

A flood on Bear Creek, July 7, 1933, is reported in the Jefferson County Republican as follows:

> Five persons known dead * * * property damage of unestimated degree and nearly all the highway between Mt. Morrison and Idledale ruined, is the toll up to date of one of the most devastating floods last Friday afternoon [July 7] ever to visit the Bear Creek watershed. * * * A cloudburst at about 1 o'clock in the neighborhood of Idledale sent a wall of water down Saw Mill Gulch leading to Bear Creek, and another raging torrent down Vernon Creek * * *. The Vernon Creek waters reached a height of 15 feet * * * in the narrow passage between the business houses. * * * The highway up beautiful Bear

[20] Colorado State Engineer, Report for the years 1895 and 1896, p. 45, 1897.

Creek Canyon between Mt. Morrison and Idledale is practically ruined. * * * The depth of the flood water * * * failed to reach the height of the all-time record in Bear Creek established * * * July 24, 1896.

The Geological Survey made a slope-area determination of the peak discharge at Morrison, above Mount Vernon Creek, and found it to be 8,110 second-feet. The newspaper reports indicate that the area receiving the heaviest rainfall was a strip not exceeding 4 miles wide across the basin, giving a drainage area of about 20 square miles, or a unit run-off of about 400 second-feet per square mile. The mean discharge for the day at the Idledale gaging station 3 miles upstream from Morrison was 600 second-feet. At the mouth 10 miles downstream the peak discharge was 3,000 second-feet, and the mean for the day 750 second-feet.

On August 9, 1934, cloudbursts occurred on Bear Creek just below Kittridge and at the head of Mount Vernon Creek, causing another flood in which six lives were lost and heavy property damage. The Jefferson County Republican reported:

> Unlike the flood of July 7 of last year when practically all of the Bear Creek highway between Morrison and Idledale was washed out, the damage in the canyon this year was comparatively small, the new Bear Creek highway which had just been opened to the public having suffered little damage, while in Mount Vernon Canyon the wall of water was of much greater volume than last year and ripped out much of the roadway in the canyon.
>
> The business section of Morrison did not suffer as greatly as last year owing to the fact that the waters of Bear Creek and Mount Vernon Creek did not meet at Morrison this year, the Bear Creek water having passed Morrison before Mount Vernon Creek water reached the junction with Bear Creek at Morrison.

This newspaper added that the flood on Mount Vernon Creek was 12 to 15 feet high, and according to a resident who had lived 40 years near the creek, was the highest flood during that period. It was exceeded, however, by the flood of September 2, 1938.

The Office of the State Engineer made a slope-area measurement of the peak discharge of Bear Creek at Idledale, 5½ miles below Kittridge, and found it to be 4,620 second-feet; the mean discharge for the day was 274 second-feet. At the mouth of Bear Creek the peak discharge was 1,300 second-feet, and the mean for the day 88 second-feet.

The flood of September 2–3, 1938, was caused by a cloudburst that centered on the divide between Mount Vernon and Bear Creeks near the top of Genessee Mountain. Unfortunately, this area had no Weather Bureau precipitation stations, and it was therefore necessary to determine the locations and approximate amounts of rainfall from such information as could be furnished by local residents who had measured the rainfall in improvised rain gages. The Bureau of Reclamation made a thorough search for such information, which is presented in the following table.

Rainfall on Bear Creek and Mount Vernon Creek drainage basins during night of Sept. 2–3, 1938

Location	Rainfall (inches)	Method of measurement	Remarks
NW¼ sec. 10, T. 5 S., R. 71 W.	3	2-lb. coffee can in open.	
Evergreen, NE¼ sec. 10, T. 5 S., R. 71 W.	4	Estimated	Rain began about 6 p. m., Sept. 2. Hardest rain lasted only about 30 minutes.
Kittridge, SW¼ sec. 35, T. 4 S., R. 71 W.	4	Gasoline barrel	Over 3 inches measured in barrel, Sept. 6.
In Cold Spring Gulch, SE¼ sec. 25, T. 4 S., R. 71 W.	[1] 5	Gallon can	Rain started about 6 p. m., Sept. 2 and continued hard until about 8:30 p. m.
Mouth of Cold Spring Gulch, Southwest corner sec. 30, T. 4 S., R. 70 W.	4	Wheelbarrow 5 inches deep.	
Southwest corner sec. 29, T. 4 S., R. 70 W.	4	Two buckets in open	Both buckets measured exactly the same.
NE¼ sec. 32, T. 4 S., R. 70 W.	4	Oil barrel	Hard rain started at 6:40 p. m., Sept. 2, and continued at least 4 hours.
Morrison, south quarter corner sec. 35, T. 4 S., R. 70 W.	3	Estimated	Rain started about 7:15 p. m., Sept. 2. Most of it fell in 2 hours.
NE¼ sec. 30, T. 4 S., R. 70 W.	4½	Gallon can	Rain started about 6 p. m., Sept. 2. Rained all night.
Northeast corner sec. 20, T. 4 S., R. 70 W.	6	2-gallon bucket	7 inches measured in flaring bucket; computed at 6 inches.
SW¼ sec. 7, T. 4 S., R. 70 W.	6¼	4-inch rain gage	Gage ran over; estimated overflow, 1 inch. Emptied gage and it read 1¼ inches additional.
SE¼ sec. 13, T. 4 S., R. 71 W.	8	Wash tub	Hard rain 6:30 to 9 p. m., Sept. 2.
North quarter corner sec. 13, T. 4 S., R. 71 W.	7½	Partly covered can	Most of rain fell in about 2 hours.
Southwest corner sec. 12, T. 4 S., R. 71 W.	6	Straight-sided can	
NE¼ sec. 11, T. 4 S., R. 71 W.	8½	Wash tub	Tub 10 inches deep ran over; no estimate of splash. Two hard rains reported.
Hosa Lodge, southeast corner sec. 10, T. 4 S., R. 71 W.	8	10-inch bucket	Bucket set on slope ran over; estimated between 8 and 9 inches. Hardest rain between 6:30 and 7 p. m., Sept. 2.

[1] Approximate.

This precipitation resulted in floods in Cold Spring Gulch and Mount Vernon Creek, which caused the flood on Bear Creek. Above Cold Spring Gulch, the upper of these two tributaries, Bear Creek experienced only a small rise. Within a short time after the flood, slope-area determinations of the peak flows were made at controlling points.

Cold Spring Gulch, a tributary of Bear Creek, in the area of highest precipitation in SE¼ sec. 25, T. 4 S., R. 71 W., had a peak discharge of 9,000 second-feet from a drainage area of 4.48 square miles, or 2,010 second-feet per square mile. A small gulch is tributary to Cold Spring Gulch between this point of measurement and the confluence of Cold Spring Gulch and Bear Creek. A slope-area measurement of this gulch at its mouth near the southwest corner of sec. 30, T. 4 S., R. 70 W., showed a peak discharge of 2,050 second-feet from a drainage area of 0.63 square miles, or 3,250 second-feet per square mile. The watermarks and erosion at the mouth of this tributary gulch showed that its peak discharge came before the peak on Cold Spring Gulch and therefore should not be added to the peak

flow of Cold Spring Gulch. As the tributary gulch has a short, narrow, steep drainage area, it appears that its flow was relatively small at the time of the peak in Cold Spring Gulch. The flow of 9,000 second-feet, as measured, represents the peak flow of Cold Spring Gulch.

The peak discharge of Bear Creek at Morrison, above the mouth of Mount Vernon Creek, was 6,200 second-feet from 164 square miles, or 37.8 second-feet per square mile. The difference between the peak on Cold Spring Gulch and that on Bear Creek at Morrison is undoubtedly due to the fact that the peak discharge on the gulch was of very short duration and flattened out in the channel of the creek between the mouth of Cold Spring Gulch and Morrison, a distance of about 5 miles. Mount Vernon Creek in SW¼ sec. 23, T. 4 S., R. 70 W., 2 miles above Morrison, had a peak discharge of 3,900 second-feet from a drainage area of 5.7 square miles, or 684 second-feet per square mile. In sec. 35, T 4 S., R. 70 W., half a mile above its mouth at Morrison, the peak discharge of Mount Vernon Creek was 9,230 second-feet from a drainage area of 9.45 square miles, or 977 second-feet per square mile. From statements by local residents it appears that the peak discharge of Mount Vernon Creek at Morrison occurred about 7 p. m. September 2, and that on Bear Creek at Morrison about 7:30 p. m. the same day. The length of time that the peak discharge lasted at Morrison is not definitely known, but several local residents state that it was about 1½ to 2 hours from the time the flood from Mount Vernon Creek reached Morrison until the water had subsided sufficiently to permit travel on the main street.

The water-stage recorder at the gaging station on Bear Creek at Morrison did not operate during the flood because a deposit of gravel and rocks blocked the intake, but a satisfactory record was obtained by the recorder at the Sheridan Junction gaging station, near the mouth of Bear Creek, about 10 miles below Morrison. The table that follows shows the stage and discharge at this station at frequent

Gage height and discharge of Bear Creek at mouth, near Sheridan Junction, Colo., Sept. 2–3, 1938

[Data furnished by the Colorado State Engineer]

Sept.	Time	Gage height (feet)	Discharge (second-feet)	Sept.	Time	Gage height (feet)	Discharge (second-feet)
2	10:00 p. m.	2.95	120	3	1:00 a. m.	4.30	815
	10:05 p. m.	3.50	218		2:00 a. m.	3.90	633
	10:10 p. m.	4.75	825		3:00 a. m.	3.75	570
	10:20 p. m.	[1] 7.21	2,810		4:00 a. m.	3.70	545
	11:00 p. m.	6.80	2,450		7:00 a. m.	3.60	500
	12:00 midnight	5.70	1,600				

[1] Peak.

intervals during the flood and indicates that the flood was of short duration. The total quantity of water discharged in the 6-hour period 10 p. m. to 4 a. m. was 732 acre-feet.

The reduction shown in the peak discharge of Bear Creek between Cold Spring Gulch and Morrison continued in greater degree below Mount Vernon Creek, as at its mouth Bear Creek had a peak discharge of only 2,810 second-feet.

CLEAR CREEK

Clear Creek emerges from the Front Range at Golden and flows for a distance of 16 miles across the plains. For a distance of 10 miles above the mouth of the canyon the fall is 103 feet per mile, and across the plains it is 37 feet per mile.

Gaging stations on Clear Creek

Station	Drainage area (square miles)	Period of record
Idaho Springs	239	October 1910 to September 1912.
Forks Creek	345	May 1899 to October 1912.
Canyon, 7 miles above Golden	374	August 1887 to September 1888.
Near Golden	392	December 1908 to December 1909; June 1911 to date.
At mouth, near Derby	600	April to November 1914; February 1927 to date.

Floods on the Clear Creek occurred in May and June 1864. The only information regarding the flood of May 18 is contained in the Central City Daily Miners Register, issue of May 18, 1864:

Clear Creek is on a bender. The rain storms of the past few days, with the melting snows * * *, together fill the mountain streams to overflowing. [North] Clear Creek, where it courses through Blackhawk, is at present far above the banks. In front of the Blackhawk foundry the water covers nearly the entire surface of the street.

And on May 29 the Register stated that the bridges over Clear Creek along the road to Denver had been washed away, except the one at Golden.

Regarding the flood of June 10, the Georgetown Courier, June 12, 1864, stated:

Clear Creek rose very rapidly Monday night [June 9] and overflowed its banks near the corner of Rose and Tenth Streets. It became necessary to construct a levee the next day to keep the stream within its limits.

High water did considerable damage on the Empire branch of Clear Creek last Thursday [June 5]. The dam above Bartt and Fletcher's mill gave way. The large county bridge below was wrecked, the bridge above Empire station, the railroad bridge, and the other bridge below the station were carried away.

The Denver Rocky Mountain News, May 29, 1867, records a flood on Clear Creek:

We had a call this morning from Mr. G. H. Bogue, acting sheriff of Clear Creek County. He reports a constant fall of rain and snow at Idaho [Springs], from Friday last up to the time when he came away yesterday, with a good prospect of a continuance for an indefinite period. The snow melted away as fast as it fell * * *. Clear Creek is so high that bar mining has been suspended for a time.

On July 14, 1872, a cloudburst flood occurred on Golden Gate Gulch, which enters Clear Creek at Golden. The account of this flood as given in the Rocky Mountain News of July 16, 1872, in which the cloudburst is termed a waterspout, is presented at length because, so far as is known, it is the earliest account of a cloudburst in this region. The last sentence of the quotation indicates the short duration of the flood.

Those who have ever witnessed a waterspout will bear testimony to its appalling nature. One of these curious phenomena occurred on the Central Stage Road in Golden Gate Gulch, 4 miles above the town of Golden, on July 14 about 4 o'clock. People residing in that vicinity report having seen, just above the higher mountains, numerous dense clouds, from which a conical pillar resembling condensed vapor, was seen to descend, and almost simultaneously a deafening peal of thunder was heard.

Mr. Jack Virden [and family] had been to Golden and were returning home in a double carriage and had reached the point indicated above, when the waterspout dispersed. * * * Presently a violent commotion, with confusion of sounds like the tumult of the elements, was heard high up in the mountains. Then came a tremendous torrent of water, bearing trees and boulders, and calculated to astonish and terrify by its magnitude, force, and violence. The horses, seeing that they were to be sacrificed to the prodigious volume, took fright, and shying to one side upset the carriage and all occupants were pitched into the bottom of the gulch. In an instant, as it were, and before they could recover their feet, the wave, with a perpendicular breast of 10 or 12 feet, was upon them and licked them up like the sands of the gulch. Mrs. Virden clung to her husband, and he, by miraculous chance, got hold of a limb and held fast until the flood subsided.

No mention has been found of the resulting flood in Golden or farther down Clear Creek, and it is probable that, like similar floods, its peak was soon reduced by channel storage to a stage at which it ceased to cause serious damage.

On August 1, 1888, another flood occurred on Clear Creek, the peak discharge of which was stated in the report of the State Engineer [21] to have been 8,700 second-feet and to have lasted 2 hours. This discharge was at the gaging station maintained in the canyon 7 miles above Golden. The gage was washed out, but the peak discharge was apparently determined from high-water marks and an extension of the station rating curve. The Colorado Transcript, August 8, 1888, states that this flood caused severe damage to the railroad tracks in

[21] Colorado State Engineer, 4th Bienn. Rept., pt. 2, 1889.

the canyon, washing them out badly. According to the Rocky Mountain News, August 2, 1888, the damage occurred between Idaho Springs and Golden.

Cloudbursts on July 24, 1896, caused a flood in Golden Gate Gulch and on Clear Creek below the mouth of Beaver Brook which enters the canyon about 6 miles above Golden. The Colorado Transcript, July 29, 1896, contains the following account of this storm and the resulting flood:

> At about 7 o'clock [evening] dense clouds had gathered low down on the surrounding mountains and at that hour an unprecedented downpour of rain and hail commenced, continuing to fall in sheets for half an hour or more * * *. Before the rain even partially ceased the water in the [Clear] creek began to rise rapidly, bringing down flood wood, railroad ties, trees, and all manner of debris, and to add to the horror, at about 8 o'clock a tremendous wall of water came down Tucker Gulch [a tributary of Golden Gate Gulch] forcing its way through the center of the town [Golden], carrying death and destruction in its path.
>
> At the point where the gulch debouches through a narrow passage in Clarks garden, additional watermarks show that the body of water must have been fully 30 feet deep. At this point stood the residence of Alderman J. F. Edwards, and the relentless flood swept from home and loved ones Mrs. Edwards, who was standing in the yard as the water approached and was unable to reach a place of safety before she was hurled to death * * *. The flood with its load of wreckage dashed on down the incline, parting at the glass works which stood alongside the railroad tracks, one body following down the gulch and Ford Street * * *, taking in its course a little cottage. [Two occupants were drowned.]
>
> By 8 o'clock Clear Creek itself was on the rampage, a body of water from 8 to 10 feet deep coming down from Beaver Brook.

These cloudburst floods were of such short duration that they were quickly flattened out when they reached Clear Creek, and apparently caused little damage, as the local newspapers do not mention high water in Clear Creek at this time.

Rain on September 9–11, 1933, covered the Clear Creek Basin, the records showing 2.75 inches at Idaho Springs and 1.10 inches at Denver near the mouth of the creek. This rain caused a peak discharge of 5,890 second-feet September 9 at the Golden gaging station. The peak was of such short duration, however, that the mean discharge for each of the calendar days was much less than the peak, as shown by the following record for the period September 8–11, 1933:

Mean daily discharge near Golden, September 8–11, 1933

		Second-feet
Sept.	8	72
	9	757
	10	552
	11	210

Golden Gate Canyon, which enters Clear Creek below the gaging station near Golden, was flooded, and the highway was damaged to such an extent that it was closed for several days. The peak discharge,

September 9, 1933, was the highest recorded for the area since the flood of August 1, 1888.

The general rains of September 2–3, 1938, which reached cloudburst proportions on the divide between Clear Creek and Bear Creek, centering around Genessee Mountain, caused Clear Creek at the gaging station 1½ miles west of Golden to reach a peak discharge of 4,090 second-feet at 9 p. m. September 2. The peak reached the gaging station 12 miles downstream, near the mouth, at 1 a. m. September 3, with a discharge of 3,650 second-feet. The flood was of such short duration that the mean discharge for September 3 was only 840 second-feet.

ST. VRAIN CREEK

St. Vrain Creek is formed by the confluence of North and South St. Vrain Creeks, which drain the Front Range and emerge on the plains, uniting below Lyons. For a distance of 10 miles above the junction North St. Vrain Creek has a fall of 121 feet per mile, and South St. Vrain Creek 189 feet per mile. From Lyons to the mouth of the creek, a distance of 31 miles, the main stream has a fall of 22 feet per mile.

Gaging stations on St. Vrain and North St. Vrain Creeks

Station	Drainage area (square miles)	Period of record
North St. Vrain Creek at Longmont Dam, near Lyons.	109	October 1925 to date.
St. Vrain Creek at Lyons	226	August 1887 to October 1892; June 1895 to date.
St. Vrain Creek at mouth, near Platteville	1,000	April to December 1915; February 1927 to date.

The storm of June 1864 caused a flood the effects of which were felt severely in the St. Vrain Valley.

The storm of May 1876 also caused a flood on St. Vrain Creek, but the only known reference to it is a statement in the Golden Tribune, May 31, 1876, that at the junction of St. Vrain Creek and Lefthand Creek, at Burlington, the water spread over the bottoms from bluff to bluff for 2 days.

The general storm of May 31, 1894, caused a flood on St. Vrain Creek, of which the Boulder Camera, June 2, 1894, reported:

> All the lower part of Lyons was washed away, probably 20 houses being destroyed or ruined. Sheriff Dyer said that, standing on the hills and looking out onto St. Vrain Valley, a lake 3 miles wide was in the picture.

From information relative to the 1894 storm it appears that South St. Vrain Creek contributed the greater part of the flood. During an investigation made by the Geological Survey in 1939, a resident who had lived near the gaging station at Lyons during 1894 said that

he remembered distinctly that the peak of that flood just reached the top of the rail of the railroad track, which passes close to the gage. This has an altitude of 8.13 feet on the gage datum. A rough slope-area determination of the peak discharge was made, using the present slope of the water surface for medium stage, and a cross section 8 feet narrower than the present cross section, because the resident stated that the channel was widened by that amount during the flood of 1919. The peak discharge was thus estimated to be 9,800 second-feet.

A series of cloudbursts during the last part of July and the first of August 1919 caused short, sharp floods on St. Vrain Creek. The Lyons Recorder, August 2, 1919, describes these floods:

> The heaviest and most destructive cloudburst and downpour of water in the memory of the oldest inhabitant visited Lyons on Wednesday [July 30] between 2:30 and 3:45 p. m. It took out all the bridges on the North St. Vrain for about 5 miles up and 5 miles downstream. The Longmont and Lyons water mains up the canyon were torn out in many places. Not only were the bridges washed away, closing the road to Estes Park, but miles of road was torn out along the narrow canyon.
>
> The people living on the lowlands along the banks of the river were flooded out, and many abandoned their homes for higher ground and safety. It was no uncommon thing to see an automobile, bridge, barn, chicken house, and other small buildings going down the stream at a high rate of speed. North-side citizens * * * gave all the assistance possible to the residents [in the lower part of town] whose homes * * * were in a roaring sea of water 2 and 3 feet deep.

On the following day, July 31, another storm, not so severe but of longer duration, raised North St. Vrain Creek nearly as high as on the 30th and again flooded the houses in the lower part of town and washed out 300 yards of railroad track east of Lyons.

During an investigation of this flood made in 1939 the Geological Survey learned from the same resident who furnished information relative to the 1894 flood, that the water surface in 1919 reached the base of the rail near the gaging station on July 30, and rose again on July 31 to nearly the same point. The stage of July 30 increased the channel width by 8 feet. Using the present cross section and slope of water surface, the peak discharge which occurred about 4 p. m. July 30 was computed as 9,400 second-feet. The right bank was inundated for a width of 300 feet. The mean daily discharge for the period July 30 to August 3, when the St. Vrain Creek gaging station was out of commission, was estimated as follows:

Daily discharge of St. Vrain Creek, July 30–Aug. 3, 1919

		Second-feet
July	30	1,900
	31	1,200
Aug.	1	950
	2	1,000
	3	1,100

As these were cloudburst floods, the peak discharges were of short duration.

The widespread rains of June 2–7, 1921, caused a flood on St. Vrain Creek, reported as follows in the Lyons Recorder, of June 9, 1921:

> While Lyons experienced an extraordinary heavy rain during June 4–6, and both St. Vrain Creeks [North and South] carried large volumes of water, very little damage was done. We were very fortunate that very little water fell up either canyon, the rise coming from rains in the Longs Peak region and the natural melting of mountain snow.

The peak discharge recorded at Lyons was 2,020 second-feet, June 7. The rainfall was particularly heavy east of the mountains, as shown by the 5.87 inches recorded at Longmont, June 2–7. No estimate of the discharge at Longmont is available, but a dispatch to the Boulder Camera, June 7, 1921, stated:

> The St. Vrain Creek here is way out of its banks and is said by people who should know to be the highest in 25 years [evidently referring to the flood of 1894]. The Creek is carrying more water and is higher in this region than during the cloudbursts at Lyons 2 years ago. The Creek at this point is three-quarters of a mile wide. Water is up to the Farmers' Mill and the depot. All bridges in the city are out or dangerous.

The storm of September 2–4, 1938, was felt in the St. Vrain Creek Basin chiefly east of the mountains, as the peak discharge at the Lyons gaging station, which occurred at 1 a. m., September 3, was only 1,650 second-feet. At Longmont the precipitation for the 3-day period was 4.54 inches, and at Fort Lupton 3.99 inches. Below Lyons the discharge increased rapidly, owing to run-off from tributary streams, some of which are ordinarily dry gulches. Boulder Creek enters St. Vrain Creek 6 miles east of Longmont, and at that point the flood was increased by the peak discharge of 4,410 second-feet from Boulder Creek. The peak at the mouth of Boulder Creek occurred at noon September 3. Ten miles farther downstream, as measured along the valley, the peak discharge at the gaging station near the mouth of St. Vrain Creek was 8,360 second-feet at 6 p. m., September 3, as shown by a slope-area measurement made by L. T. Burgess, chief hydrographer of the State of Colorado. Lefthand Creek enters St. Vrain Creek three-quarters of a mile below Longmont; its peak discharge was 812 second-feet at 11 p. m., September 2, and at the time of the peak on St. Vrain Creek the flow from Lefthand Creek was about 400 second-feet. To show the comparative discharges during the flood, the mean daily discharge, in second-feet, at the various gaging stations is presented in the following table.

Daily discharge, in second-feet, in St. Vrain Creek Basin, Sept. 2–9, 1938

Gaging station	September							
	2	3	4	5	6	7	8	9
St. Vrain Creek at Lyons	407	1,370	818	572	451	362	331	270
Lefthand Creek at mouth, at Longmont	148	432	188	123	81	63	56	49
Boulder Creek at mouth, near Longmont	160	2,300	1,630	1,020	624	415	339	366
St. Vrain Creek at mouth, near Platteville	374	3,200	5,300	2,910	2,340	1,690	1,190	934

Below the mouth of Boulder Creek the bottomlands along St. Vrain Creek were overflowed to a considerable extent.

LEFTHAND CREEK

Lefthand Creek enters St. Vrain Creek a short distance below Longmont. The only flood of definite record is that caused by the heavy rains of May 29–June 1, 1894, when 6.80 inches was reported at Ward, located on the headwaters at an elevation of 9,200 feet. Referring to this flood, the Boulder Camera, June 2, 1894, states:

> From Boston Mill to Ward that little stream is a howling river. The railroad bridges and all wagon bridges over Lefthand Creek were washed out. Lefthand Creek is 300 yards wide a mile from Niwot [on the plains]. Old timers stated that this is the worst flood since 1864.

BOULDER CREEK

Boulder Creek drains the Front Range, and its fall for a distance of 10 miles upstream from Boulder is 229 feet per mile. Between Boulder and the mouth of the creek the drainage area is a part of the plains, where the fall in the 22 miles from the edge of the plains to the mouth is 26 feet per mile.

Gaging stations on Boulder Creek

Station	Drainage area (square miles)	Period of record
Near Orodell	105	August 1887 to October 1888; March 1907 to November 1914; February 1916 to date.
Near Boulder	134	April 1888 to October 1892; May 1895 to December 1901; July 1904 to December 1908.
At mouth, near Longmont	512	March 1927 to date.

During the periods of known floods on Boulder Creek no gaging station was in operation, and the information available consists chiefly of extracts from the press, with no estimate of discharge except for the flood of May 31, 1894, a study of which was made some years later by a firm of consulting engineers.

The widespread floods during June 1864 included Boulder Creek, for Watrous [22] states that Boulder Valley suffered severely.

The general storm of May 21–23, 1876, resulted in a flood on Boulder Creek, described in the Greeley Tribune, May 31, 1876, as follows:

> The Boulder, swollen into a great river, in places fully a mile and a half wide, inundated the land and farms and meadows and swept away fences and bridges. So far as heard, the damage to farms was not so great as the magnitude of the flood would seem to indicate.

The Denver Tribune, May 24, 1876, states that Boulder was without railroad service, as both railroads were out of commission.

The severe storm of May 29 to June 1, 1894, was heaviest in the Boulder Creek Basin, particularly in the Fourmile Creek area, and the resulting flood came chiefly from that tributary, which enters Boulder Creek about 2 miles above Boulder. Regarding the flow the Boulder Camera, May 31, 1894, stated:

> A great flood came pouring down Boulder Creek at an early hour this morning. Every vestige of a bridge has been swept away, and railroad tracks torn from their moorings. [The railroad followed the canyon to Fourmile Creek and continued up Fourmile Creek to Ward.] From the Boulder Hotel to the University hill * * * was one vast lake with here and there a small patch of an island.

The Denver Republican, June 2, 1894, carried a dispatch from Boulder, dated June 1:

> Boulder and Boulder County yesterday and today experienced the worst flood ever known in the history of that place. It had rained for over 2 days, and on Wednesday night [May 30] it came down in great volumes. The melting snow which generally starts the flood in June was melted so much faster on account of the rains that it swelled the mountain stream beyond anything dreamed of. In the canyon the rush of the stream was maddening and nothing could stay its downward course. Waterspout after waterspout seemed to break on the hillsides and added to the fearfully swollen streams.

Prof. Junius Henderson, writing of this flood of 1894 in the Boulder Camera, November 15, 1921, says that as great damage was wrought in the canyon above Boulder as in Boulder itself. All bridges were swept away, and the highway and railroad almost totally destroyed as far up the canyon as Fourmile Creek, and up Fourmile Creek to Sunset. He quotes the press as stating that in Fourmile Canyon six buildings were destroyed at Crisman, eight at Sunset, and practically everything was swept away or destroyed at Copper Rock.

In 1912 the Boulder City Improvement Association employed Metcalf & Eddy, consulting engineers of Boston, who during the course of their studies made an estimate of the peak discharge of the 1894

[22] Watrous, Ansel, History of Larimer County: Conner Printing & Publishing Co., Fort Collins, Colo., 1911, p. 213.

flood in Boulder. Their report to the Association, dated April 27, 1912, contains the following statement:

The most reliable record of extreme flood level was that obtained through the courtesy of the officials of the Denver, Boulder & Western Ry., upon one of the wooden-trestle bridges crossing Boulder Creek near 4th Street. Here the wide crossing is fairly uniform in character for a considerable distance above and below the trestle. The slope is approximately 1.1 percent. The reported depth was about 10 feet at this flood level. [Later reports indicate an area of about 800 square feet, and that this depth may have been as much as 11 feet.]

We estimate the discharges corresponding to these elements to have been approximately 12,000 second-feet [or 13,600 second-feet with a depth of 11 feet]. In view of what has been said concerning the pooling action of the water at the bridges, it is possible, however, that the discharge may have been somewhat less than this—perhaps between 9,000 and 10,000 second-feet. [This discharge is computed with a value of n=0.035.]

On June 2, 1914, another flood occurred in this area. This was caused by rainfall on June 1 of more than 1 inch on the North Boulder Creek Basin near Silver Lake, at an elevation of 10,200 feet. This rainfall hastened the melting of the snow, which during the preceding winter had been 50 percent above normal. The Boulder Camera, June 2, 1914, described the flood as follows:

All bridges between Colburn Mill and Boulder Falls were washed out, numerous others were badly damaged, several hundred feet of main line of Boulder's water system was destroyed, and thousands of dollars worth of damage was done to Boulder County farm land last night and today by Boulder Creek, which has been on a rampage for the past 18 hours. * * * The flood was the worst Boulder has experienced since 1894, when all of the lowlands lying between Water Street and University Hill were flooded.

According to Water Commissioner James Platt, the creek raised 2 feet 2 inches, the greatest flow [stage] during the night measuring 5 feet 6 inches. The 2 feet raise meant an increased water flow of from 2,000 to 3,000 cubic feet [per second], bringing the total flow up to over 5,000 cubic feet [per second]. This is nearly 4,000 cubic feet [per second] greater than normal.

Precipitation for June 7–10, 1923, amounted to 3.27 inches at Boulder, the only station reported in the Boulder Creek Basin. This storm did not extend 3 miles west to the gaging station near Orodell, as the discharge at that station was less than 700 second-feet during this period. The Boulder Camera, June 9, 1923, said:

Both Middle and South Boulder Creeks have left their banks near Valmont and are cutting between the two bridges of the Valmont road. Water is running over the Valmont road for a stretch of several hundred feet. Twomile Canyon in North Boulder is reported to be doing great damage to the section lying between Wellington Heights and Eighth Avenue.

During the storm of September 1–4, 1938, the basin of Boulder Creek east of the mountains received precipitation amounting to 3.38 inches at Boulder, and 3.99 inches at Fort Lupton near the mouth.

Very little precipitation occurred in the upper part of the basin, as at the Orodell gaging station the peak discharge, which occurred at midnight September 2, was only 642 second-feet. The effect of this rainfall on the stream flow was felt at the gaging station near the mouth, where a slope-area measurement made by the office of the State engineer indicated a peak discharge of 4,410 second-feet. This peak occurred at noon on September 3. It was caused chiefly by the flood from South Boulder Creek which, about 10:30 p. m., entered Boulder Creek at a point about 18 miles above the gaging station near the mouth. The effect of channel storage was indicated by the fact that the discharge of 8,500 second-feet at Eldorado Springs plus an undetermined but very considerable flow from Boulder Creek above South Boulder Creek was reduced to a peak of 4,410 second-feet at the gaging station near the mouth. The total discharge for the 3-day period, however, increased from 4,250 acre-feet at the Eldorado Springs and Orodell stations to 9,900 acre-feet at the mouth. Prior to 1938 the greatest discharge at the mouth of Boulder Creek since the establishment of that station in 1927 had been 860 second-feet, on May 28, 1935. Little or no overflow occurred in Boulder, but at Erie, below the mouth of South Boulder Creek, the flood reached the town, and many residents left their homes for higher ground.

SOUTH BOULDER CREEK

The only recorded flood on South Boulder Creek occurred September 2, 1938. A gaging station has been maintained on this stream near Eldorado Springs since 1888, with some lapses, but the earlier records do not indicate any floods. The station was not in operation during 1894, when floods were prevalent throughout northern Colorado; it is probable that a flood occurred at that time, but no information regarding it is available.

The earliest reference to a flood on South Boulder Creek is to the one in June 1923, caused by the heavy rains of June 7–10. The rainfall at Eldorado Springs was 3.15 inches during that period. The Boulder Camera of June 9, 1923, stated that, owing to the flood, the Interurban Bridge across South Boulder Creek was considered so dangerous that service between Boulder and Louisville was stopped. Also, South Boulder Creek had overflowed its banks at Valmont.

A series of cloudbursts along the foothills of the Front Range, September 2, 1938, caused a flood on South Boulder Creek at Eldorado Springs, at the mouth of the Canyon. The Weather Bureau observer at that point stated that the rain causing the flood started about 6:30 p. m., September 2 and was particularly heavy until 2 a. m., September 3, when it lessened materially but continued during that day. The

total rainfall was 4.42 inches. Phillip Kneale, who was living 2 miles above Eldorado Springs, in sec. 26, T. 1 S., R. 71 W., stated that the rain began at 4 p. m., September 2 and was heavy until 10 p. m., being succeeded by a "slow" rain that lasted until the morning of September 4. By means of a bucket in his yard he measured about 6 inches of precipitation during the entire storm. This storm occurred after 2 days of rain which at Eldorado Springs amounted to 0.60 inch on September 1, and 0.80 inch on September 2. That the cloudburst was confined to the foothills is indicated by the fact that at Pinecliff, 8 miles west, at an elevation of about 8,000 feet and about 2,000 feet higher than Eldorado Springs, only a light shower was reported.

The Geological Survey made an investigation of this flood within a few days, and computed the peak flow over a dam a quarter of a mile above Eldorado Springs. The velocity of approach was determined by the slope of the water surface above the dam, as indicated by high-water marks. The peak flow was found to be 8,180 second-feet. A slope-area measurement made at Eldorado Springs indicated a discharge of 8,540 second-feet.

The State engineer, in cooperation with the Geological Survey, maintains a gaging station 1¼ miles above Eldorado Springs. L. T. Burgess, chief hydrographer of Colorado, made a slope-area measurement at the gaging station and found the peak flow at that point to be 7,400 second-feet. The stages on the recorder chart indicated the following discharges during the flood:

Discharge of South Boulder Creek near Eldorado Springs, Sept. 2–3, 1938

	Second-feet		Second-feet
Sept. 2, 7 p. m.	90	Sept. 2, 11:30 p. m.	5,800
7:30 p. m.	470	Midnight	4,900
8 p. m.	970	Sept. 3, 1 a. m.	3,900
8:30 p. m.	1,850	2 a. m.	3,100
9 p. m.	3,500	3 a. m.	2,400
9:30 p. m.	5,500	4 a. m.	1,800
10 p. m.	7,400	5 a. m.	1,300
10:30 p. m.	7,400	7 a. m.	1,020
11 p. m.	6,900	10 a. m.	855

Eldorado Springs is a summer resort at the mouth of a narrow canyon. Because of lack of space some of the resort buildings extend over the creek, and the flood, by undermining their foundations, wrecked these buildings. In addition, several residences not over the creek were carried away by the flood. The four bridges in Eldorado

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Springs were destroyed. The Boulder County Miner and Farmer, September 8, 1938, reports:

All the way from Eldorado Springs down the creek, there is destruction—trees, fences out, fertile soil washed away, large rocks deposited on tillable ground, bridges out, gardens ruined, and debris of all kinds.

THOMPSON RIVER

Above a point about 5 miles west of Loveland the Thompson River drains the Front Range, but below that point it leaves the mountains and crosses the plains for a distance of 29 miles to its mouth. Through the lower 13 miles of its mountain course the river has a fall of 55 feet per mile, and across the plains its average fall is 25 feet per mile.

Gaging stations on Thompson River

Station	Drainage area (square miles)	Period of record
Near Estes Park	158	June 1930 to date.
Near Drake	273	September 1917 to December 1926.
Below power house, near Drake	277	October 1928 to date.
Mouth of canyon near Drake	302	March 1927 to September 1930; April 1938 to date.
Near Arkins [1]	305	April 1888 to September 1892; May 1895 to September 1906; April 1902 to September 1911.
At mouth, near La Salle	818	April to November 1914; March 1927 to date.

[1] Large diversion just above Arkins.

During the widespread floods of May and June 1864, the lowlands in the Thompson Valley were submerged, settlers' cabins washed away, and meadows destroyed.

The general storm of May 31–June 1, 1894, caused a flood which destroyed the Home Supply Co.'s dam near the mouth of the canyon. The Loveland Reporter of June 7, 1894, stated:

Flood destroyed the Home Supply dam, its solid masonry having proved insufficient to cope with the immense volume of water. This immense body of water tearing along the river bed was bound to create havoc among the people. The Big English ditch went on a rampage. When it was cut, and its water joined the Big Thompson, the latter was fully half a mile wide and increasing.

During the operation of the Arkins station, located 600 feet below the diversion for the Home Supply ditch, near the mouth of the canyon and 9 miles west of Loveland, the highest discharge recorded was 6,000 second-feet during the flood of July 7, 1906, which washed out the bridge at the station. No additional information is available except that the mean discharge for July 7 was 2,600 second-feet, indicating that the peak, although lasting longer than that caused by a cloudburst, did not continue for more than a few hours.

During the period of operation of the other gaging stations, the maximum stage of 9.5 feet occurred below Loveland Dam, 1½ miles east of Drake, at 6 p. m. July 31, 1919, caused by a cloudburst a short

distance above Drake. The peak discharge of 8,000 second-feet was of such short duration that the mean daily discharge for July 31 was only 490 second-feet, and for August 1, only 311 second-feet. This cloudburst, which occurred during the storm that caused the flood on St. Vrain Creek, resulted in a flood on Thompson River, which was described by the Loveland Daily Herald, of August 1, 1919, as follows:

> With a rush and a roar a 10-foot wall of water swept down through the Big Thompson canyon between 7 and 8 last night after one of the worst cloudbursts in the history of this canyon. * * * The water came down, sweeping logs, planks, and bridges before it in a mad swirl. * * * The road bed was washed out to bedrock. During the worst of the flood, the entire road bed was covered with 2 feet of water, except at the highest points.

As no mention is made of damage on the plains area east of the canyon, it is evident that the peak was reduced rapidly by channel and valley storage.

In the Thompson River Basin the general rains of June 2–7, 1921, were heaviest east of the mountains. At Estes Park the precipitation for the 4-day period June 2–5, was only 2.05 inches. East of the mountains, the precipitation was 5.29 inches at Longmont and 3.02 inches at Fort Collins. High water destroyed the recorder at the Drake gaging station, and no data regarding the peak discharge are available. The heavier precipitation east of the mountains increased the flow of Thompson River very materially and caused it to overflow its banks. The Lyons Recorder, June 9, 1921, stated that at a point near the river about half a mile from Loveland a house, with its occupants, was washed from its foundation and carried nearly half a mile downstream, lodging in a grove of trees.

From June 7 to 10, 1923, rains occurred again over the Thompson River Basin. Near Longs Peak in the upper part of the basin the rainfall was 2.55 inches on June 9 and 2.99 inches for the 4-day period. At Waterdale, at the mouth of Buckhorn Creek, which enters Thompson River east of the main canyon but between two of the several hogbacks forming the foothills, the precipitation was 1.97 inches on June 9, and 2.80 inches for the 4-day period. A record of 1.27 inches at Greeley for the 4-day period indicated that the precipitation was considerably less east of the mountains. During this period the peak discharge recorded at the gaging station near Drake was 3,590 second-feet at 6 p. m. June 9 and at 6 a. m. June 10. Only two staff-gage readings per day are available, however, and it is probable that the discharge was greater during the night of June 9–10. The precipitation below the gaging station evidently increased the flow of the river very considerably, as indicated by the report in the Loveland Reporter-Herald of June 9, 1923:

> At four o'clock (today) floodwaters from the Big Thompson, which has over-

flowed its banks in a number of places, had reached West First Street in the city and covered a large portion of ground occupied by road-making machinery. The cement paving south of Loveland is covered with water to a depth of over a foot. The Estes Park road and the valley near the plaster mills are covered.

The water commissioner estimated that the flow of the river below the canyon was 7,000 second-feet, of which 5,000 second-feet was being diverted into storage reservoirs.

One of the areas of heaviest precipitation during the general storm of September 1938 was the foothills part of the Thompson River Basin as far east as Fort Collins. Records of precipitation in or near the Thompson River Basin for the period September 1–4, as reported by the Weather Bureau are given below.

Precipitation, in inches, in Thompson River Basin, Sept. 1–4, 1938

Station	Altitude (feet)	September				Total
		1	2	3	4	
Estes Park	8,000	0.12	0.71	1.93	0.19	2.95
Near Longs Peak	8,956	.09	.30	2.50	.27	3.16
Waterdale	5,206	----------	5.35	3.22	.47	9.04
Fort Collins	4,985	.32	1.14	3.54	.09	5.09

The operator at the Loveland filter plant, 7½ miles west of Loveland and 2 miles west of Waterdale, had a small rain gage formerly used by the Weather Bureau. He reported precipitation as follows:

Precipitation at Loveland filter plant

	Inches
Sept. 1, 4.15 p. m. to 7:15 p. m	3.25
Sept. 1, 7:15 p. m., to Sept. 2, 6 a. m	2.00
Sept. 2, 6 a. m. to Sept. 3, 6 a. m	2.90
Sept. 4	.58
	8.73

A second storm, consisting chiefly of a series of cloudbursts, occurred in the foothills area September 10, 1938. Like the storm earlier in September, its effect was chiefly on the tributary streams, where sharp flood flows of short duration resulted. At a point on Redstone Creek, 6½ miles above Masonville, a rancher stated that during this storm a 10-inch bucket in the yard was filled and ran over. In spite of the heavy precipitation, no outstanding flood occurred on the Thompson River; the peak discharge at the gaging station near the mouth of the canyon was 5,600 second-feet, and at the gaging station near the mouth of the river 3,000 second-feet. This was due partly to the fact that the extensive reservoir system in the Thompson Valley diverted the water during this period. The chief damage from flood

was to the recently completed highway in the canyon, which was washed out in 10 places. In its lower course the river overflowed its banks, particularly below the mouth of Little Thompson River.

The intense precipitation caused floods on several tributary streams in the foothills, and these were investigated by the Geological Survey. Dixon Gulch, draining an area of 2.15 square miles, enters Thompson River at the head of Loveland Canyon 2 miles above the canyon gaging station and 3½ miles above the Loveland Reservoir filter beds. Heavy precipitation caused a sharp rise at 7 p. m. September 1, which lasted only about 10 minutes. A slope-area measurement made near the mouth of Loveland Canyon showed a peak flow of 3,620 second-feet, or 1,680 second-feet per square mile. This flood undoubtedly was a contributing factor to the peak flow of 5,600 second-feet at 8 p. m. on the Thompson River at the canyon station. Green Ridge Glade, a small gulch that enters Thompson River at the filter beds, had a peak discharge of 980 second-feet at 7:15 p. m. September 1, as determined from high-water marks of discharge through a 7-foot concrete pipe. This represented a unit run-off of 778 second-feet per square mile. Two slightly smaller peaks occurred during the night of September 1–2; these were estimated at about 950 second-feet each. Dry Creek, ordinarily a very small stream draining the foothills south of Thompson River, which it enters midway between Buckhorn Creek and Loveland, was reported by the Water Commissioner to have had a discharge of 1,500 second-feet.

Cedar Creek, which enters Thompson River three-quarters of a mile above Dixon Gulch, had a flood about 7 p. m. September 3, of sufficient volume to wash out the bridges over the creek. The rainfall was very heavy near the mouth of the creek but did not extend very far up Thompson River above it. A second flood on Cedar Creek about 7 p. m., September 10, was higher than that of September 3. A slope-area measurement of this flood at the mouth of the creek in sec. 8, T. 5 N., R. 70 W., showed a peak discharge of 2,940 second-feet, or 156 second-feet per square mile from a drainage area of 18.9 square miles.

BUCKHORN CREEK

The lower part of the area drained by Buckhorn Creek, consists of three narrow troughlike valleys lying in the foothills west of Loveland. This part is subject to cloudbursts. Buckhorn Creek has a fall of 42 feet per mile from its mouth to Redstone Creek, and 93 feet per mile for a distance of 8 miles above Redstone Creek. Redstone Creek has a fall of 99 feet per mile, for a distance of 7 miles above its mouth. Missouri Canyon which enters Buckhorn Creek 3 miles below Masonville, has an average fall of 147 feet per mile.

Subsequent to the general storm over the Thompson River Basin,

June 7–10, 1923, heavy rains occurred June 14–16 over an area extending from a point a few miles east of Greeley to the western edge of R. 70 W. in the foothills region, and appeared to center over the lower part of Buckhorn Creek Basin. The resulting flood, the highest known on Buckhorn Creek and several of its tributaries, was investigated within a few days by the Geological Survey, and the results were published.[23] The area affected extended from the mouth of Buckhorn Creek to a point 5 miles above Masonville and a short distance above the mouth of Missouri Canyon. A 30-minute rainfall of 2½ inches was measured in a tub.

The following table shows the peak discharge at the three points measured:

Peak discharge in Buckhorn Creek Basin, June 15, 1923

Stream	Location	Drainage area (square miles)		Peak discharge		Time of flood crest
		Total	Area producing flood	Second-feet	Second-feet per square mile of area affected	
Buckhorn Creek	Half a mile south of Masonville	134	40	10,500	262	10 p. m.
Redstone Creek	Masonville	31	21	6,820	325	10 p. m.
Missouri Canyon	Near mouth, sec. 26, T. 6 N., R. 70 W.	2.4	2.4	4,350	1,810	6:30 p. m.

A peak discharge of almost equal amount occurred on Buckhorn Creek following the storm of September 1, 1938, in the foothills area. The area of precipitation did not extend more than 2 miles above Masonville on the main stream, but in the tributary basin of Redstone Creek, the storm extended practically to the head of the basin. A slope-area measurement of the flood on Redstone Creek, which occurred at 10 p. m. September 1, was made a quarter of a mile above its mouth, and the peak discharge was determined at 8,400 second-feet, or 271 second-feet per square mile from a drainage area of 31 square miles. The peak discharge of Buckhorn Creek at a point 2½ miles below Masonville was 10,200 second-feet, or 196 second-feet per square mile from the 52 square miles affected by the storm. The greater part of this flow was absorbed by Buckhorn Reservoir, which is located a mile below the point of measurement, and has a capacity of 650 acre-feet.

During the storm of September 10, 1938, a cloudburst centered over Missouri Canyon. A rancher living in sec. 23, T. 6 N., R. 70 W., 1½ miles above the mouth of Missouri Canyon, measured in a straight-sided can a rainfall of about 5 inches, which occurred between 6 and

[23] Follansbee, Robert, and Hodges, P. V., Some floods in the Rocky Mountain region; U. S. Geol. Survey Water-Supply Paper 520, pp. 123–124, 1925.

7 p. m., September 10, most of it within 20 minutes. Another rancher who lives 1 mile above the mouth of Missouri Canyon measured in a straight-sided can about 7 inches of rain which fell within half an hour. Half a mile south, a rainfall of 2½ inches was reported. A slope-area measurement of the flow of Missouri Canyon in sec. 26, T. 6 N., R. 70 W., showed a peak discharge of 2,130 second-feet from a drainage area of 2.37 square miles, or 899 second-feet per square mile.

CACHE LA POUDRE RIVER

Above Bellvue the Cache la Poudre River drains the Front Range, and for a distance of 13 miles above the gaging station at the mouth of the canyon the fall is 63 feet per mile. Across the plains from the mouth of the canyon to the mouth of the river, a distance of 41 miles, the fall is 16 feet per mile.

Gaging stations in Cache la Poudre River Basin

Station	Drainage area (square miles)	Period of record
North Fork Cache la Poudre River at Livermore.	541	May 1929 to September 1931.
Cache la Poudre River at mouth of canyon, near Fort Collins.	1,048	March 1884 to date (earlier years fragmentary).
Cache la Poudre River near Greeley	1,840	March 1903 to November 1904; February 1914 to December 1919; May 1924 to date.

In connection with meager evidence of a widespread flood in 1844, Watrous [24] quotes a letter from Antoine Janis, a French trapper who was living on the river near the present town of Laporte:

On the first of June, 1844, I stuck my stake on a claim in the valley. * * * At that time the streams were all very high and the Valley black with buffalo.

In the same volume Watrous refers to a flood in 1864:

Fort Collins, the county seat and principal town in Larimer County, owes its origin and first place on the map to the intervention of a flood in the Cache la Poudre River. This flood occured on the last days of May and first days of June 1864 and is said to have been the worst known by white men. The water poured out of the banks of the stream and inundated the valley from bluff to bluff with a torrent that carried everything not firmly attached to the soil with it.

It carried out the toll bridge at Laporte at a time when the movement of emigration westward was the heaviest, and more than 200 emigrants were stalled on the bluffs south of Laporte, being unable to ford the stream because of high water. * * *

In the spring of 1864, under the influence of the sun's warm rays, the great masses of snow melted on the hillsides and torrents of water came pouring down from the slopes into the channel of the Cache la Poudre, swelling the stream even with its banks. On the 9th of June, an extraordinary rainstorm set in on the watershed of the upper part of the river, melted the snow in the higher altitudes

[24] Watrous, Ansel, History of Larimer County: Conner Printing & Publishing Co., Fort Collins, Colo., 1911.

and an enormous volume of water laden with driftwood, poured into the already swollen channel, and the sullen roar of the rushing stream as it burst out of the canyon was heard for a long distance. On reaching the plains, the water spread out and submerged the bottom lands from bluff to bluff to a depth of several feet. The storm occurred in the afternoon and the raging torrent, plunging like the waves of the sea under the impulse of a gale, swept down through the soldiers' camp [at Laporte] in the night almost without warning. * * * When morning broke a scene of desolation presented itself to view. The campgrounds were completely submerged and only the roofs of the cabins that had withstood the onrush of water were visible, while as far as the eye could reach up and down the river nothing but a raging sea of muddy water could be seen. Fortunately, no lives were lost, but there were several narrow escapes by the settlers on the bottom lands.

Watrous also quotes a letter from Lt. Col. W. O. Collins, written August 21, 1864, to Gen. R. B. Mitchell:

The present site [of the military post] is within the town of Laporte. * * * The ground is subject to overflow, the whole having been under water and much public property damaged about the 10th of June last.

Concerning the storm of May 22 and 23, 1876, the Greeley Tribune of May 24, 1876, stated:

The Cache la Poudre is higher than at any time since the settlement of the colony [1870]. It is reported that two bridges on the [Big] Thompson have been carried away by the flood. The river bottom between Greeley and the Jackson Street Bridge is all under water. At the Oak Street Bridge the water was up to the caps; at 6 p. m. last evening [May 23] it had fallen 2 inches. From [Fort] Collins we hear that the river had fallen considerably so that our bridges may now be considered out of danger.

The melting of the unusually heavy snow cover of the winter of 1883–84 caused a total discharge for the year that was more than 200 percent of the average annual discharge for the period 1884 to date. The recording gage which had been established in the spring of 1884 at the mouth of the canyon was washed out a few days before the highest discharge, which occurred on June 28; therefore no complete gage-height record of this flood exists. At a later date the discharge during the period of missing gage heights was estimated, the maximum 24-hour discharge on June 28 being estimated at 5,610 second-feet. By comparison with peak flows of floods in later years this was not a large flood. The only known reference to overflow during the 1884 high water is the statement in the Fort Collins Express, June 17, 1923, that in 1884 the Boyd farm northwest of Greeley was entirely under water for the first time.

The failure, June 9, 1891, of the wasteway at the Chambers Lake Reservoir on the headwaters of the Cache la Poudre River caused a severe flood on that river. According to the local newspaper, the break was apparently caused by increased melting of the mountain snow, due to the warm weather a few days before. This flood de-

stroyed the recorder at the gaging station near the mouth of the canyon, hence no official record is available. The water commissioner, who was the observer, stated that the peak discharge was about 21,000 second-feet.[25] This estimate was evidently based on a high-water mark and the extension of the rating curve. Although the recorder was destroyed, a record of the mean daily discharge during the flood period was maintained, presumably by means of a staff gage, and the mean daily discharge for the entire month was computed. That for June 7–14 is as follows:

Discharge of Cache la Poudre River, June 7–14, 1891

	Second-feet		*Second-feet*
June 7	1,900	June 11	3,060
8	2,440	12	2,640
9	5,060	13	2,190
10	3,600	14	1,860

The Fort Collins Courier, in its issue of June 11, 1891, gives the following account of this flood:

About 4 p. m. June 9, the water superintendent was notified that a terrific flood was rushing down the [Cache la] Poudre canyon carrying everything before it.

On came the mad, rushing torrent toward the plains, with deafening roar, carrying everything in its way to destruction. Bridges, fences, headgates, buildings, cattle, and horses were swept into the whirling, roaring, rushing flood. The island below the LaPorte bridge, on which lived J. J. Nugent and family, was completely submerged, the water covering the floor of Mr. Nugent's house to a depth of 2½ feet.

The flood reached the railroad bridge north of the city [Fort Collins] about 5 p. m. * * * The bottomlands between the millrace and river were nearly all under water. The meadows and fields on the north and east side of the river were flooded.

An eye witness of the flood as it broke through the Poudre canyon says the wall of water was fully 10 feet high and that logs and trees were tossed about like twigs.

The flood of May 20–21, 1904, was the greatest on the Cache la Poudre River for which definite evidence is available. It was caused by heavy rains of cloudburst intensity in the foothills on the headwaters of the North Fork Cache la Poudre River and Boxelder Creek at an altitude of about 7,000 feet. The only rainfall records in this area were those at Alford (altitude 6,350 feet), and at Boxelder (altitude 7,160 feet). The Alford record showed a precipitation of 2.66 inches for the 2-day period May 19–20. As the upper foothills are at a higher altitude, the Alford record does not represent the greatest precipitation in the area. The record at Boxelder indicated a total of 8 inches for the 2-day period, but the Weather Bureau rejected this record as excessive. In view of the flood which followed, however, it would appear that the record was not greatly in error, especially as the

[25] Colorado State Engineer, 6th Bienn. Rept., p. 22, 1893.

observer stated that the storm was the worst that had occurred in that region in years.

J. A. Armstrong,[26] irrigation engineer, investigated the flood on the North Fork Cache la Poudre River, and the following is abstracted from this report:

> The floods down these creeks were caused by a continuous heavy rain, or a succession of cloudbursts commencing before noon of the 20th and lasting 5 or 6 hours, centering about Stonewall Mountain at the head of Stonewall Creek. This area is entirely clear of timber or forest growth of any kind. Stonewall, Dale, and Lone Pine Creeks are all tributary to the North Fork Cache la Poudre River. The flood was down into Livermore, only a few miles, almost before anyone could remove anything out of the way, and had it been at night, there would probably have been great loss of life as well as property. The volume of water passing Livermore has been estimated at 20,000 cubic feet per second.

The flood reached the Cache la Poudre River early in the afternoon of May 20 and was augmented above Fort Collins by floods from Dry Creek, Hook Canyon, and Moore Canyon. In describing the flood below the canyon the Greeley Tribune of May 26, stated:

> About the first warning of danger that people up the valley had was when a wall of water 10 to 14 feet high burst out of the Poudre Canyon [early in the afternoon], a couple of miles above Laporte. As quick as possible word was telephoned to Fort Collins of the coming flood, and the people of Laporte sought safety on high ground. When the water reached the open valley it spread over a surface of about a mile and its speed was somewhat slackened.

The flood reached Fort Collins late in the afternoon May 20 and continued for about 3 hours, during which time about 150 houses in the lowlands, occupied by Russian beet workers, were swept from their foundations and carried some distance downstream. All bridges but one in Fort Collins were destroyed.

Five miles below Fort Collins the flood from Boxelder Creek entered the Cache la Poudre River. Concerning Boxelder Creek the Greeley Tribune stated:

> The Boxelder, a small stream ordinarily only a few feet wide, was tearing down through a fertile valley filled from bluff to bluff with a sheet of water a mile wide, carrying buildings and bridges away in its mad rush.

Below the mouth of Boxelder Creek the flood waters of the two streams reached a width of 1½ miles in places.

The flood reached Greeley about 8:30 the next morning, May 21, and as the channel was too small to carry it, and the culvert under the Union Pacific Railroad tracks was also inadequate, the water backed up and overflowed a large area in the city. Below the railroad the lowlands were also overflowed, and the houses in that area were submerged to their window sills. Flood stage continued until noon, when the water fell almost as rapidly as it had risen.

[26] Armstrong, J. A., Flood on Cache la Poudre River: U. S. Geol. Survey Water-Supply Paper 147, pp. 154–156, 1905.

The somewhat widely held view that the dam at Chambers Lake failed and that its failure was an important factor in the flood of 1904 has been found erroneous. Chambers Lake Dam failed, not in 1904, but in 1907.

In Armstrong's report (see p. 54) no statement was made regarding the flood in the canyon of the Cache la Poudre River below the mouth of North Fork and above Hook and Moore Canyons. The gaging station in that section of river was destroyed by the flood, therefore no gage-height record exists.

Testimony regarding the relative magnitude of the flood of 1904 and that of 1864 is conflicting. Armstrong's report states that people living in the valley since 1859 reported that the flood of 1904 was about 1.5 feet higher than the flood of 1864. On the other hand, the Fort Collins Express, May 25, 1904, quotes J. J. Coy, who lived at the same place near the river during both floods, as being sure that the flood of 1904 was greatly exceeded by that of 1864 and that, although the channel was wider and carried more water in 1864 than in 1904, the flood of 1864 reached a higher point on his property.

The widespread storm of June 2–7, 1921, covered the Cache la Poudre River Basin, but was not severe in the upper part, above the canyon gaging station, nor at the mouth, as is shown by the following records:

Precipitation, in inches, in Cache la Poudre River Basin, June 2–7, 1921

	Altitude (feet)	*Precipitation (inches)*
Frys Ranch (above station)	7, 500	1. 71
Laporte	5, 063	3. 74
Fort Collins	4, 985	3. 64
Greeley	4, 637	1. 86

Mean daily discharge of Cache la Poudre River at gaging station at mouth of canyon, June 2–14, 1921

[From reports of State Engineer of Colorado]

	Second-feet		*Second-feet*
June 2	2, 660	June 9	4, 520
3	2, 780	10	4, 450
4	3, 850	11	4, 450
5	3, 480	12	4, 450
6	3, 340	13	4, 080
7	3, 620	14	3, 700
8	4, 680		

The heavy rainfall at Laporte and Fort Collins caused a considerable increase in the discharge below the canyon, as shown by the following statement in the Loveland Daily Herald of June 9, 1921:

The [Cache la] Poudre River, which has been high for the last 2 days, is dropping slowly. It is thought that the danger from a flood is over. For some time,

however, the water was bank high, and 3 inches would have put it over the bottoms.

At 2 o'clock Thursday morning [June 9] the [Cache la] Poudre was a raging torrent, threatening homes in "Jungles" district of Fort Collins and farm lands to the south and east. Within a fraction of a foot of high-water mark reached at dawn Wednesday morning [June 8]. It seemed inevitable that all former records would be broken and considerable damage done.

Subsequent issues of the newspaper contain no statement regarding the river, which indicates that it subsided without breaking any records. By the time the flood reached Greeley the peak had been so reduced that little or no overflow occurred.

The flood of June 1923 was caused by a combination of melting snow and heavy rains. At the end of March, when the last report for the season was made, the snow cover was about 50 percent above normal. During April the precipitation and temperature were below normal. During May the temperature was below normal, but the precipitation was considerably above, being 1.5 to 1.6 inches above normal at the three stations in the basin. Thus it is evident that the snow cover on June 1 was markedly above normal, although no record of its depth has been found. June was one of the wettest months on record, precipitation occurring almost every day beginning the 2d and culminating in severe rains on the 9th. After a lapse of several days, rain again fell on the 14th and 15th.

Daily precipitation, in inches, in Cache la Poudre River Basin, June 1–18, 1923

June	Frys Ranch (altitude 7,500 feet)	Laporte (altitude 5,063 feet)	Fort Collins (altitude 4,985 feet)	Estes Park (altitude 8,000 feet)	Near Longs Peak (altitude 8,956 feet)
1					
2			0.30	Tr.	
3				0.12	
4		0.38	.53	.04	0.33
5			.17		.35
6	0.60	.37	.44	.05	.25
7	Tr.	.06	.08	.20	.24
8	.30		.05	.50	.15
9	.80	2.28	2.30	1.45	2.55
10	2.10		.23	.10	.05
11	.10	.21	.01	.06	
12	.10			.13	
13	Tr.				
14		.88			
15		1.01	1.41		
16			.66	.25	.15
17	.30				
18			Tr.		

These Weather Bureau records do not show the heavy rains of cloudburst intensity which occurred June 15 in the Buckhorn Creek Basin just south of the Cache la Poudre River Basin and which extended into the Cache la Poudre River Basin above the gaging station at the mouth of the canyon, as recorded by the local press.

The daily discharge of the Cache la Poudre at the canyon gaging station, was as follows:

Daily discharge of the Cache la Poudre River, June 1–30, 1923

[Data from report of Colorado State Engineer]

June	Discharge (second-feet)	June	Discharge (second-feet)
1	2,160	16	7,550
2	2,260	17	5,800
3	2,190	18	4,270
4	2,200	19	4,000
5	2,180	20	3,740
6	2,060	21	3,240
7	2,010	22	2,920
8	2,160	23	3,000
9	5,620	24	2,670
10	7,350	25	2,920
11	6,180	26	2,780
12	4,540	27	2,620
13	4,540	28	2,480
14	4,540	29	2,330
15	[1] 6,460	30	2,480

[1] Peak discharge, 8,550 second-feet.

Regarding the flood of June 15–16, the Fort Collins Express, June 16, 1923, stated:

Fed by mountain cloudbursts and heavy general rains, the [Cache la] Poudre River last night in 2 hours became a raging torrent. Cloudbursts, one at Livermore and another at a point not far away from there, late in the afternoon sent a wall of water down the canyon. At Laporte and Fort Collins the river rose 2 feet in as many hours.

In its issue of June 17, 1923, the Fort Collins Express published a dispatch from Greeley which read:

High water on the [Cache la] Poudre second only to the flood of 1904, tonight shut off all travel on highways north and west of the city and had driven a score of families from their homes on the lowlands. The south channel of the [Cache la] Poudre is within a few inches of the Union Pacific track between here and Cheyenne. Three feet of water has driven tourists from their camp ground in the bottoms. The Boyd farm northwest of here was entirely under water for the first time since 1884.

Heavy rains in the North Fork Cache la Poudre River Basin, May 31, 1930, caused the highest flood on the North Fork since 1904 and a flood on the Cache la Poudre River at the canyon gaging station that ranked third in the list of known floods in that area. The Geological Survey investigated the flood on the North Fork Cache la Poudre River within a few days. The storm that caused the flood appeared to originate in the foothills southwest of Livermore, where the altitude ranges from 7,000 to 7,500 feet. It traveled northwest, releasing heavy precipitation about 7 miles northwest of Livermore, and ended in a hailstorm that covered the ground with hail to a depth of several inches. At Livermore the rain started at 3 p. m. and continued until 6 p. m., with the heaviest fall about 5 o'clock. No record of the amount of precipitation is available. The North

Fork Cache la Poudre River started to rise about 5 p. m. and reached its peak an hour later at a stage of 9.82 feet on the Livermore gage. The river remained high until 8 p. m., then dropped rapidly. The peak discharge was 6,800 second-feet, as determined by a slope-area measurement. A small area at Livermore was inundated. The mean daily discharge was as follows:

Mean daily discharge of North Fork Cache la Poudre River, May 30 to June 6, 1930

	Second-feet		Second-feet
May 30	150	June 3	298
31	1,670	4	241
June 1	451	5	219
2	355	6	179

Between Livermore and the canyon gaging station on the Cache la Poudre River about 14 miles downstream, the flood traversed a narrow valley terminating in a canyon with little or no channel storage. The flood reached the canyon station at 8:15 p. m., May 30, and destroyed the gage recorder, but from the high-water marks the peak stage was found to be 7.9 feet gage height and the peak discharge 10,200 second-feet. The Fort Collins Express-Courier, June 1, 1930, states that the storm, which extended into the upper basin of the Cache la Poudre River, was not sufficient to increase materially the flow above the mouth of North Fork. That flow was about 2,000 second-feet, indicating that the flood peak on North Fork was about 8,000 second-feet. No definite information regarding the duration of the flood is available, but as the flood reached Fort Collins, 12 miles downstream, about 10 p. m. and lasted only 2 hours, it is evident that its duration at the canyon station could not have been longer than 2 hours and was probably less. The mean discharge for May 31 was determined by the State engineer as 2,700 second-feet.

The chief damage by the flood was wrought on bridges, highways, and irrigation canal head gates, above Fort Collins. In that city the river, although bank full, did not overflow its channel.

The storm of September 1–4, 1938, in the Cache la Poudre River Basin appeared to be concentrated below the mouth of the canyon in the vicinity of Bellvue and Fort Collins. The only precipitation recorded in the basin was at Fort Collins, 5.59 inches, and at Greeley, 1.55 inches. The peak discharge at the gaging station in the canyon was 1,660 second-feet, and at the mouth, 1,100 second-feet. The flood run-off near Fort Collins is described in the Fort Collins Express-Courier of September 2, 1938:

Flood waters which poured into the Bellvue area from La Bow Gulch Thursday evening swept 50,000 rainbow trout from the fish hatchery half a mile west of

Bellvue. The flood, which was carried into the hatchery area about 7 p. m., inundated the roads with a foot of water and washed over the hatchery ponds.

On September 4 the same newspaper stated:

Some of the places where uncontrolled water struck were the Colorado State College campus, Bellvue, the State fish hatchery south of Bellvue, Soldier Canyon, the No. 10 district, and Spring Canyon. None of the excessive water came from the Cache la Poudre, freshets from smaller canyons and run-off from hillsides being responsible for the damage.

The flood from one of these small tributaries, Spring Canyon, was investigated. Spring Canyon drains the hogback region southwest of Fort Collins and enters Dry Creek, which in turn enters the Cache la Poudre River 2 miles below Fort Collins. The drainage area of Spring Canyon, lying immediately east of Buckhorn and Redstone Creeks, received intensive precipitation September 2. A. D. Thompson, who lived in Spring Canyon in sec. 31, T. 7 N., R. 69 W., stated that the precipitation of September 1–3 filled and overflowed a 12-inch bucket in his yard, most of the rain falling before overflow occurred. From the shape of the bucket it was estimated that 11 inches of rain fell during that period. The peak of the flood reached the Thompson residence between 3:30 and 4 p. m. September 2, and lasted but a few minutes. A slope-area measurement of the flood in sec. 32, T. 7 N., R. 69 W., indicated a discharge of 11,600 second-feet, or 1,590 second-feet per square mile from the drainage area of 7.31 square miles.

CHERRY CREEK

Cherry Creek is a plains tributary draining an area of 420 square miles which extends from the divide between the South Platte and Arkansas River Basins to the mouth of the creek in Denver. The divide is an outlying spur of the foothills having an altitude of 7,500 feet, and the upper part of Cherry Creek Basin is rugged in character. The headwater streams have a fall of 1,000 feet in 20 miles. Below that point the descent is less rapid, being 1,300 feet in 38 miles, or 34 feet per mile. The drainage basin lies in the cloudburst zone east of the foothills.

Because of the normally small discharge of Cherry Creek, no gaging station was maintained on it prior to 1939.

Since the first settlement at Denver, in 1858, Cherry Creek has been a source of lively interest, and many references to it appear in the local press. When the first settlement was made by gold seekers, Cherry Creek, with its normally insignificant flow, was not considered a menace, and preparations were made to settle at the mouth of the stream. The Rocky Mountain News of July 27, 1885, contained the following account:

There is a tradition that when Count Murat and his party of permanent settlers

first reached the mouth of Cherry Creek in the fall of 1858, friendly Indians warned them against camping in the bottoms on account of great floods which had come down the creek in times past, and when the Count and his party laughed at the idea of Cherry Creek producing floods the Indians pointed to the debris left by the falling waters in the tops of tall cottonwoods on the banks of the harmless looking gully. This unanswerable argument probably influenced the early settlers into going a few miles up the Platte and establishing the short-lived town of Montana [on Little Dry Creek at what is now Englewood].

No flood appeared, however, and the settlement at Montana was soon abandoned in favor of the site at the mouth of Cherry Creek. Later, disbelief in the flood of Indian legend was shaken somewhat, as indicated in the Rocky Mountain News, Aug. 1, 1860:

Cherry Creek appears to present a rather serious problem, for we have had a demonstration [following a heavy rain on the headwaters] of what may be expected from a heavy rainfall on the Divide, though we are not yet inclined to believe the Indian claims that the whole settlement is subject to flood.

The first large flood after Denver was settled in 1859 occurred May 19–20, 1864. A description of that flood by Albert B. Sanford, curator of the State Historical Society Museum, appeared in the Colorado Magazine for May 1927:

Encroachments of owners of lots on what was commonly called the channel, by construction of stables and outbuildings had narrowed the narrow course to what was considered, by a sort of gentlemen's agreement, a reasonable right-of-way for the creek in caring for its drainage responsibilities. On the afternoon of May 19, 1864, a moderate rain occurred in Denver, but for several hours heavy black clouds obscured the Divide and frequent rumblings of thunder were heard. * * * By midnight the great majority of citizens were in their beds. Suddenly those who chanced to be awake heard a strange sound in the south like the noise of the wind, which increased to a mighty roar as a great wall of water, bearing on its crest trees and other drift, rushed toward the settlement. * * *

The writer's parents viewed the flood at its peak, and from the journal kept by his mother, recording events of that period, we quote: "Camp Weld [barracks of the First Colorado Regiment, just south of Denver], May 25, 1864. On the night of the 19th the watchman of the Government corral pounded on our door with the startling intelligence that a great flood was coming down Cherry Creek and many people were drowning. We thought him fooling until the roar of the waters could be heard, as of a mighty tempest.

[Mr. S] rushed to the creek but returned quickly, saying I must see the awful sight. We found hundreds of people along the creek banks. Many of the women and children in their night clothes, having been rescued from their homes below by the cavalrymen from the barracks. By the light of bonfires along the creek, we could see the inky waves, 15 to 20 feet high, carrying trees, houses, cattle, and sheep—and for all we know, human beings—to certain destruction. * * *

Early in the forenoon of the 20th * * * a stout cord was thrown across the creek at its narrowest point. By gradually increasing the size of ropes, pulled back and forth, the final 2-inch ferry ropes were securely anchored and a "rope bridge" swung over the now receding but still dangerous waters.

The effect of the debris in increasing the overflow is shown by the following account in the Rocky Mountain News, July 27, 1885:

In the rising of 1864 by far the greatest amount of damage was done. * * * The bed of the creek was very narrow, comparatively, and what there was of it in the neighborhood of Larimer, Blake, and Holloday Street Bridges was taken up largely by buildings erected on timber bents which brought them to a level with the bridges. Those were swept away, of course, as were the bridges, and all together went to form a dam which restrained the flow of the engorged stream and caused the flooding of all the low land on both the east and west sides. * * * This greatly aggravated the catastrophe.

This flood is described by the Cherry Creek Flood Commission,[27] appointed by the mayor of Denver in 1912:

The first flood of which we have any record occurred on Thursday and Friday, May 19 and 20, 1864. The flood reached its maximum height about 2 a. m., May 20. This height it maintained until about 7 a. m., at which time the waters began to recede. This flood had its origin at the upper end of the Cherry Creek watershed, being occasioned by a heavy fall of alternating hail and rain, occurring on the afternoon of May 19. This storm extended over the watershed of Plum Creek also, which discharged into the South Platte River, making an unprecedented height. The two floods came together in Denver on the morning of the 20th, covering the lower portions of the city with water to a depth of from 1 to 5 feet, leaving great deposits of sand and gravel at different points, damaging property to the extent of several thousand dollars [a very serious matter to the city at that time] and drowning 19 citizens. At that time a large portion of the city was constructed directly within and near the bed of Cherry Creek and the South Platte River bottoms. The water was about 1 foot in depth at the corner of the intersection of Fifteenth and Blake Streets.

A view of this flood at Denver, taken from the above report, is shown on plate 1.

Every rise in Cherry Creek was given wide publicity. As there was no gaging station on that stream, because it ordinarily carries but little water, particularly in its lower section, definite data ragarding the flood discharge are lacking, except for a few floods. For that reason description of later Cherry Creek floods is confined to those of May 22, 1876; May 22, 1878; July 26, 1885; July 14, 1912; July 28, 1922; and August 2–3, 1933. Minor floods were noted on May 20, 1867; July 20, 1875; July 19, 1886; August 18, 1888; August 3, 1897; June 6, 1921; July 13, 16, and 18, 1923; July 3, 1925; and May 31, 1935.

The widespread storm of May 21–23, 1876, covered the Cherry Creek drainage basin. This storm started as snow, which later turned to rain in Denver, but in the upper part of the basin it is probable that a considerable part of the precipitation was in the form of snow. Referring to this flood, the Cherry Creek Flood Commission stated:[28]

This flood would in all probability have been the greatest Cherry Creek flood known had it not been for the fact that the snow and cold prevented a rapid running off of the great amount of precipitation that had fallen. Throughout

[27] Report of Cherry Creek Flood Commission, p. 28, Denver, 1913.
[28] Op. cit., p. 14.

the afternoon and evening the banks of the Cherry Creek and South Platte River were lined with men, women, and children who waited, enduring the blinding storm of snow, standing ankle-deep in mud and slush, in anticipation of a flood of greater magnitude than that of 1864, both streams being but little below the high-water mark of that flood. However, no great damage was done at that time.

J. E. Field, consulting engineer, who remembers the flood of 1876, states that the flood stage was increased by the debris from bridges that had failed lodging against the Larimer Street Bridge. Below Larimer Street there was but little overflow. The Flood Commission's statement that the high-water mark was but little below that of 1864 and that no great damage was done, appears to be explained by the situation described by Mr. Field.

The flood of May 22, 1878, was evidently caused by heavy rains of cloudburst intensity covering a limited part of the drainage basin. No widespread storm occurred at that time, as records of precipitation available for six stations in Colorado show no precipitation as great as half an inch in 24 hours except at Fort Lyon, in the Arkansas Valley. The precipitation at Denver was only 0.12 inch. The Cherry Creek Flood Commission [29] describes this flood as follows:

The fourth Cherry Creek flood recorded occurred on the morning of Wednesday, May 22, 1878. It was considered by many of the earlier residents of Denver to be as large as the flood of 1864. We are not informed as to exactly where or how this one originated. The damage resulting therefrom was not nearly so great as that from the flood of 1864. The reason for the decreased amount of damage appeared, however, to be due, not so much to any lesser flow of water, but rather to the facts that there were no buildings in the bed of the stream at the time of the 1878 flood: and, on the other hand, the channel of the creek was wider, deeper, and clearer than was the case at the time of the 1864 flood; and, furthermore, there appears to have been no especial flood in the South Platte River at this time, retarding the flow of Cherry Creek.

Albert B. Sanford, curator of the State Historical Society Museum, in an article in the Colorado Magazine, July 1937, states that all bridges across the stream in Denver were swept away within a few minutes after the first wave descended, and that two lives were lost and great damage done to property.

The flood of July 26, 1885, like that of May 22, 1878, was not caused by a general storm, but by local rains over the drainage basin of Cherry Creek, as the available records showed no heavy precipitation throughout Colorado

The Rocky Mountain News, July 27, 1885, mentions the floods of 1864 and 1878 as the two great floods prior to that of 1885. Describing the flood of 1885, it states:

Shortly after 6 o'clock last evening persons crossing the Larimer Street Bridge saw a wave coming down Cherry Creek. * * * At 6:30 the scene from

[29] Op. cit., p. 14.

Larimer Street Bridge was perfectly indescribable White-capped waves surged down in their mighty anger, threatening to engulf everything in their way, carrying on their surface huge timbers and debris from ill-fated bridges and buildings. * * * At 1:30 this morning * * * the waters of the creek had greatly fallen and the flood seemed to be rapidly subsiding. * * * George Haffer [an old-timer] said there was fully as much water as in the flood of 1864, but that West Denver had been filled up and built up from 4 to 7 feet, so that the water on this occasion did not spread as much as the great flood of 1864.

The iron bridges yesterday stood the force of the flood perfectly. When built it was supposed they would never be touched by the rising waters of a flood, but yesterday the waves rolled over most of them and reached all.

The fact that the bridges were built after the experiences of 1864 and 1878 would indicate, as the newspaper account infers, that this flood was probably greater than any previous flood.

The Cherry Creek Flood Commission [30] states:

We are not informed as to just what part of the valley was covered by this storm, or whether it was from a general storm covering the drainage area as a whole. Considerable damage was done by this flood. West Denver was flooded about as it was in the flood of July 14, 1912. Mr. C. P. Allen, engineer of the Water Company, and Mr. E. S. Nettleton, State Engineer, estimated the discharge of this flood at its maximum to be 20,000 second-feet, the estimate being made at the Curtis Street Bridge by timing floats and measuring the existing channel. All railroad bridges over Cherry Creek from Wynkoop Street to the [South] Platte were washed away. Trains from the south loaded and unloaded their passengers at Sixth and Larimer Streets for several days.

The flood of July 14, 1912, is the first one on Cherry Creek for which detailed information is available. Soon after it occurred, the Mayor of Denver appointed the Cherry Creek Flood Commission, which made an investigation of flood conditions and proposed a plan for relief from future floods. Much of the information presented here is taken from the Commission's report.[31] Two lives were lost, and property both in Denver and in the valley above Denver was damaged to the extent of more than $1,000,000. The city engineer prepared a map showing the area flooded in Denver. Along Cherry Creek from the city limits to a point about a mile above its mouth the flooded area covered a block and a half (900 feet) on the north bank and half a block on the south bank. Near the mouth the flood spread over the wide, fairly level bottom of the South Platte River, occupied chiefly by railroad yards. In all, 86 blocks in the residential district and 19 blocks in the business district were inundated. Including the railroad yards, a total of 1.7 square miles was flooded.

The only Weather Bureau station in the Cherry Creek Basin at that time was at Denver, and its records showed that although a violent rainstorm occurred, lasting 2 hours, during which 2.08 inches

[30] Op. cit., p. 14.

[31] Report of Cherry Creek Flood Commission, Denver, 1913.

of precipitation was recorded, the rise in the creek due to it had passed before the main flood reached Denver. From statements of residents throughout the basin it appears that the heaviest precipitation occurred in the lower half of the basin, extending from Franktown to a point about 5 miles north of Denver, and that the rain was particularly heavy below Parker. In this section the rain was so intermingled with hail and came down so fast that it was said to be difficult to see a hundred yards. The precipitation above Franktown was slight and, according to J. E. Field (see p. 62), did not extend to Castlewood Dam. The storm apparently traveled in a northwesterly direction and covered the entire basin, although with varying degrees of intensity. At Franktown the rain was heaviest about 2:30 p. m., continuing steadily for several hours. Between Franktown and Parker the storm was at its maximum between 3 and 4 p. m., and below Parker the maximum occurred from 4 to 4:20 p. m. The rain caused every dry gulch to run bank full, and as the storm apparently traveled downstream at about the same rate as the water in Cherry Creek, the cumulative effect was nearly the maximum for a storm of that intensity. The banks of Cherry Creek, being low, were flooded in numerous places.

The Cherry Creek Flood Commission estimated that the flood originated in the run-off from an area of less than 200 square miles, and that the greater part came from an area not exceeding 100 square miles. Two points were selected by the Commission for slope-area measurements of the peak flow, based on the cross section to the high-water mark and the slope of the creek bed, using 0.030 as the value for n in Kutter's formula. One was at the Montgomery Bridge above Parker, where the discharge was found to be 14,500 second-feet. The other was below the mouth of Goldsmith Gulch, about a mile upstream from the city limits, where a discharge of about 25,000 second-feet was indicated. In view of the results obtained in Denver, as described below, it is believed that the figure for Goldsmith Gulch is too high, even allowing for the flattening effect of storage between the two places, and for the longer peak in Denver.

In Denver, Cherry Creek started to rise shortly after 8 p. m., and reached its maximum stage at 10 p. m., when it was 11 feet deep at the Bannock Street Bridge. Soon afterward it began to fall and by midnight had fallen 8 feet. At 8 o'clock the next morning it had fallen another foot, to a depth of 2 feet in the channel, and continued to recede slowly.

The Flood Commission made no estimate of the peak flow in Denver. W. B. Freeman, consulting engineer, formerly a member of the Geological Survey, made a float determination of the velocity in the main channel about midnight, when the stage was 5 feet lower than the

crest of the flood, and from this and the cross-sectional area at the peak, including the overflow, estimated the peak discharge as 11,000 second-feet. He further estimated the total discharge for the 12-hour period 8 p. m. July 14 to 8 a. m. July 15 as 4,000 acre-feet. C. W. Comstock,[32] State engineer, in an account of this flood in Denver, states that the peak discharge at the gaging station on the South Platte River a short distance below the mouth of Cherry Creek was 12,000 second-feet, of which he estimated that 10,000 second-feet came from Cherry Creek. His estimate of the total discharge was 3,800 acre-feet.

The severe overflow was due to the fact that the channel had a capacity of only 6,000 second-feet. After the flood the capacity was increased to 10,000 second-feet.

The flood of July 28, 1922, caused by heavy rainfall over the upper part of the basin, was a major flood for the upper part but not for the lower, as channel and valley storage so reduced its peak flow that it did not overflow the channel of the creek in Denver, although reaching the top of the retaining walls. It did, however, increase the flow of the South Platte River below the mouth of the creek to such an extent that the South Platte River flooded several blocks at Globeville, in the lower part of Denver. A few days after the flood the Geological Survey and the State engineer's office made a joint investigation, the results of which have been published.[33] The heavy rainfall covered an area extending 3 miles north of Parker, 1 mile south of Franktown, to the Douglas County line on the east, and 4 miles west of the creek.

The heaviest rainfall was in the basin of Bayou Gulch. At a point 3 miles above the mouth of Bayou Gulch in sec. 30, T. 7 S., R. 65 W., the storm began about 2 p. m. and lasted for 2 hours. The total rainfall was about 3½ inches as measured in an iron wheelbarrow with nearly vertical sides. The precipitation was so intense that the water stood 2 feet deep in the road. The resulting flood at Bayou Gulch was the highest in nearly 50 years. At a point 1 mile above the mouth of the gulch the heavy rain lasted 45 minutes and the flood crest was reached about 3:45 p. m., remaining near that stage for one hour. Heavy rain at the mouth of the gulch is reported to have lasted one hour. Halfway between Bayou Gulch and Parker, in sec. 3, T. 7 S., R. 66 W., the rain lasted from 2 to 4 p. m., and amounted to 2 inches as measured in a washtub in the yard. The rise in Cherry Creek came about 3 p. m. A Weather Bureau station 4 miles east of Parker recorded 1.01 inches for the 24-hour period, but at Castle Rock 6

[32] Comstock, C. W., The Cherry Creek flood, Denver, Colo.: Eng. News, vol. 68, pp. 302-305, Aug. 15, 1912.

[33] Follansbee, Robert, and Hodges, P. V., Some floods in the Rocky Mountain region: U. S. Geol. Survey Water-Supply Paper 520, pp. 122-123, 1925.

miles west of Franktown the Weather Bureau record showed only 0.25 inches.

A slope-area measurement of Bayou Gulch was made at a favorable point 1 mile above the mouth in sec. 23, T. 7 S., R. 66 W., and a peak discharge of 8,670 second-feet obtained. This represents 456 second-feet per square mile from an area of 19 square miles. An attempt was made to make a slope-area measurement of Cherry Creek in sec. 4, T. 6 S., R. 66 W., at the lower end of the area of heavy precipitation, but conditions were so unfavorable that the computation of 17,000 second-feet discharge cannot be considered more than an estimate. Above this point the drainage area affected by the storm was 87 square miles, and the estimated unit runoff was 195 second-feet per square mile. Near this point the creek started to rise at 4 p. m. and was at maximum stage from 4:30 to 5 p. m. By 8 p. m. it had fallen 3 feet, and by the next morning it could be forded easily. From these data the total discharge was estimated at about 4,000 acre-feet.

At the point where Cherry Creek was measured, in sec. 4, T. 6 S., R. 66 W., a local resident stated that the flood of July 14, 1912, reached practically the same stage as that reached in 1922. But in 1912 the storm was closer to Denver, and therefore caused a peak flow at Denver estimated at 11,000 second-feet, as contrasted with the peak flow of about 6,000 second-feet in 1922.

The flood of August 2–3, 1933, the largest of record on Cherry Creek, was caused by the failure of Castlewood Dam, about 35 miles upstream from Denver. The storm causing this failure was confined to the 175 square miles of drainage area in the upper part of the basin above the reservoir, at altitudes between 6,500 and 7,500 feet. Had it not been for the sudden release of about 2,500 acre-feet of water stored in the reservoir, the flood crest would soon have been reduced to a stage at which it would have caused little damage. No precipitation stations are maintained in Cherry Creek Basin above Castlewood Dam, but local residents measured the precipitation at several points in improvised rain gages. R. I. Meeker, consulting engineer of Denver, visited this area shortly after the storm and obtained the information presented in the following table.

Precipitation in Cherry Creek Basin, during night of Aug. 2–3, 1933

Location	Precipitation (inches)	Method of measurement	Time
Sec. 19, T. 9 S., R. 65 W.	4	Bucket with vertical sides	6 p. m. to 3 a. m.
SE¼ sec. 19, T. 9 S., R. 65 W.	3	Not given	9 to 10 p. m.; rain very heavy.
Sec. 33, T. 9 S., R. 65 W.	4	do	6 p. m. to 1 a. m.; rain hardest from 9 to 10 p. m.
Secs. 1 and 2, T. 10 S., R. 66 W.	7	do	
Sec. 4, T. 10 S., R. 66 W.	9	10-gallon milk can (measurement corrected for shape of can).	

Ivan E. Houk, an engineer in the Bureau of Reclamation, made an investigation of the failure of the dam. He found that the flood reached the reservoir about midnight, and within 45 minutes had raised the water level 11 feet, to a point 5 feet over the spillway and 1 foot over the top of the dam itself. The overflow washed out a large part of the dam, and the reservoir level dropped 18 feet within a few minutes. On this basis, the average inflow, disregarding spillway discharge, was computed as 30,000 second-feet, and the discharge over the spillway and the dam itself just before failure was computed as 5,000 second-feet.[34] The inflow of about 35,000 second-feet represented a unit run-off of 210 second-feet per square mile from 167 square miles above the reservoir, or 350 second-feet from the 100 square miles chiefly affected by the storm. Assuming that the reservoir level dropped 18 feet in 15 minutes, the computed rate of discharge at the dam was 126,000 second-feet during that period.[35]

With no inflow below the dam, the channel and valley storage reduced the peak discharge to 34,000 second-feet at Kenwood dam site, about 23 miles downstream, as shown by slope-area determinations made by the Office of the State Engineer. Between the Kenwood dam site and the mouth in Denver, a distance of about 12 miles, the peak was further reduced to 15,000 second-feet, as determined by the increased discharge of South Platte River at the gaging station just below the mouth of Cherry Creek. At this point the flood was of short duration, its peak lasting only a few minutes. The sudden release of the stored water above Castlewood Dam resulted in a veritable wall of water rushing down the valley of Cherry Creek, flooding the bottoms to an extent greater than during any other flood of which definite information is available. By the time the flood reached Denver, the advancing front had a height of about 8 feet. As the peak which reached Denver at 8 a. m. August 3 originated at Castlewood Dam about 12:30 a. m., it traversed the intervening 35 miles at a rate of 4.6 miles per hour. Although this flood had a discharge considerably greater than the flood of 1912, the stage at the Denver tramway car house was only about 7 inches higher than in 1912, according to the Corps of Engineers, United States Army.[36] This is due to the greater capacity of the channel. The total damage is estimated at $1,700,000, of which $960,000 represents damage above Kenwood Dam.

Subsequent to the flood of 1933 the city constructed a detention reservoir on Cherry Creek 7 miles above Denver, designed to protect the city from a flood with a discharge of as much as 70,000 second-feet.

[34] Western Construction News and Highways Builder, San Francisco, Sept. 1933.
[35] Idem.
[36] Cherry Creek and tributaries: 76th Cong., 1st sess., H. Doc. 426, p. 18, 1939.

KIOWA AND BIJOU CREEKS

Below Cherry Creek part of the drainage basin of the South Platte River lying east and south of the river is made up of rolling high plains on which the normal rainfall is not sufficient to maintain perennial streams. As the so-called cloudburst zone extends roughly 50 miles east of the mountains, flood run-off from violent storms has formed numerous waterways extending from the southern boundary of the South Platte Basin to the main South Platte River. The southern boundary is the plateau forming the divide between the South Platte and Arkansas Rivers. The altitude of this plateau decreases from 7,500 feet at the head of Kiowa Creek to 5,000 feet where it becomes the divide between the South Platte and Republican Rivers. Farther east the South Platte River Basin narrows rapidly, and the Republican River drainage approaches within a few miles of South Platte River with no pronounced divide. The streams in the area have a fall decreasing from 35 feet per mile in their upper courses to 15 feet per mile in their lower courses.

The principal streams are Boxelder, Kiowa, Bijou, and Badger Creeks. These streams are subject to not infrequent cloudburst floods, the principal damage from which is to bridges, both highway and railroad. One of the earliest recorded floods on these streams was that on Kiowa Creek on May 21, 1878. The following account by A. B. Sanford is quoted from the Colorado Magazine of July 1937:

> Among the unsolved mysteries in Colorado's history is the disappearance of a standard gage Kansas Pacific [now Union Pacific] locomotive in the quicksands of Kiowa Creek * * * on the night of May 21, 1878. A sudden flood had destroyed the wooden bridge that crossed the usually dry channel a short time before a freight train was due, and owing to the bridge being the low point of a sag in the roadbed and [to] the high speed of the train, the engine and most of the cars plunged into a swirling torrent of water before the engineer realized the situation. The engineer, fireman, and brakeman went down with the engine, which was completely buried.
>
> A few days later * * * search was begun for the missing engine. Long metallic rods were driven in the sands. In some places pits were started but soon abandoned because of the heavy underflow, and the location of the * * * locomotive appeared hopeless when it was estimated the bedrock formation was probably 50 feet below the channel of the Kiowa. [It never was recovered.]

The severest floods known on Kiowa and Bijou Creeks were those of May 30–31, 1935, which caused the loss of 9 lives, the destruction of all bridges over these streams, and much damage due to overflow. Earlier in the month there had been two periods of general rainfall, May 12–22 and 26–29, during which 2 inches or more of rain fell. As a result the soil was in condition to cause a high percentage of run-off from the storm of May 30. During this storm there were two periods of intense rainfall causing two distinct floods on Kiowa and Bijou Creeks, the second being much the greater.

The Denver Post of May 31, 1935, quoted an account of the second flood on Kiowa Creek, as given by the telephone operator at Elbert:

> The water came with a roar * * * Within a few minutes the water had risen to 8 feet around the exchange [a quarter of a mile from the creek]. Down in the lowlands it was 15 feet high * * * House after house was ripped from its foundations and swept down the creek. Thirty-seven houses and stores were destroyed—more than half the town. [Later reports reduced this number to 15.]

At Kiowa 15 houses were swept away and some stores wrecked. Below Kiowa further destruction occurred, as reported by the Post:

> About three miles above Bennett the waters tore through the ranch house of the Ramseys. Sorenson, the hired man, described what occurred. "We were all inside. The wall of water came down—it must have been 10 feet high. The house was ripped right from its foundation and the three of us hurled into the stream. About a mile downstream I managed to catch hold of a branch of a tree and pulled myself to safety." [Two others were drowned].

Bennett is some distance from the creek, so no damage occurred in the town itself, but the Union Pacific Railroad bridge near Bennett was washed out, together with a long stretch of fill on each side. In the town of Wiggins water several feet deep was reported; families were stranded on high points which became islands as the water rose. Near Wiggins, Kiowa Creek washed out 1,000 feet of the Burlington Railroad track.

Bijou Creek Basin contains no towns except Byers, and although the flood was more severe there than on Kiowa Creek, less damage appears to have been done. The Deer Trail Tribune of June 7, 1935, stated:

> The business part of Byers was flooded and basements filled with water. The White Hotel had over 2 feet of water in the ground floor. Closer to the river, north of the highway, the families waded out and found shelter * * * on higher ground. * * * The Union Pacific Bridge at * * * Byers, 5 miles west of Deer Trail and 1 mile west of town [was] washed out with hundreds of feet of track and fill on both sides.

The same issue of the Tribune describes the approach of the flood on East Bijou Creek at a point 3 miles west of Deer Trail:

> At about 7:30 Thursday evening [May 30] * * * looked up the creek and saw a wall of water that he declares was 10 or 15 feet high rushing toward them with a roar like thunder. * * * The men rushed to the house * * * but were only able to get a few clothes out when they were forced to fight their way through the rushing stream to high ground. * * * In a few minutes the house and all the outbuildings were swept downstream.

Near the mouth of the stream the flood destroyed the Burlington Railroad Bridge and more than half a mile of track. Conditions near the mouth of Kiowa Creek and Bijou Creek are described in the Denver Post, June 2, 1935:

> It was only from this height [airplane] we could grasp the great breadth of the flood—the vast territory over which waters spread, especially in the district

about Fort Morgan, Brush, and Wiggins, where these raging torrents, the [South] Platte River, Kiowa, and Bijou Creeks, met and at one point formed a stream several miles wide.

The office of the State engineer investigated these floods and the storm causing them. The areas of heaviest precipitation contained no Weather Bureau stations, therefore it was necessary in determining the location and approximate amount of rainfall to obtain from local residents such information as could be furnished by those who had measured the rainfall in improvised rain gages. The following table summarizes the information.

Rainfall on Kiowa and Bijou Creeks, May 30, 1935

[Compiled from statements of local residents and from Weather Bureau records]

Location	Rainfall (inches)	Method of measurement	Time
Sec. 2, T. 8 S., R. 65 W.	Tr.		
Sec. 33, T. 11 S., R. 64 W.	8	Oil can	Occasional rain night of May 29–30; hard rain noon to 5 p. m. May 30.
Sec. 18, T. 11 S., R. 64 W.	8	Estimated	7 p. m. May 29 to 3 p. m. May 30.
Sec. 12, T. 11 S., R. 65 W.	4		8 a. m. to 6 p. m.
Sec. 34, T. 10 S., R. 64 W.	24	Stock tank, overflowed	5 a. m. to 6 p. m.; intense at noon.
Sec. 27, T. 10 S., R. 64 W.[1]	20	Stock tank	Noon to 4 p. m.
Sec. 22, T. 10 S., R. 64 W.	18	Stock tank, overflowed	9 a. m. to 5:30 p. m.
Sec. 19, T. 10 S., R. 64 W.[1]	15+	do	12:30 to 4:30 p. m.
Sec. 9, T. 10 S., R 64 W.[1]	8⅓	Coffee can	1:30 to 5:30 p. m.
At Elbert, in sec. 34, T. 9 S., R. 64 W.	24	Standard rain gage, overflowed; 12 inches caught in bucket after overflow.	1:30 to 4:30 p. m.
Sec. 32, T. 8 S., R. 64 W.		Heavy rain, not measured.	
Sec. 33, T. 10 S., R. 63 W.	4–6	Can	4:30 to 7 a. m.; 1 to 5 p. m.
Sec. 35, T. 9 S., R. 63 W.[1]	7	do	
Sec. 27, T. 9 S., R. 63 W.	6–8	3-gallon can	6 a. m. to 6 p. m.; intense at noon, and from 5 to 6 p. m.
Sec. 26, T. 3 S., R. 63 W.	Tr.		
Sec. 26, T. 10 S., R. 62 W.	4	Water barrel	2 to 9 p. m.
Sec. 16, T. 8 S., R. 62 W.	(2)		
Sec. 24, T. 8 S., R. 62 W.	12	Half-bushel measure 14 inches high.	5:30 to 10 a. m. 3 to 6 p. m.
Sec. 23, T. 7 S., R. 62 W.[1]	3		
Sec. 23, T. 6 S., R. 61 W.[1]	8½	Can, overflowing by morning.	
Sec. 9, T. 4 S., R. 61 W.	.11	Reported by Weather Bureau at Byers.	
Sec. 26, T. 10 S., R. 60 W.[1]	1½		
Sec. 4, T. 9 S., R. 60 W.	½	Estimated	
Sec. 9, T. 8 S., R. 60 W.	4	Coffee can	3 to 6:30 p. m.
Sec. 11, T. 7 S., R. 60 W.	9	Bucket with vertical sides	2 to 9 p. m.
Sec. 13, T. 5 S., R. 60 W.[1]	4		7 p. m. May 30, to morning of May 31.
Sec. 12, T. 7 S., R. 59 W.[1]	6		

[1] Data obtained by Geological Survey.
[2] 2 inches in one hour reported; probably not the total rainfall.

The following table summarizes the results of the slope-area measurements:

Peak discharge of Kiowa and Bijou Creeks, May 30–31, 1935

[Data from 28th Biennial report of the State Engineer of Colorado, p. 41, 1939]

Location	Drainage area affected by storm (square miles)	Peak discharge (second-feet)	
		Total	Per square mile
Kiowa Creek:			
Elbert, in sec. 34, T. 9 S., R. 64 W	60	[1] 43,500	725
Sec. 21, T. 6 S., R. 63 W	190	[2] 110,000	579
Bennett, in sec. 26, T. 3 S., R. 63 W	266	[1] 75,300	283
West Bijou Creek:			
Sec. 13, T. 8 S., R. 62 W	118	[3] 34,250	290
Sec. 36, T. 6 S., R. 62 W	187	[2] 44,400	237
Middle Bijou Creek:			
Sec. 26, T. 7 S., R. 60 W	151	[2] 71,270	472
Sec. 28, T. 4 S., R. 60 W	230	[3] 143,640	625
East Bijou Creek:			
Deer Trail, in sec. 13, T. 5 S., R. 60 W	294	[1] 25,000	85

[1] Based on one cross section and slope of stream bed.
[2] Based on two cross sections and high-water slope.
[3] Based on one cross section and high-water slope.

In addition to the results given in the preceding table two more discharge measurements were made. A slope-area measurement on West Bijou Creek at Byers was taken above the railroad embankment which, before its failure, ponded the flood. As the slope used in this measurement was that of the stream bed subsequent to the flood, it did not show the effect of the pondage, and the results obtained are therefore believed to be too high. A slope-area measurement on Bijou Creek in sec. 32, T. 4 N., R. 59 W., a few miles below Wiggins, gave a discharge of about 280,000 second-feet. J. E. Field, consulting engineer, made an investigation of the flood at Wiggins, from which he concluded that a very considerable body of water had been held back by the Burlington Railroad embankment. When this embankment failed it released the ponded water within a comparatively short time and greatly increased the flow in the river below. The high-water marks used to determine the peak flow were those caused by the failure of the embankment, and therefore did not represent the peak flow.

Describing the results of the investigations on Kiowa Creek and Bijou Creek, the State Engineer [37] says:

> While some of the results, particularly those of the Bijou Creek discharges appear to be incredible and entirely beyond anything which has ever occurred in Colorado or adjacent areas, they are submitted for whatever value they may have.

In view of the uncertainties as to the accuracy of these results they should be used with caution.

[37] Colorado State Engineer, 28th Bienn. Rept., p. 43, 1939.

REPUBLICAN RIVER

The headwaters of the Republican River drain an area in east-central Colorado, roughly oval in shape, extending from a point south of Fort Morgan eastward to the Colorado-Nebraska State line. This area is a part of the Great Plains province and has its characteristic topography. The streams have an average fall of about 12 feet per mile.

The greatest flood of record in this area occurred May 30–31, 1935. The severe storm on May 30 took the form of a series of cloudbursts, which in the Republican River Basin in Colorado centered on the area between the Republican and Arikaree Rivers and extended from a line drawn from Cope to Seibert eastward to the State line. An investigation was made soon after the flood, and from the published report [38] the following is abstracted:

> No Weather Bureau stations were within the area of heavy precipitation, hence it was necessary to obtain information concerning it from local residents, many of whom measured the rainfall in improvised rain gages. These statements showed rainfall ranging from 6 to 18 inches during the night of May 30–31, and one resident reported that a 24-inch stock tank overflowed during the night.

The main flood on the Arikaree River originated some distance west of Cope, where a heavy rain started at 6 p. m., May 30. The river began to rise shortly afterward, and by 3 a. m., May 31, it reached its peak stage of about 6 feet, with a corresponding discharge of 25,000 second-feet. As the flood progressed it reached a peak discharge of 54,000 second-feet and peak stage of 9 feet at a point 10 miles north of Idalia.

On the South Fork Republican River the flood started near Seibert, where four small creeks unite to form the South Fork, and increased rapidly to a peak discharge of 103,000 second-feet near Newton and 150,000 second-feet at the State line. The greatest discharge per square mile occurred near Newton. The drainage area west of the area of heaviest precipitation contributed about 20,000 second-feet to the peak, leaving 83,000 second-feet contributed by the 669 square miles directly affected by the cloudbursts, or 124 second-feet per square mile.

ARKANSAS RIVER

The Arkansas River is formed by the East Fork and Tennessee Fork, which unite near Malta. From their junction to Parkdale, the Arkansas River flows through a succession of narrow valleys divided by short canyons. At Parkdale the river plunges into the Royal Gorge, emerging from it just above Canon City, and below that point

[38] Follansbee, Robert, and Spiegel, J. B., Flood on Republican and Kansas Rivers, May and June 1935: U. S. Geol. Survey Water-Supply Paper 796–B, pp. 21–52, 1937.

flows through a valley increasing in width as far as Pueblo. Beyond Pueblo, the river flows across the plains to the State line and thence into Kansas. Between Canon City and Pueblo the fall of the river decreases from 25 feet to 10 feet per mile, and below Pueblo the average fall is about 8 feet per mile.

Above the Royal Gorge the Arkansas River is not subject to heavy floods. A few of its upper tributaries are subject to cloudburst floods, but the volume of these floods is too small to affect seriously the Arkansas River itself.

Gaging stations on Arkansas River between Canon City and Colorado-Kansas State line

Station [1]	Drainage area (square miles)	Period of record
Canon City	3,090	May 1888 to date.
Near Pueblo	4,730	May 1885 to September 1886; June to September 1887; May to August 1989; September 1894 to date.
Near Nepesta	9,130	September 1897 to October 1903; July 1909 to November 1912; January 1914 to date.
Near Rocky Ford	11,400	May 1897 to April 1900; April 1901 to October 1903.
La Junta	12,200	May to August 1889; December 1893 to December 1895 January to December 1901; April to October 1903; August to November 1908; April 1912 to date.
Lamar	19,800	May 1913 to date.
Holly	25,000	December 1893 to December 1894; May 1901 to April 1902; October 1907 to date.

[1] Stations maintained at several other points for short periods.

The earliest flood known in this area occured in 1826, long before permanent settlement in the Arkansas Valley. Knowledge of this flood is available only at fourth hand but is believed to be reliable. C. W. Beach, State division irrigation engineer, obtained the information from J. R. Gordon, of Pueblo. Mr. Gordon in turn had obtained it from a Mr. Traber who, as an elderly man, visited Pueblo in 1873. In his younger days Mr. Traber was an employee of the Hudson's Bay Company, and in 1826, with associates, spent considerable time in the vicinity of the old site of Fort Lyon. During that year a flood occurred on the Arkansas River that covered the bottom lands near the present town of Las Animas to a depth of about 15 feet. In 1873 Mr. Gordon visited Las Animas in company with Mr. Taber, who identified the site of his original camp. The fact that a great flood occurred on the Arkansas in 1826 was also verified, according to Mr. Beach, by grandchildren of Mrs. Amy Prowers, wife of John W. Prowers for whom Prowers County is named. An outstanding flood apparently occurred also on the Republican and Kansas Rivers in 1826,[39] when excessive rains throughout the middle Mississippi and Missouri River Basins, caused high stages on these rivers during April and May.[40]

[39] Follansbee, Robert, and Spiegel, J. B., op. cit., p. 51.

[40] Kansas River, Colorado, Nebraska, and Kansas: 73d Cong., 2d sess., H. Doc. 195, p. 39, 1934.

1859?

The next known flood in this area was that of the late 1850's, tentatively dated as 1859, which affected chiefly the Arkansas River below the mouth of the Purgatoire River. A. W. McHendrie, former district judge at Trinidad, obtained information from L. M. Kreeger, for many years a peace officer at Trinidad, who in his earlier years had been a guard and hunter with wagon trains following the Santa Fe Trail. In 1911 both Mr. McHendrie and Mr. Kreeger were at Lamar, and the latter told of camping in the late fifties just north of a hill beyond the south end of the present bridge at Lamar. It was raining when the wagon train camped at that point. The Arkansas River continued to rise and in 7 days it had reached the base of the hill and was 2 or 3 miles wide. Mr. Kreeger took Mr. McHendrie to the site of his old camp, which was easily identified. By sighting across the valley from the base of the hill, Mr. McHendrie estimated that the water must have been about 15 feet deep at the present site of Lamar. The peak of the flood did not last very long—a day or less—but the entire valley was under water for several days. Mr. Kreeger stated that the wagon train continued its journey up the Arkansas River to the Purgatoire River, along which they found evidence of large cottonwood trees having been uprooted and washed away during the recent flood. The Arkansas River above the Purgatoire River was also in flood, but as no mention was made of trees along it having been uprooted it is believed that the flood there was not as severe as on the Purgatoire River. This belief is strengthened by the fact that the early settlers at Pueblo left no record of this flood, apparently considering it merely the usual spring rise. As the Santa Fe Trail left the Purgatoire River a few miles above its mouth, no information on flood conditions on the upper part of that river was obtained. However, the channel of the Purgatoire River at Trinidad at that time was so narrow that it was spanned by a footlog, so it is evident that this flood did not originate in the mountains above Trinidad but on the plains, probably in the canyon section.

1864

The first flood on the Arkansas River for which detailed information has been found occurred June 11, 1864, as a result of the general storm over eastern Colorado. The early settlers agree that this flood reached a point near Third and Santa Fe Avenues in Pueblo, and if, as seems probable, the street has been graded down since 1864, the flood of that year may have been nearly as high as the flood of 1921. During the flood of 1921 all the streams in the valley were very high and overflowed their banks for great distances.[41]

[41] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3–5, 1921: U. S. Geol. Survey Water-Supply Paper 487, p. 36, 1922.

1867

A flood in May 1867 caused the removal of Fort Lyon to a place 17 miles farther west. The rainfall record at Fort Lyon was as follows: May 24–26, 1.80 inches; May 29, 1.00 inch; May 30, 1.15 inches; a total of 3.95 inches, as compared with a normal rainfall of 2 inches for the entire month. This flood was probably caused chiefly by melting snow, as the Canon City Record of June 2, 1894, quotes historian B. F. Rockafellow, as saying that the melting of the snow at the time of the flood of 1867 caused "the streams [in the vicinity of Canon City] to become swollen into rushing torrents." The Bent County Democrat, June 15, 1921, quotes John W. Powers, county clerk, as follows:

I have heard my mother tell of the great flood of 1867, which must have surpassed the one of this month. At the time to which she referred both the Arkansas and the Purgatoire were at flood stage simultaneously, with the result that the Arkansas River in the section where Lamar now stands was a solid body of water from the sand hills on the south side to the first upland on the north side of the river.

1869

During a flood in June 1869 the river is said to have contained an immense amount of water.

1875

The next flood of record on the Arkansas River is that of September 16, 1875, which was caused primarily by high water in the Purgatoire River and therefore affected the Arkansas River chiefly below the Purgatoire. The Las Animas Leader, September 18, 1875, reported:

At Fort Lyon [4 miles below the mouth of the Purgatoire] the water was 4 feet higher than ever known before. The bottom land between the bridge and the post trader's [a distance of three-fourths of a mile] was a swift, raging flood.

The upper river was also in flood as far north as Pueblo, but as the Pueblo press gave little space to it the flood at that point was evidently not serious.

1884

Rain and run-off from melting of the heavy snow cover in June 1884 caused a flood on the Arkansas River between the Grand Canyon, just above the Royal Gorge, and Pueblo. The Canon City Record, June 28, 1884, stated that the water was 2 feet deep on the railroad tracks in the Grand Canyon. The Pueblo Chieftain, July 5, 1884, stated:

The Arkansas River is booming. It rose several inches more yesterday, and during the morning a sudden run of driftwood appeared. A great quantity of it went down within a few hours and then the run stopped altogether. Immense cottonwood logs * * * threatened destruction to everything in their way. * * * The river is doing more damage to the Rio Grande road than ever

before. The Grand Canyon is wholly impassable. Between Pueblo and Canon City [the railroad tracks] are flooded for miles at a stretch by from 6 to 18 inches of water. The county bridges across the Arkansas at Parkdale, Texas, and Howard have been washed out.

1886

A flood of considerable magnitude on the lower Arkansas River, probably below the mouth of Purgatoire River, occurred July 20–25, 1886. This flood did not extend to the upper river, as the Pueblo gaging station showed a maximum of only 3,080 second-feet on July 21. The rainfall was apparently heaviest in the vicinity of Las Animas and La Junta. At the former place the rainfall was 3.36 inches July 24–25, and 4.66 inches for the month, or more than twice the normal. At Pueblo the rainfall for July was only 0.39 inch. The only available information regarding this flood relates to the section of river near La Junta, and appeared in the La Junta Tribune of July 22, 1886:

Wednesday morning the water in the Arkansas River was within 1 foot of the bottom of the sleepers of the wagon bridge. There were 5 wash-outs [on the railroad] between La Junta and a point 6 miles east.

After describing the storm, which was termed terrific, the Tribune continued:

By half past seven the streets and ravines were converted into small rivers. * * * In King Arroyo, east of town, the water came down in a wave 12 feet high. In Anderson Arroyo just west of town the water was at least 20 feet deep, running over the Santa Fe Co.'s bridge. * * * Johnson was sleeping in the house * * * 10 miles up Anderson Arroyo. About midnight he was awakened by the storm. He had been up but a few minutes when the house began to tremble, a wave about 8 feet high struck the south end, forcing in the window and almost in an instant the house went to pieces and was floating down this newly formed river.

1889

Rains on August 9, 1889, were followed by a flood that caused overflow from Grape Creek at least as far east as Pueblo. These rains must have been of the cloudburst type in the Arkansas Valley, as at none of the rainfall stations was the recorded precipitation heavy except at Pueblo, where 1.02 inches of rain in 1 hour on August 9 was recorded. This intense rainfall, with a temperature of 98° before the storm, indicates a cloudburst. From the account of the Grape Creek flood (see p. 84) it appears that the flood on the Arkansas River came primarily from that source. It was evidently augmented by rain at other points. The Denver Republican states that rain began falling about 5:30 p. m. on August 9, and flooded the region around Pueblo, and that a "terrible and disastrous rainstorm visited Florence in the evening and lasted 2 hours. The Denver & Rio Grande is having lots

of trouble caused by the cloudburst of Friday night. The Hardscrabble bridge washed out."

A Pueblo dispatch dated August 10 is quoted in the Canon City Record of August 17, 1889:

> At 1:30 this morning [Aug. 10] the water began to flood the flats west of Victoria Avenue, the water rushing through at the west end of the Santa Fe bridge. At 3 o'clock the water went over the Victoria Avenue grade and soon every basement on the west side of Union Avenue was flooded. At 4 o'clock the water went over Union Avenue grade and soon the lowlands on the east side of the street were covered with water several feet deep. The water extended from the river to the viaduct, a distance of 4 blocks, and most of the way the water was 1½ to 2 feet deep. At 7 o'clock the river had fallen 3 inches.

After this flood the city council ordered all obstructions in the channel removed and appropriated $3,000 to repair and strengthen the levee.

Discharge records for this flood are available from the gaging stations at Canon City, in the canyon above Pueblo, and at La Junta, but these records show the only mean daily discharge, which at each station is undoubtedly much less than the peak discharge.

Daily discharge, in second-feet, of Arkansas River, August 8–14, 1889

Station	August						
	8	9	10	11	12	13	14
Canon City	324	2,620	478	324	324	----------	----------
Near Pueblo	370	3,700	2,050	880	1,240	565	550
La Junta	----------	110	55	----------	1,080	1,630	900

1893

In 1893, one of the driest years of record at Pueblo, a flood occurred on July 26, which reached a stage 10 feet lower than that of the flood of 1921. The river rose 8 feet in 2 hours at Pueblo.[42] No gaging-station record of the discharge is available, but from the rating curve established for the flood of 1921, with an allowance for channel clearance made after the flood of 1893, it appears that the peak discharge was between 20,000 and 25,000 second-feet.

1894

The storm of May 29–31, 1894, also caused a severe flood. The record of rainfall in the Arkansas River Basin during the storm is given in the accompanying table.

[42] Follansbee, Robert, and Jones, E. E., op. cit., p. 38.

Precipitation, in inches, in Arkansas River Basin, May 29–31, 1894

Station	Altitude (feet)	May			
		29	30	31	Total
Canon City	5,329	0.75	4.31	----------	5.06
Pueblo	4,685	----------	1.38	1.64	3.02
Rocky Ford	4,177	----------	----------	3.50	3.50
Las Animas	3,899	----------	.07	1.09	1.16
Lamar	3,592	----------	----------	[1] 3.00	3.00

[1] Record for several days.

The local newspapers on the evening of May 30, 1894, reported that at Salida rain had fallen continuously for 36 hours and was continuing and that for duration and volume the storm exceeded anything in the memory of the oldest inhabitant. At the same time, Florence reported that rain had fallen there for the preceding 24 hours and that the amount was estimated at 3 to 4 inches. The precipitation above Canon City had little influence on the ensuing flood, as the discharge at Canon City was not greatly in excess of that during years of heavy mountain snowfall. Below Canon City, however, very considerable damage was caused. A dispatch from Pueblo, dated May 30, is quoted in the Rocky Mountain News of May 31, 1894:

> In consequence of an all-day downpour of rain such as has not occurred in this valley in 20 years, the Arkansas River tonight came up and broke the levees in four places on the north side and two on the south side. Everything is a sea of water from Union Avenue viaduct to the post office. All business cellars are filled in that territory, and the water is over the floors from 6 inches to 2 feet. This is a worse flood than any that has occurred since the town became a city. The water flows with a strong current through the streets, and everything is confusion. The flood covers the city from Union Avenue on the south side to Fourth Avenue on the north side, an area of three-quarters of a mile.

The issue of the News on June 1, 1894, stated that on Second Street between Santa Fe Avenue and Main Street the water was 4 feet deep over the floors of the buildings. Five lives were lost in Pueblo, and damage amounting to nearly $2,000,000 was done to property. At its highest stage the water was 3 feet deep in the Denver & Rio Grande Railroad freight yard and stayed at that stage from 2 to 8:30 a. m., May 31. It receded slowly and by 6 a. m., June 1, had fallen only 4½ feet. The highest stage was about 7 feet less than the flood of 1921.[43]

In the Arkansas Valley above Pueblo this flood reached a higher stage than the flood of 1921. Below Pueblo, however, it was considerably lower. At Las Animas, according to the Bent County Democrat of June 8, 1921, the flood of 1894 reached First Street, whereas the flood of 1921 was 4 feet deep at that point.

[43] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3-5, 1921: U. S. Geol. Survey Water-Supply Paper 487, p. 39, 1922.

The city engineer of Pueblo subsequently made a slope-area determination of the peak discharge and found it to be 39,100 second-feet. Subsequently the channel capacity through Pueblo was increased to 40,000 second-feet.

1904

The Purgatoire River flood of September 29–30, 1904, caused a flood in the lower part of the Arkansas Valley in Colorado. No gaging station was in operation at that time at the mouth of the Purgatoire River, and it is therefore impossible to determine the volume of the flood entering the Arkansas River. It is believed, however, to have been at least as great as the peak discharge of 44,300 second-feet at Trinidad. The recorded rainfall in the Arkansas River Basin below the Purgatoire River is given in the table following.

Precipitation, in inches, in Arkansas River Basin, Sept. 27–30, 1904

Station	Altitude (feet)	September				Total
		27	28	29	30	
Las Animas	3,899			1.20	0.45	1.65
Lamar	3,592	0.11	0.18	.41	.26	.96
Holly	3,380		.28	.52	.02	.82
Cheyenne Wells	4,279	1.23	1.00	.93	1.10	4.26
Vilas	4,155		.80	1.35		2.15

This precipitation undoubtedly increased the flood volume in the Arkansas River. At the Colorado and Kansas diversion dam, 3 miles west of Prowers, the peak discharge was computed as about 70,000 second-feet. Further information on this flood is summarized from earlier reports, as follows:[44]

The lower bottom lands were entirely inundated from the mouth of the Purgatoire to the State line, and as a flood in September was unexpected the railroad company and farmers were unprepared for it, with the result that damages were much greater than they would otherwise have been. From Fort Lyon to Holly the water covered all the lower bottom lands, and from Caddoa to Lamar, where the bottom is narrower than above or below, the waters reached from bluff to bluff, a distance varying from three-quarters of a mile to a mile in width. At the Colorado and Kansas canal dam, 3 miles west of Prowers, the gatekeeper was compelled to swim his horses out, so rapid was the rise of the water. At Lamar the water was within 1 foot of flooding the town.

1908

The flood of October 19–20, 1908, was caused by heavy rains, chiefly during the night of October 18, which covered the part of the Arkansas River Basin in Colorado east of a line running just west of La Junta, except the area south of a line from the Purgatoire River

[44] Meeker, R. I., Purgatoire River flood, in Murply, E. C., and others, Destructive floods in the United States in 1904: U. S. Geol. Survey Water-Supply Paper 147, pp. 165–167, 1905.

above Smith Canyon to the southeast corner of the State. The Geological Survey made an investigation of this flood soon after it occurred, and from its published report [45] the following information is abstracted.

Rainfall, in inches, in Arkansas River Basin, Oct. 18–19, 1908

Station	Altitude (feet)	October		Total
		18	19	
Hamps	5,400	0.90	1.36	2.26
Limon	5,360	.62	1.41	2.03
Rocky Ford	4,177	1.76	----	1.76
Las Animas	3,899	.64	1.42	2.06
Eads	4,000	----	5.95	5.95
Lamar	3,592	----	3.87	3.87
Cheyenne Wells	4,279	----	4.53	4.53
Vilas	4,155	.37	1.33	1.70
Blaine	3,935	----	1.40	1.40
Holly	3,380	.70	Tr.	.70

Rain gages were also in operation at various points along the canal, which is part of the Amity canal system, north of the Arkansas River. These gages recorded precipitation of 6.25 inches 40 miles northwest of Holly, 6 inches near Prowers, and 6.34 inches a few miles north of Lamar. Most of the rain fell within 8 hours during the night of October 18–19, 1908.

This flood of 1908 appears to have had two distinct parts. The first, October 19, due chiefly to the very heavy rains on the north side of the river. Throughout the area affected the ground was very hard and dry and had been grazed so closely that practically no vegetation remained. These conditions were conducive to an extremely high percentage of run-off, and it is believed that as much as two-thirds of the 6-inch rainfall reported appeared immediately in the streams. On the north side of the river the water was reported to have "flowed away in a perfect sheet, overspreading the whole country and running into the river chiefly below the Amity Dam at Prowers, causing a very rapid rise." [46] This run-off reached Holly sometime before midnight, October 19, and reached a stage of 9.8 feet on the gage at Holly. The flood was prolonged by the arrival of flood waters from Two Butte Creek and smaller tributaries from the south, and had only receded half a foot the morning of October 20 when the second flood arrived.

The second part of the flood was caused chiefly by floodwaters from the Purgatoire River. It reached a peak stage of 11 feet at Holly at noon, October 20. At 7 a. m. October 21 it had receded to 4.6 feet, and at 7 a. m. October 22 it was 3.0 feet.

[45] Freeman, W. B., Flood in the Arkansas Valley, Colorado, October 1908: U. S. Geol. Survey, Water-Supply Paper 247, pp. 33–40, 1910.

[46] Freeman, W. B., op. cit., p. 35.

All the bottom lands were flooded, railroad embankments were overflowed and washed out in many places, and rail traffic was delayed for about 6 days. All highway bridges on the Arkansas River from the mouth of the Purgatoire River to the State line, except those at Granada and Holly, were washed away. Several people were drowned, many farmhouses were flooded, a number of towns inundated, and many thousand sheep were lost. Much damage was also done to canal systems. The estimated property loss was about $250,000.

The peak discharge at Amity Dam, half a mile north of Prowers, was estimated at more than 100,000 second-feet, and at Holly a slope-area measurement made by the Amity Land Co. gave a discharge of 136,000 second-feet. This discharge at Holly in 1908 was slightly greater than during the flood of 1921. The gaging station at Holly was the only one in operation during 1908.

Mean daily discharge of Arkansas River at Holly, Oct. 18–24, 1908

	Second-feet		Second-feet
Oct. 18	5	Oct. 22	10,000
19	50,000	23	7,500
20	125,000	24	4,000
21	20,000		

1921

Above the mouth of the Purgatoire River no damaging flood occurred after 1894 until 1921, when the general storm that covered the State June 2–5 was concentrated in a series of cloudbursts between Canon City and Pueblo. These covered two separate areas. The larger area, roughly elliptical, extended from the northern boundary of Pueblo County to the top of the Wet Mountains near Beulah, a distance of 30 miles, and from a point a short distance above the mouth of Rush Creek nearly to Pueblo, a distance of 15 miles. The smaller area covered the south slope of the Pikes Peak uplift, which forms the northern part of the mountain valley, and extended from a point above Skaguay Reservoir to a point 3 or 4 miles south of the river, a distance of 25 miles, and from Oil Creek to Beaver Creek, a distance of 11 miles. The two areas together comprise 550 square miles.

The progress of the storm down the valley caused the resulting floods on many of the tributary streams to reach Pueblo at nearly the same time, bringing about there the greatest flood of record. The Geological Survey made an investigation of this flood, and published a detailed report.[47] The peak discharge at Pueblo, as determined by slope-area measurement, was found to be 103,000 second-feet, and the

[47] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3–5, 1921: U. S. Geol. Survey Water-Supply Paper 487, 44 pp., 1922.

total discharge of the main flood at that point, less than 90,000 acre-feet. Two views of the damage caused by this flood are shown on plate 2.

After the flood of 1921 the State Legislature enacted the Conservancy District law, which enabled various interests in the Arkansas Valley to organize the Pueblo Conservancy District. This district constructed a detention reservoir 10 miles above Pueblo, which was designed to reduce a discharge of 175,000 second-feet of normal duration to a discharge of 100,000 second-feet. Channel changes in Pueblo were designed to carry, without overflow, a flood discharge of 125,000 second-feet and thus to provide for a flood flow of 25,000 second-feet originating below the reservoir.

As floods on the Purgatoire River are necessarily a source of floods on the Arkansas River below the mouth of that tributary, the flood of 1921 was not so greatly in excess of previous floods on that section of the river as the previous floods above the mouth of the Purgatoire River. In fact the peak discharge of the flood of 1908 on the Arkansas River at Holly was 136,000 second-feet, whereas the peak discharge in 1921 at Holly, when the Purgatoire River was not at flood stage, was only 120,000 second-feet.

The following table shows the daily discharge at gaging stations on the lower part of the Arkansas River in Colorado during June 1921.

Daily discharge, in second-feet, of Arkansas River, June 1–19, 1921

[Data from reports of State Engineer of Colorado]

June	Canon City (drainage area 3,090 square miles)	Near Pueblo (drainage area 4,730 square miles)	La Junta (drainage area 12,200 square miles)	Lamar (drainage area 19,800 square miles)	Holly (drainage area 25,000 square miles)
1	3,130	2,380	396	28	26
2	3,060	5,300	678	47	36
3	3,130	20,700	959	36	26
4	3,430	[1] 34,600	[2] 61,100	305	15
5	3,500	19,200	46,500	[3] 87,300	44,800
6	3,500	10,800	25,000	33,200	[4] 59,500
7	3,500	6,650	22,000	28,000	35,000
8	3,130	5,480	16,000	23,400	15,600
9	2,850	5,080	14,000	15,500	11,800
10	3,280	5,140	11,500	13,000	10,000
11	3,730	5,950	10,500	10,700	7,300
12	4,420	5,840	9,650	9,560	7,300
13	4,580	6,470	9,890	9,000	7,700
14	4,340	5,910	8,190	8,460	7,220
15	4,900	6,350	7,790	11,400	7,200
16	4,980	5,950	8,190	10,700	8,700
17	4,500	5,480	8,600	10,100	8,590
18	4,020	5,280	7,210	9,000	8,590
19	3,800	4,400	6,460	8,460	7,920

[1] Peak discharge 103,000 second feet.
[2] Peak discharge 200,000 second-feet.
[3] Peak discharge 165,000 second-feet.
[4] Peak discharge 120,000 second-feet.

1929

The flood on the Purgatoire River, August 7, 1929, had a peak discharge of 52,800 second-feet at the mouth and caused a peak discharge of 45,300 second-feet on the Arkansas River at Lamar. The discharge from Purgatoire River was probably augmented by the rainfall that was general over the Arkansas Basin. The daily discharge of the Arkansas River above and below the mouth of the Purgatoire River August 5–10, is shown in the following table.

Daily discharge, in second-feet, of Arkansas River, Aug. 5–10, 1929

[From reports of Colorado State Engineer]

Gaging station	August					
	5	6	7	8	9	10
La Junta	898	553	[1] 10,000	7,400	6,360	4,320
Lamar	1,770	982	4,440	[2] 24,800	6,800	5,200

[1] Peak discharge 17,300 second-feet.
[2] Peak discharge 45,300 second-feet.

1934

The effect on the discharge of the Arkansas River of a flood on the Purgatoire River, September 15, 1934, and of unrecorded floods on Apishapa and Timpas Creeks, is shown by the daily discharge of the Arkansas River at Nepesta, La Junta, and Lamar. Apishapa and Timpas Creeks enter the Arkansas River between Nepesta and La Junta, and the Purgatoire River enters it between La Junta and Lamar.

Daily discharge, in second-feet, of Arkansas River, Sept. 13–18, 1934

Station	September					
	13	14	15	16	17	18
Nepesta	103	90	324	66	57	53
La Junta	19	19	[1] 2,840	110	27	20
Lamar	9	5	2,800	[2] 9,600	145	14

[1] Peak discharge 12,600 second-feet.
[2] Peak discharge 34,700 second-feet.

1944

The flood of July 4, 1944, on Wilson Creek, a tributary of Oil Creek (see p. 84), caused a flood in the Arkansas River below the mouth of Oil Creek. At the Colorado Fuel & Iron Co.'s diversion dam, 3 miles west of Florence, the crest arrived at 12:45 a. m., July 5, and lasted about 30 minutes. Its discharge was computed as about 19,000 second-feet by the Colorado Fuel & Iron Co.[47a] As the flood

[47a] Statement of H. H. Christy, assistant chief engineer.

proceeded downstream its peak was reduced to 9,720 second-feet (4:15 a. m.) at the Portland gaging station, 9 miles downstream, and to 5,980 second-feet (8:15 a. m.) at the Pueblo station, 24 miles farther downstream.

GRAPE CREEK

Grape Creek rises in the Sangre de Cristo Mountains and flows through Wet Mountain Valley, which at its lower end has an altitude of 7,800 feet. Below Wet Mountain Valley the creek flows in a canyon cut through the Wet Mountains and joins the Arkansas River near Canon City. In the canyon section the creek falls 2,300 feet in 28 miles, an average of 82 feet per mile.

Cloudbursts do not occur in Wet Mountain Valley but are frequent in the canyon section. The earliest recorded cloudburst flood on Grape Creek is that of August 9, 1889, which was described in the Canon City Record of August 17:

> A storm visited this vicinity, which will be long remembered. At about 4 o'clock in the afternoon the clouds over Grape Creek attracted attention. It was not long till rain began to pour in town so hard that observations of Grape Creek were cut off. It rained nearly an hour in the city [about 1 inch].
>
> The water came down Grape Creek in greater volume than ever before known, bringing down ties, rails, bridge timbers, etc. The water crossed Arkansas River [about 150 feet wide], washing out the track on the main line of the Denver & Rio Grande and piling it up on the north side. As the water came into the Arkansas it raised the river to a higher point than ever before known.

During 1925 a gaging station was maintained in the canyon section about 5½ miles above the mouth, and the recording gage charts showed cloudburst floods on July 10, 16, 20, 21, and 29, and on August 3, 5, and 25. The highest flood was that of July 21, which occurred at 4 p. m. and reached a peak of 13.6 feet, rising 12.5 feet in less than 30 minutes and dropping nearly as rapidly for the first 8 feet. From a slope-area measurement the peak discharge was found to be 14,500 second-feet. This flood originated wholly in the canyon section, as the small rise in Wet Mountain Valley was stored in the Deweese-Dye Reservoir near the head of the canyon. The area between the reservoir and the gaging station is 145 square miles. It is probable, judging from the characteristics of cloudbursts, that the flood came from the 32 square miles of canyon section above the station. The other floods listed were very much smaller, no one of them exceeding a few thousand second-feet.

WILSON CREEK

Wilson Creek, a tributary of Oil Creek, drains a rugged area of 68 square miles lying northwest of Canon City. A cloudburst on July 4, 1944, caused a flood in the lower part of the creek which was said locally to have been the highest since about 1906. The Bureau of

A. BRIDGE WEST OF PUEBLO.

B. RAILROAD YARDS IN PUEBLO.

DAMAGE TO DENVER & RIO GRANDE RAILROAD CAUSED BY FLOOD OF JUNE 1921.

CITY OF DENVER DURING THE FLOOD OF MAY 19–20, 1864.

Courtesy of Cherry Creek Flood Commission.

Reclamation made an investigation of the flood of 1944, and the following description is based on that agency's report.

The heaviest rainfall occurred on the north side of the creek and extended about 4 miles above the mouth. A resident living near the mouth in NE¼ sec. 9, T. 18 S., R. 70 W., stated that the storm originated in the northwest, and that the intense precipitation, accompanied by some hail, lasted from 9:30 to 10:15 p. m. A light rain continued for some hours afterward. A wooden barrel in an orchard caught 6¼ inches of water during the storm. In the SE¼ sec. 8, T. 18 S., R. 70 W., near the southern edge of the area of intense rainfall, 4½ inches was measured in a steel gasoline barrel. An incomplete record in the center of sec. 15, T. 18 S., R. 80 W., gave 2⅜ inches for about 35 minutes during the height of the storm. Oil Creek above the mouth of Wilson Creek did not have a severe flood; this indicates that the area of intense rainfall did not extend far above Wilson Creek.

A slope-area measurement made near the mouth of Wilson Creek in SW¼ sec. 3, T. 18 S., R. 70 W., indicated a peak discharge of 20,600 second-feet, or 303 second-feet per square mile for the entire drainage basin. To obtain some indication of the unit run-off from the lower part of the basin, a slope-area measurement was made in NE¼ sec. 31, T. 17 S., R. 70 W., and this gave a peak discharge of 16,800 second-feet. From these two measurements, it appears that the peak discharge from the intervening area of 6.7 square miles was at least 3,800 second-feet or 567 second-feet per square mile.

FOUNTAIN CREEK

Fountain Creek rises near Woodland Park and drains the northeast slope of Pikes Peak. It emerges from the foothills near Colorado Springs, flows 52 miles across the plains, and empties into the Arkansas River at Pueblo. In the mountains the creek has a heavy fall, but below Colorado Springs its fall decreases from 30 feet per mile to 17 feet per mile near the mouth.

Prior to September 1, 1938, no gaging station was maintained on Fountain Creek. The Weather Bureau has a staff gage near the mouth, which is read during flood stages.

The earliest record of a flood on Fountain Creek is that of June 10, 1864. The Colorado Springs Gazette of June 27, 1874, in a series of articles on early-day happenings, refers to the flood of 1864:

> There had been several thunder showers and the creeks were somewhat swollen, though not so much as to cause any apprehension. But about 4 o'clock * * * a heavy cloud came up over Cheyenne Mountain and the sky gathered darkness until nearly sundown, when rain and hail began to fall in tremendous torrents. * * * The rain came down, not in drops, but in floods, the hail consisted of huge lumps of ice, some of them over 3 inches in diameter; the whole surface of the country was flooded as though it were a vast lake, and in some of the ravines

the water rushed along in torrents 20 or 30 feet deep. The storm continued in full violence until about 9 o'clock. The area of the storm was confined within * * * a radius of 3 or 4 miles.

The vast quantity of water shed from the mountains gathered in the valley and swept downstream in a wide torrent, covering all the low country adjacent to the creek. [Near the present town of Fountain several were drowned.] About midnight the people from 20 to 30 miles below Colorado City (adjacent to present city of Colorado Springs] were alarmed to find a flood of water rushing down upon them without warning. Some took refuge in the tops of their houses, others * * * fled for their lives, and [nine] were drowned * * *. They fell into holes or ravines where the water was many feet deep. In the houses from which they fled the water was not more than 2 feet deep.

The crops were almost totally destroyed, and hundreds of acres were covered with "wash" so as to be ruined for cultivation. The flood was followed by several heavy rains in the mountains and the streams were high for many weeks. For a month or more it was impossible to ford the Fountain below Colorado City.

Near its mouth at Pueblo, Fountain Creek washed away many cabins on its banks, but no loss of life was reported. No estimate of the discharge is available, but as no mention is made of damage in Colorado City above Monument Creek, it is apparent that the peak at that point was not more than 8,000 second-feet, which is the present capacity of the Fountain Creek channel through Colorado Springs above Monument Creek.

The storm of May 21–22, 1876, which was apparently heaviest at Denver, caused 3.19 inches precipitation on Pikes Peak and 2.62 inches at Colorado Springs. It is probable, however, that this precipitation was chiefly in the form of snow and caused no serious flood. The only reference to this flood is a statement in the Colorado Springs Gazette, May 27, 1876, to the effect that Fountain Creek had risen very high, but no mention was made of overflow or resulting damage.

Although the few available precipitation records for 1878 indicate no general storm, a cloudburst near Palmer Lake caused a flood in May reported by the Rocky Mountain News of May 20, 1878, as follows:

Monument and Fountain Creeks swept out bridges. El Paso County losses very heavy, caused by cloudburst in valley near Divide, followed by hail.

The heavy snow cover in the spring of 1884 caused a flood on Fountain Creek; the high water at its mouth was referred to by the Pueblo Commercial Standard, June 28, 1884:

The Fountain at Pueblo was wide, swift, and deep on Thursday [June 26] and swept away both the wagon bridges on Fifth Street and the Denver & Rio Grande Railroad bridge.

This was about the date of the peak flows for that year in other streams of the State, caused by heavy rains augmenting the rapid melting of the deep snow cover. Although no mention was made of

rain in the Fountain Creek Basin, it is possible that heavy rain fell there also.

A severe cloudburst in the northern part of Colorado Springs on July 25, 1885, caused a sharp flood on Monument Creek which, according to the oldest inhabitant, was the highest known there up to that time.[48] It was apparently of short duration, and the resulting flood on Fountain Creek was soon flattened out.

The next serious flood, that of May 30, 1894, was caused by a general storm which resulted in floods in the South Platte and Arkansas River Basins. From May 21 to 27, precipitation of 2 inches or more in the upper basin of Fountain Creek had prepared the soil for rapid run-off of the intense precipitation of May 29–31 but as the heaviest precipitation was in the form of snow, the resulting flood was materially reduced. The flood in the vicinity of Colorado Springs was described in the Denver Republican for June 1, 1894, which quotes the following dispatch, dated May 31, from Colorado City:

> The flood has done great damage at this place. The Fountain, which flows through this town, has been very high for the past 24 hours. Early this morning the north approach of West First Street Bridge was carried away. * * * The water rose so high by noon that a large amount of bridge timber and other material was carried away. * * * At 7:30 this evening a two-room house * * * located at the south end of West First Street Bridge was carried away.

At Manitou, Ruxton Creek was reported as being at the highest stage known. A Manitou dispatch, dated May 31, is quoted in the Rocky Mountain News of June 1, 1894:

> Rain has been falling steadily all day, making a continuous fall of 50 hours, an unheard-of thing for Manitou. * * * This evening [May 31] the Ruxton is still a raging torrent, and the Fountain has been tearing away stone walls and foundations and bridges all day. * * * Canon Avenue, the road leading to Williams Canon, is a mountain torrent, down which hundreds of tons of rock have been washed.

Little damage was caused in Colorado Springs, as neither Fountain Creek nor Monument Creek overflowed its banks to any considerable extent.

In the lower valley of Fountain Creek the flood did considerable damage to the Denver & Rio Grande Railroad. It changed the creek channel in two places and in so doing washed out the railroad track. In places only the rails were left swinging across great gaps, and near Eden the double track was out for a considerable distance. Conditions near the mouth of Fountain Creek are reported in the Colorado Springs Gazette of June 2, 1894:

> The Fountain has only fallen 2 feet since morning. The damage caused by

[48] Colorado Springs Gazette, August 1, 1885.

this stream cannot be estimated. At the Eighth Street Bridge [Pueblo] the water washed away the south bank, which is 25 feet high, for a distance of 300 yards. [Another bridge with a span of 140 feet was required for the new channel.]

From May 26 to 28, 1902, rainfall was general over the Fountain Creek drainage area, the recorded precipitation being as follows:

Rainfall, in inches, in Fountain Creek Basin, May 26–28, 1902

Station	Altitude (feet)	May			Total
		26	27	28	
Husted	6,540	0.58	1.53	0.36	2.47
Glen Eyrie	6,500	.20	1.03		1.23
Lake Moraine	10,265	.10	1.10	.45	1.65
Colorado Springs	6,098	1.32	1.42	.28	3.02
Pueblo	4,685	.03	1.93	.34	2.30

A cloudburst on May 27, 1902, between the southern edge of Colorado Springs and a point several miles south of Fountain, a distance of about 15 miles, caused a sudden flood on Fountain Creek. South of Kelker the creek cut a new channel 30 feet deep, making it necessary for the Denver & Rio Grande Railroad to construct a new bridge. A former section foreman stated that at Buttes the flood moved the depot from the west side of the tracks to the east side, and twisted the rails around the section house to such an extent that the house was not washed away. As a result of that flood the railroad raised its tracks about 10 feet near Buttes. The Colorado Springs Gazette in its issue of June 5, 1902, described the experience of a rancher who was caught in the stream bed by the "wall of water 10 feet high" and hurled from his carriage, but who managed to save his life. The Pueblo Chieftain reported that the greatest volume of water since the flood of 1864 reached Pueblo and destroyed everything in the lowlands of Fountain Creek.

One of the worst floods of record for this area was caused by the general storm of June 2–7, 1921. The flood in the vicinity of Colorado Springs is described in the Colorado Springs Gazette, June 4, 1921:

> Shooks Run had before 9 p. m. [June 3] become a river. It had spread its waters over the northwestern part of the city, covering several blocks. * * * Sand Creek and Fountain Creek were roaring, [filling] the banks to overflowing, flooding gardens, farms, ranch houses, etc. * * * Old timers declared it the worst storm in 25 years. In Manitou the storm seemed not to have been as severe as in Colorado Springs.

In its issue of June 5, the Gazette continued:

> Fountain Creek, Monument Creek, and Shooks Run, which night before last

overflowed their banks and caused families to flee, * * * subsided yesterday morning. * * * At the confluence of North and South Cheyenne Creeks, the main road past Stratton Park was a roaring river. Gardeners and ranchers suffered greatly in loss of crops, washed out by swollen streams or beat down by heavy rain and hail.

The flood on Fountain Creek overflowed the valley from Colorado Springs to the mouth of the creek at Pueblo, destroying bridges and damaging the agricultural land. Its peak reached Pueblo 3 hours after the peak in the Arkansas River had passed and when the river had fallen 7 feet.

The Denver & Rio Grande Railroad Co. compiled the following synopsis from statements by its employees:

Colorado Springs: Very heavy rain from early evening June 3 until morning June 4.

Fountain: Rained practically continuously from 4 p. m. to 4 a. m. The worst storm ever witnessed in Colorado. Could not see a car length ahead with a lantern. Water running over the track and nearly to the top of the Sand Creek Bridge.

Buttes: Flood came very suddenly at 11:15 p. m. and by morning had risen about 10 feet.

Pinon: Heavy rain started at 9 p. m. Water rose to depot about 4 a. m. Pumpman marooned in pumphouse. Stayed on top of pump until morning.

Bragdon: Storm began about 8:30 p. m. and rained terribly hard all night.

Eden: Terrible storm all night.

From additional information it appears that the peak on Fountain Creek between Buttes and Bragdon occurred between 11 p. m. and midnight June 3, and the peak at the mouth at 3 a. m. June 4.

No measurement of the peak discharge at Colorado Springs was made, but F. O. Ray, city engineer, states that neither Fountain Creek nor Monument Creek destroyed any bridges and that neither overflowed its banks in the city, where the channel capacity of Monument Creek was 10,000 second-feet and that of Fountain Creek above Monument Creek was 8,000 second-feet. Therefore, the peak just below the junction of the two creeks did not exceed 18,000 second-feet. The Geological Survey made a slope-area measurement at the mouth of Fountain Creek soon after the flood and found the peak discharge to be 34,000 second-feet. The total discharge from 9 p. m. June 3 to 3 p. m. June 6 was about 70,000 acre-feet.[49]

Rain during the period July 27–30, 1932, was recorded in the Fountain Creek Basin by the United States Weather Bureau as follows:

[49] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3–5, 1921: U. S. Geol. Survey Water-Supply Paper 487, p. 33, 1922.

Rainfall, in inches, in Fountain Creek Basin, July 27–30, 1932

Station	Altitude (feet)	July				Total
		27	28	29	30	
Fremont Experiment Station	8,836	1.28	----------	0.16	0.76	3.20
Monument	7,200	----------	----------	.92	.59	1.51
Lake Moraine	10,265	1.20	0.06	----------	.89	2.15
Colorado Springs	6,018	----------	----------	1.78	1.76	3.54
Pueblo	4,685	----------	----------	1.30	.01	1.31

This storm caused a flood on Fountain Creek, which at its mouth had a peak discharge of 20,000 second-feet, as reported by the State Engineer. As rain was general over the basin, the creek was in flood from its headwaters to its mouth. A dispatch from Colorado Springs appearing in the Pueblo Chieftain of July 30, 1932, stated:

> Following a cloudburst in the Black Forest a wall of water swept down through Templeton Gap late this afternoon, flooding Papetown mining settlements just north of here and most of the northern part of the city.

A slope-area determination of the peak flow at Templeton Gap made by Paul V. Hodges indicated 6,100 second-feet. The Pueblo Chieftain of July 30, contained also the following statement:

> Storm in Colorado east and south of Denver had its greatest intensity between Colorado Springs and Pueblo. Torrential rains near Fountain caused fear of flood. Washouts [on railroads] between Buttes and Pinon consisted of several big holes undermining the track. A 200-foot section on the Denver & Rio Grande was washed to a depth of about 6 feet.

The torrential storm of May 30, 1935, which caused floods on the Republican River and on Kiowa and Bijou Creeks, was concentrated, in the Fountain Creek Basin, chiefly over Kettle Creek, a tributary of Monument Creek. The Office of the State Engineer, and the city engineer of Colorado Springs, both investigated the storm causing the flood. The following table summarizes the information obtained. The heaviest precipitation reported included an undetermined amount of hail.

In describing this flood, which was the greatest known on Monument Creek, the Colorado Springs Gazette, May 31, 1935, stated:

> The destructive flood waters from a half dozen cloudbursts swept through Monument Valley * * * shortly after noon. Earlier, a cloudburst had sent Sand Creek, east of Colorado Springs, on a tear.
>
> Dozens of houses in the low-lying areas were lifted from their foundations and moved, a few as far as 300 and 400 feet. * * * Railroads suffered heavily. Tracks of the Denver & Rio Grande Western Railroad were washed out for several hundred feet north from the road's station west of Antler's Park. The waters themselves reached the station. All bridges across Monument and Fountain Creeks in the city except [one] were destroyed.

Rainfall in Fountain Creek Basin, May 30, 1935

[Data furnished by State Engineer of Colorado, except as otherwise noted]

Location	Rainfall (inches)	Method of measurement	Time of occurrence
Sec. 15, T. 11 S., R. 67 W.[1]	0.27	Standard Weather Bureau rain gage.	
Sec. 24, T. 11 S., R. 66 W.	3		
Sec. 31, T. 11 S., R. 65 W.	8		
Sec. 5, T. 12 S., R. 65 W.	10		
Sec. 6, T. 12 S., R. 65 W.	12		
Sec. 7, T. 12 S., R. 65 W.	8–10		
NW¼ sec. 13, T. 12 S., R. 66 W.	18		
Sec. 15, T. 12 S., R. 66 W.	18	Stock tank	1 to 4 p. m.; included hail.
Sec. 16, T. 12 S., R. 66 W.	12		
SE¼ sec. 21, T. 12 S., R. 66 W.[2]	8	Standard rain gage	
Sec. 30, T. 12 S., R. 65 W.	8		
Sec. 5, T. 13 S., R. 65 W.	8		
Sec. 31, T. 12 S., R. 66 W.[2]	4.1		7:30 a. m. to 3 p. m., intermittent.
Sec. 5, T. 13 S., R. 66 W.	6		
Sec. 4, T. 13 S., R. 66 W.	6		
Sec. 21, T. 11 S., R. 67 W.	.1		
NW¼ sec. 16, T. 14 S., R. 66 W.[1]	2.34	Standard Weather Bureau rain gage.	
Sec. 1, T. 14 S., R. 66 W.	3		
Sec. 12, T. 14 S., R. 67 W.[2]	7		Three storms, 10:30 a. m. to 2:30 p. m.; heaviest, noon to 12:45 p. m.
Sec. 6, T. 16 S., R. 65 W.	0		

[1] From reports of U. S. Weather Bureau.
[2] Data furnished by F. O. Ray, city engineer of Colorado Springs.

Four lives were lost in Colorado Springs, and the property damage, exclusive of that suffered by the railroads, was estimated by the city engineer as $1,215,000. At Pikeview, 6 miles north of Colorado Springs, Monument Creek reached a stage of about 14 feet at the gaging station established September 1938.

The flood of 1935, like that of 1921, overflowed the valley of Fountain Creek from Colorado Springs to the mouth, at Pueblo, destroying bridges and damaging agricultural land. During its progress through the valley, creeks in the vicinity of Fountain that head above Colorado Springs in the region of intense rainfall were also in flood and contributed a very considerable but unknown quantity to the flood on Fountain Creek. At the site of the present gaging station on Fountain Creek below Fountain, the flood reached a peak stage of 14.4 feet and overflowed the valley to a width of about half a mile. This stage was about 2 feet higher than that reached in 1921, when the channel was somewhat narrower, and is the highest known at this site. At Pueblo the flood eroded the banks in the vicinity of the State Hospital to such an extent that several small buildings were swept away. It was estimated that 4 acres of land was eroded. According to a witness of the floods of both 1921 and 1935 at a point 1½ miles above the mouth of Fountain Creek, the flood of 1935 was higher than that of 1921. During both floods the channel was scoured

to bedrock, which lies at a depth of 3 to 9 feet below the sand in the channel.

In Colorado Springs, Monument Creek reached flood stage in less than an hour, attained its peak 1½ hours later, receded slightly for 1½ hours, and was back within its channel 1½ hours later. F. O. Ray, city engineer of Colorado Springs, made a slope-area determination of the peak discharge in the best section, on Fountain Creek about 3,000 feet below the mouth of Monument Creek. Here the discharge was found to be 55,000 second-feet. As the peak flow of Fountain Creek above the mouth of Monument Creek was determined to be about 5,000 second-feet, the peak discharge of Monument Creek was 50,000 second-feet. Of the 238 square miles drained by Monument Creek, 75 square miles was affected by the intense rainfall. Therefore, the peak discharge represents a run-off of 667 second-feet per square mile of area directly affected. The total discharge of the flood on Monument Creek was estimated to be about 8,000 acre-feet. The Office of the State Engineer made a slope-area determination of the peak discharge at the mouth of Fountain Creek and found it to be about 35,000 second-feet.

COMPARISON OF FLOODS

No definite information relative to the magnitude of the flood of 1864 throughout Fountain Creek Valley is available, but as the storm that preceded this flood was widespread, causing serious floods on other streams also, it would appear that the flood increased in magnitude throughout its course and that in the lower valley it was perhaps the greatest known.

Had it not been that much of the precipitation preceding the flood of 1894 was snow, that flood would doubtless have been greater than the flood of 1864. It appears, however, to have been less severe than the floods of 1921 and 1935.

During the flood of June 1921 the peak discharge increased from about 18,000 second-feet at Colorado Springs to 34,000 second-feet at the mouth of Fountain Creek, owing to the fact that the rainfall increased in amount toward the mouth. On the other hand, the flood of May 1935 was caused by intense rainfall on the headwaters, and there was little or no precipitation over the remainder of the valley. Had it not been for the floods on the tributary streams, whose headwaters are in the area of intense rainfall, the channel and valley storage along the main stream would have reduced the peak discharge at the mouth of Fountain Creek to a much smaller volume than 35,000 second-feet.

It is difficult to compare the magnitude of the various floods on the basis of the stages corresponding to their peak discharges, because

each successive flood widened the channel. An observer who has been familiar with the creek at Fountain for many years says that in June 1896 the 40-foot bridge was a log-crib structure whose condition indicated that it had been in use for a considerable number of years, and that the channel was narrow. That bridge was destroyed by the flood of May 1902, which so widened the channel that it was later necessary to lengthen the new bridge structure 30 feet. Succeeding floods have further widened the channel, until at the present time the bridge span is about 200 feet.

Fountain Creek is subject to sudden rises, and for many of them the discharge near the mouth at Pueblo has been measured or estimated by the Office of the State Engineer.

Miscellaneous peak discharges on Fountain Creek near mouth

	Second-feet		*Second-feet*
June 30, 1934	20,000	Aug. 1, 1923	4,000
Aug. 15, 1921	10,000	Aug. 5, 1923	4,000
July 17, 1923	10,000	Aug. 4, 1929	4,000
Aug. 21, 1923	10,000	Aug. 14, 1934	4,000

TEMPLETON GAP

A semicircular range of hills 5 miles northeast of Colorado Springs encloses a basin having a narrow outlet known as Templeton Gap. This area is subject to frequent cloudbursts and resulting floods. The earliest flood of record in this area, and apparently the most severe, occurred July 25, 1885, when cloudbursts were still called waterspouts. The Colorado Springs Gazette, July 26, 1885, gives this account:

> H. T. Cook, who resides 5 miles northeast of Templeton Gap, says that for an hour during the evening [July 25] there was an incessant fall of rain to the extent that a tub near the house filled with water in the space of an hour. This indicates a rainfall of about 16 inches.
>
> Immediately the mighty torrent came tearing down the gulch which runs through the ranch below the house, and, not withstanding the house is located 15 feet above the gulch, the water completely surrounded it for a long distance, at a depth of several feet. The mighty torrent came rushing down the gulch in massive waves, capped with white foam. After 2 hours, the water having passed off into Sand Creek, 5 miles east of Templeton Gap, the water subsided from the vicinity of the house.

This account describes the runoff east of the hills surrounding Templeton Gap. The resulting flood through the gap, which entered Shooks Run, washed away houses that were considered above possible flood stage and caused one death.

Another cloudburst occurred May 27, 1922. An investigation of the flood that followed it was made within a few days by the Geological

Survey.[50] The peak discharge of 6,120 second-feet from 7.1 square miles gave a unit runoff of 862 second-feet per square mile. The total runoff from the storm was estimated at 757 acre-feet.

HOGANS GULCH

A cloudburst occurred August 7, 1904, on Hogans Gulch, a dry channel entering Fountain Creek near Eden. The Denver & Rio Grande Railroad estimated the peak discharge of the resulting flood at 9,640 second-feet, or 1,580 second-feet per square mile from the drainage area of 6.1 square miles.[51]

ST. CHARLES RIVER

The St. Charles River drains the eastern slope of the southern half of the Greenhorn Range and the foothill region lying between that range and the Arkansas River. After leaving the mountains the St. Charles River flows through a canyon for 10 miles, below which the valley widens and the river finally emerges upon the plains, across which it flows to its junction with the Arkansas River, 8 miles below Pueblo. From Beulah to the plains the fall decreases from 119 feet to 40 feet per mile, and across the plains the average fall is 25 feet per mile.

Gaging stations on St. Charles River

Station	Drainage area (square miles)	Period of record
Burnt Mill	166	April to September 1922; March 1923 to September 1934.
At mouth	482	April 1924 to September 1925.

The earliest recorded flood on the St. Charles River was that of May 20, 1901. The only information regarding it is contained in the press. The Pueblo Chieftain of May 23, 1901, included in a dispatch from Beulah:

> On Monday evening [May 20] about 6 p. m., rain began to fall here with some hail. The storm increased until all the streams in the valley were out of their banks, and the oldest settlers * * * declared they have never seen such a rainfall. All the bridges were washed out.

The issue of the Pueblo Chieftain of the day previous, May 22, had contained the following:

> Rio Grande train 115 lies in the bed of the St. Charles River at San Carlos [about 12 miles above the mouth] a snarl of wreckage. * * * It was accomplished in less than 2 minutes * * * when the train bore down upon the trestle. Coincident with the striking of the trestle by the train came a 10-foot

[50] Follansbee, Robert, and Hodges, P. V., Some floods in the Rocky Mountain region: U. S. Geol. Survey Water-Supply Paper 520, p. 121, 1925.

[51] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3-5, 1921: U. S. Geol. Survey Water-Supply Paper 487, p. 40, 1922.

wall of water, which swept everything before it. The bridge is 12 feet high, 15 bents long, each bent being 16 feet.

During the general storm of June 2–5, 1921, the St. Charles River had its highest flood of record. There were no precipitation stations of the United States Weather Bureau in the St. Charles Basin, but at stations in the adjacent Huerfano Basin the rainfall recorded was as shown in the following table:

Precipitation, in inches, in Huerfano River Basin, June 3–5, 1921

Station	Altitude (feet)	June			Total
		3	4	5	
La Veta Pass	9,242	0.98	0.89	----------	1.87
Cuchara Camps	8,200	----------	.86	0.21	1.07
Huerfano	6,010	----------	1.06	.56	1.62

The Geological Survey made an investigation of the resulting floods on the Arkansas River and tributary streams in June 1921 and compiled statements of local residents regarding the rainfall. In Boggs Flat, adjacent to the St. Charles Basin on the north, it was reported that 5 inches of rain fell in 30 minutes on June 3, and that 6 inches of water ran over the prairie. At Beulah a hard rain during the night of June 3–4 was reported.[52] The original measurement of the peak discharge near the mouth of the St. Charles River was 71,800 second-feet. Further study of that measurement and of the precipitation in the St. Charles Basin leads to the belief that the measurement is too high and that the peak was probably nearer 56,000 second-feet, as determined by the Office of the State Engineer. On that basis the total discharge during the flood was about 47,000 acre-feet.

Only one cloudburst flood on the St. Charles River is recorded. It occurred August 22, 1925, when a cloudburst caused a peak discharge of 21,800 second-feet, with the river at a stage of 22.13 feet, at Burnt Mill. The flood was of such short duration that the mean discharge for the day was only 1,250 second-feet. This flood did not reach the mouth of the river, as it was reduced to such an extent by channel storage that diversions absorbed it.

CHICO CREEK

The 750 square miles drained by Chico Creek adjoins on the east the area drained by Fountain Creek. Chico Creek rises 15 miles east of Colorado Springs and flows southward to the Arkansas River, which it joins 14 miles east of Pueblo. Throughout the upper half of its course the creek has an average fall of 65 feet per mile; in the lower

[52] Follansbee, Robert, and Jones, E. E., op. cit. (Water-Supply Paper 487), p. 14.

half the fall is 29 feet per mile. Chico Creek carries little water except after heavy rains.

The greatest flood recorded on Chico Creek was that caused by the storm of June 2–5, 1921. The Office of the State Engineer made a slope-area measurement of the peak discharge and found it to be 28,600 second-feet. The total discharge was about 36,000 acre-feet.[53] No record of precipitation in the basin during that storm is available.

The next highest measured discharge was 8,000 second-feet, on May 19, 1935, as determined by the Office of the State Engineer.

HUERFANO RIVER

The Huerfano River rises in the Sangre de Cristo Range at an altitude of about 11,000 feet, and drains the eastern slope of that range and the south slope of the Wet Mountains, emerging on the plains near Badito. It flows across the plains for a distance of 61 miles through a series of canyons, finally entering the Arkansas River near Boone. For a distance of 11 miles above Badito the fall is 44 feet per mile, from Badito to the mouth of Apache Creek it is 49 feet per mile, and below the mouth of Apache Creek it is gradually reduced to 27 feet per mile:

Gaging stations on Huerfano River

Station	Drainage area (square miles)	Period of record
Manzanares Crossing, near Redwing	76	July 1923 to date.
Badito	519	August to December 1912; April 1923 to September 1925; March 1938 to date.
Near Undercliffe	1,702	August to December 1908; May 1938 to date.

Huerfano River is subject to cloudburst floods, although the station near Redwing appears to be near the upper limit of the cloudburst zone. The peak flow at the Redwing station during the period of record was about 1,500 second-feet on July 27, 1934, at a stage of 4.8 feet. No further information is available.

The storm of October 4–6, 1911, which was general over southwestern Colorado, extended over the eastern slope of the Sangre de Cristo Range. Rainfall in the Huerfano River Basin and in adjacent basins during that storm was reported by the Weather Bureau as shown in the following table.

[53] Follansbee, Robert, and Jones, E. E., op. cit., p. 35.

Precipitation in inches, in Huerfano River Basin and adjacent basins, Oct. 4–6, 1911

Station	Altitude (feet)	October			Total
		4	5	6	
Santa Clara	8,250	0.21	0.73	0.09	1.03
Cuchara Camps	8,200	.26	1.46		1.72
La Veta Pass	9,242	.59	1.42		2.01
Stonewall	8,000	.20	.95	.04	1.19

The rainfall caused the failure of Goose Lake Reservoir (capacity about 500 acre-feet), near the head of the Huerfano River. It is probable that the reservoir had been nearly filled before it gave way and that the sudden release of the stored water caused the flood, which was described in the Pueblo Chieftain of October 6, as follows:

With the bursting of the reservoir a huge wall of water rushed down the [narrow mountain] valley a distance of 35 miles to Gardner, where a rancher lost his life, unable to escape the onrushing waters, which took away his home and barns and all his stock. * * * [Two men] living close to Manzanares Creek were drowned.

As the rainfall did not extend east of the mountains, it is probable that the (undetermined) peak discharge was so reduced that it was not a serious flood. This is borne out by the fact that the discharge of the Arkansas River at Nepesta below the mouth of the Huerfano River, was not much greater than at Pueblo, above the mouth.

The highest flood of actual record on Huerfano River occurred during the night of July 27–28, 1936, as a result of rains that were general throughout the central part of the State. The nearest point at which a Weather Bureau precipitation record was available was North Lake, in the Purgatoire River Basin, about 25 miles upstream from Trinidad. This showed 1.80 inches of rain on July 27. The Walsenburg Independent states that 0.97 of an inch of rain was recorded at Walsenburg. An investigation of this flood was made by the Geological Survey in 1939, and the following statements regarding the precipitation were obtained:

Sec. 8, T. 27 S., R. 71 W.: Very hard rain. Deer Creek, just below, had very heavy runoff and was evidently in area of extremely high precipitation. [No one living there.]

Redwing, sec. 2, T. 27 S., R. 71 W.: 2½ inches estimated night of July 27–28. Storm hit the high ridges and dry arroyos.

Gardner, sec. 13, T. 26 S., R. 70 W.: No unusually heavy rain.

Badito, sec. 4, T. 27 S., R. 68 W.: For several-day period, ½ inch each day.

Diversion dam for Huerfano Valley ditch, sec. 22, T. 23 S., R. 63 W.: About 1 inch of rain.

The Walsenburg Independent of July 28, 1936, stated:

The Huerfano River was reported out of its banks between Gardner and Farisita, flooding lowland gardens and carrying away hogs and other small livestock

which was in the river bottom. Flooded arroyos made travel between Walsenburg and Gardner impossible. * * * The cloudbursts fell west of Gardner and Walsenburg, beginning at 1:30 Monday afternoon [July 27].

East of the mountains the river flows through a sparsely settled region, and no information regarding precipitation or flood is available, except at the gaging station near Undercliffe. It is believed, however, that precipitation occurred rather generally over the lower basin, as Weather Bureau records in the Arkansas Valley showed 1.21 inches at Pueblo and 1.05 inches at Las Animas on July 27. At the Redwing gaging station, the peak discharge was 488 second-feet and continued above 400 second-feet for several hours.

The high-water mark at Badito was connected with the gage datum established in 1938, and the peak discharge determined by extension of the rating curve was about 5,000 second-feet. The duration of the peak is not known. The gaging station near Undercliffe, in sec. 22, T. 23 S., R. 63 W., is 600 feet above the diversion dam of the Huerfano Valley ditch. From well-defined high-water marks and the length of the overflow section of the dam, which is virtually a broad-crested weir, the peak discharge, which reached a stage of 11.4 feet above the crest of the dam, was computed as 26,600 second-feet, after correction for velocity of approach. The head gates of the ditch were closed during the flood. R. F. Phillips, who lives at the dam, stated that the peak lasted from 2 to 3 hours. The only information relative to discharge at the mouth is a statement in the Pueblo Star-Journal of July 28, 1936, to the effect that the Huerfano River at its mouth had a discharge of 5,000 second-feet.

By means of a scale at the dam, which had been rated by the Office of the State Engineer, Mr. Phillips estimated the peak flow of a number of minor floods during 1936. The largest of these are listed in the following table, in the order of diminishing peak discharge.

Minor floods on Huerfano River at Huerfano Valley Dam in 1936

1936	Peak discharge (second-feet)	Duration (hours)	Rainfall at dam (inches)	1936	Peak discharge (second-feet)	Duration (hours)	Rainfall at dam (inches)
Aug. 3	4,000	3	0.03	Aug. 1	1,500	4	.03
June 11	3,000	1	.02	Aug. 4	1,500	3	.01
May 24	2,000	7	.01	Aug. 7	1,500	5	.01
June 23	1,500	2	.00	Sept. 1	1,500	7	.00

Although the lower part of the basin is subject to cloudbursts, the only cloudburst flood of record there is that of August 1, 1923. The Office of the State Engineer estimated the peak discharge on that day as 19,400 second-feet. The area affected by the storm is not known.

APISHAPA RIVER

The Apishapa River rises on the south and east slopes of the Spanish Peaks, an outlying mass of the Sangre de Cristo Range, at an altitude of 13,000 feet. It emerges from the foothills near Aguilar and flows for a distance of 83 miles across the rolling plains to its junction with the Arkansas River 4 miles east of Fowler. In its upper section the fall is 268 feet per mile, but across the plains the fall is 24 feet per mile. Prior to March 1938 no gaging station was maintained on the Apishapa River.

Of the cloudburst floods to which the upper river is subject, the highest for which definite knowledge is available occurred August 10, 1938. It had a peak discharge of 5,200 second-feet at Aguilar, from a drainage area of 149 square miles.

The highest flood of record on Apishapa River occurred August 11, 1930. According to Morris Pitti, who lives near the river at Aguilar, it remained near its peak for 18 hours, indicating that this was not a cloudburst flood but a flood caused by heavy rains well distributed over the entire drainage basin. No record of the rainfall is available, except that it occurred in the upper basin. There was no rainfall at Aguilar. A rancher living 10 miles above Aguilar stated that the summer of 1930 was a wet one with many heavy rains. His statement is borne out by the precipitation records during August 1930 which show general rainfall for the entire State. From well-defined high-water marks at the present gaging station the maximum stage was found to be 20.7 feet. This overflowed a width of 1,500 feet for a period of about 44 hours. No estimate of the peak discharge was made.

On the lower Apishapa River the greatest flood known occurred August 22, 1923, as a result of the failure of the Apishapa Dam, 35 miles above the mouth which impounded 18,000 acre-feet of water. The immediate cause of its failure was a cloudburst flood caused by rains some distance above the reservoir, as there was little or no precipitation at the reservoir. Information relative to the storage capacity of the reservoir is too meager to make it possible to compute the peak discharge of the flood entering the reservoir. Shortly after the failure, Barton M. Jones, a consulting engineer, made an investigation and computed the maximum 15-minute average discharge from the reservoir due to its failure as 242,000 second-feet.[54]

The channel and valley storage on the lower river reduced this discharge to about 50,000 second-feet at the mouth. The average rate of travel of the water through the 35 miles between the dam and the mouth was about 10 miles per hour.

[54] Jones, B. M., and Floyd, O. N., Further report on Apishapa Dam failure: Eng. News-Record, Sept. 13, 1923, p. 423.

PURGATOIRE RIVER

The Purgatoire River, one of the principal tributaries of the Arkansas River, drains the eastern slope of the Culebra Mountains. Emerging from the mountains near Trinidad, it flows 130 miles across the rolling plains to its junction with the Arkansas River near Las Animas. From a point about 20 miles east of Trinidad to the mouth of Smith Canyon, a distance of 46 miles, the river flows through a canyon. Below that point the canyon gives way to a narrow valley, which extends nearly to the mouth. For a distance of 9 miles above Trinidad the fall of the river is 39 feet per mile; below Trinidad the fall decreases to 30 feet per mile.

Gaging stations on Purgatoire River

Station	Drainage area (square miles)	Period
Trinidad	742	May 1896 to July 1899, August to December 1905, November 1906 to March 1907, October 1907 to November 1912, April 1916 to date.
Near Alfalfa (canyon entrance)	1,300	March 1905 to September 1907, March 1924 to September 1928.
Ninemile Dam, near Higbee	2,900	October 1924 to date.
Highland Dam, near Las Animas	3,320	October 1931 to date.
At mouth, near Las Animas	3,398	May to September 1889, August to October 1909, April 1922 to September 1931.

The earliest flood on the Purgatoire River to which a reference has been found is that tentatively dated as 1859; evidence of a heavy flood on the lower stretch of the Arkansas River about that time has been noted. (See p. 74.)

The next flood on the Purgatoire River, according to available information, was in 1866. Meeker [55] states that a flood occurred at Trinidad in November 1866 and that two large floods occurred between 1866 and 1904. The exact dates of the two intervening floods could not be obtained, but it is probable that the first was in September 1875 and the second in June 1878. The total precipitation at Trinidad during June 1878 was 12.82 inches; the daily amounts are not available.

The earliest flood on the Purgatoire River for which definite information is available occurred in September 1875. Nothing is known regarding this flood in the upper part of the basin, but a flood near the mouth was described in the Las Animas Leader of September 18 and 25, 1875. The following quotation from that newspaper is taken from the report by Meeker.[56]

> On September 16 a rush of water came down Purgatory [Purgatoire] River at Las Animas. The water was 5 feet higher than at any previous time that year.

[55] Meeker, R .I., Purgatoire River flood: U. S. Geol. Survey Water-Supply Paper 147, p. 163, 1905.
[56] Idem, p. 165.

The Atchison, Topeka, and Santa Fe Railway Company's tracks were under water for one-half mile on each side of the Purgatory, the bridges being 3 to 4 feet under water. Up the Purgatory considerable damage was done, the greatest losses being of cord wood, stacked hay, cattle, fences, and adobe houses.

The next flood on the Purgatoire River for which reference has been found occurred in 1883. The chief authority for this date is "83" cut in the stone doorframe of the Trinidad water-works building, which was erected in 1879 near the river. As the 1904 flood is similarly marked, it is evident that the mark "83" refers to a flood during that year. The 1883 mark is 14 inches below the 1904 mark. This difference in elevation, however, is not direct evidence of the relation between the two floods, as the 1904 flood greatly increased the width of the river channel. No records of the precipitation in the Purgatoire River Basin during 1883 are available, and the files of the local newspaper for that year have been destroyed. As no reference to a flood in the lower river during that year has been found, it appears that the flood was caused by a cloudburst above Trinidad, and that the peak flattened out as it proceeded downstream. The only information obtained in Trinidad was that the flood occurred about midsummer and reached as far south as the Presbyterian church, also for a considerable distance north of the river. The wooden bridge spanning the river was washed away. The channel was a quarter its present width and the banks were heavily timbered with large cottonwood trees.[57]

Another flood to which reference has been found is that of July 24–25, 1886, during which 2-day period the precipitation at Las Animas was 3.36 inches.[58]

The greatest flood known in this region occurred September 29–30, 1904. The Geological Survey made an investigation a short time after the flood and published a complete report of it.[59] The following account is abstracted from that report.

The storm was most severe in New Mexico and caused record floods in the Canadian River Basin. In the Purgatoire River Basin the precipitation was especially heavy in Long Canyon, which enters Purgatoire River 6 miles above Trinidad, as the greater part of the flood originated in that water course. Raton Canyon, also, was a heavy contributor. The rise and fall of the river at Trinidad was reported by an eyewitness,[60] as follows:

The river was high on the afternoon and evening of Sept. 29, and rose steadily during the early part of the night. At 11 p. m. the water level was still 1.5 feet

[57] Information furnished by Mrs. Ruth A. Justin, City Librarian, Trinidad.

[58] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3-5, 1921: U. S. Geol. Survey Water-Supply Paper 487, p. 37, 1922.

[59] Meeker, R. I., Purgatoire River flood: U. S. Geol. Survey Water-Supply Paper 147, pp. 158–169, 1905.

[60] Idem, p. 162.

below the level of the river banks and about 5 feet deep in the channel. Shortly after this time the river rose rapidly and by 2:30 a. m. was at its highest stage, being 2 feet deep on the lawn of the Cardenas Hotel [near the stream] and within 5 inches of the hotel floor. This stage lasted until about 4 a. m., when it began to fall. By 8 a. m. on Sept. 30 the river was again within its banks and was rapidly receding.

During the flood a large iron safe was washed out of the Santa Fe station at Trinidad, and some months later was found three-quarters of a mile downstream, buried in the sand, from which it was recovered by means of a large derrick. Property damage in Trinidad, which included destruction of the Commercial Street Bridge was estimated at $350,000. A slope-area measurement showed the peak discharge to have been 45,400 second-feet, or 61 second-feet per square mile. The total discharge September 28 to October 2 was about 50,000 acre-feet. After this flood a wall was built in front of the railroad property, and the present Commercial Street Bridge was constructed. With these improvements the capacity of the channel in Trinidad is now 20,000 second-feet.[61]

Weather Bureau records for the storm of September 1904 on the Purgatoire and adjacent basins were as follows:

Rainfall, in inches, in Canadian, Purgatoire, and Huerfano River Basins, Sept. 26–30, 1904

Station	Altitude (feet)	September					Total
		26	27	28	29	30	
Canadian River basin, N. Mex.:							
Folsom	6,399	0.90	0.19	------	------	[1] 5.91	7.00
Raton	6,660	1.50	.80	1.10	3.98	------	7.38
Vermejo Park	7,600	.05	.37	.63	2.30	1.60	4.95
Purgatoire River basin:							
Clear View	9,500	.48	2.03	1.36	------	------	3.87
Trinidad	5,994	.18	.72	1.92	3.13	------	5.95
Hoehne	5,270	------	.10	3.00	2.15	------	5.25
Las Animas	3,899	------	------	1.20	.45	------	1.65
Huerfano River basin:							
Santa Clara	8,250	------	.75	1.79	2.36	------	4.90

[1] Includes precipitation of previous 2 days.

Between Trinidad and the canyon section of Purgatoire river the flood caused considerable damage to the farms and ranches in the valley and destroyed all the bridges over the river or washed out their approaches. The flood traversed the 130 miles between Trinidad and the mouth of the river in about 20 hours, or at the rate of 6.5 miles per hour. No estimate of the discharge at the mouth is available, but as the storm extended over the entire basin it is probable that the discharge was increased toward the mouth. The flood of 1904 in the lower course of the river was declared by local residents to be 2 feet higher than the flood of 1875.

[61] Letter from city engineer of Trinidad.

On October 20, 1908, a flood occurred on the lower Purgatoire River below Smith Canyon, but the upper river was practically unaffected, as the increase in the discharge at Trinidad on October 18 was only from 17 to 63 second-feet. The Geological Survey made an investigation of this flood and published its report.[62] From this report it appears that the southern limit of heavy rainfall was about 40 miles below Trinidad, near the canyon section of the river. The only precipitation stations in the basin were at Hoehne, which is below Trinidad, and at Las Animas, at the mouth. The following table gives these records.

Rainfall, in inches, in Purgatoire River Basin, Oct. 18–19, 1908

Station	Altitude (feet)	October		Total
		18	19	
Hoehne	5,721	0.22	0.60	0.88
Las Animas	3,899	.64	1.42	2.06

As very heavy discharges were reported from Smith Canyon, Bent Canyon, and other tributaries in the canyon section, it is evident that the precipitation in the canyon section was much heavier than that recorded at Hoehne and Las Animas. The river was out of its banks at the railroad bridge at Las Animas, and it overflowed both banks for a considerable distance. About 10 miles south of Las Animas a family living in a house near the river was forced to take refuge on the second floor as the river flooded the first floor to a depth of several feet. The river remained in flood for 48 hours or longer. Its stage, however, was not as high as during several previous floods. No estimate of the peak discharge was made. The storm that caused the Purgatoire River flood covered also the Rule Creek Basin 18 miles southwest of Las Animas. Three thousand sheep in a corral believed to be above the danger from floods were drowned during the night. The Mexican herders were asleep nearby and knew nothing of their loss until the next morning.[63]

The general storm of October 4–6, 1911, which caused serious floods in the San Juan Basin and the San Luis Valley, extended into the Purgatoire River Basin. The Trinidad Chronicle-News of October 5, 1911, reported:

> Trinidad and vicinity was visited last night by one of the worst rainstorms of years. The river reached a high point at midnight, but steadily receded today. Arroyos were swollen and creeks running full, and lowlands were flooded. * * * Little actual damage was done.

[62] Freeman, W. B., Flood in the Arkansas Valley, Colo., October 1908: U. S. Geol. Survey Water-Supply Paper 247, pp. 33–40, 1910.

[63] Trinidad Chronicle-News, Oct. 21, 1908.

No record of the peak discharge at Trinidad is available, but it must have been of short duration, as the mean daily discharge was increased from 42 second-feet October 4, to 1,120 second-feet October 5, and fell to 390 second-feet October 6.

Heavy rains July 19–22, 1925, caused a peak discharge at Trinidad that was the second highest of record there. Weather Bureau stations reported the following amounts:

Rainfall, in inches, in Purgatoire River Basin, July 19–22, 1925

Station	Altitude (feet)	July				Total
		19	20	21	22	
North Lake	8,700	0.13	0.03	0.53	-------	0.69
Trinidad	5,994	-------	-------	.50	-------	.50
Cuchara Camps	8,200	-------	.31	-------	0.09	.40
Huerfano	6,010	.26	.46	1.91	1.70	4.33

J. H. Baily, chief hydrographer of Colorado, made an investigation of this flood and found that it originated west of Trinidad, chiefly on tributaries on the north side of the Purgatoire River, particularly in Burro and Smith Canyons. It was reported that a coal bucket at the mouth of Smith Canyon was filled with water during the 40 minutes that the storm lasted, indicating a rainfall of 5 inches.

Reporting this flood in Trinidad the Trinidad Chronicle-News of July 23, 1925, stated:

> Scores of people along the river course about Cottonwood Avenue, Linden Avenue, and immediate area and a portion of Nevada Avenue and adjacent to the river * * * were forced to leave their homes. These areas were submerged. The Santa Fe depot and Cardenas Hotel property were under water, and the torrent swept some baggage trucks into the flood.

The flood peak at Trinidad was computed by studying the flow through the contracted opening of a concrete arch bridge and making a slope-area measurement of the overflow, which amounted to 5,700 second-feet. The total peak discharge thus estimated was 33,300 second-feet.

Gage height and discharge of Purgatoire River at Trinidad July 22–23, 1925

July	Time	Gage height (feet)	Discharge (second-feet)	July	Time	Gage height (feet)	Discharge (second-feet)
22	6:30 p. m.	3.0	1,000	22	10:00 p. m.	7.0	8,500
	7:00 p. m.	5.0	3,300	23	7:00 a. m.	3.0	1,600
	7:30 p. m.	13.2	33,300				

The total discharge during the flood was 8,150 acre-feet. The maximum stage appears from available information to have been about 2 feet lower than that of September 30, 1904.

The second highest flood in the Purgatoire River Basin, so far as known, occurred April 23–24, 1942. The Geological Survey made an investigation of it in cooperation with the Corps of Engineers, United States Army, the Colorado State Engineer, and the Bureau of Reclamation.

April 1942 was one of the wettest months recorded in Colorado. At the beginning of the month the snow cover in the mountains was about normal. During the first week, temperatures above normal softened the mountain snow and started its melting. Heavy precipitation occurred April 6–8 and 16–20 over the entire Purgatoire River Basin, that in the mountains being in the form of wet snow. Precipitation again occurred April 22–25 and even in the mountains was in the form of rain which later turned to snow. This rain hastened the melting of the wet snow deposited a few days previously, and also the older snow, with the result that a severe flood occurred.

In recent years both the Corps of Engineers, United States Army, and the Soil Conservation Service have installed rain gages in the Purgatoire River Basin; their records together with those of the Weather Bureau are presented in the following table:

Precipitation, in inches, in Purgatoire River Basin, April 6–8, 16–20, 22–25, 1942

[Stations listed in order from southwest to northeast]

Station	Altitude (feet)	April						Subtotal Apr. 22–25	Total
		6–8	16–20	22	23	24	25		
North Lake (19–32–68)	8,800	1.00	1.96	------	0.62	1.06	------	1.68	4.64
Stonewall (30–33–68)[1]	8,200	1.40	2.47	1.66	------	1.64	------	3.30	7.17
Tercio (28–34–68)[1]	7,700	1.55	2.97	(2)	(2)	(2)	2.15	2.15	6.67
Weston (34–33–67)[1]	7,000	.66	2.76	(2)	(2)	2.02	------	2.02	5.44
Sarcillo (16–33–66)[1]	6,800	--------	3.30	------	1.10	.80	------	1.90	5.20
Wootton (36–34–64)[1]	6,900	(Some rain)	3.61	2.17	------	.90	------	3.07	6.68+
Longs Canyon (33–34–65)[1]	6,700	.20	3.75	------	1.30	.73	.11	2.14	6.09
Branson (9–35–58)[1]	6,280	.92	4.07	------	1.16	1.06	------	2.22	7.21
Sopris (29–33–64)	6,250	--------	3.75	------	1.30	.73	.11	2.14	5.89
Trinidad (12–33–64)	6,000	.88	3.58	------	1.38	.61	------	1.99	6.45
Hoehne (6–32–62)	5,683	.62	2.73	.28	1.11	.45	Tr.	1.84	5.19
Pipe line crossing (4–31–58)[3]	5,200	.54	4.22	------	.80	.40	.12	1.32	6.08
Box Ranch (21–32–57)	5,600	.65	3.75	------	1.35	.35	------	1.70	6.10
Troy (26–33–53)	5,735	.80	4.88	------	.56	.54	------	1.10	6.78
Tyrone (10–30–61)	5,528	--------	3.13	1.45	.60	.25	------	2.30	5.43
Kim (22–32–53)	5,600	--------	4.50	.60	------	.40	------	1.00	5.50
Andrix (12–32–52)[1]	5,400	.83	5.56	------	.60	.35	------	.95	7.34
Officer (27–29–55)[4]	5,600	.91	3.96	.96	------	.38	------	1.34	6.21
Bloom (23–27–59)[4]	4,488	.90	4.11	1.00	.90	.40	------	2.30	7.31
Whiterock (28–25–60)	4,700	1.00	1.95	1.25	(2)	.80	------	2.05	5.00
Timpas (3–26–57)[1]	4,480	.92	2.07	.74	------	.25	------	.99	3.98
Higbee (32–26–54)[4]	4,250	.99	3.30	------	.63	.28	.12	1.03	5.32
Las Animas (8–23–52)	3,899	.49	2.04	.06	.41	.19	------	--------	3.19

[1] Soil Conservation Service station.
[2] Record included in that for following day.
[3] Private station.
[4] Corps of Engineers, U. S. Army, station.

The rain of April 16–20 caused high water which reached its peak at the gaging stations, as follows:

Peak discharge of Purgatoire River, Apr. 19–20, 1942

Station	Time	Stage (feet)	Discharge (second-feet)
Trinidad	April 19, 6:30 p. m	4.85	3,240
Ninemile Dam	April 20, 1:00 p. m	7.4	15,000
Highland Dam	April 20, 7:00 p. m	8.6	17,300

The relatively low peak at Trinidad, which is close to the mountains, showed the influence of precipitation in the form of snow during that period.

The main flood was the direct result of the heavy rain which occurred April 22 and the early morning of April 23. During the previous few days the mountain snow had melted during the day and frozen during the night, causing marked diurnal fluctuations in discharge at Trinidad, the peak of the fluctuation occurring between 6 and 8 p. m. On the night of April 23 the diurnal peak of 5.7 feet was reached about 6 p. m. and instead of receding remained stationary for 4 hours. Then the increase resulting from rain on the melting snow reached Trinidad and the stage rose from 5.7 feet to a peak of 14.03 feet at 5 o'clock the next morning, April 24. This stage was maintained for half an hour or less, and then the river began to fall almost as swiftly as it had risen, and by noon was back in its banks. The sudden drop was due to the fact that the rain in the mountains turned to snow, and the accompanying drop in temperature retarded the snow melt.

As in the 1904 flood, the chief sources of the 1942 flood were Long Canyon and Raton Canyon. Other tributaries from the south as far west as Lorencito Canyon contributed, but tributaries from the north added little. Above Trinidad the Colorado & Wyoming Railroad, serving the coal mines along the river, lost several miles of track when the bank was washed away. In Raton Canyon considerable damage was sustained by the Santa Fe Railroad and U. S. Highway 85–87. The flood overtopped the retaining walls in Trinidad, inundated the Santa Fe tracks to a depth of several feet, and undermined two tracks near the depot. Two highway bridges and one approach and abutment to a railroad bridge were destroyed, and low-lying land along the river inundated. No lives were lost.

Below Trinidad, especially in the Sunflower Valley district, most of the irrigation dams and head works were either destroyed or seriously damaged, and a large area of cultivated land was inundated. Farther downstream the damage was less, and below the canyon section there was but little overflow.

To determine the peak discharges, slope-area measurements were made at the gaging stations, as follows:

Peak discharge of Purgatoire River, Apr. 23–24, 1942

Station	Time	Stage (feet)	Discharge (second-feet)
Trinidad	April 23, 5 a. m.	14.03	35,800
Ninemile Dam	April 23, 9 p. m.	14.03	50,000
Highland Dam	April 24, 3 a. m.	13.29	60,000

The exact time of the peak at Highland Dam is uncertain. The observer reported that it occurred between 1 : 30 and 5 a. m. During the flood of April 19, 1942, and that of September 15, 1934, the peaks traversed the 25 miles between Ninemile Dam and Highland Dam in 6 hours. On that basis the time of the 1942 flood peak at Highland Dam appears to have occurred at 3 a. m.

The bihourly stages and discharges for the gaging stations at Trinidad and Highland Dam are presented in the following tables.

Bihourly stage, in feet, and discharge, in second-feet, of Purgatoire River at Trinidad, Apr. 19–23, 1942

Hour	April 19		April 20		April 21		April 22		April 23	
	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
2 a. m.	3.00	700	3.45	1,400	3.85	1,590	5.30	3,690	9.15	14,000
4 a. m.	3.00	700	3.33	1,290	3.72	1,460	5.00	3,330	11.7	25,000
6 a. m.	2.87	638	3.22	1,190	3.61	1,360	4.83	3,040	13.20	[1] 32,000
8 a. m.	2.76	598	3.13	1,110	3.50	1,260	4.62	2,880	12.0	26,400
10 a. m.	2.74	592	3.07	1,050	3.41	1,180	4.43	2,600	9.75	16,600
Noon	2.77	601	3.07	1,050	3.36	1,130	4.30	2,410	7.40	9,180
2 p. m.	3.30	910	3.30	1,260	3.70	1,440	4.55	2,780	5.16	4,370
4 p. m.	3.60	1,170	3.60	1,540	4.75	2,780	5.35	4,160	5.12	4,290
6 p. m.	4.80	3,000	4.00	2,000	5.60	4,250	5.65	4,720	5.10	4,250
8 p. m.	4.28	2,240	4.30	2,410	6.00	5,020	5.63	4,690	5.08	4,210
10 p. m.	3.82	1,660	4.20	2,340	5.90	4,820	5.65	4,720	5.04	4,140
Midnight	3.57	1,410	4.04	2,110	5.62	4,190	7.40	8,620	5.00	4,040
Mean		1,180		1,560		2,540		3,980		12,400

[1] Peak stage 14.03 feet; discharge 35,800 second-feet at 5 a. m.

NOTE.—The recorder was removed at 7:30 a. m. Apr. 23, and thereafter a number of readings from the chain gage were obtained. A hydrograph based on those readings was constructed, from which the bihourly gage heights were obtained. The total discharge from 10 p. m. Apr. 22 to 2 p. m. Apr. 23, representing the main flood, was 22,600 acre-feet.

Bihourly stage, in feet, and discharge, in second-feet, of Purgatoire River at Highland Dam, Apr. 19–25, 1942

Hour	April 19		April 20		April 21		April 22	
	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
2 a. m.	3.18	580	4.65	3,470	5.75	6,240	5.00	4,210
4 a. m.	3.30	780	4.80	3,800	5.45	5,460	4.88	3,930
6 a. m.	3.75	1,550	5.75	6,100	5.27	5,030	4.75	3,650
8 a. m.	3.45	1,030	6.25	7,530	5.10	4,620	4.50	3,100
10 a. m.	3.50	1,110	6.75	9,030	4.90	4,140	4.55	3,210
Noon	3.55	1,200	7.10	10,200	5.08	4,570	5.00	4,210
2 p. m.	3.55	1,200	7.50	11,800	5.35	5,220	5.50	5,410
4 p. m.	3.50	1,100	7.75	12,800	5.50	5,580	6.00	6,740
6 p. m.	3.72	1,490	8.60	17,300	5.60	5,840	6.35	7,770
8 p. m.	3.85	1,730	8.25	15,400	5.52	5,640	6.50	8,130
10 p. m.	4.25	2,480	7.50	11,700	5.37	5,270	6.60	8,430
Midnight	4.40	2,780	6.40	7,920	5.20	4,860	6.40	7,830
Mean		1,420		9,750		5,200		5,550

Hour	April 23		April 24		April 25	
	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
2 a. m.	5.95	6,380	12.9	56,400	7.32	11,100
4 a. m.	5.40	4,980	13.0	[1] 57,600	7.30	11,000
6 a. m.	5.30	4,740	11.6	46,300	7.27	10,900
8 a. m.	5.40	4,980	10.25	32,000	7.24	10,800
10 a. m.	5.55	5,340	9.1	22,100	7.22	10,700
Noon	5.75	5,840	8.55	18,300	7.20	10,600
2 p. m.	6.10	6,660	8.0	15,200	6.95	9,340
4 p. m.	6.48	7,770	7.50	12,700	6.70	8,580
6 p. m.	6.70	8,430	7.45	12,400	6.50	7,980
8 p. m.	6.95	9,180	7.42	12,300	6.30	7,380
10 p. m.	7.50	11,200	7.38	12,100	6.15	6,880
Midnight	8.50	16,000	7.35	12,000	6.0	6,380
Mean		7,620		25,800		9,300

[1] Peak stage 13.29 feet; discharge 60,000 second-feet about 3 a. m. Apr. 24.

NOTE.—The recorder was removed at 9 p. m. Apr. 23, and thereafter the observer made frequent readings of the staff gage. A hydrograph based on these readings was constructed, from which the bihourly gage heights were obtained. The total discharge from noon Apr. 23 to midnight Apr. 25 was 78,500 acre-feet.

Although the floods of September 30, 1904, July 22, 1925, and April 23–24, 1942, were the only severe ones of record at Trinidad, the Purgatoire River is subject to flash peaks due to cloudbursts in various parts of its drainage basin. Information is available regarding flash floods that have occurred since 1923, when gaging stations in the lower basin were established by the State Engineer. In the table on p. 109, which gives the peaks and daily discharges for floods on the Purgatoire River during the period 1923–36, the data are arranged in four groups in order to show the effect of rain on various parts of the basin. These groups are as follows:

Group 1. No flood at Trinidad, at the edge of the mountains, but flood on lower river.

Group 2. Greater flood at Trinidad than in lower river, owing chiefly to rains in the mountains but not on the plains.

Group 3. Increase in flood from Trinidad to Ninemile Dam in the canyon section, but decrease farther downstream, indicating that the storms centered chiefly over the canyon section.

Group 4. Flood increasing from Trinidad to mouth. In this group the data are limited to Trinidad and Las Animas. It may be that one or all of the floods listed in this group should be in group 3.

The sharpness of the peak of most of the floods is indicated by the difference between the peak flow and the mean for the day.

Flood peak and mean daily discharge, in second-feet, at gaging stations on Purgatoire River, June 1923 to August 1936

Date	Trinidad (drainage area 742 square miles)		Alfalfa (drainage area 1,300 square miles)		Ninemile Dam (drainage area 2,900 square miles)		Highland Dam (drainage area 3,320 square miles)		Las Animas (drainage area 3,398 square miles)	
	Peak	Daily mean	Peak	Daily mean	Peak	Daily mean	Peak	Daily mean	Peak	Daily mean
GROUP 1										
July 21, 1927	(1)	36	(1)	72	(1)	50			49,000	6,760
July 13, 1927	692	129	(1)	385	2,620	1,200			18,200	7,820
June 17, 1923	(1)	313							28,400	5,650
Aug. 7, 1927	(1)	350	19,100	3,780	11,300	3,510			26,400	4,270
May 11, 1928	7,100	977	(1)	34	9,400	8,250			35,500	7,860
GROUP 2										
July 30, 1936	11,800	208			(1)	1,100				
July 31, 1930	13,200	1,620			2,090	794			2,270	854
May 30, 1929	13,200	1,680			(1)	407			320	320
Aug. 17, 1928	15,000	622	(1)	383	1,800	388			1,200	682
Aug. 23, 1927	19,600	1,990	(1)	452	4,110	1,470			5,260	2,500
GROUP 3										
Aug. 28, 1935	1,060	88			13,000	1,980	6,820	2,040		
July 22, 1935	2,790	325			16,200	4,010	5,970	3,130		
Aug. 7, 1936	(1)	542			15,000	3,290	9,200	5,240		
Aug. 3, 1927	(1)	324	(2)	800	30,100	9,200			21,200	8,730
Aug. 7, 1929	4,850	933			55,600	27,000			52,800	23,000
Sept. 15, 1934	(1)	36			64,500	11,300	33,000	2,500		
GROUP 4										
Aug. 17, 1923	3,460	895							21,500	6,840
Aug. 23, 1923	10,500	850							21,500	12,700
Aug. 12, 1923	14,100	1,550							21,500	6,370

[1] No appreciable flood rise.
[2] Data not available.

The mileage between stations is as follows: Trinidad to canyon entrance, near Alfalfa, 29; canyon entrance to Ninemile Dam, near Higbee, 62; Ninemile Dam to Highland Dam, near Las Animas, 25; Highland Dam to mouth, near Las Animas, 14.

The flood data presented shows that the entire basin from the foothills just west of Trinidad to the mouth at Las Animas is subject to heavy rains that in small areas are true cloudbursts. In the canyon section the cloudbursts are most severe, as shown by the floods in group 3. Between Ninemile Dam and Highland Dam the discharge

from Smith Canyon enters the Purgatoire River, and as this stretch is also in the canyon section it too is subject to cloudburst floods, as is shown by the floods of July 13, July 21, and August 7, 1927, and May 11, 1928, in group 1. Of the floods listed in this table a special investigation was made only of the one on September 15, 1934.

The highest peak flow actually recorded on the Purgatoire River is 64,500 second-feet at Ninemile Dam, September 15, 1934. The only reported precipitation in the basin at that time was 1.06 inches at Trinidad. Recorded daily discharges of the Purgatoire River during the 5-day period of the flood are shown in the following table.

Mean daily discharge, in second-feet, of Purgatoire River, Sept. 13–18, 1934

Station	September					
	13	14	15	16	17	18
Trinidad	13	21	36	23	19	17
Ninemile Dam	13	6	11,300	343	109	58
Highland Dam	3	1	2,300	2,500	500	100

The State Engineer's Office made an investigation of this flood, and the unpublished report by L. T. Burgess, chief hydrographer, states that the storm area was about 15 miles wide, extending in a southeasterly direction from a point south of Avondale to a point a few miles southeast of Villagreen and Tobe. The following information relative to the precipitation was obtained locally.

Rainfall on Purgatoire River, Sept. 15, 1934

[Compiled from statements by local residents]

Location	Rainfall (inches)	Method of measurement	Remarks
Sec. 3, T., 31 S., R. 58 W			Intense rain for 2 hours.
T. 29 S., R. 59 W			Water ran off prairie in sheets.
T. 30 S., R. 58 W			Do.
Sec. 23, T. 31 S., R. 55 W	1	Estimated	
Sec. 34, T. 32 S., R. 55 W	5	Measured in coffee pot	
Sec. 23, T. 33 S., R. 57 W	2	Estimated	

The storm covered 620 square miles of the Purgatoire River drainage basin, all between the Trinidad and Ninemile Dam stations. A slope-area determination of the peak discharge at the Ninemile Dam station showed that discharge to be 64,500 second-feet at a gage height of 12.0 feet, or 104 second-feet per square mile from the 620 square miles covered by the storm. The river rose 10.7 feet in 3 hours, reached its peak at 6 a. m., remained at the peak less than half an hour, then dropped 9 feet in 10 hours, and by the next day was back at normal stage. The total discharge during the flood was about 23,000 acre-feet. The flood traversed the 25 miles of channel between Ninemile

Dam and Highland Dam stations in 6 hours and was reduced by channel storage to 33,000 second-feet.

WOLF CREEK AND GRANADA CREEK

Cloudburst storms during the night of July 11–12, 1935, caused heavy floods on Wolf Creek and Granada Creek, which drain adjacent areas south of Granada in the extreme eastern part of Colorado. The Office of the State Engineer investigated these floods and furnished the data used here.

The Weather Bureau stations in the general vicinity reported the following precipitation:

Rainfall, in inches, on Wolf and Granada Creeks, July 11–12, 1935

Station	July 11	July 12
Haswell		0.22
Holly		1.43
Two Buttes	0.58	

These stations were not within the area of intense rainfall of July 11–12, but statements of local residents were compiled, as follows:

Rainfall on Wolf Creek and Granada Creeks, night of July 11–12, 1935

Location	Rainfall (inches)	Method of measurement	Remarks
Sec. 7, T. 26 S., R. 45 W.	4½	Jar	8 p. m. to 4 a. m.; mostly between 8 and 9 p. m.
Sec. 33, T. 25 S., R. 45 W.	9+	Cans; overflowed	8 to 10:30 p. m.
NW¼SE¼ sec. 25, T. 25 S., R. 45 W.			6 to 6:20 p. m.
NE¼SE¼ sec. 25, T. 25 S., R. 45 W.	8½+	Jar; overflowed	7 to 8 p. m.
Sec. 19, T. 25 S., R. 45 W.	7+	Can; overflowed	6:30 to 8 p. m.; chiefly in 30 minutes.
Sec. 23, T. 25 S., R. 45 W.	9+	Kettle; overflowed	7 to 9 p. m.
Sec. 28, T. 25 S., R. 44 W.	4½+	Can; overflowed	8 to 11 p. m.
Sec. 9, T. 25 S., R. 45 W.	8	Estimated	7 to 11 p. m.; chiefly 7 to 8 p. m.
Sec. 7, T. 25 S., R. 44 W.	6+		8 p. m. to 2 a. m.; chiefly 8 to 8:30 p. m.; 6 inches in 30 minutes, from side hill.
Sec. 33, T. 24 S., R. 44 W.	2	Estimated	8 p. m. to 1:30 a. m.
Sec. 23, T. 24 S., R. 45 W.			7:30 a. m. to midnight; very heavy.
Sec. 13, T. 24 S., R. 44 W.	8	Can	8:30 p. m. to 2:30 a. m.; hard rain first hour.
Sec. 26, T. 24 S., R. 44 W.	3	Method not stated	9 to 11 p. m.

Slope-area measurements of peak discharges were made and information relative to the duration of the floods was obtained.

Peak discharge and duration of flood on Wolf and Granada Creeks, July 11–12, 1935

Stream	Drainage area of intense rainfall (square miles)	Peak discharge (second-feet)		Duration of flood
		Total	Per square mile	
Wolf Creek	25	14,000	560	8 hours; 2 hours at peak.
Granada Creek	35	31,000	886	Do.

The Wolf Creek flood inundated the main street of Granada to a depth of 3½ feet; one citizen was caught by the flood just above town and spent the night in a tree. The Granada Creek flood is reported to have caused the loss of eight lives and very considerable property loss.

TWO BUTTE CREEK

Two Butte Creek, a southern tributary of the Arkansas River entering near Holly, drains about 900 square miles of plains in southeastern Colorado. During the storm of October 18–19, 1908, more than 1½ inches of rain fell in its basin and caused a flood that was estimated, from a high-water cross section, to have a peak discharge of 35,000 second-feet, or 39 second-feet per square mile.[64]

WILD HORSE CREEK

Wild Horse Creek is a minor tributary entering the Arkansas River near Holly. A cloudburst storm during the night of August 28–29, 1935, caused a severe flood on this creek, which destroyed the recently completed Horse Creek Reservoir. The State Engineer made an investigation of the flood, and the following data, with the exception of the Weather Bureau records, are taken from his report.[65]

Rainfall on Wild Horse Creek Basin, Aug. 28–29, 1935

From Weather Bureau records

Station	*Inches*
Haswell	Trace
Holly	1.19
Long Branch	.04
Two Buttes	.03

Rainfall on Wild Horse Creek Basin, Aug. 28–29, 1935

[Compiled from statements of local residents]

Location	Rainfall (inches)	Method of measurement	Remarks
Sec. 36, T. 19 S., R. 42 W.	8	Bucket	10 p. m. to 1 a. m.
Sec. 18, T. 20 S., R. 42 W.	8	Not stated	Hardest during first hour.
Sec. 19, T. 20 S., R. 42 W.	5	Oil barrel	10:30 p. m. to 2:30 a. m.
Sec. 20, T. 20 S., R. 42 W.	8½+	Bucket	11:30 p. m. to 2 a. m.
Sec. 35, T. 20 S., R. 42 W.	7	Estimated	11 p. m. to 1 a. m., chiefly.
Sec. 5, T. 21 S., R. 41 W.	11+	Stock tank; overflowed	10 p. m. to 5:30 a. m.
Sec. 2, T. 21 S., R. 42 W.	8	Bucket	
Sec. 4, T. 21 S., R. 42 W.			Light.

A slope-area measurement of the peak discharge above Horse Creek Reservoir was made in sec. 12, T. 21 S., R. 42 W, regarding which Hinderlider's report [66] states:

[64] Freeman, W. B., Flood in the Arkansas Valley, Colo., October 1908: U. S. Geol. Survey Water-Supply Paper 247, p. 40, 1910.

[65] Hinderlider, M. C., Report of the Horse Creek flood of Aug. 28, 1935, and the failure of the Horse Creek dam. Unpublished, in files of Office of the State Engineer of Colorado.

[66] Op. cit.

It appears that the peak of the flood entering Horse Creek Reservoir was substantially 16,500 to 20,000 second-feet, and that the total quantity of water resulting from the flood * * * amounted to about 7,500 acre-feet.

The drainage area from which the flood * * * came, as nearly as could be determined, is about 100 square miles, although the area over which occurred the greatest intensity of rainfall did not exceed about 50 square miles. It would, therefore, appear that the peak flow amounted to approximately 165 to 200 [second-feet] from the area causing the flood, and over the more limited area to a maximum of approximately 360 [second-feet].

During the flood a slope-area measurement on the main stream below the reservoir and below a tributary determined a peak discharge of 22,000 second-feet, or 220 second-feet per square mile from the 100 square miles covered by the rainfall.

MINOR TRIBUTARIES OF ARKANSAS RIVER

The minor tributaries of the Arkansas River are not subject to prolonged floods, owing to the character of the rainfall and to the steep slopes; but they are subject to cloudburst floods of high intensity, particularly those tributaries east of the Royal Gorge. The series of cloudbursts causing the Arkansas River flood of June 1921 resulted in high run-off for many of those streams, as shown in the following table.[67]

Peak discharge of minor tributaries of Arkansas River, June 3, 1921

[Streams listed in descending order. All measurements were made near the mouths of the tributaries]

Tributary	Latitude	Longitude	Drainage area (square miles)	Peak discharge (second-feet)	
				Total	Per square mile
Chandler Creek	38°24′	105°08′	13.6	1,610	118
Coal Creek	38°24′	105°06′	22.3	3,720	167
Eightmile Creek	38°24′	105°05′	65	10,000	154
Brush Hollow Creek	38°24′	105°03′	21.9	5,320	243
Fred Rohr Gulch	38°20′	104°54′	9.3	968	104
Rush Creek	38°18′	104°52′	19.6	4,670	238
Turkey Creek	38°18′	104°49′	[1] 48	9,000	188
Osteen Arroyo	38°17′	104°49′	7.8	9,060	1,160
Cameron Arroyo	38°16′	104°48′	7.3	13,900	1,900
Pecks Creek	38°16′	104°46′	34.4	19,400	564
Rock Creek	38°16′	104°45′	59	53,900	913
Unnamed arroyo	38°16′	104°45′	15.8	9,740	619
Boggs Creek	38°16′	104°44′	26.5	15,400	582
Unnamed arroyo	38°15′	104°41′	1.8	1,910	1,060
Blue Ribbon Creek	38°16′	104°40′	6.7	9,130	1,360
Dry Creek	38°16′	104°38′	86	24,400	283

[1] Turkey Creek Basin below Teller Reservoir; little or no water passed the dam during the period of maximum discharge of the creek.

[67] Follansbee, Robert, and Jones, E. E., The Arkansas River flood of June 3-5, 1921: U. S. Geol. Survey Water-Supply Paper 487, p. 21, 1922.

RIO GRANDE

The Rio Grande drains the high mountain park known as the San Luis Valley which has an altitude between 7,400 and 7,800 feet. Its basin is bounded by the almost continuous ring of mountains that separate it from the Arkansas River Basin on the east and the Colorado River Basin on the north and west. From the mouth of South Fork Rio Grande to Del Norte, at the edge of the valley proper, the Rio Grande has an average fall of 17 feet per mile; from Del Norte to the Colorado-New Mexico State line the fall decreases from 17 to 7 feet per mile.

Gaging stations on the Rio Grande

Station	Drainage area (square miles)	Period of record
Thirtymile Bridge, near Creede	163	June 1909 to date.
Wason, below Creede	705	April 1907 to date.
Near Del Norte	1,320	July 1889 to date.
Near Monte Vista	1,740	May 1926 to date.
Alamosa	1,840	May 1922 to date.
Above mouth of Trinchera Creek, near La Sauses	----------	May 1936 to date.
Lobatos	7,700	June 1899 to date.

The Rio Grande Basin, owing to its sheltered position and its relatively high altitude, is less subject to destructive floods than any other major basin in Colorado, except that of the Colorado River.

Of the five floods on the Rio Grande described on the following pages, all but one occurred during June, and perhaps also the earliest one of record, that of 1869, mentioned briefly below. All but one of the five were caused by runoff from melting snow augmented by rain. The one exception was the flood of June 1905, when practically no precipitation occurred. The flood of June 1884, caused primarily by the extraordinarily heavy snow cover, lasted much longer than the others, the river being at overflow stage at Del Norte from about May 24 to June 20, whereas in the other years it remained at flood stage for only a few days. The highest flood since gaging-station records have been kept was that of June 1927; but the flood of 1884, which occurred before any station had been established, may have been higher. The flood of 1927 was caused by a combination of all the factors usually contributing to floods in Colorado mountain streams—heavy snow cover, precipitation in the form of snow, followed immediately by sudden increase in temperature, and rain during the period of maximum snow melting. The flood of October 1911, which was severe in only one locality, was caused solely by widespread heavy rains throughout southwestern Colorado.

The earliest flood of record on the Rio Grande occurred in 1869,

probably during the late spring. The Alamosa Leader of October 14, 1911, refers to that flood as follows:

> In 1869 and 1884 the Rio Grande went on a rampage and flooded districts through which it flows. But old-timers of Alamosa who were here at that time and are still here, say that in 1884 the water came into the town, farther down in the business districts.

1884

The next flood of record occurred during June 1884 and was caused by the melting of the very heavy snow cover, augmented by heavy rains. Although records of discharge are lacking, it is believed that the flood of 1884 was one of the most severe on the Rio Grande. From the files of the Del Norte San Juan Prospector it appears that the river started to rise at Del Norte about May 15 and rose 3 feet in 3 days. Within the next week it overflowed its banks and washed out the Denver & Rio Grande Railroad tracks in several places, presumably near Creede. The San Juan Prospector, May 31, 1884, stated that two bridges over the Rio Grande above South Fork had been destroyed by drift and that the river had overflowed its banks at Del Norte and inundated a large section of land below the railroad tracks. From about May 24 to June 20 the river was out of its banks at Del Norte ,and at the peak on June 14 and 15 the statement was made that the Rio Grande was higher than since 1872 [1869]? the entire bottom lands below town were from 1 inch to 2 feet under water, but that the water did not reach the main part of the town.

The Gunnison Review Press of June 26, 1884, stated that nearly every ranch in the river bottoms between Del Norte and Alamosa was flooded. At Alamosa the lower part of the town was flooded, the water reaching nearly to the railroad tracks. The Del Norte San Juan Prospector, June 21, 1884, reported:

> Del Norte mails for the East have been sent out via Salida this week, owing to the heavy floods at Alamosa.

This statement probably refers to the flood below Alamosa where the river was about 5 miles wide. W. D. Carroll, State division iraigation engineer, stated that he believed the 1884 flood had a higher discharge than any subsequent flood. Sloughs that carried water in 1884 have since been filled in, and the development of ditches and reservoirs has materially reduced the peaks of later floods. This belief that the 1884 flood was the highest, due to the high flow of all its tributaries, is strengthened by the statement of R. I. Meeker, consulting engineer of Denver, that local residents have told him that the only time since the San Luis Valley was settled, that water from the closed basin in its northern part reached the Rio Grande was In 1884.

1905

The first flood on the Rio Grande for which records of discharge are available occurred in June 1905, was evidently caused chiefly by melting snow, as the few available records show little precipitation during that flood. The Alamosa Courier of May 20, 1905, stated that the mountains had a heavy cover of snow which was melting rapidly. The only mention of the flood on the Rio Grande made by the Del Norte, Monte Vista, or Alamosa papers was a statement on June 10, 1905, that the railroad bridge above Creede and about 800 feet of track had been washed out. It is evident that below Creede, little overflow occurred. The only gaging stations for which records were obtained were near Del Norte and at Lobatos. The daily discharge at those stations was as follows:

Daily discharge, in second-feet, of Rio Grande, June 1–15, 1905

June	Near Del Norte	Lobatos	June	Near Del Norte	Lobatos
1	6,600	7,220	9	8,510	12,700
2	8,270	7,750	10	8,270	12,200
3	9,230	8,900	11	7,550	11,800
4	9,760	10,600	12	7,330	11,100
5	10,000	11,400	13	6,890	10,100
6	7,790	12,500	14	6,890	8,380
7	8,030	12,700	15	6,780	8,170
8	8,630	13,100			

1911

The storm of October 4–6, 1911, which was so severe in the San Juan Basin, also covered the San Luis Valley, but was much less severe here, where it followed a week of lighter rainfall. The available records of precipitation are as follows:

Rainfall, in inches, on Rio Grande Basin, Oct. 4–6, 1911

Station	Altitude (feet)	October			Total
		4	5	6	
Cumbres	10,015	3.08	1.26	0.49	4.83
Wagon Wheel Gap Experiment Station	9,610	.71	1.94		2.65
Platoro	9,800	.05	3.25	.04	3.34
La Veta Pass	9,242	.59	1.42		2.01
Garnett	7,576	.74	.14		.88
Manassa	7,700	1.28	.15		1.43
Saguache	7,745		1.20	.70	1.90
San Luis	7,900	.40	1.50	.07	1.97

It is believed that in the upper part of the Rio Grande Basin, adjacent to the San Juan River Basin, the precipitation was considerably higher than that given.

The flood of 1911 was the only one recorded in the Rio Grande Basin that was caused wholly by heavy rains. It was not severe except in the vicinity of Del Norte. The flood reached Del Norte during the night and the fire bell warned the sleeping citizens in the bottom lands of their peril. The Del Norte newspaper does not mention the depth of the water, which must have been considerable, as many people were taken from their homes in wagons, buggies, on horseback, and some by boats. From these means of transportation it is assumed that the water could not have been more than 2 or 3 feet deep in the lower part of the town. The Del Norte San Juan Prospector of October 7, 1911, stated that the greatest damage, so far as known, occurred in the narrow valley from a point 20 miles west of Del Norte to a point 10 miles east, where the water spread into the ditches and sloughs in the San Juan Valley. At Monte Vista the overflow covered the low land between the main river channel and the higher ground on which the town is built, a distance of about two miles. At Alamosa the Independent Journal of October 13, 1911, stated that the peak stage was within a few inches of the highest mark ever recorded there. After the river had receded a few inches, the dike protecting the town broke, and a part of the town was flooded. Very little damage occured other than water-soaked foundations and washed-out fills under sidewalks, as only backwater from the flood reached these districts.

Below Alamosa, sloughs and channel storage so reduced the peak discharge at the Lobatos gaging station that no overflow or damage occurred. In the overflowed areas above Alamosa very little damage was done below Del Norte.

The following table shows the daily discharge at the Wason, Del Norte, and Lobatos stations.

Daily discharge, in second-feet, of Rio Grande, Sept. 29 to Oct. 15, 1911

Date	Wason (drainage area 705 square miles)	Del Norte (drainage area 1,320 square miles)	Lobatos (drainage area 7,700 square miles) [1]	Date	Wason (drainage area 705 square miles)	Del Norte (drainage area 1,320 square miles)	Lobatos (drainage area 7,700 square miles) [1]
Sept. 29	515	720	950	Oct. 8	2,430	4,540	6,890
30	900	810	1,050	9	1,840	3,580	6,890
Oct. 1	1,380	2,190	1,200	10	1,580	2,900	7,510
2	1,380	2,420	2,000	11	1,430	2,730	6,800
3	1,250	1,910	2,670	12	1,290	2,260	5,750
4	1,010	1,580	2,810	13	1,160	1,980	4,710
5	4,230	[2] 10,700	2,880	14	1,090	1,710	3,850
6	5,170	14,000	4,230	15	1,010	1,580	3,250
7	3,270	6,370	6,980				

[1] Includes 2,940 square miles in closed basin in northern part of San Luis Valley.
[2] Peak discharge 18,000 second-feet.

1921

The flood of June 1921 was probably the smallest of the Rio Grande floods described here. The general storm that caused severe floods in the Arkansas and South Platte River Basins released precipitation in the San Luis Valley from June 3 to 7, but this was insufficient to cause a flood. The primary cause of the flood was an increase in temperature of nearly 20° between June 6 and 10 as recorded at the Garnett station, which hastened the melting of the mountain snow. The runoff from the melting snow was probably augmented by light precipitation between June 11 and 15. As all mountain tributaries were at high stages during this period, the flood increased in volume throughout the valley with the contribution of each tributary. Very little overflow occurred except in Alamosa and immediately downstream, where the river was about 2 miles wide. Several bridges above Alamosa were destroyed, chiefly by drift.

The following table shows the daily discharge at gaging stations on the Rio Grande.

Daily discharge, in second-feet, of Rio Grande, June 8–23, 1921

[Data from reports of Colorado State Engineer]

June	Thirtymile Bridge (drainage area 163 square miles)	Wason (drainage area 705 square miles)	Del Norte (drainage area 1,320 square miles)	Alamosa (drainage area 1,710 square miles)	Lobatos (drainage area 7,700 square miles [1]
8	1,200	3,760	5,940	4,840	5,530
9	1,690	4,850	6,880	4,920	6,300
10	2,350	6,390	8,250	5,400	6,870
11	2,780	7,240	8,930	6,040	7,400
12	3,430	7,820	9,380	6,500	8,050
13	3,470	8,340	9,630	7,200	8,860
14	3,310	8,080	9,380	8,000	10,300
15	3,170	7,570	9,290	9,000	11,500
16	2,860	6,920	9,010	9,500	12,200
17	2,520	6,600	8,440	9,800	11,800
18	1,970	5,650	7,440	10,000	11,300
19	1,430	4,770	6,260	9,200	10,500
20	934	3,580	5,120	8,800	9,220
21	837	3,130	4,500	8,200	8,240
22	997	3,000	4,310	7,000	7,020
23	1,200	3,130	4,650	5,800	5,790

[1] Includes 2,940 square miles in closed basin in northern part of San Luis Valley.

1927

The flood in the Rio Grande Basin during the later part of June 1927 was the highest of record for that area, except in the vicinity

of Del Norte, where the flood of October 1911 was higher. The flood of 1927 was caused by runoff from the melting mountain snow, increased by precipitation. From June 11 to 16, snow fell at the higher altitudes, and the temperature dropped. This drop was followed by a rise of 20° or more in 3 days (Garnett record), which softened the snow. Beginning June 25 and continuing for 5 days, additional precipitation fell in the form of rain, accompanied by a further increase of several degrees in temperature. The combination of these factors caused the flood.

The rainfall at precipitation stations in this area, June 26–29, 1927, is shown in the table below.

Precipitation, in inches, in Rio Grande Basin, June 26–29, 1927

Station	Altitude (feet)	June				Total
		26	27	28	29	
Cumbres	10,015	0.16	0.18	0.07	----	0.41
Hermit	8,912	.68	1.04	1.06	0.36	3.14
La Veta Pass	9,242	.12	----	.28	.60	1.00
Del Norte	7,868	.05	.10	.40	----	.55
Garnett	7,576	.10	----	----	.52	.62
Manassa	7,700	----	----	.05	.27	.32

Of this flood, the San Juan Prospector, July 1, 1927, stated:

Recent heavy rains on the continental divide have swollen all the mountain streams that form the headwaters of the Rio Grande, until the main river is a raging torrent, overflowing its banks and causing great damage and loss of property through the valley. * * * The railroad yards in Del Norte are under water. * * * Part of the resident section on the north side of Del Norte is already under water and a channel has been opened through the highway to prevent the entire north side of town being flooded. Dairy herds have been driven out of valley pastures by the flood. * * * The Wason Bridge below town was taken out.

At Monte Vista the river overflowed its south bank for a width of 1½ miles, and near the Soldiers' Home, east of Monte Vista, the overflow was a mile wide.

At Alamosa, although the flood of 1927 was the highest recorded, very little overflow occurred, as the dikes protecting the city had been built higher and the channel improved since the flood of 1921.

The following table shows the daily discharge at the various gaging stations during the flood of 1927.

Daily discharge, in second-feet, of Rio Grande, June 26 to July 7, 1927

[Data from reports of Colorado State Engineer]

Date	Thirty-mile Bridge (drainage area 163 square miles)	Wason (drainage area 705 square miles)	Del Norte (drainage area 1,320 square miles)	Monte Vista (drainage area 1,590 square miles)	Alamosa (drainage area 1,710 square miles)	Lobatos (drainage area 7,700 square miles)[1]
June 26	791	1,710	2,650	857	734	1,570
June 27	1,020	2,970	3,030	1,080	705	1,540
June 28	[2] 2,870	[3] 5,820	5,940	2,610	988	1,420
June 29	5,720	8,620	[4] 12,200	5,780	2,250	2,130
June 30	3,820	8,270	12,600	[5] 12,500	5,320	4,070
July 1	2,840	6,840	9,750	8,500	[6] 10,600	5,950
July 2	2,380	5,440	6,980	6,580	7,240	7,870
July 3	2,110	4,300	5,860	5,370	5,560	[7] 9,580
July 4	1,810	3,400	5,100	4,460	4,600	8,100
July 5	1,740	2,860	4,500	3,790	4,000	6,480
July 6	1,710	2,590	4,080	3,360	3,350	5,170
July 7	876	2,060	3,730	2,840	2,630	4,390

[1] Includes 2,940 square miles in closed basin in northern part of San Luis Valley.
[2] Peak discharge 7,500 second-feet.
[3] Peak discharge 9,750 second-feet.
[4] Peak discharge 15,000 second-feet.
[5] Peak discharge 18,500 second-feet.
[6] Peak discharge 14,000 second-feet.
[7] Peak discharge 9,800 second-feet.

SOUTH FORK RIO GRANDE

The drainage basin of South Fork Rio Grande is a part of the northern slope of the ring of mountains surrounding the Rio Grande Basin in Colorado. The South Fork rises close to the Continental Divide at an altitude of about 12,000 feet and flows with heavy fall through canyons and narrow valleys to its junction with the Rio Grande at the town of South Fork, where the altitude is 8,100 feet. For a distance of 7 miles above the mouth the fall is about 41 feet per mile.

A gaging station near the mouth was maintained from August 1910 to September 1922, and from May 1936, to date. The drainage area is 216 square miles.

The highest flood of record on South Fork Rio Grande was that of October 5, 1911. It destroyed four bridges, including the Denver & Rio Grande Railroad bridge near the mouth. The gage was destroyed, but during subsequent investigation it was learned from a local resident that the river began to rise about 7 a. m. October 5, and rose at a rate of about 1 foot per hour, overflowing its banks about 11 a. m. It stayed at the highest stage until about 2:30 p. m., then started to fall, and at 7 p. m. was again within its banks. From high-water marks the peak discharge was estimated to be about 8,000 second-feet.

The flood of June 29, 1927, the highest subsequent to that of 1911, reached a stage about 1 foot lower than the flood of 1911, but no estimate of the discharge is available.

ALAMOSA CREEK

Alamosa Creek is one of the two streams that drain the eastern slope of that part of the San Juan Mountains which forms the southwestern boundary of San Luis Valley. The creek rises near the Continental Divide at an altitude of 12,000 feet, flows through canyons and narrow valleys until it emerges in the San Luis Valley, crosses that gently sloping valley, and enters the Rio Grande about 10 miles below Alamosa. From a point 7 miles above the upper gaging station to the point where the creek emerges from the foothills the average fall is 68 feet per mile, and across the valley, a distance of 30 miles, the fall is 13 feet per mile.

Gaging stations on Alamosa Creek

Station	Drainage area (square miles)	Period of record
Above Terrace Reservoir	107	September 1911 to June 1912; April 1914 to October 1919; October 1923 to September 1927; October 1934 to date.
Below Terrace Reservoir	116	April 1909 to November 1912; April to October 1915; February 1917 to October 1920; April 1922 to date.

The only flood prior to 1909 for which information is available was that of June 1905, concerning which the Monte Vista Journal, in its issue of June 10, stated:

> Transportation of machinery up the Alamosa River has been stopped temporarily by the tremendous volume of water rushing down the river, which is far out of its banks and licking at the very base of the mountains. Every grade near the river, from just below Stunner down to where the road from Monte Vista enters the canyon, has been entirely washed away.

During the period covered by the gaging-station records only one severe flood has occurred, that of October 5, 1911. The short duration of this flood, the peak of which reached a stage of 11 feet at the upper station, is shown by the discharge during the week of the flood, and the influence of the reservoir on the flow at the lower station a short distance below the reservoir.

Discharge, in second-feet, of Alamosa Creek, Oct. 4–10, 1911

Station	October						
	4	5	6	7	8	9	10
Above Terrace Reservoir	142	4,250	710	555	400	245	210
Below Terrace Reservoir	530	1,085	1,310	1,165	810	510	252

J. E. Field, engineer for the Terrace Reservoir, measured the peak of this flood at a diversion dam 8 miles above the reservoir. This was an overflow dam, and by considering it as a weir the peak discharge was computed at 5,200 second-feet.

CONEJOS RIVER

The Conejos River is one of the two streams that drain the eastern slope of that part of the San Juan Mountains which forms the southwestern boundary of San Luis Valley. The river rises near the Continental Divide at an altitude of 12,000 feet and flows through canyons and narrow valleys until it emerges in the San Luis Valley near Mogote, whence it flows 33 miles to its junction with the Rio Grande, about 18 miles south of Alamosa. For a distance of 10 miles above Mogote the average fall is 38 feet per mile, and from Mogote to the mouth it is about 17 feet per mile.

Gaging stations on Conejos River

Station	Drainage area (square miles)	Period of record
Platoro	44.4	April 1937 to date.
Near Mogote	282	September 1899 to March 1900; April 1903 to date.
Near La Sauses	887	March 1921 to date.

The only serious flood on this stream since 1899, when the first gaging station was established, occurred in 1911, and it seems safe to say that this was the only one since 1884, when severe floods were general in the Rio Grande Basin. There was a minor flood in 1905, concerning which the Del Norte San Juan Prospector of June 10, 1905, states that the stage then reached by the Conejos River was higher than had been known in 20 years. This reference to a high stage 20 years earlier is evidently to the flood of 1884. The discharge in June 1905 was only about 4,000 second-feet.

The flood of October 5–6, 1911, was caused by general rains. No gaging-station record exists, as the flood destroyed the station near Mogote, which was then the only one on the Conejos River. The local newspapers reported that the Twelvemile Bridge was swept away, the town of Guadalupe was under a foot of water, several hundred feet of railroad track was carried off the roadbed, and the head gates of irrigation ditches were destroyed. In 1939 the Geological Survey made an investigation and found an approximate high-water mark, which was verified by two well-qualified witnesses. This mark had an elevation of about 8.5 feet, based on the gage datum established in 1912. From the extension of the rating curve based on high-water measurements made since 1912, the peak dis-

charge was estimated at about 9,000 second-feet from 282 square miles of drainage area. The only additional information available is that, although the flood was not of the cloudburst type, it was of short duration.

COLORADO RIVER

The Colorado River rises in Middle Park, its source being on the east slope of Mount Richtofen, which has a height of 13,000 feet on the Continental Divide. Throughout most of its course in Colorado the river flows through canyons and narrow valleys. Near Palisade it enters Grand Valley, across which it flows to the Colorado-Utah State line.

Since records were started at Grand Junction in 1897, the Colorado River in Colorado has not been subject to flood, as that term is generally understood. The rainfall is too scanty to affect the river materially, and the high water that occurs annually due to melting mountain snow in May and June is characterized by a gradual rise and fall, depending on the amount of snow and the temperature. The tributary drainage basins above Roaring Fork, likewise, are not subject to severe or flash floods. Cloudbursts sometimes occur in this area, but the resulting floods do not have as high rates of runoff as similar floods at lower altitudes.

1853

The earliest noted reference to high water on the Colorado River is contained in a journal kept by George H. Heap, who accompanied Edward F. Beale on a trip from Westport to California in the spring of 1853.[68] Heap wrote:

> June 23. We * * * continued down its right bank [Gunnison River] until we reached Grand [Colorado] River. We had been prepared to find Grand River swollen, for its tributaries were all at their highest stage of water; but we had not anticipated so mighty a stream. It flowed with a loud and mighty current, its amber-colored water roaring sullenly past, laden with the wrecks of trees uprooted by their fury.
>
> * * * Where we now stood, anxiously gazing at its flood it had spread to a breadth of 250 yards. [This point was above the mouth of the Gunnison, where the present width of the channel is about the same.]
>
> June 25. * * * The river still maintained the same level, and the bottom land was overflowed and marshy. * * * Archilete [Indian guide] stated that he had never seen the river so high, and that it was owing to the unusual quantity of snow that had fallen in the mountains during last winter.
>
> July 18. * * * On reaching the stream [Colorado] we found it had fallen about 6 feet [from the stage of June 23–25].

The significant fact in the foregoing quotation is the statement

[68] Bonsal, Stephen, Edward Fitzgerald Beale, a pioneer in the path of empire, 1822–1903: G. P. Putnam's Sons, 1912.

that the river was "laden with the wrecks of trees." This indicates a very high stage of the river, as only an unusual flood would undermine the trees along the banks.

1884

The first flood on the Colorado River of which definite knowledge is available occurred during June and July 1884 and was caused by the melting of the very heavy snow cover.

The only stream in the State for which a record of flow was made during 1884 is the Cache la Poudre River, which rises on the eastern slope of the Continental Divide just east of the Colorado River Basin. A comparison between the discharge of the Cache la Poudre River during 1884 and its discharge during a normal year [69] indicates that this river likewise had its highest recorded total runoff in 1884—far above the average. As the Cache la Poudre rises so close to the headwaters of the Colorado, the regime of the two rivers must have been about the same. If this assumption is correct, the upper Colorado River started to rise about May 10, after a backward spring, reached a peak stage about May 20, then receded, owing probably to a drop in temperature, rose again about May 28, receded again, then began its principal rise about June 1. This rise continued until June 14, when another drop in temperature caused the river to fall for about 10 days. On June 23 it began its final rise, which culminated about June 28 in its peak stage and discharge. After that the stage dropped rapidly. The date of the peak on the upper part of the river is consistent with that of the peak on the lower part in Colorado, which was July 4, as recorded by the Weather Bureau at the Fruita gaging station. The behavior of the Colorado River was similar to that of the Gunnison River, also.

The tributary streams likewise were very high, and as a result the few small bridges spanning the Colorado River and Roaring Fork were destroyed, as were the head gates of all ditches in Grand Valley except the Grand River ditch.[70] No mention of the river overflowing its banks has been cited, however, and at Grand Junction the statement was made that it did not overflow.

Relative to the flood on the lower Colorado River, the Greeley Tribune of June 25, 1884, published a dispatch from Salt Lake City, dated June 18, which reported:

> A private letter reached here from Rioville, Lincoln County, Nev., tells of the tremendous destruction hereabouts by floods. * * *
>
> The Colorado is now 6 feet above its former highwater marks, above all the bridge approaches and tow paths the white man has ever had in this region.

[69] Follansbee, Robert, Upper Colorado River and its utilization: U. S. Geol. Survey Water-Supply Paper 617, p. 152, 1929.

[70] Gunnison Review Press, May 11, 1884.

Vast amounts of wreckage of railroad bridges, fences and wagons, and boats drifting down indicate the terrible loss and destruction on the upper tributaries of the river.

This letter was written two weeks or more before the river reached its peak.

The Weather Bureau located the high-water mark left by the peak stage of 1884 at Fruita, and in 1917 the Geological Survey by connecting this mark with the gage then being maintained, found its elevation to be 18.5 feet, as based on the gage datum. By running a line of levels across the area flooded in 1884 and extending the rating curve, the peak discharge was determined to be 125,000 second-feet.[71]

The year of highest June run-off during the period of discharge records was 1921. The large run-off was influenced to some extent by the heavy precipitation that occurred during two periods, June 3–9 and 14–15. This unusual precipitation was the result of the general storm that caused floods also in the Arkansas River and South Platte River Basins. The recorded precipitation in the main Colorado River Basin is shown in the following table.

Precipitation, in inches, in Colorado River Basin, June 4–9, 14–15, 1921

Station	Altitude (feet)	June								Total
		4	5	6	7	8	9	14	15	
Fraser	8,671	0.17	0.08	0.41	0.27	0.02	Tr.	0.07	0.06	1.08
Dillon	8,800	Tr.	.15	.23	.05	------	------	.30	------	.73
Flebbe Ranch	8,000	Tr.	Tr.	------	.30	------	------	------	1.05	1.35
Shoshone	6,120	.15	.31	.56	.19	------	0.23	.10	.54	2.08
Glenwood Springs	5,823	Tr.	.61	.40	.30	------	.21	Tr.	.70	2.22
Ashcroft	9,483	.69	.35	1.34	.12	------	.15	.98	------	3.63
Nast	8,800	------	.30	.85	.08	------	.42	.15	.57	2.37
Rifle	5,310	.27	.10	.18	.44	Tr.	.02	.04	.40	1.45
Collbran	6,000	.12	.11	.26	.46	------	------	.11	.69	1.75
Palisades	4,729	.16	.06	.23	.29	------	.17	.64	.18	1.73
Grand Junction	4,602	.03	.05	.30	.01	.06	------	.12	.06	.63
Fruita	4,590	.06	.12	Tr.	.41	Tr.	.06	.05	.16	.86

It is probable that at the higher altitudes the precipitation June 4–9 was chiefly in the form of snow. Beginning June 10 the temperature increased rapidly, and the precipitation after this date was probably rain. This later precipitation hastened the melting of the snow, which resulted in a higher discharge of the river. As even higher discharges have occurred at Glenwood Springs and nearly as high at Fruita when there has been little or no precipitation, it is probable that precipitation played only a minor part in causing the high water of 1921.

The following table shows the daily discharge of the Colorado River between the mouth of Roaring Fork and Fruita, near the Colorado-Utah State line.

[71] Follansbee, Robert, Upper Colorado River and its utilization: U. S. Geol. Survey Water-Supply Paper 617, p. 151, 1929.

Daily discharge, in second-feet, of Colorado River, May 26 to June 25, 1921

Date	Below Roaring Fork (drainage area 6,020 square miles)	Near Palisade (drainage area 8,790 square miles)	Near Fruita (drainage area 17,100 square miles)	Date	Below Roaring Fork (drainage area 6,020 square miles)	Near Palisade (drainage area 8,790 square miles)	Near Fruita (drainage area 17,100 square miles)
May 26	18,600	23,300	38,600	June 11	37,100	44,400	69,100
27	18,000	23,800	35,800	12	40,000	46,200	71,100
28	20,500	25,000	37,600	13	41,500	47,700	75,100
29	23,500	28,400	45,200	14	43,300	45,800	73,100
30	27,100	32,200	53,100	15	43,700	48,800	77,100
31	28,600	34,000	56,100	16	44,400	50,800	81,100
June 1	28,600	34,600	57,100	17	38,100	43,600	72,100
2	28,300	34,000	55,100	18	30,500	37,600	61,100
3	28,100	33,100	53,100	19	26,000	31,600	53,100
4	26,800	32,500	53,100	20	22,400	26,800	46,100
5	28,300	32,500	51,100	21	18,900	22,600	39,500
6	29,900	34,300	55,100	22	17,400	20,500	35,800
7	31,900	40,200	62,100	23	18,500	21,400	34,000
8	30,300	38,200	63,100	24	18,200	20,500	35,800
9	32,100	37,000	61,100	25	18,100	19,900	34,000
10	35,300	41,900	67,100				

GUNNISON RIVER

The Gunnison River, the principal tributary of the Colorado River in Colorado, drains some of the most rugged country in the entire Colorado River Basin. The headwater streams rise at an altitude of about 12,000 feet. The Gunnison, formed by the confluence of the Taylor and East Rivers at Almont, flows through narrow valleys and deep canyons throughout its course and joins the Colorado River at Grand Junction.

Owing chiefly to the high altitude of most of the basin the Gunnison River, like the Colorado itself, is not subject to heavy floods. Cloudbursts rarely occur on tributary streams, except in the Uncompahgre River Basin.

The earliest available reference to high water on the Gunnison River is that of 1884. About May 15, Delta reported temperatures of 70° to 80° in the shade, with warm nights. This warm weather, evidently the first of the season (the Gunnison paper, May 8, stated that the spring was a month late), caused the Gunnison to rise and overflow the lowlands near Delta. The river continued to rise, augumented by heavy rain, until about June 17, when it was reported to be falling rapidly, evidently because of a drop in temperature. The drop was only temporary, however, for a few days later the river was reported to be rising again, and about July 2 reached its peak. Four days later it was falling rapidly.

On June 4 a Denver & Rio Grande train in the Black Canyon had passed through 3 feet of water, which extinguished the fire in the locomotive; after that, railroad service was discontinued until the high water subsided, in July. It had already destroyed several bridges crossing the lower river, including four wooden structures along the Denver & Rio Grande Railroad. One of these, near Esca-

lante, collapsed just as a passenger train reached it; the engine and two cars went into the river, and several lives were lost. At Delta the Gunnison River rose at least 10 feet above bank-full stage and overflowed an area nearly three-quarters of a mile wide. As the banks were covered with trees and underbrush, the overflow was retarded somewhat, and this retardation was aided by a narrowing of the valley a short distance below Delta to form a canyon, through which the Gunnison River flows nearly to its mouth. The water in the canyon did not reach the tracks of the railroad, which are not more than 15 feet above low water.[72]

The peak discharge of the Gunnison River has been estimated by comparing it with the peak discharge of the Colorado River at Fruita, which occurred at nearly the same time, July 4. Gaging-station records show that during 5 other years, 1917, 1918, 1920, 1921, and 1923, and maximums on the two streams have occurred at practically the same time. In determining these relations it is necessary to use maximum daily discharges, as the records are based on two or more daily gage heights and do not represent the peak discharges. However, an examination of the relation between the peak discharge and daily discharge on the Colorado River near Cisco, a short distance below Fruita, for the high-water years since the installation of the water-stage recorder in 1923, and the relation between the peak discharge and daily discharge of the Gunnison River since the installation of the water-stage recorder in 1934, shows that the mean daily discharge for each stream is within a few percent of the peak discharge during high water. Therefore it is evident that the relation between the daily discharges applies to the peak discharges also.

Relation of maximum daily discharge, in second-feet, of the Gunnison River to that of the Colorado River

Year	Gunnison River	Colorado River	Percentage	Year	Gunnison River	Colorado River	Percentage
1917	24,800	62,500	40	1921	29,800	81,100	37
1918	16,900	56,200	30	1923	18,100	49,600	36
1920	35,200	77,100	46				

The average of these is 38 percent. The peak discharge of the Colorado River in 1884 was 125,000 second-feet, and by taking 38 percent of this, the peak discharge of the Gunnison River during 1884 was estimated to be about 50,000 second-feet. The highest peak discharge of record was 35,200 second-feet, May 23, 1920.

High water on the Gunnison River during the period of record has been due almost entirely to the melting of the snow cover, which is

[72] Follansbee, Robert, op. cit., p. 151.

influenced by temperature. The highest discharge since gaging-station records were started in 1896 occurred in 1920. The daily discharges, as recorded at Gunnison and Grand Junction, May 16 to June 10, 1920, are shown in the following table.

Daily discharge, in second-feet, of Gunnison River, May 16 to June 10, 1920

Date	Near Gunnison (drainage area 1,010 sq. mi.)	Near Grand Junction (drainage area 8,020 sq. mi.)	Date	Near Gunnison (drainage area 1,010 sq. mi.)	Near Grand Junction drainage area 8,020 sq. mi.)
May 16	1,840	12,600	May 29	6,240	27,400
May 17	2,340	13,300	May 30	6,380	27,400
May 18	2,780	15,600	May 31	6,670	27,700
May 19	3,720	20,000	June 1	7,480	27,400
May 20	4,750	23,400	June 2	6,820	25,500
May 21	5,080	26,200	June 3	6,730	23,400
May 22	5,220	31,500	June 4	6,520	21,400
May 23	4,930	35,200	June 5	6,520	20,400
May 24	5,510	30,100	June 6	6,380	20,000
May 25	5,860	30,100	June 7	6,820	20,700
May 26	6,960	31,500	June 8	7,100	21,400
May 27	6,670	30,500	June 9	6,820	21,400
May 28	6,090	27,700	June 10	6,240	21,400

UNCOMPAHGRE RIVER

The Uncompahgre River, a tributary of Gunnison River, rises on the north slope of the San Juan Mountain mass and flows north to its junction with the Gunnison at Delta. Although the basin is mountainous, its location on the western edge of the main Rocky Mountain uplift gives it, from the standpoint of flood occurrence, a position somewhat analogous to that of the eastern foothill region, especially in respect to rains during the summer months and cloudburst floods on the small tributaries. Floods on the main river are infrequent.

The earliest reference to a flood on the Uncompahgre River comes from the settlers who founded Delta in the early eighties. At that time, an Indian squaw, Chipeta, wife of the famous Ute Chief Ouray, stated that within her lifetime of [then] about 50 years, she had seen the Uncompahgre Valley at Delta "flooded from bluff to bluff." [73]

The melting of the heavy snowfall of the winter of 1883–84 caused the highest flood known on the Colorado and Gunnison Rivers, in June 1884, and undoubtedly caused a similar flood on the Uncompahgre River. The only available reference to such a flood, however, is an item in the San Juan Prospector of May 17, 1884, which states that "Uncompahgre is rising rapidly and an overflow is feared."

Like the Colorado River, the Uncompahgre River had its highest recorded June runoff in 1921, which was influenced to some extent by the precipitation, as was also the run-off of the Colorado River. The following table shows this precipitation.

[73] Follansbee, Robert, op. cit.

Precipitation, in inches, in Uncompahgre River Basin, June 4–9, 14–15, 1921

Station	Altitude (feet)	June								Total
		4	5	6	7	8	9	14	15	
Ames	8,750	0.89	0.03	Tr.	0.62	0.03	Tr.	0.27	0.38	2.22
Montrose	5,811	.04	.15	------	.83	------	.13	.04	.29	1.48
Delta	4,965	.04	.05	.11	.82	------	.02	.50	.29	1.83

The following table shows the daily discharge of the Uncompahgre River at the various gaging stations.

Daily discharge, in second-feet, of Uncompahgre River, June 5–19, 1921

June	Below Ouray (drainage area 76 square miles)	Colona (drainage area 403 square miles)	Montrose (drainage area 565 square miles)	Delta (drainage area 1,110 square miles)	June	Below Ouray (drainage area 76 square miles)	Colona (drainage area 403 square miles)	Montrose (drainage area 565 square miles)	Near (drainage area 1,110 square miles)
5	563	1,100	920	329	13	1,250	4,080	3,580	2,300
6	504	1,030	905	520	14	1,330	4,080	3,580	2,150
7	626	1,300	1,620	1,200	15	1,550	3,900	3,400	2,150
8	750	1,360	1,270	910	16	1,120	3,600	3,100	1,000
9	1,120	2,120	2,060	1,420	17	914	2,940	2,440	1,090
10	1,280	2,400	2,360	1,820	18	770	2,650	2,150	1,090
11	1,360	3,000	2,530	1,970	19	563	2,530	2,030	880
12	1,280	3,500	2,990	2,300					

The influence of the combination of rain and melting snow on the discharge of the river is referred to by the Delta Independent, June 17, 1921, which stated that the "heavy rains, added to the high water caused by the rapidly melting snow" had raised the Uncompahgre River to such an extent as to cause concern among the dwellers near the river. Considerable land along the river was inundated, and a number of highway bridges were destroyed. The Montrose Daily Press, June 15, 1921, stated that the crest at Montrose was 1 foot higher than had been recorded in previous years.

The only cloudburst flood in the Uncompahgre River Basin of which there is a record is that of July 20, 1923, on Skyrocket Gulch at Ouray. Skyrocket Gulch drains 1 square mile of the almost vertical walls of the mountains back of Ouray and enters the Uncompahgre River just above the gaging station, which is below Ouray. The hydrograph of the flood as made by the water-stage recorder shows that the flow of the river increased from 275 to about 2,300 second-feet in about 30 minutes and fell almost as quickly. This increase of about 2,000 second-feet in the flow of the river represents the flood on Skyrocket Gulch.

DOLORES RIVER

The drainage basin of the Dolores River lies west of the Uncompahgre Basin and north of the San Juan Basin, in the extreme western part of Colorado. The upper part of the basin lies on the western

slope of the San Juan Mountains and is extremely rugged. The Dolores River rises on the southwestern slope of the San Juan Mountains at an altitude of 13,000 feet. Throughout much of its course, which is northwest to its junction with the Colorado River, the Dolores River flows through canyons cut in the high plateaus of that region. The only available record of flood discharge is that for the flood of 1911, made at the gaging station at Dolores, on the main river.

The heavy snows of the winter of 1883–84 caused the earliest known flood on the Dolores River. The San Juan Prospector in several issues in May 1884 stated that the lower Dolores River and San Miguel River were higher than ever known, every bridge was swept away, and many ranchers and stock growers were compelled to leave the valley for the mountainsides.

No other floods on Dolores River have been noted until the fall storms of 1909 caused severe floods in southwestern Colorado. Concerning the flood of September 1909, the Durango Democrat, September 8, 1909, stated that the Dolores River at Rico was a raging torrent and that half a mile of railroad track near Lizard Head had been washed out.

The flood of October 4–6, 1911, was much more severe. Although there was no record of the rainfall at Dolores during the storm that preceded this flood, the Weather Bureau observer, who later reported rainfall at that point, stated that by comparison with subsequent records he estimated that the precipitation during October 4–6 was 8 to 10 inches. The resulting flood caused the greatest loss to the Rio Grande Southern Railroad; much of its track was entirely destroyed, and all of it was more or less damaged for a stretch of 35 miles. Severe losses were also sustained by ranchers.[74] The flood reached a stage of 10.2 feet on the gage at Dolores and an estimated peak discharge of about 10,000 second-feet. It caused the river to break through the railroad grade and flow down an old river channel, inundating a part of Dolores to a depth of 1 to 3 feet and washing out one span of the Fourth Street Bridge.[75]

WEST CREEK

West Creek drains the western part of Unaweep Canyon, which cuts across the Uncompahgre Plateau and meets the Dolores River Canyon a short distance above Gateway. A cloudburst occurred in this area, July 16, 1940, principally on Fish Creek, which enters West Creek in sec. 1, T. 15 S., R. 103 W., about 10 miles above the mouth. The resulting flood on West Creek was stated by local residents to have been the highest in 40 years. A slope-area measure-

[74] Russell, G. H., and Gray, G. A., Flood of October 1911 in the region of the San Jnan, San Miguel, and La Plata Mountains: U. S. Geol. Survey Water-Supply Paper 309, p. 247, 1914.

[75] Dolores Star, Oct. 6, 1911.

ment was made later on West Creek, in sec. 10, T. 15 S., R. 103 W., and the peak discharge found to be 11,700 second-feet, or 500 second-feet from the 23 square miles of drainage area affected by the storm.

SAN MIGUEL RIVER

San Miguel River is the principal tributary of the Dolores River. From its source on the northwest slope of the San Juan Mountains to its junction with the Dolores River 6 miles below Bedrock its course is in a canyon. The only floods in the San Miguel River Basin for which definite information is available were those of September 1909 and October 1911.

Severe rains on the headwaters of the San Miguel River on September 5, 1909, caused the failure of two small power reservoirs of the Telluride Power Co. on Lake Fork of the San Miguel. Middle Reservoir failed on September 5, and the sudden release of about 700 acre-feet of water raised the surface of Trout Lake, 1½ miles downstream, nearly 2 feet over the crest of the dam. This caused the failure of that dam also and the release of some 2,000 acre-feet of water. The State Engineer, who made an investigation of these failures, stated that the property damage caused by the flood was "appalling." [76] The Telluride Daily Journal, September 5, 1909, describing this flood, stated that the crest of the flood down the river varied from 20 to 45 feet above low water, depending on the width of the channel. In its issue of September 7 the Journal said:

> The scene along the [San Miguel] river Monday morning [Sept. 6] as the waters had partially receded forbids intelligent description. Wagon and railroad bridges and along trestles were crushed like clay pipes and entirely obliterated. The accumulated mass of water behind was described by eye witnesses as a solid wall 20 to 30 feet in height.

Concerning the flood of October 5, 1911, the Telluride Daily Journal of that date wrote:

> The continuous rains of the past week and a half saturated the soil of the watershed so that the fall of yesterday was all forced into the creeks and rivers. Reports from the river below Vance are to the effect that the water yesterday was but 4 inches lower than at the time the entire contents of Trout Lake were precipitated into the river by the giving away of the dam two years ago.

At Placerville the maximum 24-hour discharge of the San Miguel River was 1,540 second-feet, as reported by R. I. Meeker, consulting engineer, Denver, Colo.

A cloudburst flood July 27, 1914, on a tributary flowing through Telluride caused much damage. The Journal described this flood, as follows:

> At 12:50 o'clock Monday afternoon [July 27], following on the heels of the

[76] State Engineer of Colorado, 15th Bienn. Report, p. 113, 1911.

hardest rainstorm ever experienced in the city, a river of mud, very conservatively estimated at between 8 and 10 feet in height, swept out of Hornet Creek Canyon just north of town * * * and swept everything in its path. The largest portion of 15 blocks of the north-central, central, and eastern residential section and including one of the most important business blocks * * * is * * * now buried under mud to a depth of from 4 to 10 feet.

A waterspout of unbelievable volume, resulting from a cloudburst near the top of the Sawtooth Range directly north of town was the source of the flood.

If this storm was caused by a true cloudburst, it is one of the rare instances noted in Colorado of such a storm occurring at an altitude of 12,000 feet or higher.

SAN JUAN RIVER

The San Juan River rises on the southern slope of the San Juan Mountains in southwestern Colorado and flows southwestward, crossing the Colorado-New Mexico State line near Arboles. Throughout its course in Colorado it is a typical mountain stream. Between the mouth of the West Fork and Pagosa Springs its fall decreases from 188 to 47 feet per mile; between Pagosa Springs and Arboles the average fall is 27 feet per mile.

Gaging stations on the San Juan River

Station	Drainage area (square) miles)	Period of record
Pagosa Springs	298	January 1911 to November 1914; May 1935 to date.
Arboles	1,390	June 1895 to September 1899; August 1910 to December 1914.

The first flood known to the early settlers in the San Juan River Basin occurred in 1859. The Durango Evening Herald of October 17, 1911, in an article dealing primarily with the devastating flood that had occurred about 12 days earlier, has this to say of the flood of 1859:

Dr. William Schumacher, the sheep inspector, ran across an interesting incident at Carracas [recently]. An old squaw, a member of the Talian tribe of the southern Utes, told him through an interpreter that when she was a small child her people had a camp on the site that is now occupied by the house of Manuel Baker at Carracas [near the mouth of the Piedra River]. One day they all left camp to gather piñon nuts and when they returned the tepees and everything they contained had washed away. To reach that far the floodwater must have been higher by 6 feet than it was during the flood of this year.

The late Colonel Stollsteimer used to tell a story that verifies the story of the Talian squaw. He said he was shearing sheep that year on one of his flats near what is now Carracas when the Indians came to him and insisted that he move to higher ground on account of the flood. Col. Stollsteimer said he moved although he really did not think it necessary * * *. The flood swept in a raging sea over the flat where he had camped.

An apparent inconsistency in these two accounts is the indicated time of year. Sheep shearing is done in the early spring, and piñon nuts are usually gathered in the fall. However, if it had been a hard winter with heavy snowfall, as the occurrence of the flood would indicate, it is entirely possible that the Indians, because of food shortage, would search in the early spring for piñon nuts that had been hoarded by rodents.

The melting snow cover during June 1884 caused floods in the San Juan River Basin, but the only available information concerning them refers to the Animas River (see p. 136).

The San Juan River Basin is rarely subject to floods. The annual high water due to the melting of the heavy snow cover which is characteristic of the San Juan Mountains keeps the river channels scoured out to the required capacity, and storms of sufficient intensity and extent to cause floods are rare. Two such storms have occurred since precipitation records were started at a few points in the early eighties. These were the storms of September 3–6, 1909, and October 4–6, 1911. A third storm at the time of melting snow occurred June 26–29, 1927.

The storm of September 3–6, 1909, followed a month of greater than average precipitation, during which rain fell almost every day. The heavy rainfall of September 5 resulted in a flood that, in the lower basin in New Mexico, at least, was reported locally to be the greatest since the country had been settled. San Juan River and its tributaries were at very high stages, although information relative to peak crests and actual discharge is lacking. The Los Pinos overflowed its banks in many places. In New Mexico the flood was severe.

The rainfall during October 4–6, 1911, caused the highest flood of actual record in the San Juan River Basin and resulted in the loss of two lives in Pagosa Springs and a great amount of property damage. The Pagosa Springs New Era of October 6, 1911, reported:

> The rains which started in this section Wednesday evening [Oct. 4] and kept up a steady downpour all night and well into Thursday afternoon brought not only death but hundreds of thousands of dollars * * * in financial losses to the people of southwestern Colorado. For there is not a low-lying piece of farm land along the numerous streams but is either totally destroyed or rendered unfit to produce crops until it is rehabilitated. * * * Added to those losses were the crops that were swept away, the roads and bridges destroyed, the railroad and milling property lost, the orchards destroyed, the residences and personal belongings lying in the sand.

In a Survey report written soon after the flood [77] it was stated that damage on the San Juan River probably far exceeded that on any of

[77] Russell, G. H., and Gray, G. A., Flood of October 1911 in the region of the San Juan, San Miguel, and La Plata Mountains: U. S. Geol. Survey Water-Supply Paper 309, p. 248, 1914.

the other streams. Every highway bridge over the San Juan was destroyed. The Denver & Rio Grande Railroad had 7 miles of track entirely destroyed between Navajo and Arboles, and about 17 miles so damaged that repairs were necessary. (See pl. 3.) Pagosa Springs, the largest Colorado town on the San Juan River, suffered very considerable damage as water 3 to 5 feet deep covered the low-lying land close to the river. Eighteen residences and other buildings, including the old electric light plant, were destroyed or washed away with much of their contents.

The first warning of the flood at Pagosa Springs was given at 5:30 a. m., October 5, 1911, but some dwellers in the lowlands refused to believe that a great flood was approaching and did not remove their household effects. The river rose rapidly and about noon reached a peak stage of 17.8 feet, or 13 feet above normal. This stage was maintained for about 3 hours and then the flood receded, rapidly at first, then more gradually, probably returning to normal stage 3 or 4 days later. At Arboles, 35 miles downstream, the river rose about 17 feet above normal and reached the railroad station. The town, built on higher ground, escaped. The flood peak was reached at 5 p. m., October 5, indicating a rate of travel between Pagosa Springs and Arboles of 7 miles per hour.

As the gaging station was destroyed, no record of the peak discharge was obtained at that time. In 1939 an investigation was made, and from the cross section based on fairly well-defined high-water marks the peak discharge was estimated at 25,000 second-feet. At the beginning of the rise, which ocurred in about 6 hours, the discharge was less than 1,000 second-feet. The total flood discharge was about 50,000 acre-feet. During the investigation of the flood made in 1911,[78] the peak discharge at Arboles was estimated at 40,000 second-feet; at Shiprock, N. Mex., it was probably 150,000 second-feet.

Like the other streams in the San Juan River Basin, the Mancos River was in flood, reaching the highest stage known, and did considerable damage along its course. The Mancos Times Tribune of Ocotber 5, 1911, stated:

> The raging torrent brought down quantities of driftwood, trees, logs, and everything in its course that was loose. This collected at various points, causing the river to change its channel in many places with consequent damage. In town [Mancos] it cut in above the present post-office building, seriously threatening its safety, and took away a part of a warehouse.

The flood of 1911 on Los Pinos River inundated the land along the river at Bayfield for nearly a week beginning October 1. The peak occurred about noon on October 5. One house was washed away.

[78] Russell, G. H., and Gray, G. A., op. cit., p. 248.

The fair grounds were covered to a depth of 3½ to 4 feet. During the flood of September 1909 the river did not overflow at Bayfield.

Heavy rains during the period June 26–30, 1927, at a time when warmer weather was melting the mountain snow, caused the second highest flood of record in the San Juan River Basin. Precipitation, probably in the form of snow at the higher altitudes June 11–16, was followed by a rise in temperatue of about 20°, as shown by the Durango records. This caused rapid snow melting, and the heavy rains hastened the melting to such an extent as to cause the flood. The following table shows the precipitation for the period June 11–16, and for each day from June 26 to 29.

Precipitation, in inches, in the San Juan River Basin, June 11-16, 26–29, 1927

Station	Altitude (feet)	June					
		11–16	26	27	28	29	Total 26–30
Trout Lake	9,650	2.30	0.60	1.50	2.50	0.15	4.75
Silverton	9,400	.92	----------	1.50	2.00	.36	3.86
Palisade Lake	9,230	2.37	.51	1.23	2.50	1.66	5.90
Cascade	8,900	.60	.82	.74	1.64	.22	3.42
Terminal Dam	8,300	1.08	----------	1.60	2.20	.43	4.23
Tacoma	7,200	.89	.30	.95	2.65	.45	4.35
Durango	6,589	1.38	.36	.90	2.68	.21	4.15
Fort Lewis	7,610	1.10	.15	1.13	2.00	.19	3.47
Mesa Verde Park	6,930	1.19	.05	1.25	1.34	.02	2.66
Ignacio	6,425	1.95	.27	.90	1.30	.51	2.98
Cumbres	10,015	.82	.16	.18	.07	----------	.41
Rosa, N. Mex	6,500	1.07	.13	.68	1.15	1.42	3.38
Dulce, N. Mex	6,767	.70	.06	.10	.70	1.00	1.86
Aztec, N. Mex	5,590	1.02	.51	.41	.67	.21	1.80

The light rainfall at Cumbres, at the pass on the extreme southeastern edge of the basin, and in New Mexico, indicates that the precipitation was much less in the eastern and southern parts of the basin.

No gaging station was in operation in the Colorado portion of the San Juan River Basin, but at the station on the San Juan River at Farmington, N. Mex., below the mouth of the Animas River, the flood was the greatest since that of October 1911, the peak discharge on June 29 being estimated at 68,000 second-feet.

Describing the flood at Pagosa Springs, the weekly Pagosa Journal, in its issue of July 1, 1927, stated:

> The first of the week the San Juan Basin rivers experienced the highest waters in their history in June, and with the exception of October 1911, the highest ever known in the memory of the oldest inhabitant of this general section. The high water began to be noticeable on Tuesday evening when it was seen that the San Juan was steadily rising to flood stage. At that time neither the Navajo nor the [Rio] Blanco showed a rise * * * above the ordinary spring rise, but the high waters of the San Juan, Piedra, Pine [Los Pinos], and Animas were taking on the proportions of a flood. Here in Pagosa Springs, bags of sand were used to

barricade the high waters out of the park, which was inundated during the flood of 1911. The crest of the flood was reached at Pagosa Springs at 9 o'clock Wednesday morning [June 29] when water out of the San Juan ran in a small stream across the east approach of the San Juan Street bridge.

No mention of flood damage was made except that two bridges were destroyed below Pagosa Springs.

The low point in the bridge approach which was overflowed has a height of about 13 feet on the gage established in 1935. Assuming the peak to have reached a stage of 13.5 feet, the indicated discharge was about 16,000 second-feet. No estimate of the total discharge can be made.

At Bayfield, local residents stated that the Los Pinos River was nearly as high during the 1927 flood as during that of October 1911.

The Piedra River was also in flood. At the gaging station near Piedra, established in November 1939, a high-water mark of the 1927 flood was connected with the present gage datum, and found to have an elevation of 15 feet and an indicated discharge of 14,000 second-feet.

ANIMAS RIVER

Animas River joins the San Juan River at Farmington, N. Mex. It rises on the south slopes of the San Juan Mountains at an altitude of about 12,000 feet and flows through canyons and narrow valleys to a point about 15 miles north of Durango, where it enters the Animas Valley which extends nearly to Durango with an average width of a mile. Below Durango the valley closes in to a width of half a mile or less for a distance of 10 miles, then widens out in the stretch that extends to the State line. Above Silverton the river has an average fall of about 300 feet per mile; below Silverton it averages 100 feet per mile as far as the head of the Animas Valley, through which the fall is 16 feet per mile; between Durango and the Colorado-New Mexico State line the average fall is 22 feet per mile.

A gaging station has been maintained on the Animas River at Durango since 1895, except for the period 1906–09.

The first known flood on the Animas River was that of June 1884. The Denver Republican of June 28, 1884, carried the following dispatch from Silverton:

> The floods are still increasing and are causing great destruction in this vicinity. The bridge at the head of Reese Street, across Cement Creek, was carried out this evening, and the dwelling houses in that locality are seriously threatened with being swept away by the torrents. * * * The snow still lies at great depths on the mountains, and the worst is yet to come.

This was about the peak of the discharge, as shown by references to the flood of June 1884 on other streams, and no further reference to the Animas flood was made. The next issue of the Republican carried

a dispatch from Durango, dated June 28, which stated that the warm weather continued to melt the snow in the mountains and the Animas Canyon was "booming full."

The flood of September 6, 1909, is believed to have been more severe on the Animas River than on the San Juan River, as the recorded rainfall in the Animas River Basin was higher. The Durango Democrat of September 7, 1909, stated:

> Jupiter Pluvius seemed anxious to vent his rage on La Plata County and vicinity sending down water—rain is too mild—in torrents, both in valleys and on hills. These helped to swell the creeks and they the rivers, which swept away crops, bridges, and everything in its wake. In Durango, people living in the lowlands along the river were compelled to move their belongings upon the hillsides. The smelter engine room and pump house were flooded. The tipple on which was a car loaded with coal was washed into the river. The railroad has suffered immense damage.

The Geological Survey in its account of this flood[79] stated that the greater part of the flood loss was sustained by the Denver & Rio Grande Railroad. Along the Animas River between Silverton and Durango many stretches of railroad track were washed out and others were covered with immense deposits of sediment. Traffic on that branch was suspended for about three weeks. The San Juan Water and Power Co. maintained at its Durango power plant a gage which showed a maximum stage of 8.5 feet between 4 and 6 a. m., September 6.[80] From a rating curve based on a subsequent high-water measurement the peak discharge was found to be 15,000 second-feet.

The rainfall during the period October 4–6, 1911, caused the highest flood of actual record on the Animas River. The Durango Evening Herald, October 5 and 6, 1911, stated that conditions in the Animas River Valley were serious; parts of the valley were flooded to a depth of 3 to 6 feet, and many families were obliged to move to higher ground for safety. Animas Valley from Trimble Springs to Durango "resembled one big lake." There was a general destruction of crops, roads, and ditches. The Denver & Rio Grande Railroad tracks in the valley, both above and below Durango, were so seriously damaged that the Farmington line was out of commission for 50 days, and the Silverton line for 60 days. The damage in the Animas Canyon was augmented by rock slides. At Durango the entire flat between the railroad and the Main Avenue bridge was flooded, three bridges were destroyed, several houses swept away, and a new channel was cut in several places. From Main Avenue bridge the flood waters reached to the car barns and to the electric light plant.

In the original report of this flood[81] the crest was given as 13.6

[79] Freeman, W. B., and Bolster, R. H., Colorado River Basin: U. S. Geol. Survey Water-Supply Paper 269, p. 188, 1911.

[80] Freeman, W. B., and Bolster, R. H., Op. cit. p. 190.

[81] Russell, G. H., and Gray, G. A., op. cit. p. 247.

feet, but a recent investigation indicates that 13.6 feet referred to a point on an overflow channel some distance from the main channel. The present operator at the power plant, who was on duty during the 1911 flood, states that although the river was bank full it did not overflow at the gage which was located near the power house. The top of the bank is 11 feet above the gage datum, and this represents closely the crest of the flood. A recent study of all discharge measurements and of conditions at the station indicates that the corresponding discharge was 25,000 second-feet. When the river started to rise about 11 a. m. October 5, the discharge was 1,800 second-feet; 2½ hours later the big rise came and continued until about 10 p. m., when the peak discharge was reached. This stage continued 2 or 3 hours, and then the water started to recede, rapidly at first, then more slowly. No further information relative to flood volume is available.

The only tributary of the Animas River for which information is available is Hermosa Creek, which enters the river above Durango. The Durango Evening Herald of October 6, 1911, stated that "the Hermosa became a raging torrent early in the day. The water surrounded the depot and washed over the track a distance of two or three blocks."

The flood of June 28–30, 1927, caused by the rainfall of June 26–29, was the second highest of record, for this area. The Durango Evening Herald, in its issues of June 29 and 30, 1927, stated that the Animas Valley for a distance of 15 miles above Durango was under water, and the river half a mile to a mile wide in places. In many sections only the tops of fences and trees were visible. The most serious damage occurred on the Silverton branch of the Denver & Rio Grande Railroad, where more than 4 miles of track including one bridge, was washed out between Tacoma and Needleton and an unknown amount of track above. In Durango the river overflowed the south end of Animas Bridge to a depth of several inches, but no damage was reported beyond the loss of a footbridge at the power plant.

The record at the Durango gaging station showed a peak stage of 9.65 feet, which represented a discharge of 20,000 second-feet. As this flood was the largest for which fairly complete records are available, the following table of bihourly stages and discharges is presented.

Bihourly stage, in feet, and discharge, in second-feet of Animas River at Durango, Colo., June 27 to July 1, 1927

Time	June								July 1	
	27		28		29		30			
	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge	Gage height	Discharge
2 a. m.	3.90	2,100	5.29	4,440	9.6	19,700	7.17	10,500	5.84	5,820
4	4.03	2,250	5.42	4,750	9.4	19,000	7.00	9,860	5.75	5,580
6	4.21	2,480	5.56	5,090	9.3	18,600	6.90	9,500	5.67	5,370
8	4.30	2,600	5.85	5,850	9.23	18,300	6.79	9,100	5.62	5,240
10	4.50	2,900	6.25	7,180	9.00	17,400	6.72	8,850	5.55	5,060
Noon	4.66	3,160	6.93	9,610	8.68	16,200	6.61	8,460	5.49	4,920
2 p. m.	4.70	3,230	7.49	11,600	8.44	15,200	6.52	8,130	5.38	4,650
4	4.76	3,340	7.92	13,200	8.13	14,000	6.38	7,630	5.30	4,460
6	4.85	3,500	8.38	15,000	7.84	12,900	6.25	7,180	5.17	4,160
8	4.93	3,660	8.66	16,100	7.62	12,100	6.16	6,860	5.07	3,950
10	5.01	3,820	9.29	18,500	7.48	11,600	6.04	6,440	4.98	3,760
Midnight	5.15	4,120	9.65	20,000	7.32	11,000	5.95	6,140	4.94	3,680
Mean		3,100		10,940		15,500		8,220		4,720
Acre-feet		6,150		21,700		30,700		16,300		9,360

LA PLATA RIVER

The first recorded flood on the La Plata River occurred October 6, 1904. It was caused by a storm originating near the Colorado-New Mexico State line, and affected the river chiefly in New Mexico. An account of this flood at Pendleton, N. Mex., is published.[82]

The first recorded flood in La Plata River Basin in Colorado occurred October 5, 1911, and is the highest known in that region, and probably the highest that has occurred throughout the length of this river. Supporting this statement is the fact that the bridge at Pendleton, N. Mex., which withstood the flood of 1904, was destroyed by the flood of 1911. This flood also covered the main street of Hesperus, Colo., to a depth of more than a foot. The recorded rainfall at Fort Lewis was 2.30 inches on October 5, and 0.58 inch on October 6. No estimate of the peak discharge was made.

On August 24, 1927, local rains, probably of cloudburst intensity, in the basin of tributary streams between Hesperus and the gaging

[82] Hinderlider, M. C., and assistants, Floods in the Denver district, in Murphy, E. C., and others, Destructive floods in the United States in 1904: U. S. Geol. Survey Water-Supply Paper 147, pp. 150–171, 1905. Includes a paper entitled "La Plata River flood, Colorado," prepared from a report by Theo. Tobish, pp. 169–171.

station just below the Colorado-New Mexico State line, caused a flood which reached a peak of 4,750 second-feet at that station. This flood was of short duration, and the mean discharge for the day was only 965 second-feet. At the gaging station at Hesperus the discharge was only 13 second-feet.

SUMMARY OF MAXIMUM FLOOD DISCHARGES

The following table shows the recorded peak discharges of the floods described in this report. If several floods at the same place are described, the peak discharge of the highest flood only is given. The period of record at regular gaging stations is not shown, as at most stations the flood recorded as the greatest is the greatest in a much longer period than that covered by the gaging-station records. In figure 3 the peak discharge in second-feet per square mile for each place is plotted against the corresponding drainage area.

DAMAGE TO TRACKS OF DENVER & RIO GRANDE RAILROAD CAUSED BY FLOOD OF OCTOBER 1911 ON SAN JUAN RIVER NEAR PAGOSA JUNCTION.

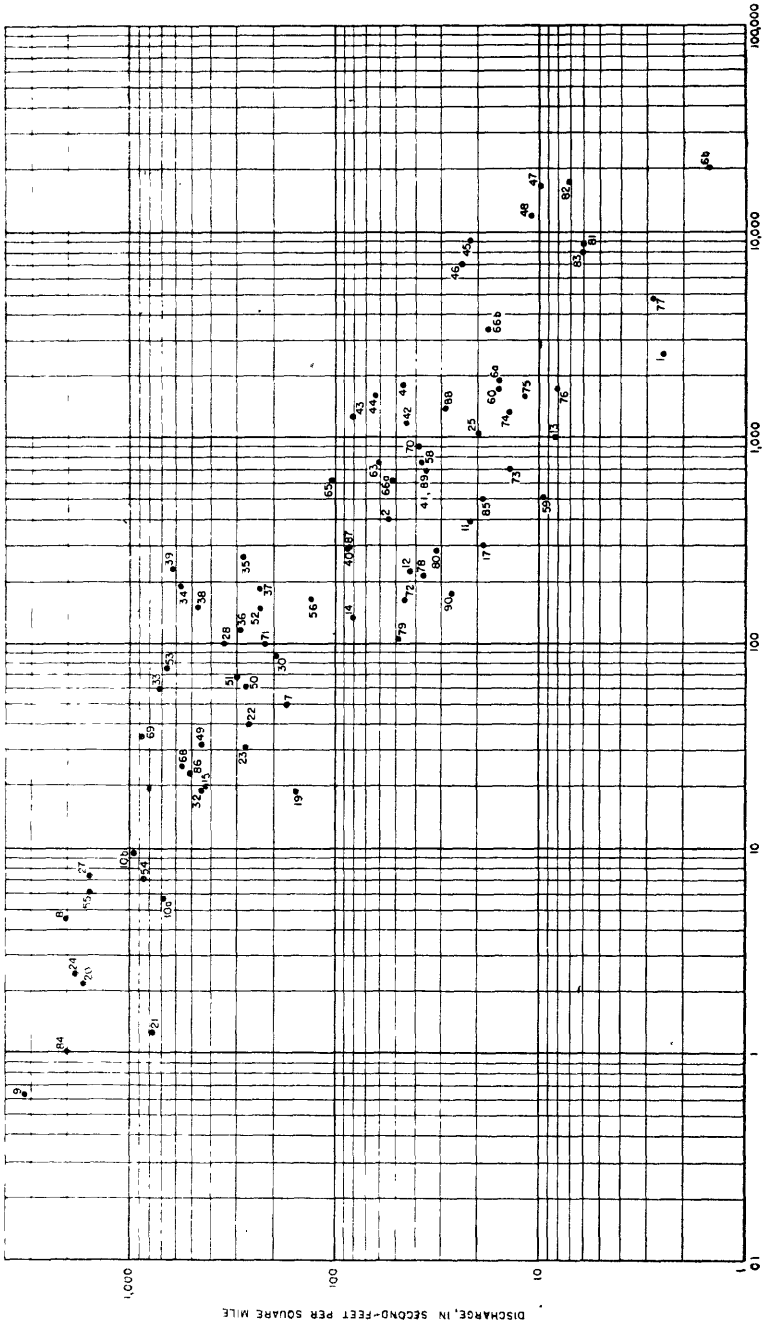

FIGURE 3.—Chart showing maximum flood discharge, in second-feet per square mile, for various places given in the summary table.

Summary of maximum flood discharges in Colorado, 1884–1944

South Platte River Basin

No.	Stream and place of determination	Latitude	Longitude	Drainage area [1] (square miles)	Peak stage and discharge			Calendar day discharge (second-feet)	Peak discharge per square miles	Remarks
					Date	Stage (feet)	Discharge (second-feet)			
	SOUTH PLATTE RIVER, MAIN STREAM									
1	South Platte River at South Platte	39°25′	105°10′	2,550	June 7, 1921	8.95	6,320	6,140	2.5	Extension of rating curve.
2	South Platte River at Denver	39°46′	105°00′	(400)	Sept. 10, 1933	10.98	22,000	3,310	55	State engineer record, extension of rating curve.
3	South Platte River at Kersey	40°25′	104°34′	9,500	June 7, 1921	8.5	----------	31,000	--------	Do.
4	South Platte River at Fort Morgan	40°17′	103°48′	(1,800)	May 31, 1935	12	84,300	----------	47	State engineer record, slope-area measurement.
5	South Platte River at Balzac	40°24′	103°29′	17,700	June 11, 1921 [2]	9.3	----------	31,200	--------	State engineer record, extension of rating curve.
6a	South Platte River at Julesburg	40°58′	102°15′	(1,900)	June 2, 1935	8.56	31,300	24,000	16	Do.
6b	----do----	40°58′	102°15′	20,600	June 16, 1921	8.17	31,000	30,800	1.5	Do.
	MOUNTAIN TRIBUTARIES									
7	Bear Creek at Morrison	39°39′	105°12′	(50)	July 24, 1896	10.9	8,600	----------	172	State engineer record, slope-area measurement.
8	Cold Spring Gluch	39°40′	105°17′	4.48	Sept. 2, 1938	8.4	9,000	----------	2,010	Slope-area measurement.
9	Tributary of Cold Spring Gluch	39°40′	105°17′	.63	----do----	5.8	2,050	----------	3,250	Do.
10a	Mount Vernon Creek near Morrison	39°41′	105°12′	5.7	----do----	5.2	3,900	----------	684	Do.
10b	----do----	39°40′	105°12′	9.45	----do----	9.0	9,230	----------	977	Do.
11	Clear Creek near Golden	39°44′	105°19′	392	Aug. 1, 1888	--------	8,700	----------	22	State engineer record, probably extension of rating curve.
12	St. Vrain Creek at Lyons	40°13′	105°15′	226	May 31, 1894	8.1	9,800	----------	43	Slope-area measurement.
13	St. Vrain Creek at mouth	40°16′	104°53′	1,000	Sept. 3, 1938	8.93	8,360	3,200	8.4	State engineer record, slope-area measurement.
14	Boulder Creek at Boulder	40°41′	105°17′	134	June 1, 1894	10	11,000	--------	82	Metcalf and Eddy record, slope-area measurement.
15	South Boulder Creek at Eldorado Springs	39°56′	105°18′	(20)	Sept. 2, 1938	11.6	8,540	----------	427	Flow computed over dam.
16	Thompson River near Drake	40°26′	105°19′	[3]	July 31, 1919	9.5	8,000	490	--------	Extension of rating curve.
17	Thompson River at mouth of canyon	40°25′	105°14′	301	Sept. 1, 1938	6.6	5,600	----------	19	State engineer record, extension of rating curve.
18	Thompson River near Arkins	40°25′	105°13′	[3]	July 7, 1906	--------	6,000	2,600	--------	State engineer record, method not known.
19	Cedar Creek	40°25′	105°16′	18.9	Sept. 10, 1938	6.3	2,940	----------	156	Slope-area measurement.
20	Dixon Gluch	40°25′	105°15′	2.15	Sept. 1, 1938	5.4	3,620	----------	1,680	Do.
21	Green Ridge Glade	40°26′	105°13′	1.26	----do----	--------	980	----------	778	Do.
22	Buckhorn Creek	40°29′	105°13′	40	June 15, 1923	12	10,500	----------	262	Do.
23	Redstone Creek at Masonville	40°29′	105°12′	31	Sept. 1, 1938	10	8,400	----------	271	Do.
24	Missouri Canyon near mouth	40°27′	105°12′	2.4	June 15, 1923	7.5	4,350	----------	1,810	Do.

25	Cache la Poudre River at mouth of canyon	40°40′	105°13′	1,048	June 9, 1891		21,000		20	State engineer record, caused by failure of dam.
26	North Fork Cache la Poudre River at Livermore.	40°47′	105°15′	(3)	May 20, 1904		20,000			Estimated.
27	Spring Creek, tributary of Dry Creek	40°32′	105°08′	7.31	Sept. 2, 1938	11.5	11,600		1,590	Slope-area measurement.
	PLAINS TRIBUTARIES									
28	Cherry Creek above Castlewood Dam	39°20′	104°45′	(100)	Aug. 2, 1933		35,000		350	Computed by I. E. Houk from inflow to reservoir.
29	Cherry Creek below Castlewood Dam	39°21′	104°45′		do		126,000			Computed by I. E. Houk, caused by failure of dam.
30	Cherry Creek, sec. 4, T. 6 S., R. 66 W	39°34′	104°47′	(87)	July 28, 1922		17,000		195	Slope-area measurement.
31	Cherry Creek at Denver	39°46′	105°00′	(3)	July 26, 1885		20,000			Float measurement by Allen and Nettleton.
32	Bayou Gulch near mouth	39°26′	104°46′	(19)	July 28, 1922	6.5	8,670		456	Slope-area measurement.
33	Kiowa Creek near Elbert	39°13′	104°32′	(60)	May 30, 1935		43,500		725	State engineer record slope-area measurement.[4]
34	Kiowa Creek, sec. 21, T. 6 S., R. 63 W	39°31′	104°27′	(190)	do	14.8	110,000		579	Do.
35	Kiowa Creek at Bennett	39°47′	104°24′	(266)	do	13.4	75,300		283	Do.[4]
36	West Bijou Creek, sec. 13, T. 8 S., R. 62 W	39°22′	104°17′	(118)	do	11.3	34,250		290	Do.
37	West Bijou Creek near Peoria	39°29′	104°17′	(187)	do	16	44,400		237	Do.
38	Middle Bijou Creek, sec. 26, T. 7 S., R. 60 W	39°25′	104°05′	(151)	May 30, 1935	10.2	71,270		422	State engineer record, slope-area measurement.
39	Middle Bijou Creek, sec. 28 T. 4 S., R. 60 W	39°41′	104°06′	(230)	do	13	143,640		625	Do.
40	East Bijou Creek at Deer Trail	39°37′	104°03′	(294)	do		25,000		85	Do.[4]
41	Arikaree River at Cope	39°40′	102°50′	690	May 31, 1935	6	25,000		36	Slope-area measurement.
42	Arikaree River north of Idalia	39°48′	102°19′	1,190	do	9	54,000		45	Do.
43	South Fork Republican River near Newton	39°37′	102°12′	1,270	do	13.3	103,000		81	Do.
	Arkansas River Basin[5]									
44	Arkansas River at Pueblo	38°16′	104°41′	(1,600)	June 3, 1921	24.66	103,000	34,600	64	Slope-area measurement.
45	Arkansas River at La Junta	37°59′	103°31′	(9,100)	June 4, 1921	18.4	200,000	61,100	22	State engineer record, slope-area measurement.
46	Arkansas River near Prowers	38°06′	102°45′	(7,000)	June 5, 1921		170,000		24	Estimated flow over Amity Dam.
47	Arkansas River at Lamar	38°06′	102°37′	(16,700)	do		165,000	87,300	9.9	State engineer record, based on flow over Amity Dam.
48	Arkansas River at Holly	38°02′	102°07′	(12,000)	Oct. 20, 1908	11.0	136,000	125,000	11	Amity Land Co.'s record, slope-area measurement.
49	Grape Creek in Canyon	38°24′	105°20′	(32)	July 21, 1925	13.6	14,500		453	Slope-area measurement.
50	Wilson Creek, near mouth	38°39′	105°13′	61.3	July 4, 1944		16,800		274	Bureau of Reclamation, slope near measurement.
51	do	38°39′	105°13′	68.0	do		20,600		303	Do.
52	Fountain Creek at Pueblo	30°15′	104°35′	(150)	May 30, 1935		35,000		233	State engineer record, slope-area measurement.
53	Monument Creek at Colorado Springs	38°50′	104°50′	(75)	do	20	50,000		667	City engineer record, slope-area measurement.
54	Templeton Gap near Colorado Springs	38°53′	104°47′	7.1	May 27, 1922	5.0	6,120		862	Slope-area measurement.

See footnotes at end of table.

Summary of maximum flood discharges in Colorado, 1884–1944—Continued

Arkansas River Basin—Continued

No.	Stream and place of determination	Latitude	Longitude	Drainage area [1] (square miles)	Peak stage and discharge			Calendar day discharge (second-feet)	Peak discharge per square miles	Remarks
					Date	Stage (feet)	Discharge (second-feet)			
55	Hogans Gulch near Eden	38°22′	104°36′	6.1	Aug. 7, 1904	------	9,640	------	1,580	Denver & Rio Grande Railroad record.
56	St. Charles River at Burnt Mill	38°03′	104°47′	166	Aug. 22, 1925	22.1	21,800	1,250	131	State engineer record, slope-area measurement.
57	St. Charles River at mouth	38°16′	104°28′	(2)	June 4, 1921	------	56,000	------	------	Do.
58	Chico Creek at mouth	38°15′	104°23′	750	----do----	------	28,600	------	38	Do.
59	Huerfano River at Badito	37°43′	105°00′	519	July 27, 1936	12.8	5,000	------	9.6	Do.
60	Huerfano River near Undercliffe	38°02′	104°25′	1,702	July 28, 1936	11.4	26,600	------	16	Computed at diversion dam.
61	Huerfano River at mouth	38°14′	104°15′	(3)	Aug. 1, 1923	------	19,400	------	------	State engineer record slope-area measurement.
62	Apishapa River at mouth	38°08′	103°57′	------	Aug. 22, 1923	24.7	50,000	------	------	State engineer record, caused by failure of dam.
63	Purgatoire River at Trinidad	37°10′	104°30′	742	Sept. 30, 1904	15	45,400	------	61	Slope-area measurement.
64	Purgatoire River at Alfalfa	37°11′	104°07′	(3)	Aug. 7, 1927	------	19,100	3,780	------	State engineer record, slope-area measurement.
65	Purgatoire River at Ninemile Dam, near Hibbee, Colo.	37°45′	103°28′	(620)	Sept. 15, 1934	12.0	64,500	11,300	104	Do.
66a	Purgatoire River at Highland Dam, near Las Animas, Colo.	37°55′	103°18′	(620)	----do----	14.0	33,000	2,300	53	Do.
66b	----do----	37°55′	103°18′	3,320	Apr. 24, 1942	13.29	60,000	25,800	18	Do.
67	Purgatoire River near Las Animas	38°04′	103°10′	(3)	Aug. 7, 1929	------	52,800	23,000	------	Do.
68	Wolf Creek near Granada	38°03′	102°20′	(25)	July 11, 1935	18	14,000	------	560	Do.
69	Granada Creek near Granada	38°02′	102°15′	(35)	----do----	21	31,000	------	886	Do.
70	Two Butte Creek near Holly	38°02′	102°08′	900	Oct. 1908	------	35,000	------	39	Estimated from high-water cross section.
71	Wild Horse Creek near Holly	38°03′	102°07′	(100)	Aug. 28, 1935	13.7	22,000	------	220	State engineer record, slope-area measurement.

Rio Grande Basin

72	Rio Grande at Thirtymile Bridge	37°44′	107°16′	163	June 28, 1927	7.03	7,500	2,870	46	State engineer record, extension of rating curve.
73	Rio Grande at Wason	37°49′	106°53′	705	do	7.65	9,750	5,820	14	Do.
74	Rio Grande near Del Norte	37°41′	106°28′	1,320	Oct. 5, 1911	6.8	18,000	10,700	14	Extension of rating curve.
75	Rio Grande near Monte Vista	37°37′	106°09′	1,590	June 30, 1927	7.85	18,500	12,500	12	State engineer record, extension of rating
76	Rio Grande at Alamosa	37°29′	105°53′	[6] 1,710	July 1, 1927	8.37	14,000	10,600	8.2	Do.
77	Rio Grande near Lobatos	37°05′	105°45′	[6] 4,760	June 8, 1905		13,100	13,100	2.8	Extension of rating curve.
78	South Fork Rio Grande at mouth of South Fork.	37°40′	106°39′	216	Oct. 5, 1911	9.7	8,000		37	Do.
79	Alamosa Creek above Terrace Reservoir	37°23′	106°21′	107	do	11.0	5,200	4,250	49	J. E. Field computed flow at diversion dam.
80	Conejos River near Mogote	37°03′	106°11′	282	do	8.5	9,000		32	Extension of rating curve.

Colorado River Basin

81	Colorado River near Palisade	39°07′	108°34′	[2] 8,790	June 16, 1921	[7] 24.2	52,400	50,800	6.0	Extension of rating curve.
82	Colorado River near Fruita	39°09′	108°45′	[2] 7,100	July 4, 1884	18.5	125,000		7.3	Slope-area measurement.
83	Gunnison River near Grand Junction	39°02′	108°34′	8,020	July 2, 1884		50,000		6.2	Estimated.
84	Skyrocket Gulch at Ouray	38°01′	107°40′	1	July 20, 1923		2,000		2,000	Measured in Uncompahgre River.
85	Dolores River at Dolores	37°28′	108°30′	[8] 508	Oct. 5, 1911	10.2	10,000		19	Estimated.
86	West Creek near Gateway	38°46′	108°54′	[9] 23	July 16, 1940		11,700		509	Slope-area measurement.
87	San Juan River at Pagosa Springs	37°16′	107°01′	298	Oct. 5, 1911	17	25,000		84	Extension of rating curve.
88	San Juan River at Arboles	37°01′	107°24′	1,390	do	17	40,000	25,000	29	Estimated.
89	Animas River at Durango	37°17′	107°52′	692	do	13.6	25,000	11,000	36	State engineer record, extension of rating curve.
90	La Plata River at Colorado-New Mexico State line	37°00′	108°11′	(175)	Aug. 24, 1927	11.36	4,750	965	27	Do.

[1] Parentheses enclosing figures representing drainage area indicate that not all of the drainage area above the place of determination was affected by the storm, and that the figures enclosed represent only the part affected.
[2] Flood of 1935 was probably higher, but discharge was not determined.
[3] Area affected by storm unknown.
[4] Slope-area measurement based on slope of stream bed.
[5] For results of peak discharge of tributary streams above Pueblo during June 1921, see p. 113.
[6] Does not include closed basin, which has an area of 2,940 square miles.
[7] Low-water stage, 12.3 feet.
[8] Drainage area prior to 1912, about 524 square miles.
[9] Contributing drainage area only.

CHANGES IN CHANNEL CAPACITY AND DEVELOPMENT OF FLOOD-PROTECTION MEASURES

The history of floods in Colorado spans the years from the early days of the nineteenth century, when the only whites in the region were transient traders, trappers, and travelers, through the middle years of that century, when the early settlers arrived, to the present day. Although severe floods occurred prior to settlement, the evidence indicates that changes in the channels of at least some of the streams subject to floods have occurred since settlement began. The gradual development of city flood-protection measures, as experiences with floods have multiplied and meteorologic and hydrologic data have accumulated, can be easily traced.

Streams subject to severe floods are chiefly those on the eastern slope of the Rocky Mountains, those in the plains area east of the mountains, and those in the Rio Grande and San Juan Basins. When settlement began, great stretches of the plains area east of the mountains were covered with a natural growth of grasses indigenous to the region, and, although varying with the seasons, it is believed to have been fairly luxuriant. The stock-raising industry developed so rapidly in the region and spread over it so widely as to cause too close grazing of the grass cover in many places. Thus the protection the grass had afforded the soil from the violent rains and resulting floods was reduced materially. The intensive grazing may have tended also to pack the soil, and by thus augmenting the run-off, increased the flood discharge in some parts of the area.

In some places streams seem to be widening as the erosion of their banks progresses. When Trinidad was first settled, about 1860, the Purgatoire River was spanned by a footbridge about 30 feet long. Floods since that time have enlarged the channel until it is now about 250 feet wide. The width of Fountain Creek at the town of Fountain was about 40 feet in the nineties but has now increased to 200 feet. Cherry Creek within the present city limits of Denver has increased in width from bout 14 to 100 feet since the sixties. This process seems to be continuing, and some floods so erode the unprotected banks of the streams that it is necessary to lengthen the bridges spanning them.

This tendency of streams to widen, at least locally, suggests erosion accelerated by some process incident to settlement of the region by white people, but the extent to which it may be evidence of greater flood flows has not been demonstrated.

In some places, particularly in the South Platte and Arkansas River Basins, the reduction of channel capacity has been incident to the development of irrigation. The many diversions for irrigation have reduced the river flow to a mere trickle except during the period

of melting snow, and even then the flow is only a small fraction of what it was before diversions for irrigation were made. This reduction in flow has resulted in a gradual choking of the channels by sediment and vegetation, until eventually their capacity has become so small that when floods occur the overflow for a given flood discharge is greater than formerly.

The development of flood-protection measures was of slow growth and passed through four stages: (1) Removal of buildings to higher ground, (2) improvement of river-channel capacity with no clear idea of the capacity required, (3) increase of channel capacity to equal the measured peak flow of the most recent flood, and (4) construction of storage or detention reservoirs to protect against the greatest probable floods. A brief discussion of these stages, in chronologic order, follows.

(1) The first settlements were made along the streams, usually close to the banks, and encroached on the channels of seemingly harmless streams. The outstanding example of such encroachment was in Denver. There Cherry Creek appeared to be such an inoffensive stream that some of the buildings, by a sort of gentlemen's agreement among property owners as to a reasonable width of channel, encroached so far on the natural channel that they were supported by stilts in the channel itself. The flood of 1864, which was the first after settlement took place, showed the folly of such procedure and destroyed many of the encroaching buildings. When rebuilt they were placed outside the natural channel. Beyond that, little was done to improve the channels. In Pueblo, similarly, buildings erected as late as the eighties intruded in the natural river channel. Fort Lyon was originally located on low ground close to the Arkansas River, but after the flood of May 1867 it was relocated 17 miles westward on higher ground.

(2) As the various settlements grew, and later floods caused overflow and resulting damage to them, steps were taken to increase the channel capacity, chiefly by raising the bridges or reducing the obstruction of the channel cross section caused by the bridges. But this remedy was haphazard, as the volume of the floods was neither measured nor estimated, and without such information it was not possible to know how much the channels should be widened or deepened in order to carry the probable volume without overflow.

(3) The second stage in channel improvement, and the third in flood protection, consisted in measurement of the peak flow of each outstanding flood as it occurred and the subsequent enlargement of the channel, if necessary, on the basis of this measured peak, to carry future floods of as large volume. In Pueblo, where the peak flow of the flood in 1894 was 39,000 second-feet, the channel through the

city was increased to 40,000 second-feet. In Denver, where the Cherry Creek flood of 1912 had a peak of about 11,000 second-feet, the channel capacity was increased from 6,000 to 10,000 second-feet; in Colorado Springs, after the peak flow of 50,000 second-feet on Monument Creek in 1935, the channel capacity was increased from 10,000 to 50,000 second-feet.

(4) As the cities grew and were able to finance flood-protection measures, they planned not merely for the greatest flood that had occurred since settlement, but for the greatest probable flood as determined from accumulated meteorologic and hydrologic data. Pueblo was the first city to take such action. The peak flow of 103,000 second-feet during the Arkansas River flood of 1921 was two and a half times that of the flood of 1894. Mindful of the inadequate protection provided after the 1894 flood, provision was made by Pueblo for protection against a flood of 175,000 second-feet. The Cherry Creek flood of 1933 had a peak flow of 15,000 second-feet in Denver, and although this was due chiefly to the failure of Castlewood Dam, the city soon afterward constructed a detention reservoir designed to reduce a peak flow of 70,000 second-feet to 10,000 second-feet, the channel capacity of the creek in Denver.

Improvement in flood protection by increasing channel capacities has been confined almost entirely to the cities, and little work toward adequate protection has been done elsewhere.

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