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FOREST AND STREAM-FLOW EXPERIMENT AT WAGON WHEEL GAP, COLO.

FINAL REPORT, ON COMPLETION OF THE SECOND PHASE OF THE EXPERIMENT

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By C. G. Bates, *Silviculturist, Forest Service*, and A. J. Henry, *Meteorologist, Weather Bureau*

CHAPTER I. HISTORY AND DESCRIPTION OF THE PROJECT

INTRODUCTION

Foresters generally, and nearly all others familiar with the conditions in mountainous regions, believe strongly in the protective value of forests, first, as binding the soil, covering it with humus and litter, and preventing its erosion; and, secondly, as exerting a modifying effect upon the flow of streams. The latter assumption is based primarily upon the obvious fact that the covering of spongy material upon the floor of the forest must prevent the rapid run-off of any normal rainfall, mainly by the absorption of a considerable portion of the water. Of this a certain amount is thus allowed to percolate into the deeper soil where through the medium of underground springs it maintains the even flow of streams. The retardation of snow melting in the western mountains of the United States is another service that forests are believed to perform in the regulation of streamflow and the protection of watersheds, and one which no other form of vegetation could accomplish as well. Thus, in a number of ways, it has been assumed that forests reduce the magnitude of ordinary seasonal floods, tend to maintain stream flow in dry weather, and, perhaps most important of all, prevent erosion of the land which they occupy or adjoin, and thereby reduce the amount of silt carried by streams, and lessen the damage done by flood waters to fertile fields.

The present paper does not attempt to prove or disprove these assumptions, but simply to state them as beliefs which require experimental proof. Present-day needs call for experimental proof of every belief and where great economic values are involved—for quantitative determinations. It is not enough to know *whether* forests influence stream flow; it is necessary to know how much, at what seasons, and under what conditions of climate, soil, and topography, and the variations between different kinds of forest, as well.

At the time of beginning the Wagon Wheel Gap project only one other serious attempt was being made to measure the influence of forests upon stream flow, precisely, and over a long period. The results of this study, comprising 15 years of observation near Emmental, Switzerland, became available in 1919 in an exhaustive report by Dr. Engler.[1] This is perhaps the most authoritative statement on the subject ever published. Yet even here the results are largely qualitative, and the conclusions open to some question, for the simple reason that experimental conditions were not fully attained by first establishing stream flow relationships under similar conditions of cover. The two watersheds on which Engler's work was based, one 97 per cent forested and the other 35 per cent forested—the remainder being in pasture, meadow, and field—were taken in their natural conditions, and comparisons of stream flow have been made only under these conditions.

There is some suggestion that the nonforested character of the one watershed may have been due in part to shallow soil and numerous rock outcrops not favorable to trees, as well as to the treatment it had received. Moreover, up to 1919, no effort was made to measure stream flow during three or four months of the winter, the total amounts of discharge being, therefore, left in doubt in this Swiss study.

The Forest Service began in 1909, with the selection of a site on the Rio Grande National Forest, near Wagon Wheel Gap, Colo., what was to be a very complete study of the effects of forest cover on stream flow and erosion under the conditions of the central Rocky Mountains. The plan, broadly stated, was to use two contiguous watersheds,[2] similar in topography and forest cover; to observe carefully for a term of years meteorological conditions and stream flow under these similar conditions of forest cover; then to denude one of the watersheds of its timber and to continue the measurements as before, until the effects of the forest destruction upon the time and amount of stream flow, the amount of the erosion, and the quantity of silt carried by the streams had been determined. This plan had been executed, and the experiment was terminated by mutual agreement on October 1, 1926.

Because the plan of study contemplated by the Forest Service called for the services of men skilled in meteorological observations as well as the use of considerable instrumental equipment, the cooperation of the Weather Bureau was solicited and, on approval of the Secretary of Agriculture, the two services began on June 1, 1910, the active work of getting material and equipment on the ground. The building of cabins for living and office quarters, the installation of the meteorological instruments, and the construction of two dams occupied the time up to October 22, 1910, when the first meteorological observations were made. Rectangular weirs installed in the beginning did not prove satisfactory and it was not until the following July that satisfactory triangular weirs were installed.

By June 30, 1919, when eight years' continuous streamflow measurements and nearly nine years' meteorological observations has been obtained, it was concluded that the

[1] Engler, Arnold. Experiments Showing the Effect of Forests on the Height of Streams. Mittellungen der Schweizerischen Centralaustalt fur das Forstliche Versuchswesen. XII, 1919, Zurich.

[2] Throughout this discussion, and in all of the records the convenient and perhaps more popular word "watershed" is used to denote a drainage basin.

first stage of the experiment had been adequately developed; it was therefore agreed that one of the watersheds (B) should be denuded at once, except that a strip of timber not to exceed 25 feet in width should be left on each side of the stream for a single season, or until the autumn of 1920. This program was carried out as planned, beginning in July, 1919. The larger timber was taken out and the loppings and most of the aspen were piled in windrows and a year later were burned. The other watershed (A) was left untouched during the remainder of the experiment.

Since the denuding operations were distributed over several months and not completed until 1920, denudation may be considered effective as of October 1, 1919. This is the most convenient time for dividing the records by 12-month periods, although it will be recognized that the full effects of denudation could not be felt during the year 1919–20.

Since denuding the one watershed, the records have been continued in the same manner for seven full years, or until October 1, 1926. Thus there are available for comparison of stream flow and contributing factors the records of more than eight years before denuding and of seven years after denuding, which are comparable in every respect except as to the forest cover affecting the one watershed, and except of course, as successive years vary in their climatic conditions.

OBJECT OF THIS REPORT

The attempt is made in this report to present the data accumulated in 15 years of study in the simplest possible form for the comparison of the two periods, the first comprising the 8 years before watershed B was denuded and the second the 7 years subsequent. First the conditions under which the experiment was performed, the methods of measurement, etc., will be stated. Next follow the climatological records. In the third section the stream-flow records are presented and discussed.

In a report [3] made at the close of the first eight years of the experiment, certain analyses of the stream-flow data were made which were expected to assist in predicting what the most probable flow of stream B ought to have been, in the postdenudation years, had the effects of denudation not been felt. These analyses, while interesting, are found to have too flimsy a basis to be mathematically sound. Furthermore, since the postdenudation period was climatologically very similar to the first eight years, these analyses as a whole add little to the direct comparisons of the records of the two periods of the experiment. They have therefore been dropped from the present report, except as they may occasionally be used to suggest the origin of the excess stream flow recorded after denudation.

The present report thus brings forward all of the pertinent data from the first years of the experiment and makes reference to the preliminary report unnecessary.

DESCRIPTION OF THE AREAS

In deciding upon an area for the experiment, the following were the major guiding considerations, their relative importance being indicated by the order in which they are named:

1. That the two watersheds to be studied should be contiguous, or practically so, in order that differences in the amount and time of precipitation reaching them should be as small as possible.

2. That the two watersheds should be on the same geological structure, should have similar altitudinal limits, and, as regards general conformation, general aspect, and steepness of gradients, should be as nearly alike as possible.

3. That the area of each watershed should not be so large as to introduce serious complications in the attempt to relate the stream discharges at the lower extremities to precipitation and other phenomena observed on the areas.

4. That the forest conditions should represent a fair average for the forests of the Rocky Mountain region, rather than the ideal or optimum. To meet this requirement it seemed essential, first, that the forest should be that of a middle elevation, and secondly, that it should not entirely have escaped injury by fires in the past.

The two areas finally selected as meeting the above requirements with a minimum of compromise are shown in Figure 1. Their areas and dimensions are given in Table 1. The general plan of the survey was to start at the dam sites, tracing a line up either slope until the ridge was reached which divides one watershed from its neighbors; then to follow this lateral ridge to the head of the drainage basin. In the present case the distance, azimuth, and vertical angle of each course was recorded so that the basic data for a contour, as well as an area map, were secured. The boundary traces were supplemented by traverses through the center of each watershed, following the course of the stream.

TABLE 1.—*Geographical data of watersheds A and B*

Datum	Watershed A	Watershed B
Total area ... acres	222.5	[1] 200.4
Extreme length ... feet	7,300	4,600
Computed mean width ... do	1,328	1,898
Absolute elevations:		
Lowest ... do	9,373	9,245
Highest ... do	11,355	10,952

[1] For some reason, not exactly known to the authors, but probably associated with the vagueness of the boundaries of watershed B at several points, the figure 200.4 has been used in all calculations in preference to 200.47 acres shown by fig. 26. This discrepancy is wholly immaterial in consideration of the fact that the first boundary survey gave B an area of 212 acres. From this it will be apparent that the possible error in placing the boundaries may account for the difference in mean annual flow of A and B before denudation.

TOPOGRAPHY

The greater area of A as compared with B, as above indicated, is of no appreciable import. That which is of importance, in so far as it complicates the relationship of the discharges of the two streams for any short period, is the fact that watershed A is considerably longer and narrower than B and includes a small area extending to an elevation about 400 feet higher than any part of B. In the discharge of any single supply of water (such as the fall of a single rain or a single period of snow melting), watershed A might be compared to a narrow trough and watershed B to a fan-shaped collector. The relatively short slopes of A enable it to deliver the first bulk of a water supply in a relatively short time, and this quick delivery is usually evident in a sharp and high flood crest; but because of its length A may continue to deliver water to the dams for a long time. By comparison, B delivers its water to the dam after a longer interval, but more largely in one mass, and completes its discharge sooner. Were the effects of a single storm under consideration the relationship above set forth might not be difficult to express by a concise formula. But, since

[3] Bates, C. G., and Henry, A. J. Stream-flow Experiment at Wagon Wheel Gap, Colo. Preliminary Report on Termination of First Stage of Experiment. Monthly Weather Review Supplement No. 17, Washington, 1922.

stream flow is necessarily built up from water contributions extending over many months, it becomes apparent that the watershed differences have introduced a maze of relationships to which exact expression can not be given. The great difficulties of this situation, of course, could not be foreseen when the watersheds were chosen, nor is it at all certain they could have been avoided, as nature has nowhere been so kind as to form two objects exactly alike.

Of some slight importance, as it affects snow melting, is the fact that the main axis of watershed A is almost directly east-west, while that of B is more nearly northeast-southwest. In consequence, the north half or southerly exposure of A contains considerable areas which face squarely the mid-day sun, while on B the corresponding position is very largely an east slope, except for a very small area at the lower end of the watershed. After a very careful survey of the several snow-scale areas, Keplinger (April 1, 1913) computed the mean gradient of watershed A to be 25 per cent and of B 26 per cent; but the mean aspect of all the slopes on A is S. 85° E., while on B it is N. 68° E., a difference of 27°.

GEOLOGICAL FORMATION

As has been stated, one of the first considerations was that the two areas studied should have similar geological origin, not only because the character of the rock defines the physical character, permeability, and retentiveness of the soil, but also because the rock in situ has the greatest influence on underground water and on the possibility of complete measurement of the water discharged from the areas.

The geological examination of these watersheds, made by E. S. Larsen, of the Geological Survey, in June, 1910, was entirely reassuring, both as to the uniformity of the structure on the two areas and the probabilities of a structure at the proposed dam sites which insures a good foundation for the dams and the loss of none of the water which flows away from the areas.

Mr. Larsen's opinion regarding two questions which had given some concern are of especial interest here.[4]

I believe that the geology of the areas covered by the four[5] basins is very favorable for the experiments. It is unusual to find four areas with so great a difference in elevation, yet so uniform geologically, and with so little variety of structure in the rocks. So far as I can judge, the basins are all exceptionally favorable for the minimum loss or gain of water from the underground drainage, and there is nothing to indicate an exceptional loss or gain for any of the basins.

Hot spots.—The so-called hot spots on the east side of the slope of basin A were recognized by Mr. H. A. Jones, of the Weather Bureau, who is located at the station, from the fact that the snow melted more rapidly along them. They appear to be on a line nearly parallel to the creek and about 50 feet in elevation along it and extend from the north (northeast) boundary of the area for about a hundred yards to the south (southwest).

Bedrock is not exposed near them, but the talus indicated some alteration of the rock, such as is commonly found associated with mineral deposits. A small cut exposes rock which has crept down the hill somewhat, but which is nearly in place. There is a little red hematite coating the fragments and some travertine-like materials. The rock is kaolinized and has some hematite deposited in it. There is no evidence of water, steam, or other gas coming up here.

I have no entirely satisfactory explanation of this, but three possible ones occur to me:

1. The oxidation of stringers of pyrite or other sulphides may generate enough heat to slowly melt the snow over a series of veinlets.

2. There may be fractures along which warm water or gas is escaping.

3. Fractures in the rock may control the circulation of underground air currents.

If the first is true, and the hematite indicates this, there is probably a strip of more or less fractured rock present and the water will tend to drain into this strip and along it to a lower level on the hill. This would tend to steal some water from the drainage area, as the fracture crosses the lower boundary of the area on a rather steep and continuous slope.

If the second explanation is true and a considerable amount of the water is being introduced into the drainage area, some evidence of this should be recognized. If the hot water escapes at a lower level on the slopes, that is, below the drainage area, and the melting of the snow is due to gases escaping through fractures, the conditions are similar to those discussed in the first explanation and there would be a loss of water.

Explanation 3 would also cause a loss of water much as would 1.

Warm springs.—The large spring which empties into basin B from the west (north) and which has a mean temperature several degrees in excess of the mean annual air temperature has all the appearances of a normal spring. The presence of hot springs only a mile or so away immediately suggests a deep source for at least a part of the water of this warm spring. However, I should not expect such water on these steep slopes, as valleys nearly a thousand feet below are present on three sides only a short distance away. A comparison of the composition of the water from the spring with that from the creek would probably show whether or not any ascending hot water mingled with the surface drainage water.

To this report the following facts should be added:

1. At the site chosen for a dam on watershed B rock in situ was found beneath only 4 to 6 feet of talus and stream deposits. This rock was only slightly fissured, and the fissures were in no case open, but well filled with clay, so that there was no question as to the practical impermeability and complete solidity of the dam foundation.

2. At the site chosen for a dam on A, rock in situ was found on the north bank of the stream, as expected, but not on the south bank. Apparently the present channel of stream A is a considerable distance above and to the north of the notch cut in the bedrock in primary erosion. This is due, no doubt, to a landslip from the slope to the south, which now has the appearance of a second bench, about 30 feet above the stream bed. By great good fortune, however, at about the depth where bedrock for Dam A was expected, a ridge of clayey material parallels the stream, apparently a stream deposit in the loose structure of the landslide. Although not entirely impervious, this dike afforded the only possible foundation. The main cross-channel wall of the dam was built somewhat beyond the clay ridge into the loose material of the landslip and a wing wall was run on the crest of the clay dike to a point upstream where its elevation was that of the top of the dam. (See fig. 16.)

That all of the run-off of watersheds A and B was successfully trapped at the dams as constructed seems amply assured by the fact that the ratio of run-off to precipitation for the two areas was practically identical over a long period. While it would be possible to have leakage at both dams, and in the same amount, such a coincidence is certainly improbable.

SOIL

The augite-quartz-latite described by Larsen as comprising the entire foundation of the two watersheds breaks down, by reason of its fine crystalline structure, into a rather fine and compact clayey loam. Because of the steepness of most of the watershed slopes, however, this quality is only partially developed; that is, steady sheet erosion prevents the accumulation of deep masses of soil and causes rock fragments to comprise a very considerable proportion of the mass, sometimes as much as 50 per cent of the first 4 feet of soil. In addition, erosion and leaching tend always to rid the soil of clay and silt, while leaving the coarser sand. The result on all the steeper slopes is a quite permeable and well-drained soil

[4] The reader interested in the petrography of these areas may find his complete later report in Monthly Weather Review Supplement No. 17, 1922, or may obtain the same by application to the U. S. Weather Bureau.

[5] Reference is here being made to two watersheds lying above A and B, in addition to these with which we are directly concerned. The proposed study of those two areas was not executed.

layer, the depth of which has never been directly investigated on the main slopes.

The figures in Table 2 represent fairly well the nature of the soil derived from the quartz-latite, except for station A–1, where the soil was taken from a pocket nearly devoid of rock fragments. By way of contrast, the soil of a bench immediately below watershed A, representing the transport from the slopes of the watershed, contains only 2.1 per cent rocks, 7.1 per cent fine sand, and 80 per cent very fine sand, silt, and clay.

It should be evident from the rocky character of the soil of the watershed, and still more from the layer of rock fragments covering its surface, that the soil is permeable and receptive to water—a fact of the utmost importance when considering the results of this experiment and their application under other conditions. (See fig. 41.) Whether this ability to absorb water is the primary factor explaining the steady flow of the streams (it is evident from certain calculations that the watersheds can not drain dry in less than 6 or possibly 12 months), or

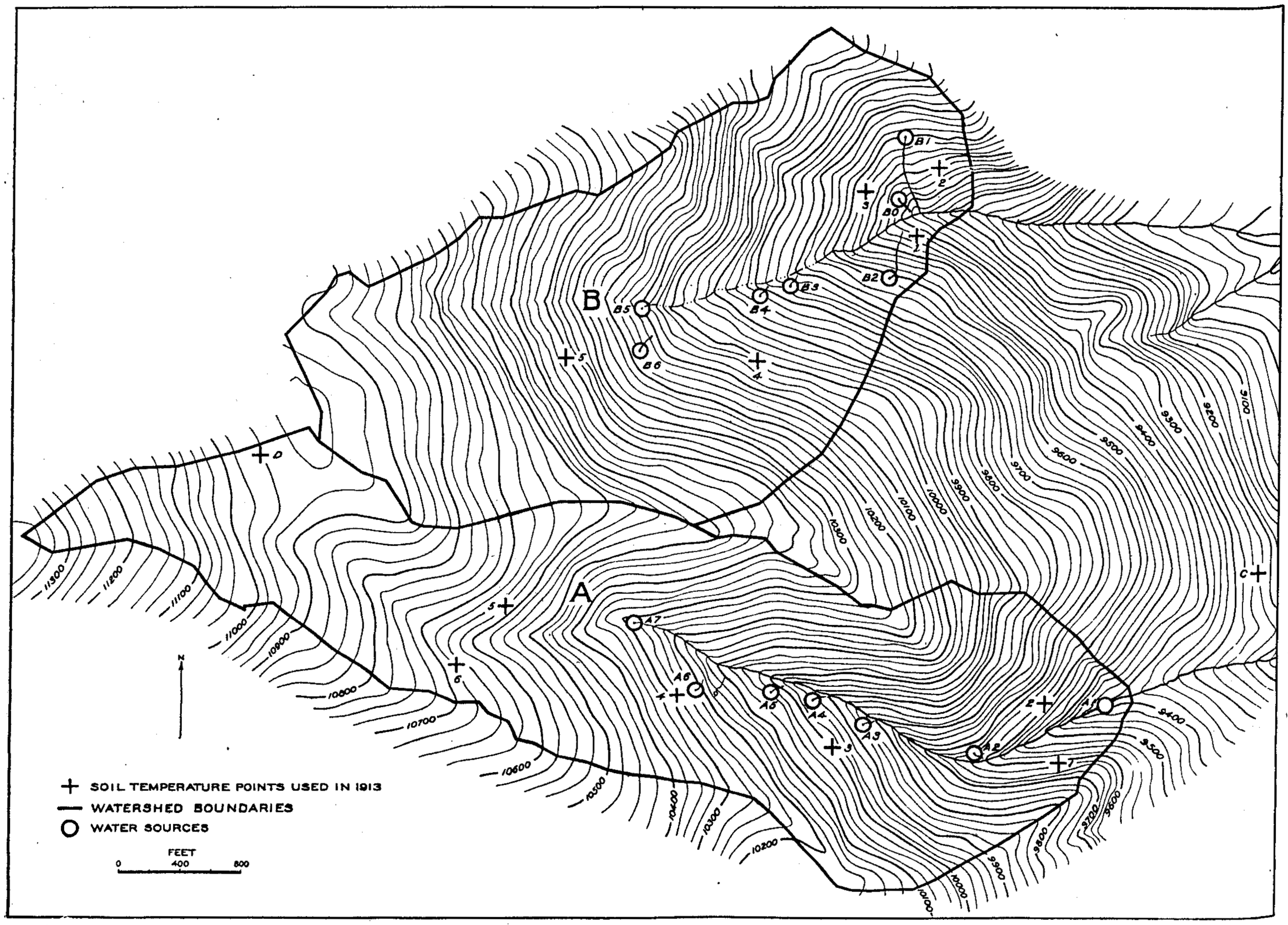


FIG. 1. Topography, water sources, and special temperature stations, Wagon Wheel Gap, watersheds A and B

TABLE 2.—*Soil composition of bench and slopes*

Class of material	Station D			A–1		A–2	
	1 foot	2 feet	3 feet	1 foot	4 feet	1 foot	4 feet
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Rocks larger than peas	14.2	47.4	34.5	11.4	10.6	30.8	26.7
Coarse gravel	8.0	2.6	1.7	11.2	21.5	17.8	29.0
Fine gravel	6.8	1.4	3.2	9.6	17.6	7.0	10.4
Coarse sand	11.0	7.5	9.9	19.6	18.6	8.8	8.6
Medium sand	6.6	6.0	7.0	10.7	7.9	5.1	3.7
Fine sand	5.4	4.8	5.9	7.4	5.1	4.0	2.7
Very fine sand	11.7	8.4	10.8	8.1	6.3	7.1	5.1
Silt	29.3	16.8	22.2	14.5	7.8	15.6	9.4
Clay	7.0	5.1	4.8	7.5	4.6	3.8	4.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

whether the rather remarkable water-holding capacity of the slopes denotes a soil of more retentive character next to the bedrock and in its crevices is perhaps unimportant. It is highly probable, however, that clay in crevices causes a very slow draining out of the water which penetrates most deeply. Such a condition was observed where the dams were constructed.

WATER SOURCES OF THE STREAMS

The principal springs which feed the two streams have been indicated in Figure 1, as well as some special observation points which were used in a study of these water sources in 1923. The latter should not be confused with the regular meteorological stations and snow-scale locations which are shown in Figure 26. It will be seen that stream A first appears about 3,500 feet from the dam, and is fed along its course by some half dozen springs, only two of which make their first appearance at any appreciable distance from the main channel, and one of these appears very insignificant.

Stream B has a total length of only about 2,300 feet, and in this distance becomes submerged several times in the detritus of the main gully.

Kadel and Grove, in 1912, measured the exposed areas of both streams, including water-soaked ground along their margins, and obtained figures of 4,039 square feet for A and 1,600 square feet for B.

Stream B, like A, has several springs along its course. One, near the head, appears at least 500 feet from the channel, soaks into the ground, and comes out again as channel seepage. Another, near station B–1, appears still higher on the northerly slope. The really striking difference between the two watersheds, however, is in the existence of the large permanent spring shown as B–1 and the temporary spring B–0. Both rise from ground with a decided southerly exposure, but probably have their origin at distant and much higher points, with a general easterly aspect.

The warmth of the spring B–1, which is mentioned in the geological report that has been quoted, has excited so much comment and apprehension that its was thought best to obtain, in the summer of 1913, some data on its actual temperature, the temperature of the ground in its vicinity, and comparable data for the other water sources. Points were very carefully chosen to represent the ground drained by the several springs. Thermometers were placed at a depth of 1 foot at each of these points. At a few of the points additional thermometers at 4 feet gave the temperature gradient in the soil. The temperatures of the springs were likewise measured. Observations were made every few days, at different hours, so that the average temperatures obtained took care of the diurnal fluctuations. These observations were necessarily subordinate to the other work, were irregular in interval, and were not entirely synchronous for all of the points. The following points are, however, noteworthy:

1. The 1-foot soil temperatures of the two watersheds were very similar if we consider only the northeasterly aspects. On watershed B, however, since the principal water sources are in ground with an easterly or somewhat southerly aspect, the mean temperature of all the contributing ground was about 2° higher than on A.

2. In spite of this warmer soil for B (as a whole), the mean temperature of all the springs on B was 0.6° less than that of the springs on A at midsummer.

3. When it is considered that the reverse was true in winter—that stream B was warmer than A, as shown by ice formations at the dams—the conclusion is unavoidable that the water sources of B are deeper than those of A.

4. Applying the mean difference of 7° F. between 1-foot and 4-foot temperatures for the summer period, it may be calculated from the summer spring temperatures that the soil reservoir of A has a mean depth of about 4.8 feet and that of B about 5.8 feet. Actually, of course, both may be deeper, as the spring water can hardly fail to be warmed somewhat as it approaches the surface. This does not, however, imply that the corresponding steep slopes of the two watersheds are essentially different as regards soil cover. The difference probably consists in a greater accumulation of soil near the stream channel, in the bowllike basin of watershed B.

5. Considering the several water sources independently, rather consistent depths are indicated. The two south-slope springs on B (B–0 and B–1) would appear to have deeper sources than the others, but only a depth of 6.5 feet is indicated by the temperature conditions in July.

It has been contended, by those inclined to view with alarm the existence of the warm spring (B–1), that, since the mean annual air temperature on these watersheds is only 34° F., water which shows a temperature of nearly 45° F. in midwinter must be arising from a source so deep as to be unaffected by local conditions, or else must be obtaining heat through some chemical reaction. The idea of chemical reaction has little weight in view of the very slight evidence of deposits on the ground over which the water trickles for several hundred feet, and the fact that the water is not in the least inimical to plant growth.

Although, as stated by Moore,[6] it is altogether probable that at a considerable depth (say, 50 feet) the ground temperature is constant and approximately equal to the annual mean temperature at the surface, still there is no basis for the assumption that the surface temperature must be the mean *air* temperature of the locality. A mean air temperature of 34.4° F. is recorded at the north-slope station, B–1. The mean 1-foot soil temperature at that point is 35.5° F. and the 4-foot soil temperature 35.1° F. (Tables 20 and 22.) On the other hand, although the air temperatures recorded for a year or more at the south-slope station B–2 were only about 2° in excess of those at B–1, the 1-foot soil temperature is 41.8° F. and the 4-foot 42.6° F. There is no reason for supposing that a lower mean temperature is found at greater depths, but every reason for supposing that at a depth of possibly 20 feet the soil temperature on this slope is approximately 42° the year around. If only the period covered by Table 3 be taken, the average soil temperature will be approximately 44°. (Table 26.)

Beginning with January, 1921, weekly observations of the temperature of the warm spring on B were made until June 30, 1925. The mean results are given in Table 3.

TABLE 3.—*Mean temperature of air and water of warm spring on B watershed, based on weekly observations, January, 1921, to June 30, 1925*

Month	Water temperature	Air temperature	Month	Water temperature	Air temperature
	°*F.*	°*F.*		°*F.*	°*F.*
January	44.5	14.1	August	45.8	52.7
February	44.7	18.3	September	45.7	46.4
March	44.8	23.7	October	45.4	36.0
April	44.8	32.3	November	45.0	24.4
May	45.1	42.4	December	44.7	15.6
June	45.4	51.9			
July	45.6	55.0	Annual	45.1	34.4

The east slope above this spring retains its snow well, was originally well forested, and is of sufficient area to supply considerable water. (See figs. 11 and 12.) It is, therefore, the final conclusion that both B–0 and B–1 represent the drainage from this extensive area. Either may represent water from the higher portion of the watershed, and this may be transported at a considerable depth, where, in view of the existence of hot springs in the locality, the possibility of slight chemical warming is not remote. This is the logical explanation of the constand lag in stream B and its carrying-over of water from wet to dry periods and years. The important point

[6] Moore, Willis L., "Descriptive Meteorology." New York, 1910.

is not that a portion of the water of this spring might originate outside the boundaries of the surface watershed, but that the existence of such a slow-traveling stream as this apparently is exercises at all times a steadying influence on the whole discharge.

That the north half of watershed A contributed through no springs of noticeable size is plainly due to the rapid melting and evaporation of snow in the winter, because of the more southerly exposure of this ground as compared with any part of B.

6. Comparison of the average spring temperatures with those of the streams as they approach the measuring dams shows that in summer the water of each stream is warmed about 3.8° during its passage down the channel. This is after making allowance for the fact that the 9 a. m. temperatures at Dam A were nearly a degree lower than the mean of maxima and minima, while at B the water has attained nearly its mean at 9 a. m. In spite of the fact that the exposed area of stream B is much less than that of A, the water is warmed as much. This is probably because the volume traveling the main channel is slightly less, and all but two of the springs of B watershed flow over the ground for considerable distances before reaching the main channel. In view of these facts we should expect just as much loss by evaporation during the day on stream B, but possibly would note the loss at a later hour because of the impeded flow. The delay may run so far into the night as really to obscure the amount of the evaporation current during the day.

DESCRIPTION OF THE FOREST

The forest of the two watersheds is a light, open one fairly typical of the middle zone of the central Rocky Mountains and is characterized by Douglas fir (*Pseudotsuga taxifolia*) as the permanent type.

However, nearly all of both watersheds was burned over about 1885, making much of the cover, at the time of this study, of a temporary and also immature type. A good deal of the Douglas fir on south exposures, as well as the scattered trees of bristlecone pine (*Pinus aristata*) escaped destruction, although probably thinned to some extent. Much more serious was the complete destruction of the stands of Douglas fir and Engelmann spruce (*Picea engelmanni*) on the north exposures and at the head of the watersheds, except for a few small areas. Thus, as shown in Table 4, only about 30 per cent of watershed A escaped with its virgin forest essentially intact, while on watershed B all but 23 per cent of the forest had to be renewed. For the sake of the reader who is entirely unfamiliar with Rocky Mountain conditions it should be pointed out that, as is usually the case, the areas thus denuded by fire probably developed cover of aspen (*Populus tremuloides*) almost immediately, while seedlings of the evergreen trees began to appear under the aspen after a greater or less interval. Hence the different stages of development indicated in Table 4 by "aspen" and "aspen with conifers."

The grass-covered areas are mostly on the south exposures of both watersheds and represent either ground on which conifers stood, but which is too dry for aspen, or ground which because of soil and exposure never has borne tree growth. The grass is of sparse growth, usually in bunches, and rarely more than a foot in height. The large amount of exposed rock precludes a continuous sod, even though moisture conditions were favorable.

A portion of the area of burned spruce at the head of both watersheds which has not restocked with aspen or conifers is also to be described as grass land. Here, however, soil and moisture conditions are favorable and the tendency is to produce a thick matted growth of grass and herbs, not very tall, but thoroughly binding the soil.

The aspen stands, which occupied 49 per cent of the A area and 61 per cent of B, vary greatly in size and density of stocking. On some of the south exposures bordering the grass areas just described the aspen had not, during the life of this experiment—that is, at an age of, say, 30 years—attained a height of more than 8 to 10 feet nor diameters of more than 2 or 3 inches. (See fig. 5.) The low spreading tops, however, tended to produce a fairly complete cover when the trees were in leaf, even though the stems were not close together. From this condition, passing through the more easterly exposures (fig. 11) and to those of northerly aspect where more moisture is retained, one might find all grades and densities of aspen up to stands with straight clean stems 30 to 40 feet in height and 6 to 7 inches in diameter. Some of these grew densely crowded together. The good stands of aspen were, however, confined to the banks of the streams and to the wet ground near springs. The few small patches of aspen on the spruce burn at the head of watershed A were moderately well developed for this locality.

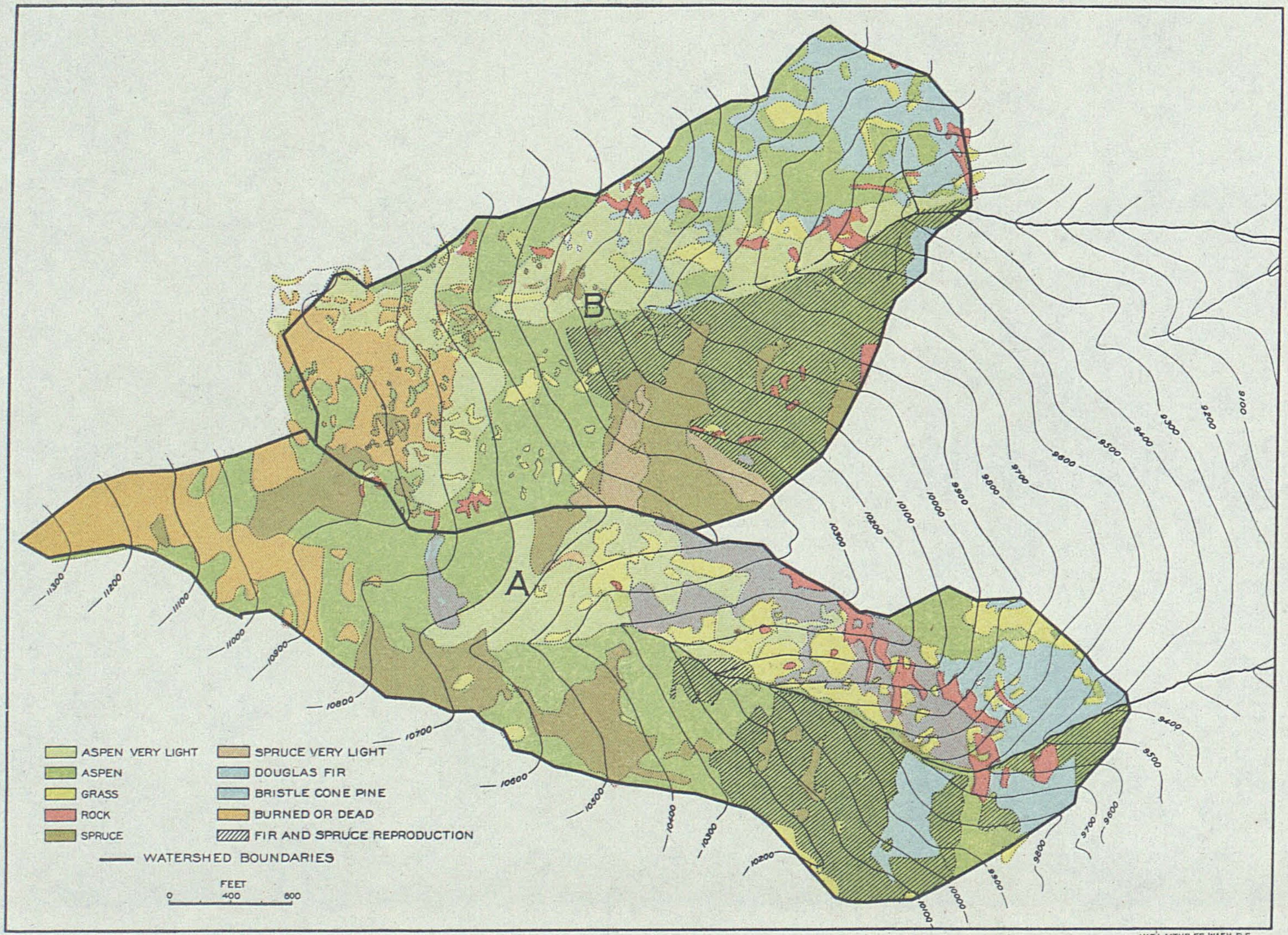
The Douglas fir on south exposures comprised a very open stand of short, stocky trees, as clearly illustrated in Figures 3 and 4. Heights rarely exceeded 40 feet, although diameters up to 20 inches might be encountered. At the best the crowns probably did not occupy more than one-third of the available space.

The above description is essentially correct also for the bristlecone pine stands, except that, as they occupied the very rocky areas near the tops of the south exposures, they were even more open than the Douglas fir stands and the trees were shorter. There were only occasional trees of this species on watershed B.

The north-slope Douglas fir as exemplified in the stands surrounding stations A–1 and B–1 (see figs. 7 and 8) was taller, straighter, and denser than that on south slopes, but nevertheless not to be called timber of good quality in comparison with other regions. The maximum height attained by any of the trees was probably about 70 feet. However, in this study there is less concern for the commercial value of the timber than for the fact that on these restricted north-slope areas portions of the stand were about as dense as possible, with, however, small openings where the ground was especially rocky.

At the higher elevations on the north slopes a few patches of Engelmann spruce remained. (See fig. 5.) These, however, were not stands of old, well-developed timber but were irregular and more or less mixed with aspen, probably as a result of being partially opened by the fire of 1885. As has been intimated, the best spruce site was undoubtedly that comparatively flat ground near the head of watershed A. Here the fire-killed trees give evidence of an approach to the optimum for this species—which means heights around 100 feet and diameters up to 30 inches—but much of this most productive area has not restocked at all.

On the lower north slopes where some Douglas fir was left for seeding, seedlings of this species, and to a less extent of spruce, must have started almost as soon as the aspen sprouts, for even as early as 1910 the small evergreens were beginning to over-top the aspen, that is, were reaching heights of 20 feet and more. (See fig. 7.) Properly speaking, this coniferous reproduction graded downward in going from east to west and from lower to higher elevations. Both the number and size of the seedlings



TYPES OF COVER, WAGON WHEEL GAP
WATERSHEDS "A" AND "B"

FIG. 2. Map of forest cover of the watersheds

decreased. Therefore, the lines between aspen with conifers and aspen without conifers are somewhat arbitrary, the latter merely denoting, for the north exposures, that the conifers were too small and infrequent to play any important cover part as compared with the aspen. The aspen stands on southerly exposures were practically devoid of evergreen seedlings.

Although aspen stands shade the ground during the summer, they can have but little effect on snow melting,

FIG. 3. Rather large Douglas fir surrounding thermometer shelter at station A-2

and their greatest value, from the standpoints of both forestry and water relations, probably lies in their soil-building power. The leaves from aspen break down more readily, mix with the mineral soil, and tend to form a spongy surface cover more fully than do the needles of conifers. Thus, even under a very sparse stand of aspen such as occurred on the south exposures, one would find what might properly be called a "leaf mulch." This is in decided contrast to the areas occupied by Douglas fir and bristlecone pine, where the mineral soil and rock frag-

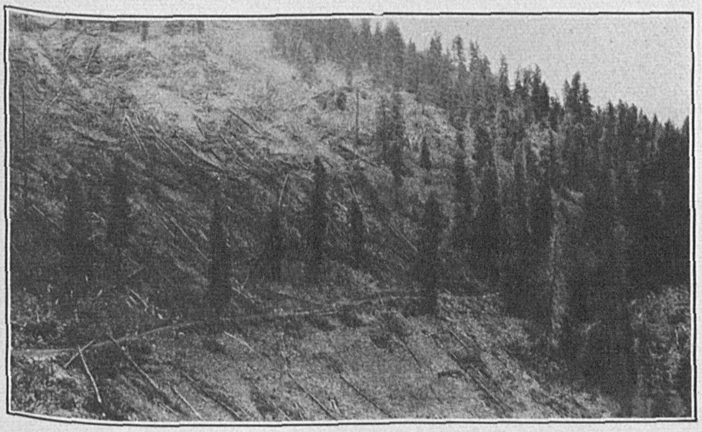


FIG. 4. South exposure near station B-2 before completion of denudation

ments were for the most part exposed, except possibly in pockets. It is thus apparent that while the overhead cover of these watersheds had only begun to develop in the direction of even that sparse standard which is typical of the Rocky Mountains, the conditions for the reception of water into the soil were on quite a different basis, both because of the loose character of the soil and the beneficial effect of the aspen growth.

The rock slides which comprised about 3 per cent of the area of both watersheds were, of course, practically devoid of cover, although occasional trees grew among them. They are of interest, not primarily because they might show greater ability than the other land surface to absorb water which fell upon them, but because of their probable ability to conduct water very quickly from their upper portions to the stream channels. This ability hinges upon the lack of fine material to retard the flow of water, which may be pictured as dropping to the inclined plane of bedrock and flowing upon that relatively smooth surface to the lower end of the area.

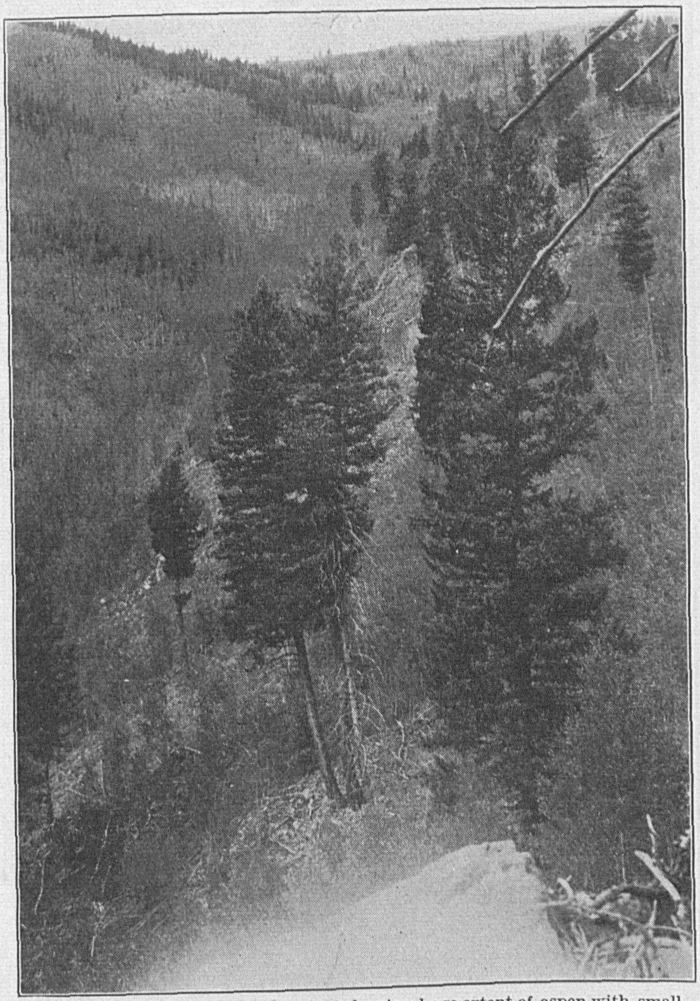


FIG. 5. Watershed B near station B-2 showing large extent of aspen with small conifers

TABLE 4.—*Forest cover of the watersheds*

Type of cover	Area percentage	
	A	B
Burned and not restocked (mostly spruce type)	9.5	6.6
Barren or rock slide	2.7	3.0
Grass covered	9.4	6.1
Aspen without conifers [1]	34.3	43.8
Aspen with conifers	14.4	17.1
Douglas fir	8.8	11.4
Mainly spruce	11.9	12.0
Bristlecone pine (open)	9.0	------
Total	100.0	100.0

[1] Conifers hardly large enough to exert any influence. See text.

CHARACTER AND EFFECT OF THE DENUDATION

As has been stated, most of watershed B was cut over during the summer of 1919, the strip purposefully left along the stream channel, not being cut or piled until 1920. The cutting was complete as to all tree growth,

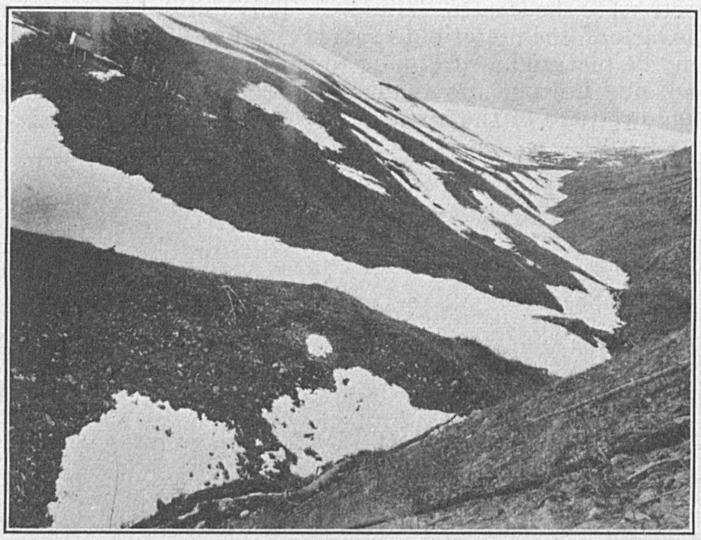


FIG. 6. View toward head of watershed B after denuding

FIG. 8. Same as 7, brush before burning

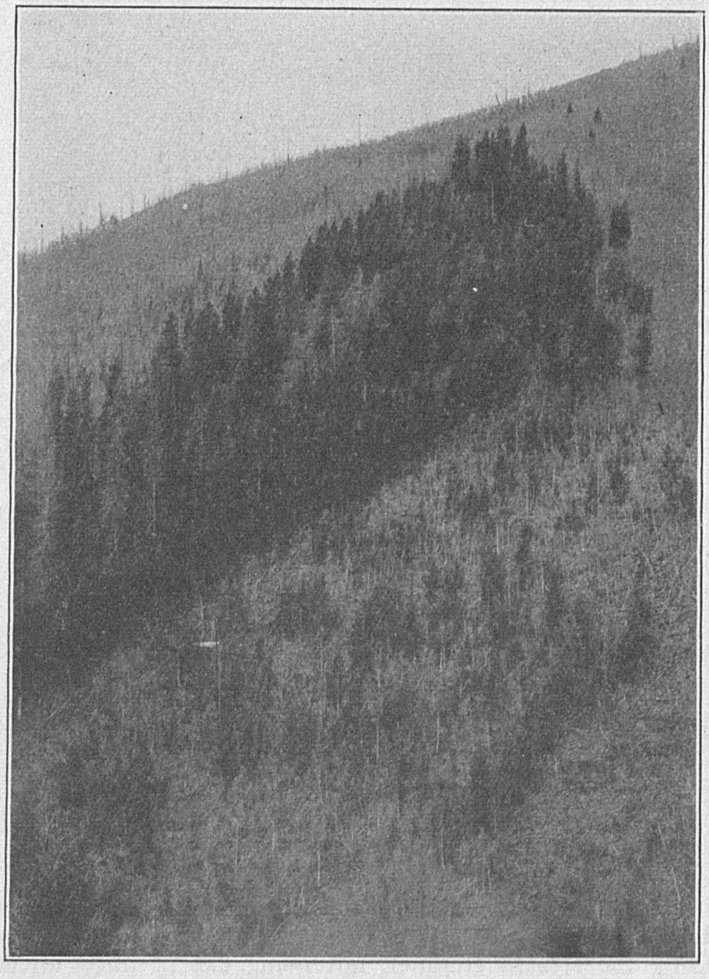


FIG. 7. Area of Douglas fir on north exposure of watershed B before deunding

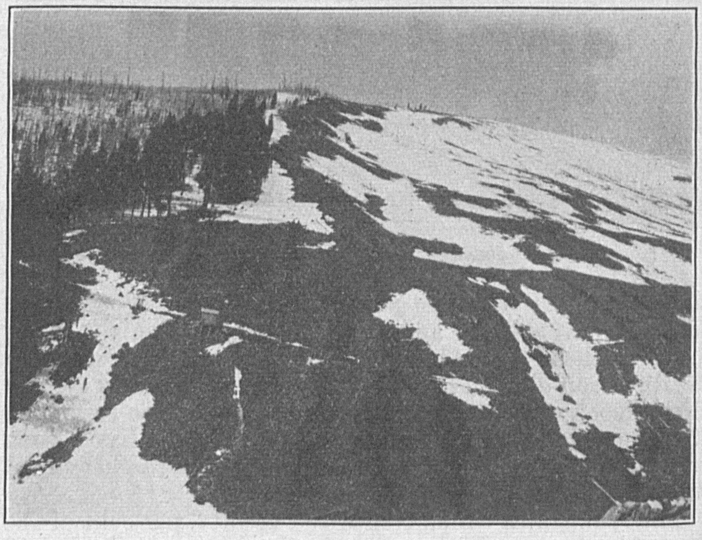


FIG. 9. Same as 7 and 8 after denudation, showing snow reserves

except that a few small aspen sprouts may have excaped notice where they occurred scatteringly.

The larger green coniferous trees were felled and limbed in the usual manner, whether or not they were to be removed and utilized. The dry timber resulting from the burn of 1885, a portion of which still stood in the aspen thickets, particularly in the upper half of the watershed, after being felled was in large part left lying on the ground, and not a little of it was consumed when

FIG. 10. Plateau at head of watershed B, showing fire-killed spruce

the slash was burned. This dry timber was for the most part so sound and firm that its decay could not be expected to add appreciable organic matter to the soil within the life of the experiment, and its position on the ground was not such that it could have checked surface run-off appreciably. Its removal was therefore thought to be unnecessary.

Small seedlings of Douglas fir and spruce were found to be numerous under most of the watershed B aspen

FIG. 11. Aspen on lower portion of east slope of watershed B

when it was removed. These little trees represented an accumulated value in soil formation and seeding of at least 35 years and gave assurance of a future stand of conifers. Yet, although plentiful enough to form the nucleus of a new forest, they had no appreciable or immediate effect as a cover. Their growth for a number of years subsequent to the aspen removal would not be sufficient to change their status as a noncovering crop. For this reason, most of the seedlings less than a foot high were left. These averaged 1 or 2 per 100 square feet, and probably not over 4 inches in height. Even if they grew to a foot in height they would not effect a cover on the area of more than 2 or 3 per cent.

All of the larger green Douglas firs, except a few high up on the slopes, were dragged to a road that followed approximately the 9,400-foot contour and thence were removed from the area in 1919 and 1920. (See fig. 4.) The most extensive stands of Douglas fir were on the south and east aspects above this road, and this was the only place where skidding was sufficiently concentrated to form any deep-cut trails. But one of the trails, within the B–2 area, was later observed to erode appreciably, forming a gully about a foot deep before the gash began naturally to heal. The material eroded from this one gully must have been considerable, but the greater portion of it was deposited on reaching the comparatively level log road. Whether the excess silt which reached the stream and was deposited in the basin of Dam B was largely from this source, it is impossible to state, but it is probable that a number of minor disturbances of the ground in immediate proximity to the stream channel were partly responsible for it.

In 1924 it became necessary to obtain additional fuel wood from the vicinity of snow scale B–8, and in the removal of this the same skid trails on the east slope

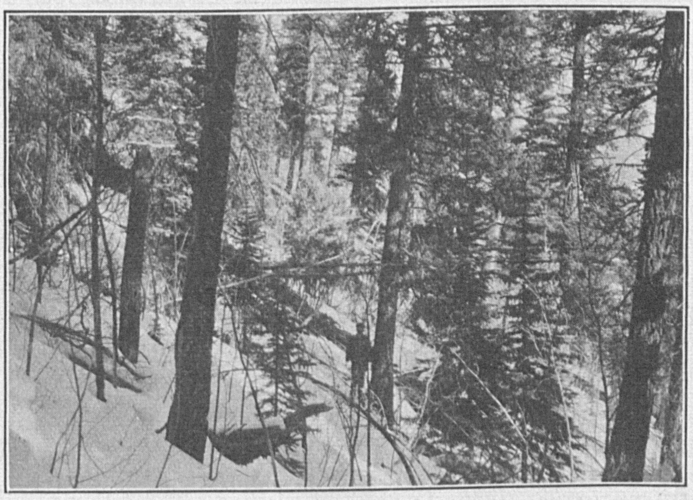


FIG. 12. Part of east-slope area of watershed B, supporting a good stand of Douglas fir

were used as in 1919 and 1920. This work, however, was not started until after the July cleaning of the dams, so that the large amount of sand taken from the B basin at that time can not be charged to this fresh disturbance.

Slash from the larger green conifers and the entire stems and tops of the smaller evergreens and aspens were piled in windrows running up and down the slopes and averaging about 30 feet apart. These were not burned until September, 1920, when all but those last piled were dry enough to burn freely. The weather at the time, however, was not such as to encourage the fires to run between the piles or to effect more than a very superficial burn where they did run. Within the area of the windrows, combustion was quite complete, destroying the humus, so that the rock fragments and mineral soil were laid bare. A number of long narrow scars on the slopes were thus created, interspersed with areas in which both green and decaying vegetation were capable of absorbing run-off. But even on the scars, no appreciable run-off was noted except when the ground was frozen, nor were any marks of erosion left—a further evidence of the very porous character of the rocky soil.

The most striking feature of the fire scars was the complete absence of aspen sprouts for several years after the windrows were burned, in contrast to the prompt and general appearance of aspen sprouts elsewhere, even in areas where fir had occupied the ground almost to the exclusion of aspen. The prompt response on the unburned ground illustrates how, even where normal top-growth of aspen is prevented by conifers, aspen roots permeating the soil in all directions may remain alive, and sprout vigorously as soon as sufficient light and moisture are made available. They may even survive most ordinary fires. In this instance, where the windrows burned with an unusual intensity of heat, the roots were all killed, and, as aspen reproduces very rarely from seed, it could appear on the burned areas only when roots invaded them from the sides.

The relatively flat area at the head of watershed B, shown in Figure 10, was an important exception to the general burning program. This includes snow-scale area 15 and parts of 10, 11, 14, and 16. The aspen

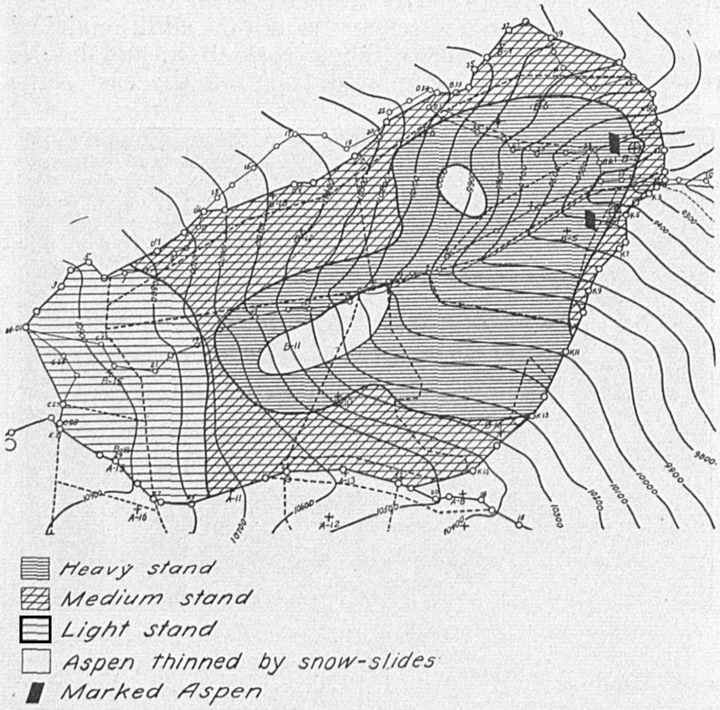


FIG. 13. Map of aspen cover of B in June, 1926

cover here was originally very light, the material had little opportunity to dry, there were a great many large sticks in the piles and consequently they could not be made to burn. The small change effected by denudation of this high area may be a matter of some significance, as will be brought our in the discussion of streamflow.

In the summer of 1925 it was planned to establish the possible effect of the new vegetative cover the more clearly by a reversal, through arresting the development of the sprouts. To this end, it was planned to put a large band of sheep on the area to consume both aspen sprouts and herbaceous vegetation. These animals, however, could not be obtained for the purpose, and in their stead a band of about 80 goats was grazed on the watershed for about 10 weeks. Their browsing, however, had no visible effect, except in the small area where they were bedded at night. Since the final interpretation of the data does not ascribe the cyclic change in streamflow to the aspen development primarily, it may be assumed that the effect on streamflow was inconsequential. The records of 1926 should nevertheless be considered with this extraneous factor in mind, since some effect upon erosion is probable. It is to be regretted that the plan could not be carried to an effective conclusion.

To summarize, watershed B after denudation, except on the severely burned streaks, presented almost immediately a thin cover of aspen sprouts augmented by a fair cover of grass on southerly exposures and of grass and herbs on northerly exposures—these plants naturally growing somewhat more luxuriantly after the removal of the woody cover. At the end of seven years, in June, 1926, a small series of measurements, presumably representative, showed the aspen sprouts to run from 3 to 6 feet in height. This is indicative of the poor quality of the site, already attested by the small stature of the original aspen stand; for on good, slightly acid soil, sprouts might readily attain these heights in one season, thereafter growing more slowly.

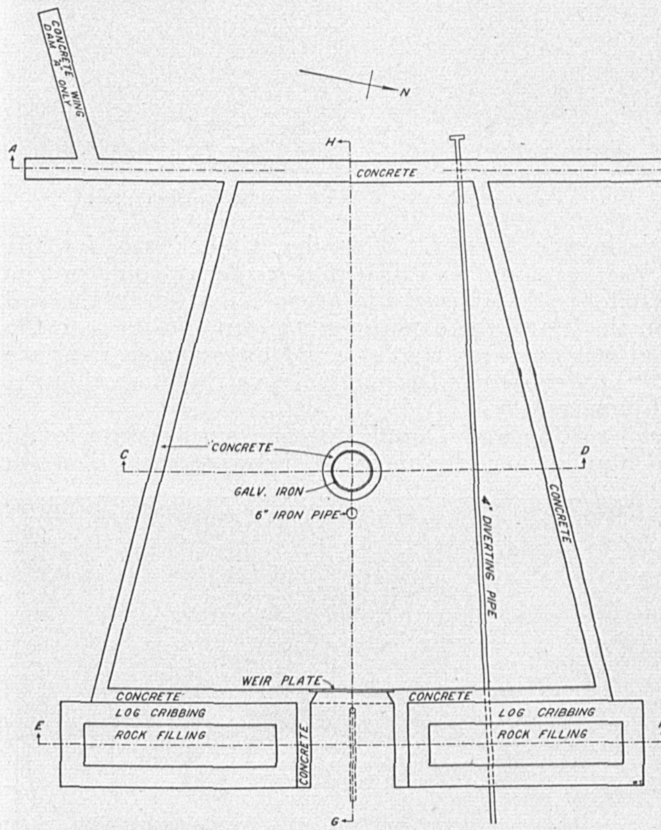


FIG. 14. General plan of dams

Figure 13 indicates the density of the aspen cover in June, 1926.

INITIAL WORK AND DAM CONSTRUCTION

The actual work of initiating this project was begun by B. C. Kadel of the Weather Bureau and C. G. Bates of the Forest Service about June 1, 1910. The time of Mr. Kadel was largely devoted at the outset to the boundary survey, and later to the innumerable tasks incident to installation of the meteorological apparatus and stream-measuring devices. The construction of the dams was left largely to Mr. Bates.

As the entire success of the experiment may be said to hinge on the structure of the dams and stream-measuring devices, the form of the dams and the method of their construction will be dwelt upon in considerable detail. (See figs. 14–22.) The rock conditions encountered at the dam sites have already been described in the geological discussion.

The primary consideration was to construct a wall across each stream channel by means of which both the surface and subflow of the channel could be collected for measurement. This was accomplished, after digging a cross trench down to a solid foundation, by pouring a solid concrete wall to a height at least a foot greater than that of the original stream bed, except at the center of the channel, where a notch was left through which the stream might flow. The thickness of this wall was 8 inches, except at the bottom, where the concrete was allowed to spread out the full width of the trench. The mixture used was about 1 part Portland cement to 5 parts of sand and gravel, insuring practical impermeability, except for an amount of sweating too small to be measured. The lower portion of the wall was necessarily

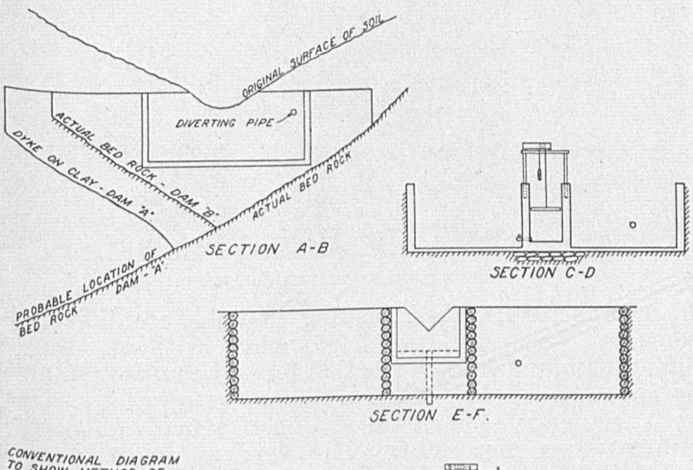


FIG. 15. Details of construction and measuring devices

poured under some water, as the pump available would not keep the trench dry, and the wall was subjected almost immediately to some hydrostatic pressure. By means of a diverting pipe, however, the stream was carried to a considerable distance down the channel, giving ample opportunity to make sure that no leakage through or around the wall developed.

With the concentration thus made possible of all the flow at a single central point in the channel, the next step was to provide means by which the amount of the flow might be measured. A consideration fully as important was to be able to trap, by settling, all of the detritus carried by the stream. The basin below the wall, then, while essential to precise measurement of the flow, was primarily a settling basin.

Each basin was made nearly 25 feet long (lengthwise of the channel), 6 feet wide at the upper end where it joined the dam, 18 feet wide at the lower end, and 4½ feet high. The lateral and end walls were 5 to 6 inches thick and were plastered with two coats of 1 to 1 cement plaster. The floor of the basin was poured about 4 inches

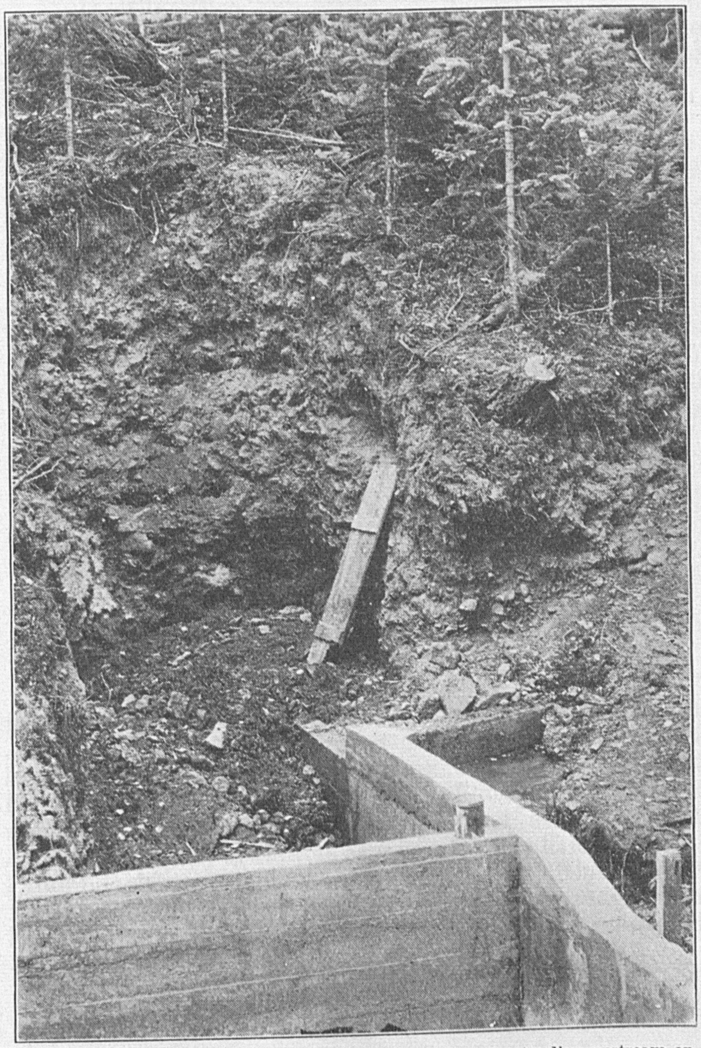


FIG. 16. Dam A, showing cross-channel wall and wing wall extending upstream on ridge of clay

FIG. 17. Completed basin at Dam A from upstream end

thick after pounding rock into the rather loose foundation. This was also plastered and thoroughly troweled.

The shape of the basin, flaring at the downstream end, was dictated solely by the conformation of the ground.

The downstream wall abutted upon a log cribbing filled with rock and earth, which comprised a secondary dam or support for the whole structure, in anticipation of floods which might exert a very heavy pressure.

In the lower wall and in the log crib which reinforced it there was left an opening 4 feet wide. (See fig. 18.) The opening in the concrete wall was really two openings 12 and 24 inches wide, respectively, separated by 12 inches of concrete. The narrower opening was about 3½ feet above the basin floor and the wider one 4 feet, these levels being defined by horizontal straight-edged steel weir plates. The plan was that the water should flow over the lower weir plate, through the 12-inch channel, until the volume was sufficient to make a stream more than 6 inches deep, after which the wider channel and higher weir would automatically come into play. This plan was made with no foreknowledge of the flood volumes to be expected. Actually, the capacity of the 12-inch weir was more than necessary, and at the low heads of late summer and winter the stream flowing over it was so shallow as not to carry off properly, so that precise computation of the volumes discharged was impossible. After a year's trial, therefore, or about July 1, 1911, a triangular or notch weir was substituted in each basin. (Fig. 21.) The new weir plates were cut 4 feet wide, so as to cover the entire area of the two original openings, the division wall being removed.

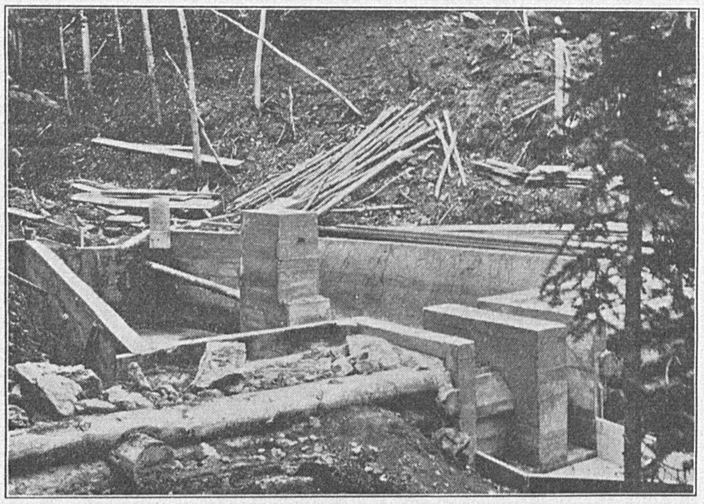


FIG. 18. Completed basin at Dam A with rectangular weirs, as seen from downstream end

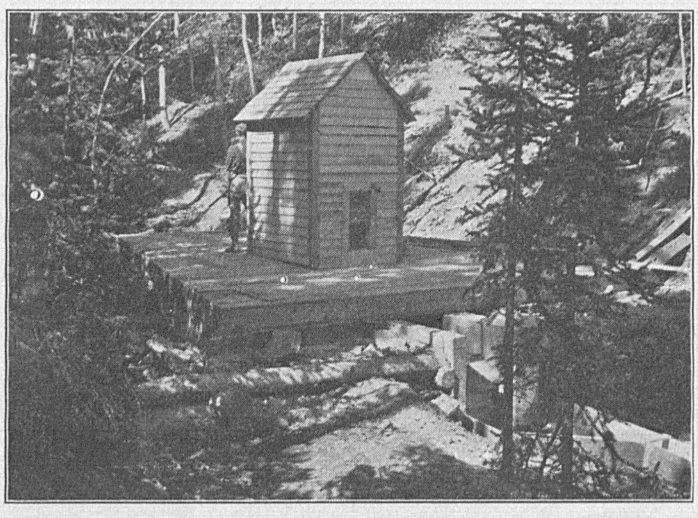


FIG. 19. Basin at Dam A covered, with shelter house for register

The advantages of triangular weirs may be stated as follows: Perfect aeration of nappe; automatic accommodation to all stages, with particular advantage in extremely low stage; and increased amplitude of oscillation of the water surface in the basin at low stage, with consequent increase in the accuracy of the measurements; the use of but one function, height, in the computations; and the elimination of the leading channels from the structural work. These leading channels are difficult to construct with uniform sides, while without them a difficult and doubtful correction for end contraction must be introduced. The weirs are simply steel plates 3 feet by 4 feet and 0.5 inch thick, out of which right-angled notches have been cut. The vertical depth of each notch is 1.5 feet, which gives a maximum capacity of 7 second-feet. The faces of the weirs are beveled off for a distance of 2 inches on the downstream side, with a crest width of one-sixteenth inch. The flow of water under gravity over a triangular weir of this form was shown by Thompson's[7] experiments to be 2.64 times the five-halves power of the head, the flow being expressed in cubic feet per second, and the head being the vertical height in feet of the still water in the pond above the vertex of the weir notch.

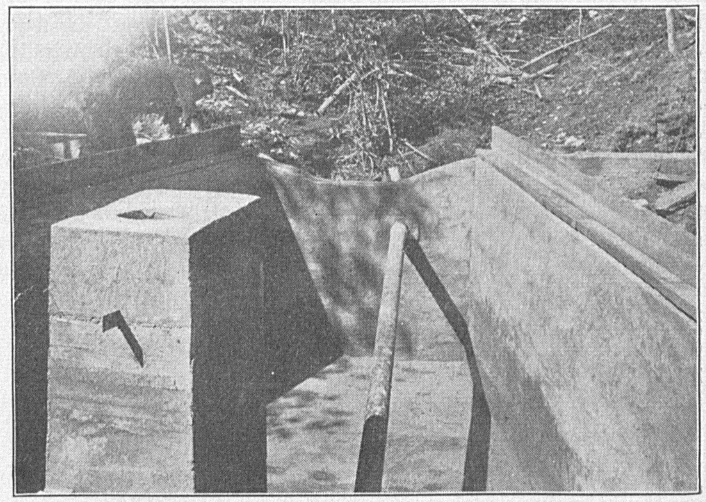


FIG. 20. Basin at Dam B just ready to cover

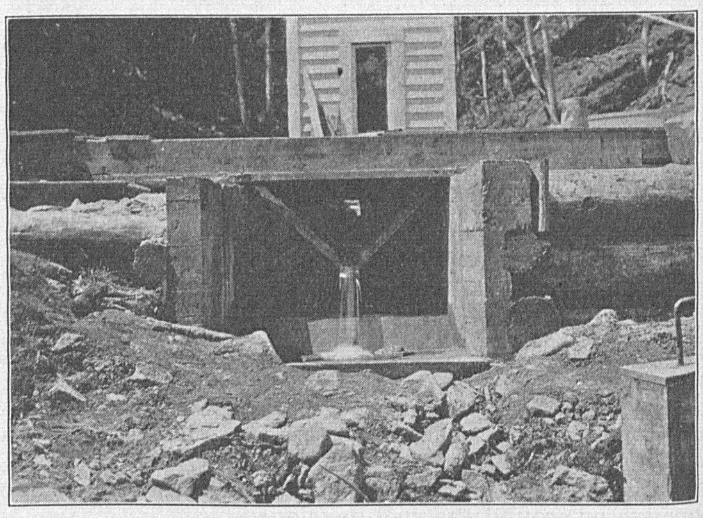


FIG. 21. Triangular weir which replaced rectangular weirs in 1911

Less essential features of the dams were the basin intakes, the diverting pipe and the tailrace. These were

[7] In "Weir Experiments, Coefficients and Formulas." By Robert E. Horton, U. S. G. S., Water Supply and Irrigation Papers, No. 200, 1907, p. 47.

all 4-inch iron pipes. As has been stated, the original plan was to have the stream enter the basin through a notch in the concrete dam wall. A little to one side and about 6 inches lower was the opening of the diverting pipe, by means of which the stream might be diverted around (to be exact, the pipe runs through) the basin when the latter was to be cleaned, or any other operations in the basin were necessary. When the cap was placed on this pipe, naturally a small amount of water had to accumulate before the stream began flowing over the dam, or, in other words, this arrangement necessitated the existence of a small pool above the dam, in which the coarser material carried by the stream was deposited.

FIG. 22. Dam B, covered and ready for use

When the diverting pipe was again opened, such material was inevitably carried away by the lowering of the water level in this pool, and the material was lost as a a part of the silt accumulation. To overcome this difficulty, in 1913 there was inserted through the dam an additional short pipe to comprise an intake to the basin. This was at the same level as the diverting pipe. There was left, therefore, no cause for an accumulation of either water or sand above the dam. Diversion of the stream was accomplished by merely removing the cap from the diverting pipe and placing it on the intake pipe. It will be understood, of course, that the intake pipe might not be able to carry the entire stream in flood stage, the water still having access to the large notch in the dam.

The so-called tailrace was merely a pipe so placed as to carry away the water as it fell from the weir, with a minimum of splashing and with the object of preventing the formation of ice about the weir in cold weather. This pipe led the water underground many feet away from the dam, where it was emptied into the natural channel of the stream.

SETTLING BASINS AND SILT MEASUREMENTS

The settling basins were originally protected with flat covers to exclude sticks and other foreign matter that might clog the weirs and also to prevent dirt from washing over the walls and to shield the basins from wind.

At Dam A it was soon found necessary to supplement this cover with a housing to protect the flow at the weir from ice formation. In severe weather artificial heat under this housing proved necessary. That there was practically no difficulty of this kind at Dam B is due, no doubt, largely to the warmth of one of the stream tributaries, and in small part to better insolation.

The effectiveness of the basins herein described in collecting the solid matter brought down by the streams was, of course, dependent primarily on the time allowed for such material to settle. The basins were originally designed to be proportionate in capacity to the watershed areas. Actual measurements in July and September, 1913, however, after the above-described changes in the weirs, showed a slight discrepancy. Basin A, with 824 cubic feet capacity, allowed 3.703 cubic feet to the acre of watershed, whereas B, with 772 cubic feet, allowed 3.852, or 4 per cent more than A.

These figures represent the capacities to the lowest points in the respective weir notches. Actually, of course, the basins always held at least 5 per cent more water than is indicated.

Computed from a mean annual flow for stream A of 570 cubic feet per hour, the above capacities mean that under average conditions the water in the basins was replaced about once in every 87 minutes, or flowed through the basins at the rate of 1 foot in 4 minutes. Actually, there was probably always a main current from the intake to the weir of much greater velocity than this. In flood times the replacement period might be reduced to one-tenth of the normal.

The basins have seemed to be very effective, even in flood times, in clearing the water of its burden of silt, except for a small amount of very fine and light organic matter. Actual study of the water which passed over the weirs was not made until the spring of 1920. Evaporation of the samples then taken indicated that the water carried a very trifling amount of silt at ordinary stages, but possibly at all times about 0.01 per cent of soluble matter, which, of course, no settling could eliminate. The soluble matter would amount, in one year, to approximately 30,000 pounds of solids for stream A, or 20 to 50 times the weight of the silt collected in the basin. This seems startling, but it should be remembered that this load carried away by the water, of which we have no record, is quite independent of any surface erosion, and it is not seen that it could be greatly affected by the presence or absence of forests.

The silt accumulated in the basins was actually measured three times a year, or about April 15, July 15, and October 15, in the following manner:

1. The stream was diverted around the basin.
2. The water in the basin was siphoned out.
3. Such water as could not be siphoned out, together with the solid matter, was shoveled into buckets and emptied

into large flat pans. Some water was added with the final sweeping of the material toward the lowest point in the floor.

4. Some water was drawn off as the material in the pans settled, until, finally, the little that remained was allowed to evaporate and the solid matter became dry enough to be handled.

5. The moist material was spread on the floor of a drying-shed. When fully air-dried, the total weight was obtained and two samples taken from the collection for each basin.

6. The moisture content of these two samples was determined through drying in hot-water-bath oven, and the net oven-dry weight of the whole collection was then computed.

7. As a matter of possible further interest, the organic content of these oven-dry samples was determined by ignition at red heat. The mineral residues have been retained for reference.

LOCATION AND EQUIPMENT OF OBSERVING STATIONS

In the beginning it was thought advisable to establish six primary meteorological stations. One near the office and living quarters was called the C station; a second on the extreme upper portion of A, represented the higher altitudes of both watersheds, and was known as the D station. Two primary stations were situated on each of the watersheds near the lower boundary, one on the north slope and the other directly across on the south slope. North-slope stations were known as A–1 and B–1, south-slope as A–2 and B–2. These two pairs of watershed stations were the most important, and were therefore located with great care, the object being to secure as nearly identical conditions of topography and timber cover as possible. A–1 occupied about the same topographical position in watershed A as B–1 in watershed B, and A–2 the same as B–2.

The general topography of the watersheds and the location of primary and secondary stations are shown on Figure 26. (See also fig. 1.)

The forest cover of Douglas fir at all four of these stations was as uniform as it was possible to find, but even so, there were slight differences in the stand as follows: B–1 densest, A–1 second, B–2 third, and A–2 fourth. Station D was in a burned area, and station C outside the experimental area and the timber. In the office quarters at this station were housed the automatic registering instruments that recorded sunshine and rainfall at the C station and wind velocity and rainfall at D.

Station A–1.—Station A–1 was 700 feet S. 40° W. of Dam A, and 9,601 feet above sea level, on a steep slope, angle 31° 21′, azimuth N. 24° W. On account of the steep north slope this station received practically no sunshine in the winter season. The trees were of Douglas fir, averaging about 14 inches in diameter, and having a crown density of 6 on a scale of 10. Although the surface of the ground at the station had a shallow covering of moss and fir needles, there was very little soil in the ordinary meaning of that term. Three or four inches below the surface small loose stones were to be found whose interstices the top soil had been insufficient to fill. It was possible to dig a good-sized hole with the hands simply by removing the loose rock. A large open rock slide to the west of the instrument shelter, free from obstruction to the falling rain, was selected for the rain gauge. The anemometer was also mounted in this open space. The instrumental equipment consisted of one small louvered instrument shelter with its floor 7.5 feet above the ground, in which were installed maximum and minimum thermometers, a thermograph, and a hygrograph. Dry and wet bulb temperatures were taken with a hand-whirled psychrometer, the observer standing on the platform approach to the shelter. The anemometer was mounted in the customary vertical fashion on a wooden post with its cups 4.9 feet above the ground. Since the wind on such a slope often has a direction up or down the slope, the anemometer really recorded a modified component of the actual velocity. The mouth of the rain gauge was 4.7 feet above ground. An ordinary 8-inch overflow rain gauge was used. A snow bin, 5 by 5 feet, was installed to the northwest of the shelter. This bin was used only for determining the depth of the newly fallen snow and was emptied at each observation. The snow caught in the 8-inch gauge was used as the standard to determine the water content. The bulb of a telethermoscope buried 1 foot in the ground, just west of the instrument shelter, gave the soil temperature at that depth. The 4-foot temperature was obtained by a thermometer in a 1-inch iron pipe. Between the instrument shelter and the anemometer a low board shanty, 6 by 8 feet, so placed as not to interfere with the exposure of the instruments, afforded shelter for the observer.

Station A–2.—Station A–2 was located 550 feet N. 80° W., of Dam A at 9,609 feet above sea level, and horizontally distant 406 feet from station A–1. The slope was, however, entirely different from that at A–1, the angle being 34° 20′ toward S. 56° E. This station was exposed to the sun at intervals throughout the day. The timber was Douglas fir, the trees being about 18 inches in diameter, with a crown density of 5 on a scale of 10. (See fig. 3.) The soil was composed of earth and large rock fragments, the rocks weighing, say, 100 to 200 pounds, and being firmly embedded in the earth. Very little humus was found. The instruments used were an 8-inch rain gauge and a maximum and minimum thermometer, exposed as at A–1 in a small louvered shelter whose floor was 6.9 feet above the ground. A thermometer in a wooden tube gave the soil temperatures at 1 foot, and another in an iron pipe was used for the temperatures at a depth of 4 feet.

Station B–1.—Station B–1 was located 381 feet S. 60° W. of Dam B, 9,426 feet above sea level. The slope of the ground was 37° 30′ toward N. 24° E. The soil was mostly a sandy loam interspersed with broken rock and well covered with fir needles. The station received but little sunshine in winter. The instrument shelter was in the densest Douglas fir on the watersheds. The trees were not large, the average trunk being probably 6 inches, but were close together, with a crown density of 9 on a scale of 10. This tract of fir is small in extent, and the timber changes abruptly at its western edge to aspen, with young fir coming on. In this aspen and young fir, which was dense and about 15 feet high, an open space well protected from the wind was cleared for the rain-gauge and anemometer. In clearing this space the rule that no object should be nearer to the rain-gauge than a distance equal to its own height was observed as far as practicable. The snow bin was located at the extreme western edge of the cleared space. The floor of the instrument shelter was 7.3 feet above the ground, the mouth of the rain-gauge 4.1 feet, and the anemometer cups 4.7 feet. The instrumental equipment consisted of maximum and minimum thermometers, a thermograph, and a hygrograph, all in a small louvered shelter of the same pattern as on A; a rain-gauge of standard 8-inch overflow pattern; an anemometer mounted vertically; a snow bin 5 by 5 feet. A telethermoscope with its bulb

1 foot in the ground was installed in January, 1912, just west of the instrument shelter. An iron pipe for 4-foot temperatures was installed September, 1913. A shanty 6 by 8 feet was built for convenience and shelter.

Station B–2.—Station B–2 was 358 feet N. 54° W. of Dam B and 9,434 feet above sea level. Although this station was but 560 feet horizontally distant from station B–1, the character of its slope was wholly different, the angle being 30° toward southeast. The timber cover consisted of Douglas fir averaging 10 inches in diameter with a crown density of 6 on a scale of 10. The soil was a sandy loam with a scant covering of fir needles. There was one bed-rock outcrop halfway between the instrument shelter and rain-gauge. The equipment consisted of a thermometer shelter of the cotton-region type, containing maximum and minimum thermometers. The floor of the shelter was 7.5 feet above the ground. A standard 8-inch rain-gauge was exposed a few feet from the thermometer shelter. A thermometer in a wooden tube gave the soil temperatures at 1 foot, and another in an iron pipe was used for the temperatures at a depth of 4 feet.

Station D.—Station D was located near the top of the mountain, at 10,949 feet above sea level. The only timber consisted of dead trees, standing and fallen. The ground in the vicinity of the station was practically level. The soil was gravelly silt loam. The station was exposed to winds from all directions except the west, where it was slightly protected by rising ground. The equipment consisted of one small louvered instrument shelter whose floor is 6.9 feet above the ground, containing maximum and minimum thermometers and a thermograph; one 12-inch tipping-bucket rain-gauge 4.9 feet above the ground, which was connected with a recorder at the C station by aerial wire; and one 8-inch overflow rain-gauge 4.9 feet above the ground and one snow bin in close proximity to the shelter. Soil temperatures were obtained from thermometers in tubes, the shorter one being of wood.

Station C.—Station C was located on the moderately steep easterly slope near the headquarters buildings, there being no trees in its immediate vicinity. This, being on neither watershed, is to be considered as representing merely general conditions of the locality. This station was from the start equipped with a rather complete set of meteorological instruments, as follows: Two standard barometers, a barograph, and a triple register recording wind direction and velocity, sunshine, and rainfall. A standard Weather Bureau instrument shelter on galvanized-iron supports was installed on a grass-covered east slope, 400 feet north of the office building, and the rain-gauge was placed 300 feet farther north in a stand of young aspen. The floor of the instrument shelter was 11.3 feet above ground, the wind vane was 16.9 feet, and the anemometer was 15.6 feet above ground.

Snow scales.—In order to determine the depth and density of the accumulated snowfall of winter, 32 permanent points of measurement were selected, 19 on A and 15 on B. At each point a permanent snow scale or stake 12 feet high was firmly set in the ground. Each scale represented a definite area and the scale reading was applied to the acreage of the area. The details of slope and exposure of the snow scales appear in Table 42 and the location may be seen by reference to Figure 26.

THE PROGRAM OF OBSERVATIONS

The program of meteorological and stream flow observations as originally adopted was not materially changed during the experiment. It involved daily observations, at 9 a. m., at stations A–1, A–2, B–1, B–2, and C.

In the beginning the north-slope stations of the two watersheds were given the more complete instrumental equipment as follows: Maximum, minimum, dry, and wet thermometers, a thermograph, a hygrograph, an anemometer, a standard 8-inch rain-gauge, a 5-foot snow bin, and a 12-foot snow scale, the latter set permanently into the ground. Later in the experiment a shielded snow gauge of the Marvin pattern was added to all of the meteorological stations. Thermometers for determining the soil temperature at depths of 12 and 48 inches were also added on north slopes in 1912. Weekly determinations of soil moisture at all watershed stations were made during the summer months of 1914 to 1926, both inclusive.

The equipment of the south-slope stations in the beginning was limited to maximum and minimum thermometers, a rain-gauge, and a snow scale. On May 31, 1913, the thermometric readings were discontinued and a little later soil temperatures at 12 and 48 inches were begun. Precipitation was continuously recorded at south-slope stations throughout the experiment.

At the D station, by reason of its remoteness from the camp, the sheets of the automatic instruments were changed at 6-day intervals and eye readings for check purposes were made on the dates when the sheets were changed. The daily record of wind velocity and of rainfall in the summer were automatically registered in the office at the C station by an electrical transmission line.

Finally measurements of depth of snow on the ground daily were made at all primary watershed stations except D. Beginning with December of each year, a trimonthly measurement of the depth and density was made at each snow scale on the watersheds until near the beginning of the snow-melting season in the spring, when the measurements were made at five-day intervals. Prior to the winter of 1913–14, the observations were on a somewhat different schedule.

STREAM-FLOW MEASUREMENTS

The height of the water in the basins above the V notch in the weirs was automatically recorded by Friez water-stage recorders. The original 6-inch floats of these recorders were replaced in 1911 by 20-inch floats, which moved the drums of the recorders easily and made them readily sensitive to changes of 0.001 foot. The larger still wells thus required were installed at the same time as were the triangular weirs.

The instrumental record was checked by the daily reading of a hook gauge. The essential principle of the Boyden hook gauge used is that the setting is effected by causing the point of a hook to approach the water surface from the under side. The method is so accurate that different observers rarely vary more than 0.001 foot from the same reading. The instrument consists of a bar, marked by a zero line and a vernier, sliding between two vertical guides, one of which is graduated to hundredths of feet. The sliding bar bears the hook on its lower end. The finer adjustments are made by means of a thumbscrew.

The Boyden gauge was secured to a concrete wall by means of bolts set in the concrete. For the purpose of stilling any waves that might be present, a piece of iron pipe, 6 inches in diameter, the top projecting about 6 inches above the water, was set under the hook gauge, resting unevenly on the concrete bottom of the basin. To provide further for the free access of water, a half-inch hole was drilled through the side of the pipe 6 inches from the lower end.

To set the zero of the hook gauge to the weir-notch level, special equipment was devised. A section of iron pipe was embedded in a concrete base weighing some 10 pounds. Into the top of the pipe a wooden plug was driven. A metal point was then screwed into the wooden block so that the length of the base pipe and point was approximately the depth of the water in the basin about a foot back of the weir. The entire apparatus was then set into the basin just back of the weir. By means of a spirit level, one end of which was filed to fit into the weir notch, the point was finally adjusted to the level of the weir notch. The water in the basin was then adjusted so that the point just pierced the surface. The hook gauge could then be set to its zero. The method is simple and accurate, permitting frequent examinations of the accuracy of the zero to be made without difficulty.

DISCHARGE COEFFICIENTS

To make certain of the requisite degree of accuracy, it was thought best to determine the discharge coefficients of the weirs employed, rather than to accept theoretical values. This was particularly necessary because the weirs differed slightly from the Thompson weir in that they had to be made one-half inch thick to provide the necessary strength, while the Thompson weirs were of thin sheet iron. Furthermore, every weir must of necessity be subject to its own departures in construction from a theoretically perfect cutting of the angle, crest width, and level. Also, in placing the weir in position the concrete may set unevenly, thus throwing the weir slightly out of plumb.

To make the necessary measurements three tanks were mounted at each dam on a platform far enough below the dam to give the required fall. Each tank, 4 feet in diameter and 4 feet in depth, was made of 16-gauge galvanized iron, with iron hoop at the top rim. The area used for each tank was the mean area from circumferences at four heights, allowance being made for the thickness of the iron. To eliminate the error due to irregularity of bottom, depth measurements were made by means of a hook gauge first at a depth of about 2 inches and again after the tank was filled.

Over the middle of the platform a galvanized-iron funnel, top 24-inch diameter, tube 6-inch diameter, was suspended in a gimbal or universal joint, so that the lower end of the funnel hung just above the tops of the tanks. The overflow from the weir was conveyed into this funnel through a V-shaped trough, lined with galvanized iron. The method of suspension of the funnel permitted the water to be directed into either of the three tanks or into a waste pipe, the change being effected in a fraction of a second.

The time of beginning and ending a test was determined from an ordinary watch. Tests were made by two men, one man making continuous readings of the hook gauge in the basin while the second man directed the filling of the tanks. The mean of all hook-gauge readings was used as the head, although practically all of the tests were made at times of very little fluctuation in the head. The detailed measurements and computations are too numerous to reproduce, some 450 tests having been made over a period of two years. Each individual entry represents a measurement of 40 to 130 cubic feet of water, most tests having been made with the larger amounts. A few tests that were undeniably bad were thrown out.

Weir-rating tables being required from the outset, the first, or "preliminary" tables were prepared about the end of the year 1911 from some 40 tests made at Dam A and 50 at Dam B. These, necessarily, covered a restricted range of heads although the rain flood of October, 1911, had been an unusual one for that season. These preliminary tables were used only through March, 1912.

The spring flood of 1912 was nearly as large as any recorded during the experiment, and permitted the testing of heads up to 0.844 foot for A and 0.901 foot for B, these being the highest employed in rating tests at any time: Measurements made both on the rise and on the decline of this flood brought the total number for A up to 165 and for B up to 234, the only region then left inadequately covered being that of unusually low heads. When the measurements of 1912 came to be computed and entered in the second pair of tables, known as the Kadel-Keplinger tables, a peculiar fact was noted. Ratings made at both A and B showed very high coefficients of discharge up to nearly the highest heads reached; thereafter both experienced a decided falling off. At Dam B, nearly as many ratings were made after the peak as before, and as many low as high coefficients were obtained, making possible the drawing of a very satisfactory average curve. At Dam A this was not true, and that portion of the rating curve applying particularly to heads of about 0.650 foot, is controlled by a group of high coefficients, the exact cause and meaning of which are not apparent. The necessity of drawing the curve relatively high for these heads, leads to possibly too high a rating for all heads up to 1 foot, which is practically the limit to which the table was ever employed.

Without drawing this discourse and explanation out to too great length, it should be said that a final careful study of the weirs, the hook gauges, and the other factors entering into the measurements led ultimately to the conclusion that errors in the setting of the hook gauges in this early stage of the experiment were possible to a sufficient extent to cause the variations in weir ratings above noted. Because of this possible variation in the standard, it was thought likely that the preliminary and Kadel-Keplinger tables applied to the current stream gaugings as accurately, if not more accurately than the final tables. For this reason, the original entries of the daily records have been allowed to stand without change, although theoretically it would be more satisfying to rate all of the discharges from one pair of tables.

The final tables were prepared after additional measurements on the weirs at artificially low heads had been made in August and September, 1913. These were obtained by diverting a portion of each stream, already at a low stage, around the dam. Their bearing on the tables is not important as they affect the ratings only for very low heads.

These tables were put into use for the B records on and after September 1, 1913, and for the A records on and after May 1, 1914. Comparison with the Kadel-Keplinger tables, based on nearly as many measurements, reveals certain changes:

For Dam A, less stress is placed upon the several high ratings obtained at heads around 0.650 foot, and the coefficients for all heads above 0.500 foot are allowed to drop slightly, as they readily do for the B weir, though not to so marked a degree. Even with this change, it is not thought possible that at high heads the final rating table for A gives values too low.

For Dam B, the final table is higher than the Kadel-Keplinger table at all points up to heads of 0.800 foot.

This change is due to the final acceptance of the high ratings as being as valuable as the lower ones. When all are employed, the B rating table is at all points higher than that for A. Whatever the cause of a difference in their behavior, it seems logical that this should be maintained at all heads.

The important point of this discussion is to bring out (*a*) the fact that due to unexplainable variations the first two years of record are not rated by the same means as the later years, although it is impossible to say which period is the more accurately rated, and (*b*) that as the source of such variations is probably in the hook-gauge readings, errors amounting to as much as 1 per cent seem likely to enter into the calculations at any point. To what extent these errors may be compensating over long periods, there is no means of determining. A reassuring fact with reference to all of the records after the preparation of the final tables is that the method of frequently adjusting the setting of the hook gauges was abandoned. The zero of each hook gauge was checked three times each year, when the basins were cleaned and necessary corrections applied to the records, but the hook gauges themselves were not disturbed.

In view of this statement, the large number of integers employed to express stream-flow values in the subsequent discussion may seem to express too high a degree of refinement. This is done with no thought of implying an accuracy which does not exist, but for the sake of showing clearly minor variations in stream flow from day to day, especially in the winter, which undoubtedly do occur and are susceptible to measurement, and because of certain arbitrary divisions of the data which have to be made. Also, the writers prefer a larger number of digits to facilitate checking in compilations of the data.

At the end of the experiment the discharge coefficients were again tested by the use of the apparatus originally used.

Table 5 shows the coefficients on which the several tables are based for identical heads. These are the figures to be substituted for 2.640 in the U. S. G. S. formula for triangular weirs. (See footnote 7 on p. 12.) The several tables are to be distinguished by the following letters: P, Preliminary tables; K, Kadel-Keplinger tables; B, Bates tables.

Table 6 gives a few of the discharges from the final or Bates tables, merely for illustration. The full tables were worked out for every 0.001 foot of head, the coefficients first being interpolated to the same basis.

TABLE 5.—*Discharge coefficients for triangular weirs used at the two dams*

Head (feet)	Coefficient (P)		Coefficient (K)		Coefficient (B)	
	A	B	A	B	A	B
0.250	2.62	2.66	2.63	2.67	2.631	2.669
.300	2.60	2.66	2.59	2.622	2.595	2.639
.400	2.55	2.620	2.56	2.590	2.562	2.606
.500	2.53	[1] 2.580	2.552	2.573	2.551	2.585
.600	2.52	--------	2.552	2.564	2.546	2.571
.700	--------	--------	2.552	2.561	2.542	2.563
.800	--------	--------	2.552	2.557	2.538	2.558
.900	--------	--------	2.552	2.554	2.534	2.553

[1] Highest point on this table 0.550 foot, with a coefficient of 2.580.

TABLE 6.—*Discharges in cubic feet per second, as shown by the final tables, for different heads of water above the weir notches*

Head in feet	Dam A	Dam B	Head in feet	Dam A	Dam B
0.100	0.0089	0.0092	0.600	0.710	0.717
.200	.048	.049	.700	1.042	1.051
.300	.128	.130	.800	1.453	1.464
.400	.259	.264	.900	1.947	1.962
.500	.451	.457	1.000	2.531	2.547

On September 8 and 9, 1926, B. C. Kadel tested the weirs at Dams A and B by catching the water in the old testing tanks. At Dam A three tanks of water were caught. The average head was 0.214 foot, the time 2,520 seconds, and the resulting discharge coefficient was 2.60. This gives a computed flow of 0.056 c. f. s. as compared with a value of 0.056 taken from the tables.

At Dam B two tanks of water were caught. The head was 0.217 foot, the time 1,500 seconds, and the resulting discharge coefficient 2.71. This gives a computed flow of 0.0594 c. f. s., as compared with 0.059 taken from the tables. On September 10 another test on Dam B gave the following: Head 0.218 foot, time 1,440 seconds, discharge coefficient 2.772. This gave a computed flow of 0.0615 c. f. s.; table gives 0.060.

PERSONNEL

The following-named employees of the Forest Service were actively connected with the work of getting the experiment station under way, viz., Niles Hughel, who did the surveying, and Claude R. Tillotson, who rendered valuable assistance in a number of ways.

On the part of the Weather Bureau, Benjamin C. Kadel planned and installed the equipment and apparatus for the meteorological observations, snow surveys, precise stream-flow measurements, and determination of coefficient of stream discharge, and started the observational work in October, 1910. In all of this work he was ably assisted by Forest Service employees on duty at the station.

The following employees of the Weather Bureau had charge of the Wagon Wheel Gap station:

Benjamin C. Kadel, June, 1910, to August, 1912.
Harris A. Jones, August, 1912, to February, 1914.
Thomas A. Blair, March, 1914, to February, 1916.
Alonzo A. Justice, February, 1916, to September, 1917.
James H. Jarboe, September, 1917, to October, 1918.
Edwin H. Jones, October, 1918, to November, 1920.
Walter M. Weld, November, 1920, to September, 1923.
Erle L. Hardy, September, 1923, to September, 1926.

J. C. Smith, Laskowski, Maguire, Wright, Howell, Murphy, Fletcher, Wells, Hamrick, Davis, Maxwell, Desmond, Torrence, and Choun also served at the station on behalf of the weather Bureau. C. R. Tillotson, R. D. Garver, J hn Murdock, jr., P. Keplinger, J. L. Glendenning, H. R. Flint, and L. C. Anderson gave assistance at various times on behalf of th Forest Service.

Paul Frederick Maxwell (1892–1923) while in the performance of the routine of snow measurements was overwh lmed by a snowslide on the denuded B watershed on the morning of March 5, 1923, and perished.

The writers find it impossible to close this recital without a word of appreciation for the zeal, loyalty, and faithfulness of all of the public servants whose efforts and sacrifices have made possible this contribution to science.

CHAPTER II. CLIMATE OF WAGON WHEEL GAP AREA, 1911–1926

The geographic location of the Wagon Wheel Gap area, remote from the oceans and in the midst of a rugged mountain area, imposes upon it a climate that partakes of the characteristics of both mountain and continental climates. State-wide means of temperature and precipitation have been examined with a view of delimiting the secular trend of the climate during the life of the experiment. On the basis of these means the period 1911–1926 may be characterized as moderately cool and wet, the temperature abnormality, annual means considered, being −0.7°. The excesses in precipitation averaged 1.34 inches.

AIR TEMPERATURE[1]

The discussion of temperature is based on daily systematic observations of standard thermometers exposed in the regulation thermometer shelter at the north-slope stations of both watersheds for a period of 15 years, 1911 to 1926, inclusive. Daily thermometric observations are also available for the south-slope stations on both watersheds from November, 1910, to May, 1913, a period of 31 months. Thermographs were maintained at north-slope stations and also at the D station for the entire 15-year period. The monthly means as deduced from hourly readings of the thermographs, checked by daily comparisons with the mercurial thermometers at A and B, are given in the series of temperature tables which follow. The data obtained prior to October, 1911, entered here for the sake of a complete record, are not included in the averages.

Table 13 shows the average monthly temperature differences between the first and the last stages of the experiment at the two north-slope stations.

The top row of figures shows that when both watersheds were in the forested condition the B watershed was the colder by small amounts in the months October to March and slightly warmer during the remaining months of the year, averaging 0.2° cooler for the year. After the denudation of B that watershed was at all times the warmer of the two, as shown in the second line of figures. The net result of the denudation, shown in the third row of figures, indicates that on a yearly average the temperature of B was raised 1.3°.

The means of the maxima and minima of temperature are treated in like manner and it appears that the greatest increase in the B watershed temperature occurred in the daily maxima, September to March, both inclusive. The average yearly increase in the maxima is 2.1°. The minima also increased after denudation but only to the extent of 0.7°.

In the preliminary report on this project it was suggested that the pronounced daily differences in the maximum temperatures recorded on the two areas at the time of the equinoxes might have a purely astronomical origin, viz, in the different angle of incidence of the sun's rays on the lower portion of A as compared with B. The azimuth of A slope at station A–1 is N. 24° W., while that of B is N. 24° E. As noon approaches in the latitude of Wagon Wheel Gap, in March for example, the sun will be moving not upward along the prime vertical, but obliquely toward the south-southwest. After reaching the meridian its course will be obliquely toward the north-northwest, in which position its rays will fall upon portions of the slopes of A at a higher angle than on B.

[1] Degrees Fahrenheit and English units are used throughout this discussion.

TABLE 7.—*Monthly mean temperature north-slope station A–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	22.4	16.6	27.7	34.2	43.2	51.1	51.9	51.7	47.5	----
1911–12	34.9	20.8	11.2	15.5	18.3	23.5	28.7	41.6	48.1	52.3	52.5	43.2	32.6
1912–13	33.6	24.6	12.3	13.0	15.7	21.1	33.2	43.7	48.5	54.6	53.7	43.3	33.1
1913–14	34.0	27.1	11.2	18.6	15.2	25.4	33.8	42.8	51.2	52.8	51.8	47.2	34.3
1914–15	36.0	28.9	12.1	11.9	17.1	22.1	35.4	38.5	50.6	54.9	51.7	45.7	33.7
1915–16	37.6	24.5	18.3	15.5	20.5	28.9	34.2	42.3	53.3	54.6	51.2	45.8	35.6
1916–17	34.9	25.1	13.9	12.5	18.7	18.0	29.3	35.5	51.2	56.0	50.7	46.0	32.6
1917–18	37.7	28.2	23.5	15.3	29.8	27.4	30.8	42.4	54.7	52.7	51.2	45.7	36.6
1918–19	38.2	19.3	15.0	12.6	12.8	21.7	34.2	43.1	49.6	54.8	54.5	48.0	33.6
Postdenudation period:													
1919–20	32.2	24.0	16.3	17.5	20.0	21.1	26.7	42.2	49.7	54.1	51.3	44.6	33.3
1920–21	32.8	21.8	13.5	18.0	18.6	28.1	29.7	41.2	50.6	54.4	51.0	48.0	34.0
1921–22	38.9	28.0	22.5	9.2	16.8	21.4	29.1	41.0	52.9	56.1	53.7	47.6	34.8
1922–23	36.2	21.8	17.9	18.8	14.4	20.6	30.3	43.0	51.6	55.4	50.2	42.2	33.5
1923–24	32.5	22.0	17.7	10.9	21.4	17.8	30.9	41.9	54.3	54.8	53.0	46.0	33.6
1924–25	35.3	25.8	14.4	11.6	18.8	26.0	35.5	45.0	49.4	54.2	50.1	45.6	34.3
1925–26	35.4	21.3	17.9	13.0	22.1	24.2	34.3	40.3	51.6	51.9	53.4	48.2	34.5
General average	35.3	24.2	15.8	14.3	18.7	23.2	31.7	41.6	51.2	54.2	52.0	45.8	34.0
Predenudation average	35.9	24.8	14.7	14.4	18.5	23.5	32.4	41.2	50.9	54.1	52.2	45.6	34.0
Postdenudation average	34.8	23.5	17.2	14.1	18.9	22.7	30.9	42.1	51.4	54.4	51.8	46.0	34.0

TABLE 8.—*Monthly mean temperature north-slope station B–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	21.5	16.4	27.4	33.9	43.4	51.0	52.0	51.6	46.9	----
1911–12	34.5	20.2	10.6	14.4	17.7	23.0	28.6	41.6	47.9	51.8	52.2	42.9	32.1
1912–13	33.6	24.0	11.3	12.2	15.5	21.0	33.2	44.0	48.8	54.6	53.9	43.1	32.9
1913–14	34.1	26.5	9.8	17.7	14.6	24.9	34.1	43.0	51.0	53.1	51.9	47.0	34.0
1914–15	35.9	28.5	11.5	11.4	16.5	22.2	35.6	39.0	50.8	55.3	52.1	45.3	33.7
1915–16	37.5	24.1	17.7	14.9	19.8	28.7	34.2	42.8	53.4	54.4	51.0	45.5	35.3
1916–17	34.5	24.8	13.3	12.0	18.0	17.5	29.1	35.4	51.1	56.0	50.7	45.8	32.4
1917–18	37.7	27.4	22.8	15.0	19.5	27.3	31.1	42.6	55.4	53.1	51.1	45.6	35.7
1918–19	38.5	19.1	14.6	11.9	12.8	21.5	34.5	43.5	50.4	55.7	55.7	49.2	34.0
Postdenudation:													
1919–20	33.7	25.0	16.3	17.6	21.2	22.4	27.6	43.4	50.9	55.7	52.8	46.1	34.4
1920–21	34.3	22.7	13.8	18.6	20.0	29.7	31.0	42.7	52.3	55.6	52.4	49.2	35.2
1921–22	40.7	29.1	22.8	9.8	17.7	22.6	30.2	42.3	54.4	57.7	55.1	49.1	36.0
1922–23	37.7	22.5	18.3	19.0	15.4	21.8	31.6	44.6	52.9	56.9	51.6	43.8	34.7
1923–24	34.0	22.7	17.5	11.0	22.2	18.9	31.8	43.5	55.6	56.2	54.3	47.4	34.6
1924–25	37.0	27.1	14.9	12.1	20.2	27.5	36.8	46.3	50.6	55.6	51.6	47.1	35.6
1925–26	37.0	22.0	18.3	13.4	23.1	25.8	35.7	41.9	53.2	53.2	54.1	49.0	35.6
General average	36.0	24.4	15.6	14.1	18.3	23.7	32.3	42.4	51.9	55.0	52.7	46.4	34.4
Predenudation average	35.8	24.3	14.0	13.7	16.8	23.3	32.6	41.5	51.1	54.2	52.3	45.6	33.8
Postdenudation average	36.3	24.4	17.4	14.5	20.0	24.1	32.1	43.5	52.8	55.8	53.1	47.4	35.1

TABLE 9.—*Monthly mean maximum temperature north-slope station A–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	31.5	25.5	39.5	46.1	56.7	65.6	64.2	66.6	60.2	----
1911–12	46.4	31.5	21.0	26.1	28.6	33.7	40.8	53.9	62.3	66.2	66.9	57.9	44.6
1912–13	44.6	36.6	22.6	23.0	26.0	33.3	46.6	57.9	63.8	70.7	69.3	57.0	46.0
1913–14	45.2	36.2	19.5	28.7	20.8	39.0	45.7	56.6	66.1	66.3	66.8	61.7	46.6
1914–15	47.1	42.5	21.5	22.3	27.7	33.5	47.5	51.2	[illegible]	71.2	67.5	59.7	46.5
1915–16	52.0	35.3	27.9	23.5	32.8	40.8	46.1	56.1	69.8	69.5	65.5	61.0	48.4
1916–17	45.2	36.9	22.4	22.9	28.8	31.2	41.7	46.8	66.8	72.9	66.4	60.7	45.2
1917–18	51.7	40.7	34.4	24.5	31.0	39.8	42.1	55.5	71.9	68.0	67.1	59.4	48.8
1918–19	49.1	29.0	24.4	24.6	23.2	33.5	46.7	57.2	66.8	70.0	71.1	62.2	46.5
Postdenudation period:													
1919–20	42.3	34.4	26.2	27.9	30.8	33.0	38.8	55.5	64.7	71.2	67.8	59.7	46.0
1920–21	44.5	31.8	23.1	27.1	30.6	40.9	42.5	54.4	66.6	70.2	65.4	63.9	46.8
1921–22	52.5	40.7	32.8	20.1	26.9	34.3	41.8	54.7	70.2	74.4	69.0	63.5	48.4
1922–23	51.1	31.3	27.8	28.7	26.5	32.5	42.7	56.5	67.4	70.7	63.6	55.5	46.2
1923–24	42.0	33.2	27.3	21.8	32.0	29.0	43.4	55.4	70.8	71.1	70.1	62.8	46.6
1924–25	48.1	37.4	24.5	22.5	30.8	38.9	49.0	59.6	64.2	69.5	64.2	59.1	47.3
1925–26	46.4	31.9	28.1	23.5	33.2	35.7	47.4	54.2	68.6	67.7	69.5	62.4	47.4
General average	47.2	35.3	25.6	24.5	29.0	35.3	44.2	55.0	67.1	70.0	67.3	60.4	46.7
Predenudation average	47.7	36.1	24.2	24.4	28.1	35.6	44.6	54.4	66.7	69.4	67.6	60.0	46.6
Postdenudation average	46.7	34.4	27.1	24.5	30.1	34.9	43.7	55.8	67.5	70.7	67.1	61.0	47.0

TABLE 10.—*Monthly mean maximum temperature north-slope station B–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	30.7	25.2	38.0	44.1	55.6	64.6	63.9	65.5	58.6	----
1911–12	45.5	30.7	20.8	25.1	28.4	32.3	39.1	53.1	62.1	65.1	65.6	56.5	43.7
1912–13	44.0	35.4	20.8	22.1	25.6	32.2	44.9	57.4	62.8	69.4	67.5	55.3	44.8
1913–14	45.0	35.1	18.0	26.7	26.1	36.6	44.7	55.1	64.7	66.1	65.4	60.2	45.3
1914–15	46.6	42.0	20.5	21.5	26.9	32.7	46.1	50.4	65.0	69.6	66.6	57.4	45.4
1915–16	50.9	34.8	26.9	22.4	31.6	39.2	45.0	54.9	68.3	68.1	63.3	58.8	47.0
1916–17	44.6	36.4	22.1	22.1	28.4	30.0	39.9	45.6	65.7	72.1	65.5	58.9	44.3
1917–18	51.5	39.4	34.0	24.5	30.5	38.2	40.8	54.4	71.3	66.8	65.1	57.5	47.8
1918–19	48.6	28.0	23.1	23.3	22.7	31.6	45.5	56.5	66.3	70.0	71.6	63.3	45.9
Postdenudation period:													
1919–20	45.4	36.0	26.2	28.4	33.8	34.8	38.8	55.8	65.2	71.9	67.7	60.8	47.1
1920–21	46.9	33.5	23.6	28.2	34.3	42.7	42.4	54.9	66.9	69.9	66.1	65.5	47.9
1921–22	55.8	42.8	33.4	21.0	28.8	35.9	41.5	54.7	70.0	74.1	69.5	64.6	49.3
1922–23	54.0	32.6	28.5	29.6	28.4	34.1	42.4	56.6	66.8	71.0	64.2	57.2	47.1
1923–24	45.1	34.7	27.9	22.5	34.4	30.5	43.1	56.3	70.7	71.1	70.1	64.1	47.5
1924–25	51.5	39.5	25.6	23.5	33.9	40.5	48.8	60.0	64.0	69.5	64.5	60.5	48.5
1925–26	49.2	33.5	29.2	24.6	35.5	37.9	47.8	54.9	68.4	67.6	69.7	63.4	48.5
General average	48.3	35.6	25.4	24.4	30.0	35.3	43.4	54.7	66.5	69.5	66.8	60.3	46.7
Predenudation average	47.1	35.2	23.3	23.5	27.5	34.1	43.2	53.4	65.8	68.4	66.3	58.5	45.5
Postdenudation average	49.7	36.1	27.8	25.4	32.7	36.6	43.5	56.2	67.4	70.7	67.4	62.3	48.0

TABLE 11.—*Monthly mean minimum temperature north-slope station A–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	13.5	8.2	18.2	24.2	31.3	38.6	43.2	40.4	38.1	----
1911–12	25.2	10.9	2.3	5.8	8.1	14.2	17.7	30.3	36.2	41.9	40.9	30.5	22.0
1912–13	24.8	14.7	2.9	2.4	6.2	10.8	22.3	30.8	36.9	41.6	42.9	33.4	22.5
1913–14	25.0	19.7	3.0	9.5	4.3	14.3	23.6	31.9	38.2	44.2	41.4	35.8	24.2
1914–15	27.0	17.7	3.3	2.1	7.4	11.8	26.4	27.2	36.3	41.6	39.1	34.9	22.9
1915–16	26.1	14.7	9.5	7.0	9.6	18.0	23.2	29.4	36.9	43.7	41.9	33.8	24.5
1916–17	26.9	14.7	4.9	2.7	9.5	5.7	18.3	26.4	35.9	43.5	39.2	35.0	21.9
1917–18	24.7	18.4	14.2	6.5	8.7	16.6	20.7	30.3	41.2	42.4	40.3	35.0	24.9
1918–19	28.9	11.0	6.2	2.1	2.5	12.0	24.3	31.8	35.9	45.1	42.0	37.7	23.3
Postdenudation period:													
1919–20	23.2	15.5	6.6	8.5	9.9	10.3	15.7	30.7	36.8	41.5	39.8	33.0	22.6
1920–21	22.9	13.7	4.1	9.1	7.8	17.7	17.8	29.3	37.4	43.5	41.6	34.3	23.3
1921–22	28.1	17.1	13.3	−1.3	7.6	9.6	18.0	28.5	38.6	42.7	43.4	35.3	23.4
1922–23	24.1	13.6	8.7	9.1	3.6	9.6	20.2	30.3	36.9	44.4	41.2	32.2	22.8
1923–24	24.0	12.1	8.2	0.8	11.6	7.1	20.0	29.6	37.8	42.3	38.9	31.7	22.0
1924–25	24.5	15.5	4.7	1.5	7.6	14.4	23.3	32.0	36.5	43.0	40.2	34.9	23.2
1925–26	25.5	11.7	8.5	3.5	11.7	14.0	24.1	29.6	37.3	40.5	41.3	36.7	23.7
General average	25.4	14.7	6.7	4.6	7.7	12.4	21.0	29.9	37.3	42.8	40.9	34.3	23.1
Predenudation average	26.1	15.2	5.8	4.8	7.0	12.9	22.1	29.8	37.2	43.0	41.0	34.5	23.3
Postdenudation average	24.6	14.2	7.7	4.5	8.5	11.8	19.9	30.0	37.3	42.6	40.9	34.0	23.0

TABLE 12.—*Monthly mean minimum temperature north-slope station B–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	12.6	8.1	18.0	23.8	31.0	37.9	43.0	39.7	37.9	----
1911–12	25.2	10.0	1.6	5.0	7.3	13.9	17.3	29.8	35.6	41.5	40.4	30.2	21.5
1912–13	24.8	14.2	2.1	1.6	5.8	10.4	22.0	30.4	36.7	41.3	42.6	33.1	22.1
1913–14	25.0	19.2	1.8	9.1	4.1	14.1	23.7	31.4	37.8	44.0	41.0	35.3	23.9
1914–15	27.1	17.7	3.4	1.5	7.0	12.1	26.5	27.4	35.9	41.4	39.0	34.3	22.8
1915–16	25.9	14.3	9.0	6.6	9.2	17.7	23.0	28.9	35.9	42.8	41.2	32.9	24.0
1916–17	26.5	14.2	4.4	2.2	8.4	5.2	18.0	26.0	34.7	42.7	38.5	34.3	21.3
1917–18	24.4	17.3	13.3	5.9	8.0	16.3	20.4	29.9	40.7	41.9	39.7	34.5	24.4
1918–19	29.0	10.7	5.5	1.6	2.6	11.8	24.2	31.5	35.2	44.9	41.8	37.5	23.0
Postdenudation period:													
1919–20	23.2	15.6	6.0	7.5	9.8	10.2	15.8	30.8	36.7	41.8	40.1	33.0	22.5
1920–21	23.1	13.2	3.8	8.6	7.6	18.3	18.8	30.0	38.1	44.2	42.5	34.7	23.6
1921–22	28.6	17.2	13.1	−1.3	7.6	9.9	18.4	28.8	39.0	43.3	44.2	36.0	23.7
1922–23	24.4	13.7	8.3	8.8	3.5	10.1	21.0	31.2	37.3	45.1	42.1	33.0	23.2
1923–24	24.4	12.0	7.3	0.1	10.9	7.1	20.3	30.3	38.2	42.8	39.2	32.3	22.1
1924–25	25.1	15.9	4.6	1.5	8.0	15.0	24.1	32.9	37.4	43.9	41.4	35.7	23.8
1925–26	26.0	11.7	8.8	3.1	12.3	14.5	25.2	30.3	37.7	41.0	40.9	36.4	24.0
General average	25.5	14.5	6.2	4.1	7.5	12.4	21.2	30.0	37.1	42.8	41.0	34.2	23.0
Predenudation average	26.0	14.7	5.1	4.2	6.6	12.7	21.9	29.4	36.6	42.6	40.5	34.0	22.9
Postdenudation average	25.0	14.2	7.4	4.0	8.5	12.2	20.5	30.6	37.8	43.2	41.5	34.4	23.3

TABLE 13.—*Differences between monthly mean temperatures of A and B during the two stages of the experiment*

[Minus signs indicate B colder than A; absence of sign the contrary]

Datum	October	November	December	January	February	March	April	May	June	July	August	September	Annual
	Monthly means (B–A)												
First period	−0.1	−0.5	−0.7	−0.7	−1.7	−0.2	0.2	0.3	0.2	0.1	0.1	0	−0.2
Second period	1.5	.9	.2	.4	1.1	1.4	1.2	1.4	1.4	1.4	1.3	1.4	1.1
Net change	1.6	1.4	.9	1.1	2.8	1.6	1.0	1.1	1.2	1.3	1.2	1.4	1.3
	Mean maximum (B–A)												
First period	−0.6	−0.9	−0.9	−0.9	−0.6	−1.5	−1.4	−1.0	−0.9	−1.0	−1.3	−1.5	−1.1
Second period	3.0	1.7	.7	.9	2.6	1.7	−.2	.4	−.1	0	.3	1.3	1.0
Net change	3.6	2.6	1.6	1.8	3.2	3.2	1.2	1.4	.8	1.0	1.6	2.8	2.1
	Mean minimum (B–A)												
First period	−0.1	−0.5	−0.7	−0.6	−0.4	−0.2	−0.2	−0.4	−0.6	−0.4	−0.5	−0.5	−0.4
Second period	.4	0	−.3	−.5	0	.4	.6	.6	.5	.6	.6	.4	.3
Net change	.5	.5	.4	.1	.4	.6	.8	1.0	1.1	1.0	1.1	.9	.7

The D station, at an elevation of 1,355 feet higher than A–1 and 1,530 feet higher than B–1, has practically the same winter mean temperature as the lower stations, a spring temperature 4° lower, summer about 3° lower, and autumn 1.5° lower. The winter minimum temperatures of the D station are considerably higher than those of the lower levels; hence the equality in the winter means.

ADVANCE OF THE SEASON

The character of the season as indicated by the rate of increase in the monthly mean temperature, month to month for the period from March to June, inclusive, is shown by the figures in Table 14. Some seasons are considerably in advance of others in the matter of the normal increase of temperature with the advance of the season. The average increase in monthly mean temperature from March to June is about 28°, but this increase may come early, as in 1913, or late, as in 1918, and in some seasons the average increase may not be realized. The average increase was 1.3° less in the first 8 years of observation, than in the second period, but the temperatures for March were 0.8° higher in the first period.

TABLE 14.—*Increase in monthly mean temperature, March to June, Station A–1*

Year	March to April	April to May	May to June	Total	Year	March to April	April to May	May to June	Total
1912	5.2	12.9	6.5	24.6	1920	5.6	15.5	7.5	28.6
1913	12.1	10.5	4.8	27.4	1921	1.6	11.5	9.4	22.5
1914	8.4	9.0	8.4	25.8	1922	7.7	11.9	11.9	31.5
1915	13.3	3.1	12.1	28.5	1923	9.7	12.7	8.6	31.0
1916	5.3	8.1	11.0	24.4	1924	13.1	11.0	12.4	36.5
1917	11.3	6.2	15.7	33.2	1925	9.5	9.5	4.4	23.4
1918	3.4	11.6	12.3	27.3	1926	10.1	6.0	11.3	27.4
1919	12.5	8.9	6.5	27.9					
Means	8.9	8.8	9.7	27.4	Means	8.2	11.2	9.3	28.7

MONTHLY EXTREMES OF TEMPERATURE

An examination of the monthly extremes of temperature at stations A–1, B–1, and D brings out the following points:

The absolute range in temperature for the 16-year period, January, 1911, to September, 1926, inclusive, was 106° for station A–1, or from 24° below zero on February 1, 1916; to 82° above on June 10, 1918, and July 4, 1916; for station B–1, 107°, or from −25° on February 1, 1916, to 82° on July 16, 1922; and for station D, 96°, from −22° on January 2, 1919, to 74° on July 15, 1922.

The extreme temperatures for each month and the year are included in Table 15.

TABLE 15.—*Monthly extremes of temperature*

ABSOLUTE MAXIMA

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
A–1	46	45	54	60	71	82	82	78	77	67	53	50	82
B–1	45	50	56	59	71	80	82	79	75	67	53	51	82
D	50	49	50	55	63	72	74	72	69	63	55	48	74

ABSOLUTE MINIMA

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
A–1	−21	−24	−14	−2	10	1	30	32	8	0	−11	−16	−24
B–1	−21	−25	−15	−2	10	1	30	31	8	−1	−11	−17	−25
D	−22	−21	−11	−10	4	12	28	29	8	−1	−13	−17	−22

This tabulation shows that during the winter period, November to February, inclusive, the absolute maximum at the higher elevation, D, is sometimes above the maxima at the lower stations, and, during the same period, the absolute minimum at the higher station is occasionally not so low as the minima at the lower elevations.

These results, while somewhat at variance with the ordinary view of change with altitude, are nevertheless quite in accord with later views upon temperature conditions prevailing in the free air at neighboring mountain and slope stations. The D station is located in a burned-over region and is not protected by the shade of the timber; it is subject to unobstructed insolation at all times of the year. It is probable that these facts, together with the greater opportunity for warming by reflected heat from the snow cover and dead timber, will account for the higher maxima observed in the cold season. The higher minima may be accounted for by the greater opportunity at the D station than at the slope stations at lower levels for air mixing due to wind movement.

Another type of temperature inversion that occasionally appears in midwinter is a decided fall of temperature at the lower stations which does not appear at the upper stations; an example is given in Table 16. The rate of increase of temperature with increase of elevations in this example is about 1° F. in 100 feet. Inversions of this character appear to occur in connection with a certain well-defined type of pressure distribution over Colorado. They are not material to this discussion.

TABLE 16.—*Temperature inversion, Wagon Wheel Gap, Colo., February 10, 1918*

Station	Elevation (feet)	Temperature, °F.		
		Mean	Maximum	Minimum
River valley	8,437	6.1	30	−13
A–1	9,601	17.5	34	4
D	10,956	25.0	41	14

MEAN DAILY RANGE OF TEMPERATURE

The mean daily range of temperature at the two north-slope stations is practically the same, averaging about 22° for the whole year. At the more elevated D station the range is about 4° less; but on the south slopes of both watersheds it is greater, the excess on watershed B being more pronounced than on watershed A.

DIURNAL VARIATION

The diurnal variation of temperature at the Wagon Wheel Gap stations is largely a matter of academic interest. It has been calculated for the A–1 and the D stations.

The amplitude of the variation at the upper station is considerably less than at the lower station and the hour of occurrence of the maximum and the minimum temperatures at the upper station is earlier in the day than at the lower station; for example, the hour of maximum in winter at D falls at 1 p. m., whereas at A it occurs two hours later. The D station is probably less affected by surface conditions of slope and surface cover than the A–1 station and reacts to atmospheric processes much as would a point in the free air.

VARIATIONS FROM THE MEAN

The record of but 15 years observations is too short to permit one to determine the extent of the variations that might occur in 40 or 50 years. The winter months, December, January, and February, have varied from 8° to 12° above the mean to 5° and 6° below or a total swing of 13° to 18°. The variation in the summer months is quite small.

ANNUAL MARCH OF MEAN TEMPERATURE

Wagon Wheel Gap, Colo., Station A–1

BY PROF. C. F. MARVIN

Having found that the harmonic analysis of weekly means of temperature is decidedly the best method of analyzing the annual march of temperature at any place, especially if the record is a relatively short one, as in the case of the observations at Wagon Wheel Gap, values of such weekly means have been computed as in the case of the former discussion and analyzed harmonically in the same way.

The entire body of observations were divided into three groups:

(1) First period, mean weekly temperature from observations from July 2, 1911, to July 2, 1919.

(2) Second period, mean weekly temperature from observations from July 2, 1919, to September 30, 1926.

(3) Whole period, mean weekly temperature from observations from July 2, 1911, to September 30, 1926.

In forming each group of weekly means, the extra day over 52 weeks in a year has been included in the week designated by the central date, July 12, which week contains 8 instead of 7 days, viz, July 9 to 16, inclusive. February 29 on leap years was similarly included in the week designated March 1, viz. February 26 to March 4, inclusive.

While observations of hourly values are available, a correction to reduce the mean of the maximum and minimum to the mean of the 24-hourly values has not been computed or applied for this relatively short period.

A harmonic analysis of long records for a considerable number of stations widely distributed over the United States shows conclusively that the annual march of temperature over large sections, especially in the Northeast, is remarkably well represented by a single fundamental sine curve. Elsewhere such a fundamental and a harmonic of the second order suffice to fit the data in a highly satisfactory manner.

This former conclusion is strictly confirmed by the almost exact identity of the two equations which represent the data for the first and second periods, notwithstanding that the periods are short, that is, comprise means of only 8 and 7 years respectively. We should expect, of course, as we actually find, that the results for the whole period would be a composite of the first and second.

The results of the present analysis were derived by exactly the same methods of computation given in the former report.[2] However, the climatological year is now assumed to begin with the week of which the first day is October 2. This date is chosen to correspond to the hydrologic year beginning October 1. The slight discrepancy between October 1 and October 2 is waived in the interest of preserving a standard schedule of weeks, such that the week of January 1 to 7 necessarily constitutes one of the schedule.

The three equations which represent the normal annual march from the epoch as of October 5, which is the midday of the week October 2 to 9, are:

$$T_1(\text{Fahr}) = 34.9 + 20.9\cos(\theta - 284°\,54') + 1.20\cos 2(\theta - 146°\,10').$$
$$T_2(\text{Fahr}) = 35.1 + 21.0\cos(\theta - 284°\,50') + 1.83\cos 2(\theta - 126°\,13').$$
$$T_3(\text{Fahr}) = 35.0 + 21.4\cos(\theta - 284°\,26') + 1.31\cos 2(\theta - 136°\,48').$$

Table 17 gives the original weekly means from which the equations were computed and the detailed results secured.

are wholly dissimilar, as are also the sinuosities between *c* and *h*. Again, the features from *h* to *m* are likewise quite unlike in the two periods. The curve for the whole period shows these details diminished in magnitude and altered in character, as must be expected in short records of this character.

In spite of these variations in details the close identity of the harmonic terms, each to each, in the separate groups, is striking. The time of the maximum (February 12) of the second harmonic is about two weeks earlier in the second period than in the first. This implies a more rapid advance or onset of summer temperatures during the second period, that is, less lag in heating up in the spring as well as cooling off during the fall season.

Meaning of the second harmonic.—It is necessary to have a proper understanding of the significance of the second harmonic, which appears well defined in all temperature records. *Its presence does not signify that any definite influence is operating which causes the temperature to rise and fall periodically twice a year.* That is, the

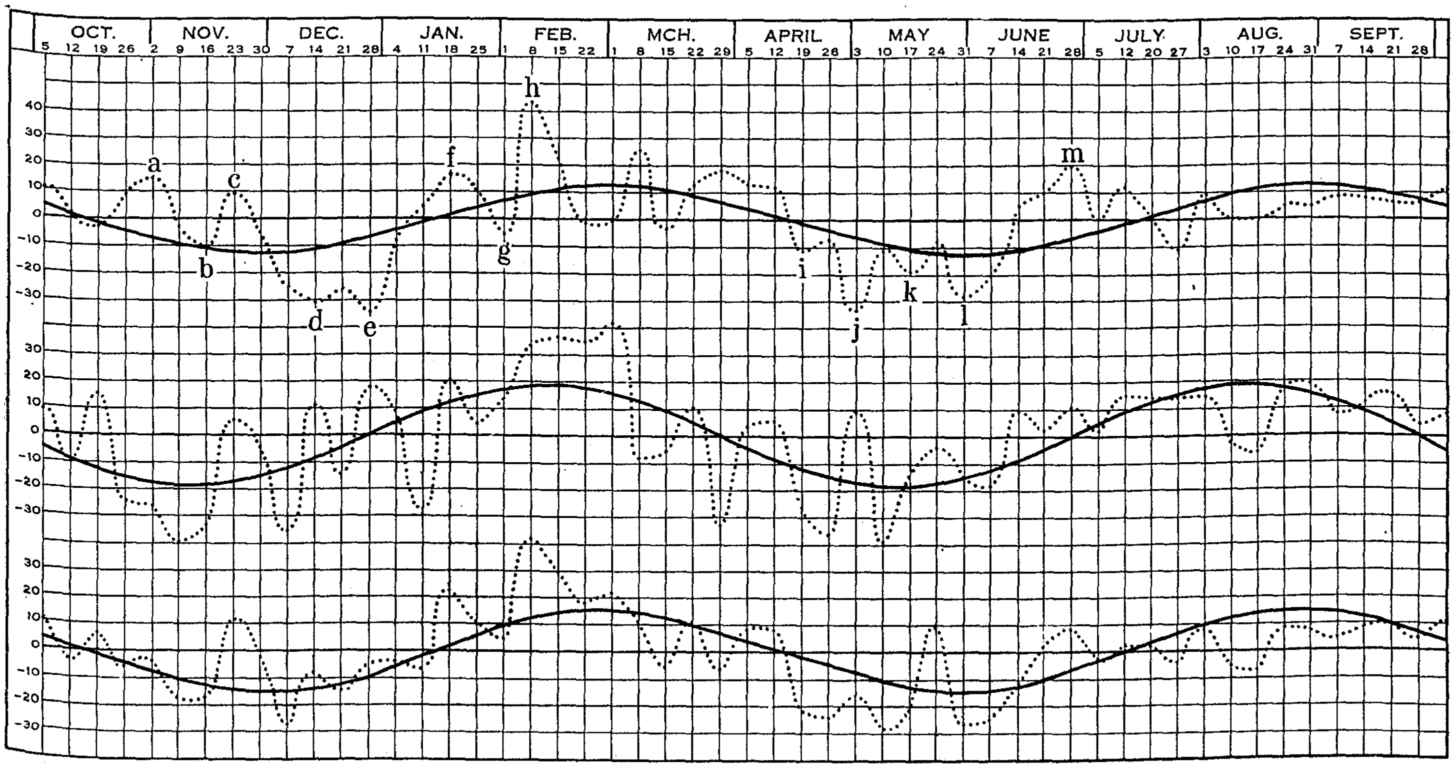


FIG. 23. Annual march of temperatures at Wagon Wheel Gap, arranged for the second harmonic

Figure 23 shows in a very graphic way the important features of Table 17. The sinuous dotted lines shows the irregular fluctuations $y-y'$ of the actual weekly values of temperature with reference to the smooth annual march of temperature represented by the fundamental first harmonic. The smooth second harmonic is shown threading its way through the larger seasonal departures from the fundamental. Visual inspection, as well as calculation, shows that no short period or higher harmonic of definite character exists. In other words, the irregular fluctuations like those marked a b c * * * m in the curve for the first period are only rarely duplicated by like features in the curve for the second period. The curve for the whole period is necessarily a composite of the first and second.

Analyzing these features in more detail, it is seen that while the feature at *c*, for example, appears in both periods those at *a* and *b*

[2] Mo. Wea. Rev Supp. 17, referred to elsewhere.

actual annual march of surface temperature is a very definite periodic function, but *the wave form is unsymmetrical.* A sine or cosine curve, however, is a perfectly symmetrical wave form, and therefore, if used alone, its fit to the observations is imperfect, but in combination with a second harmonic having but a small phase difference the unsymmetrical features of the data are almost perfectly satisfied.

Reasoning of this kind should be invoked in the interpretation of many cases of periodogram analyses, because a conspicuous period and its octave *when in appropriate phase relations* suggest a periodic function of *unsymmetrical wave form.*

It seems unnecessary to repeat here the significance which attaches to the features shown in Figure 23. These were fully discussed in the former analysis, and the special student should refer to that and develop for himself the meaning and influence on streamflow of the striking sinuousities shown in Figure 23.

TABLE 17.—*Observed and normal weekly temperatures, station A, Wagon Wheel Gap, Colo., July, 1911, to September 30, 1926*

[The dates give the midday of each week of the schedule]

Date	First period					Second period					Whole period				
	y observed	y′ first harmonic	Difference y-y′	Second harmonic	Normal temperature	y observed	y′ first harmonic	Difference y-y′	Second harmonic	Normal temperature	y observed	y′ first harmonic	Difference y-y′	Second harmonic	Normal temperature
Oct. 5	41.3	40.2	+1.1	+0.45	40.7	41.3	40.5	+0.8	−0.5	40.0	41.3	40.3	+1.0	+0.4	40.7
Oct. 12	37.9	37.8	+.1	+.17	37.9	37.0	38.0	−1.0	−.9	37.1	37.5	37.8	−.3	+.1	37.9
Oct. 19	34.9	35.2	−.3	−.12	35.1	37.0	35.5	+1.5	−1.3	34.2	35.9	35.2	+.7	−.2	35.0
Oct. 26	33.6	32.7	+.9	−.40	32.3	30.3	32.9	−2.6	−1.5	31.4	32.1	32.6	−.5	−.6	32.0
Nov. 2	31.7	30.2	+1.5	−.66	29.6	27.7	30.4	−2.7	−1.7	28.7	29.8	30.1	−.3	−.8	29.3
Nov. 9	27.5	27.8	−.3	−.88	26.9	24.0	28.0	−4.0	−1.8	26.2	25.9	27.6	−1.7	−1.1	26.5
Nov. 16	24.4	25.5	−1.1	−1.06	24.4	22.4	25.7	−3.3	−1.8	23.9	23.5	25.2	−1.7	−1.2	24.0
Nov. 23	24.2	23.3	+.9	−1.16	22.1	24.0	23.5	+.5	−1.7	21.8	24.1	23.0	+1.1	−1.4	21.6
Nov. 30	20.5	21.2	−.7	−1.20	20.0	21.1	21.5	−.4	−1.4	20.1	20.8	21.0	−.2	−1.4	19.6
Dec. 7	16.8	19.4	−2.6	−1.18	18.2	16.0	19.6	−3.6	−1.1	18.5	16.4	19.1	−2.7	−1.3	17.8
Dec. 14	14.7	17.8	−3.1	−1.08	16.7	19.1	18.1	+1.0	−.8	17.3	16.7	17.5	−.8	−1.2	16.3
Dec. 21	13.9	16.5	−2.6	−.92	15.6	15.3	16.7	−1.4	−.4	16.3	14.7	16.2	−1.5	−1.0	15.2
Dec. 28	12.0	15.4	−3.4	−.71	14.7	17.4	15.6	+1.8	+.1	15.7	14.7	15.1	−.4	−.7	14.4
Jan. 4	13.7	14.6	−.9	−.45	14.2	15.6	14.8	+.8	+.5	15.3	13.9	14.3	−.4	−.4	13.9
Jan. 11	14.5	14.1	+.4	−.17	13.9	11.6	14.3	−2.7	+.9	15.2	13.1	13.8	−.7	−.1	13.7
Jan. 18	15.6	13.9	+1.7	+.12	14.0	16.1	14.1	+2.0	+1.3	15.4	15.8	13.6	+2.2	+.2	13.8
Jan. 25	15.0	14.0	+1.0	+.40	14.4	14.7	14.3	+.4	+1.5	15.8	14.9	13.7	+1.2	+.6	14.3
Feb. 1	13.8	14.4	−.6	+.66	15.1	15.9	14.7	+1.2	+1.7	16.4	14.7	14.2	+.5	+.8	15.0
Feb. 8	19.5	15.1	+4.4	+.88	16.0	18.7	15.4	+3.3	+1.8	17.2	19.1	14.9	+4.2	+1.1	16.0
Feb. 15	18.3	16.1	+2.2	+1.06	17.2	20.0	16.4	+3.6	+1.8	18.2	18.9	15.9	+3.0	+1.2	17.1
Feb. 22	17.3	17.4	−.1	+1.16	18.6	21.1	17.6	+3.5	+1.7	19.3	19.1	17.3	+1.8	+1.4	18.7
Mar. 1	18.8	18.9	−.1	+1.20	20.1	23.3	19.2	+4.1	+1.4	20.6	20.9	18.8	+2.1	+1.4	20.2
Mar. 8	23.3	20.7	+2.6	+1.18	21.9	20.0	20.9	−.9	+1.1	22.0	21.7	20.6	+1.1	+1.3	21.9
Mar. 15	22.2	22.6	−.4	+1.08	23.7	22.3	22.9	−.6	+.8	23.7	22.2	22.7	−.5	+1.2	23.9
Mar. 22	26.0	24.8	+1.2	+.92	25.7	26.0	25.0	+1.0	+.4	25.4	26.0	24.9	+1.1	+1.0	25.9
Mar. 29	28.9	27.1	+1.8	+.71	27.8	24.0	27.3	−3.3	−.1	27.2	26.6	27.2	−.6	+.7	27.9
Apr. 5	30.9	29.5	+1.4	+.45	29.9	30.0	29.7	+.3	−.5	29.2	30.5	29.7	+.8	+.4	30.1
Apr. 12	33.1	31.9	+1.2	+.17	32.1	32.7	32.2	+.5	−.9	31.3	33.0	32.2	+.8	+.1	32.3
Apr. 19	33.4	34.5	−1.1	−.12	34.3	31.9	34.7	−2.8	−1.3	33.4	32.7	34.8	−2.1	−.2	34.6
Apr. 26	36.2	37.0	−.8	−.40	36.6	33.7	37.3	−3.6	−1.5	35.8	35.0	37.4	−2.4	−.6	36.8
May 3	36.2	39.5	−3.3	−.66	38.8	40.7	39.8	+.9	−1.7	38.1	38.3	39.9	−1.6	−.8	39.1
May 10	40.8	41.9	−1.1	−.88	41.0	38.3	42.2	−3.9	−1.8	40.4	39.6	42.4	−2.8	−1.1	41.3
May 17	42.3	44.2	−1.9	−1.06	43.2	43.1	44.5	−1.4	−1.8	42.7	42.7	44.8	−2.1	−1.2	43.6
May 24	45.6	46.4	−.8	−1.16	45.3	46.3	46.7	−.4	−1.7	45.0	47.9	47.0	+.9	−1.4	45.6
May 31	45.5	48.4	−2.9	−1.20	47.2	47.3	48.7	−1.4	−1.4	47.3	46.3	49.0	−2.7	−1.4	47.6
June 7	48.3	50.3	−2.0	−1.18	49.1	48.7	50.6	−1.9	−1.1	49.5	48.5	50.9	−2.4	−1.3	49.6
June 14	52.3	51.9	+.4	−1.08	50.8	53.0	52.1	+.9	−.8	51.3	52.6	52.5	+.1	−1.2	51.3
June 21	54.1	53.2	+.9	−.92	52.3	53.7	53.5	+.2	−.4	53.1	53.9	53.8	+.1	−1.0	52.8
June 28	56.2	54.3	+1.9	−.71	53.6	55.7	54.6	+1.1	+.1	54.7	55.9	54.9	+1.0	−.7	54.2
July 5	55.1	55.1	±0.0	−.45	54.6	55.6	55.4	+.2	+.5	55.9	55.4	55.7	−.3	−.4	55.3
July 12	56.8	55.6	+1.2	−.17	55.4	57.4	55.9	+1.5	+.9	56.8	56.4	56.2	+.2	−.1	56.1
July 20	55.9	55.8	+.1	+.12	55.9	57.5	56.1	+1.4	+1.3	57.4	56.6	56.4	+.2	+.2	56.6
July 27	54.6	55.7	−1.1	+.40	56.1	57.3	55.9	+1.4	+1.5	57.4	55.9	56.3	−.4	+.6	56.9
Aug. 3	56.2	55.3	+.9	+.66	56.0	56.9	55.5	+1.4	+1.7	57.2	56.6	55.8	+.8	+.8	56.6
Aug. 10	54.6	54.6	±0.0	+.88	55.4	54.5	54.8	−.3	+1.8	56.6	54.6	55.1	−.5	+1.1	56.2
Aug. 17	53.6	53.6	±0.0	+1.06	54.6	53.2	53.8	−.6	+1.8	55.6	53.4	54.1	−.7	+1.2	55.3
Aug. 24	52.8	52.3	+.5	+1.16	53.5	54.4	52.6	+1.8	+1.7	54.3	53.6	52.7	+.9	+1.4	54.1
Aug. 31	51.2	50.8	+.4	+1.20	52.0	52.9	51.0	+1.9	+1.4	52.4	52.0	51.2	+.8	+1.4	52.6
Sept. 7	49.8	49.0	+.8	+1.18	50.2	50.0	49.3	+.7	+1.1	50.4	49.9	49.4	+.5	+1.3	50.7
Sept. 14	47.8	47.1	+.7	+1.08	48.2	48.5	47.3	+1.2	+.8	48.1	48.1	47.3	+.8	+1.2	48.5
Sept. 21	45.5	44.9	+.6	+.92	45.8	46.7	45.2	+1.5	+.4	45.6	46.1	45.1	+1.0	+1.0	46.1
Sept. 28	43.2	42.6	+.6	+.71	43.3	43.4	42.9	+.5	−.1	42.8	43.3	42.8	+.5	+.7	43.5

SOUTH SLOPE TEMPERATURES

The south slope of each watershed is somewhat warmer than the north slope, but the excess in the monthly means is generally less than a whole degree, except that for the cold months, November to March, it may amount to as much as 2° or 3°. The excess in monthly means for these months, south over north slope, is as follows:

	November	December	January	February	March
Watershed A	2.1	1.8	1.8	1.6	0.6
Watershed B	2.5	3.0	2.7	2.6	1.8

This comparison is based upon monthly means that have been derived from the daily extremes instead of the 24-hourly readings. A series of corrections to reduce the means derived from the daily extremes to the true daily means shows that for watershed A the mean temperature, maximum and minimum, divided by 2, gives results that are in excess of the true daily means by amounts varying from 0° in February to 2.1° in August. In general, the corrections for the summer months in both watersheds are the greatest. In the B watershed small positive and negative corrections offset each other in the mean, with the result that in three months of the year the correction is zero. In the A watershed positive corrections were rarely found in the individual months and not at all in the final means. Further analysis of the excess in monthly mean temperature as above shows that this excess is due to higher maxima on the south slopes of the respective watersheds, thus:

	Excess of maxima on south over north slope (31 months' observations), means for—				
	November	December	January	February	March
Watershed A	3.6	3.3	3.4	2.7	0.8
Watershed B	5.3	4.9	5.0	4.4	3.3

The mean minima for the identical periods are slightly higher for the south than for the north slopes, although the greatest excess for any month does not equal 1°. If we go still farther and make an intercomparison between corresponding slopes of the two watersheds it is found that the mean temperature, regardless of how obtained, is substantially the same. It is obvious that the amount of solar energy received on each unit of surface in the south slopes is greater than on north slopes because the sun's rays are very nearly perpendicular at certain hours of the day. Since, however, only a small part of the solar energy is absorbed by the atmosphere, we should expect little effect upon air temperature as compared with soil temperature. The greatest effect of south slope insolation may be looked for in snow melting around and near objects which reflect the solar rays or absorb and reradiate them.

Prof. H. H. Kimball of the Weather Bureau has computed the amount of solar radiation in gram-calories (amount of heat required to raise the temperature of a gram of water 1° C.) for each of the north and south slope stations on both watersheds. The results are given in Table 18. This table shows that while the total radiation per unit of surface which falls upon the two south-slope stations is practically the same, the amount which falls upon the two north-slope stations is slightly different at different seasons. For the vernal equinox—the time of snow melting—solar radiation becomes effective at B–1 a little earlier in the morning than at A–1, but, on the other hand, the intensity of radiation at A–1 reaches a higher value than at B–1. The maximum at A–1 is 0.61 gram-calorie per minute at 1 p. m., whereas the maximum at B–1 is but 0.46 gram-calorie per minute at 11 a. m. A is constantly higher than B from 10 a. m. to 5 p. m., and the difference is especially noticeable in the afternoon hours. The daily excess A–1 over B–1 is 78 gram-calories.

THE EFFECT OF SLOPE UPON THE QUANTITY OF SOLAR RADIATION RECEIVED PER UNIT OF SURFACE

PROF. H. H. KIMBALL

Let λ equal the latitude of the place, and C the angle of slope. For a south slope the angle of incidence of the solar rays with the surface for different hour angles of the sun will be the same as on a horizontal surface at latitude $\lambda - C$. The possible hours of sunshine with *south* or *minus* solar declination will not be changed; but for *north* or *plus* solar declination they will be the same as for latitude $\lambda - C$. For a north slope the angle of incidence of the solar rays with the surface for different hour angles of the sun will be the same as at latitude $\lambda + C$. The possible hours of sunshine with *north*, or *plus* solar declination will not be changed; but for *south*, or *minus* declination they will be the same as for latitude $\lambda + C$.

Thus, on a south slope of 7 per cent, or 4°, at latitude 35°, the angle of incidence of the solar rays will be the same as on a horizontal surface at 31° N., and on a south slope of 35°, or 70 per cent, at latitude 35°, the angle of incidence of the solar rays will be the same as on a horizontal surface at the Equator, and from March 21 to September 21, inclusive, the hours of possible sunshine will likewise be the same, namely, 12 hours. On a north slope of 45°, or 100 per cent, at latitude 45° N., the angle of incidence of the solar rays will be the same as on a horizontal surface at the North Pole. It will receive sunshine only between March 21 and September 21, and the possible hours of sunshine will be the same as at latitude 45°. Such a surface will therefore receive less solar radiation than a horizontal surface at the North Pole.

In the case of a slope facing α degrees in azimuth, the angle of incidence of the solar rays will be the same as on a horizontal surface at a point which lies C degrees distant on the great circle that makes the angle α with the meridian. We may locate this point in latitude and longitude by the solution of the right-angled spherical triangle of which C, the angle of slope, is the hypotenuse; α is one of the angles, the side b is the difference in latitude between the point and the slope, and side a is the difference in longitude. The computation equations are $\tan b = \frac{\cos \alpha}{\cos c}$ and $\sin a = \sin \alpha \sin c$.

Example: At Wagon Wheel Gap, Colorado, at latitude 37° 46′ N., longitude 106° 53′ W., and elevation about 10,000 feet, are four slopes, A–2, B–2, A–1, and B–1, facing south 56° east, south 45° east, north 24° west, and north 24° east, and with angular slopes of 34° 20′, 30°, 31° 20′, and 37° 30′, respectively. The points where horizontal surfaces are parallel to these slopes are as follows:

A–2, latitude 16° 52′ N., longitude 79° W.
B–2, latitude 15° 34′ N., longitude 86° 11′ W.
A–1, latitude 66° 51′ N., longitude 119° 6′ W.
B–1, latitude 72° 48′ N., longitude 92° 33′ W.

The solar-radiation intensities upon these slopes has been computed upon the assumption that at normal incidence the intensity is as given in Table 5c, MONTHLY WEATHER REVIEW, November, 1919, **47**: 774 for latitude 37° 46′ N. increased by 1 per cent for the increased elevation at Wagon Wheel Gap. The results are given in Table 18.

On slopes A–2 and B–2, where the radiation intensity is high throughout the year, the snow that falls disappears quickly, as elsewhere shown. On slopes A–1 and B–1, which receive no direct solar radiation in midwinter and a greatly reduced amount throughout the year, the snow accumulates to a great depth.

TABLE 18.—*Radiation intensity upon slopes at Wagon Wheel Gap, Colo.*

[Gram calories per minute per square centimeter of surface. Apparent Time]

Slope	Date	Gram calories 5 a. m.	6 a. m.	7 a. m.	8 a. m.	9 a. m.	10 a. m.	11 a. m.	12 m.	1 p. m.	2 p. m.	3 p. m.	4 p. m.	5 p. m.	6 p. m.	7 p. m.	8 p. m.	Daily total
A–2	Dec. 21	......	......	......	0.53	0.92	1.08	1.09	0.98	0.77	0.50	0.18	......	......	......	......	......	379
	Mar. 21	......	0.07	0.73	1.11	1.34	1.45	1.44	1.31	1.08	.77	.41	......	......	......	......	......	588
	June 21	0.12	.51	.84	1.12	1.29	1.40	1.39	1.27	1.28	1.07	.80	0.17	......	......	......	......	643
B–2	Dec. 21	......	......	......	.49	.89	1.06	1.13	1.07	.89	.78	.32	.03	......	......	......	......	402
	Mar. 21	......	.06	.63	1.02	1.29	1.44	1.48	1.40	1.20	.92	.57	.21	......	......	......	......	596
	June 21	.08	.41	.74	1.03	1.25	1.38	1.41	1.34	1.17	.93	.64	.32	0.01	......	......	......	641
A–1	Jan. 21	......	......	......	......	......	......	.02	.08	.08	.01	......	......	......	......	......	......	11
	Feb. 21	......	......	......	......	.06	.15	.26	.32	.33	.29	.22	.11	.01	......	......	......	105
	Mar. 21	......	......	.03	.17	.32	.45	.55	.60	.61	.57	.49	.36	.20	0.01	......	......	259
	June 21	.03	.28	.45	.65	.82	.96	1.06	1.11	1.12	1.07	.98	.87	.63	.42	0.06	......	608
B–1	Feb. 21	......	......	......	.04	.11	.15	.17	.16	.12	.05	......	......	......	......	......	......	46
	Mar. 21	......	.01	.17	.29	.38	.44	.46	.45	.40	.33	.23	.11	.09	......	......	......	181
	June 21	.15	.43	.61	.74	.84	.90	.93	.93	.88	.80	.71	.59	.45	.30	.11	......	555

SOIL TEMPERATURE

The superficial soil layers receive and absorb incoming solar energy by day and lose heat as outgoing radiation both by day and by night. Whenever, therefore, the incoming radiation is in excess of the outgoing, the temperature of the soil rises and in due season reaches an annual maximum, thence receding to the annual minimum in midwinter. As in air temperature, there are also short periods of temporary rises and falls in the temperature of the soil. The magnitude of these fluctuations is largely a matter of the depth below the surface at which measurements are made. In this discussion we are concerned almost wholly with the seasonal changes at a depth of 12 inches, although observations of soil temperatures at a depth of 48 inches are also available. Between 13 and 14 years observations are available for both watersheds, and also for the D station representing the extreme upper portion of watershed A.

Very decided topographic contrasts are responsible for the differences in both air and soil temperatures, particularly the latter, which are found to exist between north and south slopes of the same watershed. It is impracticable to combine the soil observations into a mean that will truly represent the watershed as a whole; hence this discussion will be of corresponding slopes on the two watersheds. The south slopes form approximately 30 per cent of the total area of the respective watersheds. Strictly speaking, the values of Tables 19 to 26 refer only to the areas in the immediate vicinity of the observing stations.

TABLE 19.—*Mean soil temperature, watershed A, north slope, at 12 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911-12	----	----	----	----	----	----	25.5	32.0	37.8	44.2	46.6	39.6	----
1912-13	32.5	30.8	21.2	17.9	18.8	20.9	26.6	32.3	37.3	45.8	47.2	41.8	31.1
1913-14	32.5	29.9	23.0	20.8	19.3	20.2	27.1	32.1	38.5	47.6	48.1	41.2	31.7
1914-15	33.7	28.1	18.8	17.2	19.2	21.2	28.1	32.4	36.5	44.4	45.7	41.5	30.6
1915-16	32.9	28.9	23.6	21.9	21.1	23.3	27.1	32.3	38.3	47.4	49.0	40.3	32.2
1916-17	34.6	25.5	19.1	18.0	18.9	19.7	23.6	30.6	34.3	43.8	46.2	41.9	29.7
1917-18	33.3	25.4	20.1	19.9	18.6	23.4	26.7	31.8	39.9	47.7	47.4	41.4	31.6
1918-19	35.5	30.6	23.2	18.4	17.8	18.7	25.9	32.1	37.4	47.7	48.5	44.0	31.3
Postdenudation period:													
1919-20	32.6	27.0	24.7	18.9	19.6	20.4	22.9	30.8	37.9	44.7	47.2	39.6	30.5
1920-21	33.4	29.8	23.2	20.3	19.9	23.3	26.0	32.4	39.8	47.0	48.9	40.8	32.1
1921-22	34.5	26.0	21.1	19.6	16.7	19.8	24.0	32.0	39.2	46.9	50.1	43.1	31.1
1922-23	33.1	26.7	24.5	20.0	19.1	20.9	25.4	32.8	39.3	46.9	48.3	39.9	31.4
1923-24	32.7	30.6	24.1	19.7	18.0	21.8	23.9	30.5	36.6	44.6	45.4	40.3	30.7
1924-25	31.9	26.4	23.0	16.9	20.5	22.9	29.2	34.5	42.1	49.9	49.2	43.6	32.5
1925-26	34.3	30.4	23.5	20.2	19.2	21.3	26.5	32.1	39.7	45.6	46.9	43.0	31.9
General average	33.4	28.3	22.4	19.3	19.0	21.3	25.9	32.0	38.3	46.3	47.6	41.5	31.5
Predenudation average	33.6	28.5	21.3	19.2	19.1	21.1	26.3	32.0	37.5	46.1	47.3	41.5	31.6
Postdenudation average	33.2	28.1	23.4	19.4	19.0	21.5	25.4	32.2	39.2	46.5	48.0	41.5	31.5

TABLE 20.—*Mean soil temperature, watershed B, north slope, at 12 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911	----	----	----	----	----	----	30.3	35.8	----	48.5	48.9	44.7	----
1911-12	38.6	33.7	28.1	25.4	24.6	25.9	27.6	31.7	39.4	44.9	47.8	43.1	34.2
1912-13	35.5	30.0	23.2	21.7	21.8	23.4	28.2	34.7	42.2	48.2	49.2	43.8	33.5
1913-14	34.7	31.5	27.0	25.1	25.4	26.0	29.9	34.8	43.9	48.7	49.6	44.3	35.1
1914-15	36.5	31.0	23.9	21.2	22.5	23.2	29.5	34.2	42.0	49.1	48.6	44.4	33.8
1915-16	36.9	32.2	27.2	26.3	26.3	28.0	30.3	36.3	45.6	50.1	49.5	43.6	36.0
1916-17	36.9	29.9	23.1	20.8	22.5	22.1	26.2	30.6	37.0	47.2	47.2	44.1	32.2
1917-18	38.1	31.6	27.2	24.5	23.6	27.2	29.0	35.9	45.7	48.4	48.2	43.4	35.2
1918-19	39.0	30.9	26.9	24.6	23.3	24.0	28.7	35.4	42.6	51.5	52.5	47.6	35.6
Postdenudation period:													
1919-20	36.1	31.4	25.5	28.7	28.0	28.1	29.7	32.8	45.9	52.9	52.5	44.9	36.4
1920-21	37.6	34.2	29.4	26.5	25.7	27.4	29.3	35.0	47.9	54.1	52.4	44.5	37.0
1921-22	38.6	29.7	26.6	27.3	26.6	27.6	28.8	32.9	46.6	54.7	52.6	46.6	36.6
1922-23	37.7	32.0	31.6	29.9	28.8	29.4	30.4	36.0	48.6	53.9	52.1	43.9	37.9
1923-24	36.9	32.6	27.4	25.7	23.9	25.4	30.8	35.4	50.8	57.6	52.8	44.3	37.0
1924-25	35.2	28.2	25.5	22.1	22.9	25.3	29.8	40.0	50.0	55.1	52.4	46.0	36.0
1925-26	37.8	32.4	27.9	23.0	22.2	24.0	28.4	35.8	48.4	50.9	50.6	45.0	35.5
General average	37.1	31.4	26.7	24.9	24.5	25.8	29.1	34.8	45.1	51.2	50.5	44.6	35.5
Predenudation average	37.0	31.4	25.8	23.7	23.8	25.0	28.7	34.2	42.3	48.5	49.1	44.3	34.5
Postdenudation average	37.1	31.5	27.7	26.2	25.4	26.7	29.6	35.4	48.3	54.2	52.2	45.0	36.6
Net results of denudation	+0.5	+0.5	−0.2	+2.3	+1.7	+1.3	+1.8	+1.0	+4.3	+5.3	+2.4	+0.7	+2.2

TABLE 21.—*Mean soil temperature, watershed A, north slope, at 48 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1911-12	----	----	----	----	----	----	----	----	----	----	----	----	----
1912-13											40.6	39.7	----
1913-14	32.9	31.4	29.8	26.7	25.8	25.2	26.4	31.7	32.9	38.4	42.2	39.2	31.9
1914-15	34.1	31.0	28.2	24.2	23.9	23.8	26.3	31.6	32.4	35.5	39.2	38.4	30.7
1915-16	33.1	31.5	30.6	27.8	26.8	26.5	27.3	31.9	32.6	37.2	41.9	38.0	32.1
1916-17	34.1	31.2	29.0	25.5	24.7	24.5	25.2	30.1	32.1	34.5	39.2	38.3	30.7
1917-18	32.4	28.7	29.1	27.9	24.9	25.9	27.0	31.1	33.3	38.7	41.4	38.8	31.6
1918-19	34.7	31.8	29.7	26.1	24.4	23.7	25.9	32.1	32.4	37.7	41.7	40.5	31.7
Postdenudation period:													
1919-20	33.2	31.4	30.2	27.5	26.8	26.3	26.5	30.0	32.8	37.1	41.2	37.7	31.7
1920-21	33.3	31.9	30.4	28.2	26.9	25.7	27.1	31.3	33.9	38.9	42.5	38.9	32.4
1921-22	34.4	29.5	28.5	26.5	23.1	23.6	25.6	31.6	32.6	37.7	42.1	40.0	31.3
1922-23	33.8	31.7	30.0	28.4	27.2	26.9	26.9	31.3	33.1	38.0	41.8	38.4	32.3
1923-24	33.3	32.1	30.7	26.5	24.9	25.3	26.4	31.0	32.7	37.1	40.3	37.6	31.5
1924-25	32.0	30.7	29.0	23.5	23.3	23.9	27.0	32.3	34.2	39.6	41.5	39.4	31.4
1925-26	33.8	31.7	29.8	26.9	25.0	25.0	27.2	32.3	32.7	37.7	41.0	39.7	31.9
General average	33.5	31.1	29.6	26.6	25.2	25.1	26.5	31.4	32.9	37.5	41.2	38.9	31.7
Predenudation average	33.6	30.9	29.4	26.4	25.1	24.9	26.4	31.4	32.6	37.0	40.9	39.0	31.7
Postdenudation average	33.4	31.3	29.8	26.8	25.3	25.2	26.7	31.4	33.1	38.0	41.5	38.8	31.8

TABLE 22.—*Mean soil temperature, watershed B, north slope, at 48 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1913-14	36.3	32.9	31.1	29.2	28.5	28.2	29.3	31.7	35.4	42.9	45.5	42.5	34.5
1914-15	37.3	32.5	26.6	23.7	24.0	25.4	28.1	31.3	33.9	40.5	42.4	41.2	32.2
1915-16	35.8	32.0	29.4	28.2	27.9	28.1	29.3	31.7	35.2	42.8	45.8	42.6	34.1
1916-17	37.6	33.2	29.0	25.8	25.4	25.4	26.7	30.2	32.3	38.2	41.3	40.8	32.2
1917-18	35.8	31.2	28.8	26.7	25.2	27.1	28.8	31.6	37.5	43.3	44.5	42.1	33.6
1918-19	38.0	33.6	31.5	28.7	26.6	26.4	28.8	32.1	34.6	43.0	47.8	46.8	34.8
Postdenudation period:													
1919-20	38.5	33.4	32.2	31.1	30.2	30.0	30.7	32.1	38.7	46.5	49.0	45.5	36.5
1920-21	39.6	35.3	32.6	30.6	29.7	29.9	31.7	33.4	42.2	48.2	49.1	46.1	37.4
1921-22	40.8	32.9	28.9	28.4	27.4	28.4	29.8	32.6	41.2	48.3	48.9	46.9	36.2
1922-23	39.9	32.6	31.9	30.4	28.8	28.4	29.7	33.6	43.0	48.9	49.7	45.5	36.9
1923-24	38.8	34.5	32.0	30.1	28.6	28.6	30.3	32.5	39.8	47.6	48.6	45.6	36.4
1924-25	38.4	32.0	28.7	25.7	25.5	26.8	30.3	35.1	42.2	48.1	48.6	45.8	35.6
1925-26	39.0	34.5	31.7	28.2	26.2	26.8	29.8	32.8	40.8	46.3	48.0	46.1	35.8
General average	38.1	33.1	30.3	28.2	27.2	27.7	29.5	32.4	38.2	45.0	46.9	44.4	35.1
Predenudation average	36.8	32.6	29.4	27.0	26.3	26.8	28.5	31.4	34.8	41.8	44.6	42.7	33.6
Postdenudation average	39.3	33.6	31.1	29.2	28.1	28.4	30.3	33.2	41.1	47.7	48.8	45.9	36.4
Net results of denudation	+2.7	+0.6	+1.3	+1.8	+1.6	+1.3	+1.5	+1.8	+5.8	+4.9	+3.6	+3.4	+2.7

TABLE 23.—*Mean soil temperature, watershed A, south slope, at 12 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1913-14	----	37.7	31.6	29.2	27.0	31.2	34.4	40.8	49.8	53.5	52.8	49.4	----
1914-15	43.3	39.8	30.9	26.4	28.2	28.8	34.2	39.0	49.0	55.0	52.0	49.3	39.7
1915-16	44.8	39.2	33.5	31.0	30.1	33.0	35.7	42.2	51.7	55.0	52.9	49.3	41.5
1916-17	41.9	38.2	32.3	28.6	28.6	27.6	31.7	34.4	47.2	55.7	51.8	49.0	38.9
1917-18	45.9	39.3	34.8	31.2	29.9	33.4	34.6	42.6	52.3	53.0	52.5	48.1	41.5
1918-19	45.0	36.4	30.6	26.6	25.6	28.3	33.5	41.8	48.4	55.2	55.4	52.0	39.9
Postdenudation period:													
1919-20	42.3	36.6	34.6	31.9	30.6	31.1	31.4	38.9	49.3	53.2	53.5	48.4	40.2
1920-21	41.9	35.3	31.3	29.0	27.9	32.2	33.0	39.7	49.6	54.4	53.0	50.7	39.8
1921-22	46.6	40.2	35.1	31.2	29.8	30.1	32.2	40.0	51.5	56.7	54.1	51.6	41.6
1922-23	45.8	36.0	34.7	30.7	28.1	29.0	32.7	42.5	51.5	55.6	53.1	46.3	40.5
1923-24	40.4	35.5	32.0	27.0	29.9	29.5	31.8	41.8	53.1	57.0	54.7	50.9	40.3
1924-25	43.9	37.9	33.6	27.0	29.6	32.2	37.6	45.0	50.0	55.2	52.8	49.4	41.2
1925-26	42.5	35.1	31.7	27.5	29.6	31.5	34.3	41.1	52.4	53.5	54.3	52.0	40.5
General average	43.7	37.5	32.8	29.0	28.8	30.6	33.6	40.8	50.4	54.8	53.3	49.7	40.4
Predenudation average	44.2	38.4	32.3	28.8	28.2	30.4	34.0	40.1	49.7	54.6	52.9	49.5	40.3
Postdenudation average	43.3	36.7	33.3	29.2	29.4	30.8	33.3	41.3	51.1	55.1	53.6	49.9	40.6

TABLE 24.—*Mean soil temperature, watershed B, south slope, at 12 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1913-14	----	35.9	29.2	27.1	26.5	30.7	36.0	42.0	51.2	54.9	54.2	50.5	----
1914-15	42.4	36.9	27.4	22.7	26.2	28.2	35.6	40.7	51.0	56.9	53.4	49.8	39.3
1915-16	42.7	35.6	28.5	27.3	28.7	32.4	37.1	43.9	53.5	55.8	53.6	49.3	40.7
1916-17	41.1	35.3	29.7	26.4	27.0	27.0	32.1	35.8	48.3	56.7	52.4	49.4	38.4
1917-18	43.4	35.0	28.2	26.7	26.6	32.4	35.5	44.0	54.1	54.2	52.9	49.0	40.2
1918-19	44.1	34.4	27.4	24.0	23.6	26.9	34.2	42.8	50.1	56.5	60.2	55.4	40.0
Postdenudation period:													
1919-20	44.5	36.1	38.2	31.4	31.1	31.7	34.6	45.2	53.6	58.7	59.6	52.4	43.1
1920-21	43.8	34.4	30.4	28.8	29.3	33.6	38.3	45.7	55.5	59.2	57.7	55.1	42.6
1921-22	49.4	40.3	33.1	28.6	29.5	31.1	36.4	46.7	57.0	61.4	58.3	56.3	44.0
1922-23	49.5	36.0	32.7	29.0	27.4	31.1	36.7	48.4	55.5	59.6	56.8	51.5	42.8
1923-24	43.8	36.6	33.1	28.9	30.9	32.1	37.6	48.3	59.2	60.6	59.6	56.0	43.9
1924-25	47.5	39.1	32.4	25.8	31.5	35.0	43.2	50.6	53.7	58.2	56.6	54.7	44.0
1925-26	46.2	35.3	31.6	28.2	31.4	35.1	41.0	46.6	57.1	57.6	59.9	57.7	44.0
General average	44.9	36.2	30.9	27.3	28.4	31.3	36.8	44.7	53.8	57.7	56.6	52.9	41.8
Predenudation average	42.7	35.5	28.4	25.7	26.4	29.6	35.1	41.5	51.4	55.8	54.4	50.6	39.8
Postdenudation average	46.4	36.8	33.0	28.7	30.2	32.8	38.3	47.4	55.9	59.3	58.4	54.8	43.5
Net results of denudation	+4.6	+3.0	+3.6	+2.6	+2.6	+2.8	+3.9	+4.7	+3.0	+3.0	+3.3	+3.8	+3.4

TABLE 25.—*Mean soil temperature, watershed A, south slope, at 48 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1913–14	----	----	39.4	36.2	34.9	35.2	37.8	41.3	46.6	51.0	53.1	51.7	----
1914–15	49.1	45.8	40.5	35.9	34.3	33.9	36.3	40.3	45.7	51.7	52.5	52.2	43.2
1915–16	49.0	45.9	40.5	37.3	36.1	36.7	38.7	43.1	48.1	52.6	53.1	51.9	44.4
1916–17	48.2	44.0	39.4	35.6	34.3	33.8	34.0	36.9	43.5	51.3	52.5	51.6	42.1
1917–18	50.3	46.1	41.4	39.0	36.2	37.1	38.9	42.9	48.6	52.2	53.7	51.7	44.8
1918–19	50.2	43.3	37.9	34.2	33.0	32.7	35.5	41.9	47.0	52.9	55.1	54.5	43.2
Postdenudation period:													
1919–20	49.5	43.1	39.5	36.8	35.5	35.1	35.7	40.1	47.4	51.6	53.9	52.2	43.4
1920–21	48.1	40.7	36.5	33.8	32.4	33.5	36.3	40.6	47.4	52.5	53.6	52.9	42.4
1921–22	51.1	46.2	41.1	37.2	34.4	34.6	35.5	40.8	48.9	54.3	54.6	54.4	44.4
1922–23	51.7	43.9	39.3	36.1	34.3	34.4	36.1	41.8	48.2	52.6	53.8	51.9	43.7
1923–24	47.4	42.1	38.2	34.8	33.4	34.1	35.6	42.2	48.8	53.9	54.5	54.0	43.2
1924–25	50.6	45.8	40.7	35.5	35.3	36.7	40.4	45.0	48.9	53.3	53.9	53.2	44.9
1925–26	50.3	43.2	39.0	36.4	34.9	36.6	38.3	42.9	49.4	52.5	54.5	55.3	44.4
General average	49.6	44.2	39.5	36.1	34.5	35.0	36.8	41.5	47.6	52.5	53.8	52.9	43.7
Predenudation average	49.4	45.0	39.8	36.4	34.8	34.9	36.9	41.1	46.6	52.0	53.3	52.3	43.5
Postdenudation average	49.8	43.6	39.2	35.8	34.3	35.0	36.8	41.9	48.4	53.0	54.1	53.4	43.8

TABLE 26.—*Mean soil temperature, watershed B, south slope, at 48 inches*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1913–14	----	----	36.7	33.4	32.4	32.9	35.3	38.8	44.4	48.9	50.3	49.3	----
1914–15	46.3	42.5	37.0	32.4	31.4	31.3	33.5	38.0	43.9	49.8	50.1	49.6	40.5
1915–16	46.0	42.5	36.6	33.3	32.9	33.9	36.1	40.6	46.0	50.0	50.6	49.3	41.5
1916–17	45.6	40.6	36.4	33.4	31.9	31.4	31.9	33.3	40.1	47.8	49.2	48.6	39.2
1917–18	46.6	42.3	36.9	34.3	32.3	33.0	35.7	39.8	45.7	48.7	49.8	48.7	41.2
1918–19	47.0	41.2	36.0	32.4	30.8	30.4	32.6	38.4	43.9	49.3	52.7	53.8	40.7
Postdenudation period:													
1919–20	48.9	42.1	38.2	36.2	35.0	34.3	34.9	40.1	47.2	51.7	54.7	53.5	43.1
1920–21	49.4	41.4	37.2	34.5	33.1	33.1	36.6	41.5	48.0	53.1	54.6	54.3	43.1
1921–22	52.6	47.1	41.0	37.1	35.0	35.0	35.9	41.8	49.2	54.4	55.0	55.0	44.9
1922–23	53.0	45.6	40.2	37.4	35.3	35.1	37.0	43.2	49.8	53.4	54.5	52.9	44.8
1923–24	48.3	42.6	38.1	34.9	33.3	34.0	36.0	43.0	49.9	54.8	55.7	55.1	43.8
1924–25	51.1	45.5	39.5	34.4	34.2	36.0	41.1	46.7	50.6	54.6	54.9	54.3	45.2
1925–26	46.2	42.8	37.6	34.6	33.6	36.1	39.4	44.6	51.4	54.1	55.8	56.5	44.4
General average	48.4	43.0	37.8	34.5	33.2	33.6	35.8	40.8	46.9	51.6	52.9	52.4	42.6
Predenudation average	46.3	41.8	36.6	33.2	32.0	32.2	34.2	38.2	44.0	49.1	50.4	49.9	40.6
Postdenudation average	49.9	43.9	38.8	35.6	34.2	34.8	37.3	43.0	49.4	53.7	55.0	54.5	44.2
Net results of denudation	+3.2	+3.5	+2.8	+3.0	+2.8	+2.5	+3.2	+4.0	+3.6	+3.6	+3.8	+3.5	+3.3

TABLE 27.—*Annual march of soil temperature, north slopes, at 12 inches depth, from weekly averages*

Watershed	Annual extremes				Weekly mean passed—		Length of time	
	Minimum		Maximum		Above 32° in spring	Below 32° in autumn	Above 32°	Below 32°
	° F.	Date	° F.	Date			Weeks	Weeks
A, first period	18.7	Feb. 11	48.1	Aug. 6	May 20	Nov. 5	24	28
B, first period	22.9	Feb. 4	49.3	---do---	May 13	Nov. 19	27	25
A, second period	18.1	Feb. 11	48.9	July 30	May 30	Oct. 20	22	30
B, second period	25.2	Feb. 4	55.1	---do---	May 13	Nov. 19	27	25
Net change, B, second period	+2.9	----------	+5.0	----------	(1)	(2)	+2	−2

[1] 10 days advanced. [2] 7 days retarded.

North slopes at 12 inches (Tables 19 and 20).—Before denudation B was normally 2.9° warmer than A for the whole year, the greatest excess of warmth being experienced from December to February, when the average excess was 4.6°. B did not sink to so low a point in winter as A by about 4° on the monthly average, and, having that amount of advantage in the spring rise, naturally, passed above 32° a little sooner than A. Both watersheds reached their maximum in August and receded thence to the annual minimum, which occurs in February, although the mean soil temperatures of January and February are very nearly equal. The net effect of denudation was to increase the excess of B 2.2° for the year, the greatest increase being felt in June and July, probably owing to the earlier snow melting.

South slopes at 12 inches (Tables 23 and 24).—The temperatures of the two south slopes at 12 inches were before denudation much nearer to equality on the average of the year than those of the north slopes at the same depth, A being slightly warmer. The difference between the annual means was but 0.5°, and this difference was made up of an excess of warmth on A during the cold half of the year and a deficit during the warm half. The effect of denunation was to make B 2.9° warmer than A, or, in other words, to increase B 3.4°.

North slopes at 48 inches (Tables 21 and 22).—At 48 inches the temperature differences were much less pronounced before denudation than at 12 inches, B being 1.9° warmer than A on the annual average and the excess being rather uniformly distributed throughout the year, with somewhat greater excesses during the warm months. The net effect of denudation was to add 2.7° to the excess of B over A.

South slopes at 48 inches (Tables 25 and 26).—These south-slope temperatures differ rather widely from each other, as may be seen from the tables. B was originally 2.9° cooler than A, but this difference was more than made up after denudation, the net increase of B being 3.3°.

Lag between air and soil temperatures.—The weekly means of soil temperatures (not reproduced) show when certain critical temperatures occur, as for example the annual minimum and maximum, and the dates of passing above and below freezing. These data are summarized in Table 27.

As might be expected, the annual maximum soil temperature is reached on the south slope and at the D station about a month earlier than on the north-slope stations. At D there is no appreciable lag at a depth of 12 inches; at 48 inches the lag is about a month. The north slope of B appears to respond to insolation more readily than the corresponding slope of A; it is consistently warmer and in some years the annual maximum soil temperature is reached concurrently with the annual maximum air temperature. This happened on the A watershed in but a single year, viz, 1917.

Influence of snow cover.—With the coming of a snow cover in autumn, even though light, the soil temperature to a depth of 12 inches sinks for several days and continues to fall slowly until it reaches the winter minimum during the first week in February on B and the second week on A. The rate of this fall seems to depend upon the soil temperature at the time; thus, a relatively light snow cover when the soil temperature is 4° or 5° above freezing will cause a steady fall for five days at least, amounting on the average to about a degree a day. If, however, the soil temperature is near the freezing point when the snow comes, the fall in temperature will average but a fraction of a degree a day and may even rise slightly for a day or so. The cooling appears to be nearly equal on the two watersheds, if anything a little greater on A than B, the north slope temperature also sinking to a lower level on A than on B.

The soil on the south slopes naturally responds to insolation more freely than that on the north slopes for reasons before given, also because of the fact that since the snow cover melts earlier, the bare soil begins to receive and absorb solar heat about a month sooner than on the north slopes.

RELATIVE HUMIDITY

The relative humidity may be defined as the ratio of the amount of vapor actually present to that which might be present if the air were saturated at the existing temperature. It is commonly expressed as a percentage. Humidity may also be expressed in the expansive force the vapor exerts or in its weight in grains per cubic foot of air. In this case the amount of vapor actually present at any time is called the absolute humidity.

The relative humidity was determined daily from observations of the sling psychrometer about 9 a. m. at the two north-slope stations, which also were equipped with hygrographs of the Richards type. The numerical values from the hygrographs in terms of vapor pressure were tabulated for about a year, but on account of the very considerable labor involved in the tabulation and the problematical value of the results the tabulation of the hourly values was discontinued early in the experiment. The fragmentary hourly values show that the pressure of water vapor in winter is at a maximum during the warmer hours of the day. As the warm season approaches, however, the maximum occurs in the forenoon hours, 9 or 10 o'clock, and continues to occur about these hours, until November, when it reverts to the afternoon hours.

The relative humidity is generally greatest in the cold part of the year and least in the warm part. The extreme values (monthly means considered) are for B–1, 78 per cent in December and 47.4 per cent in May; for A–1, 71.5 per cent in August and 43.8 per cent in May.

THE TWO WATERSHEDS COMPARED

The record of humidity in the Wagon Wheel Gap area has been more or less puzzling from the beginning, because of unexpectedly large local variations between the two watersheds, at times as much as 25 per cent, although the two observing points are less than a mile apart.

Table 28 contains the monthly means of relative humidity derived from a single observation made daily at 9 a. m. at the north-slope stations of the two watersheds from 1910 to 1919.

TABLE 28.—*Monthly mean relative humidity on both north slopes, January, 1911, to December, 1918*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
A–1	67.3	67.0	61.3	55.8	43.8	48.5	68.1	71.5	67.6	63.0	64.1	70.1	62.3
B–1	77.0	74.6	67.6	61.1	47.4	47.5	66.8	70.6	70.1	68.8	71.8	78.0	66.8

It is clear from the above figures that the relative humidity of watershed B was considerably greater in the months October to May and slightly less in the months June to August than that of A for the corresponding months. The changes in relative humidity from one month to the next are worthy of notice. In general, the relative humidity diminishes to a minimum in May on both watersheds, the diminution from April to May amounting on the average to 12 or 14 per cent. From the minimum of May to the beginning of the rainy season in July there is a decided increase which comes almost wholly in the period June to July. This increase amounts to nearly 20 per cent on the average, although in a single year, 1916, it amounted to 39.5 per cent.

The vapor pressures are computed, of course, with regard for the existing temperatures, and are therefore a better index of the moisture content of the atmosphere than is the relative humidity. The figures in Tables 29 and 30 show that the moisture content of the air at the B–1 station is slightly greater than for the corresponding slope of A throughout the year. This constant difference in the means is rather puzzling. The wind movement at the B–1 station is very weak—less than 1 mile per hour. To determine whether the difference in the means is due to large and infrequent differences in the monthly means or to small and constant differences, Table 31 has been formed.

TABLE 29.—*Mean vapor pressure, 9 a. m.—Station A–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910–11	-----	0.098	0.066	0.080	0.067	0.087	0.113	0.110	0.204	0.319	0.269	0.235	-----
1911–12	0.121	.062	.040	.045	.049	.084	.083	.103	.189	.267	.244	.136	0.119
1912–13	.119	.062	.040	.044	.050	.060	.093	.122	.195	.243	.268	.192	.124
1913–14	.106	.094	.043	.055	.043	.057	.102	.154	.189	.316	.270	.198	.136
1914–15	.131	.064	.046	.036	.051	.059	.132	.121	.130	.222	.224	.187	.117
1915–16	.091	.068	.056	.059	.055	.078	.100	.103	.152	.272	.282	.176	.124
1916–17	.133	.062	.046	.041	.052	.050	.095	.128	.168	.292	.258	.202	.127
1917–18	.103	.078	.063	.053	.064	.096	.078	.091	.252	.303	.269	.208	.138
1918–19	.144	.071	.058	.038	.049	.080	.115	.158	.188	.327	.263	.231	.144
Postdenudation period:													
1919–20	.108	.081	.055	.054	.067	.063	.082	.145	.224	.286	.265	.183	.134
1920–21	.120	.070	.048	.061	.052	.085	.085	.137	.211	.311	.306	.178	.139
1921–22	.136	.075	.078	.041	.061	.068	.102	.149	.209	.279	.329	.233	.147
1922–23	.126	.081	.065	.058	.049	.069	.110	.155	.191	.332	.298	.209	.145
1923–24	.128	.076	.069	.040	.072	.065	.107	.160	.218	.307	.258	.171	.139
1924–25	.123	.081	.059	.046	.061	.078	.109	.171	.225	.324	.286	.220	.149
1925–26	.130	.070	.055	.048	.063	.084	.132	.201	.230	.293	.274	.214	.150
General average	.121	.073	.055	.048	.056	.072	.102	.140	.198	.292	.273	.196	.135
Predenudation average	.118	.070	.049	.046	.052	.070	.100	.122	.183	.280	.260	.191	.129
Postdenudation average	.124	.076	.061	.050	.061	.073	.104	.160	.215	.305	.288	.201	.143

TABLE 30.—*Mean vapor pressure, 9 a. m.—Station B–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910–11	-----	0.095	0.066	0.078	0.066	0.091	0.122	0.127	0.209	0.316	0.268	0.244	-----
1911–12	0.138	.069	.042	.045	.051	.079	.090	.121	.207	.279	.262	.154	0.128
1912–13	.136	.071	.042	.049	.054	.069	.111	.143	.228	.272	.298	.208	.140
1913–14	.118	.106	.048	.066	.050	.069	.122	.173	.213	.336	.285	.211	.150
1914–15	.146	.071	.052	.043	.060	.067	.150	.135	.143	.240	.248	.204	.130
1915–16	.105	.077	.064	.068	.060	.092	.120	.119	.124	.290	.301	.188	.134
1916–17	.148	.068	.058	.046	.059	.058	.104	.145	.157	.283	.262	.214	.134
1917–18	.100	.082	.062	.055	.063	.101	.103	.126	.286	.316	.277	.214	.149
1918–19	.149	.069	.055	.036	.049	.078	.124	.176	.194	.324	.265	.239	.146
Postdenudation period:													
1919–20	.113	.082	.052	.051	.068	.064	.092	.174	.238	.306	.284	.196	.143
1920–21	.118	.071	.046	.056	.052	.099	.105	.154	.218	.317	.312	.210	.146
1921–22	.153	.078	.078	.040	.064	.072	.107	.158	.237	.296	.316	.206	.150
1922–23	.113	.076	.059	.051	.046	.068	.109	.157	.209	.334	.297	.208	.144
1923–24	.127	.074	.064	.037	.068	.065	.109	.173	.219	.306	.252	.180	.140
1924–25	.125	.074	.056	.041	.057	.082	.122	.179	.230	.324	.297	.223	.151
1925–26	.134	.067	.056	.050	.063	.089	.140	.199	.238	.312	.290	.222	.155
General average	.128	.076	.056	.049	.058	.077	.114	.155	.209	.302	.283	.205	.143
Predenudation average	.130	.077	.053	.051	.056	.077	.116	.142	.194	.292	.275	.204	.139
Postdenudation average	.126	.075	.059	.047	.060	.077	.112	.171	.227	.314	.293	.206	.147

TABLE 31.—*Departure of 9 a. m. monthly mean vapor pressure at station B–1 from that at station A–1*

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Predenudation period:							
1911–12	+0.017	+0.007	+0.002	0.000	+0.002	−0.005	+0.007
1912–13	+.017	+.009	+.002	+.005	+.004	+.009	+.018
1913–14	+.012	+.012	+.005	+.011	+.007	+.012	+.020
1914–15	+.015	+.007	+.006	+.007	+.009	+.008	+.018
1915–16	+.014	+.009	+.008	+.009	+.005	+.014	+.020
1916–17	+.015	+.006	+.012	+.005	+.007	+.008	+.009
1917–18	−.003	+.004	−.001	+.002	−.001	+.005	+.025
1918–19	+.005	−.002	−.003	−.002	.000	−.002	+.009
Postdenudation period:							
1919–20	+.005	+.001	−.003	−.003	+.001	+.001	+.010
1920–21	−.002	+.001	−.002	−.005	.000	+.014	+.020
1921–22	+.017	+.003	.000	−.001	+.003	+.004	+.005
1922–23	−.013	−.005	−.006	−.007	−.003	−.001	−.001
1923–24	−.001	−.002	−.005	−.003	−.004	.000	+.002
1924–25	+.002	−.007	−.003	−.005	−.004	+.004	+.013
1925–26	+.004	−.003	+.001	+.002	.000	+.005	+.008
Predenudation average	+.012	+.007	+.004	+.005	+.004	+.007	+.016
Postdenudation average	+.002	−.001	−.002	−.003	−.001	+.004	+.008
Net change	−.010	−.008	−.006	−.008	−.005	−.003	−.008

Year	May	June	July	Aug.	Sept.	Annual
Predenudation period:						
1911–12	+0.018	+0.018	+0.012	+0.018	+0.018	+0.010
1912–13	+.021	+.033	+.029	+.030	+.016	+.016
1913–14	+.019	+.024	+.020	+.015	+.013	+.014
1914–15	+.014	+.013	+.018	+.024	+.017	+.013
1915–16	+.016	−.028	+.018	+.019	+.012	+.010
1916–17	+.017	−.011	−.009	+.004	+.012	+.007
1917–18	+.035	+.034	+.013	+.008	+.006	+.011
1918–19	+.018	+.006	−.003	+.002	+.008	+.002
Postdenudation period:						
1919–20	+.029	+.014	+.020	+.019	+.013	+.009
1920–21	+.017	+.007	+.006	+.006	+.032	+.007
1921–22	+.009	+.028	+.017	−.013	−.027	+.003
1922–23	+.002	+.018	+.002	−.001	−.001	−.001
1923–24	+.013	+.001	−.001	−.006	+.009	+.001
1924–25	+.008	+.005	.000	+.011	+.003	+.002
1925–26	−.002	+.008	+.019	+.016	+.008	+.005
Predenudation average	+.020	+.011	+.012	+.015	+.013	+.010
Postdenudation average	+.011	+.012	+.009	+.005	+.005	+.004
Net change	−.009	+.001	−.003	−.010	−.008	−.006

The observations of the second period may be summarized as follows:

On the A watershed the second period was considerably more humid than the first, the excess in the yearly average being as much as 11 per cent and single months averaging as much as 31 per cent above the corresponding average for the first period.

As in the first period the atmosphere over B watershed was more humid than that of A notwithstanding the increase of A in the second period. However, the excess of B over A is somewhat reduced in the second period, indicating a diminution of moisture content doubtless due to the denudation of B. Comparing the averages at the bottom of Table 31 it may be seen that in the first period B watershed was more humid than A by 0.010 inch vapor pressure. The excess of B over A in the second period is reduced two-thirds, the reduction being a measure of the effect of denudation on the moisture content of the air. The total change, however, is a rather insignificant amount.

WIND

The average direction of the wind as determined by the automatic register at the C station is from the northwest and north, November to March, and from west to south, May to September. In the cold season the direction is quite variable, winds being experienced from every direction except east and southeast. The hourly directions for a single year were transcribed. These show that in the cold season the winds of the night hours are quite uniformly from the northwest toward the bottom of the river valley, backing during the warmer hours of the day (10 a. m. to 4 p. m.) to the north and shifting back to the northwest at 5 p. m.

In the warmer months the winds from midnight to 6 a. m. are from the west, backing to the north and northeast, that is, down the valley from 8 a. m. to noon. From 1 to 6 p. m. they are south or up the valley of the Rio Grande, shifting to the southwest at 7 p. m. and to the northwest at 10 p. m. This is graphically indicated in Figure 24. In the warm months a true mountain-valley wind prevails.

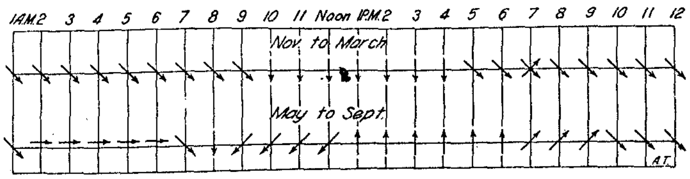


FIG. 24. Average hourly wind direction

The anemometer at the A–1 station was exposed in a small open spot, a former rock slide in the Douglas fir timber.

The B–1 anemometer was exposed in a small cleared space in the aspen and young fir, well protected from the wind. For this reason the wind travel at B–1 prior to denudation was a little less than half of that registered at the A station, the average hourly velocities being 2.2 and 1.0 m. p. h., respectively.

Neither station registered even approximately the true wind travel on the summit of the divide. The hourly average at the D station is 6.2 m. p. h.; only a small part of the A watershed experiences winds of that speed.

The wind movement at A–1 and B–1 stations for each month of the 15-year period is presented in Tables 32 and 33.

The increase in wind movement at B–1 amounting on the average of the year to 235 per cent of the average before denudation is clearly apparent in Table 33. The greatest increase was in winter and the least in summer.

TABLE 32.—*Wind movement, in miles, station A–1*

Year	October	November	December	January	February	March.	April	May	June	July	August	September	Annual
Predenudation period:													
1911–12	1,524	1,620	1,334	1,593	1,803	1,615	1,961	2,368	1,887	1,633	1,639	1,742	20,719
1912–13	1,428	1,231	1,315	1,660	1,383	1,906	2,046	2,176	1,866	1,772	1,543	1,124	19,450
1913–14	1,568	1,004	976	1,296	1,322	1,623	1,916	1,924	1,977	1,417	1,359	1,295	17,677
1914–15	1,081	1,401	946	1,321	1,372	1,943	1,561	2,013	2,091	1,898	1,731	1,549	18,907
1915–16	1,524	1,621	1,281	1,238	1,384	2,001	1,982	2,278	2,219	1,715	1,412	1,485	20,140
1916–17	1,529	1,476	1,547	1,320	1,518	1,860	1,817	1,872	2,009	1,721	1,531	1,372	19,572
1917–18	1,764	1,272	1,555	1,639	1,416	1,529	1,993	2,329	1,843	1,584	1,500	1,421	19,845
1918–19	1,443	1,105	1,191	1,410	1,287	1,441	1,756	1,931	1,808	1,365	1,524	1,399	17,660
Postdenudation period:													
1919–20	1,372	1,191	1,348	1,336	1,163	1,993	1,858	1,793	1,674	1,614	1,565	1,483	18,390
1920–21	1,345	1,300	1,337	1,535	1,496	1,613	2,037	2,039	1,953	1,608	1,311	1,358	18,932
1921–22	1,417	1,299	1,088	1,109	1,217	1,600	1,623	2,009	1,773	1,648	1,247	1,240	17,270
1922–23	1,257	1,073	1,242	1,364	1,113	1,660	1,614	1,837	1,871	1,614	1,212	978	16,835
1923–24	1,110	678	730	956	1,105	1,182	1,405	1,822	1,999	1,644	1,413	1,126	15,170
1924–25	1,176	1,111	968	1,145	1,076	1,423	1,761	1,697	1,422	1,013	905	1,186	14,883
1925–26	1,243	892	1,180	1,091	1,330	1,322	1,546	1,629	1,829	1,241	1,078	1,315	15,696
General average	1,385	1,218	1,203	1,334	1,332	1,647	1,792	1,981	1,881	1,566	1,398	1,338	18,076
Predenudation average	1,483	1,341	1,268	1,435	1,436	1,740	1,879	2,111	1,962	1,638	1,530	1,423	19,246
Postdenudation average	1,274	1,078	1,128	1,219	1,214	1,542	1,692	1,832	1,789	1,483	1,247	1,241	16,739

TABLE 33.—*Wind movement, in miles, station B-1*

Year	October	November	December	January	February	March.	April	May	June	July	August	September	Annual
Predenudation period:													
1911-12	597	644	563	756	847	707	923	1,123	759	607	587	604	8,717
1912-13	468	360	527	556	498	883	1,199	1,071	611	488	505	510	7,676
1913-14	653	495	496	616	774	915	1,046	936	928	431	552	601	8,443
1914-15	543	620	250	387	358	507	298	684	1,085	940	811	561	7,044
1915-16	585	752	534	479	591	1,079	1,074	1,159	1,116	726	608	518	9,221
1916-17	522	859	622	590	714	989	892	711	953	852	796	615	9,115
1917-18	781	568	813	718	403	733	943	1,018	764	708	752	653	8,854
1918-19	700	539	602	915	768	818	951	979	1,058	[1]1,958	[1]2,497	[1]2,205	13,990
1919-20	2,328	2,257	2,847	2,394	2,549	3,308	3,130	2,951	2,661	2,411	2,349	2,323	31,508
1920-21	2,694	3,053	2,802	3,044	3,002	2,828	3,379	3,175	2,890	2,221	1,934	2,314	33,336
1921-22	2,437	2,824	2,308	2,517	2,419	3,088	2,937	3,338	2,598	2,299	1,752	2,021	30,538
1922-23	2,195	2,068	2,828	2,862	2,126	2,948	2,958	3,076	2,676	1,604	1,416	1,464	28,221
1923-24	2,003	1,986	2,111	2,577	2,944	2,687	2,935	2,862	2,279	1,771	1,796	1,926	27,877
1924-25	2,030	2,151	1,911	1,927	2,082	2,911	3,072	2,435	1,801	1,385	1,250	1,440	24,395
1925-26	1,992	1,908	2,194	2,094	2,229	2,332	2,107	2,209	1,815	1,242	1,351	1,629	23,102
General average	1,369	1,406	1,427	1,495	1,487	1,782	1,856	1,848	1,600	1,310	1,264	1,292	18,136
Predenudation average	606	605	551	627	619	829	916	960	909	679	659	580	[2] 8,540
Postdenudation average	2,240	2,321	2,429	2,488	2,479	2,872	2,931	2,864	2,389	1,861	1,793	1,915	[2]28,582

[1] Included in the postdenudation averages, since cutting began near this station in July.
[2] Add horizontally.

SUNSHINE

The sunshine was automatically recorded at the C station. The monthly and annual mean values expressed as percentages of the possible sunshine are given in Table 34. Sunshine is greatest in October, November, and February, although June in the two years 1916 and 1917 had very high percentages. It is, quite naturally, least in July and August, the months of summer rains. The character of the summer stream flow is somewhat dependent upon the amount of sunshine in June and the amount of precipitation which occurs in that month. An early flood, as in 1913, with full sunshine in June, depletes the storage water in the watersheds and makes for low run-off in late summer and autumn unless the summer rains are generous.

TABLE 34.—*Percentage of possible sunshine*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910-11	----	70	63	46	44	49	50	50	51	31	47	43	----
1911-12	60	58	50	61	54	39	38	52	43	40	52	61	51
1912-13	51	64	62	55	57	56	61	52	39	49	40	42	52
1913-14	53	45	52	55	66	70	42	44	52	29	42	55	50
1914-15	56	70	55	61	60	65	44	53	67	54	53	51	57
1915-16	68	59	51	48	67	65	55	67	74	43	42	63	58
1916-17	60	71	57	66	58	61	51	55	74	53	48	50	59
1917-18	76	60	66	52	58	54	59	66	57	45	49	52	58
1918-19	56	58	50	70	60	59	58	52	55	43	54	51	56
Postdenudation period:													
1919-20	57	57	62	60	63	65	58	51	47	52	48	47	56
1920-21	52	60	56	54	64	58	49	48	56	46	35	66	54
1921-22	57	63	46	54	55	61	56	58.	58	51	44	54	55
1922-23	65	47	57	61	57	58	54	58	65	42	29	43	53
1923-24	52	55	45	60	60	50	54	55	65	46	50	61	54
1924-25	58	62	47	60	57	60	52	49	55	47	46	54	54
1925-26	63	61	59	59	60	51	50	41	57	44	46	55	54
General average	59	59	54	58	60	58	52	53	58	46	45	54	55
Predenudation average	60	61	55	58	60	59	51	55	58	44	48	53	55
Postdenudation average	58	58	53	58	59	58	53	51	58	47	43	54	54

PRECIPITATION

Colorado, being remote from any large body of water and somewhat south of the average path of cyclones, does not at any season receive a generous amount of precipitation. Almost 80 per cent of the 180 precipitation stations in Colorado have an annual average of less than 20 inches and but 6 per cent have as much as 30 inches. The greatest annual amount recorded at any one point is 46 inches at Corona on the summit of the Divide, elevation 11,660 feet; most of this is in the form of snow. While the extreme upper part of both watersheds involved in this study has an altitude somewhat above 10,000 feet, the situation of the area, with respect to the westerly winds, is not favorable to heavy precipitation, since westerly to northerly winds are descending winds and consequently dry. The precipitation is very nearly equally divided between rain and snow; thus, rain 52 per cent and snow 48 per cent.

There is a well-marked rainy season in July and August, at least 55 per cent of the rain falling in those months. Precipitation as rain may occur as early as April and as late as October, although in late spring and early autumn, it is quite likely to begin as rain, and change to snow before it ends. Snow in considerable quantities may fall in the latter part of September, but the real beginning of the snow season may be fixed as the last week in October. The first snowfall usually disappears by melting and evaporation, and not until the temperature remains below freezing during the afternoon hours may the snow cover be said to be permanent for the winter.

The single outstanding feature of this precipitation record is the uniformity in the annual totals, the extreme range in the 15 years being 7.34 inches on watershed A and 7.03 inches on B between 1922-23 and 1923-24. The maximum in the first named was in large part due to a great snowfall in November, 1922, and generous rains in August and September, 1923.

THE PRECIPITATION AND STREAM FLOW YEAR

It is clearly obvious that the beginning of the records of precipitation and run-off can not be arbitrarily chosen, but that they should conform as nearly as possible to the natural cycle of precipitation and run-off within the calendar year. An effort should be made so to choose the period that whatever precipitation occurs in it will be measured as stream discharge, as largely as possible, during the same period. Nevertheless, there will always be, whatever the period selected, a certain volume of ground water in the watersheds at the beginning and end of the period. The object, therefore, is to select a time when the volume of ground water in the two watersheds was approximately the same.

The latter part of September almost always shows a number of days free of precipitation, so that the streams tend to come into equilibrium at this time. September 30 is for the majority of years the end of the season of greatest draft upon ground storage from evaporation and transpiration. The streams, up to 1919, were discharging at that time practically the same amounts, as is shown in the subjoined table. Therefore, October 1 was chosen as the beginning of the precipitation and run-off year instead of January 1 as in the usual climatological studies.

TABLE 35.—*Average daily discharge at end of September; (days selected to be as free of precipitation as possible)*

Year	Inclusive dates	Daily discharge, inches over watershed		Year	Inclusive dates	Daily discharge, inches over watershed	
		A	B			A	B
1911	Sept. 23-25	0.0100	0.0098	1919	Sept. 29-Oct. 1	0.0088	0.0090
1912	Sept. 28-30	.0110	.0116	1920	Sept. 28-30	.0103	.0112
1913	do	.0098	.0102	1921	do	.0108	.0123
1914	Sept. 27-29	.0098	.0096	1922	do	.0101	.0110
1915	Oct. 1-3	.0090	.0090	1923	do	.0122	.0130
1916	Sept. 28-30	.0096	.0095	1924	do	.0098	.0118
1917	Sept. 27-29	.0105	.0102	1925	do	.0085	.0091
1918	Sept. 28-30	.0075	.0080	1926	do	.0079	.0084
	Averages	.00965	.00974		Averages	.00980	.01072

Finally, owing to the fact that the discharge record previous to July, 1911, is more or less uncertain on account of leaks in the dams and the form of weir then in use, it was thought best to start the discharge record with October, 1911, particularly since this makes possible the inclusion of the record of the greatest rainstorm during the life of the experiment which occurred in the early days of that month.

PRECIPITATION MEASUREMENTS

Precipitation was measured daily about 9:30 a. m. at the headquarters station (C) and stations A-1, A-2, B-1, and B-2, and at intervals of six days at station D, Tipping-bucket recording gauges were in operation during the warm months at the C and D stations and the records from the C station were used to apportion the measured amounts for the lower stations of both watersheds to hours, but more particularly to days beginning and ending at midnight.

The watershed precipitation for each midnight to midnight day is determined by taking the larger of the two quantities recorded at the two rainfall stations in each watershed, adding to that quantity the amount of the precipitation at D and dividing the sum by two. The higher record for the lower end of each watershed has been used, in preference to the average of the two, on the assumption that while many factors tend to lower gauge catch below the actual rainfall there is little possibility of exceeding the actual. The stations paired in this way are so close together (fig. 26) that the same rainfall is to be expected at both but there is at times considerable disparity. Theoretically, it might seem most logical to use the averages of the pairs of lower stations whenever there is evidence of a definite "drift" of precipitation across the watersheds, but actually this method leaves altogether too much opportunity for varying judgment, so that it is thought best always to take the higher of the two amounts on either of the watersheds.

The streamflow year 1912-13 showed a considerable excess of B over A in precipitation, and the month of July illustrates the common character of the variations in catch.

Watershed	Total amount at individual stations	Watershed precipitation by method of averages	Watershed	Total amount at individual stations	Watershed precipitation by method of averages
	Inches	*Inches*		*Inches*	*Inches*
A-1	1.83	2.27	B-1	2.23	2.46
A-2	1.81		B-2	2.17	
D	2.72				

By the method of selecting daily the higher of the amounts as between A-1 and A-2 and between B-1 and B-2, the watershed values are made to be 2.30 for A and 2.52 inches for B. Sometimes the differences between the two methods are greater than shown above, and sometimes less. In any event, the method used tends, of course, always to raise the averages of *both* watersheds, thus maintaining the proper relationship between the two.

COMPARISON OF THE WATERSHEDS

The daily watershed precipitation for the entire period of observations is given in Table 66, Appendix I, at the end of this paper. The monthly amounts are given in Tables 36 and 37. On the average of the 15 years, watershed A has a mean annual precipitation of 21.09 and watershed B of 20.97 inches, or practically the same amount.

TABLE 36.—*Total precipitation, in inches, over watershed A*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910-11	(1)	----	----	1.04	3.43	1.48	0.79	0.69	2.09	4.90	3.19	2.55	----
1911-12	4.41	1.13	1.53	.36	.47	3.05	1.54	.34	2.20	4.08	1.78	.43	21.32
1912-13	2.53	.44	.72	1.10	1.10	1.40	.78	.49	3.01	2.30	2.37	2.43	18.67
1913-14	.93	1.89	2.42	2.22	.67	.76	.96	2.31	1.58	5.24	2.25	1.40	22.63
1914-15	2.21	.02	1.26	.93	2.41	.35	3.84	1.53	.50	2.30	1.80	2.83	19.98
1915-16	.36	1.96	2.75	3.46	.47	1.67	1.99	.35	.10	5.10	3.01	1.49	22.71
1916-17	4.31	.20	1.47	1.85	.77	1.59	5.02	2.31	.13	1.92	2.10	1.21	22.88
1917-18	.19	1.07	.28	1.30	2.07	2.10	.71	.14	1.10	3.82	3.05	3.07	18.90
1918-19	1.06	2.53	1.92	.07	1.86	2.67	2.09	1.28	.87	4.33	1.02	1.43	21.13
Postdenudation period:													
1919-20	1.97	4.87	.85	.58	1.50	1.93	2.23	2.39	1.10	2.24	1.08	1.75	22.49
1920-21	3.46	1.89	1.49	1.36	.60	1.09	1.59	2.51	1.73	3.31	3.11	.55	22.69
1921-22	.78	.32	1.57	3.00	1.55	2.76	1.62	2.44	1.22	1.88	3.52	.78	21.44
1922-23	.63	4.83	1.15	.81	.96	1.68	2.10	.66	1.06	2.62	4.13	3.72	24.35
1923-24	2.60	1.72	1.36	.59	1.06	3.28	1.40	.71	.18	1.86	1.18	1.07	17.01
1924-25	1.42	1.07	2.18	.18	.59	3.00	1.44	1.18	2.15	3.68	3.57	1.44	21.90
1925-26	2.31	1.69	.11	.71	.38	2.15	1.50	1.89	1.01	2.57	2.28	1.66	18.26
General average	1.94	1.71	1.40	1.23	1.10	1.97	1.92	1.37	1.20	3.15	2.42	1.68	21.09
Predenudation average	2.00	1.16	1.54	1.41	1.23	1.70	2.12	1.09	1.19	3.64	2.17	1.79	21.03
Postdenudation average	1.88	2.34	1.24	1.03	.95	2.27	1.70	1.68	1.21	2.59	2.70	1.57	21.16

[1] Data for 1910-11 not included in averages.

TABLE 37.—*Total precipitation, in inches, over watershed B*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910-11	----	----	----	1.08	3.52	1.60	0.76	0.72	2.22	4.65	3.24	2.63	----
1911-12	4.66	1.17	1.47	.34	.34	3.08	1.54	.33	2.14	4.28	1.71	.43	21.49
1912-13	2.60	.44	.69	.99	1.08	1.55	.86	.54	3.20	2.52	2.42	2.77	19.66
1913-14	1.01	1.81	2.32	2.17	.64	.72	.91	2.25	1.68	4.89	2.11	1.36	21.87
1914-15	2.23	.02	1.14	.88	2.40	.35	3.63	1.54	.51	2.19	1.91	3.05	19.85
1915-16	.35	2.00	2.68	3.49	.52	1.54	1.99	.34	.08	5.32	3.26	1.56	23.13
1916-17	4.43	.20	1.49	1.93	.72	1.58	4.93	2.22	.13	1.96	2.05	1.14	22.78
1917-18	.19	1.07	.26	1.28	1.78	2.07	.72	.14	.97	3.85	3.34	3.18	18.85
1918-19	1.04	2.50	1.85	.06	1.74	2.49	2.12	1.33	.91	4.41	1.07	1.63	21.15
Postdenudation period:													
1919-20	1.99	4.75	.79	.56	1.48	1.89	2.10	2.51	1.16	1.69	1.05	1.81	21.78
1920-21	3.39	1.86	1.55	1.37	.60	1.08	1.56	2.51	1.77	3.26	2.99	.55	22.49
1921-22	.81	.32	1.42	2.90	1.44	2.68	1.69	2.50	1.18	1.66	3.22	.70	20.52
1922-23	.65	4.79	1.16	.77	.92	1.69	2.05	.65	.95	2.43	3.96	3.78	23.80
1923-24	2.60	1.62	1.32	.62	1.05	3.02	1.36	.73	.16	1.88	1.15	1.26	16.77
1924-25	1.53	1.05	2.13	.15	.57	2.85	1.48	1.17	2.18	3.97	3.84	1.48	22.40
1925-26	2.29	1.62	.12	.66	.37	2.19	1.44	1.93	.89	2.53	2.28	1.74	18.06
General average	1.98	1.68	1.36	1.21	1.04	1.92	1.89	1.38	1.19	3.12	2.42	1.76	20.97
Predenudation average	2.06	1.15	1.49	1.39	1.15	1.67	2.09	1.09	1.20	3.68	2.23	1.89	21.10
Postdenudation average	1.89	2.29	1.21	1.00	.92	2.20	1.67	1.71	1.18	2.49	2.64	1.62	20.83

If the averages be considered, the differences between A and B precipitation are not significant, and the writers are inclined to doubt whether the tendency exhibited in the first period for B to receive more than A was actually reversed in the second. It seems more probable that the more free exposure of the B gauges in the second period tended merely to reduce their effectiveness in catching precipitation.

There are, however, some differences between A and B in individual months and years which are significant and must have had some current effect on the streamflow relations. The greatest difference in any one year was 0.99 inch in 1912-13, B having the greater amount. In 1913-14 this relation was reversed, A having 0.76 inch more than B. From a tabulation of the monthly differences for the 15 years it is found that there is a much greater tendency for differences to be large in July, August, and September, when storms are frequent and of a more local character than at other seasons. This should be sufficient evidence that the variations are real, although tending largely to compensate one another through a period of years. It is also noteworthy that in the first eight years B shows an excess in its monthly averages from June to October, inclusive, amounting to a total of 0.27 inch, while the six months November to April show a cumulative deficit of 0.22 inch. In the second period this seasonal tendency is much less pronounced. The greatest monthly differences B–A were —0.55 inch in July, 1920, and +0.29 inch in August, 1918, and July, 1925. The most significant difference in a single day's precipitation was on July 10, 1920, when the A watershed value was 0.68 inch, and B 0.21 inch. For this date the 5 gauges read as follows: A–1, 1.19 inches; A–2, 1.24 inches; B–1, 0.31 inch; B–2, 0.29 inch; D, 0.11 inch.

This storm caused an excess run-off of about 0.06 inch from A, and only about 0.003 inch from B. It is again evident here that the differences did not have an orderly sequence related to the positions of the gauges.

If the differences B–A be considered cumulatively, beginning with October, 1911, it is found that B was piling up an excess over A precipitation most of the time through October, 1913, when it amounted to 1.24 inches. Then for nearly two years B was in arrears, and in July, 1915, stood 0.06 inch below A. B then gained again, reaching a high point of +0.91 inch in January, 1917. From this time on there was little change in status until November, 1919, when B began to fall behind quite steadily, the lowest point in this movement being reached in August, 1924, when B was 2.25 inches behind A. B then gained, on the whole, for nearly a year, being only 1.56 inches behind A in September, 1925, and 1.76 inches behind in September, 1926.

The significant features of these differences are the excess of B in 1912–13, and the deficit in 1913–14, which were great enough to affect the stream-flow ratio B/A in these two predenudation years. It is then to be noted that B stream flow rose steadily to a peak through 1919–20, 1920–21, and 1921–22, while B was getting more and more in arrears in the matter of precipitation. The continuation of this deficiency for two more years may possibly account for the rapid falling off in the relative height of B stream. On the other hand, it is more difficult to reconcile the excess of B precipitation in 1924–25 and the deficit in 1925–26 with the stream-flow excesses of almost the same magnitude in the two years.

Everything considered, it does not seem that the response of stream flow to the differences in precipitation was at all that to be expected, except in 1912–13. This is the primary reason for not attempting in the stream-flow discussion to assign any quantitative effects to the precipitation differences. It is obviously wiser, however, not to attempt to relate B stream flow to A precipitation, as it was hoped it would be possible to do, if only for the sake of simplicity in the treatment.

INTENSITY OF PRECIPITATION

Rainfalls of great intensity rarely occur at Wagon Wheel Gap. During the 15 years considered but a single heavy 24-hour rain occurred, viz, on October 4 and 5, 1911.

To present statistics of intensity of precipitation in some detail, the 24-hour precipitation (rain or snow) on watershed A has been classed according to the scale shown in Table 38. Since, however, the run-off from snow appears at the end of the cold season and is not immediately effective in producing increased stream flow, the precipitation from June to October, inclusive, has been segregated by months for all rains of more than 0.10 inch. It is considered that rains of 0.10 inch and less in the summer as a rule serve merely to replenish losses due to transpiration and evaporation and do not directly affect stream flow. Rains greater than 0.10 inch may considered effective in producing a slight increase in stream flow, depending, of course, so far as the lower limit of the scale is concerned, upon conditions of soil moisture and other factors. With a saturated soil a precipitation so small as 0.01 inch might produce a measurable response in stream flow.

The result of this second classification of rains is given below:

Watershed	Average intensity of rains, inches [1]				
	June	July	August	September	October [2]
A	(48) 0.31	(132) 0.31	(106) 0.28	(67) 0.31	(76) 0.35
B	(44) .33	(129) .31	(108) .28	(69) .32	(75) .36

[1] Number of rains in parenthesis.
[2] Both rains and snows included.

This tabulation shows conclusively that the intensity of the rains is practically the same for each month of the season and substantially the same on both watersheds, with a tendency at times to be greater on B than on A. The tendency for B to receive fewer of these rains in early summer and more in late summer is of interest, possibly explaining in a small degree the greater upward trend of stream B as the summer ends.

The precipitation intensity for watershed A has been independently computed by dividing the average monthly precipitation by the average number of rainy days, classing as a rainy day all days with 0.02 inch of precipitation or more.

The results are shown graphically in Figure 25 and are explained as follows: The average monthly precipitation

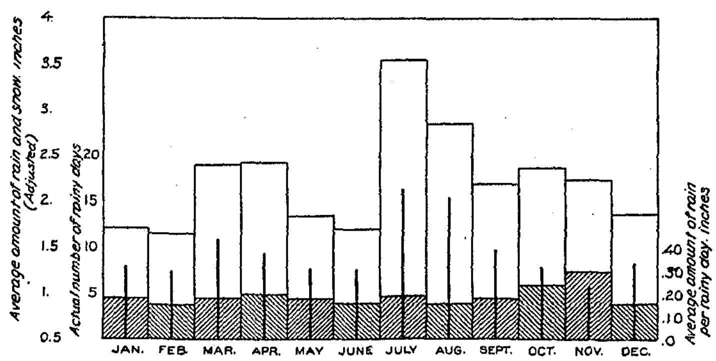


FIG. 25. Intensity of precipitation

(adjusted for inequality in length) is shown by the rectangular figures opposite the respective months. The heavy line in the center of the rectangle represents the average number of rainy days and the shaded portion of the rectangle at the bottom gives the intensity of the precipitation as above indicated. The intensity by this method is somewhat less than when only the so-called effective rains are considered.

TABLE 38.—*Days with rain, watershed A, June to September, inclusive*

Year	Trace to 0.01	0.02 to 0.10	0.11 to 0.30	0.31 to 0.50	0.51 to 1.00	1.01 and over	Total number of days: 0.11 or more	Total number of days: 0.02 or more
1912	21	25	20	5	2	0	27	52
1913	30	26	18	5	6	0	29	55
1914	26	27	22	6	2	1	31	58
1915	17	21	9	2	5	0	16	37
1916	16	24	12	6	4	1	23	47
1917	25	29	14	3	0	0	17	46
1918	29	23	18	8	4	1	31	54
1919	37	27	15	1	5	0	21	48
1920	37	31	11	0	3	0	14	45
1921	26	26	19	9	0	0	28	54
1922	32	28	9	4	2	1	16	44
1923	16	25	20	10	2	1	33	58
1924	26	19	13	1	1	0	15	34
1925	16	35	19	11	3	0	33	68
1926	28	27	13	1	5	0	19	46
Totals	382	393	232	72	44	5	353	746

GREATEST AMOUNT OF PRECIPITATION IN 24 HOURS

The greatest quantity of precipitation occurring as rain or snow, within a period of 24 hours, for each month beginning in December, 1910, and ending September, 1926, is given in Table 39. In order to show the actual concentration at one point, the data are given for station A–1. The figures for the months November to May inclusive, are for precipitation as snow, those for the remaining months mostly for rains. Months with as much as one inch of rain in 24 hours are exceptional, there being but 13 in the 16 years of record; and in 7 of the calendar years no rains equaling or exceeding an inch in 24 hours fell. Snows of an inch or more are just about as numerous, but none occurred in the months of January and February. November and July show the greatest number of heavy storms.

THUNDERSTORMS

Much of the summer rain comes in the form of afternoon thunderstorms in July and August. Thundershowers may occur, however, as early as April, before the snow cover has disappeared from north slopes. The amount of rain which falls in these early thundershowers rarely exceeds half an inch. The weather generally turns cooler during April and May thunderstorms, the precipitation which begins as rain turns to snow, and the greater part of it is absorbed by the snow cover, without markedly increasing the rising flood. The thunderstorm season is from the last half of April to the middle of October, and the months of greatest frequency are July and August. The average number per season is 70.

Table 40 gives the number of thunderstorms each month of the period of observation. The small increase in the number of these storms in the second as compared with the first period is without significance.

TABLE 39.—*Maximum 24-hour precipitation, in inches, station A–1*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910–11	----	----	0.22	0.39	0.65	0.45	0.20	0.29	0.45	0.84	1.38	0.57	1.38, Aug.
1911–12	2.93	0.37	.91	.23	.28	.50	.45	.17	.55	.78	.71	.30	2.93, Oct.
1912–13	.68	.42	.42	.62	.48	.50	.31	.21	.80	.65	.74	1.05	1.05, Sept.
1913–14	.30	.63	.92	.70	.50	.42	.29	.89	.66	1.23	.49	.80	1.23, July.
1914–15	.60	.02	.58	.51	.93	.15	.76	.42	.29	1.09	.68	.88	1.09, July.
1915–16	.32	1.34	1.12	.64	.15	.51	.51	.21	.11	1.06	.57	.42	1.34, Nov.
1916–17	1.05	.20	.34	.84	.35	.28	1.25	.43	.15	.55	.37	.35	1.25, Apr.
1917–18	.19	.69	.22	.37	.84	.92	.57	.10	.20	.91	1.00	1.13	1.13, Sept.
1918–19	.38	1.05	.79	.06	.43	.98	.46	.40	.65	.87	.42	.56	1.05, Nov.
Postdenudation period:													
1919–20	.71	2.05	.43	.23	.53	.48	.77	1.02	.51	1.24	.29	.37	2.05, Nov.
1920–21	[1]1.15	.77	.65	.50	.15	.35	.78	.84	.55	.51	.56	.23	1.15, Oct.
1921–22	.23	.21	.60	.88	.69	.96	.59	1.07	.71	1.14	1.17	.32	1.17, Aug.
1922–23	.36	1.32	.68	.29	.43	.32	.52	.23	.42	.35	.75	.85	1.32, Nov.
1923–24	.60	1.03	.36	.39	.61	.94	.36	.20	.08	.44	.36	.53	1.03, Nov.
1924–25	.44	.50	.61	.08	.37	1.71	.55	.63	.83	.75	.50	.47	1.71, Mar.
1925–26	.55	.73	.03	.32	.24	.40	.71	.30	.70	.99	1.15	.74	1.15, Aug.

[1] Snow.

TABLE 40.—*Number of thunderstorms, station C*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation peroid:													
1911	----	----	----	----	----	----	3	4	9	10	13	5	----
1911–12	----	----	----	----	----	----	3	2	18	22	13	5	63
1912–13	5	----	----	----	----	----	3	6	18	16	22	10	80
1913–14	1	----	----	----	----	----	5	12	9	24	21	10	82
1914–15	----	----	----	----	----	----	3	4	5	12	17	12	53
1915–16	----	----	----	----	----	----	2	1	2	21	21	6	53
1916–17	4	----	----	----	----	----	1	6	6	20	19	11	67
1917–18	----	1	----	----	----	1	2	----	22	24	19	6	75
1918–19	4	1	----	----	----	----	3	13	19	20	14	6	80
Postdenudation period:													
1919–20	----	1	----	----	1	----	----	5	14	23	21	12	77
1920–21	3	2	----	----	----	1	2	4	13	22	27	3	77
1921–22	3	----	----	----	----	2	2	5	18	21	27	10	88
1922–23	3	----	1	----	----	----	3	2	8	20	20	7	64
1923–24	4	----	----	----	----	----	----	5	8	16	19	9	61
1924–25	1	----	----	----	----	1	1	9	11	27	19	7	76
1925–26	1	----	----	----	----	----	2	5	9	22	15	4	58
General average	1.9	0.3	0.1	----	0.1	0.3	2.1	5.3	12.0	20.7	19.6	7.9	70.3
Predenudation average	1.8	.2	.0	----	.0	.1	2.8	5.5	12.4	19.9	18.2	8.2	69.1
Postdenudation average	2.1	.4	.1	----	.1	.6	1.4	5.0	11.6	21.6	21.1	7.4	71.6

SNOWFALL

While the snowfall forms a little less than 50 per cent of the total precipitation, it yields considerably more than 50 per cent of the run-off. The total precipitation in the months November to March, inclusive, is in the form of snow, and the precipitation of April is 91 per cent snow. A trace of snow may fall even in the summer months, but the real transition months are June with 6 per cent of snow and October with 38 per cent. The snowfall of September is apt to be light, wholly disappearing before the cold-season snowfall sets in. The character of the snowstorms depends largely upon the temperature. In October, March, April, and May wet snowstorms predominate; in the colder months dry snow is the rule.

The average depth of snow per annum from 1910 to 1926 was 122.7 inches. (Table 41.) The range in depth from year to year was from 170.5 in 1919–20 to 80.7 inches in 1917–18. March on the average was the month of greatest snowfall although the greatest falls in any months during the 16 years were 59.2 and 54.2 inches in November of 1919 and 1922, respectively, and 52.2 inches in April, 1917. The second period of the experiment averaged 16 inches more snow a season than the first, or about 14 per cent.

TABLE 41.—*Monthly snowfall, in inches, over watershed A*

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910–11	----	8.7	9.0	12.5	45.5	15.3	6.6	T.	----	----	----	----	97.6
1911–12	10.0	15.4	18.6	5.3	5.3	36.5	19.0	2.0	0.4	T.	----	T.	112.5
1912–13	18.4	6.9	13.2	13.3	13.5	16.4	7.6	.4	.3	----	----	6.9	96.9
1913–14	3.4	20.4	30.4	30.9	7.8	9.3	7.5	6.4	T.	----	----	T.	116.1
1914–15	5.3	.1	20.2	13.9	27.9	5.8	19.8	15.8	1.0	----	----	2.2	112.0
1915–16	4.0	21.3	22.4	45.7	4.4	17.5	14.1	4.4	T.	----	0.2	T.	134.0
1916–17	10.7	3.3	15.7	25.0	8.1	15.8	52.2	16.0	2.9	----	T.	T.	149.7
1917–18	2.2	13.7	3.7	13.0	20.0	21.3	6.0	.8	----	----	----	----	80.7
1918–19	3.3	36.0	21.5	1.3	18.8	28.5	9.5	1.2	.5	----	----	----	120.6
Postdenudation period:													
1919–20	15.9	59.2	10.1	6.8	18.1	24.7	27.9	6.3	----	----	----	1.5	170.5
1920–21	35.5	16.6	18.3	15.7	8.0	12.1	17.5	9.3	----	----	----	----	133.0
1921–22	3.0	3.3	19.2	35.9	19.9	29.4	17.5	22.9	----	----	----	----	151.1
1922–23	4.3	54.2	14.4	10.2	13.0	19.8	21.8	1.1	----	----	----	9.5	148.3
1923–24	18.9	15.2	17.2	7.7	13.5	41.5	13.5	T.	----	----	----	T.	127.5
1924–25	5.6	10.4	25.6	2.4	8.7	34.6	10.8	1.1	----	----	----	T.	99.2
1925–26	11.4	20.8	1.7	7.2	5.1	22.6	13.7	5.4	----	----	----	----	87.9
General average	10.1	19.8	16.8	15.6	12.8	22.4	17.2	6.2	.3	T.	T.	1.3	122.7
Predenudation average	7.2	14.6	18.2	18.6	13.2	18.9	17.0	5.9	.6	T.	T.	1.1	115.3
Postdenudation average	13.5	25.7	15.2	12.3	12.3	26.4	17.5	6.6	0	0	0	1.6	131.1

SNOW SCALES

Since precipitation in the form of snow does not become available for stream flow until it melts, it was thought to be desirable, for the purposes of this experiment, to have a record of the accumulation and melting of snow on the two watersheds, as made possible by snow-depth measurements and density determinations at fixed scales (fig. 26) of which there were 19 on A and 15 on B. The record is principally valuable, not for showing when snow water becomes available for stream flow, but for contrasting the two periods of the experiment with respect to the rate of melting on watershed B.

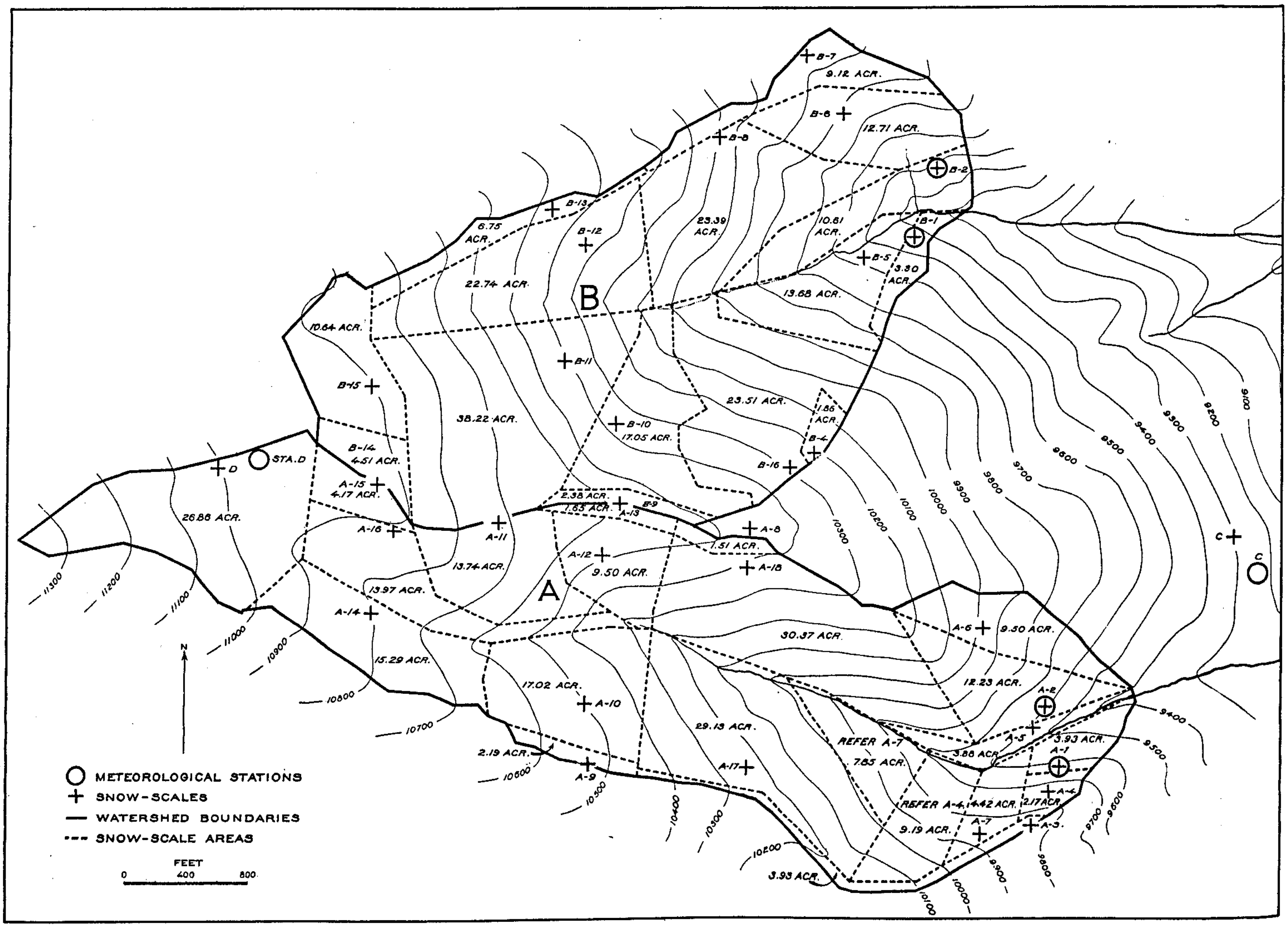


FIG. 26—Regular meteorological stations and snow-scale areas, Wagon Wheel Gap, watersheds A and B

In selecting the points for snow measurement the main types of forest cover found on the areas, and the topography, were considered in the endeavor so to place the scales as to obtain the best possible representation of the distribution of snow. In general, snow-scale areas represented (fig. 26) by scales 8 to 19 on watershed A and scale D are wholly above the 10,000-foot contour line. Areas 2, 3, 6, and 18 are, in part, above that contour. On the B watershed, areas 4, 9, and 10 to 15 are wholly above the 10,000-foot contour line and areas 8 and 16 are in part above that contour.

Certain areas were not directly represented by snow scales within them, but by scales on other areas. Thus the notation on Figure 26, "Refer A–7" indicates that snow-scale A–7 represented two areas.

SNOW MELTING IN SPRING

Snow on south slopes begins to melt as early as January provided the afternoon temperatures rise above 32°. The water so released, however, makes little or no impression upon the stream flow. The average temperature for March is 23.2° F. at A–1 and no March during the 16 years of observation had a monthly mean above 29°: but for the hours from 1 to 5 p. m., the mean is 32° or over. At the D station on the higher portion of the area, the mean maximum for March is but 31.7° and it is not until April that the mean temperature of the afternoon hours in the upper portion of the watershed passes above freezing, producing about a month's lag in temperature between the upper and lower portions of the area.

The average seasonal increase, March to April, is 8.5°; but even in those seasons with a much greater increase the March discharge does not increase proportionately. The monthly mean temperature of April is almost exactly 32° and it would naturally be expected that months having a mean greater than that amount would also have a correspondingly greater increase in the discharge. The results do not meet that expectation for several reasons, chief of which is the fact that the month is too large a time unit to use. The greatest April run-off in the 16 years was in 1924, with a monthly mean of 30.9°. The last decade of the month, however, had a mean of 33° and there was a six-day warm spell within that decade with a mean of 37.7°; this with the heavy fresh snow of March fully explains the relatively large run-off for the month.

May with a mean temperature of 41.6° is the month of maximum snow melting. May, 1920, with a mean temperature but 0.6° above the 16-year average gave the greatest run-off of the 16 years. The conditions over the watershed were very favorable to a high discharge; at the beginning of the month the water equivalent of snow on the ground was 9.13 inches. The precipitation during the month added 2.39 inches to that amount. Over the watershed 3.583 inches or 31 per cent was discharged and the discharge of June, July, and August immediately following was more than the average. It will be observed from the following average dates of disappearance that the melting in 1920 must have been unusually rapid, and that some unusual factor caused the snow to disappear earlier from B than from A.

Year	Watershed A, snow		Watershed B, snow—date disappeared	Year	Watershed A, snow		Watershed B, snow—date disappeared
	On ground[1] Apr. 30	Date disappeared			On ground[1] Apr. 30	Date disappeared	
1913	0.87	Apr. 19	Apr. 22	1920	9.13	May 10	May 5
1917	6.99	May 25	May 29	1925	.95	Apr. 23	Apr. 20

[1] Water equivalent, in inches. The discrepancy between the quantities of snow water on ground Apr. 30 for years 1913 and 1925 and the disappearance of snow for those years is due to the fact that the date of disappearance is the average of all scales, whereas snow disappears sooner from some than from others.

While the actual temperature seems to be the chief factor in snow melting the change from the month immediately preceding appears to be a contributing cause of large melting. The average change from April to May is 9.9.° When this amount is exceeded, as will happen when April is exceptionally cold and May is average, the run-off is invariably large, provided of course, that the snow cover is great enough to deliver a large quantity of water.

For each snow scale, in each year, the date of "disappearance" of snow has been taken as the first regular observation date[3] on which a "trace" or no snow was recorded, provided that at no subsequent date a depth of 3 inches or more was recorded. This provision seems desirable for obtaining a proper comparison between those areas on which there is little melting through the winter and which are not at all likely to clear until after the season of heavy spring snows, and the southerly exposures which might conceivably become temporarily bare at any time during the winter. As much as 20 inches of snow has been reported for some scales after the first disappearance of early snow from their vicinity. The general effect of the provision for late snow is to delay the average date of disappearance for all scales about four days.

The average dates of disappearance of snow are given in Table 42 for each snow scale, separately for the first and second periods of the experiment. For the watershed averages, all scales are given the same weight, regardless of the areas represented.

Snow disappears earliest from area 18 on A and area 6 on B. Both are steep southeast slopes, area 18 being practically entirely above the 10,000-foot elevation, while area 6 is about 300 feet lower. Snow disappears last, of course, from the higher east-northeast slopes of both watersheds. The average interval between the earliest and latest disappearance on A is 60 days, on B nearly the same, although in individual years snow-scale areas B 10, 15, and 16 retained some snow even later than A–14 or D.

[3] The observations after Mar. 1 being only 5 or 6 days apart (3 days in 1912 and 1913), a close approximation to the actual time of disappearance is made.

TABLE 42.—*Average dates of disappearance of snow*

A watershed					B watershed				
Scale number	Aspect	Gradient	Average date of melting		Scale number	Aspect	Gradient	Average date of melting	
			First period	Second period				First period	Second period
	°	° ′				°	° ′		
4	N. 2 E.	42 00	May 15	May 16	1	N. 12 W.	35 30	May 14	May 6
7	N. 2 E.	25 20	May 10	May 8	10	N. 12 W.	26 50	May 26	May 22
1	N. 12 E.	34 10	May 16	May 16	5	N. 6 W.	26 40	May 9	May 5
10	N. 30 E.	13 50	do	Do.					
17	N. 40 E.	21 30	May 11	May 11	4	N. 22 E.	21 50	May 10	May 8
14	N. 46 E.	15 50	May 20	May 23	16	N. 26 E.	16 20	May 18	May 12
"D"	N. 50 E.	24 40	May 23	May 22					
15	N. 52 E.	2 00	May 18	May 13	15	N. 29 E.	11 50	May 24	May 17
11	N. 72 E.	16 50	May 13	May 16	[1] 14	N. 52 E.	2 00	May 18	May 13
					11	N. 66 E.	22 10	May 11	May 17
8	N. 82 E.	9 30	May 11	May 25	13	N. 70 E.	9 10	do	May 11
6	N. 82 E.	33 50	Apr. 26	Apr. 30					
9	N. 90 E.	11 20	May 7	May 10	[2] 9	S. 84 E.	10 50	May 12	May 13
3	Level		May 1	May 6	8	S. 74 E.	32 40	Apr. 26	Apr. 28
16	S. 6 E.	13 50	May 2	May 3					
13	S. 84 E.	10 50	May 12	May 13	2	S. 66 E.	25 30	Apr. 5	Apr. 15
5	S. 40 E.	25 50	Apr. 1	Apr. 13	12	S. 52 E.	21 40	Apr. 18	Apr. 25
18	S. 36 E.	24 50	Mar. 24	Apr. 21	6	S. 50 E.	26 50	Mar. 30	Apr. 21
12	S. 32 E.	23 40	Apr. 4	Apr. 19					
2	S. 34 E.	31 50	Apr. 6	Apr. 13	7	Level		Apr. 24	Apr. 26
Average			May 3	May 8	Average			May 5	May 6

[1] Same as A–15. [2] Same as A–13.

The average date of snow disappearance on A before denudation was May 3; on B, May 5. The average date after denudation was May 8 on A; on B, May 6. Thus it is apparent that as a result of later seasons in the second period the average date of disappearance from A was 5 days later, while the date for B was but 1 day later in the second period, making 4 days the relative advance of B as a result of denudation. At snow scale B–6, melting was 22 days later in the second than in the first period. As the corresponding scale A–18 was 28 days late in the second period, the result may be considered as having no connection with denudation.

The four typical south-slope snow-scale areas on A, areas 2, 5, 12, and 18, have an average direction of slope S. 36° E. and an average angle of slope with the horizontal of 26° 32′. The four typical south-slope areas on B, Nos. 2, 6, 8, and 12, have an average direction of slope S. 60° E. and an average angle of 26° 40′. These scales on B have a little more easterly aspect than those on A. The average dates of disappearance of snow at the south-slope scales were for A April 1 before denudation and April 17 after denudation; for the B scales April 12 and April 22. For the four typical north-slope areas A 1, 4, 10, and 14, and B 1, 4, 10, and 16, with nearly the same direction and angle of slope, the average dates were for A May 17 before denudation and May 18 after denudation; for B May 17 and May 12. The snow disappeared, before denudation, about 11 days earlier on the south slopes of A than on the corresponding slopes of B and melting on B was advanced about 6 days by denudation; on the north slopes the original dates were the same for A and B, but B melting was advanced 6 days by denudation.

SNOWSLIDES

As a result of denudation, snowslides occurred several times on B watershed, where previously the aspens had evidently been able to hold them in check. The area of snow scale B–11 was most frequently affected, this accounting for the poor development of the aspen as shown in Figure 13. There may, also, have been at times the piling up of snow at this scale to account for the later disappearances of snow therefrom. The more northerly aspects of B–10 and B–16 were also subject to one or more slides, as was the east slope represented by B–8.

Following is the record of the two most important slides:

March 5, 1923: Central and lower parts of area B–11, also following stream channel as far as lower ends of areas B–8 and B–5, a total distance of 2,000 feet. On March 1 the average water equivalent of snow for the entire watershed was 7.46 inches, a very unusual amount. Temperature was high for the period March 1–10.

March 10, 1925: A large slide ran almost the entire length of the B–16 area, and two smaller ones started near its base. Another slide covered a part of the B–11 area. This occurred immediately after heavy snowfall on the 8th and 9th, the fall up to that time being much below normal.

SOIL MOISTURE

Soil moisture was measured at each of the five stations, A–1, A–2, B–1, B–2, and D weekly during the open seasons of 1914 to 1926, inclusive. Although this is not strictly speaking a climatological record, it is so suggestive as a reflection of the combined effects of precipitation, evaporation, and drainage that it deserves a reasonable amount of space. The record will later be referred to in the discussion of the possible sources of increased streamflow following denudation.

Soil moisture was measured by drying samples removed with a small auger or hollow tube from "soil wells." The soil of these wells was essentially like that of the surrounding ground, except that it had been excavated from a space possibly 2 feet in diameter, freed of rocks, and tamped back into place. At the outset enough of the sifted soil was supplied at each "well," so that as holes were made by sampling they might be refilled with the same kind of material. There must always be some question as to how closely the moisture in such a soil well corresponds with that in the surrounding ground, which may be more fully occupied by roots and may have freer drainage. It can not be doubted, however, that the two are always tending toward equilibrium.

The natural variation of soil texture at the different stations will account for the entirely different moisture contents which they show quite regularly; although, naturally, if the soil conditions were identical, the north-slope stations would be expected to be more moist than the south-exposure stations. Because of these soil variations, station to station comparisons are not permissible.

Although some measurements of soil moisture were usually made in May and October, the records here presented will be confined to the four months in which four or five measurements per month were invariably made. These are given in Tables 43 to 47 which show (disregarding the several depths, differences between which are not very significant):

TABLE 43—*Mean monthly soil moisture contents at various depths*

[In percentages of dry soil weights]

STATION A–1

Year	June				July				August				September				Season average
	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	
1914	19.4	24.5	27.1	23.7	20.4	22.3	25.0	22.6	21.6	24.1	25.7	23.8	20.2	23.0	25.4	22.9	23.2
1915	18.2	21.7	28.6	22.8	18.0	20.9	29.2	22.7	18.8	19.2	26.9	21.6	19.2	22.0	22.9	21.4	22.1
1916	27.4	22.7	24.1	24.7	18.2	20.4	23.5	20.7	20.5	21.9	28.0	23.5	19.0	19.6	20.9	19.8	22.2
1917	19.8	23.0	24.0	22.3	18.8	21.7	26.5	22.3	16.5	18.2	22.4	19.0	16.2	19.6	24.8	20.2	21.0
1918	17.6	19.3	21.7	19.5	16.9	19.6	21.3	19.3	14.6	18.1	22.0	18.2	17.8	18.9	21.7	19.5	19.1
1919	18.2	20.1	23.0	20.4	17.2	19.3	22.2	19.6	16.5	18.8	20.2	18.5	14.8	16.1	17.0	[1]16.0	18.6
Av.	20.1	21.9	24.8	22.2	18.2	20.7	24.6	21.2	18.1	20.0	24.2	20.8	17.9	19.9	22.1	20.0	21.0
1920	18.3	20.3	23.6	20.7	17.8	21.1	24.7	21.2	19.0	19.7	23.1	20.6	13.6	13.9	16.0	14.5	19.3
1921	18.4	18.1	22.0	19.5	14.4	17.5	21.8	17.9	17.2	17.0	18.7	17.6	17.7	17.0	17.5	17.4	18.1
1922	16.7	17.4	20.6	18.2	13.3	14.6	18.5	15.5	19.6	18.4	17.6	18.5	15.4	14.4	13.8	14.5	16.7
1923	17.3	20.5	22.4	20.1	15.9	16.6	18.5	17.0	15.3	15.5	14.5	15.1	12.2	14.6	12.6	13.1	16.3
1924	15.4	14.4	16.4	15.4	13.5	14.5	14.5	14.2	10.5	11.0	10.8	10.8	10.4	12.4	12.9	11.9	13.1
1925	17.9	19.1	19.2	18.7	16.3	15.8	16.7	16.3	21.1	18.4	19.5	19.7	15.3	14.4	13.3	14.3	17.2
1926	12.7	15.1	17.2	15.0	16.4	15.0	16.5	16.0	14.6	15.8	15.8	15.4	12.2	13.9	15.4	13.8	15.0
Av.	16.7	17.8	20.2	18.2	15.4	16.4	18.7	16.9	16.8	16.5	17.1	16.8	13.8	14.4	14.5	14.2	16.5

[1] See footnote 2, Table 46.

TABLE 44—*Mean monthly soil moisture contents at various depths*

[In percentages of dry soil weights]

STATION A–2

Year	June				July				August				September				Season average
	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	
1914	17.0	17.0	18.5	17.5	13.5	16.9	18.4	16.3	13.3	17.0	19.5	16.6	11.7	14.6	13.2	13.2	15.9
1915	10.0	12.1	14.3	12.1	7.5	9.2	10.5	9.1	10.0	8.6	10.5	9.7	6.8	8.4	7.7	7.6	9.6
1916	7.1	9.5	11.2	9.3	10.1	8.1	19.2	12.5	13.4	10.0	9.5	11.0	9.4	10.3	9.6	9.8	10.6
1917	13.9	16.2	17.0	15.7	10.3	18.4	12.8	13.8	11.0	11.0	11.1	11.0	8.0	8.3	9.6	8.6	12.3
1918	8.7	8.6	11.1	9.5	8.2	9.3	16.6	11.4	9.5	9.4	8.5	9.1	16.7	15.0	19.4	17.0	11.8
1919	12.1	12.0	14.1	12.7	12.8	14.0	12.9	13.2	11.6	12.0	12.6	12.1	11.2	13.5	12.2	[1]12.3	12.6
Av.	11.5	12.6	14.4	12.8	10.4	12.6	15.1	12.7	11.5	11.3	12.0	11.6	10.6	11.7	12.0	11.4	12.1
1920	11.2	12.9	13.1	12.4	12.2	13.6	15.2	13.7	10.6	11.1	12.2	11.3	8.0	7.7	8.0	7.9	11.3
1921	15.4	16.0	16.1	15.8	12.7	13.4	12.6	12.9	13.5	13.4	12.2	13.0	16.2	16.0	13.8	15.3	14.3
1922	15.6	14.9	16.6	15.7	9.2	11.3	9.8	10.1	13.6	11.6	13.8	13.0	10.7	10.8	11.7	11.1	12.5
1923	8.7	10.4	11.9	10.3	5.6	5.9	5.7	5.7	7.3	6.7	6.7	6.9	13.1	10.4	11.0	11.5	8.6
1924	10.2	11.6	10.0	10.6	4.3	3.8	4.2	4.1	4.8	5.6	5.7	5.4	6.1	6.1	6.4	6.2	6.6
1925	15.4	13.2	13.0	13.9	12.1	12.0	11.1	11.7	14.5	12.7	12.2	13.1	12.0	11.7	10.7	11.5	12.6
1926	10.6	9.7	10.9	10.4	14.4	13.5	14.1	14.0	13.6	13.5	14.1	13.7	8.7	8.5	8.8	8.7	11.7
Av.	12.4	12.7	13.1	12.7	10.1	10.5	10.4	10.3	11.1	10.7	11.0	10.9	10.7	10.2	10.1	10.3	11.1

[1] See footnote 2, Table 46.

TABLE 45.—*Mean monthly soil moisture contents at various depths*

[In percentages of dry soil weights]

STATION B–1

Year	June				July				August				September				Season average
	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	
1914	24.0	24.1	26.5	24.9	22.6	23.8	23.6	23.3	21.5	22.1	21.8	21.8	19.2	20.4	23.5	21.0	22.8
1915	19.8	22.0	28.0	23.3	14.0	17.9	19.6	17.2	14.3	16.6	19.6	16.8	13.8	16.2	15.7	15.2	18.1
1916	18.5	20.8	21.4	20.2	17.3	16.7	19.6	17.9	19.5	21.2	21.5	20.7	17.0	17.0	19.0	17.7	19.1
1917	21.2	22.8	20.7	21.6	15.4	19.4	24.0	19.6	14.8	15.4	18.6	16.3	12.1	11.0	13.1	12.1	17.4
1918	11.7	10.7	11.2	11.2	13.2	11.3	10.3	11.6	12.0	9.8	9.9	10.6	17.9	11.2	10.9	13.3	11.7
1919	16.9	18.0	20.0	18.3	14.6	16.0	17.2	15.9	16.1	15.6	19.3	17.0	17.4	16.8	18.2	[1]17.5	17.2
Av.	18.7	19.7	21.3	19.9	16.2	17.5	19.0	17.6	16.4	16.8	18.4	17.2	16.2	15.4	16.7	16.1	17.7
1920	19.4	19.8	22.5	20.6	17.0	18.6	22.7	19.4	16.5	16.7	17.1	16.8	13.4	12.5	12.1	12.7	17.4
1921	18.7	18.9	21.9	19.8	13.9	15.4	15.8	15.0	12.8	12.0	11.7	12.2	14.0	12.1	11.7	12.6	14.9
1922	16.7	17.4	19.0	17.7	11.1	13.1	12.9	12.4	15.6	12.5	11.0	13.0	12.8	11.1	10.5	11.5	13.6
1923	18.3	19.2	21.3	19.6	15.8	15.6	16.2	15.9	13.4	12.5	11.9	12.6	18.0	14.6	11.7	14.8	15.7
1924	16.0	16.9	16.8	16.6	13.6	14.0	13.1	13.6	9.5	10.2	10.4	10.0	12.0	12.0	11.2	11.7	13.0
1925	21.8	19.7	21.2	20.9	18.8	17.9	17.3	18.0	17.6	15.6	15.8	16.3	18.6	16.8	15.8	17.1	18.1
1926	18.8	18.6	20.0	19.1	17.4	17.2	16.1	16.9	14.2	13.8	13.2	13.7	13.0	12.8	11.4	12.4	15.5
Av.	18.5	18.6	20.4	19.2	15.4	16.0	16.3	15.9	14.2	13.3	13.0	13.5	14.5	13.1	12.1	13.2	15.5

[1] See footnote 2, Table 46.

TABLE 46.—*Mean monthly soil moisture contents at various depths*

[In percentages of dry soil weights]

STATION B-2

Year	June				July				August				September				Season average
	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	
1914	16.6	16.0	15.0	15.9	12.3	15.0	13.2	13.5	10.1	11.7	10.7	10.8	11.6	10.9	10.4	11.0	12.8
1915	12.6	17.4	16.7	15.6	8.7	13.6	11.6	11.3	11.7	12.5	10.9	11.7	10.4	10.6	11.4	10.8	12.3
1916	11.0	14.7	12.4	12.7	14.1	14.6	13.9	14.2	16.8	14.1	12.0	14.3	13.3	12.9	12.5	12.9	13.5
1917	16.6	19.4	21.3	19.1	13.5	15.0	17.8	15.4	12.1	14.0	14.4	13.5	11.4	9.2	12.6	[1]11.1	14.8
1918	11.5	10.8	10.2	10.8	11.8	10.8	10.7	11.1	12.9	10.6	9.8	11.1	13.1	11.0	10.2	11.4	11.1
1919	14.2	15.9	16.4	15.5	13.5	15.6	14.6	14.6	12.3	14.4	14.5	13.7	12.1	12.8	13.1	[2]12.7	14.1
Av.	13.8	15.7	15.3	14.9	12.3	14.1	13.6	13.4	12.6	12.9	12.0	12.5	12.0	11.2	11.7	11.6	13.1
1920	19.2	22.5	21.8	21.2	17.0	18.5	18.8	18.1	15.9	16.4	18.4	16.9	15.5	15.5	16.2	15.7	18.0
1921	18.6	17.6	19.2	18.5	18.1	18.4	19.0	18.5	18.5	18.5	19.2	18.7	16.0	18.0	18.1	17.4	18.3
1922	18.2	19.0	19.5	18.9	15.7	16.2	18.1	16.7	16.2	17.2	17.5	17.0	12.4	14.8	15.8	14.3	16.7
1923	17.9	19.2	19.3	18.8	15.1	15.9	16.2	15.7	17.8	16.4	16.1	16.8	14.2	13.8	13.8	13.9	16.3
1924	16.0	15.5	15.0	15.5	13.8	15.4	15.6	14.9	10.0	11.0	11.3	10.8	12.6	12.9	12.6	12.7	13.5
1925	20.0	19.2	18.6	19.3	18.4	17.6	17.9	18.0	16.6	17.0	16.4	16.7	16.2	16.2	15.7	16.0	17.5
1926	15.6	14.0	13.8	14.5	14.9	14.0	13.6	14.2	15.6	14.0	14.9	14.8	10.4	11.1	10.5	10.7	13.5
Av.	17.9	18.1	18.2	18.1	16.1	16.6	17.0	16.6	15.8	15.8	16.3	15.9	13.9	14.6	14.7	14.4	16.3

[1] Record missing for 3 feet but estimated midway between August and October percentages.

[2] Entire record for September lost through accident in drying samples. Place midway between August and October values.

TABLE 47.—*Mean monthly soil moisture contents at various depths*

[In percentages of dry soil weights

STATION D

Year	June				July				August				September				Season average
	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	1 foot	2 feet	3 feet	Average	
1914	24.3	27.4	27.8	26.5	24.1	25.8	24.6	24.8	25.2	30.1	28.7	20.0	23.2	32.9	25.1	27.1	26.6
1915	27.9	33.9	33.0	31.6	25.4	28.7	23.2	25.8	25.6	27.0	25.0	25.9	27.7	27.1	23.9	26.2	27.4
1916	21.6	24.6	25.7	24.0	20.1	23.2	23.3	22.2	25.1	23.7	23.9	24.2	21.5	22.7	24.2	22.8	23.3
1917	22.5	27.2	26.3	25.3	20.1	22.3	23.4	21.9	20.1	20.8	21.0	20.6	18.9	20.8	20.6	20.1	22.0
1918	19.4	19.4	21.1	20.0	19.0	19.9	19.9	19.6	20.2	19.0	20.7	20.0	20.6	21.2	21.3	21.0	20.1
1919	19.3	20.2	21.7	20.4	21.1	20.2	21.1	20.8	18.9	20.4	21.9	20.4	15.8	20.0	19.8	18.5	20.0
Av.	22.5	25.5	25.9	24.6	21.6	23.4	22.6	22.5	22.5	23.5	23.5	23.2	21.3	24.1	22.5	22.6	23.2
1920	18.7	21.0	22.6	20.8	18.3	19.5	21.7	19.8	18.4	20.3	21.3	20.0	17.5	21.4	21.2	20.0	20.2
1921	18.7	22.0	21.9	20.9	18.6	20.8	20.7	20.0	18.0	18.8	19.2	18.7	19.1	20.1	20.1	19.8	19.8
1922	19.4	21.6	21.0	20.7	16.8	17.7	19.5	18.0	18.4	20.2	21.3	20.0	17.6	18.0	19.5	18.4	19.2
1923	19.9	24.1	25.8	23.3	18.4	20.2	23.0	20.5	16.6	18.5	20.2	18.4	16.4	18.1	20.0	18.2	20.1
1924	16.1	17.8	20.1	18.0	16.8	16.7	17.5	17.0	16.6	16.4	16.5	16.5	17.2	18.6	19.2	18.3	17.5
1925	18.5	19.0	19.3	18.9	21.1	21.9	22.0	21.7	21.6	22.3	18.3	20.7	20.2	20.7	21.5	20.8	20.5
1926	18.4	16.0	17.6	17.3	20.0	19.3	20.9	20.1	21.3	20.6	20.5	20.8	17.0	17.2	17.6	17.3	18.9
Av.	18.5	20.2	21.2	20.0	18.6	19.4	20.8	19.6	18.7	19.6	19.6	19.3	17.9	19.2	19.9	19.0	19.5

1. At station A-1 the average moisture for all depths during the four summer months was 21 per cent for the six predenudation years and 16.5 per cent for the seven postdenudation years. The first period showed an average decline, all depths considered, of 2.2 per cent from June to September; the second period a decrease of 4 per cent. It thus appears that the second period had less moisture at the beginning of the summer and that the summer drain was somewhat more severe.

2. Station A-2 had a predenudation average of 12.1 per cent, a summer decline of 1.4 per cent, a postdenudation average of 11 per cent, and a decline of 2.4 per cent. Stations A-1 and A-2 are, therefore, consistent.

3. Station D, also not disturbed by denudation, had a predenudation average of 23.2 per cent, a summer decline of 2 per cent, a postdenudation average of 19.5 per cent and a decline of 1 per cent.

4. Station B-1 showed a predenudation average of 17.7 per cent, a summer decline of 3.8 per cent, a postdenudation average of 15.5 per cent, and a decline of 6 per cent.

5. Station B-2 had a predenudation summer average of 13.1 per cent, and a June to September decline of 3.3 per cent. In the postdenudation period the amounts were 16.3 and 3.7 per cent.

Of the above stations, only B-1 and B-2 could have been altered in the second group of years by the removal of timber. Yet four out of the five stations showed a decrease in average summer soil moisture in the second period. This decrease is so general as to raise a grave question as to how an opposite tendency could be shown by station B-2. With this increase at B-2, the B watershed (average of B-1 and B-2), increased about 0.5 per cent between the two periods, while the A watershed decreased 2.8 per cent, or 3.1 per cent if D be included.

On the other hand, the degree of summer exhaustion, or the drop in the averages from June to September, is somewhat more consistent, D being the only station which does not show a more rapid exhaustion in the second than in the first group of years. For watershed B, the average amounts would be 3.55 per cent for the first period and 4.85 per cent for the second; for watershed A, 1.8 per cent for the first and 3.3 per cent for the second.

Since the two measures of the possible effect of denudation on the soil moisture of B are contradictory, no definite conclusion can be drawn. It would seem, however, that if the forest removal did decrease the summer drain upon the soil moisture, the difference must have been very slight. There is no evidence of this decrease for the conditions of the north slope (B-1) from which most of the summer stream flow certainly comes.

EVAPORATION

In 1920 two standard Weather Bureau apparatus for measuring the evaporation from free water surface were installed at the meteorological stations in A watershed, one on the south slope and the other on the north slope.

Table 48 presents the seven years of record in the form of monthly totals for both slopes during the warm months, June–September, and for parts of October on the south slope. The total measured evaporation on the north slope is about half the total annual precipitation. On the south slope the opportunity for evaporation is considerably greater than on the north slope as was to have been expected; in some months the measured evaporation was many times greater than the measured precipitation. Thus for June, 1924, a total monthly evaporation of 7.3 inches was measured, although the total rainfall was but 0.18 inch. Evidently the evaporation from a free-water surface can not give a precise measure of the total loss from soil and vegetation. The two sets of figures in Table 48 combined give an average for four of the warmer months alone of somewhat over 75 per cent of the mean annual precipitation. Nevertheless, these figures are valuable for comparing the general dryness of the several seasons.

TABLE 48.—*Monthly evaporation, in inches of depth, from a free-water surface*

WATERSHED A NORTH SLOPE

Year	June	July	August	September	October	Total [1]
1920	3.732	3.523	2.605	1.544	----------	11.404
1921	3.807	3.189	1.832	1.977	----------	10.805
1922	4.205	4.159	2.413	1.997	----------	12.774
1923	5.156	3.492	2.152	1.509	----------	12.309
1924	5.203	3.747	3.070	2.267	----------	14.287
1925	3.212	2.937	2.206	1.455	----------	9.810
1926	4.167	2.841	2.812	1.887	----------	11.707
Means	4.212	3.413	2.441	1.805	----------	11.871

[1] Omitting October figures.

TABLE 48.—*Monthly evaporation, in inches of depth, from a free-water surface*—Continued

WATERSHED A SOUTH SLOPE

Year	June	July	August	September	October	Total
1920	4.586	4.874	4.650	3.980	[2] 1.901	18.090
1921	5.127	4.800	3.884	5.120	[3] 2.912	18.931
1922	5.413	5.840	4.557	4.584	[4] 3.952	20.394
1923	6.680	6.260	4.569	3.579	2.228	21.088
1924	7.304	6.161	6.004	5.145		24.614
1925	5.151	5.389	4.716	4.234		19.490
1926	6.487	5.492	5.647	4.888		22.514
Means	5.821	5.545	4.861	4.504		20.732

[2] For 19 days. [3] For 27 days. [4] For 25 days.

Beginning in the autumn of 1919 when denudation was under way, instruments developed by the Forest Service and known as "inner-cell" evaporimeters were exposed at each of the observation stations on watersheds A and B in order to determine the extent to which removal of the forest cover might influence the tendency toward surface drying. In order to eliminate the effect of variations between the several instruments, they were moved monthly from one station to another. This will account for occasional monthly values which may seem out of proportion to those at other stations. The instruments were replaced annually by fresh ones, usually in the spring. Evaporation losses are determined by weighing the instruments.

TABLE 49.—*Total evaporation, by inner-cell evaporimeters, in grams per 100 square centimeters of surface* [1]

Year	October	November	December	January	February	March	April	May	June	July	August	September	Total June-September	Total annual
Station A-1:														
1919-20	68	23	11	13	15	33	108	197	346	[2]360	313	174	1,193	1,661
1920-21	144	21	3	17	17	83	137	418	255	216	346	159	975	1,814
1921-22	101	58	18	4	22	45	105	250	330	294	186	169	979	1,583
1922-23	106	19	11	17	10	48	115	302	362	330	233	126	1,052	1,680
1923-24	86	16	16	3	26	28	127	253	547	242	291	231	1,311	1,867
1924-25	97	59	12	9	9	64	136	285	216	176	151	188	731	1,403
1925-26	88	22	11	6	41	55	146	151	360	417	259	267	1,302	1,823
Average	99	31	12	10	20	51	125	265	345	291	254	188	1,078	1,690
Station A-2:														
1919-20	120	57	48	75	64	86	122	269	376	369	330	284	1,359	2,200
1920-21	145	61	32	49	55	124	148	286	463	267	201	380	1,312	2,213
1921-22	138	108	54	2	50	95	167	284	360	386	251	322	1,319	2,219
1922-23	224	52	53	62	56	83	162	304	473	287	267	363	1,390	2,386
1923-24	113	55	32	41	62	80	161	301	505	445	305	654	1,909	2,754
1924-25	212	89	30	46	62	132	198	293	343	258	191	224	1,016	2,078
1925-26	197	79	43	36	68	125	147	265	304	323	438	319	1,384	2,343
Average	164	71	42	46	60	104	158	286	403	334	283	364	1,384	2,313
Station B-1:														
1919-20	166	53	7	29	61	105	208	462	388	370	346	273	1,377	2,467
1920-21	199	48	3	28	70	129	202	246	291	336	289	304	1,220	2,146
1921-22	171	125	39	10	43	43	120	307	433	439	161	151	1,184	2,042
1922-23	148	56	20	34	54	110	235	374	412	295	233	156	1,097	2,128
1923-24	152	63	33	13	52	99	188	353	521	362	413	400	1,695	2,649
1924-25	195	71	13	12	52	163	282	329	299	288	228	208	1,022	2,140
1925-26	149	53	16	13	78	115	192	266	413	290	361	321	1,384	2,267
Average	169	67	19	20	59	109	204	334	394	340	290	259	1,283	2,263
Station B-2:														
1919-20	247	104	70	48	67	103	153	427	516	486	359	260	1,620	2,839
1920-21	159	78	34	60	82	129	173	257	570	360	222	404	1,556	2,529
1921-22	211	121	63	40	71	88	104	278	432	447	270	302	1,451	2,427
1922-23	230	74	62	71	51	112	186	417	552	321	264	208	1,345	2,549
1923-24	166	77	50	13	70	87	174	283	700	435	440	382	1,958	2,879
1924-25	285	118	37	37	62	174	297	270	259	285	290	343	1,177	2,457
1925-26	168	66	52	52	110	86	200	393	521	294	383	450	1,648	2,773
Average	210	91	53	46	73	111	184	332	507	376	318	336	1,536	2,636
Station D:														
1919-20	[3] 90	31	74	104	89	32	82	272	393	545	304	454	1,696	2,471
1920-21	296	90	43	59	79	154	147	250	384	372	97	306	1,160	2,277
1921-22	225	112	81	39	5	91	137	349	369	197	274	253	1,093	2,135
1922-23	189	79	55	79	60	101	141	431	490	297	179	243	1,209	2,345
1923-24	282	116	50	43	107	76	252	304	529	407	622	270	1,827	3,058
1924-25	194	89	57	41	66	161	313	321	386	388	190	216	1,179	2,420
1925-26	133	74	53	34	69	64	120	211	346	275	319	236	1,177	1,936
Average	201	85	59	57	68	97	170	306	414	354	284	283	1,334	2,377

[1] Fractions dropped after computing averages and totals.
[2] Actual measurement much higher, probably due to erratic behavior of instrument. This amount is estimated.
[3] Estimated.

Table 49 gives the complete monthly record rounded off to whole grams.

In Table 50 the evaporation quantities are summarized for the more convenient comparison of the two watersheds, taking, for A, the average of the amounts at, A-1, A-2, and D, and for B, the average for stations B-1 B-2, and D. To transpose the amounts in grams per 100 square centimeters to inches of depth, it is only necessary to divide by 254.

TABLE 50.—*Summary of watershed evaporation for the years after denudation, expressed in inches*

Year	Whole year		Summer, June to September		Snow period, October to May [1]	
	A	B	A	B	A	B
1919-20	8.31	10.21	5.57	6.16	2.74	4.05
1920-21	8.27	9.12	4.52	5.17	3.75	3.95
1921-22	7.79	8.67	4.45	4.89	3.34	3.78
1922-23	8.41	9.22	4.79	4.79	3.62	4.43
1923-24	10.08	11.27	6.62	7.19	3.46	4.08
1924-25	7.74	9.21	3.84	4.43	3.90	4.78
1925-26	8.01	9.15	5.07	5.52	2.94	3.63
Averages	8.37	9.55	4.98	5.45	3.39	4.10

[1] By subtraction—not separately computed.

It will be noted first, that the quantities are considerably smaller than the corresponding evaporation from free-water surfaces, averaging only about one-third as much for the four summer months. This measure has the same objectionable feature as all others, that it reflects only general atmospheric conditions and takes no account of the *wetness* of the natural surfaces from which evaporation on a broad scale actually takes place. Consequently, the evaporation loss measured artificially can never be used to determine the residue which will be left for stream flow.

This record, however, has a great advantage over that obtained from pans of water, in that it permits a measure of conditions during the winter season. It will be observed that the contrast between the two watersheds is much more noticeable at this time than during the summer, since, when the sun is low, a very little cover, especially on the north slopes, is sufficient to nullify any direct sunlight which might otherwise reach the ground.

The several years, however, are extremely uniform in the total amounts of winter evaporation, while the summers of 1924 and 1925 vary in a 5:3 ratio. The corresponding precipitation amounts (A) were 4.29 and 10.84 inches.

SOURCES OF EVAPORATION LOSSES

In the preliminary report, an attempt was made to allocate the total losses by evaporation on a somewhat theoretical basis. This may now be done with a considerably better knowledge of local conditions. The average total summer or growing season evaporation shown by Table 50 is 4.98 inches for A and 5.45 for B. This leaves 3.39 for A and 4.10 for B during the time that snow is likely to be lying on the ground in appreciable quantitites.

The above evaporation quantities for B represent merely the relative opportunities for evaporation. The actual annual quantity evaporated from watershed B for the entire postdenudation period must have been of the order of 13.57 inches, or average annual precipitation (20.83 inches, Table 37) minus 7.26 inches, which in Table 52 will be shown to be the average annual run-off. This loss may then be computed according to the relative opportunity for evaporation (Table 50) as about

7.57 inches for summer and 6 inches for winter periods, a little being added to the latter because of the greater availability of moisture for evaporation throughout the winter.

The next assumption must be, since only the soil moisture data gave indication of a decreased total evaporation loss from B as a result of denudation (and this is scarcely more than a suggestion) that the summer loss from A, evaporation plus transpiration, was practically the same as the loss from B, which includes only a small item for transpiration. A loss of about 7.9 inches for A would seem to make ample allowance for any difference between A and B.

As A's total annual loss was $21.16-6.20=14.96$ inches for the postdenudation period, the winter evaporation from A must be placed at 7.06 inches.

To indicate how much of this winter loss from A is due to interception it is again necessary to revert to the instrumental evaporation for A and B during the winter.

The 6 inches of winter evaporation loss from B represents evaporation from snow and ground surfaces largely, with only a trifling amount of interception estimated at 0.5 inch, whereas the 7.06 inches from A represents unquestionably smaller snow and ground losses plus interception by trees and direct loss from snow held on their limbs. The ground and snow surface losses must stand in somewhat the ratio of the instrument losses for this period (since the instruments were under the trees on A), the instrument loss for B being 4.10 and that for A 3.39 inches, and the ground loss for B being $6-0.5=5.5$ inches, that for A must be 4.55 inches, leaving $7.06-4.55=2.51$ inches as the probable amount intercepted by the tree crowns during this period on watershed A in contrast to the 0.5 inch suggested as possible for B. This takes no account of rainfall interception which, under the conditions at Wagon Wheel Gap, might be nearly as much. This will probably explain the difference between the present figure 2.51 inches, and that suggested in the original report, 3.6 inches. The rainfall interception may best be lumped with transpiration.

There is little basis for an estimate of the proportion of the total summer loss represented by interception, transpiration, and evaporation from the ground surface, since the net results seem to be about the same with a forest cover and with the partial cover of aspen, grass, and herbs which quickly followed denudation. The

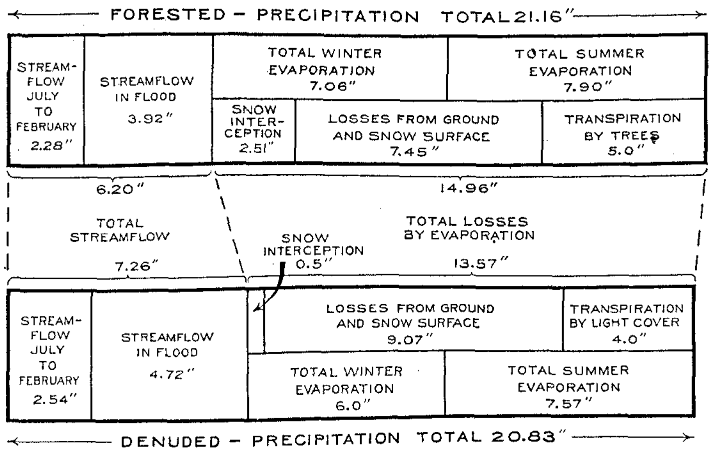


FIG. 27. Effect of forest on disposal of precipitation

basis is equally slight for judging whether either transpiration or interception by this light cover were large factors, or whether the losses were more largely from the ground surface. Consequently it is conservatively assumed that 1 inch of loss moves from the transpiration to the direct evaporation loss.

Figure 27 represents, however, the writers' ideas as to the total disposition of water with and without forest cover.

CHAPTER III. STREAM FLOW BEFORE AND AFTER DENUDATION

This chapter will be confined to a comparison of the stream-flow data for the two periods of the experiment and to such analyses of the relation of stream flow to precipitation and other factors as appear necessary for the correct interpretation of the facts recorded.

Those who may have an interest in the details of the stream-flow record, or who may desire to make a minute analysis of the comparative data, should refer to Table 66 at the end of this report, which gives the daily record of discharge of both streams, together with the "watershed precipitation" similarly allocated to midnight-to-midnight periods. The latter, as already explained, represents for each day the mean of two amounts recorded in the lower and upper portions of the watersheds, respectively.

This daily record of stream flow worked out to hundred-thousandths of an inch over the watershed[1] forms the basis of all tables. The daily value for either watershed is obtained from the sum of the 24 hourly readings of streamflow in cubic feet per second. This sum is multiplied by 3,600, the number of seconds in an hour, divided by the area of the watershed in acres, and again divided by $\frac{43560}{12}$. The final quotient is the depth in inches over the watershed. Actually the daily sums for A have been multiplied by 0.004457, and those for B by 0.004949, these figures being more nearly exact than measurements of the areas of the watersheds are likely to be. (See footnote, Table 1.)

The sum of all the readings of stream flow is a figure usually of four digits. The last digit is not significant, as shown by the weir-rating tables described in chapter 1, but is arbitrarily retained. In the final tables showing discharges in inches over watershed sufficient digits have been retained to bring out significant differences, and generally enough to establish the ratio B/A to three decimal places. No fractional amounts have, however, been dropped until after the addition of the daily values.

BROADER RELATIONS BETWEEN THE TWO PERIODS OF THE EXPERIMENT

In Tables 51 and 52 are presented the stream-discharge totals by months for each stream-flow year of the experiment, with averages for the predenudation and postdenudation periods. All of the data obtained prior to August, 1911, being of doubtful accuracy, the data for the year 1910–11 do not enter into the averages, but are given merely for their possible value in showing the conditions immediately preceding the period of more accurate measurement.

This broad presentation will permit certain general impressions to be gained of the relative behavior of the two streams and of the effects of denudation, as a preliminary to the more detailed analysis of these relations to be entered into later.

These tables, with the aid of Figure 28, show:

TABLE 51.—*Monthly discharges of A stream, in inches, over watershed*

[All figures, including totals and averages, rounded off from the 5-place data]

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910–11 [1]	[2] 0.364	[3] 0.257	0.239	0.267	0.194	0.294	0.674	1.663	0.611	0.495	0.358	0.310	5.725
1911–12	.901	.456	.367	.312	.267	.308	.460	2.951	1.044	.566	.413	.323	8.370
1912–13	.339	.300	.286	.278	.227	.284	.795	.802	.586	.356	.264	.261	4.779
1913–14	.287	.255	.249	.241	.216	.271	.545	1.639	.769	.491	.362	.304	5.628
1914–15	.308	.238	.226	.259	.218	.240	.460	1.621	.835	.402	.294	.253	5.354
1915–16	.274	.245	.226	.219	.207	.365	.652	1.721	.604	.407	.373	.303	5.593
1916–17	.424	.341	.254	.236	.211	.249	.610	3.258	2.622	.700	.419	.320	9.643
1917–18	.317	.271	.253	.233	.199	.222	.315	.420	.288	.236	.201	.240	3.195
1918–19	.238	.222	.223	.217	.191	.223	.782	2.138	.803	.480	.309	.255	6.079
Postdenudation period:													
1919–20	.276	.254	.250	.237	.218	.241	.347	3.583	1.292	.503	.357	.305	7.865
1920–21	.316	.291	.278	.266	.240	.339	.567	2.240	1.083	.534	.416	.328	6.898
1921–22	.324	.292	.282	.262	.237	.284	.457	2.549	1.001	.447	.396	.298	6.830
1922–23	.316	.300	.294	.277	.245	.272	.446	2.064	.738	.427	.366	.345	6.091
1923–24	.388	.348	.314	.282	.257	.278	.920	2.518	.789	.428	.305	.276	7.104
1924–25	.316	.289	.288	.274	.244	.294	.599	.696	.440	.308	.267	.254	4.269
1925–26	.279	.252	.247	.231	.208	.236	.444	1.068	.588	.352	.260	.212	4.379
General average	.353	.290	.269	.255	.226	.274	.560	1.951	.899	.443	.334	.285	6.139
Predenudation average	.386	.291	.260	.249	.217	.270	.577	1.819	.944	.455	.329	.282	6.080
Postdenudation average	.316	.290	.279	.261	.236	.278	.540	2.103	.847	.429	.338	.288	6.205

[1] Not included in averages since entire record before August is approximate only.
[2] Estimated from record of precipitation at a near-by station.
[3] Estimated from rate around middle of month.

TABLE 52.—*Monthly discharges of B stream, in inches, over watershed*

[All figures, including totals and averages, rounded off from the 5-place data]

Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Predenudation period:													
1910–11 [1]	[2] 0.396	[3] 0.295	0.269	0.256	0.209	0.292	0.470	1.607	0.488	0.331	0.314	0.292	5.218
1911–12	.984	.433	.362	.337	.307	.338	.504	2.928	.962	.497	.384	.335	8.371
1912–13	.380	.350	.339	.329	.289	.323	.564	1.020	.690	.378	.274	.278	5.214
1913–14	.307	.289	.288	.281	.247	.302	.464	1.734	.694	.380	.290	.277	5.553
1914–15	.315	.291	.287	.297	.261	.285	.436	1.584	.810	.337	.258	.247	5.407
1915–16	.281	.271	.268	.269	.248	.373	.570	1.784	.555	.325	.323	.289	5.555
1916–17	.457	.382	.322	.303	.266	.295	.580	2.962	3.097	.550	.341	.287	9.843
1917–18	.321	.313	.311	.303	.268	.316	.336	.372	.283	.248	.215	.250	3.534
1918–19	.252	.241	.237	.233	.206	.237	.681	2.284	.677	.362	.289	.270	5.970
Postdenudation period:													
1919–20	.285	.270	.273	.263	.243	.295	.555	4.010	1.235	.451	.340	.330	8.550
1920–21	.364	.360	.351	.336	.318	.703	.737	2.927	.977	.493	.397	.364	8.328
1921–22	.397	.366	.346	.348	.311	.377	.862	3.641	.996	.428	.379	.317	8.769
1922–23	.350	.349	.348	.325	.289	.334	.698	2.680	.697	.382	.351	.363	7.168
1923–24	.453	.411	.358	.340	.316	.353	1.006	3.093	.646	.391	.316	.332	8.016
1924–25	.382	.351	.345	.324	.294	.355	.588	.934	.447	.338	.308	.283	4.948
1925–26	.310	.286	.274	.258	.236	.291	.442	1.612	.540	.320	.254	.228	5.050
General average	.389	.331	.314	.303	.273	.345	.602	2.238	.887	.392	.315	.297	6.685
Predenudation average	.412	321	.302	.294	.261	.308	.517	1.834	.971	.385	.297	.279	6.181
Postdenudation average	.363	.342	.328	.313	.287	.387	.698	2.700	.791	.400	.335	.317	7.261

[1] Not included in averages, since entire record before August is approximate only.
[2] Estimated from record of precipitation at a nearby station.
[3] Based on rate at middle of month; evidently low compared with December, due to poor setting of hook-gage. Measured amount increased 20 per cent.

[1] This expression "inches over watershed" will hereafter be abbreviated to "inches O. W." The use of this measurement is designed, of course, to remove the factor of area, so that the records of the two watersheds here considered may be not only mutually comparable, but also comparable with any other records of stream flow or precipitation. For example, in the statement that rainfall of 1 inch yielded 0.10 inch O. W., the terms are directly comparable without consideration of the areas involved. 1 inch of stream discharge thus implies one-twelfth acre-foot of water for each acre of the watershed, and the net yield of 6 inches per annum implies that each acre is capable of supplying one-half of an acre-foot.

1. In the predenudation period the average annual discharge of A watershed was 6.08 inches, and of B 6.18 inches, either amount being, in round numbers, 29 per cent of the average precipitation, shown elsewhere to have been 21.03 inches on A and 21.10 inches on B. In the postdenudation period the discharge by A was 6.21 inches, or again 29 per cent of the A precipitation, and that by B was 7.26 inches, or 35 per cent of the B precipitation.

2. Although in the predenudation period A and B discharged so nearly the same total amounts as to dispel any fear of accessions from outside sources or of failure to record essentially the total run-off at the dams, it is to be noted that the relation of the two streams was by no means constant. In this period stream B almost invariably discharged less than A during the summer months, the two were almost on a parity in September, and B was always higher than A throughout the fall and winter.

3. This presentation by months is not very satisfactory for comparing the rapidly changing relations of the flood period. Since the date of beginning was usually at the end of March, of cresting about May 20, and of termination of the flood about the end of June, the months of

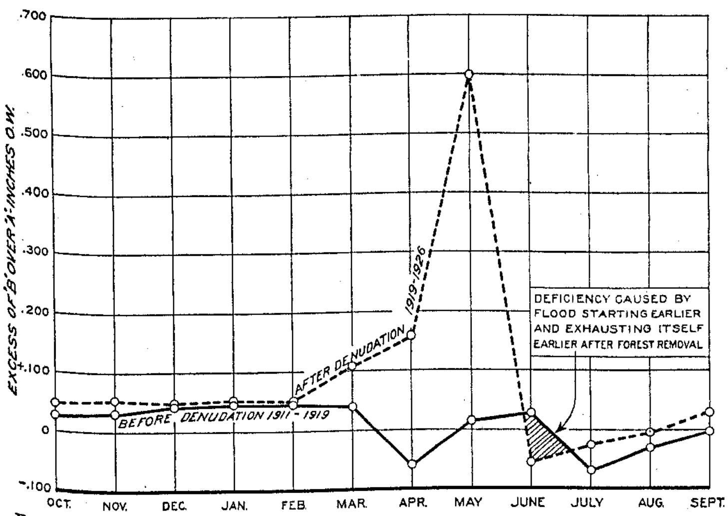


FIG. 28. Time and amount of stream flow excesses and deficiencies on monthly basis

April, May, and June may be considered as covering, respectively, rise, cresting, and decline. The aggregate figures then show that although the total discharges in flood were in the predenudation period nearly the same, B lagged a little behind A in the rise, discharged a larger amount near the crest, and again approached A on the decline. Actually, the rate for B usually fell a little below that for A before the end of the flood, but it was so much higher than A for a time after the crest that the June totals showed an excess for B.

4. In the postdenudation period, despite an apparent deficiency in precipitation on B, the discharge of B approached much nearer to that of A in July and August, and exceeded it in September, remaining appreciably higher during the winter, and decidedly higher throughout the early and middle portions of the flood period. Especially noticeable is the high ratio B/A for March and April, indicating the effect of earlier and more rapid melting as a result of denudation. From this it might be expected that B stream would fall to a lower level than A during the decline of the flood and this appears to be the case, but the deficiency in June is comparatively small. The date when B fell below A was advanced, so that June as a whole showed a deficit. There was, however, an actual deficit only for a short period immediately after the crest, as will be better seen when the flood period is further analyzed.

The outstanding facts of this general survey are that on these watersheds, despite or perhaps as a result of great porosity of soil which guarantees deep penetration of precipitation and snow water, about 70 per cent of the total precipitation goes back into the atmosphere without reaching the stream channels. An appreciable increase in stream flow is effected by removal of the trees, although this occurs mainly in the flood period when it is quite as likely to be damaging as beneficial. Stream B is at all times in a slightly different phase of its discharge from stream A, so that further careful study of the data is desirable to determine how much the discharge of the denuded watershed was affected at a given time. This may make clear the causes and sources of change, and may lead to the more intelligent application of the principles to other conditions.

THE LAG IN DISCHARGE OF STREAM B

The discussion above suggests a certain fundamental difference between the régimes of the two streams, which, since it affects all of the following discussions, may as well be clarified at this point. The fact that in the predenudation period B was almost invariably lower than A at the end of a spring flood, gradually came back to parity at the end of the summer, and then remained above A throughout the winter period when very little was being added to the ground water, suggests greater storage reservoirs for watershed B, or subterranean conditions which in some manner permit a slower escape of water. There is not much question in the minds of the writers that the south-slope spring on B, described in the introductory chapter, represents the outlet of a relatively deep storage reservoir and has, on the whole, a steadying influence on the stream. It may even lead water by a slow and circuitous route from the upper to the lower portion of the watershed, although there is no basis for believing that it has any source outside the boundaries of the watershed which the surface survey attempted to determine. Relatively speaking, it is only necessary to think of the ground water of A having a shorter distance to move before it enters the stream channel and there proceeds as a living stream with relatively high velocity. The greater length of the stream channel of A, and the fact that in its upper portion the stream may be subterranean for a considerable distance, are of importance only in comparisons involving hours or days; for example, in the delivery of water from a short rain.

Whatever the repository of the slow-draining water from B, the behavior of the two streams can be readily illustrated. This might be done by reference to any of the larger spring floods except that at this season, when snow melting covers so long a period, the exact time when water becomes available for possible stream flow can not be known, and it is probably not quite the same for the two watersheds. The flood of October, 1911, is a better example. It stands apart as being the result of an extraordinarily heavy rain covering only about 30 hours, and as being followed by cold weather which largely prevented new accessions to the ground water. The comparatively wet summer of 1911 probably made the results more striking than they would otherwise have been from a rain of 3 inches, but this earlier moisture does not appreciably confuse the relations of the two streams.

Figure 29 presents sufficiently the data that are needed, in addition to the monthly totals given in Tables 51 and 52. It will be observed that both streams reached their "crests" of hourly discharge rate very promptly after the time of heaviest precipitation, B being about an hour ahead of A. This is characteristic of all rains of sufficient intensity to put appreciable water *directly* into the stream. In this instance the crest on A was considerably higher than that on B, denoting the larger area of open water on the former stream.

There is shown, then, after October 8, a higher rate for B, amounting on October 11 to an excess of 52 per cent. B then declined more rapidly than A. By October 24 the streams had reached parity, and for the whole month of October the discharge of B was only 9.2 per cent greater than that of A. In November the discharge of B was 5 per cent less than that of A, and in December 1.4 per

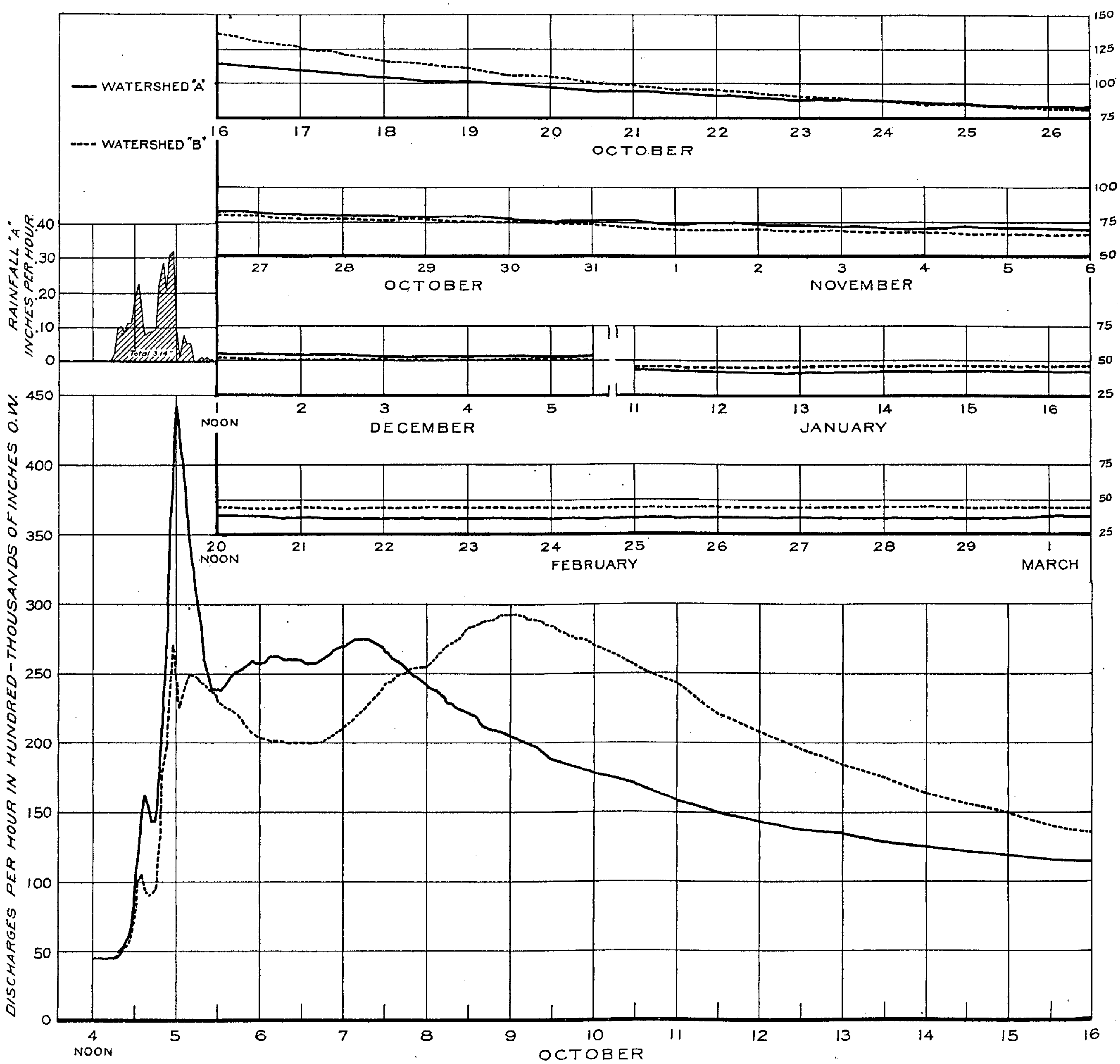


FIG. 29. Discharge of A and B at intervals after flood rain of October 4, 1911

This "surface" crest is of less importance, however, than the secondary crest from ground water, which reached its maximum on A about 52 hours after the hour of heaviest rainfall and on B 99 hours after. These secondary crests were higher than the first crest of stream B. This difference in time shows the effect of delivery from the shorter and steeper slopes of watershed A, in contrast to that from the long slopes of B.

cent less, the daily rate for B again passing above that for A, temporarily on December 20 and finally on December 31. It is thus evident that during November and a part of December, water draining from the more distant portions of the long watershed A was relatively important, while at a later date B was affected by a supply held in even greater reserve. This is of such deep source and steady delivery that the daily rate for B, on February 29, for example, was 94 per cent of the rate on the day when the streams last reached parity, while for A it had declined to 79 per cent of the December 30 rate.

It is readily apparent that where perennial streams are being considered and where rarely a month passes without appreciable precipitation, stream flow at any given time must be composed of numerous contributions to the surface and ground water, of varying ages and degrees of availability. It could readily be shown, from a composite curve, that from a high-water stage representing complete ground saturation after the spring melting of snow, neither of the watersheds involved in this study would drain to dryness in less than six months, and possibly not in 12 months. This merely means that precipitation occurring, or snow melting at least six months before a given date, as well as all of the contributions in the interval, have some effect on the régime of each stream. The above discussion makes it clear that the precipitation of a time long preceding has considerably more influence on B than on A.

A close prediction of stream flow at any time from precipitation and other meteorological records would involve so many factors as to be practically impossible of attainment. The great complications which arise should be readily apparent from Figure 30, which shows the normal distribution of precipitation and run off of A. On the other hand, if the flow of stream A be taken as the moving

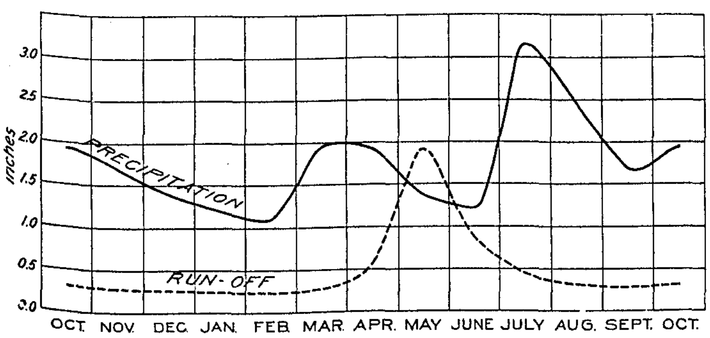


FIG. 30. Normal distribution of precipitation and runoff from watershed A, by months

reference point, and the conditions leading up to its régime at a given time are considered, some sort of prediction of the relative position of B may be made, keeping in mind the character of variations between A and B pointed out above.

RELATIONS FOR WHOLE YEARS

In Table 53 the yearly total stream discharges are summarized for more ready comparison, together with the precipitation totals, and such computed values as are necessary to obtain a picture of the variations in relation between the two streams. The following discussion brings up the various facts and relationships in an order designed to lead to their correct interpretation.

1. In the predenudation period B, on the average, discharged 0.1004 inch more per year than A, an excess of about 1.7 per cent. In the postdenudation period the average excesses of B amounted to 1.0560 inches or about 17 per cent of the discharge of A. In view of the fact that the "normal" or predenudation ratio of B to A seems to be somewhat above unity, and that it varied from 0.982 to 1.106, it is extremely important to inquire into the causes of variation from year to year. Otherwise the mean excess of the postdenudation period, and the apparent excesses of individual years, varying from 0.67 to 1.94 inches, remain somewhat meaningless.

TABLE 53.—*Precipitation and run-off summary by whole years*

Year	Total precipitation (inches)		Run-off (inches)		Difference B-A	Ratio B/A	Change in run-off of A	Proportion of precipitation appearing as run-off	
	A	B	A	B				A	B
1911-12	21.32	21.49	8.3702	8.3708	+0.0006	1.000	[1] +2.645	0.393	0.390
1912-13	18.67	19.66	4.7791	5.2139	+.4348	1.091	−3.591	.256	.265
1913-14	22.63	21.87	5.6284	5.5529	−.0755	.987	+.849	.249	.254
1914-15	19.98	19.85	5.3541	5.4066	+.0525	1.010	−.274	.268	.272
1915-16	22.71	23.13	5.5934	5.5554	−.0380	.993	+.239	.246	.240
1916-17	22.88	22.78	9.6432	9.8429	+.1997	1.021	+4.050	.421	.432
1917-18	18.90	18.85	3.1953	3.5340	+.3387	1.106	−6.448	.169	.187
1918-19	21.13	21.15	6.0793	5.9702	−.1091	.982	+2.884	.288	.282
Means [2]	21.03	21.10	6.0804	6.1808	+.1004	1.017	----------	.289	.293
After denudation									
1919-20	22.49	21.78	7.8654	8.5500	+0.6846	1.087	+1.786	0.350	0.393
1920-21	22.69	22.49	6.8983	8.3275	+1.4292	1.207	−.967	.304	.370
1921-22	21.44	20.52	6.8296	8.7690	+1.9394	1.284	−.069	.319	.427
1922-23	24.35	23.80	6.0911	7.1675	+1.0764	1.177	−.738	.250	.301
1923-24	17.01	16.77	7.1039	8.0158	+.9119	1.128	+1.013	.418	.478
1924-25	21.90	22.40	4.2686	4.9478	+.6792	1.159	−2.835	.195	.221
1925-26	18.26	18.06	4.3793	5.0505	+.6712	1.153	+.111	.240	.280
Means [2]	21.16	20.83	6.2052	7.2612	+1.0560	1.170	----------	.293	.349

[1] Approximate; record for 1910-11 very incomplete.
[2] Means of ratios are algebraic.

2. It will be noted that extremely high ratios B/A occurred in the years 1912–13 and 1917–18, when, due to low precipitation, there was a decided falling off in the discharge of both streams. This illustrates the point which the discussion of the "lag" of stream B was intended to make clear, that watershed B probably has a greater capacity than A to store water and carry it over into a dry year. The reverse relationship is true in 1913–14 and 1915–16 when increases were shown by both streams, but does not hold good in 1916–17, apparently because of the large size of the flood induced in part by late snow, and which may be thought of as exceeding the capacity of B for storage.

On the other hand, variations in precipitation between A and B, which are appreciable in 1912–13 and 1913–14, may readily account in part for the high ratio B/A of the first year, and entirely for the low one of the second. Considering all of the prenudation years, the correlation is much closer between the two run-offs if that of each watershed is related to its own precipitation than if those of both are related to a single set of precipitation values.

3. Considering the precipitation figures of the second period, it is evident that the greatest differences between A and B were shown in 1921–22, when B was 0.92 inch under A, but when B nevertheless produced its greatest excess discharge. In 1922–23, B again had less precipitation than A and its discharge remained high. In 1924–25, when B received 0.50 inch more than A, its discharge excess was relatively small (considering the apparent cyclic trend). All in all, the general deficiency of B precipitation in the second period is not to be given much weight because of the less favorable opportunities for complete catches; moreover the variations from year to year explain nothing.

The year 1923–24 might have been expected to produce a high ratio B/A if only the marked drop in precipitation be considered. However, the large run-off of both watersheds during the year points to the fact that the heavy precipitation of 1922–23—of which 11.53 inches for A fell in the months of June to September—must have been carried over to the streamflow year 1923–24 in very unusual degree. This was doubtless augmented by extraordinarily heavy snowfall in March, 1924, which tended further to produce large and concentrated floods in both streams. It is impossible to suggest what the normal ratio B/A would have been with such a combination of factors, although comparison of 1923–24 with 1916–17 would seem the safest.

Since 1925–26, with its low precipitation, did not show less run-off than 1924–25, there are no years of the second period in which very high ratios of B to A run-off might have been expected had forest conditions remained the same. It is, therefore, necessary to assume that the magnitude of the postdenudation excesses of B, from year to year, were not greatly affected by variables such as occurred in the first period: We may take them practically at face value, representing an increase in streamflow due to denudation of about 0.96 inch per year.

4. This discussion leaves unanswered three logical questions which, it seems, must be approached from a different angle. These concern the apparently "normal excess" of B over A stream flow, the source of the much larger excesses in the second period, and the apparently cyclic trend of the latter, which rose to a peak in the third year after denudation, and then declined more or less regularly. It is impossible to treat this subject adequately without anticipating a number of facts which are to be brought out by consideration of streamflow relations in the several seasons. Therefore, these questions must remain to be discussed at the end of this chapter.

RELATIONS OF THE STREAMS IN THE SPRING FLOOD

The spring [2] flood, whose rise commonly begins in the latter part of March, usually records its heaviest discharge in the second decade of May. The culmination of influences, in spite of variable weather and different amounts of snow, tends to be reached about that time. By the end of June, although the streams have not dropped back to so low a level as in early March, the flood may usually be said to have subsided.

For accurate comparison it is necessary to assume a "technical" spring flood, whose limits are variable from year to year but are always defined by the attainment of certain discharge rates by stream A, specified hereafter. Examination of the technical flood is concentrated on details of the relative position of the two streams at their beginnings, ends, and crests, and the total relative volume discharged within their limits. It has been found impossible to establish the basis for any definite relations between the rates of discharge of the two streams at intermediate stages in the flood in spite of the fact that successive floods show similar general relations of the A and B curves.

Because of the desirability of breaking up whole years into summer, winter, and flood periods of specified length, it is also important to be able to consider the total volumes discharged within an arbitrary spring period sufficiently long to cover the rise and fall of the actual flood in any but the most unusual year. This period, which extends from March 1 to July 10, inclusive, will be called the "arbitrary period" or "arbitrary flood" to distinguish it from the technical flood, and will be discussed only after the more detailed consideration of the technical floods.

[2] As there were, during this experiment, no rain floods at all comparable to the snow-melting floods, except that of October, 1911, already discussed, this treatment deals entirely with the regular spring rises.

BEGINNING OF THE TECHNICAL FLOOD

In Table 54 are presented the data bearing upon the relations of the two streams at the beginning of the technical flood. The initial date of the flood is taken to be the first day on which the discharge rate of stream A exceeds 0.100 c. f. s., or, to be more exact, equals or exceeds 0.01070 inch per day O. W. Not infrequently, after a melting period which will produce such a discharge, there occurs colder weather in which the rate for stream A may again fall to 0.100 c. f. s. or less. As neither stream during the period up to the final rise, is making any net gain, it naturally follows that the relationships during such periods are not those based on the inherent lag of stream B. The latter may have opportunity to overtake stream A before the final and more rapid rise begins. Consequently, it is thought best to consider this period of uncertain or slow melting as a separate stage, even though the volumes of water involved may be very small in comparison with the whole flood volumes.

TABLE 54.—*Conditions at beginning of technical flood* [1]

Year	Initial date for A	Corresponding date for B	Difference, days	Discharges on A's initial date			Period of uncertain melting					Expected ratio B/A [3]
				A	B	B/A ratio	Final date	Length in days	Total volume discharged			
									A	B	B/A ratio	
1912	Mar. 6	Mar. 20	14	0.01087	0.01075	0.989	Apr. 2	28	0.2820	0.3084	1.094	
1913	Mar. 29	Mar. 30	1	.01131	.01111	.982						
1914	Apr. 5	Apr. 4	−1	.01163	.01346	1.157						
1915	Apr. 12	do	−8	.01079	.01169	1.083	Apr. 17	6	.0633	.0748	1.182	
1916	Mar. 10	Mar. 13	3	.01161	.01146	.987	Apr. 7	29	.3750	.3881	1.035	
1917	Mar. 29	Apr. 13	15	.01270	.01090	.858	Apr. 8	11	.1020	.1155	1.132	
1918	Apr. 23	Apr. 24	1	.01150	.01099	.956						
1919	Apr. 4	Apr. 5	1	.01140	.01113	.976	Apr. 11	8	.0841	.0911	1.083	
Predenudation averages [4]	Mar. 30	Apr. 2	+3.2	.01148	.01144	.998		16	.1813	.1956	1.105	
1920	Apr. 8	Mar. 21	−18	.01096	.01647	1.503						
1921	Mar. 3	Feb. 23	−8	.01159	.01899	1.638	Mar. 17	15	.1502	.2980	1.984	1.079
1922	Apr. 4	Mar. 20 [2]	−15	.01156	.01700	1.471	Apr. 18	15	.1657	.2842	1.715	1.058
1923	Apr. 7	Mar. 28	−10	.01104	.01527	1.383						
1924	Mar. 27	Mar. 25	−2	.01186	.01762	1.486	Apr. 2	7	.0690	.0942	1.365	1.147
1925	Mar. 29	Mar. 22	−7	.01141	.01383	1.212						
1926	Apr. 12	Apr. 7	−5	.01074	.01153	1.074						
Postdenudation averages [4]	Mar. 31	Mar. 21	−9.3	.01131	.01582	1.395		12	.1283	.2255	1.688	1.095

[1] All discharges in inches over watershed. The equivalent of 0.100 c. f. s. for A is 0.01070 inch O. W. per day.
[2] Also on Feb. 20, but since this involved very little departure from the winter rate, it has not been considered.
[3] From fig. 31.
[4] Arithmetic means of ratios used.

1. If the behavior of the two streams before and after denudation be compared, it will be seen that a marked change in the behavior of B has occurred, owing no doubt to the greater exposure of its snow blanket to the sun. On the dates in the second period when A enters into the flood stage, stream B, instead of having practically the same discharge in inches O. W., averaged practically 40 per cent higher than A. The ratio B/A was 1.50 for 1920, despite the fact that a strip of aspen had been left along the open channel of B, and was not removed until September, 1920. It is, therefore, apparent that the earlier rise of the stream was not due wholly to melting in its immediate proximity, but probably represented thawing in many of the more exposed portions of the watershed where the snow was not entirely dissipated during the winter, melting possibly having been accelerated quite generally by a dust storm which occurred March 14.

The ratio of B to A went still higher in 1921, as was to have been expected from the burning of slash on watershed B in 1920, producing considerable blackened areas on which melting would be markedly accelerated. After 1921 the ratio declined somewhat, while volume excesses for the entire flood periods continued to increase through 1922 (Table 57), probably owing to cumulative effects.

2. The above-described tendencies do not involve any large volumes of water in comparison with the flood volumes, yet the time factor may be of considerable importance in that water *appearing as stream flow* at this early stage is probably but a small fraction of that which enters the ground and may drain out so early as to shorten the flood at its close. The possible time factor involved here is shown very plainly in Table 54 by the time elapsing between the first rise of A above 0.100 c. f. s. and the day showing an equal or greater rate of discharge for B. In general, B passed this critical point somewhat later than A before denudation, averaging three days later, despite the fact that the winter discharge rate of B was higher than that of A, showing plainly that, protected by forest cover, B was less effectively insolated by the radiation to be expected around March 30. After denudation B always rose before A, averaging nine days earlier. An advance of more than 12 days in the rise of B is indicated.

3. It is also to be noted that in every listed period of "uncertain melting" in the predenudation period (that is to say when the streams fell back following an initial rise) the discharge of B exceeded that of A by a proportion varying from 4 to 18 per cent. It is practically certain that the relations during such a period depend largely on the opportunity given stream B to overtake and exceed stream A in delivery. The longer the time elapsed after A has reached the highest point, the greater should be the ratio B/A. But this ratio will tend to be lowered, other things being equal, if stream A has reached a relatively high point and discharges a relatively large volume thereafter. The most consistent relationship is found, then, by plotting the ratios B/A for the whole period against the volume discharge of A, with a minus correction of the latter of 0.008 inch for each day elapsed from the highest day to the end of this period of uncertain or suspended melting.

This relationship is shown in Figure 31.

The "periods of uncertain melting" were less frequent in the second stage of the experiment, only three years showing this hesitant rise of the streams. It is seen that during such a period B maintains about a 53 per cent lead over A, comparing the actual ratio of 1.69 after denudation with 1.10 before denudation. This difference is not decreased if the postdenudation years be worked out from Figure 31, this showing that an average ratio of about 1.10 was to have been expected in the second period.

END OF THE TECHNICAL FLOOD

The relations existing between the two streams at the end of the flood are of some importance in indicating what may be expected during the ensuing summer season.

The end of the flood is taken to be the last day on which stream A has a discharge of 0.150 c. f. s., or more, or (to be exact) more than 0.01604 inch over the watershed. Should such a discharge occur after a dip below 0.150, it would be allocated to the summer period. One exception has been made in order to give some semblance of character to the very small flood of 1918. Here the crest day showed a rate of only 0.157 c. f. s. for A, the following day 0.148, and the third day 0.151. The third day was taken as the closing day of the flood.

For the purpose of avoiding fluctuating relationships such as might arise from current rains, the volume calculations in Table 55 are for the last 10 days of the flood.

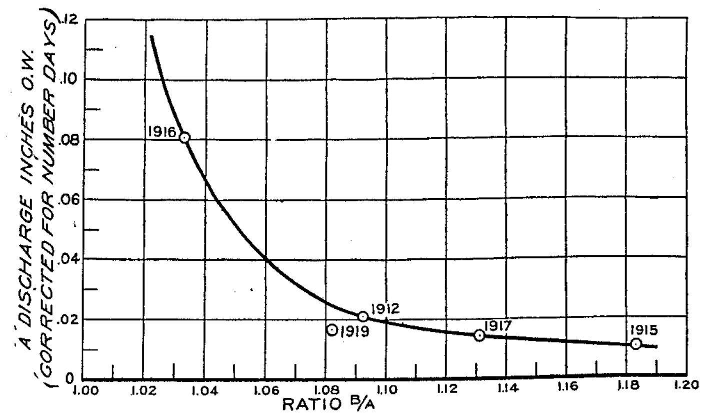


FIG. 31. Relation of A to B discharge for period of uncertain melting

Calculations for 1918 are omitted since 10 days reaches back to a date earlier than the crest of the flood.

TABLE 55.—*Conditions at the end of the technical flood periods*

Year	Last day above 0.150 c. f. s.			Last 10 days of flood			Ratio A discharge after crest to that before	Most probable ratio B/A projected from predenudation conditions[3]
	Date	A rate	B rate	A discharge	B discharge	Ratio B/A		
		C.f.s.	*C.f.s.*	*Inches*	*Inches*			
1912	July 19	0.156	0.125	0.1724	0.1525	0.885	1.033	----------
1913	June 26	.154	.175	.1933	.2436	1.260	4.337	----------
1914	July 5	.154	.114	.1700	.1360	.800	2.006	----------
1915	July 3	.151	.115	.1845	.1586	.860	1.215	----------
1916	June 22	.151	.116	.1855	.1605	.865	.918	----------
1917	Aug. 2	.152	.110	.1745	.1368	.784	2.504	----------
1918	May 8[1]	.151	.102	----------	----------	----------	----------	----------
1919	July 4	.158	.110	.1809	.1401	.774	2.051	----------
Averages[4]	June 30	.153	.121	.1802	.1612	.890	2.009	----------
1920	July 13	.151	.122	.1764	.1562	.885	1.186	.853
1921	July 14[2]	.159	.134	.1755	.1659	.945	.818	.900
1922	July 6	.154	.133	.1868	.1803	.965	.996	.875
1923	June 28	.151	.121	.1837	.1618	.881	.793	.904
1924	June 30	.153	.119	.1844	.1544	.837	1.249	.846
1925	May 31	.151	.151	.1792	.2050	1.144	.451	.976
1926	June 21	.155	.118	.1911	.1650	.863	1.934	[5].791
Averages[4]	June 29	.153	.128	.1824	.1698	.931	1.061	.878

[1] The last day according to rigid rule was May 6. See discussion in text.
[2] Due to heavy rains, the technical end of flood did not occur until July 25, but as this seems to be separate from the flood influence, the flood period is closed with the first approach to 0.150 c. f. s.
[3] Read from fig. 32.
[4] Arithmetic means exclusively.
[5] Problematical value, beyond the range of predenudation conditions.

The data and computations in Table 55 bear several significant indications:

1. The average discharge rate of B for the last days of the floods increased from 0.121 to 0.128 c. f. s., or about 6 per cent, while that of A was the same in both periods. If the questionable year 1918 be excluded from the averages, the increase due to denudation is only that from 0.124 to 0.128 c. f. s.

2. For the last 10 days of each flood, A discharged a little more, on the average, in the second period, this denoting the somewhat more rapid drop from the later crests of the second period. The average of the ratios B/A for 10-day discharges increased from 0.890 to 0.931, or about 5 per cent.

3. From these facts it would seem that by the end of the flood most of the excess had been discharged by B. In truth, however, the situation is by no means so simple as this, and deserves more careful study. Reference to the discussion accompanying Tables 51 and 52 and Figure 28 will recall the fact that for the month of June as a whole stream B showed a deficit in the postdenudation period, if its position relative to A in this period be compared with that in the predenudation period. It seems probable, therefore, that as a result of denudation, which causes an early and rapid rise, stream B drops back somewhat after the crest of the flood, but that by the end of the flood, about six weeks later, it may be again in the ascendency.

Such a possibility becomes rational if the theory be again considered that the B watershed has the power to hold back more water for late delivery than the A watershed. This is quite comprehensible, for the present discussion, when it is noted in Figure 28 that throughout the period following the flood (July–September) stream B is steadily creeping up to equality with stream A, which it usually reaches about the end of September (Table 35). To make the mental picture still clearer and to explain why the discharge ratio at the end of the flood should be as variable as is indicated by Table 55, it is only necessary to assume that the benchlike area at the head of watershed B represents a source for late streamflow somewhat separate from the main, fanlike basin of the watershed which is directly responsible for the main body of the flood. The snow on this bench, (see Fig. 10) by reason of its high elevation, is inevitably late in melting. It is not denied that there are north-slope areas near the head of watershed A which retain their snow quite as long. It is merely argued that there is nothing about the conformation of A to prevent this late water from reaching the stream quite promptly, whereas B has no surface channel within approximately 2,500 feet of the most distant part of the high bench, and the entire movement of this late water is obviously through subterranean channels. An item of some moment in connection with this water supply may be the fact that the high area which produces it was affected less by denudation than any other part of the watershed.

If the importance be recognized of this possible secondary source of water for B—only slightly separated from the main source—it will be apparent not only why stream B tends to recede more quickly than A after the flood crest, but also why its relative position at the end of the A flood will hinge upon a time factor expressing the opportunity for this secondary source to deliver. The most satisfactory form for expressing this time factor is what may be called the "relative volume-length of the declining period" of the flood. It implies that the highest day of the flood represents a turning point in the rate of melting, an implication which may be only approximately correct. Nevertheless, the ratio of A's discharge after the crest of the flood, to its discharge before the crest, seems to be an expression which indicates the probability of B stream being higher or lower than A at the end. This is illustrated in Figure 32, where it will be seen that the relative position of B becomes lower and lower as the draining-out period is prolonged, until the "discharge stage" of A is expressed by about 2.3. Thereafter, B gains upon A as it does normally in the later part of the summer. There may be some question of the single high value produced by 1913; even if this and its implication be ignored—a course scarcely justifiable—the portion of the curve applying to the more normal years of the postdenudation period would not be altered appreciably.

The values shown in the last column of Table 55, read from Figure 32, indicate that the average ratio of B to A to be expected at the end of the flood under predenudation conditions would have been 0.878 in the second period as compared to an average of 0.890 in the first. This comparison shows but two years, 1923 and 1924, when the actual position of B at the end of the flood was not higher than the "expected."

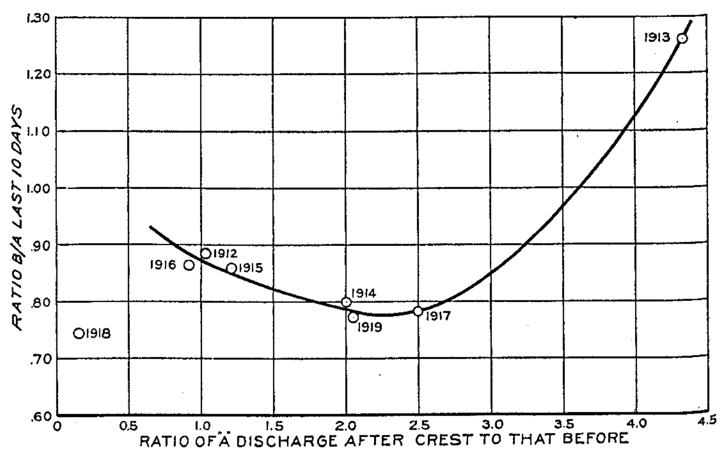


FIG. 32. Relative discharges last 10 days of flood

CREST OF THE TECHNICAL FLOOD [3]

The crests of the technical floods do not usually occur when half of the total flood volume has been discharged, nor when half of the snow has been melted, but at a time when the snow is almost entirely gone from the most protected areas. (See Table 42.) Both rapid melting, under the influence of the warm weather, and the attainment of saturation for the entire watersheds, probably contribute to the crest. Bodies of snow in proximity to the streams may be of some importance in producing a crest, for the fluctuations between day and night discharges at this stage show that the melted snow must be reaching the streams quite directly. The general tendency for B stream to crest much later than A except when A's crest comes late in the season, suggests strongly that until a late date the snow near B stream is better protected from isolation than that near A stream. As the season advances and the sun attains a greater elevation, any marked difference between the two disappears.

These facts tend to show not only that the time and perhaps also the height of the crest on A are decidedly fortuitous, depending on temporary weather conditions which have little to do with the general progress of the

[3] The term "crest" as used throughout this report refers to the day of highest discharge rate. This day would not necessarily include the highest momentary discharge rate, although it is likely to do so.

floods; but also that the relative time and height of the B crest might be influenced by such a variety of conditions that it would be practically impossible to take all of them into consideration in attempting predictions for B in the postdenudation period.

In order to show the fortuitous character of the highest crests, it is only necessary to point out that in the year 1914, for example, the highest crest of A, rate 0.0727 inch O. W., occurred on May 11. With a slight dip between, another crest occurred on May 15, rate 0.0694, and the latter was followed only a day later by the definite crest on B. In 1915, a primary crest of A occurred on May 13, a slightly higher crest on May 19, and the crest of B on May 20. Shall it be said that the "real crests" were five days apart in the first instance, and only one day apart in the second, when every other feature of the two floods was almost identical?

For fear, then, of giving to the highest crests a significance which they do not deserve, this discussion will be confined to a number of comparisons as made in Table 56, without attempt to analyze and compare the two periods. In this table data are given on the so-called "preliminary crests" which may or not be the highest ones for A, and the later or "comparable" crests which are obviously caused by the same set of conditions as those which produce the crest on B.

The use of this form of comparison leads to no complications in the second period except for the year 1921 when the crest of B fell definitely between the "preliminary" and the highest crest of A. Shall it be said that the crest of B came 8 days ahead of the "real" crest of A, as it never had done before, or, that, both of the A crests being relatively late, it was possible for B to reach its highest point along with the earlier of the two, which with slightly more sustained temperatures might easily have been the higher? Performances in other years would point to the latter as the more reasonable treatment, but considering the great advance in the volume discharge of B in this year (Table 59) it seems wiser to consider that the B crest actually came before the A crest.

Table 56 shows that (instead of the apparently critical dates for A being May 10 in the first period and May 17 in the second, as is the case under the mechanistic treatment, Table 57) the two periods averaged very much alike, and while the B crests in the first period fell 10.2 days later than the highest A crests, the average delay between comparable crests was only 2.9 days. In the second period, practically no difference appeared on the average between comparable crests. The apparent effect of denudation was therefore to advance the crests of B on the average about 3 days.

TABLE 56.—*Cresting of the floods in the two periods*

[All discharge rates in inches over watershed per day]

Year	Preliminary crest [1] on A			Comparable crest on A				Crest on B			Ratio of B crest to—		
	Date	A discharge	B discharge	Date	A discharge	B discharge	Ratio	Days from second A crest	B discharge	A discharge	Nearest crest for A	Highest crest for A	A on same day
1912				May 20	0.1757	0.1734	0.987	2	0.2335	0.1596	1.329	1.329	1.463
1913	Apr. 16	0.0406	0.0182	May 1	.0360	.0338	.939	11	.0403	.0278	1.119	.993	1.450
1914	May 11	.0727	.0551	May 15	.0694	.0799	1.151	1	.0859	.0652	1.238	1.182	1.317
1915	May 13	.0778	.0636	May 19	.0803	.0800	.996	1	.0809	.0757	1.007	1.007	1.069
1916				May 11	.0970	.0864	.891	3	.1126	.0794	1.161	1.161	1.418
1917	May 18	.2360	.1618	June 4	.1636	.1787	1.092	2	.2010	.1387	1.229	.852	1.449
1918	Apr. 26	.0150	.0117										
	May 6	.0168	.0117	May 20	[2] .0127	.0128	1.008	1	.0131	.0126	1.032	.780	1.040
1919	May 6	.0955	.0722	May 15	.0729	.0910	1.248	2	.1126	.0684	1.545	1.179	1.646
Average [3]				May 17			1.039	2.9	.1100	.0784	1.208	1.060	1.356
1920				May 23	.2269	.3097	1.365	1	.3210	.2207	1.415	1.415	1.454
1921	May 13	.0802	.1358	do	.0940	.0939	.999	[4] −8	.1469	.0768	1.832	1.563	1.913
1922	May 7	.0794	.1167	May 21	.1200	.2068	1.723	1	.2222	.1173	1.852	1.852	1.894
1923	May 12	.0868	.0889	May 20	.0879	.1510	1.718	1	.1592	.0855	1.811	1.811	1.862
1924				May 11	.1103	.1305	1.183	4	.1873	.1009	1.698	1.698	1.856
1925	May 5	.0264	.0394	do	.0275	.0403	1.465	0	.0403	.0275	1.465	1.465	1.465
1926				May 8	.0416	.0708	1.702	0	.0708	.0416	1.702	1.702	1.702
Average [3]				May 17			1.451	−0.1	.1640	.0958	1.682	1.644	1.735

[1] All "preliminary crests" are mentioned in which the discharge of A was equal to two-thirds or more of the highest value for A.
[2] Really not a crest but a cessation of the steady drop not caused by precipitation.
[3] Arithmetic means throughout.
[4] Preceded A's second crest. See reference in text.

Since in Table 56, the floods of the two periods have been brought to such a comparable basis, as to time, it seems permissible to compare directly the average figures in that table. The average ratio B/A in the first period on the "comparable" crest days for A was 1.04 and in the second period 1.45, an advance of 40 per cent. The ratio of the two streams on B's crest day increased from 1.36 to 1.74, or 28 per cent. The ratio of the B crests to the *comparable* A crests advanced from 1.21 to 1.68, or 39 per cent, and the ratio of the B crests to the *highest* A crests advanced from 1.06 to 1.64, or 55 per cent. The high and low crests of the postdenudation period show about the same proportionate increases, but it is fairly apparent that the B crests of the first two years were not stepped-up so much as those of later years.

There can, therefore, be no doubt but that the peak of the B discharge was raised about 50 per cent and advanced in time about three days by the effects of denudation.

TOTAL VOLUMES DISCHARGED IN TECHNICAL FLOOD

In the preceding paragraphs attempt has been made to depict only the temporary relations of the two streams at the beginning, end, and middle of the spring flood, in order to indicate the direction of the changes brought about by denudation. The more important total flood volumes may now be considered.

TABLE 57.—*Partial and total flood volumes for technical flood periods*

[Discharge values and differences in inches O. W. All discharges taken direct from 5-place figures]

Year	Stream	Critical dates			Duration (days)	Amount discharged			Ratio B/A	Difference, B−A		
		First	Highest	Last		Before crest	After crest	Total		Before crest	After crest	Whole flood
1912	A	Mar. 6	May 20	July 19	136	2.4941	2.5773	5.0714	0.984	−0.3639	0.2810	−0.0829
	B		May 22		[2] (76)	2.1302	2.8583	4.9885				
1913	A	Mar. 29	Apr. 16	June 26	90	.4058	1.7599	2.1657	1.033	−.1419	.2135	.0716
	B		May 12		(19)	.2639	1.9734	2.2373				
1914	A	Apr. 5	May 11	July 5	92	.9976	2.0009	2.9986	.972	−.2339	.1496	−.0844
	B		May 16		(37)	.7637	2.1505	2.9142				
1915	A	Apr. 12	May 19	July 3	83	1.2926	1.5704	2.8630	.960	−.1637	.0494	−.1143
	B		May 20		(38)	1.1289	1.6198	2.7487				
1916	A	Mar. 10	May 11	June 22	105	1.6463	1.5111	3.1574	.983	−.2713	.2180	−.0534
	B		May 14		(63)	1.3750	1.7291	3.1040				
1917	A	Mar. 29	May 18	Aug. 2	127	2.0708	5.1857	7.2565	.999	−.3081	.3003	−.0078
	B		June 6		(51)	1.7627	5.4860	7.2486				
1918	A	Apr. 23	May 6	May 8	16	.2028	.0320	.2349	.773	−.0452	−.0079	−.0533
	B		May 21		(14)	.1576	.0241	.1816				
1919	A	Apr. 4	May 6	July 4	92	1.2336	2.5298	3.7634	.974	−.2324	.1350	−.0974
	B		May 17		(33)	1.0012	2.6648	3.6660				
Average first period	A	Mar. 30	May 10	June 30	93	1.2930	2.1459	3.4389		−.2201	.1673	−.0528
	B		May 20			1.0729	2.3132	3.3861				
Ratio B/A						.8298	1.0780	.9846				
1920	A	Apr. 8	May 23	July 13	97	2.4696	2.9292	5.3988	1.099	.2522	.2832	.5354
	B		May 24		(46)	2.7218	3.2124	5.9342				
1921	A	Mar. 3	May 23	July 14 [1]	134	2.4540	2.0083	4.4622	1.245	1.2251	−.1386	1.0915
	B		May 15		(82)	3.6791	1.8747	5.5538				
1922	A	Apr. 4	May 21	July 6	94	2.0467	2.0384	4.0850	1.361	.9058	.5679	1.4737
	B		May 22		(48)	2.9525	2.6063	5.5587				
1923	A	Apr. 7	May 20	June 28	83	1.7622	1.3972	3.1594	1.256	.4481	.3597	.8078
	B		May 21		(44)	2.2103	1.7569	3.9672				
1924	A	Mar. 27	May 11	June 30	96	1.9019	2.3748	4.2767	1.126	.1184	.4198	.5382
	B		May 15		(46)	2.0203	2.7946	4.8149				
1925	A	Mar. 29	May 11	May 31	64	.9174	.4138	1.3312	1.175	.1319	.1006	.2325
	B		do		(44)	1.0493	.5144	1.5637				
1926	A	Apr. 12	May 8	June 21	71	.6405	1.2387	1.8792	1.260	.1082	.3810	.4892
	B		do		(27)	.7487	1.6197	2.3684				
Average second period	A	Mar. 31	May 17	June 29	91	1.7418	1.7715	3.5132		.4557	.2826	.7384
	B		do			2.1974	2.0541	4.2516				
Ratio B/A						1.2616	1.1595	1.2102				

[1] Flood period extended to July 26 by rain.
[2] Parenthetical figures give the duration up to and including the crest day for A.

The partial and total data for the technical flood periods presented in Table 57 permit a good visualization of the varied character of the floods.

The outstanding points differentiating the floods of the two periods are set out below:

1. The average lengths of the floods of the two periods were essentially the same, those of the second period, however, starting a day later and ending a day earlier. This was evidently not due to lesser volumes to be melted and discharged in the second period, as the average flood on A was about 2 per cent larger in that period. The difference, then, was probably the result of sharper rises in temperature in the second period, particularly from April to May. (See Table 14.)

2. The crests of the A floods came on May 10 in the first period and May 17 in the second. The B crests were 10 days later, on the average, in the first period, and no later in the second. The lateness of the A crests in the second period should have a tendency to bring the crests on the two streams closer together, but not by more than a day or two. But, as already pointed out, these highest crests may not have as much significance as is here attached to them in the effort to eliminate the factor of judgment in the comparisons.

3. The effect of the later crests in the second period is, of course, to permit the delivery of larger proportions of the floods before those crests, and thereby, in all probability, to affect somewhat the relative volumes discharged by the two streams, but especially the volumes in the rise of the floods. The volumes discharged by B before crests in the first period were always less than those discharged by A, the former being only 83 per cent of the latter, on the average. In the second period B always discharged more than A during the rise. Only when A was rising very rapidly did it show any possibility of overtaking B. In other words, during all of the period up to the crest of A, the position of B relative to that of A appears to be raised about 50 per cent by the more rapid melting due to denudation.

4. During the recession of the flood, B falls back more quickly after denudation than before, although for the period as a whole an excess discharge of about 7 per cent is indicated by comparison of the ratios B/A. The discussion already given indicates that if there is any period of actual deficit as a result of denudation and earlier discharge, it must be from about 10 to 20 days after the crest of the A flood, for at the end of the flood B has regained a position closer to A than in the predenudation period. In the average year, then, the period around June 10 may show a slight deficit. In 1921 only was there an appreciable deficit for the declining period as a whole, because of the B crest coming before the A crest as has already been mentioned.

5. Whereas in the predenudation period the average flood volume for B was slightly under 99 per cent of the corresponding total volume for A, after denudation B discharged 21 per cent more than A, thus making its apparent increase about 22 per cent. In 6 out of 8 years, before denudation, B discharged less than A; in 1917, with an exceptionally large flood, there was practically no difference; and in 1913, with a small flood, prolonged for more than the average time by slow melting and by rain, and influenced by a large hold over from 1912, B discharged more than A. During the postdenudation period the discharge of B was laways greater than that of A, amounting on the average to nearly 0.74 inch, or 0.79 inch net change from the predenudation period, this being five-sixths of the entire excess shown by Table 53.

The flood excesses, especially when expressed quantitatively, appear to rise to a definite crest in 1922, and thereafter to decrease quite steadily, except for 1925.

The large amount of the excess in the spring of 1920, immediately following the denudation of watershed B, is especially significant in indicating that the source of much of the increased streamflow must be in the winter accumulation of snow on the denuded watershed. However, the fact that the excesses grew larger during each of the next succeeding two years, clearly suggests what may be called a cumulative effect, involving some saving of water in the summer and fall, and the carrying over of an excess of ground water to the following spring.

THE ARBITRARY FLOOD

Consideration may now be given to the arbitrary floods which, because of being of the same length each year, contain one less variable than the technical floods. Calculations by the much more direct methods here found possible will serve as a check on the figures just presented.

The average period in spring during which a flood stage exists on A has been seen to be from about April 1 to June 30, but in order to include the much accelerated melting on B after denudation it is desirable to advance the initial date of the arbitrary period to March 1. Also, it should be remembered, the technical flood was closed with a head of 0.150 c. f. s., and in order to approach more closely to the same basis as was used at the beginning, namely, 0.100 c. f. s., the calculations for the arbitrary flood have been extended to July 10.

TABLE 58.—*Data for the arbitrary flood periods, March 1 to July 10*

[Discharge values in inches O. W.]

Year	Watershed	Total discharges	Ratio B/A	Partial discharges: Through May 10	Partial discharges: Through June 10	Date in May when half of flood is discharged	"Expected" ratio B/A [1]	"Expected" discharge of B [2]	Excess due to denudation
1912	A	4.9631	0.988	1.3207	4.2028	19.7			
	B	4.9038		1.2628	4.2363	21.2			
1913	A	2.5958	1.055	1.3931	2.0748	6.7			
	B	2.7397		1.2503	2.1180	13.0			
1914	A	3.3846	.982	1.2344	2.7995	16.8			
	B	3.3226		1.0556	2.8340	18.2			
1915	A	3.3060	.981	.9953	2.6776	19.2			
	B	3.2417		.9670	2.6799	20.1			
1916	A	3.4702	.976	1.6168	2.9960	11.2			
	B	3.3867		1.3702	2.9858	13.4			
1917	A	7.0301	1.020	1.2258	5.4499	26.8			
	B	7.1677		1.3282	5.5968	29.6			
1918	A	1.3215	1.048	.6919	1.0675	8.0			
	B	1.3855		.7674	1.1300	3.8			
1919	A	4.1067	.975	1.8219	3.5002	13.3			
	B	4.0042		1.5735	3.5238	15.4			
Average	A	3.7723	.999	1.2875	3.0960	15.2			
	B	3.7690		1.1969	3.1381	16.8			
1920	A	5.6468		1.2206	4.8925	23.2	0.997		
	B	6.2600		1.4887	5.5663	23.1		5.6299	0.6301
1921	A	4.4155		1.4709	3.6428	19.8	.985		
	B	5.5218		2.2128	4.7868	14.3		4.3493	1.1725
1922	A	4.4596		1.4061	3.7825	19.9	.985		
	B	6.0377		2.1682	5.3840	19.2		4.3927	1.6450
1923	A	3.6711		1.2942	3.1172	17.0	.979		
	B	4.5455		1.6389	4.0511	17.3		3.5940	.9515
1924	A	4.6616		2.0196	4.0704	12.9	.976		
	B	5.2380		2.1732	4.7414	13.2		4.5497	.6883
1925	A	2.1375		1.1472	1.7643	6.8	1.059		
	B	2.4418		1.3214	2.0541	7.4		2.2636	.1782
1926	A	2.4675		1.0496	1.9992	15.6	.977		
	B	3.0008		1.2891	2.5899	13.9		2.4107	.5901
Average	A	3.9228		1.3726	3.3241	16.5			
	B	4.7208		1.7560	4.1677	15.5		3.8843	.8365

[1] Read from fig. 35.
[2] Multiply actual discharge of A by the ratio in preceding column.

In Table 58, where the data for the arbitrary flood periods are summarized, the following facts may be noted:

1. For the predenudation period, the difference between the total volumes for A and B, which was noted for the technical floods, has practically disappeared from the averages. This is because of the inclusion of more time in March, when B is normally higher than A; on the other end, the *principal* additions were to the short floods of 1913 and 1918, following which B remained higher than A. It, therefore, appears that on the average there should be practically no difference between B and A for this 132-day period.

2. The postdenudation excesses of B, taking the figures at face value, are now scarcely any more than they were for the technical floods, amounting to only 0.80 inch for the long period as against 0.79 for the shorter.

3. A point well brought out by the average dates as computed for Table 58 is the fact that the first half of the flood on B was delivered two days later than that of A before denudation, and one day earlier afterwards. This is practically equivalent to saying that the "peak" of the flood was moved forward three days by denudation—a subject already discussed. The striking advance in the mass of the flow in 1921 is particularly noteworthy, since this probably denotes the effect upon melting of the brush burning of the previous fall. A great deal of charcoal was noticed in the silt deposit of B for 1921. In the succeeding years this material probably became more or less hidden both by dropping into depressions and by the growth of herbaceous vegetation.

While the dates representing the middle of the arbitrary floods give no exact basis for dividing them between rising and declining phases, the data given in Table 58 show that the entire excess of 0.80 inch had been accumulated by June 10, and for the next month stream B, after denudation, must have been just about normal. However, the totals for intermediate periods indicate that stream B lost ground immediately after June 10, and was again in the ascendency at the end of the flood. As this is of particular interest in connection with the summer period, which again shows a slight excess, the subject deserves amplification. Figures 33 and 34 have been drawn to compare the floods of the two periods on the same basis of time and without reference to the actual dates of individual flood crests. Comparison of the two sets of graphs showing the current discharges of A and B by 5-day periods, indicates clearly how stream B, after denudation, ran ahead of A on the rise of the flood, and still maintained a lead after its own cresting, and indeed through the period ending May 31. The curves of cumulative excesses are best referred to for the remaining period. These show that after denudation B ceased to pile up any further excess after the end of May, while in the earlier years it had continued to gain upon A through the period ending June 15. This period of about 15 days, therefore, is the only period in the postdenudation years when there was an actual deficit compared with the "normal" relation of B and A. It is this period which gives rise to the June deficit as indicated in Figure 28.

ANALYSIS OF THE VARIATIONS IN ARBITRARY FLOODS

A careful study of the data for the arbitrary floods prior to denudation convinces one that there are three somewhat distinct factors which affect the ratio of B discharge to A discharge for this period, this ratio being normally slightly below unity. These factors are:

a. A large flood which may cause a ratio somewhat above unity, if, as in 1917 only, the volume is sufficient to saturate the watersheds. It then appears that B's actual capacity to retain water is somewhat less than that of A.

b. Lateness of the flood. Every treatment of the four years normal as to volume, 1914, 1915, 1916, and period. Everywhere the fact is met that the two peculiarly low years, 1913 and 1918, were preceded by years of high flow, and that in these extreme cases, the preceding high flows must be given almost as much consideration as the current conditions. When "earliness" goes to the extreme, as in 1913 or 1918, not low, but very high ratios of B to A discharge are to be expected, especially if the preceding year has been one of heavy flow.

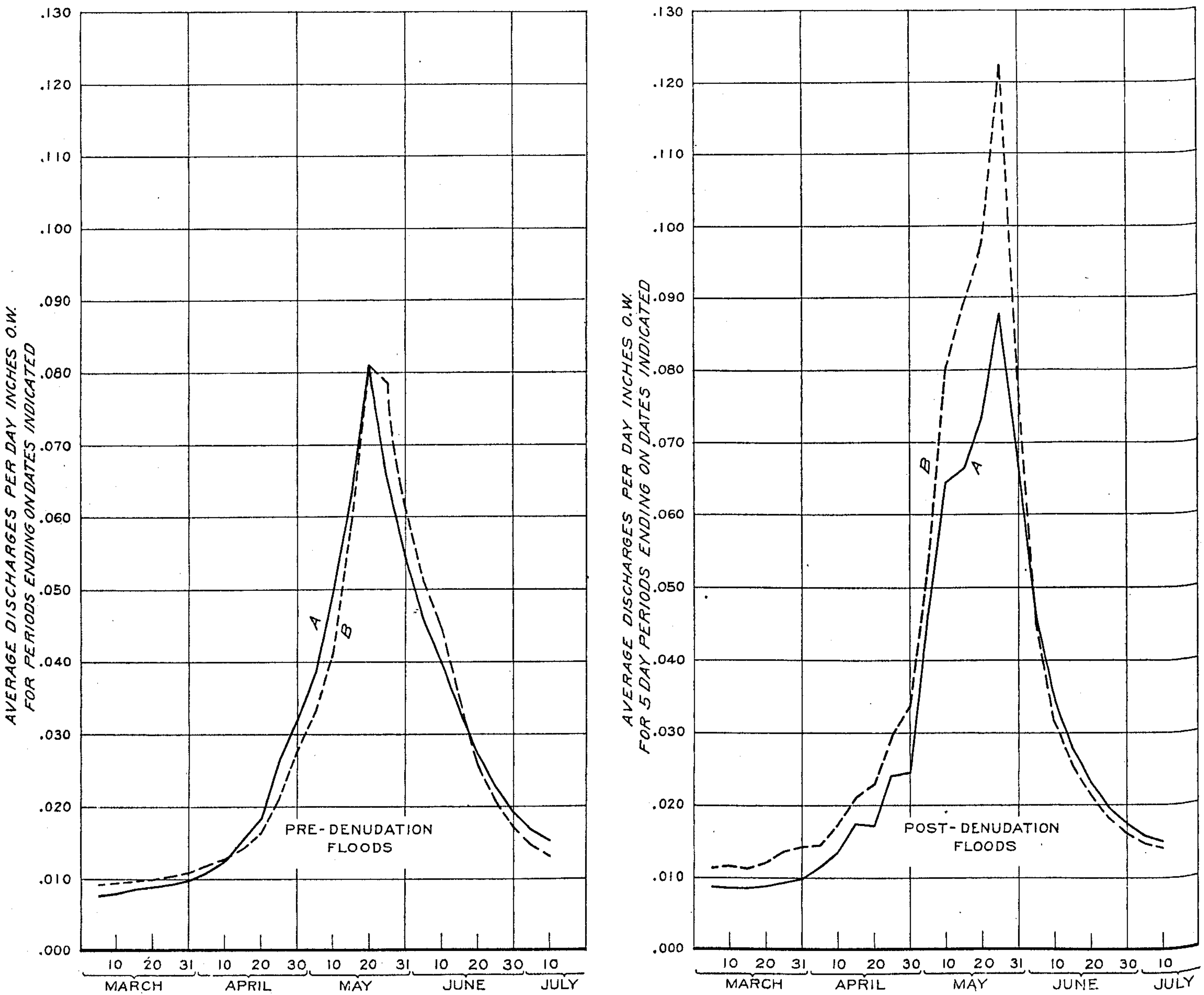


FIG. 33. Average curves for the arbitrary floods before and after denudation

1919, shows that late floods produce relatively higher discharges on B. This is probably both because of the opportunity for an early period of uncertain melting which somewhat favors B, because the flood subsides rapidly leaving B in a relatively high position, and because lateness leaves less of a gap between the primary and secondary flows from B, the latter probably being from snow at high altitudes.

c. The character of the preceding year, which affects the amount of water carried over to the current flood

To combine all of these factors into one expression which may be used with safety to "rate" the years after denudation, has required much testing of the data. The form of expression finally resorted to, is shown in Figure 35. Briefly, the license for using a single date which expresses the lateness of the flood lies in the fact that this seems to take into account, consistently, all of the factors mentioned above as likely to cause variation in the ratio B/A. Volume alone, if it *is* a separate factor, is automatically expressed since a large flood is naturally spread over more time; the very fact that a large volume of snow has to be melted makes the large flood late.

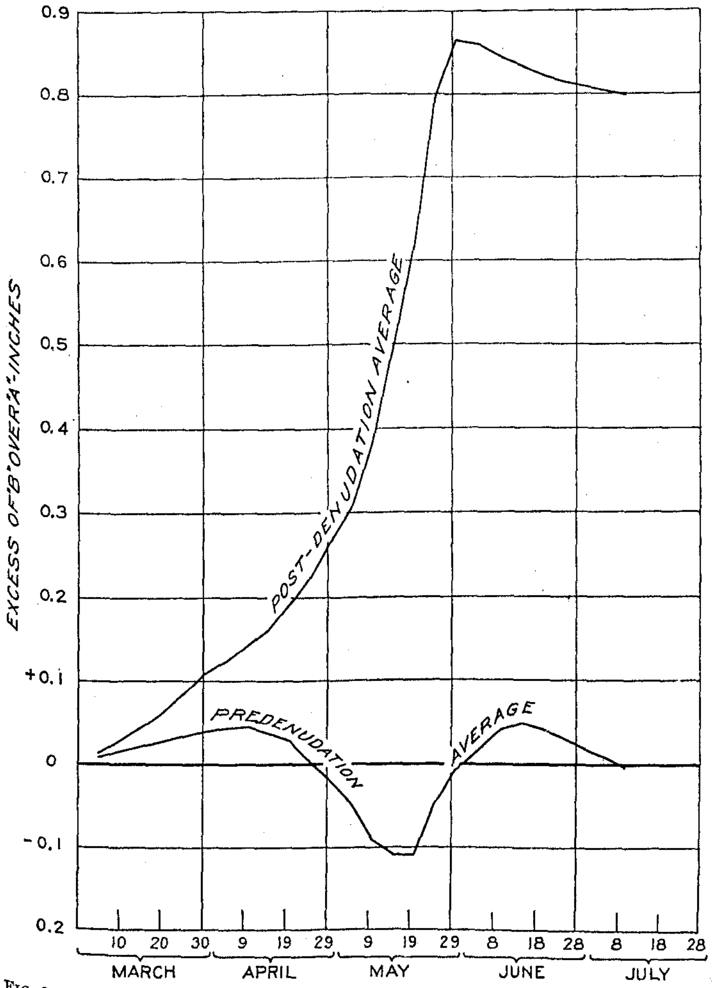


FIG. 34. Accumulative excesses of B through flood periods, before and after denudation

Variations in lateness of floods of the same size are of course covered. Finally, extreme earliness leads into a realm where the current flood *must* be small, and the effect of hold-over water, favoring the flow of B more than that of A, becomes a comparatively large factor in the whole. Only here is the essentially linear correlation departed from in the curve of Figure 35, and in this realm there must always be some doubt. It is, however, to be especially noted that for this 132-day period, the floods of 1913 and 1918 are found to be very similar.

The calculations added to Table 58 indicate that the mean excess flood discharge of B, resulting from denudation, may have been 0.84 inch instead of the 0.80 inch as shown by direct comparison of the two periods. In no

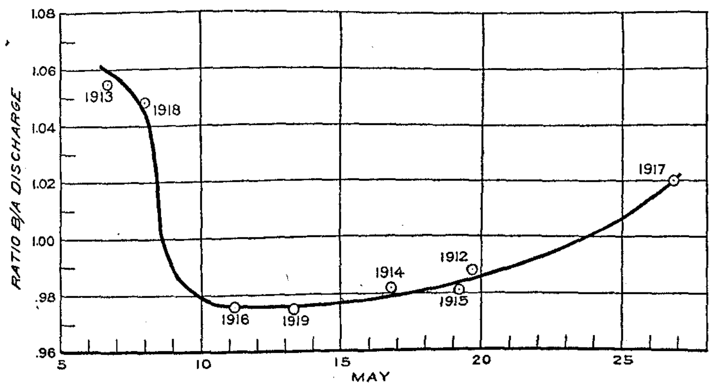


FIG. 35. Relations of B to A discharge for the flood March 1 to July 10

cases were the postdenudation floods extremely late, and therefore the expected flow of B was less than the actual flow of A, except in 1925 when the flood was very early. No exception is made for 1924 in which a large flood was produced from late snowfall, as occurred in 1917. Despite this similarity, the melting of 1924 probably did not tax the capacity of the B watershed for storage, as did the larger volume in 1917, so that the excessive immediate run-off from B was not to be expected.

No one need feel compelled to accept these latter findings in preference to the direct data of Table 58. The subject has been discussed more largely for its informative value than for its quantitative implications.

TABLE 59.—*Stream-flow relations for the summer months*

[All stream flow and precipitation quantities in inches]

Year	Stream flow, July 11-31			Stream flow, August			Stream flow, September			Stream flow, total summer			Effective precipitation, B, June to September[1]	Correction for precipitation, 3 per cent	[2] Corrected B, summer streamflow	Expected flow of B from size of A flood	Excess shown by actual flow	Expected flow of B from size of B flood	Excess shown by actual flow
	A	B	B/A	A	B	B/A	A	B	B/A	A	B	B/A							
1912	0.3668	0.3244	0.884	0.4133	0.3845	0.930	0.3233	0.3351	1.036	1.1034	1.0440	0.946	10.49	0.3147	0.7293	-------	-------	-------	-------
1913	.2278	.2354	1.033	.2644	.2739	1.036	.2609	.2780	1.066	.7530	.7873	1.046	12.72	.3816	.4057	-------	-------	-------	-------
1914	.3291	.2514	.764	.3622	.2901	.801	.3039	.2774	.913	.9951	.8188	.823	11.04	.3312	.4876	-------	-------	-------	-------
1915	.2515	.2091	.831	.2944	.2580	.876	.2527	.2470	.977	.7986	.7141	.894	6.64	.1992	.5149	-------	-------	-------	-------
1916	.2779	.2210	.795	.3725	.3226	.866	.3025	.2886	.954	.9529	.8322	.873	9.52	.2856	.5466	-------	-------	-------	-------
1917	.4089	.3162	.773	.4187	.3414	.815	.3199	.2868	.897	1.1476	.9444	.823	4.84	.1452	.7992	-------	-------	-------	-------
1918	.1594	.1678	1.053	.2012	.2150	1.069	.2397	.2500	1.043	.6003	.6328	1.054	10.72	.3216	.3112	-------	-------	-------	-------
1919	.3182	.2374	.746	.3086	.2893	.937	.2551	.2696	1.057	.8819	.7964	.903	8.12	.2436	.5528	-------	-------	-------	-------
Averages[5]	.2924	.2453	.839	.3294	.2968	.901	.2822	.2791	.989	.9040	.8212	.908	9.26	-------	-------	-------	-------	-------	-------
1920	.3201	.2860	-------	.3569	.3400	-------	.3054	.3305	-------	.9824	.9564	.973	5.96	.1788	[3] .755	0.9338	0.0226	[4] 0.9768	−0.0204
1921	.3477	.3161	-------	.4158	.3968	-------	.3284	.3641	-------	1.0918	1.0770	.986	10.07	.3021	.625	.9271	.1499	1.0441	.0329
1922	.2790	.2659	-------	.3962	.3791	-------	.2980	.3171	-------	.9732	.9622	.989	7.59	.2277	.641	.8687	.0935	1.0137	−.0515
1923	.2758	.2461	-------	.3660	.3509	-------	.3455	.3634	-------	.9873	.9605	.973	10.18	.3054	.558	.8634	.0971	.9744	−.0139
1924	.2713	.2515	-------	.3054	.3162	-------	.2758	.3318	-------	.8525	.8094	1.055	3.98	.1194	.675	.7944	.1050	.8574	.0420
1925	.1986	.2194	-------	.2673	.3077	-------	.2540	.2828	-------	.7199	.8098	1.125	12.91	.3873	.376	.7633	.0465	.7993	.0105
1926	.2217	.2035	-------	.2602	.2544	-------	.2121	.2284	-------	.6940	.6863	.980	7.46	.2238	.408	.6318	.0545	.7098	−.0235
Averages[5]	.2735	.2555	.934	.3383	.3350	.990	.2884	.3169	1.099	.9002	.9074	1.008	8.31	-------	-------	.8261	.0813	.9108	−.0034

[1] For source of this calculated value see text, and monthly precipitation values in Table 37.
[2] For flood volumes against which these values are plotted in fig. 36, see Table 58.
[3] This and following figures, as read from the upper curve of fig. 36. In next column the precipitation corrections are added.
[4] This and the following entries as read from fig. 36, lower curve, with same additions for rainfall as in preceding calculations.
[5] Since quantities involved in various years are of same magnitude, algebraic means of ratios are given.

THE SUMMER RAINY PERIOD

In conformity with the preceding discussion, which treated the spring floods as concluding on July 10, and for the sake of eliminating one variable, it has been decided to consider July 11 to September 30, inclusive, as the summer rainy period, regardless of the date of termination of the "technical" flood, which in 1917 was on August 2, and in several other years was later than July 1.

The stream-flow data for July, August, and September have been assembled in Table 59. A mere glance shows that the stream-flow relations after the termination of the arbitrary spring flood on July 10 are the most variable of any season. Since the later summer represents a period in which the water supply is likely to assume importance because of its paucity, the performance of stream B during this period deserves the most careful study, in order that there may be no mistake in interpreting the effects of denudation.

Table 59, in boldest outline, shows:

1. In the predenudation period the average discharge of A for the entire summer was 0.90 inch and of B only 91 per cent of that amount, or 0.82 inch. In the post-denudation period the discharge of A was slightly less on the average, and also slightly less variable, while that of B was even a trifle greater. There was then, on the face of the data, an increase of 0.09 inch or about 10 per cent in the average discharge of B.

2. Moreover, this increased flow of B following denudation held for each of the summer months, practically without change. The ratio for the last 21 days of July jumped from 0.839 to 0.934, or an increase of 11.3 per cent; for August from 0.901 to 0.990, or 9.9 per cent; and for September from 0.989 to 1.099, or 11.1 per cent. This constancy should in itself demonstrate sufficiently that the summer excess *did not arise from a summer saving* of moisture through decreased losses by evaporation, but rather that an excess was carried into the summer from the flood period. Only the slight elevation of the position of B in September, when its excess might be expected to be draining out, could possibly be construed as evidence of summer saving, and this is too insignificant to mention.

The soil moisture data previously discussed, although meager, do not indicate any cessation of the total losses from transpiration and ground evaporation as a result of denudation. In order to realize how clear-cut should be the effect of any reduction of evaporation losses, it is only necessary to consider how great these losses are under normal conditions with a forest cover. Thus, the A records show a 15-year average rainfall of 7.25 inches for July, August, and September. The normal stream flow for these three months is approximately 1 inch. Assuming that the rate of stream decline during this period represents merely draining out of the stored supply, and not the effect of surface evaporation, at least the equivalent of the current precipitation is lost by evaporation. Since it has been shown that the soil moisture in the surface 3 feet declines normally somewhat more than 2 per cent from June to September, it is easily conceivable that the total loss amounts to the 7.90 inches computed and shown in Figure 27, or even as much as 9 or 10 inches. Let us say it is eight times the average stream flow. Any appreciable decrease in this loss should be clearly reflected in the stream flow.

ANALYSIS OF THE SUMMER STREAM FLOW

At the risk of taxing the reader's interest, it is desirable to establish clearly at this point the conclusions (*a*) that the summer stream flow of both A and B represents largely the draining out of ground water stored at the time of the spring flood, and only in small part contribution of current precipitation; and (*b*) that the excess summer flow produced by B after denudation again represents additional spring storage rather than greater effectiveness of summer precipitation brought about by reduction in transpiration losses. These ideas are carried through the succeeding discussion, and it is therefore necessary to have them fixed in mind, if not wholly accepted by the reader. On the other hand, it is not at this point necessary to establish the cause of a greater supply of snow water after denuding, but merely to admit that it must have been on the watershed.

From the apparent cessation of any excess flow of B in the early part of June, and in fact from the usual low relative position of B at this time and its return to a higher position in the fall, it should be apparent that the water which causes summer and fall flow for B is somewhat distinct in source from that which comes down in the flood. The theory of this has already been fully discussed. Nothing could be clearer than the evidence in 1917, when a very large flood was succeeded by a summer and fall of uncommon dryness. Stream A decreased in flow every month from June to the following February. (See Tables 51 and 52.) Stream B decreased until September and then, after light precipitation in September and almost none in October, increased and held strong through January. This tends to show how slow may be the delivery of this steady supply for B, and to suggest that the earliness with which it is made available by melting will be a small factor, at least, in determining the *quantity* which may enter into the discharge of B before the end of September.

On the basis that the summer flow of the streams is largely a draining-out process, the discharge during the flood stage may be used as a criterion of the water likely to be available for flow thereafter. Variations in the lateness of melting and of the delivery of the flood can be taken into account by considering the several floods at premature stages, rather than at their completion. Furthermore, the figure employed to express flood volume must give a measure of the *residue* likely to enter into summer flow, or stated in another way, the early flow, largely from the lower portion of the watershed must be a measure of the probable later flow from the upper portion. If the time limit is too large it will include a fraction of that separate supply which is being considered as a residue, and thereby defeat its own purpose. There is no hesitation felt, therefore, in using the size of the flood up to June 10, rather than the whole flood, as a basis for predicting summer flow. If this should seem to make no allowance for occurrences in June, the latter will be found to be provided for in the precipitation correction.

In attempting to estimate the extent to which current precipitation may affect the summer flow, the only evidence as a starting point for calculations is the immediate effect of rains. (See Table 61.) This shows that, except in rains of unusual size, less than 1 per cent is usually effective on A, and about three-fifths as much on B. It is admitted, however, that the less immediate effects may be obscured by the steady downward trend of the streams. A further cue may be taken from the fact that at least 6 inches of rain in July or August would seem to be required to maintain the level of the streams which were discharging about 0.3 inch per month, and it is therefore conceivable that as much as 5 per cent of the summer precipitation may enter into stream flow before the end of the summer.

It is obvious, however, that in so far as the effect of rain is not apparent immediately, but only after addition to the ground water, its earliness must be an important factor.

Precipitation in May represents a direct addition to the water of melting snow, and it is conceivable that it may swell the flood volume disproportionately to its possible effect on summer flow. However, May precipitation has never exceeded 2.5 inches and is normally only 1.37 inches, so that it is not very important.

By June the surface of the ground has become sufficiently dry so that rains do not necessarily penetrate down to the ground water, but it is apparent that they may have more immediate effect than in July and August.

Adding together the quantities thus obtained for June, July, August, and September, as shown in Table 59, the "effective precipitation" is obtained, of which a small percentage should express the aggregate, if only approximate, stream flow due to rains, the probability of which is not expressed in the flood discharges. This percentage has been found by repeated and varied trials to be 3. By this it is meant that 3 per cent of the "effective" summer precipitation, deducted from the actual summer discharges of B, gives values of summer flow roughly proportionate to any of the measures of flood volume that one may care to make. It reduces to a minimum the "scattering" of points, when plotted as in Figure 36. It does not, nor can any arbitrary rating of the rains be

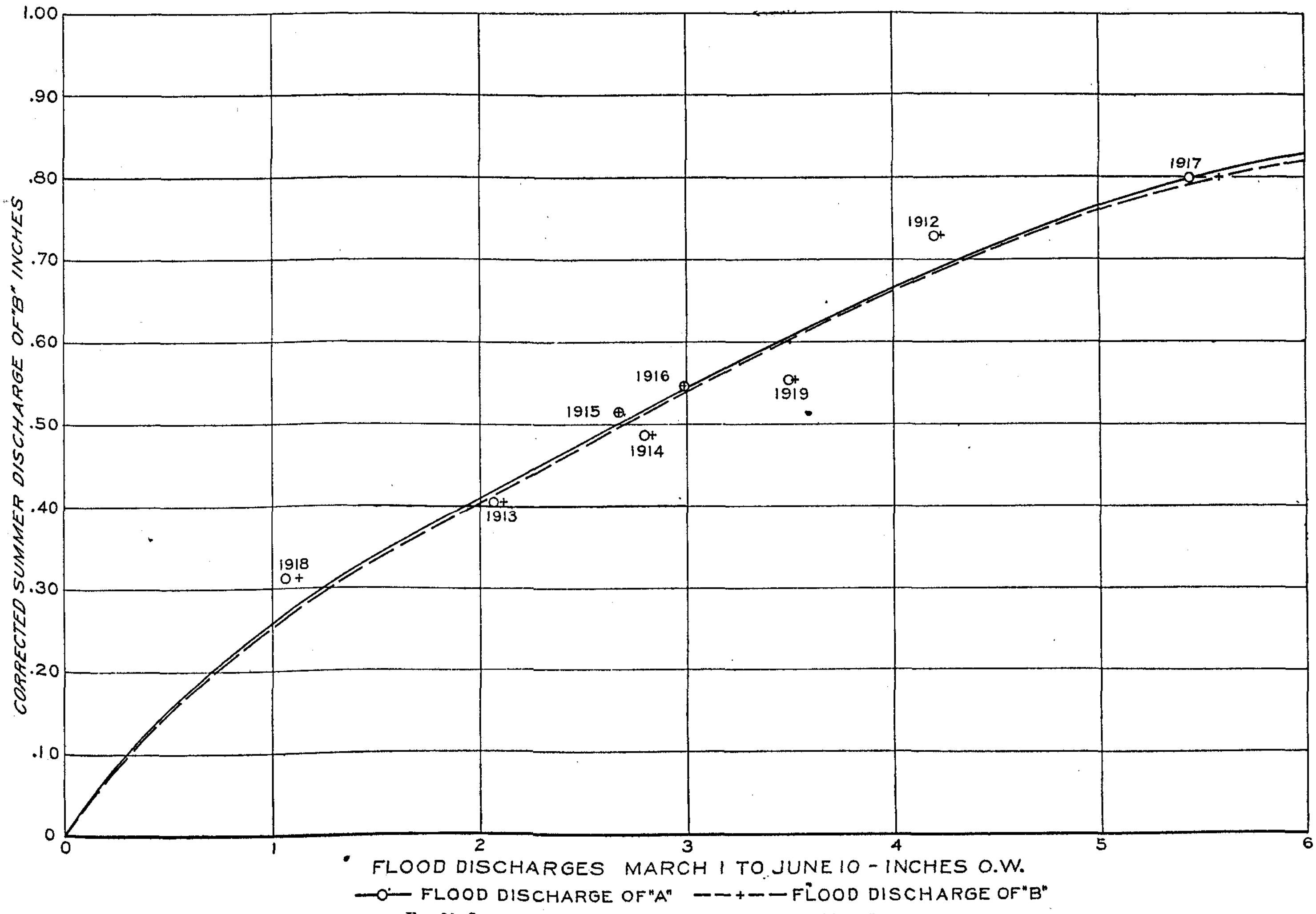


FIG. 36. Summer flow of B, based on size of flood on A and B to June 10

Although the effect of June rains is included in part in the flood flow, it is believed that they also make substantial additions to the ground water which will appear before the summer's end. Because of the longer time involved, June rains evidently have greater opportunity to appear as summer stream flow than do those of the late months. For these reasons it is believed that the usually light June precipitation should be given double value in comparison with unit value for the rains of July and August. The rains of September, while perhaps showing more immediate effect than those of midsummer because the ground is then not so extremely heated and dry, are evidently too late to appear by the ground-water route. Hence they are given but half value.

expected to eliminate entirely variations between the individual years of the predenudation period, since it is evident that no two rains can have exactly the same effect on immediate or later stream flow. There are at least a dozen variables which will make the effects variable.

Figure 36, then, expresses the summer discharge of B as a function of the flood volume of A from March 1 to June 10. The curve is drawn through points corrected as to height by 3 per cent of the effective summer precipitation. A word may be in order as to the possible justification for the convex curvature of the figure necessary to make it pass through the axis of coordinates and to bend to the comparatively low value of the corrected summer flow for 1917. This merely gives expression to the fact that when the flood is very large and the storage space very fully saturated, the immediate rate of draining out must be very rapid, and if the flood be sufficiently large, obviously all storage capacity is exceeded and there must be a definite limit to that which can be delivered later. Conversely, the watersheds may retain a relatively large proportion of the water liberated by melting during smaller floods, and are therefore able to maintain a relatively high rate of flow in the ensuing period. A straight-line relationship is, therefore, not to be expected and the fact that Figure 36 gives so nearly a straight line through the middle is possibly due to the smaller floods being earlier than the larger ones. The curve then indicates that a flood producing only a little more than an inch of water in 102 days, as in 1918, might, without further precipitation, have delivered about 0.30 inch in the 82 days of the summer period. This does not seem at all preposterous after considering other evidences of the retentive ability of these watersheds.

For the sake of a double comparison Figure 36 has been drawn using both the flood volume of A and that of B as a basis for the summer flow of B. The two flood volumes are, of course, very similar.

Turning to the results obtained from the use of Figure 36 for the postdenudation period, it may be seen in Table 59:

1. That the expected summer flow from B, judged by the size of the floods on A, was, on the average, 0.83 inch, practically unchanged from the predenudation period. A slightly lower expectation in the second period due to less summer precipitation than in the first is more than counterbalanced by the effect of larger floods in the second period. This is in conformity with the fundamental difference between A and B, the former showing more effect from current rains, the latter more dependence on storage. The actual discharges of B were greater than the expected in every year of the postdenudation period. The variations in the excesses need not be discussed, since the method is probably not very accurate for any individual year.

2. Figure 36 shows that the flood discharge of B prior to denudation expresses the probabilities for summer flow quite as well as does the flood discharge of A. By reading from the lower curve the values given in the last two columns of Table 59 are obtained, which show that the summer discharges in the postdenudation period varied on both sides of the expected and, in general, did not quite come up to expectations based on the opportunity for B to store water from its enlarged snow supply.

The conclusion is obvious, therefore, that the total water losses by transpiration and evaporation during the summer period could not have been measurably decreased by denudation and that the increased summer flow reflects a saving in evaporation losses at a much earlier period in the year. The excess flow throughout the fall and winter must be ascribed to the same source, especially as it shows a steady decline with distance from the flood period.

LOW STAGES IN SUMMER

It has been shown not only that the general level of summer stream flow for B was raised about 10 per cent after denudation as a result of greater amounts of snow and more complete ground saturation in the spring, but also that the discharge rate of B has always a tendency to turn upward when the evaporation rate declines in late summer, as well as that of A to a somewhat less degree. It is desirable to ascertain to what extent the absolute summer minima of stream flow may have been affected. It is also desirable to determine the average ratio between the high and low stages of the streams, in both periods, as a measure of their inherent evenness of flow and of the total regulatory effect of the forest cover. The evenness, especially, becomes an important idea when it is noted that the records [4] of many streams from much larger drainage areas, and therefore with more compensating factors to reduce the extremes, show much greater spreads between the high and low stages of the year's flow. The spread must be a measure of the extent to which flood-producing accessions of water appear as immediate run-off, rather than going into storage.

[4] See especially "Surface Water Supply of the U. S.," a series of papers by the U. S. Geological Survey, giving annually the results of continuous stream gauging.

TABLE 60.—*High and low stages of stream flow in the two periods*

[All discharges represent daily amounts in hundred-thousandths of inches O. W.]

Year	Watershed A						Watershed B					
	Discharge highest day [1]	Summer low		Ratio of high to low	Winter low [2]		Discharge highest day	Summer low		Ratio high to low	Winter low	
		Date	Discharge rate		Date	Rate		Date	Discharge rate		Date	Rate
1912	17566	Sept. 7	1035	17.0	Feb. 21	780	23351	Sept. 7	1038	22.5	Mar. 16	989
1913	4056	Aug. 31	760	5.3	Feb. 14	753	4026	Aug. 8	820	4.9	Feb. 15	867
1914	7270	Sept. 8	919	7.9	Mar. 6	[3] 727	8586	Sept. 7	831	10.3	Mar. 14	877
1915	8031	Sept. 12	679	11.8	Feb. 6	677	8090	Sept. 12	679	11.9	Feb. 1	843
1916	9697	Sept. 8	954	10.2	Mar. 17	[4] 710	11255	Aug. 28	882	12.8	Mar. 17	903
1917	23602	Sept. 6	995	23.7	Mar. 1	650	20096	Sept. 4	879	22.9	Feb. 3	922
1918	1679	Aug. 25	592	2.8	Feb. 17	669	1310	Aug. 1	635	2.1	Feb. 1	725
1919	9549	Sept. 4	756	12.6	Feb. 18	730	11259	Aug. 30	831	13.5	Feb. 15	825
Predenudation average [5]	10181	Sept. 4.9	835	11.4	Feb. 23.1	712	10997	Aug. 27.6	824	12.6	Feb. 21	869
1920	22692	Sept. 2	910	24.9	Feb. 10	819	32105	Sept. 2	984	32.6	Feb. 10	1032
1921	9395	Sept. 14	1028	9.1	Feb. 15	[6] 857	14688	Sept. 14	1160	12.7	Feb. 16	1063
1922	11996	Sept. 17	921	13.0	Mar. 18	836	22215	Sept. 14	985	22.6	Feb. 15	1004
1923	8791	Sept. 11	952	9.2	Feb. 5	820	15921	Sept. 11	999	15.9	Mar. 18	1035
1924	11031	Sept. 3	824	13.4	Feb. 23	858	18734	Aug. 22	931	20.1	Jan. 22	990
1925	2750	Aug. 17	763	3.6	Jan. 24	[7] 659	4029	Aug. 17	863	4.7	Jan. 28	788
1926	4160	Sept. 10	645	6.4			7077	Sept. 1	665	10.6		
Postdenudation average [5]	10116	Sept. 6.1	863	11.4	Feb. 15.3	808	16396	Sept. 2.7	941	17.0	Feb. 12.5	985

[1] For dates see Table 57.
[2] Following the flood shown on same line, that is, in succeeding calendar years.
[3] A drop to 442 in December represents effect of excessive cold and not a result of draining out, hence not used.
[4] Slightly lower in December.
[5] Arithmetic means used.
[6] The extreme low of winter, 630, evidently produced by cold.
[7] Both streams behaved so erratically in January and February that it is necessary to use the absolute minima.

In the present instance, although the absolute minima of flow for the year are usually registered in late winter, there is no difficulty in distinguishing the late summer minima, because of the September or October upturn which has been noted. These readings, readily obtainable from Table 66, are summarized in Table 60. To avoid duplication and to show at this time the steady draining out of the excesses apparent after denudation, the succeeding winter low discharges are also given in this table. In selecting these it has to be recognized that extreme cold may cause such extensive freezing of the streams as to produce temporarily very low rates. Such occurrences are usually not difficult to distinguish from the steadily approached minima of the late winter, the only ones that are significant. In all cases, of course, these minima are limited by the occurrence of the first sustained melting.

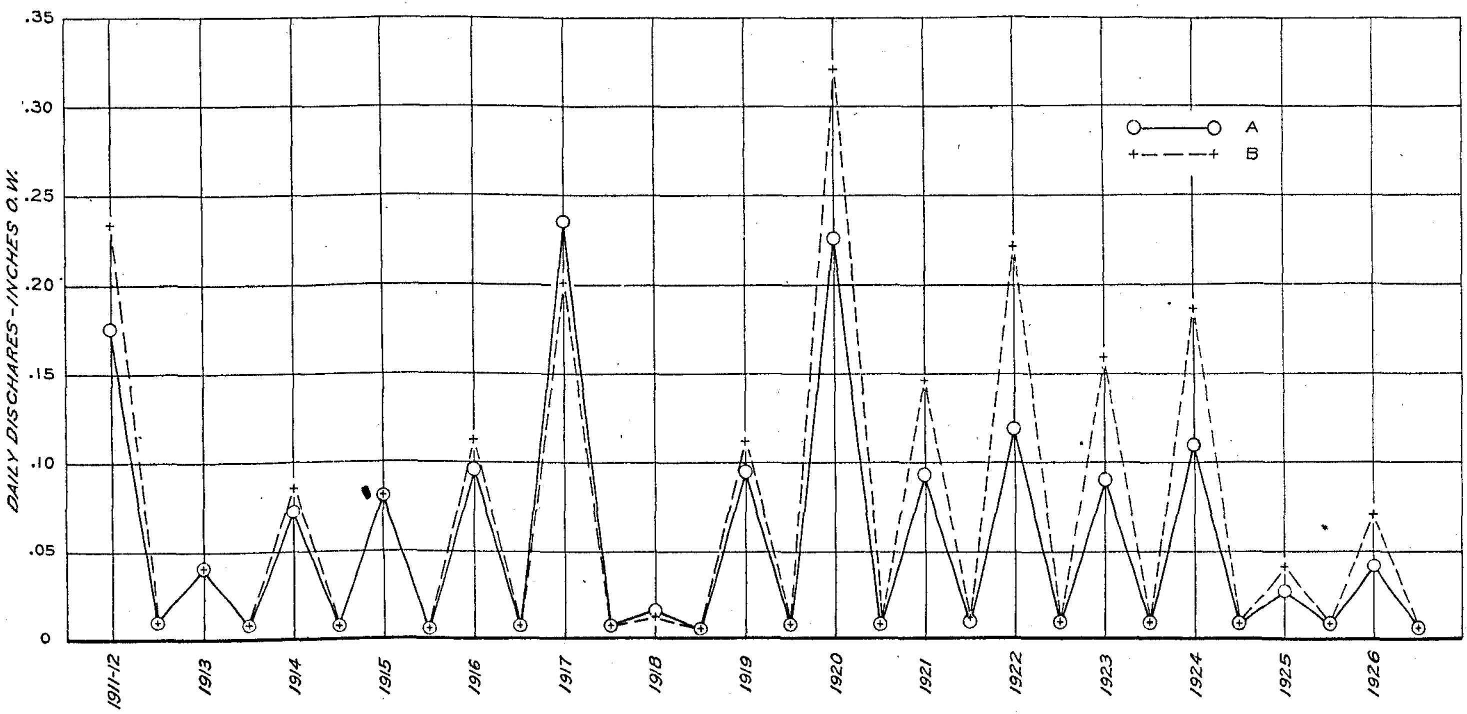


FIG. 37. Spring highs and summer lows of stream-flow

From Table 60 and Figure 37 the following facts and deductions may be drawn:

1. That both average high and average low stages were essentially alike in the two periods of the experiment is indicated by the behavior of A. The very slightly higher and later summer minima probably resulted from later crests and flood volumes in the second period. Shortage of summer rain made them, however, lower than they would otherwise have been.

2. Due to the larger postdenudation flood volumes on B, the summer minima came relatively about five days later than before and did not reach such low points as those of A by nearly 9 per cent. This increase in the minima, which is the aftermath of nearly 50 per cent increase in the maximum discharges of the second period, agrees with the volume increase of B for the whole summer.

3. That neither stream descended to such low winter levels in the second as in the first period, seems to be further evidence of the extent to which winter flow is dependent on the water of the preceding spring, rather than on summer or fall rains, which were less in the second period. However, the heavier snow blankets of the second period may have had current effects in preventing freezing and sustaining streamflow, which are difficult to estimate. The increase of B minima in the second period was in almost exactly the same proportion as the increase of A, tending to show, as has been pointed out from the monthly averages, that the excess placed in the ground in the spring flood period has just about disappeared by the following February. However, the first three or four years after denudation give indication of carrying slight excesses over into the following spring, and since a very small excess in the minimum rate of flow may represent a considerable amount of ground water, there is a basis here for the cumulative excess discharge of B which reached a culmination in the third year.

4. There can be no doubt, then, that the denuded watershed was sufficiently capable of absorbing and holding the excess water available in the spring to prevent shortage at critical seasons when small discharges were to be expected. A very different result might be possible under soil conditions conducive to surface run-off. Removal of the forest, and the destruction of the humus layer which is one of its primary features, would have a far greater effect in increasing the peak flow than was brought about on watershed B. As has been said, the natural ratio between high and low stages, in this experiment 12, and sometimes as high as 50 to 1, should be a measure of the watershed's tendency toward surface run-off at the expense of absorption for later and steady discharge. And by the same token, this ratio should express the probable effect on high flood stages of any treatment which reduces the absorptive capacity of the soil, with the evident possibility of reducing thereby the storage on which flow is dependent.

SUMMER RAINS

The summer rains need no serious consideration in this study. Because of the small precipitation in individual storms, with clear, dry days intervening, these rains play only a small part in total streamflow, being mostly held in the surface soil and quickly evaporated. Also, even when the intensity of fall is great,[5] the spongy character of the soil precludes surface run-off so that the immediate effects are very short-lived and are rarely sufficient to double the low basic summer rate of streamflow. The very small volumes of excess flow produced, as well as their almost immediate appearance, point to the fact that they seldom come to the streams by the ground-water route, and must represent almost wholly the rain which falls in the open streams and upon the constantly saturated ground adjacent. Hence, the curves of summer stream flow reflect the time distribution of the rainfall more than any special characters of the watersheds, and even though two rains may be similar in amount, their time and intensity may vary greatly so that each produces a different kind of stream-flow curve from all others, and different effects on the two streams.

Summer rains of an inch or more were of rare occurrence at Wagon Wheel Gap and usually had a duration of 24 hours or more, so that they produced only a very "flat" effect on stream flow.

Merely for the sake of record, therefore (the hourly records being not otherwise available to the reader), Table 61 presents data for seven rains in the predenudation period and seven in the postdenudation period, each of which was of sufficiently high intensity in a single hour so that the effect in producing a crest was quite distinct from other influences. Only those rains have been taken which are not confused by other rains, either shortly before, or during the following 24 hours.

In tabulating these data, the "zero hour" has been considered to be that hour preceding which the heaviest rain fell at station C, which is somewhat closer to the lower, open portions of both streams than is station D. The corresponding precipitation at D is, however, shown. The run-off of either stream for the zero hour is the rate or head in c. f. s. at the end of the hour, or as commonly expressed "on the hour." The stream flow has been tabulated for four hours before the zero hour in order to show the base rate before rain took effect. Since the rains occur almost invariably in the afternoon, the stream flow is usually on the decline owing to the midday evaporation factor.

The averages in Table 61 are carried out only far enough to show that in the first period A crested about two and one-half hours after the heaviest rain, and B one hour. In the second period, A required two hours while B crested at the end of the hour in which the heaviest rain fell, or possibly half an hour later.

[5] For the single important exception see discussion of August, 1926, rain under "Erosion and silt deposition."

TABLE 61.—*Hourly records of isolated summer rains*

[Figures opposite lines D and C represent rainfall *during* the hour at the station designated by these letters, in hundredths of an inch. Figures opposite lines A and B represent rate of stream discharge at the *end* of the hour, in thousandths of c. f. s., not corrected for the smaller area of B]

Date of storm and zero hour	Station	Hours from start																												Total
		4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
July 15, 1912, 5 p. m.	D					18	0	0	7																					0.25
	C					42	T.	0	4																					.46
	A	156	155	154	154	161	**202**	173	189	182	178	177	173	172	171	169	168	167	167	166	166	164	164	164	162	157	156	154	152	
	B	125	124	124	124	**187**	162	142	140	137	135	134	133	131	131	130	130	130	130	130	130	130	130	129	126	124	126	126	129	
July 26, 1912, 1 p. m.	D			6	0	0	49	8	7	1			2	3	7															.83
	C		T.	T.	0	63	0	0	0	0	0	0	2	4																.69
	A	152	152	151	151	213	228	**360**	317	243	219	205	197	197	197	196	196	191	189	186	183	181	178	177	176	176	175	173	177	
	B	124	123	130	123	122	**315**	191	166	153	147	145	143	156	155	153	150	149	148	147	147	145	145	145	145	145	145	145	143	
July 29, 1912, 3 p. m.	D		1	0	0	7	13	2																						.23
	[1] C		T.	0	T.	42	14	2																						.58
	A	161	160	157	156	202	228	254	**289**	264	239	224	213	208	204	199	196	194	191	189	187	186	183	182	182	182	180	175	171	
	B	135	134	133	131	141	145	**158**	149	145	143	141	140	140	139	139	139	139	139	139	139	139	138	138	138	136	134	131	131	
July 30, 1914, 4 p. m.	D				1	18	10	1																						.30
	C				T.	37	7																							.44
	A	129	126	123	122	122	**156**	149	**154**	151	143	142	141	140	140	140	140	139	139	139	139	139	139	136	132	127	123	121	120	
	B	95	93	92	92	93	110	**123**	110	105	103	102	102	101	101	101	101	101	101	101	101	101	99	98	96	93	92	92	92	
Aug. 18, 1914, 5. p. m.	D					18	4	1	1																					.24
	C				T.	34	3																							.37
	A	96	94	93	104	**139**	126	**136**	123	117	113	111	110	108	108	108	108	108	107	107	107	107	106	104	102	99	99	97	97	
	B	69	68	68	68	**104**	83	79	78	78	77	76	76	76	76	76	76	76	76	76	76	76	75	73	73	73	73	73	73	
Aug. 3, 1916, 2. p. m.	D				8	1	4																							.13
	C				11	55	1	3																						.70
	A	129	129	128	135	178	187	**203**	187	176	168	162	158	156	152	150	149	148	145	145	143	143	142	141	141	139	138	133	128	
	B	95	95	93	93	**195**	135	120	115	112	110	109	109	108	108	107	107	107	107	106	105	105	105	105	104	104	102	101	99	
Aug. 2, 1918, 3 p. m.	D						29	23																						.52
	[2] C					11	9	2	2	T.																				.24
	A	60	57	53	51	48	50	61	69	**90**	82	74	71	69	68	67	67	67	67	67	66	66	66	66	66	64	63	58	56	
	B	52	51	49	49	49	56	88	73	65	63	61	61	61	61	61	61	61	61	61	61	61	61	61	61	58	57	55	55	
Averages of 7 storms	A	126	125	123	125	152	168	**191**	190	175	163																			
	B	99	98	98	97	127	**144**	129	119	114	111																			
July 16, 1921, 3 p. m.	D				11	40																								.51
	C				T.	27	T.																							.27
	A	160	159	153	150	187	210	**256**	205	184	176	171	170	168	166	166	165	165	165	165	165	165	165	164	164	163	160	156	152	
	B	129	129	128	129	**185**	161	143	139	138	137	137	135	135	135	135	134	134	133	133	132	132	131	131	129	127	126	127	128	
July 23, 1921, 8 p. m.	D				10	24																	13							.47
	C			1	13	24	1				1	1											13							.54
	A	140	140	140	146	180	193	**218**	193	180	171	169	168	166	165	164	163	163	162	162	160	159	165	160	158	156	153	151	150	
	B	117	119	120	165	**177**	150	139	133	131	130	130	130	130	130	130	129	129	129	128	125	123	162	133	128	126	126	126	126	
Aug. 9, 1921, 4 p. m.	D		1	0	1	12	2																							.16
	C		13	0	1	18	14																							.46
	A	122	128	124	121	164	168	**181**	158	144	139	136	135	134	134	133	133	133	133	133	133	133	133	133	132	129	126	125	128	
	B	102	102	102	102	103	**135**	117	115	111	109	109	109	109	109	109	109	109	109	109	109	109	110	105	104	102	103	103	103	
Sept. 1, 1921, 6 p. m.	D					6	6			1																				.13
	C					19	5																							.24
	A	118	117	115	112	111	111	132	131	**141**	134	130	128	126	125	124	123	123	123	122	122	121	121	120	120	118	114	110	108	
	B	106	106	106	106	107	**140**	124	118	116	114	113	113	113	113	113	113	113	113	113	112	111	110	110	109	107	106	106	106	
June 23, 1922, 4 p. m.	D			10	3	21	20	19	6																					.79
	C			3	5	20	24	14	5	1																				.72
	A	204	200	200	203	223	251	291	**326**	325	293	263	245	240	233	230	228	226	226	226	224	223	223	221	221	221	215	210	200	
	B	178	177	189	190	213	265	**267**	261	224	206	201	197	195	193	193	193	191	191	191	191	191	191	189	187	186	185	179	178	
Aug. 14, 1922, 6 p. m.	D				8	44	2	3	3	7	3	2																		.72
	C			2	19	45	T.	2	2	5	3	2																		.80
	A	118	116	115	142	267	293	**347**	231	200	195	199	197	189	178	169	164	158	154	152	150	149	148	146	144	141	141	143	148	
	B	99	98	98	102	**354**	285	245	144	141	141	142	134	129	126	123	121	120	119	119	118	117	115	113	111	110	113	113	114	
July 4, 1923, 2 p. m.	D				3	14	11	3																						.31
	C				1	18	10	1																						.30
	A	142	139	133	128	136	144	150	**162**	156	150	146	145	144	144	144	144	144	144	145	145	145	145	146	148	145	141	136	133	
	B	107	104	103	120	**141**	132	124	119	118	117	117	117	117	117	117	116	116	116	116	116	116	116	115	115	110	107	110	110	
Averages of 7 storms	A	143	143	140	143	181	196	**225**	201	190	180																			
	B	120	119	121	130	**183**	181	166	**147**	140	136																			

[1] Considerably more fell on A than on B.

[2] 0.32" at lower end A, 0.60" on B.

In the first period, using the averages, A rose 68 points above its initial low stage and B 47 points. In the second, A made 85 points and B 64. Both streams had just about fallen back to their base lines after 24 hours. It is thus seen that the excess flow of B was only about two-thirds as much as that of A.

THE FALL AND WINTER STORAGE PERIOD

The period from October 1 to the end of February is one in which the stream flow is comparatively low, most of the precipitation being in the form of snow and consequently nonavailable for stream flow until March or later. Although there may be some melting during any of the winter months, and this, occurring over frozen ground, has frequently been noted to produce some surface run-off immediately affecting stream flow, it is doubtful whether before denudation there was enough of this either to have any material effect on stream volumes or to affect the ratio of B to A discharge during the period.

In Table 62 are presented the predenudation and postdenudation averages of stream flow for the storage months, except that 1911–12, a year when heavy October rains brought October alone up to 0.9 inch and the entire period up to nearly twice the normal flow, has been omitted, since there was no such occurrence as this in the postdenudation years. It is evident that the quantities being dealt with are essentially the same for the two periods.

TABLE 62.—*Average relations of A and B discharge through the fall and winter months, excluding 1911–12*

[Discharge in inches O. W.]

Month	Predenudation averages [1]			Postdenudation averages		
	A discharge	B discharge	Ratio B/A	A discharge	B discharge	Ratio B/A
October	0.3123	0.3304	1.058	0.3164	0.3631	1.148
November	.2677	.3053	1.140	.2895	.3419	1.181
December	.2452	.2932	1.196	.2793	.3278	1.174
January	.2405	.2878	1.197	.2614	.3134	1.199
February	.2098	.2549	1.215	.2355	.2868	1.218

[1] Excluding 1911-12.

Table 62 tells nearly the entire story as to the source of the winter flow and of any difference between A and B caused by denudation. Excluding 1911–12, the two periods show almost identical discharges for A in October, but in the first instance stream A did not hold up quite so well through February, as in the second period. This may be due to slightly greater October precipitation in the second period (excluding 1911 the period averages are, respectively, 1.66 and 1.88). It may be due to slightly greater contributions from melting in the second period, though the months November to February were on the average only 0.1° warmer. It is not impossible that heavier snows in the second period prevented the usual deep freezing of the soil and thus left more of the ground water free to flow, although the average soil temperatures for station A–1 do not suggest a time when this could have been a factor. The Decembers were usually warmer in the second period, and it will be noted that the drop in streamflow from November to December was not as marked in the second period.

The sunshine averaged less in the postdenudation period, and this is the largest contributor to winter melting.

Everything considered, it seems probable that the largest factor contributing to the more sustained flow of A through the winter must have been the hold-over from the preceding high floods, for the lowest years of the second period were those following comparatively small and early floods, namely 1919–20 and 1925–26. This appears true despite the fact that in September and October there was only a slight excess in the discharge of A in the second period, compared with the later months.

If it be true that stream A derives most of its winter flow from moisture left in the ground in the preceding spring, it is even more true that this is the source of the sustained flow of B. Thus, in the first period, the ratio of average B discharge in October to that of A was 1.058, and this climbed steadily to 1.215 in February. If winter melting was an important factor in winter flow of the first period, it would appear from this to be contributing more to B than to A, whereas the general observation was that B had considerably less area subject to loss of its snow during the winter than did A with its more direct south exposure. The conclusion must be that only occasionally does melting add enough to the water in deep storage, to affect the current discharge.

TABLE 63.—*Condensed winter stream-flow relations*

[All discharges, in inches, over the watershed]

Year	Watershed	Stream discharges				Ratio B/A discharge	Winter discharge of A plus 10% preceding 3 months	Expected flow of B [2]	Excess shown by actual flow
		October	November to January	February	Total				
1911–12	A	0.9012	1.1354	0.2670	2.3036	1.052	2.4200		
	B	.9844	1.1322	.3065	2.4231				
1912–13	A	.3392	.8644	.2266	1.4302	1.180	1.5605		
	B	.3798	1.0179	.2892	1.6869				
1913–14	A	.2869	.7457	.2160	1.2486	1.130	1.3367		
	B	.3068	.8576	.2470	1.4114				
1914–15	A	.3076	.7233	.2185	1.2494	1.161	1.3651		
	B	.3150	.8747	.2610	1.4507				
1915–16	A	.2736	.6901	.2065	1.1702	1.142	1.2651		
	B	.2805	.8080	.2479	1.3364				
1916–17	A	.4238	.8305	.2112	1.4655	1.181	1.5737		
	B	.4574	1.0078	.2656	1.7308				
1917–18	A	.3170	.7579	.1986	1.2735	1.190	1.4174		
	B	.3209	.9272	.2675	1.5156				
1918–19	A	.2377	.6618	.1911	1.0906	1.072	1.1583		
	B	.2524	.7111	.2061	1.1696				
Predenudation average	A	.3859	.8012	.2170	1.4040	[1] 1.133			
	B	.4122	.9170	.2614	1.5906				
1919–20	A	.2763	.7416	.2184	1.2363		1.3406		
	B	.2849	.8058	.2429	1.3336			1.421	−0.0874
1920–21	A	.3161	.8349	.2399	1.3909		1.5075		
	B	.3638	1.0467	.3184	1.7289			1.624	.1049
1921–22	A	.3236	.8364	.2367	1.3967		1.5245		
	B	.3972	1.0612	.3108	1.7692			1.655	.1142
1922–23	A	.3162	.8712	.2453	1.4327		1.5468		
	B	.3502	1.0226	.2888	1.6616			1.683	−.0214
1923–24	A	.3876	.9449	.2573	1.5898		1.7037		
	B	.4535	1.1088	.3161	1.8784			1.883	−.0046
1924–25	A	.3157	.8519	.2436	1.4112		1.5121		
	B	.3822	1.0194	.2945	1.6961			1.640	.0561
1925–26	A	.2792	.7310	.2076	1.2178		1.3007		
	B	.3099	.8171	.2364	1.3634			1.371	−.0076
Postdenudation average	A	.3164	.8303	.2355	1.3822	[1] 1.181			
	B	.3631	.9831	.2868	1.6330			1.611	.0220

[1] Algebraic means.

[2] Read from fig. 38.

In the second period B started in October with a higher ratio to A than before, as was to be expected from its position throughout the summer. The ratio of 1.148 suggests an excess of about 8 per cent, which is in close agreement with the indications for the late summer. The ratio B/A then rose, as before, somewhat irregularly to February, but in February it was 1.218, practically the same as for the predenudation period. It is thus clearly seen that by February any excess due to denudation, and which had made its first appearance in the spring flood preceding, had practically drained out. Furthermore, this failure of B in February to hold any higher, relative to A, than in the predenudation period, shows clearly that its high rate in the preceding months was not due to any appreciable acceleration of melting, unless this resulted almost wholly in surface run-off without storage. Theoretically it seems probable that there might have been more melting on B after denudation, but that this would have been counterbalanced by the increased opportunity for evaporation at the ground surface.

Turning to Table 63, it may safely be said that the excess of 0.06 inch there indicated as the net increased discharge of B in the second period, is merely the indication of an excess, without taking into account the factors which always cause B to run higher than A at this season. Whatever the amount of the total excess, it should evidently be credited to the several months in steadily decreasing amounts, so that February shows practically none.

ANALYSIS OF THE WINTER RELATIONS

Since the flow of both streams through the winter is very largely dependent on ground water which has been held over at least in part from the preceding spring, it follows from what has already been said of the capacity of B for long storage and slow exhaustion that the more both streams are reflecting the flow from water made available months previously, the more likely it is that the discharge of B will stand in a high ratio to that of A; while the more both are dependent on current or relatively recent accessions, the higher will be the relative position of A.

It has happened not infrequently in both periods that the natural course of decline has been interrupted, both streams raised, and the natural draining-out ratio disturbed by heavy precipitation in October, and as this is the latest month when precipitation can appreciably affect the winter discharges, it constitutes a critical point.

It is found, then, that with the exception of 1911–12 and 1916–17, the winter ratios B/A, when plotted against discharges of A from July to September, show a strong tendency to increase as the discharges increase. And if, again, October discharges be deducted from those of the summer, the relationship is even more direct and includes the year 1911–12 with its extraordinary October flow. The year 1916–17, however, still remains somewhat unconformable to this law with a high ratio B/A for the winter, in comparison with summer flow, and also with a high discharge in October. This appears to be due to an unusual amount of precipitation in July, August, and October, not fully reflected in the run-off before September 30, and to put this season in the same category as the others it would be necessary to advance the period expressing summer flow, and decrease the deduction for October flow. No rule by which this could be made generally applicable has been found, so that this method must be abandoned except for its suggestiveness.

It is, however, worthy of note in passing that it was undoubtedly this July–October precipitation of 1916, and somewhat the same combination in 1911 which caused the large floods of the following years, quite as much as the heavy winter snows. The difference between October, 1916, and October, 1911, lies in the fact that the 1916 precipitation was well distributed over nearly half of the month.

Figure 38 shows that the winter discharge of B may be expressed as a direct function of the winter discharge of A, with only two or three variations of importance, and that the relationship is even more satisfactory if the part which long-preceding moisture plays is accentuated by adding to the winter discharge of A 10 per cent of the summer discharge. This appears to be only a slightly different form of expression from that described above. That they embody the same controlling factors is shown by the fact that their graphic representations produce almost identical forecasts for each of the postdenudation years.

The readings from Figure 38 as given in Table 63 bring out four years in which B shows winter deficits after denudation and only three with excesses, but the latter considerably exceed the former in amount. The net result is an excess of 0.02 inch, or about 0.04 inch if the first year be excluded from the averages. The greatest deficit was shown by the winter of 1919–20 when the denudation had not been in effect long enough to increase B's storage opportunities, but was probably effective in causing evaporation losses through the summer, fall, and winter.

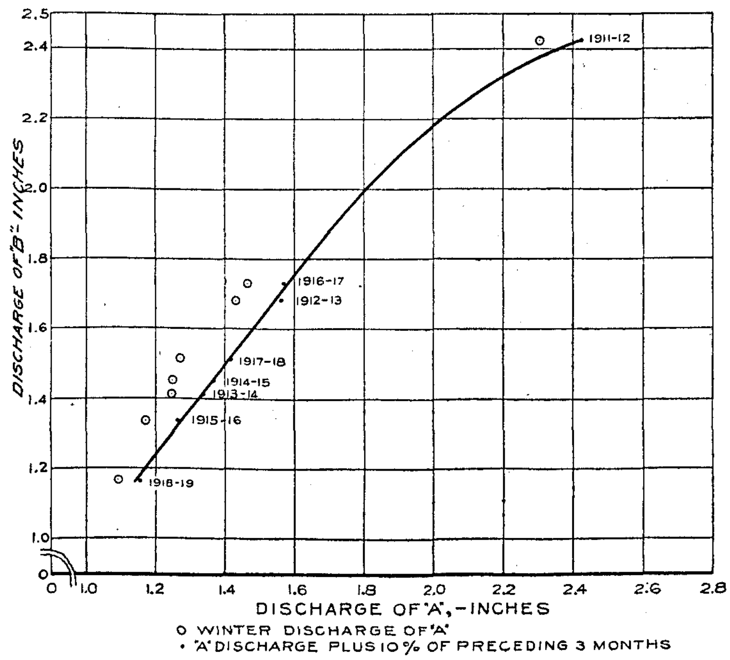


FIG. 38. Winter discharge of B in relation to corrected A discharge

The position of the other excesses and deficits is such as to confirm the belief that the first three years after denudation was a period of accumulation in which the ground-water level was being quite steadily raised.

SOURCE OF THE STREAM-FLOW EXCESSES FOLLOWING DENUDATION

It has been shown that the average of the annual streamflow excesses following denudation, amounting to approximately 0.96 inch, was divided between seasons as follows:

	Inch
Arbitrary flood period March 1 to July 10	0.80
Summer period July 11 to Sept. 30	.09
Winter period Oct. 1 to Feb. 28 (less than)	.07

This distribution might be slightly shifted by considering variations in the seasons which affect the probable opportunities for storage and for more immediate delivery, but such slight changes do not concern us. Enough evidence has been presented and analyzed to indicate that the excesses arose in the winter storage period, were largely delivered when the snow melted, and were doled out in a constantly thinning stream as the seasons rolled around, so that by the end of February, on the average, practically no evidence of an excess was left.

In the first two winters after denudation was fully in effect, 1920–21 and 1921–22, stream B apparently maintained high rates of flow relative to A that have not been accounted for by the character of the preceding seasons. It, therefore, seems comparatively certain that the general level of the storage water in B was rising during this period, and that possibly as a result of several successive winters of heavy snowfall there was what may legitimately be called a cumulative effect to produce the very large excess discharge culminating in the flood of 1922. It is hardly necessary to point out that an excess flow of a few hundredths of an inch for the winter period might

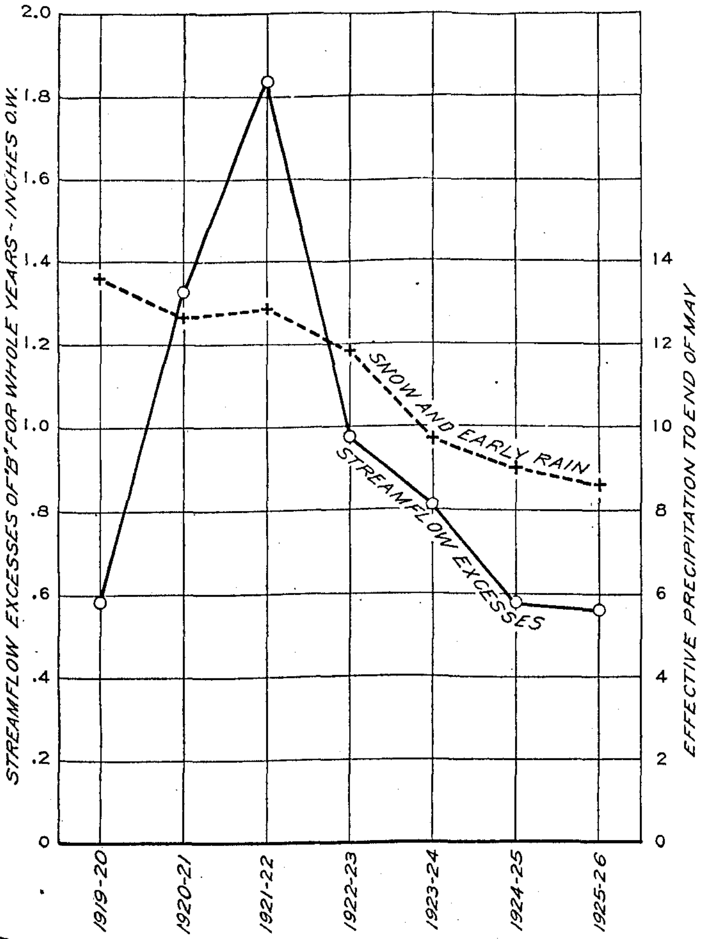


FIG. 39. Yearly stream-flow excesses following denudation in relation to amount of snow

easily represent several times as great an increase in the stored supply, since the amount in storage at the beginning of the winter must normally be several times the amount which appears before March 1. Thus, an excess discharge of 0.1 inch during the winter period might easily represent a storage excess of 0.3 to 0.5 inch. In considering this it must be remembered that moisture in the top layers of the soil, which might otherwise drain to the streams during the winter, is effectively sealed by freezing. It, therefore, seems quite probable that as much as 0.3 inch of the excess not drained out in the winter of 1919–20 or 1920–21, might have been available to increase the spring floods of 1921 and 1922, respectively.

It has been shown in Table 53—and the evidence is repeated in Figure 39—that the annual excesses climbed to a peak of about 1.84 [6] inches in the third year after denudation, and thereafter dropped to 0.58 and 0.57 inch, respectively, in the sixth and seventh years. This cyclic trend might readily be construed to express the effect of the regrowth of vegetation upon the denuded watershed, particularly the development of the aspen sprouts. Under this interpretation, however, there can be no justification for the maximum effect being deferred until the third year, since, as usually happens with sprout growth, the aspen developed sufficiently in the first year to cover much of the ground. Moreover, the careful scrutiny of the streamflow and soil-moisture data has not indicated an effective saving of moisture during the growing season, such as would be necessary for an interpretation of the cyclic trend in terms of vegetative development.

[6] The values given here are the actual differences B minus A, less the average corresponding difference for the predenudation period, 0.1004 inch.

Both because the water from snow seems to be a far more effective agent in producing stream flow than does rain, and because it is fairly evident that the stream-flow excesses from year to year have no definite relation to the total precipitation (Table 53), but came into existence at the time of the spring flood, it is logical to attempt to relate these excesses to the snowfall. This object might be attained by using the data on snowfall given in Table 41, or using the entire precipitation during the snow period and up to the end of the flood, or by considering the residual snow before effective melting begins, plus any spring precipitation likely to combine with melting snow. The last measure had been chosen, not because it promises a very close correlation with flood discharges or B streamflow excesses, but because it seems to bring out some points not heretofore brought forward.

TABLE 64.—*Snow and rain to end of May comprising principal supply for stream flow*

Year	Snow on ground end of February (inches of water)		Additional precipitation, March to May		Totals, inches	
	A	B	A	B	A	B
1911–12	[1] 3.75	[1] 4.10	4.93	4.95	8.68	9.05
1912–13	[1] 3.90	[1] 3.90	2.67	2.95	6.57	6.85
1913–14	6.43	6.76	3.03	3.88	9.46	10.64
1914–15	3.66	3.99	5.72	5.52	9.38	9.51
1915–16	6.94	7.33	4.01	3.87	10.95	11.20
1916–17	3.97	4.29	8.92	8.73	12.89	13.02
1917–18	3.40	3.85	2.95	2.93	6.35	6.78
1918–19	4.67	5.81	6.04	5.94	10.71	11.75
Predenudation averages	4.59	5.00	4.78	4.85	9.37	9.85
1919–20	7.08	7.96	6.55	6.50	13.63	14.46
1920–21	7.45	6.34	5.19	5.15	12.64	11.49
1921–22	6.08	5.86	6.82	6.87	12.90	12.73
1922–23	7.39	7.46	4.44	4.39	11.83	11.85
1923–24	4.31	4.36	5.39	5.11	9.70	9.47
1924–25	3.40	2.94	5.62	5.50	9.02	8.44
1925–26	3.06	2.40	5.54	5.56	8.60	7.96
Postdenudation averages	*5.54*	*5.33*	5.65	5.58	11.19	10.91

[1] Amounts estimated from snow-scale measurements on Feb. 22, and Mar. 7, 1912, and on Feb. 24 and Mar. 10, 1913, respectively. Not until 1913–14 were observations made to coincide with the end of the month.

The data thus presented in Table 64 show:

1. That in the predenudation period B, with only one exception in the eight years, retained more of its snow than A until March 1, despite the fact that no greater snowfall was recorded on B for the winter months. In the postdenudation period, on the contrary, B shows appreciably poorer retention of its snow on March 1, with the exception of the first year, and two later years when the differences are insignificant. In view of the vagaries shown by many of the sets of snow-scale observations, a part of this change in B's position might well be credited

to chance—1921, for example, being a year in which the measurements for B on February 28 are inexplicably low. Considering, however, that B delivered more water in the spring despite this disappearance of the snow, it is obvious that the disappearance means merely more melting during the winter. It seems quite possible, also, since this melting had no noticeable effect on stream flow as late as February, that it denotes storage in the form of ice on or in the top layers of soil, to some extent protected from the evaporation loss by which banks of snow are constantly drained. This "advance melting" implies some movement of the water toward the stream channel, and may account for the early rise of B after denudation, as much as does the melting in March.

2. This change in the status of B snow retention in the second period makes it necessary to use the quantities for A in any comparison of the two periods. It is evident that the second period was much richer in snow than the first, and that this increase applies both to the effective amount before March 1 and to the snow and rain after that date which might enter somewhat more quickly into stream flow. Therefore, no particular change in the amount of run-off could be anticipated because the flood precipitation occurred earlier or later, and it will be recalled that A showed only slightly more flood run-off in the second than in the first period of the experiment.

The data in Table 64 give a logical basis for explaining the cyclic trend of the stream-flow excesses, and thereby indicate their source. It is readily seen that the first winter after the denudation—that of 1919–20—was one of exceptionally heavy snowfall; that this was followed by three winters of heavy snowfall, and that the last years of the experiment were characterized by lighter snowfall. Thus a "climatic cycle" of a particular type is indicated, which differs from the stream-flow cycle principally in the comparatively small stream-flow response in 1919–20. Even though an exact correlation can not be shown by considering the snow quantities alone, it is evident that the occurence of this climatic cycle must throw grave doubts on any attempt to interpret the stream-flow excesses in terms of vegetative development. This leaves but one outlet for the imagination, namely, the belief that the stream-flow excesses of B after denudation, or more properly the deficits of A, arose from interception and loss of a part of the snowfall on A. The point brought out above as to winter melting and "protected storage" in the denuded watershed may be a small factor in the whole result.

No attempt will be made to explain the rather loose character of the correlation between snow quantities and stream-flow excesses as shown in Figure 39 other than the relatively small response in the first year, to the largest snowfall recorded. In considering this it must be remembered that during the winter of 1919–20 the denudation was not fully in effect. While a comparatively small area of aspen at that time remainded to be cut, it is conceivable that the slashings piled in windrows, and as yet unburned, might have had a very appreciable influence in keeping snow off the ground, and thereby exposing it to loss by evaporation, much as do the branches of standing trees. Further, it is evident from the winter flow of 1919–20 that up to that time the water level could not have been raised merely by the cutting of the trees begun in late summer.

On the other hand, a cumulative effect, meaning a general raising of the water level at all seasons up to the end of the third year, seems not only a possible but a probable explanation of the large excess delivered in the third year. The sudden dropping off from this peak in the fourth year does not find an adequate explanation; there can only be pointed out the relatively small proportion of the snow water occurring in the latter part of the winter of this year, and the relatively high winter evaporation rate, as possible contributing factors. For this year as a whole (Table 53) the stream-flow level was low compared with the high precipitation, but this appears to be because so much of the precipitation came in the summer.

It again seems desirable to point out that the development of the aspens at this stage could hardly account for a sharp return toward predenudation conditions. General observations indicate that, since even well-developed aspen has practically none of the effect of intercepting snow which may be ascribed to evergreens, it is inconceivable that the small, nearly vertical sprouts could exercise such an effect.

On the same basis—interception—the small excess shown by the discharge of B in the first half of the experiment is plausibly explained by the fact that B had noticeably more aspen cover than A. However, it can not be denied that the apparent difference between the discharge of A and that of B in the first period may be the result of incorrect area determinations.

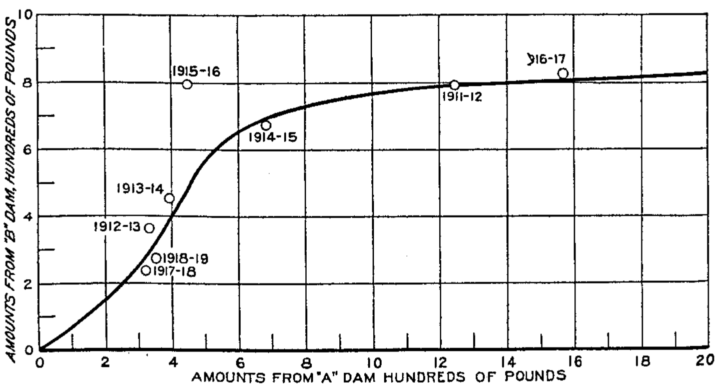


FIG. 40. Relation between A and B silt deposits

EROSION AND SILT DEPOSITION IN BASINS

It has been explained that the dams were so constructed as to form basins in which the streams were given opportunity to deposit whatever of silt and soil had been picked up along their course. The length of time permitted for settling naturally decreased as the rate of discharge increased, so that it is not surprising to find that in high stages the proportion of lighter organic material was much less than in quiet stages. This is clearly brought out in Table 65 in the so-called "humus" percentages, which refer to the proportions of the whole weights removable by combustion at red heat, any reduction of the mineral constituents in this process probably being fully counterbalanced by the incompleteness of the organic combustion. In brief, the high water of the spring flood is not only capable of carrying heavier and coarser material than is carried at other times, but also high water may tend to carry the lightest material past the settling basin. All of the systematic and complete measurements on the accumulations of silt in the basins are given in Table 65.

The relation of B deposits to A deposits is not constant, even for corresponding periods of different years, and there is no satisfactory explanation for the variations.

In Figure 40 it has been sought to express directly the relationships between the amounts deposited by streams A and B. These relationships are evidently different for the winter, flood, and summer periods, but minor variations tend to be compensated when whole years are taken.

It is hardly to be questioned that more satisfactory explanations of the variations in silt deposits of either stream could be obtained by relating each to the total or maximum discharge for each period. But this would have the objectionable feature that for the postdenudation period the most probable deposition of stream B would have to be related to its most probable discharge, and it seems very undesirable so to complicate the calculations. Therefore, the matter of silt deposits is kept distinct.

TABLE 65.—*Amounts of silt deposited in basins and relations between A and B*

Collection dates for A and B dams	Dam A		Dam B		Ratio B weight / A weight
	Weight	Humus	Weight	Humus	
	Pounds	*Per cent*	*Pounds*	*Per cent*	
1912—July 15[1]	1,246.0	-------	788.0	-------	-------
Oct. 15	71.0	-------	164.0	-------	-------
1913—Apr. 15 (no record)	-------	-------	-------	-------	-------
July 16, 15[2]	226.0	28.5	267.0	14.5	1.181
Oct. 15, 14	106.0	25.9	94.0	21.5	.887
1914—Apr. 22, 21	129.0	34.6	99.0	27.7	.767
July 14, 15	180.1	29.8	156.1	12.7	.867
Oct. 16, 15	84.1	34.4	197.9	12.9	2.354
1915—Apr. 14, 9	324.6	28.8	233.8	16.0	.720
July 16, 15	292.7	20.8	335.0	8.5	1.145
Oct. 15, 15	67.0	29.5	103.4	17.6	1.543
1916—Apr. 18, 12	138.0	32.2	132.1	20.2	.956
July 17, 14	195.5	25.1	312.0	7.5	1.596
Oct. 14, 17	115.6	39.0	350.8	11.7	3.035
1917—Apr. 16, 17	278.1	26.8	203.2	10.9	.731
July 17, 16	1,257.6	21.1	542.7	8.4	.432
Oct. 15, 15	43.3	22.8	62.1	20.0	1.434
1918—Apr. 16, 16	150.3	27.3	84.4	31.0	.562
July 17, 16	88.7	28.3	67.1	27.3	.756
Oct. 15, 16	82.8	34.5	84.8	31.2	1.024
1919—Apr. 16, 14	84.0	35.5	71.1	30.9	.846
July 15, 16	192.4	22.0	143.1	14.0	.744
Oct. 16, 15	75.6	37.2	58.6	38.0	.775
Averages first period—Apr. 15, 6 years	184.0	30.9	137.3	22.8	[5].746
July 15, 7 years	347.6	25.1	260.4	13.3	.749
Oct. 15, 8 years	80.7	31.9	139.4	21.8	1.727
Whole years[3]	691.5	-------	568.5	-------	.822
1920—Apr. 13, 14	117.9	36.8	131.3	34.6	1.114
July 15, 14	362.5	33.6	1,211.0	9.0	3.341
Oct. 14, 14	94.2	33.7	188.9	17.7	2.005
1921—Apr. 14, 13	176.6	38.0	502.8	15.6	2.847
July 14, 14	458.5	46.5	3,340.5	[4]51.0	7.286
Oct. 14, 14	118.3	35.0	256.4	21.9	2.167
1922—Apr. 12, 12	181.8	44.9	510.6	22.9	2.809
July 17, 15	309.2	27.1	3,360.6	17.5	10,869
Oct. 17, 16	68.9	29.1	329.4	15.2	4.781
1923—Apr. 13, 14	92.8	37.8	496.6	22.5	5.351
July 16, 16	224.4	32.7	1,892.2	13.0	8.432
Oct. 15, 15	123.6	29.5	292.9	25.9	2.370
1924—Apr. 16, 14	173.6	24.9	1,779.1	8.7	10.248
July 14, 15	258.8	18.6	5,576.4	10.1	21.547
Oct. 14, 14	47.3	32.0	167.9	21.6	3.550
1925—Apr. 4, 6	99.1	33.2	453.5	24.9	4.576
July 13, 13	112.5	-28.8	584.1	16.6	5.192
Oct. 14, 16	49.4	33.7	167.2	24.9	3.385
1926—Apr. 13, 12	132.4	27.8	489.2	18.3	3.695
July 14, 14	87.8	43.2	577.4	15.8	6.576
Oct. 4, 4	49.5	30.5	1,072.9	7.6	21.675
Averages second period—Apr. 15	139.2	34.8	623.3	21.1	[5]4.478
July 15	259.1	32.9	2,363.2	19.0	9.121
Oct. 15	78.7	31.9	353.7	19.3	4.494
Whole years	477.0	-------	3,340.1	-------	7.002

[1] Covers the year, from the time of installation of the triangular weirs about July 22, 1911, and includes the entire effect of the flood of October, 1911. See footnote 3.

[2] It is not certain whether this record covers only the period from April to July or the 9 months from October to July, but since the winter and spring ratios, on the average, are essentially the same, this may be used as a record for the 3-month period.

[3] Sum the quarterly averages, multiply by 7, add the amount for July 15, 1912, and divide by 8.

[4] This unusual value largely due to charcoal carried into the stream and basin. Omitting this figure the average is 13.7 per cent for July. This covers the first flood period after burning the brush in September, 1920.

[5] Algebraic means.

Broadly speaking, Table 65 shows that prior to denudation of watershed B the amount of silt carried by its stream to the basin was almost always less than that carried by A during the winter and spring flood periods, and usually more during the summer period. This would seem to denote that in both cases silt-collecting by the streams is largely a matter of channel-scouring, and the relatively smaller amounts removed by B during the spring flood leave more to be carried down later. This effect is much more pronounced in the later period.

The fact that the organic content of the A deposit is considerably greater than that of B, and the mineral matter therefore less than appears on the face of the figures, undoubtedly denotes slightly different vegetative conditions along the banks of the two streams. If we

FIG. 41. Small gully formed from skid trail on watershed B

assume, from this fact, more vegetation growing in immediate proximity to Stream A, it is possible to account in part for the lesser removal of silt of all kinds during the summer period, by the binding action of such vegetation. It is noteworthy that the humus percentages for A increased somewhat with the lower average silt loads of the second period, while those for B remained essentially unchanged. This possibly indicates a gradually growing stability of conditions on the A watershed. Aside from this, the data on humus are not seen to have much significance.

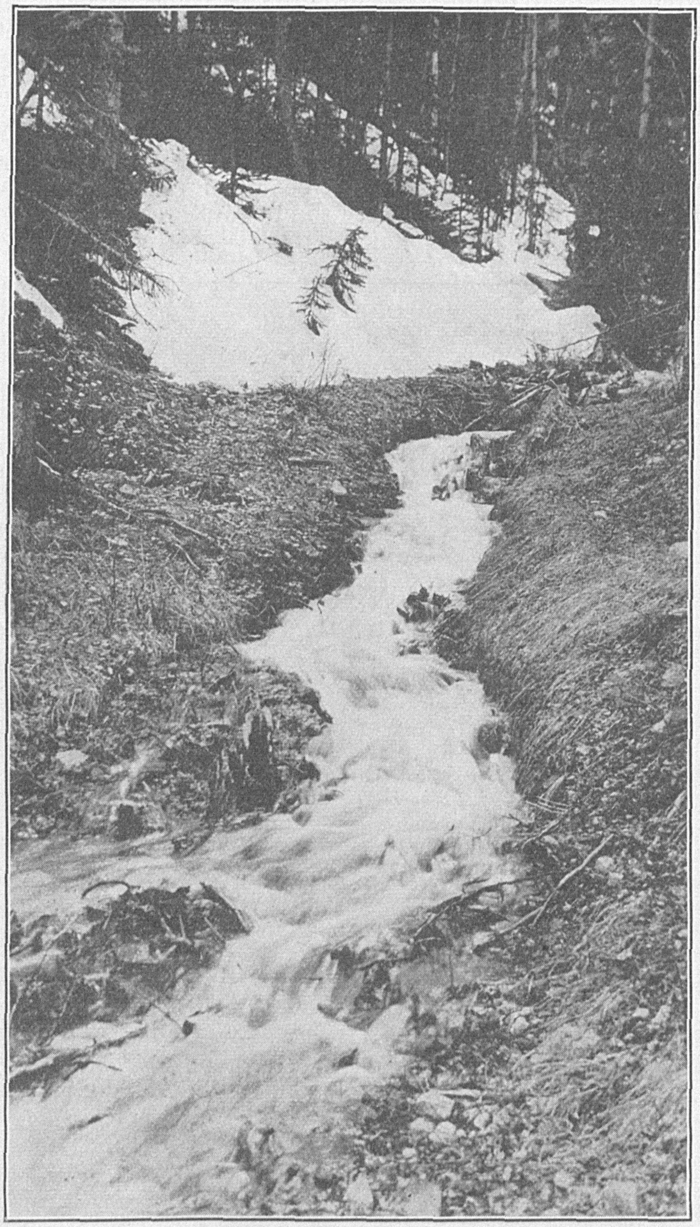


FIG. 42. Stream A in flood stage in 1920

It is seen, then, that in the first period the yearly amounts for B were only 82 per cent of those for A, while in the second period, the amounts for A now being somewhat smaller (in spite of slightly greater run off), the amounts for B were seven times as large. Taking these figures at face value, it is evident that B increased, relatively, about nine times. This, however, is slightly too high a value for the conditions existing in the second period. If reference is made to Figure 40—which is inserted here to show the general relationship of the silt deposits before denudation, rather than for any precise computing value—it will be seen that with smaller deposits by A the tendency should have been for those of B to be more nearly equal, had the conditions remained unchanged. It may then be roughly computed that, for the conditions of the second period, the deposits by B should have averaged 484 pounds per year, compared with an actual of 477 pounds for A. The erosion of B, therefore, was magnified only about seven times by the denudation. The year of greatest erosion, 1924, when 7,523 pounds was taken from B, compares with 480 pounds actual for A, and 531 pounds as the most probable for B under these conditions, or one-fourteenth of the actual. That this high value came so late is doubtless due to the large size of the flood in 1924.

That the much greater quantity of silt removed from B after denudation is not entirely due to higher floods each year—though this is an important factor since the amount plainly increases rapidly with higher water stages—is attested by the fact that the summer and winter quantities were also increased. This undoubtedly denotes some loose material being brought to the stream channel, in addition to what might be considered normal scouring and deepening of the channel. But, as has been pointed out in the introductory chapter, this erosion from the slopes was practically invisible, except for one small gulley formed from a skid trail, and even the erosion from this appeared to be largely deposited upon a leveled road, without reaching the stream channel. (See fig. 41.)

Attention is invited, however, to the last three months of the experiment, which produced the largest rain of the postdenudation period, the results of which show that revegetation had not advanced to a point to prevent erosion of Watershed B. The amount of silt collected from B basin at the end of September was nearly 22 times the quantity from A, which, in fact, was below normal for the season. For the two days August 6 and 7 the rain principally responsible for these silt deposits measured 1.48 inches for A and 1.63 inches for B, watershed averages. The exceptional fall occurred between noon and 1 p. m. of the 6th, when 0.61 inches were recorded at station C and 0.29 inches at D. A larger amount doubtless fell at this time on B than on A. Stream A rose from a rate of 0.081 c. f. s. at noon to 0.200 c. f. s. at 3 p. m., while B rose from 0.067 at noon to 0.267 at 1 p. m. The importance of the first rapid downpour is shown by the fact that by 6 p. m. of the 7th both streams had dropped back nearly to their original levels although a quiet rain had fallen up to 6 a. m. of the 7th, and between 2 and 4 p. m. However, with only very light rains thereafter both streams continued to show some excess through the 16th of August, compared with their rate on the 5th.

The erosion from Watershed B before denuding was at the rate of 2.8 pounds per acre per year, and after de-

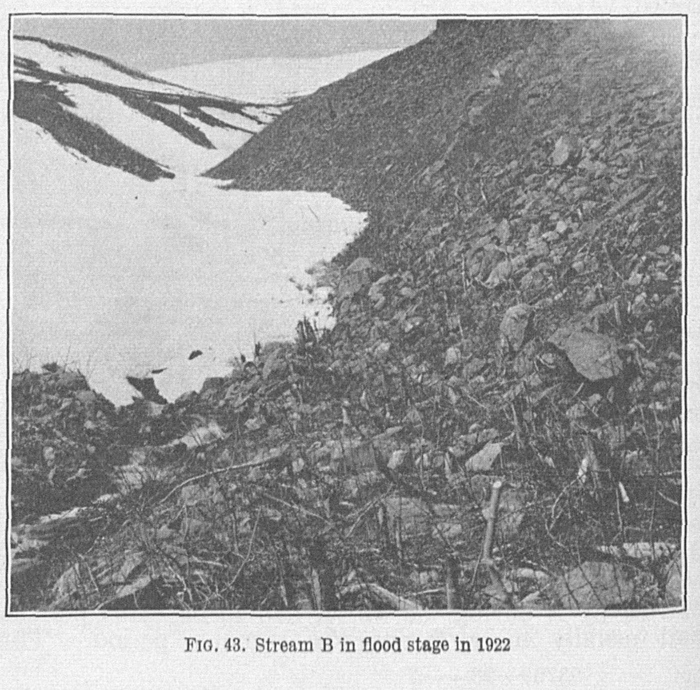


FIG. 43. Stream B in flood stage in 1922

nuding at the rate of 16.7 pounds per acre per year. It is only fair to the present discussion to point out that even this larger quantity does not represent erosion in the commonly accepted sense of a destructive process. Thus, at the Great Basin Experiment Station in Utah, where the soil is a fine clay loam from limestone and other sedimentary rocks, the erosion from 1915 to 1919 amounted to approximately 5,000 pounds per acre-year from a watershed with 40 per cent vegetative cover, and 18,000 pounds from one with a 16 per cent cover.[7] Again, in an experiment on a loam agricultural soil in Missouri,[8] a plot (one-eightieth of an acre) in blue-grass sod eroded at the rate of 563 pounds per acre-year, while one uncultivated but kept free of vegetation eroded at the rate of 69,272 pounds per year. From these data it will be readily seen that other, finer soils may be one-thousand times as erodable as those involved in the Wagon Wheel Gap experiment, even where steep slopes are not involved. It does not necessarily follow that denudation under these more mercurial conditions would have a greater proportionate effect, although that seems probable. It is merely desired point out that we are here dealing with conditions in to which the nature of the soil and rock preclude destructive erosion, and conversely, in which there is no problem of freshets caused by direct surface run off, the size and destructiveness of which is often greatly enhanced by the loads of silt which they carry.

[7] Report by C. L. Forsling. Relation of Herbaceous Vegetation to Surface Run-off and Erosion. U. S. F. S. 1925. Unpublished at this writing.
[8] Mo. Agr. Exp. Station, Research Bulletin 63 by F. L. Duley and M. F. Miller, 1923.

CHAPTER IV. SUMMARY AND CONCLUSIONS

SUMMARY

CONDITIONS OF EXPERIMENT

1. This experiment deals with streamflow from two mountain watersheds of about 200 acres each, located on the drainage of the Rio Grande in southern Colorado. Their elevations are between 9,000 and 11,000 feet, whereas the areas in Colorado producing living streams extend mainly from 8,000 to the highest peaks, some of which are 14,000 feet in altitude. These watersheds therefore should be average or only slightly below in water-yielding capacity.

2. The geological formation of the locality, a quartz-latite flow of great uniformity over the two watersheds, and the coarse, sandy soil derived therefrom, containing and covered by many small rock fragments, were conducive to a very high degree of absorption of rain and snow water. Hence there appeared very little surface run-off at any stage of the experiment, and the quantities of soil eroded were of extremely small magnitude. Only the coarse granitic soils occurring in portions of Colorado would be likely to show greater absorptive and storage capacities than the soils of these watersheds; the igneous formations, in general, produce somewhat finer soils; the sedimentaries of the high plateaus of southern Colorado and of the foothills of both the eastern and western slopes might be expected to absorb water less readily and to be much more erodable. It is, therefore, evident that a very conservative basis was selected for demonstrating the possible effects of forest removal on streamflow and erosion, particularly the effects of soil disturbance and change.

3. The forest cover of both watersheds, though far lighter than the undisturbed stands at similar elevations in the Rocky Mountain region, was fairly typical of the region as a whole, it having been heavily visited by fires. The original forest was mainly Douglas fir at the lower and Engelman spruce at the higher elevations. These areas were burned over about 35 years ago, watershed B (the one which was denuded in the experiment) having been burned somewhat more extensively than A. The burned areas had come back largely to a scrubby growth of aspen, which, while forming dense thickets and thereby protecting the soil adequately, is obviously less effective than conifers as a shade to retard the melting of snow. Consequently any effect on snow melting from the removal of such a cover would be moderate in comparison with the effect of removing a complete canopy formed by evergreens.

4. Stream flow and the meteorological conditions of both watersheds were recorded continuously from late in 1910 until October 1, 1926, triangular-notch wiers and Friez automatic water-stage recorders being employed to assure the greatest possible precision in the measurements of streamflow.

October 1 was taken as the starting point for the streamflow year, and the data both of stream flow and precipitation have been summarized accordingly from October 1, 1911, for the eight years before denudation of B and the seven years subsequent thereto.

So far as known, this experiment differs from any other experiment of a like nature ever made in that streamflow measurements were maintained throughout the extreme low temperature of winter, −25° F. (−31.7° C.).

5. The denudation of B watershed was started in July, 1919, but was not completed until late in 1920. About one-fifth of the total ground area was burned over and sufficiently heated to prevent the immediate sprouting of the aspen from rootstocks. Elsewhere the vegetation and soil were little affected and a feeble growth of aspen started almost immediately over most of the area. At the end of 1926 this had reached an average height of 4 feet, but conifers were, of course, lacking.

GENERAL CLIMATIC CONDITIONS

6. The outstanding characteristics of climate and streamflow established during the first eight years of the experiment were as follows:

(*a*) A mean annual temperature of about 34° F.

(*b*) A mean annual precipitation of about 21 inches.

(*c*) Precipitation about half snow and half rain. Except on the south slopes there is practically no melting throughout the winter until after March 1. About one-half of the total annual precipitation is released during the melting period, which ordinarily does not end until about June 1. More than 55 per cent of the total annual run-off appears during the flood stage, the average time of which is from March 30 to June 30, under the arbitrary limitations set for it.

(*d*) Owing to differences in conformation and underground conditions of the two watersheds, B is a more effective storage reservoir than A, and consequently its stream neither reaches a peak of flow quite so soon as that of A, nor drains out the excess from the spring flood and storage so soon. The lag during the rise of the flood seems to be further accentuated by the fact that the orientation and other features of B do not permit the early season insolation to be as effective as on A in melting the snow, especially near the stream channel. The importance of this is that the constant lag of B makes difficult the direct comparison of the height of the two streams at any given time. It is apparent from the ratios of run-off to current precipitation that B carries over from one year to the next a greater quantity of ground water than is carried over by A.

(*e*) As much as 42 per cent of the current year's precipitation may appear as run-off when the precipitation is sufficient and snow-melting conditions are favorable and as little as 17 per cent in years of low precipitation and unfavorable climatic conditions.

The losses of water by evaporation remain fairly constant at about 15 inches per annum, although by reason of the hold-over water from one year to another an accurate determination of this point is impracticable.

CLIMATIC COMPARISON OF TWO PERIODS

7. The mean annual temperature of watershed A as deduced from hourly readings for both periods was identical; considering monthly means, however, there

were material differences in several months, thus April, October, and November were colder in the second period than in the first and December was warmer.

The mean annual temperature of B watershed was 0.2° colder than A during the first period and 1.1° warmer during the second; apparently the effect of denudation of B was to increase the annual mean by 1.3°.

8. The mean annual maximum temperature of B in the second period was 2.5° higher than in the first period, and that of A in the second period was 0.4° higher; therefore the net increase in B maximum due to denudation was 2.1°.

9. The mean annual minimum of B watershed after denudation was 0.4° higher than before, whereas that of A watershed was 0.3° lower; the total increase in B minimum attributable to denudation was, therefore, 0.7°.

Summing the increases in both maximum and minimum gives 2.8° and dividing by two gives 1.4° as the total increase in the annual mean temperature, or one-tenth of a degree greater than was obtained by using means deduced from hourly readings.

10. Judging from the record of the A watershed the second period was the less windy of the two. The average velocity for A was 2.2 m. p. h. in the first period and 1.9 m. p. h. in the second period, or a drop of 0.3 m. p. h. The average velocity for the B watershed in the first period was 1.0 m. p. h., and in the second 3.3 m. p. h., an apparent increase due to denudation of 2.3 m. p. h.; but since according to the A record the first period was more windy than the second by 0.3 m. p. h., the corrected velocity for the second period should be 3.6 m. p. h., an increase of about 260 per cent. This result is, however, of strictly local application.

11. Snow melting at all stages was undoubtedly advanced on B as a result of denudation. Judging from the dates of disappearance of accumulated snow from the several snow scales, the average date of snow melting on B watershed has been advanced four days, using A for both periods as a basis of comparison.

12. The mean relative humidity as measured at 9 a. m. at the north slope stations was before denudation slightly greater for B than for A. After denudation most of this difference disappeared. The effect then was to make the atmosphere over B relatively somewhat drier. It is very doubtful whether the difference between B and A at either stage was significant of aything more than slightly different local conditions under which the psychrometers were exposed, of such a nature that observations at another hour might have reversed the relative positions.

EFFECTS OF DENUDATION ON STREAM FLOW

13. In the predenudation years the average annual precipitation on watershed A was 21.03 inches; the average run-off of A was 6.08 inches and that of B was 6.18 inches.

In the postdenudation period the average precipitation was 21.16 inches, the flow of A 6.20 inches and that of B 7.26 inches. These figures indicate an excess flow from B of about 0.96 inch for the average of seven postdenudation years. The greatest excess was doubtless piled up in the third year and amounted to nearly 2 inches while in the sixth and seventh years it had dwindled to a little more than one-half inch.

VOLUME AND HEIGHT OF FLOODS

14. The greater portion of the excess discharge resulting from denudation occurs in the spring flood and in the earlier part of that flood. Comparisons of the natural flood periods of both streams show that prior to denudation A discharged an average of 3.44 inches and B 3.39 inches in this period. After denudation, A discharged 3.51 inches in the three months of flood, and B 4.25 inches, an apparent increase of 0.79 inch. The distribution of these excesses by years was essentially the same as that of the whole excesses, the third year having an excess of about 1.53 inches.

Treating the floods as covering the period March 1 to July 10 of each year, gives a perhaps more reliable basis for comparison and shows the average excess for B to have been 0.80 inch, or possibly as much as 0.84 inch if factors affecting both streams in the second period be given proper weight. Of the obvious amount, 0.61 inch of 76 per cent is chargeable to the period before May 15, when A stream usually crests, and all has been delivered by June 10.

15. The period of rise from the earliest melting to the crest of the spring flood is perhaps more susceptible to close analysis than any other, because at this time the trends of the two streams are in the same direction; there is little confusion of influences. In the predenudation period B always appeared less susceptible to early melting influences than A and lagged behind from the time the rise of A became rapid and until after the crest of A. In the second period the rise of B was always ahead of A, the beginning having been advanced about 12 days. The volumes discharged up to and including the crest day for A were, in the first period 1.29 inches for A and 1.07 inches for B. In the second period the corresponding quantities were 1.74 and 2.20 inches, the average crest-day being somewhat later in this period. The excess discharge of B during the rise, as a result of denudation, reached a maximum of 1.23 inches in the second year. This occurrence was to be expected as a result of the burning in the fall of the first year. Later the charcoal spots became covered in some degree by vegetation and probably were less effective in hastening melting.

16. The crests of the floods on B were advanced only about three days by the tendency toward earlier melting after denudation, because the crests are usually brought about by, and occur very quickly after, a few exceptionally warm days. The time is usually late enough so that both watersheds are equally affected by the high temperatures. The height of the B crests, formerly averaging only 6 per cent greater than those of A were, however, increased by denudation so that their average excess over those of A was 64 per cent. One crest of B before denudation, that of 1912, exceeded the A crest by 33 per cent. In 1922 crest of B, though not quite so high as 1912, exceeded that of A by 85 per cent. These differences, perhaps more than any others, explain the increased erosion of B watershed after denuding and are characteristic of the extreme effects in the flood stage that are commonly ascribed to forest removal.

17. Except in the second year after denudation when the early flood on B was so much heavier than that on A, there is no indication of appreciable shortages during the declining periods of the floods. The average excess, however, at this time is only 0.12 to 0.19 inch, depending on the use of the "technical" or "arbitrary" flood calculation.

STREAM FLOW DEPENDENT ON STORAGE

The average summer flow of A, July 10 to September 30, inclusive, was 0.90 inch before denudation and 0.90 inch afterwards. That of B was 0.82 inch in the first period and 0.91 in the second, a gain of 0.09 inch. Analysis of the causes of variations in the summer flow of B stream for different years indicates that size of the spring flood is the most important factor, lateness of the flood has a slight effect, and current precipitation enters in to the extent of approximately 34 per cent of the predenudation flow.

Because of somewhat larger floods on A in the second period, the average summer flow of B should have been probably nearly 0.83 inch. There was thus an excess of about 0.08 inch in the average year, using the flood discharge of A as the criterion.

The distribution is irregular, but the first year after denuding apparently produced the least excess as might have been expected from the incompleteness of the denudation and the lack, at that time, of any accumulated ground water to sustain the flow.

It is well to point out that the slight summer excesses do not necessarily mean a saving of water during the summer period, as is likely to be the first impression. The volume of summer flow is nearly two-thirds dependent on the water placed in storage during the flood stage. Considering the size of the spring floods on B, an excess summer flow of about 0.09 inch on the average might have been expected. Since only this expected flow was delivered, it is more than ever evident that decreased transpiration following denudation was counterbalanced by increase in evaporation from ground surface and from such vegetation as took the place of trees.

19. The fall and winter period, October to February, inclusive, is essentially a period of storage of precipitation and draining out of deeper ground water, since precipitation occurs principally as snow.

There is usually some melting in March, and on B after denudation, nearly always enough to bring the stream up to flood stage about the end of that month. Such melting as occurs on the south exposures throughout the winter must largely be lost by immediate evaporation or may to some extent augment ground water in areas which are mostly too dry to contribute to winter stream flow, because the streams show only occasional slight rises, and in general decline to the middle of February. Possibly as much as 25 per cent of the annual precipitation evaporates during the cold weather, October to February, inclusive, or at least before the snow has all melted.

In the predenudation period the discharge of A averaged 1.40 inches for the period of 5 months and of B 1.59 inches, or, exclusive of the fall flood year (1911–12), 1.28 and 1.47 inches, respectively. The second period seems to have been essentially comparable in winter conditions, although the average December temperatures were appreciably higher in the second period. This, and probably the larger amount of storage water still held over, may account for slightly higher discharge of A, 1.38 inches when compared with the last seven years of the predenudation period; that of B was 1.63 inches. There is thus indicated a gain of 0.06 inch in discharge of B, but analysis shows that the rates earlier in the year might have produced a winter flow from B of about 1.61 inches, so that only 0.02 inch remains as the apparent excess.

20. The slight excess discharge of B during the winter, resulting from denudation, seems not to be accounted for by more effective snow melting, though this undoubtedly occurred to some extent, affecting principally the upper layers of the soil. In the first period, exclusive of 1911–12, B showed an average ratio to A of 1.06 in October, and this climbed steadily to 1.22 in February, indicating that B was being held up more than A by current melting. But it is probable that this steady relative rise reflects only the greater storage capacity of B, in other words, the more complete draining out of A. In the second period, B was absolutely and relatively higher than A in October, the ratio being then 1.15 and this ratio again climbed to 1.22 in February. Furthermore, comparison of the minima reached in February indicates that both streams remained higher in the second period, but B relatively no higher than A. The difference, then, must be due entirely to the higher stage of B throughout the flood and summer stages preceding.

CAUSES OF INCREASED STREAM FLOW

21. The discharge of B, even more markedly than stream A, is kept up after the end of the flood by water probably traceable back to the snowfall of the previous winter. The annual excess flow from B after denudation was nearly 0.96 inch. About 0.68 inch of this excess comes down before the crest of the flood, 0.12 during the decline of the flood, 0.09 in the summer months, and nearly 0.07 inch in the five winter months. If it be said that all of the excess discharge after the flood period is due to decreased transpiration during summer—which plainly is not the case—there is still left the larger part of the total, or about 0.80 inch, which appears as excess during the flood, and most of which can be accounted for only as a saving during the winter accumulation period. Both lack of interception by tree crowns, and a slightly earlier melting in spring, reducing the loss by evaporation, probably contribute to this end. Advancing the melting period in the spring by as much as 10 days may reduce the opportunity for evaporation, which amounts, on the average, to nearly one-half inch for every 10 days of the year, and must be especially great when melting is prolonged and the ground remains saturated well into summer. Another change effected by denudation is to permit the snow to fall more evenly and with less exposed surface—except as it forms drifts—to melt, settle, and crust, and to be less subject to moving about by winter winds. It would seem, however, that the advantages gained in this way would be more than balanced by the greater exposure of the snow to insolation.

The fact that the order of magnitude of the streamflow excesses during the second period is, except in the first year after the beginning of denudation, the same as that for the amounts of snowfall, makes it appear altogether probable that interception by tree crowns, which was practically eliminated by denudation, is a large factor in evaporation losses during the winter. The amount of such losses would, however, vary with the amount and character of the snow, particularly its wetness, and with the character and density of the tree cover. The savings from 1919 to 1926 were probably abnormally high for the locality of this study, since the snowfall of this period was above the average, but were undoubtedly less than might be expected from the removal of a full coniferous stand.

EROSION AND SILT DEPOSITION GREATLY INCREASED

22. A very important consideration, of course, is that this excess of water flows down the gulch at such time, and in such volume, that it can not be used even in a region in which irrigation is extensively practiced, except by artificial impounding.

Even this appears unattractive when erosion and silting are given proper weight, for engineers are beginning to realize that artificial reservoirs are of short-lived value unless silting can be controlled.

During the predenudation period the average annual silt load carried to the dam by stream A was 691.5 pounds, net dry weight, and that carried by B was 568.5 pounds. In the second period A carried an average amount of 477 and B 3,340.1 pounds. The ratio B/A therefore increased from 0.822 to 7.002, or was about eight and one-half times as high after denudation.

23. Most of the larger quantities of silt were obtained in the July cleanings of the basins, covering flood periods after April 15. The ratio of B to A for this quarter before denudation was 0.75 and after denudation 9.12. An increase of about 50 per cent in the average height of B flood crests, together with any direct effects of denudation on the soil, are seen, therefore, to have magnified the silt load of the stream twelve times.

24. Before denudation, one large flood from rain occurred in October, 1911. The silt measurement for 12 months, ending in July, 1912, shows 1,246 pounds of silt from A and 788 from B. In August, 1926, a rain which was far less effective on stream flow, though causing some quick run-off, produced for this quarter only 50 pounds of silt from A and 1,073 from B, the normal ratio for this season being about 1:1.7. The extreme danger of greatly increasing erosion by the disturbances which accompany denudation is thus apparent. And, while all of the silt quantities obtained from these areas are but a tiny fraction of those which may be obtained from highly erodable soils, it is believed the tendencies here shown are indicative of what would obtain under other conditions.

RECAPITULATION

The proportion of the annual precipitation appearing as run-off from year to year in the undisturbed condition of the two watersheds ranged from 17 to 42 per cent. The variations are obviously independent of forest cover and (seemingly more or less fortuitously) depend upon the depth of the snow cover, the time whether in midwinter or in the spring months, at which the bulk of the snow fell; and the occurrence of favorable melting temperatures at a critical time.

The flood run-off of watershed B before denudation was the same as that of A; after denudation of B the spring flood on that watershed increased to a peak discharge in the third year after denudation of about 35 per cent excess and then diminished until the end of the experiment when it was 22 per cent greater than that of A.

Before denudation the general discharge ratio B/A was 1.017, after denudation 1.170. The maximum ratio for a single year was that of the third year after denudation, viz, 1.284, diminishing from that figure to 1.153 at the end of the experiment; the increase in flood run-off did not result in lowered storage or lowered run-off at other seasons.

The load of silt carried before denudation by both streams was very small, after denudation the load on B stream increased say 5 to 15 fold; but even then the erosion was only a fraction of that which would have occurred under different soil conditions, other factors remaining unchanged. There was very little surface flow on B watershed outside of that largely induced by skid trails. Had there been heavy rains and surface run-off the erosion would have been greater.

The climatic conditions of the two periods were substantially the same, with the single exception that the snowfall of the second period was a little greater than that of the first. The changes in the several climatic elements which might be assigned to denudation of the B watershed have already been mentioned.

CONCLUSIONS

In the application of these results to other regions, types of soils, and conditions of climate, there will be many opportunities for differences of opinion. The publication of the basic data of this study—the daily measurements of precipitation and stream flow, Appendix I (Table 66)—will afford students and investigators the fullest opportunity to make independent analyses of the data and to draw their own conclusions. The still more detailed hourly records of stream flow, temperature, precipitation, etc., are on file in the United States Weather Bureau and will be made available under proper restrictions. Nevertheless the writers believe it an obligation to sum up the conditions which produced the results as hereinbefore set forth, and thereby to clarify, so much as may be possible, their application elsewhere by the following brief statements.

It has been pointed out that the areas in question, because of their geological origin and present character of soil, absorb water readily without appreciable surface run-off or erosion and therefore represent excellent reservoirs for the storage of the precipitation that is released in greatest abundance when snow melts in the spring. High heads were produced only when the ground had become saturated with snow water. Climatic and topographic conditions being uniform, it is evident that the height of a flood crest must vary inversely with the ability of a particular watershed to absorb and to hold great quantities of water. The absolute height of the flood crest under a given set of conditions is, therefore, an inverse measure of the value of the watershed for storage.

On the other hand, the low stage of stream flow is also an indicator of watershed conditions. At Wagon Wheel Gap, as elsewhere, the great increase in evaporation in the warm weather of summer, together with the demands of vegetation which flourishes on the abundant moisture left by the winter's snow, causes a rapid drying of the superficial soil layers, which is not relieved until the crest of the heat is passed, and vegetation has aged and waned. In most temperate climates, as in the locality of this study, the peak of demand is probably passed in the latter part of August. There is no evidence in this study that the summer demand for moisture was appreciably affected by the removal of the forest cover. Evidently surface drying proceeded in just about the same way with forest or herbaceous vegetation. Stream flow, then, is on the decline until the lessening of surface demands for moisture permits current precipitation to reach the deeper soil and add to the supply which is flowing slowly toward springs. Stream flow in the midsummer period, in the locality of this study is dependent quite largely on the storage capacity of the watershed. In other localities it may be more, or less, dependent, as the current precipitation is less, or more, adequate to meet the current demands of evaporation. In other words, the low stage of stream flow reached in later summer is in some degree a further measure of the storage capacity of the watershed, and still more clearly a measure of the need for storage capacity.

The ratio of the high stage of a stream to its low stage, as reached within these general limist of time is, therefore, a direct measure of the need for protection of the watershed as a storage reservoir. This ratio, if measured over a number of years, embodies all of the local climatic and soil factors which affect the régime of streams. The higher the ratio, the more apparent it is that everything possible should be done to lower flood crests by retarding the melting of snow in the spring or increasing the capacity of the soil to absorb quick accessions of water at any time. The higher the ratio, the more evident it is that either in spring freshets or those following heavy rains at any season, water is running off, often superficially, in a hasty, useless, and destructive manner.

The ability of any vegetative cover to assist absorption, thereby reducing surface run-off and erosion under nearly all conditions and the ability of a forest cover in particular to retard snow melting, can not be seriously questioned. On the other hand, a locality whose soil or climatic conditions are not conducive to extremes of run-off obviously does not have the need of a protecting influence in the same degree as a region or watershed whose streams are not permanent and whose freshets may yet be strong and destructive. In the absence of direct measurements of stream flow, the extent to which erosion of a watershed has occurred may be used as a basis for estimating the liability of great extremes of run-off.

On the watershed denuded in the present study the original ratio of high to low stages was about 12 to 1 and this was increased only to 17 to 1 by denudation. The high stages were made much higher and the low stages were made slightly higher. In other words, though the snow water was made available earlier and in more concentrated volume, the watershed was still capable of absorbing it after denudation and of retaining for discharge throughout the year a greater volume than before, although the amount retained was not increased in proportion to the flood volumes. It is obvious that the storage water could not have been increased even to this extent if these watersheds showed any markedly ncreased tendency to yield surface run-off after denudation. Any flood excess of water that does not go into the storage reservoir, can have no effect on the low water flow from that reservoir. A further factor tending to reduce the low water flow will be the advance in the time when the maximum storage is attained.

It is therefore proposed that the ratio of high to low stages indicates the liability of failure of the watershed to exercise its full storage function and hence the need for protective influences which will cause that function to be exercised to the fullest possible extent, with the *probability* that so far as spring storage is increased summer flow will be increased, and will not be appreciably decreased by the growing-season drain of the forest cover.

From the evidence of this study it is estimated that in a locality where the normal ratio of high to low stages is more than 25 to 1 with a moderate protective cover, the probabilities are strong that the low stages would be made still lower by removing that protection. The very great possible latitude in this ratio is illustrated by the stream flow records published by the water resources branch of the United States Geological Survey, which show for streams much larger than those here dealt with (and whose extremes are, therefore, subject to more compensating factors) ratios commonly as high as 50 to 1 and occasionally as high as 150 to 1 or even higher. These ratios indicate the infinite possibilities for variation in the climatic and soil factors affecting absorption and retention by watersheds and the need for careful inductive reasoning in the attempt to relate even qualitatively the results derived from one set of conditions to those which might be given by another set of conditions.

APPENDIX

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*[1]

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1911-12																								
1	26	28	1470	1239	21	21	1786	1698			1298	1245			1030	1093			964	1057	27	30	888	1033
2	2	4	1157	1156	T.	T.	1781	1684			1290	1238			1046	1091			969	1062	14	14	898	1040
3		T.	1083	1108			1725	1649			1273	1235			1038	1086			960	1069	4	4	915	1049
4	76	72	1153	1147			1706	1623			1264	1228			1036	1093			952	1069	24	24	923	1047
5	254	274	6340	4725	5	6	1711	1601			1271	1235			1048	1093			952	1069		T.	1022	1061
6	T.	T.	6161	5025			1669	1587			1262	1224			1038	1097			948	1069	20	19	1087	1075
7			6448	5193			1643	1560	4	4	1259	1222	14	13	1042	1105			944	1069	10	12	1006	1075
8			5821	6285	14	14	1654	1566			1233	1210			1048	1105			932	1063	4	4	967	1074
9			4924	6958	16	14	1626	1542			1234	1200	T.	T.	1038	1105			927	1073	1	1	947	1060
10			4252	6502	13	12	1596	1530			1239	1200			1030	1105	T.	T.	931	1072	44	44	931	1080
11			3786	5772	25	30	1584	1519			1221	1187	T.	T.	1027	1093			931	1069			912	1074
12			3454	5012			1526	1477			1219	1174			1016	1093	1	1	931	1069	5	5	905	1062
13			3197	4442	T.		1550	1479	2	2	1216	1161			1009	1098			916	1069	48	50	902	1074
14			3022	3973			1544	1460			1191	1143			1010	1107			915	1067			911	1055
15			2856	3584			1523	1429			1177	1140			1005	1105	T.	T.	920	1057			909	1055
16			2729	3247	1	1	1519	1420			1177	1140	11	10	1016	1105	4	2	914	1055	5	4	911	1054
17			2628	3022			1482	1404	8	8	1166	1140	11	11	1009	1103			917	1045			928	1051
18			2519	2815			1470	1388	88	85	1177	1144			995	1093	3	4	932	1055			1070	1063
19			2441	2645			1465	1366	4	4	1166	1154			995	1095	T.		924	1055	34	34	1035	1079
20	T.	T.	2358	2499			1443	1354			1150	1164			981	1079			909	1045	18	18	981	1111
21	2	2	2286	2360			1437	1354			1130	1164			964	1072			899	1043	2	3	983	1107
22			2210	2273	8	10	1420	1354			1123	1163			966	1062			899	1040	18	18	1057	1145
23			2142	2174			1389	1330			1123	1152			991	1057	2	2	899	1045	2	2	1053	1129
24			2105	2092			1370	1307	9	8	1123	1150			986	1057	20	14	899	1045			1068	1114
25			2045	2022			1360	1295	16	14	1123	1140			981	1057	17	11	901	1043			1099	1116
26	24	24	1990	1960	T.	T.	1358	1301	T.	1	1112	1124			981	1059			891	1050	2	2	1120	1141
27	34	38	1971	1908	10	9	1346	1294			1104	1105	T.	T.	984	1075			877	1046	2	2	1085	1133
28			1945	1873			1324	1271			1111	1105			984	1081			877	1048			1042	1144
29	23	24	1925	1853			1306	1257	22	21	1102	1105			973	1075			870	1036			1071	1158
30			1885	1804			1303	1250			1106	1105			966	1069					7	6	1086	1162
31			1822	1768							1078	1103			974	1060					14	12	1048	1151
1912-13																								
1	8	7	1093	1168			1041	1216			932	1118	6	6	929	1047	1	1	874	1059			781	1024
2	10	10	1109	1191			1030	1208	T.	T.	948	1121			920	1048	11	10	866	1057			788	1016
3	T.	T.	1104	1205	1	1	1059	1216			941	1122			920	1068			855	1061			799	1026
4	13	13	1123	1202			1043	1199	13	10	949	1122	8	6	923	1074			837	1049			819	1017
5	35	37	1178	1268	T.	T.	1037	1178	31	30	957	1116	54	44	929	1072			798	1039			842	1013
6	20	20	1173	1290			1022	1188			952	1109	2	2	920	1072			802	1039	4	4	829	1015
7	2	2	1219	1268			1024	1196			941	1109			896	1071			813	1039	4	4	825	1019
8	4	4	1150	1258			1022	1190			941	1108			892	1058	T.	T.	824	1033	T.	T.	834	1019
9	24	25	1100	1237			1029	1188	2	3	949	1109	1	1	903	1061	T.	T.	803	1033			851	1020
10	24	26	1133	1254			1027	1189			936	1105	26	28	909	1073	1	T.	806	1025			855	1033
11			1125	1262	38	36	1027	1212			921	1105			901	1067	T.	1	813	1026	10	10	872	1021
12			1095	1252			1023	1205			931	1094			888	1059			802	1021	23	26	866	1026
13			1049	1240			1012	1189			920	1105			888	1047			794	1025	4	4	854	1020
14			1040	1217			1002	1177			920	1094			888	1050			779	1021			841	1008
15			1055	1206			1000	1176	4	4	925	1099			888	1046			781	1023			824	1002
16			1055	1211			990	1164	9	8	937	1105	12	12	898	1051			781	1024			824	989
17			1057	1200			988	1164	5	4	909	1109	T.	T.	899	1048			787	1027			835	993
18			1052	1200			965	1158			898	1105			899	1012	11	11	797	1050	5	6	852	1000
19	4	6	1063	1210			963	1154			890	1104			896	1071	15	12	802	1038	3	3	870	1018
20	4	4	1059	1212			975	1157			898	1091			897	1078	34	34	804	1031	4	4	875	1012
21	4	5	1080	1218			984	1155	4	4	894	1081			888	1069	1	2	780	1024	1	1	850	1021
22			1042	1189			1003	1142	1	1	897	1080			899	1072	10	10	812	1026	6	6	899	1049
23			1050	1188			1013	1140			885	1067			888	1070			810	1026	50	52	911	1041
24			1046	1177			1006	1140			901	1066			888	1075	2	2	803	1021	20	27	888	1020
25			1034	1165			986	1134	2	4	909	1073			888	1077	10	10	804	1021	6	8	869	1011
26			1042	1173			968	1140			906	1061			888	1062	6	5	824	1028			865	1004
27	54	54	1198	1274			953	1130			905	1047			888	1044	8	10	812	1025			869	1014
28	3	3	1223	1305			941	1120			911	1049			886	1051			800	1025			936	1043
29			1066	1271			941	1109			935	1058			881	1052							1131	1111
30	43	43	1064	1246	5	7	941	1116	1	1	932	1079			878	1064							1474	1264
31	1	1	1048	1222					T.	T.	922	1053	1	T.	871	1067							1948	1409
1913-14																								
1	18	18	1054	1057	T.	T.	866	962	60	56	823	938	14	12	781	915	T.	T.	761	898			822	891
2	13	14	989	1042	16	15	861	966	3	4	817	934			788	915			770	894	39	36	838	907
3	24	27	1119	1095	62	58	875	984	60	58	822	938	10	10	792	920			770	884			821	904
4	4	6	1014	1075			870	981	61	58	837	950			782	915			774	893			800	902
5	8	10	980	1051			866	980	T.	T.	848	965			781	909	6	6	781	898	T.	T.	809	904
6			970	1036			869	971			826	941			781	906	3	2	778	893			802	901
7			949	1020			877	980			814	938			781	907			768	890			809	905
8			948	995			863	973			823	938			782	918			759	878			820	911
9	20	19	937	998			856	967			819	938	2	2	789	906			759	873			841	916
10			943	996			844	968			812	931			779	901			764	873	2	1	840	929
11			936	987			839	962			796	925			770	899			777	877	1	1	835	935
12			940	989	10	10	858	964			800	920			770	903	5	4	778	883			838	930
13			950	986	33	35	866	980			794	919			770	900			759	875			841	931
14			933	986	T.	T.	866	983			802	921			772	903			753	872			856	941
15			915	986			845	983			792	922			781	903			755	867			875	944
16	6	7	934	984			832	970	3	4	812	932	18	18	781	903			767	867			904	966
17			934	982			848	963	2	1	813	938	6	6	781	903			779	873			943	1000
18			901	974			850	968	40	38	814	938			781	909	T.	T.	774	885			941	1019
19	T.	T.	902	974	8	7	860	980			818	934	6	5	781	910	2	2	772	874			927	1033
20			899	974	32	28	878	989			802	916			781	903			781	887			903	1010

[1] For monthly totals of precipitation see Tables 36 and 37, and for monthly totals of run-off see Tables 51 and 52.

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1912																								
1			1024	1140			4512	3280			6272	6379	3	4	2202	1906	6	6	1576	1438			1128	1123
2			1067	1162			5132	3746			5854	5839	T.	T.	2148	1845			1529	1372			1095	1107
3			1256	1229	5	6	4499	4041			5447	5411	6	8	2096	1800			1484	1336			1086	1077
4	T.	T.	1391	1307		T.	3680	4067			5084	4990	10	10	2131	1800	10	8	1480	1319	8	8	1085	1083
5	10	8	1303	1322			3450	3965			4801	4622			2038	1763	2	2	1476	1311			1042	1061
6			1347	1373			3876	3855	T.	T.	4542	4313			1977	1712	1	1	1447	1298			1042	1042
7			1499	1449			5386	3969	26	27	4435	4111			1925	1659			1411	1267			1035	1038
8			1463	1487		T.	8196	4442	1	1	4168	3865			1854	1618			1367	1254	2	3	1042	1045
9			1677	1559	14	11	9227	5067	6	6	3977	3650			1807	1581	13	10	1342	1232	2	4	1067	1062
10	3	2	1851	1599			7309	5697			3770	3474	1	1	1770	1542			1313	1209	1	1	1080	1087
11	22	23	1879	1653			7561	6070	2	1	3612	3313	2	1	1771	1515	1	T.	1295	1192	25	20	1134	1116
12	30	32	1755	1701			10510	6384	3	3	3483	3184	19	22	1748	1530	2	2	1320	1199	T.		1079	1119
13			1629	1646			10983	6929	T.	T.	3353	3068	4	4	1697	1519	24	23	1384	1237	T.		1059	1104
14			1530	1602	14	14	9750	7218		T.	3233	2978	16	18	1702	1521	50	48	1634	1360	2	2	1067	1110
15	3	2	1428	1562			8910	7115			3122	2858	36	38	1786	1584	22	26	1496	1372			1067	1112
16	1	1	1439	1620			9365	7372			3006	2737	20	18	1754	1536	T.	T.	1420	1338			1054	1101
17	6	6	1399	1681			13349	8282	24	27	3038	2676	7	4	1680	1509	9	10	1420	1341			1060	1118
18	8	8	1370	1677			16534	10695	1	1	2901	2584	12	16	1659	1506	T.		1362	1307			1071	1124
19	34	32	1360	1684			17458	14571			2790	2474	16	15	1672	1485	6	2	1350	1276			1072	1135
20	18	18	1355	1704			17566	17344			2684	2376			1581	1435	2	2	1317	1255			1057	1141
21	1	1	1307	1686			17099	21685	T.	T.	2614	2291	30	32	1602	1429			1272	1224			1063	1144
22			1272	1669			15956	23351	54	62	2742	2351	20	13	1647	1450			1224	1193			1091	1164
23			1359	1682			14077	21422	3	4	2628	2274	20	18	1653	1457			1196	1154			1094	1164
24			1645	1826			12051	18069	15	12	2503	2203	32	41	1780	1536			1173	1134	3	4	1096	1173
25	2	2	1564	1950			10538	15261	1	1	2426	2112	T.	2	1658	1501			1151	1116	T.		1082	1164
26			1612	2012			9510	13261	29	22	2413	2078	76	90	2045	1726		T.	1108	1099			1091	1164
27	16	19	1609	2060			8806	11689	16	9	2444	2036	16	18	1899	1734		T.	1143	1105			1096	1164
28			1800	2168			8216	10133	4	4	2314	1967	14	15	1744	1664	2	2	1145	1104			1094	1153
29			1994	2381			7658	8900	34	33	2462	2008	48	35	2036	1659	4	4	1135	1110	T.	1	1091	1154
30			2857	2783	1	2	7236	7902	1	1	2323	1957	T.	5	1888	1615	23	24	1203	1155			1106	1164
31							6724	7045							1674	1527	1	1	1161	1142				
1913																								
1	T.	T.	1935	1416			3605	3375	T.	T.	1916	2183			1448	1649	T.	T.	902	923	22	30	801	863
2	16	18	1513	1371			3480	3601			1894	2142			1384	1595			886	909	4	8	836	888
3	T.	T.	1322	1307	2	2	3328	3763			1870	2109			1335	1535			858	882	15	23	834	904
4			1554	1262			3226	3813	T.	1	1851	2065			1291	1470			818	871	20	14	851	900
5			2037	1330			3144	3727	T.	T.	1826	2023	T.	T.	1261	1388	4	4	821	876	T.	T.	841	887
6	T.	1	[2] 2455	1406	T.		3022	3599	T.	T.	1805	1979	2	2	1267	1365	1	1	824	834	T.	T.	799	862
7	11	11	2402	1402	T.	T.	2954	3533	52	53	1949	2037	6	12	1249	1362	T.	T.	807	831	12	14	800	862
8	20	23	1997	1368	8	9	2931	3521	24	24	1995	2057	2	4	1223	1330			796	820	30	30	888	908
9	T.	T.	1651	1337			2899	3603	38	45	1933	2092	1	1	1202	1294	4	4	808	830	2	4	876	904
10			1420	1293			2848	3823	62	69	2329	2385	T.	1	1166	1265	16	22	826	849	1	1	837	911
11			1374	1278			2801	3987	10	10	2401	2473			1100	1215	26	20	896	869	8	14	850	919
12			1863	1319			2775	4026	42	45	2421	2649			1070	1164	70	66	1132	1012	4	6	849	914
13			2021	1440	2	2	2744	4015			2328	2736	2	2	1034	1124	13	12	969	974			832	910
14			3906	1602	T.	T.	2709	3974			2209	2747	4	2	1025	1083	T.	T.	898	957	T.		828	890
15			3622	1657			2635	3802			2129	2745	12	12	1030	1079			837	910	4	4	824	892
16			4056	1816	T.	T.	2580	3799	T.	1	2102	2718	T.	1	1042	1077			825	875			817	886
17	1	1	3376	1891	1	T.	2514	3635	11	9	2160	2688	9	14	1033	1105	5	6	836	866			813	893
18	20	22	2992	2015			2437	3484	21	19	2197	2664	37	44	1112	1148	16	18	891	894			823	887
19			3443	2147	5	6	2389	3353	1	1	2104	2636	46	48	1203	1203	7	6	881	895			814	889
20			3530	2344			2325	3188			2002	2561	62	65	1382	1301	8	9	885	911			809	882
21	T.	T.	3452	2503			2256	3025	T.	T.	1948	2471	24	21	1280	1286	T.	T.	873	910			824	801
22	10	10	3214	2455			2193	2867	T.	T.	1874	2417	6	6	1265	1262	14	16	839	900	58	60	975	978
23		T.	2902	2262	T.		2138	2758	16	16	1856	2369	13	12	1190	1225	T.	T.	814	871	51	55	949	973
24			2665	2125	T.	T.	2099	2678			1806	2300			1117	1161	36	39	911	930		T.	934	993
25			2528	2061	T.	T.	2056	2578			1727	2178	T.	T.	1059	1098	8	8	885	909	4	4	928	991
26			2707	2230	T.	T.	2023	2505			1653	2080			1027	1063			811	896			939	1021
27			2836	2543	30	34	2144	2521	8	9	1603	1972	T.	T.	996	1024	1	1	791	855	2	4	972	1049
28			3016	2926	1	1	2071	2467	16	18	1680	1958			975	1007	1	1	794	842			1009	1045
29			3207	3056			2003	2375			1576	1837	T.	1	955	989	2	2	792	832	T.	T.	902	1017
30			3509	3235			1970	2316			1496	1724	3	3	949	969	4	6	769	835	6	6	943	993
31					T.		1942	2247					1	1	925	954	1	1	760	826				
1914																								
1			910	1060	59	60	2702	2056	18	19	4267	4447	18	18	1722	1346	3	2	1445	1103			1035	899
2			944	1085	1	1	2728	2101	9	10	4040	4073	10	8	1673	1333	T.	T.	1370	1053			989	879
3			974	1149	T.	1	2758	2181			3835	3789	6	8	1679	1333	1	2	1339	1031			973	859
4	T.	T.	1040	1239	8	6	2762	2255	2	4	3637	3541	34	32	1790	1401	4	4	1319	1011			956	841
5	T.	T.	1163	1346	4	4	3171	2417	T.	T.	3468	3319			1648	1355	T.	T.	1244	979	3	4	964	847
6	T.	T.	1345	1406	T.	T.	3779	2645	2	2	3325	3164	10	10	1577	1296			1211	954	T.	T.	961	840
7	T.	1	1449	1407			4596	3044	4	4	3202	3006	1	1	1582	1260	15	18	1251	964			933	831
8	7	4	1432	1357			5577	3601	T.	T.	3053	2858	T.	T.	1545	1234	16	14	1296	976			919	833
9			1410	1301			6557	4079			2898	2700	5	4	1486	1182			1231	952	10	10	956	872
10	16	16	1348	1285			7269	4640			2795	2577	T.	T.	1471	1166	T.	T.	1200	951	T.	T.	964	859
11	16	17	1297	1296	T.	T.	7270	5512			2708	2462	T.	1	1432	1130			1170	926	4	4	975	875
12			1303	1303	T.	T.	6960	6413	T.	1	2612	2351	26	26	1468	1145			1118	898	32	29	1053	915
13			1389	1373			6583	6712			2504	2244	30	20	1563	1168	T.	T.	1092	873	44	42	1283	1053
14			1654	1509	68	59	6623	6807	T.	T.	2458	2131	14	17	1491	1164	T.	T.	1073	859	15	15	1129	996
15	T.	T.	1927	1565	T.	T.	6944	7992	70	74	2668	2221	22	18	1515	1184	3	2	1052	848			1063	975
16	2	2	2112	1564	T.	T.	6521	8586	7	7	2464	2147	07	08	1459	1156	29	30	1109	868			1042	951
17	4	4	1952	1551	2	1	6445	8533			2331	2041	102	96	2011	1353	4	3	1101	870			1023	942
18			1790	1542	8	6	6241	8330		T.	2232	1939	28	24	1962	1343	36	28	1164	899			1011	936
19			1896	1614	T.	T.	5857	8085	T.	T.	2174	1851	28	25	1906	1381	T.	T.	1101	887			1019	945
20	T.	T.	2138	1697	4	3	5487	7777			2115	1783	T.	T.	1678	1279	26	24	1146	922	27	26	1048	965

[2] Break in Dam A discovered and certain record begun.

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1913-14

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
21			893	965	T.	T.	866	986			802	928			765	903	39	38	799	902			877	987
22			889	962			835	971			793	919	8	8	770	903	12	12	796	903			854	983
23			877	962			819	943	4	4	796	919			770	903			774	895	T.	T.	866	984
24			875	961	20	20	829	948			785	917	7	6	771	898			761	878	23	22	883	1001
25			873	951			846	938	4	4	782	909	8	8	781	891	T.	T.	761	868			894	991
26			851	944			836	938	5	4	792	921	37	36	781	904			768	867			919	1022
27	T.	T.	851	952			825	938			784	915	94	88	781	913			761	872			961	1084
28			866	950	2	2	822	938			781	920	12	18	783	903			800	883	T.	T.	954	1108
29			848	950			813	939			781	917			781	901					8	8	965	1105
30	T.	T.	856	950	6	6	813	934	T.	1	781	912			775	895					3	4	942	1077
31	T.	T.	861	950					T.	T.	781	909			776	892							897	1048

1914-15

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	3	4	993	963			886	987	4	3	658	940			872	974			834	922	5	4	761	912
2	15	16	1009	977			877	991	2	2	711	945			850	972	14	14	834	913			759	906
3	75	76	1125	1066			867	986			754	942			836	970	44	43	847	926	2	1	759	903
4	1	1	1235	1099			854	986			836	929			848	986	T.	T.	834	927	T.	T.	749	901
5			1030	1049			846	984			796	915	6	6	866	986			811	938			748	881
6			1024	1014			836	984	10	8	800	918			864	983			788	934			727	893
7	T.	T.	1019	998			838	984	4	4	824	938			866	989			781	938			729	883
8			1006	989			836	974	3	2	804	937			861	977			781	934			738	891
9	9	9	1012	999			831	970	1	T.	767	928	2	3	866	978			781	939	4	4	738	891
10			998	986			829	973			760	927			866	968			781	937	T.	T.	738	896
11			992	986			821	975	2	1	796	918			861	958	78	77	781	938	12	10	738	902
12			975	986			804	971			747	912			852	974	34	32	781	944			732	884
13	T.		972	979			818	978			681	893			837	969			780	954			729	879
14			963	972			827	983			532	850	6	4	819	967			763	957	T.	T.	735	877
15			963	972			816	986			453	832	15	14	817	974			763	935	T.	T.	747	893
16			963	984			806	984			442	830			813	969	T.	T.	770	943			756	802
17			962	986			808	980	T.	T.	468	816	T.	T.	802	955	1	T.	761	946			762	894
18			939	986			795	970	16	15	569	849			802	976			765	943	10	12	772	905
19			936	986			759	961	52	47	627	873			802	959	10	10	764	938	T.	T.	767	903
20			931	986			787	955	14	14	687	902			805	958	14	14	770	938			764	891
21	49	50	1018	1044			740	958			664	904			823	963	12	12	769	938			749	880
22	3	3	1081	1078			736	952			702	938			828	958			758	938			776	901
23	60	58	1031	1086			744	950	4	4	774	961			804	957			755	926			804	935
24	6	6	1015	1100			727	946	12	12	702	982			825	955			744	915			812	938
25			1023	1098			742	946			728	986	T.	T.	828	945	10	12	749	913	T.		838	967
26			977	1070			745	947			889	986			832	933	24	26	759	903			855	1002
27			954	1037			749	947			903	986			820	912			776	905			866	1014
28			915	1021			737	948	2	2	909	1002			809	900			767	903			841	995
29			905	1011	2	2	698	950			888	985	50	48	833	909					2	4	830	991
30			900	1004	T.	T.	685	950			876	977	14	13	834	933							830	988
31			898	991							868	981	T.	T.	834	925							822	987

1915-16

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1			906	903			834	893			760	870			722	869			686	843	20	20	706	884
2			902	903			834	889			735	867			715	867	T.	T.	685	843			689	873
3			906	903			843	891			729	867			706	867	2	2	679	849			677	857
4	6	6	900	903			837	891	3	3	756	872			706	872	3	4	685	855			704	872
5			904	903			834	891	15	15	759	892			713	867	2	2	685	852	50	46	710	880
6			902	903	36	36	852	912			759	879	9	8	717	873			677	843			706	888
7			891	899	6	6	875	932			759	879			710	867			678	851			708	891
8			878	879			845	926			742	877			706	867			685	854			825	946
9			880	880	28	29	849	923			739	867	3	3	717	868			677	846			1021	1075
10			897	894	101	106	866	938			744	867	8	8	727	884			684	849			1161	1146
11	T.	T.	888	903			845	933			741	867	22	21	727	879			694	859			1253	1149
12	T.	T.	878	903			819	906			727	867			719	870			702	859			1367	1154
13			878	903	T.	T.	831	913			713	867			710	867			702	855	3	4	1487	1208
14			888	909			824	903	4	4	728	867	8	9	706	867			703	845			1428	1229
15	18	18	901	906			821	903	46	41	754	876			706	867			714	849			1248	1174
16	12	11	944	925	T.	T.	813	903	T.	T.	745	867			706	867			739	850			1275	1180
17			944	940			813	900	T.	T.	727	867	50	51	706	863			761	852			1364	1215
18			908	927			806	897			726	865	63	65	706	867			773	861			1418	1228
19			894	922			802	893			709	855	30	30	706	876			777	857			1461	1305
20			877	911			804	901			711	846	2	5	706	867			774	852			1565	1418
21			874	910			817	902			698	855			702	860	2	3	754	855	5	6	1652	1504
22			874	903			808	904			706	855			687	850	6	6	727	860	9	8	1580	1471
23			872	903			795	903	2	2	704	861			692	855			727	857	34	32	1502	1513
24			866	903	19	17	792	903			706	865	T.	T	701	857			720	857	T.	T.	1415	1510
25			866	903			791	903	2	2	699	849	8	8	706	867			709	861			1298	1434
26			854	902			777	883	16	16	702	867	12	12	706	867	10	10	718	862			1221	1376
27			844	900	6	6	787	895			709	866	70	69	706	867	14	16	721	869	T.	T.	1191	1359
28			838	903			763	881	T.	T.	710	855	47	46	706	874	6	7	710	877	T.	T.	1218	1408
29			839	903			763	880	14	14	717	855	6	6	706	867	2	2	706	869	T.	T.	1221	1432
30			834	899	T.	T.	770	890	56	55	717	856	8	8	706	870					46	38	1215	1395
31			834	903					117	116	721	869			692	854							1190	1367

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1914

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
21	T.	T.	2397	1693	2	1	5213	7306			2040	1712	12	10	1592	1216	22	22	1180	951	2	2	1099	998
22	28	25	2355	1715	19	20	5153	6889			1981	1641	T.	T.	1507	1159	26	23	1252	988			1024	970
23	6	6	2198	1785	34	39	5336	6639			1908	1581	2	1	1444	1114	T.	T.	1145	961			1005	959
24	T.	T.	2138	1844	18	20	5705	6698			1859	1527	3	3	1455	1101	T.	1	1089	931			1006	956
25			2492	1919			5528	6702			1800	1483	53	62	1576	1214	2	2	1070	909			1011	954
26	T.	T.	2720	1908			5626	6722			1718	1423	12	11	1518	1194	12	14	1103	918	T.		996	947
27	7	6	2725	1897	4	4	5478	6623			1691	1386	10	8	1445	1162	1	T.	1074	899			993	948
28	10	10	2616	·1901	T.	T.	5205	6297			1644	1350	23	24	1477	1164	4	2	1047	886			976	957
29			2636	1996			4865	5725	T.	T.	1619	1303	6	10	1470	1172	12	14	1079	913	T.	T.	985	968
30	T.	T.	2714	2064			4584	5236	46	47	1814	1373	34	34	1457	1187	5	4	1083	911	3	4	996	965
31							4367	4786					28	10	1482	1156	4	2	1064	915				

1915

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1			850	1004	29	28	3687	2585	10	9	4091	4605			1693	1449	T.	T.	1081	920			730	699
2			915	1037	1	T.	3354	2484			3914	4353	T.		1646	1403	T.	T.	1068	894	2	2	732	701
3			915	1059			2995	2446	5	3	3756	4125			1618	1361			1034	873	24	26	822	754
4			983	1101	1	1	2692	2415	20	22	3645	3916	4	4	1600	1334			000	855	22	24	870	787
5	15	14	915	1120	13	14	2486	2420	15	16	3671	3780	2	2	1573	1309		T.	996	837	T.	T.	834	772
6	42	40	886	1117	28	28	2464	2369	T.	1	3495	3630			1479	1262	64	58	1147	908			805	769
7	T.	T.	953	1146			2707	2372			3369	3485			1424	1226	3	3	1187	926			788	757
8	T.	T.	933	1149	T.	T.	2752	2379	T.	T.	3308	3346			1391	1196		T.	1075	907			758	739
9	9	9	891	1159	T.		2935	2437			3246	3219			1328	1152			995	867			735	720
10			964	1162			3481	2747			3176	3127			1297	1122			971	846			704	695
11			1033	1170			4640	3329			3085	3019			1260	1086	10	12	999	853			688	689
12			1079	1169			6052	4316			3014	2912	T.	T.	1259	1065			988	830	T.	T.	679	679
13	31	33	995	1192	T.	T.	7780	6365			2925	2806	25	22	1325	1092	T.	1	950	809	54	74	852	826
14	2	2	1190	1327	T.	T.	6845	6662			2852	2697			1301	1051	4	4	974	820	5	5	806	774
15	22	21	1096	1268			7163	6841			2780	2608			1219	1018	42	50	1093	900	30	29	888	851
16	44	40	981	1235			7551	6880			2700	2518			1177	988	10	13	1063	895	1	1	862	844
17	87	79	987	1294	16	17	7843	6948			2628	2433			1129	962			984	879			847	839
18			1078	1451	34	34	8029	7552	T.	T.	2579	2331	T.	T.	1084	942			915	846	9	10	860	851
19	1	1	1446	1656	18	18	8031	7997			2515	2255			1063	920			887	811	4	6	869	863
20			1593	1726	4	4	7570	8090			2425	2164	3	4	1077	922			854	785			851	855
21	4	3	1613	1680	7	8	7162	7610			2337	2082	14	12	1072	907			837	769	T.	T.	840	851
22	T.	T.	1715	1550			6622	6890			2272	1985	7	7	1090	907	8	8	850	766			839	848
23	32	29	1805	1477			6090	6389			2187	1913	2	2	1077	889	34	36	964	840			838	849
24	20	18	1834	1554			5727	5988			2115	1845	4	3	1104	907	3	4	909	810	29	28	896	883
25	T.	T.	1967	1647			5601	6012			2052	1788	56	54	1217	968	2	2	867	809	88	86	1272	1094
26	2	2	2192	1755	T.		5558	6457			1989	1719	92	89	1544	1137			845	800	T.	T.	956	998
27			2680	1895			5385	6669			1936	1664	21	20	1494	1146			821	785			912	951
28			3100	2066			5107	6435			1869	1594	T.		1249	1067	T.	T.	784	761			900	923
29	45	44	4191	2685	2	2	4838	5041			1800	1541			1184	1015	T.	T.	786	752	9	8	922	922
30	28	28	4228	2723	T.	T.	4626	5397			1736	1493			1131	975			765	730	6	6	916	918
31							4333	4933							1096	942			750	718				

1916

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1			1145	1347			4198	3103			3010	3263			1288	1071	2	1	1627	1272			1020	961
2	T.	T.	1129	1324	T.	T.	3621	2993			2846	3032			1244	1052	18	16	1406	1171			984	932
3			1106	1347			3463	2864			2735	2857			1219	1023	30	33	1596	1272	18	18	1019	933
4	51	51	1091	1374			3916	2952	10	8	2693	2728			1207	996			1428	1205	3	4	990	934
5	9	8	1127	1400			4817	3390			2586	2589	T.	T.	1209	987	47	54	1383	1224	39	46	1129	1015
6	T.	T.	1112	1425			6067	4035			2507	2457	T.	T.	1178	963	29	32	1450	1262	6	8	1079	1009
7			1065	1414			7312	4062			2456	2337	T.	T.	1169	950	7	6	1468	1238	T.	T.	991	958
8			1083	1422			8214	5262			2395	2242	18	21	1232	983			1323	1151	4	4	954	923
9			1161	1471			8889	6075			2330	2141	120	131	1679	1228	6	6	1256	1098	38	34	1067	972
10			1316	1584			9534	7299			2253	2097	12	14	1452	1123	2	2	1213	1054	2	2	1032	973
11	9	10	1546	1699			9697	8639			2185	2014	T.	1	1339	1101	5	2	1153	1005	33	32	1141	1031
12	6	6	1768	1760			9292	9253			2144	1923	1	1	1324	1067	10	10	1191	1009			1046	988
13	32	30	1776	1782	8	7	8635	10157			2099	1862	13	22	1354	1089	26	26	1229	1032			1012	973
14	2	3	1652	1729	T.	T.	7942	11255			2021	1779	T.		1291	1082	18	19	1224	1046	T.	T.	997	956
15	T.	T.	1548	1694			7048	10552			1980	1728	46	49	1325	1076	7	6	1214	1034			998	950
16			1604	1749			6292	9432			1922	1675	1	1	1395	1093	2	3	1183	1021			989	945
17			1900	1897	T.	T.	5724	8273			1870	1616	26	25	1373	1100			1129	1000			998	952
18	8	8	2401	1961			5256	7166	T.	T.	1848	1562	2	1	1340	1078			1080	960	6	8	1012	965
19	2	2	2407	1951	22	22	5056	6356			1763	1524	T.	T.	1255	1035			1085	956	T.	T.	1007	959
20			2170	1945	4	4	5012	5850			1740	1486	10	10	1258	1018	12	13	1117	966			992	950
21			2253	1998			4757	5261			1692	1436	4	4	1241	998	2	2	1079	946			994	959
22			2358	2053	1	1	4511	5161			1618	1384		T.	1211	981			1039	937	T.	T.	996	958
23			2807	2148			4328	5031			1598	1345	2	2	1190	968			1027	914	T.		1002	967
24			3291	2227			4107	4851			1564	1303	9	8	1160	941			1032	917			990	961
25	T.	1	3545	2293			3954	4632			1522	1268	40	38	1236	978	5	6	1042	911			979	959
26	2	2	3557	2408			3787	4404			1469	1236	5	4	1276	994			1037	910			976	962
27			3814	2672			3623	4231			1432	1194	9	8	1222	985		1	997	899			969	960
28			4251	2850			3493	4125			1395	1164	55	48	1339	1036			983	882			963	950
29	48	48	4677	2995			3367	3937			1353	1121	1	1	1286	1016	14	18	1013	914			963	950
30	30	30	4504	3128			3238	3736			1329	1097	76	77	1565	1152	56	66	1176	1052	T.	T.	963	950
31							3111	3512					60	66	1809	1309	3	4	1072	1006				

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1916-17

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	42	42	1026	1007			1283	1459			952	1105			770	988			743	952	4	3	751	938
2	12	14	1038	1033			1266	1446	10	10	959	1115	1	1	770	986			749	952	27	26	751	937
3	1	3	998	1011			1261	1427			963	1105	4	4	786	986			749	962	3	4	735	926
4	1	1	983	990			1249	1425			970	1105	T.	T.	792	986			736	968			727	927
5	26	27	994	1018			1243	1415			984	1106			767	986			740	964	4	3	732	937
6	36	37	1517	1319			1234	1413	3	4	989	1114			755	971	14	10	759	972	T.	T.	732	923
7	24	28	1172	1207	16	16	1236	1413			983	1102			769	970	T.	1	747	962			727	907
8	16	18	1172	1205			1212	1390			824	1082			772	986			766	944			719	926
9	38	39	1260	1291			1186	1372			762	1069			781	986			772	938			717	926
10	30	31	1459	1405			1174	1357			753	1056			779	986			772	938	31	32	724	926
11	84	86	2186	2072			1169	1334	4	4	701	1012			770	986			775	938	34	34	727	926
12			1789	1990	T.	T.	1164	1330			732	1008			770	986			763	938	T.	T.	727	926
13	3	3	1530	1767			1155	1305	16	16	714	989	T.	T.	767	986	T.	T.	759	942			727	921
14	72	70	1446	1668			1155	1268	2	2	787	996			756	984	12	9	759	950			723	919
15	T.	T.	1348	1569			1155	1236			820	988	41	40	739	986	T.	1	754	938	12	13	727	924
16			1376	1563			1155	1226			817	1001	42	41	738	986			749	940			717	906
17			1420	1589			1155	1213	2	2	802	1018	T.	T.	741	974	6	6	749	950			710	903
18	18	18	1428	1616			1155	1212			802	999			729	966	36	36	758	960			758	908
19			1496	1624			1155	1212	24	23	802	1017			745	966	8	8	747	949			800	924
20			1495	1593	2	2	1147	1212	1	1	802	1033	85	95	761	986	1	T.	739	938			823	934
21			1470	1582	T.	T.	1122	1212			802	1024	T.	T.	776	986			749	948			855	943
22			1469	1602			1093	1204	3	3	793	1031			759	986	T.	T.	749	954	8	8	792	938
23	13	12	1472	1627			1067	1189	23	24	792	1033	2	2	759	978			741	949			761	931
24	15	14	1468	1628	2	2	1065	1176	7	6	792	1033			747	967	T.	T.	743	944			804	948
25			1405	1583			1028	1156	36	39	786	1033			739	962	T.	1	777	950			866	977
26			1376	1567			983	1147	T.	T.	764	1033			751	962	T.	T.	765	943			825	966
27			1362	1544			993	1129			751	1024			758	959			757	938			851	970
28			1333	1543			980	1123			732	1010			751	970	T.	T.	759	938			1020	1031
29			1318	1532			947	1106			727	1010			753	974							1270	1090
30			1291	1507			945	1105	12	11	730	989	2	2	753	974					10	10	1100	1109
31			1280	1488					4	4	771	998	8	8	759	971					26	25	975	1089

1917-18

Date	Oct. Precip. A	Oct. Precip. B	Oct. Run-off A	Oct. Run-off B	Nov. Precip. A	Nov. Precip. B	Nov. Run-off A	Nov. Run-off B	Dec. Precip. A	Dec. Precip. B	Dec. Run-off A	Dec. Run-off B	Jan. Precip. A	Jan. Precip. B	Jan. Run-off A	Jan. Run-off B	Feb. Precip. A	Feb. Precip. B	Feb. Run-off A	Feb. Run-off B	Mar. Precip. A	Mar. Precip. B	Mar. Run-off A	Mar. Run-off B
1	1	1	1072	1033			960	1033			845	1033			783	986			744	951			650	965
2			1048	1031			954	1033	8	8	845	1033			776	986			721	938			652	954
3			1045	1019			952	1033	16	15	862	1046			781	995			713	922			673	980
4			1044	1021			941	1033			856	1037	6	4	773	998			713	926			682	986
5			1042	1023			943	1033	T.	T.	854	1033	1	1	772	998			726	934	1	2	687	987
6	T.	T.	1049	1025			953	1039	4	3	838	1033	6	6	778	986			709	930	3	3	691	1009
7			1054	1010			956	1048	T.	T.	837	1033	6	6	764	986	11	11	719	932	8	8	691	1013
8			1048	1021	6	6	958	1057	T.	T.	828	1032			774	986			726	938	92	89	689	1033
9			1055	1028			923	1035			833	1012	22	21	774	986			707	931			683	1005
10			1057	1019			909	1033			839	1005	5	5	777	986			717	948	T.	T.	697	986
11			1053	1021			909	1045			837	1012	2	1	763	996			706	950	2	2	706	1006
12			1051	1028			903	1045			831	1017	1	1	773	986			709	954	51	52	724	1032
13			1044	1033	1	1	907	1045			828	993	6	4	768	993	7	6	725	970	24	25	726	1042
14			1051	1033	56	56	914	1055			834	1000	1	1	760	976			708	960			706	1013
15			1044	1036	36	38	929	1069	T.	T.	834	1003	T.	T.	761	974	20	18	712	968			693	987
16			1044	1044			907	1060			805	992	2	2	759	979			706	950			686	986
17	T.	T.	1041	1035	2	1	897	1045			799	989	1	1	739	958			706	940			696	986
18			1014	1044			884	1045			793	985	12	12	756	974	14	14	706	954			698	986
19			1001	1037			872	1051			802	991	3	3	749	974	2	2	706	965	2	1	722	998
20			1008	1033			870	1056			797	988	1	1	735	974			705	952	6	6	742	1023
21			999	1035			875	1041			792	998			700	958	1	T.	706	950	15	14	744	1032
22			991	1045			876	1045			792	990			673	938	4	4	706	966	T.	T.	731	1006
23			984	1042			878	1045			792	986			667	938	4	2	714	904			739	1031
24	6	6	993	1047			883	1049			792	989			723	946	38	37	710	990	1	1	743	1038
25	12	12	1012	1066	5	4	884	1057			792	990	4	5	748	952			708	986	2	2	740	1033
26	T.	T.	1013	1065	1	1	884	1048			790	986	27	26	761	962			702	984			743	1039
27			985	1060			861	1047			792	986	22	24	765	974	106	84	672	986	2	1	752	1057
28	T.	T.	977	1057			846	1035			792	986			749	978			663	984	1	1	743	1061
29			959	1036			862	1033			792	986			743	974					T.	T.	745	1046
30			963	1033			858	1033			793	986	T.	T.	750	976							805	1101
31			960	1033							783	986	2	4	749	982							836	1133

1918-19

Date	Oct. Precip. A	Oct. Precip. B	Oct. Run-off A	Oct. Run-off B	Nov. Precip. A	Nov. Precip. B	Nov. Run-off A	Nov. Run-off B	Dec. Precip. A	Dec. Precip. B	Dec. Run-off A	Dec. Run-off B	Jan. Precip. A	Jan. Precip. B	Jan. Run-off A	Jan. Run-off B	Feb. Precip. A	Feb. Precip. B	Feb. Run-off A	Feb. Run-off B	Mar. Precip. A	Mar. Precip. B	Mar. Run-off A	Mar. Run-off B
1	T.	T.	756	796			742	796			727	772			716	750	24	24	685	725			674	736
2	T.	T.	758	796			738	796			727	772			706	748	11	10	685	725			713	742
3			742	796			730	796			727	772			706	748			694	725			700	748
4			746	796	34	34	751	796			720	772			706	750			695	725	22	20	709	748
5			742	796	75	72	772	829			727	766			706	762	6	6	691	732			697	736
6			751	796	49	46	767	831			736	772			706	771	14	13	685	741	3	4	688	741
7	T.	T.	741	796	4	3	759	831	15	15	729	789			699	779	6	6	685	736			685	736
8	8	8	750	797			759	831	16	16	727	796			702	796			685	733	6	6	688	727
9	2	2	765	798			751	814	2	2	727	780			706	776			685	725	6	8	687	725
10	6	6	759	796			741	808			727	772			698	772			685	730			681	725
11			759	796			734	808			720	772			706	771			687	743			680	727
12			751	796			736	800	8	8	722	772	6	5	702	760	8	8	695	748	T.	T.	706	736
13			748	796			731	798			718	772	T.	T.	706	760	4	4	686	748	1	1	723	746
14			737	796			753	808			713	765			699	759			676	748	8	8	710	748
15	T.	T.	748	796	3	4	758	808			722	760			695	748			670	731			691	739
16	8	8	769	801			749	808	20	18	718	760			697	748			675	742			681	736
17	12	14	792	808			738	796	13	11	726	706			695	748			669	738			702	743
18	20	18	795	818			727	796	2	2	717	772			709	754	20	19	674	726			749	767
19	18	16	865	871	24	24	730	796			712	765	1	1	703	752	23	21	681	742			794	812
20	16	16	861	888	13	14	738	803	6	4	717	759			699	748			683	744	16	15	765	796

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1917

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	T.	T.	856	1040	T.	T.	2920	3729	10	10	12842	17782	-----	-----	3332	2824	30	30	1651	1339	T.	T.	1148	935
2	6	6	800	1011	7	8	3221	4309	-----	-----	12368	16417	-----	-----	3206	2665	8	12	1627	1301	-----	-----	1100	924
3	-----	-----	789	1006	-----	-----	3783	4865	-----	-----	14555	16400	-----	-----	3110	2532	2	T.	1576	1254	-----	-----	1070	903
4	-----	-----	775	990	8	8	5263	5117	-----	-----	16360	17869	-----	-----	3009	2419	4	4	1551	1241	T.	T.	1030	879
5	-----	-----	836	1016	42	38	4678	5271	2	2	13658	19652	2	2	2932	2342	-----	-----	1518	1201	T.	T.	1027	883
6	2	2	875	1028	T.	T.	4060	4989	-----	-----	13869	20096	4	4	2844	2279	12	10	1450	1148	1	1	995	881
7	-----	-----	901	1055	2	1	3473	4704	T.	T.	12418	17814	2	1	2777	2164	-----	-----	1424	1113	32	31	1083	934
8	-----	-----	1026	1118	24	21	3172	4323	-----	-----	13066	16859	10	10	2711	2100	-----	-----	1344	1083	2	2	1135	947
9	30	30	1166	1197	32	30	3047	4085	-----	-----	12371	16654	1	1	2675	2085	T.	T.	1317	1080	19	6	1171	948
10	3	4	1071	1227	22	22	3065	3949	-----	-----	11808	16459	5	6	2539	2006	12	13	1353	1085	4	4	1092	938
11	T.	T.	1094	1203	8	8	3099	4072	-----	-----	11372	15289	4	2	2440	1917	16	16	1486	1152	8	8	1114	967
12	-----	-----	1278	1225	2	2	3475	4335	-----	-----	10434	13656	-----	-----	2326	1838	22	20	1573	1222	T.	T.	1067	954
13	-----	-----	1438	1274	-----	-----	4570	4992	-----	-----	9504	11676	-----	-----	2224	1752	4	2	1499	1216	20	23	1134	992
14	-----	-----	1710	1336	T.	T.	8968	6212	-----	-----	8940	10078	-----	-----	2138	1673	T.	T.	1414	1181	1	1	1098	983
15	4	5	1821	1341	12	14	18163	8031	-----	-----	8308	8902	-----	-----	2073	1597	9	9	1367	1130	-----	-----	1067	947
16	52	52	1672	1326	-----	-----	21051	11520	-----	-----	7777	7956	-----	-----	2015	1553	36	40	1524	1175	1	1	1068	940
17	142	140	1507	1302	-----	-----	23099	14268	T.	T.	7340	7206	T.	T.	1947	1510	2	3	1444	1149	-----	-----	1033	942
18	92	90	1358	1252	-----	-----	23602	16181	-----	-----	6926	6633	32	28	1987	1511	-----	-----	1353	1146	-----	-----	1007	934
19	T.	T.	1260	1230	2	4	18295	15861	T.	T.	6546	6160	26	21	2061	1527	-----	-----	1278	1112	4	5	1023	952
20	-----	-----	1227	1249	3	4	14116	13934	-----	-----	6178	5744	6	4	1995	1492	T.	T.	1276	1069	T.	T.	1025	950
21	-----	-----	1395	1387	T.	T.	13872	12564	T.	T.	5833	5370	3	4	1890	1442	-----	-----	1231	1030	-----	-----	1019	936
22	-----	-----	2082	1746	T.	T.	14945	12928	-----	-----	5520	4991	-----	-----	1799	1384	4	2	1193	1011	4	4	1027	952
23	-----	-----	2966	2408	40	37	13238	12633	-----	-----	5218	4672	14	16	1827	1381	1	1	1188	990	12	13	1068	990
24	-----	-----	4280	3151	T.	T.	12703	12143	-----	-----	4918	4336	2	3	1840	1376	1	1	1181	984	6	8	1063	989
25	-----	-----	5705	3899	2	2	12672	12743	-----	-----	4605	4082	30	31	1799	1382	-----	-----	1137	958	1	1	1050	1000
26	T.	T.	6336	4730	T.	T.	11811	12658	-----	-----	4303	3819	4	5	1827	1366	-----	-----	1101	935	-----	-----	1059	1007
27	32	32	5283	4794	-----	-----	14326	12801	1	1	4114	3577	1	3	1739	1360	26	26	1179	965	-----	-----	1054	1018
28	39	37	3712	4545	T.	T.	13495	13610	-----	-----	3874	3366	16	21	1758	1376	1	1	1193	976	-----	-----	1057	1016
29	100	95	3038	4202	T.	T.	15010	14715	-----	-----	3691	3169	28	32	1804	1433	-----	-----	1131	966	T.	T.	1053	1018
30	-----	-----	2770	3740	1	1	•15155	16689	-----	-----	3484	2994	2	2	1771	1419	10	6	1125	951	6	6	1057	1023
31	-----	-----	-----	-----	24	22	13427	17959	-----	-----	-----	-----	-----	-----	1634	1330	10	9	1190	965	-----	-----	-----	-----

1918

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	1	1	817	1157	T.	T.	1440	1080	-----	-----	1174	1135	-----	-----	655	739	T.	T.	604	635	3	2	657	706
2	1	1	843	1174	T.	1	1437	1092	-----	-----	1136	1112	15	16	661	725	42	56	668	689	2	2	637	702
3	-----	-----	851	1172	T.	T.	1518	1117	T.	T.	1133	1105	38	31	815	776	T.	T.	663	699	28	29	720	750
4	2	2	808	1133	T.	T.	1532	1130	T.	T.	1129	1098	1	T.	769	770	2	2	638	693	10	10	721	763
5	1	1	792	1096	T.	T.	1617	1139	T.	T.	1118	1079	24	32	767	799	T.	T.	619	681	7	6	697	754
6	-----	-----	801	1067	-----	-----	1679	1168	-----	-----	1099	1066	2	2	761	800	6	4	627	679	-----	-----	662	736
7	T.	T.	798	1047	T.	T.	1586	1198	T.	T.	1091	1043	33	31	809	840	2	2	610	668	-----	-----	656	712
8	-----	-----	892	1084	1	1	1617	1211	T.	T.	1076	1038	10	10	776	822	T.	T.	597	653	41	42	739	758
9	-----	-----	964	1128	-----	-----	1580	1226	-----	-----	1059	1023	30	32	852	858	24	29	670	695	102	106	1192	1000
10	T.	T.	924	1113	T.	T.	1500	1242	-----	-----	1050	1005	6	8	709	844	20	20	665	705	64	64	1649	1327
11	8	9	1015	1158	1	1	1438	1208	T.	T.	1035	996	18	18	787	842	T.	T.	644	698	T.	T.	1051	1073
12	49	48	1006	1161	-----	-----	1375	1164	16	16	1034	992	19	20	899	886.	-----	-----	593	666	T.	T.	866	925
13	6	6	984	1204	T.	T.	1365	1167	3	2	1014	976	20	22	858	885	56	57	754	758	-----	-----	807	865
14	T.	T.	956	1206	-----	-----	1338	1203	6	2	1018	940	65	66	855	887	54	54	940	855	-----	-----	765	833
15	-----	-----	938	1191	-----	-----	1309	1181	16	20	986	950	40	38	1288	1035	1	1	698	760	-----	-----	745	810
16	T.	T.	970	1163	-----	-----	1304	1180	-----	-----	924	915	5	8	953	965	-----	-----	659	712	36	44	805	858
17	T.	T.	1027	1107	-----	-----	1291	1208	-----	-----	896	888	-----	-----	791	872	-----	-----	627	689	-----	-----	797	886
18	-----	-----	1019	1087	-----	-----	1287	1217	2	1	873	876	-----	-----	729	799	-----	-----	612	668	-----	-----	763	846
19	2	2	973	1036	-----	-----	1268	1244	12	5	908	868	1	1	702	776	-----	-----	606	657	-----	-----	755	824
20	-----	-----	991	1013	T.	T.	1266	1284	14	14	892	883	5	4	735	780	T.	T.	596	647	T.	T.	751	828
21	-----	-----	1000	1008	T.	T.	1263	1310	5	4	908	889	T.	T.	725	782	31	32	673	702	-----	-----	752	813
22	-----	-----	1035	1049	-----	-----	1240	1309	12	10	938	905	8	8	716	782	16	22	706	747	-----	-----	751	806
23	T.	T.	1150	1099	-----	-----	1219	1285	15	16	898	880	1	1	694	757	T.	T.	665	716	14	13	772	810
24	-----	-----	1292	1155	-----	-----	1210	1261	1	1	866	875	28	24	728	776	T.	T.	608	687	-----	-----	759	808
25	-----	-----	1421	1163	-----	-----	1213	1231	8	6	843	866	-----	-----	700	772	T.	T.	592	674	-----	-----	744	808
26	T.	1	1504	1167	-----	-----	1188	1219	-----	-----	815	838	-----	-----	647	743	T.	1	599	666	T.	T.	752	808
27	1	1	1464	1138	-----	-----	1175	1208	-----	-----	765	795	1	2	648	738	2	1	596	655	-----	-----	752	806
28	-----	-----	1421	1126	-----	-----	1175	1191	-----	-----	728	764	T.	T.	633	717	10	11	636	671	-----	-----	755	796
29	-----	-----	1429	1107	T.	T.	1173	1163	-----	-----	716	754	-----	-----	620	681	6	7	666	693	-----	-----	755	796
30	T.	T.	1381	1075	12	11	1181	1154	-----	-----	675	732	4	4	603	655	T.	T.	631	679	-----	-----	745	796
31	-----	-----	-----	-----	-----	-----	1220	1166	-----	-----	-----	-----	8	7	624	653	33	35	663	698	-----	-----	-----	-----

1919

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	T.	T.	877	950	-----	-----	7092	4482	2	2	4393	4175	18	11	1737	1336	10	11	1377	1074	-----	-----	819	870
2	-----	-----	996	998	19	22	7623	5107	-----	-----	4163	3903	8	8	1770	1323	17	23	1361	1104	-----	-----	787	853
3	T.	T.	989	1005	-----	-----	7336	5582	T.	T.	3955	3686	24	20	1747	1319	3	3	1310	1096	-----	-----	763	839
4	-----	-----	1140	1113	-----	-----	7682	6017	-----	-----	3732	3448	T.	T.	1695	1302	T.	T.	1235	1050	-----	-----	756	838
5	-----	-----	1299	1256	-----	-----	8775	6557	-----	-----	3510	3202	-----	-----	1601	1253	-----	-----	1191	1017	8	7	779	852
6	35	34	1179	1264	-----	-----	9549	7224	T.	T.	3327	2986	16	17	1588	1236	T.	T.	1154	998	8	8	845	896
7	4	4	1022	1152	8	6	9368	7874	T.	1	3214	2802	-----	-----	1543	1212	T.	T.	1169	1008	3	3	850	890
8	22	20	946	1095	-----	-----	8666	8019	52	56	3310	2756	T.	1	1514	1179	T.	T.	1136	975	2	3	837	892
9	10	8	878	1033	12	14	7996	7612	4	4	3202	2647	-----	-----	1479	1154	2	2	1125	978	T.	T.	798	865
10	-----	-----	883	1030	6	8	7654	7050	T.	T.	2991	2497	-----	-----	1461	1108	10	6	1103	960	-----	-----	787	857
11	-----	-----	1063	1165	-----	-----	7256	6879	-----	-----	2864	2369	8	7	1482	1093	-----	-----	1067	949	12	16	768	870
12	-----	-----	1092	1279	-----	-----	6914	7086	-----	-----	2750	2272	52	52	1551	1120	-----	-----	997	920	18	23	850	919
13	T.	T.	1469	1554	-----	-----	6833	7307	T.	T.	2638	2179	21	21	1744	1205	-----	-----	976	926	56	60	988	998
14	-----	-----	1482	1664	-----	-----	7125	7836	T.	T.	2573	2092	57	52	1811	1246	12	14	1018	950	1	2	918	984
15	-----	-----	1412	1655	T.	T.	7294	9105	1	1	2495	2027	88	84	2036	1356	-----	-----	998	925	-----	-----	847	952
16	-----	-----	1452	1652	-----	-----	7136	10754	-----	-----	2449	1971	12	19	2041	1341	1	1	953	910	T.	T.	851	926
17	-----	-----	1618	1734	-----	-----	6843	11259	8	8	2393	1921	1	1	1636	1262	-----	-----	942	909	6	6	854	923
18	-----	-----	1982	1952	-----	-----	6721	11097	2	2	2343	1869	4	3	1535	1104	T.	T.	934	904	4	8	868	916
19	-----	-----	2521	2291	-----	-----	6522	10576	-----	-----	2283	1815	22	22	1569	1187	6	8	919	906	12	14	893	922
20	-----	-----	3182	2508	T.	T.	6414	9753	2	2	2219	1756	T.	T.	1498	1161	-----	-----	873	896	-----	-----	870	918

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1918-19

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
21	T.	T.	844	887	T.	T.	738	796	1	1	717	748			695	748	32	28	674	739	94	82	755	796
22			792	865	14	16	738	796	24	23	713	763			695	748	1	1	675	744	40	36	731	787
23			763	834	14	14	738	796	1	1	706	768			695	748	8	8	685	738	14	10	706	775
24	4	5	772	831	16	16	738	796			699	753			695	748	6	6	687	732	30	29	701	767
25	T.	T.	780	831	7	7	736	796			695	748			695	748			678	729	T.	T.	704	761
26			748	822			727	796			701	748			689	748	1	1	682	729			709	765
27			739	808			727	796			707	748			685	740	22	19	683	743			706	774
28	12	11	762	820			729	784			712	748			683	736			671	747	20	22	718	774
29			755	813			738	782	2	2	717	748			686	729					2	4	760	835
30			741	808			729	772	78	78	724	748			694	725					T.	T.	842	888
31			741	797					4	4	727	765			685	725					5	4	829	884

1919-20

Date	Oct. Precip. A	Oct. Precip. B	Oct. Run-off A	Oct. Run-off B	Nov. Precip. A	Nov. Precip. B	Nov. Run-off A	Nov. Run-off B	Dec. Precip. A	Dec. Precip. B	Dec. Run-off A	Dec. Run-off B	Jan. Precip. A	Jan. Precip. B	Jan. Run-off A	Jan. Run-off B	Feb. Precip. A	Feb. Precip. B	Feb. Run-off A	Feb. Run-off B	Mar. Precip. A	Mar. Precip. B	Mar. Run-off A	Mar. Run-off B
1			871	902			866	903			842	905			790	865			759	843	2	1	759	843
2			866	896			868	893			834	903			781	855			758	843	22	22	759	852
3	5	6	878	901			870	903			834	903			781	855	12	10	750	841	T.	T.	759	851
4			884	906			866	896	T.	T.	833	903	28	28	781	857			758	842			743	847
5	6	5	885	906	T.	T.	868	903	42	40	828	903	4	4	781	864	54	52	749	835	6	5	738	853
6	T.	T.	897	903			853	901			834	907	10	10	781	855			749	834			738	843
7	71	69	915	920	56	56	850	897			834	903	16	14	781	861			749	837			733	834
8			983	984	54	54	866	915	20	21	834	908			768	843	47	48	750	843			724	833
9	1	1	942	981	17	18	866	912			826	894			759	831			759	843	T.	T.	741	839
10	T.	T.	932	960			857	903			813	891			759	842			758	835	16	19	749	843
11			919	938			857	903	T.	T.	813	889	T.	T.	759	836			749	845	T.	T.	744	848
12	10	8	932	955			845	901	23	18	819	889			763	847			751	834			738	849
13	T.	T.	908	943			835	891			808	892			759	840			758	831			756	879
14	T.	T.	899	938			834	890			800	877			759	841			747	835	T.	T.	780	903
15	2	3	902	932			834	891			796	867			759	843			738	825			761	895
16			874	910			840	889			798	867			759	851			738	827	T.	T.	753	901
17			875	903			834	887			792	869			759	853			736	831	11	8	759	910
18			873	904			834	898			792	879			759	834			730	830	6	4	757	905
19			869	901	6	5	849	903			792	871			759	843			742	825			775	944
20			863	901	23	20	849	904			789	867			767	852	8	8	749	828			838	1032
21			865	893			845	900			792	867			770	845	8	9	752	831	13	14	898	1162
22			864	882			827	881			792	867	T.	T.	770	855	15	16	764	856	44	46	881	1213
23			868	891			826	891			792	867			763	843	2	2	781	862	22	24	857	1164
24	27	28	883	905			825	891			787	867			759	839	3	2	772	853			830	1106
25	38	38	913	938	1	1	834	891			792	867			759	840			762	842	T.	T.	808	1076
26	33	37	898	938	122	126	837	899			792	867			759	837			759	831	26	24	807	1070
27	T.	T.	893	938	140	135	851	914			792	867			759	854			759	831	17	16	818	1065
28			866	912	68	60	838	915			792	867			759	849	1	1	758	837	T.	T.	793	1043
29			868	903			840	915			792	867			759	858			751	837			775	1039
30			876	903	T.	T.	834	903			792	862			759	847							775	1019
31	4	4	866	905							792	867			759	843					8	6	797	1022

1920-21

Date	Oct. Precip. A	Oct. Precip. B	Oct. Run-off A	Oct. Run-off B	Nov. Precip. A	Nov. Precip. B	Nov. Run-off A	Nov. Run-off B	Dec. Precip. A	Dec. Precip. B	Dec. Run-off A	Dec. Run-off B	Jan. Precip. A	Jan. Precip. B	Jan. Run-off A	Jan. Run-off B	Feb. Precip. A	Feb. Precip. B	Feb. Run-off A	Feb. Run-off B	Mar. Precip. A	Mar. Precip. B	Mar. Run-off A	Mar. Run-off B
1	1	1	1024	1130			992	1203			911	1177	T.	T.	868	1106	T.	T.	834	1045			1047	1528
2			1023	1129			974	1203			925	1168			866	1103			834	1036			1062	1685
3			1023	1121			973	1211	4	3	931	1167			866	1093			837	1044			1159	1899
4	T.	T.	1014	1116			968	1202			913	1163	T.	T.	866	1098	15	16	845	1043	18	18	1170	2119
5			1019	1126	47	46	980	1205	4	3	909	1165			866	1093	13	12	843	1052	T.	T.	1100	2233
6	T.	T.	1022	1120	76	76	995	1215			909	1141	2	2	870	1093	12	12	834	1050	T.	T.	1051	2272
7			1022	1114	58	55	1004	1213			909	1132	T.	T.	866	1088	T.	T.	834	1052	1	1	1023	2243
8			1021	1120			1005	1235			909	1150	T.	T.	866	1087			826	1047	T.	T.	993	2103
9			1027	1127			1020	1224			908	1129			866	1076			822	1036			949	1966
10	4	4	1016	1135			1010	1226			904	1114			866	1068			819	1032			919	1863
11			1012	1126	3	4	1014	1224	6	6	907	1134	2	2	866	1061			855	1102			923	1814
12			1018	1116			996	1221	58	72	914	1156	4	4	866	1068			864	1144	T.	T.	917	1825
13	26	24	1015	1137	T.	T.	988	1213			905	1137	4	4	866	1059			858	1144	T.	T.	926	1832
14	26	24	1059	1281			972	1201			909	1138			854	1057	2	2	856	1146	2	3	929	1848
15			1057	1204			963	1180			891	1115			859	1084	14	15	866	1116	22	22	936	1867
16			1041	1186			963	1173			890	1113			858	1125			840	1105			970	1887
17			1031	1191			963	1186			904	1122	T.	T.	856	1107			834	1090			1052	2025
18	T.	T.	1024	1191			959	1190			902	1124	38	38	863	1093			834	1087			1129	2189
19	68	68	1027	1210			963	1189	15	15	888	1100	35	36	866	1091			827	1071	20	20	1134	2425
20	59	61	1045	1212			967	1203	40	36	905	1133	12	12	866	1096	4	3	824	1058	6	6	1108	2663
21	T.	T.	1029	1202			963	1196	6	6	909	1129			857	1093	T.	T.	824	1058			1118	2776
22	T.	T.	1022	1201			957	1207	T.	T.	894	1141	2	2	847	1081			824	1056	4	4	1165	2851
23	10	7	1013	1197			955	1198			881	1138	35	35	856	1086			834	1178			1185	2845
24			1000	1205			944	1182	8	7	879	1137			856	1097			875	1311			1200	2827
25			995	1234	1	1	941	1200	8	7	888	1129			846	1080			907	1364	26	24	1232	2920
26			1006	1218			933	1189	T.	T.	878	1108			836	1069			936	1398	10	10	1255	2970
27			990	1208	4	4	931	1193			868	1105			836	1067			978	1463			1258	2859
28			993	1204			931	1165			877	1105	2	2	850	1069			1024	1508			1250	2708
29			993	1187			922	1166			877	1105			846	1069							1259	2555
30	106	104	1007	1214			913	1182			877	1105			835	1066					T.	T.	1252	2394
31	46	46	1014	1213					T.	T.	877	1107	T.	T.	834	1054							1256	2293

1921-22

Date	Oct. Precip. A	Oct. Precip. B	Oct. Run-off A	Oct. Run-off B	Nov. Precip. A	Nov. Precip. B	Nov. Run-off A	Nov. Run-off B	Dec. Precip. A	Dec. Precip. B	Dec. Run-off A	Dec. Run-off B	Jan. Precip. A	Jan. Precip. B	Jan. Run-off A	Jan. Run-off B	Feb. Precip. A	Feb. Precip. B	Feb. Run-off A	Feb. Run-off B	Mar. Precip. A	Mar. Precip. B	Mar. Run-off A	Mar. Run-off B
1	18	18	1118	1292			1030	1239	5	4	968	1185			909	1141			728	1100			866	1096
2			1107	1280			1023	1230	15	15	973	1198	56	54	920	1171			739	1103			860	1084
3			1088	1269			1001	1252			961	1170	62	58	938	1172			741	1093			869	1090
4			1077	1246			998	1255			925	1122			946	1133	4	4	766	1103			868	1103
5			1073	1255			984	1257			912	1098			923	1145	7	6	784	1099	18	19	866	1112
6	14	16	1100	1301			976	1257			912	1062			913	1145			792	1093	T.	T.	866	1094
7			1082	1298			979	1267			900	1010			909	1131			793	1093			865	1095
8			1067	1276			975	1242			854	1031			909	1131	8	6	816	1100	11	12	862	1093
9			1050	1274			975	1221			840	1030			909	1140	6	4	848	1106			858	1084
10	T.	T.	1057	1281			962	1213			882	1038			909	1149	8	8	861	1113			855	1090

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1919																								
21	94	82	3919	2846	T.	T.	6275	9024	T.	T.	2167	1714			1408	1113			870	885			854	899
22			5188	3134	38	38	6398	8351	T.	T.	2093	1667	T.	T.	1364	1077	T.	T.	843	869			863	897
23	42	42	5969	3438	6	5	6379	7768	6	7	2085	1637			1326	1049			823	864			872	894
24	19	18	5944	4120	2	2	6148	7223	T.	T.	2026	1592			1310	1028	T.	T.	821	858			873	898
25	37	39	5791	4539	T.	T.	6091	6808	T.	T.	1946	1543	18	22	1347	1036	1	1	806	859	T.	T.	877	898
26	8	14	5180	4609	16	16	6007	6422	6	6	1928	1509	1	2	1330	1024	2	3	822	862			881	896
27	22	23	4556	4506	1	2	5626	5959	T.	T.	1874	1475	T.	T.	1292	1011	T.	T.	826	869	8	8	886	891
28	10	10	4225	4281	10	10	5337	5475	4	2	1855	1440	40	52	1409	1059	T.	T.	807	864	5	5	910	909
29			4336	4103	8	8	5138	5084	T.	T.	1781	1404	2	2	1359	1045			776	850	T.	T.	886	903
30			5578	4183	2	2	4892	4724	T.	T.	1758	1362	14	16	1370	1060	8	8	772	831			876	900
31					T.	T.	4680	4435					27	29	1403	1072	30	27	859	868				
1920																								
1			798	1018			2368	3207	T.	T.	11140	11486			1998	1814	28	32	1432	1265			949	994
2	3	3	785	1014			3351	4119			9883	9934	T.	T.	1947	1773	2	2	1427	1252			910	983
3			788	1009			4577	4896	T.	T.	8782	8668	1	1	1930	1744	3	2	1353	1211	T.	T.	911	988
4			771	992			5404	5280	T.	T.	7879	7702			1880	1702	T.	T.	1328	1186	T.	T.	930	993
5	T.	T.	777	1014			6308	5731	2	2	7136	6872			1793	1657	10	10	1300	1192	23	21	1043	1069
6			878	1132			6906	6330			6472	6214			1749	1618			1272	1170	21	21	1072	1100
7			1038	1399			7292	7055			5804	5590			1701	1575			1195	1138	T.	T.	1064	1096
8	T.	T.	1096	1647	T.	T.	7698	8093	T.	T.	5307	5111			1667	1537	6	6	1222	1143	10	14	1076	1127
9			1295	1998			9387	9307	18	18	4957	4690	1	1	1642	1514	8	8	1287	1155	8	8	1069	1110
10	9	10	1248	2134	T.	T.	9895	9856	2	2	4657	4367	68	21	2024	1533	T.	T.	1227	1127			1026	1097
11	3	4	1111	1958	T.	T.	8515	9781	T.	T.	4276	4073	3	2	1860	1528			1147	1083			997	1105
12			1097	1901			8100	9333	T.	T.	3990	3773			1702	1509	5	6	1176	1089			986	1112
13			1254	2102	48	50	8386	9181	T.	T.	3755	3553			1619	1445	1	1	1197	1085			971	1105
14	T.	T.	1264	2324	89	91	8317	9204	2	2	3591	3347	1	1	1579	1463	4	4	1134	1081			968	1121
15	4	4	1382	2422	12	12	7469	8357			3380	3157	1	1	1543	1411	4	4	1135	1084			962	1086
16	41	40	1321	2477	6	9	6931	7485			3210	2995	9	8	1579	1402	T.	T.	1135	1079			956	1059
17	46	41	1303	2392			7215	7213	1	2	3064	2856	2	2	1563	1404	10	9	1122	1089	4	4	993	1089
18	T.	T.	1307	2271			8598	7940			2952	2727	1	1	1547	1388	T.	T.	1133	1085	T.	T.	997	1061
19	T.	T.	1229	2120			12719	9144			2791	2612	26	22	1534	1370	3	3	1147	1097	T.	T.	992	1076
20	14	14	1212	2038			16502	11101			2684	2492	2	2	1504	1353	10	9	1168	1110	18	16	1023	1098
21	14	14	1170	1969	57	58	18496	16571			2584	2382			1421	1295	2	2	1139	1089	24	26	1083	1149
22			1122	1886	2	2	20943	24091	T.	T.	2497	2294	T.	T.	1399	1279	T.	T.	1091	1061	10	10	1047	1132
23			1128	1870	3	3	22692	30971	T.	T.	2403	2221			1380	1274			1042	1040	26	26	1142	1210
24	6	6	1188	1902			22070	32105			2308	2144	72	82	1614	1439	2	2	1012	1022	22	25	1065	1173
25	76	68	1189	1934	T.	T.	21208	29962	T.	T.	2231	2075	3	4	1523	1368	8	4	1037	1034	9	10	1138	1244
26	7	6	1165	1941	18	20	20264	26996	58	58	2489	2157	8	8	1480	1325	1	T.	1027	1031			1050	1164
27			1160	1926	4	6	18635	23619	26	30	2416	2148	2	2	1445	1318	1	1	999	1025			1034	1146
28	T.	T.	1270	2004			16572	19667	1	2	2257	2046	T.	T.	1405	1265			964	1004			1033	1124
29			1445	2157			15265	16577	T.	T.	2145	1960	18	8	1480	1264			964	995			1027	1120
30			1939	2563			13851	14744	T.	T.	2078	1893	2	1	1438	1264	T.	T.	940	991			1027	1118
31							12377	13085					4	2	1391	1232	T.	T.	942	986				
1921																								
1			1380	2278			3217	3918			6219	5424			2006	1945	T.	T.	1462	1313	18	16	1307	1325
2			1557	2349			3965	5166			5729	4941			1948	1894	2	4	1412	1279	T.	T.	1256	1308
3	T.	T.	1813	2533			4634	6554	33	33	5404	4633	T.	T.	1890	1836	10	10	1424	1800			1171	1259
4	18	17	1998	2728			5424	7729	50	48	5385	4535	26	28	2027	1886	10	9	1401	1294			1141	1223
5	8	8	1945	2692			6093	8753	25	27	5032	4275			1905	1800	T.	T.	1389	1269			1114	1202
6	8	8	1742	2635	20	22	6669	9424	19	19	4681	3932			1843	1746	2	2	1336	1243			1100	1189
7	2	2	1572	2527	1	1	6766	9143	18	18	4709	3827	T.	T.	1812	1712	2	2	1318	1237	T.	T.	1104	1201
8			1439	2334	T.	T.	6584	8864			4327	3555			1744	1639	1	1	1329	1241	T.	T.	1089	1191
9			1379	2194			6473	8534			4150	3413	6	4	1757	1657	34	24	1454	1282			1062	1175
10			1402	2140			6684	9162			4058	3392	T.	T.	1709	1624	4	4	1397	1264			1052	1164
11			1514	2217			7251	10053	1	2	4015	3447	6	6	1699	1619	T.	T.	1352	1240			1044	1175
12	4	4	1621	2197	T.	T.	7811	11634	4	3	3931	3455	12	10	1716	1612	1	1	1303	1213	T.	T.	1046	1179
13			1870	2199	T.	T.	8015	13581	4	5	3826	3487	6	6	1660	1594	19	21	1349	1268	T.	T.	1044	1163
14	8	10	1809	2240	3	4	7934	14647	8	8	3730	3517	24	21	1703	1590	18	16	1416	1316			1028	1160
15	30	34	1760	2155	30	30	7675	14688	3	3	3589	3460	16	16	1703	1585	10	10	1398	1298	4	3	1053	1198
16			1694	2186	42	42	7671	13616	T.	T.	3408	3313	44	42	1844	1631			1316	1250	T.	T.	1063	1201
17			1593	2155	4	4	7305	12426	T.	T.	3245	3178	4	4	1700	1549			1244	1210			1048	1180
18			1661	2177	81	82	7127	11292			3087	3021	33	44	1691	1582	10	8	1281	1223	20	21	1112	1244
19			1693	2225	1	1	7020	10125	T.	T.	2955	2920	32	19	1784	1517	20	20	1337	1286			1082	1209
20	T.	T.	1824	2268			7156	9645	2	3	2905	2833	T.	T.	1664	1471	25	25	1379	1342			1073	1198
21	T.	T.	2049	2268			7662	9519			2789	2728	9	10	1662	1468	10	10	1383	1345			1071	1206
22			2447	2604	T.	T.	8396	9231			2679	2600	24	24	1711	1522	16	18	1350	1346			1090	1213
23	12	11	2884	3008	64	60	9395	9391	4	6	2584	2511	36	34	1734	1539	47	50	1364	1408			1089	1213
24	68	62	2768	2987			9314	9661			2492	2387	13	16	1703	1536	2	2	1444	1384	12	14	1098	1243
25	1	T.	2478	2997	1	1	9117	9510	1	1	2421	2328	23	24	1605	1488	11	11	1325	1323	1	1	1101	1237
26	T.	T.	2132	2809	T.	T.	9396	9061			2334	2247	9	9	1716	1514	T.	T.	1276	1290			1084	1228
27			1999	2566			9026	8800			2255	2171	2	2	1572	1440			1230	1250			1079	1231
28	T.	T.	1941	2429	4	4	8428	8294	T.	T.	2196	2099			1509	1367			1211	1227			1079	1234
29			2080	2500			7811	7548			2117	2057	1	1	1482	1342	T.	T.	1177	1213			1078	1228
30	T.	T.	2607	3148			7262	6731	1	1	2070	1998			1450	1314	7	8	1172	1210			1080	1236
31							6731	6025					5	6	1461	1326	50	43	1348	1312				
1922																								
1	64	68	961	1409			5335	6300	T.	T.	6476	7205	10	13	1950	1882	18	18	1364	1316	36	32	1165	1165
2	1	1	945	1397			5563	6796	6	4	6076	6514			1886	1815	T.	T.	1326	1272	5	4	1151	1160
3			1006	1501			5841	7063	T.	T.	5661	5927			1788	1735	4	4	1278	1240	6	6	1141	1158
4			1156	1700			6094	7401	T.	T.	5372	5423			1728	1653	30	32	1311	1279	10	9	1149	1137
5	6	5	1178	1843			6576	8555			4968	4998	T.	T.	1680	1609	4	4	1337	1271			1070	1102
6			1141	1866			7697	10024	4	3	4624	4669	1	1	1650	1577	T.	T.	1276	1216			1029	1079
7	T.	T.	1104	1820	T.	T.	7942	11674			4338	4302	T.	T.	1595	1539	6	8	1267	1223			998	1063
8	6	7	1123	1893	32	34	7602	12853			4079	4042			1525	1507	2	5	1281	1219	4	4	1008	1075
9	21	22	1135	1989	122	126	7219	12075			3879	3802	T.	T.	1520	1444	40	26	1372	1252			996	1055
10			1078	1922	65	66	6595	10199			3697	3562			1460	1409	3	4	1330	1230			969	1024

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		recipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1921-22																								
11	7	6	1067	1287			971	1234			917	1057			909	1140			874	1124	18	16	858	1086
12	2	2	1053	1284			974	1240			931	1097			904	1124			878	1117	31	29	866	1095
13	T.	T.	1033	1287			972	1253			918	1136			896	1135	T.	T.	868	1103			885	1095
14			1026	1291			974	1254			910	1133			896	1149			866	1087			882	1096
15	T.	T.	1029	1288			985	1244			909	1091			895	1131			857	1071			887	1136
16			1027	1284	T.	T.	996	1212	T.	T.	895	1076			902	1134	T.	T.	859	1063	63	61	893	1145
17			1024	1273	24	24	1002	1231			809	1057	1	1	899	1135			866	1084	86	83	878	1138
18			1013	1267			977	1196	12	10	875	1024	18	19	902	1140	1	1	866	1118	26	26	866	1138
19			1026	1274			961	1215	27	25	909	1100	13	12	909	1127			873	1149			870	1154
20			1027	1265			970	1216	8	8	928	1100			909	1136	T.	T.	882	1177			887	1173
21			1029	1266			964	1225	6	6	941	1149			899	1110	34	35	889	1152			945	1177
22			1027	1274			957	1203	52	44	934	1201			873	1087	T.	T.	891	1150			1001	1262
23			1015	1269			964	1213	16	15	933	1187			812	1074	8	8	896	1122			1034	1311
24	29	31	1059	1344	4	4	960	1226			919	1162			741	1085	T.	T.	889	1110	T.	T.	1031	1409
25			1038	1311	4	4	962	1225	4	3	911	1156			682	1075			897	1110			1047	1490
26			1006	1295			953	1196	7	6	918	1163			655	1092	T.	T.	889	1118	7	6	1054	1532
27	8	8	1013	1284			960	1166	5	6	909	1167			630	1084	78	72	887	1117	6	6	1036	1521
28			1003	1251			947	1145			909	1159	12	12	634	1105	1	T.	875	1105	10	10	993	1483
29			1014	1274			948	1154			908	1152			659	1102					T.	T.	967	1445
30			1005	1288			949	1164			914	1166	84	82	666	1099					T.	T.	966	1444
31			1009	1287							909	1156	54	52	702	1116							964	1421
1922-23																								
1			1010	1092			1029	1149			974	1172			931	1089	40	40	888	1044			870	1043
2			1014	1089	T.	T.	1033	1146			973	1169			910	1067			879	1055	12	11	887	1059
3			1020	1091	86	82	1025	1164	10	10	963	1167			907	1042	11	12	877	1038	10	10	902	1070
4			1018	1106	10	8	1041	1185			963	1166			899	1054			877	1035	26	24	890	1067
5	T.	T.	1008	1109			1030	1188			963	1148			899	1052			868	1033	T.	T.	876	1063
6			1021	1103			1016	1178	1	1	963	1143			899	1058			877	1033	1	2	866	1044
7			1022	1108			1001	1164	2	2	977	1158			899	1059			868	1028			869	1067
8			1020	1117			1005	1152	10	10	963	1160			899	1055			869	1037			877	1047
9			1020	1110			1014	1158			963	1135			899	1059	20	18	877	1043	10	11	877	1051
10			1022	1110	4	4	1020	1151			953	1139			899	1041			877	1034	12	14	869	1065
11			1027	1118	15	14	1016	1164			952	1130			900	1045	4	4	876	1024	11	10	877	1037
12	5	6	1028	1156	9	9	1005	1158			959	1122			909	1040	8	8	866	1023	T.	T.	866	1033
13			1023	1137	6	8	980	1139	64	65	963	1138	T.	T.	909	1050			866	1028			856	1028
14			1020	1126			984	1130	18	18	963	1154			918	1043			866	1010	13	14	858	1022
15			1023	1128			976	1115	2	2	963	1152			901	1036			866	1004			864	1015
16	T.	T.	1025	1129	96	97	977	1141	1	1	965	1145			888	1047			874	1014			843	1007
17			1023	1134			1004	1173			952	1129			889	1055			868	1011	16	17	851	1030
18			1022	1132			1000	1162			921	1102			895	1044			889	1013			836	1019
19			1027	1126			988	1174			922	1105			899	1040			900	1016			852	1038
20			1022	1133			975	1166			931	1105	T.	T.	899	1051			905	1027	15	15	854	1062
21	6	6	1022	1141	46	44	983	1189			925	1096			889	1052			892	1028	34	34	866	1039
22			1027	1144	31	30	988	1179			936	1082			888	1050	T.	T.	876	1033	6	5	857	1032
23			1011	1132	20	20	986	1167			941	1091			888	1043			870	1049			860	1023
24			1017	1140	18	17	995	1179			941	1078	20	20	885	1048	T.	T.	877	1041			859	1021
25			1019	1133	T.	T.	984	1167	3	3	941	1100	29	30	877	1060	3	2	877	1053	T.	T.	856	1021
26			1008	1121			976	1169			937	1090	T.	T.	877	1045	10	8	876	1051	2	2	864	1056
27			1008	1141			973	1164			931	1075	T.	T.	874	1054			866	1041			878	1099
28	50	50	1032	1204			973	1167	4	4	932	1089			866	1035			866	1038	T.	T.	890	1158
29	2	3	1028	1189	140	144	986	1190	T.	T.	935	1100			873	1038							931	1261
30	T.	T.	1024	1169	2	2	994	1191			931	1088	10	8	888	1028							980	1368
31			1010	1149					T.	T.	921	1092	22	19	888	1037					T.	T.	981	1447
1923-24																								
1	T.	T.	1185	1252	36	34	1262	1544	5	4	1085	1217	37	40	967	1142			870	1103			872	1066
2	22	24	1273	1395			1269	1520	T.	T.	1071	1210			963	1128	T.	T.	876	1115	14	14	881	1091
3	T.	T.	1260	1363			1237	1479	T.	T.	1070	1209	2	3	958	1145			869	1081	T.	T.	888	1084
4	T.	T.	1246	1363			1212	1446			1070	1202			963	1131			845	1048			879	1061
5	15	17	1293	1422			1186	1440			1063	1205			961	1129			820	1053			876	1067
6			1274	1407			1165	1418			1057	1188			953	1127	3	4	834	1052			866	1095
7			1257	1393			1161	1406			1059	1222			962	1117			834	1080			866	1120
8	18	16	1228	1381	T.	T.	1189	1407	8	8	1052	1200			956	1118			848	1090	16	14	866	1080
9	3	4	1275	1390			1205	1408	10	10	1030	1158	6	6	961	1128			866	1067			862	1066
10	2	2	1259	1392	120	113	1216	1417	20	20	1027	1163			952	1120	62	62	866	1056	5	6	857	1065
11			1244	1384			1221	1447	16	16	1034	1170	4	4	952	1136			870	1062	32	28	866	1068
12	72	72	1249	1476			1189	1424			1041	1176			949	1118			897	1096	69	62	866	1077
13	12	10	1261	1536			1170	1414			1027	1143			936	1112			987	1156	16	12	866	1067
14			1282	1553			1166	1396			1017	1154			931	1112	8	7	942	1123	T.	T.	866	1064
15			1290	1544			1157	1391			1007	1112			935	1102	10	10	947	1127	18	15	866	1047
16			1303	1541			1155	1393			988	1121	10	9	928	1106			951	1105	20	16	866	1055
17			1264	1507			1147	1357			990	1132			918	1080	T.	T.	941	1094	T.	T.	865	1036
18			1239	1474			1134	1341			995	1117			912	1075			912	1099	30	32	857	1035
19			1229	1451			1135	1343			993	1123			923	1079			906	1117	4	4	866	1070
20			1216	1462			1155	1339	11	11	984	1153			896	1054			907	1118	6	6	866	1062
21			1206	1463			1146	1337	T.	T.	971	1136			885	1069			902	1119	22	20	866	1057
22	58	56	1244	1495			1125	1306			956	1130			870	1068	T.	T.	907	1101	6	6	866	1055
23	17	18	1270	1537			1123	1292			950	1106			882	1074	2	2	893	1065	5	5	858	1041
24	20	22	1261	1523			1123	1282			972	1102			880	1058	2	2	877	1082	8	8	856	1056
25	9	9	1246	1522			1121	1279			966	1108			862	1066			868	1076			921	1219
26			1235	1535	10	9	1108	1266	12	12	1000	1145			843	1069	9	8	867	1082			1069	1528
27			1217	1507	6	6	1103	1264	15	13	1003	1131			829	1060	10	10	877	1080	6	6	1186	1762
28			1236	1515			1063	1231			984	1114			822	1073			871	1079	34	32	1054	1439
29			1249	1528			1092	1262	T.	T.	984	1134			821	1078			877	1079	16	15	966	1318
30			1230	1513			1107	1255	39	38	987	1126			824	1080					1	1	938	1244
31	12	10	1241	1525					T.	T.	977	1150			841	1065							905	1207

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1922—Continued

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
11	----	----	1080	1919	T.	T.	5919	8269	----	----	3509	3363	----	----	1419	1383	4	4	1287	1208	----	----	956	1006
12	18	18	1071	1898	----	----	5576	7163	----	----	3327	3205	2	1	1411	1360	----	----	1236	1185	----	----	948	993
13	13	14	1053	1874	----	----	5549	6877	1	1	3172	3098	T.	T.	1376	1325	31	28	1263	1213	----	----	931	987
14	----	----	1055	1818	----	----	5994	7173	----	----	3021	2923	----	----	1324	1293	92	75	1725	1586	T.	T.	927	985
15	----	----	1111	1950	1	1	7525	7477	----	----	2965	2833	T.	T.	1303	1271	18	14	1657	1401	----	----	927	1002
16	1	1	1139	2010	----	----	8548	8241	2	2	2865	2753	----	----	1293	1239	23	21	1451	1359	T.	T.	922	997
17	T.	T.	1083	1964	----	----	9629	10201	----	----	2771	2649	6	3	1367	1257	1	1	1409	1310	T.	T.	921	991
18	----	----	1063	1958	----	----	11115	12300	T.	T.	2640	2530	10	4	1356	1276	8	8	1276	1241	----	----	964	1027
19	----	----	1130	2109	T.	T.	11691	14695	----	----	2507	2441	----	----	1332	1293	14	18	1340	1297	----	----	950	1027
20	----	----	1299	2490	----	----	11868	17353	T.	T.	2457	2360	----	----	1265	1244	----	----	1273	1231	T.	T.	935	1017
21	----	----	1629	3072	T.	T.	11996	20680	T.	T.	2346	2292	2	2	1257	1228	17	6	1317	1232	----	----	929	1019
22	----	----	2057	3873	----	----	11726	22215	2	1	2269	2208	----	----	1220	1191	2	1	1280	1206	----	----	927	1021
23	----	----	2192	4430	----	----	11089	20885	74	74	2508	2375	T.	T.	1176	1185	----	----	1202	1170	----	----	923	1023
24	T.	T.	2014	5006	T.	T.	10781	19875	1	1	2290	2214	T.	T.	1164	1146	1	1	1169	1144	1	1	928	1037
25	7	7	2037	5399	----	----	10322	18263	2	2	2166	2138	T.	T.	1153	1126	----	----	1115	1119	12	12	984	1074
26	19	19	2105	5139	----	----	9728	16172	1	1	2114	2052	T.	T.	1185	1147	----	----	1076	1064	T.	T.	1007	1093
27	----	----	2352	5216	----	----	8970	13883	----	----	2038	1972	----	----	1190	1158	2	2	1077	1048	4	2	1006	1102
28	2	2	2378	5136	----	----	8321	11975	10	12	1995	1967	20	14	1289	1213	T.	T.	1073	1055	T.	T.	1005	1105
29	4	5	3025	5470	----	----	7769	10370	10	9	1982	1926	111	104	1882	1530	32	42	1112	1154	----	----	1017	1090
30	----	----	4005	6113	T.	T.	7303	9002	9	8	1986	1897	24	22	1486	1375	T.	T.	1095	1103	----	----	1015	1100
31	----	----	----	----	24	23	7047	8076	----	----	----	----	2	2	1457	1349	----	----	1044	1069	----	----	----	----

1923

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	31	31	968	1426	----	----	3649	4223	----	----	4234	4668	----	----	1498	1323	2	1	1084	1020	22	32	1167	1211
2	11	12	948	1347	----	----	4329	4609	----	----	3976	4236	T.	T.	1469	1298	2	1	1063	1006	1	1	1106	1126
3	4	4	917	1292	----	----	5361	4984	----	----	3730	3898	4	6	1469	1315	2	2	1059	1004	1	1	1081	1109
4	----	----	904	1256	6	6	6114	5525	T.	T.	3532	3613	32	32	1534	1378	21	22	1140	1065	----	----	1047	1066
5	----	----	923	1279	14	13	5967	6055	----	----	3346	2302	4	6	1483	1349	T.	T.	1135	1050	4	3	1062	1075
6	24	24	1058	1424	----	----	5374	6350	----	----	3152	3091	1	1	1445	1319	----	----	1047	993	----	----	1015	1047
7	4	5	1104	1527	----	----	5771	6482	22	20	3057	2955	34	34	1505	1386	2	2	1063	1005	----	----	970	1021
8	----	----	1117	1601	----	----	6634	6770	21	20	3053	2887	39	41	1596	1443	10	12	1081	1027	T.	T.	973	1009
9	----	----	1168	1689	----	----	6923	7558	2	2	2816	2669	25	28	1595	1454	6	4	1133	1064	----	----	969	1000
10	----	----	1166	1799	----	----	7583	8110	----	----	2684	2556	18	7	1574	1373	55	57	1322	1205	----	----	953	1000
11	T.	T.	1287	2031	----	----	8411	8552	----	----	2590	2432	2	1	1498	1324	46	46	1216	1160	----	----	952	999
12	2	2	1518	2474	T.	T.	8676	8892	2	1	2518	2321	----	----	1445	1262	34	36	1243	1203	14	14	993	1043
13	----	----	1630	2724	28	30	8362	8991	----	----	2469	2218	24	22	1522	1325	20	18	1196	1234	4	4	1002	1067
14	1	1	1480	2658	2	2	7712	8297	----	----	2374	2130	16	16	1580	1371	28	28	1276	1225	12	12	1030	1092
15	----	----	1386	2460	1	1	7120	8052	1	1	2285	2034	----	----	1480	1287	8	8	1263	1237	30	28	1137	1193
16	----	----	1491	2427	14	12	6917	8638	2	2	2237	1979	T.	T.	1422	1253	34	28	1435	1334	30	30	1102	1209
17	----	----	1721	2634	1	1	7254	9224	----	----	2163	1886	T.	T.	1371	1219	43	36	1546	1370	34	32	1142	1251
18	T.	T.	1691	2863	----	----	7908	10226	T.	T.	2095	1851	8	8	1378	1204	30	30	1419	1334	105	102	1293	1570
19	16	12	1584	3046	----	----	8528	12577	----	----	2019	1762	8	4	1368	1197	16	12	1346	1272	----	----	1335	1497
20	----	----	1711	3021	T.	T.	8791	15105	34	29	2085	1831	28	19	1424	1220	3	2	1297	1242	----	----	1315	1366
21	28	28	1677	3024	----	----	8550	15921	----	----	1948	1733	----	----	1368	1185	24	28	1214	1230	----	----	1269	1289
22	65	62	1608	2894	T.	T.	7925	14712	----	----	1895	1681	T.	T.	1285	1160	1	1	1232	1209	6	5	1201	1247
23	----	----	1538	2687	----	----	7286	13487	----	----	1835	1615	----	----	1241	1115	4	4	1183	1182	73	76	1647	1538
24	----	----	1505	2593	T.	T.	6718	12094	----	----	1786	1574	----	----	1206	1080	----	----	1138	1123	----	----	1473	1448
25	12	10	1572	2549	----	----	6361	10660	----	----	1730	1517	2	3	1190	1074	T.	T.	1100	1091	----	----	1265	1341
26	10	12	1692	2613	----	----	6139	9354	22	20	1771	1560	5	5	1213	1090	----	----	1074	1044	----	----	1185	1299
27	2	2	1685	2757	----	----	5871	8214	----	----	1683	1476	2	2	1220	1097	----	----	1041	1008	36	38	1201	1318
28			1907	2792	----	----	5533	7150	----	----	1616	1433	T.	T.	1154	1068	T.	T.	1027	1015	----	----	1225	1332
29	----	----	2486	3198	----	----	5222	6256	----	----	1584	1405	----	----	1071	1033	----	----	1045	1020	----	----	1225	1305
30	T.	T.	3055	3749	----	----	4880	5706	----	----	1536	1366	----	----	1056	1019	2	2	1082	1044	----	----	1211	1277
31	----	----	----	----	----	----	4555	5231	----	----	----	----	10	8	1085	1029	20	16	1104	1074	----	----	----	----

1924

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	----	----	935	1224	----	----	4341	4169	----	----	4310	3582	----	----	1594	1380	14	12	1179	1135	T.	T.	855	992
2	14	16	917	1231	----	----	5536	4854	T.	T.	4078	3365	----	----	1551	1350	----	----	1118	1093	----	----	828	983
3	----	----	1140	1397	----	----	6518	6025	2	T.	3872	3167	----	----	1503	1328	1	1	1113	1081	----	----	824	984
4	----	----	1351	1479	3	3	7629	7232	T.	T.	3699	3017	10	9	1467	1301	14	14	1122	1089	T.	T.	825	969
5	----	----	1745	1670	6	6	8762	8761	T.	T.	3548	2877	34	33	1530	1354	2	2	1149	1091	----	----	826	960
6	----	----	2267	1883	----	----	9294	9408	----	----	3415	2759	10	10	1617	1426	----	----	1090	1056	14	11	850	1000
7	T.	T.	2349	2020	----	----	9400	9499	----	----	3308	2666	2	2	1564	1423	----	----	1020	1046	1	4	857	1015
8	T.	T.	2288	2242	----	----	9657	9626	----	----	3182	2576	17	19	1625	1471	T.	T.	984	1008	1	2	825	1022
9	14	14	2075	2281	----	----	10233	10327	----	----	3053	2482	8	6	1588	1466	T.	T.	1000	1001	10	11	839	1044
10	----	----	2030	2359	----	----	10757	11486	----	----	2967	2390	24	28	1651	1487	17	12	1018	1008	55	60	1078	1192
11	T.	T.	2151	2439	----	----	11031	13047	----	----	2880	2290	T.	T.	1555	1475	4	4	1025	1011	----	----	922	1145
12	----	----	2520	2730	T.	T.	10908	13834	3	4	2795	2222	----	----	1491	1384	2	2	1005	1014	----	----	905	1127
13	----	----	3202	3093	----	----	10643	15004	6	4	2737	2159	----	----	1428	1313	24	28	1056	1093	----	----	901	1106
14	----	----	4295	3750	----	----	10337	17219	----	----	2602	2110	T.	T.	1396	1266	19	19	1112	1120	----	----	901	1101
15	27	24	4279	4158	----	----	10089	18734	2	2	2506	2073	14	14	1424	1250	2	4	1059	1097	T.	T.	887	1083
16	14	12	2845	3961	----	----	9684	18267	T.	T.	2453	2005	10	10	1453	1279	----	----	1006	1047	26	38	972	1166
17	2	2	2191	3448	----	----	9579	17124	----	----	2364	1930	T.	T.	1440	1309	----	----	976	1022	----	----	952	1181
18	T.	T.	1964	3045	T.	T.	9439	15915	----	----	2287	1869	----	----	1343	1243	----	----	952	990	----	----	918	1166
19	----	----	2080	2895	T.	T.	9178	14560	----	----	2200	1812	----	----	1268	1187	----	----	922	969	----	----	956	1155
20	----	----	2722	3083	T.	T.	8845	12839	----	----	2174	1769	----	----	1238	1153	----	----	900	953	T.	T.	949	1144
21	----	----	4373	3616	T.	T.	8530	11229	----	----	2101	1736	----	----	1199	1135	----	----	890	939	----	----	960	1137
22	----	----	5145	4215	----	----	8114	9643	----	----	2059	1677	----	----	1166	1103	----	----	894	931	----	----	969	1143
23	----	----	5801	5214	----	----	7611	8309	----	----	1992	1628	T.	T.	1176	1081	----	----	876	934	----	----	969	1144
24	9	8	6338	6292	8	10	7133	7207	----	----	1912	1590	1	1	1159	1076	13	11	925	970	----	----	966	1165
25	20	18	5878	6520	4	4	6607	6307	----	----	1860	1539	1	2	1165	1068	T.	T.	927	989	T.	T.	972	1168
26	34	36	4583	6109	17	14	6138	5770	----	----	1777	1504	T.	T.	1166	1074	----	----	881	982	----	----	969	1171
27	----	----	3993	5283	18	19	5771	5315	----	----	1721	1469	29	28	1201	1134	3	2	874	980	----	----	970	1165
28	6	6	3571	4659	9	10	5479	4919	5	6	1710	1463	16	16	1274	1198	2	3	883	996	----	----	971	1182
29	----	----	3386	4254	5	6	5108	4555	----	----	1664	1425	6	6	1223	1157	T.	T.	873	992	----	----	981	1186
30	T.	T.	3570	4077	1	1	4855	4242	T.	T.	1640	1413	----	----	1180	1128	T.	T.	861	986	----	----	983	1179
31	----	----	----	----	----	----	4565	3900	----	----	----	----	4	4	1185	1133	1	1	854	993	----	----	----	----

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1924-25

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1			986	1167			972	1190			909	1074			909	1098			877	1070			866	993
2	1	1	994	1174			973	1193			934	1073	T.	T.	909	1109			868	1056			870	1051
3			1001	1200			968	1184	8	10	960	1081			902	1098			877	1066			876	1067
4			1008	1211			971	1188			944	1095			909	1080			874	1085			892	1091
5			1000	1198	22	20	1000	1192	T.	T.	940	1094			909	1067	T.	T.	873	1091			904	1111
6			999	1209	8	8	995	1237	52	53	950	1063			908	1083			878	1086			902	1148
7	12	11	997	1251			969	1162			962	1110			899	1087	33	32	888	1069	83	74	889	1098
8	T.	T.	1018	1224			989	1146	T.	T.	955	1124			899	1060	1	1	880	1045	133	130	888	1089
9			1012	1214			1000	1168	T.	T.	941	1102	T.	T.	899	1049	12	11	885	1040	12	12	878	1082
10			1027	1216	6	6	984	1208			932	1087	4	3	893	1045			870	1046	2	2	870	1056
11	15	17	1030	1231			963	1181			920	1100	T.	T.	897	1056			868	1060	T.	T.	877	1063
12			1019	1239	22	22	973	1181			924	1104	T.	T.	888	1022			876	1072	11	11	877	1071
13			1016	1243	T.	T.	967	1201			932	1116			888	1050	1	1	866	1072	4	3	877	1050
14	47	54	1062	1326			964	1183			933	1118			889	1031			866	1045			868	1043
15	10	12	1215	1416			963	1166			931	1116	8	8	893	1014	T.	T.	865	1047			871	1041
16			1075	1319			963	1178	50	50	935	1141	T.	T.	882	1017			866	1028	1	2	873	1046
17	26	28	1112	1316			963	1167	52	50	941	1149			875	1005			866	1022	12	11	897	1046
18			1099	1325	47	46	967	1178	17	17	939	1143			866	999			866	1046			884	1018
19			1017	1248	2	3	972	1193			913	1118	T.	T.	866	1016			866	1033			887	1027
20			1001	1207			966	1199			919	1113			866	1028	T.	T.	866	1074			927	1078
21			1008	1201			971	1201			920	1124			866	997	10	10	866	1037			955	1133
22			985	1209			964	1211	8	8	936	1134			866	990	T.	T.	865	1048			973	1180
23			984	1206			963	1171	28	22	937	1147			866	1019			858	1040	2	2	971	1196
24			997	1200	T.	T.	953	1137			917	1122	1	1	871	1040	T.	T.	866	1060			970	1208
25			993	1212			941	1119			909	1105	T.	T.	877	1042			866	1041			1030	1319
26			981	1205			943	1127			909	1105	3	2	877	1039			866	1014			1085	1366
27			968	1200			946	1116			906	1109			877	1035	T.	T.	866	1029	40	38	1022	1270
28			968	1198			952	1126			918	1119	2	1	877	1044	2	2	866	1024			1055	1302
29	30	29	1011	1222			914	1112	T.	T.	920	1125			873	1035							1141	1383
30	1	1	1013	1223			909	1102			920	1123			866	1052					T.	T.	1207	1409
31			977	1211					3	3	919	1123			868	1058							1326	1433

1925-26

Date	October				November				December				January				February				March			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1			840	913			838	949			834	920	12	12	802	882	T.	T.	759	804			731	931
2			837	904	80	77	862	990	T.	T.	834	929	22	20	804	898			749	837			735	863
3	T.	T.	858	906	23	22	866	991	2	2	833	901			813	899	T.	T.	727	833			735	878
4	6	6	866	929			865	982			818	850			806	896			727	861	1	1	738	877
5	52	47	1009	1049	1	1	857	963			813	922			794	868			720	880	17	22	746	851
6	T.	T.	928	993	65	62	859	968	2	2	813	927	1	2	792	866			735	797			738	864
7			878	962			866	986	5	6	813	922			792	848			752	824			729	872
8			866	950			866	977	T.	T.	813	908			792	835			763	857			727	909
9			866	942			856	970			802	909			792	848			764	850	26	28	727	890
10	26	24	890	980			856	977			802	911			784	848			763	857	38	40	727	860
11	34	32	1071	1130			865	981			802	908	T.	T.	783	821			762	864			744	924
12	4	4	945	1031			866	984			807	916			749	816			759	825			744	907
13	34	36	947	1144	T.	T.	866	975	2	2	813	920			753	847	2	2	757	836			754	965
14	37	40	941	1124	T.	T.	852	926	T.	T.	804	874			747	825	1	1	759	837			773	985
15			923	1071			834	924			763	814			708	821	T.	T.	755	834			788	985
16			928	1062			834	967			772	851	T.	T.	730	838	13	12	752	836			782	1012
17			915	1054			834	952			783	881			708	842	12	12	744	824	T.	T.	787	1017
18			909	1028			834	947			780	878	T.	T.	729	831			739	820	T.	T.	762	978
19			917	1004			804	923			803	867	12	11	737	793			727	839	22	22	759	987
20			892	989			792	917			796	865	20	18	718	804			727	831	30	34	759	995
21			879	982			804	922			787	869			719	797	T.	T.	733	848	15	10	759	992
22			882	982			826	924			792	854	1	1	673	796			732	845			789	1013
23	38	40	930	1043			834	931			793	864			667	798	8	8	737	835			817	1044
24			909	1011	T.	T.	834	929			792	870	1	1	659	800			735	850			825	1075
25			891	992			834	934			792	856			710	805	2	2	731	829	10	8	795	999
26			877	972			834	930			784	871			715	817			714	888	T.	T.	789	960
27			872	976			828	935			792	878			724	794			712	896	T.	T.	775	921
28			877	980			816	950			787	878			707	788			729	902	2	2	770	893
29	T.	T.	874	974			824	928			764	884			697	811					26	26	767	877
30			853	960			833	919			771	867	2	1	759	824					T.	T.	762	891
31			848	952					T.	T.	792	840			755	798					28	26	787	888

TABLE 66.—*Daily run-off in hundred-thousandths of an inch over watershed and precipitation in hundredths of an inch*—Continued

1925

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	1	T.	1388	1341	T.	T.	2523	3257	T.	T.	1594	1762			1038	1117			826	935	5	2	855	958
2			1411	1354			2533	3718	4	4	1593	1722	16	16	1049	1148	7	9	813	938	4	6	835	941
3			1415	1409			2532	3937	52	55	1627	1842	4	2	1029	1129	34	50	905	1069	T.	T.	818	921
4			1587	1488	12	12	2602	3914	64	66	2224	2156	48	58	1120	1258	18	20	887	1036	22	18	878	975
5	1	2	1753	1530	8	8	2640	3935	12	9	2118	2013	30	32	1272	1324	1	1	874	1012	4	8	856	976
6	21	24	1617	1442	1	2	2624	3839			1835	1834	1	1	1122	1213			820	966	8	6	857	967
7	25	27	1438	1373	1	T.	2607	3724			1727	1720			1041	1147			821	945			834	941
8			1359	1282	6	8	2533	3872			1653	1636	12	14	1026	1141	4	4	815	929			804	926
9			1370	1290	4	5	2446	3890	T.	T.	1611	1583	34	36	1096	1203	34	31	929	1012	7	7	806	942
10			1547	1409	14	13	2398	3803			1592	1526	29	29	1120	1205	54	56	1048	1134			812	936
11			1861	1550	48	46	2750	4029	36	38	1660	1646	11	12	1156	1234	3	3	916	1042	2	1	806	921
12			2196	1700			2670	3704			1611	1564	2	3	1017	1125	12	10	873	1015	17	20	843	957
13			2249	1745			2493	3623			1528	1498	T.	T.	970	1049	3	2	867	979	6	6	851	938
14			2305	1793	1	1	2431	3443			1484	1447			940	1029			829	941	2	2	825	933
15			2379	1849			2408	3238			1451	1405	11	15	939	1027			781	901			810	916
16			2460	1928			2374	3081	8	10	1450	1445	4	3	913	1004			767	883			798	905
17			2436	2059			2344	2985			1411	1401	7	7	899	993	T.	T.	763	863	6	6	825	934
18			2296	2071			2281	2884			1374	1359	9	9	897	999	45	58	857	1024	43	46	905	1027
19			2291	2152			2233	2765	3	2	1367	1348	22	20	855	987	24	28	912	1043	16	16	962	1049
20			2369	2414			2142	2648	4	3	1332	1356	31	30	1019	1102	5	8	860	1009			867	984
21	30	31	2354	2657	11	10	2091	2572	8	8	1314	1361	32	37	1024	1141	T.	T.	824	960	2	4	858	968
22	20	22	2246	2685			2009	2447	2	T.	1263	1335	1	2	997	1084	20	21	810	978			855	931
23	2	2	2078	2304			1945	2315			1240	1286	4	4	931	1042	33	30	938	1098	T.	T.	863	923
24			2090	2104	6	6	1909	2201			1182	1251	T.	T.	903	1005	14	12	952	1127	T.	T.	863	907
25			2131	2080			1861	2129	2	2	1145	1222	3	8	901	1016	17	16	915	1077			861	922
26			2134	2266	T.	T.	1803	2042	2	3	1135	1211	8	8	915	1006			860	1012			860	930
27	T.	T.	2166	2549	T.	T.	1759	1984	12	11	1142	1221	34	33	1007	1093	4	2	849	980			850	917
28			2245	2829			1719	1931	1	1	1136	1194	1	1	944	1034	24	22	878	986			844	912
29	30	32	2255	3023	T.	T.	1660	1854	5	6	1093	1173	10	12	920	1028			891	990			847	911
30	11	8	2447	3109			1638	1801	T.	T.	1088	1170			874	982			830	954			847	910
31					6	6	1616	1795					4	5	843	955	1	1	819	933				

1926

Date	April				May				June				July				August				September			
	Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off		Precipitation		Run-off	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	40	38	770	879	7	6	3045	3834	2	2	2724	2960	6	6	1367	1203	T.	T.	812	803			646	665
2			767	898	T.	T.	3177	4068	2	1	2676	2840	10	8	1313	1157			796	771	11	12	672	705
3	2	2	770	903	25	23	3349	4351			2621	2681	14	15	1344	1179	34	28	843	817	21	20	709	749
4			810	969	T.	T.	3613	4738			2577	2582	2	1	1317	1173	14	14	881	841	5	6	741	755
5			841	1033	34	36	3759	5355			2528	2455	10	10	1324	1179	1	T.	862	825			709	735
6	T.	T.	894	1089	2	2	4066	6103	3	1	2492	2393	22	21	1389	1218	85	97	1215	1146			690	719
7	T.	T.	956	1242	1	1	4125	6628			2455	2324	9	10	1400	1224	63	66	1229	1083	T.	T.	685	718
8	4	4	928	1213	13	14	4160	7077			2393	2193			1274	1154	2	2	1223	1034	1	1	679	708
9	T.	1	944	1108	1	1	3934	6966	T.	T.	2319	2103			1190	1079			932	939			657	707
10	4	T.	971	1068	14	14	3673	6498			2255	1992			1147	1041	12	6	919	912	T.	T.	645	711
11			1030	1071	3	3	3517	6077	T.	T.	2197	1934	96	92	1697	1300	2	1	931	895	28	28	731	796
12			1074	1153	18	20	3328	5568	25	24	2244	1950	15	6	1404	1191	2	2	918	887			710	770
13	T.	T.	1096	1202	8	6	3203	5110	T.	T.	2138	1869	T.	T.	1266	1112			885	861			683	747
14			1193	1237			3183	4763			2043	1779	2	2	1134	1054	8	7	890	859	T.	T.	660	740
15			1305	1314	12	15	3164	4622			1957	1710	T.	T.	1137	1016	2	2	878	843	3	3	676	742
16			1452	1386	1	1	3244	4591			1900	1634			1103	975	T.	T.	868	827	4	4	677	755
17	T.	T.	1434	1372	T.	T.	3380	4749	5	6	1871	1610			1057	947	T.	T.	856	817	1	1	684	757
18			1546	1444	T.	T.	3521	4955			1843	1575			1036	926	2	2	857	821			673	763
19	16	18	1450	1379			3678	5801			1759	1509			999	894			821	798			673	759
20	70	68	1372	1307			3722	6741			1698	1462	21	26	1041	920			788	770	1	2	676	742
21	2	2	1536	1471	T.	T.	3718	6805			1655	1399	4	6	1035	926	T.	T.	760	763	1	1	688	738
22	T.	T.	1732	1603			3652	6528			1556	1359	T.	T.	988	906	T.	T.	738	751	8	8	704	763
23			1956	1631			3550	6096			1493	1323	T.	T.	958	892	T.	T.	744	745			694	761
24			1995	1594	8	8	3476	5584			1432	1264	2	2	921	917			706	733			685	753
25			2271	1669			3328	4974			1385	1223	2	2	915	901	T.	T.	693	724	2	2	701	759
26			2545	1857	26	27	3312	4587	2	2	1335	1191	T.	T.	890	889			687	716	66	70	897	946
27	12	11	2508	2071	2	4	3240	4145			1307	1180	19.	18	936	931			671	699	8	8	804	870
28			2673	2575	2	3	3072	3798	T.	T.	1289	1158	11	12	948	947	1	1	665	701	T.	T.	784	841
29			2759	2986	T.	T.	2918	3560			1247	1140	12	16	947	939	T.	T.	657	694			786	828
30			2857	3466	12	9	2843	3357	62	53	1419	1218			900	902			650	689	6	8	792	838
31							2783	3145					T.	T.	854	867			646	673				