627.41 (73)

IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS DURING MARCH, 1917.

By ALFRED J. HENRY, Professor in Charge.

[Dated: Weather Bureau, Apr. 20, 1917.]

The rainfall over the southern Appalachian region in March, 1917, was considerably heavier than elsewhere in the United States (see Chart V, Total Precipitation for March, 1917). The monthly totals exceeded 10 inches at a number of points in the Tennessee and Cumberland watersheds in Tennessee and western North Carolina, also in southeastern Kentucky and southern West Virginia. As a consequence practically all of the streams of these regions were out of their banks for a greater or less time during the month. Likewise the rivers of the Piedmont region of the Carolinas and the rivers of Alabama and Georgia were also in flood.

The greatest flood of the month, however, was that in the Tennessee River due to a continuous period of rains that began on the 1st and ended on the 5th.

The meteorological phenomena that led up to this flood may be found in the development and movement of cyclonic and anticyclonic systems over the Tennessee watershed, beginning February 28 and terminating March 5. On February 28 a weak cyclonic system was centered directly over eastern Tennessee attended by general rains over that State, and adjacent regions to the east and northeast. The movement of an anticyclone eastward from the lower Missouri Valley to the Middle Atlantic seaboard in the 36 hours ending 8 a. m., March 2, 1917, evidently prevented the weak cyclonic system before mentioned from pursuing the normal northeastward movement; consequently, it was held over eastern Tennessee for a much longer time than would ordinarily be the case. Meanwhile, a second cyclonic system or area of low pressure that had remained over southern Texas for 36 hours began to move northeastward. By the morning of the 30th it had reached eastern Tennessee and again within a period of less than 48 hours atmospheric conditions favorable to heavy precipitation over that region were present. The heavy rains of the 3d and 4th (see Table 1) were due to the second disturbance which did not move from its position on the morning of the 3d until the night of the 4th–5th. The rain had practically ceased by the morning of the 5th and the next few days were clear and cold with night temperatures below freezing.

Table 1 below presents the daily precipitation at a number of stations in the Tennessee River basin above Chattanooga.

TABLE 1.—*Daily precipitation, in inches and hundredths, at points in the Tennessee Basin above Chattanooga, Tenn., March, 1917.*

Dates.	Knoxville, Tenn.	Asheville, N. C.	Dandridge, Tenn.	Newport, Tenn.	Greeneville, Tenn.	Rogersville, Tenn.	Mendota, Va.	Bluff City, Tenn.	Elizabethton Tenn.	Loudon, Tenn.	Chattanooga, Tenn.	Speers Ferry, Va.	Clinton, Tenn.	Kingston, Tenn.	McGhee, Tenn.	Tazewell, Tenn.	Charleston, Tenn.	Bryson, N. C.	Murphy, N. C.
1917.																			
Mar. 1	2.22	0.75	1.82	1.80	1.75	1.90	1.05	1.07	1.02	2.39	0.88	1.10	2.12	2.20	1.90	1.38	0.91	1.50	1.94
2	0.17	0.46	0.42	0.80	0.43	0.30	0.61	0.48	0.63	0.25	0.75	0.59	0.20	0.15	0.22	0.30	0.58	0.65	1.01
3	1.71	0.33	1.16	0.98	0.83	1.45	1.30	0.73	0.73	1.79	1.92	1.50	1.96	2.05	1.32	1.95	1.55	0.99	1.61
4	2.04	0.45	1.97	1.75	1.60	1.60	1.75	0.85	1.15	1.77	1.23	1.20	2.15	2.02	1.83	1.97	1.45	2.95	2.00
5	0.38	0.36	0.62	0.60	0.43	0.73	0.56	0.55	0	0.06	0.12	0.24	0.26	0.11	0.26	0.50	0.20	0.55	0.30
6	T.	0	T.	0.06	0.11	T.	0	0.15	T.	0	T.	0	0	0	0	T.	0	0.02	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0.22	0.15	0.53	0.30	0.26	0.24	0.37	0.18	0.10	0.14	0.16	0.10	0.20	0.17	0.35	0.24	0.05	0.50	0.24
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0.17	T.	0.08	0	0.04	0.02	0	0	0	0.19	0.18	0	0.52	0.30	0.20	0	0.06	0.05	0
12	0	0.04	0.13	0.20	0.78	0.52	0	0.50	1.00	0	0.02	0.70	0	0	0	1.50	0	0.70	0
13	1.35	0.56	1.81	1.40	0.30	0.43	0.47	0.80	0.0	0.76	0.26	0.32	1.04	0.55	1.18	0.34	0	0.25	0.14
14	0.49	0.03	0.62	0.40	0.48	0.43	0.15	0.20	0.35	0.76	0.57	0.24	0.58	0.54	0.45	0.37	0.22	0.50	0.34
15	0	0	0	0.10	0.09	T.	0.12	0.20	0	0	0	0.22	0	0	0	0	0	0.06	0.13
16	0.06	0.02	0.06	0.04	0.03	0.07	0	0.05	0	0.18	0.10	0.05	0.12	0.37	0.02	0.25	0.05	0	0.03
17	1.86	0.37	1.38	1.20	0.93	1.46	1.54	1.10	1.10	1.47	1.45	1.52	2.00	1.64	1.41	2.05	1.30	0.14	1.18
18	0	0.04	0	0.04	0.03	T.	0	T.	0	0	T.	0	0	0	0	T.	0	0.97	0
19	0	0.04	0	0	0.01	T.	0	0.04	T.	0	0	0	0	0	0	T.	0	0.06	0
20	T.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.01	0.04
21	0.72	0.15	0.75	0.32	0.68	0.66	0.16	0.30	0.65	0.65	1.42	0.21	0.73	0.65	0.81	0.62	0.98	0.97	1.40
22	0.01	0.13	0.13	0.58	0.16	0.13	0.28	0.25	0	0.13	0	0.35	0.14	T.	0	T.	0	0.23	0.08
23	0.08	0.03	0.08	0.09	0.10	0.01	0	0	0	0.26	1.04	0	0.09	0.30	0.08	T.	0.40	0.44	0.90
24	1.70	1.02	1.64	1.45	1.26	1.53	1.56	1.35	1.14	1.31	1.37	1.35	1.45	1.33	1.85	1.84	1.20	2.06	2.00
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0.40	0	0	0	0	0	0	0	0	0	0
27	1.01	0.94	0.86	0.90	0.77	0.50	0.41	0.30	0.05	0	2.48	0.32	1.20	1.32	1.32	0.86	1.60	2.50	2.00
28	T.	T.	0.04	0.12	0.12	0.03	0.02	0.05	0	1.07	0	0	0	0	0	T.	0.04	0.02	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	14.19	5.87	14.08	13.13	11.19	12.01	10.35	9.15	8.32	13.18	13.95	10.01	14.76	13.70	13.10	14.17	10.59	16.12	15.34

TABLE 2.—*Daily stages in the Tennessee and its tributaries during the flood of March, 1917.*

Dates.	Rogersville, Tenn.	Dandridge, Tenn.	Knoxville, Tenn.	Loudon, Tenn.	Guntersville, Ala.	Chattanooga, Tenn.	Florence, Ala.	Johnsonville, Tenn.	Riverton, Ala.	Bridgeport, Ala.	Decatur, Ala.
Flood stages	*14.0*	*10.0*	*12.0*	*25.0*	*31.0*	*33.0*	*18.0*	*31.0*	*32.0*	*24.0*	*21.0*
1917.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Mar. 1	5.3	3.0	5.4	4.8	17.1	17.7	11.7	23.0	26.6	10.7	12.8
2	10.5	9.8	15.0	13.2	18.2	20.9	13.3	22.3	28.1	12.2	14.0
3	11.0	8.3	17.0	16.0	22.5	29.0	16.0	24.5	33.1	17.8	15.7
4	13.0	11.2	19.5	21.0	29.4	35.6	19.9	27.0	37.6	21.6	18.0
5	17.1[a]	16.0[b]	28.2[c]	29.6[d]	32.5	40.5	21.5	28.9	40.9	25.6	19.5
6	12.0	10.5	24.2	28.0	34.0	44.5	22.1	30.5	42.8	27.8	20.4
7	7.3	7.3	15.9	20.6	35.9	47.3[f]	22.2	31.9	43.4	29.6	21.0
8	6.0	5.4	10.0	12.6	37.2	47.4	22.6	33.0	43.6	30.7[h]	21.9
9	5.4	5.0	8.0	9.2	38.5	44.9	22.6	33.7	43.8	30.6	22.4
10	4.8	4.2	7.6	8.5	39.4[e]	38.0	23.0	34.0	44.2	28.0	23.1
11	4.4	3.6	5.8	6.4	38.7	27.9	24.0	34.3	45.5	25.3	23.6
12	4.3	3.4	5.4	5.7	36.5	20.8	24.7	34.8	46.6	19.7	23.7
13					33.8	17.8	24.3	35.5	47.0	14.0	23.4
14					29.7		23.5	36.2	46.5	12.1	22.2
15					25.2		21.9	37.0	45.5		20.2
16					22.7		19.2	37.7	43.4		18.0
17							17.5	38.4	41.1		16.9
18							17.8	38.8[g]	40.2		16.5
19							16.8	38.7	39.0		16.4
20							15.7	38.3	37.4		
21								37.4	36.8		
22								36.2			
23								35.5			
24								35.0			

[a] Rogersville, Tenn., 5th, 1 p. m., stage=17.3 feet.
[b] Dandridge, Tenn., 5th, during night of 4th-5th, stage=16.7 feet.
[c] Knoxville, Tenn., 5th, 12:20 p. m., stage=28.6 feet.
[d] Loudon, Tenn., 5th, 3:00 p. m., stage=30.2 feet.
[e] Guntersville, Ala., 10th, 7 to 11 a. m., stage=39.4 feet.
[f] Chattanooga, Tenn., 7th, 8:40 p. m., stage=47.7 feet.
[g] Johnsonville, Tenn., 18th, 6 p. m., stage=38.9 feet.
[h] Bridgeport, Ala., 8th, 2:00 p. m., stage=30.9 feet.

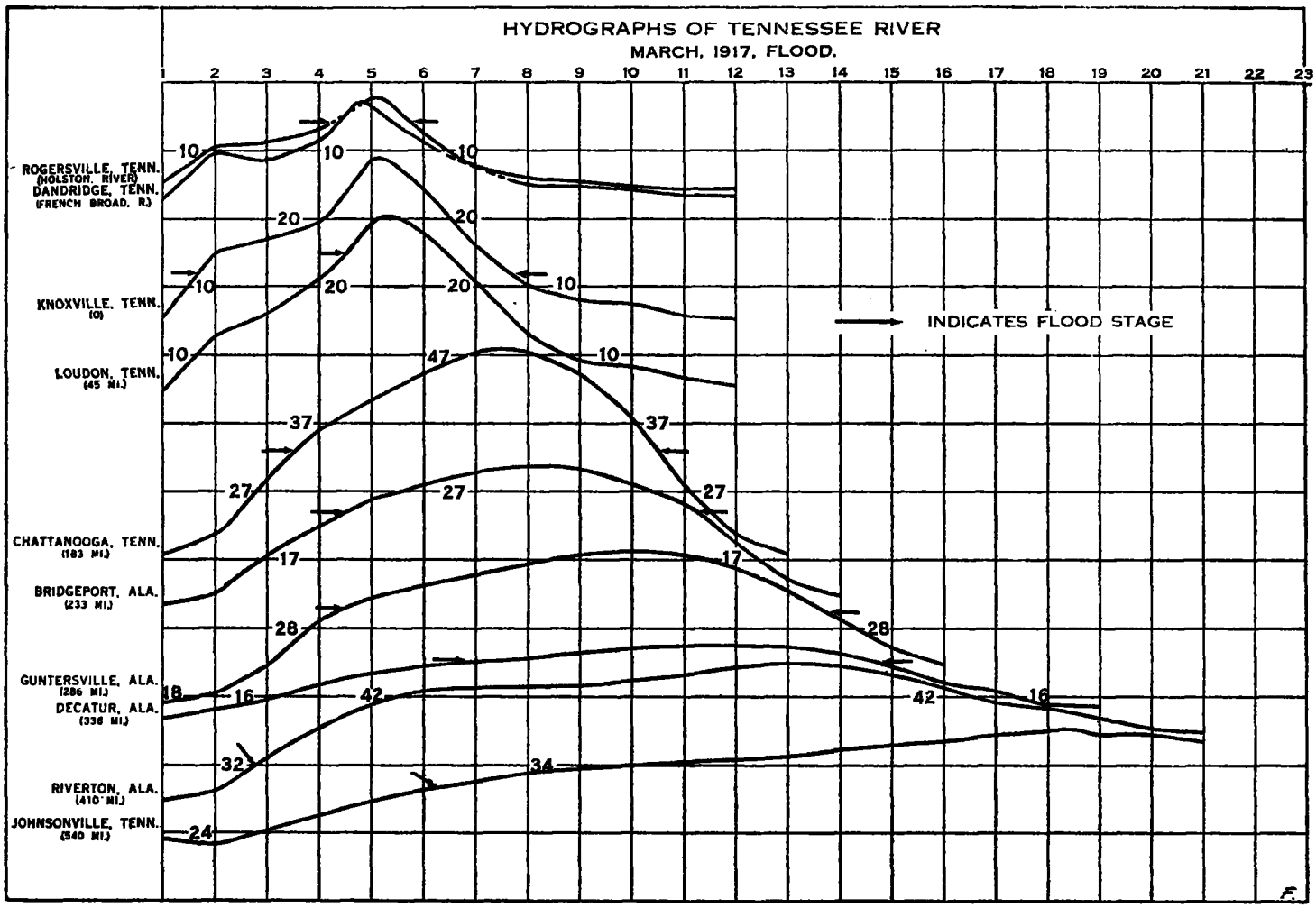

FIG. 1.—Hydrographs for stations on the Tennessee River during the floods of March, 1917. Distances below Knoxville are given by the figures in ( ) beneath the station name. (See Table 2.)

The rainfalls in Table 1 clearly show that while the daily amounts were not extraordinary the period of rainy days was practically continuous from the 1st to the 5th of the month. It is also apparent at a glance that this period of rainy days was the direct and immediate cause of the flood in the Tennessee. The areal distribution of the rainfall is fairly uniform except that in the upper French Broad, as at Asheville, N. C., there was decidedly less rain than at other points to the southwest. The French Broad at Asheville barely passed above the flood stage on the 4th and fell below flood stage on the 6th.

Figure 1 includes a hydrograph for the French Broad at Dandridge, Tenn., 46 miles above the mouth of the river. This hydrograph shows that the lower reaches of the stream were in sharp flood and that the flood crest synchronized very well with that of the Holston River, the other of the two main tributaries of the Tennessee. These two tributaries unite at Knoxville, where the flood crested about noon of the 5th. Between Knoxville and Loudon, the next down-river station, two important tributaries join the main stream, viz, the Little River and the Little Tennessee River. Both of these head in the mountains of western North Carolina, where the rainfall of the 4th and 5th was undoubtedly heavy; see the record for Bryson City and Murphy, N. C.

The hydrograph for Loudon shows that the crest of the flood at that point was reached slightly earlier on the 5th than at Knoxville, although the latter is 45 miles farther upstream. There must have been therefore a more prolonged crest at Loudon than is shown by the hydrograph. This is established by the fact that the 24-hour fall at Loudon from the 5th to the 6th was but 1.4 feet as compared with a fall of 4 feet for the same period at Knoxville.

The next down-river station is Chattanooga, 183 miles below Knoxville. Here the character of the flood wave is much altered, as might be expected, being much flatter than at up-river points, and the crest occurring about 2 days later. Below Chattanooga the flood wave is still more flattened out. At Johnsonville, Tenn., 540 miles by river below Knoxville, there was simply a long flat swell, beginning on the 2d and ending about the 18th—see fig. 1.

Numerous other floods occurred in the rivers of the South Atlantic and East Gulf drainage, as shown by Table 4.

A moderate flood swell passed down the Ohio, beginning at Pittsburgh on the 13th and passing Cincinnati on the 17th, at a crest stage of 56.1 or 6.1 feet above flood stage. The crest passed Louisville 1 or 2 days later and Evansville, Ind., on the 22d, at a stage of 42.9 feet, 7.9 feet above flood stage. The crest of this flood passed into the Mississippi at Cairo on the 25th, with the river at 49.2, at which height it remained on a stand until the 29th, when a fall of 0.2 foot was registered. The river then continued to fall slowly until the end of the month, but began to rise again in April and reached a second crest of 50.1 feet on April 4–5, 1917.

Warnings of all these floods were distributed in advance and the property loss was therefore greatly minimized. There was an unpreventable loss of nearly a million dollars, as exhibited in the statement below, the greater part of which was sustained in the city of Chattanooga, Tenn. The loss attributed to "prospective" crops may or may not be fully realized, owing to the early season of the overflow.

Loss by flood, March, 1917.

The loss in many cases was minimized by the fact that no crops were on the ground and that warnings of the approach of the flood waters were distributed sufficiently in advance to permit the withdrawal of movable property from the zone of danger.

Drainage division.	Tangible property; bridges, highways, etc.	Crops.		Live stock, other movable property.	Suspension of business.	Totals.
		Matured.	*Prospective.*			
South Atlantic	$4,000	$100	$5,500	$400	$7,375	$17,375
East Gulf	500	.....	30,000	11,000	10,100	51,600
Mississippi:						
Eastern tributaries—Tennessee and Ohio	498,185	.....	53,000	2,320	38,500	592,005
Western tributaries—Missouri	100,000	.....	.....	.....	.....	100,000
Total	602,685	100	88,500	13,720	55,975	760,980

Saved by warnings, estimated.

South Atlantic	$ 99,700
East Gulf	88,000
Mississippi, eastern tributaries	1,050,500
Total	1,238,200

The details of floods in all parts of the country are presented below in Tables 3, 4, 5, and 6. Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 3.—*Flood stages in rivers of the North Atlantic drainage, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Connecticut	Hartford, Conn.	16	26	(*)	18.3	30
Hudson	Troy, N. Y.	15	28	28	17.7	28
Do.	Albany, N. Y.	12	28	28	12.7	28
Mohawk	Utica, N. Y.	11	.....	.....	10.3	25
Do.	Schenectady, N. Y.	15	25	25	17.9	25
Delaware, E. Br.	Fishs Eddy, N. Y.	10	28	28	12.3	28
Susquehanna	Bainbridge, N. Y.	11	28	29	12.4	28
Do.	Binghamton, N. Y.	14	.....	.....	13.9	28
Unadilla	New Berlin, N. Y.	8	25	28	10.4	28
Chenango	Sherburne, N. Y.	8	24	29	8.9	28
Potomac	Cumberland, Md.	8	12	13	12.0	12
Do.	Harpers Ferry, W. Va.	18	.....	.....	17.5	13

* Continued above flood stage after the end of the month.

TABLE 4.—*Flood stages in rivers of the South Atlantic and east Gulf drainage, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
James	Buchanan, Va	15	5	5	17.6	5
Do	Columbia, Va	18	5	6	24.7	6
Do	Richmond, Va	10	5	7	14.1	6
Roanoke	Randolph, Va	21	5	7	26.6	6
Do	Weldon, N. C	30	5	9	41.8	8
Dan	Danville, Va	8			7.8	4
Do	Clarksville, Va	12	7	7	12.4	7
Tar	Tarboro, N. C	18	7	11	21.2	10
Do	Greenville, N. C	13	7	13	15.2	11
Fishing Creek	Enfield, N. C	14	6	7	14.3	7
Neuse	Neuse, N. C	18			17.6	5
Do	Smithfield, N. C	13	5	11	18.3	7
Do	do	13	27	(*)	13.6	31
Cape Fear	Elizabethtown, N. C	20	6	10	30.3	8
Do	do	20	26	29	25.3	27
Do	Fayetteville, N. C	35	6	7	41.3	6
Haw	Moncure, N. C	22	5	5	23.6	5
Pee Dee	Cheraw, S. C	27	5	8	33.3	6
Do	do	27	26	26	28.8	26
Santee	Rimini, S. C	12	(†)	18	18.7	10
Do	do	12	24	(*)	17.0	31
Do	Ferguson, S. C	12	(†)	20	14.7	10
Do	do	12	24	(*)	13.9	31
Catawba	Catawba, S. C	11	5	6	17.5	5
Do	do	11	25	25	13.5	25
Wateree	Camden, S. C	24	5	7	30.3	6
Do	do	24	26	26	27.0	26
Congaree	Columbia, S. C	15	6	6	17.8	6
Do	do	15			14.8	26
Broad	Blairs, S. C	15	5	6	18.1	6
Do	do	15	25	25	15.5	25
Saluda	Pelzer, S. C	7	5	6	8.6	5
Do	do	7	24	27	10.2	25
Do	Chappells, S. C	14	5	8	19.0	6
Do	do	14	26	29	18.0	27
Broad	Carlton, Ga	11	25	25	12.3	25
Do	do	11	27	28	13.0	27
Oconee	Milledgeville, Ga	22	5	6	24.6	5
Do	do	22	28	28	23.2	28
Ocmulgee	Macon, Ga	18	5	6	19.5	5
Do	do	18	27	29	19.4	28
Do	Abbeville, Ga	11	(†)	2	11.6	1
Do	do	11	9	14	14.3	11
Do	do	11	29	(*)	12.9	31
Do	Lumber City, Ga	15			14.5	14–15
Flint	Woodbury, Ga	10	5	5	10.1	5
Do	Montezuma, Ga	20			18.4	7
Do	Albany, Ga	20	10	12	20.8	11
Chattahoochee	Norcross, Ga	16	25	25	16.7	25
Do	West Point, Ga	20			18.4	5
Do	do	20			19.6	28
Do	Eufaula, Ala	40	5	7	43.3	6
Do	Alaga, Ala	30	5	9	36.9	7
Do	do	30	28	(*)	32.5	30
Alabama	Montgomery, Ala	35	5	11	48.3	7
Do	do	35	27	(*)	40.8	29
Do	Selma, Ala	35	5	14	50.1	9
Do	do	35	27	(*)	43.5	31
Tallapoosa	Milstead, Ala	40	4	5	45.0	5
Coosa	Rome, Ga	30	5	6	30.5	5
Do	do	30	28	28	30.0	28
Do	Gadsden, Ala	22	5	13	25.2	9–10
Do	do	22	25	(*)	25.2	31
Do	Lock No. 4, Ala	17	4	13	20.3	5
Do	do	17	25	(*)	19.4	27
Do	Wetumpka, Ala	45	5	7	47.8	6
Do	do	45			41.5	28
Etowah	Canton, Ga	11	4	5	15.6	4
Do	do	11	24	25	17.0	24
Oostanaula	Resaca, Ga	25	5	7	30.2	6
Do	do	25	25	29	28.0	26
Cahaba	Centerville, Ala	25	4	4	26.8	4
Do	do	25	24	24	25.0	24
Tombigbee	Demopolis, Ala	39	)	20	54.6	12
Do	do	39	24	(*)	52.7	31
Black Warrior	Tuscaloosa, Ala	46	4	7	54.6	5
Do	do	46	24	28	54.0	25
Pascagoula	Merrill, Miss	20	6	9	20.5	6
Chickasawhay	Enterprise, Miss	21	6	7	22.5	6
Do	Shubuta, Miss	27			26.9	9
Pearl	Edinburg, Miss	21	6	8	22.8	7
Do	Jackson, Miss	20	(†)	18	26.6	13
Do	Columbia, Miss	18	4	11	20.8	7

* Continued above flood stage after the end of the month.
† Above flood stage at the beginning of the month.

TABLE 5.—*Flood stages in the Ohio River drainage, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Ohio	Pittsburgh, Pa	22	13	13	23.1	13
Do	Beaver Dam, Pa	30	13	14	33.0	13
Do	Dam 13, near Wheeling, W. Va.	36	14	14	37.0	14
Do	Marietta, Ohio	33	14	16	36.7	15
Do	Parkersburg, W. Va	36	15	16	38.5	15
Do	Dam 19, W. Va	39	15	15	39.0	15
Do	Point Pleasant, W. Va.	40	14	18	47.3	15
Do	Dam 26, Hogsett, W. Va.	50	16	16	50.1	16
Do	Dam 28, near Huntington, W. Va.	50	16	16	50.0	16
Do	Dam 29, Normal, Ky	50	15	18	54.3	16
Do	Portsmouth, Ohio	50	15	19	54.4	16–17
Do	Maysville, Ky	50	15	19	53.4	17
Do	Cincinnati, Ohio	50	14	20	56.1	17
Do	Madison, Ind	46	16	20	46.8	19
Do	Louisville, Ky	28	16	21	30.5	19
Do	Cloverport, Ky	40	8	25	46.0	21
Do	Evansville, Ind	35	7	(*)	42.9	22
Do	Mount Vernon, Ind	35	9	(*)	43.2	23
Do	Shawneetown, Ill	35	9	(*)	45.8	24
Do	Paducah, Ky	43	16	(*)	47.1	25–26
Do	Cairo, Ill	45	17	(*)	49.4	25–27
Allegheny	Herrs Island Dam, Pa.	22	13	13	24.2	13
Kiskiminetas	Saltsburg, Pa	8	12	12	8.8	12
Stony Creek	Johnstown, Pa	10	12	12	12.0	12
Monongahela	Fairmont, W. Va	25			24.8	13
Do	Greensboro, Pa	20	12	14	23.6	13
Do	Lock No. 4, Pa	31	13	14	35.0	13
Youghiogheny	Confluence, Pa	10	12	12	10.6	12
Shenango	Sharon, Pa	9	12	12	9.0	12
Muskingum	Marietta, Ohio	32	14	17	38.1	15
Tuscarawas	Norris Point, Ohio	8	12	12	8.0	12
Do	Coshocton, Ohio	8			7.2	14
Scioto	Circleville, Ohio	7	14	16	11.4	15
Do	Chillicothe, Ohio	14	15	15	14.4	15
Little Kanawha	Glenville, W. Va	22	12	12	27.0	12
Kanawha	Charleston, W. Va	30			29.7	5
Elk	Sutton, W. Va	30	12	12	30.0	12
Do	Clay, W. Va	18	12	12	20.2	12
Big Sandy:						
Tug Fork	Williamson, W. Va	26	4	4	30.8	4
Levisa Fork	Pikeville, Ky	40	4	4	41.0	4
Miami	Tadmor, Ohio	12	14	14	12.8	14
Green	Lock 6, Ky	30			29.8	15
Do	Lock 4, Woodbury, Ky.	33	3	10	37.3	6
Do	do	33	13	21	36.6	15
Do	do	33	26	28	35.3	27
Do	Lock 2, Rumsey, Ky	34	5	(*)	40.0	21–22
White	Decker, Ind	18	18	23	20.4	22
White, East Fork	Shoals, Ind	20			19.8	19
White, West Fork	Noblesville, Ind	14			13.0	15
Do	Elliston, Ind	19	15	19	23.5	18
Wabash	La Fayette, Ind	11	14	18	15.1	16
Do	Terre Haute, Ind	16			15.4	19
Do	Mount Carmel, Ill	15	16	25	19.2	23
Cumberland	Williamsburg, Ky	22	5	5	22.4	5
Do	Celina, Tenn	45			44.4	7
Do	Carthage, Tenn	40	4	9	47.4	6
Do	Nashville, Tenn	40	5	13	45.7	10
Do	Lock A, Fox Bluff, Tenn.	43	10	12	43.3	10–11
Do	Clarksville, Tenn	46	8	14	48.7	11–12
Do	do	46	24	25	46.1	25
Tennessee	Knoxville, Tenn	12	2	7	28.6	5
Do	do	12	25	26	13.9	25
Do	Loudon, Tenn	25	5	6	30.2	5
Do	Chattanooga, Tenn	33	4	10	47.7	7
Do	do	33	27	29	34.1	28
Do	Bridgeport, Tenn	24	5	11	30.9	8
Do	do	24			23.4	29
Do	Guntersville, Ala	31	5	13	39.4	10
Do	do	31	25	(*)	36.2	29
Do	Decatur, Ala	21	7	14	23.7	11–12
Do	do	21			20.4	30–31
Do	Riverton, Tenn	32	3	(*)	47.0	13
Do	Florence, Ala	18	4	16	24.7	12
Do	do	18	23	(*)	20.6	28
Do	Johnsonville, Tenn	31	7	(*)	38.9	18
Holston, North Fork	Mendota, Va	8	2	5	13.6	5
Do	do	8	25	25	8.2	25
French Broad	Asheville, N. C	4	5	6	4.9	5
Do	do	4	24	26	4.9	25
Do	Dandridge, Tenn	10	4	6	16.7	5
Clinch	Clinton, Tenn	25	3	7	38.0	5
Do	do	25			24.0	19
Do	Kingston, Tenn	25	4	7	33.0	6
Holston	Rogersville, Tenn	14	5	5	17.3	5
Powell	Tazewell, Tenn	20	4	4	22.4	4
Big Pigeon	Newport, Tenn	6	3	5	14.4	4
Hiwassee	Charleston, Tenn	22	4	7	28.3	5
Do	do	22	25	25	24.2	25
Little Tennessee	McGhee, Tenn	20	4	5	27.7	5

* Continued above flood stage after end of month.

TABLE 6.—*Flood stages in the Mississippi River drainage, except the Ohio River, March, 1917.*

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Mississippi	Hannibal, Mo.	13			12.9	31
Do	New Madrid, Mo.	34	17	(*)	38.6	26–28
Do	Memphis, Tenn.	35	22	(*)	38.6	31
Do	Helena, Ark.	42	23	(*)	47.2	31
Do	Arkansas City, Ark.	42	21	(*)	47.5	31
Do	Greenville, Miss.	42			40.0	31
Do	Vicksburg, Miss.	45			43.9	31
Yazoo	Swan Lake, Miss.	25	18	(*)	28.2	31
Do	Yazoo City, Miss.	25			23.5	31
Cedar	Cedar Rapids, Iowa	14	26	27	17.3	27
Illinois	Peoria, Ill.	16			15.6	21
Do	Beardstown, Ill.	12	17	(*)	13.6	23–26
Cache	Jelks, Ark.	9			8.9	23–25
James	Huron, S. Dak.	9	25	(*)	12.0	31
Floyd	Merrill, Iowa	13	22	23	14.5	22

* Continued above flood stage after end of month.

A SKEW FREQUENCY CURVE APPLIED TO STREAM GAGE DATA.

551.482

By WILLIAM GARDNER REED.

[Dated U. S. Office of Farm Management, Washington, Mar. 7, 1917.]

From a study of the frequency distributions of rainfall amounts it has appeared that nearly all the records show skew frequency polygons, in which the median observation has a smaller value than the mean of all the observations.[1] Similar skewness exists in the frequency distribution of daily gage heights of the upper Paraná at Posadas (Misiones) Argentina ($\phi = 27° 24'$ S., $\lambda = 55° 50'$ W., H = 138 m.). Dr. Wolff, Chief of the Oficina Hydrométrica of Argentina, has computed the frequencies of these gage heights for the 12 years 1904–1915, representing a total of 4,383 observations.[2] His frequency polygon closely resembles those obtained for rainfall amounts. The data have been used in constructing figure 1, which is the frequency polygon and the skew frequency curve for the limiting case computed in the manner suggested by Tolley.

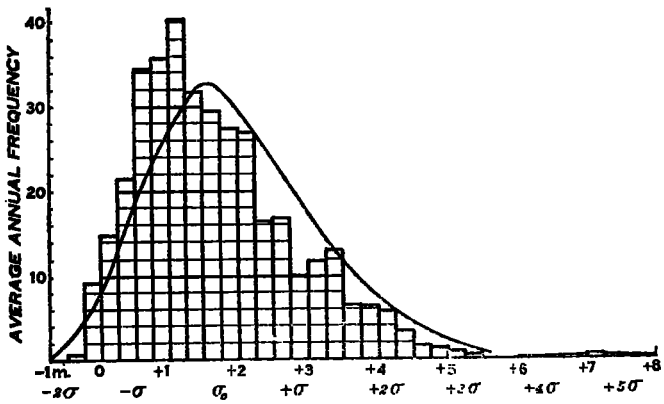

FIG. 1.—Frequency polygon and skew frequency curve for the limiting case for gage heights on the Paraná at Posadas.

Although Wolff has calculated the standard deviation, he has made little use of it in his tabulation. It may be of interest to carry the computation a little further. Using the notation suggested by Tolley, the following values have been obtained:

Quantity.	Symbol.	Value.
Number of observations	n	4383*
Mean gage height	M_0	$5.692 \frac{\text{meters}}{4}$ *
Convenient number near the mean	M	$1.620 \frac{\text{meters}}{4}$ *
Departure from M	d	
Sum of departures	Σd	$+93_1 \frac{\text{meters}}{4}$ *
Average departure from M	$\Sigma d/n$	$+0.2124 \frac{\text{meters}}{4}$ *
Sum of squared departures from M	Σd^2	$+90,293 \frac{\text{meters}}{4}$ *
Average square of departures from M	$\Sigma d^2/n$	$+20.6007 \frac{\text{meters}}{4}$ *
Average square of departures from the mean	$\Sigma d^2/n-(\Sigma d/n)^2$	$+20.557 \frac{\text{meters}}{4}$ *
Standard deviation	$\sigma = \sqrt{[\Sigma d^2/n-(\Sigma d/n)^2]}$	$4.525 \frac{\text{meters}}{4}$ *
Sum of cubed departures from M	Σd^3	$+428.063 \frac{\text{meters}}{4}$
Average cube of departures from M	$\Sigma d^3/n$	$+97,662 \frac{\text{meters}}{4}$
Average cube of departures from the mean	$\mu_3=\Sigma d^3/n-3(\Sigma d/n)(\Sigma d^2/n)+2(\Sigma d/n)^3$	$+84.580 \frac{\text{meters}}{4}$
Constant representing the value of skewness	$k=\frac{\mu_3}{\sigma_3}$	+0.913

* Values computed by Wolff.

The value of k (+0.913) is of the same sign and the same order of magnitude as that generally found in the case of rainfall amounts. This is to be expected, as variations in stream flow are closely dependent on variations in rainfall. It would be interesting to determine the variations in rainfall over the Paraná drainage basin above Posadas, but this is scarcely practicable owing to the vast extent of the area and the paucity of usable records.

In his statistical computation Wolff—like the North American engineers who have done similar work, notably Allen Hazen,[3] of New York, and R. W. Davenport, of the U. S. Geological Survey—has tacitly assumed that the standard deviation defines the frequency distribution, and has not computed any measure of skewness. He has, however, clearly shown by his polygon (fig. 1) that skewness exists and has not attempted to bring the tails of his polygon, or the summation curve, into arbitrary agreement with the normal curve. Tolley has shown that if skewness of the order here under consideration exists, its amount must be determined by the use of moments higher than the second, σ, if predictions based on the limiting case are to have value. He has also shown that the measure of skewness, k, is determined with as great accuracy as is warranted by the ordinary record when the third moment, μ_3, is used.

The results of this tabulation of the Posadas data furnish a further indication that meteorological and allied phenomena tend to follow definite frequency distributions which can be investigated by modern statistical methods. The application of these methods to stream flow data is obviously of great importance in river and flood studies as well as in irrigation and other investigations upon which depend the utilization of arid and semi-arid regions.

The skewness in the Posadas frequency distribution shows the advisability of using the third moment in the

[1] See *Tolley, H. R.* Frequency curves of climatic phenomena. MONTHLY WEATHER REVIEW, Nov. 1916, 44 : 634–642.

[2] *Wolff, E.* In República Argentina, Oficina meteorológica nacional, Boletín mensual, Buenos Aires, no. 3, marzo 1916, 1 : 40–41.

[3] *See especially* Storage to be provided in impounding reservoirs for municipal water supply. Trans., Am. soc. c. e., New York, 1914, 77 : 1539–1669.