NORTH CAROLINA GEOLOGICAL SURVEY

J. A. HOLMES, STATE GEOLOGIST

BULLETIN No. 8

PAPERS ON THE WATERPOWER IN NORTH CAROLINA

A PRELIMINARY REPORT

BY

GEO. F. SWAIN
J. A. HOLMES
E. W. MYERS

RALEIGH
GUY V. BARNES, PUBLIC PRINTER
1899

ILLUSTRATIONS.

BOARD OF MANAGERS.

GOVERNOR D. L. RUSSELL, *ex-officio Chairman*, .	Raleigh.
CHARLES MCNAMEE, ...	Biltmore.
J. TURNER MOREHEAD, ...	Leaksville.

STATE GEOLOGIST.

J. A. HOLMES, ...	Chapel Hill.

LETTER OF TRANSMITTAL.

To His Excellency, HON. D. L. RUSSELL,

Governor of North Carolina, and Chairman of the Geological Board.

SIR:—The requests for information concerning waterpower in North Carolina received at the Survey office during the past few years have been so numerous and urgent that I believe it wise to publish in the form of a preliminary report such information as we have in hand relative to this subject.

The volume of water in the several larger streams in the state is being carefully measured from time to time; and level lines showing the amount of fall are being run along portions of these streams with a view of determining suitable places for power developments. This information will be embodied in later reports. I recommend the publication as Bulletin 8 of the Survey series the information already available.

Yours obediently,

J. A. HOLMES.

CHAPEL HILL, N. C., September 1, 1898.

PREFACE.

The electric transmission of power developed during the past few years has awakened a new interest in waterpower throughout the entire country, and especially such powers as, owing to their location in regions inaccessible for railroad transportation, were not believed to be of importance. The publication of this *bulletin* as a preliminary report was decided upon with a view to meeting the urgent demands for information concerning these powers in North Carolina. In view of the fact that not enough of actual and long-continued measurements of the flow of the streams have been made to enable us to estimate accurately the value of the various powers, is was thought best for the purpose of a preliminary report to use as a basis for this, part of the 10th Census Report by Prof. Geo. F. Swain on the Waterpowers of the Southern Atlantic Watershed as relates to North Carolina.

This we have done, in general adopting the descriptions and power estimates found in his report and adding such additional data as were obtainable either by personal examination or by correspondence. The report in its final shape has been revised by Professor Swain; but he has not visited the region since 1881, and during these two decades changes in North Carolina, and throughout the South, have been great. He has been able to do little more than read the manuscript and suggest a few additions and corrections.

During the past three years gauging stations have been maintained by the United States Geological Survey and the State Survey coöperating, on each of the principal rivers in the state, at which have been made daily measurements of the height of the river surfaces; and occasional measurements of the flow and volume of water have been made by means of electric current meters. These measurements have, in general, confirmed Professor Swain's estimates as to the waterpower on the several larger streams. In the case of the Tar, Neuse and Cape Fear rivers, however, our measurements show his estimates for the absolute minimum (p. 54) are too high from 25 per cent. to more than 40 per cent.; but it has been thought best to allow his figures to remain as published in his 10th Census Report until the river measurements have been continued for a longer period of time.

The most uncertain points in a report of this character concern the estimates of the flow and power available on the streams, and it is hoped that all those who read this report will study with special care the remarks relating to this question on pages 49 to 67. Accurate data with respect to flow can only be obtained after a long series of observations. In Massachusetts, the Merrimac river has been utilized for power and its daily flow measured for over 50 years, and yet since the date of the original census report in 1881, the estimates of minimum flow have had to be materially altered. The readers of this report must, therefore, not exact great accuracy in the estimates given in the following pages. Indeed, the figures given must be simply considered as pointers indicating what may reasonable be expected in the way of waterpower during dry seasons.

PART I

WATERPOWER IN NORTH CAROLINA AS INFLUENCED BY PHYSIOGRAPHIC CONDITIONS

J. A. HOLMES
C. F. VON HERRMANN
GEO. F. SWAIN

PAPERS ON WATERPOWER IN NORTH CAROLINA.

CHAPTER I.

GENERAL PHYSIOGRAPHIC FEATURES OF NORTH CAROLINA.[1]

PHYSIOGRAPHIC PROVINCES.

The southeastern United States may be divided naturally into three well-defined provinces: the coastal plain region, which skirts the Atlantic and the Gulf from Cape Cod to the Rio Grande, extending inland from 100 to 200 miles, and extending seaward beyond the present coast line as a submerged plain for a distance nearly as great; the Appalachian mountain region, extending from northern Alabama to New Jersey and the Piedmont plateau region, which lies between these two from the Hudson river to central Alabama.

Only a small portion of the mountain region belongs with the south Atlantic watershed, but the entire region demands consideration in a study of its rivers and waterpowers. In the Carolinas the Blue Ridge mountains, which constitute the eastern front of this Appalachian region towards its southern end, form the divide separating the waters that flow into the Atlantic from those which find their way through the Ohio and Tennessee into the Mississippi, while northward the Alleghanies often constitute the divide, so that in Virginia and northward the larger rivers rise to the westward of the Blue Ridge, and flow eastward across it in deep gorges, while in North Carolina and southward the more important streams are those which rise either along the crest and southeastern slopes of the Blue Ridge or among the hills of the Piedmont plateau, and flowing across this latter and the coastal plain region, find their way into the Atlantic. The outlines of the physiographic regions and the general drainage systems in North Carolina are indicated on the accompanying map (fig. 1) to be found on the next page.

THE COASTAL PLAIN REGION.

The coastal plain region has been built up of unconsolidated sands, gravels, loams, clays and marls of recent geologic age, which inland

[1] By J. A. Holmes.

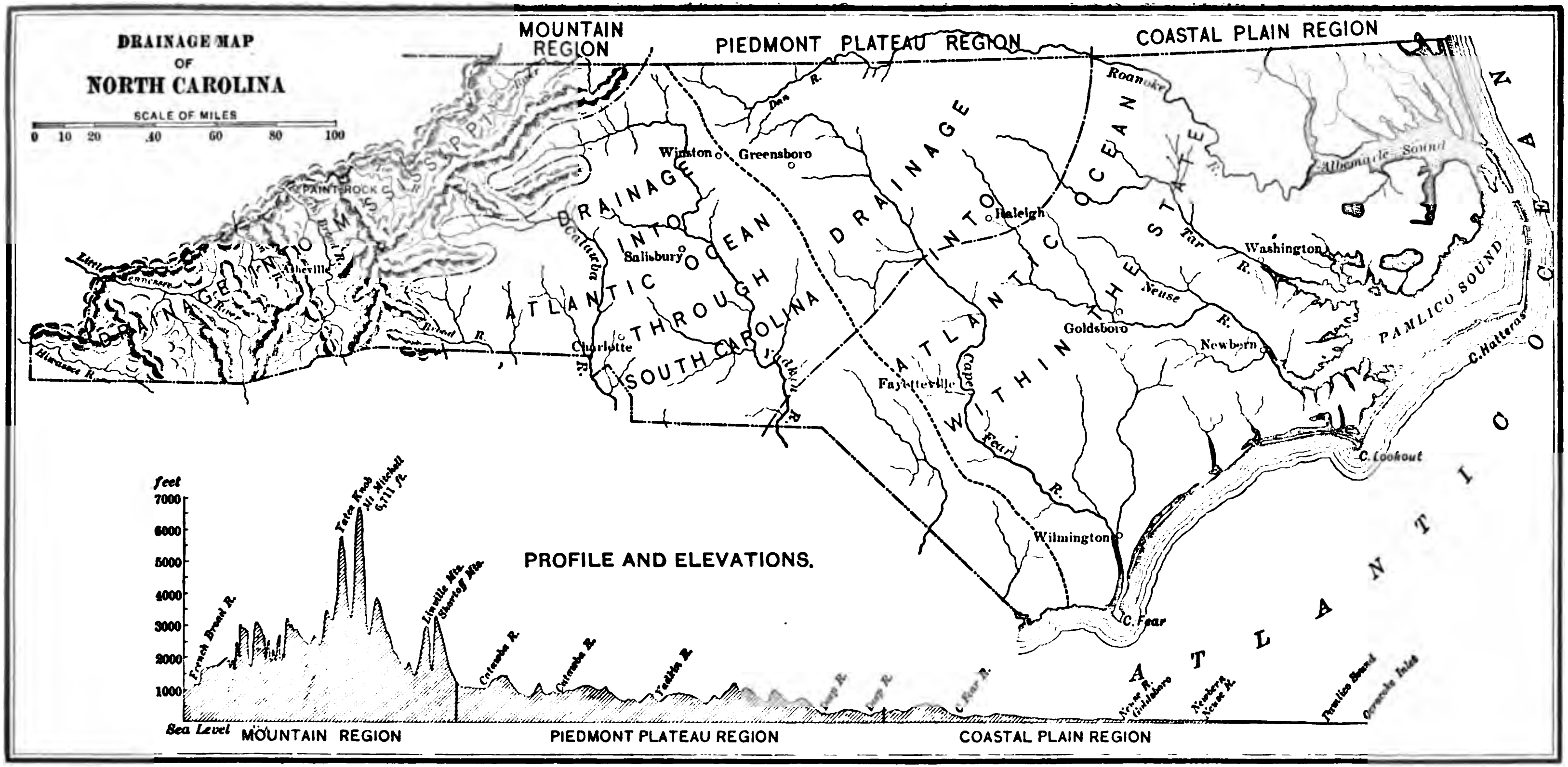


FIG. 1.—MAP OF NORTH CAROLINA SHOWING PHYSIOGRAPHIC REGIONS AND DRAINAGE; WITH A PROFILE SECTION FROM THE FRENCH BROAD RIVER AT PAINT ROCK TO OCRACOKE INLET [BETWEEN CAPES HATTERAS AND LOOKOUT].

Had the profile section been drawn either North or South of the French Broad, it would have shown higher mountains at its western end.

rest against the red lands and on the eastern sloping rocky surface of the hill country—the eastern margin of the Piedmont plateau. This contact between the two regions is one of the most clearly defined of natural boundaries, and is known geographically and industrially as the "fall line," along which are located, at the head of navigation on the more important streams, a number of important cities and towns, such as Washington, Richmond, Petersburg, Weldon, Columbia, Augusta and others given in the table below. The canals and other works constructed long ago for improving navigation at some of these places are now being used to develop waterpowers, and the cities are fast becoming manufacturing centers.

In New Jersey, Maryland and Virginia many of the streams of the Piedmont plateau cross its eastern margin at the fall line in deep, rocky gorges, and the rushing river torrents merge immediately below into tidal estuaries. Further south, however, the elevation of the fall line increases until on the Ocmulgee river at Macon, Ga., it is 250 feet above the sea. The following table shows the relative elevation of this boundary line at different points where it is crossed by the larger rivers:

Rivers.	Places.	Elevation above mean tide. Feet.
James	Richmond, Va.	0.0[1]
Appomattox	Petersburg, Va.	0.0[1]
Roanoke	Weldon, N. C.	28.0
Tar	Rocky Mount, N. C	59.5
Neuse	Smithfield, N. C.	100.0
Cape Fear	Averasboro, N. C.[2]	85.0
Pee Dee	C. C. R. R. crossing	106.0
Wateree	Ten miles above Camden, S. C.	125.0
Congaree	Columbia, S. C.	129.0
Savannah	Augusta, Ga	125.0
Ogeechee	Shoals of Ogeechee, 8¼ miles below Mayfield, Ga.	210.0
Oconee	Milledgeville, Ga.	220.0
Ocmulgee	Macon, Ga.	250.0

On the seaward side of this fall line, or fall-line zone as it might be more properly designated, we have the sluggish, navigable rivers which make their way southeasterly across the coastal plain region in valleys which, near the fall line, are usually narrow, from 50 to 100 feet deep, and with rather steeply-sloping sides, which at intervals form vertical bluffs on alternate sides of the streams. Usually the southwest side is the steeper, and the bluffs are more generally on this side. Further seaward the valleys become wider and less deep.

[1] This table is only an approximation. It was not possible to get accurate elevations on account of the difference in the datum-planes used by the various railroad companies. For instance, Richmond and Petersburg are at the head of tide water; yet the rivers there are probably several feet above mean tide at Norfolk. In some cases the above figures have been obtained by estimating the amount of fall above points whose elevations were given.

[2] Just below Smilleys falls.

The river courses in this eastern region are often exceedingly tortuous. The banks are composed of sands and clays which, along the upper reaches of the streams, are often found to be of cretaceous or Potomac age, while further seaward these older deposits are buried beneath the tertiary sands and marls, and usually all of these are overlaid by the still more recent sands and loams of the Lafayette and Columbia formations. This unstable character of the banks is unfavorable to navigation, inasmuch as the rivers frequently undermine trees, depositing both the tree and materials of the bank in the channels, and even cut new channels for themselves where conditions are favorable.

The country between the streams near the fall line has a surface that is quite undulating, rising in the sand-hill regions between the Cape Fear and the Savannah to an elevation of 500 feet, while further seaward the surface becomes more nearly level, with an elevation of from 10 to 50 feet above mean tide. Along the seaward margin the land surface is intersected by and interspersed with bays, estuaries and sounds, and even the land surface contains numerous and large swamp areas, such as the great Dismal Swamp in Virginia, and occasional small lakes, often partially or wholly surrounded by such swamps. The general seaward slope of the land surface from the fall line ranges from one to three feet to the mile. The forests, which still cover more than 60 per cent. of the total area of the region, are composed mainly of pines on the uplands and deciduous trees in the swamp areas.

Considering the coastal plain region as a whole, its surface features may be described as those of a region but recently and but slightly elevated above the sea, and a large part of whose surface is so nearly level and so unaffected by erosion that it is poorly drained. This condition, which results in the existence of numerous and large swamp areas, and the porous nature of the soil in the more sandy portions which enables it to act as a sponge in absorbing and holding rain water, gives remarkable uniformity to the flow of the streams which have their sources in this region. Along its western border, however, where we find the typical sand-hill country, the hills and ridges are more numerous and irregular, rising to elevations of from 300 to 500 feet, while the valleys and ravines are carved more deeply, and in places have made their way back into the heart of the region. In explanation of the topographic features of this sand-hill country it may be suggested that the region is not only more elevated, but has been either much longer above the sea than the country to the east, or if recently submerged, the period of submergence was so brief that the pre-existing topographic features were not obliterated thereby. It is in this sand-hill country that we find such industrially important though small streams as Rockfish and Hitchcocks creeks (see pages 138 and 190).

In North Carolina the coastal plain region extends inland from the coast 120 to 160 miles, and has an area of approximately 25,000 square miles of which more than half is still covered with pine forests. The upland soils are loamy sands, loams, and sandy and common loams, rarely stiff, moderately fine and even-grained. To the north of the Neuse river loams and sandy loams are the more frequent upland soils; to the south of this river they are more generally sandy. In the more eastern portion of this region, adjacent to the sounds and to the Atlantic, are numerous and extensive swamps which have their origin in the insufficient surface drainage of recent uplifted areas, that are often underlaid by impermeable strata, or in the gradual cutting off and filling up by silt and vegetable matter, of small bodies of water. Their soils vary considerably even in different portions of each swamp, being in their interior generally peaty and about the margins either sands and sandy loams, or clay loams and silt. Where these swamps border the larger streams that have their headwaters in the Piedmont region, their soils are generally an admixture of silt and vegetable matter and quite fertile.

THE PIEDMONT PLATEAU REGION.

The Piedmont plateau region, lying between the coastal plain and the mountains, and extending from Alabama to New Jersey, exhibits a diversity of characteristics, though there are many features common to the entire region. Along portions of its eastern margin, near the fall line, its hills are no higher and its valleys no deeper than those of the adjacent coastal plain region. Especially is this true where, as in the southern half of North Carolina, the Piedmont plateau region includes on the east a narrow belt of red sandstone which in places has been removed even more rapidly by the atmospheric agencies than have the sand-hills on the east side of the fall line. But generally the hard crystalline rocks and reddish soil of the Piedmont plateau are to be found at the fall line, and exhibit there the undulating surface characteristics of the typical red-hill country, the elevation of the surface near the coastal margin ranging from 300 to 600 feet. The eastern half of the region, taken as a whole, has an average elevation of nearly 750 feet, while the western half averages nearly 1200 feet.

Towards the western margin of this region the hills rise higher and higher above the general plain until in many cases they may be fairly considered as mountains, South and Brushy mountains in North Carolina having elevations between 2000 and 3000 feet. Toward the eastern margin the hills rise but little above the general plain, but the river channels are deep. It will be readily understood that as compared with the young and undeveloped topography of the coastal plain region, that of the Piedmont plateau is much older, more varied, and its history more complex. More than once in its recent history its surface has been so extensively removed by weathering and eroding agencies that it has been reduced, at least approximately, to a base-level plain, at no great elevation above the sea, and with only a few scattering hills and ridges rising above this plain, remnants which, owing to the obduracy of their component materials, have withstood the destructive agencies of the atmosphere even to the present time. Meanwhile, however, the surface has been lifted to higher levels above the sea, the streams have quickened their pace, carrying on anew the work of erosion until now we have left of this recent base-level plain only a secondary series of low hills and broad irregular ridges to indicate its position.

The soils, which in the main have been formed from the decay of rocks in place, are generally loams which are more gravelly and sandy and deeper in the granitic areas, and more clayey and shallow in the slaty belts. The forests, which are composed mainly of deciduous hard woods, here and there interspersed with short-leaf pines, occupy from 50 to 70 per cent. of the total area of the region.

In North Carolina this Piedmont plateau region approximates 125 miles in width and 900 feet in average elevation. Its highest ridges (South mountains) reach a height of 3000 feet above tide; but along its extreme east border its elevation does not average more than 400 to 500 feet. Its area approximates 21,000 square miles, of which more than one-half is covered with forests. The average southeasterly slope of the surface of this region is approximately three and one-half feet to the mile; but the possibility of developing waterpower on the several streams depends less upon this average slope than upon the concentration of portions of the fall at certain places, where for distances of a few rods, or at most a few miles, the streams assume the character of rapids, shoals or cascades. The descent of the surface of the various important streams of the region will be given in the body of this report as each stream is described. As may be seen from the sketch map on page 78, the several geological formations that go to make up the Piedmont plateau region cross the state obliquely, parallel to the mountains and to the seashore. In the main they form a succession of belts of slates and schists, granites and gneisses, across the steeply upturned and eroded edges of which the streams have carved their channels in making their way seaward. The fact that these rocks differ in character and are eroded with varying rapidity by the water currents, gives rise to the conditions that produce rapids, cascades and falls, and in this way makes practicable the development of waterpowers, as is described more fully on pages 68 to 76.

THE APPALACHIAN MOUNTAIN REGION.

The Appalachian mountain region, which extends from Alabama to New York, may be said to culminate in North Carolina, since it reaches here its maximum development. Along portions of its western slopes the boundary line of the region is obscure, the highly folded and uplifted strata of the mountains becoming only less corrugated in the hills and ridges of the adjacent plateau on the west; but other portions of this western, like the eastern, boundary are so well marked as to constitute not a gradual transition but an abrupt change from plateau to mountain conditions. The rugged mountain range on the eastern border is broken only by such occasional water gaps as those through which flow the Susquehanna, the Potomac, the James, and a few smaller southern streams.

In North Carolina this region embraces an irregular mountainous tableland, lying between the steep and well-defined escarpment of the Blue Ridge on the southeast, and the less regular, but in places equally prominent northwestern slope of the Great Smoky mountains. Numerous cross ridges, separated by narrow valleys and river gorges, connect these two mountain ranges. The region, taken as a whole, has a general average elevation of about 2700 feet above sea-level; but there are many mountain peaks that rise about 5000 feet, and a considerable number that are over 6000 feet high. Mt. Mitchell, the highest of the Black mountains, has an elevation of 6711 feet. The total area of the region approximates 6000 square miles. The mountain slopes, though usually steep, are forest-covered and have a deep fertile soil, usually a loam of varying physical character, but generally rich in humus, porous and easily cultivated. The Blue Ridge is in this state the great divide between the Atlantic and the Gulf waters. The streams which have their sources on the northwest slope of these mountains for the most part flow in a northwesterly direction into the tributaries of the Tennessee, having cut their way across the upturned edges of the folded strata that make the Great Smokies and their northeast extension, the Iron and Stone mountains; while further north the waters of the region flow in a northerly direction between the mountain ranges, and make their way into the Ohio. The character of the streams of this region and their basins are discussed more in detail in Part III of this report (page 233), and the geological conditions favorable to the development of waterpowers are described briefly in the following pages (68 to 76).

CHAPTER II.

CLIMATIC CONDITIONS AFFECTING WATERPOWER.[1]

GENERAL CLIMATIC CONDITIONS.

In considering the climate of any district with reference to its important influence on waterpower, the various elements which modify or control the amount of precipitation should receive the largest share of attention. Pressure, temperature, movements of the wind, and the like, may be discussed briefly for the purpose of a satisfactory general view of the subject, but these elements have a somewhat variable and complicated influence on rainfall, which is less clearly understood than the permanent effects of geographical position or topographical features. The climate of North Carolina is determined by its location in the warm temperate zone, but is modified by three important factors: the proximity of the ocean on the east, the distance of the state from the prevailing course of cyclonic storms, and lastly, the gradual elevation of the land towards the west, until in the summit of Mt. Mitchell the highest altitude east of the Rocky mountains is attained.

The statistical material employed in the tables has been obtained from the publications of the United States Weather Bureau and of the North Carolina Section (formerly the State Weather Service), and includes data collected to the end of the year 1897. For convenience of treatment the state has been divided into three districts, which correspond roughly with the geological subdivisions—the coastal plain, the Piedmont plateau and the mountain regions. The eastern district (corresponding to the first of these in a general way) includes meteorological stations having elevations of less than 100 feet, the central district elevations between 100 and 1000 feet, and the western district all points over 1000 feet above sea-level. Each division has in some respects climatic features peculiarly its own.

In the *eastern district*, which includes that portion of the state bordering on the Atlantic, the influence of the proximity of the ocean, the indentation of the land by large bays and sounds, and the projection of the coast line beyond the normal trend, is immediately evident in the increased rainfall on the coast, especially between Hatteras and Cape Lookout, as well as in the lessened changes of temperature, both diurnal

[1] By C. F. Von Herrmann, Section Director, U. S. Weather Bureau.

and seasonal. It has been the fashion to ascribe the almost insular or marine climate of this section to the influence of the Gulf Stream, but the facts that a considerable body of cooler water lies between the Gulf Stream and the coast, and that east and southeast winds are the rarest of all winds in North Carolina, and are inadequate to explain the warmer, moist climate of this region, appear to indicate that the Gulf Stream exerts less influence in this direction than was formerly supposed. The annual mean temperature varies in the east from 64° Fahr. at Southport to 59° Fahr. at Weldon, and permits in the southern portion of the district the growth of vegetation of semi-tropical origin, and the cultivation of rice, early fruits and vegetables.

In the *central district* the extremes of temperature become greater, the rainfall is less; the southern portion shows a high degree of summer heat, due in part to the sandy nature of the soil. Central North Carolina is, however, by no means as warm as central South Carolina, and the northern portion of this district is not greatly different from central Virginia. The annual mean temperature varies from 62° Fahr. at Rockingham to 57° Fahr. at Saxon. It is often the case that this section receives more snow in winter than other portions of the state.

In the *western district* the influence of elevation is supreme. The summers are cooler, the winters more severe, the air drier and more salubrious. The trend of the mountains from southwest to northeast influences the prevailing winds. The great diversity in topographical features gives rise to many interesting climatic peculiarities. The rainfall is large, especially so at the south end of the Appalachian system, while, on the other hand, many central valleys possess as small a rainfall and as mild a climate as many points east of the Blue Ridge. It is well to remember that several meteorological stations in the west have elevations of nearly 4000 feet. The annual mean temperature varies from nearly 60° Fahr. at Salisbury and Charlotte east of the mountains, to 49° Fahr. at Linville, which is nearly the mean annual temperature of Boston or Chicago.

The position of North Carolina with reference to the general path of low barometric areas is a fortunate one. Probably not more than 20 per cent. of the storms observed in the United States cross the state. The great highway for these storms is the Lake Region, and a very large majority of them pass off the United States coast over New England. While not causing heavier rainfall in the north, they do make the weather extremely severe and changeable, and give that section a high percentage of cloudiness and a high relative humidity; while in North Carolina longer periods of settled weather are experienced, fogs, though frequent enough, rarely last during the day, and cheerful, sunny weather is the rule.

The state lies in the course of sub-tropical storms from Florida which are often violent, and are accompanied by heavy precipitation, but usually pass over the state with great rapidity. They occur chiefly from August to October.

The prevailing winds are from the southwest, or in fall and winter, frequently from the northeast; the movement is generally light and variable in the interior, but often dangerous on the coast during the passage of sub-tropical storms, giving to Hatteras its world-wide reputation. In winter the winds from the south, east and northeast are wet winds; the shift to southwest is usually followed by rapidly clearing weather; in summer, wind directions and movements are very irregular. In general, the resultant annual movement is from the west.

The average *cloudiness* of the state is between 40 and 50 per cent., with a somewhat larger average on the eastern slope of the Blue Ridge.

The annual relative humidity is about 80 per cent. on the coast from Hatteras to Wilmington, is 75 per cent. in the central-east portion of the state, and in the west generally about 70 per cent. As evaporation increases with higher temperature, the maximum humidity occurs in July or August.

TEMPERATURE.

It is evident from its physical features alone that a wide variation must exist in the mean temperature of the different sections of North Carolina. In Table I (p. 30) is presented the annual and seasonal mean temperature at a large number of stations in the state, of which 28 have records covering a period of 10 years or more. From all data the normal annual mean for the state has been found to be 59° Fahr. The seasonal temperatures for the different districts are as follows:

	Spring.	Summer.	Autumn.	Winter.
Eastern District	59°	77°	62°	45°
Central District	59°	77°	60°	42°
Western District	56°	73°	57°	40°
For the state	58°	76°	60°	42°

The annual mean for the state has varied during the past 26 years between 61° Fahr. in 1890 and 57° Fahr. in 1895. From the data given it is seen that autumn is warmer than spring in nearly all parts of the state. January is the coldest month of the year, with no normal, however, lower than 31° Fahr., while July is the warmest, with no normal higher than 81° Fahr. During exceptionally warm summers July means as high as 84° Fahr. have occurred (Wilmington, Newbern, Weldon). The lowest January mean on record is 24° Fahr. at Highlands in 1893.

During the past ten years the state has probably experienced as wide a range in actual temperatures as is likely to be again observed. Remarkably warm weather occurred during the summers of 1887 and 1896, with extremes as high as 107° Fahr., while the often-quoted cold winters of 1834 and 1856 must now certainly yield their places in climatic history to those of 1893 and 1895.

Ordinarily the rivers of North Carolina remain open throughout the year, but during such winters as occurred in 1857, 1886, 1893 and 1895 all the rivers, and even the northern sounds, were frozen over. In 1893, for instance, the Cape Fear river at Fayetteville, the Neuse at Newbern, the Roanoke at Weldon, and Albemarle sound from Elizabeth City to Roanoke Island were covered with ice.

The extremes presented in Table II (p. 33) will be of interest in this connection.

If the distribution of temperature be studied graphically it is found that the isotherms do not follow the lines of latitude, but cross them in a southwest-northeast direction almost parallel with the Blue Ridge; but in summer there is a decided northward trend of the isotherms from the coast to the central portion of the state before they curve around the southern end of the Appalachian system.

TABLE I.—TABLE OF AVERAGE MONTHLY AND SEASONAL MEAN TEMPERATURES AT STATIONS IN NORTH CAROLINA.

RECORDS FROM 1820 TO 1897 INCLUSIVE.

EASTERN DISTRICT.	Latitude, ° ′	Longitude, ° ′	Elevation, ft.	Length of record, years.	AVERAGE MONTHLY AND ANNUAL MEAN TEMPERATURES.													SEASONAL TEMPERATURES.			
					Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Spring.	Summer.	Autumn.	Winter.
Beaufort*	34°43′	76°41′	13	5	46.5	47.7	53.1	59.4	69.4	75.3	79.8	80.9	74.7	64.2	56.9	48.0	63.0	60.6	78.7	65.3	47.4
Coinjock	36°20′	75°52′	20	6	41.4	42.1	47.9	55.5	64.6	72.4	78.4	76.0	70.9	61.0	50.5	42.3	58.6	56.0	75.6	60.8	41.9
Cape Lookout	34°36′	76°36′	15	6	47.6	47.0	52.8	59.9	67.7	75.0	80.2	79.4	74.7	66.1	55.6	47.2	62.8	60.1	78.2	65.5	47.3
Edenton*	36° 3′	76°36′	30	5	41.5	43.4	49.6	58.7	68.4	74.2	79.9	79.8	71.6	60.3	52.3	40.8	60.0	58.9	77.8	61.4	41.9
Fort Macon	34°42′	76°40′	20	14	44.9	46.5	51.0	59.1	68.6	76.0	80.0	79.1	75.1	65.3	56.2	47.9	62.5	59.6	78.4	65.5	46.4
Goldsboro*	35°23′	78° 0′	102	21	42.6	47.3	52.0	60.6	69.6	77.2	79.8	78.3	72.8	61.6	51.9	44.4	61.5	61.7	78.4	62.1	44.8
Hatteras*	35°15′	75°40′	11	23	45.3	47.0	50.0	57.2	66.6	74.1	77.9	77.5	73.7	64.4	55.9	48.2	61.5	57.9	76.5	64.7	46.8
Kitty Hawk*	36° 0′	75°42′	9	23	42.5	44.5	47.8	55.4	64.9	73.5	78.0	77.4	72.8	63.4	58.5	45.9	60.0	56.0	76.3	63.2	44.3
Littleton*	36°26′	77°54′	380	7	36.4	39.9	46.9	57.5	65.4	75.0	77.2	76.4	70.9	57.1	48.3	41.6	57.7	56.6	76.2	58.8	89.3
Lumberton*	34°38′	78°59′	...	10	45.1	41.7	53.1	62.9	70.6	77.4	80.0	78.3	72.0	61.6	52.9	46.7	61.9	62.2	78.6	62.2	44.5
Murfreesboro	36°26′	77° 5′	75	5	40.7	44.9	49.1	56.9	66.5	75.4	77.3	76.4	68.6	58.1	49.1	42.6	58.8	57.5	76.4	58.6	42.7
New River Inlet	34°32′	77°18′	...	5	42.2	48.4	49.3	58.8	69.6	74.7	79.1	77.6	73.1	65.2	54.4	47.8	61.7	59.2	77.1	64.2	46.1
Newbern*	35° 6′	77° 2′	12	21	42.6	47.0	51.6	59.6	68.4	75.9	78.9	77.3	72.9	61.9	53.4	46.1	61.3	59.9	77.4	62.7	45.2
Norfolk, Va*	36°51′	76°17′	69	27	40.5	42.8	47.0	56.5	66.6	74.9	78.6	76.9	71.2	60.6	50.6	42.9	59.1	56.7	76.8	60.8	42.1
Portsmouth	35° 2′	76° 4′	5	5	43.8	46.5	50.8	58.1	67.6	74.1	79.6	78.3	74.8	67.6	55.8	45.8	61.9	58.8	77.3	66.1	45.4
Southport*	33°55′	78° 1′	34	42	47.0	49.7	54.4	62.3	71.2	77.7	80.6	79.5	75.1	65.6	56.8	49.7	64.1	62.6	79.3	65.8	48.8
Scotland Neck	36° 7′	77°32′	50	10	40.7	43.5	48.9	55.8	65.7	74.0	77.8	75.6	70.1	59.3	49.4	41.0	58.5	56.8	75.8	59.6	41.7
Sloan*	34°45′	77°32′	50	5	44.8	44.5	53.4	61.2	70.0	76.0	77.1	78.1	73.8	61.2	54.0	46.5	61.7	61.5	77.1	63.0	45.3
Tarboro*	35°50′	77°35′	50	12	41.1	44.5	48.9	59.5	69.1	76.0	78.7	77.4	71.5	59.2	51.0	43.1	60.0	59.2	77.4	60.6	42.9
Weldon*	36°24′	77°32′	81	26	39.3	42.8	47.8	57.7	68.2	75.9	79.3	76.8	71.0	58.9	48.5	41.1	58.9	57.9	77.3	59.5	41.1
Willeyton*	36°28′	76°32′	45	8	38.2	44.3	48.6	58.7	66.8	74.5	76.6	76.0	71.0	58.4	50.2	42.4	58.8	58.0	75.7	59.9	41.6
Washwoods	36°33′	75°53′	10	6	40.9	44.2	44.5	54.3	66.3	74.8	79.3	77.3	72.4	61.3	51.8	43.5	59.2	55.0	77.1	61.8	42.9
Wilmington*	34°14′	77°57′	52	27	46.7	50.0	53.5	61.6	69.5	76.7	79.6	78.2	73.5	63.5	54.7	48.2	63.0	61.5	78.2	63.9	48.3

* Indicates that records were continued through 1897. Temperatures in Fahrenheit degrees.

TABLE I.—*Continued.*

CENTRAL DISTRICT.	Latitude, ° ′	Longitude, ° ′	Elevation, ft.	Length of record, years.	AVERAGE MONTHLY AND ANNUAL MEAN TEMPERATURES. Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	SEASONAL TEMPERATURES. Spring.	Summer.	Autumn.	Winter.
Attaway Hill	35° 25′	80° 12′	850	11	38.2	40.7	46.8	56.8	63.8	73.5	77.4	75.6	68.2	55.5	45.0	38.1	56.6	55.8	75.4	56.2	39.0
Chapel Hill*	35° 54′	79° 4′	500	41	39.8	44.3	49.0	59.2	67.8	75.9	78.4	76.5	71.3	59.6	49.9	42.6	59.5	58.7	76.9	60.3	42.2
Fayetteville*	35° 6′	78° 53′	170	13	42.1	45.2	53.2	61.1	70.3	76.2	79.3	77.1	70.8	61.6	50.7	42.6	60.9	61.5	77.5	61.0	43.8
Greensboro*	36° 4′	79° 49′	843	15	40.4	43.7	50.6	59.0	68.4	75.8	78.3	76.6	71.0	61.0	48.3	41.9	59.6	59.3	76.9	60.1	42.0
Henderson*	36° 20′	78° 23′	490	5	39.4	40.1	50.9	57.6	68.4	75.4	78.4	77.4	73.0	58.3	50.0	41.8	59.2	59.0	77.1	60.4	40.4
Louisburg*	36° 7′	78° 18′	375	7	36.6	40.8	48.9	58.7	67.6	75.4	76.8	76.5	71.1	57.3	47.9	40.3	58.2	58.4	76.2	58.8	39.2
Moncure*	35° 39′	79° 0′	300	5	40.4	41.0	51.6	60.0	68.2	75.1	78.1	76.5	72.2	58.2	51.0	41.1	59.5	59.9	76.6	60.5	40.8
Monroe*	34° 59′	80° 34′	586	5	41.5	45.0	50.5	62.0	69.2	75.4	78.2	76.2	70.4	58.9	52.9	46.2	60.5	60.6	76.6	60.7	44.2
Oxford	36° 22′	78° 25′	475	7	37.8	41.9	46.4	58.3	66.1	74.6	79.2	75.6	68.2	56.1	45.4	37.8	57.3	56.9	76.5	56.6	39.1
Oak Ridge*	36° 10′	80° 0′	885	8	37.5	41.6	47.0	57.8	66.1	74.2	75.9	75.0	69.2	56.1	48.0	40.5	57.8	57.0	75.0	57.8	39.9
Pittsboro*	35° 42′	79° 12′	480	9	38.2	42.2	46.9	57.6	65.6	73.5	75.6	74.6	69.8	56.2	48.0	41.6	57.5	56.7	74.6	58.0	40.7
Raleigh*	35° 45′	78° 37′	375	27	41.0	44.1	49.4	59.1	68.2	75.7	78.0	76.4	71.1	58.7	50.4	43.7	59.6	58.9	76.7	60.1	42.9
Roxboro*	36° 26′	78° 58′	600	5	35.9	39.5	48.7	58.7	66.7	74.5	77.1	76.1	71.1	57.1	48.9	40.6	57.9	58.0	75.9	59.0	38.7
Rockingham*	34° 58′	79° 46′	210	5	41.8	46.0	54.6	64.2	70.9	77.4	80.3	78.7	74.3	61.5	51.9	44.5	62.2	63.2	78.8	62.6	44.1
Southern Pines*	35° 13′	79° 22′	400	7	41.5	45.5	52.0	61.8	69.1	77.3	78.1	77.2	73.4	61.3	51.7	47.2	61.3	61.0	77.5	62.1	44.7
Soapstone Mount*	35° 46	79° 37′	900	9	37.8	39.5	47.2	57.0	65.6	73.7	76.1	74.0	69.1	55.5	46.8	41.1	57.0	56.6	74.6	57.1	39.5
Selma*	35° 31′	78° 21′	225	8	39.3	44.3	50.5	60.5	68.1	76.6	78.2	77.0	72.0	59.4	50.6	43.1	60.0	59.7	77.3	60.7	42.2
Saxon*	36° 22′	80° 6′	900	7	34.9	39.9	48.1	57.8	66.1	74.6	77.1	76.2	69.4	54.8	46.2	39.5	57.1	57.3	76.0	56.8	38.1

* Indicates that records were continued through 1897. Temperatures in Fahrenheit degrees.

TABLE I.—*Continued.*

WESTERN DISTRICT.	Latitude, ° ′	Longitude, ° ′	Elevation, ft.	Length of record, years.	AVERAGE MONTHLY AND ANNUAL MEAN TEMPERATURES.													SEASONAL TEMPERATURES.			
					Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Spring.	Summer.	Autumn.	Winter.
Asheville*	35° 37′	82° 30′	2250	23	37.8	39.8	45.7	54.8	62.6	69.6	72.0	70.7	64.9	53.2	45.2	38.9	54.5	54.4	70.8	54.4	38.8
Charlotte*	35° 13′	80° 51′	808	22	40.6	44.6	49.6	60.0	68.6	75.7	78.4	76.5	71.2	60.0	49.8	43.3	59.9	59.4	76.9	60.3	42.8
Flat Rock*	35° 15′	82° 25′	2214	5	35.3	40.0	48.5	54.0	62.5	69.3	71.9	70.4	65.5	53.0	45.5	39.4	54.6	55.0	70.5	54.7	38.2
Franklin	35° 12′	83° 27′	2141	12	39.1	41.8	44.6	53.8	61.7	68.2	70.7	70.0	63.9	53.4	45.0	38.5	54.2	53.4	69.6	54.1	39.5
Highlands*	35° 5′	83° 25′	3817	15	33.5	36.6	41.6	50.6	57.5	64.7	67.1	65.4	60.2	51.0	42.2	36.0	50.4	49.9	65.7	51.1	35.4
Horse Cove*	35° 0′	83° 6′	2800	6	35.8	38.9	45.8	55.5	62.7	69.8	71.9	71.4	67.0	54.9	45.5	40.7	55.0	54.7	71.0	55.8	38.3
Hot Springs	35° 53′	82° 49′	1330	5	45.2	45.7	46.6	58.5	63.9	70.9	74.7	72.3	67.5	55.2	49.2	44.2	57.8	56.3	72.6	57.3	45.0
Linville*	36° 5′	81° 51′	3800	5	31.0	31.0	40.5	46.7	57.6	62.4	66.1	64.9	59.7	47.3	41.4	34.8	48.6	48.3	64.5	49.5	32.3
Lincolnton	35° 9	81° 12′	944	5	32.9	39.4	43.1	55.5	65.9	72.0	77.8	74.0	68.5	56.9	42.2	37.9	55.5	54.8	74.6	55.9	36.7
Lynn*	35° 12′	82° 14′	1500	9	36.3	41.6	49.4	59.8	64.2	72.5	74.9	73.1	68.1	55.9	47.0	38.5	56.7	57.6	73.5	57.0	38.8
Lenoir*	35° 58′	81° 30′	1186	26	36.4	40.4	45.9	56.8	64.0	71.4	74.4	73.2	65.8	56.1	45.4	38.5	55.7	55.6	73.0	55.8	38.4
Murphy	35° 8′	84° 0′	1614	12	39.6	41.9	47.2	55.7	64.0	70.0	73.7	71.4	65.9	54.4	45.1	38.6	55.6	55.6	71.7	55.1	40.0
Mt. Airy*	36° 30′	80° 40′	1048	10	35.9	39.9	44.7	55.7	64.1	72.0	74.8	73.1	67.9	54.3	46.4	39.6	55.7	54.8	73.3	56.2	38.5
Morganton*	35° 45′	81° 44′	1135	10	37.3	41.2	48.3	58.1	66.1	73.0	75.7	73.7	68.8	55.6	47.1	42.9	57.3	57.2	74.1	57.2	40.5
Mocksville*	35° 51′	80° 34′	651	5	38.3	42.3	51.7	60.2	68.4	74.1	77.3	76.0	72.0	58.8	51.6	43.8	59.5	60.1	75.8	60.8	41.5
Mt. Pleasant*	35° 28′	80° 28′	650	12	40.0	43.7	48.9	59.1	67.3	75.2	76.8	75.4	70.1	57.2	49.3	43.1	58.8	58.4	75.8	58.9	42.3
Marion*	35° 30′	82° 5′	1425	5	37.6	42.0	49.1	57.6	66.0	72.3	74.1	73.3	68.9	58.1	48.7	40.4	57.3	57.6	73.2	58.6	40.0
Statesville	35° 45′	80° 53′	950	12	36.0	40.4	46.0	57.1	65.4	72.7	77.1	75.8	68.4	55.8	44.9	35.9	56.3	56.2	75.2	56.4	37.4
Salisbury*	35° 40′	80° 29′	760	13	41.0	44.2	49.7	60.9	68.8	76.0	78.9	76.9	71.1	58.8	51.3	44.5	60.2	59.8	77.3	60.4	43.2
Waynesville*	35° 29′	82° 58′	2756	5	35.9	37.3	46.5	54.9	61.8	68.2	69.7	69.8	65.3	52.6	46.5	39.3	54.0	54.4	69.2	54.8	37.5
Webster	35° 20′	83° 17′	......	5	37.1	39.5	44.7	54.4	61.3	65.3	73.4	70.0	62.0	53.0	42.3	38.4	53.4	53.5	69.6	52.4	38.3
Averages for the State	......	......	......	*27	40.3	43.6	48.5	58.5	66.9	74.3	77.6	75.8	70.4	59.5	49.8	42.6	59.0	58.0	75.9	59.9	42.0

* Indicates that records were continued through 1897. Temperatures in Fahrenheit degrees.

TABLE II.—Temperature Extremes.

Stations.	Elevation, Feet.	Length of record, years.	Highest monthly mean.	Month. Year.	Lowest monthly mean.	Month. Year.	Highest observed.	Date.	Lowest observed.	Date.
Asheville	2250	23	74.8	July, 1879.	27.2	Jan., 1893.	95	Sept. 15, 1897.	*— 9	Jan. 16, 1893. Feb. 8, 1895.
Chapel Hill	500	41	82.2	July, 1893.	28.4	Jan., 1857.	105	Aug. 10, 1892.	— 1	Jan. 16, 1893.
Charlotte	808	22	82.6	July, 1881.	32.6	Jan., 1893.	103	July, 1879.	— 5	Dec., 1880.
Fayetteville	170	13	83.2	June, 1880.	34.2	Feb., 1895.	101	Aug. 9, 1896.	7	Feb. 8, 1895.
Greensboro	843	15	82.6	July, 1893.	32.3	Dec., 1876.	101	Aug. 10, 1896.	6	Jan. 28, 1897.
Highlands	3817	15	70.9	July, 1878.	24.4	Jan., 1893.	86	June, 1891.	—17	Feb. 8, 1895.
Horse Cove	2800	6	74.4	July, 1893.	28.5	Jan., 1893.	93	Sept. 15, 1897.	—13	Feb. 8, 1895.
Hatteras	11	23	79.6	July, 1883.	36.5	Jan., 1893.	92	Aug., 1883.	11	Feb. 8, 1895.
Kitty Hawk	9	23	83.7	Aug., 1888.	32.1	Jan., 1893.	107	July 18, 1887.	6	Feb. 8, 1895.
Littleton	380	7	80.0	July, 1893.	27.6	Jan., 1893.	104	Aug. 10, 1896.	— 4	Jan. 16, 1893.
Louisburg	375	7	79.6	July, 1893.	29.4	Jan., 1893.	103	Aug. 10, 1896.	— 5	Jan. 16, 1893.
Lenoir	1186	26	77.7	July, 1877.	27.3	Jan., 1893.	95	July 18, 1887.	—16	Dec., 1880.
Morganton	1135	10	80.0	July, 1868.	26.4	Jan., 1893.	100	Sept. 16, 1897.	— 1	Jan. 16, 1893.
Mt. Airy	1048	10	77.1	July, 1872.	26.2	Jan., 1893.	98	Sept. 28, 1891.	—15	Jan. 16, 1893.
Mt. Pleasant	650	12	79.1	Aug., 1896.	29.9	Jan., 1893.	98	June 29, 1889.	— 4	Jan. 21, 1893.
Murphy	1614	12	76.9	July, 1878.	28.5	Dec., 1876.	..	....	..	....
Newbern	12	21	83.8	July, 1887.	32.0	Jan., 1893.	100	Sept. 23. 1895.	6	Jan. 17, 1893.
Oak Ridge	885	8	79.0	Aug., 1896.	29.0	Feb., 1895.	99	June 4, 1895.	— 5	Jan. 14, 1893.
Pittsboro	480	9	79.0	July, 1896.	28.0	Jan., 1893.	97	June 2, 1895.	— 5	Jan. 17, 1893.
Raleigh	375	27	81.3	July, 1887.	30.8	Jan., 1893.	103	July 18, 1887.	2	Jan. 17, 1893.
Rockingham	210	5	82.1	July, 1893.	35.7	Jan., 1893.	103	Aug. 10, 1896.	— 2	Jan. 20, 1893.
Roxboro	600	5	79.8	July, 1893.	29.7	Jan., 1893.	100	Several dates.	— 4	Feb. 8, 1895.
Southport	84	42	83.3	July, 1872.	30.4	Jan., 1880.	103	July 12, 1879.	8	Jan. 12, 1886.
Salisbury	760	13	82.0	July, 1893.	33.0	Jan., 1893.	102	Aug. 10, 1896.	5	Feb., 21, 1896.
Selma	225	8	82.4	June, 1890.	29.9	Jan., 1893.	102	July 29, 1896.	— 5	Jan. 20, 1893.
Saxon	900	7	79.2	Aug., 1896.	26.8	Jan., 1893.	105	Aug. 9, 1896	— 8	Jan. 15, 1893.
Soapstone Mt.	900	9	78.6	July, 1893.	28.7	Jan., 1893.	99	Several dates.	— 9	Jan. 21, 1893.
Southern Pines	400	7	80.2	July, 1893.	33.7	Jan., 1893.	103	July, 1892. Sept., 1895.	5	Feb. 8, 1895.
Tarboro	50	12	81.2	July, 1893.	31.3	Jan., 1893.	105	Aug. 10, 1896.	— 1	Jan. 21, 1893.
Weldon	81	26	84.3	July, 1878.	28.2	Jan., 1893.	107	July, 1879. Aug., 1881.	— 9	Jan. 17, 1893.
Willeyton	45	8	78.6	July, 1896.	29.8	Jan., 1893.	99	July 18, 1890.	— 3	Jan. 21, 1893.
Wilmington	52	27	84.5	July, 1872.	37.4	Feb., 1895.	103	July 12, 1879.	10	Dec., 1880. Feb. 8, 1895.

* The minus sign (—) indicates temperatures below zero.

PRECIPITATION.

In the introduction to a paper on the rainfall of the United States (Bulletin D, issued by the Department of Agriculture, Weather Bureau) Mr. A. J. Henry states clearly the generally accepted theory of rainfall and the manner in which the operations are brought about in nature, as modified by various causes, all of which are admirably illustrated within the limits of North Carolina. Briefly, then, rain is caused by a sudden cooling of the air below the dew-point, resulting in the condensation of the moisture contained in it to the liquid state, and its final precipitation to the earth's surface. Mr. Henry names the following as the chief ways in which the ascensional movements of the air are produced: 1, the air may be forced up the side of a mountain into a region of diminished pressure and lower temperature; 2, the lower layers of the atmosphere under the influence of solar radiation frequently reach a state of unstable equilibrium inducing ascensional currents—summer thunderstorms are generally a result of this process; 3, lastly, the circulation of air in cyclonic storms, that is, a radial inflow from all sides and an ascensional movement from the center.

North Carolina belongs to that region of the United States east of the Rockies characterized by the largest precipitation, the center of which lies on the Gulf coast about the mouth of the Mississippi; there are, however, localities on the southeastern slope of the Blue Ridge which receive an annual rainfall not exceeded anywhere except on the coast of Washington and Oregon. The average rainfall for the state given by Prof. Kerr, 53 inches, is very nearly correct. The inclusion of the period 1892 to 1897, years noted for considerable deficiencies in precipitation, has reduced the normals at many points, and the annual total is now about 52 inches.

The averages for the three sections of the state are:

Eastern District	54 inches.
Central District	48 inches.
Western District	53 inches.

Considering the monthly averages, it is observed that the maximum rainfall occurs in July and August, with the chief minimum in October or November. The August average is 134, the October average 77 per cent. of the monthly normal. An abundance of waterpower in the rivers of the state is indicated by the copious rainfall and its fairly uniform distribution throughout the year.

In Table III (p. 36) is presented the average monthly, annual and seasonal precipitation at stations in North Carolina. It is to be observed that rainfall is a climatic factor subjected to far greater variations than temperature, and that a correspondingly longer series of years of observation is required to obtain correct normals. Strictly speaking, there is not a station in North Carolina with a series of rainfall observations long enough to afford a true normal. Mr. A. J. Henry has shown that at least 35 or 40 years of continuous observation are required to obtain a result that will not vary more than plus or minus 5 per cent. from the true normal. However, records for the past 15 to 25 years include very rainy and very dry years, and may certainly be considered as near the truth. The accompanying charts (figs. 2-6 inclusive) also show graphically the seasonal and annual precipitation in the state (see pp. 43-47).

The distribution of precipitation throughout the state may now be considered in greater detail. The point which attracts attention immediately is the belt of minimum precipitation through the central portion. The greater rainfall of the eastern division is produced by the proximity of the ocean, the larger amount in the west by the effect of elevation.

TABLE III.—TABLE OF AVERAGE MONTHLY AND SEASONAL PRECIPITATION AT STATIONS IN NORTH CAROLINA.

PRECIPITATION IN INCHES AND HUNDREDTHS.

EASTERN DISTRICT.	Latitude, ° ′	Longitude, ° ′	Elevation, ft.	Length of record, years.	MONTHLY AND ANNUAL PRECIPITATION.													SEASONAL PRECIPITATION.			
					Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Spring.	Summer.	Autumn.	Winter.
Beaufort*	34° 43′	76° 41′	13	3	2.60	3.38	4.96	3.56	2.91	3.96	4.86	3.68	3.36	5.48	2.65	5.35	46.75	11.43	12.50	11.49	11.33
Coinjock	36° 20′	75° 52′	20	6	2.79	2.23	4.28	4.38	2.20	3.45	6.27	7.06	5.42	2.20	3.03	2.96	46.27	10.86	16.78	10.65	7.98
Cape Lookout	34° 36	76° 36′	15	5	6.15	4.51	4.49	5.57	5.14	5.50	5.17	10.33	9.11	6.72	6.12	6.16	74.97	15.20	21.00	21.95	16.82
Edenton*	36° 3	76° 36′	30	5	3.16	4.47	3.83	2.55	7.14	3.43	5.19	3.40	3.19	4.89	2.76	3.21	47.22	13.52	12.02	10.84	10.84
Fort Macon	34° 42	76° 40′	20	10	4.32	2.59	4.75	3.86	3.60	4.33	6.20	4.59	6.13	3.51	2.28	4.13	50.29	12.21	15.12	11.92	11.04
Goldsboro*	35° 23′	78° 00′	102	17	3.06	3.42	4.77	4.76	4.99	5.18	6.08	7.27	4.80	3.20	2.40	3.63	53.56	14.52	18.53	10.40	10.11
Greenville*	35° 38	77° 23′	75	9	3.77	2.89	4.65	4.49	3.88	4.00	5.09	7.10	5.00	3.31	2.57	3.13	49.88	13.02	16.19	10.88	9.79
Hatteras*	35° 15	75° 40′	11	23	5.66	4.56	5.89	4.50	4.44	4.52	6.53	6.10	6.14	6.29	5.13	5.47	65.23	14.83	17.15	17.56	15.69
Kitty Hawk*	36° 0′	75° 42′	9	23	4.57	4.06	4.99	4.19	3.79	4.54	5.99	6.37	4.44	3.86	4.00	4.17	54.97	12.97	16.99	12.30	12.80
Littleton*	36° 26′	77° 54′	380	7	3.18	4.51	3.79	3.53	4.58	3.65	5.52	5.15	2.70	3.34	2.29	2.70	44.94	11.90	14.32	8.33	10.39
Lumberton*	34° 38′	78° 59′	...	10	5.20	3.90	3.56	3.56	4.27	5.71	5.81	6.52	3.93	3.46	2.13	1.80	49.85	11.39	18.04	9.52	10.90
Murfreesboro	36° 26′	77° 05′	75	5	2.88	3.40	2.80	4.00	3.68	2.84	5.29	3.10	2.80	2.05	2.79	3.05	38.68	10.48	11.23	7.64	9.31
New River Inlet	34° 32′	77° 18′	...	5	6.47	3.10	3.30	2.67	2.66	4.46	6.84	4.72	5.90	3.64	2.49	3.70	49.95	8.63	16.02	12.03	13.27
Newbern*	35° 6′	77° 02′	12	21	4.25	4.08	4.01	3.72	4.44	4.75	7.07	8.08	5.45	3.59	3.27	3.37	56.08	12.17	19.90	12.31	11.70
Norfolk, Va.*	36° 51′	76° 17′	69	27	3.67	3.88	4.48	3.87	4.40	4.28	5.91	5.81	4.43	3.99	3.07	3.65	51.44	12.75	16.00	11.49	11.20
Portsmouth	35° 2′	76° 4′	5	5	6.38	3.94	5.88	6.17	4.19	5.48	6.13	8.18	7.10	5.73	4.87	5.89	69.44	17.24	19.79	16.20	16.21
Southport*	33° 55′	78° 1′	34	22	3.91	3.41	3.86	2.63	3.27	4.00	6.72	5.56	5.34	4.57	2.94	3.11	49.32	9.76	16.28	12.85	10.48
Scotland Neck	36° 7′	77° 32′	50	10	3.86	3.84	3.83	4.10	3.59	2.79	5.48	6.96	6.49	2.23	3.40	3.99	50.06	11.52	15.23	12.12	11.19
Sloan*	34° 45′	77° 32′	50	5	3.31	4.41	4.06	3.51	4.09	4.88	6.15	7.45	3.37	4.90	2.89	3.15	52.17	11.66	18.48	11.16	10.87
Tarboro*	35° 50′	77° 35′	50	20	4.30	3.70	3.71	3.27	5.58	4.50	6.50	6.76	4.01	3.85	2.77	3.75	52.70	12.56	17.76	10.68	11.75
Weldon*	36° 24′	77° 32′	81	26	3.90	3.48	3.95	3.42	4.68	4.05	5.15	5.06	4.05	3.67	2.41	3.19	47.01	12.05	14.26	10.13	10.57
Willeyton*	36° 28′	76° 32′	45	8	2.80	3.87	3.67	2.87	5.00	5.18	6.65	5.54	3.25	3.83	2.53	2.77	47.91	11.54	17.32	9.61	9.44
Washwoods	36° 38′	75° 53′	10	5	4.39	3.82	4.10	2.14	3.17	4.44	3.91	5.20	2.14	2.73	1.71	3.01	40.76	9.41	13.55	6.58	11.22
Wilmington*	34° 14′	77° 57′	52	27	3.30	3.29	3.78	2.84	4.21	5.61	6.97	7.14	6.12	4.02	2.49	2.99	53.26	10.83	19.72	12.63	10.08

* Records continued during 1897.

TABLE III.—*Continued.*

CENTRAL DISTRICT.	Latitude, ° ′	Longitude, ° ′	Elevation, ft.	Length of record, years.	MONTHLY AND ANNUAL PRECIPITATION.													SEASONAL PRECIPITATION.			
					Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Spring.	Summer.	Autumn.	Winter.
Attaway Hill..........	35° 25′	80° 12′	850	11	3.70	4.50	5.41	4.52	4.65	4.67	4.20	5.09	4.90	3.35	3.02	3.72	51.78	14.58	13.96	11.27	11.92
Chapel Hill*............	35° 54′	79° 4′	500	21	4.41	3.81	4.16	3.50	4.44	3.43	4.73	4.54	3.90	3.34	2.79	3.70	46.75	12.10	12.70	10.03	11.92
Fayetteville*...........	35° 6′	78° 53′	170	13	5.21	4.31	5.30	4.36	4.71	4.18	8.09	6.77	5.20	4.45	3.30	5.25	61.13	14.37	19.04	12.95	14.77
Greensboro*...........	36° 4′	79° 49′	843	5	2.09	4.00	3.80	2.93	4.69	5.31	5.26	4.18	3.98	3.55	3.29	2.71	45.79	11.42	14.75	10.82	8.80
Henderson*	36° 20′	78° 23′	490	5	3.96	4.31	3.98	5.19	4.98	3.82	6.15	3.79	3.16	4.15	2.60	3.19	49.28	14.15	13.76	9.91	11.46
Louisburg*	36° 7′	78° 18′	375	7	4.21	4.37	2.90	3.40	4.70	4.25	5.41	4.56	2.62	2.87	2.39	2.93	44.61	11.00	14.22	7.88	11.51
Moncure*...............	35° 39′	79° 0′	300	5	3.87	4.42	4.02	4.12	3.78	3.56	5.60	4.21	3.38	3.22	3.09	2.38	45.65	11.92	13.37	9.69	10.67
Monroe*................	34° 59′	80° 34′	586	5	3.43	4.98	4.47	2.78	4.51	4.99	6.37	2.97	5.04	2.74	3.52	2.24	48.04	11.76	14.33	11.30	10.65
Oxford..................	36° 22′	78° 25′	475	7	3.73	4.33	3.13	2.66	6.03	3.40	4.73	4.91	3.49	3.22	3.01	2.31	44.95	11.82	13.04	9.72	10.37
Oak Ridge*	36° 10′	80° 0′	885	8	3.27	5.52	3.34	3.24	5.31	4.96	6.30	3.83	4.65	3.07	2.51	2.82	48.85	11.92	15.09	10.23	11.61
Pittsboro*..............	35° 42′	79° 12′	480	9	4.63	4.14	3.45	3.56	4.83	4.43	6.19	4.68	3.38	3.22	2.96	2.62	48.09	11.84	15.30	9.56	11.39
Roxboro*...............	36° 26	78° 58′	600	5	3.63	4.88	3.06	2.91	4.91	3.26	6.34	3.78	4.24	3.25	2.86	2.69	45.83	10.88	13.38	10.37	11.20
Raleigh*................	35° 45′	78° 37′	375	27	3.95	3.99	4.17	3.22	5.45	4.32	6.44	6.24	3.22	4.11	2.27	2.86	50.21	12.84	16.97	9.60	10.80
Rockingham*...........	34° 58′	79° 46′	210	5	3.37	4.61	3.28	3.05	3.56	4.63	6.98	6.58	3.46	3.18	2.68	3.84	49.22	9.89	18.19	9.32	11.82
Southern Pines*	35° 13′	79° 22′	400	7	4.06	4.36	4.37	3.62	4.68	4.59	8.23	6.63	2.54	3.13	2.47	3.01	51.69	12.67	19.45	8.14	11.43
Soapstone Mt.*.........	35° 46′	79° 37′	900	8	4.19	4.84	4.87	3.09	4.40	4.17	6.39	4.79	4.11	3.51	3.13	3.26	50.25	11.86	15.35	10.75	12.29
Selma*..................	35° 31′	78° 21′	225	8	3.03	4.37	4.76	3.49	4.82	4.12	6.23	7.10	2.92	2.98	2.45	3.40	49.67	13.07	17.45	8.35	10.80
Saxon*..................	36° 22′	80° 6′	900	7	3.44	4.59	2.98	3.02	5.00	4.99	4.41	4.97	4.21	2.49	3.17	2.27	45.54	11.00	14.37	9.87	10.30

* Records continued during 1897. Precipitation in inches and hundredths.

TABLE III.—*Continued.*

WESTERN DISTRICT.	Latitude, ° ′	Longitude, ° ′	Elevation, ft.	Length of record, years.	MONTHLY AND ANNUAL PRECIPITATION.													SEASONAL PRECIPITATION.			
					Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Spring.	Summer.	Autumn.	Winter.
Asheville*	35° 37′	82° 30′	2250	22	3.17	3.48	3.86	3.20	3.70	3.99	5.05	4.56	2.73	2.62	2.99	2.93	42.28	10.76	13.60	8.34	9.58
Bryson City*	35° 27′	83° 23′	..	10	4.70	5.73	5.32	3.78	4.02	4.01	5.49	4.91	3.26	2.44	3.51	3.18	50.35	13.12	14.41	9.21	13.61
Charlotte*	35° 13′	80° 51′	808	22	4.77	4.89	4.87	3.43	4.12	5.35	5.26	5.33	3.40	3.38	3.14	3.82	50.76	12.42	14.94	9.92	13.48
Flat Rock*	35° 15′	82° 25′	2214	5	3.87	4.74	3.60	5.02	4.79	4.85	7.21	5.42	5.49	4.43	4.44	5.61	59.47	13.41	17.48	14.36	14.22
Franklin	35° 12′	83° 27′	2141	12	5.96	6.97	6.42	4.28	2.99	4.40	5.10	5.35	3.98	3.48	3.66	4.52	57.11	13.69	14.85	11.12	17.45
Highlands*	35° 5′	83° 25′	3817	15	6.53	8.19	5.91	6.25	4.45	5.53	6.21	6.17	6.02	4.78	5.94	6.32	72.30	16.61	17.91	16.74	21.04
Horse Cove*	35° 0′	83° 6′	2800	6	7.76	6.95	5.13	6.42	4.85	8.29	7.68	7.11	5.83	2.31	5.37	5.28	72.98	16.40	23.08	13.51	19.99
Linville*	36° 5′	81° 51′	3800	5	4.08	4.08	4.45	5.26	4.49	4.86	8.29	3.76	4.59	1.86	5.58	5.60	56.90	14.20	16.91	12.03	13.76
Lincolnton	35° 9′	81° 12′	944	5	3.71	4.15	4.10	2.92	8.08	4.02	5.03	5.42	2.03	2.64	3.35	4.65	50.10	15.10	14.47	8.02	12.51
Lynn*	35° 12′	82° 14′	1500	5	3.93	5.62	3.98	5.45	4.78	5.23	4.66	5.47	4.05	4.12	4.84	3.42	55.55	14.21	15.36	13.01	12.97
Lenoir*	35° 58′	81° 30′	1186	26	4.17	4.45	4.00	3.58	4.74	4.15	5.06	5.64	4.67	3.29	3.31	3.68	50.74	12.32	14.85	11.27	12.30
Murphy*	35° 8′	84° 0′	1614	20	6.19	6.44	6.46	5.40	3.51	5.51	6.53	5.40	3.18	2.80	4.58	4.96	60.96	15.34	17.44	10.56	17.59
Mt. Airy*	36° 30′	80° 40′	1048	10	3.27	4.20	3.75	2.85	3.86	4.07	5.51	5.34	4.08	2.24	3.10	2.73	45.00	10.46	14.92	9.42	10.20
Morganton*	35° 45′	81° 44′	1135	10	3.96	4.70	3.43	4.03	3.79	3.98	4.88	3.84	5.02	3.00	3.31	2.59	46.53	11.25	12.70	11.33	11.25
Mocksville*	35° 51′	80° 34′	651	5	3.31	4.18	3.69	2.74	3.07	4.09	4.16	5.66	3.78	3.37	2.82	2.58	43.44	9.49	13.91	9.97	10.07
Mt. Pleasant	35° 28′	80° 28′	650	12	3.84	4.46	3.87	2.81	3.90	4.88	5.46	5.69	4.00	3.63	2.65	2.99	48.18	10.58	16.03	10.28	11.29
Mt. Holly	35° 24′	81° 3′	..	6	3.58	5.62	4.82	2.48	6.12	4.34	5.10	3.96	5.22	3.51	2.45	3.26	50.46	13.42	13.40	11.18	12.46
Marion*	35° 30′	82° 5′	1425	5	3.84	4.24	3.39	3.07	5.22	4.91	5.91	4.01	4.32	4.44	3.66	2.68	49.69	11.68	14.83	12.42	10.76
Statesville	35° 45′	80° 53′	950	12	4.75	4.50	5.36	3.19	5.24	4.64	5.38	5.66	2.66	3.66	2.84	3.69	51.57	13.79	15.68	9.16	12.94
Salisbury*	35° 40′	80° 29′	760	13	3.83	4.42	4.22	2.79	4.90	4.47	4.76	5.01	3.49	3.62	2.89	2.64	46.99	11.91	14.24	9.95	10.89
Webster	35° 20′	83° 17′	..	5	3.58	5.63	4.83	3.92	2.05	1.17	2.60	2.80	1.55	3.42	2.07	2.36	35.98	10.80	6.57	7.04	11.57
Waynesville*	35° 29′	82° 58′	2756	5	5.98	3.67	5.14	3.33	4.16	4.66	5.99	3.74	1.71	1.76	3.01	3.00	46.15	12.63	14.39	6.48	12.65
For the state				27*	4.35	4.21	4.56	3.77	4.21	4.87	5.58	5.78	4.42	3.57	3.32	3.73	51.87	12.54	15.73	11.31	12.29

* Records continued during 1897. Precipitation in inches and hundredths.

PRECIPITATION IN THE EASTERN DISTRICT.

The annual rainfall on the immediate coast, from Cape Hatteras to Cape Lookout, is over 60 inches; the amount gradually decreases westward to about 50 inches at Raleigh. Throughout the entire division the chief maximum rainfall occurs in July or August, the chief minimum in October or November, with a secondary minimum in April. In some years the chief maximum has been deferred to September or even October owing to the more frequent occurrence of sub-tropical storms during these months. The explanation of the greater rainfall in the east is very simple. The prevailing track of storms which cross North Carolina is from south to north, and the heaviest rainfall usually occurs on the east side of such storms. Thus it is inevitable that the circulation of the winds, while the storm is approaching or is over the state, will be such as to draw from the ocean large masses of damp, vapor-laden air, and that the greater amount of its moisture will fall in the east. The greater precipitation on the coast is not of much influence on waterpower, since it occurs only over the lower courses of the rivers.

PRECIPITATION IN THE CENTRAL DISTRICT.

The rainfall over the central portion of the state lies between 45 and 50 inches. This includes all points within the trapezoid formed by the northern and southern boundaries of the state and oblique lines drawn from Gates to Anson counties on the east and from Surry to Union on the west. The maximum fall occurs in July, and is almost entirely due to the convectional current inducted by solar radiation (thunderstorms). The amount of rainfall is nearly equal during spring and winter and is least in autumn.

PRECIPITATION IN THE WESTERN DISTRICT.

Great diversity characterizes this section. The rainfall is very great on the southeast slope of the Appalachians. In Macon county a series of very reliable observations at Highlands gives an annual normal of 72 inches, and an equally trustworthy record for six years at Horse Cove, south of and 1000 feet lower than Highlands, gives nearly 73 inches. The effect is due to the configuration of the valleys and the influence of elevation. When cyclonic disturbances pass westward of the state, or under any circumstances which will force masses of air against the mountains from the south, southeast or east, the currents of air are deflected upwards, and the moisture they contain is precipitated by the cold of elevation. The same effect is noticeable to a more limited extent on all of the eastern slopes of the mountains at least as far north as Linville, except where the ranges are lower. Immediately beyond the crest of the Blue Ridge there is a rapid diminution in the quantity of precipitation especially prominent in the larger valleys. Asheville, with a record extending over 22 years (which is broken, however, between 1880 and 1890), has a normal fall of about 42 inches, so far the smallest reliable record in the state; Waynesville, Haywood county, averages 46 inches. At many western stations the chief maximum falls in winter or early spring.

VARIATIONS IN PRECIPITATION.

Besides the abundant supply of water, the variations in the monthly and daily rainfall which change the amount of flow or volume of water carried to the sea are of considerable importance in considering the waterpower of a district. In Table IV (p. 48) are given for selected stations the largest and least monthly rainfall, with dates, and the possible fluctuations of the highest and lowest monthly averages in percentages of the monthly mean. In respect to the frequency of heavy rains North Carolina ranks very high. Considering an excessive daily fall to be 2.50 inches or more in 24 consecutive hours, in Septemeber the state ranks first in frequency of such rains, in August and October is surpassed only by Florida, in July and December by California, Louisiana and Texas. The least heavy precipitation occurs in June.

LARGEST DAILY RAINFALL.

The following are the largest daily totals ever recorded in North Carolina for each month of the year:

January.—Fayetteville, 6.00 inches, January 8 and 9, 1879.
February.—Highlands, 6.01 inches, February 8 and 9, 1891.
March.—Hatteras, 6.72 inches, March 30, 1879.
April.—Fayetteville, 6.25 inches, April 27 and 28, 1879.
May.—Weldon, 6.03 inches, May 10, 1887.
June.—Salisbury, 7.39 inches, June 10, 1883.
July.—Wilmington, 7.33 inches, July 15, 1886.
August.—Hatteras, 9.14 inches, August 23, 1880.
September.—Ellsworth, 13.00 inches, September 15 and 16, 1881.
October.—Columbus, 5.62 inches, October 13 and 14, 1893.
November.—Hatteras, 6.16 inches, November 7 and 8, 1893.
December.—Fayetteville, 6.00 inches, December 9th and 10th, 1878.

WET AND DRY YEARS.

The year 1877 was the wettest on record in North Carolina and during that year the highest stages ever known occurred in some of the rivers of the state. The annual rainfall has been below the normal continuously since 1889 (excepting a slight excess during 1891). The dryest years have been 1890, 1894, 1896 and 1897. It would probably surprise many people to learn that at four stations in North Carolina no measurable precipitation occurred in November, 1890, a possibility usually associated only with the arid regions of the west. The lowest stages of the rivers perhaps ever known occurred during the fall drought of 1897.

SNOWFALL IN NORTH CAROLINA.

The average snowfall for the state is about 5 inches. The snowfall is not a factor of great importance, as it is rarely heavy, and that which falls one day is generally dissipated by the next. In the mountains the snow rarely remains on the ground over a week at a time. There can be no accumulation of snow sufficient to cause spring floods as such. The heaviest snows frequently occur in the central section of the state, which is more open to the north and northeast winds accompanying storms on the coast with which snow usually occurs. During the past five years the snowfall in North Carolina has been much above the normal in consequence of the occurrence of two severe winters, one shortly after the other (1893 and 1895). The snowfall of February, 1895, was especially remarkable. The totals for that year were Littleton, 22 inches; Henderson, 32; Oak Ridge, 26; Saxon, 36; Asheville, 39; Highlands, 54; Linville, 48; Mt. Airy, 32; Lenoir, 22, and Waynesville, 34 inches.

The average annual snowfall at selected stations for the past five years is given below. These amounts are much above the normal annual fall:

Asheville	16	inches.	Raleigh	12	inches.
Chapel Hill	13	"	Roxboro	13	"
Highlands	22	"	Rockingham	8	"
Henderson	16	"	Southport	3	"
Littleton	16	"	Selma	10	"
Louisburg	15	"	Saxon	17	"
Lenoir	11	"	Soapstone Mt.	17	"
Mt. Airy	12	"	Salisbury	11	"
Mt. Pleasant	11	"	Tarboro	7	"
Oak Ridge	11	"	Weldon	9	"
Pittsboro	14	"			

PRECIPITATION CHARTS.

The charts presented in Figures 2 to 6 are based on the material given in Table III (pp. 36-38). Records obtained previous to the year 1887 are not strictly comparable with those extending through 1897; and in some cases their proper weight has been estimated. It is to be observed, furthermore, that the scale of shading of necessity has not the same value in all the seasonal charts, beginning with a scale of 6 to 8 inches for autumn, 8 to 10 inches for spring and winter, and 12 to 14 inches for summer, the season of heaviest precipitation.

FRESHETS ON THE RIVERS.

All of the rivers of North Carolina are subject to freshets which occur irregularly at any time of the year. The melting of snow in the mountains and breaking up of ice in spring are never a cause of freshets in this state. Ice gorges occasionally occur in the western rivers, especially on the New river and its tributaries. Freshets may take place in a single river basin, as for instance, in August, 1894, when heavy rains occurred in the southeast portion of the state from the 3d to the 6th, which caused a rapid rise in the Cape Fear river to 34 feet on the gauge at Fayetteville, while streams further north were not affected at all. The most disastrous flood of recent years was that of July, 1896, when the Roanoke reached 42 feet at Weldon (within 5 feet of the highest stage known) and the Cape Fear 49.5 feet on the 12th. Probably the highest authentic stage known on the Cape Fear was 58 feet, January 12, 1895.

INFLUENCE OF RAINFALL ON THE FLOW OF STREAMS.

In conclusion, it may be noted that the calculation of the amount of water available for power from a given rainfall is a very complicated one. While rivers draw their entire supply of water from the precipitation over their basins, a large percentage of the rainfall is lost immediately by evaporation, absorption by vegetation, etc., and much soaks into the ground until it reaches an impervious substratum. The river supply is sustained during drought by the underground waters. There will be, then, a very great variation in the influence of rainfall at different seasons of the year. The following illustration may be given as an extreme case.

The mean stage of the Cape Fear river at Fayetteville during December, 1894, was 7 feet, and the final stage, December 31, 6 feet. The average rainfall over the entire basin of the river during January, 1895, was 6.97 inches, which maintained during January a mean stage of 20 feet, and caused a maximum flood of 58 feet on the 12th.

Consider, now, similar data for August, 1898. The mean stage during July, 1898, was 6 feet, the final stage 4 feet, which, though 2 feet lower than that at the end of December, 1894, is not material at such

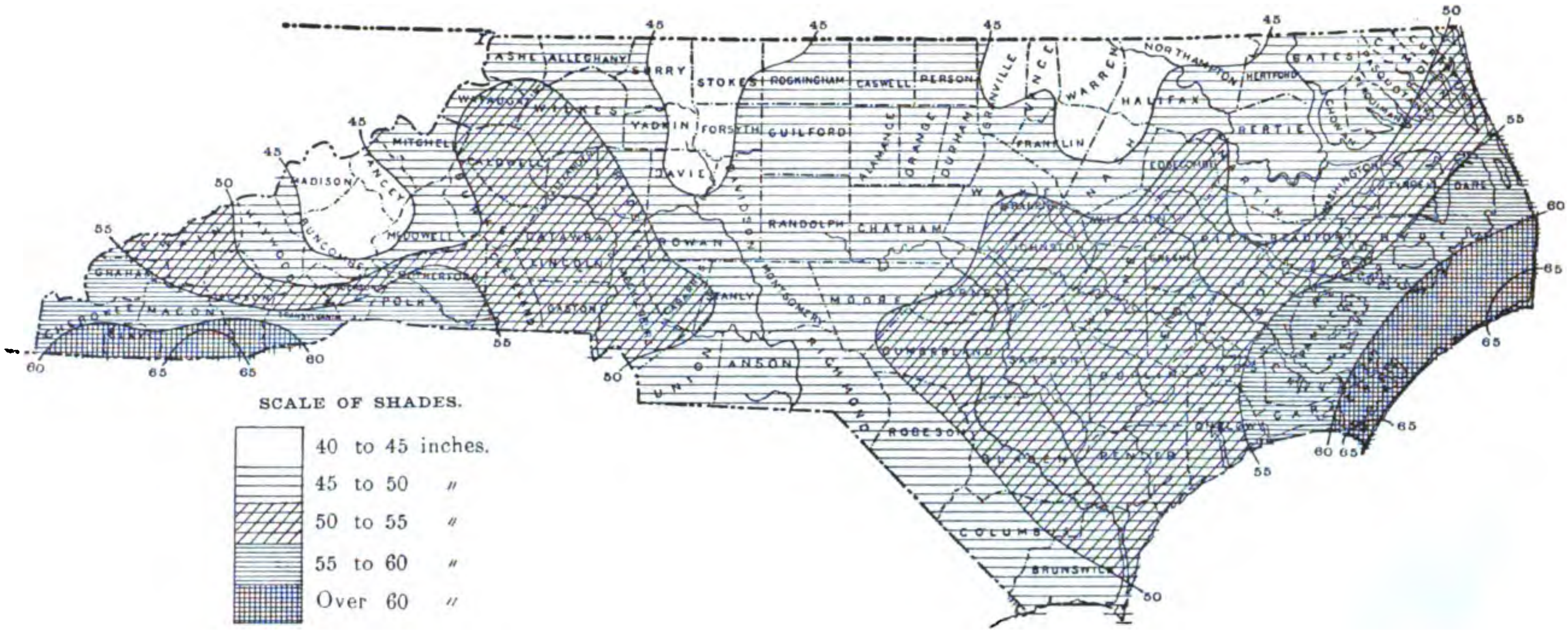


FIG. 2.—CHART SHOWING THE MEAN ANNUAL PRECIPITATION IN NORTH CAROLINA IN INCHES. (SEE P. 41.)

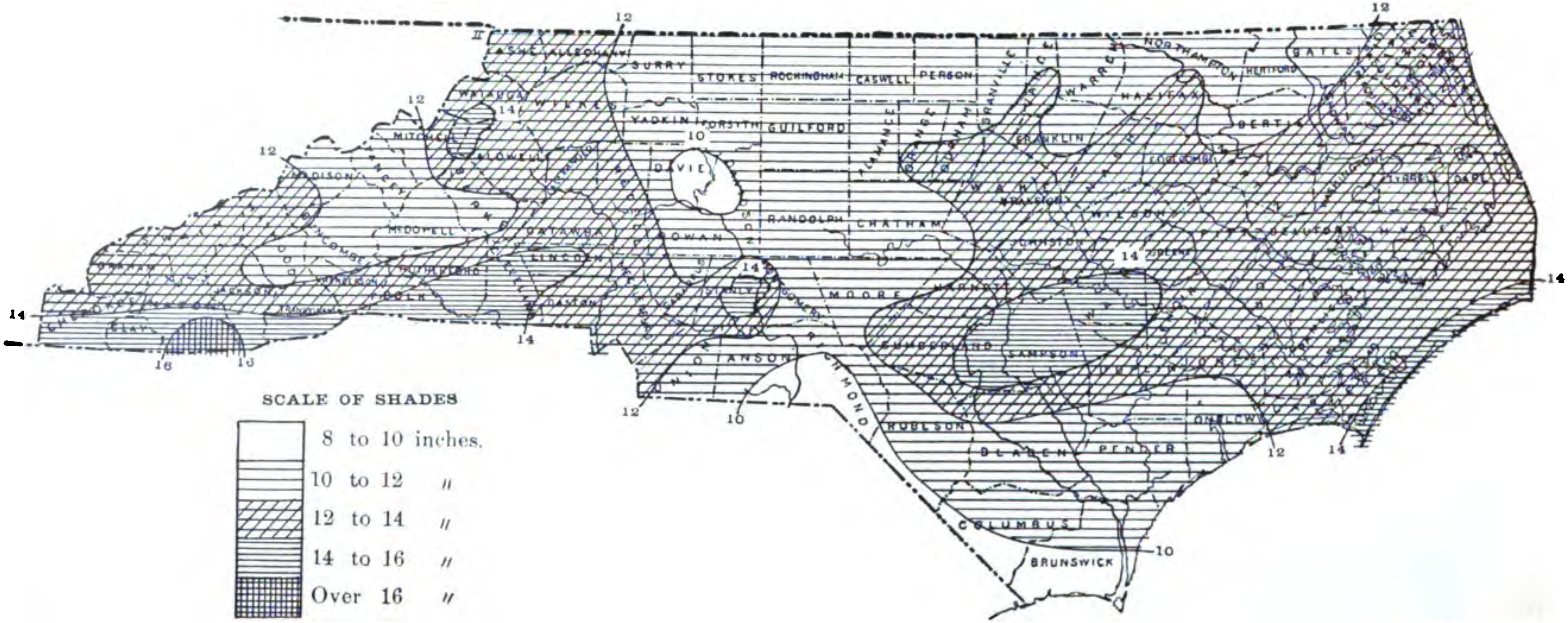


FIG. 3.—MEAN PRECIPITATION IN NORTH CAROLINA DURING THE SPRING. (SEE P. 41.)

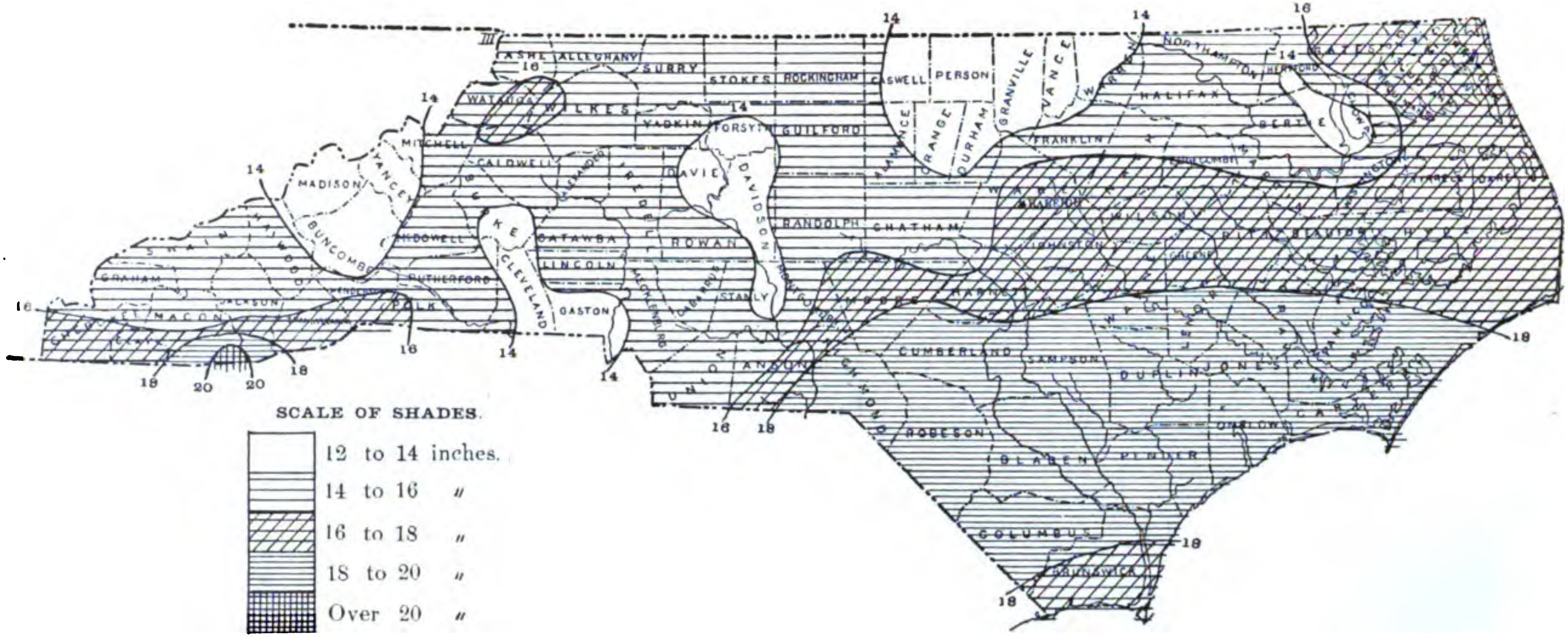


FIG. 4.—MEAN PRECIPITATION IN NORTH CAROLINA DURING THE SUMMER. (SEE P. 41.)

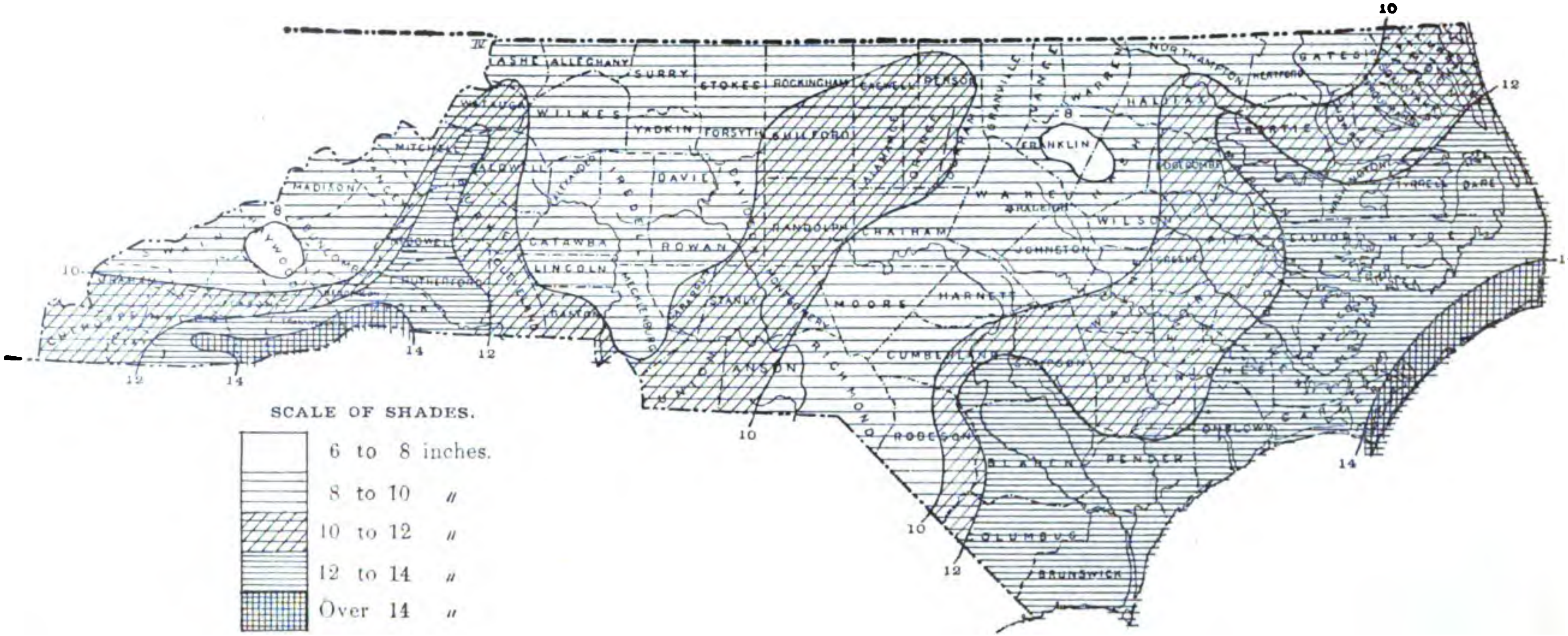


FIG. 5.—MEAN PRECIPITATION IN NORTH CAROLINA DURING THE AUTUMN. (SEE P. 41.)

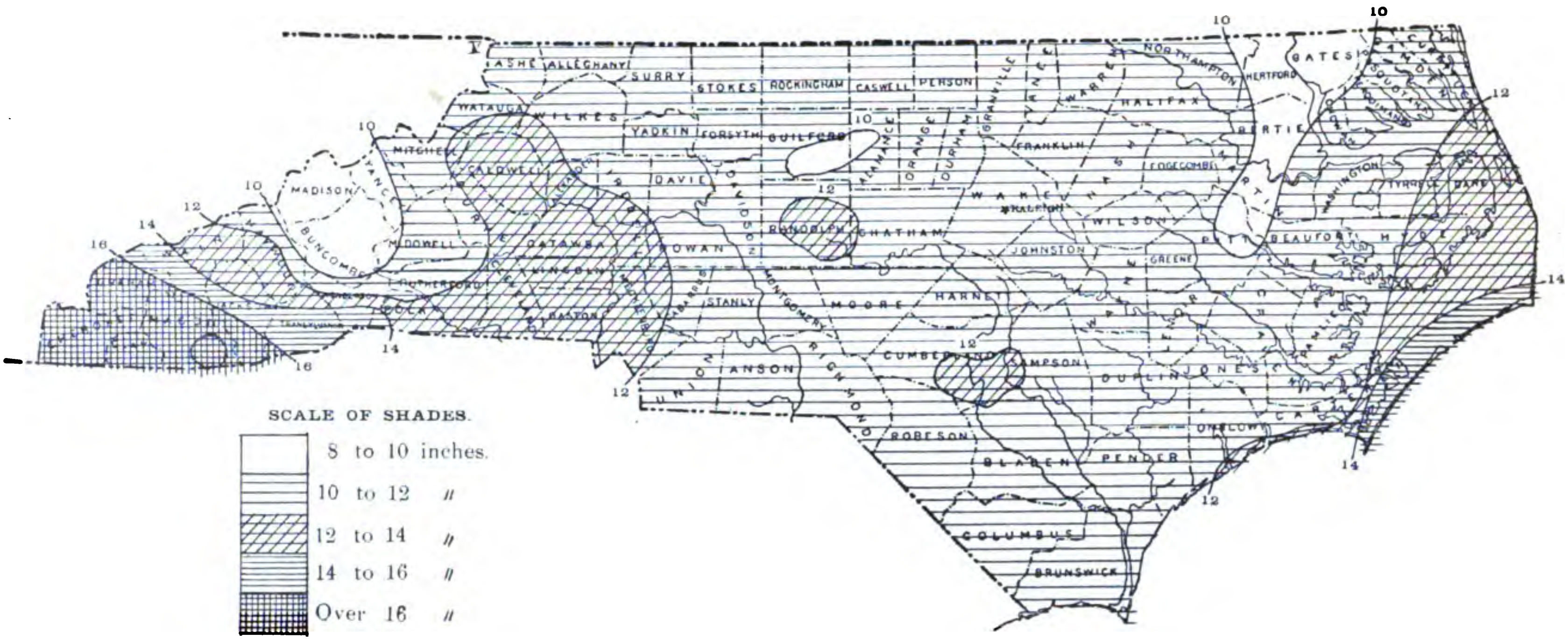


FIG. 6.—MEAN PRECIPITATION IN NORTH CAROLINA DURING THE WINTER. (SEE P. 41.)

low stages. The average rainfall for August over the entire basin was 7.59 inches, or over half an inch more than during January, 1895, yet this amount was only able to maintain a mean stage during August of 10 feet at Fayetteville, and the maximum flood was only 29 feet on the 22.

Waterpower depends on the quantity of water in cubic feet per second and the distance through which that water falls. From the data furnished by the meteorologist, and his own measurements on the volume and fall of streams, it is the province of the hydraulic engineer to calculate the available waterpower.

TABLE IV.—GREATEST AND LEAST MONTHLY PRECIPITATION.

STATIONS.	Elevation, feet.	Length of record, years.	Greatest monthly. (inches).	Month and Year.	Least monthly. (inches).	Month and Year.	Highest and Lowest monthly averages in percentages.[1]	
Asheville	2250	23	11.40[2]	July, 1874	0.21	Oct., 1895	143	74
Chapel Hill	500	41	11.71	Aug., 1891	trace	Nov., 1890	121	86
Charlotte	808	22	11.13	Mar., 1891	0.23	Nov., 1890	126	74
Fayetteville	170	13	17.20	July, 1879	0.34	Oct., 1892	159	65
Goldsboro	102	21	16.70	Sep., 1877	0.35	Oct., 1886	163	54
Greensboro	843	15	10.75	Aug., 1893	0.23	Sep., 1895	139	55
Greenville	75	9	15.10	Sep., 1877	0.35	Nov., 1879	171	62
Highlands	3817	15	20.20	Feb., 1891	0.25	May, 1883	135	79
Horse Cove	2800	6	17.02	Jun., 1892	0.62	Oct., 1892	136	88
Hatteras	11	23	16.30	Aug., 1880	trace	Nov., 1890	120	80
Kitty Hawk	9	23	15.36	July, 1882	0.05	Sep., 1895	139	83
Littleton	380	7	10.29	Aug., 1891	0.25	Sep., 1897	148	61
Louisburg	375	7	8.49	Aug., 1891	0.36	Oct., 1892	145	64
Lenoir	1186	26	11.50	May, 1873	0.00	Nov., 1890	133	78
Lumberton	....	10	12.50	Sep., 1883	0.11	Oct., 1884	157	44
Morganton	1135	10	11.20	Apr., 1878	0.20	Oct., 1892	129	67
Mt. Airy	1048	10	10.38	July, 1889	0.17	Nov., 1890	147	60
Mt. Pleasant	650	12	10.27	Aug., 1887	0.28	Oct., 1892	142	66
Newbern	12	21	19.65	Aug., 1878	0.20	Nov., 1890	178	70
Oak Ridge	885	8	10.99	July, 1891	trace	Nov., 1890	155	62
Pittsboro	480	9	13.40	Apr., 1895	0.01	Oct., 1892	154	65
Raleigh	375	27	11.23	July, 1890	0.06	Nov., 1890	154	54
Rockingham	210	5	10.16	Aug., 1893	0.37	Oct., 1892	170	65
Roxboro	600	5	12.56	July, 1896	0.36	Oct., 1896	166	70
Southport	84	42	12.53	Aug., 1887	0.10	Dec., 1889	164	64
Salisbury	760	13	16.14	Aug., 1887	0.13	Nov., 1890	128	67
Selma	225	8	16.30	Aug., 1891	0.20	Nov., 1890	171	59
Saxon	900	7	10.87	Aug., 1893	0.58	Dec., 1896	132	60
Soapstone Mount	900	9	10.50	Mar., 1891	0.25	Nov., 1890	153	74
Southern Pines	400	7	11.08	May, 1891	0.11	Sep., 1895	191	57
Tarboro	50	12	22.73	Aug., 1887	0.10	Sep., 1895	154	63
Weldon	81	26	10.56	Sep., 1888	0.05	Nov., 1890	160	62
Willeyton	45	8	10.72	Aug., 1890	0.25	Nov., 1890	167	63
Wilmington	52	27	21.12	July, 1886	0.19	Nov., 1886	161	56

[1] Explanation.—The highest and lowest monthly average rainfall from Table III, in percentages of the mean, obtained by dividing the annual total by 12. Thus, annual rainfall at Asheville (Table III), 42.28 divided by 12 = 3.52 inches. Of this the largest monthly average at Asheville, 5.05 in July, is 143 per cent.; the smallest monthly average, 2.62 in October, is 74 per cent.

[2] A larger record exists, which is not considered quite trustworthy.

CHAPTER III.

THE FLOW OF STREAMS.[1]

The essential elements of a waterpower are the fall and the quantity of water; and the amount of fall being a fixed quantity, capable of being measured once for all, and therefore not needing discussion, it is necessary to determine the amount of water that a given stream will afford at a certain point and the variation in the flow from month to month.

CONDITIONS AFFECTING THE FLOW.

The average amount of water carried past a certain point in a year depends, among other things, upon the amount and distribution of the rainfall, the area of the drainage-basin, and the character of that basin. All the water carried by is derived from the rainfall, but of the total rainfall a certain amount is lost in the following ways: By percolation and discharge through subterranean channels; by evaporation from the soil and the surfaces of streams; by absorption through the roots of trees, shrubs, and grasses, and subsequent evaporation. The amount discharged by the streams will be greater as these sources of loss are diminished, and the problem before us is to determine for each particular case what proportion of the rainfall is so discharged; and we must, moreover, endeavor to find out the laws regulating the distribution of the flow through the year, and from year to year. In the case of most streams the flow varies greatly from day to day, and from month to month, being occasionally in times of freshet 50, 100, and even several hundred times its minimum volume. Thus the table given further on shows that the Potomac river at Cumberland has been known to discharge a quantity 716 times as great as its minimum discharge, while the maximum discharge of the Merrimac is only about 70 times its minimum discharge.

A great fluctuation in the volume of water in a stream is evidently an obstacle to the extensive use of waterpower, making it necessary to depend only on the flow at times when the stream is low, or to use auxiliary steam power, or to store the freshet water in reservoirs, and so increase the flow in dry seasons. It is necessary, therefore, to discuss, to some extent, the total amount discharged by streams (or the

[1] By Geo. F. Swain, Professor of Civil Engineering in the Mass. Institute of Technology, Boston.

proportion of the rainfall flowing off) and the manner in which that total amount is distributed through the year. As regards the first of these questions, it has generally been customary to assume a certain fixed proportion of the annual rainfall as flowing from the surface and discharged by the streams; but it has always been recognized that the proportion to be thus assumed varies greatly according to numerous circumstances, such as the area and form of the drainage-basin; the distribution of the rainfall through the year, as well as its amount; the extent of the forests; the number and extent of lakes; the character of the soil and rocks, and the state of cultivation; and all of these factors affect not only the total discharge of a stream but also its distribution. With a given watershed, in any particular year, a certain proportion of the rainfall will be discharged and distributed in a certain way, but both that proportion and that distribution are liable to change if any one of the above conditions are altered. Thus the greater the area of the watershed the more uniform the flow, other things equal, because streams draining small areas are more subject to the effects of sudden rains than those draining large ones; and while in the former case there may be weeks at a time when no rain falls on the basin, and the stream draining it almost dries up, in the latter case there will probably be frequent rains on some part or other of the basin.

The table given further on illustrates this point by showing that, as a rule, the ratio of maximum to minimum discharge is greater in the case of small streams than in that of large ones. And, in like manner, the form of the drainage basin exerts a certain influence. The distribution of the rainfall is a very important point, and as an example of the great variability of the proportion of the rainfall discharged from the same watershed in different years the case of the drainage area of the Albany waterworks may be cited, where, from an area of 2,600 acres in 1850, between May and October, inclusive, 41½ per cent. of the rainfall was carried off by the streams, while in 1851, within the same period (from May to October) 82.6 per cent. was discharged.[1] Hence it is that the year of minimum rainfall may not be the year in which the streams get lowest, or the one in which the season of lowest flow occurs. An eminent authority has remarked: "This (the year with the season of least flow) is not necessarily the year of least rainfall, nor even the year of greatest apparent drought, but is the result of such a distribution of the rainfall that the excess of water over the amount needed for sustaining vegetation and supplying losses by

[1] Hughes, *Waterworks*, p. 332.

evaporation is very small for several successive months."[1] The proportion of the rainfall discharged by streams is therefore a very uncertain and variable quantity, varying not only for different streams, but for the same stream in different years; and it is evident that the attempt to deduce the distribution of the flow of streams by taking certain proportions based on the rainfall is still more uncertain. Hence it is that some eminent engineers have given up the use of any proportion at all in calculations regarding the capacity of streams to furnish water-supply, and have adopted for this climate a certain fixed number of inches of rainfall as available. Mr. Croes has remarked in another place[2] that "the few records that exist of the flow from known drainage areas establish the fact that not over 15 inches per annum can be depended upon on the Atlantic slope, and many engineers who have devoted a good deal of attention to the subject are very decided in their opinion that not more than 11 inches should in any case be calculated on."

Extended data with reference to the amount of water available from watersheds is obtainable in connection with certain New England streams, and the following figures may be of interest, although not applicable to streams in other parts of the country where the conditions are different.

On the Cochituate watershed near Boston, comprising an area of about 19 square miles, the average rainfall is 47.43 inches and the average amount collected is 21.59 inches, or 45 per cent. In 1880, however, the rainfall was 35.83 inches, the amount collected 10.3 inches, or 29 per cent., while in 1883 the rainfall was 31.2 inches, the amount collected 10.11 inches, or 32 per cent. On the Sudbury watershed, which also supplies Boston, and comprises about 75 square miles, the average rainfall is 45.75 inches, the average "run-off" 22.29 inches, or 48 per cent. In 1880, the rainfall was 38.18 inches and the "run-off" was 12.18 inches, or about 32 per cent.; and in 1883 the rainfall was 32.78 inches, the "run-off" 11.19 inches, or 34 per cent. In these cases the minimum "run-off" is about one-half the average. In the cases of larger watersheds the difference will not be so great.

The annual yield of streams, or, as it is frequently called, the "run-off," is now being studied in the case of many streams in all parts of the country, and in the near future better results than are now available will be at the disposal of hydraulic engineers. The U. S. Geological Survey is doing much in this direction, and in one of its

[1] Newark Aqueduct Board, Report on Additional Water Supply, by J. J. R. Croes and G. W. Howell, 1879.
[2] *Engineering News*, March 20, 1880, p. 104.

bulletins (Bulletin No. 140, 1896) much information is given in this connection. Regarding large streams, however, the details are comparatively meagre, and in few cases have the records been long enough continued to allow reliable estimates for the future to be made. In New England, the Merrimac and Connecticut rivers are daily measured in connection with the large waterpowers developed at Lawrence, Lowell and Holyoke, but these streams are exceptional and are no criterions in judging of the streams in the Southern states, principally because they are fed by many or by large lakes. It may be mentioned, however, that even the Connecticut river, with an average rainfall of about 44 inches and a drainage basin of 8,660 square miles, has in one year (1883) shown as low a "run-off" as 12.7 inches.

Measurements have been made, by the Geological Survey, of the flow of various streams in North Carolina. The results are interesting, but the measurements do not cover sufficient time to be of much service in connection with the estimates in this report. When extended so as to cover twenty or thirty years, these records will be of great value.

CONDITIONS AFFECTING FLUCTUATIONS IN FLOW OF STREAMS.

It may not be out of place to devote a few lines here to a closer consideration of the causes affecting the fluctuations in the flow of streams. Evaporation, the principal source of loss, acts in different months with very different degrees of intensity, being generally greatest in the summer months and least in the winter. It is sometimes the custom, in calculating the amount of water-supply available for the use of a town, to assume a certain proportion of the rainfall of each month as collectible or as discharged through the streams, that proportion varying from 20 or 30 per cent. in summer months to 70 or 80 per cent., or even over 100 per cent., in others. Now, if we assume that the rainfall at any particular time reaches the streams within a short time after it has fallen, say within a month or so, then, if the rainfall is uniformly distributed throughout the year, the flow of the streams will decrease as the evaporation increases, and will be several times greater in some month (the month of maximum flow) than in some other month (the month of minimum flow). If, now, the rainfall be so distributed that in the months when the evaporation is *least* the greatest rainfall occurs, it is evident that the proportion of the rainfall discharged will be greater than in the first case, while the variability of the flow will also be greater. In this case, then, a larger amount of water will be available, but the storage necessary will also be larger, while the minimum and low-season flow of the stream, without storage, will be less than before, for the reason that the minimum rainfall will occur during the summer months, when the evaporation will be greatest.

Again, if the greatest rainfall occurs in those months in which the evaporation is greatest, the proportion of the rainfall discharged by the streams will be less than in the first case, but the flow will be more uniform. In this case, then, a smaller amount of water will be available, but the necessary storage will be less, while the minimum flow of the stream, without storage, will be greater than in either of the previous cases. Hence we see how the distribution of the rainfall and the amount of the evaporation affect the flow of the streams, and by considering these, as well as the other elements affecting waterpower, we may be able to judge of the relative value of two streams, and to form some estimate of their flow, even if no gaugings are at hand, although such estimates are very rough and liable to be greatly in error.

CONDITIONS AFFECTING UNIFORMITY OF FLOW.

Two elements of a good waterpower are large flow, or large proportion of rainfall available, and uniform flow. The flow may be large, but if it is very variable the storage-room necessary to utilize it all may be too large, while a small flow, if uniform, could be utilized without any storage at all (except where it is desired to concentrate the power into less than twenty-four hours). But the remaining factors above named, viz. soil, forests, lakes, affect very materially the flow of streams, both in amount and in constancy. The effect of these is felt in so many ways that it would not be the place here to discuss them extensively. But, as showing what principles have guided me in making my estimates of the flow of the various streams, I may be permitted to sum up here briefly these effects.

A deep and porous soil, if underlaid by an impervious stratum, down to which the streams have cut their beds, has the effect of diminishing the evaporation and rendering the flow of the streams more constant. In some cases, however, and especially when the streams have not cut down to an impervious bed (that sheds the water that percolates to it), a deep and pervious soil is accompanied by considerable loss by flowage in subterranean courses, so that the flow of the streams may be diminished. It does not seem as though this were the case in the Southern states.

The action of lakes in regulating flow is evident, but it is next to impossible to estimate it numerically. They exert a more important influence in this respect than any other factor entering into the question.

As regards forests, I am constrained to speak of their action somewhat briefly, for the reason that the problem is one of great complexity and involves many factors which are at present not well understood, and because of the further fact that, on account of the climatic conditions in some parts of the district under consideration, their influence may be overestimated. Although authorities are not agreed as to whether forests increase the actual amount of rainfall, the weight of evidence seems to be tending to prove that they do not. All are agreed, however, that they act as regulators of the flow of streams; which they appear to accomplish through the decreased evaporation under a shaded surface, and the increased sub-drainage through the resistance to surface drainage and increased porosity of a forest-covered soil. The forests, therefore, diminish the quantity of water flowing directly from the surface in summer, and by storing it up, to be given out gradually, contribute to the constancy of the streams. (See page 64 for further remarks.)

METHOD OF ESTIMATING THE FLOW OF STREAMS.

I will now proceed to explain the general method I have followed in estimating the flow of the streams in this district. In calculating the amount of waterpower available I have considered the flow of streams chiefly with reference to three quantities, viz.:

1. The absolute minimum flow.
2. The minimum low-season flow.
3. The low-season flow in ordinarily dry years, but not the driest.

a. THE ABSOLUTE MINIMUM FLOW determines the maximum power which the stream will afford, at a given point, *at all times;* but as this minimum flow generally occurs during a period of not over a few days at intervals of a number of years, it is not of so much importance as the other quantities, and if only this flow is utilized there will be a large amount of water wasting, even in the low season, for years in succession. The amount of this flow is best approximated to, by assuming a certain discharge per square mile of watershed, varying with the area of the watershed and the local and climatic conditions. In estimating this flow I have made use of the results given in the table on page 55.

TABLE SHOWING EXTREMES OF FLOW FOR SOME AMERICAN STREAMS.

River.	Place.	Drainage area, square miles.	Mean Rainfall, Inches. Spring.	Summer.	Autumn.	Winter.	Year.	Remarks on Character of Drainage Basin.	Extremes of Flow. Maximum, cubic feet per second.	Minimum, cubic feet per second.	Ratio.	Minimum cubic feet per second per square mile.	Ordinary low-water flow, cubic feet per second per square mile.	Authority and Remarks.
Merrimack...	Lowell	4,085.00	10	11	13	9	43	Lakes and artificial reservoirs. Wooded.	81,000	1,275.00	64	0.31	......	J. B. Francis and others.
Merrimack...	Lawrence..........	4,599.00	10	11	13	9	43	Lakes and artificial reservoirs. Wooded.	96,000	1,400.00	69	0.30	0.60	Private information.
Concord	Lowell	361.00	11	11	12	10	44	Hilly and swampy	4,449	60.00	74	0.170	0.35	C. Herschel.
Sudbury	Framingham	78.00	11	11	12	10	44	Hilly and swampy. One-sixth to one-eighth wooded.	3,228	2.80	1,153	0.036	0.16	A. Fteley.
Charles	....	215.00	11	11	12	10	44	Hilly and rolling........	....	44.00	......	0.20	......	Mass. State Bd. of Health, 1879.
Hale's Brook, Mass.	....	24.00	11	11	12	10	44	....	....	3.24	.....	0.135	......	J. P. Frizell.
Connecticut..	Hartford...........	10,154.00	10	12	12	10	44	Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.	205,464	5,208.00	40	0.513	......	T. G. Ellis. (Of late years the flow has been much lower.)
Connecticut..	Hanover, N. H.....	3,316.00	10	12	12	10	44	Numerous lakes and artificial reservoirs. Wooded. Mountainous in parts.	....	1,006.00	......	0.306	0.365	Prof. Robt. Fletcher.
Housatonic...	Kent, Conn........	758.00	12	12	12	10	46	Hilly. Many ponds and reservoirs.	....	....	......	0.165	......	Measurements only one year. Trans. A. S. C. E., 1879.
"	Birmingham, Conn.	1,562.00	12	12	12	10	46		....	500.00	......	0.32	......	
Croton	....	339.00	12	13	13	10	48	....	25,380	60.00	423	0.178	......	J. J. R. Croes. Measurements about 1867-70.
W. Br. Croton	....	20.37	12	13	13	10	48	....	1,109	0.33	3,307	0.016	......	J. J. R. Croes.
Passaic	Paterson, N. J.. .	813.00	12	14	12	10	48	Some lakes and swamps. Hilly.	17,913	195.00	92	0.24	......	J. J. R. Croes and G. W. Howell.
Delaware.....	Lambertville	6,820.0±	11	13	11	9	44	Hilly and rolling. Many lakes. Well wooded.	350,000	2,000.00	175	0.29	......	Ashbel Welch.

TABLE SHOWING EXTREMES OF FLOW FOR SOME AMERICAN STREAMS.—*Continued.*

RIVER.	PLACE.	Drainage area, square miles.	MEAN RAINFALL, INCHES. Spring.	Summer.	Autumn.	Winter.	Year.	REMARKS ON CHARACTER OF DRAINAGE BASIN.	EXTREMES OF FLOW. Maximum, cubic feet per second.	Minimum, cubic feet per second.	Ratio.	Minimum, cubic feet per second per square mile.	Ordinary low-water flow, cubic feet per second per square mile.	AUTHORITY AND REMARKS.
Schuylkill	Philadelphia	1,912.00	12	14	10	9	45	Hilly and rolling. No lakes. Some reservoirs.	....	310.00	......	0.16	......	H. P. M. Birkinbine.
Ohio	Pittsburg	18,732.00	10	12	9	10	41	Hilly and mountainous. No lakes. Wooded.	....	2,271.00	......	0.12	......	J. H. Harlow.
Potomac	Cumberland	920.00	10	12	9	8	39	Narrow valleys. Steep slopes. Wooded. No lakes.	17,900	25.00	716	0.022	......	W. R. Hutton.
Potomac	Dam No. 5	5,066.0±	11	12	9	8	40	Narrow valleys. Steep slopes. Wooded. No lakes.	92,772	363.00	255	0.078	......	W. R. Hutton.
Potomac	Great Falls	11,476.00	12	13	9	8	42	Country more open. No lakes.	175,000	1,063.00	165	0.093	......	W. R. Hutton.
Rock Creek	Hoyle's Mill	64.40	11	12	11	8	42	....	9,800+	750.00	1,307	0.114	0.455	Quoted by W. R. Hutton.
Kanawha	Charleston Pool	8,900.00	12	13	9	10	44	Mountainous. Steep. No lakes. Wooded.	120,000±	1,100.00	110	0.123	......	Gill, Scott, and Hutton.
Greenbriar	Mouth of Howards creek.	870.00	11	12	8	9	40	Mountainous. Steep. No lakes. Wooded.	....	97.00	......	0.120	......	McNeill.
Shenandoah	Near Port Republic.	770.00	12	13	8	8	41	Hilly. Limestone. No lakes. Many springs.	....	128.00	......	0.167	......	James Herron.
James	Richmond	6,800.00	12	12	9	10	43	Mountainous in upper part. No lakes. Wooded.	....	[1]1,300.0+	......	0.191	......	H. D. Whitcomb and W. E. Cutshaw.
Neuse	Near Raleigh	1,000.00	12	14	10	11	47	Open. Clay and loam. No lakes. Few extensive woods.	....	....	......	......	0.193	W. C. Kerr, "low water."
Wisconsin	Portage, Wis.	8,200.00	9	12	9	5	35	Prairie	....	2,800.00	......	0.34	......	Report Ch. Eng. U. S. A., 1875.
Minnesota	Mouth	17,230.00	65	11	5.5	3	26	"	....	1,155.00	......	0.067	......	Ditto.
Illinois	Mouth	29,013.00	11	11	9	8	39	"	....	1,600.00	......	0.055	0.06	Maj. G. T. Lydecker, U. S. A.
White	....	5,511.00	13	11	10	9	43	....	....	264.00	......	0.048	......	A. Livermore.

[1] I am informed that in recent years the James river has fallen far below this figure.

TABLE OF MONTHLY FLOW IN DRY YEARS.

RIVERS.	Drainage area, square miles.	FLOW IN INCHES ON WATERSHED.													RATIO OF MONTHLY TO MEAN FLOW.											
		Driest month.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Eleventh.	Twelfth.	Total for the year.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Eighth.	Ninth.	Tenth.	Eleventh.	Twelfth.
Croton	339	0.20	0.35	0.53	0.63	0.87	0.94	1.52	1.63	1.80	1.90	2.08	2.27	14.72	0.16	0.29	0.43	0.51	0.71	0.77	1.24	1.33	1.47	1.55	1.70	1.85
Concord	352	0.25	0.32	0.36	0.43	0.54	0.68	0.85	1.07	1.36	1.70	2.15	3.62	18.33	0.22	0.29	0.32	0.39	0.49	0.61	0.76	0.96	1.23	1.53	1.94	3.26
Merrimack	4,136	0.68	0.70	0.77	0.85	1.00	1.13	1.30	1.53	1.98	2.55	3.22	5.42	21.13	0.38	0.40	0.44	0.48	0.57	0.64	0.74	0.87	1.12	1.45	1.83	3.08
Connecticut	10,234	0.65	0.68	0.71	0.74	0.88	0.90	1.28	1.51	1.80	2.02	3.28	4.71	19.16	0.41	0.43	0.45	0.46	0.55	0.56	0.80	0.95	1.13	1.26	2.05	2.95
Schuylkill[1]	1,800	0.27	0.30	0.38	0.40	0.53	0.62	0.68	0.79	0.88	0.98	1.08	1.59	8.50	0.38	0.42	0.54	0.57	0.75	0.88	0.96	1.12	1.24	1.38	1.52	2.24
TABLE OF MONTHLY AVERAGE FLOW FOR A SERIES OF YEARS.																										
Croton	339	0.56	0.95	1.12	1.21	1.43	1.82	2.30	2.57	2.77	3.02	3.60	4.00	25.35	0.26	0.45	0.53	0.57	0.68	0.86	1.09	1.21	1.31	1.43	1.70	1.90
Concord	352	0.39	0.46	0.51	0.61	0.76	0.96	1.25	1.52	1.92	2.38	3.00	4.86	18.62	0.25	0.30	0.33	0.39	0.49	0.62	0.81	0.98	1.24	1.53	1.93	3.13
Merrimack	4,136	0.77	0.88	1.06	1.26	1.52	1.80	2.12	2.49	3.03	3.73	4.63	6.56	29.85	0.31	0.36	0.43	0.51	0.61	0.72	0.85	1.00	1.22	1.50	1.86	2.63
Connecticut	10,234	0.75	0.85	0.91	1.10	1.34	1.58	2.00	2.36	2.81	3.27	4.52	6.26	27.75	0.33	0.37	0.39	0.47	0.58	0.68	0.87	1.02	1.21	1.41	1.96	2.71
TABLE OF MONTHLY FLOW IN DRY YEARS OF STREAMS OF SMALL DRAINAGE AREA																										
Cochituate	19.00	0.08	0.41	0.46	0.47	0.70	0.88	0.97	1.03	1.11	1.31	1.47	2.26	11.15	0.09	0.44	0.50	0.51	0.75	0.95	1.03	1.11	1.20	1.41	1.58	2.43
Croton, Western Branch	20.37	0.10	0.17	0.46	0.53	0.67	0.84	0.98	1.02	2.31	3.37	3.41	5.40	19.26	0.06	0.10	0.28	0.33	0.42	0.52	0.61	0.64	1.44	2.10	2.13	3.37
Sudbury	76.30	0.11	0.16	0.25	0.39	0.57	0.79	1.06	1.40	1.79	2.21	2.77	5.09	16.59	0.08	0.11	0.18	0.28	0.41	0.57	0.77	1.01	1.29	1.60	2.01	3.69
Passaic headwaters	50:100	0.11	0.15	0.21	0.27	0.49	0.67	0.90	1.22	1.77	1.87	2.13	3.65	13.44	0.10	0.13	0.19	0.24	0.44	0.60	0.80	1.09	1.58	1.67	1.90	3.26

[1] Charles G. Darrach, in *Engineering News*, April 3, 1880, p. 122.

b. THE MINIMUM LOW-SEASON FLOW is the smallest average amount flowing during a period of from six to three weeks, *generally* in summer, when the stream is at its lowest. In most years the average flow during the season of least flow exceeds this amount. It may therefore be depended upon at all times, except for intervals of a day or two, perhaps several days at a time, during which the flow approaches its absolute minimum, and may be rendered available at all times by a small amount of storage. In ordinary years there will generally be an excess all the time.

This minimum low-season flow can probably be best estimated by comparison with results of observation, some of which are given in the table on page 55. But in most cases I have estimated it as follows:

1. Seven-tenths of the mean annual rainfall may, in general, be considered the minimum rainfall.

2. Forty per cent. of this may, on the average, for tolerably large drainage basins, be considered to be discharged by the streams, subject to variation, however, according to local and climatic conditions; but in no case should the amount determined in this way as the total amount discharged in the year of the minimum low-season flow exceed say 10 to 13 inches.

3. The distribution of this flow through the year may be estimated from the results of the table on page 57, bearing in mind, however, in estimating the coefficient which expresses the proportion of the mean monthly rainfall which is discharged in the driest month, the various remarks concerning the district considered, on pages 53 and 54.

c. THE LOW-SEASON FLOW IN DRY YEARS (BUT NOT THE DRIEST) I have sometimes estimated by assuming the run-off somewhat larger than for the minimum low-season flow, and taking a certain proportion of this as the amount flowing in the one or two months when the stream is lowest, according to the table on page 57, modified according to circumstances. In many cases, however, I have simply increased the estimate given for the minimum low-season flow by an arbitrary percentage. From the above remarks it will be clear that without storage this flow may generally be depended upon except in the low seasons of very dry years when the supply may be deficient for several weeks at a time. *In ordinary years at least one-quarter more may generally be depended upon at all times* than the figures under this head in the tabular statements of power concerning the several streams described in this report indicate.

The month of least flow (the driest month) varies considerably from year to year, falling sometimes in the summer and sometimes in the winter, and the months do not succeed each other in the order of dryness. As a rule, however, the driest months fall in summer, although sometimes the difference is not very pronounced. (See a paper by Mr. Clemens Herschel, "The Gauging of Streams." *Transac. Am. Soc. Civ. Engrs.*, vol. vii, 1878, p. 236.)

In describing the separate waterpowers I have therefore given three estimates. For convenience of reference I will recapitulate them here, noting briefly their exact meaning:

1. THE ABSOLUTE MINIMUM.—This can be depended upon *always*, and with no storage at all. There will be large waste all the time, except for a few days at a time in intervals of several years.

2. THE MINIMUM LOW-SEASON FLOW.—This, with no storage, can be depended upon at all times, except for a short time in some dry seasons. With small storage it can be depended upon all the time.

3. THE LOW-SEASON FLOW IN ORDINARY DRY YEARS (NOT ORDINARY YEARS).—This, without storage, can be depended upon generally, except in the low season of dry years, when the supply will be deficient for, perhaps, several weeks; in very dry years, when the supply will be deficient for a longer time, and in ordinary years, when the supply may be deficient for a few days at a time. It can be rendered permanently available by storage. *The low-season flow of ordinary years* can be depended upon less than the *minimum* described in paragraphs 1 and 2 above; but generally it can be depended upon for nine or ten months of every year.

IN ORDINARY YEARS, during the "low season," a quantity probably at least one-quarter greater than during the "low-season flow in ordinary dry years" may be secured.

Attention is again called to the fact that all the estimates in the following pages must be considered only rough approximations. It is impossible with the data at hand to give anything better.

Especial emphasis is also directed to the fact, just mentioned, that during ordinary years the amount of power available at the different sites during the low season will be much greater than given in the tables, probably at least one-quarter greater.

EFFECT AND FEASIBILITY OF STORAGE RESERVOIRS.

The above estimates are, of course, for the natural flow of streams unaffected by storage reservoirs. By building such reservoirs, a larger quantity of water might be used in a year (by drawing on a wet season to cover the deficiency of a dry one), and it may be used more uniformly throughout the entire year than would otherwise be the case. If suitable reservoirs could be built, it would be possible (allowing, of course, for evaporation) to collect and draw the total quantity of

TIDAL WATERPOWER.

There is no tidal power either used or available in the district considered, partly because there are no facilities for storing water, and partly because, as is evident from the topography of the country, there are no facilities for the location of dams and buildings on a low and swampy coast.

TOTAL AVAILABLE POWER.

It is customary to attempt to estimate the total available power of a district by assuming the average elevation and the quantity of water discharged. Such estimates have little value, because a large proportion of the power so estimated is, in fact, unavailable, on account of topographical features. In regard to the region under consideration, however, it is to be noticed that as the elevation of the Atlantic plain, at the foot of the mountains, is much greater than in the states farther north, varying from 1200 feet in North Carolina, at the sources of the Catawba, to 500 [1] feet in Virginia and 100 to 300 feet in Pennsylvania,[1] the total theoretical power in the region we are considering will be very large in proportion to its area, especially if we exclude the eastern division from consideration.

Having presented the general features of the district under consideration, and having briefly pointed out the general principles relating to the amount of power available, and explained the method used in calculating it, it is now only necessary to show how, in the application of those principles, the general characteristics of the region show their effects and are to be taken into account.

GENERAL SUMMARY.

INFLUENCE OF WINDS AND EVAPORATION.

1. It follows from the position of the region that the warm and moist S.W. winds from the Gulf of Mexico traverse its whole extent. Hence the rainfall is greatest (62 inches) in Alabama and southern Georgia, while the evaporation is comparatively small, because the air is moist, and the rainfall diminishes to 44 inches and less in North Carolina and Virginia, while the air becomes drier and the evaporation greater. Above North Carolina the greater part of the rain comes from the Atlantic, while south of Virginia most of it comes from the Gulf. This fact—that the evaporation increases toward the north—has an important bearing on the flow of the streams, which will be referred to further on.

[1] Guyot.

INFLUENCE OF TOPOGRAPHIC FEATURES.

2. From the topography it follows that all the waterpower of importance is in the middle division. In the eastern division the streams are too sluggish, and in the western they are too small and inconstant. Although the middle division is very favorably located for waterpower, it is unfortunate that in the eastern division, just where the streams are the largest, the conditions are not favorable. The middle division is, topographically, very favorable for power. The fall of the streams is great, but as a whole tolerably uniform, and their volume moderately large. They cross the ledges of rock at large angles, forming many rapids, rifts, or falls in all parts of this region. These ledges, being composed of hard, durable, and impervious rocks, generally granite or similar rocks, insure the permanence of the powers, and afford everywhere good sites for dams. The shape of the river valleys is such as to render the utilization of the power in most cases easy, there being only a very few instances of anything approaching the cañon structure. The facilities for storing water are, on the whole, good, though the shape of the valleys does not seem to be *particularly* favorable; for in the mountains the fall is too great and the valleys too narrow to afford *large* reservoir room, while lower down the rivers are bordered by fertile bottom-lands, which it might be inadvisable to overflow, and besides, as the streams are tolerably large, it would be difficult to store sufficient water to increase the power much. In the matter of storage this region is notably less favorable than such states as Maine and Pennsylvania. The absence of lakes, also, operates unfavorably on the volume and constancy of the streams, especially in the upper parts, and this is counteracted by the action of the forests perhaps to a less extent than might be supposed. (See below.)

The country in the middle division being moderately hilly, the rainfall is neither precipitated suddenly into the river channels, rendering them subject to sudden freshets, nor is it discharged too gradually, so as to render the evaporation abnormally large. On the contrary, the depth and perviousness of the soil, the fact that it is everywhere underlaid with hard and impervious rock, and that the rivers have cut their channels down to this rock-bed, contribute to the volume and constancy of the streams, and diminish the loss by evaporation and by subterranean flowage. This depth of soil, serving to store the waters, is especially beneficial in view of the variability of the rainfall, in which respect some parts of this region stand at a disadvantage, which is thus, to some extent, compensated for. In Maine, for instance, the soil is very shallow compared with that in North Carolina, but the rainfall is very equally distributed throughout the year. (See page 52 for further remarks on this subject.)

INFLUENCE OF FORESTS.

3. The influence of the forests in the western division is favorable, yet not to such an extent as might be supposed, according to what has been said regarding the influence of woods in winter and in summer. In fact, there is reason to believe that at least in the northern parts of the region considered less water percolates into the ground in winter, to be stored and given out by springs, than in open ground. From the experiments which have been referred to, the conclusion has been drawn for Germany that the cutting down of forests has the effect in winter of increasing the discharge of springs and causing a higher average stage of the water in the streams than existed before.[1] In hot regions, and in summer, the cutting down of woods has the opposite effect, but it does not seem improbable that, for the district considered, the effect would be to a certain extent as stated, especially if (as is the case in the western part of the district in many cases) the rainfall is greater in winter than in summer. For this reason it is easy to overestimate the effect of the forests as regulators of flow. Their effect is certainly very much smaller than in regions where the rainfall is greater in summer than in winter, in which case their effect is very beneficial and only exceeded by that of lakes or artificial reservoirs and surface materials. The fact that the mountains in this district are covered with soil is one of great importance, and on this account the flow of the streams will be much more constant than it would otherwise be.

INFLUENCE OF TEMPERATURE.

4. I have already alluded to the winds and the position of this region as affecting its waterpower. As regards temperature, it is, of course, higher in this region than in New England. In summer the difference is some 12°; in winter, over 20°; and for the year, in the middle division, 12° to 15°. The average temperature in winter is far above the freezing point; hence the streams rarely freeze over. Trouble with ice is almost unknown, and, in this respect, this region has a great advantage over the more northern states, which is, however, partially offset by the fact that the evaporation is greater.

Mr. Wells, in his report on the waterpower of Maine, dwells upon the fact, which he says is founded on the testimony of persons who have had the largest and most varied experience in manufacturing in Maine and other states, that operatives can accomplish much more in winter than in summer, and more in cold than in warm states. I quote Mr. Wells' remarks on this point:

[1] Ebermayer: *Die physikalischen Einwirkungen des Waldes auf Luft und Boden, und seine klimatologische und hygienische Bedeutung.* Berlin, 1873, p. 223.

"It is well known that at the large majority of manufacturing labors the burden of the day's work is felt by the operative to be much heavier in summer than in winter. The cold of the latter season can be so guarded against and mollified that throughout the whole establishment precisely, or very nearly, that temperature can be secured which is most contributive to vigorous exertion. But the heat of summer, pervading and penetrating everything, and brought in at every open window with the necessary supplies of fresh air, cannot be shut out. It cannot be qualified. It oppresses the worker with a languor rarely experienced in out-of-door avocations, and renders it impossible for him to do so much or do so well as he can easily do in cool weather. Accordingly, the evidence is that in Maine, where the summer temperature is low, where it rises above the point of comfort for but a few days for the whole season, operatives, circumstanced equally in every other respect, accomplish more than in the interior and more southern states by the truly remarkable fraction of 10 per cent."

It must, however, be borne in mind that although in warmer climates the operatives are unable to accomplish so much, yet, on the other hand, the expense for heating the factory buildings is greatly reduced, and that, further, as the operatives can live more cheaply on account of not needing so much artificial heating in their houses, their wages may be much less in proportion. In fact, it is stated that the wages paid to operatives in cotton factories in the Southern states is from 30 to 50 per cent. less than in the New England states.[1] The table of maximum observed temperatures shows that the maximum observed temperature in Maine is about the same as in Georgia. The following table of the mean temperatures of the hottest and coldest months of the year will enable a comparison to be made between the New England states and the Southern states, and will show that the difference is not so great as is generally supposed.

[1] According to the census of 1890, the average wages paid to operatives in cotton factories in various states was as follows, in dollars, per annum: Maine, 304; New Hampshire, 321; Vermont, 281; Massachusetts, 334; Rhode Island, 314; Connecticut, 319; Pennsylvania, 348; Maryland, 250; Virginia, 188; North Carolina, 172; South Carolina, 187; Georgia, 207. The wages will depend somewhat on the quality of goods manufactured, but the average is evidently much less in the south.

TABLE OF MEAN TEMPERATURES OF HOTTEST AND COLDEST MONTHS IN VARIOUS PLACES.

PLACE.	Number of years of observation.	Mean temperature of hottest month. July.	Mean temperature of coldest month. January.
Bath, Me.	11	68.7	23.2
Castine, Me.	40	64.8	21.4
Brunswick, Me.	52	67.4	20.1
Newport, R. I.	63	70.1	29.9
Providence, R. I.	34	70.9	25.8
New Haven, Conn.	23	71.8	27.5
Hartford, Conn.	24	71.9	27.6
Manchester, N. H.	22	72.3	23.2
New York, N. Y.	25	73.5	30.5
Newark, N. J.	54	74.1	29.2
Philadelphia, Pa.	25	75.7	32.0
Harrisburg, Pa.	8	72.9	30.3
Baltimore, Md.	25	77.2	34.0
Washington, D. C.	25	76.8	33.2
Norfolk, Va.	26	78.7	40.6
Southport, N. C.	18	80.0	46.3
Chapel Hill, N. C.	36	78.6	39.9
Asheville, N. C.	18	72.4	38.9
Aiken, S. C.	{ 35 25 }	79.9	45.5
Charleston, S. C.	25	81.8	50.0
Columbia, S. C.	18	81.0	46.3
Fort Moultrie, S. C.	34	81.7	50.2
Athens, Ga.	20	78.5	42.7
Atlanta, Ga.	18	78.0	42.5
Augusta, Ga.	25	81.1	46.6

Most of the stations in the Southern states are in the eastern division, where the weather is much warmer than in the middle and western divisions, where the waterpower is. The table shows that at Athens and Atlanta, Georgia, which are the best types of the middle section, the mean temperature of the warmest month is not much different from that in the Middle states, although Maine, it is true, has a lower temperature by some 10°. It seems to me, however, that this effect of temperature has been overestimated, and that, so far as it alone is concerned, the advantages in the Southern Atlantic states more than counterbalance the disadvantages.

INFLUENCE OF RAINFALL.

5. As regards the rainfall, its distribution throughout the year on the watershed of each river is to be carefully considered. Variability in this distribution may not be a disadvantage, but on the contrary, if the summer fall is greater than the winter fall, the flow of the streams will be more regular, other things being equal. In determining the ratios to be used in estimating flow I have been influenced by this consideration, and if of two streams, similar in other respects, one has more rain in summer than in winter, and the other more in winter than in summer, I have taken the minimum flow of the former considerably greater than that of the latter. Differences in the evaporation in different parts of the district also come into consideration. If the other

climatic conditions remained the same, the effect of variability in the rainfall would be seen in a corresponding variation in the flow of the streams, and in those seasons when most rain fell the flow of the streams would be greater. Yet in the New England states, as well as in the Southern states, the streams are lowest in summer, even when more rain falls in that season, showing that the evaporation in that season is more than sufficient to make up for the greater rainfall. It is true that in the North there is a winter drought, caused by the snow lying so long on the ground, so that little of the precipitation reaches the streams; yet, although in some cases the driest month, or the month when the streams are lowest, falls in the winter, in general the summer drought is greater than the winter drought. On account of the increased evaporation, the southern streams will, in all probability, discharge a smaller proportion of the rainfall on their drainage areas than those in New England. Finally, the effect of soil and lakes must not be overlooked in comparing this region with New England, and in estimating the flow of the streams.

The foregoing remarks have been made because it is necessary to present the principles which have guided me in making the estimates in this report. The conditions determining the flow are, however, so various, that they cannot all be given due weight, even if they were all accurately known; so that the only safe guide in practical questions regarding flow is a series of gaugings extending over a number of years. But as there is not a single such series for the district considered it is necessary to resort entirely to estimate. Every engineer can form his own conclusions from the data at hand, and many may not be disposed to approve of the figures given.

CHAPTER IV.

GEOLOGIC DISTRIBUTION OF WATERPOWER.[1]

GEOLOGIC CONDITIONS AFFECTING WATERPOWER DEVELOPMENT.

Even the most casual observer must be aware of the fact that the falls and shoals in rivers, upon which we usually depend for the development of waterpowers, have a more or less intimate connection with the hardness, durability and arrangement of the rock masses that are crossed by the channels of these streams; and in calling attention to this phase of the subject it is thought best to explain briefly the nature of this connection in certain of the types more commonly met with.

IN AREAS OF HORIZONTAL BEDDED ROCK.

One of the most common and simple examples of this connection is illustrated by the accompanying diagram (fig. 7), in which the layers

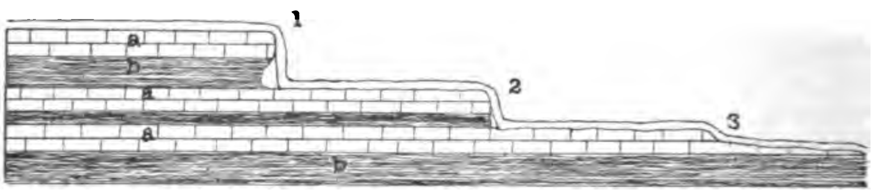


FIG. 7.—Hard and soft horizontal strata, favoring the development of waterfalls and rapids in river channels. *a*=Limestone. *b*=Shale.

of rock which underlie the stream are practically horizontal, and are alternately massive and composed of durable material, such as limestone and sandstone (*a*), and thinly bedded shales (*b*) which are softer and more easily eroded. In the course of time the sand, gravel and bowlders carried down by the stream wear through the overlying hard rock at some point and then more rapidly cut away the underlying layers of soft material, the result being, first, a succession of rapids or shoals, and later, a vertical fall (as at 1) at least as high as the thickness of the shale material. In a similar way another fall may be produced a short distance further down the stream (as at 2), the amount

[1] By J. A. Holmes.

of the fall there being less in proportion as the underlying layer of soft shale is thinner. Still further below (at 3) rapids or cascades are produced, owing to the irregularities in the character of the layers of harder rock and the consequent irregular wearing. The exact conditions here illustrated probably do not occur in North Carolina, but may be found approximated at Niagara Falls and many other places in the United States.

IN AREAS OF BEDDED SANDS AND CLAYS.

In some portions of the coastal plain region, however, where the streams are cutting their way down across the horizontal and soft strata such as alternate beds of clay and sand, we have conditions somewhat similar to those described above except that in these cases the strata, instead of being alternate layers of hard and soft rocks, are of altogether unconsolidated materials which have not yet turned to stone.

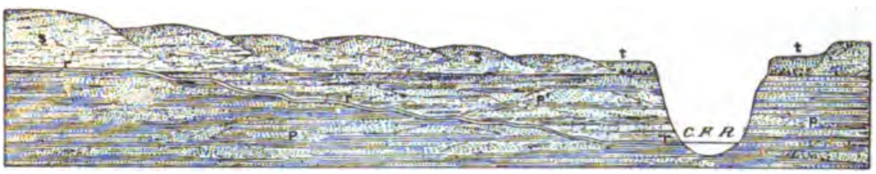


FIG. 8.—Interbedded sands and clays favoring the development of rapids in river channels.

P and *P'*=Finely laminated and in places cross-bedded, black laminated clay below, and bedded but cross-laminated clayey arkose above, the strata of both clay and arkose being separated by layers of sand varying in thickness from a small part of an inch to several feet. The strata marked *P'* above *rr* represent the same strata as *P* below the *rr*. *s*=Sand hills back from the stream border. *t*=River terraces of recent loams, gravel at their base. *rr*=Surface of the stream showing that as it washes away the laminated arkose and clay irregular rapids are produced in the stream, owing to the more rapid removal of the interbedded sand.

Such a condition of things may be illustrated by fig. 8, which represents somewhat the conditions existing on Rockfish creek in Cumberland county, described in a subsequent chapter (p. 138).

In the lower portion of its course the waters of Rockfish creek have cut their way down through the overlying sands and loams and are now cutting through the lower interbedded sands, clays and arkose, (p. 138) and the still lower more finely laminated sands and greenish-black clays. Near the mouth of Rockfish these materials in its bed have been worn away to the level of the Cape Fear river which it joins. Further back from the Cape Fear the cutting down through alternate layers of loose sand and tough clay has resulted in producing a rapid but irregular current with occasional small shoals, at several of which waterpowers have been developed by the construction of dams and factories erected.

IN AREAS OF TILTED BEDDED ROCK.

Figure 9 illustrates another condition of common occurrence. In this case the rocks resemble in character those in many portions of the country, especially in the southern Appalachian region, including portions of western North Carolina described above (p. 25), but the strata extending across the bed of the stream are inclined at high angles, often standing on edge. The upturned edges of these layers of rock vary greatly in character, some of them being (*a*) hard and durable and others (*b*) soft and easily worn away by the sand, gravel and bowlders swept along in the stream. When the water flows rapidly down such a stream we have resulting a river channel which is as a rule an extremely rough one, with here and there projecting ledges of hard

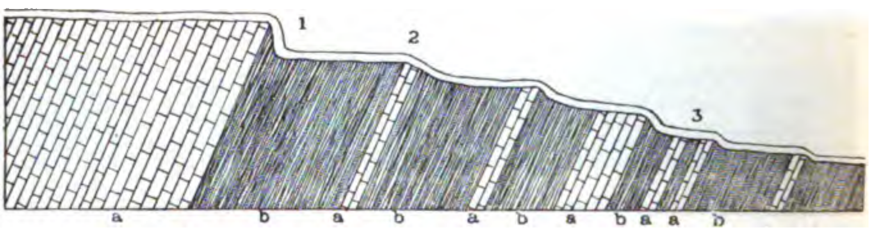


FIG. 9.—Hard and softer inclined strata, favoring the development of cascades and shoals in river channels. *a*=Limestone. *b*=Shale.

rock extending across the stream with as much regularity as though they were laid in masonry; while alternating with these are the hollows and depressions worn into the surface of the softer rock. Where a large mass of the softer rock comes just below a large mass of hard materials (as at 1 in fig. 9) the conditions are favorable for the development of a fall or cascade of considerable height; but where there is less of the hard stone (as at 2, fig. 9) the extent of the cascade or rapid will be considerably diminished; and where there are a succession of alternating hard and soft layers (as at 3) the conditions are favorable for the development of a succession of rapids or cascades. If on the other hand the strata crossed by the stream are fairly uniform in character there will be generally a corresponding uniformity in the current of water.

IN AREAS OF SLATES AND CRYSTALLINE SCHISTS.

One of the most common types of geologic structure affecting waterpower development in North Carolina and other South Atlantic states is that to be found in the great belts of slates and crystalline schists lying in the eastern part of the Piedmont plateau region. (See map, p. 78). Here, as in the structural type shown in fig. 9 above, layers or sheets of rocks are nearly vertical, and are composed of material varying in hardness and durability; but throughout much of this belt, and especially along its western border, the variations are less well defined and on a smaller scale, the thin, hard layers being so numerous and so generally distributed that in the streams like the Haw and Deep rivers, which cross the larger portions of these belts nearly at a right angle, there is almost a continuous series of small rapids or shoals with an aggregate fall of from 5 to 20 feet to the mile.

THE "NARROWS" SECTION ON THE YADKIN.

Where the Yadkin river crosses the larger of these belts of slates and schists there is a greater concentration of the hard and soft material, and consequently a greater concentration of fall in the river at certain points, than is described above as occurring on Haw and Deep rivers; yet on the whole this Yadkin river section, illustrated with approximate accuracy in fig. 10, may be considered as fairly typical for sections of

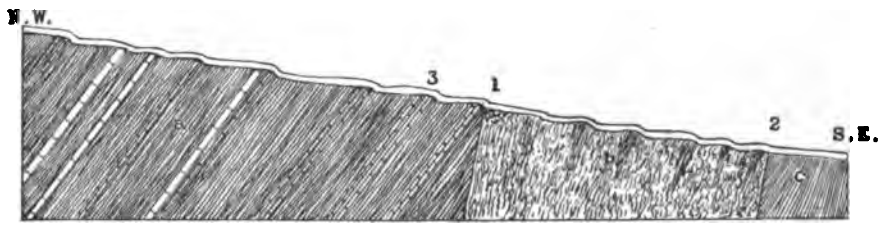


FIG. 10.—Conditions favoring the development of cascades and rapids in river channels crossing belts of inclined slates and crystalline schists.
a=Argillaceous slates dipping Northwest, with harder and more durable layers at intervals (as at 3). b=Crystalline schists, mainly of volcanic origin, obscurely schistose, more massive and obdurate in places, as where the shading is heavier. c=Finely laminated and uniform argillaceous slate.

country where these belts of rock exist. The space between 1 and 2 in the diagram represents the "narrows" section, a distance of nearly 5 miles. The rock is eruptive in character, though an obscurely bedded conglomerate at the upper (N.W.) side. It is all hard, but not uniformly so, being harder and more obdurate at certain places, arranged at intervals, producing the narrows rapids at the upper end (just below 1) and the "little falls" and "big falls" near the lower end (just above 2). The total fall from 1 to 2 is nearly 100 feet.

Below the narrows (between 2 and S.E. in fig. 10) the rock is mainly an argillaceous slate of fairly uniform character and easily eroded by water action; and the existence of this softer material beside the belt of hard, obdurate rock which itself is not uniform, but has harder and softer belts, affords just the conditions favorable for the development of rapids and cascades in the stream that crosses both belts. As might be expected, these harder rocks (*b* in fig. 10) cross the country in a high, irregular ridge, while the surface of the region to the southeast, occupied by the slaty and sandstone rocks, is less hilly and less elevated. The Yadkin crosses the harder ridge as a rushing torrent in a deep, narrow gorge—the "Narrows"—but as soon as it reaches the softer slaty rock (at 2 in fig. 10) the current slackens, the stream widens and flows on for several miles as a smooth and relatively sluggish current.

For several miles up-stream from the Narrows the rocks are mainly clay slates having a southwest-northeast course, and dipping steeply toward the northwest; and so the sheets or beds of rock stand on edge and lean down-stream (S.E.). These rock beds are for the most part fairly soft and more easily washed away than other more massive and more durable layers which occur at irregular intervals, and consequently below these more massive sheets of rock are the shoals and rapids as indicated in figs. 9 and 10 above and as described further on (pp. 178-187).

IN GRANITIC AND GNEISSIC AREAS.

In granitic and gneissic rock, the materials not being arranged in definite strata or layers, the exact conditions which cause the production of cascades and rapids in streams are less apparent than in the slaty and schistose rocks just described. The accompanying sketch (fig. 11) illustrates a few of the conditions favorable to the development of waterpowers in a region where these rocks prevail, as in portions of central and western North Carolina.

1. One often finds in such regions breaks, such as faults or joints in the rock, the material on one side of the break being somewhat crushed or sheared and hence easily removed. Of course the streams of water in crossing the section of country where these breaks or faults occur, and especially where the crushed or sheared side of the break is the lower side on a sloping surface, remove this lower side more rapidly than the upper and thus form a cascade from the higher to the lower level as seen at 1 in fig. 11. It is in that way that some of the beautiful falls of the southern Appalachian mountain region have been produced. Other cascades and shoals are developed under the following conditions:

2. In portions of the granitic area there are lines of structural weakness where, under great strain or pressure, the materials of which the

rock is composed give way and are flattened out by a process known as shearing, so as to give there a rather gneissic or schistose structure, as at 2 in fig. 11. The rock in this condition is often more rapidly attacked by the weathering and eroding forces of the atmosphere, and, consequently, as the streams cross the surface of the country where such conditions exist, they carve out their channels more rapidly, thus producing shoals or rapids, and, in extreme cases, cascades or falls.

3. Conditions somewhat similar to the above and favorable to the formation of shoals and rapids in streams are sometimes found along the line of contact between areas of granites and gneisses, as at 3 in fig. 11; and again in gneissic areas in places the rocks are harder and more obdurate, as indicated by heavier shading at 4 in fig. 11; and in the beds of streams crossing such areas the rocks wear away irregularly, the harder portions standing up as projections while the intervening softer materials are hollowed out. In this way we have produced a succes-

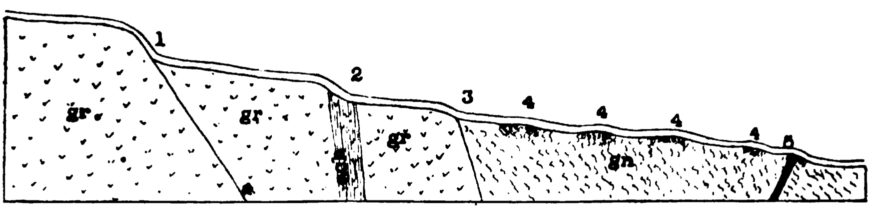


FIG. 11.—Conditions favoring the development of cascades and rapids in river channels crossing areas of granitic and gneissic rock.

gr=Granite. 1=Fault or break in the rock, the right side having moved down or the left side moved up. 2=A schistose zone in the granite resulting from the shearing or movement of the rock along a line of weakness. *gn*=Gneiss, in which there are alternately harder and softer portions, the harder and more obdurate places being more heavily shaded (as at 4). 5=Dike of diabase or other material harder and more obdurate than the gneiss, and hence producing a cascade or rapid in the stream channel.

sion of shoals, a few hundred yards or several miles apart; and between these are to be found the quiet reaches of the streams where the current moves along more smoothly and quietly.

4. Another structural feature in granitic and gneissic areas, and also in slaty and sandstone areas, which occasionally results in the production of the shoals and rapids, is the occurrence of dikes, where cracks in the earth's crust have been subsequently filled with various materials in a plastic and usually a molten condition and which materials have subsequently hardened. If the material of the dike is softer than that of the granite or gneissic rock on one or both sides of it, then there will be a drop in the course of the stream from the adjoining rock of the wall down on to the softer dike surface, as is shown at 2 in fig. 11. If

on the other hand the material constituting the dike is harder and more durable than the materials on each side of it, the country rock on the lower side of the dike, on account of its being softer and less durable than that composing the dike itself, will wear away more rapidly than the material of the dike, and consequently the water will drop from the dike surface on the country rock below it, as indicated at 5 in fig. 11 above. The occurrence of the belt of eruptive rocks between the two belts of slate, as shown in fig. 10 (p. 71), may be considered as analogous to this last-mentioned case. On Deep river near Gulf (p. 162) and on New Hope creek, a tributary of Haw river, are to be found illustrations of the development of waterpower being favored by the occurrence of diabase dikes in the Jura-trias sandstone crossing the channel of the stream.

AT GEOLOGIC CONTACTS.—THE FALL LINE.

The conditions described above apply more specifically to variations in the character of the rock within the limits of individual geologic formations, but the descriptions are applicable also to conditions existing where the stream crosses from one formation to another, the rocks of which are softer and less obdurate, and hence more easily washed away. Such a case as the last mentioned is to be found well developed at the *fall line* along the border between the Piedmont plateau and coastal plain regions.

FIG. 12.—Conditions favoring the development of cascades and rapids in stream beds crossing geologic contacts.

gr=Granite and gneiss. *sch*=Crystalline schists, in which the harder places (shaded more heavily) wear away less rapidly than the intervening softer places. The result is a series of cascades and rapids in the stream. *P*=Coastal plain deposits—gravel, sand and loam.

THE WELDON SECTION ON THE ROANOKE.

Figure 12 may be considered as illustrating fairly well a generalized section across the fall line where crossed by the Roanoke river at Weldon. The crystalline schists exposed along the river bed between Gaston and Weldon (G and W of fig. 12) are much harder and more obdurate than the unconsolidated coastal plain deposits below, and even harder than the granitic and gneissic rocks above it; and hence the latter rocks have been eroded to greater depths, and at the line of junction between the two (1 in fig. 12) the schists form a sort of barrier or natural dam, for many miles above which the river is deep and the current sluggish. But from this point down to Weldon the schists vary in hardness, and are intersected by joints, seams, fissures and probably several faults; this succession of variations giving rise to a succession of rapids and shoals, with an aggregate fall of 85 feet in a distance of 9 miles. For this distance the river flows through a deep and open gorge flanked by hills which, near Gaston and a short distance westward, are capped with unconsolidated gravels, presumably of Potomac age, and bordered by terraces of more recent age, probably post-tertiary (Columbia). In the neighborhood of Weldon and eastward the rocky hills give places to the terraces and plains of the coastal region, composed of gravels, sand, loams and clays, varying in age from Potomac at the bottom to Columbia at the top.

During recent geologic times the condition of this region has been unstable. During certain periods, as at the present time, the surface of the country has been lifted to a considerable elevation above sea-level and the river has gone on carving deeper its rocky channel; while during intervening periods the surface was lowered until the sea advanced to and even above Weldon, and the river gorge would then be filled with gravels and sands and loams brought down from the Piedmont plateau, distributed and deposited in the great tidal estuary, to be wholly or partially washed out of the channel at each successive elevation. The tongue of coastal plain deposit, shown as P in fig. 12, is an unremoved remnant of probably recent filling, the bottom of the river at this point being now too near tide level to permit of further removal of this material from the submerged eastward sloping surface of the old crystalline schists. There are also many reasons for believing that another of the results of the unstable condition of this region has been the decided eastward tilting of the irregularly eroded surface of these old crystalline rocks upon which the coastal plain loams and gravels were subsequently deposited.

GEOLOGIC CONDITIONS FAVORING WATERPOWER DEVELOPMENT AT THE FALL LINE.

(1). The eastward tilting of the surface of these older crystalline rocks, and (2) the partial removal of the loose and easily eroded loams and gravels from the channel on the eastern slope of these rocks, have given this resulting descent in the river surface at the fall line, which, in the Roanoke at Weldon, aggregates 85 feet in 9 miles. (3) The variation in the character of the rock, being harder and more obdurate at certain points, and softer, more jointed, more crushed, and hence more easily eroded in the intervening areas, results in concentrating this fall of the stream at certain places; and (4) the existence of terraces along the river banks facilitates the construction of canals which still further concentrate the fall of the water. These are the more important geologic conditions that favor the development of important waterpowers on the Roanoke at the fall line in the Weldon region.

Other striking cases illustrating the conditions favoring waterpower development on streams crossing geological contacts will be found mentioned on pp. 116 and 132 of this report.

GEOLOGIC CONDITIONS AFFECTING THE FLOW OF STREAMS.

The yearly discharge of a stream depends primarily on the amount of rainfall in the region from which the stream draws its supply, but in a measure this volume, and especially the uniformity of flow, are largely influenced by the slope of the surface, the depth and porosity of the soil, and the character of the underlying rock. In connection with this study of the geologic conditions influencing the possibilities of waterpower development, it should be noted that the occurrence of lakes, swamps or marshes and poorly-drained level areas, deep and porous soils, such as the sandy and gravelly soils from 10 to 100 feet deep, which occur in the larger part of the Piedmont plateau and mountain regions of the Carolinas, the great sand hills of the coastal plain region, and the porous sands and gravels of the glaciated regions of the Northern states, all facilitate the uniformity of the flow of the streams in these several regions; and in some regions the jointed, fissured and crushed condition of the underlying rock exerts a favorable influence in the same direction. (See also pp. 138-140; 192.)

DISTRIBUTION OF WATERPOWER IN NORTH CAROLINA.

The two conditions essential to the development of a waterpower of any considerable magnitude are a large and fairly constant stream of water and a suitable amount of fall within a reasonable distance. In the eastern counties of North Carolina we have numerous large streams of water, but, except along the western border of the region, as a rule they have sluggish currents and are lacking in the necessary fall. In the mountain counties the streams are small, but the fall available in many cases is sufficiently great to make possible waterpowers of considerable magnitude. It is in the midland counties, however, that we find the most satisfactory combination of the two essential conditions, viz. volume of water and fall; and hence it is in these counties that we may expect the largest waterpower developments and the greatest and most substantial development of manufacturing enterprises.

In the following chapters of this report will be found descriptions of the several rivers occurring in North Carolina and the more important waterpowers on each, both those already developed and those still unimproved. It is intended in the present chapter to discuss briefly the distribution of these waterpowers in their relation to the geologic features, and the accompanying map (fig. 13, p. 78), together with the illustrations and descriptions found in pages 68 to 76, will prove of service in this connection. The larger map (Plate I, frontispiece) will also be of service in showing the general distribution of waterpower in the state.

WATERPOWER IN THE COASTAL PLAIN REGION.

Along the western border of the coastal plain region there are a number of important waterpowers, like those at Weldon on the Roanoke, Rocky Mount on the Tar, and those on the Cape Fear as far east as Averasboro. These, though they lie within the limits of this region, yet structurally do not belong to it, and can best be considered under the next heading below, in which will be discussed the waterpowers which belong rather to the border zone between the coastal plain and the Piedmont plateau regions, and which can perhaps be best designated as the fall-line zone.

With the exception of the waterpowers just referred to, it may be said of the coastal plain region, as a whole, that its waterpowers are of no great importance. The water supply is ample but the fall is lacking. And yet there exist at many different points in this region conditions which are favorable to the development of waterpowers which, though small, have considerable local value. Until a comparatively recent date, practically all of the grist-mills in this section were operated by small waterpowers, and a considerable number of these grist-mills are still in operation. But such waterpowers were confined to the smaller streams, and in many cases the development of power consisted simply in the construction of a dam across the deep, narrow channel of the stream without the existence of a natural shoal, and the amount of fall was simply the height of the dam.

One not uncommon type of waterpower developed in this region is illustrated by fig. 8 (p. 69). In many cases, however, the harder and more obdurate strata which caused the fall in the water to be concentrated at one or more points, instead of being composed of compact and finely laminated beds of clay, as shown in the illustration just referred to, are composed either of more massive beds of clay or of beds of sand, the particles of which are cemented together by clay or iron or both.

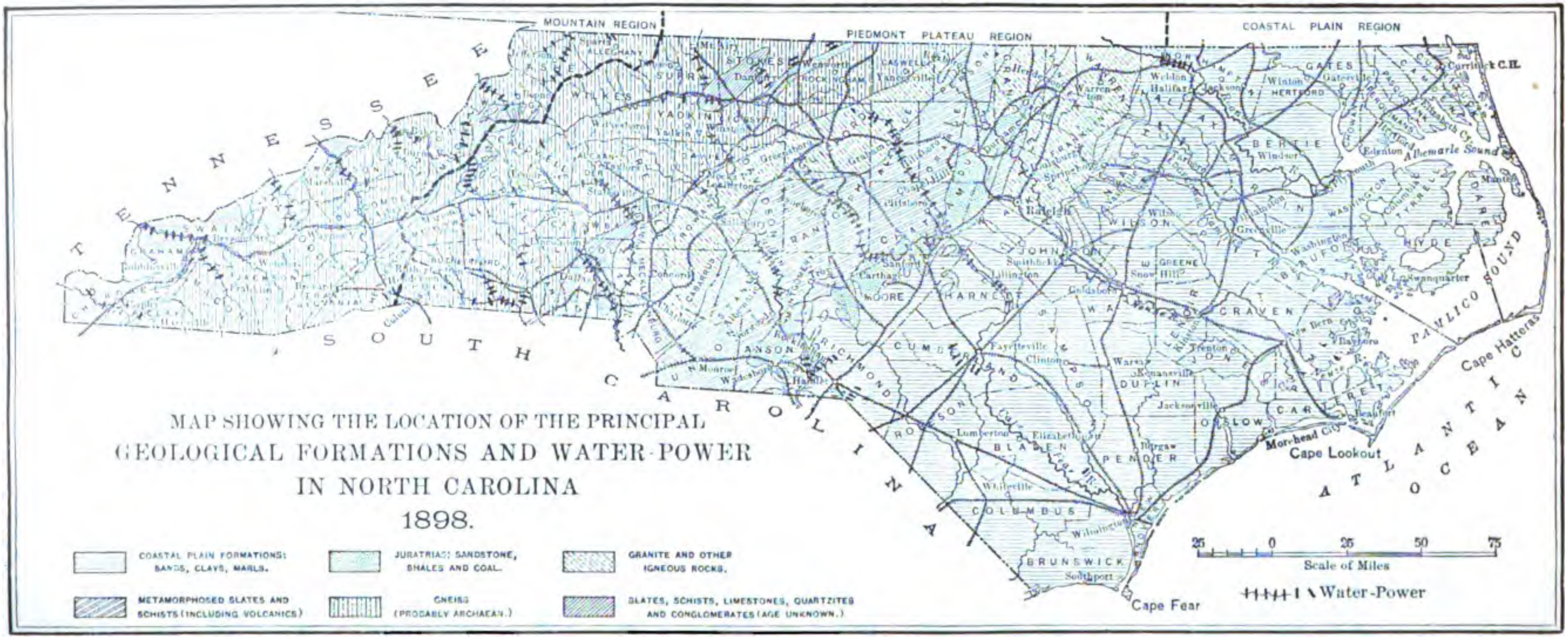


FIG. 13.—MAP SHOWING THE GEOLOGIC DISTRIBUTION OF WATERPOWER IN NORTH CAROLINA.

The most striking feature about the waterpowers developed on the majority of these smaller streams is the slight extent to which the volume of water is affected either by the rains or the dry seasons. The most widely known illustrations of this condition are Rockfish creek in Cumberland county, and Hitchcocks creek in Richmond county, both of which are described somewhat fully further on in this report (pp. 138 and 190), and the explanation there suggested of this phenomenon is undoubtedly the correct one, that the deep, porous sands of the region serve as a sponge in soaking up the rains as they fall, turning loose this water gradually during the dry season through the numerous springs in the region.

In the case of many other of the small powers in this region, as that on Colly creek in Bladen county (described on page 138) and others in the different eastern counties, the uniformity of the flow throughout the year is favored by the further condition that the tributaries of these streams pass through extensive swamp areas which also serve to store the water during wet weather.

WATERPOWER IN THE FALL-LINE ZONE.

Reference has already been made (p. 74) to the existence along what is called the "fall line" of conditions favorable for the development of waterpowers of considerable magnitude on our larger streams. It has also been suggested (p. 21) that since the exact position of this fall line is not clearly defined, and as the conditions favoring waterpower development extend across a considerable belt or zone where this line is crossed by the larger streams, it is better in this connection to consider together these conditions as they exist at and for a few miles on both sides of this boundary line between the coastal plain and the Piedmont plateau regions.

ON THE ROANOKE RIVER.

The conditions favoring waterpower development on the Roanoke river in this zone, which at this point has a width of about 9 miles, extending up the river from Weldon, have been described and illustrated briefly above (p. 74). Waterpower developments now in progress there are described in the next chapter (pp. 94-98).

ON THE TAR RIVER.

On the Tar river there is but one large waterpower, that at Rocky Mount, which may be considered as being at the eastern margin of this zone and some 20 miles eastward of the western border of the coastal plain region. As described on page 115, the Tar rises nearly 100 miles to the northwest of this point and crosses successively several granitic, schistose and slaty belts of rock, but owing to the slight elevation of this upper part of its basin above that of the coastal plain, the long period during which the rocks of this upper basin have been undergoing surface decay, and the long period during which this stream, with no great volume of water, has been slowly carving out its channel, its freedom at the present time from conditions favorable to waterpower is easily understood. At Louisburg there is a fall of several feet owing to a change in the character of the granitic rocks. Thence southeastward, for a distance of more than 15 miles, it crosses the granitic area with the conditions of rock so uniform as to yield no cascades or shoals of importance. It then enters the coastal plain region and continues for another 15 miles in a southeasterly course across the upturned edges of the crystalline schists, from the surface of which, in the channel of the stream, the (younger) loose loams and gravels have been carried away. In this distance there are two small shoals which have been developed for grist-mills, but the rocks are too soft and the channel already eroded too deeply and uniformly to leave at individual points any large amount of fall. The river then turns northeastward, and for a distance of some miles follows the course of these crystalline schists instead of cutting across them. Just at Rocky Mount it turns eastward and crosses a ledge of hard granitic rock, on the eastern slopes of which there is a natural fall of about 15 feet in the course of 100 yards. It is on the top of this granitic ledge that the dam has been built which serves for the full development of this waterpower for operating the Rocky Mount cotton-mill.

ON THE NEUSE RIVER.

On the Neuse river, as on the Tar, there is rather a remarkable absence of conditions favorable to the development of large waterpowers. Of the two powers described in the succeeding pages of this report (pp. 121-124), both lie within the granite area, one to the north and the other to the east of Raleigh, and are due to local changes in the character of the granitic rock. At ordinary low water the slaty rocks are exposed in the river bed at Smithfield some 30 miles southeast of Raleigh, and the river has a slight descent at this point but not sufficient to be favorable for waterpower developments.

ON THE CAPE FEAR RIVER.

The fall-line zone on the Cape Fear river may be said to begin where this river is formed by the junction of the Deep and Haw rivers, and to extend from that point to a short distance below Smileys falls, near

Averasboro. In this distance of about 35 miles there is a succession of shoals beginning just above with Buckhorn falls, 9 miles below the junction of the two rivers, where there is a fall of 20 feet in a distance of one and one-half miles, while the lowest of the prominent shoals, "Smileys falls," 30 miles below the junction, has a fall of 27 feet in a distance of three and one-half miles. The total fall from the junction of the two rivers to just below Smileys falls is about 100 feet. Within 17 miles below Smileys falls, by river, there are at least three different shoals, the last of which is only 8 miles above Fayetteville; but none of them are of any importance, and they need hardly be considered in this connection, for the reason that in this distance the river runs in a nearly southwesterly course, parallel to the fall line. All of the more important of these shoals are described briefly in a succeeding chapter (pp. 132 to 137).

The outlying gravels of the coastal plain deposits are to be found on the hills two miles to the west of the junction of the Haw and Deep rivers, so that all the shoals just mentioned lie within this region, and the sands and loams and gravels characteristic of the border deposits are exposed here and there in the river bluffs, though in the river channel these have been removed and the waters rush along over the upturned and irregularly eroded edges of granites and crystalline schists. Within a few miles above the junction of the Haw and Deep rivers both of these streams pass from the slates of the Piedmont plateau region to and across a narrow strip of Jura-trias sandstone, which latter is made up of materials far more easily eroded than the slates, and as might be expected there are shoals on both streams at this junction. The rivers join within this sandstone area, and for a few miles below the junction the Cape Fear is a sluggish stream.

ON THE YADKIN-PEE DEE RIVER.

On the Yadkin-Pee Dee river a condition of things exists somewhat similar to that on the Cape Fear just mentioned. The course of the Yadkin river as it crosses the slates, for some 15 miles above its junction with the Uharie, has been already briefly described (p. 71); and the numerous shoals on the river throughout its entire length are described in a following chapter (p. 172). Below its junction with the Uharie the river flows for a distance of some 20 miles in a southerly course obliquely across and in places paralleling the upturned edges of the argillaceous slates. In this distance there are only two prominent shoals, but neither of great importance as compared with those at the narrows above. These are Swift Island shoal, 42 to 44½ miles above the state line, which has a fall of 18 feet in 2½ miles; and Gunsmith shoal, 13 miles further up the river, with a fall of 9½ feet in half a mile. Further down, the river flows easterly as a somewhat sluggish stream across a few miles of red sandstone rocks, similar to those crossed by the Cape Fear at the junction of its two tributary streams. It then enters the coastal plain region, near where it is joined by Little river and follows a southerly course to Cheraw, 35 miles below. Throughout this distance there is a succession of shoals due to the fact that the river crosses the upturned and irregularly eroded edges of alternate beds of slaty and granitic rocks. The two most important of these shoals are Bluitts "falls," 12 miles above the state line, with a fall of 9 feet in a distance of 1000 feet, and Grassy Island shoal, 13 to 17½ miles above the state line, with a fall of 36 feet at a distance of 4½ miles.

The river crosses the lower limit of the fall-line zone a little above Cheraw. The shoals in the river at that point and for some distance above are not large, but they are sufficient to mark the passage of the river from its characteristics in the Piedmont plateau region to its typical coastal plain condition, that of a sluggish stream.

WATERPOWER IN THE SLATE BELTS.

The origin and nature of the shoals and rapids favorable for the development of waterpower in slaty and schistose areas have already been briefly described above (p. 70). The general distribution of these slate belts in North Carolina is shown on the accompanying small map (p. 78). The possibility of waterpower development on the Haw, Deep and Yadkin, as they cross the central and most extensive of these slate belts in Alamance, Randolph, Davidson, Stanly and Montgomery counties, is greater than on any other portion of these rivers.

ON THE HAW AND DEEP RIVERS.

Both the Haw and Deep rivers rise in the granitic and gneissic area, the former to the northwest and the latter to the southwest of Greensboro, and are sufficiently large in volume to be available for small powers by the time they reach the western border of the slate belt. Throughout their course of about 50 miles across it each river is a succession of shoals or rapids, many of which have already been developed, while a number of others are capable of being developed on a considerable scale. The slates and schists of this region have a general northeasterly course, and, as a rule, dip steeply toward the northwest, so that these streams with a southeasterly course have cut their beds directly across the upturned edges of the slates, which vary in hardness and obduracy from point to point, the harder sheets projecting upward as ledges, and the intervening softer sheets being washed out as depressions, which thus give rise to the shoals and rapids, elsewhere described in this report (pp. 146 and 159).

Deep river in the neighborhood of Carbonton leaves the slates and enters the red sandstone basin, and for a considerable distance flows in this latter material as a deep, sluggish stream. At one or two places, however, extensive trap dikes lie across the bed of the stream and have resulted in the development of small waterpowers. About one mile above Lockville the river leaves the sandstones and crosses a narrow neck of slates and again passing from this slate to the sandstone to the eastward a considerable fall is produced, and an excellent power has been developed at Lockville (p. 159).

ON THE YADKIN RIVER.

The Yadkin river strikes the slate belt some 12 or 15 miles below the Southern railroad crossing near Salisbury, and for a distance of 20 miles below this point the geologic conditions in this slate have resulted in a succession of shoals and rapids which promise to be of great value in connection with the development of manufacturing enterprises. These conditions have been described briefly above (p. 71) and the extent and character of the shoals are described at considerable length further on in this report (pp. 176 to 184). From the mouth of the Uharie to the mouth of Rocky river, a distance of some 15 miles, the river follows a general southerly course, crossing the slates so obliquely, and in the region where the character of the slates is so nearly uniform, that but few shoals are produced and these of no great magnitude as compared with those above the Uharie.

On another small stream, the south fork of the Catawba, which crosses the slate areas in Lincoln and Gaston counties, the influence of the slaty structure in the development of waterpowers is shown in a marked degree. On this small stream from Lincolnton to where it joins the Catawba river at the state line, a distance of something more than 25 miles, there is a succession of shoals not unlike those existing on the Haw and Deep rivers as described above. On not less than a half-dozen of these shoals cotton-mills have been built and are being operated.

WATERPOWER IN THE GRANITIC AND GNEISSIC AREAS.

The larger granitic and gneissic areas occupy the region from the western border of the slate belt just mentioned westward to the foot of the Blue Ridge, the typical Piedmont plateau section of the state.

ON THE DAN, MAYO AND SMITH RIVERS.

In the northern portion of this area we find a condition of things extending from the southern boundary of Stokes county to the northern boundary of Rockingham county, which illustrates in a rather striking way the influence of geologic structure in the production of waterpower. Within the limits mentioned the Dan river flows through a narrow Jura-triassic area composed of sandstones and shales, and owing to the fact that this material is much more easily eroded, the surface of the country occupied by it has been reduced to a level from one to two hundred feet below the contiguous areas of gneissic rock. The main tributary of the Dan river rises in Patrick county, Virginia, and flows in a general southeasterly course across the elevated and hilly surface of Stokes county, and across the strike of the gneissic rock which enters most largely into the geologic formation of the region. Near the southeast corner of Stokes county it enters the sandstone depression mentioned above, and takes a northeasterly course. In crossing the county the waters of this stream descend several hundred feet and the changes in the character of the rocks along its course have resulted in concentrating this fall at a number of points. Two or more of these shoals occur in the gneissic area near the border of the sandstone depression mentioned above, where the river makes its final descent from the elevated area of harder rocks into this basin. A similar condition of things exists on the Mayo and Smith rivers in Rockingham county, which, like the upper part of the Dan river, rise in Virginia, flow across the plateau of harder gneissic rocks in a southeasterly course and join Dan river in Rockingham county as it flows along this sandstone depression. The waterpowers developed on these two streams at Mayodan and Spray (pp. 111 and 109) have their origin in the sudden descent of these streams from the more elevated surface of the harder rocks into the sandstone basin at these points.

ON THE SOUTH FORK OF CATAWBA AND LINVILLE RIVERS.

Two other streams occurring in this general region may be mentioned here as of special interest though, like those just mentioned, not typical of conditions developed in gneissic and granitic areas. One of these, the south fork of the Catawba, which from Lincolnton to the mouth of the river crosses mainly rocks of a slaty and schistose character and nearly at right angles to their strike, has been briefly described already (p. 83).

The other, the Linville river, rises on the northwest slope of the Grandfather mountain and for a distance of more than ten miles flows in a southerly course just west of the crest of the Blue Ridge, which it crosses on the boundary line between Caldwell and Mitchell counties, and from this point for more than 15 miles it flows southward as a succession of falls, cascades and rapids, cutting its way through the Linville quartzites, which cap the Blue Ridge in this region, into the underlying typical gneisses. In this distance of 15 miles the descent of the river averages nearly 100 feet to the mile. The Linville joins the Catawba river in the gneissic area some 10 miles west of Morganton (p. 220).

ON THE YADKIN AND CATAWBA RIVERS.

The conditions favoring the development of waterpowers in granitic and gneissic areas have been described briefly above (p. 72), and the cascades and shoals and rapids on the Yadkin and Catawba, as well as on the tributaries of the Broad, will generally be found to have their origin in local changes in the character of the rock, in one or another of the ways there suggested. All of the conditions there described are to be found illustrated at intervals in this region.

As will be seen from the maps and descriptions given in a subsequent chapter, the shoals on the upper Yadkin, which lie within the area now under consideration, are less numerous than those on the same stream in its course across the belt of slate and schist already described. And inasmuch as the changes in the character of the rock in the region of the upper Yadkin are for the most part not radical, the amount of the fall at each of the shoals is less great than in the slate belt. This fact, together with the diminishing volume of water as we ascend the stream, render the powers on the upper portions of this stream less important.

The Catawba river, which, like the Yadkin, rises along the crest and eastern slope of the Blue Ridge, flows nearly a hundred miles in a northeasterly course and then turns southward. Its course in North Carolina lies entirely within the gneissic and granitic area. From Morganton eastward for a distance of nearly 40 miles the river either parallels the general strike of the rocks or crosses it obliquely. The changes in the character of these rocks are not numerous, and the number of shoals correspondingly small, though several of them are of considerable magnitude. The river then runs in a southeasterly and southerly direction for a distance of but little more than 25 miles; but in this distance it crosses the course or strike of the rocks at right angles. The changes in the character of the rocks are numerous, the rocks even being schistose and slaty in places, and the stream is literally a succession of shoals, the aggregate fall being not less than 175 feet. At a point some 10 miles south of Statesville, as will be seen on the small map (p. 78), the river reaches the typical granite belt of this region and flows thence southward for a distance of approximately 40 miles, where it crosses the state line into South Carolina. In this part of its course the rocks of the region are again more nearly uniform, and though there are several shoals of importance, as those at Cowans ford, Mountain Island, and Tuckaseegee, yet the number of these shoals in proportion to the distance is much smaller than in the 25-mile section next above.

ON THE TRIBUTARIES OF BROAD RIVER.

Among the tributaries of the Broad in Cleveland and Rutherford counties, the streams descend rapidly from the South mountains along the upper border of these counties down to the general plain of the Piedmont plateau, flowing in a southerly and southeasterly direction nearly at right angles to the general strike of the rock, and in this way encountering the greatest number of changes in the character of these rocks, which results in conditions most favorable for the development of waterpower. Hence it is that we have in this region a large number of valuable waterpowers, some half dozen of which are already operating cotton-mills, while others are soon to be utilized in the same way.

CONDITIONS IN THE SLATY AND GNEISSIC AREAS COMPARED.

In any study of the streams and waterpowers of the Piedmont plateau region it should be borne in mind that while the slaty belts present more favorable conditions for developing waterpowers, as shown in the case of the Yadkin (p. 71) and the other streams which cross the several belts, owing to the fact that in these belts the sheets of rock stand more on edge and vary more in hardness and durability, yet the streams which draw their supplies from the granitic and gneissic areas are more uniform in their flow for the reason that while the rainfall in the different belts is approximately the same, the soils in the granitic and gneissic areas are deeper and more porous and serve more as a sponge for storing up the surplus water of rainy seasons than does the more shallow and compact clayey soils resulting from the decay of the slates. This is one of the principal causes why the flow is less uniform in the case of the Haw and Deep rivers (pp. 144 and 157), which lie largely in the slaty belt, than in the case of the Yadkin and Catawba (pp. 172 and 203) which lie almost wholly in the granitic and gneissic areas.

WATERPOWER IN THE MOUNTAIN REGION.

A glance at the accompanying small geologic map (p. 78) will show that the larger part of this region is occupied by gneissic rocks. These have for the most part a characteristic northeast and southwest strike, and the irregular sheets of rock dip beneath the surface at varying but generally steep angles. The southern half of the region has along its western border an irregular belt of bedded slate, limestones, quartzites and conglomerates; and these rocks, which make up the bulk of the Great Smoky mountains, have a general northeasterly strike and dip at steep and varying angles. Near the eastern border of the region there is another but more narrow and irregular belt of rock of a somewhat similar character, following approximately the general position of the Blue Ridge mountains.

The general physiographic features of the region are briefly described on a preceding page (p. 25), but it may be restated here that the rivers of this region have their sources mainly along the western slope of the Blue Ridge, and that with the exception of New river, near the northern boundary, they flow in a general northwesterly direction across the upturned edges of both the gneissic and the more recent bedded rocks. The elevation of the country is so great and the descent of the streams so rapid that the general courses of the principal rivers have been but little modified by geologic structure, though their courses lie directly across the strike of the rock; and the resulting conditions are such as to produce along the streams occasional rapids and cascades. Especially would this be the case in the western counties, where the Pigeon, the Tuckaseegee, the Little Tennessee and the Hiwassee break through the Great Smoky mountains, and in doing so cross a variety of limestone, quartzite and conglomerate beds which go to make up the geologic formation of that area, but for the fact that during the long period of time that these streams have occupied their present channels, owing to the rapidity of their flow and the large quantities of abrading materials, such as sand, gravel and bowlders, carried down in their currents, the variations in the obduracy of the rocks crossing these stream beds seldom result in cascades of large proportions, for the reason that the would-be projecting ledges of rock across the stream bed are kept down near the general level by these eroding agencies.

A number of the smaller tributary streams flow in either a southwesterly or a northeasterly direction along the line of the strike of the rocks and thus develop the conditions favorable for waterpowers, mainly where they vary their courses and cross from rock of one character to one of a different character. In the extreme northern portion of the region the tributaries of New river rise both on the western slopes of the Blue Ridge and the eastern slopes of the Iron mountains, and flow in a general northeasterly or northerly direction, sometimes following the line of the strike, and sometimes crossing the latter at sharp angles. Along New river and its tributaries are a number of shoals which can be developed into valuable waterpowers, occurring mainly at points where the streams cross the strike of the gneissic rock of the region.

In connection with the development of these waterpowers, the river gorges are so narrow and the streams so rapid that while the construction of large dams is a matter attended with no insurmountable difficulties, yet it is often difficult to find suitable space for buildings, and it has been found more advisable in a number of cases to construct small dams and to convey the water from these in open ditches or flumes along the banks of the stream to suitable points where the power may be utilized. The chief difficulty which is met in storing water on these streams is that the ponds or storage reservoirs become rapidly filled with sand, gravel and bowlders brought down in time of flood. Probably the future development of these powers will be largely by electrical transmission, which is described more fully in a succeeding chapter (p. 337).

PART II

WATERPOWER IN NORTH CAROLINA EAST OF THE BLUE RIDGE

GEO. F. SWAIN

AND

J. A. HOLMES

WATERPOWER IN NORTH CAROLINA EAST OF THE BLUE RIDGE[1]

CHAPTER V.

THE ROANOKE RIVER AND TRIBUTARIES.

THE ROANOKE RIVER.

This river is formed by the confluence of the Dan and Staunton rivers, in Mecklenburg county, Virginia. Thence flowing southeast it enters North Carolina in Warren county, and forms the dividing line between Halifax and Martin counties on its right, and Northampton and Bertie on its left, emptying into Albemarle sound just above Plymouth. The total length of the river is about 125 miles in a straight line, and probably nearly twice as far by the river. The principal towns on the stream are: Clarksville, Virginia (at the junction of the Dan with the Staunton), Weldon, Halifax, Hamilton, Williamston, and Plymouth, North Carolina. The stream is navigable at low-water to Weldon (some 120 miles), or can be made so for boats drawing 2 or 3 feet, and to Hamilton (60 miles) for boats drawing 10 feet. Boats of greater draught cannot come through the sound. It is considered possible to get a low-water navigation of 5 feet to Weldon,[2] the principal obstacles to navigation being snags, stumps and sand-bars. By a system of locks and dams this river, with the Dan, was long ago made navigable to Danville, more than twice as far from the mouth as Weldon, but these old canal-works have been long in disuse. Although Weldon is now the head of navigation, yet there are still long reaches on the Roanoke and on the Dan, both above and below Danville, which are boatable.

The total area drained by the Roanoke river comprises about 9200 square miles, of which the Dan drains 3798, the Staunton 3546, and the Roanoke below the junction 1856. There are no large tributaries of the Roanoke below the confluence of the Dan and Staunton.

The drainage basin of the Roanoke proper is divided into two nearly equal parts by the fall line, which crosses the river between Weldon and Gaston. That part of the watershed below Weldon is low and flat,

[1] From the original report of Geo. F. Swain, published in the reports of the Tenth Census, with data revised and brought down to date, by J. A. Holmes.

[2] Annual Report, Chief of Engineers, 1872, p. 726; 1879, p. 624.

and partakes of the general characteristics of the eastern division. Above Weldon the country is more broken and the river has more fall, having cut its bed down to the underlying metamorphic rocks. The drainage basin is long and narrow, varying in width from 10 to 30 miles, and along the river are many fine bottoms, among which are some of the best farming lands in the vicinity. The bottoms widen out as we descend the river, and the flood-plain spreads out in places to a width of several miles, and finally is represented by the broad lowlands and cypress swamps of the eastern division. Alternating with the bottoms are bluffs, especially on the south side of the river. The proportion of the drainage basin covered with forests we have not been able to ascertain. The soil is clay and loam, with sand in the lower part of the basin, and the productions are tobacco, cotton, corn, wheat, fruits, and vegetables.

Below Weldon the country is quite heavily timbered, and large quantities of timber and shingles are shipped. It is said that between 15,000,000 and 20,000,000 shingles are made and shipped annually from this region. Above Weldon fine building stone is found in many places, and in Granville, Warren, Edgecombe, and Wilson counties, North Carolina, a fine quality of granite is occasionally quarried. Near Gaston there is a deposit of specular iron-ore, which has been very little worked. The basin is thinly settled above Weldon. The Raleigh and Gaston railroad, after leaving the river at Gaston, recedes rapidly from it, and afterward comes nowhere within 8 or 10 miles of it; while on the north the river is crossed by the Atlantic and Danville and Southern railways near Clarksville, and will probably be crossed between Clarksville and Gaston by a new line of railway recently projected from Ridgeway to Petersburg.

The average rainfall on the watershed of the Roanoke above the fall line is probably 40 or 42 inches, varying from 38 or 39 on the upper part of the Staunton to 44 inches at Gaston. Of this amount 10 or 11 inches fall in spring, about 10 inches in summer, and nearly the same in autumn and winter. Being so uniformly distributed, the flow of the stream may be expected to be very variable, especially as in all probability the evaporation is quite large; and, in fact, the general testimony is that the flow of the stream is subject to large variations.

The freshets on the river are very violent, and the fluctuations often occur very rapidly. At Weldon an ordinary freshet gives a rise of 12 or 15 feet; but generally twice in the year, in the spring and in the fall, there is a larger freshet, the water rising 25 to 30 feet. In 1865 the river rose 50 feet at that point, and 30 feet at Hamilton. For 60 or 70 miles below Weldon the rise is from 10 to 30 feet, but it gradually diminishes as the mouth of the river is approached, and for the last 15 or 20 miles of its course it is from 1 to 3 feet.[1] These floods occur so rapidly that the river rises sometimes over 10 feet in a day at Weldon,[2] and where there are no dikes it occasionally overflows the banks and inundates large areas of the adjoining lands. Daily measurements of the height of the river surface have been made and recorded at Clarksville and Neals for several years, and occasional measurements of the flow have been made at both these places. A record of these will be found in Part IV (pp. 287 and 292) of this report.

There are no lakes or artificial reservoirs anywhere in the drainage basin, neither are there facilities for storage on the Roanoke proper; but on the upper Dan and Staunton reservoirs might doubtless be constructed at many points.

The bed of the stream is generally sand below Weldon, with one or two ledges, and the banks are alluvial, not very low as a rule, and in many places lined with overhanging trees; while above Weldon the bed is generally composed of solid rock, sometimes of gravel and sometimes of sand or clay, the banks being alternately high and sometimes bluffy, and low and alluvial. Above the falls at Weldon, which extend for a distance of 10 miles above that place, the river is wide, full of rocks and islands in many places, and difficult to navigate in low water, with large areas of bottom-land subject to overflow in freshets, although the rise is smaller than at Weldon. Large areas of these lowlands below Weldon were diked before the Civil War to prevent flooding of the cultivated areas, and in places these dikes are being kept up at the present time. High dams across the river, except between Gaston and Weldon, would, in general, be accompanied by the overflowing of large areas.

The following table will give some idea of the fall of the stream:

TABLE OF DECLIVITY—ROANOKE RIVER.

PLACE.	Distance from mouth.	Elevation above tide. (Approximate.)	Distance between points.	Fall between points.	Fall between points.
	Miles.	Feet.	Miles.	Feet.	Feet per mile.
Mouth	0	0	120	44	0.36
Weldon	120	44	9	84	9.3
Head of falls	129	128	56	141	2.52
Clarksville	185	269			

In the twenty-second report of the board of public works of Virginia is a report on a survey of the Roanoke, by J. J. Couty. It is there

[1] Annual Report of the Chief of Engineers, 1872, p. 726.
[2] Annual Report of the Chief of Engineers 1876, Appendix G, 9.

stated that the fall from Rock Landing, in North Carolina, to the confluence of the Dan and Staunton, in Virginia, is 156.65 feet, the distance being 59.9 miles. The same report states that the width of the river is considerable, being even three-fourths of a mile in places, but on the average about 400 yards, and that the bed is mostly of solid rock, and remarkably favorable for dams.

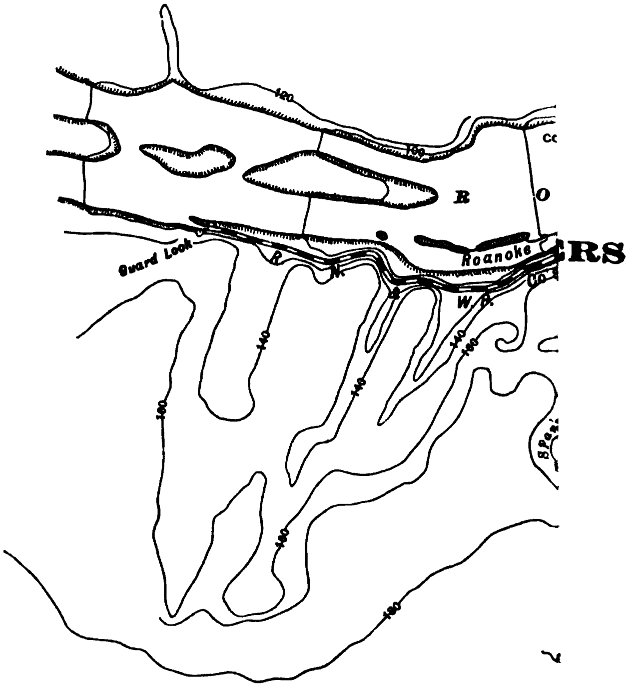
The *waterpowers* on the stream will now be described.

WATERPOWER ON THE ROANOKE NEAR WELDON.

The first power on the river as it is ascended is that at Weldon, North Carolina, where the stream crosses the fall line. The fall here is about 84 feet in a distance of 9 miles above the town, the river within this distance being very rocky and rapid, the channel very tortuous, and the bed of the river interspersed with rocks and islands, most of which are submerged at high water. Some of the larger islands are cultivated. The bed of the river is almost solid rock, and the banks generally abrupt, especially on the upper part, for several miles below the head of the falls, where they are 40 or 50 feet high, of hard granitic rock, and often extending almost perpendicularly to the water's edge. Waterpower development has been in progress here for several years by the two companies mentioned below. The accompanying map (Plate II) shows the relative location of these developments and its contour lines—with a 20-foot interval between them—indicate the general topography of the region.

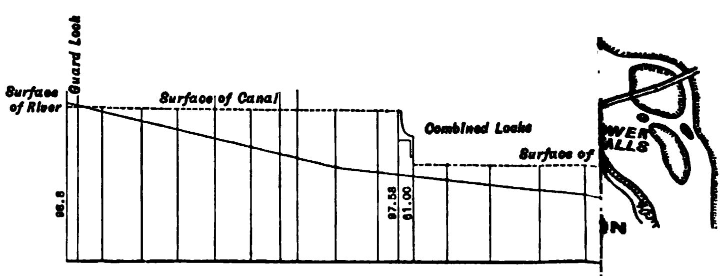
Roanoke Navigation and Waterpower Company's Canal.—Some fifty years ago the Roanoke Navigation Company extended navigation around these falls by constructing a canal on the south side of the river between Weldon and Rock Landing, 9 miles above. This canal was 30 feet wide at the top and 3 feet deep, dimensions sufficiently large for the boats then in use on the river. As a navigation enterprise this was probably never a great financial success, and with the building of railroads to Petersburg and Norfolk, the upper river navigation declined steadily until it was finally discontinued, and the works were allowed to fall into disuse, the canal being kept open only sufficiently to supply water necessary to run one or more small mills. The General Assembly of 1874-75 authorized the dissolution of the old Roanoke Navigation Company and ordered the sale of the property which was subsequently purchased by the Roanoke Navigation and Waterpower Company. This company subsequently cleaned out and repaired the canal and has begun its development as a source of waterpower.

The canal was originally substantially built, and crosses several small



SCALE:
0 ¼ ½ ¾ 1 mile.

Contour Interval 20 Feet.



Profile along the Roanoke Navigation and Water

O., N.Y.

creeks by means of stone aqueducts, all of which, as well as some of the locks, which were also of stone, are in good condition, although the gates of the latter are gone; and toward the upper end of the canal there are extensive masonry walls in places on the river side, rendered necessary by the abruptness of the banks, all of which are in good condition. At the upper end of the canal there was a guard-lock, and probably a dam, but the gates of the lock are gone, and the dam now there consists only of a few stones piled up roughly. The river at this place is said to be very favorable for the construction of a dam which might extend entirely across the channel.

Nearly four miles below the head of the canal is a flight of four locks with a total lift of 36 feet. The total fall at these locks now available for power is 31 feet. The land in the vicinity is favorable for building. See "combined locks" (Plate II).

At the lower end of the canal a fall of 48 feet between the level of the canal and the river was overcome when the canal was used for purposes of navigation by a flight of 6 locks with 8 feet lift each.[1] These locks have since been abandoned and removed. At the lower end of the canal the company has erected a corn-mill having a daily capacity of 2000 bushels with a grain elevator of 50,000 bushels capacity attached, and a cotton-seed oil mill with a capacity of 35 tons per day of 24 hours; the two mills using about 250 horsepower, the total available low-water fall for power at this point being 45 feet. The company has recently added a cotton-gin and a baling plant for the new cylindrical bale.

These mills discharge the water directly to the river, and are situated from 100 to 200 yards above the old locks. They can run full capacity all the year, except occasionally, for a few days at a time, when their running is interfered with by high water. There is practically no trouble whatever from ice.

The recent development which was completed a few years ago, consists of the enlargement of the prism of the original canal to the following dimensions, to wit: "Twenty-three feet at bottom, thirty-five feet wide at normal surface of water, and four feet deep; the construction of head-gates, with the necessary masonry, the raising and repairing of waste-ways and waste-gates, the construction of a waste-weir and gates at the foot of the basin in Weldon, the raising and repairs of the masonry of Chockeotte creek aqueduct, and the raising and strengthening of the banks of the canal throughout its length.

[1] Report of Roanoke Navigation Company in one of the reports of the board of public works of Virginia.

"The canal, with the foregoing dimensions, with smooth surfaces, and with a bottom grade of one foot per mile, as it has been constructed, has a capacity to carry 15,550 cubic feet of water per minute.

"It is constructed in two reaches or levels, the first or upper one extending from the head-gates to the combined locks, a distance of about three and a quarter miles, securing a fall of thirty-one feet at said locks. The second level extends from said locks to the terminus of the canal at Weldon, a distance of about five and one-eighth miles, where a fall of forty-five feet can be secured when the water in the river is at low-water stage."[1]

The total drainage area of the Roanoke above Gaston, or the head of the falls, is about 8200 square miles, and the rainfall over this area is about 40 or 42 inches, distributed tolerably evenly throughout the year. Records of only recent gaugings of the river are to be had. W. C. Kerr measured the flow at Haskins' Ferry, over 50 miles above Weldon, in the fall, and found it to be 2950 cubic feet per second, the drainage area above this point being about 7350 square miles, but the stage of the river is not stated. Swain has estimated the flow of the river at Gaston to be as follows:[2]

	Cubic feet per second
Minimum flow[3]	1,500
Minimum average for low-season flow	1,700
Average for the low-season flow of average dry years	1,950

The corresponding power may be tabulated as follows:

Flow, cubic feet per second.	Horsepower available, gross.		
	1 foot fall.	33 feet fall.	84 feet fall.
1,500	170	5,610	14,280
1,700	193	6,369	16,212
1,950	221	7,293	18,564

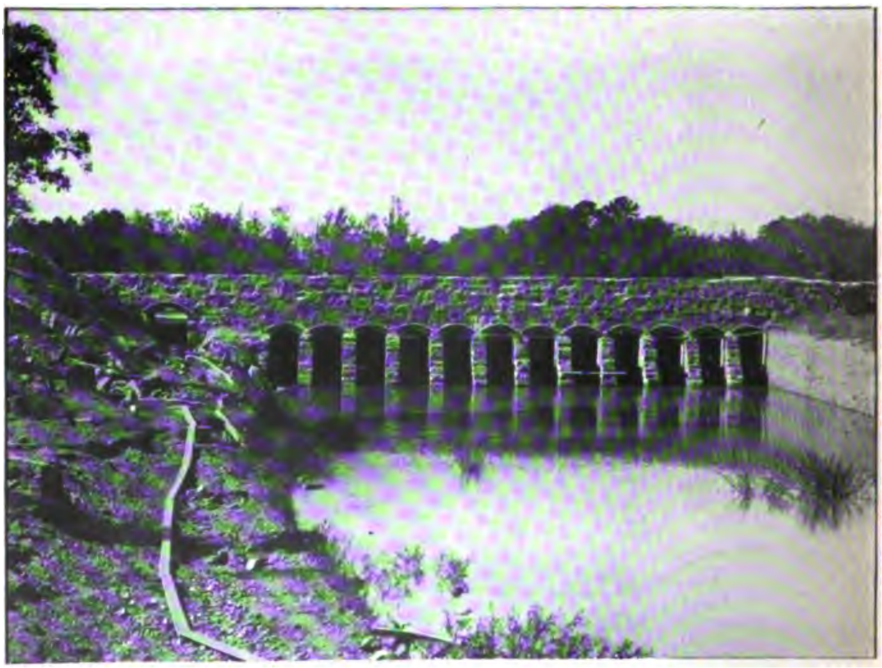
The second column of this table will also indicate the power that might be expected to be developed at the locks were the canal above this point sufficiently enlarged to allow the entire river, at low water, to flow through it to this point. This large power, only partially utilized, is available, although it would be very expensive to utilize the whole of it.

[1] Report of Byron Holly, civil and hydraulic engineer to the Roanoke Navigation and Water-power Co., 1892, published in the *Prospectus* of that company.

[2] For later measurements of the flow of this river, see pp. 292-294.

[3] See pp. 54-58.

A - DAM ADJOINING THE BULKHEAD, ROANOKE RAPIDS CANAL



B—BULKHEAD TO THE ROANOKE RAPIDS CANAL

The powers given in the above tables could be rendered available without much difficulty, but it must be remembered that all the power calculated thus far is the gross horsepower, and that the amount to be practically utilized would be less, varying according to the motor employed. With good turbine-wheels the net power will be about three-quarters or eight-tenths of the gross power.

The power at Weldon is one of the largest in the state of North Carolina, and the principal cause of its not being utilized to a greater extent until recently is probably the lack of capital. The facilities for transport are excellent, both by land and by water, for the river can be made navigable up to the town, and it is quite a railroad center. Four railroads terminate in the town, viz. the Petersburg Railroad, the Seaboard and Roanoke Railroad, the Wilmington and Weldon Railroad, and the Raleigh and Gaston Railroad, thus bringing Weldon within less than 2 hours of Petersburg, less than 3 hours of Richmond, Raleigh and Norfolk, 5 hours of Wilmington, 8 hours from Washington, and 12 hours from New York.

Good building-stone and timber can be obtained in abundance in the neighborhood, and a good deal of cotton is raised in the vicinity. The iron deposits near Gaston have only been worked to a very small extent, although the ore is said to be of good quality. The advantages for the utilization of the power are in fact excellent in all respects, and that there are no serious drawbacks is proved conclusively by the successful operation of other manufacturing plants in this region. This magnificent power is worthy of a careful examination by capitalists.

ROANOKE RAPIDS CANAL.—The development work of this company also lies on the south side of the Roanoke river, between Weldon and Gaston, beginning 1½ to 2 miles below the upper end of The Roanoke Navigation and Waterpower Company's canal and terminating nearly 2 miles below in the great bend of the river, where the factories are located. As shown by the accompanying map (Plate II, p. 94), the upper one mile of the canal lies between the right bank of the river and a chain of islands which are connected by dams made of wood and stone. The longer of these connecting dams has a length of 1465 feet and a height of from 4 to 7 feet, and the dam (Plate III) connecting the lower end of the lowest island with the outer end of the bulkhead is 685 feet long and about 11 feet high, built of log frame with rock filling and planked above. Along the surface of these islands dikes are thrown up to prevent the overflow of water from the canal into the river.

The bulkhead (Plate III) is of stone, 150 feet long, 24 feet high, at its outer or northern end, and 15 feet thick, and is penetrated by 13 gates for the admission of the water into the lower part of the canal. This lower part of the canal is three-quarters of a mile long from the bulkhead to its lower end, 90 feet wide at top, 60 feet wide at bottom, 10 feet deep, and when the canal contains its normal supply of water its cross-section below water surface is 7500 square feet. The fall at the lower end of the canal during ordinary seasons is said to be 27 feet. In dry seasons the fall is 30 feet, and the capacity of the canal is then said to be 6100 horsepower. Only a small part of this power is being utilized at the present time, but two substantial factories have been constructed and are now in operation.

The knitting mill of the United Industrial Company, located immediately against the side of the canal, contains 2310 spindles, 5 sets of cards, 30 knitting machines and 75 sewing machines. Its power is developed by 2 Leffel 40-inch turbine-wheels on a horizontal shaft, supplied with water by an iron penstock direct from the canal, and capable of developing, it is claimed, with the dry season head of 30 feet, about 800 horsepower. Of this, however, only about 150 horsepower is being used.

The cotton-mill of the Roanoke Mill Company, located about 100 yards east of the above and at a slightly greater distance from the canal, has a capacity of 18,000 spindles and 550 looms, though it has now in operation only 12,096 spindles and 320 looms, and it is using only about 400 horsepower, though its two McCormick 36-inch turbines, on a horizontal shaft, with a normal waterhead of 28 feet, are said to develop 640 horsepower. The water is supplied to these wheels by an iron penstock 9 feet in diameter and 480 feet long. A smaller single turbine, said to be capable of developing 125 horsepower, supplies power for the electric lights, fire pump, etc. As will be seen from the above statement, there is here ample power for additional manufacturing establishments, and until it is fully utilized there need be no fear of a scarcity of water during dry seasons, and there will be but little trouble from high water except during the larger freshets.

Above Gaston the river widens, and there are no other powers at all comparable with the one just described, although there are some shoals which might advantageously be utilized, alternating with long boatable stretches of smooth water. In regard to these shoals, however, we were only able to obtain a few scattered notes, and on account of their inaccessibility were unable to visit any of them.

Four miles above Rock Landing, the head of the Weldon canal, is a shoal, around which the Navigation Company constructed a canal 400 yards long, with a lock at the lower end having a lift of 9 feet.

Two miles further up there is a second mill, and above that are several others, tabulated in the table of utilized power. The available fall, however, we are unable to state. The only other place on the river where the Navigation Company found it necessary to construct a canal was at Pugh's falls, where there was one lock with 5½ feet lift,[1] but we are unable to say just where this place is located. We are also unable to give any information regarding the present condition of these canals, but the probability is that they are in very bad order.

The principal reason why these shoals have not been used more extensively is probably the fact that the river is wide, so that the dams necessary are long and expensive and subject to injury by the freshets. Of necessity, therefore, mills have usually been located on smaller streams.

Finally, it may not be out of place to say a few words regarding the causes of the low flow of the Roanoke (estimated), as compared with that of streams in New England. These causes are probably the following: (1) The rainfall on the drainage basin is not greater, and probably rather less, than on the basins of New England streams; (2) it is, on the whole, tolerably uniformly distributed throughout the year, but on some parts of the Dan and Staunton rather more falls in winter than in summer; hence, as the evaporation is very large, the streams will be very low in summer, when the evaporation is greatest and the rainfall least; (3) there are no lakes to regulate the flow.

THE ROANOKE TRIBUTARIES—DAN RIVER.

In regard to the smaller tributary streams of the Roanoke in North Carolina very little is to be said. None of them are of any importance, and possess no large waterpowers, so far as we could learn. The only power used on them is for running small grist- and saw-mills, the grist-mills generally with one, two, or three run of stones. We visited none of these streams, and the tables of the power utilized on them, compiled from the reports of the enumerators, will show that they are not of much consequence. For small powers they can be economically utilized—more economically than the Roanoke itself—because they have more fall, because the cost of a permanent dam is less, and because the mills are not troubled with high water, as those on the Roanoke are; but their flow is, of course, much more variable than that of the Roanoke.

The Dan river, one of the main forks of the Roanoke, rises in Patrick county, Virginia, near Buffalo Knob, in the Blue Ridge. It flows

[1] Report of Roanoke Navigation Company in one of the reports of the Virginia board of public works.

first in a southeasterly direction, enters North Carolina, flows through Stokes and Rockingham counties, and, pursuing a general easterly course, enters Virginia in Pittsylvania, returns to North Carolina in Caswell, and finally enters Virginia again in Halifax, to unite with the Staunton in the adjoining county of Mecklenburg, forming the Roanoke. The length of the stream, measured in a straight line nearly east and west, is about 100 miles, and by the course of the river about 180 miles. The principal towns on the river are Danbury, Madison, and Leaksville, North Carolina (all small towns of several hundred inhabitants); Danville, Virginia, with a population of over 15,000; Milton, North Carolina, and South Boston, Virginia, with five or six hundred inhabitants each.

As has already been stated, the river was many years ago made navigable by the Roanoke Navigation Company as far as Danville, and for 50 or 60 miles above that place (as far as Sauratown) for bateaux carrying 12,000 pounds, and at times bateaux have reached Hairstons falls, 12 miles below Danbury. Boats propelled by poles now ply irregularly between Danville and various other points on the river.

The river and harbor act of June 18, 1878, provided for a survey of the river from Clarksville, Virginia, to Danbury, North Carolina, and the reports on this survey by Mr. S. T. Abert, United States civil engineer, are to be found in the reports of the Chief of Engineers, 1879, p. 652, and 1880, p. 794. These reports give detailed information regarding the river, and have been used freely in the present report. By the river and harbor act of June 14, 1880, the sum of $10,000 was appropriated for the improvement of the river between Madison, North Carolina, and Danville, Virginia, "the object being to afford a channel for steam navigation not less than 35 feet wide, and not less than 1½ feet deep in the pools and 2 feet deep in the rapids at extreme low water," the estimated cost of the work being $52,000.

The total area drained by the Dan is 3798 square miles. The table on page 106 gives the drainage areas above the principal waterpowers.

The principal tributaries to the river are, from the north, going up the river, Bannister river, Birch creek, Sandy river, Smiths river, and Mayo river; from the south, going up, Hyco river, County-line creek, Moons creek, Hogans creek, and Town fork. These will be referred to again.

The drainage area of the Dan lies in the Piedmont division of North Carolina and Virginia, the sources of the river being on the eastern slope of the Blue Ridge. Its general character does not differ, as a whole, from that of the middle division, which has been described on a previous page. Its shape and dimensions may be seen by referring to the accompanying map. Geologically, it lies in the area of metamorphic rocks. Granite is found at various points; also sandstone, limestone, and slate, and fine building-stone is to be had in abundance. The valley contains coal and iron deposits, extensive beds of iron-ore, which have been worked to some extent for more than half a century, occurring near Danbury, North Carolina. The coal-fields embrace an area of over 30 square miles, and have been developed only to a very small extent. Some of the coal has been found of inferior quality, but doubtless as other openings are made coal will be found which is available for manufacturing purposes.

The watershed separating the valley of the Dan from those of the Yadkin and Cape Fear is a "long and broad ridge or swell of land, which trends due east," with an elevation of 800 feet and upward. The bed of the river is generally 200 or 300, and sometimes 400, feet below the adjacent ridges, and its tributaries have, therefore, very considerable fall, some of them affording very fine waterpower.

The principal products of the valley are tobacco, corn, wheat, rye, oats, potatoes, and fruits. There is very little, if any, cotton grown in the valley. "Between Danbury and Leaksville the land appears to be best adapted to tobacco culture, and a fine grade is produced, although there are some short stretches of very good bottom-land. Further down, the valley widens, and broad bottoms are found cultivated in corn and wheat." The country is hilly and undulating, and in the extreme west mountainous. The forests above Danville are extensive and valuable.

There are no lakes in the basin, but much of the region is forest-covered, and artificial storage-reservoirs could probably be located at many points.

The bed of the river is solid rock, overlaid between the rapids with sand and gravel. The facilities for dams are excellent. Above Danville the banks are generally moderately high, and sometimes abrupt and bluffy, and the bottoms narrow, and not often overflowed. Below Danville the banks are lower, the bottoms wider, and oftener overflowed, and bluffs more rare. There are no regular ravines of any extent, a bluff on one side of the river being generally faced by shelving or low ground on the other.

The river is subject to heavy floods, the river rising and falling very rapidly. At Madison, in 1850, it rose 28.4 feet; and at Danville, in 1873, 17 feet above ordinary low water. Below Danville the floods rise still higher. Thus, in November, 1877, the river rose to heights of 30.21 feet above low water at Milton; 33.54 feet at Oliver's mill, 28 miles below Danville; and 23.7 feet at Clarksville. Such rises are, however, very rare. There is seldom any trouble with ice, and ice-jams occur very seldom, although the river is sometimes frozen over. "Notwithstanding the height of the floods, the banks are seldom washed, their permanency being secured by a fringe of willow-growth, which borders the low grounds."

The average annual rainfall on the valley of the Dan is about 43 inches, distributed approximately as follows: spring, 11; summer, 12; autumn, 10; winter, 10. In the upper parts of the valley the rainfall is as follows: spring, 12; summer, 14; autumn, 10; winter, 14 inches. The following table will show the declivity of the stream:

TABLE OF DECLIVITY—DAN RIVER.

PLACE.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall between points.
	Miles.	Feet.	Miles.	Feet.	Feet per mile.
Clarksville	0.00	269	64.27	121	1.88
Danville, Southern railroad crossing.[1]	64.27	390	50.10	157	3.13
Madison bridge	114.37	547			
Hairstons ford	129.81	599	14.94	52	3.49
Danbury ford	142.76	695	13.45	95	7.26

Having no long-continued records of gaugings of the Dan river, Swain has estimated the flow. The following estimates are for the mouth of the stream:

TABLE OF ESTIMATED FLOW AND POWER OF THE DAN RIVER AT MOUTH.[2]

State of flow.	Drainage area.	Flow per second.	Horsepower available, gross.
(See pages 54 to 59.)	Sqr. miles.	Cubic feet.	Per foot fall.
Minimum	3,796	700	80
Minimum low season		810	92
Low season, dry years		950	108

The Dan river for a long time was not very accessible above Danville. Below that point the Richmond and Danville railroad is within 4 miles of the stream for about 50 miles, after which it leaves the river nearly at right angles. The Atlantic and Danville railroad also runs within

[1] The elevations on the Richmond & Danville (Southern) railroad were furnished by T. M. R. Talcott, then general manager, who had special measurements made of the height of the track above the water-surface.

[2] For measurements of the flow of Dan river see pp. 288, 289.

a few miles of the river all the way from Danville to Clarksville. Above Danville the river is for about 30 miles within 6 miles of the railroad, but above that it was quite inaccessible. Thus the part of the stream which was easily accessible was between the mouth of the Bannister river and the town of Leaksville. The building of the Cape Fear and Yadkin Valley railroad to Madison, the Roanoke and Southern railroad from Winston to Roanoke, and the Leaksville Narrow Gauge railroad now render that part of the river above Danville as accessible as that below, and this is doing a great deal to develop the resources of the region.

WATERPOWER ON DAN RIVER IN NORTH CAROLINA.

It has already been stated that the average fall of the Dan between Clarksville and the Richmond and Danville railroad bridge is 1.88 feet per mile. This fall is, however, not evenly distributed over the whole distance, but is mainly concentrated at a few localities, thus affording opportunities for developing large waterpowers. The only one of these in North Carolina, however, is that at Milton.

Concerning the MILTON SHOAL, it may be said that the fall is moderate in the upper 4100 feet, but for the remainder of the length very rapid, and the river is full of islands and rocks. Below the shoal the river is only 120 feet wide for a distance of three-quarters of a mile. The fall in the river from the head of Dodsons shoals to the mouth of Countyline creek at Milton is 7½ feet in a distance of 1½ miles. The conditions for building a dam on Dodsons shoals are said to be good, and a six-foot dam would give a fall of 13½ feet. The conditions for locating and constructing a canal between the two points are said to be exceedingly favorable, and the conditions for locating factory buildings at Milton are said to be equally satisfactory. Two lines of railroad (the Atlantic and Danville and the Southern) at Milton give excellent transportation facilities.

The next shoal of importance is the DANVILLE SHOAL, just below the Richmond and Danville railroad bridge, and nothing more than a continuation, with a less rapid fall, of Danville falls. The bottom is wholly rock.

In regard to the amount of power which can be utilized on the river between Danville and Clarksville, an opinion could only be formed by a personal examination. From what has been said, it is clear that there would be no difficulty in building dams almost anywhere, so far as the bed of the stream is concerned, and the banks are much more favorable than on the Roanoke; but whether much of the fall is available for power, at reasonable cost, we cannot say. In the table are given estimates of the power at only a few points. The powers given for the separate shoals are for the natural fall in the river at each shoal, and may, of course, be increased if that fall is increased by a dam.

Proceeding up the river, various shoals are encountered, all of which are mentioned in the following table. As before, the power has been calculated only for the principal ones. We are unable to describe in detail any of these shoals, not having visited any of them in person. It is evident, however, that the facilities for power are good, as far as bed and banks are concerned, both from Mr. Abert's report and from what additional information we could gather. The width of the stream between Danville and Madison varies from 190 to 430 feet, averaging perhaps 250 feet. At Hairstons ford, above Madison, it is 160, and at Danbury 120 feet. The power of the river at the time of this enquiry was utilized between Danville and Danbury at only two points, viz. at Eagle falls and at Hairstons falls, and there only by small grist- and saw-mills, using a very small amount of power. The mill at Hairstons falls was supplied by a dam at the head of the falls, extending in the form of a V across the stream, with the apex up stream, and constructed of logs. It was built in 1879, at a cost of about $125, and is about 150 yards (?) long and 3½ feet high, backing the water about half a mile. A race about 2000 feet long leads to the mill, located on the right bank, where a fall of 9 feet was used with a primitive wheel to drive the grist- and saw-mill, some 20 horsepower (net) being utilized, and in dry weather no water flowing over the dam. The bed of the river is solid rock.

A power just above Danbury was formerly used to a small extent by the iron works at that place. The dam was 10 feet high, and the water carried to the works through a tunnel about 100 yards long, cutting through a spur of the hills around which the river bends, and affording at the lower end of the canal a fall of 21 feet. The fall used by the works was about 16 feet, and the distance from the head of the canal to the foot of the tail-race about half a mile by the river. A very small proportion of the dry-weather flow of the stream was utilized. The works have not been in operation since 1865, and the dam has been entirely washed away. It is said that a dam 18 feet high could be built at this place, in which case the available fall, at the lower end of the canal, would be 29 feet.

Above Danbury the Dan is a small stream, but has a great deal of power, on account of its rapid fall. We can form no estimate of its available power, but it is safe to say that sites for small mills can be found at numerous points all the way up. The utilized power is tabulated below.

The results in the tables below must only be considered as very rough approximations, but we believe the powers given to be rather too small than too great. When it is remembered that the rainfall records for the region considered are very incomplete indeed, so that its distribution through the year is very uncertain, and that there are no long-continued gaugings of the river in existence, the engineer will be inclined to put little reliance on the figures given, and we must be distinctly understood as not claiming for them any more value than they are worth. A more accurate knowledge of the climatic and other features of the region considered would doubtless lead us to alter our estimates. And finally, it is to be remarked that these figures refer to the power available with the natural fall of the stream and with its natural flow. If the water could be stored during the night, all these powers could be doubled, and the power at many shoals could doubtless be considerably increased by putting up dams.

It has not been considered worth while to calculate the theoretical available power between the principal shoals, as it is uncertain how much of it would be practically available. It is evident that the Dan river offers a large amount of available power and good facilities for manufacturing. The estimates of power, made by Swain, are as follows: (See next page.)

Summary of Power of the Dan River in North Carolina.[1]

Locality.	Distance from Clarksville.	Drainage area.	Rainfall. Spring.	Rainfall. Summer.	Rainfall. Autumn.	Rainfall. Winter.	Rainfall. Year.	Total Fall. Height	Total Fall. Length.	Horsepower available, gross.[2] Minimum.	Horsepower available, gross.[2] Minimum low season.	Horsepower available, gross.[2] Low season, dry years.
Milton shoal	50.05	2,286	12	12	10	11	45	7.138	6,898	330	400	460
Dodsons shoal	51.61	2,270	12	12	10	11	45	2.384	1,204	......	......	......
Crowder's shoal	54.95	2,240	12	12	10	11	45	1.379	3,290	......	......	......
Rattlesnake shoal	55.78	2,230	12	12	10	11	45	1.174	3,202	......	......	......
Wilkinson's shoal	58.41	2,200	12	12	10	11	45	0.979	720	......	......	......
Pass' shoal	58.80	2,140	12	12	10	11	45	0.679	700	......	......	......
Dix's shoal	59.27	2,130	12	12	10	11	45	1.714	282	......	......	......
Noble's shoal	60.38	2,010	12	12	10	11	45	2.173	2,052	......	......	......
Devil's Jump shoal	85.86	......	11-12	12-13	10-11	11-12	44-48	0.37	658	......	......	......
Wide Mouth shoal	87.62	......	11-12	12-13	10-11	11-12	44-48	2.17	31	......	......	......
Indian shoal	91.21	......	11-12	12-13	10-11	11-12	44-48	0.64	890	......	......	......
Sauratown ford shoal	91.81	......	11-12	12-13	10-11	11-12	44-48	0.71	901	......	......	......
Double shoal	92.10	1,639	11-12	12-13	10-11	11-12	44-48	5.85	8,619	185	228	260
Hamblin's Island shoal	97.74	......	11-12	12-13	10-11	11-12	44-48	0.30	400	......	......	......
Galloway's fish-trap shoal	98.11	975	11-12	12-13	10-11	11-12	44-48	4.50	2,898	75	100	115
Galloway's Island	99.80	......	11-12	12-13	10-11	11-12	44-48	0.49	1,500	......	......	......
Reese's rock shoal	101.69	950	11-12	12-13	10-11	11-12	44-48	2.82	2,600	......	......	......
Eagle falls	103.65	940	11-12	12-13	10-11	11-12	44-48	3.14	1,290	......	......	......
Mulberry island shoal	107.37	......	11-12	12-13	10-11	11-12	44-48	1.38	1,250	......	......	......
Three Islands shoal	110.01	......	11-12	12-13	10-11	11-12	44-48	1.63	883	......	......	......
Lone Island shoal	110.51	......	11-12	12-13	10-11	11-12	44-48	1.93	1,450	......	......	......
Gravel bar	......	......	11-12	12-13	10-11	11-12	44-48	0.04	150	......	......	......
Slink shoal	112.57	......	11-12	12-13	10-11	11-12	44-48	2.58	1,074	......	......	......
Cross Rock rapid	112.87	......	11-12	12-13	10-11	11-12	44-48	0.69	150	......	......	......
Roberson's fish-trap	113.17	......	11-12	12-13	10-11	11-12	44-48	0.30	580	......	......	......
Gravel shoal	113.80	......	11-12	12-13	10-11	11-12	44-48	0.38	750	......	......	......
Gravel shoal	114.60	......	12	13	10	12	47	0.49	309	......	......	......
Beaver Island shoal	115.94	......	12	13	10	12	47	2.44	1,090	......	......	......
Wolf shoal	116.84	......	12	13	10	12	47	1.20	305	......	......	......
Cross Rock shoal	117.97	......	12	13	10	12	47	2.36	1,188	......	......	......
Shoal and fish dam	118.66	......	12	13	10	12	47	1.17	381	......	......	......
Sandy island shoal	119.48	560	12	13	10	12	47	3.51	3,241	31	44	50
Carter's shoal	120.79	550	12	13	10	12	47	4.70	3,276	42	60	69
Rutley's shoal	121.83	......	12	13	10	12	47	2.09	1,288	......	......	......
Buzzard Island shoal	122.67	......	12	13	10	12	47	0.52	220	......	......	......
Ladd's ford shoal	123.90	......	12	13	10	12	47	1.18	444	......	......	......
Dalton's fish-trap shoal	125.04	......	12	13	10	12	47	2.59	606	......	......	......
Granny Angel's shoal	125.71	......	12	13	10	12	47	1.33	441	......	......	......
Shoe-buckle Island shoal	1126.06	......	12	13	10	12	47	2.56	1,806	......	......	......
Clay's island shoal	128.48	......	12	13	10	12	47	1.40	477	......	......	......
Fish-trap shoal	129.97	340	12	13	10	12	47	3.93	1,517	18	26	30
Hairstons falls	131.15	328	12	13	10	12	47	14.89	2,629	66	98	110
	132.76	320	12	13	10	12	47	6.65	3,280	30	44	50
Big Rock shoal	134.18	315	12	13	10	12	47	8.67	4,038	38	57	65
Mount Horrible shoal	135.53	......	12	13	10	12	47	1.85	1,119	......	......	......
Williams' fish-trap shoal	135.91	......	12	13	10	12	47	1.79	390	......	......	......
Davis shoal	136.09	......	12	13	10	12	47	1.01	205	......	......	......
Cow ford shoal	136.48	312	12	13	10	12	47	4.52	1,841	19	28	32
Ducking shoal	137.35	312	12	13	10	12	47	6.44	2,616	27	40	46
Fulcher's shoal	137.92	......	12	13	10	12	47	2.01	810	......	......	......
Sink hole shoal	138.47	......	12	13	10	12	47	1.13	1,266	......	......	......
Red shoal	138.85	275	12	13	10	12	47	4.79	2,237	18	25	29
Old mill shoal	139.47	270	12	13	10	12	47	6.22	3,317	22	32	37
Danbury shoal	141.76	250	12	13	10	12	47	10.60	.....	37	55	63
Old Iron Works shoal	......	250	12	13	10	12	47	21.00	.....	75	110	125
								29.00	.....	102	150	175

[1] See pp. 103 and 105.

[2] See pages 54 to 59.

TRIBUTARIES OF THE DAN RIVER.

HYCO CREEK.

The first tributary of any importance above the confluence of the Dan and Staunton is Hyco creek, which enters from the south, its mouth being just above the head of Little Hyco falls. This stream rises in the extreme southern part of Caswell and Person counties, North Carolina, and flows in a northeasterly direction through Halifax county, Virginia, having a total length, in a straight line, of about 45 miles, and draining an area of about 400 square miles. It is about 125 feet wide near its mouth. Its tributaries are small and unimportant, and there are no important towns on the stream. We were unable to learn much about its power. The bed and banks are said to be everywhere favorable, the former being generally rock. The only power used on the stream is for small grist- and saw-mills, none of which are extensive. No sites not used were brought to our notice, but probably numerous ones may be obtained by damming. As the stream flows parallel to the general strike of the rock strata, it is probable that the declivity is quite uniform and not often broken by falls or rapids. In another table will be found the total amount of power utilized, compiled from the enumerator's reports.

COUNTY-LINE CREEK.

The next tributary worth mentioning is County-line creek, from the south, rising in Caswell county, North Carolina, and joining the Dan just on the state line (hence the name of the stream), after flowing in a northeasterly direction for a distance of about 25 miles in a straight line and draining an area of some 130 square miles. This stream, like the others in this neighborhood, is used only for running small saw- and grist-mills. The fall is considerable, but no great falls at any one place were spoken of, and probably do not exist, as the stream flows nearly parallel to the strike of the rocks. The declivity is probably quite uniform, and the powers obtained only by damming. We heard of no good sites unoccupied. Near the mouth of the stream is a grist and roller (flour) mill, with a dam 13 feet high, giving a fall of 11 feet. Opposite Yanceyville the stream is considerably smaller, and will only afford about 2 or 2½ horse-power per foot fall (gross) during eight months of the year. The waterpower of the stream is thus not very extensive.

MOONS AND HOGANS CREEKS.

The other tributaries below Danville—Moons creek, emptying just above Wilkinsons shoal, and draining about 57 square miles, and Hogans creek, emptying at Dix shoal, and draining about 114 square miles—are similar in character to Hyco and County-line creeks, and are utilized, like them, only to run small country grist- and saw-mills, the former with one or two run of stones. In a later table will be found the statement of the power used on these streams collectively, and more need not be said here.

The mills in this neighborhood are very little troubled by ice, and rarely have to stop on that account. The dams are generally of wood or of crib-work filled with stone, and there is no trouble in obtaining good foundations.

SMITHS RIVER.

Passing by several small creeks, one of the two important tributaries of the Dan is Smiths river, from the north, a very considerable stream. Rising in the Blue Ridge, in the northern part of Patrick county, Virginia, it flows first nearly east, and, after forming for a few miles the boundary between Patrick and Franklin counties, it enters Henry county, flows through it in a southeasterly direction, and empties into the Dan, in North Carolina, just below the town of Leaksville. The distance from its source to its mouth, in a straight line, is about 36 miles, but by the river it is probably at least twice that distance. The stream flows near to Martinsville, the county seat of Henry county, it and Leaksville being the only towns of importance on the river. The total drainage area of the stream is about 600 square miles, of which 39 are in North Carolina. The drainage area above Martinsville is 330 square miles. Not having examined the river in detail, on account of its inaccessibility, we are unable to describe its drainage basin very much in detail. From all that we could learn, however, it is well wooded, with a fertile soil which, in many places, is deep, sandy, and porous, and with facilities for artificial storage, although there are no lakes. The stream has a very rapid fall, a rock bottom almost everywhere, banks of moderate height, and few low grounds subject to overflow, although it is subject to freshets, during which the water rises 20 feet in places. It is fed to a considerable extent by constant springs, and is said not to be very variable in flow; and the extensive forests are a favorable feature in this respect.

The data regarding rainfall in the basin are very incomplete, but, according to the Smithsonian charts, it may be assumed at about 44 to 48 inches, of which 12 fall in spring, 12 in summer, 10 in autumn, and 12 in winter. There are no records of continued gaugings of the stream, or of its elevation at different points.

The stream is crossed at Spray, a few miles above its mouth, by the Leaksville and Danville Narrow Gauge railroad; Reidsville, on the Southern railroad, being 14 miles from the mouth of the river. The upper part of the river is crossed by the Roanoke and Southern railroad.

One and one-half miles above the mouth of the river, and in the town of Spray, are located the Leaksville woolen-mill, the Leaksville cotton-mill, the mill of the Spray Mercantile company and the Spray cotton-mill.

The Leaksville cotton-mill contains 400 looms, making colored cloths exclusively, and uses about 135 horsepower, developed by a turbine of 32½ inches in diameter and working under a head of 23 feet, capable of developing 180 horsepower. The mill of the Spray Mercantile company is a roller flour-mill of 50 barrels capacity per day and a corn-mill of two run of stones. The power is furnished by a turbine-wheel 25 inches in diameter and working under a head of 19 feet, and an overshot wheel working under a head of 14 feet, the two together developing about 50 horsepower. The Spray cotton-mill, containing 12,064 spindles, is driven by waterpower alone, using about 300 horsepower, developed by twin Leffel turbines of 36 inches diameter, on a horizontal shaft, and working under a head of 30 feet. The Leaksville woolen-mill is a two-set mill, using about 50 horsepower, obtained from a 25-inch "Perfection" turbine, working under a head of 19 feet.

A new mill, containing 400 looms, has been recently constructed at this place, opposite the Spray mill, and is using a 30-foot head.

These mills all draw their water from the same race, which is 16 feet wide at top, 4½ feet deep and 4200 feet long, with a bottom grade of 39 inches in this distance, and is estimated to be able to carry a quantity of water giving 600 horsepower with a head of 30 feet. The dam is 7 feet high and 600 feet long, of triangular wooden frames bolted to the bed of the river and planked over. The bulkhead is of solid rubble masonry, laid in cement, and is 12 feet wide and 13 feet high.

This dam backs the water about one-quarter of a mile up-stream, to the foot of another shoal owned by the same company as the power just described.

Plans are now being developed to build a dam on this upper shoal, where, it is claimed, a fall of 12 feet and 250 horsepower can be obtained. This power is to be transmitted, electrically, to Spray and used to run the Leaksville cotton- and woolen-mills and the corn- and flour-mill; and all the water of the river in the canal will then be used at the Spray cotton-mill and the new weaving mill under the head of 30 feet.

The river has been gauged near its mouth by H. Eaton Coleman, civil engineer, and county surveyor of Pittsylvania county, Virginia, who found the discharge to be 600 cubic feet per second "at mean low water." But as a single measurement of the flow has little value, other measurements should be made before attempting to estimate the available flow for waterpower purposes. The estimates as to the power used at the several mills given above are taken from the statements by the superintendents of the mills.

The power above this point is used only by saw- and grist-mills, in regard to which we have no detailed information. Enough was learned, however, to show that the river offers good sites for power all the way up. The river has no tributaries of much importance.

The town of Leaksville has a considerable trade in tobacco, which is the great staple of the county; but wheat and corn are also grown in considerable quantities on the fertile bottoms of the Dan, Smiths, and Mayo rivers.

Above Smiths river are several unimportant tributaries to the Dan, on some of which are small mills. They are similar in character to the other tributaries below Smiths river. On Cascade creek, a small stream entering from the north below Smiths river, Dr. J. G. Brodneax has a small saw- and grist-mill, and a very good small power, with a fall of 15 or 16 feet. Timber is very cheap in this vicinity, and wooden dams can be erected at very small cost.

THE MAYO RIVER.

The next large tributary above Smiths river is Mayo river, from the north, a stream which, like Smiths river, takes its rise on the eastern slope of the Blue Ridge, in the western part of Patrick county, Virginia, and which, after flowing in a general southeasterly direction through Patrick county and a corner of Henry county, Virginia, and Rockingham county, North Carolina, joins the Dan a little below Madison, and just above Roberson's fish-trap shoal. Its length, in a straight line, is about 55 miles, and along the general course of the stream about 60 miles, but probably considerably more if all of its windings are followed. The only town on the stream is Taylorsville, the county seat of Patrick county. Its total drainage area is about 350 square miles, of which 60 square miles are above Taylorsville, and its principal tributary is the North Mayo, from the north, draining about 90 square miles. Its drainage basin is, in all respects, similar to that of Smiths river. The fall of the stream is considerable, but it is said to be more uniform than that of either the Dan or Smiths river, and with not so many rapids and falls. The bed is rock almost everywhere, the banks high, and not many low grounds subject to overflow. In the absence of gaugings no estimates as to the possible available water will be given.

The first power on the Mayo river met with in ascending the stream is located about 1½ miles above its mouth and about 2 miles from the town of Madison. There is here a shoal which, in 2¾ miles, has a fall of 63.41 feet, divided about equally between what may be considered as two shoals. The lower of these shoals is the site of the Mayo mills, containing 23,000 mule spindles and 51 revolving top cards, manufacturing underwear and hosiery yarns, and using about 400 horsepower, obtained from water alone for the entire year, and there is said to be a large amount of surplus water.

The dam, which is located some distance below the top of this lower shoal, is a timber crib structure with stone abutments 12 feet high and 470 feet long, backing the water about one mile. The bulkhead is of brownstone, laid in cement, and is 150 feet long and 6 feet thick at the gates. The head race is 3200 feet long, with a cross-section of 190 square feet below the water surface, built partly in excavation and partly in embankment, and gives a head of 35.32 feet at the mill. The water is delivered to a pair of 30-inch McCormick turbines on a horizontal shaft, said to be capable of developing 846 horsepower under a head of 36 feet. There is also a turbine of 20 inches diameter, working under the same head as the main wheels and developing 100 horsepower, used for the lighting plant, fire pump, etc. There is said to be very little trouble from high water here.

The upper part of this shoal (or upper shoal) can be developed by building a dam above the pond of the Mayo mill, and thus another valuable power will be rendered available for operating a separate mill or the power here developed may be transmitted, electrically, to the mill already constructed.

About 2 miles further up the stream is a flour-mill, and above there are other small ones. There is very little bottom-land on the river for some six miles from its mouth, and the fall in that distance is very considerable, ledges of rock crossing the stream all the way. Above this, however, the stream is flat for 15 or 20 miles, and the facilities for power are not so good.

Above the Mayo there are several small creeks flowing into the Dan, some of which have power used, and all of which have considerable available. They are good streams for power, and, so far as we can learn, are not subject to such great variations in flow as those farther east. The powers they afford are small, but sufficient to run small grist- and saw-mills—sufficient for the needs of the people. Being easily dammed, and having considerable fall, they are preferred to the Dan river for small powers. The most important tributary above the

Mayo is Town fork, which joins the Dan just above Shoe-Buckle island shoal, but regarding it or the other tributaries above we have no detailed information.

All of these tributary creeks, as well as the Dan river itself, are subject to sudden and quite heavy freshets, but they have so much fall that, in general, not much damage is done, although on the Dan, even above Danville, there are many bottoms which are overflowed at times. The freshets are, in general, short, lasting usually, it is said, only four or five days.

Finally, it may be said of all the valley of the Dan, and particularly of the upper part, that the climate is exceedingly salubrious (much more so than in the lower part of the valley of the Roanoke river) the soil is fertile, and the people industrious and hospitable. The advantages for manufacturing are, in every respect, excellent.

ROANOKE RIVER AND TRIBUTARIES—TABLE OF POWER UTILIZED.[1]

Name of stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power used.
						Feet.	
Roanoke river	Albemarle sound	N. Carolina	Bertie	Saw	1	......	30
	Do	do	Northampton	Flour and grist	2	16	76
	Do	do	Halifax	Grist mill	1	45	250 (for the 3 Halifax rows)
	Do	do	do	Grain elevator	1	45	
	Do	do	do	Cotton-seed oil	2	45	
	Do	Virginia	Mecklenburg	Flour and grist	2	11½	41
	Do	do	do	Saw	2	11½	41
Tributaries of	Roanoke river	N. Carolina	Washington	Flour and grist	2	18	22
	Do	do	Bertie	do	4	34½	67
	Do	do	do	Saw	2	16	35
	Do	do	Martin	do	2	19	42
	Do	do	do	Flour and grist	3	29	40
	Do	do	Northampton	do	3	29	32
	Do	do	Warren	do	7	111	178
	Do	do	do	Saw	4	54	82
	Do	do	Granville	Flour and grist	13	178½	163
	Do	do	do	Tobacco	1	10	8
	Do	do	do	Saw	4	59½	62
	Do	Virginia	Mecklenburg	do	8	110	171
	Do	do	do	Flour and grist	17	260	331
	Do	do	do	Cotton-gin	1	31	16
Dan river	Do	do	Halifax	Flour and grist	3	21	60
	Do	do	Pittsylvania	do	2	25	65
	Do	do	do	Saw and plan'g.	1	7	50
	Do	do	do	Foundry and machine shop	2	17	70
	Do	N. Carolina	Stokes	Flour and grist	2	25	38
Hyco river	Dan river	do	Person	do	2	26	34
	Do	do	do	Saw	2	26	26
	Do	do	Caswell	Flour and grist	3	41	44
	Do	Virginia	Halifax	do	2	18	35
	Do	do	do	Saw	1	8	20
Bannister river	Do	do	Pittsylvania	Flour and grist	2	24	40
	Do	do	Halifax	do	3	45	148
	Do	do	do	Saw	1	10	20
	Do	do	do	Tobacco	1	10	18
Smiths river	Do	N. Carolina	Rockingham	Cotton factory	1	30	300
	Do	do	do	do	1	23	135
	Do	do	do	Woolen factory	1	36	50?
	Do	do	do	Flour and grist	1	19	50
	Do	do	do	Saw	1	12	20
	Do	do	do	Millwrighting	1	28	35
	Do	Virginia	Henry	Flour and grist	2	20	60
	Do	do	do	Saw	3	46	83
	Do	do	Patrick	Flour and grist	1	13	20
Mayo river	Do	N. Carolina	Rockingham	do	1	20	20
	Do	do	do	Cotton mill	1	25	..
	Do	Virginia	Patrick	do	1	15	16
Other tributaries of	Do	N. Carolina	Granville	do	3	46	40
	Do	do	do	Saw	2	33	30
	Do	do	Person	Saw	4	..	65
	Do	do	do	Flour and grist	6	80	92
	Do	do	Caswell	do	14	176	216
	Do	do	do	Saw	8	82	126
	Do	do	do	Agricultural implements	2	32	30
	Do	do	Rockingham	Flour and grist	12	169½	203
	Do	do	do	Saw	9	120+	145
	Do	do	do	Blacksmithing	1	10	6
	Do	do	Stokes	Flour and grist	18	264	285
	Do	do	do	Saw	7	96½	180
	Do	Virginia	Halifax	Flour and grist	19	344	354
	Do	do	do	Saw	11	243	194
	Do	do	do	Foundry	1	8	8
	Do	do	do	Agricultural implements	3	37	24

[1] Mainly from 10th census returns.

ROANOKE RIVER AND TRIBUTARIES—TABLE OF POWER UTILIZED.[1]—*Continued.*

Name of stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power used.
						Feet.	
	Dan river	Virginia	Pittsylvania	Flour and grist	18	307	412
	Do	do	do	Saw	4	77	70
	Do	do	Henry	Flour and grist	19	331	241
	Do	do	do	Saw	6	142	121
	Do	do	do	Agricultural implements	1	17	30
	Do	do	do	Leather	1	16	6
	Do	do	Patrick	Flour and grist	1	15	15
Staunton	Roanoke	do	Halifax	do	1	6	12
	Do	do	do	Saw	1	14	15
	Do	do	Charlotte	Flour and grist	1	10	25
	Do	do	Campbell	do	3	14½	135
	Do	do	Bedford	do	2	18	20
	Do	do	do	Saw	1	3	7
	Do	do	Pittsylvania	do	1	14	12
	Do	do	Roanoke	do	1	10	16
	Do	do	do	Flour and grist	3	30	60
	Do	do	Montgomery	do	2	25	45
	Do	do	do	Saw	1	..	20
	Do	do	do	Furniture	1	10	6
Little Roanoke	Staunton	do	Charlotte	Flour and grist	2	10	32
	Do	do	do	Saw	1	7	18
Falling creek	Do	do	Campbell	Foundry	1	10	20
	Do	do	do	Flour and grist	3	35	79
	Do	do	Appomattox	do	1	12	25
	Do	do	do	Saw	1	12	25
Otter river	Do	do	Bedford	Flour and grist	3	44	43
	Do	do	do	Saw	3	45	35
	Do	do	do	Woolen	1	..	..
	Do	do	Campbell	Flour and grist	1	2	25
Goose river	Do	do	Bedford	do	6	77	93
	Do	do	do	Saw	4	58	32
Pig river	Do	do	Franklin	Flour and grist	4	..	62
	Do	do	do	Saw	1	16	25
Blackwater river	Do	do	do	Flour and grist	2	28	22
	Do	do	do	Saw	1	9	20
Other tributaries of	Do	do	Halifax	Flour and grist	6	86	111
	Do	do	Charlotte	do	10	199	228
	Do	do	do	Saw	2	41	36
	Do	do	Campbell	Flour and grist	8	105½	238
	Do	do	do	Saw	2	26½	60
	Do	do	Bedford	Flour and grist	15	229	253
	Do	do	do	Saw	10	151	136
	Do	do	Pittsylvania	Flour and grist	1	18	12
	Do	do	do	Saw	2	26	36
	Do	do	Franklin	do	6	80	50
	Do	do	do	Flour and grist	21	310	307
	Do	do	do	Wheelwright'g	1	15	4
	Do	do	Roanoke	Flour and grist	12	176	252
	Do	do	do	Saw	8	100	105
	Do	do	do	Foundry	1	7	4
	Do	do	do	Fertilizers	1	22	15
	Do	do	Montgomery	Flour and grist	2	21	28

[1] Mainly from 10th census returns.

CHAPTER VI.

THE TAR AND NEUSE RIVERS AND TRIBUTARIES.[1]

THE TAR RIVER.

This river takes its rise in Person and Granville counties, North Carolina, flows in a southeasterly direction through Franklin, Nash, Edgecombe, and Pitt counties, and empties into the Pamlico river, in Beaufort, near the town of Washington, its length, in a straight line, being about 120 miles, and by the river perhaps 175. The principal towns on the stream are Washington, Greenville, Tarboro, Rocky Mount, and Louisburg. Tarboro, 53 miles from Pamlico river, is the head of navigation, and it is hoped to secure ultimately a channel 3 feet in depth at all stages of the water up to this point, but at present this depth exists only during nine months of the year. The obstructions to navigation consist of stumps, snags, fallen trees, and artificial obstructions placed there during the war.

The river drains an area of about 3000 square miles, the greater part of which lies north of the stream, from which side the principal tributaries—Swift and Fishing creeks—enter, draining, respectively, 350 and 760 square miles. The stream crosses the fall line at Rocky Mount, below which point there is no waterpower. The general character of the drainage basin resembles that of the Roanoke. The leading productions are tobacco, corn, and cotton, most of the cotton being raised in the eastern part, and most of the tobacco in the western. There are no lakes in the basin. The bed of the stream above the fall line is rock in places, but generally sand, clay, gravel or mud, the declivity of the stream being quite uniform. Above Rocky Mount the bottoms are narrower than on the Roanoke, and the banks are generally high enough to confine the river, except in very heavy freshets. Below Rocky Mount the banks are often overflowed, the river rising sometimes 25 feet at Tarboro.

The average annual rainfall on the basin of the Tar is about 50 inches, but above the fall line it is less—about 46 or 48 inches, distributed nearly as follows: spring, 12; summer, 14; autumn, 10; winter, 11. For gaugings on this river, see pages 294 to 297.

[1] By G. F. Swain and J. A. Holmes.

The fall of the stream below Rocky Mount is said not to exceed 1 or 1½ feet per mile, making the total fall below that point between 50 and 75 feet. The elevation of the stream at the crossing of the Raleigh and Gaston railroad is 188 feet, making the fall between that point and the head of the fall at Rocky Mount about 2 feet to the mile or less, the distance being in the neighborhood of 60 miles.

WATERPOWER ON TAR RIVER.

Ascending the stream the waterpowers met with are as follows:

Rocky Mount Mills.—The first power met with is the site of the Rocky Mount mills, situated at the fall line in the town of Rocky Mount and on the Atlantic Coast Line railroad. The dam extends entirely across the stream in a slightly broken line, with an excellent rock foundation. It is built of granite, 600 feet long and averages 11 feet high. The bed of the river is of solid rock and the banks moderately high, affording a safe development. The race is 191 feet long and the fall at the turbine-wheels is 24 feet. The mills are three in number, and contain 25,000 spindles, using, it is said, about 1000 horsepower, developed during nine months of the year by water alone; during the other three months the auxiliary steam plant is called into service to supply the deficiency. It is said that this power is capable of still further development by raising the dam and by deepening the tail race. (See Plate IV.)

The drainage area above this place is about 768 square miles, and the mean annual rainfall about 47 inches, already stated. Daily gaugings on the river at Tarboro have been made since July 25, 1896 (see p. 294), but these have not yet been continued over a long enough time to permit of waterpower estimates being made. The total available fall may be taken as 24 feet.

Above Rocky Mount the river is sluggish for some distance, after which the fall becomes considerably greater. On the upper part of the river there are only saw- and grist-mills, and there are no sites of importance not used, although on the upper part of the stream, and on its tributaries, there are many places where power could be obtained by damming.

Between Rocky Mount and Louisburg there are two small grist-mills and gins; the lower one a small mill with 8 feet fall, the dam being 215 feet long and 6 feet high, built of wood, at a cost of $600, and throwing the water back 1½ miles; and the uper one, that of Mr. N. R. Strickland, a saw- and grist-mill, with a dam of wood and stone 180 feet long, 7 feet high, and costing $1000, and backing the water 7 miles,

COTTON MILLS AND WATERPOWER DEVELOPMENT AT ROCKY MOUNT with an average width of 150 feet. At this mill a fall of 7 feet is used, and about 50 horsepower, net, with a waste of water all the time, except in times of extreme drought.

At Louisburg Col. J. F. Jones has a saw- and grist-mill, flour-mill and cotton-gin using 8 feet fall and running full capacity all the time, with water wasting. The dam is of rock, 180 feet long and 9 feet high, throwing the water back 2 miles, with an average width of 150 feet; a power of about 65 or 75 horsepower is said to be used.

Above this there are no mills of importance. It will be seen that the waterpower of the Tar river, other than that at Rocky Mount, does not amount to much, being almost all obtained by damming, and there being no natural fall of any consequence except that at Rocky Mount.

TAR RIVER—SUMMARY OF POWER.

Locality.	Distance from Tarboro.	Drainage area.	Rainfall.					Total fall.		Horsepower available, gross.[1]			Utilized.	
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length.	Minimum.	Minimum, low season.	Low season, dry years.	Horsepower, net.	Fall.
	Miles	Sq. ms.	In.	In.	In.	In.	In.	Feet.	Feet.					Feet.
Rocky Mount mills..	20±	768						24	2,800	336	408	461	1000[2]	24.00
Vivaratti's mill......	34±	615	12	14	10	11	47	8	......	80	100	115	....	8.00
Strickland's mill.....	46±	565						7	......	66	85	97	50	7.00
Louisburg............	75±	383						8	......	45	60	69	60	8.00

TRIBUTARIES OF THE TAR RIVER.

FISHING CREEK.

This creek is the first important tributary of Tar river met with in ascending the stream. It rises in Warren county, forms for some distance the boundary line between Halifax, on the north, and Nash and Edgecombe on the south, and empties into the Tar in the latter county. Its length, measured in a straight line, is about 50 miles, and its drainage area 760 square miles. Its only tributary worth mentioning is Little Fishing creek, which enters from the north. The stream crosses the fall line near Enfield, and the general character of its drainage basin is the same as that of the Tar river. The waterpower of the stream is not extensive, and is used for saw- and grist-mills, cotton-gins, and one cotton-factory.

[1] See pages 54 to 59. Also pp. 294-297.

[2] During 9 months of the year.

The first power is that of Dr. J. T. Bellamy, at the fall line, 4 miles from Enfield, where there are a saw- and grist-mill, gin, and cotton-yarn mill, the last named of which has not been operated for several years owing to the antiquated character of the machinery and the lack of capital for more modern equipment. The dam is of stone, built in 1857, at a cost of $9000, and is 168 feet long and 12 feet high, backing the water about 3 miles, and overflowing some 200 acres of swamp land to an average depth of perhaps 7 or 8 feet. At one end of the dam is the cotton-factory, and at the other the saw- and grist-mills, all using a fall of 12 feet and a total of about 50 horsepower, of which the factory formerly used perhaps 30, with a turbine-wheel, and it is said with always a waste of water. The drainage area above this place being about 500 square miles, and the rainfall 47 inches, the available power is estimated to be at least 60 horsepower in the low season of dry years, 70 in the low season of ordinary years, and twice that amount, or more, during nine months—these powers being gross, but doubtless capable of being increased to a very large extent by drawing down the water in the pond during working hours. This site is 4 miles from the railroad.

The next power is that of William Burnett, 6 miles west of the railroad, at Millbrook. The dam in 1880 was wood (crib-work), filled with stone, 260 feet long and 8 feet high, backing the water about three-fourths of a mile, but not throwing it out of its banks. A race 60 feet long lead to the mill—a grist- and saw-mill—where a fall of 5 feet (?) was used. The amount of water in the stream here is probably about the same as at Bellamy's. If the available fall is 8 feet, the available power is therefore about two-thirds of that at the latter place. The bed of the river here is rock, and very favorable for a dam.

The remaining powers on this creek and its tributaries are not worthy of special mention. They are included in the table below. The grist-mills generally have one, two, or three run of stones.

On the whole, as far as could be ascertained, the stream is not of much value for waterpower, on account of its small fall and its variable flow. We heard of no good sites not used, but there are probably places where a certain amount of power could be obtained by damming.

SWIFT CREEK.

Swift creek rises in the southeast portion of Vance county, where it is called Sandy creek; flows through Franklin, Nash, and Edgecombe, joining the Tar about 7 miles above the mouth of Fishing creek, its length, in a straight line, being about 50 miles, and draining an area of about 350 square miles. In general character it is similar to Fishing creek, but is said to be more sluggish, and to have lower banks.

Its waterpower is not valuable, and we heard of no sites not occupied. The power utilized will be found in the table. The mills are saw- and grist-mills, cotton-gins, and one cotton-yarn factory, at Laurel, belonging to Col. J. F. Jones. The latter is the most important of the utilized powers. The dam is of wood and stone, 50 feet long, 5 feet high, backing the water one mile, and giving a fall of 12 feet, with a race 60 feet long. The power is used for a grist- and saw-mill, and for a cotton-yarn factory, with 650 spindles, using perhaps, in all, 40 or 50 horse-power.

The remaining tributaries to the Tar river are of no importance, and the only mills on them are small saw-mills and grist-mills with one or two run of stones. The smaller streams nearly dry up in summer, and many of the mills have to stop grinding. The table for the utilized power of the Tar and its tributaries is compiled from the returns of the enumerators:

TABLE OF POWER UTILIZED ON TAR RIVER AND ITS TRIBUTARIES—PRINCIPALLY FROM CENSUS OF 1880.

Stream.	Tributary to what.	State.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power used.
						Feet.	
Tar river	Pamlico river	N. Carolina.	Nash	Cotton factory.	1	24	1000[1]
Do	do	do	do	Flour and grist.	8	29½	85
Do	do	do	do	Saw	1	12	30
Do	do	do	do	Cotton-gin	3	27	22
Do	do	do	Franklin	Flour and grist.	1	9	40
Do	do	do	do	Saw	1	9	25
Do	do	do	Granville	Flour and grist.	6	90	153
Do	do	do	do	Saw	5	65	98
Fishing creek	Tar river	do	Halifax	Cotton factory[2]	1	12	30
Do	do	do	do	Flour and grist.	2	19	40
Do	do	do	do	Saw	2	19	40
Do	do	do	Warren	Flour and grist.	7	100	148
Swift creek	do	do	Edgecombe	do	1	7	30
Do	do	do	Nash	do	2	19	35
Do	do	do	Franklin	do	3	30	53
Do	do	do	do	Saw	1	12	15
Do	do	do	do	Cotton factory.	1	12	20
Do	do	do	Warren	Flour and grist.	6	90	211
Other tributaries of	do	do	Pitt	do	4	29	74
Do	do	do	do	Saw	2	14	84
Do	do	do	Edgecombe	Flour and grist.	3	35	75
Do	do	do	do	Saw	2	......	49
Do	do	do	Halifax	Flour and grist.	4	62	67
Do	do	do	Nash	do	4	27	96
Do	do	do	do	Saw	1	8	12
Do	do	do	do	Agricultural implements.	1	8	12
Do	do	do	do	Cotton-gin	1	7	4
Do	do	do	Franklin	Flour and grist.	14	234	251
Do	do	do	do	Saw	9	135	163
Do	do	do	do	Cotton-gin	2	22	18
Do	do	do	do	Leather	1	15	10
Do	do	do	Warren	Flour and grist.	5	106	112
Do	do	do	do	Saw	1	15	20
Do	do	do	Granville	Flour and grist.	11	133	186
Do	do	do	do	Saw	6	91	108

[1] Said to be used during nine months of the year.
[2] Not now operated.

THE NEUSE RIVER AND TRIBUTARIES.

Drainage Areas.	Square miles.
Neuse river, at mouth	5,299
Neuse river, at New Bern	4,250
Neuse river, at Goldsboro	2,451
Neuse river, at Smithfield	1,317
Neuse river, at Milburny	995
Neuse river, at paper-mill	890
Contentnea creek, at mouth	991
Little river, at mouth	326
Little river, at Lowell	195
Flat river, at mouth	166
Little river, at mouth	130
Eno river, at mouth	134

The Neuse river is formed in the northwest corner of Wake county, North Carolina, by the union of three small streams, the Eno, Flat, and Little rivers, which themselves take their rise in Person and Orange counties. The Neuse flows in a general southeasterly direction through Wake, Johnston, Wayne, Lenoir, and Craven counties, emptying into Pamlico sound below New Bern, its general course, in its lower and navigable portion, being more nearly east. It forms for a short distance the boundary between Granville and Durham counties, and, near its mouth, between Pitt and Pamlico on its left and lower Craven on its right. Its length above New Bern, measured in a straight line, is about 150 miles, but it is much greater following the river, which is very tortuous in places. The principal towns on the stream are New Bern, Kinston, Goldsboro, Smithfield, and Hillsboro, the last being on the Eno. The head of navigation on the river is Smithfield, about 160 miles above New Bern, and the government has, at intervals, been engaged in improving the river up to this point. At present there is a navigable depth of 3 feet as far as Goldsboro (97½ miles above New Bern) during eight or nine months of the year.

The area drained by the Neuse comprises about 5300 square miles. That part above New Bern measures about 4250 square miles. The principal tributaries of the river enter from the north, viz. the Contentnea creek (mouth about 30 miles above New Bern) and Little river (mouth just above Goldsboro, 97½ miles above New Bern), draining, respectively, about 990 and 325 square miles, approximately. The river crosses the fall line near Smithfield, and below that point there is no waterpower. The fall at Smithfield, however, is not very great, and the fall line is less prominent than in the case of the Roanoke and the Tar, the ledge of rock, forming the falls at Weldon and Rocky Mount, showing itself only very slightly on the Neuse.

Below Goldsboro the river flows through a low, heavily-timbered country, and is very like the Roanoke in general character. The soil is alluvial—clay, sand, and marl; the banks from 3 to 20 feet high; the country covered with extensive pine forests and cypress swamps, and the staple product cotton. Some of the bottoms have been reclaimed by the use of dikes. Below Contentnea creek the banks and adjacent bottoms are only a few inches above low water, and the floods reach a height of 12 feet, covering large areas. The channel is very tortuous, cut-offs are often formed, and the navigation difficult. Above Smithfield the drainage basin presents no peculiarities that have not been referred to in speaking of the Roanoke and Tar. The map will show its form and dimensions. In the upper part of the valley a fine quality of granite is quarried, and in the lower part, not far above New Berne, a marl is found which is said to be a very good building-stone, being quite soft when quarried, but becoming very hard on exposure. In fact, there is no lack of building material in the valleys of the Neuse, Tar, or Roanoke.

As regards bed, banks, and freshets, the river is similar to the Roanoke, except that the bottoms are said to be less extensive (above Smithfield) and the freshets not so sudden nor violent, seldom endangering dams. Trouble with ice is very rare. There are no lakes or artificial reservoirs, but there are facilities for the latter on the upper tributaries.

The rainfall is 49.8 inches—12.18 in spring, 13.99 in summer, 11.35 in autumn, and 12.28 in winter, approximately. For gaugings on this river see pages 297 to 300.

The fall of the river below Smithfield is very small, its elevation at that point being in the neighborhood of 106 feet. At the crossing of the Raleigh and Gaston railroad, some 35 miles further up, the elevation is about 175 feet, making the fall between these points at the rate of 2 feet to the mile. Professor Kerr states that the total fall, from the northwest corner of Wake county, about 32 miles above the railroad crossing, to tide, is about 340 feet; it seems, however, scarcely probable that the fall in these 32 miles can be at the rate of 5.3 feet to the mile.

WATERPOWER ON NEUSE RIVER.

The first site for power in ascending the river is at Smithfield, where are to be found the lowest rapids, and it is said that there was once a mill there, although it is now gone. Although some power might be obtained at the place, the site is not a favorable one. The river at Smithfield is 130 feet wide, and the natural fall is but slight.

MILBURNY.—The next site, and the first one of importance, is at Milburny or Neuse mills, about 25 miles above Smithfield and 6 or 7 miles from Raleigh, formerly improved, but at present idle. There is an open frame dam across the river, 8 feet high and 250 feet long, built on the site of the old dam which was constructed years ago in connection with the old paper-mill. The fall is 11½ feet at the site of the old mill, developing about 300 horsepower at mean low water. At the present time this power is not utilized except for running a dilapidated grist-mill, which requires about 15 horsepower. It is evident that the natural fall here is not very pronounced, and it seems strange that there is no large fall on the river below this point. It is probable, moreover, that power might be got below by damming, but it is said that there are no favorable places where a dam could be built without trouble by overflowing land above. At Milburny the bed is solid rock, very favorable for a dam, and the race had to be blasted out. The banks are abrupt on the right, but not so much so on the left, and the location is said to be a safe one. The power was formerly used by a paper-mill on the left bank and a grist- and saw-mill on the other, the fall utilized being 12½ feet; but the paper-mill was burnt. It is expected, however, that the power will be again utilized in a short time.

The drainage area above this site is about 1000 square miles. Professor Kerr gauged the river at low water, and found the flow to be about 193 cubic feet per second, giving a power of 22 horsepower per foot fall. Gaugings at Selma in 1897 by the Geological Survey gave a flow as low as 109 cubic feet per second. The drainage area here is given as 1175 square miles. The water, at the time of this gauging, stood higher than it did at some other times during the year. Estimates of the flow and power, according to methods already referred to, result as follows:

TABLE OF POWER AT MILBURNY.[1]

State of flow.	Drainage area.	Fall.	Flow, per second.	Horsepower, gross.	Horsepower, gross.
(See pages 54 to 59).	Sq. Miles.	Feet.	Cubic feet.	Per foot fall.	Per 12½ feet fall.
Minimum	1,000	12½	160	18.2	227
Minimum, low season			175	20.0	250
Low season, dry years			190	21.8	272
"Low water," Professor Kerr			193	22.0	275

By storing the water during the night this power could be greatly increased, but whether such storage would be practicable we cannot say, not knowing the dimensions of the pond.

This power, as before remarked, is about 6 miles from Raleigh, from which point railroads diverge in four directions.

FALLS OF NEUSE.—The next power on the river is the paper-mill of the Raleigh Paper Company. Between this power and Milburny there

[1] For recent measurements of flow on Neuse river, see pp. 297-300.

was formerly an oil-mill, but the dam is said to have caused so much trouble by overflow, and so much sickness in the vicinity, that the property was purchased by the neighbors, and the mill torn down. The paper-mill is at Falls of Neuse, 3 miles above the Raleigh and Gaston railroad, and 13 miles north of Raleigh. The open frame dam, which extends entirely across the river, is about 410 feet long and 6 feet high, backing the water about 10 miles, the depth averaging perhaps 8 feet. A race 1000 feet long leads to the mill, where there is a fall of 18 feet. The power used is said to be 300 horsepower, but it is evident that this power can only be obtained during eight or nine months of the year. There is little trouble with high water. The dam was repaired a few years ago, but there is still some loss of power from leakage.

The drainage area above this place is about 890 square miles, and the rainfall 42 to 44 inches. Hence the power, available, per foot, would be about eight-tenths of that at Milburny, or, in round numbers, as given in the following table:

TABLE OF POWER AT FALLS OF NEUSE.[1]

State of flow.[2]	Drainage area.	Fall.	Flow, per second.	Horse-power.	Horse-power.
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	Per foot fall.	Per 18 feet fall.
Minimum	890	18	128	14.5	261
Minimum, low season			140	15.9	286
Low season, dry years			152	17.2	309

Above this mill there are no powers of importance on the river so far as we could learn. It seems strange that such a large and long river should offer so little power, especially in a section of country which abounds so largely in waterpower. The fact that there is no power on the fall line is also remarkable.

The following table gives a summary of the powers on the river utilized and available:

[1] According to all we could learn regarding this power, we are inclined to regard these estimates as too large, being informed that it is sometimes only possible to run a grist-mill in summer for several weeks at a time. But the dam is very leaky, and it may be that there are other sources of loss.

[2] For measurements of flow on Neuse river, see pp. 297-300.

NEUSE RIVER—SUMMARY OF POWER.

Locality.	Distance from head of navigation.	Drainage area.	Rainfall.					Total fall.		Horsepower available, gross.[1]			Total utilized.	
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length.	Minimum.	Minimum, low season.	Low season, dry years.	Fall.	Horsepower, net.
	Miles	Sq.m.	In.	In.	In.	In.	In.	Feet.	Miles				Feet.	
Milburny	25	1,000	11	13	10	10	44	12½	......	227	250	272	0	0
Falls of Neuse	38	890						18	......	261	286	309	18	300[2]

TRIBUTARIES OF THE NEUSE RIVER.

Most of the utilized power in the drainage basin of the Neuse is located on its tributaries, although none of them are large enough to afford very large powers.

The first important one met with in ascending the Neuse is the Trent river, which joins the Neuse at New Bern. The drainage basin of the Trent, lying entirely below the fall line and presenting no waterpower of importance, need not be further considered.

CONTENTNEA CREEK.

The next important tributary is Contentnea creek, from the north, draining an area of about 990 square miles, and joining the Neuse about 30 miles above New Bern. This stream has its sources above the fall line, in Franklin county, where it is called Moccasin creek; thence, flowing in a southeasterly direction, it forms the boundary line between Franklin and Nash counties on the north and Wake and Johnston on the south, flows through Wilson and Greene counties, and finally joins the Neuse, after forming for 6 or 7 miles the boundary between Pitt and Lenoir counties. It crosses the fall line, in Wilson county, about at the point where it changes its name to Contentnea; but, as in the case of the Neuse, there seems to be no decided fall in the stream at this point. Above the fall line it partakes of the general character of Swift and Fishing creeks, previously described, and it affords no waterpower of much importance, the declivity being gradual. There is probably power available on the stream which can be utilized by damming at suitable places, but no particular sites for powers were brought to our notice. The tributaries of the Contentnea are not of much importance.

LITTLE RIVER.

The next important tributary is Little river, which rises in Franklin, flows southeast through Wake and Johnston, joining the Neuse in

[1] See pages 54 to 59.

[2] See statement in text above.

Wayne county 2 or 3 miles above Goldsboro, and draining an area of about 325 square miles, the length of the stream, in a straight line, being nearly 60 miles. The drainage basin is long and narrow, and the tributaries of no consequence. The stream crosses the fall line, but, as in the case of the Neuse, no particular fall occurs at that place. The products of the basin are principally corn, cotton, cereals, vegetables, and fruits, and the soil fertile, generally sandy and loamy. The general character of the stream does not differ from that of the tributaries of the Tar. The banks are often low and subject to overflow, and the bed is generally of soft material—mud, sand, etc. The declivity is quite uniform, and no important sites for power could be learned of.

At Lowell, about where the stream may be said to cross the fall line, and some 25 miles from its mouth, stood the cotton-factory owned by William Egerton till 1892. This was burned in January, 1894, and on its site has since been erected a corn- and flour-mill. The power is developed by a wooden dam 170 feet long and 9 feet high, giving a fall of about 9 feet. It backs the water 4 miles, with an average width of 150 feet and an average depth of 6 feet; and the number of horsepower is about 40, which, it was said, could be obtained at all seasons of the year. The drainage area above the place being about 195 square miles, and the rainfall about 48 inches, we have estimated the minimum and the low-season flow in dry years at about 12 and 18 cubic feet per second, respectively, and the available power, with a fall of 10 feet, at 13 and 20 horsepower. With storage during the night these figures could be increased, and this may easily be done if the pond is as large as given above. Above the Lowell mills, on Little river, are only small saw- and grist-mills. The waterpower of the stream may be said to be, in general, of little value.

In the neighborhood of Goldsboro there are several small spring streams which are said to afford quite constant powers, but none of them have sufficient capacity to run any but very small mills. Such are Sleepy creek (mouth 10 miles below Goldsboro) and Falling creek (mouth 10 miles above the railroad bridge). On these streams large storage can generally be obtained, and the power resulting from the natural flow could be doubled by being concentrated into twelve hours.

The other tributaries of the Neuse below the junction of its three headwaters have numerous small grist- and saw-mills and occasionally a paper-mill, all of which are here tabulated. Most of these mills have to stop during the dryest seasons of the summer on account of low water.

Flat river, the most northerly of the three headwater streams referred to, rises in Person county and flows southeast through a corner of Durham, having a total length of some 25 miles in a straight line. It drains an area of about 166 square miles, being the largest of the three streams, has a considerable fall, and is well suited for the development of small powers. The power utilized is given in the table. The power available we cannot estimate. One of the best powers in this vicinity is reported to be at and just below the corn- and flour-mill of Mr. E. R. Moore in Person county and near the Durham county line.

Little river is the second of the three headwaters. Rising in Orange county, with perhaps a few branches in Person, and flowing a little south of east through the northern part of Orange, with a total length, in a straight line, of some 20 miles, it drains an area of about 130 square miles. None of these streams are very tortuous. Little river has the same general character as Flat river, and its power is utilized by saw- and grist-mills, and by one cotton-factory, that of the Willard Manufacturing Company. This factory contains 80 looms and 1600 spindles, operated from two-thirds to three-fourths of the year by water-power alone, the stream furnishing about 60 horsepower for 12 hours; and during the remainder of the year it is operated by water and steam combined. The dam is 21 feet high and 125 feet long, backing the water about one-half mile. This gives a fall of 22 feet at the end of a race 1200 feet long. In summer there is no waste of water, but in winter it generally flows over the dam. The flow of this stream at its mouth is estimated to be at a minimum about 5, and at its low-season flow, in dry years, 18 cubic feet per second, giving powers of 12 and 44 horsepower, with fall of 22 feet.

Eno River.—The most southerly of the three headwaters of the Neuse is the Eno, rising in the northwest corner of Orange county, flowing first nearly south and then nearly east through the county, having a length of about 25 miles in a straight line, and draining an area of about 134 square miles. It is similar in character to the others, and its power is used only by grist- and saw-mills, some of which are obliged to stop in the summer. At Hillsboro the stream is about 50 feet wide, and will probably afford not more than 8 or 9 cubic feet per second in dry years during the low season, and probably less, or about 1 horsepower per foot fall. The utilized power is given in the table.

It will be seen that the Neuse river possesses a small amount of water-power for a stream of its size in this part of the country. The lower parts of the river and the tributaries below the Raleigh and Gaston railroad are not very favorable for power—the river on account of its gradual fall and low banks, and the tributaries because of the considerable variability in their flow. Exceptions are found in the case of some tributaries not far below the fall line, which are fed by springs and keep up quite well during the summer, belonging, in fact, to the class of sand-hill streams, of which we shall meet more noticeable examples in the case of the tributaries to the Cape Fear and Yadkin. The tributaries in the upper part are more favorable, have a greater fall, higher banks, and are probably not so variable in their flow. Still, there are no such sites for power on the Neuse river as are found on the Roanoke, Tar, or on streams farther south.

NEUSE RIVER AND TRIBUTARIES—TABLE OF POWER UTILIZED.[1]

Name of stream.	Tributary to what.	State.	County.	Kind of Mill.	No. of mills.	Total fall used.	Total horse-power used, net.
						Ft.	
Neuse river	Pamlico sound	N. Carolina.	Wake	Paper	1	18	300[2]
Do	...do	... do	... do	Flour and grist.	1	10	20
Do	...do	... do	... do	...do	1	8	20
Contentnea cr'k (Moccasin)	Neuse river	... do	Wilson	...do	3	23	79
Do	...do	... do	... do	Saw	2	16	60
Do	...do	... do	... do	Cotton-gin	1	6	8
Do	...do	... do	Johnston	Flour and grist.	2	17	107
Do	...do	... do	... do	Saw	1	12	70
All tributaries to	Contentnea c'k	... do	Greene	Flour and grist.	6	63	145
Do	...do	... do	Wilson	... do	6	43	100
Do	...do	... do	...do	Saw	2	16	45
Do	...do	... do	... do	Cotton-gin	3	32	48
Do	...do	... do	Wayne	Flour and grist.	2	17	12
Do	...do	... do	... do	Saw	1	8	18
Do	...do	... do	Nash	Flour and grist.	2	....	22
Do	...do	... do	... do	Saw	2	....	22
Little river	Neuse river	... do	Johnston	Flour and grist.	2	14	77
Do	...do	... do	... do	Saw	2	16	40
Do	...do	... do	... do	Grist mill	1	9	40
Do	...do	... do	Wake	Saw	1	14	16
All other tributaries to	... do	... do	Wayne	Flour and grist.	4	50	120
Do	...do	... do	... do	Saw	1	10	10
Do	...do	... do	... do	Woolen	2	....	....
Do	...do	... do	Johnston	Agric'lt'l imp'ts	1	8	20
Do	...do	... do	... do	Flour and grist.	13	183	206
Do	...do	... do	... do	Saw	3	39	86
Do	...do	... do	Pamlico	Flour and grist.	1	8	20
Do	...do	... do	Jones	...do	3	39	70
Do	...do	... do	Craven	...do	1	8	4
Do	...do	... do	... do	Cotton-gin	1	....	....
Do	...do	... do	Lenoir	Flour and grist.	3	27	86
Do	...do	... do	Wake	...do	23	309	397
Do	...do	... do	... do	Saw	8	120	133
Do	...do	... do	... do	Woolen	1	....	15
Do	...do	... do	Franklin	Flour and grist.	1	20	15
Do	...do	... do	Granville	...do	3	49	72
Do	...do	... do	... do	Saw	1	18	30
Flat river and tributaries.	...do	... do	Orange	Flour and grist.	4	50	100
Do	...do	... do	... do	Saw	1	12	20
Do	...do	... do	Person	...do	5	61	145
Do	...do	... do	... do	...do	5	....	125
Little river and tributaries	...do	... do	Orange	...do	4	55	48
Do	...do	... do	... do	...do	6	86	90
Do	...do	... do	... do	Box	1	....	6
Do	...do	... do	... do	Cotton-factory.	1	22	60
Eno river and tributaries.	...do	... do	... do	Flour and grist.	18	271	858
Do	...do	... do	... do	Saw	4	60	55

[1] Compiled mainly from returns of 10th census.

[2] See p. 123.

CHAPTER VII.

THE CAPE FEAR RIVER AND TRIBUTARIES.[1]

THE CAPE FEAR RIVER.

This river, formed by the junction of the Haw and Deep rivers in Chatham county, North Carolina, flows in a southeasterly direction through Harnett, Cumberland, Bladen, and Brunswick counties, and for a short distance between Brunswick and New Hanover, and empties into the Atlantic at Cape Fear. Its length, in a straight line, is about 125 miles, and by the river about 192. The principal towns on the stream are Wilmington, 30 miles from the mouth; Elizabethtòn, the county-seat of Bladen county; Fayetteville, the county-seat of Cumberland county; Averasboro, and Lillington (the county-seat of Harnett county)—the two latter being small towns of a few hundred inhabitants. Fayetteville is the head of navigation for steamers of light draft, its distance from the sea being 160 miles by the course of the stream. Considerable money has been, and is being, spent by the government for the improvement of the navigation of the river below Wilmington, which is a port of entry, and present project contemplates the securing of a navigable depth of 20 feet at mean low water up to that city; but by taking proper advantage of the tides ships drawing 21 feet can easily reach that point. The average range of the tides at Southport, at the mouth of the river, is about 4 feet. The entrance across the bar to the harbor at Southport can be made by vessels drawing 25 feet at spring tides.

By a series of locks and dams the river was formerly made navigable up to the confluence of the Haw and Deep rivers, and the works were carried for some distance up the Deep river. These old navigation works, like those on the Roanoke, were never successful from a financial point of view, and before long went into disuse, and were abandoned. Between 1872 and 1874, however, a part of the works were again put in order, and navigation again opened between Battles dam and Carbonton, and kept open for several years successfully. But at present

[1] By G. F. Swain and J. A. Holmes.

they have again passed into disuse, and are practically abandoned so far as navigation is concerned.[1]

The total area drained by the Cape Fear is about 8400 square miles, of which the Deep river drains 1350, the Haw river 1675, and the Cape Fear proper 5375. The principal tributaries of the river below the forks are: From the east, in order as the river is ascended, the Northeast Cape Fear river, draining 1330 square miles, and entering the Cape Fear about 20 miles above its mouth; the South river, draining about 1430 square miles, and joining the main stream about 30 miles from its mouth; and from the west, in the same order, Rockfish creek, draining 280 square miles, and emptying 10 miles below Fayetteville; Lower Little river, draining 448 square miles, and emptying about 25 miles above Fayetteville; and Upper Little river, draining about 176 square miles, and emptying about 30 miles above Fayetteville.

The drainage basin of the Cape Fear proper, without the basins of the Deep and Haw, resembles that of the Roanoke. The river is crossed by the fall line near Averasboro, about 27 or 28 miles above Fayetteville, giving rise to Smileys falls, which is yet to be described. The map of the basin will show its form and general dimensions. The elevations of the watersheds between the Cape Fear and the adjacent

[1] The Cape Fear Navigation Company was first chartered by the state in 1796, with a capital of $80,000. In 1815 additional privileges were granted, and authority given to increase the capital stock to $100,000. Although the money was expended, no useful result was accomplished, and in 1848-49 a new company was organized, with a capital of $200,000, which was afterward increased to $350,000, the state subscribing three-fifths of the whole amount. Surveys were made, but the cost of the works which were entered upon exceeded the estimates, and although a steamer did once pass over the whole route between Fayetteville and Carbonton, on Deep river, the company was never able to keep the locks and dams in a condition requisite to secure uninterrupted communication. The failure of these works was partly due to bad engineering in the location of the dams, it being difficult to secure their ends against the action of freshets. The amount expended by the last company was about $350,000. (Annual Report Chief of Engineers, 1873, pp. 743-4.) The work was finally abandoned when the war broke out, and subsequently the works were in a measure destroyed, in part by natural causes, and in part intentionally. In 1868 the state appropriated the works to the Raleigh and Augusta Air Line railroad (then Chatham railroad), but they were afterward bought by some parties who organized as the Deep River Manufacturing Company. A little later, the Lobdell Car-wheel Company having bought an interest in the company, and also the Endor furnace, the works were again put in order from Battles dam up, in the years 1872 to 1874, for the purpose of supplying the Endor furnaces with the Buckhorn ore, for which there was no convenient transportation except by water. Navigation was kept open for several years successfully, although the company has carried on no traffic since 1876. In that year the Deep River Manufacturing Company was consolidated with the Cape Fear Iron and Steel Company, under the new name of "The American Iron and Steel Company," but the furnaces were stopped, owing to the depression in the iron business, and this, of course, put an end to the navigation, which was confined to that carried on by the company, no local trade having been built up, the single steamboat owned by the company being no more than sufficient for their own wants. Subsequent to 1876 the boat was run whenever a paying trip could be made, but not regularly, and no trips have been made since 1880. The boat has disappeared, and with it all expectation of navigation on the river. It is now the intention of the owners of the locks and other old works at Lockville and other places to develop waterpowers wherever possible.

rivers are not very great, and the tributaries do not afford much power, except in places where, by damming, the water can be thrown back for considerable distances and considerable storage room obtained; but the fall of the tributaries is, on the whole, small. As regards soil, vegetation, and building material, the drainage basin of the Cape Fear resembles that of the Roanoke, and need not be described. The facilities for storage in that part below the junction of the Haw and Deep rivers will probably be found to be not very good on account of the flatness of the country, and, in places, of the porosity of the soil—resembling in this respect, also, the Roanoke. Further up, in the valleys of Deep and Haw rivers, the storage facilities are better. As regards bed, banks, and freshets, the stream very closely resembles the Roanoke, although the bottoms are said to be not quite so extensive as on the latter river. Above Averasboro the river flows through an alluvial country, with banks generally low, and a width of from 400 to 600 feet. Below Averasboro the river is narrow, the banks high, and the soil sandy.

The rainfall on the basin of the Cape Fear is about 50 inches—12 in spring, 14 in summer, 12 in autumn, and 12 in winter; but in the valleys of the Deep and Haw rivers, although the total rainfall remains the same, the summer fall is rather smaller, and that in winter remains about the same. It would seem to follow from these facts that the flow of the Cape Fear becomes proportionately more variable as it is ascended. Another cause which tends to make the flow of the river variable is the fact that the courses of many of its tributaries in Chatham county lie in a slaty and broken region, which sheds the water with great rapidity, so that these streams become almost dry in summer; and this cause also contributes to increase the suddenness and violence of the freshets. The freshets on the Cape Fear, indeed, are said to be more violent than on any other North Carolina river. On the lower part of Deep river the banks are often overflowed, sometimes to a depth of 10 or 12 feet, and much injury is thereby done to the crops. For the upper 30 miles of the Cape Fear the banks are low and the river wide, so that the rise does not exceed 20 feet; but in the succeeding 75 miles, where the banks are high and the stream narrow, the rise is very great, amounting occasionally to 58 feet at Fayetteville. These freshets constitute a serious disadvantage to the use of waterpower on the stream. There is, however, no trouble at all with ice. Gaugings are now being made daily on the Cape Fear at Fayetteville, and on Deep and Haw rivers just above their junction (pp. 301 to 305).

The following table shows the declivity of the stream:

CAPE FEAR RIVER—TABLE OF DECLIVITY.

Locality.	Distance from Wilmington	Elevation above tide.	Distances between points.	Fall between points.	Average fall between points.
	Miles.	Feet.	Miles.	Feet.	Ft. per mile.
Junction of Haw and Deep rivers[1]	172.0	130	29.5	61	2.060
Head of Smileys falls	142.5	69	3.5	27	7.710
Foot of Smileys falls	139.0	42	27.0	35	1.250
Fayetteville	112.0	7 (?)	112.0	7	0.062 (?)
Wilmington	0.0	0			

The principal products of the region along the Cape Fear are corn, cotton, peanuts, potatoes, pease, rice, various vegetables and fruits, rye, oats, wheat, and grasses. The whole of this region lies in the cotton-belt.

The mineral resources of this region, especially of the upper part, are very great. Coal and iron are very abundant, but, owing to difficulties of transportation, the mines have been little worked. The coal-fields along the Deep river have been estimated by Emmons to cover an area of 90 square miles, and to contain at least 258,000,000 tons, easily workable. The coal is bituminous, and of superior quality. At Cumnock,[2] on Deep river, a shaft was excavated to a depth of 460 feet between 1853 and 1856, but operations were suspended on account of want of transportation. In 1887 the shaft was cleaned out and the mine reopened. Since that time mining operations have been continued to the present date. Iron has been found at Ore Hill, about 9 miles from the Gulf, and at Buckhorn, on the east bank of the Cape Fear, 8 miles below the forks; and all the way up through the valleys of the Haw and Deep rivers iron ore of excellent quality has been found in large quantities. Copper ore has also been found in the same region, and several mines have been worked.

The basin of the Cape Fear is not very thickly populated, and its population has not increased much since 1870. In that year the population per square mile was 22.7, while in 1880 it was only 28.4. (Census Bulletin No. 78, by Mr. Gannett, geographer of the Census.) At the same rate of increase the population would now (1897) be 35.9 per square mile.

[1] At crossing of Raleigh & Augusta Air Line railroad. This and the other elevations on the road were furnished by Major Winder, then general superintendent.

[2] Formerly known as Egypt.

WATERPOWER ON THE CAPE FEAR.

We proceed to describe the river more in detail and to discuss its waterpowers, commencing at its mouth.

Below Wilmington there is, of course, no power. The country is low and flat, and large quantities of rice are raised. The river is, in places, over a mile wide, and at the mouth the width is 3 miles. The country is also more or less swampy for 50 miles above Wilmington; there is no power for this distance, and rice, corn and cotton are the principal products. Thence up to Fayetteville the banks are from 15 to 50 feet high, the bed entirely sand, and the navigation difficult, on account of shifting sand-bars.

The first dam of the old Navigation Company was at Jones falls, 7.73 miles above Fayetteville, its height having been about 5 feet. It is not a good site for power.

The second dam was at Silver run, 17.11 miles above Fayetteville, its height having been probably greater, as its crest was 15.64 feet above that of the Jones falls dam. It was not spoken of as a good site for power.

The third dam was at Williams fish-trap, 25 miles from Fayetteville. The total fall from the top of the dam to low water at Fayetteville was 25.74 feet. Not a good site.

The fourth dam was at Haw Ridge, 27 miles above Fayetteville; height of crest above Fayetteville (low water), 34.97 feet. Not a good site. None of the dams thus far mentioned are now in existence.

SMILEYS FALLS.—Up to this point the fall of the river is slight, and its general character similar to what it is for some distance below Fayetteville. We now come to the fall line, where the river passes from the middle to the eastern division over a long shoal known as Smileys falls. In the table of declivity we have already stated that the fall extends through a length of about 3½ miles, with a total fall of about 27 feet. There were three dams built on these falls, viz. Green Rock, Big Island (Narrow Gap), and Sharpfield, the latter being at the head of the falls, and all of which have been completely carried away. The table following, on page 137, will show their distances from Fayetteville, and the height of their crests above the datum. "At Narrow Gap a ledge of rocks from 4 to 6 feet above the ordinary bed extends nearly across the river, leaving a narrow opening near the left bank, whence comes the name. The whole volume of water, during ordinary stages, passes through this gap."[1] Smileys falls, really the first power on the

[1] Quoted from a report on a survey of the Cape Fear and Deep rivers, by Mr. George H. Elliot, Annual Report Chief of Engineers, 1872, p. 742.

river, none of those below being worth anything as powers, are situated above the mouth of Upper Little river, and about 4 miles from the railroad. The bed is rock, and the facilities for dams and races, as well as for building, are said to be good. The greatest drawback would probably be the heavy freshets to which the river is subject, and which have been already referred to; but the fall is so great at this place that it seems as though this difficulty might be, to a large extent, obviated, if it were not endeavored to utilize the total available fall at low water. There is no power at present in use at the place, or if there is, it is only for some small country grist-mill; but none such was heard of.

The drainage area above this place being about 3400 square miles, the power is estimated in the following table:

TABLE OF POWER AVAILABLE AT SMILEYS FALLS (ESTIMATED).[1]

State of flow.	Drainage area.	Rainfall.					Flow per second.	Horsepower available, gross.		Horsepower utilized.
		Spring.	Summer.	Autumn.	Winter.	Year.				
(See pages 54 to 59.)	Sqr. miles.	In.	In.	In.	In.	In.	Cubic feet.	1 foot fall.	27 foot fall.	
Minimum	3,400	12	13	10	11	46	620	70.0	1,890	0
Minimum, low season							820	92.7	2,500	0
Low season, dry years							990	106.0	2,860	0

For the same reason a concentration of power into less than twenty-four hours would probably be impracticable, except to a very small extent.

This power, one of the finest in this section of the state, is located in a region offering many advantages for manufacturing. Fuel, in the shape of timber and coal, is abundant in the immediate neighborhood. Building materials—fine wood and stone—are also to be had with ease. The products of the neighborhood are corn, cotton, wheat, oats, rye, pease, potatoes, vegetables, and fruits of various kinds. In case of the establishment of a cotton-factory, an abundance of the raw material could probably be obtained from the surrounding country; and a branch road could be easily built to this place from Dunn station on the Atlantic Coast Line railroad only 4 miles distant. Finally, this part of the state is quite healthy, although not so much so as the western portion, chills and fever being more prevalent.

The next dam above Sharpfield dam was McAllisters, 3 miles above, the present fall in the river between these points being about 8 feet.

[1] For later measurements of flow of Cape Fear river, see pp. 302-305.

Then came Fox Island dam, 3 miles above, the natural fall being now 10 feet. The next was Douglas falls dam, rather over 8 miles above, and the fall is 9 feet. The bed of the river above Smileys falls is rock, and the fall considerably greater than below.

Battles falls.—The next dam above Douglas falls was at Battles falls, where is the first dam at present existing on the river, having been, as already mentioned, the lowest dam rebuilt by the last company (p. 128). But even of this dam only the remnants remain. The fall between Battles dam and Douglas falls, a distance of a little over 3 miles, is 9 feet. Battles dam was a wooden structure, straight across the river, and about 11 feet high and 500 feet long. This fall might be used for power, as the place is topographically favorable, but the freshets would be a drawback to the use of so small a fall. The dam originally ponded the water for 2 miles, up to the foot of Buckhorn falls. It is expected that this power will be developed at an early date.

Buckhorn falls.—This is the most important fall on the river next to Smileys, navigation through which was effected by means of a canal. At the head of the falls are the remnants of a dam, built of wood, like Battles dam, and about 1000 feet long and 3 or 4 feet high. It has the shape of a letter V, with the apex up-stream, one arm being nearly at right angles to the banks, and it is terminated on the east side by an island, behind which it turns a portion of the water, as into a natural race, which extends for a distance of a mile or so between the bank and a succession of islands, which have been connected by a series of slough-dams. At the end of the mile a slough-dam connected the last of the series of islands with the bank, and the navigation was continued by means of a canal about half a mile long, 40 feet wide at the surface, and 6 feet deep. At its head was a guard-lock, with a lift of about 4 feet, and at its foot two locks, made of crib-work filled with stone, like the guard-lock, with together 17 feet lift, one having 11 and the other 6 feet, making the total fall from the crest of the Buckhorn dam to that of Battles dam some 22 or 23 feet. A part of the fall was used by the North Carolina Iron and Steel Works to run machinery connected with their furnaces (blast, etc.), the canal having been extended some 300 yards from a point just above the outlet-locks, so as to utilize the power lower down, nearer the ore-bed. A fall of 12 feet was used, the water being discharged into a small creek having a fall of some 5 feet between the tail-race and the river. Although in freshets the backwater from the river came up to the wheel-pit, full capacity could be secured during the whole year, and no steam-power was used. These works have not been in operation since 1876, it being said that the ore-bed is exhausted, not being so extensive as was supposed, although it is not certain that this is the case.

These falls constitute a most excellent power, very easily available, and with a location perfectly safe. The existing canal constitutes a race ready for use, and by utilizing the lift of the guard-lock and discharging the water directly into the river at the works a fall of 20 feet could be rendered available, except during very severe freshets, when the works might be obliged to stop, although this would be *very* rare. The canal is in tolerably good condition, and could be made perfect at a small cost; and, if necessary, it could be easily widened so as to increase its capacity. At its lower end, where the locks are, the land is low for several hundred yards back from the river, and subject to overflow at times; but further back is a hill, on which buildings could be erected with safety, and on which stands the old furnace of the iron company.

We have estimated the available power and flow at this point, with the results given in the following table:

TABLE OF AVAILABLE POWER AT BUCKHORN FALLS (ESTIMATED).

State of flow.	Drainage area.	Rainfall.					Flow per second.	Horsepower available, gross.		Horsepower utilized.
		Spring.	Summer.	Autumn.	Winter.	Year.				
(See pages 54 to 59.)	Sq. miles.	In.	In.	In.	In.	In.	Cu. ft.	1 ft. fall.	20 ft. fall.	
Minimum	3,200	12	13	10	11	46	575	65.4	1,300	0
Minimum, low season							765	87.0	1,740	0
Low season, dry years							875	100.0	2,000	0

The present canal, or one 40 feet wide at top, 6 feet deep, and slopes of 45°, would be capable of carrying volumes of water, and of affording power, with different slopes, as per the following table:

TABLE OF POWER AFFORDED BY CANAL IN EARTH, 40 FEET WIDE, 6 FEET DEEP, SIDES AT 45°, AT BUCKHORN FALLS.

Fall of canal.	Capacity per second.	Horsepower available, gross.		Remarks.
	Cubic feet.	1 foot fall.	Total.	
1 foot per mile	450	51	1,020	Available fall about 20 feet.
2 feet per mile	625	71	1,349	Available fall about 19 feet.
3 feet per mile	790	90	1,620	Available fall about 18 feet.

The estimates of flow in the first table, and in that for Smileys falls, may seem too low, but the flow of the Cape Fear was stated to be very variable. Gaugings at Fayetteville, in 1897, as given on page 302, show that the quantity discharged was in one case as low as 424 cubic feet per second, or 0.1 cubic feet per second per square mile, and this was not the minimum stage even in that year. The theoretically available power, with storage, would be found impracticable, although the power due to the ordinary flow of the stream might be considerably increased by constructing storage reservoirs in the valleys of Deep and Haw rivers.

Buckhorn falls are fairly accessible, being only about 8 miles from Haywood, at the junction of Haw and Deep rivers, and from the Seaboard Air Line railroad, which crosses both rivers near their junction. With a dam at Buckhorn, shallow boats could be operated between this point and the railroad crossing, 8 miles above; and the construction of a branch track to the falls from the main Seaboard Air Line railroad just east of the Haw river crossing would entail but little expense for grading over the entire distance of 7 or 8 miles. As already mentioned, coal and building materials can be obtained in abundance in the vicinity. The locality is healthy, and the climate mild. The property, including land, canals, and dams, has all been owned by the Navigation Company, but it has recently (March, 1899) been sold to a newly organized electric power company, and is to be developed as a waterpower in connection with the power at Lockville.

The width of the Cape Fear at Buckhorn dam is about 700 or 800 feet, and the dam ponds the water with this average width up to the forks, and beyond, or about 8 miles. Buckhorn falls is thus the highest power on the river.

In the following table of power on the Cape Fear river we have only mentioned those powers which may be considered as available practically, viz. Smileys falls, Battles falls, and Buckhorn falls.

It will be noticed that there is not one mill in operation on the river, probably because small mills—the only kinds that have ever sought a location in this part of the state—have been more cheaply located on small streams, where there is not such danger from heavy freshets.

CAPE FEAR RIVER—SUMMARY OF POWER (ESTIMATED).

Locality.	Distance from Fayetteville.	Drainage area.	Rainfall.					Total fall.		Horsepower available, gross[1]			Total utilized		Per cent. of minimum utilized.
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length.	Minimum.	Minimum, low season.	Low season, dry years.	Fall.	Horsepower, net.	
	Miles	Sq.m.	In.	In.	In.	In.	In.	Ft.	Miles				Ft.		
Smileys falls	30 5	3,400	12	13	10	11	46	27	3.5	1,890	2,500	2,860	0	0	0
Battles falls	48 0	3,200	12	13	10	11	46	11	0.0	720	950	1,100	0	0	0
Buckhorn falls.......	51.0	3,200	12	13	10	11	46	20[2]	1.5	1,300	1,740	2,000	0	0	0

[1] See pages 54 to 59. [2] See description.

TABLE GIVING NUMBER AND LOCATION OF DAMS CONSTRUCTED ON THE CAPE FEAR AND DEEP RIVERS BY THE NAVIGATION COMPANY, TOGETHER WITH A PROFILE OF THE RIVERS BETWEEN FAYETTEVILLE AND HANCOCKS DAM.

[Taken from a map and profile of the rivers according to a survey by Hamilton Fulton, civil engineer, in the office of the State Geologist in Raleigh.]

Name of dam or place.	Distance from Fayetteville bridge.	Elevation of crest or water surface above low water at Fayetteville.
	Miles.	Feet.
Fayetteville bridge	0.00	0.00
Jones falls dam	7.73	50.00
Silver Run dam	17.11	20.64
Williams fish-trap dam	25.00	25.74
Haw Ridge dam	26.99	34.97
Green Rock dam	28.14	45.47
Big Island dam (Narrow Gap?)	29.37	53.61
Sharpfield dam	30.59	62.56
McAllisters dam	33.65	73.18
Fox Island dam	36.50	80.46
Douglas dam	44.76	88.68
Battles falls	47.97	99.51
Buckhorn falls	50.00	108.47
Buckhorn dam	51.65	122.39
Deep river, near junction with Haw	60.44	127.11
Lockville dam (lower)	......	151.67
Lockville dam (upper)	62.21	165.62
Gorgas dam (Cleggs)	64.70	172.24
Endor dam (Farishs fish-trap)	71.43	174.86
Gulf dam (Haughtons)	81.37	181.66
Carbonton dam (Evans)	87.37	190.12
Tysers dam (Hancocks)	99.87	204.64

NOTES ON THIS TABLE.—The height of each dam may be found approximately (a little too large) by subtracting from the height of its crest that of the dam below, except in cases where locks and canals were used, *i. e.* in the case of the Buckhorn dam, the lower Lockville dam, and the Gorgas dam.

These figures, having reference to the work as originally planned, are not correct for those now in existence, for in some cases these figures were altered when the works were built, and in others they have been altered since.

TRIBUTARIES OF THE CAPE FEAR BELOW THE FORKS.

The first important tributary of the Cape Fear, as we ascend the river, is the *Northeast Cape Fear*, which rises in the extreme northern part of Duplin county and flows south, through Pender and New Hanover counties, entering the Cape Fear river at Wilmington, some 20 miles from the sea. Lying entirely below the fall line, it has no water-power of any consequence, flowing mostly through swamps. There are only a few small mills on the stream and its tributaries, the fall of water in each case depending upon the height of dam.

The next important tributary is *South river*, also from the east, rising, under the name of Black river, in the northeastern part of Harnett county, and flowing south through that county, and between Cumberland, Bladen, and Brunswick counties on its right, and Sampson and Pender on its left, entering the Cape Fear about 10 miles above Wilmington, after a course, in a straight line, of about 85 or 90 miles. Its drainage area comprises about 1430 square miles. Although its sources are above the fall line, the stream is very small where it enters the eastern division, and its waterpower is, therefore, of no consequence. Some of the small tributaries near its sources have, as in the case of the Northeastern Cape Fear, small grist-mills, but of no consequence. The South river has one large tributary, the *Black river* (not the one above mentioned), which enters from the east, after having flowed, from north to south, through the whole length of Sampson county, in the northern part of which its sources lie. Its length is about 50 miles in a straight line, and its drainage area 620 square miles; but as it lies entirely in the eastern division, it possesses no waterpower. There are no towns of importance on these streams. They are so swampy that the towns are located some miles from them on higher and more healthy ground.

COLLY CREEK.

Another tributary of the Black river is Colly creek, on which, a few miles above its mouth and just over the county line in Bladen county, is a waterpower of some local importance now owned by the Colly Veneer Works Company. The fall is 9½ feet, and it can be increased to 12 feet. The dam backs the water four or five miles, the pond being ¼ to ⅜ of a mile broad. The present plant consists of two grist-mills, saw-mill and basket and veneer machinery, but only a small part of the water is said to be used. The surplus water escapes over a spillway 198 feet wide, on which it is said to stand, at a depth of 1 to 1½ feet all the time. Plans have been under consideration for utilizing this power for generating electricity for lighting the city of Wilmington, 20 miles distant. The stream is fed by numerous large swampy areas, and there is but little variation in the summer and winter water supply.

ROCKFISH CREEK.

We next come to Rockfish creek, which rises in the western part of Cumberland county, flows nearly east, forming for about 10 miles the boundary between Cumberland and Robeson counties, and empties into the Cape Fear about 10 miles below Fayetteville, in the former county. Its length, in a straight line, is about 30 miles; following the general course of the stream it is about 35 miles, but taking in all its windings it is considerably more. It drains, in all, an area of 280 square miles, and its principal tributaries are from the north, the largest being the Little Rockfish, draining an area of 77 square miles. There are no towns on the stream.

Rockfish creek is a good sample of a class of streams which we have not yet described in detail, not having had occasion to refer to any particular powers on any of them, although some tributaries of the Neuse and Tar belong to this class. These streams, located generally just below the fall line, which they sometimes cross, differ very materially in character from the majority of streams in this part of the country. We have alluded to the fact that just below the fall line there is a belt of sand-hills, some 30 or 40 miles wide, running almost parallel with that line, and sometimes extending above it. The streams of the class referred to rise and flow through this sandy region, and it is to this fact that their character is due. The sand-hill belt consists of broad, flattish swells, well wooded, as a rule, with long-leaf pine, and generally with an undergrowth. The surface deposit of sand varies generally from a foot or two to five or six feet in depth, and is in places 10, 20, and even 100 feet thick. It is underlaid with less porous strata of half-compacted sand, grit and clay of the tertiary and cretaceous formations, which are in places very thick, having been bored into to a depth of 175 feet at one place. The smaller streams in the sand-hills have not cut out their beds through the sand, and are often sluggish, stagnant, and marshy; but the larger creeks, and the rivers, have cut away the sand entirely and worn out their beds in the less pervious strata beneath, which sheds into the water-courses all the water which reaches it by percolation.

The rapidity with which the sand-hills absorb the rain which falls upon them, thus removing it from the direct action of the sun, has the effect of diminishing the evaporation, while their large thickness in places enables them to absorb considerable water, and to give it out gradually, as it reaches and flows along the impervious stratum beneath, thus enabling them to act as storage reservoirs, and to regulate the flow to a remarkable degree. Thus there is considerable difference in the sand-hill streams, according to the depth of the sand on their drainage basins, and by no means are all these streams good sources of power. Sand and gravel in general, although they absorb water rapidly, give it out rapidly also, unless occurring in sufficient masses to be able to store up considerable water without becoming saturated. Hence the depth of the sand-hills acts very beneficially, and when the sand is deep the streams of the class referred to not only discharge a large proportion of the rainfall on their drainage basins, but discharge it very uniformly, their flow being remarkably constant. The power which can be obtained from these small streams is sometimes remarkable, as we shall see further on in a study of Hitchcocks creek in Richmond county. Their value is also increased by the fact that the topography of the sand-hill region is such that large ponds can be obtained easily, and storage-room sufficient, not only to regulate the flow to a considerable extent during the year, but also to permit of the concentration of the entire flow of the stream into working hours, thus rendering it possible to double the power due to the natural flow if the mills are only worked 12 hours. Those streams which have cut deep channels for themselves through the sand down to and into the impervious stratum of hard pan flow considerably below the general surface of the country, often 50 or 60 feet. The banks of the Big Rockfish, for example, are almost 100 feet high near the Cape Fear, and well wooded. These sand-hill streams are, of course, not subject to such heavy freshets as ordinary streams. Big Rockfish has been known to rise 14 feet, but 10 feet is a very large rise, while Little Rockfish rises only 6 or 7 feet. There is, however, not much land overflowed. The smaller streams, however, are sometimes bordered by wet grounds, heavily wooded and overgrown, nearer the general surface of the ground, and lying high above the beds of the main streams. Though the sand-hills are, as a rule, well wooded, the woods have in parts been cut down to a considerable extent, and it is stated, and doubtless truly, that the flow of the streams in these sections is more variable than formerly.

Judging from observations made on the sand-hill streams tributary to the Cape Fear, Yadkin, Catawba and Savannah, it would seem a fair allowance if we assume them to discharge at their minimum about 0.5 cubic foot per second per square mile; at their low-season flow 0.65, and at their ordinary flow 0.75 to 1 cubic foot per second per square mile of drainage basin.

Regarding available power on these streams it was difficult to obtain much information, owing to the fact that the streams have a uniform declivity, with no falls, so that power may, as a rule, be obtained at almost any point where the banks are favorable for the location of a dam and buildings.

The drainage basin of Rockfish creek lies below the fall line; and the stream has no falls, but a gradual declivity. The map shows the general form and position of the basin. Like the others of this class, it has no lakes, but the facilities for constructing reservoirs are tolerably good. The banks are moderately high, and seldom overflowed; the rise in freshets is small, the flow very constant and strong, and the fall rapid. The rainfall is about 50 inches, 12 in spring, 14 in summer, 12 in autumn, and 12 in winter—a distribution which, of itself, would tend to render the flow constant. Of the available power on this stream but a small proportion is being utilized. Formerly there were one or two saw-mills located on it below the mouth of Little Rockfish creek, but these have all disappeared. Above this point there is one cotton-mill (Hope mill No. 2), a few small saw- and grist-mills, and several promising but undeveloped waterpowers.

At HOPE MILL No. 2, located on the north side of the stream but a short distance above the mouth of Little Rockfish creek, there is a wooden dam 18 feet high, giving a fall of 18 feet and backing the water for a distance of two miles. The mill contains 210 looms and 10,000 spindles, which are operated entirely by waterpower, about 200 horsepower being utilized, and the supply of water is ample during even the dryest years.

LITTLE ROCKFISH CREEK.

Little Rockfish creek, a tributary of Rockfish creek, is the same in general character as the main stream, which it enters about 7 miles, in a straight line, from the Cape Fear. The first power on this stream is an unimproved site formerly occupied by Murphy's paper-mill, with 18 feet fall, and an available power, at all seasons, of at least 100 horsepower net (with good wheels), judging by the power used at the other mills on the stream. This power is one-fourth of a mile from the mouth of the stream, with no important tributaries below it. The drainage area above is therefore about 77 square miles.

On Little Rockfish creek, about 1½ miles above its mouth, is the HOPE COTTON-MILL No. 1, a cotton-mill, with grist- and saw-mill attached, using a power of about 175 horsepower, with a fall of 22 feet. The dam is of wood, 53 feet long and 22 feet high, rebuilt in 1872 at a cost of about $2000, and ponding the water over about 200 acres to a depth of 7 feet. A race 300 feet long leads to the wheel. No steam is used for power, and by storing the water during the night full capacity may be obtained at all seasons, the factory being run during 12 hours. The present cotton-mills contain 192 looms and 5600 spindles. Mr. Oakman, the former president of this mill, carefully measured the water used by his wheels, and stated it to be 89.7 cubic feet per second, saving the water at night; *i. e.* the natural flow of the stream is never less than 44.5 cubic feet per second. The drainage area above the mill being about 70 square miles, the stream discharges at its minimum 0.63 cubic feet per second per square mile—a remarkable discharge.

Two miles above Hope mill No. 1 is the BLUFF COTTON-MILL (H. W. Lilly), a cotton-factory, containing 3100 spindles and 64 looms, with a fall of 9 feet, using 60 horsepower. The dam is earth, 900 feet long, 18 feet high, built in 1872, and costing $5000, and the pond covers 75 acres to an average depth of 8 feet. Full capacity can be secured the whole year. The drainage area above being about 55 square miles, the discharge of the stream should be very nearly 0.63 cubic foot per second per square mile to give the power stated if the water is stored at night.

On *Beaver creek,* 1¼ miles above Bluff mill, there is another water-power now utilized in running the CUMBERLAND COTTON-MILL, which contains 88 looms and 3200 spindles. There is here a dam 500 yards long and 14 feet high, giving a head of 16 feet at the mill and said to develop 189 horsepower under a full head during the entire year. A calculation, on these data, gives the discharge of the stream so great that we are inclined to think that some of the figures must be erroneous. In fact, the amount of machinery run in the mill is not much greater than in the Bluff mill.

Above the Bluff mill the Little Rockfish and its tributaries are well utilized by a number of small saw- and grist-mills.

Above the Rockfish there are a number of smaller streams belonging to the same class which flow into the Cape Fear, two of which empty almost in the town of Fayetteville, and on which there were four factories before the war, but the powers are small—not over 20 or 30 horsepower, probably, during dry seasons. There are some small grist-mills on all these streams, generally running two pair of stones.

On *Blounts creek,* in the town of Fayetteville, there is a water-power that runs the Fayetteville cotton-mill, containing 3120 spindles and operated by water supplemented by steam-power. The dam is 340 feet long and gives a fall of 19 feet. About 85 horsepower is required to operate the machinery of the mill, of which it is estimated that one-half is furnished by the water.

Carvers creek is a small tributary about 7 miles above Fayetteville, which, a short distance from its mouth, falls over a ledge of hard pan and soft rock a distance of 18 or 20 feet, but in dry weather the supply of water in the stream is much reduced. It operates King's saw- and grist-mill.

Lower Little river, which rises in Moore county and flows east through Cumberland, and between Cumberland and Harnett, emptying into the Cape Fear below Averasboro, is the next important stream above Rockfish. Its length is 45 miles in a straight line, and its drainage area about 448 square miles. The principal town on the stream is Manchester, a very small place. This stream, with its tributaries, may be classed among the sand-hill streams, but its basin lies near the upper limit of the sand-hill belt, and so the general character of the sand-hill streams (like the Rockfish) is not so pronounced here, the flow being not quite so constant and the freshets rather more violent, the water rising some 15 feet. The banks are high and well wooded, and the bed of the stream the same as has been described; the country, as a whole, is not so sandy. The fall of the stream is uniform, and at the rate of 3½ feet per mile.[1] The flow is estimated as follows:

TABLE OF ESTIMATED POWER ON LOWER LITTLE RIVER.

Place.	Drainage area.	Flow, per second.		Horsepower, gross.		Utilized.		Gross horsepower available, with fall used.
		Minimum.	Ordinary summer.	Minimum.	Ordinary summer.	Horsepower, net.	Fall.	
	Square miles.	Cubic feet.	Cubic feet.	Per foot fall.	Per foot fall.		Feet.	
At mouth...........	448	224	336	25.4	38.2	100+	12.0	304
At Manchester.....	329	164	246	18.6	28.0	20	3.5	65

In the foregoing estimate 0.5 cubic foot per second per square mile was assumed as the minimum flow, and 0.75 cubic foot per second per square mile as the ordinary low-water flow. These figures are very high —perhaps too high—but a series of gaugings only can serve as a correct guide.

The power of the stream was formerly utilized by one cotton-factory and a number of saw- and grist-mills. The first mill is 2½ miles from the mouth, with a fall of 12 feet, not subject to interruption, except sometimes for a day or two by backwater from the Cape Fear. At Manchester was the cotton- and woolen-mill of the Linwood Manufacturing Company, using a fall of 3½ feet and about 20 horsepower, but this has been abandoned for some years. Just above the railroad crossing at Manchester there is a small saw-mill operated entirely by water-power.

The Manchester mill, a cotton-factory of about the same size, uses power from a small tributary. It contains 55 looms and 2200 spindles. There is a dam 18 feet high and 60 yards long, giving a fall of 22 feet. The power obtained from this stream is estimated to be 35 horsepower during half the year. This is supplemented by steam-power. There are doubtless many places on Lower Little river where dams might be located and excellent power obtained.

Upper Little river is a stream similar to Lower Little river, except that it is still less of a sand-hill stream, and said to be not so bold or so reliable as the latter. It is only used for saw- and grist-mills, and there are, no doubt, sites not used. Each of these streams is about

[1] The elevation above tide at crossing of Raleigh and Augusta Air-Line railroad is about 221 feet, and at mouth say 31 feet. Length, measured from map, is about 55 miles.

100 feet wide at its mouth. The length of Upper Little river is about 32 miles, measured in a straight line, its drainage area 176 square miles, and its fall, from the crossing of the Raleigh and Augusta Air-Line railroad to its mouth, about 290 feet, or perhaps at the rate of 6 feet or over to the mile.

On the numerous small streams in Cumberland county there are undeveloped and partially developed waterpowers which would serve to operate saw- and grist-mills and even larger manufacturing establishments.

Above Upper Little river there are no tributaries to the Cape Fear which are worth mentioning specially, although there are some small creeks which afford good small powers, and are utilized for grist- and saw-mills.

THE CAPE FEAR TRIBUTARIES—HAW RIVER.

This river rises in Rockingham and Guilford counties, North Carolina, pursues a general southeasterly course through Alamance, a corner of Orange and Chatham counties, and in the southeastern corner of the latter unites with the Deep river to form the Cape Fear, which has just been discussed. The length of the stream, following its general course, is about 80 miles, but considerably more if all its windings are followed. Near the northwest corner of Alamance county the river forks, the north fork going by the name of Haw river, while the south fork is known as the Reedy fork of Haw river. The Reedy fork, as well as the north fork in its upper parts, flows nearly east, but the course of the stream below the junction of the two is nearly southeast. There are no large towns on the river, Haw River, at the crossing of the North Carolina railroad being about the only town, but Graham, the county-seat of Alamance county, and Burlington, are only a few miles distant.

The drainage area of the Haw river comprises about 1675 square miles, and the stream receives two important tributaries: the New Hope creek, from the east, draining about 317 square miles, entering about 3 miles above the junction of Haw and Deep rivers, and Alamance creek, from the west, draining about 237 square miles and entering the Haw river about 4 miles south of Graham. The Reedy fork receives as its principal tributary Buffalo creek, from the south, draining about 128 square miles, and the north fork receives Troublesome creek, from the north, with a drainage area of about 88 square miles. The map shows the position of all these streams.

Haw river flows through a fertile country lying in the center of the cotton-belt, and the productions of which are about the same as along the upper part of the Cape Fear, viz. corn, cotton, wheat, oats, rye, tobacco, grasses, a great variety of vegetables and fruits. It is tolerably well wooded, although not enough care is taken to preserve the forests. Topographically, the region, especially in the lower part, is more broken than the drainage basins of the Neuse, the Tar, or the Roanoke rivers. The mineral resources of the basin are considerable, iron being found in various places in quantity and of good quality. Copper has also been found, but the mines have been little worked. Building stone of good quality is found all through the basin.

The bed of the stream is generally rock, covered in places with deposits of sand, gravel, or clay, but affording almost everywhere excellent foundations for dams. The banks on the lower part of the stream are tolerably high, in some places very steep, and the bottoms are narrow and not much subject to overflow, while in the upper part of the stream, where the country is not so broken, the banks are, in places, low. In the upper parts of Alamance and Guilford counties the country is much flatter than in Chatham county. The stream is subject to very heavy freshets, and there are no lakes serving to restrain their violence; but the stream is rarely frozen over, and the mills suffer no trouble with ice. Some of the tributaries of the stream rise in a region where the prevailing rock is a slate, which is covered with a thin soil and sometimes with none at all; and from this region the rain-water is shed very rapidly, so that these small streams are nearly dry in summer. The lowest stage of flow on the Cape Fear river of which we have any record (1897) was equivalent to a discharge of 0.076 cubic foot per second per square mile of drainage area, while the mean discharge for an entire month (October, 1897), including freshets, was only 0.12 cubic foot per second per square mile. The facilities for the construction of storage-reservoirs are said to be good in the upper part of the stream, though no surveys or examinations have ever been made with a view to determining this point accurately.

The rainfall in the valley of the Haw river is about 45 inches, distributed as follows: spring, 12; summer, 12; autumn, 11; winter, 10; its distribution throughout the year appears to be quite uniform.

The fall of the stream between different points will be seen from the following table, which gives the elevation at several points; and it will be remarked that the fall of the stream is quite large for one not rising in the mountains, being much larger than that of any stream, or of any part of a stream, which we have yet considered, which lies in the middle division:

TABLE OF DECLIVITY—HAW RIVER.

Place.	Distance from mouth.[1]	Elevation above tide.	Distance between points.	Fall between points.	Fall between points per mile.
	Miles	Feet.	Miles	Feet.	Feet.
At confluence with Deep river	0	130	50	346	6.9
At crossing of North Carolina railroad	50	476	27	171	6.3
Haw river (North Fork), at crossing of Piedmont Air-Line	77	647			
Reedy fork, at crossing of Piedmont Air-Line	80	676	30	200	6.7

The flow of the stream in different seasons is not known with accuracy. Professor Kerr states the flow at its mouth to be 1760 cubic feet per second, but as this is not low water, and probably more nearly the average flow, it is of no value for our computations. It is therefore necessary to base our figures, as usual, on estimates from drainage area and rainfall. A statement of the results of flow measurements made on Haw river about 1 mile above its mouth will be found on p. 301. Measurements on the Cape Fear at Fayetteville are given on pages 302-305.

Haw river (crossed almost at right angles by three railroads) is not very accessible. Especially is this the case with that part of the river below the crossing of the North Carolina railroad at Haw River, in Alamance county, while above that point the stream is, on the average, about 8 miles from the railroad, to which the Reedy fork runs nearly parallel.

WATERPOWER ON HAW RIVER.

The foregoing general sketch shows that the Haw river ought to afford a great deal of waterpower on account of its rapid fall and the fact that it crosses the ledges of rock at large angles, and the following account of the power on the stream will show that this is the case, and that the Haw river is well fitted, in some respects, to become a considerable manufacturing stream, and indeed it is at the present time one of the principal manufacturing streams of the state.

Commencing at the mouth of the river the waterpowers met with, in ascending the stream, will now be described.

BLAND MILL SITE.—The first power is situated 3 miles from the junction, and just below the mouth of New Hope river. It was for-

[1] Distances based on measurements from a map, made to follow the windings as closely as was practicable.

[2] Professor Kerr's statement is that the river affords 200 horsepower per foot of fall at its mouth. (Geol. Rep., p. 39.)

merly utilized by a mill belonging to the American Iron and Steel Company, and known as the "Bland mill." The banks on the east are favorable for building, and not often subject to overflow, while on the west rises a rocky bluff to a height of over a hundred feet, which can supply an abundance of stone for the construction of a dam and foundations. Diagonally across and up the river from the east bank to this rocky bluff extended a dam, a wooden structure, 300 feet long, 7 feet high, vertical in front, but sloping downward on the up-stream side, and throwing the water back for over a mile, with an average width of 200 feet, the river not being thrown out of its banks. At the east end of the dam was a grist-mill, running two pair of stones, with 7 feet fall, and using perhaps 20 horsepower net. This mill was run during eleven months of the year, but during the remaining month was troubled with backwater on account of the small fall. There was at all times, of course, a great excess of water. In the summer of 1880 about 80 feet of the dam at the western extremity was undermined and carried away by a freshet. It was subsequently rebuilt, but was again washed away. The river here is about 250 feet wide, and the water rises very high in freshets, sometimes 20 or 30 feet, but there is no trouble with ice. The drainage area above this power being about 1675 square miles, the power is estimated as in the following table:

TABLE OF POWER AT THE BLAND MILL.

State of flow.	Drainage area.	Fall.	Flow per second.	Horsepower available gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	7 feet fall.
Minimum	1,675	7	280	32.3	225
Minimum, low season			335	38.0	270
Low season, dry years			380	43.5	300

The effect of the uniform distribution of the rainfall is to render the flow more variable and to decrease the minimum flow, while at the same time the total amount of power or flow available, with storage, is increased beyond what it would be were the summer fall greater. It is stated that the flow of this stream is very variable. To render the maximum flow available, with storage, would require the construction of storage-reservoirs with a capacity in all of at least 900,000,000 cubic feet, which would require, for instance, if only one reservoir were used, one of say 2 miles square and between 8 and 9 feet deep. Such a large amount of storage would, of course, be very expensive. The pond at the Bland mill was, of course, not large enough to furnish any appreciable storage, or to allow of the concentration of the available power into working hours. The site is not an especially good one for large establishments on account of the small fall and the trouble resulting from backwater. It is, however, very favorably located within a few miles of the Raleigh and Augusta Air Line railroad, and in a healthy part of the state.

HARTSAWS MILL SITE.—The next power above this is situated about 2 miles further up the stream, and is not improved. It is known as Hartsaws site, and it is said that the available fall amounts to 6 feet. Being above the mouth of the New Hope, the drainage area amounts to about 1320 square miles, and the power available will be about 0.67 of that at the Bland mill, or as follows:

POWER AT HARTSAWS SITE.

State of flow.	Drainage area.	Fall.	Flow per second.	Horsepower available, gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	6 feet fall.
Minimum	1,320	6	218	24.7	150
Minimum, low season			264	30.0	180
Low season, dry years			300	34.0	200

MOORES MILL SITE.—The next power is Moores mill, improved and in use, situated some 3 miles above Hartsaws. There is no dam, but a race some 200 yards long leads to the mill—a grist-mill, with 2 or 3 run of stones. Formerly there was also here a saw-mill, cotton-gin and foundry, using a fall of some 10 feet and a small amount of power. The shoal is about a mile long, and the total fall is said by good judges to be about 22 feet; but the place has not been examined, and this statement cannot be vouched for. In dry weather a rough dam of stone turns the water into the race, but this is disturbed in freshets, and in ordinary times is not necessary. The power formerly used we are unable to state exactly; that available, assuming the fall to be 22 feet, is estimated in the following table:

POWER AT MOORES MILL.

State of flow.	Drainage area.	Fall assumed.	Flow per second.	Horsepower available, gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	22 feet fall.
Minimum	1,300	22	214	24.0	525
Minimum, low season			260	30.0	660
Low season, dry years			295	33.7	740

This site, one of the best on Haw river, is quite easily accessible, being only about six miles from the Raleigh and Augusta Air Line railroad, and about the same distance from Pittsboro, the county-seat of Chatham county. It is well worthy of the attention of capitalists desiring to locate in this vicinity.

WILLIAMS MILL SITE.—The next power is about 1½ miles above Moores mill and is known as Williams mill. It is a small saw- and grist-mill and foundry, all very much in need of repair. There is a fall of about 7 feet in use, but the dam could be raised and from 3 to 4 feet more obtained without overflowing any valuable land. The site, however, is not a very good one for a mill of any size, as the river is divided by an island half a mile long or more and the river is very wide. The pond is about 450 yards long, and starting from its head there is a fall of 12 to 14 feet in the next three-quarters of a mile. The river is, however, full of little islands.

Next comes a second unimproved site, known as the Seven Island shoal, where the fall is said to be 7 feet. It is 2 miles above the one last mentioned, and the power is tabulated beyond.

HENLEY'S MILL SITE.—Next comes the mill site formerly owned by Stephen Henley, now owned by W. L. London of Pittsboro, about 1½ miles above Seven Islands, and just about on the road from Pittsboro to Raleigh, and 12 or 13 miles from the mouth of the stream. A wing-dam 500 feet long and 3½ feet high extended across to an island and served to turn the water into the race, which carried it about 100 yards, affording a fall at the mill of 8 feet. The dam was built in 1874 and 1875 at a cost of some $500, and is of rock, planked over, and backed the water some 600 feet. There was here formerly a grist-mill, which used about 50 horsepower. It was situated on the west bank, but the principal channel of the river is on the east side of the island above referred to, which is about half a mile long. The mill is not now used. The fall at this place is estimated at about 16 feet. Taking this estimate as correct (though we cannot vouch for it), the available power at this place may be estimated as follows:

TABLE OF POWER AT HENLEY'S MILL.

State of flow.	Drainage area.	Fall assumed.	Flow per second.	Horsepower available, gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	16 feet fall.
Minimum	1,285	16	200	22.7	360
Minimum, low season			260	30.0	480
Low season, dry years			295	33.7	540

The next power is Brown's old mill site now owned by Daniel Tillman. The fall here is about 6 feet in 350 or 400, over loose rock bottom. The east bank of the stream here is rather soft and muddy and a good dam could not be built. Two mills have been washed away here, and the site is of very little importance.

The next is an unimproved fall of some 8 feet, belonging to the

Bynum Manufacturing Company, formerly used, but now altogether abandoned. The estimated power is given in the table.

Bynums mill.—The most important waterpower on this portion of the river is that at Bynums, four miles above Henley's mill and 17 miles above the mouth of the river. Here is located the cotton-mill of the Odell Manufacturing Company (containing 4500 spindles), a cotton-gin, corn-mill, and roller flour-mill, all operated by water from the same race. The dam is 3½ feet high and 500 feet long, ponding the water over 10 or 12 acres. A race 600 yards long leads to the mill, where the fall is 16 feet and the power developed is about 125 horsepower.

The following table gives the estimated flow and power:

Table of Power at Bynums.

State of flow.	Drainage area.	Fall.	Flow per second.	Horsepower available, gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	16 feet fall.
Minimum	1,250	16	200	23.4	375
Minimum, low season			250	28.4	450
Low season, dry years			280	32.4	510

One mile or less above Bynums is R. J. Powell's mill site, the mill having been burnt some years ago. The dam was of wood and stone, extending entirely across the river, and a fall of about 7 feet was used.

Less than a mile above Powell's is Burnett's unimproved site, where the available fall is said to be about 6 feet.

Pace's mill.—A short distance above this is Pace's mill. The dam here is 100 feet long and 8 feet high, from which a race 450 feet long leads to the mill, where a fall of 14 feet is used. Mr. Pace has a flour- and corn-mill, with four pair of stones, a saw-mill, wagon-shop and blacksmith-shop. He writes that upon his property, which extends for three-quarters of a mile along the river, there are two sites not used—one below the mill, with 10 feet fall, and another above, with 13 feet fall—available, with a dam 4 feet high, 600 feet long, and a race 600 feet long.

Table of Power at Pace's mill.

State of flow.	Drainage area.	Fall.	Flow, per second.	Horsepower available, gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	14 feet fall.
Minimum	1,209	14	192	21.8	305
Minimum, low season			237	27.0	378
Low season, dry years			273	31.0	434

The next mill above Pace's is Love's, about three miles above, but between the two it is said that there are several sites not used. The river is said to be quite rapid at this point of its course. At Love's mill there is a dam across the river 700 feet long, giving with a race 400 yards long, a fall of 11 feet at mill, which is a grist- and saw-mill.

Above Pace's mill, and about 2½ miles from Love's mill, there is the old site of the Willis Dark mill. There was a grist-mill here, but at present both mill and dam are gone. The fall is small—about 6 feet in nearly a mile—but a good dam could be built and there is ample building room.

TABLE OF POWER AT LOVE'S MILL.

State of flow.	Drainage area.	Fall.	Flow per second.	Horsepower available, gross.	
(See pages 54 to 59).	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	11 ft. fall
Minimum	1,155	11	184	20.9	230
Minimum, low season			230	26.1	280
Low season, dry years			260	29.5	320

Above Love's mill, the first site is known as the "Jeanes'" fall. Here there is a fall of about 6 feet in 600, over rock ledges. The location is not a very good one for building a dam.

The first improved power above is some ten miles farther up, in Alamance county, near the Orange line. Before leaving Chatham county it may be said that, according to the foregoing, it is clear that Haw river offers a large amount of power in its course through the county, very little of which is utilized, but a large proportion of which is available. The bed and banks are almost everywhere good, the country hilly, but not mountainous, and the climate healthy. A disadvantage in the use of the small falls which have been mentioned lies in the sudden and large rise to which the river is subject on account of the narrowness of the bottoms. Although in some places the fall is considerable in a short distance, yet on the whole the declivity of the stream seems to be tolerably uniform, while the width of the stream seems to be on an average some 400 feet or more.

SAXAPAHAW.—The next power above Love's mill is Saxapahaw factory, near Saxapahaw. The dam extends entirely across the stream, and is about 375 feet long and 3 feet high, built of wood in 1878 and 1879, and backing the water about a mile, with an average width of 350 feet. A race a mile long leads to the factory, where 160 horsepower is said to be developed with 19 feet fall. The mill is a cotton-mill, containing 4704 spindles and 100 looms. Estimates of the power will be found in sufficient detail in the table giving the summary. This mill being above the mouth of the Big Cane and several other creeks, the stream is considerably smaller than at Love's.

NEWLIN'S MILL.—The next power above Saxapahaw is at Newlin's grist-mill. The dam, now in bad condition, is of wood and stone, 900 feet long and 5 feet high, built in 1875 at a cost of $3500; and from it leads a race, 400 yards long and 10 feet wide, conducting the water to the mill, where the fall is 9 feet, the power used being probably some 40 horsepower net, with three turbine-wheels. The pond covers some 30 or 40 acres, with an average depth of 6 feet or over, but the stream is not thrown out of its banks. This power is located 2½ miles above Saxapahaw in Alamance county. The power is estimated in the table on p. 155.

The next power is an undeveloped one owned by the Virginia Cotton-Mills Company, of Swepsonville, Alamance county. There was formerly a grist-mill here, operated by Seymour Puryear, but this has long since gone down. The available fall here is some 7 or 8 feet, and we understand that a project is now on foot to develop this site and transmit the power electrically to Swepsonville, about one mile above.

VIRGINIA COTTON-MILLS.—The next mill is that of the Virginia Cotton Mills Company. This mill contains 200 looms and 4160 spindles. The dam is of wood, 550 feet long, 7 feet high, built in 1876 at a cost of about $3000, and frôm it a race 450 yards long leads to the mill, where the fall is 13 feet and the power used 160 horsepower, developed by two 61-inch turbine-wheels. Full capacity can be obtained all the time except in the dryest seasons. The factory was burned in June, 1881, but has been rebuilt.

GRANITE COTTON-MILLS.—We next come to the Granite cotton-mills, owned by the Thomas M. Holt Manufacturing Company, at Haw River, just above the crossing of the North Carolina railroad. These mills contain 8500 spindles and 436 looms, all operated by waterpower. The dam is of wood and stone, 640 feet long and 12 feet high, and backs the water about 1¾ miles. There is no race, the mill being located directly at the dam. The working head is 12 feet and the power developed is 450 horsepower, developed by two 60-inch turbines, set in a forebay of masonry costing about $25,000 (fig. 14). These mills are frequently troubled by lack of water in dry seasons, and have an auxiliary steam-plant.

At the head of the Granite mill pond is Sellers' mill site, not now used, said to have 12 feet fall.

JUANITA COTTON-MILL.—Two and one-half miles above is the Juanita cotton-mill, containing 6300 spindles. The fall here is 14 feet, 7 being given by the dam, which is of wood and 467 feet long, backing water for three-quarters of a mile. The race is 200 feet long. The power developed is 136 to 140 horsepower, given by two 58-inch turbine-wheels. In very dry seasons about one-half day a week is lost for want of water. The company also operates a small grist-mill.

CAROLINA COTTON-MILL.—About one mile above the Juanita mill is the Carolina cotton-mill (J. H. & W. E. Holt & Co.), which contain 58 looms and 3070 spindles. The dam was built in 1868, and is a frame

FIG. 14.—GRANITE COTTON MILLS, HAW RIVER.

dam with stone abutments about 200 feet long and 6 feet high, making a pond of 3 acres and giving a fall of 15 feet at the mill, three-quarters of a mile below, where 150 horsepower is used.

GLENCOE MILL.—One mile above is the Glencoe mill, containing 186 looms and 3500 spindles, on the site of the old Company mills. The dam, constructed of stone and wood, was built long ago and is about 320 feet long and 9 feet high, giving a fall of 15 feet with a race 400 yards long. It is claimed that 160 horsepower can be obtained during at least 90 per cent. of the time.

Two and one-half miles north of Burlington is an old grist-mill (Ireland's) not now used. The fall is said to be 6 feet.

ALTAMAHAW COTTON-MILL.—The highest power on the river is about 5 miles from Gibsonville station on the North Carolina railroad. This is the site of the Altamahaw cotton-mill, owned by Holt, Gant & Holt, containing 394 looms and 6500 spindles. The dam is 350 yards above the mill and is 300 feet long and 15 feet high, backing the water three miles. The fall at the mill is 20 feet, and the horsepower used in the mill is 300, 50 of this being obtained from the engine, which is used all the time. The dam is of stone, built some years ago.

From the above sketch it will be seen that the waterpower on Haw river is quite extensively used, especially on the upper parts where the stream is more accessible. Haw and Deep rivers, together with the south fork of the Catawba, yet to be described, are, in fact, the principal manufacturing streams of North Carolina.

Summary of Power of Haw river.

Locality.	Distance from mouth.	Drainage area.	Rainfall. Spring.	Rainfall. Summer.	Rainfall. Autumn.	Rainfall. Winter.	Rainfall. Year.	Total fall. Height.	Total fall. Length.	Horsepower available, gross.[1] Minimum.	Horsepower available, gross.[1] Minimum low season.	Horsepower available, gross.[1] Low season, dry years.	Utilized. Horsepower, net.	Utilized. Fall.	Remarks.
	Miles.	Square miles.	In.	In.	In.	In.	In.	Feet.	Feet.					Feet.	
Bland mill	8.0	1,675	12	12	11	10	45	7.0	....	225	270	300	......	7.0	
Hartsaws site	5.0	1,320	12	12	11	10	45	6.0	....	150	180	200	......	......	Not improved.
Moores mill	8.0	1,300±	12	12	11	10	45	22.0	5,280	525	660	750	......	10.0	
Williams mill	10.0	1,295±	12	12	11	10	45	10.0	....	190	240	270	......	7.0	
Seven Island shoal	12.0	1,290±	12	12	11	10	45	7.0	....	170	210	240	......	......	Unimproved.
Henley's mill	13.5	1,285	12	12	11	10	45	16.0	....	360	480	540	......	......	
Browns mill	15.0	1,275±	12	12	11	10	45	6.0	....	165	200	230	......	......	
Bynums site	16.5	1,260±	12	12	11	10	45	8.0	....	190	270	260	......	......	
Bynums factory	17.5	1,250	12	12	11	10	45	16.0	....	375	430	510	125	16.0	
Powell's site	18.0±	1,240±	12	12	11	10	45	7.0	....	155	190	220	......	......	Mill burnt; dam still there.
Burnett's site	18.5±	1,230±	12	12	11	10	45	6.0	....	130	165	190	......	......	Not improved.
Pace's mill	20.0±	1,209	12	12	11	10	45	14.0	....	305	378	434	75±	14.0	
Several unimproved sites	....	....	12	12	11	10	45	....	....	......	......	......	......	.....	
Love's mill	22.0±	1,155+	12	12	11	10	45	11.0	....	230	280	320	?	?	Probably not over 50 horsepower used.
Saxapahaw factory	38.0±	967	12	12	11	10	45	19.0	....	310	400	460	160	19.0	
Newlins mill	41.0±	935±	12	12	11	10	45	9.0	....	160	200	230	40	10.0	
Unimproved site	....	....	12	12	11	10	45	8.0	....	......	......	......	......	......	
Virginia cotton-mill	45.0±	670±	12	12	11	10	45	13.0	....	140	190	220	160	13.0	? See description, p. 152.
Granite cotton-mills	50.0±	585	12	12	11	10	45	12.0	....	110	150	170	450	12.0	? See description, p. 152.
Sellers mill site	52.0±	....	12	12	11	10	45	12.0	....	......	......	......	......	......	
Juanita cotton-mill	55.0±	494	12	12	11	10	45	14.0	....	102	140	161	150	14.0	Expect 150 horsepower.
Carolina mill	55.0±	490±	12	12	11	10	45	15.0	....	110	150	175	150	15.0	
Glencoe mill	56.0±	475±	12	12	11	10	45	15.0	....	106	145	169	160	15.0	Expect 160 horsepower.
Ireland site	58.0±	460±	12	12	11	10	45	6.0	....	......	......	......	......	......	
Altamahaw mill	63.0±	450(?)	12	12	11	10	45	20.0	....	126	186	200	250	20.0	

[1] For explanation of powers estimated see pages 54 to 59. Power much larger than in last column during nine months of the year.

THE TRIBUTARIES OF HAW RIVER.

The first considerable tributary met with in ascending the river is *New Hope river*, which enters from the west, after flowing through Orange and Chatham counties, and draining an area of some 317 square miles. The substance of what can be learned regarding this stream is that it is generally sluggish, flowing through a level country, and without waterpower of any importance, the only mills being a few small local grist-mills and saw-mills. The power used is tabulated farther on.

CLOVER ORCHARD AND SNOW CAMP MILLS.—The succeeding tributaries of the Haw river are small and unimportant until we reach *Cane creek*, which enters from the west, at the extreme southwest corner of Orange county. It rises in the extreme west of Alamance county, with some tributaries from Chatham, and flows very nearly due east and only a mile or so from the county-line, but without leaving Alamance. It has more fall than the streams entering Haw river from the east, but is specially mentioned chiefly on account of its having had located on it one factory, the Clover Orchard cotton-factory, which is situated some 10 miles from its mouth. The length of the stream, in a straight line, is about 20 miles, and its drainage area 73 square miles. The factory above referred to was closed some years ago and the machinery removed. With it was connected a grist-mill, both using a fall of 23 feet and 50 horsepower, which could be obtained during nine months of the year, the average during the remaining three months being 25 horsepower, during which period auxiliary steam-power was used. The mill being run only during 12 hours, and there being no waste at night in dry seasons, the natural flow of the stream would afford only, say, 10 horsepower in low seasons, and probably much less when at its lowest. The dam is of rock, 120 feet long and 17 feet high, and backs the water about a mile; the factory is 300 yards below.

A mile or more above the old Clover Orchard factory site is the Snow Camp woolen-mill, which contains 11 looms and 400 spindles. A dam 12 feet high and 70 feet long gives a fall of 16 feet, and is claimed to develop 40 horsepower during the larger part of the year. This is supplemented by a small steam-plant.

ALAMANCE AND BELLEMONT COTTON-MILLS.—The next important tributary is *Alamance creek*, which rises in the eastern part of Guilford county, pursues a general direction nearly due east, emptying into Haw river about 4 miles below the railroad crossing. Its length is in the neighborhood of 25 miles, and its drainage area about 237 square miles. It receives as tributaries two creeks called Little Alamance, from the north, and Stinking Quarter creek, from the south. There are only two powers on the stream worth mentioning, viz. Alamance cotton-factory (E. M. Holt's Sons) and Bellemont cotton-mill (L. B. & L. Holt).

ALAMANCE COTTON-MILL contains 94 looms and 960 spindles, using about 50 horsepower. The dam is of stone, 10 feet high and 125 feet long, and with a race 250 yards long, gives a fall of 12½ feet at the mill. There is a supplementary steam-plant that is used during very dry seasons.

THE BELLEMONT MILL is located on Big Alamance creek about 5 miles from Burlington. It contains 2592 spindles and 126 looms and uses about 150 horsepower, developed for nine months of the year by water, for the other three it is necessary to supplement this with steam. The dam is 11 feet high and 100 feet long, built of wood. There is no race, the wheel-house being situated directly at the dam.

REEDY FORK.

The Reedy fork of Haw river and the other tributaries and forks in the upper part of the drainage basin offer some powers utilized to some extent by saw- and grist-mills, and one cotton-mill (the Ossipee). The country is quite flat in the upper part of the basin, and there are no falls in the streams.

OSSIPEE MILL.—The Ossipee mill is located on the south side of Reedy fork, about 1½ miles above the junction of this stream with Haw river. It contains 300 looms and 3600 spindles. The dam is 10 feet high and 150 feet long, giving a fall of 11 feet at the mill and developing 160 horsepower during nine months. This is supplemented by steam during the dry season.

THE CAPE FEAR TRIBUTARIES—DEEP RIVER.

This stream rises in the western part of Guilford county, North Carolina, near the sources of the Haw river, flows in a southeasterly direction through Randolph county and into Moore, where it bends quite abruptly, and flows a little north of east into Chatham county, where it joins the Haw to form the Cape Fear. Its length is about the same as that of the Haw river, and its drainage area is 1350 square miles. It has only one important tributary, Rocky river, from the north, which enters Deep river about 4 miles above Lockville, and drains an area of 205 square miles, all in Chatham county. The most important towns on Deep river are Lockville, near the mouth, Franklinville, Cedar Falls, Ramseur and Randleman, in Randolph county.

The drainage basin of Deep river resembles that of Haw river so closely that it is not necessary to describe it in detail. In its lower part the river flows, with a tortuous course, through a narrow valley with abrupt banks, and, in a few cases, perpendicular and overhanging cliffs some 100 feet high.

The rainfall on the basin is a little greater than on that of Haw river, with rather more rain in winter, as will be seen from the maps in the Smithsonian publications. The flow of the river is rather more variable, owing probably to the fact that a greater number of its tributaries rise in the slate country and become nearly dry in summer. For the same reason. the freshets are, on the whole, more violent, and the river rises oftener above its banks, overflowing the bottoms on the lower part to a depth of 10 or 12 feet. On the upper part of the river there are probably sites for reservoirs, although Guilford and the neighboring counties are, on the whole, not very favorable for their construction, being too flat.

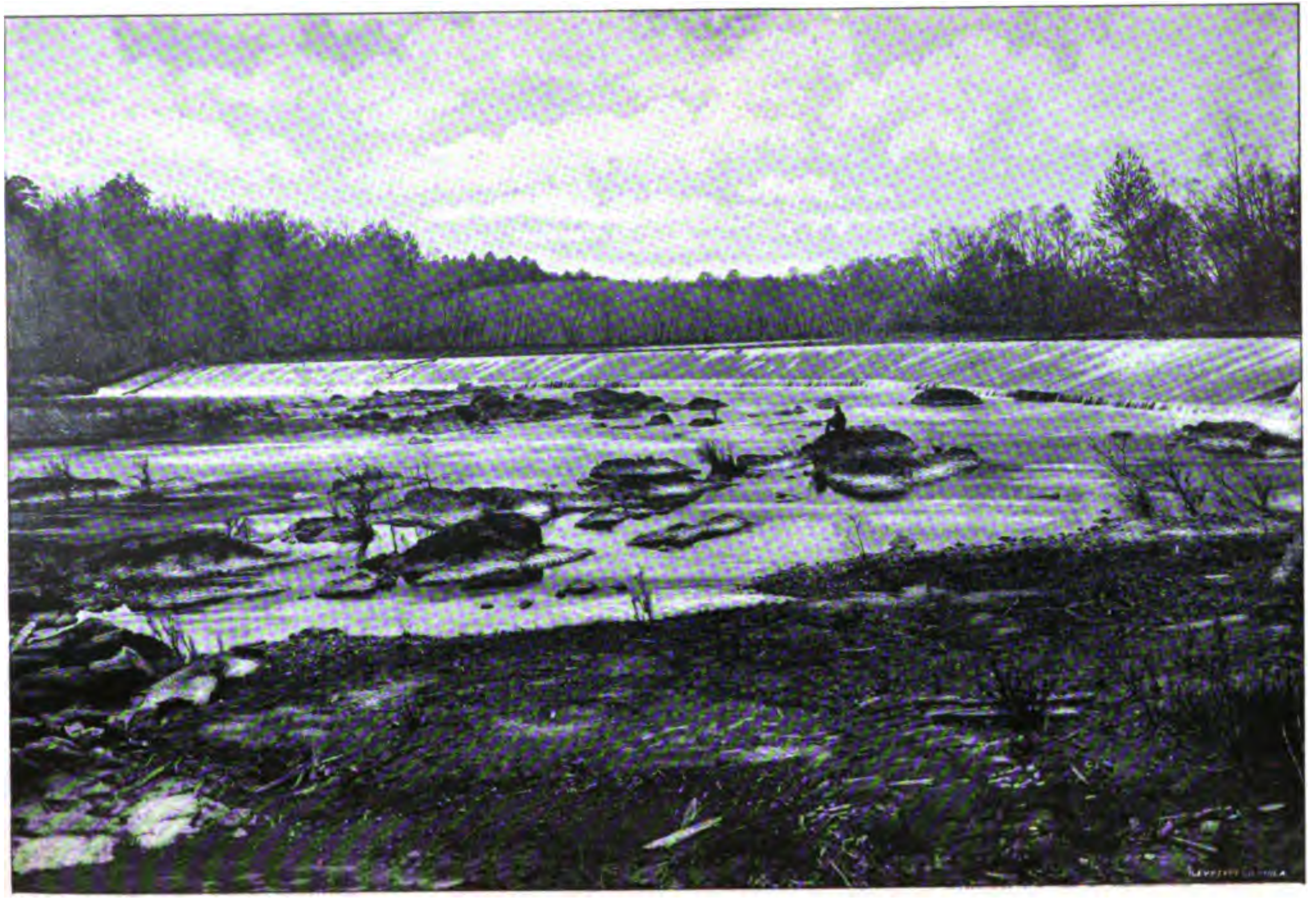
The following are some elevations on the stream, with distances measured from the map, and resulting declivities:

Place.	Distance from mouth.	Elevation above tide.	Distance between points.	Difference of elevation.	Fall per mile between points.
	Miles	Feet.	Miles	Feet.	Feet.
Mouth, or confluence with Haw	0	130	14	83	5.9
Near Egypt mine. (C. F. & Y. V. crossing is 204.60)	14	213	74	412	5.6
Northern part of Randolph county	88	625			
Crossing of Piedmont Air Line railroad	100	715	12	90	5.7

From this it appears that the fall of the stream is not much different from that of Haw river, though greater in its upper part.

Gaugings of the Cape Fear river at Fayetteville have been made by the U. S. Weather Bureau and the U. S. Army engineers for 20 years; and by the U. S. Geological Survey and State Geological Survey for three years (see pp. 302-305); and gaugings of Deep river, a short distance above its junction with the Haw, have been made during the past year (p. 301).

As will be seen from the map, the river is now fairly accessible, being crossed by the Durham and Charlotte railroad near Carbonton, and by the Southern railroad near Jamestown, and being tapped by the C. F. & Y. V. railroad at Gulf, Cedar Falls and Ramseur on the northeast side of the river, and by the Southern railroad at Randleman on the southwest side. A number of manufacturing establishments have been located at various points, especially in Randolph county, shipping their products by the railroad lines just mentioned.



LOWER DAM, LOCKVILLE, N. C., DEEP RIVER

WATERPOWER ON DEEP RIVER.

The following are the more important mills and sites:

LOCKVILLE.—The first power on the river is at Lockville, about 2 miles from the mouth of the river. The falls, known as Pullins falls, were overcome by the Navigation Company,[1] and navigation established around them by means of 2 dams and a canal leading down the river from the lower one, with an outlet-lock into the river at the lower end of the town, with a single lift of 24 feet. The lower dam is 600 or 700 feet long, 11 feet high, built of crib-work filled with stone, with a vertical back, and a face sloping down to about 1 foot above low water, the base being 30 feet wide, up and down stream. It is said to have cost about $14,000. It does not extend straight across the river, but has the shape of a letter V, apex up-stream (Plate V), and backs the water half a mile,with an average width of about 700 feet, to the upper Lockville dam. The foundation is rock, and the dam is not, to any great extent, liable to injury by freshets. The canal which leads from the dam is less than half a mile long, with a guard-lock at its head having a lift of two feet, and the high lock at its outlet below. All along this canal are magnificent sites for mills, which could use a fall varying between 11 and 24 feet, with perfectly safe locations. The following mills were in use in 1881, all owned by the Navigation Company, viz. 1 cotton-gin, 14 feet fall; 1 saw-mill, 16 feet; 1 grist-mill, 16 feet; 1 foundry, 18 feet; 1 grist-mill, 18 feet; 1 machine-shop, 18 feet; all on the canal, fed directly from it, and discharging the water into the river. The aggregate power used by these mills was not exactly known, but was, perhaps, in the neighborhood of 150 horse-power. Since that time the foundry and saw-mill have both been burned and abandoned; and the machine-shop has been replaced by a roller flour-mill, capacity 40 barrels a day, owned by John Barringer. The other sites and the general power are now owned by the American Iron and Steel Company. There was always a waste of water, and there were about 15 days in the year when there was trouble with backwater, the river at the outlet-lock being probably less than 300 feet wide. In high freshets the water rises 5 feet on the dam. The canal was 40 feet wide, and originally 6 feet deep. With a fall of a foot to the mile it could probably be made to carry the entire flow of the stream at low water; so that the entire power at this place is really at present available, except that the wood-work of all the dams of the company was in bad condition, badly rotten, and there was considerable leakage.

[1] See page 128.

The drainage area above this place being about 1350 square miles, the flow and power are estimated as in the following table:

TABLE OF POWER AVAILABLE AT LOCKVILLE.

State of flow.	Drainage area.	Fall.	Flow, per second.	Horsepower available, gross.	
(See pages 54 to 59.)	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	24 feet fall.
Minimum	1,350	24	216	24.5	590
Minimum, low season			256	29.1	700
Low seasons, dry years			298	33.8	800

In our opinion in low water the reservoir room would be sufficient to allow of the concentration of power into 12 hours to such an extent as to increase the minimum power by 50 per cent. at least.

This power is an excellent one in all respects. A branch of the Raleigh and Augusta Air Line railroad leads directly to the mills. There is an abundance of fine building stone in the neighborhood. There is no trouble with ice, and little with high water. The river is navigable up to Carbonton, so that the copper deposits near Cumnock, the coal-beds and the iron ores of the valley are easy of access. The location is healthy, and indeed there seems to be no reason why a large amount of power should not be utilized at this place. The two Lockville dams, the Gorgas site, and the Buckhorn and Battles falls properties have been purchased recently (March, 1899) by a new electric power company, and are to be developed at an early date.

The second Lockville dam, half a mile above the first one, was of similar construction, and extended straight across the river, its length being about 700 feet, its height 16 feet, and its pond 2 miles in length, up to the Gorgas canal, with an average width of about 600 feet. This dam has been largely washed away, and it would probably cost some $12,000 to rebuild it. The lock at its north end is 115 feet long, 18 feet wide, with a lift of 16 feet. The banks between this dam and the one below are steep and rocky on the north side and shelving on the south. The available power here could best be used on the south side, unless it were desired to use it at Lockville, in which case a canal or flume should be built on the north side. A canal 20 feet wide and 6 feet deep would probably suffice to carry the minimum flow, with a fall of 1½ feet per mile. During the war there was a grist-mill on the right bank, but the dam was not sufficiently secured, and it was washed around at this end. It was rebuilt in 1874, when the last company put the works in order, and 150 or 200 feet of the south part were put in, at a cost of $10,000, several accidents happening during the work. The power at this dam was easily available, although there had been no steps taken to utilize it. The amount of water is the same as at the lower dam, and the available power less in proportion to the fall, *i. e.* two-thirds of that in the last table. In this case, too, the reservoir-room would probably be ample to allow of the concentration of power and to render double the low-season flow available during 12 hours.

Gorgas dam.—Two and a half miles above the second Lockville dam was located the Gorgas dam, just below the mouth of Rocky river, extending straight across the river, about 600 feet long and 7 feet high, built of cribs filled with stone, vertical on both sides, and with a width of 6 or 8 feet, and backing the water up to the Endor dam, a distance of about 7 miles or a little less, with an average width of about 500 feet. It was washed away some years ago. This dam was at the head of a canal half a mile long, the third of the navigation canals, with guard- and outlet-locks, at the latter of which was a grist-mill taking water from the canal, using 7 to 8 feet fall and perhaps 20 or 25 horsepower, with 2 run of stones. Full capacity could be secured all the time, except for about 15 days in the year, when the river is high. The location is a very favorable one for building, and all the available power could easily be utilized along the canal, which is of ample capacity to carry the dry-weather flow. The drainage area above this place is about 1300 square miles, and the amount of water and power less than at Lockville. It may be estimated as in the following table. The pond being 7 miles long, there is no doubt that the low-season flow could be concentrated into 12 hours, so that the power given in the table would be doubled with a small diminution of head. Although this place is not quite so conveniently located as Lockville, it is easy of access from that place, as well as from Cumnock, on the Cape Fear and Yadkin Valley railroad, and the Raleigh and Western railroad touches the river near the old Endor furnace:

Table of Power at Gorgas dam.

State of flow.	Drainage area.	Fall.	Flow, per second.	Horsepower available, gross.	
(See pages 54 to 59).	Sq. miles.	Feet.	Cubic feet.	1 foot fall.	7 feet fall.
Minimum	1,300	7	208	23.6	165
Minimum, low season			247	28.1	200
Low season, dry years			282	32.1	225

The Endor dam, now washed away, was about 400 feet long and 4 feet high, crossing the river in the shape of a V, with a vertical face and inclined back half way across, and an inclined face and vertical back for the remaining distance. It was built of wood, and ponded the water back to the Gulf dam, a distance of 10 miles. As far as the location goes, it could be used for power, but the fall is so small that it would not be advisable. It is not necessary to consider it further.

Gardners shoal is the first power worthy of mention above Moffet's mill, 8½ miles below, and is a small shoal on the land of L. Moffet, which is entirely undeveloped. There is said to be here an available fall of 10 feet in half a mile or more. The bed and the banks of the stream are of rock, thus rendering the development of the power more feasible.

Moon's shoal, one and three-fourths miles further up-stream (owned by L. T. Moon), was the site of an old gun-shop. The fall here is about 6 feet in 300 yards over rock bottom. The dam and other improvements have disappeared.

Siler's shoal, one and one-half miles above Moon's, and three-fourths of a mile below the Enterprise mills, is an unimproved shoal owned by D. U. Siler, Coleridge, N. C. There is said to be an available fall here of about 20 feet, in one-fourth of a mile over good rock bottom, and the shoal is otherwise one that can be easily utilized.

The Enterprise mills are located on a shoal three-fourths of a mile above Siler's shoal. The cotton-mill on the northeast side of the river here operated by the Enterprise Manufacturing Company contains 4000 spindles and uses about 150 horsepower. The dam is constructed of cemented stone, 3½ feet high, 360 feet long, and backs the water three-quarters of a mile. The race is 250 yards long, and gives a head of 20 feet at the wheel, which is a Leffel special turbine 44 inches in diameter. There is also a small flour-mill operated by water from the same race. The supply of water is ample for all purposes throughout the entire year.

Stout shoal.—One and one-half miles above Enterprise there is a shoal owned by Thos. Davis, having a fall of about 8 feet in 300 yards.

Cox's shoal, a mile and one-half above Stout's, is similar to the latter shoal, and is owned by Seth Cox, of Coleridge, N. C. There is here a natural fall of about 7 feet in 300 yards, entirely undeveloped.

The Allen shoal is located two miles above the last and one mile below Ramseur. This undeveloped property is owned by Jackson Craven. It has a fall of about 14 feet in one-half a mile over a good rock bed with banks suitable for building.

Ramseur.—The cotton-mill of the Columbia Manufacturing Company is located here on the northeast side of the river and contains 9916 spindles and 325 looms. The dam is of stone, 12 feet high and 425 feet long, backing the water up to the Randolph Manufacturing Company's mill. The race is 300 yards long and the working head is 15 feet. The power plant consists of a Sampson 56-inch turbine-wheel, developing 180 horsepower, and a Corliss engine of 200 horsepower.

It is estimated that 250 horsepower is required to run the mill, so that steam has to be used all the time.

FRANKLINVILLE.—Between 2½ and 3 miles above Ramseur is the mill of the Randolph Manufacturing Company, which contains 3500 spindles and 112 sheeting looms, requiring 125 horsepower. The dam is of stone, 8 feet high and about 400 feet long. The race is 100 yards long and carries the water to two turbine-wheels, one of 30 inches, the other of 33 inches diameter. These are said to develop 143 horsepower under the head of 12 feet. The auxiliary steam-plant is of 125 horsepower, but this is used for only three months in the year.

Half a mile up the stream from the above is the mill of the FRANKLINVILLE MANUFACTURING COMPANY, containing 2500 spindles and 40 bag looms, and using about 90 horsepower from the water for nine months in the year. During the remaining three months steam and waterpower combined are used. The dam is of stone, 5 feet high and 400 feet long. The race is between 450 and 500 yards long and the fall at the wheel is 18½ feet. The power is developed by a special 40-inch turbine-wheel, generating 112 horsepower. There is also a grist-mill and cotton-gin drawing water from the same race and using about 30 horsepower.

CEDAR FALLS.—About two miles above the last-mentioned is the cotton-mill of the Cedar Falls Manufacturing Company, containing 3936 spindles, operated entirely by waterpower. The horsepower required is developed by a turbine working under a head of 25 feet and having an estimated capacity of 125 horsepower, given by three dams between islands, one of 10 feet high and 150 feet long, and two of 7 feet high and 280 feet long each, through a race about one-half mile in length. There is plenty of water to run the mill all the year.

About one mile above this site there is an undeveloped shoal where the available fall is said to be 12 to 15 feet.

CENTRAL FALLS.—Two miles above the last-mentioned site is the Central Falls mill of the Worth Manufacturing Company. The dam here is of wood, 9 feet high and 325 feet long, and backs the water up to the dam of the upper mill, a distance of three miles. The wheels are two in number, one 61-inch, the other 30-inch, developing about 150 horsepower. About 50 horsepower additional is developed by the supplementary steam-plant, which is used here all the time.

WORTHVILLE.—Three miles above Central Falls is the site of the upper mill of the same company. The dam here is of stone, 17 feet high and 250 feet long. There is no race, the two special design 33-inch turbine-wheels, which develop about 175 horsepower, being located directly at the dam, which backs the water for 1½ miles. There is also a steam-plant capable of developing about 200 horsepower, but there is enough water to run by waterpower alone except in the very dry seasons. The two mills at Worthville and Central Falls together contain 10,000 spindles and 328 looms.

NAOMI FALLS.—Four miles further up the stream from Worthville is the mill of the Naomi Falls Manufacturing Company, of Randleman, N. C. This mill was built in 1880, and contains 5000 spindles and 298 looms for the manufacture of cotton cloth and cotton bags. The dam here is of wood and stone, 13 feet high and 300 feet long, backing the water about one-half mile. There is no race, the water going at the dam directly to the wheels, of which there are two, each 48 inches in diameter, the two developing about 130 horsepower. This is supplemented at all times by 50 horsepower (and more in dryest seasons) from the 150 horsepower engine which is maintained for this purpose.

RANDLEMAN.—One mile above Naomi Falls and in the town of Randleman are located the two mills of the Randleman Manufacturing Company, the two containing 5000 spindles and 270 looms, both mills being run by water from the same race. The dam here is of stone, 12 feet high and 275 feet long, and backs the water 2½ miles without throwing the river out of its banks. The race is about 500 feet long and the working head is 12 feet, developing 175 horsepower, given by four turbines, three of 44 inches diameter, one of 40 inches. For about six months of the year there is enough water to run the mill to its full capacity by the use of waterpower alone. During the dry season this is supplemented by steam-power.

There is said to be a shoal called the Island Ford shoal, located 2 miles above Randleman, and said to have a fall of 10 or 12 feet.

WALKER'S MILL.—Four miles above Randleman is Walker's grist-mill, owned by S. Bostick & Son, Randleman, N. C. This mill contains two sets of corn stones, one of wheat burrs, a fan-mill and a smutter. The fall here is 10 feet from an 8-foot stone dam, 300 feet long, which backs the water about 1½ miles. The race is 110 yards long and carries the water to two 20-inch turbines. No estimates of the amount of power used or available at any of these grist-mills could be obtained, the estimate of the amount of power used in running a set of stones varying from 8 to 12 horsepower, and the other machinery in proportion. According to the statements of the millers, however, there seems to be plenty of water to run all the machinery in the mills at the same time, if so desired, during the very dry seasons.

COLTRAIN'S GRIST-MILL is three miles above Walker's and contains the same machinery as the latter. It is driven by four turbines, three of 18 inches diameter, one of 10 inches. The fall here is 10 feet, obtained by an 8-foot masonry dam through a race 100 yards long. The dam is 200 feet long and backs the water 1½ miles.

FREEMON'S GRIST-MILL is five miles above the last one. This mill was built in 1876 for a woolen-mill, and was run as such for some time, but the woolen machinery has been sold, and the building, two stories high, built of stone and brick, is used as a grist-mill. Three sets of stones are run, two corn and one wheat, and a smutter, each driven by a separate turbine, three of 12 horsepower for the stones and one of 8 horsepower for the smutter. The dam is of masonry, 12 feet high and 130 feet long and there is no race. The property is in good condition. The pond is one and one-half miles long and of an average width of 75 feet. There is said to be too little water here for running all the machinery at the same time unless the river is a little full.

The OAKDALE MANUFACTURING COMPANY'S COTTON-MILL, the next power site, is located five miles above Freemon's mill and four miles below Jamestown. The mill, which contains 3320 spindles, was built in 1889, but there has been a mill on the site since 1866. The fall here is 25 feet, obtained by means of a 20-foot wooden dam 260 feet long. The race is 250 feet long, and carries the water to a 44-inch Leffel special turbine, developing, it is claimed, 190 horsepower when the water supply is ample. The dam backs the water one mile with an average width of pond of 100 feet. There is a steam-plant of 250 horsepower capacity which is used to supplement the water in dry seasons.

The powers above this point are too small to be of any practical value; and the only one known to be now in use is that at Smith and Ragsdale's bone-mill, about one mile above the Southern railroad crossing near Jamestown, and here probably not more than six horsepower is developed with a four-foot fall during ordinary stages of flow.

Summary of Power of Deep river.

[N. B.—The powers given in this table may, in most cases, be increased to a large extent, and perhaps doubled, if the mills are run only 12 hours and the water drawn down in the ponds at night.]

Locality.	Distance from mouth.	Drainage area.	Rainfall.					Total fall.		Horsepower available, gross.[1]			Utilized.		Remarks.
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length.	Minimum.	Minimum low season	Low season, dry year.	Horsepower, net.	Fall.	
	Miles.	Sq. miles.	In.	In.	In.	In.	In.	Feet.	Feet.					Feet.	
Lockville, lower dam	2.0	1,350	12	12	11	11	46	24.0	2,000	590	700	800	......	......	Dam 11 feet.
Lockville, upper dam	2.5	1,350	12	12	11	11	46	16.0	....	390	470	525	......	......	Dam 16 feet, formerly.
Gorgas	5.0	1,300	12	12	11	11	46	7.0	....	165	200	225	......	......	Dam 7 feet, formerly.
Gulf	21.7	1,047	12	12	11	11	46	10.0	....	178	220	250	40	10.0	Dam 10 feet.
Carbonton dam	27.7	1,010	12	12	11	11	46	10.0	....	170	200	235	35	10.0	Dam 10 feet.
Glenns mills	40.2	814	12	12	11	11	46	19.0	....	265	315	361	80±	19.0	Dam 7 feet.
Prosperity mill	47.0	784	12	12	11	11	46	8.0	....	125	155	180	30	8.0	Dam 8 feet.
Big falls	50.0	746	12	12	11	11	46	18±	2,000	210	250	285	0	......	
Ritter's falls (unimproved)	51.5	....	12	12	11	11	46	....	....	......	......	......	......	......	Fall said to be 10 feet.
Howard & Moffett's mill	53.0	665	12	12	11	11	46	8.5	....	47	60	70	40	8.5	Dam 7 feet.
Unimproved powers	....	....	12	12	11	11	46	....	....	......	......	......	......	......	
Enterprise factory	63.0	453	12	12	11	11	46	20.0	....	......	......	......	150?	20.0	Dam 3½ feet.
Unimproved sites	....	440±	12	12	11	11	46	....	....	......	......	......	......	......	
Columbia Manufacturing Co.	69.0	420±	12	12	11	11	46	15.0	....	......	......	......	250	15.0	Dam 12 feet; steam-power.
Randolph Manufacturing Co.	71.0	408	12	12	11	11	46	12.0	....	......	......	......	125	12.0	Dam 8 feet; steam-power.
Franklinville Manufacturing Co.	71.5	408	12	12	11	11	46	18.5	....	......	......	......	90	18.5	Dam 5 feet; steam-power.
Unimproved site	72.5	400±	12	12	11	11	46	15+	3,000+	......	......	......	......	......	
Cedar Falls Manufacturing Co.	73.5	341	12	12	11	11	46	25.0	....	......	......	......	125	25.0	Dam 10 feet.
Unimproved site	75.0	....	12	12	11	11	46	....	....	......	......	......	......	......	
Central Falls Manufacturing Co.	77.0	300±	12	12	11	11	46	9±	....	......	......	......	150	......	Dam 9 feet, steam-power.
Worthville	80.0	300±	12	12	11	11	46	17±	....	......	......	......	175	......	Dam 17 feet, steam-power.
Naomi Falls Manufacturing Co.	84.0	257	12	12	11	11	46	13±	....	......	......	......	130	13	Dam 13 feet, steam-power.
Randleman Manufacturing Co.	85.0	257	12	12	11	11	46	12.0	....	......	......	......	175	12	Dam 12 feet, steam-power.
Walker's grist-mill	89.0	....						10.0	....	......	......	......	......	10	8 foot dam.
Coltrain's grist-mill	92.0	....						10.0	....	......	......	......	......	10	8 foot dam.
Freemon's mill	97.0	....						12.0	....	......	......	......	......	12	12 foot dam.
Oakdale Manufacturing Co.	102.0	....						25.0	....	......	......	......	......	25	20 foot dam.

[1] See pages 54 to 59.

TRIBUTARIES OF THE DEEP RIVER.

The tributaries of Deep river are of small consequence, and only one of them is worthy of special mention, viz. *Rocky river*, which rises in the northwestern part of Chatham county and flows southeast, joining Deep river just above Gorgas dam. The stream is utilized to a considerable extent by small saw- and grist-mills, but, like other streams in the vicinity, it is subject to great variations in flow, owing to its course lying in the slate region. The drainage area of the stream is about 205 square miles, and its length, in a straight line, about 25 miles; yet, during the dry season, the flow is not sufficient to afford more than 20 or 25 horsepower, with a fall of 20 feet. There are 12 mills on the river, with falls of from 8 to 25 feet, but some sites are still unimproved.

The other tributaries above Rocky river are utilized for small grist- and saw-mills, but are not of much importance. Some of them are nearly dry in summer.

TABLE OF UTILIZED POWER ON CAPE FEAR RIVER AND TRIBUTARIES.[1]

Name of stream.	Tributary to what.	County.	Kind of Mill.	Number of mills.	Total fall used.	Total horse-power used, net.
					Feet.	
Cape Fear river	Atlantic	Cumberland		1	10.0	15
Northeast Cape Fear	Cape Fear	Pender	Flour and grist	1	7.0	10
Do	do	do	Saw	1	7.0	20
	NortheastCapeFear	Duplin	Flour and grist	16	144.0	158
	do	do	Saw	8	29.0	86
	do	do	Cotton-gin	2	20.0	......
South river	Cape Fear	Sampson	Flour and grist	1	7.0	8
Do	do	Pender	do	2	16.0	18
Black river	South river	Sampson	do	2	17.0	11
Do	do	do	Cotton-gin	1	9.0	6
	do	do	do	5	50.0	27
	do	do	Flour and grist	11	115.0	98
	do	do	Saw	1	......	10
All other tributaries to	Cape Fear	Bladen	Flour and grist	2	22.0	19
Do	do	do	Veneer works	1	9.5	......
Do	do	do	Cotton-gin	1	8.0	3
Do	do	Cumberland	Flour and grist	10	95.0	150
Do	do	do	Saw	4	29.0	122
Do	do	do	Cotton-gin	8	......	......
Do	do	do	Agricult'l implem'ts	1	20.0	12
Do	do	do	Cotton-factory	1	......	......
Rockfish creek	do	do	do	1	18.0	200
Little Rockfish creek	Rockfish creek	do	do	1	22.0	175
Do	do	do	do	1	9.0	60
Beaver creek	Lit. Rockfish creek.	do	do	1	16.0	189
Blounts creek	Cape Fear	do	do	1	19.0	40
All other tributaries to	do	do	Woolen	2	......	......
Do	do	Harnett	Flour and grist	13	155.5	158
Do	do	do	Saw	2	21.0	35
Do	do	Wake	Flour and grist	6	99.0	62
Do	do	do	Saw	1	11.0	18
Do	do	do	Cotton-gin	4	78.0	42
Do	do	Chatham	Flour and grist	2	30.0	30
Do	do	Moore	do	11	132.0	139
Do	do	do	Saw	6	88.5	118

[1] Compiled mainly from records of the Tenth Census.

TABLE OF UTILIZED POWER ON CAPE FEAR RIVER AND TRIBUTARIES.—*Continued.*

Name of stream.	Tributary to what.	County	Kind of Mill.	Number of mills.	Total fall used.	Total horse-power used, net.
					Feet.	
Haw river	Cape Fear	Chatham	Grist-mill	..	10.0	......
Do	do	do	Saw- and grist-mill	1	7.0	......
Do	do	do	Cotton-factory	1	16.0	125
Do	do	do	Flour and grist	1	16.0	......
Do	do	do	Cotton-gin	1	16.0	......
Do	do	do	Flour and corn	1	14.0	......
Do	do	do	Saw-mill	1	14.0	......
Do	do	do	Blacksmith-shop	1	14.0	......
Do	do	do	Cotton-factory	1	19.0	160
Do	do	do	Grist-mill	1	9.0	40
Do	do	do	Cotton-factory	1	13.0	160
Do	do	do	do	1	12.0	450
Do	do	do	do	1	14.0	136
Do	do	do	do	1	15.0	150
Do	do	do	do	1	15.0	160
Do	do	do	do	1	20.0	300
Cane creek	Haw river	Alamance	do	1	23.0	50
Alamance creek	do	do	do	1	12.5	50
Do	do	do	do	1	11.0	150
Reedy Fork	do	do	do	1	11.0	160
All other tributaries to	do	Chatham	Flour and grist	13	179.0	176
Do	do	do	Saw	3	29.0	60
Do	do	do	Wheelwrighting	1	12.0	10
Do	do	do	Cotton-gin	3	......	......
Do	do	Orange	Flour and grist	8	161.0	188
Do	do	do	Saw	6	85.0	134
Do	do	do	Cotton-gin	1	......	20
Do	do	do	Millwrighting	1	14.0	12
Do	do	Alamance	Flour and grist	17	209.0	294
Do	do	do	Saw	4	52.0	77
Do	do	do	Cotton-gin	1	11.0	6
Do	do	do	Foundry	1	15.0	28
Do	do	do	Agricult'l implem'ts.	1	16.0	8
Do	do	Guilford	Flour and grist	24	344.0	379
Do	do	do	Saw	6	79.5	93
Do	do	do	Woolen	1	12.0	......
Do	do	Randolph	Flour and grist	1	19.0	10
Do	do	Rockingham	do	6	105.0	100
Do	do	do	Saw	8	54.0	48
Deep river	Cape Fear	Chatham	Roller mill	1	......	......
Do	do	do	Flour and corn	1	10.0	40
Do	do	do	Cotton-gin			
Do	do	do	Grist and saw	1	10.0	35
Do	do	do	Cotton-gin			
Do	do	do	Flouring-mill	1	16.0	......
Do	do	Moore	Grist and saw	..	19.0	......
Do	do	do	Cotton-gin			
Do	do	do	Grist-mill	1	8.0	25
Do	do	do	do	1	8.5	40
Do	do	Randolph	Cotton-mill	1	20.0	150
Do	do	do	Flour-mill	1	20.0	......
Do	do	do	Cotton-mill	1	15.0	250
Do	do	do	do	1	12.0	125
Do	do	do	do	1	18.5	90
Do	do	do	Grist-mill	1	18.5	......
Do	do	do	Cotton-gin			
Do	do	do	Cotton-mill	1	25.0	125
Do	do	do	do	1	9.0	200
Do	do	do	do	1	17.0	175
Do	do	do	do	1	13.0	180
Do	do	do	do	1	12.0	175
Do	do	do	Grist-mill	1	10.0	......
Do	do	do	do	1	10.0	......
Do	do	do	do	1	12.0	44
Do	do	Guilford	Cotton-mill	1	25.0	190
Tributaries of	Deep river	Chatham	Flour and grist	17	225.0	253
Do	do	do	Saw	3	45.0	69
Do	do	do	Agricult'l implem'ts.	1	9.0	10
Do	do	do	Leather	1	12.0	6
Do	do	Moore	Flour and grist	8	86.0	135
Do	do	do	Saw	4	42.0	74
Do	do	Randolph	Flour and grist	23	331.0	361
Do	do	do	Woolen	1	8.5	......
Do	do	do	Saw	8	106.0	128
Do	do	Guilford	Flour and grist	5	79.0	56
Do	do	do	Woolen	1	16.0	.....

TABLE OF DRAINAGE AREAS OF CAPE FEAR RIVER AND TRIBUTARIES.

	Square miles.
Cape Fear river at mouth	8,400
Northeast Cape Fear river at mouth	1,330
South river at mouth	1,430
Black river at mouth	620
Cape Fear river at Fayetteville	4,493
Cape Fear river at Jones falls	4,170
Cape Fear river at Silver run	3,660
Cape Fear river at Smileys falls	3,400
Cape Fear river at Buckhorn falls	3,200
Cape Fear river at forks	3,025
Haw river at mouth	1,675
Haw river at Bynums	1,250
Haw river at North Carolina railroad	585
Haw river at Reedy fork junction	173
New Hope river at mouth	317
Alamance creek at mouth	237
Reedy fork of Haw at mouth	281
Deep river at mouth	1,350
Deep river at Lockville	1,340
Deep river at Gorgas	1,300
Deep river at Gulf	1,047
Deep river at Carbonton	1,010
Deep river at Tyser's	814
Deep river at Franklinville	408
Deep river at Naomi Falls	257
Rocky river at mouth	205
Rockfish creek at mouth	280
Little Rockfish creek at mouth	77
Little Rockfish creek at factory	55
Lower Little river at mouth	448
Lower Little river at Manchester	329
Upper Little river at mouth	176

CHAPTER VIII.

THE YADKIN RIVER AND TRIBUTARIES.[1]

THE YADKIN RIVER.

The Yadkin river, or the Great Pee Dee as it is called below its junction with the Uharie river, takes its rise on the eastern slope of the Blue Ridge, in Caldwell and Watauga counties, North Carolina. It flows first a little north of east through Caldwell and Wilkes and between Surry and Yadkin counties, when it bends abruptly to the right, and flows a little east of south, forming the boundary between the counties of Forsyth, Davidson, Montgomery and Richmond on its left, and Yadkin, Davie, Rowan, Stanly, and Anson on its right, passing into South Carolina, and continuing in the same general direction between Marlborough and Marion counties on its left, and Chesterfield, Darlington, Williamsburg and Georgetown on its right, emptying into Winyah bay just at the town of Georgetown, after flowing for some distance through the county of the same name. Following the general course of the stream, the distance from its source to its mouth is between 275 and 300 miles, but following all its windings it is much greater—as nearly as can be estimated by measurement on the map, some 400 miles or more.

There are no towns of great importance on that part of the stream where there are any facilities for waterpower. In North Carolina there are no towns on the river with more than a few hundred inhabitants, the principal ones being Elkin, in the southwest corner of Surry county and Wilkesboro, the county-seat of Wilkes county.

The head of navigation on the river is Cheraw, South Carolina, about 149 miles above the mouth. An examination of the river between Cheraw and the mouth of the Uharie, a distance of 67 miles, has been made, and it is found practicable to render the river navigable as high as this point by locks and dams, but no appropriation has yet been made for the work, nor is it probable that there will be on account of the great cost of the undertaking and the small good to be accomplished thereby. Above the mouth of the Uharie the "Narrows" form an insurmountable obstacle to navigation, but above them, between the

[1]By G. F. Swain and J. A. Holmes.

Southern railway bridge and Wilkesboro, the river has been surveyed, and an appropriation of $20,000 made March 3, 1879, the object being to secure a navigable depth of 2½ to 3 feet as high as the foot of Beans shoal, a distance of 64.8 miles. Additional appropriations were made during the 10 years following. Subsequently (1887) it was decided to limit the improvements to the 33 miles immediately above the Southern railway bridge. In 1892 the work was practically abandoned after the expenditure of slightly more than $100,000.[1]

The Great Pee Dee drains a total area of about 17,000 square miles, of which about 9700 lie in North Carolina and 7300 in South Carolina. The principal tributaries to the river are the Waccamaw river, from the north, draining about 1200 square miles; the Black river, from the west, draining about 1500 square miles; the Little Pee Dee river, from the north, with a drainage area of some 3000 square miles; Lynchs creek, from the west, draining about 1350 square miles; Black creek, from the west, draining about 450 square miles; Little river, from the east, draining 400 square miles; Rocky river, from the west, draining 1400 square miles; Uharie river, from the east, draining 317 square miles; the South Yadkin, from the west, draining 820 square miles; and the Ararat river, from the north, draining about 315 square miles, besides numberless smaller streams and creeks affording fine waterpower, especially in the upper part of the drainage basin.

The Great Pee Dee crosses the fall line a little above Cheraw. The fall is not so pronounced as in the case of the Tar and the Roanoke, but consists of a series of rapids extending over a number of miles, with no very great fall at any one place, or within any short distance. The drainage basin of the river below the fall line will be understood sufficiently well from the general description which has been already given of the eastern division, and of the lower parts of the Cape Fear and other rivers, while its general shape and dimensions may be seen from the accompanying map. Neither does that part of its drainage basin lying above the fall line differ in any essential particulars from that of the Cape Fear or the Roanoke, except that it reaches farther west (and into the mountains) than that of the Cape Fear. Below the great bend, where the river turns so abruptly to the south, its valley averages 50 miles wide, and at many points the river is bordered by wide and fertile bottoms, subject to overflow at times, and forming some of the best farming lands in the state; while at others the hills close in upon the river, leaving no bottoms at all, and sometimes confining the river between steep and rocky banks on each side. In one case

[1] Annual Report Chief of Engineers, U. S. A., 1892, App. L, p. 1182,

the river flows through a ravine, confined in a very narrow channel by bold and abrupt banks for a distance of several miles, forming the noted "narrows." Above the great bend the valley is narrower (only 15 to 20 miles wide), and the divides which separate the basin of the Yadkin from those adjacent are much higher, so that the tributary streams in the vicinity have a very large fall. The level land along the stream, however, is seldom in this part of its course over a mile wide, interjected between the spurs of the parallel ranges of mountains and ridges which form the divides, and forming in places extremely picturesque little valleys, surrounded on almost all sides by mountains. Even in this part of its course the river rises above its banks in high water, although the grounds subject to overflow are not very extensive. Near Yadkinville the river passes through a gap in the mountains, and above that point its valley is flanked on the north by the Blue Ridge and on the south by the Brushy mountains, the divides having elevations of from 1500 feet upward, and from these come pouring down many mountain streams and torrents. The upper part of the valley of the Yadkin is very well wooded, and as the mountains are not bare, the streams are more constant in flow than might be expected. Between Wilkesboro and Patterson the lowlands along the river are from a few hundred yards to more than a mile in width, and exceedingly fertile. This region, known as the "Happy Valley," is one of the most picturesque and finest agricultural sections to be found in the state.

The facilities for the construction of storage reservoirs are good on some of the tributaries, and on the main stream in the very upper part of its course. Below, they would, of course, be impracticable.

The products of the Yadkin valley are cotton, tobacco, corn, rice, wheat, oats, rye, clover and grasses, sorghum cane, vegetables and fruits in the lower part, and principally grain, vegetables and fruits in the upper part. Between the cool slopes of the Blue Ridge on the north and the low and hot plains of the eastern division on the south the range of production—as in the case of the Roanoke—is very large, the mountains being well adapted to grazing, the bottom lands of the valleys to the raising of cereals, grasses, vegetables, fruits and tobacco, and the low country along the lower part of the stream to the production of cotton and rice.

The river is somewhat subject to freshets, but not more so than other South Atlantic streams. They are said not to be so violent, as a rule, as on the Cape Fear, Neuse, or Tar, probably because of the character of the upper part of the basin; and, although there are no lakes to regulate the flow, the extensive woods and the mountains, well covered with soil, serve to restrain their violence. Neither are the freshets so violent as on the Roanoke, the cause in this case being, probably, the fact that the rainfall in the upper valleys of the Yadkin is perhaps, on the whole, more uniformly distributed throughout the year than on the Dan and Staunton. At any rate, the highest flood ever known at Wilkesboro occurred in September, 1878, yet the rise was only 23 feet above low water; and at Langenhour & Neason's mill the extreme high-water mark is at 22.9 feet. The floods are short, generally subsiding in from 36 to 48 hours. It is said that twenty-five years ago high floods very rarely occurred, and their frequent occurrence now is accounted for by the clearing of the hills and the removal of obstructions from the river.[1] The low grounds adjacent to the river are more frequently overflowed than formerly, and more damage is done to the crops.

The river sometimes brings down a good deal of ice, so that it cannot be ferried; still there is not very much difficulty on this account. The rise is sudden, the water sometimes rising, it is said, 2 feet in 20 minutes at Kirk's ferry (mouth of the Uharie).

The annual rainfall in the valley varies from 44 inches near the coast to 50 inches between Cheraw and the "narrows," and 44 to 50 above the latter point. The table on page 188 gives more detailed information regarding the rainfall above the important powers, and of its distribution through the year.

The following table gives the elevations of the various points on the stream, together with the distances, and declivity:

TABLE OF DECLIVITY OF YADKIN RIVER.

Place.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall between points.
	Miles.	Feet.	Miles.	Feet.	Feet per mile.
Mouth					
Cheraw, South Carolina	149	65	149	65	0.44
Crossing of Carolina Central railroad	169	105	20	40	2.00
Foot of narrows gorge	216	263	47	158	3.36
Head of "narrows"[2]	220	354	4	91	22.75
Crossing of Southern railroad[3]	256	591	36	237	6.58
Foot of Beans shoal[4]	321	722	65	131	2.01
Head of Beans shoal[4]	325	761	4	39	9.75
Wilkesboro[4]	378	928	53	167	3.15
Patterson[5]	410	1,250	32	322	10.06

[1] Annual Report Chief of Engineers, 1879, p. 628.
[2] Capt. Jno. A. Ramsay, (p. 180).
[3] Line of special levels by U. S. and N. C. Geol. Surveys.
[4] Report of Chief of Engineers, 1879, p. 626.
[5] The elevation at Patterson was given in 1880, though the kindness of Maj. C. S. Dwight, chief engineer Chester and Lenoir railroad, and to L. C. Jones, Esq., at that time chief engineer and superintendent of the Cape Fear and Yadkin Valley railroad.

The flow of the river has been measured in 1896, 1897 and 1898 by the Geological Survey near Salisbury, where the drainage area is given as 3399 square miles, and at Norwood, where the drainage area is given as 4614 square miles.

At Salisbury, the lowest flow measured was in August, 1896, when the quantity discharged was 1293 cubic feet per second, or 0.38 cubic feet per second per square mile, while the maximum flow measured was 11,837 cubic feet per second, or 3.5 cubic feet per second per square mile. The flow of 1293 cubic feet per second was, however, not the minimum by any means.

At Norwood, the smallest flow measured was 1508 cubic feet per second, or 0.33 cubic feet per second per square mile, while the maximum measured was 11,710, or less than near Salisbury.

These measurements have not been continued long enough to serve as a reliable basis for computing the minimum or low-season flow, and we have been obliged to resort to the usual estimates. We have seen that measurements on the Cape Fear river have given the flow as low as 424 cubic feet per second where the drainage area was about 4500 square miles, or less than 0.1 cubic foot per second per square mile, and it is probable that the Yadkin at times reaches a figure below the smallest mentioned above, though it must be admitted that the conditions of both soil and forest covering in the Yadkin basin are more favorable for uniformity of flow than is the case in the Cape Fear basin.

One of the greatest drawbacks to the utilization of waterpower on the Yadkin is the inaccessibility of the river over considerable portions of its course; but there has been much improvement in this direction during the past few years. It is crossed in its waterpower portions by only three railroad lines—the Carolina Central, the Southern, and the Mocksville division of the Southern. The Salisbury-Norwood branch of the Southern passes along the entire length within from 4 miles (at Norwood) to 12 miles of the river; and the Wilkesboro division of the same road follows the north bank of the Yadkin from the eastern part of Surry county to Wilkesboro. The Atlantic Coast Line Railroad Company has recently surveyed a route up the Pee Dee and Yadkin from Wadesboro to Salisbury which passes through the gorge of the "Narrows" and near other promising but undeveloped waterpowers. We may now proceed to describe the river more in detail, with its various waterpowers, in order, commencing at its mouth.

WATERPOWER ON THE YADKIN RIVER.

Below Cheraw there is, of course, no power, and the river has the same character as the Cape Fear below Fayetteville, so it need not here be described.

Between Cheraw and the crossing of the Carolina Central railroad, a distance of 20 miles, the fall is at the rate of about 2 feet per mile,[1] and the width of the river 350 to 500 feet. There are 11 shoals in this distance, but none of much importance, and none in themselves available for power, although, by the construction of long canals, power might be secured. Such a plan would not, however, be advisable. At Cheraw the river is only 350 feet wide, and the greatest rise in freshets is 34 feet. The bed is generally rock and bowlders.

Between the Carolina Central railroad and the mouth of the Uharie river there are four prominent shoals which may be considered available for waterpowers; and between these are a number of smaller shoals which need not be mentioned in this connection.[2] The total distance is about 47 miles, and the total fall in the river between the two points about 158 feet.

BLUITTS FALLS.—The first of these shoals is about 12 miles above the state line, and 4.5 miles above the railroad. This shoal is about 1000 feet long, and has an estimated fall of 8 or 9 feet in this distance. The main body of the stream at this point is filled up with large rocks, and the water descends in a succession of plunges. There is a channel on the right side which is almost clear, and has a fairly uniform slope. A nine-foot dam is considered practicable here, and this would develop a considerable power. Some years ago this shoal was used by a grist-mill and cotton-gin on the Richmond county side; a primitive wing-dam giving a fall of 6.5 feet. These have since disappeared. In developing this power one may reasonably expect 250 horsepower for each foot of fall during ordinary dry seasons, and a considerably larger horsepower during 8 or 9 months of each year (see p. 188).

GRASSY ISLAND SHOAL, which begins about 13 miles above the state line, and 5.3 miles above the railroad, is the next above Bluitts, and has an estimated fall of 35 or 36 feet in a distance of 4½ miles. The river at this place is at least half a mile wide, with an average depth of only about 8 inches, and is full of small rocky islands, covered with a green weed. There are seventeen ledges which cross the river along the shoal, and at each there is a fall of about 6 inches; and in addition to these there are nine fish dams, with an average fall of 15 inches at each. In considering the possibility of rendering this portion of the river navigable, it was proposed to overcome this shoal by four locks and dams

[1] Annual Report of the Chief of Engineers, 1879, p. 725. From this report, on an examination of the river between Cheraw and the mouth of the Uharie, and the report of Lieut. Taylor on the same subject in the Annual Report, Chief of Engineers, 1888, p. 964, most of the following notes on that portion of the river have been taken.

[2] Annual Report, Chief of Engineers, 1888, Appendix L 19.

of nine feet lift each, 36 feet in all.[1] The banks of the river are said to be favorable for the utilization of the power. The shoal has only been utilized thus far by a small grist-mill. In the development of this power one may reasonably expect 250 horsepower per foot of fall during ordinary dry seasons, and a much larger power during 8 or 9 months of every year (see p. 188).

SWIFT ISLAND SHOAL, the next above and 42 miles above the state line, has an estimated fall of 18 feet in 2½ miles. There is one plunge of about 2 feet near the middle of the shoal. The upper end of this shoal is about 27 miles above Grassy Island and about 15 below the Narrows. There is a rock dam 4 to 5 feet high extending across the river in the form of a V with the apex up-stream, from which a race about one-half mile long leads to an abandoned cotton-factory on the east side of the river, while on the west side there is a grist-mill run from the same dam. These mills used only a small power, and they are reported to have been stopped by high water ten to twelve days in the year. Mills are said to have been in operation at this point for three-quarters of a century. Undoubtedly a considerable waterpower can be developed here, and it can be utilized on either or both sides of the river. The site is about 8 miles east of the Southern railway station at Albemarle, the county-seat of Stanly county. The power at this shoal may be expected to reach 155 horsepower for each foot of fall during ordinary dry seasons, and a much larger horsepower during 8 or 9 months of each year (see p. 188).

GUNSMITH SHOALS, 57.5 miles above the state line and about 13 miles above the upper end of Swift Island shoals, has a fall of 9½ feet in a little less than a half mile in length. In it there is one plunge of 2 feet and another of one foot. The general bed of the stream is full of large rocks, there being no particular channel, but there are narrow passages between the rocks where small boats can pass. This shoal is just below the mouth of Uharie river, and is 8 or 9 miles east of Albemarle. There is a wing-dam on the east side of the river, and a grist-mill using a fall of 4 or 5 feet.

THE NARROWS OF THE YADKIN.—The section of the river for five miles above the mouth of the Uharie is quite different in character from that both below and above this region. Over the shoals just described and those to be described further on as occurring higher up the stream, the bed of the river spreads out to a width of from 1000 to 1500 feet, and at Grassy Island is not less than one-half mile wide. But in the three and one-half miles under consideration the river runs

[1] Annual Report of the Chief of Engineers, 1879, p. 725.

THE NARROWS OF THE YADKIN RIVER, LOOKING UP THE STREAM through a deep, narrow gorge, and here, perhaps, the most remarkable waterpower in the state occurs at the "Narrows of the Yadkin." At the upper end, before reaching the Narrows, the river is nearly or quite 1000 feet wide, from which it suddenly contracts, entering a narrow ravine between the hills, which rise abruptly on either side with rocky and almost perpendicular banks, and through which it pours with great violence, preserving for a distance of about a mile an average width of not over 150 feet, while in some places the width is only 60 feet. No description can do justice to this place, which is one of the most wonderful spots that can be found in the south (Plate VI).

In the Narrows proper—the mile referred to above—the river has cut out its channel in the solid rock, the banks being almost perpendicular for a height of 5 to 15 feet above low water, when they retreat nearly horizontally, but so very broken and rough that it is difficult and tiresome to make one's way along, for a distance of about 100 to 150 yards from the immediate channel, where the hills rise very steeply. Thus the average width of the ravine is in the neighborhood of 250 yards, or rather less, while the channel of the river, through which its whole volume pours in low water, is 75 feet or less in width, while the water is said to be very deep. The stream overflows its banks in freshets and fills the whole ravine, although it is very seldom that it covers all the projecting rocks. Below the Narrows proper the stream expands to a width of 150 to 300 feet, and flows as a rapid current for the succeeding 2½ or 3 miles, through a narrow gorge, the banks on either side being very steep and rocky all the way, except at one or two places where small lateral valleys diverge, and where there is a place to put a single mill.

Some 2 miles below the Narrows, but still within the gorge, are the rapids known as the "Little falls," and half a mile below these are the rapids known as "Big falls." Just below the latter comes a long and narrow stretch called the "Lake," the river being still confined between rocky and steep banks, the fall being very small, the width of the stream only about 100 to 200 feet, and the depth very great. The banks slope down at a steep angle straightway into the river, and are of rock and forest-covered. At the lower end of the "Lake," which is between a quarter and a half-mile long, the river widens at a place called Terrapin Hole, and thence down to the mouth of the Uharie, a distance of about a mile; it is interspersed with rocks and islands, with banks ten to twenty feet high on each side, and behind them flat lands for several hundred yards.

The total fall in the river from the top of the falls at the head of the Narrows to the mouth of the Uharie river is 91 feet, and the distribution of this fall, as shown by the measurements made by Capt. John A. Ramsay of Salisbury, is as follows:

TABLE OF FALL AND DISTANCES IN THE NARROWS GORGE.

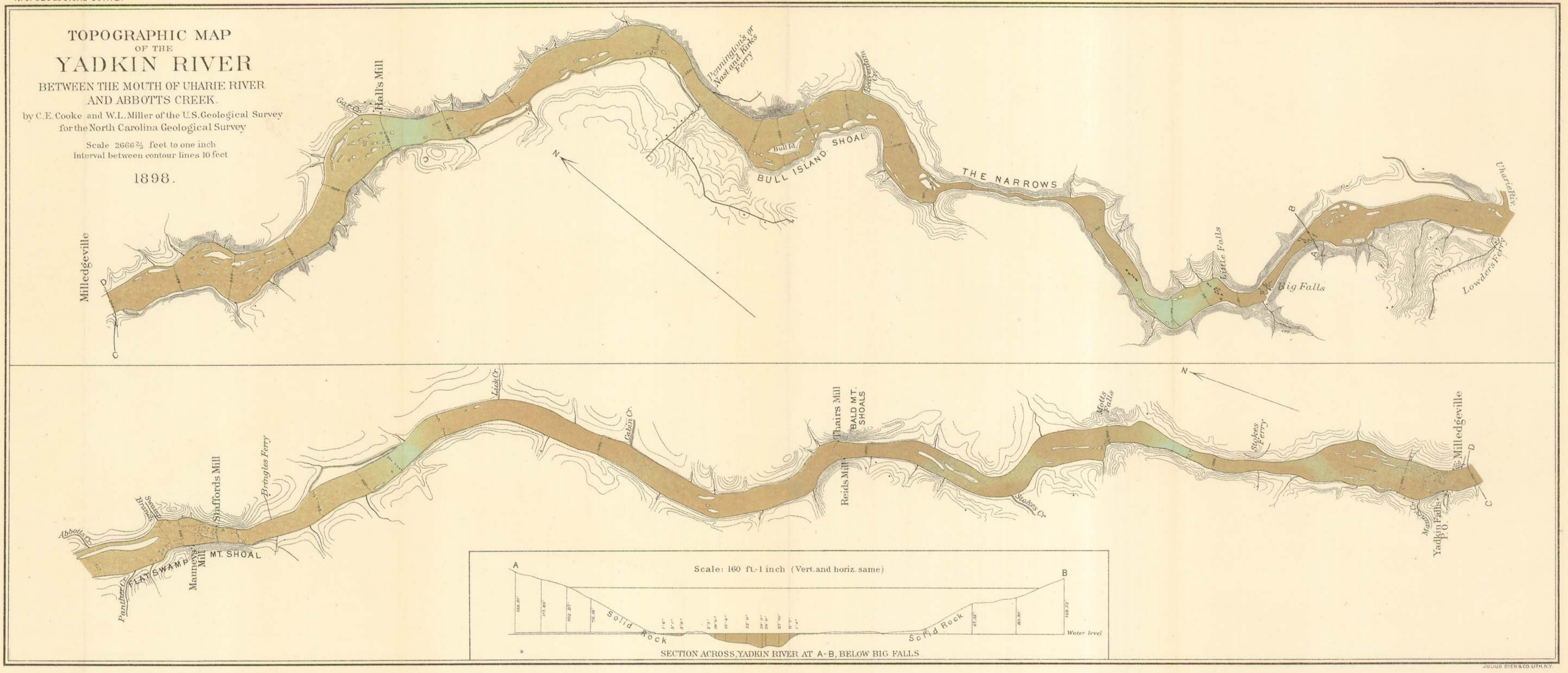
From	To	Approximate distance, miles.	Fall, feet.
Top of Narrows[1]	Bottom of main Narrows[1]	1.0	37.0
Bottom of main Narrows	Foot of Hamilton's fishery	1.0	8.7
Foot of Hamilton's fishery	Above Harris' mill	1.0	4.4
Above Harris' mill	Top of Little falls	0.5	9.0
Top of Little falls	Bottom of Little falls	0.2	7.3
Bottom of Little falls	Top of Big falls	0.3	8.4
Top of Big falls	Bottom of Big falls	0.2	7.8
Bottom of Big falls	Kirk's old ferry (now Lowder's) and mouth of Uharie river	1.3	8.9

If a 5-foot dam were constructed across the river just above the fall at the head of the Narrows and the water carried along the left or east bank in a canal or flume, allowing a fall of one foot in the canal, this would give a fall of about 41 feet at the lower end of the canal, less than a mile in length.

From the foot of the Narrows to the mouth of the Uharie river there is a total fall of 54.5 feet, the distribution of which is shown in the table given above. As indicated there, of the fall between the foot of the Narrows and the top of "Little falls," 9 feet of 22.5 feet, is within half a mile or less of the latter place. This 9 feet, added to the 23.5 feet between the top of the Little falls rapids and the bottom of the Big falls rapids, gives a total fall of 32 feet in a distance of little over a mile.

According to what has been said, it will be seen that this magnificent power is, unfortunately, not easily available. A dam could be built on the river above the Narrows and the water carried along by the flume, the power-house being located on the rocks; but while such a use of the power would be perfectly practicable no one would think of locating a large establishment in a gorge of the mountains in such an inaccessible place and on the rocky banks of the river, where it is liable to overflow in time of high water. A canal could not be cut along the Narrows except at very large cost; neither could it be carried around the hills, except with great difficulty. However, the development of this power is regarded as being entirely feasible; and indeed plans for such development are already under way.

[1]Starting on the right or west bank of the river at the top of the little fall or shoal, 690 feet above the mouth of Palmers creek and extending down-stream for a distance of 5800 feet, to the lower end of the Narrows proper, where the surface of the water becomes fairly smooth and where the right bank turns southwards.


TOPOGRAPHIC MAP
OF THE
YADKIN RIVER
BETWEEN THE MOUTH OF UHARIE RIVER
AND ABBOTTS CREEK.
by C. E. Cooke and W. L. Miller of the U.S. Geological Survey
for the North Carolina Geological Survey
Scale 2666⅔ feet to one inch
Interval between contour lines 10 feet
1898.
Milledgeville
Gar Cr.
Hall's Mill
Pennington's or Nast and Kirk's Ferry
Bull Id.
BULL ISLAND SHOAL
THE NARROWS
Little Falls
Big Falls
Lowder's Ferry
Uharie Riv.
N
Lick Cr.
Cabin Cr.
Thairs Mill
BALD MT. SHOALS
Reids Mill
Motts Falls
Stokes Ferry
Stokes Cr.
Milledgeville
Yadkin Falls P.O.
Abbotts Cr.
Swamp Branch
Staffords Mill
Bringles Ferry
Manneys Mill
MT. SHOAL
FLAT SWAMP
Panther Cr.
Scale: 160 ft.-1 inch (Vert. and horiz. same)
Solid Rock
Solid Rock
Water level
SECTION ACROSS, YADKIN RIVER AT A-B, BELOW BIG FALLS
JULIUS BIEN & CO. LITH. N.Y.

Below the Narrows proper there is no horizontal bank, as there is at the former place; but the channel is wider and the banks slope down to the water's edge, so that to canal or even to flume around this part of the fall would be difficult. There are a few places where lateral ravines make down to the river, at which the banks are not so abrupt, and where there is room for a single mill or power-house and, in fact, one small grist-mill was formerly even situated in this part of the Narrows, near Little falls, being run from a small wing-dam, and using a fall of 6 or 7 feet; but there are no facilities for the location of a manufacturing town, or even of a large mill. There are no low grounds between the head of the Narrows and the mouth of the Uharie. The rock in the Narrows is a solid altered conglomerate, probably volcanic, very hard, almost impossible to fracture, and difficult to blast. Some power might be obtained by damming the river at the Terrapin Hole and throwing the water up over the Little falls, or at Little falls itself a mill could be established; but a very small portion of the total power at this place is practically available, except by transmitting it, by electricity or some other means, by land suited for the erecting of large manufacturing establishments.

As shown by the accompanying topographic map (Plate VII, p. 182) of this part of the Yadkin river, a dam 100 feet high across the lower end of the Narrows gorge (at A-B on the map) would back water but little above the upper end of the gorge, and would flood hardly ten acres of cultivatable land. The bed and banks of the river are of solid rock, and there is also at hand an ample supply of stone suitable for the construction of such a dam. Immediately below this point the river basin widens out to such an extent that there would be but little loss of power from high water. From this point the power could be transmitted by electricity to suitable points on the Salisbury and Norwood branch of the Southern railroad, about five miles distant, where manufacturing establishments could be located or the power could be transmitted to Lexington, Salisbury, Concord or Charlotte, the distance to the last named being about 50, and to the other three places, about 30 miles in each case.

The theoretically available power is estimated in the following table:

TABLE OF POWER AT THE NARROWS OF THE YADKIN.[1]

State of flow.	Drainage area.	Flow per second.	Horsepower available, gross.			
			1 foot fall.	Narrows proper. 37 feet.	Big and Little falls. 32 feet.	Total fall. 91 feet.
(See pages 54 to 59.)	Square miles.	Cubic feet.				
Minimum	3,940	866	98.4	3,641	3,149	8,954
Minimum average for the low season		1,100	125.0	4,625	4,000	11,375
Average for the low season of average dry years.		1,250	142.0	5,254	4,554	12,922

Above the Narrows, and between this place and the Southern railway crossing near Salisbury, there are 6 important shoals and a number of intervening smaller ones.[2] The general width of the river in this portion of its course is from 600 to 1000 feet. The banks have a general height of about 10 feet above average winter water, and the level lands generally extend back from 200 yards to one-half mile from the river banks; but at all the more important shoals the banks are quite precipitous, and there are reported to be a number of excellent mill sites, some of which are partially improved.

BULL ISLAND SHOAL, the first above the Narrows, has a total fall, estimated by Lieut. Taylor at 37 feet in a length of nearly 2 miles, beginning about one-half mile below Pennington's ferry and ending 1 to 2 miles above the Narrows. Capt. Ramsay's measurements, however, show a fall of 29 feet in Bull Island shoals proper, with considerable falls both above and below, as will be seen from the accompanying map (Plate VII). The bed of the stream has a nearly uniform slope of 10 feet to the mile, and, in addition, two plunges, one of about 8 and the other of about 10 feet near the lower end. At the lower end of the shoal the river spreads out to a width of one-half mile and is considerably divided into channels by islands. The drainage area above this place is about 3900 square miles, and the flow, as well as the power available per foot fall, may be estimated the same as for the Narrows.

The PENNINGTON SHOAL, as it may be called for convenience, is the second important shoal above the Narrows, lying between Nast and

[1] For measurements of the flow of the Yadkin river see pp. 305 and 309.

[2] The notes concerning these shoals are taken in part from the report of Lieut. Taylor Annual Report, Chief of Engineers, 1888. App. L 19.

Kirks ferry and Milledgeville. It has a total fall, according to Capt. Ramsay's measurement, of 74 feet in a distance of 4½ miles. Along the entire shoal the river is spread out over a width of from 1200 to 1500 feet, the bottom being of solid ledges of rock crossing the bed of the stream at considerable angles. As shown by the accompanying river map (Plate VII), while the fall is somewhat concentrated at minor shoals, yet these are fairly well distributed throughout this distance. The flow and the power per foot fall may be estimated as but little below that given on page 188 for the Narrows.

There are two grist-mills located on this shoal, on the right or southwest bank of the river; the lower, Nast and Kirk's mill at Pennington's ferry, has a race about 2000 feet long and the fall at the mill is about 7 feet. Hall's mill, about 1½ miles above, has a race about one-half mile long and a fall of about 10 feet at the mill. In both cases the water is turned into the race by a short, low and rough wing-dam of stone loosely piled.

The MILLEDGEVILLE SHOAL, the third of importance above the Narrows, has a fall of 14 feet in a distance of about 0.7 of a mile, there being one plunge of about 6 feet near the bottom of the shoal. It is situated about 6½ miles above the Narrows, a short distance below Stokes ferry and 4 or 5 miles east of the Southern railway at New London. This shoal is utilized to a small extent as follows: The Yadkin Falls Manufacturing Company has a cotton-factory and grist-mill on the east side of the river at Milledgeville, using for both about 125 horsepower. The wing-dam on this side of the river is of rock, about 600 feet long, and gives a 10-foot fall at the factory, which contains 36 cards and 3160 spindles. On the opposite or west side of the river at this point are located a saw-mill, grist-mill, cotton-gin and wool-carding machinery, using in all about 40 horsepower, supplied with water from a small wing-dam extending from the bank across a portion of the river to an island, and which gives a fall of about 8 feet at the mill. The stoppage from high water at this point is said to be from 6 to 10 days in the year. The available power per foot fall is about the same as at the shoal below (p. 188).

MOTTS FALLS, the fourth important shoal, 2½ miles above the Milledgeville shoal, has a fall of 13½ feet in about 0.8 of a mile. There are in this distance six nearly vertical falls of from 6 inches to 2 feet each. There are several small islands scattered along the bed of the stream on this shoal, and the river is everywhere full of large rocks. There was formerly a mill located on the west bank, near the head of the shoal, but this has disappeared. From the tabular statement of the horsepower per foot fall on page 188 the power at this place can be easily calculated.

Bald Mountain shoal, about 2 miles further up the river, and the fifth important shoal above the Narrows, has a fall of 8½ feet in about half a mile. There are two mills located on this shoal, their wing-dams having the same general arrangement as that described at the next shoal above. Reid's mill, on the right or west side, has a fall of a little more than 6 feet, and Thair's mill on the opposite side has about the same fall. There appear to be no important tributaries to the river between the Narrows and this point, so that the power available per foot fall at the last two sites may be considered as but little less than at the Narrows (see p. 188).

Flat Swamp Mountain shoal, about 4½ miles above Bald mountain, and less than one mile below the mouth of Abbotts creek, has a natural fall of 10.2 feet in half a mile. Like the last mentioned, it is partly utilized by two grist-mills; Stafford's, on the left or east bank, which has a fall of between 6 and 7 feet, and Mauney's mill on the right bank opposite, which has a fall of 6½ feet at the lower end of a race about 100 yards long, into which the water is turned by a wing-dam several hundred feet long.

Between the mouth of Abbotts creek and the Southern railway crossing, a distance of some 10 miles, there are no shoals of importance, the total fall in this distance being, according to Capt. J. A. Ramsay's measurements, 28.3 feet.

Above the mouth of the South Yadkin river there are several small shoals, but none of any importance until Swicegood's mill is reached. This is a grist-mill having two run of stones, and the fall here is about four feet, utilized by means of a wing-dam and an undershot wheel.

The next power on the river, five miles higher up, is the grist-mill of Hege & Crott, using about four feet fall, obtained from a dam extending across the river. Of course only a very small part of the water is used.

At Hartley's mill, a saw- and grist-mill, 1½ miles further up the river, there is a shoal about four hundred feet long and of about four feet fall. The mill uses an undershot wheel, the water being turned to it by a wing-dam.

Four miles above Hartley's, at Ellis ferry, there is a small saw- and grist-mill located on a shoal about 600 feet long, and having a fall of about six feet. This mill diverts part of the water by means of a wing-dam, and home-made wooden wheels are used.

At the crossing of the Winston & Mocksville railroad, on the old site of Douthit's mill, a fall of 10 feet has recently been developed by the Fries Manufacturing and Power Company of Winston-Salem; a power-house has been constructed at this point, and the power is being transmitted to Winston-Salem, a distance of 13½ miles, and there used for lighting, street cars and various manufacturing purposes (see p. 188).

Langenhour & Neason's mill was situated 9½ miles above Ellis ferry. The shoal here has a total natural fall of 4.57 feet, and the dam was a substantial structure of wood and stone extending entirely across the river.

The Shallow Ford shoal, 6½ miles higher up the river, was the seat of an old grist-mill, now burned. There is here a natural fall of about 8 feet in one mile.

Above Shores island, and about 10 miles above the Shallow Ford shoal, ten miles below the head of Beans shoal, is another shoal with a fall of about 8 feet in 1¾ miles.

At Johnsons falls, at Donnaha station, on the Southern railroad, about five miles above the last mentioned, there is a fall of about four feet in half a mile above and below the station. Opposite the station there is a ledge of rock extending diagonally across the river, over which the water falls in a straight plunge for two feet. The banks here are low and the bottoms are quite broad and only about eight feet higher than the ordinary level of the river, with no indication of any rock on the surface.

Bean shoal.—The principal shoal on this part of the river is Bean shoal, the fall in four miles being over 39 feet. The most rapid descent is at the head, being nearly 17 feet in one mile. The bed of the stream is very ragged, of stratified rock, which rises in sharp points and ridges at right angles to the course of the stream, forming in some places natural dams extending nearly across, and the channel is much obstructed and cut up with rocks and islands. In the lower part of the shoal there is a fall of about ten feet in two miles. The only part of the shoal now being utilized is near the middle portion, where is situated Martin's grist-mill on the south side of the river. Between 1820 and 1835 "The Yadkin Navigation Company did considerable work at these shoals with a view to rendering the river navigable. A dam was built at the head of the shoals and a canal was commenced along the northern side of the river. The only trace of a dam now to be seen is an abutment at the entrance of the canal. The canal was completed for a little more than a mile from the head of the shoals, and was from 15 to 45 feet wide at the bottom. Where the cliff forms one wall the minimum width was 15 feet. At 2000 feet from the head of the canal are the ruins of a guard-lock 12 feet wide. The canal walls are of earth, except along the foot of the cliffs. Here a very good retaining wall was built of stone quarried on the spot. The upper wall, 700 feet in length, was built of headers and stretchers neatly pinned with small stone, and is in good condition. The outer face has a batter of 2¾ inches to the foot rise. The inner face was left rough and covered with gravel and earth. No cement was used in its construction. The dimensions are: Height, 5 to 20 feet; top width, 2.5 feet; bottom width, about 7 feet. The lower wall, about four hundred feet in length, is of the same general character, but in some places has been torn down to obtain material for the construction of fish-dams. The canal has been filled in by the floods, and where it flows through the woods is overgrown with trees and bushes. No water flows through it."

Lime Rock shoal is about 7½ miles above the head of Bean shoals, and has a fall of 10.62 feet in 2.59 miles, over rock bottom.

Twelve miles higher up the river, and about 35 miles below Wilkesboro, is the Devil's Staircase and Long shoal, where in 1.61 miles the fall is 11.18 feet over a rock bottom.

The other shoals mentioned call for no special remark. The bed of the stream is everywhere rock, overlaid sometimes with gravel, and is most favorable to the construction of dams. Beside the shoals mentioned in the table there are many others with smaller falls, but which might equally well be used for power. As regards the amount of power available, there is no doubt that it is very large indeed, and that almost every one of these shoals might be utilized to a greater or less extent. Bean shoal would seem to offer the most excellent site in this part of the state, and it having been considered practicable to build a canal around the whole shoal it would seem to follow that the power might be utilized without much difficulty. While the estimates of power given in the table are only to be regarded as approximations, it is believed that they will serve to give some idea of the amount of power which might be obtained. But until larger establishments seek a location in this vicinity, and until the means of transportation are improved, the waterpower of the smaller tributary streams will be preferred to that of the main river, on account of the smaller cost, the (in general) safer location, and the diminished liability to stoppage by high water. When large amounts of power are wanted, however, and money is at hand to develop it, the Yadkin will, no doubt, be found to afford a large supply.

PATTERSON.—Above Wilkesboro the fall of the river continually increases, and there are some sites for power, but regarding them we could procure no detailed information. The only considerable power used is that at Patterson, Caldwell county, where Messrs. Gwyn, Harper & Co. have a cotton-mill, woolen-mill, saw- and grist-mill and cotton-gin. The cotton-mill contains 56 looms and 2288 spindles, and is run by waterpower supplemented by steam in dry seasons. The dam, of wood and stone, is 15 feet high and 300 feet long, and the fall at the factory is 25 feet, which it is claimed develops 80 horsepower by means of a turbine-wheel during eleven months of the year, the mill running 12 hours. The woolen-mill contains 4 sets of cards, 20 looms and 480 spindles, which are operated by the same waterpower supplemented by steam in dry seasons. The race is of wood, 200 yards long.

Above this the stream is rapid—a mountain stream, with little or no power utilized.

It may be remarked that there are only three or four dams extending entirely across the river, all above the Narrows.

The estimates of power given in the following table are liable to large error, and it is impossible to check them. All of the powers used seem large in comparison with the drainage areas above them, as in the case of the one at Patterson, and it may be that the streams in the upper part of the basin are fed by large springs, which render the flow comparatively constant. The estimates have been therefore made larger than in ordinary cases, and they may be found too large. It is to be remarked, however, that powers are often overstated, and that turbine-wheels are rated very high as regards efficiency. A power of 50 horsepower at Patterson, with a fall of 25 feet, would correspond to a flow at all times of 0.6 cubic foot per second per square mile, see pp. 55, 56 and 57.

SUMMARY OF POWER OF THE YADKIN RIVER.[1]

Locality.	Distance from state line.	Drainage area.	Rainfall. Spring.	Rainfall. Summer.	Rainfall. Autumn.	Rainfall. Winter.	Rainfall. Year.	Total fall. Height.	Total fall. Length of shoal.	Horsepower available, gross.[2] Minimum.	Horsepower available, gross.[2] Minimum average for the low season.	Horsepower available, gross.[2] Average for the low season of average dry years.	Remarks.
	Miles	Sq.m.	In.	In.	In.	In.	In.	Feet.	Feet.				
Bluitts falls	12.0	6,650	12	12	11	13	48	9.00	1000	1,500	1,900	2,170	
Grassy Island shoal	13.0	6,624	12	12	11	13	48	36.00	4.5[3]	5,970	7,600	8,680	
Swift Island shoal	42.0	4,323	12	13	11	14	50	18.00	2.50[3]	1,942	2,476	2,796	
Gunsmith shoal	57.5	4.300	12	13	11	14	50	9.50	2,500	1,020	1,300	1.470	
Narrows	60.0	3,938	12	13	11	14	50	91.00	5[3]	8,954	11,375	12,922	
Bull Island shoal	65	3,800	12	13	11	14	50	29.00	2[3]	2,854	3,625	4,118	Undeveloped.
Penningtons shoal	67	3,900	12	13	11	14	50	74.00	4.50[1]	......	......	......	
Milledgeville shoal	70	3,500	12	13	11	14	50	14.00	0.7[3]	1,378	1750	1,988	
Motts falls	72.3	3,400	12	13	11	14	50	13.50	0.8[3]	......	......	......	Undeveloped.
Bald Mountain shoal	73.8	3,300	12	13	11	14	50	8.50	0.5[3]	......	......	......	Do.
Flat Swamp M't. shoal	78.3	3,000	12	13	11	14	50	10.20	0.5[3]	......	......	......	Do.
Fries Mfg. & Power Co.	131.5	1,865	13	14	10	14	51	10.00	1,600	......	......	......	Rock bottom.
Langenhour & Neason's dam	138.5	1,827	13	14	10	14	51	4.57	......	220	280	325	Rock bottom.
Shallow Ford shoal	145.0	1,812	13	14	10	14	51	7.89	5,560	375	485	550	Rock & gravel bottom.
Shoal above Shore's island	155.2	1,633	13	14	10	14	51	7.73	9,662	330	430	490	Do.
Bean shoal (head)	164.7	1,521	13	14	10	14	51	39.17	4[3]	1,560	2,030	2,320	Rock bottom.
Lime Rock shoal	169.3	1,165	13	14	10	14	51	10.62	[1]2.59	325	425	490	Do.
Shoal below Rockford	174.8	1,097	13	14	10	14	51	8.38	4,500	240	320	360	Do.
Seven Island shoal	177.0	1,066	13	14	10	14	51	4.02	2,630	112	145	165	Do.
Long shoal	182.0	949	13	14	10	14	51	11.18	1.61[3]	205	335	385	Do.
Woodruff Fish-trap shoal	185.0	925	13	14	10	14	51	4.55	1,800	105	134	155	Do.
Mitchell Island shoal	186.6	925	13	14	10	14	51	4.00	2,740	90	115	135	Gravel bottom
Swan Creek shoal	196.7	739	13	14	10	14	51	5.40	3,160	100	125	145	Rock bottom.
Reeve Island shoal	206.5	540	13	14	10	14	51	3.86	2,700	50	65	75	Rock & gravel bottom.
Blair Island shoal	216.5	420	13	14	10	14	51	3.44	1,700	36	46	53	Gravel bottom

TRIBUTARIES OF THE YADKIN.

The lower tributaries of the Great Pee Dee, viz. the *Waccamaw*, the *Black* and the *Little Pee Dee* rivers, scarcely call for a detailed description. Lying entirely below the fall line, their general character will be sufficiently clear from what has been already said regarding similar streams, and regarding the eastern division, as a whole, in the introduction. The Waccamaw rises in Waccamaw lake, Columbus county, North Carolina, not over 25 miles from the Atlantic, and flows for a distance of 244 (?) miles nearly parallel to the coast, joining the Great Pee Dee at its mouth. It is navigable for light-draught steamers for 163 miles, and for boats drawing 3 feet of water up to the lake. Its waterpower and that of its tributaries, does not amount to much. The Black river, which has its sources in Kershaw and Sumter counties, South Carolina,

[1] For measurements of flow on the Yadkin river, see pp. 305 and 309.
[2] For explanation of terms, see pages 54 to 59.
[3] Miles.

is similar in character, and has no waterpower except a little in the upper part among the sand hills. The Little Pee Dee, which unites with the Great Pee Dee 23½ miles above its mouth, is more important. Rising in Richmond county, North Carolina, it flows in a general southerly course, as will be seen from the map, its length along its general course being about 75 miles, but much greater by the river, which is quite crooked, like all the streams in the low region near the coast. The total drainage area of the river is about 3000 square miles, and it receives one tributary larger than itself, the Lumber river, from the east and north, which drains nearly 1800 square miles. The sources of the Little Pee Dee are just about on, or a little below, the fall line, in the sand hills; and they therefore afford some power, their general character being the same as that of the sand-hill tributaries of the Cape Fear, which has been described, on page 139. Their declivities being uniform, no sites could be specified.

GUM SWAMP CREEK.

Gum Swamp creek will serve as an illustration of the character of these small sand-hill streams. It rises among the sand hills of Richmond county, about eight or ten miles above the Carolina Central railroad at Laurel Hill, and within a dozen miles of its source it furnishes the power to operate three small cotton-mills, as follows:

The Richmond cotton-mill, located on this stream 2 miles north of the railroad and about the same distance north of Laurel Hill, contains 2556 spindles, operated by about 90 horsepower, which is maintained all the year except that the water "gets a little low" in very long dry seasons. The dam is 12 feet high, 600 feet long; the size of the pond is 1½ miles long and one-third mile wide; the fall at the wheel is 10 feet; and here, as is true of both mills below, they run only during the day, and in dry seasons, when the water is drawn down slightly in the pond during the day, it fills up at night.

The Ida yarn-mill, 2½ miles below the Richmond mill and one-eighth mile south of the railroad, contains 3024 spindles operated by about 110 horsepower during all the year. The dam is 10 feet high, 900 feet long, producing a pond about one mile long and 300 to 400 yards wide, the race being 300 yards long and the fall at the mill 8 feet.

The Springfield cotton-mill, one and one-fourth miles below the Ida yarn-mill, contains 2304 spindles, and uses about 85 horsepower. The fall at the wheel is 7½ feet; the dam 10 feet high and 525 feet long. The pond is three-fourths of a mile long and 200 to 300 yards wide; the race 200 yards long.

The *Lumber river* has its sources higher up than those of the Little Pee Dee, in Montgomery and Moore counties, North Carolina, but reaching little, if at all, above the fall line. Its character resembles that of the Little Pee Dee, and on its upper part it probably belongs to the class of sand-hill streams. There are no mills, except saw- and grist-mills, on the main stream, or on any of its tributaries.

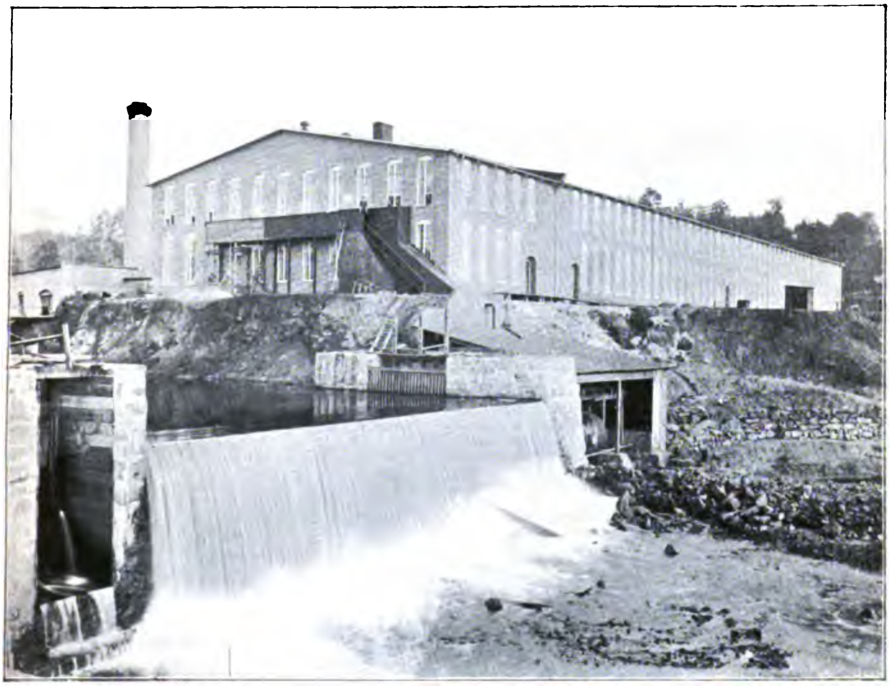
HITCHCOCKS CREEK.

The next tributary worth mentioning in North Carolina is Hitchcocks creek, although there are several streams below it which are also favorable for power. Hitchcocks creek flows entirely in Richmond county, and has a length, in a straight line, of only about 16 or 20 miles, draining an area of some 102 square miles. It receives one tributary from the south—Falling creek—worth mentioning on account of its utilized power, although it is a small stream, with a drainage area of only about 12 square miles. At the junction of these two streams is the town of Rockingham, the county-seat of Richmond county, with a population of about 1600. These streams are true sand-hill streams, so that for their general character we may refer to page 138. Falling creek, however, differs from the ordinary sand-hill streams by having a large natural fall near its mouth, which may be its crossing with the same ledge of rocks which forms the fall line. Both streams have been used to a considerable extent to drive saw- and grist-mills, as will be seen from the table of utilized power. They are principally remarkable, however, as running six cotton-mills, and they thus offer a good example of the large amount of power which may be obtained from these unpretending little sand-hill streams, as will be seen from the following statement:

STEELE'S COTTON-MILL, containing 10,304 spindles and 300 looms, is the lowest important power on Hitchcocks creek, being 2½ miles above its mouth. The dam here is built of granite laid in cement, 16 feet high and 69 feet long, developing, it is claimed, without a race, 350 horsepower (Plate VIII).

The MIDWAY COTTON-MILL, about four miles above the mouth of the creek, on the old Aycock mill site, contains 16 cards and 6200 spindles, operated by waterpower. The dam is of wood, 13 feet high and 150 feet long. The present wheels, it is claimed, develop about 200 horsepower all the year.

The PEE DEE MANUFACTURING COMPANY'S COTTON-MILL, located two miles above the Midway mill, contains 23 cards, 300 looms and 6112 spindles. The dam is of stone and dirt, 22 feet high and 107 feet long, giving 22 feet fall, which, it is claimed, develops 300 horsepower all the year round, except during short and unusually dry seasons of dry



A STEELE'S COTTON MILL, HITCHCOCK CREEK

B—ROBERDELL COTTON MILL, HITCHCOCK CREEK years. The pond extends over two miles up the stream. This company has a second mill now in course of construction.

The ROBERDEL COTTON-MILL, two and one-third miles above the Pee Dee mill and three miles northeast of Rockingham, contains 24 cards, 300 looms and 6000 spindles, all operated by waterpower. The dam is of stone, 24 feet high and 170 feet long, giving a fall of 22½ feet at the mill, which is said to generate 300 horsepower all the year (Plate VIII).

The LEDBETTER MANUFACTURING COMPANY'S COTTON-MILL is located two miles above the Roberdel mill, and operates 2080 spindles and two sets of cards by water from this creek. The dam is of brick, 13 feet high and 140 feet long, giving a fall at the mill of 10 feet. The pond covers about 150 acres. About 100 horsepower is reported to be developed, of which about 75 horsepower is used all the year round, except during a few days when high water interferes. At the opposite end of the dam the company has a corn- and flour-mill.

On *Falling creek*, near its junction with Hitchcocks creek, is located the cotton-mill of the GREAT FALLS MANUFACTURING COMPANY, three-quarters of a mile above the Midway cotton-mill. This factory contains 130 looms and 4512 spindles, all operated by waterpower. This waterpower is one of considerable interest because of the comparatively large amount of power continuously developed on this small sand-hill stream with a drainage area of not more than 12 square miles. Where the dam is now located there was originally a natural fall of 25 feet over the bed rock which here underlies the sand-hill formations, and on this rock has been built a dam 18 feet high and 95 feet long (75 feet of this being brick and 20 feet wood), thus giving a fall of 43 feet. The pond has an area of 10 to 15 acres, and from this the water is carried to the wheels through an iron flume 75 feet long. The power generated in ordinary years is 150 horsepower for the entire year, the mill running only during the day, and in drier seasons the pond fills up at night and supplies a full head in the morning. In exceptionally dry years there are a few weeks during which the mill cannot run full head during more than three days of the week, but it is reported that nothing of this kind has occurred for several years. The storage of water has been carried to a greater degree of efficiency on this stream than on any other of the sand-hill streams in the state. Above the pond at the mill three earth dams have been built across the course of Falling creek and its tributary branch, thus producing three reservoirs, one of 10 to 15 acres, and two others of 20 to 30 acres each; each of these being 5 to 6 feet deep. These store up a quantity of water which is turned out as needed by the factory in dry seasons.

It is interesting to calculate the amount of water which may be depended upon from these sand-hill streams, as was done in the case of the tributaries of the Cape Fear, but the inaccuracy of the available maps renders the result liable to error to an uncertain extent. The drainage area of Hitchcocks creek above the Pee Dee factory is, according to the map, about 86 square miles. If we assume that in the low season of dry years 100 horsepower (gross) may be obtained with a fall of 22 feet during 12 hours, or 50 with the natural flow of the stream, then the flow will be about 0.23 cubic foot per second per square mile. If we assume that 250 horsepower (gross) can be obtained at ordinary stages of the stream by drawing down the water at night, then the flow will be about 0.6 cubic foot per second per square mile. For Falling creek, if we take the capacity at low seasons at 70 horsepower (gross) during 12 hours, we find the corresponding flow to be over half a cubic foot per second per square mile, or more than in the case of Hitchcocks creek; and if the capacity in ordinary seasons be taken at 150 horsepower (gross) during 12 hours, we obtain a flow of over 1 cubic foot per second per square mile. It would therefore seem that these sand-hill streams discharge from one-third to 1 cubic foot per second per square mile of drainage area, except during freshets. Compare this statement with the remarks on pages 138-40; 145 and 197.

In addition to the cotton-mills on these two small streams there are on Hitchcocks creek the following: (1) S. Gibson's saw- and grist-mill; and (2) Joe Gibson's saw-, grist- and flour-mill above Ledbetter's cotton-factory, each having a fall of about 6 feet and using 25 to 30 horsepower; (3) Ledbetter's corn- and flour-mill opposite the cotton-factory, and using a small power from the same pond with a fall of 10 feet; (4) a cotton-gin and dynamo-house opposite the Roberdel cotton-mill, using 25 horsepower; (6) a cotton-gin and grist-mill opposite the Midway cotton-mill. And near the mouth of Hitchcocks creek is the old Wall mill, not now used. On Falling creek there is now being operated but one small grist-mill in addition to the Great Falls cotton-factory, though there are two other abandoned sites. The fall of Hitchcocks creek from the foot of the Great Falls dam, on Falling creek, to the Pee Dee, a distance of 5¼ miles, is 41 feet, or about 8 feet to the mile. The pond of the Great Falls factory is about 187 feet above tide, and the mouth of the creek 103 feet. The fall is said to be equally great for several miles above Rockingham.

The tributaries to the Pee Dee from Anson county are not of much value for waterpower, as they appear to lie above the sand-hill belt, and are said to be very variable in flow. They are used only for small grist- and saw-mills, which often have to stop in dry weather.

LITTLE RIVER.

Little river, which rises in the southern part of Randolph county and flows south through Montgomery and into Richmond, joining the Pee Dee above Grassy Island shoal, is the next tributary worthy of mention, although its waterpower is not of much importance. The length of the stream is about 40 miles in a straight line, and it drains an area of about 400 square miles. None of its tributaries are of any consequence. It passes within a mile or so of Troy, the county-seat of Montgomery county, but there are no large towns directly on its course. Its fall is not large, and its flow is said to be very variable—very much more so than that of the sand-hill streams just discussed—and it is much more subject to freshets. There are only a few small saw- and grist-mills on the stream, and although it was said that there are some sites for power, especially on its upper parts, none of them are of value. The mills in use have 2 or 3 pair of stones and falls of from 6 to 10 feet, generally with a dam of about the same height. The flow of the stream is estimated at not over 50 cubic feet per second at a minimum, and 90 or 100 during the low season of *ordinary* years. The rainfall is about 46 inches, 12 in each season, except autumn.

ROCKY RIVER.

The next important tributary is Rocky river, which rises in the southern part of Iredell county, flows in a general southeasterly direction, making, however, several abrupt bends, and passing through Mecklenburg and Cabarrus counties, and then between Stanly on the north and Union and Anson on the south, its total length along its general course being about 75 miles, and its drainage area 1405 square miles. The stream receives a number of considerable tributaries, viz. from the south and west, Lanes creek (140 square miles), Richardsons creek (199 square miles), and other smaller ones; and from the north, Long creek (158 square miles), Irish Buffalo creek, Coddle creek and others. There are no towns of importance on the stream. As the drainage basin lies entirely above the fall line, the stream offers some power. The bed is rock, and in freshets the stream often rises over its banks. The power utilized is for small saw- and grist-mills and a cotton-factory. The grist-mills have generally 2 run of stones, which they can run almost all the time, although the flow of the stream is said to be quite variable. The cotton-factory, which is located not far from Concord, uses probably not over 25 horsepower with a fall of 13 feet, and can run all the time. No particular sites on the river were visited, none having been brought to our notice. The information which has been collected is very meager, but it seems probable that there is not very much power on the stream.

The flow at its mouth is estimated at between 400 and 500 cubic feet per second during the low season of ordinary years. The rainfall is about 50 inches.

UHARIE RIVER.

The Uharie river, which enters the Yadkin in Montgomery county just below the Narrows, rises in the northwestern part of Randolph county, and pursues a course nearly due south through that county and Montgomery, its length in a straight line being about 37 miles, and its drainage area 317 square miles. It passes by no important towns, and has no large tributaries. Its waterpower is not considered valuable, and is only used for country saw- and grist-mills, having generally 2 run of stones. The bed is rock, and the banks generally tolerably high on the lower part, though the low grounds are more extensive on the upper parts. There are no falls on the stream, and all the power has to be obtained by damming. The stream is, on the whole, rather sluggish, having a small fall, and crossing the ledges of rock at small angles, as has been noticed when speaking of the Narrows of the Yadkin. Its flow is exceedingly variable—in fact, the stream is said to become nearly dry in summer—due, perhaps, to the fact that it comes out of the slaty region, which has been referred to when speaking of the Deep river. On this account its waterpower is of small value, and the mills have often to stop in summer. The lowest mill is about 6 miles from the Yadkin, below which the fall is very small. A short distance above it is an old site, now not used, but probably not of much value. The freshets are heavy and sudden, as is to be expected in the case of a stream from the slate region.

Above the Uharie there are several small streams in Rowan and Davidson counties, but they are hardly worthy of special mention, being utilized only by saw- and grist-mills, and are, as a rule sluggish, with no fall or available power of much importance.

SOUTH YADKIN RIVER.

The next important affluent is the South Yadkin river, which rises on the southern slope of the Brushy mountains, in Alexander county, and flows a little south of east through Iredell, and between Davie and Rowan counties, joining the Yadkin a little above the railroad bridge, its total length in a straight line being about 42 miles, and its drainage area 820 square miles. Two of its tributaries from the north are worth naming, viz. Hunting and Rocky creeks, which drain respectively 146 and 94 square miles. The bed of the stream is rock, overlaid in places by detritus; the banks moderately high, although overflowed in places in times of freshet; the fall considerable, and the flow more constant than in the case of any of the tributaries thus far mentioned above the sand-hill belt. The power of the stream and of its tributaries is utilized to a considerable extent by saw- and grist-mills and a few cotton-factories, as will be seen by the table of utilized power.

The first mill on the stream is 4 miles from its mouth, at South river (Foard & Lindsay's), and has a fall of 6 feet, with a dam of the same height and about 240 feet long. About 30 horsepower is utilized, but the available power is much greater. The drainage area above being about 800 square miles, the capacity may be estimated at perhaps 15 horsepower per foot fall during very dry seasons, and at 25 to 30 during the low seasons of ordinary years. This mill is sometimes troubled with backwater. The dam backs the water about 3 miles, nearly up to the foot of the next power above, Hairstons or Perkins shoal.

HAIRSTONS SHOAL is the most important one on the stream, and is some 12 miles from Salisbury, and above the mouth of Third creek. The stream has, with a dam 3½ feet high, a fall of 15 or 16 feet in a quarter of a mile, but the principal part is at the upper end, being 13 or 14 feet in 200 yards. There was at one time a race cut on the north bank to the foot of the shoal, a quarter of a mile long, and along it were a foundry, a woolen-mill, and a grist-mill. When examined (1897) there was a race 200 yards long, at the end of which is a grist-mill, with a fall of 13 feet; and there was also a saw-mill 50 yards from the dam with a fall of 12 feet. The power used is probably not over 40 horsepower. The dam, which extends entirely across the stream, is 250 feet long, 3½ feet high, built of wood some years ago at a cost of $1250, and backing the water for a mile or so, it is said. The location is an excellent one—safe, and with good facilities for canals and buildings.

This power has recently been purchased by the Cooloomee Water-power Company and it is proposed to develop it at an early date. We understand that the development plans include a dam 18 feet high, which, it is said, will back the water about 5 miles, and it is expected that 1000 horsepower will be secured. This power will be transmitted electrically to suitable localities and sold to consumers.

The Cooloomee Manufacturing Company propose, it is said, to erect a large cotton-mill near this place in the near future, to be supplied with power by the waterpower company.

By means of proper storage dams, permitting the total water-supply to be concentrated into 10 or 12 hours, the power due to the natural flow of the stream may be increased by 100 per cent or more.

Above this shoal there are no mills for a long distance, and there are no important powers. Sharpe's saw- and grist-mill, about 35 miles above the mouth of the river is reported to have a dam 100 feet long and 8 feet high, giving a fall of 14 feet, and to use about 35 horsepower in its operations. On the upper part of the stream there are small mills, but none worth mentioning in this connection.

The tributaries to the South Yadkin afford a number of very good small powers. Second, Third, Fourth and Fifth creeks, from the south, are all utilized to a greater or less extent by small mills, but are not very favorable; and Hunting, Rocky, Bear and Snow creeks, especially the two first named, from the north, are used to a considerable extent for small powers.

Hunting creek has a cotton-factory (recently burned) at Eagle mills with a fall of 18 feet and 60 horsepower, it is said, the dam being 3½ feet high, and the race 400 feet long. This stream is said to offer a number of sites not used, Mr. Thos. Holcomb's undeveloped shoal being reported as equal to that at Eagle mills. Miss Alice Campbell's grist-mill is reported as having a dam 110 feet long, 8 feet high, with a fall of 12 feet and using 25 horsepower; and Troy's saw-mill, and Nicholson's grist- and saw-mills, both lower down, are said to use 50 horsepower each. A cotton-mill was built at Nicholson's, but its operations were discontinued and its machinery sold several years ago. It is probable that the tributaries from the north all have a much greater fall than those from the south. Hunting creek drains an area of about 146 square miles, and the area above the factory is about 100. We would estimate the power at the factory at between 2 and 3 horsepower gross per foot fall during low seasons of ordinary years—nearer 3 than 2—or perhaps 40 horsepower net, with 18 feet fall and a good motor. The amount of power actually used in the factory is uncertain.

Rocky creek, with a drainage area of 94 square miles, has located on it Stimpson & Steele's cotton-factory (1152 spindles) and a grist- and saw-mill at Turnersburg, using a fall of 19 feet and about 80 horsepower during ten months, and 60 horsepower during the remaining two months. The dam is about 300 feet long and 6½ feet high. Above the cotton-mill are the following mills in about the order named, the waterpowers given being the amounts used during the average season:[1] Summers & King's grist- and saw-mills, fall of 15 feet, 75 horsepower;

[1] Data for this statement were furnished by Mr. N. T. Summers, of Olin, N. C.

Huies' grist- and saw-mill; 12 feet fall, 35 horsepower; Jenings' grist- and saw-mill, 11 feet fall, 35 horsepower; A. G. Meyers & Co., grist- and saw-mill, 12 feet fall, 20 horsepower; Williams' grist- and saw-mill, 12 feet fall, 20 horsepower; M. H. Shoemaker's grist-mill, 12 feet fall, 20 horsepower; Robert Maberry's grist- and saw-mill, 12 feet fall, 20 horsepower. A short distance above the cotton-mill at Turnersburg there is reported to be an excellent undeveloped waterpower belonging to Mr. T. M. Gill. Rocky creek is similar in character to Hunting creek.

The tributaries to the Yadkin from Forsyth, Davie, and Yadkin counties are not worthy of special mention, as they are small, and in some cases very sluggish, offering no powers of importance. In Surry and Wilkes counties we come to a number of streams which rise in the Blue Ridge and pursue a southerly course to the river, draining a country very well wooded, and having a very considerable fall. In Wilkes county there are also a few streams of this class which rise on the south, on the northern slope of the Brushy mountains, and flow nearly north. All of these streams are said to afford numerous excellent sites for power, only a few of which are at present utilized. They flow over rocky beds, with banks generally favorable for the construction of dams, and their flow is said to be not very variable. They are bordered with fertile and cultivated bottom-lands. Their drainage areas are given in the table on page 200. The mean annual rainfall over all this upper part of the Yadkin valley is about 51 inches—13 in spring, 14 in summer, 10 in autumn, and 14 in winter. As regards the flow of the streams, detailed estimates are not presented, because they are liable to be too far in error. According to all the information which could be obtained regarding power utilized, the flow must be large compared with other streams of similar drainage area thus far considered. We would be inclined, however, to estimate the average flow during the low season of ordinary years at between 0.20 and 0.35 cubic foot per second per square mile of drainage area, varying between these figures for drainage areas between 30 and 300 square miles in area.

The first of these streams met with is the *Little Yadkin*, which rises among the Sauratown mountains in Stokes county and flows in a southwesterly course, entering the Yadkin river near the northwest corner of Forsyth county. No important powers are reported on this stream.

THE ARARAT RIVER.

The Ararat river, the next and largest of these upper tributaries, rises among the spurs of the Blue Ridge mountains in Patrick county, Virginia, and flowing in a general southerly course enters the Yadkin some ten miles above the mouth of the Little Yadkin. It drains an area of 315 square miles, of which something over two-thirds is forest-covered, and the soil of which, formed of granitic and gneissic rocks, is generally open or porous. The fall in the stream which descends from the slopes of the Blue Ridge to the Yadkin in a distance not greater than 40 miles, is considerable, and there are reported to be a number of good powers along its course. Above Mt. Airy are a number of grist- and saw-mills using from ten to twenty-five horsepower each.

The HAMBURG COTTON-MILL, grist- and flour-mill and machine-shop are located on the Ararat about 25 miles above its mouth, one-half mile east of Mt. Airy, the small cotton-mill operating 1600 spindles. The wooden dam is ten feet high and 150 feet long, ponding the water for half a mile up the river. The fall at the mills is 14 feet, and the entire plant uses 40 horsepower all the year, the stream developing a much larger amount.

At BUCK SHOALS, some two miles below Mt. Airy, and 23 miles above the mouth of the river, is a saw- and grist-mill with a dam about 6 feet high and 200 feet long and a fall of 15 feet, only a small portion of the power being utilized. Two miles below (21 miles above the mouth of the stream), at TUMBLING ROCK, there is said to be a natural shoal of 10 feet fall.

At FLAT SHOALS (Forge mills), three miles further down and about 18 miles above the mouth of the river, there was a dam about 350 feet long and 8 feet high, which gave a fall of 24 feet, affording what is said to be an excellent power. Half-way between the Flat shoals and the mouth of the river is located the MATTHEWS grist-mill, where a 7-foot dam gives a fall of 16 feet.

On *Stewarts creek*, a tributary of the Ararat, and four miles above where it joins the latter stream, is located the LAUREL BLUFF cotton-mill, a small factory with 2500 spindles, and a grist-mill attached. There is a dam 11 feet high and 125 feet long, giving a fall at the mill of 16 feet which, it is claimed, develops 100 horsepower nearly all the time.

On *Lovills creek*, another tributary of the Ararat, is located the ALPINE woolen-mill, about 3 miles from Mt. Airy, the mill operating 20 looms and 432 spindles. There is a dam 150 feet long and 5 feet high, giving a fall of 8 feet. The mill uses 30 horsepower, the available power being estimated at much more than this amount.

ALLRED'S woolen-mill, operating 240 spindles, 4 looms, 1 set card and 1 roll card, was located on this creek, 1½ miles below the Alpine mill; but this has been burned.

Fishers river and *Mitchells river* are the other tributaries of the Yadkin in Surry county, and on both of these there are a number of small waterpowers available, but none of special value have been reported. Both rise on the slopes of the Blue Ridge and flow through a region largely forest-covered, and the supply of water is but slightly affected by the dry seasons.

Elkin creek, which flows for the greater part of its course in Wilkes county, is used at Elkin for a cotton-factory (Elkin Manufacturing Company), with a fall of 22 feet from a dam 100 feet long and 7 feet high, and using 70 horsepower during nine months and about 50 during the remaining time. The factory contains 2000 spindles and 3 sets of cards. The waterpower is supplemented by steam-power.

About one-half mile above the Elkin Manufacturing Company's mill are the ELKIN VALLEY MILLS, which consist of a grist- and flour-mill, a shoe-factory and a tannery, and which use about 65 horsepower during the larger part of the year, from a pond which has a wood dam 13 feet high and 126 feet long, giving a fall of 18 feet at the wheel. This site was, until 1894, occupied by the woolen-mill of the Chatham Manufacturing Company.

About three miles above the Elkin Valley mills is a site known as CARTERS FALLS, which is an excellent small waterpower with an exceptionally large fall in a short distance.

In Wilkes county the more important tributaries of the Yadkin, *Roaring river*, *Rock creek*, *Mulberry river*, *Reddies river*, *Lewis fork*, *Stony fork* and *Elk creek*, all rise among the spurs of the Blue Ridge and flow as rapid mountain streams through forest-covered areas; and all afford numerous small powers, large enough and constant enough to run small factories, saw-, grist- and flouring-mills. The banks of these streams being generally high, dams can be built cheaply and without danger of overflowing large tracts of fertile land; so that a large part of the total fall of these streams may thus be rendered available for power, and there seems no doubt that a large amount of power can be utilized in this region. In the case of a majority of these streams it is probable that near their junction with the Yadkin they would afford from 2 to 4 horsepower per foot fall in dry seasons, and sites can be found here and there which can be easily developed so as to have falls of 20 to 30 feet. These powers have been rendered more accessible by the construction of the Wilkesboro railroad. The climate throughout this region is remarkably healthy and salubrious.

Reddies river rises on the southeastern slopes of the Blue Ridge and after flowing for about 20 miles, following the general course of the stream, in a southeasterly course, it empties into the Yadkin river just above the town of North Wilkesboro, draining in its course through the county an area of 47 square miles.

A short distance above the mouth of the stream there is a sash, door, blind and building material factory which obtains its power from this stream. There is a shoal with a natural fall of 4.6 feet and on this is built a 9-foot dam, giving a total fall of 13.6 feet. It is said that a 40-barrel capacity roller flour-mill will soon be completed here which will also use power from this development.

The following table will give in a more connected form a view of the drainage areas of the various streams tributary to the Yadkin:

DRAINAGE AREAS OF THE TRIBUTARIES OF THE YADKIN.

Stream.	Tributary to what.	Above what place.	Drainage area.
			Sq. miles.
Waccamaw river	Yadkin-Pee Dee	Mouth	1,295
do	....do	In North Carolina	782
Black river	....do	Mouth	1,510
Little Pee Dee river	....do	....do	3,022
Do	....do	In North Carolina	1,942
Do	....do	Mouth of Lumber river.	415
Lumber river	Little Pee Dee	Mouth	1,790
Black creek	Yadkin-Pee Dee	....do	457
Jones creek	....do	....do	96
Hitchcocks creek	....do	....do	102
Do	....do	At mouth of Falling creek	86
Falling creek	Hitchcocks creek	Mouth	12
Little river	Yadkin-Pee Dee	....do	400
Browns creek	....do	....do	206
Uharie river	....do	....do	317
Rocky river	....do	....do	1,405
Do	....do	At Garmen's mills	523
Long creek	Rocky river	Mouth	158
Richardsons creek	....do	....do	199
Lanes creek	....do	....do	140
Crane creek	Yadkin	....do	103
Grants creek	....do	....do	84
South Yadkin river	....do	....do	820
Do	....do	Hairstons falls	591
Third creek	South Yadkin	Mouth	215
Fourth creek	Third creek	....do	68
Bear creek	South Yadkin	....do	40
Dutchmans creek	....do	....do	18
Hunting creek	....do	....do	146
Do	....do	Factory	100
Rocky river	....do	Mouth	94
Do	....do	Factory	88
Second creek	South Yadkin	Mouth	108
Muddy creek	Yadkin	....do	179
Abbotts creek	....do	....do	198
Dutchmans creek	....do	....do	97
Deep creek	....do	....do	106
Little Yadkin river	....do	....do	58
Ararat river	....do	....do	315
Do	....do	Mount Airy	60
Stewarts creek	Ararat	Mouth	51
Lovills creek	....do	....do	52
Elkin creek	Yadkin	....do	63
Fishers river	....do	....do	90
Mitchells river	....do	....do	81
Roaring river	....do	....do	89
Mulberry creek	....do	....do	56
Reddies river	....do	....do	47
Cub creek	....do	....do	37
Moravian creek	....do	....do	31
Warrior creek	....do	....do	33
Buffalo creek	....do	....do	41

TABLE OF POWER UTILIZED ON THE YADKIN RIVER.[1]

Name of stream.	Tributary to what.	County.	Kind of mill.	Number of mills.	Total fall utilized.	Total horsepower utilized.
Yadkin-Pee Dee river	Atlantic ocean	Richmond	Flour and grist	1	6.5	8
Do	do	do	Cotton-gin	1	6.5	4
Do	do	Anson	Flour and grist	2	.....	24
Do	do	Montgomery	do	4	.....	49
Do	do	do	Cotton-mill	1	10.0	125
Do	do	Stanly	Grist-mill	2	17.0	.....
Do	do	do	Saw-mill and grist-mill	1	8.0	40
Do	do	Rowan	Grist-mill	3	16.0	.....
Do	do	Davidson	do	6	31.0	.....
Do	do	do	Saw-mill	2	10.0	.....
Do	do	Forsyth	Electric Power Co	1	10.0	1,000
Do	do	Yadkin	Grist-mill	1	18.0	10
Do	do	do	Saw-mill	2	29.0	26
Do	do	Caldwell	Cotton-factory	1	25.0	80
Waccamaw and tributaries.	Pee Dee	Brunswick	Flour and grist	1	9.5	6
Do	do	do	Saw	1	9.0	12
Little Pee Dee and tributaries	do	Columbus	Flour and grist	3	23.5	20
Do	do	do	Cotton-gin	3	24.0	.....
Do	do	Robeson	Flour and grist	27	195.0	259
Do	do	do	Saw	10	68.0	134
Do	do	Richmond	Ag. implements	1	5.0	6
Do	do	do	Flour and grist	8	6.0	74
Do	do	do	Saw	2	10.0	18
Gum Swamp creek	Little Pee Dee	do	Cotton-factory	1	12.0	90
Do	do	do	do	1	10.0	110
Do	do	do	do	1	7.5	85
Hitchcocks creek	Yadkin	do	do	1	16.0	350
Do	do	do	do	1	13.0	200
Do	do	do	do	1	22.0	300
Do	do	do	do	1	24.0	300
Do	do	do	do	1	10.0	100
Do	do	do	Grist-mill	4	.....	.....
Do	do	do	Saw-mill	2	.....	.....
Do	do	do	Cotton-gin, power-house	1	24.0	25
Falling creek	Hitchcocks creek	do	Cotton-factory	1	45.0	150
Do	do	do	Grist-mill	1	.....	.....
Little river	do	Montgomery	Saw-mill	2	27.0	42
Do	do	do	Flour and grist	7	77.0	127
Rocky river and tributaries	do	Anson	do	3	21.0	45
Do	do	do	Saw	2	14.0	22
Do	do	Stanly	Flour and grist	12	85.0	258
Do	do	do	Saw	4	28.0	80
Do	do	Union	do	1	10.0	20
Do	do	do	Flour and grist	8	72.0	122
Do	do	Cabarrus	do	20	220.0	321
Do	do	do	Saw	8	.....	60
Do	do	do	Cotton-gin	8	34.0	55
Do	do	Mecklenburg	Flour and grist	2	38.0	27
Do	do	Rowan	do	6	92.0	42
South Yadkin river and tributaries	Yadkin river	do	do	11	124.0	148
Do	do	Davie	do	8	101.0	171
Do	do	do	Saw	8	87.0	88
Do	do	Iredell	do	6	97.0	109
Do	do	do	Leather	1	15.0	10
Do	do	do	Cotton gin	8	56.0	31
Do	do	do	Flour and grist	30	456.0	480
Do	do	do	Cotton-factory	2	37.0	140
Do	do	Alexander	do	4	60.0	92
Do	do	do	Saw	1	12.0	15
Do	do	do	Furniture	1	7.0	10
Do	do	do	Blacksmithing	1	7.0	4

[1] Compiled principally from returns of the tenth census.

TABLE OF POWER UTILIZED ON THE YADKIN RIVER.—*Continued.*

Name of stream.	Tributary to what.	County.	Kind of mill.	Number of mills.	Total fall utilized.	Total horsepower utilized.
Other tributaries of	Yadkin	Richmond	Flour and grist	3	50.0	54
Do	do	do	Cotton-gin	1	10.0	20
Do	do	Montgomery	Flour and grist	9	.....	92
Do	do	do	Saw	1	8.0	15
Do	do	Randolph	do	6	52.0	66
Do	do	do	Flour and grist	13	206.0	192
Do	do	Davidson	do	28	240.0	446
Do	do	do	Saw	12	80.0	154
Do	do	do	Cotton-gin	1	9.0	4
Do	do	Forsyth	Flour and grist	13	227.0	188
Do	do	Stokes	do	5	70.0	56
Do	do	do	Saw	3	.....	73
Do	do	Anson	do	2	23.0	36
Do	do	do	Flour and grist	7	125.0	137
Do	do	Mecklenberg	do	2	38.0	27
Do	do	Rowan	do	13	.....	132
Do	do	Davie	do	7	.....	75
Do	do	do	Saw	1	9.0	8
Do	do	Yadkin	Flour and grist	12	....	171
Ararat river	do	Surry	Cotton-mill	1	14.0	40
Do	do	do	Grist and flour			
Do	do	do	Saw and grist	1	15.0	.....
Do	do	do	Grist-mill	1	16.0	.....
Stewarts creek	Ararat	do	Cotton-mill	1	16.0	100
Lovills creek	do	do	Woolen-mill	1	8.0	30
Elkin creek	Yadkin	do	Cotton-factory	1	22.0	70
Do	do	do	Shoe-factory	1	18.0	65
All other tributaries of	do	do	Saw	4	53.0	37
Do	do	do	Flour and grist	11	163.0	110
Do	do	Wilkes	do	12	140.0	102
Do	do	do	Saw	2	12.0	14

CHAPTER IX.

THE CATAWBA RIVER AND TRIBUTARIES.[1]

THE CATAWBA RIVER.

The Catawba river rises on the eastern slope of the Blue Ridge, in McDowell county, North Carolina, its main source being between the Blue Ridge and a spur of the same known as Bald mountain. It first flows nearly northeast into Burke county, and then nearly east between Caldwell and Alexander on its left and Burke and Catawba counties on its right. It then bends quite abruptly toward the south, and flows in a direction a little east of south between Iredell and Mecklenburg counties, North Carolina, and Lancaster, Kershaw and Sumter counties, South Carolina, on its left, and Catawba, Lincoln and Gaston counties, North Carolina, and York, Chester, Fairfield and Richland counties, South Carolina, on its right, uniting with the Congaree to form the Santee. It also flows for a short distance through Kershaw county, South Carolina. Its general course is seen to be nearly parallel to that of the Yadkin and Great Pee Dee. The river is known as the Catawba down as far as the mouth of the Big Wateree creek, in Fairfield county, South Carolina, below which point it is known as the Wateree. Its total length, in a straight line, is about 160 or 170 miles, but by the general course of the river it is nearly 225 miles, and over 300 miles if all its windings are followed. The length of the Wateree is about 105 miles, and the total length in South Carolina about 160 miles. The principal town on the river is Camden, South Carolina, there being no important ones above.

The stream is navigable as high as Camden, it being probably practicable to secure a depth of 2 feet and over up to this place. Above Camden the fall of the stream is so great that navigation is not practicable. About the year 1826 the state of South Carolina attempted to render the river navigable by means of locks, dams, and canals, and several very extensive and important works were constructed at great expense; but the undertaking is said to have been given up before the works were completed.

The total area drained by the stream embraces about 5225 square

[1] By Geo. F. Swain and J. A. Holmes.
[2] Annual Report Chief of Engineers, 1880, p. 915.

miles (of which 3085 are in North Carolina), and the drainage basin resembles in many respects that of the Yadkin, so that it need not be described here in detail. Like the Yadkin, the upper part of the river flows between parallel ranges of mountains, from which it receives a number of tributaries, affording considerable waterpower, and with a rapid fall, the width of the valley being about the same as that of the Yadkin. In the lower half of its course in North Carolina the valley of the Catawba is very narrow—not over 15 or 20 miles in width—and it receives only one important tributary, the South fork, which enters from the west near the South Carolina line, after draining an area of about 730 square miles. Below this point the valley is wider, but there are no tributaries of much importance. A few miles above Camden the river crosses the fall line, and below that point it partakes of the general character of the streams of the eastern division. The country drained by the river is very fertile and well populated, the productions being about the same as in the Yadkin valley. The valley abounds in building stone of the best kind. In Gaston, Lincoln, and Catawba counties there are fine deposits of iron ore and a number of deposits of gold ore; and in Gaston county are several valuable deposits of pyrites.

As regards bed, banks, freshets and bottoms, the river resembles the Yadkin, except that the bottoms are narrower in the lower half of its course in North Carolina. There are no lakes in the basin, but in the upper part the facilities for storage are said to be good. The soil in this upper part is generally porous, and at least 65 per cent. of the area in Burke, Alexander, Caldwell and McDowell counties is forest-covered.

The average rainfall in the basin is about 50 inches, of which about 12 fall in spring, 14 in summer, 10 in autumn, and 14 in winter. Toward the upper part of the stream, however, the rainfall in winter increases, and is probably greater than in the summer.

The elevation of the stream at different points is given in the following table, from which it will be seen that the fall is very great for such a large stream; and it is this large fall which has prevented the river from having ever been made navigable, although, as already remarked, many years ago the state of South Carolina expended a great amount of money endeavoring to make it navigable by means of locks, dams and canals.

The flow of the river was measured by Professor Kerr near Hickory, giving 2156 cubic feet per second, which is evidently not the low-season flow, as the drainage area above this point is not much over 1000 square miles.

Measurements of flow were made by the Geological Survey in 1896, 1897 and 1898 at Rock Hill, S. C. (drainage area given as 2987 square

TABLE OF DECLIVITY OF THE CATAWBA AND WATEREE RIVERS.

Place.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall between points.
	Miles.	Feet.	Miles.	Feet.	Feet per mile.
Junction with Congaree	0	80±			
			125	285	2.28
Crossing of Charleston and Northwestern railroad (narrow gauge)	125	365			
			25	131	5.24
Crossing of Charlotte, Columbia and Augusta railroad	150	496			
			20	52	2.60
Crossing of Piedmont Air Line (Southern) railroad	170	548			
			55	206	3.75
Crossing of Western North Carolina railroad	225	754			
			25	161	6.45
Five miles northwest of Hickory	250	915			
			18	104	5.78
Morganton	268	1,019			
Mill creek, two miles east of Old Fort		1,370	50	413	8.26
Mill creek at Old Fort	318	1,432			
			8+	598	74.75
Mill creek, last crossing of Western North Carolina railroad	326±	2,030			
			8+	628	78.50
Swannanoa gap (headwaters)	334±	2,658			

miles), and at Catawba, N. C. (drainage area given as 1535 square miles); and a statement of the results will be found on pp. 312-319 of this report.

At Rock Hill, S. C., the smallest flow measured was 1336 cubic feet per second, or 0.45 cubic foot per second per square mile, and the maximum was 46,040 cubic feet per second, or 15.5 cubic feet per second per square mile.

At Catawba, N. C., the smallest flow measured was 732 cubic feet per second, or 0.48 cubic foot per second per square mile, and the maximum was 9711 cubic feet per second, or 6.3 cubic feet per second per square mile.

These measurements, however, have not been extended over a sufficiently long period of time for them to serve as a reliable basis for computing the minimum or the low-season flow.

The map shows the railroads which cross the stream, from which it will be seen that it is easily accessible in almost all of its parts.

It may be mentioned here that the width of the river between the mouth of Wateree creek in South Carolina (where the Catawba becomes the Wateree) to the North Carolina line varies from 300 to 3000 feet, while its banks vary in height from 10 to 100 feet, being generally nearer the lower figure.

WATERPOWER ON THE CATAWBA RIVER.

We may now proceed to describe with as much detail as the information in hand will permit, the more important waterpowers on the Catawba in North Carolina, ascending from the mouth of the South fork at the South Carolina line.

The river was surveyed in 1824, under authority of the state of North Carolina, between the state line and Moores shoals, 10 miles below Morganton, by Mr. Hamilton Fulton, a portion of whose map and profile is in the office of the state geologist in Raleigh, from which the table of shoals further on is condensed.[1] Beside the shoals mentioned in the table, there are numerous others of smaller fall, but which, however, may be more favorable for power than those named, being perhaps more favorably located, and permitting the erection of high dams. All these points can only be determined by a survey.

Near the state line there are several shoals with falls of from 3 to 5 feet, some of which have been used to a limited extent, but there is so often trouble from high water that these sites are unsuitable for factories.

At Ross FALLS, located a short distance above the state line, there is said to be a fall of 8.1 feet in a distance of 0.9 mile.

At ROCK ISLAND SHOAL is now located, on the Mecklenburg side of the river, a grist- and saw-mill, owned by Hilton & Erwin. There is a wing-dam about 350 feet long and 5 feet high which gives a fall at the mill of about 9 feet, and the power used is about 60 horsepower. There were formerly located here the Rock Island woolen-mills.

The TUCKASEGEE SHOAL, about 9 miles above the state line and one mile below the Carolina Central railroad crossing, is a waterpower of considerable importance, and has been more largely developed than those below it. The natural fall here is said to be 11.22 feet in a distance of 1.02 miles. The Tuckasegee Manufacturing Company's cotton-mill, located on the Gaston or west side of the shoal, contains 55 cards and 6000 spindles, all operated by water, about 150 horsepower being used. There is a wooden wing-dam about 200 feet long, giving a fall of water at the mill of 11 feet. There is never any trouble from low water, but high water interferes with the running of the mill during an average of 6 days in the year. As seen from the table given on page 212, the "minimum" or lowest possible power of the dryest season here should be about 425 horsepower.

MOUNTAIN ISLAND SHOAL.—Three miles above the Tuckasegee shoal is the fourth power on the Catawba in North Carolina, at Mountain

[1] Extract from Annual Report Chief of Engineers, 1876, p. 33, *et seq.*

Island shoal, about 3 miles above the Carolina Central railroad, and above the mouth of Dutchmans creek. The fall in the river between a point one mile above the factory, or a little above the head of the shoal, and the railroad bridge below is 38 feet,[1] but of this fall nearly 30 feet occurs in one mile near the factory. The bed of the stream is rock, the banks on the east side steep, while they are shelving on the west and very favorable for building, with no danger from high water. The power is utilized to a small extent by the cotton-factory of the Catawba Electric Power Company, containing 6300 spindles, 100 looms and 48 cards. At the head of the shoal is a series of three small islands near the right bank, with the distance of only a few feet between them and the shore, and between the islands and the shore a certain amount of water flows naturally, with no dam to turn it in. This water is all that is used by the factory, there being no dam at the head of the islands except a wing-dam of wood, 300 feet long and 4 feet high, used to turn the water into the "race," and the only other dams are three slough-dams, connecting the islands with each other and the lowest one with the shore, the two former of which are of rough stone and the third of crib-work, and about 40 feet long and 8 feet high. From the foot of the lowest island an artificial race about 600 feet long leads to the factory, where a fall of 22½ feet is used and about 190 horsepower; in addition to which there is a grist- and saw-mill and a cotton-gin, using together 50 to 60 horsepower and 15 to 16 feet fall. Full capacity can be secured all the time. The total distance between the head of the small islands referred to and the factory is about three-quarters of a mile, below which the fall continues for a short distance. The fall in the canal is considerable, and the total fall down to the factory is in the neighborhood of 26 feet.

The drainage area above this shoal being about 1538 square miles, the power is estimated as follows:

TABLE OF POWER AT MOUNTAIN ISLAND SHOAL.

State of flow.	Drainage area.	Fall.	Flow, per second.	Horsepower available, gross.		
(See pages 54 to 59.)[2]	Square miles.	Feet.	Cubic feet.	1 foot fall.	25 feet fall.	30 feet fall.
Minimum	1,538	30[3]	300	34.1	850	1,000
Minimum average for the low season			380	43.2	1,080	1,300
Average for the low season of average dry years.			450	51.1	1,275	1.500

[1] From information furnished by B. S. Guion, C. E., Lincolnton, N. C.

[2] For later measurements of the flow of Catawba river, see pp. 312 to 319.

[3] See description.

The whole of this power is easily available on the west bank, with good facilities for buildings and canals. A series of mills could be built, using an average fall of 25 feet or more, and with little trouble from high water, and none from ice. The east side is not so favorable. It is to be remarked that the pond would probably be small, and the power could not be concentrated into fewer than 24 hours except by reservoirs elsewhere. The shoal is 12 miles from Charlotte and 3 miles from the Carolina Central railroad, with which it might easily be put in communication by rail. It is in the cotton-belt, and in a most healthy part of the country. It is one of the most available powers in North Carolina.

Just above Mountain island the river makes a remarkable bend, or horseshoe, the distance by land across the chord being 1½ miles, while it is 7½ miles around by the river.[1] This bend has been talked of as a site for waterpower, which would afford a large fall if the bend were cut through. According to Professor Kerr, however, the river is sluggish along the bend, and the total fall is small, some 9 or 10 feet only.

Of the shoals above Mountain island but few have been utilized, and these to only a small extent. They have not been examined by the writers, and the information here given concerning them has been derived from the reports of the Chief of Engineers of the United States Army, the chart made by Hamilton Fulton in 1824, and by correspondence from persons living in the region through which the river passes. The names given to these shoals are those which were in use many years ago, and in a few cases other names may have been in part substituted for those here given.

Cowan ford shoal, the first important shoal reported above Mountain island, has a fall of 27.25 feet in a distance of 4.17 miles. As shown in the table below (p. 212), the estimated minimum power here for the dryest seasons is 900 horsepower; but the extent to which this power can be rendered available can only be determined by a careful survey of the entire shoal.

Beatties ford shoal is about 6 miles further up the river. This latter is reported to be a good power but is undeveloped. Its availability can be determined only by a careful examination. It has a fall of 13 feet in 2.38 miles, and 8 feet of this fall is said to occur in about 1000 feet, where the stream has a width of about 100 yards and a good rock bottom suitable as a foundation for a dam. Its estimated power for the total fall (13 feet) in the dryest of dry seasons is 420 horsepower.

[1] Annual Report Chief of Engineers, 1876, app. G, p. 31.

In ordinary seasons the power would be considerably greater. A fuller tabular statement of the power of this shoal is given below (p. 212).

The MONBO SHOAL (old Granite shoal), 2 miles above Sherrills ford and 2 miles below the Buffalo shoal, is the first of the shoals above Mountain island which is now utilized to any considerable extent. Here the cotton-mill of the Monbo Manufacturing Company (formerly the Granite shoals mill of the Catawba Manufacturing Company), operating 7 cards, 43 looms and 1600 spindles, is located on the west bank of the river 8 miles southeast of Catawba, the nearest station on the Western North Carolina railroad. At this point the river is about one-fourth mile wide and divided by islands. From the Monbo mill a dam 225 feet long and 4 feet high extends across a division of the river to Goat island, and thence a wing-dam 2 feet high extends up the river nearly 800 feet to the lower end of Long island, which many years ago was known as Crawfords island. This wing-dam and island divide the river into two parts; the western portion forms the power for the Monbo mill, the eastern or Iredell side is still an undeveloped shoal. The Monbo mill has a six-foot fall of water at the wheel and uses about 60 horsepower, this being but a small part of the power available. The running of the mill is never interfered with by low water, but high water interferes during a few days of each year.

LONG ISLAND SHOAL (formerly known as the Crawford Island shoal), about one mile above the Monbo mill, like the latter, is located on the Catawba or west bank of the river, and derives its power from a shoal in that part of the river between the west bank and Long island. The cotton factory (Long Island mill) located here is 7 miles southeast of the nearest railroad depot—Catawba station, on the Western North Carolina railroad. It operates 10 sets of cards and 3000 spindles, using about 60 horsepower, a small part of the power available. The dam is about 300 feet long, extending from the west bank to Long island, and is 3 to 6 feet high, the fall of water at the mill being 6.5 feet. The old Crawford Island shoal as measured by Hamilton Fulton (1824) is recorded as having a fall of 23.44 feet in 1.69 miles, and this shoal has an estimated minimum of 700 horsepower in the dryest of dry seasons, while in ordinary seasons the power would be much greater. Whether this measurement included both the Monbo and Long Island shoals as described above, or only the latter, cannot now be determined without a remeasurement. The table below gives the estimated power of the total fall (23.44 feet) at these shoals (p. 212).

BUFFALO SHOAL, about 2 miles above Long Island shoal, has a fall of 11.4 feet in a little more than half a mile (.66). It is said to be a good site for waterpower, but is undeveloped at the present time. The minimum dry season power estimated for this fall (11.4 feet) is 325 horsepower, while in ordinary seasons the power would be much greater. This shoal is but a short distance below the Western North Carolina railroad. (See table of power, p. 212.)

About 7 miles above Buffalo shoals and a less distance above the railroad, is a shoal with a fall of 9.7 feet in a distance of 2.18 miles, and 2 miles higher up the river is another shoal with a fall of 8.6 feet in a distance of 1.32 miles. The first of these has an estimated minimum dry season flow equivalent to 250 horsepower; and the latter of 225 horsepower. During ordinary seasons the power would be much greater than this (p. 212).

LOOKOUT SHOAL, the lower end of which is 1.3 miles above the last-mentioned shoal and 6 miles (across country) above the Western North Carolina railroad at Catawba station, has the greatest fall of any shoal on the river in North Carolina, the descent being 54.25 feet in a distance of 3.2 miles. About 30 feet of this fall is said to occur in a distance of three-fourths of a mile, the river at this place having a width of about 900 feet. The bed of the river is of rock, and there is said to be an abundance of stone of good quality convenient for building, and good factory sites on both sides of the river. The shoal has been developed to only a small extent, being used for a saw- and roller flour-mill. It is evidently an excellent waterpower, as shown by the table below, which indicates the minimum estimated power for the total fall (54.25 feet) in the very dryest possible season to be 1450 horsepower, while the power during ordinary dry seasons would be much greater than this (p. 212).

LOWER LITTLE RIVER SHOAL, about one and one-third miles above the top of Lookout shoal, is between the upper end of Druin island and the lower end of Three-cornered island, with a fall of 9.7 feet in a length of 1.16 miles. Its estimated minimum in the dryest season is 260 horsepower, that in ordinary dry seasons being much greater than this. Between the upper end of this shoal and the mouth of Lower Little river are small shoals having a fall of 3.36 feet in a distance of nearly one mile.

CANOE-LANDING SHOAL, about two miles above the mouth of Lower Little river, has a fall of 8.94 feet in a distance of 1.87 miles. As will be seen from the tables given below, the estimated minimum power of this shoal on the basis of the natural fall (8.94 feet) in the dryest season of the dryest year is 225 horsepower. During ordinary dry seasons the power would be much greater (page 212).

GREAT FALLS SHOAL, just above the Canoe-landing shoal, has a fall of 14.82 feet in a distance of 1.02 miles. It has an estimated minimum in the dryest possible season of 375 horsepower, while in ordinary dry seasons the power would be much greater than this (page 212).

These two shoals considered together have a total fall of 23.76 feet in a distance of 2.89 miles. And it may be possible to develop the two together into one fine power, but the cost and practicability of this can be determined only by careful surveys.

HORSEFORD SHOAL, 3 miles north of Hickory, and about 5 miles below the crossing of the Carolina and Northwestern (narrow gauge) railroad, as will be seen from the table below, has a fall of 31.4 feet in 2.9 miles. The power is being utilized here to a limited extent only. On the upper part of the shoal a fall of 6 feet is being used to run the Catawba lumber-mills, and on the middle portion of the shoal are located the Horseford saw- and grist-mills (the latter with three run of stones), using about 25 to 30 horsepower. This is undoubtedly one of the largeest and most available, as well as most accessible, waterpowers of the upper Catawba river. It has been purchased recently by the Odell Manufacturing Company, with the reported purpose of developing the entire power at an early date. Transportation facilities are good, the site being within 3 miles of the Western North Carolina railroad at Hickory, and within a shorter distance of the narrow gauge railroad. A track could easily be built to the shoals from either of these roads. The table below indicates the estimated minimum power at this shoal in the dryest of dry seasons to be 700 horsepower, and for ordinary dry seasons the figure would be considerably larger (page 212). The development of this shoal is said to be already in progress.

DEVIL SHOAL, the lower end of which is 6 miles above the Horseford shoal, has a fall of 13.78 feet in a distance of 1.01 miles and is said to be a fine location. The estimated power of this shoal is indicated in the general table given below, where it will be seen that the estimated minimum in the dryest season of the dryest year is 290 horsepower, and much greater during ordinary dry seasons (p. 212). The shoal is about three miles from the Western North Carolina railroad, very close to the line of the narrow gauge railroad, and is about 6 miles northwest of Hickory. A ledge of rock is reported to extend entirely across the river, offering a good site for a dam.

ROCKY FORD SHOAL, at Morganton, and some 20 miles above Devil shoal, has a natural fall of 9.5 feet in a distance of about 1500 feet. As shown in the table below, the estimated minimum in the dryest possible season is 100 horsepower, while during ordinary dry seasons the power would be considerably greater than this (see table on p. 212). This power was formerly used for a grist-mill and there was a dam 2 feet high and 400 feet long, giving a fall of 11.5 feet at the mill; and the wheel gave 60 to 70 horsepower with water wasting all the while. This mill is not now in use.

Above Morganton the river has a rapid fall, but it is more uniform than below, the shoals being more numerous, but not with such sudden descents. Between Morganton and the mouth of Mill creek there are 197 shoals, with an average fall of about 2 feet, the distance being 50 miles. The valley narrows gradually to one-half mile in width.

In McDowell county the river forks into Mill creek, which the Western North Carolina railroad follows, and the South Catawba, on which occur the Catawba falls, where the fall is said to be several hundred feet in a short distance, but the stream is too small to be much used for power. Both of these streams, as well as the others which enter the Catawba in McDowell county, are mountain streams, with a large fall and often abrupt descents of many feet, forming cascades and cataracts of great beauty. Some of them are used by small grist- and saw-mills.

SUMMARY OF POWER ON THE CATAWBA RIVER.[1]

Locality.	Distance from state line (or mouth of South fork).	Drainage area.	Rainfall.					Total fall.		Horsepower[2] available, gross.			Utilized.	
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length of shoal.	Minimum.	Minimum average for the low season.	Average for the low season of average dry years.	Horsepower, net.	Fall.
	M's	Sq.m.	In.	In.	In.	In.	In.	Feet.	Miles					Feet.
Mouth of South fork Catawba (state line)	.0	......	....	....	....	....	....	......	......	......	......	......	......	......
Ross falls	1.2	1,725	12	14	10	14	50	8.13	0.90	300	400	450	......	......
Rock Island shoal	....	1,700	12	14	10	14	50	9.00	....	260	400	480	60	9.0
Tuckaseegee shoal	9	1,670	12	14	10	14	50	11.22	1.02	425	525	600	150	11.0
Mountain Island shoal	15	1,538	12	14	10	14	50	46.52	3.10	1,600	2,000	2,300	250	22.0
Abernathy's falls	18	1,500±	12	14	10	14	50	3.93	0.22	130	170	200	......	......
Cowans ford shoal	28	1,455	12	14	10	14	50	27.25	4.17	900	1,125	1,300	......	......
Beatties ford shoal	34	1,420	12	14	10	14	50	18.00	2.38	420	520	600	......	......
Sherrills ford shoal (Monbo shoal)	50	1,342	12	14	10	14	50	13.13	1.88	400	500	600	60	6.0
Crawford Island or Long Island shoal	52	1,307	12	14	10	14	50	23.44	1.69	700	870	1,000	60	6.5
Small shoals	54	1,290	12	14	10	14	50	3.93	0.65	120	150	175	......	......
Buffalo shoals	55	1,287	12	14	10	14	50	11.41	0.66	325	400	475	......	......
Buffalo shoals	63	1,205	12	14	10	14	50	9.71	2.18	250	325	375	......	......
Buffalo shoals	64	1,200	12	14	10	14	50	8.64	1.32	225	300	350	......	......
Lookout shoals	65	1,184	12	14	10	14	50	54.25	3.20	1,450	1,850	2,100	small	small
Lower Little river shoals	71	1,180	12	14	10	14	50	9.70	1.16	260	325	375	......	......
Canoe-landing shoal	73	1,125	12	14	10	14	50	8.94	1.87	225	280	325	......	......
Great falls	75	1,100±	12	14	10	14	50	14.82	1.02	375	475	515	......	......
Horseford shoal	85	964	12	14	10	14	50	31.43	2.91	700	875	1,000	small	small
Shoal	89	935	12	14	10	14	50	8.88	1.82	190	240	275	......	......
Devil shoal	91	918	12	14	10	14	50	13.78	1.01	290	360	425	......	......
Rocky ford shoal	102	557	12	14	10	14	50	9.50	0.30	100	140	160	......	9.5

[1] For measurements of the flow of the Catawba river, see pp. 312 to 319.

[2] See pages 54 to 59.

TRIBUTARIES OF THE CATAWBA—SOUTH FORK.

The first of the tributaries to the Catawba river in North Carolina is the South fork, which enters the main stream just at the state line, and which is noted for its waterpower. It is formed near the center of Catawba county by the union of two forks, Henrys and Jacobs forks, both of which take their rise among the South mountains in the southern part of Burke county and flow nearly east into Catawba county. From the junction of these forks the river pursues a course a little east of south through Catawba, Lincoln and Gaston counties, entering the Catawba river at the southeastern corner of the latter, after draining a total area of about 730 square miles. Its tributaries, with the exception of the forks above mentioned, are all small streams, not worthy of special notice. The river passes within a mile or two of Lincolnton and within 3 or 4 miles of Newton, the county-seats of Lincoln and Catawba counties, respectively, and the most important towns in the vicinity. The character of the drainage area and of the stream, differing in no particular respect from that of the Catawba river in its course in North Carolina, need not be described in detail. The rainfall is about 51 or 52 inches, distributed as follows: spring, 12; summer, 14; autumn, 10; winter, 16.

The stream has a rapid fall from Lincolnton down to its mouth, as will be seen from the following table, and in fact it is nothing but a series of rapids between those points, with few bottoms subject to overflow. From Lincolnton up to the junction of Henrys and Jacobs forks it is flat, with no large powers, and with considerable areas subject to overflow.

TABLE OF DECLIVITY OF THE SOUTH FORK OF THE CATAWBA.

Locality.	Distance from mouth.	Elevation above tide.	Distance between points.	Difference of level between points.	Fall between points.
	Miles.	Feet.	Miles.	Feet.	Feet per mile.
Crossing of Charlotte and Atlanta Air Line railroad	8	610			
			17	94	5.5
Crossing of Charleston and Northwestern (narrow gauge) railroad	25	704			
			6	45	7.5
Crossing of Carolina Central railroad	31	749			

There are no reliable records of gaugings of the river. The stream is subject to heavy freshets, which overflow the banks in places, but the fall is so rapid below Lincolnton that the rise is not extreme in that portion of its course. The bed is uniformly rock at the shoals, overlaid between by gravel, clay and sand. The stream is easily accessible from three railroads, as the map shows. The Charleston and Northwestern (Chester and Lenoir) narrow gauge road has done much towards opening up the resources of the region along this stream, as well as on the Catawba.

The more important powers on this stream are as follows, in their order, ascending:

STOWESVILLE COTTON-MILL, 3 miles from Belmont station on the Southern railroad, is utilizing the first important shoal on the river, being located on its east bank, about 4 miles above its junction with the Catawba. The mill contains 24 looms, 2250 spindles and 16 cards, operated by waterpower alone. The dam is 5 feet high and 200 feet long, built of wood and stone, making a small pond, giving, through a race 500 to 600 feet long, a fall of 16 feet at the wheel. There is ample power all the time, but high water causes occasional short interruptions, the power used being perhaps 50 to 60 or more horsepower for the factory. Near the latter is a grist-mill, and on the opposite side of the river a saw-mill and cotton-gin, the total power used being perhaps 100 horsepower. The factory is run night and day, and there is always waste of water. The estimate of the power available at this place will be found in the table.

SPRING SHOAL, the next power on the river, is the site of the McAden mills, located six miles above the Stowesville mill, just above the mouth of Duharts creek and 1½ miles from Lowell station on the Southern railroad. The mill contains 320 looms and 15,000 spindles. The dam is 5 feet high and 500 feet long, and the fall at the factory is 23½ feet, developing one of the best powers on the river. The fall of the shoal is about 24 feet in about 500 feet, and in less than half a mile there is said to be nearly 30 feet fall over a bed of solid rock, with rock banks, very favorable for building on one side. The dam, built in 1881 at a cost of $1200, is of timber bolted to the rock, extending diagonally across the stream, 2½ feet high and 600 feet long, backing the water about three-fourths of a mile. From it a race 350 feet long, 50 feet wide and 6 feet deep leads to the factory, where the fall is 23½ feet. The two 42-inch Victor turbines on horizontal shafts are said to be capable of developing 750 horsepower under a head of 24 feet. Only part of this is necessary to operate the machinery. The table on page 218 gives an estimate of the power available. This shoal is in the middle of the cotton belt, with good building stone (gneiss) near-by, an abundance of timber, and in very healthy country (Plate IX).

MASSEY SHOAL.—This name has been applied primarily to the lower of three shoals so close together that they can be developed as one power. The upper shoal was formerly occupied by the mill of the

B - McADEN MILLS AND TAIL RACE, SOUTH FORK OF CATAWBA RIVER

A - DAM AND HEAD OF RACE, McADEN MILLS

Woodlawn Manufacturing Company, and the middle shoal by the cotton-factory of the Lawrence Manufacturing Company; but all three of the shoals now belong to the Coats Company of Philadelphia. They have a combined fall of 25.9 feet in a distance of about a mile. The estimated minimum power of the combined shoals in the dryest of dry seasons is about 375 horsepower, while during ordinary dry seasons it would be much greater than this.

SPENCER MOUNTAIN MILL, 3 miles above the Massey shoal and 12 or 13 miles above the mouth of the river, contains 6000 spindles and 30 cards, and uses about 100 horsepower. The wooden frame dam, 600 feet long and from 2 to 7 feet high, gives a fall of 13 feet at the wheel through a race 190 feet long. The fall here might be increased, it is said, the available fall being reported as 18 feet or more. There is considerable fall below the mill, which is therefore never troubled with high water. If the full 18 feet fall be developed the resulting power should not be less than 240 horsepower even in the dryest possible seasons, and during ordinary seasons it should be much greater (p. 218).

The next is an unimproved site with about 4 feet fall, where there was formerly a mill.

FRIDAY SHOAL, a rock shoal, said to have 10 feet fall and to be a good power. It is below the mouth of Kettle-shoal creek and about one mile from the Carolina and Northwestern railroad. This site is now occupied by the cotton-mill of the Harden Manufacturing Company, which contains 2080 spindles. The dam is 6 feet high and 200 feet long, giving a fall of 16 feet at the mill, which probably uses 80 to 85 horsepower, available during the dryest possible seasons.

HIGH SHOALS, the next power, is one of the best on the stream. It is situated between the mouths of Kettle-shoal creek and Hynes creek, 7 miles from Lincolnton and one from the Carolina and Northwestern railroad, which crosses the river just below it. The stream here flows over a ledge of solid gneiss rock, the fall being about 22 feet in 300; but the fall continues below for some distance, amounting to 27 feet in 600, and probably 35 feet in a quarter of a mile or more. The banks are quite abrupt on both sides, but there is still abundance of room for building, the best location being on the left bank. The whole flow of the stream can easily be controlled, the facilities being in all respects most excellent. The width of the stream is 300 feet above the fall, and probably greater below, the channel being cut up with islands and rocks. Just below the principal fall a small creek enters the river from the left, which could be utilized well as a tail-race if the mills were situated on the hill by which it flows. This power was used until about 25 or 30 years ago to drive iron works (rolling-mill, nail-factory and others), together with a grist- and a saw-mill situated on the left bank, and using together 180 horsepower. The ruins of the old iron works are still to be seen, and it is evident that they utilized a fall of between 22 and 27 feet. The drainage area above is 518 square miles. No gaugings have been made which will enable us to estimate the power at this fine site. In the immediate vicinity are some of the most noted deposits of iron ore in the state. The Carolina and Northwestern railroad will afford the best facilities for transportation. It is expected that this excellent power will be fully developed in the near future by a company of which D. A. Tompkins of Charlotte is the manager.

LONG SHOALS COTTON-MILL is situated on the river just below the mouth of Indian creek, and four miles below Lincolnton, on a shoal of the same name. The banks here are favorable for building on the left side, where the mill is situated. This mill contains 5200 spindles, and is run by waterpower alone. The fall of water at the mill is 13 feet from a race about 300 feet long, and it is expected to develop 300 horsepower in ordinary seasons. The dam, of wood and stone, is 13 feet high and 300 feet long.

MOSTELLERS SHOAL, unimproved, about one-half mile above Long shoal, has a fall of 7 feet over rock bottom.

The LINCOLN MILL, the next power on the river, is on the site of the old paper mill owned by W. & R. Tiddy, of Charlotte, and is located four miles below Lincolnton. The mill contains 5000 spindles. The dam is of wood, about 276 feet long and 11 feet high, giving a fall of 13 feet at the wheel, and it is said that 150 horsepower can be obtained here at all times and with no waste in summer.

THE LABORATORY COTTON-MILL, containing 6500 spindles, is located on the river half a mile above the Lincoln mill and above the mouth of Indian creek but below that of Sand branch. The dam is of logs, 6 feet high and 500 feet long, giving a fall of 9 feet at the mill. The pond is large, and the power used can be obtained practically all the time, though there is a reported loss of a few days on account of high water.

The LINCOLNTON SHOAL, located within the town limits, is the next power and is the site of Elm Grove cotton-mill, which was formerly operated by waterpower, obtained from a fall of 6½ feet. But the factory is now operated entirely by steam; the waterpower has been abandoned and the dam removed. Further up the river and on its higher tributary branches there are a number of excellent small powers, some of which are utilized in operating saw- and grist-mills and others are undeveloped, but no special examination of these has yet been made, and they cannot be described in the present report.

It will be seen that the south fork of the Catawba is an excellent stream for power, a large amount of which is already utilized. The climate in the vicinity is salubrious, the agricultural and mineral resources of the country very large, and the facilities for manufacturing in all respects hardly to be excelled.

TRIBUTARIES OF CATAWBA ABOVE SOUTH FORK.

DUTCHMANS CREEK.

Dutchmans creek enters the Catawba just above the crossing of the Carolina Central railroad, and is the next tributary worth mentioning above the South fork. It rises in Lincoln county and flows nearly south, draining an area of 88 square miles, and is a small stream with only three powers worth referring to.

The Mount Holly mill, located in the town of Mount Holly, one and one-half miles above the mouth of the creek, operates 2500 spindles. Here a fall of 8 feet is used and 50 horsepower is obtained for nine months of the year and 35 for the remaining three, a steam-engine being used for that time. There is no water waste in dry summers, the mill being run all the time. There is some trouble from high water, the stream being subject to heavy freshets, and there not being many low grounds subject to overflow.

The Nims Manufacturing Company's cotton-mill, also on Dutchmans creek, contains 3000 spindles, operated by waterpower, supplemented by steam-power for two or three months of the year. The dam is 8 feet high and 110 feet long, the fall of water 10 feet, and the power said to be developed 80 to 100 horsepower for nine months.

The Mariposa cotton-mill, containing 1664 spindles, is located on Leipers creek, known as Dutchmans creek in the lower part of its course, about 12 miles above its junction with the Catawba river.

The dam is of wood, 10 feet high and 100 feet long, and backs the water about one-fourth of a mile with an average width of 60 feet. There is no race, the fall at the wheel is 14 feet, and about 60 horsepower is developed by a 40-inch Leffel turbine. It is stated that about 100 horsepower is required to operate the machinery, and the deficiency, amounting to about one-half the required power, is supplied by an auxiliary steam-plant of 75 horsepower capacity.

Above this factory there are only small saw- and grist-mills, the latter generally with two pair of stones. There are some sites not occupied where there have formerly been mills. The dams are all of wood, founded on rock and sometimes bolted down. The stream averages 100 feet in width for some distance from its mouth. On one of the tributaries a small amount of power was formerly used for an iron-furnace.

SUMMARY OF POWER (ESTIMATED) ON THE SOUTH FORK OF THE CATAWBA.

[Powers are for natural flow, without drawing down water at night in pond.]

Locality.	Distance from mouth.	Drainage area.	Rainfall.					Total fall.		Horsepower available, gross.[1]			Utilized.		Remarks.
			Spring.	Summer.	Autumn.	Winter.	Year.	Height.	Length of shoal.	Minimum.	Minimum low season.	Low season, dry years.	Horse-power, net.	Fall.	
	Miles	Sq.m.	In.	In.	In.	In.	In.	Feet.	Feet.					Feet.	
Stowesville cotton-factory, etc.	6±	720	12	14	10	16	52	16.0	....	240	320	373	100±	16.0	
Spring shoal	8±	688	12	14	10	16	52	24.0	500±	350	450	500	450	23.5	Solid rock.
Coats Co. shoals	9-10	675	12	14	10	16	52	25.9	5,000±	375	480	550	0	0.0	
Spencer Mountain mill	13±	640	12	14	10	16	52	18.0+	....	240	320	375	100±	13.0	
Unimproved site	......	600±	12	14	10	16	52	4.0	....	50	70	75	0	0.0	
Friday shoal.....................	20±	550	12	14	10	16	52	16.0	....	160	240	280	80	16.0	
High shoal.......................	22±	518	12	14	10	16	52	27.0	600	280	380	450	0	0.0	Rock.
Long shoals mill.................	......	493	12	14	10	16	52	13.0	....	118	165	177	100	13.0	
Mostellers shoal	......	450±	12	14	10	16	52	7.0	....	60	85	100	0	0.0	Rock.
Lincoln mill	......	430	12	14	10	16	52	13.0	....	104	149	169	100	13.0	No waste in summer.
Laboratory mill	......	400+	12	14	10	16	52	9.0	....	68	90	101	110	9.0	Mill run 12 hours. No waste in dry weather.
Lincolnton shoal	......	325	12	14	10	16	52	6.5	....	40	55	60	0	0.0	Mill run by steam.

[1] See pages 54 to 59.

CROWDERS CREEK.

The Crowders Mountain mill is located on Crowders creek about four miles from Kings Mountain station on the Southern railroad. The mill contains 2500 spindles and 63 looms, operated by water and steam-power combined, about 75 horsepower being developed by the water-power plant. The race is a steel pipe 125 feet long and 2 feet in diameter, giving a fall of 50 feet at the mill and developing 75 horsepower by means of a 17½-inch Leffel turbine.

It is stated that about 100 horsepower is necessary to run the machinery, and there is an auxiliary steam-plant of 125 horsepower capacity.

THE MINOR TRIBUTARY STREAMS.

There are no important tributaries to the Catawba in Mecklenburg, Catawba and Iredell counties, the small streams which join the river being only capable of running small grist-mills with one or two run of stones, for which purpose they are in some cases used. The tributaries from the north are more important. The three Little rivers—Upper, Middle and Lower—have considerable fall, but are very small streams, draining respectively 31, 33 and 53 square miles.

On *Lower Little river* there are several grist-mills and one small cotton-factory three miles south of Taylorsville—the Taylorsville cotton-mill, with 700 spindles and 24 looms, operated by thirty horsepower, available all the year round. The dam is nine feet high and 200 feet long and the fall 13 feet. There is also a saw-mill operated by this power along with the cotton-mill. Both above and below this cotton-factory are a number of small powers on which are located grist- and saw-mills. On both Middle and Upper Little rivers are a number of grist- and saw-mills and undeveloped sites suitable for the same. These streams can probably hardly be depended on for one horsepower per foot-fall in dry seasons at their mouths.

The tributaries of the Catawba in Caldwell and Burke counties are larger and of more importance. *Gunpowder creek*, from the north, drains an area of about 31 square miles, and is about like the Little river in general character. Near Granite falls on this creek is located the Granite Falls Manufacturing Company's cotton-mill, containing 3352 spindles and 4 sets of cards operated by waterpower only. The dam is 14 feet high, 120 long and the fall is 48 feet. *Lower creek*, from the same side, drains 117 square miles, but is said to have little power. *Johns river*, also from the north, drains 120 square miles, but is not used except for one or more saw-mills, although it has considerable fall. *Upper creek* (north side) drains 45 square miles, and has a cascade about 18 miles from Morganton, but of little value for power.

LINVILLE RIVER.

This river rises on the west slopes of the Grandfather mountain, in Mitchell county, and flows in a general southerly course near the west border of Burke county until near the southern end of Linville mountains, where it bends southeastward and joins the Catawba river. It has a drainage area of 90 square miles, nearly all of which is forest-covered and much of its upper part with gentle slopes and occasional swampy areas. The rainfall of the Linville area is given by the United States Weather Bureau as 46 inches for the year, distributed as follows: spring, 11.50; summer, 13.50; autumn, 9.50; winter, 11.50. The drainage area of the river and tributaries above the falls is 50 square miles, while that of the entire river above its mouth is 90 square miles. Plate X, shows the general appearance of Linville falls (fig. B) and of the rapids just above the falls (fig. A).

At the falls, which are located about 3 miles below the Mitchell-Burke county-line crossing and about 22 miles above the mouth of the river, there is one perpendicular plunge of 40 feet, and the cascades just above give an additional fall of 50 feet more in a horizontal distance of less than 100 feet, thus giving an available natural fall of 90 feet. The power at this place, owned by the Linville Improvement Company of Morganton, is entirely undeveloped.

There are also several lesser undeveloped powers on the stream within a few miles above the falls, owned by the Linville Improvement Company; one on the Linville river at the mouth of Grandmother creek, 1½ miles southwest of the town of Linville, Mitchell county, where there is a fall of 20 feet, and the other on the Grandmother creek near its mouth with a fall of 40 feet. The fall at both of these can be considerably increased by the construction of inexpensive dams. For a distance of 10 miles in a general southerly course below the falls the river runs as a series of cascades through a narrow gorge from 500 to nearly 2000 feet deep, the walls being cut down through the bedded Linville quartzites above and granite below. At a point about 8 miles above its mouth the river emerges from this gorge and runs with a less rapid but by no means sluggish current across the open but hilly border of the plateau to its junction with the Catawba. In the first six miles below the "falls" the descent averages 208 feet[1] to the mile; and from just above the "falls" to the lower end of the gorge, in a distance of 10 miles, there is a fall of about 1800 feet. Along the upper 6 or 7 miles of this distance the bottom of the gorge is scarcely wider than the stream, and the large boulders of quartzite and granite rock at the foot

[1] As determined by a line of levels run by W. E. Walton, C. E., of Morganton.

A UPPER LINVILLE FALLS OR RAPIDS

B—LINVILLE FALL (LOWER FALL)

of the bluffs and in the bed of the stream render travelling, even on foot, exceedingly difficult. And the location of factories of any kind in this part of the gorge would be entirely impracticable.

One way in which this power might be developed is that of conveying the water of the river from just above the "falls" down the gorge in iron pipes to the lower end of the gorge or to a point 2 miles above, where a power-house could be located and the power conveyed to Morganton (about 15 miles) or some still nearer point on the Southern railroad (about 7 miles). A large power can be developed in this way, but sufficient gaugings have not yet been made to serve as a basis for estimating accurately its amount.

On the lower part of the river are several good powers. The lowest is one mile above the mouth of the river, where Major J. W. Wilson has a saw- and grist-mill with a fall of 9 feet; the next, 3 miles above this (following the stream), is Dickson's grist-mill with a fall of 9 feet; and 4 miles above this latter is an undeveloped power with a natural fall of 8 feet.

For tabular statement of utilized power on the Catawba river and tributaries see page 222.

TABLE OF UTILIZED POWER ON THE CATAWBA RIVER AND TRIBUTARIES.

Name of stream.	Tributary to what.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horse-power used.
Catawba	Santee	Mecklenburg	Grist- and saw-	1	9.0	60
Do	do	Gaston	Cotton-factory	1	11.0	150
Do	do	do	do	1	22.0	190
Do	do	do	Grist- and saw- } Cotton-gin }	1	16.0	60
Do	do	do				
Do	do	Iredell	Flour- and grist-	1	15.0	15
Do	do	do	Saw	2	32.0	40
Do	do	Catawba	Flour- and grist-	1	6.0	16
Do	do	do	Cotton-factory	1	6.0	60
Do	do	do	do	......	6.5	60
Do	do	do	Saw- and flour-	1	....	....
Do	do	Alexander	Flour- and grist-	1	3.0	6
Do	do	Caldwell	do	1	9.0	20
Do	do	do	Saw-mill	2	21.0	30
Do	do	do	Wagon-factory	1	9.0	10
Do	do	Catawba	Saw mill	1	....	....
Do	do	do	Saw- and grist-	......	....	30
Do	do	McDowell	Flour- and grist-	2	23.0	32
South fork Catawba	Catawba	Gaston	Cotton-factory	......	16.0	60
Do	do	do	do	......	23.5	450
Do	do	do	do	......	13.0	100
Do	do	do	do	......	16.0	80
Do	do	do	do	......	13.0	300
Do	do	Lincoln	do	......	13.0	....
Do	do	do	do	......	9.0	....
Do	do	Catawba	Flour- and grist-	3	52.0	37
Do	do	do	Saw	3	50.0	34
Tributaries to	South fork Catawba	Gaston	Flour- and grist-	8	128.0	122
Do	do	do	Saw	4	68.0	100
Do	do	Lincoln	Flour- and grist-	8	131.5	113
Do	do	do	Saw	3	32.0	35
Do	do	do	Cotton-gin	5	48.0	44
Do	do	do	Leather works	3	52.0	28
Do	do	do	Millwrighting	1	18.0	16
Do	do	Catawba	Flour- and grist-	4	60.0	47
Do	do	do	Woolen	1	8.0	6
Do	do	do	Iron casting, etc	1	10.0	20
Do	Catawba	Gaston	Cotton-factory	1	8.0	50
Do	do	do	do	1	10.0	80
Do	do	do	Flour- and grist-	3	40.0	34
Do	do	do	Saw	2	28.0	19
Do	do	do	Cotton-gin	1	20.0	10
Do	do	do	Cotton-mill	1	50.0	75
Do	do	Lincoln	Flour- and grist-	6	71.5	60
Do	do	do	Saw	4	36.0	33
Do	do	do	Woolen	1	....	12
Do	do	Catawba	Flour- and grist-	7	125.0	110
Do	do	do	Saw	3	34.0	30
Do	do	do	Miscellaneous	3	45.0	23
Do	do	Alexander	Flour- and grist-	10	115.0	153
Do	do	do	Saw	4	58.0	62
Do	do	do	Cotton-factory	1	13.0	30
Do	do	Caldwell	Flour- and grist-	13	250.0	157
Do	do	do	Saw	7	104.0	155
Do	do	do	Woolen	1	6.0	....
Do	do	do	Cotton-mill	1	48.0	120
Do	do	Burke	Flour- and grist-	13	213+	255
Do	do	do	Saw	4	60+	55
Do	do	do	Woolen	2	16.0	28
Do	do	McDowell	Flour- and grist-	9	133.0	92
Do	do	do	Woolen	2	16+	20

CHAPTER X.

THE BROAD RIVER AND TRIBUTARIES.[1]

THE BROAD RIVER.

Broad river takes its rise on the eastern slope of the Blue Ridge near Hickory-nut gap, in the southwestern part of McDowell county and the northeastern part of Henderson county, and after flowing in a general southeasterly direction through Rutherford county and a corner of Cleveland county, North Carolina, and in South Carolina between the counties of York, Chester, Fairfield, and Richland on its left, and Spartanburgh, Union, Newberry and Lexington on its right, it unites with the Saluda river just above Columbia to form the Congaree. The length from source to mouth, measured in a straight line, is about 128 miles, but following the course of the river it is very considerably greater. There are no towns of any importance on the river.

The Broad river drains a total area of about 4950 square miles, of which 3550 are in South Carolina and 1400 in North Carolina. The important tributaries in North Carolina are as follows: Green river, draining an area of 198 square miles, First Broad river, draining 302 squares miles, and Second Broad river, draining 193 square miles.

The general character of the drainage basin resembles that of the Catawba. It lies entirely above the fall line; is well wooded, especially in the upper parts; is without lakes; affords fine building stone in numerous localities; and as regards soil, etc., is similar to the valley of the Catawba, the soil being generally loose and porous. The rainfall for the general basin of the Broad river may be given as follows: spring, 13; summer, 13; autumn, 10; winter, 15; total 51 inches. But the rainfall in the region about the headwaters of the river is probably much greater than this. The bed of the stream is rock, clay, sand, or gravel, and in many places the banks are low and the bottoms overflowed in freshets. The declivity of the stream is less than that of the Catawba, but still very large.

Daily readings of water height and occasional measurements of discharge have been made on this river since 1896, and these measurements and the computations from them will be found on pp. 319-322.

[1] By Geo. F. Swain and J. A. Holmes.

The waterpowers on the Broad river may be described briefly as follows, starting at the South Carolina state line and proceeding up the stream:

HOPPER AND BLANTON SHOALS.—One-fourth of a mile above the mouth of the First Broad river is the beginning of a horseshoe bend, convex eastward, which is two miles around, while the distance across the neck is about five hundred yards. This neck is low, rising about fifty feet above the river at the highest point. The fall has been roughly measured across this neck and is said to be between 25 and 30 feet. On the lower side of this neck there is a short shoal in the river known as the Hopper shoal; on its upper side there is a similar one known as Blanton shoal. There has been some talk of developing a

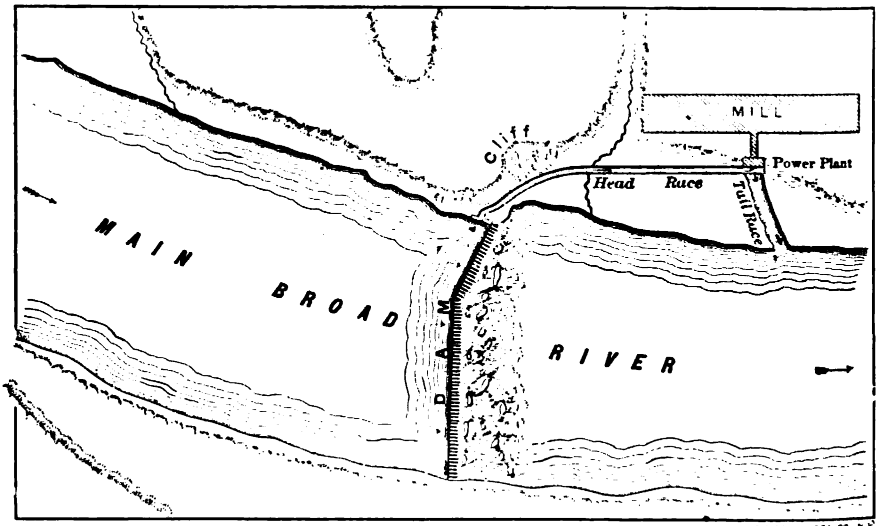


FIG. 15.—PLAN OF PROPOSED DEVELOPMENT AT DURHAM SHOAL MAIN BROAD RIVER.[1]

power here by cutting a canal and tunnel across the neck of this bend and turning the river through this canal by constructing a dam across it just above Blanton shoal.

PALMER SHOAL.—This power is located just above Cleveland and Jollys ferry, one mile above the mouth of the first Broad river and about 7 miles below the mouth of Second Broad river. There is here a natural fall of about 18 feet in a distance of half a mile. The rock

[1] Figs. 15 and 16 are reproduced through the courtesy of Messrs. Ladshaw & Ladshaw, of Spartanburg, S. C., who planned the constructions and furnished drawings from which these plates were made.

cliff is almost continuous on the north side, but the south bank is lower and nearly level.

A grist-, saw-mill and cotton-gin were once operated here by throwing up a loose rock wing-dam about 4½ feet high and 600 feet long, extending out about two-thirds the width of the river and turning the current to the south side. There was a fall of 7 feet at the wheel.

DURHAM SHOAL is located one mile above Palmers shoal, 6 miles below the mouth of Second Broad river, and 6 or 7 miles from the nearest points on the Seaboard Air Line and Ohio River and Charleston railroads. The shoal is formed by a ledge of granite about 100 yards wide extending directly across the river, which would form an excellent foundation for a dam. The natural fall here is 7 feet, with favorable conditions for the erection of a dam that will increase the fall to 12 feet. The north (left) bank affords good building sites just below the shoal. Arrangements for the development of this excellent power are now being made by J. Y. Hamrick and others (see fig. 15, p. 224, for proposed development).

The next shoal on the river is an unimproved site located below Island ford and not far above the mouth of the Second Broad. There is said to be a small shoal about one mile below the same ford. In the absence of definite information concerning these two shoals they can only be mentioned here.

One and one-half miles below Poor's ford, and two and one-half to three miles above Big Island ford, there is a shoal said to have a natural fall of three feet and good rock beds and banks, upon which a dam could be safely and easily constructed.

At BIG ISLAND FORD SHOAL the larger part of the water flows on the south side of the river, and between the south bank and the island, in a distance of about one-fourth of a mile, there is said to be a fall of 8 feet; but this estimate is probably too high.

Above Island ford there are a number of small shoals on Broad river and its upper tributaries in Rutherford county, some of which could be developed into valuable powers, and a few of which are already utilized for grist- and saw-mills. The shoals on Green river will be described briefly below (p. 229).

TRIBUTARIES OF BROAD RIVER.

FIRST BROAD RIVER.

This tributary stream rises in the extreme northern part of Cleveland and Rutherford counties and flows south through the former, passing within three miles of Shelby, joining the main Broad river a mile below Palmers shoal. It drains an area of 302 square miles, and its fall from the crossing of the railroad from Shelby to Rutherfordton to the mouth of the stream is about 105 feet, or at the rate of 8 feet or more per mile. The width of the stream at its mouth is about 90 feet.

The powers on the river in their order ascending are as follows:

The Buck McSwain shoal is located about one mile above the mouth of the river. It has a natural fall of about three feet in 150 yards. The bottom is of solid rock with a sandy bank on the east side and a clay hillside on the west.

Stices shoal, located, following the course of the stream, about four miles above its mouth, two and one-half miles from Pattersons, on the Ohio river and Charleston railroad, and about five miles southwest of Shelby, on the Seaboard Air Line railroad. The shoal has a natural fall of 6 feet in a distance of 80 feet over a smooth rock bed, and below this there is said to be about the same amount of fall in a distance of 200 yards. By the construction of a dam across this upper part of the shoal this fall could be still further increased. This excellent power belongs to Dr. R. H. Morrison of Shelby. It was used during the Civil War to operate iron-works, and had been utilized for half a century before that time for grist- and saw-mills, but it is now unoccupied.

At Chambers' grist-mill there is a fall of 9 feet, though it is said that a fall of 15 feet is available. The stream is almost as large here as at its mouth, and will probably afford 7 to 8 horsepower per foot fall in the low season of dry years, 9 or 10 in the low season of ordinary years, and 20 to 25 for nine months.

The Lauraglen cotton-mill occupies the next site on the river above Chambers, situated three miles southwest of Shelby. This factory contains 3500 spindles and is operated entirely by waterpower. The dam here is 14 feet high and 200 feet long, and the fall of water at the mill is 15 feet.

Double shoals, the next important power on the river, is the site of the cotton-factory known as the Double Shoals mill, about eight miles north of Shelby and four miles east of the Cleveland mills. It contains 2000 spindles, run by waterpower alone. The dam is 9 feet high, and the water falls 15 feet at the mill.

Cleveland cotton-mill No. 2 is also located on this stream ten miles north of Shelby and three miles north of the Double shoals. This mill contains 4224 spindles, run by waterpower exclusively. The dam is 12 feet high and 270 feet long, and the fall of water at the factory is 13 feet.

There are other small shoals on this stream both above and below the Cleveland mill, some of which are utilized for grist- and saw-mills, and some of them undeveloped, but the information concerning them is too incomplete to permit of their being described in this report.

On *Knob creek*, a small tributary stream which joins the First

Broad at Gardners ford, is situated the CLEVELAND MILL No. 1, twelve miles north of Shelby. This factory contains 884 spindles, run by waterpower alone. The dam is 15 feet high and 90 feet long, and the fall is 15 feet at the factory.

SECOND BROAD RIVER.

This river, the next tributary worth mentioning, rises in McDowell county and flows through Rutherford county, draining an area of 193 square miles. It is a small stream, only thirty feet wide at its mouth, but there are several good powers on it.

TUMBLING SHOAL, three miles from the mouth of the river, not now used, is the first, and a fall of 11 feet with good building sites can be obtained here in a distance of 200 yards. The stream would probably give from 4½ to 5 horsepower per foot of fall in the low seasons of dry years.

HIGH SHOALS, on which is located HENRIETTA COTTON-MILL No. 1, is four miles above the mouth of the river and one mile above Tumbling shoal. A branch road connects the place with the Seaboard Air Line railroad. The original shoal had a fall of 23.4 feet, over a narrow and rough rocky bed, in a distance of about 800 feet. The dam is of stone curving slightly up the stream, 200 feet long and 17.8 feet high, with an 18-foot base and 5-foot coping. It is pierced by 3 waste ways having an area of 12 square feet each, for use in drawing down the pond. The race is 300 feet long, 35 feet wide and 10 feet deep, giving a fall of water at the wheel of 32 feet, the power being generated by two pairs of twin turbines mounted on horizontal shafts and located 16 feet and 3 inches above the surface of the water in the tail-race. The mill contains 25,000 spindles and 1000 looms (see fig. 16, p. 228, for the plan of development of this mill).

The HENRIETTA MILL No. 2 occupies the next two shoals about two miles above High shoal, formerly known as Harrell's and the old "Burnt factory" shoals, the two having a total natural fall of 18 feet. The dam is placed on the lower shoal and backs water over the upper, giving a fall of 29 feet at the wheel. This mill contains 35,000 spindles and 1000 looms. A branch of the Seaboard Air Line railroad is now in operation to these mills.

SETTLEMEYERS SHOAL is situated on Sandy Run creek about one mile above its confluence with the main Broad river and about six miles from Mooresboro on the Ohio River and Charleston and Seaboard Air Line railroads. The shoal is utilized to operate a grist- and saw-mill and a cotton-gin, using about 80 horsepower under a head of ten feet, which can be increased to 25 feet.

On other smaller or less important streams tributary to Broad river in this region are numerous small powers, some of which are utilized in running grist- and saw-mills, while many of them are as yet undeveloped.

On *Buffalo creek*, near where it is crossed by the Seaboard Air Line railroad, is a small cotton-mill containing 3000 spindles, operated by the Buffalo Manufacturing Company, run entirely by waterpower. The dam here is 90 feet long and 25 feet high, giving a fall of 30 feet at the

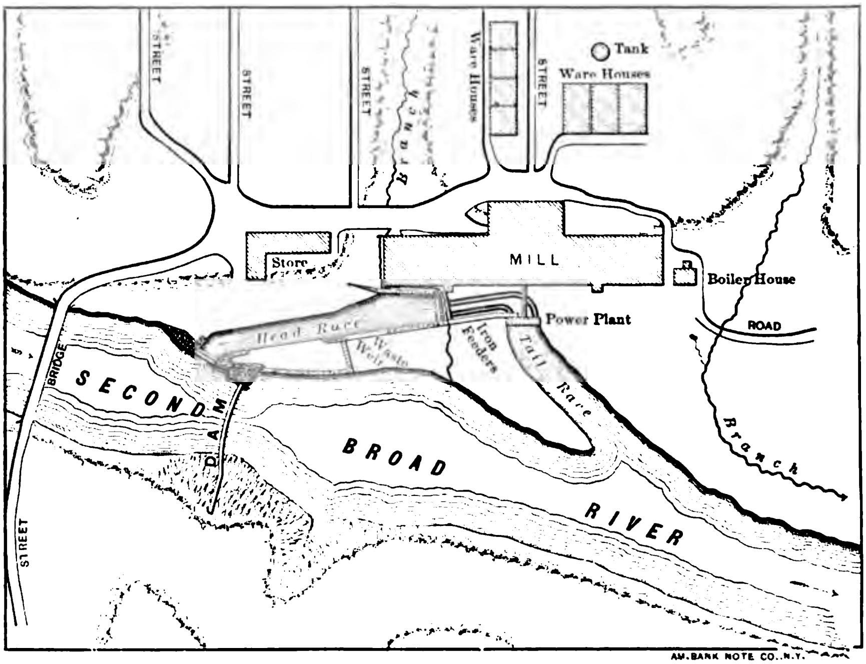


FIG. 16.—PLAN OF DEVELOPMENT AT HENRIETTA COTTON-MILL, No. 1, SECOND BROAD RIVER.[1]

wheel. Below this and just above the mouth of Muddy Fork creek, at the site of the old Roberts forge, there is said to be a good power. About two miles above the cotton-mill is Beams grist-mill, and three or four miles above this latter is Bakers grist-mill.

On *Muddy fork*, a tributary to Buffalo creek, there is said to be, about one mile above its mouth, an excellent small unimproved shoal, with a fall of 20 feet in 200 yards, which is said to be capable of yielding 40 horsepower in dry weather.

[1] Figs. 15 and 16 are reproduced through the courtesy of Messrs. Ladshaw & Ladshaw, Spartanburg, S. C., who planned the constructions and furnished the drawings from which the plates were made.

QUINN & HARRELL'S MILLS.—Wheat, corn and saw, 2 turbine-wheels, 32 inches and 28½ inches, and a Willis wheel for the saw-mill. 8 feet fall at the wheel, practically all given by the dam which is 8 feet high. Water flows off rapidly below and about one-fourth of the water used when all the machinery is running. This site is two miles over good road from the Ohio River and Charleston railroad.

All these streams have, as a rule, rock beds and good banks, which are not often overflowed. They are subject to heavy but short freshets. The typical soil in all this region is a loam which becomes more clayey in some regions and sandy in others.

GREEN RIVER.

This, the last important tributary of the Broad, rises in the mountains of Henderson county and flows a little north of east into Polk county where it joins the Broad. The upper part of its course lies in a narrow valley not over four miles wide for over twenty miles from the head of the stream, but below that the basin is much wider. The length of the stream in a straight line is about 36 miles and its drainage area about 188 square miles. It has a rapid fall and considerable power is available, though very little is used. The bed is rock, and the banks in some places are nearly vertical rock walls, while at others the river winds through fertile bottoms, subject at times though not extensively, to overflow, these bottoms being specially frequent in the lower part of its course. The stream is very inaccessible, being crossed by only one railroad—the Spartanburg and Asheville branch of the Southern railroad—about 16 miles from its head. The stream is about 100 feet wide where this road crosses it and about 90 feet wide at its mouth.

We obtained information regarding three shoals on the stream, but on account of the rapid fall there are doubtless other places where power could be obtained by damming. The lowest point is at Green river cove, where there is said to be considerable fall, not utilized, extending over some distance. This site is at a considerable distance from the railroad and not easily accessible.

POT SHOAL, which is just below the railroad crossing, is much more favorable, and is said to be the best site on the river. The falls commence just below the bridge and continue for some distance, the fall being very rapid, with now and then an abrupt fall of several feet. The bed is solid rock and the banks generally high, but near the foot of the shoal there is said to be a very good building site. The shoal takes its name from a number of curiously worn-out holes ("pot-holes") in the rock forming the bed of the stream, almost circular, and looking very much like large auger holes.

About two miles above the railroad and, therefore, not so favorably located as Pot shoal, are the "FALLS" OF THE GREEN RIVER, the third site above referred to and the only one visited in person. The fall is about 30 feet in 100, preceded by rapids for three-eighths of a mile, making a total fall of 45 feet. The banks are rocky and very steep, so that building facilities are not good. The drainage area above this place is 67 square miles and the available power would perhaps be one horsepower per foot in the low season of dry years and 3½ to 4 horsepower per foot for nine months of an ordinary year. The building facilities at Pot shoal are said to be much better than at these "falls," and the fall is also said to be greater.

The First and Second Broad rivers are crossed by the Carolina Central and the Ohio river and Charleston railroads, and the Green river is crossed by the Asheville and Spartanburg division of the Southern. Still, some of the best waterpowers in this region are so far from railroad transportation that it will be cheaper in their development to transmit by electricity the power for factories located on railway lines.

TABLE OF UTILIZED POWER ON BROAD RIVER AND TRIBUTARIES.

Stream.	Tributary to what.	County.	Kind of mill.	No. of mills.	Total fall used.	Total horsepower used.
Broad	Congaree			....	....	....
Tributaries of	Broad	Cleveland	Flour and grist	16	240.0	220
Do	do	do	Saw	10	179.0	147
Do	do	do	Cotton-gin	1	....	....
Do	do	do	Paper-mill	1	16.0	75
First Broad river	do	do	Cotton-factory	1	15.0	....
Do	do	do	do	1	15.0	....
Do	do	do	do	1	13.0	....
Second Broad	do	Rutherford	do	1	32.0	620
Do	do	do	do	1	29.0	....
Tributaries of	Second Broad	Cleveland	do	1	15.0	48
Do	do	do	do	..	...	....
Buffalo creek	Broad	do	do	1	30.0	....
Tributaries of	do	Polk	Flour and grist	1	23.0	35
Do	do	do	Saw	1	22.0	34
Do	do	Rutherford	Flour and grist	18	254.0	277
Do	do	do	Saw	4	....	45
Do	do	do	Woolen	1	12.0	4
Do	do	do	Leather	1	50.0	40
Do	do	do	Cotton-gin	1	12.0	20
Do	do	McDowell	Flour and grist	4	51.0	51

PART III

NOTES ON THE WATERPOWER IN NORTH CAROLINA WEST OF THE BLUE RIDGE

E. W. Myers, J. V. Lewis

WATERPOWER IN NORTH CAROLINA WEST OF THE BLUE RIDGE.

By E. W. Myers and J. V. Lewis.

INTRODUCTION.

No thorough examination of the streams and waterpowers of the mountain counties in North Carolina has yet been made. It is expected, however, that this will be undertaken by the State Geological Survey during the next two years. The data upon which the present paper is based were collected by the writers during a reconnoissance trip through the mountain counties in the summer of 1895. They visited all of the larger streams and many of their tributaries, and made numerous inquiries concerning the more inaccessible localities which were not examined by them in person. The estimates as to the fall in the various streams were based on measurements made with a Locke hand-level for short distances and an aneroid barometer for greater distances. All the gaugings of the streams north of Asheville were made by the use of a series of surface floats, ⅔ or ¾ of the surface velocity being taken as the mean velocity of the current, according to the stage of the water, whether high or low.

Of course it is not claimed that examinations of waterpowers made in this way are sufficiently accurate to serve as a basis for the investment of capital and development work. It was simply the best that could be done at the time, and the results obtained serve to indicate only where further investigations are needed, and where waterpower developments in future would probably prove successful. A series of more elaborate and accurate observations is already under way, and during the past three years on the French Broad at Asheville, the Tuckaseegee at Bryson City, the Little Tennessee at Judson (a few miles above its junction with the Tuckaseegee) and on the Hiwassee at Murphy, daily measurements have been made and recorded showing height of water in these streams at these stations, and occasional gaugings have been made to determine the velocity and volume of water in the streams at high, low and intermediate stages of water.

It is expected that this work will be continued for a number of years, and that additional gaugings will also be made at intervals on the streams to the north of Asheville in order that we may be able to determine with greater accuracy the volume of flow and the horsepower per foot fall at different points on these streams. It is also expected that during the next two years lines of levels will be run up all the larger of these streams in order that the fall at different points may be determined more accurately, and in this connection special examination will be made of the various shoals in these rivers, not only as to the fall of water within a given distance, but also as to the conditions, favorable or unfavorable, for the construction of dams and canals or races. Additional rainfall stations are also being established at different places in this mountain region in order that we may determine more accurately the amount of rainfall in each of the several river basins, but all of this work requires time, and its value increases almost in proportion to the number of years during which the records of river gaugings and rainfall extend.

Meanwhile, this preliminary statement is published in hope that information given may be of service in aiding intelligent development of additional powers and manufacturing enterprises in this region. A brief description of the geologic conditions influencing waterpower development in this mountain region is to be found on pages 86 to 88. One point of special interest mentioned there is that in these mountain streams the number of falls, and even the number of shoals occurring along the larger streams, is much smaller than might be expected under the circumstances. Instead of these, we have simply in large portions of these streams very rapid currents or a succession of rapids. The explanation of this condition of things is to be found in the fact that these streams have occupied their present channels for such long periods of time; and the great rapidity of their flow has enabled them to carry suspended in the water large quantities of sand and gravel and bowlders, and these have worn away the projecting masses of harder rock, keeping these more nearly on a level with the adjacent softer beds. This condition has been further facilitated by the comparative absence of such radical differences in the character of the beds of rock crossed by these streams as are described in the pages 86 to 88 referred to above. Hence, while these streams descend rapidly towards the lowlands, their descent has become in the course of time more or less uniform for considerable distances.

In the following pages the effort is made to indicate those points on the streams there considered where waterpower development has been made or is considered practicable, and the word "shoal" there used refers to this condition. The height given for the various shoals is in most cases that determined by hand-level from comparatively smooth water below the shoal to comparatively smooth water above, and, as a rule, takes no account of the fall in the smooth water above and below, although this may be large.

As the fall per mile on all these streams is so great, it was hard to decide definitely as to what constituted a shoal of sufficient importance to be noted here, so only those localities are mentioned where the fall in the stream is noticeably concentrated, even though the amount of fall thus concentrated may be small. Shoals of only a few inches fall usually indicate that a ledge of rock crosses the river at that point and the water flows over this in a miniature cascade. Such localities are noted more with reference to the possibilities for building dams and races than for the fall.

In the development of waterpower in this mountain region where, for the most part, the streams run as rapid currents through deep rocky channels, two general plans suggest themselves. One is the building of high stone dams—20, 50, or even 100 feet high—across these narrow, rocky gorges, the construction of wheel-pits at or near the dams, and the construction of power-houses immediately above the wheels (see Plate XV, p. 348). In this case, where there would either be no race at all or a short one, the fall of water would be practically the same as the height of the dam, the steep descent of the river channel below the dam securing the rapid removal of the water from beneath the wheel. The other plan which suggests itself is the construction of lower dams and the conveying of the water either through open canals or closed pipes for some distance along the banks of the stream until some point is reached where a sufficient fall can be obtained and the power-house constructed. As the conditions will vary at different points, so it may be found that one or the other of these plans, more or less modified, will be better adapted to the development work contemplated. Whether the dam constructed be a low or high one, the pond produced at most places will be comparatively small, and will be sooner or later filled with sediment brought down by the rapid streams above unless this is guarded against in the construction of the dam.

The majority of locations in this mountain region where waterpower developments are practicable are not within easy reach of transportation facilities over either railroads or good wagon-roads, and in many cases the gorges are so narrow and the country so rough that the conditions are not favorable to the establishment of adjacent manufacturing plants. Hence, in the development and utilization of these waterpowers, it would seem not only advisable, but necessary, that the power should be transmitted electrically from the places of development to points on the railroads where locations for the establishment of manufacturing plants and transportation facilities are both within easy reach. Fortunately, in this connection, the electric transmission of power is no longer a matter of experiment, but is now accepted as one of the most satisfactory and economic methods of both transmitting and distributing power, and this method of transmitting power is entirely practicable in the roughest and most rugged sections of country. A discussion of the advantages and methods of transmitting and distributing power in this way will be found on pages 337 to 350.

CHAPTER XI.

THE NEW, WATAUGA AND TOE RIVERS.[1]

NEW RIVER AND TRIBUTARIES.

New river rises on the northwest slope of the Blue Ridge in the southern part of Watauga county near Blowing Rock. Thence it flows in a general north-northeasterly course across the counties of Watauga and Ashe into Virginia. Over the larger part of its course in these two counties it is known as the South fork of New river, which will be described more fully further on. Just before reaching the Virginia line it is joined by the "North fork," which rises on the east slope of the Iron mountains along the southwest border of Ashe county. After crossing the line into Virginia the river follows an easterly course near the North Carolina line for a distance of about 12 miles, when it changes to a southeasterly course and crosses the North Carolina line and runs for a distance of 4 or 5 miles in Alleghany county. It then again crosses the state line into Virginia and flows in a general northerly course into the Kanawha and the Ohio.

In its course across Watauga and Ashe counties it is everywhere a rapid mountain stream, running for the greater part of this distance through narrow, rather deep gorges, with in many places a rocky bottom and rocky slopes, furnishing at numerous points conditions favorable for the construction of dams. The total drainage area of the North and South forks of New river above their junction in 631 square miles. Of this area, in 1880, 92,000 acres were reported as being in cultivation, 57,000 acres in grass and 240,000 acres, or 61 per cent. of the whole, were still forest-covered. The total rainfall of the basin as indicated by the records of a single station—that at Blowing Rock—which extends over a period of three years, is 49 inches for the year, distributed as follows: for the spring, 11.3; summer, 16.2; autumn, 9.7; winter, 11.8 inches. A considerable portion of the cleared land is in grass and is used for the pasturage of cattle. It is a fine country agriculturally, the soil being quite deep and for the most part a fertile, sandy and gravelly loam, and the lower part of the basin in Ashe county is rich in mineral deposits, including a number of large beds of high-grade magnetic iron

[1] By E. W. Myers and J. V. Lewis.

ore and several fine copper properties. There are numerous tributary streams, on practically all of which, owing to the rapid descent of their basins, small waterpowers could be easily developed. Owing to the steepness of the mountain slopes, all of these streams are at times subject to freshets, and after hard freezes in the winter occasionally ice dams of considerable magnitude are formed, so that the stone dams constructed in connection with waterpower developments need to be built strongly and with considerable care in order to secure their permanency against the freshets and these ice dams.

WATERPOWER ON NEW RIVER.

Nearly all of the shoals which are capable of being developed into waterpowers are to be found on the North and South forks of the river, and will be described under these headings further on. The lowest shoal on the main river in North Carolina which deserves mention here is that in the northern part of Ashe county where the river makes its bend into North Carolina. Here for a distance of about 4 miles the river is almost a continuous series of rapids, and is reported to contain a number of shoals which might be utilized, especially about Horse ford. In the lower portion of this section there is a natural fall of about 7 feet in a half mile, and the width of the river at the head of this shoal is about 350 or 400 feet with steep sloping bluffs on either side.

From where New river first crosses the North Carolina-Virginia line up to the junction of the North and South forks, a distance of about 4 miles, no shoal of importance was reported except the Blevins shoal, which is to be found just below the junction of the two forks. This shoal was not visited and no definite information concerning it could be obtained except that it is "a good shoal."

As will be seen on the map (Plate I, frontispiece) after crossing into Virginia near the northeast corner of Ashe county, New river again enters North Carolina, and remains in the northern central part of Alleghany county for a distance of 3 or 4 miles before turning northeastward again into Virginia.

TRIBUTARIES OF NEW RIVER.

The three tributaries on New river which deserve description in the present connection are the Little river and the North and South forks of New river.

LITTLE RIVER.

Little river rises on the north slope of the Blue Ridge in the southern part of Alleghany county and flows across this county in a northeasterly course until it reaches the Virginia line, and then it turns north-northwest and joins New river at a point three or four miles north of the state line. The stream is rapid throughout its entire course and at intervals its narrow gorge, with rocky bottom and sides, would be favorable for power development if the water supply were sufficient.

No information was obtainable concerning any important shoal or available mill site on this stream below the mouth of Brush creek; but we were informed that there is a fine fall all the way from this point to the Virginia line. Just below the mouth of Brush creek there is reported to be a good shoal, but no definite data in regard to the fall of water there and availability for power development were obtainable. There is also said to be a good power site, with a small natural fall between this point and the FENDER MILL above. This mill is one mile south of Edwards Cross-roads, and is situated on the north bank of the river. The shoal is formed by the water flowing over a ledge of granite which gives an almost perpendicular natural fall of about 5.5 feet. On top of this ledge there is a log dam three feet high. The mill is a combination corn-, wheat-, saw- and shingle-mill run with about half of the water available.

Just above and below the mouth of Bledsoes creek there are said to be one or more old mill sites capable of being developed into a good power. Above this, and two and a half miles southeast of Sparta, is a good power developed by a fourteen-foot wood dam, which now runs a saw-, flour-, grist- and carding-mill. Three miles above this, and one mile below Whitehead, is Joynes & Richardson's flouring-mill, the power to operate which is developed with a small natural fall and a ten-foot wood dam. One-half mile above this latter place there is said to be another good shoal. At Whitehead a saw-, flour- and grist-mill are operated by a fourteen-foot overshot wheel.

On Brush creek, one of the largest tributaries of Little river, there are said to be several important shoals, one on this creek just above its mouth and another several miles further up the stream near the mouth of Laurel creek.

NORTH FORK OF NEW RIVER.

North fork of New river, which rises near the Ashe-Watauga county line on the northern and eastern slope of the Iron mountains, flows as a rapid stream across Ashe county in a southeasterly course, joining the South fork a few miles before New river reaches the Virginia line. It has a total drainage area of 298 square miles, the upper portion of which is entirely forest-covered. On the northwest side it has three prominent tributaries, on each of which small waterpower developments are possible—*Helton creek*, with a drainage area of 47 square miles; *Horse creek*, with a drainage area of 58 square miles; with *Laurel fork* or Big

Laurel creek with a drainage area of 32 square miles. Its principal shoals, which are promising for small waterpower developments, are the following:

About two miles and a half above the junction of the two forks of New river and a mile above Weaversford is DIXON'S MILL (corn and wheat), with an eight-foot wood dam and a nine-foot working head. The dam is 212 feet long and rests on a rock foundation with solid rock abutment on the east bank. The rock rises into the hillside on the west bank at a distance of a few feet from the end of the present dam. The river is here quite rapid for 200 yards below the mill and the tail water flows off readily. A pit has been constructed for a turbine-wheel, but the small power used when the region was visited is developed by Willis wheels. It is estimated that over 300 horsepower could be obtained here at all seasons with the proper development. The property belongs to Mr. J. A. Dixon of Weaversford.

Two miles above Dixon's mill and a mile below the mouth of Helton creek is a shoal known as the FALLS, the property of the widow Plummer. The river at this point has a width of about 150 feet, and the shoal consists of heavy rock ledges which continue up the hills on either side at an inclination of about 40° on the east and about 25° on the west. The natural fall is three feet in about 600 or 800 feet, and there is a fall of about four feet in a quarter of a mile above the shoal. A dam fifty feet high could be built from rock on the spot; but there is little level space for building. The highest recorded water-mark was reached in September, 1878, and is about 18 feet above the ordinary water level.

About five miles above the "Falls," and just above the mouth of Silas creek, there is said to be a good available shoal with a satisfactory place for a dam, the bed and banks of the stream being of rock. This property is owned by P. Ballou and Calvin Brinegar.

For several miles above this latter point the stream is very rapid, and there are good mill sites at intervals of every two or three miles; but there are no shoals of much importance till we reach SHARPS SHOAL, which is about four miles above the mouth of Buffalo creek and opposite the northeastern extremity of Three Top mountain. The natural fall of this shoal is about 7.5 or 8 feet in a distance of about 200 feet. The river is about 70 feet wide at the head of the shoal, and there are good rock abutments on either side for a ten-foot dam. There is swift water below and plenty of good level ground for buildings. The rock is a hard, compact gneiss of almost granitic structure, and a high ledge up the hill to the north of the shoal will furnish great quantities of this material for foundations, dam, and other building purposes. Above this point no shoals of any considerable importance were observed or heard of.

SOUTH FORK OF NEW RIVER.

This fork of New river has already been briefly described (p. 237) as the upper portion of New river. Its drainage area above where it joins the North fork is 333 square miles. Its principal shoals and water-powers are as follows:

On the South fork, about three-quarters of a mile above the junction of the two branches of New river, is the WALLACE FORGE SHOAL, which has a natural fall of about three and a half feet in one thousand. There is an excellent rock foundation for a dam and solid rock bluffs in the hills on either side, rising at an angle of 40° to a height of 50 feet or more. The width of the river where dam would probably be built is 250 feet, and the current for some distance below the shoal is very rapid, having about two feet fall in the next 200 yards. There is no level space for building, though buildings could be placed near the foot of the shoal on gently-sloping hillside. There was once an old forge here with a wooden dam, but this was washed away about twenty years ago.

DOG CREEK SHOAL.—For the next twenty miles above the Wallace Forge shoal the river is as compared with other mountain streams, shoaly, rather sluggish, and in this distance no shoal with a natural fall that is worthy of special note was observed until near the mouth of Dog creek, which is about five miles east of Jefferson. Here there is a natural fall of about six feet in 350 to 400 yards, a good foundation for a dam and excellent grounds for buildings. The dam would necessarily be quite long, as there is a strip of bottom-land along the whole of the west side of the shoal.

About a mile above the mouth of Dog creek, and just above the mouth of Roans creek, is the old BOWERS MILL site, which is regarded as a good shoal.

The next shoal of importance, about a mile and a half above this, is the WITHERSPOON FORD SHOAL, just below a ford of that name. This has a natural fall of about 5 feet with good rock foundations and abutments for dam and abundant level building space.

About half a mile above Witherspoon ford, and a short distance above the mouth of Bear creek, is the YATES SHOAL, which is said to be a good site, but we did not see it and have no definite data concerning it. About two miles further up is the BRUSH CREEK SHOAL, of about the same character as the last-named, just above the mouth of Brush creek.

Two miles above this last-mentioned is TURTLE SHOAL, which has about 5 or 6 feet fall in 100 yards, but there is a broad level bottom on the left bank which would greatly interfere with building a substantial dam.

ROARING SHOAL is about two miles above the last-named and a mile and a half above the mouth of Obids creek. It has about the same fall as Turtle shoal, but there is no good building room.

ELK SHOAL is a mile and a half still higher up the South fork, and has a natural fall of about 10 or 11 feet in a short distance. It affords a good solid foundation for dam and has good rock abutments on the sides, but there is no level ground for building.

There are also said to be good shoals just below the mouth of Pine Swamp creek and about a mile above it, but of no considerable fall. About three-fourths of a mile below the mouth of Old Field creek there is a good short shoal having a natural fall of about four feet. This is an excellent dam site and there is plenty of available building room.

Three miles above this last, and just below the mouth of Mill creek, is ROCKY SHOAL, with a natural fall of 4 feet in about 250 feet. A solid rock ledge runs across the river and up the hills on both sides, giving an excellent dam foundation. There is plenty of good building room at the foot of the shoal. A shoal very similar to the last, and said to be as favorably situated, is about three miles further up the river, just above the mouth of Grassy creek.

At Elk Cross-roads (Todd P. O.), and just above the mouth of Elk creek, there is a good rock shoal with steep, rocky banks on either side, suitable for building a dam forty or fifty feet high if necessary. For a mile above this the stream is very rapid and probably gives a fall of 15 or 20 feet. The whole of this distance is shut in by a rocky, narrow gorge. The water is also quite swift below the shoal.

For fifteen miles above this point there are no shoals or available mill sites. Half a mile below the mouth of Hardin creek and three miles east of Boone, a mill was being built at the time of our visit (1895). There is a small rapid with a good foundation for dam and rock abutment on the north side of the stream, but there is a broad meadow on the other bank. A brush dam about 4 feet high has been built, and a race dug in the soil about 800 feet long, giving a fall of about 8 feet at the wheel.

WATAUGA RIVER.

The Watauga river rises on the north slope of the Grandfather mountain and flows a distance of about 10 miles in a northeasterly course and then runs in a northwesterly course for a distance of something more than 20 miles before reaching the Tennessee line, where it flows through a deep gorge cut through the ridge of the Iron mountains. Its total drainage area above the Tennessee line is 162 square miles. Of this total area about 22,000 acres are cultivated, and about 12,000 acres are in grass, and 70,000 acres, or 67 per cent. of the whole, are still in forests. The soil is generally deep and open or porous, being usually a gravelly or sandy loam. The stream is everywhere a rapid one, and for a considerable portion of its course runs through a deep, narrow gorge with rocky bottom and rocky sides, furnishing at many points excellent facilities for the construction of dams.

The fall of the stream is very great throughout its length, and the selection of shoals for utilization becomes largely a matter of convenience. For several miles above the Tennessee line it flows in a deep gorge, and is practically a succession of rapids; along this portion of its course it is accessible in only a very few places. Between the Tennessee line and Shulls mill, a distance, following the course of the stream, of about 19 miles, the total fall in the river, as taken from the topographic map of the U. S. Geological Survey, is about 900 feet, and the average fall per mile is therefore about 47 feet.

The more important shoals of which there is information at hand are the following:

The first available shoal is about four miles above the state line, and above and below the mouth of Beech creek. Here is a fine site for dam and buildings; the fall could not be estimated, as the river is a series of rapids for long distances above and below the creek mouth, so that almost any desirable fall could be obtained.

About five miles further up, at the CALVIN WARD PLACE, just below the mouth of Laurel creek, there is a good mill and dam site with small natural fall.

One mile above this there is another good locality for a small mill. Rock ledges rise on either side for dam abutments, but there is very little concentrated natural fall, though the river is quite rapid. A small bottom affords plenty of level building room.

About two miles further up the river, just below the mouth of Cove creek, is a shoal with nine feet natural fall in 500 to 600 feet, with good abutments for a dam, almost perpendicular on one side and quite steep on the other. A fairly good building site is at the lower end of the shoal. About three feet of the fall is utilized by a small sawmill.

Six miles above the last-mentioned place, and just above the first ford above Valle Crucis, is a shoal with about 2 feet fall in 100 feet. Ledges of rock lie directly across the stream and extend up the hills on either side. A dam 14 or 15 feet high could easily be built, and there is plenty of room for buildings.

For four miles above this point the river is almost a continuous series of rapids and cascades in a deep gorge; and dams up to 60 or 70 feet high could be built in many places. But there is only an occasional narrow strip of bottom to afford building space.

A mile and a half above the mouth of Laurel creek there is a shoal with a fall of fifteen feet in about 150 feet. An excellent dam and building site with plenty of rock on the grounds for foundations and a dam.

A single discharge measurement of the Watauga was made just below the mouth of Cove creek, showing a discharge of about 68 cubic feet per second, equivalent to 7.7 horsepower per foot of fall.

The Watauga river receives as tributaries several large creeks, of which Cove creek (draining 41 square miles) and Beaverdam creek, entering from the north, and Elk creek (draining 47 square miles) from the south are the principal ones. On Cove and Beaverdam creeks the fall is very large, and though the quantity of water is small, there are numerous small powers on them, some of which are used to operate the small saw-mills and grist-mills which supply the local needs.

The most noteworthy power on any of these tributary streams is ELK FALLS (Plate XI), located on *Elk creek*, just above the Mitchell-Watauga county-line. Here there is a sheer jump of from 26 to 28 feet, and from the top of this fall there is a fall of 85 feet in one mile, then for four miles the fall will average 100 feet per mile. Above Elk falls there are numerous small shoals and rapids as high up as Banners Elk, giving small compact powers of from 20 to 40 feet fall.

TOE RIVER AND TRIBUTARIES.

This river, which in North Carolina has its tributaries mainly in the counties of Mitchell and Yancey, and flows thence into Tennessee, is in the latter state known as the Nolechucky; and in North Carolina this same designation is sometimes applied up to the junction of the North and South Toe rivers, about 5 miles east of Burnsville. It is more generally called Toe river throughout its entire course in North Carolina. It rises in the extreme northeastern portion of Mitchell county between Cranberry and Grandfather mountain, and flows thence for a distance of nearly 30 miles in a southerly course. It then flows westerly for a distance of some 15 miles to where it is joined by the South Toe river. Thence it flows north for a distance of 10 miles, where it is joined by Cane creek near Bakersville, and then runs in a deep, rocky channel west-northwesterly for a distance of some 20 miles to where it cuts through the mountains and flows out into the valley of east Tennessee, joining successively the French Broad, Holston and Tennessee rivers. Its total drainage area above the Tennessee line is 640 square miles, of which about 67,000 acres are in cultivation, 21,000 in grass, and 331,-

ELK FALLS, ON ELK CREEK, MITCHELL COUNTY

000 acres, or 78 per cent. of the whole, still forest-covered. The total rainfall of this region is 51.2 inches for the year, divided as follows: spring, 11.4; summer, 15.7; autumn, 11.6; winter, 12.5 inches. The soil is deep, porous and fertile. The grasses grow vigorously on the cleared lands, and the cattle industry is quite an important one. The principal crops grown are corn and small grains such as wheat, oats and rye. At Cranberry and at a number of other points along the Iron mountain range are valuable magnetic iron ore deposits, and in both Mitchell and Yancey counties there are numerous mica deposits which are considered the most valuable in the United States. A projected and partly built railroad follows the course of the river for some miles both above and below the Tennessee state line, and when completed this will render many of these latent waterpowers accessible.

The more important tributaries are Caney river and North Toe on the south, Big Rock creek and Cane creek on the north. The stream is a rapid one throughout almost its entire course, and in many places it runs through a deep, rocky gorge, where the construction of dams for waterpower could be easily accomplished. There are occasional high freshets during which the water rises and goes down quite rapidly, and at rarer intervals in the early spring there is some little trouble from the breaking up of the ice, which, moving down the streams, forms temporary dams, but this is nothing like so serious as in the more northern states.

WATERPOWER ON TOE RIVER.

The more important shoals on this river are as follows:

One and one-half miles below the mouth of Caney river there are rock cliffs on either side of the gorge, here about 200 feet wide. The current is very swift, and there is a fall of 25 feet in about half a mile. There is a small building space about one-fourth of a mile below the best location for a dam.

In all this lower portion of the river the water is quite swift, and there are several places where dams might be built, but there is very little space for building on the banks, and for much of the distance it would be difficult to construct races in the rocky slopes.

Just above the ford, a mile above the mouth of Pigeon-roost creek, there is a good foundation for a dam and rock abutment on the north side, an island lying south of the main part of the stream about 15 feet high, which is never overflowed. A 5-foot dam here would raise the water at this point about to the level of the water at the upper end of the island, and a 6-foot dam across the narrow channel south of the island (50-75 feet wide) would allow a dam 10 feet high on the shoal in the main channel. A strip of bottom of about 15 acres affords ample space for buildings just below the shoal.

A gauging of Toe river was made about one mile above the mouth of Pigeon-roost creek (one-half mile above Relief post-office) when the water was about 6 inches above normal height. This showed the flow at that time to be 785 cubic feet per second, which is equivalent to about 89 horsepower per foot fall. Average surface velocity, 1.75 feet per second. Taking two-thirds of this (1.16) as the normal velocity, and 505 square feet as the normal cross-section, the normal discharge is 586 cubic feet per second, which gives 66.6 horsepower per foot fall.

One and one-half miles above the mouth of Pigeon-roost creek there is a good shoal with a natural fall of 6 feet in 300, and a width of about 175 feet. A rocky ledge crosses the river and extends up the bluffs on both sides, that on the south side rising some 40 feet back from the bank of the stream, at an angle of 30°, to a height of more than 100 feet. The north side is steeper and about the same height. There is a small level space on both banks about 200 yards below. There are no mills on the river above the Tennessee line except those named below, but there are several on the creeks. There is a considerable fall in the river all the way from the mouth of South Toe to the Deaton Bend (just above the mouth of Cane creek). Below Cane creek the river is very rapid, having 30 or 40 feet natural fall to the mile, with rock bottom all the way with steep, rocky sides to the gorge. There is practically no level building room except a narrow strip of bottom on the north side, half a mile below Cane creek. If a race were constructed on the side of the gorge it would pass through solid rock all the way—mostly dark, fine-grained basic massive rock.

Just below the mouth of Bear creek is John Bailey's grist-, saw- and mica-mill. This is a good site for a dam.

Two miles above Bear creek there is a coniderable fall in the "Narrows," just below where the road leaves the river.

Just below the bridge near Spruce Pine there was a mill, now washed away. There is a small shoal here, but no rock ledges crossing the stream or outcropping on the banks, which would serve to secure a dam.

Three miles below Wiseman's mill is Joseph Lovin's grist-mill.

Two miles below Three-mile creek is Lafayette Wiseman's mill. This was formerly a saw-mill and a corn- and wheat-mill, but the saw-mill has been washed away. There is a rock abutment on either side of the river and a shoal extends half way across, but there is little natural fall. The dirt side of the river bank has been washed out, but it is now walled in with rock.

Just below Three-mile creek (Elsie post-office) are Jas. H. Wiseman's saw-, wheat-, and corn-mills and wool cards.

A quarter of a mile below Plum Tree there is a mica-mill (H. R. Jones) which is operated by water conveyed in a ditch three-eighths of a mile long, the water being taken out of the river above the mouth of Plum Tree creek.

Three-fourths of a mile below Hensons creek (marked " Powder Mill creek " on the U. S. Geological Survey topographic map) there is said to be a good site for a dam.

Just above the mouth of Roaring creek there is a good rock shoal and sides for a dam with a natural fall of 4 or 5 feet reported.

TRIBUTARIES OF TOE RIVER.

CANEY RIVER.

The first of the important tributaries above the Tennessee line is Caney river, which rises on the western slope of the Black mountains in the southern part of Yancey county and flows in a general northerly course for a distance of some 20 miles to where it joins the Toe river, about 5 miles above the state line. Its drainage area is about 158 square miles. It is everywhere a rapid stream, and through a considerable portion of its course runs through a deep, narrow, rock-bound gorge, where the construction of dams for waterpower development would be an easy matter. While the stream is everywhere a rapid one there are but few shoals with concentrated fall to be found.

A gauging of the river was made about 1½ miles above its mouth at a point where the stream was about 200 feet wide, at a time when the water was said to be about three inches above its normal height. The result showed a flow of 511 cubic feet per second, which would indicate at this stage of water and place about 57 horsepower per foot fall. This gauging was made the morning after a very hard rain when the water was very turbid and is manifestly a high-water measurement, the discharge of 3.4 second feet per square mile being entirely too large for any normal stage of flow. The average dry season flow will probably be about 150 cubic feet per second and 17 horsepower per foot fall. The few shoals on this stream which may be considered suitable for waterpower development are described below.

About 5 miles above the mouth of the river there is a shoal with a natural fall of 5 feet in a distance of 200 yards, with a suitable place, with rock bed and sides, for a dam at the head of the shoal. The distance between the rocky banks on the opposite sides of the stream is about 150 feet. At the lower end of the shoal there is a small space suitable for buildings.

Just above the mouth of Bald Mountain creek there is a shoal with about 10 or 12 feet fall in a quarter of a mile with a number of good locations with good stone foundations for a dam and ample supplies of rock suitable for its construction. The walls of the gorge in which the river runs here have a slope of about 30°. The total length of the shoal, paced, is 1250 feet. The fall was estimated with hand-level and aneroid. On the south side of the river, about 200 yards below the foot of the fall, there is a small level area suitable for buildings. This shoal is the property of Jacob Lewis, Bee Log, N. C.

Still further above Bald Mountain creek, and about one and one-half miles below Higgins and Brown's grist- and saw-mill, there is a natural fall of 4 feet in a distance of 200 feet, with a suitable place for a dam a short distance from the top of the rapids. The bed of the stream at this point is of rock, and the rocky walls of the gorge are quite steep, having a slope of about 40° to a height of over 100 feet. There is about 3 feet fall through a narrow gorge for the next 300 yards, then there is a small space for buildings.

About half a mile above the last-mentioned, and a mile below Higgins and Brown's mill, there is a fall of 5 feet in about 250 yards with a good place for a dam about half way.

At Higgins and Brown's saw- and grist-mill, some 7 miles below Caney river post-office (following the river), there is a dam 4 feet high or less with good rock foundations and abutments, the width of the shoal being about 75 feet. There is here an excellent site for a dam, but the space for buildings is not extensive.

About 7 miles below Caney river post-office there is a four-foot fall in about 200 yards. The river is 50 feet wide with good rock shoal and steep rocks up both sides to a height of about 200 feet. There is some building space at the ford 200 yards below.

At the next ford above this last, one mile below Elk Shoal creek, there is a fairly good place for the location of a dam, and there is ample space for building room in the bend.

SOUTH TOE RIVER.

This stream rises at the extreme southern point of Yancey county between the Black mountains on the west and the Blue Ridge mountains on the east, and near where they join at the High Pinnacle. It flows in a general northerly course, and joins the North Toe river about 5 miles east of Burnsville. Its total drainage area is about 91 square miles, of which probably more than 90 per cent. is forest-covered. The few shoals worthy of mention on this stream are briefly described as follows:

About two miles below the mouth of Browns creek and 4 miles (straight line) above the mouth of the river, between Fawn Knob and

Celos Ridge, there is a shoal with a fall of 3½ feet in 100 feet over a ledge of coarse granite (pegmatite). The rock rises at an angle of about 15° on both sides (somewhat steeper on the south side). The width of the stream at the head of the shoal is 50 feet, but it is only about 15 feet wide at the narrowest place. There is ample level space for buildings on the south side just below shoal.

There is also a small shoal just above the mouth of Browns creek.

A short distance below the mouth of White Oak creek there is a shoal with a fall of about 4 feet in a distance of 300 feet. A ledge of solid rock crosses the bed of the stream, but this rock is not exposed in the banks for abutments, and the stream is here bordered by broad bottom-lands.

There is a small shoal between the last-mentioned and the mouth of Locust creek, and at the mouth of Locust creek is another small shoal with a fall of about 3 feet with good rock foundation for a dam.

Again, about one-half mile above the mouth of Locust creek, there is a fall of about 5 feet in a distance of 100 feet, with bottom and banks to the height of 10 feet solid rock.

There are almost continuous rapids in the bend below Colberts creek about 2 miles above Locust and 4 miles above Browns creek. In a steep, rocky gorge the stream flows as a continuous rapid, having a fall of 6 feet in 200 yards, the width of the stream being about 75 feet. There is an excellent site for a dam, with solid foundations and sides.

There is another small shoal about 200 yards above this mentioned at the mouth of Colberts creek, where there is a nearly perpendicular fall of 3 feet. The stream is here only 30 feet wide, but a dam 60 feet long would be required to develop this power fully.

Two smaller tributary streams may be mentioned: *Big Rock creek*, which rises on the southern slopes of the Iron mountains and just west of Roan mountain in the northwestern portion of Mitchell county, and flows in a southwesterly course, joining Toe river about 7 miles west of Bakersville, has along its course several small shoals, one or two of which have been already partially developed, and at one point, a short distance above its junction with Toe river, there is said to be a natural fall of 10 feet, which, with a dam, could be greatly increased.

Cane creek, which rises on the south side of Roan mountain and flows westward for a distance of about 10 miles, joins Toe river about 3 miles west of Bakersville. For one or more miles above its junction with the river it runs in a deep, narrow gorge with rocky sides, and is said to have a fall of more than 60 feet in a distance of less than a quarter of a mile.

CHAPTER XII.

THE FRENCH BROAD AND PIGEON RIVERS.[1]

THE FRENCH BROAD RIVER AND TRIBUTARIES.

The French Broad river rises on the eastern slope of Tennessee Ridge which lies between Jackson and Transylvania counties, and flows in a general northeasterly course across Transylvania and Henderson counties for a distance of about 30 miles, and thence northward across Buncombe county for a distance of something more than 20 miles; thence across Madison county for a distance of 20 miles, across Great Smoky mountains at Paint Rock into eastern Tennessee, where it joins the Nolechucky, the Holston and the Tennessee, flowing thence into the Mississippi and the Gulf.

The drainage area of the river above Asheville is 987 square miles, and the total drainage area in North Carolina is 1745 square miles. Of this, according to the statistics of the tenth census (1880) at that time, 191,000 acres were in cultivation, 41,000 acres in grass and 879,000 acres, or 78 per cent. of the whole, were still forest-covered. The total annual rainfall of this basin as represented by the station at Asheville is 42.6 inches, distributed as follows: spring, 11.7; summer, 13.8; autumn, 7.7; winter, 9.4 inches. The soil of the entire basin is deep and fertile, and is generally loose and porous, being a sandy and gravelly loam. The lands along the valley of the French Broad in Transylvania and Henderson counties are among the finest in the state. Through Buncombe and Madison counties the river for the most part runs through a deep gorge with but little land bordering it which can be cultivated, but on the hills back from the river there are many cultivated acres which yield abundant crops of tobacco, corn, wheat, oats and rye. Throughout the upper portion of the stream, while the current is not sluggish as compared with streams in the coastal plain region, it is not rapid as compared with other mountain streams. Its descent is fairly uniform, and no waterpowers have been developed, nor are the conditions there favorable for waterpower development. At a few places, however, where the river passes through a narrow, rock-bound gorge, permanent dams could be easily constructed which would yield

[1] By E. W. Myers and J. V. Lewis.

MOUNTAIN ISLAND SHOAL, FRENCH BROAD RIVER waterpowers of considerable magnitude. From Asheville to Paint Rock the river flows as a rapid current for the entire distance in a rocky gorge, the depth of which increases as the Tennessee line is approached, where the river makes its way across the Smoky Mountain ridge.

For measurements of the flow of the French Broad river at Asheville see pp. 322-326.

WATERPOWER ON THE FRENCH BROAD RIVER.

The total descent of the river from Asheville to Paint Rock is 710 feet. While this descent is fairly uniform, yet at several places there are shoals of greater or less prominence. A serious difficulty in the way of developing these shoals into waterpowers is that throughout this distance the river is closely followed by the Western North Carolina division of the Southern Railway, the track being for the most part only a few feet above high water. The more prominent of these shoals are the following:

From the Tennessee line up to Hot Springs, a distance of about 6 miles, the total fall in the river is 59 feet, an average fall of 9.8 feet per mile. This fall is well distributed, the river being smooth, running between stretches of bottom-land and having no shoals worthy of mention.

The first shoal on the river is a small shoal just above the bridge across the river at Hot Springs. The shoal has but small fall and is of no importance.

Above Hot Springs the character of the river changes abruptly. From a smooth, though rapid, stream it suddenly becomes a dashing mountain torrent, running between high hills on either side, its bed obstructed by ledges of rock that project in jagged ridges across the stream. There are also several small islands and large numbers of huge boulders, and in places the river becomes very wide. In the 7.7 miles between Hot Springs and the mouth of Brush creek the fall is 201 feet, an average fall of 26.1 feet to the mile, and this may be called practically one shoal. At intervals, however, the fall within this distance is much more concentrated, and there is even one short space where the water appears sluggish, just below Mountain island. Here the river contracts, just below the lower end of the island, to a width of not more than 60 feet, and the water is said to be 60 feet deep.

MOUNTAIN ISLAND SHOAL is the first shoal on the river possessing any concentrated fall. Here there is a small rapid at the lower end of the island and an almost vertical plunge at the upper end of about 4 feet. There is also a small amount of land suitable for the erection of buildings at the lower end of the island (Plate XII).

From the upper end of the island to the mouth of Brush creek the river is a continuous rapid, but with concentration of fall about as follows:

About two miles above Mountain island, just below the mouth of Big Laurel creek and for about half a mile above its mouth, there is a large fall, estimated by eye alone as 15 feet or more in the half mile above the creek mouth. There is very little level ground bordering this part of the river, but situations suitable for buildings might be found at Frisby station, where also a good dam site may be found.

For the next mile the fall is large but well distributed, there being only two small shoals noticeable in this distance.

There is a long rapid, with large fall in the bend of the river, about 2 miles below Barnard. The aggregate fall here is not known. There is but very little room suitably situated for buildings.

Below, and extending for some distance above the mouth of Brush creek, the bed of the river seems to be of solid rock for a quarter of a mile; the fall is large, the banks rocky and very steep, and the river is narrow. The conditions for the construction of a dam are very favorable, plenty of building material being found on the spot. No ordinary development of any of these powers is possible, while the railroad track retains its present position, quite close to the river and only a few feet above the high-water level.

From the mouth of Brush creek to Asheville, a distance of 29.3 miles, the stream is still very rapid, but the average fall per mile is much less than in the section of the river from Brush creek to Hot Springs. The total fall from Brush creek to Asheville is 450 feet, and the average fall per mile is 15.37 feet.

This fall is well distributed, there being very little concentration of fall above this point.

Just below Barnard station there a small shoal with good building room and a site for a dam, but the fall is not very great.

A mile and a half above Barnard, and a mile above the mouths of Papaw and Walnut creeks, there is a shoal which has only a small fall, but the river is narrow, affording a good site for a dam but little room for buildings. The river is very rapid for half a mile below this shoal.

There are small rapids above Alexander station and again about 3 miles above this station, but there are no very favorable sites for dams and not much space for buildings.

Above Asheville the character of the river again changes, and from a very rapid mountain stream it comes to remind the observer of the streams of the eastern part of the state. The bed of the river is overlaid with a stratum of coarse sand and gravel, and in general is quite smooth, though the current is interrupted at intervals by ledges and boulders. The fall is very much more gradual and evenly distributed than is usual with mountain streams. The distance from Asheville to Brevard by river is 48.35 miles, and the total fall only 130.9 feet, the average fall per mile in this distance being 2.7 feet.

There are only two shoals on this part of the river of more than a few inches fall. Eight and one-half miles above Asheville is the SANDY BOTTOM SHOAL, the largest in this part of the river. The total fall is 22.6 feet in about 18,000 feet.[1]

About 12 miles above Asheville, and 3½ miles above the Sandy Bottom shoal, is LONG SHOAL, where, in 12,920 feet, the fall is 18.3 feet.

TRIBUTARIES OF THE FRENCH BROAD RIVER.

The French Broad has a number of tributary streams upon which have been already or can be developed small waterpowers by the construction of dams across the narrow, rocky gorges through which these streams make their way to the river. The more important of these are as follows:

Spring creek, which rises on the eastern slope of the Newfound mountains in the extreme southwestern portion of Madison county, flows in a northerly direction and joins the French Broad river at Hot Springs, above which point it has a total drainage area of 66 square miles.

Laurel river, which rises in the Bald mountains in the extreme northeastern corner of Madison county, flows in a southwesterly course and joins the French Broad about 1½ miles above Hot Springs, having a drainage area of 141 square miles.

Ivy river, the next of the important tributaries in the ascending order, rises on the western slopes of the Craggy mountains near Yates Knob and, flowing in a general westerly course, joins the French Broad river a little more than 2½ miles above Marshall, having a total drainage area of 176 square miles. On this stream there are several shoals, which, though not of great importance, are yet deserving of mention in this connection.

One mile above the mouth of the stream there is a natural fall of 6 feet in a distance of 200 feet, and there is an excellent location for a dam on solid rock where most of the fall is concentrated. The width of the stream here is 60 to 70 feet. The adjacent ground is not very satisfactory for large building sites, but the power can be easily transmitted electrically to the town of Marshall only a few miles distant.

[1] The information concerning the shoals between Asheville and Brevard was obtained from the Annual Report, Chief of Engineers, 1876, p. 722.

On Big Ivy, just above the mouth of Little Ivy, there is a grist- and saw-mill, located on a good site, with a dam about 8 feet high, giving a fall of 10 feet. Below this the stream is rapid and descends rapidly, so that this fall could doubtless be increased.

At Democrat post-office, one mile above the Burnsville road, there is a grist-mill, located on a good site, with a 10-foot log dam. This power might be considerably improved by adding the 2 feet fall just below the dam and in other ways. There is a suitable place for building just at or near the dam.

On the Middle fork of Little Ivy river, just at its junction with Paint fork, there is a mill with an overshot wheel using about 15 feet fall.

Sandy Mush creek, which is joined by the Turkey creek, both having their rise in the slopes of Newfound mountains in the western part of Buncombe county, flows in a northeasterly course and joins the French Broad at the west side of the river at a point about 4½ miles above Marshall. It has a total drainage area of 86 square miles.

The *Swannanoa river*, which rises against the southern end of the Black mountains between the Craggies and the Blue Ridge and flows thence in a general southwesterly course, joins the French Broad about a mile above Asheville, having a total drainage area of 132 square miles. The only power on this stream worthy of mention is that a few miles above the mouth, which is now being utilized by the Asheville city authorities to pump the water supply up to the city reservoir.

Hominy creek rises near the southern end of Newfound Mountain ridge, a few miles east of Canton, in Haywood county, and flowing eastward joins the French Broad about 2 miles above the mouth of the Swannanoa, having a total drainage area of 93 square miles. On its course there are several shoals and 2 or 3 small mills, but none of great importance. A short distance above its mouth its largest power has been improved and is used for developing electricity by one of the Asheville street railway companies. There is here a total fall of 30 feet, and it is reported that 300 horsepower is used during the larger portion of the year.

Cane creek, the next above, rises on the western slope of the Blue Ridge just south of Swannanoa Gap, and, flowing in a northwesterly course, joins the French Broad river on the east between Henderson and Buncombe counties. It has a total drainage area of 90 square miles.

Muddy creek, which enters the French Broad a few miles above the last-mentioned, rises in the Blue Ridge some miles to the southwest of Hendersonville and flows first in a northerly and then a northwesterly direction, having a total drainage area of 113 square miles.

Mills river, which enters the French Broad on the west, nearly half a mile above the mouth of Muddy creek, rises on the southern slopes of the Pisgah mountains and flows in a general easterly course, having a total drainage area of 74 square miles.

PIGEON RIVER.

Pigeon river rises in the extreme southern portion of Haywood county and against the northern and eastern slopes of the southern end of the Balsam mountains near their junction with Tennessee ridge; it flows thence in a northerly course for a distance of some 20 miles, when it crosses the Murphy division of the Western North Carolina railroad at Canton. Thence it flows westerly for a distance of about 10 miles, and then northwesterly about 25 miles to the Tennessee border, where it breaks across the Great Smoky mountains in a deep, rocky and inaccessible gorge. From this point it flows on in a northwesterly course for a distance of some 25 miles more, where it joins the French Broad, and its water ultimately reaches the Gulf through the Tennessee and the Mississippi.

Where this river is crossed by the Western North Carolina railroad at Canton it is to be seen as a rather quiet, placid stream, and it maintains this character to a greater or less degree for a distance of 10 to 15 miles below this point. Lower down, however, and on to where it crosses the state line into Tennessee, it becomes a rapid, rushing stream, flowing in a deep, narrow, rock-bound gorge. The total distance from Canton to the Tennessee line, following the windings of the river, is not much short of 50 miles, and in this distance its aggregate fall is approximately 1300 feet, or 26 feet to the mile.

Just above its junction with Richland creek it has a drainage basin of 268 square miles. It has a total drainage area above the Tennessee line of 572 square miles. Of this total area in 1880, 40,000 acres were reported as being in cultivation, 11,000 acres in grass, and 315,000 acres, or about 86 per cent. of the total area, were still forest-covered. The total rainfall of the basin for the year as determined by a single station at Waynesville, observations at which extend over between 3 and 4 years, is given by the United States Weather Bureau as 48.4 inches, distributed as follows: spring, 13.7; summer, 16.6; autumn, 7.5; winter, 10.6 inches.

WATERPOWER ON PIGEON RIVER.

But few waterpowers on this stream have been developed, and there are but few shoals about which much is known. From the Tennessee line, up the stream for 20 or 25 miles following its windings, the river gorge is deep, narrow and irregular. The country is exceedingly rugged and inaccessible, and the stream is almost a continuous rapid. At a number of points the conditions are favorable for the construction of dams, which would yield a fall of water varying with the height of the dam, and while at most of these points there is no space available for extensive buildings, the power could be easily transmitted to Waynesville by electricity and there used in manufacturing enterprises. Further up the river the first shoal to be met with is one located about three-quarters of a mile below the mouth of Crabtree creek, where there is a fall of about 3½ feet in a distance of 400 feet, but as there is here no place suitable for the construction of a dam, the power is not a promising one for development.

About 3 miles below Clyde there is another small shoal now occupied by a small grist-mill. The development here consists of an ordinary log dam 4 feet in height, built across the top of the shoal. The mill is operated by an undershot wheel, which uses only a small portion of the water available.

About one-half mile below Clyde there is still another small shoal, partially developed for the operation of a saw- and grist-mill. There is here a log dam 8 feet high, and, as in the last-mentioned case, this mill uses only about half of the water at the period of the lowest flow.

At a point 1½ miles above Canton there is said to be a fall of several feet in a short distance, where the conditions are quite favorable for the construction of a dam, which would increase this fall considerably. Still further up the river there are a number of shoals where small waterpowers may be developed for the operation of small grist- and saw-mills.

On the three principal tributaries lying on the west side of the river —Cataluche, Jonathan and Richland creeks—there are also a number of small shoals capable of being developed to powers either for local use or for transmission, electrically, to Waynesville.

CHAPTER XIII.

THE TENNESSEE AND HIWASSEE RIVERS.[1]

THE TENNESSEE RIVER AND TRIBUTARIES.

The Tennessee river is the largest of the North Carolina streams west of the Blue Ridge, being slightly larger than the French Broad. It rises on the north slope of the Blue Ridge in Rabun county, Georgia, and flows in a general northerly course across Macon and a portion of Swain county to a point about 10 miles east of Bryson City, where it is joined by the Tuckaseegee river and flows in a general westerly course, forming the line between Swain and Graham counties, and, like the mountain streams already described, crosses the Great Smoky mountains in a deep, narrow, rocky gorge. From this point the river flows in a northwesterly course for a distance of 40 to 50 miles, to where it joins the Holston, and thence flows to and through the Mississippi to the Gulf. The total drainage area of the river basin above the Tennessee line is 1831 square miles, of which, according to the United States Census Report in 1880, there were 83,000 acrès of land in cultivation, 11,000 acres in grass, and 1,078,000 acres, or 90 per cent. of the whole, in forests. The total rainfall of the year in this region is given by the United States Weather Bureau as 62.2 inches, distributed as follows: spring, 14.6; summer, 17.5; autumn, 12.7; winter, 17.4 inches. In most of these mountainous counties autumn is the driest season. The soil of this region is deep and fertile, being well adapted to the grasses, cereals and tobacco. It contains a larger portion of clay than is found in some of the more northeastern mountain counties, but still may be fairly considered as a loam. The basin contains numerous valuable mineral deposits, notably the mica and corundum deposits in Jackson and Macon counties.

Throughout the larger portion of its course from the Georgia line to Franklin, the river is, for this region, a rather sluggish stream with occasional shoals, but from five miles below Franklin to beyond the Tennessee line, it runs through a deep gorge with rock bottom and sides, and for this entire distance is practically a succession of shoals. A few important waterpowers have already been developed, but there are a

[1] By E. W. Myers and J. V. Lewis.

number of places where the conditions are favorable for the development of much larger powers, as shown by the following notes.

For 15 miles below Rocky Point ferry the river plunges through a deep gorge formed by the spur of the Bald mountain on the north and the Unicoi mountains on the south, the stream varying in width from 30 to 150 yards, and the fall from 10 to 40 feet per mile. From Rocky Point ferry up to the mouth of the Tuckaseegee river, a distance of about 23 miles, the mountains dwindle gradually, the river becomes broader and the fall diminishes to an average of about 15 feet per mile.

The character of the river bed for the larger part of its course in North Carolina is practically uniform. It is crossed by bodies of gneissic, schistose and slaty rock, in some places flat and in other places inclined at steep angles. The variations in the rock are not great enough nor abrupt enough to produce vertical falls of great height, but sufficient to produce here and there numerous small rapids and plunges of from 6 inches to 2 feet each, giving an aggregate fall of from 10 to 40 feet per mile.

TABLE OF DECLIVITY IN NORTH CAROLINA.[1]

Locality.	Distance.	Altitude.	Fall per mile.
State line	0.0	1224	
Rocky Point	5.0	1306	16.5
Calhouns	19.0	1512	15.0
Alarka creek	35.0	1745	14.0
Franklin ford	59.5	2055	13.0
State line (Georgia and North Carolina)	80.0	2240	9.66

Average fall per mile in North Carolina 13.5 feet.

For measurements of the flow of the Little Tennessee river at Judson, 4 miles above its junction with the Tuckaseegee, see pp. 329 to 331.

WATERPOWER ON THE TENNESSEE RIVER.

The first 4 miles of the river up from the Tennessee line lies in a deep, rocky gorge, through which it passes as a succession of rapids. The volume of water and the fall are ample for large possibilities in waterpower development, but the rocky walls of the stream are so steep and high, the gorge so narrow, and the region so rugged as to be quite inaccessible. The first accessible shoal of importance is half a mile above Rocky Point ferry and just below the mouth of Twenty-mile

[1] See Annual Report, Chief of Engineers, 1876, p. 716.

creek; it has a fall of about 5½ feet in a distance of 200 yards. The river here is quite narrow, not being more than 40 feet wide in portions of the shoal. At the head of the shoal it is considerably wider, though there are good abutments and foundation for a dam. There is also an abundance of space for buildings.

Three-fourths of a mile above Twenty-mile creek there is a rapid with a fall of about 4 feet in 100 feet. Here the rocky banks of the river are so steep and high that a dam 100 feet high would not be over 300 feet long at the top. Stone for the construction of such a dam and for other purposes is abundant in the vicinity, but there is no space for buildings. There are the possibilities here for a waterpower of considerable magnitude.

About a mile above this last, and just below Fairfax post-office, there is a rapid with a fall of about 5 feet, distributed somewhat uniformly through a distance of 250 yards. The river is quite wide here, however, and the country is exceedingly rough. A dam could be built almost anywhere on the shoal, but there is no suitable building space for a mill.

Half a mile above this shoal, and again one mile above it, there are rapids of small fall, extending over considerable distances, and not, therefore, of much importance.

About 2 miles above Fairfax there is a better rapid, having more fall than the last-mentioned and a little space for buildings, but the channel is quite broad, and the locality is not regarded of much importance as a waterpower possibility.

During the next 7 miles up the river there are no shoals with any important concentrated natural fall, though there are a number of places where dams might be built and powers developed, the current being sufficiently rapid to prevent the accumulation of water below the dams in time of freshets.

About a quarter of a mile above the mouth of Hazel creek there is a rapid having a natural fall of about four feet in two hundred yards, and consisting of two equal parts separated by about a hundred yards of smooth water. Neither place is suitable for building a dam, as the banks are not good, the south bank in particular being bad, and besides the river here is quite wide.

From this point to about one and a quarter miles above Wayside post-office, a distance of about one and three-quarter miles, the river is very placid, running smoothly and containing no rapids to speak of. One and a fourth miles above Wayside there is a small rapid having a fall of about 18 inches in 200 to 250 feet. The river is broad, however, and neither bank is good, nor is there much level room for building,

so that the shoal is practically of no importance. There are two rapids between this place and Bushnell, but they are small and of little interest.

From the mouth of the Tuckaseegee river, at Bushnell to the mouth of the Nantahala river, a distance of about 7 miles, the stream is very rapid and there are available places for dams, but there are no shoals of any consequence, and the railroad follows the river so closely that it would be impracticable to utilize fully any power that might lie in this section of it. For the five miles above the junction with the Nantahala the stream was not examined, but it is said to be of about the same general character as the five miles below this point.

Five miles above the mouth of the Nantahala we found a small shoal having a fall of about two feet in one hundred. There is good foundation for a dam and rock abutments on the banks, but the space for buildings is small.

From this point to the mouth of Brush creek, a distance of something over four miles, the river is quite rapid and shoaly, but there are no large concentrated natural falls.

At the mouth of Brush creek the river divides and includes an island about a quarter of a mile long. On the east side of the island there is a shoal having ample fall for fair power development, but the location is not favorable for a permanent dam. On the west side, and at the foot of the island, there is now a small saw- and grist-mill, using a head of about six feet, produced by a log dam of the same height built at the foot of the shoal. Also, just above the mouth of Brush creek, there is a small shoal, but of no particular importance.

Two miles and a half above the mouth of Brush creek, and about fourteen miles from Franklin, there is a shoal having a natural fall of about two feet with a good site for a dam and an ample space for buildings.

Then, for the distance of about one mile, the river is comparatively placid and sluggish. Above this for about a mile or a mile and a half, there is a rapid consisting of a series of small cascades 100 to 150 yards apart, none of them having separately a fall of more than a foot.

For a distance of about three miles there is very little fall in the river, and the only shoal is a mile below the mouth of Cowee creek and ten miles from Franklin. This shoal has a fall of about one foot over a solid rock ledge extending entirely across the river and giving good foundation for dam and a good abutment on the north side, but on the south side the conditions are not so favorable. There is, however, ample space for buildings.

About a quarter of a mile below the mouth of Watauga creek there

is a small shoal with a fall of about one foot, but the rock in the bed of the stream is not favorable for the foundations and abutments of a dam.

Just above the mouth of Iola creek, and about 5 miles from Franklin, there is a small shoal with a little fall consisting of rock ledges across the river, and there is plenty of good building room, but the banks are not favorable for a dam.

Above this point the river is comparatively of gentle grade, and there are no available waterpowers.

A discharge measurement at Franklin, September 13, 1895, gave 426.9 cubic feet per second, equivalent to 48.5 horsepower per foot fall. The measurement was made at low water.

TRIBUTARIES OF THE TENNESSEE RIVER.

The Tennessee has numerous tributary streams in North Carolina, one of which, the Tuckaseegee, has a drainage basin above the junction of the two slightly larger than that of the Tennessee. The more important of these tributaries are the Cheowah, the Tuckaseegee, the Nantahala, and numerous smaller streams. These more important tributaries, together with their possible waterpower development, may be briefly described as follows:

THE CHEOWAH RIVER.

The Cheowah river rises on the western slopes of the Long Ridge mountains in the neighborhood of Red Marble gap in the extreme southwestern corner of Graham county. Thence it flows in a general northwesterly and northerly course, joining the Tennessee river 2 or 3 miles above the state line. Its drainage basin embraces 219 square miles, lying between the Cheowah mountains on the north, Long Ridge on the south, and the Unicoi mountains on the west, and is fed by numerous small mountain streams. Owing to the fact that more than 80 per cent. of the region is still forest-covered and the soil is deep and porous, the water in this region has a fairly uniform flow.

The total fall in the river from the forks to the mouth is about 780 feet, the distance in a straight line about 9 miles, following the course of the river about 14 miles, and the average fall per mile between 55 and 60 feet.

For about 6 miles up from its mouth this river has not been carefully examined. It runs through a deep, rugged gorge, and is a succession of shoals and rapids for the lower 7 or 7½ miles of its course. The first place at which the river was observed was about 6 miles from its mouth and about one mile below the mouth of Cochran creek. The river was one continuous rapid, with a fall of not less than 50 feet in

so that the shoal is practically of no importance. There are two rapids between this place and Bushnell, but they are small and of little interest.

From the mouth of the Tuckaseegee river, at Bushnell to the mouth of the Nantahala river, a distance of about 7 miles, the stream is very rapid and there are available places for dams, but there are no shoals of any consequence, and the railroad follows the river so closely that it would be impracticable to utilize fully any power that might lie in this section of it. For the five miles above the junction with the Nantahala the stream was not examined, but it is said to be of about the same general character as the five miles below this point.

Five miles above the mouth of the Nantahala we found a small shoal having a fall of about two feet in one hundred. There is good foundation for a dam and rock abutments on the banks, but the space for buildings is small.

From this point to the mouth of Brush creek, a distance of something over four miles, the river is quite rapid and shoaly, but there are no large concentrated natural falls.

At the mouth of Brush creek the river divides and includes an island about a quarter of a mile long. On the east side of the island there is a shoal having ample fall for fair power development, but the location is not favorable for a permanent dam. On the west side, and at the foot of the island, there is now a small saw- and grist-mill, using a head of about six feet, produced by a log dam of the same height built at the foot of the shoal. Also, just above the mouth of Brush creek, there is a small shoal, but of no particular importance.

Two miles and a half above the mouth of Brush creek, and about fourteen miles from Franklin, there is a shoal having a natural fall of about two feet with a good site for a dam and an ample space for buildings.

Then, for the distance of about one mile, the river is comparatively placid and sluggish. Above this for about a mile or a mile and a half, there is a rapid consisting of a series of small cascades 100 to 150 yards apart, none of them having separately a fall of more than a foot.

For a distance of about three miles there is very little fall in the river, and the only shoal is a mile below the mouth of Cowee creek and ten miles from Franklin. This shoal has a fall of about one foot over a solid rock ledge extending entirely across the river and giving good foundation for dam and a good abutment on the north side, but on the south side the conditions are not so favorable. There is, however, ample space for buildings.

About a quarter of a mile below the mouth of Watauga creek there

is a small shoal with a fall of about one foot, but the rock in the bed of the stream is not favorable for the foundations and abutments of a dam.

Just above the mouth of Iola creek, and about 5 miles from Franklin, there is a small shoal with a little fall consisting of rock ledges across the river, and there is plenty of good building room, but the banks are not favorable for a dam.

Above this point the river is comparatively of gentle grade, and there are no available waterpowers.

A discharge measurement at Franklin, September 13, 1895, gave 426.9 cubic feet per second, equivalent to 48.5 horsepower per foot fall. The measurement was made at low water.

TRIBUTARIES OF THE TENNESSEE RIVER.

The Tennessee has numerous tributary streams in North Carolina, one of which, the Tuckaseegee, has a drainage basin above the junction of the two slightly larger than that of the Tennessee. The more important of these tributaries are the Cheowah, the Tuckaseegee, the Nantahala, and numerous smaller streams. These more important tributaries, together with their possible waterpower development, may be briefly described as follows:

THE CHEOWAH RIVER.

The Cheowah river rises on the western slopes of the Long Ridge mountains in the neighborhood of Red Marble gap in the extreme southwestern corner of Graham county. Thence it flows in a general northwesterly and northerly course, joining the Tennessee river 2 or 3 miles above the state line. Its drainage basin embraces 219 square miles, lying between the Cheowah mountains on the north, Long Ridge on the south, and the Unicoi mountains on the west, and is fed by numerous small mountain streams. Owing to the fact that more than 80 per cent. of the region is still forest-covered and the soil is deep and porous, the water in this region has a fairly uniform flow.

The total fall in the river from the forks to the mouth is about 780 feet, the distance in a straight line about 9 miles, following the course of the river about 14 miles, and the average fall per mile between 55 and 60 feet.

For about 6 miles up from its mouth this river has not been carefully examined. It runs through a deep, rugged gorge, and is a succession of shoals and rapids for the lower 7 or 7½ miles of its course. The first place at which the river was observed was about 6 miles from its mouth and about one mile below the mouth of Cochran creek. The river was one continuous rapid, with a fall of not less than 50 feet in

so that the shoal is practically of no importance. There are two rapids between this place and Bushnell, but they are small and of little interest.

From the mouth of the Tuckaseegee river, at Bushnell to the mouth of the Nantahala river, a distance of about 7 miles, the stream is very rapid and there are available places for dams, but there are no shoals of any consequence, and the railroad follows the river so closely that it would be impracticable to utilize fully any power that might lie in this section of it. For the five miles above the junction with the Nantahala the stream was not examined, but it is said to be of about the same general character as the five miles below this point.

Five miles above the mouth of the Nantahala we found a small shoal having a fall of about two feet in one hundred. There is good foundation for a dam and rock abutments on the banks, but the space for buildings is small.

From this point to the mouth of Brush creek, a distance of something over four miles, the river is quite rapid and shoaly, but there are no large concentrated natural falls.

At the mouth of Brush creek the river divides and includes an island about a quarter of a mile long. On the east side of the island there is a shoal having ample fall for fair power development, but the location is not favorable for a permanent dam. On the west side, and at the foot of the island, there is now a small saw- and grist-mill, using a head of about six feet, produced by a log dam of the same height built at the foot of the shoal. Also, just above the mouth of Brush creek, there is a small shoal, but of no particular importance.

Two miles and a half above the mouth of Brush creek, and about fourteen miles from Franklin, there is a shoal having a natural fall of about two feet with a good site for a dam and an ample space for buildings.

Then, for the distance of about one mile, the river is comparatively placid and sluggish. Above this for about a mile or a mile and a half, there is a rapid consisting of a series of small cascades 100 to 150 yards apart, none of them having separately a fall of more than a foot.

For a distance of about three miles there is very little fall in the river, and the only shoal is a mile below the mouth of Cowee creek and ten miles from Franklin. This shoal has a fall of about one foot over a solid rock ledge extending entirely across the river and giving good foundation for dam and a good abutment on the north side, but on the south side the conditions are not so favorable. There is, however, ample space for buildings.

About a quarter of a mile below the mouth of Watauga creek there

is a small shoal with a fall of about one foot, but the rock in the bed of the stream is not favorable for the foundations and abutments of a dam.

Just above the mouth of Iola creek, and about 5 miles from Franklin, there is a small shoal with a little fall consisting of rock ledges across the river, and there is plenty of good building room, but the banks are not favorable for a dam.

Above this point the river is comparatively of gentle grade, and there are no available waterpowers.

A discharge measurement at Franklin, September 13, 1895, gave 426.9 cubic feet per second, equivalent to 48.5 horsepower per foot fall. The measurement was made at low water.

TRIBUTARIES OF THE TENNESSEE RIVER.

The Tennessee has numerous tributary streams in North Carolina, one of which, the Tuckaseegee, has a drainage basin above the junction of the two slightly larger than that of the Tennessee. The more important of these tributaries are the Cheowah, the Tuckaseegee, the Nantahala, and numerous smaller streams. These more important tributaries, together with their possible waterpower development, may be briefly described as follows:

THE CHEOWAH RIVER.

The Cheowah river rises on the western slopes of the Long Ridge mountains in the neighborhood of Red Marble gap in the extreme southwestern corner of Graham county. Thence it flows in a general northwesterly and northerly course, joining the Tennessee river 2 or 3 miles above the state line. Its drainage basin embraces 219 square miles, lying between the Cheowah mountains on the north, Long Ridge on the south, and the Unicoi mountains on the west, and is fed by numerous small mountain streams. Owing to the fact that more than 80 per cent. of the region is still forest-covered and the soil is deep and porous, the water in this region has a fairly uniform flow.

The total fall in the river from the forks to the mouth is about 780 feet, the distance in a straight line about 9 miles, following the course of the river about 14 miles, and the average fall per mile between 55 and 60 feet.

For about 6 miles up from its mouth this river has not been carefully examined. It runs through a deep, rugged gorge, and is a succession of shoals and rapids for the lower 7 or 7½ miles of its course. The first place at which the river was observed was about 6 miles from its mouth and about one mile below the mouth of Cochran creek. The river was one continuous rapid, with a fall of not less than 50 feet in

a short distance, the water being very swift. The stream could be dammed anywhere and large power secured, the amount of fall being in proportion to the height of dam or the length of race. Owing to the depth and narrowness of the gorge there is but little space for any buildings other than power-houses, and the power would need to be transmitted electrically to points on the railroad where manufacturing plants can be located. There is an especially good place for a dam at the mouth of Cochran creek, as the river is there quite narrow.

For about half a mile above this point the river is quite rapid, but contains no shoals of any special importance, the only one worthy of notice being nearly a half mile above the entrance of the creek, and this one has only about 2 feet fall, but it has a good site for a dam, by which the fall could be decidedly increased.

Between this point and the mouth of Santeetla creek, a distance of about 3 miles, there are 2 small shoals, the lower midway, with a natural fall of 4 feet in a distance of 150 feet, and the upper shoal, half a mile below Santeetla creek, where there is a fall of about 3 feet in 100 feet. In both cases the rocky bed of the stream and rocky walls of the gorge afford conditions favorable for building dams which would greatly increase the fall, the stone near-by being abundant and suitable for the purpose. At both shoals there is also ample space for the location of buildings.

Near and above the mouth of Santeetla creek there is, in the Cheowah, a series of little cascades, each from 6 inches to one foot in height, the water flowing over a floor of solid rock all the way for a distance of a mile or more. Three-quarters of a mile below the mouth of East Buffalo creek there is a shoal having a fall of 3 feet in a short distance over a solid rock ledge. At this point there is ample space for necessary buildings and an abundance of stone suitable for dams and building purposes.

Half a mile above this there is a shoal having a fall of 2 feet in 50 over solid rock ledges extending across the river, and offering good foundations and abutments for a dam; and there is ample space for buildings in the vicinity.

About three-quarters of a mile above the last-mentioned point, and half a mile above the mouth of East Buffalo creek, there is a small rapid having about 2 feet fall in 100 yards, most of the fall being in 2 small plunges, one at the head and the other at the foot of the shoal. Solid rock ledges extend completely across the stream, and the banks are steep and rocky, furnishing a good site for a dam; and the supply of stone suitable for the construction of dams and buildings is ample and near at hand.

THE TUCKASEEGEE RIVER.

The Tuckaseegee river rises on the northern slopes of the Blue Ridge and the Tennessee Ridge mountains in the southern part of Jackson county, and flows in a general northwesterly course, thence across this county and the southern part of Swain county to its junction with the Little Tennessee. It has a drainage area of 833 square miles. Above the mouth of the Occoneeluftee its drainage area, which lies almost wholly in Jackson county, embraces an area of 418 square miles.

Like other mountain streams, the Tuckaseegee, for the larger portion of its course, flows rapidly through a narrow, rocky channel, and along its course there are numerous places where, by the construction of dams, excellent waterpowers can be developed.

For measurements of the flow of the river at Bryson City see pp. 326-328.

Proceeding up the river, the shoals will be named in the order of occurrence:

About one and one-fourth miles above Bushnell, where the Tuckaseegee joins the Little Tennessee, there is a shoal having a fall of about 7 feet in 200 yards. A dam could easily be built here, although the river is wide, but there is no level ground suitable for the erection of buildings. There is a somewhat similar shoal about 200 yards above this place having a fall of about 2 feet, the two shoals in reality constituting the same shoal.

About one mile above the last-mentioned site, and just below the mouth of Forneys creek, there is a small shoal having only a few inches fall and is of no importance.

One-fourth of a mile above Forneys creek there is a short shoal having a fall of about 18 inches or 2 feet in about 50 feet, caused by ledges of rock extending straight across the river. There is here no place where a dam could be built on account of the railroad which is here very close to the river. There is ample building room in the bottom on the west side of the river about 20 yards from the top of the shoal.

A quarter of a mile above this shoal there is another, having a fall of about 5 feet in 200 feet, but though the channel is quite narrow, any dam which might be built would have to be quite long, the river banks being flat and rocky and extending back some distance from the river. The river fills the whole space in time of high water. Immediately above this shoal there are a number of small rapids of a few inches fall each, but there is no concentration of fall in noteworthy amount until within half a mile below Bryson City.

Here there is a shoal having, in a distance of about 150 yards, a fall estimated by the eye as certainly not less than 5 feet. The site is of little importance, as there are broad bottoms on each side of the river lying only a few feet above the level of ordinary high water, and a large proportion of them is subject to overflow in time of freshet.

Between Bushnell and Bryson City the river is uniformly very swift, and although there is no concentrated fall the fall is large, being certainly not less than 15 feet to the mile and in all probability more than that amount.

About 200 yards above Bryson City there is a shoal very similar to the one below the place, the fall being 3 or 4 feet, estimated as before. The conditions for development at this shoal are somewhat more favorable, the south bank being very steep and rocky and the north bank much higher. The site is not regarded as of any special importance.

Throughout this part of its course the river is between 200 and 300 feet wide.

From this point, up to within three miles of Dillsboro, there are no shoals, and the river is skirted by strips of bottom-land.

Three miles below Dillsboro there is a small, short shoal having a fall of about 2 feet. The river is wide, but there is plenty of room for buildings.

About half a mile above this place, and just below the mouth of Dicks creek, is the beginning of a series of rapids that extend for half a mile up the river. There is a large fall in the rapids, the river is narrow and down in a deep gorge.

Just below the town of Dillsboro there is an abandoned waterpower which was used until a few years ago to operate a large saw-mill. The dam, part of which is still standing, was built of triangular wooden frames bolted to the bed of the river and planked over on the up-stream side, and extended in a broken line across the river. At each of the angles, timber cribs, filled with stone, were placed to add strength to the dam, which was about 8 feet high. There was no race, the water being turned directly to the wheels. The construction of the Murphy branch of the Southern Railway cut through the north end of this dam and the mill and power have since been abandoned.

A discharge measurement of this river, made September 9, 1895, at the railroad bridge just below Dillsboro, gave a discharge of 398.5 cubic feet per second at low water, equivalent to 44.2 horsepower per foot fall.

Between Dillsboro and the forks of the Tuckaseegee, a distance of 10 miles in an air-line and about 17 miles following the course of the river, the average fall is at the rate of 10 feet per mile. The course of the river is tortuous and the bottom-lands bordering the river are frequently quite broad. The fall is well distributed, there being no shoals of importance in this distance.

TUCKASEEGEE FALLS, JACKSON COUNTY

Above the forks the character of the stream changes; the fall is greatly increased and there are numerous places where large fall can be obtained and powers of corresponding magnitude developed in consequence. The most noted of these possible power sites is that known as THE FALLS OF THE TUCKASEEGEE, situated on the smaller or west fork, about five miles above the junction with the east fork. The fall here in a distance of less than one mile is about 400 feet, and is over 500 feet in less than two miles. The drainage area above this place is nearly 40 square miles, and it is about 12 miles on an air-line to the nearest railroad station, the distance to Dillsboro and Sylva being about the same (Plate XIII).

On this stream, as on the French Broad river below Asheville, the main obstacle in the utilization of the powers between Bushnell and Dillsboro is the position occupied by the railroad track which skirts the river bank for the entire distance, and any but a very low dam would seriously interfere with the road-bed, even in time of low water, and would cover it altogether in time of flood.

Below Bushnell the country is extremely rough and mountainous and very thinly settled, and the present roads are entirely impracticable for any traffic.

The principal tributaries of the Tuckaseegee river in their order ascending the stream are *Forneys creek*, *Nolans creek*, *Deep creek*, the *Occoneeluftee river*, *Scotts creek* and *Caney fork*, all entering from the north.

Forneys creek, Nolans creek and Deep creek are all small streams, rising far up on the mountain slopes, having a large fall and affording some very good small powers, at present used for running small saw- and grist-mills.

The *Occoneeluftee river*, the largest tributary, rises in the Great Smoky mountains in the extreme northeastern part of Swain county, and flowing in a southerly and then in a southwesterly course, joins the Tuckaseegee about four miles east of Bryson City, draining an area of 198 square miles. The current is uniformly rapid and the fall appears to be large but is very uniformly distributed, there being no shoals on the river as far as it was seen, of any considerable value for power purposes, though doubtless there are numbers of places where power may be secured by damming.

Only two were seen between the mouth and Yellow Hill, each having a fall of about two feet in about 200 feet. In both places the river is wide and the channel much obstructed. Above Yellow Hill the river becomes still more rapid and there are, it is said, a number of places where small powers can be developed.

Scotts creek, the next important tributary of the Tuckaseegee, has its head springs on the west slopes of the Balsam mountains near Balsam Gap, and, after flowing for about 12 miles, measured in a straight line, it empties into the Tuckaseegee just below the town of Dillsboro, draining an area of 65 square miles.

The first power on this stream is in the town of Dillsboro, where is located a small saw-mill and locust-pin factory, using a small amount of power, obtained by a dam across this creek.

About 2 miles above Dillsboro, and in the town of Sylva, there is a small power, developed some time ago for the purpose of running a corundum-mill. The fall used, about 5 feet, was all obtained from the dam. The power here is, of course, very limited in quantity, only suitable for operating a small plant. There are no other developed powers on this creek.

NANTAHALA RIVER.

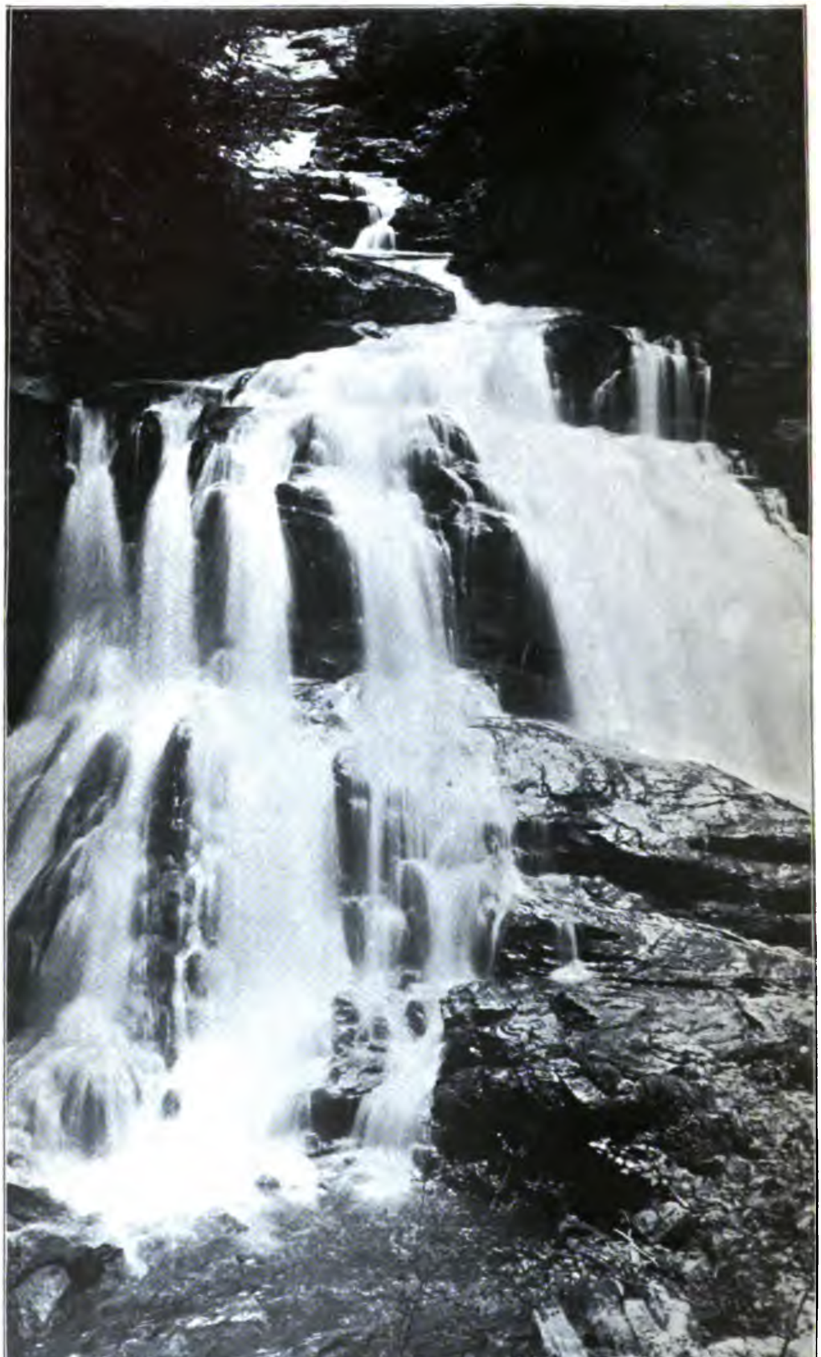
The Nantahala river, which joins the Tennessee about 5 miles (by a straight line) above the mouth of the Tuckaseegee, rises on the northern slopes of the Blue Ridge in Rabun county, Georgia, and flows in a general northerly direction throughout its entire course. It has a total drainage area of 184 square miles, as compared with the Tennessee river, which rises near the same general region, and which has above the mouth of the Nantahala a drainage area of 467 square miles. This shows that the Nantahala throughout its entire course runs in a narrow, deep basin and has but few tributary streams. For the lower third of its course it runs in a narrow gorge from one to two thousand feet deep, having in this part of its course, which parallels the Murphy division of the Western North Carolina railroad, practically no tributaries.

Waterpowers have been developed on the Nantahala at two points:

(1) At Ricard and Hewitt's talc-mill, about 10 miles (straight line) above the mouth of the river, where a small dam and a race furnish power sufficient for operating this mill.

(2) At Hubbard and Mertz's saw-mill, about 3 miles further up the stream, where the river has cut through the Nantahala mountains, where it first reaches the railroad. The drainage basin of the river above this point has a total area of 152 square miles, practically all of which is forest-covered. At this latter point it is said that quite a large power could be developed, as the river flows here through a deep, narrow, rocky gorge into a wider channel below.

From this last-mentioned place down to the mouth of the river there are numerous undeveloped shoals with suitable places for the construction of dams, the stream-bed being narrow and its bottom and sides being of rock. The fact that the railroad track is but a few feet above



CULLASAJA LOWER FALLS, MACON COUNTY

the bed of the stream would interfere with the large development of any of these shoals.

CULLASAJA CREEK.

There are numerous other small tributaries of the Little Tennessee on which either have been or can be developed important though small waterpowers. Thus, on the Cullasaja, one of these smaller tributaries of the Little Tennessee, at Corundum Hill the power is developed by a 7-foot dam, giving a fall of 9 feet at the mill, this water turning a 40 horsepower turbine-wheel. At the CULLASAJA FALLS, 7 miles above Franklin, there is said to be a vertical fall of 95 feet and a total fall of 310 feet in one-fourth of a mile.[1] This is known as "Cullasaja lower falls." About 6 miles above this there is a succession of rapids and falls, in a narrow gorge, which together, are known as the "Cullasaja upper falls." An excellent power could be developed here also (Plate XIV).

HIWASSEE RIVER AND TRIBUTARIES.

The Hiwassee river rises on the northern slopes of the Blue Ridge in Towns county, Georgia, and flows in a general northerly-northwesterly course by way of Hayesville, Clay county, North Carolina, and then in a general west-northwesterly course across Clay and Cherokee counties into Tennessee, where it joins the Tennessee, and through it flows into the Mississippi.

The two most important of its tributary streams are the Nottely, which rises on the north slopes of the Blue Ridge mountains not far from the source of the Hiwassee in Union county, Georgia, and flows in a general northwesterly and northerly course, joining the Hiwassee some 5 miles below Murphy; and the Valley river, which rises in the extreme northwestern corner of Cherokee county, near Red Marble Gap, and flows in a southwesterly course, joining the Hiwassee at Murphy. The Nottely river has a drainage area of 305 square miles, and the Valley river, 128 square miles.

The drainage basin of the Hiwassee above the Tennessee line is 1084 square miles. Of this area, according to the census of 1880, there were 40,000 acres of land in cultivation, 35,000 in grass, and 619,000, or 89 per cent. of the whole, were still forest-covered, and in portions of the Valley river basin there are numerous valuable deposits of marble, talc and iron ore, and also some gold, silver and lead. Along portions of Nottely and Hiwassee rivers also there are some fine farming lands and valuable deposits of marble and talc.

[1] The fall here was measured by Dr. H. S. Lucas, with an engineer's level.

For measurements of the flow of the Hiwassee river at Murphy see pp. 331-334.

WATERPOWER ON HIWASSSEE RIVER.

In connection with the following notes concerning possible water-power developments on the Hiwassee river, it must be said that the part of the river at and for 13 miles above the Tennessee state line has not yet been carefully examined owing to its inaccessibility. But according to the best information obtainable, there are in this portion of the river no shoals which could be developed into large powers; and, indeed, it is reported that there are no shoals in this part of the river with a fall greater than a few inches.

Below Murphy the river is a rapid stream, but the fall is well distributed, there being no places where there is any considerable amount of concentrated fall. The distance from Murphy to the North Carolina-Tennessee state line, following the course of the river, is about 28 miles, and the total fall in the stream is about 300 feet, or between 10 and 11 feet to the mile.

Between Murphy and Hayesville, a distance of about 19 miles following the course of the river, the total fall is about 250 feet and the average fall per mile about 13 feet.

The first shoal seen was about a mile above Ogreta post-office and about 15 miles above the state line. This shoal had a fall of about 3 feet in 200, and at its crest there is an excellent foundation for a dam and an abundance of rock on the spot for building purposes, but the river at this point is about 300 feet wide. There is ample space for buildings on the northeast bank.

From this point on up to within a half mile of Murphy there are occasional rapids in the river but no important shoals, and though places where dams could be built are numerous, no fall could be secured beyond what the dam would give, and the river is from 250 to 300 feet wide.

Half a mile below Murphy is a site that is said to be probably the best in the county. There is no natural fall in the river at this place, but the stream is rapid and wide enough to allow of the easy escape of water below the dam, and there is here a good foundation for a dam and good abutments on both banks. On the southwest bank of the river there is a precipitous bluff of solid rock 100 feet or more in height, and this recedes from the river almost at right angles. Below this bluff can be found ample space for buildings, which would here be in a measure protected from the effects of flood. A dam at this place would need to be quite long, but an ample supply of rock can be obtained close at hand for its construction. The drainage of the river above this point is 570 square miles and the rainfall 61 inches per annum. This power might be developed, conveyed electrically to the town of Murphy, and used there for operating a variety of manufacturing establishments. In the same manner the shoals mentioned on the river in the succeeding paragraphs might be developed and the power from each be brought to Murphy and there used for lighting and manufacturing purposes.

About 5½ miles above Murphy there is a shoal having a fall of about 2 feet in 100. The river is quite narrow and could easily be dammed, as there are good foundations and abutments for a dam, and plenty of stone on the spot for building purposes. The locality is not favorable for buildings, but the power could easily be transmitted to Murphy as suggested above.

Eight and one-fourth miles above Murphy the Cherokee Lumber Company has in part utilized the finest power on the upper part of the river, though not for power purposes.

There is a fall of about 3 feet in the river at this point over a solid rock ledge, and across the top of this a dam has been built for the purpose of floating logs to the steam saw-mill which they have at this point. This place could be well used for power purposes, as the foundations and abutments for a dam are good and there is ample space for a powerhouse and the other necessary buildings.

About 10 miles from Murphy, just above the Shallow ford, there is a small shoal having a fall of about one foot in 50. Here again the river is narrow and the channel restricted, and a good dam could easily be built, thus greatly increasing the fall available, and there is plenty of good level building room.

The Hiwassee is a very rapid stream, flowing in a channel which it has cut out of the solid rock, and in many places the banks are quite steep and precipitous and rocky, thus affording good sites for dams. It, like the other mountain streams, is subject to violent floods, frequently rising to a height of 10 feet above its normal level in a very short time, and dams would need to be strongly built to withstand these floods.

From Murphy to Hayesville the stream has not been very closely examined, but it possesses the same general characteristics as noted above for the river in general, only its channel is more rocky and more restricted, and the banks higher and steeper.

Nothing is known as to the waterpower of the Nottely river, as it was not examined and inquiry failed to bring to light anything of interest concerning the stream. There is no power worthy of mention in this connection on Valley river.

PART IV

DISCHARGE MEASUREMENTS ON THE NORTH CAROLINA RIVERS

E. W. Myers

DISCHARGE MEASUREMENTS ON THE NORTH CAROLINA RIVERS.

CHAPTER XIV.

STREAM MEASUREMENTS.[1]

The power that can be developed at any point on a stream is dependent solely on the available fall and on the available quantity of water.

The fall can be easily and accurately measured once for all with an engineer's level, but the determination of the quantity of water flowing is by no means such a simple matter, for this is varying constantly, from hour to hour and from day to day, so that an accurate gauging of the flow made on one day will not of itself serve to determine the volume of the water on some other day when the stage of the river is different.

To the engineer who has to plan a hydraulic construction, and to the investor who desires to purchase waterpower, an accurate knowledge of the flow of the stream where the power is located is a matter of the first importance. It is necessary to know the minimum flow, that the construction may be so planned as to give the desired power, and the maximum flow that the structure may be proportioned to withstand the enormous forces that may be brought to bear on it in time of flood. With all its importance, information of this character has been available for but a few streams, and these mainly located in the New England states, where the peculiarities of climate and topography are such as to render the data thus gained of little use in estimating the probable flow from other areas, lying under widely different conditions such as prevail in the South Atlantic states.

It is evident that an accurate investigation of the flow of a stream under all conditions cannot be carried out in one year or in a few years, and so in almost every case where the volume of water carried by a stream was desired it has been necessary to rely on computations based on the rainfall over the drainage basin, supplemented by perhaps a single

[1] By E. W. Myers.

gauging of the stream, and from this an effort is made to determine the minimum and average dry-season flows. It is scarcely necessary to say that such estimates are open to very serious error, the correctness of the figures for the flow thus determined being entirely dependent on the training and judgment of the engineer and his knowledge of the conditions prevailing over the drainage basin. Even with the most accurate knowledge of the topography of the basin the flow is a result which is dependent on so many varying factors such as the amount and distribution of the rainfall in different years or periods, the temperature of earth and air, the wind movements, and the conditions of saturation of the soil and sub-soil, which, so far as known, follow no definite laws and cannot be predicted, that estimates of flow based on such calculations must be very unsatisfactory and are frequently the source of much inconvenience and sometimes of serious money loss.

Owing to the recent developments in the electrical transmission of power and the growing tendency to bring the cotton-mill to the cotton instead of carrying the cotton to the mill, together with the growth of other manufacturing interests, waterpowers which have heretofore been of little commercial value have become valuable, for, generally speaking, waterpower is much cheaper than steam-power. Thus the numerous waterpowers of the South Atlantic states have come into prominence and information concerning them has been eagerly sought.

Realizing the need of more accurate knowledge of this very valuable source of wealth, in the autumn of 1895 the Geological Survey, in co-operation with the U. S. Geological Survey, began the investigation of the flow of streams as recorded in the following pages. To this end regular gauging stations have been established as follows: On the Dan and Staunton rivers at Clarksville, Va., and on the Roanoke at the crossing of the Norfolk and Carolina railroad near Neals in North Carolina; on the Tar at Tarboro, N. C.; on the Cape Fear at Fayetteville, and on the Deep and Haw rivers at Moncure, N. C.; on the Yadkin at the Southern railroad crossing near Salisbury and at Blalock's ferry, a short distance from Norwood; on the Catawba at Catawba, N. C., and at the crossing of the Southern railroad between Fort Mill and Rock Hill, S. C.; on the Broad near Blacksburg, S. C., and at Alston, S. C.; on the Saluda river at the crossing of the P. R. & W. C. R. R. near Waterloo, S. C.; on the French Broad river at Asheville, N. C.; on the Tuckaseegee river at Bryson City, N. C.; on the Little Tennessee river at Judson, N. C., and on the Hiwassee river at Murphy, N. C.

Thus it is seen that from one to two gauging stations have been established on every main stream in North and South Carolina where there is any possibility of waterpower development. Stations have not been located on the tributary streams for the reason that such stations would be of only local utility, and the data gained from the station on the main stream can be applied to solve the problem of the flow from each one of its tributaries.

In order that accurate results may be obtained at any station certain conditions must be filled. The course of the river must be straight for some distance above and below the point where it is proposed to make the gauging; the current velocity should be neither too great nor too small, as in neither case does the meter give its best results, and this velocity should be well distributed across the stream, which should be of moderate depth, flowing over a smooth bottom that is permanent and not subject to change of form through high water or other means, so that the relation between the gauge height and the area of the cross-section may be constant, and the banks should be of such height as to keep the river between them even during floods. When it is desired to establish a station on any stream, search is made for some locality which fulfills the requirements noted above, and is, in addition, so located as to be easily accessible, preferably where some bridge crosses the stream at right angles to its course, or at some ferry. When such a place is found, a permanent gauge is set up, an observer employed to take daily readings of the stage of the water-surface and the series of instrumental gaugings is begun.

The gauges which have been installed are of two classes, both consisting primarily of a strip of wood, painted white and graduated into feet and tenths and sufficiently long to measure the height of the extreme flood volume of the stream. In one form of the gauge this rod is securely spiked or bolted in a vertical position to the side of a bridge-pier or similar object so that it cannot be carried away by the water, and so that its lower end will be constantly immersed in the water. The gauge height is then read directly from the position of the water-surface on the rod. In the other form of gauge the rod is nailed or screwed in a horizontal position to the railing or guard rail of a bridge. A short distance from the end of the rod and in the same horizontal line is fastened a small pulley, and through this runs a flexible wire rope carrying a weight of from 3 to 5 pounds at its end. At an appropriate distance from the lower end of this weight there is fastened to the wire rope a small pointer of brass or copper wire. When it is desired to take a reading of the water-level, the weight is lowered by means of the wire rope until the lower end is seen to just touch the surface of the water and the place on the rod indicated by the pointer is noted. This will then be the gauge-reading, and this may be estimated to a hundredth of a foot with ease and accuracy.

These gauge rods are referred to bench marks well out of the reach of the highest floods, so that they may be replaced when they are torn out, as they are sure to be.

METHOD OF GAUGING THE FLOW OF STREAMS.

In measuring the flow of a stream it is to be remembered that the flow varies from time to time. The measurement made on any given day while the river keeps a steady flow for an hour or two is good only for that day and hour and for times when the river is at the same stage. A small rise in the stream is accompanied by a large increase in the flow, and a small fall by a large decrease in the flow. To ascertain the flow during a considerable period of the time and thus obtain an average for varying stages, two distinct classes of measurements are necessary: First, the amount of flow corresponding to each and every stage; second, a continuous record of the rise and fall. The method by which this last is secured has just been given.

There are four methods of gauging the flow of a stream: By weirs; by floats; by formula; by meters.

Weirs are practicable and economical only in the case of small streams at low water, and in such case the system is preferable to all others.

Gauging by floats is the crudest and most unreliable of all methods. It consists in throwing floating objects into the water and noting the length of time occupied by the float in moving through a measured distance down the stream. The distance divided by the time is the mean velocity of the motion of the float. But this velocity of the float is not the velocity of the stream, which varies at different points in the width and at different depths. As a rough-and-ready rule, the mean velocity of the stream is taken as about four-fifths of the velocity of the float. This is no doubt a fair approximation when the cross-section of the stream is symmetrical, the current smooth, regular, and free from eddies, and its course free from obstructions. But in small or medium-sized rivers such conditions are rare, and the whole method of measuring is liable to great uncertainty and is impracticable in large rivers.

Gauging by formula is based on the assumption that, with a given cross-section, the mean velocity of the flow bears a certain relation to the declivity down which the water flows. This may be obtained with the spirit-level, but this method is of very limited utility.

GAUGING WITH THE CURRENT METER.

Gauging by a current meter is the most satisfactory and complete method of all. A current meter is a mechanical contrivance so arranged that by lowering it into a stream the velocity of the current at any point below the surface can be obtained with accuracy by a direct reading of the number of revolutions of a wheel made to revolve by the force of the current, and a comparison of this with a table of corresponding velocities. A great many forms of current meters have been designed and used, the three general classes being the direct recording meter, in which the number of revolutions is indicated directly on a series of small gear-wheels driven by a cog-wheel connected with the revolving head of the meter; the electric meter, in which the counting is done by a simple make-and-break circuit, the registering device being placed at any convenient distance from the meter; and the acoustic meter, in which the counting is done by hearing through an ear-tube the clicks made by the revolution of a wheel and counting the same. The electric meter is the form of meter most used by the Geological Survey, and it has been found that results of a high degree of accuracy may be obtained by the careful use of this instrument. The velocity at any depth is readily obtained, and hence the problem of finding the mean velocity in any vertical is made a very simple one.

The method of making the gauging is as follows:

The width of the stream from bank to bank at the water-surface is accurately measured, and at regular intervals of 10 or 20 feet in the case of large streams, of 5 feet for smaller ones, soundings are taken by means of a heavy weight and line to determine the depth.

At each of these places where the soundings are taken the meter is run to determine the velocity in that vertical plane. This mean velocity is found in one of several ways.

In streams having a depth of 5 feet or less it has been customary to take observations at a distance below the surface sufficient to immerse the meter approximately 0.5 of a foot, and at a distance above the bottom sufficient to allow the wheel to turn freely. With meters having large lead weights, the center of the wheel is usually about 0.8 foot above the bottom. The average of the velocities thus determined is thus assumed to represent the average velocity at this portion of the river. In deeper rivers the attempt is usually made to determine the velocity at points near the surface and at intervals of about 5 feet to the bottom, the mean velocity being obtained by averaging these.

It has also been ascertained that the velocity at a depth down from the surface, equal to 0.6 of the total depth, represents very accurately the true mean velocity in that vertical. The mid-depth velocity may be gotten and 98 per cent. of it be used as the mean.

Taking, therefore, the average velocity in the vertical plane as obtained in either of these ways, this is assumed to represent the average velocity of the stream for a distance on either side of the point of observation equal to half the distance to the points of observation on either side.

The mean depth in any sub-section is taken, in the case of a broad, smooth channel, as the depth where the meter is run, or as an average obtained by adding to the depth of the water half-way to the point of observation on either side, twice the depth at the point where the meter is run and dividing the sum by four. This mean depth in feet, multiplied by the width of the sub-section in feet, gives the area of the subsection in square feet. The area multiplied by the velocity in feet per second gives the discharge of the sub-section in cubic feet per second, and the sum of the discharges of the sub-sections is the discharge of the river.

THE RATING CURVE.

Since in the eastern United States these gaugings are primarily to aid in planning waterpower development in the future by furnishing accurate knowledge of the flow of the streams, the low stages of the water are carefully watched and accurately gauged. High-flood measurements are taken where possible, the object of the gaugings being the construction of a station rating-table or series of tables showing the relation between the gauge height of the river and the discharge at any time. In order to do this it is of course necessary to obtain the discharge at various stages of water covering the ordinary range of fluctuation. This is a comparatively simple matter if the channel does not change. The simplest method of procedure in constructing a rating-table is to plot on rectangularly-ruled paper each point representing the gauge height and discharge for a given measurement, the vertical distance from the bottom line being taken to represent the height of the water at the time the measurement was taken, and the distance from left to right the discharge in cubic feet per second. If there are a half dozen or more of these points well distributed according to height of water, it will usually be found that they will lie approximately in the path of a parabolic curve. This curve can be sketched through or near the points, the hydrographer, from his intimate knowledge, giving greater weight to some points than others, and this curve will then show the relation of gauge height to discharge for the period under consideration.

The rating-table is the numerical expression for the curve above described. In order to make this table it is simply necessary to read off the figures from the drawing, starting with the lowest value in the lower left-hand corner of the drawing. To do this the lowest horizontal line representing a tenth of a foot is followed from left to right until it intersects the curve. The value represented by this distance is set opposite the tenth of foot taken. The line representing the next higher tenth of a foot is again followed out, and its length from the margin at the left to the curve on the right is also obtained and so on, setting opposite each tenth of a foot the corresponding value of the discharge. When a table has been prepared in this way it will be found that there is an increasing value for the discharge, and that the difference between the values is also constantly increasing. Owing, however, to the small scale on which such a sketch is necessarily made, the figures read off from the drawing do not always have this constantly increasing value, some being too large, others proportionally too small. In order, therefore, to smooth out this curve it is convenient to set off between the lines of the rating-table the difference in quantities of discharge, making a third column. On running the eye down this column, several points are quickly detected where the differences are not regular. It will be seen that a slight adjustment of the differences and the addition or subtraction of a small amount from the figures of discharge will smooth out these irregularities. This should be made, and as a check upon the accuracy of the work the resulting figures should be plotted on the original drawing to determine by inspection that the rating-table as finally adjusted is accordant with the original observations. This method of graphic construction avoids difficulties and liability to blunder in the use of the higher mathematics, and its accuracy is well within that of the original data (see fig. 29, p. 310, for an example of this method of construction).

The question now arises for how long a period will this rating-table be true, or its values fall within the limits of allowable error? Every river is constantly modifying its channel to some extent, alternately cutting it away and filling it in to suit the ever-varying conditions of velocity. The station is, in the first instance, so located that this action will be a minimum, but usually there is an appreciable change, especially during or after a flood or a protracted period of low water.

The rating curve is founded as far as possible on measurements under all the varying conditions of depth of water, and is in itself of the nature of an average of these conditions. Thus it is evident for any height of water for a particular stage of the river the discharge, as given by the rating-table, may not be as accurate as the result of a careful gauging made on that day, but the value given by the rating-table should be an average value of the discharge for that particular height, whether the river is rising, falling or stationary. In other words, it is assumed for a given height of water the discharge may vary between certain limits, dependent upon circumstances such as the amount of silt carried, condition of channel above and below, and other modifying conditions, and the rating-tables cannot be expected to discriminate between these conditions but must represent the average between them.

In this connection it may be interesting to note the following laws governing the flow of water in river channels which were deduced by Humphreys and Abbott in their experiments on the Mississippi river, and which, paradoxical as they may appear, are in perfect accordance with the laws governing flowing water. (See page 324, Physics and Hydraulics of the Mississippi river.)

1. For any given level there is much more water passing when the river is rising than when it is falling.

2. At any given gauge reading, there is usually more water passing in a long and rapid than in a short and slow rise; but this is not always the case, the discharge being governed by the relative stage of the water in the channel above and below.

3. The maximum discharge, in any normal rise, occurs when the river has reached a point a few inches below the highest point attained.

4. If, when a freshet has culminated, and the water either comes to a stand or begins to fall, a second rise occurs, it will cause the surface to rise considerably higher than would have been the case had the same volume passed without a previous diminution of supply.

It is therefore to be borne in mind that the maximum discharges of two floods are not necessarily proportional to the relative water-levels attained by them. Under some circumstances the lesser discharge may cause the higher water-mark.

CALCULATION OF POWER.

From such a table the flow corresponding to any given gauge height may be easily taken out. The flow of the stream may then be calculated as follows:

In the tables of mean daily gauge heights the values of the discharge as taken from the rating-table are set opposite the several gauge heights. The mean flow for the month in cubic feet per second is then found by dividing the sum of all the daily discharges by the number of days in the month. The terms "maximum" and "minimum" discharge explain themselves. It may be well to note, however, that these quantities are daily averages, and that it may be possible that at some time during the day very much more or considerably less water was passing than is shown in the tables.

From the flows as thus determined it is a matter of simple multiplication to determine the total theoretical horsepower per foot fall at the station where the gaugings are made. A theoretical horsepower is an energy of 33,000 foot-pounds per minute, or of 550 foot-pounds per second. A cubic foot of river water may be taken to weigh 62.45 pounds. As an example of the calculation of the power from the flow, suppose a stream is discovered to discharge 100 cubic feet per second. This quantity, multiplied by 62.45, gives the total weight of water passing the section every second, and this total weight divided by 550, the foot-pounds of energy per second necessary to give one horsepower, gives 11.35, the theoretical horsepower of the stream per foot of fall. In practice this process may be somewhat shortened by multiplying the quantity of water in cubic feet per second by 0.1135, which will give the theoretical horsepower direct. The actual horsepower which can be obtained will range from 70 to 84 per cent. of the theoretical, according to the efficiency of the motor employed. This may be obtained approximately by multiplying the discharge in cubic feet per second by 0.087, corresponding to an efficiency of 77 per cent. in the motor.

The approximate theoretical power at other points on the same stream may be estimated by a simple comparison of the areas draining past the places, it being assumed that all the area has an equal rate of flow per square mile and that, therefore, the power at any two points on the stream is simply proportional to the areas drained past the points. Strictly speaking this is not true, since the discharge per square mile from any drainage area increases as the head of the stream is approached, but the law of the increase is not well known. Any error thus introduced will, however, be on the side of safety, giving the discharge as smaller than it should be.

THE AVERAGE FLOW OF A STREAM.

At first sight it would seem that, knowing the daily discharges of a stream throughout the year, the question of its average flow would be an easy one to answer, but it is soon seen that a variety of answers may be given. By an examination of the discharge diagrams given in this report (pp. 289 to 334), it will be seen that the streams fluctuate so widely in the amounts of water flowing in them from day to day or from year to year that they cannot be said to flow with anything like regularity for any appreciable length of time, except during summer droughts, when for a time the stream gradually sinks lower and lower or maintains its flow within small limits for a considerable period. An average flow for such a period may be readily obtained, but it will not be applicable for the whole year, though such an average is unquestionably of value in determining the waterpower of a stream.

In the computations of the discharge given further on, the mean flow has been estimated by months and from this by years, but this does not fulfil the conception of average flow since it includes flood gaugings and is notably increased thereby.

An arbitrary method has been suggested by Mr. Leslie [1] for computing the "average summer discharge" or "ordinary" flow of a stream from the daily gaugings, as follows:

[1] Minutes of Proceedings of the Institution of Civil Engineers, vol. x, p. 327, quoted by Fanning, Water Supply and Hydraulic Engineering, 9th ed., p. 80.

"Range the discharges as observed daily in the order of their magnitude.

"Divide the list thus obtained into an upper quarter, a middle half and a lower quarter.

"The discharges in the upper quarter of the list are to be considered as *floods*, and in the lower quarter as *minimum flows*.

"For each of the gaugings exceeding the average of the middle half, including flood gaugings, substitute the average of the middle half of the list, and take the mean of the whole list, as thus modified, for the *ordinary* or *average discharge, exclusive of flood waters*."

Fanning notes that this rule applied to the discharge of several New England streams gave results varying from one-fourth to one-third of the mean flow, including floods.

This rule was applied to the daily discharges of the Yadkin river at Norwood, N. C., for 1898, giving as the average flow, excluding floods, 3,937 cubic feet per second, while the mean flow for the year, including floods, was 5,432 cubic feet per second. It will be noted, however, that during this year the floods on this stream were relatively infrequent and generally small in volume.

VALUE OF THESE MEASUREMENTS.

While measurements of this sort extending over only a short period are of value, it is obvious that the value increases vastly as the time over which they extend is increased, since in the longer period there is the greater probability that the extremes of the conditions producing variations in the flow will be met with, that the abnormal years and seasons will occur as well as the normal years and seasons, and that thus a more accurate knowledge of the flow under all the conditions which effect it will be obtained.

The stages of flow of most interest to those who have to do with waterpower are the *minimum flow,* or that quantity which is permanently available even during the most severe and long-continued droughts; and that stage of flow which may be called the *low season flow of dry years,* and which can be depended on at all times save on a few days in the dryest seasons of the dryest years when the flow is approaching its absolute minimum (see pp. 54 to 58). These low stages of flow are only maintained for short periods of time, but they represent the power which can be depended upon as limited above, and it becomes a question to be solved by economical considerations whether any construction shall be planned requiring more power than these stages of flow will yield. If part of the machinery can economically remain idle for a part of the time, then such a development can be made, otherwise auxiliary steam or electrical power must be secured to supply the deficiency during the dry seasons.

In general, the knowledge of these stages of flow cannot be obtained by a short series of observations, but it seems that these measurements were begun in the South Atlantic states at a time very favorable for obtaining these stages of flow or certainly a very close approximation to them.

THE DROUGHT OF 1897.

The flow of a stream is primarily dependent on the precipitation on the drainage basin, but the year of minimum rainfall is not necessarily the year when the streams will attain their lowest stages of flow. Variability of flow depends largely on the distribution of the rainfall throughout the year. The average yearly flow will be least in the year when least rain falls, but the average flow for a period of from one to three months in the year when the rainfall is near or even a little above the normal may be less than for any similar period in the year of minimum rainfall. A period of several months may occur when the evaporation is large, the quantity of water absorbed by vegetation is large also, the sub-surface supply which tends to regulate the flow of the stream has been drawn down in previous periods of drought, and very little rain falls, then, in such a period as this, the streams will attain a very low stage of flow only possible when some such series of circumstances all act together to this end. When, in addition to this, the year when such a condition occurs is also the year of minimum rainfall, then the streams in the region thus affected will attain the lowest possible stage of flow. It was this condition that existed in North Carolina and for the Southern states generally during 1897.

For the entire South Atlantic states the period from 1894 to 1897 inclusive was a period of less than the average rainfall, the deficiency for the area for 1896 alone amounting to 10.7 inches, and for the period of 11 years, from 1887 to 1897 inclusive, eight of these years have been years of less than normal precipitation, the deficiency varying from 10.7 inches to 1.5 inches, the greatest excess over the normal being only 2 inches in 1889.[1]

In North Carolina since 1891 there has been an annual deficiency in precipitation, only one year, 1895, showing an amount above the normal, and, according to the testimony of numerous persons, during all this time the level of the underground waters as shown by wells and springs, was gradually sinking, reaching in September and October of 1897 the lowest point certainly in a quarter of a century.

[1] Bull. D., U. S. Dept. Agr. Weather Bureau, p. 9.

The drought beginning in August, 1897, was the most severe in the history of the state, and caused the lowest stages of the rivers ever known. For the month of September the precipitation was the next smallest on record for that month, amounting to an average of 1.47.[1] inches for the entire state.

During the month of October, 1897, many of the rivers attained a stage of flow even lower than in September, for the very dry period was not broken till the last half of the month, and the demands of the vegetation and evaporation being greater than the supply, and the subsurface water-level having been drawn down, the rivers continued to fall. The following table, giving the monthly average precipitations at all stations in North Carolina, shows that the rainfall in this state for 1897 was less than the normal by 5.91 inches, and that this year was the dryest year with one exception, 1872, in all the time covered by the records of the Weather Bureau, a period of over 26 years. Thus all the conditions for a period of minimum stream-flow were fulfilled, and it seems improbable that the flow will ever fall very much lower than in this year.

PRECIPITATION IN NORTH CAROLINA.

Monthly averages for entire area.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1872	1.96	4.76	4.42	2.42	3.82	4.23	4.02	5.40	3.29	3.85	2.73	4.65	45.55
1873	4.99	9.03	2.87	1.76	7.11	3.50	4.55	7.14	4.37	3.11	3.70	3.49	55.62
1874	4.49	4.99	4.30	7.96	3.58	4.09	6.11	5.73	5.58	1.68	3.30	2.83	54.64
1875	4.81	4.93	7.20	4.74	2.52	4.29	5.84	7.45	3.54	3.18	3.96	4.40	56.36
1876	1.72	3.70	5.20	3.09	4.28	5.80	4.95	5.44	8.35	3.37	2.67	3.53	52.10
1877	3.97	1.91	6.29	6.91	2.56	4.84	6.52	5.37	10.13	5.55	5.53	5.30	64.88
1878	6.32	3.09	2.23	5.05	4.92	4.09	3.57	8.56	4.00	5.36	3.46	6.23	56.88
1879	4.63	3.68	3.80	3.71	3.48	2.14	5.70	7.52	3.57	3.55	3.31	4.58	49.67
1880	2.59	3.23	6.63	3.91	2.03	3.56	6.49	7.96	3.53	3.62	6.75	3.98	54.28
1881	4.65	4.15	4.31	4.39	2.34	4.10	4.65	2.91	3.57	3.86	4.36	4.88	48.17
1882	7.50	4.54	5.41	3.97	3.29	2.87	5.84	5.98	5.45	4.60	2.74	3.81	55.50
1883	7.82	3.44	5.16	6.99	3.35	6.74	3.12	3.45	7.25	3.21	2.60	2.96	56.09
1884	5.90	5.66	8.50	3.31	2.75	5.66	5.93	3.90	2.04	0.81	3.08	6.77	54.31
1885	5.78	3.79	2.58	2.28	6.61	4.04	4.03	4.08	3.49	6.05	4.32	4.15	51.20
1886	4.45	2.31	5.46	3.08	5.15	7.20	7.41	6.80	2.28	0.84	3.00	3.86	51.84
1887	3.30	3.92	3.22	2.84	4.45	4.02	6.13	9.89	2.11	6.72	1.29	4.70	52.09
1888	4.15	4.25	6.33	1.74	7.04	3.11	3.26	4.66	9.06	4.64	3.38	3.36	54.98
1889	5.26	3.72	2.89	3.63	4.62	5.91	7.73	5.55	4.04	2.48	4.31	0.59	50.73
1890	1.41	4.20	3.40	2.75	4.79	2.83	7.19	6.86	5.33	4.29	0.35	3.59	46.49
1891	4.66	5.70	7.70	2.37	5.38	3.69	6.75	8.23	2.11	2.55	3.07	2.84	54.55
1892	6.05	3.35	3.30	3.98	3.57	6.68	5.73	3.84	3.48	0.59	3.66	2.81	47.04
1893	2.91	5.41	2.81	3.58	5.57	5.74	4.01	7.18	5.61	5.54	2.77	3.13	52.66
1894	3.91	4.82	2.05	1.75	4.00	2.62	6.07	6.13	4.77	5.50	1.42	3.53	46.57
1895	6.41	2.42	5.27	7.35	4.83	3.53	5.25	5.50	1.25	1.86	3.15	3.41	50.23
1896	2.79	5.64	2.59	1.99	4.28	5.36	8.19	2.31	5.31	1.90	4.67	2.51	47.54
1897	2.30	5.90	5.56	3.68	3.78	3.99	5.60	3.41	1.47	3.99	2.89	3.67	46.19
1898	2.63	1.03	4.02	3.70	3.69	3.41	6.98	7.94	4.24	6.42	3.24	2.74	50.04
Normals	4.35	4.21	4.56	3.77	4.21	4.37	5.58	5.85	4.41	3.67	3.32	3.80	52.10

[1] Climate and Crops, U. S. Dept. Agr., N. C. Section, 1897. p. 3.

The dryest month of which there is any record was November, 1890, when the precipitation for the entire state was only 0.35 inch, and the rainfall for this year was but very little more than fell in 1897, but the years that preceded were years of more than average rainfall, and so the underground supply had been kept up and was ready to be drawn upon to maintain the flow of the streams at about the normal low-water flow.

This table also shows the amount and the distribution of the rainfall in North Carolina. It is seen that the precipitation is large in amount, well distributed throughout the year, the dryest months occurring in October and November, and that periods of drought are rare and of short duration. Since the rainfall is large, we are led to expect a large annual flow in the streams, and since the dryest periods fall at a time when the demands of plant life and of evaporation are still great, we are led to expect a variable flow and such is the case, all the rivers in North Carolina on which there is any waterpower being subject to periods of low flow and to violent freshets. Any hydraulic construction on any of these streams needs be as firmly founded as the hills themselves, else some day its ruins will go dashing along toward the ocean on the crest of some flood wave.

CHAPTER XV.

RESULTS OF STREAM MEASUREMENTS.[1]

UNITS OF MEASUREMENT.

The results of the stream measurements shown in the following pages are expressed in second-feet, this having been found to be the most convenient unit in which to express the discharge of rivers. A second-foot of water may be defined as a stream of one foot wide and one foot deep, flowing with a velocity of one foot per second.

The unit of quantity or of capacity employed is the acre-foot, equivalent to that quantity of water which, if spread out over an area of one acre, would cover it to a depth of one foot. This is equal to 43,560 cubic feet. There is a convenient connection between these units. One second-foot flowing for 24 hours will deliver 86,400 cubic feet of water, equivalent to nearly 2 acre-feet (more exactly, 1.983471 acre-feet). Many engineers are still inclined to use the million gallons as the unit of storage, as this is well fixed in computations relating to municipal supply. For convenience, it may be stated that one acre-foot equals 325,851.45 gallons, or a little less than a third of a million gallons.

In the following tables the maximum, minimum and mean quantity in the streams each month are given in second-feet and the total discharge in acre-feet. To obtain this total for the month in acre-feet it is the usual practice to multiply the mean daily discharge in second-feet by a factor which is the product obtained by dividing the number of seconds in each month by the number of square feet in an acre. For a month containing 31 days this factor is 61.49; for a month of 30 days it is 59.50; for a month of 29 days it is 57.52; and for a month of 28 days it is 55.54.

The depth of run-off over the whole basin is also given for each month in inches for convenience of comparison with the rainfall, and also in cubic feet per second for every square mile of drainage area. The former is obtained by multiplying the acre-feet per month by 12 to obtain acre-inches and dividing this by 640, the number of acres in a square mile and also by the number of square miles in the drainage basin. The run-off in second-feet per square mile is simply the mean

[1]By E. W. Myers.

monthly discharge divided by the total area of the basin in square miles, the whole area being assumed to discharge at a uniform rate. The mean discharge for the year is taken to be the average of all the mean monthly discharges, and the total quantity of run-off is the sum of the monthly run-offs.

CLARKSVILLE STATION, ON THE DAN AND STAUNTON RIVERS.

At Clarksville, Virginia, the Dan and Staunton rivers unite, forming the Roanoke. The Southern railway bridge crosses the river about one thousand feet above the junction, the sections being suitable for measurement at both points.

About four miles above the junction of the Dan and Staunton rivers is a cut-off, apparently occupying an old channel, diverting water from the Dan to the Staunton. At its mouth is a shoal or riffle about 70 feet long, the water being on December 4, 1895, about one foot deep and having an estimated velocity of approximately 3 feet per second, giving a total discharge from the Dan to the Staunton of 200 second-feet. The average width of the water surface in the channel was 150 feet. The total fall between the two rivers was estimated to be approximately 2 feet, this being principally at the riffle at the mouth of the channel. The total length of the channel was about 1000 feet. This cut-off, by carrying water from the Dan, vitiates the separate computations of discharge made, but does not affect the total discharge for the Roanoke.

Gauging stations were established on the Dan and Staunton rivers at Clarksville on October 28, 1895. On Dan river the gauge is fastened to the inside of the guard-rail of the fourth panel of the third span west of the Southern railroad bridge. The distance from the zero of the rod to the outside of the pulley-wheel is 3 feet; the length of the wire rope is 33.17 feet. The waterpower of Dan river has been developed to a considerable extent at Danville. An examination at points above showed that the dams at Danville pond the water, and, as a result, modify the natural characteristics of the stream.

The gauge on the Staunton river is fastened to the inside of the guard-rail of the fourth panel of the third span from the west. The distance from the zero of the rod to the outer rim of the pulley-wheel is 3 feet; the length of the wire gauge is 33 feet; the distance of the top and upper end of the third floor beam of the second span from the west from the water surface was 27.15 feet when the gauge height was 0.25 foot. The distance from the east abutment of the Dan river bridge to the west abutment of the Staunton river bridge is 165 feet. The tables of daily gauge heights for these stations will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON DAN RIVER AT CLARKSVILLE, VIRGINIA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1895.						
1	Oct. 2	C. C. Babb	29	0.38	591	1.31	773
2	Oct. 28	....do	29	0.65	719	1.44	1,032
3	Dec. 5	....do	62	1.12	865	1.60	1,382
	1896.						
4	Apr. 22	E. W. Myers	21	1.90	1,209	1.89	2,291
5[1]	May 26	....do	21	1.77	1,465	1.47	2,155
6	July 15	....do	21	2.97	1,932	2.39	4,626
7	Sept. 15	A. P. Davis	68	1.17	953	1.50	1,433
	1897.						
8	Feb. 25	E. W. Myers	2154	12.32	7,443	3.49	26,015
9	Mch. 18	....do	2154	4.20	2,867	2.70	7,755
10	Sept. 29	....do	2154	0.10	797	1.07	856
	1898.						
11	Jan. 8.	E. W. Myers	2154	1.05	1,138	1.76	2,009

RATING-TABLE FOR DAN RIVER AT CLARKSVILLE, VIRGINIA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
0.00	590	3.20	4,800	6.20	12,650	9.40	21,350
0.20	700	3.40	5,250	6.40	13,200	9.60	21,900
0.40	825	3.60	5,725	6.60	13,750	9.80	22,450
0.60	965	3.80	6,225	6.80	14,300	10.00	23,000
0.80	1,115	4.00	6,725	7.00	14,800	10.20	23,550
1.00	1,280	4.20	7,225	7.20	15,350	10.40	24,100
1.20	1,450	4.40	7,725	7.40	15,900	10.60	24,650
1.40	1,645	4.60	8,250	7.60	16,450	10.80	25,200
1.60	1,880	4.80	8,800	7.80	17,000	11.00	25,750
1.80	2,130	5.00	9,250	8.00	17,550	11.20	26,300
2.00	2,425	5.20	9,800	8.20	18,100	11.40	26,850
2.20	2,725	5.40	10,350	8.40	18,650	11.60	27,400
2.40	3,075	5.60	10,900	8.60	19,200	11.80	27,950
2.60	3,525	5.80	11,450	8.80	19,750	12.00	28,500
2.80	3,925	6.00	12,100	9.00	20,300	12.20	29,050
3.00	4,350	...	......	9.20	20,800	.....	.....

ESTIMATED MONTHLY DISCHARGE OF DAN RIVER AT CLARKSVILLE, VIRGINIA.

[Drainage area, 3798 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
February	20,163	2,091	5,070	291,626	1.48	1.37
March	17,245	2,231	4,935	303,453	1.53	1.33
April	24,017	2,091	4,777	284,231	1.44	1.29
May	7,650	1,255	2,715	166,940	0.84	0.73
June	5,900	1,255	2,145	127,636	0.64	0.58
July	[2]33,000	1,131	4,800	295,152	1.49	1.29
August	2,605	839	1,204	74,034	0.37	0.32
September	10,542	825	1,373	81,698	0.41	0.37
October	20,218	1,131	1,856	114,125	0.58	0.50
November	14,620	1,251	2,260	134,470	0.68	0.61
December	8,855	1,469	2,365	145,424	0.72	0.63
	33,000	825	3.050	2,018,784	10.18	0.82

[1]For measurement No. 5 channel had cut out badly, averaging almost all way across a cut of 1 foot.

[2]Estimated.

RATING-TABLE FOR DAN RIVER AT CLARKSVILLE, VIRGINIA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
−1.50	400	0.40	890	3.80	6,704	7.50	15,066
−1.40	420	0.60	990	4.00	7,156	8.00	16,196
−1.30	440	0.80	1.100	4.20	7,608	8.50	17,326
−1.20	460	1.00	1,240	4.40	8,060	9.00	18,456
−1.10	480	1.20	1,400	4.60	8,512	9.50	19,586
−1.00	500	1.40	1,620	4.80	8,964	10.00	20.716
−0.90	520	1.60	1,900	5.00	9,416	10.50	21,846
−0.80	540	1.80	2,250	5.20	9,868	11.00	22,976
−0.70	560	2.00	2,636	5.40	10,320	11.50	24,106
−0.60	580	2.20	3,088	5.60	10,772	12.00	25,236
−0.50	600	2.40	3,540	5.80	11,224	12.50	26,366
−0.40	620	2.60	3,992	6.00	11,676	13.00	27,496
−0.30	645	2.80	4,444	6.20	12,128	13.50	28,626
−0.20	670	3.00	4,896	6.40	12,580	14.00	29,756
−0.10	700	3.20	5,348	6.60	13,032	.....	......
0.00	730	3.40	5,800	6.80	13,484	.....	......
0.20	810	3.60	6,252	7.00	13,936	.....	......

ESTIMATED MONTHLY DISCHARGE OF DAN RIVER AT CLARKSVILLE, VIRGINIA.

[Drainage area, 3798 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	7,269	1,135	2,565	157,715	0.78	0.68
February	27,044	2,340	9,212	511,610	2.53	2.43
March	10,908	2.749	6,030	370,770	1.83	2.59
April	7,382	1,820	3,481	207,135	1.02	0.92
May	10,094	1,900	5,014	308,298	1.52	1.32
June	2,075	1,100	1,326	78,902	0.39	0.35
July	3,201	1,045	1,404	86,330	0.43	0.37
August	1,320	830	984	60,504	0.30	0.26
September	890	730	755	44,926	0.22	0.20
October	4,896	400	1,609	98,933	0.48	0.42
November	10.320	750	1,703	101,335	0.50	0.45
December	7.382	990	2.231	137,180	0.68	0.59
The year	27.044	400	3.026	2.163,638	10.68	0.80

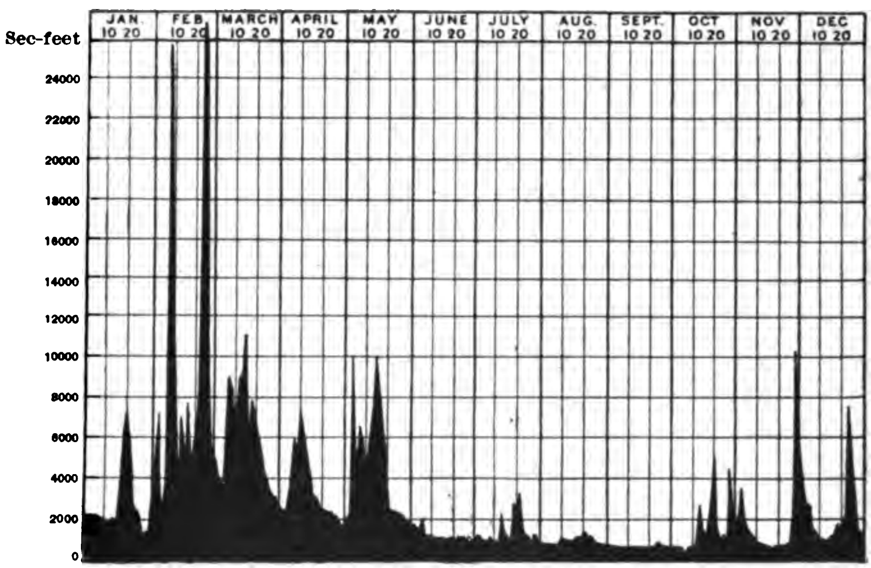


FIG. 17.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE DAN RIVER AT CLARKSVILLE VA. FOR 1897. (U. S. G. S.)

LIST OF DISCHARGE MEASUREMENTS MADE ON STAUNTON RIVER AT CLARKSVILLE, VIRGINIA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second feet).
	1895.						
1	Oct. 8	C. C. Babb	29	0.07	550	0.97	533
2	Oct. 28	....do	76	0.28	659	1.31	861
3	Dec. 5	....do	62	0.61	917	1.25	1,151
	1896.						
4	Apr. 22	E. W. Myers	21	1.37	1,256	1.58	1,971
5	May 26	....do	21	1.14	1,401	1.39	1,956
6	July 15	....do	21	2.64	1,890	2.25	4,252
7	Sept. 15	A. P. Davis	68	−0.06	723	1.03	748
	1897.						
8	Feb. 25	E. W. Myers	2154	11.95	7,250	4.03	29,259
9	Mch. 18	....do	2154	3.68	2,838	2.93	8,326
10	Sept. 29	...do	2154	−0.25	610	1.25	763
	1898.						
11	Jan. 8	E. W. Myers	2154	0.70	992	1.97	1,960

RATING-TABLE FOR STAUNTON RIVER AT CLARKSVILLE, VIRGINIA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
0.00	685	1.40	2,095	5.00	10,100	8.60	20,200
−0.10	630	1.60	2,395	5.20	10,650	8.80	20,800
−0.20	580	1.80	2,715	5.40	11,200	9.00	21,400
−0.30	535	2.00	3,050	5.60	11,750	9.20	22,000
−0.40	500	2.20	3,395	5.80	12,300	9.40	22,600
−0.50	470	2.40	3,760	6.00	12,850	9.60	23,200
−0.60	440	2.60	4,150	6.20	13,400	9.80	23,800
−0.70	410	2.80	4,600	6.40	13,950	10.00	24,400
−0.80	380	3.00	5,100	6.60	14,500	10.20	25,000
−0.90	350	3.20	5,600	6.80	15,050	10.40	25,600
−1.00	330	3.40	6,100	7.00	15,600	10.60	26,200
0.00	685	3.60	6,600	7.20	16,180	10.80	26,800
0.20	820	3.80	7,100	7.40	16,660	11.00	27,400
0.40	980	4.00	7,600	7.60	17,240	11.20	28,000
0.60	1,160	4.20	8,100	7.80	17,820	11.40	28,600
0.80	1,350	4.40	8,600	8.00	18,400	11.60	29,200
1.00	1,560	4.60	9,100	8.20	19,000	11.80	29,800
1.20	1,810	4.80	9,600	8.40	19,600	12.00	30,400

ESTIMATED MONTHLY DISCHARGE OF STAUNTON RIVER AT CLARKSVILLE, VIRGINIA.

[Drainage area, 3546 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
February	19,660	1,852	4,554	261,946	1.42	1.32
March	16,554	1,852	3,084	189,635	1.02	0.89
April	23,890	1,732	3,990	237,405	1.28	1.15
May	7,325	916	2,240	137,737	0.75	0.65
June	5,450	680	1,608	95,682	0.52	0.46
July	[1]36,000	823	3,611	222,040	1.20	1.04
August	2,459	635	860	52,881	0.28	0.24
September	3,899	645	1,150	68,425	0.37	0.33
October	19,900	892	1,620	99,614	0.54	0.47
November	14,005	1,028	1,979	117,850	0.63	0.57
December	5,125	1,245	2,008	123,472	0.67	0.58
	36,000	635	2,427	1,606,687	8.68	0.70

[1] Estimated.

RATING-TABLE FOR THE STAUNTON RIVER AT CLARKSVILLE, VIRGINIA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
−0.70	540	1.80	3,496	5.00	11,560	8.20	19,624
−0.60	560	2.00	4,000	5.20	12,064	8.40	20,128
−0.50	580	2.20	4,504	5.40	12,568	8.60	20,632
−0.40	600	2.40	5,008	5.60	13,072	8.80	21,136
−0.30	625	2.60	5,512	5.80	13,576	9.00	21,640
−0.20	650	2.80	6,016	6.00	14,080	9.50	22,900
−0.10	675	3.00	6,520	6.20	14,584	10.00	24,160
0.00	700	3.20	7,024	6.40	15,088	10.50	25,420
0.20	800	3.40	7,528	6.60	15,592	11.00	26,680
0.40	1,000	3.60	8,032	6.80	16,096	11.50	27,940
0.60	1,220	3.80	8,536	7.00	16,600	12.00	29,200
0.80	1,470	4.00	9,040	7.20	17,104	12.50	30,460
1.00	1,760	4.20	9,544	7.40	17,608	13.00	31,720
1.20	2,100	4.40	10,048	7.60	18,112	13.50	32,980
1.40	2,530	4.60	10,552	7.80	18,616	14.00	34,240
1.60	2,992	4.80	11,056	8.00	19,120	14.50	35,500

ESTIMATED MONTHLY DISCHARGE OF STAUNTON RIVER AT CLARKSVILLE, VIRGINIA.

Month.	Discharge.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	11,686	1,540	5,773	354,970	1.88	1.63
February	29,326	4,504	10,593	588,306	3.11	2.99
March	11,938	3,118	6,459	397,150	2.10	1.82
April	7,906	1,685	3,584	213,285	1.13	1.01
May	10,804	1,760	5,367	330,004	1.74	1.51
June	[1]8,410	[1]1,220	[1]2,301	136,920	0.72	0.65
July	3,118	900	1,378	84,730	0.45	0.39
August	1,470	720	983	60,442	0.32	0.28
September	900	625	705	41,951	0.22	0.20
October	5,008	550	1,540	94,691	0.49	0.43
November	10,804	600	1,640	97,587	0.52	0.46
December	10,300	950	2,401	147,631	0.78	0.68
The year	29,326	550	3,560	2,547,647	13.46	1.00

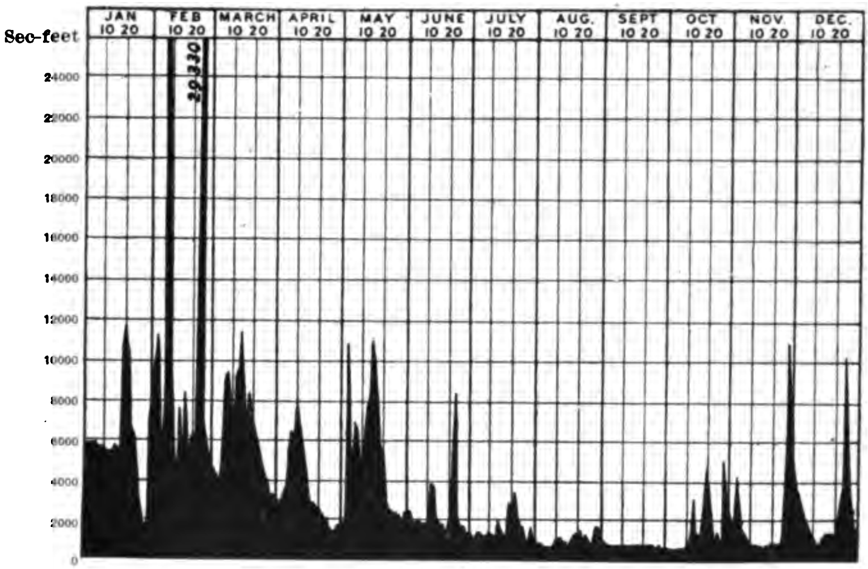


FIG. 18.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE STAUNTON RIVER, AT CLARKSVILLE, VA., FOR 1897. (U. S. G. S.)

[1]Records for month not complete.

NEALS STATION, ON THE ROANOKE RIVER.

The gauge on this stream is located on the Norfolk and Carolina railroad bridge which crosses the river near Neals station. The zero of the gauge-rod is over the center of the fourth floor beam of the second span from the north end of the bridge. The distance from the zero of the rod to the outer rim of the pulley-wheel is 2.47 feet, and the distance from the end of the weight to the pointer on the wire is 44.66 feet. The section is a fairly good one, the river being straight for some distance above and below the station and the bottom smooth, but being muddy it is apt to cut out in seasons of high water, and both banks are also subject to overflow, the river sometimes attaining a width of one and one-half miles during high rises.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON ROANOKE RIVER AT NEALS, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	July 27	E. W. Myers	2154	7.06	3,152	1.53	4.849
2	Sept. 7	....do	2154	1.31	2,148	1.21	2,610
3	Dec. 19	....do	2154	11.60	5,214	1.76	9,180
	1897.						
4	Jan. 23	E. W. Myers	2154	12.65	5,551	2.37	13,155
5	Feb. 27	....do	2154	27.95	44,666	1.44	64,132
6	Mar. 17	....do	2154	24.71	31,590	1.19	37,659
7	May 17	....do	2154	18.40	7,240	2.65	19,219
8	Oct. 1	....do	2154	1.00	1,544	1.24	1,928
	1898.						
9	Jan. 11	E. W. Myers	2154	4.43	2,606	1.65	4,334
10	May 10	....do	2154	22.50	8,140	3.42	27,880

RATING-TABLE FOR ROANOKE RIVER AT NEALS, NORTH CAROLINA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
0.00	2,000	4.20	3,300	8.40	6,060	16.50	15,950
0.20	2,020	4.40	3,400	8.60	6,240	17.00	16,750
0.40	2,040	4.60	3,500	8.80	6,420	17.50	17,565
0.60	2,060	4.80	3,600	9.00	6,600	18.00	18,400
0.80	2,100	5.00	3,700	9.20	6,780	18.50	19,310
1.00	2,140	5.20	3,805	9.40	6,960	19.00	20,300
1.20	2,190	5.40	3,915	9.60	7,140	19.50	21,380
1.40	2,240	5.60	4,025	9.80	7,320	20.00	22,500
1.60	2,290	5.80	4,135	10.00	7,500	20.50	23,720
1.80	2,340	6.00	4,235	10.50	8,000	21.00	25,000
2.00	2,400	6.20	4,355	11.00	8,500	21.50	26,320
2.20	2,475	6.40	4,465	11.50	9,040	22.00	27,700
2.40	2,540	6.60	4,585	12.00	9,600	22.50	29,190
2.60	2,610	6.80	4,705	12.50	10,190	23.00	30,800
2.80	2,680	7.00	4,850	13.00	10,800	23.50	32,570
3.00	2,750	7.20	5,010	13.50	11,460	24.00	34,550
3.20	2,830	7.40	5,180	14.00	12,150	25.00	39,200
3.40	2,915	7.60	5,350	14.50	12,860	26.00	44,800
3.60	3,005	7.80	5,520	15.00	13,600	27.00	52,500
3.80	3,100	8.00	5,700	15.50	14,370	28.00	64,300
4.00	3,200	8.20	5,880	16.00	15,150	.....	......

ESTIMATED MONTHLY DISCHARGE OF ROANOKE RIVER AT NEALS, NORTH CAROLINA.
[Drainage area 8717 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
August	4,105	2,750	3,154	193,933	0.41	0.36
September	6,510	2,400	3,217	191,424	0.41	0.37
October	39,720.	2,890	9,117	560,586	1.21	1.05
November	23,220	2,890	5,896	350,836	0.75	0.68
December	21,820	3,415	7,423	456,425	0.98	0.85
					3.76	0.66
1897.						
January	12,010	2,790	4,501	276,755	0.60	0.52
February	64,300	2,915	28,178	1,564,930	3.36	3.23
March	37,700	7,320	22,824	1,403,390	3.02	2.62
April	22,270	4,525	8,440	502,215	1.08	0.97
May	21,160	4,410	8,707	535,350	1.15	1.00
June	9,040	3,005	4,252	253,010	0.55	0.49
July	7,410	2,790	3,956	243,245	0.52	0.45
August	3,650	2,240	2,678	164,360	0.36	0.31
September	3,150	2,000	2,217	131,920	0.28	0.25
October	4,465	2,010	2,561	157,470	0.33	0.29
November	8,710	2,340	3,095	184,165	0.40	0.36
December	10,190	3,250	5,520	339,410	0.72	0.63
The year	64,300	2,000	8,077	5,756,220	12.87	0.93

RATING-TABLE FOR ROANOKE RIVER AT NEALS, NORTH CAROLINA, FOR 1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
1.00	2,060	4.40	3,384	8.80	6,080	18.00	18,300
1.10	2,095	4.60	3,476	9.00	6,250	18.50	19,180
1.20	2,130	4.80	3,568	9.20	6,430	19.00	20,100
1.30	2,165	5.00	3,660	9.40	6,610	19.50	21,100
1.40	2,200	5.20	3,760	9.60	6,800	20.00	22,300
1.50	2,235	5.40	3,860	9.80	7,000	20.50	23,575
1.60	2,270	5.60	3,965	10.00	7,200	21.00	24,900
1.70	2,305	5.80	4,075	10.50	7,700	21.50	26,300
1.80	2,340	6.00	4,185	11.00	8,200	22.00	27,750
1.90	2,375	6.20	4,295	11.50	8,750	22.50	29,270
2.00	2,410	6.40	4,405	12 00	9,300	23.00	30,900
2.20	2,480	6.60	4,518	12.50	9,950	23.50	32,640
2.40	2,550	6.80	4,634	13.00	10,600	24.00	34,550
2.60	2,623	7.00	4,750	13.50	11,300	24.50	36,780
2.80	2,699	7.20	4,880	14.00	12,000	25.00	39,150
3.00	2,775	7.40	5,010	14.50	12,750	25.50	41,950
3.20	2,855	7.60	5,150	15.00	13,500	26.00	45,000
3.40	2,935	7.80	5,300	15.50	14,275	26.50	49,500
3.60	3,020	8.00	5,450	16.00	15,075	27.00	54,250
3.80	3,110	8.20	5,600	16.50	15,875	27.50	59,200
4.00	3,200	8.40	5,750	17.00	16,600	28.00	64,300
4.20	3,292	8.60	5,910	17.50	17,440	......	......

ESTIMATED MONTHLY DISCHARGE OF ROANOKE RIVER AT NEALS, NORTH CAROLINA.
[Drainage area 8717 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	11,300	3,200	4,618	284,115	0.61	0.53
February	5,910	2,985	3,544	196,834	0.43	0.41
March	6,900	2,985	3,737	230,182	0.49	0.43
April	14,120	3,568	6,849	407,515	0.87	0.78
May	29,891	3,200	13,139	809,231	1.74	1.51
June	14,755	2,159	5,387	310,526	0.69	0.62
July	5,910	2,353	3,760	231,190	0.49	0.43
August	14,595	2,975	4,815	296,062	0.63	0.55
September	34,043	2,060	8,426	501,389	1.07	0.96
October	28,762	2,855	8,580	527,563	1.12	0.97
November	17,204	3,810	5,443	323,880	0.70	0.63
December	24,735	3,910	8,943	549,883	1.19	1.03
The Year	34,043	2,060	6,436	4,688,370	10.03	0.74

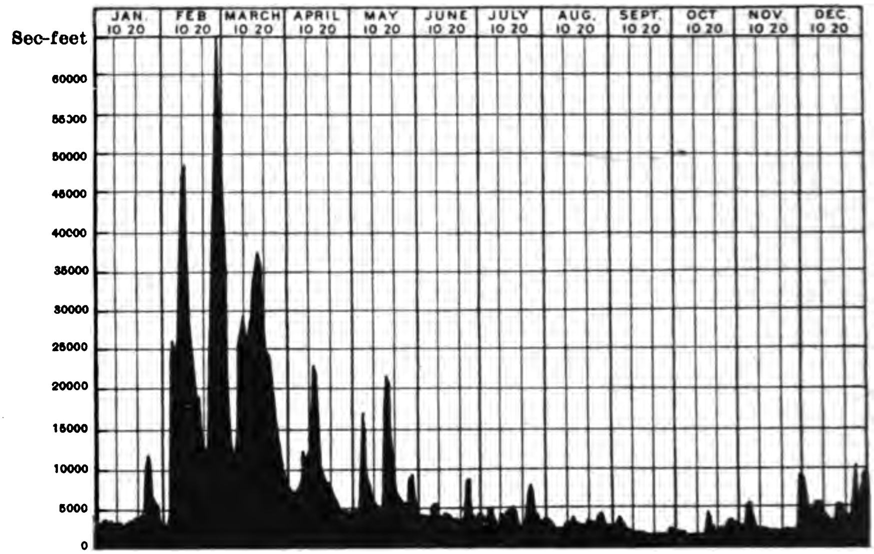


FIG. 19.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE ROANOKE RIVER, AT NEALS, N. C., FOR 1897. (U. S. G. S.)

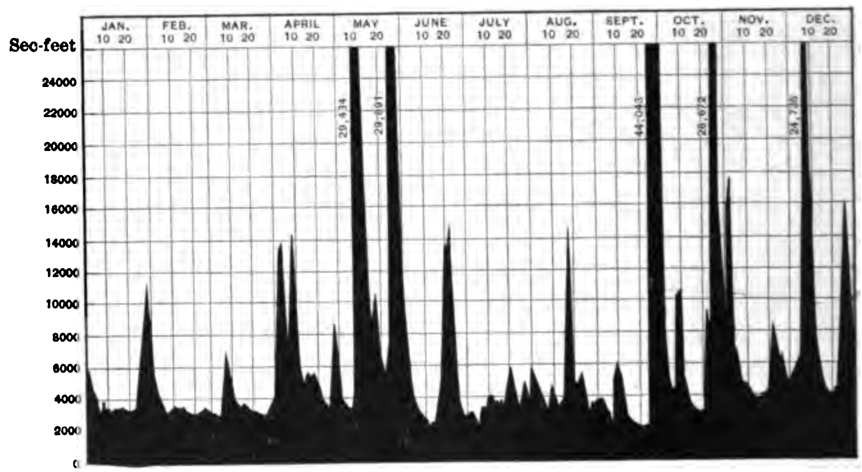


FIG. 20.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET FER SECOND OF THE ROANOKE RIVER, AT NEALS, N. C., FOR 1898.

TARBORO STATION ON THE TAR RIVER.

This station is in the town of Tarboro and is located on the bridge of the Atlantic Coast Line, which crosses the river here. This gauge was established July 25, 1896. The zero of the gauge-rod is over the center of the fifth floor beam from the east end of the bridge. The outer rim of the pulley-wheel is 3 feet from the zero of the gauge-rod, and the distance from the end of the weight to the pointer on the wire is 38.30 feet. The gauge-reading is zero when the weight touches the bottom of the stream. Measurements were taken here temporarily while the steel county bridge which crosses the river about one hundred yards above was under construction, and since that time have been made at the latter place. The section here is a good one, there being only one pier obstruction, caused by a steel tubular pier, 13 feet in diameter. The bottom is of sand and mud but seems to change very little.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON TAR RIVER AT TARBORO, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	July 25	E. W. Myers	2154	4.35	1,061	1.85	1,963
2	Sept. 5	....do	2154	0.43	225	1.67	376
3	Sept. 17	A. P. Davis	68	4.51	1,081	2.12	2,294
4	Dec. 17	E. W. Myers	2154	13.20	3,676	2.35	8,651
	1897.						
5	Jan. 23	E. W. Myers	2154	6.65	1,822	1.98	3,520
6	Feb. 26	....do	2154	13.53	3,489	2.32	8,106
7	Mar. 15	....do	2154	18.13	5,263	2.46	12,993
8	May 17	....do	2154	6.30	1,629	1.87	3,058
9	July 29	....do	2154	2.25	744	1.44	1,079
10	Oct. 2	....do	2154	−0.65	238	0.80	192
	1898.						
11	Jan. 13.	E. W. Myers	2154	2.30	877	1.51	1,323

RATING-TABLE FOR TAR RIVER AT TARBORO, NORTH CAROLINA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
0.00	280	4.00	1,880	8.00	4,400	12.00	7,260
0.20	324	4.20	2,000	8.20	4,540	12.20	7,420
0.40	368	4.40	2,120	8.40	4,680	12.40	7,580
0.60	412	4.60	2,240	8.60	4,820	12.60	7,740
0.80	456	4.80	2,360	8.80	4,960	12.80	7,920
1.00	500	5.00	2,480	9.00	5,100	13.00	8,100
1.20	560	5.20	2,600	9.20	5,240	13.20	8,280
1.40	630	5.40	2,720	9.40	5,380	13.40	8,460
1.60	710	5.60	2,840	9.60	5,520	13.60	8,640
1.80	790	5.80	2,970	9.80	5,660	14.00	9,000
2.00	870	6.00	3,100	10.00	5,800	14.50	9,460
2.20	950	6.20	3,220	10.20	5,940	15.00	9,960
2.40	1,035	6.40	3,340	10.40	6,080	15.50	10,440
2.60	1,120	6.60	3,460	10.60	6,220	16.00	10,940
2.80	1,220	6.80	3,580	10.80	6,360	16.50	11,420
3.00	1,320	7.00	3,710	11.00	6,500	17.00	11,920
3.20	1,420	7.20	3,840	11.20	6,640	17.50	12,400
3.40	1,530	7.40	3,980	11.40	6,780	18.00	12,900
3.60	1,640	7.60	4,120	11.60	6,940	.....	......
3.80	1,760	7.80	4,260	11.80	7,100	.....	......

ESTIMATED MONTHLY DISCHARGE OF TAR RIVER AT TARBORO, NORTH CAROLINA.

[Drainage area, 2290 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
July 26 to 31	1,618	774	1,268	15,090	0.13	0.55
August	1,574	390	628	38,614	0.31	0.27
September	3,910	302	1,190	70,809	0.58	0.52
October	2,000	408	703	43,226	0.35	0.30
November	1,910	476	842	50,102	0.41	0.37
December	9,460	1,420	3,739	229,904	1.88	1.63
					3.66	0.60

RATING-TABLE FOR TAR RIVER AT TARBORO, NORTH CAROLINA, FOR 1897-1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
−1.00	170	0.00	270	3.50	1,680	11.00	6,370
−0.90	177	0.20	310	4.00	1,935	12.00	7,180
−0.80	185	0.40	360	4.50	2,197	13.00	8,050
−0.70	192	0.60	410	5.00	2,460	14.00	8,950
−0.60	200	0.80	470	5.50	2,735	15.00	9,900
−0.50	210	1.00	540	6.00	3,015	16.00	10,900
−0.40	220	1.50	730	7.00	3,600	17.00	11,900
−0.30	230	2.00	950	8.00	4,250	18.00	12,900
−0.20	240	2.50	1,180	9.00	4,950	19.00	13,900
−0.10	255	3.00	1,430	10.00	5,650	20.00	14,900

ESTIMATED MONTHLY DISCHARGE OF TAR RIVER AT TARBORO, NORTH CAROLINA.

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	4,460	1,155	1,814	111,539	0.91	0.79
February	8,725	1,480	4,888	271,466	2.22	2.13
March	14,600	2,197	6,789	417,440	3.41	2.96
April	9,800	1,280	3,636	216,357	1.77	1.59
May	3,915	690	1,580	97,150	0.79	0.69
June	1,280	360	689	40,999	0.33	0.30
July	3,725	310	1,198	73,665	0.60	0.52
August	860	247	399	24,533	0.20	0.17
September	2,460	196	490	29,155	0.23	0.21
October	770	170	295	18,139	0.15	0.13
November	2,250	347	694	40,105	0.32	0.29
December	3,072	770	1,430	87,928	0.71	0.62
The year	14,600	170	1,990	1,428,476	11.64	0.87
1898.						
January	2,959	906	1,411	86,761	0.70	0.61
February	1,580	730	1,051	58,372	0.48	0.46
March	3,795	754	1,697	104,347	0.85	0.74
April	5,510	906	2,524	150,190	1.23	1.10
May	8,610	1,088	3,437	211,330	1.73	1.50
June	3,425	470	1,601	95,261	0.77	0.69
July	6,937	385	2,420	148,804	1.21	1.05
August	4,880	505	1,720	105,760	0.86	0.75
September	4,250	360	1,351	80,389	0.65	0.59
October	1,430	385	839	51,588	0.41	0.36
November	2,735	654	1,317	78,362	0.64	0.58
December	8,050	1,480	3,070	188,764	1.54	1.34
The year	8,610	360	1,870	1,357,924	11.07	0.81

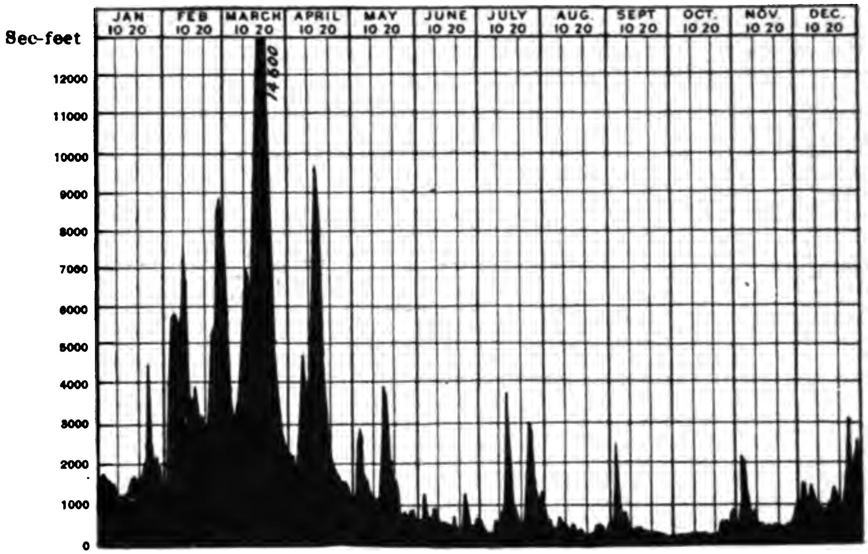


FIG. 21.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE TAR RIVER, AT TARBORO, N. C., FOR 1897. (U. S. G. S.)

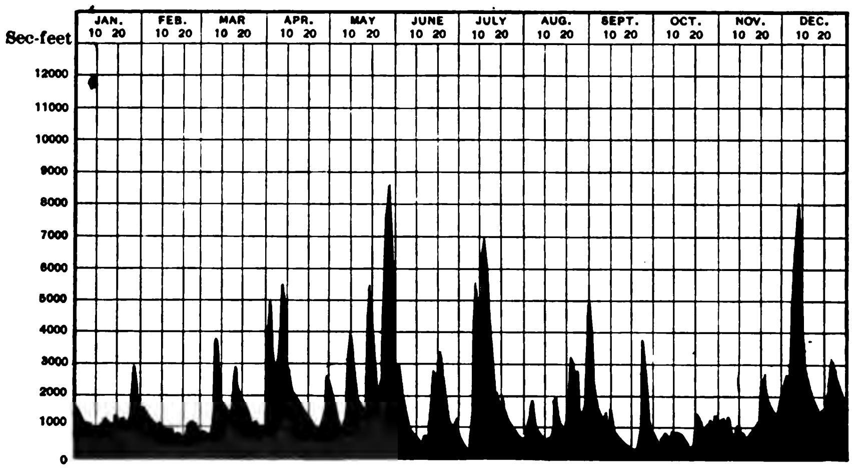


FIG. 22.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE TAR RIVER, AT TARBORO, N. C., FOR 1898.

SELMA STATION ON THE NEUSE RIVER.

This station is located on the Southern railroad bridge about three miles from Selma, and the gauge was put in on July 29, 1896. The zero of the gauge-rod is over the center of the fifth floor beam of the first span from the south end of the bridge. The distance from the zero of the gauge to the outer rim of the pulley is 4 feet, and the distance from the end of the weight to the pointer on the wire is 41.05 feet. The bed of the river here is of sand and is liable to change by high water. The course of the river is straight and there is only one pier obstruction.

A better section is found at the county bridge which crosses the river about three hundred yards below the railroad bridge, and it is here that the measurements are taken. The bottom here is harder and there are no pier obstructions.

The tables of daily gauge heights for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON NEUSE RIVER AT SELMA, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	July 29	E. W. Myers	2154	1.18	285	1.28	333
2	Sept. 5	....do	2154	0.30	215	0.94	203
3	Sept. 19	A. P. Davis	68	0.00	220	0.56	123
	1897.						
4	Jan. 24	E. W. Myers	2154	8.00	1,038	1.74	1,810
5	Feb. 23	....do	2154	10.60	1,842	2.19	4.052
6	Mar. 10	...do	2154	7.95	1,379	1.92	2,639
7	May 18	....do	2154	2.40	497	1.58	789
8	July 27	....do	2154	1.60	466	1.48	694
9	Oct. 1	....do	2154	−0.30	146	0.75	109
	1898.						
10	Jan. 9	E. W. Myers	2154	1.20	327	1.30	426
11	Aug. 31	....do	9	6.75	1,208	2.40	2,902
	1899.						
12	Feb. 6	....do	87	15.68	2,712	2.88	7,807

RATING-TABLE FOR NEUSE RIVER AT SELMA, NORTH CAROLINA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. Feet.
0.00	125	2.80	700	5.60	1,515	8.40	2,590
0.20	155	3.00	750	5.80	1,580	8.60	2,695
0.40	185	3.20	800	6.00	1,650	8.80	2,805
0.60	220	3.40	850	6.20	1,720	9.00	2,920
0.80	260	3.60	900	6.40	1,790	9.20	3,040
1.00	300	3.80	960	6.60	1,860	9.40	3,160
1.20	340	4.00	1,020	6.80	1,930	9.60	3,280
1.40	380	4.20	1,080	7.00	2,000	9.80	3,400
1.60	420	4.40	1,140	7.20	2,080	10.00	3,540
1.80	460	4.60	1,200	7.40	2,160	10.20	3,690
2.00	500	4.80	1,260	7.60	2,240	10.40	3,855
2.20	550	5.00	1,325	7.80	2,320	10.60	4,050
2.40	600	5.20	1,390	8.00	2,400	10.80	4,230
2.60	650	5.40	1,450	8.20	2,490	11.00	4,410

ESTIMATED MONTHLY DISCHARGE OF NEUSE RIVER AT SELMA, NORTH CAROLINA.

[Drainage area, 1175 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
August	1,480	170	443	27,239	0.44	0.38
September	1,337	125	213	12,674	0.20	0.18
October	2,080	140	315	19,369	0.31	0.27
November	1,260	185	321	19,101	0.30	0.27
December	2,920	340	874	53,741	0.85	0.74
					2.10	0.36

RATING-TABLE FOR NEUSE RIVER AT SELMA, NORTH CAROLINA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Sec. feet.	Feet.
—0.5	70	2.2	698	5.6	1,700	10.5	3,950
—0.4	75	2.4	754	5.8	1,760	11.0	4,260
—0.3	92	2.6	810	6.0	1,830	11.5	4,570
—0.2	110	2.8	866	6.2	1,900	12.0	4,880
—0.1	127	3.0	922	6.4	1,970	12.5	5,190
0.0	145	3.2	980	6.6	2,040	13.0	5,500
0.1	165	3.4	1,040	6.8	2,110	13.5	5,810
0.2	185	3.6	1,100	7.0	2,190	14.0	6,120
0.4	230	3.8	1,160	7.2	2,270	14.5	6,430
0.6	275	4.0	1,220	7.4	2,350	15.0	6,740
0.8	325	4.2	1,280	7.6	2,430	15.5	7,050
1.0	375	4.4	1,340	7.8	2,510	16.0	7,360
1.2	425	4.6	1,400	8.0	2,590	16.5	7,670
1.4	475	4.8	1,460	8.5	2,825	17.0	7,980
1.6	530	5.0	1,520	9.0	3,075	....	.....
1.8	586	5.2	1,580	9.5	3,355	....	.....
2.0	642	5.4	1,640	10.0	3,650	....	.....

ESTIMATED MONTHLY DISCHARGE OF NEUSE RIVER AT SELMA, NORTH CAROLINA.
[Drainage area 1175 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	3,243	400	846	52,020	0.83	0.72
February	5,624	558	2,302	177,846	2.04	1.96
March	7,856	810	2,903	128,500	2.85	2.47
April	6,430	586	811	48,258	0.77	0.69
May	2,975	475	920	56,570	0.90	0.78
June	1,830	252	570	33,920	0.54	0.48
July	1,700	230	658	40,460	0.64	0.56
August	586	165	232	14,265	0.23	0.20
September	185	92	145	8,627	0.13	0.12
October	230	75	126	7,747	0.13	0.11
November	726	145	265	15,768	0.26	0.23
December	1,830	375	795	48,882	0.78	0.68
The year	7,856	75	881	632,863	10.10	.075

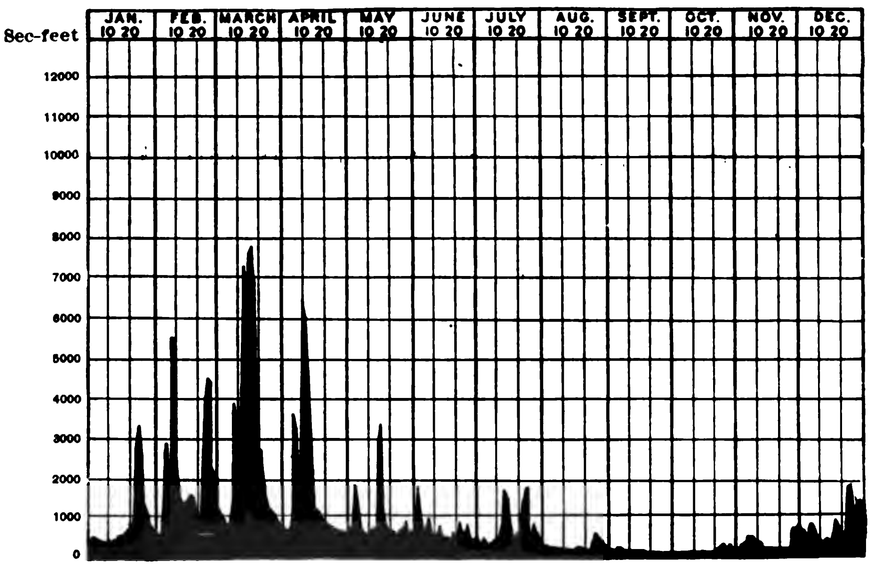


FIG. 23.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE NEUSE RIVER, AT SELMA, N. C., FOR 1897. (U. S. G. S.)

RATING-TABLE FOR NEUSE RIVER AT SELMA, NORTH CAROLINA, FOR 1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
0.00	145	2.30	732	5.20	2,066	9.80	4,590
0.10	165	2.40	762	5.40	2,172	10.00	4,700
0.20	185	2.50	792	5.60	2,280	10.20	4,810
0.30	207	2.60	822	5.80	2,390	10.40	4,920
0.40	230	2.70	855	6.00	2,500	10.60	5,030
0.50	252	2.80	890	6.20	2,610	10.80	5,140
0.60	275	2.90	930	6.40	2,720	11.00	5,250
0.70	300	3.00	972	6.60	2,830	11.20	5,360
0.80	325	3.10	1,017	6.80	2,940	11.40	5,470
0.90	350	3.20	1,062	7.00	3,050	11.60	5,580
1.00	375	3.30	1,110	7.20	3,160	11.80	5,690
1.10	400	3.40	1,160	7.40	3,270	12.00	5,800
1.20	425	3.50	1,210	7.60	3,380	12.50	6,075
1.30	450	3.60	1,260	7.80	3,490	13.00	6,350
1.40	475	3.70	1,310	8.00	3,600	13.50	6,625
1.50	502	3.80	1,360	8.20	3,710	14.00	6,900
1.60	530	3.90	1,410	8.40	3,820	14.50	7,175
1.70	558	4.00	1,460	8.60	3,930	15.00	7,450
1.80	586	4.20	1,560	8.80	4,040	15.50	7,725
1.90	614	4.40	1,660	9.00	4,150	16.00	8,000
2.00	642	4.60	1,760	9.20	4,260	.....	....
2.10	672	4.80	1,860	9.40	4,370	.....	....
2.20	702	5.00	1,960	9.60	4,480	.....	....

ESTIMATED MONTHLY DISCHARGE OF NEUSE RIVER AT SELMA, NORTH CAROLINA.

[Drainage area 1175 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	3,050	350	661	40,644	0.64	0.56
February	792	325	429	20,271	0.37	0.36
March	4,150	375	1,151	70,775	1.13	0.98
April	5,470	400	1,613	95,975	1.53	1.37
May	5,250	275	1,798	110,557	1.76	1.53
June	1,960	230	557	33,144	0.53	0.47
July	3,050	252	926	56,938	0.90	0.78
August	4,920	252	1,314	80,797	1.29	1.12
September	6,350	325	1,385	82,409	1.32	1.18
October	822	185	421	25,886	0.41	0.36
November	2,390	425	857	50,995	0.81	0.73
December	5,470	475	1,300	79,937	1.28	1.11
The year	6,350	185	1,034	748,328	11.97	0.88

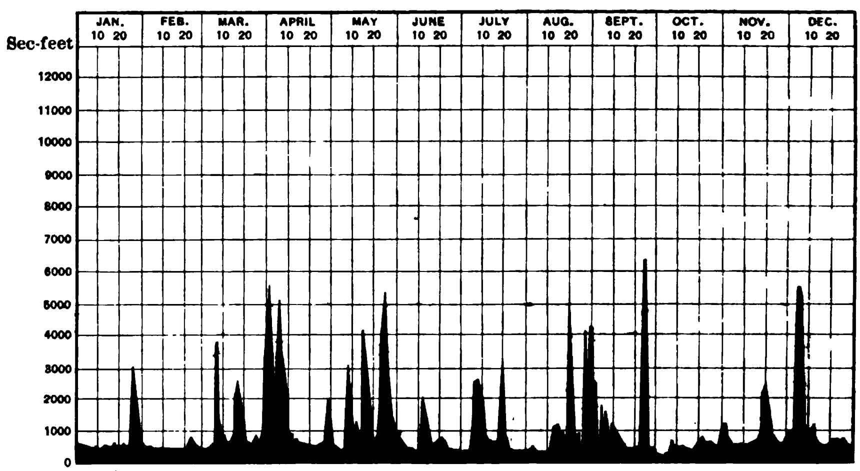


FIG. 24.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE NEUSE RIVER, NEAR SELMA, N. C., FOR 1898.

MONCURE STATION ON THE DEEP RIVER.

This station is located about one-fourth of a mile south of Moncure, Chatham county, North Carolina, at the covered wooden bridge of the Seaboard Air Line which crosses the river here, and about two miles above the junction with the Haw river to form the Cape Fear.

This station was established May 5, 1898. The name of the observer is M. A. Moore, Moncure, Chatham county, N. C., a farmer and also bridge watchman, living about one hundred yards from the bridge.

The gauge is a horizontal rod, well painted, divided into feet and tenths and securely nailed to the guard-rail of the bridge.

The zero of the rod is 50 feet south of the north end of the second span of the bridge from the north. The outer rim of the pulley-wheel is 3.7 feet from the zero of the rod, and from the end of the weight to the pointer on the wire rope is 45.16 feet, the gauge reading zero when the weight touches the bottom of the river.

The initial point for soundings is a notch cut in the guard-rail opposite the south end of the bridge and on the down-stream side.

The channel is straight for some distance above and below the station. The current velocity is not great but sufficient for the purpose, and is well distributed across the stream. Both banks are rather low and subject to overflow.

The bed of the river is of fine sand and mud and is probably subject to change in high water.

MONCURE STATION ON THE HAW RIVER.

This station is located about one and three-fourths miles north of Moncure, Chatham county, North Carolina, at the bridge of the Seaboard Air Line which crosses the river here, and about two miles above the junction with the Deep river to form the Cape Fear.

The station was established May 6, 1898. The name of the observer is M. A. Moore, Moncure, Chatham county, N. C.

The gauge is a horizontal rod, well painted, divided into feet and tenths and securely nailed to the outer side of the guard-rail of the bridge on the up-stream side. The two-foot mark on the rod is over the center of the second floor beam from the south end of the second span from the south end of the bridge. The outer rim of the pulley-wheel is 0.3 foot from the zero of the gauge-rod and the distance from the end of the weight to the pointer on the wire rope is 43.45 feet, the gauge reading zero when the weight touches the bottom of the stream.

The initial point for soundings is a notch cut in the guard-rail opposite the south end of the bridge and on the up-stream side, the section on this side being better than that on the down-stream side.

The channel is straight for some distance above and below the station. The current velocity is good and uniformly distributed across the stream. Both banks are rather low and somewhat subject to overflow in time of flood. The bed of the stream is of coarse sand and gravel and is probably not subject to any decided change in high water. The current here is somewhat modified by a fish dam about 150 yards above the bridge.

The station is reached by private conveyance from Moncure.

FAYETTEVILLE STATION ON THE CAPE FEAR RIVER.

In the summer of 1895 an examination was made of the river, and a station for measuring the flow was established at Fayetteville. The Weather Bureau has a substantial gauge fastened to the lower side of the east abutment of the covered highway bridge, this being about 400 feet above the railroad bridge from which discharge measurements are made. For the lower 29 feet this gauge consists of a rod divided into tenths and firmly fastened to the abutment. Above the 29-foot mark, a scale is painted on the rock.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON CAPE FEAR RIVER AT FAYETTEVILLE, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second feet).
	1895.						
1	Sept. 26	C. C. Babb	....	1.59	....	....	489
2	Dec. 7	....do	....	2.90	....	....	1,109
	1896.						
3	Apr. 5	E. W. Myers	21	19.30	4,868	2.16	10,525
4	Apr. 25	....do	21	4.00	982	1.78	1,618
5	May 23	....do	21	4.00	1,270	1.04	1,322
6	June 8	....do	21	10.00	2,901	1.78	5,041
7	June 8	....do	21	9.20	2,446	1.72	4,207
8	July 11	....do	21	49.10	22,852	2.24	51,115
9	Sept. 2	....do	2154	1.10	400	1.29	519
10	Sept. 19	A. P. Davis	68	1.88	517	1.50	770
	1897.						
11	Mar. 12	E. W. Myers	2154	23.00	7,110	2.35	16,777
12	July 27	....do	2154	7.00	1,701	1.57	2,682
13	Sept. 30	....do	2154	0.70	327	1.29	424
	1898.						
14	Jan. 10	E. W. Myers	2154	3.55	758	1.72	1,303
15	Aug. 22	....do	9	28.85	9,132	2.54	23,215

RATING-TABLE FOR CAPE FEAR RIVER AT FAYETTEVILLE, NORTH CAROLINA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
1.00	489	7.20	3,334	13.40	6,913	22.00	14,287
1.20	550	7.40	3,442	13.60	7,033	23.00	15,646
1.40	612	7.60	3,550	13.80	7,153	24.00	17,005
1.60	678	7.80	3,658	14.00	7,273	25.00	18,364
1.80	744	8.00	3,766	14.20	7,393	26.00	19,723
2.00	810	8.20	3,878	14.40	7,513	27.00	21,082
2.20	876	8.40	3,990	14.60	7,633	28.00	22,441
2.40	942	8.60	4,102	14.80	7,753	29.00	23,800
2.60	1,008	8.80	4,214	15.00	7,873	30.00	25,159
2.80	1,075	9.00	4,326	15.20	7,993	31.00	26,458
3.00	1,145	9.20	4,438	15.40	8,113	32.00	27,877
3.20	1,229	9.40	4,550	15.60	8,233	33.00	29,236
3.40	1,319	9.60	4,672	15.80	8,355	34.00	30,595
3.60	1,417	9.80	4,784	16.00	8,479	35.00	31,954
3.80	1,517	10.00	4,898	16.20	8,603	36.00	33,313
4.00	1,620	10.20	5,013	16.40	8,727	37.00	34,627
4.20	1,728	10.40	5,129	16.60	8,851	38.00	36,031
4.40	1,836	10.60	5,245	16.80	8,975	39.00	37,390
4.60	1,940	10.80	5,361	17.00	9,099	40.00	38,749
4.80	2,048	11.00	5,477	17.20	9,223	41.00	40,108
5.00	2,156	11.20	5,593	17.40	9,347	42.00	41,467
5.20	2,264	11.40	5,713	17.60	9,471	43.00	42,826
5.40	2,372	11.60	5,833	17.80	9,595	44.00	44,185
5.60	2,470	11.80	5,953	18.00	9,719	45.00	45,554
5.80	2,578	12.00	6,073	18.20	9,843	46.00	46,903
6.00	2,686	12.20	6,193	18.40	9,967	47.00	48,262
6.20	2,794	12.40	6,313	18.60	10,091	48.00	49,621
6.40	2,902	12.60	6,433	18.80	10,215	49.00	50,980
6.60	3,010	12.80	6,553	19.00	10,339	50.00	52,339
6.80	3,118	13.00	6,673	20.00	11,569	.....	......
7.00	3,226	13.20	6,793	21.00	12,928	.....	......

ESTIMATED MONTHLY DISCHARGE OF CAPE FEAR RIVER AT FAYETTEVILLE, NORTH CAROLINA.

[Drainage area, 4,493 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
October	810	399	608	37,369	0.16	0.14
November	4,270	1,075	1,833	109,071	0.46	0.41
December	10,029	1,008	2,737	168,292	0.70	0.61
1896.						
January[1]	19,723	1,620	6,463	246,387	1.07	1.44
February[2]	49,621	2,956	10,190	586,129	2.47	2.29
March	5,477	2,318	3,501	215,269	0.91	0.789
April[2]	14,967	1,367	3,087	183,676	0.77	0.689
May	9,347	843	2,686	165,260	0.69	0.598
June[2]	11,569	1,041	3,492	207,774	0.81	0.777
July[2]	52,340	1,319	7,303	449,061	1.87	1.625
August	7,093	612	1,081	66,471	0.28	0.240
September	4,616	489	1,240	73,780	0.30	0.275
October[2]	26,458	843	2,623	161,278	0.67	0.583
November[2]	10,954	975	2,399	142,740	0.59	0.534
December	8,113	1,940	4,158	255,667	1.06	0.92
Per annum (1896)	52,340	489	4,019	2,758,492	11.49	0.897

[1] Twenty days in January.

[2] Maximum approximate.

RATING-TABLE FOR CAPE FEAR RIVER AT FAYETTEVILLE, NORTH CAROLINA, FOR 1897-'98.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. Feet.	Feet.	Sec. feet.
0.0	300	5.8	2,400	11.8	5,780	21.0	13,400
0.1	320	6.0	2,500	12.0	5,900	22.0	14,500
0.2	340	6.2	2,600	12.2	6,020	23.0	15,650
0.4	380	6.4	2,700	12.4	6,140	24.0	16,940
0.6	430	6.6	2,800	12.6	6,260	25.0	18,300
0.8	480	6.8	2,900	12.8	6,380	26.0	19,660
1.0	530	7.0	3,000	13.0	6,500	27.0	21,020
1.2	580	7.2	3,100	13.2	6,640	28.0	22,380
1.4	630	7.4	3,200	13.4	6,780	29.0	23,740
1.6	690	7.6	3,300	13.6	6,920	30.0	25,100
1.8	750	7.8	3,400	13.8	7,060	31.0	26,460
2.0	810	8.0	3,500	14.0	7,200	32.0	27,820
2.2	875	8.2	3,620	14.2	7,340	33.0	29,180
2.4	945	8.4	3,740	14.4	7,480	34.0	30,540
2.6	1,020	8.6	3,860	14.6	7,620	35.0	31,900
2.8	1,100	8.8	3,980	14.8	7,760	36.0	33,260
3.0	1,180	9.0	4,100	15.0	7,900	37.0	34,620
3.2	1,260	9.2	4,220	15.2	8,040	38.0	35,980
3.4	1,340	9.4	4,340	15.4	8,180	39.0	37,240
3.6	1,420	9.6	4,460	15.6	8,320	40.0	38,600
3.8	1,500	9.8	4,580	15.8	8,460	41.0	39,960
4.0	1,580	10.0	4,700	16.0	8,600	42.0	41,320
4.2	1,670	10.2	4,820	16.5	9,000	43.0	42,680
4.4	1,760	10.4	4,940	17.0	9,400	44.0	44,040
4.6	1,850	10.6	5,060	17.5	9,850	45.0	45,400
4.8	1,940	10.8	5,180	18.0	10,300	46.0	46,760
5.0	2,030	11.0	5,300	18.5	10,800	47.0	48,120
5.2	2,120	11.2	5,420	19.0	11,300	48.0	49,480
5.4	2,210	11.4	5,540	19.5	11,800	49.0	50,840
5.6	2,300	11.6	5,660	20.0	12,300	50.0	52,300

ESTIMATED MONTHLY DISCHARGE OF CAPE FEAR RIVER AT FAYETTEVILLE, NORTH CAROLINA.

[Drainage area, 4,493 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	17,688	1,580	3,694	227,140	0.94	0.82
February	33,688	2,255	12,802	710,966	2.97	2.85
March	35,708	3,100	12,233	752,280	3.14	2.72
April	22,788	1,760	6,871	408,850	1.71	1.53
May	9,760	1,580	3,191	196,210	0.82	0.71
June	3,860	750	1,833	109,070	0.46	0.41
July	18,708	780	3,180	195,530	0.82	0.71
August	2,900	875	1,570	96,535	0.40	0.35
September	1,850	360	664	39,510	0.17	0.15
October	875	340	517	31,790	0.14	0.12
November	4,520	630	1,281	76,230	0.32	0.29
December	4,700	1,180	2,165	133,120	0.55	0.48
The year	35,708	340	4,167	2,977,251	12.44	0.93
1898.						
January	7,273	1,273	2,071	127,555	0.53	0.46
February	2,686	1,109	1,757	97,584	0.41	0.39
March	12,257	1,229	3,252	200,291	0.83	0.72
April	13,616	1,567	4,342	258,349	1.07	0.96
May	8,665	1,145	2,505	154,016	0.64	0.56
June	3,228	519	1,163	69,203	0.29	0.26
July	8,665	489	2,858	175,736	0.72	0.63
August	23,972	942	5,632	346,300	1.44	1.25
September	10,277	876	3,674	218 615	0.91	0.82
October	4,955	612	1,745	107,298	0.45	0.39
November	7,833	1,417	2,975	177,027	0.73	0.66
December	9,781	1,904	3,887	208,255	0.86	0.75
The year	23,972	489	2,947	2,140,229	8.88	0.65

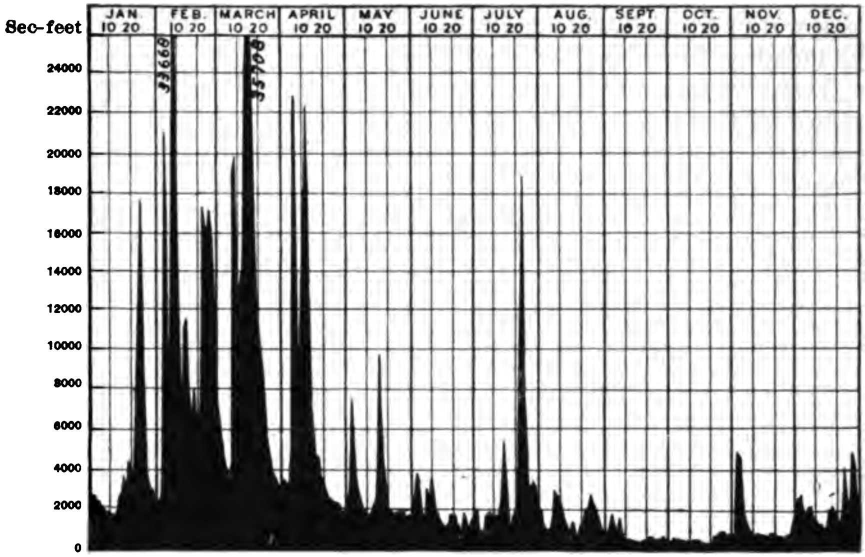


FIG. 25.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CAPE FEAR RIVER, AT FAYETTEVILLE, N. C., FOR 1897. (U. S. G. S.)

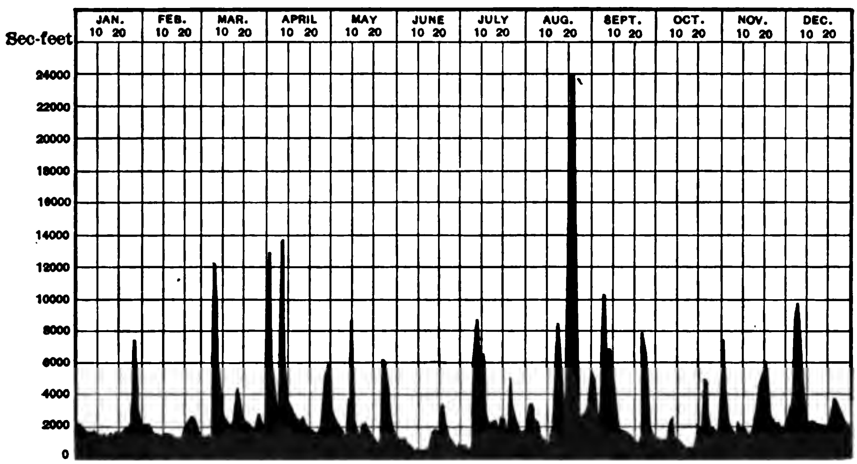


FIG. 26.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CAPE FEAR RIVER, AT FAYETTEVILLE, N. C., FOR 1898.

SALISBURY STATION ON THE YADKIN RIVER.

The upper point of measurement for the Yadkin river is at the Southern railway bridge near Salisbury. The section here is favorable. A gauge was located here on September 24, 1895. The 10-foot mark on the rod is opposite the centre of the sixth floor beam on the lower side of the first span from the west end. The distance from the zero of the rod to the outer rim of the pulley-wheel is 1.85 feet. The length of the wire rope and the weight is 55.10 feet. The locality is reached by private conveyance from Salisbury.

This river is known as the Yadkin for about thirty miles below this point, or down to the mouth of the Uharie river, entering from the north in Montgomery county. Below this point it is known as the Pee-Dee.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON YADKIN RIVER AT SALISBURY, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1895.						
1	Oct. 5	C. C. Babb	29	1.44	1,190	1.22	1,457
2	Oct. 26	....do	76	1.45	1,159	1.33	1,538
3	Dec. 10	....do	62	1.74	1,534	1.57	2,415
	1896.						
4	Apr. 20	E. W. Myers	21	2.00	1,558	1.87	2,916
5	Aug. 29	....do	2154	1.50	1,318	0.98	1,298
6	Sept. 14	....do	21	1.79	1,486	1.66	2,368
	1897.						
7	Feb. 18	E. W. Myers	2154	4.20	2,997	3.38	10,141
8	Mar. 20	....do	2154	4.45	3,436	3.44	11,837
9	Apr. 18	....do	2154	3.90	3,223	3.10	9,992
10	Aug. 4	....do	2154	2.18	1,768	1.93	3,422
11	Oct. 6	....do	2154	1.40	1,013	1.28	1,300
	1898.						
12	Jan. 17	E. W. Myers	2154	2.10	1,412	1.81	2,567
13	Apr. 1	....do	2154	3.90	2,700	3.37	9,110
14	Aug. 13	....do	2154	5.00	3,323	3.38	11,237
	1899.						
15	Feb. 9	...do	87	6.50	3,851	3.83	14,781

RATING-TABLE FOR YADKIN RIVER AT SALISBURY, NORTH CAROLINA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.00	500	2.00	3,000	3.00	6,400	4.00	9,800
1.10	650	2.10	3,340	3.10	6,740	4.10	10,160
1.20	850	2.20	3,680	3.20	7,080	4.20	10,540
1.30	1,050	2.30	4,020	3.30	7,420	4.30	10,940
1.40	1,275	2.40	4,360	3.40	7,760	4.40	11,390
1.50	1,500	2.50	4,700	3.50	8,100	4.50	11,840
1.60	1,740	2.60	5,040	3.60	8,440	4.60	12,290
1.70	1,980	2.70	5,380	3.70	8,780	4.70	12,740
1.80	2,320	2.80	5,720	3.80	9,120	4.80	13,200
1.90	2,660	2.90	6,060	3.90	9,460	4.90	13,700

ESTIMATED MONTHLY DISCHARGE OF YADKIN RIVER AT SALISBURY, NORTH CAROLINA.
[Drainage area, 3,399 square miles.]

Month.	Discharge in second-feet. Maximum.	Discharge in second-feet. Minimum.	Discharge in second-feet. Mean.	Total in acre-feet.	Run-off. Depth in inches.	Run-off. Second-feet per square mile.
1895.						
October	1,500	1,400	1,426	87,681	0.48	0.42
November	4,020	1,310	2,004	119,246	0.65	0.59
December	10,160	1,640	2,683	164,971	0.91	0.79
1896.						
January	10,940	1,640	4,485	275,774	1.52	1.32
February	[1] 24,200	2,320	7,817	449,638	2.48	2.30
March	5,380	2,320	3,472	213,485	1.18	1.02
April	[1] 29,200	2,660	5,242	311,920	1.72	1.54
May	6,060	1,310	2,507	154,149	0.85	0.74
June	9,460	1,310	3,159	187,974	1.03	0.93
July	[1] 64,200	1,640	11,584	712,277	3.94	3.41
August	6,060	1,000	2,411	148,248	0.82	0.71
September	[1] 32,200	1,000	3,087	183,689	1.01	0.91
October	[1] 31,200	1,310	3,122	191,965	1.06	0.92
November	[1] 23,200	1,980	5,206	309,779	1.65	1.48
December	[1] 22,700	3,000	6,037	371,202	2.05	1.78
Per annum (1896)	[1] 64,200	1,000	4,844	3,510,100	19.31	1.42

RATING-TABLE FOR THE YADKIN RIVER AT SALISBURY, NORTH CAROLINA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.0	560	3.2	7,116	5.4	14,860	7.6	22,604
1.2	900	3.4	7,820	5.6	15,564	7.8	23,308
1.4	1,310	3.6	8,524	5.8	16,268	8.0	24,012
1.6	1,760	3.8	9,228	6.0	16,972	8.5	25,772
1.8	2,300	4.0	9,932	6.2	17,676	9.0	27,532
2.0	2,920	4.2	10,636	6.4	18,380	9.5	29,292
2.2	3,596	4.4	11,340	6.6	19,084	10.0	31,052
2.4	4,300	4.6	12,044	6.8	19,788	10.5	32,812
2.6	5,004	4.8	12,748	7.0	20,492	11.0	34,572
2.8	5,708	5.0	13,452	7.2	21,196	11.5	36,332
3.0	6,412	5.2	14,156	7.4	21,900	....	......

ESTIMATED MONTHLY DISCHARGE OF THE YADKIN RIVER AT SALISBURY, NORTH CAROLINA.
[Drainage area, 3,399 square miles.]

Month.	Discharge in second-feet. Maximum.	Discharge in second-feet. Minimum.	Discharge in second-feet. Mean.	Total in acre-feet.	Run-off. Depth in inches.	Run-off. Second-feet per square mile.
1897.						
January	12,044	2,600	4,039	248,350	1.37	1.19
February	34,924	4,652	11,597	644,065	3.45	3.41
March	25,068	4,652	10,522	646,970	3.58	3.10
April	31,756	3,948	7,761	461,810	2.54	2.28
May	14,156	3,250	5,776	355,150	1.96	1.70
June	19,788	2,300	5,652	336,320	1.85	1.66
July	11,692	2,600	4,821	296,430	1.64	1.42
August	5,708	1,760	2,943	180,960	1.00	0.87
September	3,250	900	1,785	106,215	0.59	0.53
October	25,772	900	3,557	218,600	1.21	1.05
November	7,116	900	2,708	161,140	0.89	0.80
December	5,708	2,300	3,086	189,750	1.05	0.91
The year	34,924	900	5,354	3,845,760	21.13	1.58

[1] Estimated.

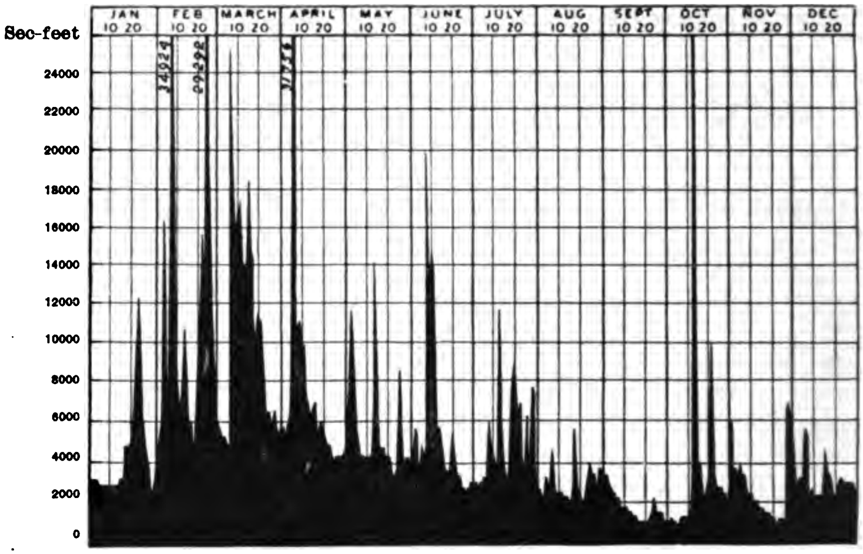


FIG. 27.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE YADKIN RIVER, AT SALISBURY, N. C., FOR 1897. (U. S. G. S.)

RATING-TABLE FOR YADKIN RIVER AT SALISBURY, NORTH CAROLINA, FOR 1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.20	1,000	3.20	6,850	5.50	12,410	10.50	42,115
1.40	1,250	3.40	7,150	6.00	13,585	11.00	46,520
1.60	1,550	3.60	8,000	6.50	14,780	11.50	50,925
1.80	1,900	3.80	8,850	7.00	15,960	12.00	55,330
2.00	2,325	4.00	9,290	7.50	18,830	12.50	59,735
2.20	2,850	4.20	9,675	8.00	21,700	13.00	64,140
2.40	3,450	4.40	10,065	8.50	25,300	13.50	68,545
2.60	4,100	4.60	10,450	9.00	28,900	14.00	72,950
2.80	4,800	4.80	10,840	9.50	33,305	14.50	77,355
3.00	5.550	5.00	11,235	10.00	37.710	15.00	81.760

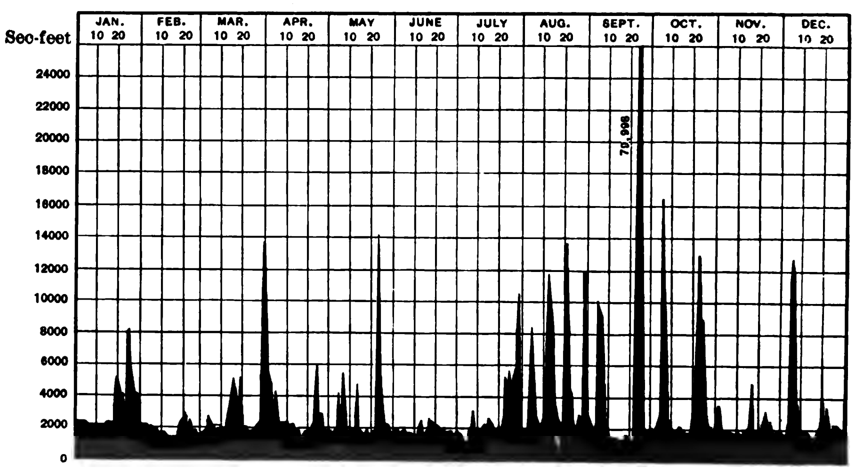


FIG. 28.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE YADKIN RIVER NEAR SALISBURY, N. C., FOR 1898.

ESTIMATED MONTHLY DISCHARGE OF THE YADKIN RIVER AT SALISBURY, NORTH CAROLINA.

[Drainage area 3,399 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	9,290	2,100	3,341	205,427	1.13	0.98
February	2,850	1,400	1,950	108,300	0.60	0.58
March	13,820	1,725	3,039	186,858	1.02	0.89
April	10,645	1,550	2,965	176,432	0.97	0.87
May	14,230	1,400	2,982	183,361	1.00	0.87
June	2,567	1,550	1,832	109,007	0.60	0.54
July	10,450	1,100	3,167	194,728	1.07	0.93
August	13,820	1,725	4,993	307,007	1.35	1.17
September	79,998	1,400	8,295	493,584	2.81	2.44
October	16,550	1,725	4,246	261,076	1.44	1.25
November	4,800	1,725	2,197	130,732	0.69	0.62
December	12,645	1,550	3,284	201,923	1.10	0.96
The year	79,998	1,100	3,524	2,558,435	13.78	1.01

NORWOOD STATION ON THE YADKIN RIVER.

This gauge was established September 1, 1896, at Blalock's ferry, about two miles from Norwood, N. C. The gauge is a vertical rod securely spiked and braced to an overhanging tree near the ferry, and is divided into feet and tenths. The rod is referred to a bench mark, consisting of a large nail driven into a notch cut in the root of a birch tree about 50 feet northwest of the rod, and the tree is immediately in front of the turn of the road leading to the ferry. The zero of the gauge is 5.93 feet below the elevation of the bench mark. The river here is about 960 feet wide, shallow, with a bottom of sand and small rocks, not subject to change by high water, and giving a good section for gauging. The measurements are taken from the ferry-boat.

The tables of daily gauge height for this station will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON YADKIN RIVER NEAR NORWOOD, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height. (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	Sept. 1	E. W. Myers	2154	1.00	1,859	0.82	1,537
2	Sept. 15	....do	2154	1.34	2,211	0.92	2,036
	1897.						
3	Feb. 12	E. W. Myers	2154	3.32	3,779	2.54	9,607
4	Mar. 21	....do	2154	3.80	4,517	2.59	11,710
5	Aug. 4	....do	2154	1.65	2,544	1.33	3,392
6	Oct. 6	....do	2154	1.00	1,821	0.82	1,508
7	Oct. 25	A. P. Davis	94	1.48	2,152	1.26	2,715
	1898.						
8	Jan. 16	E. W. Myers	2154	1.63	2,474	1.22	3,041
9	May 1	....do	2154	5.75	6,465	3.84	24,825

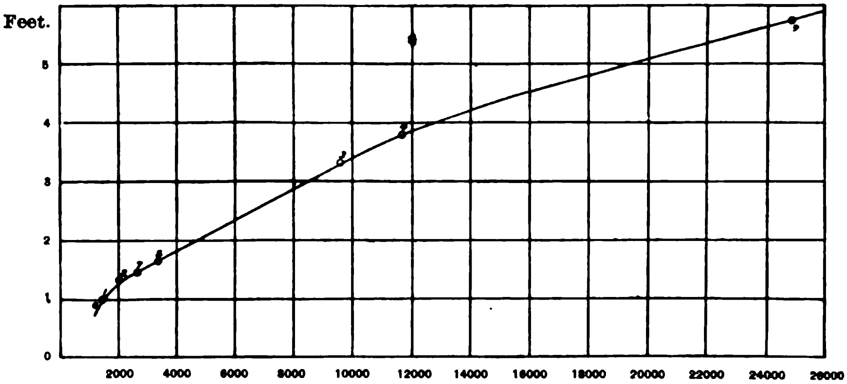


FIG. 29.—RATING CURVE FOR NORWOOD STATION, ON THE YADKIN RIVER, N. C.

RATING-TABLE FOR YADKIN RIVER AT NORWOOD, NORTH CAROLINA, FOR 1896.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
0.70	1,300	1.60	3,100	2.50	6,565	3.40	10,100
0.80	1,370	1.70	3,485	2.60	6,950	3.50	10,500
0.90	1,450	1.80	3,870	2.70	7,335	3.60	10,900
1.00	1,540	1.90	4,255	2.80	7,720	3.70	11,300
1.10	1,640	2.00	4,640	2.90	8,110	3.80	11,700
1.20	1,830	2.10	5,025	3.00	8,500	3.90	12,100
1.30	2,080	2.20	5,410	3.10	8,900	4.00	12,500
1.40	2,380	2.30	5,795	3.20	9,300	....	......
1.50	2,720	2.40	6,180	3.30	9,700	....	......

RATING-TABLE FOR YADKIN RIVER AT NORWOOD, NORTH CAROLINA FOR 1897-98.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
0.7	1,250	2.6	6,960	4.8	18,000	7.0	34,060
0.8	1,310	2.8	7,720	5.0	19,460	7.2	35,520
0.9	1,380	3.0	8,480	5.2	20,920	7.4	36,980
1.0	1,480	3.2	9,240	5.4	22,380	7.6	38,440
1.2	1,820	3.4	10,000	5.6	23,840	7.8	39,900
1.4	2,400	3.6	10,860	5.8	25,300	8.0	41,360
1.6	3,160	3.8	11,800	6.0	26,760	8.2	42,820
1.8	3,920	4.0	12,800	6.2	28,220	8.4	44,280
2.0	4,680	4.2	13,800	6.4	29,680	8.6	45,740
2.2	5.440	4.4	15,100	6.6	31,140	8.8	47,200
2.4	6.200	4.6	16.540	6.8	32,600	9.0	48,660

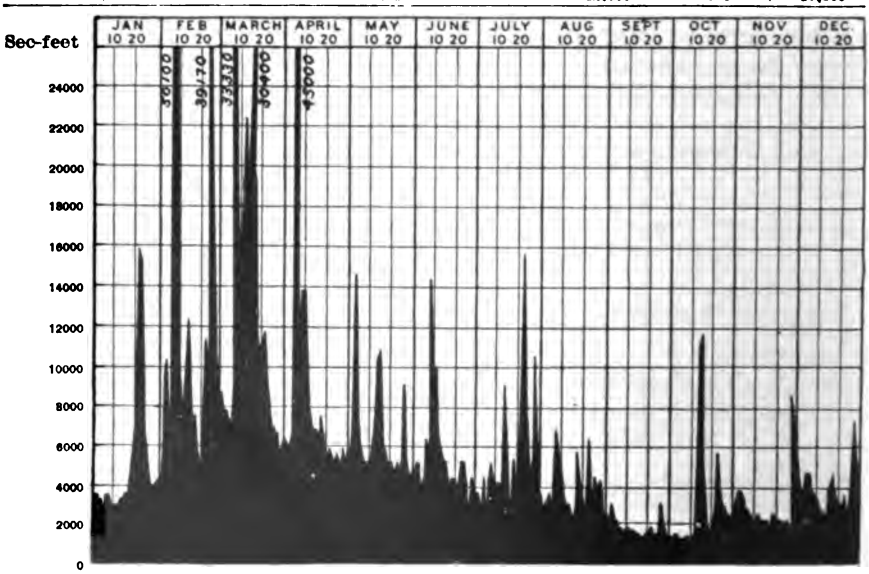


FIG. 30.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE YADKIN RIVER, AT NORWOOD, N. C., FOR 1897. (U. S. G. S.)

ESTIMATED MONTHLY DISCHARGE OF YADKIN RIVER AT NORWOOD, NORTH CAROLINA.

[Drainage area, 4,614 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
September	9,700	1,450	2,409	143,344	0.58	0.52
October	26,100	1,640	3,225	198,297	0.81	0.70
November	20,500	2,080	4,176	248,489	1.01	0.91
December	11,700	2,080	4,885	300,369	1.22	1.06
1897.						0.80
January	15,810	2,780	4,880	300,060	1.22	1.06
February	50,120	4,300	13,760	764,190	3.10	2.98
March	33,330	5,440	13,017	800,385	3.25	2.82
April	45,010	5,060	9,755	580,465	2.35	2.11
May	14,400	4,300	6,388	392,785	1.59	1.38
June	14,400	3,160	5,397	321,145	1.31	1.17
July	15,810	2,400	5,495	337,875	1.37	1.19
August	6,580	2,400	3,712	228,240	0.93	0.81
September	2,780	1,310	1,774	105,560	0.43	0.38
October	26,900	1,480	2,999	184,400	0.75	0.65
November	8,480	1,820	2,973	176,910	0.71	0.64
December	7,340	2,080	4,171	256,465	1.04	0.90
The year	50,120	1,310	6,193	4,448,480	18.05	1.34
1898.						
January	11,300	2,720	4,429	272,782	1.10	0.96
February	4,255	2,720	3,390	188,280	0.76	0.73
March	26,900	2,720	5,886	362,519	1.48	1.28
April	15,100	3,485	6,004	357,238	1.47	1.32
May	16,950	2,380	4,536	279,372	1.18	0.98
June	5,795	1,830	2,626	155,258	0.63	0.57
July	8,480	1,380	3,819	234,818	0.95	0.83
August	12,800	1,820	5,329	327,669	1.33	1.15
September	64,660	1,820	8,645	514,410	2.09	1.87
October	23,840	3,160	7,229	444,491	1.80	1.56
November	9,240	3,540	5,858	348,574	1.42	1.27
December	17,270	3,540	7,435	457,157	1.86	1.61
The year	64,660	1,380	5,432	3,942,568	16.02	1.18

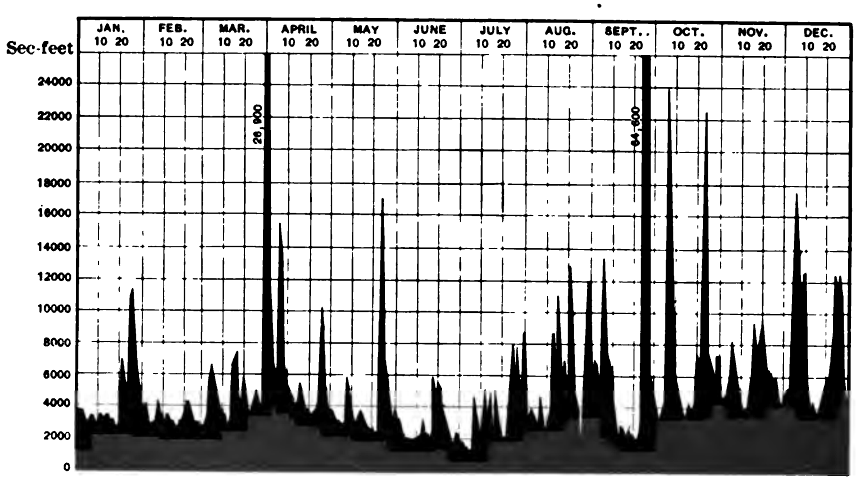


FIG. 31.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE YADKIN RIVER, AT NORWOOD, N. C., FOR 1898.

CATAWBA STATION ON THE CATAWBA RIVER.

This, the upper point at which measurements of discharge are made on this river, is located about one-fourth of a mile from the town of Catawba, on the Southern railway bridge that crosses the river at this point. The zero of the gauge-rod is 23 feet east of the west end of the second span of the bridge, and the distance from the zero of the gauge to the outer rim of the pulley-wheel is 3 feet. The distance from the end of the weight to the marker on the wire is 35.58 feet, the reading being zero when the weight touches the bottom of the stream. The section here is a fairly good one as the bottom is smooth, but of sand or clay and seemingly liable to change by high water. The river is straight for several hundred yards above and below the station and the current velocity is fairly uniform all the way across. The section is somewhat obstructed by a sand-bank on the east side of the river a little up-stream from the station, which throws most of the water to the west bank, and the water near the east bank is shallow.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON CATAWBA RIVER AT CATAWBA, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	June 30	E. W. Myers	21	2.25	938	1.11	1,044
2	July 4	....do....	21	3.03	1,238	1.83	2,266
3	Aug. 30	....do....	2154	1.45	743	0.98	732
4	Sept. 13	....do....	2154	1.94	1,059	1.37	1,458
	1897.						
5	Feb. 8	E. W. Myers	2154	5.52	2,915	3.33	9,711
6	Aug. 3	....do....	2154	1.90	975	1.39	1,358
7	Oct. 5	....do....	2154	1.60	825	0.93	775
8	Oct. 26	A. P. Davis	94	1.82	1,098	1.16	1,279
	1898.						
9	Jan. 14	E. W. Myers	2154	2.01	1,072	1.14	1,228

RATING-TABLE FOR CATAWBA RIVER AT CATAWBA, NORTH CAROLINA, FOR 1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.00	540	2.50	1,630	4.00	5,000	5.50	9,500
1.10	570	2.60	1,740	4.10	5,300	5.60	9,800
1.20	610	2.70	1,860	4.20	5,600	5.70	10,100
1.30	655	2.80	1,990	4.30	5,900	5.80	10,400
1.40	710	2.90	2,140	4.40	6,200	5.90	10,700
1.50	770	3.00	2,300	4.50	6,500	6.00	11,000
1.60	835	3.10	2,480	4.60	6,800	6.10	11,300
1.70	910	3.20	2,700	4.70	7,100	6.20	11,600
1.80	980	3.30	2,950	4.80	7,400	6.30	11,900
1.90	1,060	3.40	3,220	4.90	7,700	6.40	12,200
2.00	1,140	3.50	3,500	5.00	8,000	6.50	12,500
2.10	1,230	3.60	3,800	5.10	8,300	6.60	12,800
2.20	1,320	3.70	4,100	5.20	8,600	6.70	13,100
2.30	1,420	3.80	4,400	5.30	8,900	6.80	13,400
2.40	1,530	3.90	4,700	5.40	9,200	6.90	13,700

ESTIMATED MONTHLY DISCHARGE OF CATAWBA RIVER AT CATAWBA, NORTH CAROLINA.

[Drainage area, 1535 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
July 4 to 31	16,100	1,420	4,466	248,024	3.35	2.91
August	1,420	770	1,071	65,858	0.79	0.69
September	5,000	770	1,090	64,859	0.79	0.71
October	1,630	770	865	53,187	0.64	0.56
November	15,200	835	2,222	132,218	1.62	1.45
December	9,800	1,060	2,149	132,137	1.61	1.40
					8.80	1.29

RATING-TABLE FOR CATAWBA RIVER AT CATAWBA, NORTH CAROLINA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.5	750	3.8	4,535	6.6	12,795	10.0	22,825
1.6	850	4.0	5,125	6.8	13,385	10.5	24,300
1.7	950	4.2	5,715	7.0	13,975	11.0	25,775
1.8	1,050	4.4	6,305	7.2	14,565	11.5	27,250
1.9	1,160	4.6	6,895	7.4	15,155	12.0	28,725
2.0	1,270	4.8	7,485	7.6	15,745	12.5	30,200
2.2	1,490	5.0	8,075	7.8	16,335	13.0	31,675
2.4	1,730	5.2	8,665	8.0	16,925	13.5	33,150
2.6	1,980	5.4	9,255	8.2	17,515	14.0	34,625
2.8	2,250	5.6	9,845	8.4	18,105	14.5	36,100
3.0	2,560	5.8	10,435	8.6	18,695	15.0	37,575
3.2	2,980	6.0	11,025	8.8	19,285	15.5	39,050
3.4	3,450	6.2	11,615	9.0	19,875	16.0	40,525
3.6	3,960	6.4	12,205	9.5	21,350	....	......

ESTIMATED MONTHLY DISCHARGE OF CATAWBA RIVER AT CATAWBA, NORTH CAROLINA.

[Drainage area, 1535 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	6,452	1,050	1,647	101,270	1.23	1.07
February	40,230	1,550	7,006	389,095	4.79	4.60
March	17,663	1,550	5,637	346,605	4.24	3.67
April	40,525	2,180	5,014	298,355	3.64	3.26
May	11,025	1,435	2,600	159,870	1.95	1.69
June	3,450	1,270	1,833	109,070	1.33	1.19
July	3,210	1,270	1,774	109,080	1.34	1.16
August	2,560	950	1,321	81,225	0.99	0.86
September	1,380	900	1,017	60,515	0.73	0.66
October	16,925	850	1,787	109,880	1.35	1.17
November	2,560	950	1,233	73,370	0.89	0.80
December	1,850	1,105	1,328	81,656	0.99	0.86
The year	40,525	850	2,683	1,919,991	23.47	1.75

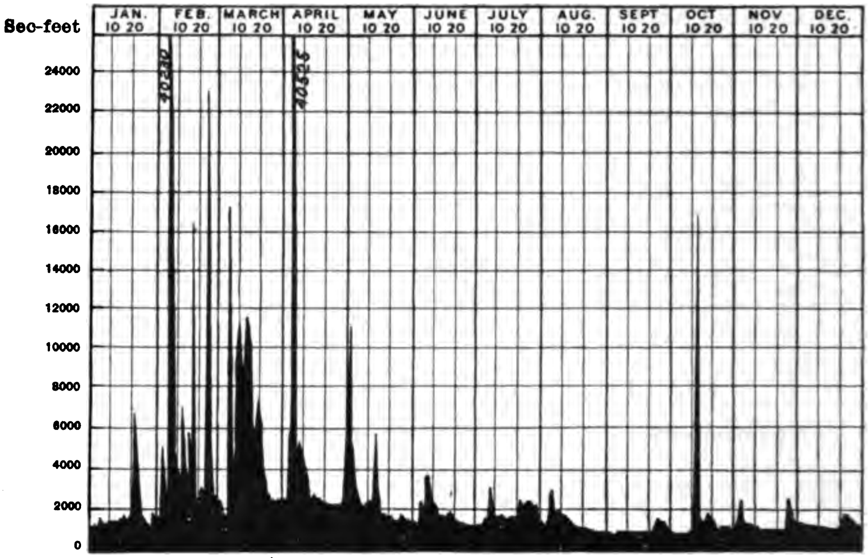


FIG. 32.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CATAWBA RIVER, AT CATAWBA, N. C., FOR 1897. (U. S. G. S.)

RATING-TABLE FOR CATAWBA RIVER AT CATAWBA, NORTH CAROLINA, FOR 1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.5	750	3.6	4,375	7.2	14,715	13.5	33,300
1.6	870	3.8	4,875	7.4	15,305	14.0	34,775
1.7	1,000	4.0	5,400	7.6	15,895	14.5	36,250
1.8	1,140	4.2	5,940	7.8	16,485	15.0	37,725
1.9	1,280	4.4	6,495	8.0	17,075	15.5	39,200
2.0	1,425	4.6	7,065	8.2	17,665	16.0	40,675
2.1	1,575	4.8	7,640	8.4	18,255	16.5	42,150
2.2	1,725	5.0	8,225	8.6	18,845	17.0	43,650
2.3	1,875	5.2	8,815	8.8	19,435	17.5	45,150
2.4	2,025	5.4	9,405	9.0	20,025	18.0	46,650
2.5	2,175	5.6	9,995	9.5	21,500	18.5	48,150
2.6	2,825	5.8	10,585	10.0	22,975	19.0	49,650
2.7	2,500	6.0	11,175	10.5	24,450	19.5	51,150
2.8	2,675	6.2	11,765	11.0	25,925	20.0	52,650
2.9	2,860	6.4	12,355	11.5	27,400	20.5	54,150
3.0	3,050	6.6	12,945	12.0	28,875	21.0	55,650
3.2	3,450	6.8	13,535	12.5	30,350	21.5	57,150
3.4	3,900	7.0	14,125	13.0	31,825	22.0	58,650

ESTIMATED MONTHLY DISCHARGE OF CATAWBA RIVER AT CATAWBA, NORTH CAROLINA.

[Drainage area, 1535 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	9,500	1,100	1,710	105,145	1.28	1.11
February	1,320	1,100	1,172	65,092	0.79	0.76
March	15,500	1,060	1,983	121,932	1.49	1.29
April	2,950	1,230	1,493	88,835	1.07	0.96
May	3,500	1,020	1,276	78,461	0.95	0.83
June	3,500	910	1,069	63,605	0.77	0.69
July	14,125	1,140	3,292	202,415	2.47	2.14
August	21,990	1,425	5,018	308,556	3.76	3.26
September	52,500	1,500	6,667	396,709	4.85	4.35
October	27,400	2,675	7,202	442,831	5.40	4.69
November	3,675	2,325	2,689	159,917	1.95	1.75
December	9,995	2,175	3,162	194,421	2.37	2.06
The year	52,500	1,000	3,251	2,365,196	28.80	2.11

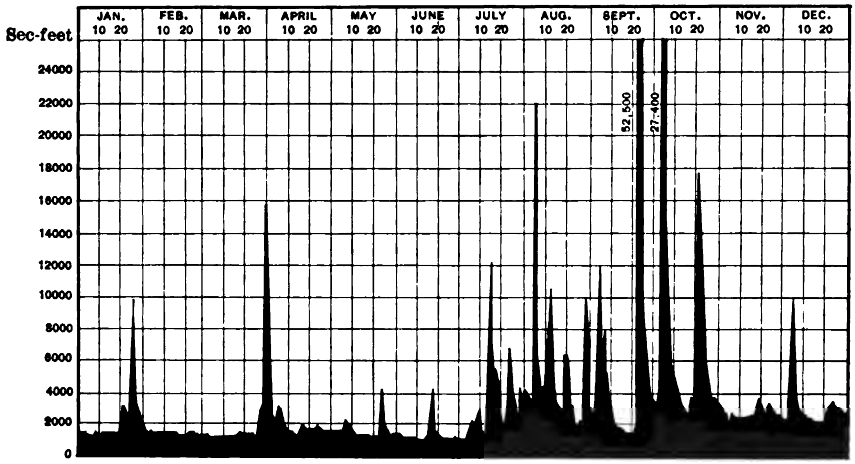


FIG. 33.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CATAWBA RIVER, AT CATAWBA, N. C., FOR 1898.

ROCK HILL STATION ON THE CATAWBA RIVER.

The Catawba river, a short distance south of the North Carolina state line, is crossed by three railroad bridges, these being in succession down stream, the bridge of the Southern railway, three miles south of Fort Mill, the bridge of the Seaboard Air Line (Georgia, Carolina and Northern) about three miles from Catawba Junction, and below this the bridge of the Ohio river and Charleston railroad. Each of these was examined to ascertain the most desirable point for making river measurements. It was decided that the highest of these crossings near Fort Mill was the most desirable, and a gauge was placed here on September 3, 1895. It is fastened to the upper side of the guard-rail, the two-foot mark of the rod being over the center of the second vertical of the second truss from the south end of the bridge. The distance from the zero of the rod to the outer rim of the pulley-wheel is 1.30 feet, and the length of the wire rope from the pointer on the wire to the end of the weight is 52.96 feet. The station is reached by private conveyance from Rock Hill, S. C.

Above this point observations of river height have been kept by the Weather Bureau at Mount Holly, N. C., this point being five miles north of the state line and nearly 25 miles from the Rock Hill station. A gauge here is attached to one of the piers, but readings have not been made since 1884. Measurements of discharge could not be satisfactorily made at this point, as the river is very sluggish just under the bridge, and is said to be ponded by a dam one mile below.

The tables of daily gauge height for this station will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON CATAWBA RIVER AT ROCK HILL, SOUTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1895.						
1	Sept. 23	C. C. Babb	29	1.58	806	1.66	1,340
2	Oct. 25	....do	76	1.51	852	1.73	1,477
	1896.						
3	Apr. 16	E. W. Myers	21	1.90	1,159	1.54	1,787
4	Aug. 20	....do	2154	1.78	924	1.63	1,508
5	Sept. 17	....do	2154	1.53	979	1.36	1,336
	1897.						
6	Feb. 9	E. W. Myers	2154	4.50	3,178	3.05	9,711
7	Apr. 6	....do	76	12.10	10,121	4.54	46,040
8	Aug. 15	....do	2154	1.55	1,091	1.83	2,006
9	Oct. 8	....do	2154	1.21	896	1.71	1,532
10	Nov. 1	A. P. Davis	94	1.45	1,254	2.09	2,619
	1898.						
11	Jan. 26	E. W. Myers	2154	3.20	2,297	3.36	7,732
12	Oct. 26	....do	2154	3.50	2,033	3.49	7,108
	1899						
13	Feb. 23	...do	87	3.61	2,556	3.16	8,086

RATING-TABLE FOR CATAWBA RIVER AT ROCK HILL, SOUTH CAROLINA.
[This table is applicable from September, 1895, to December, 1896.]

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.	Feet.	Sec. feet.
1.20	1,140	4.20	8,720	7.20	21,900	10.20	36,500
1.40	1,260	4.40	9,340	7.40	22,800	10.40	37,500
1.60	1,400	4.60	10,150	7.60	23,700	10.60	38,500
1.80	1,550	4.80	11,050	7.80	24,600	10.80	39,500
2.00	1,900	5.00	12,000	8.00	25,500	11.00	40,500
2.20	2,520	5.20	12,900	8.20	26,500	11.20	41,500
2.40	3,140	5.40	13,800	8.40	27,500	11.40	42,500
2.60	3,760	5.60	14,700	8.60	28,500	11.60	43,500
2.80	4,380	5.80	15,600	8.80	29,500	11.80	44,500
3.00	5,000	6.00	16,500	9.00	30,500	12.00	45,500
3.20	5,620	6.20	17,400	9.20	31,500	12.20	46,500
3.40	6,240	6.40	18,300	9.40	32,500	12.40	47,500
3.60	6,860	6.60	19,200	9.60	33,500	12.60	48,500
3.80	7,480	6.80	20,100	9.80	34,500	12.80	49,500
4.00	8,100	7.00	21,000	10.00	35,500	13.00	50,500

ESTIMATED MONTHLY DISCHARGE OF CATAWBA RIVER NEAR ROCK HILL, SOUTH CAROLINA.
[Drainage area, 2,987 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
September 23 to 30	1,350	1,300	1,318	20,912	0.13	0.44
October	1,400	1,300	1,364	83,869	0.53	0.46
November 1 to 9, 17 to 30	2,237	1,400	1,546	70,518	0.44	0.52
December	6,860	1,400	2,192	134,782	0.84	0.73
1896.						
January	9,700	1,550	3,062	188,275	1.19	1.03
February	19,850	2,237	6,098	350,478	2.20	2.04
March	2,851	1,700	2,009	123,528	0.77	0.67
April	16,040	1,470	2,645	157,389	0.99	0.89
May	9,060	1,400	2,277	140,008	0.87	0.76
June	5,620	1,330	2,014	119,841	0.74	0.67
July	[1]62,500	1,400	10,215	628,095	3.95	3.42
August	1,930	1,330	1,604	98,626	0.62	0.54
September	9,060	1,330	1,873	111,451	0.70	0.63
October	7,790	1,330	1,670	102,684	0.64	0.56
November	14,120	1,400	2,661	158,340	0.99	0.89
December	14,600	1,550	3,169	194,855	1.22	1.06
Per annum (1896)	[1]62,500	1,330	3,274	2,373,565	14.88	1.10

[1] Estimated.

RATING-TABLE FOR CATAWBA RIVER NEAR ROCK HILL, SOUTH CAROLINA, FOR 1897.

Gauge height.	Discharge. Jan. 1 to Feb. 6.	Discharge. Feb. 7 to Dec. 31.	Gauge height.	Discharge. Jan. 1 to Feb. 6.	Discharge. Feb. 7 to Dec. 31.	Gauge height.	Disch'rge Feb. 7 to Dec. 31.	Gauge height.	Disch'rge Feb. 7 to Dec. 31.
1.00	.....	1,600	2.40	2,700	3,450	5.00	9,800	9.00	25,500
1.20	.....	1,700	2.60	3,100	3,800	5.50	11,300	10.00	31,000
1.40	1,250	1,900	2.80	3,500	4,200	6.00	13,000	11.00	38,000
1.60	1,450	2,200	3.00	3,900	4,600	6.50	14,750	12.00	45,300
1.80	1,700	2,500	3.50	5,050	5,750	7.00	16,550	13.00	52,700
2.00	2,000	2,800	4.00	6,400	7,000	7.50	18,500	14.00	60,100
2.20	2,350	3,100	4.50	8,050	8,375	8.00	20,500	15.00	67,500

ESTIMATED MONTHLY DISCHARGE OF CATAWBA RIVER NEAR ROCK HILL, SOUTH CAROLINA.

[Drainage area, 2987 square miles.]

Month.	Discharge in second-feet. Maximum.	Discharge in second-feet. Minimum.	Discharge in second-feet. Mean.	Total in acre-feet.	Run-off. Depth in inches.	Run-off. Second-feet per square mile.
1897.						
January	5,550	1,575	2,097	128,940	0.81	0.70
February	65,650	1,775	9,277	515,220	3.24	3.11
March	19,300	3,275	7,537	463,430	2.91	2.52
April	54,920	3,100	7,055	419,800	2.63	2.36
May	8,100	2,650	3,571	219,575	1.38	1.20
June	7,825	2,200	3,128	186,130	1.17	1.05
July	10,550	2,050	2,900	178,815	1.12	0.97
August	8,925	1,975	2,587	159,070	1.00	0.87
September	2,200	1,700	1,817	108,120	0.68	0.61
October	9,200	1,900	2,311	142,100	0.89	0.77
November	4,000	1,900	2,186	130,075	0.81	0.73
December	3,100	2,125	2,528	155,185	0.97	0.84
The year	65,650	1,575	3,916	2,806,120	17.61	1.31

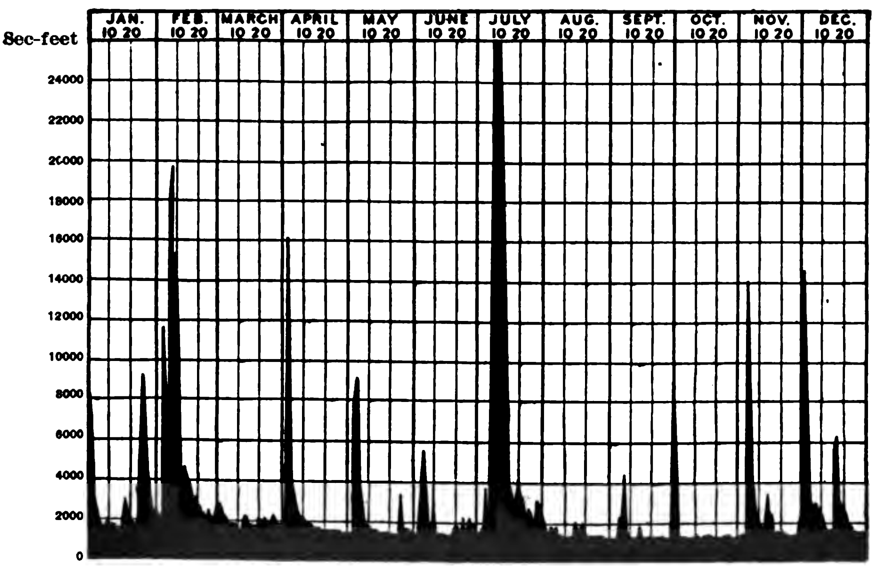


FIG. 34.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CATAWBA RIVER, AT ROCK HILL, S. C., FOR 1896. (U. S. G. S.)

RATING-TABLE FOR CATAWBA RIVER AT ROCK HILL, SOUTH CAROLINA, FOR 1898.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.0	1,800	2.5	5,000	5.0	12,400	9.5	32,500
1.1	1,950	2.6	5,270	5.2	13,120	10.0	35,000
1.2	2,100	2.7	5,540	5.4	13,840	10.5	37,500
1.3	2,260	2.8	5,810	5.6	14,560	11.0	40,000
1.4	2,430	2.9	6,080	5.8	15,280	11.5	42,750
1.5	2,610	3.0	6,350	6.0	16,000	12.0	45,500
1.6	2,810	3.2	6,930	6.2	16.800	12.5	49,550
1.7	3,020	3.4	7,510	6.4	17,600	13.0	53,600
1.8	3,240	3.6	8,100	6.6	18,400	13.5	57,700
1.9	3,460	3.8	8,700	6.8	19,200	14.0	61,800
2.0	3,700	4.0	9,300	7.0	20,000	14.5	65,900
2.1	3,960	4.2	9,900	7.5	22,500	15.0	70,000
2.2	4,220	4.4	10,500	8.0	25,000	15.5	74,100
2.3	4,480	4.6	11,120	8.5	27,500	16.0	78,200
2.4	4,740	4.8	11,760	9.0	30,000	...	.....

ESTIMATED MONTHLY DISCHARGE OF CATAWBA RIVER NEAR ROCK HILL, SOUTH CAROLINA.

[Drainage area, 2967 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	7,668	2,200	2,794	171,816	1.08	0.94
February	2,800	2,050	2,369	131,563	0.82	0.79
March	15,125	2,050	2,860	175,854	1.09	0.96
April	7,240	2,050	3,066	182,439	1.14	1.02
May	3,275	1,700	2,142	131,706	0.83	0.72
June	5,290	1,600	2,091	124,423	0.81	0.70
July	9,600	1,800	3,822	235,002	1.48	1.28
August	28,000	3,240	6,532	411,641	2.51	2.18
September[1]	6,930	3,460	6,042	71,899	0.45	2.02
October	36,500	4,480	10,493	641,214	4.05	3.51
November	7,800	5,000	5,594	332,865	2.09	1.87
December	12,080	4,480	6,186	380,367	2.38	2.07
The year	36,500	1,800	4,869	3,258,048	20.39	1.63

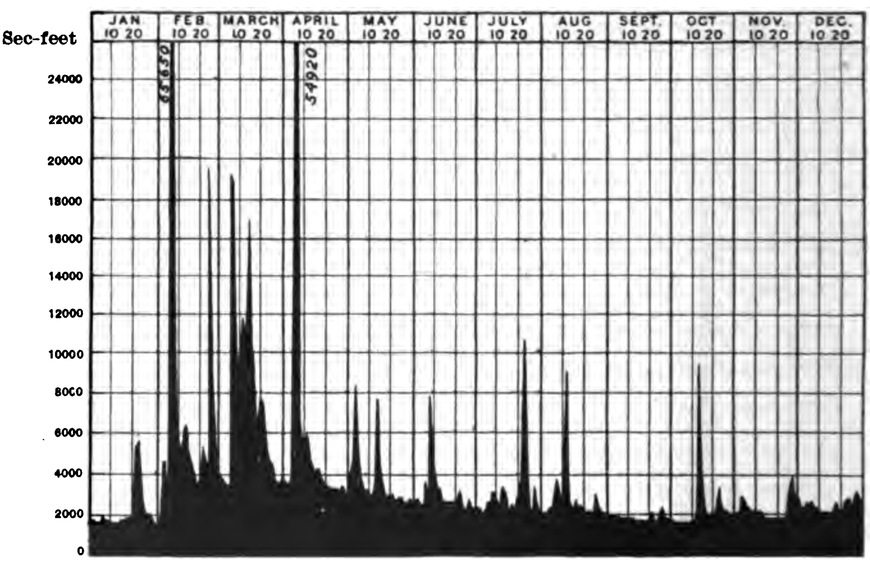


FIG. 35.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CATAWBA RIVER, AT ROCK HILL, S. C., FOR 1897. (U. S. G. S.)

[1] 6 days' record.

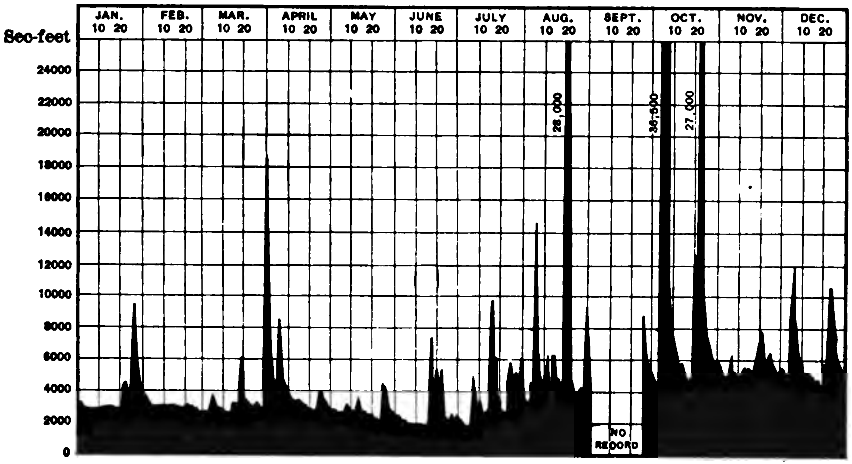


FIG. 36.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE CATAWBA RIVER, AT ROCK HILL, S. C., FOR 1898.

GAFFNEY STATION ON THE BROAD RIVER.

This gauge is located on the Southern railway bridge about three miles from Gaffney, S. C., and was established July 1, 1896. The zero of the gauge is 18 feet east of the west end of the third span of the bridge from the east. The distance from the zero of the gauge to the outer rim of the pulley-wheel is 2.5 feet, and from the end of the weight to the pointer on the wire is 50.71 feet. The section under the bridge is a good one, as the river is straight for several hundred yards above and below the bridge and the current velocity is uniformly distributed all the way across. The river here is broad and there are several pier obstructions. The measurements are therefore taken at a ferry about one-fourth of a mile above the bridge, where the river is much narrower. The measurements are taken from the ferry-boat. The section here is very good except that the bottom seems liable to cut out in high water.

This gauge was broken September 30, 1898, and when it was replaced it was moved to the ferry above where the gaugings have been made.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet.)	Area of section (square feet.)	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	Aug. 18	E. W. Myers	2154	0.25	732	1.36	956
2	Sept. 16	....do	2154	0.10	792	1.20	950
	1897.						
3	Mar. 9	E. W. Myers	2154	2.85	2,077	2.10	4,364
4	Apr. 7	....do	76	3.49	2,286	2.32	5,324
5	Aug. 6	....do	2154	1.64	1,201	1.08	1,297
6	Oct. 9	....do	2154	0.92	1,106	0.75	829
7	Oct. 31	A. P. Davis	94	1.38	1,190	0.72	861
	1898.						
8	Jan. 27	E. W. Myers	2154	2.67	1,784	1.71	3,052

RATING-TABLE FOR BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA.
[This table is applicable from July, 1896, to April 1897.]

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
0.00	800	1.10	1,910	2.20	3,305	3.30	5,010
0.10	885	1.20	2,035	2.30	3,450	3.40	5,170
0.20	975	1.30	2,160	2.40	3,600	3.50	5,330
0.30	1,075	1.40	2,285	2.50	3,750	3.60	5,500
0.40	1,175	1.50	2,410	2.60	3,900	3.70	5,670
0.50	1,275	1.60	2,535	2.70	4,050	3.80	5,840
0.60	1,375	1.70	2,660	2.80	4,210	3.90	6,010
0.70	1,475	1.80	2,785	2.90	4,370	4.00	6,180
0.80	1,575	1.90	2,910	3.00	4,530		.....
0.90	1,685	2.00	3,035	3.10	4,690		.....
1.00	1,795	2.10	3,170	3.20	4,850		.....

ESTIMATED MONTHLY DISCHARGE OF BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA.
[Drainage area, 1,485 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
July 12 to 31	2,585	1,255	1,496	59,340	0.77	1.04
August	1,445	885	1,093	67,206	0.87	0.76
September	2,585	843	1,119	66,585	0.87	0.78
October	1,585	930	1,086	66,776	0.87	0.76
November	8,800	1,055	1,955	116,331	1.52	1.36
December	3,945	1,545	1,977	121,561	1.59	1.38
					6.49	1.01

RATING-TABLE FOR BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA, FOR 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
0.7	780	2.6	3,504	4.6	8,264	6.6	13,024
0.8	790	2.8	3,980	4.8	8,740	6.8	13,500
0.9	810	3.0	4,456	5.0	9,216	7.0	13,976
1.0	845	3.2	4,932	5.2	9,692	7.5	15,166
1.2	940	3.4	5,408	5.4	10,168	8.0	16,356
1.4	1,070	3.6	5,884	5.6	10,644	8.5	17,546
1.6	1,250	3.8	6,360	5.8	11,120	9.0	18,736
1.8	1,600	4.0	6,836	6.0	11,596	...	......
2.0	2,076	4.2	7,312	6.2	12,072	...	......
2.4	3,028	4.4	7,788	6.4	12,548	...	......

ESTIMATED MONTHLY DISCHARGE OF BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA.
[Drainage area, 1485 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
January	2,790	800	1,026	63,090	0.82	0.71
February	18,022	970	4,111	228,315	2.99	2.87
March	11,596	1,719	4,556	280,140	8.67	8.18
April	18,736	1,957	4,196	249,800	8.26	2.93
May	7,550	4,694	5,402	332,155	4.34	2.76
June	10,287	3,623	5,126	305,020	3.98	3.57
July	7,074	2,076	4,310	265,010	3.46	3.00
August	3,861	1,070	1,951	119,960	1.57	1.36
September	1,600	790	929	55,280	0.72	0.65
October	7,312	790	1,244	76,490	1.00	0.87
November	3,266	845	1,264	75,215	0.98	0.88
December	3,266	940	1,521	93,520	1.22	1.06
The year	18,736	790	2,970	2,143,995	28.01	1.99

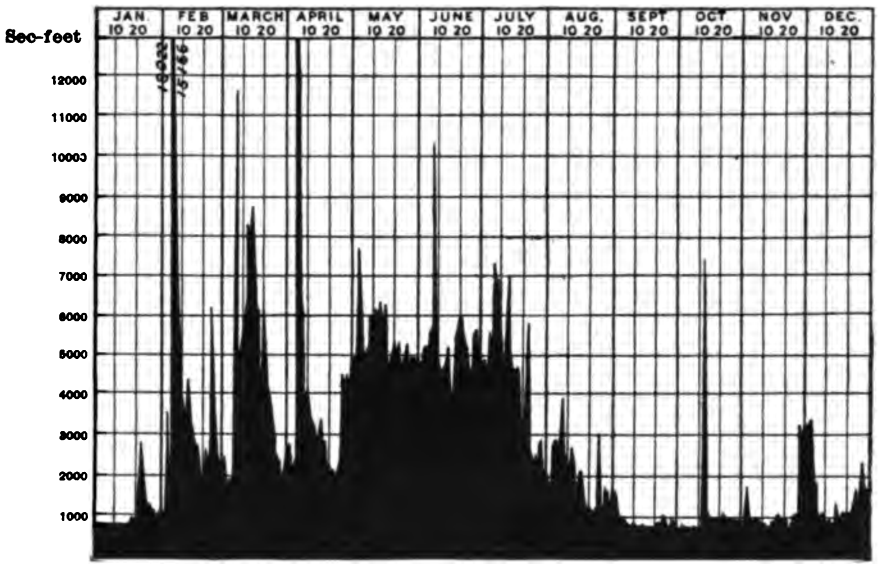


FIG. 37.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE BROAD RIVER, NEAR GAFFNEY, S. C., FOR 1897. (U. S. G. S.)

RATING-TABLE FOR BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA, FOR 1898.
[This table is applicable only from October 25, 1898, to December 31, 1898.]

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge Height.	Discharge.	Gauge height.	Discharge
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.6	1,350	2.2	2,000	3.2	3,510	4.2	6,250
1.7	1,450	2.4	2,250	3.4	3,950	4.4	7,050
1.8	1,550	2.6	2,550	3.6	4,450	....	....
1.9	1,650	2.8	2,850	3.8	4,975	....	....
2.0	1,750	3.0	3,150	4.0	5,550	....	....

ESTIMATED MONTHLY DISCHARGE OF BROAD RIVER NEAR GAFFNEY, SOUTH CAROLINA.

[Drainage area, 1485 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	4,242	802	1,398	85,765	1.12	0.97
February	3,599	863	1,477	82,031	1.07	1.03
March	5,941	871	1,311	80,610	1.05	0.91
April	3,966	994	1,744	103,775	1.35	1.21
May	1,205	869	1,011	62,164	0.82	0.71
June	1,338	769	864	51,411	0.67	0.60
July	4,542	782	1,394	85,715	1.04	0.90
August	6,337	890	1,721	105,822	1.37	1.19
September	21,306	985	3,707	220,579	2.88	2.58
October[1]	3,000	2,250	2,741	27,190	0.48	1.91
November	2,700	1,750	1,981	118,814	1.54	1.38
December	6,650	1,450	2,418	148,682	1.94	1.68
The year	21,306	769	1,814	1,172,558	15.28	1.25

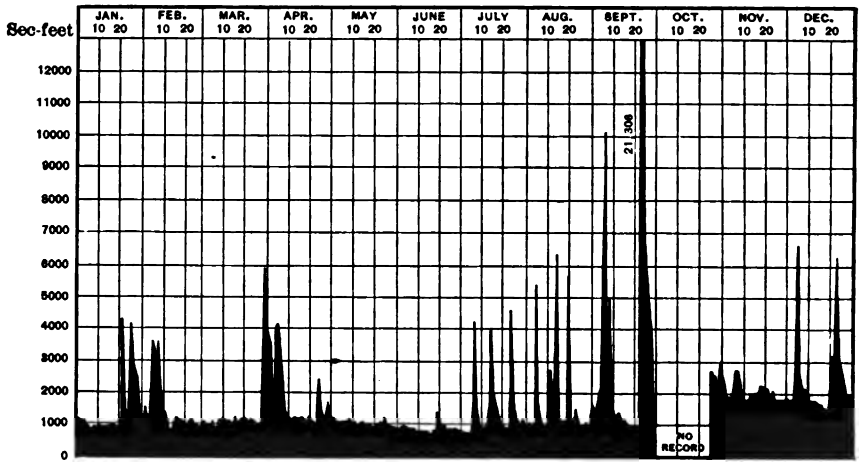


FIG. 38.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE BROAD RIVER NEAR GAFFNEY, S. C., FOR 1898.

ASHEVILLE STATION ON THE FRENCH BROAD RIVER.

The French Broad river rises in western North Carolina and flows northeasterly, crossing the state line into Tennessee, where it flows into the Tennessee river. An examination was made from about Asheville down to the state line to determine the best point to make continuous measurements of discharge. The principal points examined were at the bridges at Asheville, at Marshall, 22 miles below, and at Hot Springs, 16 miles further down.

[1] Six days' record.

At Asheville four bridges cross the river. The uppermost of these is located just below the mouth of Swannanoa river, about 1.5 miles above the city. This locality would be desirable for making measurements, but for the fact that the current is ponded and modified on the south side by a log boom directly under the bridge. The river has a broad bend to the south above the bridge, tending to throw the greatest velocity toward the north shore during high water. This place can be reached from town by electric cars. The old three-span highway bridge, about one-fourth mile below the railway station, is at a poor section, the bottom being rough and uneven. The railroad four-pier bridge one-fourth of a mile below this is at a still poorer place, and crosses the river diagonally. The Bingham School bridge, 1.5 miles below the town, offers the best opportunity presented by any one of the four, although the bed of the river is rough and rocky. The bridge has three spans, each 91 feet in length. The two piers in the stream are cylindrical columns, two feet in diameter, and thus offer but little resistance to the current. It was therefore decided to locate a measuring station here after an inspection of the river as far down as Hot Springs. The zero of the gauge-rod here is opposite the east edge of the fifth upright of the first span from the east and on the upper side of the bridge. The outer rim of the pulley-wheel is 3 feet from the zero of the gauge-rod, and from the end of the weight to the pointer on the wire rope is 26.03 feet.

On September 3 Mr. Babb measured the French Broad at Hot Springs, N. C., 38 miles below Asheville, the water at that time being 22.80 feet below the top of the sixth iron support in the foot-rail on the lower side of the bridge, opposite the middle member of the first truss from the railroad side. The total discharge was ascertained to be 1359 second-feet. On the same day a measurement was made at Marshall, 16 miles above Hot Springs and 22 miles below Asheville. At that time the water surface was 19.69 feet below the upper end of the second floor beam of the second span from the north side. The discharge was computed to be 1490 second-feet. The section at this place is poor, the bottom rough, and it is not considered that the results obtained at this place are as accurate as those obtained at Hot Springs.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON FRENCH BROAD RIVER AT ASHEVILLE, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1895.						
1	Sept. 2	C. C. Babb	29	4.30	650	1.84	1,192
2	Sept. 17	....do	29	3.22	585	1.72	1,006
	1896.						
3	Apr. 18	E. W. Myers	21	2.90	538	1.22	659
4	June 19	....do	21	3.42	685	2.18	1,495
5	Aug. 16	....do	2154	3.25	543	2.00	1,089
6	Sept. 19	....do	2154	2.50	438	1.58	694
	1897.						
7	Aug. 18	E. W. Myers	2154	2.86	531	1.65	882
8	Oct. 14	....do	2154	2.84	469	1.72	806
9	Oct. 27	A. P. Davis	94	2.50	434	1.69	734
	1898.						
10	Jan. 18	E. W. Myers	2154	2.75	502	1.82	918
11	Sept. 8	....do	9	5.45	1,089	3.06	3,332

RATING-TABLE FOR FRENCH BROAD RIVER AT ASHEVILLE, NORTH CAROLINA.

Gauge Height.	Discharge.	Gauge Height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
2.0	620	3.6	1,530	5.2	3,130	6.8	4,730
2.1	633	3.7	1,630	5.3	3,230	6.9	4,830
2.2	645	3.8	1,730	5.4	3,330	7.0	4,930
2.3	665	3.9	1,830	5.5	3,430	7.1	5,030
2.4	685	4.0	1,930	5.6	3,530	7.2	5,130
2.5	715	4.1	2,030	5.7	3,630	7.3	5,230
2.6	745	4.2	2.130	5.8	3,730	7.4	5,330
2.7	782	4.3	2,230	5.9	3,830	7.5	5,430
2.8	820	4.4	2,330	6.0	3,930	7.6	5,530
2.9	875	4.5	2,430	6.1	4,030	7.7	5,630
3.0	930	4.6	2,530	6.2	4,130	7.8	5,730
3.1	1,030	4.7	2,630	6.3	4,230	7.9	5,830
3.2	1,130	4.8	2,730	6.4	4,330	8.0	5,930
3.3	1,230	4.9	2,830	6.5	4,430	....	...
3.4	1,330	5.0	2,930	6.6	4,530	....	....
3.5	1,430	5.1	3,030	6.7	4,630	....	....

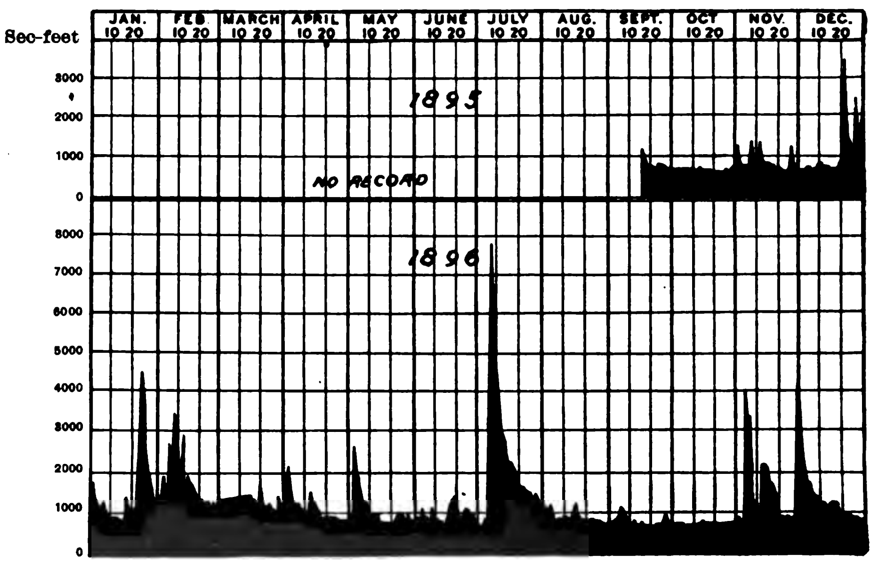


FIG. 39.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE FRENCH BROAD RIVER, AT ASHEVILLE, N. C., FOR 1895 AND 1896. (U. S. G. S.)

ESTIMATED MONTHLY DISCHARGE OF FRENCH BROAD RIVER AT ASHEVILLE, NORTH CAROLINA.

[Drainage area, 987 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1895.						
September 17-30	1,130	745	823	23,854	0.43	0.83
October	780	710	732	45,009	0.85	0.74
November	1,230	745	844	50,221	0.94	0.85
December	3,330	745	1,154	70,956	1.35	1.17
					3.57	0.89
1896.						
January	4,430	800	1,439	88,481	1.68	1.46
February	3,380	1,130	1,733	99,684	1.90	1.76
March	1,630	1,080	1,227	38,944	0.74	1.24
April	2,130	820	1,092	64,978	1.24	1.11
May	2,530	780	1,063	65,362	1.25	1.08
June	1,330	745	922	54,863	1.08	1.93
July	7,780	727	2,191	134,719	2.56	2.22
August	1,130	710	866	53,248	1.01	0.88
September	1,180	672	772	45,937	0.87	0.78
October	762	685	705	43,348	0.82	0.71
November	4,130	762	1,634	97,230	1.85	1.66
December	3,730	845	1,281	78,765	1.50	1.30
The year	7,780	672	1,244	865,759	16.45	1.26
1897.						
January	2,330	780	1,164	71,570	1.36	1.18
February	5,830	1,530	2,709	145,450	2.85	2.74
March	5,180	1,630	3,036	186,680	3.56	3.06
April	5,530	1,580	2,607	155,130	2.04	2.64
May	5,080	1,130	1,920	118,056	2.25	1.95
June	2,430	980	1,410	83,900	1.60	1.43
July	1,530	800	1,187	72,985	1.38	1.20
August	1,980	710	906	55,830	1.06	0.92
September	762	672	698	41,535	0.79	0.71
October	1,280	652	792	48,698	0.92	0.80
November	1,780	652	841	50,040	0.94	0.85
December	1,580	697	950	58,412	1.10	0.96
The year	5,830	653	1,518	1,088,284	20.75	1.54
1898.						
January	3,230	815	1,348	82,885	1.57	1.36
February	1,450	810	967	53,704	1.02	0.98
March	3,930	745	1,047	64,377	1.22	1.06
April	2,580	908	1,576	93,779	1.77	1.59
May	1,930	782	1,096	67,329	1.28	1.11
June	2,430	715	1,020	60,694	1.15	1.03
July	4,930	675	1,991	124,424	2.33	2.02
August	6,580	1,630	2,915	179,241	3.40	2.95
September	5,230	1,330	2,327	138,467	2.63	2.36
October	6,230	1,230	2,951	181,454	3.44	2.99
November	1,530	940	1,197	71,222	1.35	1.21
December	3,430	875	1,682	103 425	1.96	1.70
The year	6,580	675	1,676	1,221,001	23.12	1.70

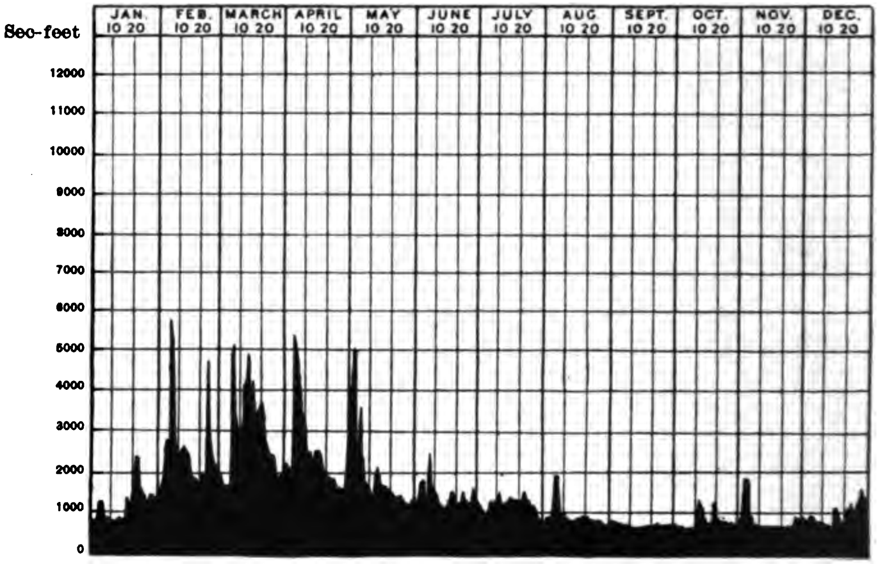


FIG. 40.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE FRENCH BROAD RIVER, AT ASHEVILLE, N. C., FOR 1897. (U. S. G. S.)

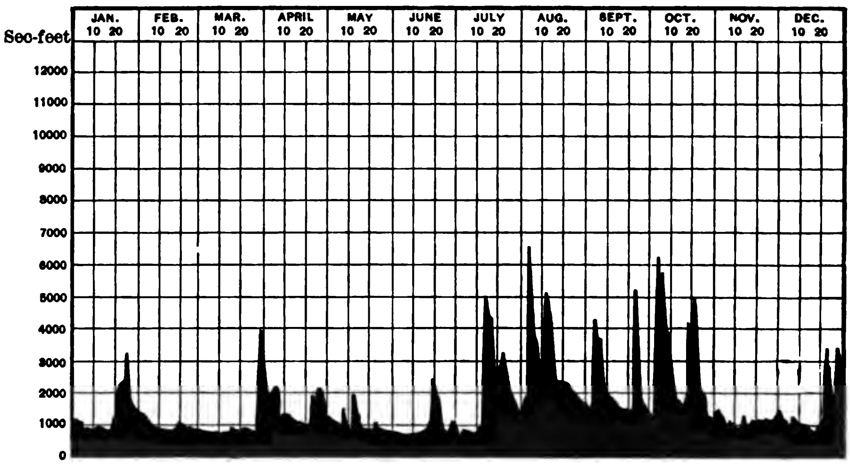


FIG. 41.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE FRENCH BROAD RIVER, AT ASHEVILLE, N. C., FOR 1898.

GOVERNOR'S ISLAND STATION ON THE TUCKASEEGEE RIVER (NOW BRYSON CITY STATION).

This station was located on the Southern railway bridge about three miles above Bryson City and just below Governor's Island P. O., and was established June 26, 1896. The zero of the gauge-rod was 20 feet from the end of the second span from the south end of the bridge. The outer rim of the pulley-wheel was one foot from the zero of the gauge-rod, and from the end of the weight to the pointer on the wire was 26.75 feet, the gauge reading zero when the weight touched bottom. The bottom is rocky and not subject to change, and the banks are high, but the section is not a good one as there are two bad pier obstructions and the bridge is across a bend in the river, the greater part of the current being thrown toward the west bank. The discharge measurements are not sufficiently comprehensive to justify the construction of a rating table for this station, which was abandoned March 25, 1897.

On November 7, 1897, a new station was established on the highway bridge across this river, in the town of Bryson City. The bottom here is muddy and the water sluggish. The gauge-rod is of wood, well painted and is spiked and bolted by drift bolts to the down-stream side of the north pier. The gauge is read from the bridge. The initial point for soundings is the south end, up-stream hand-rail. The observer is H. H. Welch.

LIST OF DISCHARGE MEASUREMENTS MADE ON THE TUCKASEEGEE AT BRYSON CITY, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1897						
1	Oct. 28	A. P. Davis	94	1.00	518	0.33	168
	1898						
2	Jan. 19	E. W. Myers	2154	2.20	1217	1.78	2,175
3	Jan. 20	....do	2154	3.30	1396	2.64	3,695
4	Sept. 3	....do	9	6.95	2420	7.83	18,959
5	Sept. 4	....do	9	3.92	1843	3.40	6,059
6	Sept. 5	... do	9	5.00	1914	6.15	11,777
7	Sept. 5	....do	9	4.50	1615	5.56	9,086

RATING-TABLE FOR TUCKASEEGEE RIVER AT BRYSON CITY, NORTH CAROLINA.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
1.0	168	2.8	2,900	4·6	8,850	6.4	16,500
1.1	234	2.9	3,075	4.7	9,275	6.5	16,925
1.2	400	3.0	3,250	4.8	9,700	6.6	17,350
1.3	535	3.1	3,425	4.9	10,125	6.7	17,775
1.4	670	3.2	3,600	5.0	10,550	6.8	18,200
1.5	810	3.3	3,825	5.1	10,975	6.9	18,625
1.6	950	3.4	4,050	5.2	11,400	7.0	19,050
1.7	1,100	3.5	4,425	5.3	11,825	7.1	19,500
1.8	1,250	3.6	4,800	5.4	12,250	7.2	19,950
1.9	1,400	3.7	5,175	5.5	12,675	7.3	20,400
2.0	1,550	3.8	5,550	5.6	13,100	7.4	20,850
2.1	1,710	3.9	5,950	5.7	13,525	7.5	21,300
2.2	1,870	4.0	6,350	5.8	13.950	7.6	21,750
2.3	2,035	4.1	6,750	5.9	14.375	7.7	22,200
2.4	2,200	4.2	7,150	6.0	14,800	7.8	22,650
2.5	2,375	4.3	7,575	6.1	15,225	7.9	23,100
2.6	2,550	4.4	8,000	6.2	15,650	8.0	23,550
2.7	2,725	4.5	8,425	6.3	16,075		

List of Discharge Measurements made on Tuckaseegee river, at Governor's Island North Carolina.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896						
1[1]	June 22	E. W. Myers	21	....	1100	0.81	892
2	June 26	....do...	21	2.26	272	3.08	821
3	Aug. 12	....do....	2154	2.42	207	3.90	809
4	Sept. 21	....do	2154	1.84	238	2.48	593

[1] Measurement made at Bryson City.

Estimated Discharge of the Tuckaseegee at Bryson City, North Carolina.

[Drainage area, 629 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1897.						
November	670	168	240	14,280	0.43	0.38
December	4,050	284	941	51,860	1.73	1.50
1898.						
January	8,425	400	1,865	114,668	3.41	2.96
February	1,325	608	893	49,695	1.48	1.42
March	17,775	535	1,936	119,042	3.53	3.08
April	3,425	1,475	2,107	125,366	3.73	3.35
May	1,550	810	1,123	69,058	2.05	1.78
June	1,400	468	643	38,260	1.17	1.02
July	4,425	535	1,114	68,449	2.04	1.77
August	22,650	1,250	3,027	186,030	5.54	4.81
September	25,800	1,100	3,863	230,159	6.85	6.14
October	21,750	1,100	3,826	235,248	7.01	6.08
November	2,375	1,250	1,763	104,901	3.12	2.80
December	3,075	950	1,838	113,016	3.36	2.92
The year	25,800	643	2,000	1,453,387	43.29	3.17

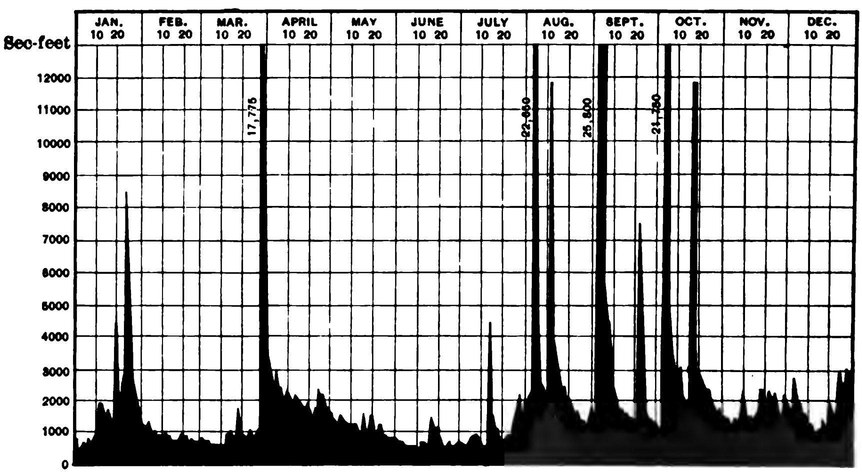


FIG. 42.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE TUCKASEEGEE RIVER, AT BRYSON CITY, N. C., FOR 1898.

JUDSON STATION ON THE LITTLE TENNESSEE RIVER.

This station is located on the Southern railway bridge, about one-fourth of a mile below Judson and above the mouth of Sawyer branch. The zero of the gauge-rod is 25 feet west of the east end of the second span from the east. The outer rim of the pulley-wheel is 2 feet from the zero of the gauge-rod, and the distance from the end of the weight to the pointer on the wire is 26.25 feet. The gauge reads zero when the weight touches the bottom of the river. On the west side of the stream the bottom is rocky and very rough; on the east side sandy, and the current is very swift. The river is straight for several hundred yards above and below the station. The section is not a very good one as there are two bad pier obstructions. The observer is R. C. Sawyer, Judson, N. C.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON LITTLE TENNESSEE RIVER AT JUDSON, NORTH CAROLINA.

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	June 25	E. W. Myers	21	2.76	345	2.69	929
2	Sept. 23	....do	2154	3.00	286	2.71	775
	1897.						
3	Aug. 21	E. W. Myers	2154	3.21	278	2.78	771
4	Oct. 13	....do	2154	2.75	247	2.83	701
5	Oct. 23	A. P. Davis	94	2.44	207	2.77	448
	1898.						
6	Sept. 6	E. W. Myers	9	7.30	920	10.67	9,821

RATING-TABLE FOR LITTLE TENNESSEE RIVER AT JUDSON, NORTH CAROLINA.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
2.0	225	4.0	2,650	6.0	6,750	8.4	13,700
2.1	250	4.1	2,835	6.1	6,995	8.6	14,475
2.2	300	4.2	3,020	6.2	7,240	8.8	15,275
2.3	370	4.3	3,205	6.3	7,485	9.0	16,100
2.4	445	4.4	3,390	6.4	7,730	9.2	16,950
2.5	525	4.5	3,575	6.5	7,975	9.4	17,825
2.6	610	4.6	3,770	6.6	8,240	9.6	18,725
2.7	705	4.7	3,965	6.7	8,505	9.8	19,500
2.8	805	4.8	4,160	6.8	8,770	10.0	20,600
2.9	925	4.9	4,355	6.9	9,065	10.2	21,600
3.0	1,060	5.0	4,550	7.0	9,300	10.4	22,600
3.1	1,205	5.1	4,760	7.1	9,580	10.6	23,600
3.2	1,360	5.2	4,970	7.2	9,860	10.8	24,600
3.3	1,515	5.3	5,180	7.3	10,140	11.0	25,600
3.4	1,670	5.4	5,390	7.4	10,430	11.2	26,600
3.5	1,825	5.5	5,600	7.5	10,700	11.4	27,600
3.6	1,990	5.6	5,830	7.6	11,010	11.6	28,600
3.7	2,155	5.7	6,060	7.8	11,600	11.8	29,600
3.8	2,320	5.8	6,290	8.0	12,275	12.0	30,600
3.9	2,485	5.9	6,520	8.2	12,975	....	.....

ESTIMATED DISCHARGE OF THE LITTLE TENNESSEE RIVER, AT JUDSON, NORTH CAROLINA

[Drainage area, 738 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
July	14,805	705	3,614	222,213	6.08	4.89
August	2,403	725	1,285	76,458	2.01	1.74
September	1,515	290	693	41,236	1.04	0.94
October	1,205	550	684	42,057	1.06	0.92
November	11,300	686	2,351	139,895	3.54	3.18
December	11,300	1,639	3,542	217,797	5.53	4.80
					19.21	2.74
1897.						
January	4,199	1,670	2,390	146,951	3.73	3.24
February	14,135	1,852	4,575	254,084	6.44	6.19
March	16,195	1,875	7,750	447,027	12.18	10.51
April	11,930	1,278	4,365	259,738	6.58	5.90
May	4,991	1,389	2,449	150,587	3.83	3.32
June	4,160	939	1,968	117,100	2.94	2.64
July	4,970	1,515	2,376	146,222	3.71	3.22
August	2,656	775	1,640	100,843	2.56	2.22
September	925	392	719	42,783	1.08	0.97
October	3,723	334	829	50,973	1.29	1.12
November	1,515	430	792	47,127	1.19	1.07
December	3,751	565	1,528	93,955	2.38	2.07
					47.91	3.54

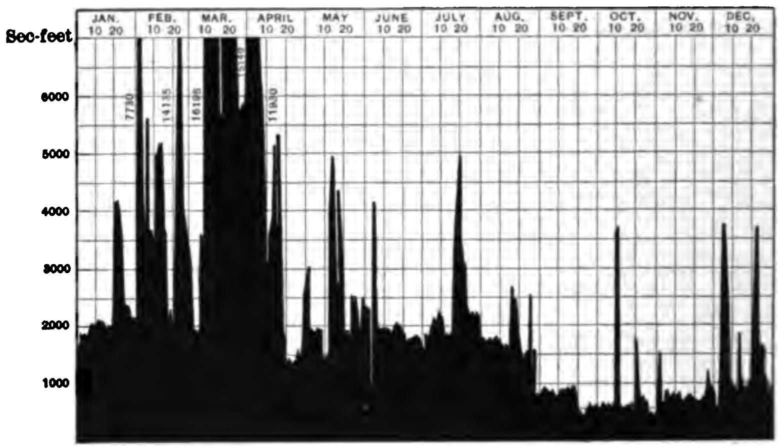


FIG. 43.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE LITTLE TENNESSEE RIVER, AT JUDSON, N. C., FOR 1897.

ESTIMATED DISCHARGE OF THE LITTLE TENNESSEE RIVER, AT JUDSON, NORTH CAROLINA.

[Drainage area, 738 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	5,784	686	1 495	91,926	2.33	2.02
February	1,220	370	759	42,152	1.07	1.03
March	13,160	370	1,781	109,511	2.78	2.41
April	6,244	1,060	2,411	143,464	3.63	3.26
May	8,075	300	1,882	115,722	3.04	2.55
June	785	300	563	33,500	0.84	0.76
July	8,797	265	1,250	76,862	1.95	1.69
August	22,500	1,598	5,836	358,848	9.10	7.90
September	30,250	1,701	5,187	308,646	7.83	7.02
October	45,600	1,732	6,093	374,648	9.51	8.25
November	3,750	2,369	2,902	172,673	4.38	3.93
December	4,548	1,825	2,184	134,135	2.41	2.96
The year	45,600	265	2,695	1,955,082	48.87	3.65

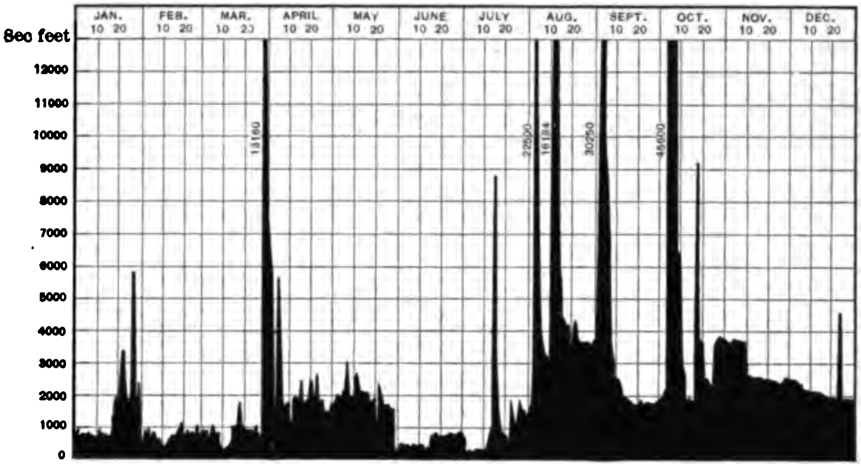


FIG. 44.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE LITTLE TENNESSEE RIVER, AT JUDSON, N. C., FOR 1898.

MURPHY STATION ON THE HIWASSEE RIVER.

This station is located on the highway bridge crossing the river at Murphy, North Carolina, one-half mile above the mouth of Valley river. The zero of the gauge-rod is 8 feet north of the center of the second full-length compression member from the north end of the bridge and on the down-stream side. The outer rim of the pulley-wheel is 2 feet from the zero of the rod, and the distance from the end of the weight to the marker on the wire is 29.1 feet. The reading of the gauge is zero when the weight touches the bottom of the stream. The section here is a good one, though somewhat obstructed by the remains of two old piers directly under the present bridge. The course of the river is straight for several hundred yards above and below the station and the current is fairly rapid. The bottom is hard and rocky and is not subject to any decided change by high water and the banks are high.

During 1897 the wire gauge was twice cut and was replaced each time according to the figures for the elevation of the bench mark. On the final replacing, October 20, 1897, it was discovered that there was a difference of a foot between the old and the new data. At the time of the establishment of the station a tape was used which was broken at about the 1-foot mark, and it is thought that the allowance of this amount was not made in reporting the elevation of the bench mark. The discharges for 1896 and till October, 1897, are calculated on this supposition, and there is liability to error for the higher stages of flow, as no extreme flood height gaugings have been made. These figures are then to be taken as only an approximation.

The tables of daily gauge height for this station for 1896 and 1897 will be found in Water Supply and Irrigation Papers Nos. 11 and 15, published by the U. S. Geological Survey.

LIST OF DISCHARGE MEASUREMENTS MADE ON HIWASSEE RIVER AT MURPHY, NORTH CAROLINA

No.	Date.	Hydrographer.	Meter No.	Gauge height (feet).	Area of section (square feet).	Mean velocity (feet per second).	Discharge (second-feet).
	1896.						
1	June 23	E. W. Myers	21	3.82	311	1.17	366
2	Aug. 10	....do	2154	3.95	278	1.37	382
3	Sept. 22	....do	2154	4.01	353	1.46	517
	1897.						
4	Aug. 20	E. W. Myers	2154	5.23	308	1.71	528
5	Oct. 14	....do	2154	4.76	264	1.01	267
6	Oct. 29	A. P. Davis	94	4.71	277	0.91	253
	1898.						
7	Jan. 21	E. W. Myers	2154	6.05	490	2.61	1,170
8[1]	Sept. 8	....do	9	6.80	634	2.56	1,620

RATING-TABLE FOR HIWASSEE RIVER AT MURPHY, N. C., FROM JULY, 1896, TO AUGUST, 1897.

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
3.4	135	4.2	540	5.0	1,130	5.8	1,790
3.5	175	4.3	605	5.1	1,210	5.9	1,875
3.6	215	4.4	675	5.2	1,290	6.0	1,950
3.7	260	4.5	745	5.3	1,370	7.0	2,810
3.8	310	4.6	820	5.4	1,450	8.0	3,660
3.9	360	4.7	895	5.5	1,535	9.0	4,510
4.0	415	4.8	970	5.6	1,620	10.0	5,510
4.1	475	4.9	1,050	5.7	1,705	....	.....

RATING-TABLE FOR HIWASSEE RIVER AT MURPHY, NORTH CAROLINA.

[Applicable from October 20, 1897, to December 31, 1898.]

Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.	Feet.	Sec.-feet.
4.6	225	5.4	570	6.2	1,320	7.0	2,120
4.7	250	5.5	640	6.3	1,420	7.1	2,220
4.8	280	5.6	720	6.4	1,520	7.2	2,320
4.9	315	5.7	820	6.5	1,620	7.3	2,420
5.0	350	5.8	920	6.6	1,720	7.4	2,520
5.1	400	5.9	1,020	6.7	1,820	7.5	2,620
5.2	450	6.0	1,120	6.8	1,920	....	......
5.3	510	6.1	1,220	6.9	2,020	....	......

[1] Meter damaged.

ESTIMATED MONTHLY DISCHARGE OF HIWASSEE RIVER AT MURPHY, NORTH CAROLINA.
[Drainage area, 410 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1896.						
July [1]	8,848	260	792	48,799	2.22	1.93
August	481	238	320	19,709	0.90	0.78
September	540	199	241•	14,339	0.65	0.59
October	360	179	237	14,597	0.63	0.55
November [1]	3,188	206	646	38,437	1.76	1.58
December	1,290	360	500	30,795	1.41	1.22
					7.57	1.11
1897.						
January	1,210	360	556	34,244	1.56	1.35
February [1]	2,727	488	1.092	60,650	2.77	2.66
March [1]	4,610	745	1,824	112,340	5.13	4.45
April [1]	3,320	820	1,328	79,116	3.61	3.24
May	1,180	540	683	42,066	1.91	1.66
June	605	415	464	27,608	1.26	1.13
July [1]	8,510	335	813	49,991	2.28	1.98
August [2]	640	475	556	7,515	0.26	1.35
September [3]	....	....	....	....	....	....
October [4]	350	237	268	6,380	0.29	0.65
November	570	315	342	20,350	0.92	0.83
December	2,470	350	737	45,316	2.08	1.80
The year	8.510	237	788	515,776	22.07	1.92

ESTIMATED MONTHLY DISCHARGE OF HIWASSEE RIVER AT MURPHY, NORTH CAROLINA.
[Drainage area, 410 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Depth in inches.	Second-feet per square mile.
1898.						
January	2,320	400	899	55,277	2.53	2.19
February	720	462	543	30,157	1.37	1.32
March	6,220	450	895	55,031	2.52	2.18
April	3,870	770	1,281	77,225	3.48	3.12
May	920	400	612	37,698	1.72	1.49
June	640	332	406	24,159	1.10	0.99
July	1,320	315	631	38,799	1.78	1.54
August	6,980	720	1,712	105,268	4.80	4.17
September	13,580	720	1,976	117,576	5.41	4.82
October	10,060	640	1,948	119,780	5.47	4.75
November	1,820	840	1,086	64,617	2.94	2.64
December	1,220	820	980	60.258	2.75	2.39
The year	13,580	315	1,081	785,840	35.87	2.63

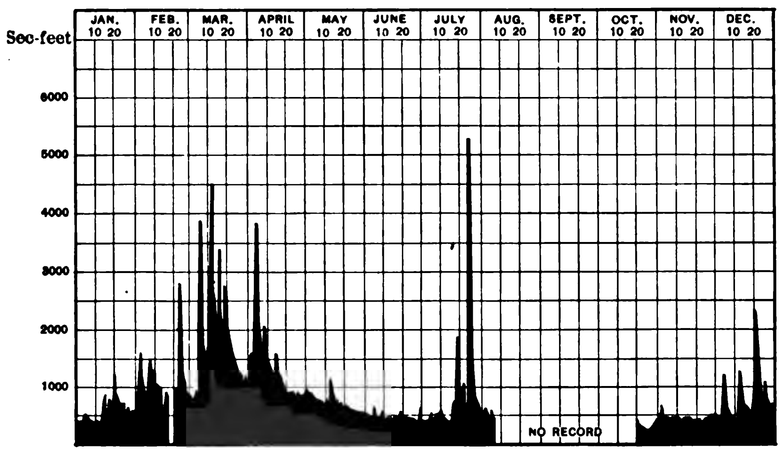


FIG. 45.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE HIWASSEE RIVER, AT MURPHY, N. C., FOR 1897.

[1] Maximum estimated. [2] 7 days' record. [3] No record. [4] 12 days' record.

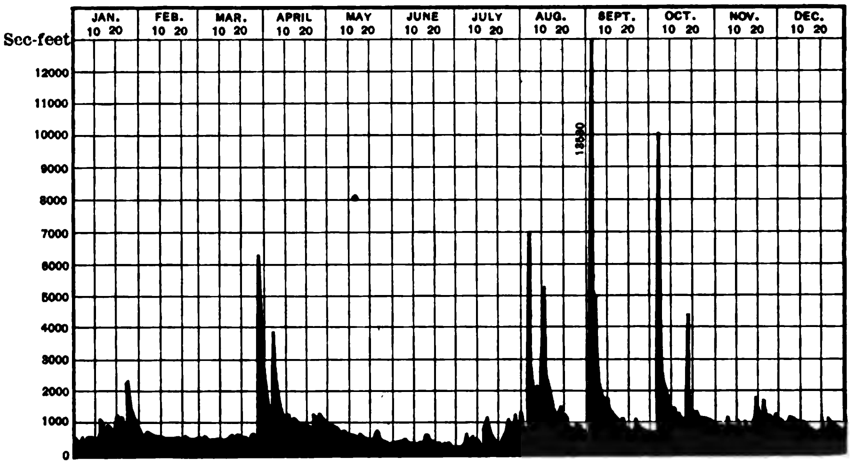


FIG. 46.—DIAGRAM OF THE DAILY MEAN DISCHARGE IN CUBIC FEET PER SECOND OF THE HIWASSEE RIVER, AT MURPHY, N. C., FOR 1898.

PART V

ELECTRIC POWER TRANSMISSION

By J. W. Gore

ELECTRIC POWER TRANSMISSION.

CHAPTER XVI.

ELECTRIC POWER TRANSMISSION.[1]

A question of great importance with every manufacturing enterprise is the cost of power, since, in many such industries, labor constitutes the largest item in the cost of the products, and in none is it to be disregarded.

SOURCES OF ENERGY FOR OPERATING MACHINERY.

The sources of energy upon which man relies for operating machinery and doing useful work are few: fuel, waterpower, wind, solar radiation. We are practically limited to the first two, fuel and waterpower. The wind is used to a very limited extent, as it is too uncertain and intermittent to meet the usual requirements of a source of power, and, though solar radiation furnishes an enormous amount of energy, yet, as a source of power for directly operating machines, it remains practically unused.

Sometimes one or the other of the two available forms of energy is to be found at or near the raw material, yet more frequently the material has to be transported to the power or the power transmitted to the material. The location of many of our manufacturing towns has been decided by desirable and ample waterpowers or the abundance and cheapness of fuel, without reference to the nearness of the raw materials or the markets for the finished products. But as the item of cost of labor lessens by improvements in machinery and methods of manufacture, the item of cost of transportation constitutes a larger per cent. of the cost of the finished product; hence the question of conveying the power to the material or conveying both power and material to some advantageous point grows in importance.

DIFFERENT MEANS OF TRANSMITTING POWER.

The means employed for conveying or transmitting power for distances exceeding a few hundred feet, other than by hauling fuel, are: cables, compressed air, hydraulic pressure and electricity.

The hydraulic system of transmitting power is limited to a special

[1] By J. W. Gore, Professor of Physics, University of North Carolina.

class of work under favorable circumstances, and hence need not here be compared with the other methods of power transmission.

In a recent book, "Electric Power Transmission," by Dr. Louis Bell, the three systems of power transmission—rope, pneumatic and electric—are compared. He assumes that 100 horsepower is developed by a steam plant, then transmitted two miles and delivered as a unit by each of these systems, the conditions under which they are operated being such as may be found in the practical working of the respective systems. The following table gives the data needed for a comparison. Under the head of operating expenses are included attendance, maintenance and interest on the money invested:

System.	Efficiency.	Total cost.	Operating expense.	Cost per horsepower per year.
Rope..........	67%	$92,000	$33,500	$49.00
Pneumatic	54	82,000	26,000	48.00
Electric	73	84,000	27,000	38.00

The great difference in cost of the power delivered in favor of electric transmission would be increased had a higher efficiency been assigned the electrical equipment—an efficiency of 80 to 85 per cent. being now commonly attained; and, also, if a comparison were made when the systems were operating at less than full load.

Had the distance of transmission been limited to one mile the probability is that the rope and the electric systems would have delivered the power at practically the same cost.

Both the pneumatic and electric systems have the advantage over rope transmission when the power is to be divided into several units instead of being delivered as one unit.

DEVELOPMENT OF ELECTRIC POWER TRANSMISSION.

Electric power transmission had its commercial beginning in 1837 with the introduction of Morse's system of telegraphy, the amount of energy transmitted being small and the cost quite high, but it has only been since the invention of the modern machines for generating electricity in large quantities, and so much more cheaply than by the use of primary batteries, that the use of this form of power and its transmission have become such important factors in the commercial world.

It is to street-car traction and lighting, two demands for energy in which the margins of profit are sufficiently wide to assure capital of a fair return on investment, that we are mainly indebted for the stimulus to the inventors and manufacturers of generators and motors, together with their various accessories, which has resulted in so brief a time in producing the highly efficient electrical machinery in operation to-day.

In the lighting industry the generator has proven its reliability and durability; the regulation and distribution of the current is completely solved, and the great rapidity with which the electric system of lighting has been extending is ample proof of efficiency and economy.

The successful application of motors to the severe and varying requirements of the motive power for street cars demonstrates their ability to endure rough treatment, and the readiness with which they can respond to the changing demands for power.

DISTRIBUTION OF POWER IN THE FACTORY. ELECTRICITY COMPARED WITH SHAFTS AND BELTS.

In manufacturing plants of any size, power is needed at several more or less widely separated points, and as it is more economical to generate the power in large units than in several small ones, it becomes necessary to transmit the power from the place where it is generated to the several points where it is to be employed.

This distribution of power through the mill or factory is usually accomplished by shafts and belts.

Without considering the cost of shafts and belts, the troubles that arise when shafts get out of alignment, or the annoyance of slipping belts, the dust they stir up and the room they occupy, we may briefly consider the efficiency of distributing power by shafts and belts, and compare with it the efficiency of power-distribution by electricity.

The loss of power when transmitted by shafts depends upon several conditions besides accuracy of the construction of the line of shafting; such as distance, size of the units of power delivered at the several points, whether the line is straight or is angular, etc.

From the most reliable sources we learn that it is exceptional to find the loss of power at full load to be as small as 25 per cent. in its transmission by shafts from engine to driven machine, and that from 30 to 50 per cent. is the more usual loss. At half load and less, as much as 75 to 80 per cent. may be lost in transmission.

Should the power be transformed into electricity by a direct-connected generator of moderately large size, distributed by conducting wires of proper size to motors ranging in size from 5 to 15 horsepower the efficiency would be about 78.6 per cent., since the efficiency of the generator would be 92 per cent., the line 97 per cent., and the motors would have an average efficiency of about 87 per cent Even at half load or less the efficiency of the electric-motor system would probably not fall below 70 per cent.

In large plants the difference in the efficiency of transmission of power by shafting, even assuming it to be as high as 70 per cent., and electric transmission with an efficiency of 78 per cent., means a large difference in operating expense. If the plant is not run at full load the difference in efficiency in favor of the distribution by electricity is far greater.

There are other questions besides efficiency to be considered in deciding in favor of either system. The cost of the installation of the electric system would doubtless be the greater in all cases except under extraordinary conditions. However, there would be a saving in cost of buildings, as the wires take up practically no room and do not need special foundations as shafting does. Then, too, the cost of maintenance is less, and certain classes of machines do more work when operated by separate electric motors under the immediate control of the operator than when dependent on the common power of the mill or factory.

It is readily seen that many points would have to be considered in any given case before deciding in favor of either method of distributing power, when the greatest efficiency and economy is the aim, and the means for installing either system of transmission are available.

FACTORIES OPERATED BY ELECTRICALLY TRANSMITTED POWER.

A few examples of the distribution of power by electricity will suffice to prove that the great efficiency claimed is not theoretical only, but has the endorsement of capital, and hence must be profitable.

A fire-arms factory at Herstal, Belgium, is operated by electric motors, supplied by electricity from a generator, direct-coupled to a 500 horsepower steam-engine. There are 17 motors distributed through the factory with an aggregate capacity of 305 horsepower. The efficiency of the system from the shaft of the engine to the pulley of motors is 77 per cent. The installation has given such satisfactory results that the plant has been enlarged by the addition of another such unit.

The motor has been tried at the Dunnell Print Works in Pawtucket, operating a seven-roll printing-machine. It is said that printing-machines present the greatest difficulties in the application of power of any machinery in textile manufacture, requiring varying speed without shock in the gradations, frequent stopping and an excess of power to start.

It is stated that the production of this machine is at least 33⅓ per cent. greater, driven by an electric motor, than when run by steam-power. After a trial of eighteen months Mr. Dunnell was so thoroughly convinced of the superiority of electricity as the motive power for this class of work that he advised the employment of the electrical system of distribution and application of power in all new print-works that may be constructed.

The Page Belting Company, Concord, N. H., substituted electrical distribution of power for shafting in their extensive mills, and found it cheaper and more efficient.

In this instance, according to the statement of the president of the company, the installation of the electrical plant was cheaper than a steam plant, capable of accomplishing the same amount of work.

Probably we would not have had this direct comparison of cheapness of the two systems of distributing power generated by steam had it not been the expectation of the company to use electricity developed by waterpower at Sewalls falls on the Merrimac river, four miles north of Concord. This waterpower, of 5000 horsepower, has been developed, and the belting mills are equipped to use 2000 horsepower of the electrically transmitted energy.

An interesting case, in which the questions of transmission and the distribution of power were somewhat equally prominent, is afforded by the power plant of the Columbia Cotton Mills, Columbia, S. C. The waterpower is obtained from a canal, built many years ago, for transporting boats past the rapids in the river. Between the canal and river is barely room for the power house, and a desirable location for the mill is on the opposite side of the canal, 800 feet from the power house. Had it been simply a question of transmitting the power this short distance and employing it as one unit, the chances are that rope transmission would have been adopted, but upon considering also the distribution of the power through the mill, it was decided that electrical transmission and distribution was the more efficient and economical method. The power plant consists of two turbine water-wheels, direct connected, with two 500 kilowatt, three-phase generators, two 10 horsepower direct-current generators to excite the fields of the large generators, an electric water-governor and switchboard. The current is carried to the mill by cables placed under ground and distributed in the mill to 17 motors of 45 horsepower each. The motors make 540 revolutions per minute, start with full load, and will not stop if overloaded up to 125 horsepower. Being rotary-field motors, there is no rubbing contact and hence no injurious or dangerous sparking. The efficiency of the transmission of power from the shaft of the turbines to the pulley of the motors is between 75 and 80 per cent. The mill was started June 22, 1894, and has been in continuous operation ever since, the power transmission and distribution meeting the expectation of the General Electric Company that put in the electrical installation, and fulfilling the requirements of the owners of the mills. (Plate XV—B.)

One of the most complete electric-power distribution plants that may be cited is doubtless the one that has recently been installed in the Government Printing Office, Washington, D. C. A small electric plant was put in over a year ago as an experiment, and the public printer was so completely convinced of the reliability and efficiency of the electric system that the entire office has been equipped with this service. The power house is supplied with three engines and generators designed to run thirty days without shutting down, and to regulate so perfectly that the lights will not perceptibly vary under any change of load. The current generated supplies 4000 16 candle-power lamps and 167 motors, aggregating 579 horsepower. The motors are direct-connected to the presses and also to many of the other machines. The production of the presses has been increased many per cent. and the character of the work much improved, due largely to the constant speed of the motors. Among the many advantages derived from the application of motors to the machinery of this great establishment may be mentioned the removal of miles of belting which cut off a great deal of light, and many tons of shafting and pulleys, which produced a great deal of noise and dirt, besides the great strain on the floors.

The efficiency of electrical distribution has been dwelt upon because it enters as an important factor in the more general question of electric-power transmission.

RELATIVE COST OF DIRECT STEAM-POWER AND ELECTRICALLY TRANSMITTED POWER.

The cost of power provided by each of the two methods must be ascertained by a careful determination of the existing conditions in any particular case. That is, an accurate estimate should be made of the cost of a power-transmission plant, its efficiency and expense of maintenance and operating it; also a similar estimate for a steam plant.

While it is only possible to compare the cost of supplying power by these two ways for an average condition of things, yet this may be of service in calling attention to the probability of a given waterpower being economically available, as it may lead to the investigation of questions which will doubtless result in developing some of the unused waterpowers of the state.

COST OF INSTALLING AND OPERATING ELECTRICAL PLANTS.

The data used in the following estimates are obtained from reliable sources, and illustrate the various items of cost that obtain under average conditions: cost of installing a power-transmission plant of 100 horsepower; distance of transmission 10 miles; voltage 5000, total efficiency 80 per cent.:

Hydraulic work, including wheels, etc.	$6,000.00
Generators and switchboard	2,500.00
Power-house	1,000.00
Line	3,500.00
Miscellaneous	1,000.00
Total	$14,000.00

Operating Expenses:

Interest and depreciation @ 10%	$1,400.00
Attendance	750.00
Maintenance	1,200.00
Interest @ 5% on cost of water rights	200.00
Total	$3,550.00

This calculation gives $3,550 as the cost of 80 horsepower delivered, or at $44.37 per horsepower per year.

Taking a larger unit, say, 1000 horsepower; transmission 10 miles; voltage 1000; total efficiency 80 per cent., we would have:

Hydraulic work, wheels, etc	$55,000.00
Generators	25,000.00
Power-house	2,500.00
Line	7,500.00
Miscellaneous	10,000.00
Total	$100,000.00

Operating Expenses:

Interest and depreciation @ 10%	$10,000.00
Attendance	3,000.00
Maintenance	6,000.00
Interest on cost of water rights @ 5%	2,000.00
Total	$21,000.00

Cost per horsepower per year of $26.25.

The General Electric Company gives as the result of its experience in Circular No. 1008, "Electrical Transmission of Power," the following as a fair average cost of installing a plant:

Development of waterpower	$50.00	per H. P.
Generators, switchboard, and power-house	40.00	"
Line	25.00	"
Water rights and incidentals	60.00	"
Total	$175.00	"

The efficiency of transmission being 80 per cent., the cost would be nearly $220 per horsepower delivered. Allowing 15 per cent. for depreciation and operating expenses, we have a total cost per electrical horsepower per year of about $33.

The cost increases some with distance, but not very much, until the distance reaches some forty or fifty miles, for by increasing the voltage, the cost of the copper may be kept practically constant and the poles should not cost over $250 per mile.

Under favorable conditions the cost of transmitted power may be very much less than the above estimates indicate. A recently installed plant near Butte, Montana, for developing 5000 horsepower and transmitting 75 per cent., or 3750 horsepower, 21 miles, cost, complete, $400,000, or $106.66 per horsepower. Estimating operating expenses at 15 per cent., would give the power ready for distribution at $16 per horsepower per year.

COST OF INSTALLING AND OPERATING STEAM PLANTS.

From the time during which steam-power has been employed, it would naturally be supposed we would have definite data for computing its cost when the price of fuel is given. Accurate tests have frequently been made, and the results may be relied upon, provided the conditions under which the tests were made are maintained. But there is such a variety of boilers, with such varying ratios of grate surface to heating surface, and ratios of either to the amount of water to be converted into steam, that the problem is in general of uncertain solution. Then the rate of combustion of the fuel is a varying quantity, as also the temperature at which the products of combustion are allowed to escape into the air. The condition of the atmosphere, whether it is moist or dry, light or heavy, effects the burning of the fuel.

Users of steam-power rarely have a definite knowledge of what it costs them per horsepower. They doubtless know the amount of bills for fuel, wages, interest on plant, taxes, supplies and incidentals, but the unknown quantity is the amount of power that has been generated at the shaft of the engine. Usually the estimate per horsepower per year, if made, is computed on the rated horsepower of the engine without considering that the chances are that they were actually obtaining an average of only a comparatively small fraction of the nominal capacity of their plant.

The nearest we can come to a satisfactory solution of the cost of steam-power is to give the results of those who have made the subject a special study and have determined the cost under stated conditions.

The following table, giving the cost of steam power per horsepower per year, is a summary of the researches on this subject by Dr. C. E. Emory.

Capacity of engine 500 horsepower, run at full load for 10 hours a day, 308 days per year:

Kind of engine.	Coal $3.00 per ton.	Coal $4.00 per ton
Simple low speed.............	$34.20	$39.94
Simple low speed, condensing ..	26.77	30.73
Compound, condensing	25.53	29.09

In ordinary practice the real cost would be from 25 to 50 per cent. more than that given in the table, since it is unusual for engines to run continuously at full load, and even when they do, the stoking is likely to be carelessly done, and it is most certain that the average engine does not measure up to its rating.

After considering the efficiency of the various forms and classes of heat engines, Dr. Louis Bell summarizes results as follows, coal being taken at $3 per ton:

Kind of engine.	Cost per horsepower hour, fully loaded.	Cost per horsepower hour, partial load.
Large compound, condensing	0.8 c. to 1 c.	1 c. to 1.5 c.
100 horsepower, simple..........	1.5 c. to 2.5 c.	3 c. to 5 c.
20 horsepower, and less, simple...	7 c. to 12 c.	12 c. to 20 c.

Taking an average from the data given, and from other equally reliable sources, it is safe to say that steam-power will cost between $30 and $50 per horsepower per year of 3080 hours, using engines of 250 horsepower and over, while engines of, say, 100 horsepower, will put the cost at from $45 to $75.

ADVANTAGES IN FAVOR OF ELECTRICALLY TRANSMITTED POWER.

In connection with the relative cost of delivering power electrically transmitted and by steam, the advantages of electrical distribution must be considered.

The convenience, safety and economy of space of the motor are sufficient to decide in favor of the use of electricity even when it can be obtained no more cheaply than steam-power.

Indeed, there are very few places where steam-power can be developed cheap enough to prevent electric-power finding a market in small amounts, even at $50 to $75 per horsepower per year.

When the power is used 24 hours a day the advantage of electrically transmitted power becomes much more decided. In a steam-plant all the items in the expense of operating increase in proportion to the time of running except interest on the plant, taxes and insurance, while with the transmission plant only attendance, depreciation and incidentals increase in proportion to the time.

Since at least three-fourths of the operating expense of a steam plant is increased in proportion to the time of running, it is easily shown that the cost per horsepower for a 24-hour day is slightly more than double the cost for a 10-hour day, while electrically transmitted waterpower is only increased a little more than one-third for the increased time.

The Niagara Falls Power Company has offered developed waterpower at $13 per horsepower per year, and electric-power at the generator at $18. Assuming that its transmission to Buffalo cost as much as generating the electricity, or $5 per horsepower, we would have the cost of electrical power at Buffalo $23 per horsepower per year, of 308 days and 24 hours per day.

A careful estimate of the cost of steam-power in Buffalo was made before introducing electricity generated at Niagara, and found to be from $45 to $60 per horsepower per year (24-hour days), the units being large and coal very cheap.

The only exact method of comparing the cost of power supplied by the two sources we are considering would be by ascertaining the cost of the products of a mill or factory operated by a transmission plant and the cost of similar products of a mill or factory at the same place operated by steam. Such a comparison would include the efficiency of the machines run by the different sources of power as well as the cost of power. Such statistics are difficult to obtain, as manufacturers do not advertise the cost of the products of their mills.

From the number of power transmission plants installed within the past few years and the rapidly increasing demand for electric power, we are assured that in many cases at least there is a decided margin of profit in favor of electrically transmitted power. It might be said that it is the fashion now to use electricity for all power purposes were it not an assured fact that capital invested in industrial enterprises expects a return in kind.

SOME TYPICAL MANUFACTURING PLANTS USING ELECTRICALLY TRANSMITTED POWER.

A brief reference to a few plants that have been in operation for a longer or shorter time may illustrate the efficiency and reliability of this kind of power, as well as the various conditions under which it may be used and the distance transmitted.

The first of these plants to be installed was by S. D. Warren & Co., Cumberland Mills, Maine. Their paper mills were at first driven by waterpower; upon enlarging the mills, steam was employed. In 1891 they developed a waterpower one mile lower down the stream and installed four 80 horsepower Mather generators, and put six 40 horsepower motors in the mills. The plant has been continuously in operation since it was started, running 24 hours per day, and has given satisfaction, both as to efficiency and cost. As a result of their experience, they have, within the past three years, developed a waterpower of 500 horsepower at a distance of five miles. This installation consists of two 250 horsepower alternating-current generators, each driven by two water-wheels. The current is transmitted at 7600 volts, transformed at the mills to 400 volts and distributed to the motors, doing various kinds of work. This addition to their power was not called for by an enlargement of the mills, but because electrically transmitted power proved to be cheaper than steam, even though their steam plant is to a considerable extent idle.

Another electrical power plant which has been in operation long enough to give reliable results is furnishing part of the motive power for running the Nonatuck silk-mills at Leeds and Haydensville, Mass. These mills were first run by waterpower, then steam was added, and about seven years since a waterpower was developed and transmitted electrically to the mills. This waterpower had not been developed previously, as the narrow gorge through which the small river runs at this point does not offer a favorable location for a mill. The generator station is of special interest because of its compactness. Three water-wheels are in one case. One wheel drives two generators, which supply current for 1000 lights in the mills; another wheel drives two 500-volt Thompson-Houston generators, which supply current at the Leeds mill, one-half mile distant, to drive a 45 horsepower motor belted to the main shaft, to which is connected the water-wheels of the mill and also a steam engine when needed; and it also furnishes current for two motors of 20 horsepower each and one of 10 horsepower, which drive machinery in separate rooms not connected with the other sources of power. The Haydensville mill, one and a half miles distant, receives current to drive a 45 horsepower motor, which is belted to the main shaft as at Leeds. Connecting motor and engine to shaft with water-wheels has proved very satisfactory, each supplying its quota of power and also acting as a regulator. The efficiency of the machines run directly by motors has been so much increased that it is probable the company will distribute all the power electrically. These mills only run 10 hours a day and coal is quite cheap, $4 per ton in the furnace. The plant has fulfilled the expectation of the company and has given satisfaction.

The Sampson Cordage Company, at Shirley, Mass., has been transmitting 50 horsepower a distance of a half mile since 1893, using a 500-volt, direct-current generator. The interesting feature of this small power plant is the dispensing with the services of an attendant at the generator station. The water is turned on in the morning and off at the end of the day; the regulation, while in operation, is accomplished by the aid of electricity by the attendant at the motor end of the line. Small streams of water are numerous, of sufficient fall, to allow several generating stations to be located within short distances of each other, and the power from all transmitted to a common point sufficient to operate a large mill. Since all the generators may be regulated by one attendant at the motor end of the system, the cost of the power thus assembled should, in many cases, be less than the cost of steam-power.

At the Columbia Cotton Mills, Columbia, S. C., which have already been referred to (p. 341), since the distance of transmission is so small (800 feet), the distribution of the power was as important an element as its transmission in determining the system to be employed.

The Columbia Waterpower Company, Columbia, S. C., has recently completed an installation of a 3000 horsepower plant, which may be increased to 10,000 horsepower. It consists of three turbines of 1250 horsepower each, three 750 kilowatt generators (3-phase alternators, 3540 volts) with their exciters, water-governors, switchboards, etc. The Granby mills, manufacturing print cloths, is the largest customer at present. The current is transmitted 1½ miles and reduced by transformers to 550 volts for the motors and to 110 volts for lighting. The installation at the mills consists of four 150 horsepower and one 75 horsepower induction motors and 1200 lights. (Plate XV—B.)

There have been two other important power-transmission plants put into successful operation in South Carolina within the past three years.

The Pelzer Manufacturing Company, Pelzer, S. C., began operating their large mill, No. 4, during the early part of 1896, using electricity generated by a waterpower, developed at a lower dam, 700 feet long and 50 feet high, on the Saluda river, three miles from the mill. The power-station, located on and just below the dam (Plate XV—A) is equipped with three 1000 horsepower, 3-phase, 3300-volt generators, exciters and necessary station apparatus. The installation of the mill consists of 21 induction motors and 1200 lights. Mill No. 3 is also supplied with current for one 400 horsepower motor and two 5 horsepower motors.

During the latter part of 1895 the Anderson Water, Light and Power Company, Anderson, S. C., began the transmission of electricity generated by waterpower on the Seneca river, six miles distant. This was the first long-distance transmission plant in the South, and the 200 horsepower Stanley generator, 5500 volts, was the largest machine in

A DAM AND POWER-HOUSE, SALUDA RIVER, PELZER, S. C.

B—CANAL AND POWER-HOUSE, COLUMBIA, S. C

the country of so high voltage. The current is used for incandescent and arc lamps and motors. During the past year the Anderson Company has greatly enlarged its transmission plant by installing two 600 kilowatt, 3-phase, 10,000-volt generators, the distance of transmission being 10 miles. The current is supplied to three 300 horsepower synchronous motors in the cotton-mills at 600 volts, 70 arc lights and 1500 incandescents, and several small motors in the town; the total horsepower delivered is reported to be 1425.

The first power-transmission plant in North Carolina has been installed by the Fries Manufacturing and Power Company of Winston-Salem. A waterpower in the Yadkin river, at the crossing of the

Fig. 47.—Power-house of the Southern California Power Company and transmission line, of which the six No. 1 copper wires are intended to transmit 1000 horsepower each to Los Angeles, a distance of 80 miles. It is said that the generator transmits to the switchboard 96% of the power delivered to it; and that this power (2000 horsepower) is now (Jan., 1899) being transmitted to Los Angeles at a voltage of 33,000 with a loss in transmission of less than 10%.

Mocksville branch of the Southern railroad, has been developed by the erection of a stone dam yielding 1000 horsepower at mean low water, the head being 10 feet. The power-house is placed immediately at the eastern end of the dam. Eight turbine wheels are geared to one shaft, which drives a 750 kilowatt, 3-phase, alternating-current Stanley generator of 10,000 volts. Provision has been made for the installation of another equal unit by the construction of wheel-pits and foundations for another generator. Two water-governors control six of the eight wheels. The electricity is transmitted 13½ miles by three No. 6 bare copper wires. Two barbed iron wires are placed above the copper conductors to protect them from lightning. The upper cross-arms also carry two telephone wires. In the erection of the pole line provision has also been made for the enlargement of the plant. The voltage is reduced at a transformer station in Winston-Salem to 1250 by two sets of transformers, of three each, and distributed to the consumers of power as follows: Arista Cotton Mills, 300 horsepower; Wachovia grain mills, 80 horsepower; F. & H. Fries woolen mills, 80 horsepower; Fogle Bros., 50 horsepower; J. A. Vance, 30 horsepower; Winston-Salem Railway and Electric Company, 300 horsepower. The South Side cotton mill is supplied with current to operate a 300 horsepower motor from the station at 10,000 volts and reduced to 1250 volts by transformers at the mill. The Southern Chemical Company will be similarly supplied with 80 horsepower. These two customers being from 2½ to 3½ miles distant from the station, the voltage is not reduced until the mills are reached. Application for over 200 horsepower more has been made. The rated capacity of the plant has already been exceeded, and to supply the demand the contemplated enlargement will have to be made. (Plate XVI.)

The motors and electrical installation in the various mills belong to the power company. All motors of 50 horsepower and over are of the Stanley synchronous type, while the smaller motors for power and starting purposes are of the Westinghouse induction type. Electricity is sold by the meter at the rate of $20 per horsepower per year, 12 hours per day, with a minimum charge for 25 horsepower. For a 24-hour per day service the charge is $40 per horsepower per year. The tested efficiency of the entire transmission, from shaft of generator to pulleys of motor is 88½ per cent. The cost of the installation so far has been about $125,000.

The plant was started for regular working the latter part of April of the present year.

J. W. Gore.

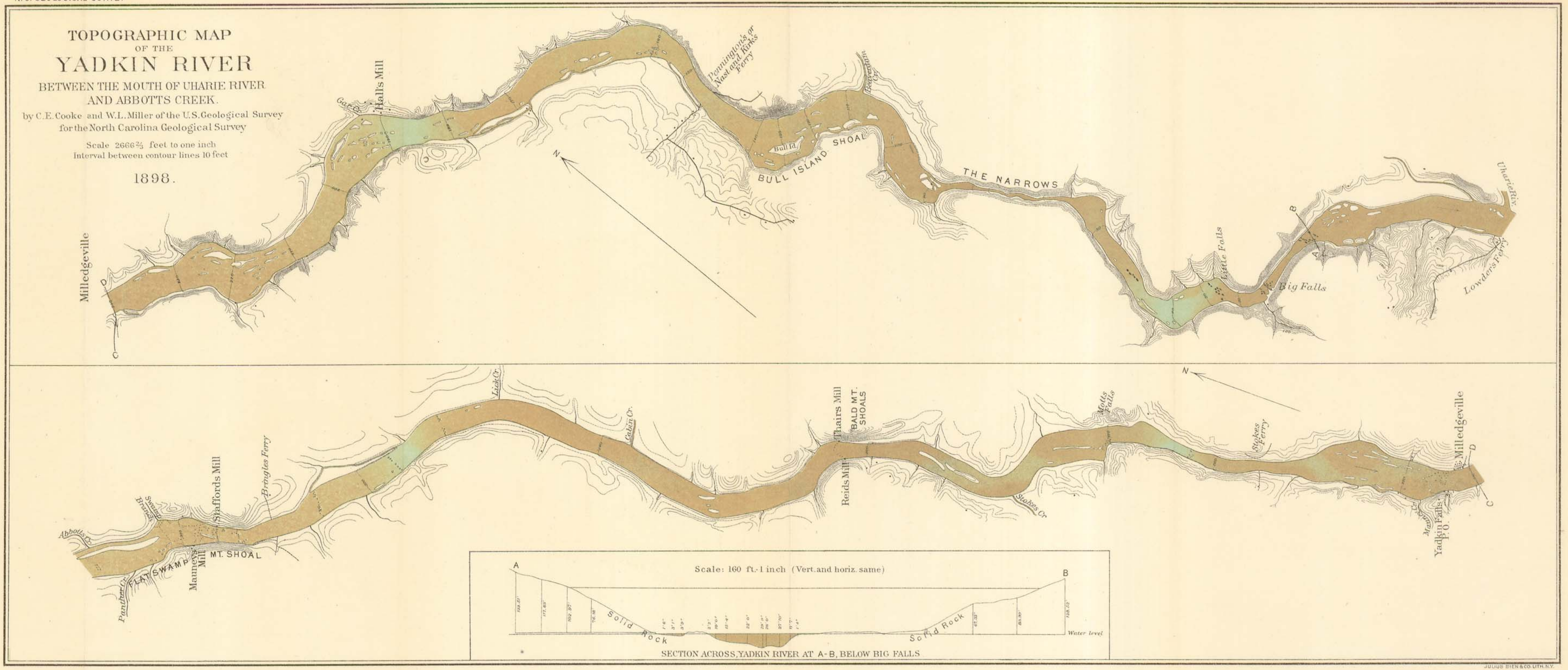
University of North Carolina, *July 6th*, 1898

A—DAM AND POWER-HOUSE, FRIES MANUFACTURING AND POWER CO., ON THE YADKIN RIVER

B.—INTERIOR VIEW, UPPER PART OF POWER-HOUSE, FRIES MANUFACTURING AND POWER CO.

THE GENERATOR IS AT THE FAR END OF THE HORIZONTAL WHEEL SHAFT WHICH IS HERE SHOWN

INDEX.



JULIUS BIEN & CO. LITH. N.Y.