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DENUDATION AND EROSION

IN THE

SOUTHERN APPALACHIAN REGION

AND THE

MONONGAHELA BASIN

BY

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DENUDATION AND EROSION IN THE SOUTHERN APPALACHIAN REGION AND IN THE MONONGAHELA RIVER BASIN.

By L. C. Glenn.

INTRODUCTION.

This report presents a brief summary of the results of an examination of the southern Appalachian region during the field seasons of 1904 and 1905 and of the Monongahela Basin in West Virginia and Pennsylvania in 1907, made for the purpose of studying the effect of deforestation and consequent erosion of the steep mountain slopes on geologic, hydrologic, and economic conditions, both in the mountain region itself and in the surrounding areas through which the many streams that rise in the high Appalachians flow on their way to the Mississippi, the Gulf, or the Atlantic.

In the southern Appalachians a detailed examination was made of an area some 400 miles long, reaching from a point near Pulaski, Va., southward to Gadsden, Ala., and from 75 to 125 miles wide, extending from the valley of east Tennessee, in which Tennessee and Holston Rivers flow, eastward across the mountains and out some distance on the Piedmont Plateau. This area, which comprises about 35,000 square miles, includes a part of southwestern Virginia, the eastern borders of Tennessee, the western part of North Carolina, the northwestern part of South Carolina, the northern part of Georgia, and a portion of northeastern Alabama. In West Virginia and Pennsylvania a detailed examination was made of the entire basin of the Monongahela.

A more cursory examination was made of an additional area comprising about 15,000 square miles of the southern Appalachian region, the work being carried throughout the length of several of the main rivers that head in the region and flow out across the bordering plains. No attempt was made to study the valleys of all of the many tributaries of these streams. Even had such detailed work been possible in the time available, it would not have been desirable, since in any portion of a major stream basin in which the rocks are homogeneous the features of one minor tributary are much like those of any other. Consequently, selected minor stream basins were examined and careful inquiry was made as to others. A comparison of the results of inquiry with the results of subsequent actual observation has served to check the reports and to give, it is believed, an adequate idea of the conditions in the entire area.

It was at first intended to examine only the upper or mountainous portion of the stream basins, but in the course of this work it was found that enormous volumes of cobbles, gravels, sands, and clays were being shed from the steep slopes into the mountain streamlets and were working their way down into the major streams, and that the progress of this material was attended by a train of consequences that are disastrous to the owners of the property along the streams. To determine what ultimately became of all of this material, a study was made of the channels of certain major streams after they had left the mountains and were crossing the plains well on their way to the sea.

Tennessee River was followed to its mouth, over 700 miles, from the mountains at its headwaters. The Coosa-Alabama River was studied as far down as Selma, Ala; Chattahoochee River was followed to a point beyond Atlanta, Ga.; Savannah River down to Calhoun Falls, S. C.; the Broad and Saluda down to Columbia, S. C.; the Catawba 100 miles or more out on the Piedmont Plateau until it had passed the great power plants found along its middle course; the Yadkin from its headwaters along the eastern front of the Blue Ridge far out across the North Carolina Piedmont. New River was examined in detail as far north as Pulaski, Va., and a less detailed examination was made of its lower portion along the Chesapeake and Ohio Railway and its continuation as the Kanawha to below Charleston, W. Va. A

FIGURE 1.—Map showing areas examined.

cursory examination was made of the basin of Elk River, one of the Kanawha's tributaries, from its mouth at Charleston, W. Va., up to its headwaters in northern West Virginia. A detailed examination of the entire basin of the Monongahela River was made, ending with a study of the causes of the disastrous flood of March, 1907, in Pittsburg, Pa. Because of the large proportion of their cleared area kept permanently sodded in grass lands, the basins of New and Monongаhela rivers furnish instructive contrasts, as regards erosion, to the streams farther south, where sodded lands are the exception rather than the rule and where erosion is much more active and destructive.

In examining these rivers attention was centered mainly on their channels and flood plains, but considerable information concerning the country adjacent to their courses was also obtained. The areas included in the examination are shown in figure 1.

Where there were roads and trails travel was mainly on horseback; where these were lacking, as along wild stream gorges or rough mountain sides, travel was afoot. The larger streams in the areas below the mountains proper were traversed by means of rowboat, gasoline launch, or river steamer. The region adjacent to nearly every railway in the region was also examined.

It is believed that no important body of facts bearing on the subject of the inquiry escaped notice and that the frequency of recurrence of the conditions noted affords a fair measure of their relative importance as factors in the changes now in progress in the region.

Personal observation was supplemented by inquiries made of county officials who were familiar with local conditions or whose duty it was to maintain roads and bridges or assess the valuation of lands damaged by erosion or by floods.

Much information was also obtained from lumbermen, land owners, and manufacturers, from officers of power, mining, and railway companies, from river men, including captains and pilots of river steamers, and from the United States Army engineers engaged in river improvements in the region. To all of these the writer's indebtedness is gratefully acknowledged.

PHYSICAL FEATURES OF THE SOUTHERN APPALACHIANS.

TOPOGRAPHY.

From the Virginia-North Carolina line the Appalachians extend southwestward 250 miles to northern Georgia, where their ridges almost die out, but farther southwest they rise again and extend some distance into Alabama before they finally disappear. The Appalachian belt proper varies in width from 50 to 70 miles.

The mountains rise from a base that ranges in elevation on the southeast side from 1,000 to 1,200 feet above the sea, and on the northwest side from 900 feet in northwest Georgia to 1,600 feet on the Tennessee-Virginia line. The mountain belt proper is really an elevated plateau walled in on its western margin by a higher mountain range from which numerous short spurs project out upon its general surface. Here and there on the plateau are other short, isolated ranges, one of which, the Black Mountain Range, includes Mount Mitchell, which rises to an elevation of 6,711 feet and is the highest point east of the Rocky Mountains. More than forty peaks rise above 6,000 feet. Almost a hundred square miles are above 5,000 feet, and almost half of the North Carolina portion is above 3,000 feet in elevation. Part of the eastern edge of the plateau is marked by peaks that rise above its general surface level and part by an abrupt escarpment that overlooks the Piedmont Plateau to the east. This eastern edge of the mountain plateau region is called the "Blue Ridge." The general surface of the mountain plateau has been carved by streams into a multitude of hills and minor ridges, and in this region most of the highest areas lie between the headwaters of adjacent major streams, where erosion is and has always been least efficient in lowering the general surface level.

The mountains generally have well rounded soil-clad slopes that show softened outlines. Only here and there do they present abrupt slopes and sheer precipices of bare rock. The profiles are the flowing curves that are characteristic of mature or old mountains rather than the abrupt lines of young mountains.

The higher summits afford magnificent views of wooded mountain slopes with softly rounded outlines or of fertile coves and valleys dotted with fields and homes. Along some river gorges, such as the Linville, the Nolichucky, the Doe, the Big Pigeon, the Nantahala, the Ocoee, the Tallulah, and the Broad, the mountain walls in many places rise in sheer precipices and the scenery is wild and rugged; along others, such as the New, Watauga, French Broad, Little Tennessee, Hiwassee, Etowah, Saluda, Catawba, and Yadkin, it is usually less wild and rugged but equally picturesque and beautiful.

Except along the river gorges there is usually little in the landscape that is rough and rugged, because deep disintegration has almost everywhere mantled the rock with a soil covering that gives to the surface smooth instead of jagged outlines.

GEOLOGY.

The rocks of the region are principally gneisses, schists, and granites, but include smaller areas of quartzites and limestones, especially in the western part, and volcanic rocks in the northern part. All are ancient, and in many places they have been much folded, crushed, and distorted or have been broken and faulted. In the course of the movements that produced the distortions many new minerals have been formed in the rocks by chemical rearrangement or have been brought into them in solution by circulating water or gases and deposited in cracks and fissures.

Not only are the rocks all ancient, but they have been so long exposed to weathering that they have been deeply rotted, and in most of the region the residual material covers the solid rock, forming in places a layer many feet deep. This disintegrated rock, when protected from erosion, absorbs much of the rainfall and afterward feeds the water slowly to the streams, thus regulating the stream flow by preventing floods when heavy rains fall and excessively low water when dry seasons come.

DRAINAGE.

The region is drained by a multitude of streams whose waters flow to the Ohio, the Tennessee, the Gulf of Mexico, or the Atlantic. The Blue Ridge, lying along the eastern border of the mountain belt, forms the main divide and contains the sources of the principal stream systems of the region. New River occupies the northern part of the area under consideration and flows northwestward, joining the Ohio as the Kanawha. South of it are the Holston, Watauga, Nolichucky, French Broad, Big Pigeon, Tuckasegee, Little Tennessee, Hiwassee, and Ocoee, all flowing westward and forming a part of the Tennessee system. From the southern end of the Appalachians the Coosa and the Chattahoochee flow southwestward into the Gulf of Mexico. The Savannah, Saluda, Broad, Catawba, and Yadkin rivers rise on the steep eastern face of the Blue Ridge escarpment and flow southeastward into the Atlantic.

The drainage from the southern Appalachians is thus radial and far-reaching, and the flow of the streams directly affects the industries and welfare of the people in much the larger part of the southeastern United States.

Most of the small headwater streamlets rise high on the steep mountain sides, flow in narrow gorges, and descend in a few miles by a series of falls and rapids to an elevation between 2,000 and 3,000 feet, uniting to form larger streams, which, as a rule, flow without much additional fall across the middle part of the mountain plateau in broad, open valleys with gently to steeply rounded slopes, but which invariably cut deep, narrow gorges through the chain that forms the western rim of the mountain plateau. Most of the small tributary streams in the middle part of the plateau have considerable fall.

Water powers of 10 to 50 horsepower exist in almost every part of the region, and a series of small mills may be found along a single small stream. Few of the larger streams have sufficient fall to afford much power until they enter the gorges by which they leave the mountains, where their fall is mainly concentrated and where power may be developed in large units.

FORESTS.

The entire region, with the exception of a few high "balds" and an occasional steeply rounded scarp or precipice of bare rock, was originally covered with forests which were remarkable for the extraordinary size and height and the wonderful variety of the trees. About 74 per cent of the area is still forested, but large areas have already been stripped of much or all of their valuable timber by reckless lumbering, forest fires, and agricultural butchery.

Around the southern end of the Appalachians short-leaf yellow pine forms a considerable part of the forest, but elsewhere the cover consists of walnut, cherry, poplar (or tulip), oak, chestnut, hickory, and many other species on the lower and middle slopes; beech, hemlock, and white pine on the higher slopes, and spruce and balsam at greater heights. The trees are larger and more perfect on northern slopes and in coves, where the soil is moister, deeper, and richer. On southern slopes the soil is likely to be dryer and to contain less humus and consequently to be less fertile. The forest there is more open, and both the trees and undergrowth are more stunted. These southern slopes, especially along the Blue Ridge, are in many places steeper also, and these characteristics all combine to make them more liable to erosion. On lands once cut over reproduction of the forest is generally rapid, provided the soil layer has not been removed by erosion before the new growth has had time to establish itself. In a similar way abandoned old fields that have not been denuded of their soil rapidly grow up again.

These southern Appalachian forests form to-day the largest and most valuable hardwood area left in the United States and if properly cared for they may be made the permanent source of our national hardwood supply.

CLIMATE.

The average rainfall in the northern and northwestern parts of the region is in places only 40 to 50 inches a year, but on the southeastern slopes of the Blue Ridge the annual rainfall is greater than in any other part of the United States except the North Pacific coast. The average rainfall in this part of the southern Appalachians is 70 to 80 inches, and the yearly maximum exceeds 105 inches. The rainfall is not uniformly distributed throughout the year, but reaches a maximum either in July and August or, less commonly, in February and March. In summer much of it is torrential in character and the downpours may continue several days. Not unusually it rains 20 or 25 days in a month, and a month's precipitation may reach or exceed 30 inches, and the rainfall in a single day may be as much as 9 inches. In winter a considerable amount of the precipitation is in the form of snow, and by its slow melting this snow, which remains on sheltered northern slopes for some time after it has disappeared in the valleys below, aids greatly in regulating the stream flow.

The climate of the region is much cooler than that of the Atlantic slope to the east or the Mississippi Valley to the west; it is not, however, the same throughout the entire mountain region. Areas close together may differ in elevation more than 5,000 feet and their average temperatures may show differences as marked. On the higher peaks the vegetation is of Canadian type. The northern part, in North Carolina and Virginia, is considerably colder, even at the same elevation, than the southern end, in Alabama. The southern and southeastern slopes are sheltered by the higher crests and chains from the cold waves from the interior of the continent and have a milder and more equable climate than have the northwestern slopes, which are more exposed to cold waves and hence show greater temperature variations than the southeastern slopes. In summer the temperature may fall as low as 40° on the mountain tops, or may rise to 75°, 80°, or 85° in the valleys. From December to March the temperature anywhere in the mountain region may drop below zero for a day or two at a time, and minimum temperatures of —10°, —15°, and —19° F. are recorded for the region. The mean monthly winter temperature for stations at elevations between 3,500 and 4,000 feet ranges from slightly below the freezing point to several degrees above.

In summer it is warm everywhere in the direct rays of the sun, but is cool in the shade, and the nights are cool enough to make blankets necessary. It is said that on some of the higher plateaus in the northern part of the region frost has been known to occur every month in the year. In winter the climate is cold and dry enough to be bracing, but is not harsh and trying, even for delicate constitutions.

The average humidity is not so great as in the surrounding region, but the average rate of wind movement is greater. Direct evaporation is consequently more active than on the plains.

The following table gives the monthly precipitation and mean temperature for a number of selected stations in the region.

Average temperature and precipitation at selected stations.

		January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual average.
Linville, N. C. (12 years)	t.	31	30	40	46	58	63	66	65	59	49	40	32	48°
	p.	3.4	5.3	6.1	4.6	3.7	5.3	6.1	5.2	5.6	5.3	3.9	5.7	60.2″
Lenoir, N. C. (31 years)	t.	37	40	46	56	65	72	75	74	66	56	46	38	56°
	p.	4.1	4.5	4.6	3.8	4.7	4.6	4.9	5.9	4.5	3.4	3.2	3.8	52″
Waynesville, N. C. (10 years)	t.	37	36	48	52	62	68	70	70	64	54	46	38	54°
	p.	4.3	5.1	6.4	4.1	3.7	4.4	4.6	4.5	2.4	2.1	2.5	3.6	47.7″
Asheville, N. C. (24 years)	t.	38	40	46	54	63	69	72	71	65	54	45	39	55°
	p.	3.0	3.7	4.2	3.4	3.5	4.1	4.9	4.6	2.9	2.6	2.7	3.0	42.6″
Highlands, N. C. (21 years)	t.	34	35	42	50	58	65	67	66	60	51	42	35	50°
	p.	6.2	8.5	7.8	6.5	4.4	6.9	6.8	7.6	5.8	5.2	5.6	6.9	78.2″
Clayton, Ga. (10 years)	t.	40	39	50	56	66	72	75	74	68	57	48	40	57°
	p.	5.9	7.4	7.8	6.3	3.2	5.3	7.0	7.2	4.9	4.0	3.9	5.6	68.5″
Dahlonega, Ga. (10 years)	t.	41	41	50	58	67	73	75	75	70	60	50	42	58°
	p.	5.3	7.0	6.4	4.3	4.2	5.5	5.9	5.5	4.5	3.0	3.0	5.3	59.9″
Elizabethton, Tenn. (p. 14; t. 15 years)	t.	37	37	46	55	65	73	76	75	68	57	46	38	56°
	p.	2.9	3.5	4.6	3.4	4.4	7.2	4.6	4.1	2.7	2.2	2.4	3.2	45.2″
Knoxville, Tenn. (33 years)	t.	38	41	48	58	66	73	76	75	69	58	47	39	57°
	p.	5.1	4.9	5.6	4.7	3.8	4.2	4.1	4.1	2.9	2.6	3.6	4.1	49.7″
Newport, Tenn. (t. 8; p. 13 years)	t.	38	40	48	57	66	74	77	76	69	58	46	38	57°
	p.	3.6	4.3	5.4	3.6	4.1	4.2	4.3	4.4	2.2	1.8	2.6	3.1	43.6″

t.=temperature, °F.; p.=precipitation in inches.

POPULATION.

The population of the region as a whole averages between 30 and 40 to the square mile. Taken by counties, it ranges from 15 to 75 to the square mile. Most of the towns are small, and the population is in the main rural. In the towns a small proportion of it is colored; in the country it is almost exclusively white and of native parentage, composed of the descendants of the pioneers of the colonial days. Very few foreigners live in the region.

The settlers are most numerous in the valleys, on the low rolling hills of the Asheville Plateau, and in the little coves that nestle among the high mountains, but many isolated cabins, surrounded by small clearings, are found far up on the steep slopes of such of the higher peaks and ridges as have a fertile soil. The more rocky and barren slopes are entirely uninhabited, and one may travel for miles across some of the wilder mountain areas without seeing a cabin or a clearing.

TRANSPORTATION.

RAILWAYS.

Considered as a whole the railway transportation facilities of these mountains are poor. Many of the settlements are 20 to 35 miles from the nearest railway, and this distance in some areas must be traversed by rocky paths or poor mountain roads. One railway crosses the mountains from east to west about midway their length; another crosses their southern end, and these two lines are connected by a line, some 150 miles long, that runs lengthwise along the mountains. Several small lines have been extended into the mountains, and two others are now under construction across them from northwest to southeast. For large lumbering operations narrow-gauge railroads or tramways have been built, and some of these become permanent. Many parts of the region, however, will be remote from transportation lines for years to come.

ROADS.

Very few of the wagon roads have been graded or otherwise improved, so that hauling by wagon is generally slow, difficult, and expensive, yet the price of lumber has become so high that in many places it is hauled 15 to 25 miles, and within this distance of the railways most of the good lumber has been cut. As the price rises the practicable hauling distance steadily increases.

RIVERS.

The streams are utilized to some extent for floating logs; otherwise there is no river transportation within the region itself, though many of the streams that flow out from the mountains unite on the plains to form navigable rivers. New River joins the Ohio. The Holston, French, Broad, Little Tennessee, and Hiwassee, which are navigable in their lower courses through the valley of east Tennessee, form Tennessee River, which is navigable 650 miles, from Knoxville to its mouth, and touches in its course Tennessee, Georgia, Alabama, Mississippi, and Kentucky. The Oostanaula, Coosawattee, and Etowah, which flow from the southern end of the mountains, become navigable soon after leaving the mountains and unite to form the Coosa, the main head member of the Alabama River system, which is now navigable from Rome, Ga., to below Gadsden, Ala., and when the system of locks and dams now under construction is complete will become navigable down to the Gulf at Mobile. The lower courses of all of the main rivers on the eastern side of the mountains become navigable at the outer edge of the Piedmont Plateau.

RELATION OF INDUSTRIES TO EROSION AND DENUDATION.

AGRICULTURE.

The population is largely agricultural. In the higher mountains grasses grow well and grazing is an important industry. Much of the cleared land there is kept in grass and so is prevented from washing badly, but some of the cleared slopes are so steep that even though kept in grass they soon erode to the bare rock and become useless wastes. During prolonged wet weather the turf and soil become thoroughly softened, and on steep slopes the hoofs of the cattle easily break the turf and start small landslides that quickly develop into gullies. Some of the so-called balds, once well sodded, have become bare, rocky wastes from erosion induced by the trampling of cattle. This conversion of sodded balds into rocky wastes is actively in progress to-day on the top of Roan Mountain.

When first cleared, the land is usually planted in corn for about two or three years, is then for two or three years put in small grain or grass to be mowed—not grazed—and then back into corn for several years. Unless it is well cared for the land has by this time become poor, for it has lost its original humus. The soil has become less porous and less able to absorb the rainfall and erosion begins. Means are rarely taken to prevent or check this erosion, so it increases rapidly and the field is soon abandoned and a new one cleared.

When the clearing is intended for grazing, the preliminary rotation practiced by the more progressive farmers is nearly the same. Corn is planted 2 years, then meadow for 2 years, then corn a year, then grass for permanent pasture. This first pasture sod usually lasts 8 or 10 years, when the land is again put in corn for a year, then oats and grasses are sown, and the sod is again as good as the first one. When properly cared for and not too steep, grazing land should be capable of indefinite use. The erosion of such lands is due chiefly to ignorance and neglect, and the remedy is not reforestation but education. Grazing lands, however, comprise but a small part of the entire area of cleared land, which has recently been estimated by several investigators at 24 per cent of the total mountain area. The writer believes that this estimate is approximately correct, but that it errs, if at all, in slightly overstating the cleared area.

In clearing land only the undergrowth and small trees are as a rule removed. The large trees are killed by girdling and left standing. Many fields are worn out and abandoned before the trees girdled in its clearing have all fallen. Then new grounds are usually cleared beside the abandoned field and the same destructive process is repeated.

The clearing of virgin forests for agriculture is going on steadily from year to year to replace worn-out, eroded, and abandoned lands. When the region was settled, the more level lands along and near the streams were first cleared and those that have been properly cared for and are out of the reach of the stream floods have remained in cultivation and are in good condition to-day. After these lands had been largely cleared the steeper slopes were next invaded by the axman and then still steeper slopes, so that very much of the land now being cleared is too steep for cultivation under present farm practice and should be kept in forests.

Numerous attempts have been made to estimate the percentage of the area of these mountains that might safely and profitably be cleared for cultivation. These estimates average about 15 per cent. It is difficult to give any definite estimate of such area, for the allowable limit of slope of lands that may be safely cleared—which is generally put at 10° and which alone has usually been considered—is not the only factor of the problem, for the nature of the soil, which is dependent on the geology of the underlying rock formations, and the intelligence and care of the cultivator should also be considered. On some soils 10° may be the maximum slope for safe cultivation; on other soils slopes of 20° do not wash. Slopes themselves may be changed by terracing, and education may so greatly increase the intelligence and care of the cultivator that estimates of cultivable area that consider these varying factors must of necessity vary, and the variation tends to increase the estimate of cultivable area as time passes. The increase, however, must be slow, and for present methods of cultivation 18 to 20 per cent is probably a liberal estimate for the area that may be cleared safely. The present cleared area, 24 per cent, is undoubtedly in excess of the limit of safety under the existing conditions of agriculture.

Tobacco growing has in the past been peculiarly injurious to the soil. The plant requires clean cultivation, and when planted year after year soon exhausts the fertility of the soil, depletes the humus, and leads to erosion and early abandonment. Some 15 or 20 years ago tobacco growing became quite profitable in some sections and lands were rapidly cleared, worked in tobacco a few years, worn out, and abandoned. The effect of this clearing and cultivation on the streams in general will be discussed later.

LUMBERING.

Lumbering has been so active in this region that practically all the timber that is easily accessible to the railway or to streams large enough to float it has been cut. As prices of lumber have advanced the mills have been moved farther back from the railroads until now a part of the product of the small mills is hauled 15 to 25 miles over rough mountain roads, and the owners of the larger mills have built their own logging railways or tram roads back into the heart of even the more distant mountains.

Most of the valuable timber has already passed into the hands of lumbermen, who are now actively buying lands in even the most remote and almost inaccessible localities. Prices of timber lands are rapidly advancing, and if cutting is continued at the present rate the primeval forests of these southern mountains will soon be a thing of the past.

A few large forest tracts are being preserved by private individuals or corporations or are being lumbered according to modern conservative methods, but except in these few areas lumbering is carried on so as to yield the largest possible immediate returns without thought or care for the future.

In recent years a number of large tanneries and several tanning-extract plants have been established in the region, and these insure the destruction of most of the chestnut, chestnut oak, and oak left by the lumbermen. Recently, also, one of the largest wood-pulp plants in the country has been built in the region and has begun to strip the forests and to pollute the stream on which it is located.

Forest fires may follow in the wake of the lumberman and complete the destruction of the young growth, and the blackened waste may be abandoned to the county as not worth paying taxes on. In many places destructive forest fires have not occurred and there the young growth retains possession of the land and begins the production of a second crop of timber, though only a few of the lumbermen in the region are looking ahead far enough to count this second crop as an asset of any value. Very many of them would part with the land for a small price when they have once thoroughly lumbered it.

MINING.

The southern Appalachians are noted for the great variety of their mineral deposits. Although many of these have never been developed, others, such as the deposits of gold, copper, marble, mica, corundum, talc, asbestos, slate, baryta, and kaolin, have become the basis of important mining operations, and annually yield mineral products to the value of several million dollars.

Mining is affecting erosion in several ways, one of which is locally important. The timbering required in underground mining creates a demand for mine props and other timbers. So far this has not been a serious menace to the forests, partly because underground mining operations are not generally extensive throughout the region and partly because the rocks are ancient crystallines that below the limit of surficial weathering are strong enough to stand without much timbering.

Much of the mining, especially of gold and monazite, is of the placer type. The gold mining is centered chiefly around Dahlonega, Ga. Stream gravels are washed to some extent, but mining is most active in the saprolite or surface rock that, though decomposed, is still in place. Entire hillsides are washed down into the streams by hydraulic giants. Careful examination and inquiry, however, failed to show that much damage is being done along the streams within the Dahlonega region itself as a result of this placer mining, partly because there are in most places little or no bottom lands susceptible of cultivation, but chiefly because most of the streams have much fall and sweep away the sand and clay as fast as the mines furnish it, or the frequent floods carry away any material that tends to lodge along the streams. Much of it lodges farther out along the Piedmont part of the streams, where their grade is less and their transporting power is correspondingly reduced, and there it may aid in doing damage.

In the Dahlonega region very little of the upland is cleared and the normal amount of waste furnished to the streams from agricultural lands is small. The streams are consequently able to transport the additional waste furnished by the hydraulic mines; but should the clearing of uplands be extended, as is to be expected, the increased agricultural waste, together with the mine waste, will soon overload the streams and cause the accumulation along their courses of sand and clay which they would then be unable to carry.

Dredging for gold is carried on in some of the streams of the Dahlonega region and large quantities of stream waste are moved in this way. The effect on the stream channels and on the adjacent bottom lands depends on the extent of the pay gravel and on the mode of disposing of the tailings. Where pay gravel underlies the bottoms they are worked and their future agricultural value is largely or entirely destroyed.

After the streams have left the Dahlonega region their slopes and velocity decrease and the waste carried out from the mining region is being deposited along the way, filling the stream channels, lodging on bars, and causing islands to form, thus further obstructing the channels and making overflows easier and the destruction of the bottom farming land more speedy, certain, and complete. With the further clearing of lands that may normally be expected this condition will become constantly worse.

The third and most injurious kind of mining studied in the region is that at Ducktown, Tenn., where sulphur fumes from the roasting and smelting of the copper ores have killed all vegetation for a number of miles around and the perfectly bare surface has eroded with wonderful rapidity (see pp. 24–25, 78–79).

POWER DEVELOPMENT.

Careful estimates made by competent engineers show that the streams of the southern Appalachians afford, in units of considerable size, about 3,000,000 undeveloped horsepower, and probably as many more in small units suitable for a great variety of minor industrial uses. Nearly all of the water power in the mountains has heretofore remained undeveloped because of its inaccessibility, but since the electrical transmission of water power has been made practicable, its utilization has become possible. As the opening of new railroads through the mountains renders the water powers more accessible, as population steadily increases and turns for a livelihood to new avenues of industrial activity, and as cotton mills and other manufacturing enterprises in the South utilize the available power sites in the Piedmont, the demand for this mountain stream power must yearly increase and will naturally lead to its utilization. At any reasonable valuation per horsepower the undeveloped power of these mountain streams is an important industrial asset. In Georgia and the Carolinas more than 100,000 horsepower has been developed and is being used by cotton mills alone, and public-service corporations in these three States are to-day developing 300,000 to 400,000 additional horsepower to turn the hundreds of mills and light the many towns and cities in the region. One of these power plants is shown in Plate I (opposite) and views of others are given in Plate XII, *A* and *B* (p. 36). In the operation of the power plants already constructed and in the financing and building of those yet to be developed the erosion problems of the region are becoming important factors, deserving serious consideration.

From the slopes along these streams a steadily increasing amount of waste is working its way down their channels, filling the dams and destroying their storage capacity; and this loss of storage means a decrease of efficiency that is calculated by the most experienced mill engineers to amount to 30 to 40 per cent in plants that have been built especially for storage and a somewhat less marked decrease in other plants, the exact amount depending on the topography of the basin and the régimen of the particular stream on which the plant is located. So universal is this silting of storage basins that a prominent mill engineer of wide experience in his reports on the construction of power plants no longer calculates on power or on anything except the flow of the stream, and he has increased his usual construction estimates by an allowance for increased storm waters that must be taken care of without endangering the dam or plant.

Experience has shown that storage basins constructed in this region in recent years are rapidly filled with sand and silt, through which the stream maintains a channel only large enough to carry the ordinary flow. On a few streams diversion dams without storage furnish the most economical development, but the dams at most of the cotton mills have been built to store water over night or over Sunday, and at one dam, at least, the original storage capacity was sufficient to hold a week's ordinary flow.

At one large plant storage basins that originally had capacity to hold the water accumulated by several days of ordinary stream flow have been so filled that they can not now hold even the flow of a single night. When the filling first began to cause serious trouble efforts were made to keep the material dredged out with centrifugal pumps, but the cost was soon found to be prohibitive. It has been necessary to maintain this dredging plant, however, in order to keep the channel to the wheel pits open.

At one dam where two years before, when the dam was first closed, there was a depth of 28 feet, an island had recently appeared. At another place, where a high dam had been built on a small stream, the pond has been so filled that its storage capacity has all been lost. At another place a pond in the Spartanburg region, cleared out by the bursting of a dam in the flood of June, 1903, and since rebuilt, was in 1905 again almost full of sand and silt. A pond about 4 miles long and 40 feet deep at the lower end was in four years entirely filled in its upper part and near the dam was three-fourths full. Another pond, seven-eighths of a mile long and 35 feet deep, filled within 300 feet of the intake gates in less than two years.

On one river eight dams were built within a few miles of one another. The upper pond soon filled with sand and clay; then the second; then the third; soon all the rest will be filled. The mills can then utilize only the unregulated stream flow. Auxiliary storage reservoirs built on the stream above the power plant have filled completely with sand and silt and are useless.

Wide ponds fill most rapidly because the current through them has less velocity. In other words, they act as settling basins. Long, narrow ponds fill less rapidly because of the greater velocity of current through them, and they scour out more during floods.

All the power plants recently built practically ignore storage and depend on the flow of the stream only. When sluicing out is attempted the stream cuts merely a vertical walled

COLUMBUS POWER COMPANY'S PLANT ON CHATTAHOOCHEE RIVER AT COLUMBUS, GA.

See page 14.

channel down through the material and removes only enough for a channel way. The expense of dredging has been found to be prohibitive. The dredge merely keeps open the way to the wheel pits.

Another result of erosion is the greater frequency, greater suddenness, and greater height of the floods, since the run-off from bare washed slopes is more rapid than from wooded slopes. These floods endanger dams and property of all kinds within their reach. During a single year recently the flood loss in these southern mountains reached some $18,000,000, and during the succeeding year the loss was about $9,000,000 more.

Still another result is a change in the normal stream flow. When so large a proportion of the rainfall rushes at once into the streams and is carried away, a correspondingly smaller proportion is left to soak into the ground and feed the springs that sustain the stream flow during periods of no rainfall. The flow of the springs is weakened, and low water in the streams follows more rapidly after floods than it formerly did. The period of high water is shortened and made abnormally high; the period of low water is correspondingly lengthened and made abnormally low.

NATURE, EFFECTS, AND REMEDIES OF EROSION.

PROCESSES.

Erosion may conveniently be regarded as of two kinds. One kind occurs along streams as a result of either normal or flood flow and may be called stream erosion; the other kind occurs over all other parts of drainage basins and may be called general surface erosion.

In the humid regions stream erosion results from the activities of the perennial streams, large and small, and hence is a continuous process, though its effects vary greatly in intensity, being at a minimum during low-water stages of the streams and at a maximum during flood periods. Its work is restricted to that portion of the basin within reach of the flood waters, or, in other words, to the flood plain. Stream erosion involves the transportation of the eroded material and the deposition of much of it along the reaches of lower slope and lessened velocity. During a single great flood a stream may first cut great runways across its flood plain or dig great holes in it, and then, in later stages, deposit upon it a thick covering of sand and bowlders.

General surface erosion results from the complex interaction of a number of forces, chief among which are the various atmospheric agencies, producing rock disintegration and decomposition and preparing the material for removal, and the more active effect of the rainfall striking the ground. The steepness of the slope, the nature of the soil, and the forested or cleared condition of the surface are also direct factors. In the region under consideration the actual erosion or removal of surface materials is due almost entirely to the work of the rain as it gathers into rills and rushes down the surface slopes to join the permanent streams. General surface erosion is therefore most active in periods of rainfall, and might be regarded as an intermittent rather than as a continuous process. This view, of course, disregards the erosive activity of the wind, since it is unimportant in a region like the southern Appalachians, and the slow but more important creep of the surface material down the slopes, due to freezing and thawing and to the action of plants and animals.

During heavy rainfall a grass sod will absorb less water than a good humus cover in a forested area and run-off from the grass land will therefore be greater than from the forest, and flood heights in areas left in grass must show a corresponding increase. ///

EROSION IN FORESTED AREAS.

In forested areas general surface erosion is at a minimum. The force of the blow struck by the raindrops is lessened by the forest cover, and, indeed, very many of the drops do not strike the ground at all, but hit the litter of fallen leaves and twigs or the mat of moss or other low vegetation that completely carpets and conceals the soil surface. The forest soil is thus effectively protected from the blows of the raindrops that would cause the loose soil on the bare surface of a freshly plowed field to melt away like snow before a summer sun.

As the fallen drops gather to flow down the slope they are checked in their movement by the leaves and litter or they are absorbed by the spongy mass of soft moss or turf, so that very much of the rainfall flows slowly and gently down beneath the actual surface and within or through the matting of leaves and moss. The movement is so gentle that scarcely any soil particles are removed, and so slow that for hours after a rain has passed the soil covering is filled with water and even days later is still moist.

This protective effect of the forest cover was observed by the writer many times while he was at work in the region. Forested surfaces showed no signs of erosion; bare gullies or other indications of general surface or sheet wash were notably absent. The bottoms of the gullies in many forested areas were covered with leaves, soft vegetable mold, or moss, and the vegetation growing in them showed that though some material was being removed along their immediate courses, this removal was proceeding at an exceedingly slow rate. A small gully under these conditions is evidently the result of long years of erosive activity. Indeed, under conditions of a stable forest cover the gullies or channels for the removal of surface rainfall doubtless slowly assume a slope and width that are in adjustment with the usual intensity of rainfall, and when this adjustment is once established the woodland rain-water channels become stable and would change exceedingly little, perhaps, even in hundreds of years, were it not for an occasional cloud burst or storm of extraordinary intensity which furnishes them a volume of surface water with which their cross section and slope are not commensurate. At such times erosion takes place along their courses and holes may be gouged out that during succeeding years once more become clad with vegetation.

In the course of the long geologic ages that these southern Appalachians have been subjected to atmospheric erosion there has come about, in all but a very small part of the area, such an adjustment between the steepness of the forested slope and the average rainfall and other erosive agencies that the wasting of the slope is reduced to a minimum. In places where the surface may have once had excessive slope erosion was rapid and the slope was gradually reduced; with lowered slope erosive power decreased until the two were brought into harmony. The material prepared by disintegration and decomposition for erosion then became just equal to the removing capacity of the erosive agents, and somewhat later, with further decrease of slope and of erosive power, more loose material was furnished than could be removed and it began to accumulate and form a soil covering. This soil covering has continued to increase in most of the area until now it is many feet deep over much of the region and mantles and conceals the underlying hard rock from which it has been derived.

This long-continued process of adjustment between surface slope and erosive action has given these mountains the rounded contours and softened outlines that characterize the southern Appalachian landscape and constitute one of its chief charms. Jagged ridge crests have long since become rounded domes and vertical cliff faces have given place to the gently flowing outlines of graded, forest-clad slopes. Cliffs are rare and are due to some rapid change in rock texture or structure or to a situation especially favorable for stream erosion.

On these graded forested slopes the removal of the soil cover of disintegrated material is perhaps due more to soil creep than to direct surface erosion, and it is probable also that under such conditions soil creep reaches its maximum of efficiency as an agent of general surface reduction. Movement of the soil layer due to such creep is necessarily slow, does not result in producing bare earth or rock surfaces and is not attended with danger to the surface, the forests, or the future industrial development of the region.

Streams that flow from such forest-clad graded slopes show certain well-defined characteristics. During rains they rise more slowly than similar streams in cleared areas; they also continue longer in flood and fall to normal stages again more slowly because of the retardation of the surface run-off by the leaves and litter of the forest.

Such streams, even when highest, are, as a rule, only slightly discolored, and this discoloration is due largely to macerated leaf fragments and decaying organic matter and only to a very

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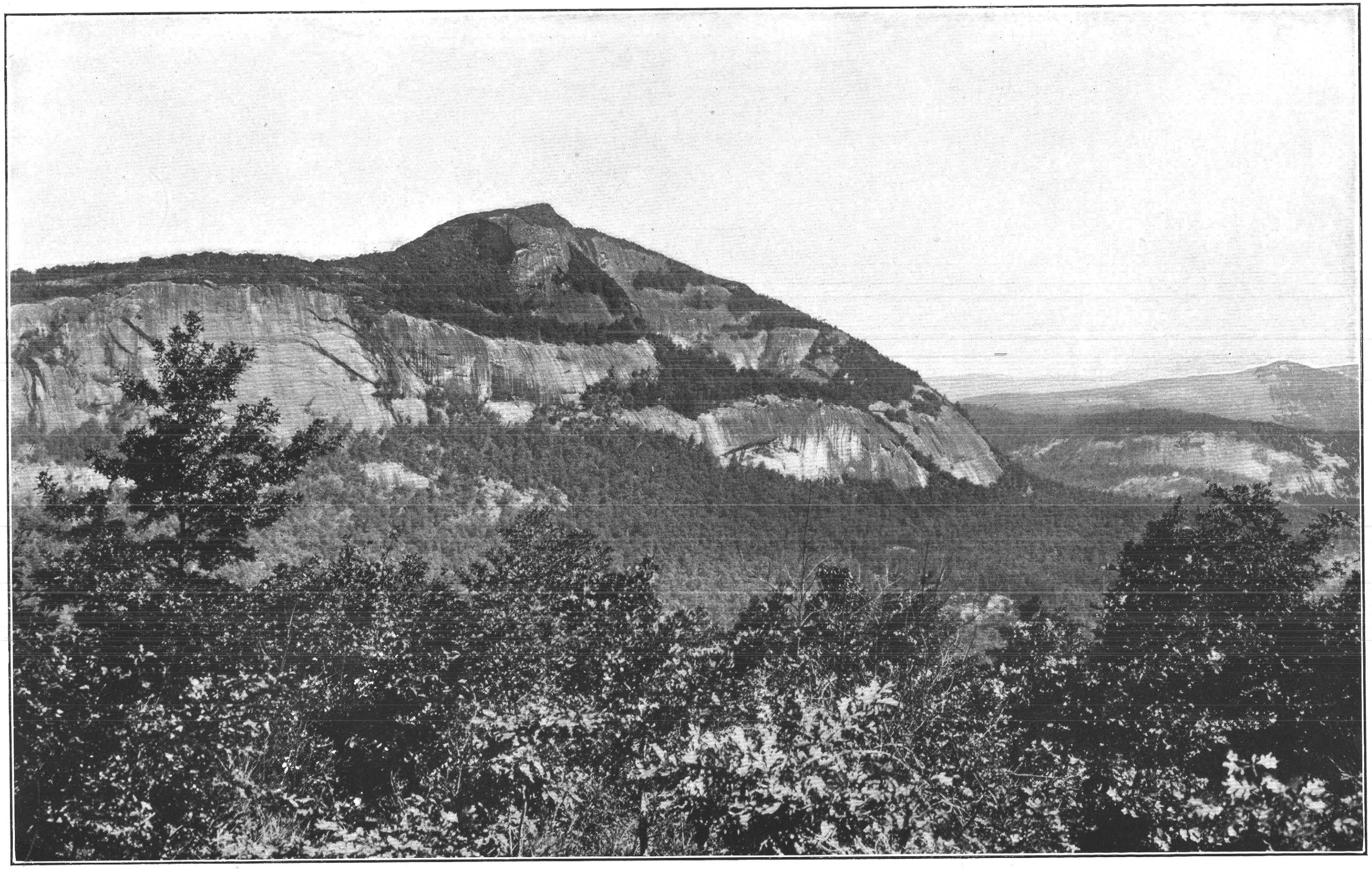


SOUTHEAST FACE OF WHITESIDE MOUNTAIN, SHOWING ROUNDED PRECIPICES OF ROCK.

Much of the rock is bare and part of it is covered by a thin layer of soil held on the rock only by the mat of forest roots. See page 17.

slight extent to soil particles held in suspension. Some of the streams flowing from forested regions are perfectly clear, even when swollen by continued rains far beyond their normal size. Such, for example, are many of the streams in the Toxaway region, the headwaters of Pigeon River, the numerous small streams flowing from the Balsam and Great Smoky Mountains, the headwaters of Cane River flowing north from Mount Mitchell, and others that might be mentioned whose basins are unbroken forests.

Streams of this class carry almost no load of waste from the general surface of their basins and so are free to expend their energies in eroding materials from their bed and banks. Hence over all the territory examined such streams were generally found to have scoured their channels between steep and usually high banks, to be flowing over beds of cobbles and bowlders or across ledges of hard rock, and to have gouged out deep and quiet pools here and there in softer rock. Such stream channels change slowly. They are in stable equilibrium—an equilibrium or adjustment which would remain undisturbed for ages, during which the region would continue to waste away as slowly as in the past, were it not for the work of man in clearing the land and throwing out of equilibrium both the surface slopes and the stream gradients.

The removal of the forest brings the slopes that represent the adjustment of a forested surface to erosive agencies into unstable equilibrium, active erosion begins, the soil accumulated, it may be through centuries, is quickly swept down into the valleys, and the mountain side is left a scarred waste of bare rocks and bowlders. For such areas the only safety is the retention of the forest now there, for once removed neither the soil nor the forest cover can be replaced.

Bare rock surfaces are more numerous in granite or granite gneiss areas along the eastern face or scarp of the Blue Ridge than elsewhere in the southern Appalachians. Such, for example, are the surfaces of Table Rock, S. C., Mount Whiteside (Pl. II, p. 16), and numerous other bare, steeply domed or precipitous rock scarps in the Highland-Toxaway region, in the Hickory Nut Gap region and at other places northward. Rock surfaces of the same type are also found in the upper Davidson River country and at a few places elsewhere in the region west of the Blue Ridge. These granitic rocks weather spheroidally, and wherever erosion produces very steep slopes the surface soil and underlying rotten rock tend to shell off and leave a bare domed or precipitous granite surface. In these particular areas, where this tendency is so strong that nature has not been able wholly to counteract it, it would be especially regrettable should man cut away the forests which, even when unhindered, are scarcely able to hold a soil covering, and thus permit the few feet of soil now overlying the granite or gneiss to be swept away, as it would be swept away in a few years after extensive clearing, down to the bare rock.

The effectiveness of such a thin root-matted soil layer in protecting steep surfaces from erosion may be observed when its continuity is once broken by the clearing of a field, the cutting of a road, or even the upturning of a tree. On the lower side of the break the turfed soil layer—it may be a foot or even less in thickness—may be seen to slip off bodily in avalanche fashion or to roll back from the bare granite like the bark when stripped from a tree.

Fortunately for the region, this spheroidal type of weathering, with its peculiarly disastrous consequences when erosion becomes active, is restricted almost entirely to granitic and gneissic rocks and even in them is not found in all types and under all conditions, so that a large part of the mountain region, where such rocks either are not found or do not possess the requisite texture or mineralogical character, is free from that particular danger.

Another type of forested area in which the soil cover is thin occurs in the belt of steeply tilted and folded quartzite and slate rocks found chiefly along the North Carolina-Tennessee line. These rocks disintegrate so slowly that a soil mantle sufficiently thick to conceal the rock nowhere forms, but the meager residual material lodges in the chance crevices and irregularities of the surface, between which bare jagged ledges project. On such areas the growth of trees and other vegetation is too scant to aid greatly in soil development. The projecting ledges, as well as the poverty of the soil itself, render the land useless for agriculture, and it can be utilized only for the growth of such timber as it can support. The undergrowth is sparse, and during the summer the surface becomes very dry. These areas need guarding from forest fires and protection from deforestation.

Though forest tracts in the southern Appalachians are, under natural conditions, subjected to relatively little erosion, yet man's activities are causing destructive erosion. Much forest destruction may be caused by gullying attended by undercutting and caving (see pp. 19–20) starting in cleared areas and extending upward into higher forested areas. Where the slopes are too steep to be cleared, many of the more gently rounded crests are cleared as far down as possible, and the surface drainage from these ridge-crest clearings, gathering at the lower edges of the fields into a few channels, rushes down across the steep forested slopes below, excavating deep channels where otherwise the surface would remain unbroken.

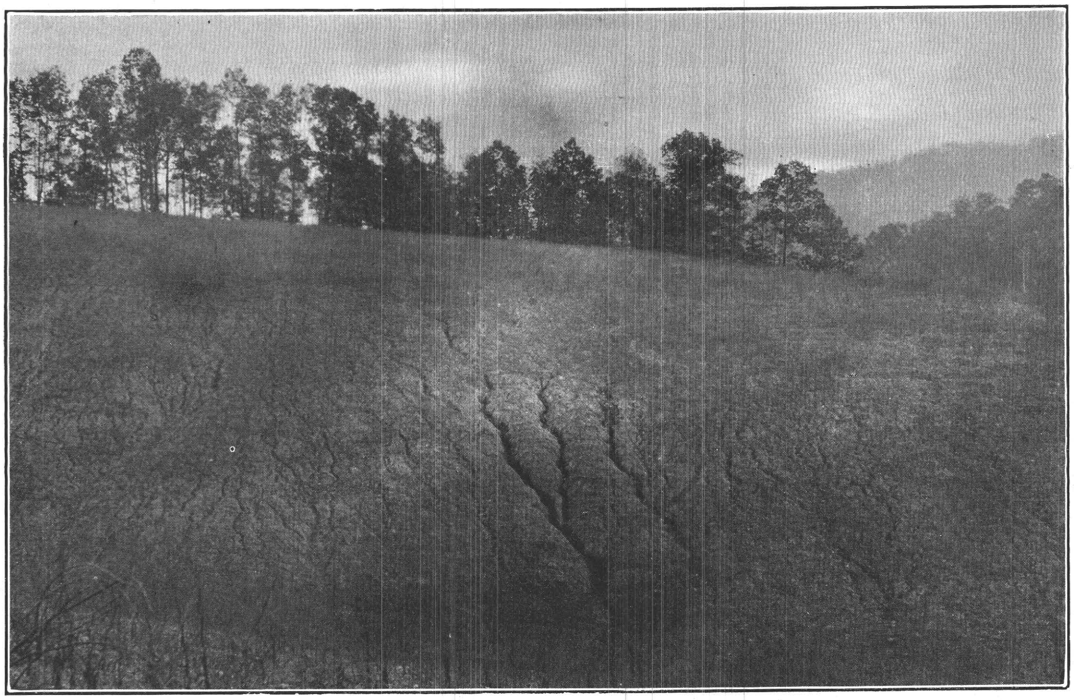
A much more common and far more destructive cause of erosion in steep, forested slopes is the dragging of logs along the ground in lumbering. The logs quickly wear in the soft earth smooth grooves or trenches, which during rain are converted into chutes, down which the water rushes with great velocity, sweeping rocks and soil before it. The effects of this log dragging may be seen in the many runways opened through the forests and in the great amount of soil and loose rock swept down the slope and deposited as cones at the lower ends of the chutes on little flood plains or narrow stream channels. The principal injury is not usually confined to the lumbered area itself, though this becomes furrowed wherever logs have been dragged, but extends to the lands and property along the streams below, where the floods are increased in height and in destructive effect. These dragways exist wherever lumbering has been carried on, for few of the lumbermen have taken precaution to prevent this danger. Caring little for the land after the timber is removed, they feel neither moral nor legal responsibility for the condition of the lands and other property along the stream below.

EROSION ON CLEARED SLOPES.

The clearing of graded forest-clad surfaces destroys the slowly reached adjustment between slope and erosive power and gives great impetus to erosion. In this erosion of cleared slopes the influence of the geology on the rate and the results of erosion becomes plainly apparent.

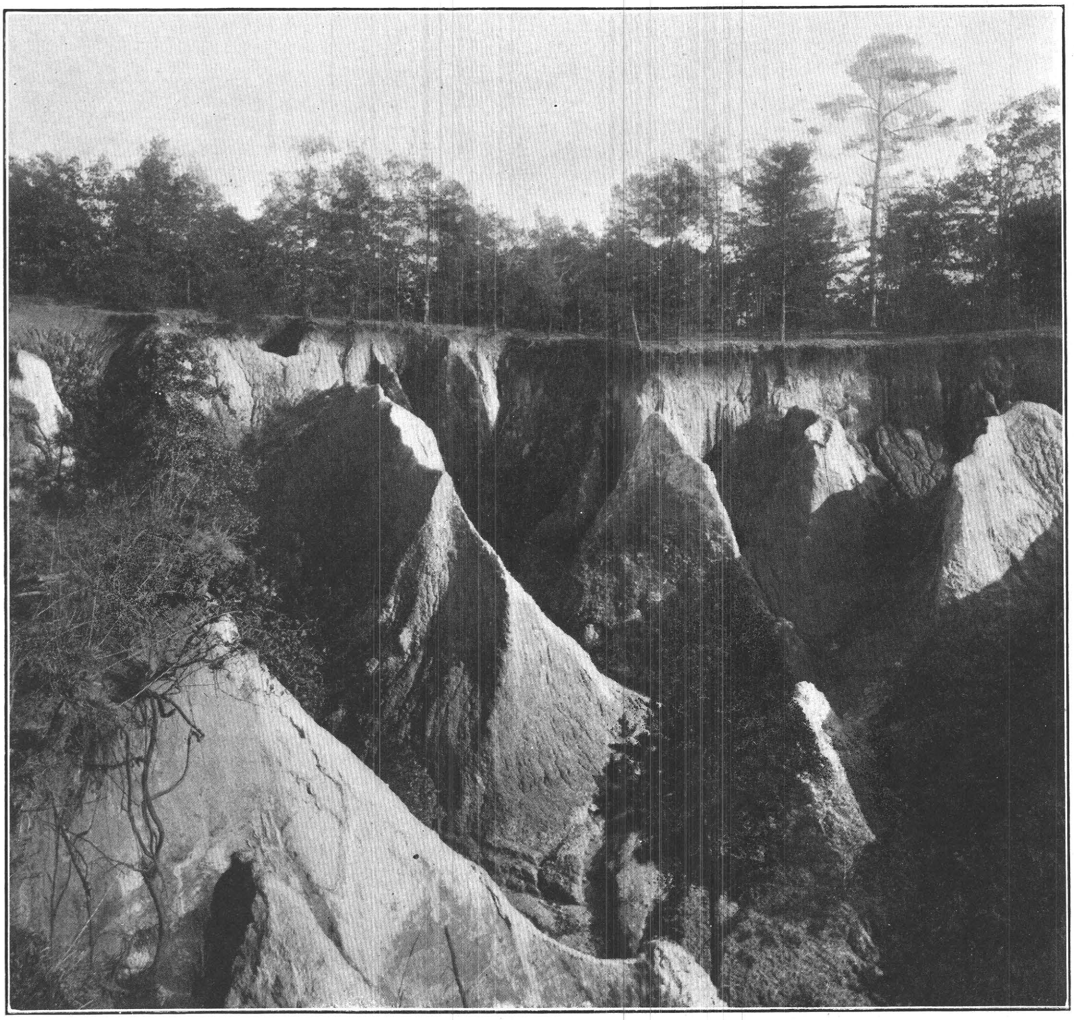
Other things being equal, the extent and character of the general surface erosion observed varies with the geology. It may be said that in a large measure geology controls erosion, for the nature of the rock determines the character of the soil, and variations in the character of the soil determine corresponding variations in the liability, manner, and rate of erosion. Two areas that are equally steep may when cleared differ greatly in character and rate of erosion. One may not erode at all; the other may erode rapidly down to the barren subsoil or the bare rocks.

In some parts of the region the soil on even the steepest cleared slopes was observed to be scarcely at all affected by erosion, although tilled year after year, and inspection usually verified the truth of the general reply to questions concerning erosion asked in such regions—"Our mountain-side fields do not wash away." It was found that such soils were permanently more or less loose and porous, and that their resistance to surface erosion varied directly with their porosity or permeability to rain water. A large proportion of the rainfall immediately soaked into the ground and found its way downward through underground channels; very little flowed off over the surface. Generally such resistant soils were also characterized by many small undisintegrated rock fragments, which aided both in keeping the soil open-textured and in checking the velocity of the downward-moving surface portion of the rainfall by opposing themselves as obstacles to its flow and causing it to drop many of the finer soil particles it might have started to carry. Certain schists and gneisses, especially the more siliceous types with mica and hornblende and those of nonhomogeneous grain, were the rocks found to weather most commonly into erosion-resisting soils. Some quartzites were also found to produce open-textured stony soils that did not erode badly. In general it may be said that a porous or a stony soil, whatever the type of rock from which it has originated, will be apt to resist general



A. INCIPIENT GULLYING OF SHOESTRING TYPE; BUNCOMBE COUNTY, N. C.

See page 19.



B. RAPID EROSION IN DEEPLY DECOMPOSED SOIL MANTLE NEAR MARION, N. C.

See page 20.

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surface erosion more or less effectively. Such soils may be cleared and cultivated with safety, even when they slope at an angle that would be quickly destructive to all other types of upland soil examined in the region.

The aggregate area of such erosion-resisting soils, however, is not great when compared with the total area of the mountain country. By far the larger part of the region is underlain by rocks that weather into soil that is easily eroded when exposed on deforested slopes.

In some places it was found that the entire surface wore away slowly, each heavy rain removing a thin layer or sheet of material, so that the fertile soil layer gradually wore thin and poor and the field was at last abandoned as worn out. Erosion of this type, which may be called sheet-wash, occurs characteristically on close-grained, compact clay soils whose particles cling together firmly and do not readily yield to corrasion by flowing water, so that channels are not readily cut beneath the surface and undercutting and caving are not possible. Soils of this kind usually result from the weathering of the finer grained and more basic varieties of igneous rocks, such as diorites, diabase, and gabbro, and also from the weathering of fine clay shales that are free from mica particles. Sheet-wash erosion is so slow and gradual that some farmers fail to recognize it and believe that their soils have deteriorated through exhaustion of the fertility, whereas they have slowly and almost imperceptibly worn away to the subsoil. Such farmers, ignorant of the process by which ruin has been wrought, clear other fields and start anew the same destructive process.

One of the most common types of general surface erosion is that which is characterized by the formation of parallel gullies, and which occurs on slopes covered with clay soils, homogeneous in texture and somewhat softer and more loamy than those described in the preceding paragraph. Such soils result from the weathering of sandy shales or, more commonly, of granite or other crystalline rocks which contain considerable quartz but no mica. Certain schists also produce soils of the same texture. (See Pls. III, *A*, and XVII, *A*, pp. 18, 78.) In such soils erosion begins by producing innumerable small parallel gullies that extend straight up and down the slope and divide the surface into a minute fluting of sharp grooves and ridges. As these gullies deepen they become wider, and the smaller ones are encroached upon and obliterated by their larger, more active neighbors until, instead of a dozen or more in a yard's width, their number is reduced to one in a yard or one in a number of yards. Their bottoms are sharp, their sides steep and convex, and the tops of the divides between adjacent gullies, at first jagged, afterwards become rounded and sharply or broadly convex, the differences depending on differences in the soil texture and in the rate of vertical downcutting along the gully ways. (See Pl. XVII, *B*, p. 78.) Such systems of gullies concentrate the surface rainfall so that it works very efficiently as an agent of corrasion, and the process once started is very difficult to stop. The fields attacked are soon abandoned and left as scarred wastes while new ones are cleared.

Erosion of the parallel gully type occurs in many parts of the southern Appalachians. It is typically shown at Ducktown, Tenn. (Pls. XVI and XVII, p. 78), and near Balsam Gap, N. C., as well as at many other places.

Of all forms of general surface erosion, gullying, characterized by rapid downcutting accompanied by undercutting and caving, is most rapid in its progress and most difficult to check, as well as most spectacular in its appearance and most destructive in its effects. Erosion of this type occurs in soils underlain by a deep, relatively soft micaceous subsoil. Deeply decomposed material of this kind results from the weathering of micaceous and feldspathic schists—rocks that cover considerable areas in the region and determine the type of surface erosion wherever they occur. The surface in such areas may have weathered to a fairly compact clay soil that offers moderate resistance to erosion, and if the slope is gentle careful attention may keep this clay surface intact; if it is once broken through, however, a gully quickly develops in the soft subsoil, deepens easily by corrasion, and the soft and arkosic material on the sides is rapidly undermined and slips or caves in, leaving vertical or overhanging walls. The head of such a gully is commonly more or less amphitheater-shaped and is rapidly extended up the slope by headwater erosion, in which caving plays a prominent part. Into these gullies many square yards of surface soil may cave during a single heavy rain, and as the decomposed micaceous and arkosic material in which such gullies grow is usually scores of feet in thickness they may become chasms of great depth and width. This type, which may be called chasm gullying, is illustrated in Plate III, *B*, page 18.

When begun in cleared land, chasm gullying may advance upward into a higher forested area and undermine and destroy even the largest trees. Once well started it is almost impossible to check.

Still another form of erosion in cleared areas originates in small landslides, which usually occur after the soil has been thoroughly saturated and softened during a period of prolonged rainfall.

On steep slopes the surface soil may begin moving of its own accord, either slipping bodily off in a mass or becoming so soft as to flow off, when once started, as a stream of soft mud. This change of soil into flowing mud is likely to take place where a small wet-weather spring on the steep hillside happens to occur in a certain kind of soil. More frequently, however, landslides are caused by the trampling of cattle on steep slopes after the soil has been softened by prolonged rain. One cow climbing up or down such a slope may cause a number of such landslides, each of which, when once started, usually grows both in width and in length until it becomes a great bare scar in the field.

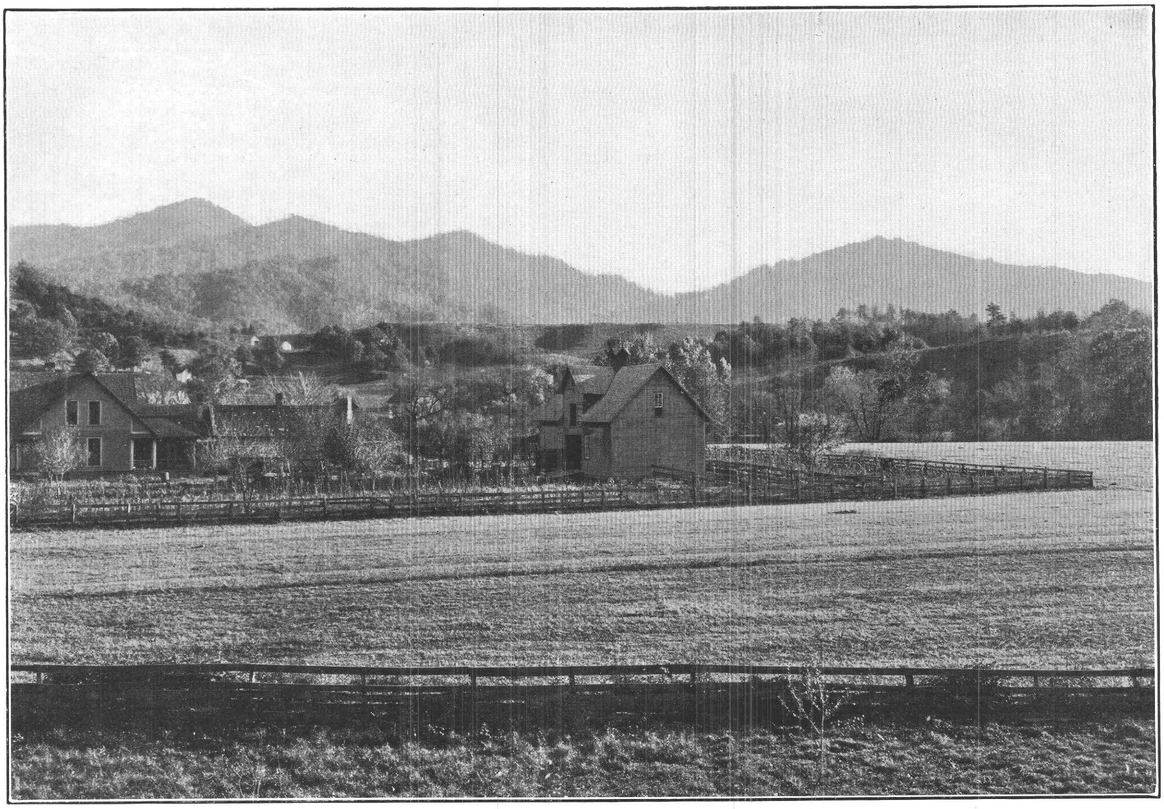
Landslides are likely to occur where the soil is micaceous or where it has resulted from the weathering of slickensided granitic or gneissose rocks. The slickensided surfaces are preserved in the weathered soil and when wet become planes of easy movement. Such surfaces aid greatly in the extensive caving that occurs in some areas where chasm gullying is the characteristic form of erosion. Landslides are also likely to occur where weathering of the exfoliation type has produced a sharp line or division plane between the soil cover and the underlying hard rock. In such places the soil layer easily slips off. Landslides of this type may occur in the forest, but, like those of the other types, are more common in cleared areas. During prolonged wet seasons it would be well to keep cattle or other animals off steep slopes that show any tendency to slide.

Level or nearly level upland areas may in themselves be comparatively safe from erosion, but they may nevertheless be affected by intimate relation with erosion, for water from areas lying still higher may erode channels across them, and the waste from such higher areas may cover their surface soil and destroy its fertility; or their own drainage, after being gathered into a few channels, may be shed upon still lower lands with the same effect as that produced by water received by them from the higher areas.

EROSION ON FLOOD PLAINS.

The typical mountain stream of this region flows so swiftly in its upper course that it sweeps away all loose material in its path and flows over bare rock, which it is actively eroding. Somewhat farther downstream, as its slope and consequently its velocity decreases, the stream reaches a point where, though still swift, it can no longer sweep away all loose material, so that the coarsest material begins to accumulate, making what may be called a bowldery or a cobbly torrent plain. As the current varies in velocity at flood and at low-water stages, this material is continually being reworked, and in the course of the cut and fill characterizing this reworking the stream, largely because of the heterogeneous nature and different sizes of the material, constantly shifts its position as it tears to pieces and rebuilds its torrent plain. The surface of such a plain fashioned by an impetuous current of greatly varying power is characteristically irregular or hummocky.

Farther downstream, as the velocity of the current decreases, the coarseness of the material composing the torrent plain and the irregularity of its surface correspondingly decrease. The tendency to lateral shifting of the channel also diminishes, but, if from any cause the stream be overloaded with waste and forced to deposit much of the waste in its channel, this channel filling deflects the current and the tendency to undercut one bank and build a cobbly or sandy



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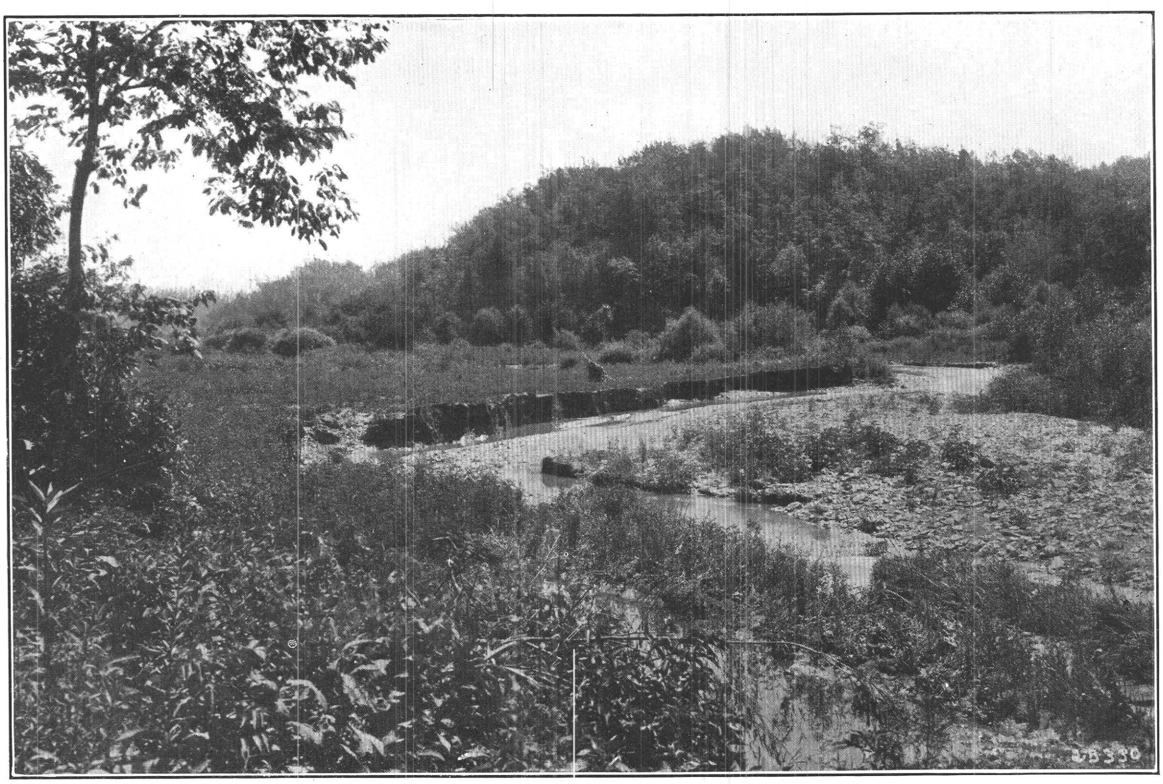
A. OLD AND NEW FLOOD PLAINS.

Extraordinary or possibly fossil flood plain in the foreground, with dwellings, and a high terrace or older fossil flood plain in the distance. See page 21.



B. STREAM WITH SHIFTING CHANNEL.

The stream is undercutting its flood plain on one side and building a cobble zone on the other. See page 21.

ASHEVILLE PLATEAU AS DEVELOPED IN PIGEON RIVER BASIN 2 MILES SOUTHEAST OF WAYNESVILLE.

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waste zone on the other becomes strong. An example of such filling and cutting may be seen in Plate IV, *B*, page 20.

Still farther downstream the velocity of the current diminishes until the stream carries and builds into its flood plain only fine material, and the flood-plain surface then becomes a level surface, which still lower may build in the familiar way a higher portion parallel and near to the stream.

If the stream cuts down as it swings laterally, it develops on the side away from which it swings a sloping flood plain, which will here be called a beveled or hanging flood plain, the exact slope of which depends on the ratio of down cutting to lateral swing. Only the lower edge of such a flood plain is ever covered and damaged by floods.

If the stream is not overloaded with waste it normally develops a channel whose width and depth are proportioned to its volume, velocity, and flood height, and this channel usually has a sufficient capacity not only to carry away the ordinary flow of the stream, but also to carry a considerable volume of flood waters. With increase of flood volume in excess of the capacity of the channel the waters spread beyond the banks and flood an additional area on which deposits are laid down and a flood plain is built.

The inspection of many flood plains shows that they may generally be divided into two classes, the forms of one class commonly differing from those of the other in width and invariably in position and height and in the frequency with which they are covered with floods. The stream channel is usually bordered on one or both sides by a more or less narrow shelf cut in the flood-plain material and rising only a few feet above ordinary stream level. The exact height and width of this flood-plain shelf vary with the size and character of the stream. This shelf, or notch, is covered by the ordinary floods of the stream and may be called the ordinary flood plain. It may be only a rod or a few rods in width, even on a large river, or it may be much wider.

On the side away from the stream this ordinary flood-plain shelf is bordered by a scarp that is usually regular and well defined and separates a higher part of the flood plain from the lower one. The height of the scarp or the difference in level between the two flood plains varies greatly on different streams and even on different portions of the same stream, but on all streams this higher flood plain is reached and covered only at comparatively long intervals—measured perhaps by years—by floods of extraordinary height. The floods that now and then cover this extraordinary flood plain deposit sediment on it in some places and so build it up somewhat; but more commonly they scour runways across it and thus start subaerial erosion lines along which it is ultimately cut to pieces. Because of these scourways its surface is usually uneven. Deposition during the rare flood periods does not equal erosion during the long intervals between floods, and the plain soon shows signs of wasting away.

On many streams there are to be found above the level of this extraordinary flood plain more or less perfectly preserved portions of other, still older flood plains or terraces, whose height places them above the reach of even the highest floods. These may be called fossil flood plains to distinguish them from the ordinary and extraordinary flood plains, which may be spoken of as living flood plains. Such topographic features are so common and in many places so prominent along the streams, large and small, of the southern Appalachians that it has been thought best to define the terms, as their use in this paper will give conciseness to the description of flood plains. A view of an extraordinary flood plain is shown in Plate IV, *A*; fossil flood plains are seen in Plate IV, *A*, and Plate V, page 20.

The ordinary flood plain may have runways cut across it by floods or may be cut or gouged into holes wherever the flood current becomes deflected downward, as by pouring over a rock wall or other obstruction, or by forcing its way under logs that have lodged on it.

In other places the stream may be overloaded with waste and forced to drop a part of it until it fills its channel. It then flows here and there in irregular shifting meanders across its flood plain, depositing great quantities of waste and building up or aggrading the flood plain (see Pl. VI, *A*, p. 22). Such flood plains rapidly become useless for agriculture.

Elsewhere the flood may strip off the alluvial soil down to the underlying bowlders or the bare rock (Pl. VI, *B*), or it may be checked so as to deposit a bed of sand on the former flood-plain surface and convert it into a barren sand waste (Pl. VII, *A*). Under other conditions the covering spread over the flood plain may be of cobbles or even bowlders.

The channel of a stream that is not overloaded retains its normal depth, and the great increase in its depth during floods gives a channel prism so large that the stream can remove a much greater volume of water; moreover, the speed of the current, which is greatly accelerated by the increase in depth, is still so much slower on the outer edges than in the middle of the stream that it deposits on the flood plain the finer material that was carried in suspension and thus benefits instead of injures the adjacent lands over which it flows. The Chattooga, for example, which has an unusually swift current, its average slope being 28 feet per mile, frequently floods its bottoms at Russells, but instead of cutting them to pieces deposits sediment that enriches them. The upper Yadkin is another good example. It is enlarging its channel by scouring away its banks in order to handle more efficiently the steadily increasing volume of flood water it is now receiving.

The cobble zones scoured out along the main channels of many of the streams examined are the results of the effort of the streams to adjust themselves to changed conditions by providing themselves with auxiliary channels to carry off flood water. Where man's selfishness or shortsightedness or an unusual combination of circumstances make these efforts of the streams inadequate, disaster results. Where man has increased erosion so as to overburden the streams with waste and to force them to fill their channels he has foredoomed his lands to be cut to pieces by floods. Wherever from any cause flood heights have increased, fences, bridges, dams, mills and all other property, as well as human and other lives within reach of the water, are endangered and liable to be destroyed, as they have so often been destroyed in the southern Appalachians in the last decade.

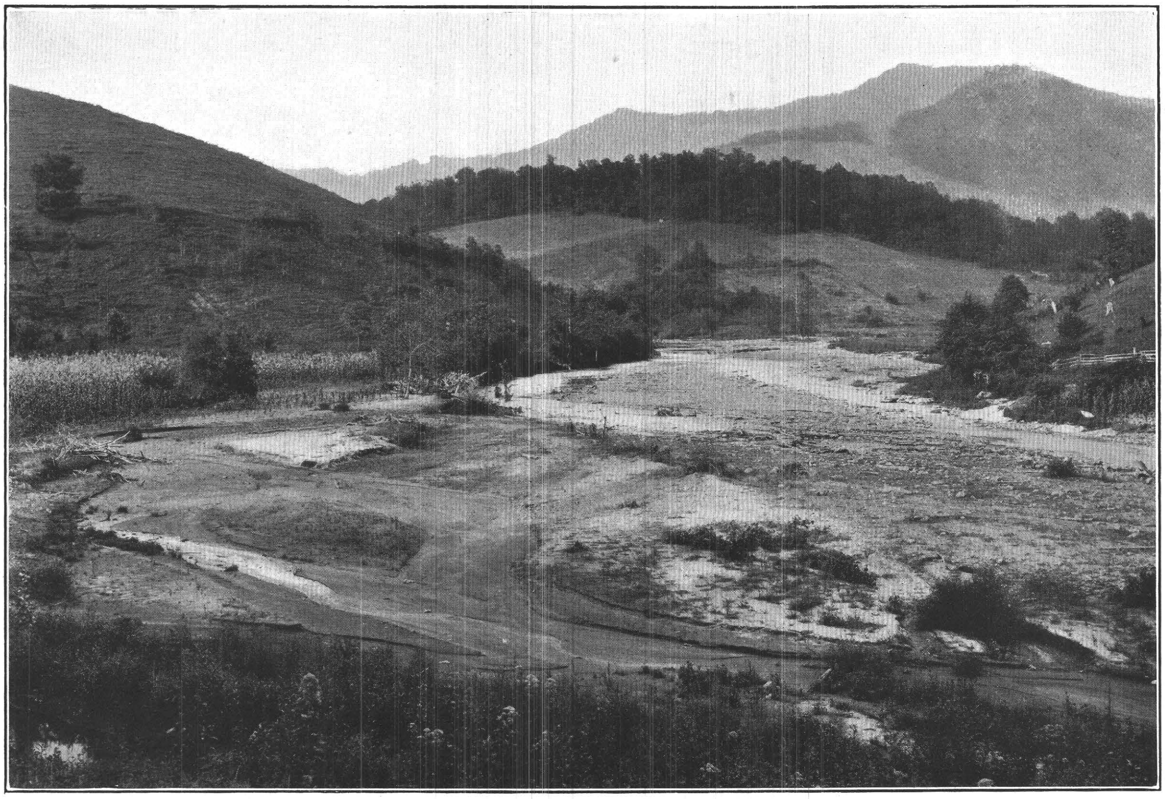
On the other hand, in regions such as the basins of the Holston, the New, and the Monongahela, where man's agency in clearing the soil has not greatly accelerated the erosion of upland slopes, and so has not so increased the supply of waste furnished to the streams from these slopes as to fill the stream channels, but has chiefly hastened the movement of storm waters into the streams and so augmented flood heights, the damage wrought by the streams will consist not so much in tearing lands to pieces as in sweeping away all classes of property within reach of the flood. Where stream channels have been filled by the progress of erosion, as in most of the southern Appalachians, the disaster includes lands as well as property and life.

REMEDIES FOR EROSION ON SLOPES.

The most obvious method of preventing erosion is to prevent the clearing of the steep slopes. Just how steep a slope may safely be cleared is a problem to which there is no one solution. It has often been said that no slope steeper than 15° should ever be cleared, and this is probably as good a general statement as can be made. In some places, however, under certain conditions of soil texture and rainfall, slopes less than 15° erode badly; in others slopes of 20° or even more may be cultivated without serious danger of erosion, the secret of the immunity being in the texture of the soil. In regions where slopes of more than 30° were cultivated the author was frequently told that the lands did not erode, and this statement was largely confirmed by ocular evidence.

The allowable limit of steepness for cleared lands varies, then, with local conditions, but it may be said that almost everywhere throughout the southern Appalachians this allowable limit is exceeded, and in many places so greatly exceeded that rapid erosion of the cleared slopes is inevitable.

All cleared slopes should be thoroughly terraced if they are to be cultivated. Terraces can be so constructed that little or no water will flow from the terraced fields during even the hardest rains. In fields cultivated under these conditions there is no removal of soil particles and no filling of stream channels and resultant destruction of flood-plain lands. Terracing

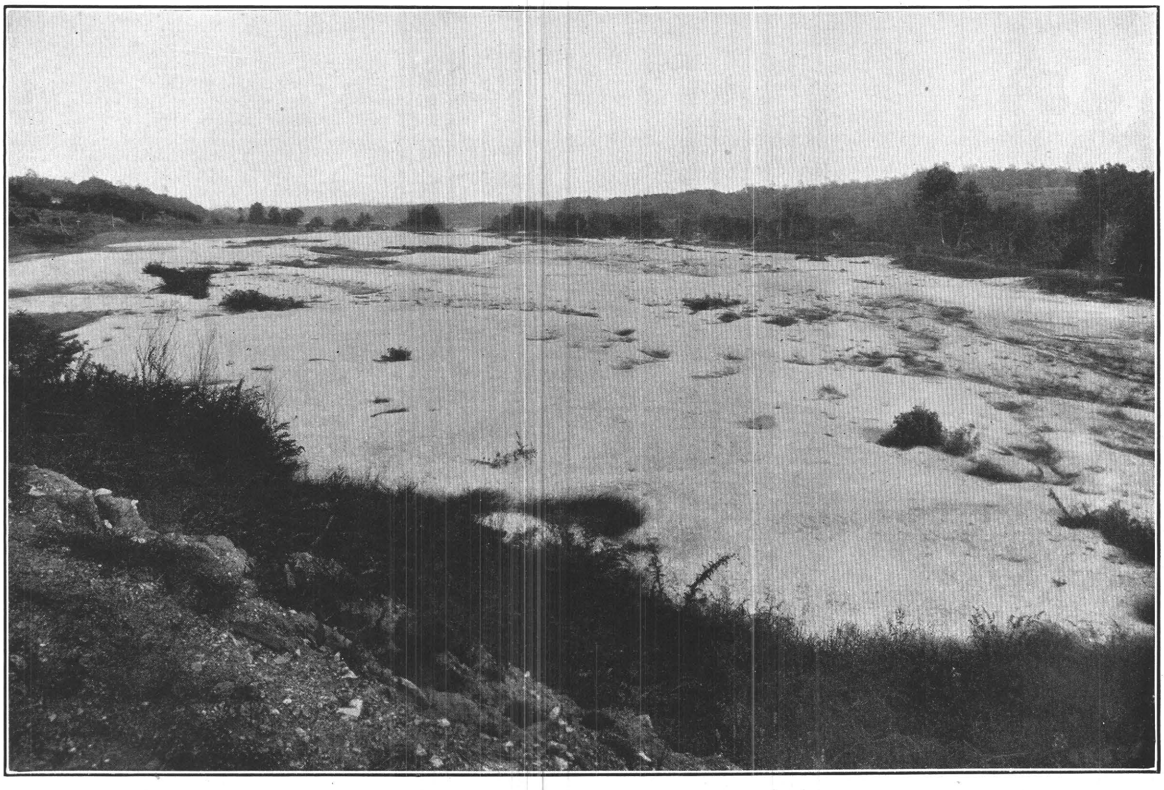


A. STREAM OVERBURDENED WITH WASTE AND AGGRADING.

See page 21.

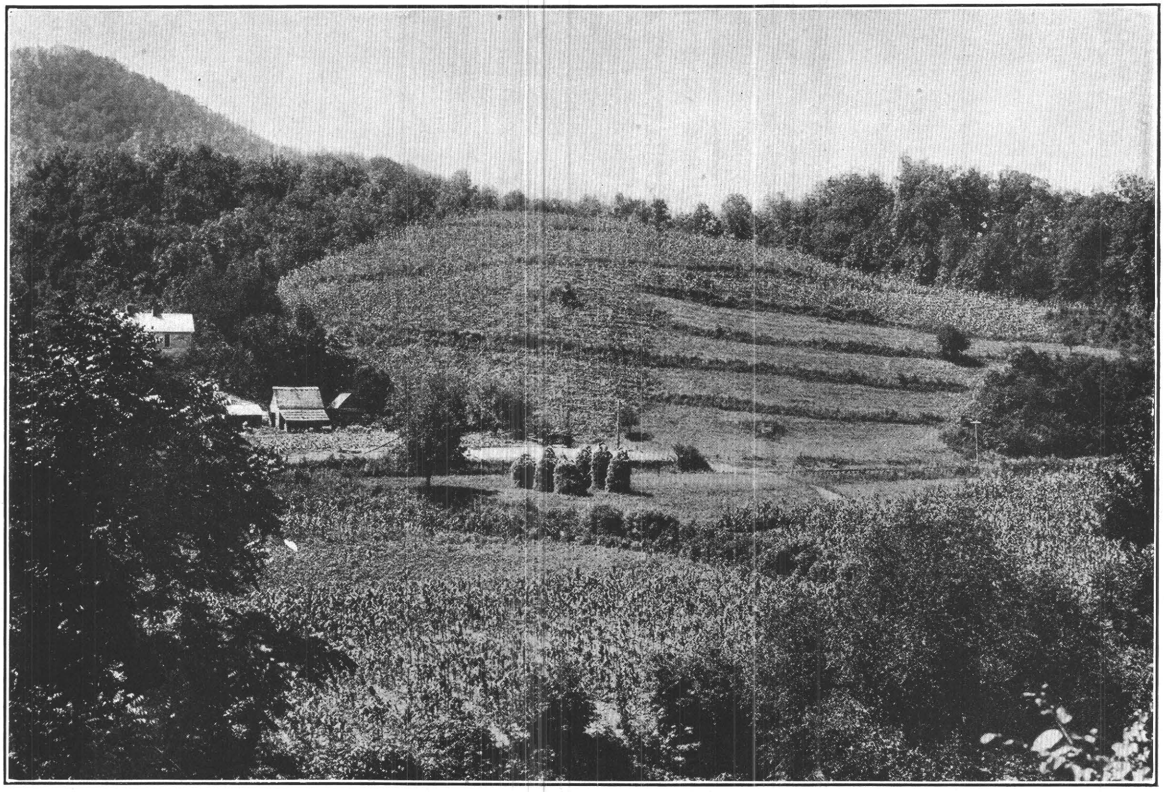
B. ALLUVIAL SOIL STRIPPED TO THE BOWLDERS.

See page 22.



A. LAND COVERED WITH SAND.

See pages 22, 45.



B. HILLSIDE TERRACED TO PREVENT EROSION.

See page 23.

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can be far more generally practiced than it is all over the region examined and is necessary to insure a really safe system of agriculture. The best terraced region observed was in the Savannah River Basin, between Toccoa and Elberton, Ga. Good terracing was also noted about Greenville and elsewhere on the Piedmont in upper South Carolina. An example of crude but effective terracing is illustrated in Plate VII, *B* (p. 22).

Grass will effectually prevent erosion after the sod has once become well established. The farther south one goes, however, in the southern Appalachians, the more difficult it is to obtain and keep a good sod. In the Watauga and New River basins it is easy to protect the lands by grass, but on the Chattahoochee, in northern Georgia, it would be much more difficult, because the elevation there is much lower and the climate is therefore dryer and hotter and less favorable to the growth of grass.

If erosion has already occurred on steep slopes one of the best remedies, if conditions have not become too bad, is to cover the surface with straw, leaves, or forest litter, and over this cover to place brush to hold it in place. This mechanically protects the soil, much as does the humus cover in the forest itself, and holds it until plant growth has again taken possession and arrested rapid erosion. Except in a few places where the soil is exceedingly poor, weeds and briars will now spring up rapidly and will be followed in a short while by wind-sown tree seedlings that will start the new forest growth on the denuded slope. Natural reforestation in the southern Appalachians is usually rapid, but if for any reason it is desired to hasten it or to control more closely the kind of growth, artificial reforestation is easy, though of course this is more expensive than natural reforestation.

Where deep gullies have once started log or rock dams may be used to prevent their further growth and to catch material with which to fill them. The use of such dams is not always advisable, since the water tends to work beneath them and thus to concentrate and increase the vertical scour. Moreover, they become in themselves mechanical obstructions that may interfere with the subsequent use of the land for agriculture. If used they should be faced on the upper side with brush or straw to prevent the water from working through them. If thus made tight they soon become filled with the material that is being carried down the hillside, and the former gully or inclined trench is converted into a series of terraced steps. For a view of brush dams used to check erosion see Plate VIII, *A* (p. 24).

In places where the slope is not too great and the cutting has been shallow, gullies may be filled with straw so as to catch the sand and clay that is being removed. This device affords an effective remedy for gullies and has the added virtue of not leaving mechanical incumbrances on the reclaimed area.

Erosion may be checked by preventing the fires that usually follow in the wake of the lumberman and by guarding against the formation of erosion chutes by the dragging of logs down steep slopes. The mere removal of the mature forest itself need in no wise affect erosion or flood problems in a region like the southern Appalachians, where, if unhindered, the natural reproduction of the forest is rapid. In a few years the new growth makes an even denser cover of trunks, branches, and root mattings than the old, and protects the soil at least as effectually.

REMEDIES FOR EROSION ON FLOOD PLAINS.

On flood-plain areas the most important thing that can be done to the area itself to prevent erosion and flood damages is to maintain by all possible means a deep, straight channel for the rapid removal of flood waters and waste. The removal of obstructions and the straightening of the channels of small streams aid greatly in scouring out and improving the channels and hastening the run-off. Means of regulating and confining the shifting channel of a wild mountain torrent are widely used in Europe, but practically unknown in America. Retaining walls of stone or rock-filled cribs serve this purpose wherever the interstices may become filled with fine material and so closed to the free passage of water through the wall. Where such filling is impracticable a facing of sheet piling may answer the purpose. A rough rock-filled log crib used for restraining such a stream is illustrated in Plate VIII, *B*. In Europe the bottom and sides of some such channels are paved with stone, and dams or sills of rock are built at short intervals across the stream.

Another protection to banks that are being cut by streams that do not tend to shift so rapidly as torrents is to plant willow, aspen, balm of Gilead, or other easily propagated trees of rapid growth along the banks and over the entire denuded area. In starting such growth it is usually sufficient to plant small branches or sections of limbs at short intervals in the moist earth; they root readily and grow rapidly. The balm of Gilead throws up many shoots from its ramifying rootlets and soon makes an efficient bank protection.

In places protection may be had by building levees, but these are so expensive that their construction is warranted only when the lands or property to be protected are of considerable area and value. Lands that have been badly cut to pieces by floods, such as those illustrated in Plate IX, *A*, or deeply buried beneath sand (see Pl. VII, *A*, p. 22) or beneath gravel or cobbles, can usually be put to little or no immediate use. There is more ultimate hope of reclaiming lands that have been cut to pieces than those that have been buried beneath sand or stone, since later floods of less height may deposit material in the eroded places and in time may heal the scars and restore to use the once ruined land. A flood channel that is once established, however, is likely to be occupied by subsequent floods and to become a permanent flood runway. Planting trees and building walls across it may protect it and permit it to fill, but if the surface has been covered by stony or sandy waste there is little hope that it can soon be recovered.

In most places in the southern Appalachians both cutting and filling tend rather to grow worse than to improve by subsequent changes, since they have been started by floods whose tendency for a number of years has been to become gradually worse, because of the constant extension of clearing and of erosion on slopes that should have remained forested.

Now and then it is suggested that impounding reservoirs may be built with capacity sufficient to hold the flood waters, but this scheme is generally impracticable because of the great size and the cost of the necessary dams and the large area of land that would be submerged and rendered useless, as well as the danger that the dams might break and destroy life and property below. Furthermore, on many of our southern streams such reservoirs would become filled with sand and silt in a decade or two, as a number of private power dams in the Piedmont region of the South already have been filled.

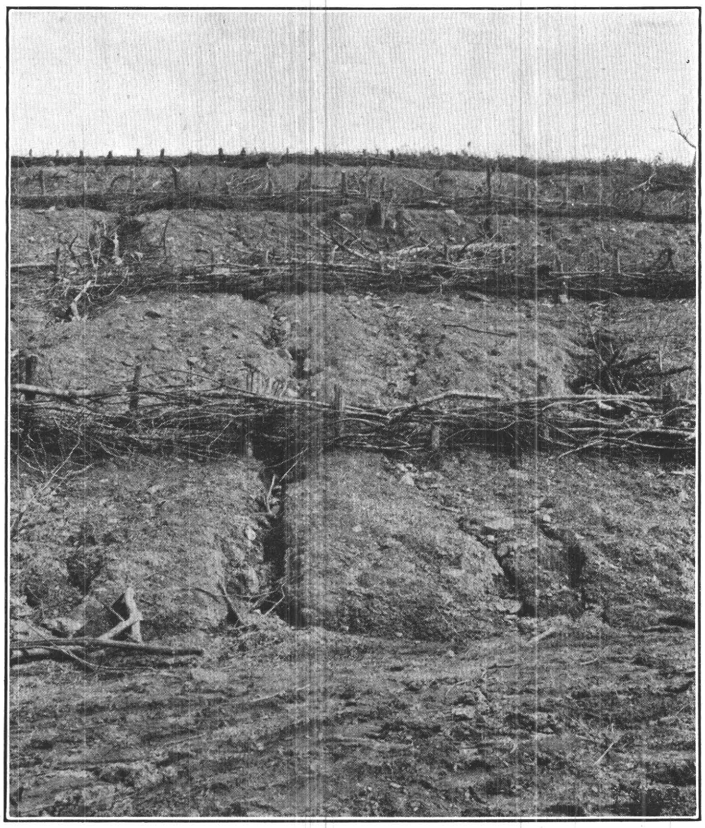
Far the most efficient reservoir for impounding flood waters is a good forest humus over the steep slopes of the stream basins. The only thorough means to check and prevent the destruction now going on in the Appalachian region from erosion, floods, and droughts is to maintain such a humus cover where it already exists and to replace it where it has been destroyed.

EROSION AT DUCKTOWN, TENN.

In discussing processes that vary in the character or intensity of their effects, it is well, if possible, to show the limits of the variation. A most notable example of the ultimate limit or extent to which erosion may go in the area under consideration is furnished by the Ducktown copper region, in the extreme southeast corner of Tennessee.

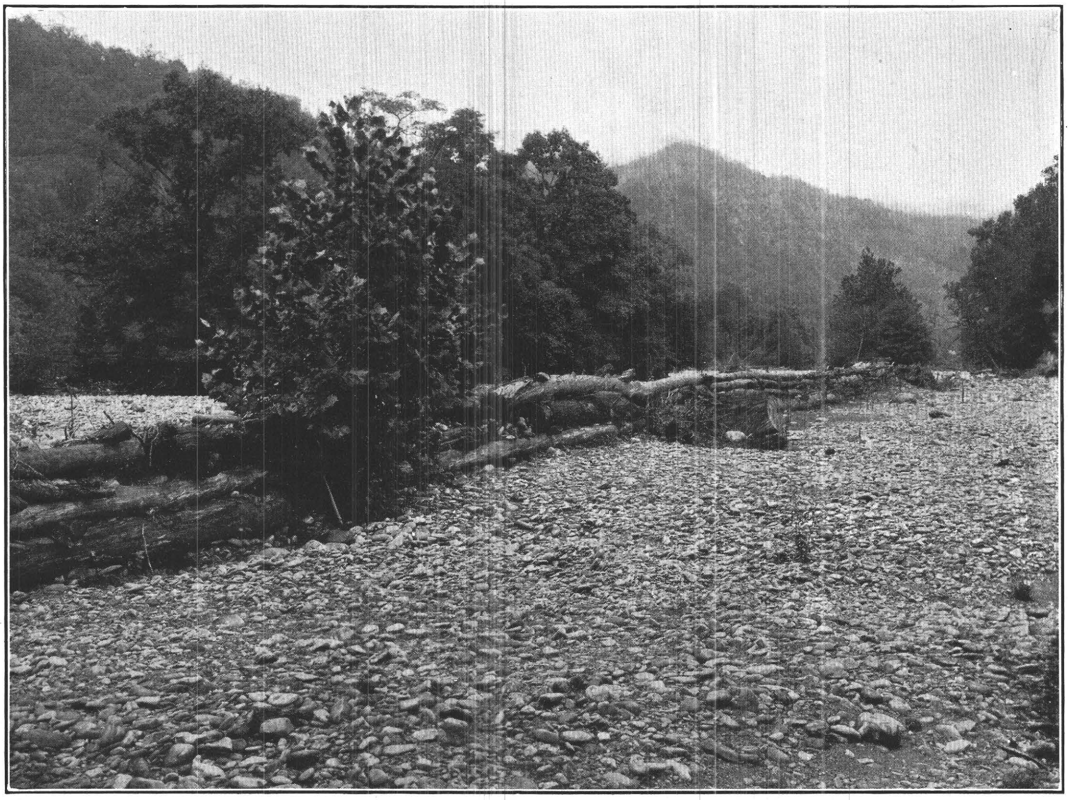
This region is an old peneplain that has been uplifted some 1,600 feet above sea level and has since been cut by stream erosion into a series of ridges separated by narrow valleys. The crests of the ridges are gently rounded, but their sides slope more steeply, and near the base become in places almost precipitous. The rocks of the region are deeply decomposed schists, which have yielded the heavy soil to which the rounded surface slopes are due. Only here and there are the schists exposed in bare ledges and these exposures are as a rule small. The dissecting streamlets formerly flowed in relatively narrow valleys and were actively eroding the rock ledges across their paths, depositing along their courses little or no waste.

The annual rainfall in the Ducktown region is between 50 and 60 inches and is often torrential. During the downpours soil surfaces almost literally melt away. Copper is mined and



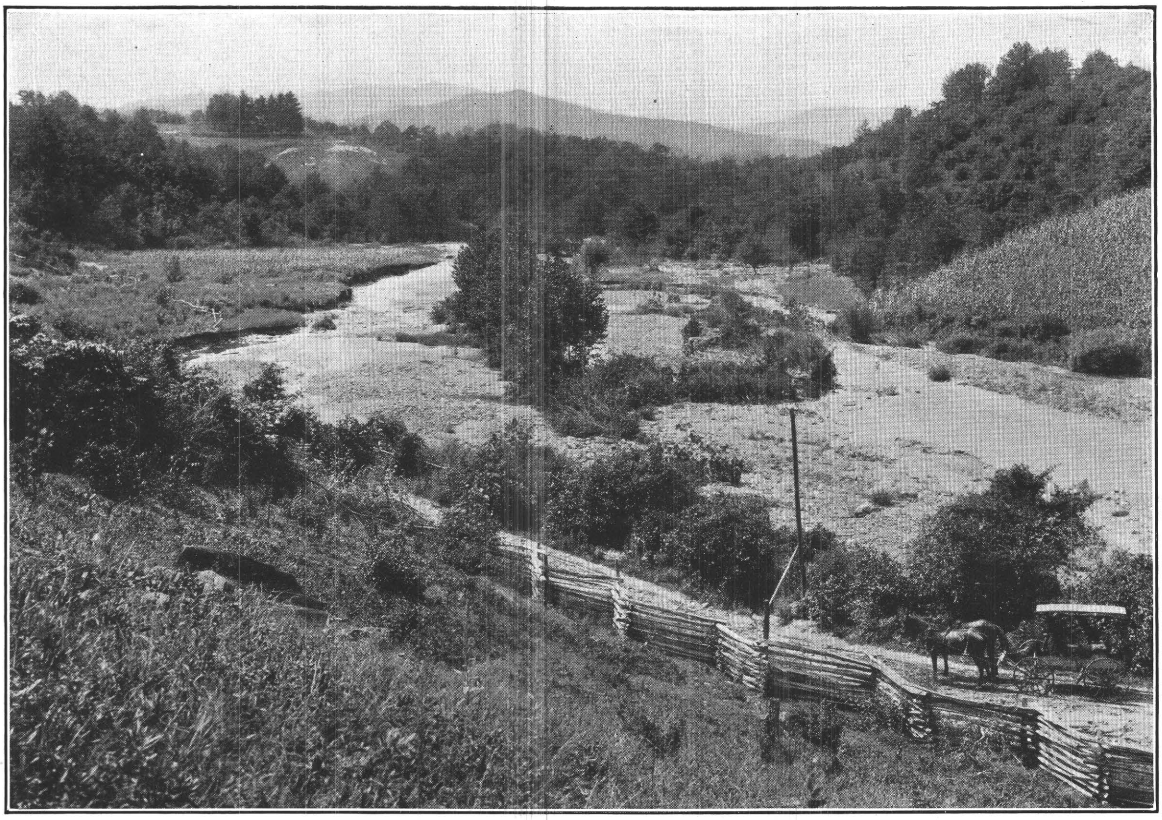
A. BRUSH DAMS BUILT TO CHECK EROSION.

See pages 23, 24, 25.



B. COBBLE ZONE AND LOG TRAINING WALL.

See page 24.



A. ALLUVIAL BOTTOM WASHED AWAY BY FLOODS.

The stream on the right, at the foot of the hill, formerly flowed to the left of the sycamores in the center of the picture. See page 24.

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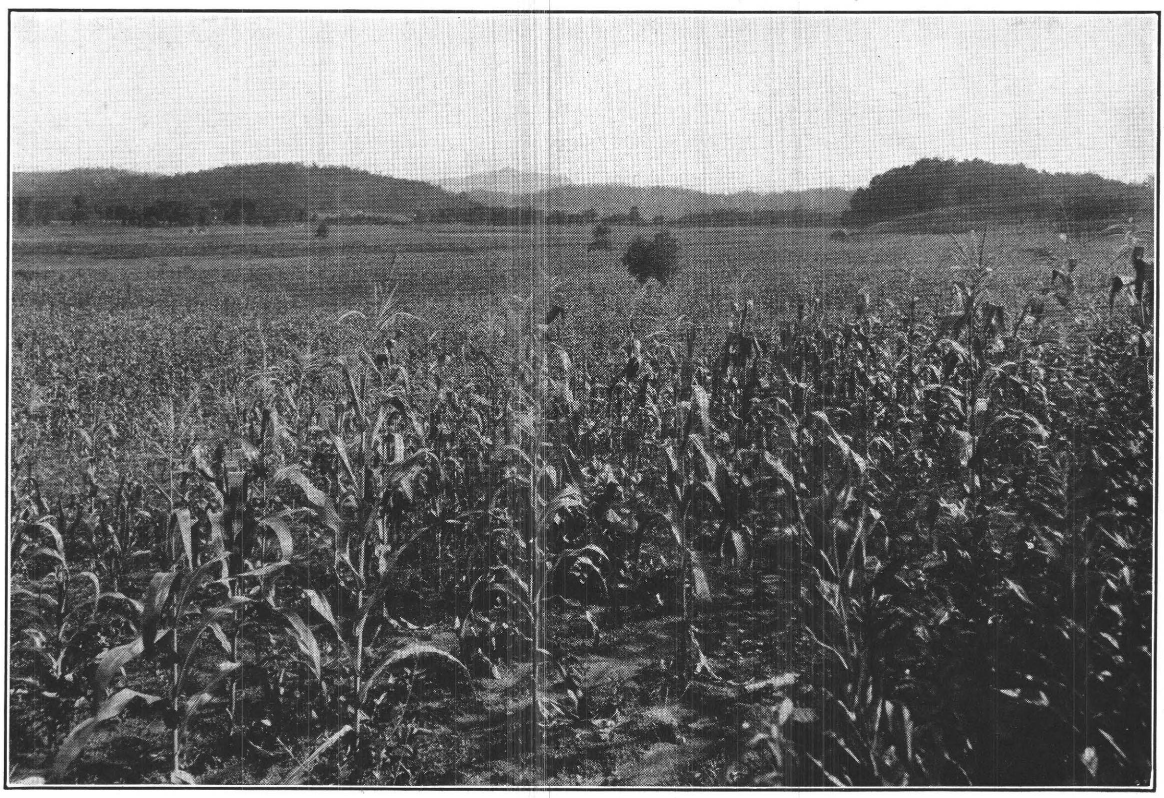


B. PART OF CATAWBA VALLEY NOT INJURED BY FLOODS.

See page 112.

smelted in the region on an extensive scale, and the sulphuric-acid fumes from the smelters have in the last few years killed all vegetation in an area a number of square miles in extent. In the short time since this was done erosion has deeply scarred the hills with gullies and the eroded material from these slopes has overloaded the streams and rapidly built waste plains of sand and silt along them. In places the soil has been entirely removed from these slopes and the bare red clay exposed, and in a few years the surface will be worn down to the underlying rock. Any small flood plain that may have previously existed along the streams has been buried beneath the rapid accumulation of waste from the hillsides, so that both hill slope and flood plain have been destroyed, the one by erosion and the other by sedimentation or aggradation.

Very little of the rainfall now soaks into the ground to feed the springs and they show the result of the change by their greatly diminished flow during dry seasons. Wells also go dry more often than formerly. A better idea of present conditions in this region may be obtained from the views in Plates XVI and XVII (p. 78) than from a number of pages of description. A more detailed statement concerning processes and results around Ducktown will be found on pages 77–79.

The result of erosion in the Ducktown region may be looked upon as the goal to which all erosion in the southern Appalachians is tending. If elsewhere in these southern mountains the cover of vegetation be removed as completely as at Ducktown, the rapid erosion that has wrought the destruction seen there may confidently be expected to follow, and with like results.

CHANGES IN STREAM REGIMEN.

Wherever mountain stream basins in the southern Appalachians have been extensively cleared the regimen or normal habit of flow of the streams has been changed. This change is believed to be due chiefly to increased erosion and consequent increased rapidity of run-off.

In the natural forested state comparatively little rock waste is furnished to the mountain streams, which therefore expend their energies largely in eroding their beds and cutting deep channels, such as may be seen in the Great Smokies, much of the Pisgah Range, or any other well-wooded part of the mountains. These deep, steep-sided stream channels are very effective in removing flood waters, and it takes considerable rain to fill them higher than their banks and produce a flood. They are amply able, even in flood, to carry away at once all the waste material furnished to them.

The removal of the forest on steep slopes generally increases the tendency to erosion. This increase may be very slight if the land is kept well sodded or if the soil is of a certain porous or stony type, but in a region like the southern Appalachians, with its deep soil and abundant, often torrential, rainfall, erosion is generally more rapid—it may be very much more rapid—on cleared than on forested slopes.

Erosion once begun, as a rule, soon develops gullies that furnish so much sand, clay, and cobble to the streams that they become overloaded and are unable to carry away all the waste that is brought to them. The excess waste is therefore deposited first in the channel, until that is practically filled, and then over the alluvial flood plain, which is thus converted into a barren waste of sand or loose stones. Such a sand-covered flood plain is illustrated in Plate VII, *A* (p. 22). The waste then begins working downstream, filling dams and pools as it goes, and soon gets down into the navigable parts of the great river systems, such as the Tennessee, making more difficult the problem of maintaining navigable channels. This condition may be readily understood by examining the Tennessee at low water and studying the growth of its sand, gravel, and bowlder bars and of its towheads and islands, and also by comparing the detailed reports made annually by the Army engineers concerning the improvements made by them in the open channel of the river. The knowledge gained by personal examination of the river adds much significance to the statements found in these reports. Some of the most notable changes on the Tennessee will be described briefly in connection with the general characteristics of this river on pages 79–83.

The waste filling a mountain stream causes an immediate change in the frequency and height of floods. When, under normal forested conditions, the channel is deep, a heavy rainfall is necessary to raise the stream to the bank-full stage; when the channel has become well-nigh filled with eroded material much less rainfall will put the stream out of its banks and cause a flood—in other words, floods will become more frequent.

The channel filling has another important effect. The same amount of rainfall will necessarily cause a higher flood when the channel is filled or partially filled with eroded material than when it was free from it, partly because the capacity of the channel to hold water is diminished, but more especially because the filled channel is not so efficient an agent for the rapid removal of flood waters. They pile up, as it were, and rise higher than before. Their height is further increased by the fact that the gullies on the eroded slopes and the bare surface of the cleared land deliver the storm waters to the streams almost as rapidly as they would flow from house tops or along city gutters. This rapid delivery of the storm water from the steep cleared slopes aids greatly in raising floods to abnormal heights. In other words, floods in steep, denuded, and eroded basins assume much the character of floods caused by cloudbursts, not only in their very rapid rise and great velocity, but also in their destructive violence and rapid decline to ordinary stages. Their height and velocity are increased and their length is diminished as compared with floods in the same stream when the stream basin was forested.

It might be thought that as rivers are but the sum or aggregate of their tributaries they will rise to the same height during floods and become correspondingly low during droughts. This, however, could be true only if stages of stream height varied synchronously on all the tributaries, and if all these tributaries were so adjusted as to position, length, and slope that they discharged into the main stream their abnormally high or low flows at the same time These conditions, however, are manifestly impossible in any large river system whose head-waters include areas that are diverse in geography and climate. Some tributaries may be in flood when others carry little water; some are long and of gentle slope, others are short and of abrupt descent. The river into which they flow represents, then, not the sum of their extremes, but more nearly their mean, and in its phenomena of flow will tend to preserve a mean.

The general variations in rainfall in all parts of any large river basin in the Appalachians are probably similar in kind though not exactly synchronous or of equal amount everywhere throughout the basin. The period of maximum rainfall, for instance, in this entire region usually occurs late in the winter or early in the spring, and the period of minimum rainfall late in the summer and autumn. The average stages of the small and large streams of the region vary in a general way in harmony with the rainfall, and just as the tributaries become, on the average, lowest late in the summer and fall, the main stream into which they flow becomes lowest then also, but this is a mean low, not an extreme low. In the same way the main stream is highest when the tributaries are highest.

It is probable that within recent years the mean low-water flow has been decreased on main streams whose tributary basins have been largely cleared. In the same way, the mean high-water stages of these streams have probably been similarly increased by excessive clearing. By this increase in high-water stages a larger proportion of the total rainfall is immediately carried away as run-off, and consequently a smaller proportion is left to supply evaporation and maintain the flow of springs and other ground waters. Evaporation in cleared and cultivated areas is at least as great as in forested areas, and as the average annual rainfall has probably remained unaffected by the clearing of the forest, the increased run-off must constantly leave a decreased supply for the springs, which must therefore suffer partial or total failure during prolonged drought.

Occasionally it is maintained that in any large river system the flow during low-water stages is kept up by the run-off from frequent rain storms on small areas scattered here and there over the basin, and that the river is consequently not dependent on the flow of the springs or ground water for its maintenance. The failure of springs, it is argued, would consequently not materially affect the flow of the main stream of the basin, though it is admitted they would stop the flow of the streamlets to which they ordinarily give rise.

Local thunderstorms that involve considerable precipitation in small areas may, in times of general drought, contribute somewhat to the maintenance of the stream's flow, but these local storms are probably not so frequent in any particular large river basin as to maintain by themselves or even to nearly maintain the low-water flow of the main stream. In a basin like the upper Ohio, for instance, many days at a time will often elapse during prolonged dry seasons without the occurrence of enough local thunderstorms anywhere in the basin to affect materially the extreme low-water discharge of the river, and during some droughts in the Ohio basin there are so many days or even weeks together during which no rain falls anywhere within the entire basin that if the streams depended during such periods on the local thunder showers alone, the last water thus falling would have ample time to flow down the entire length of the river and out at its mouth and leave its bed entirely dry before another local shower would occur. The low-water flow of a stream during droughts depends very largely or almost entirely on springs and other ground water within its basin, and as they fail it will fail.

It has been suggested that, assuming that there has been no climatic change, and that rainfall is as heavy and thunderstorms are as frequent in forested as in deforested areas, it should be obvious that the discharge of springs plus the run-off in forested areas would exceed the run-off from thunderstorms alone in deforested areas and that of two streams the one from the forested area would show the larger flow.

It would be interesting to compile records of rainfall at all possible stations in, say, the upper Ohio basin, and ascertain as accurately as possible how often and in what areas local rainfall occurs during a general dry season throughout the basin, and thus test the matter so far as records would afford a test.

The streams of the southern Appalachian Mountain region furnish many illustrations of the various phases of the change of regimen outlined in preceding pages and leave no doubt in the writer's mind that floods are now more frequent, rise higher, move downstream more rapidly, and are sooner succeeded by low water, and that this becomes lower and lasts longer than formerly. The writer contends that the belief that these changes have occurred rests on so large a body of observed facts that it can not be successfully controverted.

Rainfall records and flood-gage readings are often appealed to by those who discuss the effect of forests on stream flow or those who attempt to determine whether or not changes have occurred in the regimen of streams, but each great flood is primarily the result of unusual rainfall, and many variable factors combine to determine the height to which a flood will rise at a given place or the height that will be reached by different floods.

Gage readings and rainfall records are not necessary to prove change of stream regimen, nor would their failure to show an absolute increase in flood heights at any given point disprove it, since some of these readings and records are subject to error and are inexact.

The discharge of a river can not be determined by and does not vary with the gage heights alone, for the velocity of the current is also an essential factor in the determination, and this velocity, though varying in certain respects with the depth of the current as shown by the gage height, also varies independently of the gage height—that is, it depends on the steepness of surface slope of the advancing flood wave. A flood of more sudden rise and consequently steeper front slope at the same gage height will have greater velocity and will discharge much more water than a flood of slow rise but of the same height. For the same reason the front part of any flood wave has a greater velocity than the hinder part, and hence as the wave advances downstream its length increases and its height and velocity diminish independently of any changes in width or slope of the stream channel. On this account floods in the lower part of a river rise more slowly, reach less heights, and subside more slowly than those in the upper part of the same stream. Humphreys and Abbot state, for instance, that in the flood of 1858 the Mississippi at Columbus, Ky., discharged more than 56 per cent more water at the 37-foot stage as the flood rose than it did at the same stage of the same flood as the river fell.

In a rapidly rising flood the transverse profile of the water surface is convex, being highest near the center or at the point of greatest velocity, and readings taken from gages near mid-stream give too great a cross section, while those near the bank give too small a cross section. Unless the river bottom is bare rock the cross section may vary rapidly during floods because of scour and fill and thus introduce additional sources of error in calculating discharge.

If a gage is situated a short distance below an important tributary, its flood records when there is heavy rainfall in the basin of this tributary will show abnormalities due to the superimposition of the floods of this tributary on the more general flood of the main stream. Such locally superimposed flood waves will usually disappear farther downstream. This or other local and ephemeral factors play parts that are so important in determining the heights of floods at given points that a series of gages situated at intervals along the same stream will not give proportionately high records of a series of floods. The flood giving the highest record at any one gage usually fails to give the highest record at any other of the series. A 40-foot stage, for instance, at one gage may at the next gage make at one time a 20-foot stage, at another a 30-foot stage, and at another some other stage. When one attempts, then, to tabulate flood stages on a river his results for the same series of years will vary according to the gage station he selects. This is well shown by comparing for a series of years the highest gage reading of the year on Tennessee River at Chattanooga and at Florence. In 1867 a stage of 58.6 feet at Chattanooga corresponded to a stage of 31.1 feet at Florence, whereas in 1897 a stage of only 37.9 feet at Chattanooga corresponded to one of 32.2 feet at Florence, and in 1901 a 37.4-foot stage at Chattanooga was synchronous with only an 18.8-foot stage at Florence. These differences are doubtless due partly to differences in the velocity of the flood wave and partly to differences in rainfall in the intervening part of the river basin. One who contends that floods on the Tennessee have increased in absolute height in recent years would find one of these stations better suited to his purpose than another, whereas some other station would be selected by his opponent.

Conclusions as to stream regimen that are drawn from tables of mean monthly and annual stages of a river at a given point, and that show nothing of the range of the variable heights that produce them, are worthless to show change of regimen. An average monthly stage at a given point might be compiled at one time from gage readings that at no time during that month varied a foot from the monthly mean, whereas at another time they might be the average during the month of numerous variations of wide range on either side of the mean. The mean tells nothing of the actual daily regimen of the river and is worthless to prove that there either has or has not been a change in this regimen.

The writer, indeed, believes that the mean annual discharge—not the mean gage height—of a river at any given point does not vary for a long series of years except as rainfall varies, but that if the region were deforested during the time the distribution of this mean discharge during the year would be affected unless the rainfall were distributed uniformly through the year.

The unreliability of conclusions as to stream discharge that are reached by considering gage heights alone is further illustrated by the fact that where large storage reservoirs, like those at the head of the Mississippi, for instance, are used to supplement the extreme natural low-water flow, their effect in raising the level of the water diminishes downstream and is sometimes entirely lost within a comparatively short distance; so that although the volume of water flowing past a given point is undoubtedly increased by the discharge from the reservoir, the fact is not shown by a notable increase in the gage height. Although the artificial reservoirs at the head of the Mississippi are said to raise the low-water level an average of 14 inches at St. Paul, Minn., their effect steadily diminishes as the river becomes wider and finally disappears entirely 51 miles below St. Paul.

Increased flood heights and flood frequency are most evident on the headwaters and not down on the navigable middle and lower reaches of a large river system, and the chief destructive effect occurs both along the headwaters and at points where the streams first leave the mountains and run out upon the plains. It was in and above Pittsburg, for instance, and not down at Louisville or Cairo that the flood of 1907 on the Ohio was most destructive. It was at Elizabethton on the Watauga and at other places similarly situated on other Appalachian mountain tributaries of the Tennessee, and not down at Chattanooga, Florence, or Paducah, that the floods of 1901 and 1902 on that river were most destructive.

So far as the navigable portions of any of the larger river systems are concerned, the effects of erosion in filling stream channels with sand, gravel, and bowlders are of more importance than the increased height of floods. The increased frequency of floods on the navigable portions of streams is, however, of greater importance than increased height, since floods many feet lower than the highest floods known are able to destroy crops, and their increased frequency makes farming more hazardous on flood plains and decreases greatly the value of such lands.

There is abundant evidence on rivers such as the Tennessee of increased silting in the navigable portions of streams because of the increased erosion resulting from deforestation.

The various factors that regulate stream-flow and regimen may be classified under five heads—climate, topography, geology, vegetation, and artificial control. Since the effect of each of these factors can not as a rule be sharply distinguished, it is difficult to determine their relative magnitude, so that only their general tendency can be considered.

Many of those who have discussed the effect of forests on stream regimen have been disposed to consider one class of data or one group of conditions and to overlook others. Gage heights, for example, have been commonly used in presenting arguments for and against the effect of deforestation on stream regimen, without proper regard for the conditions that have caused the gage heights. Therefore, some of the deductions drawn from gage heights in regard to the effect of deforestation have been unwarranted and misleading.

The writer, though considering the various conditions affecting change of regimen, has based his conclusions chiefly on the record made during long ages in the flood plains, the slopes, and other features of the valley floors and sides.

Flood-plain deposits built up during long ages reveal the character of the floods by which they were formed. If the floods have been small or gentle the deposits will consist of fine alluvium; if they have been great or violent, the deposits in a region like the southern Appalachians will be coarser and will consist of sands, cobbles, or bowlders. If, then, the sands, cobbles, and bowlders that have been repeatedly strewn over their flood plains in the last decade by such rivers as the Watauga, the Doe, the Nolichucky, the French Broad, the Catawba, the Yadkin, and other southern rivers had been the kind of material those rivers had for ages been accustomed to deposit, their entire flood plains would be formed of such coarse material, instead of being composed, as they generally are, of fine sandy loam or clay. Had they at any time in the past been accustomed to carry material so coarse and built it into their flood plains, that material would be there to-day as a mute witness of the fact. Moreover, the normal change in the regimen of a river as the ages pass causes its flood-plain deposits to grow constantly finer. In these rivers, however, this process has been reversed; their deposits have recently grown coarser because there has been a recent increase in the height, velocity, and power of their floods.

This anomalous change in the regimen of these rivers is not due to any change of climate nor to any earth warping or other crustal movement. It is not due to the drainage of swamps and ponds, for these do not exist in the region. It is not due to road building, paving, or ditching, nor to the building of levees or dams or other engineering works, for such changes in the region are quantitatively insufficient to produce the results noted. It is, therefore, reasonably believed to be due to the denudation of the steep mountain slopes and their consequent erosion.

It is difficult to fix any definite period as the beginning of the change recorded, since it was more or less gradual and was not synchronous in all parts of the mountains. In general terms, however, the period extending from 1885 to 1890 may be taken as the start, for it witnessed the revival of industrial activity after the long period of exhaustion and slow recuperation that followed the Civil War. Railroad building then became more active; lumbering began to be an important industry; agriculture was stimulated, tobacco especially in some mountain sections becoming an important crop. Lumbering and clearing for agriculture have increased steadily since then, and their harmful effects began to be felt in certain areas within five to ten years. To-day reckless lumbering and careless and ignorant methods of agriculture are still potent causes of erosion.

PROBLEMS INVOLVED IN THE STUDY.

From the preceding discussion it is evident the subject presents two distinct problems, whose relative magnitude and importance differ in different parts of the region. One of these problems relates to agriculture and the other to forestry.

THE AGRICULTURAL PROBLEM.

The agricultural problem involves the selection of the areas best suited for agriculture because of fertility of soil and moderate slope of surface and the study of the ways in which such areas may best be handled to prevent their destruction through erosion and the destruction of other lands and property by the waste they yield and the floods they help to generate.

Much of the mountain area is properly agricultural land, and as the population increases more and more of this area must be brought under cultivation. This means that steeper and steeper slopes must be cleared, and that danger of erosion must increase unless improved methods of agriculture are introduced. Terracing, contour plowing and ditching, crop rotation, sodding to pasture or meadow, as well as the crops best adapted to the region, especially those most helpful in holding soil on steep slopes, should be studied, and to be of practical value this study must consider all these things as they are directly related to the specific and sometimes peculiar climatic, rainfall, soil, slope, labor, and other natural and economic conditions in the region. It can not profitably be a long-range or general study.

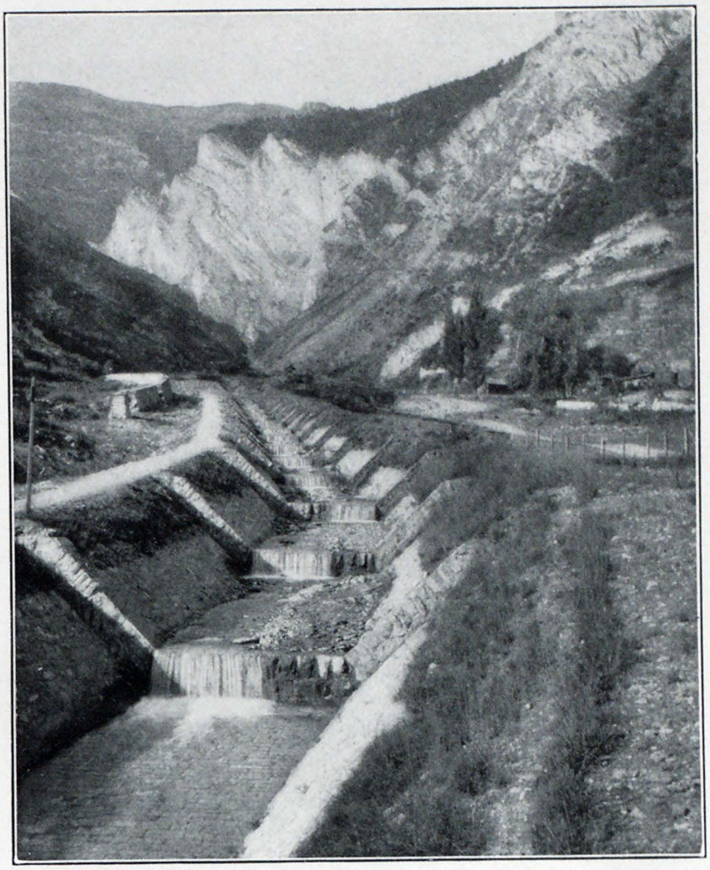
The study of the agricultural problem should also include a consideration of practicable methods of reclaiming eroded and abandoned lands, and of the effectiveness of brush, straw, or other filling for gullies, of brush, log, or rock dams across them, and of tree, vine, or other vegetative covering for bare areas. Such a study should also include a consideration of methods of regulating and restraining both the wild headwaters or torrent reaches, and the lower, but still rapid and easily changeable courses of the mountain streams along whose banks lie the most fertile agricultural lands of the region—lands that are now at the mercy of their uncurbed destructive activities in times of flood.

In studying these problems much could be learned of Europe, where for hundreds of years man has slowly won to agriculture area after area of steeper and steeper slope as population has pressed hard upon subsistence. Doubtless the methods employed in Europe should not be exactly followed, because of differences in climate, crop, soil, labor, and other factors, but, warned by their failures, and profiting by their achievements, we can adapt their successful methods to our own peculiar conditions. Examples of their methods of regulating mountain torrents and preventing erosion on steep slopes are shown in Plate X, opposite. The agricultural lands of the Appalachian Mountains are generally fertile, and if wisely handled will support safely and permanently a much greater population than now inhabits the region.

THE FOREST PROBLEM.

Much of the area is not properly agricultural land, and should not be cleared and forced into agricultural use, because that forcing means quick destruction both of the area itself and of the lower lying areas on the same stream ways. It means also slower, but none the less sure, interference with navigation on the more remote parts of the major stream systems.

The forester would protect steep slopes by keeping them clothed with timber, would coax back tree growth on denuded areas, keep down forest fires, protect and perpetuate the supply



A. A EUROPEAN MOUNTAIN TORRENT THAT HAS BEEN REGULATED.

See page 30.

B. ROCK WALLS BUILT ON A STEEP MOUNTAIN-SIDE FIELD IN EUROPE TO KEEP THE SOIL FROM ERODING.

See page 30.

of hardwood, protect the game and fish, and enhance the beauty and charm of the region as a health and pleasure resort, as well as prevent the navigable streams that flow from these mountains from filling up with the sand and silt, whose removal is now costing annually large sums of money.

DETAILS OF CONDITIONS IN THE REGION.

METHOD OF TREATMENT.

The specific descriptions embodied in the following pages give the data necessary for judgment as to the seriousness of the conditions now existing in various parts of the southern Appalachians and afford some basis, it is hoped, for the intelligent and successful application of remedial measures. The units considered are the major stream basins, which are discussed in the geographical order in which they are found to succeed each other, as one encircles the southern Appalachians by passing southwestward from the Virginia-Tennessee line along the west side of the mountains to central eastern Alabama, there turns eastward around their southern end and then goes northward across Georgia and the Carolinas back to Virginia. The upper portion of the New River basin is then described; and, finally, the Monongahela basin, heading in West Virginia and extending northward to Pittsburg.

The order of description follows the order in which the basins were examined. The position, extend, and relations of the major basins are shown in Plate XI, page 32, and the areas examined in detail in figure 1. The names used for the streams and other geographic and geologic features are those given on the topographic and geologic maps of the United States Geological Survey. These maps, which are listed below, will be found exceedingly helpful in following the discussion.

List of atlas sheets and geologic folios (F) covering the southern Appalachian region and the New and Monongahela River basins.[a]

Abbeville.
Abingdon.
Accident (F).
Anniston.
Asheville (F).
Ashland (Ala.).
Athalia.
Atlanta (Ga.).
Bessemer.
Birmingham (F).
Blacksville.
Briceville (F).
Bristol (F).
Brockton.
Brookwood.
Buckhannon (F).
Burnsville.
Carnesville.
Cartersville.
Centerpoint.
Charleston (F).
Charlotte.
Chattanooga (F).
Clanton.
Clarksburg.
Cleveland (Tenn.) (F).
Columbia (S. C.).
Columbus.
Cowee.
Cranberry (F).
Crawfordville.
Cullman.
Cumberland Gap.
Dadeville.
Dahlonega.
Dalton.
Dublin.
Elberton.
Ellijay.
Estillville (F).
Fairmont.
Fort Payne.
Frostburg.
Gadsden (F).
Gaffney.
Gainesville (Ga.).
Glenwood.
Grantsville (F).
Greeneville (F).
Hickory.
Hillsville.
Hinton.
Huntington (F).
Huntsville.
Jasper.
Jonesville.
Kanawha Falls.
Kenna.
Kings Mountain.
Kingston (F).
Knoxville (F).
Lewisburg.
Littleton.
Loudon (F).
McCormick.
Mannington.
Marietta (Ga.).
Maynardville (F).
Monroe.
Morganton.
Morgantown.
Morristown (Tenn.) (F).
Mount Guyot.
Mount Mitchell (F).
Murphy.
Nantahala (F).
Nicholas.
Oceana.
Opelika.
Philippi.
Pickens.
Piedmont (F).
Pikeville (F).
Pisgah (F).
Pocahontas (F).
Point Pleasant.
Raleigh (F).
Ravenswood.
Ringgold (F).
Roan Mountan (F).
Rome (F).
St. George (W. Va.).
Saluda.
Scottsboro.
Sewanee (F).
Sharon.
Springville.
Statesville.
Stevenson (F).
Sutton.
Suwanee.
Talbotton.
Talladega.
Tallapoosa.
Vadis.
Walhalla.
Walton.
Wartburg (F).
Wedowee.
Weston.
Wetumpka.
Wilkesboro.
Winfield (W. Va.).
Wytheville.
Yadkinville.

[a] The atlas sheets are sold by the United States Geological Survey for 5 cents each; the folios for 25 cents each.

TENNESSEE RIVER BASIN.

Tennessee River is formed by the union of Holston and French Broad rivers 4½ miles above Knoxville, Tenn. An examination of these streams shows that the Holston is the direct continuation of the Tennessee up the great Appalachian Valley, and for this reason the head of the Holston is here treated as the head of the Tennessee.[a] The main tributary basins from the eastern or Appalachian Mountain side will first be described in order from the Holston southward to the Hiwassee, and the description of these will be followed by a description of the Tennessee itself from Knoxville, Tenn., to Paducah, Ky. No examination was made of the streams entering from the west or Cumberland Mountain side of the basin.

HOLSTON BASIN.

GENERAL FEATURES.

The basin of Holston River has an extreme length of about 170 miles, of which the lower 141½ miles, below the junction of the north and south forks near Kingsport, Tenn., is narrow and receives but little drainage. Above this junction the basin has an average width of perhaps 50 miles. The slope of the north fork of the Holston is about 6 feet per mile; that of the lower 141½ miles is 2.55 feet per mile. This slope is, however, by no means uniformly distributed, but quiet pools and shallow reaches succeed each other at varying intervals throughout the course.

All of the larger streams of the Holston basin flow either on rock bottom or over bed rock that is covered at ordinary stages by a foot or two of loose sand and gravel. During floods this loose material is undoubtedly set in motion and the bottom is subjected to powerful scouring action. The streams are thus actively degrading or deepening their channels, and the material consequently has no general tendency to lodge and accumulate in great quantities, so that bars and islands as a rule are not growing. During floods, however, more material is furnished than can be removed and the excess is deposited to build flood plains, which waste as erosion progresses; and as the channels are deepened new flood plains at lower levels are formed and the older ones are left as fossil flood plains, many of which may be observed at different levels along the sides of the valleys.

Flood crests on the Holston, as well as on other streams of equally high gradient, as a rule have steep fronts, advance rapidly, and recede with almost equal rapidity. As might be expected, such floods are usually destructive.

HOLSTON BASIN ABOVE THE MOUTH OF WATAUGA RIVER.

No detailed examination was made of the extreme upper part of the Holston basin, but in the course of several trips across it the general conditions were noted.

The upper Holston basin is drained by the North and South forks of the Holston, which flow southwestward in harmony with the general trend of the mountain ridges of the region and which, with their tributaries, show a marked parallelism in their courses. This parallel arrangement is due to the folding, faulting, and subsequent erosion of the rocks of the region, whose upturned and eroded edges trend northeast and southwest. These Paleozoic rocks offer unequal resistance to erosion; some weather rapidly and others very slowly, so that areas of soft shales and limestones have been carved into valleys and beds of resistant chert and sandstone or quartzite stand up as ridges. The country is therefore characterized by long, narrow valleys, separated by equally long, narrow ridges, with steep slopes and in many places sharp crests.

The valleys are usually fertile and level or gently rolling, and are largely cleared. The soil, which is commonly formed of limestone or calcareous shale, the elevation, which ranges

[a] In the stream-measurement reports of the United States Geological Survey the French Broad, because of its greater drainage area, is treated as the upper extension of the Tennessee.

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from 1,400 to 2,500 feet, and the rainfall, which averages about 45 inches a year, make this a natural grass region, and a very large proportion of the cleared area is in meadow or pasture land, though some corn and small grains are raised. Many of the richer slopes also are cleared for several hundred feet up their sides, and the tops of many of the ridges are also in grass. Where the land is sodded there is practically no erosion. Each year more and more of the cultivated land is being put in grass.

Most of the Holston valley in Virginia lies in Washington and Smythe counties. About 77 per cent of the area of these counties is classed as farm lands by the Twelfth Census, and of this farm area about 57 per cent is cleared. The 23 per cent not in farms consists largely of timber areas in the rougher or more mountainous portions of the counties. Much of the timber has been or is being cut, and practically all of it is in the hands of lumber companies. From 45 to 50 per cent of the area of these two counties and probably 50 per cent of the entire Holston basin in Virginia is cleared, and much more than half of the cleared area is in grass.

That the erosion of this cleared land is in most places very slight is evident, but close examination of some of the slopes reveals the presence of isolated gullies or bare, eroded areas, and here and there a slope of shale, which weathers to a fine-grained, compact clay, also shows a tendency to gully. In flood the streams in the region do not carry so large an amount of sediment as is borne by streams draining areas where a larger part of the slopes are bare, as, for instance, those farther south in the Appalachians. The flood waters are usually brownish or grayish in color and not the deep yellow or red shown by the more southern streams when in flood, the discoloration being due more to decaying vegetable matter than to suspended particles of soil.

The upper Holston valley is traversed lengthwise by the Norfolk and Western and Southern Railways and crosswise by the Virginia and Southwestern and by several branches of the Norfolk and Western, one branch extending southeastward from Abingdon, Va., into the Holston, Iron, and Stone mountains, one going down Shady Valley, and another up White Top Laurel Valley, making available the timber within the southeast edge of the basin. Another branch extends southward from Marion, Va., across the Iron Mountains into the edge of the New River basin. These roads furnish transportation for large quantities of lumber, cross-ties, pulp wood, tan bark, and tanning-extract wood. Along the main lines of railway lumbering has been active for years and most of the good timber has been cut. The construction of these branch roads has made it possible to extend the operations back into the mountains, and only a few of the more remote and inaccessible coves of the upper Holston basin remain untouched by the ax. Large lumber plants are established at Bristol, Abingdon, and other points in the region, and many small mills are located on the branch railways or back in the mountain coves. Lumber from these small mills is hauled by wagon 20 miles or more to reach one of the railways.

The main part of the upper Holston valley needs no protection from erosion. Most of the forested areas lie along narrow ridges, each of comparatively small extent, that are so separated that they could not be segregated from the cleared lands of the basin. Moreover, they do not appear to be in special danger nor are they apt to become a menace to the valleys between. It is true that the run-off from the sodded slopes and valleys during heavy rains is much more rapid than that from a wooded area with abundant humus, yet undoubtedly these lands are now being put to the best possible use, and though they give an increased run-off during rains and perhaps a slightly greater flood-crest height, such conditions should probably be regarded as unavoidable consequences of man's use of the region.

The upper Holston valley is not subject to extraordinary damage from floods. In some places, it is true, the streams are cutting; in others they are building; but no serious damage is being done and there is not the great volume of detritus working into the stream channels that is found farther south, where the cleared areas are not sodded. The amount of destruction along the streams is consequently much less than along the streams farther south.

Along its southeastern edge the upper Holston basin is separated from the New and Watauga basins by a rough, mountainous country, which is crossed by the Holston, Iron, and Stone Mountain ranges, and a large portion of which is so steep, rough, and stony that it can never be used for farming. In this region lumbering is active.

WATAUGA RIVER BASIN.

Watauga River rises in the Blue Ridge near the head of New River and flows northwestward to its junction with the south fork of the Holston. Its basin is compact in shape and may be divided into two parts—a larger eastern part, lying within the mountains proper, and a smaller western one, which lies in the great valley of east Tennessee. The conditions in the mountainous portion are of chief interest for the purposes of this report, but the conditions along the lower part of the stream will also be described.

UPPER WATAUGA BASIN.

The upper part of the Watauga basin has an elevation along the stream itself of 1,700 to to 3,000 feet above sea level, but a large part of its surface is much higher and within or around its margin there are many peaks 5,000 feet or more in altitude. Grandfather Mountain is 5,964 feet high, Hanging Rock is 5,237 feet, and Roan Mountain is 6,313 feet. The surface is much broken by long-continued erosion. The tributary stream valleys are narrow and deep and are separated by steep and usually densely wooded ridges. The streams have steep gradients and high velocity, and consequently great destructive power during floods. The damage from floods in this basin in 1901 amounted to $2,000,000.

The examination of the Watauga basin began at Johnson City, Tenn. At Watauga Valley, where the river itself was first reached, evidences of the great flood of 1901 were seen on all sides. The bottom lands had been badly washed and torn to pieces. In some places the roads had been entirely destroyed by the erosion of great holes; in others white sand had been spread deeply over lands that had previously been highly fertile. At one place the railway company now has a sand pit where large crops of corn were formerly raised. Much of this Watauga bottom land can not be remade in years. Estimates of the average amount of damage place it at about 75 per cent of the original value of the land. Considerable areas of land, formerly worth from $75 to $100 an acre, were unsalable after the flood. The greatest destruction occurred near the river. In many places 6 or 8 feet of soil has been stripped from a belt 100 to 150 yards wide, exposing the underlying stream bowlders or the edges of upturned limestone beds.

At Elizabethton the river broke from its channel and swept through the town, destroying one street entirely and cutting a new channel, which the town has attempted to close by building a stone and crib work dam across its upper end. It will be years, however, before the channel thus excavated in a few hours can be filled up and obliterated.

Doe River above Elizabethton shows similar flood effects, much of the bordering land having been destroyed by the same process of soil stripping or sand covering.

The Watauga and the Doe are in most places bordered by a narrow ordinary flood plain, above which is an extraordinary flood plain 100 to 1,000 yards in width. The narrow, ordinary plain is frequently covered by floods, so that crops growing on it are liable to destruction at almost any time. Formerly the higher, extraordinary plain was rarely seriously injured by high waters, but in recent years high water has reached it more frequently and covered it more deeply, and very much of the destruction in 1901, both of bottom lands and of crops, roads, and railways, was on this extraordinary flood plain. It can no longer be regarded as reasonably safe from floods, and its value has been greatly lessened, both because of this fact and because of the actual destruction already wrought on the land itself.

Older fossil flood plains may be seen along both rivers at various heights. One that is particularly well preserved is 80 feet higher than the extraordinary plain now being damaged by floods. It contains in places an abundance of rounded bowlders up to 1 or 2 feet in diameter that once formed its base, just as many present-day flood plains of fine alluvial material are underlain by a bowlder bed at their base. About 50 feet higher there is another still older fossil flood plain or terrace, whose surface is also characterized by rounded bowlders, but is much dissected by erosion and is preserved to-day only in remnants. These old flood plains, formed when the river flowed at a distinctly higher level than now, are, of course, above the reach of even the most extraordinary floods, but long leaching and the cessation of alluvial deposition have left the soil little of its original fertility.

Five miles above Elizabethton Doe River passes through a narrow, precipitous, rocky gorge. The railway through this gorge was practically destroyed, and above the gorge practically all bridges as well as much of the track of the remainder of the line up to Cranberry, N. C., were swept away and destroyed in 1901.

Allentown suffered much from the same flood. County bridges were destroyed and many houses were swept from their foundations or wrecked. A large part of the destruction here, as elsewhere, was caused by sawmill refuse—slabs and other floating timbers—which, in the grasp of the swift waters, acted as battering rams or lodged and formed rafts that grew until they ultimately swept everything before them.

From Allentown northeastward to Watauga River a considerable area of steep slopes has been cleared, but the soil is somewhat porous and sandy and much of the rainfall is absorbed, so that there is comparatively little erosion. Along the Watauga, above its gorge through the Iron Mountain, evidences of flood damages are numerous; bottom lands were washed away, roads were torn to pieces, and railroad bridges and embankments were generally destroyed.

The bottoms up to Butler are cleared, although the steep slopes on either side are usually wooded. At Butler a steel highway bridge was swept away, much land along the river was injured, and cleared areas on the hillsides were badly washed. Above Butler the Watauga Valley contains practically no bottom lands. In this part of its course the river cuts through Stone Mountains in a narrow, steep-sided gorge that is not cleared, and only small patches of flood plain are found until the valley widens near Valle Crucis, N. C.

The lands about and above Valle Crucis, past Shulls Mill and on to the head of the river, have in recent years been much injured by floods. The channel of the stream has been filled with débris to such an extent that the river overflows its banks easily, and its descent is so rapid that many parts of the adjacent bottom lands have been much washed and gouged, or once fertile fields have been thickly overspread with cobbles and gravels. Along the steep valley slopes are considerable areas of cleared land which in places show much gullying.

Practically all of the upper part of the Watauga Valley is an area of granite. Where the granite is coarsely crystalline in texture it weathers into a soil that is porous enough to absorb much of the rainfall and prevent extensive erosion; where it is finely crystalline it weathers into a more compact clayey soil that is not nearly so pervious, and erosion is much more pronounced. Steeply sloping areas underlain by the fine-textured type of this granite should, if possible, be kept in timber; those underlain by the coarse-grained type can be cleared with much less risk of destruction by erosion.

Another effect of the rapid erosion and filling of the channel of the Watauga appears in the bars and islands, which may be seen at many places above and below Valle Crucis. Sand and gravel lodging in shallow places becomes covered with various plant growths, and in a few years forms an island which deflects the stream current and causes erosion of the banks. At other places where the steep tributary basins have been cleared, the Watauga is unable to remove all the débris brought to it by the streams, and broad fans or cones of sand and gravel are forming at the mouths of these tributaries and are tending to push the Watauga to the opposite side of the valley. The obstruction of the main channel that originates in this way may in time increase to such an extent as to pond the Watauga and convert the bottoms immediately above into marshes or lakes. Dutch Creek has formed an especially well-marked alluvial fan of this type, which has already ruined a number of acres of fine bottom land. The owners of the land along this upper part of the Watauga have tried in various ways to prevent its destruction by the river and its tributaries. In some places they have built stone cribbing or brush training walls; in others they have faced the cribbing with sheet piling.

Above Shulls Mill every mill and dam was washed away by the flood of 1901 and bottoms were damaged from 15 to 25 per cent of the former value of the land. Mills, dams, and bridges on several of the tributaries of the upper Watauga were also carried out, and some of the steep cleared hillsides were damaged more than 25 per cent. A considerable part of the damage to cleared hillsides is alleged to have been due to the snaking trails, made by the lumbermen on the higher wooded slopes, which furnished runways for the water and concentrated it on the lower cleared slopes. The county has, at no little cost, replaced the bridges, and in places has relocated and graded roads along the hillsides above the reach of future floods.

Above Foscoe the higher slopes on the south side of Hanging Rock Mountain have been largely cleared and many of them have washed badly, especially within recent years, so that they now present many bare red-clay areas. On the north and west slope of Grandfather Mountain very little clearing has been done. The cleared land is practically all in grass and has not washed to any appreciable extent. The Moody Mill Creek and Boone Fork regions are not largely cleared, and erosion does not seem to be especially active in either of these basins.

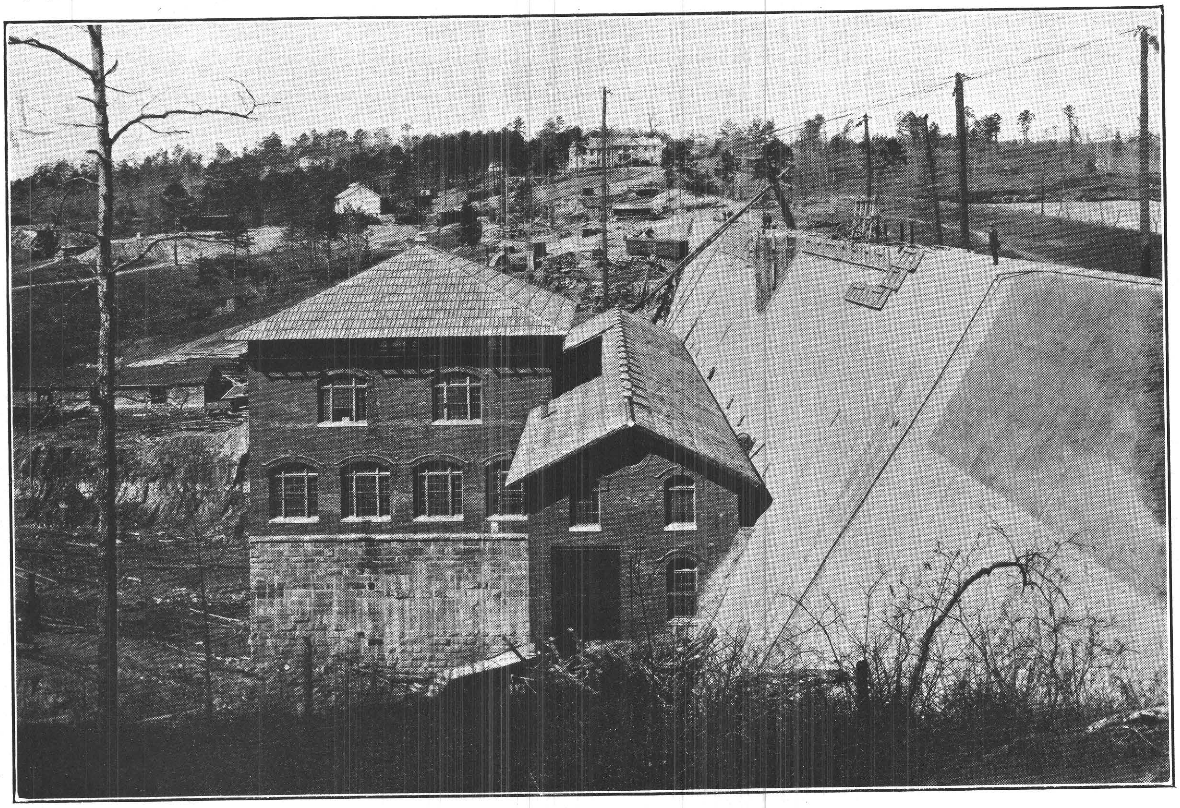
At the head of Banners Elk Creek there is a good example of erosion of a lower wooded slope caused by water concentrated by ditches from fields on the higher slopes above. Two miles above Banners Elk cleared bottom lands are seen; the stream is very swift, however, and in floods cuts new channels at many places and leaves the flood plain surface in a hummocky condition. It is, in fact, rather a cobble torrent plain than an alluvial plain and can be made safe from erosion only by building extensive retaining walls or other devices for holding the stream in check. The land is not especially fertile and some parts are poorly drained and swampy.

Much the larger part of the area between Beech Mountain and Hanging Rock is wooded and wild. Most of the cleared areas noted were on the slope of Beech Mountain and were not eroding badly, perhaps because the rocks of the Beech Mountain area consist of a coarse porphyritic granite, which weathers into a loose, porous soil that permits the rapid downward percolation of the rainfall and thus greatly decreases the run-off. From Banners Elk to Elk Park the stream flows in a steep-sided more or less rocky gorge, its descent is rapid, and erosion has been so active that, except in a few areas of soft rock, it has built little or no flood plain. Where flood plains have been made they are rather beveled, sloping plains than true flood plains, the edge near the stream being much lower than the part near the valley wall. Such plains result where the stream slowly shifts laterally while cutting down vertically, forming on one side a beveled slope of which only the lower edge is ever covered by floods and which embraces in successively higher portions the ordinary, extraordinary, and fossil flood plains; on the other side there is usually a steep slope or an undercut bluff. Here and there where the gorge is not exceedingly steep the fields have been cleared and in places these show the effects of erosion.

Forty to 60 per cent of the area from Elk Park northward across Beech Mountain to the valley of Loggy Gap is cleared and some of it is rather steep, but it shows little erosion, for its soil is made up of decomposed granite of coarse texture and is usually porous enough to absorb a large portion of the rainfall. Near Loggy Gap, however, the rocks weather into a closer-grained soil that is more liable to erosion on steep slopes.

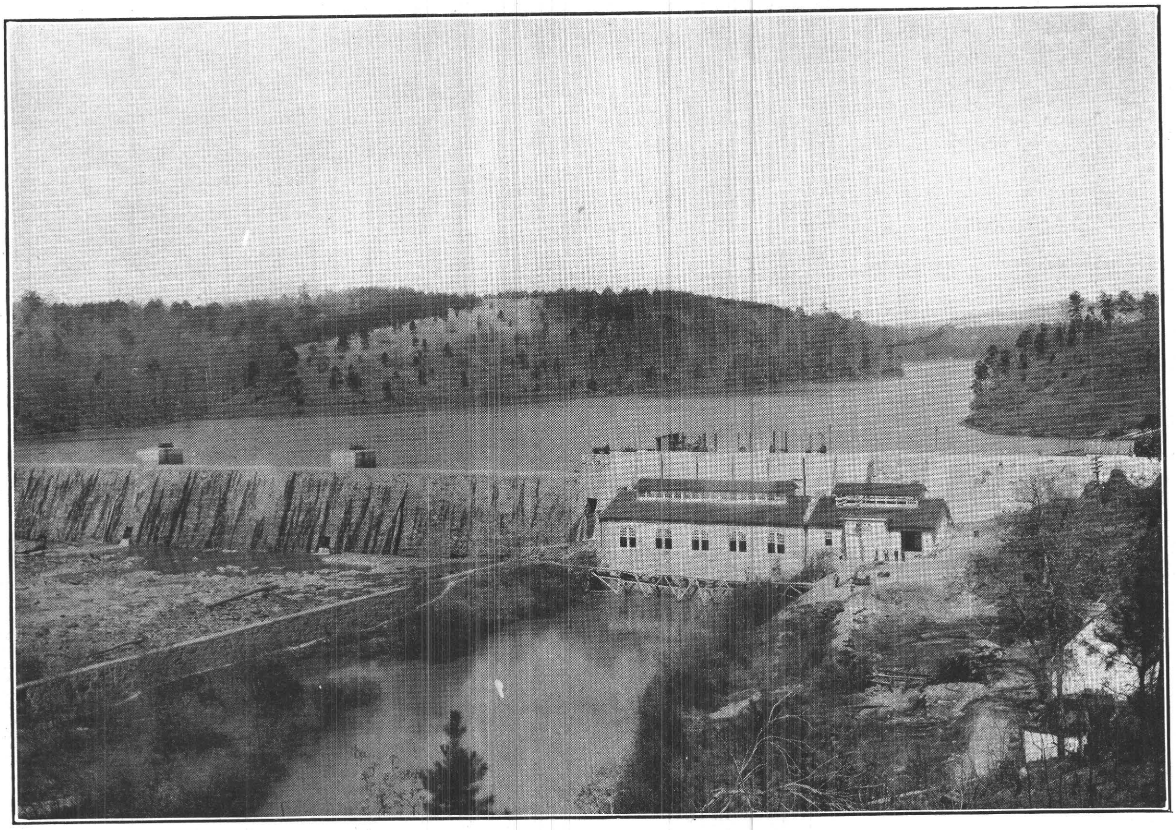
The mountain sides from Loggy Gap to the mouth of Beech Creek are 30 to 40 per cent cleared; from Beech Creek down to Norris only the higher slopes are cleared, the lower portion of the slope forming an almost precipitous gorge. About Norris there are some small areas of rock which weather to a compact clay, and where cleared these areas show extensive gullying.

Elk Creek, one of the important southern tributaries of the Watauga, flows in its lower course in a narrow valley cut in shales. At ordinary stages the stream is actively degrading its channel and flows almost everywhere on the upturned edges of the shales; during floods, however, it can not remove all the débris brought to it, and at a number of places where the shales are rather soft it has built a flood plain 100 to 300 yards in width. This flood plain is usually about 10 feet above ordinary water level, and is underlain near water level by a cobble



A. POWER HOUSE AND BULKHEAD AT GREAT FALLS STATION OF THE SOUTHERN POWER COMPANY, ON CATAWBA RIVER, CHESTER COUNTY, S. C.

See page 14.



B. PORTMAN PLANT OF ANDERSON (S. C.) WATER, LIGHT, AND POWER COMPANY, ON SENECA RIVER.

See page 14.

and bowlder bed, such as is left in this region by most streams having considerable slope and rapid current. At Elk Mills the flood plain is about 300 yards wide, but the stream is so active and restless that during floods it is constantly undercutting its banks on one side or the other and shifting its position. In this way it has stripped a zone 100 to 150 yards wide and converted it into a cobble and bowlder belt. This shifting is not, properly speaking, meandering, for the stream is too vigorous to develop conventional meanders. The shifting is irregular and spasmodic, occurs during floods, and seems to be due to choking by chance obstructions or to abrupt bends in the channel, which during floods strongly deflect the current against one bank or the other. The swift current rapidly sweeps away the alluvial soil and forms a new channel.

The amount of waste carried by this stream has increased notably during recent years. A dam at Elk Mills that was originally only 3 feet high has been so filled with débris that the owners have been compelled to raise it 2 feet in order to regain its storage capacity. It is evident, however, that this expedient will afford but temporary relief, for the dam will soon be full again and the owners must lose the value of the dam and either utilize merely the flow of the stream or abandon the mill.

The source of this waste is easily recognized. The hills on the sides of the stream are unusually steep and have been so deeply cut by erosion that they have a rounded, knob-like appearance. They are very largely cultivated, and the fine, close-grained soils resulting from the weathering of the shales permit but little percolation and have gullied badly. Crude efforts have been made to check erosion by building loose rock dams at intervals across the gullies, but these dams are rapidly filled with fine clay and have not greatly checked, much less remedied, the evil. The hills are planted largely in grain, only a small area being kept in grass, and these lands must therefore soon lose their soil and be abandoned unless they are terraced and sodded.

Some 3 miles above Elk Mills granite succeeds the shale, the flood plain disappears, and the valley walls remain uncleared, though of but moderate slope. In this region lumbering was actively in progress when the stream was visited, and a logging chute was being made from the eastern valley side down to the Elk. This chute will ultimately be converted into an erosion channel, as have other older logging chutes higher up the stream. At the foot of these older chutes notable fan-like or cone-like accumulations of rock and gravel have already formed.

Near the State line there are some clearings and small flood plains. One at least of these plains has been formed by the complete filling of the impounding area above a milldam. In some places the flood plains have been covered by barren white sand during floods, and in these localities they are now of little or no agricultural value. In other places they have been badly eroded during floods and are now abandoned. At no place in this upper portion of the stream is the flood plain more than a very few feet above ordinary water level, so that overflows are frequent, crops are extremely uncertain, and conditions are tending to become constantly worse. Under present conditions these lands may be regarded as of practically no value.

Roane Creek enters the Watauga from the north a short distance below the mouth of Elk Creek. From its mouth at Butler, Tenn., for several miles upstream its living flood plain is relatively broad and stands at an average height of about 8 feet above water level. In places this flood plain is badly washed and at a point 2 miles northeast of Butler a railway bridge and several acres of fertile lands have recently been swept away and some bad runs or diversion channels have been developed across the once fertile bottoms. Such runs are especially likely to form across meander curves, as may be seen in Plate XIII (p. 38). About 35 feet above this living flood plain there is a well-defined high or fossil flood plain, which is safe from any possible overflow. This stream channel, like that of Elk Creek, is shifting, and although it is not generally degrading its bed, it has developed a bowlder zone that is in places more than 100 yards wide. The hillsides are steep and most of them are cleared and cultivated for a vertical distance of 100 to 300 feet above the valley. The soil on these slopes is porous and does not wash badly.

Doe Creek enters Roane Creek at Mouth of Doe in a narrow gorge. Across this gorge has been built a milldam, the pond above which in recent years has filled completely with sand and stones. In its stretch above the dam the stream is unable to remove the débris furnished to it by its tributaries and is distributing silt along its way, aggrading its flood plain and menacing its bottoms. The steep hillsides show many washes, which end on the edge of the flood plain in stony alluvial fans or cones. The aggradation in the main stream has given it a tendency to meander, and just below Doeville a long rock-filled crib has recently been built to protect the bottoms. The steep shale slopes west and northwest of Doeville are cultivated and are washing and gullying. Above Doeville the numerous tributaries of Doe Creek from the west have built long, low sandy or stony fans where they strike the Doe Creek flood plain and have in the aggregate destroyed a considerable area of good bottom lands. In some places the steep slopes erode into gullies; in other places several small, shallow gullies have coalesced into one broad erosion plain from which the soil has been entirely stripped.

At Pandora the valley narrows and steep shale hills rise abruptly on its sides. These slopes are cleared in large part and in many places show the characteristic results of shale erosion. Several miles farther upstream the valley widens again and about Little Doe a broad, sloping, or beveled flood plain has been developed. The valley walls are not so steep here and the erosion of the cleared slopes, though under way, is not so vigorous nor so destructive as along the lower course of the stream.

At Mountain City the slopes in general are moderate, and, though largely cleared, do not suffer badly from erosion.

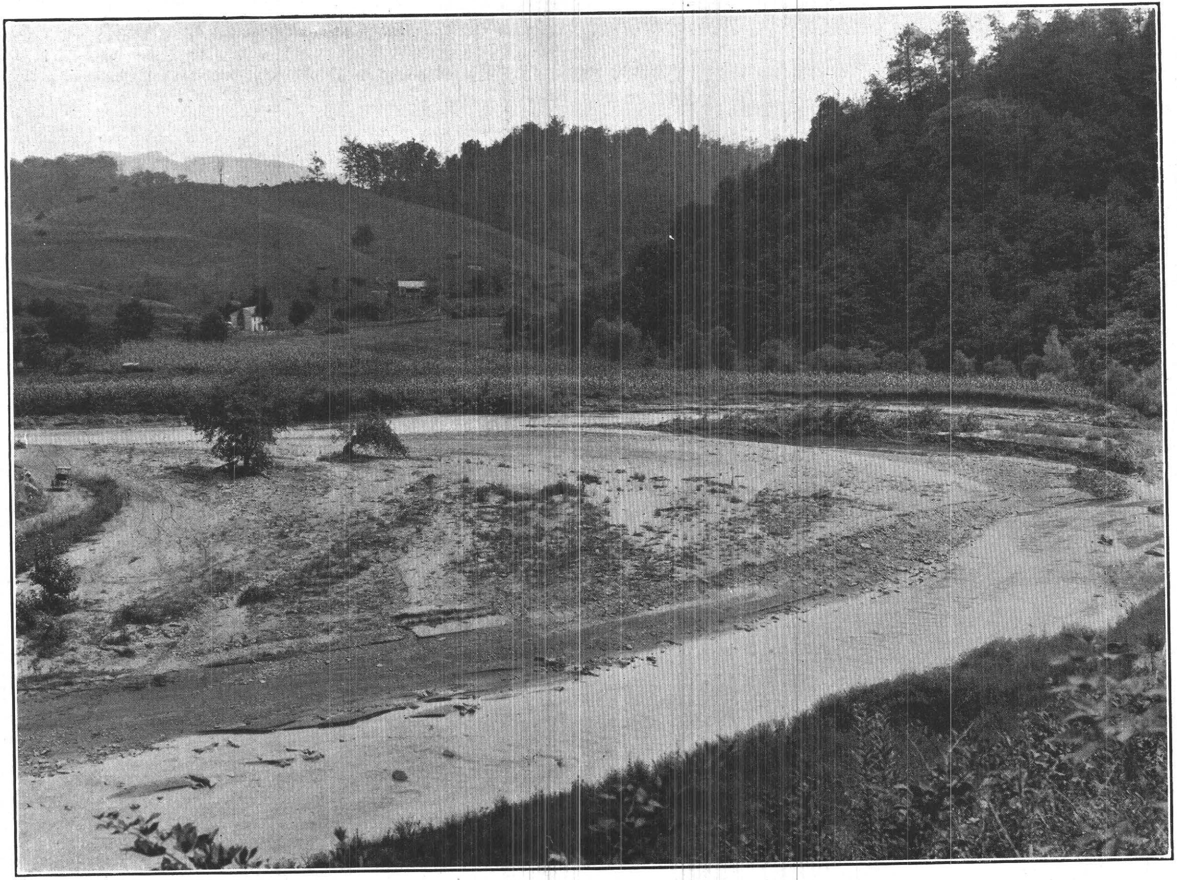
At Rhea Forge, and for a number of miles down Roane Creek, there is a relatively broad, well-developed flood plain, which has been affected in many places by recent floods. The railway along the flood plain has also been seriously damaged. Forge Creek, one of the tributaries of Roane Creek, has done much damage. Many of its valley slopes are badly washed, and the ponded area above the dam that once furnished power for an iron forge and furnace has been completely filled with sediment and is now converted into a cornfield.

Along Roane Creek, above Rhea Forge, there is very little bottom land. The hillsides are exceedingly steep and in many places are cleared, especially on the east side of the creek, and are washing to a considerable extent. Still farther upstream the forest-clad gorge is wild, rocky, and narrow. Just below Key Station the valley widens again and the slopes become gentler. These slopes have been cleared and are mostly in small grain or corn. Much of the clearing has been done recently, and the soil still retains a portion of its humus and has not yet begun to erode badly. The granite rocks of this region weather into a porous soil, which tends to minimize surface erosion.

About Trade and on to the State line 70 to 80 per cent of the steep mountain slopes have been cleared. Perhaps over half of this cleared area is in grass and is not being injured by erosion; the remainder is kept in corn and small grain and would rapidly wash away were it not for the porousness of the soil. Notwithstanding this, however, considerable areas have been badly gullied, and the only safe course for the farmer to pursue in order to prevent erosion is to keep the lands in grass.

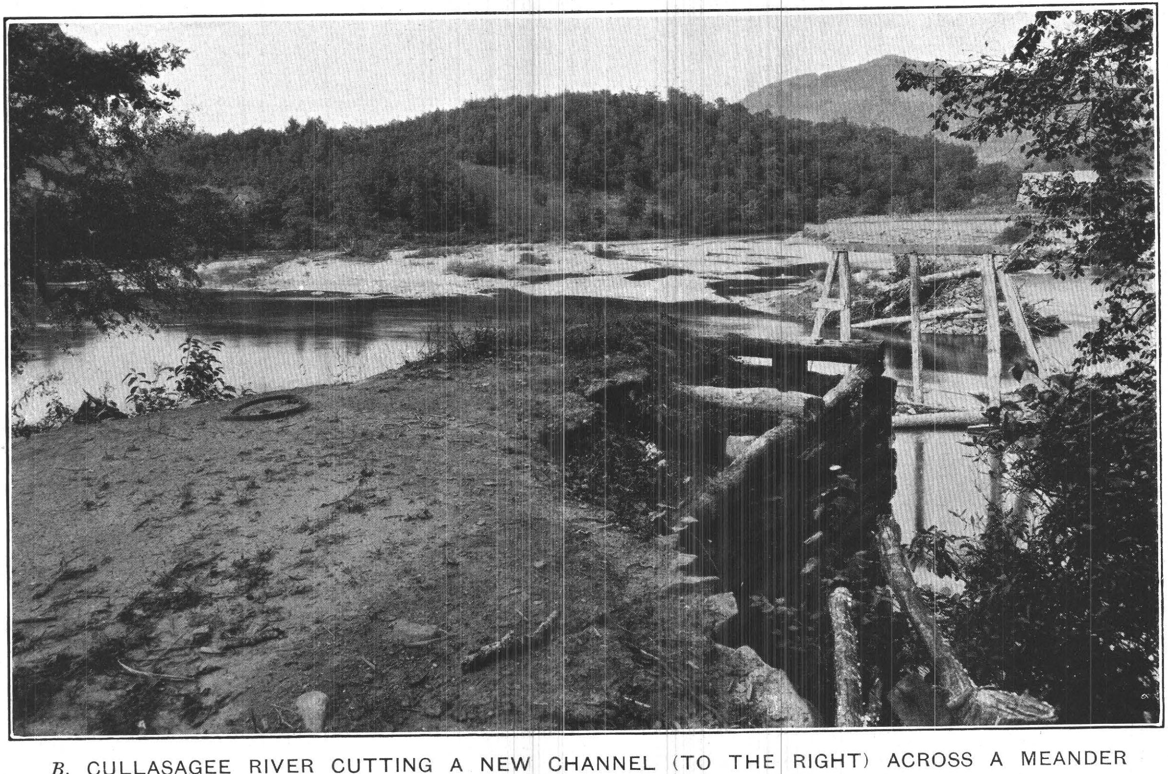
At Zionsville many of the steep hillsides are cleared to the very tops. Cove Creek is a steep torrential stream that is frequently shifting its channel, so that its narrow flood plain is composed of coarse material and is repeatedly being cut to pieces and refashioned. Along the stream there are indications that aggradation is going on rapidly. A few miles below Zionsville the stream gradient is not so steep and the position of the channel is consequently more stable. The alluvial flood plain in this lower part of the creek is composed of finer material and is more valuable for agriculture. It has not yet been seriously injured by floods.

Farther down Cove Creek valley there are numerous mountain-side clearings, and although the rocks of the region are granitic many of the cleared slopes are so steep that erosion is active. At a point a mile north of Mast, for instance, many steep mountain-side fields have been abandoned to gullies, briers, and broom sedge; others, though badly washed, are still cultivated. From these cultivated areas most of the fertile soil has already been removed, and the crops



A. EROSION ON INSIDE OF MEANDER CURVE.

See page 37.



B. CULLASAGEE RIVER CUTTING A NEW CHANNEL (TO THE RIGHT) ACROSS A MEANDER CURVE.

See page 37.

now grown scarcely warrant the little work bestowed upon them. In general, little or no effort is being made to prevent the erosion of these steep fields, and it will not be many years before they, too, must be abandoned. Milldams along this valley, even those built only a few years ago, are nearly full of sand and gravel.

These granitic soils erode into long, narrow, parallel gullies that run straight down the steep slopes. They gradually deepen and widen until the entire original surface has been removed and the edges of adjacent gullies coalesce, leaving the once fertile fields a maze of erosion-formed ridges and grooves, whose cross section has a serrate profile. From some cleared areas on these granitic slopes, as, for example, near Sugar Grove, portions of the surface have slipped off and left bare spots. Erosion by such landslides is more likely to occur where the granite is micaceous or is of a gneissoid type, or has suffered spheroidal weathering and is fractured in planes of easy parting that may be inclined at angles favorable for the production of landslides. Such slides occur usually in wet weather, especially late in the winter or early in the spring, and may be started by the trampling of cattle.

The flood plain of the lower valley of Cove Creek is 100 to 300 yards wide, and the position of the stream channel is mainly stable, although here and there it shows a tendency to shift and has produced a narrow zone of cobble. The stream is also aggrading somewhat. The mountain-sides are cultivated up to a vertical distance of 300 or 400 feet above the valley. Cove Valley is bounded on the east by Beech Mountain Range, which rises to a height of 5,369 feet. The upper slopes of this range are densely wooded, but some clearings occur on its lower slopes. These, as well as clearings on other high mountains in the vicinity, are kept in grass and grazed, so that erosion here is not active.

The cleared lands on the steep slopes on the sides of some tributaries of Cove Creek have been kept largely in grass, and the condition of the narrow flood plain along these streams, as well as that of the steep slopes themselves, is very much better than where clean culture has prevailed.

The inhabitants of the Cove Creek region generally realize that erosion is becoming worse and that damages from floods are becoming greater. They say that destructive floods are more frequent than in former years and attribute these changes to the operations of lumbermen and the clearing of steep lands, but they are taking practically no measures to remedy the evils. The steep fields are cultivated as long as possible and are then abandoned.

Lumbering is active in most of the Watauga basin, and long trains of wagons carry lumber to the railways at Mountain City, Butler, Cranberry, Elk Park, and other places. In some localities destructive forest fires have followed in the wake of the lumberman; in others the forest is reproducing itself where the area lumbered has not subsequently been cleared and placed in cultivation or grass.

For about 3 miles from the head of Wilson Creek the stream flows with a rapid current in a narrow valley devoid of flood plain. The mountain sides are steep and generally wooded, so that the valley may be said to remain in a state of nature and to be occupied merely by the stream and railway. Farther down the creek the valley widens gradually and the stream has formed a flood plain. At the mouth of Shell Creek this flood plain is some 200 yards wide, but about half of it has recently been ruined by floods and abandoned. From this point down to Roan Mountain station from one-half to three-fourths of the flood plain has been similarly destroyed. The principal belt of destruction is a cobble zone on either side of the stream, where the soil has been entirely stripped from the flood plain. This zone of destruction is more nearly straight than the stream channel itself, which winds irregularly back and forth across it and is constantly shifting its position. As a rule the belt of destroyed flood plain is wider just below the mouths of tributary streams, undoubtedly because of the cross currents set up during floods by the entrance of such tributaries.

Along its entire course, from above Shell Creek downward, Wilson Creek is overloaded with débris and is depositing on its flood plain the material it is unable to remove. The flood plain is consequently building up or aggrading, and distributaries are given off by the main channel at short intervals. These streamlets cut narrow channels, which are only 2 or 3 feet below the surface of the flood plain, and after short courses many of them end in fans of sand and cobbles that they have spread over the once fertile surface.

The valley walls are retreating, and at many places poorly preserved remnants of an old stream terrace stand between 100 and 150 feet above the present surface of the flood plain. The valley sides are largely cleared and cultivated. If after clearing they are kept for a year or two only in grain and then sodded the surface is protected from erosion reasonably well, but if they are cultivated for several years until the original humus has been lost it becomes difficult to establish a sod, and erosion almost invariably occurs. Several such eroded areas may be found, especially on the south side of the valley. The surface generally cuts into deep, narrow gullies that run radially down the rounded hills. In a few places sheet wash was observed.

At Roan Mountain the flood plain is 300 to 400 yards wide and the tributary entering from the south has built an alluvial fan of sand, cobbles, tree trunks, and other débris that extends entirely across the main flood plain and has pushed the larger stream against the opposite valley wall. A mill here develops 40 horsepower, but the owners report that during the last twenty years the character of the stream has materially changed, its flow having become less constant, so that during the low-water season in September and October they are now able to develop only about 20 horsepower, and are then forced to cease operating a part of their machinery.

Below Roan Mountain the valley narrows and the little flood plain that was once there has been largely destroyed by floods in recent years. A few years ago the railroad was almost entirely washed away and had to be practically rebuilt. All of the small mills and dams on the stream were torn away and many of them have never been replaced.

The stream was formerly almost always clear and was stocked with fish. Now it is usually clouded with silt; the pools that were once the home of the fish have been filled with sand and mud and the fish have disappeared. The people of the region attribute this change to the greater erosion caused by the lumbering and the increased clearing of steep slopes that have resulted from the building of the railway up the valley, and they realize that conditions are becoming worse yearly. In places the cutting of timber on high slopes and the dragging of it down have caused serious damage to the lower slopes. No special effort is being made to guard against erosion, either along the valley or on the slopes.

For some distance south of Roan Mountain station, on the road to Cloudland, the flood plain is relatively narrow, the stream is rapid, and the bottom lands have been largely washed away. Three miles south of the station the valley widens somewhat, but about half of the flood plain has been rendered useless by recent floods. Above this the flood plain again narrows, becomes more stony and hummocky, and is constantly shifting and reforming under the influence of the torrential stream. Above Burbank the flood or torrent plain is so stony and rough as to be practically worthless. Below Burbank 40 per cent of the hillsides have been cleared. From Burbank upstream practically all the hillsides are in forest, though the best timber has been removed.

Well up on the north side of Roan Mountain there are a few small clearings, above which the mountain is densely wooded almost to the top, where it becomes an open, naturally treeless sodded slope—a "bald." Most of these balds are well grazed, but the trampling of cattle has broken the turf on the bald of the Roan and started gully erosion in many places. The porous, disintegrated granitic or gneissose soil, 2 to 6 feet deep, is quickly removed down to the solid rock. The gully then widens until it has become a channel 10 to 15 feet wide. No effort is being made to check this erosion. From Cloudland the spurs of the Roan to the north are heavily wooded and show no clearings. To the northwest, near the head of Big Rock Creek, some of the steep slopes have been cleared. About half of the cleared area is in grass and the other half shows some erosion. At the head of Little Rock Creek there are many mountain-side clearings, which show little erosion, undoubtedly because they are underlain by a granite whose disintegration produces a porous soil.

LOWER WATAUGA BASIN.

The valley of the Watauga below Johnson City, Tenn., is relatively narrow for about 8 miles. In this stretch the Southern Railway bridge and a $7,000 county bridge has recently been swept away. At De Vaults Ford the valley again widens and for a few miles the stream is bordered by excellent bottom lands, which were damaged about 20 per cent in 1901, when half of De Vaults Island was destroyed. From the ford down to the mouth of the Watauga the bottoms are in relatively narrow strips, many of which were utterly destroyed, and just at the mouth of the Watauga the piers for a railway bridge were wrecked. These bottom lands were previously worth $75 to $100 an acre, and the average damage on the entire lower portion of the river was 20 to 25 per cent.

The lands at De Vaults Ford had not been covered with water since the first settlement of the country in 1768 until the floods of 1860 and 1867, which ran through them but did practically no damage. The flood of May 21, 1901, and that of February, 1902, which was almost as high, completely covered and seriously injured these lands. This land of De Vault's lies on an extraordinary flood plain—that is, one so high that only floods of exceptional height ever reach it—hence it is rarely subject to flood damage. It is bordered on the stream side by a narrow ordinary flood plain that stands 8 to 10 feet lower and on the other side by an older terrace, 40 to 50 feet higher, which is covered with stream cobbles and separated from it by a sharp scarp. About 75 feet above this older terrace is a spur with stream bowlders that mark another old flood plain. A third old or fossil stream plain, with rounded bowlders up to 1½ feet in diameter, lies 60 feet higher still, at an elevation of 1,555 feet above sea level.

The flood in the lower valleys of small tributaries of the Watauga was ponded at places where they enter the main stream, and at these places rich soil was deposited which greatly benefited the lands.

HOLSTON BELOW THE MOUTH OF WATAUGA RIVER.

Much damage was done on the south fork of the Holston from the mouth of the Watauga down to Kingsport. Where the north fork enters, 25 per cent of Long Island was destroyed, and though a farm here and there was improved by being covered with rich silt deposits borne by the eddying waters, the assessment for taxation of the bottom lands of Sullivan County was lowered 20 per cent on the average because of damage done by the floods of 1901 and 1902, and the assessment on some farms was reduced 75 per cent. Besides the damage to the lands, considerable additional damages resulted from the sweeping away of fences and young growing crops. The damage to buildings was slight for few of them stand within the reach of floods.

Near Kingsport the ordinary flood plain, or first bottoms, as it is called, is about 12 feet above ordinary water stages. About 8 feet higher there is another flood plain—the extraordinary one. Both of these were covered by water and greatly damaged. About 65 feet higher there is a third high-stream terrace or fossil flood plain, and 75 feet still higher there is a fourth, at an elevation of 1,300 feet above sea level. This last is broad and flat and is well strewn with stream cobbles.

Down the Holston the ordinary and extraordinary flood planes are typically developed and together average probably 200 yards in width. These lands are worth $50 to $60 an acre. About two-thirds of the farmers in this region report recent flood damages ranging from 20 per cent to 50 per cent of the land's value, while the remaining one-third were benefited by rich silt deposits from eddy water. The average damage for the entire area would amount to perhaps 25 per cent. A number of islands were badly damaged, the upper, more exposed ends having been washed off and the lower ends covered with sand. Some new islands were formed where the stream cut across bends.

At Stony Point the bottoms are a half mile in maximum width and the river meanders from side to side, cutting bluffs where it touches the valley walls. In some places the river had cut across these meander curves and ruined the lands on the concave side. In others, where it had kept to its channel around curves, the land within them had been benefited. Lands situated just below a bluff that deflects the current toward the opposite side of the valley were usually protected from erosion and benefited by rich silt deposits. Bottoms on convex sides of river curves were almost invariably badly damaged by the scour from the swift current.

At Stony Point a rise of 10 feet covers the ordinary flood plain, but this is so broad that the extraordinary one, though only 6 feet higher, is never flooded. Where the maximum width of the two is half a mile or more this extraordinary flood plain would seem now to be passing into a fossil one—that is, one permanently above the reach of even the highest floods. There are abundant indications that the Holston as a whole is actively cutting its channel deeper or is degrading its course, so that any flood plain is constantly becoming higher above ordinary water level, and as a result ordinary flood planes are becoming extraordinary ones, and extraordinary ones in turn pass into fossil ones, while new ordinary flood planes are formed along the margin of the deepening channel.

The actual difference in elevation between these flood planes on any stream or on any portion of the same stream is determined by flood heights, and this is in turn dependent on stream slope and on the width of the channel and of the valley, and these are functions of the geology of the area and vary with the resistance of the rocks to the forms of erosion to which they are subjected. Differences in the interval between these several plains may be seen along the Holston or almost any other river in the region on which the valley width or the stream slope varies. As a rule they tend to lie farther apart on the upper reaches of the stream, where stream erosion is more active and the valley is narrower and flood crests are higher, and nearer together on the lower reaches of the stream, where opposite conditions prevail. Where the valley is locally constricted the interval is greater; where locally broadened it is less.

Just above the bend at Surgoinsville the bottom is three-fourths of a mile to a mile wide. One-half or one-fourth of this width is occupied by the ordinary flood plain and the rest by the extraordinary one, which here rises along a somewhat indefinite marginal line to a height only 3 to 5 feet above the ordinary one. Just on the point within the bend there is a large area which has recently been ruined and abandoned.

Near Chissolms Ford there were no signs of destruction, and, in general, where the course of the river remained straight the destruction of bottom lands was at a minimum; where it was most curved the destruction rose to a maximum.

At Spear's mill the sawmill, cabinet shop, and stave mill were destroyed, and much machinery was ruined by the flood of 1901. The high-water mark of 1867 is there 36 feet above ordinary water level. The high-water mark of 1901 is 3 feet 8 inches lower. The flood crest in 1901 then, though higher than that of any previously recorded flood on the Watauga, did not reach an equally abnormal height on the lower Holston, but was lower than that of the flood of 1867. The heaviest rains in 1901 were in the North Carolina mountains, and not on the headwaters of the Holston, in Virginia.

At Spear's mill the river turns westward, and for several miles cuts across the trend of the upturned Paleozoic rocks in a narrow valley that is bordered by a narrow flood plain. The bottoms on the small tributary streams in this reach were benefitted by the rich silt deposits left by the high water that backed up on them.

At Three Springs the valley widens and good bottoms occur. Some of these, especially those on the convex sides of bends, were badly injured. The average damage reached about 20 per cent. At Williams Ferry some farmers reported a damage of 50 per cent, and a few others have been benefited.

Just below Longs Ferry a farm in the bend, which the current swept across and ruined in 1867, had about made back again and was in cultivation in 1901, when it was badly damaged and again abandoned. From Longs Ferry to Noeton the river flows westward across upturned hard strata and is bordered by a narrow flood plain. Below Noeton the river turns southwestward along softer rocks, and the flood plain again broadens. The river has there cut away some bottoms and has covered others with barren white sand.

Turleys Island has been badly damaged by washing and by covering with sand. About one-third of the farmers on the island report damage, some of which has been repaired by the settlings from later lower floods, so that scour or deposit is a function of flood height as well as of position with reference to stream curves.

From Turleys Island down to the mouth of the river, just above Knoxville, the damage was confined largely to points on the inner sides of bends. The current very generally swept across these and ruined them, but a few farmers whose lands were protected from the forces of the flood current reported that their lands were benefited. The average damage for miles along this lower stretch of the river will amount to about 10 per cent. The damaged lands were as a rule thrown out of cultivation in the hope that they would ultimately make back again, unless other equally high floods prevented.

NOLICHUCKY BASIN.

GENERAL FEATURES.

Nolichucky River is formed by the junction of Toe and Cane rivers about 8 miles east of the Tennessee State line, flows almost due north for several miles, then turns and flows in a general northwesterly direction to its junction with French Broad River just above Leadvale, about 7½ miles southeast of Morristown, Tenn. Its basin lies south of that of the Watauga, is about 75 miles long, and has an average width of about 25 miles, and, like that of the Watauga, comprises an upper part lying in the North Carolina mountains and a lower part extending into the great valley of east Tennessee.

The upper or mountainous part of the basin is itself part of a far greater basin whose surface forms the Asheville plateau. Beneath its general surface the many branches of the Nolichucky have cut gorges that are mostly sharp bottomed and steep sided and range in depth from a hundred to several hundred feet. Here and there rise above its general surface higher residual peaks or ranges that bound and delimit this basin from the neighboring basins. One of these ranges—the Black Range—includes Mount Mitchell, the highest peak east of the Rockies. To the southeast the basin floor rises gently to the crest of the Blue Ridge, but to the northeast it is separated from the Watauga basin by a steep-walled, sharp-crested divide that in Roan Mountain reaches a height of 6,313 feet. On the southwest are other bounding ridges that in places reach elevations of 6,000 feet or more and that separate it from the basin of French Broad River. To the northwest this upper part of the Nolichucky basin is separated from the lower or valley portion in east Tennessee by the high wall of the Unaka Mountains, through which the river has cut a deep and narrow gorge, 12 miles or more in length, whose sides rise precipitously in many places and in a short distance from the river reach elevations of 3,000 feet above its surface. West of this mountain wall, with its wild and narrow gateway, the river enters the great valley of east Tennessee, where its immediate valley is not so deep or so steep sided as in the upper mountainous area, and the mood of the river changes from an impetuous to a gentler one.

In the mountain basin the deeply dissected surface of the old Asheville plateau or peneplain is composed of ancient granitic or metamorphic rocks that are deeply decayed and in many places form rich soils. The numerous residual ridges rising above this old plateau level have been cleared to a considerable extent, and in many places, as, for example, about Burnsville and toward Bakersville, the plateau itself has long been cleared and farmed. Comparatively few of the farmed areas have been kept in grass. The culture is usually clean and the principal crops are corn and small grain. As a result the soils on many of the steep slopes have washed badly, and the destructive effects of mountain-side erosion and of floods along streams have probably been worse in this basin than anywhere else in the mountains. The detailed discussion of the basin begins with the lower or great valley portion of the river and follows it upward.

Where the Nolichucky enters the French Broad it is wide and shallow, and for a short distance above its mouth its current is broken by numerous islands. In the last few years some of these islands have been completely ruined by floods, and for 6 or 8 miles above the mouth of the river the farms on the bottoms have been damaged 10 to 20 per cent. Farther upstream, below Beulah, where the river makes some sharp bends, the damage was heavier, ranging from 15 to 25 per cent. In some places the alluvial soil was stripped down to the cobbles; in others sluices or runways were cut across the bottoms; in still others white sand was deposited on the lands.

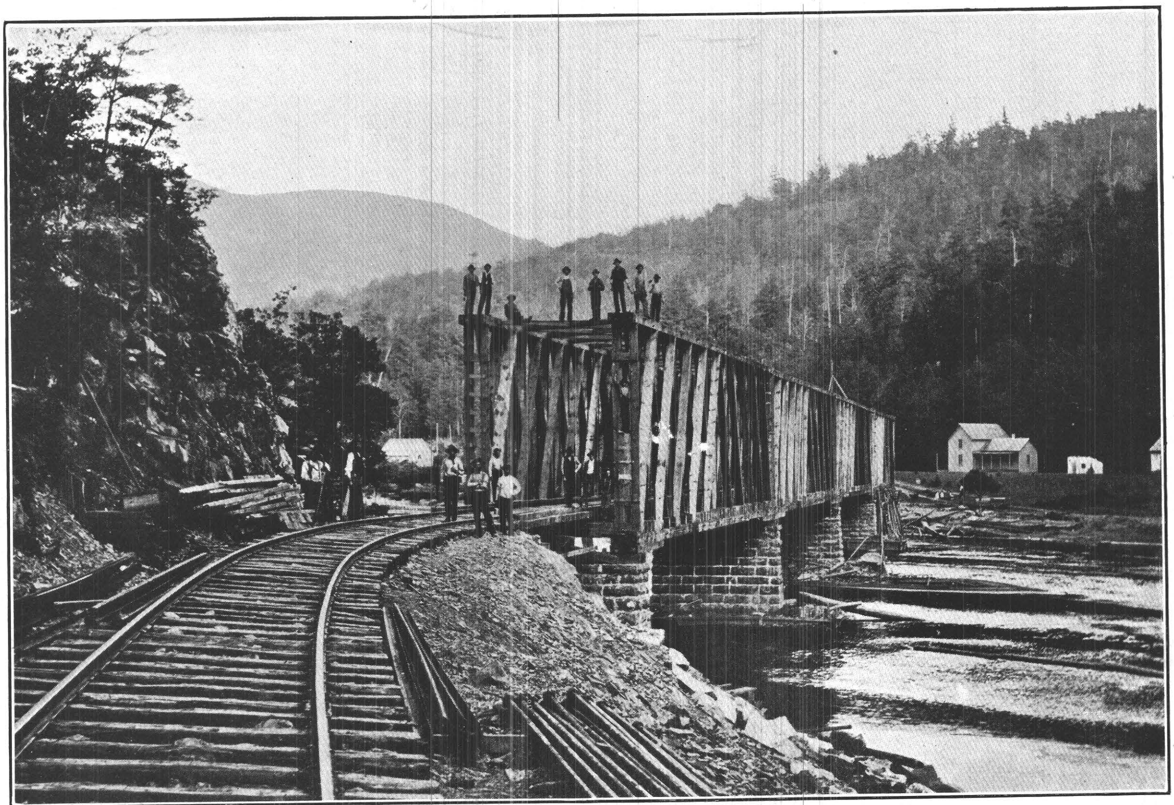
From Beulah up to Bird Hill, a distance of 5 or 6 miles, the valley opens out into a kind of flood-plain basin, at whose lower end, just below Beulah, the hills close in and constrict the river. During floods the lower portion of this tract has acted as a great settling basin and farms just above the lower end received deposits of rich sediment and were benefited by the flood. The current in the middle and upper part of this stretch, however, was strong enough to do much injury to lands on both sides. Above Bird Hill there is another similarly inclosed flood-plain basin, whose lower end was likewise benefited by the flood, but whose upper end was ruined. It was generally found that in broad basins lying above constricted valleys the flood waters were ponded by the constriction, and lands at the lower end of the basin were benefited instead of injured. In the reach above Bird Hill there is an ordinary flood plain of varying width, and 5 to 10 feet above it an extraordinary one, and the two appear in this relation along most of the course of the Nolichucky, although the relative width and the difference in altitude of the two flood plains differs from place to place, as controlling conditions vary. Commonly the lower flood plain is badly washed, gouged, or sand covered; the higher one is almost invariably scored by channels cut across it by extraordinary floods. When by the further down-cutting of the stream this extraordinary flood plain is finally abandoned, these stream-made scorings or flood channels guide the rainfall and determine the pattern of subaerial erosion forms that will develop upon it as a fossil flood plain. Above the extraordinary flood plain there are almost everywhere remnants of other old stream terraces that are still more or less covered with well-rounded cobbles. In one place there was a second old plain, 60 feet above the present ordinary flood plain; 50 feet higher there was a third; and a fourth occurred 50 feet higher still. These old terraces are usually cleared, and their steep scarps are in places eroded as badly as any lands in the region.

On the south side of the valley, at Allens Bridge, rounded cobbles occur on the general country level at an elevation of 220 feet above the present flood plain; 150 feet above the flood plain there is another prominent plain with rounded cobbles; and 100 feet above is another with a very heavy cobble bed. Still another old plain, whose surface is irregular and undulating, occurs at an elevation of 60 to 80 feet above the present plain and is well developed on the north side of the river, where it contains river sands and gravels, in places 10 to 12 feet thick and much indurated and reddened.

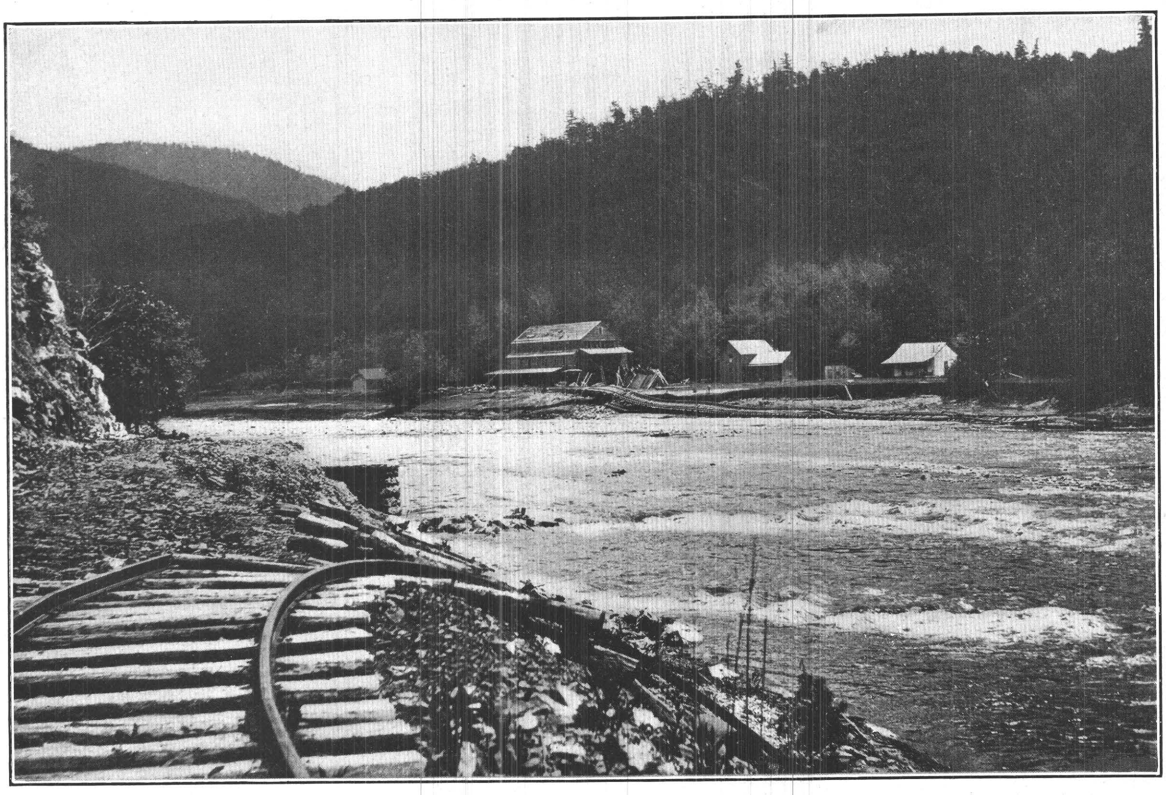
From Allens Bridge up the river for 15 or 20 miles the flood plain is relatively narrow and in many places a belt adjacent to the river was entirely swept away; in other places it was gouged or covered with sand. Islands, except those protected by timber on their upper ends, suffered severely. All bridges and ferries were destroyed. Some of these bridges were replaced or rebuilt, but these new bridges were also swept away, and other bridges have since been built.

From Henshaw, where a large mill was ruined, up to Brownsboro, all bridges were destroyed and the bottom lands were greatly damaged.

From Brownsboro up to Embree Furnace, a distance of 10 miles, the valley of the river is much wider than in many other places. The first bottom, or present living flood plain, ranges in width from 100 to 600 yards; the second or fossil flood plain, which is not now reached by even the highest floods, ranges in width from 1 to 2 miles and in altitude from 20 to 60 feet above the present flood plain, and has a surface that is quite irregular. Throughout this stretch of the river flood damages were very general and very heavy. On some farms the entire



A. RAILWAY BRIDGE OVER NOLICHUCKY RIVER AT UNAKA SPRINGS, TENN.



B. SAME PLACE AFTER THE BRIDGE AND PIERS WERE SWEPT AWAY BY THE FLOOD OF MAY, 1901.

See page 45.

tax assessment has since been removed; on many others 50 per cent has been deducted; and on practically all others 25 per cent reduction has been made. One farm, however, which lay in an area that was washed by an eddy, was so greatly benefited that its assessment was raised 25 per cent—a notable exception that serves only to emphasize the rule. Along a belt of varying width adjacent to the main channel of the river the alluvial surface was removed down to the bare rock. Farther from the river holes were gouged out, some of them of considerable size and depth; in other places immense quantities of white sand were deposited in a belt that extended usually from 100 to 200 yards from the main channel. In some places no attempt had been made to cultivate this barren white sand; in others a few melons were being grown on it. The great extent of this sand deposit made it an especially striking feature in this region. Its occurrence is easily comprehended when it is remembered that just above this stretch of broad valley the river emerges from its long and narrow gorge in the Unaka Mountains, in which its current had sufficient velocity to sweep everything before it. On emerging from the gorge the stream spreads across a broad flood plain and its velocity is immediately checked, so that it deposits large quantities of the coarser materials it carries. A sand waste of similar origin is shown in Plate VII, *A* (p. 22). At Embree Furnace the railway bridge and all other bridges were swept out and a 60-acre island was converted into a rock bar. Near Erwin the river has made considerable changes in its channel and is undercutting a portion of its flood plain.

At Chestoa a large lumber plant and dam had recently been swept away; at Poplar and at Unaka Springs railway bridges have been destroyed. Views of the bridge at Unaka Springs before and after the flood of 1901 are shown in Plate XIV (p. 44). Through the 12-mile gorge in the Unaka Mountain much of the railway track and roadbed were destroyed, and at present the rails and ties are anchored to the rocks by cables to prevent their loss when the roadbed underneath them goes out.

In Greene and Washington counties, Tennessee, along the west slopes of the mountains forming the North Carolina-Tennessee line the headwater portions of the many small streams tributary to the Nolichucky are being extensively logged. This logging is causing increased erosion, and the eroded material is carried down to the middle or lower courses of the steams where, because of the lower gradient, much of it is being deposited. These bottoms were once fertile and valuable corn and wheat lands, but by the present process of aggradation they have been made so much more difficult to drain that they are coming to be used for meadows and grass. The owners of the many small mills situated on these streams assert that the water power now fails much more frequently in dry weather during late summer and fall than in former years, and that low water comes earlier, goes lower, and lasts longer than formerly. They attribute this change to the clearing and logging on the headwaters of the streams.

Hollow Poplar Creek has comparatively little flood plain except near its mouth and does not seem to have suffered much damage. Its basin has not been cleared to any considerable extent and shows no traces of active erosion. Much of the soil is derived from quartzite and is poor and sandy.

From Poplar to Huntdale the Nolichucky flows in a steep-walled gorge 300 or 400 feet deep, whose sides are, as a rule, rough and almost entirely uncleared. Along the stream itself there are no bottom lands worthy of mention. Above the top of the gorge the higher slopes are gentler and soon reach up to the old Asheville Plateau level, where farms are numerous. Where they have not been well cared for the fields usually show distinct evidences of active erosion.

TOE RIVER.

Above Huntdale the gorge-like character of the river continues beyond the junction of the North and South Toe, although the gorge gradually decreases in depth upstream. A view of this part of the Nolichucky Gorge and of the Asheville Plateau surface beneath which it is cut are given in Plate XV, *A* (p. 46).

The North and the South Toe flow in similar gorges for a number of miles above their junction. In fact only near their headwaters do their gorges entirely disappear and their valleys open and almost merge into the old plateau surface. No important flood plain appears throughout the gorges, though here and there narrow strips occur, especially on the concave side of bends and near the mouths of small tributaries. These flood-plain areas have been much damaged by flood. In some places the soil has been entirely swept away, leaving the bare rock; in others it has been buried beneath sand and cobbles.

CANE RIVER.

From Huntdale to the mouth of Bald Creek, Cane River also flows in a sharply cut gorge, 300 or 400 feet deep in its lower portion and 200 or 300 feet in its upper. In this distance there is almost no alluvial land, and the steep valley walls are but little cleared. Back from the brink of the gorge the old plateau slopes are more gentle and in places are cleared and show signs of considerable erosion. Some of the fields have been abandoned.

Bald Creek is the only important tributary along this portion of the Cane. Its narrow flood plain and steep-sided valleys slopes are generally cleared and in cultivation for a distance of 300 or 400 feet from the stream bed. The higher slopes and the entire upper portion of its basin are in original forest, which is now rapidly being lumbered and carried by tramway to Huntdale for shipment.

At the mouth of Bald Creek the gorge opens into a wide valley in which there is a broad fertile flood plain that stands about 8 feet above ordinary water level. A belt 150 yards wide adjacent to the stream has been denuded of its soil, and attempts have been made to protect and reclaim the devastated area by building rock walls and cribwork and by planting balm of Gilead trees over the denuded area as well as along the undercutting banks. From this point upstream to the vicinity of Athlone there is comparatively little bottom land. Along Cane River 50 to 75 per cent of the slopes are cleared and in many places show erosion of the worst type. The rocks are fine-grained gneisses and are deeply weathered into soils that are generally micaceous and loamy and easily eroded.

As a rule the valleys of all of the creeks and other small tributaries of the upper Nolichucky are receiving from their bordering hillsides more waste than they can remove. This waste is accumulating along their courses, filling their channels and spreading over the bottoms and rendering it impossible, without expensive ditching, to drain these once fertile and valuable lands. In many places these bottoms have been abandoned and are growing up in rushes and willows, so that they do not now furnish even good pasture.

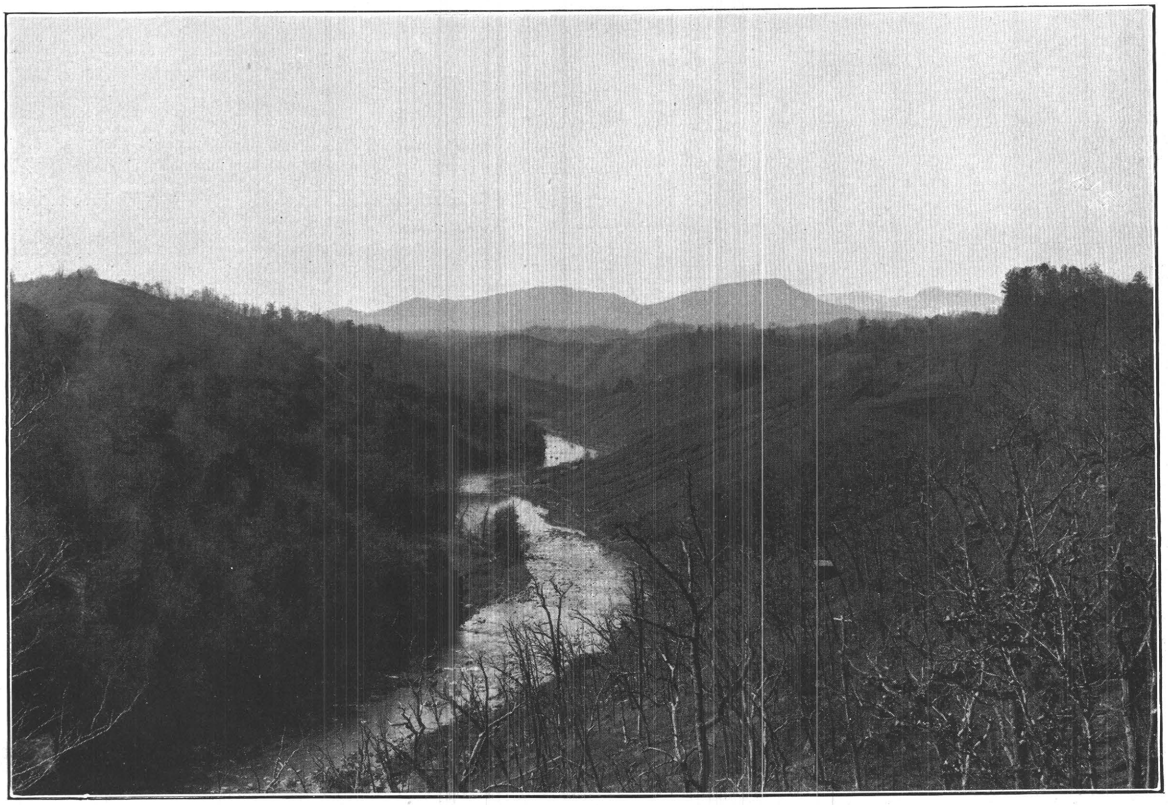
On Bald Creek the hill slopes are extensively cleared and in many places badly eroded.

Hinton Creek shows badly washed uplands and its bottoms have been greatly damaged by the sand and clay washed upon them from the eroding slopes.

Jack Creek basin has, perhaps, the most cleared land and also the worst eroded land to be found in the entire region. Nearly all of the erosion has occurred in recent years.

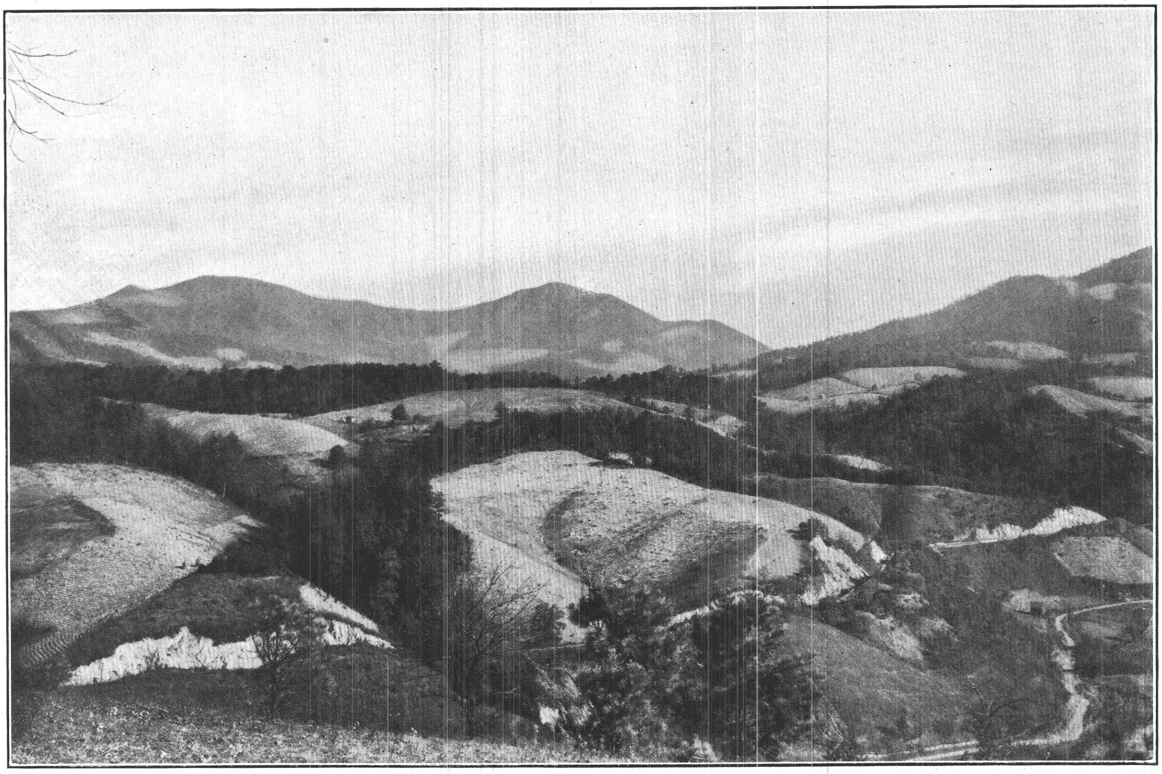
Though the severe erosion of this region is due primarily to the steepness of the cleared slopes, the heavy rainfall, and the nature of the soil, much of it is due also to the reckless system—or want of system—of cultivating these slopes, for most of them have been planted year after year in corn or small grain. Farmers are now beginning to realize the danger of this practice and are putting more of their mountain-side fields into clover and grass, so that grazing and haymaking are becoming important industries. It is only by some such practice that these lands can be saved and at the same time used for agriculture. A better and safer use of many of these slopes would be to reforest them.

Above Athlone, Cane River flows in a steep-sided valley in which there is a heavy torrential flood plain that is 100 to 400 yards wide and that stands in most places between 3 to 6 feet (locally as much as 8 feet) above ordinary water level. This flood plain has a rather undulating surface and, although for the most part fertile, is in places composed of micaceous sand and



A. NOLICHUCKY GORGE CUT INTO THE ASHEVILLE PLATEAU.

See page 45.



B. A WELL-DISSECTED PART OF THE ASHEVILLE PLATEAU.

Residual mountains in the distance. See page 50.

rounded cobbles that make an exceedingly poor soil. It is practically all cleared and in grain or grass. In its lower portion there is a stream-swept waste zone of bare cobbles, 50 to 100 yards wide, and in places along the edge of this cobble zone the stream is undercutting the flood plain. Rock walls and cribbing, such as are illustrated in Plate VIII (p. 24), have been used at many points to protect the lands from further erosion.

In the upper part of this basin the slopes retain their primeval forest cover. The stream flows with a clear, swift current, the flood-swept cobble zone disappears, and the flood plain itself becomes narrower, and above Big Tom Wilson's is but little cleared. It is still a natural trout stream. Its flow is fairly constant throughout the year, and the mills somewhat lower down do not lack water during the dry season in late summer and autumn.

LITTLE CRABTREE CREEK.

About Burnsville, which is practically on the level of the old Asheville Plateau surface, the uplands and the slopes down to the drainage-ways have in many places been cleared for years and present all too frequently the bare red-clay surfaces that indicate the entire absence of soil. Many of these fields are deeply gullied; in others bare red areas have taken the place of the former gullies. When the fields have reached this stage it is almost impossible to reclaim them in any reasonable time or at any outlay which would be warranted by their value. Many of them are abandoned as worthless and remain indefinitely as bare red-clay spots on the face of the country; others are turned into pasture lands, and the trampling of hoofs, together with the too close grazing to which they are usually subjected, effectually prevents their reclamation by plant growth; others, from which cattle are kept off, eventually grow up in briars and broom sedge; a few sprouts of locust, pine, or persimmon take root, and in several generations a forest cover once more becomes established. At intervals, however, prominent bare-sided gullies may remain, and these slowly undermine the forest cover and prevent the land from ever again being used for agriculture.

In some places about Burnsville the aggrading flood plains have been extensively ditched in the effort to lower the subsurface water level and keep the lands dry enough for the culture of corn and small grain. Many of these ditches are filled with sand and gravel during a single rain. While examining the region just east of Burnsville the writer noticed that the rain of the previous day had in many places washed a foot or more of sand and clay over the roadbed. In one place a loaded wagon, left by the roadside when the rain began, had been buried almost to its axles by mud washed from the hillside above. The roadside ditches were entirely filled, and in many places extensive areas of bottom lands were covered with muddy alluvial fans and the growing crops of 24 hours before were buried and utterly destroyed. So rapid had been the erosion that in a few hours fences had been buried, on their upper sides, to their tops. This particular rainfall was not extraordinary in amount but had come soon after most of the fields had been plowed, so that a considerable layer of loose material was ready for rapid removal. Results of this kind are liable to happen at any time under the conditions that prevail so widely in the Nolichucky basin and plainly teach that such slopes should not be farmed but should be held in timber or grazed.

East of Burnsville, the tributaries entering Little Crabtree Creek from the north have been especially destructive, spreading alluvial fans of rock and sand in many places well across the once good bottom lands on each side of this small stream. When seen, these tributaries were still muddy from the heavy rainfall of the day before and the muddiness persisted for several days after the rain had ceased and the streams had fallen again to their ordinary level, indicating that large quantities of very fine clayey material were still being carried. In this respect these streams showed decided contrast to the tributaries of the South Toe River, which flow northward from the steep wooded slopes of the Black Mountains. When the tributaries of the South Toe were examined it had been raining almost steadily for 24 hours or more, and although the streams were much swollen they were practically clear; they flowed from basins entirely forest covered and were carrying almost no sediment. This contrast between the amount of sediment carried by streams flowing from cleared and those flowing from wooded basins was observed time and again throughout the entire region, and it would be exceedingly interesting, were it possible, to determine quantitatively the relative amounts of silt carried out during the year by streams of these two types. The difference is perfectly constant and characteristic and must quantitatively be very considerable.

The rocks along Little Crabtree Creek, as elsewhere in the Burnsville region, are deeply decomposed micaceous gneisses and granite, which erode readily when once the forest cover is removed.

BURNSVILLE SOUTHWARD TO MOUNT MITCHELL.

Bowlens Creek, which enters Cane River about a mile south of Burnsville, has a torrential flood plain 200 to 300 yards wide along its lower course, and 100 to 200 yards wide along its upper course. This plain has an exceedingly irregular surface, due to the choking and abandonment by the stream during floods of certain portions of its winding channels and the forced cutting of new channels before the flood plain had been cleared of timber. Many of the wooded flood plains of the small streams, especially of those on the east slope of the Black Mountain range, show this process actively in operation. Rafts form at favorable places on the wooded flood-plain and the stream cuts a new channel and abandons the old. This is especially true where the descent of the stream is steep and its consequent velocity is great. The materials of this Bowlens Creek flood plain are heterogeneously mixed sands, clays, and cobbles. The soil is fertile and the principal damage to-day is that caused by the constant shifting of channel due to the high velocity of the stream and its tendency to undercut its banks. The high slopes of the basin are wooded and so are not damaged.

SOUTH TOE RIVER.

From Micaville southward to the ford of South Toe River above Celo much of the road is on the well-dissected plateau level. The region is generally rough and for the most part wooded, but there are a few scattered farms, some of which have been cleared too recently to show pronounced erosion. Some fields that were cleared long ago have eroded badly and are abandoned. The river itself flows in a narrow trench, which is generally uncleared.

Along the upper part of the South Toe the valley broadens and the stream is shallow and clear, with a swift current that in most places flows across and is actively eroding the upturned edges of the ancient gneiss and schist. It is bordered by an ordinary flood plain that stands 4, 6, or locally as much as 8 feet above ordinary water level. At and just above water level this plain consists of cobbles, which are overlain by 3 to 5 feet of silt and sand. Much of the sand is too poor to sustain more than a scanty vegetation. This ordinary flood plain, though about 300 yards wide, is badly gouged or cut by flood channels and is cultivated in but few places. At a vertical distance above the ordinary flood plain that varies considerably but in many places reaches 15 to 20 feet there is an old, high-level flood plain or terrace, whose surface is undulating from ancient flood channels that are similar in origin to those on the present flood plain. This terrace is largely cultivated and many houses are built upon it. It had been considered safe from all danger of overflow, but during the floods of 1901 and 1902 it was covered in numerous places.

Above the mouth of Rock Creek the river is slowly shifting laterally as it cuts down and is forming a sloping or beveled flood plain, only the lower edge of which is ever covered by floods. This flood plain is cleared in many places but the land is mostly sandy and poor and is now largely in pasture.

On the headwaters of the river there are very few clearings, the slopes being covered with virgin forests, especially on the Black Mountain side. Some lumbering has been done in this region, the product being hauled by wagon to the railway at Old Fort. Most of the timber, however, remains standing and some of it is held in large tracts.

NORTH TOE RIVER.

The country about Sevenmile Ridge, Crabtree Creek, eastward to the North Toe, up its basin to Elsie, and eastward to the Blue Ridge is largely in forest, except along the stream ways, where narrow flood plains occur, either continuously or in broken strips. The uplands are generally poor and these narrow flood plains are by far the best lands of the region. Some of the best timber has already been removed, but renewed activity has been manifested in lumbering since the building of the Carolina, Clinchfield & Northern Railway to Spruce Pine and beyond. In some places, notably on Crabtree Creek and along North Toe River, the alluvial bottom lands have been much damaged in the last few years by floods, and those who are familiar with the region say that these floods are rapidly becoming more severe. The average damage to bottom lands in this section during the last few years is 25 to 35 per cent.

FROM CLOUDLAND TO MAGNETIC AND BAKERSVILLE.

From Cloudland the road to Magnetic follows the top of Roan Mountain for about 2 miles and then rapidly descends the western slope, which is densely wooded down to an elevation of about 3,800 feet, where fields begin. A short distance below this level 75 per cent of the mountain side has been cleared, though the slope in places is exceedingly steep. Fields that have been kept in grass have been measurably safe from erosion, but on others the soil, which is a compact red clay derived from the weathering of diabase, has been badly eroded, leaving a maze of steep-sided gullies where it was thick and an area of bare rocks where it was thin. On the headwaters of Big Rock Creek above Magnetic there are many mountain-side clearings, and the flood plain of the stream has been much damaged by recent floods. The owner of the mill at Magnetic says that he can now run only about half the machinery during seasons of low water that he once could.

Below Magnetic the creek cuts across alternate belts of diabase and granite. In the areas of diabase it occupies a narrow, rocky gorge having steep walls, which in many places are cleared and have eroded badly; in the granitic rocks its valley walls have gentler slopes and it shows a tendency to develop flood plains. These granitic areas have a more porous soil and are not washing as badly as those in the diabase, but many of the flood-plains lands have been ruined by débris washed down upon them from the narrow, sharp-bottomed diabase gorges above. Some fences on hillsides are banked to the top on the upper side with soil washed from the field above, and in some places new fences have been built on this filling. Practically every mill and dam below Magnetic was swept away by the floods of 1901 and 1902.

On both Big and Little Rock creeks every milldam pond examined was full or almost full of sand and clay, so that it had become valueless.

The Asheville Plateau is strikingly developed in the region about Bakersville at elevations of 2,600 to 2,700 feet above sea level. Cane Creek and its upper tributaries have cut 200 to 300 feet below this old level and 50 to 75 per cent of the remnants of the plateau and the slopes from it down to the present streams are cleared. The rocks are granitic or gneissose and in many places are micaceous, so that the deep soils that have been formed from them usually erode easily. During the flood of 1901 Cane Creek destroyed practically its entire flood plain throughout a distance of some 10 miles. At Bakersville a number of houses, mills, and dams and a quantity of logs and lumber were swept away and several lives were lost. Roads and bridges in the region were almost entirely destroyed and had to be rebuilt at great cost to the county. Some of them had not been replaced in 1904.

The stream now flows practically on its flood-plain level, and the waste of sand and cobbles is almost without drainage so that the land would be unfit for cultivation however fertile it might be. Before the recent change in stream regimen that has resulted in destructive floods these lands were the best in the region. The stream is now constantly aggrading and shifts its position with every flood. In some places land owners have attempted to restrain it by building walls and planting trees, such as willow, cottonwood, and balm of Gilead, but for the most part they have ceased all attempts at reclamation and have abandoned the lands as worthless. People in the region are generally aware of the danger that the clearing of steep slopes has brought upon them and some attempts have been made to check the evil.

FRENCH BROAD BASIN.

GENERAL FEATURES.

The French Broad rises in the Blue Ridge and flows northwestward across the entire width of the Carolina mountains and halfway across the great valley of East Tennessee to its junction with the Holston near Knoxville. Its basin, 45 miles wide by 90 long, lies between the Nolichucky basin[a] on the northeast and the Little Tennessee basin on the southwest, from both of which it is separated by mountain ranges, some of whose peaks rise to elevations of 5,000 or 6,000 feet above sea level.

The basin is divided transversely by the high range of the Great Smoky Mountains, which form the North Carolina-Tennessee line, into a smaller, lower part lying in the valley of east Tennessee, and a larger, upper part, 60 miles long by 45 miles wide, lying wholly in the North Carolina mountains and forming an elevated plateau, bounded on the northeast, northwest, and southwest by high mountain walls, but rising gently to the crest of the Blue Ridge on the southeast and there overlooking the steeply sloping, eastward-facing scarp of this so-called ridge and the Piedmont Plateau, which lies at its base. This upper part is known as the Asheville Plateau.

UPPER FRENCH BROAD BASIN.

GENERAL FEATURES.

The plateau-like floor of this old river basin slopes gently northwestward. From its bounding mountain walls spurs project into the basin, and at numerous points within it isolated residual peaks rise above its general level. Below this level the French Broad has cut a channel to a depth ranging from a few feet along its upper course to 400 feet or more at the place where the river cuts its way through the Great Smoky Range, which forms the western rim of the basin. The larger tributaries have, in like manner, sunk their channels beneath this general surface, and with their many branches have cut the once continuous plain into a maze of rounded, domelike hills or subacute ridges such as are illustrated in Plate XV, *B* (p. 46). The smaller tributaries have not been able to keep pace with the rapid downcutting of the French Broad, but flow practically on the old plateau surface and descend to the level of the French Broad, generally in the last mile or less of their course, in a series of rapids or falls, so that they may more properly be called hanging valleys. The rocks of almost the entire basin are granites and gneisses, which are nearly everywhere deeply decayed. Only along the sides of the steeper and deeper stream gorges do bare rocks appear. Elsewhere the surface is mantled with a deep soil, usually of red clay. The soils of this basin are among the most fertile in the entire mountain region. It was one of the earliest-settled areas and has been cleared longer and farmed more extensively than perhaps any other stream basin in these mountains. Disregarding the residual peaks and ridges that rise steeply above the plateau surface, more than 50 per cent of the basin is cleared, and some of the minor valleys or parts of the basin may be more than 75 per cent cleared.

Grass does not seem to flourish in this basin as well as it does nearer the Virginia line at the same elevation, probably because the basin is somewhat warmer and dryer by reason of its more southern position and exposure. Therefore a smaller proportion of the cleared land is in grass than in the Watauga Valley, for instance. In places, however, especially on the higher cleared slopes, grass seems to thrive well and is extensively grown. The principal crops are corn, buckwheat, and small grains. Apples are grown in considerable and increasing quantities. Some years ago tobacco was an important crop, especially in the region north and

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[a] The Nolichucky, though a tributary of the French Broad, is discussed separately. See pp. 43–50.

northwest of Asheville, in the basin of Ivy River and its tributaries. The destructive effects of the clean culture required by this crop were quickly manifest, and, although it has been abandoned almost entirely, the erosion induced by its cultivation has continued to injure the lands where it was once grown and has caused profound changes in the streams.

Many of the hillsides sloping from the old plateau level down to the streams throughout the entitre French Broad basin have been badly gullied and in places abandoned. Here and there the soil has been entirely stripped off in sheet fashion, leaving bare red-clay hills.

FROM ASHEVILLE EAST TO SWANNANOA GAP.

The valley of the Swannanoa, one of the principal tributaries of the French Broad, is relatively wide, its bounding mountain walls standing in places 1 to 2 miles back from the stream itself. The channel of the Swannanoa is broad and shallow and is usually much filled with sand and gravel. Its flood plain rises but a few feet above stream level and a considerable part of it has a rather porous sandy or gravelly soil. In some places this flood plain is only a few rods wide; in others, as at Swannanoa, it is several hundred yards wide. Its narrower portions have been cut into holes or covered during floods by sand and have thus been practically destroyed, and along most of its broader parts a belt near the stream has been injured in like manner. Its surface is so low that a rise of only a few feet covers it with flood water, and within the last few years floods have become so frequent that the production of crops on this flood plain has become very uncertain and, as a consequence, much of it that was formerly successfully cultivated is now growing up in weeds and bushes.

Where it is narrow this flood plain is bordered, at an elevation of 15 to 20 feet, by a fossil flood plain which is safe from inundation by even the highest floods, whose undulating surface is covered with stream-borne materials and whose soil is usually of good quality. It is very largely cleared. Above this old flood plain level, low, gently rounded or flat-topped hills rise 100 to 150 feet, their tops marking the position of the surface of the old Asheville Plateau. Their lower slopes are steep and subject to severe erosion when not properly cared for. Fifty per cent or more of the entire valley is cleared and only the second bottom and the flat plateau surface are safe from destructive erosion.

The lower slopes of the bounding mountains, especially on the south side, are cleared at intervals up for a short distance from the valley level. In a few places the higher slopes show isolated mountain-side fields, but most of them are in dense forests.

At Black Mountain station the river has a broad, beveled plain rather than a flood plain, and this has not been eroded.

The North Fork of the Swannanoa has a broad valley, much like that of the upper part of the main Swannanoa, and it is cleared and has been eroded in much the same manner. Its bounding mountain walls are heavily forested. Like the other mountains of the Swannanoa basin, they are accessible to railways and have therefore been stripped of much of their best timber. In the lumbering operations many runways have been formed, which have caused considerable erosion on their steep slopes and consequent damages by floods along the streams.

Beetree Creek is largely torrential and has very narrow bottoms. Its bounding slopes are cleared for only short distances up the mountain sides.

Bull Creek has less descent and has broader and better bottoms, only the upper parts of which have been greatly eroded. Some lands near the head of the main creek have been abandoned within late years because of damage by floods. On Elk Mountain side some of the high slopes and much of the mountain top have been cleared, but the clearings are kept in grass and are thus protected from erosion.

The valley of Gazes Creek is perhaps 60 per cent cleared, and there is more than the usual proportion of clearings on the steep slopes of the Swannanoa Mountains. These high mountain lands, like those on the Elk Mountains, are protected from erosion by being kept largely in sod.

Throughout the Swannanoa basin there are many small streams at whose head are coves large enough for individual mountain farms. When first cleared these lands are fertile, and they do not erode badly until the humus has been destroyed; but when long cultivated, unless carefully guarded, they are subject to erosion, and in many places they have been abandoned as worthless.

FROM ASHEVILLE SOUTHEASTWARD TO FRUITLAND, EDNEYVILLE, THE BLUE RIDGE, AND HENDERSONVILLE.

In the Busbee Mountains there are some clearings but no marked signs of erosion. The soil is sufficiently porous to prevent serious washing. On the steep slopes near the head of Caney Creek and of its tributaries there is much cleared land that has washed badly in the last few years, and floods on the main stream have risen higher than usual and been especially destructive to the bottoms in the middle and lower portions.

On Hoopers Creek the soil is as a rule thin, and the lands have not been extensively cleared except in the small coves at the heads of the various tributaries around its basin. The channel of the main stream has in recent years deepened because many of the fences, with their obstructing water gaps, have been removed in consequence of the adoption of the stock law. As a result, flood water is now carried away more effectively than formerly and floods are not so destructive.

Fruitland, in the valley of Clear Creek, is situated on the rolling surface of the old Asheville Plateau. The stream here has not cut deeply below this old surface, so that the slopes are gentle, and erosion may be easily prevented. The rock in this region is deeply decayed porphyritic granite-gneiss, which weathers into a porous soil that does not suffer much from erosion. There is no reason why this area may not be entirely cleared and farmed without injury if proper precautions are taken. On the mountains around Fruitland there are a few clearings, especially on the domelike crests and gentler upper slopes; the lower slopes are steep and are almost entirely wooded. Floods on Clear Creek are reported as having been worse for the last three years than previously, and in some places bottom lands have been damaged; in other places, however, they have been improved, so that the average condition along this stream is about as it has been for years. Just west of Edneyville there are some steep cleared fields that show considerable erosion, which was said to have occurred within the last three years.

The entire region from Fruitland to Edneyville and southward to the Blue Ridge and Hendersonville is characterized by gentle slopes and may be cleared almost anywhere without serious danger of erosion. Mud Creek and its tributaries flow for the most part in broad, flat valleys and are either aggrading their channels or at a balance between cutting and filling.

Near and above Hendersonville, Mud Creek and its tributaries have broad, swampy flood plains and the stream channels are practically on the surface. These flood plains are grazed to some extent, but are too wet for cultivation. In most places they are bordered by a fossil flood plain with an undulating surface that is covered by rounded gravel and cobbles. At Hendersonville this old terrace is 20 to 30 feet high and part of the town is built upon it. Above Hendersonville it is usually from 30 to 60 feet high and includes nearly all of the cleared land of the upper portion of Mud Creek. The mountain sides there are rarely cleared.

The valley of Crabtree Creek, to the west, has a narrow flood plain bordered by an undulating terrace plain 30 to 50 feet higher, both of which are cultivated; the mountain slopes on either side are almost entirely forested. The stream channel is deep and the current swift, so that flood waters are quickly carried away and do little or no damage.

The mountain slopes and some of the knobs south of Crabtree Creek show considerable areas of rounded, precipitous, bare, granitic rock, and much of the wooded area has an exceedingly thin soil layer above the hard granite surface. A large part of this wooded area is made up of steep slopes; and deforestation, which, fortunately, has not yet begun here, would soon convert much more of it into bare rock surface, for when once the cover of vegetation has been removed from these domelike granitic masses there is nothing to hold the thin soil layer on the smooth surface of the underlying rock. When once removed by erosion it would be the work of ages to disintegrate the granite sufficiently to produce a second soil cover.

Just south of Grange, Little River flows from a narrow rock-bound gorge out upon a broad, somewhat sandy, but comparatively fertile flood plain, all of which is cleared and farmed. The stream has recently cut channels across portions of this flood-plain surface, and here and there has been undercutting its banks. At a number of places rock walls or brush and earth embankments have recently been built to protect the lands from floods, which have not yet been so disastrous as they will be when the upper part of the basin of Little River has been further cleared. More or less logging is being done in the area, and on steep slopes runways for flood waters are increasing in number; and as they become converted into rills they deliver storm waters and rock débris with greater rapidity to the main stream ways. Above this there are no important bottom lands on the river north of Sheep Mountain; south of it up to Cox's store there are some comparatively large separate tracts. Above Cox's store the flood plain is continuous, has an average width of 100 to 250 yards, and is fertile. Throughout this distance the river is not materially injuring the bordering bottom lands. Its channel is comparatively deep and has not been filled by sand and, as a rule, the adjacent lands have not been cut away nor covered with sand. The bordering slopes are cleared only in small areas and at considerable intervals for a distance of 100 to 200 yards up from the bottoms. The higher and more remote slopes are entirely wooded. Indeed, away from the immediate stream ways there is comparatively little clearing anywhere in Little River basin. At the time of examination the river was considerably swollen but the waters were almost clear. It is a good example of a stream still fairly well protected by natural forest cover.

Carson Creek flows in a narrow, rocky gorge in a basin that is almost entirely forested. When examined it was much swollen by several days of heavy rain but was nevertheless almost as clear as crystal.

BETWEEN ASHEVILLE AND LAKE TOXAWAY.

At the mouth of Carson Creek the French Broad has a flood plain averaging a half mile or more in width. The stream itself is 100 to 150 feet wide, and flows with a swift current between banks whose exact height could not be determined, but which were perhaps between 6 and 10 feet. At the time it was examined the stream was considerably swollen from intermittent but sometimes heavy rains that had continued for a week.

Almost the entire basin of the river above this point is forested and the absence of a sudden and destructive flood at any time during the week furnished a good example of the slowness with which the run-off from these continued rains had been carried away by the river. On the contrary the rise of the river had been slow, and residents reported that it would take some days for the water to fall to normal stage again after the rain had ceased. The bottoms nowhere along the stream, either above or for a number of miles below, showed any signs of material injury from floods, and the reports of farmers in the region agreed with the observations. The lands are not being injured by floods, and for explanation one needs but to turn to the forested slopes of the entire basin.

Above Rosman the many branches into which the river separates are bordered by very little bottom land and are but little cleared; the steep slopes are in forest, practically untouched by the ax until the recent building of a railway to Toxaway. Now lumbering operations have been begun, and before many years conditions will change and the rich valley lands will begin to suffer from the floods resulting from the cutting of the forests, the erosion of the steep slopes, and the filling of the stream channels. Between Rosman and Lake Toxaway there are a few plateau clearings, but the area is so small that the total erosion is negligible.

In the trip from Rosman down the west side of the French Broad Valley to Brevard, taken on the following day, the many tributaries flowing from the wooded mountain slopes on the west were still much swollen, though the rains had ceased 24 hours before. A few of them were slightly discolored by decaying vegetable matter, but most of them were perfectly clear. Practically the only discoloration in the French Broad itself was due to decaying vegetable matter. It is carrying exceedingly little silt in this upper portion and its basin is being eroded at an almost infinitely slow rate. These conditions can not long be preserved if the reckless cutting of timber is once started here as it has been in almost every other stream basin of the region.

Davidson River flows from the Pisgah Range southeastward into the French Broad just below Brevard. Near its mouth it is 75 to 150 feet wide, is shallow, and flows swiftly over gravel and cobbles. Here and there along its way are gravel bars and tree-grown islets. Its banks are but 2 to 4 feet high, and its flood plain has an average width of a fourth of a mile and is level, but is composed of sands that are poorly adapted to agriculture. So swift is the current of the stream that flood crests can reach no considerable height, as is indicated by the lowness of the flood-plain surface. The stream has not materially injured this flood plain. The hills rise abruptly from the edge of the flood plain and are entirely wooded. The soil is produced by the weathering of a micaceous schist in most places and is relatively poor.

Avery Creek, a branch of Davidson River, has for about 2 miles up from its mouth some narrow flood-plain areas that, with the lower slopes, especially on the south side of its valley, had once been cleared, but are now within the Pisgah forest reserve of Mr. G. W. Vanderbilt, and are being reforested largely by the natural growth which is springing up abundantly everywhere. The middle and upper part of the basin of Avery Creek is forested to the summits of the surrounding mountains. At Bennett Gap and just beyond, on the south slope of the ridge, there are a few old fields that show some erosion but are now being reforested. From this elevated viewpoint southward and westward the entire region is an unbroken forest, no clearings whatever being visible.

In the Pink Bed country the surface is generally level, and the porous, coarse-grained granitic soil has but little natural fertility, and in some places is dry enough for the growth of pines. There are no large clearings in this region. The streams run with clear currents, but are discolored in some places by swampy vegetation. From the Pink Beds northeastward through Yellow Gap to Rocky Fork of Mills River the country is an unbroken forest, with usually deep, rich soil and an excellent forest growth. Some of this has been culled of its best timber, but the logging was under forestry supervision, as, indeed, is the entire Pisgah reserve, so the conditions there are excellent throughout. Fireways and other means for protection have been liberally provided.

On Rocky Fork of Mills River clearings along the narrow flood plain begin within a mile from the point where the road reaches the river and gradually widen downstream until they are from one-fourth to one-third of a mile wide and contain some excellent lands. The river flows with rapid current over a bed of gravel and cobbles, with a channel 3 to 4 feet below the flood-plain level. The flood plain, like that of Davidson River, is flat and the stream is clear. Flood crests are low and there has been practically no flood damage.

In this region low, rounded hills rising to a common elevation, 100 to 120 feet above the flood plain, appear as the valley widens. They are remnants of the old Asheville Plateau surface and are generally cleared. In places their steep slopes show the erosion forms elsewhere typical of the steep slopes of the dissected Asheville Plateau. They are largely kept in grass, however, as are also the lower slopes of the higher ridges where cleared, as they are in places up 100 or 200 yards, so that there is comparatively little erosion.

From Angeline northward to Sandy Bottom the road is mostly on the rolling surface of the Asheville Plateau. Sixty per cent of the land has been cleared, but much of it has lost its original fertility through careless farming, and has been cut to pieces with gullies and abandoned. The higher knobs to the west of the road are being cleared in their upper portions and are being put in grass. All the land is rather thin and will need careful protection to prevent erosion.

From Stradley Mountain to the southeast and east less than 50 per cent of the plateau appears to be cleared; to the northeast about 50 per cent is cleared; and to the north and northwest 60 to 70 per cent is cleared. The peaks that rise above the plateau surface, such as Spivey and others northwest of it, are 40 to 50 per cent cleared on the sides visible from Stradley. This area is mostly in grass and shows very little erosion. The rounded hills of the plateau surface are badly scarred in numerous places by gullies and have been abandoned.

They appear as bare red-clay areas, visible for long distances in their contrasted setting in the green of summer field or forest. Near Asheville the proportion of cleared land becomes greater, but agricultural conditions have also improved and there is less erosion than is usual in this region in areas having similar topography.

BETWEEN ASHEVILLE AND HOT SPRINGS.

Between Asheville and Hot Springs the French Broad flows in a narrow, steep-sided gorge, which is about 200 feet deep at Asheville, but gets gradually deeper until at Hot Springs it is approximately 400 feet deep. Throughout most of this distance the walls of the gorge are wild and rocky and are covered with a scant forest. Here and there, where they are composed of granite or gneiss, they have weathered so as to produce a fertile soil. In such areas they are largely cleared, though they are entirely too steep for most agricultural uses. Many of these areas have not been properly cared for, but have been worn-out and are abandoned.

The river is 100 to 300 yards wide, has a rapid descent, and flows over exposed ledges of rock throughout this part of its course. Just below Asheville it is bordered by a beveled flood plain, which is in places 200 or 300 yards wide, but as a rule is found, in any given stretch, on but one side of the river. The portion of this flood plain nearest the river has in recent years been cut to pieces by floods or covered with sand, and its outer, higher portion, near the gorge wall, has been badly injured by overwash from the steep slope above wherever the slope has been cleared. Most of this flood plain just below Asheville has been abandoned and now makes only a very poor pasture. Farther down the river the flood plain soon practically disappears, and in much of the distance to Hot Springs there is scarcely room in the bottom of the gorge for the river and the railway. In some places a road lies along on the river bank, but in others it has been forced to climb out of the gorge to the old plateau level.

There is abundant fall along the entire distance, but the development of water power has been attempted at only a few points, and is, in fact, practically prevented by the slight elevation of the railroad above ordinary water level. Power has, however, been developed just below Asheville and also at Marshall. In recent years the scant flood plain, the highway bridges, and the railway tracks have been much damaged by floods, the railway being the chief sufferer, though at Marshall a number of houses were carried away.

All the tributaries, including even Ivy River, flow in narrow, steep-walled, and usually rocky gorges in their lower courses, and enter the French Broad by a series of rapids or falls. One must go some distance up their channels to find open valleys and flood plains.

The country back on either side from the brink of the French Broad gorge is a rolling or hilly upland, once a part of the Asheville Plateau surface, but now deeply dissected. Many of the hills near the river are exceedingly steep, but those farther back from the river, down to a point below Barnard, have gentler slopes.

The valley of Shut-in Creek is in an area of quartzite, shale, and limestone. The land is rough and poor. The bottom lands are narrow and of no great value, and the hillsides are only slightly cleared. The land is soon worn out when once the humus has been destroyed.

Spring Creek enters the French Broad at Hot Springs, and for 5 or 6 miles above its mouth has no flood plain and but few tributaries. At Bluff, Meadow Fork enters it from a valley that for some miles is likewise narrow and rough, but that widens farther up and contains some excellent bottom lands. These bottom lands have not been injured by floods, for the surrounding mountain slopes are very largely forested, only about 20 per cent being cleared, and most of this is in grass and pasture. It shows, as a rule, no signs of washing. The valley of Spring Creek itself, above the mouth of Meadow Fork, is narrow for several miles, but broadens at Spring Creek post office and contains some of the very best lands in Madison County. These lands have not been injured by overflow. Farther upstream bottoms exist only in isolated patches or narrow strips and are relatively unimportant. Probably 80 per cent or more of the steep mountain slopes in the upper part of the basin are in timber, but most of the merchantable trees have been cut in the last 15 or 20 years.

Big Pine Creek is very rough along most of its course, the valley walls being close to the stream and rather steep. They are, however, very productive where cleared, but are inclined to wash except when kept in grass, as most of them have been. Only a relatively small proportion, perhaps 15 or 25 per cent, of the valley slopes have been cleared.

Little Pine Creek shows about the same conditions as Big Pine. There is a narrow flood plain here and there, and the lower slopes have been cleared in slightly greater proportion. The stream has done no notable damage to lands along its course.

Sandymush Creek has no bottoms for 4 or 5 miles from its mouth; farther upstream some small separate flood-plain areas occur, but there are no important bottom lands below the forks. On Little Sandymush the bottoms are good but narrow, but on Big Sandymush they are considerably broader and more valuable. The hillsides have been cleared in larger proportion than on the streams already mentioned, the cleared area averaging perhaps 40 to 50 per cent. These cleared lands contain a smaller proportion of sodded area than is usual, and as a consequence they show many more signs of serious erosion, and it is not surprising that the bottoms along both Little and Big Sandymush had in some places been greatly damaged by floods. Below the junction of the two streams several mills, as well as the soil on many small flood-plain areas, had been swept away. From this difference in these neighboring streams it would appear that under such climatic and other conditions as are found in these mountains the danger line between a safe and an excessive amount of clearing would lie somewhere between 20 and 40 per cent. It would, of course, vary considerably with local conditions of soil texture and slope. If this conclusion is correct, then the French Broad basin, as a whole, is already cleared to an excessive extent.

From Marshall to Leonard and the mouth of Big Laurel Creek the road is on the old plateau surface, here steeply rounded by many sharply incised streams. The land has been cleared to a varying extent, depending on the nature of the soil and the geology. Where the rocks are granitic the soil is deeper and better and 75 to 80 per cent of the area is cleared; where the rocks are slates or quartzites the soil is thinner and much poorer and only 10 to 20 per cent is cleared. The granitic areas show considerable hillside erosion, and the small streams are being choked with débris, so that in many places the narrow strips of bottom lands along them have been ruined. In the slate areas the streams show no signs of aggradation but are actively cutting away the rock along their courses.

Big Laurel Creek has no flood plain for a number of miles up from its mouth, and its valley sides are steep and rocky and practically uncleared. Little and Big Hurricane creeks flow from quartzite and slate areas, in wild, rough, narrow gorges, with no flood plains worthy of mention, and their basins show very few hillside clearings. Little Laurel Creek is bordered here and there by a few acres of poor, sandy bottoms which do not show material damage from floods. The lower slopes are in some places cleared for short distances up the mountain side and many such areas are kept in grass. The higher slopes are practically uncleared, and much of the basin is rough and wild. Shelton Laurel Creek has somewhat more bottom land than Little Laurel, and about 20 per cent of the lower mountain slopes are cleared; the higher slopes are largely in forest. The amount of damage by floods has been inconsiderable. There are no mills, dams, or bridges to be washed away, and only exceptionally have the lands been much eroded. All the tributaries of Big Laurel, as well as Big Laurel itself, flow most of the time with clear currents and are as a rule bordered by little or no flood plain.

From the mouth of Shelton Laurel Creek to the mouth of Spillcorn the hills rise to the old plateau level, are deeply incised by many small streams, and are steeply rounded. The land, however, is very fertile and 75 to 80 per cent of it is cleared. Some of it is in grass, but much of it resists erosion to a remarkable extent even when kept in clean culture, owing undoubtedly to the porosity of the soil, which is the result of the weathering of a coarse porphyritic granite. Along Big Laurel itself in this stretch there are no bottoms for a number of miles. In some places 20 to 25 per cent of its lower valley sides have been cleared, in others they are practically untouched.

The basin of Spillcorn Creek contains very little bottom land. Almost all of the cleared land is on the lower slopes of the mountain sides, some 25 per cent of which has been cleared. Much of this cleared land has been under cultivation for a number of years, and probably a fourth of it has been practically ruined by gullying within the last few years. No mills or dams have been destroyed along the stream.

From Big Laurel post office, near the mouth of Spillcorn Creek, to Little Creek post office, the occasional flood plain areas are more or less sandy and stony and show some tendency to undercutting by shifting of the stream channel during floods. Above Little Creek post office the valley is somewhat broader and the flood plain more continuous and better. A considerable area on both valley walls has been cleared. That on the northern side is old and worn with gullies; that on the south side is fresh and as yet uneroded. More of the cleared area is in grass than farther downstream. The bottom lands along Little Creek show some signs of stream aggradation, so that the drainage is not so good as it should be, and it is said to be slowly becoming worse.

An old resident of the region, a highly intelligent and close observer, believes firmly that there have been marked changes in the regimen of the Big Laurel in the last 25 years, during which time most of the lumbering and clearing has been under way. The floods in former days rose more slowly, reached lower heights, endangered property less, and went down more slowly, so that it was no unusual thing for the stream to remain up during flood periods for several days. Within recent years, however, floods have come abruptly, rising within a few hours to heights previously unknown, sweeping away everything in reach, and subsiding almost as rapidly as they rose. Many springs that were formerly perennial now go dry or practically dry late in summer. During this season the small grist mills along the stream are unable to grind the grain, and steam mills must soon be built to replace them. Houses that several decades ago were high and dry above the greatest known floods have in recent years been repeatedly surrounded by water. There can be little doubt therefore of the truth of the contention that there has been a change of stream regimen. This material change in the character of the stream, especially in its flood flow, has been a result of the lumbering and subsequent clearing away of the forest, which have caused the more thorough drying out of the soil and the more rapid surface run-off of the rainfall.

About Windy and Ivy gaps there are numerous old mountain-side clearings that have been eroded and abandoned and are now practically covered with second growth. South of Ivy Gap the valley of Little Ivy River abruptly broadens until it is several miles wide. For the most part it is made up of rounded hills, 100 to 200 feet high, whose tops form part of the old Asheville Plateau level. The flood plain itself is narrow at the head of the river but gradually broadens until it averages 100 to 300 yards in width in the middle and lower parts. The stream is broad and shallow and flows over sand and cobbles, and in many places the water level is very little below the flood plain surface. Parts of the flood plain can be drained with difficulty and in recent years have been converted into a somewhat swampy meadow of no great value. This stream is unable to remove the eroded material furnished it and is aggrading and ruining its flood plain.

The history of changes in the basin of Little Ivy River during the last twenty years is exceedingly interesting, and typifies the general tendency of changes in all mountain basins that have been extensively cleared. Some 15 or 20 years ago a certain grade of tobacco was found to grow well on the gneiss soils of the region, and its culture was so profitable that in a few years the low rounded hill lands and the lower slopes of the higher mountains about the edge of the basin had been largely cleared and planted in tobacco. The cultivation of tobacco was continued year after year until a decrease in the price, together with a decrease in the yield through the depletion of the humus in the soil, finally caused it to be abandoned. As soon as the humus had been destroyed the hills began eroding badly, and to-day the old red-gullied fields and an occasional tobacco barn are the only evidences of this agricultural episode visible on the hills themselves. Other evidences are, however, visible on the bottom lands. My informant stated that when he was a boy, some 40 years ago, the stream channel was bordered by high banks, contained but little sand, and in may places its bottom was rock. The water was clear and contained abundant trout and other fish. Deep pools, he said, were numerous, and he pointed out the location of several that were memorable as boyhood swimming and fishing holes. The bottom lands near his residence were never known by his father, or by himself in his early years, to be covered by floods; floods resulted only from several days of continued rains, and even when at their highest the water was measurably clear, the discoloration being of grayish cast. A mill erected 30 years ago, had the dam so arranged that half of the water was turned into the race and went to turn the wheel. Since then no change has been made in the height of the dam, in the wheel, or in the gearing, nor has any additional machinery been put in; the power demands, in other words, have not been changed. Note, however, the other changes. Since the rapid clearing incident to the introduction of tobacco culture in the basin, sand is everywhere. The deep channel has been filled with it, so that the water level is now close to the flood-plain level, and a slight rise suffices to raise the stream over its banks. Floods are frequent, and the growing of crops has become uncertain, even where the land itself has not been destroyed by being washed away or covered with sand. A heavy rain of a few hours now produces a flood that rises rapidly and as quickly subsides; the water becomes red with mud and remains so for several days after it has fallen to normal height. The sand and the mud have filled the swimming holes and driven away the trout and bass; a mud cat or sun perch is the only fish now to be found. The bottoms, formerly never covered by high water, were flooded for the first time six or eight years ago, and have been covered several times since then. The low-water flow of the stream is so much less than of old that all of it is now turned into the mill race, and yet there is more difficulty in grinding with the entire stream flow than there formerly was with but half of it. Springs that in former years were never known to fail now go dry in summer and remain dry for several months.

Paint Fork and California Fork have similar topography and soils and have had the same agricultural history, followed by the same disastrous results as those just described in detail for Little Ivy River.

Holcomb Branch and Poverty Branch have small basins with narrow flood plains and steep slopes, both of which have been much eroded and abandoned. A few days before Holcomb Creek was examined the worst flood in its history occurred; it swept away the growing corn, the shocks of oats, and the fences, and in many places washed off the soil to the bare rocks and tore up the road. The flood was scarcely less severe on Poverty Branch.

At Democrat a milldam pond on Ivy River has so filled with sand and clay that it has no storage capacity, and the low-water flow permits but very little grinding in late summer and fall. The miller claims the stream volume is less than half of what it was some years ago during this season. There are no bottoms worthy of mention along this portion of the river.

The miller at Barnardsville says that in autumn he now has only about half the water that he had some years ago and is in that season forced to shut down a part of his machinery. Above Barnardsville much of the valley land forms part of the old Asheville Plateau surface; about 50 per cent is cleared. The mountain slopes proper are probably not more than 15 per cent cleared.

On the day before it was examined Martins Creek, a small stream flowing into North Ivy at Barnardsville, had a flood that was described as coming downstream with an almost precipitous front and subsiding almost as suddenly as it came. Although the basin is insignificant in size, the incident is important as showing the character of the floods that have become so destructive in these mountains.

From Barnardsville southward to Reems Creek the uplands have been cleared to a considerable extent, but in many places have been kept in grass. Along Reems Creek and Ox Creek the slopes have been largely cleared, and where they have not been properly cared for show much erosion. These streams are small and rather torrential and in places are undercutting their bottom lands or have washed runways across them. The higher slopes of the mountains to the east are largely uncleared. Portions of the crest of the Elk Mountains are cleared and in excellent grass, as the soil is fertile.

FROM HOT SPRINGS THROUGH THE MOUNTAIN.

Below Hot Springs the French Broad flows for 20 miles in its mountain gorge. Its current is very swift and its channel in places contains abundant cobbles and bowlders. Here and there it is bordered by small flood plain areas, most of them on the concave side of a meander curve, which, as a rule, are sloping, are somewhat stony, and have a sandy soil that is rarely fertile. Around the curves the bottom lands have been gouged into holes or in places have washed away. The total amount of injury done in this gorge portion of the stream, however, is inconsiderable, because of the small amount of flood plain that could be destroyed. The mountain slopes are generally very steep and many of them are rough and rocky. They are practically uncleared, though nearly all of the timber on them has already been cut.

GREAT VALLEY PORTION OF THE FRENCH BROAD BASIN.

GENERAL CONDITIONS.

For a few miles below the point at which the river leaves the mountain it has no flood plain, but about 4 miles above the mouth of Big Pigeon River a broad flood plain begins and extends thence to the mouth of the river—75 or 80 miles—on one side or both. Its width ranges from a half mile to a mile or even more. It is composed of fine sands and clays that almost invariably make fertile soil. None of these bottom lands are worth less than $60 and many of them bring $100 or more an acre. In many places the yield per acre is 80 to 100 bushels of corn.

From Leadvale down to its mouth—a distance of 70 miles—the river is navigable. The bottom lands on the concave side of the bend at Leadvale had been damaged to the extent of $3,000, and the railway pier on the same side had been partly undermined by the floods of 1901 and 1902. Morris Island, below Leadvale, was not greatly damaged, but on the bend immediately below it there was much washing, and at Allens Ford an 8-acre island was washed completely away, and the western bank of the river was badly scoured. Much of the surface soil of the farm in the bend just south of Allens Ford had been swept away by the current. In general it may be said that on this river, as on the Holston and the Nolichucky, farms within bends are more injured than those elsewhere. Many of them have been scoured down to the hard clay or the bare rock. At Oak Grove two or three farmers reported damages ranging from $500 to $1,000, and conditions at this point are typical for this portion of the river.

Between Oak Grove and Elliott Ferry the bottom lands lie on the west side of the river. They are about three-fourths of a mile wide and are protected in a large measure by a levee built across their upper end. Their surface ranges from 12 to 20 feet above stream level and only the lower parts of it are covered by floods. These parts have been slightly injured in recent years, but the damage has been much less than the average in other places.

From Elliott Ferry down practically to Dandridge the flood plain has an average width of three-fourths of a mile and is confined almost entirely to the north side of the river. At the ferry there is on the north side an ordinary flood plain 10 to 20 yards wide and 6 feet above ordinary water level. It is bordered by an extraordinary flood plain some 10 to 15 feet higher and 250 yards wide. From the ferry to Dandridge the flood plain has been injured not so much by the river current as by the cutting of channels during the return of the flood waters to the river as it falls. These channels are transverse to the main river channel and have scarred the flood plain in many places.

Swan Island, with an area of 150 acres, has had 30 or 40 acres of its upper end scoured off down to hard clay; its lower end, however, has been benefited by a deposit of fertile silt. Another small island near by, comprising 22 acres, had all of its top soil washed away.

At Dandridge a farm on the south side, just above the ferry, was in an eddy and was considerably benefited; the soil on a farm on the same side just below the ferry was washed away to hard clay. McManns Islands appear to have been benefited by deposition of silt. These islands, however, deflected the currents, so that the bottom lands west of them and below them were badly injured. In the first farm below on the south side of the river numerous holes, 6 to 10 feet deep, were cut; the next farm below was covered with sand 4 to 5 feet deep and rendered practically worthless. Other farms in Jefferson County have been damaged, chiefly by the cutting of holes and the washing of the surface, to an average of about 10 or 15 per cent of their value. In some places later floods have deposited sediment where earlier ones had washed, so that some lands show improvement and may be reclaimed in a few years; in other places the damage seems permanent and there are no signs of the land making back again after three or four years of disuse.

In general, the areas covered by white sand become fewer toward the lower end of Jefferson County, but near the mouth of Little Pigeon River, in Sevier County, the damage from the covering with white sand becomes greater. It is evident that the Pigeon delivers a larger amount of such material than the French Broad can remove and the latter is consequently forced to deposit its excess of load within a short distance below the mouth of the Pigeon. Throughout this portion of the French Broad there are many changes in the channel, some of which have interfered with the ferries, and many channels back of islands have either materially filled or scoured in the last few years. Places that are shallow after one flood are scoured out deep by another, and vice versa. At Huffaker Island the north channel has practically filled. At Pickle Island, just below, the south channel has in like manner filled.

The height of the flood determines whether deposition or scouring shall occur in a given place, and as the flood height varies from time to time the frequent changes in the depth of the river may be easily explained. River men and boatmen claim that the channel, as a whole, shows a tendency to fill. It is believed that the average depth of the stream is not so great as it formerly was, and it is confidently asserted that boats can not run as far upstream in summer and fall or as constantly as they could in former years.

The changes in depth and the tendency to fill, because of the great and increasing volume of sand now being carried down the river, repeatedly make difficulties for steamboats and largely nullify the efforts of the Army engineers to maintain a navigable channel. Sand bars dredged to-day may be re-formed to-morrow, and as long as the sand and cobbles are permitted to get into the stream no permanent improvement is possible. Dredging must be continued.

PIGEON RIVER BASIN.

Pigeon River rises among the Balsam and Pisgah Mountains, cuts its way through the Unaka Mountains, and joins French Broad River on the Tennessee plain. It drains an interior agricultural basin which is oval in outline, the longer axis extending northwest-southeast, parallel to the general course of the stream, and almost entirely within the Appalachian Mountain region. It is circumscribed by lofty mountains, many of the peaks reaching altitudes above 6,000 feet. Many minor ranges springing from the surrounding mountains converge toward the middle of the basin, dividing it into deep, narrow valleys, except near its upper end, between the towns of Canton and Waynesville, where there is a broad, open valley of alluvial plains and rolling hills, dotted with low mountains.

The basin has an area of about 667 square miles.

The soils are loams and sandy loams, mostly fine grained, derived from gneiss and schists, though in the mountains they are more siliceous and coarser, being the product of metamorphosed sandstones, quartzites, and conglomerates.

Waynesville is situated on a part of the old Asheville plateau that has been dissected by the river and its tributaries in the same manner as the region about Asheville has been dissected. The soils are eroding much as they are elsewhere on this old plateau.

From Waynesville eastward to Davis Gap much of the country is cleared. The surface is rolling to hilly and eroded areas occur here and there. In the gap itself, especially on the north side, the lands have been badly gullied. East of the gap, toward Sonoma, about 85 per cent of the lower and 30 per cent of the higher slopes are cleared. Some clearings extend well to the tops of the ridges.

At Sonoma a prominent terrace lies 25 feet above the broad semitorrential flood plain. Viewed broadly, this terrace appears level, but viewed in detail it presents minute undulations caused by numerous obscure runways and small hummocks over its surface. It is rather fertile, as such torrential flood plains usually are, and is now fossil.

Above Sonoma, nearly up to Lavinia, the West Fork of Pigeon River has considerable flood plain, practically all of which is cleared. A large proportion of the lower mountain slopes is also under cultivation, much of it being in grass. From Lavinia up to Three Forks the narrow flood plain and the lower 100 to 200 yards of the valley sides have largely been cleared. In places the older of these mountain-side fields are badly eroded.

Above Three Forks the basin of the Pigeon is practically uncleared and is largely in original forest, untouched as yet by the lumberman.

On Little East Fork there are few flood-plain areas, as the valley is narrow and the stream torrential, but the valley sides are cleared to a greater extent than on the West Fork. These lands are more fertile and are largely kept in grass, so that their condition is usually good.

Along the East Fork a large part of the flood plain is torrential, a poor, sandy soil, 2 to 3 feet deep, overlying a cobble stratum. It is crossed by flood channels and cut by holes, especially where it is forested. The scouring out of holes during floods is commonly caused by the lodging of logs and the formation of rafts. Such obstructions are especially likely to form on forested plains and the water deflected beneath them exerts great scouring force and quickly removes all loose material down to the underlying rock. For some distance up East Fork the mountain sides are practically uncleared, but at and above Springdale considerable areas of fertile land are being cleared and put into apple orchards. Grass is usually grown on the same land until the trees come into bearing. A very large part of this basin, however, consists of the steep slopes of the Pisgah Mountains, whose peaks include many that stand more than 5,000 feet and several more than 6,000 feet above sea level.

From Sonoma down to Canton the flood plain is broad and fertile and the larger part of it is cleared and cultivated. Many remnants of a well-developed fossil flood plain rise by a steep scarp about 25 feet above the living flood plain. The stream is doing comparatively little damage to the lands along it. Perhaps 50 per cent of the mountain slopes on each side are cleared and on some of them fields reach to the tops.

At Canton a large pulp mill, having a capacity of 500 cords of wood a day, has been erected. Much of the wood comes from the upper Pigeon basin, but a considerable part is shipped in by the Southern Railway.

From Canton westward to Clyde the river has not seriously damaged its bottom lands, which are, in general, sandy and lie less than 10 feet above ordinary water level. The rapid current of the river prevents floods from reaching even this height, though they are said to have become higher in recent years than they were formerly. The removal of the timber in the upper basin will probably cause floods to become steadily worse.

From Clyde to Waynesville the uplands are hilly and have a deeply rotted gneissose soil that in many places has been cultivated for years and has become badly gullied. A few miles below Clyde, Pigeon River valley closes in and has very little flood plain down to the mouth of Jonathan Creek, but a large proportion of its valley slopes are cleared. Many of these cleared slopes are kept in grass and are uninjured by erosion, though some of the older fields, not so protected, have eroded badly.

Below the mouth of Jonathan Creek the river cuts for 25 miles through the Great Smoky Mountains in a steep-sided gorge whose walls rise 2,000 to 3,000 feet above stream level, are generally rough and rocky and in many places precipitous and are uncleared. There is no flood plain in this part of the river.

After the river leaves the mountains its flood plain for 10 miles is narrow and has been badly washed or has been covered by sand. A few miles above its mouth its valley broadens, its slope decreases, and it has developed a wide flood plain, chiefly of sand and therefore only moderately fertile. The floods of the last few years have injured it about 15 per cent and in places have washed away the railway embankments.

On the north side of the Pigeon, below Canton, the sides of the basins of Crabtree, Fines, and several smaller tributaries include many areas of fertile land, a large part of which has been cleared. Much of it is kept in grass and is generally in good condition. The flood-plain lands along these streams are narrow but have not been materially injured by floods.

Soco Gap, at the head of Jonathan Creek, is a small cleared area which is well grassed and thus completely protected from erosion. The upper part of the basin for 2 miles below the gap is in forest that has recently been lumbered and is now cut by numerous runways made by the lumbermen. Below this lumbered area the entire narrow flood plain has been cleared and is partly in grass and partly cultivated. It is a torrent plain, 2 to 15 feet above stream level, and ranges in width from 200 to 600 yards. The rounded stones on its surface are prominent in the portion above Tito, though its soil is fairly fertile. Fertility is, indeed, a common characteristic of such torrent plains, but whether because or in spite of the stony débris is not always apparent. If in spite of, the source of the fertility is to be sought in the large amount of humus usually present in cove soils, much of which would readily be washed down the steep slopes and incorporated in the torrent plain; if the stony débris aids fertility, it must be because it helps to keep the soil more open and loose by preventing baking during the drought and by retarding evaporation.

The stream itself is rough and swift and its bed is made up of a succession of small bowlders and gravel bars. In many places it is bordered by a cobble zone 50 to 100 yards wide, and over this cobble zone the stream constantly shifts its position. Log and rock cribs have been built to restrain and confine it.

The valley walls on each side rise steeply and are cleared in an irregular manner; in some places both sides are in timber; in others clearings extend up the mountain side 300 to 600 feet above stream level; on the west side there is a large cleared area on the higher slopes. Most of the cleared land is in grass and in good condition; perhaps 10 per cent of the remainder shows gullying, though much of that not gullied has been cleared within the last few years. At Tito the creek turns sharply northward from its old course to the Pigeon and flows for a mile or more in a narrow gorge, below which its lower valley opens and broad bottoms appear. These bottoms are generally in good condition. The valley wall on the east side shows occasional clearings on the high mountain slopes, but no erosion was seen.

Along Hemphill Creek, on the west, the small flood plain is cleared, and also some 60 per cent of its valley walls up to an elevation of 600 feet above its channel; on the north side there are many fields up to the tops of Purchase and High knobs, nearly 3,000 feet above the stream. When newly cleared these are in good condition, but some of the old clearings are badly gullied.

Below Hemphill Creek the flood plain on Jonathan Creek is broad and in good condition. It is bordered by a terrace whose surface stands about 75 feet above the stream and is almost entirely cleared. Areas comprising about 20 per cent of the low valley slopes are also cleared and are largely in grass. Below the mouth of Cove Creek there is no flood plain.

In Cove Creek valley all of the bottom lands and 60 per cent of the valley walls, for 300 to 400 feet vertically, have been cleared. About 10 per cent of the cleared land is in old fields that show erosion.

West of Camp Gap the entire country from the Balsam Mountain across to Pigeon River and from Camp Gap to the Great Smokies on the Tennessee line is almost entirely uncleared; the clearings would include perhaps 2 per cent of the area. Some of the lands in these clearings are fresh and part of them are in grass. On most of them the soil is loose and porous, containing as a rule many small rocky fragments, so that even the few fields that have long been cleared show much less erosion than might seem probable from the steepness of the slopes.

At the time of the examination both Cataluchee and Big creeks were much swollen by several days' rain. Cataluchee Creek was almost clear and Big Creek was quite so. The explanation of their clearness lay in the almost completely forested condition of their basins, which therefore furnished no eroded mineral soil particles to their flood waters. A lumbering railway has recently been built from Newport up the Pigeon and up the valley of Big Creek. The lumbering operations will probably produce important changes in the stream's regimen, and the results so familiar in other basins where forests have been extensively cut will be repeated here.

From the State line westward across the headwaters of Cosby Creek and Webb Creek to Little Pigeon River much of the road is on an old, well-dissected plateau, which in the great valley of east Tennessee is regarded as the equivalent of the Asheville Plateau, though it lies at a somewhat lower elevation. West of the Great Smoky Mountain this old plateau is from 1,900 to 2,100 feet above sea level and is remarkably well preserved in its broad features, though cut to pieces in minute detail. Isolated peaks or short ridges rise steeply above it, and innumerable streams and streamlets have cut sharply beneath it. In many places a large part of its surface is cleared. The slopes downward to the streams are cleared in like or greater proportion. The slopes upward on the mountain sides have been practically untouched by the farmer, though the lumberman is actively at work and in many places has already removed the best timber.

The creek bottoms vary in width from 100 to 300 yards. As a rule a narrow cobble zone borders the stream channel, but the general condition of the bottom lands is good. There has been no marked increase in erosion recently. In many places the streams flow over the upturned edges of Paleozoic rocks and are actively eroding their channels. Their bounding mountain slopes are forested and furnish to the streams very little sand and gravel.

At the mouth of Webb Creek Little Pigeon River flows with a very swift and perfectly clear current over ledges of upturned slate or bars of cobbles and bowlders. In some places its valley sides close in so narrowly that the river is bordered only by a cobble zone; in others they recede and there is a fertile flood plain 300 to 400 yards in width and 10 to 15 feet in average height above stream level. On the higher parts of the flood plain houses, barns, and churches have been built. From the mouth of Webb Creek well up to the head of the stream the bottoms are cleared and much of the lower mountain slopes are also in cultivation.

Though floods on Little Pigeon seldom do serious damage, they are generally thought to be growing worse. The stream is slowly cutting away its flood plain and widening its bowlder zone; fences and roads on the edge of the flood plain next the stream have had to be moved back repeatedly. The flood plain appears to have been a fossil one, but within recent years seven houses, two barns, and a schoolhouse, as well as much fencing and roadway, have been swept away by high waters. It may, however, have been an extraordinary flood plain, reached by floods only at long intervals; or it may have been a plain abandoned by floods because of the constantly deepened stream cutting under natural forested conditions, now reoccupied by floods whose height has been abnormally increased by man's activities.

Between Middle Fork and Gatlinburg the flood plain of Dudley Creek is entirely cleared and is in good condition. The bounding valley slopes up to a height of 100 to 200 feet above the stream are 60 per cent cleared, and there is at rare intervals a cleared field on higher slopes. The high mountains here, as practically everywhere else on this west slope of the Great Smokies, are uncleared.

At Gatlinburg the conditions are about the same as on Middle Fork. The destruction by floods is growing, the zone of bowlders bordering the stream channel is slowly widening, and roads, fences, and small houses have to be moved back from the crumbling edge of the flood plain.

Alum Cave Creek is a typical clear mountain torrent, with a descent of 200 to 400 feet per mile in a channel that in places is cut 30 to 40 feet below an exceedingly rocky or bowldery but fertile torrent plain. The channel is filled in many places with bowlders, the largest 10 or 15 feet in diameter. On the steep mountain side there are a few clearings whose soil is usually stony but has not eroded appreciably. The higher valley slopes are timbered and from a point about 6 miles above Gatlinburg to the crest of the Great Smokies at Indian Gap there are no houses or clearings and the forest is primeval, untouched by the ax. The region east of the gap belongs to the drainage system of the Little Tennessee.

LITTLE RIVER BASIN.

Little River heads on the west slope of the Great Smokies, flows northwestward, and enters Tennessee River 12 miles below Knoxville. Its basin lies between the basin of the French Broad and that of the Little Tennessee and is divided by the Chilhowee Mountains into a lower northwestern part, in the great valley of east Tennessee, and an upper southeastern part, inclosed by the Great Smokies and their spurs.

The lower or valley part of the river is bordered by a narrow flood plain that is in most places fertile and is in generally good condition as regards erosion. The upper, mountainous part of the stream has as a rule no important flood plain, although here and there a narrow, rather sandy strip of bottom land occurs, and at one place the erosion of a small area of limestone infolded among the ancient schists of the region has produced a beautiful broad valley known by its Cherokee Indian name of Tuckaleeche Cove. The land in this cove is very fertile and is practically uninjured by floods. In it a lumber company has in recent years erected a large sawmill, around which has sprung up a considerable town. From the town a logging railway follows the river up practically to its head, at the very base of the Great Smokies. Above Tuckaleeche Cove there is practically no flood plain and almost no mountain-slope farm clearing, so that until lumbering began the region was an unbroken forest. The timber is now being rapidly removed. The cutting is close and leaves the land almost bare.

Much of the area is steep, rough, and stony, and not suitable for agriculture. It needs protection from fire and should have careful attention until the forest cover is reproduced.

LITTLE TENNESSEE RIVER BASIN.

GENERAL FEATURES.

The headwater tributaries of the Little Tennessee rise along the Blue Ridge in North Carolina or northeastern Georgia, and the main stream flows northwestward across the mountain region to its junction with Tennessee River in the middle of the great valley of east Tennessee. The basin lies southwest of the basin of the French Broad and northeast of that of the Hiwassee, and is 85 miles long, from southeast to northwest, and 40 miles wide. It is more nearly inclosed by high mountains than is the French Broad Basin. Many peaks on the Blue Ridge along its southeastern rim rise sharply to heights of 4,000 to 5,000 feet above sea level. Along its northeastern side the bounding rim is a nearly continuous chain that in numerous places is between 5,500 and 6,500 feet high. The Great Smokies, on the northwest, reach elevations of 3,500 to 6,000 feet, and though the bounding ridge on the southwest is somewhat more broken, yet parts of it are more than 5,000 feet high.

The immediate river valley is broad and has gentle slopes where the rocks are less resistant to weathering, but is narrow, steep walled, and in many places rocky where they are more resistant. In common with the other westward-flowing streams in this region, the depth of the gorge increases downstream, being 1,500 to 2,000 feet deep where the river breaks through the Great Smokies on the Tennessee line. The open, flat-floored basin-like character of the Little Tennessee Valley is much less perfect than that of the French Broad, its interior being broken by numerous high ranges, some of which extend for several miles and reach elevations of 4,000 or 5,000 feet above sea level. The Cowee Mountains, for instance, are 30 miles long and reach heights of more than 5,000 feet. The Plott, Balsam, and Hughes Ridges, though less than 12 miles long, rise to elevations between 5,000 and 6,000 feet and culminate where the Plott Balsam joins the main Balsam, at an elevation of 6,399 feet. Other ridges, such as Cheoah and Nantahala mountains, are of almost equal extent and height.

The old plateau surface which forms the floor of the basin is identical in age with and similar to the Asheville Plateau and is well preserved about Webster, above and below Franklin, and in the Cheoah basin about Robbinsville. These places are situated on its level.

TUCKASEGEE BASIN.

BALSAM GAP.

West of Balsam Gap 40 per cent of the steeply rounded hills at the head of Scott Creek have been cleared. Many of these cleared areas have been cultivated for years and have become deeply gullied. A large number of such gullied fields have been abandoned, and in numerous places nature has not yet succeeded in repairing the damages wrought by man, so that the bare red clay surface on these scarred hillsides is becoming constantly larger, and new fields are being cleared whose ultimate fate will be the same as that of these eroded areas.

This region vies with the Burnsville and Bakersville regions in the amount of damage caused by erosion on the steep uplands, but, luckily, conditions elsewhere in the Little Tennessee basin are not so bad as in the part of it just west of Balsam Gap, although badly eroded areas are by no means unknown or even infrequent in many other parts of the basin.

Down Scott Creek many hilltops and hillsides have long been cleared and show serious gulleying and sheet-wash erosion. The small streamlets flow in narrow, sharply incised valleys.

On Scott Creek from Hall down to Dillsboro areas of bottom lands from 100 to 400 yards wide occur here and there in bends of the river. Many of the steep valley slopes are partly cleared and cultivated, and almost every field has been badly eroded before the deadened trees that were left standing when the land was first cleared have disappeared. The old fields are abandoned. This policy of clearing, temporary cultivation, and abandonment is, indeed, general; and in many places throughout the mountain region the succession from forest to freshly cleared fields, old fields, and abandoned badly eroded fields may be seen on adjoining parts of the same mountain side.

At Webster, as indeed through most of its course above Dillsboro, the Tuckasegee is deeply incised beneath the old plateau level and is bordered by little bottom land. A county road follows it throughout almost its entire course, and within recent years the many high floods have torn to pieces long stretches of this road and have swept away a number of bridges.

Just below Dillsboro the river has little or no flood plain. For a short distance it flows in a narrow gorge and has a considerable fall, and this section has recently been purchased for use as a power site. Between Wilmot and Whittier there are good bottoms 100 to 300 yards wide showing comparatively little injury from floods. In some places sand has been washed over them to a slight extent. The uplands on the north side of the river are cleared but not to the extent that they are above Dillsboro. The slopes here are gentler and the surface is not washing so badly.

Below the mouth of Oconalufty River the bottom land is made up of poor, micaceous sand, and additional deposits of such sand are being brought down from the Oconalufty, evidently from the basin of Soco Creek, since that is the only tributary of the Oconalufty in whose basin conditions as regards erosion are bad.

Just above and at Bryson City the flood plain is 300 to 400 yards wide, and most of it is either an extraordinary or a fossil flood plain, usually or always safe from flood damage. From Bryson to Bushnell the river flows in a narrow, rocky trench in which there is practically no flood plain, and the sides are too steep and rocky to be cleared and cultivated. Above this trench the uplands back on the plateau level are 30 to 40 per cent cleared. The soil is gravelly to sandy, is porous, and shows very little erosion. The steep slopes of the higher mountains are not cleared.

At Bushnell, where the Tuckasegee joins the Little Tennessee, there are no flood plains worthy of note, but some houses are being built within the reach of extraordinary floods. The highest flood reported at Bushnell occurred in 1867, and it is said that one in 1840 was nearly as high. Since 1867 there have been several floods that have reached within 3 to 4 feet of the 1867 stage. In recent years several bridges and a mill or two in the vicinity have been destroyed by high water, and in 1900 some 2,000,000 feet of logs were swept away by the breaking of a lumber company's boom, and the company went bankrupt.

OCONALUFTY RIVER.

Oconalufty River is tributary to the Tuckasegee on its north side, and its basin contains much of the highest, widest, and most densely forested land to be found in western North Carolina. It is bounded on the north by the Great Smokies and the Balsams, which rise to a height of more than 6,000 feet. The larger part of the basin is occupied by the Qualla Reservation of the Cherokee Indians, and this fact accounts for the large proportion of uncleared land within it. The Indians usually do but little farming, and the clearings are confined to the better bottom lands and the lower valley slopes, many of which are rented and farmed by whites.

From Indian Gap for several miles down the headwaters of Mingus Mill Creek the region is in virgin forest that at the time of the examination was just beginning to be lumbered on an extensive scale. Thousands of feet of the finest poplar and other hard woods had been felled and cut into saw lengths but had not been moved to the mill. A tramway down the valley was being built to carry the lumber to the railway. Some 4 or 5 miles from the head the narrow flood plain begins to be cleared, and from there to the mouth, at Oconalufty, it is almost continuous and averages somewhat less than 200 yards in width. Some parts of it are flat, but most of it is a beveled plain and is above the reach of floods. The valley walls are cleared to a slight extent only, and then merely for a short distance above stream level. The higher slopes are in unbroken forest.

Below the mouth of Mingus Mill Creek Oconalufty River has a bottom 200 to 500 yards in width that is, as a rule, fertile and is uninjured by floods; the upper portion of the Oconalufty is in practically the same condition as to clearing and flood damages. The forested slopes have everywhere protected the bottoms from serious injury.

Soco Creek, also in the Cherokee Indian Reservation, has moderate fall and a flood plain that, though here and there quite narrow, averages 200 to 400 yards in width. This flood plain is in some places normal, having a flat surface and rising 4 to 6 feet above stream level; in other places the stream is receiving more waste than it can carry away and is aggrading its flood plain, so that the part next to the channel is higher than that more remote from it. The flood-plain surface is accordingly convex, and, during floods, distributary channels are frequently cut from the main stream to lower parts of the flood plain nearer the valley wall. Here and there these channels are occupied by the stream, which consequently widely shifts its position. The surface is being scored by such channels, and islands are frequently formed and as frequently tied to one side or the other of the flood plain by the abandonment of one of the channels around them. The material deposited by the stream is for the most part coarse and stony, and the hill slopes are moderately steep, and only some 25 per cent of them up to an elevation of about 200 feet above stream level is cleared. Part of the cleared area has been worn thin and abandoned, but does not show profound gullying. The higher slopes are entirely forested. The soil has resulted from the weathering of granites and gneisses and is somewhat stony and porous. It is much like that on the Oconalufty, and yet there is a notable contrast in the flood-plain conditions on the two streams. On the Oconalufty the flood plain is generally in good condition; on the Soco much has already been ruined, and the remainder will soon be in like condition. An explanation of this difference is found in the fact that from about 1896 to 1898 the Soco basin was thoroughly lumbered and many runways were opened down the steep slopes, and these have furnished the coarse material that has since overloaded the stream and is now accumulating on its flood plain, burying and ruining the alluvial soil.

From Hall station southward to Painter, on the Tuckasegee, many old fields have been eroded and abandoned. Where these have not been turned into pasture lands they have generally grown up in timber and the erosion scars have in time been covered by vegetation, though in many places the surface is left too rough for subsequent clearing. They are, however, more frequently fenced in for pasture, and, when grazed and trampled, erosion conditions grow constantly worse until many of the fields become areas of bare red clay. Throughout this region the best timber has been culled and hauled by wagon to the railway.

Cove Creek has a narrow flood plain and 25 to 40 per cent of its slopes are cleared; the older fields are eroding.

Weary Hut Creek has almost no flood plain and its valley sides are not greatly cleared.

Caney Fork is in places bordered by some good bottom lands, but its current is relatively swift, and though many of the lower slopes have been cleared, all of the higher ones are in forest. Conditions throughout the basin as regards erosion are generally satisfactory. In recent years, however, some damage has been done to the flood plain on the lower course of the stream.

Floods on the Tuckasegee are said by old residents, some of whom have known the river for 60 years, to be generally higher, to come more suddenly, to disappear quicker, and to be much more destructive than 50 years ago. Both the river and its tributaries are said to be much muddier during floods and for a considerable time afterwards than they formerly were. and many springs that were once perennial now go dry in late summer. During the fall the river and the smaller streams tributary to it get lower than of old, and mills have more difficulty in running. It is thought that the increased height of floods and irregularity of flow are the result of clearing for agriculture, and especially of logging, by which chutes have been formed on many steep slopes.

At Painter a few years ago the Tuckasegee swept away its north bank and shifted its channel so that it left the north end of the iron bridge that spanned it standing in what then became the middle of the river. The building of rock walls and planting of trees have not as yet repaired the damage caused by this change or effectually regulated the river's course.

The highest flood known at this point is said to have occurred in 1840; one in 1867 was nearly as high, and the next highest was in 1876. Though recent floods have not been as high as these earlier floods, it is asserted that their average height is greater than that of the usual flood of former years, and that their destructive powers have been increased by the greater velocity of the flood crest combined with its greater average height. This greater velocity with which floods pass a given point is due to the more sudden gathering of the storm waters from tributaries and the consequent increased steepness of the front slope of the advancing flood wave or crest as well as its greater height. This increased steepness of the front slope of the advancing flood crest and its greater velocity cause a more rapid rise at any given point than formerly and a more rapid fall to ordinary stages.

General conditions along the flood plain of any stream represent the effects of the high floods that occur every year or every few years rather than those of the extremely high floods that occur once or twice in a century—floods due to an extraordinary combination of circumstances. The evidence is as yet too scant—for few such floods have occurred since the white man occupied the region—to determine whether or not they show tendency to become higher as man works his changes in the valley.

Cullowhee Creek has a flood plain 400 to 700 yards wide, which is entirely cleared and under cultivation and is fairly fertile. Some 75 per cent of the bounding slopes, up to an elevation of 200 to 400 feet above the stream level, are also cultivated, and those that have long been cleared show the effects of erosion. Above these fields the mountain slopes become steeper, and in many places bold ledges or precipitously rounded masses of gneiss project. Such a projecting mass causes the falls on the Tuckasegee.

The crest of Cullowhee, Big Ridge, and other mountains in the vicinity have gentler, more rounded slopes than those above mentioned, and there are usually extensive clearings that in places have a thin, poor, gravelly soil, and in other places a soil that is more compact and fertile. The general condition as regards erosion on these high clearings is satisfactory, though in some places where they are steep and have long been cleared they are seamed with gullies. Such slopes need reforesting.

From Cullowhee Gap to Norton and on to Highlands the small streams have, as a rule, narrow flood plains, many of which are quite poor. They are not eroding to any marked extent, as practically all of the steep slopes up to the higher mountain crests are in timber. In this entire basin the clearings possibly amount to as much as 2 per cent of the total area. The soil is a loose, light-colored, coarse-textured granitic sand or gravel. The timber is generally poor and thin. Some of the streams have a fall so slight that they are bordered by extensive swamp areas—as, for instance, in the valley of Big Creek, just north of Highlands.

Many of the higher mountain masses in this region, such as Whiteside, Scaley, Satulah, Fodderstack, and Black Rock, show extensive areas of bare precipitous granite surfaces that have been produced and rounded by subaerial erosion; and in other extensive areas the bare rock surface is concealed beneath only a foot or two of soil that is held together by a dense turf-like matting of rootlets from the vegetation upon it. When such areas are cleared these rootlets rapidly decay and disappear, and in a few years the thin soil cover is swept away and the bare granite is exposed. Once this condition is reached the area becomes permanently worthless, since hundreds of years would not suffice to reproduce a soil cover. The scarp-like eastern face of the Blue Ridge shows many more of these steep, bare granite slopes or domes than the gentle western slope, and the damage from further clearing in those slopes would be immediately felt along the streams that flow southeastward to the Atlantic and furnish along their way tens of thousands of horsepower that has already been or is now being developed electrically to run the many mills and furnish light and power for the towns of the Piedmont Plateau in the two Carolinas.

FROM HIGHLANDS SOUTHWESTWARD TOWARD RABUN GAP, GA.

For a number of miles the road from Highlands to Rabun Gap lies on the very crest of the Blue Ridge, and from many points along it there is visible to the west a gently sloping and deeply dissected plateau, above which here and there residual mountains rise, while to the east there is a precipitous descent of 1,000 to 2,000 feet to stream basins that lie but little above the level of the Piedmont Plateau. The scarp-like character of the eastern face of the Blue Ridge is perhaps as well developed in the Highlands region as anywhere in its entire course, unless it be near Roaring Gap, N. C., and many of the scarp slopes consist of bare granite precipices—as, for example, the east face of Whiteside Mountain (Pl. II, p. 16). The Blue Ridge crest in this region is made of a granite which weathers to a loose, porous, light-colored, and very poor soil. For a number of miles there are no clearings. Along the road south of Mount Scaley there are a few farms. Within the next 2 miles recently cleared fields are in good condition, but old fields have worn thin and are abandoned. They are not gullying or washing away to any marked extent but become poor as soon as the humus is exhausted.

The many small streams crossed between Mount Scaley and the valley of the Little Tennessee are swampy and forested on their upper portions, but along their middle and lower courses are bordered by narrow bottom lands that are cleared and farmed. In some places the gentle side slopes are cleared up to 100 to 200 feet above the stream level, but in others these slopes are in unbroken forest. The streams themselves flow in relatively deep channels and there is no evidence of damage from floods. All of the higher slopes and ridges are timbered, and there has been almost no lumbering because of a lack of transportation facilities.

RABUN GAP TO BUSHNELL.

In the valley of the Little Tennessee, 2 miles south of the North Carolina line, numerous remnants of a high flood plain stand 60 to 80 feet above the present stream level. The river valley at this point is unusually wide, with lower slopes of gentle gradient and a flood plain averaging half a mile to a mile in width and remarkably level. This flood plain has a rich soil and is practically all cleared and under cultivation. The stream flows in a channel from 3 to 6 feet deep, and has but very slight gradient. It was somewhat swollen when seen, and the water was discolored from vegetable matter and not reddened by clay particles. Overflows because of the shallowness of the stream bed are of frequent occurrence, but though they sometimes wash the bottoms they more commonly leave deposits of rich sediment and are regarded as beneficial rather than injurious. The river maintains this general character down to Franklin, N. C., though the flood plain is in places contracted to a width of a few hundred yards.

Below Franklin the Little Tennessee flows across upturned edges of schists or other rocks that have resisted disintegration and erosion much more effectively than have the granitic rocks above Franklin. These weaker rocks in its upper valley have doubtless always weathered more rapidly than those below, and the river in its upper portion has always maintained as low a gradient as would enable it to remove the water and waste of its basin. The remarkably low grade from the head of the stream at Rabun Gap, Ga., to Franklin, N. C., has prevented floods from having sufficient velocity to injure the bottoms, and the unusual width of the flood plain, by giving a large cross section to these floods, has contributed much to the same end. The valley walls have weathered back with equal ease, and as a result the upper portion of the valley is unusually broad. This broadening has been produced by subaerial weathering and rill erosion rather than by cutting on the tips of meander curves by the river itself. Such meander curves are in reality most notable for their absence here, and it seems certain that the river has not widened its valley by this process. By the slow retreat of the valley walls material has been furnished to the main stream for building its present flood plain, and with its low gradient it is now just about able to remove the silt furnished from its wooded slopes. Once these slopes have been cleared, however, not only a much larger quantity, but much coarser kinds of waste will be furnished to the stream, and the present delicate adjustment of load to transporting ability will be destroyed. The stream will quickly become overloaded and will be forced to deposit the excess of load, first in the stream channel, but when that is practically full it will spread over the present fertile flood-plain surface, and by aggradation with barren clay and sand and rocky waste it will bury and ruin the only really fine agricultural lands in the region.

Here and there along the valley sides a flat-surfaced terrace, 60 to 80 feet above stream grade, is very prominent. In many places the surface of this terrace is covered with rounded bowlders, the largest 1½ feet in diameter; in other places a rich, deep red, loamy clay overlies the bowlder bed, which is here and there cemented with iron crusts but not so thoroughly as to prevent good underdrainage. These terraced lands are above the reach of floods and if properly cared for may easily be kept in a high state of fertility, but in many places their edges and the scarp down to the present flood plain have been abandoned as worthless. Above the level of this old terrace parts of the lower 100 to 200 feet of the valley wall have been cleared, farmed for awhile, permitted to erode, and then been abandoned, so that in this region there are many old fields covered by briars, persimmon trees, and scrub timber.

Between Otto and Franklin 60 to 75 per cent of the slopes have been cleared, and one-fifth of the cleared area is worn and old. About half of this worn land is deeply gullied; the other half has been washed down to the underlying barren clay by sheet flood erosion.

Franklin is on the old river terrace, which is there 80 to 100 feet above stream level. Its surface is of deep red loam, underlain by a cobble bed. On the east side of the river the same terrace level is also prominently developed, is cleared, and is in good condition as regards erosion.

The valley above Franklin contains here and there projecting knobs, 100 to 200 feet high, which are unreduced remnants dating from the time when the now fossil flood plain was the living flood plain. Some of these residual knobs have been cleared, but most of them remain wooded.

At the bridge over the river at Franklin floods have caused some slight damage, and here and there, especially on curves, there has been some erosion, though as a rule the flood plain of the Little Tennessee is remarkably free from such damage. A short distance below Franklin the valley walls close in on the river, and where any flood plain exists it forms either narrow border strips, in many places of coarse sand or cobbles, or here and there larger areas on the concave sides of bends or near the mouths of tributary streams.

Through much of the distance from Franklin to Bushnell the stream flows in a narrow gorge without flood plain. It is broad and shallow and is actively eroding the upturned edges of the ancient schists which are exposed along nearly all of this distance.

The road from Franklin northward to Watauga Gap runs for a number of miles on the old Asheville Plateau level, and its dissected and rounded surface shows the usual features of clearing, erosion, and abandonment.

Along Cat Creek there is very little bottom land, and comparatively little erosion has taken place. On the upper part of Watauga Creek the bottoms vary in width from an exceedingly narrow strip up to 100 yards. Not more than 5 per cent of the bottoms have been destroyed by floods in recent years, although the lower parts of the bounding hill slopes have largely been cleared and many of the fields have been worn out by erosion and abandoned. Three-fourths of the abandoned clearings are so gullied or so thoroughly stripped of their soil as to appear practically irreclaimable; on the remaining fourth vegetation seems to be catching hold and erosion is being slowly checked. Near the head of the creek clearings exist, especially on the eastern side near the top of the ridge, and all these high fields have been badly gullied. The freedom of the bottom lands from serious injury, under such conditions of erosion of the valley walls, can be attributed only to the sharp gradient and deep channel of the stream, which favor the rapid removal of flood waters.

North of Watauga Gap cleared lands extend almost continuously down Savannah Creek. Many of the clearings extend high up the valley sides, and practically all of the older fields have been injured by erosion. The inhabitants claim that it is easier to clear new fields than to keep the old fields from washing, and they accordingly cultivate the land as long as it is possible, usually 6 to 10 years, then abandon it and clear another field by its side. The lower portion of Savannah Creek has a relatively narrow flood plain, and the stream channel is so filled with sand and gravel that ordinary rains produce floods that cover the bottoms and destroy the crops. Five such destructive floods had already occurred in the summer in which the examination was made, and many fields have been ruined and growing crops killed by the deposit of sand and mud. New channels are frequently cut during such floods.

Much of the land along Johns Creek, a tributary of Caney Fork, in the eastern part of the county, has also been cleared. Erosion and abandonment of the valley slopes is common, and conditions are reported to be almost as bad as in the basin of Savannah Creek.

Webster, at an elevation of 2,188 feet above sea level, is on the deep, red soil, with underlying bowlder bed, which characterizes the old high flood plain found on the Tuckasegee. From Webster northeastward to Hall the slopes of the old dissected plateau level consist chiefly of red clays resulting from the disintegration of granite. Many of these slopes have long been cleared and in a number of places they have been abandoned because of erosion. Recently cleared fields, that are as yet in good condition, are numerous, but in a few years they, too, will begin to erode.

On Forneys Creek, which enters the Tuckasegee just above Bushnell, there are only a few farms, and on the high slopes but two clearings were observed. On the lower slopes, just above stream grade, there are a number of small clearings. The land was not being damaged by erosion. The proportion of cleared lands in the basin was entirely too small to affect floods on the stream itself, so that the narrow bottom lands were in satisfactory condition as regards erosion.

FROM BUSHNELL DOWN THE LITTLE TENNESSEE.

For some miles below Bushnell the Little Tennessee is bordered in many places by narrow flood-plain strips that extend for some hundreds of yards. Most of these areas are of medium fertility, and they have not been seriously injured by the river. It is generally believed, indeed, that floods benefit the lands by depositing sediment rather than injure them by erosion. In a few places rock walls have been built parallel to the stream channel. Behind these, sediment has accumulated to depths of 8 to 10 feet. From a point a short distance below Wayside through the mountain gorge to the Tennessee line the river has practically no bottom lands.

The valley is narrow and its sides are rough and steep and scantily timbered. The soil on the few cleared areas is full of stones and is too poor and dry to be of much agricultural value. The stream itself flows with a broad, shallow, swift current over the upturned edges of conglomerates, quartzites, and slates. Here and there are rapids that would seem suitable for power development, and between the rapids there is an occasional deeper pool—such, for instance, as the one at Rocky Point Ferry.

All the tributaries, except the larger ones, such as Hazel and Eagle Creek, enter the Little Tennessee by a series of rapids, along which their valleys are narrow gorges; but some miles back from the river, where their steep gradient has raised them to the old plateau surface, their valleys are broader and in many places have been extensively cleared and cultivated. Most of these broader valleys have gentler slopes than those farther downstream and have not been greatly eroded.

Panther Creek, which enters the Little Tennessee about 4 miles west of Bushnell, is bordered along its middle and upper course by areas of good bottom lands, which are for the most part cleared. Its basin slopes are practically all in forest, and its flood plain showed no damage from floods. A lumber company has, however, built a tramway from Judson, and has prepared to log the entire Panther Creek basin within the next few years.

Along the middle courses of both Sawyer and Tuckasegee creeks are considerable areas of fertile agricultural land, much of which has been cleared and is in satisfactory condition as regards erosion. The upper portions of these creeks and the upper slopes of their valley walls, as well as the entire area of their lower or gorge stretches, are in forest.

Hazel Creek has been cleared from a short distance above its mouth practically to its head, both along its bottom and up the sides of its valley. These valley-slope fields are thin when not properly cared for, but do not gulley deeply. Throughout all this region, where the rocks are conglomerates and slates, the soils as a rule are porous and are filled with small, unweathered pieces of stone. Such soils, it has been found, rarely erode badly.

On Eagle Creek the land is poorer than on Hazel Creek, and the slopes are rougher, so that clearings are unimportant. There is little or no bottom land.

From Rocky Point Ferry the road up Cheoah River runs for a number of miles along the poor, dry ridge of Yellow Creek Mountain. Four or five families live along the road between the ferry and Yellow Creek, but their clearings aggregate less than 100 acres. The lands are poor and sandy and do not wash badly.

CHEOAH RIVER.

From Johnson to its mouth, a distance of 7 miles, Cheoah River flows in a narrow, rocky gorge and has a fall of some 700 feet. It is bordered by no flood-plain areas, and the steep sides of its gorge are uncleared. The mountains west of the river to the State line and beyond are practically untouched by the ax, not a single clearing being visible from Yellow Creek Mountain.

Above Johnson the valley of the Cheoah broadens, and the river has developed a flood plain of varying width. This flood plain has not been damaged by erosion. Along this portion of the river there are preserved many remnants of the old Asheville Plateau surface, which here rises 100 feet or more above stream level and has been largely cleared. The higher mountain slopes are almost entirely in original forest.

Yellow, Buffalo, and Mountain creeks have narrow flood plains, all of which are in cultivation. The streams are as a rule meandering, but they have deep channels and are doing little, if any, damage. Numerous low, flat-topped terrace spurs, 20 to 60 feet high, project from their valley sides. Many of these have been cleared, and in places their steep slopes are eroding. The gullies formed are narrow, shallow, and stony.

All small streams in the region from Bushnell down the Little Tennessee to the mouth of the Cheoah, and the Cheoah itself and all its tributaries, were clear when examined, and it is certain that in this immediate region no extensive erosion is in progress. With the completion of the railway down the Little Tennessee, however, transportation facilities will be furnished for the shipment of lumber, mills will quickly spring up, and in a few years all the timber of merchantable size and quality will have been removed. It will be interesting to note the changes produced in the streams as a result of the changed conditions brought about by the lumbering.

NANTAHALA RIVER.

In the lower 5 miles of its course the Nantahala flows in a narrow gorge whose walls are but a few hundred feet high, but in the next 12 to 14 miles upstream its gorge is one of the deepest and most precipitous to be found in western North Carolina. A portion of the valley wall at Hewitt rises 2,000 feet above the stream and is exceedingly steep. In this stretch of the stream there are no flood plains worthy of mention, and the valley walls are uncleared. They have, however, been extensively lumbered, for transportation is readily accessible by the Murphy branch of the Southern Railway.

The upper part of the valley of the Nantahala is broader, and its walls are more irregular and retreating and are much dissected by numerous tributaries from both sides, but the flood plains comprise only isolated tracts, a few acres in extent, lying near the mouths of tributaries or within meander curves. Even such areas are not, properly speaking, flood plains, but rather beveled plains, of which only the lower edge is ever in reach of floods. The stream is actively eroding its channel and is constantly undercutting on curves and shifting its position, thus beveling its floor. These beveled valley slopes are best developed just above and below Aquone. They are only moderately fertile, and their aggregate area is not great. Above Aquone much of the valley is without flood plain of any kind. From Aquone up to Wallace Gap road the basin has been lumbered, but above this road the forest is practically untouched. A few families live in the upper part of the basin, but the aggregate cleared area is so small as to be negligible.

Between Aquone and Burningtown Gap the numerous small streams are bordered by narrow, sloping, semitorrential flood plains, which are relatively fertile and in good condition as regards erosion. All of the higher slopes are in timber. In Burningtown Gap there are some old fields, long since turned into pasture, which are still grazed and are holding remarkably well. East of the gap, part of the amphitheater-like head of Burningtown Creek had recently been cleared, and when examined its steep slopes were in corn. The soil contained abundant humus and showed no erosion. Lower down the valley walls close in, and the creek flows for some distance in a narrow gorge, beyond which the walls retreat and a torrential flood plain about 400 yards wide has been built. Still lower the slopes again close in, and in this alternating fashion narrow gorge and broad flood plain succeed each other well down to the mouth of the stream. The middle and lower portions of the valley contain remnants of the old plateau surface, some of which are cleared and others are entirely wooded. The higher valley walls are everywhere wooded except at the head of the stream. The valley is in good condition as regards erosion.

HIWASSEE RIVER BASIN.

GENERAL FEATURES.

The basin of the Hiwassee, the most southerly stream tributary to the Tennessee from the Carolina mountains, lies immediately southwest of the Little Tennessee basin and extends northwestward from the Blue Ridge to the point where the river enters the Tennessee, some 30 miles above Chattanooga. It is about 85 miles long, varies in width between 35 and 50 miles, and comprises 2,725 square miles. Like the basins to the north, it consists of an upper mountainous portion, in which the river is torrential in character, and a lower valley portion, in which the stream flows with deep channel and low grade. The river is navigable for 35 miles, from the mouth of the Ocoee, its chief southern tributary, to its junction with the Tennessee, and is traversed by a regular line of steamboats. Many appropriations have been made by the Federal Government for the improvement of its channel.

UPPER HIWASSEE RIVER.

FROM THE HEAD TO HAYSVILLE.

On its northeastern side the upper or mountain part of the Hiwassee basin is made up of a succession of mountain ridges and intervening tributary valleys, but southwest of the river, between it and the Ocoee, much of the old plateau surface is preserved.

The southeastern end of the basin, along the Blue Ridge, does not rise gently to the ridge crest as do the basins of the streams farther north, but is walled in by a distinct mountain ridge, which separates it from the Tallulah and Chattahoochee basins. The divide on the southwest, separating the Hiwassee basin from the headwaters of the Coosa River system, is much lower and more irregular, having, in fact, no marked prominence anywhere, and in some places it would be crossed without being noticed as a divide, as, for instance, at Blue Ridge, Ga., on the Louisville & Nashville Railroad. On the northeast the divide between the Hiwassee and the Little Tennessee is well defined and reaches altitudes of 4,000 to 5,000 feet above sea level. The upper mountainous portion is sharply delimited on the west, where the stream cuts across Beans Mountain and enters the broad valley of east Tennessee.

At its head the Hiwassee has no flood plain and all the steep slopes are in forest, but within 2 or 3 miles of Unicoi Gap a small flood plain begins, which gradually widens until it is from a fourth to a third of a mile wide. It is usually 6 to 10 feet above stream level, is fertile, and is cleared and cultivated. The stream itself is swift and clear, and flows over either bedrock or gravel bars, interspersed here and there by deep pools. This flood plain shows an occasional washed area on the inside of a bend or near some bridge abutment or other obstruction, but under usual conditions it does not show erosive damage, and the stream as a whole can not be said to be injuring its bottom lands more than would be expected of any stream subject to floods. During floods, indeed, many parts of the flood plain are improved by a deposit of silt.

On the high slopes of Rocky Mountain, near the head of the river, one tract comprising 30 or 40 acres has been cleared and farmed, but half the cleared land has been worn thin and gullied to some extent, and part of this has been abandoned. Except for this farm the slopes are uncleared down to within 100 to 200 feet of stream level, and throughout much of the distance down to Murphy not more than 30 to 50 per cent of these lower slopes has been cleared. The valley has long been settled, and many of these hillside fields are old and worn and in places have eroded badly and been abandoned.

Along the valley sides many remnants of old stream terraces are visible. They are not all at the same level, but represent several distinct terraces and indicate pauses in the down-cutting of the stream. In the upper part of the basin these terraces range from 12 to about 60 feet above the present flood plain, and in some places remnants of the terraces at two levels are to be found either adjoining or within short distances of each other. The height of the terraces, especially that of the higher, shows some slight increase down the stream, so that this old flood plain is to-day more nearly horizontal than the present flood plain. Almost everywhere these high terrace remnants are covered with a deposit of red clay, beneath which is a bowlder bed from 1 foot to 3 feet thick. The bowlders are rounded stream cobbles, most of which are less than a foot in diameter, though a few are larger. Many of these terrace remnants are flat topped and slope in an irregular, undulating manner to a lower level, and the connecting slope is as a rule cobble strewn. The margins of these terraces are in many places steep sided, and those long cleared are especially likely to be eroded.

At Mountain Scene a prominent, well-defined 60-foot terrace is connected by an irregular scarp with a terrace at a 10 to 12 foot level. At Buck Knob there is a well-preserved terrace, whose higher portions are 50 feet above the present flood plain, but slope irregularly down to a height of 30 feet. Just below Presley is another well-developed terrace with a broad, sloping, cobble-covered surface, whose upper and lower limits are 75 and 55 feet, respectively, above the present flood plain. Two miles farther downstream there is a still more perfect terrace, 75 to 100 feet high, which is undulating and irregular on its streamward edge and which rises by a gentle slope to its junction with the valley wall. A portion of the same terrace is also well developed across the river to the west.

At the town of Hiwassee the upper limit of this old stream terrace is about 1,994 feet above sea level. The present flood plain is about 1,875 or 1,880 feet above sea level. The vertical interval between this high terrace and the present flood plain has therefore increased from about 60 feet, along the upper part of the river, to at least 115 feet at Hiwassee. Further increase in this vertical interval downstream is exceedingly slow, if, indeed, the interval of more than 100 feet is maintained at all, since the elevation of the terrace is a function, at least in part, of valley width, being higher where the valley is narrower and lower where broader.

Next to the present flood plain these old high or fossil flood plains are the most fertile lands in the region and are the best adapted to agriculture. They were cleared very early in the settlement of the valley and many houses and barns have been built on them, as they furnish level ground well above the reach of floods. Where their surface is relatively level they are not eroded, but erosion has caused considerable damage in many places along their steep-scarped edges. The worst examples of such erosion were seen about Buck Knob, but as this steep scarp is relatively narrow the total area of land so injured is correspondingly small, and it might be protected by terracing the lands cultivated on it.

North of Hiwassee the river valley broadens greatly and the present flood plain is 8 to 15 feet above water level and occupies but a small part of the width of the valley. Above this flood plain an irregularly sloping terrace that contains rounded cobbles rises to an average elevation of 100 feet. This old terrace is surmounted by many low domes, peaks, or ridges that stand 100 to 200 feet higher and are residuals formed when the old high terrace was a living flood plain. They are very much like the residuals found on the upper French Broad at Brevard and on the Little Tennessee at and above Franklin, have had the same history, and are of the same age. Like them they are largely uncultivated or when long cleared have been generally eroded, because their sides are steep and their soil is a well-decomposed clay. The residual clays here, however, do not show a tendency to deep and rapid erosion with undercutting and the production of broad, vertical-walled flat-bottomed gullies, but cut into numerous narrow, shallow, V-shaped trenches.

Near the Georgia-North Carolina State line there is a low terrace, 25 to 30 feet above the present flood plain, and another terrace at 100 feet; remnants of the two terraces may also be distinguished at several places farther down the valley.

Haysville is on an old terrace which is there 80 feet above flood-plain level, and many other remnants of the same terrace are visible near by. These have been largely cleared, and many of them are worn out and abandoned, but they are commonly covered with briers and bushes, which are slowly checking erosion and preparing the way for a future forest cover.

FROM HAYSVILLE TO MURPHY.

Valley River heads in Red Marble Gap and flows southwestward in an almost direct line to the Hiwassee at Murphy, N. C. Its valley is, as a rule, broad with very gentle slopes on both sides. These gently sloping valley sides have been deeply trenched by many small tributaries of the river, and the projecting spurs between the streams reach down well toward the river itself and end in elevations of a few hundred feet above the valley floor. Between the ends of these projecting spurs on either side of the river there is a flood plain a mile to 2 miles wide. The river flows along a belt of marble, and the width of its flood plain varies with the width of the outcrop. Where this belt is widest the valley is broadest; where it is narrowest the valley is narrowest. Practically all of the valley walls are forested, although in most places the lands have been lumbered.

The flood plain of Valley River is almost everywhere cleared. A tract of varying width lying next the stream is covered by ordinary floods, but as the stream gradient is low its flood velocity is so slight as to prevent material damage. This flood plain is bordered in many places by an old terrace whose upper surface is quite irregular and varies on its flood-plain edge from 10 to 20 or even 30 feet in height, but back from its streamward margin slopes gently upward to an elevation of as much as 150 feet in places where it joins the valley walls. This slope is commonly cobble strewn and is plainly an old beveled flood plain or slope made by the stream while cutting vertically and swinging laterally at the same time. This old terrace comprises some excellent farming lands and is nowhere being greatly eroded. In very few places were any of the valley walls above this plain cleared, and generally only a small amount of clearing has been done along the tributaries of Valley River. In its lower course the gravels of both the living and the fossil flood plain contain some gold, and considerable hydraulic work has been done.

On Hightower Creek there is some good bottom land at Osborne, but the largest and best area is some miles above, near Visage, though narrow bottoms extend well up to the head of both the main stream and its tributaries and are for the most part cleared. Practically all the slopes are in forest. No considerable areas have been cleared, even on the lower valley side, of either the main creek or its tributaries. At the very head of the creek, on the dividing ridge, are some recent clearings which have not yet begun washing as they are likely to do as soon as the humus has disappeared from the soil. Bottom lands along the creek have in recent years been slightly damaged by floods, but the damage has not been greater than may normally be expected on any stream similar in gradient and rainfall.

The forested slopes have been purchased by lumber companies, it is reported, at an average price of $1 to $2 per acre. Until a railway can be built some 30 miles up the river from Murphy no extensive logging can be undertaken.

Practically all of the slopes in the basin of Shooting Creek are wooded, and little or no lumber has been cut except for local needs. The bottoms along the stream are cleared and farmed, but the stream channel is deep, the current is relatively swift, and floods have not been serious. The forested slopes have, like those on Hightower Creek and elsewhere in the upper Hiwassee basin, passed into the hands of lumber companies and doubtless will before many years be extensively lumbered.

The flood plain on Tusquitee Creek is rather broader and better than that on Shooting Creek, and the bordering slopes are even less cleared. No damage has been done by floods. The timber in this basin also has been sold.

Fires Creek drains a very steep-sided basin, much of which is rough and practically all of which is wooded. The residents of the basin comprise only a few families, and their aggregate clearings are very small. There are scarcely any bottoms along the stream itself, and there has been no damage from floods.

During the examination of this region it was accidentally discovered that the United States Government owns tracts of timber land in this basin and in the basin of Cheoah River west of Robbinsville. It is estimated that good titles may still be had to some 32,000 acres. The existence of such Government holdings seems to have been practically lost sight of, as the title is lodged with the Treasury Department and not with the Land Office. The land is said to have been seized as one of the assets of a defaulting contractor. A request was sent by the writer to the proper officials urging that these lands be withheld from sale and retained as a nucleus for a possible forest reserve.

Along Brasstown Creek there are some good bottom lands which are bordered in many places by the old high terrace and by rolling hills whose higher slopes are wooded. No flood damages are reported there.

Between Haysville and Murphy a flood plain is lacking in a few places where the river cuts across resistant rocks, but more commonly it is present and is broad and fertile. Near the mouth of Peachtree Creek it is from three-fourths of a mile to a mile wide. Many remnants of the old high terrace are visible above it. A mile above the mouth of Brasstown Creek and on the opposite side of the river, where the present flood plain is relatively narrow, a terrace is well preserved at an elevation of 60 feet. At the mouth of Peachtree Creek, where the river flood plain is very much broader, an admirably preserved terrace, that is regarded as of the same age as the terrace just mentioned, has an elevation of 40 to 50 feet above the present flood plain, the decrease in elevation being due to the greater width of the valley.

Up and down the river and up the valley of Peachtree Creek there are many low, ragged-topped hills and ridges that rise 100 to 150 feet above the old terrace level. Most of these are timbered. On the sides of the valley the lower slopes are in some places cleared to a height of 100 to 300 feet above stream level, but in many places these slopes are wooded, although much of the best timber has been cut and rafted down the river to Murphy. Murphy is situated on the old high-terrace plain, which there stands 90 to 120 feet above the present flood plain and is bordered by a much more recent but quite prominent terrace at an elevation of 40 to 50 feet above the present stream grade.

FROM MURPHY TO THE MOUTH OF THE OCOEE.

For some 40 miles below Murphy the Hiwassee flows across the trend of the mountain structure in a narrow gorge-like valley cut to a depth of several hundred to a thousand feet or more. The stream channel is as a rule broad and shallow, the slope is so great that the current is swift, and the erosion of the hard rocks that form its bed, except where there are local gravel bars, is rapid. Combined with the present active down-cutting there is considerable lateral shifting due to frequent irregular meanders, and where small flood plains occur they are usually of the beveled or hanging type. Where the flood plains are flat the grade and the width of the stream are so great that floods rise but a few feet and flood-plain level is accordingly but a few feet above stream level.

At Murphy the river is 75 yards wide and the narrow flood plain is 8 to 15 feet above the stream. Just below Murphy the river enters a gorge and is bordered by a narrow sandy strip of flood plain that is not cleared. Just above the mouth of Nottley River, where the living flood plain is 5 to 8 feet high and the river is 100 to 150 yards wide, there is a prominently developed fossil flood plain 80 feet above the living plain; just below the mouth of the Nottley stream gravels are found up to an elevation of 130 feet, but no well-developed terrace is seen at this height. Ordinary floods are here rarely more than 3 to 5 feet high, and the highest recorded flood is said to have been 18 feet. The entire flood wave passes within 24 hours if rains on the headwaters have not been continuous. Floods do very little damage, as there is very little bottom land within their reach.

At the mouth of Great Creek the valley sides are only moderately steep, and up to an elevation of 200 or 300 feet above the river 40 to 60 per cent of them are cleared. These fields show scarcely any erosion, probably because of the slight slope and the somewhat porous, stony character of the soil. About 5 feet above stream level there is a well-developed ordinary flood plain some 10 yards wide, and 10 feet higher an extraordinary flood plain. Up Great Creek valley the hills are low and retreating and much of the area has been cleared, farmed until worn thin, and then abandoned. Some of this abandoned land is badly cut with narrow gullies.

Along the river for several miles below Great Creek the upland marking the level of the old river valley is largely cleared, its slopes are low, and it has not been greatly damaged by erosion. From just below Beaverdam Creek down to the State line the uplands have a poor, thin soil derived from the weathering of slates and schists. When such uplands are cleared they produce about three good crops before the humus of the original forest has disappeared. They then begin to gully and are soon abandoned. The tributary streams are in most places bordered by narrow and relatively fertile bottom lands which have locally been somewhat damaged by floods. The higher mountain slopes are in forest, but the forest is ordinarily thin because of the poor, dry soil. The best of the timber has been culled and hauled by wagon to Murphy.

Along Coker Creek the soil is for the most part poor, as it is derived from the weathering of slates or schists. All of the higher slopes are wooded. A large part of the lower slopes were once cleared, but their fertility was soon exhausted, and they were abandoned to grow up in bushes, briers, and broom sedge. Along the stream itself most of the scattered flood-plain areas have a poor soil. In many places these areas have been torn up by placer gold mining. Gold occurs sparingly in the gravels of this stream basin and has been mined in a desultory way for nearly a century.

From Coker Creek westward to Springtown and from Springtown southward to the river wooded ridges alternate with narrow stream valleys. The bottoms and in places the lower slopes of the ridges are cleared and cultivated. The soils are as a rule thin, and those on the slopes are generally eroded to a considerable extent except where they are freshly cleared. The aggregate area of cleared land is, however, small. Along the streams near Springtown the lower 75 to 100 yards of the slopes are gentle and are more largely cleared. The soil is poor and slaty, and as soon as the original humus is exhausted it begins to erode, so the old areas are constantly being abandoned. Just at Springtown the soil is derived from limestone and is more fertile, but it is also more easily eroded.

On Hiwassee River just below the mouth of Childers Creek there is a fertile flood plain 250 to 300 yards wide, which is 6 to 10 feet above stream level and has not been greatly damaged by floods. In the river are several islands that are stable or are slowly growing and are protected from erosion by a fringe of willows around their edges. Their soil is fertile and is cultivated.

LOWER HIWASSEE BASIN.

The lower or valley part of Hiwassee River was not examined in detail. Below the mouth of the Ocoee the river is navigable, but navigation is interfered with to some extent by sand and gravel bars. Government employees engaged in maintaining a channel report a constant tendency of the sand and gravel to refill channels once dredged or cleared. The writer believes that this tendency on the Hiwassee is not as marked as on some other streams of the Tennessee system, because the Hiwassee does not carry as great a volume of coarse débris as is carried by the Little Tennessee, the French Broad, and other tributaries. The amount or débris carried by the Hiwassee must, however, increase with the increase of lumbering and of clearing in its middle and upper basins, and much of this added material must find at least temporary lodgment in bars and islands and thus become a constantly increasing obstacle to the maintenance of a navigable channel.

Ellis Creek has opened a steep-sided valley along a narrow belt of upturned limestone. Its valley slopes are cleared for a short distance above stream level, and the clay surface is being cut into many narrow, sharp-bottomed gullies.

OCOEE RIVER.

From Ellis Creek to the mouth of Caney Creek, on Ocoee River, the small streams are bordered by narrow bottom lands that are for the most part cleared. In some places where the lower slopes of the bordering uplands have been largely cleared these bottoms have washed badly. The sloping fields more than a few years old also show marked erosion and many of them have been abandoned. Here and there still higher slopes have been cleared and these, too, erode freely.

For 10 miles above the mouth of Caney Creek, Ocoee River occupies a deep, narrow, rock-bound gorge, in which it cuts its way in an almost continuous series of rapids. No flood plain has been developed in this distance and there are no mountain-side clearings. At the upper end of the gorge the valley widens and a flood plain has been built, but within recent years it has been covered by a deposit of barren sand and has thus been practically ruined for agriculture. This sandy material has been furnished by the abnormal erosion occurring about Ducktown (see p. 78), and deposition at this point is due to the ponding and checking of the flood current by the gorge below. The checking is just sufficient to cause the river to deposit the sand, leaving in suspension the finer silt, which is thus carried through the gorge and deposited where the river assumes a much lower gradient as it flows out into the great valley of east Tennessee. The flood plain there built of this finer material is fairly fertile.

Above Ducktown the flood plain varies much in width but averages 100 to 200 yards. It is rather sandy and only moderately fertile, and is being damaged to some extent, especially along its streamward edges, by the floods of recent years. Though tributary stream grades in the upper valley of Ocoee River are as a rule moderate, many low hills reach the old plateau level. In places these have been cleared, or much of the timber has been removed and runways have been opened that have resulted in a material increase in flood damages.

DUCKTOWN COPPER REGION.

Ducktown, Tenn., located in the southeastern part of the Hiwassee basin, is situated on an elevated and now deeply dissected plateau, presumably of the same age as the Asheville Plateau, and is walled in on almost all sides by mountain ridges. Copper is mined and smelted here, and in the immediate vicinity of the smelters all vegetation has been killed by sulphuric acid fumes. The region is peculiarly adapted for the study of erosion problems, since it affords an extreme example of the limits to which erosion may go in this climate when all protective vegetation has been removed. One smelter began operations about 12 years before the region was examined; another had started only 4 years previously; the complete destruction of vegetation had taken place within the latter period. During this short time the second-growth timber and the bushes and grass beneath it, which had covered most of the area, had been killed, and the dead trees had been removed for firewood; but though the ground is in many places still covered with small branches and twigs, the litter-covered surface is already cut to pieces by erosion.

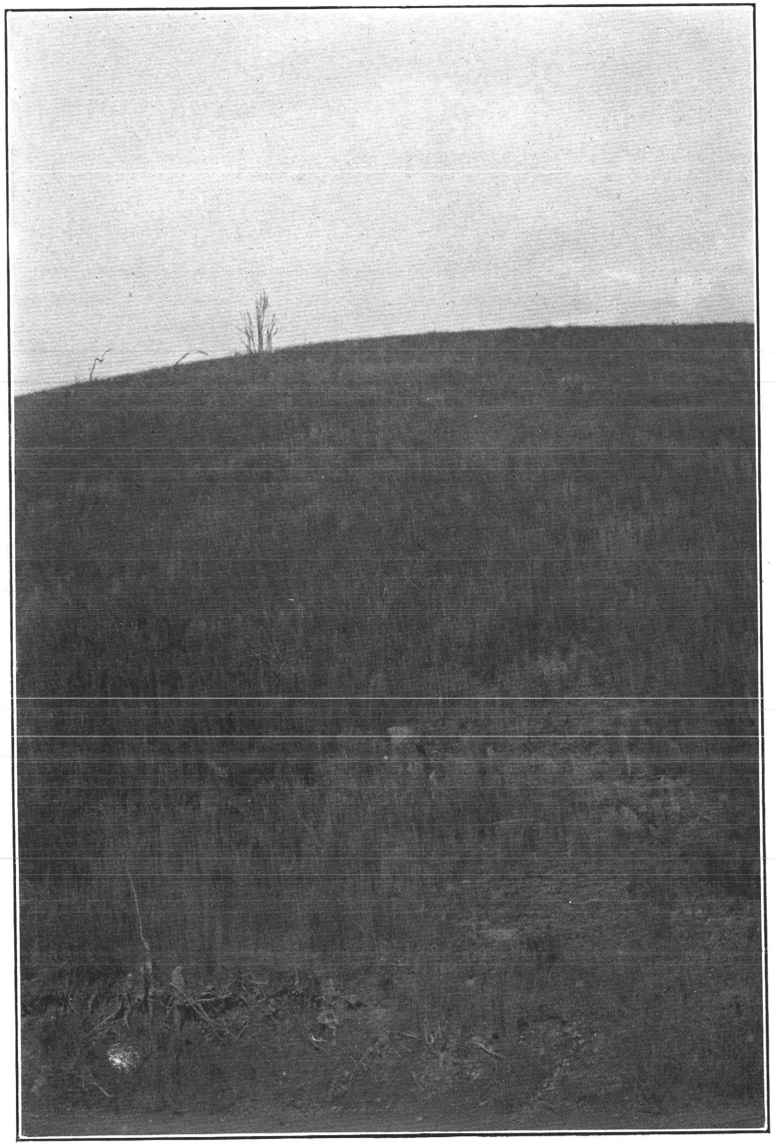
The erosion starts near the bottom of a slope, and where the soil is porous rapidly cuts a steep-sided gully to a depth of 5 to 12 feet below the surface, where the underlying schist is as a rule still measurably firm. After a gully has reached its limit in depth it widens until its walls coalesce with the walls of adjacent gullies, by which time most of the soil has been removed. Where the soil is a more impervious clay, erosion begins, likewise, at the foot of a slope, and eats out amphitheater-like areas such as are shown on Plate XVI, opposite. Like the deep-grooved gullies, they rapidly grow headward until they reach the top of the hill and completely denude it. Hills gullied in these two ways are illustrated in the two views in Plate XVII.

The quantity of waste furnished by these bare slopes, being too large for the streams to remove, rapidly accumulates along the stream courses as flood or waste plains, which soon extend up even to the foot of the slopes at the head of the streamlets.

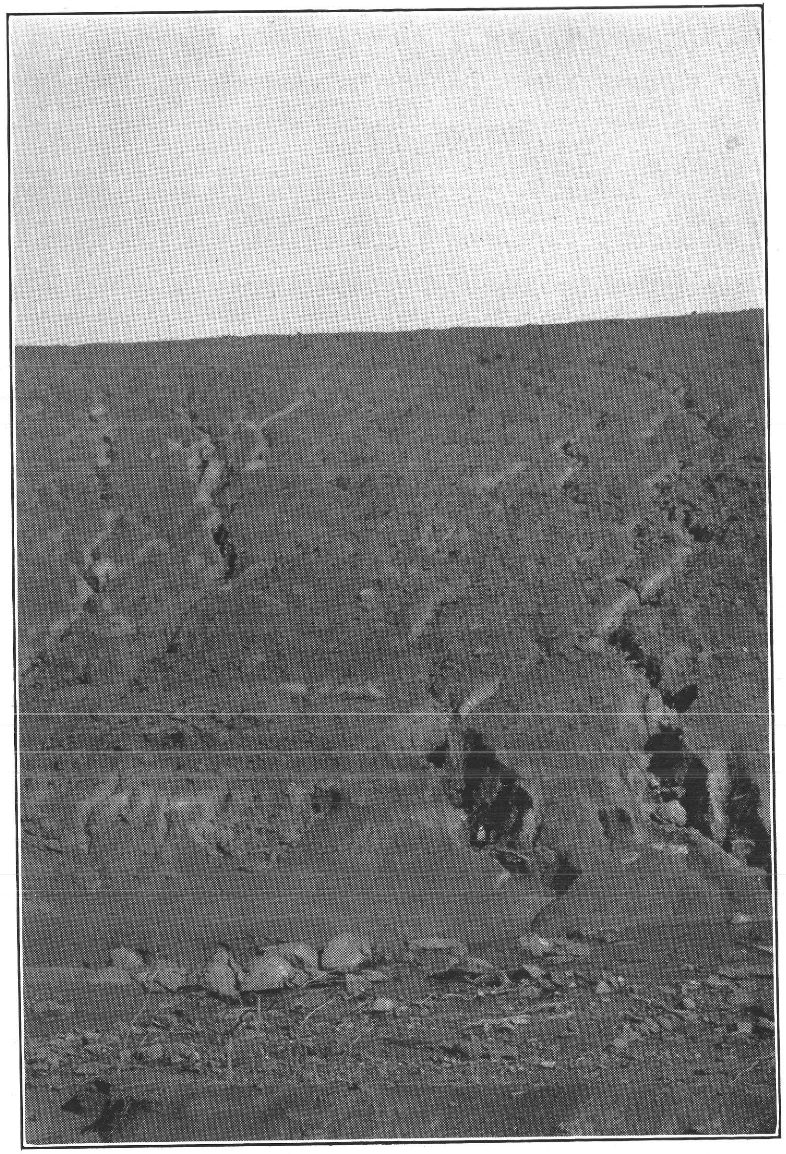
On Potato Creek this waste has been accumulating for a number of years at the rate of a foot or more each year, and has been built into a flood plain from 100 to 300 yards wide, in which telephone poles have been buried almost to their cross-arms, and highway bridges, roadbeds, and trestles have either been buried by the débris or have been carried away by floods. At Isabella smelter recent floods have swept through the store and other houses, and the waters have risen to the level of the furnaces. This increase in the height of floods is due largely to the rapid building up of the flood plain, and extensive diking or other protective measure will soon be necessary to prevent serious damage to the smelter and other property.

Such great quantities of sand are carried into Ocoee River by each large flood as to prevent the running of the two ferries at the smelter until the river has had time to scour its channel clear again. Much sand has accumulated on the flood plain of the Ocoee in the few miles just above the river's entrance into the gorge below Ducktown.

This abnormal denudation and erosion has also affected the underground water level in the region. During the last few years wells have been going dry, and a number of springs, some of which supply water to the miners' families, flow less than formerly. This lowering of the ground-water level and decreased flow of springs can not be attributed to drainage effected by



A.

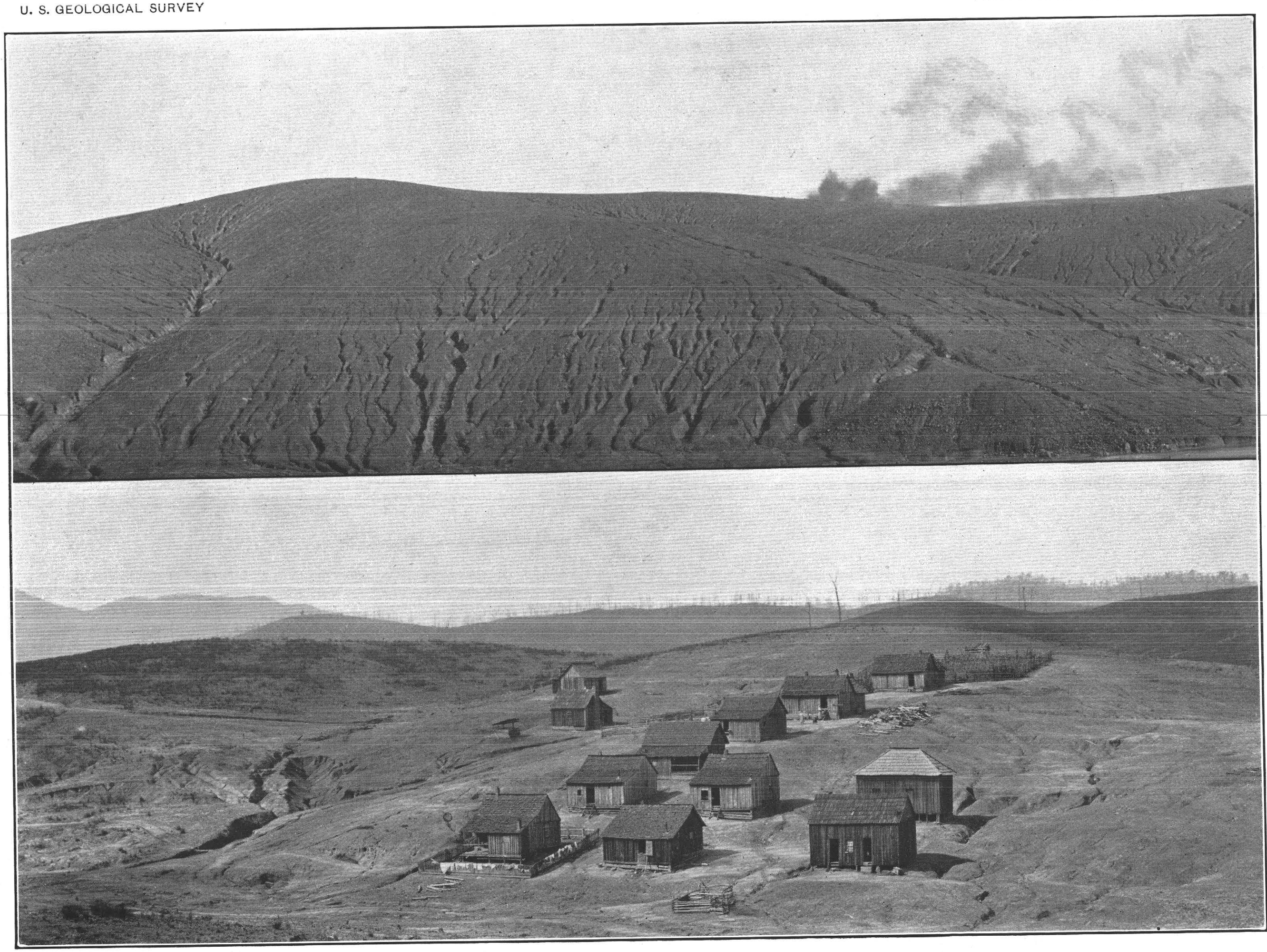


B.

EROSION NEAR DUCKTOWN, TENN.

A. View taken several miles from Ducktown, where a broom sedge turf, yet living, has thus far prevented erosion. See page 45.

B. View taken nearer Ducktown. Surface has no protecting turf and is fast eroding. See page 50.



Keith 597 similar to this

A. DENDRITIC EROSION NEAR DUCKTOWN, TENN.
B. SURROUNDINGS OF HOUSES NEAR DUCKTOWN, TENN.

See pages 19, 78.

the deep mining shafts, for the mines are nearly dry. The normal flow of Potato Creek is said to be only about half as large as it used to be, and there can be no question that a much larger part of the rainfall now finds its way immediately into this stream and is carried off in floods, leaving a much smaller part to soak into the ground to supply the wells, springs, and streams during periods of dry weather.

Erosion about Ducktown to-day is limited only by the rainfall, the steepness of the slopes, and nature of the soil. The destruction of the soil on the slopes by erosion and of all of the alluvial land along the streams by flood-plain building is complete, and over an area comprising several square miles the entire country—flood plain and valley slope alike—has become a barren waste. The Ducktown region is, then, not only an impressive object lesson, but an emphatic warning of the extent and character of the disaster that may result in these southern mountains from the thorough destruction of the forests.

TENNESSEE RIVER PROPER.

GENERAL CONDITIONS.

A detailed examination was made of the Tennessee from Knoxville down to its mouth at Paducah, Ky., a distance of 650 miles, in order to determine what became of the abnormally great amount of rock débris being furnished by the steep slopes of the high Appalachians of western North Carolina to the many headwater tributaries of the river, and whether it was in any way interfering with navigation or with plans for the further improvement of the Tennessee River system. The Government has already spent in such improvements between \$8,000,000 and \$9,000,000, and in order to complete the plans prepared will be required to spend several additional millions. The river drains a territory that is rich in natural resources and contains important water powers, two of which, one just below Chattanooga and one at Muscle Shoals, are now being developed. The exploration was made in a small gasoline launch when the river was at its lowest stage and stops were made wherever they seemed desirable.

Through the courtesy of Maj. Newcomer, United States Army, then in charge of the improvement work, and of the several officers immediately responsible for the work on several sections of the river, sets of blue prints and tracings of detailed surveys and of the plans for improvement were obtained, together with much information as to present and past conditions on the river. With these maps and plans in hand and copies of all important Army engineer reports on the river, as well as a reconnoissance map of the lower river made in 1865, pronounced by an Army engineer in charge of work on the river to be very accurate, it was possible on this trip to study the river to great advantage, although even without the aid of maps or plans a very satisfactory study could have been made by noting the present condition and the general character of the changes now in progress.

Through much of its course, especially in its upper stretches, the Tennessee meanders irregularly. On the convex sides of curves it is generally bordered by bluffs, in many places of bare limestone; on the opposite side, within the meander curves, there are usually fertile flood plains, some of which terminate in gently beveled slopes that extend down into the meander curves. Where the stream is straight it is generally bordered on both sides by flood plains, whose height above ordinary water level varies with the width of the flood plain itself and with the width and velocity of the river, but ranges from 20 to 40 feet in the upper part and 30 to 50 feet in the lower part of the river. In many places there is a narrow ordinary flood plain, which is usually bordered by a much broader extraordinary one whose soil is poorer and whose undulating surface has been produced by incipient erosion, for on these extraordinary flood plains destructive forces have become more powerful than constructive forces. At various higher levels there are cobble or gravel strewn remnants of still older fossil flood plains that exist now as more or less prominent terraces.

Islands are numerous along the entire course of the river and, except where conditions have been affected by the building of Government dams or other regulative works, are generally growing. The growth is, as a rule, especially rapid on the upper end of the island and on one side or the other, but not on both sides. Some islands also grow at the lower end. This upward and lateral growth of the island causes constantly greater deflection of the river current, which in turn produces changes in the position and depth of the channel and in the configuration of the opposite bank. Along the upper course of the river the growth of the islands seems to be more marked just above Chattanooga than just below Knoxville.

As a rule the surface of these islands is fertile and is cultivated wherever it is high enough to be reasonably safe from ordinary floods. Many of the better managed of these island farms have been protected from erosion during floods by a fringe of timber planted or preserved around the upper ends and down the sides. In some places floating material lodges in great rafts in this fringe of timber during floods and by the powerful scouring action of the strong current deflected beneath it causes extensive gouging on the upper end of the island. In other places the river shows a marked tendency to deposit gravel on the sides of the island just below the point where the currents are deflected away from it. These lateral accumulations, whose lower ends may project downstream as sharp pointed barbs or spits, generally become attached to the islands and are the chief means of lateral growth. Slow alterations in the shape of the upper end of an island and of the gravel bar that usually extends upstream below water level for some distance rarely permit the chutes formed on either side of a growing island to remain unchanged. Fortuitous changes in the growth of the island deflect the current more and more to one side or the other and cause a gradual filling of the abandoned channel. Thus in time, by a lateral shift of channel that involves serious property losses on one bank and concomitant gains on the other, the island becomes tied to the bank and ceases to be an island.

Most bars are made up of gravel and cobble and some bowlders. A marked decrease in the average size of the material composing the bars is easily observable in going down the river. Near Knoxville the bars contain many rounded cobbles a foot or more in diameter; at Chattanooga the average diameter of the largest particles is 3 or 4 inches or less; on the lower river the cobbles have long since disappeared and the average diameter of the largest gravel is an inch or slightly more. On the upper river the bars contain comparatively little sand; on the lower river they generally contain a large proportion of sand. Silt deposits are not prominent on the upper river, but are characteristic features of the lower river. The cause of these changes is easily understood. The coarse material in the upper part of the river is being constantly ground and worn to pieces as it is rolled downstream, so that the size of individual bowlders or cobbles constantly decreases until they finally disappear as such, and the amount of finer material produced by the grinding to pieces of the coarse material increases down the river in just the same proportion as the cobbles decrease. The increase and decrease are correlative. The average velocity of the stream is greater in the upper part of the river, and hence in many places only gravel and cobbles can lodge and accumulate; on the lower river, with its gentler current, sand and silt are characteristic accumulations, and sand and gravel bars are more numerous than on the upper river.

In some places the gravel becomes firmly cemented by limonite, which is probably continually carried along in the river as a flocculent precipitate. It is not known how rapidly this limonitic cement is deposited. Where the gravel remains loose the current may be strong enough at ordinary stages to roll it along the bottom. During floods not only the sand and gravel of the river bottom are in active motion downstream but even the loose bowlders on the upper river may at certain flood stages be heard pounding and grinding on one another as they are rolled along by the strong current. During such stages the bedrock underlying the sand and gravel on the bottom of the river is doubtless scoured bare and subjected to active corrasion.

From Knoxville, Tenn., to Riverton, Ala., the banks of the river are generally stable. Undercutting and caving are noticeable at only a few places, and at none of these is it of serious proportions. This is undoubtedly due in large measure to the fact that the bottom of the river through most of this distance is in solid rock, though the actual bedrock surface is covered almost everywhere by loose sand and gravel, generally several feet and in some places

20 feet or more thick. No very rapid undercutting and lateral shifting are possible where a stream channel is cut into hard rock.

Below Riverton, Ala., the banks of the river are undercutting and caving in many places. This lack of stability throughout the lower section of the river is due to the character of the alluvial materials of which the banks are formed and the decreased slope of the river, which renders easier the accumulation of deposits of sand and gravel in the channel. These deposits deflect the current and cause undercutting of the banks and a tendency to the development of meander curves.

The bed and banks of the river below Riverton are mainly of clay, but hard rocks are found in a few places along the river even down nearly to Paducah, and these rocks are usually scoured bare at certain stages, so that it is certain that through its entire length the river is actively eroding its bed. This erosion, however, is concomitant with the deposition of loose material at many places along the river, for most of the active erosion of the river bed occurs during the rising stages of floods and most of the deposition takes place during the succeeding slack-water stage, at the crest, and during the decline of the flood, when the decreased velocity forces the stream to drop a large part of its load. This process is known as scour-and-fill.

From Riverton to Paducah the current is gentler than on the middle and upper stretches of the river and the deposition has consequently been more rapid, so that island growth and bar formation have been more pronounced and have caused more changes here than elsewhere. Bars have grown into islands and islands have grown until they have lost all semblance of their former selves. This growth has been accomplished mainly by increase in length at the upper ends of the islands and by increase in width. These changes have forced the current against the banks on the sides of the river and have caused undercutting and caving in places. Both the caving and the shifting of the position of the channel necessitate changes in the position of the range lights.

In this lower section of the river the large cobbles of the upper section are unknown; the materials carried are small well-rounded chert gravel and sand and silt, the latter in large amounts.

In the middle section of the river, from Chattanooga down to Riverton, the gravel particles are noticeably smaller than in the section above Chattanooga and are more easily moved. During floods the gravel deposits in this part of the river seem to change more rapidly than those on the upper section. This change may be merely one of form or it may involve change of volume. Practically all the gravel in this middle section is composed of chert and has been derived in part from the long, narrow cherty mountain ridges in the great valley of east Tennessee and in part from the cherty limestones in the region below Chattanooga.

The crystalline and metamorphic rocks carried by the headwater streams from the North Carolina mountains have been ground into finer and finer particles as they have worked down the river until in this middle stretch they have disappeared as cobbles and gravels, but are present in equal volume as sands and silts. An unusually large amount of fine material seems to be produced by the river as it cuts through the mountains below Chattanooga. In the next 50 to 100 miles much of this silt is deposited and has become a very prominent constituent of the islands and bars.

It seems beyond question that deposition in the channel of the river is more active to-day than it was 50 years ago. Wherever it has occurred there is almost always evidence that it has either been recent, or, if long continued, has been more rapid in recent than in former years. Such changes can be attributed only to the great changes that are occurring on the mountain headwaters of the river in consequence of which much greater amounts of sediment are now being furnished to it than ever before. Although in working downstream this material is constantly being ground finer, the fine equivalents of the coarse torrent material are overloading and choking the middle and lower part of the river, and year by year are undoubtedly making the maintenance of navigable channels more difficult. There is a general tendency toward shoaling on bars, and in certain areas channels dredged across them quickly fill up again and have to be repeatedly reopened. A number of new bars have formed in recent years and some of them have already become serious obstacles to navigation.

In harmony with these findings are the statements made both orally and in their public reports by members of the Army Engineer Corps engaged in improvements on the various parts of the river. Brief references to a few of the more salient features of these annual reports may aid in giving an understanding of the conditions that prevail on the river.

Early reports of Army engineers describe the upper Tennessee River as free from sediment, as of unusually stable bed and banks, and as admirably suited to improvement by open-channel work, consisting principally of blasting out rock ledges, building longitudinal training walls, and closing side channels around islands by dams. In the report made in 1830 by Lieut. Col. S. H. Long almost nothing is said of any necessity for gravel excavation, and even in the report of the detailed examination of the river above Chattanooga made in 1893 the project for obtaining a 3-foot channel includes only $20,000 worth of dredging in a total estimated cost of $650,000, of which much the larger part was to be expended in building dams.

Although gravel bars had always existed on the upper river, they had probably long been stable in form, but these bars evidently began to grow larger in the nineties of the last century and soon caused trouble, for in the Army engineers' report for 1897 it is said that the construction of wing dams and training walls on the upper river has almost invariably been followed by the formation near their ends of bars that may be more troublesome than the original obstruction, that the effects of dredging through these bars of recent formation is likely to be temporary, and that the resulting benefits are soon lost. This is a new note and is in decided contrast to assurances previously given and frequently repeated—that the river was admirably suited to the system of open-channel walls and dams that had been adopted and followed for years.

The succeeding annual report of the Army engineers for some years give evidence of a growing necessity for dredging, and in 1900 the officers in charge of the work deemed it desirable to buy a dredging plant for this upper section. Accordingly a dredge was bought and used, and although, for lack of appropriation, no work was done in 1901 and 1902, it became necessary to rebuild this dredge in 1907 at the Muscle Shoals shipyard, because "it had begun to show too much weakness to continue the heavy digging on which it was engaged in the upper river." In the report for 1907 the doubt that had been raised 10 years before as to the practicability of improving the river by the plan adopted is further strengthened by the statement that there is some question whether the river above Chattanooga can ever be satisfactorily improved by regulation. The statement made in recent reports that the Tennessee is a sediment-bearing river is also in contrast to the old description of it as nonsediment bearing. Rather than to assume that the many Army engineers who had previously decided that this upper section was admirably fitted for open-channel improvement were all so entirely mistaken in their conclusions, it would seem more reasonable—especially in the light of the recognized change in the character of the river—to attribute the failure of open-channel work to a change of regimen.

The survey from Scott Point to Lock A includes most of the open-channel portion of the middle section of the river from Chattanooga to Riverton. The bottom profiles of the 159 miles in this stretch show that of the portions having a depth of less than 5 feet at mean low water 81,850 linear feet, measured along the channel, have a gravel bottom, 77,800 feet have gravel and rock bottom, and 27,900 feet have rock bottom. Between Guntersville and Hobbs Island shoaling constantly occurs on a number of bars, from which over 200,000 cubic yards of gravel have been dredged in recent years. Bars are constantly forming in the open river at the entrance to the upper end of the Elk River Canal and of the Muscle Shoals Canal, and regular dredging is required to keep the entrance to the canals open.

On the lower river, from Riverton to Paducah, because of the decreased fall, there is more opportunity for sand and gravel to lodge. The survey of 1896 showed 49 bars, all but two or three composed of gravel. It was calculated that the removal of 650,000 cubic yards of sand

and gravel would be sufficient to open a channel across these 49 bars. Channels were dredged through a number of them, only to fill up at the next season of high water. One has been opened five times in 8 years. In a few years it has been necessary to remove from certain bars several times as much material as was originally calculated. For example, the calculated amount of gravel dredging required at Big Chain bar was 16,716 cubic yards, but 66,345 have been removed. At Rockport bar 13,321 cubic yards needed removal; 80,262 have been removed. At Beech Creek Island the calculation was 34,948 cubic yards; 174,500 cubic yards have been removed. Moreover, several new bars have developed since 1896, and have interfered with navigation so seriously that it has been necessary to dredge them before certain of the older bars had even been touched. The Army engineer in charge sums up general conditions on this lower part of the river by saying in the report for 1908 that in 1896 it contained 49 shoals, and that several others have since been formed; that 1,127,660 cubic yards of gravel had been dredged at 31 localities, and that the results were fairly permanent at two-thirds of the places.

These brief abstracts from the reports of the Army engineers indicate that, though permanent improvements on the Tennessee may be made by building locks and dams, such as those at Muscle Shoals and elsewhere, and by blasting rock ledges from the channel, the improvement resulting from building training walls is of uncertain value, and that the improvement by dredging is in many places only temporary, the benefit being soon lost. This conclusion does not imply that it may be wise not to dredge at all, but rather that, however wisely planned and faithfully performed, the task of improving a river like the Tennessee, under the conditions of erosion and silting that now exist in its basin, is never ending, and that dredging will always be necessary to maintain an open channel as long as present conditions on its headwater tributaries prevail. A single sand bar may effectually block the river and render useless the locks and dams, nullifying the results of the expenditure of millions of dollars for their construction. To what extent these conditions would be improved by extensive reforestation of the steep headwater slopes it is impossible to predict, but it is believed, both from the logic of the case and from the contrasted example of such rivers as those of the Coosa-Alabama system, that the benefit would be material, and either alone or in connection with other benefits flowing from such a policy would be well worth the necessary outlay.

It is to be regretted that no thorough examination and survey of the river was made long enough ago to enable a more detailed comparison of previous conditions to be made with the conditions found to-day. Most old examinations were made where rock ledges reach near the river surface or where gravel bars had already grown so near the surface that the current prevented much further growth; and in many areas changes that would have naturally occurred at critical points have been prevented or masked by dredging and the building of rock training walls during the improvement of the river. Places where no efforts at improvement have been made usually afford the best opportunity to observe the natural changes that are occurring in the river. It is chiefly such places that are described in detail in the following pages.

It is recognized that any individual bit of evidence may be misleading, but when innumerable bits, gathered from many sources and varying greatly in kind, harmonize and point to the same general conclusion, it is difficult to believe that conditions are in reality just the opposite of what they seem to be. The conclusion is irresistible that the evidence is an accurate index of the facts and may be accepted as trustworthy. In presenting this detailed evidence of change along the Tennessee the river will be considered in three sections—an upper section from Knoxville to Chattanooga, Tenn.; a middle section, from Chattanooga, Tenn., to Riverton, Ala.; and a lower section from Riverton, Ala., to Paducah, Ky.

DETAILS OF CONDITIONS.

FROM KNOXVILLE TO CHATTANOOGA.

The first point below Knoxville at which changes were observed was Lyons Shoals. The main or right-hand channel is said to be shallow enough to permit horses to ford across to the island from May until late in fall; years ago it was necessary to ferry them during the crop-working part of the summer, and only late in fall did the river get low enough to ford. Either ordinary stages of the river must now be lower there during the summer than formerly or the channel must have filled considerably with gravel; the latter seems more probable. Army engineers report that the channel is shoaling and that a bar of gravel is forming at the lower end of their dam. The two main islands are being tied together by the filling of the channel between them. At low water this chute now becomes dry.

At Williams Islands the upper and middle islands are being extended by a deposit of gravel on their upstream ends; the lower island seems to be stationary. Army engineers report that the right chute, which is the steamboat channel, is shoaling with gravel.

At Little River Island the dams built for the improvement of navigation have so changed the currents that though both cutting and filling are going on it is impossible to say which process dominates.

At Post Oak the two islands will before long be united by the gravel bar forming in the channel between them. The right-hand channel is also filling.

At Prater Island cutting is in progress on the upper end and filling on the lower. The channel on the left side is filling and now goes dry during the summer and fall. Before long these islands will be tied to the left bank and the entire current will pass down what is at present the right-hand channel.

On Cox Island the timber protecting the upper end has been cut away and this end has been especially damaged by floods that have swept across the island. The bar at the head of the island seems to be growing slowly.

Russel Shoals show an accumulation of gravel on the bar, shoaling in the channel below the dam, and a shifting of the position of the channel as compared with its condition in former years.

Roger Islands show a slow growth upstream, and above the upper end of the larger island a shallow gravel bar is forming—a feature that is generally characteristic of other islands in this part of the river. The right-hand side of the islands seems to be growing by the deposition of gravel and silt and is pushing the river channel farther to the right.

The upper end of Chota Island is protected by a rock dam, behind which gravel and sand are accumulating and extending down the upper part of the island. Just below Dam No. 2 bars are constantly forming and obstructing the channel on both the right and left sides.

Behind the dam across the upper end of Coulter Islands filling is in progress. The channel between the middle and the lower island is filling, so that these two will soon be united.

At Leipers Ferry the river is reported to have filled considerably in the last 20 or 30 years.

Sister Islands are situated in a relatively straight reach of the river and seem to have reached equilibrium; they are neither visibly growing nor wearing away.

The upper end of the uppermost of Belle Canton Islands shows a recent upstream growth of 100 yards; on the right-hand side there has been a lateral growth of 20 yards, and the steamer channel has been pushed farther to the right. The second of these islands shows a growth of 150 yards on its upper end, but its sides, as well as the lower ends of all three islands, are stationary.

At Lenoir Ferry the river is reported to be lower, as a rule, during the summer and fall than it was 40 or 50 years ago.

At Lenoir Shoals, just below the mouth of Little Tennessee River, navigation of the narrow, crooked steamboat channel is rendered still more difficult by an accumulation of gravel, seemingly due to the great amount of material furnished the river by the Little Tennessee.

Rock Quarry Bar is reported to be growing and the channel across it is shallower than formerly.

Carmichael Island seems to be slowly growing upstream, but some 200 yards of its upper end has been badly scoured and much of its soil has been removed by recent floods. This scouring has injured some of the cultivated land on the island and has washed up trees, 6 to 10 inches in diameter, that formerly protected the head of the island from erosion.

At the upper end of Loudon Island four small towheads that appeared years ago have been growing until they will shortly unite with one another and with the island below them. The upper ends and the sides of the islands were already growing slowly when their owner began to aid their growth by cutting the willows around their edges so that, though their gain in area has been notable in recent years, it is not a fair index to the natural rate of growth. It shows, however, that only slight encouragement is needed to cause sediment to lodge at any point, so great is the amount carried by the river.

Harrison Island and two towheads above it have, by the filling of the channel to the left of them, been united to the left bank of the river. This process has been aided by the owner, although it was started by the stream itself.

Sweetwater Island is protected above by a rock dam behind which gravel has lodged in large quantities during recent years. The sides and lower end of the island seem stationary. Halfway between Sweetwater Island and Bogart Island, near the left bank of the river, a recently accumulated gravel bar, some 25 yards long at ordinary stages, has deflected the boat channel to the right. At the upper end of Bogart Island a towhead is growing and a gravel bar is filling out to the left of it. The two main islands are being tied together by the filling of the channel between them.

An uncharted gravel bar, which probably had recently formed, was observed near the right bank just below Marble Bluff Landing.

Wilson Island is stationary except at the upper end, where a gravel and cobble deposit is forming behind a dam.

At Seven Islands a towhead has appeared above the upper island and become attached to it by a deposit of gravel and the channel between the two islands is closing. In the same way the lower end of Long Island is being extended downstream by the deposition of fine silt. Deposits of sand and gravel are forming about the dams that unite the upper end of Round Island to the left bank of the river. The upper end of Long Island itself is growing, and on the right side, just below the shoulder which deflects the main current to the right, two small towheads have formed and are becoming attached to the island.

Just above the mouth of Clinch River the right bank of the river is being undercut, and undercutting was noted on the same side some 4 miles farther down, just below Hoods Ferry. The amount of the cutting, however, is slight and it is mentioned merely because the banks, as a rule, show little or no signs of such change.

At Pickles Bar the recent accumulation of gravel is said to have greatly changed the steamboat channel and rendered it more difficult to follow.

Kings Bar is also reported to be shoaling.

Just below Rockwood landing Bracket Bar has shoaled so much in recent years that it has been necessary to cut and buoy the channel through it. It is not described in any report previous to 1893 and is evidently of recent formation. In 1904 about 29,000 cubic yards of sand and gravel were removed. The distance dredged was 2,100 feet.

The upper end of Halfmoon Island is being undercut by the current, which sets strongly against it. Back of the rock dam that deflects the current to the left, however, a deposit now forming is uniting the main island to the two small islands above it.

At Whites Creek Islands in the last few years much gravel and silt have been deposited on the main island and the several towheads above it. One of the towheads has recently grown into a fertile island, which was patented from the State of Tennessee by one man and claimed by another on the ground of riparian right, and thus became the cause of personal strife and later of lawsuits between the claimants. Gravel bars are also forming in Whites Creek Shoals in spite of the long dam built to improve them. A bar persistently forms below the end of the dam, although the dam has been repeatedly extended in order to prevent such accumulation.

At Preston Island a towhead, formed in recent years to the right of the head of the island, has grown so rapidly that it is now 250 yards long, rises 10 feet above low-water level and has willows 20 feet high growing on it.

At Euchee the left bank is 45 feet high and the undulating, irregular flood plain is covered only at long intervals and by floods of extreme height. A mile back from the river, however, there is a lower sluice across which floods ordinarily run and have done much damage.

Piney Island shows a relatively rapid growth upstream. The main body of the island rises 20 feet above water level and is protected by well-grown trees. Above it there is a crescentic sloping belt, which extends 150 yards upstream and above this a still lower belt 250 yards broad, reaching down to water level. Beneath water level there is a gravel bar that may be traced for some distance upstream and is undoubtedly growing.

Behind the dam that protects its upper end Watts Island is growing by the deposition of abundant flood-borne detritus.

Hunter Island is now almost tied to the left bank by the filling of the intervening channel. The upper end is growing slightly. The gravel bar opposite this island is 4,000 feet long.

Just below the middle of Good Field Shoals a gravel bar has accumulated near the left bank in recent years, and now rises considerably above ordinary water level.

Across Martin Bar the deflection of the channel is reported to be decreasing, owing to an accumulation of gravel now in progress. This bar was 1,000 feet long in 1893 but had not previously been described.

At the mouth of Hiwassee River the upper island is slowly growing upstream, and on its right side towheads are forming and uniting with it, so that the current is deflected to the right and the main channel is slowly shifting in that direction.

Above the upper end of Upper Sale Creek Island a large gravel bar has been formed, and a towhead 300 yards in length is forming and has almost joined the island. On the lower island a similar large gravel bar and towhead have been developed, and the main channel is reported by Army engineers and others to be growing shallower by constant accumulation of gravel.

Soddy Islands are growing on both their upper and their lower ends, but as these ends are connected by longitudinal dams it is uncertain whether the entire growth may not possibly be due to the influence of the dams. It is practically certain that the accumulation of débris so generally noted about dams is in general due to their influence in checking or producing eddies in the current.

Dallas Island was washed badly in 1876 but has grown somewhat since then on the upper end. The channel is shoaled by a gravel bar that has accumulated at the head of the island.

An octogenarian at Harrison Landing reported that the flood of 1867 was the highest within his memory, and that that of 1876 was the next highest. Floods during recent years, in his opinion, have been more numerous than formerly. He also stated that low water in summer and fall in olden times was lower than to-day. This was the only statement of the kind heard on the river, but the opposite observation and belief was reported by many persons.

Chickamauga Island shows a slow growth on the upper end. Just below this end there is during floods active deposition of sand and gravel, which are dug as building material for Chattanooga markets. The pits dug out during low water rapidly fill again during floods, so that the supply perpetually renews itself. In the last few years a gravel and sand bar has grown several hundred yards from the upper end of some small islands just below and to the right of Chickamauga Island.

At Colwell Bar there is a gravel deposit that is growing upstream, and just below it gravel bars have formed on the right, deflecting the main stream channel sharply to the left. The gravel bar here is 4,000 feet long.

FROM CHATTANOOGA TO RIVERTON.

The stretch of river between Chattanooga, Tenn., and Riverton, Ala., is 238 miles long and may be conveniently divided into three parts. The upper part is $17\frac{1}{2}$ miles long; in this stretch the river cuts through the mountains just below Chattanooga and has a fall of 27.9 feet, or an average of 1.9 feet per mile. The current in this part is generally swift. In some places where the stream is sawing its way down through hard sandstones it is much contracted in width.

Rock débris entering this mountain stretch has little opportunity to lodge anywhere but is swept along with impetuous force and is well ground to pieces before it enters the succeeding stretch. The middle stretch extends 158.3 miles, to the head of Muscle Shoals Canal, falling in this distance 63.8 feet, or an average of 0.4 foot per mile. In this stretch the current is gentler, and in it much of the silt ground down by the river on its way through its mountainous stretch finds lodgment and is building bars and islands. In the third part, which extends from the head of Muscle Shoals 61.5 miles to Riverton, the fall is 168.5 feet, or 2.73 feet per mile. In this stretch are included Big and Little Muscle shoals and Colbert Shoals.

The first deposit of sand and gravel in the river below the Chattanooga wharf is at Ross's towhead, where there are sand and gravel pits from which material is dug for Chattanooga markets. These pits fill quickly during floods and the supply is consequently inexhaustible. The towhead does not seem to be materially growing or wasting. The chute to the left of the towhead was originally selected as a boat channel and was improved, but it was so difficult to keep open because of the constant accumulation of sand and gravel in it that in 1894 the Army engineers abandoned it and began blasting a new channel near the right bank.

Williams Island, 6 miles below Chattanooga, is not changing in any manner.

The Skillet towhead is composed of sand and gravel and seems to be in stable condition, as is also Savannah towhead, some miles below.

Burns Island, in the middle stretch as here defined, may be wasting slightly on its upper left side, but the lower end has grown 100 to 125 yards downstream in the last six or eight years, and its height has been so greatly increased by deposits during floods that the lower branches of the old trees are now being buried by the sand and silt.

Bridgeport Island is not changing in form, but the upper end is growing higher by the deposition of silt.

Crowtown Island shows an unchanged outline but is becoming higher on the upper end. Above it there is a well-developed gravel bar, which seems to be stationary.

The sides of Bellefonte Island are stationary but the upper end has grown some 50 yards in the last five years and the lower end is becoming higher and is extending slowly down the river. The deposit on the lower end is very fine silt. The bar just below the island is shoaling, and at low water several acres of sand and gravel are now exposed.

Thirty years ago Larkin's towhead was above water only at long intervals, at exceedingly low stages of the river; 22 years ago it is reported to have been 150 to 200 yards long; now it is over 500 yards long and is cultivated in corn. Its growth has been more rapid within recent years than formerly.

At Ferry's landing, on the right side, 100 to 125 feet above present river level, there is an old river terrace whose gravels and pebbles are very similar to gravel deposits found in West Tennessee, and they may be of the same age.

Across the upper part of Pine Island a runway formed in the great flood of 1867, cutting off the upper end of the island. Since then this runway has filled up and the island has grown upstream 150 yards. The lower end is growing higher by the deposition of silt and has recently grown some 50 yards farther downstream.

The upper end of Buck Island is growing in height and has extended upstream 150 yards in the last 10 years. The sides and lower end are stationary.

The towhead above McKee Island is said to be growing, but Henry Island and McKee Island are not changing.

Flint River towhead is reported unchanged and Byrds Island has changed very little. The lower end of the island has extended downstream some 30 yards in the last 17 years, but the upper end is wasting somewhat. The area of the island 100 years ago was 324 acres and is approximately the same to-day.

From Lock A to Florence so many artificial changes have been made by dredging channels and building locks and dams around Big and Little Muscle shoals that it is impossible to draw any important conclusions as to the natural changes. Bars are forming in the open river at the upper entrances of both the Elk River and the Big Muscle Shoals canals and require the almost constant use of a dredge to keep the channel clear.

Sevenmile and Big Buck islands are probably stationary. On their bars there are large deposits of well-rounded chert gravel, and though this gravel is constantly changing from flood to flood the bars themselves seem to be neither wasting nor growing. Halfway down the side of Big Buck Island, however, there is a towhead above which a gravel bar has grown since the Government dam was built in 1878, and below it another towhead has formed in the last 15 or 20 years and is steadily growing.

Little Buck Island is actively growing. There are bare gravel areas at its upper and lower ends.

Coker Island is almost tied to the right bank by the filling of the channel on that side; otherwise it has not changed.

Just above Bee Tree Shoals a towhead 175 yards long, near the right bank, has within recent years grown about 50 yards.

FROM RIVERTON TO PADUCAH.

Riverton is 426 miles below the head of the river just above Knoxville and 226 miles above the mouth at Paducah. The fall in this lower portion of the river is 78.5 feet or 0.34 foot per mile. The obstructions in this section are practically all sand and gravel bars.

At Bear Creek Shoals gravel is accumulating on the left side near the lower end of the shoals and is forcing the current against the right bank, which is being undercut near the Government light. The banks here are 30 to 35 feet high, the lower 10 feet being of yellow chert gravel and the upper part of clay; caving is relatively rapid. The current is deflected from this bank to the opposite side of the river and has begun undercutting at Paynes Landing just below, and this swinging when once started tends to become more pronounced and to develop additional meander curves farther downstream. It will soon cause material changes in the boat channel.

At Shaws Landing the right bank for 500 yards is scouring away and caving. The material is a gravel overlain by clay.

State Line Island is growing higher by deposit of fine sediment and is extending upstream. The change is reported to be much more rapid in the last few years than formerly, and the bar at the head of the island is extending out into the channel farther than it did. The lower end of the island seems to be growing slowly downstream, while the chute to the left is filling up, so that the island will ultimately be tied to the left bank of the river.

At Pittsburg, Crump, and Coffee landings, all of which are on the left bank of the river, there are bluffs of relatively soft sands and clays that are being undercut, and the banks are caving at such a rate as to interfere materially with the maintenance of the boat landing.

A bar at the upper end of Diamond Island has grown 200 or 300 yards in the last 15 years. During this time a bar has formed to the left of the head of the island and has grown to it and extended down the left side of the island. It is deflecting the current to the left bank of the river and is now causing undercutting and caving. Below this bar a gravel fringe has grown along the side of the island to within 300 yards of the lower end; this fringe is 2 to 5 rods wide and is evidently growing. By the survey of 1896 it was calculated that this bar could be improved by dredging 8,000 cubic yards of sand and gravel; in 1901 the amount dredged was 19,500 cubic yards.

Wolf Island, at Crump Landing, has been formed by the union of two islands that existed there in 1865, as is shown by a map published in that year. Since then it has been growing upstream, and on the left side the gravel fringe has widened so much that the main current has been deflected against the opposite bank and is undercutting it just below the landing. A small gravel towhead that was just visible at low water 30 years ago now covers several acres. Dredges removed 37,800 cubic yards of gravel from the channel here in 1901.

Petticoat Bar has only in recent years begun to be regarded as a serious obstacle to navigation, but in 1908 it became necessary to dredge a channel a distance of 1,900 feet across it.

Swallow Bluff Island has been united by a gravel and sand bar to a smaller islet and a towhead above it and to the right. The bar is growing slowly, but the towhead has grown much larger than it was 25 years ago. The chute on the right is reported to be filling up.

Below Indian Creek a gravel bar is forming on the right bank. This bar is reported to extend much farther out into the river now than formerly. Below it, on the west side, another bar is also growing.

Eagle Nest Island is now filling slowly on its upper end and in the last 15 years a gravel spit has been building along its left side. The deposites of silt are building the island higher yearly, while the river current deflected by the deposit of gravel on the side of the island is undercutting its left bank. This island, shown on the 1865 map as only about half a mile long, is now 1½ miles long.

Roches Bar is said to be shoaling and extending farther upstream, so that boats have more trouble than formerly in making the landing on the west bank. This bar was not indicated at all on the map of 1865.

Kirkpatricks Island is steadily growing on the west side and the upper end and the chute to the right is filling up. In 1865 the island was insignificant. To-day it is over a half mile long.

Beech Creek Island has grown greatly since 1865, but its upper end is being eroded by a cross channel. Its lower end is growing, and the former steamboat channel between it and Culps Island, just below, is now practically dry at low water, and in a few more years these two islands will be united. The channel dredged in 1900 filled the following season and has had to be redredged. From the survey of 1896 it was calculated that improvement would require 35,000 cubic yards of gravel to be removed. In 1900 65,000 cubic yards were dredged, and in 1902 109,000 more.

The smaller of the Double Islands is cutting away on its right side along the lower third of its length, while from the upper end of the larger one a sand bar is growing downstream on the right side, deflecting the current of the river to the right and undercutting the right bank. These islands seem to have grown notably since 1865.

Kelleys Island has not changed in the last 15 years, but the bar near the lower end has been growing, and within recent years boats have had to keep much nearer the shore to avoid it.

The sand bar opposite Cedar Creek, just below the narrows, has not changed in the last 15 or 20 years; but the sand bar on the right side of the upper end of Densons Island is growing and pushing the steamer channel to the right and causing the right bank of the river to undercut and cave.

Just below the mouth of Duck River there is on both sides of Tennessee River a large deposit of sand and gravel, most of which has been brought down by Duck River. This deposit is apparently slowly growing.

Rockport Island is nearly stationary; the lower end may be growing slightly. The chute to the left is becoming shallower. The channel across Rockport Bar persistently closes after being opened. It has been opened five times in eight years and will probably continue to close with each year's spring floods. Each reopening requires on the average over 20,000 cubic yards of sand and gravel to be dredged.

A bar at Duck River Suck is shoaling and pushing the current against the west bank. In 40 years this bank has caved some 400 feet. Most of this erosion has occurred within the last 10 or 15 years, in which time the river here has engulfed a house and an orchard.

At Johnsonville a gravel bar, which now shows some 10 acres at low water, has grown since 1865, and is causing the left bank of the river to undercut. It is filling the steamboat channel, and has already required the dredging of 110,000 cubic yards of sand and gravel.

To the left side of the upper end of Reynoldsburg Island a gravel bar is growing downstream and extending to the left, pushing the river current against the left bank and causing caving. It was less than a mile long in 1865 but is now 1½ miles long.

Turkey Creek Island is not changing.

White Oak Island is reported to have grown 200 yards on its upper end in the last five years; a bar on its upper end is crowding the main current to the left, and the right-hand chute is shoaling.

The channel between the two Hurricane Islands is filling and also narrowing by the growth of a bar that will soon unite them into one.

On Leatherwood Shoals the bar on the right side is said to be growing and the chute on the left closing. The channel across the bar has recently required dredging.

Panther Creek Island is reported to have grown considerably since it was patented in 1870. In 1904 the bar gave much trouble and required extensive dredging.

Blood River Island is growing on both its upper and lower ends, and the channel to the left has shoaled so rapidly that it is now completely dry in low water.

Pentecost Towhead is slowly growing on its upper end.

Birmingham Island has not changed in the last 40 years, but a bar just below it has grown from 2 to 10 acres at low-water stages during this time.

Threemile Island has extensive gravel bars at both its head and its foot, and the channels dredged through them have refilled and required redredging. Over 140,000 cubic yards of sand and gravel have been removed.

Sevenmile Island is said by an old resident not to have changed in the last 40 years, and its entire outline seemed to be in stable condition.

The towhead just above Tennessee Island at the mouth of the river seems to be growing slightly, though Tennessee Island itself has not materially changed within recent years.

COOSA-ALABAMA RIVER SYSTEM.

The headwaters of the Coosa-Alabama River system—Oostanaula and Etowah rivers—rise in the mountains of northern Georgia and northeastern Alabama and unite at Rome, Ga., to form the Coosa, which in its lower course becomes the Alabama and flows southward and westward into the Gulf of Mexico near Mobile. A detailed examination was made of the headwaters of this system in northern Georgia, and the Coosa was traversed by steamer from Rome, Ga., 165 miles, to Gadsden, Ala. Below Gadsden conditions along the river were studied at several points, the lowest of which was Selma, Ala.

OOSTANAULA BASIN.

COHUTTA MOUNTAIN REGION.

The main mass of the Cohutta Mountains is in northwestern Georgia, some miles southwest of Ducktown, Tenn., but the mountains extend northward into Tennessee, where they are deeply trenched by the gorge of Ocoee River. Most of this mountain area, however, drains into the Coosa system. The rocks are ancient granites, gneisses, schists, and slates, which have been greatly weathered and eroded. The mountain mass is deeply cut by numerous streams, which flow from it in a somewhat radial fashion. The ridges are sharp topped and steep sided; the intervening valleys are narrow and most of them contain only the merest traces of a flood plain. The highest parts of the mountains are between 4,000 and 4,500 feet in elevation. The land is poor as a rule, and very little of it is cleared for agriculture. Most of the timber has been purchased by lumbermen and is being cut wherever transportation is possible.

The entire basin of Jacks River is wooded, with the exception of its upper 2 miles. It was being actively lumbered when examined, but showed no material erosion as a result of lumbering. At its very head the slopes have been cleared to a considerable extent and some of the fields are old and have become badly gullied. The total cleared area in the basin, however, is less than 2 per cent. The west side of the basin has been logged down to Cowpen Mountains, but the country farther down is in original forest. The soil is so poor that in some places it is reported that lumbermen have abandoned their holdings after they have cut them over.

South of Sassafras Gap, at the head of Mountaintown Creek, the entire country is wooded for several miles; then a flood plain begins to appear along the small creek and soon becomes a third of a mile wide. It is cultivated in places, as are also the lower slopes on either side. These lands do not show erosion or damage by floods.

The small headwater tributaries of Mountaintown Creek are bordered by narrow flood plains of moderate fertility, most of which are cleared and in good condition, and some of the lower slopes are also cultivated. There seems to be no marked erosion in this basin.

The basin of Holly Creek is wooded from its head to the point where the stream leaves the mountains, some 5 miles downstream. Below this point the creek has formed a flood plain which is at first beveled or sloping and is almost entirely above the reach of floods, but within a few miles becomes more nearly level and extends continuously down to the mouth of the creek. During floods the upper 10 miles of this flood plain receives deposits that enrich it; the lower 10 miles is not so fertile, lies lower, and is in places swampy. It is not damaged anywhere by floods.

CONASAUGA RIVER.

Above Treadwell, Ga., Conasauga River has a fertile flood plain that ranges in width from half a mile to 1½ miles. The grade of the river is low and its velocity during floods is not great enough to seriously injure the lands by erosion.

The bottoms below Treadwell are neither so broad nor so fertile as those above, but both are uninjured. The flow of the stream seems rather constant. The owner of the mill at Treadwell reports that only a few times during the last 20 years has it been necessary to shut down for want of water. This freedom from flood damages and regularity of flow are undoubtedly due to the forest protection on its headwaters.

Conasauga River unites just above Resaca with the Coosawattee to form the Oostanaula. The Oostanaula meanders irregularly across a flood plain that is perhaps half a mile in average width and on either side is bordered alternately by bluffs and flood-plain areas. Its bottoms are not greatly damaged by floods, it is navigable throughout its entire course, and it contains no bars or islands that seem to be growing.

COOSAWATTEE RIVER.

The Coosawattee is navigable to Carters, at the foot of the mountains. The width of its flood plain varies greatly, but averages from one-fourth to one-half mile, though in a few places it is a mile or more. The ordinary flood plain of the stream is bordered in many places by an extraordinary one, 10 to 20 feet higher, and rounded stream gravels are found on the valley sides 50 to 60 feet above present flood-plain level. The highest flood recorded occurred in 1866, when some places were so badly washed that they have only just about made back again. In some localities to-day ordinary floods erode the bottoms and do considerable damage, but the farmers along the river generally regard floods as beneficial, rather than harmful, because of the sediment they deposit. This deposition of rich sediment is especially marked at Carters, where the mountain stretch of the stream, which has a high gradient, runs out upon a broad plain and assumes a low gradient and at once begins to build a flood plain.

From Carters southeastward to Silver only the lower slopes of the bordering uplands are cleared and along the streams there are narrow bottoms, most of which are also in cultivation. Some of the older hillside clearings have become badly washed.

On Talking Rock Creek, west of Blaine, 50 or 60 per cent of the uplands have been cleared and some 10 per cent of them show extensive erosion. East of Blaine about 30 per cent of the uplands are cleared and there is but little erosion. At Talking Rock Station there is a broad flood plain bordered by a fossil one 15 feet higher, whose back part rises gently upward to the tops of the low hills. These hill slopes are in places largely cleared, but the cleared areas, upland and bottom alike, are generally in good condition. Farther east, at the heads of Fishing and Price creeks, the lands are very poor and the clearings are confined to the very lowest slopes of the valley sides and the narrow bottoms along the streams. Perhaps not more than 10 per cent of the entire area of these stream basins is cleared.

In and just west of the gap at the head of Clear Creek there are numerous old fields, most of which have been worn thin and abandoned, but only here and there are there signs of marked erosion. Northeast, east, and southeast of the gap the entire region is forested except in two small areas, one covering a few acres, the other a few score acres.

ETOWAH RIVER BASIN.

Etowah River heads on the southern slopes of the Blue Ridge northwest of Dahlonega and after flowing southward 25 miles turns to the southwest and unites with the Oostanaula at Rome to form the Coosa. Its headwater region is largely uncleared except for narrow flood-plain areas and an occasional low valley slope.

No clearings were seen west of Amicalola Creek, but along that stream some bottoms 200 or 300 yards wide have been cleared and are in good condition.

From Amicalola Creek eastward to Etowah River the soil of the rolling to hilly uplands is generally poor and practically all the land is wooded. Along the many small streams in this region there are some narrow flood plains, most of which have been cleared and are uninjured by floods. Some small areas of the bordering slopes have also been cleared, but much the larger part of the region is in forest and is not eroding.

Etowah River is shallow and swift, with steep banks 12 to 15 feet high. It has a level sandy flood plain of moderate fertility, bordered by a flat-topped terrace 15 feet high. East of the river is an old, flat, cobble-strewn terrace that stands 80 feet above the present flood plain.

In some parts of its course the rocks are more resistant and it flows in a narrow gorge without a flood plain. Throughout the greater part of its length, however, it winds irregularly, and on one side or the other has developed a flood plain that in places may be half a mile or more in width. During floods it carries a large quantity of sand and gravel, a considerable part of which is due to hydraulic mining on the uplands, but a part of which is due to dredging operations which are carried on extensively along the river near Auraria and Landrum.

In many places the Etowah has a very narrow ordinary flood plain, 6 or 8 feet above water level and 1 or 2 rods wide; above this there is an extraordinary flood plain with undulating surface 12 or 15 feet higher and of varying width, but in places as much as 200 to 400 yards wide, especially on the concave side of incised meander curves. In a few places this extraordinary flood plain is half a mile or more wide. Both the ordinary and extraordinary flood plains are generally formed of a sandy loam and rarely show great damage by floods. In many places there is also a well-developed fossil flood plain or terrace 20 or 30 feet above the present extraordinary flood-plain level.

From Landrum down to Canton flood-plain areas have not been seriously injured by floods. At Canton the ordinary flood plain is 300 yards wide, stands about 15 feet above stream level, and is quite flat. It shows slight erosion from floods. The extraordinary flood plain is not well developed just at this point, but may be seen both above and below.

Just west of Field's bridge, on the north side of the river, there is a good example of the flood-plain topography found in so many places along this river. From the northern valley wall an old beveled fossil flood plain, produced while the river was cutting down and swinging southward, slopes to the south with a very gentle grade. It is about half a mile wide and at its lower edge there is a descent of 8 to 12 feet by a well-defined scarp to the present flood plain, which is much more nearly level and also about a half mile wide.

This last or living flood plain has a somewhat undulating surface, produced by the scouring action of the higher floods, which have cut occasional runways, so that it has been necessary to build dikes or low walls to prevent serious erosion. The highest floods cover this bottom to a depth of 12 to 16 feet; the lower or ordinary ones cover it but a few feet. On the south side of the river there is a similar living flood plain at the same height but of less width.

The soil on both the fossil and the living flood plains is fertile and, though the river occasionally injures the lower one by washing, the farmers regard floods as beneficial in their general results rather than injurious. The greatest injury done by them consists of the destruction of a crop when high water happens during the growing season.

From Canton to Cartersville much of the upland on either side of the river is poor and the larger part is uncleared. In some places the cleared lands have a porous soil and do not erode badly; in others the soil is a more compact clay, and steep slopes that have been long cleared show gullying.

The Etowah for some distance below Canton has an average fall of 2 to $2\frac{1}{2}$ feet a mile—a slope that tends to produce broad flood plains, such as those at Field's bridge.

Two miles below Galt's ferry the river enters a narrow, rock-bound gorge and for 6 miles descends in rapids at the rate of $14\frac{2}{3}$ feet a mile. Below these rapids the gradient again decreases to about $2\frac{1}{2}$ feet a mile, and this, which may be called the normal slope of the Etowah, continues for 45 miles, to its mouth at Rome, Ga. Throughout this distance the stream has formed a flood plain that is in many places 200 to 400 yards wide, especially in the upper part of this 45-mile stretch. On concave sides of bends, where the stream cuts across limestone belts, the width may increase to a mile or more; where more resistant rocks occur the hills may close in and practically shut off the flood plain. Width of flood plain is a function of both river gradient and rock resistance.

Immediately below the rapids, where the gradient decreases to the normal again, flood velocities are checked and much sand is deposited, so that for about a mile the bottoms are poor and sandy and show some gouging by floods. Below this they are, as a rule, composed of fertile loam.

Just south of Cartersville broad bottom lands—now very largely fossil—have been developed on a limestone belt. The living flood plain is very narrow here and is fertile and in good condition. Below this limestone belt the hills close in at several places on the river, but at others the valley opens again and there is the usual development of an old, undulating, sloping fossil flood plain, as a rule somewhat irregular, but distinct, and from 8 to 12 feet high. The upper limit of the old beveled flood plain is generally about 60 feet above the present one. This fossil flood plain is above the reach of all floods and its slope is too gentle for serious subaerial erosion. The present flood plain, as a rule, receives deposits of silt during floods and is being built higher and enriched. At bends or where rafts lodge—as at bridges and other obstructions—some holes and flood channels were observed, but these may soon be filled by succeeding floods of less height and velocity of current. The flood of 1886 is the highest reported. It cut across and scoured many bends and in a number of places washed out flood channels that have not yet been filled.

Below Kingston the banks of the river are 20 to 25 feet high and the present flood plain is narrower. In most places it is distinctly separated from the fossil flood plain by an 8 to 12 foot scarp, but locally this scarp is absent and the boundary between the two is indefinite. The surface of the old higher flood plain is very undulating and in many places slopes irregularly upward to an indefinite union with the old high valley wall. On the valley sides are many cultivated tracts. Where the soil is composed of a cherty clay the clearings do not erode greatly, but where the clay is more compact erosion generally begins within 5 or 10 years after clearing and in a few more years the fields are abandoned.

COOSA RIVER FROM ROME, GA., TO GADSDEN, ALA.

The 165 miles of river between Rome and Gadsden were examined from a steamboat that ran only during the day, so that an opportunity was had of examining the Coosa for its entire length. Many landings were made along the way and the passengers and officers on the boat furnished information concerning the condition of the river and the changes that have occurred in recent years.

The banks of the river are generally covered down to the water's edge with trees which effectively protect them from erosion. At only a few places was any undercutting of banks and caving noted, and at these it was so insignificant in amount and extent as to be negligible. The banks are everywhere very stable.

At and just below Rome the banks are 20 to 25 feet high and very steep, and the flood plain was either narrow or absent. About 30 miles farther down their average height had decreased to 15 or 18 feet and they were still steep and wooded. Still farther downstream the river widened and deepened and the average height of the banks was yet lower, until at Greensport, below Gadsden, they were reported to be only 4 or 5 feet high. There is a corresponding decrease in the height of floods down the river. A stage of 30 feet at Rome, which covers the flood plain, at Greensport makes a stage of only 5 feet, which barely suffices to cover the flood plain. This concomitant decrease in height of flood crest and of flood plain surface down the river is normal and necessary. The flood wave tends to lengthen or flatten out as it advances downstream and thus lowers the height of the flood crest, and since the flood plain is built by the flood it is necessarily limited in elevation by the height of the crest of the floods that produce it.

There are comparatively few gravel bars in this 165 miles of river, and those known are reported by the pilots to be stationary in position and height. Some of them have been dredged in recent years by the Federal Government. The material thrown out on the banks is chiefly well rounded chert gravels and cobbles, most of which are less than 3 inches in diameter, though the large cobbles have a diameter of 12 inches. In some places pieces of blue shale or slate are mixed with the chert. In only a few localities are there any visible gravel accumulations below the mouth of tributary streams, and where such gravel beds occur they seem to have reached points of equilibrium between the forces that built and the forces that destroy them.

The islands in the river are small and most of them are the ordinary midstream islets, but a few others of unusual type were observed, 100 or 200 yards long, 6 or 8 feet high, and only 20 or 30 feet wide. Such islands lie very close to one bank or the other and were covered with trees. Inquiries and personal examination failed to discover that any changes are in progress on such islands. They would seem to have originated by the undercutting of a portion of root-matted river bank until it broke loose, slipped into the river, and became a long, narrow islet, parallel and very close to the bank from which it was derived. If this be the mode of origin the time was remote enough for all trees that may have been tilted when the island was formed to have disappeared, as all now standing are perfectly erect.

At many places the bed of the river contains rock ledges that lie as a rule at sufficient depth to be no serious menace to navigation. In many other places the rock in the bed of the river is covered by a very few feet of loose gravel. The river seems to be eroding its channel.

At 9½ miles and again at 10 miles below Rome there are two gravel bars that have been dredged within the past few years. This dredged channel has not since shown any tendency to fill. The material removed was chert gravel. There is little or no sand on any of the bars or islands. The river meanders in long, irregular curves, but during floods shows little tendency to cut across these meander bends, for the stream does not generally rise high enough above the bottoms or flood plain within the bends to carry a strong current across them. Foster Bend was the only place where cutting across a meander curve was observed. A runway formed here in 1886 badly damaged some of the land. Later floods have not been high enough to reoccupy this runway, so that it has not yet been filled by later deposits.

Just above Poole's ferry a gravel bar has recently been dredged and the channel would seem to be able to maintain itself without the aid of further dredging.

Just below the mouth of the Chattooga there are two gravel bars whose material has evidently been furnished by the Chattooga. This material seems to be carried away to-day by the river as fast as the tributary stream brings it in, so that the bars have reached a stable size and form and are reported not to have changed in the last 40 years.

At Center Landing there are two small islets, each about 150 or 200 yards long and 25 yards wide. These islets have not changed materially within the last 40 years.

Just below the mouth of Terrapin Creek there is a gravel island about 2 acres in area, which rises 3 or 4 feet above ordinary water level and is scored longitudinally by the river floods. Just below it is a shallow gravel shoal. Both of these have been built of material furnished by the creek and, like the bars below the mouth of the Chattooga, have been in equilibrium for at least the last 40 years.

Just below Wood's ferry there is an island, between 5 and 10 acres in area, whose upper end is kept scoured by floods, but whose size and form are reported as unchanged during the last 40 years.

At Gadsden the river is 150 yards wide and its banks are somewhat higher than usual so far down the river; they are 22 to 26 feet in height. The ordinary flood plain is 150 to 200 yards wide and is bordered on the east by an extraordinary one 10 or 12 feet higher, which rises eastward by imperceptible gradations until it becomes fossil and ultimately merges with the general country level. On the west side a bluff rises from the ordinary flood-plain level to an old high-terrace level, whose surface at the west end of the railway bridge is about 71 feet above ordinary water level. Gadsden is situated on this old high terrace. Its surface is composed of a clay stratum, 10 or 12 feet thick, beneath which there is a bed of 8 or 10 feet of well-rounded river gravel, whose average maximum diameter is 2 inches or less, though some pieces reach 6 inches.

This gravel is a rusty, brownish yellow and very much resembles the gravels seen on the lower Tennessee and on the bluffs along the Mississippi above Memphis and may be of the same age. Very few floods are high enough to cover the ordinary flood plain, and the extraordinary one has been covered within recent years only by the flood of 1886, when the stage reached was 36 feet, and even this stage lacked 2 feet of covering the highest parts of this old extraordinary flood plain. The ordinary flood plain is not much injured by the floods that occasionally cover it.

COOSA RIVER BELOW GADSDEN, ALA.

The river was examined some 50 miles below Gadsden, at Riverside, where it is 150 yards wide and its banks are 8 or 10 feet high. The present flood plain on either side of the stream has an aggregate width of some 100 yards, and above it, at a height of 10 or 12 feet, there is an older flood plain, perhaps never reached by floods of to-day, which rises slowly until it merges along its outer edges into the general country level. There were no signs of flood damages and inquiry failed to elicit any information of such damages. Some 40 miles below Riverside the river was examined at Childersburg. At the railway bridge north of the town it is 180 yards wide and has banks 15 feet high, which are covered with trees and quite stable. At this point there seems to be no ordinary flood plain. On the south side is an undulating extraordinary flood plain that slopes gradually upward for a half mile until it merges into the general upland surface. Floods reach its edge or occasionally cover some unusually low runway on its surface. The flood of 1886 is the only one recorded that might be said to have covered any considerable part of this flood plain.

At Chancellor Ferry, 2 miles farther downstream, there is on the north side of the river a fossil flood plain with very gentle slope, separated on its riverward margin by a 10 to 15 foot scarp from an extraordinary flood plain, 50 or 60 yards wide, whose surface is slightly undulating and has been covered only by the very highest floods, such as the one of 1886. It is 15 feet above water level. Immediately above the ferry there is a small island whose outline has not perceptibly changed in the last 40 years. On the south side of the river there is an ordinary flood plain 10 feet above water level, forming a very narrow shelf, and 5 or 6 feet higher an extraordinary one, which is 150 yards wide and rises gradually in this distance some 12 feet, merging into an old fossil flood plain, remarkably level and broad, which extends southward and eastward several miles beyond Childersburg.

Below Childersburg the river was again examined at Montgomery and at Selma, but the conditions at these places, both of which are on the Coastal Plain, where the whole country is made of soft sands and clays or partly indurated marl, were so extremely different from the conditions on the middle and upper part of the river system that no fair comparison could be made. Changes in the position of the navigable channel by the formation and growth of bars and islands and by the undercutting of the banks made it an entirely different kind of river from that exhibited in its middle and upper courses.

The middle and upper portions of the river are evidently not much clogged by material eroded from its steep headwater slopes; bars and islands are not growing; the position of the steamboat channel and of the river itself is unchanged. All this is undoubtedly due to the fact that there is comparatively little active erosion in the mountains in northern Georgia, where this stream system heads. Most of the region there is still in forest, and the Coosa presents the best observed example of a stream system on which conditions are still satisfactory. These conditions can, however, be maintained only by adopting preventive measures before lumbering and clearing have started serious erosion and begun to establish the same unsatisfactory conditions that are found on the Tennessee and other streams flowing from the more largely cleared portions of these southern mountains. The accumulation of sand bars and the changes in the stream channel in the coastal-plain portion of Alabama are due to local causes or conditions that are commonly characteristic of large streams flowing with low gradient on broad alluvial plains and can not be attributed to abnormal erosion on their headwaters. If they were they would undoubtedly be producing changes in the low-grade portions of the stream both above and below Rome, Ga. An examination of this stretch of the river showed that no great changes are in progress and that present conditions have been maintained for many years.

CHATTAHOOCHEE DRAINAGE BASIN.

GENERAL CONDITIONS.

The headwaters of the Chattahoochee basin, on the eastern slope of the Blue Ridge, were examined and the river itself was followed across the Piedmont Plateau as far as Atlanta.

The headwater tributaries of the Chattahoochee rise on the southeastern slope of the Blue Ridge and flow for several miles southeastward as if to enter the Atlantic, but are then gathered into a master stream that flows to the southwest and enters the Gulf of Mexico.

The tributaries descend from the crest of the Blue Ridge 2,000 or 3,000 feet in a few miles, and reach the inner edge of the Piedmont Plateau at an elevation of about 1,500 feet above sea level, below which their descent, until they join the Chattahoochee, is probably not more than 20 feet to the mile. Along the eastern face of the Blue Ridge headwater erosion is exceedingly active, and the scarp has been intricately carved into narrow gorge-like valleys, separated by sharp-crested, sloping spurs. This minutely dissected Blue Ridge scarp is in some places rough and rocky, but in others is covered with a residual soil layer. Except along the stream channels themselves it is almost everywhere wooded, though the soil is dry and thin and the forest growth is open and of poorer quality than that at similar elevations on the same range 100 miles to the north. On shaded northern slopes, where there is more moisture, there is a greater accumulation of humus and the forest growth is denser and larger. Most of these headwater streams are bordered by no flood plains until they have descended almost to the level of the plateau, where, at some distance from the base of the hills, a narrow flood plain appears, which rapidly grows broader until it may exceptionally attain a width of a quarter of a mile, a half mile, or even a mile. Some miles farther down, however, these streams begin to incise their channels beneath the plateau level and soon flow in narrow gorges whose depth increases until in many places it reaches 100 to 200 feet. Few of these gorges have flood plains and their sides are generally too steep and rugged for cultivation. Such, for example, is the character of the Chestatee near Dahlonega, of the lower part of the Soque, and of the Chattahoochee itself for a number of miles both above and below the mouth of the Soque.

The general upland surface of the Chattahoochee basin is an old plateau, whose elevation near the head of the river is about 1,500 feet above sea level. It is bounded on the north and northwest by the scarp of the Blue Ridge, which overlooks it, and on the southeast by a somewhat similar but lower scarp, well seen from Mount Airy and other points in its vicinity that overlook the Atlantic portions of the Piedmont Plateau. The Chattahoochee Plateau thus forms an intermediate step, as it were, between the Piedmont Plateau and the crest of the Blue Ridge.

This lower scarp, between the upper part of the Chattahoochee basin and the streams flowing southeastward to the Atlantic, decreases in height southwestward until it disappears in the region northeast of Atlanta, where the Chattahoochee Plateau and the Piedmont Plateau merge into one. The surface of this Chattahoochee Plateau is broken by streams that have incised their channels beneath it and by isolated residual peaks and broken ridges that rise above it. In other words, its topographic relations are exactly similar to those that are characteristic of the Asheville Plateau, or to those of the remaining part of the Piedmont Plateau to the southeast.

These three plateaus are undoubtedly of the same age and were formed by long-continued erosion that reduced each to a low plain, usually called a peneplain, that has since been uplifted, their difference in height being due to difference in distance along their drainageways to the sea. They have undergone the same amount of atmospheric weathering, and where the rainfall, slope, and soil are similar, show the same effects of erosion. The rocks of this Chattahoochee Plateau are like those of much of the Asheville Plateau—deeply decomposed schists, gneisses, and granites. Much of the soil is a red clay and on steep slopes erodes rapidly.

The most serious injury noted in this basin is the filling of the Chattahoochee channel with sand, which is destroying the ferries and threatening to fill several dams recently built to utilize the large water power furnished by this stream. This sand deposit has not yet greatly injured the bottom lands, but with further increase in its accumulation, which is inevitable under present conditions of clean culture on steep slopes and their subsequent rapid erosion, the bottom lands will soon be so covered with sand that in a few years their fertility will be destroyed. With the filling of the dams at power plants and the burying of the rich bottom lands beneath barren sand the river will have practically completed the destructive processes which it is only too evident have already been well begun.

DETAILS OF CONDITIONS.

For a few miles above Nacoochee Valley the Chattahoochee has a narrow flood plain, which is commonly bordered by a terrace 30 feet higher, beyond which runs another one 20 feet higher still, though in some places these two merge into one, forming one old flood plain 50 feet above the present flood plain. Higher up the river there is practically no flood plain, and there is very little clearing along its upper 10 miles, either on the stream itself or on the adjacent mountain slope. Much of this region is rough and practically all of it is wooded.

In the Nacoochee Valley there is a flood plain half a mile to a mile wide, through which the stream flows in a broad, shallow channel 2 to 5 feet below flood-plain level. Along its course there are many gravel bars, which alternate with deep, quiet pools. In most places the channel is bordered by a narrow cobble zone, produced in time of floods. The river sometimes destroys the crops in this valley, but has not greatly injured the lands. At its eastern end Nacoochee Valley is joined by the valley of Sautee Creek. This valley is very similar to Nacoochee Valley, and conditions in it are similar to those just described.

A few miles below the junction of these two valleys the Chattahoochee begins cutting its way beneath the plateau level and forms a narrow gorge that contains little or no flood plain almost down to Gainesville. Here and there in this distance, inside of bends or at the mouths of tributary streams, there are small flood-plain areas, but the aggregate amount of such land is small.

In the Chestatee basin about Dahlonega the upland is an old, well-dissected plateau, whose topographic form is very similar to that of the Asheville Plateau in western North Carolina, and its age and origin are doubtless also the same. Around Dahlonega the soil is a poor mica schist, worth but little for agriculture. In many places it carries considerable quantities of gold, and for years more or less hydraulic mining has been done in this region. The great quantities of material washed in this way to the streams have not caused the complaint from farmers that might be expected, since the swift currents of these streams remove all this material during periods of high water. The streams are actively eroding their channels and have high banks and velocity enough, it would seem, to remove more material than is being furnished them even by the hydraulic mining.

For 7 miles east of Dahlonega, on the road to Cleveland, the numerous small streams have narrow flood plains that are farmed, but the uplands are practically uncleared. Where the road crosses the Chestatee there are some bottoms. On the Little Tesnatee and again at Pleasant Retreat there are excellent bottoms. The uplands about Pleasant Retreat and farther east, toward Cleveland, have much better soil than that around Dahlonega and are much more largely cleared. This soil is a deep clay and erodes in many places much as it does about Asheville, N. C. The small streams show the influence of this hillside erosion and are depositing sand and clay on their flood plains and cutting channels across the meander curves that have begun to form.

North of Cleveland the same conditions—largely cleared uplands, erosion, stream aggradation, and flood damage—also prevail, until the divide separating the Chestatee from the Chattahoochee is reached.

In the upper part of Soque River basin much of the upland is poor and comparatively little of it has been cleared. Along most of its small tributaries there are narrow flood plains, and on some streams the lower 50 yards of adjacent hillsides are cleared, although the aggregate of such clearings is less than 10 per cent of the area. In places two-thirds of the cleared land has been worn out and abandoned. In some localities it is gullying, in others it seems to be growing up again in forest.

The Soque is bordered by a flood plain from a point near the mouth of Shoal Creek down to a point some distance below Clarksville, where it begins to cut sharply beneath the plateau level and develops a gorge, just as the Chattahoochee does below Nacoochee Valley.

Less than 15 per cent of the uplands along the Soque above Clarksville is cleared, and on the steep southern slope of the Blue Ridge there is practically an unbroken forest cover, though this cover here, as elsewhere in this region in similar situations, is thin and the timber is inclined to be scrubby.

From a point below Clarksville toward Mount Airy and down the Chattahoochee, more than half of the plateau surface is cleared. Much of it has been farmed for years, and in many places it is eroding badly, especially where the rocks are granitic or gneissose. Where they are micaceous schists the soil is usually full of small rock fragments and is more porous, and erosion is less rapid.

Deep Creek enters the Soque from the northeast about 2 miles above Clarksville. A large part of its basin is comparatively level and 50 to 75 per cent of it has been cleared. Much of its area is a sandy clay that erodes readily, and from this basin great quantities of sand have been carried into the Soque and have almost filled its bed, so that ordinary water level is now but little below flood-plain level. During floods immense quantities of this sand are spread over the bottoms and have greatly injured them. About Clarksville much of the river bottom has been set in Bermuda grass, which seems to prevent erosion better than anything else and at the same time stands being covered by floods better than other grass.

The basins of Flat Creek, White Creek, and Mossy Creek are generally fertile and have been largely cleared. In these basins rainfall gathers quickly and floods are usually high and do much damage. Three weeks before the region was visited in 1905, floods on these streams had swept away a number of bridges and damaged growing crops 25 to 50 per cent, besides severely damaging the lands themselves in many places.

Mud Creek basin has been cleared to much the same extent and is eroding in the same way. The uplands between it and the river are 60 to 70 per cent cleared, and much of this cleared area has been badly gullied and is now abandoned.

At Bolton Ridge the channel of the river is reported to have filled greatly with sand within the last few years, so that floods now occur much more frequently than formerly. There is a well-preserved old terrace at 60 feet and another 20 feet higher. The higher slopes are 80 per cent cleared and 10 per cent of this area is eroded and abandoned.

At Seven Island Ford the injuries and benefits from floods are said to about balance each other; crops are damaged to a considerable extent every five or six years, and at somewhat longer intervals a crop is entirely lost. Intermediate floods enrich the lands.

At and below Clark's bridge the ordinary flood plain is 15 feet above the water level and shows considerable flood scour. About 60 feet above it is another fossil flood plain with a red, loamy, fertile soil that overlies a cobble zone, and 40 feet higher are poorly preserved remnants of another still older flood plain. The edges of this older flood plain are steep enough to erode badly when not terraced. More than a third of the uplands has been cleared, and when old these fields erode unless terracing is practiced. Farmers in this region have lately begun terracing their lands as the only means of preventing erosion under the cultural conditions that prevail where cotton is the principal crop, and where, as a consequence, the land must be kept clean.

From Gainesville down to Atlanta 60 per cent of the uplands on either side of the river are cleared. On some of the poorer soils the clearing is not more than 40 per cent, but in others the proportion rises to 80 or 90 per cent. Much of the soil in this area is a deeply rotted granite, and everywhere the old plateau surface has been carved by erosive agencies into forms that are as a rule sharply rounded. These uplands are practically all kept in cotton, and where they are not terraced erosion is rapid. Practically all of the small tributary streams on both sides of the river carry enormous quantities of sand into the river. The channels of many of these streams had filled so that it was impossible to drain their flood plains, and the lands along them had become practically worthless. The flood plains of others had been covered by sand or cut to pieces during floods and rendered useless. The sand brought down by these streams has accumulated in low-gradient reaches of the river so as to practically fill the channel.

At Stringer's ford the North Georgia Electric Co. has developed power by a dam 36 feet high, which backs up the water 8 miles, to a point beyond Clark's bridge. This dam was completed July 4, 1904, and signs of filling with sand and silt were apparent a year later. This filling must steadily increase and will ultimately destroy the storage value of the dam and force the company to depend on the capacity of the stream alone.

At Shallow Ford there is an ordinary flood plain 6 to 8 feet above the water level, and an extraordinary one 12 feet higher, which in 1905 had recently been cut to pieces in places by unusually high floods. About 40 feet above the extraordinary flood plain is an old, well-preserved terrace, and 40 feet higher is still another terrace, which is, however, poorly preserved. In the bed of the river sand has lodged on bars, behind piers and projecting rocks, and wherever opportunity has offered. The stream is evidently overloaded with such waste.

At Brown's bridge the river is 150 yards wide. The ordinary flood plain is 10 to 12 feet above water level and aggregates on both sides 75 yards in width. Floods had recently destroyed about 10 per cent of the crops, but had not injured the land. There are two terraces, one 15 and the other 60 feet above the flood plain.

At Shadburn's ferry the river channel has been greatly filled with sand, so that the running of the ferry during the summer and fall has become exceedingly difficult. Late in the winter the sand is swept out by floods, but it begins to accumulate again early in the spring. Floods are reported to be more frequent than formerly, and the annual damage to crops averages 15 to 20 per cent. Forty years ago the river was deep at this point and accumulations of sand were unknown.

At Pirkle's ferry it was reported that sand has been filling the channel for the last six or eight years, and that it had prevented ferrying for more than half of the time during the last four years. The conditions here have steadily grown worse, and the owners of the ferry have petitioned the county court to be allowed to discontinue it as a public thoroughfare. Ten or fifteen years ago horses frequently swam the river at this point; now sand has accumulated in quantities so great that a flatboat drawing 6 or 8 inches can not cross during more than half of the year. The river is now muddy most of the time, whereas it was formerly clear.

Baldridge, Twomile, Fourmile, and Sixmile creeks have basins that are very largely cleared and farmed in cotton. They furnish immense quantities of sand to the river.

At Strickland's ferry the channel began filling with sand 8 or 10 years ago, and conditions became so bad 2 years ago that the ferry was discontinued and a bridge was erected instead. The bottoms here are good and are several hundred yards wide; they are injured by some floods and are benefited by others, since floods of one stage erode and those of another stage deposit fertile sediment. The flood plain is bordered by a 60-foot terrace, the steep edge of which is eroding in places. The small creeks on the west side of the river, like those farther up, are filled with sand and have greatly injured or entirely destroyed their bottom lands.

At Terry's ferry the river banks are 8 to 10 feet high and floods frequently destroy crops, but rarely cut the land to pieces. In the last six years the channel has so filled with sand that the ferry has practically been abandoned.

At Hutchin's, Maynard's, Roger's, Abbot's, and Warsaw ferries the same difficulties from the channel filling with sand were found to exist, and at some times of urgent need for ferriage temporary ferryboat channels through the sand had been made with horses and scrapers. These ferries are now being abandoned, and in the place of some of them bridges will be built, though the cost of bridges prohibits their immediate erection by the county at each of the ferries, and much inconvenience to the people on either side of the river is occasioned by this forced abandonment of long-established crossing places. Bottom lands near these ferries are in places a half mile wide. They are not generally hurt by the floods, but crops are frequently seriously damaged or totally lost, and the frequency and severity of this loss has become much greater since the river channel has filled with sand.

An examination of the profile of Chattahoochee River shows that the gradient along this part is in many places less than 1 foot per mile, so that the stream at ordinary stages is not able to remove the amount of sand furnished by its tributaries. The excess, therefore, accumulates in the channel and fills it until continued or repeated high waters in late winter and early spring scour it out.

At Jetts and Johnsons ferries there is no serious inconvenience from the accumulation of sand, since the river gradient has increased to nearly 9 feet per mile and the sand is kept moving.

At Bull Sluice the Atlanta Water Power & Electric Co. had recently completed a dam that gives a head of 50 feet and backs the water up to the highway bridge at Roswell. It will be interesting to watch the gradual accumulation of sand above this dam and the decrease of storage capacity, which is bound to occur unless erosion in the upper Chattahoochee basin is checked. The water wheels installed have a larger capacity than is warranted by the normal flow of the river, so that they are designed to take advantage of the flood discharge as well as the storage capacity of the dam.

At Powers Ferry the stream gradient again decreases and sand accumulates. Floods have injured the lands somewhat by spreading sand over them, but the chief damage is done to the crops. On the east side is a 60 or 70 foot terrace; on the west side a considerable area is covered with sand or cut into holes.

At Paces Bridge an old terrace 70 or 80 feet high, on the west side of the stream, has long been cultivated, but its steep sides are now eroding. The present flood plain is cut by numerous flood runways and is covered here and there with barren white sand.

SAVANNAH RIVER BASIN.

GENERAL CONDITIONS.

The northwestern boundary of the Savannah River basin is formed by the crest of the Blue Ridge. Measured along its windings, the bounding line extends for 100 miles in northeast Georgia and southwestern North Carolina, though in an air line the distance is only 55 miles. From the crest of the Blue Ridge the basin extends southeastward to the Atlantic Ocean. The mountain headwater streams of the basin were examined, and the Savannah itself was followed out across the Piedmont Plateau nearly 100 miles, more than halfway to the outer edge of this plateau.

The principal headwater components of the Savannah system from southwest to northeast are the Tallulah, the Chattooga, and the Little Keowee rivers. These streams, like those in the Chattahoochee basin, descend from the crest of the Blue Ridge scarp, 1,000, 2,000, or 3,000 feet for the first few miles, where they reach the inner edge of the Piedmont Plateau at an elevation of 1,000 to 1,200 feet above sea level. The Tallulah, however, whose middle and upper course is in a higher plateau than the South Carolina Piedmont, is exceptional, for near its mouth it crosses exceedingly resistant quartzose rocks that have prevented it from cutting its channel as deep and reducing its basin as low as those of the other streams of the system. The river falls 525 feet in $2\frac{2}{3}$ miles in crossing these resistant rocks. The gorge developed below the falls, though exceeded by many others in depth, is unsurpassed for beauty and wildness in the southern Appalachians. The State of Georgia has created a small park to include the falls and insure their permanent preservation.

In crossing the Piedmont the Savannah and its tributaries flow with relatively gentle slope, and in their course of 150 miles descend, as a rule, less than 1,000 feet. This gradient is by no means uniform, for most of the fall is concentrated at certain places, where rapids occur. Between these rapids the gradient is slight and the current gentle. On Savannah River, for instance, at Calhoun Falls, there is a fall of $10\frac{1}{2}$ feet per mile for 7 miles, but for the next 26 miles the fall is less than 2 feet per mile. Below this point Long Shoal has a fall of about 8 feet per mile for $4\frac{1}{2}$ miles, when the rate again drops to less than 3 feet per mile for the next 22 miles.

On reaches of low gradient flood plains appear and fertile agricultural lands may be found. Where the gradient is high, flood plains disappear, but there is opportunity for the development of water power. What is true of the Savannah River is equally true of other Piedmont rivers to the northeast. On Catawba River, for example, there are three falls within 4 miles, whose aggregate horsepower is said to be greater than any other power developed in the United States except Niagara. A third of this power is already developed and another third is being developed as rapidly as construction can be pushed. Other large powers are found on this river, both above and below this group. Some of them have been developed; others are not yet utilized. Great power is developed on Yadkin River at the Narrows, and plants have been built on other streams in this section. Regularity of stream flow and freedom from silting and from exceedingly high floods become, then, extremely important to towns and manufacturing companies within a radius of 100 miles of these plants, which transmit electric current that distance for generating heat, light, and power.

TALLULAH RIVER.

The extreme upper part of the basin of Tallulah River lies in North Carolina. On the steep southern slopes of the Blue Ridge it is a practically untouched forest, since it is at present far from transportation. South of the Georgia line the stream begins to develop a narrow flood plain, especially near the mouths of its upper tributaries. This land is cleared and sustains no damage from floods, for the velocity of the stream is great and its channel is deep enough to carry most of its flood waters.

From a point a few miles below the Georgia line small flood plains and narrow gorges alternate for some 10 miles down the stream. The flood plains occur mostly near the mouths of tributary streams or on the concave side of bends; the gorges occur where the river cuts across the more resistant rocks.

On Calhoun River there are two small farms. The rest of its valley is in spruce and laurel, and the mountain slopes are in unbroken forest.

On Plum Orchard Creek the bottoms are narrow and the soil is poor. In a few places these bottoms and the lower slopes are cleared, but practically the entire creek basin had been recently sold to a lumber company. Most of the families along the creek had moved out and their little clearings had been turned out to grow up in forest once more.

On Persimmon Creek there are a number of areas of poor bottom land, and in places the lower hillsides have been cleared, worn out, and abandoned. Here and there are remnants of an old 60-foot terrace, whose slope in some places is of red clay and where cleared has generally been gullied. As a rule, however, in the Tallulah basin, old cleared lands wear thin, but do not usually cut into gullies, for the soil is more or less porous and is filled with small stones.

On Popcorn Creek the first settler was not injured by floods for a number of years. Later some 20 families moved into the basin above him, began clearing the narrow bottoms and the lower hillsides, cutting roads, and burning woods, and within a few years floods began destroying his bottom lands.

Throughout the upper part of the Tallulah basin much damage has been done by forest fires, and their results have been so serious that measures have been taken in the last few years to prevent them. Not only did the fires destroy much timber, but the floods that followed were considered to be more severe than they would otherwise have been.

On Dicks Creek, near its mouth, there are some good bottom lands, but elsewhere on the stream there is but little bottom and the lower slopes of the bounding mountain side are cleared in but few places. Nearly all of the families on this creek have sold their holdings to a lumber company and moved out.

Timpson Creek along its lower 3 miles is bordered by bottom lands that average several hundred yards in width. They are the best lands on any tributary of the Tallulah. The slopes on both sides are cleared for several hundred yards and have in many places been worn out and abandoned. The land here does not gully, but wears thin. Floods on this stream do more damage than on any other stream in the basin. At several places remnants of an old 60-foot stream terrace may be seen. This terrace has very largely been cleared, but much of it has been worn out and abandoned to grow up in briers and bushes.

At Burton and for 3 miles below that place there are some excellent bottom lands on the Tallulah. The river flows with a swift current within banks that average 6 to 8 feet in height, and though floods frequently cover the bottom they enrich rather than injure it. Crops are, however, frequently injured or destroyed. Three miles below Burton the flood plain is 300 or 400 yards wide; the stream is rapid, with banks 6 to 10 feet high, and there is a well-preserved terrace 55 feet above flood-plain level, with abundant 8 to 12 inch cobbles on its surface. Its slopes have long been cleared and have eroded until they are practically worthless.

Along Bridge Creek there are some fertile bottoms that are in places a hundred yards wide. Near the stream there is usually a narrow cobble zone, produced during floods. A few of the lower hillsides have been cleared, worn thin, and abandoned. At the mouth of Bridge Creek there is a 10-acre bottom in good condition. Below that point there are numerous remnants of two old terraces at elevations of 40 and at 80 feet, respectively, above the present flood-plain level. There is, however, comparatively little bottom land along this creek. The valley sides are steep and rough, and, along with the higher ridges, are still in original forest. At intervals down to Tallulah Falls patches of bottoms, each a few acres in extent, are found here and there, but most of the area is uncleared. Below Tallulah Falls the river flows in a canyon for 2 miles to its junction with the Chattooga. It is believed that certainly less than 10 per cent and probably less than 5 per cent of the entire area of the Tallulah basin is cleared.

FROM RABUN GAP TO TALLULAH FALLS.

The streams between Rabun Gap and Tallulah Falls have generally narrow flood plains, most of which have been cleared and are in cultivation. In some places the soil on the valley side is fertile, and clearings have been made 100 or 200 yards up the valley slopes. These lands have worn thin, much as have those in the Tallulah basin that have been long cleared, and many fields have been abandoned. Away from the streams the country is entirely forested. Along the streams there are no marked evidences of erosion by floods, and, in fact, floods are usually regarded as beneficial, for they enrich the bottoms with fertile sediment. Less than 10 per cent of this area has been cleared.

CHATTOOGA RIVER.

Chattooga River heads in Cashiers Valley and flows southwestward some 60 miles to its junction with the Tallulah, where it turns southeastward to cross the Piedmont Plateau on its way to the Atlantic. In its upper course, except in Cashiers Valley and Whiteside cove, the river flows in a narrow gorgelike valley whose slopes are wild and uncleared. Five miles above Russells Bridge a narrow flood plain, in places 200 to 300 yards wide, begins and extends some 4 miles below the bridge. The river flows with a swift current between banks 10 to 12 feet high; floods cover the lower part of the flood plain, but in the last 36 years at Russells the river has extended from hill to hill only once—in June, 1876. A similar flood occurred in 1835, but the relative height of these two floods could not be ascertained. The flood of 1876 destroyed all crops, but improved the land; and the same may be said of ordinary floods that cover only the lower part of the flood plain.

Four miles below Russells the valley walls close in and the river flows in a rock-bound gorge, 500 feet deep, to the mouth of the Tallulah. The fall in the 29 miles from Russells Bridge to the mouth of the Tallulah is 810 feet, or nearly 28 feet per mile.

At Russells there are on the South Carolina side of the river a few remnants of a terrace 60 feet above the present flood plain; on the Georgia side terrace remnants appear about 80 feet above the present flood plain, and though remnants on numerous spurs up and down the river differ somewhat in elevation, this terrace would seem from its proximity to the 60-foot terrace on the Carolina side to represent an older and higher flood plain.

The river is actively eroding its bed and is deepening its channel. The sediment carried either at ordinary times or during floods is relatively small in quantity and does not accumulate in the channel, but as the water spreads over the flood plain the checking of its velocity causes deposition and the deposits build up the flood plain. In this way the interval between the stream bed and the flood-plain surface is constantly becoming greater, and a considerable part of the flood plain is now above the reach of all but the highest floods. In the stream many of the rounded bowlders are a foot or more in diameter.

Along War Womans Creek are some narrow flood-plain areas, most of which have been cleared; but only one, 8 miles east of Clayton, is of considerable size. On the lower 100 to 200 yards of the valley slopes are many cleared areas which have washed badly and have then been thrown out to grow up again. Considerable lumbering has been done on this creek, and some of the bottom lands have been damaged by floods.

Between Russells Bridge and Highlands less than 5 per cent of the upland has been cleared and comparatively little timber has been cut because of the distance to transportation lines. This land is passing rapidly into the hands of lumber companies, which up to 1905 had been paying from $1 to $2 per acre, with prices steadily rising.

Along West Fork the narrow flood plains and a small part of the lower slopes have been cleared. The soils wear thin, but are generally stony and do not gully. The higher slopes and ridges are uncleared.

The upper part of Clear Creek is bordered by a flood plain which is 200 or 300 yards wide and is cultivated. The valley slopes, especially on the northwest side, have been cleared in many places, and near the head of the creek scattered fields extend well to the top of the ridges or to the foot of the precipitous face of Mount Satulah. Some of the fields on the lower slopes are old and somewhat gullied, but the effects of erosion were nowhere prominent along this creek.

On the road from Russell to Walhalla both the east and west slopes of Chattooga Ridge are wooded. Below the point where the road crosses Taylor and Village creeks there is a tract comprising 30 to 40 acres of cleared bottom land, which is of medium fertility and near the stream channel shows some erosion. A few acres of the lower slopes are also cleared. The forest extends to Jerrys Creek, where there is another narrow cleared flood plain. The country is wooded across Stump House Mountain except for two farms aggregating 40 to 60 acres of fairly level but poor land on top of the mountain.

From the ridge east of this mountain the rolling surface of the Piedmont Plateau extends eastward to Walhalla and far beyond and is largely cleared. Many of these Piedmont hills are eroding and furnish great quantities of sand to the streams that drain them. From Walhalla to Westminster the Piedmont uplands are rolling to hilly and 60 to 70 per cent cleared. Where their slopes are of red clay they have gullied considerably.

Coneross Creek cuts across upturned crystalline rocks, and as these vary greatly in resistance to weathering and to stream erosion, its valley is alternately broad and narrow. Where the valley is broad the stream is bordered by a fertile flood plain, 100 yards or more in width; where it is narrow the flood plain is absent and the stream flows in a gorge-like channel. This condition causes ponding on the broader areas during floods and a deposition of fine sediment just above the constrictions in the valley. The velocity of the current increases greatly through the constricted places and causes rapid scour. Below such a constriction the stream again spreads out, loses its velocity, and deposits a broad sheet of sand over the fertile bottoms, and may ruin the upper half of the next flood-plain area below. Such topographical relations and erosion results are seen along many streams on the Piedmont Plateau.

CHAUGA RIVER.

When examined in the midsummer of 1905 Chauga River had recently been in high flood, during which there had been much gouging and scouring on curves and deposition of large quantities of barren white sand in places where the flood plain was constricted. Below the constrictions all crops were ruined, and moderate estimates place the damage to the bottom lands themselves at half their value. All but two highway bridges on the stream were swept away, and the steel bridge on the main line of the Southern Railway was also carried out, tying up traffic for several days. Near the mouth of the Chauga the water reached into buildings that had never before been flooded. The upper part of the Chauga basin is not greatly cleared, but it had recently been quite thoroughly lumbered, and the severity of the flood was generally attributed to this fact.

HIGHLANDS TO TOXAWAY.

Between Highlands and Toxaway the only considerable area of cleared land is in Cashiers Valley, on the head of Chattooga River. Slopes there are low, and the soil, which has been derived from the disintegration of a granite, is poor, gravelly, and generally porous. Though much of this valley is in old fields, erosion is not marked. Below it, in Whiteside cove, lands are steeper and about 15 per cent of the cleared area shows evidence of erosion. Some of it has been abandoned. In the upper part of the Horse Pasture basin a few clearings appear on the stream bottoms and lower slopes, but almost the entire basin is wooded. Near Lake Toxaway there are a few farms.

The basins of White Water, Horse Pasture, and Toxaway rivers contain some of the finest areas of hard wood, white pine, and hemlock to be found anywhere in the southern Appalachians.. They are largely owned by lumber companies.

TOXAWAY TO WALHALLA.

Northeast of Lake Toxaway there are some small cleared tracts along the top of the Blue Ridge. Some of these clearings have a close-grained red-clay soil and are gullying. Several of the tributaries of Toxaway Creek are bordered by narrow flood plains that are largely cleared, and a little of the immediately adjacent valley slopes is also farmed. Most of the basin, however, is in original forest.

Along Laurel Creek there is a little cleared land, but Laurel Branch Mountain is entirely forested except for one old field near its top. Practically the entire country visible from its sides and crest is forested.

Big and Little Estatoe rivers are bordered by flood plains that are 100 to 300 yards wide and are generally in good condition as regards erosion. The lower 100 to 200 yards of the valley slopes are cleared. Where the slopes are gentle the cleared land is in good condition, but where they are steep they begin to erode after a few years' cultivation. Above these uplands, of which about 40 per cent is cleared and in cotton, rise many small residual mountain peaks or ridges that are practically all forested.

On Crow Creek the bottoms are a few hundred yards wide and have been damaged by floods. The bordering slopes and uplands are for the most part cleared. Where the soils have resulted from the weathering of granites they are eroding; where they have been derived from hornblende schists erosion is much less prominent.

Remnants of an old 60-foot terrace appear along practically all the streams in this area, though the elevation in some places drops down to about 40 feet and in others rises to 70 feet. It seems probable that this variation is due to local variations of rock resistance and of valley width and that the terraces are therefore of the same age. The scarps or slopes of these terraces in many places show gullying.

On Keowee River flood-plain areas a few hundred yards wide on soft rocks alternate with constricted reaches cut through hard rocks, on which a flood plain is practically absent. The velocity of the stream is relatively great and its banks are as a rule high. Floods cover the bottom lands and destroy crops, but are reported to benefit the lands more frequently than to injure them. West of the river the uplands for several miles are poor and forested. Active lumbering was in progress when the region was examined.

The valley of Little River is to a large extent cleared. Many of the slopes were eroding, as are also slopes along other creeks between Little River and Walhalla. On several of these creeks floods had recently destroyed much of the crops and in places had ruined the land either by gouging or by covering it with sand.

TUGALOO AND SAVANNAH RIVERS DOWN TO SEABOARD AIR LINE CROSSING.

From the junction of the Tallulah and the Chattooga the Tugaloo flows 48 miles to its junction with the Seneca, where its name changes to the Savannah.

The average fall of the Tugaloo in this 48 miles is somewhat more than 5 feet per mile, but it is concentrated at a few places. Between these places the rocks are less resistant and the average slope is much lower. In the 35 miles from Prather Creek to Averys Ferry, for example, the average fall is less than 3 feet per mile.

Below the mouth of the Seneca the Savannah is characterized by a similar succession of rapids and low-gradient reaches as it crosses the alternating belts of hard and soft rock. The average fall is 2 or 3 feet per mile through the entire distance of 149 miles to Augusta, Ga.

Along the low-gradient stretches of the Tugaloo and the Savannah the velocity is so slight as to permit sand to accumulate in the channel wherever the tributary streams furnish it in large quantities. So far this deposit of sand has not reached the serious proportions attained on the Chattahoochee, but it no doubt marks the beginning of a similar condition, which may be expected to become worse each year. As clearings are extended and erosion becomes more universal, the quantity of sand furnished the stream will steadily increase, the excess will be deposited first in its channel and then over the flood plain, until the value of the bottom lands has been destroyed and the power dams along its course have been filled, when the ruin capable of being wrought by the stream will have been completed.

The Tugaloo has very little flood plain for 6 or 7 miles below the mouth of the Tallulah. Thence to the mouth of the Chauga, about 8 miles, the flood plain is from a fourth to a half mile wide and is fairly fertile. The river in most places flows between high banks, and floods, though frequently covering the land, rarely injure but rather enrich and benefit it. These floods, however, often ruin crops and have of recent years been more frequent than formerly. Farmers along the river claim that they now lose an average of one crop out of every three or four. On July 1, 1905, three weeks before this region was examined, a severe flood had occurred, and from one-third to three-fourths of the corn on the river bottom had been destroyed. In some places nothing was left growing; everything was covered by a deposit of mud 6 to 15 inches thick.

On Brasstown Creek the bottoms are good and average 300 yards in width. The slopes have not been largely cleared, but when examined the entire basin had lately been lumbered, and the recent flood had swept away cribs and barns that had never before been reached.

Panther Creek also did much damage at this same time, but the destruction was due to the cleared condition of much of the basin and not to lumbering. In one place the creek had recently shifted its channel during a flood and left a mill high and dry.

Near Prathers Bridge the lands along the small creeks were greatly damaged by the recent flood. The creeks were universally reported to have been higher than ever before known. Many bridges were swept away in the region, and moderate estimates placed the damage to the bottom lands at one-third to one-half their value. The destruction of crops was in most places complete. On the river bottom at Prather all of the crop was destroyed; below Prather the creeks entering from the east side down to Fort Madison had destroyed half to three-fourths of the crops growing along them. In some places the lands were badly injured, but in others they were covered with rich alluvial material and greatly benefited. Just above Fort Madison the river had spread sand over a part of its flood plain adjoining the channel.

At the mouth of Rock Creek the river had scoured and cut to pieces the bank on the convex side of the curve and the crops for some miles above and below were reported as a half to a total loss.

At Perkins's ferry there is an ordinary flood plain 6 feet above water level and 20 feet wide, and 8 feet higher an extraordinary flood plain, bordered on its river side by a low sand ridge, which has in recent years been repeatedly submerged. The growing crop had been lately damaged from one-half to three-fourths its former value. In places lands were reported injured, in others benefited.

On Estanolle Creek the greater part of the valley has been cleared and planted in cotton. Many of the slopes are steep and are washing badly where terracing has not been rigorously and systematically practiced. The stream carries much mud and great quantities of sand during floods. Its channel has been filled with sand and its floods do proportionately more damage to the lands along it than those of the river do. Much of its flood plain is either covered by sand or cut into holes. This sand works into the river during floods and is helping to overload it and cause the ultimate filling of its channel, just as the creek channel has already been filled.

At Shelor's ferry the bottom land is one-fourth to one-half mile wide and had recently been enriched by a 12 to 15 inch layer of rich soil, but crops were a total loss. Similar reports of ruined crops were received at the mouth of Gun Log Creek and at Knox Bridge. About 50 to 60 per cent of the upland in that vicinity is cleared; much of it is hilly and erodes readily. Some 20 per cent of the cleared land is terraced; of the unterraced land, one-fourth has been badly eroded. The terracing, when properly done, effectually prevents erosion. At the mouth of Seneca River the Tugaloo is 105 yards wide and its banks 5 to 6 feet high. Just at the ferry there is no flood plain, but both above and below it there is one, from a fourth to a third of a mile wide. Crops on these bottoms had generally been destroyed and the land itself had been somewhat damaged. For the last few years sand had been noted in greater quantities and was beginning to cause trouble in ferrying. It has accumulated during medium and low-water stages, but during high floods, which occur especially in late winter or early spring, it has so far been swept out.

At Brown's ferry the river had recently injured its bottoms 10 per cent and its crops 50 per cent.

At Dooley's ferry so many crops have been lost by floods that the bottoms have been set in Bermuda grass, and some of this had recently been buried under several feet of sand. This grass is undoubtedly the best growth to protect such bottom lands, while at the same time it furnishes an excellent pasturage and is injured by floods less than any other grazing crop.

At Park's ferry a third to a half of the crop had been destroyed, and half of the bottom land had been cut by runways or covered with sand.

For 8 miles below McGee's ferry the valley sides close in on the river, and there are no bottom lands worth mentioning.

At Harper's ferry, where the upland on the west is 160 feet above the flood plain, there is first, at 8 feet above water level, an ordinary flood plain 20 to 30 feet broad; then a sharp rise of 10 feet to the top of a long sand belt which parallels the river and is 100 to 200 feet wide; and back of the sand belt there is a descent of 6 to 8 feet to a fertile flood plain which lies next the valley wall and is covered annually by floods. On the east side of the river the bottom land is 6 feet above water level, and a low sand ridge near the bank rises 6 feet higher. Remnants of an old terrace at 25 to 40 feet are seen here and there. The channel is reported to be filling with sand, and the average depth of the river is said to be notably less than it was 20 years ago.

A power plant on Seneca River is illustrated in Plate XII, *B* (p. 36).

SALUDA RIVER BASIN.

The northwestern border of the basin of Saluda River extends 17 miles along the Blue Ridge and about an equal distance along the Saluda Mountains, the northeastward continuation of the Blue Ridge. The upper part of the basin is a fan-like expansion; the middle and lower parts are extremely narrow and lie between the Savannah basin on the southwest and Broad River basin on the northeast.

The steep southeastern slope or scarp of the Blue Ridge in this basin is relatively simple and abrupt, the drop being in places, as at Cæsars Head or Standing Stone Mountain, practically precipitous. A characteristic view of this scarp and of the Piedmont Plateau below it, looking southwest from Cæsars Head, is shown in Plate XVIII (p. 108). The difference in elevation between the top of the ridge and the plateau below is 2,300 feet. This steeply sloping southeastern scarp is practically an unbroken forest of hardwood. Along its southwestern part lumbering companies had been actively buying within very recent years, at prices ranging from $1 to $3 per acre, and in 1905 some land was still changing hands at these prices.

The headwaters of the stream flow in narrow, rocky gorges, which are being rapidly eroded. Like other streams rising on the southeast face of the Blue Ridge, they descend a distance of 1,000 to 1,200 feet or more in a few miles, reaching the Piedmont Plateau at an elevation of 1,000 to 1,200 feet above sea level. As they reach the Piedmont level their gradient decreases and narrow flood plains begin. These flood plains and more or less of the adjacent lower slopes of the Piedmont uplands are cleared and farmed.

On the head of North Saluda River the mountain sides are practically uncleared. The streams descend with a steep grade and have developed narrow, torrent plains, most of which have been cleared and within recent years have been badly injured in places by abnormally high floods. Their aggregate area, however, is relatively small. Somewhat lower the steep slopes have been more extensively cleared and floods had injured the growing crops from one-third to one-half. Below Humphreys's store lands away from the stream are poor and uncleared; along the stream the narrow flood plains showed much injury to land and crops. In many places the channel is almost filled with sand. From Terrys Creek to Lima along the North Saluda cleared flood plain areas alternate with narrower uncleared stretches. The river is swift and shallow and is moving great quantities of sand derived from the deep decomposition of the gneisses and granites in its upper basin.

At Cleveland Mills one-third to one-half the crops on the bottoms had been destroyed by floods, and it was reported that crops on the Middle Saluda had been damaged three-fourths of their value. The bottom here is 150 to 200 yards wide and is being cut to pieces by floods. The hill slopes are not generally cleared, but there has been considerable lumbering.

On the South Saluda some narrow flood-plain areas extend well up to its head near Table Rock and are cleared and cultivated. Along the lower course of the stream the bordering slopes are steep and uncleared, but above Venus they become more gentle and clearings extend some distance up either valley wall. A portion of this cleared area may be seen in the view from Cæsars Head in Plate XVIII. From Venus to Cæsars Head there are no clearings of any kind.

BROAD RIVER BASIN.

GENERAL FEATURES.

The basin of Broad River lies northeast of that of the Saluda, and its northwestern border extends 35 miles in an air line along the crest of the Blue Ridge, or 53 miles by its windings. The southwestern side of the basin is drained chiefly by two tributaries, the Tiger and the Pacolet. The headwaters of the Tiger do not reach the Blue Ridge but flow from an outlying mountain mass in the northern part of Greenville County, S. C. The headwaters of the South Pacolet rise in this same detached mountain mass, and those of the North Pacolet flow from the Saluda and Tyron mountains and likewise fail to reach the Blue Ridge. The next tributary of Broad River, Green River, heads in the Blue Ridge and flows northeastward parallel to it for an air line distance of 16 miles before turning to the southeast and cutting through the Saluda Mountains, which are the structural continuation of the Blue Ridge in northwestern South Carolina. After passing through these mountains the Green again turns and flows northeastward, parallel to them, for some 10 miles before finally bending to the southeast to cross the Piedmont Plateau. Some of its tributaries likewise parallel the Blue Ridge, but they flow to the southwest and cut the mountain mass into detached ridges parallel to its general trend.

As a result of this unusual stream alignment the mountain chain that is the structural continuation of the Blue Ridge receives another name, and the so-called Blue Ridge (the water parting between the Gulf and the Atlantic drainage) becomes an inconspicuous divide that lies farther west and no longer overlooks as a scarp the Piedmont Plateau of upper South Carolina, but is separated from it by several more or less parallel ranges. This series of somewhat detached ranges or spurs from the Blue Ridge is grouped about Saluda, N. C. It has been produced by stream activities that, while interesting in themselves, are not pertinent to the purposes of this report.

The steep mountain slopes between the heads of the Tiger, the Pacolet, and the Green River basins are for the most part uncleared, but in places, especially on the upper slopes and rounded crests of the ridges, there are extensive clearings, most of which are kept in grass. Where the soil is porous erosion is not active unless the surface is very steep, but lands with compact clay soil begin to erode after a few years' cultivation. Between 5 and 10 per cent of the mountain areas at the head of these basins has been cleared.

The many small streams between the mountain ridges and spurs flow with rapid currents in high-walled channels, and are bordered by narrow flood plains that reach within a few miles of their heads. Many of these flood plains are torrential in character, having an irregular surface and steep downstream slope and being composed of much coarse, stony material, heterogeneously mixed with sand and clay, but some of them are fertile. During floods these

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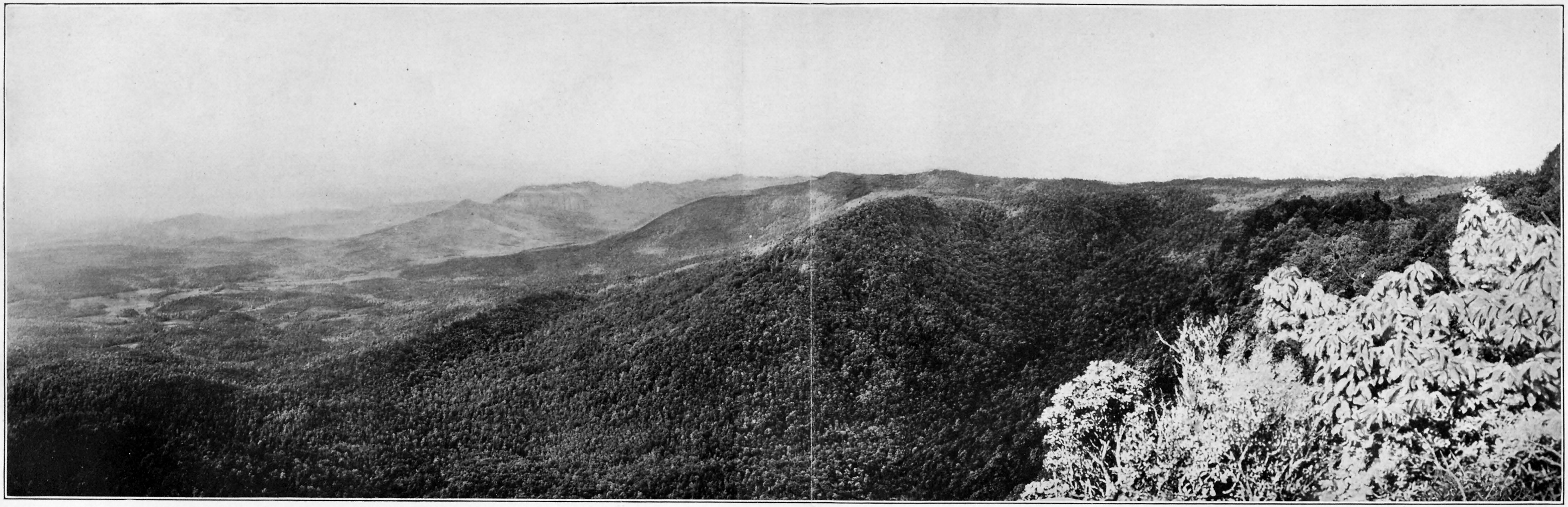

PANORAMIC VIEW OF PLATEAU AND ESCARPMENT OF THE BLUE RIDGE.

Looking S. 30° W. to N. 80° W. from Cæsars Head, S. C. The plateau on the right is 2,300 feet higher than the Piedmont plain on the left. See page 107.

mountain streams occasionally tear up their small flood plains, but as a rule the flood damage is not serious. Their steep slopes are forested, so that the streams are not overloaded with sand and are consequently able to carry away their storm waters rapidly.

The portion of the Blue Ridge to the northeast, however, within the basin of Broad River itself, has been more extensively cleared, and many of the small tributaries are overloaded with sand and gravel and have practically destroyed the little flood-plain areas along them. Such cleared areas may be seen in the region near Sugar Loaf Mountain, especially on its southeast slope.

GREEN RIVER BASIN.

The extreme upper end of Green River basin is forested, but a narrow flood plain begins a few miles below the head of the river and is practically continuous down nearly to the crossing of the Southern Railway just above Saluda, N. C. This flood plain varies in width, but averages about a third of a mile. In some places it is fairly level and fertile, but in others it is rather a beveled plain than a true flood plain and is semitorrential in character because of the locally steep gradient of the river. Only where the stream gradient is greatly decreased does the flood plain show signs of erosion. Just above the Southern Railway Crossing, for example, some areas have been scoured and others have been covered with sand. Some of the lowest of the bordering valley slopes have been cleared, but much the larger part of the basin is forested. The occasional clearings on the upper slopes and crests of the Saluda Mountains seemed to be in good condition, partly because many were new and others were kept in grass.

Below the Southern Railway bridge the river flows for some 8 miles through the Saluda Mountains in a narrow, rocky gorge. Below the gorge the stream flows with swift current in a broad channel and the valley widens into Green River cove. This cove is about 4 miles long and 100 to 300 yards wide and is inclosed on all sides by mountains. In some places it is level, in others it is gently beveled. Here and there a narrow cobble zone next the stream channel has been swept bare by floods which have not, however, greatly injured the lands. Flood heights are low because of the great velocity of the stream, and much of the land in the cove is above their reach. In a few places the lower valley slopes, especially to the southeast, are cleared for a short distance above the flood plain, but much the larger part is in forest or is rocky and precipitous. Remnants of an old terrace 60 or 80 feet above the present flood plain may be seen here and there.

Below the cove the mountain sides close in and the river flows for a number of miles in a narrow, wooded valley.

The uplands on the southeast are included in the basins of Ostins and Silver creeks and are of the usual Piedmont type, the general surface being rolling to hilly and rising 100 to 150 feet above the bottom lands. These bottoms themselves are narrow, rise gently upward on both sides of the stream, and meet the valley walls in a curve slightly concave upward, giving the valleys a broadly U-shaped cross section, and showing that the stream is slowly eroding its bed while the hillsides gradually weather backward in gentle curves. The streams are just about able to remove the waste furnished by their valley slopes and slightly deepen their beds. Any material increase in their load of waste will stop their downcutting and start deposition and aggradation.

At the bridge over Green River north of Mill Springs the channel is 60 yards wide and the banks some 20 feet high. The bottom lands vary in width up to 150 yards and are rather too sandy to be first-class agricultural land. Floods rarely reach them and flood damages are slight.

On the northern slope of Tryon Mountain only a small area is cleared. In Bright's Creek basin there are some steep clearings, and at the head of Walnut Creek, southeast of Sugar Loaf Mountain, steep clearings average 20 or 30 per cent of the area, and the older ones are gullying.

BETWEEN GREEN AND BROAD RIVERS.

Between Green River and the mouth of Buffalo Creek, on Broad River, the soil of the Piedmont Plateau is poor. The timber is thin and of medium quality. About 30 per cent of the area is cleared. The chief crops are corn, cotton, and small grain. Many of the old fields have worn thin where the land is stony or gullied where it is clayey, and have been abandoned to grow up again in briars and bushes. The small streams carry much sand and at many places have filled their channels and ruined the bottoms along their courses.

Cain Creek is bordered by a narrow but excellent flood plain, with here and there a rod or two of gouged surface or undercut banks. The lower 200 yards of the adjacent slopes are generally cleared. Part of this cleared area is badly washed, and the cultivation of one-half to two-thirds of the area originally cleared has since been abandoned.

Here and there on the mountains southeast of the Pinnacle small tracts have been cleared on benches at various levels. Halfway up the scarp there is a bare, rounded, granite cliff, and the soil on much of the rest of the slope is very thin and would quickly strip off to the bare rock if cleared.

Clearings on Buffalo Creek aggregate not more than 5 per cent of the area and are confined to the bottoms and the lowest slopes. Most of the slope fields have been washed to pieces and abandoned.

ABOVE MOUTH OF BUFFALO CREEK.

Along Broad River itself some good bottoms extend for a few miles above the mouth of Buffalo Creek. Thence practically up to its head the river flows in Hickory Nut Gap gorge, a deep and exceedingly picturesque gorge which is, however, much deeper and bolder below Bat Cave than above it. The walls of this gorge are either steep and wooded or are bare granite precipices, a thousand feet or more in height, but are separated sufficiently to permit at their bases occasional narrow steep-slope clearings along the river itself and to give room for a few houses and summer-resort hotels.

The basin of Reedy Patch Creek comprises much cleared land. The creek is overloaded with sand and is injuring its flood plain.

The basins of Little and Big Hungry rivers are practically unbroken wilderness except for a few clearings about Mills's gap and some narrow but fertile flood plain areas near the junction of the two streams. Lumbering operations were in progress when these basins were visited.

THE SPARTANBURG FLOODS.

In June, 1903, in the vicinity of Spartanburg, S. C., a flood, confined chiefly to the Pacolet, Tiger, and other small tributaries of Broad River, swept away 14 cotton mills and many bridges and houses and destroyed more than 50 lives. The property loss involved was not less than $3,500,000.[a]

All the streams of the devastated area rise on the steep slopes of Glassy, Saluda, or Tryon mountains, and the channels of all except Green River are more or less completely filled with sand and gravel, and similar conditions characterize all of their smaller tributaries that rise on the Piedmont Plateau. The unusually heavy rainfall of June, 1903, found the many stream ways in this region in no condition to remove the waters as rapidly as they once could have done, and the pent-back flood rose to abnormal heights and finally swept away everything in its path.

In this connection the changes that have taken place in the Spartanburg area since 1871 are significant.

Prior to 1871 the uplands north of the Southern Railway were practically uncleared, but at that time the introduction of commercial guano made it possible to grow cotton successfully on these lands and by 1880 or 1885 they had been largely cleared and year after year

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[a] For details of this destruction see Water-Supply Paper U. S. Geol. Survey No. 96, pp. 13–19.

were farmed in this crop. For the first few years after being cleared the land was full of humus and readily absorbed a large part of the rainfall, but later, when this humus had been exhausted, the lands began to erode, the stream channels to fill with sand, and the bottom lands—formerly the most valuable in the region—became at first difficult and then impossible to drain, owing to the rise in the ground-water level incident to the filling of the stream channels with sand. Floods became much worse and buried under sand or gouged to pieces other considerable areas, so that the bottom lands are now practically worthless.

Before the period of destructive floods the bottoms had furnished the corn supply for the county. The failure of the corn crops necessitated the shipment of large quantities of corn from the upper Mississippi Valley, and this necessity continued for a number of years, until the farmers learned to grow corn on their uplands. Since then they have once more grown the larger part of their corn supply, but in order to do so have trenched on their cotton areas.

At first no attempt was made to check the erosion of the steep slopes of the cleared uplands, but about 1884 or 1885 terracing was begun. The early results were not satisfactory, chiefly because many of the terraces were so poorly constructed that they broke after concentrating the water and caused worse destruction on the lower slopes than if they had not existed. To-day all the best farms are effectively terraced, but many of the smaller farms have not been terraced and upland erosion and stream filling are still active agents of destruction.

In this region rains run off rapidly, the streams rise to unprecedented heights, and during the succeeding dry weather their flow becomes abnormally low. The result of these abnormal conditions is most conspicuously shown by the flood loss of $3,500,000 at one time; but that the low-water damage, if less apparent, is none the less real, is evident from conditions at the cotton mills erected on these streams. These mills report that within recent years the horsepower available during the dry season has decreased one-fourth to one-third. The mills from which these data have been collected are numerous and widely scattered, and the decrease in power can not be explained as either local or imaginary. It is obviously the result of a change in stream regimen.

Another evidence that less of the rainfall soaks into the earth and becomes available to sustain stream flow during dry weather is afforded by the fact that many natural ponds in the Piedmont region, well remembered by men still in the prime of life, have gone dry, not from being drained or filled, but from the drying out of the soil and the failure of the springs that supplied and maintained them—a failure caused by the cutting away of the surrounding timber.

If such results have followed the cutting away of timber on the comparatively gentle slopes of the Piedmont Plateau, it can not be doubted that more rapid and complete disaster would follow the equally extensive clearing of the steep mountain slopes, since their soil, produced by the decomposition of similar ancient gneisses and granites, would yield to erosion with greater ease because of their steeper slopes and greater rainfall.

CATAWBA RIVER BASIN.

GENERAL FEATURES.

The headwaters of the Catawba extend 55 miles along the Blue Ridge, from which the streams flow southeastward, descending rapidly within a few miles from the ridge crest to the Piedmont Plateau, whose surface there has an average elevation of 1,200 feet above sea level. The scarp of the ridge is relatively simple and straight, but is buttressed by many sloping spurs that extend southeastward 6 to 10 miles before they merge into the general Piedmont surface. The narrow valleys carved between these spurs have steep gradients and sharp V-shaped cross-sections. Some of the higher mountain masses on or adjacent to the Blue Ridge have a rich soil and in places have been largely cleared. Northward along the ridge a steadily increasing proportion of these high cleared areas is in grass. The middle and lower slopes are as a rule steeper, rougher, and much less cleared, but within a few hundred yards of stream level cleared areas again appear.

A few miles below the sources of the small streams torrential flood plains begin, which broaden as the streams descend and on the Piedmont level are commonly several hundred yards or, exceptionally, a half mile or more in width.

On the Piedmont the interstream areas are largely cleared. The soils of the Catawba basin are derived chiefly from deeply decomposed micaceous gneisses and granites. In many places these soils erode into deep, vertical-sided gullies, that develop almost canyon-like proportions. They rapidly undercut and cave and soon extend up steep slopes to the hill crests. These are most typically developed along the Southern Railway east and west of Marion (Pl. III, *B*, p. 18) and some miles south of Marion along the railway to Rutherfordton.

At the head of the Catawba and about Round Knob the steep slopes are more heavily forested and much lumbering has been done. Near Round Knob a few small areas have been cleared, but their aggregate acreage is small.

A flood plain begins on the Catawba a few miles above Old Fort and extends almost continuously to Morganton, although it varies greatly in width and in places the walls close in and almost shut it off. East of Old Fort this flood plain is half a mile wide and its soil is excellent; near Greenlee it is one-third to one-half mile wide, and in places remnants of an old terrace appear 50 to 60 feet above the present flood plain. A characteristic view of the Catawba flood plain is given in Plate IX, *B*, page 24.

East of Nebo the uplands begin to be extensively cleared. The cleared slopes in a few years are cut into gullies, and much land has been ruined by this process.

East of Bridgewater the bottom lands show some erosion where the river curves, but where its course is straight there has been no serious damage.

Near Morganton the river banks are 15 to 18 feet high and the stream is usually swift, so that ordinary floods do little damage. In 1901, however, floods destroyed one-third to one-half of the crops on the bottom lands and practically ruined some farms, though the damage to lands was not proportionately as great as to crops. It is claimed that high floods are more frequent in recent years than formerly. In many places a narrow first bottom or ordinary flood plain about 15 feet above stream level is surmounted at an interval varying from 5 to 15 feet by a second bottom, which is, as a rule, much broader and quite undulating, and which is reached by the highest floods. Floods rarely damage this higher flood plain, but at times ruin the crops on the lower part of it, as well as on the entire first bottom. In some places remnants of an older stream terrace or fossil flood plain appear 30 feet above this second or extraordinary flood plain.

From the Catawba Valley near Morganton northeastward to Table Rock post office the upland is rolling to hilly and 10 to 15 per cent of it is cleared. The lands are somewhat stony and the soils wear thin rather than gully. Along Table Rock Creek there is a very narrow but excellent flood plain, a good portion of which is in grass. The slopes are practically all forested and no erosion damages are apparent.

Steels Creek is bordered by a narrow flood plain for a short distance above Joy, but farther up its basin is all wooded.

The road to Pineola along Ripshin Ridge is in an unbroken forest, scarcely an acre of cleared land being visible anywhere within miles on either side.

At the head of Upper Creek there are several cleared areas that aggregate from 100 to 200 acres. Some of these fields are steep and stony and have worn thin. At intervals along the crest of the ridge between Ball Ground and Pineola there are small farms, many of which are in grass. Their general condition as regards erosion is good. The cleared area, however, will aggregate not more than 1 or 2 per cent of the total area within this distance.

LINVILLE RIVER.

Pineola is situated on the broad, flat, and in places swampy flood plain of Linville River. This flood plain is not cleared or farmed to any extent. At Pineola a lumber company had for six years been cutting thirteen to fifteen millions of feet of lumber per year, and in 1905 had a supply sufficient to last several years more. Between Pineola and Linville there is but one clearing, and that comprises only a score or more acres. At Linville 75 to 100 acres along the river have been cleared. A few clearings in the basin above Linville are in pasture, but 98 per cent of the area is in timber, much of which has not even been culled by the lumberman.

From Linville the Yonahlossee Pike extends 22 miles eastward around the southern slope of Grandfather Mountain and along the crest of the Blue Ridge to Blowing Rock. On Grandfather Mountain there is one cleared area of 30 or 40 acres.

Around the southern slope of Grandfather Mountain one may look from the pike to the southeast for miles across a series of thinly wooded spurs and narrow intervening valleys that are practically without a clearing as far as eye can see. This large uncleared area is on the headwaters of Wilson Creek and Johns River.

East of Grandfather Mountain the crest of the Blue Ridge is cleared in places and much of it is in grass. The soil is generally porous and erosion is not prominent, though in a few places fields have been ruined by gullying. The soils are as a rule derived from deeply rotted schists, which give place near Blowing Rock to gneisses.

BLOWING ROCK DOWN JOHNS RIVER TO MORGANTON.

From Blowing Rock the road down Johns River valley descends the mountain at a steep grade, and for several miles there are no clearings. Most of the small mountain-side clearings that then appear have been so recently made that the deadened timber is still standing and erosion has not yet begun. Still farther down the valley the stream has built a narrow torrent flood plain which continues with some interruptions to a point about 2 miles above Globe, where the grade flattens and the flood plain broadens, extending a mile below Globe, with a width ranging from 200 to 600 yards. A mile above Globe, where the swift shallow stream is 40 to 50 yards wide and flows within banks 3 to 5 feet high, there is near the stream channel a washed zone that is 25 yards wide and extends some distance. The flood plain at that point is only 75 to 100 yards wide and is fairly fertile. A mile below Globe the valley walls close in and from this point down to Collettsville the bottom lands are absent or narrow. Most of the steep slopes and all of the ridges are uncleared, though they have been quite thoroughly lumbered since the building of the railway to the John River valley.

A few miles down Johns River from Collettsville the uplands are of the usual Piedmont rolling or hilly type, have been largely cleared, and in many paces are eroding. The river valley is relatively narrow and the flood plains are more or less disconnected and vary greatly in width, which ranges from almost nothing to 200 or 300 yards. In many places they have been injured by floods, and within recent years many crops have been destroyed.

At the bridge on the Catawba just north of Morganton the flood plain of the river is narrow and shows many visible signs of extensive scouring and gouging during floods. The river valley contracts at this point and for miles down the Catawba the flood plain is narrow or absent, except near the mouths of tributary streams or on concave sides of bends. In this narrow valley the river flows with great velocity during floods and has caused much damage to lands and crops, as well as to bridges and dams.

Where the Southern Railway crosses the river east of Hickory much of the flood plain, which is there 200 to 300 yards wide, has been ruined by the runways cut across it or by sand that has spread over it a number of feet deep, and many once-fertile areas have been abandoned. The stream is broad and shallow and its channel is well filled with sand.

YADKIN RIVER BASIN.

GENERAL FEATURES.

The Yadkin basin lies northeast of the Catawba, and its northwestern margin, for an air-line distance of 70 miles, is formed by the crest of the Blue Ridge. From Blowing Rock northeastward for 45 miles in an air line to Roaring Gap the Blue Ridge scarp does not descend abruptly to the Piedmont Plateau level, but is buttressed by many more or less parallel spurs whose sloping crests extend southeastward 8 to 10 miles before ending on the plateau. These spurs represent a part of the mountain mass that during long ages has been deeply dissected by the headwater tributaries of the Yadkin, which are steadily gnawing into the mountain divide at their heads and slowly but surely pushing it westward, so that the Atlantic streams are gaining in length and drainage area at the expense of the Mississippi Valley streams.

Most of the buttressing spurs east of the Blue Ridge have steep lateral slopes, which in places are rocky, and as a rule their soil is poor. Here and there on gentler slopes are more fertile areas, many of which have been cleared. Some of the streams between these spurs are eroding their channels so rapidly that they have narrow, sharp-bottomed valleys without flood plains, and the whole basins of such streams are generally forested. Where, however, down-cutting is less rapid or has already reached its limit, or where the valley walls are less resistant and have weathered back more rapidly, the streams have built small flood plains. These flood plains and the better parts of the lower 100 to 300 yards of the adjacent valley slopes are cleared, and a considerable portion of them is usually kept in grass. The flood-plain clearings as a rule show no injury from floods, but the slopes, unless kept in sod, gradually wear thin or wash away.

Just east of Blowing Rock, on the very headwaters of the Yadkin, narrow flood-plain areas occur and some of the adjacent slopes are farmed. As a rule the soil is porous or stony, and the effects of erosion are not serious. Below the headwater region, however, there is but little cleared land along the stream for a number of miles.

At the mouth of Mill Fork is a flood plain several hundred yards wide which extends up Mill Fork and down the Yadkin, but flood plains are not conspicuously developed for some miles below the mouth of Mill Fork until the Yadkin turns to the northeast and begins its long course parallel to the Blue Ridge. For several miles below this point the flood plain ranges in width from three-fourths of a mile to a mile. It then narrows for a mile, and then broadens to three-fourths of a mile or more for the next 2 miles, and this alternate broadening and narrowing is characteristic of the river for a long distance. Where the flood plain narrows it is commonly bordered by a finely developed terrace, 40 or 50 feet higher, with an extremely well-preserved level or gently rounded surface and definite, well-marked scarps. The interval between this fossil flood plain and the living plain becomes gradually greater downstream.

On Elk Creek bottom lands are not found along the lower 5 miles; above that the valley widens somewhat and contains several good farms, but their bottom lands have been greatly injured by floods in recent years. The slopes are broken and rough, but are cleared in many places and are eroding.

Stony Fork and West and East forks are much like Elk Creek. Most of the land in these and other basins on the east slope of the Blue Ridge has passed into the hands of lumber companies, the average prices recently paid being reported as $3.50 or $4 an acre. When examined, this region lacked road facilities for marketing the lumber.

From the mouth of Elk River to Wilkesboro the hills in many places close in on the river and practically cut off the bottoms, but between these contracted portions are broader stretches, with a fertile flood plain a fourth to a half mile wide.

At some points, especially on the concave side of bends, this flood plain has been swept bare by floods, but elsewhere it is in good condition as regards erosion.

Along the valley walls are many remnants of an old cobble-strewn terrace whose average elevation is here about 60 feet above the present flood plain. Above it the valley walls rise gently and irregularly.

Many of the slopes have long been cleared, and on these clearings erosion is more or less prominent almost everywhere.

The Brushy Mountain Range, on the south side of the valley, is forested to its tops, though some scattered clearings have been made on its upper slopes. These clearings, many of which are kept in grass, seem to be free from erosion damages. Along the small streams between the spurs of the mountains there are narrow flood-plain areas, and these, as well as the little amphitheater-like coves at the heads of the streams, are generally cleared. Below Wilkesboro the hills in many places close in on the river and cut off the flood plain, but where the flood plain is present its width ranges from 200 to 400 yards.

Where the flood plain is broad the narrow notch or shelf representing the ordinary flood plain changes to a flood-scoured, sand-covered tract, 25 yards or more in width at first, but wider farther down, which has been formed by flood currents cutting away the ordinary flood plain. These sandy wastes, which are especially likely to occur on the inside of bends, even those of very slight curvature, are generally 100 to 300 yards long, and rise either just to ordinary stream level or 1 foot to 3 feet above it. Along the edge away from the river the bordering flood plain is being undercut, so that the width of the scoured belt is evidently becoming greater. The residents of this region say that much of this damage has been done in recent years and that it is steadily increasing. In a few places sand has been spread over the fertile bottom lands, as, for example, just east of Elkin. More commonly, however, the floods cut the rich alluvial deposits away and deposit sand in their place. The river is building sand bars behind projecting ledges or rock or chance obstructions on the concave side of curves and is evidently overloaded with waste, the source of which is, as is equally evident, the eroded slopes of its upper tributaries.

At a number of places the river flows across ledges of hard igneous rock, through which it is slowly but persistently cutting its way. The shoals and rapids that have developed at these places furnish many opportunities for power development. Storage basins constructed along the stream, however, would doubtless as quickly fill with sand and silt as do those on the similar streams southwest of the Yadkin.

The valley walls are as a rule low and retreating and join the flood-plain surface at their base in very gently rounded curves. The valley sides and the upland beyond are generally 60 to 75 per cent cleared, and half of the cleared slopes show gullying of the long, narrow, shoe-string type. The width of the river varies greatly. Where it is widest the flood plain is 3 to 5 feet; where narrow it is 8 to 12 feet above ordinary stream level. A few miles above Shoals, on the north side of the river flood plain, a projecting knob 250 yards long and 30 yards wide rises 40 feet above flood-plain level. It was doubtless formed as an island when the stream flowed at the level of the old terrace mentioned, and as the river cut down to the present level it maintained both channels nearly until the present day before the left-hand channel became filled. The interval at this fossil island between the old terrace level and the present flood plain is 70 to 80 feet, and much of the terrace scarp has long been cleared, and parts of it are now eroded.

REDDIE RIVER.

For several miles from Wilkesboro Reddie River flows in a narrow trench cut 150 to 175 feet beneath the Piedmont level and has no flood plain, but above this stretch, up to a point a mile below Reddie River post office, narrow bottoms, consisting generally of hanging or beveled plains, occur here and there. In this distance 20 per cent of the low slopes on each side of the stream have been cleared. The hillsides erode as usual where the soil is of clay but are well preserved where it is stony.

From Reddie River post office up to Whittington the bottoms are fair to good in quality and include a narrow, washed cobble or gravel zone near the stream. Up North Fork the hill-side clearings extend 100 to 200 yards up the slope and are not washing. Up Middle Fork there are narrow bottoms for 2 miles, above which the valley shuts in for some miles, but in the upper 4 miles the stream has a shifting channel and narrow beveled torrent plain. This torrent plain and the lower hill slopes are cleared. The soil is stony and is not eroding except where the slopes are steep.

For a number of years lumbering has been active on Reddie River well up to its head, and much of the best timber has been removed. It is hauled by wagon to Wilkesboro. Along the crest of the Blue Ridge 20 to 35 per cent of the drainage area is cleared and much the larger part of it is in grass.

MULBERRRY GAP TO WILKESBORO.

Near Mulberry Gap 25 to 30 per cent of the Blue Ridge crest is cleared and in grass. The loose, porous soil generally contains many small stones and erosion is at a minimum. On the south side of the ridge the soil is poor and the higher slopes are uncleared. The timber is of medium quality and much of it has been cut by small mills and hauled 25 miles or more to Wilkesboro.

Up Mulberry River the bottom is a torrent plain which is narrow in some places, but in others attains a width of half a mile. It has a fairly good sandy soil underlain by cobbles and is in moderately good condition as regards erosion. The clearings on the lower upland slopes are cut into gullies or show sheet erosion as they grow old and include many areas of worn-out old fields.

NEW RIVER BASIN.

GENERAL FEATURES.

The New River basin was examined in detail south of Fries and Galax, Va., and the river itself was traversed down to the point at which the New River branch of the Norfolk & Western Railroad leaves it, just south of Pulaski, Va.

New River rises near Blowing Rock, N. C., and flows with many meanders northeastward over an air-line distance of 90 miles to Radford, Va., where it turns to the northwest, cuts through the mountains of Virginia and West Virginia, and as the Kanawha finally joins the Ohio.

Its basin is bounded on the southeast by the crest of the Blue Ridge and on the northwest by the basins of the Watauga and Holston. The upper end of the basin, which lies on the Asheville Plateau level, here 3,000 feet above sea level, narrows to a point at Blowing Rock, N. C.

From many points along the crest of the Blue Ridge the valley of New River appears as a great ampitheater-like basin, walled in by high mountains on the south, west, north, and northwest. Within this basin New River and its tributaries, like the streams in the Asheville region itself, have incised their channels in narrow, steep-sided trenches, varying from a shallow groove to a gorge 200 feet in depth, and above the general surface there rise many residual mountain masses, such as Bald Knob, Peach Bottom Mountain, Nigger Mountain, and others, most of which reach elevations of 4,500 to 5,500 feet, and, consequently, tower some 1,500 to 2,500 feet above the plateau level.

From a short distance below its head down to the point at which it enters a limestone valley near Ivanhoe Furnace, Va., New River has cut down through crystalline rocks so rapidly that its valley has not had time to weather back appreciably, and very little flood plain has been developed. Similar conditions prevail on practically all of its tributaries, so that stream slopes are usually steep and are mostly wooded, and flood plains are narrow or absent. The amount of waste carried by the river and its tributaries is relatively small, except in the Independence region, where erosion of cleared slopes is more active than elsewhere. Outside of the Independence area the streams are able not only to carry away all of the waste furnished from their slopes but to vigorously erode their channels besides. They flow on bare rocks and have sufficient fall to remove rapidly all flood waters.

The most striking feature in the basin is the activity in lumbering which has resulted from the recent extension of a railway into it. Small portable sawmills have been located in even the most remote mountain coves, and lumber, tanbark, and crossties are hauled as much as 30 miles over mountain roads that are in many places execrable. Those who are engaged in the industry get for their product prices that amount only to low wages for themselves and their teams. They practically give their timber away, cut their roads to pieces in hauling it, and by its removal hasten the erosion of their steep mountain slopes and narrow flood-plain areas.

The climate of the region is favorable to the growth of grass, which readily sets on cleared land, and the region in general resembles the upper Holston Valley. Some corn and small grain are raised, but grazing is the chief industry of the region and much of the cleared land is kept in grass, which is used for pasture or cut for hay. The cleared slopes when held in grass do not erode, and in this respect also the region is comparable to the Holston. Erosion, however, is by no means entirely absent, for some slopes have been cleared that are too steep for even grass to hold, and in places the steep land has been unwisely cultivated in corn and grain instead of being put in grass. Such cultivated lands erode readily and are visible at distances of even 10 to 20 miles as bare red areas on the hillsides.

DETAILS OF CONDITIONS.

Galax is situated in an expansion of the valley of Chestnut Creek, where there is a wide flood plain, bordered on the west by a broad 50-foot terrace on which most of the town is situated. The land along the creek above Galax is for the most part cleared, and the lower slopes as well as the bottoms are nearly all in grass and are in good condition as regards erosion.

Below Galax, Chestnut Creek has scarcely any flood plain, and its immediate valley walls are so steep that they are largely wooded.

On the uplands of Wards Mill Branch the cleared area amounts to 60 per cent or more, much the larger part being in grass. Thence eastward to Piper Gap the cleared area is confined more largely to the vicinity of the streams and comprises only about 3 per cent of the total area. In no place was active erosion in progress, though in a few places small areas of especially steep slope had been stripped of their sod. The rocks of the region are mostly a mica gneiss which has weathered deep, making a soft loamy soil. In a few places the underlying rock is a hornblende schist that weathers less deep and produces a more compact clayey soil, which would erode readily were it not for the fact that it usually contains many small scattered pieces of the rock that prevent rapid erosion.

The southern slope of the Blue Ridge near Pipers Gap is very steep and is well wooded. Northeast of the gap, on the higher slopes along the ridge crest, there are some clearings which are in good condition because they are kept sodded.

Above Lambsburg the streams show narrow torrent flood plains, bordered by old beveled terrace scarps that range in height from 40 to 100 feet. The streams are damaging their flood plains and occasionally destroy crops.

From Lambsburg to Low Gap the uplands are usually rough and poor, and only a small part of the area is cleared. The small streams are bordered by narrow flood plains, which are usually farmed and are in good condition as regards erosion. The best timber has been cut out and in places forest fires have followed the cutting and injured the remaining growth.

On the head of Fishers River there is much good bottom land, and nearly all of the uplands near it are cleared. The land is prevailingly stony, bears good crops, and does not wash easily. On the higher southern slopes of the Blue Ridge 30 to 40 per cent of the area to the east of Low Gap is cleared and is largely in grass. Lumbering on the head of this river has been active during the last 10 years, and the farmers on its bottom lands claim that floods have greatly increased in frequency, height, and destructiveness during this period.

A very large portion of the Blue Ridge crest from Low Gap southward to Roaring Gap is forested, and the soil, which is derived from mica schist, is, as a rule, poor and loamy. In places the forest is poor, but in the more sheltered northern coves there are some good hardwood areas and along the small streams some hemlock and white pine. West of the range the slope is exceedingly gentle, and in many places more than half of the area is cleared. As seen from a point on the ridge just south of Low Gap, 50 per cent of New River basin seems to be cleared and 45 or 50 per cent of the visible slopes of the high bounding ridges to the south and west seem also cleared. These mountain slopes appear not to have eroded as easily as the slopes from the dissected plateau level down to the present stream channels.

Indeed, in the entire range of vision, embracing an angle of 180° and extending for a distance of 10 to 20 miles, comparatively few eroded areas were visible. Some erosion was manifest on the slopes of Bald Knob, Fender Knob, Buck Mountain, Bullhead Mountain, and Peach Bottom Mountain, but in any one of these places a few acres would include the reddened eroded areas. Later detailed examination showed this apparent absence of erosion to be as characteristic of the New as of the Holston basin and to be in marked contrast to erosion conditions farther south, as, for instance, in the French Broad or Nolichucky basins.

The land on Big and Little Pine creeks is poor and only 10 to 20 per cent of it is cleared.

On Laurel Branch the valley floor and lower slopes are nearly all in grass. On the ridge near Roaring Gap 15 to 20 per cent will include the cleared area, practically all of which is sodded.

From Roaring Gap to Sparta the stream valleys as well as much of the plateau surface are in meadow, and in some places the steep slopes on the residual peaks show red from gullying.

Between Sparta and Whitehead more than half the area is in excellent grass and lands are worth more than $100 an acre.

On the higher slopes on the east side of Peach Bottom Mountain badly eroded areas were seen in three places. These lands were too steep to be cleared under any circumstances and should have been left permanently in forest.

From Whitehead to Laurel Springs the land is largely in grass and in good condition, much as it is between Sparta and Whitehead.

From Laurel Springs west to New River 40 per cent of the land is in grass and erosive effects are prominent at only two points, which are southwest and west of Ore Knob. The erosion at these points and immediately around the copper mine at Ore Knob was probably started as it has been at Ducktown, Tenn., by the killing of the vegetation by sulphuric acid fumes from the roasting heaps and smelter. As the smelter has not been in operation for several years, new areas bare of vegetation are not developing, and only an occasional old area tends to enlarge. Throughout this region of prevailing meadow land the grass grows along the small streams down to the water's edge, so that their banks are well protected and the position of their channels is fixed. The streams themselves are limpid and clear, and flow usually with rapid currents over clean-washed gravel and cobbles. The contrast between their condition and that of the muddy, overloaded streams farther south is striking.

East and south of Jefferson the bottom lands along New River vary greatly in width. In some places they are absent; in others they form a strip 200 yards wide. These bottoms are kept in grass. Floods are reported to do little or no damage either to land, bridges, or crops. The uplands are more than half in forest and as a rule are not eroding. The eroded areas in this region are confined to the very steepest cleared slopes, and even such areas are reported to be decreasing in size during recent years, since the farmers have been practicing a better system of agriculture, whereby the raising of corn and small grain is being transferred more and more to level bottom lands and the steep hill lands are being sodded for meadow or pasture. This change has been accelerated by increases in the price of stock. Much of the best lumber has been cut from this region and hauled a long distance to the railroad, either at Wilkesboro on the east or to some point near Butler, Tenn., on the west.

From Jefferson to Beaver Creek the higher hilltops are largely wooded, but the rest of the country is three-fourths cleared. Between Beaver Creek and Elk Crossroads the cleared land is in much smaller proportion and is confined to the stream valleys and lower hill slopes. Its condition is satisfactory, though some effects of erosion appear just north of the crossroads.

At Elk Crossroads three-fourths of the region is wooded, though in some places steep slopes are cleared to the tops of the ridges. The soil is stony and most of it is kept in grass, so that injury from erosion is much less than would be expected from the steepness of the slope. Flood damages along the streams are practically absent.

From Elk Crossroads westward to Snake Mountain gap four-fifths of the area is wooded and the cleared slopes do not show conspicuous erosion damages. Lumbering has been active for a number of years and much of the best timber has been removed.

The middle and upper slopes of Snake Mountain and the neighboring higher knobs are almost entirely wooded.

On Hoskins Fork a cleared flood plain extends from about 2 miles below its head down to its mouth at Sutherland, and much the larger part of the slopes and ridge crests on each side are also cleared. One of the best grass areas in the entire New River basin is found on this creek about Sutherland.

From Sutherland to Creston the lower slopes are cleared, and the higher are forested, much as in the area just described.

The river from Creston to the mouth of Rich Hill Creek has a broad, shallow channel, bordered by a zone of cobbles, and very little flood plain. The basin of Rich Hill Creek was being actively lumbered in 1907. About 50 to 60 per cent of it is cleared, and in some places the steepest slopes show bare areas of red clay. These eroded areas are said to be decreasing since better care has been taken of the land.

It is claimed that in three or four years these "galls," as they are called, may be reclaimed by covering them with leaves and brush and thus checking further erosion until vegetation may once more take hold.

On the head of Rich Hill Creek and in the region to the northeast, across the basins of Little Horse Creek, Windfall Creek, Horse Creek, and Holton Creek, the rocks change to an epidote-bearing granite or to highly acidic eruptives that weather into a more impervious clay soil than the gneiss and schist farther east and south and so are more inclined to erode where steep slopes are cleared and left bare of grass. These rocks produce, however, a richer soil, and the growth of grass, to which most of the cleared area is devoted, is more vigorous than on the poorer soils and largely prevents erosion.

The timber on the mountains at the heads of these creeks has been purchased by lumber companies within the last few years, most of it in fee simple, at prices reported to average $15 an acre, though recent purchases had been made at $18 and some even at $25. Most of this land when cleared sets naturally in grass and makes most excellent grazing land, so that its agricultural value is high and justifies the prices that have been paid for it.

From Holton toward Mouth-of-Wilson the ridges become lower, the slopes gentler, and the bottoms broader, the amount of cleared land increases, and though grass still predominates the proportion of cultivated land becomes greater eastward until, west of Independence, the area of cultivated land exceeds that of grass land.

The rocks of the region are chiefly granitic, with greenstone and other schists and some acidic intrusives in subordinate amounts.

At Mouth-of-Wilson there is no flood plain along the river. The small creeks have narrow flood plains which are occupied very largely by gravel and cobble zones, the channels themselves being well filled with sand.

Near Independence granite becomes abundant and produces by its decomposition red clay soils. The steep slopes show a tendency to rapid erosion. The granite is poor in mica, however, and gullies do not become deep and then undercut and cave, but are long, narrow, and sharp-bottomed, and extend radially down the steep slopes.

From Mouth-of-Wilson eastward to Independence more hillside erosion was observed than in any part of the New River basin thus far described. The effects of erosion were especially prominent in the basin of Fox Creek, on the west side of Bridle Creek, and on some of the southern spurs of Buck Mountain, as well as just north and again just southeast of Independence. Erosion is reported to be worse in the eastern side of Grayson County than in the western, because the eastern part has been settled and cleared longer, and as the lands have grown old the tendency to erosion has increased.

From Independence to Sparta 50 to 60 per cent of the area is cleared. Much of the soil is a red clay derived from granite, and in the first few miles south of Independence, and again in the 2 miles just south of New River, the hillsides were badly eroded by parallel gullies of the deep, narrow, granitic-soil type. All of these lands have been cleared for years, and some of the erosion is the result of neglect, but in other places the slopes are too steep to be cleared and cultivated with safety. Between Sparta and Galax the steep slopes are mostly on granite rocks, and the fields, except where freshly cleared, are usually radially scored with sharp-bottomed gullies. Where the rocks are of diabase or other basic igneous rock erosion is much less active. About half of the land is cleared; three-fourths of the cleared area is in grass and the rest is principally in corn and buckwheat.

Little River near Sparta and downstream to its mouth flows in a very narrow trench cut 100 to 200 feet below the plateau level, in few places wide enough to accommodate both the river and a flood plain. The slopes from the plateau down to the stream are usually very steep and in most places are uncleared.

MONONGAHELA RIVER BASIN.

GENERAL FEATURES.

In March, 1907, an unusually high flood on the Monongahela inflicted great loss at Pittsburg and made it seem desirable to study conditions in the entire Monongahela basin and determine, if possible, the causes of the damage wrought. This study was made late in the summer of 1907.

The Monongahela rises in northern West Virginia and flows northward to join the Allegheny at Pittsburg, thereby forming the Ohio. The upper and middle parts of its drainage basin lie mainly in northern West Virginia, although a bit of its eastern margin is included in the extreme western end of Maryland; the lower or northern part of its basin is in Pennsylvania. The basin is 150 miles in length and averages 70 miles in width. Much of its area is a plateau that stands 1,500 to 2,000 feet above sea level, though what is presumably this same plateau rises to an elevation of over 3,000 feet in some places, as, for example, near Davis, W. Va. The eastern rim of the basin has an average altitude of 3,000 feet in Pennsylvania and Maryland, but in West Virginia rises rapidly southward to elevations of 3,500, 4,000, and in places even 4,800 feet above sea level. The rim in its southeastern portion ranges in altitude from 4,000 to 4,600 feet, but along its western edge declines abruptly to 3,500, 2,500, 1,800, and farther north sinks to an altitude of about 1,600 feet, an elevation which it retains in its middle and northwestern part.

The rocks of the entire basin are conglomerates, sandstone, shale, and limestones, and nearly all are of Carboniferous age.

In the eastern part of the basin in West Virginia, Maryland, and Pennsylvania these rocks have been folded into long, narrow anticlines and synclines whose crests have been planed off by erosion, which has laid bare the edges of beds that vary much in their resistance to erosion. The harder conglomerates and sandstones form ridges; the softer shales and limestones have been eroded and form the valleys. The topography is consequently characterized by long, parallel ridges and valleys which trend northeast-southwest. The parallelism of the eastern members of the Monongahela drainage system is due to the folding and the subsequent differential erosion of the hard and soft beds. The rough topography, the narrow stream gorges, and, in places, the stony surfaces, are due to these same causes.

In the middle and western parts of the Monongahela basin the strata lie nearly flat and are composed largely of shale, but include some sandstone. The surface has been so deeply and so generally cut by the numerous branching streams that the slopes are nearly everywhere steep, though, as a rule, they are precipitous only where, for short stretches, heavy sandstone outcrops in a valley wall. The streams have cut to depths of 300 to 500 feet, and most of them are still actively down cutting, but are doing comparatively little widening, so that they flow in relatively narrow valleys, though on many of them there are narrow flood plains.

YOUGHIOGHENY RIVER BASIN.

The largest eastern tributary is the Youghiogheny. The upper portion of this river, in Maryland, has recently been described in a report on Garrett County, published by the Maryland Geological Survey, and does not differ essentially from that of the Monongahela, in the same State, for the topography, soil, amount of cleared land, mining development, and other features are essentially the same.

CHEAT RIVER BASIN.

The next tributary of the Monongahela west of the Youghiogheny on the eastern side of the basin is Cheat River. Shavers Fork of Cheat River rises in Pocahontas County, W. Va., and flows northeastward between two parallel mountain ridges, whose elevation in places reaches 4,000 to 4,800 feet. Its basin is 50 miles long and only 4 to 6 miles wide. Between ridge crest and streamway the difference in elevation on Shavers Fork is generally 1,000 to 1,500 feet, and its valley slopes are therefore in places exceedingly steep. Most of the country is rough from the outcrop of resistant sandstones, and the area of cleared land on the slopes is small. Along the stream there is almost no flood plain. The basin is largely in timber, nearly all of which has been sold to lumbermen. Some of it has already been cut and the rest is being cut at a rapid rate.

On Shavers Ridge there is a considerable area of good cleared land, which is largely in grass and is not eroding.

On Cheat Mountain, west of Shavers Fork, there is much rough land, but 20 or 25 per cent of the ridge is in grass. The timber either has been cut or is being cut rapidly.

The basin of Dry Fork of Cheat River, though rough, includes narrow flood plains and fertile lower slopes that have been cleared and now suffer erosion, especially where the soil is sandy. The stream frequently cuts to pieces or covers with sand all of the flood plain within its reach, and in July, 1907, swept away every bridge on the Dry Fork Railroad. Most of the timber has been removed, and in places 25 per cent of the slopes have been cleared.

Much of the western slope of Allegheny Mountain is rough and in brush, the timber having been cut. Only 5 or 10 per cent of its area is farmed, and this part is mostly used for grazing. One-third of the crest of Rich Mountain near its south end is in grass; the rest of it is rough, but has some good timber left, some of which is still in small holdings.

Laurel Fork has a rough basin, all of which is in timber. It was being logged in 1907.

Glady Fork has some good farm lands near its head, but the rest of its basin is rougher and the timber in it was being cut.

Middle Mountain has some fertile land, and 25 per cent of it is cleared and is principally in grass.

Blackwater River flows in a deep gorge below Davis and is largely in brush and swamp above Davis, except in Canaan Valley, which is level and fertile and is nearly all well sodded. All of the Blackwater basin except its lower part has been thoroughly lumbered and then burned over, so that in many places the bare rocks are exposed and scarcely anything but briers and fire-scald cherries have since been able to take hold. It will be years before a commercial forest can be started and centuries before the magnificent hemlock, spruce, and pine that once covered it can grow again.

The plateau on either side of the gorge on the lower part of the river is still forested, and many of the hemlocks show between 300 and 400 rings of annual growth. Logging railroads have recently been built into this magnificent forest and it is being rapidly cut and will soon be gone, as the forest about Davis has already gone.

Near Parsons and down to St. George there are some broad bottoms along the river, but they are rather too sandy for grass and are planted in corn. From St. George down practically to its mouth, just beyond the Pennsylvania line, the Cheat flows in a wild, rock-bound gorge that is 1,000 to 1,200 feet deep. In a few places, just before crossing into Pennsylvania, it has developed small flood-plain areas, but they are relatively unimportant.

On the west slope of Backbone Mountain, north of Blackwater, the timber remains and is held by a lumber company. There is some timber left on Horseshoe Run and Mill Run. The soils in the basins of these creeks, as well as in those of Clover and Haddocks runs, on the opposite side of the river, are poor but are largely cleared. The soils of the narrow flood plains along the smaller streams are of medium quality only. In July, 1907, however, nearly all of these small bottoms were destroyed by a flood and the crops on the rest of them were ruined. The loss to farms and roads in Tucker County by this flood is estimated at $30,000. The West Virginia Central's roadbed was so badly damaged that no trains ran for a week along the Blackwater gorge, and the Dry Fork Railroad was some two weeks in rebuilding the bridges and roadbed swept away.

On the east side of Cheat River, around Aurora, in Preston County, about a third of the area is cleared. About half of this is in grass and the rest in corn, potatoes, and oats. Most of the remaining two-thirds has been lumbered and then burned over and is now in brush. The steepest slopes facing the river and along the larger tributaries are either rough and uncleared, or, if cleared, are in grass.

From the Baltimore & Ohio Railroad northward on the east side of Cheat River there is much good land away from the river front, and a very large proportion of it is cleared and used for grazing. The soil does not wash except along the steep river slopes. During the 1907 floods the only damages sustained were the destruction of small bridges along a few of the streams in Portland district of Preston County. The more level parts are almost entirely under cultivation or in grass. Erosion is not serious and floods have not greatly damaged lands or property.

The eastern edge and the central part of Grant district, which extends northward to the Pennsylvania line, are largely cleared; the western portion is bordered by Chestnut Ridge. The lands here are poor and rough, with much timber, most of which is in the hands of lumber companies.

On the western side of Cheat River, as it flows through Preston County, lands back from the river front are generally good and are largely cleared. Along the Laurel Hills, however, in the south end of the county and along the northwestern border near the Cheat, the lands are quite rough, owing to the influence of the Cheat Ridge uplift. Near the river there is a larger proportion of forested land than elsewhere, but most of the timber has been removed.

TYGART VALLEY RIVER.

From Elkins to the head of the river the basin of the Tygart Valley is very fertile and is for the most part largely cleared. Lands are worth $50 or more per acre. Much the larger part of the area is in grass, but corn enough for home consumption is raised. Floods, as a rule, do no damage to the lands, but in 1907 they destroyed some 10 per cent of the hay crop. The previous flood of similar height to that of July 17, 1907, was in 1896. The 1907 flood destroyed many logging roads and inflicted a damage of $150,000 on the people of Randolph County.

Just below Elkins, on Leading Creek, a tributary of Tygart Valley River from the northeast, are some relatively broad and fertile bottom lands, practically all of which are in grass. In places the lower hill slopes have been cleared, but some 90 per cent of the upland is in forest. The soil is poor; the timber is scant and the best of it has been cut. Farther north, on the east side near Meadowville and on Teter Creek and Brushy Fork, there are some excellent grass lands.

Along the Big and Little Sandy bottom lands and uplands have been largely cleared. The flood of July, 1907, was especially destructive both to the lands and to the crops along these creeks. The basins are long and relatively narrow and the flood swept down them with great violence. The rainfall in this region seems to have been heavier than anywhere else, unless at the very head of Buckhannon River, near Pickens.

Three Fork basin has, as a rule, a poor soil, some 20 per cent of which has been cleared and is about evenly divided between grass and cultivated crops. Lying along the main line of the Baltimore & Ohio Railroad, this basin has been thoroughly lumbered and a large part of it has since grown up in brush. Floods in July, 1907, were very high on this creek and tore up many of the roads, but caused greatest loss to the Baltimore & Ohio Railroad, whose tracks down near the stream level were much damaged.

In Marion County, on the east side of the river, the bluffs and slopes for a little distance back are usually steep and uncleared, but farther away from the river the country becomes better and 50 to 75 per cent is cleared. Two-thirds of the cleared area is sodded. Practically no commercial timber is left.

On the Tygart Valley River itself the broad bottoms disappear in a few miles below Elkins, and the river flows practically to its mouth near Fairmont in a narrow, steep-sided channel, cut 300 to 400 feet below the general level, with no flood plain of any importance. The walls of the river valley are cleared where they are composed of shale, but are rough and rugged where heavy sandstones outcrop and are there forested. The lumber has been cut and in many places mine props have also been taken. Farther back from the river on both sides the country is less rugged and a large proportion is cleared and in grass.

Middle Fork drains a rough region just west of the upper part of Tygart Valley River, to which it is tributary. There are no bottom lands along the stream, and as the rocks in its basin are chiefly sandstones the soil is poor. It is reported that not more than 5 per cent of its area is cleared. Much of the timber has been removed and active logging is now going on where any salable material is left. The land has not been damaged by erosion or floods.

On Rich Mountain, which forms the dividing ridge between Middle Fork basin and the main Tygart basin, the soil is derived from a conglomerate and the lands are rough and poor and very little farmed. On the south end much of the timber remains, but on the middle and northern part it has already been cut and the region is growing up in brush.

Buckhannon River is the next tributary of Tygarts Valley west of Middle Fork. The upper part of its basin is made rough by the sandstones and conglomerates into which the streams have cut sharply along the river and on its principal tributaries. Flood plain is either lacking or is sandy, stony, and of poor quality. On the headwaters in Randolph County not more than 15 per cent of the area is cleared. The remainder has been heavily forested, but in 1907 lumbering was being actively carried on. At Pickens and elsewhere there are large lumber mills, and back along the smaller streams there are numerous small portable mills. Where the land is not too rough it sods well when cleared and makes excellent pasture. No damage has been done by erosion, but the flood of July 17, 1907, greatly injured or destroyed whatever was in its reach, the principal loser being the railway company, whose tracks for the entire length down to Buckhannon run close by the river bank. At many places the roadbed was badly washed. Several of the logging tramways in the upper part of the basin were also damaged by the flood, the losses ranging from $10,000 to $30,000.

Farther down the Buckhannon, in southern Upshur County, where the sandstones largely disappear and shaly soils predominate, 35 per cent of the land is cleared, and the remainder has been lumbered—some of it twice. Northward the proportion of cleared land increases, and near Buckhannon and in the northern part of the county on Turkey and Hassicks runs 75 to 95 per cent of it is cleared, the proportion being larger in the western part of the county than in the eastern.

In the western and northern parts of Upshur County red shales are in places abundant, and where on steep slopes are likely to cause landslips that may do considerable damage to lands, roads, or even railway tracks that happen to be built on them. Where such areas are cleared they are kept in grass as much as possible. The streams in this northern and western part of the county have, as a rule, narrow, sodded flood plains, and flood damages during 1907 were confined chiefly to the growing grass and to the steep red-shale surfaces. No bridges were lost along the streams.

For several miles below Buckhannon the river is bordered by some beautiful fertile flood plains; it then enters a narrow trench and thence to its mouth has scarcely any flood plain, and the valley slopes are so steep that they are practically uncleared. Some of its tributaries, however, such as Pecks Run and Big Run on the west side, have excellent meadows, and their uplands are 90 per cent or more cleared. On the east side of the river the country is rough and poor, and comparatively little has been cleared. The merchantable timber has been removed and much of the land is in brush.

In the region west of Grafton the surface rocks are largely shales, and 60 to 90 per cent of the area is cleared; perhaps three-fourths of the cleared area is sodded. At no place was erosion conspicuous, though its work was apparent in some places, especially on red shale slopes where the land is cultivated. Floods during 1907 had damaged growing crops, but had improved rather than injured lands. No bridges were lost.

The valley of Lost Run is rougher and poorer and in its lower part is uncleared, though its commercial timber has been removed.

It is generally believed in this region that in basins where 60 to 90 per cent of the area is cleared and largely in sod, the floods rise more rapidly and reach greater heights now than formerly. It is also claimed that the streams in such basins show a greater tendency to go dry during summer and fall than formerly, when their basins were wooded. Many of the small streams invariably go dry at this season, and it is said that larger streams that were never known to go dry in olden times now fail entirely.

WEST FORK OF MONONGAHELA RIVER.

The upper end of the basin drained by West Fork of the Monongahela was formerly heavily timbered, but since the Sutton branch of the Baltimore & Ohio Railroad was built practically all of this timber has been removed. Three-fourths of the area is cleared and nearly all of it is in grass. The soil is derived mainly from soft shales. Somewhat lower in the basin, around Weston, 80 per cent or more has been cleared.

Almost all of the small tributary streams have narrow, flat bottoms that are in meadow and that have not been injured by recent floods. Above Weston there is no flood plain on the river, but below it in a few bends there are small areas of tillable land, and at a number of places there are terraces with flat tops and steep slopes, all of which are now high above the reach of floods. There is but little to injure along the river, and even the severest floods can do no great damage.

Along Hackers Creek there is some flood plain, and the hay and potato crops were greatly injured by the July, 1907, flood. The lands themselves, however, were unhurt. In some places red shale slopes had washed somewhat, but in no place had there been serious damage from this cause.

The rocks of Harrison County, across which West Fork flows after leaving Lewis County, consist chiefly of flat-lying shales, among which are interspersed some sandstone beds. The surface is steeply rounded, and the many tributary streams have minutely dissected it by trenches cut 400 to 500 feet below the general surface level. The narrow flood plains and nearly all of the uplands are cleared and sodded. There is only timber enough for farm use. It is estimated that between 80 and 90 per cent of the total area of the West Fork basin is in grass. The streams carry very little waste, and, as a rule, flow in deep channels. Floods escape rapidly and have caused no great damage. The heavy rains of July 16 and 17, 1907, did not extend so far west as this basin, but were confined to the Cheat and Tygart Valley rivers and their tributaries. The highest flood reported on West Fork is said to have occurred in 1888, when every bridge but one in the country was washed out and much other damage done.

The Winfield district, on the east side of the river, has more waste land than any district in Marion County. About 50 per cent of it is farmed, but much of the county is poor and rocky. On the west side 75 per cent or more is cleared, and two-thirds of the cleared area sodded. On the rest there is very little marketable timber left. The streams have at best very narrow flood plains, but since the flood of 1888 they have not been damaged by high water. The flood of July, 1907, was destructive farther east and that of March, 1907, farther north. At neither time was the river extraordinarily high in this part of the basin.

Some 15 years ago a railway was built from Morgantown up Deckers Run to Kingwood and on to Rowlesburg. The region was an almost primeval forest, densely wooded and covered with thick undergrowth, and contained many clear, cold springs. The streams rose slowly during floods and maintained a constant volume during dry seasons. With the building of the railroad, lumbering became active, and the region was soon stripped of its magnificent forests. Fires followed in the wake of the lumberman, and the dense undergrowth was also gone. The summer sun now beats down on a bare and parching land; in dry seasons the springs flow weakly or disappear, and the streams shrink to tiny rivulets. Forest and stream, cool shade, and cold spring are all gone, and the land is desolate.

At Morgantown the water supply was formerly obtained from several small streams, and although the necessity for supplementing the supply by drawing on the river has been caused by the growth of the town, the amount now available from the small streams during low-water stages has lately decreased to such an extent that it is impossible to supply from this source as large a part of the city as formerly.

On Deckers Creek in the last 40 years eight mill sites that were once profitable have been abandoned because for several months in the year the water is so low that they can not be operated steadily and profitably. The one mill that now survives is forced to remain idle a good part of the time from the same reason. Similar changes have occurred on Buffalo Creek and other streams that have been denuded of their timber to the same extent.

MONONGAHELA BASIN IN PENNSYLVANIA.

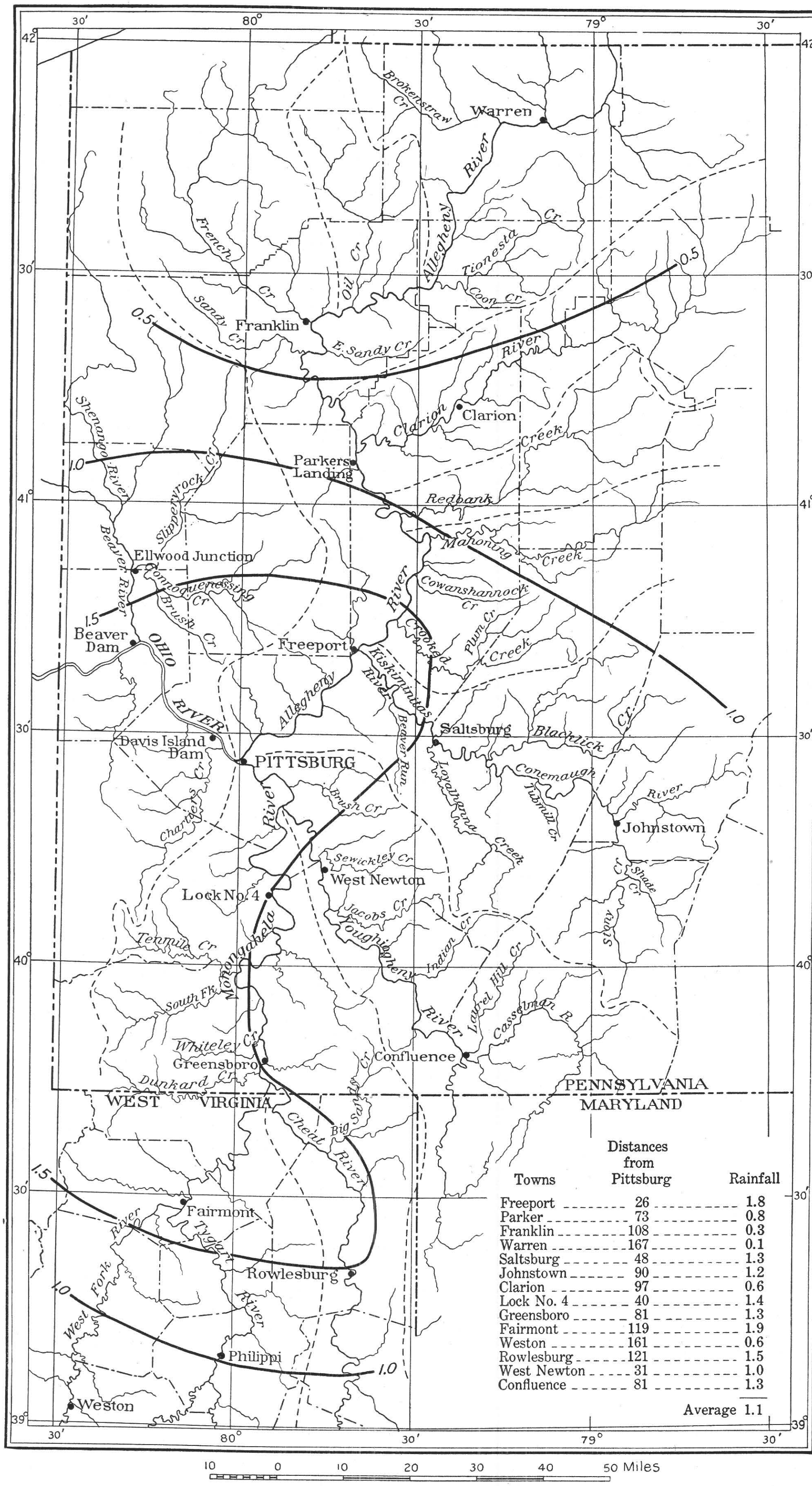
In Pennsylvania the Monongahela basin includes Fayette County, the eastern part of Green and Washington counties, the southern part of Allegheny County, and the western parts of Westmoreland and Somerset counties. With the exception of small areas in Laurel and Chestnut ridges, the rocks of the Pennsylvania part of the Monongahela basin are of Carboniferous age. On these ridges the soils are in general poor, but some small areas of limestone or calcareous shale have yielded good soils. In some places there are still areas of uncut timber, but much the larger part of the timber has been removed. Outside of these mountain ridges the surface rocks are shales, limestones, and sandstones. The limestone and the shale have yielded a soil that is generally fertile, but the soil on sandstones is thinner and the surface is generally rough. Where the streams cut through the shale the slopes, though in many places very steep, are rounded, but where they cut through sandstone the slopes are, as a rule, rough or precipitous. The steep shale slopes are mostly cleared and farmed; the sandstone slopes are generally forested.

The topography in these shales is much alike everywhere in the basin. The differences are those of degree and not of kind. As in the West Virginia part of the basin, the surface of the basin in Pennsylvania is an old plateau, now at an elevation of 1,200 to 1,400 feet and thoroughly dissected by the streams. The hill slopes are gentle or steeply rounded. The valley bottoms are not as a rule broad, but many of them meet the hills in gentle, flowing curves. In some places these hills stand up sharply; in other places their outlines are more subdued. In general cutting is deepest near main drainage ways and decreases near the heads of tributaries.

Wherever shale predominates 80 to 90 per cent of the land is cleared, and three-fourths or four-fifths of the cleared land is kept in grass. The slopes are not, on the average, as steep as in West Virginia and show less tendency to erosion, except on red shale, where the conditions in both States are the same.

The damages from all types of erosion on hill slopes and along stream ways are unimportant, and in many places damages from floods are reported to be rare. It is the general impression that stream flow in dry seasons is now much less than formerly; and on many of the creeks the grist, saw, and paper mills of earlier days have had to shut down for want of water. Some have quit business or moved elsewhere; others have substituted more expensive but more dependable steam power. On Redstone Creek, for instance, there is only one mill left, and only one or two remain on Georges Creek. Many springs of former days have dried up and disappeared, and streams now go dry in summer that are said not to have failed in olden times.

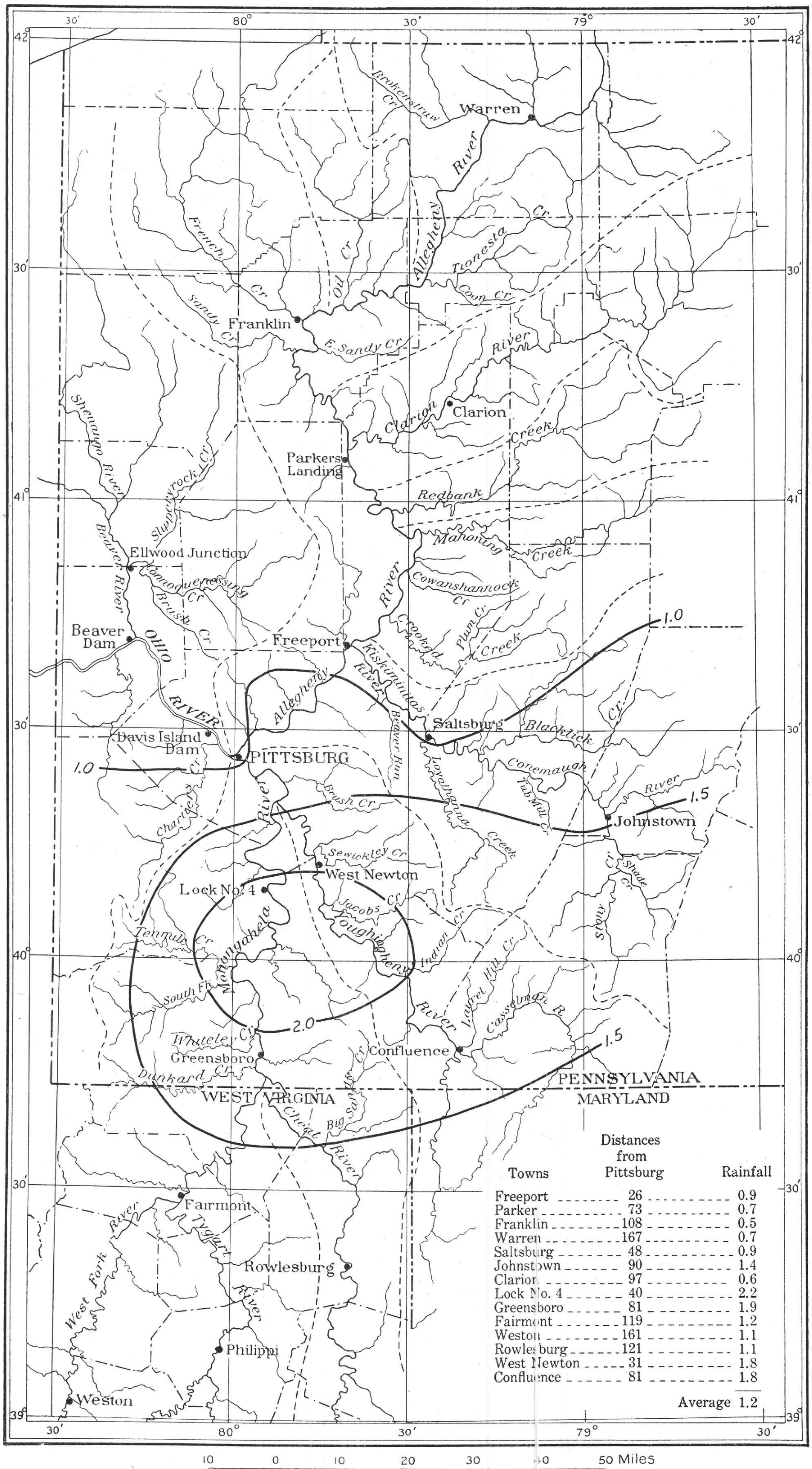
It would seem that man has made important changes in the Monongahela basin through deforestation. The deforested land has largely been put into grass, so that erosion such as characterizes so much of the Southern Appalachians is not common. For the same reason the stream channels in the Monongahela basin are not filling with sand and gravel and causing widespread destruction of bottom lands. The cleared grassland, however, permits the rainfall to run off more rapidly than formerly when the lands were forested, so that average flood heights have become greater and flood damages have increased accordingly, as is shown by the recent disastrous flood in Pittsburg.



Towns	Distances from Pittsburg	Rainfall
Freeport	26	1.8
Parker	73	0.8
Franklin	108	0.3
Warren	167	0.1
Saltsburg	48	1.3
Johnstown	90	1.2
Clarion	97	0.6
Lock No. 4	40	1.4
Greensboro	81	1.3
Fairmont	119	1.9
Weston	161	0.6
Rowlesburg	121	1.5
West Newton	31	1.0
Confluence	81	1.3
	Average	1.1

WEATHER MAP SHOWING RAINFALL NEAR PITTSBURG, PA., FOR TWENTY-FOUR HOURS ENDING 8 A. M. MARCH 13, 1907.

Distances in miles; rainfall in inches.

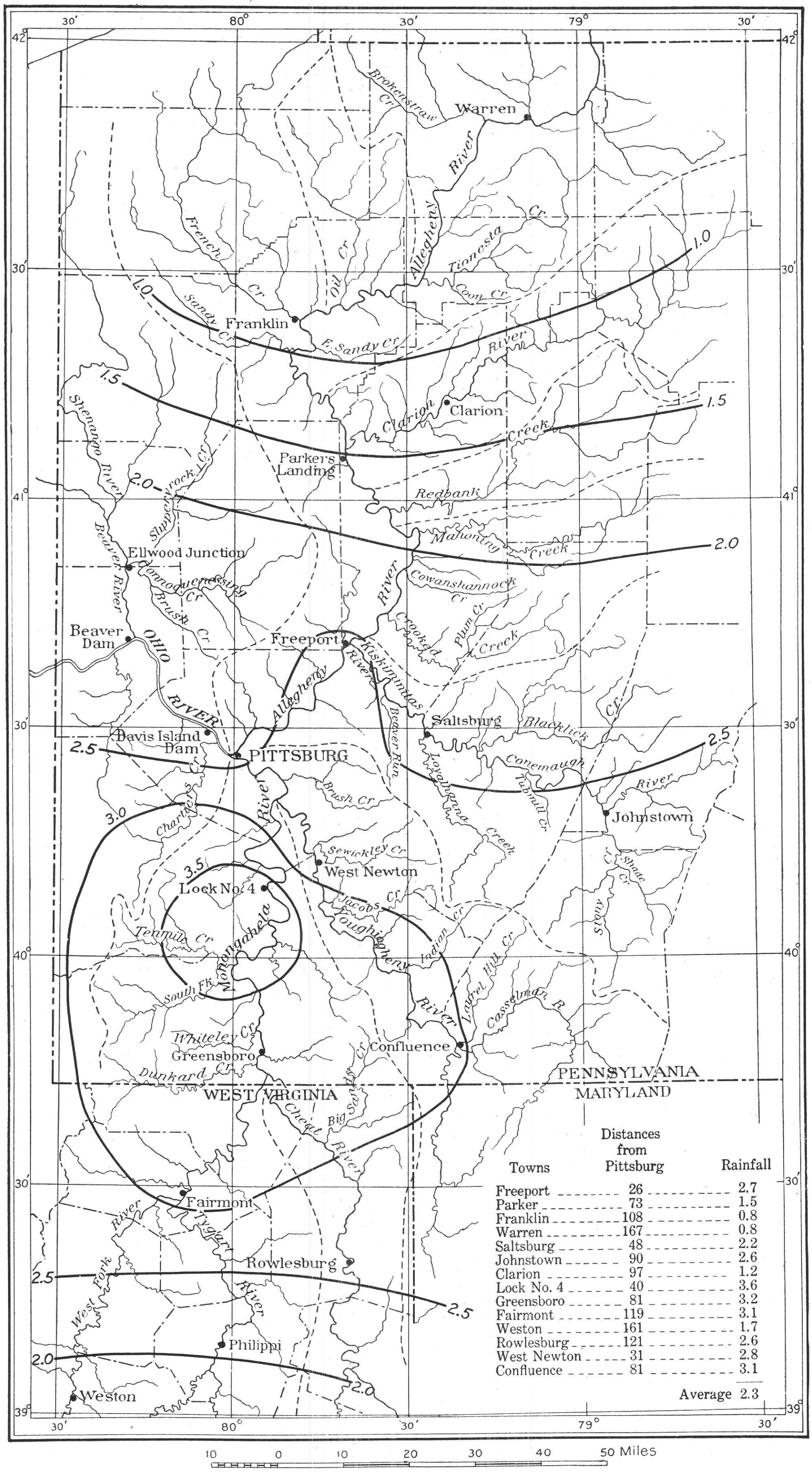


Towns	Distances from Pittsburg	Rainfall
Freeport	26	0.9
Parker	73	0.7
Franklin	108	0.5
Warren	167	0.7
Saltsburg	48	0.9
Johnstown	90	1.4
Clarion	97	0.6
Lock No. 4	40	2.2
Greensboro	81	1.9
Fairmont	119	1.2
Weston	161	1.1
Rowlesburg	121	1.1
West Newton	31	1.8
Confluence	81	1.8
	Average	1.2

10 0 10 20 30 40 50 Miles

WEATHER MAP SHOWING RAINFALL NEAR PITTSBURG, PA., FOR TWENTY-FOUR HOURS ENDING 8 A. M. MARCH 14, 1907.

Distances in miles; rainfall in inches.



Towns	Distances from Pittsburg	Rainfall
Freeport	26	2.7
Parker	73	1.5
Franklin	108	0.8
Warren	167	0.8
Saltsburg	48	2.2
Johnstown	90	2.6
Clarion	97	1.2
Lock No. 4	40	3.6
Greensboro	81	3.2
Fairmont	119	3.1
Weston	161	1.7
Rowlesburg	121	2.6
West Newton	31	2.8
Confluence	81	3.1
Average		2.3

WEATHER MAP SHOWING RAINFALL NEAR PITTSBURG, PA., FOR FORTY-EIGHT HOURS ENDING 8 A. M. MARCH 14, 1907.

Distances in miles; rainfall in inches.

PITTSBURG FLOOD OF MARCH, 1907.

In March, 1907, a disastrous flood in the Monongahela basin caused a loss of more than $8,000,000, chiefly in Pittsburg and its immediate vicinity. The conditions at Pittsburg preceding the flood, which reached the unprecedented height of 35.5 feet at 5 a. m., March 15, 1907, were unusual and in large measure produced the extraordinary stage and the great destruction wrought.

On March 10 and 11 there were between 4 and 8 inches of moist snow in the basin of the Allegheny and Monongahela rivers, and the temperature was 10° to 25° above the normal. Heavy rain fell in these basins on March 13 and 14 and rapidly melted the snow. The heavy rain and the melted snow at once ran into the streams, especially those in the Youghiogheny and Monongahela basins, and quickly raised the stream heights to dangerous levels. The absence of forest over so large a part of these two basins greatly hastened the run-off and raised the height of the flood beyond the stage that it would have reached under forested conditions. The great damage to property ($8,000,000) and the loss of nine lives are believed to be largely due to the deforested condition of these lands.

The weather maps reproduced in Plates XIX, XX, and XXI show that there was an unusually heavy rainfall in the two 24-hour periods ending at 8 a. m. on March 13 and 14 in the region just above West Newton on the Youghiogheny and Lock 4 on the Monongahela. The precipitation during the first of these 24-hour periods extended over the entire basins of the two rivers, but that ending on March 14 was by far the heavier and reached a maximum in the portions of the basins about West Newton and Lock 4, when both of the streams were already dangerously high from the melting of the snows and the heavy general rains of the preceding 24 hours. In the vicinity of both places 80 to 95 per cent of the country has been cleared, and this unusually heavy rainfall rushed rapidly down the steep cleared slopes to the streams and produced a local flood crest on top of the more general one which was already at a dangerous height, causing the unprecedented gage heights at West Newton on the Youghiogheny and at Lock 4 on the Monongahela. The flood crest on each of these streams some distance above these points failed by several feet to reach heights attained by previous floods.

This second flood gathered from the cleared hillsides suddenly and raised both rivers so rapidly that above this area of maximum rainfall the normal flood on each stream was checked, and for a very brief interval there is reported to have been a dead eddy in the Youghiogheny above West Newton and in the Monongahela above Lock 4.

The combination of unusual high temperature, melting snow, and heavy rainfall can not be foreseen or prevented, but when these were combined with a steep surface that had been largely denuded by man and so prepared to hurry the waters from the melting snow and the storm into the stream channels with the greatest possible rapidity the flood crest was raised to an extreme height. Had the basins of the Youghiogheny and Monongahela been more largely forested the river would probably not have reached the stage it did at Pittsburg.

It has been suggested that the encroachment on the river channel at Pittsburg was a cause of the extreme stage reached there, but when examined the encroaching structures seem too insignificant to produce this result, and it is very certain they could not cause the Youghiogheny at West Newton to rise 6.2 feet above all previous high records. It has also been suggested that the dumping of quarry refuse in the Ohio River had built out the point on its south bank just below the lower end of Brunots Island sufficiently to deflect the current flowing south of the island as it rejoined the northern current in such a way as to cause eddies that would greatly check the velocity of the Ohio and raise the flood level in Pittsburg. An examination of the quarry dump at this point showed that it was insignificant in amount and was not in proper place to produce such a result. It seems that the great flood, with its attendant damages, was due primarily to an unusual combination of natural conditions and was greatly augmented by man's agency in cutting away the forest within the watershed that received the great bulk of the rainfall.

TABLES.

The following tables give the names and location, by counties, of the streams considered in this paper. The streams are grouped to show main streams and tributaries and are arranged in classes, the basis of the classification being the character of the basins as regards timber.

Streams in timbered basins in which floods rise and fall slowly, carry little sediment, and do little damage.

Main stream.	Tributary.	County.
Nolichucky	Caney River, upper basin	Yancey County, N. C.
Watauga	No examples.	
French Broad above Asheville	Clear Creek	Henderson County, N. C.
	Crabtree Creek	Henderson and Transylvania counties, N. C.
	Little River	Transylvania County, N. C.
	Carson Creek	Do.
	Main stream, headwaters	Do.
	Davidson River	Do.
	Avery Creek	Henderson County, N. C.
	Mills River	Do.
Asheville to Hot Springs	Shut-in Creek	
	Little Pine Creek	Madison County, N. C.
	Big Laurel Creek	Do.
	Little Hurricane	
	Big Hurricane	
	Little Laurel Creek	Do.
	Shelton Creek	
Big Pigeon	Cataluchee Creek	Haywood County, N. C.
	Big Creek	
Little Pigeon	Alum Cave Creek	Sevier County, Tenn.
Little Tennessee	Oconalufty Creek	Swain County, N. C.
	Main stream (upper part)	Macon County, N. C.
	Forneys Creek	Swain County, N. C.
	Main stream from Bushnell to Wayside	Between Swain and Graham counties, N. C.
	Panther Creek	Graham County, N. C.
	Sawyer Creek	
	Tuckasegee River	Jackson and Swain counties, N. C.
	Cheoah River	Graham County, N. C.
	Nantahala, tributaries	Macon and Swain counties, N. C.
Hiwassee	Valley River	Cherokee County, N. C.
	Main stream down to Murphy	Clay and Cherokee counties, N. C.
	High Tower Creek	Towns County, Ga.
	Shooting Creek	Clay County, N. C.
	Tusquitee Creek	Do.
	Fires Creek	Do.
	Brasstown Creek	Towns County, Ga., and Clay County, N. C.
Oostanaula	Jacks River	Fanin County, Ga.
	Conasauga River	Murray County, Ga.
	Clear Creek	Gilmer County, Ga.
Etowah	Main stream (upper part)	Lumpkin County, Ga.
	Amicalola Creek	Dawson County, Ga.
Savannah	Upper tributaries in North Carolina, and main stream.	Jackson and Transylvania counties, N. C.
Chattooga	Main stream at Russell's bridge	Between Rabun County, Ga., and Oconee County, S. C.
Chauga		
Tugaloo		
Saluda		
Broad	Headwaters of Tiger River	Union, Spartanburg, and Cherokee counties, S. C.
	Pacolet River	
	Green River	Henderson, Polk, and Rutherford counties, N. C.
Catawba	Tablerock Creek	Burke County, N. C.
Yadkin		
New		

Streams in cleared basins in which floods are sudden, high, subside quickly, carry much sediment, and injure their flood plains by erosion, sedimentation, or dissection.

Main stream.	Tributary.	County.
Nolichucky	Main stream, upper basin	Yancey and Mitchell counties, N. C.
	Jack Creek	Yancey County, N. C.
	Little Crab Tree Creek	Do.
	Big Rock Creek	Mitchell County, N. C.
	Cane Creek	Do.
Watauga	Elk Creek	Carter County, Tenn.
	Roan Creek (lower)	Johnson County, Tenn.
	Doe Creek	Do.
	Wilson Creek	Carter County, Tenn.
French Broad above Asheville	Caney Creek	Buncombe County, N. C.
Asheville to Hot Springs	Main stream	In parts of Buncombe and Madison counties, N. C.
	Big Sandy Marsh, Little Sandy Marsh	Buncombe and Madison counties, N. C.
	Little Ivy River	Madison County, N. C.
Big Pigeon	No examples.	
Little Pigeon	No examples.	
Little Tennessee	Savannah Creek and tributaries	
	Johns Creek	Jackson County, N. C.
	Lower course of Tiger River and Pacolet River.	Union, Spartanburg, and Cherokee counties, S. C.
Catawba	Johns River	Caldwell and Burke counties, N. C.
Yadkin	Elk River	Wilkes County, N. C.
	Main stream near Elkin	Surrey and Wilkes counties, N. C.
New River	No examples.	
Chattahoochee	Deep Creek, tributary to Soque Creek	Habersham County, Ga.
	Tributaries near Pleasant Retreat and north of Cleveland.	White County, Ga.
	Flat Creek	Hall County, Ga.
	White Creek	Do.
	Mossy Creek	White County, Ga.
	Mud Creek	
	Lower main channel and tributary creeks.	Hall, Forsyth, Milton, Gwinnett, Dekalb, Fulton, and Cobb counties, Ga.
Savannah	Popcorn Creek	Rabun County, Ga.
	Timpson Creek	Do.
Chattooga	War Womans Creek	Do.
Chauga	No examples.	
Tugaloo	Crow Creek, Little River, Panther Creek, Oostanaula Creek, main stream at Shelors Ford.	Stephens County, Ga.
Saluda	No examples.	
Broad	Tributaries between Green River and Broad River.	Rutherford and Polk counties, N. C.

Streams in cleared basins in which tributaries carry little sediment, and do little damage.

[Basins generally grassed or with porous soil.]

Main stream.	Tributary.	County.	Reason.
Nolichucky	No examples.		
Watauga	Cove Creek	Watauga County, N. C.	Porous soil and swift current.
French Broad above Asheville.	No examples.		
Asheville to Hot Springs	Spring Creek	Madison County, N. C.	Clearings in grass.
	Big Pine Creek	do	Do.
Big Pigeon	Jonathans Creek	Haywood County, N. C.	Clearings largely kept in grass.
Little Pigeon	No examples.		
Little Tennessee	Upper Watauga Creek		Steep gradient of stream.

Streams in timbered areas in which tributaries do damage to flood plains during floods following erosion caused by logging on steep slopes.

Main stream.	Tributary.	County.	Reason.
Nolichucky	No examples.		
Watauga	Do.		
French Broad above Asheville.	North Fork of Swannanoa	Buncombe County, N. C.	Slopes injured during lumbering.
Asheville to Hot Springs	No examples.		
Big Pigeon	Do.		
Little Pigeon	Do.		
Little Tennessee	Soco Creek	Jackson County, N. C.	Lumbering.
Hiwassee	No examples.		
Oostanaula	Do.		
Etowah	Do.		
Chattahoochee	Do.		
Savannah	Tallulah River basin, upper part.	Rabun County, Ga	Forest fires.
Chattooga	No examples.		
Chauga	Chauga River	Cone County, S. C	Lumbering.
Tugaloo	Brasstown Creek.		
Saluda	North Saluda (headwaters)	Greenville County, S. C.	Not given.
Broad	No examples.		
Catawba	Do.		
Yadkin	Do.		
New	Do.		

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