Water-Supply and Irrigation Paper No. 192

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DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE POTOMAC RIVER BASIN

GEOGRAPHIC HISTORY—RAINFALL AND STREAM FLOW—POLLUTION, TYPHOID FEVER, AND CHARACTER OF WATER—RELATION OF SOILS AND FOREST COVER TO QUALITY AND QUANTITY OF SURFACE WATER—EFFECT OF INDUSTRIAL WASTES ON FISHES

BY

HORATIO N. PARKER, BAILEY WILLIS, R. H. BOLSTER,
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INTRODUCTION.

SCOPE OF THE PAPER.

Hardly a river basin in the country is of more importance from the point of view of the utilization of water resources than that of the Potomac. The water power developed in this area drives the wheels of many mills, and the waters of the streams are used in the processes of diverse industries. The beauty of the streams and the supply of fish have made a large portion of the basin a recreation ground for thousands of people, while the Potomac itself furnishes drinking water for the National Capital. In order to obtain definite information on the character of the water supply an extensive investigation was undertaken jointly by the Geological Survey, the Bureau of Forestry, and the Bureau of Fisheries. The result of this work is the present paper, in which are described all the conditions that affect the economic utilization of the water resources. The scope of the paper is best shown by enumerating the principal features of the investigation, which are as follows:

1. A study of the geographic history of the basin.
2. The determination of the amount of water flowing in the principal streams, a compilation of all data relating to the quantity of water, and a study of the distribution of the rainfall.
3. A complete reconnaissance of the drainage area with respect to sources of pollution, a study of the prevalence of typhoid fever in the District of Columbia and at other points, and an investigation of the quality of the surface water as shown by field assays and sanitary and mineral analyses of water taken at many points.
4. A study by the Bureau of Forestry of the effect of the soils and forest cover on the turbidity of the water and the flow of the streams, and the preparation of a map showing the forest conditions.
5. A study by the Bureau of Fisheries of the effect of industrial wastes on fishes.

ACKNOWLEDGMENTS.

The lively interest shown by many citizens of the Potomac basin in this report and the help they have given in its preparation are much appreciated. Especial recognition is due to W. D. Bryon & Sons, the United States Leather Company, J. R. Cover & Sons, the Hambleton Leather Company, the West Virginia Pulp and Paper Company, the Potomac Pulp Company, the Blue Ridge Knitting Company, the Washington Gas Light Company, and the Clapp Ammonia Company for furnishing samples of the effluents from their factories. This cooperation on their part has added materially to our knowledge of the effect of industrial wastes on fish life.

Acknowledgment should be made to the United States Weather Bureau for rainfall data; to the Chief of Engineers of the United States Army for profiles and elevations along certain portions of the river, and to the Maryland Geological Survey for the maintenance of the gages on Monocacy River and Antietam Creek.

HISTORICAL SKETCH OF THE POTOMAC BASIN.

By Horatio N. Parker.

The Potomac became of moment in English annals with the settlement of Jamestown, Va. Capt. John Smith discovered the river (Patawomek, as he spelled it) June 16, 1608, and sailed upstream about 30 miles to a point where, after having met with a hostile reception from the Indians, he landed on the Virginia shore. From this place, probably Nomini Bay, he continued up the river, touching at various points, until he had passed the present site of Washington, "having gone up as high as they could in a boat." Here they were met by savages in canoes loaded with the flesh of deer, bears, and other animals, of which they obtained a portion. On their return journey they met with many adventures, but reached Jamestown in safety. In early colonial times the name Potomac was applied to the river from its mouth to its junction with the Shenandoah at Harpers Ferry. The portion of the river from that point to its source at the headwaters of North Branch was called the Cohongoruton, a name said to be a corruption of the Indian Kohonk-on-roo-ta, or "wild goose stream," from the great number of wild geese that inhabited it, the "ko-honk! ko-honk!" of the bird suggesting the term.

Lord Fairfax in his land grants on this part of the watercourse designated it Potomac, by which means it gradually lost its ancient name. Shenandoah River was first called Gerando, then Sherandoah, and finally Shenandoah. For a long time after the settlement of Jamestown the colonists, terrified by the gloomy forests of the interior, clung to the coast; but in 1716 Governor Spottswood led an expedition to the Blue Ridge and reached its summit, probably near Swift Run Gap. He descended into the valley, crossed the river, which he named Euphrates, and took possession of the country in the name of the King of England. There were no direct results from the expedition, but it had the good effect of dispelling the mystical terror with which the colonists had invested the region.

Prior to its occupation by the settlers the valley of Virginia was a hunting ground for various Indian tribes, who burned the grass every fall before going into winter quarters in order to keep down the forests. Consequently the only timber was along the streams and well back in the mountains. The forests that now exist have sprung up since those times. The trails followed by the colonists through the mountains were established by the buffaloes and other large game and were well worn by the Indians. The valley, as has been said, was a hunting ground rather than a permanent abode of the aborigines. Hence the few villages in it were of a temporary nature and had a fitful existence. The game consisted of buffalo, elk, deer, bear, panther, and wild cats, besides beavers, wolves, foxes, and other animals. The Indians welcomed the Pennsylvania colonists because of the trust they had in William Penn, but they showed great hostility toward the settlers from tide water, whom they called "The Long Knives," and whom they hated. In 1753 emissaries from west of the Alleghenies came among the valley Indians and invited them to cross the mountains, which they did in 1754. Their sudden exodus caused much uneasiness among the Virginia colonists, who feared that the action foreboded impending hostilities. This proved true enough, for it was probably French influence that coaxed the Indians away, and after Braddock's defeat they terrorized the valleys of South Branch and the Shenandoah, committing many outrages, and not being driven back until the close of the French and Indian war.

The upper and lower portions of the valley of Virginia were settled at about the same time. The colonists of the tide-water region made their way up the lowland rivers and finally passed over the mountains into the valley, and at the same time, or a few years before, the region toward the Potomac was settled by Scotch-Irish and Germans from Pennsylvania. The Scotch-Irish were the pioneers and established homesteads along Opequon Creek from the Potomac to what is now Winchester. The Germans followed. Joist Hite, in 1732, obtained a grant of 40,000 acres and with 16 families moved from Pennsylvania, cutting the road from York, crossing the Cohongoruton 2 miles above Harpers Ferry, and settling on Opequon Creek 5 miles south of Winchester. His followers built Strasburg and other towns along Massanutten Mountain. In 1733 Jacob Stover took a grant for 5,000 acres of land on South Fork of the Shenandoah, and in 1734 settlers from Monocacy, Md., located on North Fork of the Shenandoah, 12 miles south of Woodstock. Two cabins, erected in 1738 near Shawnee Springs, were the beginning of the town of Winchester, long a frontier post of the colony in that quarter. John Lewis brought over from Ireland and Scotland 100 families and settled near what is now Staunton, Augusta County. Conococheague Creek was settled at Greencastle, Pa., in 1734, the place being first known as the Conococheague Settlements. In 1734 Richard Morgan obtained a tract of land near Shepherdstown, the oldest town in West Virginia. Romney, W. Va., was laid out by Lord Fairfax in 1742 and is the second oldest town in the State. In 1748 Robert Harper, an English millwright, came to Harpers Ferry. Benjamin Allen, Riley Moore, and William White built homes on the Monocacy prior to 1734, and in 1735 the Schleys, with about 100 families from Germany, Switzerland, and France, established themselves on the Monocacy, the first house in Frederick being erected by Thomas Schley in 1735. By 1748 the German immigrants had taken possession of many valuable tracts along Monocacy River and Catoctin Creek. At an early period many immigrants became occupants of the Cacapon and Lost River valleys and numerous settlements were made on Back and Cedar creeks. In 1741 Col. Thomas Cresap, with his own and several other families, located at "Shewaneese" Oldtown, on North Branch of the Potomac.

The first settlers on the Wappatomaka, as South Branch of the Potomac was called, located in 1734 or 1735. They failed to secure title to their lands, and so became involved in a dispute with Lord Fairfax, who, they felt, dealt harshly with them. There is a tradition that Lord Fairfax became interested in his Virginia venture through meeting John Howard, who, with his son, is said to have explored the valley of Virginia prior to its settlement and to have discovered the valley of South Branch, crossed the Allegheny Mountains, and gone down Ohio and Mississippi rivers to New Orleans, where they were arrested as suspicious characters and sent to Paris; thence, no cause being found for holding them, they went to London, where the meeting with Lord Fairfax is said to have occurred. Lord Fairfax came to Virginia in 1742 and opened an office in Fairfax County for granting land warrants. A few years later he moved to what he called Greenway Court, 12 or 14 miles southeast of Winchester, where he kept his office until he died in 1781. His surveyors decided that North Branch was the main stream of the Potomac and located the "Fairfax Stone" at its head October 17, 1746. This action was greatly to his advantage, for had South Branch been chosen as the "first fountain" the Fairfax holdings would have been much reduced. Later the States of Virginia and Maryland became involved in a dispute as to the location of the boundary line between them, and though the question has never been settled Virginia has been able to maintain the North Branch as the boundary, basing her claim on the location of the "Fairfax Stone."

In 1725 John Van Metre, a trader from Hudson River, traversed the lower Shenandoah, upper Potomac, and South Branch valleys, and at Hanging Rocks witnessed a bloody battle between two parties of Indians. He returned home much impressed with the richness of the South Branch region and advised his sons to move there, which they subsequently did. The earliest settlers found a natural clearing in the woods at Oldfields and built a fort there, which was the scene of many fights with the savages.

Lands on Patterson Creek began to attract the pioneers a little before Fort Cumberland was completed in the winter of 1754–55. In 1728 there was an Indian town known as Caiuc-tu-cuc on the ground between Wills Creek, or, as it was then known, Caiuc-tu-cuc Creek, and North Branch; it was located for the most part upon the site of the west side of what is now Cumberland. The Indian village was abandoned and in its place a settlement of whites slowly grew up. The last Indian to remain and have authority was known as Will, and the town for a long time was known as Will's Town, the creek as Will's Creek, and the mountain where he had his home as Will's Mountain. His rights in the country appear to have been recognized, for the early settlers always made him a present when they took up land. The first comer to Cumberland of whom there is record was an Englishman named Evitt, who led the life of a recluse in his cabin on top of Evitts Mountain, where he died before 1749.

Georges Creek took its name from an Indian, George, who had his hunting lodge on the present site of Lonaconing. He was a favorite of and lived with Col. Thomas Cresap, of Oldtown, who had employed his father, Nemacolin, to mark out the road from Cumberland to Brownsville, on the Monongahela. General Braddock followed the path and the national road varies but little from it. This testifies to the excellent manner in which the Indian did his work.

Cumberland was long the outpost of civilization in the Potomac Valley. The last refuge of the Indians was on Savage Mountain; hence its name. The first settlers on Georges Creek came from New Jersey and Virginia. Prior to 1830 there were not more than 30 houses in Georges Creek valley. North Branch above Westernport seems to have been well known at an early date. Washington, on his return from the trip to Ohio in 1784, crossed the stream and mentions in his journal for September 26 that he was told by Joseph Logston, who had hunted along the river, that there was no fall in it, and that from Fort Cumberland to the mouth of Savage River the water was frequently made use of in its natural condition for canoes, and that from thence upward it was rapid only in places, with loose rocks which could be easily removed.

September 27 Washington crossed Stony River, which he speaks of as appearing larger than North Branch. On his return to Mount Vernon he made a map of the country he had visited, on which was shown North Branch with the tributaries Difficult Creek, Stony River, Abrams Creek, New Creek, Georges Creek, Savage River, and the head of Patterson Creek. A map by Joseph Shriver, published in 1824, shows North Branch from Westernport to its source, the only town above Westernport being Paddytown, now Keyser, W. Va.

Coal seems to have been known to the earliest settlers. In 1804 it was discovered near the present site of Frostburg. In 1810 a tremendous freshet stripped the earth from the banks of Guinea Run, displaying the coal on what is known as the Barton property. People came from miles around to see "the mountain of coal." For some time is was mined with mattocks and the ore was hauled to Winchester and Romney for blacksmithing purposes. In 1814 or 1815, while the national road was being made, coal was found at Eckhart Mines and was hauled in wagons to Cumberland and Baltimore. Three or four bateaux arrived at Washington April 20, 1826, laden with coal from the rich mines at Cumberland. Up to 1842 merchants, laborers, and others engaged in various pursuits in the summer and worked in the mines or coal banks, as they were called, in the winter, some as teamsters, some as boat builders, and some as miners. The coal was hauled to the river bank and piled there in large quantities. In the spring freshets the boats, which hauled from 1,000 to 1,500 bushels, were sent down the river to the purchasers. The flatboats were not returned, but occasionally a keel boat laden with supplies was laboriously poled back. From 50 to 60 boats, carrying an aggregate of 75,000 bushels of coal, comprised the total shipment each year previous to the completion of the Baltimore and Ohio Railroad in 1842. As the coal business was conducted up to that time, it was hazardous to capital and destructive to the lives of those engaged in carrying it on, many boats being wrecked on the rocks in the river. Hence few mines were worked, the chief being the old Eckhart mine, 9 miles west of Cumberland. The Georges Creek Coal and Iron Company was the first to develop mines west of Frostburg. It began excavations for its iron furnace in 1836. Coal was first shipped on the Chesapeake and Ohio Canal in 1850. The coal fields of North Branch above Piedmont were described by Prof. W. B. Rogers in 1839 in his report on the geology of Virginia.

The orderly development of the Potomac Valley proceeded until the outbreak of the civil war, when the arts of peace were suspended and this battle ground of the Indian became that of the white man. The great battles of Antietam and Gettysburg were fought within the valley's borders, as were a host of other no less bravely contested engagements. For four years the work of destruction went on, but with the advent of peace in due time came prosperity, which has continued, until to-day the growth of the industries and population in the valley is healthy and vigorous.

GEOGRAPHIC HISTORY OF POTOMAC RIVER.

By Bailey Willis.

GENERAL DESCRIPTION OF BASIN.

The Potomac, rising among the Allegheny Plateaus and Appalachian Ranges,[a] gathers its waters in a main channel which crosses the grain of the country in a southeasterly course. Its mouth is an estuary, a branch of Chesapeake Bay. Washington is situated at the head of tide water, where the estuary receives the river proper. The stretch from Washington upstream to Cumberland, a distance of 108 miles in a direct line and 186 miles by the river, is the trunk channel. The Shenandoah, Great Cacapon, and South Branch are its principal feeders. They enter from the southwest. North Branch is the actual head of the river. The tributaries from the northeast are relatively short, Wills Creek, Conococheague Creek, and Monocacy River being the principal ones.

Although the Potomac watershed is a mountainous region, characterized by ranges of notable height and continuity, it is not limited by the greater elevations. We are apt to think of the basin of a river as an area surrounded by a high or at least obvious divide, but that is not true of the Potomac. Its trunk channel cuts across the ranges; its branches embrace them; its headwaters in North Branch invade even the plateau whose bold scarp suggests an unbroken divide. The principal streams rise in valleys which extend with undiminished width and without change of the gentle slope beyond the head springs. In their continuation other springs and brooks gather and flow in a direction opposite to that taken by the waters of the Potomac. The parting streams are opponents, which compete for territory. The basin which the Potomac may drain is limited by its competitors. The Susquehanna holds the valley of Pennsylvania, the James is entrenched in southern Virginia, and the Big Kanawha and Monongahela contest the western plateau region.

The shape of the Potomac drainage basin west of the Blue Ridge is oval; its length, northeast to southwest, being 160 miles and its width

[a] Powell, J. W., Physiographic regions of the United States: National Geographic Monographs, vol. 1, No. 3, 1895, map.

but 80 miles. In consequence of the great length of the southern tributaries, the trunk channel crosses the northern part of the basin and leaves the oval at its northeast corner, where it and the brooks that join it constitute a triangular expansion of the watershed.

The arrangement of streams within the watershed deserves notice. By a study of the outline map (Pl. II) it will be seen that there is a peculiar parallelism among the many rivers flowing to the northeast or southwest, and also a marked tendency to courses which for short distances are at right angles to the general direction. The arrangement is a common one in certain regions, and a stream system thus developed is known as "trellised drainage," from the resemblance which the rivers bear to the stems of a vine on a trellis. While a trellised plan exists in much of the Potomac basin, it does not extend throughout. Another plan is to be noted, for example, in the Monocacy, Goose Creek, headwaters of the Shenandoah, and highest forks of North Branch. This is a plan characterized by acutely branching streams which divide as do the limbs of an elm tree.

Trellised drainage of the Potomac is restricted to the Appalachian Ranges and results from the grain of the country; that is to say, from the fact that the rocks are arranged in layers which show their edges at the surface and thus extend long distances in one direction. Some are hard (sandstones) and some are soft (shales and limestones). Ridges persist on the hard belts as valleys develop on the soft rocks between, and the streams for the most part follow the grain. There are conditions, however, under which they must cross from one valley to another, which they do in a gap at right angles to the sandstone ridge; hence the short, transverse courses at right angles to the longitudinal ones.

Where the rocks which appear at the surface are of the same texture and solubility over a considerable area, the streams find no belts especially adapted to the development of valleys; neither are there any harder layers peculiarly competent to maintain ridges; and in engraving the bas-relief of hills and ravines, the streams grow according to minor accidents of the surface, as gullies grow in a field.

Specific names have been given to the various patterns which river systems assume. Where the valleys are developed on belts of soft rocks, and ridges are maintained by hard rocks, the streams are said to be "adjusted." Trellised drainage is adjusted. Where the branches diverge upstream from one another like the gullies in a field or the branches of an elm, they are called "self-grown," or "autogenous." The Monocacy presents an example of the autogenous pattern.

We have thus far considered the plan of the Potomac system as it appears on a map. The vertical profile and cross section also present significant peculiarities.

DRAINAGE MAP OF THE POTOMAC BASIN.

An ideal river profile is a curve which descends sharply near the source, becomes flatter and flatter, and at the mouth is a straight line, tangent to the level of discharge. The ideal curve is concave upward from source to mouth. The Potomac departs very decidedly from this ideal. The trunk channel from Cumberland to Washington is interrupted by rapids, which separate long flat reaches; at each rapid the profile is broken by a sharp bend, which is convex on the upper side—the reverse of the ideal. Near the very mouth of the river is Great Falls, over which the waters plunge to a series of lesser rapids that descend sharply to tide water. This is not at all the normal tangent. (See profiles, Pls. V and VI, p. 182.)

The tributaries exhibit profiles possessing similar irregularities, and it is particularly noticeable throughout the system that wherever a smaller stream enters a larger one a rapid or cascade marks the final descent of the smaller.

The ideal cross section of a river valley is, like the ideal profile, a curve which is concave upward and flattens from the divide to the stream. In this respect also the Potomac and its tributaries depart from the normal. The cross sections of the valleys are made up of steep slopes and flats, which constitute an irregular curve. Descending steeply from a divide, the traveler comes upon a flat or plain, which may extend for several miles. Although the surface of the flat is as a rule deeply cut by brooks, the journey may be continued nearly at a level by following the spurs between them. But wherever a stream, large or small, is approached, it is necessary to descend sharply into a trench. Along the lower Potomac, below Great Falls, this trench is a picturesque canyon 220 feet deep. The flat on each side of it is an outer valley several miles across. Along the Shenandoah similar features are found, the river flowing at the bottom of a ravine, while the broad plain of the great valley of Virginia stretches away with nearly level though dissected surface to the Blue Ridge and Massanutten Mountain.

DEVELOPMENT OF THE RIVER SYSTEM.

Enough has been suggested in the preceding description to show that the Potomac and its tributaries are regarded as an individual stream system which has developed from some previous condition to its present proportions. It has been limited in growth by competition with neighboring rivers. Its development has been directed along lines of least resistance and its branches have extended in belts of weak rocks. It has sculptured the surface, its rills, rivulets, brooks, creeks, and branches everywhere constantly taking some material in solution or as sediment and delivering it to the trunk stream, which carried it away. The features which the river has modeled are the channel or inner canyon in which it flows, the broader valley that expands at a higher level, and the steep slopes of the ridges that rise within and around the basin. But these are the features of the entire landscape, except perhaps the highest parts of the ridges; and they, too, owe their long level crests to the activity of the river, as will be better understood when the history is traced.

We recognize that the Potomac has been, and indeed is, a working, growing system. Its task is to excavate its basin, to erode valleys and mountains till no elevations remain. Its power depends on its volume, its fall, and a just proportion of sand with which to cut away the hard rocks in its course.

The trunk channel being deepened, the tributary channels have also been cut down, but not so speedily; hence the rapids near their mouths. The deepening, spreading from the main stream to large branches, from the large branches to their forks, and from each fork to the smallest rivulets, has extended outward over the entire basin. It proceeds immediately from an elevation of the land. Its limit is the lowest level to which the main stream can cut its channel at its mouth—the level of discharge, from which when the work of channel cutting is done the profile will rise in the long ideal concave curve. A stream that has reached that stage is said to be graded. It is evident that the Potomac has much work to do before it can be called a graded stream.

The channel of the main river will usually become graded before those of its tributaries, and the next step is the grading of the valley slopes. Each brook, rivulet, and rill goes through the same process as the main stream. The effect is reduction of the slopes to the inclination on which the waters flow but do not cut. As the grade extends to the higher divides, even they are reduced, and in time the lowest possible slope is established over the entire surface of a river basin.

Anyone familiar with the mountains among which the Potomac flows may well pause to ask if such a leveling of their heights can ever be accomplished; but the student of the river's history learns not only that in time they must be leveled, but also that in times past the river has had the work then before it much more nearly accomplished than now. It now runs in a canyon which it is deepening. It once flowed on the level of the outer valley, which it had cut to that level and widened to an extensive grade. Indeed, long before that it had taken its course over a plain which coincided with the tops of the present ridges and which it had graded from still older mountains.

The history of the river's work has been one of successive gradings in consequence of successive elevations of the land. Let us attempt to follow its major outlines.

Age is a subject not usually discussed with reference to rivers and mountains. They all appear very old. But some are older than others, and among the rivers of North America the Potomac and its neighbors are of an older generation. The Appalachian Ranges, on the other hand, are relatively young; and so it happens that the Potomac is older than the mountains in which it rises and across which it flows. It may, however, be compared to a tree of which the trunk is aged, while the branches and branchlets are younger, some of them very young. The careful student of physiography will some day search out the history of the system as a whole and of each branch separately—a complex study, for which the data are not yet available; but we can indicate the principal facts and, where our present knowledge halts, point out the problem to be attacked.

Before there was a Potomac, in the age of the coal deposits of the Carboniferous, streams flowed southwestward from New York, eastern Pennsylvania, and eastern Virginia toward the interior sea that lingered over the Southwestern States. We feel confident of this, because the relative positions of land and coal marsh and sea are recorded in the rocks laid down at the time, but we can not identify the position of any particular river. There were then no mountains where the Appalachians now extend, but ranges began to develop in the next succeeding epoch, during what is known as the Appalachian revolution. Very great changes occurred in the relative positions of land and water, and the movement of the earth's crust was such that a belt of strata 100 miles or more in width, extending from New York to Alabama, and from 10,000 to 30,000 feet thick, was folded so as to produce arches and troughs. The effects were no doubt of gradual development, but in all probability they were such that the arches attained the height of notable mountains, and the troughs became open valleys or inclosed basins. The previously existing streams were more or less checked and diverted by folding of the strata, and we suppose that they were so effectually changed that a new river system was substituted for them. A portion of that system flowed on a surface above the Potomac basin, and the Potomac is probably descended from it.

The geologic age referred to in the last paragraph is the Permian, an age during which aridity was a common, if not a general, condition of the climate of several continents. It is possible that the climate of the Appalachian province was for a longer or shorter epoch so arid that rivers ceased to flow, but there is no direct evidence of the condition.

We suppose that the oldest rivers, which developed courses on the surface of the folded strata, flowed along the troughs and across from trough to trough, between and across the arches that stood as mountain ridges. The courses were essentially parallel to those of the trellised system of the present time, but the trunk channel may have led the waters westward toward the interior sea, instead of southeastward to the Atlantic, as is now the case.[a]

The surface was then several thousand feet above the present surface. Even the mountain tops which we now see were then deeply buried beneath solid rock and lay below sea level. A swelling of the earth's crust has since raised the mass of the Appalachian Mountains.

Thus the earliest rivers with which the Potomac may be related are those which developed in consequence of the folding that occurred in the Appalachian region during the Permian age. Their courses are supposed to have been determined by the troughs or valleys which resulted from folding, and they are therefore called "consequent."

Consequent streams are those which flow in the direction of slope that is due to folding or warping of the surface. They differ from adjusted streams in that they take their courses along a low line or down a slope instead of working out a valley in soft rocks. But in a region like that of the Potomac, where beds of hard and soft rocks occur in long parallel folds, a consequent system becomes an adjusted system at an early stage of valley cutting.

The folded structure of the Appalachian Ranges has been carefully studied, and we are able to locate the lines which were the bottoms of troughs in the Permian surface. Though high above the present surface, the deeper troughs closely corresponded in position with Massanutten Mountain, Great North Mountain, and South Branch Mountain. Rivers which occupied them flowed parallel to the present streams, but along and above the now existing mountain tops. The old valleys have become mountain ridges. This change is of frequent occurrence in the process of adjustment, as streams sink their channels through alternate hard and soft strata,[b] and there is no difficulty in understanding how the rivers that now flow by the sides of the former troughs, or even in valleys along the crests of arches which correspond with former mountains, are related to the old consequent system.

Another trough which should be mentioned is the valley of Georges Creek and North Fork above Bloomington. It is one of the deepest troughs in the Potomac basin, and we need not doubt that it was occupied by a branch of the consequent drainage, but on a valley bottom high above the present surface.

Following the line of thought suggested in the preceding paragraphs, we may state the simplest outline of the history of the Potomac in the following way: The Potomac is the descendant of a consequent drainage system which developed on the Permian surface during or after the Appalachian folding. Being established in a region which presents an alternation of decidedly hard and soft

[a] Davis, W. M., Rivers and valleys of Pennsylvania: Nat. Geog. Mag., vol. 1, 1889, pp. 222 et seq.

[b] Willis, Bailey, Topography and structure of the Bays Mountains: School of Mines Quarterly, vol. 8, 1887, pp. 242-252.

rocks arranged in long, narrow belts, the streams have become adjusted to the softer strata. In sinking their channels down through several thousand feet of varying rock they have indeed become so thoroughly adjusted that stretches beneath the old valleys have become mountain ridges capped with hard sandstone, and valleys are developed on either side, in places even along the tops of arches.

Granting this statement the advantage of being probably true, we may compare it with one that we are descended from Adam. Many links are omitted and much is unaccounted for. It is not enough to know the structure of a river basin and the adjustment of the river system to it. We need to know also the profiles and cross sections of the valleys and the deposits which the river from time to time in the course of its long existence has made in them, as well. Furthermore, we need to look over the mountain tops to ascertain what remnants of old surfaces are there visible.

To pursue the subject more closely it is necessary to digress to the history of the mountains before the elevation of the ranges which we now see.

The Permian Appalachians are known to have been greatly elevated in the process of folding. It is possible that elevation progressed so slowly that erosion nearly kept pace with it in wearing down the heights, and if so, the mountains never attained great altitude; but it is more likely that the elevation went on with comparative rapidity and was attended by the development of conspicuous heights. This inference rests, however, on geologic reasoning. There are no great mountains to which one, looking abroad over the Appalachian Ranges, can point as Permian mountains. On the contrary, he who looks across from Massanutten to Great North and from Great North to the Allegheny Front sees long, even-crested ridges, which suggest a plain. If the valleys were filled to the rim with the material which the streams have carried away, the region would become a plain; and above such a surface stood the mountains of Permian time. They are no longer there.

In the lowlands of New Jersey, eastern Pennsylvania, Maryland, and Virginia there are deposits of red sandstone and mud rock, the materials of which were derived from adjacent areas, in large part from the district of the Permian mountains. The strata are Triassic, slightly more recent than the Permian, and are of such volume that if restored en masse to the place of their origin they would form a considerable mountain chain. They no doubt represent a part of the Permian mountains which wasted away under attacks of eroding agents.

It is a somewhat surprising conclusion that the Permian Appalachian Mountains not only wasted to low hills, but disappeared so completely that a plain extended from sea level across much of the region where they previously stood; yet that such was the fact we are led to believe by two lines of reasoning. Spread over the Atlantic Coastal Plain are deposits of gravel, sand, and clay washed from the region to the west during the epochs succeeding that of the strata which represent part of the waste of the Permian Appalachians. Geologists class the epochs as Jurassic and Cretaceous. The deposits are small in amount, and if restored to the watersheds of the streams which carried them away would not materially increase the altitude of the surface. As there is no mass of sediments of that time equivalent to a mountain range in volume, we reason that there was no range. The only escape from the conclusion is through the assumption that thicker deposits lie buried out to sea; but well borings show that the strata which do exist there are of fine calcareous material, chiefly marine sediment, which does not represent the immediate waste of mountains.

In corroboration, if we look over the Appalachian Ranges for remnants of highlands which may have existed during Jurassic and Cretaceous times, we find them of slight extent. The principal summits of the Blue Ridge, scattered heights of the Allegheny Plateaus, and the big balds of the Great Smoky Mountains were then low, rounded hills.[a] They still possess that form. Extending from them at a lower level are the long, even crests of the Appalachian Ranges, which, if the valleys between them were filled, would correspond with the surface of a plain. Once nearly level, this plain is so no longer. In West Virginia it lies at an altitude of 4,000 feet above the present sea level, but west of Washington it sinks to 1,000 feet, and near the city passes under the surface, being buried by the gravels and clays of the so-called Potomac formation, which is at the base of the Jurassic and Cretaceous sediments above referred to. The topographic features of the time are thus distinguished from those of later epochs by the fact that in the existing mountains they possess peculiar roundness and flatness and occur at high altitudes, whereas along the Coastal Plain the representative surface passes beneath the strata of later age.

The recognition of the ancient plain which characterized the eastern United States and also Canada during the Jurassic and Cretaceous ages was a most important step in the understanding of the history of the mountains and rivers. From its conspicuous character in the crest of Schooley Mountain, New Jersey, it has been named the Schooley peneplain.[b]

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[a] Hayes, C. W., and Campbell, M. R., Geomorphology of the southern Appalachians: Nat. Geog. Mag., vol. 6, 1894, pp. 63-126, Pl. V.

[b] Peneplain is a technical term meaning almost plain. It is used to avoid the suggestion of a perfectly plain surface. It is consistently applied to a region of wide valleys among low hills, or to a true plain, the degree of unevenness being indeterminate; but it carries by definition the implication that the surface has been planed by the ordinary processes of atmospheric erosion.

We may now return to the Potomac, to discover, if possible, its course on the Schooley peneplain and to trace its further development.

It has already been stated that the consequent drainage of the Permian Appalachians probably joined in a trunk channel and flowed to the southwest. The Potomac above Harpers Ferry could not then have existed, except perhaps as a stream rising in the Blue Ridge and pursuing a course toward Cumberland. The Shenandoah, South Branch, and other large tributaries, which are now adjusted to the valleys in limestone and shale, were then represented by streams flowing along the troughs produced by folding. By the time the Permian Appalachians had wasted to a peneplain still having pronounced relief the adjustment of the branches was accomplished and they were probably established along the lines of their present valleys, but near the level of the now existing sandstone ridges. The trunk channel may still have descended westward. East of the Blue Ridge there were rivers that carried down sediment to the Coastal Plain and spread it there. Part of it constitutes the base of the Potomac formation, and consists of coarse pebbles and bowlders of quartz and quartzite derived from ledges in the Blue Ridge. It was distributed by streams meandering over the eroded surface of the ancient gneisses, with the sands of which the cobbles are mingled. A river corresponding with the Potomac below Harpers Ferry probably had a more or less important share in this work, which was accomplished during the later part of the Jurassic age. It is possible that the river even then rose west of the Blue Ridge.

When the Schooley peneplain had been eroded to very low relief, conditions were favorable for extension of drainage lines on the part of strong streams at the expense of weaker ones. The processes by which such extension is accomplished are complex and subject to many qualifying conditions. They can not be detailed here, but in general there are three principal factors which affect the result.

A river of large volume is commonly stronger than one of less volume. One which has rapid fall—that is, one which takes a short course to a low point of discharge—is advantageously situated. Finally, one which is developing a channel in soft rocks is likely to reach a low level sooner than one which is working in hard rocks, and may thus develop a steep fall near its head, which gives it a local advantage.

In attempting to understand how the consequent drainage that initially flowed westward became reversed, so that the present direction of flow was established, we find that the item of relatively short course and steeper fall appears to have been the determining factor. Whether the divide be assumed at the Blue Ridge or at any other point within the Potomac basin, the course to tide level near Washington is much shorter than that toward the southwest, in which direction there was then, so far as we know, no sea nearer than the Gulf of Mexico, if as near. The eastern course, being shorter, was steeper, and streams pursuing it attacked the divide between themselves and western rivers more vigorously than the latter did. The rocks of the Blue Ridge are hard and no doubt formed a height which long resisted the work of the gnawing brooks that ran down its eastern slope; but inasmuch as it was leveled to a low ridge by the very slow process of general denudation, it must have yielded sooner to the more effective abrading action of running water and sand.

At some time, probably early in the development of the Schooley peneplain, the Blue Ridge was thus cut through from the east. This result follows directly from its geographic position in relation to tide water, but it may have been accelerated by elevation of the western or depression of the eastern region in such a way as to increase the advantage of the eastward course. Davis, who first recognized the reversal,[a] suggests that it occurred when the basin in which the Triassic sediments from the Permian Appalachians were deposited was developed, in which case the present course of the Potomac has been established since Triassic time instead of only since late Jurassic or early Cretaceous.

The Potomac at Harpers Ferry was not the only stream which succeeded in crossing the ridge. Each of the several gaps that notch the Blue Ridge, as, for example, Snickers Gap at the head of Goose Creek, though a wind gap now, was a water gap then, and was occupied by the successful stream. The Blue Ridge being cut through, the eastern waters were divided only by limestone from the rivers which drained the Great Valley, and having gained ground in the contest for the main divide, they were able to continue doing so; but as the hard rocks of the Blue Ridge lay across their upper courses their progress beyond was probably slow at first, until they had cut the gaps below the general level of the peneplain on the limestone. That they should eventually expand in the Great Valley and capture the streams which still formed the headwaters of the westward-flowing main river was an inevitable result of their shorter course to the sea. The development of several systems, among which the basin of the present Potomac was divided, was a natural result.

The preceding explanation of the growth of the Potomac across the Blue Ridge and beyond to the Allegheny Front is based on a well-known action by which streams grow at their heads as a tree grows at the tips of twigs. It is technically known as "headwater" erosion or "retrogressive" erosion.

A somewhat different account of the development of the Potomac may be based on what is known as a "superimposed" course. If it be assumed that the Schooley peneplain was covered with alluvium to a

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[a] Davis, W. M., Rivers and valleys of Pennsylvania: Nat. Geog. Mag., vol. 1, 1889, p. 229.

sufficient depth to bury the lowest parts of sandstone ridges, then it is probable that streams would become established across the ridges as well as between them. Transverse channels would develop rapidly if the plain were so warped as to increase the declivity toward the east. In the progress of warping the deepening channel would be cut down to hard rocks, but the river would then be intrenched and could not depart from its established course across the grain. This process implies very uniform planation of the surface, and might have led to a less direct course than that which the Potomac has; but it may have played some part in the river's early history, as it probably did in some later episodes.[a]

Leaving the problem of the exact manner of development to the careful investigation which it merits, we may consider the course of the Potomac from Cumberland to Harpers Ferry as having been established on the Schooley peneplain. The trunk channel was then fed by tributaries which entered it as the principal branches now do, and the system was one which may fairly be called the "Potomac." It did not, however, have the expansion of watershed which it now has, but was probably much more restricted toward the south, the Shenandoah, South Branch, and others on that side being at the time comparatively short. The northern branches, on the other hand, may have been longer.

In the preceding discussion one important fact has been tacitly passed over—the altitude of the Schooley peneplain at the time of its development with reference to sea level. The evenness of the plain is attributed to planation by streams, which are able to produce such a surface only when they have cut their channels down to the lowest possible grade—that is, to a slope which is tangent with the sea level or with some other fixed level of discharge. A barrier of hard rock, a dam, for instance, may for a time constitute a local level of this sort. The Schooley peneplain is so extensive that no local level can have sufficed to fix it. Sea level alone could determine the grade common to many streams draining thousands of square miles. We reason accordingly, from the laws of river action and the extent of the peneplain, that the surface of the land rose gradually from sea level to a very moderate altitude only. This was in the Jurassic and Cretaceous periods.

At the present time the Schooley peneplain in West Virginia lies at an altitude of 4,000 feet and its surface has the form of a very broad, somewhat uneven dome, sloping from the greatest height in that region to a position below the Coastal Plain on the east and to one nearly as low in the Mississippi Valley on the west. It is a warped

[a] Willis, Bailey, The northern Appalachians: Physiography of the United States: National Geographic Monographs, vol. 1, No. 6, 1896, p. 190.

surface, raised on a gentle swelling of the underlying rocky crust from the low grade at which it was developed to its present form. The consequences of elevation where streams flow upon swelling surfaces are increased velocity of flow and deeper cutting of the channels. Large rivers may do so nearly or quite as rapidly as the mass beneath them rises, and may thus maintain a relatively low grade at the bottom of a canyon; but smaller streams do not keep pace and acquire steep profiles. At their headwaters the branches tend to grow as their channels deepen; competition is renewed between opponent brooks across a divide; and if the changed conditions favor one more than another the favored one grows accordingly. Furthermore, rivers flowing across rock masses which consist of alternate hard and soft layers sooner or later cut down to a change of rock, from soft to hard, or vice versa, and thus become favored or retarded in the process of deepening their channels. The advantages thus gained or lost lead to readjustments of watersheds—a kind of natural gerrymander, to borrow a political phrase—and to the diversion of streams from one course to another by the process known as stream capture.

The growth which the Potomac and its tributaries had in consequence of the doming of the Schooley peneplain resulted in the existing arrangement, which probably differs notably from that of the older river. The detailed changes within the Potomac basin escape our present knowledge, but they may be more or less closely traced by study of the wind gaps, which represent abandoned channels, and by investigation of the relations which streams had to the underlying rocks during the process of sinking their valleys from the level of the mountain tops to their present position.

One fact is, however, so striking that it stands out clearly—the great length of the southern tributaries of the Potomac as compared with the opponent streams that flow to the James. The headwaters of the Shenandoah, for example, in Augusta County, 120 miles from the Potomac at Harpers Ferry, are but 25 miles from the James at Balcony Falls. A sufficient reason is found in the fact that the warped surface of the Schooley peneplain slopes toward the Potomac. It is highest above the region where the divide extends between the Shenandoah and South River (the opposing tributary of the James),[a] and the long course of the Shenandoah corresponds with the long slope of the old surface. The inference is that the Shenandoah grew to its present dimensions because, when it was a much smaller river, its fall was increased by the northward tilting of the surface. Having a low point of discharge it extended its basin by headwater erosion, capturing in succession the heads of those streams which rose in the Great Valley and flowed eastward across the Blue Ridge. Their

[a] Hayes, C. W., and Campbell, M. R., Geomorphology of the southern Appalachians: Nat. Geog. Mag., vol. 6, 1894, Pl. V.

abandoned gaps, such as Snickers Gap, remain as evidence of their former existence. In the course of its conquests the Shenandoah became opposed by the tributaries of the James, but it continued to push the divide southward until an equilibrium was established between the opponents across the area where the Schooley peneplain was most elevated.

The northern tributaries of the Potomac are short as compared with the southern branches of the Susquehanna opposed to them. They were at a disadvantage, as their fall southward was lessened by the rise of the northward slope of the peneplain, and they lost ground to the Susquehanna, as the James did to the Potomac.

The doming of the Schooley peneplain has been a gradual process, involving in the Virginias a maximum change of level of about 3,500 feet. As the uplift progressed the Potomac developed a canyon which in due process widened to a valley. Had the uplift been accomplished and ceased long ago, the valleys would be very wide, especially along the master stream, and much of the region would be eroded to grade. Had the upward movement been continuous, the river would exhibit a simple profile and the valleys simple cross sections, generally concave upward and broken only by hard beds of rock, which would project above the average slope. Neither of these cases corresponds with the facts. There are wide valleys, but within them are narrow canyons. The greater width was developed when the stream had worked down to grade during a pause in the elevation; the narrower channel was sunk when the activity of the river was renewed by renewed uplift. Thus it is apparent that warping has been an intermittent process.

At every stage of sculpture through which the surface passed, the Potomac and other streams bore to their lower courses the sediment taken from upper districts and spread it upon the Coastal Plain or delivered it to tidal waters in estuaries or the open sea. The volume of sediment and its character, whether coarse or fine, varied with the rate of uplift. The strata are thus a record of the river's work and indirectly of the height of land. Something may be inferred from them regarding the rate of warping. There is, however, another factor which complicates the problem—variation of climate, according to which the river's volume, and consequently its ability to carry sediment, changed from time to time. Though probably subordinate to uplift, it is not negligible. Bearing in mind that there are two factors which have determined the river's action, the careful student may investigate the sediments on the one hand and the valley profiles on the other and work out a more detailed history than we now possess. At present we are not able to describe the successive stages accurately, but certain marked ones stand out clearly with such decided character that we can with confidence attribute them to the more effective of the two variable factors, the progress of uplift.

The wide valley of the Shenandoah marks the earliest pause in excavation of which there is record in the sculptured surface. No general view of it can be had from the river, which, near its mouth, in consequence of later cutting, runs 350 feet below the valley level, but it may be inspected from any of the numerous low shale hills that diversify the former valley plain. It is not difficult, when looking down on the river's turbid flood, to realize that it has sunk its channel among the hills. It is but another step to recognize that if we could restore what the river and its branches have carried away the hills would be joined together by the fills and the whole wide valley would present a plain. That it once did have such a plain surface, which was worked out to the grade of the river, is not questioned, and the laws of river action lead directly to the conclusion that the level of discharge which the river then had was the level of the plain near its mouth.

From its characteristic development in the Shenandoah Valley the valley plain has come to be known as the Shenandoah. It is not, however, a local feature, but a surface which is present throughout the Appalachian Mountains wherever the rocks are soft shale or the even less resistant limestone.

As the Shenandoah plain is thus a general fact of sculpture, to a greater or less extent worked out by all the rivers of the region, its grade could have been determined only by a common level of discharge—sea level—and a plain of such wide development as it exhibits could not have been sculptured while the level of discharge was changing in course of uplift, but only during a prolonged interval of constant level. We divide the uplift and erosion of the mountains accordingly into an earlier cycle, during which valleys were sunk 1,000 to 2,000 feet below the Schooley peneplain in the Potomac region and the Shenandoah plain was eroded over all the areas of softer rocks, and the later cycles, during which the lower features of the valleys have been cut.

During the earlier or Shenandoah cycle the Potomac and its southern branches grew very nearly or quite to their present lengths; the northern branches diminished as they gave ground to the Susquehanna; and thus the competing streams established the watersheds that now exist. North Branch of the Potomac held a very advantageous position in opposition to the western streams on the plateau, as it reached a relatively low level on soft rocks in a much shorter distance than they. It was therefore able to extend such branches as Savage River and Crabtree into their territory, and it is still doing so.

The Shenandoah plain (recently rechristened the Harrisburg peneplain[a]) no longer exists as a continuous surface. Cut by the larger rivers and their branches, even out to the smallest, it is represented only by hilltops that approach its level. Its altitude near Harpers Ferry is about 600 feet above the sea; about the headwaters of the Shenandoah it is 1,200 feet. Between it and the channel of the river, 200 to 350 feet below, are sculptured the terraces and slopes of later development. Among these is a lower valley level, about 100 feet below the Shenandoah plain, which apparently corresponds to a surface that extends about Somerville, N. J., and is known as the Somerville peneplain.[b] It is eroded on the limestones or very soft Triassic sandstones and represents a shorter pause in the progress of uplift than did the Shenandoah.

The Shenandoah and Somerville plains are not everywhere distinguishable one from the other, being represented in some places by one extensive surface. Toward the close of their development, in the epoch known to geologists as the late Tertiary or Pliocene, they became covered by a widespread deposit of gravel and loam, which is called the Lafayette formation.

The Lafayette covers the outer slopes from the Appalachian Mountains toward the Atlantic and Gulf coasts and the Mississippi Valley with an almost continuous mantle. It is represented in the districts of the Appalachian Ranges and Allegheny Plateaus by deposits of gravel that now cap terraces and hills. It is composed throughout of alluvial material, carried, sorted, and deposited by streams in the first instance and to some extent rearranged by marine waters about the margins. What part is fluviatile and what part marine is to be determined only by further studies; but it is probable that the activity of rivers in spreading the material has been underestimated and that the degree of marine submergence has been correspondingly overestimated. The Potomac, like other rivers of the Lafayette epoch, flowed in a wide alluvial plain, which coalesced with those of adjacent rivers in the lower courses.

The epoch of low, level, and wide-spreading plains was followed by one during which the land was again elevated and the rivers incised the channels they had assumed. It is probable that the elevation was not constant, especially in the outer Coastal Plain, for there is evidence that the lower valleys were at times submerged after having been eroded.[c] Other influences were, however, almost if not quite as important. It was the time called Pleistocene, the time of the

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[a] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York: Bull. Geol. Soc. America, vol. 14, 1903, pp. 277-296.

[b] Davis, W. M., and Wood, J. W., jr., Geographic development of northern New Jersey: Proc. Boston Soc. Nat. Hist., vol. 24, 1890, pp. 391-392.

[c] Darton, N. H., Washington folio: Geologic atlas U. S., folio 70, U. S. Geol. Survey, 1901.

glacial and interglacial epochs, when the climate varied from temperate to semiarctic and back to temperate again; the rivers changed their activities accordingly and alternately cut their channels or partially filled them. The minor gorges that characterize all the valleys, the cascades that beautify the rivers, and the wide rocky shallows that are peculiar features in streams so large as the Potomac and Susquehanna resulted from these activities, as did also the later gravel and silt deposits constituting the Columbia formation, which are extensively spread upon terraces along the Potomac, especially in the vicinity of Washington.

As we approach the present, the seeming importance of details increases. The deposition of the Columbia formation, for example, marks an episode which seems to compare with the erosion of the old Permian mountains, though it is indeed a relatively insignificant fact. But every detail of the river's course or profile or deposits is significant of some past circumstance, if we can but understand.

Old as the Potomac is and varied as have been the activities affecting its development, a new agent has appeared in its watershed within the last three hundred years and is acting as the chill climate of the ice age acted to denude the surface and load the river with sediment. Throughout the Tertiary age, when the Schooley peneplain was cut away, when the Shenandoah plain was graded, and when the inner canyons were sculptured, the region constantly bore a luxuriant deciduous forest, in which the tulip tree and the magnolia appeared at an early date and the more modern oaks and maples and many others found place later. With the advent of the ice age the climate changed from semitropic to temperate, and then to that of the Barren Grounds of the Far North to-day. Vegetation died; the surface was bared; rain or waters from melting snow swept away the frost-loosened earth; winds carried the dust in eddying clouds; the rivers were surcharged with sediment, and the Columbia deposits resulted. The new agent in his own peculiar way is preparing another such deposit. He has bared the surface almost as effectually as did the blasts of the ice age, but with an ax only, and he is causing a new record to be made in the hills that are scored with gullies and in the lowlands that are buried beneath deposits of gravel and mud.

The Potomac's long history has been influenced by great forces—the internal energy of the earth, that has shaped the surface on which the river grew; the attraction of gravitation, that has caused the river to flow; the external force of the sun, that has set the atmospheric agents to work. They were sometimes conservative, sometimes destructive. The new force has demonstrated his capacity to destroy; in his own interest he needs to acquire the art to protect. The future of the Potomac and the fitness of its watershed to be a home for man depend on his intelligent use of what the ages have fashioned.

STREAM FLOW IN THE POTOMAC BASIN.

By R. H. Bolster.

INTRODUCTION.

METHODS OF WORK.

FIELD METHODS.

The methods by which the records of stream discharge have been made are those in common use in the United States Geological Survey. They are described in detail in Water-Supply and Irrigation Papers Nos. 94 and 95 and briefly in the annual progress reports for 1904 to 1906. An outline of the method used in the Potomac River drainage basin is given below, to assist in making clear the data which follow.

A gage for observing the stage of the river is established at a bridge or other place where the record of flow is to be made. This gage is a vertical staff or some other device by which the height of water may be observed, and is read each day by a person living near by. The average of the gage readings, if more than one, in any day is used as the mean gage height for that day.

At various stages of the river one of the hydrographers of the Survey visits the station and measures with a current meter the amount of water flowing. This meter is primarily an instrument for measuring the velocity of moving water, and consists essentially of a wheel with vanes, which may be shaped like those of a windmill or of a screw, or with cups like those of an anemometer, the necessary qualification being that moving water shall readily cause the wheel of the meter to turn. Each meter is rated before use. The rating is done by moving the meter through still water at various observed speeds to determine the relation between the velocity with which the meter moves through the water and the revolutions of the wheel. This relation having been determined, the meter is used in running water, the revolutions per unit of time noted, and the velocity of the water computed.

Observations of depth of water are also made, and from them the area in cross section of each portion of the stream is computed; each partial area multiplied by the mean velocity of that area gives a partial discharge. The sum of the partial discharges is the total discharge of the stream.

OFFICE METHODS.

Measurements of flow as outlined above are made covering a considerable range of gage height. They are then plotted on coordinate paper, with gage heights for ordinates and discharges for abscissas, and a smooth curve, called the rating curve, is drawn through the points. From this curve a rating table is made which shows the discharge of the stream for any gage height.

The data necessary for the construction of a rating table for a gaging station as just stated are the results of the discharge measurements, which include the record of stage of the river at the time of measurement, the area of the cross section, the mean velocity of the current and the quantity of water flowing; and a thorough knowledge of the conditions at and in the vicinity of the station.

The construction of the rating table depends on the following laws of flow for open permanent channels: (1) the discharge will remain constant so long as the conditions at and near the gaging station remain constant; (2) the change of slope due to the rise and fall of the stream being neglected, the discharge will be the same whenever the stream is at a given stage; (3) the discharge is a function of, and increases gradually with, the stage.

The plotting of results of the various discharge measurements, using gage heights as ordinates and discharge, mean velocity, and area as abscissas, will define curves which show the discharge, mean velocity, and area corresponding to any gage height. For the development of these curves there should be, therefore, a sufficient number of discharge measurements to cover the range of the stage of the stream. Fig. 1 shows a typical rating curve with its corresponding mean velocity and area curves.

As the discharge is the product of two factors, the area and the mean velocity, any change in either factor alone will produce a corresponding change in the discharge. Their curves are therefore constructed in order to study each independently of the other.

The area curve can be definitely determined from accurate soundings extending to the limits of high water. It is always concave toward the horizontal axis or on a straight line unless the banks of the stream are overhanging.

The form of the mean velocity curve depends chiefly on the surface slope, the roughness of the bed, and the cross section of the stream. Of these the slope is the principal factor. In accordance with the relative change of these factors the curve may be either a straight line, a curve convex or concave toward either axis, or a

FIG. 1.—Discharge, mean-velocity, and area curves for Potomac River at Point of Rocks.

combination of the three. From careful study of the conditions at any gaging station the form which the vertical velocity curve will take can be predicted, and it may be extended with reasonable certainty to stages beyond the limits of actual measurements. It is used principally in connection with the area curve in locating errors in discharge measurements and in constructing the rating table.

The discharge curve is defined primarily by the measurements of discharge, which are studied and weighted in accordance with the local conditions existing at the time of each measurement. The curve may, however, be best located between and beyond the measurements by means of the curves of area and mean velocity. This curve under normal conditions is concave toward the horizontal axis and is generally parabolic in form.

In the preparation of the rating table the discharge for each tenth on the gage is taken from the curve. The differences between successive discharges are then taken and adjusted according to the law that they shall either be constant or increasing.

DEFINITIONS.

The volume of water flowing in a stream, the "run-off," is expressed in various terms, each of which is associated with a certain class of work. These terms may be divided into two classes: Those which represent a rate of flow, as second-foot, gallons per minute, and run-off in second-feet per square mile; and those which represent actual quantities of water, as run-off in depth in inches. They may be defined as follows:

"Second-foot" is an abbreviation for cubic foot per second, and is the rate of discharge of water flowing in a stream 1 foot wide 1 foot deep at the rate of 1 foot per second. It is generally used as a fundamental unit from which the others are computed.

"Gallons per minute" is generally used in connection with pumping and city water supply.

"Second-feet per square mile" is the average number of cubic feet of water flowing per second from each square mile of area drained, on the assumption that the run-off is distributed uniformly both as regards time and area.

"Run-off in inches" is the depth to which the drainage area would be covered if all the water flowing from it in a given period were conserved and uniformly distributed over the surface. It is used for comparing run-off with rainfall, which is usually expressed in depth in inches.

EXPLANATION OF TABLES.

For each regular station are given, as far as available, the following data:

1. Description of station.
2. List of discharge measurements.
3. Gage-height tables.
4. Rating tables.
5. Tables of estimated monthly and yearly discharges, run-off, and precipitation, based on all the facts available to date.

The descriptions of stations give such general information about the locality and equipment as would enable the reader to find and use the station, and, as far as possible, a complete history of all the changes that have occurred since the establishment of the station that would affect the use of the data collected. They also give statements concerning the probable percentage of error of the estimates. The probable errors have been based principally on the errors of the discharge measurements with reference to the rating curves.

The discharge-measurement table gives the results of the discharge measurements made during each year, and includes the date, the gage height, and the discharge in second-feet.

The tables of daily gage heights give for each day the height of the surface of the river above the zero of gage, as found from the mean of the gage readings taken on that day.

The rating tables give discharges in second-feet corresponding to each stage of the river as given by the gage heights and statements concerning the measurements on which it has been based and the portion of the curve which is well defined.

In the tables of estimated monthly discharges the column headed "Maximum" gives the mean flow for the day when the mean gage height was highest; this is the flow as given in the rating table for that mean gage height. As the gage height is the mean for the day, there might have been short periods when the water was higher and the corresponding discharge larger than given in this column. Likewise in the column headed "Minimum," the quantity given is the mean flow for the day when the mean gage height was lowest. The column headed "Mean" is the average flow for each second during the month.

On this, the computations for the columns under the general heading "Run-off" are based. The mean precipitation, which has been entered in the column headed "Precipitation in inches," for gaging stations which have been maintained for a series of years has been determined from the United States Weather Bureau records. The mean precipitation has been determined from well-distributed rainfall stations in the drainage basin above the gaging station.

From the precipitation in inches and the run-off in depth in inches the run-off in per cent of precipitation has been determined, also the loss of precipitation in inches or the amount which for several causes does not flow past the gaging section.

ACCURACY OF ESTIMATES OF STREAM FLOW.

The description of each gaging station is followed by a statement indicating the probable percentage of error in the values for mean monthly flow. This percentage is only approximate, as no refinement has been attempted in its determination. The probable errors have been based principally on the errors of the discharge measurements with reference to the rating curves and the known conditions of the flow in the vicinity of the gaging section. It is impossible to estimate closely the errors caused by temporary or gradual changes in the conditions of flow, unreliability or ignorance of the observers, changes in wire or chain length, or ice conditions.

Errors due to changes in conditions of flow are relatively small for the large streams except at a few stations. On small streams, however, a temporary obstruction at or below the gaging section, causing a change in area of cross section or in velocity of the current, may cause large errors in daily estimates of discharge. These changes as a rule do not occur frequently and are usually of a temporary character; for example, the lodging of driftwood on the controlling point below the gage reduces the velocity, and hence the discharge for a given gage height. A few days later a sudden rise in the stream may clear the channel and restore normal flow. Unless the hydrographer has chanced to make a measurement of discharge during the period of abnormal conditions, an error has been introduced into the monthly estimates. Owing to the limited appropriation for stream gaging and the large number and wide separation of the gaging stations, it is impossible for the hydrographers to make measurements frequently enough to eliminate all errors arising from these abnormal conditions. It has further been found impracticable to so instruct the observers that they will correctly report unusual conditions.

Gradual changes in the conditions which affect the flow can be estimated and corrected more readily than temporary changes. Here again the hydrographer is often handicapped by inability to make sufficient measurements to show properly the varying rate of change in channel conditions. In such cases the estimates are obtained either by an indirect method which is based on the assumption of a constant rate of change from day to day between measurements or by a series of rating curves.

Observers are as a rule conscientious in reading the gages, but with few exceptions they are wholly unfamiliar with engineering work of any description. The observers' records, however, are examined and checked by hydrographers, and large errors are thus eliminated. The observers are usually instructed to read the gage to the nearest tenth or half tenth of a foot twice each day, and at times of floods several times a day. At high and medium stages the errors in reading the gage are thus negligible; but at low stages, when a difference of one or two hundredths in the stage of the river or slight fluctuations during the day cause errors of several per cent it is evident that the regular method of observation is inadequate. Hence, monthly minimums may be considerably in error; but in general the monthly means for months of low flow are good, owing to the tendency of positive and negative errors to offset each other.

Prior to the fall of 1903 wire gages were used at many of the stations for observing the stage of the river. The correct length of gages of this type was difficult to maintain on account of the stretching of the wire. Small changes of length took place frequently, making necessary the application of corrections to the observed gage heights at the station. In some instances the magnitude of the corrections and the time over which they should have been applied were not recorded, and the proper adjustments are therefore somewhat in doubt. In such instances, if the data warranted it, the gage heights were corrected by the amount that the measurements of the period in question were vertically above or below the curve. It is believed that by the use of corrected gage heights reasonably accurate estimates of discharge have been made for all the rivers described.

The extent of frozen periods at many of the stations is very uncertain. All ice notes are from observers' gage-height records, but as the observers' notes prior to 1904 are very incomplete their absence does not always imply open-channel conditions. Estimates for ice periods have been made as if open-channel conditions existed except as noted. This method involves errors for the relatively short ice periods of a few to 40 per cent.

The errors which are described above are not to be considered as applying to every station. They have been fully described here in order to call to the attention of the reader the possible sources of error and the limitations of engineering work of this kind. Although the resulting error may seem large, it should be remembered that stream-gaging data and estimates of flow are used mainly as a basis for predicting the maximum, minimum, and mean discharge which may be expected in future years. Since the mean annual flow of a stream may be several times larger one year than it is the next, it is evident that for records of short duration an estimate which involves an error as great as 50 per cent is not without value. On the other hand, it is a waste of money and needless refinement—indeed, virtually impossible—to obtain estimates much closer than 3 per cent in ordinary current-meter work.

Special emphasis is laid on the fact that the value of stream-gaging data is determined mainly by the number of years during which the record has been maintained and not so much by the degree of accuracy of the discharge for each year. That is, the longer the record the more nearly does it indicate the maximum, minimum, and mean flow which may be expected in the future.

Monthly means which are stated in the descriptions to be within 5 per cent of the true flow are considered to be very good, and those within 10 per cent are considered close enough for all practical purposes. Errors in estimates which are greater than 15 per cent are due either to an insufficient number of measurements, or to poor natural conditions which could not be avoided, or to changes at the gaging station which could not be foreseen at the time of its establishment. The larger errors in daily discharge values occur at the highest stages, which continue only for a few days, and hence the effect on the accuracy of the monthly mean is not so great as might at first appear. Also by far the greater number of gage heights are for medium stages, at which the error of the rating curve is seldom as great as 10 per cent and is usually much less than 5 per cent. The errors in the daily discharge values are often considerable, owing to fluctuation of the river height. The values for the maximum and the minimum flows for the month may also contain an additional error, because they are based on the extreme low or high part of the rating curve, which is usually not so well defined as the intermediate portion. In the case of the mean monthly flow, for which the estimates of accuracy are made, the error is reduced to a very small amount by reason of the compensation of variable negative and positive errors.

COMPARISONS OF FLOW.

The figures in the following table have been brought together for the purpose of comparing the flow from a partial drainage area with the flow from the total drainage area over a relatively long period of time.

The totals show that the ratio of the run-off from the tributaries to the run-off from the total basin is 6 per cent greater than the ratio of their respective drainage areas. This is entirely reasonable and just what should be expected, for during medium and especially during high stages the run-off is greater on the tributaries, owing to somewhat greater rainfall and more precipitate slopes.

In the comparison of the run-off from month to month it should be remembered that there is a considerable time interval between the stations. For example, a flood on the tributaries occurring at the end of a month does not reach the Point of Rocks station until the following month. It is believed that this accounts for most of the larger deviations of discharge from the normal for the individual months.

Mean monthly discharge in second-feet, Potomac River basin.

Date.	Potomac River at Point of Rocks, Md.	South Branch Potomac River near Springfield, W. Va.	Shenandoah River at Millville, W. Va.	North Branch Potomac River at Piedmont, W. Va.	Total, exclusive of Point of Rocks.	Ratio of discharge of tributaries to that of main stream at Point of Rocks.
1903.						
September	4,669	336	2,249	90	2,675	0.57
October	3,212	271	1,454	103	1,828	.57
November	2,175	206	961	134	1,301	.60
December	[a] 2,926	[a] 286	927	193	1,406	.48
1904.						
January	[a] 7,287	1,009	....	643	....	....
February	[a] 17,480	1,004	....	795	....	....
March	11,170	1,451	....	1,433	....	....
April	7,406	1,660	2,191	937	4,788	.65
May	9,362	2,143	2,779	792	5,714	.61
June	10,160	1,121	2,430	392	3,943	.39
July	4,510	568	1,930	160	2,658	.59
August	2,394	238	1,096	37	1,371	.57
September	1,592	123	620	17	760	.48
October	1,164	81	521	28	630	.54
November	1,340	80	528	34	642	.48
December	2,201	[a] 296	780	243	1,319	.60
1905.						
January	[a] 8,626	[a] 821	2,065	360	3,246	.38
February	5,625	[a] 831	1,684	232	2,747	.49
March	23,480	4,793	4,387	2,484	11,664	.50
April	6,581	1,015	1,945	585	3,545	.54
May	4,493	1,744	1,382	496	3,622	.80
June	6,579	1,948	2,552	588	5,088	.77
July	10,190	1,673	2,994	653	5,320	.52
August	5,830	854	1,557	376	2,787	.48
September	3,205	228	810	195	1,233	.39
October	2,888	229	640	348	1,217	.42
November	2,267	190	624	267	1,081	.48
December	10,640	2,298	2,336	815	5,449	.51
1906.						
January	14,990	3,321	3,719	1,255	8,295	.55
February	5,116	664	1,643	220	2,527	.49
March	15,900	5.076	3.888	1,161	10,125	.64
April	22,440	4,538	4,464	2,013	11,015	.49
May	5,538	1,085	1,803	323	3,211	.58
June	7,007	770	2,895	413	4,078	.58
Mean ratio						[b] .537
Ratio of tributary drainage areas to drainage area above Point of Rocks						[b] .505

[a] Ice conditions. [b] September, 1903, to March, 1904, not included.

As a practical application of such comparisons as have been given above, the following may be of interest and value.

1. The observers' gage heights for the Point of Rocks station from January 1 to June 18, 1896, were corrected 0.7 by the hydrographer at that time; 0.4 was due to change of datum, but there are no data available to show why the correction for the remaining 0.3 was made. There has been a good deal of doubt in the mind of the writer whether it should have been made at all. The following comparisons strengthen this doubt still further. The mean daily discharge for the total period from January 1 to February 29 and from May 11 to June 17, 1896,[a] was found at all stations, except that an allowance of four days was made for flow from Cumberland and Spring-

[a] No record at Point of Rocks March 1 to May 10, 1896.

field to Point of Rocks. The estimate of the discharge at the Springfield station for May and June, during which there was no record was based on a comparison of Springfield and Millville estimates from May, 1895, to February, 1896, inclusive.

Discharge at various stations, January 1 to February 29 and May 11 to June 17, 1896.

Cumberland	second-feet	882
Millville	do	2, 635
Springfield	do	725
		4, 242
Mean daily discharge at Point of Rocks, 0.7 correction being used	do	5, 910
Ratio of discharge at upper stations to that at Point of Rocks (0.7 correction)		.72
Ratio of drainage area at upper stations to that of Point of Rocks		.55

If the 0.3 correction had not been made the approximate mean daily discharge for the Point of Rocks station would have been 7,270 second-feet and the ratio of discharge of the upper stations to Point of Rocks would have been .58.

2. During 1897 the gage length was greatly in error, the final error recorded in January, 1898, being 1.8 feet. These gage heights were corrected by varying amounts for several periods. The amounts of the corrections were based on the gage-height distance that the several measurements of 1897 plotted above or below the rating curve. That this gave essentially correct results for the year is borne out by the following figures:

Discharge at various stations, December 28, 1896, to November 24, 1897.

Mean daily discharge at Cumberland December 28,[a] 1896, to November 20, 1897	second-feet	1, 086
Mean daily discharge at Millville January 1 to November 24, 1897	do	3, 058
Total		4, 144
Mean daily discharge at Point of Rocks January 1 to November 24, 1897	do	11, 175
Ratio of discharge at upper stations to that at Point of Rocks		.37
Ratio of drainage area at upper stations to that at Point of Rocks		.40

The ratio of discharge is thus about 92 per cent of that of the drainage area. An allowance of 20,000 second-feet per day was made for omitted gage heights at Millville February 7, 8, and 9. There is every reason to believe that about 30,000 second-feet each day should also have been added for February 23 and 24, first, because it was known that the observer recorded gage heights above the top of the 10-foot gage on those days as 10.0 feet, and second, because of the flood at Point of Rocks the latter part of February, which shows a discrepancy of about this amount by a comparison of the relative drainage basins. If this is done the difference of the ratios is about 4

[a] Four days allowed for flow at Cumberland to reach Point of Rocks.

per cent. However, this still leaves a negative error of approximately 10 per cent, since the ratio of the discharges should be about 6 per cent greater than that of the drainage areas, according to the comparisons presented in the table (p. 31).

RAINFALL.

Probably no phenomenon has so important a bearing on the development of the country as rainfall. A study of this phenomenon, although an essential part of the hydrography of a district, is difficult, owing to the numerous and various conditions which regulate it. The fluctuations of both the yearly and monthly precipitation are great, and it is only by having a long series of records at many well-distributed points over an area that even a fair estimate of the conditions prevailing may be made.

The United States Weather Bureau has for a number of years regularly maintained rainfall stations well distributed throughout the United States. On the data collected at about 40 such stations, located either in or near the Potomac drainage basin, the accompanying discussion, tables, and map have been based.

The map (Pl. I, pocket) shows, by means of lines of equal rainfall, the average annual distribution of precipitation over the basin of the Potomac during the ten years from 1896 to 1905.

At many of the stations the data were missing for some portions of the period, and in order to complete the records for such stations the missing values were obtained by comparison with other near-by stations by the method of interpolation and extrapolation. This is made possible by the fact that the ratio between the precipitation at two adjacent stations remains fairly constant, although there is considerable variation in the actual amounts.

Since the prevailing wind directions are as important as the topographic surroundings in determining the precipitation at any given pair of stations, it seemed desirable to compute the ratios for many of the individual months as well as for the whole year. This proceeding involved more labor than would have been required to determine the ratios for whole years only; but it seems to have increased the accuracy of the results, especially in those cases where an interpolation of only a few months was required to fill out an otherwise complete series. This calculation of monthly ratios also makes it possible to obtain an approximately true annual ratio for two stations, one of which has many scattered monthly records, but few or no complete annual records. Another valuable feature of these ratios is that they make it possible to readily detect and eliminate errors in the rainfall records due to changes in gage exposure or to errors in recording or computing. This is illustrated by the ratios for the pair of stations, Point of Rocks and Harpers Ferry, where an excessive ratio of 7.43 was found for October, 1895, as against an average ratio of 0.98 for that month.

In preparing the map of the Potomac basin the annual means as given on pages 34 to 40 were first plotted; then with the aid of several approximate means not given on the map, all points having the same precipitation were connected by meandering lines. Inspection shows that these lines, called "isohyets," follow closely the surface contours of the base map, while it will at once strike the reader that nearly all the stations are located in the valleys. Only a few stations in western Maryland and one station on the Blue Ridge of Virginia (Mount Weather) can be classed as mountain stations. Consequently we have at present no sufficient basis for calculating the rate of increase of precipitation with altitude in this basin. On this account also the course of the isohyet of 40 inches is, with few exceptions, to be regarded as hypothetical, although wherever possible it has been made to accord with such scanty and imperfect records as are obtainable.

Although the net of rainfall stations is not so finely meshed as is desirable for an area of the importance of the Potomac basin, yet the map shows distinctly that the rainfall of the lowlands decreases upstream from Washington. The lower-lying portions of the valley of the Shenandoah and its continuation, the Cumberland Valley of Maryland and Pennsylvania, were characterized by an annual fall of 35 to 40 inches of rain and melted snow. Generally the smaller amount is found along the Potomac itself, but the driest portion of the great valley lies in that section drained by Opequon Creek.

There seems to have been an exception to the rule just stated about the headwaters of South Branch of the Potomac. In that region there is a considerable area, inclosed by the isohyet of 35 inches, which has a rainfall of less than that amount. The two stations inclosed by the curve show amounts of 33.7 and 34.7 inches. This is apparently the dryest portion of the whole Potomac basin and, to judge from the neighboring portions of other river basins, it is but a portion of a relatively arid district which embraces the whole valley occupied by Bull Pasture River and South Branch of the Potomac.

Mean precipitation, in inches, at stations in drainage basin of Potomac River.

BACHMAN VALLEY, MD., ALTITUDE 860 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.77	5.92	5.46	2.80	6.26	3.67	4.01	3.92	3.19	3.01	5.16	3.36	49.56
1901–1905	4.65	4.17	6.30	4.21	3.57	6.87	7.76	7.35	4.93	5.26	[a]2.51	6.28	63.93
10-year mean	3.70	5.04	5.88	3.50	4.91	5.27	5.88	5.63	4.06	4.13	3.83	4.82	56.74

[a] 1 year interpolated, based on observations at Taneytown.

Mean precipitation at stations in drainage basin of Potomac River—Continued.

BAYARD, W. VA., ALTITUDE 2,500 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													[a] 45.02
1901–1905													[b] 43.84
10-year mean													

BOETTCHERVILLE, MD., ALTITUDE 780 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	1.96	2.59	4.05	1.86	4.21	3.41	3.60	2.58	3.01	2.35	3.07	1.99	34.73
1901–1905	2.39	2.48	3.55	3.86	3.72	3.71	3.50	4.91	1.95	2.43	1.49	3.18	37.18
10-year mean	2.17	2.53	3.80	2.86	3.96	3.56	3.55	3.74	2.48	2.39	2.28	2.58	35.95

BURLINGTON, W. VA., ALTITUDE 875 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.15	3.85	3.58	[c] 1.99	4.30	2.94	4.05	2.93	3.08	2.14	2.91	2.10	36.05
1901–1905	2.53	2.21	3.11	3.04	3.87	4.21	4.23	4.25	2.21	2.08	1.52	3.39	36.67
10-year mean	2.34	3.03	3.34	2.51	4.08	3.57	4.14	3.59	2.64	2.11	2.21	2.74	36.36

CHAMBERSBURG, PA., ALTITUDE 1,000 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	1.86	3.31	4.06	1.65	4.20	3.57	3.62	4.75	2.44	2.55	3.56	1.70	37.28

CHEWSVILLE, MD., ALTITUDE 530 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													[d] 37.62
1901–1905	2.88	1.91	2.75	3.09	3.27	5.50	5.36	3.39	2.21	2.90	1.76	2.90	37.94
10-year mean													37.78

CLEARSPRING, MD., ALTITUDE 500 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													[e] 37.83
1901–1905	3.52	2.21	[f] 3.89	[g] 3.49	3.55	3.75	4.86	3.90	2.88	2.60	1.73	4.37	40.65
10-year mean													39.24

CUMBERLAND, MD., ALTITUDE 700 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.51	3.32	3.91	2.06	4.06	3.02	3.11	2.60	2.77	2.61	3.41	2.29	35.90
1901–1905	2.70	2.13	3.14	3.48	2.46	3.52	3.13	3.80	1.94	2.11	1.35	3.41	33.20
10-year mean	2.60	2.72	3.52	2.77	3.26	3.27	3.12	3.20	2.35	2.36	2.38	2.85	34.55

DALE ENTERPRISE, VA., ALTITUDE 1,350 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.15	3.62	3.54	1.74	3.62	4.55	4.54	3.28	3.62	2.86	2.51	1.89	37.92
1901–1905	2.86	2.40	3.51	2.95	3.61	7.47	5.54	4.63	2.48	2.24	1.43	3.44	42.58
10-year mean	2.50	3.01	3.52	2.34	3.61	6.01	5.04	3.95	3.05	2.55	1.97	2.66	40.25

[a] 5 years interpolated, based on observations at Westernport.
[b] 2 years interpolated, based on observations at Westernport.
[c] 1 year interpolated, based on observations at Romney.
[d] 2½ years interpolated, based on observations at Hagerstown.
[e] 3 years 5 months interpolated, based on observations at Greenspring Furnace.
[f] 2 years interpolated, based on observations at Greenspring Furnace.
[g] 1 year interpolated, based on observations at Greenspring Furnace.

Mean precipitation at stations in drainage basin of Potomac River—Continued.

DEER PARK, MD., ALTITUDE 2,457 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	3.14	3.73	4.56	2.42	4.84	4.38	5.81	3.86	2.46	1.97	3.56	3.37	44.10
1901–1905	4.29	[a]3.16	[b]2.42	3.95	4.58	5.26	4.65	[a]3.14	1.74	2.66	[a]2.16	[a]3.67	41.70
10-year mean	3.71	3.44	3.47	3.18	4.71	4.82	5.23	3.50	2.10	2.31	2.86	3.52	42.90

DISTRIBUTING RESERVOIR, D. C., ALTITUDE 120 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.26	4.26	2.84	1.64	3.44	2.71	3.32	3.83	2.82	2.00	2.44	[c]2.06	33.64
1901–1905	[c]3.05	[c]2.00	3.68	3.31	2.87	3.91	5.47	4.17	2.86	3.05	1.62	[c]4.40	40.42
10-year mean	2.65	3.13	3.17	1.65	3.10	3.31	4.39	4.00	2.84	2.52	2.03	3.23	37.03

FREDERICK, MD., ALTITUDE 345 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.52	4.47	3.69	1.63	3.09	2.61	4.06	2.92	2.39	2.71	3.36	2.49	35.99
1901–1905	3.31	2.74	3.81	3.33	2.78	2.85	5.17	4.28	2.69	2.85	1.98	4.35	43.17
10-year mean	2.91	3.60	3.80	2.48	2.93	4.23	4.61	3.60	2.54	2.78	2.67	3.42	39.58

GETTYSBURG, PA.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	......	......	......	......	[d]44.75
1891–1905	......	......	......	......	......	......	......	......	......	......	......	......	[e]46.76
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	45.75

GRANTSVILLE, MD., ALTITUDE 2,400 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	3.21	4.30	5.00	2.53	4.05	3.84	6.57	3.59	2.85	2.56	4.16	2.88	45.59
1901–1905	3.51	2.98	3.83	3.79	3.96	4.24	3.50	3.32	2.12	2.63	1.78	4.11	39.81
10-year mean	3.36	3.64	4.41	3.16	4.00	4.05	5.03	3.45	2.48	2.59	2.97	3.49	42.70

GREAT FALLS, MD., ALTITUDE 150 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.46	4.35	3.04	1.68	3.45	2.19	3.52	2.73	2.71	1.90	2.91	1.91	32.87
1901–1905	2.89	2.20	3.65	3.27	2.34	4.84	6.29	3.24	3.10	3.39	1.47	[f]4.61	41.32
10-year mean	2.67	3.27	3.34	2.47	2.84	3.51	4.90	2.98	2.90	2.64	2.19	3.26	37.09

GREENSPRING FURNACE, MD., ALTITUDE 500 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.65	[g]3.80	3.43	1.63	4.12	2.85	3.52	3.39	2.69	2.21	3.11	2.16	35.71
1901–1905	2.98	2.27	3.18	3.32	3.13	4.61	5.04	3.87	2.37	2.53	1.82	3.64	38.81
10-year mean	2.81	3.03	3.30	2.47	3.62	3.73	4.28	3.63	2.53	2.37	2.46	2.90	37.26

HAGERSTOWN, MD., ALTITUDE 550 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.27	4.28	4.13	1.31	[h]3.02	[i]3.54	[j]3.73	[j]3.85	[i]2.56	[i]2.37	3.25	2.21	36.52
1901–1905	......	......	......	......	......	......	......	......	......	......	......	......	[k]33.89
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	35.20

a 1 year interpolated, based on observations at Oakland.
b 2 years interpolated, based on observations at Oakland.
c 1 year interpolated, based on observations at Washington.
d 5 years interpolated, based on observations at Mount St. Mary College.
e 2 years interpolated, based on observations at Mount St. Mary College.
f 2 years interpolated, based on observations at Washington.
g 1 year interpolated, based on observations at Clear Spring.
h 1 year interpolated, based on observations at Chewsville and Sharpsburg.
i 3 years interpolated, based on observations at Chewsville and Sharpsburg.
j 2 years interpolated, based on observations at Chewsville and Sharpsburg.
k 4 years interpolated, based on observations at Chewsville and Sharpsburg.

Mean precipitation at stations in drainage basin of Potomac River—Continued.

HANCOCK, MD., ALTITUDE 455 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													a 33. 74
1901–1905	2. 76	1. 83	3. 17	3. 79	2. 67	5. 27	4. 71	3. 81	b 2. 16	b 2. 45	b 1. 48	b 3. 41	37. 54
10-year mean													a 35. 64

HARNEY, MD., ALTITUDE 500 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													c 39. 34
1901–1905	3. 30	2. 91	4. 13	3. 30	2. 67	4. 83	5. 70	4. 14	3. 09	3. 14	1. 85	4. 36	43. 46
10-year mean													c 41. 40

HARPERS FERRY, W. VA., ALTITUDE 277 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2. 64	4. 18	3. 60	1. 66	4. 63	3. 12	3. 74	3. 80	2. 75	2. 91	3. 58	2. 76	39. 37
1901–1905	3. 19	1. 95	4. 27	3. 75	3. 42	4. 50	5. 14	3. 21	3. 16	2. 76	1. 89	3. 89	41. 13
10-year mean	2. 91	3. 06	3. 93	2. 70	4. 02	3. 81	4. 44	3. 50	2. 95	2. 83	2. 73	3. 32	40. 25

LINCOLN, VA., ALTITUDE 500 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													d [33. 11]
1901–1905	2. 58	e 2. 34	e 3. 07	4. 05	3. 00	7. 14	4. 44	3. 74	2. 72	2. 69	2. 05	3. 70	41. 53
10-year mean													37. 32

MARION, PA., ALTITUDE 640 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900													f [37. 50]
1901–1905													a 40. 89
10-year mean													39. 19

MARTINSBURG, W. VA., ALTITUDE 435 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	1. 92	3. 60	3. 13	1. 65	3. 25	3. 82	3. 27	3. 28	2. 78	2. 09	3. 05	2. 16	34. 02
1901–1905	2. 72	1. 70	3. 46	3. 82	4. 24	4. 99	6. 18	3. 69	2. 55	2. 70	2. 20	3. 01	41. 29
10-year mean	2. 32	2. 15	3. 29	2. 73	3. 74	4. 40	4. 72	3. 48	2. 66	2. 39	2. 62	2. 53	37. 65

MOUNT ST. MARY COLLEGE, MD., ALTITUDE 720 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2. 28	3. 87	3. 89	1. 67	g 4. 31	3. 35	4. 66	4. 42	3. 01	3. 06	3. 95	2. 57	41. 07
1901–1905	3. 65	2. 48	4. 47	4. 36	3. 17	5. 12	4. 74	g 3. 81	g 2. 85	3. 38	2. 00	4. 02	44. 06
10-year mean	2. 96	3. 17	4. 18	3. 01	3. 74	4. 23	4. 70	4. 11	2. 93	3. 72	2. 97	3. 29	42. 56

NEW MARKET, MD., ALTITUDE 550 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2. 62	4. 48	h 4. 26	1. 99	3. 74	2. 76	5. 13	3. 36	2. 82	2. 58	4. 04	2. 37	40. 18
1901–1905	3. 61	3. 00	4. 12	3. 53	2. 72	6. 86	6. 44	4. 82	2. 91	3. 50	2. 13	4. 75	48. 65
10-year mean	3. 11	3. 74	4. 19	2. 76	3. 23	4. 81	5. 78	4. 09	2. 86	3. 04	3. 08	3. 56	44. 41

a 2 years interpolated, based on observations at Greenspring Furnace.
b 1 year interpolated, based on observations at Greenspring Furnace.
c 3 years interpolated, based on observations at Mount St Mary College.
d 5 years interpolated, based on observations at Frederick.
e 1 year interpolated, based on observations at Frederick.
f 5 years interpolated, based on observations at Greenspring Furnace.
g 1 year interpolated, based on observations at Harney.
h 1 year interpolated, based on observations at Frederick.

Mean precipitation at stations in drainage basin of Potomac River—Continued.

OLD FIELD, W. VA., ALTITUDE 800 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.16	3.73	2.74	1.57	4.00	3.10	3.89	3.74	2.85	2.12	[a]2.19	[a]1.77	33.87
1901–1905	......	......	......	......	......	......	......	......	......	......	......	......	[b]33.64
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	33.75

POINT OF ROCKS, MD., ALTITUDE 235 (?) FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.39	3.66	3.55	1.79	3.98	3.38	3.82	3.30	2.98	2.54	2.97	2.11	36.69
1901–1905	2.68	2.15	3.27	3.43	3.57	4.91	4.48	3.69	2.31	[c]2.19	[d]1.46	[d]3.32	37.30
10-year mean	2.53	2.90	3.41	2.61	3.77	4.14	4.15	3.49	2.64	2.36	2.21	2.71	36.99

RECEIVING RESERVOIR, MD., ALTITUDE 160 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.44	4.05	3.04	1.77	3.40	3.16	4.03	4.74	3.26	2.01	3.04	[e]2.13	37.05
1900–1905	[e]3.01	2.01	3.61	3.73	2.70	3.82	6.08	3.85	2.92	3.44	1.65	[e]4.76	41.61
10-year mean	2.72	3.03	3.32	2.75	3.05	3.49	5.05	4.29	3.09	2.72	2.34	3.44	39.33

RIVERTON, VA., ALTITUDE 493 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	......	......	......	......	[f][32.50]
1901–1905	......	......	......	......	......	......	......	......	2.01	2.28	1.35	3.40	[g]32.58
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	32.54

ROMNEY, W. VA., ALTITUDE 824 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	......	......	......	......	[h]35.40
1901–1905	2.29	[h]1.78	3.04	3.13	3.77	3.78	[h]4.34	[h]3.99	1.59	2.36	1.80	2.91	34.79
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	35.09

SHARPSBURG, MD., ALTITUDE 440 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.56	3.83	3.26	[d]1.46	[d]3.94	3.22	3.78	3.16	[d]2.62	[d]2.29	3.07	2.16	35.37
1900–1905	......	......	......	......	......	......	......	......	......	......	......	......	[i]38.11
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	36.74

SHENANDOAH, VA., ALTITUDE 937 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	......	......	......	......	[j][33.80]
1901–1905	......	......	......	......	......	......	......	......	......	......	......	......	[k]34.28
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	34.04

[a] 1 year interpolated, based on observations at Romney.
[b] 5 years interpolated, based on observations at Romney.
[c] 2 years interpolated, based on observations at Harpers Ferry.
[d] 1 year interpolated, based on observations at Harpers Ferry.
[e] 1 year interpolated, based on observations at Washington.
[f] 5 years interpolated, based on observations at Stephen City.
[g] 1 year interpolated, based on observations at Stephen City.
[h] 1 year interpolated, based on observations at Burlington.
[i] 3 years interpolated, based on observations at Harpers Ferry.
[j] 5 years interpolated, based on observations at Staunton.
[k] 1 year interpolated, based on observations at Staunton.

Mean precipitation at stations in drainage basin of Potomac River—Continued.

SOMERSET, PA., ALTITUDE 2,250 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	3.84	4.82	5.80	3.48	4.04	5.48	5.81	4.73	3.50	2.67	4.25	4.02	52.48
1901–1905	4.86	3.95	5.71	5.95	4.30	6.01	5.55	4.71	2.38	3.06	2.31	4.56	53.37
10-year mean	4.35	4.38	5.75	4.71	4.17	5.74	5.68	4.72	2.94	2.86	3.28	4.29	52.87

STAUNTON, VA., ALTITUDE 1,380 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.56	3.32	3.93	1.95	4.30	3.59	3.62	3.83	3.71	3.57	2.53	1.90	38.85
1901–1905	2.69	2.95	3.16	3.95	4.09	5.45	4.32	3.55	2.62	1.99	1.68	3.53	40.02
10-year mean	2.62	3.13	3.54	2.95	4.19	4.52	3.97	3.69	3.16	2.78	2.10	2.71	39.43

STEPHENS CITY, VA., ALTITUDE 710 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.39	4.16	3.69	1.57	4.22	3.90	4.01	4.11	2.99	3.17	2.51	2.41	39.17
1901–1905	......	......	3.64	......	......	......	......	......	2.85	2.34	......	......	[a] 39.95
10-year mean	......	......	3.66	......	......	......	......	......	2.92	2.75	......	......	39.56

SUNNYSIDE, MD., ALTITUDE 2,500 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	4.73	5.78	6.46	3.49	5.68	5.69	7.04	4.63	3.99	3.01	5.44	4.42	60.38
1901–1905	......	......	......	......	......	......	......	......	......	......	......	......	[b] 51.32
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	55.85

TAKOMA PARK, MD., ALTITUDE 250 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	......	......	......	......	....
1901–1905	4.23	3.07	4.10	4.05	3.12	5.07	7.23	5.34	4.17	3.37	1.95	5.29	51.02
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	....

TANEYTOWN, MD., ALTITUDE 490 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	[c]2.15	[c]4.14	[c]3.19	[c]1.82	[c]3.91	[c]3.22	4.56	3.96	3.00	2.26	3.66	2.52	38.39
1901–1905	......	......	......	......	......	......	......	......	......	......	......	......	[d] 45.08
10-year mean	......	......	......	......	......	......	......	......	......	......	......	......	41.73

UPPER TRACT, W. VA., ALTITUDE 1,230 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	......	......	......	......	[e][35.62]
1901–1905	2.22	1.87	2.67	2.95	3.82	[c]4.89	3.96	4.16	1.87	1.67	1.64	3.14	34.69
8-year mean	......	......	......	......	......	......	......	......	......	......	......	......	35.15

WASHINGTON, D. C., ALTITUDE 112 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.76	4.97	3.67	1.94	3.87	3.94	3.93	4.16	3.27	2.33	2.58	2.28	39.73
1901–1905	3.40	2.97	3.69	3.70	2.95	4.39	5.81	4.64	3.06	3.37	1.96	4.69	44.67
10-year mean	3.08	3.97	3.68	2.82	3.41	4.16	4.87	4.40	3.16	2.85	2.27	3.48	42.20

[a] 1 year interpolated, based on observations at Riverton.
[b] 3 years interpolated, based on observations at Deer Park and Oakland.
[c] 1 year interpolated. based on observations at Bachman Valley.
[d] 3 years interpolated, based on observations at Bachman Valley.
[e] Mean for 1898–1900.

Mean precipitation at stations in drainage basin of Potomac River—Continued.

WESTERNPORT, MD., ALTITUDE 1,000 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	2.35	3.10	3.52	2.41	4.08	3.51	4.10	3.10	2.81	2.35	2.98	1.70	36.02
1901–1905	2.28	1.93	2.92	3.08	3.68	4.76	4.71	3.14	2.33	1.92	1.17	2.89	34.81
10-year mean	2.31	2.51	3.22	2.74	3.88	4.13	4.40	3.12	2.57	2.13	2.07	2.29	35.41

WOODSTOCK, VA., ALTITUDE 927 FEET.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1896–1900	......	......	......	......	......	......	......	......	3.12	2.92	2.11	1.80	[a]35.15
1901–1905	2.59	1.77	2.99	3.25	3.57	5.71	3.03	4.04	2.23	2.06	1.41	3.00	35.67
10-year mean	......	......	......	......	......	......	......	......	2.67	2.49	1.76	2.40	35.41

[a] 1 year interpolated, based on observations at Stephens City.

COMPARISON OF RAINFALL AND RUN-OFF.

At eight river-measurement stations in the Potomac drainage basin the records of run-off were of sufficient extent for the comparison of rainfall and run-off. These stations are as follows:

Potomac at Point of Rocks, Md.
Monocacy near Frederick, Md.
Antietam Creek, near Sharpsburg, Md.
South Branch of Potomac near Springfield, W. Va.
North Branch of Potomac near Piedmont, W. Va.
South Branch of Shenandoah near Front Royal, Va.
North Branch of Shenandoah near Riverton, Va.
Shenandoah at Millville, W. Va.

The rainfall stations in the areas above these stations are so distributed as to represent fairly well the conditions over the various areas. It has been assumed that for any area the mean rainfall for a given month is the mean of the monthly rainfall at the various stations in that area. Based on this assumption, the monthly and yearly rainfall for the years for which run-off records are available has been determined. These values are included in the tables of mean monthly run-off given for each gaging-station in other parts of this report. When these monthly rainfall tables were prepared some of the data given on pages 34–40 were not available.

From the monthly rainfall and the monthly run-off the run-off in per cent of rainfall has been determined and also the loss of rainfall.

In the comparison of run-off and rainfall the following facts must be kept in mind. First, run-off is a resultant quantity, being the amount of water left after evaporation, vegetation, seepage, etc., in the area have been satisfied; second, a rain gage shows only the rain that falls on a few square inches of surface. There should be many rain gages in order to ascertain the average precipitation over a watershed, and, as maximum precipitation often occurs in comparatively small areas, it may not be recorded. Third, ground and surface storage modify the relation between precipitation and run-off. The run-off for a month in early spring may be much larger than the precipitation for that month, on account of melting snow that falls during the winter months. Again, in the early fall, when the ground water is low, a small rainfall yields a much smaller run-off than it would during the spring, when the ground is nearly saturated with water. Fourth, heavy rainfall frequently occurs at the end of the month, and as the run-off data are computed for the calendar months, the results from such rainfall may appear in the following month's record. Fifth, data are not available relative to snow storage, which produces the high percentages of run-off usually obtained for the late winter and early spring. To account fully for this storage, a sample of snow extending from top to bottom should be melted at the end of each month, in order to determine the total amount of water stored on the ground. The quantity available for run-off during the following month would be the amount thus determined plus the precipitation during the following month minus the amount left in snow storage at the end of that month plus or minus the change in ground water. These and other causes make the monthly ratios of run-off to rainfall appear very erratic. A month is too short a period for the comparison of these quantities. A year is a better period, but not entirely satisfactory, especially if the calendar year is taken, as the snow and ground-water storage are not in the same conditions at the end of each year.

Notwithstanding the above facts, the rainfall and stream data and the comparison between the two are very consistent from year to year and from station to station, and are of great interest both for comparative purposes and to show the general conditions existing in the drainage.

GAGING STATIONS.

In the following table are listed the stations in the Potomac basin at which stream measurements have been made by the United States Geological Survey:

Gaging stations of the United States Geological Survey in the Potomac basin.

Station.	Period of observations.
Savage River at Bloomington, Md	May 3, 1905, to July 15, 1906.
North Branch of Potomac River at Piedmont, W. Va	June 27, 1899, to July 15, 1906.
Georges Creek at Westernport, Md	May 4, 1905, to July 15, 1906.
Wills Creek at Cumberland, Md	May 6, 1905, to July 14, 1906.
North Branch of Potomac River at Cumberland, Md	June 11, 1894, to Nov. 20, 1897.
South Branch of Potomac River near Springfield, W. Va	June 3, 1894, to Oct. 20, 1894; Apr. 11, 1895, to Feb. 29, 1896; June 26, 1899, to Feb. 24, 1902; Aug. 28, 1903, to July 14, 1906.
Potomac River at Great Cacapon, W. Va.[a]	
Tuscarora Creek at Martinsburg, W. Va	May 8 to Dec. 30, 1905
Opequon Creek near Martinsburg, W. Va	May 9 to June 4, 1905; Oct. 8, 1905, to July 15, 1906.
Antietam Creek near Sharpsburg, Md	July 1, 1897, to Aug. 25, 1905.
South River at Basic, Va	June 29,1905, to July 15, 1906.
South River at Port Republic, Va	Aug. 6, 1895, to Apr. 1, 1899.
Cooks Creek at Mount Crawford, Va	July 1, 1905, to July 15, 1906.
Lewis Creek at Staunton, Va	Do.
North River at Port Republic, Va	Aug. 6, 1895. to Apr. 1, 1899.
Elk Run at Elkton, Va	June 28, 1905, to July 15, 1906.
Hawksbill Creek near Luray, Va	June 27, 1905, to July 15, 1906.
South Branch of Shenandoah River near Front Royal, Va	June 26, 1899, to July 16, 1906.
Passage Creek at Buckton, Va	Oct. 26, 1905, to July 15, 1906.
North Branch of Shenandoah River near Riverton, Va	June 26, 1899, to July 14, 1906.
Shenandoah River at Millville, W. Va	Since Apr. 15, 1895.
Potomac River at Point of Rocks, Md	Since Feb. 17, 1895.
Monocacy River near Frederick, Md	Since Aug. 4, 1896.
Rock Creek at Lyon's mill, Washington, D. C	Aug. 18, 1892, to Nov. 30, 1894.
Rock Creek at Zoological Park, D. C	Jan. 18, 1897, to Nov. 10, 1900.

[a] Gage-height records were obtained from June 21, 1894, to March 7, 1896, but are not republished on account of their unreliability.

Daily gage-height records are at present maintained by the Weather Bureau in the Potomac drainage basin at Cumberland, Md.; Riverton, Va., and Harpers Ferry, W. Va. General information and tables of gage heights at these stations can be found in the Weather Bureau Report of Daily River Stages of the Principal Rivers of the United States.

The Cumberland station on North Branch of Potomac River was established September 1, 1901, at the dam just below the mouth of Wills Creek. The range of stage since the date of establishment has been from 0 to 11.5 feet. The danger line is at 8 feet. The datums of the Weather Bureau and Geological Survey gages have not been connected by level at this point. It is not considered advisable to attempt to obtain additional estimates at Cumberland based on the Weather Bureau records, because no discharge measurements have been made there since 1898.

The Riverton station on Shenandoah River was established September 1, 1901, at the Norfolk and Western Railway bridge below the junction of North and South branches. Gage heights were also obtained at this point during 1892 to 1894. The highest water was

47 feet September 30 and October 1, 1870; the lowest since 1900 was −1.7 feet. The danger line is at 22 feet.

The Harpers Ferry station on Potomac River was established in 1882 at the Baltimore and Ohio Railroad bridge. November 1, 1901, the gage datum was lowered 2.00 feet. The highest water was 36 feet, June 1, 1889; the high water of November, 1877, was 29.2 feet; the lowest on various dates −3 feet. The danger line is at 18 feet. Elevations have been reduced to new datum.

Records were also kept of the elevation of the water surface at high tide at Long Bridge, Washington, D. C., from June 1, 1891, to April 15, 1893. For flood stages see page 181. The danger point is 8 feet on the gage, or about 7 feet above mean sea level. Daily gage heights at Great Falls have likewise been published from 1890 to 1892 inclusive.

NORTH BRANCH OF POTOMAC RIVER BASIN.

GENERAL DESCRIPTION.

The general features of the basin of North Branch of Potomac River are described on page 213. The country drained comprises steep mountain slopes and narrow valleys. The run-off is rapid and fluctuations in flow are great. The fall of the stream both above and below Cumberland is large. Facilities for dams are excellent. The tributaries of North Branch are comparatively small and the fall of many of them is rapid.

SAVAGE RIVER AT BLOOMINGTON, MD.

Savage River rises on Bog and Little Savage mountains, in the northeastern part of Garrett County, Md., and flows in a general southwesterly direction for about 20 miles, then turns to the southeast, and enters North Branch of Potomac River near Bloomington. The drainage area is practically uninhabited and the watershed is given over to lumbering. The river receives the waters of a number of small runs. The gaging station on Savage River was established May 3, 1905, and was discontinued July 16, 1906. It is located at a highway bridge about 800 feet above the junction of Savage River with North Branch of the Potomac.

The channel is straight for 200 feet above and below the station. The current is swift. The right bank is low and clean and has an overflow channel at high water. The left bank is high and does not overflow. The bed of the stream is rocky, very irregular, and permanent. There is but one channel at low and ordinary stages; during high-water stages there are two channels.

Discharge measurements were made from the downstream side of the steel bridge to which the gage is fastened. The initial point for soundings is the center of the bridge pier at the left abutment, downstream side.

A standard chain gage is attached to the downstream side of the bridge near the left abutment. The length of the chain from the end of the weight to the marker is 21.15 feet. The gage was read twice each day by F. S. Cline. Bench mark No. 1 is a chiseled cross on the downstream corner of the left abutment. Its elevation is 16.49 feet above gage datum. Bench mark No. 4 is the top of the pulley wheel of the gage. Its elevation was 20.82 feet above gage datum March 16, 1906.

Estimates are considered to be within 5 per cent of the true discharge for stages above 30 second-feet. Below this limit the probable error may be somewhat greater. The estimates do not include the flow in the 10-inch pipe which carries the Piedmont water supply. This pipe rests upon the river bottom at the bridge and in low water carries an appreciable percentage of the total flow of the river. Ice conditions did not affect the flow at this station during the winter of 1905–6.

Discharge measurements of Savage River at Bloomington, Md.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
April 18	2.96	89	March 16	2.95	87
May 4	2.68	72	April 10	5.60	1,139
June 7	2.88	81	Do	5.40	1.027
July 17	2.47	37	April 11	4.79	685
November 7	2.59	66	May 28	3.25	141

Daily gage height, in feet, of Savage River at Bloomington, Md.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1						2.8	2.32	2.6	2.18	1.98	2.82	3.58
2						2.72	3.3	2.42	2.2	2.12	2.78	3.92
3					2.7	2.62	2.92	2.22	2.13	2.08	2.62	5.22
4					2.7	2.52	2.82	2.12	2.12	2.15	2.55	4.58
5					2.62	2.52	2.72	2.05	1.9	2.05	2.5	4.28
6					2.62	2.42	2.48	2.1	1.88	1.9	2.58	3.7
7					2.62	2.97	3.62	1.92	1.85	1.9	2.58	3.52
8					2.58	3.42	4.32	1.85	1.7	1.8	2.48	3.35
9					2.5	3.22	3.75	1.9	1.9	1.85	2.52	3.18
10					2.45	2.92	3.52	1.85	1.78	1.78	2.42	3.25
11					2.4	3.93	3.38	1.85	4.48	2.22	2.4	2.88
12					2.78	4.55	3.1	2.25	3.85	2.75	2.35	2.88
13					2.7	4.25	2.92	2.08	3.4	2.48	2.28	2.82
14					3.0	3.75	2.88	1.95	3.08	2.42	2.25	2.72
15					4.15	3.4	2.72	2.05	2.75	2.32	2.22	2.62
16					3.92	3.18	2.52	2.45	2.58	2.22	2.42	2.45
17					3.75	2.92	2.4	2.22	2.52	2.18	2.32	2.82
18					3.65	2.78	2.32	2.19	2.45	2.02	2.25	2.65
19					3.48	2.68	2.28	2.15	2.42	2.1	2.22	2.52
20					3.25	2.72	2.4	2.05	2.28	4.42	2.2	2.65
21					3.1	2.78	2.28	2.05	2.18	3.75	2.08	3.75
22					2.92	2.6	2.22	1.95	2.12	3.28	1.92	4.52
23					2.78	2.52	2.6	1.82	2.05	3.05	2.05	4.48
24					2.62	2.85	2.35	1.85	2.3	2.92	2.22	4.25
25					2.6	2.82	2.18	3.05	1.9	2.85	2.28	3.9
26					2.6	2.68	2.18	3.55	1.9	3.55	2.2	3.7
27					2.6	2.8	2.02	2.92	1.95	3.6	2.12	3.48
28					2.48	2.58	1.9	2.68	1.9	3.48	2.1	2.78
29					2.4	2.48	2.15	2.62	1.9	3.35	3.42	3.4
30					2.4	2.32	2.62	2.48	1.85	2.7	4.2	2.2
31					2.5		2.82	2.32		2.92		2.15

Daily gage height, in feet, of Savage River at Bloomington, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	2.8	2.75	2.55	5.32	3.22	3.35	2.48	......	......	......	......	......
2	2.75	2.55	2.43	4.82	3.18	3.28	2.38	......	......	......	......	......
3	3.05	2.65	2.75	4.98	3.32	2.95	2.28	......	......	......	......	......
4	4.28	3.03	4.45	5.22	3.22	2.75	2.2	......	......	......	......	......
5	4.52	2.75	3.83	5.88	3.0	2.75	2.12	......	......	......	......	......
6	4.15	2.6	3.5	5.92	3.0	3.35	1.98	......	......	......	......	......
7	3.85	2.67	3.37	4.88	2.92	4.62	1.88	......	......	......	......	......
8	3.6	2.6	3.25	4.48	2.82	5.15	1.88	......	......	......	......	......
9	3.3	2.53	3.17	4.42	2.82	4.05	1.98	......	......	......	......	......
10	3.12	2.6	3.15	5.95	2.8	3.6	1.88	......	......	......	......	......
11	3.18	2.37	2.97	4.9	2.72	3.32	1.92	......	......	......	......	......
12	3.2	2.47	3.05	4.35	2.68	3.05	1.88	......	......	......	......	......
13	2.75	2.5	2.87	3.95	2.58	2.88	1.88	......	......	......	......	......
14	3.18	2.47	2.93	3.8	2.52	3.05	1.92	......	......	......	......	......
15	3.02	2.37	3.2	4.78	2.52	2.85	1.78	......	......	......	......	......
16	3.25	2.4	2.93	4.6	2.48	2.65	......	......	......	......	......	......
17	3.52	2.47	2.88	4.3	2.38	2.55	......	......	......	......	......	......
18	3.6	2.27	2.74	4.05	2.32	2.38	......	......	......	......	......	......
19	4.02	2.33	2.78	3.75	2.42	2.3	......	......	......	......	......	......
20	4.0	2.33	2.95	3.55	2.32	2.52	......	......	......	......	......	......
21	4.15	2.47	2.9	3.52	2.3	2.98	......	......	......	......	......	......
22	4.32	2.63	2.98	3.4	2.3	2.82	......	......	......	......	......	......
23	7.08	2.63	2.75	3.48	2.25	2.78	......	......	......	......	......	......
24	5.5	2.35	3.18	3.4	2.2	2.78	......	......	......	......	......	......
25	4.55	2.47	3.05	3.52	2.2	2.62	......	......	......	......	......	......
26	4.1	2.37	3.05	3.62	2.2	2.65	......	......	......	......	......	......
27	3.6	2.23	4.85	3.65	2.42	2.78	......	......	......	......	......	......
28	3.52	2.25	6.5	3.58	3.4	2.75	......	......	......	......	......	......
29	3.48	......	6.0	3.48	3.35	2.55	......	......	......	......	......	......
30	3.2	......	7.15	3.35	2.95	2.42	......	......	......	......	......	......
31	3.18	......	6.05	......	2.82	......	......	......	......	......	......	......

Rating table for Savage River at Bloomington, Md., from May 3, 1905, to July 15, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.70	8	2.90	84	4.00	344	5.20	912
1.80	10	3.00	98	4.10	380	5.40	1,030
1.90	12	3.10	114	4.20	418	5.60	1,150
2.00	15	3.20	132	4.30	458	5.80	1,280
2.10	19	3.30	152	4.40	500	6.00	1,415
2.20	23	3.40	174	4.50	544	6.20	1,555
2.30	28	3.50	197	4.60	591	6.40	1,695
2.40	34	3.60	222	4.70	640	6.60	1,840
2.50	41	3.70	249	4.80	691	6.80	1,990
2.60	50	3.80	278	4.90	744	7.00	2,140
2.70	60	3.90	310	5.00	799	7.20	2,300
2.80	71						

[a] This table is strictly applicable only for open-channel conditions. It is based upon eight discharge measurements made during 1905 and 1906. It is well defined between gage heights 2.4 feet and 5.6 feet.

Estimated monthly discharge of Savage River at Bloomington, Md.

[Drainage area, 120 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
May 3-31	399	34	97.8	0.815	0.879
June	568	29	118	.983	1.10
July	466	12	85.0	.708	.816
August	210	10	34.0	.283	.326
September	535	8	56.0	.467	.521
October	509	10	82.1	.684	.789
November	418	13	51.1	.426	.475
December	924	21	220	1.83	2.11
1906.					
January	2,204	66	330	2.75	3.17
February	103	24	43.8	.365	.380
March	2,260	36	348	2.90	3.34
April	1,380	163	521	4.34	4.84
May	174	23	69.9	.582	.671
June	884	28	138	1.15	1.28
July 1-15	40	10	17.8	.148	.082

NORTH BRANCH OF POTOMAC RIVER AT PIEDMONT, W. VA.

This gaging station was established June 27, 1899, by E. G. Paul, and was discontinued July 16, 1906. It is located at the iron highway bridge connecting Luke, Md., with Piedmont, W. Va.

The channel is straight for 1,200 feet above and 600 feet below the station. The current has a moderate velocity. The right bank is high and rocky and does not overflow. The left bank is low and liable to overflow, but all water passes beneath the bridge. The bed of the stream is composed of gravel and cobblestones, overlain in the left channel and in part of the right channel by refuse from pulp mills above the bridge. It is free from vegetation. Discharge measurements were made from the downstream side of the bridge to which the gage is attached. The initial point for soundings is the face of the pier on the right bank.

The standard chain gage is attached to the hand rail on the lower side of the bridge in the second span from the right end. The length of the chain from the end of the weight to the marker is 38.87 feet. The gage was read twice each day by Charles H. Beck. The bench mark is the top of a small shoulder in the face of the sandstone ledge which forms the right abutment of the bridge. It is about 4 feet above the ground and 10 feet downstream from the bridge. The point is indicated by an arrow cut in the vertical face of the ledge. Its elevation is 20.40 feet above gage datum.

The plotting of the discharge measurements made during 1899 to 1906 indicates that the channel has been gradually filling in at the control below the gaging section, and also to some extent at the gaging section itself, thus causing a gradually diminishing discharge for a given gage height. This apparently is due to refuse discharged into the river from pulp mills immediately above the bridge. The amount of refuse affecting the flow does not increase at a constant rate, and at times of high water part of it may be washed away. Owing to these changing conditions of flow all estimates at this station are somewhat uncertain, there being a varying error of from 5 to 20 per cent. The larger percentages of error occur at low-gage heights, especially during periods when no measurements were made. The three rating curves prior to 1906 have been united at about gage height 4.5 feet. This is not strictly correct, but the percentage of error involved is relatively small. Ice conditions at this station probably do not greatly affect the discharge. No corrections were made in estimates for ice periods. Estimates for the period from June 27, 1899, to December 31, 1903, previously published have been revised. Estimates for 1904 and 1905, as published in the 1905 report, have not been changed.

A summary of the records furnishes the following results: Maximum discharge for twenty-four hours, 13,450 second-feet; minimum discharge for twenty-four hours, 6 second-feet; mean annual discharge for six years, 687 second-feet; mean annual rainfall for seven years, 38.66 inches.

Discharge measurements of North Branch of Potomac River at Piedmont, W. Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Second-feet.*		*Feet.*	*Second-feet.*
January 27	3.00	350	September 9	1.99	14.7
			September 28	1.99	20
1900.					
February 22	3.75	735	1905.		
June 20	4.40	1,249	March 9	6.70	4,516
September 12	1.80	34	March 10	7.47	6,047
			March 29	4.25	1,096
1901.			April 18	3.46	416
July 24	2.90	275	April 24	3.63	526
November 7	2.10	39	May 4	3.22	326
			June 7	3.44	441
1902.			July 17	3.15	280
August 19	2.14	50	November 7	3.38	439
1903.			1906.		
August 31	2.80	208	March 16	3.51	412
			March 30	7.15	5,819
1904.			April 11	5.64	2,589
July 8[a]	2.80	116	May 28	3.49	391

[a] Measurement unreliable, owing to defective meter.

Daily gage height, in feet, of North Branch of Potomac River at Piedmont, W. Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
1	......	......	......	......	......	......	3.15	2.5	2.2	2.2	3.75	2.6
2	......	......	......	......	......	......	2.9	2.35	2.2	2.2	3.9	2.6
3	......	......	......	......	......	......	2.8	2.25	2.1	2.15	3.05	2.6
4	......	......	......	......	......	......	2.7	2.4	2.0	2.1	2.8	2.6
5	......	......	......	......	......	......	2.65	2.4	2.3	2.1	2.8	2.5
6	......	......	......	......	......	......	2.7	2.4	2.2	2.1	2.55	2.4
7	......	......	......	......	......	......	2.8	2.55	2.15	2.2	2.5	2.4
8	......	......	......	......	......	......	2.7	2.45	2.1	2.1	2.4	2.4
9	......	......	......	......	......	......	2.7	2.3	2.2	2.15	2.4	2.35
10	......	......	......	......	......	......	2.7	2.25	2.3	2.1	2.4	2.4
11	......	......	......	......	......	......	2.65	2.1	2.95	2.1	2.4	2.5
12	......	......	......	......	......	......	2.5	2.15	3.4	2.2	2.4	5.2
13	......	......	......	......	......	......	2.4	2.1	2.75	2.1	2.3	4.6
14	......	......	......	......	......	......	2.85	2.1	2.45	2.1	2.3	3.75
15	......	......	......	......	......	......	2.85	2.1	2.35	2.0	2.3	3.6
16	......	......	......	......	......	......	2.5	2.0	2.3	2.2	2.3	3.35
17	......	......	......	......	......	......	2.7	2.0	2.3	2.1	2.3	3.05
18	......	......	......	......	......	......	2.9	2.0	2.15	2.1	2.2	3.15
19	......	......	......	......	......	......	2.65	2.0	2.1	2.1	2.4	3.2
20	......	......	......	......	......	......	2.5	2.0	2.45	2.1	3.35	3.7
21	......	......	......	......	......	......	2.4	2.0	2.9	2.1	3.0	3.3
22	......	......	......	......	......	......	2.35	1.95	2.65	2.0	2.8	3.2
23	......	......	......	......	......	......	2.3	1.9	2.4	2.0	2.85	3.1
24	......	......	......	......	......	......	2.3	1.9	2.4	2.1	3.3	3.0
25	......	......	......	......	......	......	2.3	1.9	2.25	2.1	3.2	3.0
26	......	......	......	......	......	......	2.2	1.9	2.2	2.1	3.0	2.9
27	......	......	......	......	......	3.0	2.15	2.1	2.3	2.1	2.8	2.8
28	......	......	......	......	......	2.9	2.5	3.0	2.55	2.1	2.8	2.8
29	......	......	......	......	......	2.85	2.35	2.9	2.4	2.2	2.7	2.8
30	......	......	......	......	......	3.5	2.3	2.55	2.25	2.15	2.6	2.8
31	......	......	......	......	......	......	2.45	2.35	......	2.15	......	2.7
1900.[a]												
	2.7	3.0	3.55	4.6	3.15	3.3	3.0	2.95	2.1	2.85	2.1	3.55
2	2.7	3.05	4.5	4.8	3.1	3.25	2.85	2.75	2.0	2.45	2.1	3.45
3	2.7	3.1	4.1	4.65	3.1	3.25	2.7	2.65	2.0	2.2	2.25	3.25
4	2.7	3.1	4.0	4.5	3.1	3.05	2.7	2.6	2.0	2.1	2.65	5.8
5	2.7	3.35	4.3	4.25	3.0	2.9	2.7	2.4	2.0	2.2	2.7	5.65
6	2.8	3.6	4.25	4.15	2.95	2.85	2.6	2.3	1.95	2.2	2.5	4.7
7	2.9	3.7	5.8	4.15	2.9	2.85	2.7	2.3	1.9	2.2	2.4	4.25
8	3.0	[b]5.3	5.0	4.3	2.9	3.15	3.0	2.2	1.9	2.1	2.3	4.0
9	3.3	5.4	4.55	4.2	2.95	3.15	2.85	2.2	1.9	2.05	2.4	3.8
10	3.5	4.65	4.4	3.95	3.2	2.95	2.7	2.1	1.9	2.0	2.5	3.6
11	3.5	4.4	4.3	3.75	3.05	2.8	2.6	2.05	1.8	2.0	2.5	3.4
12	[b]4.7	4.05	4.15	3.7	3.0	2.7	2.45	2.0	1.8	2.0	2.6	3.4
13	4.25	5.9	4.1	3.65	2.9	2.7	2.6	2.1	1.8	2.0	2.6	3.4
14	3.9	5.5	4.1	3.55	2.8	3.15	2.65	2.0	1.8	3.05	2.5	3.3
15	3.9	4.8	4.0	3.4	2.8	3.2	2.55	2.0	1.8	3.2	2.5	3.3
16	3.9	4.35	3.8	3.4	2.8	3.95	2.35	2.1	1.8	2.65	2.4	3.2
17	4.4	4.15	3.7	3.4	2.8	7.55	2.3	2.4	1.9	2.5	2.4	3.05
18	4.1	4.05	3.7	3.55	2.7	5.85	2.25	2.25	1.9	2.4	2.4	3.15
19	4.15	3.7	4.0	3.75	3.4	4.95	2.35	2.25	1.9	2.25	2.4	3.2
20	5.8	3.65	5.95	3.65	3.95	4.45	2.9	2.45	1.9	2.2	2.5	3.3
21	5.7	3.6	5.35	3.5	3.55	3.95	2.75	2.2	1.8	2.1	2.6	3.25
22	4.75	3.75	4.75	3.5	3.35	3.65	2.55	2.2	1.8	2.1	3.2	3.05
23	4.35	4.0	4.6	3.65	3.2	3.5	2.45	2.65	1.8	2.15	3.0	3.0
24	4.1	3.7	4.6	3.85	3.15	3.35	2.4	2.45	1.8	2.35	2.9	3.05
25	3.95	3.6	4.5	3.65	3.05	3.25	3.2	2.4	1.8	2.8	3.35	3.05
26	3.8	3.4	4.25	3.5	3.0	3.25	4.05	2.45	1.8	2.5	7.95	3.0
27	3.55	3.4	4.35	3.4	2.95	3.05	4.4	2.45	1.85	2.35	5.2	2.9
28	3.4	3.4	4.15	3.4	2.9	2.9	3.2	2.3	1.9	2.3	4.45	2.9
29	3.3	......	4.0	3.3	3.3	3.55	3.0	2.2	1.95	2.2	4.05	3.45
30	3.2	......	4.75	3.25	3.25	3.15	3.0	2.15	2.7	2.2	3.75	3.05
31	3.1	......	4.6	......	3.1	......	3.25	2.1	......	2.2	......	3.3

[a] Slight ice conditions during January and February, 1900.
[b] Ice passed down the river January 12 and February 8, 1900.

Daily gage height, in feet, of North Branch of Potomac River at Piedmont, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.[a]												
1	3.4	3.3	2.85	3.8	4.0	4.25	3.35	2.5	3.2	2.55	2.1	2.5
2	3.2	3.2	3.0	3.65	3.9	4.4	3.15	2.5	3.0	2.4	2.1	2.7
3	2.95	3.2	4.0	4.0	3.8	4.1	3.0	2.4	2.9	2.4	2.1	5.6
4	2.95	3.2	5.2	4.0	3.75	3.9	3.0	2.4	2.8	2.5	2.1	5.2
5	3.15	3.3	4.6	4.45	3.6	3.7	2.9	2.3	2.7	2.4	2.1	4.2
6	3.1	3.3	3.85	6.55	3.4	3.6	2.8	2.4	2.6	2.4	2.1	3.5
7	3.0	3.2	3.8	6.3	3.4	4.0	2.8	3.35	2.55	2.35	2.1	3.5
8	2.9	3.2	3.8	5.65	3.3	4.0	2.8	2.85	2.5	2.25	2.1	3.5
9	3.0	3.1	4.7	5.0	5.75	3.8	2.7	2.6	2.5	2.2	2.0	3.55
10	3.0	3.1	6.2	4.65	7.55	3.55	2.6	2.5	2.4	2.2	2.0	5.7
11	4.0	3.2	6.9	4.5	5.9	3.35	2.45	2.45	2.6	2.2	2.0	4.55
12	5.75	3.1	5.65	4.3	5.25	3.15	2.4	2.35	2.7	2.2	2.05	4.05
13	4.65	3.0	5.15	4.2	4.9	4.25	2.6	2.3	2.6	2.25	2.1	3.8
14	4.15	3.0	5.2	4.65	4.6	3.95	3.5	2.45	2.6	2.3	2.2	4.3
15	4.1	2.9	4.75	5.25	4.25	4.3	3.8	2.3	2.5	2.3	2.3	8.15
16	4.0	3.0	4.4	5.6	4.1	4.9	5.3	2.3	2.45	2.25	2.2	5.55
17	3.9	3.1	4.1	5.7	3.95	4.95	5.1	2.45	2.55	2.2	2.1	4.65
18	3.55	3.15	4.05	5.4	3.8	4.7	4.25	3.15	2.6	2.2	2.1	4.2
19	3.25	3.6	4.05	4.95	3.7	4.3	4.15	3.1	2.6	2.1	2.1	3.8
20	3.35	3.4	4.15	7.6	3.75	4.05	3.55	3.35	2.5	2.1	2.1	3.4
21	3.5	3.2	4.55	7.55	3.7	3.75	3.2	3.6	2.4	2.1	2.1	3.4
22	3.9	3.1	4.35	6.35	4.55	3.55	3.1	3.35	2.4	2.1	2.1	3.4
23	3.7	3.0	4.2	5.85	5.6	3.35	2.95	3.35	2.3	2.1	2.15	3.55
24	3.6	2.85	4.05	5.65	4.65	3.2	2.9	4.95	2.3	2.1	2.7	3.5
25	4.0	2.95	4.15	5.35	4.3	3.1	2.8	4.8	2.3	2.1	3.0	[b]4.7
26	3.7	2.95	4.15	5.05	4.55	3.2	2.7	3.9	2.2	2.1	2.85	4.3
27	3.7	2.9	4.55	4.65	6.25	3.95	2.7	3.55	2.2	2.1	2.65	4.95
28	3.55	2.85	4.25	4.35	6.15	4.8	2.7	3.65	2.25	2.1	2.55	4.25
29	3.35	......	4.05	4.2	5.9	4.4	2.6	3.45	2.9	2.1	2.45	6.65
30	3.5	......	3.9	4.1	5.55	3.7	2.5	3.15	2.9	2.1	2.6	5.8
31	3.35	......	3.75	......	5.05	......	2.5	3.0	......	2.1	......	4.8
1902.[c]												
1	4.45	3.8	8.05	4.9	3.55	3.3	4.75	2.85	1.9	3.3	2.55	4.0
2	4.0	3.6	7.1	4.65	3.4	3.2	3.8	2.7	1.9	3.35	2.5	3.75
3	4.3	3.5	6.2	4.4	3.7	3.1	3.35	2.6	1.9	2.85	2.5	5.25
4	3.8	3.2	5.4	4.7	3.7	3.0	3.2	2.5	2.0	2.7	2.4	4.55
5	3.55	3.4	4.95	5.05	3.55	3.0	3.1	2.5	2.2	2.9	2.4	4.3
6	3.6	3.5	4.5	5.95	3.45	2.85	2.95	2.5	2.35	2.9	2.4	3.9
7	3.6	3.5	4.2	6.2	3.5	2.8	2.8	2.5	2.2	2.85	2.4	3.8
8	3.6	3.4	4.2	6.45	3.4	2.85	3.05	2.4	2.1	2.6	2.5	3.75
9	3.45	3.3	4.65	5.85	3.3	2.95	3.2	2.4	2.0	2.5	2.5	3.5
10	3.45	3.2	4.95	5.7	3.2	2.85	2.95	2.45	2.0	2.4	2.5	3.45
11	3.4	3.15	5.65	6.2	3.4	2.7	3.2	2.5	2.0	2.4	2.5	5.55
12	3.3	3.15	6.85	7.05	3.25	2.7	3.05	2.4	2.0	3.25	2.5	6.45
13	3.1	3.1	8.1	6.25	3.2	2.6	2.8	2.35	1.9	3.7	2.5	6.0
14	3.2	3.05	6.6	5.8	3.15	3.1	2.7	2.3	1.9	3.35	2.5	5.8
15	3.2	3.1	5.85	5.55	3.1	2.9	2.6	2.25	1.9	3.15	2.4	5.0
16	3.1	3.0	5.85	5.25	3.05	2.8	2.5	2.2	1.9	2.95	2.4	7.6
17	3.05	3.0	6.75	5.1	3.0	2.7	2.45	2.2	1.9	2.7	2.4	6.45
18	2.9	3.0	5.65	4.95	3.0	2.6	2.4	2.2	1.9	2.7	2.5	5.45
19	3.0	3.0	4.95	4.55	2.9	2.5	2.4	2.15	1.9	2.7	2.5	4.9
20	2.9	2.85	4.6	4.4	3.45	2.5	2.55	2.1	1.9	2.6	2.5	4.7
21	2.9	2.8	4.45	4.25	3.75	2.6	2.6	2.15	1.9	2.5	2.5	5.0
22	2.9	2.8	4.5	4.15	3.45	2.9	2.5	2.5	2.0	2.4	2.5	5.9
23	2.9	3.0	4.5	4.25	3.4	2.7	2.4	2.4	2.0	2.4	2.5	5.15
24	3.0	3.05	4.5	4.15	3.3	2.5	2.4	2.3	2.0	2.4	2.5	4.7
25	3.0	[d]3.35	4.45	3.8	3.3	2.4	2.3	2.2	2.0	2.4	2.75	4.5
26	3.3	6.55	4.25	3.7	3.6	2.8	2.3	2.1	2.2	2.4	5.45	4.1
27	[d]5.75	6.05	4.15	3.65	4.1	3.0	2.3	2.1	2.2	2.4	4.5	3.8
28	5.0	10.5	4.2	3.55	4.0	2.7	2.3	2.0	2.65	......	3.85	3.7
29	4.35	......	5.5	3.6	3.8	2.6	2.3	1.9	2.4	......	3.6	3.55
30	4.1	......	5.3	3.7	3.6	2.75	3.2	1.9	2.45	2.8	3.5	4.0
31	4.05	......	5.25	......	3.35	......	3.3	1.9	......	2.7	......	3.7

[a] Slight ice conditions during December, 1901.
[b] Ice passed down the river December 25, 1901.
[c] Ice conditions January and February, 1902.
[d] Ice passed down the river January 27 and February 25, 1902.

Daily gage height, in feet, of North Branch of Potomac River at Piedmont, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.[a]												
1	[a]3.45	5.2	6.7	4.85	3.6	3.75	4.45	2.9	2.8	2.05	2.3	2.4
2	3.6	6.05	5.55	4.75	3.5	3.55	4.05	2.95	2.65	2.1	2.3	2.45
3	6.8	6.4	5.0	4.45	3.55	3.4	3.75	2.9	2.5	2.1	2.2	2.25
4	6.15	8.2	4.65	4.95	4.55	3.3	3.7	3.0	2.4	2.2	2.2	2.25
5	5.25	6.15	4.5	4.45	3.75	3.2	4.15	3.0	2.3	2.2	2.25	2.3
6	4.8	5.25	4.5	4.2	3.6	3.25	5.2	2.8	2.5	2.45	2.4	2.3
7	4.5	4.75	4.6	4.2	3.6	5.25	4.05	2.8	2.5	......	2.7	2.3
8	4.2	4.6	5.2	5.15	3.5	4.55	3.65	2.7	2.35	......	2.5	2.2
9	3.8	4.35	6.1	5.95	3.45	4.1	3.45	2.65	2.3	......	2.35	2.3
10	3.8	4.0	5.4	5.2	3.4	3.9	3.3	2.5	2.7	......	2.3	2.3
11	3.8	4.15	4.95	4.7	3.35	4.5	3.25	2.5	2.45	......	2.3	2.3
12	4.35	5.05	4.8	4.6	3.2	4.35	3.3	2.5	2.4	......	2.3	2.2
13	3.95	4.65	4.5	4.45	3.2	4.8	4.0	2.45	2.3	......	2.3	2.15
14	3.75	4.5	4.3	5.3	3.1	4.8	4.1	2.4	2.2	......	2.3	2.2
15	3.7	4.8	4.15	5.6	3.1	5.1	3.75	2.4	2.15	......	2.3	2.2
16	3.7	6.95	4.0	6.05	3.1	4.55	3.5	2.4	2.1	2.5	2.3	2.3
17	3.7	5.7	3.9	5.45	3.1	4.3	3.3	2.4	2.35	2.5	2.85	2.4
18	3.5	4.95	3.8	5.0	3.0	4.0	3.45	2.6	2.7	2.6	3.65	2.2
19	3.75	4.5	3.7	4.7	3.0	3.6	3.4	2.5	2.65	2.7	3.1	2.2
20	3.5	4.35	3.6	4.4	2.9	3.65	3.4	2.95	2.5	2.65	2.7	2.3
21	3.45	4.15	3.75	4.2	2.9	4.5	3.5	2.8	2.3	2.6	2.7	2.7
22	3.5	4.0	4.55	4.0	2.8	4.15	3.35	2.6	2.2	2.5	2.7	3.2
23	3.45	3.85	6.65	3.9	3.25	6.1	3.15	2.5	2.2	2.4	2.6	2.7
24	3.2	3.9	6.0	3.8	3.9	5.15	3.0	2.4	2.15	2.4	2.6	2.85
25	3.2	3.8	5.15	3.8	4.7	4.45	2.95	2.3	2.1	2.4	2.6	4.45
26	3.25	3.7	4.7	4.3	4.6	4.0	2.9	2.4	2.1	2.3	2.5	3.8
27	3.25	4.05	4.4	4.2	4.15	3.85	2.8	2.4	2.05	2.3	2.4	3.25
28	[b]4.75	8.8	4.25	3.85	4.0	4.1	2.7	2.65	2.1	2.3	2.3	3.2
29	5.85	......	4.05	3.7	3.8	6.65	2.65	2.55	2.0	2.3	2.4	3.5
30	7.3	......	4.0	3.7	3.7	5.2	2.7	2.7	2.0	2.3	2.4	2.92
31	5.7	......	4.1	......	3.8	......	3.0	2.8	......	2.3	......	2.85
1904.[c]												
1	2.9	3.2	4.7	4.7	4.45	3.95	3.0	2.35	1.9	2.0	2.0	2.1
2	2.95	3.05	4.55	5.25	4.2	3.85	3.1	2.55	1.9	2.0	2.0	2.05
3	3.0	3.1	4.85	4.75	3.95	3.8	3.05	2.4	2.0	2.05	2.05	2.2
4	3.55	3.05	5.55	4.35	3.85	3.7	2.85	2.4	1.85	2.0	2.1	2.3
5	3.1	3.05	4.4	4.15	3.75	3.8	2.7	2.4	2.0	1.95	2.1	2.2
6	2.95	3.1	4.2	4.0	3.65	3.9	2.65	2.35	2.1	1.95	2.0	2.2
7	3.15	6.2	4.65	3.9	3.6	3.75	2.7	2.25	1.9	2.0	2.1	2.25
8	3.0	6.1	5.55	3.9	3.5	3.6	2.8	2.2	1.9	2.15	2.1	2.2
9	2.9	4.7	4.7	4.3	3.5	3.5	2.8	2.05	1.95	2.1	2.1	2.05
10	2.8	4.05	4.3	4.15	3.6	3.6	3.45	2.15	2.1	2.1	2.1	2.0
11	2.8	3.8	4.25	3.95	3.45	3.5	3.2	2.2	2.0	2.15	2.2	2.1
12	2.8	3.6	4.3	3.85	3.35	3.4	3.05	2.2	2.0	2.2	2.2	2.1
13	2.7	3.25	4.05	3.85	3.2	3.25	2.9	2.2	2.0	2.4	2.2	2.2
14	2.7	3.35	3.95	3.7	3.2	3.2	2.8	2.2	2.0	2.25	2.2	2.3
15	2.6	3.45	3.85	3.7	3.4	3.2	2.7	2.15	2.05	2.2	2.2	2.3
16	2.6	3.25	3.65	3.75	3.4	3.0	2.6	2.15	2.1	2.15	2.2	2.3
17	2.6	3.05	3.55	3.9	3.2	3.1	2.5	2.2	2.1	2.1	2.2	2.3
18	3.15	3.0	3.85	3.8	3.7	3.0	2.45	2.1	2.1	2.05	2.2	2.3
19	3.0	3.1	3.95	3.7	5.95	2.9	2.35	2.1	2.1	2.1	2.3	2.3
20	2.95	3.0	4.4	3.6	5.0	3.0	2.35	2.15	2.0	2.1	2.3	2.3
21	3.8	3.2	4.5	3.5	5.0	3.05	2.5	2.2	2.1	2.2	2.3	2.3
22	[d]6.8	4.45	4.95	3.45	4.6	3.6	2.9	2.2	2.15	2.2	2.3	2.3
23	6.65	4.25	6.6	3.4	4.25	3.45	3.2	2.2	2.1	2.2	2.3	2.3
24	5.3	4.85	5.6	3.35	4.05	3.05	2.9	2.2	2.1	2.2	2.3	2.45
25	4.25	4.1	5.05	3.45	3.9	2.9	2.7	2.2	1.9	2.2	2.25	4.8
26	4.0	3.7	4.95	3.9	3.75	2.8	2.7	2.1	2.05	2.2	2.25	4.0
27	3.55	3.55	4.8	4.65	3.85	2.7	2.6	2.1	2.0	2.1	2.2	4.1
28	3.25	3.5	4.4	5.25	3.85	2.75	2.5	1.9	2.0	2.2	2.15	4.8
29	3.3	4.75	4.1	4.95	3.6	3.25	2.6	2.0	2.0	2.1	2.1	4.05
30	3.4	......	4.0	4.55	3.5	3.05	2.5	2.0	2.0	2.0	2.1	3.2
31	3.25	......	4.45	......	3.5	......	2.4	1.9	......	2.1	......	3.2

[a] Ice conditions January, 1903.
[b] Ice passed down the river January 28, 1903.
[c] Ice conditions January, 1904.
[d] Ice passed down the river January 22, 1904.

Daily gage height, in feet, of North Branch of Potomac River at Piedmont, W. Va.—Continued.

Day.	Jan.	Feb	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.[a]												
1	3.05	2.75	[a]3.35	3.85	3.5	4.75	3.3	3.85	2.8	2.3	3.2	3.9
2	3.05	2.7	3.25	3.7	3.3	4.0	3.85	3.45	2.8	2.3	3.1	3.75
3	3.05	2.65	3.15	3.6	3.3	3.65	3.55	3.2	2.8	2.4	3.05	5.75
4	2.95	2.55	3.15	3.55	3.2	3.4	3.4	3.1	2.8	2.45	3.0	4.9
5	2.95	2.55	3.35	3.55	3.2	3.3	4.05	3.5	2.7	2.4	3.0	4.4
6	2.95	2.55	4.15	3.8	3.2	3.2	4.2	3.15	2.6	2.35	3.15	3.95
7	2.9	2.55	[b]4.5	3.95	3.3	3.55	4.3	3.0	2.5	2.3	3.36	3.85
8	2.8	2.55	5.0	3.95	3.2	4.15	5.45	2.85	2.5	2.2	3 2	3.7
9	2.75	2.55	7.05	3.95	3.1	3.65	4.55	2.8	2.5	2.2	3.2	3.65
10	2.65	3.15	7.45	4.0	3.1	3.45	4.05	2.8	2.45	2.2	3.05	3.6
11	2.75	3.1	6.3	3.95	3.15	3.85	4.1	3.2	4.2	2.65	3.0	3.3
12	2.8	3.05	5.7	3.95	3.5	4.2	4.0	3.25	4.15	3.6	2.9	3.25
13	5.95	3.05	5.65	3.85	3.9	4.15	3.95	3.0	3.6	3.05	2.9	3.35
14	4.45	3.4	5.3	3.75	3.65	3.75	3.5	2.8	3.25	2.75	2.9	3.25
15	3.65	3.3	5.0	3.65	5.02	3.45	3.35	2.85	3.05	2.6	2.9	3.0
16	3.3	3.05	4.85	3.55	4.4	3.25	3.3	4.15	2.9	2.55	2.85	2.95
17	3.25	2.95	6.1	3.5	4.55	3.05	3.15	3.5	2.8	2.5	3.05	3 3
18	3.25	2.95	6.45	3.5	4.05	3.65	3.05	3.15	2.8	2.45	3.0	3.2
19	3.25	2.85	6.75	3.45	3.95	3.45	2.95	3.0	2.8	3.8	2.9	3.1
20	3.25	2.85	6.7	3.75	3.75	3.65	3.35	2.95	2.7	4.45	2.9	3.1
21	3.25	2.85	8.1	3.85	3.55	3.65	3.3	2.9	2.6	4.0	2.9	4.0
22	3.3	2.95	6.75	3.9	3.5	3.65	3.1	2.75	2.55	3.4	2.75	5.4
23	3.15	3.4	5.8	3.85	3.4	3.4	3.65	2.65	2.5	3.15	2.75	4.9
24	3.05	3.3	5.25	3.7	3.2	3.45	3.6	2.5	2.4	3.0	2.85	4.9
25	2.85	3.25	5.65	3.6	3.1	3.65	3.25	4.35	2.45	2.95	2.8	4.05
26	2.55	3.25	5.05	3.5	3.1	3.45	3.05	4.9	2.4	4.85	2.8	4.0
27	2.55	3.55	4.9	2.8	3.1	4.4	2.9	3.7	2.4	4.4	2.8	3.85
28	2.75	3.45	4.6	2.9	3.0	3.65	2.8	3.35	2.3	3.9	2.8	3.65
29	2.75	......	4.3	3.65	2.9	3.35	2.9	3.15	2.3	3.6	3.65	3.8
30	2.85	......	4.15	3.5	2.9	3.2	5.05	3.0	2.3	3.45	4.55	4.15
31	2.75	......	4.0	......	3.15	......	4.2	3.0	......	3.3	......	3.65
1906.[c]												
1	3.55	3.65	2.75	6.05	4.0	3.25	3.0	......	......	......	......	......
2	3.35	3.55	3.1	5.55	3.9	3.45	2.9	......	......	......	......	......
3	3.65	3.2	3.3	5.7	4.0	3.3	2.8	......	......	......	......	......
4	5.65	3.4	5.15	6.0	3.8	3.1	2.8	......	......	......	......	......
5	5.3	3.5	4.35	6.15	3.7	3.3	3.1	......	......	......	......	......
6	4.6	3.0	3.95	6.8	3.6	4.6	2.85	......	......	......	......	......
7	3.9	3.1	3.8	5.7	3.7	5.25	2.75	......	......	......	......	......
8	4.05	3.1	3.8	5.05	3.6	4.7	2.6	......	......	......	......	......
9	3.65	3.1	3.7	5.15	3.5	4.1	2.6	......	......	......	......	......
10	3.55	2.9	3.6	6.45	3.5	3.65	2.6	......	......	......	......	......
11	3.55	2.75	3.4	5.5	3.4	3.35	2.5	......	......	......	......	......
12	3.7	2.85	3.6	5.45	3.4	3.1	2.65	......	......	......	......	......
13	3.95	3.0	3.5	4.55	3.3	3.25	2.6	......	......	......	......	......
14	3.8	3.05	3.5	4.45	3.2	3.1	2.6	......	......	......	......	......
15	3.8	3.0	3.5	6.15	3.2	3.0	2.55	......	......	......	......	......
16	3.95	2.75	3.5	5.45	3.1	3.0	......	......	......	......	......	......
17	4.15	2.8	3.4	4.85	3.1	2.9	......	......	......	......	......	......
18	4.1	2.9	3.15	4.45	3.0	2.9	......	......	......	......	......	......
19	4.7	2.8	3.4	4.25	3.0	2.9	......	......	......	......	......	......
20	4.35	2.95	4.05	4.1	2.9	2.95	......	......	......	......	......	......
21	4.5	3.0	3.8	3.95	2.9	3.1	......	......	......	......	......	......
22	4.85	3.2	3.7	4.0	2.8	3 3	......	......	......	......	......	......
23	8.2	3.1	3.7	4.0	2.8	3.2	......	......	......	......	......	......
24	6.4	3.05	3.75	4.0	2.7	3.1	......	......	......	......	......	......
25	5.1	3.1	3.55	4.1	2.7	3.0	......	......	......	......	......	......
26	4.6	3.1	3.6	6.5	2.7	3.0	......	......	......	......	......	......
27	4.35	3.05	5.05	5.4	2.7	3.6	......	......	......	......	......	......
28	4.3	2.6	7.3	4.65	3.35	3.35	......	......	......	......	......	......
29	4.15	......	6.25	4.35	3.45	3.25	......	......	......	......	......	......
30	3.95	......	7.4	4.15	3.2	3.0	......	......	......	......	......	......
31	3.8	......	7.4	......	3.0	......	......	......	......	......	......	......

[a] Ice conditions during January, February, and March, 1905.
[b] Ice passed down the river March 7, 1905.
[c] No ice during the winter of 1905-6.

Rating tables for North Branch of Potomac River at Piedmont, W. Va.

JUNE 27, 1899, TO AUGUST 25, 1901.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.80	34	2.60	210	3.30	490	4.00	910
1.90	50	2.70	240	3.40	540	4.10	985
2.00	67	2.80	275	3.50	595	4.20	1,070
2.10	85	2.90	310	3.60	650	4.30	1,160
2.20	105	3.00	350	3.70	710	4.40	1,250
2.30	128	3.10	395	3.80	775	4.50	1,345
2.40	153	3.20	440	3.90	840	4.60	1,445
2.50	180						

AUGUST 26, 1901, TO DECEMBER 31, 1903.[b]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
1.90	20	2.60	152	3.30	406	4.00	860
2.00	28	2.70	180	3.40	457	4.10	945
2.10	40	2.80	210	3.50	512	4.20	1,035
2.20	57	2.90	242	3.60	571	4.30	1,130
2.30	77	3.00	277	3.70	635	4.40	1,230
2.40	100	3.10	316	3.80	705	4.50	1,335
2.50	125	3.20	359	3.90	780		

JANUARY 1, 1904, TO DECEMBER 31, 1905.[c]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
2.00	15	3.30	347	4.60	1,440	6.80	4,720
2.10	24	3.40	397	4.70	1,550	7.00	5,100
2.20	36	3.50	453	4.80	1,660	7.20	5,500
2.30	51	3.60	515	4.90	1,775	7.40	5,910
2.40	68	3.70	584	5.00	1,890	7.60	6,330
2.50	88	3.80	660	5.20	2,130	7.80	6,760
2.60	110	3.90	742	5.40	2,390	8.00	7,200
2.70	134	4.00	830	5.60	2,670	8.50	8,350
2.80	161	4.10	923	5.80	2,970	9.00	9,550
2.90	191	4.20	1,020	6.00	3,290	9.50	10,800
3.00	224	4.30	1,120	6.20	3,630	10.00	12,100
3.10	261	4.40	1,225	6.40	3,980	10.50	13,450
3.20	302	4.50	1,330	6.60	4,340		

JANUARY 1 TO JULY 15, 1906.[d]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
2.50	70	3.60	457	4.70	1,430	6.40	3,785
2.60	88	3.70	519	4.80	1,540	6.60	4,140
2.70	109	3.80	587	4.90	1,655	6.80	4,515
2.80	133	3.90	661	5.00	1,770	7.00	4,900
2.90	160	4.00	740	5.20	2,015	7.20	5,300
3.00	190	4.10	825	5.40	2,270	7.40	5,710
3.10	224	4.20	915	5.60	2,535	7.60	6,130
3.20	262	4.30	1,010	5.80	2,820	7.80	6,570
3.30	304	4.40	1,110	6.00	3,125	8.00	7,030
3.40	350	4.50	1,215	6.20	3,450	8.20	7,500
3.50	401	4.60	1,320				

[a] This table is strictly applicable only for open-channel conditions. It is based on four discharge measurements made during 1899 and 1900. It is fairly well defined between gage heights 1.8 feet and 4.5 feet. As applied to 1901 gage heights it is liable to give estimates several per cent too high, owing to changes in the condition of flow at and below the section during 1901. Above gage height 4.60 feet the table is the same as the 1904-5 table.

[b] This table is strictly applicable only for open-channel conditions. It is based on three discharge measurements made during 1901–1903 and on the form of other curves at this station. It is fairly well defined. Above gage height 4.50 feet the table is the same as the 1904–5 table.

[c] This table is strictly applicable only for open-channel conditions. It is based on discharge measurements made during 1904–1905. It is fairly well defined between gage heights 3.0 feet and 7.5 feet. Below 3 feet the table is based on two measurements at 2 feet. The above table as applied to 1904 gage heights is liable to give estimates several per cent too low above gage height 2.5 feet. As applied to 1905 gage heights it is liable to give estimates several per cent too high below gage height 2.5 feet.

[d] This table is strictly applicable only for open-channel conditions. It is based on three discharge measurements made during 1906 and the form of previous curves at this station. It is well defined between gage heights 3.5 feet and 5.5 feet.

Estimated monthly discharge of North Branch of Potomac River at Piedmont, W. Va. [a]

[Drainage area, 410 square miles.]

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1899.								
January	....	....	....	....	....	....	2.01	....
February	....	....	....	....	....	....	3.85	....
March	....	....	....	....	....	....	5.08	....
April	....	....	....	....	....	....	1.93	....
May	....	....	....	....	....	....	6.60	....
June 27-30	595	292	387	0.944	0.140	....	[b] 4.81	....
July	418	95	209	.510	.588	22	2.64	2.05
August	350	50	119	.290	.334	16	2.11	1.78
September	540	67	157	.383	.427	11	3.91	3.48
October	105	67	88.4	.216	.249	11	2.29	2.04
November	840	105	275	.671	.749	43	1.76	1.01
December	2,130	140	421	1.03	1.19	49	2.44	1.25
The year	....	....	....	....	....	....	39.43	....
1900.								
January	2,970	240	838	2.04	2.35	137	1.72	−0.63
February	3,130	350	1,032	2.52	2.62	73	3.59	.97
March	3,210	622	1,306	3.19	3.68	109	3.37	− .31
April	1,660	465	821	2.00	2.23	170	1.31	− .92
May	875	240	392	.956	1.10	50	2.22	1.12
June	6,225	240	804	1.96	2.19	49	4.47	2.28
July	1,250	116	308	.751	.866	20	4.24	3.37
August	330	67	136	.332	.383	14	2.64	2.26
September	240	34	53.6	.131	.146	20	.74	.59
October	440	67	143	.349	.402	19	2.07	1.67
November	7,090	81	577	1.41	1.57	29	5.46	3.89
December	2,970	310	692	1.69	1.95	79	2.46	.51
The year	7,090	34	592	1.44	19.49	57	34.29	14.80
1901.								
January	2,895	310	705	1.72	1.98	54	3.68	1.70
February	650	292	407	.993	1.03	79	1.30	.27
March	4,910	292	1,387	3.38	3.90	114	3.42	− .48
April	6,330	680	2,234	5.45	6.08	102	5.93	− .15
May	6,225	490	1,681	4.10	4.73	67	7.03	2.30
June	1,832	395	925	2.26	2.52	72	3.52	1.00
July	2,260	153	490	1.20	1.38	51	2.69	1.31
August	1,832	128	409	1.00	1.15	24	4.89	3.74
September	359	57	149	.363	.405	19	2.09	1.69
October	138	40	63.5	.155	.179	28	.65	.47
November	277	28	70.3	.171	.191	7	2.69	2.50
December	7,545	125	1,472	3.59	4.14	72	5.73	1.59
The year	7,545	28	831	2.03	27.68	63	43.62	15.94
1902.								
January	2,895	242	644	1.57	1.81	57	3.19	1.38
February	13,450	210	1,082	2.64	2.75	72	3.83	1.08
March	7,430	990	2,578	6.29	7.25	173	4.18	−3.07
April	5,200	542	1,980	4.83	5.39	130	4.14	−1.25
May	945	242	483	1.18	1.36	42	3.26	1.90
June	406	100	219	.534	.596	14	4.34	3.74
July	1,605	77	265	.646	.745	21	3.62	2.87
August	226	20	85.8	.209	.241	11	2.14	1.90
September	166	20	40.9	.100	.112	4	2.84	2.73
October [c]	635	100	213	.520	.600	20	3.00	2.40
November	2,460	100	288	.702	.783	34	2.32	1.54
December	6,330	484	1,764	4.30	4.96	94	5.29	.33
The year	13,450	20	804	1.96	26.60	63	42.15	15.55

[a] See description and footnotes to the rating tables.
[b] Precipitation for complete month June, 1899.
[c] Discharge interpolated October 28 and 29, 1902.

Estimated monthly discharge of North Branch of Potomac River at Piedmont, W. Va.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1903.								
January	5,700	359	1,292	3.15	3.63	102	3.57	−0.06
February	9,070	635	2,223	5.42	5.64	103	5.50	− .14
March	4,530	571	1,662	4.05	4.67	122	3.82	− .85
April	3,375	635	1,506	3.67	4.10	113	3.64	− .46
May	1,550	210	580	1.41	1.63	51	3.18	1.55
June	4,435	359	1,292	3.15	3.51	54	6.50	2.99
July	2,130	166	570	1.39	1.60	32	4.96	3.36
August	277	77	163	.398	.459	14	3.18	2.72
September	210	28	90.5	.221	.247	14	1.77	1.52
October [a]	180	34	103	.251	.289	12	2.36	2.07
November	603	57	134	.327	.365	20	1.78	1.42
December	1,282	48	193	.471	.543	37	1.47	.93
The year	9,070	28	817	1.99	26.68	64	41.73	15.05
1904.[b]								
January	4,720	110	643	1.58	1.82	59	3.07	1.25
February	3,630	224	795	1.96	2.11	108	1.96	− .15
March	4,340	484	1,433	3.53	4.07	163	2.50	−1.57
April	2,195	372	937	2.31	2.58	98	2.62	.04
May	3,210	302	792	1.95	2.25	70	3.20	.95
June	786	134	392	.966	1.08	27	3.95	2.87
July	425	60	160	.394	.454	12	3.69	3.24
August	99	9	37	.091	.105	6	1.96	1.85
September	30	6	17	.042	.047	3	1.81	1.76
October	68	12	28	.069	.080	5	1.76	1.68
November	51	15	34	.084	.094	17	.54	.45
December	1,660	15	243	.599	.691	24	2.92	2.23
The year	4,720	6	459	1.13	15.38	51	29.98	14.60
1905.[b]								
January	3,210	99	360	.887	1.02	33	3.13	2.11
February	484	99	232	.571	.595	34	1.75	1.16
March	7,420	282	2,484	6.12	7.06	201	3.52	−3.54
April	830	161	585	1.44	1.61	82	1.97	.36
May	1,914	191	496	1.22	1.41	49	2.87	1.46
June	1,605	242	588	1.45	1.62	40	4.03	2.41
July	2,460	161	653	1.61	1.86	28	6.55	4.69
August	1,775	88	376	.926	1.07	28	3.88	2.81
September	1,020	51	195	.480	.536	25	2.16	1.62
October	1,718	36	348	.857	.988	24	4.08	3.09
November	1,385	148	267	.658	.734	31	2.36	1.63
December	2,895	208	815	2.01	2.32	74	3.13	.81
The year	7,420	36	617	1.52	20.82	53	39.43	18.61
1906.								
January	7,500	327	1,255	3.06	3.53			
February	488	88	220	.537	.559			
March	5,710	121	1,161	2.83	3.26			
April	4,515	700	2,013	4.91	5.48			
May	740	109	323	.788	.908			
June	2,078	160	413	1.01	1.13			
July 1–15	224	70	120	.293	.163			

[a] Discharge interpolated October 7–15, 1903.
[b] Drainage area of 406 square miles used to obtain 1904 and 1905 run-off.

GEORGES CREEK AT WESTERNPORT, MD.

Georges Creek rises on Mount Savage, in the northwestern part of Allegany County, Md., and flows southwestward into North Branch of Potomac River at Westernport. Its length is about 15 miles.

The gaging station was established May 4, 1905, and was discontinued July 16, 1906. It is located at a highway bridge in Westernport, Md., about one-half mile above the mouth of the creek.

Above the station the channel is straight for about 50 feet and then makes a sharp bend. Below the station it is straight for 300 feet. The current is swift. Both banks are fairly high, clean, and do not overflow. The bed of the stream is rocky and shifting. There is but one channel at all stages.

Discharge measurements were made from the upstream side of the bridge to which the gage is attached. The initial point for soundings is the inside face of the left abutment, upstream side.

A standard chain gage is attached to the middle of the upstream side of the bridge. The length of the chain from the end of the weight to the marker is 16.23 feet. The gage was read twice each day by G. A. Biggs. Bench mark No. 1 is the top of the downstream bedplate at the left abutment, on the downstream corner toward the railroad track. Its elevation is 11.58 feet above the datum of the gage. Bench mark No. 3 is the top of the pulley wheel of the gage. Its elevation was 15.88 feet above the datum of the gage May 4, 1905.

The bed of Georges Creek at the gaging section is rather unstable and subject to frequent changes on account of the high velocity of the current. The estimates are therefore subject to varying errors of from 5 to 20 per cent of the true flow. Ice conditions did not affect the estimates during the winter of 1905–6.

Discharge measurements of Georges Creek at Westernport, Md.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
April 18	1.60	53	March 16	1.49	65
May 4	1.35	33	March 30	3.38	1,230
June 7	1.98	131	April 10	2.50	476
July 17	1.58	43	May 28	2.25	353
November 7	1.35	45			

Daily gage height, in feet, of Georges Creek at Westernport, Md.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	......	......	......	......	......	1.45	1.38	1.22	1.05	0.95	1.5	1.62
2	......	......	......	......	......	1.45	1.58	1.12	1.05	1.28	1.5	1.8
3	......	......	......	......	......	1.38	1.32	1.1	1.08	1.18	1.45	2.35
4	......	......	......	......	1.45	1.3	1.48	1.1	1.12	1.1	1.38	2.22
5	......	......	......	......	1.4	1.25	1.52	1.08	1.1	1.05	1.4	2,12
6	......	......	......	......	1.42	1.2	1.48	1.05	1.1	1.02	1.52	2.55
7	......	......	......	......	1.5	1.98	3.45	1.05	1.05	1.0	1.4	2.35
8	......	......	......	......	1.4	1.58	3.38	1.05	1.0	1.0	1.32	2.22
9	......	......	......	......	1.35	1.42	2.65	1.05	1.0	1.0	1.25	2.12
10	......	......	......	......	1.38	1.35	2.15	1.05	1.28	.98	1.2	2.02
11	......	......	......	......	1.38	2.05	2.05	1.08	2.55	1.75	1.12	1.9
12	......	......	......	......	1.5	1.98	1.98	1.12	1.9	1.55	1.1	1.88
13	......	......	......	......	1.38	1.85	1.92	1.15	1.65	1.25	1.05	1.82
14	......	......	......	......	1.48	1.72	1.8	1.12	1.5	1.12	1.0	1.78
15	......	......	......	......	1.72	1.62	1.7	1.28	1.42	1.08	.95	1.42
16	......	......	......	......	1.68	1.52	1.62	1.25	1.32	1.05	.98	1.45
17	......	......	......	......	1.65	1.5	1.52	1.12	1.38	1.0	1.0	1.3
18	......	......	......	......	1.62	1.48	1.42	1.05	1.28	1.0	1.0	1.3
19	......	......	......	......	1.58	1.4	1.32	1.02	1.22	1.18	1.02	1.35
20	......	......	......	......	1.52	1.55	1.4	1.0	1.18	2.3	1.02	1.4
21	......	......	......	......	1.5	1.48	1.38	1.0	1.12	1.65	1.0	3.4
22	......	......	......	......	1.45	1.42	1.35	1.0	1.1	1.52	1.0	3.08
23	......	......	......	......	1.4	1.38	1.7	.98	1.05	1.48	1.0	2.2
24	......	......	......	......	1.38	1.5	1.48	.92	1.05	1.42	1.0	2.2
25	......	......	......	......	1.28	1.55	1.22	1.72	1.0	1.52	1.08	2.12
26	......	......	......	......	1.28	1.4	1.18	1.65	1.0	2.02	1.05	2.15
27	......	......	......	......	1.25	1.32	1.15	1.45	1.0	1.85	1.08	1.98
28	......	......	......	......	1.3	1.25	1.15	1.25	1.0	1.72	1.1	1.95
29	......	......	......	......	1.3	1.22	1.2	1.1	.95	1.62	1.55	2.08
30	......	......	......	......	1.28	1.2	1.45	1.12	.95	1.52	1.65	1.88
31	......	......	......	......	1.32	......	1.38	1.08	......	1.5	......	1.75
1906.												
1	1.68	1.8	1.6	3.18	1.68	1.65	1.18	......	......	......	......	......
2	1.55	1.8	1.78	2.98	1.72	1.55	1.15	......	......	......	......	......
3	2.3	1.75	2.05	2.88	1.62	1.55	1.15	......	......	......	......	......
4	2.58	1.72	2.1	2.92	1.52	1.32	1.1	......	......	......	......	......
5	2.45	1.68	2.02	2.85	1.5	1.6	1.1	......	......	......	......	......
6	2.38	1.65	1.98	2 52	1.55	1.68	1.1	......	......	......	......	......
7	2.2	1.6	1.8	2.32	1.5	2.22	1.05	......	......	......	......	......
8	2.2	1.55	1.75	2.32	1.5	2.25	1.05	......	......	......	......	......
9	1.88	1.52	1.68	2.55	1.45	1.95	1.05	......	......	......	......	......
10	1.95	1.5	1.6	2.58	1.4	1.8	1.1	......	......	......	......	......
11	1.95	1.45	1.55	2.32	1.4	1.72	1.1	......	......	......	......	......
12	2.0	1.45	1.52	2.32	1.4	1.75	1.1	......	......	......	......	......
13	1.95	1.42	1.5	2.22	1.4	1.75	1.1	......	......	......	......	......
14	1.88	1.4	1.5	2.22	1.42	1.7	1.05	......	......	......	......	......
15	1.78	1.4	1.5	2.2	.4	1.62	1.02	......	......	......	......	......
16	1.82	1.4	1.45	2.22	1.3	1.55	......	......	......	......	......	......
17	2.0	1.4	1.32	2.12	1.32	1.25	......	......	......	......	......	......
18	2.05	1.4	1.32	2.12	1.32	1.2	......	......	......	......	......	......
19	2.12	1.4	1.38	2.22	1.25	1.2	......	......	......	......	......	......
20	2.15	1.45	1.5	2.0	1.22	1.35	......	......	......	......	......	......
21	2.18	1.45	1.55	2.05	1.2	1.35	......	......	......	......	......	......
22	2.22	1.4	1.58	1.9	1.2	1.35	......	......	......	......	......	......
23	3.28	1.35	1.55	1.88	1.15	1.38	......	......	......	......	......	......
24	3.08	1.32	1.58	1.88	1.15	1.4	......	......	......	......	......	......
25	2.68	1.3	1.6	1.82	1.1	1.3	......	......	......	......	......	......
26	2.2	1.3	1.68	1.9	1.1	1.32	......	......	......	......	......	......
27	2.12	1.38	2.62	1.85	2.02	1.38	......	......	......	......	......	......
28	2.1	1.42	3.2	1.75	2.08	1.25	......	......	......	......	......	......
29	2.05	......	3.2	1.7	2.2	1.2	......	......	......	......	......	......
30	1.98	......	3.42	1.72	1.95	1.2	......	......	......	......	......	......
31	1.9	......	3.45	......	1.88	......	......	......	......	......	......	......

Rating tables for Georges Creek at Westernport, Md.

MAY 4, 1905, TO JUNE 6, 1905.[a]

Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*
1.20	22	1.60	66
1.30	29	1.70	87
1.40	38	1.80	112
1.50	50		

JUNE 7 TO SEPTEMBER 10, 1905.[b]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.90	5	1.60	48	2.30	252	3.00	700
1.00	8	1.70	64	2.40	301	3.10	780
1.10	11	1.80	84	2.50	355	3.20	865
1.20	15	1.90	108	2.60	415	3.30	955
1.30	20	2.00	137	2.70	480	3.40	1,045
1.40	27	2.10	170	2.80	550	3.50	1,140
1.50	36	2.20	208	2.90	625		

SEPTEMBER 11, 1905, TO JULY 15, 1906.[c]

0.90	10	1.70	115	2.50	495	3.30	1,150
1.00	15	1.80	145	2.60	560	3.40	1,250
1.10	21	1.90	180	2.70	630	3.50	1,350
1.20	29	2.00	220	2.80	705	3.60	1,455
1.30	39	2.10	265	2.90	785	3.70	1,560
1.40	52	2.20	315	3.00	870	3.80	1,670
1.50	69	2.30	370	3.10	960	3.90	1,780
1.60	90	2.40	430	3.20	1,055	4.00	1,895

[a] This table is based on one discharge measurement made during 1905 and the form of the 1906 curve. It is not well defined.

[b] This table is based on three discharge measurements made during 1905 and the form of the 1906 curve. It is fairly well defined between gage heights 1.5 feet and 2.0 feet.

[c] This table is strictly applicable only for open-channel conditions. It is based on five discharge measurements made during 1905 and 1906. It is fairly well defined between gage heights 1.3 feet and 3.5 feet.

Estimated monthly discharge of Georges Creek at Westernport, Md.

[Drainage area, 76 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
May 4-31	92	26	44.8	0.589	0.613
June	154	15	45.7	.601	.670
July	1,092	13	127	1.67	1.92
August	68	6	15.1	.199	.229
September	528	8	46.4	.611	.682
October	370	12	65.8	.866	.998
November	102	12	33.8	.445	.496
December	1,250	39	267	3.51	4.05
1906.					
January	1,131	80	320	4.21	4.85
February	145	39	71.2	.937	.976
March	1,300	42	260	3.42	3.94
April	1,036	115	378	4.97	5.54
May	315	21	83.0	1.09	1.26
June	342	29	91.4	1.20	1.34
July 1-15	27	16	20.8	.274	.153

WILLS CREEK AT CUMBERLAND, MD.

Wills Creek rises on the western slope of Savage Mountain, in the southeastern part of Somerset County, Pa., and flows northwestward to Mance, eastward to Hyndman, Pa., and southward to Cumberland, Md., where it enters North Branch of Potomac River. Its length is about 25 miles.

The gaging station was established May 5, 1905, and was discontinued July 15, 1906. It is located at the highway bridge at the upper end of "The Narrows," Cumberland, Md.

The channel is straight for 200 feet above and 500 feet below the station. The current is fairly swift. Both banks are high and do not overflow. The bed of the stream is rocky, very rough, and permanent. There are two channels at all but very low stages.

Discharge measurements were made from the downstream side of the two-span bridge to which the gage is fastened. The initial point for soundings is the face of the right abutment.

A standard chain gage is fastened to the downstream side of the bridge, near the middle of the right span. The length of the chain from the end of the weight to the marker is 26.98 feet. The gage was read twice each day by H. E. McKenzie. Bench mark No. 1 is a square chisel draft on the top of the bridge-seat stone at the downstream side of the right abutment. Its elevation is 21.88 feet above the datum of the gage. Bench mark No. 2 is the top of the pulley wheel of the gage. Its elevation was 26.65 feet above the datum of the gage March 17, 1906.

Estimates are considered to be within 5 per cent of the true flow. Ice conditions probably did not affect the flow during the winter of 1905–6.

Discharge measurements of Wills Creek at Cumberland, Md.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
April 17	4.20	236	March 17	4.01	175
May 6	3.72	130	April 2	6.32	1,486
June 8	4.22	248	April 10	6.05	1,200
November 6	3.68	130	April 11	5.88	1,066
			May 26	3.27	55

Daily gage height, in feet, of Wills Creek at Cumberland, Md.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	......	......	......	......	......	3.72	3.65	3.55	3.62	3.05	3.92	4.52
2	......	......	......	......	......	3.95	4.0	3.45	3.55	3.2	3.8	4.38
3	......	......	......	......	......	3.82	3.75	3.4	3.6	3.35	3.75	7.08
4	......	......	......	......	......	3.7	3.65	3.3	3.55	3.3	3.75	6.22
5	......	......	......	......	......	3.68	3.6	3.3	3.45	3.18	3.65	5.45
6	......	......	......	......	3.7	3.6	3.58	3.28	3.38	3.08	3.65	5.02
7	......	......	......	......	4.0	4.2	6.58	3.2	3.32	3.0	3.65	4.7
8	......	......	......	......	3.82	4.25	6.7	3.18	3.22	3.0	3.6	4.5
9	......	......	......	......	3.8	4.05	5.7	3.15	3.2	3.0	3.6	4.38
10	......	......	......	......	3.8	3.9	5.42	3.08	3.18	3.0	3.55	4.25
11	......	......	......	......	3.8	6.2	5.05	3.1	5.25	4.05	3.5	4.05
12	......	......	......	......	4.08	5.42	4.7	3.8	5.0	4.0	3.45	4.02
13	......	......	......	......	3.98	4.88	4.6	3.48	4.6	3.72	3.42	3.98
14	......	......	......	......	4.05	4.48	4.98	3.45	4.15	3.55	3.4	3.8
15	......	......	......	......	5.42	4.25	4.58	5.85	3.98	3.42	3.35	3.55
16	......	......	......	......	5.08	4.52	4.32	4.85	3.82	3.4	3.38	3.42
17	......	......	......	......	4.85	3.9	4.1	4.35	3.72	3.32	3.45	3.32
18	......	......	......	......	4.6	3.9	3.85	4.02	3.78	3.3	3.4	3.68
19	......	......	......	......	4.45	3.9	3.82	3.85	3.68	3.3	3.35	3.92
20	......	......	......	......	4.28	3.7	4.25	3.72	3.55	5.15	3.3	3.75
21	......	......	......	......	4.1	4.05	3.88	3.68	3.45	4.65	3.25	6.6
22	......	......	......	......	4.0	4.15	3.88	3.52	3.4	4.38	3.2	6.25
23	......	......	......	......	3.92	4.32	4.32	3.42	3.32	4.15	3.25	5.8
24	......	......	......	......	3.82	4.45	3.98	3.32	3.28	4.02	3.3	5.32
25	......	......	......	......	3.72	4.5	3.8	5.1	3.18	3.9	3.35	5.0
26	......	......	......	......	3.62	4.38	3.68	4.58	3.15	4.45	3.3	4.75
27	......	......	......	......	3.98	4.3	3.6	4.18	3.1	4.25	3.25	4.55
28	......	......	......	......	3.7	4.02	3.55	3.98	3.1	4.18	3.25	4.35
29	......	......	......	......	3.6	3.9	3.6	3.82	3.05	4.12	5.1	5.22
30	......	......	......	......	3.52	3.72	3.85	4.08	3.05	4.02	4.88	5.05
31	......	......	......	......	3.52	......	3.65	3.72	......	4.0	......	4.65
1906.												
1	4.45	4.25	3.5	6.7	4.02	3.5	3.35	......	......	......	......	......
2	4.25	4.05	3.5	6.3	4.25	3.48	3.3	......	......	......	......	......
3	4.45	3.7	4.15	6.3	4.18	3.38	3.25	......	......	......	......	......
4	5.95	4.02	5.25	6.2	4.08	3.3	3.25	......	......	......	......	......
5	5.78	4.02	4.6	6.32	4.0	3.5	3.2	......	......	......	......	......
6	5.5	3.7	4.25	6.32	4.0	3.65	3.18	......	......	......	......	......
7	5.12	3.6	4.25	5.45	3.9	6.6	3.15	......	......	......	......	......
8	4.95	3.68	4.3	5.3	3.88	5.5	3.1	......	......	......	......	......
9	4.65	3.75	4.22	5.6	3.8	4.75	3.05	......	......	......	......	......
10	4.38	3.75	4.18	6.0	3.8	4.3	3.05	......	......	......	......	......
11	4.32	3.7	4.12	5.9	3.8	4.0	3.05	......	......	......	......	......
12	4.45	3.7	4.08	5.6	3.75	3.8	3.18	......	......	......	......	......
13	4.42	3.6	4.02	5.42	3.7	3.78	3.08	......	......	......	......	......
14	4.4	3.68	4.05	5.1	3.65	3.72	3.02	......	......	......	......	......
15	4.45	3.65	4.05	6.3	3.6	3.68	......	......	......	......	......	......
16	4.7	3.6	4.1	5.92	3.55	3.6	......	......	......	......	......	......
17	5.0	3.55	4.1	5.58	3.6	3.55	......	......	......	......	......	......
18	4.88	3.5	4.1	5.32	3.52	3.62	......	......	......	......	......	......
19	5.1	3.5	4.1	5.02	3.48	3.85	......	......	......	......	......	......
20	5.02	3.5	4.18	4.88	3.45	3.9	......	......	......	......	......	......
21	5.12	3.7	4.2	4.72	3.45	3.88	......	......	......	......	......	......
22	5.25	3.68	4.2	4.68	3.4	3.78	......	......	......	......	......	......
23	7.3	3.58	4.2	4.62	3.4	3.78	......	......	......	......	......	......
24	6.95	3.55	4.2	4.52	3.35	3.7	......	......	......	......	......	......
25	5.88	3.65	4.2	4.5	3.3	3.58	......	......	......	......	......	......
26	5.48	3.5	4.2	4.45	3.3	3.52	......	......	......	......	......	......
27	5.08	3.5	6.1	4.4	3.5	3.5	......	......	......	......	......	......
28	4.9	3.5	7.7	4.32	3.9	3.55	......	......	......	......	......	......
29	4.75	......	7.2	4.22	3.65	3.5	......	......	......	......	......	......
30	4.55	......	7.05	4.12	3.55	3.38	......	......	......	......	......	......
31	4.42	......	7.9	......	3.4	......	......	......	......	......	......	......

Rating table for Wills Creek at Cumberland, Md., from May 6, 1905, to July 14, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.00	30	4.30	270	5.60	860	6.80	2,030
3.10	38	4.40	301	5.70	930	6.90	2,160
3.20	48	4.50	334	5.80	1,005	7.00	2,295
3.30	60	4.60	368	5.90	1,085	7.10	2,435
3.40	73	4.70	404	6.00	1,170	7.20	2,575
3.50	88	4.80	442	6.10	1,260	7.30	2,720
3.60	104	4.90	482	6.20	1,355	7.40	2,870
3.70	122	5.00	525	6.30	1,455	7.50	3,020
3.80	142	5.10	570	6.40	1,560	7.60	3,170
3.90	164	5.20	620	6.50	1,670	7.70	3,320
4.00	188	5.30	675	6.60	1,785	7.80	3,480
4.10	214	5.40	735	6.70	1,905	7.90	3,640
4.20	241	5.5	795				

[a] This table is strictly applicable only for open-channel conditions. It is based on nine discharge measurements made during 1905 and 1906. It is well defined between gage heights 3.0 feet and 6.5 feet.

Estimated monthly discharge of Wills Creek at Cumberland, Md.

[Drainage area, 240 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
May 6–31	747	91	221	0.921	0.891
June	1,355	104	272	1.13	1.26
July	1,905	96	353	1.47	1.70
August	1,045	36	174	.725	.836
September	647	34	128	.533	.595
October	595	30	149	.621	.716
November	570	48	115	.479	.534
December	2,407	63	529	2.20	2.54
1906.					
January	2,720	256	637	2.65	3.06
February	256	88	122	.508	.529
March	3,640	88	626	2.61	3.01
April	1,905	219	806	3.36	3.75
May	256	60	126	.525	.605
June	1,785	60	207	.862	.962
July 1–14	66	32	44.6	.186	.097

NORTH BRANCH OF POTOMAC RIVER AT CUMBERLAND, MD.[a]

Gage-height records were obtained at this station from June 11, 1894, to November 20, 1897. The gage was located about 1,000 feet below the mouth of Wills Creek and consisted of a vertical rod 10 feet long, bolted to the east side of the abutment of the head-gate of the eastern feeder of the Chesapeake and Ohio Canal, just above the diversion dam. The top of the rod, or the 10.00-foot mark, was 5.40 feet below the top of the abutment. The crest of the dam was at elevation about 2.65 feet above the datum of the gage, hence for stages below that point no water passed the gaging section, which was below the dam, all flow being diverted to the canal. Discharge measurements of the river were made from the West Virginia Central Railroad bridge, about 200 yards below the dam. The channel is straight both above

[a] For description of Weather Bureau station maintained at this point see p. 42.

and below the bridge. The left bank does not overflow; the right bank is liable to overflow at times of high water. The bed of the stream is composed of bowlders and loose rocks and is not liable to change. At high water the section is fairly smooth and the velocity high. At low water rocks, riffles, and angular currents appear, making it difficult to obtain accurate discharge measurements. Measurements of the canal feeders were also made near the head-gates.

All estimates previously published for this station have been revised. The monthly discharge as given in the accompanying table is for the section at the bridge only, the flow diverted to the canal feeders not being included, as it is an uncertain function of the total discharge of the river. (See discharge measurements.) No statement of the run-off is given, because the flow in the canal is a large percentage of the total run-off of the drainage basin above Cumberland.

Owing to the poor conditions at this station the measurements plot somewhat erratically, but since the rating curve is defined by a large number of measurements the monthly estimates which are based on it are probably within 10 per cent of the true results for normal conditions of flow above gage height 3.0 feet. Estimates for stages below 3.0 feet are somewhat uncertain. Ice conditions at this station were not recorded by the observer. It is probable, however, that ice collecting at the crest of the dam may at times have affected the gage heights, and hence the estimates.

Discharge measurements of North Branch of Potomac River at Cumberland, Md.

Date.	Gage height.	Discharge of river.	Discharge of canal feeders.	Date.	Gage height.	Discharge of river.	Discharge of canal feeders.
1894.	*Feet.*	*Second-feet.*	*Second-feet.*	1896.	*Feet.*	*Second-feet.*	*Second-feet.*
May 24	....	3,037	....	June 24	3.31	696	126
				August 6	3.30	552	54
1895.				November 18	3.38	548	217
March 30	4.50	3,446	....				
April 10	5.40	6,054	....	1897.			
April 25	3.30	630	....	February 10	3.75	1,307	....
May 3	3.75	1,728	....	March 27	3.93	1,971	24
May 9	3.40	777	....	June 25	3.00	289	136
May 23	3.40	831	45	September 1	2.60	0	86
June 5	2.95	216	40	September 22	2.70	7	85
June 6	3.10	530	79				
June 13	3.00	149	38	1898.			
July 17	3.05	266	79	May 12	3.80	1,659	170

Daily gage height, in feet, of North Branch of Potomac River at Cumberland, Md.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1894.												
1	......	......	......	......	......	......	2.9	3.0	0.7	1.7	3.5	2.9
2	......	......	......	......	......	......	2.9	3.0	.5	3.0	3.5	3.1
3	......	......	......	......	......	......	2.9	3.1	.6	2.8	3.3	3.1
4	......	......	......	......	......	......	2.8	3.1	.6	2.7	3.0	3.3
5	......	......	......	......	......	......	2.8	2.9	.5	2.5	2.9	3.2
6	......	......	......	......	......	......	2.8	2.8	1.0	2.3	3.0	3.2
7	......	......	......	......	......	......	2.8	2.8	1.0	1.7	3.0	3.1
8	......	......	......	......	......	......	2.8	2.6	1.1	1.5	3.0	3.1
9	......	......	......	......	......	......	2.8	2.5	1.1	1.6	3.1	3.0
10	......	......	......	......	......	......	2.8	2.1	1.1	1.9	3.1	3.0
11	......	......	......	......	......	3.5	2.7	2.0	1.0	2.0	3.2	3.2
12	......	......	......	......	......	3.4	2.6	2.1	1.0	3.0	3.1	3.4
13	......	......	......	......	......	3.4	2.6	2.0	1.2	2.9	3.1	4.1
14	......	......	......	......	......	3.3	2.7	3.0	1.2	2.9	3.1	4.7
15	......	......	......	......	......	3.3	2.6	3.0	1.3	2.9	3.0	3.3
16	......	......	......	......	......	3.3	2.5	2.9	1.4	2.9	3.0	3.2
17	......	......	......	......	......	3.3	2.4	2.8	1.7	2.9	3.0	3.2
18	......	......	......	......	......	3.3	2.3	2.7	2.9	2.9	3.0	3.1
19	......	......	......	......	......	3.3	2.2	2.0	2.9	2.8	2.3	3.1
20	......	......	......	......	......	3.2	2.0	1.9	3.1	2.8	2.3	3.0
21	......	......	......	......	......	3.1	1.9	1.9	3.2	2.7	3.1	3.0
22	......	......	......	......	......	3.1	1.5	2.5	3.2	2.7	3.0	3.0
23	......	......	......	......	......	3.4	2.0	3.0	2.9	2.7	3.0	2.9
24	......	......	......	......	......	3.4	3.0	2.8	2.9	2.2	3.0	3.1
25	......	......	......	......	......	3.3	3.0	2.8	2.8	1.9	3.2	3.1
26	......	......	......	......	......	3.3	2.9	2.5	2.7	1.8	3.1	3.0
27	......	......	......	......	......	3.3	2.9	1.9	2.7	1.7	3.0	3.0
28	......	......	......	......	......	3.3	2.8	1.8	2.5	1.7	3.0	3.1
29	......	......	......	......	......	3.2	2.7	1.3	2.0	1.7	3.0	3.1
30	......	......	......	......	......	3.0	2.8	1.0	1.8	1.7	3.0	3.1
31	......	......	......	......	......	......	2.9	.9	......	2.0	......	3.1
1895.												
1	3.0	3.6	6.0	3.9	3.4	3.0	3.1	2.8	1.0	......	......	......
2	3.0	3.6	5.7	3.8	3.8	3.0	3.4	2.7	1.0	......	......	......
3	3.0	3.5	4.9	4.4	3.8	3.0	3.3	2.7	1.0	......	......	......
4	3.0	3.5	4.6	3.9	3.6	2.9	3.1	2.7	.9	......	......	......
5	3.0	3.5	4.2	3.8	3.6	2.9	3.1	2.7	.9	......	......	......
6	3.1	3.5	4.0	3.7	3.4	3.0	3.2	2.6	.9	......	......	......
7	4.8	3.5	3.8	3.6	3.3	3.0	3.2	2.6	.8	......	......	......
8	6.0	3.5	3.8	3.8	3.2	3.0	3.2	2.6	.8	......	......	......
9	4.8	3.5	4.2	5.6	3.4	2.9	3.3	2.5	.7	......	......	......
10	4.7	3.5	4.0	5.5	3.2	2.9	3.7	2.5	.5	......	......	......
11	4.1	3.5	4.0	4.7	3.2	2.9	3.4	2.4	.5	......	......	......
12	3.8	3.4	3.8	4.7	3.7	2.8	3.2	2.4	.6	......	......	......
13	3.5	3.4	3.8	3.9	3.7	2.8	3.2	2.4	1.1	......	......	......
14	3.5	3.4	4.5	3.8	3.7	3.3	3.3	2.3	1.2	......	......	......
15	3.5	3.4	4.8	3.8	3.5	3.3	3.3	2.2	1.0	......	......	......
16	3.9	3.3	5.2	3.8	3.3	3.2	3.3	2.1	.9	......	......	......
17	3.9	3.4	4.7	3.8	3.4	3.2	3.0	2.0	.9	......	......	......
18	3.9	3.4	4.5	3.7	3.4	3.1	3.0	1.9	.8	......	......	......
19	3.8	3.4	4.3	3.6	3.4	3.0	2.9	1.8	.7	......	......	......
20	3.8	3.4	4.1	3.5	3.3	3.0	2.9	1.7	.5	......	......	......
21	3.9	3.4	3.8	3.4	3.4	2.9	2.7	1.6	.4	......	......	(a)
22	4.6	3.4	3.7	3.4	3.4	3.0	2.7	1.3	.3	......	......	3.0
23	4.0	3.4	3.7	3.3	3.4	3.0	2.7	1.2	.2	......	......	3.2
24	3.7	3.4	3.7	3.3	3.4	3.0	2.7	1.1	.1	......	......	2.9
25	3.6	3.4	3.7	3.2	3.3	2.9	2.7	1.0	(a)	......	......	2.9
26	3.5	3.6	4.5	3.3	3.2	3.0	2.7	.9	......	......	......	3.0
27	3.5	4.1	4.3	3.3	3.3	3.0	2.7	.9	......	......	......	2.9
28	3.4	5.0	4.3	3.3	3.2	3.3	2.8	.9	......	......	......	2.9
29	3.4	......	5.1	3.3	3.1	3.2	2.9	.9	......	......	......	2.9
30	3.7	......	4.5	3.4	3.1	3.0	2.9	.8	......	......	......	3.1
31	3.7	......	4.5	......	3.1	......	2.8	.9	......	......	......	3.0

a Water surface below gage zero September 25 to December 21, 1895.

Daily gage height, in feet, of North Branch of Potomac River at Cumberland, Md.—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1	2.9	4.6	3.9	5.0	4.5	3.6	3.1	3.8	2.6	5.5	3.1	3.7
2	2.9	4.8	3.7	4.8	4.5	3.5	3.1	3.8	2.7	4.5	3.1	3.5
3	3.0	4.0	3.0	4.4	4.5	3.4	3.1	3.8	2.7	4.5	3.1	3.4
4	2.9	3.8	3.3	4.2	4.5	3.5	3.1	3.7	2.7	3.5	3.2	3.3
5	2.9	3.8	3.1	3.8	3.4	3.3	3.1	3.3	2.7	3.4	3.2	3.3
6	2.9	3.8	3.1	3.8	3.3	3.3	2.9	3.3	2.8	3.3	5.5	3.3
7	2.9	4.5	3.1	3.7	3.1	3.8	2.9	3.2	2.9	3.1	4.5	3.3
8	2.9	3.9	3.6	3.7	3.0	3.7	2.9	3.2	2.9	3.1	3.8	3.2
9	2.9	3.0	3.4	3.7	3.0	3.4	3.1	3.4	2.9	3.1	3.8	3.3
10	2.9	3.4	3.3	3.7	3.0	3.4	3.7	3.4	2.9	3.0	3.7	3.3
11	2.9	3.1	3.3	3.7	2.9	3.4	3.4	3.3	2.8	3.0	3.6	3.4
12	3.0	3.3	3.4	4.3	2.9	3.4	3.3	3.3	2.7	3.1	3.5	3.6
13	3.0	4.9	3.1	4.3	3.5	3.2	3.1	3.1	2.9	3.1	3.5	3.4
14	3.0	4.1	3.1	4.1	3.5	3.2	3.0	3.6	3.0	3.0	3.4	3.3
15	3.0	3.8	3.1	3.9	3.3	3.3	3.0	3.5	3.1	3.0	3.2	3.3
16	3.0	3.8	3.2	3.8	3.2	3.3	3.0	3.3	3.5	3.0	3.1	3.3
17	3.0	3.5	3.3	3.8	3.1	3.7	3.0	3.1	3.0	3.0	3.1	3.3
18	3.0	3.5	3.3	3.7	3.4	4.1	3.3	3.0	3.0	3.0	3.2	3.3
19	2.9	3.2	3.5	3.5	3.5	3.7	3.1	2.9	3.0	2.9	3.3	3.3
20	2.9	3.2	3.6	3.5	3.8	3.6	3.1	2.9	2.9	2.9	3.3	3.3
21	3.0	3.2	3.7	3.5	3.8	3.3	3.3	3.0	3.0	3.1	3.2	3.2
22	3.0	3.2	3.7	3.5	3.6	3.3	4.0	3.0	3.1	3.1	3.3	3.2
23	3.0	3.3	4.0	3.3	3.4	3.2	4.7	3.0	3.1	3.1	3.3	3.2
24	3.1	3.1	3.9	3.4	3.4	3.5	4.6	3.2	3.0	3.3	3.4	3.2
25	3.5	3.3	3.7	3.5	3.5	3.5	10.0	3.0	3.0	3.7	3.3	3.2
26	3.3	3.3	4.0	3.5	3.5	3.6	6.5	2.9	3.0	3.5	3.3	3.2
27	3.1	3.3	5.0	3.5	4.0	3.5	4.7	2.9	3.0	3.2	3.2	3.1
28	3.0	3.2	4.5	3.5	3.7	3.3	4.9	2.9	2.9	3.2	3.2	3.1
29	3.0	3.7	5.8	3.5	4.1	3.3	4.5	2.9	2.9	3.1	3.9	3.1
30	3.7	......	8.0	3.4	4.0	3.2	4.5	2.9	10.0	3.1	4.0	3.1
31	4.2	......	6.0	......	3.8	......	4.5	2.8	......	3.1	......	3.2
1897.												
1	3.2	3.4	4.0	3.5	3.5	2.9	2.7	3.0	2.6	2.2	2.8	.....
2	3.2	3.5	3.8	3.4	7.5	2.8	2.7	3.0	2.5	2.0	3.0	.....
3	3.3	3.6	3.9	3.4	5.5	2.8	2.7	2.9	2.5	1.9	3.0	.....
4	3.3	3.4	5.2	3.7	5.0	2.8	2.7	2.9	2.5	1.7	3.1	.....
5	4.0	3.4	4.9	3.8	4.6	2.8	2.7	3.5	2.4	1.7	3.0	.....
6	4.0	3.5	6.0	3.7	4.1	2.8	2.6	3.2	2.4	1.6	2.9	.....
7	3.7	4.5	5.0	3.6	4.1	2.8	2.6	3.1	2.2	1.5	2.9	.....
8	3.4	4.2	4.4	5.2	3.9	2.8	2.7	3.2	1.9	1.4	3.0	.....
9	3.3	4.0	4.6	5.4	3.7	2.9	2.7	3.1	1.8	1.4	4.0	.....
10	3.4	3.7	4.2	4.5	3.7	2.7	2.7	3.0	1.8	1.5	3.4	.....
11	3.2	3.6	4.0	4.5	3.6	2.7	2.8	3.0	1.7	1.3	3.4	.....
12	3.2	3.5	4.0	4.1	4.0	2.7	2.9	2.9	1.6	1.3	3.3	.....
13	3.2	3.7	3.9	4.0	4.4	2.6	2.9	2.9	1.5	1.3	3.2	.....
14	3.2	4.0	3.8	3.8	5.4	2.5	2.8	2.8	1.4	1.4	3.2	.....
15	3.2	4.2	4.0	3.9	4.6	2.5	2.8	3.0	1.3	1.5	3.5	.....
16	3.2	4.7	3.8	3.9	4.3	3.0	2.8	3.0	1.2	1.5	3.5	.....
17	3.4	4.5	3.7	3.7	3.9	3.0	2.7	2.9	1.2	1.4	3.4	.....
18	3.7	5.0	4.0	3.7	3.8	2.9	2.8	2.8	3.2	1.4	3.3	.....
19	3.5	4.8	4.5	3.6	3.7	2.9	2.8	2.9	3.0	1.4	3.3	.....
20	3.4	3.5	4.8	3.7	3.5	2.9	2.9	2.9	2.9	1.4	3.2	.....
21	3.4	3.5	4.6	3.5	3.3	3.0	3.2	2.9	2.8	1.4	.....	.....
22	3.5	10.5	4.2	3.3	3.3	3.0	3.0	2.9	2.7	1.3	.....	.....
23	3.4	8.7	4.0	3.3	3.3	2.9	3.0	2.9	2.6	1.3	.....	.....
24	3.4	6.2	4.2	3.3	3.0	2.9	3.0	2.9	2.8	1.5	.....	.....
25	3.3	5.1	4.1	3.2	3.0	3.0	3.0	2.9	3.0	1.6	.....	.....
26	3.3	4.5	4.0	3.1	3.0	2.9	2.9	3.0	3.0	1.6	.....	.....
27	3.3	4.3	3.9	3.0	3.0	2.9	3.2	3.0	2.9	1.7	.....	.....
28	3.3	4.0	3.8	3.0	3.0	2.9	3.1	3.0	2.8	1.7	.....	.....
29	3.3	......	3.7	3.0	2.9	2.9	3.1	2.9	2.8	2.4	.....	.....
30	3.3	......	3.6	2.9	2.9	2.8	3.1	2.8	2.7	2.7	.....	.....
31	3.3	......	3.6	......	2.9	......	3.0	2.6	......	2.7	.....	.....

Rating table for North Branch of Potomac River at Cumberland, Md., from June 11, 1894, to November 20, 1897.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.65	0	3.70	1,420	4.80	4,280	5.90	7,590
2.70	7	3.80	1,650	4.90	4,570	6.00	7,900
2.80	50	3.90	1,890	5.00	4,860	6.50	9,500
2.90	135	4.00	2,130	5.10	5,150	7.00	11,150
3.00	235	4.10	2,380	5.20	5,450	7.50	12,850
3.10	350	4.20	2,640	5.30	5,750	8.00	14,600
3.20	480	4.30	2,900	5.40	6,050	8.50	16,400
3.30	630	4.40	3,170	5.50	6,350	9.00	18,250
3.40	800	4.50	3,440	5.60	6,660	9.50	20,150
3.50	990	4.60	3,720	5.70	6,970	10.00	22,100
3.60	1,200	4.70	4,000	5.80	7,280	10.50	24,100

[a] This table is strictly applicable only for open-channel conditions. It is based on 20 discharge measurements made during 1895–1898. It is fairly well defined between gage heights 3.0 feet and 5.5 feet. Below 3.0 feet it is uncertain. The extension above 5.5 feet is probably fairly accurate.

Estimated monthly discharge of North Branch of Potomac River at Cumberland, Md.[a]

Month.	Discharge in second-feet.		
	Maximum.	Minimum.	Mean.
1894.			
June 11–30	990	350	632
July	235	0	56.5
August	350	0	77.5
September	480	0	63.8
October	235	0	47.0
November	990	0	323
December	4,000	135	547
1895.			
January	7,900	235	1,669
February	4,860	630	1,099
March	7,900	1,420	3,094
April	6,660	480	1,810
May	1,650	350	853
June	630	50	267
July	1,420	.7	348
August	50	0	2.5
September	0	0	0
October	0	0	0
November	0	0	0
December	480	0	71.3
The year	7,900	0	768
1896.			
January	2,640	135	357
February	4,570	350	1,426
March	14,600	235	2,024
April	4,860	630	1,709
May	3,440	135	1,275
June	2,380	480	927
July	22,100	135	2,224
August	1,650	50	568
September	22,100	0	916
October	6,350	135	820
November	6,350	350	1,073
December	1,420	350	627
The year	22,100	0	1,162
1897.			
January	2,130	480	801
February	24,100	800	3,770
March	7,900	1,200	2,704
April	6,050	135	1,554
May	12,850	135	2,156
June	235	0	103
July	480	0	132
August	990	0	215
September	480	0	55.6
October	7	0	.45
November 1–20	2,130	50	572

[a] These estimates do not include flow in canal feeders.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN NORTH BRANCH OF POTOMAC RIVER BASIN.

The following miscellaneous discharge measurements have been made in the basin of North Branch of Potomac River:

Miscellaneous discharge measurements in North Branch of Potomac River drainage basin.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Feet per sec.*	*Second-feet.*
Sept. 24, 1897	Buffalo Creek	At mouth near Bayard, W. Va.	15	12	1.92	*a* 23
Sept. 23, 1897	North Branch of Potomac River.	Near Gormania, W. Va	61	74	.73	54
July 17, 1905	do	do	67	65	.58	38
July 16, 1905	Difficult Creek	At mouth, 4 miles below Gormania, W. Va.	12	9	1.11	10
Sept. 25, 1897	Stony River	200 yards above mouth near Schell, W. Va.	29	30	1.27	38
July. 16, 1905	do	500 feet above bridge near Gormania, W. Va.	45	57	1.37	78
Sept 25, 1897	North Branch of Potomac River.	200 yards above mouth of Laurel Run near Schell, W. Va.	44	100	1.36	136
Sept. 25, 1897	Abram Creek	100 yards above railroad bridge near Harrison, W. Va.	13	19	.39	7.4
Sept. 27, 1897	North Branch of Potomac River.	100 yards above mouth of Savage River near Bloomington, Md.	36	62	1.97	122
Oct. 27, 1897	do	Above mouth of Savage River and below Baltimore and Ohio R. R. bridge near Bloomington, Md.	45	64	1.59	102
Sept. 27 1897	Savage River	Above junction with North Branch of Potomac River near Bloomington, Md.	20	7.5	.93	*b* 7
Oct. 27, 1897	do	½ mile above mouth and above Piedmont water supply intake near Bloomington, Md.	13	12	.92	11
Sept. 28, 1897	Georges Creek	At Cumberland and Pennsylvania R. R. bridge, Westernport, Md.	9	13	.46	6
Sept. 29 1897	New Creek	150 yards above mouth near Keyser, W. Va.	9	4.9	.71	*a* 3.5
Oct. 28, 1897	North Branch of Potomac River.	Near Twenty-first, Md	80	110	1.15	126
Oct. 28 1897	do	Near Gerstell, Md	187	268	.52	138
Sept. 28, 1897	Wills Creek	Above paper mill near Cumberland, Md.	22	10	1.20	12
May 12, 1898	do	Pulp-mill bridge, Cumberland, Md.	86	262	1.45	381
May 13, 1898	do	do	86	262	1.40	368
July 18, 1905	Town Drain	Mechanics street bridge, Cumberland, Md.	20	12	1.50	*b* 18
Sept. 25, 1897	Evitts Creek	200 yards above railroad near Cumberland, Md.	12	9	2.33	21
Sept. 28, 1897	Patterson Creek	Baltimore and Ohio R. R bridge near Patterson Depot, W. Va.	14	5	2.40	12

a Increased discharge caused by rain Sept. 23, 1897.
b Discharge does not include Piedmont water supply.
c Discharge does not include water pumped to Baltimore and Ohio R. R. car shops and two mills where it is used for boiler feed. Creek stated to be exceptionally low.
d Measured at 7 a. m., when flow was largely house sewage.

SOUTH BRANCH OF POTOMAC RIVER BASIN.

GENERAL DESCRIPTION.[a]

The bed of South Branch of the Potomac is mostly coarse gravel, the banks are of loose sediment, and on account of the sudden and local swells to which the river is subject the channel is continually changing. At no places are there falls of any magnitude. The slope of the stream is as follows:

Slope of South Branch of Potomac River.

Locality.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Mouth	0.0	0			
			29.6	127	4.3
Opposite Romney	29.6	127			
			24.0	151	6.3
Moorefield	53.6	278			
			12.0	97	8.1
Petersburg	65.6	375			

SOUTH BRANCH OF POTOMAC RIVER NEAR SPRINGFIELD, W. VA.

A gaging station was first established at the Baltimore and Ohio Railroad bridge 3 miles southwest of Springfield, by C. C. Babb, June 3, 1894. The channel above and below the station is straight and the water rather swift. The banks are liable to overflow at times of high water. The bed of the stream is composed of rock and gravel and is probably permanent. A wire gage 34.00 feet long was used. April 10, 1895, the gage datum was raised 1.00 foot. The bench mark was a cross cut in a broad capstone of the lower wall of the north abutment of the bridge. Its elevation was 28.18 feet above gage datum. February 29, 1896, this station was discontinued on account of difficulty in obtaining an observer.

June 26, 1899, a station was established by E. G. Paul at an iron highway bridge one-fourth mile from Grace Station and 1½ miles southwest of Springfield. The channel of the stream at this point is curved and the current too sluggish to make satisfactory discharge measurements, and they were therefore made at the railroad bridge where the station was originally located, 1½ miles above. A wire gage was used to determine the stages of the river. February 2, 1902, the highway bridge and the gage were carried away by ice.

August 28, 1903, a station was established by E. G. Paul at the steel highway bridge 2½ miles east of Springfield. It was discontinued July 15, 1906.

The channel is straight for several hundred feet above and below the station. Both banks are liable to overflow at very high stages of

[a] Additional information relating to this basin is given on pp. 223-226.

the river. The bed of the stream is of gravel and probably subject to some changes in conditions of flow from time to time. The bridge has two spans of 150 feet each. During high water the river flows beneath both spans, but at low stages beneath the left span only. There is a small island just above and also one below the station.

Discharge measurements were made from the bridge, to which the gage is attached. The initial point for soundings is the river face of the left abutment at the downstream side of the bridge.

A standard chain gage is located in the center of the left span on the downstream side of the bridge. The length of the chain from the end of the weight to the marker is 37.59 feet. The gage was read twice each day by James R. Blue. Bench mark No. 1 is a nail in a large sycamore tree 15 feet downstream from the left approach to the bridge. The nail is in the side of the tree away from the river and about 6 feet above the ground. Its elevation is 18.80 feet above gage datum.

The estimates given below for the station at the railroad bridge during 1894 to 1896 are essentially the same as previously published, the same rating curve being used. Some slight changes were necessary, however, on account of corrections made in the gage heights. No estimates have heretofore been made for stages below gage height 2.5 feet, but the accompanying table was extended to include a discharge of 80 second-feet at gage height 2.0 feet (the minimum gage height in 1895), on the assumption that the minimum discharge of 1895 was the same as the minimum discharge of 1904. Comparisons of 1895 and 1904 minimums at other stations in the Potomac River basin indicate that this assumption is very nearly correct. Estimates for 1894 to 1896 are considered to be within 10 per cent of the true discharge for normal conditions of flow.

Estimates for the station at the highway bridge during 1899 to 1902, as previously published, have been revised. Estimates for stages between 4.0 feet and 8.0 feet are probably within 10 per cent of the true discharge for normal conditions of flow. At gage height 3.0 feet the probable error may be as high as 20 per cent. Estimates for stages above 8.0 feet are somewhat uncertain, especially for the winter months, owing to occasional ice gorging and backwater effects at this station. (See measurement made December 31, 1901.) However, it is considered that the probable error is less than 25 per cent at gage height 20 feet.

Estimates of flow corrected for the effect of ice conditions during ice periods from 1896 to 1902 have been made. They were based on a comparison of the flow at this station with the flow at other stations in the Potomac River basin, and should be reasonably close.

Estimates for 1903 to 1906 are considered to be within 5 per cent of the true discharge below gage height 5.0 feet. At 11.0 feet the error may be as high as 20 per cent. They are the same as those published in the 1905 report. Estimates for 1903 to 1906 were not corrected for ice conditions.

A summary of the records gives the following results: Maximum discharge for twenty-four hours, 19,350 second-feet; minimum discharge for twenty-four hours, 78 second-feet; mean annual discharge for four years, 1,311 second-feet; mean annual rainfall for seven years, 33.94 inches.

Discharge measurements of South Branch of Potomac River near Springfield, W. Va.

Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*
1894.		
May 31	4.70	1,074
1895.		
March 29	5.90	2,049
April 11	8.95	4,389
April 26	4.20	968
May 3	7.40	3.539
May 9	5.25	1,588
May 22	8.30	3,886
June 4	3.90	710
June 6	3.90	759
June 14	3.47	586
June 19	3.10	349
July 16	3.10	378
July 17	3.00	355
1896.		
August 6	4.40	1,058
November 18	3.60	634
1897.		
June 25	3.40	622
September 2	2.40	133
1899.		
June 26 [a]	4.00	617
1900.		
February 23 [a]	7.70	3,808
June 20 [a]	7.00	3,435
September 11 [a]	....	144
1901.		
July 23 [a]	4.50	922
December 31 [a]	[b]11.50	5,470
1903.		
August 29	2.20	201
1904.		
September 9	2.00	115
September 29 [c]	1.99	133
1905.		
March 29	4.48	2,283
April 24	3.02	746
June 8	3.11	781
November 6	2.30	282
1906.		
March 17 [d]	4.50	1,960
May 26	2.63	455

[a] Measurement made at railroad bridge; gage height taken from gage at highway bridge near Grace Station.
[b] Owing to ice jam below the station, this gage height is about 2.6 feet higher than for normal conditions of flow.
[c] By wading below station.
[d] Discharge may be small on account of ice about the meter pivot.

Daily gage height, in feet, of South Branch of Potomac River near Springfield, W. Va.

Day.	June.	July.	Aug.	Sept.	Oct.
1894. [a]					
1	......	3.1	3.2	2.7	2.6
2	......	3.1	3.1	2.7	4.1
3	4.4	3.1	2.8	2.6	3.8
4	4.2	3.0	2.8	2.6	3.5
5	4.1	3.0	2.7	2.6	3.3
6	4.0	3.0	2.6	2.6	3.1
7	4.5	3.0	2.5	2.5	3.0
8	5.4	3.0	2.5	3.0	2.9
9	5.0	3.0	2.5	3.0	2.9
10	4.7	2.9	2.5	2.9	2.8
11	4.3	2.8	2.5	2.8	4.2
12	4.1	2.8	2.5	2.8	4.1
13	3.9	2.8	3.0	2.7	3.8
14	3.85	2.7	2.8	2.7	3.6
15	3.8	......	2.7	2.6	3.5
16	3.8	......	2.6	2.6	3.4
17	3.6	......	2.5	2.6	3.3
18	3.65	......	2.5	3.6	3.2
19	3.9	......	2.8	5.7	3.1
20	4.2	......	2.7	5.1	3.1
21	3.65	......	2.7	4.0	......
22	3.6	2.6	2.65	3.6	......
23	3.5	3.0	2.6	3.3	......
24	3.4	3.0	2.6	3.1	......
25	3.4	2.9	2.6	3.1	......
26	3.3	2.8	2.6	3.0	......
27	3.4	2.8	2.6	2.9	......
28	3.4	2.8	2.7	2.9	......
29	3.25	2.8	2.7	2.7	......
30	3.2	2.7	2.7	2.6	......
31	......	3.8	2.7	......	......

[a] 1894 gage heights have been reduced 1.00 foot to the new datum established April 10, 1895.

Daily gage height, in feet, of South Branch of Potomac River near Springfield, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	......	......	......	......	7.7	4.4	4.8	3.1	2.5	2.0	2.5	2.5
2	......	......	......	......	7.0	4.2	4.5	3.0	2.4	2.0	2.4	2.4
3	......	......	......	......	6.8	4.0	4.2	3.0	2.4	2.0	2.4	2.3
4	......	......	......	......	6.8	3.9	4.0	2.9	2.3	2.0	2.3	2.3
5	......	......	......	......	(a)	3.8	3.8	2.7	2.3	2.0	2.5	2.3
6	......	......	......	......	......	4.2	4.2	2.8	2.3	2.0	2.4	2.3
7	......	......	......	......	......	3.9	3.9	2.7	2.3	2.0	2.4	2.3
8	......	......	......	......	......	3.8	3.5	2.7	......	2.0	2.4	2.3
9	......	......	......	......	5.2	3.7	3.9	2.7	......	2.0	2.4	2.4
10	......	......	......	......	5.4	3.5	3.6	2.7	......	2.0	2.5	2.4
11	......	......	......	8.95	5.1	3.4	3.4	2.7	......	2.0	2.4	2.4
12	......	......	......	7.5	5.7	3.4	3.3	2.7	......	2.0	2.3	2.4
13	......	......	......	7.0	6.8	3.3	3.1	2.6	......	2.0	2.3	2.4
14	......	......	......	6.6	6.2	3.5	3.0	2.6	......	2.0	2.2	2.4
15	......	......	......	6.4	6.2	3.5	3.3	2.6	......	2.0	2.2	2.4
16	......	......	......	6.1	6.0	3.4	3.1	2.6	......	2.0	2.3	2.3
17	......	......	......	5.9	5.9	3.4	2.9	2.6	......	2.0	2.3	2.3
18	......	......	......	5.6	6.2	3.3	2.9	2.6	......	2.0	2.3	2.3
19	......	......	......	5.4	6.4	3.2	2.8	2.6	......	2.0	2.3	2.3
20	......	......	......	5.2	6.0	3.1	2.8	2.6	......	2.0	2.3	2.3
21	......	......	......	5.0	5.8	3.0	2.8	2.5	......	2.0	2.3	2.6
22	......	......	......	4.7	7.9	2.9	2.7	2.5	......	2.0	2.3	4.9
23	......	......	......	4.6	7.6	2.9	3.0	2.5	2.0	2.0	2.3	4.3
24	......	......	......	4.5	6.6	2.8	3.2	2.5	2.0	2.1	2.3	4.0
25	......	......	......	4.4	6.2	3.0	3.2	2.4	2.0	2.1	2.3	......
26	......	......	......	4.2	5.8	3.2	3.3	2.4	2.0	2.0	2.3	3.4
27	......	......	......	4.15	5.5	4.4	3.4	2.3	2.0	2.6	2.3	3.2
28	......	......	......	4.0	5.4	4.0	3.2	2.3	2.0	2.0	2.3	3.0
29	......	......	......	4.2	5.0	3.7	3.0	2.3	2.0	2.0	2.5	2.8
30	......	......	......	4.9	4.7	3.5	2.9	2.3	2.0	2.1	2.6	3.2
31	......	......	......	......	4.5	......	2.9	2.6	......	2.1	......	3.9

Day.	Jan.	Feb.	Day.	Jan.	Feb.	Day.	Jan.	Feb.
1896.[b]			1896.[b]			1896.[b]		
1	5.0	4.0	12	......	5.3	23	3.0	4.0
2	4.7	4.6	13	......	5.7	24	3.6	3.9
3	4.1	6.9	14	......	9.1	25	6.9	3.9
4	4.0	7.85	15	......	8.3			
5	......	7.1				26	6.2	3.7
			16	......	7.2	27	5.0	3.7
6	......	6.3	17	......	5.5	28	4.5	3.5
7	......	9.4	18	......	5.3	29	4.2	3.4
8	......	8.6	19	......	4.7	30	3.9	......
9	......	7.4	20	......	4.4	31	3.8	......
10	......	6.0	21	......	5.1			
11	......	5.5	22	......	6.2			

[a] Repairing bridge; record lost May 5–8, 1895.
[b] River frozen January 4–23, 1896.

Daily gage height, in feet, of South Branch of Potomac River near Springfield, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.[a]												
1							3.2	3.4	3.4	3.4	4.6	4.6
2							3.7	3.6	3.4	3.4	4.8	4.1
3							3.7	3.5	3.5	3.4	4.8	4.0
4							3.7	3.4	3.6	3.3	4.8	4.0
5							3.6	3.2	3.6	3.3	4.6	3.8
6							3.6	3.2	3.6	3.2	4.6	3.7
7							3.6	3.2	3.5	3.2	4.5	8.7
8							3.7	3.2	3.5	3.2	4.4	3.5
9							4.2	3.1	3.5	3.2	4.2	3.4
10							3.9	3.1	3.5	3.2	4.1	3.8
11							3.8	3.1	3.4	3.1	4.1	4.0
12							3.6	3.0	3.4	3.1	4.0	5.8
13							3.4	3.0	3.4	3.1	4.0	5.6
14							3.2	3.1	3.4	3.2	4.0	5.6
15							3.1	3.2	3.5	3.2	3.9	5.4
16							3.0	3.2	3.5	3.2	3.8	5.6
17							2.9	3.1	3.5	3.2	3.7	5.6
18							3.0	3.1	3.4	3.2	3.6	5.5
19							3.4	3.0	3.4	3.1	3.6	5.5
20							3.2	3.0	3.4	3.1	3.9	5.4
21							3.2	3.1	3.3	3.1	4.9	5.4
22							3.2	3.2	3.3	3.1	5.9	5.4
23							3.4	3.2	3.2	3.0	5.8	5.0
24							3.5	3.3	3.1	3.0	5.6	4.0
25							3.5	3.3	3.1	3.2	5.6	
26						4.0	3.4	3.2	3.0	3.4	5.4	
27						4.2	3.4	3.2	3.0	3.5	5.2	
28						3.9	3.2	3.1	3.2	3.5	4.8	
29						4.1	3.2	3.1	3.3	3.8	4.7	
30						3.4	3.2	3.2	3.4	4.2	4.6	
31							3.2	3.2		4.4		
1900.[b]												
1			9.8	7.4	4.4	4.0	5.0	3.6	3.5	4.0	3.6	5.2
2			8.4	7.0	4.3	4.8	5.0	3.4	3.4	3.8	3.6	5.0
3			6.8	6.5	4.2	4.4	5.0	3.4	3.4	3.7	3.6	5.0
4			6.8	5.6	4.2	4.4	5.2	3.4	3.4	3.5	4.0	5.0
5			6.4	5.2	4.1	4.2	5.2	3.4	3.3	3.4	4.0	5.9
6			6.2	5.2	4.1	4.2	5.0	3.2	3.3	3.4	3.8	10.6
7			7.0	5.0	4.1	4.1	5.0	3.2	3.2	3.6	3.8	12.0
8			7.8	5.0	4.0	4.0	4.7	3.2	3.1	3.6	3.6	10.0
9			9.4	4.8	4.0	4.0	4.4	3.1	3.8	3.5	3.6	5.0
10		5.8	6.0	4.6	4.0	4.0	4.4	3.0	4.5	3.5	3.6	5.0
11		6.0	7.4	4.2	4.0	3.9	4.2	3.0	4.0	3.5	3.5	4.8
12		6.4	6.8	4.2	3.9	3.9	4.0	3.0	4.0	3.3	3.4	4.7
13		6.4	6.2	4.0	3.8	3.9	3.6	3.0	3.6	3.2	3.8	4.7
14		6.8	5.7	4.0	3.8	5.6	3.2	3.0	3.4	3.2	3.2	4.5
15		7.2	5.4	3.8	3.7	5.2	3.2	3.0	3.0	3.8	3.2	4.5
16	4.2	7.0	5.0	3.5	3.6	7.65	3.2	2.9	3.0	3.7	3.1	4.4
17	4.6	6.8	4.8	3.4	3.6	13.0	3.1	2.9	2.9	3.6	3.1	
18	4.8		4.6	3.4	3.6	10.2	3.1	2.9	2.9	3.6	3.1	
19	4.9		5.0	3.2	3.5	9.5	3.0	2.9	2.9	3.6	3.4	
20	5.0		7.8	4.4	4.0	7.0	3.0	2.9	2.8	3.5	3.4	4.2
21	9.0		11.4	5.6	3.7	5.4	3.0	2.8	2.8	3.5	3.6	4.0
22	7.0	6.4	10.8	6.0	3.5	5.1	3.4	3.2	2.8	3.5	3.8	4.0
23	6.8	7.7	9.2	6.8	3.4	5.0	3.6	3.4	3.0	3.5	3.8	3.8
24	6.2	7.4	8.4	6.2	3.4	4.9	3.8	3.4	3.0	3.4	3.8	3.7
25	5.6		7.6	6.0	3.2	4.9	3.8	3.4	3.0	3.2	4.0	3.7
26	5.2		6.5	5.6	3.1	5.2	4.6	4.2	3.0	3.2	10.2	3.6
27			6.4	5.2	3.4	5.4	5.0	4.0	3.0	3.2	12.0	3.5
28			6.1	5.0	3.4	5.6	5.4	4.0	3.4	3.2	9.8	3.5
29			6.8	4.7	3.5	5.6	5.4	3.8	3.5	3.2	8.2	3.5
30			7.4	4.4	3.6	5.4	4.5	3.6	4.0	3.4	6.8	3.4
31			7.8		4.0		4.0	3.5		3.5		3.4

[a] Ice conditions December 25–31, 1899.
[b] Ice conditions January 1–15, January 27 to February 9, February 18–21, 25–28, and December 17–19, 1900.

Daily gage height, in feet, of South Branch of Potomac River near Springfield, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.[a]												
1	3.4	....	....	4.8	5.8	7.6	5.0	3.6	7.25	4.0	3.2	3.4
2	3.4	....	....	4.5	5.6	6.8	5.0	3.4	4.6	4.2	3.4	3.4
3	....	....	3.8	4.2	5.4	6.2	5.4	3.1	4.4	4.6	3.4	3.4
4	....	4.0	3.8	8.2	5.5	5.8	5.6	3.1	4.4	3.8	3.3	7.0
5	....	4.0	5.0	8.6	5.0	5.8	5.6	3.1	4.2	3.6	3.3	6.4
6	....	....	....	9.4	4.9	6.0	5.3	3.6	4.2	3.6	3.2	6.0
7	....	....	4.5	8.6	4.5	6.4	5.8	4.2	4.1	3.5	3.2	....
8	....	....	4.6	8.0	4.8	6.2	5.8	4.0	4.1	3.5	3.2	4.8
9	3.6	....	4.8	7.6	6.1	5.4	5.4	3.6	4.1	3.5	3.2	4.6
10	3.6	....	4.8	6.8	16.5	5.0	5.0	3.2	4.0	3.4	3.2	4.5
11	3.8	....	12.2	6.4	12.1	4.8	4.8	3.8	4.0	3.4	3.1	4.5
12	7.6	....	11.4	5.8	8.2	4.5	4.2	3.8	4.0	3.4	3.1	4.5
13	9.2	....	9.4	5.6	7.4	4.4	4.0	3.6	5.2	3.3	3.1	4.8
14	8.0	....	8.2	6.4	6.5	5.3	4.0	3.6	5.4	3.3	3.1	5.0
15	6.4	....	7.4	11.2	6.0	5.6	6.0	3.5	5.0	3.2	3.1	20.0
16	5.6	....	6.0	10.0	5.8	12.4	6.2	3.5	4.4	3.2	3.1	15.0
17	5.4	....	5.8	9.2	5.6	10.2	6.5	3.4	3.8	3.2	3.1	11.2
18	5.4	....	5.4	9.0	5.2	8.1	6.8	3.4	3.6	3.2	3.1	6.8
19	5.2	....	5.2	8.6	5.0	7.8	5.4	3.4	3.6	3.2	3.1	5.7
20	....	....	5.2	10.5	5.0	7.0	5.0	3.8	3.6	3.2	3.1	....
21	....	....	5.0	18.4	4.8	6.1	4.2	4.0	3.5	3.1	3.1	....
22	....	....	6.8	16.0	11.5	5.6	4.0	4.2	3.5	3.1	3.0	....
23	....	....	7.0	12.2	9.0	5.4	4.5	4.5	3.5	3.1	3.0	....
24	4.4	....	7.0	8.9	7.6	5.4	4.0	3.8	3.4	3.1	3.0	....
25	4.4	....	6.8	8.4	5.4	5.2	3.8	3.8	3.4	3.1	5.2	....
26	4.2	....	6.5	7.6	5.0	5.6	4.2	3.5	3.4	3.1	4.6	....
27	4.2	....	6.2	7.2	6.5	6.4	3.6	3.5	3.4	3.1	4.0	....
28	4.2	....	6.0	6.8	8.7	6.0	3.4	3.8	3.3	3.1	3.8	....
29	....	....	5.6	6.4	12.2	6.1	3.0	4.5	3.3	3.1	3.7	8.6
30	....	....	5.4	6.0	11.6	5.0	3.0	4.5	3.2	3.1	3.5	14.6
31	....	....	5.2	....	8.4	....	3.4	4.4	....	3.1	....	12.2

Day.	Jan.	Day.	Jan.	Day.	Jan.	Day.	Jan.
1902.[b]		1902.[b]		1902.[b]		1902.[b]	
1	8.2	10	8.6	18	....	25	....
2	6.8			19	....		
3	6.4	11	5.6	20	....	26	....
4	6.0	12	4.5			27	5.2
5	....	13	....	21	....	28	7.6
		14	....	22	....	29	7.8
6	....	15	....	23	....	30	....
7	....			24	....	31	....
8	....	16	....				
9	8.8	17	....				

[a] Ice conditions January 3-8, 20-23, January 29 to February 3, February 6 to March 2, March 6, December 7, 20-28, 1901.

[b] Ice conditions January 5-8, 13-26, and January 30 to February 24, 1902. Bridge and gage carried away by flood February 24, 1902.

Daily gage height, in feet, of South Branch of Potomac River near Springfield, W. Va.—Continued.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.[a]					
1	......	2.75	2.2	2.2	2.2
2	......	2.7	2.2	2.2	2.1
3	......	2.6	2.2	2.2	2.1
4	......	2.55	2.2	2.2	2.2
5	......	2.45	2.2	2.2	2.1
6	......	2.4	2.2	2.2	2.1
7	......	2.3	2.1	2.2	2.1
8	......	2.3	2.3	2.2	2.15
9	......	2.3	2.6	2.2	2.15
10	......	2.55	2.6	2.2	2.2
11	......	2.45	2.6	2.1	2.25
12	......	2.45	2.6	2.1	2.4
13	......	2.3	2.5	2.1	2.2
14	......	2.3	2.4	2.1	2.25
15	......	2.25	2.4	2.1	2.5
16	......	2.2	2.4	2.1	2.5
17	......	2.25	2.4	2.2	2.5
18	......	2.45	2.4	2.2	2.5
19	......	3.0	......	2.2	2.5
20	......	2.85	......	2.3	2.1
21	......	2.65	......	2.3	2.2
22	......	2.5	......	2.3	2.4
23	......	2.45	......	2.2	2.65
24	......	2.4	......	2.2	2.4
25	......	2.35	2.2	2.2	2.3
26	......	2.25	2.2	2.2	2.3
27	......	2.2	2.2	2.2	2.65
28	2.2	2.2	2.2	2.2	2.6
29	2.2	2.2	2.2	2.2	2.6
30	2.55	2.2	2.2	2.2	2.6
31	2.8	......	2.2	......	2.6

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.[b]												
1	2.6	2.8	3.75	3.65	5.4	3.45	2.8	2.4	2.0	1.8	1.8	1.8
2	2.6	2.8	4.6	4.05	4.85	3.5	2.65	2.5	2.0	1.8	1.8	1.8
3	2.6	2.8	4.2	3.95	4.35	3.45	2.6	2.7	2.0	1.8	1.8	1.8
4	2.6	2.7	4.35	3.7	4.15	3.4	2.6	2.8	2.0	1.8	1.8	1.9
5	2.6	2.6	4.1	3.5	3.9	4.35	2.6	2.8	2.0	1.8	1.8	1.9
6	2.6	2.6	3.65	3.35	3.65	4.3	2.5	2.6	2.0	1.85	1.8	1.9
7	2.6	3.0	3.45	3.2	3.3	3.9	2.5	2.6	2.0	1.85	1.8	1.9
8	2.6	6.4	5.55	3.2	3.5	3.8	2.6	2.55	2.0	1.8	1.8	1.9
9	2.6	4.85	5.6	3.15	3.4	3.35	2.5	2.5	2.1	1.8	1.8	1.95
10	2.6	3.55	4.6	3.2	3.6	3.1	2.85	2.4	2.15	1.8	1.9	2.0
11	2.6	3.2	4.05	3.3	3.4	2.95	4.5	2.3	2.1	1.8	1.9	2.0
12	2.6	2.7	3.85	3.25	3.25	3.1	3.85	2.25	2.1	1.8	1.9	2.2
13	2.6	2.85	3.65	3.2	3.1	3.1	3.5	2.2	2.1	1.8	1.9	2.2
14	2.6	2.95	3.5	3.2	3.0	3.0	2.95	2.1	2.2	1.8	1.9	2.2
15	2.6	3.05	3.35	3.0	3.0	2.7	2.85	2.1	2.15	1.8	1.9	2.2
16	2.6	2.95	3.15	2.85	3.0	2.95	2.55	2.1	2.05	1.8	1.9	2.2
17	2.6	2.9	3.1	2.8	3.0	2.85	2.45	2.0	2.0	1.8	1.8	2.2
18	2.6	2.65	3.1	3.0	3.25	3.1	2.5	2.0	2.0	1.8	1.8	2.2
19	2.6	2.95	3.1	3.0	8.05	3.0	2.55	2.0	2.0	1.8	1.8	2.1
20	2.6	2.9	3.05	3.0	7.95	5.65	2.6	2.0	1.9	1.8	1.8	2.1
21	2.6	2.95	3.05	3.0	6.3	4.7	2.7	2.0	1.9	1.9	1.8	2.1
22	2.85	3.5	3.4	2.9	5.4	3.95	2.6	2.0	1.9	1.9	1.8	2.1
23	9.05	4.5	3.9	2.8	4.8	3.6	2.8	2.0	1.9	1.9	1.8	2.1
24	5.4	4.05	4.55	2.8	4.3	3.45	2.9	2.0	1.9	1.9	1.8	2.1
25	4.05	3.0	4.45	2.7	3.95	3.2	2.8	2.0	1.8	1.8	1.8	2.2
26	3.45	3.25	4.15	2.8	3.75	2.9	2.5	2.0	1.8	1.8	1.8	2.25
27	3.0	2.95	3.95	3.05	3.8	2.75	2.7	2.0	1.8	1.8	1.8	2.5
28	2.9	2.95	3.8	8.6	4.2	2.55	2.6	1.9	1.8	1.8	1.8	2.85
29	2.65	2.95	3.45	8.1	3.65	2.75	2.5	2.1	1.8	1.8	1.8	3.5
30	2.75	......	3.45	6.6	3.45	2.9	2.4	2.1	1.8	1.8	1.8	3.9
31	2.9	......	3.35	......	3.45	......	2.4	2.0	......	1.8	......	3.9

[a] Ice conditions December 4-31, 1903.
[b] River frozen over January 1-22, 1904; river clear January 23-27, 1904; ice conditions January 28 to February 7, 1904; river frozen over December 19-31, 1904.

Daily gage height, in feet, of South Branch of Potomac River near Springfield, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.[a]												
1	2.35	2.9	4.1	3.55	2.9	2.9	3.55	2.9	2.7	2.0	2.4	2.3
2	2.45	2.9	3.9	3.35	2.9	3.0	3.7	2.75	2.6	2.0	2.35	2.3
3	2.3	2.9	3.8	3.3	2.8	2.95	3.45	2.6	2.5	2.0	2.3	3.2
4	2.45	2.9	3.4	3.1	2.8	2.75	4.15	2.6	2.5	2.0	2.2	5.15
5	2.55	2.9	3.7	3.1	2.7	2.7	3.8	2.5	2.4	2.0	2.2	4.35
6	2.35	3.0	4.55	4.0	2.7	2.7	5.35	2.5	2.4	2.0	2.2	3.9
7	2.3	3.0	4.9	4.7	2.7	2.7	4.35	2.65	2.3	2.0	2.2	3.5
8	2.2	3.0	5.25	4.55	2.8	3.0	3.9	2.65	2.25	2.0	2.2	3.2
9	2.3	3.1	7.05	4.2	2.8	2.75	3.65	2.55	2.2	2.0	2.2	3.05
10	2.4	3.1	11.1	3.95	2.8	2.65	3.35	2.5	2.25	2.0	2.2	2.95
11	2.4	3.1	8.75	3.9	2.8	2.6	3.4	2.85	2.45	2.0	2.2	2.85
12	2.3	3.1	7.25	3.8	3.85	2.65	3.85	2.85	2.45	2.0	2.1	2.7
13	4.7	3.1	6.15	3.5	7.5	2.65	4.85	2.5	2.3	2.0	2.1	2.65
14	6.05	3.1	5.35	3.35	5.8	2.55	5.95	3.6	2.4	2.25	2.1	2.55
15	4.75	3.1	4.9	3.3	7.55	2.45	5.6	4.4	2.45	2.2	2.1	2.45
16	3.6	3.1	4.75	3.2	7.05	2.4	4.75	3.9	2.3	2.1	2.1	2.55
17	3.2	3.1	4.75	3.2	5.75	2.3	3.9	3.4	2.2	2.0	2.1	2.6
18	3.1	3.1	5.25	3.1	4.9	2.3	3.5	3.1	2.2	2.0	2.1	2.5
19	3.15	3.1	5.55	3.0	4.3	2.3	3.25	3.0	2.1	2.0	2.1	2.4
20	3.2	3.1	5.9	3.0	4.0	2.2	3.05	2.95	2.1	2.1	2.1	2.35
21	3.3	3.1	7.1	2.9	3.6	2.55	3.2	2.75	2.0	2.1	2.1	6.1
22	3.2	3.1	10.05	2.9	3.45	3.9	3.25	2.7	2.0	2.15	2.1	9.45
23	3.2	3.1	7.55	2.9	3.25	6.0	3.95	2.6	1.9	2.25	2.1	7.75
24	3.05	3.1	6.15	2.8	3.05	9.2	5.2	2.55	1.9	2.3	2.1	7.05
25	3.0	3.1	7.25	2.7	2.95	8.55	4.15	4.0	1.9	2.45	2.1	6.15
26	2.85	3.8	6.2	2.7	2.9	5.9	3.55	5.65	1.8	2.55	2.1	5.65
27	2.7	3.9	5.4	2.8	2.8	6.85	3.3	4.2	1.8	2.9	2.1	5.2
28	2.5	4.1	4.8	2.8	2.8	5.8	3.0	3.35	1.8	3.25	2.1	4.65
29	3.0	......	4.3	2.6	2.7	4.45	3.0	3.0	1.8	2.65	2.1	4.05
30	2.9	......	4.0	2.9	2.7	3.85	3.85	2.8	2.0	2.55	2.2	4.4
31	2.5	......	3.85	......	2.6	......	3.1	2.7	......	2.45	......	4.6
1906.[b]												
1	4.0	4.05	2.6	9.65	4.85	2.8	3.0	......	......	......	......	......
2	3.95	3.85	2.7	8.75	4.55	2.7	2.8	......	......	......	......	......
3	3.85	3.55	2.8	7.85	4.35	2.7	2.68	......	......	......	......	......
4	6.75	3.4	7.05	6.25	4.2	2.8	2.7	......	......	......	......	......
5	8.65	3.4	6.65	5.3	4.0	2.7	3.15	......	......	......	......	......
6	6.7	3.2	5.65	5.4	4.15	2.7	2.9	......	......	......	......	......
7	5.3	3.05	4.8	5.15	3.9	2.85	2.85	......	......	......	......	......
8	4.6	3.0	4.35	4.95	4.0	2.85	2.55	......	......	......	......	......
9	4.15	3.0	4.05	4.65	3.85	2.85	2.4	......	......	......	......	......
10	3.75	3.1	3.85	5.35	3.7	2.85	2.48	......	......	......	......	......
11	3.6	2.9	3.65	5.45	3.65	2.65	2.3	......	......	......	......	......
12	3.9	2.9	3.5	5.15	3.4	2.5	2.25	......	......	......	......	......
13	4.3	2.85	3.35	4.75	3.3	2.58	2.3	......	......	......	......	......
14	4.5	2.7	3.3	4.4	3.25	2.4	2.1	......	......	......	......	......
15	4.55	2.7	3.65	5.4	3.2	2.5	......	......	......	......	......	......
16	5.15	2.7	4.25	6.6	3.4	2.7	......	......	......	......	......	......
17	5.2	2.6	4.45	5.9	3.3	2.7	......	......	......	......	......	......
18	4.75	2.5	4.4	5.5	3.2	2.75	......	......	......	......	......	......
19	4.45	2.4	4.4	4.85	3.1	2.9	......	......	......	......	......	......
20	4.05	2.4	4.8	4.45	3.0	3.0	......	......	......	......	......	......
21	3.85	2.6	5.15	4.0	3.05	3.85	......	......	......	......	......	......
22	3.75	2.65	5.65	3.85	2.85	4.0	......	......	......	......	......	......
23	5.15	2.7	6.1	3.75	2.75	3.65	......	......	......	......	......	......
24	9.5	2.6	5.95	3.65	2.7	3.35	......	......	......	......	......	......
25	7.2	2.6	5.35	3.6	2.6	3.5	......	......	......	......	......	......
26	5.25	2.6	5.6	6.35	2.6	4.2	......	......	......	......	......	......
27	4.85	2.6	8.65	9.85	2.5	4.1	......	......	......	......	......	......
28	4.65	2.6	13.55	7.3	2.6	3.45	......	......	......	......	......	......
29	4.75	......	10.85	5.75	2.7	3.05	......	......	......	......	......	......
30	4.45	......	10.65	5.05	2.65	3.0	......	......	......	......	......	......
31	4.25	......	10.95	......	2.7	......	......	......	......	......	......	......

[a] Ice conditions during portions of January and February, 1905.
[b] Flow probably unaffected by ice conditions during 1906.

Rating tables for South Branch of Potomac River, near Springfield, W. Va.

JUNE 3, 1894, TO FEBRUARY 29, 1896.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.00	80	2.90	300	3.80	700	5.40	1,720
2.10	96	3.00	330	3.90	750	5.60	1,860
2.20	113	3.10	360	4.00	800	5.80	2,000
2.30	132	3.20	400	4.20	910	6.00	2,145
2.40	154	3.30	450	4.40	1,030	7.00	2,895
2.50	180	3.40	500	4.60	1,160	8.00	3,645
2.60	210	3.50	550	4.80	1,300	9.00	4,395
2.70	240	3.60	600	5.00	1,440	10.00	5,145
2.80	270	3.70	650	5.20	1,580		

JUNE 26, 1899, TO JANUARY 29, 1902.[b]

2.70	85	4.00	615	5.60	1,785	8.00	4,370
2.80	110	4.10	670	5.80	1,965	8.50	4,975
2.90	140	4.20	730	6.00	2,150	9.00	5,600
3.00	170	4.30	790	6.20	2,345	10.00	6,850
3.10	205	4.40	855	6.40	2,545	11.00	8,100
3.20	240	4.50	920	6.60	2,755	12.00	9,350
3.30	280	4.60	990	6.80	2,975	13.00	10,600
3.40	320	4.70	1.060	7.00	3,200	14.00	11,850
3.50	365	4.80	1,135	7.20	3,430	15.00	13,100
3.60	410	4.90	1,210	7.40	3,660	16.00	14,350
3.70	460	5.00	1,285	7.60	3,890	18.00	16,850
3.80	510	5.20	1,445	7.80	4,130	20.00	19,350
3.90	560	5.40	1,615				

AUGUST 28, 1903, TO JULY 14, 1906.[c]

1.80	78	3.00	702	4.10	1.790	5.40	3,690
1.90	96	3.10	778	4.20	1,912	5.60	4,030
2.00	125	3.20	860	4.30	2,038	5.80	4,380
2.10	163	3.30	947	4.40	2,168	6.00	4,745
2.20	210	3.40	1,039	4.50	2,302	6.50	5,750
2.30	261	3.50	1,135	4.60	2,440	7.00	6,890
2.40	315	3.60	1,235	4.70	2,582	7.50	8,120
2.50	372	3.70	1,339	4.80	2,728	8.00	9,370
2.60	432	3.80	1,447	4.90	2,879	9.00	12,000
2.70	495	3.90	1,558	5.00	3,035	10.00	15,000
2.80	561	4.00	1,672	5.20	3,355	11.00	18,000
2.90	630						

[a] This table is strictly applicable only for open-channel conditions. It is based on discharge measurements made during 1894–1896. It is fairly well defined between gage heights 3.0 feet and 10.5 feet. Above gage height 5.9 feet the rating curve is a tangent, the difference being 75 per tenth.

[b] This table is strictly applicable only for open-channel conditions. It is based on four discharge measurements made during 1899–1901. It is not well defined. Above gage height 8.4 feet the rating curve is a tangent, the difference being 125 per tenth. For high stages a tangent is considered to give the best results, owing to conditions below the station, which cause a backwater effect at the gage.

[c] This table is strictly applicable only for open-channel conditions. It is based on eight discharge measurements made during 1903–1906. It is fairly well defined between gage heights 2 feet and 4.5 feet. Above 6 feet gage height the discharge is approximate.

Estimated monthly discharge of South Branch of Potomac River near Springfield, W. Va.

[Drainage area, 1,440 to 1,475 square miles.][a]

Month.	Discharge in second-feet.			Run-off.		Per cent of precipitation.	Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.		In inches.	Loss in inches.
1894.								
June 3-30	1,720	400	775	0.538	0.560	....	....	....
July [b]	700	210	296	.206	.238	....	....	....
August	400	180	233	.162	.187	....	....	....
September	1,930	180	403	.280	.312	....	....	....
October 1-20	910	210	500	.347	.258	....	....	....
1895.								
April 11-30	4,357	800	1,792	1.24	.922	....	....	....
May [c]	3,570	1,090	2,203	1.53	1.76	....	....	....
June	1,030	270	582	.404	.451	....	....	....
July	1,300	240	512	.356	.410	....	....	....
August	360	132	217	.151	.174	....	....	....
September [d]	180	80	108	.075	.084	....	....	....
October	96	80	82.1	.057	.066	....	....	....
November	210	113	145	.101	.113	....	....	....
December [e]	1,370	132	307	.213	.246	....	....	....
1896.								
January [f]	2,820	250	635	.441	.508	....	....	....
February	4,695	500	2,023	1.40	1.51	....	....	....
1899.								
January	....	....	....	....	....	....	2.44	....
February	....	....	....	....	....	....	3.99	....
March	....	....	....	....	....	....	2.92	....
April	....	....	....	....	....	....	.98	....
May	....	....	....	....	....	....	5.34	....
June 26-30	730	320	579	.399	.074	....	[g] 3.81	....
July	730	140	337	.232	.268	9	2.86	2.59
August	410	170	238	.164	.189	5	3.46	3.27
September	410	170	314	.217	.242	6	3.98	3.74
October	855	170	293	.202	.233	14	1.63	1.40
November	2,055	410	1,001	.690	.770	71	1.09	.32
December [h]	1,965	320	984	.679	.783	53	1.48	.70
The year	....	....	....	....	....	....	33.98	....
1900.								
January [i]	5,600	500	1,103	.761	.877	59	1.49	.61
February [i]	4,010	800	1,971	1.36	1.42	51	2.79	1.37
March	8,600	990	3,497	2.41	2.78	92	3.01	.23
April	3,660	240	1,400	.966	1.08	95	1.14	.06
May	855	205	509	.351	.405	19	2.10	1.70
June	10,600	560	1,945	1.34	1.50	33	4.59	3.09
July	1,615	170	783	.540	.623	20	3.17	2.55
August	730	110	287	.198	.228	13	1.78	1.55
September	920	110	299	.206	.230	9	2.65	2.42
October	615	240	359	.248	.286	14	2.12	1.83
November	9,350	205	1,361	.939	1.05	26	4.04	2.99
December [h]	9,350	320	1,507	1.04	1.20	67	1.80	.60
The year	10,600	110	1,252	.863	11.68	38	30.68	19.00

[a] Various drainage areas are used to obtain run-off on account of changes in location of stations.
[b] Discharge interpolated July 15-21, 1894.
[c] Discharge interpolated May 5-8, 1895.
[d] Discharge interpolated September 8-22, 1895.
[e] Discharge interpolated December 25, 1895.
[f] River frozen January 4-23, 1896; discharge corrected for ice conditions, the discharge of Shenandoah River at Millville, W. Va., being used as a basis.
[g] Precipitation for complete month June, 1899.
[h] Ice conditions December 25-31, 1899; discharge corrected for this period, the daily discharges at Piedmont, Riverton, and Millville being used as a basis.
[i] Ice conditions January 1-15, January 27 to February 9, February 18-21, 25-28, and December 17-19, 1900. Discharge corrected for these periods, the daily discharges at Piedmont, Riverton, and Millville being used as a basis.

Estimated monthly discharge of South Branch of Potomac River, etc.—Continued.

Month.	Discharge in second-feet.			Run-off.		Per cent of precipitation.	Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.		In inches.	Loss in inches.
1901.								
January [a]	5,850	300	1,119	.772	.890	52	1.70	.81
February [a]	615	400	426	.294	.306	115	.27	− .04
March [a]	9,600	400	2,423	1.67	1.92	82	2.33	.41
April	17,350	730	4,987	3.44	3.84	62	6.20	2.36
May	9,600	920	3,631	2.50	2.88	44	6.54	3.66
June	9,850	855	2,560	1.77	1.98	81	2.44	.46
July	2,975	170	1,185	.817	.942	32	2.92	1.98
August	920	205	484	.334	.385	6	6.60	6.22
September	3,488	240	721	.497	.554	27	2.02	1.47
October	990	205	322	.222	.256	137	.19	− .07
November	1,445	170	326	.225	.251	11	2.25	2.00
December [a] [b]	19,350	320	3,326	2.29	2.64	50	5.31	2.67
The year	19,350	170	1,792	1.24	16.84	43	38.77	21.93
1902.								
January [c]	5,350	800	1,810	1.25	1.44	66	2.19	.75
February							3.83	
March							4.34	
April							2.77	
May							2.38	
June							3.67	
July							2.32	
August							2.37	
September							1.95	
October							2.84	
November							2.93	
December							3.87	
The year							35.46	
1903.								
January							2.76	
February							2.85	
March							2.98	
April							3.02	
May							3.17	
June							5.33	
July							3.79	
August 28–31	561	210	346	.235	.035		[d] 3.89	
September	702	210	336	.228	.254	13	1.91	1.66
October [e]	432	163	271	.184	.212	8	2.78	2.57
November	261	163	206	.140	.156	20	.79	.63
December [f]	463	163	286	.194	.224	55	.40	.18
The year							33.67	
1904.								
January [g]	12,150	432	1,009	.684	.789	48	1.66	.87
February [g]	5,540	432	1,004	.681	.734	74	.99	.26
March	4,030	740	1,451	.984	1.13	61	1.84	.71
April	10,930	495	1,660	1.13	1.26	51	2.45	1.19
May	9,500	702	2,143	1.45	1.67	56	3.01	1.34
June	4,118	402	1,121	.760	.848	16	5.47	4.62
July	2,302	315	568	.385	.444	8	5.58	5.14
August	561	96	238	.161	.186	10	1.95	1.76
September	210	78	123	.083	.093	5	1.83	1.74
October	96	78	80.9	.055	.063	5	1.14	1.08
November	96	78	79.9	.054	.060	8	.76	.70
December [g]	1,558	78	296	.200	.231	9	2.64	2.41
The year	12,150	78	814	.552	7.50	26	29.32	21.82

[a] Ice conditions January 3–8, 20–23, January 29 to February 3, February 6 to March 2, March 6, December 7, 20–28, 1901. Discharge corrected for these periods, the daily discharge at Piedmont, Riverton, and Millville being used as a basis.

[b] There was backwater at the gage December 29–31, 1901, owing to an ice jam, but since the discharge when applied to the gage heights as observed is relatively small as compared with that at Riverton and Millville, it was considered best to allow them to stand without reduction for backwater effect.

[c] Ice conditions January 5–8, 13–26, and January 30 to February 24, 1902. Discharge corrected for January, the daily discharges at Piedmont, Riverton, and Millville being used as a basis.

[d] Precipitation for complete month August, 1903.

[e] Discharge interpolated October 19–24, 1903.

[f] Ice conditions December 4–31, 1903. No correction made in estimates.

[g] Ice conditions Jan. 1 to 22, Jan. 28 to Feb. 7, and December 19–31, 1904; no correction made in estimates.

Estimated monthly discharge of South Branch of Potomac River, etc.—Continued.

Month.	Discharge in second-feet.			Run-off.		Per cent of precipitation.	Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.		In inches.	Loss in inches.
1905.								
January [a]	4,840	210	821	.557	.642	27	2.34	1.70
February [a]	1,790	630	831	.563	.586	48	1.22	.63
March	18,300	1,039	4,793	3.25	3.75	162	2.32	−1.43
April	2,582	432	1,015	.688	.768	63	1.23	.46
May	8,245	432	1,744	1.18	1.36	37	3.64	2.28
June	12,600	210	1,948	1.32	1.47	25	5.78	4.31
July	4,652	702	1,673	1.13	1.30	21	6.26	4.96
August	4,118	372	854	.579	.668	14	4.63	3.96
September	495	78	228	.155	.173	15	1.12	.95
October	904	125	229	.155	.179	6	3.02	2.84
November	315	163	190	.129	.144	13	1.10	.96
December	13,350	261	2,298	1.56	1.80	59	3.06	1.26
The year	18,300	78	1,385	.939	12.84	36	35.72	22.88
1906:								
January	13,500	1,235	3,321	2.26	2.61			
February	1,731	315	664	.452	.471			
March	25,650	432	5,076	3.45	3.98			
April	14,550	1,235	4,538	3.09	3.45			
May	2,804	372	1,085	.738	.851			
June	1,912	315	770	.524	.585			
July 1-14	819	163	449	.305	.159			

[a] Ice conditions January and February, 1905; no correction made in estimates.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN SOUTH BRANCH OF POTOMAC RIVER BASIN.

The following miscellaneous discharge measurements have been made in the basin of South Branch of Potomac River:

Miscellaneous discharge measurements in South Branch of Potomac River drainage basin.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Ft. per second.*	*Second-feet.*
1897. September 24	North Fork of South Branch of Potomac River.	500 feet above mouth near Petersburg, W. Va.	38	33	0.52	17
Do	South Branch of Potomac River.	300 yards above mouth of North Fork, near Petersburg, W. Va.	80	58	1.65	96
Do	South Fork of South Branch of Potomac River.	Near Moorefield, W. Va.	24	23	1.48	34
September 26	Mill Creek	Near mouth near Romney W. Va.				3
Do	South Branch of Potomac River.	A short distance above Romney bridge near Romney, W. Va.	65	91	2.25	205

POTOMAC RIVER BASIN BETWEEN MOUTH OF SOUTH BRANCH AND SHENANDOAH RIVER.

POTOMAC RIVER AT GREAT CACAPON, W. VA.

Gage-height records were obtained of Potomac River at Dam No. 6 of the Chesapeake and Ohio Canal near Great Cacapon, from June 21, 1894, to March 7, 1896. The gage was located above the dam. Discharge measurements were made of the main river and also of the canal feeder by wading at a point about 1,000 feet below the diversion dam. The channel at this point is rocky and the current swift. The crest of the dam is not level and no data are available for determining the point on the gage at which zero flow over the dam occurs. No estimates of discharge have been made, as the number of measurements is insufficient. The gage heights are not considered of enough value for republication.

Discharge measurements of Potomac River at Great Cacapon, W. Va.

Date.	Gage height.	Discharge of river.	Discharge of canal feeder.
1895.	*Feet.*	*Second-feet.*	*Second-feet.*
June 20 [a]	[b] 0.90	331	([c])
July 18	.90	543	[d] 164
August 26	— .50	132	[e] 92

[a] No water flowing over the West Virginia end of the dam for about one-eighth of the total length.
[b] Gage height not considered accurate.
[c] Water flowing in feeder, but no measurement made.
[d] Feeder gate open 3.0 feet.
[e] Feeder gate wide open.

OPEQUON CREEK NEAR MARTINSBURG, W. VA.[a]

The gaging station was established May 8, 1905, and was discontinued July 16, 1906. It is located at the highway bridge known as "Rileys Ford Bridge," about 4 miles southeast of Martinsburg, W. Va.

The channel is straight for about 300 feet above and below the station. The current is swift. Both banks are clean. The right bank is high and does not overflow. The left bank has a flood plain extending 600 feet across a level meadow. The bed of the stream is rocky, very rough, free from vegetation, and permanent. There is but one channel at ordinary stages. The stream is liable to extreme fluctuations at high water, covering the entire flood plain on the west.

Discharge measurements were made from the downstream side of the steel bridge to which the gage is attached. The initial point for soundings is the top face of the left abutment, downstream side.

A standard chain gage is fastened to the downstream side of the bridge near the left abutment. The length of the chain from the end of the weight to the marker is 19.90 feet. The gage was read twice

[a] General description of this basin is given on p. 230.

each day by Frank Mose. Bench mark No. 1 is a cross chiseled on the upstream left abutment. Its elevation is 18.44 feet above the datum of the gage. Bench mark No. 2 is the top of the pulley wheel of the gage. Its elevation was 19.55 feet above the datum of the gage March 18, 1906.

Low-water measurements at this station plot very erratically, and since the section at the gaging station has remained unchanged it is assumed that the trouble lies with the controlling point below the gage. This assumption is borne out by the fact that it is known that refuse matter is thrown into the creek from the bridge and collects on a bar a short distance below. It has seemed best to determine the discharge by means of three rating curves of the same general form.

Estimates based on the first two curves may be 10 to 20 per cent in error. Estimates based on the third curve are probably within 5 to 10 per cent of the true flow for normal conditions. The 1905–6 estimates are not affected by ice conditions.

Discharge measurements of Opequon Creek near Martinsburg, W. Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
May 7	1.33	141	April 2	3.32	600
November 8	1.25	63	April 12	2.57	338
			Do	2.56	332
1906.			May 29	1.57	152
March 18	1.51	137			

Daily gage height, in feet, of Opequon Creek near Martinsburg, W. Va.

Day.	May.	June.	Oct.	Nov.	Dec.	Day.	May.	June.	Oct.	Nov.	Dec.
1905						1905.					
1	......	1.32	......	1.2	1.28	17	1.52	......	1.1	1.5	1.35
2	......	1.28	......	1.18	1.2	18	1.42	......	1.3	1.1	1.38
3	......	1.22	......	1.15	2.45	19	1.38	......	1.5	1.1	1.22
4	......	1.2	......	1.12	2.52	20	1.32	......	1.38	1.1	1.2
5	......	......	......	1.1	1.78						
						21	1.28	......	1.32	1.1	7.62
6	......	......	......	1.1	1.38	22	1.25	......	1.25	1.1	7.3
7	......	......	......	1.1	1.3	23	1.25	......	1.18	1.1	3.8
8	......	......	1.15	1.15	1.28	24	1.22	......	1.12	1.1	2.92
9	1.35	......	1.12	1.12	1.25	25	1.18	......	1.18	1.1	2.5
10	1.38	......	1.1	1.1	1.22						
						26	1.15	......	2.0	1.1	2.18
11	1.38	......	1.2	1.12	1.2	27	1.18	......	1.68	1.1	2.2
12	1.38	......	1.28	1.5	1.2	28	1.2	......	1.42	1.1	1.8
13	1.32	......	1.22	1.5	1.2	29	1.18	......	1.38	1.5	3.1
14	1.4	......	1.18	1.5	1.18	30	1.15	......	1.3	1.52	2.55
15	1.98	......	1.12	1.5	1.15	31	1.22	......	1.22	......	2.0
16	1.72	......	1.1	1.5	1.22						

Daily gage height, in feet, of Opequon Creek near Martinsburg, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	1.73	1.6	1.26	4.72	1.92	1.5	1.7					
2	1.65	1.6	1.4	3.48	1.9	1.48	1.55					
3	1.77	1.55	1.56	3.0	1.88	1.45	1.9					
4	8.73	1.48	3.24	2.72	1.85	1.42	7.9					
5	4.2	1.45	2.4	2.55	1.82	1.4	2.88					
6	3.12	1.4	1.9	2.45	1.8	2.92	2.4					
7	2.68	1.37	1.84	2.32	1.78	2.18	2.4					
8	2.27	1.33	1.8	2.22	1.75	1.58	1.88					
9	2.15	1.32	1.72	2.48	1.72	1.58	1.78					
10	1.98	1.37	1.6	4.02	1.68	1.62	1.72					
11	1.92	1.4	1.52	3.02	1.65	1.48	1.68					
12	1.9	1.4	1.48	2.48	1.65	1.42	1.62					
13	1.98	1.4	1.48	2.25	1.62	1.48	1.6					
14	2.17	1.45	1.5	2.18	1.6	1.58	1.58					
15	2.7	1.48	1.52	8.5	1.58	1.52	1.52					
16	2.58	1.42	1.52	5.0	1.55	1.48						
17	2.25	1.4	1.52	3.28	1.52	5.38						
18	2.32	1.4	1.58	2.9	1.5	3.0						
19	1.98	1.4	1.72	2.62	1.5	2.75						
20	1.85	1.38	1.83	2.45	1.5	2.48						
21	1.78	1.37	1.82	2.35	1.48	5.18						
22	1.72	1.48	1.92	2.28	1.45	5.0						
23	1.75	1.42	2.28	2.22	1.45	2.58						
24	1.93	1.38	2.3	2.15	1.42	2.35						
25	1.85	1.35	2.35	2.1	1.4	2.18						
26	1.8	1.32	2.78	2.3	1.4	2.05						
27	1.75	1.3	4.0	2.25	1.42	1.88						
28	1.7	1.28	7.52	2.0	1.52	1.82						
29	1.67		5.45	1.98	1.52	2.08						
30	1.65		5.78	1.95	1.48	1.85						
31	1.63		7.2		1.4							

Rating tables for Opequon Creek near Martinsburg, W. Va.

MAY 9 TO JUNE 4, 1905.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.15	116	1.40	152	1.70	200	1.90	237
1.20	123	1.50	167	1.80	218	2.00	257
1.30	137	1.60	183				

OCTOBER 8 TO DECEMBER 20, 1905.[b]

1.10	50	1.50	88	1.90	140	2.30	205
1.20	58	1.60	100	2.00	155	2.40	223
1.30	67	1.70	113	2.10	171	2.50	242
1.40	77	1.80	126	2.20	188		

DECEMBER 21, 1905, TO JULY 15, 1906.[c]

1.20	97	2.20	251	3.20	549	4.40	1,092
1.30	109	2.30	271	3.30	589	4.60	1,193
1.40	122	2.40	293	3.40	630	4.80	1,295
1.50	135	2.50	317	3.50	672	5.00	1,399
1.60	149	2.60	343	3.60	715	5.20	1,504
1.70	164	2.70	371	3.70	759	5.40	1,610
1.80	180	2.80	402	3.80	804	5.60	1,717
1.90	197	2.90	436	3.90	850	5.80	1,825
2.00	214	3.00	472	4.00	897	6.00	1,935
2.10	232	3.10	510	4.20	993		

[a] The rating curve on which this table is based has been drawn through one measurement made May, 1905, and has the form of the 1906 curve.

[b] This table is strictly applicable only for open-channel conditions. The rating curve has been drawn through one measurement made November, 1905, and has the form of the 1906 curve.

[c] This table is strictly applicable only for open-channel conditions. It is based on five discharge measurements made during 1906. It is fairly well defined between gage heights 1.5 feet and 3.4 feet. Above gage height 6.0 feet the rating curve is a tangent, the difference being 55 per tenth.

Estimated monthly discharge of Opequon Creek near Martinsburg, W. Va.

[Drainage area, 275 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
May 9-31	253	116	144	0.524	0.448
June 1-4	140	123	131	.476	.071
October 8-31	155	50	67.4	.245	.219
November	90	50	61.1	.222	.248
December	2,826	54	337	1.23	1.42
1906.					
January	3,436	153	352	1.28	1.48
February	149	107	123	.447	.466
March	2,771	104	480	1.75	2.02
April	3,310	205	509	1.85	2.06
May	200	122	151	.549	.633
June	1,599	122	338	1.23	1.37
July 1-15	2,980	138	387	1.41	.786

TUSCARORA CREEK AT MARTINSBURG, W. VA.

Tuscarora Creek rises in Little North Mountain, in the western part of Berkeley County, W. Va., and flows southeastward into Opequon Creek about 2 miles southeast of Martinsburg.

The gaging station was established May 8, 1905, by F. H. Tillinghast. It is located at the dam formerly used to impound water for the use of the city of Martinsburg.

The channel is curved for 20 feet above the dam and straight for 200 feet beyond this point. The channel below is a steep race way from the crest of the dam, paved with riprap. The current is swift. Both banks are low, clean, and not liable to overflow. The bed of the stream above the dam is fairly uniform and shallow, with a mud bottom. There is but one channel at all stages. The stream is liable to small fluctuations, owing to the varying demands of factories above the station. The water level at the gage is somewhat unsteady. The velocity of approach is high.

It was intended to determine the discharge by applying the weir formula to the flow over the crest of the dam.

A vertical staff gage is bolted to the upstream face of the left abutment, the zero being set at the level of the floor of the spillway. The gage was read twice each day by B. N. Martin. Bench mark No. 1 is the crest of the dam at the left corner; elevation, 0.04 foot below the gage datum. Bench mark No. 2 is the crest of the dam at the right corner; elevation, 0.04 foot above the gage datum.

A current-meter measurement, made May 9, 1905, at gage height 0.78 foot, gave a discharge of 25.2 second-feet.

Owing to poor conditions and especially to the collection of debris on the crest of the dam, rendering estimates based on the gage heights of little value, this station was abandoned December 31, 1905.

Daily gage height, in feet, of Tuscarora Creek at Martinsburg, W. Va.

Day.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.								
1	....	0.72	0.6	1.55	0.68	0.75	0.85	0.55
2	....	.64	.7	1.75	.75	.82	.9	.65
3	....	.62	.72	1.65	.85	.70	.88	1.45
4	....	.65	.75	1.7	.75	.85	.88	.85
5	....	.62	.68	1.75	.65	.75	.8	.65
6	....	.61	.85	1.75	.6	.68	.85	.55
7	....	.9	.82	1.3	.58	.75	.88	.55
8	0.75	.68	.72	1.4	.7	.78	.6	.55
9	.8	.62	.78	1.3	.55	.68	.58	.55
10	.8	.62	.78	1.25	.6	.65	.55	.55
11	.74	.6	.85	.88	.58	.55	.58	.58
12	.75	.18	1.45	.88	.7	.55	.58	.55
13	.72	.5	2.65	.85	.65	.78	.55	.58
14	.75	.7	3.0	.78	.55	.68	.55	.58
15	.82	.68	2.35	.92	.55	.65	.58	.65
16	.76	.72	1.15	.78	.55	.70	.6	.7
17	.8	.65	.85	.8	.65	.78	.52	.58
18	.78	.75	.82	1.25	.55	.68	.55	.68
19	.75	.78	.78	1.02	.55	.72	.5	.65
20	.72	.72	.78	1.05	.6	.65	.52	.75
21	.72	.78	.68	1.02	.65	.58	.55	.88
22	.74	.8	.7	1.1	.6	.75	.52	2.15
23	.72	.72	1.02	1.08	.55	.75	.58	1.8
24	.74	.28	1.45	1.5	.55	.68	.5	1.25
25	.68	.14	1.25	1.15	.55	.58	.58	1.0
26	.62	.42	1.1	.98	.48	.65	.55	.75
27	.6	.72	1.6	1.35	.48	.68	.62	.65
28	.6	.75	1.5	2.0	.75	.58	.65	.7
29	.62	.72	1.85	.85	.65	.85	.55	.75
30	.59	.68	1.55	.8	.75	.92	.5	.7
31	.78	....	1.55	.7	....	.82	....	....

ANTIETAM CREEK NEAR SHARPSBURG, MD.

Antietam Creek drains a rolling, fertile country with uniform declivity and is uninterrupted by natural falls or rapids. It is utilized to a considerable extent to run mills of various kinds.

The gaging station was established June 24, 1897, by A. P. Davis, and was discontinued August 26, 1905. It is located 1 mile east of Sharpsburg, a few hundred feet below the bridge on the toll road from Sharpsburg to Keedysville, Md. There is an old dam, not now in use, just below the bridge.

The channel is straight for 300 feet above and below the station. It has a width at ordinary stages of about 90 feet, and is shallow and unobstructed. There is a good measurable velocity at all stages. The right bank is low and liable to overflow; the left bank is high and rocky; both are fringed with trees. The bed of the stream is composed of gravel, is free from vegetation, and is permanent. There is but one channel at all stages.

Discharge measurements were made from a steel-wire cable, which is supported by the forks of a sycamore tree on each bank and is anchored to timbers set in the ground.

The gage was a vertical rod driven into the gravel of the stream bed and spiked to a tree on the left bank near the cable. It was read once each day. The bench mark is a copper bolt set in a ledge of rock on the left bank at a point about 125 feet above the cable. Its elevation is 16.34 feet above gage datum.

All estimates previously published have been revised. Estimates for stages below gage height 2.0 feet are probably within 10 per cent of the true discharge for normal conditions of flow; estimates between gage heights 2.0 feet and 4.0 feet are within 5 per cent, and estimates above gage height 4.0 feet are within 10 per cent. Allowance has been made for the discharge of the overflow section. The flow is probably affected to a greater or less extent by ice conditions.

A summary of the records gives the following results: Maximum discharge for twenty-four hours, 6,835 second-feet; minimum discharge for twenty-four hours, 59 second-feet; mean annual discharge for five years, 350 second-feet; mean annual rainfall for seven years, 37.56 inches.

Discharge measurements of Antietam Creek near Sharpsburg, Md.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*		*Feet.*	*Second-feet.*
1897.			1900.		
June 24	2.00	251	September 16	1.77	131
July 2	2.05	240	1901.		
September 3	1.60	122	July 30	1.90	185
October 12 [a]	1.70	120	December 28	2.20	266
1898.			1902.		
January 24	2.70	427	September 1	1.70	126
August 19	3.50	831	1903.		
1899.			March 13	3.06	584
January 27	2.80	495	September 4	2.10	224
May 20	2.60	418	1904.		
September 5	1.80	118	July 1	1.79	158
1900.			July 11	1.79	150
June 28	1.80	139			

[a] Measurement made near mouth of stream.

Daily gage height, in feet, of Antietam Creek near Sharpsburg, Md.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897.							1897.						
1	1.9	1.5	1.7	1.5	1.45	1.7	16	1.8	1.9	1.7	1.65	1.75	2.4
2	2.1	1.7	1.7	1.6	2.7	1.6	17	1.75	1.8	1.6	1.6	1.7	2.2
3	1.85	1.7	1.6	1.4	2.1	1.6	18	1.7	1.7	1.6	1.4	1.6	2.1
4	1.7	1.75	1.6	1.6	1.9	1.7	19	1.75	1.6	1.6	1.5	1.5	2.0
5	1.75	1.6	1.5	1.7	1.6	2.25	20	1.75	1.5	1.5	1.7	1.6	2.1
6	1.8	1.7	1.7	1.6	1.6	2.45	21	1.85	1.5	1.6	1.7	1.7	2.0
7	1.7	1.7	1.7	1.7	1.7	2.05	22	1.85	1.55	1.6	1.6	1.6	2.0
8	1.7	1.5	1.6	1.6	1.75	2.0	23	1.7	1.6	1.7	1.6	1.5	2.1
9	1.7	1.4	1.65	1.5	1.8	1.8	24	1.7	3.0	1.9	1.65	1.7	2.5
10	1.7	1.7	1.6	1.4	1.6	1.9	25	1.55	2.9	1.8	1.65	1.8	2.2
11	1.55	1.9	1.6	1.5	1.55	1.9	26	1.65	2.0	1.5	1.8	1.8	2.0
12	1.75	1.85	1.5	1.6	1.5	1.9	27	1.75	1.75	1.7	1.7	1.9	2.0
13	1.95	1.6	1.4	1.7	1.6	2.05	28	1.8	1.7	1.6	1.6	2.0	1.9
14	1.8	1.7	1.5	1.5	1.4	2.0	29	1.85	1.55	1.6	1.6	1.9	1.8
15	1.8	2.45	1.6	1.6	1.5	2.35	30	1.8	1.8	1.5	1.6	1.8	1.8
							31	1.7	1.7	......	1.5	......	1.9

Daily gage height, in feet, of Antietam Creek near Sharpsburg, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.												
1	2.0	2.4	2.1	2.8	2.0	2.4	1.8	2.0	1.9	1.8	2.1	2.3
2	2.4	2.6	2.1	2.7	2.0	2.3	1.7	1.9	1.9	1.8	2.1	2.2
3	2.1	2.9	2.1	2.6	2.0	2.2	1.8	1.8	1.9	1.7	2.0	2.0
4	1.8	2.5	2.1	2.5	2.0	2.2	1.8	1.9	1.9	1.7	2.1	2.6
5	1.7	2.4	2.2	2.6	2.0	2.1	1.8	2.5	2.1	1.7	1.9	7.8
6	1.5	2.2	2.1	2.5	2.1	2.2	1.8	2.0	2.0	1.6	1.8	3.85
7	1.9	2.4	2.1	2.5	2.2	2.2	1.7	1.8	1.9	1.7	1.8	3.25
8	1.8	2.2	2.1	2.5	2.4	2.1	1.7	1.8	1.9	1.6	1.7	3.0
9	1.7	2.1	2.0	2.4	3.25	2.1	1.8	2.0	1.9	1.6	1.7	2.9
10	2.0	2.1	2.0	2.4	2.7	2.1	1.8	3.1	1.8	1.6	1.9	2.8
11	2.1	2.3	2.1	2.4	2.5	2.1	1.8	3.05	1.7	1.6	2.5	2.7
12	1.9	2.2	2.1	2.3	2.4	2.15	1.8	2.3	1.9	1.8	2.15	2.7
13	2.0	2.2	2.0	2.3	2.5	2.2	1.8	2.1	1.8	1.7	2.2	2.7
14	1.8	2.2	2.0	2.3	2.3	2.2	1.8	2.0	1.8	1.8	2.2	2.8
15	2.9	2.2	2.1	2.35	2.3	2.1	1.8	2.05	1.9	1.7	2.0	2.7
16	3.15	2.1	2.0	2.4	2.9	2.1	1.7	2.0	1.8	1.5	2.0	2.8
17	2.9	2.0	2.2	2.3	3.0	2.1	1.7	2.0	1.8	1.6	1.9	2.5
18	2.5	2.2	2.2	2.3	2.8	2.1	1.8	5.07	1.7	2.75	2.0	2.4
19	2.3	2.3	2.2	2.3	2.6	2.0	1.8	3.65	1.9	1.8	2.6	2.5
20	2.4	2.1	2.0	2.3	2.4	2.1	1.8	2.95	1.8	2.4	2.5	3.15
21	2.4	2.6	2.1	2.2	2.4	2.0	1.8	2.45	1.8	2.2	2.4	2.9
22	2.2	2.6	2.5	2.2	3.1	1.9	1.8	2.3	1.8	2.9	2.4	2.8
23	2.85	2.4	2.55	2.2	2.5	2.1	1.8	2.1	1.9	2.8	2.3	3.85
24	2.8	2.6	2.7	2.2	3.0	2.1	1.8	2.0	1.9	1.9	2.4	3.2
25	2.6	2.3	3.25	2.3	2.7	1.9	2.2	1.9	1.8	1.7	2.3	3.0
26	2.6	2.3	2.95	2.3	2.9	1.9	1.9	2.0	1.8	2.4	2.3	2.9
27	2.6	2.2	2.8	2.2	2.7	1.9	1.9	2.0	1.9	2.3	2.3	2.8
28	2.5	2.3	2.7	2.2	2.7	1.8	1.8	1.9	1.8	2.1	2.3	2.6
29	2.5	......	2.75	2.2	2.6	1.8	1.8	2.0	1.9	2.1	2.2	2.6
30	2.4	......	3.1	2.1	2.5	1.8	1.8	2.0	1.8	2.1	2.2	2.5
31	2.5	......	2.9	......	2.4	......	1.9	2.0	......	2.1	......	2.6
1899.												
1	2.8	2.7	4.75	3.4	2.4	2.4	2.1	1.7	1.8	1.8	2.4	1.6
2	2.7	2.6	4.2	3.3	2.45	3.75	1.9	1.6	1.8	1.8	2.25	1.6
3	2.6	2.6	4.1	3.2	2.9	2.6	2.0	2.55	1.7	1.7	2.0	1.6
4	2.7	2.6	3.85	3.2	2.5	2.6	1.85	1.9	2.0	1.6	1.8	1.5
5	3.0	2.8	4.8	3.1	2.5	2.4	1.9	1.8	1.8	1.6	1.8	1.6
6	3.4	2.8	4.4	3.0	2.5	2.4	1.8	1.7	1.8	1.5	1.9	1.5
7	3.55	2.5	4.05	2.9	2.4	2.3	2.0	1.9	1.7	1.5	1.8	1.5
8	3.2	2.4	3.9	3.25	2.55	2.3	1.9	1.7	1.7	1.5	1.5	1.6
9	3.0	2.6	3.6	3.1	2.7	2.45	1.9	1.7	1.85	1.7	1.6	1.6
10	3.0	2.8	3.5	3.0	2.55	2.7	2.0	1.8	1.6	1.6	1.7	1.5
11	2.9	2.6	3.5	2.9	2.5	2.65	1.9	1.8	2.3	1.5	1.6	1.5
12	2.8	2.8	3.4	2.8	2.5	2.4	1.8	2.35	2.1	1.5	1.7	1.6
13	2.9	2.8	3.3	2.8	2.5	2.4	2.15	1.9	1.85	1.5	1.7	1.6
14	3.0	2.8	3.2	2.8	2.4	2.35	2.0	2.0	1.8	1.5	1.6	1.7
15	3.0	2.9	3.2	2.8	2.3	2.3	1.9	1.9	1.7	1.4	1.6	1.8
16	3.0	2.9	3.5	2.8	2.4	2.3	1.85	1.8	1.6	1.8	1.6	1.8
17	3.0	2.8	3.2	2.7	2.2	2.3	1.95	1.9	1.6	1.7	1.8	1.7
18	3.0	2.9	3.2	2.7	3.15	2.2	1.8	1.8	1.7	1.6	1.7	1.7
19	2.9	2.9	3.7	2.7	2.8	2.25	1.85	1.8	2.0	1.6	1.7	1.6
20	2.8	2.8	3.75	2.6	2.6	2.2	1.8	1.6	1.9	1.6	1.7	1.6
21	2.8	3.2	3.4	2.6	2.5	2.2	1.8	1.8	1.9	1.6	1.7	1.7
22	2.8	4.3	3.4	2.6	2.5	2.1	1.8	1.7	1.8	1.6	1.8	1.6
23	2.8	4.1	3.5	2.5	2.5	2.0	2.05	1.8	1.8	1.7	1.8	1.6
24	2.8	3.7	3.4	2.4	2.4	2.1	1.9	1.7	1.7	1.6	1.7	1.85
25	3.25	3.5	3.3	2.5	2.3	2.05	1.7	1.65	1.9	1.6	1.6	2.65
26	2.9	4.5	3.2	2.45	2.3	2.2	1.75	1.7	1.9	1.5	1.6	1.9
27	2.9	5.4	3.0	2.5	2.3	2.1	1.7	3.45	1.8	1.5	1.7	2.0
28	2.8	5.15	3.5	2.5	2.3	2.15	1.6	2.8	1.8	1.5	1.6	1.9
29	2.8	......	3.9	2.5	2.2	2.1	1.6	2.3	1.9	1.5	1.7	1.8
30	2.7	......	3.7	2.4	2.45	2.2	1.6	2.0	1.9	1.6	1.7	1.6
31	2.7	......	3.5	......	2.4	......	1.8	1.9	......	1.6	......	1.6

Daily gage height, in feet, of Antietam Creek near Sharpsburg, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900.												
1	1.5	1.6	3.8	2.5	2.1	2.0	1.7	1.4	1.6	1.4	1.7	1.55
2	1.5	1.7	3.6	2.5	2.1	1.9	1.7	1.4	1.6	1.5	1.5	1.55
3	1.5	1.6	3.0	2.4	2.0	1.9	1.6	1.5	1.4	1.4	1.5	1.5
4	1.6	1.5	2.8	2.3	2.1	2.0	1.5	1.5	1.6	1.4	1.5	2.3
5	1.6	1.5	2.7	2.3	2.0	1.9	1.7	1.4	1.7	1.5	1.5	2.4
6	1.7	1.6	2.7	2.3	1.9	1.9	1.7	1.4	1.6	1.4	1.4	2.0
7	1.7	1.5	2.75	2.4	2.1	1.9	1.6	1.4	1.5	1.4	1.5	1.6
8	1.8	2.0	2.6	2.3	2.0	1.9	1.6	1.4	1.5	1.3	1.6	1.7
9	1.9	2.2	2.5	2.3	2.0	1.9	1.7	1.45	1.4	1.5	1.6	1.7
10	1.8	2.0	2.5	2.2	1.9	1.7	1.6	1.5	1.4	1.6	1.6	1.6
11	1.8	1.9	2.5	2.2	1.8	2.0	1.5	1.4	1.4	1.6	1.5	1.6
12	1.8	2.0	2.5	2.3	1.9	1.9	1.55	1.5	1.4	1.5	1.4	1.5
13	1.7	2.7	2.4	2.3	1.8	1.8	1.5	1.5	1.5	1.5	1.7	1.5
14	1.7	2.7	2.4	2.3	1.8	1.7	1.55	1.4	1.6	2.05	1.5	1.5
15	1.8	2.4	2.4	2.2	2.0	1.7	1.6	1.7	1.6	1.9	1.7	1.4
16	1.7	2.4	2.4	2.3	1.9	1.85	1.45	1.6	1.8	1.7	1.5	1.3
17	1.7	2.2	2.3	2.2	2.0	2.1	1.5	1.6	......	1.6	1.5	1.5
18	1.7	2.1	2.25	2.3	2.0	2.2	1.5	1.6	1.4	1.4	1.4	1.4
19	1.8	2.2	2.4	2.35	2.4	2.55	1.5	1.6	1.5	1.6	1.5	1.5
20	2.1	2.2	2.9	2.3	3.1	2.1	1.6	1.7	1.5	1.6	1.5	1.5
21	2.5	2.3	3.1	2.7	2.4	2.0	1.5	1.8	1.5	1.4	1.6	1.5
22	2.0	4.15	2.8	2.3	2.2	1.9	1.4	1.8	1.4	1.5	1.5	1.5
23	1.9	3.75	2.7	2.4	2.1	1.8	1.9	1.7	1.4	1.5	1.5	1.5
24	1.8	3.05	2.7	2.3	2.1	1.7	1.85	1.7	1.3	1.8	1.5	1.4
25	1.7	3.8	2.6	2.2	2.1	1.8	1.65	1.8	1.4	1.7	1.5	1.3
26	2.3	3.3	2.5	2.2	2.0	1.8	2.0	1.7	1.4	1.5	2.5	1.6
27	2.2	3.0	2.6	2.1	1.9	1.9	1.9	1.7	1.4	1.5	2.1	1.5
28	2.0	3.0	2.5	2.1	1.9	1.8	1.8	2.0	1.4	1.4	1.8	1.5
29	1.8	......	2.5	2.1	2.0	1.8	1.55	1.9	1.5	1.3	1.7	1.5
30	1.6	......	2.6	2.0	1.9	1.7	1.4	1.8	1.6	1.4	1.6	1.4
31	1.6	......	2.6	......	2.1	......	1.4	1.7	......	1.6	......	1.5
1901.												
1	1.5	1.5	1.5	2.8	2.5	2.8	2.2	1.9	2.5	2.0	1.6	......
2	1.5	1.4	1.5	2.7	2.5	2.8	2.1	1.8	2.3	1.9	1.6	......
3	1.4	1.4	1.4	3.3	2.4	2.6	2.1	1.7	2.1	2.2	1.4	......
4	1.4	1.4	1.5	5.25	2.4	2.5	2.0	1.7	2.0	2.0	1.5	......
5	1.4	1.5	1.6	3.65	2.4	2.5	2.1	1.8	2.0	1.8	1.5	......
6	1.4	1.6	1.5	3.4	2.3	2.5	2.1	2.1	1.9	1.8	1.5	......
7	1.4	1.6	1.8	3.3	2.2	2.8	2.1	2.6	1.8	1.8	1.6	......
8	1.4	1.5	1.7	3.2	2.3	2.7	2.1	2.4	1.7	1.7	1.6	......
9	1.4	1.5	1.6	3.1	2.3	2.6	2.0	2.2	1.6	1.7	1.6	......
10	1.5	1.4	1.6	2.85	2.2	2.4	2.0	2.0	1.6	1.6	1.6	......
11	1.5	1.4	5.35	2.7	2.1	2.3	2.1	1.9	1.6	1.6	1.6	......
12	1.7	1.4	3.35	2.6	2.3	2.3	2.2	1.8	1.7	1.6	1.6	......
13	1.6	1.3	2.45	2.5	2.2	2.2	2.1	1.8	1.7	1.6	1.5	......
14	1.6	1.5	2.2	2.7	2.2	2.2	2.1	1.7	1.6	1.7	1.5	......
15	1.5	1.4	2.3	4.3	2.2	2.4	2.1	3.9	2.6	1.7	1.5	......
16	1.5	1.6	2.2	3.45	2.2	2.8	2.2	2.2	2.0	1.6	1.4	......
17	1.6	1.4	2.2	2.9	2.2	2.6	2.5	2.1	2.1	1.6	......	......
18	1.5	1.5	2.1	2.7	2.2	2.5	2.2	2.0	2.0	1.5	......	......
19	1.4	1.6	2.1	2.6	2.2	2.4	2.1	1.9	1.8	1.5	......	......
20	1.4	1.6	2.0	2.95	2.15	2.3	2.0	1.8	1.7	1.6	......	......
21	1.5	1.7	2.45	3.6	2.1	2.3	2.5	1.9	1.7	1.6	......	......
22	1.5	1.7	2.4	3.6	4.8	2.3	2.2	1.8	1.7	1.5	......	......
23	1.6	1.8	2.2	3.2	6.3	2.3	2.1	1.9	1.7	1.5	......	......
24	1.6	1.6	2.2	3.0	3.7	2.3	2.1	2.0	1.7	1.5	......	......
25	1.6	1.3	2.1	2.9	3.85	2.2	2.5	2.0	1.6	1.5	......	......
26	1.6	1.4	2.2	2.8	3.4	2.2	2.1	2.0	1.6	1.8	......	......
27	1.4	1.5	2.25	2.9	3.4	2.3	2.1	1.9	1.7	1.7	......	......
28	1.4	1.5	2.2	2.8	3.1	2.3	2.0	1.7	1.7	1.7	......	2.2
29	1.5	......	2.2	2.7	3.0	2.35	1.9	1.7	1.6	1.6	......	4.7
30	1.5	......	2.1	2.6	3.5	2.2	1.9	1.7	2.15	1.7	......	4.5
31	1.5	......	2.2	......	3.0	......	1.8	2.05	......	1.7	......	3.3

Daily gage height, in feet, of Antietam Creek near Sharpsburg, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	2.9	2.4	7.0	2.9	2.6	2.1	2.2	2.6	1.7	1.7	1.6	1.8
2	2.7	2.4	5.05	2.9	2.5	2.2	2.1	2.4	1.6	1.8	1.7	2.4
3	2.7	2.6	4.6	2.8	2.5	2.2	2.1	1.8	1.6	1.6	1.7	4.05
4	2.5	2.5	3.9	2.8	2.5	2.2	2.0	1.8	1.7	1.6	1.6	3.6
5	2.4	2.4	4.0	2.8	2.5	2.1	2.0	1.9	1.6	2.3	1.6	2.6
6	2.4	2.3	3.6	2.7	2.4	2.1	1.9	1.9	1.5	2.1	1.7	2.5
7	2.3	2.2	3.5	2.9	2.4	2.1	2.3	1.9	1.5	1.9	1.7	2.3
8	2.3	2.1	3.5	3.9	2.4	2.0	2.7	1.7	1.4	1.7	1.7	2.1
9	2.3	2.1	3.7	6.45	2.3	2.0	2.7	1.7	1.6	1.7	1.7	1.8
10	2.3	2.3	4.2	4.45	2.3	2.0	3.5	1.6	1.6	1.6	1.7	1.9
11	2.3	2.4	4.4	3.9	2.4	2.0	2.0	1.8	1.7	1.8	1.6	2.0
12	2.2	2.2	4.4	3.6	2.3	2.1	2.0	1.8	1.6	1.8	1.6	2.4
13	2.2	2.3	4.8	3.5	2.3	2.2	1.8	1.7	1.7	2.1	1.6	2.8
14	2.2	2.2	4.7	3.3	2.3	2.2	1.8	1.6	1.5	1.9	1.5	2.7
15	2.1	2.2	3.9	3.2	2.3	2.2	1.8	1.6	1.4	1.8	1.5	2.7
16	2.1	2.0	3.7	3.1	2.2	2.3	1.8	1.6	1.6	1.7	1.6	2.8
17	2.1	2.2	5.1	3.1	2.2	2.4	1.7	1.4	1.6	1.7	1.7	4.1
18	2.1	2.1	4.2	3.0	2.2	2.4	1.7	1.4	1.6	1.7	1.7	3.8
19	2.1	1.9	3.7	2.9	2.9	2.2	2.4	1.5	1.6	1.6	1.6	3.8
20	2.1	2.0	3.5	2.9	2.4	2.3	2.7	1.5	1.5	1.8	1.6	3.5
21	3.8	3.15	3.6	2.8	2.3	2.3	1.8	2.0	1.5	1.7	1.6	3.6
22	4.25	4.7	3.4	2.8	2.3	2.0	1.8	2.0	1.4	1.7	1.5	3.8
23	2.7	3.6	3.4	2.8	2.2	2.0	1.7	1.9	1.5	1.8	1.5	3.6
24	2.4	3.5	3.4	2.7	2.2	2.0	1.7	1.7	1.7	1.7	1.5	3.1
25	2.4	6.2	3.1	2.7	2.4	1.9	1.9	1.5	1.7	1.7	1.6	3.1
26	2.3	10.5[a]	3.0	2.6	2.6	2.2	1.8	1.5	1.8	1.7	1.8	2.8
27	4.25	5.15	3.0	2.6	2.2	2.2	1.8	1.5	2.3	1.7	2.2	2.9
28	3.2	7.45	2.9	2.6	2.3	2.2	1.7	1.6	1.6	1.7	2.1	3.0
29	2.7	......	3.4	2.6	2.2	2.2	1.7	1.5	1.6	2.1	1.8	3.2
30	2.6	......	3.1	2.7	2.2	2.4	1.9	1.5	1.5	1.8	2.3	3.1
31	2.4	......	3.0	......	2.2	......	2.55	1.4	......	1.6	......	3.1
1903.[b]												
1	3.7	3.5	4.3	3.2	2.9	2.5	3.9	2.5	2.3	2.0	1.85	1.9
2	3.9	3.2	3.8	3.1	2.9	2.4	3.0	2.5	2.2	1.95	1.9	1.9
3	4.8	3.4	3.6	3.1	2.9	2.3	2.8	2.4	2.2	1.95	1.9	1.8
4	4.5	4.1	3.9	3.2	2.8	2.3	3.0	2.4	2.1	2.0	1.9	1.9
5	4.3	3.8	4.1	3.0	2.9	2.3	3.0	2.6	2.1	1.9	1.8	1.9
6	4.3	3.5	3.8	2.9	2.8	2.35	3.8	2.6	2.05	1.9	1.8	1.85
7	4.1	3.2	4.0	3.0	2.7	2.4	2.9	2.7	2.0	1.85	1.8	1.85
8	3.8	3.2	3.8	3.2	2.7	2.45	2.8	2.5	2.1	3.0	1.85	1.85
9	3.6	3.4	3.6	3.3	2.7	2.6	2.7	2.6	2.3	2.5	1.85	1.9
10	2.8	3.3	3.5	3.1	2.6	2.4	2.7	2.6	2.2	2.2	1.85	1.9
11	2.8	4.5	3.3	3.1	2.6	2.35	3.3	2.5	2.1	2.1	1.8	1.85
12	2.7	4.7	3.2	3.1	2.5	2.5	[c]7.9	2.5	2.1	2.1	1.9	1.8
13	2.7	4.5	3.1	3.1	2.5	2.5	6.1	2.3	2.1	2.1	1.9	1.8
14	2.6	4.0	3.0	4.5	2.4	2.45	3.7	2.3	2.2	2.0	1.9	1.9
15	2.6	3.8	3.0	5.7	2.4	2.5	3.3	2.2	2.2	2.0	1.85	2.0
16	2.7	3.7	2.9	6.7	2.4	2.4	3.0	3.6	2.1	2.1	1.85	2.3
17	2.6	3.5	2.9	5.45	2.5	2.3	3.0	3.2	3.0	2.15	1.95	2.0
18	2.6	3.2	2.8	4.6	2.4	2.4	3.2	2.4	2.4	2.05	1.9	2.0
19	2.7	3.0	2.8	4.3	2.4	2.3	3.2	2.4	2.2	2.0	1.9	1.9
20	2.9	2.8	2.7	4.0	2.4	2.5	3.0	2.3	2.2	2.1	1.9	2.6
21	3.5	2.6	2.9	3.8	2.4	2.4	3.0	2.2	2.1	2.1	1.9	2.5
22	3.9	2.5	3.0	3.6	2.4	2.3	3.0	2.2	2.0	2.1	1.95	2.0
23	3.7	2.5	3.1	3.5	2.4	2.4	2.7	2.2	1.9	2.1	1.95	1.9
24	3.5	2.3	3.5	3.4	2.6	2.3	2.7	2.2	1.9	2.1	1.95	1.9
25	3.5	2.6	3.3	3.4	2.5	2.35	2.6	2.2	1.9	2.0	2.0	1.85
26	3.6	3.0	3.2	3.3	2.5	2.3	2.6	2.3	2.0	2.0	1.8	1.9
27	4.2	4.45	3.1	3.2	2.4	2.3	2.5	2.1	2.0	2.0	1.8	1.8
28	4.4	5.75	2.9	3.1	2.4	2.3	2.5	2.0	2.0	2.0	1.9	2.0
29	4.2	......	2.8	3.0	2.3	3.6	2.7	2.7	1.9	2.0	1.9	2.0
30	3.9	......	4.2	3.0	3.3	3.1	2.8	2.5	1.9	1.9	1.9	1.9
31	3.5	......	4.0	......	2.6	......	2.7	2.4	......	1.9	......	1.9

[a] Gage height estimated February 26, 1902.
[b] Ice conditions during part of December, 1903.
[c] Highest record, 10.2 feet, 6 p. m., July 12, 1903.

Daily gage height, in feet, of Antietam Creek near Sharpsburg, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.[a]												
1	1.9							1.6	1.5	1.45	1.5	1.45
2	1.9							1.6	1.5	1.45	1.5	1.45
3	1.75							1.8	1.5	1.4	1.45	1.45
4	2.1							1.65	1.6	1.55	1.5	1.45
5	1.9							1.6	1.55	1.5	1.5	1.4
6	1.9							1.6	1.5	1.45	1.45	1.5
7	1.8							1.6	1.45	1.5	1.4	1.45
8	1.8							1.5	1.55	1.45	1.5	1.45
9	1.8							1.5	1.45	1.45	1.5	1.45
10	1.85							1.5	1.85	1.5	1.5	1.5
11	1.85							3.0	1.6	1.5	1.5	1.55
12	1.9						[b]2.2	1.8	1.55	1.5	1.5	1.4
13	1.85						2.2	1.65	1.5	1.75	1.6	1.6
14	1.85						1.9	1.55	1.65	1.6	1.5	1.5
15	1.7						1.75	1.6	1.65	1.5	1.65	1.45
16	1.7						1.7	1.6	1.8	1.45	1.5	1.55
17	1.7						1.7	1.6	1.6	1.4	1.5	1.55
18	1.8						1.7	1.6	1.5	1.5	1.4	1.55
19	1.8						1.7	1.65	1.4	1.5	1.4	1.55
20	1.8						1.6	1.6	1.65	1.5	1.5	1.6
21	1.85						1.65	1.6	1.6	1.65	1.5	1.65
22	3.9						1.6	1.6	1.6	1.95	1.55	1.65
23	[b]6.0						1.7	1.85	1.55	1.65	1.55	1.55
24							1.75	1.75	1.5	1.6	1.5	1.6
25							1.85	1.6	1.45	1.5	1.55	1.65
26							1.7	1.6	1.5	1.55	1.5	1.75
27							1.6	1.55	1.55	1.5	1.45	1.7
28							1.6	1.45	1.5	1.5	1.35	1.8
29							1.85	1.5	1.5	1.55	1.45	2.15
30							1.7	1.5	1.45	1.45	1.5	2.05
31							1.6	1.5		1.5		1.75
1905.[c]												
1	1.65	1.85	1.75	2.75	2.1	1.85	1.8	2.25				
2	1.6	1.9	1.7	2.6	2.1	1.9	1.8	2.05				
3	1.7	1.9	1.7	2.6	2.05	1.8	1.85	2.0				
4	1.75	1.8	1.7	2.6	2.05	1.75	1.8	2.0				
5	1.9	1.75	1.95	2.7	2.0	1.7	2.95	2.0				
6	1.75	2.0	2.0	2.8	2.0	1.75	2.1	2.0				
7	3.5	1.9	2.1	2.65	2.0	2.15	2.0	2.0				
8	2.7	2.0	2.15	2.55	2.05	2.1	1.95	2.2				
9	2.25	1.85	2.8	2.5	2.0	1.95	1.85	2.35				
10	2.1	1.85	3.4	2.5	2.0	1.8	1.8	2.3				
11	2.1	1.9	3.05	2.55	1.95	1.8	1.75	2.0				
12	2.05	1.8	2.95	2.55	2.0	2.1	1.85	2.0				
13	2.45	1.9	2.8	2.45	1.95	2.2	1.8	1.9				
14	2.2	1.9	2.8	2.5	1.95	2.0	1.85	1.9				
15	2.05	1.75	2.7	2.45	2.05	1.9	3.25	2.0				
16	2.45	1.8	2.6	2.4	2.0	1.8	2.15	2.3				
17	2.55	1.8	2.7	2.4	2.0	1.8	2.05	2.3				
18	2.1	1.85	2.95	2.3	2.25	1.75	2.0	2.1				
19	1.95	1.8	3.1	2.3	2.05	1.7	2.45	2.1				
20	1.9	1.85	3.6	2.3	2.05	1.8	2.4	2.1				
21	1.9	1.8	3.6	2.3	1.95	2.05	1.9	2.1				
22	1.9	1.7	3.4	2.3	1.9	2.0	1.8	2.3				
23	1.85	1.7	3.2	2.2	1.85	2.0	2.25	2.2				
24	1.75	1.7	3.05	2.2	1.8	2.6	5.0	2.1				
25	1.8	1.7	3.95	2.2	1.8	2.2	3.65	6.05				
26	1.8	1.75	3.8	2.1	1.8	1.9	2.25	([d])				
27	2.05	1.95	3.35	2.1	1.85	2.0	2.0					
28	2.0	1.85	3.1	2.1	1.8	1.95	2.0					
29	2.0		3.0	2.1	1.85	1.95	2.0					
30	1.9		2.9	2.1	1.9	1.85	2.65					
31	1.9		2.8		1.9		2.45					

[a] Ice conditions during January, 1904.
[b] Ice carried gage away January 23, 1904; reestablished July 12, 1904.
[c] Ice conditions during part of February, 1905.
[d] Gage washed out August 26, 1905.

Rating table for Antietam Creek near Sharpsburg, Md., from June 24, 1897, to August 25, 1905.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.30	59	2.60	399	3.90	1,035	6.40	2,795
1.40	74	2.70	437	4.00	1,095	6.60	2,955
1.50	91	2.80	476	4.20	1,215	6.80	3,125
1.60	110	2.90	517	4.40	1,345	7.00	3,295
1.70	131	3.00	560	4.60	1,475	7.50	3,740
1.80	153	3.10	605	4.80	1,610	8.00	4,205
1.90	177	3.20	652	5.00	1,750	8.50	4,690
2.00	203	3.30	701	5.20	1,890	9.00	5,195
2.10	231	3.40	752	5.40	2,030	9.50	5,720
2.20	261	3.50	805	5.60	2,180	10.00	6,270
2.30	293	3.60	860	5.80	2,330	10.50	6,835
2.40	327	3.70	915	6.00	2,480		
2.50	362	3.80	975	6.20	2,635		

[a] This table is strictly applicable only for open-channel conditions. It is based on discharge measurements made during 1897-1904. It is well defined between gage heights 1.7 feet and 3.5 feet. Estimates above 3.5 feet and below 1.7 feet are based on the extension of the area and velocity curves. Overflow at this section begins at about gage height 6.0 feet. It was assumed to amount to 300 second-feet at gage height 10.0 feet, or a mean velocity in the overflow portion of about one-half the velocity in the main channel.

Estimated monthly discharge of Antietam Creek near Sharpsburg, Md.

[Drainage area, 295 square miles.]

Month.	Discharge in second-feet.			Run-off.		Per cent of precipitation.	Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.		In inches.	Loss in inches.
1897.								
July	231	100	146	0.495	0.571			
August	560	74	161	.546	.630			
September	177	74	114	.386	.431			
October	153	74	109	.369	.425			
November	437	74	140	.475	.530			
December	362	110	210	.712	.821			
1898.								
January	628	91	303	1.03	1.19			
February	517	203	302	1.02	1.06			
March	676	203	312	1.06	1.22			
April	476	231	316	1.07	1.19			
May	676	203	375	1.27	1.46			
June	327	153	226	.766	.855			
July	261	131	159	.539	.621			
August	1,799	153	322	1.09	1.26			
September	231	131	167	.566	6.32			
October	456	91	200	.678	.782			
November	399	131	249	.844	.942			
December	4,015	203	598	2.03	2.34			
The year	4,015	91	294	.997	13.55			
1899.								
January	832	399	529	1.79	2.06	103	2.00	—0.06
February	2,030	327	682	2.31	2.40	56	4.30	1.90
March	1,610	560	897	3.04	3.50	88	4.00	.50
April	752	327	483	1.64	1.83	193	.95	— .88
May	517	261	358	1.21	1.40	28	5.08	3.68
June	945	203	317	1.07	1.19	28	4.19	3.00
July	246	110	169	.572	.660	60	1.10	.44
August	778	110	200	.678	.782	20	3.85	3.07
September	293	110	160	.542	.605	13	4.68	4.07
October	153	74	109	.369	.425	26	1.63	1.20
November	327	91	144	.488	.544	22	2.46	1.92
December	418	91	133	.451	.520	23	2.26	1.74
The year	2,030	74	349	1.18	15.92	44	36.50	20.58

Estimated monthly discharge of Antietam Creek near Sharpsburg, Md.—Continued.

Month.	Discharge in second-feet.			Run-off.		Per cent of precipitation.	Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.		In inches.	Loss in inches.
1900.								
January	362	91	158	.536	.618	26	2.34	1.72
February	1,185	91	372	1.26	1.31	34	3.82	2.51
March	975	277	432	1.46	1.68	62	2.71	1.03
April	362	203	291	.986	1.10	80	1.38	.28
May	605	153	222	.753	.868	34	2.52	1.65
June	380	131	181	.614	.685	15	4.52	3.84
July	203	74	115	.390	.450	10	4.34	3.89
August	203	74	112	.380	.438	15	3.00	2.56
September [a]	153	74	91.7	.311	.347	16	2.25	1.90
October	217	59	99.1	.336	.387	28	1.37	.98
November	362	74	114	.386	.431	14	3.07	2.64
December	327	59	110	.373	.430	27	1.59	1.16
The year	1,185	59	192	.649	8.75	27	32.91	24.16
1901.								
January	131	74	90.5	.307	.354	16	2.16	1.81
February	153	59	92.4	.313	.326	52	.63	.30
March	1,995	74	285	.966	1.11	28	3.92	2.81
April	1,925	362	632	2.14	2.39	42	5.73	3.34
May	2,715	231	523	1.77	2.04	36	5.71	3.67
June	476	261	341	1.16	1.29	29	4.43	3.14
July	362	153	238	.807	.930	25	3.77	2.84
August	1,035	131	218	.739	.852	20	4.33	3.48
September	399	110	171	.580	.647	26	2.51	1.86
October	261	91	130	.441	.508	57	.89	.38
November 1–16	110	74	98.4	.334	.199		[b] 2.36	
December 28–31	1,540	261	978	3.32	.494		[b] 5.83	
The year							42.27	
1902.								
January	1,248	231	410	1.39	1.60	48	3.30	1.70
February	6,835	177	871	2.95	3.07	69	4.44	1.37
March	3,295	517	1,068	3.62	4.17	105	3.98	− .19
April	2,835	399	662	2.24	2.50	98	2.54	.04
May	517	261	313	1.06	1.22	97	1.26	.04
June	327	177	249	.844	.942	22	4.28	3.34
July	805	131	232	.786	.906	29	3.09	2.18
August	399	74	141	.478	5.51	60	.91	.36
September	293	74	113	.383	.427	26	1.64	1.21
October	293	110	150	.508	.586	16	3.73	3.14
November	293	91	131	.444	.495	20	2.48	1.99
December	1,155	153	570	1.93	2.22	56	3.98	1.76
The year	6,835	74	409	1.39	18.69	52	35.63	16.94
1903.								
January	1,610	399	843	2.86	3.30	84	3.95	0.65
February	2,292	293	849	2.88	3.00	109	2.74	− .26
March	1,280	437	750	2.54	2.93	91	3.23	.30
April	3,040	517	926	3.14	3.50	94	3.73	.23
May	701	293	398	1.35	1.56	36	4.28	2.72
June	860	293	350	1.19	1.33	23	5.86	4.53
July	4,110	362	738	2.50	2.88	40	7.20	4.32
August	860	203	354	1.20	1.38	27	5.10	3.72
September	560	177	242	.820	.915	57	1.60	.68
October	560	165	226	.766	.883	27	3.21	2.33
November	203	153	172	.583	.650	47	1.38	.73
December [c]	399	153	195	.661	.762	69	1.11	.35
The year	4,110	153	504	1.71	23.09	53	43.39	20.30

[a] Discharge interpolated September 17, 1900.
[b] Precipitation for complete month, November and December, 1901.
[c] Ice conditions during part of December, 1903; no correction made in estimates.

Estimated monthly discharge of Antietam Creek near Sharpsburg, Md.—Continued.

Month.	Discharge in second-feet.			Run-off.		Per cent of precipitation.	Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.		In inches.	Loss in inches.
1904.								
January 1-23 [a]	2,480	131	300	1.02	.872		[b] 2.42	
February							1.08	
March							1.98	
April							1.95	
May							2.73	
June							5.54	
July 12-31	261	110	145	.492	.366		[b] 4.05	
August	560	82	126	.427	.492	19	2.54	2.05
September	165	74	101	.342	.382	13	2.86	2.48
October	190	74	96.7	.328	.378	15	2.53	2.15
November	120	66	92.8	.315	.351	41	.85	.50
December	246	74	110	.373	.430	17	2.46	2.03
The year							30.99	
1905.								
January	805	110	229	.776	.895	22	4.00	3.10
February [c]	203	131	161	.546	.569	31	1.86	1.29
March	1,065	131	508	1.72	1.98	79	2.50	.52
April	476	231	332	1.13	1.26	68	1.84	.58
May	231	153	196	.664	.766	33	2.31	1.54
June	399	131	190	.644	.718	12	5.84	5.12
July	1,750	142	311	1.06	1.22	18	6.84	5.62
August 1-25	2,518	177	326	1.11	1.03		[d] 4.84	
September							2.11	
October							3.71	
November							1.92	
December							3.48	
The year							41.25	

[a] Ice conditions during January, 1904; no correction made in estimates.
[b] Precipitation for complete month, January and July, 1904.
[c] Ice conditions during part of February, 1905; no correction made in estimates.
[d] Precipitation for complete month, August, 1905.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN POTOMAC RIVER BASIN BETWEEN MOUTH OF SOUTH BRANCH AND SHENANDOAH RIVER.

The following miscellaneous discharge measurements have been made in the drainage basin of Potomac River between the mouth of South Branch and Shenandoah River:

Miscellaneous discharge measurements in Potomac River basin between mouth of South Branch and Shenandoah Rivers.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Ft. per second.*	*Sec.-ft.*
1897.						
September 25	Town Creek	200 yards above Chesapeake and Ohio Canal, and 3 miles below junction of North and South branches of Potomac River.	22	11	1.00	11
September 29	Little Cacapon River	Near Little Cacapon, W. Va.	4	1.8	.89	1.6
September 26	Purslane Run	Near Pawpaw, W. Va.				.5
Do	Fifteenmile Creek	Near Little Orleans, Md				.5
Do	Sideling Hill Creek	Above slackwater, near Lineburg, W. Va.	9	2.1	.67	1.4
September 29	Great Cacapon River	One-half mile above mouth, near Great Cacapon, W. Va.	64	123	.66	[a] 81
October 11	Sir Johns Run	Near Sir Johns Run, W. Va.	2.5	.55	1.63	.9
Do	Tonoloway Creek	Near Hancock, Md	8	3.2	1.68	5.4
Do	Potomac River	At Hancock, Md	180	364	.56	202

[a] Residents state river very low.

Miscellaneous discharge measurements in Potomac River basin between mouth of South Branch and Shenandoah Rivers—Continued.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
1897.			*Feet.*	*Square feet.*	*Ft. per second.*	*Sec.-ft.*
September 30..	Warm Spring Run...	Below Baltimore and Ohio R. R., near Hancock, Md.	6	2.1	1.28	2.7
October 1......	Great Tonoloway Creek.	Short distance above Chesapeake and Ohio Canal aqueduct, near Hancock, Md.	9	4	1.40	5.6
Do........	Sleepy Creek..........	One-fourth mile above Baltimore and Ohio R. R. bridge, near Munson, W. Va.	8	3	.77	2.3
Do........	Licking Creek.........	Short distance above Chesapeake and Ohio Canal aqueduct, near Ernstville, Md.	33	36	.61	22
October 7......	Back Creek............	Near Baltimore and Ohio R. R. bridge, above North Mountain, W. Va.	29	11	.59	6.5
October 8......	.....do................	Near mouth, near North Mountain, W. Va.	....	....	....	50
October 7......	Big Spring Run.......	At Charles Mills, near Big Spring, Md.	4	7.2	.53	3.8
Do........	Little Conococheague Creek.	At Charles Mills, near Four Locks, Md.	2.5	1.2	2.08	2.5
October 2......	Conococheague Creek.	500 feet below northeast turnpike bridge, near Williamsport, Md.	125	124	1.60	198
October 8......	Opequon Creek.......	Near mouth, near Bedington W. Va.	58	65	.77	50
October 9......	Marsh Run (tributary to Antietam Creek).	Street crossing, below south end drain, Hagerstown, Md.	4	3.1	1.16	3.6
1898.						
October 2.....	Antietam Creek.......	At Stonebreaker's paper mill, near Hagerstown, Md.	68	68	1.03	[a] 70
1894.						
July 2..........	Potomac River........	At Harpers Ferry, W. Va....	....	....	....	[b] 1,223
1897.						
October 13.....	.....do................	.....do....................	....	....	....	[c] 377

[a] Gage height on Antietam Creek at Sharpsburg, Md., 1.8 feet.
[b] Gage height on Potomac River at Harpers Ferry, W. Va., 2.52 feet.
[c] 77 second-feet in river, and 300 second-feet in Pulp Company's canal.

SHENANDOAH RIVER BASIN.

SOUTH FORK OF SHENANDOAH RIVER BASIN.

SOUTH RIVER BASIN.

SOUTH RIVER AT BASIC CITY, VA.

South River rises near Greenville, in the southern part of Augusta County, Va., and flows eastward and northward to Port Republic, Rockingham County, where it unites with North River to form South Fork of the Shenandoah. Its drainage area is 245 square miles. It is fed by numerous springs and is utilized to a considerable extent by small mills.

The gaging station was established June 29, 1905, by N. C. Grover, in connection with the investigation of stream pollution in the Shenandoah Valley. It was discontinued July 16, 1906. It is located at the highway bridge one-half mile below the Chesapeake and Ohio Railway bridge at Basic City, Va.

The channel is straight for 300 feet above and 500 feet below the station. The current is sluggish at ordinary stages. Both banks are subject to overflow, the right bank only during very high water. The bed of the stream is composed of rocks and mud and is liable to change after floods. The approximate depth of water is 3 to 4 feet at medium stage. Gage-height observations and measurements are affected by flour mills above the station, which cause rapid fluctuations in the gage height at times.

Discharge measurements were made from the upstream side of the single span bridge to which the gage is fastened. The initial point for soundings is the face of the right abutment.

A standard chain gage is fastened to the upstream hand rail of the bridge. The length of the chain from the end of the weight to the outer edge of the ring is 20.84 feet. The gage was read once each day by F. J. Bates. Bench mark No. 1 is the upstream corner of the lowest step of the wing wall of the bridge at the right bank, nearest the river. It is marked with red paint. Its elevation is 13.97 feet above the datum of the gage.

Estimates at this station above gage height 2.4 feet are considered to be within 5 per cent of the true discharge for normal conditions of flow. Below 2.4 feet the probable error is from 5 to 20 per cent. The flow during the winter of 1905–6 was probably unaffected by ice conditions.

Discharge measurements of South River at Basic City, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1895.	*Feet.*	*Second-feet.*	1905.	*Feet.*	*Second-feet.*
August 5[a]	....	72	December 29	4.05	454
1905.			1906.		
June 11	2.59	64	April 11	3.25	221
June 29	2.62	90	June 14	2 69	86
September 16	2.52	63			

[a] At rapids, 200 feet above iron bridge.

Daily gage height, in feet, of South River at Basic City, Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1							2.6	2.6	2.5	2.4	2.3	2.2
2							2.5	2.7	2.5	2.3	2.1	2.3
3							2.7	2.5	2.5	2.5	2.2	2.4
4							2.6	2.5	2.5	2.3	2.1	2.9
5							2.55	2.5	2.6	2.2	2.2	2.9
6							2.6	2.5	2.3	2.2	2.3	2.8
7							3.0	2.5	2.2	2.4	2.3	2.6
8							2.8	2.5	2.3	2.4	2.3	2.5
9							2.7	2.5	2.4	2.5	2.3	2.5
10							3.0	2.6	2.5	2.4	2.3	2.5
11							2.7	2.6	2.5	2.5	2.1	2.5
12							4.25	2.6	2.5	2.7	2.3	2.6
13							4.3	2.6	2.2	2.3	2.4	2.3
14							5.0	2.7	2.2	2.2	2.3	2.4
15							3.5	2.7	2.2	2.4	2.2	2.3
16							3.2	2.9	2.2	2.4	2.1	2.3
17							3.0	2.8	2.6	2.2	2.4	2.5
18							2.9	2.7	3.2	2.6	2.2	2.5
19							2.9	2.7	2.8	2.6	2.3	2.5
20							2.8	2.7	2.7	2.4	2.3	2.5
21							2.8	2.6	2.7	2.3	2.1	5.5
22							2.7	2.6	2.6	2.4	2.3	4.1
23							2.4	2.5	2.4	2.5	2.3	3.9
24							2.5	2.5	2.5	2.4	2.3	3.7
25							2.9	2.5	2.6	2.1	2.1	3.4
26							2.8	2.8	2.5	2.4	2.3	3.2
27							2.8	2.6	2.6	2.5	2.1	3.1
28							2.7	2.5	2.6	2.3	2.0	2.9
29						2.5	2.8	2.5	2.4	2.4	2.2	3.7
30						2.5	2.7	2.3	2.4	2.4	2.3	3.3
31							2.6	2.3		2.6		3.2
1906.												
1	3.0	3.4	2.8	3.6	2.9	2.75	2.6					
2	2.9	3.3	2.8	3.6	2.9	2.7	2.6					
3	3.2	3.2	5.3	3.5	2.8	2.6	2.6					
4	4.4	3.2	4.9	3.4	2.9	2.6	2.7					
5	3.7	3.2	4.0	3.2	2.9	2.5	2.6					
6	3.4	3.1	3.8	3.3	2.8	2.4	2.65					
7	3.2	3.1	3.5	3.2	3.0	2.6	2.45					
8	3.0	3.0	3.5	3.1	3.0	2.6	2.55					
9	2.9	2.9	3.3	3.1	2.8	2.5	2.65					
10	2.8	2.9	3.0	3.2	2.85	2.5	2.6					
11	2.7	2.9	3.1	3.25	2.85	2.4	2.3					
12	2.8	2.9	3.1	3.2	2.7	2.5	2.4					
13	3.1	2.9	3.1	3.15	2.8	2.6	2.55					
14	3.1	2.9	3.0	3.1	2.8	2.7	2.35					
15	3.1	2.9	3.1	4.5	2.7	2.6	2.4					
16	3.0	2.8	3.2	4.1	2.75	2.6						
17	3.0	2.7	3.3	3.75	2.8	3.2						
18	3.1	2.7	3.3	3.55	2.65	2.5						
19	3.2	2.7	3.3	3.4	2.7	2.8						
20	3.2	2.7	3.2	3.25	2.7	5.45						
21	3.1	2.7	3.3	3.25	2.6	4.9						
22	3.1	2.8	3.2	3.2	2.6	3.45						
23	4.9	2.8	3.2	3.2	2.6	3.2						
24	4.4	2.8	3.2	3.1	2.5	3.0						
25	3.9	2.8	3.1	3.0	2.6	2.9						
26	3.6	2.8	3.2	3.1	2.6	3.2						
27	3.6	2.8	3.5	3.05	2.65	2.95						
28	3.7	2.8	3.7	3.0	2.75	2.85						
29	3.7		3.7	3.0	3.0	2.8						
30	3.6		3.5	2.9	2.7	2.7						
31	3.5		3.8		2.75							

Rating table for South River at Basic City, Va., from June 29, 1905, to July 15, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
2.00	7	2.90	135	3.80	377	4.70	678
2.10	12	3.00	159	3.90	407	4.80	714
2.20	19	3.10	183	4.00	438	4.90	750
2.30	29	3.20	208	4.10	470	5.00	786
2.40	41	3.30	234	4.20	503	5.10	823
2.50	55	3.40	261	4.30	537	5.20	860
2.60	72	3.50	289	4.40	572	5.30	897
2.70	91	3.60	318	4.50	607	5.40	934
2.80	112	3.70	347	4.60	642	5.50	972

[a] This table is strictly applicable only for open-channel conditions. It is based on six discharge measurements made during 1905–6. It is fairly well defined between gage heights 2.5 feet and 4.1 feet

Estimated monthly discharge of South River at Basic City, Va.

[Drainage area, 142 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
July	786	41	159	1.12	1.29
August	135	29	70.9	.499	.575
September	208	19	58.2	.410	.457
October	91	12	42.2	.297	.342
November	41	7	23.4	.165	.184
December	972	19	160	1.13	1.30
1906.					
January	750	91	258	1.82	2.10
February	261	91	141	.993	1.03
March	897	112	276	1.94	2.24
April	607	135	241	1.70	1.90
May	159	55	106	.746	.860
June	953	41	154	1.08	1.20
July 1–15	91	29	62.5	.440	.245

SOUTH RIVER AT PORT REPUBLIC, VA.

This station was established August 6, 1895, and discontinued April 1, 1899. It was located at the highway bridge about 300 feet above the junction of this river with North River. The banks are high and not subject to overflow. Part of the flow of the river is diverted and used above the bridge in a power plant. This water flows under the bridge in the tailrace, and was always included in the measurements. It did not, however, affect the observed gage height. The bed of the river is composed of gravel and cobblestones and is permanent. The current is swift at all stages and normal to the bridge.

Estimates previously published for South River at Port Republic have not been revised. As based on the plotting of the discharge measurements, they are probably within 15 per cent of the true flow for low stages. This estimate of accuracy is founded on the assumption that the flow in the power canal is practically constant. For high stages the estimates are probably too low and may be in error 20 to 25 per cent.

Discharge measurements of South River at Port Republic, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1895.	*Feet.*	*Second-feet.*	1897.	*Feet.*	*Second-feet.*
August 6	1.62	114	April 19	1.88	202
August 29	1.34	87	June 1	1.87	182
1896.			July 24	1.40	132
June 5	1.40	113	November 7	1.80	173
July 30	1.63	139	1899.		
1897.			March 11	3.70	1,592
March 23	2.30	426			

Daily gage height, in feet, of South River at Port Republic, Va.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.						1895.					
1	......	1.34	1.2	1.2	1.3	16	1.05	1.3	1.2	1.3	1.3
2	......	1.34	1.2	1.2	1.4	17	1.05	1.3	1.2	1.3	1.3
3	......	1.34	1.2	1.3	1.4	18	1.05	1.3	1.2	1.3	1.3
4	......	1.32	1.2	1.3	1.35	19	1.05	1.25	1.2	1.3	1.3
5	......	1.32	1.2	1.3	1.3	20	1.05	1.25	1 2	1.25	1.3
6	1.15	1.32	1.2	1.3	1.3	21	1.05	1.25	1.2	1.25	1.3
7	1.12	1.3	1.2	1.3	1.3	22	1.05	1.25	1.2	1.25	2.1
8	1.1	1.3	1.2	1.3	1 3	23	1.05	1.25	1.2	1.25	1.8
9	1.1	1.3	1.2	1.3	1.4	24	1.04	1.25	1.2	1.25	1.6
10	1.1	1.45	1.2	1.3	1.3	25	1.42	1.25	1.2	1.25	1.6
11	1.1	1.35	1.2	1.3	1.3	26	1.4	1.25	1.2	1.3	1.6
12	1.08	1.35	1.2	1.3	1.3	27	1.4	1.2	1.2	1.3	1.8
13	1.06	1.32	1.2	1.3	1.3	28	1.37	1.2	1.2	1.3	2.1
14	1.06	1.3	1.2	1.3	1.3	29	1.34	1.2	1.2	1.3	2.1
15	1.06	1.3	1.2	1.3	1.3	30	1.3	1.2	1.2	1.3	2.1
						31	1.3	......	1.2	......	2.0

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1	1.8	2.0	2.0	3.2	1.7	1.6	1.8	1.5	1.4	5.0	1.6	2.7
2	1.8	2.0	2.0	3.0	1.7	1.5	1.8	1.5	1.4	3.3	1.6	2.55
3	1.8	2.3	2.0	2.8	2.2	1.5	1.7	1.5	1.4	3.0	1.6	2.4
4	1.7	2.5	2.0	2.7	2.2	1.5	1.6	1.5	1.4	2.75	1.6	2.4
5	1.6	2.5	2.0	2.5	2.2	1.5	1.6	1.5	1.4	2.4	4.1	2.35
6	1.5	3.15	1.9	2.5	2.2	1.5	1.7	1.45	1.4	2.3	3.5	2.1
7	1.4	3.6	1.9	2.4	2.1	2.5	1.7	1.45	1.4	2.3	3.0	2.1
8	1.4	3.1	1.9	2.3	2.0	2.5	1.7	1.4	1.4	2.2	2.6	2.0
9	1.3	3.1	1.9	2.3	1.9	2.5	4.8	1.4	1.4	2.1	2.4	1.9
10	1.3	2.7	1.9	2.2	1.9	2.0	3.2	1.4	1.4	2.0	2.3	1.8
11	1.3	2.5	1.85	2.2	1.9	1.8	2.7	1.4	1.4	2.0	2.15	1.7
12	1.3	2.3	1.85	2.2	1.8	1.8	2.5	1.4	1.4	1.95	2.15	1.6
13	1.3	2.3	1.85	2.2	1.7	1.7	2.4	1.4	1.35	1.95	2.1	1.5
14	1.2	2.8	1.85	2.15	3.0	1.6	2.3	2.0	1.35	1.9	2.1	1.5
15	1.2	2.7	2.0	2.15	2.0	1.6	2.3	1.6	1.35	1.85	2.0	1.5
16	1.2	2.5	2.0	2.1	1.8	1.6	2.0	1.6	1.35	1.85	2.0	1.45
17	1.2	2.4	2.2	2.0	1.8	2.5	2.0	1.6	1.35	1.85	1.9	1.45
18	1.2	2.3	2.2	2.0	1.7	2.2	1.7	1.5	1.35	1.85	1.9	1.45
19	1.2	2.3	2.8	1.9	1.6	2.2	1.8	1.5	1.35	1.85	1.85	1.45
20	1.2	2.2	4.3	1.9	1.6	2.5	1.8	1.5	1.35	1.8	1.85	1.45
21	1.2	2.2	3.0	1.9	1.6	2.0	1.7	1.5	1.35	1.75	1.8	1.45
22	1.2	2.2	2.6	1.8	1.6	2.0	1.7	1.5	1.3	1.7	1.8	1.45
23	1.3	2.1	2.6	1.8	1.6	1.8	1.7	1.5	1.3	1.65	1.8	1.45
24	4.9	2.1	2.5	1.8	1.6	1.7	1.7	1.5	1.25	1.65	1.8	1.45
25	3.6	2.1	2.5	2.0	1.6	1.7	1.7	1.65	1.25	1.65	1.75	1.45
26	3.0	2.0	2.4	2.0	1.6	2.0	1.7	1.5	1.25	1.65	1.7	1.45
27	2.7	2.0	2.4	1.9	1.6	2.0	1.7	1.5	1.25	......	1.65	1.45
28	2.4	2.0	2.4	1.8	1.6	2.0	1.7	1.5	1.25	1.6	1.65	1.45
29	2.3	2.0	2.5	1.75	1.6	1.9	1.6	1.5	9.7	1.6	2.0	1.45
30	2.2	......	3.3	1.7	1.6	1.9	1.6	1.45	17.0	1.6	3.1	1.45
31	2.1	......	3.2	......	1.6	......	1.5	1.45	......	1.6	......	1.45

Daily gage height, in feet, of South River at Port Republic, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897.												
1	1.45	1.85	2.6	2.0	1.75	1.85	1.6	1.5	1.2	1.3	1.75	1.5
2	1.45	1.85	2.5	2.0	9.3	1.8	1.65	1.5	1.2	1.3	2.8	1.5
3	1.45	1.85	2.4	2.0	4.5	1.75	1.65	1.5	1.2	1.3	2.5	1.5
4	1.45	1.85	2.4	2.0	3.3	1.75	1.6	1.5	1.2	1.3	2.1	1.5
5	1.45	1.85	2.35	2.0	3.0	1.9	1.55	1.5	1.2	1.3	2.0	1.5
6	1.45	1.95	2.3	2.1	2.8	1.75	1.55	1.5	1.2	1.3	2.0	1.5
7	1.45	5.0	2.3	2.1	2.5	1.7	1.55	1.5	1.2	1.3	1.8	1.5
8	1.45	4.1	2.3	2.1	2.5	1.65	1.55	1.45	1.2	1.3	1.75	1.5
9	1.45	3.2	2.25	2.1	2.4	1.6	1.55	1.4	1.2	1.3	1.7	1.5
10	1.45	3.05	2.25	2.1	2.3	1.55	1.55	1.4	1.2	1.3	1.7	1.5
11	1.45	2.95	2.25	2.0	2.3	1.5	1.55	1.4	1.2	1.3	1.7	1.5
12	1.45	2.9	2.25	2.0	2.3	1.5	1.55	1.4	1.3	1.3	1.65	1.5
13	1.45	3.15	2.2	1.9	3.2	1.65	1.5	1.4	1.3	1.45	1.65	1.5
14	1.45	3.15	2.3	1.9	4.8	1.65	1.5	1.4	1.3	1.45	1.65	1.5
15	1.45	3.15	2.4	1.9	3.2	1.65	1.5	1.35	1.3	1.45	1.65	1.45
16	1.45	3.4	2.6	1.9	2.85	1.65	1.5	1.35	1.3	1.45	1.65	2.4
17	1.45	3.4	2.6	1.9	2.7	1.6	1.5	1.35	1.3	1.45	1.65	2.0
18	1.45	3.2	2.6	1.85	2.5	1.6	1.5	1.3	1.3	1.45	1.65	1.9
19	1.45	3.2	2.6	1.85	2.4	1.6	1.7	1.25	1.3	1.45	1.65	1.9
20	1.45	3.1	2.6	1.8	2.35	1.65	1.6	1.2	1.3	1.45	1.65	1.85
21	1.45	3.1	2.7	1.8	2.3	1.8	1.55	1.2	1.3	1.5	1.6	1.8
22	1.45	3.6	2.5	1.8	2.25	1.7	1.5	1.2	1.3	1.5	1.55	1.8
23	1.45	6.75	2.3	1.8	2.2	1.65	1.5	1.2	1.3	1.5	1.55	1.8
24	1.65	4.1	2.35	1.8	2.2	1.6	1.5	1.2	1.3	1.5	1.55	1.8
25	1.85	3.3	2.25	1.8	2.2	1.6	1.45	1.2	1.3	1.5	1.5	1.8
26	1.85	3.2	2.15	1.8	2.15	1.6	1.4	1.2	1.3	1.5	1.5	1.8
27	1.85	3.1	2.05	1.8	2.15	1.6	1.4	1.2	1.3	1.5	1.5	1.8
28	1.85	2.8	2.1	1.8	2.1	1.6	1.4	1.2	1.3	2.0	1.5	1.8
29	1.85	......	2.1	1.8	2.1	1.6	1.4	1.2	1.3	1.9	1.5	1.8
30	1.85	......	2.1	1.75	2.0	1.6	1.4	1.2	1.3	1.85	1.5	1.8
31	1.85	......	2.0	......	1.95	......	1.4	1.2	......	1.75	......	1.8
1898.												
1	1.8	2.0	1.5	2.25	2.1	1.75	1.6	2.1	1.6	1.35	2.5	1.9
2	1.8	2.0	1.5	2.25	2.05	1.65	1.6	2.0	1.5	1.35	2.35	1.8
3	1.8	2.0	1.6	2.25	2.0	1.6	1.55	2.0	1.5	1.35	2.2	1.8
4	1.75	2.0	1.6	2.2	2.0	1.6	1.55	2.0	1.5	1.35	2.15	2.5
5	1.75	2.0	1.6	2.15	1.9	1.6	1.55	4.4	1.5	1.75	2.1	4.0
6	1.65	1.95	1.6	2.15	2.2	1.6	1.55	3.0	1.5	3.0	2.1	3.0
7	1.65	1.9	1.6	2.15	4.1	1.6	1.55	2.4	1.5	2.9	2.05	2.9
8	1.6	1.85	1.6	2.1	5.0	1.6	1.55	2.4	1.5	2.6	2.0	2.7
9	1.6	1.8	1.6	2.0	4.1	1.55	1.55	2.3	1.5	2.3	2.0	2.5
10	1.6	1.75	1.6	2.1	3.5	1.55	1.5	6.4	1.5	2.15	2.0	2.4
11	1.6	1.7	1.6	2.05	3.1	1.5	1.45	6.6	1.5	2.0	2.0	2.35
12	1.55	1.7	1.6	2.0	2.9	1.85	1.4	3.6	1.5	1.95	2.0	2.3
13	1.55	1.65	1.6	2.0	2.6	1.75	1.4	3.0	1.5	1.9	2.0	2.3
14	1.55	1.6	1.6	2.0	2.6	1.65	1.4	3.0	1.5	1.8	1.9	2.25
15	1.55	1.55	1.6	2.75	2.5	1.55	1.6	2.8	1.5	1.8	1.9	2.2
16	1.55	1.5	1.6	3.0	2.4	1.75	1.6	2.6	1.5	1.8	1.9	2.15
17	1.55	1.5	1.85	2.8	2.4	1.75	1.6	2.4	1.5	1.75	1.9	2.1
18	1.55	1.5	1.85	2.7	2.3	1.75	1.6	2.3	1.5	1.75	1.85	2.1
19	1.55	1.5	1.85	2.5	2.2	1.75	1.6	2.3	1.5	7.5	1.85	2.1
20	1.55	1.5	1.8	2.4	2.1	1.75	1.6	2.2	1.5	3.8	2.15	2.0
21	1.55	1.5	1.8	2.25	2.0	1.75	1.6	2.2	1.5	3.8	2.1	2.0
22	1.55	1.5	1.8	2.15	2.6	1.75	1.6	2.2	1.5	7.6	2.1	2.0
23	2.0	1.5	1.8	2.1	2.0	1.7	1.6	2.2	1.65	4.5	2.1	2.6
24	2.0	1.5	1.9	2.1	2.0	1.7	1.7	2.1	1.65	4.0	2.1	2.6
25	2.0	1.5	1.9	2.2	1.9	1.7	1.7	2.0	1.6	3.1	2.1	2.5
26	2.0	1.5	1.9	2.5	1.9	1.7	1.7	1.9	1.5	3.0	2.1	2.45
27	2.0	1.5	2.0	2.3	1.85	1.65	1.7	1.8	1.45	2.8	2.1	2.4
28	2.0	1.5	2.0	2.25	1.8	1.6	1.7	1.7	1.4	2.6	2.1	2.35
29	2.0	......	2.0	2.2	1.8	1.6	1.7	1.6	1.35	2.5	2.1	2.3
30	2.0	......	2.0	2.1	1.8	1.6	1.7	1.6	1.35	2.5	2.0	2.3
31	2.0	......	2.2	......	1.8	......	2.1	1.6	......	2.5	......	2.3

Daily gage height, in feet, of South River at Port Republic, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	Day.	Jan.	Feb.	Mar.	Apr.
1899.					1899.				
1	2.5	2.1	4.0	2.5	17	2.5	2.6	3.2	......
2	2.5	2.1	3.6	......	18	2.4	2.6	2.9	......
3	2.4	2.1	3.5	......	19	2.2	2.8	3.2	......
4	2.3	2.1	5.1	......	20	2.2	3.0	3.7	......
5	2.3	2.1	12.0	......					
					21	2.2	3.5	3.5	......
6	3.4	2.1	6.7	......	22	2.2	5.0	3.2	......
7	5.0	2.1	5.5	......	23	2.2	5.6	3.1	......
8	3.8	2.2	4.0	......	24	2.2	4.1	2.9	......
9	3.6	2.2	3.6	......	25	2.2	3.5	2.8	......
10	3.0	2.3	3.9	......					
					26	2.2	4.4	2.8	......
11	2.9	2.3	3.7	......	27	2.2	6.5	2.8	......
12	2.75	2.3	3.6	......	28	2.2	5.3	2.7	......
13	2.6	2.3	3.4	......	29	2.2	......	2.7	......
14	2.6	2.4	3.3	......	30	2.2	......	2.6	......
15	2.6	2.5	3.4	......	31	2.1	......	2.5	......
16	2.6	2.6	3.3	......					

Rating table for South River at Port Republic, Va., from August 5, 1895, to April 1, 1899.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.3	95	2.2	350	3.8	1,535	5.2	2,575
1.4	105	2.4	495	4.0	1,685	5.4	2,720
1.5	120	2.6	645	4.2	1,835	5.6	2,870
1.6	140	2.8	795	4.4	1,980	5.8	3,015
1.7	160	3.0	945	4.6	2,125	6.0	3,165
1.8	180	3.2	1,090	4.8	2,275	6.5	3,535
1.9	210	3.4	1,240	5.0	2,425	7.0	3,905
2.0	250	3.6	1,390				

[a] This rating table is strictly applicable only for open-channel conditions. It is not well defined.

Estimated monthly discharge of South River at Port Republic, Va.

[Drainage area, 246 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1895.					
August 6–31	105	70	80	0.33	0.32
September	112	85	94	.38	.43
October	85	85	85	.35	.40
November	95	85	93	.38	.43
December	290	95	136	.55	.63
1896.					
January	2,350	85	305	1.24	1.43
February	1,390	250	517	2.10	2.19
March	1,905	195	473	1.11	1.28
April	1,090	160	375	1.52	1.70
May	945	140	218	.89	1.02
June	570	120	255	1.04	1.16
July	2,275	120	322	1.31	1.51
August	250	105	123	.50	.58
September	9,200	90	597	2.43	2.71
October	2,425	140	362	1.47	1.69
November	1,760	140	376	1.53	1.71
December	720	112	208	.85	.98
The year	9,200	85	344	1.33	17.96

Estimated monthly discharge of South River at Port Republic, Va.—Continued.

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1897.					
January	195	112	131	.53	.61
February	3,717	195	1,072	4.36	4.54
March	720	250	459	1.87	2.16
April	290	170	211	.86	.95
May	5,607	170	797	3.24	3.74
June	210	120	152	.62	.69
July	160	105	125	.51	.59
August	120	85	103	.42	.48
September	95	85	91	.37	.41
October	250	95	119	.48	.55
November	795	120	192	.78	.87
December	495	112	166	.67	.77
The year	5,607	85	301	1.23	16.36
1898.					
January	250	130	175	.71	.82
February	250	120	162	.66	.69
March	350	120	177	.72	.83
April	945	250	408	1.66	1.85
May	2,425	180	561	2.28	2.63
June	195	120	153	.62	.69
July	290	105	142	.58	.67
August	3,605	140	690	2.80	3.23
September	150	100	121	.49	.55
October	4,345	100	835	3.39	3.91
November	570	195	282	1.15	1.28
December	1,685	180	484	1.97	2.27
The year	4,345	100	349	1.42	19.42
1899.					
January	2,425	290	638	2.59	2.99
February	3,535	290	964	3.92	4.08
March	7,700	570	1,525	6.20	7.15

NORTH RIVER BASIN.

COOKS CREEK AT MOUNT CRAWFORD, VA.

Cooks Creek rises near Harrisonburg, in Rockingham County, Va., and flows southwestward and southeastward into North River near Mount Crawford.

The gaging station was established July 1, 1905, by N. C. Grover, in connection with the investigation of stream pollution in the Shenandoah Valley. It was discontinued July 16, 1906. It is located at the upper highway bridge across Cooks Creek, three-fourths of a mile from Mount Crawford.

The channel is straight for 200 feet above and 100 feet below the station. The current is very sluggish at low water. Both banks are low and liable to overflow during high water, but all the water passes beneath the bridge. The bed of the stream is composed of mud and gravel. The stream is polluted by tanneries.

Discharge measurements were made from the side of the bridge to which the gage is attached, or by wading a short distance below, at a point where the velocity is greater.

A standard chain gage is fastened to the outside of the downstream guard rail of the bridge. The length of the chain from the end of the weight to the outer edge of the ring is 14.38 feet. The gage was read once each day by S. H. Craun. Bench mark No. 1 is a nail driven vertically into a root on the downstream side of a large tree 150 feet below the gage, on the left bank. Its elevation is 4.24 feet above the gage datum.

Estimates at this station are within 10 per cent of the true flow between gage heights 1.9 and 2.7 feet. Above and below these stages the estimates are liable to error of 10 to 25 per cent. The flow may have been slightly affected by ice conditions during the winter of 1905–6.

Discharge measurements of Cooks Creek at Mount Crawford, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
July 1	2.10	20	April 10	2.32	32.4
December 30 [a]	2.08	22.6			

[a] Measurement made by wading.

Daily gage height, in feet, of Cooks Creek at Mount Crawford, Va.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.						
1	2.1	2.2	1.8	1.8	1.7	1.8
2	2.1	2.2	1.9	1.8	1.7	1.8
3	2.0	2.1	1.9	1.8	1.7	2.0
4	2.0	2.1	1.8	1.8	1.7	1.8
5	5.5	2.1	1.8	1.8	1.7	1.8
6	3.3	2.1	1.8	1.8	1.7	1.8
7	2.9	2.0	1.7	1.7	1.7	1.8
8	2.4	2.0	1.8	1.7	1.7	1.8
9	2.2	2.0	1.8	1.7	1.7	1.8
10	2.1	2.0	1.8	1.7	1.7	1.8
11	2.5	2.0	1.8	1.7	1.7	1.8
12	2.1	2.1	1.8	1.7	1.8	1.8
13	2.3	2.1	1.8	1.7	1.8	1.7
14	2.2	2.1	1.8	1.7	1.7	1.7
15	2.8	2.0	1.8	1.7	1.7	1.7
16	2.4	2.0	1.8	1.7	1.7	1.7
17	2.3	1.9	1.8	1.7	1.7	1.7
18	2.2	2.0	1.8	1.7	1.7	1.7
19	2.2	1.9	1.8	1.8	1.8	1.7
20	2.4	2.0	1.8	1.7	1.8	1.7
21	2.1	2.0	1.8	1.7	1.8	2.9
22	2.2	1.9	1.8	1.7	1.8	2.6
23	2.4	1.9	1.8	1.7	1.8	2.4
24	2.3	1.8	1.8	1.7	1.8	2.3
25	2.2	1.9	1.7	1.8	1.8	2.1
26	2.2	2.1	1.7	2.0	1.8	2.0
27	2.2	2.0	1.8	1.8	1.8	2.0
28	2.0	2.0	1.7	1.8	1.8	2.0
29	2.0	2.0	1.7	1.8	1.8	2.3
30	3.1	1.9	1.8	1.7	1.8	2.1
31	2.4	1.9	......	1.7	......	2.2

Daily gage height, in feet, of Cooks Creek at Mount Crawford, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	2.05	2.0	2.0	2.5	2.1	2.0	2.1	......	......	......	......	......
2	2.05	2.0	2.0	2.4	2.1	2.0	2.1	......	......	......	......	......
3	2.05	1.8	2.0	2.3	2.1	2.0	2.1	......	......	......	......	......
4	3.0	2.0	2.4	2.3	2.1	2.0	2.1	......	......	......	......	......
5	2.5	2.0	2.2	2.2	2.1	2.0	2.0	......	......	......	......	......
6	2.3	2.1	2.1	2.3	2.1	1.9	2.0	......	......	......	......	......
7	2.3	2.0	2.1	2.2	2.2	1.9	2.0	......	......	......	......	......
8	2.2	2.0	2.1	2.2	2.2	1.9	2.0	......	......	......	......	......
9	2.2	2.0	2.1	2.3	2.1	1.9	2.0	......	......	......	......	......
10	2.1	2.0	2.1	2.3	2.1	1.9	2.0	......	......	......	......	......
11	2.1	2.1	2.1	2.2	2.1	1.9	3.0	......	......	......	......	......
12	2.1	2.0	2.1	2.2	2.0	1.9	2.1	......	......	......	......	......
13	2.1	2.0	2.05	2.2	2.1	1.8	2.0	......	......	......	......	......
14	2.3	2.0	2.4	2.2	2.1	1.8	2.0	......	......	......	......	......
15	2.3	2.0	2.6	2.5	2.0	1.8	2.0	......	......	......	......	......
16	2.2	1.9	2.5	2.4	2.0	1.8	......	......	......	......	......	......
17	2.2	2.0	2.4	2.3	2.0	2.0	......	......	......	......	......	......
18	2.2	2.0	2.3	2.2	2.0	2.0	......	......	......	......	......	......
19	2.1	1.9	2.4	2.2	2.0	2.0	......	......	......	......	......	......
20	2.1	1.9	2.3	2.2	2.0	2.5	......	......	......	......	......	......
21	2.1	2.0	2.3	2.2	1.9	2.1	......	......	......	......	......	......
22	2.1	2.0	2.3	2.2	1.9	2.2	......	......	......	......	......	......
23	2.3	2.0	2.3	2.2	1.9	2.1	......	......	......	......	......	......
24	2.3	1.8	2.3	2.1	2.0	2.0	......	......	......	......	......	......
25	2.2	2.0	2.3	2.1	2.0	2.0	......	......	......	......	......	......
26	2.1	2.0	2.3	2.2	2.0	2.1	......	......	......	......	......	......
27	2.1	2.0	2.6	2.2	2.0	3.0	......	......	......	......	......	......
28	2.2	2.0	2.5	2.1	2.0	2.0	......	......	......	......	......	......
29	2.2	......	2.5	2.1	2.0	2.2	......	......	......	......	......	......
30	2.1	......	2.4	2.1	2.0	2.1	......	......	......	......	......	......
31	2.1	......	2.5	......	2.0	......	......	......	......	......	......	......

Rating table for Cooks Creek at Mount Crawford, Va., from July 1, 1905, to July 15, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.70	10	2.70	52	3.70	126	4.70	235
1.80	13	2.80	58	3.80	135	4.80	248
1.90	16	2.90	64	3.90	144	4.90	261
2.00	19	3.00	71	4.00	154	5.00	274
2.10	23	3.10	78	4.10	164	5.10	288
2.20	27	3.20	85	4.20	175	5.20	302
2.30	31	3.30	92	4.30	186	5.30	316
2.40	36	3.40	100	4.40	198	5.40	331
2.50	41	3.50	108	4.50	210	5.50	346
2.60	46	3.60	117	4.60	222		

[a] This table is strictly applicable only for open-channel conditions. It is based on two discharge measurements made during 1905-6. It is not well defined. Estimates based on this table are only roughly approximate.

Estimated monthly discharge of Cooks Creek at Mount Crawford, Va.

[Drainage area, 41 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
July	346	19	43.8	1.07	1.23
August	27	13	19.7	.480	.553
September	16	10	12.7	.310	.346
October	19	10	11.4	.278	.320
November	13	10	11.4	.278	.310
December	64	10	18.7	.456	.526
1906.					
January	71	21	27.5	.671	.774
February	23	13	18.5	.451	.470
March	46	19	30.6	.746	.860
April	41	23	28.7	.700	.781
May	27	16	20.6	.502	.579
June	71	13	21.0	.512	.571
July 1–15	71	19	23.8	.580	.324

LEWIS CREEK NEAR STAUNTON, VA.

Lewis Creek rises in the central part of Augusta County, Va., about 4 miles southwest of Staunton, and flows northeastward into Middle River.

The gaging station was established June 30, 1905, by N. C. Grover, in connection with the investigation of stream pollution in the Shenandoah Valley. It was discontinued July 16, 1906. It is located at the private bridge across Lewis Creek, on the property of William Glenn, 2 miles from Staunton.

The chanel is straight for 300 feet above and below the station. The current is sluggish. Both banks are about 5 feet high and do not overflow, except during very high water. The bed of the stream is composed of soft mud. There is but one channel at all stages. The stream is composed almost wholly of sewage from the city of Staunton, and is very shallow at ordinary stages.

Discharge measurements were made from the downstream side of the bridge, the initial point for soundings being the gatepost near the left end of the bridge.

A vertical staff gage, graduated to feet and tenths, is fastened to a tree 6 feet downstream from the bridge. The gage was read once each day by Ashby Glenn. Bench mark No. 1 is a nail in the locust tree to which the gage is attached, 1 foot above the ground, on the upstream side. Its elevation is 7.56 feet above the zero of the gage.

Prior to about May 27, 1906, the estimates for this station are accurate within 5 to 10 per cent for gage heights 0.45 to 0.9 foot. Above and below these stages the error may be as high as 15 per cent. Estimates after about May 27, 1906, may be in error 15 to 20 per cent. The flow was probably not affected by ice conditions during 1905–6.

Discharge measurements of Lewis Creek near Staunton, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
June 30	0.51	3.8	April 10	0.83	12.5
December 29	.63	6.2	June 14	.55	6.6

Daily gage height, in feet, of Lewis Creek near Staunton, Va.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.						
1	0.65	0.45	0.5	0.4	0.4	0.5
2	.88	.55	.4	.4	.5	.5
3	.7	.45	.45	.65	.5	.6
4	.65	.45	.4	.4	.5	.4
5	.5	.6	.45	.4	.5	.5
6	.5	.5	.45	.35	.6	.5
7	.7	.5	.45	.4	.65	.45
8	.6	.45	.45	.4	.5	.5
9	.55	.5	.45	.6	.4	.5
10	.5	.45	.45	.5	.4	.4
11	.5	.35	.45	1.0	.55	.4
12	1.1	.45	.45	.8	.5	.4
13	.7	.45	.5	.7	6	.45
14	.5	.45	.6	.5	.6	.5
15	.55	.5	.6	.4	.5	.6
16	.55	.5	.5	.4	.5	.65
17	0.5	0.45	0.5	0.5	0.45	0.5
18	.5	.6	.45	.45	.75	.5
19	.55	.5	.45	.45	.45	.5
20	.4	.45	.45	.6	.4	.45
21	.5	.45	.45	.6	.45	.4
22	1.05	.45	.5	.5	.55	.45
23	.6	.55	.45	.6	.35	.45
24	.6	.45	.45	.7	.35	.5
25	.55	.5	.45	.65	.5	.5
26	.5	.5	.4	.6	.5	.5
27	.6	.5	.4	.6	.5	.45
28	.45	.5	.4	.6	.45	.65
29	.5	.5	.4	.4	.4	.55
30	.45	.4	.4	.45	.4	.5
31	.5	.5	......	.5	......	.4

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	0.54	0.49	0.74	0.74	0.48	0.54	0.64	......	......	......	......	......
2	.43	.53	.70	.70	.53	.53	.53	......	......	......	......	......
3	.54	.60	.71	.64	.60	.54	.54	......	......	......	......	......
4	1.43	.53	.53	.49	.49	.58	.53	......	......	......	......	......
5	.94	.54	.64	.54	.53	.59	.49	......	......	......	......	......
6	.83	.53	.59	.48	.54	.48	.53	......	......	......	......	......
7	.64	.49	.54	.44	.53	.54	.64	......	......	......	......	......
8	.53	.53	.53	.57	.54	.53	.53	......	......	......	......	......
9	.49	.44	.71	.44	.43	.49	.54	......	......	......	......	......
10	.43	.48	.53	.83	.49	.53	.48	......	......	......	......	......
11	.59	.44	.54	.84	.48	.44	.44	......	......	......	......	......
12	.48	.53	.59	.73	.49	.53	.48	......	......	......	......	......
13	.69	.49	.74	.79	.43	.54	.53	......	......	......	......	......
14	.53	.59	.63	.63	.44	.53	.64	......	......	......	......	......
15	.59	.54	1.04	.74	.48	.49	.43	......	......	......	......	......
16	.53	.48	.83	.63	.49	.63	......	......	......	......	......	......
17	.44	.54	.84	.74	.33	.49	......	......	......	......	......	......
18	.48	.53	.83	.53	.34	.43	......	......	......	......	......	......
19	.59	.49	.84	.49	.48	.49	......	......	......	......	......	......
20	.53	.43	.78	.53	.44	.53	......	......	......	......	......	......
21	.74	.49	.74	.49	.43	.49	......	......	......	......	......	......
22	.63	.53	.70	.53	.49	.43	......	......	......	......	......	......
23	.74	.54	.64	.64	.38	.44	......	......	......	......	......	......
24	.63	.43	.63	.63	.34	.93	......	......	......	......	......	......
25	.54	.54	.64	.54	.33	1.94	......	......	......	......	......	......
26	.48	.53	.59	.54	.94	1.83	......	......	......	......	......	......
27	.54	.49	.54	.59	1.18	.94	......	......	......	......	......	......
28	.63	.43	1.13	.49	1.64	.73	......	......	......	......	......	......
29	.54	......	.84	.63	1.13	.54	......	......	......	......	......	......
30	.48	......	.93	.64	.64	.53	......	......	......	......	......	......
31	.44	......	1.24	......	.58	......	......	......	......	......	......	......

Rating tables for Lewis Creek near Staunton, Va.

JULY 1, 1905, TO MAY 27, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.30	1.0	0.65	6.8	1.00	18.9	1.35	39.0
.35	1.4	.70	8.2	1.05	21.0	1.40	42.5
.40	1.9	.75	9.7	1.10	23.5	1.45	46.5
.45	2.6	.80	11.3	1.15	26.0	1.50	50.5
.50	3.4	.85	13.0	1.20	29.0	1.55	54.5
.55	4.4	.90	14.9	1.25	32.0	1.60	59.0
.60	5.5	.95	16.8	1.30	35.5	1.65	63.5

MAY 28, 1906, TO JULY 15, 1906.[b]

0.25	1.3	0.60	7.9	0.95	20.5	1.50	55
.30	1.8	.65	9.4	1.00	23.0	1.60	63
.35	2.5	.70	11.0	1.10	28.5	1.70	71
.40	3.3	.75	12.7	1.20	34.5	1.80	79
.45	4.2	.80	14.5	1.30	41	1.90	88
.50	5.3	.85	16.3	1.40	48	2.00	97
.55	6.5	.90	18.3				

[a] This table is strictly applicable only for open-channel conditions. It is based on three discharge measurements made during 1905. It is fairly well defined between gage heights 0.5 and 0.8 foot.
[b] This table is based on one discharge measurement made during 1906 and on the form of the preceding curve.

Estimated monthly discharge of Lewis Creek near Staunton, Va.

[Drainage area, 20 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
July	24	1.9	5.98	0.299	0.345
August	5.5	1.4	3.15	.158	.182
September	5.5	1.9	2.76	.138	.154
October	19	1.4	4.58	.229	.264
November	9.7	1.4	3.46	.173	.193
December	6.8	1.9	3.34	.167	.192
1906.					
January	45	2.3	6.58	.329	.379
February	5.5	2.3	3.61	.180	.187
March	31	4.0	9.70	.485	.559
April	13	2.3	6.06	.303	.338
May	66	1.2	7.41	.370	.427
June	92	3.8	12.3	.615	.686
July 1-15	9.1	3.8	6.17	.308	.172

NORTH RIVER AT PORT REPUBLIC, VA.

North River rises in the Shenandoah Mountains in the northwestern part of Augusta County, Va., and flows in a general easterly and southeasterly direction to Port Republic, Rockingham County, Va., where it unites with South River to form South Fork of the Shenandoah. Its drainage area is 805 square miles. It is fed by numerous springs and is utilized to a considerable extent by mills of various kinds.

An important tributary is Middle River, which has been considered by some authorities as the main stream, North River being regarded as the tributary. Middle River rises on Little North Mountain, in the southern part of Augusta County, and flows in a general northeasterly direction, uniting with North River 4 miles above Port Republic. Its drainage area is 365 square miles. It is fed by numerous springs and is utilized to a considerable extent by mills of various kinds.

The gaging station at Port Republic was established August 6, 1895, and was discontinued April 1, 1899. It was located at the highway bridge, about 500 feet above the junction of North River with South River. Measurements were made from the downstream side of the bridge. The banks are high and not subject to overflow. The bed is very rough, but permanent. The current is broken and uneven at low stages. A dam about 200 feet above the bridge controls the flow at low stages.

Estimates previously published for North River at Port Republic have not been revised. They are probably within 15 per cent of the true flow. Ice conditions probably do not affect the flow at this station.

Discharge measurements of North River at Port Republic, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1895.	*Feet.*	*Second-feet.*	1897.	*Feet.*	*Second-feet.*
August 6	2.18	375	April 19	2.60	712
August 29[a]	2.09	258	June 1	2.60	552
			July 24	2.30	431
1896.			November 7	2.00	245
June 5	2.20	427			
July 31	2.48	428	1899.		
July 31[b]	2.46	335	March 11	4.80	3,423
1897.					
March 23	3.54	1,466			

[a] Result obtained by deducting the discharge of South River, 87 second-feet, from total discharge of South Fork of Shenandoah River, 345 second-feet, measured below the junction.

[b] Result obtained as on August 29, 1895, by deducting 139 second-feet, discharge of South River, from 474 second-feet, discharge of South Fork.

Daily gage height, in feet, of North River at Port Republic, Va.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.						1895.					
1	......	2.03	1.9	1.75	1.85	17	2.07	1.9	1.75	2.0	1.8
2	......	2.03	1.9	1.75	1.9	18	2.07	1.9	1,75	2.0	1.8
3	......	2.0	1.9	1.85	1.9	19	2.07	1.9	1.75	2.0	1.8
4	......	2.0	1.9	1.85	1.85	20	2.07	1.9	1.75	1.9	1.8
5	......	2.0	1.9	1.85	1.8						
						21	2.05	1.9	1.75	1.9	1.8
6	2.2	2.0	1.9	1.85	1.85	22	2.05	1.9	1.75	1.85	2.1
7	2.2	2.0	1.9	1.85	1.85	23	2.05	1.9	1.75	1.85	1.9
8	2.15	2.0	1.85	1.85	1.85	24	2.05	1.9	1.75	......	1.8
9	2.15	4.3	1.85	1.85	1.9	25	2.4	1.9	1.75	......	1.8
10	2.15	2.2	1.85	1.85	1.8						
						26	2.3	1.9	1.75	......	1.8
11	2.15	2.1	1.85	1.9	1.8	27	2.2	1.9	1.75	......	1.9
12	2.08	2.1	1.85	1.9	1.8	28	2.15	1.9	1.75	......	2.4
13	2.08	2.0	1.85	1.9	1.8	29	2.09	1.9	1.75	1.85	2.45
14	2.08	2.0	1.85	1.9	1.8	30	2.05	1.9	1.75	1.85	2.4
15	2.08	2.0	1.85	2·0	1.8	31	2.03	......	1.75	......	2.5
16	2.07	2.0	1.75	2.0	1 8						

Daily gage height, in feet, of North River at Port Republic, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.												
1	3.0	2.5	2.6	5.4	2.32	2.42	2.8	2.43	2.0	7.5	2.35	4.4
2	2.7	2.5	2.6	5.0	2.52	2.32	2.7	2.43	1.95	4.5	2.35	3.5
3	2.5	2.8	2.6	4.6	2.52	2.32	2.7	2.55	1.9	4.0	2.35	3.3
4	2.4	3.8	2.6	4.2	3.32	2.22	2.6	2.45	1.9	3.5	2.35	3.3
5	2.4	3.8	2.6	4.0	3.32	2.2	2.6	2.4	1.9	3.3	4.7	3.25
6	2.4	5.0	2.5	3.6	3.32	2.2	2.8	2.4	1.85	3.2	6.0	3.1
7	2.4	5.7	2.5	3.5	3.12	4.5	2.8	2.3	1.85	3.1	4.3	3.05
8	2.3	4.5	2.5	3.5	2.92	3.0	2.8	2.3	1.8	3.0	3.6	2.9
9	2.3	4.1	2.5	3.4	2.72	2.6	7.5	2.3	1.8	2.9	3.3	2.8
10	2.3	3.7	2.5	3.3	2.72	2.5	5.3	2.25	1.75	2.8	3.3	2.7
11	2.3	3.5	2.4	3.3	2.72	2.3	3.9	2.2	1.7	2.65	3.2	2.65
12	2.3	3.3	2.4	3.2	2.62	2.3	3.6	2.2	1.7	2.55	3.0	2.6
13	2.3	3.3	2.4	3.2	2.52	2.2	3.3	2.2	1.7	2.5	2.8	2.55
14	2.2	5.2	2.4	3.0	5.82	2.2	3.0	3.6	1.7	2.5	2.8	2.55
15	2.2	4.7	2.6	3.0	3.82	2.2	3.3	2.7	2.0	2.5	2.7	2.5
16	2.1	3.8	2.6	....	3.22	2.2	3.0	2.7	1.9	2.5	2.7	2.5
17	2.1	3.6	2.8	....	3.02	2.5	3.1	3.0	1.8	2.5	2.65	2.45
18	2.0	3.1	3.2	....	2.82	2.4	2.7	2.4	1.8	2.45	2.65	2.45
19	2.0	3.0	4.8	....	2.62	2.4	2.7	2.3	1.8	2.45	2.6	2.45
20	2.0	2.7	7.2	....	2.62	3.3	2.7	2.25	1.7	2.4	2.6	2.45
21	2.0	2.7	5.0	....	2.62	3.0	2.6	2.25	1.7	2.4	2.55	2.45
22	2.0	2.7	4.8	....	2.62	2.9	2.5	2.25	1.7	2.35	2.5	2.45
23	2.1	2.7	4.0	....	2.62	2.5	2.5	2.2	1.7	2.35	2.5	2.45
24	6.15	2.7	3.8	....	2.52	2.4	2.5	2.2	1.65	2.35	2.45	2.45
25	5.3	2.7	3.5	....	2.52	2.4	3.0	2.4	1.65	2.35	2.4	2.4
26	4.0	2.6	3.5	....	2.52	3.2	2.7	2.2	1.65	2.35	2.4	2.4
27	3.3	2.6	3.5	....	2.52	3.0	2.7	2.2	1.65	....	2.35	2.4
28	3.0	2.6	3.5	2.22	2.42	3.0	2.6	2.15	1.65	2.35	2.35	2.4
29	2.8	2.6	4.4	2.22	2.42	2.9	2.6	2.15	7.2	2.35	3.0	2.4
30	2.6	....	6.5	2.22	2.42	2.9	2.5	2.1	18.0	2.35	5.5	2.4
31	2.5	....	5.9	....	2.42	....	2.45	2.1	....	2.35	....	2.35
1897.												
1	2.35	2.35	3.6	2.7	2.4	2.6	2.35	2.15	2.0	1.8	2.2	1.85
2	2.35	2.35	3.5	2.7	11.5	2.55	2.45	2.15	2.0	1.8	2.0	1.85
3	2.35	2.35	3.4	2.6	7.3	2.5	2.45	2.15	2.0	1.8	2.6	1.85
4	2.35	2.35	3.4	2.6	5.15	2.5	2.4	2.15	2.0	1.8	2.0	1.85
5	2.35	2.35	3.35	2.6	4.3	3.0	2.35	2.15	1.95	1.8	2.0	2.0
6	2.3	2.55	3.3	2.9	3.8	2.85	2.25	2.15	1.95	1.8	2.0	2.0
7	2.3	7.0	3.3	2.9	3.5	2.6	2.2	2.1	1.9	1.8	2.0	1.95
8	2.3	5.5	3.3	2.9	3.3	2.55	2.4	2.1	1.9	1.8	1.95	1.95
9	2.3	4.8	3.25	2.9	3.1	2.5	2.3	2.1	1.9	1.8	1.9	1.9
10	2.3	4.3	3.25	3.0	3.0	2.5	2.2	2.1	1.85	1.8	1.9	1.85
11	2.3	4.0	3.25	3.0	3.0	2.45	2.15	2.05	1.85	1.8	1.9	1.85
12	2.3	3.9	3.25	3.0	3.0	2.4	2.5	2.05	1.85	1.8	1.85	1.85
13	2.3	5.45	3.2	2.9	4.9	2.4	2.4	2.05	1.85	2.0	1.85	1.85
14	2.2	4.7	3.3	2.9	7.5	2.4	2.4	2.05	1.85	2.0	1.8	1.85
15	2.25	5.0	3.5	2.9	5.2	2.4	2.3	2.0	1.85	2.0	1.8	2.65
16	2.25	5.3	3.5	2.9	4.4	2.4	2.2	2.0	1.85	1.95	1.9	2.45
17	2.25	5.2	3.7	2.9	4.0	2.4	2.2	2.0	1.85	1.95	1.9	2.25
18	2.25	4.6	3.7	2.8	3.6	2.4	2.15	2.0	1.85	1.95	1.9	2.1
19	2.25	4.5	3.7	2.65	3.45	2.4	3.5	2.0	1.8	1.95	1.9	2.25
20	2.25	4.3	3.7	2.6	3.25	2.5	3.5	2.0	1.8	1.95	1.9	2.25
21	2.25	4.2	3.9	2.55	3.15	2.45	2.5	....	1.8	2.0	1.85	2.25
22	2.25	4.8	3.6	2.5	3.1	2.4	2.4	2.0	1.8	2.0	1.85	2.25
23	2.25	9.85	3.35	2.5	3.0	2.4	2.35	2.0	1.8	2.0	1.85	2.25
24	2.25	6.7	3.4	2.5	2.95	2.4	2.35	2.0	1.8	2.0	1.85	2.25
25	2.25	5.4	3.3	2.5	2.9	2.4	2.3	2.0	1.8	2.0	1.85	2.25
26	2.25	4.5	3.2	2.5	2.85	2.4	2.25	2.0	1.8	2.0	1.85	2.25
27	2.25	4.4	3.1	2.45	2.8	2.35	2.2	2.0	1.8	2.0	1.85	2.25
28	2.25	3.8	3.0	2.45	2.75	2.35	2.15	2.0	1.8	2.1	1.85	2.25
29	2.25	....	2.9	2.45	2.7	2.35	2.15	2.0	1.8	2.05	1.85	2.25
30	2.25	....	2.8	2.4	2.65	2.35	2.15	2.0	1.8	1.95	1.85	2.2
31	2.35	....	2.7	....	2.6	....	2.15	2.0	....	1.95	....	2.15

Daily gage height, in feet, of North River at Port Republic, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.												
1	2.15	2.7	2.1	3.85	2.65	2.35	2.2	4.25	2.6	2.4	3.0	2.4
2	2.15	2.7	2.1	3.5	2.6	2.3	2.2	4.25	2.5	2.4	2.8	2.3
3	2.15	2.7	2.1	3.3	2.5	2.15	2.2	4.0	2.5	2.4	2.65	2.3
4	2.1	2.7	2.1	3.15	2.45	2.15	2.2	4.5	2.5	2.4	2.6	3.0
5	2.1	2.7	2.1	3.0	2.4	2.15	2.2	8.0	2.5	3.0	2.6	7.0
6	2.1	2.65	2.1	2.9	3.0	2.1	2.2	5.0	2.5	2.9	2.6	5.0
7	2.05	2.65	2.1	2.9	6.4	2.1	2.2	5.0	2.5	2.8	2.5	3.6
8	2.05	2.6	2.1	2.8	7.25	2.1	2.2	4.6	2.5	2.6	2.5	3.3
9	2.0	2.5	2.1	2.6	6.3	2.1	2.2	4.0	2.5	2.4	2.45	3.0
10	2.6	2.4	2.1	2.75	5.0	2.0	2.15	9.0	2.5	2.25	2.4	2.9
11	2.55	2.3	2.1	2.75	4.0	2.0	2.1	9.0	2.5	2.1	2.4	2.8
12	2.5	2.2	2.1	2.75	3.6	2.6	2.1	7.0	2.5	2.1	2.4	2.7
13	2.45	2.2	2.1	2.75	3.3	2.5	2.0	6.0	2.5	2.1	2.35	2.65
14	2.45	2.15	2.1	2.75	3.2	2.35	2.0	6.0	2.5	2.0	2.35	2.6
15	2.45	2.15	2.1	4.15	3.0	2.2	2.1	6.0	2.5	2.0	2.3	2.55
16	2 45	2.1	2.1	5.2	2.8	4.2	2.1	4.5	2.5	2.0	2.3	2.5
17	2.45	2.1	2.25	4.5	2.8	3.4	2.25	4.2	2.5	2.0	2.25	2.5
18	2.45	2.1	2.8	4.0	2.7	3.0	2.5	4.0	2.5	2.0	2.2	2.4
19	2.55	2.1	2.95	3.5	2.6	3.0	2.4	4.0	2.5	9.5	2.15	2.3
20	2.55	2.1	2.85	3.2	2.6	3.0	2.3	3.6	2.5	5.0	2.6	2.3
21	2.55	2.1	2.75	3.0	2.6	3.0	2.3	3.3	2.5	5.0	2.6	2.3
22	2.55	2.1	2.75	2.9	3.35	2.9	2.3	3.2	2.5	10.0	2.6	2.3
23	2.7	2.1	2.75	2.75	3.3	2.8	2.3	3.1	2.75	6.5	2.6	4.0
24	2.8	2.1	2.75	2.75	3.2	2.65	3.0	3.1	2.75	5.0	2.6	4.3
25	2.8	2.1	2.85	2.75	3.0	2.5	2.8	3.0	2.65	3.8	2.6	3.6
26	2.8	2.1	2.9	2.75	2.9	2.5	2.7	2.9	2.65	3.65	2.6	3.3
27	2.8	2.1	3.0	2.75	2.75	2.5	3.5	2.8	2.6	3.5	2.55	3.0
28	2.7	2.1	3.0	2.7	2.65	2.4	4.75	2.7	2.6	3.3	2.5	2.8
29	2.7	......	3.0	2.65	2.65	2.4	5.0	2.7	2.5	3.15	2.5	2.6
30	2.7	......	3.3	2.65	2.5	2.4	5.0	2.6	2.4	3.15	2.5	2.6
31	2.7	......	4.2	......	2.4	......	4.5	2.6	......	3.15	......	2.6

	Jan.	Feb.	Mar.	Apr.		Jan.	Feb.	Mar.	Apr.
1899.					1899.				
1	2.75	2.3	7.1	3.0	17	2.7	3.0	4.0	......
2	2.75	2.3	5.5	......	18	2.7	3.0	3.7	......
3	2.7	2.3	5.0	......	19	2.6	3.4	4.0	......
4	2.65	2.3	7.4	......	20	2.6	4.0	4.3	......
5	2.65	2.3	14.0	......	21	2.6	5.5	3.9	......
6	5.4	2.3	8.9	......	22	2.6	7.0	3.6	......
7	6.7	2.3	7.5	......	23	2.6	7.6	3.4	......
8	5.0	2.4	5.8	......	24	2.6	6.0	3.2	......
9	4.0	2.4	4.8	......	25	2.6	4.9	3.1	......
10	3.6	2.5	5.3	......	26	2.6	4.9	3.1	......
11	3.4	2.5	4.8	......	27	2.6	6.0	3.0	......
12	3.2	2.5	4.6	......	28	2.6	9.0	3.0	......
13	3.0	2.5	4.0	......	29	2.5	......	3.0	......
14	2.9	2.7	3.8	......	30	2.5	......	3.0	......
15	2.8	2.8	4.5	......	31	2.4	......	3.0	......
16	2.8	3.0	4.2	......					

Rating table for North River at Port Republic, Va., from August 5, 1895, to April 1, 1899.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.6	165	3.2	1,050	4.8	3,410	8.5	9,145
1.8	215	3.4	1,290	5.0	3,720	9.0	9,920
2.0	275	3.6	1,550	5.5	4,495	9.5	10,695
2.2	350	3.8	1,860	6.0	5,270	10.0	11,470
2.4	445	4.0	2,170	6.5	6,045	10.5	12,245
2.6	555	4.2	2,480	7.0	6,820	11.0	13,020
2.8	700	4.4	2,790	7.5	7,595		
3.0	865	4.6	3,100	8.0	8,370		

[a] This table is strictly applicable only for open-channel conditions. It is not well defined.

Estimated monthly discharge of North River at Port Republic, Va.

[Drainage area, 804 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1895.					
August 6–31	445	292	319	0.40	0.39
September	2,635	245	346	.44	.49
October	245	202	219	.27	.31
November [a]	275	202	239	.30	.33
December	500	215	251	.31	.36
1896.					
January	5,502	275	799	.99	1.14
February	4,805	500	1,488	1.85	1.93
March	7,130	445	1,653	2.05	2.37
April 1–15, 28–30	4,340	350	1,594	1.98	1.33
May	4,960	395	824	1.02	1.18
June	2,945	350	642	.80	.89
July	7,595	472	1,085	1.35	1.56
August	1,550	310	458	.57	.66
September	23,870	177	1,224	1.52	1.70
October	7,595	420	931	1.16	1.34
November	5,270	420	1,088	1.35	1.51
December	2,790	420	699	.87	1.00
1897.					
January	420	372	388	.48	.55
February	11,240	420	3,138	3.90	4.06
March	2,015	625	1,250	1.55	1.79
April	865	445	642	.80	.89
May	13,790	445	2,212	2.75	3.17
June	865	420	489	.61	.68
July	1,420	330	463	.58	.67
August	330	275	292	.36	.41
September	275	215	234	.29	.32
October	310	215	250	.31	.35
November	555	215	256	.32	.36
December	590	230	319	.39	.45
The year	13,790	215	829	1.03	13.70
1898.					
January	700	275	491	.61	.70
February	625	310	414	.51	.53
March	2,480	310	581	.72	.80
April	4,030	555	1,110	1.38	1.54
May	7,207	445	1,430	1.78	2.05
June	2,480	275	585	.73	.81
July	3,720	275	822	1.02	1.18
August	9,920	555	3,030	3.77	4.35
September	662	445	520	.65	.72
October	11,470	275	1,814	2.26	2.61
November	865	330	507	.63	.70
December	6,820	395	1,089	1.35	1.56
The year	11,470	275	1,032	1.28	17.55
1899.					
January	6,355	445	1,126	1.40	1.61
February	9,920	395	2,132	2.65	2.76
March	17,670	865	3,452	4.29	4.95

[a] Discharge interpolated November 24–28, 1895.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN NORTH RIVER BASIN.

The following miscellaneous measurements have been made in the basin of North River:

Miscellaneous discharge measurements in North River basin.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Feet per second.*	*Second-feet.*
1897.						
March 22	Middle River	At mouth near Mount Meridian, Va.	114	396	1.58	625
April 19	do	do		228	1.00	229
November 7	do	do	90	151	.61	92
March 22	North River	Above junction with Middle River near Mount Meridian, Va.				841
November 7	do	do				153

SOUTH FORK OF SHENANDOAH RIVER BASIN BELOW PORT REPUBLIC, VA.

GENERAL DESCRIPTION.

South Fork of Shenandoah River is formed at Port Republic, Rockingham County, Va., by the union of North and South rivers, and flows northeastward to Riverton, Va., where it unites with North Fork to form the main Shenandoah. Its length by river course is about 96 miles.

South Fork of the Shenandoah is to a certain extent navigable for small boats, and works have at various times been executed for improving it. The basin is traversed by the Norfolk and Western Railway, and nearly every part of it is accessible. Theoretically a large amount of power is available, but very little is utilized. The bed and banks are favorable for the construction of dams, but space for canals and buildings is in places small.

The river is subject to frequent and rapidly rising freshets. The stream flows alternately in pools of comparatively slack water and over ledges and shoals, forming rapids and falls, the pools being shorter and the ledges more numerous in the upper reaches than in the lower.

In August, 1899, a reconnaissance survey of South Fork of Shenandoah River between Port Republic and Riverton, Va., was made by F. H. Anschutz, under the direction of D. C. Humphreys, for the purpose of obtaining a profile of the river and a map showing the location of the mills, the unused falls, and the localities where water power might possibly be developed.

The results of the work are shown by the profile (Pl. III, p. 134). The distances along the profile and map are measured along the center line of the stream, the initial point being the forks of the river at Port Republic.

The developed and undeveloped power of the river at the time of the survey was briefly stated, as follows:

At Port Republic a combined sawmill and gristmill utilizes a fall of 10 feet in South River, which is obtained by a dam about a quarter of a mile above the mouth.

On North River, in the first 1,500 feet above the forks, there is a fall of 6 feet which was once used for power and which could easily be developed again.

At Shendun, 4 miles above Port Republic, on South River, an excellent power was partially developed during what is known as "boom times" in 1890. The fall is said to be about 20 feet.

Two miles downstream from the forks there is a gristmill utilizing about 6 feet fall, obtained by a brush dam and a long race.

At 6 miles there is a fall of 4.5 feet, but the banks are low.

At 7½ miles there is a small gristmill with a 3-foot timber dam.

Between the 7½-mile point and the next mill, at 11 miles, there is a total fall of 25 feet, but the river banks are much broken and generally are low.

At 11 miles there is a small gristmill using about 6 feet fall.

At 12½ miles there is a gristmill using 5½ feet fall.

At 17 miles, opposite Elkton, there is a combined gristmill and sawmill, with a 4-foot dam, using 6 feet fall.

In the neighborhood of Shenandoah the fall is rapid, but the banks are low.

At 31½ miles there is an old mill and a timber dam 4 feet high, the first course of timbers of which is missing.

At 32½ miles, Grove Hill, there is a gristmill and a good dam of timber and loose rocks, 4 feet high.

At 37½ miles, Kemple Falls, there is a fall of 15 feet in three-fourths of a mile. The bank on the left side is fairly good, but on the right side of the main group of channels the river spreads out over and runs through a large area of bowlders, and the bank for a considerable distance back is but little above the surface of the stream.

At 38 miles, Newport, there is a combined sawmill and gristmill that uses about 6 feet fall. The dam is about 4 feet high, loosely made of timber and stonework.

At 41 miles is Manks' mill, a gristmill with a dam 3½ feet high, rudely constructed of brush and loose stone. The fall below the mill is good and about 7 feet are utilized.

At 50 miles there is an old mill site, nothing being left except the foundation of the dam.

At 55 miles, Schuler, there is a gristmill, with a dam 3½ feet high.

At 66½ miles is Goode's mill, the dam for which is 3 feet high, of timber and planking backed by loose rock. The mill uses a fall of about 6 feet.

At 79½ miles is Hazard's mill, on the left bank of the stream, at a point where the river splits and runs around a large island. The dam is in the left branch and is substantially constructed of timber; it is 4½ feet high.

At 97½ miles is Blackmore's dam. It was a stoutly built dam of timber and dry masonry, but it is broken at each end and part of the upper course is missing at the middle. The mill is no longer standing.

At 101 miles, Riverton, are the Riverton mills. The dam is 6 feet high,[a] of timber and is well constructed.

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[a] See description of station on North Fork of Shenandoah River near Riverton, Va., pp. 125–126.

ELK RUN AT ELKTON, VA.

Elk Run rises in the Blue Ridge in the eastern part of Rockingham County, Va., and flows northwestward into South Fork of Shenandoah River near Elkton.

The gaging station was established June 28, 1905, by N. C. Grover, in connection with the investigation of stream pollution in the Shenandoah Valley. It was discontinued July 16, 1906. It is located at the highway bridge 500 feet south of the railroad station at Elkton, Va.

The channel is straight for 100 feet above and 200 feet below the station. The current is sluggish at the gage. Both banks are low and overflow during high water. All the water passes beneath the bridge, except during extreme floods. The bed of the stream is composed of gravel and is permanent. The stream is highly polluted by waste from tanneries along its banks.

Discharge measurements were made at ordinary stages at a footbridge 1,000 feet downstream from the bridge to which the gage is fastened. During high water discharge measurements were made from the highway bridge.

A standard chain gage is fastened to a floor beam on the downstream side of the bridge, near the right end. The length of the chain from the end of the weight to the marker is 8.74 feet. The gage was read once each day by C. L. Gooden. Bench mark No. 2 is the underside of the coping at the southwest corner of the first railway-bridge pier on the right bank of the creek, marked with red paint "U. S. G. S. B. M." Its elevation is 11.96 feet above the datum of the gage.

Unsatisfactory conditions of flow prevail at this station. The discharge measurements plot very erratically, owing probably to changes at the controlling point below the station. It was necessary to obtain the discharge by an indirect method based on the assumption of a gradual change in channel conditions between successive measurements. The estimates can probably be considered accurate within only 20 per cent of the true flow. Ice conditions probably affect the flow somewhat.

Discharge measurements of Elk Run at Elkton, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
May 22		4.9	April 11	2.78	15.7
Do		4.0	June 14	2.57	6.5
June 28	2.80	17.4			
July 20	2.10	3.4			
December 28	2.78	11.0			

Daily gage height, in feet, of Elk Run at Elkton, Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	......	......	......	......	......	......	2.7	2.6	2.6	2.5	2.7	2.7
2	......	......	......	......	......	......	2.7	2.55	2.5	2.5	2.7	2.7
3	......	......	......	......	......	......	2.6	2.55	2.5	2.5	2.7	2.7
4	......	......	......	......	......	......	2.6	2.5	2.5	2.45	2.7	2.7
5	......	......	......	......	......	......	2.6	2.5	2.6	2.45	2.7	2.7
6	......	......	......	......	......	......	2.6	2.5	2.5	2.5	2.7	2.7
7	......	......	......	......	......	......	2.6	2.5	2.4	2.5	2.7	2.7
8	......	......	......	......	......	......	2.6	2.65	2.4	2.5	2.8	2.65
9	......	......	......	......	......	......	2.5	2.6	2.4	2.6	2.7	2.65
10	......	......	......	......	......	......	2.55	2.5	2.4	2.6	2.7	2.7
11	......	......	......	......	......	......	2.55	2.7	2.45	3.2	2.7	2.7
12	......	......	......	......	......	......	3.5	2.7	2.4	2.9	2.7	2.65
13	......	......	......	......	......	......	3.1	3.2	2.45	2.7	2.7	2.65
14	......	......	......	......	......	......	2.9	3.9	2.45	2.6	2.8	2.65
15	......	......	......	......	......	......	2.7	3.0	2.45	2.6	2.7	2.6
16	......	......	......	......	......	......	2.6	2.8	2.4	2.6	2.7	2.6
17	......	......	......	......	......	......	2.6	2.7	2.4	2.7	2.7	2.6
18	......	......	......	......	......	......	2.6	2.6	2.4	2.65	2.7	2.6
19	......	......	......	......	......	......	2.55	2.65	2.4	2.65	2.7	2.7
20	......	......	......	......	......	......	2.5	2.6	2.9	2.65	2.75	3.3
21	......	......	......	......	......	......	2.55	2.6	2.6	2.7	2.7	3.5
22	......	......	......	......	......	......	2.7	2.65	2.5	2.7	2.65	2.8
23	......	......	......	......	......	......	2.5	2.6	2.5	2.7	2.65	2.7
24	......	......	......	......	......	......	2.5	3.1	2.5	2.7	2.65	2.7
25	......	......	......	......	......	......	2.5	3.2	2.5	2.8	2.65	2.8
26	......	......	......	......	......	......	2.5	3.0	2.5	2.8	2.65	2.7
27	......	......	......	......	......	......	2.5	3.0	2.5	2.7	2.65	2.8
28	......	......	......	......	......	2.75	2.6	2.8	2.5	2.7	2.65	2.8
29	......	......	......	......	......	2.8	2.6	2.7	2.5	2.7	2.65	3.0
30	......	......	......	......	......	2.65	2.6	2.7	2.5	2.7	2.65	2.95
31	......	......	......	......	......	......	2.6	2.6	......	2.7	......	2.9
1906.[a]												
1	2.85	2.9	2.7	3.1	2.9	2.67	2.5	......	......	......	......	......
2	2.8	2.95	2.7	3.8	2.88	2.5	2.5	......	......	......	......	......
3	2.75	2.9	3.35	3.0	2.75	2.6	2.5	......	......	......	......	......
4	3.25	2.9	3.3	2.95	2.8	2.65	2.6	......	......	......	......	......
5	3.1	2.9	2.9	2.85	2.8	2.51	2.5	......	......	......	......	......
6	3.0	2.85	2.85	2.9	2.9	2.6	3.5	......	......	......	......	......
7	2.91	2.85	2.8	2.85	2.95	2.59	2.8	......	......	......	......	......
8	2.8	2.8	2.8	2.8	2.9	2.5	2.78	......	......	......	......	......
9	2.96	2.8	2.81	2.95	2.8	2.6	2.7	......	......	......	......	......
10	2.91	2.8	2.7	2.8	2.87	2.58	2.72	......	......	......	......	......
11	2.9	2.8	2.8	2.85	2.85	2.53	2.7	......	......	......	......	......
12	2.8	2.78	2.75	2.8	2.7	2.6	2.72	......	......	......	......	......
13	2.8	2.77	2.85	2.8	2.75	2.58	2.7	......	......	......	......	......
14	2.8	2.75	2.95	2.85	2.7	2.47	2.7	......	......	......	......	......
15	3.0	2.7	3.0	4.5	2.55	2.58	2.75	......	......	......	......	......
16	2.9	2.77	3.1	3.5	2.64	2.6	......	......	......	......	......	......
17	2.85	2.7	3.0	3.2	2.6	2.6	......	......	......	......	......	......
18	2.8	2.7	2.95	3.0	2.6	2.65	......	......	......	......	......	......
19	2.8	2.8	2.9	2.95	2.6	2.7	......	......	......	......	......	......
20	2.75	2.72	2.85	2.85	2.6	3.65	......	......	......	......	......	......
21	2.75	2.7	2.9	2.9	2.55	2.9	......	......	......	......	......	......
22	2.8	2.78	2.9	2.9	2.62	3.2	......	......	......	......	......	......
23	3.0	2.77	2.85	2.85	2.6	2.9	......	......	......	......	......	......
24	3.1	2.8	2.8	2.8	2.5	2.87	......	......	......	......	......	......
25	3.0	2.75	2.7	2.8	2.6	2.82	......	......	......	......	......	......
26	2.95	2.78	2.9	2.95	2.62	2.72	......	......	......	......	......	......
27	3.0	2.75	2.85	3.0	2.5	2.63	......	......	......	......	......	......
28	3.15	2.75	2.9	2.95	2.72	2.6	......	......	......	......	......	......
29	2.95	......	3.0	2.95	2.7	2.6	......	......	......	......	......	......
30	3.0	......	2.9	2.85	2.65	2.55	......	......	......	......	......	......
31	2.9	......	3.1	......	2.7	......	......	......	......	......	......	......

[a] Slight ice conditions during the winter season.

Estimated monthly discharge of Elk Run at Elkton, Va.

[Drainage area, 15.8 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
July	57	7.0	11.9	0.753	0.868
August	85	7.0	14.1	.892	1.03
September	15	5.5	6.73	.426	.475
October	27	6.0	9.39	.594	.685
November	12	8.5	9.40	.595	.664
December	46	7.5	11.8	.747	.861
1906.					
January	29	10	15.8	1.00	1.15
February	18	11	13.5	.854	.889
March	42	11	19.3	1.22	1.41
April	132	15	27.0	1.71	1.91
May	20	6.5	11.5	.728	.839
June	54	5.5	9.9	.627	.700
July 1–15	44	6	10.7	.677	.378

HAWKSBILL CREEK NEAR LURAY, VA.

Hawksbill Creek rises in the Blue Ridge in the southeastern part of Page County, Va., and flows northward into South Fork of Shenandoah River about 4 miles north of Luray.

The gaging station was established June 27, 1905, by N. C. Grover, in connection with the investigation of stream pollution in the Shenandoah River valley. It was discontinued July 16, 1906. It is located a short distance above the mouth of Dry Run, 1½ miles north of Luray.

The channel is straight for 500 feet above and 200 feet below the station. The current is moderate above and swift below the station. Rapids below the gage prevent backwater influence from Dry Run, except in case of extreme floods. From well-defined marks the highest stage known was found to be 19.55 feet above the zero of the gage. This stage occurred October 13, 1893. The right bank is high, rocky, and wooded, and does not overflow. The left bank is low and subject to overflow during high water. The bed of the stream is composed of gravel, is free from vegetation, and is permanent. There is but one channel at all stages. The approximate depth of the water at the bridge is 2 to 3 feet.

Discharge measurements were made from the footbridge in front of the observer's house. The initial point for soundings is the edge of rock at the right end of the bridge.

A staff gage in two sections, the lower one inclined and the upper vertical, graduated to feet and tenths, is fastened to the left bank 100 feet above the footbridge. The gage was read once each day by J. S. Miller. Bench mark No. 2 is the top of the stone under the vertical post on the upstream side of door frame in the old dairy building, 200 feet from the left end of the footbridge. Its elevation is 15.10 feet above the zero of the gage.

Estimates at this station are within 5 per cent of the true flow for normal conditions between gage heights 1.4 and 2.0 feet. Above and below these stages the probable error is 10 per cent. The flow was probably unaffected by ice conditions during the winter of 1905–6.

Discharge measurements of Hawksbill Creek near Luray, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
May 21	1.44	35	April 12	1.86	75
June 27	1.74	64	June 15[a]	1.50	36
December 28	1.81	72			

[a] Measurement made by wading below footbridge.

Daily gage height, in feet, of Hawksbill Creek near Luray, Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1							1.6	1.45	1.4	1.35	1.4	1.4
2							1.6	1.4	1.4	1.35	1.4	1.4
3							1.6	1.4	1.4	1.4	1.4	1.65
4							1.55	1.4	1.35	1.35	1.4	1.6
5							1.55	1.4	1.3	1.35	1.4	1.5
6							1.55	1.4	1.3	1.35	1.45	1.45
7							1.55	1.4	1.3	1.35	1.45	1.45
8							1.55	1.4	1.3	1.35	1.4	1.45
9							1.5	1.4	1.3	1.35	1.4	1.45
10							1.5	1.4	1.4	1.35	1.4	1.45
11							1.5	1.4	1.4	1.45	1.4	1.45
12							1.5	1.4	1.4	1.45	1.4	1.45
13							1.5	1.4	1.35	1.4	1.4	1.45
14							1.5	1.4	1.3	1.4	1.4	1.45
15							1.45	1.35	1.3	1.4	1.4	1.45
16							1.4	1.35	1.3	1.35	1.4	1.45
17							1.4	1.35	1.35	1.35	1.4	1.4
18							1.4	1.45	1.5	1.35	1.4	1.4
19							1.4	1.45	1.35	1.35	1.4	1.5
20							1.4	1.45	1.35	1.35	1.4	1.5
21							1.4	1.45	1.35	1.35	1.4	2.9
22							1.4	1.45	1.35	1.35	1.4	2.75
23							1.45	1.45	1.35	1.35	1.4	2.65
24							1.45	1.75	1.4	1.4	1.35	2.5
25							1.45	1.5	1.4	1.5	1.35	2.35
26							1.4	1.65	1.4	1.6	1.35	2.2
27						1.75	1.4	1.4	1.4	1.5	1.35	2.0
28						1.7	1.4	1.4	1.35	1.45	1.4	1.85
29						1.65	1.4	1.4	1.35	1.45	1.45	1.75
30						1.6	1.6	1.4	1.35	1.45	1.4	2.4
31							1.5	1.4		1.4		2.25

Daily gage height, in feet, of Hawksbill Creek near Luray, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	2.0	1.9	1.55	2.3	1.9	1.6	1.6					
2	1.9	1.9	1.55	2.2	1.85	1.6	1.55					
3	3.3	1.9	1.8	2.1	1.85	1.55	1.55					
4	2.7	1.85	2.0	2.05	1.85	1.55	1.55					
5	2.45	1.85	1.95	2.0	1.8	1.5	1.55					
6	2.25	1.75	1.85	1.95	1.75	1.5	1.5					
7	2.2	1.7	1.85	1.95	1.75	1.5	1.5					
8	2.1	1.7	1.85	1.9	1.75	1.5	1.5					
9	2.0	1.7	1.8	1.9	1.75	1.5	1.5					
10	2.05	1.65	1.8	1.95	1.75	2.0	1.5					
11	2.0	1.65	1.75	1.9	1.75	1.8	1.8					
12	1.9	1.65	1.7	1.9	1.7	1.6	1.6					
13	1.8	1.65	1.7	1.8	1.7	1.55	1.55					
14	1.8	1.7	1.7	1.8	1.65	1.55	1.55					
15	1.8	1.65	1.75	[a]3.35	1.65	2.65	1.55					
16	1.8	1.6	1.8	3.05	1.65	1.95						
17	1.75	1.6	1.75	2.55	1.65	2.5						
18	1.75	1.6	1.75	2.35	1.6	1.8						
19	1.75	1.55	1.85	2.25	1.6	1.6						
20	1.75	1.55	1.9	2.2	1.6	1.6						
21	1.7	1.6	1.9	2.1	1.6	2.45						
22	1.65	1.55	1.9	2.0	1.55	1.75						
23	1.75	1.55	1.9	1.85	1.5	1.7						
24	1.75	1.5	1.9	1.85	1.5	1.7						
25	1.8	1.55	1.9	1.85	1.5	1.7						
26	1.8	1.55	1.9	2.1	1.5	1.8						
27	1.9	1.55	2.15	2.05	1.5	1.8						
28	1.9	1.55	2.4	2.0	1.6	1.75						
29	1.9		2.35	1.9	1.6	1.7						
30	1.9		2.3	1.9	1.55	1.65						
31	1.9		2.4		1.5							

[a] Gage height estimated Apr. 15, 1906.

Rating table for Hawksbill Creek near Luray, Va., from June 27, 1905, to July 15, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
1.30	24	1.90	83	2.50	196	3.00	326
1.40	30	2.00	98	2.60	220	3.10	355
1.50	37	2.10	115	2.70	245	3.20	384
1.60	46	2.20	133	2.80	271	3.30	414
1.70	57	2.30	152	2.90	298	3.40	445
1.80	69	2.40	173				

[a] This table is strictly applicable only for open-channel conditions. It is based on five discharge measurements made during 1905–6. It is fairly well defined between gage heights 1.4 feet and 2.0 feet.

Estimated monthly discharge of Hawksbill Creek near Luray, Va.

[Drainage area, 52 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1905.					
June 27 to 30	63	46	54.5	1.05	0.156
July	46	30	36.1	.694	.800
August	63	27	32.6	.627	.723
September	37	24	27.5	.529	.590
October	46	27	30.0	.577	.665
November	34	27	30.0	.577	.644
December	298	30	81.7	1.57	1.81
1906.					
January	414	52	100	1.92	2.21
February	83	37	53.9	1.04	1.08
March	173	42	85.2	1.64	1.89
April	430	69	123	2.37	2.64
May	83	37	53.6	1.03	1.19
June	232	37	68.8	1.32	1.47
July 1 to 15	69	37	42.7	.821	.458

SOUTH FORK OF SHENANDOAH RIVER NEAR FRONT ROYAL, VA.

South Fork of Shenandoah River is formed at Port Republic, Rockingham County, Va., by the union of North and South rivers, and flows northeastward to Riverton, Va., where it unites with North Fork to form the main Shenandoah. Its length by river course is about 96 miles.

The gaging station at Front Royal was established June 26, 1899, by A. P. Davis, and was discontinued July 17, 1906. It is located about 1 mile above the bridge, which is near the Norfolk and Western Railway station.

The channel is straight for 600 feet above and below the station, and the current is sluggish. The railroad follows the right bank of the stream, and the railroad embankment, a few feet back from the river, is overflowed at extreme flood stages only. The bed of the stream is composed of bed rock and is very uneven; in places the rock is overlain by silt, and this is liable to shift.

Discharge measurements were made from a cable, which has a span of 300 feet and is suspended over the branches of two large sycamore trees, with its right end fastened to the tree and its left anchored in the ground. The initial point for soundings is on the main cable 0.5 foot from the tree on the left bank.

The gage is a vertical timber spiked to a large sycamore tree on the left bank, about 800 feet upstream from the cable. A high-water gage, reading from 14 to 26 feet, was established September 18, 1905. It is a vertical board spiked to the shore side of a large sycamore tree, 325 feet upstream from the regular gage. The gage was read twice each day by Miss Brentie Johnson. The bench mark is a headless spike on the river side of an elm tree on the left bank, 8 feet downstream from the gage. It is 1.5 feet above the ground and has an elevation of 10.49 feet above the zero of the gage.

Estimates for this station are within 5 per cent of the true discharge for normal conditions of flow for gage heights below 9.0 feet. Above gage height 9.0 feet the probable error of the extension of the curve may be as much as 15 to 20 per cent. Estimates for the winter months are affected by ice conditions. All estimates published prior to 1905 have been revised.

A summary of the records furnishes the following results: Maximum discharge for twenty-four hours, 76,800 second-feet; minimum discharge for twenty-four hours, 305 second-feet; mean annual discharge for five years, 2,238 second-feet; mean annual rainfall for seven years, 37.45 inches.

Discharge measurements of South Fork of Shenandoah River near Front Royal, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1899.	*Feet.*	*Second-feet.*	1904.	*Feet.*	*Second-feet.*
September 1	4.40	616	June 11	4.79	1,140
			June 30	4.55	906
1900.			September 27	3.50	390
February 14	5.75	1,955	October 19	3.42	331
June 19	7.90	5,703			
September 8	4.00	536	1905.		
			April 4	4.78	1,203
1901.			May 16	5.28	1,663
July 21	6.95	4,211	September 18	3.95	527
			October 27	3.84	459
1902.			December 26	5.94	2,387
August 15	4.20	527			
			1906.		
1903.			June 16	4.70	1,066
August 19	4.90	1,065			

Daily gage height, in feet, of South Fork of Shenandoah River near Front Royal, Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
1							4.3	4.4	4.4	4.45	5.5	4.4
2							4.3	4.35	4.35	4.4	8.05	4.4
3							4.2	4.2	4.3	4.3	6.7	4.3
4							4.2	4.25	4.2	4.3	5.85	4.3
5							4.1	4.25	4.5	4.3	5.8	4.2
6							4.2	4.2	4.3	4.3	5.65	4.2
7							4.2	4.3	4.2	4.3	5.35	4.2
8							4.25	4.65	4.15	4.35	5.2	4.2
9							4.55	4.3	4.25	4.4	5.05	4.3
10							4.7	4.5	4.75	4.4	4.85	4.3
11							4.3	4.45	4.65	4.4	4.8	4.3
12							4.2	4.3	4.55	4.4	4.7	4.45
13							4.15	4.2	4.45	4.3	4.7	6.95
14							4.2	4.2	4.4	4.3	4.6	6.25
15							4.15	4.2	4.3	4.3	4.6	5.75
16							4.25	4.3	4.3	4.2	4.55	5.45
17							4.15	4.35	4.3	4.2	4.5	5.25
18							4.15	4.25	4.2	4.2	4.5	5.15
19							4.15	4.3	4.2	4.2	4.5	5.0
20							4.1	4.25	4.55	4.2	4.5	4.95
21							4.1	4.2	5.8	4.1	4.5	4.85
22							4.1	4.1	5.3	4.15	4.4	4.75
23							4.15	4.1	4.85	4.2	4.4	4.7
24							4.1	4.0	4.6	4.2	4.5	4.9
25							4.1	3.9	5.0	4.2	4.5	4.9
26						4.4	4.05	4.0	4.6	4.2	4.55	5.1
27						4.3	4.1	4.0	4.55	4.2	4.5	5.1
28						4.25	4.2	4.3	4.6	4.2	4.4	5.0
29						4.35	4.3	5.15	4.5	4.2	4.4	5.0
30						4.3	4.8	5.05	4.5	4.2	4.4	5.15
31							4.25	4.6		4.2		5.65

Daily gage height, in feet, of South Fork of Shenandoah River near Front Royal, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900.												
1	5.55	4.95	6.4	5.9	5.3	4.95	4.8	4.6	4.1	4.3	4.5	5.3
2	5.55	4.8	10.65	5.75	5.25	4.85	4.7	4.55	4.1	4.25	4.5	5.35
3	5.6	5.0	8.8	5.7	5.15	4.8	4.6	4.45	4.1	4.25	4.4	5.15
4	5.55	5.6	7.55	5.6	5.1	4.8	4.6	4.4	4.1	4.25	4.45	5.55
5	5.5	5.2	6.9	5.5	5.0	4.8	4.6	4.4	4.1	4.4	4.55	5.8
6	5.35	5.65	6.6	5.4	5.0	4.8	4.5	4.3	4.0	4.3	4.6	7.6
7	5.1	5.4	6.35	5.4	5.0	4.7	4.5	4.3	4.0	4.4	4.5	6.75
8	5.05	5.0	6.2	5.3	4.9	4.7	4.5	4.3	4.0	4.4	4.5	6.1
9	4.95	5.0	6.1	5.2	4.8	4.7	4.4	4.2	4.0	4.3	4.5	5.95
10	5.05	5.0	6.0	5.2	4.8	4.6	4.4	4.2	4.0	4.4	4.4	5.85
11	4.85	5.0	5.9	5.2	4.8	4.6	4.4	4.2	4.0	4.45	4.45	5.6
12	4.95	4.95	5.8	5.1	4.7	4.5	4.4	4.2	3.9	4.45	4.45	5.45
13	5.0	5.1	5.7	5.1	4.7	4.4	4.3	4.2	3.9	4.4	4.4	5.15
14	5.6	6.35	5.6	5.1	4.7	4.7	4.3	4.2	3.9	4.25	4.4	5.1
15	5.65	7.2	5.6	5.1	4.7	5.7	4.3	4.1	4.3	4.25	4.4	5.0
16	5.0	6.5	5.5	5.1	4.7	6.25	4.3	4.1	4.65	4.3	4.3	4.9
17	4.8	6.2	5.5	5.0	4.6	7.25	4.3	4.1	4.95	4.3	4.3	4.85
18	4.8	5.95	5.5	5.0	4.5	7.95	4.2	4.0	4.65	4.4	4.3	4.8
19	5.0	5.7	5.65	5.0	4.7	7.65	4.2	4.0	4.15	4.4	4.3	4.75
20	7.2	5.55	6.55	5.4	5.3	6.85	4.2	4.0	4.15	4.3	4.3	4.7
21	10.7	5.45	9.55	5.75	5.75	6.2	4.1	4.1	4.15	4.25	4.3	4.6
22	8.35	6.25	8.35	5.9	5.55	5.8	4.9	4.2	4.15	5.05	4.4	4.6
23	7.15	8.9	7.5	6.55	5.35	5.3	4.85	4.25	4.1	6.25	4.85	4.6
24	6.5	8.65	6.6	6.7	5.25	5.35	4.65	4.3	4.2	6.95	4.95	4.6
25	6.15	7.35	6.55	6.25	5.2	5.2	4.85	4.3	4.3	6.75	5.65	4.6
26	5.8	6.85	6.45	6.3	5.35	5.1	4.95	4.3	4.35	5.6	6.65	4.6
27	5.6	6.55	6.3	5.75	5.05	5.1	5.0	4.25	4.15	6.35	8.45	4.5
28	5.55	6.2	6.25	5.55	4.9	5.2	4.9	4.2	4.05	5.05	7.3	4.5
29	5.55	....	6.15	5.4	4.85	5.05	4.85	4.2	4.0	4.65	6.35	4.5
30	5.5	....	6.0	5.4	4.8	4.9	4.8	4.1	4.2	4.55	5.85	4.5
31	5.2	....	5.95	....	5.45	....	4.7	4.1	....	4.5	....	4.5
1901.												
1	4.5	4.65	4.3	5.45	6.25	7.7	7.2	6.05	6.75	9.55	4.5	5.7
2	4.5	4.6	4.25	5.6	6.1	7.3	7.05	5.95	6.6	9.35	4.5	5.55
3	4.4	4.6	4.3	5.85	5.95	6.9	6.8	5.9	6.35	8.6	4.9	5.4
4	4.4	4.9	4.3	9.8	5.8	6.75	6.4	6.05	6.1	7.45	4.8	5.35
5	4.4	5.1	4.3	8.3	5.75	6.55	6.05	5.45	5.85	6.65	4.75	5.25
6	4.4	4.9	4.3	8.2	5.6	6.45	6.2	6.65	5.65	5.8	4.65	5.15
7	4.4	4.9	4.2	7.7	5.55	6.7	6.3	8.2	5.45	5.65	4.6	5.1
8	4.4	4.5	4.25	7.25	5.5	7.5	6.2	7.8	5.9	5.45	4.5	5.2
9	4.2	4.5	4.3	6.7	5.9	7.15	6.05	7.0	5.75	5.25	4.5	5.35
10	4.25	4.9	4.35	6.45	7.4	6.85	5.95	6.45	5.55	5.05	4.5	5.4
11	4.4	4.9	7.05	6.15	7.25	6.6	5.7	6.8	5.35	4.95	4.5	5.5
12	5.3	4.8	10.25	5.85	7.0	6.15	5.45	6.65	5.2	4.8	4.5	5.55
13	7.35	4.7	7.7	5.6	6.5	5.95	5.3	6.55	5.05	5.3	4.45	5.6
14	7.15	4.5	6.7	5.65	6.2	5.85	11.5	6.45	4.9	5.05	4.4	5.7
15	6.75	4.5	6.25	16.3	6.45	5.7	9.6	6.25	5.4	4.95	4.4	11.5
16	6.3	4.5	5.85	11.0	6.45	7.15	9.3	6.15	5.25	4.9	4.4	14.95
17	5.75	4.9	5.65	8.65	5.95	9.9	8.1	5.95	5.05	4.8	4.5	10.1
18	5.45	4.85	5.5	7.95	5.8	8.7	7.5	5.9	4.95	4.75	4.4	8.05
19	5.3	4.75	5.4	7.55	5.65	7.3	7.35	5.75	4.8	4.7	4.4	7.6
20	5.3	4.6	5.25	7.25	5.6	6.85	7.0	6.55	4.75	4.9	4.4	7.25
21	5.3	4.5	5.2	18.5	5.5	10.3	6.75	7.5	4.7	4.85	4.4	6.45
22	5.3	4.3	5.7	15.8	8.25	8.65	6.55	8.05	4.9	4.8	4.4	5.85
23	5.15	4.3	5.35	11.35	17.5	7.6	6.35	7.75	4.75	4.7	4.55	5.65
24	5.0	4.4	5.4	8.9	10.5	6.75	6.25	7.45	4.7	4.7	5.7	5.45
25	4.95	4.4	5.4	7.8	9.4	6.45	6.0	4.95	4.65	4.6	6.15	5.4
26	4.85	4.35	5.5	7.35	11.5	6.25	5.8	5.5	4.6	4.6	6.0	5.35
27	4.9	4.3	5.65	7.2	10.9	6.15	5.4	6.4	4.5	4.8	5.55	5.55
28	4.8	4.3	5.75	6.95	9.5	6.1	6.85	6.45	5.15	4.7	5.3	6.55
29	4.8	....	5.95	6.65	8.9	6.0	6.7	6.25	6.9	4.6	4.95	10.0
30	4.7	....	5.85	6.35	8.5	7.35	6.6	5.95	8.7	4.6	4.75	18.0
31	4.7	....	5.5	....	6.1	....	6.35	5.8	....	4.55	....	13.5

Daily gage height, in feet, of South Fork of Shenandoah River near Front Royal, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.												
1	9.5	6.1	23.5	6.55	5.4	4.9	4.6	4.4	4.0	5.0	4.25	5.8
2	9.15	5.25	13.0	6.45	5.35	4.8	4.55	4.4	4.0	4.3	4.25	6.3
3	8.3	6.7	9.9	6.25	5.3	4.75	4.5	4.6	3.95	6.0	4.4	6.95
4	7.7	6.05	9.5	6.15	6.5	4.7	4.45	4.6	3.9	5.1	4.3	7.25
5	8.4	6.6	8.9	5.95	6.35	4.6	4.4	4.6	3.9	5.0	4.3	7.85
6	8.15	5.9	8.4	7.4	6.15	4.55	4.5	4.5	3.8	4.3	4.3	7.6
7	8.0	5.7	7.95	7.25	5.85	4.5	4.45	4.5	3.8	4.3	4.2	6.85
8	7.75	6.9	7.5	7.7	5.65	4.9	4.4	4.4	4.0	4.25	4.2	6.55
9	7.55	5.9	9.1	9.1	5.5	4.9	4.4	4.3	4.2	4.2	4.2	6.4
10	7.3	5.7	10.5	10.5	5.35	4.85	4.3	4.4	4.1	4.1	4.2	6.15
11	6.55	5.9	13.25	10.5	5.5	4.8	4.3	4.35	4.1	4.1	4.25	5.95
12	6.0	6.1	11.85	9.6	5.45	4.8	4.2	4.3	4.65	4.9	4.35	5.75
13	5.9	6.1	10.1	6.9	5.4	4.7	4.6	4.3	4.0	5.5	4.35	6.4
14	5.8	5.75	8.5	6.75	5.4	4.6	4.6	4.2	4.0	5.65	4.25	6.35
15	5.75	5.45	8.1	6.6	5.3	4.8	4.5	4.2	4.0	5.35	4.1	6.3
16	5.65	5.5	8.8	6.45	5.3	4.8	4.5	4.15	4.0	5.0	4.1	6.55
17	5.55	5.4	8.45	6.25	5.3	4.7	4.45	4.25	4.1	4.65	4.6	6.85
18	5.5	5.35	8.2	6.15	5.4	4.65	4.4	4.3	4.1	4.45	4.5	8.1
19	5.5	5.3	7.8	6.0	5.4	4.6	4.35	4.35	3.9	4.4	4.5	7.6
20	5.45	5.25	7.35	6.2	5.4	4.55	4.5	4.35	3.85	4.4	4.45	6.6
21	5.35	5.2	6.75	6.15	5.3	4.45	4.5	4.3	3.8	4.35	4.4	6.5
22	6.3	7.45	6.45	6.0	5.25	4.8	4.4	4.2	3.8	4.3	4.35	6.4
23	5.75	6.2	7.9	5.8	5.2	4.75	4.4	4.1	4.0	4.3	4.3	6.35
24	5.3	7.35	7.9	5.7	5.1	4.7	4.3	4.2	4.1	4.3	4.35	6.25
25	5.3	11.0	7.8	5.55	5.2	4.6	4.25	4.15	4.15	4.35	4.4	5.9
26	5.25	15.0	7.7	5.5	5.1	4.5	4.2	4.1	4.2	4.35	4.5	6.15
27	6.4	20.0	7.6	5.6	5.1	4.5	5.5	4.1	4.2	4.4	5.75	5.55
28	7.3	14.5	7.45	5.55	5.0	4.4	5.35	4.0	4.2	4.5	6.25	5.5
29	8.55	....	6.55	5.45	4.9	4.7	5.05	4.0	6.0	4.35	5.7	5.5
30	6.7	....	6.7	5.4	4.8	4.7	4.75	4.0	5.55	4.3	5.2	5.4
31	5.45	....	6.65	....	4.75	....	4.55	4.0	....	4.3	....	5.3
1903.												
1	5.25	7.05	12.25	9.15	5.8	7.4	8.55	4.9	7.6	4.6	4.4	4.75
2	6.1	6.6	9.4	8.1	5.7	6.5	7.0	4.9	6.45	4.6	4.45	4.8
3	9.3	6.4	7.9	7.6	5.7	5.95	6.75	4.9	5.65	4.5	4.5	4.8
4	11.25	8.2	7.45	7.35	5.6	5.75	6.55	5.35	5.35	4.5	4.55	4.9
5	8.75	7.65	7.1	7.25	5.45	5.4	6.15	5.5	5.2	4.5	4.55	4.5
6	7.7	7.15	6.75	6.95	5.5	6.0	5.75	5.6	5.15	4.5	4.5	4.5
7	7.15	6.95	6.55	6.8	5.4	7.95	6.25	5.15	5.05	4.4	4.45	4.4
8	6.7	6.65	6.65	6.7	5.4	11.0	5.95	4.85	4.85	5.5	4.4	4.35
9	6.5	6.45	6.85	6.65	5.35	10.15	5.75	4.75	4.75	5.5	4.4	4.3
10	6.1	6.25	6.75	6.55	5.3	7.9	5.55	4.7	4.8	6.0	4.45	4.4
11	5.8	6.05	6.7	6.45	5.3	7.85	5.35	4.85	4.75	4.5	4.5	4.5
12	5.75	6.1	6.6	6.35	5.25	7.7	5.25	5.3	4.7	4.7	4.4	4.55
13	5.7	6.3	6.5	6.25	5.2	7.7	5.5	5.1	4.7	4.6	4.4	4.6
14	5.75	6.15	6.45	8.4	5.15	6.7	8.15	4.8	4.7	4.55	4.4	4.5
15	5.75	6.1	6.25	10.55	5.1	6.65	7.6	4.75	4.6	4.5	4.4	4.5
16	5.4	6.7	6.15	9.35	5.05	6.6	5.9	4.7	4.5	4.4	4.4	4.4
17	5.4	7.6	6.0	8.4	5.1	6.5	5.6	4.75	4.4	4.4	4.4	4.4
18	5.4	8.75	5.9	7.9	5.1	6.45	5.35	4.8	7.8	4.5	4.5	4.3
19	5.3	7.7	5.85	7.45	5.0	6.4	5.25	4.7	7.5	4.6	4.5	4.3
20	5.3	7.1	5.75	7.1	5.0	6.4	5.05	4.7	6.7	4.65	4.4	4.3
21	5.75	6.65	5.7	6.9	5.0	6.4	5.0	4.6	6.55	4.55	4.3	4.35
22	6.95	6.25	5.85	6.8	4.95	6.35	5.9	4.6	5.55	4.5	4.3	4.4
23	7.25	6.15	7.4	6.65	4.9	6.3	5.6	4.5	5.4	4.5	4.3	4.5
24	6.6	6.6	11.6	6.45	4.9	6.25	5.75	4.5	5.3	4.5	4.4	4.5
25	6.25	6.8	9.65	6.25	5.0	5.95	5.7	4.5	5.2	4.5	4.4	4.75
26	5.85	6.65	8.15	6.2	5.0	5.75	5.6	4.5	5.1	4.45	4.5	5.1
27	5.95	6.7	7.65	6.15	5.1	6.35	5.45	4.4	4.95	4.5	4.5	5.05
28	7.3	7.3	6.95	6.05	5.15	7.4	5.25	4.5	4.85	4.5	4.7	5.1
29	9.75	....	6.85	6.0	5.2	8.55	4.95	4.9	4.75	4.45	4.65	5.5
30	8.6	....	7.0	5.9	5.5	8.45	4.75	5.3	4.6	4.4	4.7	5.5
31	7.6	....	10.65	....	5.95	....	4.8	5.75	....	4.4	....	5.2

Daily gage height, in feet, of South Fork of Shenandoah River near Front Royal, Va.—
Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.[a]												
1	4.95	4.2	4.85	5.2	6.4	4.95	4.5	4.1	3.6	3.4	3.42	3.45
2	4.75	4.1	4.85	5.05	5.85	5.05	4.4	4.05	3.6	3.4	3.4	3.4
3	4.75	4.15	5.05	4.85	5.45	5.3	4.3	4.1	3.6	3.4	3.4	3.5
4	5.05	4.25	4.95	4.7	5.15	6.2	4.2	4.3	3.6	3.4	3.4	3.5
5	5.05	4.25	5.05	4.65	5.1	6.45	4.1	4.4	3.6	3.4	3.42	3.5
6	4.8	4.0	5.0	4.6	5.0	6.5	4.1	4.5	3.65	3.4	3.4	3.45
7	4.7	4.05	5.05	4.6	5.0	6.0	4.05	4.7	3.7	3.4	3.42	3.42
8	4.6	4.85	7.3	4.6	5.0	5.4	4.0	4.45	3.7	3.4	3.45	3.45
9	4.55	4.65	7.4	4.7	5.15	5.05	4.2	4.4	3.7	3.4	3.5	3.45
10	4.45	4.85	6.7	5.25	5.7	4.95	5.5	4.75	3.7	3.4	3.42	3.52
11	4.4	4.85	6.0	5.75	5.85	4.75	7.95	4.6	3.7	3.4	3.4	4.15
12	4.5	4.7	5.75	5.7	5.65	4.7	7.45	4.5	3.7	3.45	3.4	4.4
13	4.55	4.6	5.55	5.35	5.35	4.65	5.4	4.4	3.7	3.55	3.4	4.6
14	4.55	4.5	5.2	5.15	5.25	4.55	4.75	4.2	3.65	3.45	3.55	4.8
15	4.4	4.4	5.1	4.95	4.9	4.5	4.55	4.15	4.15	3.4	3.5	3.95
16	4.25	4.4	5.0	4.85	4.9	4.4	4.4	4.1	3.95	3.4	3.52	4.1
17	4.25	4.35	4.9	4.8	4.9	4.6	4.35	4.0	3.7	3.4	3.5	4.1
18	4.3	4.4	4.9	4.65	5.3	4.65	4.3	4.0	3.6	3.4	3.45	4.2
19	4.4	4.6	4.9	4.55	5.7	4.4	4.35	3.9	3.6	3.4	3.45	3.9
20	4.35	4.75	4.7	4.5	7.6	4.55	4.25	3.8	3.6	3.45	3.4	3.9
21	4.35	4.85	4.7	4.5	6.75	5.0	4.1	3.8	3.5	3.55	3.42	3.7
22	4.9	5.4	4.7	4.4	5.9	5.15	4.1	3.75	3.5	3.5	3.4	3.7
23	6.75	6.9	4.95	4.4	5.45	5.05	4.0	3.65	3.5	3.45	3.42	3.88
24	8.15	7.9	4.95	4.3	5.25	4.75	4.3	3.6	3.5	3.4	3.42	3.95
25	[b] 5.75	[b] 7.7	4.95	4.4	5.1	4.4	4.4	3.6	3.5	3.4	3.42	3.9
26	5.05	7.15	5.05	4.45	5.0	4.3	4.3	3.55	3.5	3.4	3.4	3.8
27	4.8	6.35	5.1	5.5	4.95	4.35	4.2	3.5	3.4	3.42	3.4	3.95
28	4.65	5.75	5.1	6.25	4.9	4.4	4.35	3.5	3.4	3.4	3.4	3.9
29	4.45	5.2	5.0	6.8	4.9	4.7	4.15	3.5	3.4	3.4	3.4	4.5
30	4.35	....	5.25	6.65	4.8	4.5	4.2	3.55	3.4	3.4	3.4	4.2
31	4.25	....	5.3	....	4.8	....	4.2	3.6	....	3.4	....	4.0
1905.[c]												
1	3.7	4.15	....	5.4	4.3	4.35	4.85	4.85	4.3	3.7	3.82	3.7
2	3.85	4.05	....	5.4	4.2	4.25	4.7	4.7	4.38	3.7	3.7	3.8
3	3.95	4.0	....	5.28	4.2	4.15	4.55	4.6	4.85	3.7	3.8	3.8
4	4.0	4.15	....	5.2	4.0	4.3	4.5	4.5	4.65	3.6	3.78	3.75
5	4.0	4.35	6.15	4.75	4.2	4.25	6.25	4.4	4.5	3.6	3.75	3.8
6	4.0	4.25	5.85	5.15	4.15	4.2	5.7	4.4	4.4	3.6	3.8	3.82
7	4.6	4.2	5.4	5.3	4.2	4.1	5.35	4.35	4.35	3.55	3.75	3.88
8	5.15	4.3	5.05	5.15	4.1	4.1	5.05	4.25	4.3	3.6	3.7	4.25
9	5.2	4.3	5.5	5.1	4.05	4.0	4.95	4.2	4.15	3.6	3.72	4.18
10	4.6	4.5	6.65	5.1	4.0	4.0	4.8	4.1	4.0	3.6	3.72	4.05
11	4.45	4.45	8.25	5.0	4.05	4.0	4.65	4.1	3.9	3.6	3.7	4.0
12	4.85	4.4	7.4	4.8	4.15	4.0	5.15	4.0	3.88	3.65	3.8	4.12
13	4.85	4.35	6.9	4.9	4.0	4.0	6.2	4.25	3.8	3.6	3.72	4.05
14	5.1	4.4	6.52	4.8	5.45	3.9	7.45	4.4	3.9	3.7	3.7	3.95
15	5.55	4.45	6.15	4.8	5.2	3.9	6.8	5.25	4.0	3.72	3.6	4.05
16	5.2	4.35	6.0	4.7	5.28	3.8	7.6	6.2	3.95	3.8	3.65	4.15
17	5.05	4.35	5.85	4.7	5.55	3.8	6.45	6.28	3.9	3.7	3.58	4.15
18	4.9	4.4	5.8	4.6	5.55	3.8	5.7	5.65	3.9	3.7	3.65	4.25
19	4.9	4.3	5.8	4.5	5.2	3.8	5.25	5.1	3.9	3.75	3.7	4.12
20	4.45	4.3	5.75	4.4	4.45	4.2	5.0	4.78	3.9	3.75	3.7	4.0
21	4.32	4.4	5.95	4.35	4.65	5.25	4.85	4.45	3.9	3.72	3.75	5.5
22	4.22	4.4	7.0	4.3	4.45	4.95	4.6	4.3	3.8	3.72	3.68	8.32
23	4.28	4.75	7.6	4.3	4.4	5.05	5.8	4.25	3.82	3.6	3.68	8.0
24	4.1	4.95	6.9	4.3	4.35	6.2	6.9	4.2	3.82	3.5	3.62	6.75
25	3.95	5.7	6.75	4.42	4.3	9.35	6.55	4.15	3.75	3.6	3.6	6.4
26	4.15	6.45	5.55	4.4	4.25	7.3	6.35	4.1	3.7	3.65	3.65	5.95
27	4.15	8.0	6.35	4.5	4.2	6.1	6.2	4.1	3.7	3.78	3.7	5.55
28	4.1	....	6.25	4.45	4.3	5.65	6.05	4.3	3.78	3.82	3.7	5.25
29	4.3	....	5.95	4.3	4.15	5.25	5.5	4.4	3.8	3.8	3.65	5.25
30	4.25	....	5.65	4.3	4.55	4.9	5.15	4.35	3.68	3.8	3.62	5.45
31	4.05	....	5.55	....	4.55	....	5.0	4.3	....	3.82	....	5.85

[a] Ice conditions during January (ice about 8 inches thick) and December (ice about 3 inches thick), 1904.
[b] Gage heights January 25 to February 25, 1904, approximate. Gage not in correct position.
[c] Ice conditions during January and February, 1905

Daily gage height, in feet, of South Fork of Shenandoah River near Front Royal, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	5.65	5.43	4.2	7.05	5.22	4.7	5.45					
2	5.45	5.3	4.17	6.8	5.1	4.62	5.28					
3	5.25	5.2	4.23	6.45	5.0	4.5	5.25					
4	6.13	5.1	5.05	6.25	4.95	4.42	5.25					
5	8.47	4.85	7.02	5.85	4.9	4.38	4.9					
6	7.22	4.82	6.33	5.68	4.85	4.3	4.45					
7	6.4	4.9	5.8	5.52	4.88	4.22	4.65					
8	6.0	4.73	5.47	5.4	5.0	4.2	4.62					
9	5.65	4.65	5.15	5.32	5.1	4.18	4.4					
10	5.38	4.5	5.15	5.3	5.05	4.1	4.28					
11	5.17	4.52	5.05	5.4	5.0	4.1	4.3					
12	5.0	4.45	4.9	5.35	4.9	4.15	4.38					
13	5.0	4.4	4.83	5.28	4.8	4.22	5.32					
14	5.0	4.4	4.7	5.2	4.78	4.2	4.65					
15	5.05	4.43	4.8	6.35	4.6	4.4	4.4					
16	5.3	4.32	5.25	7.75	4.62	4.65	4.25					
17	5.3	4.4	5.95	6.8	4.52	5.45						
18	5.3	4.33	5.77	6.38	4.55	5.75						
19	5.2	4.3	5.8	6.08	4.45	5.35						
20	5.12	4.3	5.75	5.8	4.4	5.35						
21	5.0	4.3	5.8	5.55	4.35	6.2						
22	4.9	4.25	6.1	5.45	4.3	6.9						
23	4.93	4.22	5.9	5.35	4.28	6.05						
24	6.8	4.28	5.8	5.25	4.2	5.5						
25	6.85	4.25	5.6	5.05	4.2	5.35						
26	6.22	4.25	5.58	5.1	4.2	5.28						
27	5.75	4.12	5.77	5.35	4.22	5.72						
28	5.63	4.25	6.75	5.45	4.3	6.15						
29	5.6		7.35	5.4	4.65	5.5						
30	5.55		7.1	5.3	4.4	5.35						
31	5.55		6.9		4.72							

Rating tables for South Fork of Shenandoah River near Front Royal, Va.

JUNE 26, 1899, TO DECEMBER 31, 1903.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.80	305	5.10	1,220	6.40	2,990	11.00	13,610
3.90	350	5.20	1,330	6.50	3,150	12.00	16,590
4.00	400	5.30	1,440	6.60	3,320	13.00	20,000
4.10	455	5.40	1,560	6.70	3,490	14.00	24,000
4.20	515	5.50	1,680	6.80	3,660	15.00	28,500
4.30	580	5.60	1,810	7.00	4,010	16.00	33,300
4.40	650	5.70	1,940	7.20	4,370	17.00	38,300
4.50	720	5.80	2,080	7.40	4,750	18.00	43,500
4.60	795	5.90	2,220	7.60	5,150	19.00	48,900
4.70	870	6.00	2,370	7.80	5,570	20.00	54,700
4.80	950	6.10	2,520	8.00	6,000	22.00	66,900
4.90	1,030	6.20	2,670	9.00	8,300	24.00	80,200
5.00	1,120	6.30	2,830	10.00	10,910		

[a] This table is strictly applicable only for open-channel conditions. It is based on five discharge measurements made during 1899–1903. It is well defined between gage heights 4.2 feet and 6.0 feet. Above gage height 8.0 feet estimates are based on a discharge curve which is the product of a well-defined area curve and an approximate extension of the velocity curve. The discharge curves for the periods 1899–1905, inclusive, are the same above gage height 10.6 feet.

Rating tables for South Fork of Shenandoah River near Front Royal, Va.—Continued.

JANUARY 1, 1904, TO JULY 16, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.40	320	4.50	890	5.60	2,070	6.70	3,770
3.50	350	4.60	970	5.70	2,210	6.80	3,940
3.60	385	4.70	1,060	5.80	2,350	6.90	4,120
3.70	425	4.80	1,150	5.90	2,490	7.00	4,300
3.80	465	4.90	1,250	6.00	2,640	7.20	4,680
3.90	510	5.00	1,350	6.10	2,790	7.40	5,080
4.00	560	5.10	1,460	6.20	2,940	7.60	5,480
4.10	610	5.20	1,570	6.30	3,100	7.80	5,900
4.20	670	5.30	1,690	6.40	3,260	8.00	6,320
4.30	740	5.40	1,810	6.50	3,430	9.00	8,550
4.40	810	5.50	1,940	6.60	3,600	10.00	10,980

[a] This table is strictly applicable only for open-channel conditions. It is based on 9 discharge measurements made during 1904 to 1906. It is well defined between gage heights 3.4 feet and 5.3 feet. Above gage height 8.0 feet estimates are based upon a discharge curve which is the product of a well defined area curve and an approximate extension of the velocity curve. Above gage height 10.6 feet both rating tables are the same.

Estimated monthly discharge of South Fork of Shenandoah River near Front Royal, Va.

[Drainage area, 1,570 square miles.[a]]

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1899.								
January							2.52	
February							4.95	
March							5.12	
April							1.16	
May							4.95	
June 26–30	650	547	594	.378	.070		[b] 2.09	
July	950	428	538	.343	.395	16	2.51	2.11
August	1,275	350	599	.382	.440	11	3.94	3.50
September	2,080	485	759	.484	.540	14	3.78	3.24
October	685	455	559	.356	.410	18	2.34	1.93
November	6,110	650	1,236	.788	.879	109	.81	—.07
December	3,920	515	1,121	.714	.823	61	1.34	.52
The year							35.51	
1900.								
January	12,800	950	2,265	1.44	1.66	65	2.57	.97
February	8,060	950	2,492	1.59	1.66	45	3.73	2.01
March	12,680	1,680	3,551	2.26	2.61	70	3.72	1.14
April	3,490	1,120	1,755	1.12	1.25	66	1.89	.67
May	2,010	720	1,160	.739	.852	35	2.42	1.57
June	5,890	650	1,708	1.09	1.22	20	5.98	4.76
July	1,120	515	776	.495	.571	15	3.76	3.19
August	795	400	538	.343	.395	21	1.93	1.53
September	1,070	350	499	.318	.355	11	3.14	2.78
October	3,920	547	1,042	.664	.765	24	3.19	2.43
November	7,005	580	1,285	.819	.914	31	2.94	2.03
December	5,150	720	1,417	.903	1.04	57	1.83	.79
The year	12,800	350	1,540	.982	13.29	36	37.10	23.81

[a] Drainage area of 1,570 square miles used to obtain the run-off for 1906, and 1,569 used for all other years.
[b] Precipitation for complete month, June, 1899.

Estimated monthly discharge of South Fork of Shenandoah River near Front Royal, Va.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1901.								
January	4,655	515	1,366	.871	1.00	43	2.31	1.31
February	1,220	580	818	.521	.542	164	.33	—.21
March	11,580	515	1,975	1.26	1.45	38	3.80	2.35
April	46,200	1,810	8,374	5.34	5.96	95	6.24	.28
May	40,900	1,680	5,768	3.68	4.24	73	5.82	1.58
June	11,720	1,940	4,302	2.74	3.06	41	7.54	4.48
July	15,070	1,440	3,912	2.49	2.87	65	4.38	1.51
August	6,440	1,075	3,204	2.04	2.35	40	5.92	3.57
September	7,580	720	1,825	1.16	1.29	34	3.78	2.49
October	9,730	758	2,020	1.29	1.49	216	.69	—.80
November	2,595	650	966	.616	.687	34	2.01	1.32
December	43,500	1,220	5,984	3.81	4.39	72	6.12	1.73
The year	46,200	515	3,319	2.11	29.33	60	48.94	19.61
1902.								
January	9,600	1,385	3,730	2.38	2.74	102	2.69	—.05
February	54,700	1,330	6,439	4.10	4.27	96	4.46	.19
March	76,800	3,070	9,871	6.29	7.25	201	3.61	—3.64
April	12,260	1,560	3,826	2.44	2.72	122	2.23	—.49
May	3,150	910	1,579	1.01	1.16	44	2.64	1.48
June	1,030	650	861	.549	.612	21	2.93	2.32
July	1,680	515	754	.481	.554	25	2.17	1.62
August	795	400	571	.364	.420	19	2.22	1.80
September	2,370	305	531	.338	.377	15	2.59	2.21
October	2,370	455	848	.540	.623	17	3.65	3.03
November	2,750	455	784	.500	.558	17	3.21	2.65
December	6,220	1,440	3,040	1.94	2.24	66	3.38	1.14
The year	76,800	305	2,736	1.74	23.52	66	35.78	12.26
1903.								
January	14,320	1,385	3,859	2.46	2.84	70	4.08	1.24
February	7,700	2,445	3,768	2.40	2.50	72	3.49	.99
March	17,390	1,940	5,043	3.21	3.70	89	4.15	.45
April	12,400	2,220	4,494	2.86	3.19	88	3.62	.43
May	2,295	1,030	1,417	.903	1.04	39	2.69	1.65
June	13,610	1,560	4,308	2.74	3.06	40	7.63	4.57
July	7,225	910	2,338	1.49	1.72	56	3.06	1.34
August	2,010	650	1,046	.667	.769	22	3.53	2.76
September	5,570	650	1,738	1.11	1.24	51	2.42	1.18
October	2,370	650	842	.537	.619	26	2.39	1.77
November	870	580	691	.440	.491	60	.82	.33
December	1,680	580	853	.544	.627	66	.96	.33
The year	17,390	580	2,533	1.61	21.80	56	38.84	17.04
1904.								
January [a] [b]	6,650	705	1,293	.824	.950	53	1.80	.85
February [b]	6,110	560	1,649	1.05	1.13	90	1.26	.13
March	5,080	1,060	1,746	1.11	1.28	62	2.08	.80
April	3,940	740	1,486	.947	1.06	40	2.64	1.58
May	5,480	1,150	1,875	1.20	1.38	40	3.43	2.05
June	3,430	740	1,375	.876	.977	18	5.57	4.59
July	6,215	560	1,117	.712	.821	16	5.04	4.22
August	1,105	350	613	.391	.451	18	2.53	2.08
September	640	320	395	.252	.281	14	1.95	1.67
October	368	320	326	.208	.240	20	1.20	.96
November	368	320	329	.210	.234	24	.95	.72
December [a]	1,150	320	530	.338	.390	16	2.46	2.07
The year	6,650	320	1,061	.676	9.19	30	30.91	21.72

[a] Ice conditions during January and December, 1904; no correction made in estimates.
[b] Estimates January 25 to February 25, 1904, approximate.

Estimated monthly discharge of South Fork of Shenandoah River near Front Royal, Va.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1905.								
January [a]	2,005	425	917	.584	.673	24	2.79	2.12
February 1-27 [a]	6,320	560	1,140	.726	.729	....	[b] 2.11	....
March 5-31	6,870	1,405	3,104	1.98	1.99	....	[b] 2.25	....
April	1,810	740	1,143	.728	.812	39	2.08	1.27
May	2,005	560	920	.586	.676	20	3.45	2.77
June	9,380	465	1,372	.874	.975	23	4.30	3.32
July	5,480	890	2,236	1.42	1.64	26	6.23	4.59
August	3,068	560	1,014	.646	.745	25	2.90	2.16
September	1,200	417	595	.379	.423	25	1.68	1.26
October	474	350	417	.266	.307	12	2.65	2.34
November	474	378	425	.271	.302	36	.83	.53
December	7,024	425	1,476	.941	1.08	28	3.81	2.73
The year	....	....	....	....	....	....	35.08	....

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1906.					
January	7,354	1,250	2,283	1.45	1.67
February	1,849	622	957	.610	.635
March	4,980	652	2,233	1.42	1.64
April	5,795	1,405	2,393	1.52	1.70
May	1,594	670	1,049	.668	.770
June	4,120	610	1,464	.932	1.04
July 1-16	1,875	705	1,139	.725	.431

[a] Ice conditions during January and February, 1905; no correction made in estimates.
[b] Precipitation for complete month, February and March, 1905.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN SOUTH FORK OF SHENANDOAH RIVER BASIN BELOW PORT REPUBLIC.

The following miscellaneous discharge measurements were made in the basin of South Fork of Shenandoah River below Port Republic:

Miscellaneous discharge measurements in South Fork of Shenandoah River basin below Port Republic.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Feet per sec.*	*Second-feet.*
1895.						
August 7	South Fork of Shenandoah River.	At Southern Rwy. bridge, 400 feet above junction of North and South Forks, near Riverton, Va.	....	304	2.60	791
1897.						
October 4	.....do	.....do	....	252	2.27	572
October 31	.....do	Near Elkton, Va	....	464	.84	389
Do	Elk Run	.....do	11	8.4	.65	5.5
October 30	Naked Creek	Near Verbena, Va., ½ mile above mouth	....	....	....	[a] 25
October 27	Hawksbill Creek	Near Luray, Va	31	66	1.08	[b] 71
October 6	Flint Run	Near mouth, 5 miles above Front Royal, Va.	8	5	.64	[c] 3.2
Do	Gooneys Creek	100 yards above mouth, under Norfolk and Western Rwy. bridge, 5 miles above Front Royal, Va.	6	5	.46	[d] 2.3

[a] Includes 11 second-feet in tail race below mill.
[b] Discharge probably increased by rains of preceding week.
[c] Flint Run fed by large springs.
[d] Flow stated to be exceptionally low.

NORTH FORK OF SHENANDOAH RIVER BASIN.

PASSAGE CREEK AT BUCKTON, VA.

Passage Creek rises on Massanutten Mountain, in the western part of Page County, Va., flows northeastward, and joins North Fork of Shenandoah River about 5 miles above Riverton, Va.

The gaging station was established October 26, 1905, by Robert Follansbee and was discontinued July 16, 1906. It is located about 700 feet above the mouth of the creek, at the trestle of the Southern Railway at Buckton, which is a siding 1 mile east of Waterlick, Va.

The channel is straight for 200 feet above and 100 feet below the station. The current is moderate at the measuring section, but from a point 100 feet below the section to the mouth of the creek the velocity is rapid, the fall in that distance being from 6 to 8 feet. The banks above the bridge are fairly high, wooded, and not liable to overflow. Below the bridge they are low and liable to overflow during very high water, the flood plain being several hundred feet wide at such times. The channel between abutments is broken by seven trestle bents, and there are from three to eight channels, according to the stage of the river.

Discharge measurements at ordinary and low stages were made from the railway trestle or by wading a short distance above at a point where conditions are better. High-water measurements can be made from the highway bridge 2 miles upstream. This latter is not a good section at ordinary stages, as the current is too sluggish.

A staff gage, which is read once each day and oftener in floods by Nehemiah Messick, is nailed vertically to the third trestle bent from the left abutment.

The bench mark is the head of a nail 4 feet above ground, driven horizontally in a blaze on a tree situated 15 feet downstream from the lower end of the wing wall on the right bank; elevation, 5.41 feet above gage datum.

No estimates of flow have been made for this station, as the number of measurements is insufficient.

Discharge measurements of Passage Creek at Buckton, Va.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*	1906.	*Feet.*	*Second-feet.*
October 26	1.23	40	April 13	1.40	91
December 27	1.25	50	June 16	1.72	132

Daily gage height, in feet, of Passage Creek at Buckton, Va.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1905.				1905.				1905.			
1	......	0.95	0.9	12	......	0.85	0.9	23	......	0.9	2.35
2	......	.9	.9	13	......	.9	.95	24	......	.85	2.0
3	......	.95	.95	14	......	.85	.9	25	......	.9	1.95
4	......	.9	1.4	15	......	.9	.95	26	1.2	.9	1.45
5	......	.95	1.2	16	......	.95	1.15	27	1.15	.85	1.4
6	......	.95	1.2	17	......	.85	[a]1.1	28	1.15	.9	1.25
7	......	.9	1.1	18	......	.9	[a]1.15	29	.9	.85	2.2
8	......	.95	1.15	19	......	.85	[a]1.1	30	.95	.95	1.8
9	......	.9	.95	20	......	.95	1.15	31	.95	......	1.4
10	......	.95	.95	21	......	.9	3.15				
11	......	.95	.95	22	......	.9	3.1				

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.[b]												
1	1.4	1.2	1.1	2.6	1.3	.85	1.3	......	......	......	......	......
2	1.35	1.25	1.0	2.2	1.3	.95	1.2	......	......	......	......	......
3	1.3	1.3	1.1	1.9	1.3	.9	1.2	......	......	......	......	......
4	3.4	1.3	3.1	1.8	1.25	.85	1.2	......	......	......	......	......
5	2.0	1.3	2.2	1.7	1.25	.9	1.1	......	......	......	......	......
6	1.8	1.4	1.6	1.6	1.25	1.1	1.0	......	......	......	......	......
7	1.5	1.4	1.5	1.6	1.25	1.0	.9	......	......	......	......	......
8	1.5	1.6	1.5	1.5	1.3	.9	.9	......	......	......	......	......
9	1.5	1.7	1.5	1.3	1.25	.85	.85	......	......	......	......	......
10	1.55	1.6	1.4	1.9	1.2	.85	.85	......	......	......	......	......
11	1.55	1.5	1.3	1.6	1.2	.85	.85	......	......	......	......	......
12	1.5	1.5	1.3	1.5	1.2	1.1	.8	......	......	......	......	......
13	1.4	1.2	1.3	1.4	1.2	1.0	1.0	......	......	......	......	......
14	1.4	1.1	1.3	1.4	1.2	.9	.85	......	......	......	......	......
15	1.5	1.1	1.4	2.5	1.1	.9	.85	......	......	......	......	......
16	1.45	1.2	1.4	2.4	1.1	1.6	......	......	......	......	......	......
17	1.4	1.15	1.35	2.0	1.0	2.55	......	......	......	......	......	......
18	1.3	1.15	1.4	1.85	1.0	3.2	......	......	......	......	......	......
19	1.3	1.1	1.6	1.7	1.0	2.2	......	......	......	......	......	......
20	1.3	1.1	1.5	1.6	1.0	2.1	......	......	......	......	......	......
21	1.2	1.0	1.6	1.55	1.0	2.4	......	......	......	......	......	......
22	1.2	1.0	1.8	1.5	.95	2.52	......	......	......	......	......	......
23	1.2	1.0	2.2	1.4	.9	2.1	......	......	......	......	......	......
24	1.25	1.0	2.1	1.4	.9	1.95	......	......	......	......	......	......
25	1.2	1.0	2.1	1.4	.8	1.9	......	......	......	......	......	......
26	1.2	1.0	2.1	1.4	.75	1.7	......	......	......	......	......	......
27	1.2	1.0	2.6	1.65	.8	2.6	......	......	......	......	......	......
28	1.25	1.1	3.4	1.5	.95	1.7	......	......	......	......	......	......
29	1.2	......	3.4	1.4	1.0	1.6	......	......	......	......	......	......
30	1.2	......	3.3	1.35	.9	1.4	......	......	......	......	......	......
31	1.2	......	2.6	....	.85	......	......	......	......	......	......	......

[a] Creek frozen December 17-19, 1905. [b] Ice conditions February 4-13, 1906.

NORTH FORK OF SHENANDOAH RIVER NEAR RIVERTON, VA.

North Fork of Shenandoah River rises in the northern part of Rockingham County, Va., and flows in a very tortuous southeastward and northeastward course to Riverton, Va., where it unites with South Fork to form the main Shenandoah. Its drainage area is 1,040 square miles.

The flow of this stream is rather variable, although the discharge of some of its tributaries, especially in the upper part of the valley, is constant. The mills on North Fork are small, and the dams are generally of wood or brush.

The gaging station was established June 26, 1899, by A. P. Davis, and was discontinued July 15, 1906. It is located about 2 miles above Riverton, on the farm owned by L. W. Burke. It is most easily reached by driving from Front Royal.

The channel is straight for 600 feet above and below the station. The current has a moderate velocity. Both banks are low and liable to overflow and are fringed with trees. The bed of the stream is composed of rock and mud and shifts somewhat, but the flow is controlled by the dam at Riverton, 2 miles below. There is but one channel at all stages.

Discharge measurements were made by means of a cable, car, and tagged wire just above the ford. The cable has a span of 260 feet, is supported by timbers, and is anchored in the ground at each end. The initial point for soundings is 0.5 foot from the timber which supports the tag wire on the left bank.

The original gage was a vertical timber bolted to a large sycamore tree on the right bank. On September 10, 1900, the gage was removed to the left bank, and its datum was lowered 1 foot, causing all readings to be increased by 1 foot. The gage at this station was washed out in the flood of February 22, 1902, and the station was abandoned until August 17, 1902, when it was reestablished, the zero of the new gage being at the same elevation as the zero of the preceding gage. The vertical gage rod is spiked to a sycamore tree on the left bank 100 feet above the cable station. The gage was read twice each day by L. W. Burke. The bench mark is a wire nail driven into a pear tree, located near a fence, 150 feet from the left bank of the river. Its elevation above the zero of the gage is 26.75 feet.

All estimates published prior to 1905 have been revised. The plotting of the discharge measurements gives three distinct curves. The change from the first to the second curve occurred some time between June 20, 1901, and August 16, 1902. It was due, to a slight extent, to changes at the cable section, but chiefly to a radical change at some controlling point below the cable. The change from the second to the third curve was due to an increase in the height of the dam at Riverton from 8 feet to 10 feet during August, 1904. Estimates below gage height 6.5 feet as based on the first two curves are considered to be within 5 per cent and as based on the third curve within 5 per cent or less of the true discharge for normal conditions of flow. Estimates above gage height 6.5 feet may be in error from 10 to 15 per cent. Estimates for June 20, 1901, to August 16, 1902, are also liable to errors as high as 20 to 50 per cent owing to lack of information concerning the exact date when the change in conditions of flow took place. Estimates for August, 1904, are also liable to considerable error from the same cause. Ice conditions at and below the gage affect the flow during the winter months.

A summary of the records furnishes the following results: Maximum discharge for twenty-four hours, 21,630 second-feet; minimum discharge for twenty-four hours, 90 second-feet; mean annual rainfall for seven years, 37.91 inches.

Discharge measurements of North Fork of Shenandoah River near Riverton, Va.

Date.	[a] Gage height.	Discharge.	Date.	[a] Gage height.	Discharge.
1899.	*Feet.*	*Second-feet.*	1904.	*Feet.*	*Second-feet.*
September 2	3.85	270	June 10	4.81	578
September 2 [b]	3.85	287	July 1	4.71	480
			September 27	3.95	93
1900.			October 19	4.11	130
February 13	4.25	645			
June 18	6.30	2,923	1905.		
September 10 [b]	3.60	146	April 3	5.18	645
			May 17	5.68	989
1901.			October 27	4.48	273
July 20	5.95	2,410	December 27	5.60	961
1902.			1906.		
August 16	4.20	256	April 13	5.60	969
1903.					
August 21	4.40	388			

[a] All gage heights refer to 1905 datum. [b] Measured by wading.

Daily gage height, in feet, of North Fork of Shenandoah River near Riverton, Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.[a] [b]												
1							3.8	3.68	3.88	3.7	4.2	3.68
2							3.8	3.68	3.88	3.68	3.95	3.7
3							3.78	3.68	3.95	3.6	3.95	3.65
4							3.8	3.7	3.85	3.65	3.95	3.65
5							3.73	3.65	3.72	3.7	3.85	3.62
6							3.78	4.0	3.72	3.68	3.8	3.6
7							3.8	3.95	3.72	3.65	3.8	3.62
8							3.8	3.95	3.7	3.65	3.8	3.65
9							3.8	3.82	3.7	3.68	3.8	3.6
10							3.8	3.8	3.7	3.7	3.8	3.62
11							3.8	3.72	3.7	3.7	3.78	3.65
12							3.78	3.7	3.72	3.7	3.75	3.68
13							3.75	3.7	3.72	3.7	3.73	3.8
14							3.75	3.72	3.7	3.7	3.7	3.85
15							3.7	3.7	3.7	3.7	3.7	3.9
16							3.68	3.78	3.68	3.65	3.7	3.9
17							3.68	3.78	3.7	3.65	3.7	3.9
18							3.78	3.78	3.68	3.7	3.7	3.9
19							3.75	3.7	3.6	3.68	3.7	3.88
20							3.7	3.65	3.8	3.7	3.7	3.8
21							3.68	3.62	3.8	3.65	3.7	3.8
22							3.68	3.62	3.8	3.65	3.7	3.8
23							3.65	3.68	3.8	3.65	3.7	3.8
24							3.58	3.65	3.8	3.65	3.7	3.8
25							3.62	3.62	3.8	3.7	3.7	3.82
26						3.85	3.7	3.65	3.8	3.7	3.7	3.88
27						3.88	3.68	3.62	3.78	3.7	3.7	4.0
28						3.88	3.85	3.7	3.75	3.7	3.7	4.0
29						3.88	4.12	3.68	3.7	3.7	3.65	4.0
30						3.8	3.8	3.95	3.7	3.68	3.68	4.0
31							3.7	3.9		3.75		4.0

[a] All gage heights June 26, 1899, to September 10, 1900, refer to 1906 datum. Datum lowered 1.00 foot September 10, 1900.
[b] River frozen December 26–31, 1899.

Daily gage height, in feet, of North Fork of Shenandoah River near Riverton, Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1900.[a] [b]												
1	4.0	5.0	5.05	4.7	4.25	3.8	3.9	3.72	3.6	3.8	3.7	4.15
2	4.0	5.0	7.85	4.58	4.17	3.8	3.9	3.65	3.6	3.8	3.72	3.92
3	4.0	5.0	6.55	4.52	4.15	3.8	3.85	3.6	3.62	3.75	3.7	4.02
4	4.0	5.0	5.4	4.48	4.1	3.9	3.78	3.55	3.62	3.7	3.75	4.48
5	4.0	4.9	5.1	4.4	4.05	3.88	3.72	3.52	3.58	3.7	3.7	6.1
6	4.0	4.5	4.88	4.32	4.05	3.82	3.72	3.5	3.6	3.7	3.7	5.7
7	4.0	4.38	4.82	4.28	4.0	3.8	3.7	3.5	3.6	3.78	3.7	5.15
8	4.0	4.1	4.75	4.25	3.98	3.8	3.7	3.55	3.58	3.8	3.7	4.7
9	4.0	4.0	4.68	4.2	3.95	3.8	3.68	3.58	3.6	3.7	3.65	4.45
10	4.0	3.95	4.6	4.15	3.92	3.8	3.68	3.6	3.6	3.7	3.62	4.45
11	4.0	4.0	4.5	4.15	3.9	3.75	3.62	3.6	3.6	3.68	3.7	4.35
12	4.0	3.98	4.42	4.15	3.9	3.72	3.62	3.58	3.6	3.65	3.6	4.0
13	4.0	4.12	4.38	4.15	3.9	3.7	3.62	3.5	3.58	3.7	3.6	3.95
14	3.98	5.1	4.35	4.15	3.9	3.72	3.65	3.5	3.6	3.7	3.68	3.95
15	3.92	5.2	4.35	4.1	3.9	3.75	3.62	3.5	3.6	3.7	3.65	4.0
16	3.9	4.87	4.35	4.1	3.82	3.78	3.6	3.55	3.7	3.7	3.6	3.95
17	3.8	4.62	4.3	4.1	3.8	4.45	3.68	3.6	3.68	3.78	3.6	4.05
18	3.8	4.42	4.25	4.1	3.8	5.75	3.62	3.6	3.65	3.8	3.62	3.9
19	3.92	4.35	4.5	4.2	3.8	5.75	3.6	3.55	3.68	3.75	3.62	3.9
20	4.92	4.35	6.95	4.55	3.8	4.98	3.6	3.55	3.6	3.7	3.65	3.78
21	7.3	4.25	8.2	4.6	3.8	4.62	3.62	3.5	3.6	3.7	3.7	3.7
22	5.65	4.75	6.7	4.6	3.8	4.3	3.7	3.62	3.58	3.7	3.62	3.6
23	4.9	6.98	5.9	5.22	3.8	4.2	3.82	3.6	3.58	3.7	3.6	3.8
24	4.55	6.3	5.42	5.4	3.8	4.15	5.28	3.6	3.6	3.75	3.68	3.75
25	4.25	5.63	5.18	5.1	3.8	4.08	4.32	3.6	3.6	3.78	3.7	3.7
26	4.02	5.15	5.0	4.75	3.8	4.0	4.22	3.6	3.6	3.85	4.65	3.75
27	4.0	4.9	5.0	4.62	3.8	3.92	4.0	3.55	3.6	3.9	7.0	3.8
28	4.0	4.8	4.9	4.5	3.8	3.9	3.92	3.6	3.62	3.8	5.25	3.78
29	4.5	......	4.9	4.42	3.8	3.9	3.82	3.62	3.72	3.75	5.35	3.78
30	5.0	......	4.85	4.32	3.8	3.9	4.08	3.6	3.95	3.72	4.45	3.72
31	5.0	......	4.8	......	3.75	......	3.8	3.62	......	3.7	......	3.72
1901.[c]												
1	3.72	3.95	3.7	4.38	4.98	6.1	4.95	4.2	5.25	5.02	3.8	3.95
2	3.75	3.9	3.7	4.4	4.9	5.65	4.75	4.28	5.55	4.65	3.8	3.82
3	3.8	3.85	3.7	6.0	4.8	5.15	4.7	4.1	5.2	4.4	3.8	3.98
4	3.78	3.78	3.8	7.65	4.72	5.48	4.7	4.05	4.92	4.35	3.8	4.42
5	3.8	3.8	3.78	6.6	4.65	4.85	4.5	4.05	4.75	4.3	3.8	4.45
6	3.85	3.9	3.8	6.25	4.6	5.95	4.8	4.3	4.4	4.22	3.8	4.52
7	3.75	3.95	3.85	6.25	4.5	6.6	5.5	5.8	4.25	4.1	3.8	4.35
8	3.8	3.88	3.85	5.9	4.42	7.1	4.3	5.5	4.22	4.15	3.8	4.25
9	3.72	3.82	3.8	5.4	5.15	5.9	4.45	4.8	4.1	4.1	3.8	4.38
10	3.7	3.82	3.85	5.1	6.25	5.4	4.35	4.45	4.05	3.95	3.8	4.3
11	4.15	3.82	11.25	4.85	6.62	5.0	4.4	4.3	4.2	3.95	3.7	4.4
12	5.3	3.8	9.05	4.7	6.25	4.78	4.7	5.2	4.1	4.0	3.6	4.4
13	5.75	3.9	6.5	4.6	5.65	5.1	4.7	5.55	4.02	3.95	3.6	4.35
14	5.1	4.0	5.68	7.45	5.3	5.3	6.4	4.7	4.0	3.9	3.7	4.4
15	4.85	3.95	5.35	12.6	4.85	4.95	6.9	4.4	4.0	3.9	3.7	10.6
16	4.68	3.88	4.98	8.3	4.68	12.15	6.82	4.6	4.15	3.82	3.8	9.1
17	4.45	3.8	4.75	6.9	4.6	11.1	7.1	4.58	4.15	3.8	3.8	6.2
18	4.3	3.8	4.62	6.25	4.72	7.5	6.48	4.35	4.15	3.8	3.8	5.5
19	4.3	3.82	4.52	5.85	4.55	6.25	6.95	4.55	4.1	3.8	3.7	5.1
20	5.55	3.78	4.2	7.4	4.52	5.9	6.1	4.4	4.05	3.82	3.7	4.9
21	4.95	3.8	4.9	16.5	4.65	6.95	5.3	4.15	3.95	3.78	3.7	8.0
22	4.35	4.0	4.9	12.45	7.05	6.75	4.95	4.05	3.88	3.75	3.8	7.5
23	4.05	3.98	4.9	8.5	14.7	6.2	4.75	4.05	3.88	3.7	3.85	7.5
24	3.98	3.95	4.82	6.8	8.7	5.75	4.55	4.2	3.8	3.7	5.25	7.5
25	4.0	3.92	4.7	6.65	7.15	5.25	4.5	4.6	3.8	3.72	4.85	7.5
26	3.98	3.85	4.62	6.1	6.55	5.3	4.3	4.75	3.7	3.8	4.5	7.5
27	4.0	3.82	4.75	5.7	6.65	5.55	4.35	4.5	3.65	3.8	4.25	7.5
28	4.0	3.72	4.75	5.3	7.05	4.7	4.3	4.25	3.65	3.8	4.35	6.9
29	3.95	......	4.55	5.1	7.2	5.4	4.15	4.3	5.15	3.82	4.05	8.2
30	3.92	......	4.5	5.0	6.7	5.6	4.65	4.5	5.9	3.82	4.0	13.1
31	3.9	......	4.45	......	6.2	......	4.35	4.9	......	3.8	......	8.25

[a] All gage heights June 26, 1899, to September 10, 1900, refer to 1906 datum. Datum lowered 1.00 foot September 10, 1900.

[c] River frozen January 1–14 and January 30 to February 6, 1900.

[d] Ice conditions during part of January and February, 1901; river frozen December 21 to 28, 1901.

Daily gage height, in feet, of North Fork of Shenandoah River near Riverton, Va.—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.[a]												
1	7.05	4.9	......	......	......	......	......	......	4.05	4.3	4.1	5.45
2	6.2	4.88	......	......	......	......	......	......	4.05	4.2	4.15	5.75
3	5.75	4.8	......	......	......	......	......	......	4.1	4.2	4.1	5.85
4	5.4	5.2	......	......	......	......	......	......	4.35	4.2	4.15	5.9
5	5.0	5.5	......	......	......	......	......	......	4.1	4.2	4.05	5.85
6	4.9	5.5	......	......	......	......	......	......	4.05	4.2	4.2	5.8
7	4.85	5.5	......	......	......	......	......	......	4.0	4.3	4.2	5.55
8	4.8	5.5	......	......	......	......	......	......	4.05	4.2	4.1	5.5
9	4.7	5.5	......	......	......	......	......	......	4.05	4.15	4.1	5.3
10	4.68	5.5	......	......	......	......	......	......	4.1	4.1	4.1	5.15
11	4.55	5.5	......	......	......	......	......	......	4.05	4.15	4.0	5.05
12	4.5	5.5	......	......	......	......	......	......	4.1	4.25	4.1	5.35
13	4.6	5.5	......	......	......	......	......	......	4.05	4.3	4.1	6.25
14	4.55	5.5	......	......	......	......	......	......	4.0	4.6	4.1	6.6
15	4.6	5.5	......	......	......	......	......	......	4.0	4.35	4.1	6.3
16	4.55	5.5	......	......	......	......	......	4.2	3.9	4.3	4.1	5.85
17	4.48	5.5	......	......	......	......	......	4.2	4.0	4.2	4.1	8.15
18	4.35	5.5	......	......	......	......	......	4.1	4.0	4.2	4.1	7.65
19	4.28	5.5	......	......	......	......	......	4.15	4.0	4.2	4.2	7.1
20	4.2	5.5	......	......	......	......	......	4.2	4.0	4.15	4.2	5.75
21	4.3	5.5	......	......	......	......	......	4.2	4.0	4.1	4.2	5.5
22	5.4	5.5	......	......	......	......	......	4.2	4.05	4.1	4.2	5.45
23	5.15	5.5	......	......	......	......	......	4.25	4.05	4.1	4.2	5.3
24	4.75	5.5	......	......	......	......	......	4.2	4.1	4.1	4.2	5.2
25	4.6	8.8	......	......	......	......	......	4.2	4.1	4.1	4.35	5.0
26	4.75	......	......	......	......	......	......	4.2	4.1	4.1	5.0	4.95
27	5.0	......	......	......	......	......	......	4.1	4.1	4.15	5.15	4.85
28	6.15	......	......	......	......	......	......	4.1	4.1	4.2	5.2	4.9
29	5.5	......	......	......	......	......	......	4.15	4.15	4.2	5.1	5.0
30	5.05	......	......	......	......	......	......	4.1	4.2	4.2	5.0	4.85
31	4.95	......	......	......	......	......	......	4.1	......	4.2	......	4.7
1903.[b]												
1	4.7	......	9.0	7.15	5.1	9.05	6.3	4.45	4.3	4.3	4.3	4.75
2	4.8	......	7.15	6.8	5.0	6.75	5.75	4.5	4.6	4.3	4.25	4.4
3	10.9	......	6.5	6.4	5.0	5.95	5.4	4.45	4.6	4.3	4.2	4.3
4	8.95	......	6.1	6.25	4.95	5.45	5.25	4.6	4.4	4.4	4.3	4.3
5	7.15	......	5.78	6.05	4.8	5.15	5.6	5.2	4.4	4.25	4.25	4.3
6	6.45	......	5.6	5.75	4.85	6.2	6.45	4.85	4.4	4.3	4.2	4.3
7	6.05	......	5.65	5.6	4.85	8.4	5.5	4.7	4.4	4.4	4.2	4.2
8	5.75	......	5.95	5.6	4.8	9.95	5.15	4.55	4.35	4.9	4.2	4.25
9	5.4	5.4	5.95	5.8	4.75	7.5	4.95	4.5	4.3	4.95	4.2	4.2
10	5.3	5.25	5.75	5.65	4.8	12.0	4.85	4.4	4.4	4.9	4.2	4.2
11	5.25	5.2	5.7	5.6	4.75	7.5	4.8	4.45	4.65	4.8	4.25	4.2
12	6.3	5.2	5.6	5.4	4.7	6.75	4.9	4.45	4.6	4.55	4.2	4.3
13	8.15	5.15	5.55	5.3	4.7	6.65	5.4	4.4	4.5	4.45	4.3	4.3
14	7.9	5.1	5.45	9.85	4.7	7.0	6.2	4.4	4.4	4.6	4.3	4.2
15	7.9	5.1	5.4	9.3	4.7	6.35	5.7	4.4	4.35	4.6	4.2	4.2
16	7.9	5.35	5.25	8.8	4.65	5.9	5.2	4.4	4.3	4.5	4.2	4.2
17	7.9	5.7	5.2	8.0	4.6	5.55	5.0	4.5	5.0	4.5	4.25	4.2
18	7.35	5.75	5.15	7.1	4.6	5.45	4.85	4.55	6.25	4.5	4.2	4.2
19	5.65	5.35	5.1	6.6	4.6	5.2	4.8	4.55	5.65	4.5	4.2	4.2
20	6.35	5.5	5.1	6.25	4.55	5.1	4.7	4.5	5.1	4.5	4.3	4.2
21	7.0	5.7	5.0	6.0	4.55	5.05	4.7	4.4	4.75	4.4	4.25	4.2
22	(c)	5.5	5.75	5.75	4.5	4.9	4.6	4.3	4.7	4.4	4.2	4.2
23	5.6	5.4	7.7	5.65	4.5	4.9	4.6	4.3	4.6	4.4	4.2	4.5
24	5.4	5.55	10.0	5.5	4.7	4.9	4.5	4.3	4.6	4.35	4.2	4.4
25	5.25	5.95	7.8	5.45	4.95	4.85	4.5	4.3	4.6	4.3	4.2	4.35
26	5.1	6.05	6.75	5.4	4.75	5.4	4.4	4.3	4.55	4.3	4.2	4.2
27	5.0	6.05	6.25	5.4	4.7	5.25	4.4	4.3	4.4	4.3	4.2	4.2
28	6.8	7.65	5.95	5.3	4.8	5.95	4.4	4.2	4.3	4.3	4.2	4.2
29	......	......	5.65	5.2	4.7	8.1	4.4	4.2	4.3	4.3	4.2	4.2
30	......	......	6.25	5.1	4.8	7.75	4.45	4.3	4.3	4.3	4.2	4.2
31	......	......	7.6	......	5.9	......	4.4	4.3	......	4.3	......	4.2

[a] River frozen February 4 to 24, 1902.
[b] River frozen January 12-28, December 16-23, 26-31, 1903.
[c] Freshet January 22, 1903; gage pushed over by ice.

Daily gage height, in feet, of North Fork of Shenandoah River near Riverton, Va.—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.[a]												
1	4.2	....	....	4.88	5.85	5.65	4.72	4.3	4.1	4.05	4.0	4.02
2	4.2	....	....	5.0	5.7	5.05	4.5	4.45	4.05	4.0	4.0	4.05
3	4.2	....	....	4.98	5.4	4.85	4.38	4.4	4.15	3.95	4.05	4.1
4	4.2	....	....	4.88	5.1	4.8	4.3	4.5	4.15	4.0	4.05	4.1
5	4.2	....	4.7	4.8	5.05	4.85	4.35	4.5	4.1	4.1	4.0	4.1
6	4.2	....	4.65	4.72	5.0	6.05	4.35	4.8	4.05	4.1	4.05	4.2
7	4.2	....	4.7	4.72	4.9	6.7	4.32	4.5	4.05	4.0	4.05	4.2
8	4.2	....	6.2	4.7	4.9	5.3	4.35	4.5	4.1	4.05	4.0	4.1
9	4.2	....	6.2	4.75	4.9	4.95	4.4	4.45	4.05	4.0	4.0	4.1
10	4.2	....	5.6	5.1	5.0	4.8	6.15	4.38	4.1	4.0	4.1	4.15
11	4.2	....	5.15	5.38	4.95	4.72	6.82	4.4	4.1	4.0	4.1	4.2
12	4.2	....	5.0	5.15	4.9	4.6	6.0	4.35	4.1	4.1	4.05	4.5
13	4.2	....	4.9	5.0	4.8	4.5	5.75	4.35	4.05	4.0	4.1	4.5
14	4.2	....	4.8	4.9	4.8	4.5	5.1	4.3	4.2	4.05	4.1	4.5
15	4.2	....	4.78	4.8	4.75	4.4	4.85	4.2	4.2	4.0	4.05	4.5
16	4.2	....	4.7	4.72	4.8	4.45	4 7	4.3	4.15	4.05	4.1	4.5
17	4.2	....	4.7	4.65	4.7	4.45	4.55	4.2	4.15	4.05	4.1	4.5
18	4.2	....	4.68	4.55	4.7	4.42	4.55	4.22	4.1	4.05	4.02	4.5
19	4.2	....	4.6	4.58	4.78	4.5	4.5	4.2	4.1	4.0	4.0	4.5
20	4.2	....	4.52	4.5	6.45	4.75	4.7	4.22	4.05	4.05	4.0	4.5
21	4.2	....	4.55	4.45	5.7	5.25	4.55	4.2	4.25	4.05	4.0	4.5
22	4.2	....	4.52	4.48	5.35	5.3	4.4	4.2	4.1	4.0	4.1	4.5
23	4.2	....	4.65	4.4	5.15	4.85	4.38	4.3	4.05	4.1	4.1	4.5
24	(b)	....	4.75	4.4	4.95	4.62	4.35	4.35	4.1	4.1	4.1	4.5
25	....	....	4.8	4.35	4.78	4.45	4.5	4.2	4.0	4.0	4.02	4.5
26	....	....	4.8	4.5	5.15	4.4	4.5	4.25	4.0	4.1	4.0	4.55
27	....	....	4.8	4.6	4.95	4.35	4.4	4.2	3.98	4.05	4.05	4.6
28	....	....	4.78	6.0	4.8	4.4	4.4	4.2	4.05	4.05	4.0	4.65
29	....	....	4.7	7.05	4.7	4.38	4.65	4.1	4.05	4.1	4.05	4.45
30	....	....	4.7	6.4	4.6	4.75	4.55	4.1	4.1	4.02	4.1	4.45
31	....	....	4.78	....	4.8	....	4.45	4.15	....	4.05	....	4.35
1905.[c]												
1	4.28	5.5	5.5	5.45	4.6	4.6	5.3	5.05	4.4	4.2	4.35	4.22
2	4.2	5.5	5.5	5.3	4.7	5.05	5.45	4.8	4.4	4.2	4.4	4.15
3	4.35	5.5	5.5	5.2	4.6	4.85	5.25	4.65	4.35	4.15	4.3	4.45
4	5.55	5.5	5.5	5.15	4.6	4.68	5.05	4.6	4.3	4.25	4.3	4.7
5	5.9	5.5	....	5.15	4.52	4.55	5.3	4.6	4.38	4.2	4.38	5.05
6	5.9	5.5	5.8	5.6	4.6	4.5	6.9	4.48	4.45	4.15	4.35	4.9
7	5.9	5.5	5.75	5.8	4.6	4.9	5.75	4.4	4.4	4.15	4.35	4.75
8	....	5.5	6.0	5.65	4.52	4.95	5.5	4.35	4.4	4.15	4.3	4.7
9	....	5.5	6.4	5.5	4.55	4.7	5.7	4.38	4.35	4.15	4.22	4.55
10	....	5.5	7.65	5.4	4.5	4.5	5.3	4.4	4.3	4.05	4.32	4.5
11	....	5.5	7.45	5.25	4.5	4.42	5.35	4.4	4.28	4.25	4.38	4.42
12	....	5.5	6.75	5.3	4.5	4.25	6.15	4.4	4.3	4.35	4.32	4.42
13	....	5.5	6.4	5.25	4.5	4.65	5.75	4.32	4.3	4.25	4.28	4.42
14	....	5.5	5.95	5.15	4.55	4.4	6.9	5.1	4.3	4.2	4.15	4.48
15	....	5.5	5.75	5.1	5.45	4.4	7.1	4.7	4.28	4.2	4.22	4.38
16	....	5.5	5.6	5.05	6.15	4.3	6.1	5.48	4.32	4.25	4.2	4.4
17	....	5.5	5.5	4.98	5.65	4.2	5.5	5.45	4.32	4.25	4.18	4.55
18	....	5.5	5.4	4.92	5.35	4.2	5.2	5.0	4.4	4.25	4.1	4.7
19	....	5.5	5.4	4.9	5.2	4.25	5.05	4.8	4.32	4.2	4.18	4.62
20	....	5.5	5.4	4.9	4.55	4.2	4.92	4.7	4.32	4.25	4.2	4.6
21	....	5.5	5.95	4.8	4.92	6.2	4.8	4.6	4.28	4.2	4.15	7.3
22	....	5.5	6.4	4.8	4.8	6.95	4.8	4.4	4.25	4.2	4.18	9.55
23	4.75	5.5	6.5	4.75	4.7	7.5	5.55	4.4	4.3	4.15	4.2	7.75
24	5.5	5.5	6.05	4.7	4.62	10.75	5.95	4.35	4.2	4.1	4.2	6.95
25	5.5	5.5	7.45	4.7	4.6	9.05	5.4	5.0	4.2	4.2	4.22	6.5
26	5.5	5.5	6.95	4.7	4.55	7.0	5.15	6.1	4.15	4.5	4.22	5.95
27	5.5	5.5	6.5	4.7	4.4	6.2	4.92	5.45	4.2	4.48	4.18	5.55
28	5.5	5.5	6.2	4.8	4.5	6.2	4.78	4.9	4.2	4.35	4.12	5.4
29	5.5	....	5.9	4.8	4.42	5.7	4.75	4.75	4.2	4.3	4.2	5.7
30	5.5	....	5.7	4.7	4.4	5.4	5.6	4.6	4.2	4.32	4.2	6.28
31	5.5	....	5.55	....	4.45	....	5.7	4.5	....	4.42	....	6.0

[a] River frozen January 1-23, and December 12-26, 1904.
[b] Gage removed January 23, 1904, to protect from ice; replaced March 5, 1904.
[c] River frozen January 5 to March 4, 1905.

Daily gage height, in feet, of North Fork of Shenandoah River near Riverton, Va.—Cont'd.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906.												
1	5.7	5.3	4.55	7.9	5.65	4.62	5.05	......	......	......	......	......
2	5.45	5.2	4.5	7.1	5.5	4.7	4.88	......	......	......	......	......
3	5.4	5.1	4.75	6.7	5.4	4.58	4.85	......	......	......	......	......
4	8.6	[a] 5.5	6.45	6.32	5.35	4.52	6.12	......	......	......	......	......
5	7.75	5.0	6.55	6.1	5.25	4.65	5.52	......	......	......	......	......
6	6.83	4.98	5.9	5.92	5.32	4.62	5.2	......	......	......	......	......
7	6.2	[a] 5.15	5.55	5.75	5.32	4.55	4.95	......	......	......	......	......
8	5.85	[a] 5.6	5.45	5.6	5.48	4.75	4.82	......	......	......	......	......
9	5.58	[a] 5.5	5.35	5.52	5.45	4.62	4.7	......	......	......	......	......
10	5.35	[a] 5.25	5.25	6.1	5.3	4.6	4.6	......	......	......	......	......
11	5.37	[a] 5.45	5.15	5.95	5.22	4.85	4.6	......	......	......	......	......
12	5.27	4.9	5.0	5.75	5.2	4.78	4.6	......	......	......	......	......
13	5.25	4.68	5.0	5.62	5.05	4.65	4.65	......	......	......	......	......
14	5.3	4.6	5.0	5.28	5.0	4.58	4.62	......	......	......	......	......
15	5.4	4.68	5.05	6.4	4.9	5.05	......	......	......	......	......	......
16	5.48	4.65	5.2	6.98	4.88	5.25	......	......	......	......	......	......
17	5.4	[a] 4.8	5.45	6.4	4.82	5.5	......	......	......	......	......	......
18	5.38	4.55	5.58	6.05	4.8	5.85	......	......	......	......	......	......
19	5.33	4.52	5.8	5.88	4.8	5.9	......	......	......	......	......	......
20	5.27	4.6	5.9	5.7	4.72	5.65	......	......	......	......	......	......
21	5.2	4.6	5.95	5.58	4.62	6.85	......	......	......	......	......	......
22	5.1	4.6	6.2	5.48	4.6	7.25	......	......	......	......	......	......
23	5.05	4.6	6.55	5.4	4.6	6.6	......	......	......	......	......	......
24	5.7	4.6	6.45	5.28	4.55	5.8	......	......	......	......	......	......
25	5.9	4.53	6.2	5.2	4.55	5.55	......	......	......	......	......	......
26	5.55	4.55	6.1	5.2	4.52	5.3	......	......	......	......	......	......
27	5.33	4.52	7.5	7.48	4.52	6.1	......	......	......	......	......	......
28	5.3	4.58	9.4	6.7	5.08	6.2	......	......	......	......	......	......
29	5.37	......	8.45	6.15	4.9	5.7	......	......	......	......	......	......
30	5.43	......	8.35	5.85	4.75	5.35	......	......	......	......	......	......
31	5.35	......	8.1	......	4.65	......	......	......	......	......	......	......

[a] Backwater due to ice conditions February 4, 7-11, and 17, 1906.

Rating tables for North Fork of Shenandoah River near Riverton, Va.

JUNE 26, 1899, TO FEBRUARY 25, 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.50	90	4.50	800	5.40	1,760	6.30	2,910
3.60	140	4.60	895	5.50	1,880	6.40	3,050
3.70	195	4.70	990	5.60	2,000	6.50	3,190
3.80	255	4.80	1,090	5.70	2,130	6.60	3,330
3.90	320	4.90	1,190	5.80	2,260	6.70	3,470
4.00	390	5.00	1,300	5.90	2,390	6.80	3,610
4.10	465	5.10	1,410	6.00	2,520	6.90	3,750
4.20	545	5.20	1,520	6.10	2,650	7.00	3,890
4.30	625	5.30	1,640	6.20	2,780	8.00	5,380
4.40	710						

[a] This table is strictly applicable only for open-channel conditions. It is based on six discharge measurements made during 1899-1901. It is fairly well defined between gage heights 3.5 feet and 6.5 feet. Estimates above gage height 8.0 feet were determined directly from the curve; no rating table was prepared.

Rating tables for North Fork of Shenandoah River near Riverton, Va.—Continued.

AUGUST 16, 1902, TO AUGUST 15, 1904.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.90	165	5.00	670	6.10	1,520	7.20	2,640
4.00	190	5.10	735	6.20	1,610	7.30	2,760
4.10	220	5.20	800	6.30	1,700	7.40	2,880
4.20	255	5.30	870	6.40	1,790	7.50	3,010
4.30	295	5.40	940	6.50	1,890	7.60	3,140
4.40	340	5.50	1,015	6.60	1,990	7.70	3,270
4.50	390	5.60	1,090	6.70	2,090	7.80	3,400
4.60	440	5.70	1,170	6.80	2,190	7.90	3,540
4.70	495	5.80	1,255	6.90	2,300	8.00	3,680
4.80	550	5.90	1,340	7.00	2,410		
4.90	610	6.00	1,430	7.10	2,520		

AUGUST 16, 1904, TO JULY 14, 1906.[b]

4.00	100	5.10	595	6.10	1,320	7.10	2,270
4.10	125	5.20	655	6.20	1,405	7.20	2,380
4.20	155	5.30	720	6.30	1,495	7.30	2,490
4.30	190	5.40	785	6.40	1,585	7.40	2,600
4.40	230	5.50	855	6.50	1,680	7.50	2,720
4.50	275	5.60	925	6.60	1,775	7.60	2,840
4.60	325	5.70	1,000	6.70	1,870	7.70	2,960
4.70	375	5.80	1,075	6.80	1,970	7.80	3,080
4.80	425	5.90	1,155	6.90	2,070	7.90	3,210
4.90	480	6.00	1,235	7.00	2,170	8.00	3,340
5.00	535						

[a] This table is strictly applicable only for open-channel conditions. It is based on four discharge measurements made during 1902, 1903, and the first half of 1904. It is fairly well defined between gage heights 4.2 feet and 4.8 feet. Estimates above gage height 8.0 feet were determined directly from the curve.

[b] This table is strictly applicable only for open-channel conditions. It is based on seven discharge measurements made during the latter part of 1904 and 1905-1906, after the dam had been raised. It is well defined between gage heights 4.0 feet and 5.5 feet. Estimates above gage height 8.0 feet were determined directly from the curve. During August, 1904, the dam below the station was raised 2 feet. The exact date is uncertain, so the table is assumed to apply from August 16, 1904.

Estimated monthly discharge of North Fork of Shenandoah River near Riverton, Va.

[Drainage area, 1,040 square miles.[a]]

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1899.								
January							2.52	
February							4.95	
March							5.12	
April							1.16	
May							4.95	
June 26-30	307	255	293	.282	.052		[b] 2.09	
July	481	130	228	.220	.254	10	2.51	2.26
August	390	151	220	.212	.244	6	3.94	3.70
September	355	140	227	.219	.244	6	3.78	3.54
October	225	140	185	.178	.205	9	2.34	2.14
November	545	168	238	.230	.257	32	.81	.55
December [c]	390	140	255	.246	.284	21	1.34	1.06
The year							35.51	

[a] Drainage area of 1,040 square miles used to obtain run-off for 1906; 1,037 used for all other years.

[b] Precipitation for complete month, June, 1899.

[c] River frozen December 26-31, 1899; no correction made in estimates.

Estimated monthly discharge of North Fork of Shenandoah River near Riverton, Va.—Continued.

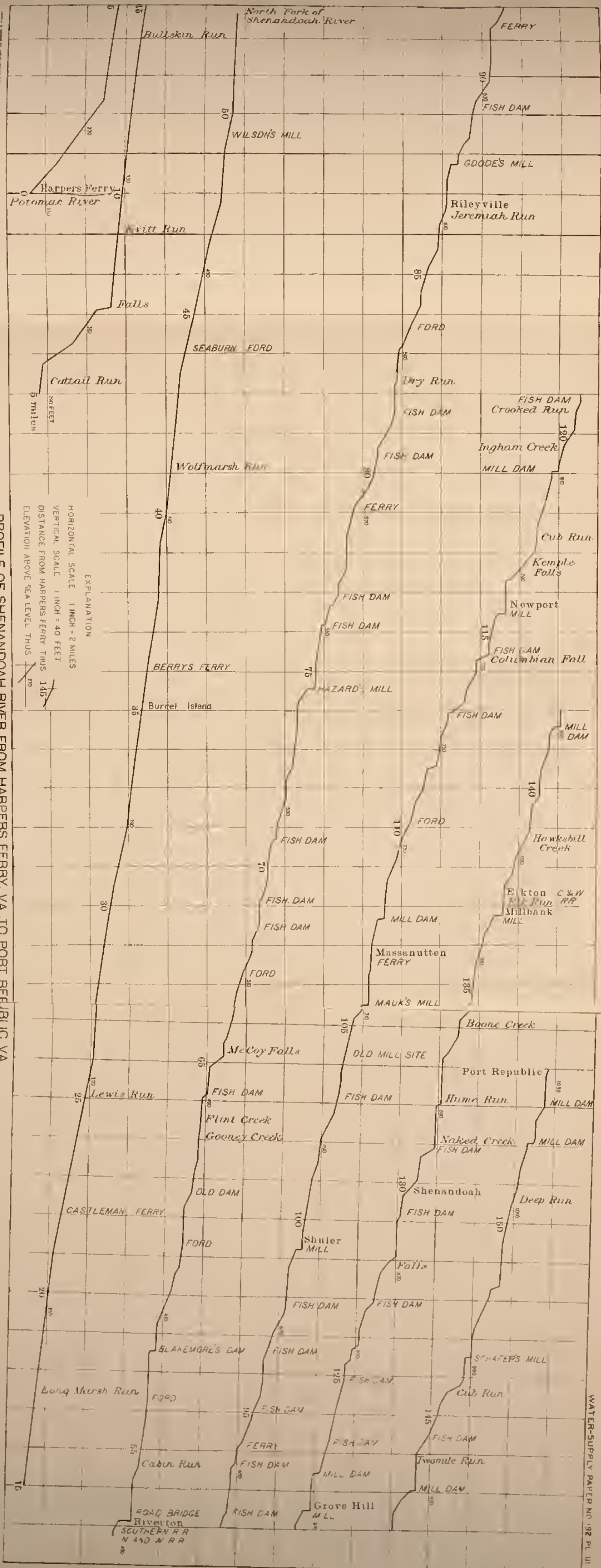
Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1900.								
January [a]	4,330	255	702	0.677	0.780	30	2.57	1.79
February [a]	3,862	355	1,128	1.09	1.14	31	3.73	2.59
March	5,700	585	1,620	1.56	1.80	48	3.72	1.92
April	1,760	465	765	.738	.823	43	1.89	1.07
May	585	225	324	.312	.360	15	2.42	2.06
June	2,195	195	504	.486	.542	9	5.98	5.44
July	1,616	140	294	.284	.327	9	3.76	3.43
August	207	90	128	.123	.142	7	1.93	1.79
September	355	130	155	.149	.166	5	3.14	2.97
October	320	168	219	.211	.243	8	3.19	2.95
November	3,890	140	441	.425	.474	16	2.94	2.46
December	2,650	140	548	.528	.609	33	1.83	1.22
The year	5,700	90	569	.549	7.41	20	37.10	29.69
1901.								
January [b]	2,195	195	627	.605	.698	30	2.31	1.61
February [b]	390	207	299	.288	.300	91	.33	.03
March	10,960	195	1,391	1.34	1.54	41	3.80	2.26
April	21,630	693	4,034	3.89	4.34	70	6.24	1.90
May	17,850	728	2,653	2.56	2.95	51	5.82	2.87
June	12,680	990	2,842	2.74	3.06	41	7.54	4.48
July	4,030	505	1,499	1.44	1.66	38	4.38	2.72
August	2,260	428	862	.831	.958	16	5.92	4.96
September	2,390	168	684	.660	.736	20	3.78	3.05
October	1,322	195	396	.382	.440	64	.69	.25
November	1,580	140	363	.350	.390	19	2.01	1.62
December [c]	14,580	268	3,091	2.98	3.44	56	6.12	2.68
The year	21,630	140	1,562	1.50	20.51	42	48.94	28.43
1902.								
January	3,960	545	1,304	1.26	1.45	54	2.69	1.24
February 1–25 [d]	6,660	1,090	1,969	1.90	1.77	....	[e] 4.46	....
March	....	....	....	....	....	....	3.61	....
April	....	....	....	....	....	....	2.23	....
May	....	....	....	....	....	....	2.64	....
June	....	....	....	....	....	....	2.93	....
July	....	....	....	....	....	....	2.17	....
August 16–31	275	220	243	.234	.139	....	[e] 2.22	....
September	318	165	211	.204	.228	9	2.59	2.36
October	440	220	259	.250	.288	8	3.65	3.36
November	800	190	317	.306	.341	11	3.21	2.87
December	3,890	495	1,228	1.18	1.36	40	3.38	2.02
The year	....	....	....	....	....	....	35.78	....
1903.								
January 1–28 [f] [g]	8,390	495	2,225	2.15	2.24	....	[h] 4.08	....
February 9–28	3,205	735	1,127	1.09	.811	....	[h] 3.49	....
March	6,860	670	1,750	1.69	1.95	47	4.15	2.20
April	6,605	735	1,848	1.78	1.99	55	3.62	1.63
May	1,340	390	549	.529	.610	23	2.69	2.08
June	10,360	580	2,208	2.13	2.38	31	7.63	5.25
July	1,840	340	736	.710	.819	27	3.06	2.24
August	800	255	371	.358	.413	12	3.53	3.12
September	1,655	295	464	.447	.499	21	2.42	1.92
October	640	275	373	.360	.415	18	2.39	1.97
November	295	255	265	.256	.286	35	.82	.53
December [f]	522	255	284	.274	.316	33	.96	.64
The year	....	....	....	....	....	....	38.84	....

[a] River frozen January 1–14 and January 30 to February 6, 1900; no correction made in estimates.
[b] Ice conditions during part of January and February, 1901; no correction made in estimates.
[c] River frozen December 21–28, 1901; no correction made in estimates.
[d] River frozen February 4–24, 1902; no correction made in estimates.
[e] Precipitation for complete months, February and August, 1902.
[f] River frozen January 12–28, December 16–23, 26–31, 1903; no correction made in estimates.
[g] Freshet January 22, 1903. Gage pushed over by ice; discharge estimated.
[h] Precipitation for complete months, January and February, 1903.

Estimated monthly discharge of North Fork of Shenandoah River near Riverton, Va.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1904.								
January 1-23 [a]	255	255	255	0.246	0.210	....	[b] 1.80	....
February	....	....	....	....	....	....	1.26	....
March 5-31	1,610	400	620	.598	.600	....	[b] 2.08	....
April	2,465	318	661	.637	.711	27	2.64	1.93
May	1,840	440	718	.692	.798	23	3.43	2.63
June	2,090	318	606	.584	.652	12	5.57	4.92
July	2,212	295	554	.534	.616	12	5.04	4.42
August	550	125	255	.246	.284	11	2.53	2.25
September	172	96	124	.120	.134	7	1.95	1.82
October	125	90	110	.106	.122	10	1.20	1.08
November	125	100	112	.108	.120	13	.95	.83
December [a]	350	105	225	.217	.250	10	2.46	2.21
The year	....	....	....	....	....	....	30.91	....
1905.								
January 1-7, 23-31 [c]	1,155	155	759	.732	.436	....	[d] 3.39	....
February [c]	855	855	855	.824	.858	44	1.95	1.09
March [c] [e]	2,900	785	1,335	1.29	1.49	61	2.44	.95
April	1,075	375	596	.575	.642	37	1.74	1.10
May	1,362	230	406	.392	.452	14	3.21	2.76
June	7,450	155	1,042	1.00	1.12	17	6.54	5.42
July	2,270	400	908	.876	1.01	16	6.29	5.28
August	1,320	198	417	.402	.464	13	3.58	3.12
September	252	140	192	.185	.206	14	1.50	1.29
October	275	112	170	.164	.189	6	2.99	2.80
November	230	125	172	.166	.185	22	.88	.69
December	5,575	140	889	.857	.988	26	3.81	2.82
The year	....	....	....	....	....	....	38.31	....
1906.								
January	4,160	565	1,036	.996	1.15	....	....	....
February [f]	720	285	418	.402	.419	....	....	....
March	5,350	275	1,421	1.37	1.58	....	....	....
April	3,210	655	1,324	1.27	1.42	....	....	....
May	962	285	545	.524	.604	....	....	....
June	2,435	285	787	.757	.845	....	....	....
July 1-14	1,337	325	523	.503	.262	....	....	....

[a] River frozen January 1-23, and December 12-26, 1904; no correction made in estimates.
[b] Precipitation for complete months, January and March, 1904.
[c] River frozen January 5 to March 4, 1905; no correction made in estimates.
[d] Precipitation for complete month, January, 1905.
[e] Estimate March 5, 1905, interpolated.
[f] Backwater due to ice conditions February 4, 7-11, and 17, 1906; discharge corrected.



PROFILE OF SHENANDOAH RIVER FROM HARPERS FERRY, VA.,TO PORT REPUBLIC, VA.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN NORTH FORK OF SHENANDOAH RIVER BASIN.

The following miscellaneous discharge measurements have been made in the basin of North Fork of Shenandoah River:

Miscellaneous discharge measurements in North Fork of Shenandoah River Basin.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Feet per sec.*	*Second-feet.*
1895.						
August 7	North Fork of Shenandoah River.	300 feet below dam at county bridge and ⅝ mile above junction with South Fork of Shenandoah River, near Riverton, Va.	....	210	1.72	362
1897.						
October 4	do	do	150	100	1.40	140
Do	Happy Creek	200 feet above mouth, near Riverton, Va.	3.5	2.1	1.47	3.1
October 12	Cedar Creek	½ mile above mouth, near Strasburg, Va.	18	16	1.69	[a] 27
October 15	Passage Creek	At entrance to Fort Valley, near Riverton, Va.	8	3	2.00	6
October 7	Crooked Run	Near highway bridge, near Riverton and on road to Cedarville, Va.	6	6	.58	3.4

[a] Discharge increased by heavy rains of preceding night.

SHENANDOAH RIVER BASIN BELOW NORTH AND SOUTH FORKS.

SLOPE.

The slope of the Shenandoah and South Fork from Harpers Ferry to Port Republic, Va., is shown on Pl. III. The following table shows the elevations above tide of a number of points on Shenandoah River:

Slope of Shenandoah River.

[Pl. III.]

Locality.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Harpers Ferry, junction with Potomac	0.0	242	2.5	44	17.6
Bulls Falls	2.5	286	5.5	40	7.3
Near mouth of Evitts Creek	8.0	326	10.0	34	3.4
Castlemans Ferry	18.0	360	13.0	40	3.1
Berrys Ferry	31.0	400	23.0	53	2.3
Confluence of North and South forks	54.0	[a] 453	96.0	586	6.1
South Fork, near Port Republic	150	1,039			

[a] Profiles of the Norfolk and Western Railway give this elevation as 445 feet.

SHENANDOAH RIVER AT MILLVILLE, W. VA.

The Millville station was established April 15, 1895, by C. C. Babb. It is located about one-fourth mile above the Baltimore and Ohio Railroad station at Millville, W. Va. The highway runs within a few rods of the stream at the gaging station. The station is best reached by driving from Harpers Ferry, W. Va.

The channel is straight for several hundred feet above and below the station, and the current is swift and unobstructed. Both banks are low and liable to overflow. There is but one channel at all stages. The bed of the stream is composed of mud and rocks.

Discharge measurements are made from a ¾-inch cable, from which is suspended a car. The cable, which is suspended over the branches of two large sycamore trees and is securely anchored to the bank at both ends, has a total span of 500 feet. The initial point for soundings is the side of the tree to which the cable is attached on the left bank.

The vertical gage is spiked to a large sycamore tree on the left bank a few hundred feet downstream from the cable. The gage is read once each day by W. R. Nicewarner, the railroad station agent. The bench mark is a copper plug in the upstream side of the base of the second tree downstream from the gage. Its elevation is 6.68 feet above the zero of the gage.

All estimates published prior to 1905 have been revised. For normal conditions of flow the estimates are probably within 5 to 10 per cent of the true discharge up to gage height 6.0 feet. Above gage height 6.0 feet the probable error is from 10 to 15 per cent, or even greater at extreme flood stages. Ice conditions affect the flow at this station during the winter months.

A summary of the records furnishes the following results: Maximum discharge for twenty-four hours, 139,700 second-feet; minimum discharge for twenty-four hours, 480 second-feet; mean annual discharge for eight years, 3,352 second-feet; mean annual rainfall for eleven years, 38.05 inches.

Discharge measurements of Shenandoah River at Millville, W. Va.

Date.	Gage height.	Discharge.
1895.	*Feet.*	*Second-feet.*
April 24	1.90	2,162
May 1[a]	7.50	19,710
May 2[a]	6.80	15,860
May 4	5.20	10,980
May 8	3.08	4,311
May 24	3.60	5,745
June 8	1.50	1,516
June 15	2.35	3,044
June 22	1.10	1,126
July 12	1.30	1,150
1896.		
June 22	1.99	2,513
1897.		
June 24	1.20	1,371
July 23	1.82	2,791
September 4	.52	632
October 25	.72	814
1898.		
January 24	2.20	3,001
August 16	[b]4.30	7,834
October 1	.90	1,001
1899.		
January 27	2.40	3,156
March 10	5.00	10,840
May 16	2.10	2,753
September 3	.90	1,086
October 29	.60	766
1900.	*Feet.*	*Second-feet.*
February 24	5.90	12,980
June 19	4.55	9,132
September 15	.40	500
1901.		
July 22	3.30	5,419
December 27	2.35	3,291
1902.		
August 17	.70	811
1903.		
August 26	1.00	1,107
1904.		
June 13	1.70	1,883
July 4	1.20	1,137
July 10	1.34	1,371
September 28	.50	564
October 20	.41	494
1905.		
April 22	1.40	1,595
September 20	.84	799
1906.		
May 29	1.58	1,790

[a] The data for these measurements were partly estimated. They were not considered in preparing the rating tables.

[b] Gage height is uncertain.

Daily gage height, in feet, of Shenandoah River at Millville, W. Va.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	......	......	......	......	7.4	2.1	2.0	1.1	0.7	0.6	0.5	0.6
2	......	......	......	......	6.9	1.9	4.1	1.0	1.3	.6	.5	.6
3	......	......	......	......	6.2	1.8	3.0	1.0	1.0	.6	.6	.6
4	......	......	......	......	5.45	1.7	2.4	1.0	.9	.5	.6	.6
5	......	......	......	......	4.4	1.7	2.0	1.0	.8	.5	.6	.6
6	......	......	......	......	3.85	1.6	1.8	1.0	.6	.5	.6	.6
7	......	......	......	......	3.3	1.6	1.7	.9	.6	.5	.6	.6
8	......	......	......	......	3.05	1.5	1.5	.9	.6	.5	.6	.6
9	......	......	......	......	2.9	1.4	1.4	.9	1.0	.5	.6	.6
10	......	......	......	......	2.6	1.4	1.4	.9	.8	.5	.7	.6
11	......	......	......	......	2.6	1.3	1.4	.9	.7	.5	.7	.6
12	......	......	......	......	2.4	1.3	1.3	.9	1.0	.5	.7	.6
13	......	......	......	......	2.4	1.3	1.3	.9	.9	.5	.7	.6
14	......	......	......	......	2.3	1.4	1.3	.8	.9	.5	.7	.6
15	......	......	......	2.8	2.3	2.4	1.2	.7	.7	.5	.7	.6
16	......	......	......	3.0	2.3	1.8	1.1	.7	.7	.5	.6	.6
17	......	......	......	2.7	2.2	1.5	1.2	.6	.6	.5	.6	.6
18	......	......	......	2.5	2.2	1.3	1.5	.6	.6	.5	.6	.6
19	......	......	......	2.4	2.2	1.2	1.2	.8	.6	.5	.6	.7
20	......	......	......	2.3	2.3	1.2	1.1	.8	.6	.5	.6	.7
21	......	......	......	2.3	2.4	1.1	1.0	.8	.7	.5	.6	.7
22	......	......	......	2.0	2.7	1.1	1.0	.8	.6	.5	.6	.7
23	......	......	......	2.0	3.85	1.0	1.0	.7	.6	.5	.6	.7
24	......	......	......	1.9	3.75	1.0	1.2	.6	.6	.5	.6	.7
25	......	......	......	1.8	3.2	1.0	1.2	.6	.6	.5	.6	1.1
26	......	......	......	1.8	2.8	1.0	2.1	.6	.6	.5	.6	1.0
27	......	......	......	1.8	2.7	1.0	2.2	.6	.6	.4	.6	1.0
28	......	......	......	1.7	2.7	2.2	1.9	.5	.6	.4	.6	1.0
29	......	......	......	2.1	2.5	1.9	1.7	.5	.6	.4	.6	1.3
30	......	......	......	3.1	2.3	1.8	1.5	.5	.6	.4	.6	1.4
31	......	......	......	......	2.1	......	1.3	1.5	......	.4	......	1.4
1896.												
1	1.3	1.4	2.6	4.6	1.4	.9	1.6	1.3	.7	[a]19.7	.9	2.6
2	1.9	1.6	2.4	4.2	1.4	.9	1.6	1.2	.6	[a]10.0	.9	3.8
3	1.8	1.8	2.3	3.8	1.5	.9	1.5	1.1	.6	5.6	.9	3.1
4	1.8	2.0	2.0	3.6	1.7	.9	1.5	1.0	.6	4.0	.9	2.6
5	1.7	2.6	1.7	3.2	1.8	.9	1.5	1.0	.6	3.4	1.0	2.0
6	1.6	2.9	1.5	2.8	1.9	.8	1.5	1.0	.6	2.8	1.1	2.0
7	1.6	3.8	1.4	2.6	2.4	1.0	1.6	1.1	.5	2.1	3.2	2.0
8	1.6	5.6	1.5	2.6	2.2	1.4	1.6	1.1	.5	2.0	2.7	2.0
9	1.4	4.1	1.5	2.0	2.0	1.9	3.15	1.0	.5	1.9	2.4	2.0
10	1.3	3.7	1.5	2.0	2.0	2.7	4.65	1.0	.5	1.8	2.1	2.0
11	1.3	3.2	1.5	2.0	1.9	2.8	3.6	1.0	.6	1.8	1.9	1.9
12	1.2	2.9	1.4	2.0	1.7	2.4	2.5	1.4	.6	1.6	1.9	1.9
13	1.2	2.5	1.4	2.0	1.7	1.6	2.2	1.6	.6	1.4	1.9	1.8
14	1.0	2.4	1.4	1.9	1.6	1.6	2.2	1.5	.6	1.4	1.9	1.8
15	1.0	3.8	1.5	1.7	2.4	1.9	2.2	1.4	.6	1.4	1.9	1.7
16	1.0	3.5	1.5	1.7	3.0	1.9	2.2	1.4	.6	1.4	1.8	1.7
17	1.0	3.0	1.6	1.6	2.5	1.8	2.1	1.7	.6	1.3	1.7	1.7
18	1.0	2.7	3.0	1.6	2.4	1.9	2.0	1.6	.6	1.3	1.6	1.7
19	1.0	2.5	4.2	1.6	2.4	2.2	2.0	1.3	.6	1.3	1.6	1.7
20	1.0	2.4	4.6	1.5	2.2	2.0	1.8	1.2	.8	1.2	1.5	1.6
21	.9	2.4	5.5	1.5	1.8	1.9	1.6	1.2	.8	1.1	1.5	1.5
22	.9	2.3	4.6	1.5	1.6	2.0	1.5	1.2	.8	1.1	1.5	1.5
23	.9	2.2	4.0	1.5	1.5	2.2	4.1	1.0	.7	1.0	1.5	1.4
24	2.4	2.2	3.5	1.5	1.6	2.0	3.0	1.0	.6	1.0	1.5	1.4
25	5.1	1.8	3.0	1.5	1.5	1.9	3.3	1.0	.6	1.0	1.4	1.6
26	5.3	1.7	2.9	1.4	1.5	1.8	2.6	.9	.6	1.0	1.4	1.6
27	4.35	1.6	2.8	1.4	1.5	1.8	2.0	.9	.6	1.0	1.4	1.6
28	3.35	1.5	2.7	1.4	1.4	2.2	1.7	.8	.6	1.0	1.4	1.8
29	2.0	2.0	2.7	1.4	1.4	2.3	1.5	.8	.6	1.0	1.4	1.8
30	1.9	......	2.6	1.4	1.4	1.9	1.4	.8	5.75	1.0	1.6	1.8
31	1.7	......	4.6	......	1.1	......	1.3	.8	......	.9	......	1.8

[a] Gage heights estimated October 1 and 2, 1896.

Daily gage height, in feet, of Shenandoah River at Millville, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897. [a]												
1	1.6	1.1	3.8	2.1	1.5	1.6	1.1	1.1	0.7	0.5	0.9	0.8
2	1.5	1.1	3.6	2.1	1.8	1.6	1.0	1.0	.7	.5	.9	.8
3	1.4	1.6	3.6	2.0	9.35	1.5	1.0	.9	.7	.5	.9	.7
4	1.4	2.0	3.6	2.0	7.2	1.7	1.0	.9	.6	.5	1.1	.8
5	1.3	2.2	3.6	2.2	5.2	1.7	1.1	.9	.6	.5	1.4	1.0
6	1.3	2.2	3.6	2.4	4.7	1.9	1.0	1.5	.6	.5	1.1	1.8
7	1.3	....	3.4	2.3	3.6	1.8	.8	.9	.5	.35	.8	1.2
8	1.2	....	3.3	2.4	3.2	1.7	.8	.9	.5	.35	.8	1.1
9	1.2	....	3.0	2.4	2.9	1.3	.8	.9	.5	.35	.7	.9
10	1.1	6.1	2.8	2.4	2.5	1.6	.8	.8	.4	.35	.8	.9
11	1.1	5.4	2.7	2.4	2.4	1.4	....	1.2	.4	.4	.7	.8
12	1.1	4.8	2.6	2.4	2.4	1.4	1.1	1.0	.4	.5	.7	.9
13	1.4	4.1	2.6	2.3	2.5	1.4	1.0	.9	.4	.5	.5	.9
14	1.4	6.0	2.8	2.3	4.35	1.3	1.0	.8	.4	.5	.5	1.0
15	1.3	4.7	2.8	2.3	6.6	1.3	1.2	.7	.4	.5	.7	1.7
16	1.2	5.75	3.5	2.2	4.9	1.3	.9	.7	.4	.5	.65	2.4
17	1.1	5.9	3.6	2.2	3.9	1.3	.9	.7	.4	.5	.7	2.7
18	1.1	5.3	3.4	2.1	3.5	1.2	.9	.7	.4	.45	.6	2.2
19	1.1	4.9	3.2	2.1	3.2	1.2	.8	.6	.4	.4	.6	1.8
20	1.1	4.6	3.2	2.0	2.9	1.6	1.9	.6	.4	.4	.5	1.6
21	1.1	4.5	3.6	1.9	2.6	1.6	2.6	.6	.4	.45	.6	1.3
22	1.2	6.45	3.4	1.8	2.4	1.4	2.6	.6	.4	.5	.6	1.3
23	1.2	10.05	3.3	1.8	2.3	1.3	1.8	.6	.4	.5	.6	1.3
24	1.2	10.05	3.2	1.7	2.2	1.2	1.5	1.0	.6	.55	.55	1.3
25	1.1	6.7	3.0	1.7	2.2	1.1	1.3	1.3	1.2	.7	.5	1.3
26	1.1	5.5	2.9	1.6	2.2	1.1	1.2	1.0	.5	.8	.5	2.0
27	1.1	4.6	2.7	1.5	1.8	1.1	1.1	.9	.5	.9	.8	1.5
28	1.1	4.6	2.5	1.5	1.6	1.0	1.2	.8	.5	.8	.9	1.6
29	1.1	....	2.4	1.4	1.6	1.0	1.5	.7	.4	.8	.7	1.5
30	1.1	....	2.1	1.4	1.6	.9	1.3	.7	.4	.8	.6	1.2
31	1.0	....	2.0	....	1.6	....	1.1	.8	....	.9	....	1.1
1898. [b]												
1	1.5	2.1	1.1	4.0	2.3	1.9	1.2	2.2	1.5	.9	2.8	2.1
2	1.3	2.1	1.1	3.9	2.2	1.8	....	1.4	1.5	.9	2.4	2.1
3	1.2	1.8	1.1	3.2	2.0	1.7	.8	1.2	1.55	1.0	2.5	2.1
4	1.4	1.7	1.1	3.0	1.9	1.6	.8	1.4	1.5	1.0	2.7	2.5
5	1.0	2.1	1.0	2.8	1.7	1.6	.9	3.6	1.4	1.2	2.1	5.4
6	1.2	1.6	1.1	2.6	1.7	1.6	.9	8.3	1.4	1.8	2.0	6.0
7	.9	1.8	1.0	2.4	2.0	1.4	.9	4.1	1.4	1.5	2.0	4.6
8	1.3	1.8	1.0	2.3	6.3	1.3	.9	1.9	1.4	1.7	1.9	3.8
9	.9	1.6	1.0	2.2	8.9	1.2	.9	3.9	1.3	1.5	1.9	3.0
10	1.1	1.3	.9	2.0	7.4	1.1	.9	6.6	1.3	1.4	1.8	2.8
11	1.6	1.3	.9	1.8	5.4	1.1	.8	c11.7	1.1	1.3	1.9	2.6
12	1.2	1.3	.9	1.7	4.4	1.1	.7	10.0	1.1	1.2	1.8	2.4
13	2.0	1.1	.9	1.7	3.7	1.0	.7	6.0	1.1	1.0	1.7	2.4
14	1.9	1.1	.9	1.7	3.3	1.4	.7	5.1	1.1	1.0	1.8	2.2
15	2.0	1.1	.9	2.2	2.9	1.4	.7	4.1	1.0	1.0	1.7	1.9
16	3.6	1.0	.9	4.5	2.8	1.4	.7	3.9	1.0	1.0	1.7	2.2
17	2.9	.9	1.1	5.6	2.7	1.3	.7	3.6	1.0	1.1	1.7	2.2
18	2.6	.9	2.3	4.4	2.4	1.4	.7	3.4	1.1	1.1	1.7	2.2
19	2.1	1.0	2.0	3.8	2.2	1.9	.8	2.8	1.0	7.75	1.8	2.3
20	2.1	1.0	2.1	3.4	2.1	1.8	.9	3.4	1.0	8.4	2.3	2.0
21	2.1	1.0	2.1	2.8	2.0	1.5	1.1	2.7	1.0	5.0	2.7	2.0
22	2.0	1.3	2.0	2.6	2.0	1.7	1.1	2.4	1.0	5.0	2.5	2.0
23	2.0	1.3	1.9	2.4	2.4	1.4	1.0	2.3	1.1	9.1	2.5	2.3
24	2.3	1.3	1.9	2.2	2.9	1.4	.9	2.1	1.1	5.7	2.5	2.9
25	2.3	1.2	2.9	2.1	3.4	1.5	1.6	2.0	1.1	4.4	2.3	4.0
26	2.2	1.2	3.1	2.1	2.9	1.2	1.5	2.0	1.4	3.5	2.3	3.5
27	2.6	1.1	2.9	2.1	2.4	1.1	1.5	1.6	1.2	3.4	2.2	3.0
28	2.4	1.1	2.6	2.3	2.4	1.1	1.4	1.8	1.1	2.2	2.0	2.8
29	2.2	....	2.6	2.2	2.4	1.1	1.4	1.6	1.1	3.0	2.0	2.5
30	1.5	....	2.9	2.2	2.1	1.1	2.6	1.6	1.0	2.9	2.2	2.4
31	1.8	....	3.4	....	1.9	....	2.1	1.6	....	2.9	....	2.3

[a] Ice conditions during January and December 24–31, 1897.
[b] Ice conditions during February, 1898.
[c] Gage height estimated August 11, 1898.

Daily gage height, in feet, of Shenandoah River at Millville, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
1899. [a]												
1	2.5	2.3	....	3.1	1.7	2.05	0.9	1.0	1.1	0.8	1.55	0.8
2	2.2	2.1	....	3.0	1.6	2.35	.9	.8	.9	.7	2.75	.8
3	2.8	1.7	....	2.8	1.6	3.0	.8	.9	.9	.7	3.2	.75
4	2.6	2.0	....	2.7	1.6	2.1	.8	1.3	1.1	.7	2.4	.7
5	3.3	2.4	....	2.6	2.0	1.8	.8	.9	.8	.7	1.9	.75
6	3.8	2.5	....	2.5	1.9	1.5	.8	.8	.7	.7	1.8	.7
7	4.6	2.3	....	2.4	1.9	1.4	.7	1.1	.8	.7	1.6	.7
8	6.7	2.5	....	2.5	1.8	1.4	.8	1.0	.7	.7	1.4	.7
9	5.0	2.5	....	3.1	2.0	1.5	.9	1.2	.7	.8	1.3	.7
10	4.5	2.3	5.0	3.0	2.3	1.4	1.0	1.0	.7	.8	1.2	.7
11	3.8	2.4	5.5	2.9	3.1	1.3	.9	1.6	.8	.7	1.1	.7
12	3.5	....	5.2	2.7	2.8	1.4	.8	.9	1.2	.8	1.0	.75
13	3.3	....	4.6	2.6	2.6	1.4	.8	.8	.9	.7	1.0	.9
14	3.0	2.3	4.0	2.5	2.7	1.3	.7	.9	.8	.7	1.0	2.9
15	2.9	2.4	4.0	2.4	2.2	1.3	.7	.8	.8	.7	.9	2.2
16	3.0	2.5	4.0	2.3	2.1	1.3	.9	.7	.7	.6	.9	1.9
17	2.9	2.7	4.5	2.2	1.9	1.2	.8	.8	.7	.6	.9	1.6
18	2.9	3.0	3.9	2.2	1.9	1.1	.7	.8	.6	.6	.8	1.4
19	2.9	3.0	3.8	2.2	2.5	1.0	.7	.8	.6	.6	.9	1.3
20	2.8	3.4	3.8	2.2	2.3	1.0	.7	.7	.8	.6	.8	1.2
21	2.6	4.0	3.8	2.2	2.0	1.0	.7	.7	.9	.6	.8	1.2
22	2.4	....	3.7	1.9	1.9	.9	.7	.6	.9	.6	.8	1.1
23	2.4	....	3.5	1.9	1.7	1.0	.6	.6	1.5	.6	.8	1.1
24	2.4	....	3.3	1.9	1.7	.9	.6	.6	1.1	.6	.8	1.1
25	2.4	....	3.1	1.8	1.6	.9	.7	.5	1.0	.6	.8	1.3
26	2.3	....	3.0	2.0	1.5	.9	.6	.5	.9	.5	.85	1.2
27	2.5	....	2.9	1.9	1.5	.9	.6	.6	.9	.6	.85	1.7
28	2.3	....	2.9	1.8	1.4	.9	.6	.7	.9	.6	.8	1.4
29	2.2	....	3.0	1.8	1.4	.9	.6	.8	.8	.6	.8	1.65
30	2.1	....	3.6	1.7	1.3	1.0	1.5	1.0	.8	.6	.8	1.1
31	2.1	....	3.3	....	1.6	....	1.0	1.3	....	.7	....	1.1
1900.												
1	1.25	2.1	3.0	2.55	1.8	1.5	1.3	1.15	.6	.6	.8	2.0
2	1.3	1.2	4.8	2.5	1.75	1.5	1.25	1.0	.6	.7	.8	1.7
3	1.2	1.6	6.5	2.4	1.7	1.3	1.25	1.05	.6	.7	.8	1.5
4	1.15	1.55	4.8	2.25	1.6	1.3	1.2	1.0	.6	.7	.9	1.6
5	1.2	[b] 2.0	3.9	2.2	1.6	1.3	1.2	.9	.55	.6	.9	2.25
6	1.3	[b] 2.0	3.4	2.1	1.5	1.25	1.3	.85	.5	.55	.9	4.8
7	1.3	1.5	2.9	2.0	1.5	1.15	1.1	.8	.5	.5	.85	3.6
8	1.3	1.4	2.8	1.9	1.4	1.1	1.0	.75	.45	.5	.9	2.8
9	1.2	1.4	2.7	1.85	1.4	.95	.9	.7	.45	.75	.85	3.4
10	1.15	1.4	2.6	1.8	1.4	1.0	.85	.7	.45	.6	.8	2.2
11	1.2	1.4	2.5	1.7	1.3	.95	.8	.7	.45	.55	.8	1.9
12	1.1	1.4	2.4	1.7	1.3	.9	.8	.65	.45	.5	.8	1.75
13	1.3	1.5	2.3	1.7	1.3	1.0	.8	.7	.4	.5	.8	1.6
14	1.4	1.9	2.2	1.7	1.2	.9	.75	.6	.4	.7	.75	1.5
15	1.5	3.8	2.1	1.7	1.2	1.1	.75	.6	.4	.9	.75	1.4
16	1.3	3.3	2.1	1.6	1.15	1.3	.7	.55	.5	1.1	.75	1.35
17	1.2	2.8	2.1	1.6	1.1	2.3	.7	.6	.6	.9	.7	1.3
18	1.15	2.5	2.0	1.55	1.1	2.7	.65	.6	.55	.8	.7	1.2
19	1.2	2.3	2.0	1.6	1.2	4.5	.65	.6	1.1	.8	.65	1.15
20	1.8	2.2	3.3	1.65	1.1	3.7	1.2	.6	.8	.7	.65	1.15
21	6.0	2.5	5.95	2.1	1.9	3.0	.8	.65	.7	.6	.6	1.1
22	5.9	2.45	6.2	2.4	1.9	2.6	1.0	.6	.6	.55	.65	1.0
23	4.2	4.35	4.7	2.55	1.7	2.1	1.1	.55	.55	.5	.7	1.0
24	3.3	5.9	3.9	3.0	1.6	1.9	1.4	.6	.55	.65	.7	1.0
25	2.8	4.5	3.45	3.0	1.4	1.7	2.5	.6	.5	.8	.7	1.0
26	2.5	3.8	3.15	2.7	1.25	1.55	2.8	.55	.5	2.1	1.1	1.0
27	2.25	3.4	3.0	2.5	1.5	1.45	1.7	.65	.45	1.6	2.1	.95
28	2.0	2.8	2.95	2.3	1.5	1.4	1.5	.7	.5	1.25	4.5	.9
29	1.9	....	2.8	2.15	1.5	1.35	1.3	.6	.55	1.1	3.15	.9
30	1.8	....	2.7	2.0	1.4	1.3	1.3	.6	.65	.95	2.45	.9
31	1.85	....	2.6	....	1.3	....	1.2	.6	....	.9	....	.9

[a] Ice conditions January 1 to February 21, 1899. River frozen February 22 to March 9, 1899; no readings taken.
[b] Backwater from ice February 5-6, 1900.

Daily gage height, in feet, of Shenandoah River at Millville, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901. [a]												
1	0.9	1.5	0.7	2.0	3.0	4.7	3.5	1.8	2.8	3.7	0.95	1.3
2	.9	1.6	.7	1.95	2.8	4.2	2.7	1.6	3.3	2.8	.95	1.2
3	.9	1.1	.7	2.5	2.7	3.7	2.4	1.5	3.0	2.4	.9	1.25
4	.95	1.0	.75	4.7	2.5	3.35	2.2	1.45	2.8	2.1	.9	1.5
5	.7	1.2	.75	5.7	2.4	3.3	1.15	1.4	2.3	1.8	.9	1.7
6	.9	2.3	.75	4.6	2.3	3.6	2.0	1.7	2.0	1.7	.9	1.8
7	.7	1.6	.8	4.2	2.2	4.1	2.5	2.1	1.9	1.5	.85	1.9
8	.8	1.6	.7	4.15	2.1	4.9	2.6	5.1	1.8	1.5	.85	1.8
9	.7	1.2	.8	3.6	2.1	4.5	2.0	3.8	1.6	1.5	.85	1.7
10	.8	1.2	.8	3.2	5.5	3.7	1.9	2.7	1.5	1.4	.85	1.7
11	.9	1.2	1.7	2.85	3.25	3.1	1.8	2.2	1.45	1.4	.85	1.7
12	2.1	.9	7.3	2.6	4.2	2.8	1.85	2.3	1.5	1.35	.85	1.7
13	2.3	1.2	5.3	2.4	3.5	2.6	2.1	3.1	1.9	1.35	.85	2.0
14	3.5	1.3	3.9	3.0	3.0	3.5	3.0	3.4	1.6	1.4	.8	2.0
15	2.9	1.3	3.2	10.25	2.7	2.9	4.3	2.6	1.5	1.35	.8	7.35
16	2.4	1.5	2.75	9.6	2.5	5.8	5.8	2.2	1.6	1.3	.8	10.5
17	2.1	1.0	2.4	6.1	2.3	10.1	5.2	2.75	1.5	1.2	.8	6.2
18	1.9	.9	2.2	4.9	2.25	5.7	4.2	2.6	1.5	1.1	.8	4.7
19	1.8	.8	2.0	4.3	2.2	4.6	4.3	2.6	1.45	1.1	.8	3.8
20	1.4	.8	1.8	4.6	2.15	3.9	3.9	2.6	1.4	1.1	.8	3.2
21	1.4	.8	2.0	10.55	2.0	3.5	3.5	2.2	1.3	1.0	.8	2.8
22	1.5	.9	2.2	(b)	2.5	5.7	3.2	2.1	1.25	1.0	.8	1.2
23	1.4	.9	2.4	8.5	11.1	5.5	2.7	2.0	1.2	1.0	1.0	1.2
24	1.3	.8	2.55	6.5	8.4	3.8	2.4	1.9	1.2	1.1	2.4	2.5
25	1.3	.9	2.3	5.3	6.3	3.2	2.2	2.2	1.15	1.0	2.7	2.4
26	1.3	.6	2.1	4.8	6.0	2.9	2.0	2.1	1.15	1.0	2.3	1.8
27	1.3	.8	2.1	4.3	6.7	2.9	2.1	2.2	1.1	1.0	1.8	2.3
28	1.3	.8	2.1	3.9	6.2	3.1	1.85	2.5	1.1	1.0	1.7	2.7
29	1.5	......	2.6	3.5	6.3	2.7	1.8	2.6	1.3	1.0	1.5	4.0
30	1.4	......	2.4	3.2	5.6	3.0	1.8	2.3	5.3	1.0	1.3	10.8
31	1.2	......	2.15	......	4.9	......	1.85	3.0	......	1.0	......	(b)
1902. [c]												
1	7.4	3.1	14.5	3.75	2.2	1.45	1.3	.9	.65	.9	.8	2.7
2	5.3	2.85	9.0	3.4	2.15	1.4	1.2	1.5	.65	.85	.8	2.45
3	4.5	3.0	7.2	3.2	2.2	1.35	1.15	1.9	.6	.8	.8	3.1
4	4.0	3.0	5.7	3.1	2.25	1.3	1.1	1.7	.6	.7	.8	3.2
5	3.5	2.8	5.0	2.9	2.1	1.3	1.05	1.3	.6	.9	.75	4.5
6	3.25	2.5	4.5	2.8	2.05	1.3	1.1	1.2	.65	1.0	.75	3.4
7	3.0	2.8	4.2	2.6	2.0	1.4	1.1	1.1	.6	.8	.7	3.7
8	2.85	2.7	4.2	2.8	4.0	1.25	1.05	1.05	.55	.75	.7	3.2
9	2.75	2.2	5.5	6.0	2.7	1.2	1.05	1.0	.6	1.1	.7	2.9
10	2.6	2.2	7.8	6.9	2.4	1.2	1.0	.9	.55	1.0	.65	2.65
11	2.5	2.1	8.0	7.2	2.1	1.15	.95	.8	.55	.9	.65	2.6
12	2.4	2.2	7.4	6.2	2.0	1.1	.9	.8	.55	1.0	.6	2.35
13	2.25	2.1	7.2	5.6	2.0	1.1	.9	.8	.5	1.2	.65	2.8
14	2.4	2.0	7.0	5.0	1.95	1.0	.9	.8	.5	1.75	.7	3.4
15	2.2	2.1	6.0	4.4	1.9	1.1	.8	.8	.55	1.55	.65	3.4
16	2.1	1.5	5.0	3.9	1.8	1.2	.8	.75	.55	1.3	.6	3.4
17	2.0	1.9	5.2	3.6	1.7	1.2	.8	.7	.5	1.15	.65	4.4
18	1.9	2.0	5.9	3.4	1.7	1.1	.8	.7	.5	1.0	.8	4.3
19	1.85	2.0	5.0	3.2	1.75	1.6	.75	.85	.5	.95	.8	4.0
20	1.8	1.7	4.4	3.0	1.8	1.4	.75	.8	.55	.9	.9	3.5
21	1.9	1.0	4.1	2.8	1.75	1.2	.8	.8	.6	.85	.8	3.1
22	3.2	2.4	3.8	2.7	1.7	1.2	.8	.8	.6	.8	.9	2.9
23	3.4	4.5	3.5	2.6	1.65	1.1	.8	.8	.6	.75	1.0	2.7
24	2.9	3.9	3.2	2.5	1.6	1.1	.75	.8	.55	.7	1.0	2.5
25	2.5	4.7	3.1	2.4	1.6	1.2	.75	.75	.55	.7	1.0	2.3
26	2.3	(d)	2.95	2.3	1.6	1.2	.8	.75	.6	.7	1.2	2.2
27	2.5	(d)	2.8	2.25	2.2	1.15	1.0	.7	.6	.65	2.0	2.1
28	3.6	11.0	2.75	2.2	1.75	1.1	.9	.7	.6	.9	2.5	2.1
29	4.4	......	3.0	2.2	1.6	1.3	1.3	.7	.65	.85	2.4	2.1
30	3.6	......	3.8	2.2	1.55	1.4	1.3	.65	1.0	.8	2.1	1.9
31	3.3	......	3.9	......	1.5	......	1.4	.65	......	.8	......	1.8

[a] Water backed by ice during part of January and February, 1901.
[b] No reading; river out of banks April 22 and December 31, 1901.
[c] Ice conditions during part of February, 1902.
[d] Flood; no observation February 26–27, 1902.

Daily gage height, in feet, of Shenandoah River at Millville, W. Va.—Continued

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.												
1	1.7	4.0	7.2	6.4	2.5	4.4	4.6	1.3	1.2	1.1	0.9	0.7
2	1.7	3.6	6.5	5.0	2.4	3.8	4.2	1.35	2.2	1.1	.9	.7
3	6.1	3.3	5.0	4.4	2.3	3.2	3.0	1.3	2.7	1.1	.9	.7
4	8.7	3.3	4.2	4.1	2.2	2.5	2.75	1.5	2.05	1.05	.9	.65
5	5.9	3.8	3.8	3.9	2.15	2.2	2.5	1.6	1.7	1.05	.95	.6
6	4.75	4.2	3.5	3.7	2.1	2.0	3.4	1.9	1.55	1.0	1.0	.6
7	4.0	3.7	3.25	3.5	2.1	3.9	4.65	2.0	1.45	1.0	.9	.6
8	3.5	3.3	3.2	3.3	2.05	9.2	3.7	1.7	1.3	1.8	.9	.55
9	3.1	2.7	3.6	3.3	2.0	6.5	2.3	1.5	1.25	2.1	.9	.6
10	2.8	2.5	3.4	3.3	1.9	8.9	2.0	1.55	1.2	2.0	.9	.8
11	2.7	2.3	3.3	3.2	1.85	4.9	1.95	1.4	1.2	1.8	.9	.7
12	2.7	2.1	3.2	3.0	1.8	4.6	1.9	1.4	1.3	1.65	.9	.7
13	2.2	2.3	3.2	3.1	1.75	4.0	2.7	1.35	1.2	1.55	.9	.7
14	2.3	2.7	3.0	5.4	1.7	4.3	2.6	1.3	1.2	1.5	.85	.8
15	2.0	2.6	2.95	7.8	1.7	3.6	2.8	1.3	1.2	1.4	.85	.8
16	2.3	2.6	2.8	6.6	1.65	3.1	2.7	1.25	1.1	1.3	.85	[a]1.1
17	2.2	3.3	2.7	6.1	1.65	2.8	2.2	1.25	1.3	1.3	.9	.5
18	2.35	4.6	2.6	5.0	1.6	2.6	2.0	1.2	2.1	1.25	.9	.7
19	2.3	4.1	2.55	4.4	1.55	2.4	1.9	1.5	4.6	1.2	.85	.8
20	1.95	3.6	2.5	3.9	1.55	2.1	1.8	1.45	3.1	1.2	.85	.9
21	2.2	3.4	2.5	3.7	1.5	2.0	1.7	1.3	2.7	1.2	.85	1.1
22	3.5	3.3	2.5	3.6	1.5	2.0	1.65	1.25	2.2	1.15	.85	1.0
23	6.0	3.0	4.1	3.3	1.5	1.9	1.6	1.2	1.8	1.1	.8	1.2
24	3.4	3.0	7.3	3.1	1.5	1.9	1.55	1.1	1.6	1.05	.8	1.4
25	2.8	3.2	7.6	3.0	1.5	1.85	1.5	1.05	1.5	1.0	.8	1.2
26	2.6	3.5	5.7	2.9	1.8	1.8	1.5	1.0	1.4	1.0	.8	.8
27	2.3	3.5	4.3	2.8	1.8	2.65	1.45	.95	1.3	1.0	.75	.9
28	3.35	4.0	3.8	2.7	1.7	3.2	1.35	1.1	1.25	.95	.7	1.0
29	6.9	......	3.4	2.65	1.7	5.2	1.3	1.8	1.2	.95	.6	.9
30	5.2	......	3.4	2.55	1.85	5.7	1.25	1.25	1.15	.95	.6	.8
31	4.5	......	5.5	......	2.05	......	1.25	1.2	......	.95	......	.8
1904.[b]												
1	.8	......	......	1.8	3.3	4.0	1.5	1.15	.6	.45	.45	.45
2	.85	......	......	1.8	3.3	2.6	1.4	1.05	.6	.4	.45	.45
3	1.2	......	......	1.75	2.7	2.3	1.3	1.1	.6	.4	.4	.5
4	1.2	......	......	1.7	2.4	2.1	1.2	1.25	.6	.4	.5	.5
5	1.0	......	......	1.6	2.15	2.6	1.1	1.4	.6	.4	.45	.5
6	1.0	......	......	1.5	2.1	2.85	1.2	1.4	.6	.4	.45	.55
7	1.1	......	......	1.5	1.95	4.0	1.15	1.7	.6	.45	.45	.5
8	1.1	......	2.3	1.5	2.0	2.9	1.3	1.8	.6	.45	.45	.5
9	1.3	......	4.9	1.6	2.0	2.4	1.25	1.45	.55	.4	.4	.5
10	1.2	......	3.5	1.7	2.3	2.15	1.35	1.4	.55	.4	.4	.5
11	1.2	......	3.0	2.45	2.5	2.0	5.6	1.35	.5	.4	.5	.85
12	1.1	......	2.5	2.4	2.45	1.85	3.7	1.4	.5	.5	.45	.5
13	1.1	......	2.3	2.2	2.3	1.75	2.8	1.35	.6	.5	.5	.65
14	1.0	......	2.0	2.0	2.05	1.5	2.1	1.3	.6	.55	.6	.65
15	1.0	......	1.9	1.75	1.9	1.4	1.75	1.1	.9	.5	.6	.75
16	1.0	......	1.8	1.65	1.85	1.35	1.5	1.05	.9	.5	.5	.6
17	1.0	......	1.75	1.6	1.8	1.4	1.4	1.0	.8	.5	.5	1.65
18	1.0	......	1.7	1.55	1.8	1.65	1.3	1.0	.75	.5	.5	1.8
19	1.1	......	1.6	1.45	1.9	1.4	1.3	.95	.7	.5	.55	1.55
20	1.1	......	1.5	1.45	2.3	1.35	1.2	.9	.65	.45	.5	.8
21	1.3	......	1.45	1.3	3.5	1.6	1.2	.9	.6	.6	.5	.7
22	1.6	......	1.5	1.25	2.95	1.7	1.2	.85	.65	.6	.5	.7
23	2.3	......	1.6	1.2	2.45	1.9	1.15	.9	.6	.6	.5	.7
24	2.6	......	1.6	1.15	2.15	1.6	1.1	.8	.55	.55	.5	.7
25	......	......	1.65	1.1	2.0	1.45	1.2	.9	.5	.5	.5	.8
26	......	......	1.8	1.1	1.95	1.3	1.3	.8	.5	.5	.45	1.15
27	......	......	1.85	1.3	2.3	1.2	1.2	.75	.5	.45	.45	1.1
28	......	......	1.8	2.5	1.95	1.15	1.1	.7	.5	.4	.45	1.3
29	......	......	1.75	4.3	1.7	1.1	1.1	.6	.5	.4	.45	2.25
30	......	......	1.7	3.85	1.7	1.6	1.25	.55	.45	.4	.45	1.2
31	......	......	1.7	......	1.55	......	1.1	.6	......	.4	......	1.1

[a] Backwater from ice December 16, 1903. [b] Backwater from ice during part of December, 1904.

Daily gage height, in feet, of Shenandoah River at Millville, W. Va.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	1.0	1.4	3.35	2.2	1.2	1.2	1.9	2.1	1.15	0.6	0.7	0.6
2	.95	1.2	2.75	2.05	1.15	1.2	1.75	1.7	1.0	.55	.7	.6
3	.85	1.3	2.7	1.9	1.15	1.5	1.75	1.4	.95	.5	.65	.65
4	1.4	1.3	2.8	1.8	1.1	1.2	1.6	1.3	.9	.5	.65	.6
5	1.6	1.2	2.8	1.8	1.1	1.1	1.6	1.2	1.0	.5	.65	.6
6	1.55	1.2	[a] 4.1	2.0	1.0	1.0	1.6	1.1	1.05	.5	.65	.8
7	2.1	1.2	2.5	2.45	1.0	1.15	2.3	1.1	1.0	.5	.65	1.35
8	2.8	1.25	2.5	2.45	1.0	2.0	2.1	1.1	1.0	.5	.65	1.2
9	2.5	1.25	2.8	2.3	.95	1.2	2.3	1.1	.95	.5	.65	1.1
10	2.0	1.3	3.7	2.1	.95	1.0	2.1	1.05	.8	.5	.65	1.0
11	1.8	1.35	4.75	2.0	1.0	1.0	1.9	1.05	.8	.5	.6	.95
12	1.5	1.45	4.3	1.95	1.0	1.1	2.0	1.0	.85	.55	.6	.9
13	2.0	1.4	3.3	1.9	1.0	.9	2.8	.95	.8	.7	.6	.85
14	2.6	1.25	3.2	1.8	.95	.8	2.6	.95	.8	.7	.6	.8
15	2.9	1.25	2.9	1.7	2.0	.8	3.8	1.1	.8	.7	.6	.8
16	2.5	1.3	2.6	1.7	2.0	.75	5.3	1.1	.75	.7	.6	.8
17	2.0	1.55	2.4	1.65	2.1	.75	3.3	3.2	.8	.65	.6	.8
18	2.0	1.55	2.3	1.6	2.3	.7	2.7	2.3	.8	.65	.6	.8
19	2.0	1.5	2.2	1.5	2.1	.7	2.3	1.9	.85	.65	.55	.9
20	1.7	1.6	2.1	1.45	1.8	.7	2.0	1.5	.8	.65	.55	.9
21	1.6	1.55	2.4	1.4	1.7	.9	1.8	1.4	.8	.6	.6	2.3
22	1.5	1.5	2.7	1.4	1.5	3.3	1.8	1.3	.8	.6	.6	4.1
23	1.4	1.55	4.0	1.4	1.4	3.2	1.8	1.2	.8	.6	.6	5.3
24	1.3	1.6	3.4	1.35	1.3	3.5	2.8	1.1	.8	.6	.6	4.25
25	1.6	2.0	3.2	1.3	1.3	5.9	2.4	1.1	.75	.6	.6	3.6
26	1.6	2.2	3.6	1.2	1.2	4.8	2.2	1.9	.6	.65	.6	3.2
27	1.85	2.6	3.2	1.2	.9	3.5	1.9	2.1	.6	.8	.6	2.75
28	1.6	3.0	2.9	1.2	1.0	3.0	1.6	1.8	.6	.9	.6	2.4
29	1.5	....	2.7	1.3	1.0	2.5	1.4	1.5	.55	.85	.6	2.2
30	1.6	....	2.5	1.3	1.0	2.1	1.9	1.25	.55	.85	.6	2.3
31	1.5	....	2.3	....	1.1	....	2.4	1.1	....	.85	....	2.3
1906.												
1	2.7	2.3	1.1	4.75	2.3	1.5	2.0	1.3	3.55	1.45	2.7	1.85
2	2.45	2.2	1.1	4.2	2.2	1.5	1.8	1.4	3.8	1.45	2.5	1.8
3	2.25	2.0	1.2	3.8	2.1	1.4	1.6	1.8	2.7	1.4	2.4	1.75
4	3.4	[b] 2.4	2.2	3.4	2.0	1.3	1.3	1.4	2.2	1.7	2.3	1.7
5	5.3	2.0	2.5	3.1	1.95	1.2	2.15	2.5	2.2	2.5	2.2	1.65
6	4.5	1.95	3.5	2.9	1.9	2.1	1.7	2.3	2.0	3.5	2.1	1.7
7	3.6	1.9	2.9	2.7	1.85	1.3	1.55	2.1	1.9	3.1	2.05	1.65
8	3.0	1.8	2.5	2.6	1.8	1.2	1.6	2.0	1.8	2.6	2.0	1.6
9	2.7	1.6	2.3	2.4	2.1	1.2	1.5	2.2	1.65	2.3	1.9	1.55
10	2.45	1.6	2.1	2.45	2.05	1.65	1.35	2.3	1.6	2.05	1.85	1.5
11	2.3	1.75	2.0	2.6	1.9	1.9	1.3	2.0	1.5	1.8	1.8	1.6
12	2.15	1.5	1.9	2.6	1.85	1.5	1.3	2.0	1.5	1.8	1.8	1.65
13	2.0	1.45	1.75	2.45	1.8	1.2	1.3	3.0	1.45	1.65	1.75	1.55
14	2.0	1.3	1.7	2.3	1.7	1.2	1.3	3.4	1.9	1.5	1.75	1.5
15	2.0	1.35	1.7	3.2	1.6	1.2	1.4	3.8	1.6	1.4	1.75	1.4
16	2.2	1.3	1.8	4.7	1.55	2.0	1.3	3.9	1.5	1.4	1.7	1.45
17	2.3	1.3	1.9	4.2	1.4	2.6	1.3	3.2	1.35	1.4	1.65	1.7
18	2.25	1.2	2.6	3.6	1.35	2.1	1.3	4.1	1.3	1.5	1.6	4.2
19	2.2	1.2	2.7	3.2	1.45	3.8	1.4	3.35	1.35	4.1	1.8	4.5
20	2.1	1.2	2.7	2.95	1.4	2.4	1.5	4.2	1.3	11.3	2.25	4.0
21	2.0	1.2	2.7	2.7	1.3	2.7	1.4	3.9	1.25	12.8	4.3	3.5
22	1.9	1.2	2.9	2.5	1.25	4.8	1.3	3.4	1.2	8.3	3.8	3.6
23	1.8	1.2	3.15	2.4	1.2	3.7	1.2	3.3	1.2	6.5	3.85	3.4
24	1.8	1.2	3.1	2.25	1.2	2.9	2.0	4.0	1.2	5.7	2.9	3.0
25	3.8	1.15	2.9	2.1	1.15	2.5	1.6	4.5	1.1	4.9	2.7	2.6
26	3.2	1.1	2.9	2.0	1.1	2.15	1.5	4.5	1.25	4.2	2.7	2.2
27	2.7	1.1	3.0	2.0	1.2	2.4	1.4	3.8	1.25	3.8	2.25	2.0
28	2.5	1.1	4.8	3.4	1.3	3.5	1.4	5.4	1.25	3.5	2.15	2.4
29	2.4	....	4.9	2.9	1.5	3.25	1.4	4.7	1.25	3.2	2.1	2.4
30	2.4	....	4.6	2.5	1.4	2.4	1.5	5.0	1.35	3.0	2.0	2.25
31	2.5	....	4.6	....	1.4	....	1.3	4.2	....	2.8	....	2.2

[a] Backwater March 6, 1905.

[b] Backwater from ice February 4, 1906.

Rating tables for Shenandoah River at Millville, W. Va.

APRIL 15, 1895, TO FEBRUARY 6, 1897, AND MARCH 8, 1904, TO DECEMBER 31, 1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.30	430	2.30	2,940	4.60	8,860	8.40	26,400
.40	480	2.40	3,130	4.80	9,540	8.60	27,700
.50	540	2.50	3,330	5.00	10,260	8.80	29,000
.60	610	2.60	3,530	5.20	11,020	9.00	30,400
.70	690	2.70	3,730	5.40	11,780	9.20	31,800
.80	780	2.80	3,940	5.60	12,580	9.40	33,200
.90	880	2.90	4,150	5.80	13,400	9.60	34,600
1.00	980	3.00	4,370	6.00	14,240	9.80	36,000
1.10	1,090	3.10	4,600	6.20	15,120	10.00	37,500
1.20	1,200	3.20	4,840	6.40	16,000	11.00	45,100
1.30	1,320	3.30	5,080	6.60	16,920	12.00	53,500
1.40	1,450	3.40	5,320	6.80	17,840	13.00	62,700
1.50	1,580	3.50	5,570	7.00	18,800	14.00	72,700
1.60	1,720	3.60	5,830	7.20	19,780	15.00	83,200
1.70	1,870	3.70	6,100	7.40	20,780	16.00	94,300
1.80	2,030	3.80	6,380	7.60	21,820	17.00	105,900
1.90	2,200	3.90	6,670	7.80	22,880	18.00	118,000
2.00	2,380	4.00	6,960	8.00	24,020	19.00	130,600
2.10	2,560	4.20	7,560	8.20	25,200	20.00	143,700
2.20	2,750	4.40	8,200				

FEBRUARY 10, 1897, TO JANUARY 24, 1904.[b]

0.20	470	2.10	2,770	4.00	7,380	6.80	18,300
.30	520	2.20	2,960	4.10	7,700	7.00	19,220
.40	580	2.30	3,150	4.20	8,020	7.20	20,140
.50	650	2.40	3,350	4.30	8,340	7.40	21,100
.60	730	2.50	3,560	4.40	8,680	7.60	22,060
.70	820	2.60	3,770	4.50	9,020	7.80	23,060
.80	910	2.70	3,990	4.60	9,360	8.00	24,060
.90	1,010	2.80	4,210	4.70	9,700	8.20	25,100
1.00	1,120	2.90	4,440	4.80	10,060	8.40	26,200
1.10	1,230	3.00	4,670	4.90	10,420	8.60	27,300
1.20	1,350	3.10	4,910	5.00	10,800	8.80	28,500
1.30	1,480	3.20	5,150	5.20	11,560	9.00	29,800
1.40	1,620	3.30	5,400	5.40	12,320	9.20	31,200
1.50	1,760	3.40	5,650	5.60	13,120	9.40	32,700
1.60	1,910	3.50	5,910	5.80	13,940	9.60	34,200
1.70	2,070	3.60	6,180	6.00	14,780	9.80	35,800
1.80	2,240	3.70	6,460	6.20	15,640	10.00	37,500
1.90	2,410	3.80	6,760	6.40	16,520		
2.00	2,590	3.90	7,060	6.60	17,400		

[a] This table is strictly applicable only for open-channel conditions. It is based on 14 discharge measurements made during 1895 and 1904. It is well defined between gage heights 0.4 feet and 5.2 feet. Estimates above 5.0 feet are based on a discharge curve which is the product of a well-defined area curve and a fairly accurate extension of the velocity curve. The discharge curves 1895–1906 are the same above gage height 10.0 feet.

Th s table is strictly applicable only for open-channel conditions. It is based on 14 discharge measments made during 1897–1903. It is well defined between gage heights 0.5 foot and 5.0 feet. The discharge curves 1895–1906 are the same above gage height, 10.0 feet.

Estimated monthly discharge of Shenandoah River at Millville, W. Va.

[Drainage area, 3,000 square miles.[a]]

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss of, in inches.
1895.								
January							5.54	
February							1.34	
March							2.73	
April 15-30	4,600	1,870	2,904	0.970	0.576		[b] 3.78	
May	20,780	2,560	5,570	1.86	2.14	65	3.28	1.14
June	3,130	980	1,613	.539	.601	14	4.14	3.54
July	7,260	980	1,880	.628	.724	16	4.44	3.72
August	1,580	540	806	.269	.310	17	1.82	1.51
September	1,320	610	722	.241	.269	41	.66	.39
October	610	480	537	.179	.206	20	1.06	.85
November	690	540	621	.207	.231	15	1.57	1.34
December	1,450	610	754	.252	.290	9	3.09	2.80
The year							33.45	
1896.								
January	11,400	880	2,434	.813	.937	38	2.49	1.55
February	12,580	1,450	3,709	1.24	1.34	35	3.78	2.44
March	12,180	1,450	3,842	1.28	1.48	35	4.25	2.77
April	8,860	1,450	2,807	.937	1.05	85	1.24	.19
May	4,370	1,090	2,127	.710	.819	36	2.28	1.46
June	3,940	780	2,056	.686	.765	13	5.71	4.95
July	9,030	1,320	2,858	.954	1.10	18	6.21	5.11
August	1,870	780	1,150	.384	.443	14	3.20	2.76
September	13,190	540	1,042	.348	.388	5	7.22	6.83
October[c]	139,700	880	7,768	2.59	2.99	623	.48	−2.51
November	4,840	880	1,835	.613	.684	16	4.16	3.48
December	6,380	1,450	2,296	.767	.884	383	.23	−.65
The year	139,700	540	2,827	.944	12.88	31	41.25	28.37
1897.								
January[d]	1,720	980	1,220	.407	.469	33	4.41	.94
February (25 days)	37,870	1,090	11,680	3.90	3.63		[e] 6.28	
March	6,760	2,590	4,946	1.65	1.90	81	2.34	.44
April	3,350	1,620	2,671	.892	.995	53	1.90	.90
May	30,620	1,760	6,243	2.08	2.40	47	5.13	2.73
June	2,410	1,010	1,632	.545	.608	19	3.18	2.57
July[f]	3,770	910	1,426	.476	.549	13	4.14	3.59
August	1,760	730	987	.330	.380	27	1.41	1.03
September	1,350	580	664	.222	.248	25	1.01	.76
October	1,010	550	692	.231	.266	10	2.59	2.32
November	1,620	650	859	.287	.320	12	2.59	2.27
December[d]	3,990	820	1,619	.541	.624	18	3.51	2.89
The year							35.49	
1898.								
January	6,180	1,010	2,435	.813	.937	31	3.05	2.11
February[g]	2,770	1,010	1,612	.538	.560	75	.75	.19
March	5,650	1,010	2,227	.744	.858	23	3.73	2.87
April	13,120	2,070	4,353	1.45	1.62	61	2.66	1.04
May	29,150	2,070	5,711	1.91	2.20	42	5.21	3.01
June	2,410	1,120	1,647	.550	.614	21	2.86	2.25
July[h]	3,770	820	1,249	.417	.481	11	4.18	3.70
August[i]	50,900	1,350	8,164	2.73	3.15	41	7.73	4.58
September	1,835	1,120	1,360	.454	.506	26	1.97	1.46
October	30,500	1,010	5,684	1.90	2.19	31	7.10	4.91
November	4,210	2,070	2,827	.944	1.05	59	1.79	.74
December	14,780	2,410	4,498	1.50	1.73	55	3.13	1.40
The year	50,900	820	3,481	1.16	15.90	36	44.16	28.26

[a] 3,000 square miles used to obtain run-off for 1906; 2,995 used for all other years.
[b] Precipitation for complete month, April, 1895.
[c] Estimates October 1-2, 1896, approximate.
[d] Ice conditions during January and December 24-31, 1897. No correction made in estimates.
[e] Precipitation for whole month, February, 1897.
[f] Estimate July 11, 1897, interpolated.
[g] Ice conditions during February, 1898. No correction made in estimates.
[h] Estimate July 2, 1898, interpolated.
[i] Gage height August 11, 1898, estimated. Discharge approximate.

Estimated monthly discharge of Shenandoah River at Millville, W. Va.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss of, in inches.
1899.								
January [a]	17,840	2,770	5,116	1.71	1.97	78	2.52	0.55
February 1–21 [a] [b]	7,380	2,070	3,675	1.23	.960	....	[c] 4.95	....
March 10–31	12,720	4,440	7,065	2.36	1.93	....	[c] 5.12	....
April	4,910	2,070	3,289	1.10	1.23	106	1.16	— .07
May	4,910	1,480	2,533	.846	.975	20	4.95	3.97
June	4,670	1,010	1,607	.537	.599	29	2.09	1.49
July	1,760	730	877	.293	.338	14	2.51	2.17
August	1,910	650	992	.331	.382	10	3.94	3.56
September	1,760	730	989	.330	.368	10	3.78	3.41
October	910	650	785	.262	.302	13	2.34	2.04
November	5,150	910	1,403	.468	.522	64	.81	.29
December	4,440	820	1,398	.467	.538	40	1.34	.80
The year	....	....	....	....	....	....	35.51	....
1900.								
January	14,780	1,230	2,970	.992	1.14	44	2.57	1.43
February [d]	14,360	1,350	3,833	1.28	1.33	36	3.73	2.40
March	16,960	2,590	5,866	1.96	2.26	61	3.72	1.46
April	4,670	1,835	2,803	.936	1.04	55	1.89	.85
May	2,410	1,230	1,689	.564	.650	27	2.42	1.77
June	9,020	1,010	2,249	.751	.838	14	5.98	5.14
July	4,210	775	1,374	.459	.529	14	3.76	3.23
August	1,290	690	829	.277	.319	17	1.93	1.61
September	1,230	580	696	.232	.259	8	3.14	2.88
October	2,770	650	947	.316	.364	11	3.19	2.83
November	9,020	730	1,453	.485	.541	18	2.94	2.40
December	10,060	1,010	2,232	.745	.859	47	1.83	.97
The year	16,960	580	2,245	.750	10.13	27	37.10	26.97
1901.								
January [e]	5,910	820	1,812	.605	.698	30	2.31	1.61
February [e]	3,150	730	1,315	.439	.457	139	.33	— .13
March	20,620	820	3,376	1.13	1.30	34	3.80	2.50
April [f]	50,000	2,500	12,840	4.29	4.79	77	6.24	1.45
May	45,920	2,590	8,704	2.91	3.36	58	5.82	2.46
June	38,240	3,770	8,225	2.75	3.07	41	7.54	4.47
July	13,940	1,290	4,437	1.48	1.71	39	4.38	2.67
August	11,180	1,620	3,528	1.18	1.36	23	5.92	4.56
September	11,940	1,230	2,496	.833	.929	25	3.78	2.85
October	6,460	1,120	1,769	.591	.681	99	.69	.01
November	3,990	910	1,341	.448	.500	25	2.01	1.51
December [f]	50,000	1,350	8,124	2.71	3.12	51	6.12	3.00
The year	50,000	730	4,831	1.61	21.98	45	48.94	26.96
1902.								
January	21,100	2,240	5,176	1.73	1.99	74	2.69	.70
February [g]	50,000	1,120	8,611	2.88	3.00	67	4.46	1.46
March	77,900	4,100	13,880	4.63	5.34	148	3.61	—1.73
April	20,140	2,960	6,785	2.27	2.53	113	2.23	— .30
May	7,380	1,760	2,606	.870	1.00	38	2.64	1.64
June	1,910	1,120	1,402	.468	.522	18	2.93	2.41
July	1,620	865	1,097	.366	.422	19	2.17	1.75
August	2,410	775	1,062	.355	.409	18	2.22	1.81
September	1,120	650	724	.242	.270	10	2.59	2.32
October	2,155	775	1,069	.357	.412	11	3.65	3.24
November	3,560	730	1,157	.386	.431	13	3.21	2.78
December	9,020	2,240	4,728	1.58	1.82	54	3.38	1.56
The year	77,900	650	4,025	1.34	18.15	51	35.78	17.63

[a] Ice conditions during January and February, 1899. No correction made in estimates.
[b] Estimates February 12–13, 1899. interpolated.
[c] Precipitation for complete months, February and March, 1899.
[d] Backwater from ice February 5–6, 1900. Discharge corrected.
[e] Slight backwater from ice during part of January and February, 1901; no correction made in estimates.
[f] April 22 and December 31, 1901, river out of banks; discharge estimated 50,000 second-feet.
[g] Ice conditions during part of February, 1902; no correction made in estimates. February 26–27, 1902, river out of banks; discharge estimated 50,000 second-feet.

Estimated monthly discharge of Shenandoah River at Millville, W. Va.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss of, in inches.
1903.								
January	27,900	2,070	6,802	2.27	2.62	64	4.08	1.46
February	9,360	2,770	5,448	1.82	1.90	54	3.49	1.59
March	22,060	3,560	7,907	2.64	3.04	73	4.15	1.11
April	23,060	3,665	7,880	2.63	2.93	81	3.62	.69
May	3,560	1,760	2,321	.775	.894	33	2.69	1.80
June	31,200	2,240	7,448	2.49	2.78	36	7.63	4.85
July	9,530	1,415	3,453	1.15	1.33	43	3.06	1.73
August	2,590	1,065	1,590	.531	.612	17	3.53	2.92
September	9,360	1,230	2,249	.751	.838	35	2.42	1.58
October	2,770	1,065	1,454	.485	.559	23	2.39	1.83
November	1,120	730	961	.321	.358	44	.82	.46
December [a]	1,620	650	927	.310	.357	38	.96	.60
The year	31,200	650	4,037	1.35	18.22	47	38.84	20.62
1904.								
January 1 to 24	3,770	910	1,428	.477	.426	....	[b] 1.80	....
February	....	....	....	....	....	....	1.26	....
March 8 to 31	9,900	1,515	2,546	.850	.759	....	[b] 2.08	....
April	7,880	1,090	2,191	.732	.817	31	2.64	1.82
May	5,570	1,650	2,779	.928	1.07	31	3.43	2.36
June	6,960	1,090	2,430	.811	.905	16	5.57	4.67
July	12,580	1,090	1,930	.644	.742	15	5.04	4.30
August	2,030	575	1,096	.366	.422	17	2.53	2.11
September	880	510	620	.207	.231	12	1.95	1.72
October	610	480	521	.174	.201	17	1.20	1.00
November	610	480	528	.176	.196	21	.95	.75
December [c]	2,845	510	.780	.260	.300	12	2.46	2.16
The year	....	....	....	....	....	....	30.91	....
1905.								
January	4,150	830	2,065	.689	.794	28	2.86	2.06
February	4,370	1,200	1,684	.562	.585	27	2.14	1.56
March [d]	9,370	2,560	4,387	1.46	1.68	69	2.44	.76
April	3,230	1,200	1,945	.649	.724	38	1.90	1.18
May	2,940	880	1,382	.461	.531	14	3.93	3.40
June	13,820	690	2,552	.852	.950	17	5.50	4.55
July	11,400	1,450	2,994	1.00	1.15	19	5.98	4.83
August	4,840	930	1,557	.520	.600	19	3.19	2.59
September	1,145	575	810	.270	.301	18	1.65	1.35
October	880	540	640	.214	.247	9	2.84	2.59
November	690	575	624	.208	.232	26	.90	.67
December	11,400	610	2,336	.780	.899	24	3.82	2.92
The year	13,820	540	1,915	.639	8.69	23	37.15	28.46
1906.								
January	11,400	2,030	3,719	1.24	1.43	....	....	....
February [e]	2,940	1,090	1,643	.548	.571	....	....	....
March	9,900	1,090	3,888	1.30	1.50	....	....	....
April	9,370	2,380	4,464	1.49	1.66	....	....	....
May	2,940	1,090	1,803	.601	.693	....	....	....
June	9,540	1,200	2,895	.965	1.08	....	....	....
July	2,655	1,200	1,578	.527	.608	....	....	....
August	11,780	1,320	5,220	1.74	2.01	....	....	....
September	6,380	1,090	1,980	.660	.736	....	....	....
October	60,820	1,450	8,248	2.75	3.17	....	....	....
November	7,880	1,720	3,021	1.01	1.13	....	....	....
December	8,520	1,450	3,052	1.02	1.18	....	....	....
The year	60,820	1,090	3,459	1.15	15.77	....	....	....

[a] Backwater December 16, 1903, discharge corrected.
[b] Precipitation for complete months, January and March, 1904.
[c] Backwater during part of December, 1904, discharge corrected.
[d] Backwater March 6, 1905; discharge corrected.
[e] Backwater February 4, 1906; discharge corrected.

The following table gives the horsepower, 80 per cent efficiency per foot of fall, that may be developed at different rates of discharge, and shows the number of days on which the flow and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Discharge and horsepower table for Shenandoah River at Millville, W. Va., for 1895 to 1906.

Discharge in second-feet.	Horsepower, 80 per cent efficiency, per foot fall.	Days of deficient flow.											
		[a] 1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
495	45	......	......	......	......	......	......	......	......	......	15	......	......
550	50	33	4	......	......	......	......	......	......	......	73	9	......
660	60	98	24	50	......	3	20	......	5	1	106	60	......
770	70	118	26	67	......	29	54	1	26	8	114	73	......
880	80	125	34	85	7	70	89	11	63	19	122	101	......
990	90	154	75	107	11	112	109	38	97	37	133	137	......
1,100	100	160	82	146	32	141	128	55	112	59	147	155	7
1,320	120	166	89	179	91	167	161	78	145	82	180	180	36
1,540	140	185	130	210	116	184	202	104	167	118	215	208	85
1,760	160	192	192	220	143	194	219	120	174	129	234	238	116

[a] April 15 to December 31, 1895.

NOTE.—The minimum flow during the period covered by the above table was 480 second-feet, giving 44 horsepower per foot of fall, for fifteen days during October and November, 1904.

MISCELLANEOUS DISCHARGE MEASUREMENTS IN SHENANDOAH RIVER BASIN BELOW NORTH AND SOUTH FORKS.

The following miscellaneous discharge measurements have been made in the basin of Shenandoah River below the junction of North and South forks.

Miscellaneous discharge measurements in Shenandoah River basin below North and South forks.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
			Feet.	*Square feet.*	*Feet per sec.*	*Second-feet.*
1897.						
October 7	Wappan Run	Near mouth near Linden, Va.	5	1.4	0.79	[a] 1.1
October 9	Stonebridge Run	Near Milldale, Va	....	....	....	[b] 3
Do	Parker Creek	Near Millwood, Va	....	....	....	4
October 8	Crystal Run	Near Berryville, Va	....	....	....	[b] 3
October 2	Bullskin Run	At Johnson's factory, at mouth near Kabletown, W. Va.	8	12	.62	[c] 7.5
October 1	Evitt Run	At bridge near mouth near Charles Town, W. Va.	16	13	.92	12
October 25	Flowing Run	Near Millville, W. Va	6	7.2	.63	4.5
1894.						
July 6	Shenandoah River	Harpers Ferry, W. Va	....	467	2.61	1,218

[a] Low discharge; it may be due to storage of water at dam above.
[b] Stonebridge Run and Crystal Run fed by large springs.
[c] Water considered very low.

POTOMAC RIVER BASIN BELOW SHENANDOAH RIVER.

POTOMAC RIVER AT POINT OF ROCKS, MD.

This station was established by C. C. Babb February 17, 1895. It is located at the steel highway bridge at Point of Rocks, Md.

The channel is straight for 500 feet above and 200 feet below the station. It is 1,300 feet wide, broken by seven bridge piers. Both banks overflow only at extremely high water, and are not wooded. In the two right spans the bed is composed of mud, and is subject to some change; in the other spans the bed is composed of gravel and cobblestones and is permanent. The current does not flow at right angles with the bridge in all of the spans.

Discharge measurements are made from the eight-span steel toll bridge, to which the gage is attached. The initial point for soundings is the left end of the lower guard rail, 0.4 foot beyond the center of the end pin, on the downstream side of the bridge.

As originally placed the gage was located in the third span of the bridge from the left bank. The length of the wire from the end of the weight to the marker was 48.0 feet. The zero of the gage was 40.9 feet below bench mark No. 1, described below. June 18, 1896, a new wire gage was placed on the lower side of the first span of the bridge. The zero of the gage was changed to 41.3 feet below bench mark No. 1, the wire length being 44.19 feet. During 1896 and 1897 the wire became rusted and broke frequently; the changes in wire length were not recorded. January 25, 1898, a new wire was put in, the length being 44.22 feet, and this length has been maintained since that date, the datum elevation continuing at 41.3 feet below bench mark No. 1.

During the period between the measurements of April 16 and July 29, 1901, a large quantity of earth excavated from the canal was thrown into the river along its left bank, changing the section and possibly affecting the flow of the river. The shifting of this material necessitated moving the gage farther from the shore. This was done by the observer, who attempted to install a temporary gage to read the same as the old one. The indications are, however, that the gage was not set to read exactly the same, and the gage heights between April 16, 1901, and September 2, 1902, are somewhat in error.

A standard chain gage was installed at this station September 2, 1902. It is bolted to the hand rail on the lower side of the bridge on the first span from the left bank. The length of the chain is 44.22 feet, the same length as had been previously used. In placing the box, however, the gage datum was lowered 0.45 foot, making elevation of the bench mark above gage datum 41.75 feet, instead of 41.3 feet. The gage is read once each day by George H. Hickman. Bench mark No. 1, established November 16, 1896, is a copper bolt in a large capstone on the lower wing wall of the north abutment, about 10 feet from the north end of the first iron truss and 41.75 feet above the datum of the gage.

All estimates published in Progress Reports prior to 1905 have been revised. Estimates do not include the discharge of the Chesapeake and Ohio Canal, which forms an appreciable percentage of the total flow of the river at low stages. Uncertain length of gage wire or chain and ice conditions are the chief sources of error at this station. Two rating curves are necessary on account of the change in gage datum made September 2, 1902. For normal conditions of flow and correct wire or chain length the estimates as published below are probably within 5 per cent of the true discharge of the river section.

For the period January 1 to June 17, 1896, when the gage-height records are in doubt, a comparison of the Point of Rocks estimates was made with the Cumberland, Springfield, and Millville estimates. This comparison seems to indicate that the Point of Rocks estimates for this period may be as much as 20 per cent too low.

During 1897 the gage-wire length was greatly in error. The proper correction to be applied to the gage heights was determined by the amount that the discharge measurements of that year plotted above or below the rating curve. A comparison of the Point of Rocks estimates with the Cumberland and Millville estimates indicates that the former are well within 10 per cent of the true discharge for 1897.

It is believed that estimates from April 16 to December 31, 1901, can be considered within 10 per cent of the correct discharge. Although the difference between the gage zero and the datum plane was not known with certainty, it is believed to have been very small, because the measurements for that period plot on the first rating curve, and because the hydrographer's and the observer's gage-height observations on the dates of the measurements agree.

It is believed that the second rating curve, which is applied after March 31, 1902, gives estimates correctly within 10 per cent from June 22 to September 1, 1902, because the measurement of June 22 plots on this rating curve and the gage height agrees with the observer's gage height. There are no data available, however, for determining the exact date on which the change should be made from the first to the second rating curve. The date was arbitrarily chosen as April 1, 1902, which is about halfway between the measurements of December 27, 1901, and June 22, 1902. It should be noticed that during the two most doubtful months—March and April—much high water exists, and hence the percentage error during those months is not large. But if the date for changing rating tables was not chosen correctly there is liability of errors from 15 to 40 per cent during the remainder of the doubtful period.

A summary of the records furnishes the following discharge data: Maximum discharge for twenty-four hours, 218,700 second-feet; minimum discharge for twenty-four hours, 900 second-feet; mean annual discharge, 1897 to 1906, inclusive, 10,575 second-feet; mean annual rainfall for eleven years, 36.21 inches.

Discharge measurements of Potomac River at Point of Rocks, Md.

Date.	Gage height.[a]	Discharge.
	Feet.	*Second-feet.*
1895.		
March 25	3.05	10,520
April 5	3.42	14,030
April 13	4.27	17,520
April 23	2.10	7,371
May 1	4.35	21,070
May 7	3.10	12,480
May 17	2.35	8,918
May 28	2.45	9,189
June 3	1.53	4,536
June 17	1.30	4,233
July 10	1.50	4,695
November 6	.40	1,202
1896.		
June 23	1.82	6,462
August 4	1.86	7,057
November 16	1.60	6,109
1897.		
February 9	[b]7.95	40,650
February 23 [c]	[b]21.70	154,800
March 8	5.70	27,380
March 27	4.05	17,120
July 23	[b]2.85	8,130
October 29	[b].20	2,141
April 12	[b]5.00	20,620
1898.		
January 25	6.50	33,340
August 19	3.30	14,310
October 3	.65	1,939
1899.		
January 28	3.80	17,330
May 20	8.15	45,990
September 5	.80	2,360
October 29	.50	1,628
1900.		
June 28	1.50	5,212
October 2 [d]	.30	1,259
September 19	[b].30	2,277
1901.		
April 16	14.30	100,800
July 29	1.85	6,530
December 27	2.89	11,410
1902.		
June 22	1.25	2,921
September 2	.87	1,717
1903.		
March 12	4.84	18,880
April 17	13.70	86,420
Do	13.10	80,520
April 18	9.60	54,080
September 14	1.50	3,770
November 9	1.12	2,140
1904.		
July 11	3.87	13,750
1905.		
March 13	6.56	28,640
June 20	1.29	2,997
October 30	2.05	4,889
November 9	1.20	2,531
Do	1.20	2,467
1906.		
May 30	1.70	3,892
Dec. 7	1.76	4,450

[a] All gage heights refer to datum 41.30 feet below bench mark No. 1, 1895 to 1901, inclusive, and 41.75 feet below the same bench mark, 1902 to 1906.
[b] Gage height inaccurate.
[c] Measurement recomputed, 1905.
[d] Measurement made by wading.

Discharge measurements of Chesapeake and Ohio Canal at Point of Rocks, Md.

Date.	Gage height.	Discharge.
1905.	*Feet.*	*Second-feet.*
October 30	[a] 21.51	78.8
November 9	[a] 21.51	90.0

[a] Elevation of water surface of canal above Potomac River gage datum determined with a level.

Daily gage height, in feet, of Potomac River at Point of Rocks, Md.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1895.												
1	......	......	6.1	3.1	3.3	1.8	2.0	1.0	0.6	0.3	0.4	0.4
2	......	......	9.7	3.0	5.9	1.7	2.7	.9	.7	.3	.4	.5
3	......	......	10.6	2.9	5.8	1.5	2.3	.8	.9	.3	.3	.5
4	......	......	9.6	3.6	5.4	1.4	2.1	.8	.7	.3	.3	.5
5	......	......	7.1	3.5	4.4	1.4	1.9	.9	.6	.3	.3	.5
6	......	......	5.6	3.0	3.7	1.4	1.7	.8	.6	.3	.4	.6
7	......	......	4.8	2.7	3.1	1.2	1.5	.8	.6	.3	.3	.8
8	......	......	4.3	2.6	2.7	.8	1.5	.8	.5	.3	.3	.8
9	......	......	4.1	3.0	2.7	1.3	1.7	1.1	.5	.3	.4	.6
10	......	......	4.1	10.8	2.8	1.2	1.6	1.0	.6	.3	.4	.5
11	......	......	4.0	7.9	2.8	1.1	1.5	.9	.5	.3	.4	.5
12	......	......	3.6	5.8	2.7	1.1	1.5	.8	.5	.4	.5	.5
13	......	......	3.6	4.5	2.7	1.2	1.3	.8	.5	.2	.4	.6
14	......	......	3.6	3.8	2.8	1.2	1.2	.7	.5	.2	.4	1.6
15	......	......	4.7	3.5	3.0	1.5	1.1	.7	.5	.3	.4	.6
16	......	......	5.9	3.4	2.6	1.3	1.0	.6	.5	.3	.4	.5
17	......	1.6	8.1	3.3	2.4	1.2	1.0	.6	.4	.3	.4	.4
18	......	1.6	6.9	3.0	2.3	1.1	1.0	.6	.4	.3	.4	.4
19	......	1.6	5.4	2.7	2.2	1.1	1.1	.6	.5	.3	.4	.3
20	......	1.6	4.9	2.6	2.4	1.0	1.0	.6	.5	.3	.4	.3
21	......	1.7	4.1	2.4	2.3	.9	1.0	.6	.4	.2	.4	.3
22	......	1.8	3.8	2.2	2.4	1.0	1.0	.5	.4	.2	.4	.6
23	......	2.0	3.4	2.1	2.8	1.0	1.1	.5	.4	.2	.4	.6
24	......	2.0	3.2	2.0	3.8	.9	.9	.5	.5	.3	.4	1.3
25	......	2.0	3.0	2.0	3.3	.8	.9	.4	.5	.3	.4	1.3
26	......	2.1	2.9	1.9	2.6	.8	1.0	.4	.4	.3	.4	1.2
27	......	2.9	3.0	1.8	2.5	1.2	1.2	.4	.4	.3	.4	1.3
28	......	3.6	3.8	1.8	2.4	2.1	1.3	.4	.4	.3	.5	1.4
29	......	......	3.2	1.8	2.4	1.6	1.2	.4	.3	.3	.5	.9
30	......	......	4.3	2.2	2.2	1.5	1.1	.5	.3	.3	.4	.9
31	......	......	3.5	......	2.0	......	1.1	.5	......	.3	......	1.3
1896.[a]												
1	1.3	1.3	......	......	......	1.1	1.6	2.0	.5	21.85	.8	2.0
2	1.2	1.2	......	......	......	.8	1.4	2.2	.5	12.05	.8	3.0
3	1.3	1.3	......	......	......	.6	1.2	2.5	.4	6.3	.7	2.8
4	1.4	1.8	......	......	......	.5	1.1	2.0	.4	4.0	.7	2.3
5	1.4	2.8	......	......	......	.4	1.0	1.8	.4	3.0	.8	2.0
6	1.4	3.5	......	......	......	.3	1.3	1.6	.5	2.4	6.0	1.8
7	1.3	7.0	......	......	......	.6	1.2	1.4	.3	2.1	6.0	1.7
8	1.3	7.0	......	......	......	.6	1.6	1.2	.3	1.8	5.1	1.7
9	1.3	5.0	......	......	......	1.6	1.9	1.1	.3	1.5	3.8	1.6
10	1.3	3.8	......	......	......	2.0	2.5	1.2	.3	1.3	3.0	1.5
11	1.0	2.9	......	......	0.8	2.2	4.0	1.1	.4	1.2	2.5	1.7
12	.8	2.8	......	......	.7	1.7	3.8	1.0	.3	1.1	2.2	1.7
13	.7	2.4	......	......	.6	1.4	2.7	1.0	.3	1.1	1.9	1.6
14	.6	2.3	......	......	.6	1.1	2.3	1.1	.3	1.0	1.7	1.5
15	.5	2.7	......	......	.5	1.0	2.3	1.1	.3	1.0	1.5	1.4
16	.5	3.9	......	......	1.6	1.1	1.6	1.1	.8	1.0	1.5	1.3
17	.5	3.5	......	......	1.1	1.2	1.5	1.2	.5	1.0	1.4	1.2
18	.4	2.9	......	......	1.0	3.4	1.4	1.0	.4	1.0	1.3	1.1
19	.3	2.3	......	......	.8	3.2	1.4	.8	.4	.9	1.2	1.0
20	.3	1.3	......	......	.6	2.7	1.3	.7	.7	.9	1.1	1.0
21	.3	.9	......	......	.6	2.2	1.2	.6	.4	.8	1.0	1.0
22	.5	1.1	......	......	.7	1.8	1.1	.6	.5	.8	1.0	1.0
23	.6	1.5	......	......	1.0	1.8	1.2	.6	.4	.8	1.0	1.0
24	2.3	1.5	......	......	1.0	1.8	1.6	.6	.4	.7	1.0	1.0
25	5.1	1.6	......	......	.9	1.6	3.3	.6	.3	.7	.9	.9
26	4.8	1.4	......	......	.8	1.7	8.7	.5	.4	.9	.9	1.1
27	3.7	1.3	......	......	.7	1.9	6.0	.5	.4	1.0	.9	1.0
28	2.9	1.2	......	......	.6	2.3	3.3	.5	.3	.9	1.0	.7
29	2.1	1.8	......	......	.8	2.0	2.7	.6	.4	.9	1.0	.7
30	1.6	......	......	......	1.0	1.8	2.8	.6	5.3	.8	1.2	.8
31	1.4	......	......	......	1.6	......	2.4	.5	......	.8	......	.9

[a] Gage heights January 1 to June 17, 1896, approximate. See Introduction, page 31.

NOTE.—See description of station in regard to datum of gage.

Daily gage height, in feet, of Potomac River at Point of Rocks, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897.[a]												
1	0.8	2.0	5.3	2.3	1.7	2.0	1.3	1.5	1.0	0.7	0.7	0.9
2	.8	1.9	4.4	2.2	1.9	1.9	1.2	1.4	.9	.7	.8	.9
3	.8	2.5	4.2	2.1	6.5	1.8	1.3	1.3	.9	.7	1.0	.9
4	.9	2.0	4.1	2.1	14.0	1.9	1.3	1.3	.9	.7	1.4	1.0
5	.9	2.1	4.6	2.2	8.5	2.0	1.2	1.3	.9	.7	1.0	1.1
6	1.0	5.1	5.4	2.5	6.0	2.0	1.2	1.8	.9	.6	.8	3.2
7	1.4	8.0	6.0	2.8	5.4	1.9	1.2	1.3	.9	.6	.7	3.6
8	1.7	10.5	5.8	3.0	4.6	2.0	1.2	1.2	.8	.6	.5	3.2
9	1.5	7.9	5.0	2.9	4.0	2.0	1.1	1.3	.8	.6	.5	2.4
10	1.3	5.8	4.5	3.7	3.5	1.8	1.0	1.3	.8	.6	.5	1.5
11	1.1	4.6	4.2	5.7	3.2	1.7	1.4	1.4	.7	.7	.7	1.3
12	1.1	4.0	4.0	4.6	3.0	1.7	1.3	1.3	.7	.8	1.2	1.1
13	1.1	3.9	3.9	3.9	3.3	1.6	1.3	1.3	.7	.6	.8	1.0
14	.9	4.6	3.7	3.5	8.9	1.6	1.4	1.2	.8	.7	.5	.9
15	.9	5.7	3.7	3.3	12.6	1.7	1.4	1.2	.8	.7	.5	1.5
16	1.0	7.0	3.8	3.1	8.0	1.7	1.5	1.3	.7	.6	.6	4.1
17	.9	7.4	4.2	3.0	5.0	1.6	1.3	1.2	.7	.6	1.1	4.3
18	.9	7.7	4.4	2.9	4.4	1.6	1.1	1.2	.7	.6	.9	3.3
19	.9	7.6	4.7	2.8	4.1	1.7	1.4	1.1	.7	.6	.7	2.6
20	1.5	7.2	5.3	2.6	3.9	1.7	1.4	1.1	.7	.6	.7	2.2
21	1.5	6.4	6.2	2.5	3.5	2.1	2.1	1.1	.7	.6	.6	2.1
22	1.4	6.7	6.0	2.3	3.2	2.0	2.6	1.1	.7	.7	.6	1.6
23	1.4	21.2	5.5	2.2	2.9	1.8	2.7	1.1	.8	.6	.6	1.5
24	1.4	24.6	4.8	2.1	2.8	1.7	2.1	1.2	1.0	.6	.4	1.4
25	1.5	16.8	4.7	2.1	2.9	1.6	1.9	1.7	.8	.7	.4	1.3
26	1.8	9.3	4.6	2.0	3.0	1.6	1.9	1.6	.8	.7	.4	1.3
27	2.0	7.3	4.1	1.9	2.8	1.6	2.1	1.3	.9	.7	.8	1.2
28	2.3	6.0	3.8	1.9	2.5	1.5	2.2	1.3	.9	.8	.6	1.2
29	2.2	....	3.6	1.8	2.2	1.4	2.1	1.3	.9	.9	.5	1.1
30	2.1	....	3.3	1.7	2.1	1.3	1.9	1.3	.9	.9	.6	1.1
31	2.0	....	2.9	....	2.0	....	1.8	1.3	....	.9	....	1.1
1898.												
1	1.1	2.8	1.9	6.1	2.6	2.2	.9	1.5	1.2	.7	2.7	2.1
2	1.1	1.7	1.8	5.2	2.4	2.0	.8	1.7	1.1	.7	2.5	2.1
3	1.2	2.0	1.7	4.6	2.2	1.8	.8	1.4	1.1	.6	2.3	2.0
4	1.4	1.9	1.7	4.1	2.0	1.7	.7	1.2	1.0	.7	2.2	2.5
5	1.4	1.9	1.6	3.8	1.9	1.6	.7	2.2	1.0	.8	2.0	5.1
6	1.5	2.0	1.6	3.6	1.8	1.4	.7	7.2	1.0	.8	1.8	9.2
7	1.4	2.0	1.6	3.2	2.2	1.3	.7	6.1	1.1	1.0	1.8	6.1
8	1.1	1.9	1.5	2.9	5.4	1.3	.8	3.7	1.0	1.1	1.7	4.5
9	1.2	1.9	1.5	2.4	11.05	1.2	.7	3.9	1.0	1.0	1.6	3.6
10	1.4	1.8	1.4	2.5	9.6	1.2	.7	5.6	.9	1.0	1.6	3.0
11	2.1	1.8	1.4	2.5	6.5	1.1	.7	14.0	.9	.9	2.0	2.6
12	4.0	1.9	1.5	2.4	5.2	1.1	.6	16.05	.9	.9	1.8	2.4
13	3.9	2.0	1.5	2.4	4.2	1.1	.5	9.5	.8	1.4	1.8	2.2
14	3.5	1.9	1.6	2.5	3.7	1.3	.5	8.0	.8	1.2	2.0	2.2
15	3.7	1.9	1.6	2.5	3.1	1.3	.5	7.2	.8	1.0	2.0	2.0
16	4.9	2.0	1.7	4.0	3.0	1.3	.5	6.1	.8	.8	1.8	1.8
17	6.2	2.0	1.7	9.0	3.2	1.3	.5	5.2	.8	.8	1.8	1.8
18	4.9	1.8	2.0	6.7	4.6	1.2	.5	4.3	.8	.8	1.8	2.0
19	3.8	1.7	5.8	5.1	4.4	1.5	.7	3.3	.8	1.4	2.2	2.1
20	3.1	1.7	4.6	4.2	3.5	1.4	.7	3.1	.7	9.0	3.0	2.2
21	2.9	2.8	3.5	3.5	2.3	1.3	.9	3.0	.7	5.4	3.6	2.6
22	2.8	3.8	3.5	3.2	2.9	1.3	.9	3.8	.7	5.35	3.3	3.3
23	3.2	4.1	6.6	2.9	3.1	1.3	1.1	2.8	.7	13.1	3.2	4.7
24	7.6	3.4	6.2	2.6	3.9	1.2	.9	2.3	.7	10.1	3.1	6.2
25	6.5	2.9	6.4	2.6	5.1	1.1	.8	2.0	.7	5.9	3.0	6.9
26	5.1	2.6	10.5	2.6	5.6	1.1	.9	1.8	.7	4.5	2.7	5.3
27	5.0	2.3	7.2	2.5	4.1	1.0	1.2	1.5	.9	3.8	2.6	4.3
28	5.1	2.1	5.3	3.3	3.4	1.0	1.0	1.5	.8	3.6	2.4	3.7
29	5.1	....	4.4	3.0	3.0	.9	1.2	1.4	.7	3.4	2.2	3.2
30	3.6	....	4.3	2.8	2.8	.9	1.4	1.3	.7	3.0	2.1	3.0
31	3.4	....	6.2	....	2.4	....	1.7	1.3	....	2.8	....	2.7

[a] 1897 gage heights subject to errors of several tenths.

Daily gage height, in feet, of Potomac River at Point of Rocks, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1899.												
1	3.0	2.4	11.9	5.3	1.6	2.0	1.0	0.7	0.9	0.7	0.8	0.8
2	3.4	2.0	9.2	4.5	1.6	2.4	1.0	.7	.9	.6	1.5	.8
3	2.9	2.1	8.2	4.0	2.1	3.8	1.1	.7	.8	.6	2.5	.8
4	2.7	2.1	7.6	3.6	1.7	2.6	1.0	.9	.8	.6	2.0	.8
5	2.3	2.0	8.5	3.3	1.7	2.1	.9	1.0	.8	.6	1.8	.8
6	4.1	2.0	16.55	3.0	2.1	1.8	1.0	1.1	.7	.6	1.4	.7
7	6.9	2.0	12.9	2.8	2.0	1.6	2.0	1.1	.7	.6	1.4	.7
8	8.1	2.3	10.0	3.0	1.9	1.5	1.0	1.1	.6	.7	1.3	.7
9	6.8	2.3	8.1	3.5	2.0	1.4	1.0	1.0	.6	.7	1.2	.7
10	5.4	3.6	6.0	3.4	2.4	1.7	.9	1.0	.6	.6	1.0	.7
11	4.6	4.2	5.8	4.2	4.5	1.8	.9	.9	.6	.6	.9	.7
12	3.9	4.2	5.6	4.5	3.8	1.7	.8	.8	.8	.6	.9	.8
13	3.6	4.0	5.0	3.4	3.4	1.7	.8	.6	1.2	.6	.8	.8
14	3.4	3.9	4.8	3.2	3.2	1.6	.8	.6	1.1	.5	.8	1.2
15	3.4	3.8	4.5	3.0	2.8	1.5	.9	.6	1.0	.5	.8	3.0
16	4.0	4.0	4.6	2.8	2.5	1.5	1.1	.7	.9	.5	.8	2.1
17	5.7	4.5	4.7	2.7	2.3	1.4	.9	.7	.8	.5	.8	1.7
18	5.2	5.0	4.4	2.6	2.4	1.4	.7	.6	.7	.5	.7	1.5
19	4.7	5.2	5.2	2.5	8.55	1.3	.7	.6	.7	.5	.7	1.6
20	4.4	5.4	5.4	2.4	6.3	1.3	.7	.6	.9	.5	.7	1.5
21	4.0	6.0	5.3	2.2	5.0	1.2	.7	.6	.7	.5	.7	1.3
22	3.5	8.5	4.7	2.1	3.6	1.2	.7	.5	.8	.5	.7	1.1
23	3.3	14.8	4.2	2.0	3.0	1.1	.7	.5	.9	.5	.8	1.0
24	3.2	13.7	4.0	2.0	2.7	1.1	.6	.5	.9	.5	.8	1.2
25	3.3	9.0	3.9	2.0	2.4	1.0	.6	.5	.9	.5	.9	1.8
26	4.8	6.0	3.7	1.9	2.1	1.0	.6	.5	1.0	.5	.9	2.1
27	4.7	9.25	3.5	1.9	2.0	1.0	.6	1.2	.8	.5	.8	1.6
28	3.9	13.9	3.4	1.8	1.8	1.2	.6	1.1	.7	.5	.8	1.5
29	3.2	....	4.6	1.7	1.7	1.1	.5	1.1	.7	.5	.8	1.6
30	2.8	....	8.6	1.7	1.7	1.0	.8	1.0	.8	.5	.8	1.6
31	2.6	....	7.0	....	1.8	....	.8	1.0	....	.6	....	1.6
1900.												
1	1.5	1.0	3.5	4.8	1.9	1.3	1.2	1.2	.7	.3	.5	2.4
2	1.5	1.6	4.5	3.8	1.7	1.3	1.1	1.1	.7	.3	.5	1.9
3	1.4	2.0	6.6	3.4	1.6	1.3	1.0	1.0	.6	.3	.5	1.6
4	1.5	2.1	5.9	3.1	1.5	1.4	1.0	.9	.6	.3	.5	1.6
5	1.5	2.2	4.4	2.8	1.5	1.6	.9	.9	.5	.3	.5	2.0
6	1.4	1.9	4.0	2.7	1.4	1.6	1.3	.8	.6	.3	.4	4.1
7	1.4	1.8	3.6	2.6	1.4	1.5	1.0	.8	.5	.3	.4	5.9
8	1.3	1.5	3.9	2.5	1.3	1.4	.9	.7	.4	.3	.4	3.7
9	1.3	1.8	4.5	2.4	1.3	1.4	.8	.6	.4	.3	.5	3.0
10	1.2	2.3	4.0	2.3	1.3	1.3	.7	.6	.3	.3	.6	2.5
11	1.3	3.0	3.6	2.1	1.2	1.2	.6	.5	.4	.3	.5	2.1
12	1.4	2.5	3.2	2.1	1.2	1.1	.6	.5	.3	.3	.4	1.8
13	1.4	3.0	2.9	2.0	1.1	1.0	.5	.4	.3	.3	.4	1.6
14	1.5	4.5	2.8	1.9	1.1	.9	.5	.4	.4	.3	.4	1.5
15	1.8	5.3	2.7	1.9	1.1	1.3	.5	.4	.4	.9	.4	1.4
16	2.1	4.5	2.6	1.8	1.1	1.0	.4	.4	.4	.5	.4	1.4
17	1.9	3.8	2.4	1.8	1.0	1.8	.4	.4	.3	.4	.4	1.5
18	1.7	3.1	2.3	1.7	1.0	2.8	.4	.4	.3	.3	.3	1.2
19	1.6	2.6	2.4	1.7	1.2	8.5	.5	.4	.3	.3	.2	1.1
20	2.2	2.3	2.6	1.6	1.3	6.2	1.4	.4	.3	.3	.2	1.1
21	3.6	1.9	5.8	1.7	1.8	4.6	1.0	.4	.3	.3	.3	1.0
22	6.8	3.0	8.7	2.2	1.9	3.6	.9	.4	.3	.5	.4	.9
23	5.5	6.9	6.6	2.5	2.0	2.7	.8	.4	.3	.4	.4	.9
24	4.0	7.1	5.4	2.8	1.7	2.3	1.8	.4	.3	.4	.4	.8
25	3.3	5.6	5.0	3.0	1.5	2.1	1.6	.5	.3	.4	.4	.8
26	2.8	3.9	4.5	2.8	1.4	2.0	2.0	.6	.3	.4	1.2	.8
27	2.5	3.3	4.1	2.5	1.4	1.8	1.4	.7	.3	.5	3.3	.8
28	2.1	3.0	3.7	2.3	1.3	1.5	1.2	.9	.2	.5	8.2	.8
29	1.8	....	3.5	2.1	1.2	1.4	1.0	.9	.3	.5	5.4	.8
30	1.3	....	3.3	2.0	1.3	1.3	1.3	.8	.3	.5	3.2	.8
31	1.2	....	3.2	....	1.3	....	1.3	.8	....	.5	....	.8

Daily gage height, in feet, of Potomac River at Point of Rocks, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1901.[a]												
1	0.8	1.2	.8	2.2	3.4	7.5	2.6	1.7	2.8	3.0	0.9	1.6
2	.9	1.1	.8	2.0	3.1	6.0	2.4	1.5	5.7	2.4	.9	1.5
3	.9	1.0	.8	3.3	2.8	4.8	2.3	1.4	5.3	2.1	1.0	1.7
4	.9	1.1	.8	5.4	2.6	4.0	2.1	1.4	4.1	1.9	1.0	1.5
5	.9	1.1	.8	7.7	2.5	3.5	2.0	1.3	3.2	1.9	.9	3.4
6	.8	1.1	.9	6.8	2.3	4.0	2.0	1.3	2.3	1.7	.9	2.9
7	.7	1.3	1.8	6.8	2.1	4.7	1.9	1.6	2.0	1.5	.9	2.6
8	.7	1.2	1.4	7.8	1.9	4.8	2.2	4.5	1.8	1.4	.9	2.4
9	.6	1.2	1.3	6.3	1.8	4.1	2.0	3.5	1.7	1.4	.9	2.2
10	.6	1.2	2.7	5.3	2.0	3.2	1.7	2.8	1.7	1.3	.9	2.3
11	.7	1.3	4.2	4.2	8.0	2.7	1.6	2.3	1.6	1.3	.9	2.8
12	1.1	1.4	12.4	3.3	9.1	2.5	1.5	2.3	1.6	1.2	.9	3.2
13	1.8	1.7	9.9	3.0	6.0	2.2	1.6	2.2	1.5	1.2	.9	3.0
14	4.6	1.7	6.2	3.2	4.6	2.4	2.0	2.2	1.5	1.2	.8	2.8
15	3.5	1.8	4.5	9.0	3.5	2.7	3.6	2.1	1.5	1.2	.8	8.1
16	2.8	1.7	3.9	15.0	3.0	3.0	5.1	2.0	1.8	1.2	.9	17.2
17	2.2	1.4	3.2	8.3	2.7	5.7	5.2	2.0	1.6	1.1	.9	13.3
18	2.0	1.1	2.8	7.4	2.4	8.5	5.5	2.3	1.5	1.1	.9	6.9
19	1.9	1.1	2.5	6.2	2.3	5.6	5.1	2.4	1.5	1.1	.9	5.0
20	1.7	1.0	2.3	5.4	2.2	4.5	4.6	2.6	1.4	1.1	.9	4.1
21	1.5	.9	2.5	11.4	2.0	3.7	3.6	3.0	1.4	1.1	.9	3.2
22	1.4	.9	3.0	20.8	1.9	5.6	3.1	2.7	1.4	1.1	.9	3.0
23	1.3	.8	3.2	15.8	12.6	4.6	2.8	2.3	1.3	1.1	.9	2.7
24	1.3	.9	3.3	11.2	14.2	4.5	2.5	2.0	1.3	1.0	1.8	2.5
25	1.4	.9	2.8	7.9	9.3	4.3	2.2	2.0	1.3	1.0	4.1	2.5
26	1.5	.9	2.5	6.6	7.2	4.0	2.1	2.0	1.2	1.0	4.4	2.7
27	1.5	1.0	2.6	5.6	7.5	3.6	2.2	2.2	1.2	1.0	3.2	3.0
28	1.3	1.0	2.5	4.8	7.6	3.3	2.0	2.7	1.2	.9	2.5	2.9
29	.9	....	2.6	4.2	9.0	3.0	1.8	2.4	1.2	.9	2.0	4.4
30	1.0	....	2.7	3.8	9.7	2.8	1.7	2.2	3.2	.9	1.7	13.8
31	1.2	....	2.4	....	8.6	....	1.7	2.3	....	.9	....	18.4
1902.[b]												
1	11.7	3.7	22.5	5.7	2.7	1.8	1.6	1.6	.8	1.2	1.0	2.7
2	7.2	3.5	29.0	5.0	2.6	1.8	1.7	1.4	.9	1.2	1.0	2.8
3	5.6	3.3	16.1	4.5	2.6	1.7	1.8	1.7	.9	1.1	1.0	2.9
4	4.8	3.2	10.2	4.1	2.6	1.6	1.8	1.7	.9	1.0	1.0	3.4
5	4.2	2.8	8.1	4.0	2.5	1.6	1.7	1.8	.9	1.1	1.0	5.5
6	3.8	2.4	6.7	3.8	2.5	1.5	1.7	1.6	.9	1.2	1.0	4.4
7	3.5	2.5	5.8	4.0	2.5	1.5	1.6	1.5	.8	1.2	.9	4.2
8	3.2	2.6	6.7	6.4	2.4	1.5	1.6	1.5	.8	1.1	.9	4.0
9	3.1	2.5	7.4	16.4	3.1	1.4	1.5	1.4	.8	1.1	.9	3.8
10	3.0	2.5	8.5	14.3	2.7	1.4	1.5	1.3	.8	1.1	.9	3.5
11	2.8	3.5	12.0	12.9	2.5	1.4	1.5	1.2	.8	1.1	.9	3.2
12	2.7	4.0	12.4	12.2	2.3	1.4	1.4	1.1	.8	1.4	.9	3.6
13	2.5	4.2	14.0	11.5	2.2	1.3	1.4	1.1	.7	1.6	1.0	4.9
14	2.3	4.4	13.8	9.3	2.2	1.4	1.4	1.0	.7	1.9	1.0	7.2
15	2.1	5.2	12.0	7.8	2.1	1.4	1.3	1.0	.7	2.0	1.0	6.8
16	2.1	5.4	10.2	6.5	2.1	1.4	1.3	1.0	.7	2.1	1.0	5.7
17	2.1	5.5	8.2	5.0	2.0	1.3	1.2	1.0	.7	2.0	1.0	7.2
18	2.1	5.2	10.6	5.3	1.9	1.3	1.2	1.0	.7	1.8	1.0	9.9
19	2.1	4.8	8.7	4.9	1.9	1.3	1.2	1.0	.7	1.6	1.0	8.0
20	2.1	4.5	6.6	4.6	2.6	1.3	1.2	1.0	.7	1.4	1.0	5.9
21	2.3	4.5	5.5	4.0	2.0	1.3	1.3	.9	.7	1.2	.9	5.2
22	3.0	5.6	4.5	3.5	2.0	1.3	1.3	.9	.7	1.1	.9	4.8
23	6.7	7.0	4.1	3.3	1.9	1.3	1.2	.9	.7	1.0	.9	5.0
24	5.2	4.1	3.8	3.0	1.9	1.3	1.1	.9	.7	.9	.9	5.2
25	3.2	4.4	3.6	2.9	1.9	1.2	1.1	1.0	.9	.9	1.3	4.8
26	3.0	17.75	3.5	2.8	2.0	1.4	1.1	1.0	.8	.9	1.5	4.2
27	3.5	27.2	3.5	2.9	2.2	1.5	1.0	.9	.8	.8	1.9	3.6
28	5.2	18.0	3.6	2.8	2.0	1.4	1.0	.9	.8	1.0	3.0	3.5
29	5.0	....	3.7	2.7	1.9	1.4	1.0	1.0	.8	1.0	3.5	3.0
30	4.5	....	4.3	2.7	1.9	1.4	1.6	.9	1.0	1.1	2.8	2.6
31	4.2	....	6.4	....	1.9	....	1.7	.8	....	1.1	....	2.8

[a] Gage heights April 16 to December 31, 1901, are somewhat in error on account of uncertainty of the gage datum.

[b] Gage heights January 1 to September 1, 1902, somewhat in error; datum not known. Gage heights September 2 to December 31, 1902, refer to datum 41.75 feet below bench mark No. 1. Rise in gage February 11-23, 1902, due to ice gorging.

Daily gage height, in feet, of Potomac River at Point of Rocks, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903.[a]												
1	2.6	6.5	14.2	7.7	3.0	3.7	8.7	1.7	2.0	1.2	1.1	1.1
2	2.4	6.1	15.3	7.0	2.9	4.9	5.8	1.7	2.1	1.1	1.1	1.1
3	4.9	6.0	8.9	6.1	2.8	4.0	4.5	1.6	2.2	1.1	1.0	1.1
4	11.6	6.3	6.6	5.0	2.8	3.4	4.0	1.7	2.1	1.1	1.0	1.1
5	10.3	8.2	5.7	4.9	2.8	3.0	3.5	1.8	2.0	1.0	1.0	1.1
6	7.6	9.2	5.3	4.6	2.7	2.6	4.7	1.9	1.9	1.0	1.0	1.1
7	5.7	6.7	5.0	4.3	2.7	2.4	8.2	2.3	1.8	1.0	1.0	1.1
8	4.8	6.3	4.8	4.1	2.6	6.4	5.8	2.3	1.7	1.1	1.1	1.1
9	4.2	5.2	4.6	4.5	2.5	8.2	4.0	2.2	1.6	2.3	1.1	1.0
10	3.5	4.5	4.8	6.1	2.4	7.4	3.4	2.0	1.5	2.0	1.1	1.0
11	3.0	4.1	5.4	5.6	2.3	6.5	3.0	2.9	1.5	1.9	1.0	1.0
12	2.8	3.7	5.0	5.4	2.3	5.1	3.5	2.8	1.4	1.8	1.0	1.0
13	2.7	3.7	4.6	5.3	2.2	5.3	5.6	2.5	1.4	1.8	1.0	1.0
14	2.6	3.9	4.3	5.6	2.1	6.0	3.9	2.3	1.5	1.7	1.0	1.0
15	2.7	3.9	4.0	14.4	2.1	5.6	3.5	2.0	1.5	1.7	1.0	1.1
16	2.8	4.0	3.8	15.1	2.0	4.5	3.2	2.0	1.4	1.6	1.0	1.2
17	2.9	6.8	3.6	14.0	2.0	4.0	3.0	1.9	1.5	1.5	1.1	1.7
18	2.8	7.4	3.4	10.4	1.9	3.6	2.8	1.8	2.6	1.5	1.1	1.5
19	2.8	6.0	3.2	7.8	1.9	3.2	2.8	1.8	4.5	1.5	1.1	1.4
20	2.8	4.9	3.1	6.7	1.9	3.0	3.1	1.7	2.9	1.6	1.1	1.5
21	2.9	4.5	3.0	5.5	1.8	2.8	2.8	1.7	2.4	1.6	1.1	1.6
22	3.6	4.2	3.1	5.0	1.8	2.6	2.5	1.6	2.0	1.5	1.1	1.7
23	4.4	4.1	5.1	4.5	1.8	2.4	2.3	1.6	1.9	1.5	1.1	1.7
24	3.8	3.8	7.0	4.1	1.9	2.5	2.1	1.5	1.7	1.4	1.2	1.6
25	3.3	4.2	12.1	3.8	2.0	3.3	2.0	1.4	1.6	1.4	1.1	1.6
26	3.1	4.4	8.6	3.6	2.0	3.6	2.0	1.3	1.4	1.3	1.0	1.6
27	2.8	4.5	6.6	3.5	2.1	3.2	1.9	1.3	1.3	1.3	1.0	1.6
28	3.6	5.4	5.3	3.4	2.3	2.7	1.9	1.5	1.3	1.2	1.3	1.6
29	6.2	......	4.7	3.2	2.4	6.2	1.8	2.1	1.2	1.2	1.1	1.7
30	7.3	......	4.5	3.1	2.6	12.2	2.0	2.5	1.2	1.1	1.1	1.7
31	7.0	......	5.1	......	2.8	......	1.8	2.1	......	1.1	......	1.6
1904.[b]												
1	1.5	3.0	5.3	2.4	5.6	6.7	1.4	1.4	.9	.6	.6	.8
2	1.5	2.9	4.4	2.6	4.0	7.8	1.3	1.3	.8	.6	.6	.8
3	2.0	2.9	4.0	3.0	3.6	5.2	1.3	1.2	.8	.6	.7	.8
4	2.3	3.3	3.8	3.5	3.0	4.6	1.3	1.2	.8	.6	.7	.8
5	1.8	4.8	4.0	3.1	2.8	4.1	1.2	1.2	.9	.6	.7	.8
6	1.5	4.9	4.2	3.5	2.6	5.0	1.5	1.2	1.0	.6	.7	.8
7	1.5	4.9	4.5	3.0	2.5	4.4	1.5	1.3	.9	.6	.7	.8
8	1.5	3.3	5.0	2.4	2.8	4.0	1.6	1.4	.8	.6	.7	.8
9	1.6	3.5	4.8	2.3	2.7	3.6	1.6	1.5	.7	.5	.7	.8
10	1.6	5.7	5.4	2.3	2.6	3.2	1.7	1.4	.7	.5	.7	.9
11	1.6	5.0	4.5	2.6	2.5	2.8	2.9	1.3	.7	.5	.7	.9
12	1.7	3.9	3.8	3.1	2.5	2.6	2.6	1.3	.8	.6	.7	.9
13	1.6	3.6	3.3	2.8	2.4	2.5	3.4	1.2	1.0	.7	.7	.9
14	1.6	3.5	2.8	2.6	2.3	2.4	3.1	1.2	.9	.7	.8	.9
15	1.6	3.4	2.6	2.5	2.2	2.2	3.0	1.1	.9	.6	.8	.9
16	1.5	3.8	2.4	2.2	2.2	2.1	2.8	1.1	1.0	.6	.8	.9
17	1.5	3.8	2.4	2.1	2.1	2.0	2.4	1.1	1.0	.5	.7	.9
18	1.5	3.9	2.2	2.1	2.2	1.8	2.0	1.0	.9	.5	.8	.9
19	1.5	3.9	2.1	2.0	2.3	1.6	1.8	1.0	.8	.5	.8	.9
20	1.5	3.8	2.2	1.9	3.1	1.5	1.6	1.0	.7	.6	.8	1.0
21	1.5	3.8	2.3	1.9	6.2	1.5	1.4	1.0	.8	1.0	.7	1.0
22	2.0	4.5	2.4	1.8	4.7	2.5	1.4	.9	1.0	.9	.7	1.0
23	4.0	5.6	2.5	1.7	4.0	3.0	1.3	.9	.9	.8	.7	1.0
24	5.2	6.0	2.7	1.7	3.6	2.8	1.3	1.0	.8	.7	.7	1.0
25	7.4	6.6	3.7	1.6	3.1	2.5	1.3	1.0	.8	.7	.7	1.1
26	5.1	6.6	3.4	1.5	2.8	2.1	1.4	1.2	.8	.7	.7	1.4
27	3.6	7.6	3.0	1.6	2.5	1.7	1.4	1.1	.7	.7	.7	1.5
28	3.3	6.6	2.8	2.0	2.4	1.5	1.4	1.1	.7	.7	.7	1.8
29	3.2	6.0	2.6	3.7	2.3	1.5	1.5	1.0	.7	.6	.8	1.8
30	3.0	......	2.5	6.3	2.2	1.4	1.5	1.0	.7	.6	.8	1.9
31	3.0	......	2.4	......	2.4	......	1.5	.9	......	.6	......	2.0

[a] Ice conditions December 17 to 31, 1903.
[b] Ice conditions during part of January and February, 1904.

Daily gage height, in feet, of Potomac River at Point of Rocks, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1905.												
1	2.0	2.4	2.4	3.2	1.6	1.5	2.1	2.9	2.2	1.0	1.6	1.6
2	2.4	2.4	2.5	3.0	1.6	1.4	1.8	2.7	2.0	1.0	1.5	1.6
3	2.5	2.3	2.6	2.7	1.6	1.4	1.6	2.4	1.8	1.0	1.5	2.5
4	2.8	2.2	2.8	2.5	1.5	1.4	1.5	2.2	1.7	1.0	1.4	4.6
5	3.0	2.2	3.4	2.6	1.5	1.3	3.0	2.0	1.6	1.0	1.4	4.0
6	3.2	2.2	4.0	2.7	1.5	1.3	3.5	1.8	1.5	1.0	1.3	3.4
7	4.4	2.2	4.4	2.8	1.4	1.5	4.0	1.6	1.5	1.0	1.3	3.0
8	4.6	2.1	5.1	3.0	1.4	1.6	4.5	1.5	1.4	1.0	1.3	2.4
9	4.0	2.1	6.0	3.0	1.4	1.9	4.0	1.5	1.4	1.0	1.2	2.3
10	3.4	2.0	6.4	2.9	1.4	2.0	3.6	1.4	1.3	.9	1.2	2.2
11	3.0	2.0	11.0	2.8	1.4	1.9	2.8	1.4	1.3	.9	1.0	2.1
12	2.8	2.0	10.1	2.8	1.4	1.9	2.3	1.3	1.4	1.2	1.0	2.0
13	2.6	2.0	6.9	2.9	1.4	2.3	3.2	1.3	1.4	1.1	1.0	1.9
14	2.5	2.0	6.0	2.8	1.4	2.2	4.1	1.3	2.0	1.4	1.0	1.8
15	2.5	2.0	5.9	2.6	3.0	2.0	5.0	1.6	1.7	1.6	1.0	1.8
16	2.9	2.0	5.5	2.4	2.8	2.0	5.4	2.0	1.5	1.5	1.0	1.7
17	3.8	2.1	5.0	2.3	2.7	1.9	4.2	2.9	1.4	1.3	1.0	1.6
18	3.2	2.1	4.5	2.2	2.6	1.8	4.0	3.4	1.4	1.2	.9	1.5
19	2.8	2.1	4.4	2.1	2.5	1.6	3.6	2.5	1.4	1.0	.9	1.5
20	2.6	2.2	5.0	2.0	2.4	1.4	3.3	2.1	1.3	1.2	.9	1.5
21	2.6	2.2	5.9	2.0	2.3	1.3	3.0	1.8	1.3	1.4	.9	2.8
22	2.7	2.2	7.5	1.9	2.2	1.5	2.8	1.7	1.2	1.8	.9	7.6
23	2.8	2.2	8.4	1.9	2.2	2.5	2.6	1.5	1.2	1.6	.9	7.5
24	2.4	2.2	6.7	1.9	2.0	3.6	4.0	1.5	1.2	1.4	.9	6.1
25	2.1	2.2	5.8	1.9	1.8	5.2	3.5	2.0	1.2	1.4	.9	5.5
26	1.9	2.3	6.9	1.8	1.7	7.0	3.0	2.9	1.1	1.5	.9	4.8
27	[a] 3.0	2.3	5.9	1.8	1.6	5.0	2.6	3.4	1.1	1.6	.9	4.1
28	2.6	2.4	5.2	1.7	1.5	3.6	2.3	3.9	1.1	1.7	.9	3.4
29	2.6	....	4.6	1.7	1.5	3.0	2.0	2.9	1.1	2.1	.9	3.1
30	2.5	....	4.0	1.7	1.4	2.6	1.8	2.8	1.0	2.0	1.3	3.0
31	2.5	....	3.6	....	1.3	....	2.5	2.5	....	1.8	....	3.2
1906. [b]												
1	3.6	3.0	1.9	11.1	3.3	1.8	2.2	1.6	3.7	1.2	2.6	1.9
2	3.4	2.9	1.8	9.6	3.1	1.7	1.9	1.5	3.1	1.2	2.5	1.8
3	3.3	2.7	1.8	7.7	2.8	1.7	2.0	1.5	2.8	1.4	2.3	1.9
4	3.7	2.5	2.0	6.5	2.8	1.6	2.9	4.3	2.6	1.5	2.3	1.7
5	8.0	2.4	4.0	5.5	2.6	1.5	2.6	3.6	2.3	2.2	2.1	1.8
6	8.6	2.2	5.45	5.1	2.5	1.7	2.4	2.8	2.1	2.5	2.1	1.8
7	7.0	2.2	4.5	4.8	2.6	1.9	2.2	2.4	1.9	2.7	2.1	1.85
8	4.8	2.0	3.6	4.8	2.5	1.7	2.0	2.6	1.8	2.6	2.0	1.7
9	4.0	1.9	3.0	4.3	2.4	2.4	1.9	2.8	1.8	2.5	2.0	1.75
10	3.5	1.8	2.7	4.2	2.4	3.0	1.7	3.2	1.7	2.2	1.9	1.8
11	3.1	1.8	2.6	5.5	2.4	2.5	1.5	7.6	1.7	2.0	1.8	2.0
12	2.9	1.9	2.5	5.6	2.2	2.2	1.4	5.7	1.6	1.9	1.8	2.2
13	2.8	1.8	2.3	4.9	2.3	1.8	1.3	4.3	1.6	1.6	1.8	3.5
14	3.0	1.8	2.3	4.0	2.2	1.6	1.2	3.7	1.5	1.5	1.7	3.1
15	3.3	1.9	2.3	5.75	2.0	1.6	1.3	3.0	1.5	1.6	1.8	2.65
16	3.6	1.8	2.4	8.45	2.1	1.6	1.2	5.1	1.4	1.4	1.7	2.7
17	3.7	1.7	2.5	7.5	2.0	1.6	1.2	4.8	1.6	1.4	1.8	2.8
18	4.1	1.6	2.5	6.3	1.8	2.5	1.5	4.2	1.5	1.5	1.8	4.7
19	3.9	1.6	2.6	5.1	1.9	3.2	1.8	3.5	1.4	1.7	1.9	10.0
20	3.5	1.6	2.9	4.5	1.8	2.9	1.7	4.4	1.4	12.5	1.9	7.2
21	3.4	1.7	2.9	4.1	1.6	3.1	1.5	4.0	1.4	16.1	3.0	5.6
22	3.3	1.8	3.1	3.6	1.6	5.0	1.4	5.3	1.3	11.65	4.2	5.2
23	3.2	1.9	3.4	3.3	1.6	4.3	1.5	4.8	1.3	8.5	4.0	4.6
24	3.1	2.0	3.9	3.1	1.4	3.6	2.0	3.7	1.3	6.6	3.3	3.8
25	6.35	2.0	3.9	2.9	1.5	3.1	2.1	4.1	1.3	5.4	3.0	3.2
26	5.1	1.9	3.9	2.9	1.4	2.6	1.9	4.8	1.3	4.5	2.7	2.8
27	4.2	1.8	3.7	2.8	1.3	2.4	1.7	4.6	1.2	4.1	2.6	2.85
28	3.6	2.0	7.8	5.1	1.9	2.3	1.8	6.7	1.2	3.6	2.2	2.9
29	3.4	....	12.9	5.0	1.9	3.1	1.9	6.0	1.2	3.3	2.1	3.0
30	3.2	....	10.5	4.3	1.7	3.0	2.0	5.3	1.2	3.1	2.1	3.1
31	3.1	....	10.9	....	1.7	....	1.7	4.4	....	2.8	....	3.2

[a] Ice gorge January 27, 1905.
[b] Flow probably unaffected by ice conditions during 1906.

Rating tables for Potomac River at Point of Rocks, Md.

FEBRUARY 17, 1895, TO MARCH 31, 1902.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
0.20	1,040	2.00	7,120	3.80	16,380	7.20	38,560
.30	1,180	2.10	7,580	3.90	16,940	7.40	40,080
.40	1,340	2.20	8,060	4.00	17,520	7.60	41,600
.50	1,540	2.30	8,540	4.20	18,680	7.80	43,160
.60	1,760	2.40	9,020	4.40	19,840	8.00	44,720
.70	2,000	2.50	9,500	4.60	21,040	8.50	48,700
.80	2,280	2.60	10,000	4.80	22,240	9.00	52,700
.90	2,600	2.70	10,500	5.00	23,480	10.00	61,000
1.00	2,940	2.80	11,000	5.20	24,740	11.00	69,300
1.10	3,300	2.90	11,520	5.40	26,020	12.00	77,600
1.20	3,680	3.00	12,040	5.60	27,340	13.00	85,900
1.30	4,080	3.10	12,560	5.80	28,660	14.00	94,200
1.40	4,480	3.20	13,080	6.00	30,020	15.00	102,500
1.50	4,900	3.30	13,620	6.20	31,380	16.00	110,800
1.60	5,320	3.40	14,160	6.40	32,780	17.00	119,100
1.70	5,760	3.50	14,700	6.60	34,180	18.00	127,400
1.80	6,200	3.60	15,260	6.80	35,620	19.00	135,700
1.90	6,660	3.70	15,820	7.00	37,080	20.00	144,000

APRIL 1, 1902, TO DECEMBER 31, 1906.[b]

0.50	900	2.30	6,130	4.20	15,150	7.80	38,500
.60	1,090	2.40	6,520	4.40	16,270	8.00	39,980
.70	1,295	2.50	6,920	4.60	17,430	8.50	43,740
.80	1,515	2.60	7,330	4.80	18,610	9.00	47,600
.90	1,750	2.70	7,750	5.00	19,820	9.50	51,560
1.00	2,000	2.80	8,180	5.20	21,060	10.00	55,600
1.10	2,260	2.90	8,620	5.40	22,300	11.00	63,900
1.20	2,530	3.00	9,070	5.60	23,560	12.00	72,200
1.30	2,810	3.10	9,530	5.80	24,840	13.00	80,500
1.40	3,100	3.20	10,000	6.00	26,140	14.00	88,800
1.50	3,400	3.30	10,480	6.20	27,460	15.00	97,100
1.60	3,700	3.40	10,970	6.40	28,780	16.00	105,400
1.70	4,010	3.50	11,470	6.60	30,100	17.00	113,700
1.80	4,330	3.60	11,980	6.80	31,460	18.00	122,000
1.90	4,670	3.70	12,490	7.00	32,820	19.00	130,300
2.00	5,020	3.80	13,010	7.20	34,220	20.00	138,600
2.10	5,380	3.90	13,530	7.40	35,620		
2.20	5,750	4.00	14,070	7.60	37,060		

[a] The above table is strictly applicable only for open-channel conditions. It is based on 23 discharge measurements made during 1895–1901, inclusive. It is well defined between gage heights 0.3 foot and 14.0 feet. Above 9.00 feet the rating curve is a tangent, the difference being 830 per tenth.

[b] This table is strictly applicable only for open-channel conditions. It is based on discharge measurements made during 1902–1906, inclusive. It is fairly well defined between gage heights 1.0 foot and 14.0 feet. Above gage height 10.0 feet the rating curve is a tangent, the difference being 830 per tenth.

Estimated monthly discharge of Potomac River at Point of Rocks, Md.

[Drainage area, 9,650 square miles.[a]]

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1895.								
January							3.25	
February 17-28	15,260	5,320	7,413	0.768	0.343		[b]1.16	
March	65,980	11,520	24,560	2.54	2.93	122	2.41	—0.52
April	67,640	6,200	14,500	1.50	1.67	71	2.37	.70
May	29,340	7,120	12,540	1.30	1.50	61	2.46	.96
June	7,580	2,280	4,033	.418	.466	12	3.88	3.41
July	10,500	2,600	4,443	.460	.530	18	3.03	2.50
August	3,300	1,340	1,997	.207	.239	11	2.10	1.86
September	2,600	1,180	1,565	.162	.181	21	.85	.67
October	1,340	1,040	1,163	.120	.138	12	1.19	1.05
November	1,540	1,180	1,333	.138	.154	11	1.37	1.22
December	5,320	1,180	2,259	.234	.270	10	2.59	2.32
The year							26.66	
1896.								
January [c]	24,100	1,180	5,257	.545	.628	32	1.97	1.34
February [c]	37,080	2,600	10,470	1.08	1.16	33	3.48	2.32
March							3.55	
April							1.61	
May 11-31 [c]	5,320	1,540	2,560	.265	.207		[a]2.91	
June [c]	14,160	1,180	5,429	.562	.627	13	5.01	4.38
July	50,300	2,940	9,283	.962	1.11	19	5.79	4.68
August	9,500	1,540	3,449	.357	.412	24	1.69	1.27
September	25,380	1,180	2,175	.225	.251	4	6.09	5.84
October	159,400	2,000	12,490	1.29	1.49	162	.92	—.57
November	30,020	2,000	6,928	.718	.801	26	3.02	2.22
December	12,040	2,000	4,723	.489	.564	76	.74	.18
The year							36.78	
1897.[d]								
January	8,540	2,280	4,284	.444	.512	33	1.55	1.04
February	182,200	6,660	42,660	4.42	4.60	78	5.88	1.28
March	31,380	11,520	20,850	2.16	2.49	104	2.40	—.09
April	28,000	5,760	10,830	1.12	1.25	55	2.28	1.03
May	94,200	5,760	22,950	2.38	2.74	57	4.77	2.03
June	7,580	4,080	5,997	.621	.693	28	2.43	1.74
July	10,500	2,940	5,315	.551	.635	16	4.08	3.44
August	6,200	3,300	4,092	.424	.489	17	2.93	2.44
September	2,940	2,000	2,337	.242	.270	17	1.60	1.33
October	2,600	1,760	1,968	.204	.235	17	1.43	1.19
November	4,480	1,340	2,096	.217	.242	6	4.10	3.86
December	19,260	2,600	6,579	.681	.785	24	3.22	2.44
The year	182,200	1,340	10,830	1.12	14.94	41	36.68	21.74
1898.								
January	41,600	3,300	14,660	1.52	1.75	46	3.78	2.03
February	18,100	5,760	8,339	.864	.900	84	1.07	.17
March	65,150	4,480	15,470	1.60	1.84	41	4.44	2.60
April	52,700	9,020	15,970	1.65	1.84	78	2.36	.52
May	69,720	6,200	18,060	1.87	2.16	45	4.76	2.60
June	8,060	2,600	4,178	.433	.483	27	1.81	1.33
July	5,760	1,540	2,418	.250	.288	9	3.21	2.92
August	111,400	3,680	22,140	2.29	2.64	38	7.00	4.36
September	3,680	2,000	2,497	.259	.289	22	1.32	1.03
October	86,730	1,760	13,580	1.41	1.63	25	6.41	4.78
November	15,260	5,320	8,557	.886	.988	41	2.41	1.42
December	54,360	6,200	15,330	1.59	1.83	63	2.91	1.08
The year	111,400	1,540	11,780	1.22	16.64	40	41.48	24.84

[a] 9,650 square miles used to obtain run-off for 1906; 9,654 used for all other years.
[b] Precipitation for complete month, February, 1895, and May, 1896.
[c] Estimates January 1 to June 17, 1896, liable to considerable error, owing to possible error in gage heights. See Introduction, page 31.
[d] 1897 estimates may be only approximate, owing to large errors in the wire length during the year. See Introduction, page 32.

Estimated monthly discharge of Potomac River at Point of Rocks, Md.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1899.								
January	45,500	8,540	20,870	2.16	2.49	98	2.54	0.05
February	100,800	7,120	28,130	2.91	3.03	70	4.44	1.41
March	115,400	14,160	35,240	3.65	4.21	106	3.96	—.25
April	25,380	5,760	11,750	1.22	1.36	99	1.37	.01
May	49,140	5,320	11,600	1.20	1.38	27	5.15	3.77
June	16,380	2,940	5,314	.550	.614	18	3.47	2.86
July	7,120	1,540	2,519	.261	.301	13	2.28	1.98
August	3,680	1,540	2,335	.242	.279	10	2.84	2.56
September	3,680	1,760	2,345	.243	.271	7	3.94	3.67
October	2,000	1,540	1,663	.172	.198	11	1.88	1.68
November	9,500	2,000	3,171	.328	.366	22	1.69	1.32
December	12,040	2,000	4,068	.421	.485	25	1.94	1.46
The year	115,400	1,540	10,750	1.11	14.98	42	35.50	20.52
1900.								
January	35,620	3,680	8,166	.846	.975	47	2.10	1.12
February	37,820	2,940	13,340	1.38	1.44	42	3.44	2.00
March	50,300	8,540	18,470	1.91	2.20	64	3.42	1.22
April	22,240	5,320	9,295	.963	1.07	80	1.34	.27
May	7,120	2,940	4,466	.463	.534	23	2.32	1.79
June	48,700	2,600	8,394	.869	.970	23	4.19	3.22
July	7,120	1,340	3,008	.312	.360	10	3.74	3.38
August	3,680	1,340	1,917	.199	.229	11	2.08	1.85
September	2,000	1,040	1,344	.139	.155	8	1.95	1.79
October	2,600	1,180	1,333	.138	.159	8	2.08	1.92
November	46,300	1,040	4,570	.473	.528	15	3.62	3.09
December	29,340	2,280	6,218	.644	.742	42	1.77	1.03
The year	50,300	1,040	6,710	.695	9.36	29	32.04	22.68
1901.[a]								
January	21,040	1,760	4,929	.511	.589	30	1.95	1.36
February	6,200	2,280	3,649	.378	.394	85	.46	.07
March	80,920	2,280	13,800	1.43	1.65	48	3.46	1.81
April	150,600	7,120	39,750	4.12	4.60	76	6.05	1.45
May	95,860	6,200	26,920	2.79	3.22	50	6.47	3.25
June	48,700	8,060	18,840	1.95	2.18	48	4.56	2.38
July	26,680	4,900	10,720	1.11	1.28	34	3.82	2.54
August	20,440	4,080	8,337	.864	.996	16	6.23	5.23
September	28,000	3,680	7,636	.791	.882	28	3.15	2.27
October	12,040	2,600	4,303	.446	.514	90	.57	.06
November	19,840	2,280	4,648	.481	.537	22	2.50	1.96
December	130,700	4,480	25,610	2.65	3.06	54	5.71	2.65
The year	150,600	1,760	14,100	1.46	19.90	44	44.93	25.03
1902.[a]								
January	75,110	7,580	17,520	1.81	2.09	75	2.78	.69
February[b]	203,800	9,020	32,520	3.37	3.51	90	3.88	.37
March	218,700	14,700	54,410	5.64	6.50	149	4.35	—2.15
April	108,700	7,750	28,760	2.99	3.34	104	3.20	—.14
May	9,530	4,670	5,973	.619	.714	36	1.97	1.26
June	4,330	2,530	3,186	.330	.368	11	3.45	3.08
July	4,330	2,000	3,086	.320	.369	13	2.75	2.38
August	4,330	1,515	2,464	.255	.294	13	2.16	1.87
September	2,000	1,295	1,490	.154	.172	8	2.01	1.84
October	5,380	1,515	2,767	.287	.331	10	3.36	3.03
November	11,470	1,750	2,837	.294	.328	13	2.49	2.16
December	54,780	7,330	18,970	1.96	2.26	50	4.50	2.24
The year	218,700	1,295	14,500	1.50	20.28	55	36.90	16.62

[a] Estimates April 16, 1901, to September 1, 1902, liable to some error on account of uncertainty of the gage datum.
[b] Ice gorge February 11–23, 1902; no correction made in estimates.

Estimated monthly discharge of Potomac River at Point of Rocks, Md.—Continued.

Month.	Discharge in second-feet. Maximum.	Minimum.	Mean.	Run-off. Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	Precipitation. In inches.	Loss in inches.
1903.								
January	68,880	6,520	17,200	1.78	2.05	58	3.51	1.46
February	49,160	12,490	22,190	2.30	2.40	69	3.49	1.09
March	99,590	9,070	26,730	2.77	3.19	89	3.59	.40
April	97,930	9,530	28,900	2.99	3.34	89	3.75	.41
May	9,070	4,330	6,212	.643	.741	25	2.92	2.18
June	73,860	6,520	17,970	1.86	2.08	32	6.57	4.49
July	45,260	4,330	12,760	1.32	1.52	33	4.67	3.15
August	8,620	2,810	4,826	.500	.576	16	3.67	3.09
September	16,850	2,530	4,669	484	.540	24	2.29	1.75
October	6,130	2,000	3,212	.333	.384	15	2.57	2.19
November	2,810	2,000	2,175	.225	.251	27	.91	.66
December [a]	4,010	2,000	2,926	.303	.349	45	.78	.43
The year	99,590	2,000	12,480	1.29	17.42	45	38.72	21.30
1904.								
January [b]	35,620	3,400	7,287	.755	.870	42	2.05	1.18
February [b]	37,060	8,620	17,480	1.81	1.95	163	1.20	—.75
March	22,300	5,380	11,170	1.16	1.34	64	2.08	.74
April	28,120	3,400	7,406	.767	.856	35	2.46	1.60
May	27,460	5,380	9,362	.970	1.12	33	3.43	2.31
June	38,500	3,100	10,160	1.05	1.17	24	4.78	3.61
July	10,970	2,530	4,510	.467	.538	12	4.54	4.00
August	3,400	1,750	2,394	.248	.286	12	2.32	2.03
September	2,000	1,295	1,592	.165	.184	8	2.25	2.07
October	2,000	900	1,164	.121	.140	8	1.66	1.52
November	1,515	1,090	1,340	.139	.155	19	.79	.64
December	5,020	1,515	2,201	.228	.263	10	2.52	2.26
The year	38,500	900	6,339	.657	8.87	30	30.08	21.21
1905.								
January [c]	17,430	4,670	8,626	.894	1.03	33	3.12	2.09
February	6,520	5,020	5,625	.583	.607	35	1.73	1.12
March	63,900	6,520	23,480	2.43	2.80	97	2.89	.09
April	10,000	4,010	6,581	.682	.761	44	1.72	.96
May	9,070	2,810	4,493	.465	.536	18	3.05	2.51
June	32,820	2,810	6,579	.681	.760	15	5.23	4.47
July	22,300	3,400	10,190	1.06	1.22	18	6.63	5.41
August	13,530	2,810	5,830	.604	.696	17	4.08	3.38
September	5,750	2,000	3,205	.332	.370	20	1.86	1.49
October	5,380	1,750	2,888	.299	.345	10	3.47	3.13
November	3,700	1,750	2,267	.235	.262	21	1.22	.96
December	37,060	3,400	10,640	1.10	1.27	36	3.52	2.25
The year	63,900	1,750	7,534	.780	10.66	28	38.52	27.86
1906.								
January	44,500	8,180	14,990	1.55	1.79			
February	9,070	3,700	5,116	.530	.552			
March	79,670	4,330	15,900	1.65	1.90			
April	64,730	8,180	22,440	2.33	2.60			
May	10,480	2,810	5,538	.574	.662			
June	19,820	3,400	7,007	.726	.810			
July	8,620	2,530	4,381	.454	.523			
August	37,060	3,400	15,200	1.58	1.82			
September	12,490	2,530	4,275	.444	.495			
October	106,200	2,530	16,310	1.69	1.95			
November	15,150	4,010	6,341	.657	.733			
December	55,600	4,010	11,000	1.14	1.31			
The year	106,200	2,530	10,710	1.11	15.14			

[a] Ice conditions December 17–31, 1903; no correction made in estimates.
[b] Ice conditions during portions of January and February, 1904; no correction made in estimates.
[c] Ice gorge January 27, 1905: no correction made in estimate.

The following table gives the horsepower, 80 per cent efficiency per foot of fall, that may be developed at different rates of discharge and shows the number of days on which the flow and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Discharge and horsepower table for Potomac River at Point of Rocks, Md., from 1895 to 1906.

Discharge in second-feet.	Horsepower 80 per cent efficiency per foot fall.	Days of deficient flow.											
		1895.[a]	1896.[b]	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
990	90	......	......	......	......	......	......	......	......	......	6	......	......
1,100	100	5	......	......	......	......	3	......	......	......	23	......	......
1,320	120	40	14	......	......	......	39	......	12	......	58	......	......
1,540	140	79	28	3	......	......	78	......	25	......	86	......	......
1,760	160	107	43	9	6	23	101	......	51	......	107	14	......
1,980	180	124	60	29	8	50	110	2	51	......	107	14	......
2,200	200	128	72	56	29	82	115	5	83	22	126	32	......
2,750	250	150	101	98	59	133	140	49	109	59	140	46	9
3,300	300	162	130	107	71	152	152	60	142	74	161	90	28
3,850	350	182	162	137	95	172	173	88	162	103	196	130	59
4,400	400	190	187	162	106	176	193	101	175	128	207	149	106
4,950	450	201	222	186	128	188	223	126	185	139	210	162	128
5,500	500	208	238	195	136	197	233	133	195	161	223	195	151

[a] February 17 to December 31, 1895.
[b] Missing days estimated from Millville records.

NOTE.—The minimum flow during the period covered by the above table was 900 second-feet, giving 82 horsepower per foot of fall for two three-day periods during October, 1904.

MONOCACY RIVER NEAR FREDERICK, MD.

Monocacy River rises in Adams County, Pa., flows somewhat west of south, and enters Potomac River in the southeastern part of Frederick County, Md. Its length below the confluence of Rock and Marsh creeks is 55 miles. Its drainage area is 940 square miles. It has a number of tributaries on which small mills are located.

The gaging station was established August 4, 1896, by E. G. Paul. It is located at the county bridge on the toll road leading from Frederick to Mount Pleasant, Md. It is 4 miles northeast of Frederick, about 2,000 feet above the mouth of Israel Creek and 3,000 feet below the mouth of Tuscarora Creek.

The channel is straight for 300 feet above and 100 feet below the bridge. Both banks are low, liable to overflow, and covered with a fringe of trees, but all water passes beneath the bridge. The bed is composed of gravel and cobblestones, except near the banks, where it is composed of silt and is subject to change.

Discharge measurements are made from the two-span highway bridge, which has a total span of 310 feet. The channel at this point is divided by a small, low island, which serves as a foundation for the pier of the bridge. The right channel is measured from the lower and the left from the upper side of the bridge, as the results are better than would be furnished by a continuous section on either side of the bridge. The pier and island obstruct the flow to some extent, causing dead water for 20 feet to the right of the pier at low water and eddies at high water. The initial point for soundings is a crosscut in the face of the parapet wall on the lower wing of the right abutment.

September 3, 1902, the original wire gage was replaced by a standard chain gage which is located in the middle of the first span from the right bank and is attached to the bridge floor on the lower side of the bridge. The length of the chain from the end of the weight to the marker is 35.04 feet. The gage is read twice each day by E. L. Derr. The bench mark is a hole drilled in the top of a coping stone on the lower wing of the right abutment, about 100 feet back from the initial point for soundings. Its elevation is 29.17 feet above gage datum. On October 31, 1905, the elevation of the top of the pulley was found to be 25.47 feet above gage datum.

Estimates published for 1896 to 1903 have been revised; 1904 and 1905 estimates, as previously published, have not been changed. Two rating curves have been used to determine the discharge of the river. The estimates are probably well within 10 per cent of the true discharge for normal conditions of flow. Owing to gorging below the bridge at high stages, the tangent has been considered to give the best results above gage height 12.0 feet. Ice conditions probably affect the discharge to a considerable extent.

A summary of the records gives the following results: Maximum discharge for twenty-four hours, 20,460 second-feet; minimum discharge for twenty-four hours, 49 second-feet; mean annual discharge for ten years, 1,130 second-feet; mean annual rainfall for ten years, 45.04 inches.

Discharge measurements of Monocacy River near Frederick, Md.

Date.	Gage height.	Discharge.
	Feet.	*Second-feet.*
1896.		
August 5	4.10	176
September 16	3.80	88
November 19	4.20	206
1897.		
February 9	6.00	1,019
February 24	8.95	3,569
March 9	6.00	1,085
April 10	7.55	2,264
July 3	4.30	220
September 3	4.15	182
October 29 [a]	4.05	122
1898.		
January 26	7.55	2,342
August 20	6.95	1,605
1899.		
May 22	5.20	633
September 6	4.00	153
1900.		
June 29	4.10	191
September 20	3.80	88
1901.		
July 31	4.10	179
1901—Continued.		
December 28	6.30	1,226
1902.		
September 4	3.74	100
1903.		
March 13	6.49	1,282
April 17	11.03	4,708
April 18	9.40	3,733
September 14	4.60	356
November 10	4.32	212
1904.		
July 12	5.18	475
September 26	3.96	100
October 20 [b]	3.92	98
1905.		
March 11	10.13	4,659
March 12	9.73	4,253
June 21	4.16	170
October 31	4.68	319
1906.		
May 31	4.70	328

[a] Measurement made at mouth of river.

[b] Measurement made above bridge by wading.

Daily gage height, in feet, of Monocacy River near Frederick, Md.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1896.						1896.					
1	......	3.6	4.8	3.9	4.8	17	3.8	3.9	4.0	4.2	4.0
2	......	3.6	4.4	4.0	4.5	18	4.4	3.9	3.9	4.2	4.0
3	......	3.6	4.1	4.0	4.5	19	4.15	4.0	3.9	4.2	4.0
4	4.1	3.6	4.0	4.0	4.3	20	3.9	4.0	3.8	4.2	4.0
5	4.1	3.6	3.9	5.45	4.3						
						21	3.9	4.0	3.9	4.2	4.0
6	4.0	3.7	3.9	7.5	4.1	22	3.9	3.9	3.9	4.0	3.9
7	4.0	3.8	3.9	5.0	4.1	23	3.8	3.9	3.9	4.0	3.9
8	3.9	3.9	3.9	4.5	4.1	24	3.7	3.8	3.9	4.0	4.1
9	3.9	3.9	3.9	4.5	4.2	25	3.7	3.9	3.9	4.0	4.2
10	3.9	3.8	3.9	4.8	4.2						
						26	3.9	3.8	3.9	4.0	4.1
11	3.8	3.7	3.8	4.5	4.3	27	3.9	3.8	3.9	4.0	4.1
12	3.9	3.7	3.8	4.5	4.2	28	3.8	3.8	3.9	4.0	4.1
13	3.9	3.7	3.9	4.3	4.1	29	3.7	3.8	3.9	4.35	4.0
14	3.9	3.7	4.2	4.3	4.1	30	3.6	5.0	3.9	5.2	4.0
15	3.9	3.7	4.1	4.2	4.1	31	3.7	......	3.9	......	4.2
16	3.8	3.75	4.1	4.2	4.1						

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897.[a]												
1	4.2	4.4	5.7	5.0	4.6	5.0	4.2	4.9	4.15	3.95	4.15	5.25
2	4.2	4.4	5.5	5.0	6.3	4.8	4.2	4.7	4.05	3.95	14.85	5.15
3	4.2	5.0	5.6	4.9	6.2	4.7	4.3	4.5	4.15	3.85	8.15	5.15
4	4.2	6.0	7.5	4.9	6.2	5.0	4.2	4.4	4.05	3.85	6.55	8.15
5	4.2	5.5	7.5	6.9	6.0	7.5	4.2	4.4	4.05	3.75	5.35	12.4
6	4.3	8.4	8.0	5.9	5.9	5.6	4.2	4.3	3.95	3.85	5.05	8.65
7	4.3	15.0	7.6	5.6	5.6	5.4	4.2	4.3	3.95	3.75	4.85	7.2
8	4.5	8.45	6.2	5.4	5.4	4.95	4.2	4.2	3.95	3.75	4.75	6.55
9	4.4	6.0	6.0	9.3	5.1	6.15	4.9	4.2	3.95	3.75	5.55	5.95
10	4.3	5.6	6.5	8.55	5.0	5.8	4.5	4.2	3.95	3.85	5.55	5.75
11	4.2	5.2	6.2	6.55	5.1	5.3	4.2	10.6	3.95	3.85	4.85	5.55
12	4.3	5.2	5.8	6.6	5.1	5.0	4.2	8.5	3.95	3.85	4.75	6.85
13	4.3	4.9	5.8	5.7	15.6	4.9	7.0	5.45	3.95	4.25	4.65	6.65
14	4.3	4.6	5.7	5.8	15.6	4.7	5.2	4.45	3.85	4.15	4.55	10.65
15	4.0	4.6	5.7	5.9	10.9	4.7	4.6	4.25	3.85	4.05	5.15	14.6
16	4.0	5.7	5.8	6.2	7.4	4.7	4.3	5.35	3.85	3.95	5.55	13.85
17	4.0	7.4	5.4	5.8	6.8	4.8	4.3	4.85	4.45	3.95	4.95	7.15
18	4.0	7.4	6.6	5.8	6.5	4.8	5.1	4.3	4.45	3.85	4.75	6.65
19	4.3	6.7	7.0	5.5	6.1	4.7	4.95	4.1	4.05	3.75	4.65	6.15
20	4.7	6.1	9.8	5.3	5.8	4.7	5.25	4.1	3.85	3.75	4.55	5.95
21	4.5	5.7	7.6	5.1	5.9	4.9	4.95	4.1	3.85	3.85	4.65	5.85
22	5.5	12.1	6.6	5.0	6.0	4.7	6.4	5.5	3.95	3.95	4.55	6.55
23	5.4	14.6	6.5	5.0	5.5	4.5	5.65	4.8	3.95	3.95	4.75	6.05
24	4.8	8.85	7.4	5.0	5.3	4.5	4.95	16.2	5.65	3.95	5.6	5.65
25	5.2	8.3	7.3	4.9	6.7	4.4	4.45	6.75	5.15	4.05	4.85	5.15
26	5.0	7.0	6.1	4.9	6.0	4.4	4.35	5.75	4.65	4.35	6.55	5.55
27	5.0	6.5	5.8	4.9	5.3	4.4	7.7	5.1	3.95	4.25	7.05	5.45
28	5.0	6.0	5.6	4.8	5.2	4.4	9.9	4.7	3.95	4.15	6.55	5.45
29	5.0	....	5.4	4.7	5.0	4.2	7.8	4.35	3.95	4.05	5.85	5.35
30	4.8	....	5.3	4.6	4.9	4.2	6.1	4.15	3.95	4.05	5.65	5.35
31	4.5	....	5.2	....	5.0	....	5.3	4.15	....	3.95	....	5.45

[a] River frozen at the gage January 25 to February 2, 1897. All gage heights from July 3 to December 31, 1897, are liable to errors of one or two tenths owing to incorrect wire length.

Daily gage height, in feet, of Monocacy River near Frederick, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.[a]												
1	5.25	5.4	5.4	7.1	4.7	5.5	4.4	4.7	4.0	3.8	5.5	6.3
2	4.85	6.5	5.3	6.9	4.7	5.4	4.3	4.6	4.0	3.8	5.3	6.2
3	5.65	6.5	5.3	6.0	4.6	5.3	4.3	4.4	4.0	3.8	4.7	5.5
4	5.35	6.5	5.7	5.8	4.6	5.2	4.3	4.1	4.0	3.8	4.6	7.0
5	5.15	6.1	6.2	5.8	4.6	5.1	4.4	7.65	3.9	3.8	4.5	17.95
6	5.15	6.1	6.0	5.8	4.6	5.1	4.4	6.9	3.9	3.8	4.4	8.5
7	5.15	5.5	5.9	5.8	6.2	5.1	4.4	5.1	3.9	3.8	4.4	7.0
8	5.25	5.0	5.5	5.5	8.25	5.0	4.4	4.2	4.0	3.9	4.4	6.4
9	5.35	5.2	5.3	5.5	13.4	5.0	4.4	4.1	4.0	3.9	4.4	5.7
10	6.15	5.4	5.2	5.2	7.5	5.0	4.4	6.7	4.0	3.8	4.7	5.5
11	6.75	5.4	5.2	5.2	6.5	5.0	4.3	12.4	3.9	3.8	9.7	5.3
12	6.85	6.0	5.1	5.2	6.5	5.0	4.2	6.0	3.8	3.9	6.9	5.3
13	7.75	6.2	5.1	5.1	8.2	5.0	4.2	5.4	3.8	3.8	5.4	5.3
14	8.15	5.6	5.1	5.1	6.0	4.9	4.2	5.4	3.8	3.8	5.3	5.3
15	11.55	5.5	5.0	5.3	5.6	4.9	4.2	4.6	3.8	4.0	5.2	5.2
16	11.05	5.3	5.0	5.9	6.75	4.8	4.1	4.5	3.8	4.2	5.0	5.0
17	8.4	5.2	5.0	5.5	11.55	4.7	4.1	4.5	3.8	3.9	5.5	5.0
18	7.15	5.1	5.0	5.0	7.5	4.6	4.1	6.35	3.8	5.5	6.1	5.0
19	6.55	6.4	5.0	4.9	6.5	4.5	4.1	10.1	3.8	6.5	12.35	6.0
20	6.55	6.5	4.9	4.9	6.5	4.5	4.3	7.0	3.8	5.6	9.5	9.6
21	8.65	14.8	6.1	4.9	6.4	4.5	5.4	5.5	3.8	4.9	6.85	8.6
22	9.15	12.0	7.3	4.8	6.0	4.5	4.4	4.9	3.9	11.55	5.9	8.8
23	12.4	7.5	7.6	4.8	6.0	4.5	4.1	4.6	4.15	9.0	5.9	13.6
24	9.15	6.5	7.6	5.0	6.6	4.4	4.0	4.5	4.2	7.1	6.3	8.0
25	7.15	6.3	10.75	5.3	6.7	4.4	3.9	4.4	4.1	5.2	5.9	7.5
26	8.5	5.7	8.5	5.3	6.6	4.4	3.9	4.3	3.9	5.2	5.4	6.1
27	8.0	5.6	6.6	5.0	6.3	4.4	4.3	4.3	3.9	5.5	5.2	6.0
28	7.3	5.4	6.6	4.9	5.9	4.4	4.3	4.2	3.9	5.3	5.2	5.9
29	6.5	....	7.7	4.9	5.8	4.4	4.3	4.1	3.9	5.1	5.3	5.5
30	5.9	....	9.5	4.8	5.7	4.4	4.2	4.1	3.8	5.1	5.7	5.5
31	5.7	....	7.9	....	5.6	....	4.0	4.0	....	6.0	....	5.5
1899.[b]												
1	5.4	5.2	11.5	7.1	4.8	7.1	4.1	3.9	4.3	4.0	7.3	4.1
2	5.0	5.2	10.1	6.9	4.8	11.1	4.1	4.0	4.3	3.9	6.4	4.1
3	5.5	5.8	9.2	6.5	5.0	7.05	4.1	5.1	5.4	3.9	6.3	4.1
4	6.0	5.6	8.7	6.1	4.9	5.2	4.0	5.0	5.0	3.9	6.0	4.1
5	6.3	5.9	17.2	6.0	4.9	4.9	4.0	5.0	4.5	3.8	5.3	4.1
6	12.75	5.7	11.45	6.0	4.8	4.7	4.5	4.9	4.0	3.8	5.0	4.0
7	14.85	5.5	8.9	7.6	4.8	4.5	4.4	4.5	3.9	3.9	4.5	4.0
8	12.5	5.4	7.8	12.6	5.2	4.5	4.2	4.0	3.8	3.9	4.4	3.9
9	10.2	6.0	7.5	7.8	6.6	5.5	4.3	4.0	3.7	4.1	4.3	3.9
10	6.1	6.0	7.4	6.9	5.6	6.85	4.2	4.0	4.0	4.1	4.3	3.9
11	6.1	6.0	7.4	6.5	5.4	6.9	4.2	4.0	4.0	4.0	4.2	3.9
12	5.7	6.0	7.3	6.2	5.8	6.5	4.1	4.2	3.9	4.0	4.1	4.8
13	5.8	6.0	7.1	5.9	5.4	5.2	4.3	4.0	3.9	3.9	4.1	5.95
14	6.0	6.0	6.5	5.6	5.0	4.9	4.2	3.9	3.8	3.9	4.1	5.5
15	6.8	6.0	6.5	5.6	5.0	6.2	4.2	3.9	3.8	3.9	4.1	4.5
16	6.6	6.0	9.7	5.6	4.9	5.1	4.5	3.9	3.8	3.9	4.1	4.4
17	6.6	6.2	6.9	5.6	5.2	4.8	4.3	3.9	3.7	3.9	4.1	4.4
18	7.1	6.8	7.9	5.6	6.5	4.5	4.3	3.8	3.7	4.0	4.1	4.3
19	6.4	7.9	13.9	5.6	7.7	4.4	4.2	3.8	3.7	3.9	4.1	4.2
20	5.6	9.0	10.1	5.4	6.9	4.4	4.1	3.8	6.0	3.9	4.1	4.2
21	5.6	12.5	7.9	5.2	6.3	4.4	4.0	3.8	5.3	3.8	4.1	4.5
22	5.6	13.5	7.8	5.1	5.2	4.3	3.9	3.8	5.0	3.8	4.1	4.4
23	5.6	15.65	7.6	5.1	5.2	4.3	3.9	3.8	4.9	3.8	4.1	4.3
24	5.7	11.6	7.2	5.0	5.0	4.3	3.9	3.8	4.5	3.8	5.3	7.1
25	10.4	9.1	6.7	5.0	4.9	4.2	4.3	3.8	4.3	3.8	4.7	6.9
26	8.2	9.1	6.7	5.0	4.8	4.2	4.5	3.8	5.25	3.8	4.4	6.2
27	6.5	17.8	6.7	5.0	4.7	4.2	4.4	4.7	5.5	3.8	4.3	6.0
28	5.2	12.5	10.15	4.9	4.7	4.2	4.3	4.95	5.3	3.8	4.3	5.1
29	5.2	....	11.0	4.9	4.6	4.2	4.2	4.7	5.0	3.8	4.3	[a] 5.1
30	5.2	....	8.1	4.8	5.0	4.2	4.0	4.3	4.5	3.8	4.2	[a] 5.1
31	5.2	....	7.9	....	5.0	....	3.9	4.3	....	5.0	....	[a] 5.4

[a] River frozen February 2-9, 1898.
[b] River frozen at the gage January 2, February 9-21, and December 28-31, 1899.

Daily gage height, in feet, of Monocacy River near Frederick, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900.[a]												
1	5.4	5.1	13.45	6.4	4.7	4.4	4.0	3.95	3.85	3.9	3.7	5.2
2	5.4	5.1	12.0	5.7	4.7	4.4	4.0	3.85	3.75	3.8	3.7	4.3
3	5.4	5.1	9.5	5.5	4.7	4.4	3.9	3.85	3.75	3.8	3.7	4.3
4	5.2	5.1	8.2	5.5	4.9	4.4	3.9	3.75	3.6	3.8	4.1	7.2
5	5.0	5.2	7.3	5.5	4.8	4.4	3.9	3.65	3.6	3.8	4.1	12.1
6	4.9	5.1	7.1	5.4	4.6	4.3	3.9	3.65	3.65	3.7	4.0	6.0
7	4.8	5.3	8.0	5.3	4.5	4.2	3.8	3.65	3.65	3.7	4.0	5.5
8	4.5	6.9	7.5	5.2	4.4	4.2	3.8	3.65	3.65	3.7	4.0	5.2
9	4.5	7.55	6.5	5.1	4.4	4.2	3.7	3.65	3.6	3.7	3.9	4.9
10	4.9	6.9	6.3	5.1	4.4	4.1	3.7	3.65	3.6	3.7	3.9	4.5
11	5.0	5.3	6.3	5.0	4.4	4.1	3.7	3.55	3.55	3.7	3.9	4.3
12	10.2	5.5	5.9	5.0	4.4	4.1	3.7	3.55	3.55	3.7	3.9	4.2
13	9.2	15.1	5.7	5.0	4.3	4.1	3.7	3.45	3.55	3.7	3.9	4.0
14	5.4	12.85	5.6	5.0	4.3	4.1	3.7	3.45	3.5	3.9	3.9	4.0
15	4.9	7.0	5.5	5.0	4.3	4.4	3.7	3.45	3.5	4.1	3.9	4.0
16	4.8	6.5	5.4	4.9	4.3	4.8	3.6	3.45	3.85	4.1	3.9	4.0
17	4.6	5.9	5.4	4.9	4.3	5.0	3.6	3.55	3.85	4.1	3.9	4.0
18	4.6	5.9	5.4	5.1	4.3	5.8	3.6	3.85	3.85	3.9	3.8	4.0
19	4.9	5.8	5.4	5.2	6.5	6.0	3.7	3.75	3.8	3.8	3.8	3.9
20	9.0	5.5	13.5	5.1	7.0	5.1	4.55	3.75	3.8	3.7	3.8	3.9
21	9.5	5.5	10.2	5.0	6.5	4.9	4.55	3.75	3.8	3.7	3.8	3.9
22	7.05	20.8	9.1	5.0	5.9	4.5	3.75	4.75	3.7	3.7	3.8	4.0
23	6.5	15.0	8.2	5.5	4.9	4.4	4.05	4.65	3.65	3.8	3.9	4.0
24	6.0	10.5	6.5	5.6	4.8	4.2	5.45	4.05	3.5	3.8	3.9	4.1
25	5.7	8.5	6.1	5.4	4.7	4.2	4.75	4.05	3.5	3.8	3.9	4.1
26	5.5	7.1	6.0	4.9	4.6	4.2	4.15	3.95	3.5	3.7	9.2	4.1
27	5.1	6.5	5.9	4.8	4.5	4.2	4.15	3.85	3.5	3.7	7.3	4.1
28	4.9	6.5	5.7	4.8	4.5	4.1	4.05	5.45	3.6	3.7	7.1	4.1
29	4.6	....	5.5	4.8	4.5	4.1	3.95	5.25	....	3.7	6.9	4.0
30	4.5	....	5.5	4.7	4.5	4.0	3.95	4.25	4.0	3.7	6.3	4.0
31	4.5	....	6.5	....	4.5	....	3.95	3.95	....	3.7	....	4.5
1901.[b]												
1	4.4	4.6	4.5	5.7	5.9	6.0	4.3	4.1	4.3	5.2	4.2	4.9
2	4.2	4.4	4.5	5.6	5.8	5.6	4.3	4.0	4.9	5.1	4.2	4.7
3	4.2	4.4	4.4	18.0	5.6	5.4	4.2	4.0	4.5	4.9	4.2	4.9
4	4.3	4.4	5.0	15.5	5.4	5.3	4.2	4.0	4.4	4.8	4.2	4.9
5	4.3	4.8	5.5	10.5	5.3	5.3	4.2	4.0	4.3	4.6	4.2	4.9
6	4.2	4.8	5.3	7.9	5.2	5.0	4.4	5.4	4.3	4.4	4.2	4.9
7	4.1	4.7	5.0	8.3	5.1	5.5	4.3	7.1	4.3	4.3	4.2	4.8
8	4.0	4.6	5.0	7.2	5.1	7.1	4.3	6.0	4.3	4.3	4.3	4.8
9	4.1	4.5	5.1	6.5	5.1	5.4	4.2	4.7	4.3	4.2	4.3	4.8
10	4.1	4.5	5.5	6.2	5.5	5.2	4.1	4.6	4.2	4.2	4.3	7.5
11	5.5	4.5	20.5	5.9	5.5	4.9	4.1	4.2	4.2	4.2	4.3	6.5
12	7.6	4.5	11.9	5.6	5.4	4.9	5.1	4.1	4.2	4.1	4.3	6.1
13	6.9	4.4	8.0	5.6	5.3	8.0	5.5	4.6	4.2	4.1	4.3	5.3
14	6.4	4.3	7.3	5.4	5.1	6.4	4.8	4.4	4.2	4.8	4.3	5.4
15	5.9	4.3	6.9	6.9	4.9	6.75	4.8	4.3	4.2	5.0	4.3	19.75
16	4.9	4.3	6.1	6.5	4.9	7.45	4.9	5.6	5.5	4.9	4.3	9.5
17	4.8	4.3	5.9	6.3	4.9	7.2	5.0	4.9	4.7	4.8	4.2	7.1
18	4.7	4.3	5.8	5.9	4.9	6.1	4.9	5.1	4.5	4.4	4.2	6.9
19	4.7	4.4	5.6	5.5	4.85	5.9	5.2	4.5	4.5	4.2	4.2	6.5
20	4.5	4.9	5.3	9.6	4.8	5.4	5.1	6.4	4.4	4.2	4.2	6.2
21	4.3	5.0	10.5	14.6	4.8	5.2	5.1	6.1	4.3	4.1	4.2	6.0
22	4.3	5.1	7.6	9.6	4.8	5.2	4.9	5.2	4.3	4.1	4.2	5.9
23	4.2	5.0	7.1	8.1	11.3	5.1	4.5	4.5	4.2	4.1	4.5	5.9
24	4.2	5.0	6.0	8.5	9.1	4.9	4.4	4.6	4.1	4.1	9.4	5.7
25	4.2	4.9	6.0	7.9	7.9	4.7	4.2	5.0	4.1	4.1	7.5	5.5
26	4.3	4.8	6.1	7.3	7.1	4.6	4.2	4.9	4.1	4.2	5.9	5.5
27	4.3	4.6	13.55	6.9	9.0	4.5	4.5	4.5	4.1	4.2	5.5	7.35
28	4.3	4.5	10.4	6.4	9.2	4.5	4.3	4.3	4.1	4.2	5.3	6.5
29	4.8	....	7.4	6.1	11.5	4.5	4.2	4.2	4.7	4.2	5.1	13.25
30	4.7	....	5.9	6.0	9.1	4.5	4.2	4.2	6.7	4.2	5.0	18.5
31	4.7	....	5.8	....	8.6	....	4.1	4.2	....	4.2	....	12.5

[a] River frozen at the gage January 1–6 and February 1–4, 1900.
[b] No gage weight on the wire June 1–4, 1901; gage heights estimated by the observer.

Daily gage height, in feet, of Monocacy River near Frederick, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1902.[a]												
1	8.5	5.9	25.2	7.0	5.2	4.3	6.9	5.2	3.7	4.6	5.1	9.5
2	8.2	5.9	14.5	6.9	5.1	4.3	6.4	4.5	3.7	6.0	5.0	7.9
3	7.1	5.9	10.9	10.5	5.1	4.3	4.9	4.2	3.7	5.1	4.9	16.0
4	6.0	8.5	10.2	8.5	5.0	4.2	4.8	4.1	3.7	4.2	4.7	8.6
5	7.9	8.5	9.6	8.3	4.9	4.2	4.8	4.1	3.9	4.5	4.6	8.2
6	8.2	8.1	9.2	8.0	4.9	4.1	4.8	4.2	3.7	7.1	4.5	7.9
7	8.1	7.9	9.1	7.9	4.8	4.1	4.8	4.2	3.6	5.2	4.4	7.8
8	7.5	7.8	8.9	7.5	4.8	4.1	4.6	4.1	3.6	5.1	4.6	7.8
9	5.9	7.4	9.9	17.9	4.7	4.1	4.5	4.0	3.6	5.0	4.5	7.5
10	5.5	6.9	15.2	16.9	4.7	4.1	4.4	4.0	3.6	4.9	4.5	7.4
11	5.4	6.5	15.5	8.2	4.7	4.1	4.3	4.0	3.6	5.5	4.5	7.9
12	5.4	6.5	12.2	7.5	4.6	4.0	4.2	4.0	3.55	12.8	4.4	9.2
13	5.3	6.5	14.5	7.3	4.6	7.1	4.1	3.9	3.5	8.1	4.4	11.5
14	5.3	6.3	10.1	6.9	4.6	5.5	4.0	3.9	3.5	6.5	4.4	9.5
15	5.2	6.1	10.0	6.5	4.6	4.2	4.0	3.8	3.5	5.1	4.3	8.2
16	5.1	5.9	9.5	6.3	4.6	4.2	3.9	3.8	3.5	4.9	4.2	15.3
17	4.9	5.9	14.6	6.1	4.5	4.2	3.9	3.8	3.5	4.7	4.2	14.5
18	4.9	5.9	10.2	5.9	4.5	4.1	3.9	3.8	3.5	4.6	4.2	8.5
19	4.9	5.9	8.4	5.8	4.5	4.1	4.1	3.8	3.5	4.5	4.6	8.2
20	4.9	6.1	8.1	5.7	4.5	4.1	4.1	3.8	3.6	4.4	4.5	9.5
21	7.2	10.2	7.9	5.6	4.5	4.2	5.2	3.7	3.6	4.3	4.4	10.5
22	18.05	14.4	7.4	5.5	4.5	4.2	4.3	3.7	3.6	4.2	4.3	17.1
23	7.1	9.6	7.1	5.4	4.5	4.1	4.2	3.7	3.5	4.2	4.2	14.2
24	6.9	9.4	6.9	5.3	4.4	4.1	4.1	3.6	3.5	4.2	4.2	8.4
25	6.1	10.5	6.5	5.3	4.4	4.1	4.1	3.6	3.8	4.1	4.2	7.5
26	6.9	24.0	6.3	5.2	4.4	5.9	4.0	3.6	4.0	4.1	5.9	7.2
27	11.15	21.4	6.0	5.1	4.5	5.6	4.0	3.6	9.1	4.1	9.4	6.9
28	7.5	19.35	6.0	5.0	4.5	5.1	3.9	4.1	5.1	13.7	7.9	6.5
29	6.9	....	5.9	5.2	4.4	4.5	3.9	3.9	4.9	9.5	5.9	6.4
30	6.5	....	5.6	5.2	4.3	4.5	4.5	3.7	4.8	5.5	5.9	6.2
31	6.2	....	6.2	....	4.3	....	5.5	3.7	....	5.3	....	5.5
1903.[b]												
1	5.5	7.6	21.4	7.9	5.6	6.5	9.5	5.3	6.5	4.4	4.3	4.3
2	15.8	7.3	9.5	7.4	5.5	6.4	8.1	5.1	5.9	4.4	4.3	4.2
3	13.35	8.3	8.1	6.9	5.5	6.1	7.5	4.9	5.5	4.3	4.3	4.2
4	10.5	16.35	7.9	7.9	5.5	5.1	8.1	4.9	5.4	4.3	4.3	4.2
5	9.5	10.5	7.5	7.2	5.4	4.9	11.5	4.9	5.2	4.3	4.3	4.1
6	8.2	7.9	7.2	6.5	5.3	4.9	9.5	4.9	5.0	4.3	4.3	4.1
7	7.3	7.5	6.9	6.9	5.3	5.8	7.3	5.4	4.9	4.4	4.3	4.6
8	6.9	7.3	7.5	7.5	5.3	5.8	6.2	5.2	4.8	5.2	4.3	4.2
9	6.3	7.5	8.6	12.2	5.2	5.4	6.1	5.1	5.4	7.2	4.3	4.2
10	6.9	6.9	7.4	7.9	5.1	5.1	5.9	4.9	7.2	5.2	4.3	4.2
11	9.6	7.1	7.2	7.2	5.0	5.8	5.8	4.9	6.9	6.1	4.3	4.2
12	9.3	10.5	7.1	6.7	4.9	8.1	9.15	4.8	5.5	5.9	4.3	4.1
13	8.6	7.5	6.3	7.4	4.9	6.5	18.8	4.8	4.9	5.6	4.3	4.1
14	8.4	7.3	6.2	19.3	4.8	6.2	8.5	4.7	4.7	5.2	4.3	4.2
15	8.2	7.8	6.2	21.6	4.8	5.8	7.5	4.7	4.6	5.1	4.3	4.5
16	8.2	11.2	6.2	20.4	4.7	5.4	6.8	7.5	4.6	4.9	4.3	4.6
17	7.9	7.9	6.1	11.4	4.7	5.2	6.5	7.1	6.5	4.9	4.4	4.8
18	7.3	7.4	5.9	9.4	4.8	5.6	8.2	6.2	11.1	5.5	4.9	4.6
19	7.3	7.1	5.9	8.4	4.8	5.4	11.5	5.9	5.8	5.4	4.7	4.2
20	7.2	6.9	5.8	7.9	4.7	6.65	6.9	5.7	5.2	5.2	4.5	6.5
21	8.55	6.7	5.8	7.4	4.7	7.5	6.4	4.9	4.9	4.9	4.4	12.05
22	11.7	6.4	9.4	7.1	4.7	6.4	6.2	4.7	4.8	4.7	4.3	6.5
23	8.6	6.2	17.1	6.7	4.7	5.7	5.6	4.6	4.7	4.6	4.3	4.9
24	7.1	6.2	18.2	6.5	6.5	6.3	5.4	4.5	4.7	4.6	4.3	4.8
25	6.5	6.2	8.6	6.4	6.1	5.9	5.3	4.5	4.6	4.5	4.3	4.7
26	6.3	6.2	7.9	6.2	5.4	5.6	5.2	4.8	4.5	4.5	4.3	4.6
27	6.1	7.3	7.5	6.1	4.9	5.6	5.2	4.7	4.5	4.4	4.3	4.5
28	9.8	21.2	7.1	5.9	4.9	5.6	5.1	10.5	4.4	4.4	4.2	4.5
29	10.6	....	6.5	5.7	4.8	21.2	5.1	12.1	4.4	4.4	4.2	4.6
30	11.2	....	9.5	5.7	14.8	14.9	5.4	7.9	4.4	4.3	4.2	4.5
31	8.1	....	13.9	....	7.5	....	5.4	7.4	....	4.3	....	4.5

[a] River frozen at gage February 4–19, 1902. Observer estimated gage heights March 20 to April 8 1902, the gage being broken.
[b] River frozen at gage January 12–20, 1903.

Daily gage height, in feet, of Monocacy River near Frederick, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1904.[a]												
1	4.6	5.0	8.1	5.9	4.9	7.5	4.5	4.2	3.8	4.0	4.0	4.0
2	4.9	4.9	7.5	7.2	4.8	6.4	4.3	4.9	3.8	4.0	4.0	4.0
3	4.8	5.4	6.2	6.4	4.7	6.0	4.3	4.7	3.8	3.8	4.0	4.0
4	5.5	4.9	6.2	5.5	4.8	5.3	4.2	4.5	3.8	3.8	4.0	4.0
5	5.1	4.6	5.9	5.4	4.7	7.4	4.2	4.3	3.8	3.8	4.0	4.0
6	4.9	4.7	6.0	5.5	4.8	7.0	4.2	4.0	3.9	3.8	4.0	4.0
7	4.7	8.2	17.0	5.4	4.7	6.8	4.4	4.0	3.9	3.8	4.0	4.0
8	4.6	14.15	17.2	5.6	5.0	5.7	6.2	4.2	3.9	3.8	4.0	4.0
9	4.6	6.4	8.2	7.8	4.9	5.4	7.1	4.5	3.9	3.8	4.0	4.0
10	4.6	6.1	6.5	7.2	5.7	5.2	8.2	4.5	4.9	3.8	4.2	4.2
11	4.6	6.0	6.6	6.4	5.4	5.4	7.3	12.6	5.2	3.8	4.0	4.2
12	4.6	5.4	7.0	5.9	4.8	5.1	6.1	5.6	4.9	3.8	4.0	4.2
13	4.6	5.1	6.2	5.6	4.7	5.0	7.4	4.6	4.8	6.0	4.2	4.2
14	4.6	4.9	5.9	5.4	4.8	4.7	6.4	4.2	4.8	5.4	4.4	4.2
15	4.6	4.9	5.8	5.1	5.0	4.6	5.2	4.2	4.7	4.8	4.4	4.2
16	4.6	5.0	5.6	5.2	5.0	4.6	4.2	4.1	4.7	4.0	4.2	4.2
17	4.5	4.9	5.5	5.0	4.8	4.5	4.1	4.1	4.6	4.0	4.2	4.2
18	4.5	4.9	5.6	4.9	4.9	4.6	4.1	4.0	4.6	3.8	4.2	4.2
19	4.5	4.9	5.5	4.9	5.2	4.5	4.1	4.0	4.6	3.8	4.2	4.2
20	4.5	4.9	5.8	4.8	5.2	9.8	4.0	4.2	5.6	3.8	4.2	4.2
21	4.5	5.0	6.2	4.8	4.9	7.4	4.0	4.7	5.2	4.0	4.0	4.2
22	4.5	13.75	6.5	4.6	4.8	5.9	4.0	4.7	4.9	5.0	4.0	4.2
23	19.9	12.2	6.8	4.6	4.6	4.9	4.0	4.6	4.6	4.6	4.0	4.2
24	11.5	9.0	6.2	4.7	4.6	4.5	5.1	4.5	4.4	4.4	4.0	4.4
25	6.1	6.8	5.9	4.6	4.4	4.4	5.1	4.2	3.9	4.2	4.0	4.6
26	5.9	5.2	5.7	4.8	4.5	4.3	5.1	4.2	4.0	4.0	4.0	5.4
27	4.6	4.9	5.7	4.9	4.4	4.1	5.1	4.1	4.2	4.0	4.0	6.8
28	4.6	4.8	5.4	5.3	4.5	4.2	5.0	3.9	4.4	4.0	4.0	9.4
29	5.5	4.8	5.2	5.3	4.3	4.2	4.9	3.8	4.2	4.0	4.0	9.2
30	6.1	......	5.2	5.1	4.4	4.3	4.4	3.8	4.0	4.0	4.0	7.8
31	5.9	......	5.4	......	4.5	......	4.2	3.8	......	4.0	......	5.8
1905.[b]												
1	6.0	5.2	5.8	6.0	4.8	4.6	4.5	5.7	5.0	4.2	4.7	8.1
2	6.4	5.0	5.8	5.8	4.8	4.4	5.2	5.1	4.9	4.1	4.7	7.2
3	6.8	5.0	5.4	5.6	4.8	4.4	4.9	4.9	7.5	4.2	4.7	9.5
4	6.4	4.8	5.2	5.4	4.6	4.4	4.6	4.7	6.4	5.0	4.6	9.
5	6.2	4.8	6.6	6.4	4.6	4.2	4.5	4.6	6.1	4.5	4.6	8.3
6	6.2	4.8	6.8	6.4	4.6	4.2	8.0	4.5	5.9	4.3	4.6	6.1
7	17.4	4.8	7.4	6.2	4.6	4.6	7.9	4.4	5.1	4.4	4.6	5.6
8	9.8	4.8	7.4	5.8	4.6	7.4	7.6	4.5	5.1	4.2	4.5	5.5
9	7.2	4.8	10.9	5.6	4.6	7.2	6.5	4.5	4.9	4.3	4.5	5.4
10	6.8	4.8	14.6	5.4	4.6	5.6	5.6	4.5	4.8	4.3	4.4	5.3
11	6.6	4.8	11.8	7.6	4.4	4.4	4.9	4.5	4.9	4.4	4.4	5.1
12	6.4	4.8	9.8	6.8	4.4	4.9	4.9	4.5	7.2	6.7	4.4	5.0
13	6.4	4.8	9.0	6.4	4.4	8.3	4.9	5.8	5.5	6.1	4.4	5.0
14	6.2	4.8	8.8	6.0	4.8	6.0	6.1	6.1	5.1	5.9	4.4	5.0
15	5.8	4.8	8.2	5.8	5.0	5.2	10.6	5.5	4.9	5.3	4.3	4.9
16	5.8	4.8	8.2	5.6	4.8	4.8	7.9	5.4	4.6	4.9	4.3	4.9
17	6.0	4.8	9.0	5.4	4.8	4.6	5.9	5.3	4.7	4.4	4.3	5.0
18	6.2	4.8	9.2	5.4	4.8	4.4	4.9	4.6	5.1	4.4	4.3	5.0
19	6.4	4.8	8.6	5.2	4.8	4.4	4.6	4.4	5.2	4.9	4.3	5.0
20	6.4	4.8	9.4	5.2	4.6	4.4	4.6	4.5	5.1	7.4	4.3	5.75
21	5.8	4.8	14.8	5.2	4.6	4.1	4.6	4.5	4.9	7.0	4.3	18.65
22	5.6	4.8	10.4	5.0	4.6	4.3	4.6	4.5	4.6	6.9	4.3	12.6
23	5.4	4.8	8.8	5.0	4.4	6.3	5.9	4.4	4.6	6.1	4.3	10.5
24	5.2	4.8	8.2	5.0	4.4	7.4	12.1	4.4	4.5	5.1	4.3	7.5
25	5.4	4.8	8.0	4.8	4.2	7.5	7.9	16.0	4.4	4.7	4.3	6.9
26	6.2	5.0	8.0	4.8	4.2	6.9	6.9	18.8	4.4	5.6	4.3	6.5
27	5.8	5.6	7.6	4.8	4.2	6.5	5.1	12.5	4.3	5.7	4.3	5.9
28	5.6	5.6	6.8	5.8	4.2	5.1	4.9	6.4	4.2	5.3	4.3	5.7
29	5.6	......	6.4	5.2	4.2	4.9	4.8	5.7	4.2	4.8	7.4	10.65
30	5.6	......	6.4	5.0	4.2	4.6	7.6	5.4	4.2	4.8	8.5	8.7
31	5.6	......	6.2	......	4.2	......	6.9	5.3	......	4.7	......	6.7

[a] River frozen at the gage Jan. 4–22 and Feb. 15–22, 1904.

[b] From Jan. 27 to Feb. 28, 1905, the river was frozen entirely across except for a narrow channel in the middle. Gage heights are to the surface of the water in a hole in the ice. Thickness of ice about 1 foot.

Daily gage height, in feet, of Monocacy River near Frederick, Md.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1906. [a]												
1	6.2	4.9	5.3	9.7	5.4	4.7	4.5	4.5	5.5	4.3	5.6	4.5
2	5.7	4.8	5.5	7.8	5.4	4.7	4.5	9.1	5.2	4.3	5.5	4.5
3	7.5	4.5	9.1	7.4	5.3	4.6	4.5	16.1	5.1	4.3	5.3	4.5
4	18.35	4.5	16.65	6.9	5.3	4.5	5.3	10.1	4.9	4.8	5.2	4.5
5	12.6	5.1	9.1	6.5	5.2	4.4	5.1	5.5	4.9	7.1	5.1	4.5
6	7.6	5.0	6.9	6.3	5.3	4.4	4.6	5.3	4.8	6.1	5.0	4.7
7	6.7	4.9	6.5	6.2	5.3	4.4	4.6	5.1	4.7	5.8	4.9	4.8
8	6.6	4.8	6.4	6.1	5.3	4.4	4.5	4.9	4.6	4.9	4.8	4.8
9	6.2	5.2	6.3	7.5	5.2	4.4	4.5	4.8	4.6	4.7	4.8	4.7
10	5.9	5.1	6.1	16.8	5.0	5.5	4.4	4.8	4.5	4.6	4.8	5.9
11	5.7	5.0	5.9	9.1	5.0	5.1	4.4	6.1	4.4	4.5	4.8	6.8
12	6.9	4.9	5.8	8.5	4.9	4.5	4.9	5.1	4.4	4.4	4.7	6.4
13	6.7	4.8	5.8	7.1	4.9	4.5	4.5	6.1	4.4	4.3	4.7	5.3
14	6.2	5.9	5.8	6.9	4.9	4.4	4.4	4.8	4.4	4.3	4.7	5.2
15	6.5	8.1	5.8	21.8	4.7	4.4	4.4	4.7	4.4	4.3	4.8	5.2
16	7.1	5.4	5.8	15.5	4.8	4.5	4.4	4.6	4.4	4.3	4.8	7.6
17	6.9	4.9	5.7	10.2	4.8	4.6	4.5	4.6	4.4	4.3	4.8	9.8
18	6.2	4.8	5.7	8.1	4.7	7.1	4.5	4.5	4.4	4.3	4.9	12.1
19	5.9	5.0	5.6	7.5	4.7	9.7	4.4	8.5	4.4	9.5	5.2	8.5
20	5.7	5.0	5.6	7.1	4.5	9.5	4.4	7.5	4.4	13.2	5.5	6.5
21	5.7	5.4	5.5	6.7	4.5	10.5	4.3	6.5	4.8	9.5	5.1	9.5
22	5.7	9.4	5.5	6.4	4.5	10.7	4.4	5.4	4.6	11.5	5.0	7.5
23	5.6	6.5	5.5	6.3	4.5	6.7	4.8	7.35	4.4	8.5	4.9	6.9
24	5.6	6.1	5.6	6.1	4.5	6.1	5.1	6.5	4.4	7.5	4.8	5.8
25	5.6	6.7	5.6	5.9	4.4	5.9	4.8	7.5	4.4	8.5	4.7	5.7
26	5.5	6.9	5.5	5.8	4.5	5.8	4.6	7.8	4.3	8.1	4.6	5.6
27	5.5	5.9	9.0	5.7	4.5	5.1	4.4	11.0	4.3	7.5	4.6	7.8
28	5.55	6.1	17.45	5.5	5.6	4.9	4.35	9.8	4.3	6.7	4.6	6.9
29	5.3	....	12.5	5.4	5.1	4.8	4.5	7.5	4.3	6.2	4.5	5.8
30	5.2	....	10.5	5.4	4.8	4.7	4.3	6.1	4.3	5.8	4.5	5.7
31	5.1	....	9.6	....	4.7	....	4.3	5.8	....	5.7	....	8.4

[a] River frozen at the gage February 6–9, 1906.

Rating tables for Monocacy River near Frederick, Md.

AUGUST 4, 1896, TO DECEMBER 31, 1903.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
3.40	43	5.10	525	6.80	1,600	10.00	4,600
3.50	55	5.20	575	6.90	1,680	10.50	5,100
3.60	69	5.30	625	7.00	1,760	11.00	5,600
3.70	85	5.40	675	7.20	1,930	11.50	6,100
3.80	103	5.50	730	7.40	2,105	12.00	6,600
3.90	124	5.60	785	7.60	2,285	13.00	7,650
4.00	147	5.70	840	7.80	2,465	14.00	8,700
4.10	172	5.80	900	8.00	2,650	15.00	9,750
4.20	198	5.90	960	8.20	2,840	16.00	10,800
4.30	226	6.00	1,025	8.40	3,030	17.00	11,850
4.40	256	6.10	1,090	8.60	3,220	18.00	12,900
4.50	288	6.20	1,155	8.80	3,410	19.00	13,950
4.60	322	6.30	1,225	9.00	3,600	20.00	15,000
4.70	358	6.40	1,295	9.20	3,800	22.00	17,100
4.80	396	6.50	1,370	9.40	4,000	24.00	19,200
4.90	437	6.60	1,445	9.60	4,200	26.00	21,300
5.00	480	6.70	1,520	9.80	4,400		

[a] This table is strictly applicable only for open-channel conditions. It is based on discharge measurements made during 1896–1903. It is fairly well defined between gage heights 4.0 feet and 9.0 feet. Above gage height 12.0 feet the rating curve is a tangent, the difference being 105 per tenth

Rating tables for Monocacy River near Frederick, Md.—Continued.

JANUARY 1, 1904, TO DECEMBER 31,1906.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet*	*Second feet.*
3.80	80	5.30	584	6.80	1,545	9.60	4,100
3.90	99	5.40	632	6.90	1,625	9.80	4,300
4.00	120	5.50	682	7.00	1,705	10.00	4,500
4.10	144	5.60	734	7.20	1,875	10.50	5,000
4.20	170	5.70	789	7.40	2,045	11.00	5,500
4.30	198	5.80	846	7.60	2,220	11.50	6,000
4.40	228	5.90	906	7.80	2,400	12.00	6,500
4.50	260	6.00	969	8.00	2,580	13.00	7,550
4.60	294	6.10	1,034	8.20	2,765	14.00	8,600
4.70	330	6.20	1,102	8.40	2,955	15.00	9,650
4.80	368	6.30	1,172	8.60	3,145	16.00	10,700
4.90	408	6.40	1,242	8.80	3,335	17.00	11,750
5.00	450	6.50	1,315	9.00	3,525	18.00	12,800
5.10	493	6.60	1,390	9.20	3,715	19.00	13,850
5.20	538	6.70	1,465	9.40	3,905	20.00	14,900

[a] This table is strictly applicable only for open-channel conditions. It is based on discharge measurements made during 1904–1906. It is fairly well defined between gage heights 4.0 feet and 10.0 feet. Above gage height 12.0 feet the rating curve is a tangent, the difference being 105 per tenth.

Estimated monthly discharge of Monocacy River near Frederick, Md.

[Drainage area, 660 square miles.[a]]

Month	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1896.								
January							1.48	
February							5.83	
March							5.32	
April							1.43	
May							2.04	
June							4.31	
July							5.05	
August 4–31	256	69	125	.189	.197		[b] 1.44	
September	480	69	115	.174	.194	6	2.94	2.75
October	396	103	144	.218	.251	19	1.31	1.06
November	2,195	124	306	.464	.518	14	3.82	3.30
December	396	124	187	.283	.326	41	.81	.48
The year							35.78	
1897.								
January [c]	730	147	307	.465	.536	28	1.95	1.41
February [c]	9,750	256	2,062	3.12	3.25	63	5.16	1.91
March	4,400	575	1,384	2.10	2.42	84	2.88	.46
April	3,900	322	907	1.37	1.53	53	2.86	1.33
May	10,380	322	1,650	2.50	2.88	50	5.73	2.85
June	2,195	198	492	.745	.831	27	3.10	2.27
July [d]	4,500	198	710	1.08	1.24	18	6.81	5.57
August [d]	11,010	172	968	1.47	1.70	46	3.70	2.00
September [d]	812	114	191	.289	.322	15	2.12	1.80
October [d]	241	94	137	.208	.240	12	1.96	1.72
November [d]	9,592	185	1,008	1.53	1.71	26	6.53	4.82
December [d]	9,330	550	1,980	3.00	3.46	99	3.48	.02
The year	11,010	94	983	1.49	20.12	43	46.28	26.16

[a] 660 squares miles used for all years except 1904 and 1905, when 665 was used.
[b] Precipitation for complete month August, 1896.
[c] River frozen at the gage January 25 to February 2, 1897; no correction made in estimates.
[d] Estimates July 3 to December 31, 1897, liable to some error owing to uncertainty of wire length during that period.

Estimated monthly discharge of Monocacy River near Frederick, Md.—Continued.

Month	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Means.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1898.								
January	7,020	416	2,099	3.18	3.67	95	3.86	0.19
February [a]	9,540	480	1,479	2.24	2.33	146	1.60	− .73
March	5,350	437	1,319	2.00	2.31	59	3.94	1.63
April	1,845	396	692	1.05	1.17	45	2.61	1.44
May	8,070	322	1,575	2.39	2.76	38	7.34	4.58
June	730	256	408	.618	.690	58	1.18	.49
July	675	124	223	.338	.390	12	3.14	2.75
August	7,020	147	926	1.40	1.61	24	6.75	5.14
September	198	103	128	.194	.216	15	1.46	1.24
October	6,150	103	693	1.05	1.21	20	5.97	4.76
November	6,968	256	1,132	1.72	1.92	43	4.42	2.50
December	12,850	480	1,943	2.94	3.39	81	4.17	.78
The year	12,850	103	1,051	1.59	21.67	47	46.44	24.77
1899.								
January [b]	9,592	480	1,971	2.99	3.45	109	3.16	− .29
February [b]	12,690	575	2,939	4.45	4.63	88	5.27	.64
March	12,060	1,370	3,428	5.19	5.98	115	5.19	− .79
April	7,230	396	1,179	1.79	2.00	115	1.74	− .26
May	2,375	322	680	1.03	1.19	25	4.74	3.55
June	5,700	198	759	1.15	1.28	41	3.09	1.81
July	288	124	196	.297	.342	11	3.17	2.83
August	525	103	208	.315	.363	9	4.02	3.66
September	1,025	85	309	.468	.522	10	5.18	4.66
October	480	103	133	.202	.233	9	2.64	2.41
November	2,015	172	401	.608	.678	30	2.23	1.55
December [b]	1,845	124	449	.680	.784	33	2.35	1.57
The year	12,690	85	1,054	1.59	21.44	50	42.78	21.34
1900.								
January [c]	4,800	288	1,030	1.56	1.80	81	2.22	.42
February [c]	15,840	525	2,641	4.00	4.16	73	5.69	1.53
March	8,175	675	2,188	3.32	3.83	111	3.44	− .39
April	1,295	358	576	.873	.974	68	1.43	.46
May	1,760	226	438	.664	.766	41	1.89	1.12
June	1,025	147	294	.445	.496	11	4.51	4.01
July	702	69	154	.233	.269	8	3.34	3.07
August	702	49	150	.227	.262	8	3.16	2.90
September [d]	147	55	82.1	.124	.138	6	2.31	2.17
October	172	85	102	.155	.179	7	2.59	2.41
November	3,800	85	454	.688	.768	21	3.64	2.87
December	6,705	124	520	.788	.908	30	3.02	2.11
The year	15,840	49	719	1.09	14.56	39	37.24	22.68
1901.								
January	2,285	147	438	.664	.766	27	2.82	2.05
February	525	226	329	.498	.519	69	.75	.23
March	15,530	256	2,167	3.28	3.78	69	5.48	1.70
April	12,900	675	2,742	4.15	4.63	72	6.47	1.84
May	6,100	396	1,521	2.30	2.65	49	5.36	2.71
June	2,650	288	839	1.27	1.42	33	4.26	2.84
July	730	172	316	.479	.552	11	5.04	4.49
August	1,845	147	445	.674	.777	13	6.22	5.44
September	1,520	172	296	.448	.500	13	3.77	3.27
October	575	172	268	.406	.468	34	1.38	.91
November	4,000	198	480	.727	.811	31	2.59	1.78
December	14,740	358	2,313	3.50	4.04	52	7.76	3.72
The year	15,530	147	1,013	1.53	20.92	40	51.90	30.98

[a] River frozen February 2–9, 1898; no correction made in estimates.
[b] River frozen at the gage January 2, February 9–21, and December 28–31, 1899; no correction made in the estimates.
[c] River frozen at the gage January 1–6 and February 1–4, 1900; no correction made in the estimates.
[d] Discharge interpolated September 29, 1900.

Estimated monthly discharge of Monocacy River near Frederick, Md.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Means.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1902.								
January	12,950	437	1,924	2.92	3.37	93	3.61	0.24
February [a]	19,200	960	3,902	5.91	6.15	127	4.85	−1.30
March	20,460	785	4,677	7.09	8.17	173	4.72	−3.45
April	12,800	480	2,261	3.43	3.83	134	2.85	− .98
May	575	226	339	.514	.593	55	1.08	.49
June	1,845	147	323	.489	.546	12	4.44	3.89
July	1,680	124	335	.508	.586	16	3.74	3.15
August	575	69	143	.217	.250	15	1.67	1.42
September	3,700	55	232	.352	.393	9	4.52	4.13
October	8,385	172	1,157	1.75	2.02	28	7.20	5.18
November	4,000	198	552	.836	.933	28	3.28	2.35
December	11,960	730	3,981	6.03	6.95	110	6.33	− .62
The year	20,460	55	1,652	2.50	33.79	70	48.29	14.50
1903.								
January [b]	10,590	730	3,319	5.03	5.80	123	4.72	−1.08
February	16,260	1,155	3,124	4.73	4.92	85	5.78	.86
March	16,470	900	3,400	5.15	5.94	105	5.66	− .28
April	16,680	840	3,532	5.35	5.97	105	5.69	− .28
May	9,540	358	898	1.36	1.57	42	3.78	2.21
June	16,260	437	1,806	2.74	3.06	35	8.68	5.62
July	13,740	525	2,342	3.55	4.09	76	5.36	1.27
August	6,705	288	1,063	1.61	1.86	28	6.74	4.88
September	5,700	256	795	1.20	1.34	47	2.84	1.50
October	1,930	226	477	.723	.834	26	3.16	2.33
November	437	198	239	.362	.404	40	.99	.59
December	6,652	172	540	.818	.943	42	2.26	1.32
The year	16,680	172	1,795	2.72	36.72	66	55.66	18.94
1904.								
January [c]	14,800	260	1,069	1.61	1.86	54	3.46	1.60
February [c]	8,758	294	1,502	2.26	2.44	122	2.00	− .44
March	11,960	538	1,812	2.72	3.14	97	3.23	.09
April	2,400	294	729	1.10	1.23	56	2.21	.98
May	789	198	375	.561	.647	22	2.98	2.33
June	4,300	144	817	1.23	1.37	29	4.80	3.43
July	2,765	120	586	.881	1.02	17	5.88	4.86
August	7,130	80	436	.656	.756	18	4.32	3.56
September	734	80	251	.377	.421	17	2.49	2.07
October	969	80	209	.314	.362	17	2.12	1.76
November	228	120	138	.208	.232	17	1.37	1.14
December	3,905	120	549	826	.952	36	2.63	1.68
The year	14,800	80	706	1.06	14.43	38	37.49	23.06
1905.								
January [d]	12,170	538	1,503	2.26	2.61	63	4.15	1.54
February [d]	734	368	409	.615	.640	35	1.83	1.19
March	9,440	538	3,056	4.60	5.30	129	4.11	−1.19
April	2,220	368	790	1.19	1.33	49	2.71	1.38
May	450	170	279	.420	.484	26	1.84	1.36
June	2,860	144	748	1.12	1.25	21	5.88	4.63
July	6,605	260	1,296	1.95	2.25	27	8.32	6.07
August	13,640	228	1,427	2.15	2.48	46	5.40	2.92
September	2,130	170	546	.821	.916	29	3.17	2.25
October	2,045	144	583	.877	1.01	23	4.39	3.38
November	3,050	198	390	.586	.654	32	2.00	1.35
December	13,480	468	2,124	3.19	.368	77	4.75	1.07
The year	13,640	144	1,096	1.65	22.60	47	48.55	25.95

[a] River frozen at the gage February 4–19, 1902; no correction made in the estimates.
[b] River frozen at the gage January 12–20, 1903; no correction made in the estimates.
[c] River frozen January 4–22 and February 15–22, 1904; no correction made in the estimates.
[d] River frozen January 27 to February 28, 1905; no correction made in the estimates.

Estimated monthly discharge of Monocacy River near Frederick, Md.—Continued.

Month.	Discharge in second-feet.			Run-off.			Precipitation.	
	Maximum.	Minimum.	Means.	Second-feet per square mile.	Depth in inches.	Per cent of precipitation.	In inches.	Loss in inches.
1906.								
January	13,170	493	1,657	2.51	2.89			
February[a]	3,905	260	824	1.25	1.30			
March	12,220	584	2,275	3.45	3.98			
April	16,790	632	2,877	4.36	4.86			
May	734	228	422	.639	.737			
June	5,200	228	1,037	1.57	1.75			
July	584	198	284	.430	.496			
August	10,800	260	1,776	2.70	3.11			
September	682	198	290	.439	.490			
October	7,760	198	1,494	2.25	2.59			
November	734	260	418	.633	.706			
December	6,605	260	1,428	2.17	2.50			
The year	16,790	198	1,232	1.87	25.41			

[a] River frozen at the gage February 6–9, 1906; no correction made in the estimates.

The following table gives the horsepower, 80 per cent efficiency per foot of fall, that may be developed at different rates of discharge, and shows the number of days on which the flow and the corresponding horsepower were respectively less than the amounts given in the columns for "discharge" and "horsepower."

Discharge and horsepower table for Monacacy River near Frederick, Md., from 1896 to 1906.

Discharge in second-feet.	Horsepower, 80 per cent efficiency, per foot fall.	Days of deficient flow.										
		1896.[a]	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.
55	5					4						
66	6					16		10				
88	8	16			4	63		22		21		
110	10	32	6	22	29	89		29		27		
132	12	74	19	37	56	119		38		78		
154	14	98	45	48	75	142	1	48		85	2	
176	16	114	56	58	100	163	25	72	4	123	17	
198	18	115	63	59	100	165	25	72	4	123	17	
220	20	128	86	68	118	174	74	94	15	129	36	18
275	25	136	115	99	149	196	131	115	56	152	78	82
330	30	142	130	116	163	213	155	147	78	187	106	96
385	35	142	149	123	169	224	165	152	94	216	151	138
440	40	145	171	138	187	244	204	170	128	240	169	154
495	45	147	192	157	206	254	216	176	130	259	195	175
550	50	147	199	169	213	265	229	185	138	269	205	184
660	60	148	222	206	231	275	243	207	154	285	220	202
770	70	149	243	234	243	299	264	217	173	297	237	226

[a] August 4 to December 31, 1896.

NOTE.—The minimum flow during the period covered by the above table was 49 second-feet, giving 4.5 horsepower per foot of fall for four consecutive days during August, 1900.

POTOMAC RIVER AT GREAT FALLS, MD., AND AT CHAIN BRIDGE, D. C.

Estimates of the flow of Potomac River at Chain Bridge and at Great Falls are not considered sufficiently accurate for republication owing to poor conditions at the Chain Bridge section and the effect on the flow of the river of a daily range of tide of about 3 feet. Estimates at Great Falls, as previously published, were based on the discharge at Chain Bridge, and hence are subject to the same errors. The flood discharges as determined at these two stations are probably accurate enough for all practical purposes, but for medium and low stages the estimates are considered too high and likely to be very misleading if used.

ROCK CREEK AT LYON'S MILL AND ZOOLOGICAL PARK, D. C.

Rock Creek rises south of Laytonsville, in the central part of Montgomery County, Md., and flows southward into Potomac River at Washington, D. C. The total drainage area at the mouth is 86 square miles.

A study of the discharge of Rock Creek was begun in July, 1892, at the request of the Commissioners of the District of Columbia. August 18, 1892, a self-registering gage was placed at Lyon's Mill Road Bridge, at the east corner of Oak Hill Cemetery, Georgetown, by C. C. Babb. The gage-height record was continued until November 30, 1894.

January 18, 1897, a new station was established by E. G. Paul at the Park Bridge, near the eastern entrance of the National Zoological Park, Washington, D. C. The staff gage was above and within the influence of a dam. Measurements were made at various cross sections. The bridge was rebuilt and the gage destroyed in November, 1900.

The estimated discharge of Rock Creek at Lyon's mill, which is published below for the first time, is probably within 5 per cent of the true discharge above gage height, −0.3 foot. Below gage height, −0.3 foot, the probable error may vary from 5 to 15 per cent. The effect of ice conditions is not known.

No estimates are possible for Rock Creek at Zoological Park, owing to the insufficient range of stage at which measurements were made.

Discharge measurements of Rock Creek, at Lyon's mill, Washington, D. C.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1892.	*Feet.*	*Second-feet.*	1893.	*Feet.*	*Second-feet.*
July 28	0.00	89	April 11	−.12	58
August 2	−.30	49	May 4	4.14	959
August 3	−.30	48			
August 5	.19	102	1894.		
			May 7	1.10	220

Discharge measurements of Rock Creek referred to Zoological Park Bridge gage, District of Columbia.

Date.	Gage height.	Discharge.	Date.	Gage height.	Discharge.
1897.	*Feet.*	*Second-feet.*	1900.	*Feet.*	*Second-feet.*
August 18[a]	2.90	26	April 24[d]	2.75	77
November 21[b]	3.00	37			
1898.			1902.		
January 28[c]	3.23	89	February 27[d]	....	1,810
May 18[c]	3.20	95			

[a] Measured at Woodley Bridge.
[b] Measured at Klingle Ford.
[c] Measured at Lyon's mill.
[d] Measured at Rustic Bridge.

Daily gage height, in feet, of Rock Creek at Lyon's mill, Washington, D. C.

Day.	Aug.	Sept.	Oct.	Nov.	Dec.
1892.					
1	......	−0.65	−0.68	−0.68	−0.40
2	......	− .69	− .70	− .70	− .52
3	......	− .66	− .72	− .64	− .55
4	......	− .62	− .72	− .61	− .56
5	......	− .71	− .72	− .68	− .54
6	......	− .68	− .71	− .66	− .53
7	......	− .67	− .70	− .65	− .53
8	......	− .72	− .68	− .65	− .50
9	......	− .71	− .58	− .30	− .52
10	......	− .71	− .65	− .15	− .53
11	......	− .72	− .70	− .25	− .61
12	......	− .72	− .70	− .51	− .61
13	......	− .72	− .71	− .45	− .60
14	......	− .10	− .72	− .54	+ .30
15	......	.00	− .70	− .44	+ .50
16	......	− .58	− .62	− .44	− .20
17	......	− .65	− .68	− .42	− .20
18	−0.58	− .72	− .65	− .55	− .21
19	− .60	− .72	− .58	+ .22	− .30
20	− .60	− .72	− .68	− .33	− .11
21	− .63	− .70	− .63	− .52	− .05
22	− .63	− .55	− .62	− .52	− .30
23	− .62	+ .50	− .62	− .60	− .69
24	− .62	.00	− .62	− .59	− .30
25	− .58	− .58	− .70	− .61	− .51
26	− .61	− .60	− .65	− .61	− .31
27	− .66	− .62	− .65	− .61	− .52
28	− .61	− .66	− .66	− .55	− .52
29	− .68	− .65	− .65	− .51	− .52
30	− .68	− .68	− .66	− .46	− .61
31	− .63	....	− .68	....	− .58

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1893.												
1	+1.00	− .21	+1.38	−0.27	+0.10	−0.30	−0.42	−0.75	−0.70	−0.87	−0.65	−0.20
2	+1.22	− .12	+ .54	− .30	− .10	− .22	− .47	− .76	− .66	− .88	− .65	− .32
3	− .17	− .15	+ .22	− .35	− .20	− .13	− .50	− .80	− .80	− .90	.65	+ .30
4	− .20	+ .03	+ .18	− .30	+4.20	− .17	+1.00	− .79	− .82	− .80	− .62	+ .95
5	− .29	− .31	.00	− .30	+ .75	+ .20	+ .16	− .76	− .91	− .70	− .64	− .05
6	− .20	− .32	− .01	− .32	+ .52	− .25	− .52	− .79	− .92	− .72	− .68	− .54
7	− .41	− .22	.00	− .32	+ .20	− .35	− .55	− .80	− .90	− .75	− .66	− .05
8	− .59	.00	− .02	− .30	+ .05	− .25	− .60	− .85	− .93	− .80	− .66	− .05
9	− .40	− .44	+ .40	− .30	.00	− .46	.00	− .85	−1.00	− .81	+1.65	− .20
10	− .28	− .02	+ .50	− .30	+ .10	− .45	− .48	− .86	− .99	− .82	+ .05	− .26
11	− .20	+ .25	+ .08	− .20	− .12	− .50	− .55	− .88	− .97	− .90	− .37	− .29
12	− .41	+ .20	+ .22	− .28	− .12	− .52	− .60	− .90	− .66	− .90	− .38	− .26
13	− .41	+2.00	+ .34	− .08	− .15	− .45	− .60	− .90	− .74	− .90	− .45	− .26
14	− .35	+1.30	.00	− .18	.00	− .50	− .61	− .95	+ .10	+2.20	− .50	− .34
15	− .35	+ .95	.00	− .09	− .15	− .51	+2.20	−1.00	− .56	− .20	.00	− .45
16	− .10	+ .35	− .10	− .09	− .15	− .51	− .18	−1.00	− .50	− .50	− .27	− .46
17	− .32	+ .12	− .10	− .36	+ .40	− .52	− .40	−1.00	− .60	− .75	− .34	+ .46
18	− .32	.00	− .06	− .22	.00	− .51	− .34	− .90	− .62	− .62	− .40	− .32
19	− .32	− .04	− .06	− .26	− .05	− .51	− .45	−1.00	− .68	− .70	− .45	− .27
20	− .33	− .12	− .10	− .27	− .10	− .51	− .53	−1.05	− .85	− .75	− .50	− .34
21	− .38	− .32	− .10	+ .40	− .10	− .54	− .57	− .96	− .90	− .76	− .40	− .36
22	− .38	− .09	− .10	.00	− .05	− .55	− .61	−1.08	− .80	− .75	+ .25	− .40
23	− .38	− .46	− .11	+ .18	− .07	− .55	− .65	− .88	− .90	+ .30	− .30	− .37
24	− .36	− .12	− .06	− .05	− .12	+ .47	− .67	−1.00	− .90	− .40	− .34	− .38
25	− .36	− .09	− .06	− .22	− .15	− .32	− .69	−1.05	− .92	− .54	− .35	− .39
26	− .21	+ .15	− .05	− .21	− .20	− .37	− .70	−1.09	− .94	− .61	− .36	− .40
27	+ .15	+ .10	− .08	+ .20	− .20	− .35	− .65	− .92	− .85	− .61	− .35	− .38
28	+ .23	.00	− .08	+ .20	− .12	− .39	− .71	− .94	− .85	− .60	+ .85	− .40
29	+ .15	....	− .08	.00	− .12	− .40	− .71	+1.36	− .80	− .60	.00	− .36
30	+ .15	....	− .08	+ .10	− .15	− .45	− .72	− .50	− .80	− .60	− .15	− .28
31	− .15	....	− .20	....	− .02	....	− .74	− .80	....	− .60	....	− .25

Daily gage height, in feet, of Rock Creek at Lyon's mill, Washington, D. C.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1894.												
1	−0.22	−0.14	−0.20	−0.24	−0.45	−0.40	......	......	......	−0.60	−0.10	......
2	− .32	− .14	− .12	− .24	− .41	− .41	......	......	−0.85	− .60	− .50	......
3	− .34	− .28	+1.00	− .26	− .39	− .44	......	......	− .80	− .50	− .10	......
4	− .31	− .30	+ .62	− .25	− .34	− .50	......	......	− .80	− .60	.00	......
5	− .33	− .36	+ .12	− .30	− .20	− .51	......	......	− .82	− .40	− .45	......
6	− .30	− .30	+ .04	− .36	+ .21	− .51	......	......	− .85	− .50	− .50	......
7	− .31	− .30	+ .05	− .36	+ .60	− .52	......	......	− .85	− .60	− .55	......
8	− .33	− .31	− .05	− .28	+ .03	− .55	......	......	− .80	− .70	− .60	......
9	− .31	− .32	− .12	− .28	− .20	− .64	− .85	......	− .70	− .80	− .30	......
10	− .33	− .30	− .21	− .18	− .26	− .64	− .92	......	− .60	− .50	− 45	......
11	− .33	− .27	− .20	+1.18	− .28	− .66	− .92	......	− .55	− .20	− .50	......
12	− .28	− .28	− .20	+ .69	− .28	− .68	......	......	− .65	− .60	− .60	......
13	− .31	− .32	− .22	+ .65	− .29	− .69	......	......	− .70	− .70	− .60	......
14	− .24	− .34	− .25	+ .21	− .31	− .71	......	......	− .65	− .70	− .65	......
15	− .24	− .20	− .24	.00	− .31	− .73	......	......	− .65	− .70	− .70	......
16	− .24	.00	− .24	− .07	− .32	......	......	......	− .65	− .70	− .70	......
17	− .25	+ .12	− .22	− .11	− .48	......	......	......	− .65	− .70	− .70	......
18	− .26	+ .42	− .23	− .15	− .32	......	......	......	− .70	− .70	− .70	......
19	− .29	+ .65	− .23	− .18	− .28	......	......	......	− .70	− .70	− .65	......
20	− .30	.00	− .23	− .19	+ .65	......	......	−1.10	− .70	− .75	− .70	......
21	− .26	− .12	− .21	− .22	+ .23	......	......	−1.10	− .70	− .80	− .70	......
22	− .24	− .20	− .20	− .25	− .10	......	......	−1.10	− .70	− .80	− .70	......
23	− .20	− .20	− .18	− .30	− .27	......	......	−1.00	......	− .75	− .70	......
24	− .21	− .20	− .20	− .33	− .30	......	......	−1.10	......	− .75	− .70	......
25	− .20	− .20	− .20	− .37	− .33	......	......	−1.20	......	− .75	− .70	......
26	− .20	− .20	− .17	− .31	− .30	......	......	−1.25	......	− .75	− .70	......
27	− .20	− .26	− .20	− .39	− .30	......	......	− .90	......	− .75	− .65	......
28	− .21	− .20	− .20	− .34	− .32	......	......	−1.20	......	− .75	− .70	......
29	− .16	......	− .22	− .40	− .36	......	......	−1.10	......	− .72	− .70	......
30	+1.00	......	− .21	− .42	− .36	......	......	......	......	− .70	− .70	......
31	.00	......	− .22	......	− .36	......	......	......	......	− .70	......	......

Daily gage height, in feet, of Rock Creek at Zoological Park, D. C.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897.												
1	......	2.9	2.35	2.3	2.3	2.3	3.1	3.05	2.85	2.8	3.1	3.05
2	......	3.5	2.35	2.25	2.4	2.5	3.1	3.0	2.85	2.85	3.5	3.05
3	......	4.15	2.35	2.25	2.45	2.65	3.1	3.0	2.85	2.85	3.3	3.05
4	......	3.45	2.4	2.25	2.55	2.95	3.05	2.95	2.85	2.85	3.1	3.25
5	......	3.15	2.35	2.5	2.5	3.15	3.05	2.95	2.85	2.85	3.05	3.9
6	......	3.25	2.35	2.65	2.35	3.1	3.05	3.0	2.85	2.85	3.0	3.35
7	......	4.25	2.4	2.45	2.3	3.25	3.05	2.95	2.8	2.85	2.95	3.2
8	......	2.7	2.35	2.4	2.2	3.4	3.6	2.95	2.8	2.85	3.0	3.15
9	......	2.45	2.35	3.15	2.2	3.45	3.15	2.95	2.8	2.85	3.2	3.1
10	......	2.4	2.35	2.9	2.15	3.4	3.1	2.95	2.8	2.85	3.35	3.1
11	......	2.3	2.3	2.6	2.2	3.4	3.1	3.0	2.8	2.85	3.1	3.1
12	......	2.45	2.3	2.5	2.5	3.35	3.25	3.0	2.8	3.15	3.05	3.1
13	......	2.6	2.35	2.45	3.7	3.35	3.3	2.95	2.8	2.85	3.05	3.1
14	......	2.6	2.45	2.45	2.65	3.35	3.3	2.9	2.8	2.85	3.0	3.25
15	......	2.7	2.6	2.4	2.95	3.35	3.1	2.9	2.8	2.85	3.05	4.3
16	......	2.45	2.4	2.45	2.6	3.35	3.0	2.95	2.8	2.85	3.1	3.35
17	......	2.35	2.35	2.45	2.5	3.35	3.1	3.0	2.8	2.85	3.05	3.2
18	3.0	2.3	2.95	2.4	2.4	3.35	3.1	2.9	2.9	2.9	3.05	3.15
19	2.95	2.3	2.85	2.35	2.4	3.2	3.45	2.9	2.85	2.9	3.05	3.1
20	2.9	2.25	3.05	2.3	2.35	3.3	3.25	2.9	2.8	3.0	3.05	3.1
21	3.15	2.4	2.9	2.3	2.3	3.25	3.25	2.9	2.8	3.0	3.0	3.15
22	3.3	3.75	2.65	2.3	2.3	3.15	4.0	2.9	2.8	2.95	3.0	3.2
23	3.35	4.1	2.55	2.3	2.25	3.15	3.4	2.9	2.9	2.95	3.05	3.2
24	3.05	2.9	2.5	2.3	2.6	3.15	3.1	2.95	3.2	3.0	3.05	3.3
25	2.85	2.6	2.55	2.3	3.45	3.25	3.05	2.9	2.9	3.1	3.0	3.05
26	3.0	2.5	2.4	2.25	2.55	3.15	3.0	2.9	2.8	3.1	3.05	3.1
27	2.9	2.45	2.4	2.25	2.4	3.1	3.45	2.9	2.8	3.0	3.95	3.1
28	2.9	2.45	2.35	2.2	2.35	3.1	4.3	2.85	2.8	2.95	3.3	3.05
29	2.95	......	2.3	2.25	2.3	3.1	3.1	2.85	2.8	2.9	3.15	3.0
30	2.9	......	2.3	2.25	2.3	3.1	3.1	2.85	2.8	2.9	3.1	3.1
31	2.9	......	2.3	......	2.25	......	3.1	2.85	......	2.9	......	3.1

Daily gage height, in feet, of Rock Creek at Zoological Park, D. C.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1898.												
1	3.1	3.15	3.1	3.3	3.5	2.95	2.85	2.8	2.45	2.3	2.8	2.95
2	2.95	3.15	3.1	3.2	3.5	2.95	2.8	2.8	2.4	2.35	2.65	2.8
3	3.1	3.1	3.1	3.2	3.5	2.95	2.8	2.8	2.4	2.35	2.6	2.8
4	3.05	3.1	3.15	3.1	3.0	2.9	2.8	2.8	2.4	2.4	2.6	3.15
5	3.05	3.05	3.15	3.2	3.5	2.9	2.85	3.9	2.4	2.4	2.6	4.45
6	3.0	3.05	3.1	3.15	3.2	2.9	2.85	2.85	2.4	2.4	2.65	3.15
7	3.05	3.05	3.1	3.1	3.95	2.9	2.8	2.8	2.4	2.4	2.65	3.0
8	3.05	3.05	3.1	3.1	3.4	2.9	2.8	2.8	2.35	2.35	2.6	2.9
9	3.05	3.1	3.05	3.1	3.3	2.9	2.8	2.9	2.35	2.35	2.6	2.85
10	3.9	3.1	3.05	3.1	3.0	2.9	2.8	3.45	2.35	2.35	2.65	2.85
11	3.35	3.1	3.05	3.05	3.0	2.9	2.8	3.7	2.35	2.35	3.4	2.75
12	3.2	3.1	3.05	3.15	3.15	2.9	2.75	4.0	2.3	2.4	3.85	2.8
13	3.3	3.1	3.05	3.15	3.15	2.9	2.75	4.15	2.3	2.4	2.7	2.85
14	3.2	3.05	3.05	3.15	3.15	3.2	2.75	3.95	2.3	2.45	2.65	2.8
15	3.4	3.05	3.05	3.15	3.1	2.9	2.8	2.75	2.3	2.4	2.65	2.8
16	4.1	3.05	3.05	3.1	3.1	2.85	2.8	2.8	2.3	2.45	2.65	2.8
17	3.3	3.0	3.25	3.1	3.9	2.85	2.75	2.55	2.3	2.45	2.8	2.75
18	3.25	3.05	3.2	3.1	3.1	2.85	2.75	2.55	2.3	2.4	3.25	2.75
19	3.15	3.25	3.1	3.6	3.1	2.9	2.95	3.15	2.3	2.9	4.05	2.8
20	3.2	3.5	3.1	3.2	3.1	2.85	2.9	2.75	2.3	2.75	3.1	3.35
21	3.35	3.75	3.05	3.3	3.3	2.85	2.9	2.75	2.25	2.6	2.85	3.35
22	3.2	3.4	3.05	3.3	3.5	2.85	2.8	2.7	2.3	2.75	2.8	2.9
23	3.25	3.25	3.05	3.3	3.5	2.8	2.75	2.6	2.45	2.9	2.8	3.6
24	3.3	3.2	3.1	3.1	3.5	2.8	2.75	2.6	2.6	2.7	2.8	3.05
25	3.15	3.15	3.5	3.15	3.65	2.8	2.75	2.55	2.35	2.65	2.75	2.9
26	3.65	3.1	3.2	3.1	3.5	2.8	2.75	2.55	2.35	2.55	2.8	2.8
27	3.4	3.1	3.1	3.65	3.5	2.8	3.1	2.5	2.3	2.6	2.75	2.8
28	3.25	3.1	3.1	3.1	3.0	3.1	3.1	2.5	2.3	2.6	2.75	2.8
29	3.15	....	3.15	3.1	3.0	2.95	3.0	2.5	2.3	2.6	2.8	2.7
30	3.15	....	3.95	3.1	2.95	2.9	2.8	2.5	2.3	2.85	2.85	2.75
31	3.15	....	3.45	....	2.95	....	2.8	2.45	....	2.95	....	2.85
1899.												
1	3.05	2.78	3.3	3.0	2.75	2.88	2.4	2.35	2.4	2.58	3.65	2.53
2	2.75	2.88	3.23	2.93	2.7	2.68	2.4	2.35	2.4	2.5	2.83	2.58
3	2.88	2.88	3.13	2.9	2.73	2.63	2.35	3.9	2.4	2.5	2.8	2.53
4	2.9	2.95	3.1	2.9	2.7	2.6	2.35	3.2	2.4	2.5	3.1	2.5
5	3.33	3.13	4.5	2.9	2.7	2.55	2.6	2.65	2.38	2.5	2.8	2.5
6	3.65	3.0	3.4	2.9	2.7	2.55	2.58	2.9	2.3	2.75	2.7	2.5
7	4.25	3.0	3.18	2.95	2.75	2.55	2.7	2.55	2.3	2.7	2.63	2.5
8	3.23	2.93	3.1	3.8	2.75	2.55	2.5	2.5	2.3	2.58	2.6	2.5
9	3.05	2.63	3.1	3.08	3.23	2.5	2.78	2.48	2.3	2.6	2.6	2.5
10	3.0	2.93	3.08	3.0	2.83	3.63	2.48	2.53	2.3	2.58	2.6	2.5
11	3.0	2.78	3.23	2.9	2.83	2.98	2.43	2.5	2.4	2.55	2.6	2.5
12	3.1	2.78	3.18	2.9	2.98	2.73	2.4	2.48	2.43	2.5	2.58	2.78
13	2.9	2.78	3.13	2.9	2.78	2.65	2.5	2.45	2.3	2.5	2.55	2.75
14	3.0	2.78	3.0	2,9	2.73	2.63	2.7	2.75	2.3	2.5	2.55	2.63
15	3.0	2.95	3.1	2.85	2.7	2.55	2.45	2.5	2.3	2.5	2.55	2.53
16	3.0	2.95	3.3	3.05	2.68	2.5	2.45	2.7	2.25	2.5	2.55	2.5
17	3.1	4.0	3.0	3.0	2.73	2.5	2.9	2.5	2.25	2.5	2.55	2.5
18	3.08	4.25	3.05	2.9	3.25	2.5	2.58	2.45	2.3	2.5	2.55	2.55
19	2.98	4.43	3.9	2.85	2.95	2.5	2.45	2.43	2.43	2.5	2.58	2.6
20	2.93	4.05	3.33	2.85	2.78	2.5	2.4	2.4	3.0	2.5	2.55	2.6
21	3.13	3.88	3.1	2.8	2.7	2.48	2.4	2.4	2.63	2.5	2.55	2.6
22	2.85	4.18	3.18	2.8	2.7	2.45	2.4	2.73	2.55	2.45	2.55	2.55
23	2.85	4.1	3.18	2.8	2.68	2.45	2.4	2.45	2.4	2.45	2.6	2.5
24	2.85	3.5	3.03	2.8	2.65	2.45	2.4	2.35	2.35	2.48	2.63	2.93
25	3.68	3.2	3.0	2.8	2.6	2.48	2.4	2.3	2.65	2.45	2.6	2.95
26	3.08	3.15	3.0	2.8	2.6	2.53	2.5	2.3	5.25	2.45	2.6	2.68
27	3.0	3.7	3.0	2.83	2.6	2.5	2.5	2.55	3.75	2.5	2.55	2.53
28	2.88	3.33	3.23	2.78	2.6	2.48	2.4	2.75	2.85	2.5	2.55	2.6
29	2.85	....	3.45	2.75	2.65	2.45	2.4	2.48	2.6	2.5	2.55	2.53
30	2.83	....	3.15	2.75	2.6	2.43	2.4	2.4	2.6	2.5	2.55	2.53
31	2.85	....	3.03	....	2.6	....	2.38	2.4	....	2.63	....	2.5

Daily gage height, in feet, of Rock Creek at Zoological Park, D. C.—Continued.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900.												
1	2.45	2.43	3.3	2.75	2.6	2.45	2.35	2.35	2.15	2.4	2.1	......
2	2.43	2.43	3.25	2.7	2.6	2.73	2.35	2.28	2.13	2.3	2.15	......
3	2.43	2.38	2.88	2.7	2.6	2.6	2.35	2.3	2.1	2.2	2.15	......
4	2.4	2.4	2.78	2.7	2.6	2.55	2.4	2.28	2.1	2.2	2.28	......
5	2.38	3.03	2.75	2.68	2.6	2.5	2.38	2.25	2.1	2.2	2.35	......
6	2.4	2.6	2.8	2.65	2.55	2.45	2.38	2.25	2.1	2.2	2.28	......
7	2.4	2.53	2.85	2.65	2.55	2.45	2.38	2.23	2.1	2.15	2.25	......
8	2.4	2.83	2.73	2.65	2.55	2.58	2.35	2.2	2.1	2.25	2.4	......
9	2.4	2.95	2.7	2.63	2.6	2.45	2.33	2.2	2.1	2.25	2.48	......
10	2.4	2.68	2.68	2.6	2.63	2.45	2.3	2.2	2.1	2.2	2.43	......
11	2.43	2.6	2.65	2.6	2.58	2.4	2.3	2.2	2.1	2.2	......	......
12	3.6	2.68	2.7	2.8	2.55	2.35	2.3	2.15	2.1	2.2	......	......
13	3.03	3.88	2.7	2.75	2.53	2.45	2.3	2.18	2.1	2.23	......	......
14	2.88	3.0	2.7	2.68	2.5	2.48	2.3	2.15	2.1	2.35	......	......
15	2.58	2.8	2.68	2.65	2.5	2.68	2.3	2.15	2.13	2.35	......	......
16	2.53	2.75	2.7	2.65	2.5	2.65	2.3	2.15	2.65	2.3	......	......
17	2.8	2.7	2.78	2.7	2.5	4.3	2.3	2.15	2.4	2.25	......	......
18	2.8	2.7	2.8	2.7	2.5	3.45	2.3	2.15	2.2	2.2	......	......
19	2.83	2.7	2.8	3.1	2.9	2.78	2.3	2.1	2.17	2.2	......	......
20	3.08	2.78	3.75	2.8	2.73	2.7	2.4	2.1	2.15	2.2	......	......
21	3.13	2.73	3.18	2.73	2.55	2.58	2.4	2.18	2.15	2.2	......	......
22	2.88	5.2	2.85	2.8	2.5	2.55	2.48	2.28	2.15	2.2	......	......
23	2.8	3.35	2.8	2.8	2.5	2.5	2.4	2.23	2.15	2.2	......	......
24	2.75	2.9	2.78	2.75	2.45	2.5	2.73	2.25	2.15	2.25	......	......
25	2.68	2.9	2.73	2.7	2.5	2.5	2.48	2.48	2.15	2.23	......	......
26	2.6	3.08	2.75	2.7	2.5	2.48	2.35	2.28	2.15	2.18	......	......
27	2.58	3.05	2.8	2.7	2.45	2.48	2.38	2.2	2.15	2.15	......	......
28	2.68	2.78	2.8	2.65	2.45	2.43	2.3	2.2	2.45	2.15	......	......
29	2.48	......	2.8	2.6	2.45	2.35	2.3	2.2	2.4	2.1	......	......
30	2.48	......	2.8	2.6	2.45	2.35	2.3	2.2	2.6	2.1	......	......
31	2.55	......	2.8	......	2.4	......	2.5	2.15	......	2.1	......	......

Rating table for Rock Creek at Lyon's mill, Washington, D. C., from August 18, 1892, to November 30, 1894.[a]

Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.	Gage height.	Discharge.
Feet.	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*	*Feet.*	*Second-feet.*
—1.30	5	—0.10	68	1.10	220	2.60	533
—1.20	6	.00	78	1.20	235	2.80	583
—1.10	8	.10	89	1.30	251	3.00	635
—1.00	10	.20	100	1.40	268	3.20	689
— .90	13	.30	112	1.50	286	3.40	744
— .80	17	.40	124	1.60	305	3.60	800
— .70	22	.50	137	1.70	325	3.80	858
— .60	28	.60	150	1.80	346	4.00	918
— .50	34	.70	163	1.90	368	4.20	980
— .40	41	.80	177	2.00	390		
— .30	49	.90	191	2.20	436		
— .20	58	1.00	205	2.40	484		

[a] This table is strictly applicable only for open-channel conditions. It is based on seven discharge measurements made during 1892–1894. It is well defined between gage heights —0.3 foot and 4.2 feet.

Estimated monthly discharge of Rock Creek at Lyon's mill, Washington, D. C.

[Drainage area, 85 square miles.]

Month.	Discharge in second-feet.			Run-off.	
	Maximum.	Minimum.	Mean.	Second-feet per square mile.	Depth in inches.
1892.					
August 18-31	29	23	26.4	0.311	0.162
September	137	21	32.8	.386	.431
October	29	21	23.7	.279	.322
November	102	22	35.4	.416	.464
December	137	27	44.5	.524	.604
1893.					
January	238	29	65.7	.773	.891
February	390	37	94.0	1.11	1.16
March	265	58	88.5	1.04	1.20
April	124	44	65.9	.775	.865
May	980	58	107	1.26	1.45
June	133	31	46.0	.541	.604
July	436	20	53.0	.624	.719
August	261	8	22.0	.259	.299
September	89	10	19.8	.233	.260
October	436	13	39.3	.462	.533
November	315	23	56.5	.665	.742
December	198	32	58.6	.689	.794
The year	980	8	59.7	.703	9.52
1894.					
January	205	46	56.0	.659	.760
February	156	44	63.0	.741	.772
March	205	54	68.6	.807	.930
April	232	40	67.8	.798	.890
May	156	35	59.6	.701	.808
June 1-15	41	20	29.8	.351	.196
August 20-29	13	6	8.1	.095	.035
September 2-22	31	15	21.4	.252	.197
October	58	17	24.9	.293	.338
November	78	22	31.3	.368	.411

MISCELLANEOUS MEASUREMENTS IN POTOMAC RIVER DRAINAGE BASIN BELOW SHENANDOAH RIVER.

William Rich Hutton, of New York, states that in the summer of 1856 he made a careful examination of the flow of Potomac River a short distance below Great Falls, using loaded poles reaching as near as possible to the bottom and placed at 5-foot intervals across the width of the river. The water was then at the lowest stage known to persons who had observed the river for many years. The discharge was 1,063 second-feet. Mr. Hutton was of the opinion that the river was as low in 1862, but no measurements were made in that year.

In 1839 a civil engineer, M. C. Ewing, assistant to Major Turnbull, United States topographic engineer, during the construction of the Alexandria Aqueduct above Georgetown, reported the discharge below Little Falls to be 1,904 second-feet. Thomas L. Patterson, of Cumberland, is reported to have found the discharge of North Branch of the Potomac at that point in the low water of 1838 to be 24 second-feet, and at Patterson Creek, about 12 miles below, 48 second-feet. Figures of discharge of Potomac River are given in the statement regarding the extension of the Chesapeake and Ohio Canal in House Ex. Doc. No. 208, Forty-third Congress, first session; also in House Ex. Doc. No. 137, Forty-fourth Congress, first session.

The following miscellaneous discharge measurements were made in the Potomac River drainage basin by hydrographers in the United States Geological Survey. Measurements in the fall of 1897 were made in connection with a study of the sources of pollution in the Potomac drainage basin. They were made at a time when the flow throughout the basin was considered generally lower than usual, although a few measurements were affected by local rains which preceded them.

Miscellaneous discharge measurements in Potomac River basin below Shenandoah River.

Date.	Stream.	Locality.	Width.	Area of section.	Mean velocity.	Discharge.
1897.			*Feet.*	*Square feet.*	*Feet per second.*	*Second-feet.*
October 14	Carroll Creek (tributary to Monocacy River).	Zentz's mill race, Frederick, Md.	7	4	1.40	5.6
Do.	do	At Frederick, Md	11	6	1.00	6
Do.	Goose Creek	¾ mile above mouth, near Edwards Ferry, Md.	34	38	.50	19
Do.	Catoctin Creek, in Maryland.	Above Baltimore and Ohio R. R. bridge near Catoctin station, Md.	21	9	2.22	20
Do.	Broad Run	Near Edwards Ferry, Md.				1
October 15	Seneca Creek	In Seneca mill race, Seneca, Md.	11	20	1.25	25
Do.	Catoctin Creek in West Virginia.	½ mile above mouth and 1 mile above Point of Rocks, Md.	16	6	1.17	7
Do.	South Tuscarora Creek.	Near Baltimore and Ohio R. R. bridge near Licksville, Md.	5	2.5	1.24	3.1
Do.	Monocacy River	Between Baltimore and Ohio R. R. bridge and canal aqueduct near Dickerson, Md.	203	184	1.19	[a]219

[a] Gage height on Monocacy River at Frederick, Md., 4.4 feet.

FLOODS NEAR WASHINGTON, D. C.

FLOOD OF FEBRUARY, 1881.[a]

February 12 and 13, 1881, there occurred in the vicinity of Washington the greatest flood, with the exception of that of June 2, 1889, hereinafter described, of which there is any record.

This flood was caused by the gorging effect of an ice jam, and the discharge did not equal that of the freshet of 1877 or 1889, but the amount of damage inflicted on shipping, wharf property, and private property was far greater. The low portion of the city along the Mall and extending across Pennsylvania avenue was flooded, and a large amount of damage was caused by the flooding of cellars and first floors. The area of the flooded district was about 254 acres.

The winter had been unusually severe in the long continuance and intensity of its period of cold, during which 23.2 inches of snow had fallen and unusually thick ice had formed over the river. A rise of only a few feet in the river from rains and melted snow caused a

[a] Chiefly from Ann. Rept. Chief of Engineers, U. S. Army, 1881, pt. 1, pp. 940-942.

breaking up of this ice, which gorged and so obstructed the waterway that although the freshet above Georgetown did not attain the height of 1877 by 3 feet, the water rose to a height of 12.25 feet above low water at Long Bridge, or 3.19 feet higher than the freshet of 1877.

The ice broke at Georgetown about 1 a. m. on Saturday, February 12, 1881, the stage of the river being then 2 to 3 feet above high tide, but rapidly rising as the ice passed down and added to the gorge below, until the highest water was reached at 7 p. m., when it was about 0.8 foot higher than the flood of 1877.

At Georgetown comparatively little damage was done, owing chiefly to the precaution taken to secure shipping and movable property on the wharves. Along the Washington wharves the ice began to break about 2 a. m., the water being 4 to 5 feet above high tide, and moved off rapidly with the current, the channel at times being nearly clear of ice.

The gorge did not at first form at Long Bridge, so far at least as concerned the Washington Channel, as is proved from the fact that between 3 and 4 a. m. on Saturday, February 12, a long boat and several scows were swept away from the Seventeenth street wharf and carried through the Washington draw, and the long boat was found later in the day lodged in the gorge below Arsenal Point, the scows having been carried still farther down the river.

The complete gorge was formed below Arsenal Point, commencing about 7.30 a. m., and the successive additions of floating ice soon caused it to extend to Long Bridge.

Whether a gorge was complete across Georgetown Channel at this point before the lower gorge extended to the bridge was not determined, but subsequently the gorge became complete for the whole length of the bridge. It is probable, however, from the fact that large quantities of ice came across the flats above Long Bridge and passed through the Washington Channel, that a gorge independent of that below was formed across Georgetown Channel at Long Bridge at or about the time of its formation below.

By 9 a. m. the entire waterway of Long Bridge was choked. An occasional movement of short duration served only to jam the ice more closely and raise it higher, until the water passed over the causeway and 2.2 feet above it. The pressure on the bridge became greater than it could withstand, and about 8.30 p. m. three spans of the north end gave way and were swung around on the flats below. This movement, together with a break in the railroad embankment between the river and Fort Runyon (which is one-third of a mile from the Virginia end of Long Bridge, on the railroad to Alexandria) 1,006 feet in length, so far relieved the pressure that no further damage was done to the bridge.

GREAT FALLS OF THE POTOMAC.

By Sunday morning the water, which had been 2½ feet higher on the Washington wharves than in the freshet of 1877, was off the wharves, but large piles of ice remained upon them, and many which escaped serious injury from lateral pressure while the ice was running were crushed when the water, by its subsidence, withdrew its buoyant support.

The following are the heights above low water of the freshets of 1877 and 1881 at the several points named:

Height of Potomac River above low water in floods of 1877 and 1881.

Locality.	1877.	1881.	Locality.	1877.	1881.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Outlet lock above Georgetown	19.72	16.73	Below Long Bridge		11.20
Aqueduct Bridge	15.96	14.29	Arsenal Point	8.44	7.01
Rock Creek	13.35	13.77	Giesboro Point	7.66	4.93
Easbys Point	11.99	13.54	Navy-yard	7.73	5.01
Above Long Bridge	9.06	12.26			

FLOOD OF JUNE, 1889.[a]

June 2, 1889, there occurred the greatest freshet in Potomac River of which there is any authoritative record. The Potomac at Harpers Ferry rose to the height of 34 feet above the low stage. The water was at one time 2.8 feet above the rails of the Baltimore and Ohio Railroad on the bridge and 6.8 feet higher than the freshet of 1877. At Great Falls the maximum height was 16 feet above the top surface of the coping of the dam, 4 feet higher than in the freshet of 1877. At Chain Bridge it was 43.3 feet above tide level. The freshet was preceded by strong southeasterly winds, which made the tides at this point unusually high.

Observations were taken while the freshet was running to determine the levels above low water at various points from Chain Bridge down to Arsenal Point. The freshet attained its maximum height at about 10 a. m. on June 2. At that time the height of the water surface above low water at Chain Bridge was 43.3 feet, at Aqueduct Bridge 19.5 feet, at Easby's wharf and at the sewer canal 13.3 feet, at Long Bridge 12.7 feet, and at Arsenal Point 11.1 feet. It was within 3 feet of its maximum height for a period of about twenty-four hours and within 6 feet of it for about thirty hours. After the river began to fall it fell rapidly, but for more than twenty-four hours it was too high for the sewers in the low part of the city to discharge their contents. Hence if a heavy rainfall had occurred during this period the sewers could not have carried off the rain water at all, and a still larger area of the city would have been flooded. The highest point reached by the water at the sewer canal at the foot of Seventeenth street was 13.26 feet. Before this height was reached the

[a] Chiefly from Ann. Rept. Chief of Engineers, U. S. Army, 1889, pt. 2, pp. 985-986.

water backed up in the B street sewer and came into the streets from the sewer outlets. After the water rose above the level of B street it came into the city from the sewers and from the river direct. Great damage was done to private property in the city, as the water on B street was in many places over 4 feet deep, and reached to the store doors on the north side of Pennsylvania avenue, between Ninth and Tenth streets. At B and Fifteenth streets the high water of the 1889 freshet was 3.2 feet above that of 1877 and 0.7 foot higher than in 1881.

The discharge area of the river at Aqueduct Bridge when the freshet was at its maximum was about 38,000 square feet. No velocity observations were taken, but on the assumption that C. C. Babb's estimate of 470,000 second-feet discharge at Chain Bridge was correct, the mean velocity at Aqueduct Bridge was about 12.4 feet per second.

Rock Creek, which enters Potomac River 4,000 feet below Aqueduct Bridge, was estimated to have a maximum discharge of 20,000 to 25,000 second-feet during the night of May 31 to June 1, 1889.

SLOPE OF POTOMAC RIVER.

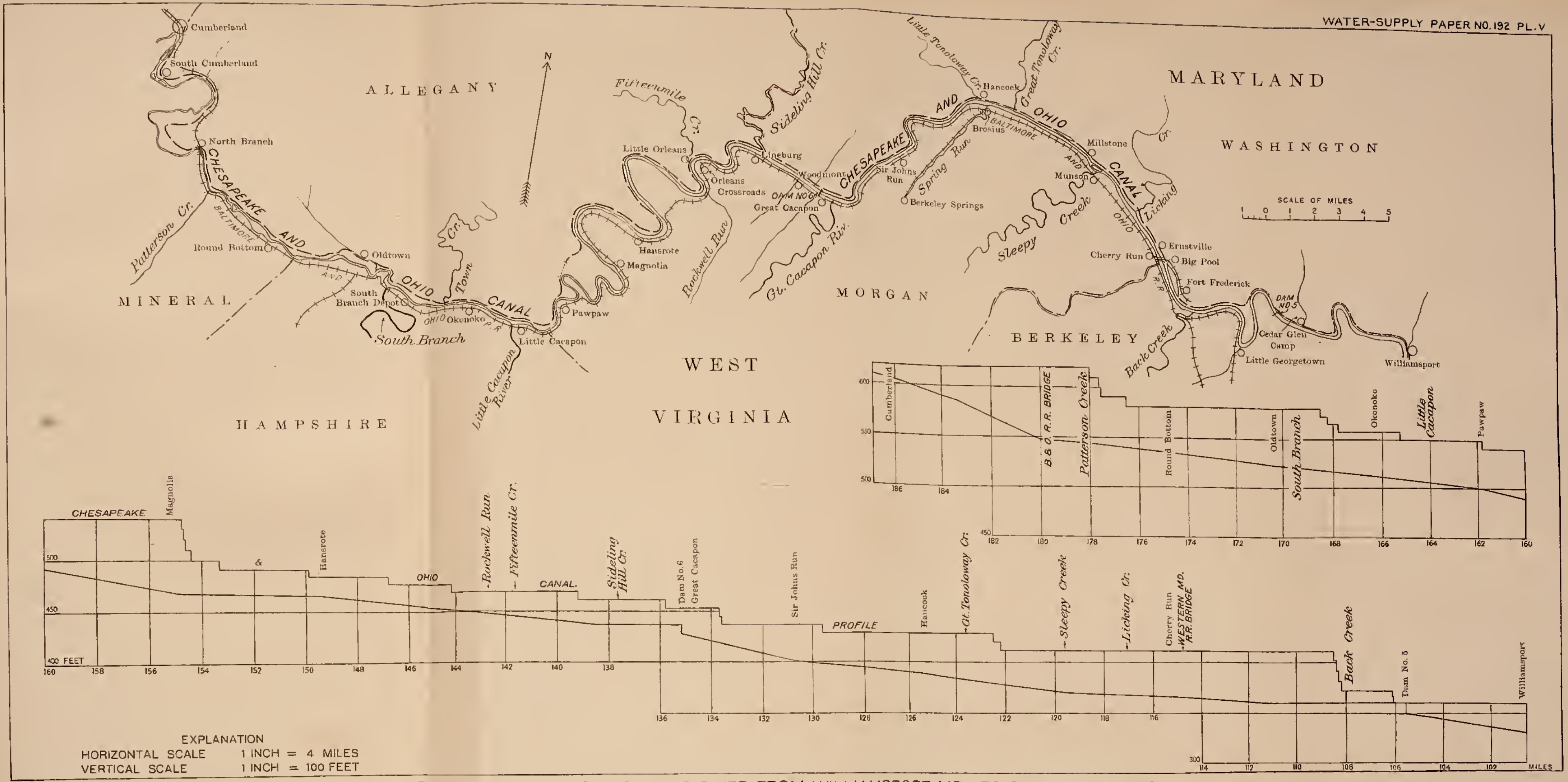
The fall of the Potomac below Harpers Ferry is about 245 feet. Of this about 90 feet occurs in a short distance at Great Falls (Pl. IV); and if this be subtracted the fall in the remaining distance is found to average about 2.5 feet per mile.

As a water-power stream the principal disadvantage of the Potomac is the great variability of its flow. Good rock foundations for dams can generally be found at small depth, the banks are as a rule favorable, and there are several sites where large falls could be rendered available. Building materials are generally obtainable, and facilities for transportation are excellent. A very insignificant amount of power has been developed.

Slope of the Potomac River.

[Pls. V and VI.]

Locality.	Distance from mouth.	Elevation above tide.	Distance between points.	Fall between points.	Fall per mile between points.
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Feet.*
Georgetown	0.0	0			
Harpers Ferry	61.5	245	61.5	245	4.0
Shepherdstown	71.0	280	9.5	35	3.7
Dam No. 4	85.0	319	14.0	39	2.8
Dam No. 5	107.0	357	22.0	38	1.7
Cumberland	185.0	610	78.0	253	3.2



EXPLANATION
HORIZONTAL SCALE 1 INCH = 4 MILES
VERTICAL SCALE 1 INCH = 100 FEET

ANDREW B. GRAHAM CO. PHOTO LITHOGRAPHERS, WASHINGTON, D. C.

PLAN AND PROFILE OF POTOMAC RIVER FROM WILLIAMSPORT, MD., TO CUMBERLAND, MD.

PLAN AND PROFILE OF POTOMAC RIVER FROM GEORGETOWN, D. C., TO WILLIAMSPORT, MD.

ANDREW B. GRAHAM CO. PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

THE CHESAPEAKE AND OHIO CANAL.[a]

By Horatio N. Parker.

The idea of building a chain of internal improvements to connect the Potomac with the headwaters of the Ohio was conceived by George Washington, whose life had made him thoroughly familiar with the country. In 1748 he was active in the organization of the Ohio Company, which was formed to trade with the Indians west of the Alleghenies, and whose charter made it incumbent on the stockholders to settle a certain number of families in the Ohio Valley. His interest in that company, his expedition to Fort Duquesne in 1753, and, finally, his connection with the Braddock expedition of 1754 convinced him that it was imperative to establish water communication with the West. Accordingly, in the fall of 1774, he procured the passage of a law by the general assembly of Virginia, empowering such individuals as were disposed to embark in the enterprise to open the Potomac so as to render it navigable to Wills Creek. In a letter to Jefferson dated March, 1774, he said that the project was in good train and would have been in an excellent way had it not been for the opposition of the Maryland assembly, which was supposed to be instigated by Baltimore merchants, who feared the consequences of water transportation to Georgetown. The outbreak of the Revolution interrupted his plans, though he seems always to have had this problem on his mind, for a little before the close of the war he left the Continental camp at Newburgh and made a long and perilous journey up the Mohawk Valley with a view of determining the practicability of a water route to the West through that valley, returning convinced that the great rival route to the Potomac would be through New York. With the close of the Revolution, the problem became more acute than ever, for it seemed likely that unless quick and cheap communication could be established with the territory west of the Alleghenies it would ally itself with the Mississippi Valley interests and be forever lost to the eastern colonies. Washington strove to rouse Virginia and Maryland to meet the problem, with the result that the Potomac Company, incorporated by Virginia and confirmed by Maryland, was organized May 17, 1785. So far as known, the first minutes extant are now in the possession of the Chesapeake and Ohio Canal Company and are of the meeting held May 30, 1785. George Washington was its first president, but his services were required by his country and he was compelled to resign to accept the Presidency of the United States. The Potomac Company was only moderately successful under the immediate presidency of Washington, and when it was deprived of his counsels it became markedly less

[a] Ward, G. W., Early development of the Chesapeake and Ohio Canal project: Johns Hopkins Univ. Studies in Historical and Political Science, series 17, Nos. 9-10 and 11, 1899.

efficient, and finally with his death lost the confidence of the public. However, it accomplished much work during its existence. At the time it was organized little more was expected of it than to render the Potomac navigable from Georgetown to Cumberland, from which point it was thought to be an easy matter to connect with the waters of the Ohio by means of a well-built road. The chief obstacles encountered in descending the Potomac were five in number. The first of these was at House Falls, 5 miles above Harpers Ferry, where a canal 50 yards long, with a total fall of 3 feet, was built. The second difficulty was at Shenandoah Falls, immediately above Harpers Ferry, and was overcome by a canal 1 mile long, with a total fall of 15 feet. At Seneca Falls a third canal, three-fourths of a mile long, with a total fall of 17 feet, was constructed. To this point no locks were found necessary, but at Great Falls they were used in connection with a canal 6,000 feet long on the Virginia shore. The fifth and last canal, built for passing Little Falls, was on the Maryland shore, and was over 2 miles long, with a total fall of 37 feet.

The charter of the company originally provided that the work for which it was organized should be completed in three years. It soon became evident that it would be impossible to finish the work in that period, and the general assemblies of Virginia and Maryland passed an act extending the time. Five such acts were passed by the Maryland legislature and ten by that of Virginia. Finally, in 1819, after existing thirty-five years and spending $700,000, the Potomac Company applied to the board of public works of Virginia for relief. The board ordered Thomas Moore, its chief engineer, to make a survey of the river with a view of locating a canal in its valley, a policy suggested by the board to the general assembly of Virginia in 1816.

Moore's work was begun on June 30, 1820, and in his report dated December 27, 1820, he stated that the construction of the canal was practicable, and estimated the cost at $1,114,300. The board transmitted this report to the governor of Virginia and he sent it to the general assembly, which adopted a resolution authorizing the governor to appoint a committee to cooperate with a similar one appointed by the governor of Maryland to examine into the affairs of the Potomac Company. The committee met in Georgetown July 2, 1821, and found the Potomac Company bankrupt. Having satisfied themselves that there were no means available for opening the Potomac River to navigation, they believed the time had come to recommend a continuous canal from tidewater to Cumberland, so they proceeded to that city July 15, and spent the rest of the month examining the river westward to Savage River. Having completed this work, under the guidance of Moore's survey of 1820, the commissioners began the location of a canal whose construction they believed would at once be undertaken by the States of Maryland and Virginia. Sickness among their engineers and finally that of Moore himself, September 18, compelled the abandonment of the work after it had proceeded 157 miles eastward from its beginning. Moore died and was succeeded by Isaac Briggs, who rapidly completed the work. For the basis of their estimate the commissioners adopted a canal 30 feet wide at the surface, 20 feet wide at the bottom, and deep enough for 3 feet of water. Its cost was estimated at $1,574,954. The general assembly of Virginia passed a bill incorporating the Potomac Canal Company in February, 1823, but the Maryland assembly under pressure from Baltimore failed to do so; hence the project was held up for a time. The failure of the Maryland legislature aroused the friends of the canal and popular meetings were held in Virginia, Maryland, and Pennsylvania during the spring and summer of 1823. The sentiment in favor of the canal was found to be so strong that it was determined to hold a convention in Washington during the autumn for the purpose of uniting counsels, proposing legislation, and enlisting the cooperation of Maryland, Pennsylvania, and Virginia and especially that of the Federal Government, which up to this time had steadfastly refused to inaugurate a system of internal improvements. The convention met at Washington November 6, 7, and 8, 1823, and declared in favor of a canal. It appointed committees in each of the States interested to advance legislation and a central committee to give direction to all the various forces at work on behalf of the canal. Among other things, the central committee was empowered to memorialize Congress, gather all information possible, hasten the surveys, have commissioners appointed, open books for the subscription of stock, and, if occasion required, to call another meeting of the convention. This convention is a landmark in the history of internal improvements in the United States, for the Federal Government had up to this time held it to be unconstitutional for it to construct such works, but it now unshackled itself from this impediment and entered into the canal project heartily. The Virginia assembly passed an act incorporating the Canal Company in 1824. Maryland passed one, too, after the jealousies of the Baltimore merchants had been allayed by an amendment permitting them to tap the canal with a branch canal at some convenient point in Maryland or the District of Columbia. The United States confirmed the incorporation and President Monroe signed the bill March 3, 1825. Finally, Pennsylvania passed an act sanctioning the canal.

The United States engineers, under the immediate direction of Gen. S. Bernard, made an elaborate and detailed report; which was not ready for publication until October, 1826. They proposed a canal divided into the Chesapeake and Ohio Canal proper from tidewater to

Pittsburg, and the Ohio and Erie Canal from Pittsburg to Lake Erie. The Chesapeake and Ohio Canal proper was divided into three sections—the eastern section, from tidewater to the mouth of Savage River; the middle section, from Savage River to the Youghiogheny at the mouth of Bear Creek; and the western section, from the mouth of Bear Creek through the valley of the Youghiogheny to Pittsburg. The work done in preparing this report was very thorough and elaborate and necessarily consumed much time. The friends of the canal grew restive and in March, 1826, induced General Bernard to give out his estimate for the eastern section. It was, exclusive of the item of contingencies, $8,085,000, which was, of course, for those days, prohibitive. The central committee called another convention, which met in Washington December 6, 1826. This body decided to their own satisfaction that when the errors of the United States engineers in estimating labor and materials were corrected, the canal could be built for less than $5,000,000. At the instance of twenty members of Congress, President Adams ordered a new survey by James Geddes and Nathan S. Roberts, who reported that the eastern section of the canal could be built for $4,479,346.93. Subscription books were opened October 1, 1827. The beginning of work on the canal was an event. A party was formed in Washington and went to Little Falls, where, on the Fourth of July, 1828, President Adams removed the first spadeful of earth, and speeches were made by prominent men to the crowd which had assembled to see the ceremony.

The company's charter required 100 miles of canal to be built in three years. Contracts were closed for 43 miles of the canal before March, 1829, and soon the whole 48 miles between Georgetown and Point of Rocks was under contract. By May 1, 1829, work had been done on all five "residences" into which the section had been divided. However, labor proved scarce, and it was found necessary to import it from Europe. Sickness broke out among the men, who contracted fever in the valley, and some of the contractors were compelled to suspend operations. It was late in October before the various gangs were all in good condition, but the winter proved an open one, and it was possible to continue the work far into it. The men proved disorderly, and the laws of those days were not stringent enough to deal with them promptly, so that ultimately the importation of foreign labor by the company was abandoned. The canal from Seneca Creek to a point within sight of Georgetown was completed in 1831. In the meantime, about January, 1828, the canal company became involved in a suit with the Baltimore and Ohio Railroad. This railroad had the active support of the Baltimore merchants, and the first spadeful of earth which marked the inauguration of work on it was removed by James Carroll, of Carrollton, on the very day and only a few miles from the spot where President Adams celebrated the beginning of work on the Chesapeake and Ohio Canal. By its charter the Chesapeake and Ohio Canal Company had obtained a right of way for a canal on the Maryland bank of the Potomac from Washington to Cumberland. By its surveys the railroad was compelled to gain the Potomac at Point of Rocks, 12 miles below Harpers Ferry, and follow the river to the latter point; otherwise a tunnel would have to be built under the mountain spurs, a financially impossible alternative. The canal company now sought to exclude the railroad from laying tracks between Point of Rocks and Harpers Ferry on lands to which it claimed prior rights. The suit was finally decided in favor of the canal company in 1832, but by that time it was bankrupt and Federal aid had been withdrawn. Such a predicament offered an opportunity which was successfully utilized by the Baltimore and Ohio Railroad to complete its tracks to Harpers Ferry. After a series of compromise proposals by the railroad to the canal company had been refused, the Maryland legislature took up the matter. May 9, 1833, a compromise was effected by the passage of a law calling for the joint construction of a canal and railroad through the disputed territory. The compromise cost the railroad heavily, for it was compelled to subscribe for 2,500 shares of the canal company's stock ($266,000), and the canal company built the road through the disputed territory (Point of Rocks). In 1834 the railroad completed the road to the Maryland side of the Potomac, opposite Harpers Ferry, where it was compelled to stop, for the agreement signed by the two companies demanded that the railroad should not be built across the Potomac until the canal should have been completed to Cumberland, if that was done within the time named in the charter—1840. At the time of the compromise, in 1834, Maryland came to the rescue of the canal with a loan of $2,000,000. This was soon exhausted, and $3,000,000 more was appropriated by the State June 4, 1836, but on condition that the Baltimore and Ohio Railroad be allowed equal rights between Harpers Ferry and Cumberland. This enabled the railroad to complete its line before the canal was finished. The summer of 1837 found the canal completed only to Dam No. 5, 127 miles from Georgetown. The next 27 miles of the canal, to Dam No. 6 at Great Cacapon, were in process of construction, and the last 50 miles, from Great Cacapon to Cumberland, were under contract. More funds were needed, and the general assembly of Maryland in 1838 advanced an additional amount of $1,375,000. By 1841 the waterway was completed only to Dam No. 6, and both the canal and the State of Maryland were in financial difficulties, so that further aid was not given until 1844, when the State of Maryland permitted the company, under certain conditions, to issue bonds to the amount of $1,700,000. With the funds thus raised the canal was completed to Cumberland in October, 1850.

Since its completion the canal has not been prosperous. In 1877 the works of the canal were seriously damaged by a freshet, and this provided an excuse to burden the canal with more debt by issuing additional bonds, which was done with the consent of the State of Maryland. In 1889 another freshet did even greater damage; and as those in charge of the canal had no funds with which to pay for repairs, it was left in this condition for two and one-half years, during which time the elements added to the damage and increased the cost of reconstruction.

At this time a movement was begun to dispose of the canal to certain railroad interests, but the bondholders of 1844 asserted their rights and began proceedings to get possession of the canal. As trustees they were given control for a certain number of years on condition that they would repair it, retire the bonds of 1878, and carry out other conditions imposed by the court. Apparently the trustees have satisfied the court of the feasibility of their plans, for the period given them to operate the canal has been extended from time to time and it is still in their possession.

To-day the canal between Georgetown and Cumberland lies on the Maryland side of the Potomac and pursues the immediate valley of the river to a point 1 mile below Pawpaw, where it passes through a spur of Town Hill by means of a tunnel 3,636 feet long and of circular cross section 27 feet across. This tunnel saves about 6 miles. The total rise from the level of midtide at Georgetown to the Cumberland basin is 609.7 feet. This ascent is broken by 74 lift locks and a tide lock that connects Rock Creek basin with the Potomac. The canal has a depth of 6 feet throughout, and from Georgetown to Harpers Ferry, 60 miles, it is 65 feet wide at the surface and 41 feet at the bottom. From Harpers Ferry to Dam No. 6, 47 miles, the width at the surface is 60 feet and at the bottom 36 feet. From Dam No. 6 to Cumberland, 50 miles, the surface width is 55 feet and the bottom width 31 feet. The average lift of the locks is a little in excess of 8 feet, though there are thirteen 10-foot locks and four 6-foot locks. The locks are 100 feet long and 15 feet in the clear and pass boats carrying 122 tons of 2,240 pounds. The canal is fed with water at eight different points. The first is at the Beal mill race in Cumberland, which is connected by gates with Wills Creek at the dam near the tannery of the United States Leather Company. The enormous amount of sewage which this race receives is, to a large extent, deposited as sludge in the head basin of the canal. This action is probably facilitated by the nature of the water received at the second supply point, the head-gates of the canal. This water is, as a rule, largely from Wills Creek, mixed with considerable water from North Branch, though in times of low water the entire flow of both North Branch, above Dam No. 7, and Wills Creek goes down the canal. The Wills Creek water is heavily polluted by mine waters, and therefore con-

A. CHESAPEAKE AND OHIO CANAL ABOVE WILLIAMSPORT, MD.

B. POTOMAC RIVER AND CHESAPEAKE AND OHIO CANAL AT DAM NO. 5.

tains considerable quantities of iron and sulphuric acid, which are precipitating elements, as is the lime of North Branch. So great is the accumulation of precipitated sewage in the head basin that the canal company finds it necessary to dredge it out every other spring. When this is done the sludge is distributed over the towpath and river side of the embankment. It becomes very hard and most of it remains in place, though some of it is carried off by the river. In the winter, after the water is drawn off from the canal, the contents of the race discharge into the head basin as usual, but instead of continuing down the canal, as when the canal is in use, they return to the river near the foot of the basin and below Dam No. 7. This first supply is not properly a part of the works of the canal. The precipitating action continues for 51 miles down the canal to the third supply point, Dam No. 6, where the water in the canal is said to be much clearer than at Cumberland. Dam No. 6, below Greenspring, admits river water, which to a large extent comes from South Branch, and hence is usually of better quality than the river water at Cumberland and by dilution greatly improves the water in the canal. From Dam No. 6 to Dam No. 5 the distance is 29 miles. About 6 miles above Dam No 5 the canal passes through what are known as Little and Big pools. These were originally high-water channels of the river, which have been incorporated into the canal. Big Pool is 2 miles long. The occurrence of these pools is noted, because the current through them must necessarily be very small and so gives opportunity for sedimentation of material suspended in the canal water and also because they must add to the time it takes the water to complete its passage from Cumberland to the river. The canal and the river unite half a mile above Dam No. 5 (Pl. VII, *B*), and in the half-mile stretch above the dam the canal and river waters are thoroughly mixed. At Dam No. 5 the canal resumes its separate course and a fourth point of water supply is established.

From Dam No. 5 to Dam No. 4, the fifth point where water is received by the canal, the distance is 21½ miles. About 4½ miles above Dam No. 4 the canal reenters the river and continues united with it for 3.3 miles to a point 6,000 feet above the dam. In this distance the waters of the canal and river have become thoroughly mixed, and it is well to remember that this dam is but 67½ miles above Great Falls. From Dam No. 4 the canal continues 23 miles to Dam No. 3, at Harpers Ferry, the sixth point of water supply. Dam No. 2. half a mile east of Seneca Falls and 40 miles below Harpers Ferry, is the seventh and last point of water supply until Dam No. 1 is reached at Little Falls.

Throughout its length the canal is built on the surface of the land and so receives little ground water; in fact, the water has a tendency to seep out through the canal banks and in places to make the farm lands too wet to be successfully cultivated. The current in the canal is very variable, changing in its different sections and with the stage of the river. Perhaps it would be correct to assume a current of 1 mile an hour in normal sections. At times of flood portions of the canal are under water.

Two expensive aqueducts carry the canal over Conococheague Creek and Monocacy River. The myriad little runs that come down from the hillsides to the river are excluded from the canal by means of passages made for them beneath the canal through masonry culverts. Thus these streams find direct entrance to the Potomac, except three, which enter Big Pool, and a few dry runs, the most important of which are one a little east of Monocacy River, one just above Harpers Ferry, and one 2 miles below Dam No. 6.

Every winter the water is drained off from the canal and its service discontinued. The length of the canal season is usually eight to nine months, and repairs are made every spring before the canal is reopened. It is not found necessary to clean out the canal on account of suspended matter deposited during the season's use, but certain points on the canal need rather frequent dredging because of earthy material that is brought in over its banks by water flowing over cultivated ground and in other ways. The canal company has no sanitary regulations and the crews of canal boats use the canal as a receptacle for feces and for kitchen offal. A few of the privies of the lock keepers overhang the canal, but the feces do not get into the river except in times of freshet. The canal company has succeeded in abolishing all but two or three of the other privies which overhang its line, and these, it is expected, will soon be removed. During the season of 1905 but one man employed on the canal boats was known by the officials of the company to have suffered from typhoid fever.

The canal company claims that by the terms of its charter it is entitled to all the water power of the river from Washington to Cumberland, but it has never developed it for manufacturing purposes, one reason being that a survey made to determine the amount of power which could be made available indicated that the outlook in this direction was not promising. A small mill at Williamsport and one at Seneca are the only ones above Washington to which power is sold by the company. At Dam No. 5 surplus water is sold for power purposes to a plant on the West Virginia side of the river, and the same people are contemplating the development of works at Dam No. 4. At Georgetown about 1,000 horsepower is sold. The water of the canal is not furnished to any community for domestic supply, though a few individuals here and there along the line use it for washing purposes.

STREAM POLLUTION, OCCURRENCE OF TYPHOID FEVER, AND CHARACTER OF SURFACE WATERS IN POTOMAC BASIN.

By Horatio N. Parker.

STREAM POLLUTION.

GENERAL ASPECTS.

The prosperity of the industries of the Potomac Valley, with its attendant increase of population, is justly a cause of congratulation to the several States within which the basin lies. Yet this success brings responsibilities that can not be shirked, but must be wisely met if growth is to continue and health and happiness prevail. In dealing with the new problems it should be borne in mind that the wealth of every region is limited. Resources which were extravagantly wasted when there were few to claim them have to be carefully husbanded when there is hardly enough to go around. Acts which may be viewed with indifference in a sparsely settled country become crimes in densely populated communities. No resource will be more seriously affected by changed conditions than water. It is strictly limited in amount, and therefore to injure any source which is valuable for manufacturing or domestic use is a spendthrift deed, sure in the end to increase the cost of living. For, one by one, the sources of pure water which are not too expensive to utilize will be preempted, and then will come the time when the supplies that have been ruthlessly damaged must be purified. It can be done, but it costs money. Water rates will rise, and then every man will have to decide for himself whether it will be more profitable for him to remain where he has built up his business or to migrate to some place where the supply of water is yet unpolluted, or where the citizens have been forehanded enough to keep, by well-considered legislation, the cost of purifying their water supply within reasonable limits.

Often before industry is crippled by bad water a town or city experiences epidemics of water-borne disease that result from an impure water supply. This condition is brought about by contamination of the water by the feces of persons sick with Asiatic cholera or typhoid fever. Happily in this country outbreaks have generally been limited to the latter disease. At first the policy of concealment is adopted by the afflicted community, and "malaria" is said to be present. Later, when suspicion arises that the trouble is something more serious, the terms "fever" or "typhoid malaria" are used, and when the outside world can be no longer deceived by euphuistic names it is admitted that "there was some typhoid last year." By this time the degree of contamination in the supply has either become sufficiently great to produce typical cases of typhoid fever, or so many cases develop at one time that an epidemic is said to be present. Public opinion is aroused, the town is bonded for the construction of a new water supply or for purification works, and the tribute of human lives demanded by pollution is stopped.

Both sewage and industrial pollution may inflict great loss in the community by making its streams unfit for harvesting ice. The late Prof. Thomas M. Drown[a] showed that ice in freezing has a decided tendency to exclude impurities, but he found this action to be most marked in the layers that are formed by the slow growth of the ice downward, because the surface in its rapid congealing entangles suspended matter, particularly if the water is stirred up by the wind. Moreover, if the ice is frozen after surface flooding, which is frequently brought about intentionally by the harvesters, it will contain all the impurities of the water so added. In making artificial ice in the ordinary way the entire body of the water is frozen and all the impurities are concentrated in the last part of the cake to freeze. Hence an impure water is particularly undesirable for ice manufacture. Likewise, when shallow ponds freeze solid, the impurities are concentrated in the bottom ice.

The fact that ice forms in greater purity than its surrounding medium undoubtedly has permitted it to be obtained from questionable sources and still to be used with impunity. But outbreaks of typhoid fever have been attributed to polluted ice, and it is certain that a stained or ill-smelling ice is unsalable, so that consumer and producer alike suffer from river pollution. Indeed, probably most readers know of ice ponds which have had to be abandoned because the ice from them was no longer marketable.

The question how best to get rid of the wastes of human life and of the industries which are a part of it is a very pressing one. Every health officer is familiar with the subterfuges adopted to avoid the expense attendant on the proper disposal of these wastes. Very naturally, rivers have been seized on as the easiest way to solve the problem, because they passively accept all burdens given to their charge and carry them away. Indeed, water has been called the great scavenger, and not a few manufacturers regard the streams as natural sewers created by Providence for their use.

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[a] Jour. New England Waterworks Assoc., vol. 8, No. 1, 1893.

Natural beauty has a distinct value, and those who mar it impair the resources of a country, for a discolored repulsive stream will not be utilized for recreation purposes, and a stinking one will not be featured in realty advertisements. The monetary loss to communities arising from severe pollution of the streams on which they are located is often very heavy, and the damage is reparable only at great expense.

The constantly increasing cost of food has become a serious factor in the development of the country. Dishes that were common on the tables of our fathers have become rarities to many and are entirely foregone by not a few. In spite of this we are carelessly curtailing our fish supply, as the filth poured into our streams and rivers drives the fish from their spawning grounds. Some streams they have quite abandoned; others they visit in decreasing numbers. It is true that we place large quantities of fry in various streams every year, but some fish—the sturgeon, for example—can not be perpetuated in this way.

It should be remembered that some one always pays for water pollution. If the laws are such that they relieve one corporation of caring for the wastes it creates, it is likely that they entail great expense on another. Thus a railroad which is compelled to use polluted water in its locomotives will in consequence have many repairs to make, and the increased cost of mileage caused thereby will have to be borne by those who travel and transport goods over the road. Similarly, if one man is unmolested in turning the effluent from his mill into a stream, it may drive his neighbor downstream to drill deep wells in order to introduce a new water supply into his works. Instances of this sort of thing might be multiplied, but it is enough to recognize the fact that though a river basin may lie in several States, as does the Potomac, its people are more closely bound together by its waters than are the inhabitants of a single State by the arbitrary boundary lines established for them. The silver river threads are direct lines of communication between each individual and every other below him on the stream. The offenses that he commits against the water are paid for by his fellow countrymen in the basin, and the bill is large or small according to the gravity of the transgressions.

INDUSTRIES DISCHARGING WASTES INTO THE STREAMS.

In order that a clear understanding may be had of the various wastes which enter the Potomac, a description of the manufacture of the principal products of the Potomac basin is subjoined.

LEATHER TANNING.

Pelts are divided into three classes, according to their size. Hides are skins from large and fully grown animals, such as the cow, ox, and horse, and make heavy leather, such as shoe soles, belting, and trunk leather. Kips are the skins from yearlings of the above species or from undersized animals. Skins are obtained from small animals, such as calves, goats, sheep, and dogs, and yield a lighter leather, suitable for a great variety of purposes. The thickest and heaviest hides come from sparsely settled countries, and a hide varies in thickness and texture in different parts, being thicker on the neck and butt than on the flank and belly. The skin of the animal is made up of three layers. The first or outer layer is known as the epidermis, and consists of a dead layer which is continually being worn off and of a live layer which renews the dead layer as it wears away. To this epidermis the hairs of the animal are attached. The second layer, or corium, is the true skin, and the only part of the hide which is valuable in making leather. It consists of connective tissue composed of bundles of fibers which interlace somewhat closely on the under side, but are closely matted on the epidermal side. The third and inmost layer is a loose network of connective tissue, containing muscular fibers, fat cells, blood vessels, and sudorific glands, whose ducts pass through the corium and epidermis.

The pelts come to the tanner "green" (fresh from the slaughterhouse), wet, or dry salted (with the salt rubbed on the flesh side), or as dry hides. The dry hides are mostly imported from South America. Green pelts are usually washed in clear water to free them from blood and dirt; salted pelts, if not dried, are washed in several changes of water to remove the salt, which retards the action of the lime in the unhairing processes and also induces efflorescence (spewing) on the finished leather. Dried hides must be softened by soaking them in lukewarm water or in the liquor drawn from the soaking of a previous lot. The water dissolves a part of the hide substance and putrefaction soon begins, the liquor developing an alkaline reaction, owing to the formation of amines and ammonia, which give it a much more rapid softening action on the skin. Great care is necessary in using this "putrid soak," for it is likely to attack the hide itself. The time of soaking varies from two or three days to as many weeks, depending on the thickness and dryness of the hide and the age and temperature of the soak liquors. When the hide is soft enough to bend in a short turn without cracking, it is put into the "stocks," where it is pounded and rolled under heavy wooden mallets and rolls.

The character of the water used in a tannery is important. Soft water makes the skins thin and slim, which is desirable in light leather. Water containing calcium or magnesium sulphate "plumps" or swells the hide, thus exposing a larger surface to the action of the tan liquors, which is desirable for heavy hides. Water bearing carbonates of lime or magnesia gives trouble, because in the tan pits these salts are transmuted into tannates of lime and magnesia, and these rapidly oxidize in the air into tan-oxalic and tan-melanic acids, which impart a reddish-brown color to the leather. Ferruginous waters can not be used in tanning, for the ferric salts combine with the tannin and produce a black coloration of tannate of iron. Chlorides cause the hides to "fall;" that is, to become thin and flabby. Perhaps this is due to the greater solubility of the coriin in saline liquors. If used for washing after the liming, water having temporary hardness tends to fix the lime among the fibers in an insoluble form, thus causing the leather to be harsh on the grain and producing color spots because of unequal deposits of tannin and coloring matters while the skin is in the tan pits. If the water contains organic impurities it may have an acid nature and cause the hides to "fall" after liming. Highly polluted waters can not be used in tanning, because the putrefactive bacteria attack and destroy the hides.

The "putrid soak" and the liquor from the washings of the green and salted hides are uniformly discharged into the nearest creek, being regarded by the tanner as so much dirty water and nothing more. As a matter of fact, this liquor contains much salt and organic matter. The putrid soak may also contain cresol or other preservatives, which are sometimes used in conserving the dried hides. The soak liquors may be the means of spreading anthrax. An outbreak of this disease occurred in Pennsylvania in the spring and autumn of 1897 and was investigated by Ravinel. Three tanneries operated by the United States Leather Company were involved. It was found that each of them had received a part of a cargo of hides from Chicago, and it was believed that they were the fomites which spread the disease. In one of the tanneries twenty-four cases of "malignant pustule" developed, one of which proved fatal. Below this tannery 12 head of cattle died, some of the deaths occurring as much as 10 miles downstream. In all, 12 men and 60 head of cattle died near the tanneries. The men were without exception operatives, while the cattle were on pastures watered by the streams carrying tannery effluents.

Bacteriological experiments were conducted which led to the conclusion that the process of tanning as ordinarily carried out does not in any way protect the operative from infection by the anthrax germ.[a]

The second step in tanning is the "unhairing" of the hides, and this is accomplished in two ways—either by sweating or liming. Green hides are usually sweated by allowing them to hang in a room where the temperature is 70° F., and permitting disintegration to advance to the point at which the hair can be readily removed mechanically, but beyond which the hide is injured by being itself attacked. Before passing to the next stage, treating with tannin, sweated hides must be "plumped" by immersion in dilute acid, such as hydrochloric acid. In liming, the skins are laid in a vat or pit with milk of lime, which

[a] Trans. Am. Pub. Health Asso., vol. 24, 1899, p. 303.

loosens the epidermis and forms a soap with the fatty matter. It also dissolves the coriin—the intercellular substance which fills the spaces between the bundles of fibers—loosening the fibers, which swell and plump the hides. Lime is used in excess in amounts varying from half a pound for a small, light skin, to 4 pounds for a heavy one. The vats or pits when prepared to receive the skins are called limes. The skins are turned over and worked about at intervals while in the vats. Heavy hides, which are to form a stiff, hard leather are limed for only few days, but when a soft, elastic, and pliable product is desired the process is continued for fifteen to twenty days or longer. Warming the limes to 85° or 90° F. hastens the action very much, but causes the skins to "fall." Dried hides are often treated by adding sodium sulphide to a thick cream of lime, forming a paste which is spread on the hair side of the skin, after which the hide is folded together, when the hair can be easily removed after a few hours. This process depends on the formation of calcium sulphide, which dissolves the hair, in contrast to the process employing lime alone, which dissolves the hair sheath as well as the intercellular substances and softens the epidermis, which comes off when the hair is scraped. Sometimes the sodium sulphide is added in solution to the milk of lime instead of being applied as a paste. Still another process for unhairing dried hides is the adding of arsenic sulphides to the amount of 10 per cent of the weight of lime. This forms calcium sulfarsenite ($HCaAsS_3$), which is a very rapid depilatory. The waste from the lime pit is frequently turned directly into the nearest stream, but the best tanners utilize it as a fertilizer by running it into pools, where it is allowed to evaporate. The accumulated material is applied to the land, on which it seems to have a very good effect, probably on account of the large amount of organic matter derived from the hides, though the lime itself may in some cases be valuable to neutralize acid soils. It is not likely that those "limes" which contain arsenic could be used in this manner, and they cause much trouble in those places where entire tannery wastes are treated by intermittent filtration, because they kill the bacteria, which, of course, destroys the action of the filter bed. It is wasteful and unnecessary to dispose of the lime waste by running it into a stream. It should always be recovered as a fertilizer.

When the hide has been unhaired by one of these processes, it is washed, and the washings are added to the liquors wasted from the lime vats; it is then ready for the "beam," a peculiar sloping bench or table on which the hides can be spread out and conveniently worked. On the beam the hair and epidermis are scraped off with a blunt knife, and the fatty tissues are removed with a sharper one. After trimming off the waste parts of the skin it is thoroughly washed and is usually again scraped on the beam ("scudded"), to remove as much of the lime as possible. The hair is sold for cheap cloth and blanket manufacture, or most usually is disposed of to plasterers. The flesh and partially saponified fat which are removed from the inside of the hide are collectively known as "fleshings," and are either dried and sold to glue manufacturers or are rendered and the fat sold for the manufacture of dégras. The liquor which results from rendering the fleshings is turned into the nearest watercourse, but it should go to the lime pool. From the beam house the hides which are not to be made soft and pliable go directly to the tanning liquors, while those skins to which it is desired to impart these qualities are "bated" or "puered." Bating consists in soaking hides in a mixture of dog or bird dung in warm water. This quickly becomes putrid and evolves hydrogen sulphide. By some it is claimed that the bate merely removes the lime from the pores of the hide, while others assert that it also takes away some of the coriin, thus leaving the fibers looser and allowing more perfect action of the tan liquors. The latter view seems to be more probable, for there is little doubt that the bacteria in the bate do feed on the hide substances. Moreover, the forms of tripepsin, pancreatin, etc., present undoubtedly have some function, for when used alone they will cause a "plump" skin to "fall." Also the ammonia salts formed probably assist in the solution of the lime and the skin. The process lasts from two to four days, according to the thickness of the skin and the temperature. It is largely dependent on atmospheric conditions, being much more rapid in warm, sultry weather, such as precedes a thunderstorm, when a few hours are often sufficient to injure the skin. At all times great care must be used and the skins stirred about frequently to prevent too great local action, which would produce thin places or holes in the leather. Many proposals have been made to replace the offensive bate with pure solutions of weak mineral and organic acids, but such substitutes have not been successful, the objection being that they make the leather harsh and of a bad grain.

To effect a complete removal of the lime the skins are passed from the bate into the "bran drench," an infusion of bran and water at a temperature of about 89.5° F. Acetic and butyric acids are developed and neutralize the lime. The wastes from the bate and drench are not large and should be utilized for fertilizer in the same way as the spent lime liquors. This, however, is rarely done, the custom being to turn them loose into some stream. Both the light and the heavy hides are now ready for the tanning process. There are three kinds of tanning—with tannin in any form (vegetable tannage), with metallic salts (mineral tannage or tawning), and with oils or fats (oil tannage). As only the first process is used by Potomac valley tanneries it alone will be described.

The tanning liquors are usually made by extracting finely ground chestnut-oak or hemlock bark with water. Hides treated with infusions of the former make a tough, durable leather known as oak-tanned; infusions of hemlock bark make a hard, stiff leather known as hemlock-tanned; a combination of the two produces union-tanned goods. Hemlock-tanned leather is of two varieties—acid and non-acid. In oak, nonacid, and union tanning the processes are essentially the same, and so only oak tanning and acid hemlock tanning will be described.

Good tanning material yields other extractive matters than tannic acid when treated with water. They are nontannins and consist mainly of sugars, gums, resins, and coloring matters, which assist in tanning in several ways. Some of them are directly absorbed by the skin, increasing its weight and solubility; others set up fermentation in the tan pit, producing organic acids, which assist in the formation of a leather of good body and weight. Tannins derived from gallic acid cause a white efflorescence (ellagic acid) on the leather, while those of the protocatechuic-acid group deposit red coloring matters (phlobaphenenes). The tan liquors are prepared by systematic lixiviation of the ground tan stuffs. Warm water is generally used for extracting the ground bark, and the process is usually carried on at the top of the tannery, so that the liquor can be readily distributed about the works, either to pits which are to be strengthened up or to those which are to be filled anew. Prepared tanning extracts are often used, either alone or in conjunction with the liquor obtained by extracting the bark at the tannery. These prepared extracts are frequently adulterated with glucose or molasses, so that tests with the barkometer—a special form of hydrometer used for determining the strength of tan liquors—are of no value. In tanning, the hides ("butts") are first hung from frames in vats ("suspenders") containing weak or nearly spent tan liquors from a previous lot. There they are mechanically agitated in order that they may take up the tannin evenly. Weak liquors are used at first, because strong ones would harden the surface of the butt and prevent the thorough penetration into the interior of the hide. This partial tannage strengthens the hides sufficiently for them to withstand the rough usage which they receive when transferred to the "handlers"—vats where the hides lie flat in a pile and are worked over ("handled") once or twice a day for a month or six weeks. There are several of these vats, and the hides are treated systematically first with weak and then with stronger liquors, after which they are put into the "layers"—pits filled with alternate layers of hides and ground bark and velonia, etc. Strong liquor ("ooze") of 35° barkometer is run in until the hides are submerged, and the pit well is then covered with ground bark to exclude the air. After eight or ten days the hides are taken out, rubbed clean, and "laid away" again in fresh tan and stronger liquor, in which they remain a longer time. This process is often repeated, the time consumed being on an average from eight to ten months. The process may be hastened by keeping the liquor in the tan pit in constant circulation, or by using pressure to force the liquor into the skins, or by using strong extracts and continually moving the skins. As a rule, however, rapid tannage makes the hides lacking in substance ("hungry") or brittle. In oak tanning, of sole leather, usually one hundred and twenty to two hundred days are consumed. When the hide comes from the lay-away vats it is covered with a "bloom" of ellagic acid, which sole-leather and harness-leather tanners remove with "scouring machines" to improve the appearance of the goods. Scouring requires considerable water, which is stained red by the process. The waste is uniformly turned into the nearest stream and of course discolors it.

In acid hemlock tanning, the hides are first colored with a weak solution of tannin, after which they are abnormally swelled by being put in a 10 to 30 per cent bath of sulphuric acid, where they remain for twenty-four to forty-eight hours. They are then put in a stronger tannin solution and are finished in one hundred and sixty days.

The waste tan liquors or sour bark liquors, as they are usually termed, are usually the most voluminous wastes from a tannery and consist of a small percentage of tannic and gallic acids, with considerable organic matter in suspension. They are usually discharged into a stream, either constantly or in large volumes, at regular intervals, and are always strong enough to color the water a deep red and to stain the banks and bottom of the stream. The volume is so large that this waste is difficult to treat. The most successful way of dealing with it known at present is that devised by the Massachusetts State board of health; in this process it is mixed with city sewage and treated by intermittent filtration. Such a method of treatment could not be applied in the Potomac drainage area, because the tanneries are located in places where city sewage is unavailable. Some tanners claim that they have practically no waste of sour bark liquor, because they maintain a constant circulation of the liquor through their works; that is, when the liquor is so depleted as to be of no further use for tanning it is run back onto fresh ground bark, where its strength is renewed. In tanneries of this type it is generally found necessary to waste the tan liquor which first receives the hide after it comes from the "beam," as the lime salts extracted at that time are thought to be sufficient in amount to affect large volumes of tan liquor, making it turn out a brittle leather. Many tanners refuse to adopt this continuous-circulation process, claiming that they can not get the kind of leather they are in the habit of producing by its use.

After hides are tanned they are washed in clear liquor, and when they have dried somewhat they are oiled on the grain and hung on poles in the drying loft. When about half-dry they are laid in piles ("sammed") and allowed to sweat, so as to facilitate the "striking" operation which follows; this is done by hand or machinery. They are then allowed to dry a little more, and finally they are rolled again, after which they are ready for the market, though in some factories the hides are colored on the grain side by a mixture of ocher with size and oil to give the leather gloss.

In the final finishing up of the leather—that is, in cases where hides are oiled or stuffed at the tannery—considerable oil escapes into the nearest creek, making it unsightly.

The spent tan bark, which formerly caused much complaint when it was discharged into the stream and allowed to accumulate about the tannery, is now disposed of without trouble, because it has been discovered to be a valuable fuel and is used for such both in extract plants and tanneries. But a single instance was found in the course of this investigation where any trouble was caused by spent tan bark. This was at Moorefield, where a tanner had accommodated the proprietor of a gristmill by furnishing him spent tan bark to stop the many leaks in the old dam which furnished power to the mill. It was said that the stream was considerably discolored in consequence.

To sum up the wastes from the processes of tanning, most of them are putrefactive and therefore add materials to the stream which make it capable of sustaining bacterial life, and for this reason their presence is objectionable. Moreover, when all the wastes are turned into a stream, unless it is a very large one, they discolor it, making it unsightly and also cause a great nuisance by the odors of decomposition which rise in the stream and in the vicinity of the tannery. Where tannery effluents are discharged into streams polluted with mine waters large quantities of tannate of iron are formed, thus literally converting the waters into rivers of ink. It is needless to say that this condition is vigorously resented by all who are unfortunate enough to be brought into contact with it.

MANUFACTURE OF TANNING EXTRACTS.

Tanning extracts are made by leaching various finely ground tannin-bearing materials, such as sumac and chestnut-oak wood, in water and then evaporating the solution to a thick sirup. It is perfectly possible to manufacture the extracts without offense, but leaky vats produce extensive discoloration of the streams into which they discharge, and in certain places this causes much complaint. An entirely negligible amount of tannin escapes in the condenser water from all extract factories. Carbonate waters are unsuitable for the manufacture of extracts for use in dyeing, as they form "lakes" with the dyes, and consequently loss of coloring matter ensues. The concentration of large volumes of the tannic juice made with carbonate waters causes the precipitation of normal carbonates of lime and magnesium, which are harmful in the tan pits. Iron in the water combines with the tannic and other acids extracted, forming ferric compounds, which give dark-blue, olive, and green precipitates that not only discolor hides, but waste the tannin-forming materials from which the extract is made. Moreover, compounds of the tannic acids with salts of the alkaline earths result when water containing appreciable quantities of these salts is used in extracting. Thus the extracts produced are poorer, and the process of manufacture is slower, because the deposits prevent the water from penetrating into the woody fiber.

MANUFACTURE OF WOOD PULP.

There are three common ways of manufacturing wood pulp, known as the mechanical, the soda, and the sulphite processes. The first two of these are used in the Potomac Valley and will be briefly described.

Mechanical wood pulp.—The bark is first shaved off the wood and then the knots are removed, after which it is cut up into blocks, gaged to the width of the stones used in grinding. These stones are usually imported from Scotland and are of sandstone, covered over three quadrants with an iron casing, the fourth being left bare. The faces of the stones are kept rough, as they revolve, by a steel roller studded with points, which is pressed against them. In addition to this, two sets of channels, which cross each other in the center of the stones, are cut into them about one-quarter of an inch deep at distances of 2 to 3 inches. They carry the pulp to the sides of the stones and give them increased grinding surface.

The wood is forced against the revolving stones, over which a water jet plays, and by means of screws worked by a suitable gearing is held at the steady pressure necessary to insure a pulp of uniform character. The water jet carries away the pulp as fast as it forms, first to the rake, which catches the splinters that have escaped grinding; then the stream of pulp passes through the sorters, cylinders 3 feet long and 2 feet wide, of wide-meshed wire cloth, which separate the insufficiently disintegrated fragments. The fibers that are retained are subsequently reduced to the proper size in the "refiners," which are cylinders of sandstone, one above the other, the upper one of which revolves. The material that passes the refiners is again screened and returned to the pulp stream, from which the sorter is conducted through a series of screens of gradually increasing fineness, and thus graded into different qualities. The ground and sorted pulp, mixed with water, flows into a tank in which revolves a cylinder covered with wire gauze. The water passes through the cylinder, while the pulp adheres and is delivered to an endless belt, which carries it to a pair of squeeze rollers. The pulp is compacted in passing through these rolls and sticks to the upper one, from which it can be readily removed when it has become sufficiently thick. Finally, it is cut into sheets, which are pressed into boards of convenient size for transportation. Mechanical wood pulp is suitable only for the cheapest kind of paper, such as newspapers, because the fibers are short and do not felt together well, hence the paper lacks strength; moreover, it yellows readily, as the lignin and resin which the pulp contains predominate. Mechanical wood pulp is much used as a filler in manufacturing certain kinds of paper.

No chemicals are used in this method of pulp production, so that there are no liquid wastes to produce noxious effects on streams and lakes, but the shavings and the finest fiber that escape cause bitter complaint. (See Pl. VIII, *B*, p. 222.) They soon become water-logged and sink, accumulating rapidly on the bottom of the stream, with the result, as one old fisherman aptly put it, "that the bedding, feeding, and breeding grounds of the fish are destroyed." The effect on the spawn is particularly bad, for the motion of the water rolls the material over the eggs and smothers them. Besides, in time the mass begins to rot and then certain gases are liberated, which also may have a harmful effect on fish life.

It is wholly unnecessary to dispose of the shavings in the streams, for they can be burned at no great expense, and the laws which prohibit sawmill pollution should be extended to cover mechanical pulp mills.

Soda wood pulp.[a]—In the manufacture of soda wood pulp the logs are cut to thin shavings and are treated for about eight hours in digesters with a caustic-soda solution at a pressure of about 100 pounds of steam. After being washed the pulp is bleached by a solution of chloride of lime, the process consuming from six to eight hours. When the bleaching is complete the mass is reduced to a more fluid state by the addition of water and is pumped into large vats with porous bottoms through which the water runs. When the bleached pulp is thoroughly drained it is pumped into a large storage vat, from which it is taken to a cylinder machine and is felted in the usual manner.

The soda solution drained from the wash pans is treated in order to recover the soda. It is evaporated and the concentrate is turned into rotary furnaces where the lignin and other organic materials are burned off. The residue is composed almost entirely of carbon and sodium carbonate and is known as black ash. This substance is then passed through a bleaching process, the liquid or recovered soda

[a] For a full description of the processes used in the manufacture of soda wood pulp see Water-Sup. and Irr. Paper No. 121, U. S. Geol. Survey, 1905, pp. 24–33.

(sodium carbonate) being conducted to the causticizing plant, while the sludge, known as black-ash sludge, remains in the tanks and is subsequently washed out with water and carried away as waste.

The soda recovered in the form of carbonate is converted to a hydrate or caustic soda by the application of caustic lime. The result is a sodium hydrate or caustic soda in the solution, while the calcium carbonate, or common lime, remains in the bottom of the container as a heavy sludge. The solution is drawn off for use in the digestion process. Considerable soda remains in the lime sludge after causticization, and repeated washings are necessary to recover all the soda. When the washings are completed the lime sludge is discharged.

The solution used to bleach the pulp is prepared by the treatment of chloride of lime in solution tanks fitted with rotary agitators. The bleach is drawn off from the tank and the sludge is again treated in order to utilize all the bleaching solution, and the lime sludge left after the second treatment is discharged as waste.

The important wastes are (1) the black-ash sludge, which is mainly carbon, with a small percentage of undissolved carbonate of soda; (2) the lime sludge ($CaCO_3$) from the causticizing process, which also contains a little soda; (3) the lime sludge ($CaCO_3$) from the bleaching process, which contains a very appreciable amount of chlorine. To these should be added the considerable amount of wood fiber that escapes from the mill, and the bits of wood from the chipper. In some factories the various sludges are sedimented with good results, large quantities of suspended matter being thus kept out of the streams.

At Luke, Md., there are no sedimentation beds and North Branch receives the entire waste of the West Virginia Pulp and Paper Company, which, in addition to the effluents above enumerated, contains alum, kaolin, a little ultramarine blue, and size. The effect of this pollution on North Branch is to increase the chlorine and alkalinity of the water. But these elements serve to neutralize the acid waters of Georges Creek, with good results.

MANUFACTURE OF ILLUMINATING GAS.

Coal gas.—Coal gas is made by the destructive distillation of bituminous coal. The by-products of the process are ammoniacal liquors, tar, and coke. In large plants the first of these is sold to ammonia works; the second to works for recovering coal-tar products, and the third is used for fuel in the plant or sold for domestic consumption. Small works are compelled to waste the coal-tar products and the ammoniacal liquors into the nearest watercourse, unless they are sufficiently near to recovery plants to make it profitable to ship them.

The retorts in which the coal is distilled are of fire clay, and in the various works are differently designed. The gas is led from the mouth of the retorts by vertical pipes to a pipe dipping downward into a hydraulic main and extending beneath the surface of the water which partially fills the main, the back flow of gas to the retorts being thus prevented. The hydraulic main is a long covered trough to which all the retorts are connected. In it most of the tar and oily products condense beneath the water and flow to the tar wells, while the water itself dissolves most of the ammonium salts out of the gas.

The hydraulic main leads the gas to the condenser, which is constructed in several ways, but always with the purpose of cooling the gas in long iron pipes, whose lower ends dip beneath the surface of water held in an iron tank. The lowering of temperature effects a condensation of those constituents of the coal gas which at ordinary temperatures are not volatile, and forms a tar of them, which sinks to the bottom of the tank and flows to the tar well. At the end of the condenser is an exhauster, which keeps under suction the gas in its passage from the retorts to the end of the condenser and puts the rest of the plant under pressure.

From the condenser the gas is passed by the exhauster into the tar extractor, a short tower filled with many horizontal, perforated plates, in passing through which the gas is relieved by friction of its last traces of tar. It then goes to the scrubber, where it comes into contact with thin films of ammoniacal liquid from the hydraulic main or condenser, which trickles over pebbles, coke, etc. This liquid absorbs from the gas some of the carbon dioxide and hydrogen sulphide, which combine with the ammonia. From the scrubber the gas goes to the washer, where clean running water removes the ammonia.

The gas next flows to the purifiers, where its sulphur compounds are taken out. The purifiers are covered iron boxes which hold on a grating either slacked lime or hydrated ferric oxide. The gas enters from below and passes through the lime or iron, yielding up its sulphur as it does so. Usually the gas passes through four purifiers in succession. The lime in addition to removing the sulphur compounds combines with the carbon dioxide which the gas carries and which is an undesirable constituent. The iron extracts only the sulphur. In time both iron and lime become exhausted, being converted by the sulphur into very ill smelling sulphides. The iron can be renewed two or three times by exposing it to the air, which oxidizes it. In the end, both substances have to be disposed of, which is done by dumping them into the nearest stream, or sometimes by selling them. From the purifiers the gas goes through the meter house into the holders, from which it is delivered to the mains. The wastes in the manufacture of coal gas in works of considerable size favorably situated for shipment are all recovered, because the by-products obtained from them are valuable. Many small plants scattered about the country find it impossible to ship these products at a profit and therefore they turn them into the nearest watercourse, where they produce a highly objectionable state of affairs. The light tars float as an oily iridescent film on the surface of the water, giving it a disgusting appearance. The heavy tars sink to the bottom and foul the bed of the stream. The effect of the ammoniacal wastes is not visible, but ammonium salts are good food material for bacteria and microscopic organisms, and therefore the tendency of such wastes would be to foster their development. Moreover, gas wastes are believed to be very fatal to fish, and even when present in quantities insufficient to kill the hardy varieties, they impart a flavor of gas to the flesh which compels their abandonment as food.

Water gas.—Water gas is produced by the action of steam on incandescent carbon and is composed mainly of hydrogen and carbon monoxide. It has a high heat value, but is a poor illuminant, and therefore it has to be enriched with various hydrocarbons, such as ethane, ethelyne, acetylene, and benzene, which impart to it the necessary light-giving quality. As these substances are yielded by petroleum, it is used to carburet the gas.

The manufacture of water gas is carried on in three chambers. The first is called "the generator," the second "the carburetor," and the third "the superheater." The chambers are circular, the superheater being the tallest. Both it and the carburetor are lined with fire brick and are filled with a checker work of the same material.

Anthracite is put into the generator and brought to incandescence by a blast of air which is introduced at the bottom. Thus is liberated a gas known as "producer gas," which consists mostly of nitrogen, carbon dioxide, and a little carbon monoxide. This producer gas escapes into the top of the carburetor, and in circulating down through it is partly burned by a blast of air introduced near the top of the chamber. This combustion makes the brickwork hot. From the bottom of the carburetor the gas is conducted to the bottom of the superheater, where another blast accomplishes the complete combustion and raises the checkerwork to red heat, the gases finally escaping through a hood at the top of the chambers. When both the carburetor and superheater have reached the desired temperature the air blasts are shut off and superheated steam is blown in at the bottom of the generator. This forms carbon monoxide, or water gas, which passes into the carburetor, where it meets a stream of oil introduced at the top. The oil is decomposed into illuminants which mix with the water gas and pass into the superheater, where they are completely fixed as incombustible gases.

From the superheater the gas is led to a holder, from which it passes through a purifying apparatus involving principles identical to those that obtain in the manufacture of coal gas.

Water gas is very poisonous owing to the large percentage of carbon monoxide that it carries, and much of the harm that is commonly attributed to so-called sewer gas comes from defective gas piping and inefficient burners in conjunction with the water-gas service.

The tar from the manufacture of water gas is of less value than that from coal-gas production. It can be recovered and used as fuel in the plant, thus obviating the objectionable effects, similar to those of coal-gas tar, which result when the waste is turned directly into a stream.

MANUFACTURE OF AMMONIA.

The chief source of ammonia is the gas liquor from the hydraulic mains and scrubbers of coal-gas works. By destructive distillation the nitrogen contained in coal is largely converted into ammonium salts, the principal of which are the carbonate, sulphide, and sulphohydrate, which are volatile in steam, and the sulphate, thiosulphate, sulphite, sulphocyanide, and ferrocyanide, which are not. All of these compounds, together with free ammonia, are found in gas liquor.

The gas liquor received at the ammonia works is allowed to stand in order that the tar may settle out, and then clear liquor is distilled to separate the ammonia. There are several forms of apparatus for this purpose. In the simplest of them the liquor is heated in one still until all the volatile salts are expelled, after which it is drawn into another, where milk of lime is added. Then heat is again applied until the fixed salts are decomposed and the ammonia is driven off. The ammonia and volatile salts are condensed in a chamber containing sulphuric or hydrochloric acid. Some hydrogen sulphide and other foul-smelling gases pass out of the absorption vessel and are led into the chimney or otherwise disposed of.

The only liquid waste from ammonia works is the lime sludge from the exhausted milk of lime. It should be sedimented and the solid portion sold as fertilizer, for which it is well suited on account of the traces of ammonia salts that it contains. The supernatant liquid on the sedimentation beds contains lime salts in solution and is usually disposed of by running it into a convenient stream.

WOOL SCOURING.

Before raw wool can be manufactured it must be freed from the impurities which constitute 30 to 80 per cent. of its total weight. They consist of the "yolk" and suint, which exude from the body of the animal with the perspiration, and the dirt and dung mechanically mixed with them. The yolk is made up of fatty or waxlike bodies which are not easily saponified with alkali, but which can be emulsified with soap solutions and thus easily removed from the fiber. The suint consists mainly of potassium salts of acetic and fatty acids, together with sulphates, chlorides, phosphates, and nitrogenous bodies. All these substances are generally removed by washing the raw wool in especially designed machines. It was formerly a common practice to wash wool in stale urine, which was effective because of the ammonium carbonate it contained. This has been largely replaced by ammonia, soaps, etc. The wool is first immersed in a soap solution which contains more or less impurities from its previous use. From this machine it passes into a second containing cleaner water and finally into a third which contains clear water or fresh soap liquor.

The wool is then taken out and dried, while the foul-smelling, dirty-brown liquor from the first machine is sometimes drawn off, evaporated, and calcined to recover the potassium salts, which amount to 1 to 8 per cent of weight. In some countries the liquor in which the wool is washed is treated to recover the wool grease. To do this the liquor from the third tank is settled to remove the coarse dirt, and then sulphuric acid is added to decompose the salts and set free the fatty acids, which rise to the surface and carry the wool grease with them. The water is drawn off from the magma, which is placed in canvas bags. The grease is kept in liquid condition until all sediment is deposited, when it is turned into casks, in which it solidifies on cooling. It is used as a lubricant and in leather dressing.

In this country the potassium salts are rarely recovered, it being customary to run the entire waste to the stream. Some of the largest mills now remove the fats by a gasoline process and afterwards wash the wool to free it from dirt. The fats thus saved are valuable by-products. The amount of water used in scouring wool is usually 100 gallons to the pound, though in some works it rises to 200 gallons. In a modern process of washing now coming into use the amount of water is reduced to 50 gallons. The liquid resulting from scouring wool is large in volume and rich in organic matter and in mineral matter in suspension and solution, and is not readily acted on by the agents of decomposition, putrefaction, and nitrification, so it is a most undesirable addition to the waters of a stream. It is well to distinguish between the scouring liquor proper, which is small in volume and contains most of the impurities, and the rinse water, which is of great volume and is relatively clean. The Massachusetts State board of health has found that wool scourings can be purified by sand filtration, after being mixed with considerable quantities of city sewage. So far as Potomac River is concerned, however, this is not important, for city sewage in many places is not to be had.

WASHING WOOLEN CLOTH.

In the process of washing woolen cloth large quantities of water are used, and the water is grossly polluted thereby, for it becomes charged with organic matter. When the rinse from the finished goods is discharged into streams, it adds considerably to the putrescible material they contain and is therefore exceedingly undesirable.

Waste from shoddy mills consists of dirt and organic matter washed from the rags and stock. Large quantities of acid are often used and the wastes are decidedly deleterious in their effect.

DYEING.

General discussion.—The art of dyeing consists of imparting to various substances, mostly fabrics, a color of considerable permanence. Dyes are distinguished from pigments by their solubility in water, and a pure supply of that element is a necessity to the trade. The solution of the colors requires care, those derived from coal tar being particularly prone to spot and streak the goods, if this part of the process is carelessly performed. The dyeing is done in iron, wooden, or stone vessels, whose shape and capacity are adapted to the amount and quantity of goods handled. Some dyes require a high temperature, while others are injured by much heat. In any case, direct heating is always avoided, it having been found best to heat the vats by steam coils.

The phenomena of dyeing are explained by the mechanical and the chemical theories. The former assumes a mechanical absorption of the coloring matter into the pores of the fiber, while the latter regards the process as a chemical combination between the dye and some or all of the constituents of the fiber. The chemical theory seems the better adapted to animal fibers, but the mechanical theory is perhaps more applicable to vegetable fibers.

Thorp groups dyes into five classes, according to the method of their application—(1) direct dyes, which yield full colors with the use of a mordant; (2) basic dyes, which form insoluble tannates and require a mordant on vegetable fibers, but which dye animal fibers without a mordant; (3) acid dyes, which do not require a mordant on animal fibers, but which have only a limited use on vegetable fibers; (4) mordant dyes, which require a mordant on both animal and vegetable fibers; and (5) special dyes, which can be applied to the fiber only by special processes.

The trade distinguishes between substantive and adjective dyeing. In substantive dyeing the colors are applied to all fibers without a mordant, but "assistants," such as Glauber's salt, sodium phosphate, borax, soda, and soap are used with them to insure an even disposition of the color, thus avoiding streaky results. The assistants do not combine with the color. As direct dyes are very soluble, the goods are likely to bleed when washed, but silks take them very well, giving brilliant shades and fast colors. A little acetic acid makes them fast milling. Adjective dyeing requires the use of a mordant. Mordanting is of prime importance, and has for its object the precipitation on the fiber of some substance which has an affinity for and which will effect a more or less complete fixing of the coloring matter used for dyeing. The nature of the mordant depends on the character of the fiber, the kind of dye, and the effect sought. Wool is usually mordanted by boiling it in a solution of a metallic salt in the presence of some acid; bichromate of potassium and sulphuric acid are often used. Silk can be mordanted in this way, but it is usually done at lower temperatures. Cotton has little affinity for coloring matters and has to be specially prepared. It has an affinity for tannic acid and so is commonly steeped in a solution of sumac or catechu, after which it is washed and worked in a bath of some soluble metallic salt. An insoluble compound results which then has the property of uniting with the dye. It is not always necessary to treat cotton with tannin, for an immersion in the mordant followed by oxidation or ageing is sometimes sufficient. The operations of dyeing are multifarious, and it would be out of place to detail them here. Only the enumeration of some of the chief mordants will be attempted, with the description of a few common processes, in order to give an idea of some of the substances that may be met in dye-house effluents. The mordants are both mineral and organic. They are as follows:

Mineral mordants:
- Aluminum acetate.
- Aluminum sulpho-acetate.
- Ferrous sulphate.
- Ferrous acetate.
- Nitrates of iron.
- Nitro-sulphates of iron.
- Potassium bichromate.
- Copper sulphate.

Mineral mordants—Continued.
- Copper nitrate.
- Tartar emetic.
- Stannous chloride.
- Stannous nitrate.

Vegetable mordants:
- Tannic acid.
- Sumac.
- Catechu.

As assistants the common mineral acids are used, also acetic, oxalic, tartaric, and citric acids.

Cotton dyeing.—Indigo requires no mordant and is always applied cold. A common method is to make a mixture in definite proportions of water, lime, copperas, and indigo, and apply it in a series of vats. Zinc powder often replaces the copperas.

Methylene blue is used to produce indigo shades. The cotton is mordanted with sumac at 160° F., given several turns, and allowed to steep for ten hours, after which it is wrung out and worked for twenty minutes in a 2½ per cent solution of tartar emetic. Then it is washed and dyed in a bath prepared with 3 per cent acetic acid at 75° F., the temperature being gradually raised to 160° F.

Aniline black is a dye of unknown constitution, and the color is produced directly on cotton by means of aniline oil in the presence of oxidizing agents. Two methods of procedure are used—the warm and the cold. In the warm method 75 parts of water, 32 of hydrochloric acid, 16 of potassium bichromate, and 8 of aniline oil are taken. The acid and aniline are each diluted with water and carefully mixed. The solution thus obtained is then added to the main volume of the water. The potassium bichromate is previously dissolved and added after the aniline. The cotton is immersed and worked for three-fourths of an hour in the cold, after which the temperature is gradually run up to 140° or 150° F. In the cold method 18 parts of hydrochloric acid, 8 to 10 of aniline oil, 20 of sulphuric acid at 66° B., 14 to 20 of potassium bichromate, and 10 of copperas are compounded as in the warm process, except that much less water is used. The goods are worked in one-half of the material for an hour or so, after which the rest is added and the operation continued for about one and one-half hours longer, when the goods are washed and boiled in a soap solution. In both processes the cotton is subjected to further oxidation with potassium bichromate, copperas, and sulphuric acid, which tends to prevent greening. Chlorate of soda is frequently used as an oxidizing agent in the dye bath, in which case the replacing of the potassium bichromate with vanadium chloride or vanadate of ammonium has been recommended.

Linen dyeing.—The uses to which linen is commonly put make it necessary that the colors it is dyed be fast. Accordingly, alizarin and indigo are generally used.

Wool dyeing.—Indigo is easily applied and extensively used to produce light and dark shades on wool by simply boiling the goods in a bath of the dye, sulphuric acid, and sodium sulphate. Loose wool is dyed in the so-called fermentation vat by keeping the wool below the surface of the liquid and working it with long rakes. After a sufficient time it is taken out and put in cord bags or upon rope screens and drained and oxidized, being then dipped into a dilute acid to remove the soluble impurities. Finally it is washed and dried.

Logwood is the real base of the blacks on wool, and is used with potassium bichromate as a mordant. As a rule the coal-tar colors are applied to wool without special treatment at boiling temperatures in a bath of 10 per cent sodium sulphate and 2 to 4 per cent of sulphuric acid.

Silk dyeing.—Silk has a great affinity to coal-tar colors, and can be dyed without a mordant, though soap is commonly used to prevent spotting and streaking. Heavily weighted goods are obtained by dipping them in an iron solution and then in liquids containing tannin, a process that is often repeated several times.

Besides the dyes mentioned in the above processes the following are in common use: Fuchsine, safranine, methyl-violet, and methyl-green.

Résumé.—The amount of organic matter contained in dye wastes is as a rule small, so that apparently they hurt the streams chiefly by discoloring the water. In places this may be a serious nuisance, while elsewhere it may be a trifling matter. The extent of the injury is determined by the use to which the water that receives these dyes is put. In some processes of dyeing much organic matter is washed from the cloth, and then the pollution assumes a new character and becomes important.

MANUFACTURE OF WHISKY.

The first step in whisky manufacture is the making of the mash, which is done by mixing in the mash tub raw and malted grains, the former largely predominating, with water at 150° F., and agitating the mixture. The first malting requires about fourteen hours. Successive additions of water at 190°–200° maintains the temperature, the object being to convert all of the starch into maltose, which is directly fermentable by the action of the yeast, and to accomplish this the mashing must be done at a temperature of about 146°, for above it maltose production begins to decrease. By keeping within this limit of temperature the diastase from the small admixture of malt will not only greatly change the starch, but will bring about a hydration of the residual dextrine, converting it into maltose. When the wort has attained its maximum density, as found by the saccharimeter, it is drained off and a quantity of water at 190° F. is run upon the residue in the mash tub and allowed to infuse with it for one or two hours. The second wort is then added to the first. A third weak wort is often obtained and used to infuse new lots of grain. It is stated that in this direct mashing 10 per cent of the starch escapes decomposition, even though the grain may be finely ground. Hence a little preliminary warming with the water, to which has been added a little ground malt, followed by heating with water under a pressure of several atmospheres, often precedes the addition of the main quantity of malt, which is to complete the conversion of the starch and dextrine into maltose. Reduction of the loss by 5 to 10 per cent is reported by this method.

The second step in the manufacture of whisky is the fermentation of the wort. This is done by adding to the wort, which is always cooled before beginning the process, yeast (usually fresh brewer's or compressed yeast) that has previously been softened in water. For 100 liters of grain, 8 to 10 liters of liquid yeast or $1\frac{1}{2}$ kilograms of compressed yeast are used, and the best results are obtained when the temperature through fermentation rises to 94° F. Three stages of fermentation are recognized—a preliminary fermentation, during which the yeast cells grow without producing much alcohol; a main fermentation, during which the maltose is fermented; and an after fermentation, during which the dextrine is largely changed into maltose, which in turn is changed into alcohol. The time of fermentation varies from three to nine days, and the process is carried on until the density of the liquor as determined by the saccharimeter ceases to lessen.

The third step in the manufacture is the distillation of the fermented wort, which is done in stills varying from great simplicity to extreme complexity in construction.

The refining of spirits consists of the redistillation of the "low wines," as the product of the first distillation is known. The low wines have a specific gravity of 0.975, and the first product of the redistillation is a milky-white spirit abounding in oil. This is followed by a clear spirit that is caught separately, and the remaining weak spirit, known as "faints," is mixed with the low wines for another distillation.

After distillation the whisky is put in barrels, the inside of which has been charred. This is done to give the well-known amber color to the whisky and more particularly to assist in its aging, for the charred wood brings about a very complete oxidation of certain constituents of raw whisky, thereby imparting a delicate bouquet to it, and also relieves it of the injurious constituents. The barreled liquor is stored under bond for various periods and then is marketed.

The waste in the manufacture of whisky is the exhausted mash and residue from the stills. In many cases it is disposed of by feeding it to hogs and cattle. These animals are often herded under the most disgusting conditions, and the nuisance they create is almost greater than that which would result from turning this highly putrescible waste into a small water course. Sometimes the animals raised on the waste are disposed of to packers at favorable prices, and as often they are sold at a loss, so that from both a sanitary and a financial standpoint this method of disposal may be considered a failure.

The exhausted mash is a valuable food material when properly dried, and many works are recovering it and placing it on the market as a cattle food. The large volume of liquor treated makes the process an expensive one, and the profits are not always sure. A profitable method of disposing of this waste has been devised, and the reader is referred to Water-Supply and Irrigation Paper No. 179 for information concerning it.

POLLUTION IN NORTH BRANCH OF POTOMAC RIVER BASIN.

GENERAL DESCRIPTION.

North Branch of Potomac River rises at the Fairfax Stone, the extreme southwestern point of Maryland, at the eastern edge of the high plateau which divides the waters of Potomac and Blackwater rivers. The stream is the boundary line between Maryland on the north and West Virginia on the south. From its source to the towns of Piedmont, W. Va., and Westernport, Md., the river flows in a general northeasterly direction in the narrow valley it has carved for itself between Backbone Mountain, Maryland, and New Creek Mountain, West Virginia. The course of the river is tortuous and its current is swift. It has high steep banks, and the bed is filled with stones and bowlders. The channel lies nearer Backbone than New Creek Mountain, with the result that the northern or Maryland streams, with the single exception of Savage River, which has cut its way across the northern valley wall, are shorter than those on the West Virginia side. Both the northern and southern tributaries are torrential in character, being typical bright, tumbling mountain brooks. The West Virginia feeders are most important, the largest of them taking on the dignity of rivers, while most of the others are locally known as creeks, in contradistinction to the little runs that enter from Maryland. Both sets of streams have precipitous, quick-spilling watersheds; consequently in winter and spring the river and its tributaries are high and even impassible; in summer the feeders shrink and become relatively less important, and the main stream dwindles away to a thread which winds its hurried way through the stony bed. This region is sparsely settled, but mining and lumbering, the chief industries, have concentrated the population in about twenty hamlets, situated on the railroad, which closely follows the river as it winds in and out among the mountains.

NORTH BRANCH OF POTOMAC RIVER FROM WILSONIA TO GEORGES CREEK.

Wilsonia, W. Va., was formerly the westernmost of these settlements and had a sawmill which supported a small population; now it is abandoned, and Henry, W. Va., the station next below it, is the first important place in the valley. A coal mine here discharges a considerable amount of mine water into a little stream to the west of Elk Run. This is the first important pollution which North Branch receives, and the amount is large as compared to the total volume of the river at this point. The houses set well back from the river and such pollution as is received from them is indirect.

At Dobbin, W. Va., 2 miles below Henry, a dam is built across the river to furnish power for a sawmill, which is the life of the settlement. As the company uses the sawdust for fuel, it is disposed of without injury to the river. The houses of the operatives are on both sides of the river and most of them are at some distance from it, consequently only a few of the privies pollute the river directly. A primitive water supply is provided, the source being several springs in the neighborhood. The water is piped through the main streets on the southern side of the river only.

At Bayard, W. Va., 4 miles below Dobbin, is a tannery of the American Hide and Leather Company, employing 50 hands. The waste, which consists of leakage from the bark-liquor vats and water from the boiled fleshings, together with a little lime water, enters North Branch a short distance below Buffalo Creek. At the time of the last inspection lime sludge was piled dangerously near the edge of the river bank. At no time during these inspections have any large amounts of waste liquors been observed discharging from the tannery into the river, but the fact that the bed of the stream is stained a deep brown color would indicate either that such has been the case in former times or that it occurs now at infrequent intervals. It is said that recently, when the tops of the bark-liquor vats were shortened 18 inches, a considerable pollution took place. There is no public water supply in Bayard, and the tannery takes its water from Buffalo Creek, which flows through the town and is somewhat polluted with mine water. The water from this stream is said to be less damaging to boilers than that of North Branch at this point. The pollution from privies in Bayard is mostly indirect, but there are a few dangerously near Buffalo Creek.

At Gormania, W. Va., 2 miles below Bayard, the A. G. Hoffman & Sons Company maintains a tannery, with 75 employees. The only wastes that enter the river directly are the weak lime liquor and that from the scouring machines. The company has built a settling pool at the edge of the stream near the factory and into it drain the heavy lime liquor, sewage from the employees' houses, and the small quantity of bark liquor that is wasted. The liquors from the pool seep slowly through the earth into North Branch, and as occasion requires the sludge at the bottom is removed to farms to be used as a fertilizer. This arrangement is a great improvement on the common practice of turning all tannery wastes directly into the river. The appearance of the river above the tannery is clear and it has some color, but more is acquired as it flows by the Hoffman tannery. As the current is somewhat slackened by a bend in the stream below the tannery the river has a tendency to deposit such material as it has in suspension. The water supply of the town consists of private cisterns, wells, and springs. Some of the privies in the town are too near the river and all of them furnish indirect pollution. On the whole, however, Gormania is an unusually clean town for this section of the country.

Stoyer, Md., is the next town downstream. It has no public water supply and the use of privies is universal. A coal mine on the heights above the town discharges its mine water into a run which enters North Branch at this point.

Wallman, Md., owes its existence to a sawmill which is polluting the river with sawdust. To escape the Maryland authorities it dumps the sawdust within 10 feet of the West Virginia shore, and by this subterfuge works continuous injury to the stream without molestation.

Opposite Hubbard, W. Va., is a coal mine, and a short distance above a sawmill, with a huge pile of sawdust not far from the river.

At Harrison, W. Va., Abram Creek empties its waters, polluted by mine waste, into North Branch. On the Maryland side of the river, somewhat below the town, is Wolfden Run, which is likewise polluted by mine water. Below this run, at the edge of the river, are 23 privies, besides those belonging to the houses at intervals all the way to Blaine.

Blaine is an unincorporated town situated on both the Maryland and West Virginia banks, 1 mile below Harrison. Here a woolen mill which employs 10 men turns into the river spent dyes and rinse water from the finished goods to the amount of 750 gallons a day, besides the sewage of its employees. The water supply at Blaine is from private wells and cisterns. The use of latrines is universal and some of them pollute the river and the race which supplies power to the woolen mill. Others are located upon low ground in the center of the town and are scoured out by the river in times of high freshets. The privies are not cleaned, but are moved to new trenches when it becomes necessary to fill the old vaults. Thus the indirect pollution of the river is considerable.

Three Fork Run enters North Branch at Chaffee, W. Va., 4 miles below Blaine. This stream carries its quota of mine water and is likely to become more polluted in the future than it is now, because of the probable extension of mining in its valley.

At Shaw, W. Va., 4 miles farther downstream, the river receives Deep Run, which is heavily polluted with mine water and with the wastes of Atlantic and Elk Garden, two mining towns high up among the hills far back from North Branch. Elk Garden is the more important of the two, having, in fact, a considerable population. Its water supply is from private wells and cisterns, and it has no sewerage, the use of privies being general. When these are cleaned, the soil is removed to the commons on a tributary of Deep Run and buried. Elk Garden has no sewers, but there is one drain for surface water only, which reaches North Branch by way of Deep Run.

Savage River, whose watershed supports no mines and is given over to lumbering, joins North Branch near Bloomington. As its drainage area is practically uninhabited, the water is relatively pure and, being of nearly equal volume to that of North Branch at this point, serves greatly to improve its character by diluting the impurities.[a]

Between Bloomington and West Virginia Central Junction, North Branch receives a considerable amount of mine water. The town of West Virginia Central Junction contributes its share of indirect pollution. The river passes over a dam here and with its fall changes its environment and character. Up to this point it is a turbulent mountain stream to whose immediate banks the population is confined. Back from the river the Maryland watershed is uninhabited save for a few isolated farm houses here and there, and the population supported on the upland drained by its West Virginia tributaries is scattered, except that in some places about the country stores a few homes are clustered. From this point on, North Branch becomes less wild and on its banks appear populous towns with varied industries and in some cases sewerage systems. The influences of nature are less manifest and the artificial conditions imposed by man are everywhere visible.

A little below the dam the town of Luke, Md., has been built up by the West Virginia Pulp and Paper Company. Seven hundred men are employed in the factory, and the sewage which they create is turned straight into North Branch, as is also the waste from the factory, which is the largest industrial plant in the whole Potomac basin. Soda pulp, mechanical wood pulp, and paper are made here, and enormous quantities of alum, soda bleach, and lime are used, besides kaolin, glue, size, and ultramarine blue. The discharge of the waste chemicals and the shreds of wood fiber radically alter the character of the river at this point.

From Luke it is but a short distance to Westernport, Md., and Piedmont, W. Va., two towns on opposite sides of the river, which have identical interests and form one community. Piedmont has a sewerage system and pollutes North Branch both directly and indirectly.[b] The town owns its water supply, which, by arrangement with the West Virginia Pulp and Paper Company, is pumped from Savage River. Though the water undergoes no process of purification, it has so far been used with good results, being only slightly polluted, owing to the almost entire absence of population on the watershed from whence it is derived. Westernport for the last three years has bought its water from Piedmont. Its use is general in the town, for the wells along Georges Creek have been destroyed by infiltrating waters from the creek, so that the only wells in use are those in the western part of town, which is higher than the other parts. The town has two sewers. One of them has 50 connections, runs parallel with the main street, and is 600 feet long and 30 inches in diameter. The other has 500

[a] The results of measurements of Savage River at Bloomington are given on pp. 43–46.

[b] The results of measurements of North Branch of Potomac River at Piedmont are given on pp. 46–54.

connections, is partly open, and is 500 feet long and 36 inches in diameter. Both discharge into Georges Creek near its mouth. Besides these a few private sewers empty into the creek and North Branch.

GEORGES CREEK.[a]

Georges Creek has its source on Big Savage Mountain, and drains the heart of the soft-coal region of Maryland. At its very head at New Shaft a large stream of mine water is constantly running, and thence all along its course accessions of mine water are received at short intervals, so that by the time Westernport is reached the waters are surcharged with mine drainage, and are lethal instead of life giving in character. They destroy all vegetable and animal life in the channel, and stain the rocks on which they flow yellow with a deposit of iron hydrate.

At the head of the creek on a high peak of Big Savage Mountain is the city of Frostburg. It has a good public water supply from springs on the mountain, and the Frostburg Water Company furnishes an auxiliary supply derived from a well and springs. The city for the last three years has had about 15 cases of typhoid fever each year. Some of the cases are of outside origin. There is no sewerage system in Frostburg nor is there need of any, for the coal mines beneath the town drain all the cesspools and care for some of the surface water as well.

Below Frostburg are Borden Shaft, Ocean, and Midland, all mining communities in which crude sanitary conditions exist.

Lonaconing, about midway between Frostburg and Westernport, is also a mining town. It has developed a public water supply on Jackson Run for a reservoir fed by two mountain streams upon whose watersheds but two or three families live. The water is at present delivered to 523 families, but the available supply is 5,000,000 gallons a day. The fact that but nine cases of typhoid appeared in the city during eleven months of 1904 points to the comparative purity of the water. The death rate in the town is about 10 per thousand and is said to be augmented by the high birth rate, for the local statistics seem to show that a large number of children die before reaching 5 years of age. There are some sewers which serve a few houses, stores, and hotels and which empty into Georges Creek, as do the many privies that directly overhang it. Besides these, four shambles exist, one of which is far from the town, and buries its offal. The three others are in the middle of the town and are used by six butchers, who throw much of the offal into the creek, though some of it is fed to hogs. There is one steam laundry which drains into Koontz Run.

[a] The results of stream measurements of Georges Creek at Westernport are given on pp. 55–57.

NORTH BRANCH OF POTOMAC RIVER FROM GEORGES CREEK TO WILLS CREEK.

At Westernport North Branch turns and flows in a southeasterly direction across the foothills of New Creek Mountain until it reaches Keyser. At this place the most obvious contamination is from the mill of the Patchett Worsted Company, which scours 1,800 pounds of wool a day and uses 100 pounds of aniline dyes a week. The wastes are turned directly into the river. This company has had some trouble with its water supply. The Potomac water, it is claimed, makes the wool which is washed in it harsh, while the waters of New Creek stain the wool badly.

On New Creek, 6 miles above Keyser, a plant of the United States Leather Company is located. Above this plant the water is colorless, or nearly so, while below the place where the tannery discharges liquors the stream becomes red or almost black. Though the color is reduced in the course of flow to the river, the water is still tawny at the creek's mouth. The tannery employs 99 men. In the summer of 1904 there was an outbreak of typhoid among them, due, it is thought, to contaminated springs and wells in the neighborhood. New Creek is polluted by sewage also, for while the use of privies is common in Keyser a part of the town is pretty thoroughly sewered, and the sewer empties into the creek, as does that of the Baltimore and Ohio Railroad shop, with 300 employees. The latter connection is indirect, reaching the creek through Longs Gut. Typhoid fever is said to be rare in Keyser, by reason of the purity of the water supply in general use. The source is a mountain spring 4 miles east of the town. The reservoir has a capacity of 6,750,000 gallons and affords a pressure of 160 pounds per square inch in the lowest part of the town.

WILLS CREEK AND CUMBERLAND.[a]

At Keyser the Potomac resumes its northeasterly course and flows between Dans Mountain on the north and Knobly Mountain on the south to Cumberland, where it receives the waters of Wills Creek. The drainage area of this creek must be carefully studied in order to understand sanitary conditions in Cumberland.

Wills Creek rises on the western slope of Savage Mountain, Pennsylvania, and runs northwestward to Mance, where it turns and flows eastward to Hyndman. The population on its entire watershed above Hyndman is not more than 1,000, and not many of the small villages need especial notice.

Foley is a railroad station, with a few houses huddled about it. Most of these are provided with privies that pollute the creek, which runs on to Fairhope, where there is a brick factory, and where the stream is further contaminated by overhanging latrines. Identical

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[a] The results of measurements of Wills Creek and North Branch of Potomac River at Cumberland are given on pp. 58-64.

conditions exist at Williams, the next town below, and at Hoblitzell, a small agricultural community, a few more houses add their filth to the water course.

Hyndman is the largest town on Wills Creek. Its public water supply comes from a spring on the west side of Wills Mountain, 1½ miles from town, and its purity is evidenced by the fact that there is rarely any typhoid fever in the place. There is one sewer, about a quarter of a mile in length, which takes slops from the houses on the line and soil from a few of them and from the bank and hotels. The rest of the inhabitants use privy vaults, which seem to be well cared for by the local board of health. The tannery of the Elk Tanning Company, which employs 55 men and makes oak-tanned sole leather, on the eastern bank of Wills Creek, when first visited poured all its wastes directly into the creek. Since then conditions have been bettered, for the company has constructed at the edge of the stream near the plant a settling pool with a capacity of 5,500 cubic feet, and all wastes are turned into it. At the time it was inspected it was full and overflowing a little, and it was observed that a sluice with a gate had been provided by which direct communication with the creek could be established in case the capacity of the pool was overtaxed. In spite of these defects the new arrangement is commendable, and has done a great deal toward clearing up the waters of the stream. A privy which is used by the employees overhangs the creek and a water closet in the office of the company is also connected with it. The capacity of the plant is 105 hides a day, and the total wastes are estimated at 2,000 gallons a day.

Some distance below Hyndman is Ellerslie, where there is a planing mill and a pumping station of the Standard Oil Company. At Corriganville Jennings Run joins the creek. This stream heads at Frostburg, and both near that town and at other places in its narrow valley receives large quantities of mine water. At Mount Savage it is joined by Mount Savage Run, which is polluted by many overhanging privies, and upstream by the acid waters of a fire-clay mine. Mount Savage is located on the steep slopes of high hills, so that the run-off through the town is very quick, and in times of heavy rains a great deal of the refuse of the town is washed into Jennings Run or its tributary, Mount Savage Run. At Barrelville a small tributary enters Jennings Run from Wellersburg, and that too is contaminated by mine water from the coal mines which are being opened up in its valley; but from Barrelville to its mouth the run is befouled but little more.

Below Corriganville there is no notable pollution until Braddock Run is reached. This stream heads at Eckhart Mines, a thriving mining town that is supplied with water by the Frostburg Water Company. Privies and domestic wastes defile the run, but it is free from mine water, owing to the fact that the waters of the mines beneath the town are pumped into Georges Creek near Borden Shaft. The completion near Clarysville of a tunnel, now far advanced in construction, 11,000 feet long and 7 by 8 feet in cross section, will divert the drainage of the Eckhart and Hoffman mines from Georges Creek to Braddock Run, into which it was formerly pumped. The effects of the consummation of this project will be far-reaching. Braddock Run, whose waters are now comparatively soft and suitable for boiler purposes, will be converted into a stream with the characteristics of Georges Creek at the present time, while the water of Georges Creek will become less acid and so less potent in its effect on the limy waters of North Branch at Westernport. Moreover, with the reduction of its acidity the Georges Creek water is likely to become less noxious to bacteria, so that the sanitary conditions which prevail along the creek will be vastly more important than they now are to the towns below it, notably to the city of Cumberland, whose waterworks intake is at Ridgely, on North Branch, one-half mile above Wills Creek. The Cumberland water now receives the benefit of the clarification and germicidal action which the united waters of Georges Creek and North Branch accomplish about 30 miles above it, and should this action become less effectual it is conceivable that Cumberland might find its water supply less pure than it is now. The acid waters of Braddock Run after this change is made effective will increase the acidity of Wills Creek, and that in turn will work its effect below. At present Braddock Run flows from Eckhart Mines to Allegany Grove, a camping and picnic resort where many large privies pollute it badly. Somewhat below Allegany Grove is the plant of the James Clark Distilling Company, whose wastes, consisting of slops from the distilled grains, are conducted through a 10-inch terra-cotta pipe along the sides of the run to the Narrows, where they are discharged into Wills Creek. The concern mashes 300 bushels of grain a day, but the amount of waste disgorged into Wills Creek is problematical, as a farmer below the distillery taps the pipe line and withdraws what he needs for his cattle, while another one hauls away enough to supply a herd of forty. The fact that the distillery is closed down in summer is undoubtedly of benefit, for the waste, which is putrescible, is thus usually discharged only in times of comparatively high water, which tends to dilute it. Moreover, at summer temperatures a local nuisance would be created about the Narrows by rapid decomposition of the distillery slops, whereas under present conditions, at the lower temperatures of autumn and winter, decomposition is more gradual, as it takes place at a comparatively slow rate and over a considerable distance.

Below the Narrows of Wills Creek is a tannery of the United States Leather Company, where the course of the stream varies with its stage. In times of low water practically the entire stream is diverted by the dam at the tannery into the Beal mill race, which flows through the most populous part of Cumberland into the Chesapeake and Ohio Canal. When the creek is high, so much of its waters as do not go through the race continue over the dam and flow through the business section of Cumberland to the head of the Chesapeake and Ohio Canal, into which, when the gates are open, some of the water goes, while the rest joins North Branch. At a point a little below the confluence Dam No. 7 has been built. Its purpose, like that of the other dams on the Potomac, is to hold back the waters of the river and make them available for feeding the canal; its effect is to check the current of Wills Creek and to create slack water for 3 miles up North Branch. It can be easily understood that in times of drought, when no water passes over the dam at the tannery on Wills Creek and none over Dam No. 7, there is formed a bow-shaped pool of practically stagnant water, one arm of which extends from the Wills Creek dam to North Branch and the other from Dam No. 7 up North Branch for 3 miles. The river arm is but little polluted, while the creek arm throughout its length of a mile through the center of Cumberland is very much so. Into it slaughter barns, privies, steam laundries, breweries, and some of the sewers of the city discharge, producing a thoroughly regrettable condition of affairs. In time of high water this corruption is carried into the canal or river, but whenever there is a drought it lies festering in the midst of the city.

Cumberland is the largest city on the Potomac watershed above Washington. It is a vigorous, growing place, but its rapid increase in population has outstripped its development in sanitary matters. The water of the city is not free from contamination. As private wells are commonly polluted, most of them have been closed up. Cisterns are used to some extent, but the city supply is generally relied on by the citizens. It is pumped directly out of North Branch opposite Ridgely, 1 mile above Wills Creek, and is consumed without purification of any kind. This would probably be more disastrous than it now is were it not for the beneficial purification which, as explained elsewhere, takes place about 30 miles above the city. There is no system of sewage purification, though there is a sewerage system which serves about 75 per cent of the city. Soil, slops, and some surface drainage are taken by the sewers, though about 95 per cent of the system carries no storm water, as most of the surface drainage goes directly to the race, canal, creek, and river. Six of the city sewers discharge into the race; two of these are 36 inches in diameter, one 12 inches, one 10, one 8, and one 6. Besides these the race receives the droppings from many overhanging privies and is polluted by many private sewers. The dye works of Thomas Footer & Son discharge wastes consisting of rinse water and spent dyes, estimated at 10,000 gallons a day, into the race, together with the sewage of its 310 employees. Moreover, the race is somewhat obstructed by ashes which are thrown into it. Besides the sewers discharging into the race, the following empty into the river: One 24-inch sewer, whose full capacity is probably never required, entering at Valley street; one 6-inch private sewer for sewage only, entering at a point about opposite the Town Hall; one 12-inch city sewer, and the 8 or 12 inch sewer owned by Allegany County. In South Cumberland a sewer empties into a brook that flows into the Chesapeake and Ohio Canal near the Queen City glass factory. In winter, when the canal is drained off, the stream and sewage flow over the canal banks directly into North Branch. About 5 per cent of the houses in South Cumberland are connected to this sewer.

Many people along Wills Creek find it to their advantage to sewer directly into it. Above the Market Street Bridge the United States Leather Company, which employs 100 men, discharges its tannery wastes, amounting to 10,000 gallons in twenty-four hours, together with the sewage of its employees, into the creek. Below this tannery the Cumberland Brewing Company, employing 50 men, empties the washings from its barrels and sewage from its employees. At the Market Street Bridge, on the west bank, the German Brewing Company pours out the washings from its barrels, amounting to 1,500 gallons per day, together with the sewage of its 35 employees. On the opposite bank a gas company lets some of its waste liquors escape. From this point down, on the eastern side of Wills Creek, there is a succession of overhanging privies, interspersed by the sewers of two steam laundries and by a few slaughterhouses, whose floors drain the blood of the animals and with it a small amount of offal into the creek (Pl. VIII, *A*).

Throughout the southwest part of that section of Cumberland lying west of Wills Creek flows a small run that is undoubtedly the recipient of much promiscuous refuse, which it empties into North Branch about one-fourth of a mile below the waterworks intake at Ridgeley. Whether this imperils the city water supply or not can not be stated, but the possibility of its doing so should be borne in mind.

The Chesapeake and Ohio Canal receives most of the irregular pollution of South Cumberland. The Baltimore and Ohio Railroad shops, employing 600 men, sewer into it, and so does the N. & G. Taylor Company, a concern which employs 300 men and which makes steel and rolls it for manufacture into tin plate. In the process of manufacture large quantities of sulphate of iron are used, and this when pretty well exhausted finds its way into the canal.

There are many other industries in Cumberland, but none of them have liquid wastes. That other manufacturers will come to the city is more than likely, for Cumberland is advantageously situated and

A. WILLS CREEK FROM MARKET STREET BRIDGE, CUMBERLAND, MD.

B. POLLUTION OF POTOMAC RIVER BY WASTES FROM THE MECHANICAL WOOD-PULP MILL AT HARPERS FERRY.

seems destined to enjoy much greater prosperity. This, however, will be still further increased by bettering the conditions above described. The city should adopt some method of disposing of its wastes which will relieve the river of doing so, and its water supply should be placed above criticism.

NORTH BRANCH OF POTOMAC RIVER BELOW WILLS CREEK.

Below Cumberland North Branch enters the Greater Valley of the Appalachian Plateau in that part known as the Allegheny Ridges, from the fact that mountains trending northeast and southwest cross it at frequent intervals. In the valleys between these ridges flow many streams, and the most prominent of these will be taken up in the order in which they empty into North Branch.

Evitts Creek, which drains the thinly settled country between Shriver Ridge and Evitts Mountain, enters North Branch from the north a short distance below South Cumberland, where its water is used for boiler purposes in the Baltimore and Ohio Railroad roundhouse. At one time it was advocated as a source of public water supply for Cumberland, but was rejected partly because of the prevalence of typhoid in its drainage area. Patterson Creek, the next important tributary, comes in from the south at Patterson Depot. Burlington, with a population of 250, is the largest town in the Patterson Creek Valley; its inhabitants gain their livelihood by farming and logging. From Patterson Depot North Branch flows on to a point 2 miles east of Greenspring and then loses its identity, being joined by South Branch of the Potomac to form the main stream, whose conditions will be described after taking up South Branch.

POLLUTION IN SOUTH BRANCH OF POTOMAC RIVER BASIN.[a]

South Branch of the Potomac rises in Highland County, Va., at Hightown, on the divide separating the headwaters of James and Potomac rivers. The stream flows northeastward to a point 6 miles west of Petersburg, W. Va., where it receives North Fork of South Branch, which is formed at the north end of Middle Mountain by the confluence of Laurel Fork with Straight Fork and flows northeastward to its junction with South Branch. The stream continues in a northeasterly direction to Moorefield, where it receives the waters of Moorefield River, a stream that flows in a northeasterly course from its source on Shaw Ridge north of Palo Alto, Highland County, Va., near the head of Cow Pasture River, a tributary of the James. The entire country drained by South Branch of the Potomac is very rugged. Several of the mountains rise to the height of 3,000 feet

[a] The results of stream measurements on South Branch of Potomac River at Springfield, W. Va., are given on pp. 66-77.

and there are many less lofty peaks. The watershed is much cut up by the multitude of creeks and runs that are tributary to the main stream, and these waters fall precipitously into the river from the mountains, making it rise and fall suddenly. In spring the melting of the snow produces very high water, which recedes quickly.

South Branch from its source to a point 6 miles west of Petersburg flows between North Fork and South Fork mountains, and lies between North Fork of South Branch and Moorefield River, both of which are parallel to it, all three streams flowing in a northeasterly direction. North Fork Valley has been eroded between Spruce and North Fork mountains. Its population of woodsmen and mountaineers is very sparse, so that the stream may be dismissed with the statement that it reaches South Branch almost unsullied. Moorefield River has cut its valley between Shenandoah and South Fork mountains; the region is unsettled and, like North Fork, the stream is but little polluted. The only source of contamination is a tanning-extract factory located in Brandywine, Pendleton County, W. Va., a place where it is said there has been much typhoid. When this plant was started the stream was discolored greatly by the leakage from the vats where the chestnut-oak wood was steeped. At the present time this leakage is insignificant and such coloring matter as enters the stream comes from the condenser water, which absorbs some of the abstract in the process of manufacture.

South Branch itself in its upmost reaches is polluted only by the wastes at Monterey, Highland County, Va., and by those of a few scattered settlements. At Franklin, however, where the stream has attained considerable size, the pollution is important. This town has a water supply from springs on Entry Mountain, but about one-third of the people use wells. The sewage must reach the river very indirectly, for the houses are a long way from the river bank and there is no public sewerage. One or two private sewers lead from the main streets of the town to the bottoms, but most of the people use privies, and the soil removed from these, when they are cleaned, is deposited in boxes near the river, which are scoured out by occasional floods. So far as information goes typhoid is rare in Franklin, though once in a while a case comes into town from the outside. The most extensive pollution of the river here is accomplished by the Franklin Tannery Company, whose wastes amount to practically 10,000 gallons a day. The factory is located in the southwestern part of the town, and its effluents are carried 1,100 feet through a 6-inch terra-cotta cement-jointed pipe line to a settling pool 83 yards from the river. Here the solid matters sediment out, and the liquids usually filter slowly through the ground to the river. In times of high water the earth becomes saturated, causing the pool to discharge at its south end directly into the stream, while in times of flood the entire settling basin is invaded by the river. This is considered unavoidable by the tannery company, because in its opinion the best available place has been utilized for the disposal of the waste. The company claims that this refuse, which must ultimately go into the river, is best discharged at such times, for in the huge volume of water that rushes downstream it is hardly noticed and presumably does comparatively little harm.

The country between Franklin and Petersburg is given over to grazing and farming and is very beautiful. The pollution received by the river in this interval is very small and is such as comes from scattered farmhouses and the domestic animals about them. At Upper Tract there is a country store and something of a settlement. Petersburg is a small town at which there is a tannery of the United States Leather Company that employs 30 hands. The wastes from this plant amount to 3,000 gallons daily and are discharged into Lunice Creek very near the point where it enters South Branch. At the time of inspection South Branch was in flood, so that the effects of the tannery wastes were not discernible, but it is entirely probable that in low water they discolor the stream, for there is no attempt to purify them. Petersburg has neither public water supply nor sewerage, and the only receptacles for soil are privies. The next town below Petersburg is Moorefield, which takes its water from Moorefield River, a short distance above the tannery dam on that stream. The daily consumption is 36,000 gallons. Besides this, nearly every house has its well, and these are locally supposed to furnish water of good quality. There are no sewers, but there are one or two drains for surface water. The tannery at Moorefield at the time of the inspection was owned by the Cover & Drayton Company, but has now passed into the hands of the United States Leather Company. It is situated well back from the bank of Moorefield River, about 2 miles from the center of the town. The plant has a capacity of 50 hides a day, and its wastes, which amount to 10,000 gallons a day, are carried to a settling pool near the edge of Moorefield River. This pool is believed to be large enough to take care of the tannery wastes at all times, but in case it is not the liquors will be discharged directly into the stream. Like the settling pool of the tannery at Franklin this one is flushed out by floods.

At Old Field, a short distance below Moorefield, South Branch flows between Mill Creek Mountain and South Branch Mountain in a precipitous valley locally known as the Trough, while the highway turns around the southwest end of Mill Creek Mountain and follows the valley of Mill Creek to Romney, passing on the way the settlements of Purgitsville and Moorefield Junction. The inhabitants of these places are farmers and the population is very small.

Romney is situated on a high hill well back from South Branch, where it emerges from the Trough. It has a public water supply from springs, but no public sewerage. The State asylum for the deaf and blind located here has a private sewer that discharges into Big Run, and this rivulet carries the sewage into South Branch one-half mile below the town limits. From Romney to its mouth the valley of South Branch is peopled by farmers and there is no further important pollution.

The waters of this large stream are remarkably pure and should be protected from contamination. Its beautiful valley, with its rugged mountains, interesting streams, and fair intervales, so near the populous cities of the seacoast, is likely to yield a richer return as a wisely developed region of summer resorts than under exploitation by industrial interests.

POLLUTION IN POTOMAC RIVER BASIN BETWEEN MOUTH OF SOUTH BRANCH AND SHENANDOAH RIVER.

POTOMAC RIVER FROM MOUTH OF SOUTH BRANCH TO PAWPAW.[a]

The first important stream entering Potomac River below the confluence of North and South branches is Little Cacapon River, a southern tributary. A few miles below this stream is Pawpaw, W. Va., a small town at which there is a tannery that employs 140 men. The tannery wastes amount to 15,000 gallons a day. Part of them are sedimented near the river's edge, but the rest are discharged directly into the river and markedly discolor it.

From Pawpaw the river takes a meandering course between Town Hill and Sideling Hill. At the hamlet of Little Orleans Fifteenmile Creek enters from the north, and 4 miles farther downstream is the mouth of Sideling Hill Creek. The Potomac then cuts across Sideling Hill and Tonoloway Ridge, on the eastern side of which lies the village of Great Cacapon.

GREAT CACAPON RIVER.

A short distance east of Great Cacapon is the mouth of Great Cacapon River, which is formed at Forks of Capon by the junction of North River and Cacapon River.

North River rises in South Branch Mountain, Hardy County, W. Va. Two tanning-extract factories are located in this stream, one at Inkerman and the other at Rio. Cacapon River, or Lost River, as it is known above Wardensville, on account of its sinking beneath its bed for a short distance, rises in North Mountain, Hardy County, W. Va. There are two tanneries in its basin, one at Lost City and the other at Capon Bridge. Each employs 25 men and turns out 50 hides a day. The wastes are said to be sedimented before being turned into the river.

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[a] Results of measurements of Potomac River at Great Cacapon are given on p. 78.

Great Cacapon River is less than 75 miles long. For a considerable distance above its mouth it is about 150 feet wide. It is made up of a succession of rapids and pools. In some of the pools the water is deep, but the rapids are shallow. In ordinary stages the river is fordable at almost any place except in the pools. The lower part of the river has a considerable fall per mile and is full of large rocks and bowlders.

POTOMAC RIVER FROM GREAT CACAPON RIVER TO CONOCOCHEAGUE CREEK.

The next important tributary below the Great Cacapon is Warm Spring Run, which enters the Potomac from the south at Brosius. This stream is polluted by sewage from the town of Berkeley Springs, which is 6 miles from the Potomac and which owes its existence to thermal springs that supply the community with water and are held in high esteem. The hotels and leading houses are served by a sewer which discharges into the run about one-half mile north of the town.

Opposite Brosius is Hancock, one of the oldest towns in Maryland. It is a small place without factories, and as it is located well back from the river the trivial refuse that is created there must reach the stream either very indirectly or by the two runs which flow along the extreme east and west ends of the town. The pollution at Hancock may become more important in the future if the stimulus recently received from the advent of the Wabash Railroad is sufficient to develop steady growth. From Hancock the Potomac continues its way eastward. From the north, a little east of Hancock, it receives Great Tonoloway Creek; from the south, a considerable distance farther on, Sleepy Creek; and beyond that, from the north, Licking Creek, a stream which rises in Bedford County, Pa., and receives the indirect pollution of McConnellsburg, a sizable country town, where there is a tannery having a capacity of about a hide a day. A few miles below Licking Creek, Back Creek joins the river from the south. Above Dam No. 5 the Chesapeake and Ohio Canal enters the Potomac and becomes one with it for miles, not resuming its separate course until it reaches Dam No. 5, 7 miles above Williamsport, Md., where Conococheague Creek enters the river.

CONOCOCHEAGUE CREEK.

Conococheague Creek has intrenched itself in the eastern edge of Cumberland Valley and drains a well-populated, prosperous region. The stream rises in South Mountain, Adams County, Pa., and flows in a westerly direction by many villages. At Scotland there is a large industrial school, which disposes of its sewage by the Waring system, a matter of importance to Chambersburg, the city next below it. The water supply of this flourishing city is pumped from Conococheague Creek at a point 2 miles upstream and is delivered without purification to the citizens, nearly all of whom are dependent on it, for the well water is too hard to be used satisfactorily in boilers and is commonly so polluted that the wells have fallen into disuse. Chambersburg has no public sewerage system, probably because the seams of the much fractured limestone on which the city is built act as conduits for the sewage of the cesspools that are as a matter of course provided for every house and carry it away, presumably to the creek. There are two private 10-inch sewers, to one of which are connected three hotels and fifteen private dwellings and to the other a hotel, the trust company, and the court-house. There is also a private 8-inch sewer which is used by 25 families and another for the 300 employees of the Wolf Company. All these sewers empty into Conococheague Creek, which is further corrupted by a part of the sewage of the Wilson College for Girls, an institution having 400 students, by the washings of a creamery and of a beer-bottling establishment, by the spent lye of J. G. Gerbig & Sons' soap factory, by the residues of the Chambersburg Gas Company, and by the spent dyes of a small dyehouse which maintains its own connection to the creek. Moreover, three slaughterhouses utilize the stream for the disposal of their offal. Its tributary, Falling Spring Run, increases the pollution, for to this little stream are connected the urinals of the Cumberland Valley Railroad shops, which are used by 230 men, and the five water-closets of its main office building, where there are 50 employes. The run is also the recipient of the sewage of the 90 hands of the Chambersburg Shoe Company. The Chambersburg Woolen Company voids into it the sewage of the 95 employees, together with wastes consisting of spent dyes and rinse water from the finished goods; and, finally, a steam laundry adds its affluent. From Chambersburg Conococheague Creek runs southwestward for 15 miles to the point where it receives the waters of Back Creek, a stream on which is located Williamson, a small town, where a large dairy and butter factory pollutes the water.

Four miles below its confluence with Back Creek, Conococheague Creek is joined by Moss Bank Run. This little stream probably receives practically all of the sewage which leaks away from the cesspools in the limestone that underlies the city of Greencastle. The run at the eastern edge of the city receives the washwater and dyes of a little woolen mill and then disappears below ground, apparently to reappear on the western side of the city, from which point it flows eastward 1 mile to Conococheague Creek. Greencastle is supplied with water by the Greencastle Water Company from Eshleman and Spangler springs, 2 miles east of the city. It is a gravity supply and was put in at a cost of $30,000.

From Moss Bank Run Conococheague Creek flows southward for 5 miles, and then receives the waters of its West Branch, which rises on the divide between Cumberland and Franklin counties and flows southward until it reaches the main stream. The first contamination of West Branch is received a short distance above Mercersburg Junction, where the waters of Trout Run come in. This stream heads in Cove Mountain a little to the west of Foltz, in Cove Gap, and passes through the hog yard of a small distillery. The animals are fed on the slops, and while they doubtless dispose of most of it probably a part escapes, and with the excrement of the swine contaminates the stream.

From Mercersburg Junction, West Branch continues to a point about 2 miles east of Mercersburg. This city has a public water supply derived from Trout Run, before mentioned, at a point above the distillery known as Buchanan's birthplace, where there is a dam across the run, the slackened waters being piped to an equalizing reservoir and thence to the city. The supply is probably very satistory, because the waters are tapped in the Pennsylvania Forest Reserve, which insures their freedom from contamination. The water is used generally in the city, but is supplemented by six public wells, which are on the main street. The sewerage system consists of two sewers, one a 6-inch pipe 2,500 feet long, laid through the main street, and the other an 8-inch pipe 800 feet long, known as the Church street sewer. Besides these, Mercersburg College, which has 300 students, has a private sewer. All this sewage, together with the effluent of the tannery, is discharged into a little rivulet known locally as Dickeys Run, heading back of the town. When inspected at the point where it crosses the main street this run was simply a brooklet of blood owing to the discharge of a slaughterhouse near by. Below the slaughterhouses is located the tannery of W. D. Bryon & Sons. The capacity of the plant at present is 75 hides a day, but it is being increased. The wastes now amount to 2,500 gallons a day, and by agreement with the property owners below are discharged only at night. The length of the run to West Branch is 2 miles. Near its mouth, at the time of inspection, it did not show evidence of the gross pollution which it receives, though as it was inspected in daytime the tannery effluent was not a factor.

West Branch joins Conococheague Creek 10 miles below Dickeys Run, and from the confluence the creek continues without conspicuous pollution to Williamsport, Md., where it joins the Potomac. This town was at one time visited by General Washington to determine its advantages as the future capital of the United States. At present it is a large, beautifully located village without a public water supply and without sewerage, though authority to construct the former was given at the last session of the legislature. There is a little manufacturing done, but the industries do not create liquid wastes, with the single exception of the tannery of W. D. Bryon & Sons. This firm employs 250 men, and its wastes, amounting to 16,000 gallons a day, are discharged into Conococheague Creek but a short distance above its mouth.

OPEQUON CREEK.

Opequon Creek rises east of Stephens City, Frederick County, Va., and flows northeastward, emptying into the Potomac River 2½ miles east of Martinsburg, W. Va. In general its course is straight, but from Middleway to Martinsburg it is somewhat meandering. Although this stream is small, and through most of its course flows in a farming region in which it receives but little pollution and that mostly indirect and derived from enriched land, domestic animals, and a score of scattered hamlets, yet from the sanitary standpoint it is important because of the nature and amount of sewage received at three different places.

Winchester, the county seat of Frederick County, Va., is situated on Abrams Creek, 5 miles from Opequon Creek. It has a public water supply which consists of what are known as the old and the new waterworks. The old works date from colonial times and derive water from a spring three-fourths of a mile west of the court-house; the new works, installed in 1894 at a cost of $55,000, are supplied from a spring three-fourths of a mile southwest of the court-house and afford 2,500,000 gallons in twenty-four hours. There is no sewerage system and the use of cesspools and privy vaults is universal; they care for themselves by draining away through the crevices of the limestone. Probably much of the pollution ultimately enters Town Run, which passes through the center of the town and joins Abrams Creek. Besides the indirect contamination, Town Run receives waste from a steam laundry and gas house; the latter makes the run foul and ill smelling. Near the gas house. W Graichen's tannery discharges its effluent, made up of lime, sour-bark liquor, and water from wool scourings, all of which amount to 200 gallons a day; the Winchester creamery contributes the washings of its floors, vats, and cans; the Lewis Jones Knitting Company adds spent dyes and run-down lime bleach; and the Virginia Woolen Company discharges its waste, consisting of 1,000 gallons a day of scouring liquors and spent dyes. This unsavory burden is delivered by Town Run to Abrams Creek on the southeastern outskirts of Winchester. West of Winchester, nearly 3 miles above the mouth of Town Run, Abrams Creek receives the waste of the American Strawboard Company's factory, which makes paper board from old newspapers. The effluent is dirty water full of shreds of paper and is run into a settling pool from which it flows into Abrams Creek. The sediment is occasionally taken out of the pool by farmers for use as a fertilizer. A. C. Williamson & Brothers, manufacturers of woolen goods for public institutions, pour the rinse from their manufactured goods and some spent dyes into the creek, after which it flows 7 miles to Opequon Creek without further industrial pollution other than that delivered by Town Run, as already mentioned.

Two miles below the mouth of Abrams Creek, Opequon Creek receives Lick Run, which, at Jordan Springs, is polluted from June to September by the sewage of a summer hotel and its cottages, planned to accommodate 300 guests.

Martinsburg, W. Va., is on Tuscarora Creek, 1 mile from Opequon Creek.[a] In past years the city suffered seriously from typhoid, but the citizens finally delivered themselves from the scourge by closing up the wells and abandoning the old water supply, both of which were considered to be polluted. A new and satisfactory water supply from Kilmer Spring, 1 mile west of the city, was installed in 1903, at a cost of $30,000. There is no sewerage other than four drains, aggregating 2,000 feet in length; these are for surface water only, which they discharge into a tributary of Tuscarora Creek. About 5 per cent. of the houses have water-closets, and these empty into cesspools; the rest of the people are dependent on privies. Both cesspools and privies are well looked after, owing to the city's experience with typhoid, but they undoubtedly furnish Tuscarora Creek with considerable indirect pollution. Only one privy, that of the electric-light company, was noticed to overhang the creek directly.

Tuscarora Creek is greatly polluted by industrial wastes. The first and most noticeable of these is that of the Hannis Distilling Company, amounting to 8,000 gallons in twenty-four hours. Inasmuch as it consists of slops from the mash, which is a good cattle feed, much thought has been spent by the company in devising means to separate the solid portion from the liquid in which it is suspended. By means of a somewhat elaborate system of settling and filtering, all but the finest impalpable material is saved and put on the market. The part that is discharged into the creek is finely subdivided matter in suspension in weakly acid liquor, and has defied every device of the company to recover it. Once in the stream it collects in long undulating streamers, which adhere to the banks and bottom, giving the creek an unsightly appearance. As this effluent is undoubtedly good food for algæ and bacteria, it favors their development.

A considerable distance from the Hannis distillery, at the south end of the city, the gas company discharges ammoniacal liquors into the stream. Opposite the gas works a little run enters which carries most of the manufacturing effluents received by Tuscarora Creek. The Kilbourn Knitting Machine Company's waste amounts to 10,000 gallons a day, and consists of wool scourings, spent dyes, and rinse waters from the manufactured goods. These liquors are run into a sedimenting pool, whence they overflow into the run. The solid matter is pumped out from time to time and allowed to stand in the vicinity of the pool. The Crawford Woolen Company discharges directly into the

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[a] Results of stream measurements on Opequon and Tuscarora creeks near Martinsburg are given on pp. 78-82.

run 10,000 gallons of spent dyes and 5,000 gallons of wool scourings in twenty-four hours. The Martinsburg Worsted and Cassimere Company utilizes the run for its spent-dye liquors, which amount to 5,000 gallons in twenty-four hours.

No other important contamination taints Tuscarora Creek below this little run. Before leaving the discussion of Martinsburg, however, it should be noted that the ice consumed in the city, though mainly of local manufacture, is in part cut on the Tuscarora Creek above the city and in part on Opequon Creek above Tuscarora Creek. The latter source is undoubtedly unsafe on account of the pollution of Opequon Creek by the city of Winchester, and the practice of harvesting ice on it should be prohibited. From the mouth of Tuscarora Creek, Opequon Creek flows for a few miles through a farming country to the Potomac.

POTOMAC RIVER FROM OPEQUON CREEK TO ANTIETAM CREEK.

On the Potomac, 20 miles below Opequon Creek, is Shepherdstown, a village with no public water supply and but few wells, most of the inhabitants using cistern water. There is no sewerage system, but a small run which courses through the town performs the functions of one. It is lined with privies and hogpens, which pollute it badly. The town is too small to contaminate the Potomac greatly, but its contribution of excrement should not be overlooked, for small outbreaks of typhoid fever are very likely to occur in places without water supply and sewerage, and the disease can easily be disseminated by means of infected feces through the agency of the river. Six miles below Shepherdstown is the mouth of Antietam Creek.

ANTIETAM CREEK.[a]

Antietam Creek rises in the Green Ridge Mountains, Franklin County, Pa., and discharges into the Potomac 5 miles below Sharpsburg. On Little Antietam Creek is the town of Mont Alto, which furnishes some indirect pollution to the stream. Between East Branch and Little Antietam Creek, in Franklin County, is the borough of Waynesboro, which contains several large industrial plants, but none of them have liquid wastes. The Frick Company, however, runs the sewage of its 700 employees into Little Antietam Creek through an open sewer. The water supply of Waynesboro is well adapted to boiler use, and gives general satisfaction. It is derived from two sources. One of them, Bailey Spring Run, is 4 miles northeast of the town. The reservoir was constructed in 1885, and is now rarely used, being simply a reserve which can be called on in case of emergency. The main supply of the town is derived from Rattlesnake Run, across which a dam has been built at its confluence with East Branch of Antietam Creek in the Pennsylvania Forest Reserve. From this point the

[a] Results of stream measurements on Antietam Creek at Sharpsburg are given on pp. 82-90.

water is carried 7 miles southward and served to the town. There is no sewerage other than an irregular system of drains, which are supposed to exclude soil. The cesspools, which are universally used, drain through the broken limestone, presumably to one or the other of the branches of the Antietam. The result is that practically all the wells of the town are polluted, and have been abandoned both on this account and because the water is hard and not adapted to domestic or manufacturing use.

The next town of importance below Waynesboro is Hagerstown, a large industrial center of western Maryland. Its public water supply is furnished by the Washington County Water Company, and is derived from runs on South Mountain, 11 miles from the city. The present waterworks were started in 1896 and completed in 1903. Their capacity is 1,500,000 gallons in twenty-four hours; that of the old works, established in 1881, was 400,000 gallons. In 1902, owing to the depleted condition of the reservoirs, it was found necessary to establish a pumping station on Antietam Creek at Bridgeport. Water was pumped for thirty days only, and since that time this source has never been used, but it is still available. Hagerstown has no regular sewerage system, but is pretty thoroughly drained by terra-cotta pipes, which are supposed to exclude all soil. Slops, however, undoubtedly enter these pipes. Fifty per cent of the houses have water-closets; the rest depend on privies. Cesspools which serve the water-closets are in many cases abandoned wells, and estimates have been made that 40 per cent of them are so. Privy-vault matter is sometimes buried in the town, but more commonly it is carried outside of the city limits and disposed of on farms. Owing to the fact that cesspool drainage and other pollution finds its way through the crevices and seams in the rocks that underlie the town to the general water level, most of the wells have become polluted, and consequently many of them have been closed up. The fact that a considerable number of typhoid cases occur every year in Hagerstown and that these are as a rule confined to users of well water seems to indicate that the remaining wells should be abandoned. The indirect pollution is probably largely carried off by Town Run, a tributary of Marsh Run, which in turn enters Antietam Creek. Town Run receives the condenser water and washings from beer barrels of the Hagerstown Brewery Company, which claims that it is this flux of water alone that keeps the run from stagnating and becoming very foul and offensive in summer time. The Blue Ridge Knitting Company does considerable dyeing not only for itself, but for other firms in Maryland and Pennsylvania. Its wastes are spent dyes and rinse water from the finished goods and amount to 2,400 to 3,600 gallons in twenty-four hours. They are disposed of in the Town Run. J. C. Roulette & Co. bleach their goods, and the rinse water, amounting to 3,500 gallons in twenty-four hours, and the wasted spent bleach enter Marsh Run. The Antietam Creek Paper Company is located outside of Hagerstown, and makes paper from wood, rags, and paper by the soda process. The most important waste is spent lime bleach, which is sedimented near the mill and applied to a farm owned by the company.

Below its confluence with Marsh Run, Antietam Creek receives important pollution from but one other source—the town of Sharpsburg, Md., located on a little run a short distance from the creek. The town is a small one, but it is near the battlefield of Antietam, and therefore is periodically visited by crowds who severely tax its limited sanitary facilities. The run on which it is located heads in a spring which is in common use as a water supply, though the inhabitants have to go to it for water. In the summer of 1904 there was a typhoid epidemic which some persons attributed to the use of the spring water. At that time there was a general cleaning out of the privy vaults and hog pens that line the run, and now very few of the hog pens directly overhang it, though it undoubtedly receives much fecal matter of both man and animals. While the amount must be small in proportion to pollution from other sources, it is perhaps important because Sharpsburg is but 60 miles above Washington, where the Potomac is used as a public water supply, and pollution from Sharpsburg would probably reach Washington in a day or two.

POTOMAC RIVER FROM ANTIETAM CREEK TO SHENANDOAH RIVER.

Elk Branch, which enters the Potomac a little above Harpers Ferry, receives the sewage of Shenandoah Junction, W. Va., where a considerable number of travelers find victuals and temporary lodging. Ten miles below the mouth of Antietam Creek, at Harpers Ferry, the Potomac is joined by the Shenandoah. The town is situated on the tongue of land between the rivers and is unsewered, so that various ways are adopted to get the soil into the Potomac, where practically all the refuse of the town goes. The Baltimore and Ohio station is right on the river, into which its water-closets conveniently discharge beneath the railroad bridge. The subject of the sanitation of the railroads in the Potomac basin is not an unimportant one, for besides the stations, which are, of course, fixed and can always be carefully provided for, there are 1,200 miles of track over which pass every day many hundreds of people from all parts of the Union, many of them from cities and towns in which typhoid fever is common. The usual method of caring for the excreta of these travelers is to let it drop along the tracks. It has generally been assumed that this is the best way of handling this material, but it seems a fair question whether it is or not. Undoubtedly the method was originally adopted because of its simplicity, and it has received general acceptance without much thought as to its possibilities for spreading infection. Perhaps in the future this problem will receive more careful attention and some other means of disposing of the feces, such as collecting them and leaving them at definite points for disposal, may be adopted.

One of the hotels in Harpers Ferry has its fixtures connected to a cesspool, the overflow of which is piped to the river. Another is connected by a sewer to the old arsenal yard, where abandoned raceways conduct the sewage to the river. It is said that not a few private houses dispose of their sewage in the same way. Privies are common in Harpers Ferry, and the vault matter is disposed of as suits the owners; it is believed that some of them throw the soil into the rivers. There is no public water supply, the people for the most part relying on cisterns, though a few take water from the brewery, which brings its water from springs in the Blue Ridge Mountains across the bed of the Shenandoah. The Hill Top Hotel pumps some of its water from Potomac River. The only industrial wastes in Harpers Ferry are those of the brewery and two pulp mills, one of which is on the Potomac and the other on the Shenandoah. Both mills manufacture mechanical wood pulp, in which process the logs are freed from their bark before being ground (Pl. VIII, *B*, p. 222). The shavings were formerly disposed of by being put into the rivers, and at the time of the inspection evidences of this pollution were very manifest. Since that time both mills have installed apparatus for burning the shavings and the nuisance is abated. The brewery discharges the washings from its beer kegs into the Shenandoah.

POLLUTION IN SHENANDOAH RIVER BASIN.

Shenandoah River is formed at Riverton, Va., by the confluence of North and South forks. South Fork in turn is formed at Port Republic by the junction of North and South rivers.

SOUTH FORK OF SHENANDOAH RIVER BASIN.

SOUTH RIVER.[a]

South River rises west of Greenville, Augusta County, W. Va., and flows eastward past Basic City and Waynesboro, towns on opposite banks of the river, forming a considerable center of population. Here the stream receives its initial industrial pollution. Basic City has a small blanket factory and a factory for the manufacture of tanning extract from chestnut-oak wood. The pollution furnished by the former consists of rinse water from the finished goods, and from the latter, at the present time, such amounts of extract as are absorbed by the condenser water. When the plant was new the leaching vats leaked and caused much complaint because the extract stained the river

[a] The results of measurements of South River at Basic City and Port Republic are given on pp. 91-98.

badly. Several factories have located at different times in Basic City, but their existence has been short. A large summer hotel annually attracts many visitors. The city is supplied with water from a spring close to the river. There is no sewerage system, but one of the hotels has a private sewer which discharges into a run that enters North River below the waterworks.

Waynesboro is supplied with water from Bakers Spring, which is owned by private parties, and for the use of which the town pays a small sum every year. The mains and service pipes, together with a storage tank of 50,000 gallons capacity, are owned by the town, and were installed in 1897 at a cost of $10,000. The introduction of this supply reduced the typhoid rate and has led to the general abandonment of wells. A stove factory is the largest industrial plant in Waynesboro. It has no liquid wastes, but the sewage from its 100 employees is discharged into a race which enters the river. Brunswick Inn is also reported as sewering into the river, and it is said that the material from the many privies in town is thrown into it. The slaughterhouses in both Waynesboro and Basic City dispose of their offal in the stream.

From Basic City South River flows in a northerly direction. At Crimora a small run enters, which is very turbid owing to the washing of manganese ore by the Crimora Manganese Company near its head. This concern employs 100 men, who are established in small huts scattered over the watershed of the run. A long tunnel is being driven in the mines which will drain them more thoroughly and deliver the water on lands of the company instead of to the run. It is proposed to construct settling basins to clarify the water, which will then be led, in some way not determined, to the river.

NORTH RIVER.[a]

North River rises in the Shenandoah Mountains in the northwest corner of Augusta County, on the slopes of Briery Branch Knob. The upper part of its watershed is given over to lumbering, and at Stokesville, just east of Narrow Back Mountain, are located a sawmill and a tanning-extract factory. The latter is still uncompleted and unless unusual precautions are taken when the plant is started, the leaking vats may discolor the river. In the summer of 1905 this town was the seat of an outbreak of typhoid fever. The first case, which was probably imported, was in a family whose spring was in common use in the town. About two weeks afterwards two other users of the waters of this spring were taken sick. One of them was removed to the west end of the town, where he remained for a few days, after which he was taken to Harrisonburg. In this interval he apparently infected a privy which was used by several families,

[a] The results of stream measurements in the North River basin are given on pp. 98-108.

situated directly opposite the house where he was confined. Later, typhoid germs from this source must have been disseminated in the neighborhood by flies, for 4 cases appeared close by and they were the only ones in the whole town among those who did not use the spring water. Other cases, 13 in number, occurred among the users of the spring and people who lived along the run which rises in it, and who either had access to the spring itself or used the water of the run for one purpose or another in their homes. This epidemic illustrates very well how typhoid fever originates and spreads in the basin of the Potomac. As a rule, the outbreaks occur in small towns where there are no facilities for disposing of ordure and where the limited water supply is in general use and is derived from some source surrounded by dwellings. Sanitary precautions, through the ignorance of the people, are entirely neglected and twelve months in the year conditions are ripe for an outbreak of typhoid. All that is needed is to have the initial case imported. Once that is accomplished, the disease spreads rapidly. In many towns where repeated outbreaks have occurred, the disease may be said to have established itself permanently, a case or two being present all the time. This can be readily understood, for the stools are not sterilized, and it needs only a transportation of privy matter or some other infectious material to start fresh cases.

The next town below Stokesville is Bridgewater, which also has been subject to outbreaks of typhoid fever. There is no public water supply, the people being dependent on cisterns and wells. On the river somewhat west of the town is a woolen factory where blankets are made. It is run only part of the year and the wastes, consisting of a small quantity of wool scourings, spent dyes, and rinse from the finished goods, are emptied directly into North River.

Below Bridgewater is Mount Crawford, located on North River somewhat to the west of Cooks Creek.[a] Typhoid has been prevalent here, which may perhaps be partly accounted for by the fact that the citizens have cut and used ice from Cooks Creek, a stream receiving the sewage of Harrisonburg.

Harrisonburg is about 8 miles northeast of Mount Crawford. It is one of the largest cities in the valley and seems to be growing steadily. It has a public water supply derived from Dry River, 13 miles farther west. It is said that since the supply was introduced typhoid, which was formerly very common, has been materially reduced. The sewerage system is a combined one and is available in nearly all parts of the city. The flow, which is estimated at 250,000 gallons in twenty-four hours, is discharged a quarter of a mile south of the city into Blacks Run, a tributary of Cooks Creek. This sewage is augmented by the waste from the plant of the J. P. Houck

[a] The results of measurements of Cooks Creek at Mount Crawford are given on pp. 98–101.

Tanning Company, estimated at 2,500 gallons a day. The waste from the lime vats is sedimented and the liquor run into the sewer, as is the waste sour bark liquor. The liquor from the scouring machines and a waste made up of various small leakages that occur in various parts of the tannery are turned directly into the run. Together they make the water very foul, especially in summer, when the city authorities have occasionally been obliged to flush out the stream on account of the bad odors arising from it. Whenever observed, the run has appeared to be taxed to its utmost, and it is reported that in summer the waste from the tannery has decidedly discolored North River as far as Mount Crawford railroad station. No other factories in Harrisonburg have liquid wastes.

Four miles above Port Republic North River receives Middle River, which rises in Little North Mountain southwest of Staunton. Middle River flows northeastward to Long Glade, then southeastward to Laurel Hill, where Lewis Creek enters.[a] This creek is heavily polluted by the sewage of Staunton, an energetic, prosperous city estimated to have 12,000 buildings, 50 per cent of which are connected with the sewer. There are no manufacturing plants having liquid wastes; therefore the sewage is almost entirely domestic. The system, which is a combined one, was established twenty-five years ago and has grown slowly and irregularly ever since. The first water supply was introduced in 1849 and is still in use, but the main supply was put into service in 1876, at a cost of $100,000, and comes from springs on the bank of a stream one-half mile west of the city. The wells of the city are badly polluted and most of them have been closed up by the local authorities. The typhoid rate of the city is very low, only one death being recorded in 1904.

The water supply of Staunton was at one time unpleasantly affected by fresh-water sponge which grew in one of the reservoirs. The trouble was investigated by Prof. J. W. Mallet, whose report is on file with the city authorities. The sponge was killed and the trouble completely overcome by fluctuations of the water level.

SOUTH FORK OF SHENANDOAH RIVER BELOW PORT REPUBLIC.

Below Port Republic, South Fork of Shenandoah River flows northeastward through the Page Valley, being separated by Massanutten Mountain from North Fork, which joins it at Riverton.

Keezletown is located on the west side of the mountain, but discharges its refuse into South Fork through Cub Run. It is a small town, but the run receives some pollution there from the tannery of A. D. Bertram, which has a capacity of 700 hides a year.

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[a] The results of measurements of Lewis Creek near Staunton are given on pp. 101–103.

A little below the mouth of Cub Run South Fork receives Stony Run, which rises on the east side of the mountain and flows through McGaheysville, where it is contaminated by a tannery having a capacity of about a hide a day.

At Elkton South Fork is much befouled by the waters of Elk Run, which rises in the Blue Ridge Mountains and flows westward to the river.[a] Elkton has a public water supply which is furnished from springs by the Wampole Lithia Company. There is no sewerage; the inhabitants depend entirely on outhouses, the soil of which is said to be thrown into Elk Run when they are cleaned. One of the hotels has a trench for its urinal and slops which leads directly to the run. The stream also receives pollution from the tannery of J. R. Cover & Sons. This plant employs 25 hands, and has a privy directly overhanging a ditch that leads to the run. Through this ditch are discharged the wastes, which amount to 1,500 gallons a day. Inspection makes it quite evident that this amount is too large for the little run to carry off promptly and easily. Indeed, the effect of the pollution on the river itself must be considerable. In the summer a hotel is opened in Elkton which is said to accommodate many guests. While such places add to the wealth of the towns that are fortunate enough to possess them, they contain an element of danger, for their patrons come from many different places and may carry in their persons germs of disease contracted in their homes. In due time these unfortunates sicken and then the infection elaborated by them is likely to lay hold of the community they are visiting and make it a center from which contagion spreads.

Below Elkton is Shenandoah, a prosperous town which can pollute the river but indirectly. Thirty miles below is the mouth of Hawksbill Creek, on which is located, in Page county, the town of Luray.[b] The creek divides the town into very nearly equal portions which rise somewhat abruptly from it; consequently the run-off through the town is quick and carries with it considerable refuse. A water supply was installed in 1900. Typhoid fever is said to have been prevalent prior to its introduction, but such is not now the case. There is no regular sewerage system in town, and cesspools are commonly used. As a rule they do not need cleaning, because they leak away through the underlying limestone. A number of water-closets and one of the hotels discharge directly into Hawksbill Creek. At one time there was some agitation against permitting them to do so, but it died out, and now the suggestion has been made that the town establish a sewerage system and utilize the creek for an outlet. Luray has usually a large transient population, attracted thither by

[a] Results of measurements of Elk Run at Elkton are given on pp. 110–112.

[b] Results of measurements of Hawksbill Creek at Luray are given on pp. 112–115.

the wonderful caverns. Thus the town is considerably exposed to the danger of infection being imported from outside. The chief pollution of Hawksbill Creek is by the Luray tannery, owned by the Deford Company, of Baltimore. This plant employs 170 hands, and the waste poured into the creek amounts to 10,000 gallons a day. The waste from the beam house and the scouring liquor are run into two cesspools, where they are allowed to evaporate. The residue is used for a fertilizer on a farm owned by the company. The volume of sour bark liquor, which with the soil of six water-closets is carried in a long trench to the creek, is so large in proportion to that of the stream that the latter is colored a deep red and maintains the hue to its mouth, 5 miles below the factory. An acetylene-gas company in the center of the town piles its lime sludge on the banks of the Creek.

NORTH FORK OF SHENANDOAH RIVER BASIN.

North Fork of the Shenandoah rises in the northern part of Rockingham County and flows southeastward to Broadway, where it turns to the northeast. North Fork is not much polluted until it reaches New Market, where, on a tributary of Smiths Creek, there is a small tannery owned by F. M. Tusing. The next town below is Mount Jackson, which is on Mill Creek a little way from its mouth. It has neither public water supply nor sewerage, the people relying almost wholly on cistern water, as there are but a few wells in town. The pollution here is inconsiderable and very indirect. From Edinburg to Strasburg the course of North Fork is decidedly meandering. At Tomsbrook a creamery pollutes North Fork. At Woodstock a creamery pollutes Hollow Run, but the rest of the refuse of the town is insignificant. There is no public water supply nor sewerage, and the river receives only a little very indirect pollution from the town.

Strasburg is the largest town in the valley of North Fork of the Shenandoah. It is traversed by Hupp Spring Run, and this stream carries off most of the waste from the town, and is also polluted by the sludge from a small acetylene-gas plant and by the effluent from O. F. Chandler's tannery, which has a capacity of about a hide a day. At the time of inspection Strasburg was depending on springs and wells, but as the well water is very hard a public water supply was being installed which it was expected to follow up with a sewerage system.

The only other town to be noticed in the discussion of North Fork is Middletown, a place without water supply and sewerage, located on Marsh Run, a tributary of Cedar Creek, which flows into North Fork below Strasburg. The pollution from Middletown is only slight and very indirect.

SHENANDOAH RIVER BASIN BELOW NORTH AND SOUTH FORKS.

Riverton lies between North and South forks of Shenandoah River and pollutes the rivers but little, as it is a small place, with most of the houses some distance from the two streams. The town purchases its water from Front Royal, and therefore enjoys the same immunity from typhoid as that town. There is a large duck farm which drains into the North Fork of the Shenandoah. No other pollution here is worthy of note.

A short distance below Riverton, Shenandoah River receives the drainage of Front Royal, which is on Happy Creek, 3 miles from its mouth. Most of the pollution of the creek by the town is indirect, for there are few water-closets, most of the people using outhouses, though some of the privies are dangerously near the stream. One of the hotels has a cesspool from which the overflow is carried in a private sewer toward the creek. The town is a clean one, and is free from typhoid fever. The chief source of pollution on the creek is a slaughter barn. The offal is fed to swine kept in a yard that reaches down to the creek in order that the animals may drink there. When observed, no slaughtering was being done, but that considerable offal and blood goes into the creek when killing is in progress seems to be the general opinion. Formerly there used to be many cases of typhoid fever in Front Royal every year, but this stopped twelve years ago, when a public water supply was introduced from Chester Gap, 4 miles to the southeast. The source of supply is from springs whose flow is collected in a reservoir of 1,500,000 gallons capacity and run by gravity into the town. The cost of the works was $40,000.

Twenty-four miles below Riverton is the mouth of Lewis Run, which drains the town of Berryville, the county seat of Clarke County. There is no manufacturing in Berryville, but the run is polluted by hogpens and privies which are near it. Moreover, many of the houses have sewers for their slops which empty into the run. The town has a public water supply which is said to be excellent. Previous to its introduction, typhoid was rampant in the town and now it is of rare occurrence.

Fifteen miles below Berryville Evitt Run enters the Shenandoah. This is a rather attractive stream of clear water, which does not show ocular evidence of pollution, though it carries the indirect pollution of Charles Town, the county seat of Jefferson County. This city has no sewerage system and has not been compelled to construct one because of the fact that if there are not seams enough in the limestone to carry away the leakage of the numerous cesspools, the explosion of a dynamite cartridge in the rock at the bottom of the cesspool is sufficient to insure its caring for itself. The water supply of the town was originally obtained from several town pumps, all but two of which have been given up because the above-mentioned method of caring for sewage has allowed cesspool matter to enter the wells.

The present water supply is sufficient and satisfactory. It is furnished by the Charles Town Water and Manufacturing Company, which brings it from a spring 1 mile west of town.

Between Evitt Run and Harpers Ferry Flowing Run enters the river. This stream is contaminated by the paper box board factory of Eister & Sons at Halltown, W. Va. The firm makes box board from old paper, and the effluent, consisting of dirty water with much paper and fiber in suspension, is turned directly into the run and muddies it. Additional pollution is furnished by the privies of the concern, which overhang the stream for the convenience of its 35 employees.

POLLUTION IN POTOMAC RIVER BASIN BELOW SHENANDOAH RIVER.

POTOMAC RIVER FROM SHENANDOAH RIVER TO MONOCACY RIVER.

At Harpers Ferry the Potomac cuts through the Blue Ridge Mountains between Loudoun Heights on the south and Maryland Heights on the north, and enters the upper Coastal Plain region. Along the northern bank there is a scattered population, most of whom are densely ignorant of sanitary laws. The privy vaults and hogpens are near the houses except where there is a little stream, in which case the structures are located over it, and thus the offal is carried to the river. At Weverton and Knoxville, Md., this population is somewhat concentrated, and at Knoxville the privies and hogpens which overhang the creek that passes through the town are more numerous than is usual in this region. The migratory character of the population in these towns and the accompanying crude sanitary conditions constitute a decided menace to the river. During the summer of 1905 typhoid fever prevailed in these settlements, and probably if records could be obtained for the past dozen years it would be found that it had done so every year. They are not more than 35 miles from Washington, and should be subjected to rigid sanitary supervision.

Below Knoxville is Brunswick, Md., a town which has sprung into existence on account of the location of the Baltimore and Ohio Railroad shops there. These shops employ 400 men, and while there are no liquid wastes the sewage of the employees furnishes the Potomac with considerable indirect pollution. The privy which is used by the roundhouse force is located close to the canal and is nearly surrounded by a green pool caused by seepage from it; about 100 yards distant is another privy in a large cinder bed. The town is on a high, steep hill and is crossed by four different runs along which are a number of privies, some of them actually overhanging the streams.

Second Culvert Run furnishes the most important pollution, for into it is discharged the sewage of the railroad bunk house, which is fitted with water-closets, bath tubs, and urinals. This sewage is created by a roving population, and consequently by one more exposed to disease than a settled one would be, and the excrement is correspondingly more dangerous. It is expected that a large Y. M. C. A. building will be erected alongside the bunk-house, and that too will discharge into the run. There are a few water-closets in the town, some of which are connected to the runs, but in general privies are used. For water the town is dependent on wells and cisterns, though at the east end of town there is a private supply which comes from the Potomac. The peculiar topography and population of Brunswick make it very necessary that sanitary matters be thoroughly looked after there. The fact that it is on the steep sides of a high hill insures all the offal finding its way promptly to the river, and the shifting population, however well intentioned it may be, is more or less likely to bring disease into the community from without. Finally, the town is near Washington, and therefore typhoid germs will be transported by the Potomac to that city in a short time. In the summer of 1905, at the time the inspection was made, it was reported that there were five cases of typhoid fever in Brunswick, but what precautions were taken to sterilize the stools and otherwise protect the public were not ascertained.

A few miles below Brunswick the Potomac receives Catoctin Creek of Virginia and Catoctin Creek of Maryland, after which it cuts through Catoctin Mountains and emerges at Point of Rocks, in the lower Coastal Plain region. Point of Rocks and Washington Junction form a single settlement skirting the Chesapeake and Ohio Canal.[a] Like the other places below Harpers Ferry, they are lacking in sanitary arrangements. At Washington Junction the water-closet of the railroad station discharges into the river. From Point of Rocks it is 3 miles to the mouth of Tuscarora Creek, on which at Adamstown there is a small cannery. The creek is also polluted at Doubs.

MONOCACY RIVER BASIN.

Two miles east of South Tuscarora Creek Monocacy River enters the Potomac. It has three large feeders that rise in Adams County—Marsh, Rock, and Middle creeks. Between the two former, on the watershed of Rock Creek, is the borough of Gettysburg, and on Middle Creek is the town of Emmitsburg. Gettysburg derives most of its water supply from Marsh Creek, southwest of the town. The watershed above the intake is not heavily polluted, though at McKnightstown there is a tannery with a capacity of 100 hides a week. The water is filtered through a Warren filter that was installed

[a] Results of measurements of Potomac River at Point of Rocks are given on pp. 148–161.

twelve years ago. Coagulent is used only when the creek is very turbid. This supply is supplemented and mixed with water obtained from two driven wells on Cemetery Hill. These are pumped by wind power and are constantly in use. The borough is now installing a sewerage system for soil only which when finished will have 7 miles of pipe line and it is expected will be generally utilized by the citizens. The sewage will be treated in two septic tanks, and the effluent from them will be filtered through brick walls and then run into Rock Creek into which the private sewers of the town now discharge. It is to be hoped that the treatment of the sewage will be effective, for Gettysburg is almost daily visited by large numbers of sight-seers. The throng of pilgrims is variable, sometimes being small and sometimes rising to 10,000 in a single day. The people come to see the beautiful battlefield, which has been carefully preserved by the National Government. As the park is a permanent one, there will probably never be any diminution in the number of visitors. In a throng of this kind there are apt to be many who seize the opportunity for a rest because they are out of condition, run down, or sick, and think that a little excursion will restore them. Among such people there are likely to be some in one stage or another of typhoid fever, so that the transient population that visits Gettysburg may be something of a menace to the waters of the Potomac; hence the desirability of carefully purifying the sewage before it is discharged into the creek.

Stevens Run, a tributary of Rock Creek, is polluted by the effluent of a gas works. The waste makes the run ill smelling and repulsive in appearance. Moreover, it is said to injure fish life, and a suit has been brought by the Fish Commission against the company. Culps Run, another tributary of Rock Creek, receives the sewage and effluents from W. S. Duttera's tannery, which turns out 50 hides a week, and the wastes from which are similar to those discharged from other tanneries.

Emmitsburg, on Middle Creek, is the site of Mount St. Mary's Academy, St. Joseph's Academy, and the mother house in the United States of the Sisters of Charity. The population of the town, including the sisterhood, is 2,000. There is neither public water supply nor sewerage.

On Double Pipe Creek is Westminster, a large town without public water supply or sewerage.

From the junction of Marsh and Middle creeks to the mouth of Carroll Creek the distance is 25 miles. Carroll Creek rises in Catoctin Mountain, northwest of Frederick, Frederick County, Md., and flows southeastward through the southern part of the city to the Monocacy. The Frederick water supply is obtained from Big Tuscarora Creek, Little Tuscarora Creek, and Fishing Creek and is said to be wholesome, a statement that is borne out by the low typhoid rate of the city.

Each of the two main streets has a single drain, which was put in primarily with the object of carrying off the water from cellars of abutting houses. They have developed into sewers from which soil is excluded, but which take in slops and surface water and discharge into Carroll Creek. In many of the streets of the city the slops run through the gutters and ultimately reach the creek.

The indirect industrial pollution of Carroll Creek consists of an insignificant amount of waste from a cannery and from the scrubbers of a gas house. It is directly contaminated by the scouring liquor from the Brierly tannery, together with some lime sludge that is piled on the banks of the creek; by the effluent from a steam laundry, by the sewage of the Carroll County almshouse, and, most obviously, by the pollution from the works of the Union Knitting Company, consisting of the sewage of 200 employees and a large quantity of spent dyes.

The pollution received by the Monocacy from the mouth of Carroll Creek to the Potomac is, for the most part, very insignificant, being only that incident to the life of widely separated farms. At Frederick Junction the closets of the Baltimore and Ohio Railroad station empty into the river. Buckeystown is the most considerable settlement below Frederick on the Monocacy. It is drained by a little run which receives the washings of a cannery and a small creamery, besides the discharge of water-closets. The unvaulted privies of a large brick works in the town are about 20 feet from the stream. The water used in Buckeystown is derived from cisterns.

POTOMAC RIVER FROM MONOCACY RIVER TO GREAT FALLS.

The largest and most important tributary of the Potomac between the mouth of the Monocacy and Great Falls is Goose Creek. It has a large drainage area, which is on the south side of the river and lies east of the Blue Ridge Mountains. The watershed is given over to agriculture and contains but one town of much size. Hence the proximity of the basin to Washington is not nearly so important as it would be if the population was large and concentrated at a few points. The development of this drainage area will be watched with interest, for should it become the home of a large summer population, or should other considerable towns spring up in it, the creek might become a serious menace to Washington, inasmuch as disease germs from it could be transported to the city in a few hours.

Leesburg, the important town alluded to, is on Tuscarora Creek, a tributary of Goose Creek. There is no sewerage system in the town, but 800 feet of 2-foot terra-cotta drains, which are supposed to carry surface water only, discharge into Tuscarora Creek. Therefore the pollution caused by Leesburg is indirect save for the few privies that overhang Tuscarora Creek. The water supply of the town is inadequate and was suspected at one time of being contaminated, for in the summer of 1904 there was considerable typhoid fever, and this impelled the citizens to bond the town for $30,000 to enable it to increase its water supply. The new system will furnish an abundant supply and will probably result in the construction of a complete sewerage system, which will have its outlet in Goose Creek.

Eight miles above Great Falls is Seneca Creek, whose watershed is given over to small farming and which does not contain a single important center of population. The creek would not be worth mentioning here did not its proximity to Washington make it possible for disease germs originating in its basin to be transmitted to the capital in a very short time.

POPULATION AND DRAINAGE AREAS.

The following tables show the population and the drainage areas of the smaller basins that make up the Potomac watershed:

Population of the Potomac River basin.

[According to the census of 1900.]

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
NORTH BRANCH POTOMAC RIVER BASIN.	*Miles.*		
Savage River	209		1
Swanton		87	
Other towns		87	
		174	
Georges Creek	207		174
Barton		1,287	
Frostburg		5,274	
Lonaconing		2,181	
Midland		1,800	
Ocean		1,500	
Other towns		1,194	
		13.236	
Wills Creek	174		116
Cumberland		17,128	
Eckhart Mines		1,600	
Hyndman		1,242	
Jennings Run			
Mount Savage		2,000	
Vale Summit		800	
Other towns		2,623	
Estimated remaining population on Wills Creek and tributaries		6,000	
		31,493	
Evitts Creek	169		
Cumberland Valley		157	
Hazen		104	
Other towns		142	
Estimated remaining population on Evitts Creek and tributaries		1,500	
		1,903	
Patterson Creek	166		4
Alaska		183	
Burlington		259	
Medley		140	
Other towns		483	
		1,065	

Population of the Potomac River basin—Continued.

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
NORTH BRANCH POTOMAC RIVER BASIN—continued.	*Miles.*		
North Branch Potomac River	158		
Bayard		540	
Blaine		395	
Bloomington		496	
Dobbin		581	
Elk Garden		344	
Gormania			
Keyser		2,536	
Piedmont		2,115	
Westernport		1,998	
Luke		510	
Other towns		1,434	
Estimated remaining poputlaion on the North Branch and minor tributaries		15,000	
		25,949	
Total for North Branch Potomac basin		73,820	
SOUTH BRANCH POTOMAC RIVER BASIN.			
South Branch Potomac River	158		14
Circleville		119	
Franklin		205	
Monterey		246	
Moorefield		460	
Petersburg		312	
Purgitsville		102	
Romney		580	
Springfield		142	
Other towns		1,431	
Estimated remaining population on South Branch and tributaries		18,000	
		21,597	
POTOMAC BASIN BELOW NORTH AND SOUTH BRANCHES.			
Town, Sideling, and Fifteenmile creeks			4
Chaneysville		147	
Flintstone		250	
Gilpin		100	
Other towns		224	
Estimated remaining population on Town, Fifteenmile, and Sideling creeks		11,070	
		11,791	
Little Cacapon River	152	2,423	11
Great Cacapon River	122		18
Augusta		126	
Capon Bridge		193	
Forks of Capon		66	
Inkerman		40	
Lost City		55	
Wordensville		152	
Other towns		1,036	
Estimated remaining population on Great Cacapon River and tributaries		10,800	
		12,468	
Great Tonoloway Creek	112		19
Covalt		151	
Sipes Mill		113	
Other towns		529	
Estimated remaining population on Great Tonoloway Creek and tributaries		1,600	
		2,393	
Sleepy Creek and tributaries	107	2,941	20

Population of the Potomac River basin—Continued.

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
POTOMAC BASIN BELOW NORTH AND SOUTH BRANCHES—cont'd.	*Miles.*		
Licking Creek	105		39
McConnellsburg		572	
Plumrun		110	
Sylvan		190	
Webster		122	
Other towns		466	
Estimated remaining population on Licking Creek and tributaries		6,200	
		7,660	
Back Creek	96		28
Baxter		102	
Hedgesville		342	
Shanghai		143	
Other towns		923	
Estimated remaining population on Back Creek and tributaries		6,500	
		8,010	
Conococheague Creek	90		47
Ambersons Valley		312	
Chambersburg		8,864	
Dryrun		230	
Fannetts		314	
Fort Loudon		335	
Greencastle		1,463	
Mercersburg		956	
St. Thomas		410	
Williamsport		1,472	
Brownsville		1,552	
Fayetteville		672	
Other towns		3,987	
Estimated remaining population on Conococheague Creek and tributaries		6,744	
		27,311	
Opequon Creek	78		74
Brucetown		338	
Bunker Hill		228	
Darkesville		231	
Gerrardstown		239	
Jordan Springs			
Kearnesville		203	
Martinsburg		7,564	
Middleburg		466	
Winchester		5,161	
White Post		250	
Other towns		1,167	
Estimated remaining population on Opequon Creek and tributaries		8,800	
		24,647	
Antietam Creek	56		141
Antietam		163	
Benevola		103	
Blue Mountain		100	
Boonesboro		700	
Breathedsville		114	
Cavetown		287	
Chewsville		152	
Downsville		152	
Eakles Mills		120	
Fairplay		114	
Fiveforks		113	
Funkstown		559	
Hagerstown		13,591	
Keedysville		426	
Leitersburg		347	
Mont Alto		658	
Pondsville		100	
Quincy		410	
Ringgold		114	

Population of the Potomac River basin—Continued.

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
POTOMAC BASIN BELOW NORTH AND SOUTH BRANCHES—cont'd.			
Antietam Creek—Continued.	*Miles.*		
Shadygrove		186	
Sharpsburg		1,030	
Smithsburg		462	
Waynesboro		5,396	
Other towns		1,201	
Estimated remaining population on Antietam Creek and tributaries		16,342	
		42,940	
Shenandoah River basin:			
North River	203		
Bridgewater		384	
Dayton		425	
Harrisonburg		3,521	
Mount Clinton		225	
Mount Crawford		330	
Mount Solon		172	
Sangerville		175	
Stokesville		284	
Other towns		1,026	
		6,542	
Middle River	208		
Churchville		239	
Longglade		120	
Middlebrook		300	
Mount Sidney		197	
New Hope		124	
Plunkittsville		100	
Staunton		7,289	
Other towns		936	
		9,305	
South River	203		
Greenville		328	
Grottoes		381	
Port Republic		200	
Shendun		381	
Waynesboro		856	
Other towns		1,749	
		3,895	
South Fork of Shenandoah River	102		
Alma		127	
Bentonville		197	
Browntown		143	
Elkton		511	
Front Royal		1,005	
Keezletown		225	
Luray		1,147	
McGaheysville		375	
Shenandoah		1,220	
Stanleyton		225	
Other towns		1,353	
		6,528	
Passage Creek	108	205	
North Fork of Shenandoah River	102		
Broadway		400	
Dovesville		512	
Edinburg		143	
Edom		176	
Forestville		104	
Laceys Spring		105	
Lantz Mill		250	
Luniville		125	
Marlboro		100	
Mauertown		423	
Middletown		153	
Milldale		153	

Population of the Potomac River basin—Continued.

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
POTOMAC BASIN BELOW NORTH AND SOUTH BRANCHES—cont'd.			
Shenandoah River basin—Continued.			
North Fork of Shenandoah River—Continued.	*Miles.*		
Mount Jackson		472	
New Market		684	
Riverton		650	
Singers Glen		108	
Strasburg		690	
Timberville		173	
Toms Brook		280	
Woodstock		1,069	
Other towns		2,322	
		9,092	
Shenandoah River below confluence of North and South forks.	49		
Berryville		938	
Bolivar		781	
Boyce		275	
Charles Town		2,392	
Halltown		115	
Kabletown		106	
Millwood		400	
Stephens City		490	
Summit Point		217	
Other towns		590	
		6,304	
Estimated remaining population in Shenandoah River basin		74,300	
Total population in Shenandoah River basin		116,171	39
Catoctin Creek, Maryland	38		64
Bolivar		112	
Burkittsville		229	
Harmony		126	
Jefferson		320	
Middletown		665	
Myersville		150	
Petersville		210	
Wolfsville		110	
Other towns		360	
Estimated remaining population on Catoctin Creek, Maryland, and tributaries		6,000	
		8,282	
Catoctin Creek, Virginia	33		31
Hillsboro		131	
Other towns		721	
Estimated remaining population on Catoctin Creek, Virginia, and tributaries		2,000	
		2,852	
Monocacy River	27		92
Barnesville		125	
Boneauville		139	
Bruceville		137	
Buckeystown		436	
Cashtown		146	
Catoctin		150	
Creagerstown		132	
Double Pipe Creek		100	
Emmittsburg		849	
Fairfield		395	
Fountaindale		172	
Frederick		9,296	
Gettysburg		3,495	
Graceham		185	
Harney		150	
Johnsville		196	
Lewistown		235	
Liberty Town		589	
Lime Kiln		400	

Population of the Potomac River basin—Continued.

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
POTOMAC BASIN BELOW NORTH AND SOUTH BRANCHES—cont'd.			
Monocacy River—Continued.	*Miles.*		
Littlestown		1,118	
McKnightstown		148	
Middleburg		140	
New London		100	
New Market		360	
New Midway		100	
New Windsor		430	
Pleasant Valley		117	
Redland		146	
Sabillasville		180	
Seven Stars		115	
Silver Run		143	
Taneytown		665	
Taylorsville		175	
Union Bridge		663	
Union Mills		250	
Uniontown		309	
Unionville		240	
Urbana		219	
Walkersville		359	
Westminster		3,199	
Woodsboro		400	
York Road		175	
Other towns		4,583	
Estimated remaining population on Monocacy River and tributaries		55,000	
		86,661	
Goose Creek	18		35
Aldie		147	
Bluemont		175	
Delaplane		150	
Hamilton		364	
Leesburg		1,513	
Lincoln		175	
Marshall		250	
Middleburg		296	
Paris		168	
Philomont		172	
Purcellsville		247	
Rectortown		111	
Round Hill		351	
The Plains		140	
Unison		104	
Upperville		376	
Other towns		838	
Estimated remaining population on Goose Creek and tributaries		8,000	
		13,577	
Broad Run	16		14
Ashburn		203	
Other towns		336	
Estimated remaining population on Broad Run and tributaries		550	
		1,089	
Sugarland Run	12	848	38
Seneca Creek	11		50
Boyds		125	
Cedargrove		125	
Clarksburg		150	
Gaithersburg		547	
Germantown		170	
Poolesville		236	
Other towns		557	
Estimated remaining population on Seneca Creek and tributaries		4,600	
		6,510	

Population of the Potomac River basin—Continued.

	Distance of mouth above Great Falls.	Population.	Estimated population per square mile.
POTOMAC BASIN BELOW NORTH AND SOUTH BRANCHES—cont'd.			
Potomac River and minor tributaries below North and South branches	*Miles.*		
Adamstown		256	
Berkeley Springs		781	
Brunswick		2,471	
Clear Spring		474	
Darnestown		148	
Great Cacapon		131	
Hancock		824	
Harpers Ferry		896	
Knoxville		363	
Magnolia		153	
Oldtown		112	
Paw Paw		693	
Point of Rocks		364	
Potomac		127	
Shenandoah Junction		318	
Shepherdstown		1,184	
Sir Johns Run		239	
Weverton		136	
Other towns		2,186	
Estimated remaining population on Potomac River and minor tributaries below North and South branches		15,800	
		27,656	
Grand total: Estimated population on Potomac River and tributaries above Great Falls		501,647	44

Drainage areas of Potomac River and of its principal tributaries at several points in the river basin.

NORTH BRANCH POTOMAC RIVER BASIN.

	Square miles.
North Branch Potomac River above Bloomington, Md	290
Savage River at mouth	120
Georges Creek at mouth	76
North Branch Potomac River at Piedmont, W. Va., including Savage River and Georges Creek	490
North Branch Potomac River at United States Geological Survey gaging station at Piedmont	410
New Creek at Keyser, W. Va	56
Wills Creek at mouth	270
North Branch Potomac River at Cumberland, Md., including New Creek and Wills Creek	890
Patterson Creek below Mill Creek at Burlington	155
Patterson Creek at mouth	280
North Branch Potomac River at junction with South Branch	1,360

SOUTH BRANCH POTOMAC RIVER BASIN.

South Branch Potomac River at Franklin, W. Va	190
South Branch Potomac River at junction with North Fork of South Branch	320
North Fork of South Branch Potomac River below Seneca Creek	240
North Fork of South Branch Potomac River at mouth	320
South Branch Potomac River, including North Fork of South Branch	640
South Branch Potomac River at Moorefield, W. Va	900
Mill Creek at mouth	100

	Square miles.
Moorefield River at St. Seybert, W. Va	155
Moorefield River at mouth at Moorefield, W. Va	300
South Branch Potomac River below Moorefield, including Moorefield River.	1,200
South Branch Potomac River at Romney, W. Va	1,410
South Branch Potomac River at United States Geological Survey gaging station near Springfield	1,470
South Branch Potomac River at mouth	1,490

POTOMAC RIVER BASIN BETWEEN SHENANDOAH RIVER AND JUNCTION OF NORTH AND SOUTH BRANCHES.

Potomac River at junction of North and South branches	2,850
Little Cacapon River at mouth	115
Town Creek	190
Sideling Creek	120
Potomac River above Great Cacapon River, including Little Cacapon River.	3,390
Great Cacapon River at mouth	670
North River at mouth	205
Lost River at mouth	190
Cacapon River above North River	405
Potomac River below Great Cacapon River	4,060
Potomac River at Hancock, Md	4,100
Warm Spring Run at mouth	16
Sleepy Creek at mouth	145
Licking Creek at mouth	195
Back Creek at mouth	290
Great Tonoloway Creek at mouth	125
Conococheague Creek at mouth	580
Potomac River at Williamsport, Md., including Warm Spring Run, Great Tonoloway Creek, Sleepy Creek, Licking Creek, Back Creek, and Conococheague Creek	5,560
Opequon Creek at mouth	335
Antietam Creek at mouth	305
Antietam Creek at United States Geological Survey gaging station near Sharpsburg	295
Potomac River at Harpers Ferry above Shenandoah	6,350

SHENANDOAH BASIN.

North River above Bridgewater	295
Cooks Creek at mouth	42
North River to Middle River	420
North River to South River	805
Middle River to North River	365
Lewis Creek at mouth	28.5
South River to North River	245
North, South, and Middle rivers above Port Republic	1,050
South Fork of Shenandoah River at Shenandoah, Va	1,290
Hawksbill Creek at mouth	94
Hawksbill Creek at United States Geological Survey gaging station	52
South Fork of Shenandoah River at Overall	1,490
South Fork of Shenandoah River at mouth at Riverton	1,590
North Fork of Shenandoah River at Brocks Gap	215
North Fork of Shenandoah River at Mount Jackson	510
North Fork of Shenandoah River at mouth at Riverton	1,040

	Square miles.
South and North forks of Shenandoah River at Riverton	2, 630
Shenandoah River at United States Geological Survey gaging station above Millville	3, 000
Shenandoah River at Harpers Ferry	3, 010
POTOMAC BASIN BELOW SHENANDOAH RIVER.	
Potomac River below Harpers Ferry, including the Shenandoah	9, 360
Potomac River at Weverton, Md	9, 370
Potomac River at Point of Rocks, Md	9, 650
Catoctin Creek, Maryland, at mouth	130
Catoctin Creek, Virginia, at mouth	93
Monocacy River at United States Geological Survey gaging station	660
Monocacy River at mouth	940
Goose Creek	385
Broad Run, Virginia	80
Sugarland Run	22
Seneca Creek	130
Rock Creek	86
Potomac River at Edwards Ferry	11, 100
Potomac River at Great Falls	11, 400
Potomac River at Chain Bridge	11, 500

OCCURRENCE OF TYPHOID FEVER.

CAUSES OF TYPHOID FEVER.

It is now the generally accepted view that typhoid fever is caused by the typhoid bacillus and that only by the multiplication of this organism in the human body is a person brought down with the disease. The bacillus is readily demonstrated in the spleen of those who die from typhoid and is eliminated in the saliva, feces, and urine of the sick. In the latter excretion it is known to be very persistent, so much so that one who has recovered may for a long time thereafter scatter the specific bacteria through this discharge. The evacuations of those not suffering from typhoid never contain the organism. Thus it is that a well or other water supply may be long polluted by dejecta without causing this disease, and may be quickly converted to a plague center by the advent of one stricken with it. Such a person is a menace to the public health, and the infection from him may be diffused in several ways. The simplest of these is by direct contact. Cases are common where those nursing the patient are brought low as a result of handling the discharges or soiled linen of the sick room, and perhaps by using the knives and forks or drinking cups of the sick. Sometimes the infected objects are not confined to the domicile of the patient. Thus in Montclair, N. J., an outbreak was brought about on one milk route by infection spread from an unreported case. The milk bottles were brought into the sick room, where they became infected, and were then returned to the dealer, who used them without sterilizing them. In consequence typhoid broke out among those of his customers who took their milk in pint bottles, the only kind left at the house in question, none of the other customers being attacked. With the withdrawal of the supply the epidemic ended. It is possible for the disease to be even more widely disseminated by objects handled by the sick. In collecting facts in the Potomac watershed, it was reported that an epidemic had prevailed among the pickers in a certain peach orchard, and it is quite conceivable that the unclean fingers of the laborers may have infected the fruit, which transmitted the disease to the cities where it was marketed.

Unhappily the sickness is not always severe enough to compel its victim to take to bed. He may go about and ease himself not at a single privy, but at the one nearest at hand when necessity is on him. Thus several unsuspected infection centers may be established. Even when the patient is shut up his stools may be thrown, through ignorance or carelessness, without disinfection into a cesspool or privy or, still worse, on the bare ground.

Typhoid is most frequently spread from the ordure of those afflicted, and this is accomplished by several agencies. The common house fly visits such matter to feed and occasionally to deposit its eggs, and, having accomplished the purpose, returns, with its legs and proboscis bedraggled with filth, to the kitchen or pantry and tracks the infection through the food, which then becomes the vehicle of the disease.

This matter was thoroughly investigated by the typhoid-fever commission of the United States Army in 1898. It was found that the flies alternately visited and fed on the infected stools of the soldiers and the food in the mess tents. More than once, when lime had been scattered over the fecal matter in the pits, flies with their feet covered with lime were seen walking over the food. Moreover, typhoid fever was much less frequent among members of messes who had their tents screened than it was among those who did not take this precaution. The disease gradually died out in the fall of 1898 in Camp Knoxville and Camp Meade with the disappearance of the flies, and this occurred at a time of year when in civil practice typhoid fever is generally on the increase. This was not due to the fact that all those susceptible to the disease had developed it, because the army at these places was considerably recruited at this time. It was also found that flies may carry infected material from soiled bedding and bed pans spattered with the discharge of patients. So this commission pointed out that the typhoid patient should be protected from the annoyance of this insect, not only because he will be more comfortable, but in order to prevent the spread of the disease through its agency.

The fly has also the habit of biting the mouth of man, who frequently moistens his lips with his tongue, and may so infect himself.

L. O. Howard[a] enumerates thirteen different flies that are commonly found in houses. Of these, the common house fly he finds to be far the most numerous. In 1900 he made a collection of flies in dining rooms in different parts of the country, and out of a total of 23,087 flies, 22,808 were *Musca domestica* L.—that is, 98.8 per cent of the whole number captured. The remainder, 1.2 per cent of the whole, comprised various species. The next most abundant fly is *Stomoxys calcitrans* L., which is vulgarly called the stable fly. It differs from the house fly in that its mouth parts are formed for piercing the skin, which the house fly's are not. It is a common impression that the house fly bites. This is not true, the impression being given by the presence of stable flies in houses.

Musca domestica commonly lays its eggs upon horse manure. This substance seems to be its favorite larval food. It will deposit upon cow manure, but it has been impossible to rear it in this substance. It will also breed in human excrement and will lay its eggs upon other decaying vegetable and animal matter, but of the flies that infest dwelling houses, both in cities and on farms, the vast proportion come from horse manure. Packard[b] states that at Salem, Mass., he bred a generation in fourteen days in horse manure. The duration of the egg state was twenty-four hours, the larval state from five to seven days, and the pupal state from five to seven days. At Washington, Howard found that in midsummer each female lays about 120 eggs, which hatch in eight hours, the larval period lasting five days and the pupal period five days, making the total time for the development of the generation ten days. This was at the end of June. The periods of development vary with the climate and with the season, and the insect hibernates in the puparium condition in manure or at the surface of the ground under a manure heap. The adult also hibernates in houses, hiding in the crevices. The Washington observations indicate that the larvæ molt twice, and the insect averages, thus, three distinct larval stages. The periods of development were found to be about as follows: Egg from deposition to hatching, one-third of a day; hatching of larva to first molt, one day; first to second molt, one day; second molt to pupation, three days; pupation to issuing of the adult, five days; total life round, approximately ten days. There is thus abundant time for the development of twelve or thirteen generations in the climate of Washington every summer.

The number of eggs laid by individual flies is undoubtedly large, averaging about 120, and the enormous numbers in which the insects occur are thus plainly accounted for, especially in view of the abundance and universal occurrence of appropriate larval food.

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[a] Circular No. 71, U. S. Dept. Agriculture, Bureau of Entomology.
[b] Idem, p. 3.

Howard says that people living in agricultural communities will probably never be rid of the pest, but that in cities, with better methods of disposal of garbage and with the lessening of the numbers of horses and horse stables due to the advent of automobiles and electric street railways, the time may come when window screens may be discarded. The prompt gathering of horse manure, which may be variously treated or kept in a specially prepared receptacle, would greatly abate the nuisance, and city ordinances compelling horse owners to follow some such course are desirable.

During the summer of 1897 a series of experiments was carried out by Howard with the intention of showing whether it would be possible to treat a manure pile in such a way as to stop the breeding of flies. It was found to be impracticable to use air-slacked lime, land plaster, or gas lime with good results. Few or no larvæ were killed by a thorough mixing of the manure with either of these substances. Chloride of lime, however, was found to be an excellent maggot killer. Where 1 pound of chloride of lime was mixed with 8 quarts of horse manure, 90 per cent of the maggots were killed in less than twenty-four hours. However, chloride of lime costs at least 3½ cents a pound in large quantities, so that frequent treatment of a large manure pile with this substance would be out of the question in actual practice.

Kerosene was also tested. Hundreds of thousands of flies were destroyed by its use in the experiments, but it was found far from perfect, since if used at an economical rate the kerosene could not be made to penetrate through the whole pile, so that a considerable portion of the house-fly larvæ in the manure escaped injury in this treatment, which was found to be so laborious that hardly anyone could be induced to adopt it.

The most efficient preventive measure was found to be the preparation of a special receptacle for the manure, which was very readily accomplished. A closet was built in a corner of the stable nearest the manure pile. It had a door opening into the stable proper and also a window. A door was built in the outside wall of this closet and the hostlers were directed to abolish the outside manure pile, and in future to throw all the manure collected each morning into this closet, the window of which was furnished with a wire screen. A barrel of chloride of lime was put in the corner of the closet. Since that time every morning the manure of the stable is thrown into the closet and a small shovelful of chloride of lime is scattered over it. At the expiration of ten days or two weeks the gardeners open the outside door, shovel the manure into a cart, and carry it off to be thrown upon the grounds. This treatment has proved very successful at the stable of the United States Department of Agriculture.

The experiments described above have reference only to the prevention of the breeding of flies in horse manure. Somewhat different measures are necessary to prevent them from breeding in human excrement. The box privy is always a nuisance from any point of view, and is undoubtedly dangerous as a breeder of flies. Hence box privies should not be permitted to exist unless they are conducted on the earth-closet principle. With a proper vault or other receptacle, closed except from above, the breeding of house flies can be prevented. Covering the refuse with lime, however, is more certain than the use of earth. The privy-vault nuisance is a real one, and no community can hope to stamp out typhoid entirely without either exercising the most unremitting, rigid supervision of the latrines or abolishing them altogether.

Wind may also affect the distribution of infected feces. Cases are on record where pits have been dug for the accommodation of considerable numbers, such as soldiers in camp, and the material has become dried and been blown by a violent wind into food which was exposed. Perhaps at the same time persons were infected by inhaling the swirling dust through the mouth.

It is known that typhoid is distributed by vegetables commonly eaten raw, which have been cultivated with contaminated night soil. Often infected privy vault or cesspool matter is used as a fertilizer with disastrous results. An epidemic of typhoid fever in a Massachusetts institution was traced to the use of celery which was enriched with manure which was known to contain enteric feces.

About the 1st of August, 1892, there appeared at Springfield, Mass., a typhoid-fever epidemic that was confined to the customers of one milkman, who, it was found, purchased his milk from several dairymen. On one of these farms had occurred a case of "bilious typhoid fever" and others of the household had been obliged to go to bed with "slow fever." The stools of the patients went into the privy, it is believed, without disinfection. It was the practice on this place to cool the milk by submerging the cans in a well in such a manner that they rested on the bottom and were covered by 2 to 4 feet of water. As the stoppers leaked, it followed that if the water was polluted with typhoid germs the milk would become infected. It was at first difficult to account for the pollution of the water, for the well was at some distance from the house and the water was not used therein. However, the construction of the well, which was an ordinary dug one of unusually large diameter, admitted of its being readily polluted from the top. The mouth was covered with a platform of old and badly worn planks, loosely laid on, with rounded edges bordering on wide cracks. Furthermore, the planks were separate in order that they might be readily lifted to put the milk in the well to cool. The spout of the pump overhung the platform, so that careless pumping easily washed matter on the planks through the wide cracks into the well. Lumps of manure, evidently from the dirty boots of men, were on the platform, and it was found that ordinary stepping about upon the boards shook this dung into the well and also that a little pumping washed it in. Shortly before the typhoid fever broke out in Springfield, the contents of the privy vault before mentioned were spread upon a tobacco field, and from this field the laborers frequently passed to get water and to work about the milk. Thus fecal matter originally from the privy clung to their boots as they worked in the field and was scraped off and shaken into the well as the men performed their duties about it. So the well water and milk were polluted and the epidemic was established.[a]

Milk is a medium in which the typhoid bacillus multiplies with great rapidity and contaminated milk supplies have repeatedly propagated the disease. The infection is usually brought about by a case of "walking typhoid" (i. e., where the patient is not confined to his bed) in the dairy, or the washing of the utensils or adulteration of the milk with polluted water. The infective matter is circulated about a dairy with such facility that the milk ordinances of cities forbid in the most positive terms the delivery of milk from farms where the disease exists.

In late years it has been discovered that shellfish, such as oysters and clams, which live in sewage-polluted water are apt to convey typhoid. Several occurrences of the disease have been found to be due to this cause. This source of typhoid should arouse the solicitude not only of sanitarians but also of fish dealers, clam diggers, and oyster dredgers, who have a right to demand protection in their business.

While all these factors according to circumstances play a more or less important rôle in the dissemination of typhoid, it is generally recognized that impure water is the principal agent in the transmission of the disease. Every one of the bad epidemics has been indubitably traced back to polluted water, and there is not a State in the Union or a country in the world that does not pay its monthly toll of lives to contaminated water.

Augusta, Me.; Lowell, Lawrence, and Newburyport, Mass.; New Haven, Conn.; Ithaca, N. Y.; Butler, Plymouth, and Pittsburg, Pa.; Cumberland, Md.; Ashland, Wis.; Chicago, Ill.; Washington, D. C., and many other places have passed through the ordeal of a water-borne typhoid epidemic. The supplies are always contaminated by the introduction of infected feces, usually suddenly, but sometimes for considerable lengths of time. Typhoid-fever epidemics due to impure water are characterized by being very limited or very widespread, according to whether the water is used by few or many. The former

[a] Sedgwick, W. T., Ann. Rept. Massachusetts State Board of Health, 1892.

type pertains to well waters and the latter to city supplies of considerable size. In many well-water epidemics it is possible to draw a circle of short radius, with the well for a center, which includes nearly all of the cases. That is, the victims are among those who habitually use the well. The onset of such epidemics is usually sudden, their period of extreme virulence is brief, and they have a tendency to disappear.

When large supplies are infected the cases are distributed throughout the community and appear either in a desultory fashion, as the result of slight pollution, very likely at different times and places, or in great numbers at one time, owing to the sudden introduction of a large quantity of pollution, which is usually effected by heavy rains or rapid thaws. In the case of epidemics from large supplies the period of malignancy is somewhat less sharply marked than in well-water outbreaks, but the proclivity to die out is as noticeable.

This tendency of epidemics to run out brings us to a consideration of the typhoid bacillus itself, for it is manifest that if this organism is the cause of the disease something must have happened to it or the outbreak would continue indefinitely. At the outset it must be frankly admitted that we have not so certain a knowledge of the history of the bacillus in water as is desirable. Great ingenuity and much work have been spent in the effort to determine the longevity of the typhoid bacillus in water. The difficulty has been to reproduce in experiments the conditions that surround the germ in flowing streams, wells, and reservoirs. Such environments appear to have been most nearly approximated in the methods introduced by Jordan and Zeit[a] and developed by Russell and Fuller.[b] The results of the latter investigations are as a whole concordant with those of the former, and show that the typhoid bacillus lives five days in sewage and eight to ten in water. They indicate also that the life of the bacilli is shorter when they are in direct contact with sewage bacteria than it is when they are exposed in sewage but protected from the bacteria therein. The experiments are so perfect that it seems justifiable to assume a life of ten days for the typhoid bacillus in water, but great caution should be exercised in generalizing further, though the results may tempt one to infer that the existence of the germ is but little, if at all, prolonged beyond the maximum period observed in the experiments. Whipple and Mayer[c] have by experiments suggested that the amount of oxygen dissolved in the water may have an important influence on the longevity of the typhoid bacillus and query whether the rapid disappearance of the germ in sewage is not in part due to the absence of this element. It seems to be the prevalent belief that the various mineral salts commonly held in solution by natural waters neither

[a] Jour. Infectious Diseases, vol 1, no. 4; Engineering Record, December 24, 1904.

[b] Reports and Papers, Am. Pub. Health Assoc., vol. 21, pt. 2, p. 40.

[c] Reports and Papers, Am. Pub. Health Assoc., vol. 21, pt. 2, p. 76.

favor nor inhibit the growth of the typhoid organism. The literature on this subject appears to be scanty, and it is suggested that here is a field for investigation. Thus it appears that before definite opinions as to the longevity of the typhoid bacillus can be formulated it will be necessary to prosecute every feasible bacteriological experiment and to carefully collate and study the facts gleaned from inquiries into epidemics.

Although the science of bacteriology has not determined the length of life of the typhoid bacillus in water, it has adduced certain facts in regard to bacteria in general that it seems reasonable to suppose apply to that germ. These are:

1. That all bacteria multiply rapidly in their natural habitat, and conversely that multiplication is checked elsewhere.
2. That an abundant food supply and an optimum temperature are prime factors in bacterial development.
3. That insolation has an injurious effect on bacteria.
4. That they are slightly heavier than water and so tend to sink in it.
5. That certain microscopic organisms, namely, algæ and infusoria, feed on them and so reduce their numbers.

The typhoid bacillus thrives best in the human intestine, where food is abundant and the temperature is high, so that its invironment becomes unfavorable when it is brought into water. There it has to compete for food with the bacteria that live in that element. The low temperature, the sunlight, the tendency to sink, and microscopic organisms all work to exterminate it. These are the natural factors that kill the germ and end epidemics without the intervention of human aid.

In regard to the temperature of rivers, it is to be regretted that no measurements are available, nor have any very extended observations been made on any American river with a delicate instrument, such as the thermophone. Kofoid,[a] however, did some careful work with thermometers on Illinois River from August, 1892, to March, 1899. According to his observations, the temperature of river water follows an annual cycle of the same general character year after year, with ever present minor variations of local origin. In winter the water is coldest and varies least in temperature; the minimum observed was 32° F., the average was 32.75°, and the maximum was rarely higher than 34°. This constancy is doubtless due to the ice which normally covers the stream and especially its backwaters. When the temperature is below 39.2° F., the point of greatest density of water, the colder waters are at the surface, though there is usually very little difference of temperature at different levels during this season. In spring the temperature of the water commences to rise

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[a] Kofoid, C. A., Bull. Illinois State Lab. Nat. Hist., vol. 6, 1903, pp. 168 et seq.

very early, the beginning and rate of increase depending on the peculiarities of individual years; the observations made indicate a gradual increase from an average of 40.45° F. in March to 60.46 ° in April and to 68.27° in May, which is a month not only of marked rise but also of considerable fluctuation in temperature. In summer the water is warmest and varies greatly in temperature; the average maximum rose from 77.75° in June to 81.49° in August and fell to 74.21° in September. The average fluctuation during this season was less than 10° F., though the absolute range for August in five years was from 74.3° to 89°. These rises and falls, combined with the effects of the wind and diurnal changes in temperature, cause considerable vertical circulation of the water, because the surface waters, especially on still hot days, are from a fraction of a degree to 5° warmer than the deeper waters. In autumn the fall of temperature begins late in September and becomes practically complete in November; like the rise in spring, it is subject to irregularities in its rate and permanence. The maximum and minimum observed in the river during this season were respectively 96° and 32° F. When the temperature of the air falls in autumn below that of the water the consequent convection of the surface and bottom layers of the river causes the water temperature to become practically uniform at all points in the vertical section. These well-defined periods of minimum, increasing, maximum, and decreasing temperature doubtless cause in the minute organisms in the water corresponding seasonal changes as fundamental and as extensive as those that affect the plant and the animal life of aerial environment.

In addition to the influence of season there are several minor causes of variation in temperature, such as the entrance of water from tributary streams, springs, and impounded backwaters, the local shallowness of the water, and the diurnal range of temperature in the air. The changes produced by the entrance of water are of course individual and variable. The depth of the stream determines the effect of the temperature of the bed, though the difference between the surface and bottom temperatures of stream water is, as a rule, very small. The daily variations in temperature depend essentially on those of the air. On August 5, 1898, the temperature of the water near the surface varied from 79.5° F. at 5 p. m. to 74° at 2 a. m., while that of the water near the bottom (depth 8 feet) varied from 74° at 8 a. m. to 76° at 11 a. m., a fluctuation of only 2° F.

Some of the conclusions reached by Kofoid are particularly pertinent to the relation of river temperature to typhoid fever. The average temperature of Illinois River in August was 81.49° F., only 16.7° below body temperature, and the maximum observed in that month was 89° F., only 9.2° below body temperature. Accordingly it would appear that at times the bacillus of typhoid fever may be in water at a temperature not far from the optimum. The fact that in summer the temperature causes a vertical circulation in the river water should be borne in mind in deciding on the efficacy of sedimentation in removing bacteria. The fact that the seasonal variations in temperature cause corresponding variations in the vitality of micro-organisms indicates that decrease of heat is of unequal moment at different seasons of the year in destroying bacterial life. Finally, it would be interesting to know whether, on account of the small difference noted between surface and bottom temperatures, it is ever possible for sewage to flow a considerable distance in a river without mixing with the stream water. If it is, then sewage might in some cases flow from one citv to another and arrive in a fairly concentrated condition.

With regard to the Potomac itself, it may be remarked that the large quantity of water received from ground flow from mountain tributaries and from mines all tend to influence its temperature.

The destruction of food material in rivers apparently bears an intimate relation to temperature, as was shown by investigations on Illinois River and the Chicago drainage canal between Bridgeport and Joliet. "Ordinarily in the warm weather there is a marked oxidation here with evident destruction of organic matter. This was shown in the investigations of 1888 and in striking degree in those of the summer of 1886. In the cold winter and spring months of 1889, on the contrary, the oxidation was slight between Bridgeport and Joliet, and this is probably the normal low-temperature condition."[a]

It is an interesting fact that the period of minimum temperature, as defined by Kofoid, coincides with the months of the minimum prevalence of typhoid fever in Washington, and that the influence of the period of maximum temperature extends over all the months during which the disease is at its height except only the second half of October. If it be admitted that by reason of the geographic situation of the Potomac basin the temperature of the stream remains at the maximum a few weeks longer than it does in Illinois River, the months of the maximum occurrence of the disease fall quite within the period of maximum temperature. Furthermore, the decline of typhoid fever in autumn seems to coincide very closely with the fall of temperature, and the increase of typhoid fever that succeeds its period of minimum prevalence seems to occur near the end of the period of increase of temperature. This apparently indicates that it is necessary for the water to attain a rather high temperature before it reaches its most favorable condition for transporting the germs of typhoid fever. It is true that it has not been uncommon for water-borne epidemics of the disease to occur in early spring and

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[a] Egan, J. A., Pollution of the Illinois River: Sanitary Investigations of the Illinois River and its Tributaries, Illinois State Board of Health. 1901, p. xxiii.

also in early winter. However, it is believed that in these cases the time that elapsed between the introduction of infected feces into the water and the lodgment of the bacilli in their victims was brief, and that therefore the germs were able to withstand untoward temperature conditions to which they would have succumbed had the interval of exposure been longer.

It should be remembered that, as Kofoid has determined, the temperature of a river responds very quickly to fluctuations in the temperature of the air above it. Sedgwick and Winslow[a] have pointed out that "in communities with reasonably pure water supplies the typhoid fever follows the curve of seasonal temperature with extraordinary regularity. If the monthly deaths from the disease be plotted and compared with the monthly temperatures, it will be found that the curves are almost parallel, the typhoid rising with the temperature after about two months, an interval representing the incubation period of the disease and the time which elapses before death." So, in a measure, these river-temperature periods but reflect typhoid conditions which prevail under like temperature conditions on land; and it is felt that the river temperatures act in the same direction as the air temperatures and play a considerable part in fostering or restraining the dissemination of the disease. In this connection the statement made by Clark and Gage[b] that in a river as polluted as the Merrimac the numbers of *Bacillus coli*, the common intestinal bacillus, are more numerous in warm than in cold weather is possibly significant.

How much importance should be attributed to microscopic organisms in reducing the bacteria in water is a moot question. There seems to be a concurrence of opinion that they play only a minor part, but the matter will have to be investigated more carefully than it has been before the possibility of their having a considerable beneficial influence in this direction can be positively denied. However, it is certain that at some seasons of the year they are present in the water in very small numbers and therefore that their action is not constant.

As water is not the normal habitat of typhoid bacilli, it is universally admitted that their detention in that medium is of the utmost importance in their elimination. By giving the factors of insolation, unfavorable temperature, and reduction of their food supply an opportunity to act through considerable time the vitality of the germ is reduced and its final destruction is brought about. The quicker the journey from intestine to intestine is accomplished the better is the chance for the survival of the bacillus. Now, sedimentation is recognized as potent in delaying the germ in its travels.[c] The process is

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[a] Jour. New England Waterworks Assoc., vol. 20, No. 1, 1906, p. 59.
[b] Rept. Massachusetts State Board of Health, 1892, p. 279.
[c] Whipple, G. C., The Microscopy of Drinking Water, 1899.

a simple one in reservoirs and lakes, for it is interfered with only by the convectional currents established by the heating of the water and by the very considerable circulation of the water brought about by the wind. But in rivers it is further complicated by the phenomena of transportation.[a] Everyone knows that the solid material brought to a river by various agencies does not sink to the bottom as soon as it reaches the stream, but is carried forward by the current. By careful experimentation some of the laws that govern this action have been discovered. It is well known that the power of flowing water to transport débris increases with increasing velocity, and that the size, specific gravity, and form of the loose material determine whether or not it will be moved by a current of given velocity. The smaller the divisions of any mass the larger the ratio of surface to weight, and the force which a current of given velocity exerts against objects in its path varies as the area of the opposing surface. Therefore the finer the particles the more easily will they be transported. But the ability of streams to carry débris in suspension is dependent not only on these factors but on the presence of secondary and especially of upward currents, which tend to lift up the particles brought within their influence. Were it not for these minor currents particles would sink in a regular curve, whereas the path actually traveled by them is a very broken line, sometimes tending toward the bottom, at others toward the banks of the stream, and again upward toward the surface. When the particles finally reach the bottom they remain there only so long as they do not come within the influence of a current strong enough to lift them into circulation, which may be for either a long or a short period. It has been found that the change in the velocity of streams in horizontal planes is greatest near the shore and least near the thread of maximum current; and that in vertical planes it is greatest near the bottom and surface and least at about one-third of the depth of the stream—that is, where the absolute velocity is greatest. If, then, the water be either charged to its maximum capacity or overcharged with sediment, the highest percentage of material will be found near the banks, surface, and bottom, and the least amount at a depth of about one-third that of the stream. If, however, the water is undercharged with suspended material, as is the case with most streams, the distribution will not follow any law, the amount at any locality being dependent on the chance swirls and boils. It is an important fact that the transporting power of running water increases in a greater ratio than the increase in velocity. It has been found that if the surface of an object remains constant the force of a current striking it varies as the square of its velocity; also that the transporting power of a current, or the weight of the largest fragment it can carry,

[a] Russell, Rivers of North America.

varies as the sixth power of the velocity. It will be seen that under this law doubling the velocity of a current increases its transporting power 64 times. An increase in the volume of a stream increases its velocity; hence floods multiply the transporting power of water and by so doing acquire a destructive power which is accounted for by the foregoing law.

Besides the material which a stream carries in suspension, there is that finely divided matter which it rolls along over its bed. This does not travel in sheets, but moves along in wave-like forms which have a long, gentle slope in the direction of the current and an abrupt drop on the downstream end. Thus particles which reach the bottom of a stream do not come to rest unless they are too heavy for the stream to drag along.

From this discussion it is evident that sedimentation is profoundly affected by any factor which tends to quicken or retard stream flow, and that it is exceedingly difficult to follow material after it is once committed to a stream. At one time it will be in suspension, at another at rest. Now it may travel near the bottom, again at the surface, or at another time it may be deflected against the banks of the river. But it is evident that all these migrations take time, and this is what is desired to accomplish bacterial purification. Thus food material may become exhausted before it has traveled far downstream, or some other agent may have worked considerable change in a few miles of river flow.

It should be noted that sedimentation means more than the mere settling out of bacteria by their own weight, for other and heavier materials in sinking mechanically entrain the germs and drag them toward the bottom. This action is most effective when large quantities of silt are being rapidly deposited—that is, when the action is taking place in turbid waters. In relatively clear water it loses much of its importance.

Rapid sedimentation is often brought about by chemical means. Thus, when highly acid mine waters are discharged into rivers whose waters contain notable amounts of lime, insoluble salts are formed, which sink rapidly to the bottom. As they do so they carry a large proportion of the bacteria with them, so that mine wastes are not always an unmixed evil.

Though the Potomac is as a whole a swift river, sedimentation is undoubtedly active in much of its course. Even in its upper reaches this force is at work, as anyone can test for himself by walking along the banks from Westernport to Keyser, where large quantities of salts resulting from the action of the waters of Georges Creek on the limy wastes of the West Virginia Pulp and Paper Company have been deposited on the rocks and in the shallows. In the many pools in the bed of the river the current must necessarily be checked and deposition accelerated. Particularly important are the seven dams, which cause slack water for miles. In low stages of the river the water must move toward the dams very slowly, and they undoubtedly afford the forces of purification by deposition the greatest play. Some question has been raised whether the protection against typhoid accorded in this way does not contain an element of danger. Thus Sedgwick has noted that in Lowell and Lawrence, Mass., the summer typhoid occurred after sudden rises in Merrimac River caused by thunder-storms and the like, and has suggested that the increase of the disease might be partly accounted for by the fact that considerable infected material had collected behind the dams on the river and had been carried downstream when the water flowed over the dams in considerable quantities.

This raises the important question as to what becomes of germs after they are deposited at the bottom of streams. If they simply rest there until they are again brought into circulation by the scouring of the beds in floods and by other forces, much more importance has been attached to sedimentation than it deserves. But it would seem that the environment of the bottom of a stream must be hostile to germs which live in the human body. Jordan has pointed out that a careful examination of the bed of Illinois River failed to reveal any accumulation of sludge from the large amounts of sewage it receives, and therefore it may be concluded that the amount of available food material for bacteria at the bottom of streams can not be very great. It is conceivable that the sewer of a small village might be made to discharge into a pool of a stream, instead of into the current, and so convert the pool in times of low water into a place favorable for the multiplication of germs, which would be carried into circulation by a sudden flood, with disastrous results. But these factors are not generally considered of serious import as affecting the belief that sedimentation is one of the most powerful factors in purifying water. Rather, it is held that they operate only under special conditions, at rare intervals, if at all. However, the sediment of sewage-polluted streams would undoubtedly be a fruitful field of investigation.

There has been much quibbling over the question whether the dilution of a severely polluted stream with the waters of a pure one should be considered as purification or not. It would seem that the result achieved is clear—namely, the chance of drinking typhoid germs has been lessened. In that sense there has been purification, but it does not necessarily mean that there has been any destruction of food material nor that any germs have been killed.

The deaths from typhoid fever in the principal cities of the world are shown in the following table :

Population, total deaths, and deaths from typhoid in the principal cities of the world, 1880–1904.[a]

Year.	New York (old city).			Brooklyn.			Boston.			St. Louis.			Chicago.			Philadelphia.			Washington.		
	Population.	Total deaths	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.
1880	1,209,268	31,937	372				368,839	8,531	154				503,298	10,462		846,980	17,711	498	183,060	4,075	95
1881	1,246,011	38,624	594				368,190	9,016	207				540,000	13,874		868,000	19,515	645	188,653	4,430	153
1882	1,283,870	37,924	516				373,623	8,995	212				560,639	13,234		886,539	20,059	650	191,980	4,223	123
1883	1,322,880	34,011	625				379,129	9,740	198				580,000	11,555		907,041	20,076	579	196,490	4,558	118
1884	1,363,075	35,044	476				384,270	9,622	216				630,000	12,471		927,995	19,999	662	201,110	4,841	153
1885	1,404,401	35,682	405	687,000	15,369	153	390,393	9,618	152	400,000	7,490	125	665,000	12,474	496	949,432	21,392	610	205,840	4,982	134
1886	1,447,166	37,351	433	747,000	15,790	123	401,374	9,268	135		8,268	124	704,000	13,699	483	971,363	20,005	618	210,680	4,728	151
1887	1,491,137	38,933	421	778,800	17,079	143	412,663	10,073	183		9,155	116	760,000	15,400	381	993,801	21,719	621	215,630	4,694	167
1888	1,536,444	40,175	364	810,000	18,061	153	424,274	10,197	170		9,015	130	830,000	15,772	375	1,016,758	20,372	785	222,830	5,225	188
1889	1,583,120	39,679	397	842,000	18,480	161	436,208	10,259	186		8,004	146	1,106,000	16,946	453	1,040,245	20,536	736	232,460	5,158	213
1890	1,631,232	40,103	352	875,000	19,827	182	448,477	10,181	155	452,000	8,409	140	1,200,000	21,869	1,008	1,046,964	21,732	666	242,520	5,534	257
1891	1,680,796	43,659	384	910,000	21,349	180	457,772	10,571	154		9,530	165	1,250,000	27,754	1,997	1,069,264	23,367	684	253,010	6,103	186
1892	1,708,124	44,317	399	898,256	20,807	162	467,260	11,236	137		10,225	441	1,438,000	26,219	1,489	1,092,168	24,305	539	260,800	6,416	216
1893	1,758,010	44,479	381	928,408	21,017	179	476,945	11,710	148		10,303	215	1,600,000	27,095	670	1,115,562	23,655	456	265,600	6,119	202
1894	1,809,353	41,175	326	959,572	21,183	158	486,830	11,520	141		8,710	171	1,567,727	23,701	491	1,139,457	22,680	369	270,514	5,869	228
1895	1,873,201	43,420	322	991,782	22,568	173	501,083	11,329	163		9,425	107	1,600,000	24,319	518	1,163,864	23,797	469	272,337	5,782	235
1896	1,906,139	41,622	297	1,025,074	22,497	163	516,305	11,634	162		9,897	108	1,619,226	23,262	751	1,188,793	23,982	402	275,562	5,832	148
1897	1,940,553	38,887	299	1,060,483	20,674	173	528,912	11,154	173		9,554	123	1,619,226	21,809	437	1,214,256	22,735	401	277,782	5,486	130
1898	1,976,572	40,438	376	1,095,047	21,856	267	541,827	10,866	185		8,908	95	1,650,000	22,747	636	1,240,266	22,790	639	283,100	5,815	191
1899	2,014,330	39,911	294	1,131,805	21,649	205	555,057	11,167	165		10,024	131	1,950,000	25,503	442	1,266,832	23,796	948	288,500	5,863	199
1900	2,053,979	43,227	372	1,169,796	23,057	301	560,892	11,678	143	575,000	9,849	148	1,698,575	24,491	337	1,293,697	25,078	449	294,000	6,059	220
1901	2,095,686	43,307	412	1,209,064	23,271	274	573,579	11,300	142	598,000	10,601	176	1,758,025	24,406	509	1,321,408	24,137	444	299,600	6,050	172
1902	2,139,632	41,704	400	1,249,650	22,344	322	584,553	10,983	139	621,000	10,353	222	1,820,000	26,455	801	1,349,712	23,847	588	305,400	5,788	226
1903	2,186,017	41,776	350	1,291,597	22,192	267	600,929	10,632	119	645,000	11,145	288	1,885,000	28,923	588	1,378,624	25,947	957	311,300	5,944	140
1904	2,235,060	48,743	309	1,334,952	24,831	303	614,522	10,757	135	685,000	11,506	225	1,932,315	26,302	373	1,408,154	25,972	744	317,200	6,221	135

[a] Rept. Boston Health Dept., 1904.

Population, total deaths, and deaths from typhoid in the principal cities of the world, 1880–1904—Continued.

Year.	Paris.			Berlin.			Vienna.			London.			Liverpool.			Glasgow.		
	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.	Population.	Total deaths.	Typhoid deaths.
1880	...	55,706	2,003	1,123,749	32,823	527	721,016	20,453	171	3,771,139	81,832	702	...	...	...	...	13,303	278
1881	2,239,938	55,103	1,955	1,158,539	31,055	352	741,208	21,549	171	3,824,960	81,071	977	...	...	...	511,415	12,909	166
1882	...	56,854	3,214	1,196,205	30,465	357	749,919	21,595	187	3,861,876	82,905	975	...	...	...	...	12,985	162
1883	...	54,763	1,880	1,232,716	35,056	222	750,762	21,194	157	3,901,164	80,578	935	...	...	...	...	14,476	167
1884	...	55,050	1,503	1,271,677	32,932	243	759,849	20,353	95	3,939,832	83,050	936	541,031	14,382	112	...	13,839	184
1885	...	52,726	1,320	1,315,656	31,483	214	769,889	21,976	106	3,978,883	80,000	585	537,548	13,764	95	...	13,444	102
1886	2,260,945	55,110	954	1,363,031	34,293	181	780,066	20,869	85	4,018,321	82,276	618	534,088	13,919	140	...	13,053	81
1887	...	52,836	1,385	1,415,269	30,336	193	790,381	20,459	80	4,058,150	82,304	612	530,649	14,006	130	...	12,055	100
1888	...	51,230	756	1,472,151	29,298	188	800,836	20,349	107	4,098,374	79,099	694	527,233	12,159	125	...	11,533	59
1889	...	54,083	1,008	1,528,721	34,460	290	811,434	20,106	103	4,138,996	76,026	528	523,838	13,047	167	...	12,890	111
1890	...	54,566	665	1,579,524	33,393	143	822,176	20,324	77	4,180,021	89,554	618	520,426	14,293	99	...	13,222	108
1891	2,424,705	54,443	549	1,601,327	...	166	1,378,530	34,479	85	4,221,452	90,216	547	517,145	13,911	92	565,710	14,149	123
1892	...	54,536	691	1,656,715	32,696	137	1,406,933	35,134	116	4,263,294	87,749	436	513,818	12,671	111	669,059	15,128	102
1893	...	52,955	570	1,714,938	36,032	161	1,435,931	34,515	105	4,306,411	91,536	719	510,514	13,919	221	677,833	15,798	120
1894	...	49,205	697	1,655,235	30,961	69	1,465,637	33,994	74	4,349,166	77,039	635	507,230	12,073	248	686,820	13,674	150
1895	...	51,451	274	1,677,304	33,627	95	1,495,764	34,879	86	4,392,346	86,937	614	638,291	16,215	192	695,876	16,332	121
1896	2,511,629	47,929	262	1,695,313	30,578	80	1,526,623	34,132	79	4,421,955	83,511	591	632,512	14,617	206	705,052	14,388	139
1897	...	46,988	249	1,758,885	30,622	71	1,551,129	33,187	84	4,463,169	80,944	593	644,129	15,590	145	714,419	15,727	172
1898	...	49,574	256	1,805,054	30,571	78	1,590,295	32,356	93	4,504,766	83,936	585	668,645	15,380	148	724,349	15,333	223
1899	...	50,511	754	1,817,952	34,011	74	1,623,134	33,333	66	4,506,752	89,689	801	668,645	16,269	174	733,903	15,828	179
1900	...	51,725	912	1,864,203	35,409	109	1,656,662	34,303	137	4,589,129	86,007	756	668,645	16,393	120	755,730	15,924	158
1901	2,660,494	50,195	363	1,891,900	34,091	88	1,691,996	33,502	76	4,544,983	79,924	548	686,322	15,493	154	761,712	...	210
1902	2,660,559	49,275	17	1,920,459	30,737	52	1,726,604	33,857	51	4,579,110	82,540	585	710,337	15,392	190	775,601	15,054	110
1903	...	46,557	280	1,955,875	31,879	63	1,744,177	33,172	68	4,613,812	72,019	396	716,810	14,210	108	786,897	14,483	142
1904	...	47,354	334	2,040,455	31,557	75	1,797,992	32,931	60	4,649,038	76,694	297	723,430	15,851	82	798,357	14,794	84

TYPHOID FEVER AT WASHINGTON, CUMBERLAND, AND MOUNT SAVAGE.

When this inquiry was begun a thorough investigation of the typhoid-fever mortality was contemplated, for the ravages of this disease are in general caused by the contamination of water supplies by privies, cesspools, and sewers, and it was thought that no better measure of financial loss through river pollution could be had than the destruction of human life it caused. But it was discovered that none of the four States in which the basin lies had registration laws. Accordingly this study had to be confined to the District of Columbia, where the records extend over thirty-one years. The law has been administered with great fidelity by the health department, which has assembled the results with intelligence and discrimination. It is to be regretted that the statistics do not cover the entire period through which the Potomac has been the water supply of Washington, but they were not collected from the troublous times of the civil war until August, 1874. Effective registration really began in January, 1875, and only from that date on are the results of value. Recently Pennsylvania has enacted an excellent registration law and Maryand has adopted one which it is hoped may prove serviceable, but Virginia and West Virginia have none. This is to be regretted, for the faithful registration of births and deaths more than repays its cost by the aid it gives in establishing property rights and in suppressing child murder. Moreover, by the lack of vital statistics sanitary science is deprived of a great help in the fight against communicable disease. Unless the health of a community is a matter of knowledge, of record, and not of hearsay, it is impossible to tell whether its condition is normal or whether its water supply, its milk supply, or some other function is deranged and diseased. It is to be sincerely hoped that this defect will soon be cured by wise legislation.

At Washington the undue prevalence of typhoid fever has been caused by the public water supply, which has been taken from Potomac River since December, 1863, and which was consumed without purification until October 5, 1905.

Some of the other factors which have been mentioned as producing typhoid undoubtedly are responsible for a part of the cases. There are many privies in the city, and they have in all probability been at times foci from which contagion spread. There are polluted wells which must have played their part. Cases of auto-infection were probably numerous. Small epidemics caused by infected milk have been traced to their sources, and the disease has been brought in from outside. But the typhoid has been too constant and too generally distributed in the city to lay more than a small part of it to the door of these sporadic outbreaks. It can be accounted for only by an impure water supply, and it now remains to consider what scope the natural and artificial forces at work on the Potomac give to the several factors that favor or militate against bacterial life. Food supply for the germs must be plentiful, being furnished by the numerous sewers and privies that discharge into the river, the distillery wastes, the rinse water from the finished goods of several factories, and most of the organic wastes received by the stream. The action of sunlight is regarded as only mildly inhibitory, but it has full play on the Potomac, for the water is light colored and is clear except during rather short periods of freshets. Moreover, much of the river is shallow, so that the light rays penetrate quite to the bottom over considerable stretches.

In the early days of Washington the feasibility of supplying the city with water from the Potomac was considered, but it was not till 1859 that water was turned into the aqueduct. It came from Dalecarlia Reservoir, then wholly supplied by Little Falls Branch. This reservoir was built with the idea of affording an opportunity for clarification of the water by sedimentation as it passed through. The same year the distributing reservoir in Georgetown was built. In the early days these reservoirs may have afforded considerable protection, but with the present daily consumption of 65,000,000 gallons the former gives a storage of only sixteen hours and the latter of only twenty-three hours. In 1902 the Washington city reservoir was put in use and gives an additional storage of forty-five hours. In December, 1863, water from the Potomac at Great Falls, 14 miles above Washington, was received, and it has been the main supply of the city ever since. As there were no vital statistics kept at that time, it is impossible to say what effect the introduction of the supply had on the public health. Indeed, had such records been kept their interpretation would demand great caution, for it was at the time of the civil war and the soldiers of both armies suffered terribly from typhoid, as may be seen from the subjoined figures taken from the Medical and Surgical History of the War of the Rebellion. The figures do not include typhoid malaria, and it is to be remembered that the troops did not operate in the Potomac basin all the time. The table does not include all the troops operating in the basin, and some of the cases were of men who belonged to the armies cited, but who were temporarily detached therefrom at the time of sickness. However, the figures it is believed give an idea of the prevalence of the disease, which is all that is desired. The armies of the Confederacy are believed to have suffered more heavily than did those of the Union.

Typhoid fever in Federal Army during civil war.

Date.	Army of the Potomac.		Department of Shenandoah.		Department of Western Virginia.		Middle division.	
	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.
July, 1861–June, 1862	8,228	917	735	84	2,766	232		
July, 1862–June, 1863	8,442	1,323			655	79		
July, 1863–June, 1864	1,693	220			812	83		
July, 1864–June, 1865							819	281

It is evident that the whole Potomac drainage area was thoroughly seeded with typhoid during the war.

Other events have had an intimate relation to the prevalence of typhoid fever in Washington.[a] In 1888 there were many complaints against the character of the water, both on account of its turbidity and its supposed pollution. Accordingly at that time Dalecarlia Reservoir, which was still fed by Little Falls Branch, was cut out of the supply and used only on the rare occasions when repairs to the aqueduct made it necessary. This expedient does not appear to have had any effect on the typhoid death rate of the city. In 1893 it was decided to divert the waters of Little Falls Branch, Mill Creek, and East Creek, together with other waters, from Dalecarlia Reservoir, into which they fed. The work was completed May 27, 1895. The typhoid death rate of that year was 53.7, as against 86.3 in 1894. The following year it was still lower, but it rose again in the three succeeding years, yet it never has attained the figures of the years immediately preceding the execution of this work.

There are probably mild outbreaks of typhoid fever at one or more places on the Potomac watershed every year, but two well-marked epidemics are on record which produced decided effects in the District.[b]

The first of these was at Cumberland, Md., and was brought about by typhoid dejecta finding their way into Sulphur Run, which empties into the Potomac somewhat above the waterworks intake. The trouble began about December 10, 1889, and was not quelled until the beginning of June, 1890. In all 485 cases and 97 deaths of the disease were reported in Cumberland. The river was said to be in middle stage at the time, and soon after the outbreak at Cumberland typhoid appeared at Hancock, 60 miles downstream. Captain Gaillard[c] estimates the time of flow of water from Cumberland to Washington as from four to seven days, but the disease did not appear in unusual measure in Washington until March, 1890. The number of typhoid deaths continued to be abnormally high after that until August, when it was not much above the usual number for the city. The following table gives an idea of the sequence of the disease:

[a] Ann. Repts. Chief of Engineers U. S. Army, 1893–1895.
[b] Kober, George, Medical News, April 12, 1890.
[c] Ann. Rept. Chief of Engineers U. S. Army, 1894.

Deaths from typhoid fever at Cumberland and Washington, January to July, 1890.

Month.	Deaths.		Month.	Deaths.	
	Cumberland.	Washington.		Cumberland	Washington.
January	18	11	May	5	13
February	27	6	June		24
March	39	19	July		36
April	8	11			

The second epidemic which is known to have produced calamitous results in Washington occurred at Mount Savage, Md., in 1904, and was studied by Dr. M. L. Price, whose report, by the courtesy of Dr. John S. Fulton, secretary of the Maryland State board of health, is made the basis of this account. Mount Savage is situated on Jennings Run, about 10 miles west of Cumberland and 185 miles above Washington. The town lies at an elevation of about 1,200 feet, on a mountain whose steep sides descend abruptly to Jennings Run and Mount Savage Run, both of which flow through the town. The inhabitants are mostly employees of the Union Mining Company and of the Cumberland and Piedmont Railroad. They live largely in tenement houses or rows, boarding houses, and cottages, which are scattered along the side of the mountain up to an elevation of several hundred feet above the streams. The occurrence of house epidemics among the Union Mining Company's laborers is favored by the general lack of household furnishings, which makes it necessary for one utensil or set of utensils to serve a whole family. In the majority of families one dipper is used for drinking purposes, water being taken from a common bucket. Cheaply constructed privies are in universal use and receive very little care, for every heavy rain washes the excess of excrement into the streams. Jennings Run is at all times grossly polluted by human sewage, and contains a miscellaneous collection of offal, dead animals, and refuse. The odor during the day is usually offensive, but becomes sweet whenever a heavy rain flushes the run and carries its filth into Wills Creek, which in turn delivers it to the Potomac. The water of Jennings Run is unpotable, because it is very heavily polluted by mine drainage, which contains free sulphuric acid and large quantities of iron salts, besides sulphates and carbonates of lime.

The water supply of Mount Savage was obtained from 15 private springs and 3 artesian wells. After the epidemics broke out several of these were found to be contaminated and were closed by the county board of health. The roundhouse of the railroad company has an artesian well. Only one of its 125 employees had typhoid fever, and it is certain that he did not confine himself to the company's well. The brickyard spring was the only source of water known to have been specifically polluted by typhoid dejecta, and the victims of the epidemic were confined to those who drank from it.

The outbreak at Mount Savage is interesting, for we have here a story which is probably repeated yearly at one place or another on the Potomac watershed. A number of the wells were polluted by human excreta, no care whatever was given to the privy vaults, and the stream that ran through the town was abominably defiled, yet year after year went by and Mount Savage was not scourged by any pestilence; but the penalty for ignorance and neglect was paid in full when the germs of disease were introduced into the midst of such conditions.

July 4, Mrs. ———, who occupied a small house about 300 feet above the brickyard, on a rather steep incline forming the north bank of Jennings Run, and who had just returned from nursing her brother, a typhoid-fever patient, at Luke, Md., was taken ill with the same

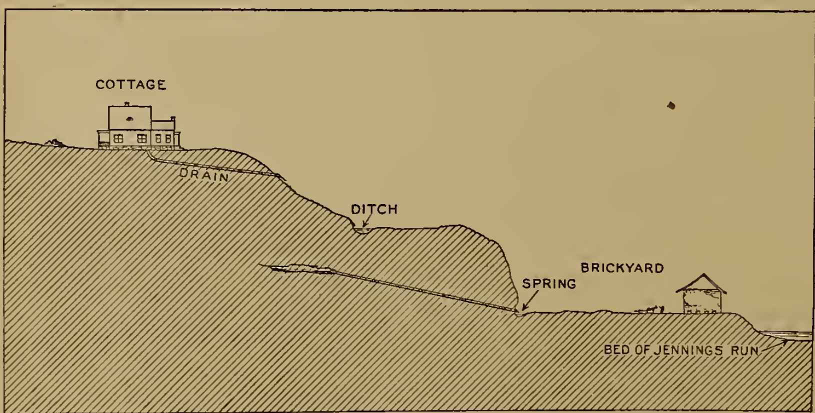

FIG. 2.—Elevation of north bank of Jennings Run, showing course of drainage.

disease. The brother probably contracted the disease in Piedmont, W. Va. Mrs. ———'s infection was evidently contracted at the same place or from her brother. All of the drainage from this house was conveyed through a 4 or 6 inch iron pipe which emerges from the ground and ends 40 or 50 feet below on the side of the hill (fig. 2). This mixed drainage found its way down the hill, a small portion of it reaching an open drain. A road runs along the side of the open drain, over a bank of fire clay above the brickyard. At the bottom of the fire-clay bank, a short distance from the open drain, was a large flowing spring, which furnished an abundant supply of clear water of pleasant taste and appearance and of agreeable coolness. The water was drunk by all of the brickyard employees, about 200 in number. During the early part of July heavy rains occurred, washing surface impurities down the side of the mountain upon which the

——— cottage was located into the spring and Jennings Run. July 11, about one week after Mrs. ———'s arrival, 20 workmen from the brickyard reported to Doctor Murray, the company doctor, complaining of headache, backache, lassitude, and digestive disorders. The strict limitation of these cases to the brickyard employees and the similarity of their symptoms suggested a common source of infection. Accordingly, on the following day, July 12, Doctor Murray posted a notice declaring the water bad and directing the discontinuance of its use. Five additional men reported on this day with typhoid prodromata. From the railroad and other shops supplied with artesian water no cases appeared. The brickyard men were again enjoined against the use of the spring, but a certain number continued to use it during the succeeding twelve or thirteen days. Additional cases were now appearing at the rate of five or six daily, and some of the original cases were showing unmistakable evidences of enteric fever. July 25 Doctor Murray effectually prevented further use of the water by the destruction of the spring, mineral ashes and fire clay being thrown into it till it was buried several feet deep. The chemical and bacteriological reports of water samples drawn by Doctor Murray were received by this time and indicated that the brickyard spring was badly polluted and that other wells and springs in the town were polluted to a greater or less degree. Cases of typhoid fever continued to develop until August 10, sixteen days after the last of the brickyard spring water was drunk. The destruction of this spring by Doctor Murray effectually removed the source of infection and ended the epidemic, but with the arrival of Doctor Price, August 11, other wise measures were taken. The most important of these had for their object the prevention of a secondary epidemic that might be caused by the spreading of contagion from the infected stools broadcast through the community by means of flies. To accomplish this, the privy vaults were thoroughly cleaned through the cooperation of the Union Mining Company, which furnished horses and men to carry on the work. The method adopted was the digging of pits and the burying of the vault contents. Those contaminated springs which could be sealed were closed up and the water of the others was made undrinkable by the use of a harmless emetic, such as copper sulphate or alum. In this work the Allegany County board of health was active, as well as in posting notices requiring the boiling of water, the policing of front yards, and the use of earth ashes or lime in the privies to cover evacuations as soon as they were passed, and in the appointing of district nurses to teach and secure personal prophylaxis in the homes. Disinfectants were used in the stools and urine of the sick. The extermination of the epidemic was due to the effective cooperation of the local physicians, Doctors Murray and Quarles, with officials of the county and State boards of health. The results of this epidemic up to August 17 were as follows:

Statistics of typhoid-fever epidemic at Mount Savage, Md., July 4 to August 17, 1904.

Total number of cases	115
Bed cases	80
"Walking cases"	35
Deaths	3
Sick August 17	40
Convalescent August 17	72

By August 22 five more cases had appeared, raising the total to 120.

The health department of Washington did not learn of the epidemic until August 20, when it sent out warnings to boil the Potomac water. The step was a commendable one, but as the epidemic in Mount Savage was practically over at the time, it was impossible to avert the consequences of the early cases. The effect of the epidemic on Washington may be seen in the following table:

Typhoid cases and deaths in Washington, D. C., five months of 1902–1904.

Month.	1902.		1903.		1904.	
	Cases.	Deaths.	Cases.	Deaths.	Cases.	Deaths.
July	130	21	121	17	101	16
August	328	39	188	26	226	22
September	290	25	138	18	212	25
October	247	32	148	19	138	14
November	156	19	88	8	104	11
Total	1,151	136	683	88	781	88

As in 1902 and 1903, the number of cases and deaths made a sudden jump in August, 1904, but the September figures, unlike those of the two other years, remained as high as they were in August. In October, 1904, there was a quick drop in both cases and deaths, which was not the case in 1902 and 1903. It is evident, therefore, that the specific cause of typhoid fever in Washington in 1904 was discovered and removed. Moreover, the prevalence of the disease was synchronous with that at Mount Savage, which it is known was stamped out. Hence it is concluded that the typhoid at Mount Savage caused that in Washington.

It is interesting to note that the germs at Mount Savage must have gone pretty directly into the highly acid waters of Jennings Run and then into the acid waters of Wills Creek before reaching the Potomac. From this it would seem that mine waters can not be relied on to kill the typhoid bacillus. On the other hand it should be remembered that the supply of food material was probably abundant in the initial stages of the journey of the germs to Washington, for there are two tanneries on Wills Creek, and the sewage of Cumberland must also have been available.

Another factor which has influenced the degree of prevalence of typhoid fever in Washington is that the cities and towns in the basin have been procuring new and pure water supplies. At many places the information was given during this investigation that typhoid fever is not common at present, but was so before the new water-supply system was installed. In protecting themselves these communities have protected others, because if typhoid fever is reduced to a minimum the privies and sewers must necessarily turn fewer of the bacilli into the streams. The sources of the water supplies of the most important places in the Potomac basin are given in the following table:

Public water supplies in the Potomac basin.

City.	Supply.	When introduced.
Winchester, Va	Springs	Colonial period.
	....do	1894.
Gettysburg, Pa	Driven wells	1830.
	Marsh Creek	1893.
Frederick, Md	Two deep wells	1844.
	Big Tuscarora Creek	1869.
	Little Tuscarora Creek	1891.
	Fishing Creek	1899.
Leesburg, Va	Rock spring, one-half mile northwest of town	1845.
	New supply	1905.
Staunton, Va	Buttermilk Spring	1849.
	Springs northwest of city	1876.
Martinsburg, W. Va	Spring	1873.
	Spring 1 mile west of city	1903.
Romney, W. Va	Springs	1871.
Chambersburg, Pa	East Branch Conococheague Creek	1875–76.
Hagerstown, Md	Diffendal reservoir and Ingram Creek	1881.
	Raven Rock Run	1896.
	Warners Hollow Run	1896.
	Antietam Creek (temporary)	1902.
Waynesboro, Pa	Mountain brooks	1881.
	....do	1886.
Harrisonburg, Va	Artesian well	
	River water	1897–98.
Elkton, Va	Springs	1891.
Front Royal, Va	Spring	1892.
Riverton, Va	Buys water of Front Royal, Va	
Hyndman, Pa	Mountain spring	1892.
Frostburg, Md	Spr ngs	1892.
	C.ty Water Co., from artes:an well and spr.ngs	
Piedmont, W. Va	Savage River	1893.
Westernport, Md	Buys water from Piedmont, W. Va	1896.
Keyser, W. Va	Spring	1893.
Greencastle, Pa	Eshleman Spring	1894.
	Spangler Spring	1902.
Berkeley Springs, W, Va	Springs	1894.
Lonaconing, Md	Charlestown Run	1895.
Waynesboro, Va	Bakers Spring	1897.
Berryville, Va	Spr.ng	1899.
McConnellsburg, Pa	Mountain stream	1900.
Luray, Va	Spr ng	1901.
Basic City, Va	....do	1901.
Moorefield, W. Va	South Fork of South Branch	1903.
Mercersburg, Pa	Trout Run	1903–4.
Strasburg, Va		1904.
Charles Town, W. Va	Spring 1 mile west of town	
Franklin, W. Va	Spring	
Woodstock, Va	Springs	

The only places of considerable size, aside from Washington, that use Potomac River or any of its large tributaries for a water supply are Moorefield, W. Va., Cumberland, Md., and Brunswick, Md. Of these Cumberland is the most important. In Brunswick the Potomac water is served to only a few and in Moorefield more people use wells than the water of South Fork.

The minimum flow of the Potomac at Great Falls occurred in 1856 and was 1,063 second feet, and the maximum, 470,000 second-feet, was in 1889; but there are long periods every year when the flow is 3,000 second-feet or less. Several observers have noted that it is in the times of low flow that typhoid fever is rampant in Washington. This investigation points to the same conclusion, as is shown by the figures obtained from the hydrograph of the river at Point of Rocks. (See Pl. IX.) It is to be regretted that the gaging station is above Monocacy River, but it is unlikely that the addition of the waters of that stream would materially alter the results obtained and it is considered singularly fortunate that it was possible to secure both stream gagings and vital statistics for the same river covering a long period.

Pl. IX shows for the years 1902, 1903, 1904, and 1905 the daily flow of Potomac River at Point of Rocks, the daily deaths from typhoid fever in the District of Columbia, and the number of cases of typhoid fever reported daily at the health office of the District. The total deaths and the deaths from typhoid fever in the District from August, 1874, to December, 1905, inclusive, are shown in the table on pages 281–282.

Pl. IX shows that typhoid fever is prevalent during periods of low water, while there are comparatively few cases in the portions of the year when the water is high. At first thought these results seem surprising, for it would perhaps be natural to expect that the periods of excessive typhoid would occur in flood seasons, when a great deal of filth and excrement are washed into the river. But one who is thoroughly familiar with the river realizes that it is the constant recipient of large amounts of fecal matter from the many sewers and multitude of privies that line its banks and that the scourings intermittently washed into the stream are small, indeed, compared to the excrement that is every day dropped into it. Therefore it is perfectly natural that when this everyday defilement is concentrated in a small stream flow the results should be disastrous, for at such times, when typhoid germs are present, the chances of one's drinking a considerable dose of them are many times multiplied. Typhoid fever is known to be a disease of summer and autumn, and therefore the bacilli are most likely to be in the stools at the very time the river is low. If the germs are not present, there will not be typhoid in times of low water. It can be seen from an inspection of the diagram (Pl. IX) that low water has occurred in winter, but that there has not been a large increase of typhoid following. It would be foolish to maintain that a rain never brings about an increase of typhoid among the users of Potomac water. It may do so, provided it washes in a large quantity of bacilli and does not at the same time bring about such a dilution of the water containing them that the possibility of drinking them is no greater than it was before. There is an ever-

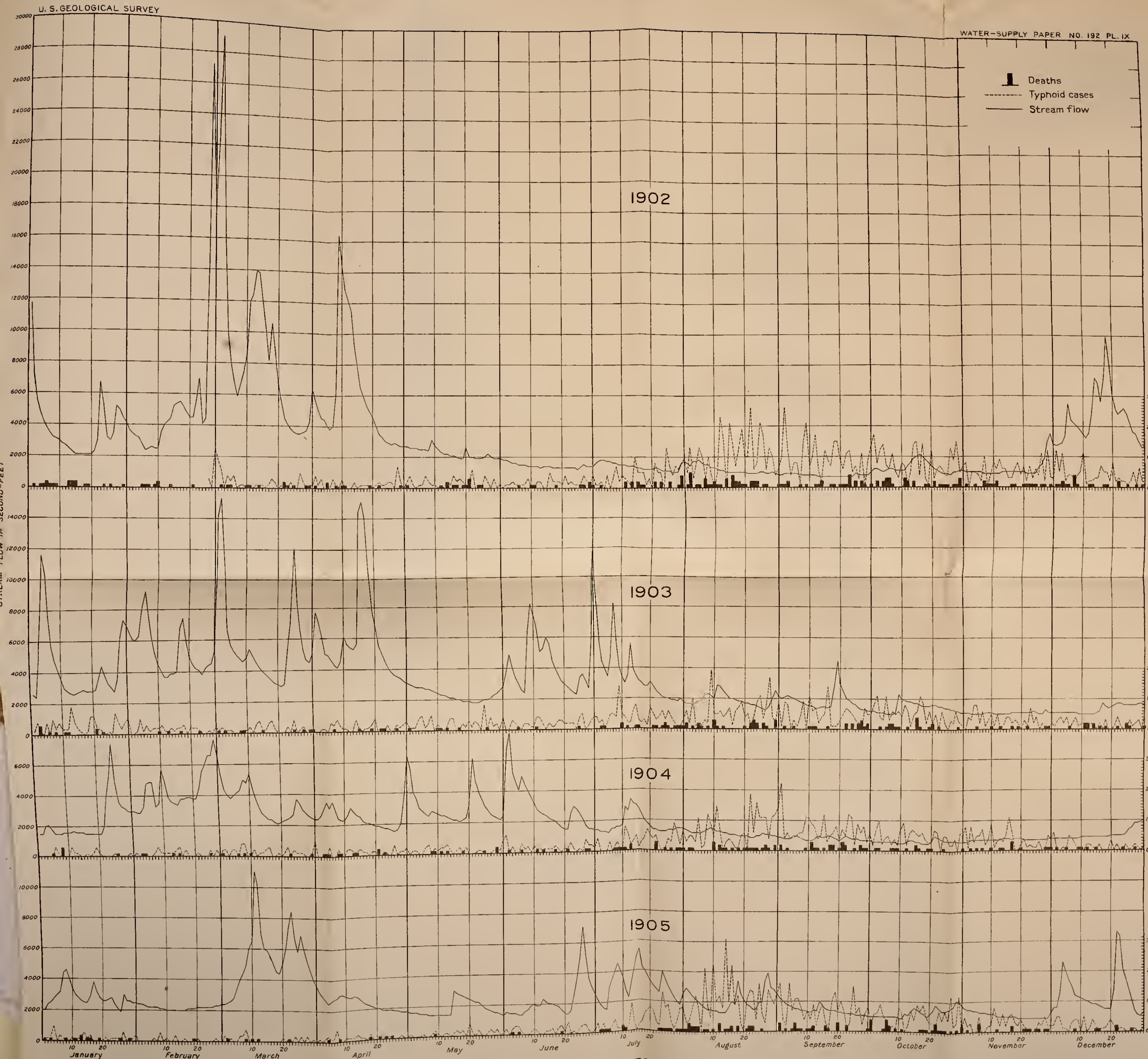

DIAGRAM SHOWING RELATION OF STREAM FLOW TO CASES OF TYPHOID FEVER IN THE DISTRICT OF COLUMBIA

balancing adjustment between dilution and concentration. Whenever dilution is in the ascendant, the chances of drinking typhoid germs are reduced; whenever concentration prevails, the reverse is true. It is conceivable that in the case of a city pumping water from a river there might be an opportunity for a small quantity of excreta deposited on the bank to be carried rapidly past the intake by the very flood that washed it into the stream, at a time when the pumps were not in service or were pumping at a low rate. Thus the city would escape infection entirely or would feel the effects thereof only slightly. So it is that no rigid law can be laid down concerning the time at which typhoid fever may prevail at Washington, for it depends principally on the play of three factors—the presence of the bacilli in the water, the dilution of the water containing them, and their concentration in it.

There are two distinct types of water-borne typhoid epidemics. One is illustrated in the case of New Haven, Conn., which for years enjoyed a pure supply, but was suddenly overwhelmed by an epidemic caused by the careless disposal of typhoid defecations on the watershed and their sudden precipitation into the water thereafter. That is, the city for years enjoyed a considerable degree of immunity, suddenly experienced an epidemic, and then returned to another period of immunity with the passing of accidental conditions. To this type the disease in Washington does not show a resemblance. It is more like the type described by Whipple and Levy[a] in their investigation of typhoid fever in the Kennebec Valley in 1902–3. Here the towns which used the Kennebec water experienced a certain amount of typhoid for some time previous to the epidemic, which was severe enough to impel the citizens to an investigation of the conditions that surrounded them. In one respect, however, the prevalence of typhoid in Washington differs from that in the Kennebec Valley. There several large towns, one below another, drew their water supply from the river and sewered into it as well. The result was that one city passed the contagion on to another and that the excessive prevalence of the disease was extended from the normal period of three months (August to October) into nine months (August to April). From the danger of such a position Washington is happily relieved at present, for Cumberland, Md., is the only other large city in the basin that uses the polluted river as a public water supply. If Brunswick, Md., increases its present limited use of Potomac water, such increase may be fraught with serious consequences to Washington. With the growth of the cities in the Potomac basin the time is bound to come when the springs and mountain brooks that now supply them will become inadequate. Then they will have to turn to the river, and then conditions will be like those on the Kennebec.

[a] Journ. New England Water Works Assoc., vol. 19, No. 2.

Typhoid statistics of Washington, D. C., 1874–1905.[a]

Year.	January.		February.		March.		April.		May.		June.		July.	
	Total deaths.	Typhoid deaths	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.
1874														
1875	397	7	385	3	432	6	342	4	303	2	430	6	426	14
1876	297	2	310	5	365	6	296	4	279	3	491	7	567	19
1877	329	1	347	5	367	3	293	4	288	7	388	7	476	12
1878	343	7	286	4	346	4	319	6	374	12	436	12	473	15
1879	374	2	335	2	377	3	334	4	296	7	444	6	480	15
1880	309	6	362	2	333	6	311	2	333	7	447	6	359	10
1881	332	7	348	4	357	3	376	5	284	9	311	4	481	10
1882	333	7	367	10	388	6	338	5	326	8	390	3	444	15
1883	340	6	328	7	432	8	381	9	356	7	368	6	510	18
1884	453	4	402	4	414	6	400	5	349	5	443	10	425	8
1885	379	8	445	4	467	5	430	3	388	1	509	13	595	20
1886	378	10	399	5	438	10	378	8	329	7	388	5	440	17
1887	369	4	310	8	383	7	355	5	331	3	499	5	545	21
1888	408	8	433	8	528	8	407	7	347	5	465	11	515	14
1889	430	16	383	9	470	9	402	6	346	6	484	8	532	28
1890	598	11	394	6	485	19	393	11	455	13	596	24	489	36
1891	414	12	414	7	572	12	697	9	457	6	553	9	550	7
1892	643	14	504	13	491	9	446	7	434	10	584	13	835	22
1893	535	6	461	7	591	6	482	12	473	11	596	12	609	23
1894	471	11	442	5	534	6	474	7	451	6	686	24	535	33
1895	448	3	475	8	515	2	485	2	407	8	425	9	571	12
1896	508	9	493	8	528	4	479	4	394	4	475	7	678	9
1897	492	13	528	4	498	4	415	4	380	6	469	10	520	10
1898	428	8	436	4	480	2	420	9	439	6	508	20	608	26
1899	586	10	515	4	489	7	448	6	425	3	459	7	539	10
1900	489	17	433	6	564	8	576	10	461	6	489	12	730	21
1901	608	7	545	2	554	8	461	2	415	4	457	10	727	16
1902	529	19	449	8	467	12	534	9	453	13	506	9	568	21
1903	575	9	573	5	568	9	459	6	450	6	482	3	530	17
1904	592	5	556	5	621	6	513	6	517	8	500	8	569	16
1905	567	11	551	1	580	5	549	6	423	1	477	3	582	15
Total	13,954	260	13,209	173	14,634	209	13,193	187	11,963	200	14,755	289	16,958	530
Per cent[b]	5.11		3.40		4.11		3.68		3.93		5.68		10.42	

[a] In this table deaths from typhoid-malarial fever have been classed as typhoid deaths.
[b] Percentage of total typhoid deaths for each month in the period to typhoid deaths for entire period.

Typhoid statistics of Washington, D. C., 1874–1905—Continued.

Year.	August.		September.		October.		November.		December.		Total deaths.	Total typhoid deaths.	Population.	Total death rate per 1,000.	Typhoid death rate per 100,000.
	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.	Total deaths.	Typhoid deaths.					
1874	391	12	277	12	306	12	267	18	263	2	1,504	56	....	....	....
1875	445	24	356	21	317	25	285	10	293	6	4,411	128	157,600	27.99	79.9
1876	397	24	349	10	331	21	254	10	298	3	4,234	114	162,375	26.07	70.3
1877	414	23	318	20	333	11	284	7	302	5	4,139	105	167,300	24.74	62.8
1878	425	12	303	23	331	21	296	2	321	2	5,253	120	172,377	30.47	69.6
1879	349	18	318	12	251	15	268	9	301	5	4,127	98	177,638	23.23	55.2
1880	313	13	352	13	350	16	280	6	326	8	4,075	95	183,060	22.26	51.3
1881	434	20	403	22	413	40	380	23	311	6	4,430	153	188,653	23.48	81.1
1882	341	20	304	13	356	26	316	7	320	3	4,223	123	191,980	22.00	64.1
1883	399	10	336	19	284	11	357	7	467	10	4,558	118	196,490	23.20	60.0
1884	444	15	426	29	368	32	351	15	366	20	4,841	153	201,110	24.07	76.1
1885	398	19	363	16	325	21	327	9	356	15	4,982	134	205,840	24.20	65.1
1886	423	26	439	18	409	16	360	12	347	17	4,728	151	210,680	22.24	71.7
1887	412	34	433	24	353	21	343	19	361	16	4,694	167	215,630	21.76	77.4
1888	543	24	424	32	428	41	337	20	390	10	5,225	188	222,830	23.45	84.4
1889	506	23	412	35	404	17	367	24	422	32	5,158	213	232,460	22.15	91.6
1890	423	28	443	29	427	35	380	25	451	20	5,534	257	242,520	22.82	105.9
1891	508	25	477	29	495	39	449	26	517	5	6,103	186	253,010	24.12	73.5
1892	529	22	526	37	507	22	424	27	493	20	6,416	216	260,800	24.60	82.8
1893	512	24	470	29	462	25	408	24	520	23	6,119	202	265,600	23.04	76.0
1894	425	33	453	28	482	31	409	27	457	17	5,869	228	270,514	21.69	84.4
1895	556	29	459	61	563	56	449	24	429	21	5,782	235	272,337	21.23	86.3
1896	565	17	410	27	476	25	399	18	427	16	5,832	148	275,562	21.16	53.7
1897	435	18	455	20	400	13	441	10	453	18	5,486	130	277,782	19.75	45.7
1898	469	24	482	23	497	31	480	22	568	16	5,815	191	283,100	20.54	67.1
1899	497	39	509	30	481	28	422	29	493	26	5,863	199	288,500	20.32	68.9
1900	525	41	401	29	452	25	438	28	501	17	6,059	220	294,000	20.59	74.4
1901	471	36	452	28	475	21	429	22	456	16	6,050	172	299,600	20.19	56.4
1902	459	39	421	25	490	32	415	19	497	20	5,788	226	305,400	18.95	74.0
1903	424	26	396	18	450	19	477	8	560	14	5,944	140	311,300	19.09	44.4
1904	507	22	433	25	444	14	454	11	515	9	6,221	135	317,200	19.61	42.5
1905	535	[a] 29	412	23	482	[b] 26	502	14	543	6	6,203	140	323,346	19.18	41.1
Total	14,474	769	13,012	780	13,072	788	12,048	532	13,324	424	165,666	5,141	....	....	....
Per cent [c]	14.89		15.10		15.26		10.10		8.30		....	....	....	....	....

[a] First filtered water turned into mains August 18, 1905.
[b] All water filtered after October 5, 1905.
[c] Percentage of total typhoid deaths for each month in the period to typhoid deaths for entire period.

In the last thirty-one years there have been 5,085 deaths in Washington from typhoid fever, or an average of 164 a year. If the deaths during this time have been 10 per cent of the cases, as experience in many places shows that they usually are, there have been 50,000 cases of typhoid fever, or an average of 1,600 a year. The table on pages 280 and 281 shows to what degree typhoid fever has been present in Washington since the disease has been reported.

Cases of typhoid fever in the District of Columbia, 1902–1905.

Month.	1902.	1903.	1904.	1905.	Total.
January		84	17	31	132
February		42	23	10	75
March	49	35	41	23	148
April	40	39	25	23	127
May	52	63	32	28	175
June	48	57	41	40	186
July	130	121	101	123	475
August	328	188	226	321	1,063
September	290	138	212	218	858
October	247	148	138	154	687
November	156	88	104	82	430
December	129	54	38	53	274
Total	1,469	1,057	998	1,106	4,630

To protect the District of Columbia against so serious a menace a filtration plant has been built, at a cost of $3,500,000, which it is estimated will cost $100,000 a year to run. Undoubtedly the expenditure is a wise one, but it is an impressive lesson in pollution. Moreover, the end is not yet, for if the pollution is unrestrained the evil results therefrom will make the water more difficult to purify. This means that the present rates of filtration can not be maintained, which will add to the cost of treating the same amount of water and necessitate a larger plant. Common sense demands, therefore, that some check be placed on the extravagance of needlessly fouling the river, for what Washington has been compelled to do will become necessary for other cities in the basin.

QUALITY OF SURFACE WATERS.

FIELD ASSAYS.

Inasmuch as large quantities of coal-mine water are poured into North Branch at sundry points along its course from Henry to Piedmont, W. Va., it was deemed advisable to investigate its effect on the river, and the study also covered the changes wrought by the large quantities of lime sludge and spent lime bleach from the mill of the West Virginia Pulp and Paper Company at Luke, Md.

Mine waters are characterized by large amounts of free sulphuric acid, sulphates of lime, magnesia, and alumina, and ferrous sulphate of iron. The protosulphate of iron on exposure to the air breaks up, with the formation of ferric hydrate and ferric sulphate. The hydrate precipitates; the sulphate remains in solution. The protosulphate of iron has a very destructive corrosive action on steam boilers and the sulphates of lime and magnesia form hard incrustations on them which can be removed only at considerable expense and not without damaging the plates. The appearance of a stream contaminated by mine water is striking and somewhat uncanny, for all vegetable and animal life is destroyed, and the bright, clear waters splash forbiddingly over the bed, which is stained yellow by the iron.

Field assays were made from September 20 to 23 and from October 4 to 14, 1905. The first trip covered the river from Dam No. 5, above Williamsport, to West Virginia Central Junction, and was not interfered with at all by the weather. The second extended from Wilsonia to Piedmont, W. Va., and was very satisfactory, for there was no rainfall until the 11th to increase the stream flow and thereby change the concentration of the water, which was at low stage.

North Branch above Henry contains but a trace of sulphates and is of low alkalinity. The mine water that enters at Henry through a little nameless run increases the sulphates in the river to such a point that the lumber company at Dobbin has been compelled to abandon the river water for boiler use.

Between Dobbin and Wilson the tributary streams have no sulphates, so that by the time Wilson is reached the sulphates have been diluted to 35 parts per million, and at Bayard the sulphates have all but disappeared and the water is suitable for boiler use. Buffalo Creek, which enters at Bayard, is said to be polluted by mine wastes, but the amount received must be small, because the water is nearly normal for the region. For some reason which could not be ascertained the sulphates in the river between Bayard and Gormania rise to 30 parts per million. Notwithstanding the fact that the run at Stoyer adds more mine water, North Branch at Stony River contains but a trace of sulphates.

It is interesting to follow the chlorine from Bayard to Schell. The tanneries wash out large quantities of salt from the hides and discharge it in the soaks. Above Bayard the river contained but 6 parts per million of chlorine. At Gormania it rose to 34 parts; inflowing waters diluted this to 19 parts at Stony River and to 14 parts at Schell. Samples taken below this point were collected after a rain, so that the results are not comparable, but this process of dilution undoubtedly would have continued regularly. This is an excellent example of the way factory effluents may be traced in a river by selecting some characteristic, readily detectable salt, and following it downstream.

At Schell the water of North Branch is very soft, owing to the fact that it has received the waters of Stony River, which are remarkably low in dissolved mineral substances. There is no change by the time it reaches a point a little above Harrison, but at this town the waters of Abram Creek, slightly polluted by mine water, fall in. From Harrison downstream, Wolfden Run, Three Fork Run, and Deep Run, in order, join North Branch. All of them are polluted by mine water, and Deep Run, which drains the extensive Elk Garden coal regions, carries a heavier quota of mine waste than any other stream tributary to North Branch, with the exception of Georges Creek. Despite these additions, the river above Elk Lick Run, near Shaw, W. Va., does not contain an objectionable amount of incrusting constituents, though the total hardness is considerably increased. Above Savage River the total hardness becomes low again and the river is in good condition. The entrance of Savage River and of a small volume of mine water below it does not change the water very much, and it soon after flows over the dam of the West Virginia Pulp and Paper Company.

In the entire distance from Henry to West Virginia Central Junction the tributary streams are normally low in objectionable mineral ingredients and by dilution counteract the mine waters which are poured into the river, so that the water arrives at the paper company's dam with practically the same mineral content that it has above Henry. This is somewhat surprising, for prior to the investigations it was believed that the mine water was so considerable as to have a decidedly deleterious effect on the stream.

A short distance below the dam the factory of the West Virginia Pulp and Paper Company discharges its effluent, consisting of carbonate of lime, chloride of lime, and sulphate of soda, into North Branch. The quantity is so great that it converts the clear stream into a turbid, milky-white one, and the tests applied to the water showed the marked effect of the chemicals on it. October 14, 1905, the lime rose from 26 parts per million above the dam to 105 at a point opposite the Baltimore and Ohio roundhouse in Piedmont, the alkalinity rose from 31 parts per million to 44, the sulphates from a trace to 56, and the chlorine from 9 to 29. Thus the character of the stream is radically altered by this effluent, and it is still further changed by the influx of the waters of Georges Creek, which enter at Westernport and which are heavily charged with mine waters. The waters of the creek when they unite with those of North Branch react with the matter which it contains in suspension and solution. Free sulphuric acid combines with the carbonate of lime, producing a precipitate which makes the water roily and may be observed all the way from Westernport to Keyser. The iron salts, including the ferric sulphate, are precipitated in the form of ferric oxide.

September 23 there were in the waters of North Branch above the dam at West Virginia Central Junction 26 parts per million of lime, 18 of alkalinity, a trace of sulphates, and 9 parts of chlorine. At the Baltimore and Ohio roundhouse there were 130 parts of lime, 47 of alkalinity, 117 of sulphates, 24 of chlorine, and 1 of iron. Georges Creek contained 288 parts of calcium, 522 of sulphates, and 54 of iron. One mile below Westernport, North Branch contained 130 parts of calcium, 6 parts of alkalinity, 185 parts of sulphates, and 2.8 parts of iron. It is evident from these results that the sulphuric acid combined with the carbonates represented in the test by alkalinity to the extent of nearly eliminating them. The sulphate of lime formed thereby was considerable, and the iron for the most part precipitated out or became obscured by dilution. By following the tests in the table on pages 287–290, it becomes apparent that from a point 1 mile below Westernport the alkalinity steadily increased in amount to Dam No. 5, being 38 parts per million 2 miles below Keyser, 46 at the Cumberland waterworks intake, and 73 at Dam No. 5, at Williamsport. That is, after partial elimination the carbonates tended to return to the normal for the region. Moreover, the sulphates dropped steadily, being 181 parts per million 2 miles below Keyser, 140 at Cumberland, and but a trace at Dam No. 5.

This extensive precipitation has a potent influence on the bacterial content of North Branch, for the sulphates in settling out entangle the germs and drag them to the bottom, thus decidedly improving the water. In Georges Creek the acid waters are undoubtedly inimical to the bacteria and tend to destroy the organic matter which is so abundantly supplied to the stream at the numerous thriving mining towns in its valley. This reduces the effect of the pollution of North Branch at Westernport. Finally, as has been shown by experiments described elsewhere,[a] the waste discharged by a soda pulp mill is a powerful germicide and an excellent precipitant of sewage.

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[a] Leighton, M. O., Preliminary report on the pollution of Lake Champlain; Water-Sup. and Irr. Paper No. 121, U. S. Geol. Survey, 1905.

Together, these several influences effect so considerable a reduction of the bacteria in North Branch that its water is used raw by the city of Cumberland with results much less evil than the gross pollution of the watershed would lead one to expect. While this is fortunate, it is to be remembered that the purification is effected by a number of factors acting independently of each other, without intent of improving the water. A diminution of the output of the paper mill or of the flow from the pumps at the mines would at once interfere with the purification and might lead to serious results. Fortunately, the stream flow is usually low at that season of the year when typhoid fever is most prevalent, so that the proportion of chemicals in the water is greatest when it is most needed. It is manifest that this quasi purification must be uncertain and that it is dangerous to depend on it. Therefore it is obvious that the city of Cumberland should install proper water-purification works without delay. As it is a manufacturing city, and as the sulphates in the North Branch water at this point are sufficient to cause some trouble by the formation of hard scale in boilers, it might be profitable to establish also a water-softening plant. The amount of iron in the surface and subsoil waters of North Branch above Cumberland is usually great enough to compel the use of casings to exclude it from wells which are driven for industrial enterprises.

The field tests made on the waters of Wills Creek indicate that above Jennings Run the water is low in incrustants. The run is heavily polluted by mine water, and consequently raises the sulphates in Wills Creek sufficiently to make the water harmful for steam-producing purposes. The assays of various springs and wells in the Wills Creek valley show them to differ considerably, the water in some being soft and in others very hard.

The tests applied to Conococheague Creek show that a small amount of sulphates is usually present and that the water has a varying amount of temporary hardness, which is more marked in the waters of West Branch than in those of the main stream.

The headwaters of the Monocacy about Gettysburg, Pa., to wit, Rock Creek, Marsh Creek, Stevens Run, and Willoughby Run, show different characteristics by the field tests. Marsh Creek water is the softest and gives more satisfaction in Gettysburg for boiler use than those from the deep wells, all of which are corrosive and high in incrustants. Some of these wells will very likely soon be abandoned on account of these bad qualities.

Field assays of waters in Potomac River basin.

[Parts per million.]

Stream.	Date.	Acidity.[a]	Calcium.	Alkalinity.	Total hardness.	Sulphates.	Chlorine.	Iron.
Silcott Run at Wilsonia, W. Va.	Oct. 4, 1905	8	Trace.	259	......	0	9	1
North Branch Potomac River above Henry and above creek[b]	do	8	Trace.	24	22	Trace.	6	2
Creek at Henry, W. Va.[c]	do	20	119	38	90	155	9	4
Elk Run near mouth	do	5	0	15	12	0	6	0
North Branch Potomac River above dam at Dobbin, W. Va.	do	8	67	22	51	77	6	2
Pond on run that supplies Dobbin sawmill	do	15	Trace.	8	12	0	4	1
Spring at Dobbin, W. Va., east of sawmill and West Virginia Central and Pittsburg R. R. track	do	45	Trace.	8	22	0	6	0
Laurel Creek northwest of Dobbin, W. Va.	do	10	Trace.	16	12	0	4	2.2
Red Oak Run at Wilson, W. Va.[d]	do	5	Trace.	16	18	0	6	0
North Branch Potomac River at Wilson, W. Va., below Red Oak Run	do	8	32	17	......	29	6	2.2
Sand Run, Md., opposite Wilson, W. Va.	do	10	Trace.	17	18	0	6	2
North Branch Potomac River at Bayard, W. Va., above Buffalo Creek	do	5	24	18	......	Trace.	6	1.5
Buffalo Creek at Bayard, W. Va.	do	5	Trace.	8	18	Trace.	6	0
North Branch Potomac River at Bayard, below Buffalo Creek and tannery	do	5	28	19	27	Trace.	6	1.5
J. G. Hoffman & Sons Co.'s drilled well at Gormania, W. Va.[d]	Oct. 9, 1905	12	47	143	51	0	8	.5
North Branch Potomac River below highway bridge at Gormania, W. Va.	Oct. 10, 1905	15	55	35	49	33	34	2
North Branch Potomac River[e]	Oct. 6, 1899	......	41.04	......	128.2	22	28.7	2.86
Nydegger Run at Gorman, Md.	Oct. 9, 1905	8	26	36	27	Trace.	4	1
Glade Run at mouth	Oct. 10, 1905	5	26	34	22	Trace.	4	.5
Run at Stoyer, Md.	Oct. 8, 1905	5	39	22	32	Trace.	6	.5
Difficult Run at mouth	do	5	Trace.	24	32	0	9	0
North Branch Potomac River short distance above Stony River.	do	5	26	24	27	Trace.	19	1
Stony River, W. Va., at mouth	do	5	0	9	12	0	9	1
North Branch Potomac River above Laurel Run and opposite Schell, W. Va.	do	5	Trace.	21	12	Trace.	14	1
Laurel Run at mouth	do	5	Trace.	18	18	0	4	0
Lostland Run near mouth	do	5	0	14	10	Trace.	9	0
North Branch Potomac River above Abram Creek	Oct. 12, 1905	10	Trace.	13	18	Trace.	9	1.5
Abram Creek at mouth	do	10	Trace.	13	32	Trace.	9	1.5
Wolfden Run, Md.[f]	do	60	48	Acid.	66	60	9	7
Three Fork Run, Md., northeast of Harrison, W. Va.	do	10	Trace.	24	22	Trace.	4	0
Deep Run at Shaw, W. Va.[f]	do	140	119	Acid.	......	273	19	8
Howell Run at Shaw, W. Va.	do	5	Trace.	28	22	Trace.	4	1
North Branch Potomac River above Elk Lick Run, Md.	do	15	Trace.	17	61	Trace.	14	2.2
Elk Lick Run northeast of Shaw, W. Va.	do	5	23	40	......	Trace.	9	......
North Branch Potomac River above Savage River	Oct. 14, 1905	10	24	20	27	Trace.	9	1.7
Savage River near mouth[g]	Apr. 5, 1905	......	0	25	......	0	9	Trace.
Savage River, tap in Kenny House, Piedmont, W. Va.	Oct. 3, 1905	5	27	44	......	Trace.	9	0
Savage River near mouth	Oct. 14, 1905	5	Trace.	26	18	Trace.	9	0
North Branch Potomac River above West Virginia end of dam at Luke, Md.	Sept. 23, 1905	......	26	18	32	Trace.	9	1
Do	Oct. 14, 1905	5	26	31	27	Trace.	9	1

[a] Parts per million of $CaCO_3$ required to neutralize the acidity.
[b] Contaminated by mine water.
[c] Receives much mine water.
[d] Cased 30 feet to keep out iron-bearing water, which is said to be found 10 to 20 feet below surface of the ground in North Branch of Potomac valley above Cumberland, Md.
[e] Analysis by Prof. J. W. Mallet.
[f] Polluted by mine water.
[g] Assay by S. J. Lewis.

Field assays of waters in Potomac River basin—Continued.

Stream.	Date.	Acidity.	Calcium.	Alkalinity.	Total hardness.	Sulphates.	Chlorine.	Iron.
North Branch Potomac River above pulp mill at Luke, Md.[a]	July 14, 1899	......	6.93	......	24.7	17	4.6	1.92
North Branch Potomac River opposite Baltimore and Ohio roundhouse, Piedmont, W. Va.	Sept. 23, 1905	......	130	47	......	117	24	1
Do	Oct. 14, 1905	5	105	44	90	56	29	1.5
North Branch Potomac River at Piedmont, W. Va.[b]	Apr. 4, 1905	......	73	40	......	10		1
Georges Creek at mouth	do	......	......	Acid.	......	410	......	28
Do	Sept. 23, 1905	......	288	......	......	522	......	54
Do	Oct. 14, 1905	462	228	......	......	359	19	36
Do.[a]	July 14, 1899	......	129.54	......	439.1	502	10	191.44
North Branch Potomac River, West Virginia side, 1 mile below Westernport, Md.	Sept. 23, 1905	......	130	6	......	185	19	2.8
North Branch Potomac River, Maryland side, 1 mile below Westernport, Md.	Oct. 14, 1905	10	130	26	100	115	14	.5
North Branch Potomac River, West Virginia side, 2½ miles below Westernport, Md	Sept. 23, 1905	......	126	8.5	......	185	19	3
North Branch Potomac River, West Virginia side, 1 mile above Keyser, W. Va	do	......	133	19	......	164	19	1.2
North Branch Potomac River at Keyser, W. Va.[a]	Apr. 27, 1905	......	73	10	104	64	9	4
Do	Sept. 23, 1905	......	130	17	......	159	19	
New Creek[a] ¼ mile above mouth	July 14, 1899	......	45.08	......	113.7	20	32.4	1.97
New Creek at mouth	Sept. 23, 1905	......	123	128	......	Trace.	39	0.5
Keyser city supply (impounded spring water)	Apr. 27, 1905	......	261	171	......	15	9	Trace.
Do	Sept. 23, 1905	......	179	211	......	Trace.	4	0.0
North Branch Potomac River below Keyser, W. Va[a]	——, 1899	......	48	......	156	202	11.9	29
Do[a]	——, 1899	......	78.6	......	200	406	22.6	47.7
Do[a]	——, 1899	......	63.1	......	156	290	20.3	20.5
North Branch Potomac River at Baltimore and Ohio R. R. bridge 21, Maryland side, 2 miles below Keyser	Sept. 23, 1905	......	130	38	......	151	19	1.0
North Branch[b] Potomac River above Cumberland, Md.	——, 1899	......	56	......	171	206	12.1	7.0
North Branch Potomac River (hydrant in Cumberland, Md.)[a]	——, 1899	......	31.12	......	128.5	110	13.6	11.79
North Branch Potomac River, at Ridgely above Cumberland waterworks intake[b]	Apr. 4, 1905	......	55	20	118	78	9	2.5
North Branch, Potomac River, at Cumberland waterworks intake	Sept. 22, 1905	......	123	46	......	117	14	1.0
North Branch Potomac River, 300 feet below dam at Cumberland, Md.[b]	Apr. 3, 1905	......	96	25	......	84	9	5.0
North Branch Potomac River above sewage outfall at South Cumberland[b]	Apr. 4, 1905	......	......	......	......	68	......	2.75
Chesapeake and Ohio Canal at lock above Dam No. 5, where canal enters river	Sept. 20, 1905	......	69	62	61	33	15	Trace.
North Branch Potomac River below Dam No. 5	do	......	70	73	......	Trace.	9	0
Kilmer Spring, public water supply, Martinsburg, W. Va.[b]	Aug. 14, 1905	......	126	205	......	0	27	Trace.
Public water supply, Hyndman, Pa.	Apr. 7, 1905	......	0	7	......	0	7	0
Wills Creek west of Hyndman, Pa.[b]	Apr. 8, 1905	......	0	10	35	Trace.	9	0
Wills Creek, 100 yards below tannery[b]	Apr. 9, 1905	......	0	15	......	Trace.	9	Trace.
Wills Creek at Corriganville[b]	Apr. 4, 1905	......	Trace.	25	......	10	9	Trace.
Jennings Run at mouth[b]	do	......	63	Acid.	......	239	79	16
Braddock Run at narrows[b]	do	......	30	35	......	10	9	......
Wills Creek at Cumberland[b]	Apr. 3, 1905	......	110	......	......	99	......	5.5
Wills Creek, west side, 2,000 feet above mouth[a]	July 15, 1899	......	48.6	......	168.6	245	41.7	6.9

[a] Analysis by Prof. J. W. Mallet. [b] Assay by S. J. Lewis.

Field assays of waters in Potomac River basin—Continued.

Stream.	Date.	Acidity.	Calcium.	Alkalinity.	Total hardness.	Sulphates.	Chlorine.	Iron.
Bradigans well, 20 feet deep, 1 mile northeast of Foley, Pa.[a]	Apr. 8, 1905	......	55	44	......	18	19	Trace.
Becks spring ⅞ mile east of Foley, Pa.[a]	....do.......	......	0	12	28	0	9	0
Shaffers Run at Fairhope, Pa., ½ mile above Wills Creek[a]	....do.......	......	0	13	21	0	9	Trace.
Spring at Fairhope, Pa., south side of road 30 feet above Wills Creek[a]	....do.......	......	0	17	35	0	9	0
Gooseberry spring at Hoblitzell, Pa.[a]	....do.......	......	82	62	97	Trace.	9	0
Spring on west bank Wills Creek opposite brick factory[a]	....do.......	......	Trace.	14	28	Trace.	9	Trace.
Spring on top Wills Mountain, piped to Shaffer's house, 2 miles east of Hyndman, Pa.[a]	Apr. 7, 1905	......	0	20	......	0	9	0
Anthony Shaffer's well, 1½ miles east of Hyndman, Pa., at Stringtown.[a]	....do.......	......	228	152	......	24	80	0.5
Spring ½ mile from Cooks Mills, Pa.[a]	....do.......	......	20	29	63	6	9	0
Emrich's well at Cooks Mills, Pa.	....do.......	......	146	44	......	30	22	....
Spring 1 mile west of Cooks Mills, Pa.[a]	....do.......	......	173	187	......	6	9	....
Well 112 feet deep at Spangler Hotel, Hancock, Md.	Apr. 18, 1906	......	142	115	......	108	129	0
Great Tonoloway Creek at National Road between Hancock and Millstone, Md.	....do.......	......	Trace.	14	21	Trace.	4.5	0
Licking Creek at National Road between Millstone, Md., and Big Pool, Md.	....do.......	......	34	45	35	Trace.	45	0
Conococheague Creek above Wolf Co.'s dam, Chambersburg, Pa.	Sept. 15, 1905	......	46	58	42	0	4	0.0
Falling Spring Run above mouth.	....do.......	......	186	[b] 178	......	Trace.	4	Trace.
Conococheague Creek below Gerbig's soap factory, Chambersburg, Pa.	....do.......	......	96	96	80	Trace.	4	0.0
Conococheague Creek, tap in Washington Hotel, city supply.	Sept. 16, 1905	......	35	56	......	0	9	Trace.
Conococheague Creek, 1 mile west of Greencastle, Pa.	Sept. 18, 1905	......	110	118	80	Trace.	9	0.0
Greencastle, Pa., public supply, tap in National Hotel, supply from 3 springs.	....do.......	......	0	202	......	Trace.	9	0.0
Trout Run at Mercersburg Water Co.'s Reservoir 1 mile north of Foltz, 2½ miles east of Mercersburg, and above Dickys Run.	Sept. 17, 1905	......	Trace.	26	......	0	9	0.5
West Branch of Conococheague Creek	Sept. 16, 1905	......	113	[b] 127	90	Trace.	9	0.5
Dickys Run near mouth	....do.......	......	71	208	......	Trace.	14	0.5
West Branch of Conococheague Creek 3 miles southeast of Mercersburg, Pa., below Dickys Run.	....do.......	......	90	[b] 98	71	Trace.	9	Trace.
Licking Creek near mouth	....do.......	......	94	132	80	Trace.	9	Trace.
Conococheague Creek near mouth.	Sept. 20, 1905	......	96	[b] 108	80	Trace.	14	Trace.
Stevens Run at Gettysburg, Pa.	Sept. 9, 1905	......	200	204	......	36	89	0.0
Rock Creek below Culps Run, Gettysburg, Pa.	....do.......	......	84	91	......	Trace.	14	2.5
Marsh Creek below Gettysburg Water Co.'s intake	....do.......	......	32	[b] 41	......	Trace.	9	Trace.
Willoughby Run at Gettysburg, Pa.	....do.......	......	100	106	71	Trace.	4	0.0
Mountain stream 1 mile west of McConnellsburg, Pa., public supply.	Sept. 17, 1905	......	Trace.	27	......	Trace.	4	0.0
Cove Creek at west end of McConnellsburg, Pa.	....do.......	......	137	158	......	Trace.	4	0.0
Little Antietam Creek west of Waynesboro, Pa.	Sept. 12, 1905	......	137	[b] 194	......	Trace.	9	0.0
Waynesboro, Pa., public supply above dam of Waynesboro water Co., at confluence of Rattlesnake Run and East Branch Antietam Creek	....do.......	......	0	[b] 21	......	0	4	Trace.

[a] Assay by S. J. Lewis.

[b] Alkaline carbonates, 21 parts per million.

Field assays of waters in Potomac River basin—Continued.

Stream.	Date.	Acidity.	Calcium.	Alkalinity.	Total hardness.	Sulphates.	Chlorine.	Iron.
East Branch Little Antietam Creek east of Waynesboro, Pa.	Sept. 12, 1905	......	28	[a] 51	......	0	4	Trace.
Spanglers Spring at Gettysburg, Pa.	Sept. 9, 1905	......	39	85	42	0	9	0.0
Well of Gettysburg Brick Co. at Gettysburg, Pa.	....do....	......	218	250	......	0	14	0.0
Well of Gettysburg Transit Co. at Gettysburg, Pa.	....do....	......	200	173	......	Trace.	29	0.0
Well of Western Maryland R. R. at Gettysburg, Pa [b]	....do....	......	123	291	......	110	258	0.5
Steam laundry dug well at Gettysburg, Pa.	Sept. 10, 1905	......	72	79	......	Trace.	29	0.0
Gettysburg Water Co.'s Well No. 1, Gettysburg, Pa.	Sept. 9, 1905	......	23	41	51	Trace.	9	0.0

[a] Alkaline carbonates, 21 parts per million.

[b] Magnesium present.

SANITARY AND MINERAL ANALYSES.

By Raymond Outwater.

Numerous chemical analyses of the waters of the Potomac have been made during the course of this investigation, and the results are given in the accompanying table. It is very difficult to draw definite conclusions of a general nature from these sanitary analyses. Inspection of the various places on the river and its tributaries points to a considerable pollution at practically all of the places examined and the chemical analyses confirm the inspections. Evidences of pollution can, in some instances, be seen in the main stream after pollution has entered it; yet chemical analysis does not indicate that the water is much more polluted at Great Falls than at many points farther up the river and on its tributaries.

The tap water was collected in the McKinley School of Manual Training. The water supplied to this building flows from the river to the Dalecarlia Reservoir, thence to the distributing reservoir in Georgetown, and thence to the Washington City Reservoir, from which it flows by gravity through the street mains to the laboratory. None of the water supplied to Washington during the progress of the chemical examination was filtered.

A study of the analyses leads to the following conclusions:

1. The variations in the amount of each component have been considerable, and these are to a certain extent unaccounted for.

2. A certain proportion of the variations can possibly be accounted for by the variation in the rainfall.

3. If these analyses are of accuracy equal to those obtained by previous investigations they indicate that the river has become more impure, the figure for required oxygen being the only one which shows a decrease.

The mineral analyses which were made represent the main stream and all of the principal tributaries, and it is believed that they give an insight into the chemical denudation of the basin. The purpose of these analyses was to determine the amount and the nature of the dissolved mineral matter. The water was filtered through a Pasteur-Chamberland filter; measured quantities were then evaporated nearly to dryness in porcelain vessels, after which the evaporation was completed in platinum dishes. The residue thus obtained was treated with hydrochloric acid and twice evaporated to dryness, after which it was redissolved in hydrochloric acid and the silica was separated by filtration, ignited, and weighed. The residue left after treatment with hydrofluoric acid was added to the "iron and alumina." The filtrate from the silica was diluted to 200 c. c. and one portion of 100 c. c. was taken for the estimation of iron and alumina, calcium, and magnesium, and the other portion for the estimation of sulphuric acid, sodium, and potassium. This method of determining sodium and potassium is preferable to the common one of separating sodium and potassium in the filtrate from the magnesium. It is unnecessary to detail the methods, which may be found in standard text-books on quantitative chemical analysis.

Some interesting facts are brought out by comparing the flow of the Potomac with the analytical results. For this purpose, the gage readings at Point of Rocks, Md., 7 miles above the Monocacy River, were used, no gage being maintained by the United States Geological Survey below this point. As most of the analyses were of samples from the Washington city taps, which are fed with water diverted from the river at Great Falls, the results are not strictly accurate, but they are approximately so.

The average flow of the Potomac at Point of Rocks for 1905 was calculated from observations made by the United States Geological Survey and was found to be 7,534 second-feet. As the weight of a cubic foot of water is 28.3 kilograms (62.4 pounds), this is equal to 213,212 kilograms per second. Calculating the total amount of water flowing past this point from the average, we have for the year 6,724,000,000,000 kilograms or liters. From the figures on analyses we have: Total solids in the unfiltered water, 146.1 parts per million; total solids in solution, 114.6 parts; in suspension, 31.5 parts; from which we find that the following amount of material is carried past this point in the course of a year: Total solids, 982,000,000 kilograms; in solution, 771,000,000 kilograms; in suspension, 212,000,000 kilograms; or, in solution, 850,000 tons; in suspension, 234,000 tons.

The drainage area of the Potomac above Great Falls is 11,400 square miles. By comparing this area with the amount of material being carried down in suspension and in solution, the following figures, showing the average amount of solid material being carried off annually from each square mile of territory in the Potomac basin, are obtained: In solution, 74.4 tons; in suspension, 20.5 tons; total, 94.9 tons.

Sanitary analyses of surface water in the Potomac basin.

[Parts per million.]

Stream.	Date.	Required oxygen.	Nitrogen as— Albuminoid ammonia.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrogen as— Nitrates.	Chlorine.	Unfiltered water. Total residue.	Unfiltered water. Loss on ignition.	Unfiltered water. Total hardness.
North Branch Potomac River above Bayard	Feb. 27, 1905	1.65	0.16	0.12	Trace.	3.00	6	26	19	29.4
Buffalo Creek at mouth	...do...	1.70	.06	.05	Trace.	1.50	9	39	15	39.7
North Branch Potomac River above Gormania	Feb. 25, 1905	2.15	.11	.07	.002	1.25	4	30	15	42.6
North Branch Potomac River below Gormania [a]	Oct. 6, 1899	26.42	.676	.182	.023	.261	28.7	311.6	140.7	128.2
Do	Feb. 25, 1905	1.95	.13	.06	Trace.	2.00	9	46	17	55.9
Abram Creek at mouth	Feb. 27, 1905	.85	.15	.19	Trace.	2.50	5	47	26	51.5
North Branch Potomac River above Savage River	Feb. 25, 1905	1.80	.15	.02	0	3.00	11	23	9	50
Savage River	...do...	.80	.06	Trace.	0	3.00	5	32	15	33.8
North Branch Potomac River above mill of West Virginia Pulp and Paper Co. at Luke	July 14, 1899	7.76	.234	.154	Trace.	.171	4.6	59.4	25.5	24.7
Do	Feb. 25, 1905	1.45	.18	.09	0	2.50	15	57	18	50
North Branch Potomac River below mill of West Virginia Pulp and Paper Co. at Luke	...do...	3.20	.09	.05	Trace.	3.00	25	448	177	120.5
Georges Creek at Westernport	July 14, 1899	13.05	.446	.591	.011	1.422	10.1	1013	222.6	439.1
Do	Feb. 25, 1905	2.35	.06	.51	Trace.	2.50	17	1057	442	524.8
North Branch Potomac River between Keyser and Piedmont	...do...	1.80	.06	.06	0	2.5	10	145	50	63.2
North Branch Potomac River below mill at Keyser	...do...	2.35	.09	.05	Trace.	2.50	11.0	189	60	97.0
New Creek ¼ mile above mouth [a]	July 14, 1899	11.26	.371	.137	.069	.933	32.4	218.8	69.4	113.7
New Creek at mouth	Feb. 25, 1905	2.80	.46	.30	.004	2.50	22	233	81	105.8
North Branch Potomac River below Keyser [a]	, 1899	......	.380	.054	.16	2.31	11.9	452	194.5	100.6
Do	, 1899	......	.483	.081	.11	.74	22.6	853	368	140.3
North Branch Potomac River above Cumberland	, 1899	......	.295	.075	......	2.86	12	491.8	220.8	110.5
Do	, 1899	......	.397	.142	......	1.09	20.3	658	315.4	100.9
Hydrant in Cumberland	July 15, 1899	23.689	.374	.163	.005	.219	13.6	276.5	104.9	128.5
Cumberland water supply	Dec. 29, 1904	7.45	.32	.37	Trace.	1.20	5.0	126	47	73.3
Wills Creek above Jennings Run	Dec. 27, 1904	4.60	.17	.03	Trace.	.80	15	82	38	50.8
Jennings Run at mouth	Dec. 29, 1904	1.75	.08	.44	Trace.	.80	20	632	243	290
Braddock Run at Allegany Grove	Dec. 27, 1904	1.70	.28	.06	Trace.	1.00	14	115	33	78
Wills Creek above dam of United States Leother Co., Cumberland	Dec. 30, 1904	8.95	.74	.52	.002	.80	7	147	38	92
Wills Creek above Baltimore Street Bridge, Cumberland	...do...	13.95	.66	.40	.004	.90	17	224	60	137.3
Wills Creek 100 yards above dam at mouth [a]	July 15, 1899	32.476	.909	.827	.008	.257	41.7	372.5	135.2	168.6
Patterson Creek at mouth	Feb. 13, 1905	.45	.05	Trace.	0	1.00	8.0	142	55	129.5
North Branch Potomac River at Greenspring	Feb. 10, 1905	2.10	.35	.27	.008	2.00	14.5	219	63	152.9
South Branch Potomac River at Franklin above tannery	Mar. 11, 1905	1.70	.29	Trace.	0	1.12	3.50	85	35	80.9
North Fork of South Branch Potomac River above South Branch	Mar. 12, 1905	1.75	.17	.01	0	1.00	2.5	83	25	42.6

[a] Analysis by Prof. J. W. Mallet.

Sanitary analyses of surface water in the Potomac basin—Continued.

Stream.	Date.	Required oxygen.	Nitrogen as— Albuminoid ammonia.	Free ammonia.	Nitrites.	Nitrates.	Chlorine.	Unfiltered water. Total residue.	Loss on ignition.	Total hardness.
South Branch Potomac River above Petersburg	Mar. 10, 1905	1.85	0.31	0.03	0	1.25	4.0	171	26	55.9
Mill Creek, Hardy County, W. Va	do	2.10	.17	.03	0	1.30	3.5	199	48	66.2
South Branch Potomac River below Petersburg	do	1.95	.22	.07	0	1.25	3.0	220	41	50.0
South Branch Potomac River above Moorefield	do	2.00	.13	.03	0	1.25	2.5	276	32	47.0
Moorefield River above tannery at Moorefield	Mar. 9, 1905	1.90	.12	.02	0	1.50	4.5	258	29	47.0
Moorefield River below tannery at Moorefield	do	2.40	.21	.01	0	1.25	4.0	471	44	44.1
South Branch Potomac River below Moorefield	Mar. 10, 1905	2.10	.13	.03	0	1.50	3.5	498	77	60.3
Mill Creek at Romney	Mar. 13, 1905	1.65	.12	.03	0	1.25	4.5	119	32	50.0
South Branch Potomac River above Romney	do	1.30	.14	.03	Trace.	1.25	3.0	98	28	55.4
Cherry Run at Romney	do	1.70	.36	.03	Trace.	1.40	7.5	93	29	35.3
South Branch Potomac River at mouth	Feb. 10, 1905	1.15	.11	Trace.	Trace.	2.00	7	120	43	123.2
Potomac River below South Branch	do	1.15	.13	Trace.	Trace.	2.00	8.1	127	48	121.7
Potomac River above Pawpaw	do	1.30	.22	.09	.004	2.00	8	156	49	127.9
Potomac River below Pawpaw	do	2.20	.24	.10	.004	2.00	14	176	57	157.6
Potomac River above Great Cacapon River	Feb. 12, 1905	.90	.10	.01	Trace.	.88	8	162	54	135.7
Great Cacapon River at mouth	do	1.35	.11	.08	0	1.00	5	108	37	82.7
Potomac River below Great Cacapon River	do	.70	.03	Trace.	0	.75	4	94	35	93.6
Warm Spring Run	Feb. 10, 1905	.50	.03	.08	.012	2.25	6	181	53	165.4
Conococheague Creek above Chambersburg	Mar. 31, 1905	.40	.04	.03	0	1.00	3.5	135	93	47.0
Conococheague Creek below Chambersburg	do	.50	.08	.03	Trace.	4.00	8	233	147	91.0
West Branch of Conococheague Creek above Dickys Run	Apr. 1, 1905	.65	.14	.02	Trace.	3.00	4.5	159	31	130.8
West Branch of Conococheague Creek below Dickys Run	do	.70	.08	.01	Trace.	3.50	5.0	127	43	105.8
Back Creek above Williamson	Mar. 31, 1905	.25	.22	.02	Trace.	2.00	4.5	101	40	126.4
Back Creek below Williamson	do	2.10	.16	.04	Trace.	3.50	5.5	77	66	129.4
Conococheague Creek below Back Creek	do	.60	.13	.05	Trace.	5.00	5.5	222	66	192.6
Conococheague Creek below junction with West Branch	Apr. 1, 1905	.55	.12	.02	Trace.	2.50	5.0	115	80	137.6
Potomac River above Conococheague Creek		.50	.12	.02	Trace.	2.25	4.0	104	16	47
Potomac River below Conococheague Creek		.50	.17	.03	Trace.	2.75	7.0	165	33	125
Opequon Creek above Abrams Creek	Feb. 18, 1905	.40	.10	.01	.008	2.50	9	271	121	276.1
Abrams Creek	do	2.25	.19	.03	.016	5.00	17	334	140	224.9
Opequon Creek below Abrams Creek	do	2.05	.17	.04	.012	2.75	15	305	25	157.3
Opequon Creek above Tuscarora Creek	Feb. 17, 1905	.45	.04	.03	.004	5.00	19	303	62	280.8
Tuscarora Creek	do	1.50	.46	.07	.128	5.00	17	328	129	305.8
Opequon Creek near mouth	do	.70	.11	.03	.024	5.50	12	284	56	266.4
Potomac River above Opequon Creek	do	.40	.12	.10	.004	2.50	13	178	87	123.5
Potomac River below Opequon Creek	do	.90	.10	.03	.024	2.75	20	164	22	210.2
Potomac River above Antietam Creek	Jan. 17, 1905	3.33	.25	.08	Trace.	1.00	8.5	185	22	93.2

Sanitary analyses of surface water in the Potomac basin—Continued.

Stream.	Date.	Required oxygen.	Nitrogen as— Albuminoid ammonia.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrogen as— Nitrates.	Chlorine.	Unfiltered water. Total residue.	Unfiltered water. Loss on ignition.	Unfiltered water. Total hardness.
Antietam Creek at mouth	Jan. 17, 1905	1.95	0.15	Trace.	0.004	2.50	10	216	46	148.8
Potomac River below Antietam Creek	do	2.65	.41	0.03	.004	2.50	2.5	238	67	150.1
North River above Cooks Creek	Jan. 28, 1905	1.35	.16	Trace.	Trace.	1.00	11	137	39	137.3
Blacks Creek	do	4.35	.69	.86	.032	2.50	33	344	81	248
North River below Cooks Creek	do	1.05	.16	.02	Trace.	1.25	.15	147	39	170
Middle River above Lewis Creek	do	1.15	.07	.12	0	1.25	4	219	42	218.4
Lewis Creek near mouth	do	2.25	.47	1.52	.064	3.00	16	365	67	230.9
South River above Basic	Jan. 25, 1905	1.25	.17	.01	Trace.	1.50	6	110	36	117
South River below Basic	do	1.90	.13	.03	.002	1.00	4	112	35	109.2
South Fork of Shenandoah River above Elk Run	Feb. 4, 1905	1.15	.14	.02	.003	3.50	6	152	52	105.3
Elk Run	do	21.45	1.12	.06	Trace.	4.00	67.0	214	145	55.4
South Fork of Shenandoah River below Elk Run	do	3.85	.14	.02	.002	4.00	12	157	66	145.
South Fork of Shenandoah River above Hawksbill Creek	Jan. 26, 1905	1.15	.14	.01	Trace.	1.75	7	143	42	137.3
Hawksbill Creek above Luray	do	1.00	.09	.01	0	2.00	9	124	45	69.2
Do	Feb. 3, 1905	1.05	.8	Trace.	.001	4.00	15	138	44	77
Hawksbill Creek below Luray	do	4.35	.48	.03	.002	3.50	24	175	85	94.5
South Fork of Shenandoah River below Hawksbill Creek	Jan. 26, 1905	2.35	.21	.05	Trace.	1.50	10	143	47	120.1
South Fork of Shenandoah River at Riverton	do	1.15	.08	.30	Trace.	1.25	13	109	29	121.5
North Fork of Shenandoah River above Passage Creek	Feb. 2, 1905	1.70	.14	.09	Trace.	2.00	9	200	82	180.1
Passage Creek	do	1.50	.10	.01	0	1.00	5	78	37	89.1
North Fork of Shenandoah River below Passage Creek	do	1.95	.16	.24	Trace.	1.25	6	189	81	160.6
Happy Creek	Feb. 3, 1905	1.00	.24	.03	Trace.	1.7	8	71	12	75.6
Shenandoah River below confluence of North and South forks	Feb. 2, 1905	1.25	.15	.16	Trace.	1.75	6	173	65	141.8
Evitt Run	Jan. 16, 1905	.95	.06	.01	.004	2.50	11.5	278	93	312
Flowing Spring Run	Jan. 18, 1905	3.00	.72	.21	.024	5.00	9.5	373	123	277.7
Shenandoah River at mouth	July 4, 1904	1.55	.32	.02	.004	.50	4.0	243	55	117.3
Do	Dec. 12, 1904	1.85	.10	.25	Trace.	2.00	4.0	182	34	124.2
Do	Dec. 20, 1904	1.20	Trace.	Trace.	.001	.50	4.0	241	51	172.5
Potomac River above Shenandoah River	July 4, 1904	1.45	.33	.01	.004	.50	5.0	195	59	89.7
Do	Dec. 12, 1904	3.35	.24	.01	Trace	2.00	7.0	215	......	138
Do	Dec. 20, 1904	2.15	.12	Trace.	.004	.50	8.0	229	55	158.7
Potomac River below Shenandoah River	Dec. 12, 1904	2.75	.22	.01	Trace.	2.00	7.0	217	20	148.9
Do	Dec. 20, 1904	1.35	.70	.25	.004	.50	8.0	222	57	151.8
Catoctin Creek, Md	Jan. 19, 1905	1.40	.14	Trace.	Trace.	2.50	7.0	260	13	42.6
Catoctin Creek, Va	Jan. 18, 1905	.95	.01	.05	Trace.	1.50	6.0	71	26	40.2
Monocacy River above Carroll Creek	Jan. 12, 1905	1.88	.26	.22	.008	1.50	6.0	111	21	......
Carroll Creek above Frederick	Jan. 13, 1905	2.05	.14	.20	.008	1.50	9.0	182	40	129
Carroll Creek near mouth	do	2.65	.38	.48	Trace.	2.50	10.0	220	76	127
Monocacy River below Carroll Creek	Jan. 12, 1905	2.00	.18	.13	Trace.	1.35	8.0	100	28	62
Monocacy River at mouth	Jan. 16, 1905	1.40	.13	.02	Trace.	1.50	3.0	115	42	82.8
Potomac River above Monocacy River	Jan. 12, 1905	2.20	.17	.10	Trace.	1.45	6.0	219	47	138
Do	Jan. 16, 1905	1.50	.12	.02	Trace.	2.00	6.0	222	64	138
Potomac River below Monocacy River	Jan. 12, 1905	1.50	.34	.01	Trace.	2.00	4.5	111	39	89
Do	Jan. 16, 1905	1.40	.14	.10	Trace.	2.00	5.5	121	41	89
Goose Creek	Jan. 30, 1905	1.50	.16	.92	.002	1.75	5.0	61	14	43.7
Seneca Creek	Mar. 27, 1905	.20	.18	.05	Trace.	......	6.5	74	13	36.8
Calvin Run	Mar. 10, 1905	2.40	.18	.09	0	2.25	5.0	73	24	211.7

Sanitary analyses of tap water at Washington.

[Parts per million.]

Date.	Required oxygen.	Nitrogen as— Albuminoid ammonia.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrogen as— Nitrates.	Chlorine.	Unfiltered water. Total solids.	Unfiltered water. Loss on ignition.	Total hardness.	Suspended matter.
1904.										
May 4		0.37	0.02		0.2	3.0	127			40
May 11							109	26		30
May 19		.19	.08	0	.25	3.0	91			11
May 27						2.5	121			13
June 3		.26	.04	Trace.	.25	4.0	106			14
June 4		.24	.06							
June 11							365			289
June 18	1.60	.28	.09	.002	.50	7.0	134	26	55.2	45
June 30	2.13	.14	.04	Trace.	.25	4.0	138	33		19
July 14	1.15	.24	Trace.	.003	.50	3.0	156	48	82.8	41
July 29	3.10	.45	.02	.002	.50	6.0	273	47		139
August 29	1.80	.32	.03	.002	.125	4.0	163	46	85.6	56
September 17	1.70	.23	.02	.008	.50	4.0	173	46	96.6	45
September 28	1.10	.36	.03	.004	.50	5.0	147	32	117.3	13
October 13	1.10	.29	.11	.002	.50	5.0	149	41	111.8	12
October 26	1.30	.20	.10	.006	.25	4.0	134	38	110.4	
November 10	.80	.28	.10	.0125	.50	3.0	143	47	117.3	2
November 28	1.65		.03	.030	Trace.	5.0	159	39	117.3	28
December 13	1.70	.18	.28	.080	2.50	5.0	158	30	117.3	1
December 16	1.35	.12	.08	Trace	2.00	4.5	170	61	117.3	22
December 22	1.55	.11	.02	.003	.75	5.5	161	40	214.2	0
December 31	2.40	.20	.03	Trace.	1.00	5.0	134	29	106.1	
1905.										
January 5	2.75	.31	.10	Trace.	1.00	5.0	120	50	85.8	9
January 14	3.30	.29	.24	Trace.	1.00	5.0	112	25	66.4	33
January 20	1.50	.21	.05	Trace.	1.35	12.0	100	42	65.5	13
January 28	2.75	.30	.09	Trace.	1.75	4.0			78	
February 4	1.90	.20	.06	.002	2.00	6.0			70.2	
February 11	1.10	.05	.02	Trace.	2.25	7.0	132	47		0
February 18	2.35	.12	.10	.004	2.50	7.0	106	48	106.1	18
February 25	.85	.07	.07	Trace.	2.50	6.0	116	56	100.0	28
March 11	1.50	.17	.17	Trace.	2.00	6.0			60.3	
March 18	1.10	.34	.04	Trace.	2.00	6.5	67	29	59.3	137
March 24	.40	.26	.02	Trace.	2.00	5.5			57.3	
April 4	2.85	.14	.06	Trace.	2.00	6.0			57.3	
April 14	1.50	.18	.14	Trace.	2.50	7.0			59.0	
Average	1.72	.229	.073	.0054	1.16	5.23			88.98	

Comparison of analysis of Potomac water by several investigators.

[Parts per million.]

	Required oxygen.	Nitrogen as— Albuminoid ammonia.	Nitrogen as— Free ammonia.	Nitrogen as— Nitrites.	Nitrates.	Chlorine.	Total solids.
Health Office, 1904–5	1.72	0.229	0.073	.0054	1.16	5.23	146.1
Health Office, 1897–1900	2.56	.111	.0008	Trace.	.639	3.78	126.7
Surgeon-General's Office, 1899	2.10	.150	Trace.	Trace.	1.100	4.00	125.0
R. S. Weston	4.50	.105	.013	.002	.73	2.60	139.0

Mineral analyses of surface waters in Potomac basin.

[Parts per million.]

	North Branch Potomac River above Bayard, Feb. 27, 1905.	Buffalo Creek at mouth, Feb. 27, 1905.	Abram Creek at mouth, Feb. 27, 1905.	Savage River, Feb. 25, 1905.	Georges Creek at mouth, Feb. 25, 1905.	North Branch Potomac River above Savage River, Feb. 25, 1905.	North Branch Potomac River above mill at Luke, Feb. 25, 1905.
SiO_2	6.30	6.10	5.75	9.46	17.40	4.95	9.55
Fe_2O_1, Al_2O_3	5.20	3.19	4.40	6.00	127.60	4.90	6.30
Ca	6.29	8.21	....	9.65	138.96	10.00	9.15
Mg	1.33	1.62	1.44	1.07	33.66	1.44	1.86
Na	Trace.	5.22	Trace.	Trace.	6.97	Trace.	Trace.
K	Trace.	Trace.	Trace.	Trace.	Trace.	None.	Trace.
Cl	6.0	9.0	5.0	5.0	17.0	11.0	15.0
SO_4	95.69	5.42	113.65	60.94	577.08	....	81.10
CO_3	None.	None.	None.	None.	None.	None.	None.
HCO_3	33.3	27.3	30.3	30.3	None.	36.3	27.3
Quantity analyzed (cubic centimeters)	2,000	2,000	2,000	1,500	1,500	2,000	2,000

	North Branch Potomac River below mill at Luke, Feb. 25, 1905.	North Branch Potomac River between Keyser and Piedmont, Feb. 25, 1905.	North Branch Potomac River above New Creek, Feb. 25, 1905.	Wills Creek above Kreigbaum, Dec. 29, 1904.	Jennings Run at mouth, Dec. 29, 1904.	Braddock Run at Allegheny Grove, Dec. 29, 1904.	Wills Creek at Cumberland, Dec. 30, 1904.
SiO_2	5.00	6.06	5.09	4.67	11.1	5.13	5.70
Fe_2O_3, Al_2O_3	78.92	40.39	26.79	69.84	28.49	2.17	1.47
Ca	2.52	8.45	40.02	22.24	85.49	24.88	40.18
Mg	1.75	4.61	4.07	2.28	1.51	4.53	5.11
Na	....	4.12	Trace.	6.59	.32	Trace.	5.89
K	....	Trace.	Trace.	Trace.	1.77	Trace.	Trace.
Cl	25.0	10.0	11.0	10.0	15.0	9.0	12.0
SO_4	73.95	14.42	15.93	22.81	274.44	33.41	59.46
CO_3	None.	None.	11.92	None.	None.	None.	None.
HCO_3	78.7	36.3	39.4	42.4	9.1	54.5	59.6
Quantity analyzed (cubic centimeters)	2,000	1.500	1,000	2,000	2,000	1,500	7,000

	North Branch Potomac River at Cumberland, Dec. 30, 1904.	Potomac River above Pawpaw, Feb. 10, 1905.	Potomac River below Great Cacapon, Feb. 12, 1905.	Potomac River at Opequon Creek, Feb 17, 1905.	Pótomac River above Harpers Ferry, July 4, 1904.	North Fork of Shenandoah River above Passage Creek, Feb. 2, 1905.	Passage Creek at mouth, Feb. 2, 1905.
SiO_2	7.31	6.14	8.63	7.47	6.48	6.66	9.56
Fe_2O_3, Al_2O_3	3.52	7.20	43.87	5.66	32.75	94.92	43.90
Ca	38.04	52.33	3.01	47.76	40.26	.38	1.99
Mg	5.52	4.92	4.10	4.78	3.95	9.90	3.13
Na	2.97	2.47	1.94	1.17	1.00	None.	2.11
K	1.19	None.	None.	Trace.	Trace.	None.	Trace.
Cl	5.0	8.0	4.0	11.5	5.0	12.5	10.0
SO_4	42.16	140.54	3.95	48.36	18.37	4.71	3.42
CO_3	None.	None.	None.	None.	14.89	None.	None.
HCO_3	45.4	215.0	106.0	125.7	42.39	202.9	70.6
Quantity analyzed (cubic centimeters)	4,500	1,500	1,900	3,000	5,000	3,000	2,500

Mineral analyses of surface waters in Potomac basin—Continued.

	South River, Jan. 25, 1905.	Elk Run below Elkton, Feb. 4, 1905.	Hawksbill Creek, Jan. 26, 1905.	Hawksbill Creek, Feb. 3, 1905.	Shenandoah River at mouth, July 4, 1904.	Patterson Creek at mouth, Feb. 13, 1905.	South Branch Potomac River at mouth, Feb. 10, 1905.
SiO_2	11.37	11.47	14.14	9.44	10.84	10.54	6.13
Fe_2O_3, Al_2O_3	3.60	22.12	11.30	37.95	21.70	7.00	6.00
Ca	33.74	2.77	39.54	3.29	40.52	51.47	51.47
Mg	8.66	4.89	9.11	5.17	5.23	4.48	4.92
Na	.54	11.35	None.	2.36	1.0	Trace.	.75
K	Trace.	2.15	None.	None.	Trace.	Trace.	.35
Cl	10.0	67.0	13.5	21.0	9.0	8.0	7.0
SO_4	7.19	2.17	11.3	7.23	6.22	163.0	44.16
CO_3	None.	None.	None.	None.	10.43	None.	None.
HCO_3	115.0	75.7	143.8	117.0	96.90	112.0	816.6
Quantity analyzed (cubic centimeters)	3,500	1,500	3,500	5,000	5,000	1,500	1,500

	Great Cacapon River at mouth, Feb. 12, 1905.	Warm Spring Run at mouth, Feb. 10, 1905.	Opequon Creek at Abrams Creek, Feb. 17, 1905.	Antietam Creek at mouth, Jan. 17, 1905.	Catoctin Creek, Md., Jan. 19, 1905.	Monocacy River above Carroll Creek, Jan. 12, 1905.
SiO_2	32.93	27.60	9.46	4.4	14.80	6.90
Fe_2O_3, Al_2O_3	64.51	85.59	8.00	31.70	19.48	2.73
Ca	4.47	5.80	78.64	56.84	3.42	16.30
Mg	3.50	6.30	13.61	1.90	2.80	2.63
Na	2.00	7.80	4.08	3.88	1.80	5.00
K	Trace.	Trace.	.15	4.00	Trace.	2.71
Cl	5.0	6.0	12.0	10.0	7.0	6.0
SO_4	3.11	6.06	64.92	11.78	5.23	4.46
CO_3	None.	None.	None.	None.	None.	None.
HCO_3	96.9	145.3	308.9	197.7	39.4	51.5
Quantity analyzed (cubic centimeters)	1,500	1,500	1,500	1,500	2,000	2,000

Monthly analyses of dissolved mineral matter in tap water at Washington, D. C.

[Parts per million.]

	1904.								1905.				Average.
	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Aug.	
SiO_2	3.28	5.87	9.10	4.16	5.10	4.11	3.02	3.00	6.10	6.62	5.41	6.06	5.15
Fe_2O_3, Al_2O_3	.50	1.00	.93	12.67	0.82	1.36	2.47	2.53	.67	30.19	.96	1.46	4.63
Ca	10.37	13.90	33.93	34.67	53.50	48.51	38.54	54.41	23.17	11.41	20.27	28.61	30.94
Mg	1.87	3.03	8.00	3.68	5.26	8.38	3.99	8.29	2.74	5.07	2.14	2.97	4.62
Na	3.44	2.88	.91	2.56	3.47	4.17	5.14	3.04	.38	9.47	2.05	.97	3.20
K	2.41	4.51	Trace	Trace	Trace	Trace	Trace	Trace	.51	Trace	Trace	Trace	.62
Cl	2.76	5.00	4.5	4.0	4.5	4.5	4.5	5.0	6.5	6.5	6.0	6.5	5.02
SO_4	11.01	11.92	9.98	8.96	9.64	11.20	3.30	8.38	4.92	3.06	11.18	10.55	8.68
CO_3	......	None.	5.96	2.98	5.96	7.45	Trace	None.	None.	None.	None.	None.	2.03
HCO_3	......	68.13	84.78	84.78	118.1	121.1	136.3	133.1	74.17	112.0	54.3	88.7	97.77
Quantity (liters)	20	10	10	10	10	10	10	10	20	10	10	10	....

Determination of the different forms of carbon dioxide in the tap water at Washington, D. C.

Date.	CO_3 (parts per million).	HCO_3 (parts per million).	CO_2 (cubic centimeter).		
			Bicarbonate.	Excess.	Free.
1904.					
August 29	2.98	84.8	15.5	14.9	None.
September 17	5.96	109.0	19.9	23.1	3.2
September 28	5.96	109.0	19.9	24.2	4.3
October 26	5.96	121.1	22.1	27.9	5.8
November 10	5.96	130.2	23.8	27.9	4.1
December 13	None.	139.3	25.4	39.5	14.1
December 16	None.	142.3	25.9	42.3	16.4
December 22	None.	142.0	26.0	32.0	6.0
December 31	None.	109.0	19.9	26.7	6.8
1905.					
January 5	None.	87.8	16.1	26.6	15.1
January 14	None.	63.6	11.5	16.6	5.1
January 20	None.	69.6	12.7	7.0	None.
January 28	None.	75.7	13.9	3.0	None
February 4	None.	87.8	16.0	30.1	14.1
February 11	None.	181.7	55.7	18.9	None.
February 18	None.	105.9	19.3	22.2	2.9
February 25	None.	99.9	18.2	18.9	.7

RELATION OF SOILS AND FOREST COVER TO QUALITY AND QUANTITY OF SURFACE WATER IN THE POTOMAC BASIN.

By W. W. Ashe.

EFFECT OF SOILS ON TURBIDITY OF WATER.

GENERAL DISCUSSION.

The turbidity or muddiness of the Potomac River water, which to the majority of the users is considered its most objectionable quality, is derived from no one section of the basin and from no single geologic formation or type of soil, and comes in part from land of gentle gradient and in part from sections where the topographic features are stronger. The farming land furnishes the largest amount, but small amounts are due to the wash from woodland on certain types of soil. Certain parts are washed from roads, and some comes from the cutting away of their banks by streams during freshets. The turbidity during freshets is unduly increased above the normal by the fact that the more rapid current again takes up the sediment deposited as silt beds and sand bars at points of slack water during periods of slower flow, and by the additional fact that on very few of the tributaries are there flood plains to form natural settling basins for some of the heaviest silt.

Turbidity of the Potomac is not a recent phenomenon. The silt and clay which the older geologic formations west of the Blue Ridge have contributed to the building of the Coastal Plain were washed in muddy streams from their valleys of shale and limestone. The Piedmont region has also contributed its share. The deep gorges and ravines which, starting at the river, ramify through the soft schists, shales, and sandstones that form this portion of the Piedmont region, indicate that natural erosion of the friable soils has been proceeding at a rapid rate.

The fertile red soils are not entirely responsible for the turbidity; the broken topography, the long, warm summer, and heavy intermittent rainfall are also active factors, and when these occur together turbidity is an inalienable accompaniment of a rapid stream.

In a humid climate farther north the growing season is short, the nitrifying and oxidizing capacity of the soil lower; humus rapidly accumulates, both in woodland and in tilled land; the porosity of the soil is maintained, and granulation, even in a heavy soil, seems to be almost a natural condition. The heavy humus content, with the concomitant porosity, whether in a forest soil or in tilled land, promotes absorption and retention of rainfall and minimizes erosion.

Similarly, sod, which is maintained with difficulty in the desiccating autumn climate of the South, naturally sets in a cooler climate in ditches, on stream banks, and in waste places, and forms nearly as perfect a protection against erosion as a forest cover. In those sections where thick sod does not form, a forest cover is the best protection against erosion on steep land.

The conditions which surround the upper headwaters of North Branch of Potomac River above Cumberland are largely those which determine the clearness of northern streams; and until it reaches Cumberland it is a clear stream. Below Cumberland there is a rapid change; both the soil and climatic conditions become more favorable for increased muddiness, reaching the optimum conditions just above Washington and in the Shenandoah and Cumberland valleys.

The present turbidity, however, is excessive. The washed-out beds of the smaller streams, extending in places from hill to hill without banks, and the many-gullied and thin-soiled slopes all indicate that erosion is taking place now more rapidly than formerly and that the turbidity is greater. Its further increase from certain sources can be checked, and it can undoubtedly be considerably lessened from other sources, to the general benefit of the valleys, as well as to the improvement of the potability of the water.

While the turbidity is from many different sources, the greater part of it is from the wash from steep or badly tilled cleared land. Where it is the fault of the manner of tillage, more rational cultural methods can eliminate or reduce it. Where it is from the erosion of steep land and can not be prevented by better methods of culture, and it is evident that the amount and rapidity of the erosion are such as to jeopardize the future earning power of the land, this land and other areas of the same character that are yet in timber should be regarded as forest land and nonagricultural. Far higher and more potent reasons than the clarification of the water demand the withdrawal of the land from a use which means its ultimate loss of earning power, to be preserved by applying it to a different use as an active factor in the nation's future wealth.

SOILS EAST OF THE ALLEGHENY FRONT.

SOIL FORMATIONS.

The important soil formations[a] of the Potomac River basin, east of the Allegheny Mountains, are the Cecil soils, marked by stiff, heavy, usually red subsoils, heterogeneous in texture, underlying more friable and looser surface soils; the Chester series, until recently[b] included in the Cecil, distinguished by lighter, less coherent, and usually more micaceous soils, which are more subject to erosion than either the Cecil or Penn soils, represented on the Potomac watershed by only two soil types, the Chester mica loam and Chester loam; the Penn series, dark-red soils and subsoils, more homogeneous in texture than the Cecil soils and resembling them in cohesion, but far less friable than the Chester soils; the Hagerstown series, generally heavy limestone soils; the yellow shale soils, compact yellow or reddish clays or leachy gravel; the Upshur series, dark-red shallow loams and sandy loams, and the Dekalb series, gray somewhat sandy soils, usually shallow, stony, and coarse grained.

The first five are, as a rule, valley types, and when not on steep slopes are generally farmed. The Upshur soils are partly cleared, but are little farmed. The Dekalb series are largely mountain types. They are but little cleared and where cleared are largely in grass.

The Cecil and Penn soils are largely drained by the streams east of the Blue Ridge, only small areas of these types lying on its western side. The other soils very largely lie to the west of the Blue Ridge. The Cecil and Chester soils are responsible for most of the turbidity of the Piedmont streams of the South Atlantic States.

The streams east of the Blue Ridge contribute very largely to the turbidity of the Potomac, and it is probable that they add a large, if not the largest, part of the coarser silt that is brought down during seasons of medium heavy rain, with 1½ to 2 inches of rainfall distributed over a period of twenty-four to thirty-six hours. The prevailing soil types are of the Penn and Cecil series, which are usually of sufficient depth for cultivation, but in many of their phases loose and incoherent, and, if denuded, eroding under moderate rains. Their tendency to wash is increased, especially near the river, by their situation on steep slopes.

CECIL AND CHESTER SOILS.

Cecil silt loam is a gray soil of fine texture derived from the decay of partly metamorphosed sandy shales. On surfaces which are at all steep it erodes badly, forming deep gullies down to the undecom-

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[a] The classification and nomenclature of soils used in this paper are those adopted by the Bureau of of Soils, Department of Agriculture. In no sense are they geologic, and the names should not be confused with the names of geologic formations.

[b] Soil Survey Field Book, U. S. Department of Agriculture, 1906, p. 108.

posed rock from which it was formed, and entirely destroying the value of the land for farming purposes. Its composition is such that its washings add a very fine and undesirable matter to the water. The mechanical analyses[a] of this soil made by the Bureau of Soils from a sample 3 miles east of Leesburg, Va., give it the following percentage of silt and clay: Silt (0.05 to 0.005 mm.), 60.06 per cent; clay (0.005 to 0.001 mm.), 22.80 per cent.

Most of the areas of this soil on the basin are badly situated to prevent washing. Some of the largest are on the south side of the river at the mouth of Goose Creek, where the rough topography—the river hills being steep and 200 or more feet high—is unfavorable for clean tillage. Other areas lie on the steep upper slopes of Broad Run and below that stream, all close to the river, and frequently showing, in spite of attempts at careful cultivation, gullying and washing. The agricultural limits of the soil are partly recognized, and less than one-half of these areas are cleared. It does not hold a grazing sod, and when the slope becomes at all steep it ceases to be an agricultural soil and its earning capacity in such situations can be perpetuated only by retaining it in timber. The forests are largely of black oak, chestnut oak, scarlet oak, and pitch pine. Its situation so close to the river and the relatively short distance above the intake of the Washington water supply render the protection of this soil from further erosion important. The humus formed is not deep except in the bottom of the deep hollows, and in spite of it some erosion takes place, the run-off from wooded areas of this soil being slightly turbid.

The Chester mica loam is a loose, incoherent, red soil, derived from mica schist. On steep surfaces it washes badly and considerable soil transportation habitually takes place. On account of its composition, 25 per cent being clay and about 30 per cent fine silt, such washing adds an objectionable element to the water. This soil occurs in small areas along the eastern base of the Catoctin Mountains, in Virginia; in larger areas in the eastern part of Frederick County, Md., on Monocacy River; in Montgomery County, Md., on the upper waters of Seneca Creek; and in the lower portion of Fairfax County, Va. On Seneca Creek it is extensively farmed and contributes much to the objectionable turbidity of that stream. Where level and undulating it does not erode so rapidly, but on steep slopes a great deal of badly gullied land can be seen, and in such situations it ceases to be a farming soil and its preservation is possible only by keeping it in forest. It is not a good grazing soil, becoming too dry in the autumn. The characteristic forest growth on this soil is composed of chestnut and chestnut oak on the better phases, and scarlet oak and pitch or Jersey

[a] Field Operations, 1903, p. 223.

pine on the drier portions, usually with an underwood of mountain laurel. The humus varies from good to thin. When this soil is in forest there is little washing. A large area of this type has been cleared, and much of it has deteriorated appreciably. The roads on this soil wash very badly, often being several feet below the surface level. The beds of streams also are much washed, and they are often without banks; turbidity comes from both sources.

The Cecil clay loam is a dark-red soil having an extensive distribution on Monocacy River in Adams County, Pa., and Frederick County, Md., and is extensively cleared and used for farming. Soil transportation steadily takes place, and while gullies are not formed, there is a constant and uniform removal of soil from even moderate slopes. Fortunately, it is in few places deeply dissected, and careful methods of tillage can do much to reduce turbidity from these soils. It grasses only moderately well. The remaining forest is of oak and hickory and forms a sufficient humus to insure protection.

The Chester loam and Cecil clay form large areas on Monocacy River in Carroll and Frederick counties, Md., on Seneca Creek in Montgomery County, Md., and on Broad Run and other small streams in Loudoun and Fairfax counties, Va., between Broad Run and Great Falls. They also form extensive areas in upper Loudoun County and in western Frederick County, on the two Catoctin creeks and at the head of Goose Creek. These soils are derived largely from the Catoctin schist and granite and from other mica schists. They are light brown or red in color, deep, and rather porous, but the lighter phases are often incoherent and when dry much resemble the mica loams in texture and behavior toward water. While they form large areas of productive and well-farmed land, considerable washing takes place, especially in the spring, when raw-plowed surfaces, already saturated, are exposed to heavy rains, and this washing increases with the gradient. The surface of these soils, especially near the mountains and along the river, is deeply carved into high, rolling-topped hills, the stream valleys in many places being 200 to 300 feet deep. Only an insignificant portion of these soils remains uncleared, and while they generally grass well, there is on steep land considerable gullying. In Virginia, except on Catoctin Creek, these lands are mostly held in large estates and are used for grazing, some of the sod not having been turned for sixty years. In Maryland they are divided into small farms and tillage is the rule. Roads wash badly on these soils, and the beds of the smaller streams, especially on the Maryland areas, are badly eroded and much enlarged, the banks being steep, naked, and cut back to the base of the hill on either side. On account of the fertility of these soils, clearings have been extended to slopes which are much too steep even for grazing, and several thousand acres of such slopes lying in deep hollows can have the soil retained only by reforesting. The mechanical analyses of the Bureau of Soils show that from 50 to 70 per cent of these soils consist of clay and fine silt. On account of their extensive area and situation on steep slopes close to the river and only a short distance above the Great Falls intake, they contribute much to the turbidity of the Washington water. The forests are of oak and hickory on the heavier phases; chestnut on the lighter. Humus on both types is good, and where forested there is no appreciable erosion, except on the steepest slopes during very heavy rains.

PENN SOILS.

The Penn soils cover extensive areas in the valley of Monocacy River and also on the lower part of Goose Creek. The heavier members have usually a rolling surface, and there is sufficient cohesion to prevent excessive erosion, which is also reduced by the fact that the soils grass very well and are excellently tilled. Many of the areas lie close to the larger streams, and some steep banks have been cleared which would have held better in timber. Roads wash somewhat; stream beds only slightly. These soils are largely cleared. The forests were of oak, hickory, walnut, and ash.

The Penn shale loam, on the other hand, which is a dark-red soil, extending southwest from Gettysburg, Pa., in a broad belt, undergoes continuous erosion. A great portion of it is gently rolling, but near the larger streams it is much broken, and since it does not grass well much erosion takes place from cultivated land in such situations. Erosion is usually in the manner of uniform soil transportation, resulting in the gradual thinning of the entire slope and not in the formation of gullies. Some of the cleared slopes are too steep to justify tillage. This soil has from 50 to 80 per cent of fine silt and clay, and undoubtedly the steeper gradients contribute to the turbidity of the Potomac. The smaller stream valleys are shallow and broad, and there is little erosion from them. Pitch and Jersey pines, with scarlet, black, and chestnut oaks, and in some places chestnut, form the forest. There is considerable old field pine. This type of forest forms only a thin humus, but there seems to be very little washing from beneath it. The greater part of this soil is cleared.

LIMESTONE SOILS.

The limestone soils of the Hagerstown series of the classification of the Bureau of Soils constitute the most sought for, best-farmed, and highest-priced soils of the Potomac basin. Together with some calcareous and argillaceous shale soils they form more than three-fourths of the cleared land in the valley of Virginia and the Cumberland Valley. The Hagerstown clay is a residual soil from the weathering of the purer limestones, and represents the less soluble portion of the rock. The loamy and sandy phases are from limestone that is less pure and has more quartz veins in it, and more and coarser insoluble residue has been left to form the soil; or they are derived from shales. On gentle slopes there is very little erosion of these soils. There is more, however, on the heavy types, where the compact texture of the clay greatly impedes absorption, than on the looser, more porous types. On steeper slopes there is, at least on the heavier soils, continual though often slight transportation, which reaches its minimum when the soil is in permanent sod or in timber. On account of the fertility of these soils, and especially their high productivity in wheat, they are in constant cultivation under a short rotation, including both corn and wheat as well as hay.

While the gradients are usually slight on these soils in the Cumberland Valley, in the valley of Virginia, and in the smaller areas on Monocacy River in Adams County, Pa., and Frederick County, Md., yet there are local areas, especially contiguous to the larger streams, where the slopes are very steep, and many badly eroded fields are to be seen in such places. Even when deep plowing and careful tillage has prevented excessive gullying on steep slopes, rapid soil transportation takes place, though it is largely distributed over the entire surface, and the soil after each heavy rain is left thinner than before, and this unchecked waste portends its ultimate depauperation.[a] In fact, this has already taken place on extensive areas of limestone soil, which are closely similar to the heavier types of the Hagerstown soils. These are limestone soils in the Martin Mountains in Bedford county, Pa., in the Patterson Creek Mountains in Grant and Mineral counties, W. Va., in a portion of the Tonoloway Ridge in Hampshire County, W. Va., in the elevated valleys of the Knobly Mountains, and in the high steep limestone slopes which lie just beneath the crest of North Fork Mountain and in nearly similar situations on South Fork Mountain just east of Franklin, Pendleton County, W. Va. There are, moreover, many fields in each of the soil areas just mentioned so badly gullied that grassing has become impossible. The soils have become so shallow, and transportation of soil from the raw surfaces takes place so constantly, that the blue-grass sod, which is the natural covering of these lands, can not spread and hold, and reforestation will be the only means of again giving them a permanent earning power. The difficulty with soils of this character is that they can not be manured, on account of the impossibility of getting a wagon and team on the steep

[a] In the southern Piedmont region such long-continued partial erosion gives rise to sandy surface soils underlain by heavy subsoils.

slopes, and every crop of grain or grass which is removed robs them of fertility, while nothing except mineral fertilizers of the acid-phosphate type are added to them in compensation. When these soils are kept in grass there is very little washing, but on account of their productivity, as compared with either the shale soil of the valleys or the surrounding thin soils of the sandstones, their cultivation by the small landholder is a necessity until their final ruin precludes cultivation of any kind.

The well-known case of the soil-denuded limestones of the Alps of Bosnia and southern Austria, the Karst region, is being reproduced here under almost the same conditions. Both are regions of steep slopes. and naturally rather shallow but very fertile limestone soils, which have by the exhaustion of humus through constant tillage lost their granulation and had their absorption capacity for rainfall so reduced that extensive washing has taken place, leading to the destruction of the agricultural value of the soils. The highest earning power which such soils now have is in timber production. Their natural forests are of hickory, white oak, walnut, locust, red oak, and, on dry knolls, black oak, and since all these except the black oak yield high-priced woods, and rapid growth is made by timber on the limestone, reforestation could be regarded as a financially profitable undertaking. When forested there is a heavy humus on even the steepest limestone land and a heavy undergrowth of weeds, bushes, and vines. The thick humus not only holds a great deal of water, but the heavy clays of the limestone have a higher capacity for absorption than any other soil on the Potomac, and the humus allows those soils to become fully saturated. On account of the heavy humus there is almost no turbid run-off from even the steepest limestone soils when in timber. In addition to the areas already mentioned, other heavy limestone soils cover several thousand acres in Highland County, Va., between Monterey and Hightown, and areas of less extent in the "Hunting Ground" in Pendleton County, W. Va., on the upper waters of North Fork of the Potomac; on Evitts Creek, Bedford County, Pa., in the Little Cumberland Valley; and in the Cove Valley about McConnellsburg, Fulton County, Pa. In these areas the topography is rolling or the hills have long, moderately gentle slopes, except along the larger streams, where the slopes are steeper, as they are in the valley of Virginia, and erosion takes place in the same manner and under the same conditions as on the Hagerstown soils farther east. The soils are worked in short rotations, more than two-thirds of the land being habitually in tillage and the rest in grass.

Mechanical analyses[a] of the Hagerstown clay, which will cover the composition of the heaviest limestone soils in the Potomac basin,

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[a] Field Operations Bureau of Soils, 1903, p. 212.

show it to contain from 34 to 38 per cent of clay less than 0.005 mm. in size, and from 40 to 46 per cent of fine silt between 0.05 and 0.005 mm. More than three-fourths of its composition is matter sufficiently divided to be transported on the most quietly moving portions of Potomac River, and practically none of the wash from these lands settles above the Great Falls intake.

The more sandy members of the calcareous soils show a lower percentage of clay content and a higher of silt, the clay forming from 14 to 36 per cent,[a] while the silt forms from 31 to 50 per cent. While the relative proportions of the light and heavy soils are not known, at least one-half of the limestone soils are referable to the heavy members. The above analyses of texture are of the top soils. On the eroded land on the mountains, where gullying is taking place, the material is largely from the subsoil, and this shows a far higher proportion of fine, transportable clay, the amount being from 50 to 63 per cent[a] of the entire soil. The proportion of fine silt, however, is slightly smaller.

So great is the erosion from steep limestone lands that during heavy summer storms the turbid streams which bear their wash strongly exhale the argillaceous odor characteristic of a freshly cut surface of heavy clay. This is especially noticeable with the water of Town Creek, which bears the wash from Martin Mountain; Big Cove Creek, which has the wash from the limestones in the vicinity of McConnellsburg; Conococheague Creek, which drains the Cumberland Valley; and the two branches of Shenandoah River, which drain the valley of Virginia and the Page Valley; and there are other streams in which it is probably at times as noticeable as in these.

In addition to the wash from the agricultural lands a small amount takes place from the roads, but most of the roads through the limestone are surfaced with crushed stone and have been graded or washed to a level before being surfaced.

Near the banks of streams the limestone soils grass well, and there is very slight erosion of banks on any of the smaller streams.

It is evident, on account of the constant erosion that takes place on the limestone soils, which rapidly increases with the gradient, and the large proportions of transportable clay that these soils contain, that they contribute a large proportion of the turbidity to the river, probably even a larger proportion than the soils of the Cecil and Chester groups; but with this difference in respect to the Washington water supply, that local showers on the Cecil soils, on account of their nearness to the Washington intake, and especially rains on the lower part of Monocacy River and on Seneca Creek, which empty into the Potomac on the same side on which the intake is situated, produce high

[a] Field Operations Bureau of Soils, 1903, pp. 214, 215.

turbidity for short periods, especially during summer thunderstorms. The turbidity produced by similar storms higher up on the watershed is largely reduced by dilution, opportunity being given for thorough mixing with the water across the entire channel of the river, and also by distribution, a portion being carried far ahead in the main current of the river, while those parts which mixed with the water near the bank, where friction is greatest, get farther and farther behind. The total effect on the water by the time the intake is reached is a slight rise in turbidity, which is distributed, however, over a day's flow or more. Such local rains on the Cecil soils in Maryland, as has been explained, cause high turbidity along the north bank, and there is neither time for further dilution nor opportunity for distribution. The rapidity and unexpectedness with which this condition is produced occasionally cause a considerable amount of highly turbid water to enter the reservoirs which supply Washington.

About one-tenth of the mountain land between the Allegheny Front and Shenandoah Mountain is limestone or limestone shales. The largest part of the land lies in Highland County, Va., and Pendleton, Grant, Hardy, and Mineral counties, W. Va. The average slope of this land is more than 1 foot in 5. Probably one-half of it is at present cleared, and the rest is being cleared rapidly. The limestone soils, including both the valley and mountain lands, constitute about one-sixth of the total area of the Potomac River basin, or about 2,000 square miles.

There are very few springs on the limestone soils, in spite of their very great water-storage capacity, but such as there are show great constancy and boldness. Many of them are undoubtedly streams which permeate fissures or caverns in the limestone.

SHALE SOILS.

Shale soils are of two different series—those derived from massive or fissile argillaceous shales, known throughout the basin as "yellow-slate soils," largely the product of weathering of the Romney shale and the shales of the Jennings formation; and those derived from the weathering of the sandy shales and sandstone of the Hampshire formation, which are known as "red-slate soils." The yellow-slate soils are soft, erode rapidly, and constitute essentially a valley type of soil; the red-slate soils form plateaus and low mountains.

The yellow-shale soils are extensively distributed, and some of their phases are the source of considerable turbidity. The first of the two extreme types is the typical "slate soil," largely formed of small, sharp-angled pieces of argillaceous shale. Occasionally it is called gravelly soil. Only a small amount of fine earth is associated with it. It is extremely porous and leachy, and transportation takes place so rapidly that very little finely divided earth accumulates. It is essentially a thin, light soil, and its condition is due not only to the fact that the shale decomposes slowly, but also to the erosion of the finer material proceeding practically at the same rate at which it is formed, and to its situation on steep slopes high above the base-level of erosion; or it is in places the wornout shale clay of the type described in the next paragraph, from which the fine soil has been removed by washing when cultivated.

The second type embraces yellow-shale clay and its loamy phases. It is the residual product from the weathering of the argillaceous and moderately sandy shales, where there has been but little soil transportation. On broad flats near the heads of streams and where the valley hills have been eroded nearly to stream level, soil has accumulated to the depth of several feet, but as the slope becomes steeper the soil rapidly becomes shallower and "slate" chips more abundant, a rapid transition taking place with increased slope into the "slate-soil" type. These soils do not hold grass well except at high elevations, and constant tillage rapidly changes their character and lessens their earning value, as the fine soil is eroded. Above 1,500 feet altitude and in cool situations along moist slopes sheltered in part from the heat of the sun, especially on the heavier and more calcareous shales of the Rockwood formation, and some in the Romney formation, a permanent grazing sod can be maintained. In other situations the grass dies in a few years and a scant growth of pennyroyal and spring and early summer weeds takes its place. When the shale soils are on high slopes the characteristic topographic features are the small size of the hills and the number and depth of the fissures which indent them, the surface features being in strong contrast to the rolling summits and broad, flat slopes, even where steep, which mark the limestone. This broken surface of the shale hills is another drawback to general farming on them, making the fields small and their cultivation difficult, and causing some inequality in the maturing of the crops. A crop makes on the typical leachy slate soil only when there is a wet growing season, and for this reason wheat, growing largely during the wet spring, is more successfully raised on it than corn. The soils are not, however, adapted to farming, and large areas which have been cleared are turned out nominally as pasture, but in fact are practically waste. Where the soils are deep and the slopes gentle the soils are very productive in corn, hay, small grain, and apples.

Mechanical analyses of these soils show that the earthy portion includes from 22 to 40 per cent of clay. They are responsible for a considerable portion of the turbidity of South Branch of the Potomac, and of Patterson, Back, Sleepy, Sideling Hill, Great Tonoloway, and Licking creeks. While a large part of the wash comes from cleared land, the washing of the banks of small streams, especially when the trees and bushes have been entirely cut off, is a notable feature. Some also comes from roads, which are inclined to wash, especially on the compact clay soils. A small amount comes from the woodland, as the streams which drain forested watersheds becomes conspicuously clouded during heavy and especially prolonged rains.

The forests on the shale soils vary with the drainage of the soil. Where the topography is gentle and the clay soil is deep, white oak, a small amount of chestnut oak, and in the hollows red oak form the timber, the white oak always being the aggressive species. With increased dryness, due either to the thinness of the decomposed clay soil or to greater inclination of slope, Jersey pine and chestnut oak become the dominant species, white oak being of minor importance. A moderate humus accumulates under the red and white oaks, but elsewhere the humus is very light on this soil. The springs in the shales are numerous, but small and irregular in their flow, many of them going dry during the summer and autumn. Probably one-half of the total area of shale soils has been cleared, but a large part of it is idle. On steep slopes and in its leachy phases the shale soils are not agricultural, and while they have a low earning power in forest they are best preserved by being wooded. On gentle slopes the shale soils can be made highly productive. A feature about them is the rapidity with which the bits of shale disintegrate when exposed to the weather; for this reason these soils can not be completely exhausted.

The red shales and sandstones of the Hampshire formation west of Shenandoah Mountain yield soils which are referred by the Bureau of Soils to the Upshur series. On the Potomac watershed the country rock of this formation is largely a sandy dark-red shale. It occurs usually in elevated valleys, as Long Hollow, in Washington County, Md., or in broken plateaus, as the "Levels," in Hampshire County, W. Va., and Timber Ridge, in Fulton County, Pa.; or it forms low, flat-topped mountains, as Town Hill and the foothills of Sideling Hill, in West Virginia, Maryland, and Pennsylvania. The larger streams have in most places cut deep gorges through it, with steep, precipitous sides. The gently rolling surface, which is generally farmed, is in sharp contrast with the much broken surface of the yellow shales, and when the two occur side by side the red shale is usually at a higher elevation. The soils derived from it east of the Allegheny Front are usually loams and sandy loams, in few places passing into stiff phases; they are shallow, rarely more than 2 feet deep, with much broken shale and bits of sandstone disseminated through them, and dark-red or chocolate in color. The porosity is excellent and, the underlying shale being much fissured, there is comparatively little erosion except on steep slopes, where considerable sand and even coarse gravel is transported. The sandy members are too light, thin, and leachy for successful production of corn and wheat, the staple crops of the region, and large areas which have been cleared, amounting probably to more than 10,000 acres, have been abandoned and are offered for sale at prices between $5 and $8 an acre. Other extensive areas, which are held in connection with operated farms as pasture land, are practically waste. The lighter phases will not hold a grazing sod, and hay grass lasts only a season or two on it. Except on the heavier phases or the most gentle slopes, as about Three Churches and the middle portion of Timber Ridge, this soil yields, if worked in grain and grass, only the scantiest living to the tiller. Under the current system of tillage it is not a productive general farming soil. Recently, however, extensive areas of this soil on the "Levels" and elsewhere have been planted in peaches, to which it is well adapted. The soil can be used profitably for this purpose and similar intensive farming, to which it seems to be adapted, only where transportation is available, which excludes at present the largest areas. It is, when shallow and on steep slopes, a forest soil and must ultimately be regarded as such unless planted in peaches, small fruit, or truck. More than one-half of this soil is yet in woodland. As would be expected from its lightness, the timber is neither tall nor the stand heavy. On the heavier members shortleaf pine, black oak, and pignut hickory form the growth, which changes to scarlet oak and pitch pine as the soil becomes more sandy and shallower. The humus is light.

Not so much turbidity originates from these soils as would be supposed from their red color, although the run-off from tilled land is always muddy. The waters which come from wooded areas, however, seem always to be clear.

SANDSTONE SOILS.

Sandstones form the greater part of the mountains, the limestones and smaller areas of shale and granite forming the rest; and since the sandstone yields a sandy soil, this is the prevailing and characteristic mountain type. The soils of the sandstone, forming the sandy members of the Dekalb series, are all very sandy, some very shallow, and most of them stony, their final form being determined by the hardness of the rock from which they originated and the steepness of the slope on which they are formed.

The deepest sandy soils and those best suited to tillage come from the "Monterey sandstone" and the sandy beds of the Jennings and Hampshire formations. These are loams and sandy loams, and while they are deep in but few places they are usually found at the higher elevations and are well supplied with organic matter. Even in the case of some of these formations which rapidly decompose, there is, where they lie on steep slopes, constant soil transportation, and the residual soil is shallow. On account of this constant loss there is around the base of many of the sandstone mountains a heavy talus of sand washed from the heights, forming a mantle over the valley formations of shale and limestone. This is especially noticeable in the Cumberland Valley, in the valley of Virginia, and, to a less extent, elsewhere.

The more indurated sandstones and the quartzite yield only the thinnest kinds of mountain soils, which are strewn with large and angular fragments of stone. Such stony land is suitable only for forest growth, and no attempt has yet been made to clear it. At least one-half of the mountain land east of the Allegheny Mountains is of this character. The sandy soils of the valleys, as well as those of the level benches of the mountains, except where light and leachy, are farming and fruit-raising soils. Considerable areas of sandy land on the mountains, with soil of some depth, were cleared originally for grass land. It is well suited for sod land, and so long as the turf is not turned it holds very well, its porosity being sufficient to absorb heavy rains readily without washing. When cultivated, especially in corn, it washes very badly; less so when in oats and buckwheat.

While these soils contribute very little to the turbidity of the river, their preservation on the mountains is necessary on other grounds. They and the underlying sandstone, which is in most places well fissured, form the natural reservoirs at the head of nearly all the streams of the Potomac basin. The springs from the sandstone are numerous and constant in their flow, though few of them have the volume and boldness of the limestone springs.

The forests on the sandy soils vary widely in composition and quality, according to the depth of the soil, its drainage, and the aspect. Where the soil is deep and mellow, especially at high elevations or on cool slopes, chestnut and red oak are the characteristic trees, and the humus naturally formed is excellent. In somewhat drier situations white oak is the dominant tree, chestnut oak also becoming abundant, the proportion of the latter increasing with better drainage. The humus becomes thinner as the amount of chestnut oak increases. On cool western slopes, especially in elevated valleys, white pine was a factor in the original growth, but very few trees are now seen, even of young growth. On ridges, especially those that are warm and sunny, pitch and table-mountain pine form groves in many places, almost unmixed with other trees, and in such groves the humus is very thin and poor.

SOILS WEST OF THE ALLEGHENY FRONT.

The soils of the Allegheny Mountains are loams and sandy loams from conglomerates, sandstone, and sandy shales, with smaller areas of clay from more argillaceous shales and from limestone. They are generally gray or yellow, in a few places red or brown, and for the most part are stony. Large areas are so thin soiled and stony as to be entirely worthless for agriculture of any kind. These include especially the soils from the harder conglomerates and sandstone of the Blackwater and Pocono formations and the sandstone of the Bayard formation. These are extensively developed on Spruce Mountain, along Backbone, Savage, and Dans mountains, and on Stony River, where many acres at some places are covered with large angular stones, such places being locally known as rock bars.

The humus content of the soil is large for the several reasons which have been pointed out, and their absorptive capacity for water is high. The humus, as well as the general looseness, permits rapid percolation of water through the soil to the subsoil. Unless subject to clean tillage on the slopes there is very little erosion of cleared land. Fields were seen, however, on Wills Creek and on Georges Creek, which from the cultivation of corn or potatoes had washed badly and are now too thin to form a good sod. On the slopes of Red Oak Mountain also, and along the Allegheny Mountain farther north, the grazing land on the steep southern slopes has become thin and the sod is scant. Some of the clearings, however, are old, situated along the early pikes and trails which crossed the Allegheny Mountains to the fertile lands of the Ohio Valley. They clearly indicate, though, that much of this land which grows well when fresh gradually becomes exhausted even in sod on the steep slopes and must eventually again be timbered to hold the soil.

Very little turbidity comes from North Branch of Potomac River above Cumberland, and the same is true of the headwaters of Wills Creek, in Somerset County, Pa., and of Seneca Creek, Laurel Fork, and the intermediate streams in Pendleton County, W. Va. Only the heaviest summer rains, or spring rains after the loosening of fall-plowed ground by frost, cause evident washing of farmed land, except on the steepest slopes. In spite of the fact that so large a part of the cleared land is in sod, the number and constancy of the springs are noteworthy.

The forests in the Alleghenies vary widely in composition; chestnut, red oak, and chestnut oak are the prevailing species in the warmer and drier situations. The chestnut forms a good humus, and the quantity of humus is largely determined by the proportion of this tree.

On northern slopes and in the moister situations birch, sugar maple, basswood, and beech form most of the timber, while hemlock occurs with these in many of the ravines. This type of forest occurs in many places on very rough and stony land. The humus is very deep, having accumulated locally to a depth of 8 to 10 inches. Above 4,000 feet elevation, on the headwaters of Stony River, Difficult Creek, and Buffalo Creek, in Grant County, and on Seneca Creek and Laurel Fork, in Pendleton County, W. Va., the forests are largely of spruce.

The soil is of the thinnest character, much of it only beds of stone. In forest which has been unlumbered or unburnt the moss and humus are deep and largely replace the soil for supplying the necessary moisture. There is no discernible erosion of the forest soils where the humus has not been destroyed or lessened. The smaller streams are at times discolored by the leaching of the humus, but to an insignificant degree.

More than one-half of the area of the Allegheny Mountains is forest covered, including nearly all of the steepest slopes.

It is evident that the soils which most largely contribute to the turbidity of Potomac River are those that are most valuable for farming, which are largely cleared. Considerable forest, however, is yet situated on the steeper slopes of some of these soils, especially on certain members of the Cecil series and on much of the limestone on the mountains west of North Mountain. When these areas are cleared the wash from them will augment the already high turbidity of the river. As a matter of civic policy it would be advisable to retain these lands in forest and to reforest extensive areas of similar soils which have been pauperized by erosion incidental to culture or whose permanence is threatened by tillage, since the erosion from them when in forest is insignificant.

EROSION OF FARM LAND.

The primary cause of erosion is the failure of the soil to absorb the rain water which falls upon it. If the rainfall is all absorbed, as by a coarse, sandy soil, there is no run-off and no erosion. As the soil becomes finer in texture, more compact, and correspondingly less pervious, the rain is not absorbed as fast as it falls, and the very smallness of the grains which form the soil facilitates its transportation whenever the attitudinal factors are favorable. The impact of the raindrops loosens the fine particles of soil, and unless absorption takes place the drops gather into small streams and rivulets, transporting with them, by a system of natural elutriation, the finest particles of soil and leaving behind the larger and heavier grains. At first this is entirely due to the hydraulic action of the impinging raindrops, but no sooner do the rivulets gather power, either by the added volume of water or by increased gradient, than they likewise begin cutting loose and transporting the soil. The eroding and transporting action of water is increased by the increase in its volume; it is also increased four times by doubling the gradient. For this reason the steepest land erodes most easily, and since the slope of a rain-formed hill is an ogee and steepest in the middle the most rapid erosion takes place on the middle slope, while the heaviest transported material is deposited by the slackened current on the more gently sloping base.

The capacity of a stiff soil for water is in practice 35 to 50 per cent of its volume, or for ordinary farmed soils 4 to 5 inches of rainfall to the surface foot. In spite of this capacity, the greater part of a heavy shower will usually not be absorbed. The coarse structure of a sandy soil permits the rainfall to be absorbed as rapidly as it falls. In a clay soil, unless in a high state of tilth, the pores are smaller and there is less open cellular communication between them, and absorption must largely take place through cracks, worm holes, and root holes, and when there are few of these absorption is largely retarded until the air can be expelled. In the extreme case, that of a raw clay soil with its surface puddled by a previous heavy rain, the result is, as King[a] points out, "that when a heavy rain falls, the close structure and feeble granulation result in the surface pores of the soil becoming so quickly closed that the soil air has little opportunity to escape, and yet only so fast as it does escape can rain enter the soil, and hence during heavy rains the water accumulates quickly and extensively upon the surface."

The greater portion of the tilled soils of the Potomac basin, especially of the lower part, are of heavy type and close texture, and the run-off from them indicates failure to absorb. But were they well granulated and in good tilth they, as well as the more permeable sandy soils, could readily absorb, without undue accumulation of surface water, a much heavier rain than commonly falls at one time on the Potomac basin.

The porous condition or granulation of a heavy soil necessary to effect absorption is best procured by the addition of humus.

There is over a greater portion of the tilled area a deficiency in the organic content or humus. The soils of the great valley and the region to the east lie well within the southern field of long, hot summers and heavy, irregularly distributed rainfall. The organic content of typical tilled soils of this region, as given by the Bureau of Soils, is for the Iredell clay loam, 1.43 per cent; Penn loam, 1.70 per cent; Penn clay, 1.92 to 3.04 per cent; Hagerstown clay, 1.51 per cent; Cecil loam, 1.07 per cent; Cecil clay, 1.63 per cent.[b] These are from typical areas in Virginia, West Virginia, and Maryland, in a well-farmed section, and without doubt adequately represent the humous content of these and similar soils throughout the lower cultivated portion of the Potomac River basin.

For the same or similar soils in the more southern Atlantic States, the organic matter is given[c] as from 5 to 7 per cent for the Cecil clay, 2.4 to 4 per cent for the Cecil sandy loam, and 4.15 to 4.75 for the Iredell clay, and it is recognized that even these large amounts are generally too small[d] to maintain soils in that latitude in good tilth and sufficiently porous and strongly granulated to prevent washing.

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[a] Yearbook U. S. Dept. Agric., 1903, p. 164.
[b] Field Operations Bureau of Soils, 1903, pp. 210 et seq.
[c] Idem, 1901, pp. 280 et seq.
[d] Idem, 1901, p. 281; Yearbook U. S. Dept. Agric., 1903, p. 168.

The growing season in the lower part of the Potomac basin is hotter and longer than in the basin of the Susquehanna and the other streams to the northeast. Except near the coast, where the relative humidity is high; on certain types of soil, which are very well adapted to grass; and at high elevations, a permanent sod is with difficulty maintained or even established. Many of the soils have high oxidizing power, and humus, either in the shape of leaf mold in the forest, as manure in farming land, or litter in grass land, is rapidly oxidized. The result is that a low soil porosity is maintained, with small absorptive capacity, saturation quickly taking place and the heavy run-off from the steep slopes causing erosion.

Spillman[a] has shown in actual practice that the large increase in the organic content of a yellow-shale soil in eastern Pennsylvania produced a soil structure more largely independent of weather conditions than any soil he had ever seen. "Torrential rains are soaked up," he says, "in a very short time, so that the soil may be handled after a rain much sooner than that of adjacent forms."

On account of their inability to absorb the necessary rain, the moisture content of the heavy clays is often insufficient in the autumn for the proper maturing of the corn crop and causes the grass to "burn badly."

On clay soils, such as the heavy phases of the limestone, tile drainage also increases the thickness of the permeable layer of top soil and its water-storage capacity. Such drainage would undoubtedly be beneficial over a large area of the nearly level or gently rolling clay lands of the limestone, shale, and Penn series in lessening erosion from saturated soils.

The run-off can also be reduced by terracing, which is especially adapted to the deep-soiled Penn, Cecil, and Chester series east of the Blue Ridge and to the shale soils west of it. This permits the absorption and the subsoil storage of the heavy spring and summer rains, which are so badly needed for plant growth and which are so largely lost to the crop by the run-off. Terracing has been done, in isolated cases, in more southern States, and the increased yield and greater immunity from drought have more than compensated for the reduced area and increased cost of tillage.

Another element in the run-off from farming land which is fully as important as the loss of the water is the loss of the solid mineral elements which form the turbidity as well as the soluble matter which is washed off. Mr. Outwater states in another part of this report that the soluble matter removed, if derived largely from the agricultural land, amounts to about 400 pounds per acre per year, and the plant food in it is about equal to that removed by a crop. While the soluble material lost by leaching is replaced with about the same

[a] Yearbook U. S. Dept. Agric., 1903, p. 363.


DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, Director
POTOMAC RIVER DRAINAGE BASIN
ABOVE WASHINGTON
SHOWING
FOREST AREAS
AND CLEARED LANDS
Scale 1: 633,600
30 miles
40 kilometers
Contour interval 500 feet. Sketch contours dotted
Datum is mean sea level
Topography
Compiled from U. S. Geological Survey atlas sheets and other sources
Field and forest data by
William W. Ashe
Forest Service, Department of Agriculture
June, 1906
LEGEND
Cleared land largely in tillage
Cleared land largely in grass
Forest land in which the humus has been partly destroyed by occasional fires
Forest land in which the humus and ground cover have been very largely destroyed by frequent fires and the soil is subject to more or less erosion
Forest land in which the humus has been undisturbed by fire
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
WASHINGTON
Hanover
Westminster
Chambersburg
Hagerstown
Williamsport
Harpers Ferry
Winchester
Strasburg
Woodstock
New Market
Luray
Harrisonburg
Staunton
Waynesboro
Alexandria
Falls Church
Somerset
Everett
Grantsville
Deer Park
Petersburg
Monterey
79° 30′
79°
78° 30′
78°
77° 30′
77°
40°
39° 30′
39°
38° 30′
38°

rapidity as it is removed, the fine particles of silt and clay are replaced very slowly. This fine solid matter represents the most valuable portion of the mineral soil on account of its favorable influence on the retention of soil moisture and the large surface it offers for root absorption. This indicates the necessity from an agricultural standpoint of storing in the soil the heavy spring and summer rains, that the water may be available for the growing crops and that at the same time the fertility of the soil may be maintained by retaining in it the silt and clay which form the turbidity and the soluble plant food, which is also washed away.

EFFECT OF FOREST COVER ON STREAM FLOW.

EXTENT AND INFLUENCE OF FOREST COVER.

Originally the greater portion of the Potomac basin was wooded, although the Indians kept much of the Shenandoah and Cumberland valleys burned off, as well as certain areas on Monocacy River in Adams County, Pa., which even now, on account of this, are known as the "Barrens," and smaller areas elsewhere, as at Petersburg, Grant County, W. Va., and below Moorefield, Hardy County, W. Va. It is also probable that they regularly burned over portions of the mountains to facilitate hunting, although they do not seem to have kept the timber suppressed, as was the case in the "Barrens" and elsewhere in the valleys.

Woodland at present covers about one-third of the area of the basin. (Pl. X.) It has been very largely removed from the Great Valley, from the Blue Ridge and Catoctin Mountains, and from the Piedmont area east of the Blue Ridge. The Shenandoah and Tuscarora mountains are yet well wooded, and there is a more or less continuous strip of forest on the upper slopes of many of the Appalachian ridges. In places it is continuous for several miles and will cover a great portion of the slope; elsewhere it is a very narrow strip along the rocky crest, or it is entirely segmented into wood lots and covers less than one-fourth of the mountain slope.

In the Allegheny Mountains the forest covers most of the very stony and rough land and many of the steep slopes, especially in Maryland and West Virginia; but in Somerset County, Pa., large areas of even, steep land have been cleared and put into grass, and there are no extensive bodies of forest. From this it is evident that the forests have not yet been cleared from a large part of the steep land of the basin, and the facts as brought out go to show that they are sufficient in extent to play an important rôle in connection with the quality of the Potomac water, although their influence is not as potent as formerly and must continue to decrease as their area becomes smaller. The forests are influential in improving the potability of the Potomac water in three ways: They prevent greater erosion from certain soil types on steep slopes which are yet partly in forest and which wash badly when deforested, and lessen in this way the very high turbidity of the water. They maintain the volume, already very low, of the summer and autumn run-off, which by dilution adds to the real purity of the water, although this is of relatively slight value. They also steady and equalize the flow of the smaller streams and lessen the erosion of their banks.

The water of the smaller streams which flow from forest-covered mountain watersheds is clear and pure. The water of such mountain streams is being used by several towns in the Potomac basin, which obtain their water supply from streams in the Pennsylvania forest reserves, this water being less open to pollution than that of springs and wells. The protection of such forested watersheds in other States than Pennsylvania, to insure their permanence and the general utilization of these streams in place of springs and wells, which are now in general use, or in place of the polluted river water which is used by Cumberland, will, by furnishing a pure supply, largely eliminate these towns as foci of infection of typhoid fever and other water-borne diseases.

One of the tributaries of the Potomac, Great Cacapon River, affords clear and reasonably pure water which would be sufficient for the requirements of Washington, D. C. It drains a valley whose soils are, for the most part, loam and sandy loam, largely nonagricultural and forest covered. Three small villages are the chief sources of contamination. Its distance, 117 miles above the Great Falls intake, is probably too great to render it available as a present source of supply.

There is, as has been pointed out, room for a large storage of storm water in farming soils, and more rational farming methods must ultimately lead to this. The effect of such storage would be reflected in a diminished run-off of flood water, especially of heavy midsummer rains. Little of the water thus accumulated would normally pass off as seepage to spring and river flow. The improved growth of the crops would utilize such stored water, and, given a more constant and available amount of soil moisture, two crops a year would be the rule and not the exception as at present over much of the warmer part of the basin, and in place of the crops transpiring from 4 to 6 inches of the rainfall, as at present, they would use about double that amount.

Any additional storage, either transient, tending to prolong or distribute a flood crest, or deep seated, tending to increase the amount of the dry-season flow, can be secured only in the forest soil. Storage in forest soil, except in sandy phases, takes place very largely through the medium of humus. The amount of water which is actually retained by a thin humus is small, in fact, a thin humus is usually far more litter than humus and has a very low retentive capacity; but the chief functions of humus, except where it has accumulated to a great depth, are (1) to maintain the volume and depth of the soil by preventing erosion; (2) to secure the porosity of the soil; (3) to promote the absorption of rainfall by the soil in retarding the run-off of heavy showers until the water can be absorbed, as the air is gradually expelled from the soil; (4) to act as a mulch and lessen the evaporation of soil moisture.

On coarse, deep sands of low gradient the office of humus is at a minimum. There is no surface flow of storm water and no soil transportation; evaporation of soil moisture is low both from the surface of the soil and from transpiration by the xerophytic flora, and the larger part of the rainfall passes as percolation. With an increase in the clay component, greater gradient, and a decrease in soil depth, humus becomes more essential in supplementing the water-absorbing and water-carrying capacity of the soil, its functions in this respect attaining a maximum on heavy, shallow clays of mountain slopes. Much of the mountain area of the Potomac River basin affords such conditions; the slopes are steep and the soils are shallow, in part loams and in part clays of limestone and shale derivation.

Where the humus is thick, however, it possesses a high storage capacity. While there is some doubt in regard to the exact amount of water humus is capable of holding, the quantity is relatively large. The lowest estimates by Ebermayer place it at considerably more than its own weight, and Wiley's investigations of Florida mucks give it about the same capacity, while Wollny, as quoted by Henry,[a] places it at about four times its weight, and Henry's laboratory experiments tend to confirm Wollny's high limit. The capacity of humus must vary, however, not only with the state of decomposition, but with its origin as well, since the pore space is the final determinant of its water-bearing capacity. The undecomposed litter, which covers the humus and from which humus is formed, does not exhibit the characters of humus toward water. It protects the humus, as humus does the underlying soil, from excessive transportation by surface water and in addition from excessive evaporation, acting as a mulch.

The accumulation of humus on forest soil depends, if it has neither been disturbed nor destroyed, on the kind of species forming the forest and to some extent on the soil, the destruction of humus proceeding rapidly on loose, porous soils, which permit freer circulation of air and afford the condition best suited for bacteriological activity, and since many species of trees, especially the white oak and chestnut, have a wide range of soil adaptability, their capacity to accumulate humus is modified both by their rate of growth on the soil and by the oxidizing capacity of the soil on which they happen to be growing.

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[a] Revue des eaux et forêts, 1904, pp. 353 et seq.

FOREST TYPES.

The forest types can be arranged in respect to their humus-forming capacity about in the following order, those forming the smallest amounts being named first and those beneath which humus and absorbent material accumulate to the greatest depth last: Pine type, chestnut oak-white oak type, chestnut type, birch-linden-red oak type, beech-maple-hemlock type, and spruce type.

PINE TYPE.

Beneath the pine the humus is not only shallow, but seldom accumulating to a greater depth than 2 inches. It is destroyed so rapidly that in the main it is barely replaced annually by the decomposition of litter. Where conditions are normal and the humus has not been destroyed or lessened, the top soil contains for a depth of 2 to 4 inches a varying amount of organic material which adds greatly to its absorptive capacity. On account of the open character of most of the pine forests and their situation, which is usually on exposed ridges, especially with southern aspects, and on crests, it is much exposed to desiccation by both insolation and wind. Such humus is largely protective. Forests of this character are situated on both sandy and clay soils. The pitch pine and table-mountain pine, with their associated trees, are on the sandiest phases. The soils are usually shallow or porous. They include members of the Dekalb and Upshur soil series. Shortleaf pine, with its associated trees, occurs on the driest aspects of loams and clays both of the limestone and of the yellow-shale and Upshur series. Jersey pine occurs on crests and more leachy phases of clays from yellow shale, as well as on many of the friable and easily eroded Cecil and Chester soils east of the Blue Ridge. Close-textured soils with low absorptive capacity probably form one-half of the pine type, the total area of which amounts to more than 600 square miles. Nearly all of this area has a highly dissected topography, many of the slopes being both long and steep, and offers, when denuded of humus, favorable opportunity for excessive erosion. Under the conditions of this type the protective value of humus is high in preventing erosion and increase of turbidity, as well as in lessening evaporation of soil moisture during the summer and autumn, to which this type of forest soil is much exposed on account of the thin and incomplete canopy of the crown of the pines and associated intolerant species.

Unfortunately, in much of this forest the humus has been badly burned and its accumulation prevented by repeated, in some places almost annual, fires. This condition exists over large areas. The summit of Tussey Mountain, a broad, flat-topped ridge, has been badly burned. It now forms a part of the Pennsylvania State Forest

Reserve, and it is probable that fires will hereafter be less frequent on it. The humus has also been burned from large areas on the west slope of Town Hill, the burned areas extending for several miles on both sides of the Maryland-Pennsylvania State line; from extensive areas on Sideling Hill, in both Maryland and Pennsylvania; from the Pratt woods on Tenmile Creek, in Allegany County, Md.; from the broken region below Buck Valley, in the southwest corner of Fulton County, Pa., and the eastern part of Allegany County, Md.; from several long, narrow strips on the western slope of Tonoloway Ridge in both Maryland and Pennsylvania; from large areas on the lower part of Fourmile Creek, and from smaller areas on Scrub Ridge and on the west side of Tuscarora Mountain, in Fulton County, Pa. The accumulation of humus is prevented on large areas of pine forest on both slopes, but especially on the western, of Shenandoah Mountain in Virginia and West Virginia. Sandy Ridge, in Hardy County, W. Va., is frequently burned, as are smaller areas in Hardy, Hampshire, Mineral, Grant, and Pendleton counties, W. Va.; larger areas of pine forest on the western slope of the Blue Ridge in the valley of Virginia, and on the interior slope of the west ridge of Massanutten Mountain, and many smaller areas in other places. On many of the slopes with little or no humus soil transportation and erosion freely take place, especially where the soil from long exposure has entirely lost its humus content. Much of the forest has been reduced to sprout wood or scrub oak, and since the pines when fire killed do not sprout, they are gradually being eliminated. Owing to the suppression of young timber by fire the forest density on other areas is far too low to check the wind, and the soil, already too dry, is exposed to excessive evaporation. There are more than 200 square miles of the pine type on which the humus is too thin to perform its functions adequately and on which the soil has undergone evident deterioration in absorptive capacity. The results from this condition must be reflected in excessive run-off during heavy storms and in increased evaporation during the summer.

CHESTNUT OAK-WHITE OAK TYPE.

Humus beneath the chestnut oak-white oak type of forest seldom exceeds 3 inches in depth. This forest, like the pine type, is largely situated on slopes and ridges and occupies loams and clay soils on both the mountains and valleys. It is well represented east of the Blue Ridge, and west of that range it is the prevailing type on the dry phases of the valley clays, on all the thin-soiled, loamy slopes of the mountains below an elevation of 3,000 feet and above that elevation in numerous crests and ridges, especially those with southern aspects. On account of its situation on slopes, especially where on heavier soils, as on the mountain limestones and the heavy shale-clay phases, the protective function of its humus is important in preventing erosion, and it is likewise important in promoting absorption by these close soils, as well as in preventing the excessive evaporation which takes place from the clays, three or four times that from the sandy soils. This type covers more than 2,000 square miles, of which about 700 square miles are clay soils, the remainder being sands, loams, and clay loams, largely thin and in many places extremely stony or strewn with rock bars.

The humus of this type has a small water-carrying capacity, but its chief function is protective. It has been reduced in thickness over more than one-half of the area of this forest type, and over more than 300 square miles it has been destroyed and its reaccumulation prevented. The reduction in thickness is due to the pasturage of sheep, occasional fires, and the desiccation incidental to thorough opening of the forest cover in lumbering or peeling bark, which industries are being extensively prosecuted in the area of this type. Where the humus is subjected to a part or all of these deteriorating influences simultaneously, the result is usually its complete destruction. This has happened on large areas on the east slope of Sideling Hill west of Needmore, Fulton County, Pa., where the destruction is so effectual that the soil has washed badly on many of the steeper wooded slopes. The same conditions exist over larger areas on the west slope of the Blue Ridge, in Rockingham County, Va., and to a less extent in Augusta County, on the same range, while many of the foothills of Shenandoah and Great North mountains in these counties and in Frederick County, Va., and in Hardy and Hampshire counties, W. Va., have been repeatedly burned, and the forest cover has been so thinned that large areas of mineral soil are exposed and washing. Injury of a less degree exists over areas of this type throughout Grant, Pendleton, and Mineral counties, W. Va., Bedford and Fulton counties, Pa., and Allegany County, Md. It is worse in the oldest settled communities and near the routes of transportation, and gradually diminishes as distance from these destructive elements increases. Since the causes which lead to the destruction of humus are cumulative in their effects, the continued activity in lumbering, with the inevitable fires and pasturage, is gradually enlarging the area of sprout wood, scrub oak, and brush land, on which there is little humus or none at all.

CHESTNUT TYPE.

The chestnut, with which usually red oak is associated at higher elevations and white oak at lower, produces a better humus than either of the types already described. Its humus frequently attains a depth of 4 inches and is best when the chestnut is associated with red oak or beech. Chestnut requires a deep soil, preferring a loam or loamy clay or lighter soil, and for this reason on the mountains it grows in many places on benches where there has been little soil transportation and on lower slopes where transported material has accumulated. In the latter situation it is partly sheltered from wind and excessive evaporation of soil moisture, but on benches it is much exposed. Humus of the depth formed by chestnut has an appreciable water-carrying capacity and exerts a highly beneficial influence on the soil. There are more than 700 square miles of this type, nearly all of it on mountains. In very little of it has the humus been so completely destroyed as in the types already discussed, but there are large badly burned areas on which accumulation is seriously checked. Such areas occur on the Blue Ridge in many places, especially on the upper slopes in Page and the adjoining counties in Virginia; in many situations in the South Mountains, Tuscarora Mountains, and Scrub Ridge, in Adams, Franklin, and Fulton counties, Pa.; on the east face and fore knobs of the Allegheny Mountains in Grant and Pendleton counties, W. Va.; and on Savage Mountain and Backbone Ridge, in Allegany County, Md., and Somerset County, Pa. The total area on which the humus shows the effects of recent fires is more than one-third of the entire area of the chestnut type.

BIRCH-BASSWOOD-RED OAK TYPE.

The birch-basswood-red oak type often yields humus 5 inches deep. It is normally confined to hollows or northern slopes and sheltered situations, mostly at high elevations, and even on extremely shallow soils in such situations the humus frequently attains a depth of 6 inches, besides filling large and deep crevices between the rocks. Water can be wrung from such humus for several days after a rain, and it becomes dry and crumbly only during periods of long drought. Many of the birch and hemlock roots lie within the humus, and it undoubtedly furnishes some transpiration moisture to these species in spite of the low absorptive power they have in acid humus. This type covers a considerable area on the mountains of the watershed, being represented near the crests on northern slopes and in the hollows. The proportion of it increases with the altitude. It is especially well represented on the Allegheny Mountains and is least abundant east of the Blue Ridge and in the Shenandoah River valley. The total area probably amounts to less than 300 square miles. On account of the moist floor, only small and inconsiderable areas have been burned, and in these the burning was limited to the upper layers of humus. Heavy cutting in lumbering has caused deterioration of the humus in many places, and cattle have done some damage.

BEECH-HARD MAPLE-HEMLOCK TYPE.

Humus accumulates beneath the beech-hard maple-hemlock type to depths of 6 inches or more, and is of very fine quality, fine grained, and always moist. On very rocky land it is in places deep enough to fill the crevices between the large rocks and seldom becomes at all dry except on top. This type is best developed on the Allegheny Mountains at high elevations, especially above 2,000 feet, on moist slopes, and in deep hollows and in similar situations at the head of North Fork of Potomac River and on the mountains drained by Seneca Creek, Laurel Fork, and adjoining streams. Locally on very rocky soil the humus seems to be almost the only soil there is. Here and there this type is well developed on good soil, especially on limestone at high elevations, as at the head of North Fork of Potomac River. On limestone soils the humus and litter are in places a foot or more deep and the weeds and small undergrowth are extremely rank and thick. Where there has been no lumbering the forest cover is dense and there is low soil evaporation. This low evaporation is partly offset, however, by high transpiration from the deciduous trees of this type. Humus of this type has a high storage capacity. It is burned but rarely, and then the fire is usually confined to the top layers. Considerable areas have been badly burned, after lumbering, on Stony River, Difficult Creek, and Buffalo Creek, in Grant County, W. Va., in the south end of Garrett County, Md., and smaller areas elsewhere. Unless burnings are frequently repeated, which is rarely the case except where cutting in lumbering is severe, and unless brambles and such shrubs as make large amounts of dry brush become thick, the humus is replaced in a few years. This type of forest covers about 300 square miles. In 60 square miles of this area the humus is shallow on account of fires.

SPRUCE TYPE.

Humus accumulates to a depth of several inches beneath spruce forests, and in addition there is a deep moss, the lower layers of which hold a large amount of water. In the Potomac basin spruce is confined to the thinnest soiled, stoniest land at elevations above 3,000 feet. Much of the land has no soil at all, the loose stone lying on the undecomposed sandstone; in other places the soil is only a few inches deep, or, if deeper, is so coarse as to be scarcely more than gravel. There are 69 square miles of such spruce land situated on Stony River, Difficult Creek, and Buffalo Creek, in Grant County, W. Va., and on Seneca Creek, Laurel Fork, Spruce Mountain, and Tamarack Ridge, in Pendleton County, W. Va., and Highland County, Va., on the very headwaters of North Branch and North Fork of the Potomac. This is the region of heaviest rainfall in the basin (pp. 34–40) and the region where the best humus is needed. Of the total area of spruce land, 48 square miles, or considerably more than half, has been burned either before or after lumbering, and the humus and forest soil have been entirely destroyed. The burned areas are southwest of Bismarck, at the head of Stony River, and at the head of Buffalo Creek, in Grant County, W. Va., and on Spruce Mountain and along the face of the Allegheny Mountains, in Pendleton County, W. Va. Most of this is burned bare or has a scant cover of blueberry and brambles, which have gradually spread. Over other areas, especially where the soil is best, birch and popple and fire cherry are colonizing and reestablishing forest conditions. The area of this burned land, however, is rapidly increasing as lumbering proceeds. The absence of the absorbent humus and moss over these thin-soiled areas, where it is most necessary, must have an appreciable influence on the movement of storm waters in the streams which drain these areas. No turbidity comes directly from this land.

While the reestablishment of normal humus conditions would undoubtedly have a beneficial effect in alleviating the danger from high floods, the division of the forest into so large a number of narrow strips on the mountains, its diverse ownership, its location in four States, and the rapid progress of lumbering assure a progressive accentuation of the unfavorable conditions.

MELTING OF SNOW.

High turbidity usually accompanies the spring floods of April and May caused by the melting of the snow on the mountains at the head of the river, especially on the Allegheny Mountains. The longer the process of melting the lower is the flood crest and the lower the accompanying turbidity. The coniferous forests are instrumental in prolonging the melting of the snow. Near Hancock, Md., at an elevation of 600 feet above sea level, a 20-inch snow which fell during March, 1906, was nine days longer in melting beneath the cover of Jersey pines than on adjacent field land with the same soil, slope, and aspect. At the head of the river the spruce forest, with its more dense foliage, must exert a greater effect than Jersey pine in prolonging melting. Some difference, though much less marked, was noticed in the melting of snow in the deciduous forest of oak and in the adjoining fields. The total area of coniferous forest in the Potomac basin is more than 700 square miles, and its influence must be considerable in distributing the crest of floods from melting snow, by retarding melting in the forest land and by promoting absorption and subterranean drainage.

PROTECTIVE FORESTS.

The State of Pennsylvania, realizing the inability of private owners to supply the technical knowledge necessary to manage small forest areas in such a manner as to make them permanent earning investments, as well as the necessity of properly protecting by forests the headwaters of the large rivers of the State, has purchased extensive areas of mountain forest land within its borders. Portions of this land, lying on Tussey Mountain, Tuscarora and its associate mountains, and Jack and Green mountains, are on the Potomac watershed, although the greater portion is on the Susquehanna, which is essentially a Pennsylvania stream. The further extension of this protective forest to the south and southwest, to include the most important mountain areas in the Potomac basin in Maryland, West Virginia, and Virginia, is desirable. Where the States are unable to assume either the cost or the responsibility of acquiring and managing such large areas for the protection of interstate streams, this duty devolves on the Federal Government, whenever the States concerned grant the Government the right to acquire and hold such property. This right has already been granted by the legislatures of two of the States under consideration—Virginia and West Virginia—in connection with the establishment of the proposed Southern Appalachian Forest Reserve, and it would doubtless be extended by them to include the Potomac drainage basin. On account of the importance of the Potomac as a source of domestic water supply, an Appalachian forest-reserve system could fittingly be inaugurated by the acquisition of the important forested mountain lands in its basin, and, with the already extensive Pennsylvania system, two important watersheds of the Middle Atlantic drainage, the Susquehanna and Potomac, would be protected.

The control of the waters of the East by the Federal Government for the benefit of the people is as important as the control of those of the West for extending irrigation, and the principle which underlies the withholding of public money by not selling forest land is the same as that which underlies the acquiring of forest land by purchase for similar purposes.

One consideration in the selection of such forests on the Potomac basin should have reference to their protecting small mountain streams which can be utilized as sources of water supply for near-by towns and cities. The water from such forest-protected basins is of great purity, clearness, and softness, and its general use by the towns is desirable, not only on their own account, since it furnishes them a pure supply, but because by purifying their supply these towns are largely eliminated as sources of typhoid fever.

The limestone springs which are used by many towns are more exposed to contamination than freestone springs. The latter are open only to local surface contamination, while many sink holes on farms, which are the dumping places for waste, communicate with underground streams that are in numerous places the sources of limestone springs. Many limestone springs are also streams which have sunk and reappeared on the surface at the spring. Numbers of such springs are easily traceable to streams which have sunk in the Cumberland Valley, in the valley of Virginia, and on South Branch of the Potomac.

When the towns using springs or water from small streams which are open to pollution, such as that used by Chambersburg, Pa., find it necessary to obtain new sources of supply, either because of inadequacy of their present supply or on account of its known pollution or questionable purity, as is the case with Leesburg, Va., no purer water can be obtained than that from streams of forest-protected watersheds. Two towns on the Potomac watershed in Pennsylvania are already taking advantage of the permanent purity which the Pennsylvania forest reserves guarantee and have made use of streams in forest reserves as sources of supply. These towns are Mercersburg, which uses Trout Run in the Tuscarora Mountains, and Waynesboro, which uses streams in the South Mountain Forest Reserve. The near-by city of Hagerstown, Md., has recently sought a purer supply from the streams of South Mountain in Maryland, a few miles south of the streams which supply Waynesboro. There is assurance neither of permanency or purity to its supply, however, since the watershed is privately owned and the number of farms is increasing, with the constant danger of contamination.

Such a system of protective forests as has been suggested need not be designed to include the headwaters of all the streams in the basin, but should, primarily at least, be planned to include all those which now afford a water supply to towns of the basin or which by their situation will, in the future, be necessary as sources of water supply. With many of these towns the amount of the supply will be a matter for consideration as well as the purity, and the protection of the humus and the forest floor will be beneficial, while the regular cutting which would be carried on under the policy of protection forests would in no way jeopardize the amount or regularity of the stream flow.

EXTENSION OF THE CLEARED AREA.

While for a mountain region a large proportion of the land in the Potomac basin has been cleared, the limit has by no means been reached. During the period between 1880 and 1890 the uninterrupted emigration to the West checked further clearing of rough land for small farms, and on account of the agricultural depression in the following decade there was little incentive for further extension of the farmed area. In fact, much land was abandoned in Franklin and Bedford counties, Pa., and in Allegany and Garrett counties, Md., and some in Hardy, Hampshire, Mineral, and Grant counties, W. Va. The present feeling in the East that the West no longer offers any better opportunity for farming for the man of limited means than the East has checked emigration and given a new impetus to farming in this section. In addition to the fact that the man of small means, who twenty years ago would have gone West, is now buying a small farm at home, usually in timber which he clears, two other causes have stimulated additional clearing. (1) One of these is the release for farming purposes of recently logged timber land or recently opened coal land. Much of this land is of good quality for farming, and as rapidly as it is lumbered it is cleared and put in cultivation, or if too rough for tillage the large trees are killed by girdling, the ground is burned over to kill the brush, and the land is put in grass. The high price of sheep has made this profitable, and large areas of rough land, some of it extremely steep and thin soiled, are being sodded in this way on and along the Allegheny Mountains. Extensive areas are being opened for grass land on Laurel and Straight forks of North Fork of the Potomac, following the lumbering of hemlock and hardwoods, and for general farming on Savage River, following the lumbering of hardwoods, while over the entire basin there is at present a steady addition to the farming area of recently lumbered land. (2) The extension of fruit and especially of peach culture during the past decade has led to the clearing of a large amount of steep, sandy mountain land. Some of the largest orchard districts which have been cleared in the past few years are on the south slope of Tonoloway Ridge, in Washington and Franklin counties, Pa., where a heavy limestone soil has been selected for apple culture. Large areas on the southern slopes of Town Hill, in Allegheny County, Md., and on Patterson Creek Mountain, Knobly Mountain, North Mountain, Jersey Mountain, and the Allegheny Front, near Keyser, have been cleared for peaches. Much of this land would seem to be too steep and the slopes too long for permanent profitable cultivation. While the soil beneath an orchard is protected by a cover crop during the winter, clean culture is given during the summer, subjecting steep slopes to the erosion of heavy summer rains. It is possible that with the lessening of the profits which are now obtained and which are due to the freshness of the land and the immunity from insect pests the portion of this land which is least favorably situated will be abandoned.

Further contraction of the forest area tends to increase the already large disparity between maximum and minimum flows of the streams, with the concomitant influences on the potability of the water.

TURBIDITY IN RESERVOIRS AT WASHINGTON, D. C.

The water supply for Washington, D. C., before going to the filter beds usually passes through three settling reservoirs. From the intake at Great Falls it is piped to the Dalecarlia Reservoir, about eight hours being required for the journey. The water remains in the Dalecarlia Reservoir about one day and is then pumped to the Georgetown Reservoir. Thence it passes to the Washington Reservoir, which is located at the filtration plant, about 5 miles distant. About two days are consumed in the passage from the Georgetown Reservoir through the Washington Reservoir and through the filter beds. From these beds the water passes to a distributing reservoir. The conduits at the reservoirs are so arranged that any reservoir can be cut out of service without interrupting the flow from the other reservoirs or from the river.

The river water which enters the Dalecarlia Reservoir is usually turbid, the turbidity varying, according to the standard of the United States Geological Survey, from 3,000 or more during periods of flood in the river to 15 or 20 after long periods of little or no rainfall on the Potomac watershed above the intake. In general, it may be said that the turbidity will be in excess of 300 for about forty-three days in the year, above 50 and less than 300 for about one hundred and twenty-three days, and less than 50 for the remaining period. It will exceed 1,000 for probably less than eighteen days. The first settling to lessen the turbidity takes place in the Dalecarlia Reservoir and removes the greater portion of the heaviest silt and a large part of the clay from the water, but the clearness of the water when it leaves this reservoir depends largely on its initial turbidity. Further clarification by settling, though slight compared with that which takes place in the Dalecarlia Reservoir, occurs in both the Georgetown and Washington reservoirs. The finer material which occasions most of the turbidity after the water leaves the Dalecarlia Reservoir settles very slowly. Sedimentation usually proceeds with a certain expected uniformity, a high percentage of turbidity being eliminated from water of a high turbidity and a smaller percentage from that of a lower turbidity, owing to the slower settling of the finer particles which cause the low turbidity. The greater proportion of clarification in water of high turbidity is suggested by Mason as being due to the well-known tendency of larger falling particles to drag down with them very fine particles, and even matter in solution. The subsiding, heavier silt drags down not only much of the finest clay, but bacteria as well. It is important, therefore, that the sedimentation in the Dalecarlia Reservoir be as thorough and uninterrupted as possible, since after the settling of the heavier particles the finer material which is left, having failed to be carried down by the coarse material, remains in suspension a great while and is with difficulty eliminated from the water by further sedimentation. Only a certain proportion of it is removed by filtration, and it follows that the lower the turbidity of the water as it goes to the filter beds the more pellucid the effluent.

At different times, but usually during the winter and spring, on account of wave action produced by wind, sedimentation in the reservoirs not only takes place very slowly and irregularly or not at all, but additional turbidity is acquired by the water from the scouring of the sides or, at shallow places, the bottoms of the reservoirs, a portion of the thin coating of silt and clay that has previously been deposited being again taken up in suspension. With this increase in turbidity a portion of the recently deposited bacteria are also redistributed through the water.

The period of wind agitation of water in small lakes and reservoirs, as has been pointed out by Birge, is largely limited to the winter and early spring months, after the water has become homothermous. During the summer and early fall the temperature of the surface water becomes much higher than that of the water at the bottom of the reservoir, and the surface water is consequently much lighter, there being a warm, superficial stratum of water, the colder bottom stratum, and a thin stratum between them in which the temperature rapidly falls, called by Birge the thermocline.

Wind agitation of water during the summer and autumn, when the stratified condition is present, is largely confined to the lighter superficial layer, which does not readily mix with the dense layer at the bottom, and there is little churning of this bottom layer to cause added turbidity. The depth of the water, however, has some influence, the stratification being most marked and the difference in temperature and density greatest in deep water. The upper and lower layers become more uniform in thermal and physical properties with lessened depth, and the susceptibility to wind agitation during the summer increases. For this reason the deep reservoir is least disturbed by wave action.

During winter and spring, however, when the temperature of the water is about the same throughout, constant wind action, though light, from any one direction, will easily cause a complete overturning of the water in the reservoir. The thermal resistance to wind action which is offered by water is greatest in summer. In the winter it is greater in the day than at night and greater during sunny days than during cloudy weather. For this reason wind agitation is at its maximum during cloudy winter weather. The situation of Washington favors the existence of a long period in which the thermal conditions are conducive to wave action. The winter and spring period is long; there are a large number of cloudy, windy days, and on comparatively few days is the weather so cold that the reservoirs are frozen and protected against wind influences.

March, 1906, was a windy month, and, notwithstanding the low turbidity of the raw river water, except for a few periods of short duration, the turbidity of the water in the reservoirs remained higher than that in the river, exhibiting constantly the influence of wind action. The turbidity of the water in the Dalecarlia Reservoir remained so high that it was temporarily dropped from service and water from the river diverted direct into the Georgetown Reservoir; and during a short period of very high turbidity in the Georgetown Reservoir and lower turbidity in the river, March 9 and 10, the river water was pumped direct to the Washington Reservoir and thence to the filter beds. There was scarcely a day between March 13 and March 22 when the turbidity of the water in each of the reservoirs was not higher than that of the river water.

After filtration the water is passed into the distributing reservoir. Under low wind conditions water turned into this reservoir at a turbidity of 8 or 9 will become during the day slightly clearer by sedimentation, but during this period no subsequent clarification whatever took place. The following table shows the influence of the wind in raising the turbidity in each of the reservoirs for seventeen days in March:

Turbidity record of Washington water supply, March 6–22, 1906.

Day.	Turbidity of water at—				Turbidity of effluent after filtration.	Turbidity of water in the distributing reservoir.	Maximum wind velocity (miles per hour).[a]	Total wind during 24 hours (miles).	Direction of wind at time of maximum velocity.[a]
	Great Falls intake.	Dalecarlia Reservoir.	Georgetown Reservoir.	Washington Reservoir.					
6	820	250	70	35	5	....	14	146	South.
7	180	[b] 350	110	40	5	....	11	77	South.
8	120	[b] 250	[b] 120	45	5	....	9	110	North.
9	110	[b] 250	[b] 120	65	5	....	24	233	West.
10	95	[b] 350	[b] 110	80	5	....	31	327	West.
11	130	[b] 350	[b] 100	80	....	....	15	154	South.
12	50	[b] 300	100	80	6	....	26	278	Northwest.
13	35	[b] 180	90	65	7	7	12	168	Northeast.
14	26	[b] 180	70	80	8	7	11	160	Northeast.
15	20	[b] 250	55	90	9	8	21	266	Northeast.
16	65	[b] 350	45	60	9	8	18	183	Northwest.
17	40	[b] 250	50	55	9	8	24	274	Northwest.
18	28	[b] 250	45	50	....	....	11	138	Northwest.
19	22	[b] 180	35	53	9	8	13	141	Southeast.
20	22	[b] 180	....	55	8	8	31	380	Northwest.
21	35	[b] 180	28	45	....	....	18	248	South.
22	40	[b] 180	26	35	8	8	22	302	Northwest.

[a] Wind velocity and direction taken from records of the U. S. Weather Bureau.
[b] Reservoir not in service on account of high turbidity.

During January, 1906, for a period of more than a week, the turbidity, both in the river and in the Dalecarlia Reservoir, was low, but there was a high increase in that of both the Georgetown and Washington reservoirs. The wind velocities were low, but the wind was constant, the prevailing directions being from the west and northwest. The high turbidity of the effluent after filtration is due to only a portion of the filter being in operation.

Turbidity record of Washington water supply, January 13-19, 1906.

Day.	Turbidity of water at—				Turbidity of effluent after filtration.	Maximum wind velocity (miles per hour).	Total wind during 24 hours (miles).	Direction of wind at time of maximum velocity.
	Great Falls intake.	Dalecarlia Reservoir.	Georgetown Reservoir.	Washington Reservoir.				
12	26	45	50	70	20	15	170	West.
13	35	28	55	65	20	16	248	North.
14	28	28	85	60	....	10	122	West.
15	35	28	80	60	15	17	203	South.
16	35	35	70	60	12	28	226	Northwest.
17	30	35	60	60	10	20	183	West.
18	30	30	45	55	11	17	203	Northwest.

During the summer and autumn, when the water is stratified, even wind velocities of 15 to 25 miles an hour usually have little effect if the weather is bright and warm. A five-day period of high wind—May 6–10, 1906, during bright, warm weather—was accompanied by constant decrease in the turbidity of water in the reservoirs. A period of cloudy and rainy weather, very cool for the season, two weeks later, May 24–26, so far equalized the temperature of the water in the reservoirs that even lighter but steady winds showed an appreciable influence in preventing sedimentation, and the effluent after filtration, which normally should have shown a turbidity of 1 or less, rose to 3. The same effects, and usually to a greater degree, are apparent on windy, cloudy days, especially when cold, throughout every month in the year. The comparatively low velocity of the wind which occasionally, especially during the winter months, causes high turbidity, suggests the use of wind-breaks of heavy-foliaged, coniferous trees around the reservoirs, or at least on those sides from which the prevailing winter and spring winds blow, which are now unprotected.

To be most efficient a wind-break must begin a few feet back of the water level of the reservoir. The shelter power of a wind-break is variously estimated, but for winds of low velocity such as prevail here, even a low wind-break would lessen wind action for a considerable distance from the edge of the reservoir. The overturning of the water would require higher winds and would be less complete. *Libocedrus* or a mixture of *Libocedrus* and Norway spruce would probably be sufficiently tolerant not to become open below until 50 feet high, when they could be underplanted with a more tolerant species, or rows of young trees could be planted behind them. These species will also probably stand the warm summers and autumns of Washington, on account of the high humidity. Hemlock would be an ideal tree but for its slow growth, while the native red cedar has a desirable shape, but is too small and too intolerant.

The Dalecarlia Reservoir, where the raw water is received from the Potomac, and where the first settling of the coarsest matter in suspension takes place, is an irregularly shaped basin with an extreme length, including the narrow arms, of more than half a mile. The depth of the water in many of the arms and over a considerable portion of the body of the reservoir, owing to settling up by the sediment which has been deposited from the water for many years, is less than 12 feet, and at the end of one of the arms it is even more shallow, the bottom sloping up from a depth of about 9 feet to the shore. This reservoir occupies a deep valley, with partly wooded hills rising more or less abruptly from the edges of the reservoir to heights of 50 to 200 feet, the summits of the hills lying from one-eighth to one-half mile distant from the reservoir. The reservoir valley is entirely open toward the south end, through which it drains into the river, and at the northwest end, where it is fed by a small stream. There are several other deep diverging gorges, two of which are sufficiently deep to hold arms of the reservoir.

The highest hills, rising more than 200 feet above the surface of the water in the reservoir, lie to the north and east, but their summits are about half a mile distant from the reservoir, and probably only the steep lower slopes, with a height not exceeding 100 feet, afford any protection to the reservoir as a wind barrier. On the south and west sides the hills are only about 65 feet above the surface of the water, and on account of the great length of the reservoir they protect less than half of it from southwesterly and westerly winds. The greater portion of the west end of the reservoir is exposed to winds which come up the open south valley. A portion of the west end of the reservoir is likewise unprotected from northerly winds, which would follow the north prong of the valley, or from northeasterly winds, which would follow the east prong of the valley.

The rebound of the wind from the steep slopes on the eastern side of the reservoir and the wind currents which follow the gorge-like valleys possibly explain the quick response of the water to winds of even low velocity. The period when this agitation is most constant and most pronounced is the season of defoliation of the hardwood timber on the surrounding slopes, when these trees are of least efficiency as a windbreak. It is pointed out by Professor Bigelow, of the Weather Bureau, that local windstorms frequently follow these narrow, gorge-like valleys, either in converging toward Potomac River or in spreading from it.

This constant wind action during the spring at the Dalecarlia Reservoir can be reduced by the construction of breakwaters, one across the northwestern arm and one across the southern arm. The tops of the breakwaters should be 20 feet wide, and a double row of evergreen trees should be planted alternately along each, which will still further decrease the amount of water surface exposed to the full sweep of the wind, by protecting parts of the body of the reservoir from winds which come through the southern and northern gorges. Similar breakwaters could be placed across the other arms and one across the middle of the reservoir, the tops of all being planted with a double row of evergreen trees. Every contraction of the large unbroken water surface, which is now offered for wave action, as well as any diversion of the wind from the surface of the water, will be beneficial. It is desirable to have the settling which takes place in this reservoir as perfect as possible irrespective of whether the sides of the reservoir are paved or not, since the clearness with which the water leaves this reservoir in large measure controls the condition of the effluent of the filter. Undisturbed subsidence of the coarser silt is very desirable, as has been previously explained, since when this takes place much of the very fine suspended matter, including bacteria as well as the clay particles, is carried to the bottom by the silt as it descends.

The Georgetown Reservoir is situated about 200 yards north of Potomac River, on the south slope of the river hills. It is about 75 feet above the river, while to the north the hill gradually rises, within the distance of a mile, about 200 feet higher than the reservoir. It is entirely exposed to winds from the northwest and west, which come down the river gorge, and to those from the east, southeast, and south, which come up the river. On account of the gentle slope of the hills to the north the shelter afforded by them is slight. A breakwater separates the reservoir, which is nearly a third of a mile long, into two lagoons and lessens the violence of wind action, especially under high northwest winds. The southern and southeastern sides of the reservoir are formed by high banks, which have been built up and are rather steep on the outside. Except at a few points along these banks, where some additional banking to broaden the crest might be necessary, there is room around the entire reservoir for a double row of trees for a windbreak, and in places for three or more rows. Protection against wind is especially desirable on the west, northwest, and southwest sides of the reservoir, since these are the directions of the prevailing winds during winter and spring, when the water is in an unstable condition and lacks adequate thermal stratification to prevent overturning. The planting of the breakwater is also desirable.

The Washington City Reservoir is situated at the northeastern edge of the city, on an abrupt rise about 120 feet above the river and more than 2 miles distant from it. To the southwest and south the country is lower than the reservoir, and the wind has no check when coming from these directions. To the north and west nearby buildings and the gently sloping hills on which Petworth and the Soldiers' Home are situated rise much above the reservoir. The slope of these hills, however, is so gradual that their protective value is doubtful. The reservoir, which has a surface of about 45 acres, is about one-fourth mile long and crescent shaped, and since its longer dimension lies northwest and southeast, both the high northwesterly winds of winter and the southeasterly winds of early spring have unchecked play upon the surface. At times when the water is unstratified a breakwater in the center would lessen churning from wind. Its sides should be paved and its top sufficiently widened for two rows of trees to be planted. Windbreaks of three rows of trees should be planted on the north, west, and south sides of the reservoir. On the northeast side the filter beds are so close to the reservoir that not more than two rows can be planted.

THE EFFECT OF SOME INDUSTRIAL WASTES ON FISHES.

By M. C. Marsh.

INTRODUCTION.

At the instance of the United States Geological Survey, through which most of the samples were furnished, the experiments herein detailed were made by the United States Bureau of Fisheries for the purpose of learning the approximate concentrations at which the various industrial and other pollutions flowing into the Potomac basin are fatal to the food and game fishes of the region. The sources of the industrial wastes with which experiments were made are discussed on pages 191–246.

The species on which the observations were chiefly made are the large-mouthed black bass (*Micropterus salmoides* Lacépède) and the yellow perch (*Perca flavescens* Mitchill). These were selected as typical species of the Potomac fresh-water fishes, comparatively hardy and prolific, and valuable both as game and food. The perch were young and vigorous individuals, about 15 cm. in length, taken from the fish lakes of the Bureau of Fisheries in Washington. They were hatched naturally in Potomac River and had strayed through the screens of the ponds when small. The black bass were young fish of a length of 7 to 12 cm. and were hatched and reared in these fish lakes.

The bass and perch were brought from the lakes in small lots at short intervals and held in flowing tap water, and may be considered equal in vigor and resisting powers to normal wild fish not affected by aquarium conditions. When any material difference of temperature existed between the water from which the fish were taken and the pollution or dilution into which they were transferred the change of temperature was gradually made.

In addition to these two species a few salmon and trout fry and others were used as indicated in the discussion. The "shiner" is *Notropis hudsonius*.

The reaction of water which will support fish life must be slightly alkaline. When the water becomes even slightly acid fishes can not live in it, and in experimenting with acid pollutions the alkalinity of the water used as a diluent of course affects the results. In all the present trials Potomac service water was used for diluting the pollutions and for the controls. Its alkalinity was determined at intervals during the winter by titration with decinormal sulphuric acid, methyl orange indicator, and varied from 46 to 52 parts per million of calcium carbonate equivalent.

METHODS.

The conditions under which foreign substances exercise an effect on fishes in the streams can not for the most part be exactly duplicated in the laboratory. A continual flow of water impregnated constantly with a known amount of the foreign matter under observation has not been practicable in these tests. The method followed consisted in making a known dilution of the pollution with Potomac tap water, introducing a small number of fish into the dilution held in open glass jars at the room temperature and leaving them until they died or until the experiment was otherwise ended.

All pollutions were tried with no aeration of the dilution save that occurring spontaneously at the surface, and many of them were in addition tried with artificial aeration by introducing at the bottom of the jar a continuous current of air broken into minute bubbles by passing it through linden plugs, as is usual in maintaining large aquaria. The volume of the diluted pollution used in a single trial was usually 10 liters, but varied from 5 to 30 liters. The fish were not fed while subjected to the trials. In the cases where a dilution failed to kill the trial was continued as long as circumstances allowed, in some instances two or three months. Controls were carefully carried and are separately discussed.

It is obvious that these laboratory conditions differ in some important particulars from those prevailing in polluted streams. In the first place, the fishes can not be subjected for very long periods to the influence of the pollution, for other causes will terminate the experiment, and thus the long-continued influence of very diluted pollutions which are not fatal for short periods are not covered. The aeration which occurs in flowing streams is greater than in standing dilutions and less than in dilutions artificially aerated as described, and aeration in many cases modifies considerably the polluting agent. The fish in jars are of course held under very unnatural conditions as to their immediate surroundings, particularly in the matter of space, but this does not complicate the matter much, since in aquaria with flowing water they may be held almost indefinitely.

Notwithstanding these differences between the experimental pollution and that naturally occurring, which obviously impair the accuracy of the results in the one case as applied to the other, it is equally obvious that information of value may be obtained and that reliable inferences may be drawn from such experiments. Standing dilutions without artificial aeration, which are quickly fatal, will be likewise fatal in natural waters, and standing dilutions copiously aerated, which are uniformly fatal even after considerable time, would be practically certain to kill in the same or shorter period in streams. Where unaerated dilutions fail to kill during exposures which terminate after a few days, it is not unreasonable to make some inference respecting the further dilution necessary to render the pollution harmless, remembering that an acclimating process will tend to offset the influence of the more prolonged exposure.

The temperature of the dilutions was substantially that of the controls.

A check jar in Potomac water was not set for every trial, but a series of checks was started at different times covering the whole series of pollution experiments. The results from the fish in the 10-liter samples of Potomac water are given in the accompanying table and show that one perch and one bass will live for weeks in that amount of water standing without other than the natural surface aeration, without food and at a temperature between 15° and 20° C. They may be summed up briefly, as follows:

In three trials one small bass lived an average of 72 days in 10 liters of water, and none less than 50 days. In two trials a perch lived 44 and 46 days, respectively, in the former case nearly half the water evaporating, owing to the greater surface area. In two trials with two bass in each, one died after 55 days and the other in the same jar after 71 days. In the other jar one died after 69 days, while the other was alive at the close of this record, on the seventy-fourth day.

In eight trials with one bass and one perch together in 10 liters both survived an average period of 24 days. There is considerable individual variation, for among these eight trials, the fish being selected by chance from presumably healthy individuals in the supply tank, in one case the bass died on the third day, while in another neither fish died until the forty-third day. Some unnoticed injury may possibly account for the death of this bass within 3 days.

One bass 3 inches long in 5 liters of water in a McDonald hatching jar, with occasional aeration, lived 102 days, the surface area of water exposed to the air being 215 sq. cm.

In general the fish in Potomac water survived much longer than the fatal periods for fish in polluted water and fulfilled their office as controls for the latter.

In the few cases where the pollution trial was carried on in a volume less than 10 liters accompanying controls were set of which no further statement is made. The control is implied if not expressed, and no uncontrolled results are included in the statements of fatal concentrations.

Each pollution or refuse matter which is customarily thrown into the waters of the Potomac or its tributaries will be described briefly, and the quantity or concentration necessary to kill stated as nearly as the experiments permit. The concentration is expressed as parts of the pollution sample in parts of the dilution. For example, "1 in 100" means 1 part of the pollution as received, plus 99 parts of water by volume or a 1 per cent solution.

The following table shows the results of experiments in 10-liter samples of Potomac water in glass jars; temperature of water, 4.5° to 8° C. at beginning, fluctuating with the room temperature, and never higher than 20° C.; area of exposed surface of water, 500 sq. cm. unless otherwise stated:

Results of experiments on fish in Potomac service water.

Date of beginning.	Number of— Perch.	Number of— Bass.	Length of bass (cm.).[a]	Perch lived (days).	Bass lived (days).	Remarks.
January 9		1	7.5		50	
Do		1	7.5		92	
Do	1			44		967 sq. cm. water surface exposed; 4.3 liters evaporated.
Do	1			46		2 liters evaporated; 4 c. c. of oxygen per liter after 18 days.
January 21	1	1	11		3	Abandoned on third day.
January 31	1	1	11	11	7	
February 9		2	11		55, 71	
Do		2	11		69, [b]78	
Do		1	10		[b]78	
February 15	1	1	11-12	13	13	
Do	1	1	16	17	50	
Do	1	1	11-12	34	34	Perch spawned after thirty-first day.
Do	1	1	11-12	37	37	
Do	1	1	9.5	41	55	
Do	1	1	11-12	43	66	

[a] The length of the individual perch was not taken, as they were all of nearly the same size—from 12.5 to 15 cm.
[b] Alive at close of record.

PAPER AND PULP MILL WASTES.

Spruce fiber.—This consists of coarse short fibers of spruce wood which do not pass through the screen that separates the finer fibers from the pulp made by grinding the logs. It was received from mills at Harpers Ferry, W. Va., in damp balls which lost about 38 per cent in weight by air drying.

One kilogram of the damp fibers in 28 liters of tap water failed to kill or apparently harm black bass during 10 days. During the first 4 days the fibers were held in a cheese-cloth bag, and during the remainder of the time they were free in the water without causing any mechanical injury, though the fish were annoyed when the fibers were occasionally distributed by stirring. The bass were about 6 inches in length, and the water was constantly aerated.

Spruce strips or shavings, partly bark.—These are sliverings from the outer portion of the log and include both wood and bark.

Two hundred and fifty grams of the shavings, in 28 liters of water, with continuous aeration, was fatal to bass within 24 hours. Fifty grams was not fatal during 7 days, though the solution became very dark brown. A small constant flow of water prevents any fatal effect. Three hundred c. c. per minute passing through 2 kilograms of the shavings held in a 30-liter jar failed to kill bass during 7 days, the brown tinge of extracted bark disappearing from the effluent after the first day.

Spruce bark.—One hundred grams of the bark stripped or cut from the above-mentioned shavings, in 28 liters of water, with aeration, killed bass within 19 hours. Fifty grams failed to kill during 3 days. The woody portion of the shavings without the bark has no effect.

Poplar chips and dust.—When logs are prepared for digesting to pulp by cutting instead of grinding, the product of the cutter is screened. That which passes the screen is the dust referred to and the larger pieces the chips. The two portions differ only in the size of the pieces, the dust consisting of particles larger than coarse sawdust, while the chips are much larger. This material was from the mill at Luke, Md.

The aqueous extract from both chips and dust is fatal, the latter more rapidly so, since it extracts more readily. One kilogram of the chips, free and floating in 28 liters of water, with aeration, killed 10 quinnat salmon fry within 17 hours, the solution being colored slightly brown. Five hundred grams killed 2 out of 10 fry within 22 hours, 8 within 30 hours, and all within 50 hours. Three hundred grams of the dust, wrapped in cheese cloth, killed 10 fry within 22 hours, the water taking on a brown tinge within one-half hour. One hundred grams killed 10 fry between the third and fourth days.

Five hundred grams of the chips were placed in 28 liters, with aeration, and 1 mummichog, 1 sunfish, 1 goldfish, and 1 shiner were introduced. Four days later 1 kilogram of chips was added, but after 10 days all were alive. Three hundred grams of dust, wrapped in cheese cloth, were placed in 28 liters, with aeration, and 1 each of the species named added. They soon showed symptoms of being affected, but did not succumb, and on the fourth day 500 grams of dust were added. On the seventh day the mummichog and shiner were dead, but after 10 days no more deaths had occurred.

The action of fish in poplar-wood extract was unusual and seemed to be characteristic. They came to the surface when its effects began to be felt, but not for lack of oxygen, since the water was constantly aerated. Later they swam about in a slanting position, and the salmon fry assumed the perpendicular, some of them whirling slowly or rapidly on a vertical axis before succumbing.

Sulphite liquor.[a]—This is the spent liquor from the digesters in paper-pulp manufacture by the sulphite process, and is a dark-brown liquid of peculiar odor, markedly acid in reaction, and of 1.028 specific gravity at 11° C. It is a complex of imperfectly known substances designated technically as "sulphonated lignone bisulphite compounds," and is a waste of considerable importance occurring in large amounts in some regions. These samples were from the West Virginia Pulp and Paper Company, Covington, Va. The following table gives the results in detail:

Effect of sulphite liquor on perch, bass, and brook-trout fry.

[10-liter dilutions for perch and bass; 1 to 3 liters for trout fry. Perch and bass trials with 1 individual of each species.]

Dilution.	Time (hours) required to kill—		
	Perch.	Bass.	Brook-trout fry.
Without aeration:			
1 in 10	....	2½	
1 in 20	....	4¼	
1 in 30	....	....	22 (all of 12).
1 in 40	....	....	22–41 (all of 12).
1 in 50	....	....	48 (9 of 12).
1 in 60	76	47	
1 in 70	70	43	
1 in 75	....	....	113 (10 of 12).
1 in 80	46	46	
1 in 100	52	[a] 17	
1 in 120	46	29	
1 in 140	70	70	
1 in 150	....	[a] 18	
1 in 170	....	89	
1 in 200	....	48	
1 in 200 (second trial)	....	[a] 10	
With aeration:			
1 in 50	([b])	([b])	

[a] Days

[b] Not killed in 27 days.

The marked irregularity in the reaction of the fishes to the sulphite liquor is presumably due to their individual variation. Even with the rather extended series of trials the dilution which is certainly harmless to bass and perch can not be stated, but may be inferred to be slightly weaker than 1 in 200. Brook-trout fry in the sac stage are more resistant to the sulphite than either bass or perch. Aeration of the dilutions lessens their toxicity very markedly, 1 in 50 with continuous artificial aeration failing to kill either bass or perch during 27 days, when the trial was abandoned. It has, in fact, been suggested that the harmful effects of sulphite pollution in streams were due to the abstraction of dissolved oxygen from the water by the oxidizable sulphite and the consequent suffocation of fishes. Determinations of the oxygen on sulphite dilutions protected from the air appear to show that no loss of dissolved oxygen sufficient to account for the death of fishes occurs. A long, narrow-necked flask, holding about 1,300 c. c., was filled to the brim with a 1 in 100 sulphite dilution at 3°

[a] One sample of this was furnished by Dr. E. C. Levy, director of the laboratory of the city water department, Richmond, Va.

C. (tap water) and kept for 23 hours at 14° C. The dissolved gases were then boiled off and 6.5 c. c. of oxygen per liter were found, which is not much short of air saturation. Since there was a slight exposure to the atmosphere the experiment was repeated, using a 1 in 25 dilution at 14.5° completely sealed and held for 19 hours, at the end of which period its temperature was 18° C. and it contained 4 c. c. of oxygen per liter. A 1 in 25 dilution causes the death of all ordinary fishes in a few hours, but this could not occur from suffocation in water thus oxygenated.

Bleach sludge.—A clear, colorless, strongly alkaline liquid of 1.006 specific gravity at 9° C. and containing a heavy white sediment. The clear liquor alone was used. Chloride of lime is the basis of the bleaching liquor. This waste comes from paper-pulp manufacture by the soda-lime process.

In unaerated dilutions 1 in 300 killed perch within 23 hours, and 1 in 400 on the ninth day; 1 in 500 was abandoned as not fatal after 14 days. In aerated dilutions 1 in 300 killed perch in 20 to 44 hours and 1 in 400 was not fatal during 5 days. Aeration does not materially affect the toxicity.

TANNERY WASTES.

"*Sour bark liquor.*"[a]—A dark-colored acid waste containing small amounts of tannic acid from the aqueous extraction of oak bark; specific gravity 1.005 at 17° C.

In unaerated dilutions 1 in 2 killed sunfish in 30 minutes; 1 in 10 killed bass, perch, and shiners in 16 hours, 1 in 20 within 24 hours, 1 in 30 within 30 hours, and 1 in 40 within 24 hours; 1 in 50 failed to kill bass during 65 hours. 1 in 30, aerated, failed to kill bass and shiners during 47 hours. The dilutions darken in color very rapidly with aeration and more slowly when standing without artificial aeration.

"*Rocker sour bark liquor.*"[a]—A brownish, cloudy, acid liquor labeled "valueless in tannic acid;" specific gravity 1.007 at 10° C.

Unaerated, 1 in 30 fatal to bass in 41 to 68 hours; 1 in 60 failed to kill bass during 9 days, but was fatal to perch in 20 hours; 1 in 100 killed perch in 22 hours, 1 in 120 in 3 days, and 1 in 140 failed to kill perch in 4 days. Aerated, 1 in 20 fatal to bass in 18 hours; 1 in 30 not fatal during 6 days, but killed perch in 16 hours; 1 in 40 killed perch in 17 hours. Perch are much more susceptible to this liquor than bass. Like the other bark liquors, the dilutions grow very dark by exposure to air.

"*Dye-house liquor.*"[a]—A greenish liquid with some dark sediment about neutral in reaction; specific gravity 1.003 at 16° C.; without pronounced taste. Dilutions have a yellow color and the undiluted

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[a] From tannery of W. D. Byron & Sons, Williamsport, Md.

liquor tinges the stock bottle a yellow color, which does not readily wash out.

Undiluted and unaerated, bass are killed in 1½ hours. Unaerated, 1 in 2 was fatal to bass and perch in 19 hours; 1 in 5 to bass in 24 hours; 1 in 6 to perch and bass in 43 hours; 1 in 8 to bass in 20 hours, to perch in 23 to 42 hours; 1 in 10 to bass in 11 days, but failed to kill perch in 12 days; 1 in 15 failed to kill perch in 31 days, but killed bass in 9 days. The fish killed by the stronger dilutions were dyed yellow in color.

"Bate."[a]—A straw-colored liquor; specific gravity 1.004 at 9° C.; alkalinity 400 parts per million (Ca CO_3 equivalent); contains caustic lime.

The undiluted liquor killed a bass in 20 minutes. Unaerated, 1 in 5 killed bass in 16 hours, 1 in 6 in 4 days; 1 in 7 and 1 in 10 failed to kill during 4 days.

"Soak liquor" from hides.[b]—A colorless neutral liquid, of 1.002 specific gravity. It contains merely small amounts of sodium chloride soaked from the hides preserved in salt and appears to be harmless, the aerated undiluted liquor failing to affect bass during 4 days.

A sample of only 1 liter from Cumberland, Md., labeled "sample from soaks" is apparently of a similar nature, but was too small for extended trials. Undiluted and aerated, a bass was killed within 18 hours, but the fish was anemic and unhealthy at the beginning. A perch died in a 1 in 3 aerated dilution after 15 days, but since this fish had survived previous experiments with other pollutions, and the dilution was less than 3 liters in volume, the result tends rather to show that the soak has no toxic properties.

Bass changed directly from fresh Potomac water into a solution of common commercial salt of 1.025 specific gravity, which is approximately the density of sea water, are killed within a few minutes. Bass were killed in less than 16 hours, perch within 42 hours, by transfer from fresh water to a 1.015 solution. The change from fresh water to a 1.010 solution failed to kill either during 14 days.

"Sour liquor tail handler."—An acid liquor of pinkish color and foul odor, extracted originally from hemlock bark; specific gravity, 1.013.

Unaerated, 1 in 15 killed bass in 4 hours; 1 in 20 in 6 hours; 1 in 30 bass, perch, and mummichogs in 18 hours; sunfish in 24 hours; 1 in 40 killed bass and perch in 17 hours; 1 in 50 killed bass in 24 hours, perch in 29 hours; 1 in 60 killed bass in 29 hours and failed to kill perch in 54 hours. Aerated, 1 in 10 killed a shiner in 30 minutes, bass in 2 hours; 1 in 30 killed a mummichog in 41 hours, perch in 19 hours; 1 in 35 and 1 in 40 killed perch and bass in 17 hours; 1 in 50 failed to kill perch and bass during 5 days. The dilutions

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[a] From tannery of W. D. Byron & Sons, Williamsport, Md.

[b] From tannery of Hambleton Leather Company, Hambleton, W. Va.

are darkened by exposure to air, this taking place more rapidly when they are artificially aerated, which turns them grayish black.

"Lime liquor."[a]—A small sample of liquor showing caustic lime alkalinity.

Unaerated, 1 in 20 killed perch in 5½ hours, while 1 in 50 was not fatal during a trial of 30 days.

"Sample from hair washer."[a]—A cloudy grayish liquid, of 1.004 specific gravity at 14° C., and alkalinity 630 parts per million.

Unaerated, 1 in 10 killed perch in less than 17 hours, 1 in 20 in less than 23 hours, and 1 in 50 failed to kill during 13 days.

Lime and sodium sulphide.[b]—A dirty-yellowish, strongly alkaline (4,000 parts per million) liquor, specific gravity 1.015 at 7° C.

Unaerated, with bass, 1 in 5 fatal in 30 minutes, 1 in 120 in 70 hours, 1 in 150 failed to kill during 43 days, 1 in 180 fatal in 90 hours; with perch, 1 in 10 fatal in less than 20 hours, 1 in 40 in 19 hours, 1 in 100 in 21 hours, 1 in 160 in 20 hours, 1 in 180 not fatal during 4 days, and 1 in 200 not fatal during 44 days. Aerated, 1 in 100 killed perch in 17 hours, 1 in 150 killed perch in one case in 24 hours, in another only after 8 days. Brook-trout fry in the sac stage are more resistant than either perch or bass. With unaerated dilutions 1 liter in volume, at 10° C., 1 in 40 killed all of 12 fry in less than 17 hours, 1 in 50 killed 9 of 15 in 40 hours, and 1 in 80 killed 7 of 12 in 40 hours.

This liquor is the most toxic of all the tannery pollutions examined.

DYE WASTES FROM KNITTING MILLS.[c]

Spent chrome liquor.—A brownish, transparent, strongly acid liquor, of 1.005 specific gravity at 10° C.

Undiluted, the liquor killed bass in 1 hour. Unaerated, 1 in 10 killed bass in 3 hours, 1 in 20 in 20 hours, 1 in 30 in 16 hours, 1 in 40 in 45 hours, 1 in 50 in 44 hours, 1 in 60 not fatal in 45 hours; 1 in 30 fatal to perch in 24 hours, and 1 in 50 not fatal during 4 days. Aerated, 1 in 30 killed bass in 25 hours, 1 in 40 in 43 hours, 1 in 50 in 4 days, 1 in 60 in 43 hours, 1 in 70 in 48 hours; 1 in 30 and 1 in 60 failed to kill perch in 14 days.

This liquor acts as a coagulant of the turbidity in Potomac water.

Spent dye liquor.—A brownish, nearly neutral liquid, specific gravity 1.010 at 10° C.

The undiluted and unaerated liquor was fatal to bass in 3 hours. Unaerated, 1 in 2 was fatal to bass in 20 hours, 1 in 5 in 17 hours, 1 in 7 in 3 days, and 1 in 10 only after 88 days. The bass in 1 in 10 received no food and its death was no doubt hastened by starvation.

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[a] From tannery of United States Leather Company, Cumberland, Md.

[b] From J. R. Cover & Sons, Elkton, Md.

[c] From mill of Blue Ridge Knitting Company, Hagerstown, Md.

This dilution, though of a marked brownish-yellow color, is probably entirely harmless, and the result may be regarded as a control. Unaerated, 1 in 8.5 failed to kill perch during 8 days.

SEWAGE.

Sewage from human habitations is fatal to fishes on account of the exhaustion of the dissolved oxygen caused by the luxuriant growth of aerobic bacteria. Ten liters from the Seventeenth street canal in Washington killed bass and perch in less than 17 hours when the sewage was not aerated. Another portion aerated artificially failed to kill during the 53 hours in which the fish were kept under observation. A sample from the James Creek canal, unaerated, killed perch and bass at the end of 16 hours. With aeration no deaths or distress occurred during 48 hours. In the unaerated samples the fish give evidence of suffocation, leaping about spasmodically and then sinking weakly to the bottom as if exhausted. Oxygen determinations after the death of the fish showed about 1 c. c. per liter, and a sample in which no fishes had been held contained scarcely more.

WASTES FROM MANUFACTURE OF ILLUMINATING GAS.

Illuminating gas is itself markedly fatal to fishes. Gas from the service pipes was allowed to bubble into 20 liters of tap water near the surface for 3 to 4 minutes, and the resulting solution killed a perch within 20 hours.

WASTES FROM THE WATER-GAS PROCESS.

Filter effluent.—A cloudy grayish liquid with a moderate odor of gas; specific gravity 1.00 at 24° C. This is the effluent from filter beds which remove the tarry oils at the plant of the Washington Gas Light Company.

Undiluted and unaerated, it was fatal to bass within 6 minutes. Unaerated, 1 in 10 killed bass in 22 hours, 1 in 20 killed perch in 68 hours, 1 in 30 failed to kill perch during 32 days, and in 1 in 50 a perch spawned after 24 days and died the next day. Control perch usually died after spawning.

Tar from wells.—This sample consisted of two parts, a floating black tarry liquor and a grayish watery liquid beneath.

The lighter liquid, which floats diluted 1 in 1,000, unaerated, killed a perch in a few minutes, and 1 in 100,000 caused evident distress within 9 hours, but did not kill until the fifth day.

The heavier grayish liquid, diluted to 1 in 40, unaerated, was fatal to perch within a few hours, while 1 in 80 failed to kill during 34 days and 1 in 100 had no effect during a trial of 21 days.

Tarry liquor.—A black, tarry, strongly aromatic liquor, lighter than water; specific gravity 0.95 at 21° C. It has the highest toxicity of all the wastes of whatever nature with which experiments were made. It does not visibly mix with water, but spreads out in a film on the surface. The dilutions were made by volume, as in other cases, though evidently only a small portion of the liquor attains solution in the water.

Eight solutions stronger than 1 in 100,000 were first tried, but all were fatal in a few minutes or hours. Unaerated, 20 liters of 1 in 100,000 killed perch in 102 to 117 hours; 1 in 200,000, in 100 to 115 hours; 1 in 300,000, in 52 to 67 hours, and 1 in 400,000 killed a perch in 12 days, but failed to kill bass during 41 days. A solution of 1 in 500,000 was made up by weighing off 40 milligrams of the liquor in a watch glass and placing it with the glass in 20 liters of water. Two perch lived in this for 24 days, when one spawned and both died the next day. The weather had become warm and the temperature of the dilution reached 19° C. A dilution of 1 in 500,000 may be considered practically harmless to perch and bass.

Aeration reduces markedly the poisonous effect. Aerated, 1 in 60,000 killed one perch in 24 hours, another after 3 days; 1 in 80,000 failed to kill during 11 days, and 1 in 100,000 during 9 days.

The sealing of the water from contact with the air, by means of the surface film, may possibly contribute slightly to the harmful effects in the higher dilutions not artificially aerated. That the substance is tremendously poisonous, however, is evident from the fact that even dilutions as weak as 1 in 40,000 kill in a very few hours, long before the exhaustion of oxygen could play a part. Moreover, the symptoms at death are manifestly not those of suffocation. Nearly all the fishes dying from gas wastes in the higher dilutions display characteristic movements. There is a rapid nervous fluttering of the fins, particularly the pectorals, with rapid respiration, and the body may assume the perpendicular. They sometimes appear to be dying for days before they finally succumb.

WASTES FROM THE COAL-GAS PROCESS.

Tar from wells.—This is ordinary coal tar, a thick black liquid with the typical odor. When dropped into water, the main portion of the drop sinks, while a lesser part separates and spreads gradually into a surface film.

The dilutions were not made volumetrically. The amount desired was weighed in drops on a strip of bristol board and then smeared in a thin layer and the strip placed in the measured quantity of water, which was stirred thoroughly. Only unaerated dilutions were used. One of 1 to 4,000 (5 grams of tar in 20 liters of water) was fatal to perch within less than 19 hours, 1 to 66,666 was fatal to both bass and perch in 4 days, and 1 to 200,000 failed to kill perch during a trial of 34 days.

Ammoniacal liquor.[a]—A nearly clear pink liquid of marked ammoniacal odor, specific gravity 1.029 at 14° C.

Unaerated, 1 in 100 killed perch in 5 minutes; 1 in 1,000, in 40 minutes; 1 in 2,000, in less than 18 hours, and 1 in 3,000 failed to kill during 24 days.

Effluent from ammonia sludge bed.[b]—A clear watery liquid with no very marked odor, specific gravity about 1.00 at 12° C.

Undiluted and unaerated, the effluent killed bass in 18 minutes. Unaerated, 1 in 10 killed perch in 20 hours, and 1 in 100 was not fatal during 34 days.

WASTES FROM BOTH WATER AND COAL-GAS PROCESSES.

Lime from "purifiers."—This is a coarse gray powder consisting originally of quicklime and having a strong odor of illuminating gas. The gas is passed through large tanks of the substance in order to remove carbon dioxide.

Five grams in 10 liters of unaerated tap water caused distress to perch in a few hours and was fatal in less than 21 hours; 1 gram in 10 liters, unaerated, killed a bass within about 69 hours; 1 gram in 20 liters, unaerated, failed to kill bass during 41 days.

Calcium oxide alone is fatal to trout fry at about 18 parts per million.

Iron oxide from "purifiers."—Iron rust is used to purify the gas of sulphur compounds. Iron filings and small pieces are mixed with wet wood shavings or thin chips and allowed to rust. The material is held in large purifiers, through which the unrefined gas is passed. The sample received for the tests was of a dark-brown color, with a strong odor of gas.

Twenty grams in 10 liters of water, unaerated, killed a perch in less than 20 hours; 5 grams in 10 liters killed a perch in 29 hours; 4 grams in 20 liters was fatal to perch in 56 hours, and 2 grams in 20 liters failed to kill during 9 days.

SUMMARY.

In reviewing the effects of the various wastes of industrial processes in the Potomac watershed, it appears that a wide gap in poisonous properties exists between the liquid wastes which come from the manufacture of illuminating gas and those from all other sources. The most toxic of the latter are made harmless by the addition of a few hundred parts of water, while the tarry by-products from the gas works require hundreds of thousands parts of water before they are diluted to the point of safety.

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[a] From the Clapp Ammonia Company, Washington, D. C. It comes originally from the ammonia well of the gas-manufacturing company.

[b] From works of the Clapp Ammonia Company, which recovers ammonia from the waste products of the coal process of gas manufacture.

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D.

CLASSIFICATION OF THE PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 192.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists can be had on application.

Most of the above publications can be obtained or consulted in the following ways:

1. A limited number are delivered to the Director of the Survey, from whom they can be obtained, free of charge (except classes 2, 7, and 8), on application.
2. A certain number are delivered to Senators and Representatives in Congress, for distribution.
3. Other copies are deposited with the Superintendent of Documents, Washington, D. C., from whom they can be had at practically cost.
4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they can be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the fourteenth in Series H, the eighteenth in Series L, and the twentieth in Series M, the complete lists of which follow (PP=Professional Paper; WS=Water-Supply Paper):

SERIES H—FORESTRY.

PP 4. The forests of Oregon, by Henry Gannett. 1902. 36 pp., 7 pls.

PP 5. The forests of Washington, a revision of estimates, by Henry Gannett. 1902. 38 pp., 1 pl.

PP 6. Forest conditions in the Cascade Range, Washington, between the Washington and Mount Rainier forest reserves, by F. G. Plummer. 1902. 42 pp., 11 pls.

PP 7. Forest conditions in Olympic Forest Reserve, Washington, from notes by A. Dodwell and T. F. Rixon. 1902. 110 pp., 20 pls.

PP 8. Forest conditions in the northern Sierra Nevada, California, by J. B. Leiberg. 1902. 194 pp., 12 pls.

PP 9. Forest conditions in Cascade Range Forest Reserve, by A. D. Langille, F. G. Plummer, A. Dodwell, T. F. Rixon, and J. B. Leiberg, with introduction by Henry Gannett. 1903. 298 pp., 41 pls.

PP 22. Forest conditions in the San Francisco Mountains Forest Reserve, Arizona, by J. B. Leiberg, T. F. Rixon, and A. Dodwell, with an introduction by F. G. Plummer. 1904. 95 pp., 7 pls.

PP 23. Forest conditions in the Black Mesa Forest Reserve, Arizona, prepared by F. G. Plummer, from notes by T. F. Rixon and Arthur Dodwell. 1904. 62 pp., 7 pls.

PP 29. Forest conditions in the Absaroka division of the Yellowstone Forest Reserve, Montana, and the Livingston and Big Timber quadrangles, by J. B. Leiberg. 1905. 48 pp., 3 pls.

PP 30. Forest conditions in the Little Belt Mountains Forest Reserve, Montana, and the Little Belt Mountains quadrangle, by J. B. Leiberg. 1904. 75 pp., 2 pls.

PP 33. Forest conditions in the Lincoln Forest Reserve, New Mexico, by F. G. Plummer and M. G. Gowsell. 1904. 47 pp., 12 pls.

PP 37. The Southern Appalachian forests, by H. B. Ayres and W. W. Ashe. 1905. 291 pp., 37 pls.

PP 39. Forest conditions in the Gila River Forest Reserve, New Mexico, by T. F. Rixon. 1905. 89 pp., 2 pls.

WS 192. The Potomac River basin: Geographic history—rainfall and stream flow—pollution, typhoid fever, and character of water—relation of soils and forest cover to quality and quantity of surface water—effect of industrial wastes on fishes, by H. N. Parker, Bailey Willis, R. H. Bolster, W. W. Ashe, and M. C. Marsh. 1907. 364 pp., 10 pls.

SERIES L, QUALITY OF WATER.

WS 3. Sewage irrigation, by G. W. Rafter. 1897. 100 pp., 4 pls. (Out of stock.)

WS 22. Sewage irrigation, Pt. II, by G. W. Rafter. 1899. 100 pp., 7 pls. (Out of stock.)

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WS 64. Accuracy of stream measurements, by E. C. Murphy. 1902. 99 pp., 4 pls.

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WS 150. Weir experiments, coefficients, and formulas, by R. E. Horton. 1906. 189 pp., 38 pls.
WS 162. Destructive floods in the United States in 1905, by E. C. Murphy and others. 1906. 105 pp., 4 pls.
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MARCH, 1907.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, Director
POTOMAC RIVER DRAINAGE BASIN
ABOVE WASHINGTON
SHOWING
MEAN ANNUAL PRECIPITATION
FOR DECADE 1895-1905
Scale 1: 633,600
Contour interval 500 feet. Sketch contours dotted
Datum is mean sea level
Topography
Compiled from U. S. Geological Survey atlas sheets and other sources
Lines of equal precipitation
based on all available observations
reduced to the common period 1895-1905
By Cleveland Abbe, jr.
June, 1906
LEGEND
Lines of equal precipitation in inches
Hypothetical lines of equal precipitation in inches