Water-Supply and Irrigation Paper No. 76

Series { L, Quality of Water, 4
M, Methods of Hydrographic
Investigation, 3

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

OBSERVATIONS ON THE FLOW OF RIVERS

IN THE

VICINITY OF NEW YORK CITY

BY

HENRY ALBERT PRESSEY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

The 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) Topography Atlas of the 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 may be had on application.

The Bulletins, Professional Papers, 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, Methods of hydrographic investigation; N, Water power; O, Underground waters; P, Hydrographic progress reports. Complete lists of papers relating to water supply and allied subjects follow. (B=Bulletin, PP=Professional Paper, WS=Water-Supply Paper.)

SERIES I—IRRIGATION.

WS 2. Irrigation near Phoenix, Ariz., by A. P. Davis. 1897. 98 pp., 31 pls. and maps.
WS 5. Irrigation practice on the Great Plains, by E. B. Cowgill. 1897. 39 pp., 11 pls.
WS 9. Irrigation near Greeley, Colo., by David Boyd. 1897. 90 pp., 21 pls.
WS 10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker. 1898. 51 pp., 11 pls.
WS 13. Irrigation systems in Texas, by W. F. Hutson. 1898. 68 pp., 10 pls.
WS 17. Irrigation near Bakersfield, Cal., by C. E. Grunsky. 1898. 96 pp., 16 pls.
WS 18. Irrigation near Fresno, Cal., by C. E. Grunsky. 1898. 94 pp., 14 pls.
WS 19. Irrigation near Merced, Cal., by C. E. Grunsky. 1899. 59 pp., 11 pls.
WS 23. Water-right problems of Bighorn Mountains, by Elwood Mead. 1899. 62 pp., 7 pls.
WS 32. Water resources of Porto Rico, by H. M. Wilson. 1899. 48 pp., 17 pls. and maps.
WS 43. Conveyance of water in irrigation canals, flumes, and pipes, by Samuel Fortier. 1901. 86 pp., 15 pls.
WS 70. Geology and water resources of the Patrick and Goshen Hole quadrangles, Wyoming, by G. I. Adams. 1902. 50 pp., 11 pls.
WS 71. Irrigation systems of Texas, by T. U. Taylor. 1902. 137 pp., 9 pls.
WS 74. Water resources of the State of Colorado, by A. L. Fellows. 1902. 151 pp., 14 pls.

The following papers also relate especially to irrigation: Irrigation in India, by H. M. Wilson, in Twelfth Annual, Part II; two papers on irrigation engineering, by H. M. Wilson, in Thirteenth Annual, Part III.

SERIES J—WATER STORAGE.

WS 33. Storage of water on Gila River, Arizona, by J. B. Lippincott. 1900. 98 pp., 33 pls.
WS 40. The Austin dam, by Thomas U. Taylor. 1900. 51 pp., 16 pls.
WS 45. Water storage on Cache Creek, California, by A. E. Chandler. 1901. 48 pp., 10 pls.
WS 46. Physical characteristics of Kern River, California, by F. H. Olmsted, and Reconnaissance of Yuba River, California, by Marsden Manson. 1901. 57 pp., 8 pls.
WS 58. Storage of water on Kings River, California, by John B. Lippincott. 1902. 100 pp., 32 pls.
WS 68. Water storage in Truckee Basin, California-Nevada, by L. H. Taylor. 1902. 90 pp., 8 pls.
WS 73. Water storage on Salt River, Arizona, by A. P. Davis. 1902. 54 pp., 25 pls.

The following paper also should be noted under this heading: Reservoirs for irrigation, by J. D. Schuyler, in Eighteenth Annual, Part IV.

SERIES K—PUMPING WATER.

WS 1. Pumping water for irrigation, by Herbert M. Wilson. 1896. 57 pp., 9 pls.
WS 8. Windmills for irrigation, by E. C. Murphy. 1897. 49 pp., 8 pls.
WS 14. New tests of certain pumps and water lifts used in irrigation, by Ozni P. Hood. 1898. 91 pp., 1 pl.
WS 20. Experiments with windmills, by T. O. Perry. 1899. 97 pp., 12 pls.
WS 29. Wells and windmills in Nebraska, by E. H. Barbour. 1899. 85 pp., 27 pls.
WS 41. The windmill; its efficiency and economic use, Part I, by E. C. Murphy. 1901. 72 pp. 14 pls.
WS 42. The windmill, Part II (continuation of No. 41). 1901. 73-147 pp., 15-16 pls.

(Continued on third page of cover.)

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, D. C., June 23, 1902.

SIR: I transmit herewith manuscript for Water-Supply and Irrigation Paper No. 76, by H. A. Pressey, entitled Observations on the Flow of Rivers in the Vicinity of New York City.

Respectfully,

F. H. NEWELL,
Hydrographer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

OBSERVATIONS ON THE FLOW OF RIVERS IN THE VICINITY OF NEW YORK CITY.

By H. A. PRESSEY.

INTRODUCTION.

One of the chief resources of the United States is its water supply. The prominent industrial position of several States is due largely to the abundance of their available water. It has recently been stated that "the preeminent position of the State of New York is due almost entirely to her great natural resources;" that "her inland rivers, with their great water powers, have been in the past and will continue to be in the future a perpetual source of wealth," and that "the history of the State's progress during the nineteenth century is largely a history of the development of her water resources." These remarks apply quite as aptly to some of the New England States, as they could not have held the front rank in the industrial world for so many years were it not for the very extensive utilization of the magnificent waterfalls of that region. In the Southern Atlantic States the great developments during the last few years are due largely to the development and utilization of water powers.

There is not a State along the Atlantic coast, except Delaware, that does not contain water powers, developed and undeveloped, and, contrary to the opinion of many, there never was a decade in the history of our country when the development of water power made such strides as during the last ten years. According to the returns of the Twelfth United States Census the increase in the utilization of water power in the United States in the ten years from 1890 to 1900 was about 30 per cent, or 472,361 horsepower. In some States this increase was remarkable, as, for instance, in Maine, where in the last decade the developed power increased 60 per cent.

The importance of our water powers as a source of wealth can hardly be overestimated. This power is not confined, however, to the Eastern States, for in the great Central Northwest, on the Pacific slope, and elsewhere there are water powers of great size and value, many of which form the basis of the industrial life of large communities. In the broad, flat plains of the United States west of the Mississippi the rivers are valuable from another standpoint. In this region the streams commonly lack the fall required for power development, but here the water supply is, perhaps, more vital to the life of the region than in the coastal States. Great areas of land depend for water largely upon the rivers in their vicinity and upon artificial means for raising and distributing it over their soils. Without water there can be no life in this region; with water, vast areas can be reclaimed as agricultural land of great fertility.

In most parts of the country the public water supply of the cities and towns must be derived from the rivers. Large sums are expended every year in conducting water from the streams to the centers of population. Before this money is expended it is of the greatest importance to know that there is sufficient water at all times for the use of the town. Too often have great hydraulic works been built before proper investigation has been made of the flow of a stream, and great financial loss has resulted.

It is to furnish information upon which to base estimates of available water supply that the Hydrographic Division of the United States Geological Survey has been, during the last fourteen years, collecting data in regard to the flow of rivers in the United States, and their variation from season to season and throughout a series of years. The necessity for such data is frequently brought to the attention of the engineer, sometimes in a most startling manner. The lack of this information frequently leads to the most disastrous mistakes in the construction of hydraulic works. One of the best examples of this in the design of a hydraulic plant was the construction of a dam and water-power plant at Austin, Tex. After an expenditure of $1,600,000 it was found that a grave mistake had been made in the estimate of the low-water flow. The works were constructed by the city in accordance with a vote of the citizens of Austin in 1890. It was estimated that 14,000 horsepower could be developed, and the people felt that their city was to become a great manufacturing center. No hydrographic data had been collected, except from the hazy memory of the "oldest inhabitant." In the spring of 1890 a measurement of flow giving 1,000 cubic feet per second was taken as the minimum. This estimate was more than five times too great, as was shown by subsequent measurements. An error of 500 per cent had been made in the estimate, but this was not ascertained until the works were nearly completed.

Mistakes of this kind have occurred in every part of the country in hydraulic works. The Sweetwater dam in California in a good example of a project carried through on insufficient data. The dam was built after a series of wet years and was soon after filled to overflowing, so that increased spillways were constructed, but since that time the water in the reservoir has never reached an elevation near the crest of the spillways, and during most of the time there has been the greatest scarcity of water.

The Bear Valley dam is a more marked case, as the reservoir formed by the dam has been practically dry for several years, so that wells have been driven in the bottom of it.

The Gila Bend, Arizona, project is another example of the expenditure of a large sum—$900,000—upon insufficient data, and subsequent abandonment of the scheme. In this project the dam was carried away before its completion, but had it been completed the scheme must have proved a financial failure.

Many diversion canal projects for irrigation have been either partial or complete failures on account of shortage of water; that is, developments have been made far beyond the capacity of the stream.

A great number of water-power plants have been constructed upon insufficient data, and later, auxiliary steam has been found necessary. Allowance was not made in the original estimates, so that in a number of instances the project has been found unprofitable. Knowl- of the flood flow is also of great importance in designing the dams and waste ways.

Frequently the cause of such errors is a complete ignorance of the hydrographic conditions in the drainage basin of the stream and often of the region in which the stream is located. In a few cases no adequate efforts have been made to obtain information; perhaps a single measurement may have been made at a time when a local resident informed the investigator that the "river is now as low as it ever gets." In order to test the accuracy of such methods, the writer has often asked old inhabitants on the banks of the river as to the variation in the river height, and has been informed that "it is now at its lowest stage;" or, that "it never falls more than 2 or 3 inches below its present height." At a later visit to the stream in the same season the river surface has been found to be at an elevation 2 or 3 feet below its previous stage. The word of the oldest inhabitant is sometimes fairly reliable as to high water, but his information as to low-water stages should be carefully checked, and the fact that a number of the inhabitants say that the river never goes lower is not sufficient evidence upon which to construct hydraulic works.

Rainfall data are often used in discussing the variation of flow of a stream, and numerous theories and formulas are applied to show that the flow can never fall below a certain amount, these theories to be sadly shaken later, when measurements are made and the facts ascertained. In a few cases greater weight has been given to these theories than to actual measurements, even though the measurements were made by a careful and reliable engineer. The measurements were lower, perhaps, than theory would suggest, and therefore the measurements must be wrong.

In studying the flow of a stream every possible source of information should be utilized—even the ideas of the oldest inhabitants—but to most engineers it is very reassuring to know that actual measurements of the discharge have been made and are available for use. If measurements of the stream under consideration have not been made, then results obtained from measurements of rivers in the immediate vicinity can be used to advantage, care being taken that the hydrographic, topographic, geologic, and forest conditions in the two basins are similar.

As an example of the difficulties under which a prospective investor labors, there are now before the writer reports upon a certain stream in New York State made by five different engineers, all of good standing, in which estimates of the minimum flow of the stream under consideration vary from 0.20 to 0.40 cubic foot per second per square mile; that is, the minimum flow given by one engineer is just twice that given by another. As the development of a water power is limited largely by the low-water flow, the uncertainties arising from such divergent opinions are apparent. Since these reports were made (1900–1901) the flow of this stream has been measured, and the lowest estimate made by the engineers has been shown to be at least 100 per cent too great. In estimates of this kind facts are needed—that is, actual measurements of discharge.

No further discussion is probably necessary to convince most thinking people that the measurement of the larger streams of the United States is an important undertaking, and that capital will be invested in power developments, irrigation, sanitary and other hydraulic works more freely when information as to the flow of the streams is available.

In making measurements of streams it is of course desirable that rapid and economical methods be used, if such are of sufficient accuracy. Methods of stream measurements have been discussed in Water-Supply Paper No. 56, and it is not the purpose of this paper to deal with that question extensively, but rather to point out certain facts developed, during the last few months, by measurements of streams in the southern part of New York State, with the idea that some of the data obtained from these measurements may be useful in studying the flow of other streams and may assist in the selection of methods that will expedite the work and yet give results sufficiently accurate for all practical purposes.

In considering the future demands of the city of New York for water several additional sources of supply have been suggested: Housatonic River, Tenmile River, Wallkill River, Rondout Creek, Esopus Creek, and Catskill Creek, the Hudson River or some of its upper tributaries, Lake George, Lake Champlain, and the Great Lakes. The three last-named sources have been discussed in print somewhat extensively[a] and will not be taken up here. It has been found that the supply from Lake George would not be adequate; that Lake

[a] Report of Merchants' Association of New York on the water supply of the city of New York, August, 1900.

Champlain is at too low an elevation for economical use, and that the supply from the Great Lakes would entail great and unnecessary expense. The water from the Hudson River might be taken near its headwaters and conducted to New York City by a long aqueduct, or the intake might be located just above Poughkeepsie, in which case the water would have to be pumped from the river and filtered before delivery to the city. In either case it is important to know the discharge of the Hudson at various seasons of the year to determine the quantity available and also the effect of the diversion of water upon the regimen of the river.

The United States Geological Survey has for several years been measuring the daily flow of streams throughout the United States, the results of these measurements being used for different purposes, including irrigation, water-power, and sanitary constructions.

Measurements of flow of Schroon River at Warrensburg and of the Hudson at Fort Edward and Mechanicville have been made, also of the Mohawk and its chief tributaries at various points, and the results of these have been published in the annual reports.

The measurements of the rivers discussed in this paper were started at the suggestion of Mr. George N. Birdsall, chief engineer Bureau of Water Supply, New York City, in order that data might be available for investigations as to additional water supply for New York City. The following stations were established by the United States Geological Survey during the summer of 1901 and have been maintained continuously since that time.

Gaging stations on rivers near New York City.

Stream.	Location of gaging station.	Drainage area—		
		Above proposed reservoir.	Above gaging station.	Above mouth.
		Sq. miles.	*Sq. miles.*	*Sq. miles.*
Tenmile River	Dover Plains, N. Y	200	195	195
Housatonic River	Gaylordsville, Conn	1,020	1,020	1,580
Catskill Creek	South Cairo, N. Y	140	260	394
Esopus Creek	Kingston, N. Y	242	312	417
Wallkill River	New Paltz, N. Y	464	735	779
Rondout Creek	Rosendale, N. Y	184	365	[a]369
Fishkill Creek	Glenham, N. Y	158	198	204

[a] Above junction with Wallkill River.

A reconnaissance of each of these streams was made, and stations were selected at points where measurements could be most accurately made, and as far as practicable at points where it was thought knowledge of the flow would be most desired in the future study of these watersheds as sources of increased supply for New York. The results of the observations at these stations have been published in the Water-Supply Papers of the Survey. The height of the water at each station has been noted twice each day by a local observer and current-meter measurements have been made at frequent intervals by a hydrographer. From these meter measurements a rating curve has been drawn for each station which shows the relation between the height of the water in the river and the discharge. From this curve and the daily mean gage height the flow of the river for each day in the year since the establishment of the station can be determined. These data will be of the greatest importance to the engineers selecting the source of supply, as they furnish the first continuous record of the flow of these streams and give a basis upon which to compute the supply available from each stream, which, with the topographic maps of the survey and the detailed surveys of the reservoir sites, will give complete data for the estimate of the quantity of water that can be furnished by each of these drainage basins and of the relative cost per million gallons of the supply from each.

In addition to the measurement of the discharge, determinations of turbidity, color, alkalinity, and hardness have been made upon each of these streams and are now being continued, and it is thought that these data will prove valuable in the final selection of the new source of supply. Results are given in the Water-Supply Papers of the United States Geological Survey, and are tabulated at the end of this paper.

In making gagings at these stations it was thought desirable to investigate the variations of flow in different parts of the river channel, in order to determine at what points the velocity could be measured to ascertain the mean velocity in the channel without unnecessary expense or loss of time. Before taking up the measurements and the vertical velocity curves constructed, it may not be out of place to describe briefly some of the methods used for the measurement of streams.

METHODS OF MEASURING VELOCITY IN RIVER CHANNELS.

There are in common use a number of methods of measuring the flow of rivers. In general these involve the determination of the mean velocity of the current and the area of the cross section of the stream. The latter is easily computed from soundings made at frequent intervals across the channel. These soundings must be taken at intervals so short that the bottom of the river may be considered a straight line between soundings. Usually the velocity of the current is determined in sections of the river channel, these sections extending between the points of soundings. The summation of the area of each of these sections gives the total area of the cross section. When the total flow of the river is known and is divided by the area of the cross section the result is called the mean velocity of the river. It is this mean velocity that we try to determine in any method of stream measurement, but, as a matter of fact, it can not be actually determined until the total flow is known.

In the determination of the mean velocity of the current there are a number of methods giving results more or less accurate, all of which should be familiar to the engineer, so that the method best suited to the conditions at hand may be applied.

FLOATS.

GENERAL METHODS.

Floats are frequently employed to determine the velocity of the current. There are three general types in common use: First, surface floats; second, subsurface or double floats; third, tube or rod floats. The general method of procedure is the same whichever form of float is used. The site for making a float measurement should be on a straight reach, having a fairly uniform cross section. The flow of the water should be regular, without sudden rapids or stretches of still water, and should exhibit no tendencies to form eddies or cross currents caused by irregularities in the channel or resulting from the effect of a sharp bend above the reach. The course of the floats should have a length of from 100 to 300 feet, and the areas of cross section at the upper and lower ends of this course should be carefully determined by soundings. When courses more than 100 feet in length are selected, it is desirable that additional cross sections, at equal intervals from one another, should be measured. As a preliminary step, a base line should be laid out by tape on the bank as nearly as possible parallel with the stream, and points should be marked opposite the cross sections to be used. If the stream is not too wide the soundings in the cross sections can be taken most conveniently along a tagged rope stretched across the channel at right angles to the base. If the depth does not exceed 4 feet this can be done by wading, the depth being read on a rod graduated to feet and tenths. Should the depth of the channel or the temperature of the water make wading impossible, a boat may be used. On large rivers, where a tagged rope can not be employed, the boat from which the soundings are to be made should be located by simple triangulation. Soundings should be read to tenths of a foot and be taken preferably at equal distances apart. In deep rivers a tagged rope or chain with lead weight can be substituted for the rod.

SURFACE FLOATS.

In reconnaissance work, in which the equipment is as a rule limited by transportation facilities, surface floats consisting of chips will be found most convenient. The use of rod floats, though giving more directly the mean velocity, has many disadvantages, and should not be attempted unless the time and opportunity permit of obtaining floats of the required lengths. In the simplest case but one man is needed to make the observations. The surface floats should be thrown into the stream a considerable distance above the first cross section. The hydrographer should attempt to start the floats, successively, at different distances from the shore in order to determine the velocity in different parts of the channel. The time of the passage of each float between the upper and lower cross section should be noted, preferably by a stop watch, and also the position of each float with respect to the tags on the ropes. This will enable the hydrographer to determine whether or not he succeeds in covering the different parts of the stream, and it will serve as an aid in the computation. The observations should be continued until all parts of the stream have been covered.

On wide rivers range poles may be established on opposite shores to mark the upper and lower cross sections. The location of each float as it crosses these imaginary lines can readily be recorded by triangulation. A light traverse plane table will be found especially useful in obtaining a graphic record.

The surface floats show approximately the surface velocity of the stream at the point of measurement. The results obtained by this method are subject to errors due to wind and surface currents and eddies. The velocity shown is that of the surface of the river, while that required for computation of discharge is the mean velocity of the cross section. Unfortunately, the relation of the surface to the mean velocity of the vertical is not constant, yet for streams of the same general character of bed, banks, velocity, etc., the ratio is sufficiently constant to allow the mean velocity to be computed with fair precision from the surface velocity observations.

SUBSURFACE OR DOUBLE FLOATS.

The double float consists of a small surface float connected by a fine cord to a larger subsurface float, which is so arranged that it shall always remain at the point of mean velocity in the current. The surface float may consist of a flat block of wood or a tin water-tight drum, which floats upon the surface of the water with sufficient buoyancy to prevent the larger subsurface float from sinking. The subsurface float may consist of two sheets of galvanized iron set at right angles, weighted at the bottom, with an air-tight cylindrical device at the top, in order that it may at all times keep its vertical position. A round, hollow cylinder of tin also makes an excellent subsurface float. The tension on the connecting cord should be at least 2 or 3 pounds, and the cord should be of silk and as fine as possible in order that its resistance to the current should not have a marked effect upon the velocity of the floats. The length of the cord should be so regulated that the lower float may be at the point of mean velocity, and the resistance of the upper float and the cord should be made as small as practicable. A small flag should be placed upon the upper float in order that its position may be easily determined at all times. The chief objection to double floats is the uncertainty as to whether the cord is vertical and the consequent uncertainty as to the position of the subsurface float. Another objection is the modifying effect of the surface float and the cord upon the velocity of the lower float, as in great depth the exposed surface of the cord may exceed that of the float. A third objection is the uncertainty as to the vertical position of the lower float, as, owing to changes in depth of water and local conditions, the point of mean velocity may change, whereas the length of the connecting cord must remain constant in each run. This may introduce a noticeable error if the increase in depth is large, as the retarding effect of the slow velocity near the bottom of the river will not be felt by the float, and the result will show too high a velocity. The lower float may tip slightly, owing to eddies or other causes, thereby changing the exposed surface, or, unknown to the observer, the lower float may strike a bowlder, causing its velocity to be checked. In many cases these objections would not be at all serious, but, in general, when floats are to be used better results can be obtained, when the depth is not too great, by the use of rod or tube floats.

ROD OR TUBE FLOATS.

These consist of long, cylindrical tin tubes or wooden poles, 2 or 3 inches in diameter, weighted at the bottom, so that they will float vertically with only 2 or 3 inches exposed above the water surface. These rods integrate the velocities in a vertical section and give approximately the mean velocity of the current. It is important that they should extend nearly to the bottom, as otherwise the velocity, as shown, will be too great, yet the greatest care must be taken that they do not at any time scrape upon the rocks at the bottom or sides so as to retard their movement. Rod floats are free from many of the objections to double floats, as there is no uncertainty as to their position nor as to the point of mean velocity in the channel. They are not, however, suitable for very deep rivers, or for channels where the depth varies considerably, or where weeds grow in the bed of the stream. Mr. James B. Francis has stated that the rod floats travel a little faster than the mean velocity of the water even for the depth of immersion. The float will be subject to pressures proportional to the square of the relative velocities of the water at different points, and when it has attained its full speed there will be equilibrium between these different pressures. This equilibrium may exist, however, when the speed of the float is somewhat different from the mean velocity of the water, the latter being the arithmetical mean of all the different velocities throughout the depth of immersion. The following formula for correcting an observed velocity was derived by James B. Francis from his Lowell experiments:

$$V_m = V_o\left[1 - .116\left(\sqrt{\frac{d-d'}{d}} - 0.1\right)\right]$$

Where V_m is equal to true mean velocity in vertical, V_o equals observed velocity of tube, d equals mean depth along path of tube, d^1 equals depth of immersion of tube.

Col. Allan Cunningham[a] has, however, calculated that such floats move somewhat slower than the water in which they are immersed. The error of assuming that the velocity of the tube represents the mean velocity in the vertical will not be material unless tubes too short are used, in which case the velocity as shown by the tube should be somewhat reduced.

WEIRS.

By the method of weirs the discharge of the stream is computed by means of an empirical formula, which varies for different types of dams or weirs. On creeks or small rivers it is sometimes practicable to build a timber weir across the channel, causing the total flow of the stream to pass over the sharp edge of the weir crest. By observing the head on the weir, computations of the flow can be made. This is probably the most accurate method applicable to small streams. On large rivers, however, the cost of a weir is usually so great as to be prohibitive, so that if there is not a weir or dam already in the stream it is necessary to resort to measurements by floats or current meters.

On many of the rivers of moderate size the conditions are unfavorable for successfully applying either of these methods. For instance, on streams used for manufacturing purposes dams occur at frequent intervals, interrupting the regular flow, and in many cases holding back the night flow for use during the following day, so that the discharge during the night may be either nothing or a very small percentage of the day flow. Then, too, the shutting down of the mill wheels for an hour at noon may have a pronounced effect upon the results of float or meter measurements made below the mill. Unfortunately these variations are not always apparent to the hydrographer, and surprise and annoyance are caused by finding that the river height differs by several tenths from the gage as read by the regular observer a short time before the hydrographer arrived at the station.

Under the conditions described, better results can undoubtedly be obtained if there exists upon the stream a good dam which can be used as a weir. It should have a level, even crest and a constant cross section, with sufficient pondage to reduce the velocity of approach, and it should be free from leakage. Masonry dams are better for

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[a] Recent hydraulic experiments: Min. Proc. Inst. Civil Eng., Vol. LXXI 1883.

A. CURRENT METER IN USE, SUSPENDED FROM A BRIDGE.

B. CABLE AND CAR USED TO MEASURE DISCHARGE OF RIVER this purpose, for they are more likely to be tight and to have an even crest. Timber dams, although level when first constructed, are likely to settle at various points, thus producing an uneven crest elevation. There are, however, many good timber dams practically free from leakage and with crests sufficiently uniform for accurate work.

Having selected a dam as the proper site for a station, a careful survey must be made of the crest line and of the upper and lower slopes, so that it can be compared with other dams or with experimental sections for which the coefficients of flow are known. The experiments of James B. Francis, of Ftèley and Stearns, and of John R. Freeman, George W. Rafter, and others at Cornell University, have given coefficients upon many sections of various forms. It is probable that the dam selected for the station will not be exactly like any of the experimental forms, but it will resemble some of them so closely that coefficients can be selected for the computations.

When the mill gates are open a part of the flow is diverted from the river through the mill race, the gates, and the tailrace.

The amount of the diversion must of course be measured and added to the quantity flowing over the dam, in order to determine the total discharge of the stream. In many factories the quantity flowing through the wheels varies from day to day, and also during different hours of the day, so that careful records must be kept of gate openings, in order that proper allowance may be made for these variations. The size and the make of the water wheels must be ascertained, and the wheels be used as water meters for the determination of the flow through them. Many of the modern wheels have been carefully rated. Where such ratings have not been made, usually records of wheels of the same type, though possibly of different makes, can be found and the records be compared. Water wheels as meters give fairly accurate records of the discharge.

The Chezy formula or surface-slope method has been extensively employed in gaging large rivers. The proper coefficients to be applied are usually determined from the auxiliary formula of Gauguillet and Kutter. One difficulty in the application of this method lies in the selection of suitable friction factor or coefficient of roughness.

CURRENT METERS.

The current meter has been found best adapted to the general measurements made by the United States Geological Survey, and is used almost exclusively in its hydrographic investigations. (Pls. I and II.) Occasionally, however, either a meter is not available or the conditions are not favorable for its use. In such cases weirs or floats have been used, though a Pitot's tube, hydrometric pendulum, or hydrometric balance might in exceptional case be used to advantage.

The current meter has been described, and instructions for the care and use of the instrument have been given in Water-Supply Paper

No. 56. The object of the present discussion is to give a few additional facts as to the point at which the meter should be held to determine the mean velocity in a channel, as deduced from measurements recently made upon rivers in the southern part of New York State. The current meter may be used to determine the velocity of a river in four ways: First, by making point measurements at a depth corresponding to the approximate position of the thread of mean velocity; second, by deducing the mean velocity from observations made at other points in the same vertical; third, by the integration method; fourth, by point measurements made at regular intervals throughout cross sections of the river. In the first two of these methods it is important to know the relation between the velocities at various points in the section. In the first method the position of mean velocity must be known, and in the second method the relation between the surface velocity, or the velocity at mean depth, to the mean velocity must be known. In either of these cases the form of the vertical velocity curve will determine the coefficient to be applied to the observations.

VERTICAL VELOCITY CURVES ON STREAMS WITHOUT ICE COVER.

Studies of the vertical velocity curve made on the Mississippi River by Humphreys and Abbott, on the Connecticut by T. G. Ellis, on the Merrimac flume by Wheeler and Lynch, on the Potomac by C. C. Babb, and recent experiments by others, notably those at Cornell University by E. C. Murphy, indicate that the point of mean velocity in a given vertical section is at a depth varying from six-tenths to two-thirds of the total depth of the section, measured from the surface down. The values found in the experiments were as follows:

Depth from surface of point of mean velocity.

Experimenter.	Stream.	Depths.
Cyrus C. Babb	Potomac River	0.58
Humphreys and Abbott	Mississippi River	.63
T. G. Ellis	Connecticut River	.64
E. C. Murphy	Cornell flume	[a].65
Wheeler and Lynch	Merrimac flume	.67

[a] For depths between 6 and 9 feet, the proportionate depth of point of mean velocity becoming less as the depth of the water decreased, and becoming 0.55 for depths of water between 1 and 2 feet.

The Cornell experiments indicate that measurements made at six-tenths of the depth yield results 3.5 per cent too large, the depth of

PRICE ELECTRIC CURRENT METERS.

mean velocity being nearly two-thirds of the depth. The measurements at Cornell were, however, made in the canal, the cross sections of which have a greater ratio of depth to width than most rivers, and decidedly more than the Mississippi, Connecticut, and Potomac, upon which the above coefficients were obtained. There can be no doubt but that the difference in the ratio of the depth to width is a factor likely to affect the position of mean velocity.

The bottom and sides of the channel retard the flow close to them in proportion to their roughness, this retardation being due more to the impeding of the flow by eddies than by friction alone. The retardation of the surface velocity has been attributed to the rising, by vertical motion, of the lower water to the surface after being checked in its flow by striking against the rough bottom and sides of the channel. The variation of the velocity in the river channel is shown in Pl. VIII (p. 30) and fig. 1.

Mr. Frederick P. Stearns has attributed the reduction of surface velocity to the general retarding of the layers of water adjacent to the banks of the stream, this water rising to the surface and thereby making the edges of the channel higher than the center and causing a flow of the slowly moving water from the sides toward the middle, thereby decreasing the surface velocity, depressing the point of maximum velocity, and lowering in general the filament of mean velocity. This depression of the maximum velocity is known to become more pronounced with an increase in the roughness of the lining, in the steepness of the banks, and in the ratio of depth to width. In an extreme case of a wide, shallow stream, where the bottom merges imperceptibly into the banks, maximum velocity occurs, under normal conditions, at or very near the surface of the center of the stream. On the other hand, in a deep, narrow channel, as for instance, in a canal with vertical sides, the maximum velocity occurs a considerable distance below the surface, and, as the Cornell experiments indicate, this depression may amount to as much as one-third and even two-fifths of the total depth. Evidently, then, in such cases depression of maximum velocity must result in a lowering of the thread of mean velocity, and engineers, in making unit measurements for mean velocity, should bear in mind that while the observations at six-tenths depth give fair values for mean velocity in wide, shallow rivers this ratio should be increased to two-thirds in the case of canals and flumes or narrow natural channels.

The friction of flowing water against the air has a similar influence, and, though in general less marked, it may, in the case of a strong upstream wind, have a decided influence upon the surface velocity and the point in the vertical of the maximum and mean velocity. On account of these resistances on the bed and bank of a stream, the maximum velocity of the river in a straight reach is found in the central portion of the stream, and somewhat below the surface—the actual position depending upon the size and condition of the river and the velocity of flow. The velocity increases from the surface downward for a short distance—say, one-tenth of the depth—and then decreases down to the bottom, where it reaches the minimum.

Various writers who have studied the form and equation of the curve representing the variation in velocities in a vertical section have

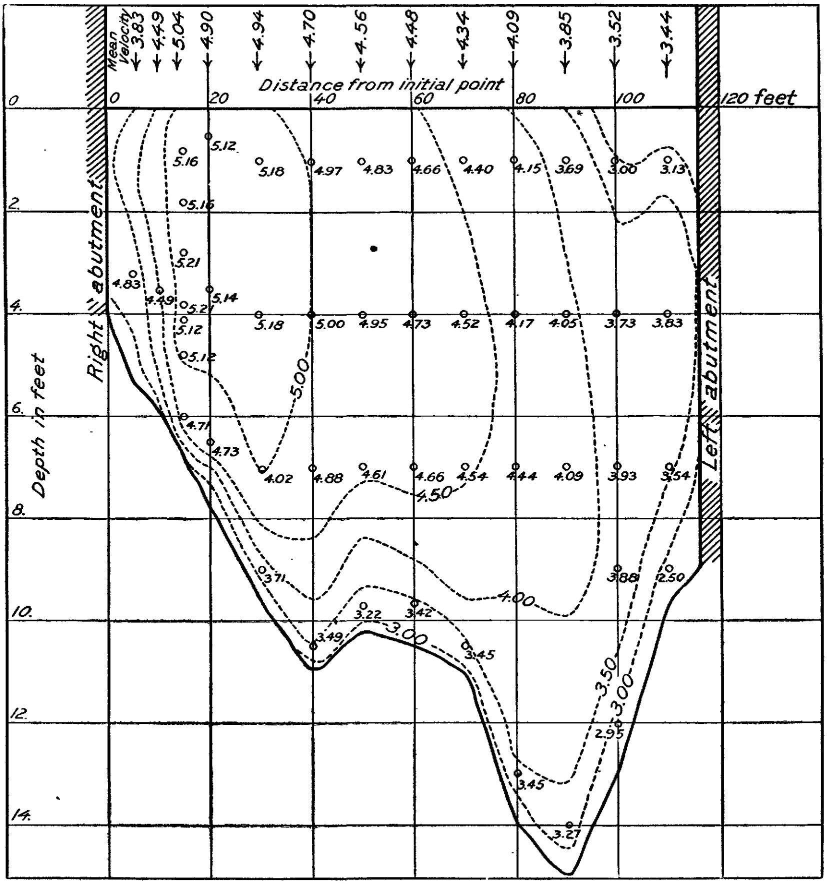


FIG. 1.—Cross section on Esopus Creek, at Kingston, showing curves of equal velocity as determined by current-meter measurements, there being no ice cover.

come to different conclusions as to the form of this curve, the inclined straight line, the parabola with horizontal axis, the parabola with vertical axis and vertex at or below the surface, the ellipse, and the hyperbola each having its advocates. Humphreys and Abbott showed by their experiments on the Mississippi River that the curve did not differ materially from a parabola having its axis parallel to the surface and at the depth below the surface of the position of maximum velocity, the abscissas representing the velocities at the different depths and the ordinates the vertical distances of these depths from the point of mean maximum velocity. In the Mississippi River experiments the position of maximum velocity was on an average nearly one-third of the whole depth below the surface, varying with the direction of the wind. Bazin also found that the vertical velocity curve was in the form of a parabola, the curve varying with different channels and the position of maximum velocity. Professor von Wagner agreed with the above experimenters, but found that the curve differed from the parabola toward the bottom and near the surface, and that the point of maximum velocity varied from a little below the surface to a little over one-fourth of the full depth.

The exact mathematical form of a vertical velocity curve is not a vital question in the measurement of streams, but it is greatly to be desired that the relation between the surface, maximum, and mean velocities should be known, so that if any one of these be measured accurate computations of the flow can be made, and so that if the velocity of the stream be measured at some particular point the mean velocity of the whole section can be calculated. It has been shown by a series of measurements, the results of which are given herein, that the typical vertical velocity curve is in general of the form shown in fig. 2; that the surface velocity is somewhat greater than the mean; that the maximum velocity is below the surface but above mid depth; and that the point of mean velocity is from 0.6 to two-thirds of the depth below the surface. The relation between the surface velocity and the mean velocity is, of course, important in the use of surface floats and current meters when the velocity is measured only near the surface, for some coefficient must always be applied to obtain the mean velocity in the vertical section. In this connection, some results obtained by Mr. J. B. Lippincott on rivers in southern California, in April, 1902, are of interest:

On the Sacramento River, at Jellys Ferry, observations for velocities have been taken at the top, middle, and bottom of each section at intervals of 20 feet. The channel is of bowlders and has a depth of from 3 to 5 feet in the low-water stages. The relation of the mean velocity to the top velocity on each section was determined, and then the mean ratio for the entire measurement. The measurements were arranged in 6 groups according to gage heights. In the first group the mean velocity was 87 per cent of the surface velocity; in the second 88; in the third 88; in the fourth 89; in the fifth 87; in the sixth 87. The last group represents the highest water. The mean of 30 measurements gives a ratio of 88 per cent. In this case the coefficients are quite constant.

A determination on the Tuolumne River, at Lagrange, also gives a coefficient of 88 per cent. This river has a pebbly or stony bed, and the depths range from 1.12 to 1.84 feet. The velocities range from 3 to 5 feet.

On the smaller rivers the determinations were less satisfactory, because when depths become as low as 1 foot, top, middle, and bottom velocities were seldom observed with meters, and unless we had three observations for velocity the mean velocity was not considered sufficiently accurate to justify a comparison with the surface velocity.

The relative irregularities of the beds of the smaller streams also introduced wider ranges in the relation of surface to mean velocities.

On the San Gabriel River the following results were obtained at different points on the stream: 0.83, 0.94, 0.95, 0.89, 0.90, 0.98; mean, 0.92.

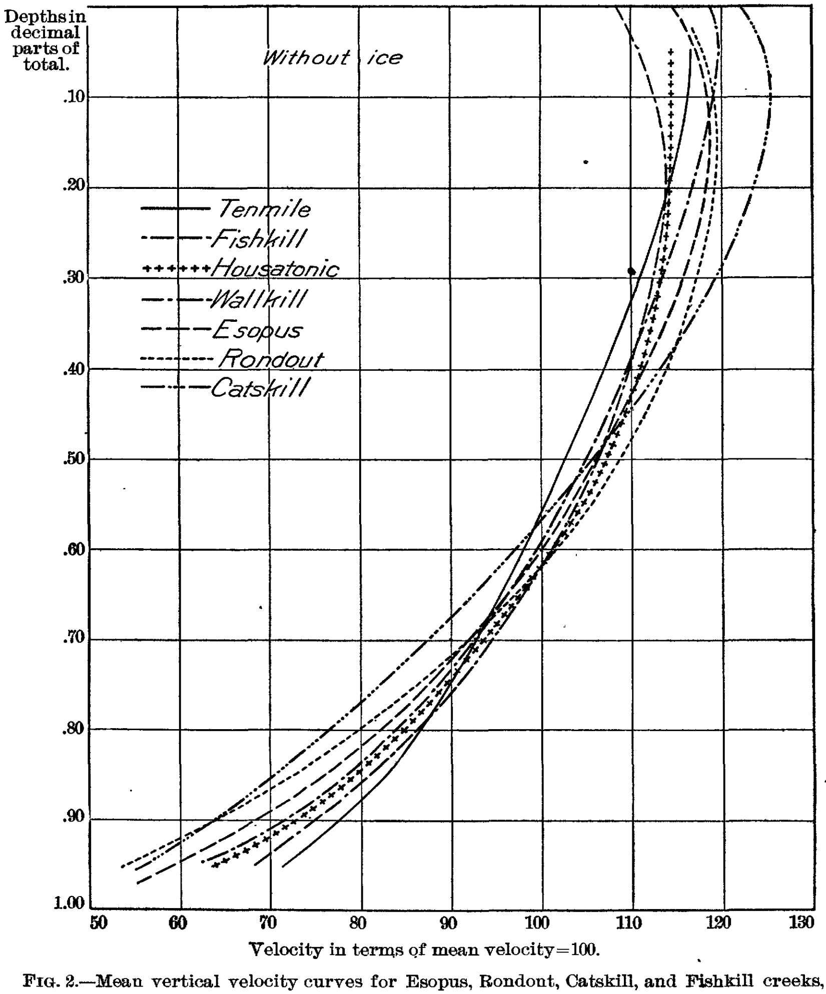


FIG. 2.—Mean vertical velocity curves for Esopus, Rondout, Catskill, and Fishkill creeks, and Wallkill, Tenmile, and Housatonic rivers.

On the Santa Ana River the following determinations were made at Warm Springs: 0.96, 0.95, 0.91, 0.86, 0.90, 0.91, 0.96, 0.93; mean, 0.92.

The channels of these two streams are relatively rough, the water surface is usually from 10 to 20 feet in width, and the depths vary from 0.25 foot to 1 foot for the stage of water observed upon. It is rather singular to note that the determination of these coefficients in the smaller and relatively rough channels shows a higher value than in the larger channels. As previously remarked, however, the determinations for the San Gabriel and the Santa Ana are not considered as entirely satisfactory nor as reliable as the determination for the Sacramento. It is possible that the coefficients which we have determined for the smaller streams are too high, owing to the fact that the current meter could not be placed in the slowest film of water immediately adjacent to the bottom and sides of the channel, so that the mean velocity as shown may be slightly above the true

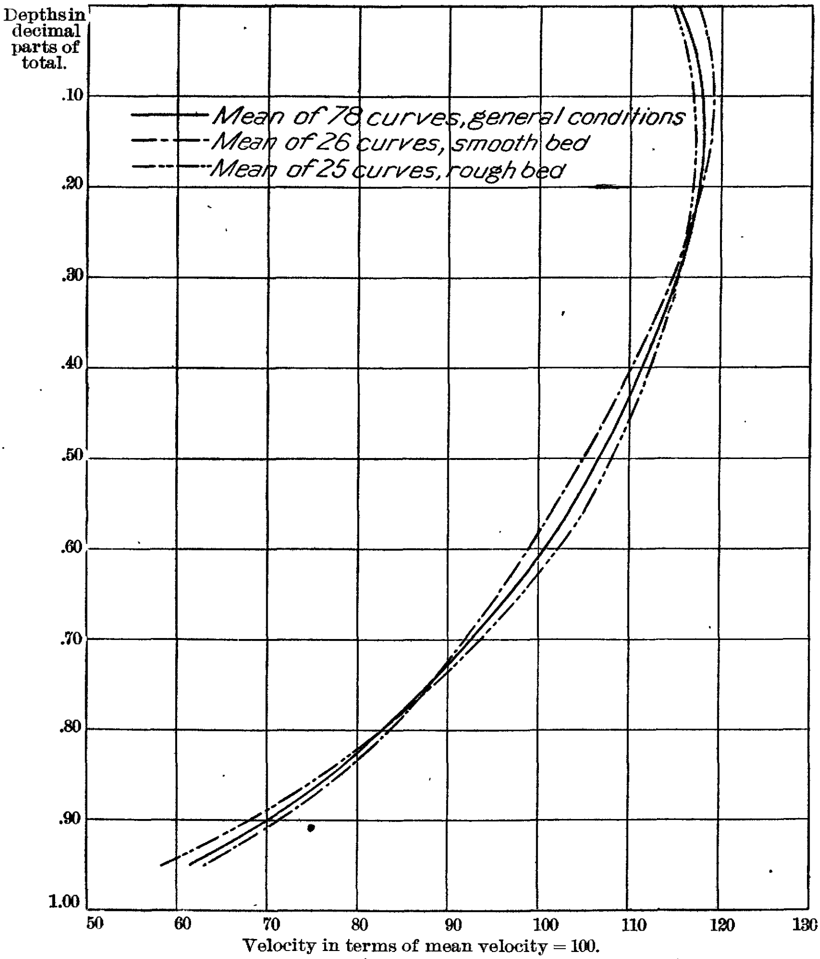


FIG. 3.—Comparison of the general mean velocity curve with the mean curve for smooth bed and the mean curve for rough bed. (Note: The general mean curve includes all data obtained in 78 vertical velocity curves; the mean curve for rough bed includes the data for 25 vertical velocity curves, and the mean curve for smooth bed includes the data for 26 vertical velocity curves. All of these curves were taken when there was no ice cover.)

mean velocity. This error would be relatively greater in small than in large streams, however. In the measurements of the small stream a Price acoustic meter has been used, which permits the center of the meter to be placed within 3 inches of the bed of the creek.

In consideration of the above data it is believed that for ordinary streams discharging 100 cubic feet per second of water, or less, on stony beds, that 0.9 of the mean surface velocity for the section will represent the mean velocity for that section, said surface velocities being observed at numerous points across the stream.

[a] With the object of determining the ratio between the maximum surface velocities and the mean velocity, De Prony made some experiments in wooden troughs, and Messrs. Baldwin, Whistler, and Slosson in channels lined with planks. The coefficients obtained for converting the observed surface velocity into mean velocity were 0.816 by De Prony and from 0.810 to 0.847 by the latter observers in different channels. Subsequent experiments indicate that the coefficient is generally comprised within the limits of 0.8 and 0.9, depending upon the size of the channel and the nature of the bed. The Mississippi River experiments show the coefficients to exceed 0.9, but it is quite possible that the influence of the long connecting cord and surface float caused too large values to be recorded for the velocities toward the bottom, and thus gave too high a value to the mean velocity, as Mr. Robert Gordon, in checking his experiments on the Irrawaddi with a current meter, obtained considerable reduction in the velocities approaching the bottom compared with those obtained by double floats. The coefficient would be greatest for large, deep rivers with smooth, uniform channels, and least for small, shallow streams with rough beds. Messrs. Darcy and Bazin derived from their experiments the following formula giving the relation between the maximum velocity and the mean velocity:

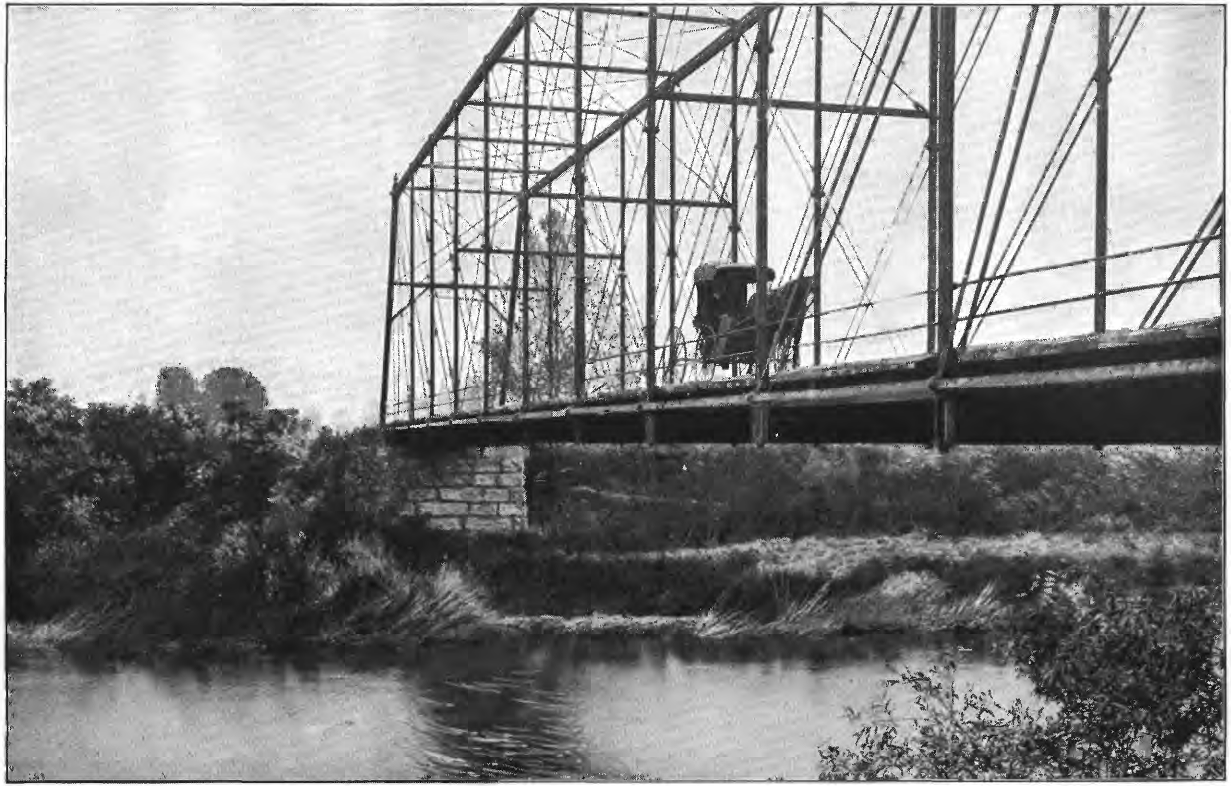
$$U-V=25.36\sqrt{R\,S}$$

where U is the maximum velocity in feet per second, V the mean velocity, R the hydraulic radius in feet, and S the slope.

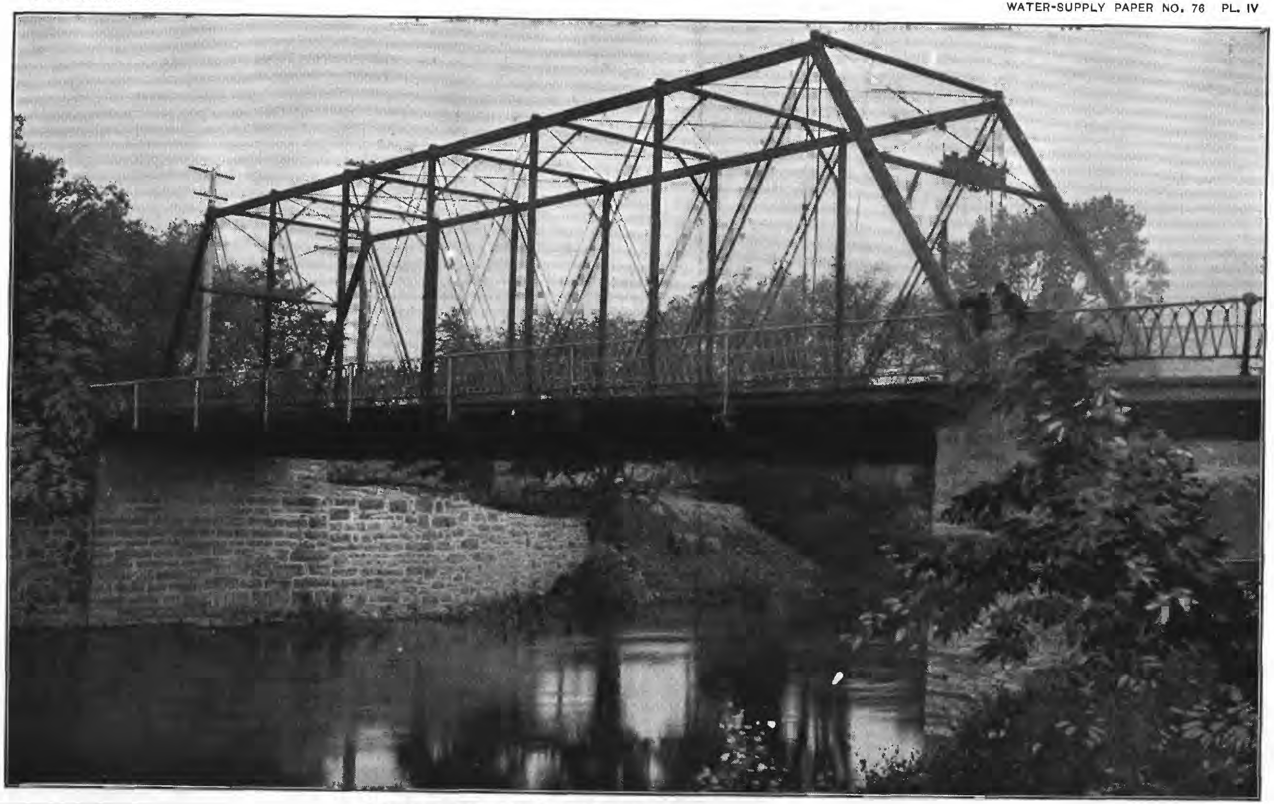
The variation in the coefficient to be applied to the surface velocity gives rise to a possible error large enough to preclude the use of this method of measurement when accurate results are desired. As a quick method it may often be used, and in a few cases, as, for instance, at the time of high floods, when it is impossible to use other means, the results obtained by this method may be of considerable value.

The mean of 78 velocity curves taken upon rivers in the southern part of New York State, described further on in this paper, shows that the mean velocity was 0.87 of the surface velocity in the vertical section (shown in fig. 3). This coefficient varied from 0.82 in the case of Catskill Creek to 0.93 on Fishkill Creek (fig. 2). It will be noted that these coefficients apply to the mean velocity in the vertical in which the float is run. If only one surface float is used, and that in the center of the river, or point of maximum velocity, it appears that 0.8 is the proper coefficient to apply, though the chances of error are much greater than when surface floats are used at intervals across the channel.

[a] From Rivers and Canals, vol. 1, p. 38, by L. F. Vernon-Harcourt.



GAGING STATION ON CATSKILL CREEK AT SOUTH CAIRO, N. Y.



GAGING STATION ON ESOPUS CREEK AT KINGSTON, N. Y.

GAGING STATION ON WALLKILL RIVER AT NEW PALTZ, N. Y.

RIVER STATIONS AT WHICH CURVES WERE OBTAINED.

In June, 1901, a reconnaissance was made of Catskill, Esopus, and Rondout creeks, and Wallkill River west of the Hudson, and Fishkill Creek and Tenmile and Housatonic rivers east of the Hudson. Nearly the entire length of each stream was traversed, and a site for a gaging station selected on each. Early in July the stations were established, with the exception of that on Tenmile River, which was established in September of the same year. Persons living near at hand were employed as gage readers to take observations of the stage of the stream twice each day. Mr. A. E. Place was in charge of these stations until September, 1901, when Mr. W. W. Schlecht was placed in charge as resident hydrographer. The measurements given in this paper were obtained by Messrs. Place and Schlecht, and the tables and several of the diagrams were prepared by Mr. Schlecht. The object of the measurements made at these stations was to determine primarily the run-off from the various drainage basins and the availability of the streams as sources of additional supply of water for New York City. The results of the measurements, together with the heights of water in the river on each day, have been published in Water-Supply Paper No. 65. Incidentally it was thought best to make observations as to the point of mean velocity in each of these streams for use in future measurements on the same rivers, as well as for general information as to the most desirable method of making current-meter measurements on rivers in general. In making measurements of rivers of this character it has been the custom of the Hydrographic Division of the United States Geological Survey to divide the cross section into partial areas of regular width, say 5 or 10 feet, and to determine the velocity in each of these small areas by holding the meter at a point six-tenths of the total depth below the surface. The velocity obtained at this point was assumed to be the mean velocity in the small area in which the meter was used. It was realized that this relation would not hold true in all streams, but in rivers with the general characteristics of those under discussion it was considered that no serious error would result from this assumption. The data in the following pages were collected in order to check the above assumption or to enable the hydrographer to determine by a point measurement the velocity at some other depth which might be considered the mean in the channel. Each of the stations established will now be briefly described. The drainage basins were described in detail in Water-Supply Paper No. 65.

CATSKILL CREEK AT SOUTH CAIRO, N. Y.

The gaging station is located at the highway bridge in the village of South Cairo, a view of which is shown on Pl. III. The total span of the bridge is 194.5 feet between abutments, the faces of which are vertical. The stream bed is of earth for 25 feet from the right abutment. At this point the bluestone rock ledge outcrops, covered with patches of loose shingle and shifting gravel, while the left side of the channel is covered with small gravel. The entire flow of the stream at all stages passes under this bridge. High-water marks at the bridge indicate a maximum elevation of 17.5 feet on the gage. The stage of the stream is observed each morning and evening by the local gage reader, and current-meter measurements are made at intervals by the resident hydrographer.

ESOPUS CREEK AT KINGSTON, N. Y.

This gaging station was established at Washington avenue bridge in Kingston July 5, 1901, a view of which is shown in Pl. IV. This bridge has a clear span of 106.6 feet between abutments, which are nearly vertical. In addition there is on the left side a channel 19 feet in width through which water passes at high stages of the river. Gage readings are made here each morning and evening. The bed is covered with small stone over part of the channel, the rest of the bed being made up of sand, silt, and small gravel.

WALLKILL RIVER AT NEW PALTZ, N. Y.

A gaging station is situated at the New Paltz highway bridge, a view of which is given in Pl. V. The bridge is a span of 146.6 feet between the vertical faces of the masonry abutments. The entire flow passes under this bridge except in extreme freshets, when the left bank is overflowed.

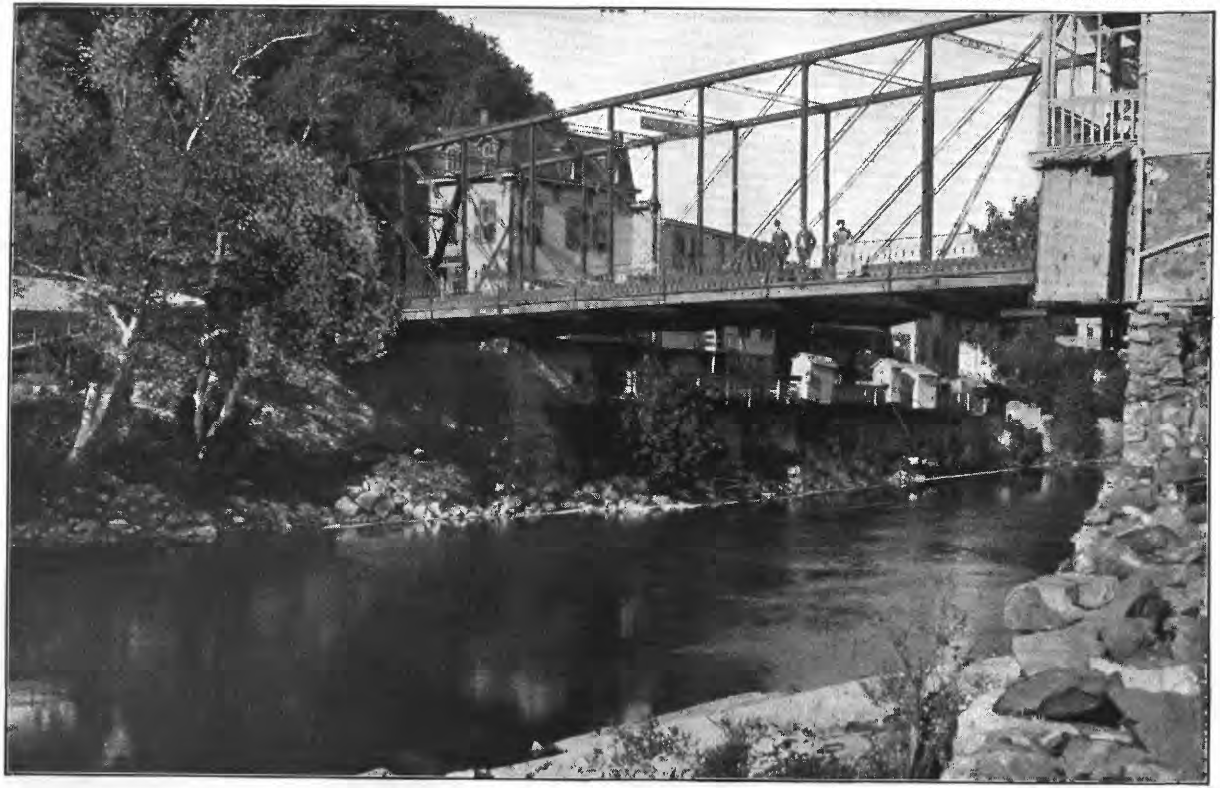
The bed of the river is for the most part smooth, and composed of sand and silt.

RONDOUT CREEK AT ROSENDALE, N. Y.

A gaging station was established at the highway bridge at Rosendale, 3 miles above the junction of the Wallkill, July 6, 1901. The bridge is a single span of 136 feet, and is shown in Pl. VI. The bed of the channel is rock with bowlders for 40 feet from right bank, the rest of the bed being covered with broken rock from 6 inches to 1 foot in diameter. The entire flow, aside from the diversion to the Delaware and Hudson Canal, passes under the bridge at all stages.

FISHKILL CREEK AT GLENHAM, N. Y.

A gaging station is located at the Newburg, Dutchess and Connecticut Railroad bridge, in Glenham. It was established July 8, 1901. The bridge consists of the main central span with two auxil-



GAGING STATION ON RONDOUT CREEK AT ROSENDALE, N. Y.

GAGING STATION ON HOUSATONIC RIVER AT GAYLORDSVILLE, CONN.

iary overflow channels at the ends, the length of span being as follows: Left overflow, station zero to 22.5; main span, station 27.5 to station 122; right overflow, station 127 to station 149. The bed of the main channel is earth and gravel; that of the overflow channels is broken stone.

TENMILE RIVER BELOW DOVER PLAINS, N. Y.

A gaging station was established September 16, 1901, at Tabor's bridge, which crosses Tenmile River about 2,000 feet below the point of inflow of Swamp River. The gaging station is situated about 2 miles below Dover Plains Village. Tabor's bridge consists of a single span, 85 feet between abutments. The bridge stands square across the stream, the bed of which is sand and gravel. The entire flow passes between the abutments of this bridge, except at the time of extreme high water, which occurs nearly every spring when the river overflows its banks, and some water passes around one end of the bridge.

HOUSATONIC RIVER AT GAYLORDSVILLE, CONN.

A gaging station was established at Gaylordsville, Conn., October 24, 1900. The station is situated 3 miles east of the New York State line and 2 miles below the mouth of Tenmile River. Owing to the unfavorable conditions under the bridge, the discharge measurements are made from a cable of 200 feet span placed across the stream $1\frac{1}{4}$ miles below the bridge. A view of the river at this point is shown in Pl. VII. The cable is supported on the right bank by timber shears 25 feet high and is anchored to a large buried rock. On the left bank a sycamore tree serves as a support for the cable, which is anchored to the base of a large oak.

DISCUSSION OF TABLES.

In the tables that are given in the following pages the measurements recorded were taken at the time of the regular gagings of the rivers, and with the same degree of accuracy with which current-meter measurements have been made upon these streams. Only one instrument was used at one time, the velocity being taken at the various points in regular order vertically, usually at intervals of one-half foot. When other space intervals were used it is shown in the tables.

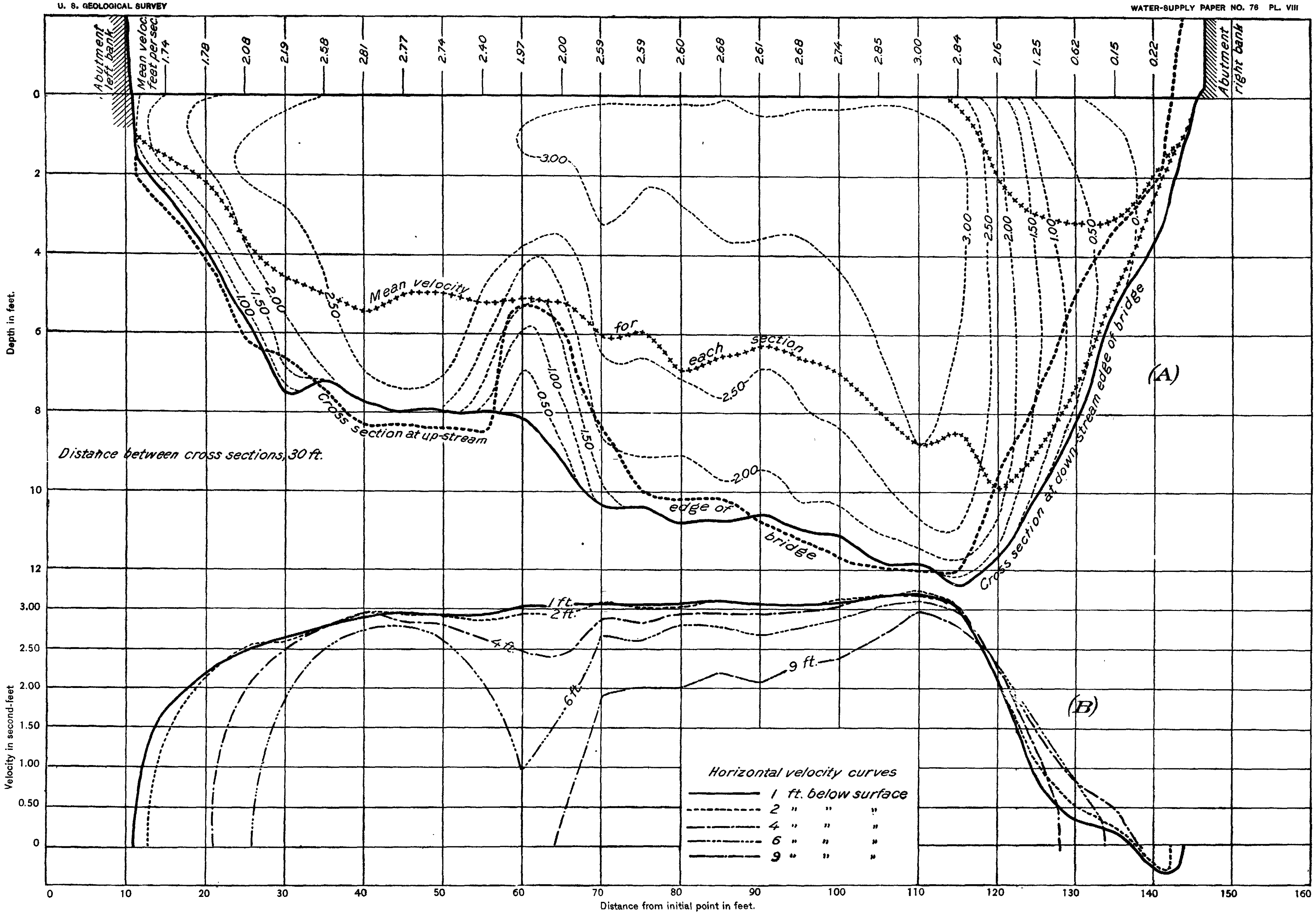
In Pl. VIII is shown the variation in the velocity of Wallkill River at New Paltz. The dotted lines are lines of equal velocities and are determined by observations of velocity at regular intervals throughout the cross section. The line marked "mean velocity for each section" shows the depth at which may be found the filament of mean velocity. Near the right bank there is slack water and some return current, which accounts for the peculiar position of the curve, and the fact that there are two lines of mean velocity. This condition would not usually occur at a gaging station.

At the bottom of Pl. VIII are lines showing the velocity at various depths, as 1 foot, 2 feet, etc., across the river section. The effect of the ledge of rocks is clearly shown in the plate.

A small Price current meter was used, and was in each case suspended from a bridge and hung freely in the water. The meter was held fifty seconds at one point to determine the velocity, and in each case the first reading was checked by a second, and if there was a discrepancy a third reading was taken. The results were plotted upon cross-section paper, the depths as ordinates and the velocities as abscissas, and a smooth curve drawn through the points, so that in case there was an error of sufficient magnitude to affect the final results it would be found when the curve was plotted. Before the work was commenced, and after the completion of these curves, the meter was rated and showed very slight change in its readings. The gage height was read at the beginning of each measurement and at its completion, and in general no change of stage of the stream during the measurement was noted.

In Table I the date of each measurement is given at the head of the column, then the point of measurement—that is, the distance in feet from the initial point of soundings which had been previously established and marked permanently on the bridge. Next is given the gage height at the time the velocities were measured and the depth of water at the point of measurement at the time of making the measurement. The character of the bed of the river and the force and direction of the wind are also given. The depths, as given in the alternate columns, were measured by a wire attached to the meter and a tape. The column headed "Velocities" gives the actual observed velocity in feet per second at each observation.

Table II is computed from Table I, the observations being the same, but the velocities being given at regular depths as shown in percentages of the whole in the first column. The velocities as shown in the columns of this table were found from the plotted vertical velocity curves based upon the figures in Table I, the velocities at each depth being taken by scale directly from the curve. The sum of the velocities in each column of Table II divided by 10 gives the mean velocity in that section, and is the quantity that should be obtained by a single meter observation at a point in the section which represents the point of mean velocity. For comparison, the velocity as actually found at six-tenths of the depth is given at the bottom of Table II, from which



A. CROSS SECTION OF WALLKILL RIVER AT NEW PALTZ, SHOWING CURVES OF EQUAL VELOCITY, AS DETERMINED BY CURRENT-METER MEASUREMENTS; *B*. HORIZONTAL VELOCITY CURVES ON WALLKILL RIVER AT NEW PALTZ, CONSTRUCTED FROM DATA OBTAINED ON THE SAME DATE AS THAT PLOTTED IN *A*.

it will at once be seen that the error in measuring the velocity at six-tenths depth is in general only slight on a stream of the general character of the Esopus.

Tables III, V, VII, IX, XI, and XIII show the results of the measurements on the Rondout, Wallkill, Catskill, Fishkill, Tenmile, and Housatonic, respectively; Tables IV, VI, VIII, X, XII, and XIV show the data obtained from the preceding tables, and were derived by the same method as Table II from Table I.

TABLE I.—*Velocities in vertical sections on Esopus Creek at Kingston.*

Date	July 19.		Aug. 10.		Aug. 19.		Aug. 29.		Aug. 29.		Aug. 29.		Sept. 6.		Sept. 6.		Sept. 21.		Sept. 26.	
Point of measurement	90.		90.		95.		75.		80.		90.		40.		80.		90.		85.	
Gage height	4.40.		4.85.		4.60.		5.50.		5.50.		5.50.		5.46.		5.46.		4.78.		4.55.	
Depth	6.4.		6.2.		5.7.		4.4.		6.1.		7.2.		2.6.		5.3.		6.6.		5.6.	
Bed of river	Silt and gravel.		Silt and gravel.		Silt and sand.		Bowlders.		Bowlders.		Silt and gravel.		Bowlders.		Bowlders.		Silt and gravel.		Bowlders.	
Wind force	Strong.		Gentle.		Light.		Gentle.		Gentle.		Gentle.		None.		None.		Gentle.		Gentle.	
Direction of wind	Upstream.		Down-stream.		Upstream.		Down-stream.		Down-stream.		Down-stream.		......		......		Upstream.		Down-stream.	
	Depth	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*
	0.4	0.77	0.2	1.03	0.2	0.82	0.2	1.44	0.2	1.42	0.2	1.31	0.2	1.40	0.2	1.44	0.5	0.85	0.5	0.86
	.9	.77	.7	1.00	.7	.89	.7	1.45	.7	1.54	.7	1.38	.7	1.35	.7	1.47	1.0	.87	1.0	.84
	1.4	.73	1.2	1.03	1.2	.82	1.2	1.38	1.2	1.52	1.7	1.35	1.2	1.07	1.2	1.40	1.5	.87	1.5	.80
	1.9	.71	1.7	1.05	1.7	.86	1.7	1.29	1.7	1.42	2.7	1.24	1.7	1.07	1.7	1.40	2.0	.95	2.0	.85
	2.4	.70	2.2	1.00	2.2	.86	2.2	1.31	2.7	1.40	3.7	1.17	2.1	.96	2.2	1.40	2.5	.85	2.5	.80
	2.9	.66	2.7	.98	2.7	.82	2.7	1.19	3.7	1.05	4.7	.91	......	......	2.7	1.38	3.0	.86	3.0	.77
	3.4	.61	3.2	.91	3.2	.75	3.2	1.05	4.7	1.24	5.7	.94	......	......	3.7	1.20	3.5	.87	3.4	.75
	3.9	.57	3.7	.86	3.7	.68	3.7	.89	5.6	1.05	6.2	.75	......	......	4.2	1.16	4.0	.78	3.5	.72
	4.4	.57	4.2	.77	4.2	.67	3.9	.68	......	......	......	......	......	......	......	......	4.5	.70	4.0	.75
	4.9	.48	4.7	.75	4.7	.65	......	......	......	......	......	......	......	......	......	......	5.0	.65	4.5	.68
	5.4	.54	5.2	.68	5.2	.61	......	......	......	......	......	......	......	......	......	......	5.5	.48	5.1	.47
	5.9	.54	5.7	.63	......	......	......	......	......	......	......	......	......	......	......	......	6.1	.40	......	......

Date	Oct. 16.		Oct. 16.		Oct. 21.		Nov. 1.		Nov. 1.		Nov. 18.		Nov. 18.		Nov. 18.		Nov. 26.		Nov. 26.	
Point of measurement	40.		90.		90.		80.		95.		77.		87.		97.		95.		90.	
Gage height	6.64.		6.64.		5.56.		4.74.		4.74.		4.45.		4.45.		4.45.		5.06,		5.06.	
Depth	4.0.		8.6.		7.4.		5.0.		5.9.		4.4.		6.0.		5.0.		6.0.		6.8.	
Bed of river	Bowlders.		Silt and gravel.		Silt and gravel.		Bowlders.		Silt and sand.		Bowlders.		Silt and gravel.		Silt.		Silt.		Silt and gravel.	
Wind force	None.		None.		Gentle.		None.		None.		Gentle.		Gentle.		Gentle.		Gale.		Gale.	
Direction of wind					Upstream.						Upstream.		Upstream.		Upstream.		Down-stream.		Down-stream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*
	0.5	2.26	0.5	1.89	0.5	1.42	0.5	0.98	0.5	0.85	0.5	0.85	0.5	0.80	0.3	0.67	0.5	0.97	0.5	1.04
	1.5	2.29	1.5	1.86	1.5	1.37	1.5	.92	1.5	.82	1.5	.82	1.5	.80	.8	.70	1.5	.97	1.5	1.05
	2.4	2.12	2.5	1.86	2.5	1.32	2.5	.91	2.5	.71	2.5	.77	2.5	.77	1.7	.67	2.5	.84	2.5	.91
	2.5	2.07	3.5	1.79	3.5	1.22	3.0	.91	3.5	.67	2.6	.76	3.5	.62	2.7	.57	3.6	.80	4.1	.82
	3.0	1.52	4.5	1.74	4.4	1.10	3.5	.87	3.5	.66	3.5	.60	3.6	.65	3.0	.52	4.5	.70	5.0	.67
	3.5	1.25	5.2	1.65	4.5	1.07	4.5	.60	4.5	.62	3.8	.46	4.5	.62	3.7	.51	5.5	.60	6.3	.51
			5.5	1.57	5.5	.97			5.4	.42			5.5	.47	4.5	.27				
			6.5	1.42	6.5	.85														
			7.5	1.22	7.0	.72														
			8.1	1.15																

TABLE II.—*Velocities at regular intervals in vertical sections on Esopus Creek, deduced from data in Table I.*

[Velocities in feet per second.]

Depth in parts of total.	July 19.	Aug. 10.	Aug. 19.	Aug. 29.	Aug. 29.	Aug. 29.	Sept. 6.	Sept. 6.	Sept. 21.	Sept. 26.	Oct. 16.	Oct. 16.	Oct. 21.	Nov. 1.	Nov. 1.	Nov. 18.	Nov. 18.	Nov. 18.	Nov. 26.	Nov. 26.
0.05	0.77	1.02	0.83	1.45	1.48	1.34	1.40	1.45	0.85	0.83	2.24	1.88	1.41	0.97	0.84	0.85	0.79	0.67	0.97	1.03
.15	.76	1.04	.87	1.44	1.51	1.38	1.38	1.46	.88	.84	2.28	1.89	1.42	.97	.85	.85	.82	.70	.98	1.04
.25	.74	1.05	.87	1.41	1.47	1.35	1.35	1.44	.90	.85	2.30	1.87	1.37	.96	.82	.84	.81	.69	.95	1.01
.35	.71	1.02	.85	1.36	1.42	1.29	1.29	1.42	.89	.83	2.29	1.84	1.30	.94	.78	.82	.78	.67	.92	.97
.45	.68	.96	.82	1.29	1.37	1.21	1.22	1.40	.86	.81	2.26	1.77	1.23	.92	.74	.80	.74	.63	.87	.92
.55	.64	.90	.77	1.22	1.30	1.13	1.64	1.37	.81	.78	2.17	1.68	1.15	.90	.68	.77	.69	.58	.92	.85
.65	.60	.83	.72	1.14	1.22	1.04	1.06	1.32	.73	.74	2.00	1.56	1.06	.87	.63	.73	.64	.52	.77	.77
.75	.56	.76	.66	1.02	1.14	.94	.98	1.25	.63	.68	1.70	1.44	.96	.83	.57	.66	.58	.44	.72	.68
.85	.52	.68	.60	.85	1.05	.83	.89	1.17	.48	.58	1.39	1.29	.85	.69	.49	.54	.52	.35	.65	.58
.95	.43	.60	.51	.56	.94	.69	.79	1.02	.27	.36	.97	1.08	.65	.45	.40	.34	.43	.25	.55	.45
Mean	.64	.89	.75	1.17	1.29	1.12	1.15	1.33	.73	.73	1.96	1.63	1.14	.85	.68	.72	.68	.55	.82	.83
.60	.63	.87	.75	1.18	1.26	1.09	1.11	1.34	.77	.76	2.08	1.63	1.11	.88	.66	.75	.67	.55	80	.81

Character of the bed: From station 0 to 86 broken rock from 0.5 feet to 1.0 foot in diameter. From station 86 to 105 smooth and even bed, composed of sand, silt, and small gravel. From 105 to 116 broken rock 0.5 feet to 1.0 foot in diameter.

TABLE III.—*Velocities in vertical sections on Rondout Creek at Rosendale.*

Date	Aug. 8.		Aug. 8.		Aug. 8.		Sept. 4.		Sept. 24		Oct. 11.		Oct. 11.		Oct. 11.		Oct. 18.		Nov. 7.		Nov. 16.		Nov. 26.		Dec. 21.	
Point of measurement	90.		105.		45.		35.		75.		65.		75.		85.		65.		80.		70.		65.		70.	
Gage height	7.50.		7.50.		7.15.		7.55.		6.45.		6.47.		6.47.		6.47.		7.03.		6.42.		6.55.		7.21.		7.60.	
Depth	7.2.		5.9.		5.2.		4.7.		5.6.		5.6.		5.6.		6.2.		6.3.		6.2.		5.6.		6.6.		6.4.	
Bed of creek	Bowlders.		Bowlders.		Bowlders.		Rock.		Bowlders.		Bowlders.		Bowlders.		Bowlders.		Bowlders.		Bowlders.		Bowlders.		Bowlders.		Bowlders.	
Wind force	None.		None.		None.		Gentle.		Gentle.		Gentle.		Gentle.		Gentle.		Strong.		Gentle.		Strong.		None.		Gentle.	
Direction of wind	.....		.....		.....		Down-stream.		Down-stream.		Up-stream.		Up-stream.		Up-stream.		Down-stream.		Up-stream.		Down-stream.		.....		Up-stream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Ft.	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*	*Ft.*	*Feet per sec.*
	0.2	1.70	0.2	1.33	0.2	1.29	0.2	1.58	0.3	0.51	0.5	0.55	0.5	0.60	0.8	0.52	0.3	1.41	0.5	0.48	0.5	0.65	0.5	7.76	3.5	1.94
	.7	1.60	1.2	1.42	.7	1.40	1.2	1.52	1.0	.52	1.5	.52	1.5	.55	1.8	.50	.5	1.42	1.5	.46	1.5	.65	1.5	1.71	1.5	1.96
	1.2	1.65	2.2	1.22	1.2	1.42	2.2	1.49	2.0	.50	2.5	.52	2.5	.47	2.8	.50	1.5	1.42	2.5	.45	2.5	.60	2.5	1.70	2.5	1.89
	2.2	1.54	3.2	1.24	1.7	1.44	3.2	1.44	3.0	.47	3.4	.45	3.4	.47	3.7	.45	2.5	1.37	3.5	.43	3.4	.56	3.5	1.69	3.5	1.77
	3.2	1.33	4.2	1.05	2.2	1.40	4.2	1.19	3.4	.46	3.5	.40	3.5	.42	3.7	.45	3.5	1.35	3.7	.45	3.5	.50	4.0	1.70	3.8	1.70
	4.0	1.29	5.2	.75	3.2	1.14	.....	.....	4.0	.43	4.5	.32	4.3	.35	4.7	.40	3.8	1.22	4.6	.32	4.5	.32	5.0	1.30	1.5	1.50
	4.2	1.24	.....	.....	4.2	.89	.....	.....	5.1	.30	5.1	.37	5.1	.25	5.7	.22	4.5	1.07	5.6	.20	5.0	.20	4.0	1.04	5.5	.80
	5.2	1.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.5	.82	.....	.....	.....	.....	.....	.....	5.9	.62
	6.2	.98	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.8	5.2	.....	.....	.....	.....	.....	.....	.....	.....
	6.7	.86	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE IV.—*Velocities at regular intervals in vertical sections on Rondout Creek at Rosendale, deduced from data in Table III.*

[Velocities in feet per second.]

Depth in parts of total.	Aug. 8.	Aug. 8.	Aug. 8.	Sept. 4.	Sept. 24.	Oct. 11.	Oct. 11.	Oct. 11.	Oct. 18.	Nov. 7.	Nov. 16.	Nov. 26.	Dec. 21.
0.05	1.65	1.36	1.33	1.57	0.51	0.55	0.58	0.50	1.41	0.46	0.65	1.75	1.93
.15	1.66	1.39	1.40	1.57	.52	.55	.57	.52	1.42	.47	.65	1.76	1.97
.25	1.59	1.37	1.43	1.55	.52	.54	.56	.51	1.41	.47	.65	1.75	1.96
.35	1.50	1.34	1.40	1.53	.51	.52	.54	.50	1.40	.47	.63	1.73	1.93
.45	1.40	1.28	1.33	1.50	.49	.50	.52	.49	1.37	.46	.60	1.70	1.86
.55	1.29	1.21	1.23	1.47	.47	.46	.48	.47	1.30	.43	.55	1.66	1.77
.65	1.18	1.11	1.10	1.42	.44	.41	.44	.43	1.20	.39	.49	1.53	1.60
.75	1.07	.99	.97	1.35	.40	.36	.37	.39	1.08	.34	.39	1.37	1.35
.85	.95	.82	.83	1.28	.34	.30	.29	.32	.92	.28	.28	1.17	1.02
.95	.81	.63	.68	1.16	.26	.21	.20	.17	.59	.18	.17	.88	.61
Mean	1.31	1.15	1.17	1.44	.44	.44	.45	.43	1.21	.40	.51	1.53	1.60
.60	1.24	1.16	1.17	1.45	.46	.44	.46	.45	1.25	.41	.52	1.60	1.69

Character of bed: From station 0 to 40, rock bed with some bowlders; from station 40 to bank, broken rock from 0.5′ to 1′ in diameter.

TABLE V.—*Velocities in vertical sections on Wallkill River at New Paltz.*

Date	Aug. 10.		Oct. 1.		Oct. 9.		Oct. 24.		Oct. 24.		Nov. 9.		Nov. 16.		Nov. 16.		Nov. 16.	
Point of measurement	70.		70.		105.		80.		105.		90.		105.		90.		80.	
Gage height	10.0.		7.36.		6.48.		6.33,		6.33.		5.94.		6.50.		6.50.		6.50.	
Depth	9.8.		7.5.		7.8.		6.4.		7.6.		6.2.		7.8.		6.6.		6.4.	
Bed of river	Silt.		Silt.		Silt.		Silt.		Silt.		Silt.		Silt.		Silt.		Silt.	
Wind force	Gentle.		Gentle.		Fresh.		Fresh.		Fresh.		Gentle.		Fresh.		Fresh.		Fresh.	
Direction	Downstream.		Downstream.		Downstream.		Upstream.		Upstream.		Downstream.		Downstream.		Downstream.		Downstream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*
	0.3	3.00	0.3	1.79	0.5	1.22	0.3	0.89	0.5	0.95	0.5	0.62	0.5	1.21	0.5	1.20	0.5	1.16
	1.0	3.05	1.3	1.70	1.5	1.15	0.8	.91	1.5	.97	1.5	.55	1.5	1.11	1.5	1.17	2.0	1.05
	2.0	2.77	2.3	1.67	2.5	1.12	1.5	.86	2.5	.92	2.5	.50	2.5	1.05	2.5	1.05	3.0	.92
	3.0	2.91	3.3	1.60	3.5	1.12	2.5	.77	3.5	.95	3.5	.42	3.5	1.05	3.5	.89	3.8	.90
	4.0	2.86	4.3	1.50	4.5	1.08	3.5	.70	4.5	.92	3.7	.46	4.5	1.05	4.0	.91	5.0	.72
	5.0	2.86	4.5	1.52	4.7	1.05	3.8	.75	4.6	.92	4.5	.36	4.7	1.07	4.5	.81	5.9	.66
	6.0	2.58	5.3	1.40	5.5	.97	4.5	.65	5.5	.82	5.7	.26	5.5	.91	5.5	.62		
	7.0	2.47	6.3	1.32	6.5	.87	5.5	.47	6.5	.73			6.5	.80	6.1	.54		
	8.0	2.35	6.9	1.15	7.3	.50	5.8	.37	7.1	.60			7.3	.60				
	9.0	1.98																

TABLE VI.—*Velocities at regular intervals in vertical sections on Wallkill River at New Paltz, deduced from data in Table V.*

[Velocities in feet per second.]

Depth in parts of total.	Aug. 20.	Oct. 1.	Oct. 9.	Oct. 24.	Oct. 24.	Nov. 9.	Nov. 16.	Nov. 16.	Nov. 16.
0.05	3.00	1.77	1.23	0.90	0.94	0.62	1.20	1.20	1.16
.15	3.04	1.75	1.18	.90	.97	.59	1.15	1.18	1.13
.25	2.99	1.70	1.14	.87	.97	.56	1.13	1.15	1.08
.35	2.91	1.65	1.12	.83	.96	.53	1.10	1.08	1.03
.45	2.82	1.59	1.10	.79	.94	.49	1.07	1.01	.97
.55	2.72	1.52	1.07	.75	.92	.45	1.02	.93	.91
.65	2.60	1.45	1.03	.69	.86	.40	.97	.83	.84
.75	2.44	1.37	.95	.63	.80	.35	.90	.73	.77
.85	2.20	1.27	.82	.53	.71	.30	.77	.61	.68
.95	1.88	1.13	.46	.35	.53	.24	.49	.48	.58
Mean	2.66	1.52	1.01	.724	.86	.453	.98	.92	.91
.60	2.66	1.49	1.05	.72	.89	.43	1.00	.88	.88

Character of bed of stream: At all of the above stations the bed of the creek is smooth, composed of sand and silt.

TABLE VII.—*Velocities in vertical sections on Catskill Creek at South Cairo.*

Date	July 20		July 25		July 25		Aug. 1.		Aug. 1.		Aug. 9.		Aug. 23.		Sept. 2.		Sept. 2.		Sept. 7.		Sept. 23.		Oct. 22.		Nov. 8.		Sept. 2.	
Point of measurement	55.		55.		45.		55,		60.		50.		60.		35.		40.		35.		55.		30.		50.		60.	
Gage height	3.60.		3.00.		3.00.		2.80.		2.80.		3.00.		3.12.		3.00.		3.00.		2.92.		2.74.		2.82.		2.70.		3.00.	
Depth	3.6.		2.9.		3.6.		2.7.		2.7.		3.1.		2.9.		4.4.		3.9.		4.3.		2.7.		2.3.		2.9.		3.0.	
Bed of creek	Rock.		Rock.		Rock.		Rock.		Gravel.		Rock.		Gravel.		Gravel.		Gravel.		Rock.		Gravel.		Rock.		Rock.		Gravel.	
Wind force	None.		Gentle.		Gentle.		Strong.		Strong.		Gentle.		Gentle.		Gentle.		Gentle.								Fresh.		Gentle.	
Direction			Down-stream.		Down-stream.		Down-stream.		Down-stream.		Up-stream.		Down-stream.		Up-stream.		Up-stream.		None.		None.		None.		Down-stream.		Up-stream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Ft.	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*
	0.2	1.67	0.2	0.75	0.2	0.66	0.2	0.52	0.2	0.48	0.2	0.61	0.3	1.05	0.2	0.61	0.2	0.73	0.2	0.48	0.2	0.48	0.2	0.37	0.5	0.37	0.2	0.77
	.5	1.72	.5	.77	.5	.63	.5	.50	.5	.48	.7	.67	.8	1.03	.7	.59	.7	.71	.7	.50	.7	.42	.7	.36	1.0	.35	.6	.75
	1.0	1.54	1.0	.75	1.0	.66	1.0	.45	1.0	.43	1.2	.66	1.3	.99	1.2	.52	1.2	.69	1.2	.41	1.2	.35	1.2	.32	1.5	.30	1.1	.73
	1.5	1.52	1.5	.63	1.5	.57	1.5	.43	1.5	.36	1.7	.59	1.8	.73	1.7	.50	1.7	.61	1.7	.43	1.6	.35	1.4	.31	1.7	.31	1.6	.54
	2.0	1.47	1.7	.59	2.0	.57	1.6	.43	1.6	.38	2.0	.50	2.3	.57	2.2	.43	2.2	.63	2.7	.29	1.7	.25	1.8	.27	2.0	.28	2.1	.54
	2.5	1.21	2.0	.52	2.2	.61	2.0	.36	2.0	.25	2.2	.54	2.8	.34	2.7	.38	2.7	.61	3.8	.23	2.2	.17			2.4	.25	2.6	.36
	3.0	1.07	2.4	.45	2.5	.50	2.2	.25	2.2	.25	2.7	.54			3.2	.29	3.2	.58										
	3.1	1.13			3.0	.50									3.7	.22	3.7	.52										

TABLE VIII.—*Velocities at regular intervals in vertical sections on Catskill Creek at South Cairo, deduced from data in Table VII.*

[Velocities in feet per second.]

Depth in parts of total.	July 20.	July 25.	July 25.	Aug. 1.	Aug. 1.	Aug. 9.	Aug. 23.	Sept. 2.	Sept. 2.	Sept. 7.	Sept. 23.	Oct. 22.	Nov. 8.	Sept. 2.
0.05	1.69	0.75	0.64	0.52	0.48	0.65	1.06	0.60	0.72	0.48	0.47	0.37	0.37	0.77
.15	1.70	.76	.65	.51	.49	.68	1.05	.59	.71	.49	.44	.38	.37	.76
.25	1.65	.76	.65	.50	.47	.68	1.03	.56	.70	.46	.41	.37	.36	.75
.35	1.58	.73	.63	.48	.44	.67	.98	.51	.68	.43	.38	.36	.35	.73
.45	1.50	.68	.60	.45	.41	.65	.92	.46	.66	.39	.35	.34	.33	.68
.55	1.41	.62	.57	.42	.37	.61	.84	.40	.64	.35	.32	.32	.31	.61
.65	1.32	.56	.54	.38	.32	.57	.74	.34	.62	.31	.28	.30	.29	.53
.75	1.21	.50	.50	.32	.27	.52	.62	.28	.59	.26	.23	.28	.26	.45
.85	1.10	.43	.46	.26	.21	.47	.50	.22	.56	.20	.17	.25	.23	.37
.95	.94	.36	.40	.18	.14	.40	.36	.14	.52	.13	.10	.19	.19	.25
Mean	1.41	.61	.564	.40	.36	.59	.81	.41	.64	.35	.31	.31	.31	.59
.60	1.37	.59	.56	.40	.35	.59	.80	.37	.63	.33	.30	.31	.30	.57

Character of river bed: From station 0 to 55 the bed is a rock ledge, and from station 55 to the left bank it is small gravel, none over 0.2 foot in diameter.

TABLE IX.—*Velocities in vertical sections on Fishkill Creek at Glenham.*

Date	July 24.		Aug. 15.		Aug. 15.		Aug. 30.		Aug. 30.		Aug. 30.		Sept. 6.		Sept. 6.		Sept. 27.		Oct. 5.		Oct. 25.		Nov. 11.		Nov. 20.	
Point of measurement	51.		50.		55.		45.		50.		55.		60.		65.		75.		55.		85.		55.		50.	
Gage height, feet	3.60.		3.85.		3.85.		4.60.		4.60.		4.60.		4.15.		4,15.		3.86.		3.98.		4.05.		3.85.		3.95.	
Depth	3.6.		4.0.		3.4.		4.4.		4.4.		4.2.		3.8.		3.2.		2.9.		3.5.		2.8.		3.4.		4.0.	
Bed of creek	Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.		Gravel.	
Wind	Gentle.		Strong.		Strong.		Gentle.		Gentle.		Gentle.		None.		None.		Gentle.		Gentle.		Fresh.		None.		Gentle.	
Direction	Up-stream.		Down-stream.		Down-stream.		Down-stream.		Down-stream.		Down-stream.						Down-stream.		Down-stream.		Up-stream.				Up-stream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Ft.	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*
	0.2	0.54	0.2	0.75	0.2	0.73	0.2	1.70	0.2	1.42	0.2	1,47	0.2	1.05	0.2	1.21	0.3	0.66	0.4	0.93	0.3	1.05	0.4	0.62	0.5	0.69
	.7	.54	.7	.75	.7	.75	.7	1.89	.7	1.77	.7	1.75	.7	1.17	.7	1.24	.8	.64	.9	.90	.8	1.02	.9	.60	1.0	.64
	1.2	.45	1.2	.73	1.2	.71	1.2	1.87	1.2	1.75	1.2	1.70	1.2	1.17	1.2	1.17	1.3	.61	1.4	.87	1.3	.97	1.9	.56	1.7	.65
	1.7	.38	1.7	.68	1.7	.68	1.7	1.96	1.7	1.72	1.7	1.67	1.7	1.14	1.7	1.14	1.7	.56	1.9	.87	1.7	.97	2.0	.57	2.4	.65
	2.2	.38	2.2	.66	2.2	.63	2.2	1.79	2.2	1.67	2.2	1.61	2.2	1.03	2.2	.98	1.8	.57	2.1	.85	2.3	.67	2.9	.42	2.9	.59
	2.7	.29	2.4	.66	2.7	.59	2.7	1.75	2.7	1.61	2.7	1.54	2.7	.94	2.9	.50	2.3	.46	2.5	.85					3.5	.54
	3.1	.27	2.7	.54			3.2	1.61	3.2	1.52	3.2	1.54	3.3	.73					3.0	.70						
			3.2	.45			3.7	1.49	3.7	1.30	3.7	1.38														
							3.9	1.29	3.9	1.03																

TABLE X.—*Velocities at regular intervals in vertical sections on Fishkill Creek at Glenham, deduced from data in Table IX.*

[Velocities in feet per second.]

Depths in parts of total.	July 24.	Aug. 15.	Aug. 15.	Aug. 30.	Aug. 30.	Aug. 30.	Sept. 6.	Sept. 6.	Sept. 27.	Oct. 5.	Oct. 25.	Nov. 11.	Nov. 20.
0.05	0.54	0.75	0.74	1,77	1.64	1.63	1.06	1.21	0.67	0.95	1.05	0.62	0.67
.15	.54	.75	.75	1.87	1.74	1.71	1.15	1.22	.66	.93	1.05	.62	.68
.25	.51	.74	.74	1.92	1.75	1.71	1.18	1.21	.65	.90	1.04	.61	.67
.35	.47	.72	.72	1.91	1.73	1.68	1.16	1.19	.63	.88	1.02	.60	.66
.45	.43	.68	.70	1.86	1.69	1.64	1.12	1.16	.61	.87	1.00	.59	.65
.55	.39	.63	.67	1.78	1.64	1.60	1.06	1.11	.58	.86	.97	.57	.64
.65	.34	.56	.63	1.69	1.58	1.56	.98	1.02	.55	.85	.89	.54	.62
.75	.29	.48	.59	1.59	1.50	1.51	.88	.88	.52	.81	.80	.50	.58
.85	.23	.40	.55	1.45	1.38	1.44	.76	.70	.45	.75	.67	.44	.54
.95	.16	.30	.51	1.26	1.15	1.32	.62	.50	.35	.65	.53	.35	.49
Mean	.39	.60	.66	1.71	1.58	1.58	1.00	1.02	.57	.85	.90	.54	.62
.60	.37	.60	.65	1.74	1.61	1.58	1.02	1.07	.57	.86	.93	.56	.63

Character of bed of creek: Bowlders from 0.2 foot to 0.6 foot in diameter.

TABLE XI.—*Velocities in vertical sections on Tenmile River at Dover Plains.*

Date	Oct. 15.		Oct. 26.		Oct. 26.		Nov. 11.		Nov. 22.	
Point of measurement	55.		25.		55.		25.		25.	
Gage height	7.19.		5.01.		5.01.		4.75.		4.76.	
Depth	6.8.		4.6.		4.8		4.4.		4.2.	
Bed of creek	Sand.		Sand.		Sand.		Sand.		Sand.	
Wind	Fresh.		None.		None.		None.		Gentle.	
Direction	Downstream.		----------		----------		----------		Downstream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*
	0.5	2.43	0.3	1.10	0.5	1.00	0.4	0.90	0.3	0.84
	1.5	2.38	.8	1.07	1.5	.95	.9	.87	.8	.84
	2.5	2.31	1.3	1.00	2.5	.93	1.4	.77	1.5	.73
	3.5	2.19	1.8	.92	2.9	.92	2.0	.70	2.0	.75
	4.1	2.17	2.3	.90	3.5	.90	2.6	.67	2.5	.67
	4.4	2.09	2.8	.82	4.3	.77	3.0	.61	3.0	.56
	5.3	2.00	3.3	.75	--------	--------	3.5	.55	3.5	.55
	6.3	1.84	4.1	.62	--------	--------	3.9	.50	3.7	.49

TABLE XII.—*Velocities at regular intervals in vertical sections on Tenmile River at Dover Plains, deduced from data in Table XI.*

[Velocities in feet per second.]

Depths in parts of total.	Oct. 15.	Oct. 26.	Oct. 26.	Nov. 11.	Nov. 22.
0.05	2.44	1.08	0.99	0.89	0.84
.15	2.42	1.06	.99	.86	.84
.25	2.36	1.03	.98	.83	.82
.35	2.30	.98	.97	.79	.78
.45	2.23	.93	.95	.75	.74
.55	2.16	.87	.93	.70	.70
.65	2.09	.81	.91	.64	.65
.75	2.02	.73	.88	.58	.59
.85	1.95	.65	.82	.52	.51
.95	1.83	.46	.68	.44	.43
Mean	2.18	.86	.91	.70	.69
.60	2.13	.84	.92	.67	.68

TABLE XIII.—*Velocities in vertical sections on Housatonic River at Gaylordsville.*

Date	Aug. 8.		Oct. 29.		Nov. 13.		Nov. 23.	
Point of measurement	60.		60.		60.		60.	
Gage height	3.50.		4.05.		4.82.		4.11.	
Depth	3.8.		4.8.		6.2.		4.8.	
Bed of creek	Gravel.		Gravel.		Gravel.		Gravel.	
Wind	None.		None.		Very strong.		Gentle.	
Direction					Downstream.		Upstream.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*
	0.20	2.19	0.5	2.98	0.5	3.84	0.5	3.03
	.30	2.23	1.5	2.90	1.5	3.93	1.5	2.92
	.8	2.25	2.5	2.85	2.5	3.84	2.5	2.81
	1.3	2.14	2.9	2.68	3.5	3.50	2.9	2.61
	1.8	2.07	3.5	2.39	3.7	3.44	3.5	2.38
	2.3	2.05	4.3	1.92	4.5	3.23	4.3	1.90
	2.8	1.72			5.6	2.50		
	3.3	1.35						

TABLE XIV.—*Velocities at regular intervals in vertical sections on Housatonic River at Gaylordsville, deduced from data in Table XIII.*

[Velocities in feet per second.]

Depths in parts of total.	Aug. 8.	Oct. 29.	Nov. 13.	Nov. 23.
0.05	2.21	3.00	3.89	3.02
.15	2.23	2.97	3.90	3.01
.25	2.21	2.94	3.91	3.00
.35	2.17	2.90	3.89	2.94
.45	2.10	2.85	3.79	2.85
.55	2.02	2.77	3.60	2.72
.65	1.85	2.57	3.38	2.52
.75	1.66	2.35	3.11	2.34
.85	1.45	2.10	2.79	2.10
.95	1.20	1.75	2.04	1.80
Mean	1.91	2.62	3.43	2.63
.60	1.94	2.67	3.49	2.62

For the purpose of comparison a mean curve for each of the streams has been determined by taking the mean of all the velocities shown in each of Tables II, IV, VI, VIII, X, XII, and XIV. To facilitate comparison, the data for these mean curves have been expressed in percentages of the mean velocity in a vertical section, and are shown in Table XV, the total number of curves being 78. By this arrangement a figure in the column greater than 100 shows a velocity greater than the mean in the vertical section being considered, and a velocity less than 100 shows a velocity less than the mean. The mean curves have been plotted in fig. 2. It will be seen from these curves that the general character of the vertical velocity curves is much the same in each case, showing fairly conclusively that we may prophesy as to the general character of the vertical velocity curve in natural streams with steep banks and from smooth to moderately rough bottoms, and depths of from 3 to 8 feet. It will be noted that the ratio of the mean velocity to the surface velocity varies from 92 per cent on the Fishkill to 82 per cent on the Catskill, and that the maximum velocity of these streams varies from 13 to 25 per cent greater than the mean, and that at no point do all of the curves fall so closely together as at six-tenths depth. At that point the greatest variation from the mean is 2½ per cent. This shows that the measurements made at six-tenths depth were subject to less variation than those made at any other point, and that in general, on streams of the character here represented, a measurement made at that point would represent approximately the mean velocity in the section. It will be noted that none of the curves cross the line of mean velocity at a greater depth than 0.63, nor at a less depth than 0.56, showing that the point of mean velocity on these streams lies between these two depths.

TABLE XV.—*Averages of velocity curves expressed in terms of mean velocity in a vertical section (represented as 100).*

Stream	Esopus.			Rondout.	Wallkill.	Catskill.	Fishkill.	Tenmile.	Housatonic.	Average of all the streams.
No. of velocity curves.	12.	8.	20.	13.	9.	14.	13.	5.	4.	78.
Bed of stream	Small gravel.	Bowlders.	Average.	Bowlders.	Silt.	Small gravel and rock ledge.	Large gravel.	Sand.	Gravel.	Various.
Mean depth	6.5.	4.7.	5.8.	6.	7.3.	3.2.	3.7.	5.	4.9.	5.07.
Depth below surface in parts of total:										
0.05	118.6	115.9	117.3	117.9	119.7	124.7	110.7	116.8	114.4	117.0
.15	120.8	116.6	118.8	119.6	118.4	124.8	113.7	115.6	114.3	117.9
.25	118.9	115.5	117.3	118.5	115.4	121.8	113.4	112.7	113.9	116.3
.35	115.0	112.7	113.9	115.9	111.6	116.5	111.3	109.0	112.4	113.2
.45	109.3	109.4	109.3	111.7	107.4	109.7	108.2	104.9	109.5	109.0
.55	102.3	104.8	103.5	105.9	102.5	101.5	104.0	100.4	105.0	103.6
.65	94.4	98.6	96.4	97.2	96.3	92.5	98.3	95.5	97.4	96.5
.75	85.5	89.7	87.5	86.3	89.0	81.9	91.0	89.9	89.3	87.9
.85	74.9	77.8	76.3	72.8	78.6	70.7	81.2	83.3	79.7	77.2
.95	60.3	59.0	59.7	54.2	61.1	55.9	68.2	71.9	64.1	61.4
Mean	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
.60	98.9	101.7	100.2	101.8	99.6	97.2	101.4	98.1	101.2	100.26

In Table XV, under the heading "Average of all the streams," the mean velocity of each depth given in the table is shown, and the curve representing this mean vertical velocity curve is platted in fig. 3 as a solid line. This curve represents the mean of 78 vertical velocity curves, the mean of the vertical velocity curves platted in fig. 2.

It will be noted in this curve that the relation between the mean velocity and the surface velocity is 87; that the maximum velocity is 18 per cent greater than the mean, and that the point of mean velocity is almost exactly at six-tenths depth, the variation, as shown in the last column of Table XV, being about one-fourth of 1 per cent. This shows clearly that a measurement made at six-tenths of the depth of a stream having the general characteristics of those considered will in general represent closely the mean velocity in that section.

To show the relation between the velocity at mid depth and the mean velocity in a vertical section Table XVI has been compiled from Table XV. From this table it will be seen that, upon streams like these being considered, if the mid depth is known, the mean velocity in the vertical section may be found by applying a coefficient of 0.94.

TABLE XVI.—*Relation between velocity at mid depth to mean velocity in a vertical section.*

Stream.	Velocity at mid depth expressed in percentage of the mean.	Coefficient to be applied to velocity at mid depth to obtain mean velocity.
Esopus	106.4	0.94
Rondout	108.8	.92
Wallkill	104.9	.95
Catskill	105.6	.94
Fishkill	106.1	.94
Tenmile	102.6	.97
Housatonic	107.2	.93
Average	106.3	.94

Humphreys's and Abbott's observations on the Mississippi River gave a coefficient of 0.98, while Ellis, on the Connecticut, found 0.94, and Wheeler and Lynch, on the Merrimac flume, found 0.95. It will be seen that there is a variation of 5 per cent on the streams being considered in this paper, and that the results of Humphreys and Abbott on the Mississippi and Ellis on the Connecticut vary from each other by 4 per cent, although the rivers are both large and have somewhat the same characteristics. In view of these facts, it seems that it is somewhat better to measure the velocity at the point of mean velocity than to measure the velocity at mean depth and apply a coefficient.

It is very evident that the character of the bed will affect to some extent the form of the vertical velocity curve. A rough bed would be expected to retard the velocity near the bottom of the stream. None of the streams under investigation may be considered to have extremely rough beds, but by comparison the beds of Rondout Creek and Housatonic River may be said to be rough, while those of the Wallkill River and Tenmile Creek are smooth at the point of measurement. Part of the bed of the Esopus is rough and part smooth. In order to determine the effect of the variation in the beds on the flow, the results in Table XV have been classified in Table XVII into streams with rough and smooth bottoms, the Rondout, Housatonic, and part of the curves on the Esopus being in the first column, and the Wallkill, Tenmile, and remaining observations on the Esopus in the second. The results shown in these two columns have been plotted in fig. 3.

It will be seen that the rough bed causes a drag at the lower end of the vertical velocity curve, due largely to eddies formed at the bottom of the stream. This retardation of the water near the bed of the stream causes the point of mean velocity in the vertical section to rise, and a measurement of velocity made at 0.60 depth will therefore be too small. With a smooth bed a measurement made at 0.60 depth will, in general, be too large, the filament of mean velocity being nearer the surface. In other words, in making a measurement of mean velocity in a vertical section the meter should, in general, be suspended above 0.60 depth in streams of rough bed and below 0.60 depth in streams of smooth bed. In the rivers here considered the variation of roughness of beds is so small in the different streams that the error in assuming the velocity at 0.60 depth to be the mean velocity in the vertical section would not be great, but in streams of very rough beds the variation would be more marked.

TABLE XVII.—*Relation between velocities in vertical sections with smooth and rough bottoms.*

Depth below surface—in parts of total.	Smooth bottom: Esopus, Wallkill, Tenmile.	Rough bottom: Rondout, Housatonic.
	Velocity in percentage of the mean.	*Velocity in percentage of the mean.*
0.05	118.7	116.2
.15	118.8	117.0
.25	116.2	116.0
.35	112.4	113.8
.45	107.6	110.3
.55	102.0	105.3
.65	95.4	97.7
.75	87.8	88.3
.85	78.1	76.5
.95	63.0	58.9
Mean	100.0	100.0
.60	99.0	101.6

FLOW OF RIVERS UNDER ICE, SMOOTH AND UNBROKEN COVER.

It is frequently desirable to measure the flow of rivers and canals when they are covered with a coating of ice. It is quite clear that the same relations in various parts of the channel do not hold good when the channel is covered with ice as when the surface is open. The friction between the water and the ice retards the surface velocity, and it is possible that in a few cases the river may flow under a head if the ice cake is heavy and held firmly in position. In making measurements of the flow of a river when frozen over, floats can not be used, and in general a current meter is the most serviceable instrument.

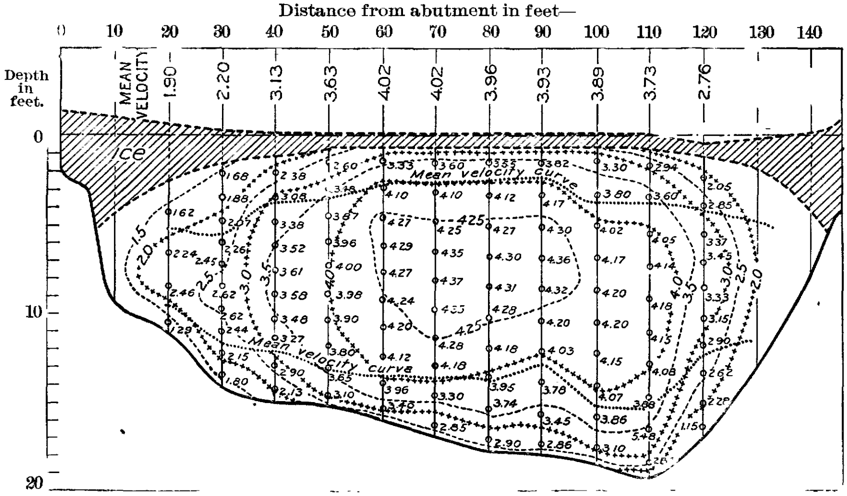


FIG. 4.—Cross section of Wallkill River at New Paltz, showing ice cover and curves of equal velocity in river channel. (Note.—Measurements taken January 23, 1902; 117 measurements of velocity being made with the current meter; mean velocity, 3.23 feet per second; discharge, 6,063 second-feet. The dotted line shows the position of mean velocity in the vertical section.)

During the winter of 1901–2 observations to determine the change of velocity in a vertical plane below the ice were made on Wallkill River, and Esopus, Rondout, and Catskill creeks, and the data collected are presented in the following tables.[a] The observations were made by cutting holes through the ice large enough to admit a current meter. The thickness of the ice in each case is given in the table, and the fact that the water rose in most cases to a point about flush with the surface of the ice shows that there was some pressure upon the flowing stream. It may be of interest in passing to note the distribution of the velocity in the cross section, as shown in fig. 4, the result of the gagings made on the Wallkill River at the New Paltz gaging station, January 23, 1902. The total area of the water section was 1,880 square feet, the mean velocity 3.23, and the discharge 6,063 second-feet. One hundred and seventeen measurements were

[a] These observations were made incidental to the discharge measurements of the streams.

made with the current meter, and the points are platted in the figure, the velocity in feet per second being noted beside each point. The mean velocity in feet per second in a vertical section is shown by the figures across the top of the section. A dotted line showing the position of the mean velocity in the vertical sections has been drawn on the cross section. It will be seen that the maximum velocity occurs near the center of the channel, and at about mid depth, and that the effect of the ice covering is to form a covered flume, the curves of equal velocity being much the same as have been plotted occasionally for such flumes. The water just below the ice is so retarded that there are two points of mean velocity, as shown in figs. 4 and 5.

In the following tables are given the results of measurements made in vertical sections upon the above-mentioned rivers. These measurements were made with a single meter, the velocities being taken at intervals of from 1 to 2 feet, these distances being shown in each case in the table. Tables XVIII, XX, XXII, XXIV, and XXVI show the velocities as determined by actual measurements. At the head of the table are given the date, distance from initial point of sounding, gage height at the time of measurement, total depth of the river (including ice), the thickness of ice, and the depth of water under the ice. In every case the depth, as given in the body of the table, refers to the depth of water under the ice, the lower surface of the ice being considered as zero, and the distances being measured in feet and tenths. Where not otherwise stated, the ice was smooth on the lower side. Some curves were made with ice broken and tilted, but the results were quite different from those obtained with smooth ice, and the results have been given in separate tables (XXIX to XXXIII). The retarding influence of the rough ice was decidedly greater than that of the smooth ice and is so variable that no law can be formulated.

Tables XIX, XXI, XXIII, XXV, and XXVII are derived from the preceding tables by platting the vertical velocity curves, as shown by the original data, and taking from this curve the velocities at regular intervals, one-tenth of the depth apart. The sum of these velocities divided by 10 will give the mean in the section.

In Table XIX, and the others of a similar character, a column has been added, headed "Per cent of mean." The figures of this column are obtained by dividing the corresponding figures in the adjacent column by the mean velocity, which reduces the data for each velocity curve to a similar curve whose mean is 100, and as the depths are then expressed as percentages of total depth, and the velocities as percentages of the mean velocity, the comparison between the curves is facilitated. In all cases for which the data are included within these tables the ice on the surface was smooth both on its upper and lower faces. The few velocity curves taken at times when the ice was broken and tilted are shown in separate tables.

TABLE XVIII.—*Velocities in vertical sections under ice on Wallkill River.*[a]

1901-1902.

Date	Dec. 11.		Dec. 11.		Dec. 11.		Dec. 11.		Jan. 21.		Jan. 21.		Jan. 21.		Jan. 21.		Jan. 23.		Jan. 23.		Jan. 23.		Jan. 23.		Jan. 23.	
Point of measurement	85.		75.		53.		40.		50.		80.		90.		100.		40.		50.		60.		70.		80.	
Gage height	11.50.		11.50.		11.50.		11.50.		7.24.		7.24.		7.24.		7.24.		17.33.		17.33.		17.33.		17.33.		17.33.	
Total depth	12.3.		12.2.		9.9.		9.4.		4.6.		6.8.		7.6.		8.8.		15.4.		16.0.		14.8.		16.8.		17.7.	
Thickness of ice	0.7.		0.7.		0.7.		0.4.		1.2.		1.0.		1.0.		1.0.		1.4.		1.0.		0.8.		0.8.		0.7.	
Depth of water	11.6.		11.5.		9.2.		9.0.		3.4.		5.8.		6.6.		7.8.		14.0.		15.0.		14.0.		16.0.		17.0.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Ft.	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*
	0.8	2.52	0.8	2.43	0.8	2.14	0.3	2.24	0.3	0.80	0.3	0.77	0.3	0.62	0.3	0.87	0.5	2.21	0.5	2.61	0.4	3.23	0.4	3.15	0.3	1.45
	2.8	3.03	2.8	3.13	2.8	2.68	1.3	2.64	1.3	.95	1.3	1.12	1.3	1.22	1.3	1.15	1.5	3.13	1.4	3.50	1.3	3.91	1.2	3.72	1.0	3.37
	4.8	3.11	4.8	3.18	4.8	2.68	3.3	2.90	2.3	.85	2.3	1.22	2.3	1.25	2.3	1.25	3.5	3.37	2.2	3.84	2.3	4.19	2.8	4.12	2.6	4.12
	6.8	2.78	6.8	2.73	6.8	2.71	5.2	2.76	2.8	.67	3.3	1.12	3.3	1.20	3.3	1.27	5.5	3.55	3.8	3.93	4.2	4.30	4.4	4.21	4.2	4.26
	8.8	2.38	8.8	2.43	8.7	2.12	7.0	2.31			4.3	1.00	4.3	1.05	4.3	1.22	7.5	3.60	5.7	3.93	6.0	4.26	5.8	4.32	5.8	4.28
	10.8	1.62	11.0	1.65			8.5	1.62			5.3	.77	5.3	.87	5.3	1.15	9.5	3.41	7.6	3.95	7.9	4.23	7.4	4.37	7.4	4.32
													6.1	.70	6.3	.95	11.5	3.03	8.5	3.97	9.8	4.19	9.0	4.35	9.0	4.30
															7.3	.70	13.5	1.96	9.3	3.97	11.7	4.12	10.5	4.26	10.5	4.23
																			10.2	3.97	12.6	3.79	12.0	4.21	12.0	4.07
																			11.0	3.95	13.5	3.18	13.6	4.02	13.5	3.88
																			12.0	3.74			14.2	3.84	15.0	3.60
																			12.8	3.48			14.9	3.03	15.8	3.06
																			13.7	3.01			15.5	2.36	16.5	2.43
																			14.5	2.24						

Date	Jan. 23.		Jan. 23.		Jan. 23.		Jan. 31.		Jan. 31.		Jan. 31.		Jan. 31.		Jan. 31.		Feb. 10.		Feb. 10.		Feb. 24.		Feb. 24.		Feb. 24.	
Point of measurement	90.		100.		110.		40.		70.		80.		90.		100.		80.		90.		90.		80.		40.	
Gage height	17.33.		17.33.		17.33.		9.07.		9.07.		9.07.		9.07.		9.07.		7.78.		7.78.		7.33.		7.33.		7.33.	
Total depth	17.7.		18.8.		19.8.		6.8.		8.8.		8.8.		10.0.		11.5.		7.5.		8.5.		8.0,		7.3.		5.9.	
Thickness of ice	0.7.		0.8.		0.8.		1.0.		1.0.		1.0.		1.0.		1.2.		1.0.		1.0.		2.0.		2.0.		2.4.	
Depth of water	17.0.		18.9.		19.0.		5.8.		7.8.		[a]7.8.		9.0.		10.3.		6.5.		7.5.		6.0.		5.3.		3.5.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Ft.	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*	*Ft.*	*Ft. per sec.*
	0.3	3.23	0.3	2.36	0.7	2.73	0.3	1.32	0.4	1.98	0.3	1.65	0.3	1.70	0.3	1.77	0.3	1.10	0.3	1.15	0.2	0.73	0.3	0.75	0.25	0.42
	1.1	3.88	1.2	3.58	1.7	3.03	1.3	1.65	1.3	2.21	1.3	2.31	1.5	2.33	0.8	2.03	1.0	1.45	1.0	1.52	0.5	.82	.8	.85	0.5	.55
	2.6	4.21	2.2	3.72	3.4	3.55	2.3	1.72	2.3	2.43	2.3	2.45	3.5	2.45	2.8	2.38	3.0	1.65	2.0	1.72	1.5	1.05	1.8	1.00	1.0	.62
	4.2	4.26	4.0	3.93	5.1	4.02	4.3	1.52	4.3	2.29	4.3	2.31	5.5	2.24	4.8	2.47	5.0	1.34	4.0	1.50	2.5	1.02	2.8	.97	1.5	.62
	5.8	4.30	5.7	4.12	6.8	4.12	5.3	1.20	6.3	1.79	6.3	2.00	7.5	1.72	6.8	2.43	6.0	1.10	6.0	1.22	3.5	.92	3.8	.87	2.0	.59
	7.4	4.35	7.4	4.17	8.5	4.17			7.3	1.37	7.3	1.62	8.5	1.37	8.8	2.07			7.0	1.07	4.5	.74	4.8	.62	2.5	.50
	9.0	4.26	9.1	4.21	10.2	4.14									9.8	1.65					5.5	.65			3.0	.42
	10.5	4.09	10.8	4.17	11.9	4.09																				
	12.0	3.95	12.5	4.09	13.6	4.00																				
	13.5	3.65	14.2	4.05	15.3	3.88																				
	14.3	3.53	15.9	3.91	17.0	3.23																				
	16.0	3.01	16.7	3.70	17.8	2.94																				
	16.5	2.52	17.5	2.43	18.5	2.52																				

[a] Bed of river, silt.

TABLE XIX.—*Velocities at regular intervals in vertical sections on Wallkill River, under ice, deduced from data in Table XVIII.*

[Velocities in feet per second.]

Depth in parts of total.[a]	Dec. 11.		Dec. 11.		Dec. 11.		Dec. 11.		Jan. 21.		Jan. 21.		Jan. 21.		Jan. 21.		Jan. 23.		Jan. 23.		Jan. 23.		Jan. 23.		Jan. 23.	
	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.
0.05	2.47	95	2.35	89	2.02	81	2.22	89	0.75	92	0.77	76	0.76	69	0.90	84	2.38	76	2.60	72	3.33	83	3.60	89	3.55	90
.15	2.81	108	2.81	107	2.32	93	2.53	101	.87	107	1.00	99	1.10	108	1.12	104	3.08	98	3.48	96	4.10	102	4.10	102	4.12	104
.25	3.06	117	3.15	119	2.57	103	2.74	110	.93	114	1.14	113	1.23	121	1.22	113	3.38	107	3.87	107	4.27	106	4.25	106	4.27	107
.35	3.13	120	3.22	122	2.70	109	2.88	115	.95	117	1.20	118	1.25	123	1.27	117	3.52	113	3.96	109	4.29	107	4.35	108	4.30	109
.45	3.07	118	3.12	118	2.74	110	2.89	116	.94	115	1.18	117	1.23	121	1.27	118	3.61	115	4.00	110	4.27	106	4.37	109	4.31	109
.55	2.88	111	2.94	111	2.75	111	2.82	113	.92	113	1.15	114	1.17	115	1.23	114	3.58	114	3.98	109	4.24	105	4.35	108	4.28	108
.65	2.67	102	2.69	102	2.72	110	2.66	107	.87	107	1.08	107	1.06	105	1.16	108	3.48	111	3.90	107	4.20	104	4.28	106	4.18	105
.75	2.41	92	2.42	92	2.60	105	2.42	97	.78	96	.99	98	.94	93	1.05	98	3.27	104	3.80	105	4.12	103	4.18	104	3.99	101
.85	2.06	79	2.06	78	2.38	96	2.15	86	.65	80	.88	87	.82	81	88	82	2.90	93	3.65	100	3.96	99	3.90	97	3.74	94
.95	1.50	58	1.64	62	2.05	82	1.63	66	.48	59	.72	71	.65	64	67	62	2.13	69	3.10	85	3.40	85	2.85	71	2.60	73
Mean	2.61	100	2.64	100	2.48	100	2.49	100	0.81	100	1.01	100	1.01	100	1.08	100	3.13	100	3.63	100	4.02	100	4.02	100	3.96	100

Depth in parts of total.[a]	Jan. 23.		Jan. 23.		Jan. 23.		Jan. 31.		Jan. 31.		Jan. 31.		Jan. 31.		Jan. 31.		Feb. 10.		Feb. 10.		Feb. 24.		Feb. 24.		Feb. 24.	
	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.
0.05	3.82	97	3.20	85	2.94	79	1.30	85	1.94	93	1.78	83	1.81	87	1.91	85	1.15	80	1.18	83	0.78	92	0.68	80	0.36	71
.15	4.17	106	3.80	98	3.60	96	1.53	100	2.24	108	2.26	106	2.28	109	2.21	99	1.44	101	1.56	110	.90	106	.87	103	.55	108
.25	4.30	109	4.02	103	4.05	109	1.68	110	2.40	115	2.42	113	2.44	117	2.36	105	1.58	111	1.70	120	1.04	122	.96	114	.61	120
.35	4.36	111	4.17	107	4.14	111	1.73	113	2.44	117	2.44	114	2.46	118	2.45	110	1.65	115	1.72	121	1.03	121	1.00	118	.62	121
.45	4.32	110	4.20	108	4.18	112	1.72	113	2.40	115	2.40	112	2.42	116	2.48	111	1.64	115	1.68	118	.99	116	.99	117	.61	119
.55	4.20	107	4.20	108	4.15	111	1.68	110	2.30	110	2.32	109	2.32	111	2.47	110	1.60	112	1.58	111	.93	109	.96	114	.58	114
.65	4.03	103	4.15	107	4.08	109	1.62	107	2.14	103	2.22	104	2.17	104	2.44	109	1.52	107	1.45	102	.85	100	.90	107	.55	108
.75	3.78	96	4.07	105	3.88	104	1.52	100	1.95	94	2.10	98	1.96	94	2.33	104	1.40	99	1.30	92	.76	90	.83	98	.49	96
.85	3.45	88	3.86	99	3.48	93	1.34	88	1.69	81	1.89	89	1.69	81	2.08	93	1.23	87	1.12	79	.66	78	.71	84	.42	82
.95	2.86	73	3.10	80	2.84	76	1.12	74	1.33	64	1.53	72	1.32	63	1.64	74	1.04	73	.90	64	.56	66	.55	65	.31	61
Mean	3.93	100	3.89	100	3.73	100	1.52	100	2.08	100	2.14	100	2.09	100	2.24	100	1.42	100	1.42	100	0.85	100	0.84	100	0.51	100

[a] The lower surface of the ice is zero depth.

TABLE XX.—*Velocities in vertical sections under ice on Esopus Creek.*[a]

Date	Jan. 9		Feb. 20		Feb. 28		Dec. 4		Dec. 4		Jan. 9		Jan. 9		Feb. 20	
Point of measurement	80.		80.		40.		90.		100.		90.		100.		90.	
Gage heights	6.55.		5.38.		9.14.		5.28.		5.28.		6.55.		6.55.		5.38.	
Total depth	6.8.		5.8.		6.3.		6.85.		5.05.		8.1.		6.1.		6.6.	
Thickness of ice	0.2.		0.1.		0.3.		0.05.		0.05.		0.1.		0.1.		0.2.	
Depth of water	6.6.		5.7.		6.0.		6.8.		5.0.		8.0.		6.0.		6.4.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*
	0.3	1.25	0.3	0.67	0.5	2.56	0.5	0.72	0.5	0.97	0.3	1.10	0.3	0.97	0.2	0.75
	1.3	1.50	1.2	.97	1.5	3.01	1.5	.85	1.5	1.07	1.3	1.35	1.3	1.27	0.9	.97
	2.3	1.52	2.2	.91	2.5	2.99	2.5	1.05	2.5	1.07	2.3	1.40	2.3	1.32	1.9	1.02
	3.3	1.50	3.2	.90	3.5	2.90	3.5	1.10	3.0	1.07	3.3	1.37	3.3	1.30	2.9	.95
	4.3	1.42	4.2	.87	4.5	2.29	4.1	1.09	3.5	1.07	4.3	1.32	4.3	1.25	3.9	.85
	5.3	1.32	5.2	.66	5.5	1.65	4.5	1.00	4.5	.62	5.3	1.17	5.5	1.02	4.9	.72
	6.1	1.10					5.6	.82			6.3	.90			5.9	.57
							6.3	.59			7.5	.60				

[a] Bed of river 40 to 80 is bowlders, 90 to 100 silt.

TABLE XXI.—*Velocities at regular intervals in vertical sections on Esopus Creek under ice, deduced from data in Table XX.*

[Velocities in feet per second.]

Depth in parts of total.[a]	Jan. 9.		Feb. 20.		Feb. 28.		Dec. 4.		Dec. 4.		Jan. 9.		Jan. 9.		Feb. 20.	
	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.
0.05	1.26	91	0.67	81	2.40	93	0.67	75	0.93	98	1.14	99	0.97	81	0.73	88
.15	1.45	105	.85	102	2.75	107	.82	93	1.00	105	1.34	116	1.18	98	.93	112
.25	1.52	109	.94	113	3.00	116	.94	106	1.05	111	1.40	121	1.30	108	.99	119
.35	1.53	110	.95	114	3.08	119	1.03	116	1.07	113	1.40	122	1.33	111	1.01	122
.45	1.51	109	.93	112	3.02	117	1.09	122	1.08	114	1.36	118	1.32	110	.96	115
.55	1.49	107	.91	110	2.88	112	1.10	122	1.08	114	1.30	113	1.30	108	.90	108
.65	1.44	105	.88	106	2.70	105	1.05	118	1.05	111	1.19	103	1.27	106	.83	100
.75	1.37	99	.83	100	2.45	95	.92	102	.96	101	1.03	89	1.23	102	.75	91
.85	1.26	91	.75	91	2.07	80	.77	86	.78	82	.83	72	1.14	95	.66	80
.95	1.02	74	.59	71	1.45	56	.53	60	.50	51	.54	47	.97	81	.54	65
Mean	1.385	100	.83	100	2.58	100	.89	100	.95	100	1.15	100	1.20	100	.83	100

[a] The lower surface of the ice is zero depth.

TABLE XXII.—*Velocities in vertical sections under ice on Rondout Creek.*[a]

Date	Dec. 6.		Dec. 6.		Jan. 14.		Jan. 14.		Feb. 26.		Feb. 26.		Feb. 26.		Feb. 26.	
Point of measurement	80.		90.		80.		90.		92.		92.		80.		40.	
Gage height	6.80.		6.80.		7.00.		7.00.		8.13.		8.43.		8.13.		8.13.	
Total depth	6.2.		6.6.		6.5.		7.0.		7.7.		8.0.		7.9.		6.4.	
Thickness of ice	0.1.		0.2.		0.2.		0.2.		1.5.		1.4.		1.5.		1.0.	
Depth of water	6.1.		6.4.		6.3.		6.8.		6.2.		6.6.		6.4.		5.4.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*	*Feet.*	*Feet per sec.*
	0.4	0.62	0.3	0.55	0.8	1.05	0.8	1.07	0.3	0.92	0.3	1.70	0.3	1.40	0.4	1.30
	1.4	.73	1.3	.70	1.8	1.32	2.3	1.27	1.5	1.47	1.1	1.91	0.9	1.62	0.9	1.55
	2.4	.77	2.3	.65	2.8	1.47	3.3	1.27	2.5	1.59	2.1	2.00	1.9	1.67	1.9	1.67
	3.4	.71	3.3	.61	3.8	1.40	4.3	1.15	3.5	1.52	3.1	1.98	2.9	1.67	2.9	1.65
	4.5	.62	4.4	.55	4.8	1.35	5.3	1.10	4.6	1.25	4.1	1.73	3.9	1.60	3.9	1.57
	5.6	.51	5.9	.45	5.8	1.07	6.3	1.07	5.7	.82	5.1	1.32	4.9	1.42	4.9	1.32
	....	....	....	....	....	....	....	....	....	....	6.1	.85	5.9	1.15	....	....

[a] Bed of creek is rock, with some bowlders from 0 to 40 and broken rock from 0.5 to 1 foot in diameter the remainder of width.

TABLE XXIII.—*Velocities at regular intervals in vertical sections on Rondout Creek under ice, deduced from data in Table XXII.*

[Velocities in feet per second.]

Depth in parts of total.[a]	Dec. 6.		Dec. 6.		Jan. 14.		Jan. 14.		Feb. 26.		Feb. 26.		Feb. 26.		Feb. 26.	
	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.
0.05	0.61	93	0.55	95	0.85	69	0.96	84	0.95	74	1.60	98	1.40	93	1.23	81
.15	.68	104	.65	112	1.09	88	1.12	98	1.30	101	1.90	116	1.62	107	1.50	99
.25	.75	114	.68	117	1.27	102	1.23	108	1.52	118	1.98	121	1.67	110	1.62	107
.35	.76	116	.67	116	1.40	113	1.27	112	1.58	122	2.02	123	1.68	111	1.67	111
.45	.75	114	.64	111	1.47	119	1.27	112	1.57	121	2.02	123	1.67	111	1.67	111
.55	.72	110	.61	106	1.46	118	1.25	110	1.53	118	1.87	114	1.64	109	1.65	109
.65	.67	102	.57	99	1.41	113	1.20	105	1.44	112	1.67	102	1.57	104	1.60	106
.75	.62	94	.53	91	1.31	106	1.12	99	1.27	99	1.42	86	1.46	97	1.54	102
.85	.55	84	.48	83	1.18	95	1.04	91	1.03	80	1.13	69	1.32	87	1.42	94
.95	.45	69	.40	70	.96	77	.92	81	.71	55	.79	48	1.07	71	1.20	80
Mean	.66	100	.58	100	1.24	100	1.14	100	1.29	100	1.64	100	1.51	100	1.51	100

[a] The lower surface of the ice is zero depth.

TABLE XXIV.—*Velocities in vertical sections under ice on Catskill Creek.*[a]

Date	Feb. 27.		Feb. 27.		Feb. 27.		Feb. 27.		Feb. 27.	
Station	23.		23.		30.		40.		60.	
Gage height	4.50.		4.96.		4.60.		4.70.		4.80.	
Total depth	4.1.		4.7.		4.5.		5.8.		4.7.	
Thickness of ice	.7.		.5.		1.		1.2.		1.5.	
Depth of water	3.4.		4.2.		3.5.		4.6.		3.2.	
	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*
	0.4	1.37	0.3	1.50	0.3	1.42	0.3	2.31	0.3	1.55
	.9	1.57	.7	1.94	.5	1.84	.7	2.41	.7	1.77
	1.4	1.57	1.2	1.96	1.0	2	1.1	2.44	1.2	1.77
	1.9	1.49	1.7	1.89	1.5	2.03	1.0	2.47	1.7	1.61
	2.4	1.16	2.2	1.79	2.0	1.91	2.1	2.44	2.2	1.35
	2.9	1.0	2.7	1.62	2.5	1.74	2.6	2.38	2.7	1.02
			3.2	1.37	3.0	1.55	3.1	2.31		
			3.7	1.07			3.6	2.14		
							4.1	1.89		

[a] Bed of stream rock ledge from 0 to 55, with gravel and silt over remainder of bed.

TABLE XXV.—*Velocities at regular intervals in vertical sections on Catskill Creek under ice, deduced from data in Table XXIV.*

[Velocities in feet per second.]

Depth in feet.	Feb. 27.		Feb. 27.		Feb. 27.		Feb. 27.		Feb. 27.	
	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.	Velocity.	Per cent of mean.
0.05	1.24	94	1.45	92	1.21	69	2.30	101	1.38	97
.15	1.42	108	1.82	115	1.85	106	2.42	106	1.68	117
.25	1.55	117	1.95	123	1.98	113	2.46	108	1.76	122
.35	1.60	121	1.91	121	2.04	117	2.47	108	1.78	124
.45	1.56	118	1.86	118	2.03	116	2.44	107	1.71	120
.55	1.48	112	1.75	111	1.95	111	2.40	105	1.58	111
.65	1.34	102	1.60	101	1.85	106	2.32	102	1.43	100
.75	1.19	90	1.42	90	1.72	98	2.20	97	1.22	85
.85	1.01	77	1.19	75	1.55	89	2.04	89	1.01	70
.95	.81	61	.85	54	1.32	75	1.75	77	.75	54
Mean	1.32	100	1.58	100	1.75	100	2.28	100	1.43	100

The data contained in Tables XIX and XX have been rearranged and combined in Table XXVI. The mean of the 26 vertical velocity curves taken on the Wallkill is shown in the column headed "Mean." The 26 curves are then separated according to the depth of water under ice at the point whence the observations were taken. In two observations the depth of water was less than 5 feet; in thirteen it was from 5 to 10 feet, and in 11 it was from 10 to 20 feet.

To bring out graphically the form of the vertical velocity curve under ice the data in Table XXVI have been plotted in fig. 5, where the solid line represents the mean of the 26 vertical velocity curves taken in the Wallkill. It will be noted that a decided drag occurs at the surface as well as at the bottom of this mean curve; that the maximum velocity occurs at a point about 0.35 of the depth, and that the mean velocity in the vertical occurs at about 0.13 and 0.73 of the depth. There will, in general, always be two points of mean velocity in vertical velocity curves taken under ice.

The results shown in the three last columns in Table XXVI are also plotted in fig. 5, and show the effect of the variation in depth upon the form of the curve. It will be seen that the curves drag more at shallow depths, the curve for depths under 5 feet being more concave than the others, the curve representing the measurements when the water was from 5 to 10 feet in depth being next most concave, while the curve representing the deepest measurement is flattest. This seems reasonable, and would probably hold true in all rivers.

It is frequently desirable to measure the flow of the river when frozen over. This can best be done by taking a large number of point measurements, as represented in fig. 4, but this is a slow process, so that it is important to know at what point the measurement of velocity can be made which will represent the mean velocity in the vertical section.

It will be seen from the four curves in fig. 5 that measurements made at 0.13 and 0.73 of the total depth measured from the bottom of the ice will represent in general the mean velocity in a vertical on a stream with the same general character as the Wallkill. The variation, however, between the curves representing different depths is greater at these two points than at points six hundredths and two-thirds of the depth. At these two points the curves almost coincide. The variation between the various curves was less—in fact within limits only one-half as great—at two-thirds depth as at six-hundredths depth. This shows that in these curves the limit of error is least when measurements are made at two-thirds depth and a coefficient is applied to determine the mean velocity. The mean curve shows a velocity of 105 per cent of the mean at two-thirds depth, so that it would appear that the most accurate method of determining the velocity under ice by observation at one point in the vertical would be to hold the meter at two-thirds depth and apply a coefficient of 0.95 to the observed velocity at that point. This would give a better result than measuring directly the velocity at 0.13 or 0.73 of the depth. In Table XXVII is shown the means of all the curves in the Esopus, Rondout, and Wallkill. These have been plotted in fig. 6. The variation of these three curves is not large, showing that the curve as plotted represents fairly well the typical velocity curve of rivers of this character under ice cover. In Table XXVIII the results shown in all the preceding tables, for ice cover, including Wallkill, Esopus, Rondout, and Catskill, have been combined according to depth of

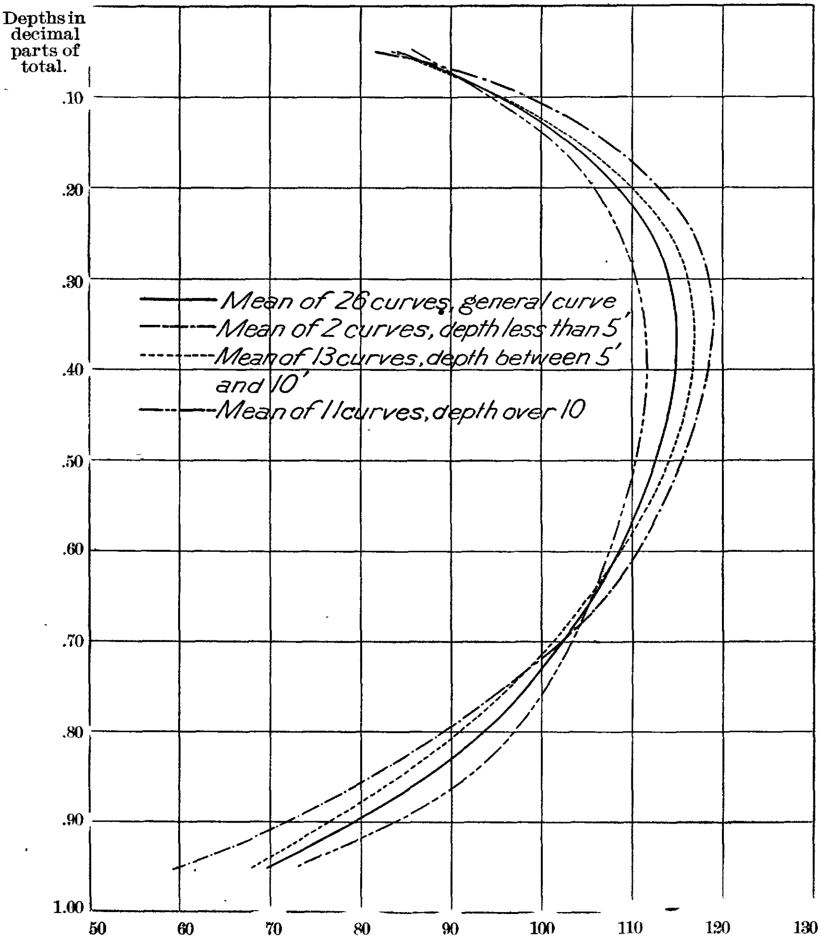


FIG. 5.—Mean vertical velocity curves on Wallkill River, with ice cover, showing the effect upon the curve of variation in depth of water.

NOTE.—The solid line is the mean of 26 vertical velocity curves at all depths; the dot-dash line the mean of two vertical velocity curves at depths less than 5 feet; the dotted line the mean of 13 vertical velocity curves at depths between 5 and 10 feet, and the dash-two-dot lines the mean of 11 vertical velocity curves at depths greater than 10 feet.

water under the ice, and have been plotted in fig. 7, together with the mean of all 47 curves. The form of these curves does not differ materially from those for the Wallkill, plotted in fig. 5. The point at which these curves fall closest together is, however, somewhat higher, at 0.6 depth. To a single measurement made at 0.6 depth a coefficient of 0.92 should be applied to obtain the mean velocity in the vertical section, while the coefficient 0.95 should be applied to a single measurement made at two-thirds depth, as in the case of the Wallkill, shown in fig. 5.

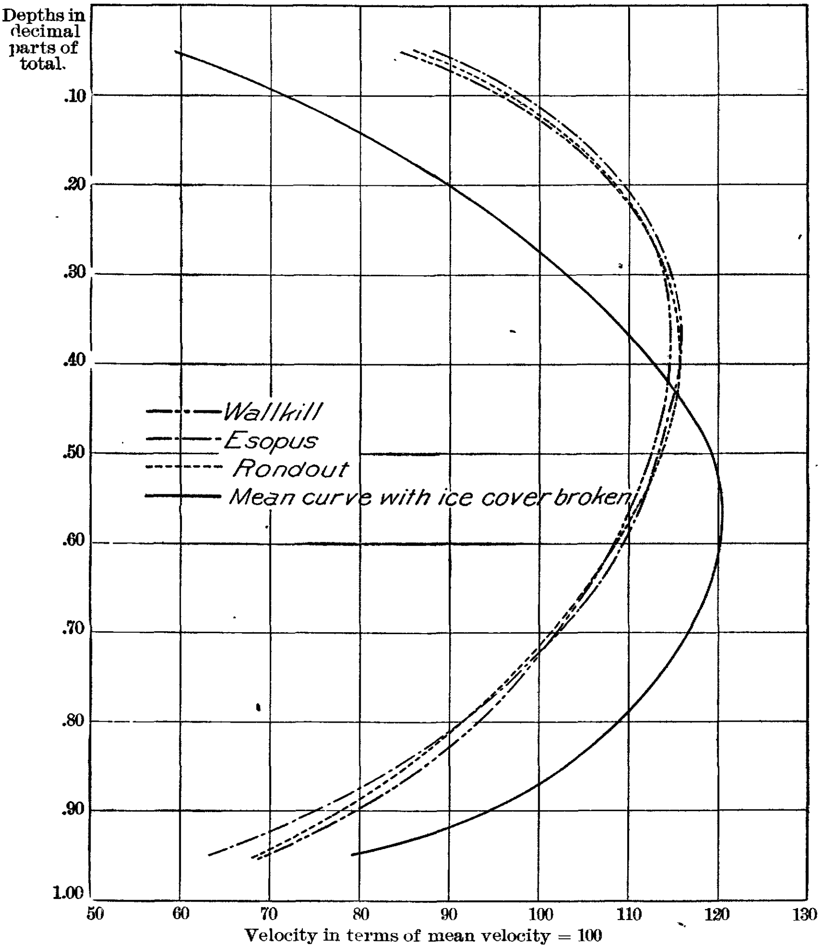


FIG. 6.—Mean vertical velocity curves on Esopus and Rondout creeks and Wallkill River, under ice cover, showing the comparatively slight variation in vertical velocity curves of rivers of this character.

NOTE.—The solid line shows the mean vertical velocity curve on the Wallkill and Rondout with the ice broken and tilted, and shows the decided drag caused by the increased friction at the surface.

There are many engineers who prefer to measure the velocity at mid-depth, and apply a coefficient to obtain the mean velocity in the vertical section. The observations recorded in Table XXVII show that the proper coefficient to apply is 0.88. Observations upon the flow of water under ice cover on the Upper Mississippi were made by

A. O. Powell, assistant engineer, under the direction of Col. Chas. J. Allen, Corps of Engineers, U. S. Army, in 1882 and 1890, and the pub-

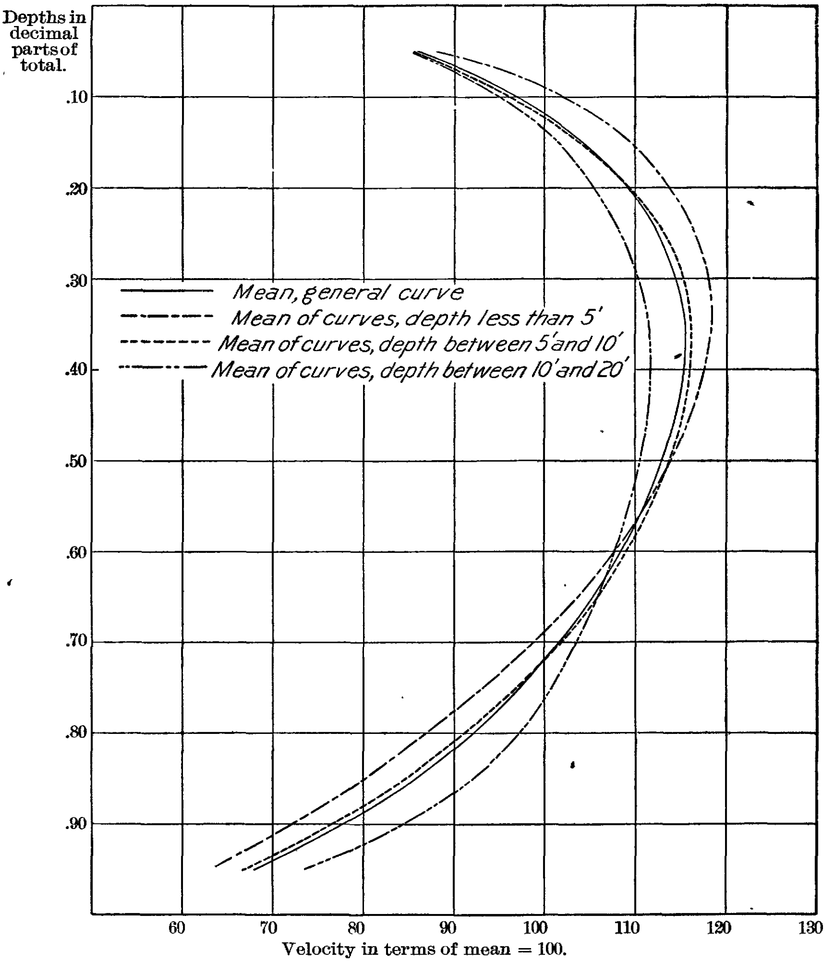


FIG. 7.—Comparison of curves for various depths of water under ice cover with the mean of all curves taken under ice.

NOTE.—The solid line is the mean curve and represents 47 vertical velocity curves. The dash-dot line is the mean of 7 curves with depths of water under ice of less than 5 feet. The dotted line is the mean of 29 vertical velocity curves with depths of water under ice ranging from 5 to 10 feet, and the dash-two-dot line is the mean of 11 vertical velocity curves for a depth of water under ice ranging from 10 to 20 feet.

lished results[a] show that this coefficient varied from 0.87380 to 0.88057.[b]

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[a] Ann. Rept. Chief of Engineers, U. S. Army, Part III, 1890.

[b] Owing to the inaccuracies in observations of this kind, it does not seem to the author justifiable to carry the coefficient beyond the second place of decimals. The results obtained in the streams in New York agree with those in the Mississippi to the second place of decimals.

TABLE XXVI.—*Mean vertical velocity curve on Wallkill River and curves separated according to depths of water.*

[Velocities given in percentages of mean velocity.]

Number of velocity curves	26.	2.	13.	11.
Depth below bottom of ice.	Mean.	Depth of water under ice.		
		Less than 5 feet.	Between 5 and 10 feet.	Between 10 and 20 feet.
0.05	84.0	81.5	83.2	85.5
.15	103.0	107.5	103.7	101.5
.25	112.0	117.0	114.0	108.6
.35	114.8	119.0	116.8	111.5
.45	114.0	117.0	115.7	111.4
.55	110.8	113.5	111.8	109.3
.65	105.8	107.5	105.5	105.9
.75	98.4	96.0	96.6	100.9
.85	87.5	81.0	84.5	92.1
.95	69.7	60.0	68.2	73.3
Mean	100.0	100.0	100.0	100.0

TABLE XXVII.—*Mean vertical velocity curves for Esopus, Rondout, and Wallkill, based upon a mean of 100.*

Stream	Esopus.	Rondout.	Wallkill.
Number of velocity curves	8.	8.	26.
Depth below bottom of ice.	Mean.	Mean.	Mean.
0.05	88.2	85.9	84.0
.15	104.7	103.1	103.0
.25	112.9	112.1	112.0
.35	115.9	115.5	114.8
.45	114.6	115.2	114.0
.55	111.8	111.7	110.8
.65	106.8	105.4	105.8
.75	97.4	96.8	98.4
.85	84.6	85.4	87.5
.95	63.1	68.9	69.7
Mean	100.0	100.0	100.0

TABLE XXVIII.—*Mean velocity curves upon Wallkill, Esopus, Rondout, and Catskill for various depths.*

[Velocities given in percentages of mean velocity.]

Number of velocity curves.	7.	29.	11.	47.
Depth below bottom of ice.	Depth of water under ice.			Mean of all curves.
	Less than 5 feet.	5 to 10 feet.	10 to 20 feet.	
0.05	88.0	85.3	85.5	85.8
.15	109.6	103.8	101.5	104.1
.25	116.7	113.2	108.6	112.6
.35	118.4	116.2	111.5	115.5
.45	116.1	115.3	111.4	114.5
.55	111.0	111.8	109.3	111.1
.65	103.7	105.8	105.9	105.5
.75	93.2	96.9	100.9	97.3
.85	80.6	84.8	92.1	85.8
.95	63.0	66.9	73.3	67.8
Mean	100.0	100.0	100.0	100.0

FLOW OF RIVERS UNDER ICE, BROKEN AND TILTED COVER.

A few vertical velocity curves were taken on the Wallkill and Rondout when the ice on the river was broken and more or less tilted. No general law can be determined for such conditions, as the impeding power of the ice varies between wide limits. It is interesting, however, to note in a general way the effect of the ice. The drag at the surface is greatly increased and the curve is changed considerably in form. In Tables XXIX to XXXII will be found the results of the measurements, while in Table XXXIII is the summary of these results. The mean curve, as shown in Table XXXIII, is plotted in fig. 8, together with the mean curves when the ice covering was smooth. It will be seen from this diagram that the point of maximum velocity is 0.55 of the depth, much lower than with smooth ice; that the surface velocity is much less, and that the bottom velocity is greater. This curve would without doubt vary greatly at different times, depending upon the condition of the ice, so that measurement at any point for the determination of the mean velocity would not be advisable. Point measurements at frequent intervals would be necessary in order to obtain reliable results. It is not considered that the results show any decided law of relation between velocities at various depths, but the general form of the curve is characteristic in conditions similar to those under which these were taken.

TABLE XXIX.—*Velocities in vertical section on Wallkill River under ice broken and tilted.*

Date	Dec. 19.		Dec. 19.		Dec. 19.		Dec. 19.		Jan. 23.	
Point of measurement	115.		95.		85.		75.		30.	
Gage height	13.70.		13.70.		13.70.		13.70.		17.33.	
Total depth	18.0.		16.0½.		15.6½.		14.5.		14.4.	
Thickness of ice	4.0.		0.0½.		0.0½.		1.0.		1.4.	
Depth of water	14.0.		16.0.		15.6.		13.5.		13.0.	
	Depth.	Velocity.	Depth.	Velocity	Depth.	Velocity.	Depth.	Velocity.	Depth.	Velocity.
	Feet.	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*	*Feet.*	*Ft. per sec.*
	0.5	0.30	1.5	2.73	1.1	2.52	1.0	1.52	1.0	1.72
	1.5	1.27	3.5	3.30	3.1	3.08	3.0	2.50	2.5	1.96
	3.5	2.33	5.5	3.48	5.1	3.48	5.0	2.94	4.5	2.26
	5.5	2.71	7.5	3.84	7.1	3.91	7.0	3.03	6.5	2.56
	7.5	2.99	9.5	4.12	9.1	3.95	9.0	3.13	8.5	2.64
	9.5	2.94	11.5	3.93	11.1	3.86	11.0	2.88	10.5	2.24
	11.5	2.64	13.5	3.60	13.1	3.50	13.0	2.45	12.5	1.67
	13.5	1.94	15.5	2.61	15.1	2.64				

TABLE XXX.—*Velocities at regular intervals in vertical section on Wallkill River under ice broken and tilted, deduced from Table XXIX.*

Depth in parts of total.	Dec. 19.		Dec. 19.		Dec. 19.		Dec. 19.		Jan. 23.	
	Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.
0.05	1.10	45	2.35	68	2.40	71	1.40	54	1.68	77
.15	1.94	80	3.00	86	2.95	87	1.94	74	1.88	86
.25	2.41	99	3.35	97	3.33	98	2.60	99	2.07	94
.35	2.70	111	3.65	105	3.62	106	2.87	109	2.26	103
.45	2.90	119	3.90	112	3.86	113	3.04	115	2.45	111
.55	3.00	123	4.10	118	3.95	116	3.11	118	2.62	119
.65	2.94	120	4.07	117	3.90	115	3.08	117	2.62	119
.75	2.80	115	3.88	112	3.76	111	2.98	113	2.44	111
.85	2.55	104	3.60	103	3.42	101	2.78	106	2.15	98
.95	2.05	84	2.85	82	2.80	82	2.50	95	1.80	82
Mean	2.44	100	3.48	100	3.40	100	2.63	100	2.20	100

TABLE XXXI.—*Velocities in vertical sections on Rondout Creek at Rosendale under ice broken and tilted.*

Date	Dec. 6.		Jan. 14.		Jan. 14.		Jan. 14.	
Point of measurement	50.		40.		50.		60.	
Gage height	6.80.		7.00.		7.00.		7.00.	
Total depth	5.6.		4.8.		6.4.		6.4.	
Thickness of ice	0.2.		0.8.		0.4.		0.4.	
Depth of water	5.4.		4.0.		6.0.		6.0.	
	Depth.	Velocity in feet per second.	Depth.	Velocity in feet per second.	Depth.	Velocity in feet per second.	Depth.	Velocity in feet per second.
	0.3	0.21	0.5	0.35	0.5	0.72	0.5	0.55
	1.3	.54	1.5	.75	1.5	.82	1.5	.87
	2.8	.55	2.5	.97	2.5	.90	2.5	1.17
	3.8	.57	3.5	.85	3.5	.90	3.5	1.15
	4.9	.36			4.5	.87	4.5	1.10
					5.5	.72	5.5	.85

TABLE XXXII.—*Velocities at regular intervals in vertical section on Rondout Creek under ice broken and tilted, deduced from Table XXXI.*

Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.	Velocity in feet per second.	Per cent of mean.
0.25	53	0.24	34	0.67	81	0.48	51
.46	99	.40	57	.76	92	.68	72
.54	115	.55	79	.82	100	.87	93
.57	122	.70	100	.88	107	1.06	112
.57	122	.85	121	.90	110	1.19	127
.56	120	.95	136	.91	111	1.19	126
55	117	.97	139	.90	109	1.14	121
50	107	.95	135	.88	107	1.06	113
.43	92	.88	126	.82	100	.96	102
.25	53	.51	73	.69	83	78	83
.468	100	.70	100	.823	100	.941	100

TABLE XXXIII.—*Summary of curves on Wallkill and Rondout, under ice broken and tilted.*

Stream	Wallkill.	Rondout.	
Number of velocity curves	5.	4.	9.
Depth of water below bottom of ice.	13 to 16 ft. River bed: Silt.	4 to 6 ft. River bed: Bowlders and gravel.	Mean.
0.05	63.0	54.8	59.3
.15	82.6	80.0	81.4
.25	97.4	96.8	97.1
.35	106.8	110.2	108.3
.45	114.0	120.0	116.7
.55	118.8	123.2	120.8
.65	117.6	121.5	119.3
.75	112.4	115.5	113.8
.85	102.4	105.0	103.6
.95	85.0	73.0	79.7
Mean	100.0	100.0	100.0

QUALITY OF RIVER WATER.

A study of the turbidity, color, alkalinity, and hardness of these streams has been made in conjunction with the discharge measurements. It is thought that the information derived from such determinations will be of value to engineers investigating the future supply of New York City.

TURBIDITY AND COLOR.

Water in its ideal condition is perfectly clear and limpid, and has a slightly blue color. Filtered water, distilled water, and many spring waters approach closely to the ideal water. Most river waters are, however, either colored by contact with peat, muck, or decaying vegetation, or are turbid by reason of mud or silt carried in suspension. Muddy waters are often spoken of as colored waters, and in a sense this is correct where the mud consists of clays or other materials having distinct colors, but for convenience of classification it is better to refer to such waters as turbid waters, and to limit the term "colored waters" to those containing in solution vegetable matters which color them.

It has been observed that highly colored waters are usually free from turbidity, and vice versa, this being due to the fact that colored waters usually flow from drainage areas underlain by hard rocks not easily disintegrated, or from regions where the soils are firm or sandy, and especially from swamps. On such areas there is but little material that would be washed from the river banks and held in suspension, while the coloring material is present in the greatest abundance. In many parts of the United States shales or other soft materials form the underlying beds. These readily disintegrate and form clay soils that are readily washed by hard rains. Waters from such areas are usually turbid and very highly colored.

Turbidity and color are principally important in their effect upon the appearance of water, whereas the other impurities discussed in this paper have absolutely no effect upon the appearance, and can be found only by their chemical action.

TURBIDITY.

The turbidity of water is a subject of great importance to the sanitary engineer. In questions of water supply, turbidity is often the important feature in the selection of a source of town supply; the number of days upon which the turbidity is above a certain fixed standard is also important, in that it may determine the size of reservoir required to store clear water sufficient to tide over the time of greatest turbidity, or for the sedimentation of suspended matters in the reservoir water. The importance of this subject varies with the part of the country studied, the waters in the New England States and New York being comparatively clear, while in the Southern Atlantic States and in the Ohio and Mississippi valleys high turbidities are the rule.

In the Northeast the terms "very slight, "slight," "distinct," and "decided" have been used by analysts to express the amount of suspended matter present. These degrees of turbidity have been estimated by the appearance of the sample to the eye when viewed toward the light. As the importance of these analyses has been more appreciated, particularly in connection with the purification of waters and the extended studies upon waters of high turbidity, it has been found that a more definite scale was necessary in order that proper comparisons of waters from various sources might be made.

In the filtration of water the engineer desires to know the amount of coagulant necessary to properly clarify the water, and it has been found that the turbidity gives a reliable index of the quantity of coagulant required. The object of the more recent studies has been, therefore, to express it numerically on some scale, referred to some standard, which can be easily reproduced and will be permanent.

There has been considerable difference of opinion as to the proper standard for turbidity comparisons, and some confusion has resulted. It is important that any standard selected should be applicable to both field and laboratory practice, and that observations made by different methods should be readily comparable.

The United States Geological Survey has had occasion, from time to time, to make observations of turbidity of rivers of which discharge measurements were made. Realizing the importance of a uniform standard for turbidity, the Survey has cooperated with Mr. Allen

Hazen and Mr. George C. Whipple in order that such a standard might be adopted. Mr. Hazen and Mr. Whipple have made joint investigations and studies, and have recommended the standard given below. This will be used in the future by the Survey, and it is hoped may be adopted generally throughout the United States.

PROPOSED TURBIDITY STANDARD.[a]

The standard of turbidity shall be a water which contains 100 parts of silica per million in such a state of fineness that a bright platinum wire 1 millimeter in diameter can just be seen when the center of the wire is 100 millimeters below the surface of the water and the eye of the observer is 1.2 meters above the wire, the observation being made in the middle of the day, in the open air, but not in sunlight, and in a vessel so large that the sides do not shut out the light so as to influence the results. The turbidity of such water shall be 100.

The turbidity of waters more turbid than the standard shall be computed as follows: The ratio of the turbidity of the water to 100 shall be as the extended volume is to the original volume, when the water is diluted with a clear water until the mixture is of standard turbidity.

The turbidities of waters lower than the standard should be computed as follows: The ratio of the turbidity of the water to 100 shall be as the ratio of the original volume of water of standard turbidity is to the extended volume when such water is diluted with a clear water until its turbidity is equal to that of the water under examination.

This standard can be used in both field and laboratory. In the field the wire method will be carried out as at present, except for a new graduation, while in the laboratory the methods of dilution and comparison now in use for the silicia standard will be used.

METHOD OF APPLICATION TO THE PLATINUM-WIRE PROCESS.

A rod with a platinum wire inserted in it at a fixed point and projecting from it at a right angle will be used as at present. The graduation shall be as follows: The graduation mark of 100 shall be placed on the head at a distance of 100 millimeters from the center of the wire. Other graduations will be made, based on the best obtainable data, in such a way that when a water is diluted the readings will decrease in the same proportion as the percentage of the original water in the mixture. Such a rod, having the graduation shown in the table below, shall be known as the United States Geological Survey turbidity rod of 1902. When this rod is immersed in water the visibility of the projecting platinum wire at the depth from the surface shown in the second column will determine the degree of turbidity, as indicated in the first column.

[a] From a letter signed by Messrs. Allen Hazen and George C. Whipple.

Graduation of rod.

Turbidity.	Depth of wire.	Corresponding value on reciprocal scale.	Turbidity.	Depth of wire.	Corresponding value on reciprocal scale.
	Mm.			*Mm.*	
7	1095	0.023	70	138.0	0.184
8	971	.026	75	130.0	.196
9	873	.029	80	122.0	.208
10	794	.032	85	116.0	.219
11	729	.035	90	110.0	.230
12	674	.038	95	105.0	.242
13	627	.041	100	100.0	.254
14	587	.043	110	93.0	.273
15	551	.046	120	86.0	.295
16	520	.049	130	81.0	.314
17	493	.052	140	76.0	.334
18	468	.054	150	72.0	.35
19	446	.057	160	68.7	.37
20	426	.060	180	62.4	.41
22	391	.065	200	57.4	.44
24	361	.070	250	49.1	.52
26	336	.076	300	43.2	.59
28	314	.081	350	38.8	.65
30	296	.086	400	35.4	.72
35	257	.099	500	30.9	.82
40	228	.111	600	27.7	.92
45	205	.124	800	23.4	1.09
50	187	.136	1000	20.9	1.21
55	171	.148	1500	17.1	1.49
60	158	.160	2000	14.8	1.72
65	147	.172	3000	12.1	2.10

This table is compiled from observations made at Cincinnati, St. Louis, New Orleans, Pittsburg, Brooklyn, Philadelphia, and Boston, for records of which we are indebted to several observers. The values of the turbidities by the reciprocal scale are included in the table as a matter of convenience, but they do not form a part of the standard.

This graduation is subject to revision whenever additional data shall make it necessary, and revised rods shall be designated by the same name, but with the year of revision substituted for 1902. The revisions shall have as their basis the one hundred mark, 100 millimeters from the wire.

Near the end of the rod, at a distance of 1.2 meters from the platinum wire, a wire ring shall be placed directly above the wire, through

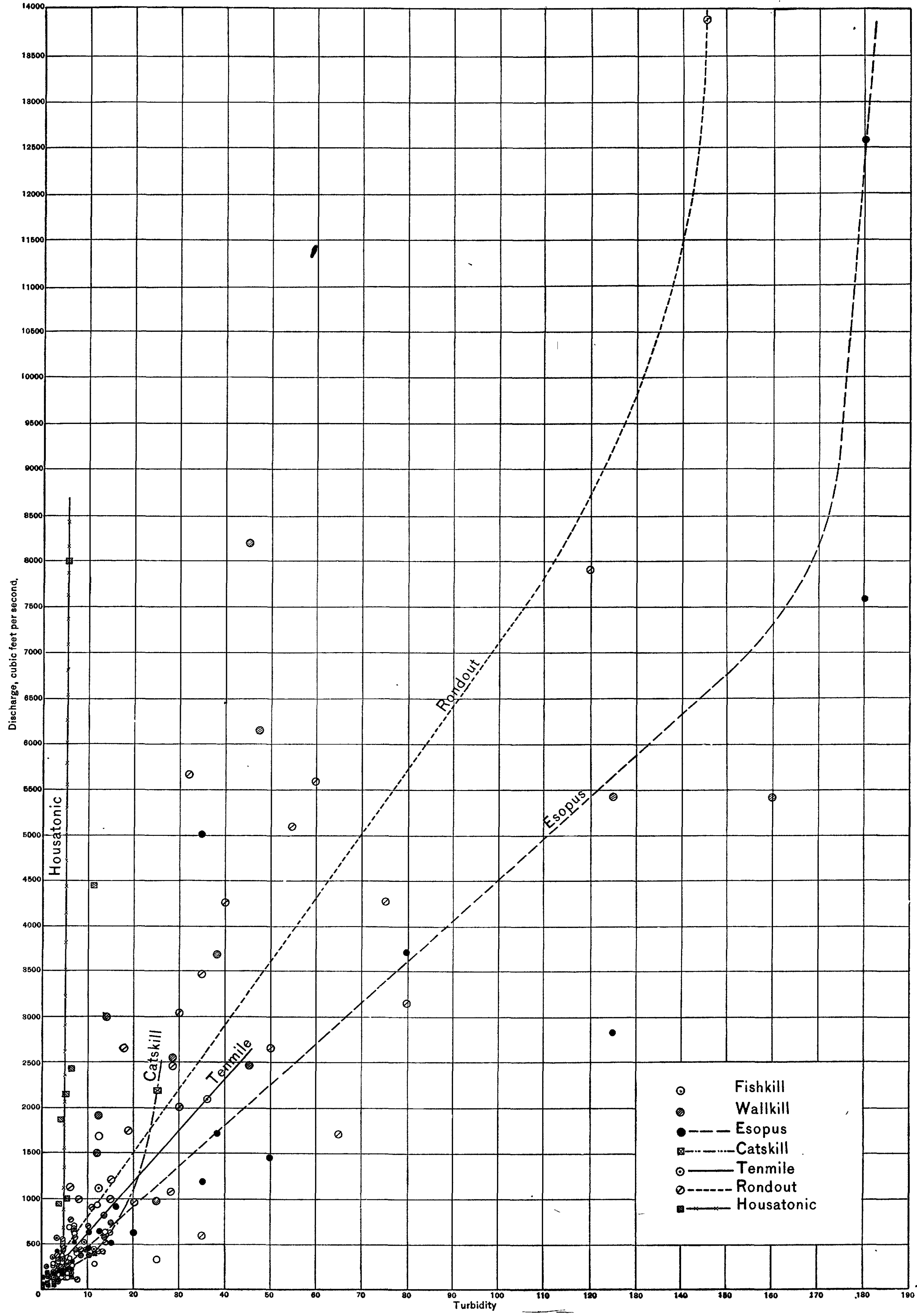


DIAGRAM SHOWING RESULTS OF TURBIDITY OBSERVATIONS.

which the observer will look, the object of the ring being to control the distance from the wire to the eye.

When the turbidity is greater than 500 the water should be diluted before the observation is made. When the turbidity is below 7 this method can not be used, and comparison should be made with the silica standard properly diluted in bottles or tubes.[a]

The number obtained by dividing the weight of suspended matter in parts per million by the turbidity as obtained above shall be called the coefficient of fineness. If greater than unity, it indicates that the matter in suspension in the water is coarser than the standard; if less than unity, that it is finer than the standard.

This standard is proposed with the idea of combining the best features of the platinum-wire and silica methods of measuring turbidities as commonly used, and of avoiding, as far as possible, the objections to each.

The wire method is most convenient as a field method. With the reciprocal scale, which until now has been used, it is open to the serious objection that the readings are not proportional to the amount of turbidity-producing matter in the water.

The silica standard is free from this objection and is more convenient as a laboratory method, but is not well adapted to field use, and is open to the objection that it is possible that the value may be changed by variations in the fineness of the silica particles composing the standard.

The standard now proposed is intended to overcome the above-mentioned defect in the platinum-wire method with the reciprocal scale, and at the same time to put a control on the value of the silica standard. Applying it in one way or the other, it is adapted to both field and laboratory use, and the results obtained should check substantially.

METHOD OF MAKING OBSERVATIONS.

The method of making the observations by means of the platinum wire is as follows: Take a stick of wood about 5 feet long and five-eighths of an inch square, more or less, and insert a platinum wire at a point about 1 inch from the end, so that the wire will be at right angles to the stick and project at least 1 inch. The wire should be 0.04 inch or 1 millimeter in diameter; the stick is then graduated, the lines for the various turbidities being at distances from the wire shown in the table on page 2.

Observations of turbidity are taken by putting this stick into the water under examination as far as the wire can be seen; the turbidity is then read from the scale. This is most conveniently accomplished by having a second or smaller stick placed in front of the first, the end of which is brought to the water line when the wire can just be

[a] Described by Whipple and Jackson in Technology Quarterly, Vol. XII, No. 4, December, 1899.

seen. Upon removing the two together the position of the smaller stick on the scale gives the turbidity.

Observations are to be taken in all cases in open air, as too high results are obtained under a roof, even with very good light; and they should preferably be taken in the middle of the day and not in direct sunlight. In case the sun is shining the observer can stand so that his shadow covers the water immediately about the stick and wire. The observations are taken with the eye of the observer at the ring before mentioned, 1.2 meters from the wire, although some variation in this does not materially influence the result. The wire should be kept bright and clean. In case it is lost, a clean bright pin can be used until another wire can be obtained. When the surface of the water in the stream is agitated by currents, waves, etc., or in case the depth is not sufficient to give the required immersion, or if for any reason observations can not be well taken from the bank, a pail or tub may be filled with water and the turbidity observations taken in it. In many cases this procedure is preferable to measurement in a stream, but the observation must be taken immediately upon filling the vessel. The diameter of the vessel should be equal to at least twice the depth at which the wire is immersed, as otherwise the results of the reading will be affected.

When the turbidity of the water is above 500, that is, in case the wire can be seen through less than 1 inch of water, the results obtained by direct measurement are not accurate. Such water should be diluted by 1, 2, or 4 volumes of clear water in the pail or tub, and thoroughly mixed.

The turbidity is taken as above described, and multiplied by the ratio that the total volume of water bears to the water in the mixture. Clear water can be obtained from a well or any other source obviously clear, or nearly so.

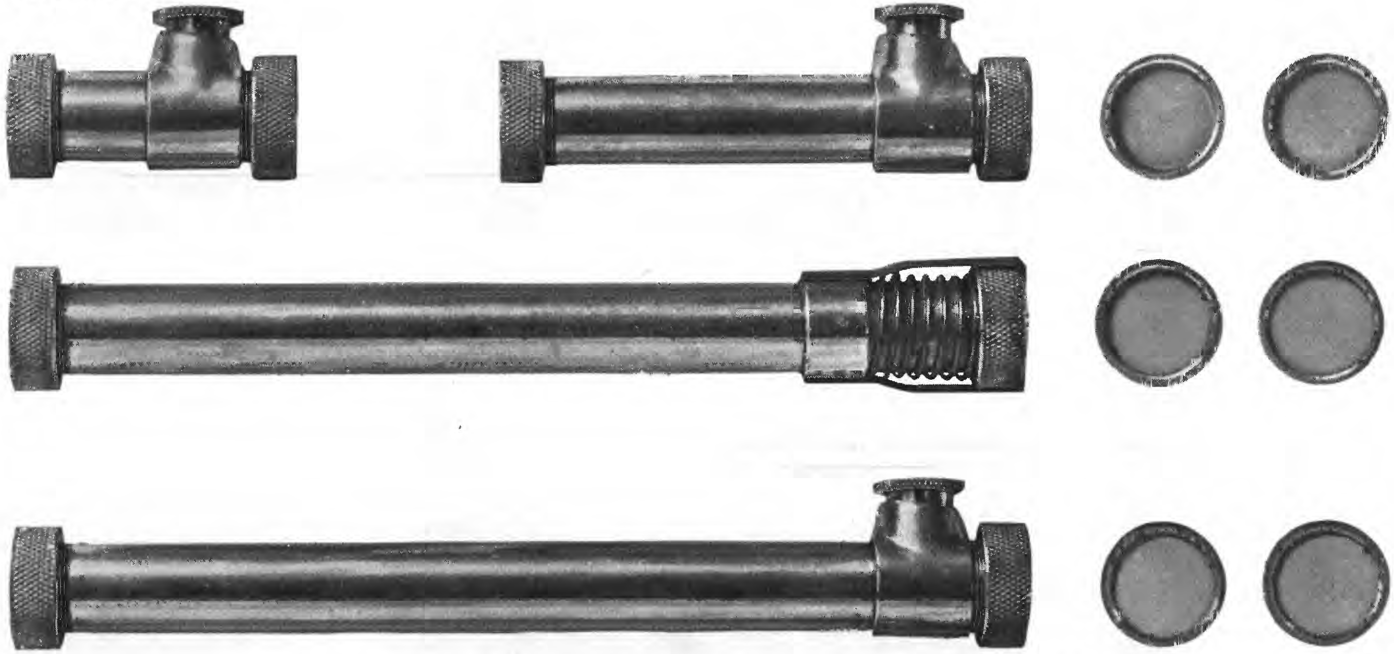
The statement of turbidity in such cases should contain memoranda that the observations were taken in this way, and should give the amount of dilution.

If waters have a turbidity less than 7 direct reading can not be used, and indirect methods must be resorted to.

The "wire method" has been described first in this paper, as it is best suited to field work. Besides this method, there are two others that have commended themselves to practical use. First, the use of standards of comparison; second, the diaphanometer.[a]

In the determinations of turbidity of waters in rivers considered in this paper, the turbidities were in general too low for accurate measurements by the wire method, and as the samples had to be shipped to the laboratory for other determinations, the turbidity was found by comparison with standards. These standards were made up from dia-

[a] These are both laboratory methods, and have been described by Mr. George C. Whipple and Daniel D. Jackson, in the Technology Quarterly, Vol. XII, No. 4, December, 1899.



TUBES AND DISKS FOR MEASURING IN THE FIELD THE COLOR OF RIVER WATER.

tomaceous earth thoroughly washed and ignited to remove the organic matter. The earth is then washed in hydrochloric acid and rinsed with water, after which it is pulverized. One-half grain is added to 500 c. c. of distilled water and thoroughly agitated. This stock mixture contains 1 grain of pure silica per liter, or 1,000 parts per 1,000,000, and when well shaken will always give the same turbidity, which is called a standard 1,000. For waters of low turbidities, like those found in New York State, standards are made by diluting the stock mixture with distilled water in measured proportions and comparing the collected samples with the various standards in gallon bottles, while with higher turbidities smaller quantities of the standards are placed in 100 c. c. Nessler tubes, with which the samples in like tubes are compared. This is a laboratory method, and is more precise than the wire method of making determination of turbidity, but requires that samples be collected and shipped to the laboratory.

In order that some idea of the meaning of the various standards may be obtained, the following table is inserted:

Table showing meaning of various numbers on silica scale.

Silica standard.	Destriptive term.
0	None.
1–2	Very slight.
2–5	Slight.
5–20	Distinct.
Above 20	Decided.

COLOR.

The platinum-cobalt method of measuring color, as devised by Allen Hazen, is generally considered the standard.

A standard solution which has a color of 500 shall be made by dissolving 1.246 grams potassium-platinic chloride[a] ($PtCl_4,2KCl$), containing 0.5 gram platinum, and 1 gram of crystallized cobalt chloride ($CoCl_2,6H_2O$), containing 0.25 gram of cobalt in water, with 100 cubic centimeters concentrated hydrochloric acid, and making up to 1 liter with distilled water. By diluting this solution standards shall be prepared having values of 0, 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, and 70. The numbers correspond to the metallic platinum in the solutions in parts per million. These shall be kept in 100-cubic-centimeter Nessler jars of such diameter that the liquid shall have a depth between 20 and 25 centimeters and shall be protected from dust. The

[a] Potassium-platinous chloride is a salt that is often substituted by dealers in place of the potassium-platinic chloride. It is sometimes incorrectly labeled. The platinous salt has a reddish color while the platinic salt has a yellow color.

color of a sample shall be observed by filling a similar tube with water and comparing it with the standards. The observation shall be made by looking vertically downward through the tubes upon a white surface placed at such an angle that light is reflected upward through the column of liquid. The reading shall be recorded to the nearest unit. Waters that have a color darker than 70 shall be diluted before making the comparison, in order that no difficulties may be encountered in matching the hues. Water containing matter in suspension shall be filtered until no visible turbidity remains. If the suspended matter is coarse, filter paper may be used for this purpose; if the suspended matter is fine, the use of the Berkfeld filter is recommended, but it must be thoroughly washed each time before using. The use of a Pasteur filter is to be avoided, as it exerts a decolorizing action.

The determinations of color upon the streams considered in this paper, and given on the following pages, were made by the above laboratory method. For the sake of completeness, however, the field method of making determinations of color will be described.

It is impracticable to carry the standard tubes above described into the field for observations, and yet field observations are of great convenience and value to the sanitary engineer, and in general to the investigations of the United States Geological Survey.

Standard disks of colored glass have been prepared by Mr. Allen Hazen, in cooperation with the Survey, as standards for measuring color of water in the field (Pl. X). These disks have been rated by Mr. George C. Whipple to correspond with the platinum-cobalt standard. The color is measured by balancing the color of the water in a metallic tube with glass ends against the colors of glass disks of known value. The number on each disk represents the corresponding color of a water. This is not a new standard, but a new application of an old standard. The glass disks are rated to correspond with the platinum-cobalt color standard. The process bears the same relation to the usual laboratory process that an aneroid barometer bears to a mercurial barometer. The metallic tubes and glass standards are more portable and better adapted to field use than the Nessler tubes and color solutions previously used.

Color standards.—The standards are disks of amber-colored glass, mounted with aluminum. Each disk carries two numbers. One number is over 100, and is a serial number for the purpose of identification. The other number is less than 100, and shows the color value of the disks; that is to say, the color of each disk is equal to the color of a solution of the designated number of parts per million of platinum with the required amount of cobalt to match the hue when seen in a depth of 200 millimeters.

Each apparatus has a series of glass disks of varying values, so that waters within a reasonable range can be matched by them. When a water comes between two disks its value can be estimated between them by judgment. Two or more disks can be used, one behind the other, in which case their combined value is the sum of the individual values. By combining the disks of a series in different ways a considerable number of values can be produced, allowing the closer matching of many waters.

Filling the tubes.—The tube, having an aluminum stopper, is to be filled with water, the color of which is to be determined. Rinse the tube once or twice by filling and emptying it. The second tube, having the clips to hold the glass disks, is made much like the one holding the water to facilitate comparison. Theoretically this tube should be filled with distilled water. Practically it makes very little difference whether it is filled with distilled water or empty. Use distilled water when it is convenient to do so, and when distilled water of unquestionable quality is at hand; otherwise wipe the inside of the tube dry to prevent fogging of the glass ends, and proceed with the tube empty.

Holding the tubes.—Hold the tubes at such a distance from the eye that the sides of the tubes just can not be seen. This occurs when the near end of the tube is 8 or 9 inches from the eye. Hold the tubes at such an angle that both can be seen at once with one eye. Good results can not be obtained in any other way. Let the tubes change places once or twice, as sometimes the light on the right and left is not quite equal.

Background.—There should be a clear white background with a strong illumination. The best results can not be obtained with either too little or too much light. In a gray day look at the sky near the horizon and away from the sun. In a bright day look at a piece of white paper or tile, upon which a strong light falls. The white surface may be vertical and the tubes held horizontally, or the tubes may be held at an angle directed downward toward a horizontal surface, as may be most convenient. Good results can not be obtained by artificial light.

Turbid water.—The colors of very turbid waters can not be measured in this way. Slight turbidities do not interfere seriously with the results. Waters too turbid for direct observations should be filtered through thick filter paper before being tested, and in case the turbid matter is fine and in large amount even this method may fail. The turbidity of water should be taken as far as possible in connection with color observations, except in cases where it is obvious from inspection that there is practically no turbidity.

Highly colored waters.—Some waters will be found having a higher color than can be matched by the standards. In general, waters with colors above 100 should not be matched in 200-millimeter tubes, and the results with waters having colors below 80 will be considerably more accurate than with more highly colored ones. Two procedures are possible with waters having higher colors—namely, to dilute with distilled water before measuring the color or to use shorter tubes. The latter procedure is the more convenient, but both are equally accurate. To measure the color with short tubes, put the highly colored water in a tube of one-half the usual length and match as usual. It is not necessary to have a short standard holder. The 200-millimeter tube can be used. After the water is matched the result is multiplied by 2. In case the color is too high to be read in a 100-millimeter tube it can be put in a 50-millimeter tube, and the result multiplied by 4. When dilution is used the highly colored water is mixed with one or more volumes of distilled water, the color matched, and the result multiplied by a corresponding factor. The tube itself can be used for measuring the colored water and the distilled water, and the mixing can be done in a tumbler or any convenient clean vessel.

Cleaning the tubes.—The tubes should always be kept clean and the glass ends protected. All the ends are removable for the purpose of cleaning, and should not be screwed on too tightly. They should be water-tight when only screwed up loosely, and if screwed on hard they may stick so as to come off with difficulty.

ALKALINITY.

The alkalinity of water is practically a measure of the carbonates and bicarbonates present. The determination is made as follows: Put 100 c. c. of the sample into a 6-inch porcelain evaporating dish. Add two or three drops of a 0.1 per cent aqueous solution of methyl-orange. If the water is alkaline, this will impart to it a faint yellowish brown color. Then from a burette graduated in tenths of a cubic centimeter run in a fiftieth-normal solution of sulphuric acid until the color of the water changes to a faint pink. The acid must be added in small portions (only one drop at a time as the end point is reached) and the water stirred with a glass rod after each addition. The number of cubic centimeters of fiftieth-normal acid required, when multiplied by ten, gives the alkalinity of the water expressed in equivalent parts per million of calcium carbonate. That is, if 1.8 c. c. is required to cause the color of the indicator to change from brown to red, then the alkalinity of the water is 18 parts per million. Inasmuch as it is necessary to add a certain amount of fiftieth-normal acid to 100 c. c. of water which has no alkalinity in order to produce the typical color change, the reading obtained must be corrected for this amount. This correction for the indicator varies with different individuals, but it seldom exceeds 0.3 c. c.

Other indicators, such as lacmoid or erythrosine, may be used in place of methyl-orange, and in certain instances their use is to be preferred, but for general field work methyl-orange is most convenient.

PERMANENT HARDNESS.

The Clark's soap method has been used in the examinations of river waters given in the following tables. This method gives reliable

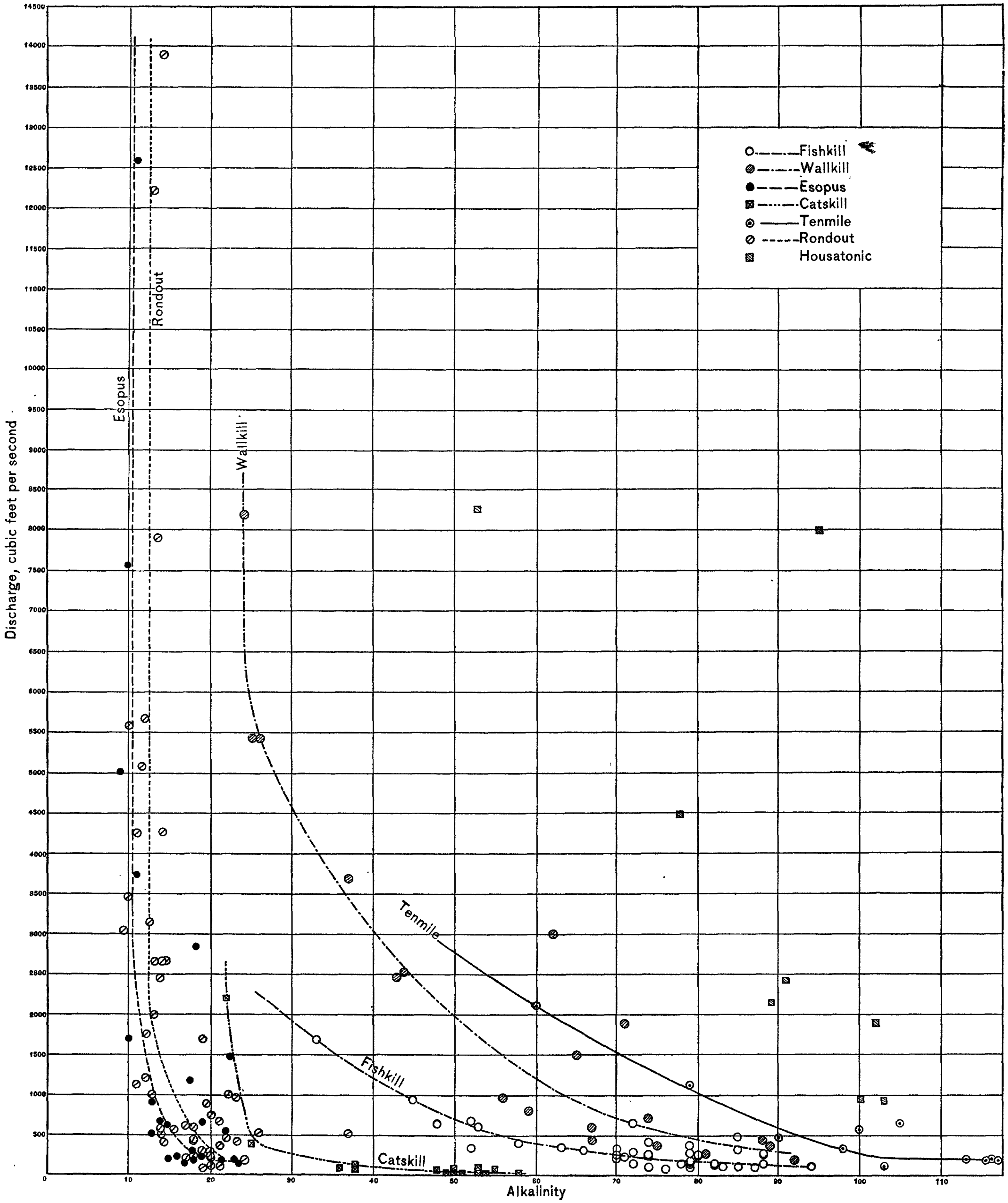


DIAGRAM SHOWING RESULTS OF ALKALINITY OBSERVATIONS.

results for waters as soft as those under consideration, but for the hard waters of the Central States Hehner's acid method will perhaps give more reliable and uniform results.

Results of determinations of hardness obtained by various observers are frequently very discrepant, and it is not uncommon to have results reported by chemists which are worthless on account of faulty methods. It is hoped that the determinations of hardness may be made upon a more uniform basis throughout the country, so that the results may be comparable.

In the following tables are given the results of the observations upon turbidity, color, alkalinity, and hardness, together with the discharge of Esopus, Rondout, Wallkill, Catskill, Fishkill, Tenmile, and Housatonic:

Turbidity color, alkalinity, and hardness of streams.

CATSKILL CREEK.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Aug. 19	a2.62	6	1	58.0		28
Aug. 27	a2.95	11	2	48.0		77
Sept. 2	a3.00	7	2	53.0		89
Sept. 8	a2.90	9	2	55.0		66
Sept. 23	2.73	2	2	54.0		39
Oct. 4	2.70	4	1	51.0		36
Oct. 10	2.65	1		53.0	53.0	31
Oct. 22	2.82	6	3	50.0		51
Nov. 8	2.70	1		49.0	50.0	36
Nov. 19	2.75	3	1	50.0	50.0	42
Dec. 9	3.30	2		38.0	44.5	110
1902.						
Jan. 15	3.50	2	1	38.0	42.0	144
Feb. 27	4.90	22	11	25.0	26.0	400
Apr. 10	6.70	22	25	22.0	24.0	2,200
May 10	3.47	4	6	36.0	42.0	133
June 3	2.82	6	1	42.0	50.0	99
June 24	2.70	9	3	47.0	51.5	43
July 9	3.40	9	2	45.0	47.0	113
July 23	6.11	35	25	35.0	44.5	1,602
Aug. 2	5.36	33	12	42.0	49.0	1,005
Aug. 13	3.49	12	1	50.0	50.5	135
Aug. 27	2.74	11	4	56.0	52.0	394
Sept. 5	2.79	6	4	56.0	56.0	50

a Taken from gage height record.

Turbidity, color, alkalinity, and hardness of streams—Continued.

RONDOUT CREEK.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Aug. 28	7.15	42	4	37.0		620
Sept. 1	7.62	32	20	23.0		980
Sept. 3	7.80	66	6	11.0		1,126
Sept. 4	7.13	68	15	18.0		602
Sept. 19	6.87	30	12	18.0		430
Do	6.87	30	13	14.0		430
Oct. 11	6.50	26	4	17.0		185
Oct. 3	6.95	40	4	22.0	22.0	481
Oct. 15	7.65	26	8	22.0	[a] 21.0	1,001
Oct. 22	6.70	28	3	20.0	[a] 19.0	314
Oct. 31	6.50	24	4	24.0	[a] 24.0	185
Nov. 13	7.00	21	14	26.0	27.0	515
Nov. 16	6.60	26	5	20.0	26.0	249
Nov. 19	6.40	21	2	20.0	24.0	123
Nov. 22	6.35	23	3	19.0	25.0	92
Nov. 26	7.30	32	7	17.0	23.0	728
Nov. 29	6.80	31	3	21.0	24.0	380
Dec. 3	6.40	23	7	21.0	24.5	123
Dec. 6	6.80	21	3	19.0	23.5	280
Dec. 10	9.80	32	65	19.0	25.0	1,700
Dec. 11	9.50	38	([b])	13.0	20.0	2,650
Dec. 12	8.50	34	19	12.0	17.5	1,750
Dec. 15	16.70	80	([b])	13.0	18.0	12,230
Dec. 16	11.00	48	75	11.0	20.0	4,250
Dec. 25	7.25	13	7	14.0	26.0	592
Dec. 30	12.20	32	60	10.0	20.0	5,574
1902.						
Jan. 7	7.00	17	5	14.0	24.0	515
Jan. 14	6.70	14	4	20.0	23.5	240
Jan. 18	6.70	14	3	18.0	21.0	240
Jan. 23	10.30	32	3	10.0	12.5	3,480
Jan. 25	7.90	23	1	12.0	14.5	1,212
Jan. 28	7.70	80	10	21.0	25.5	675
Feb. 4	9.50	14	18	14.5	21.5	2,650
Feb. 11	8.20	11	11	19.5	24.5	900
Feb. 14	7.85	10	6	20.0	24.5	742
Feb. 27	10.45	22	30	13.0	15.9	2,000

[a] Likely too low.

[b] Bottle broken.

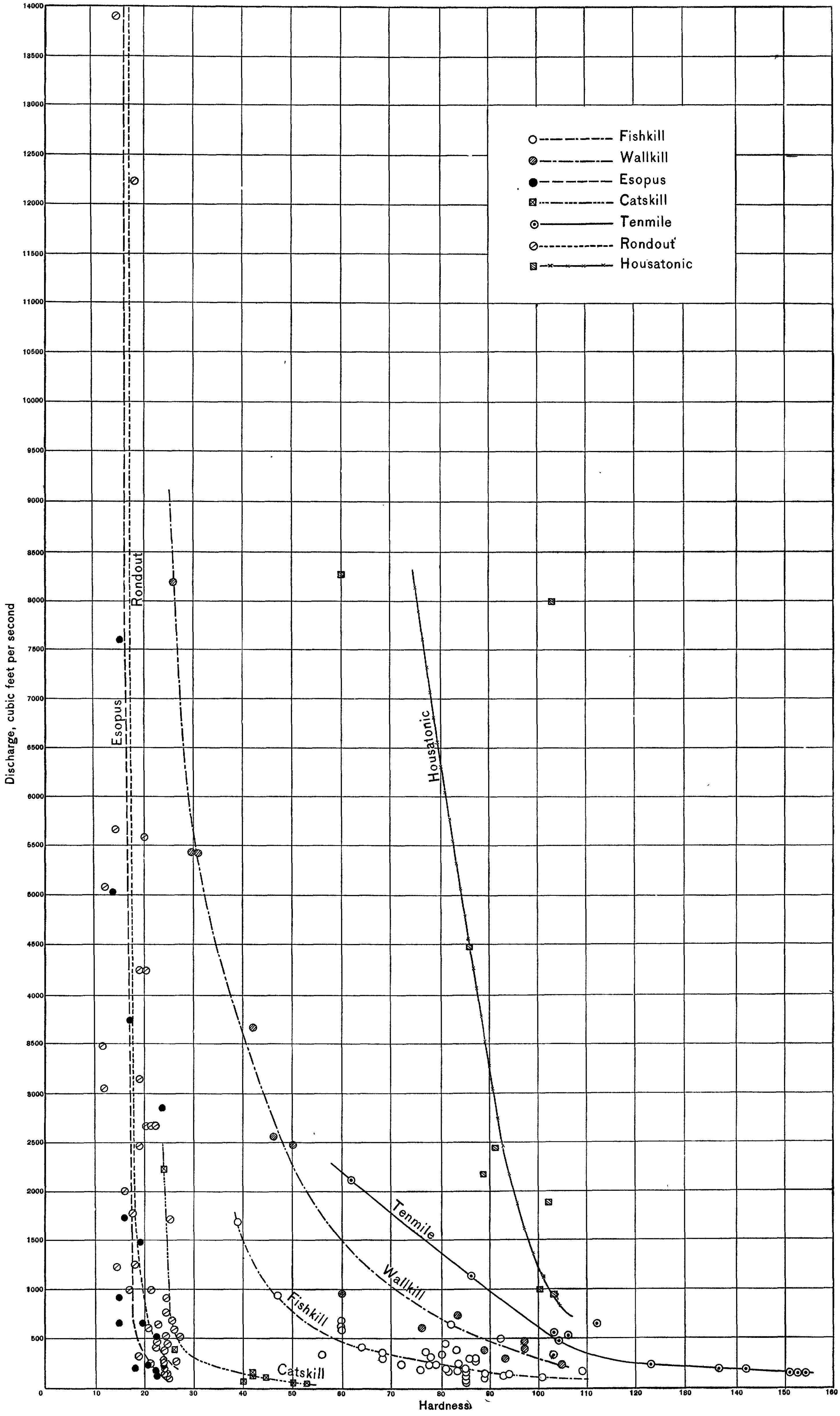


DIAGRAM SHOWING RESULTS OF HARDNESS OBSERVATIONS.

Turbidity, color, alkalinity, and hardness of streams—Continued.

RONDOUT CREEK—Continued.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1902.						
Mar. 1	17.55	42	145	14.0	14.3	13,900
Mar. 2	14.00	40	120	14.5	13.5	7,900
Mar. 3	11.75	31	55	11.0	11.9	5,075
Mar. 4	9.90	21	30	9.5	12.0	3,043
Mar. 8	7.75	30	28	14.0	16.5	1,084
Mar. 9	12.70	35	48	12.5	15.0	6,120
Mar. 9	9.50	19	50	14.0	21.0	2,650
Mar. 10	10.00	23	80	12.5	19.5	3,150
Mar. 29	11.00	25	40	14.0	19.0	4,250
Apr. 8	7.65	21	15	13.0	17.0	1,000
Apr. 10	11.95	32	32	12.0	14.0	5,665
Apr. 24	6.90	14	4	18.0	22.0	447
Apr. 26	7.10	16	35	15.5	20.5	585
Apr. 30	9.30	25	28	13.5	19.0	2,470
May 26	6.90	12	8	23.0	24.5	447
May 28	7.10	14	21	23.0	24.5	585
June 5	6.45	14	18	27.0	28.0	156
June 6	6.40	13	7	23.0	25.0	163
June 18	6.50	13	10	28.0	30.0	185
June 19	6.30	13	14	32.0	32.5	75
June 22	7.20	12	20	25.0	31.2	656
June 28	7.55	21	24	20.5	24.7	920
July 3	6.80	31	30	21.5	22.8	380
July 19	6.30	15	2	27.0	30.5	75
July 21	8.65	40	95	21.0	22.0	1,885
July 22	9.75	35	105	15.0	19.5	2,890
July 23	8.60	45	35	13.0	17.0	1,840
July 26	9.85	45	45	15.0	24.0	2,991
July 31	7.35	30	14	14.0	24.0	765
Aug. 7	7.39	28	8	19.0	26.0	838
Aug. 13	6.80	17	2	18.0	23.0	380
Aug. 15	6.50	16	1	22.0	22.5	185
Aug. 20	6.40	20	2	24.0	28.0	123
Aug. 21	6.35	16	2	25.0	27.0	92
Aug. 25	6.25	11	5	23,0	24.5	60
Aug. 27	6.30	14	13	30.0	29.0	75
Aug. 30	6.35	12	5	26.0	27.5	92
Sept. 5	6.10	11	4	26.0	31.0	35

Turbidity, color, alkalinity, and hardness of streams—Continued.

RONDOUT CREEK—Continued.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1902.						
Sept. 8	6.20	11	2	28.0	31.0	50
Sept. 11	6.50	14	6	23.0	24.5	185
Sept. 16	6.30	17	3	23.0	26.0	75
Sept. 17	6.20	17	3	23.0	28.0	50

ESOPUS CREEK.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Aug. 25	7.67	52	35	17.5	([a])	1,200
Aug. 27	6.02	34	7	22.0		540
Aug. 29	5.72	28	3			430
Sept. 4	6.27	19	13	19.0		640
Sept. 21	4.78	11	3	23.0		198
Sept. 26	4.55	9	4	23.5		167
Oct. 3	5.25	16	6	18.0		295
Oct. 8	4.70	14	3	18.0		188
Oct. 17	6.30	14	10	14.0	15.0	650
Nov. 1	4.75	9	4	15.0	18.0	195
Nov. 14	4.75	9	4	21.0	22.0	195
Nov. 18	4.45	9	2	17.0	22.0	153
Dec. 4	5.30	10	6	16.0	20.5	223
Dec. 11	[b]11.40	45	38	10.0	16.0	1,721
Dec. 19	8.35	22	50	22.5	19.0	1,470
Dec. 30	12.10	25	80	11.0	17.0	3,723
1902.						
Jan. 9	6.50	15	15	13.0	21 0	514
Jan. 22	16.00	29	180	10.0	15 0	7,600
Feb. 7	6.80	16	20	15.0	19.5	628
Feb. 20	5.35	8	5	19.0	23.5	231
Mar. 1	20.40	48	180	11.0	16.5	12,600
Mar. 12	9.90	25	125	18.5	23.5	2,843
Apr. 10	13.25	22	35	9.0	13.5	5,021
Apr. 23	6.94	16	21	13.0	15.0	910
May 14	5.83	12	10	16.0	20.0	474
May 24	5.02	8	4	19.0	24.0	238
June 5	5.03	14	17	20.0	22.5	2,345
June 16	4.48	10	5	24.0	26.0	1,358
June 26	5.00	18	13	20.0	22.0	2,312

[a]From Aug. 25 to Oct. 8, hardness not determined. [b]Backwater.

Turbidity, color, alkalinity, and hardness of streams—Continued.

ESOPUS CREEK—Continued.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1902.						
July 9	5.80	20	12	16.0	27.5	4,504
July 16	5.13	10	10	18.0	27.5	2,688
July 24	8.11	35	15	15.0	28.5	1,348
July 30	7.65	23	8	14.0	24.0	1,155
Aug. 12	6.28	21	8	24.0	26.5	550
Aug. 21	4.94	14	6	23.0	25.5	191
Sept. 4	4.49	11	6	34.0	31.0	133

WALLKILL RIVER.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Aug. 17	6.75	78	3	77.0	....	565
Aug. 20	7.2	110	9	48.5	....	794
Aug. 23	6.25	104	6	58.0	....	321
Aug. 24	6.05	110	12	64.0	....	232
Aug. 28	5.85	82	14	62.0	....	165
Aug. 31	5.95	86	12	71.0	....	196
Sept. 5	8.55	82	12	65.0	....	1,503
Sept. 19	7.30	45	13	59.0	....	814
Oct. 9	6.50	60	7	67,0	....	440
Oct. 31	6.10	46	5	81.0	93.0	264
Nov. 9	5.94	28	4	92.0	105.0	202
Nov. 16	6.50	45	9	88.0	97.0	440
Dec. 11	[a] 11.50	60	45	43.0	50.0	2,480
Dec. 19	13.70	55	38	37.0	42.0	3,680
Dec. 30	20.20	35	45	24.0	26.0	8,190
1902.						
Jan. 13	8.05	33	15	74.0	83.0	717
Jan. 23	16.40	38	125	25.0	30.0	5,422
Feb. 10	7.78	21	14	67.0	76.0	596
Feb. 24	7.30	19	10	89.0	97.2	382
Mar. 10	16.40	31	160	26.0	31.0	5,422
Apr. 21	7.55	29	25	56.0	60.0	977
May 1	10.00	60	28	44.0	46.0	2,540
May 21	6.33	39	8	75.0	89.0	356
June 6	6.40	20	13	73.0	84.0	381
July 17	5.70	33	5	82.0	90.0	126
July 29	7.49	52	23	54.0	72.0	942

[a] Backwater.

Turbidity, color, alkalinity, and hardness of streams—Continued.

WALLKILL RIVER—Continued.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1902.						
Aug. 6	7.98	68	25	62.0	71.0	1,150
Aug. 15	6.72	48	8	83.0	84.0	518
Aug. 28	5.86	24	5	88.0	89.0	169
Sept. 6	5.78	38	5	57.0	61.0	145

TENMILE RIVER.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Sept. 12	5.90	13	2	121.0		364
Oct. 26	5.00	12	4	134.0	142.0	166
Nov. 11	4.75	8	2	146.0	151.0	120
Nov. 22	4.80	8	2	147.0	154.0	129
Dec. 2	4.75	6	1	137.0	152.5	120
Dec. 17	8.41	25	12	79.0	86.0	1,120
Dec. 27	6.54	22	9	103.0	106.0	524
1902.						
Jan. 10	5.75	11	4	98.0	103.0	328
Feb. 4	6.30	13	11	90.0	104.0	460
Feb. 13	5.00	8	6	126.0	137.0	166
Mar. 3	[a] 10.41	21	36	60.0	61.1	[b] 2,100
Apr. 7	[a] 6.18	12	3	100.0	103.0	558
May 2	6.46	19	7	105.0	112.0	640
May 15	4.88	12	1	118.0	123.0	230
June 9	4.44	16	15	130.0	139.0	122
June 30	4.90	19	6	133.0	160.0	249
July 21	7.20	40	25	88.0	90.0	821
Aug. 4	4.69	11	3	129.0	141.0	1,848
Aug. 19	4.28	10	4	138.0	160.0	100
Sept. 2	3.95	10	4	139.0	155.0	63

FISHKILL CREEK.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Aug. 21	[c] 4.45	39.0	2	88		286
Aug. 31	[c] 4.57	24.0	4	85		335
Sept. 4	[c] 4.42	24.0	6	88		277
Oct. 8	3.90	13.0	3	82	93.0	113

[a] All readings on this and following dates made on new gage placed 0.33 foot higher than the old gage.

[b] Approximate.

[c] Taken from daily gage height record.

Turbidity, color, alkalinity, and hardness of streams—Continued.

FISHKILL CREEK—Continued.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Oct. 10	3.85	11.0	2	94	100.0	100
Oct. 17	4.50	36.0	4	72	[a]68.0	305
Oct. 25	4.05	16.0	2	88	[a]84.0	154
Oct. 31	4.00	12.0	3	87	89.0	140
Nov. 5	3.90	12.0	5	85	89.0	113
Nov. 8	3.95	11.0	4	85	92.0	500
Nov. 13	4.35	17.0	4	80	87.0	250
Nov. 15	4.05	21.0	4	78	109.0	154
Nov. 19	3.95	13.0	4	79	94.0	126
Nov. 23	3.90	8.0	4	83	89.0	113
Nov. 26	4.30	22.0	5	74	84.0	233
Dec. 17	6.10	29.0	12	45	47.0	926
Dec. 19	5.10	21.0	7	58	64.0	409
Dec. 24	4.55	11.0	5	71	78.0	224
Dec. 26	4.55	13.0	4	74	79.0	224
Dec. 31	7.30	24.0	12	33	39.0	1,682
1902.						
Jan. 2	5.65	15.0	7	52	60.0	673
Jan. 7	4.80	12.0	3	66	78.0	300
Jan. 9	4.65	11.0	2	70	81.0	[b]253
Jan. 14	5.00	5.0	3	79	83.0	[b]370
Jan. 16	4.35	6.0	5	79	85.0	[b]172
Jan. 21	4.15	6.0	3	82	85.0	[b]128
Jan. 28	4.90	30.0	25	52	55.5	[b]334
Jan. 30	4.95	9.0	4	63	77.0	[b]352
Feb. 4	5.50	13.0	7	53	60.0	[b]594
Feb. 7	5.20	11.0	6	72	82.0	640
Feb. 11	4.80	7.0	4	74	81.0	430
Feb. 18	4.40	5.0	6	80	86.0	268
Feb. 20	4.40	7.0	11	79	87.0	268
Mar. 7	5.20	11.0	14	48	60.0	640
Apr. 18	4.60	10.0	5	63	68.0	345
Apr. 22	4.30	9.5	4	70	72.0	233
Apr. 24	4.10	11.0	3	72	76.0	169
Apr. 29	4.00	13.0	3	79	82.0	140
May 15	3.90	11.0	4	74	85.0	113
May 20	3.80	11.0	3	76	85.0	88
May 22	3.70	13.0	2	79	85.0	66

[a] Likely too low. [b] Taken from daily gage height record.

Turbidity, color, alkalinity, and hardness of streams—Continued.

FISHKILL CREEK—Continued.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1902.						
May 28	4.55	34.0	5	70	80.0	405
June 6	3.50	11.0	3	79	81.0	115
June 10	3.80	19.0	4	79	85.0	175
June 16	3.50	14.0	5	84	90.0	115
June 19	3.50	16.0	5	86	91.0	115
July 5	3.60	15.0	4	81	90.0	135
July 8	3.50	20.0	2	83	85.0	115
July 11	3.40	14.0	3	86	86.0	95
July 16	3.10	10.0	2	89	94.0	55
Aug. 4	3.60	13.0	2	81	86.0	135
Aug. 6	3.40	11.0	3	82	89.0	95
Aug. 11	3.60	14.0	12	74	81.0	135
Aug. 13	3.60	17.0	2	74	81.0	135
Aug. 19	3.20	10.0	3	84	90.0	65
Aug. 21	3.10	7.0	2	84	86.0	55
Sept. 1	2.90	12.0	4	94	96.0	35
Sept. 2	2.80	12.0	5	93	96.0	30
Sept. 5	2.90	8.0	3	89	97.0	35
Sept. 9	3.00	9.0	3	85	89.0	40
Sept. 12	3.05	12.0	3	73	85.0	45
Sept. 15	3.20	12.0	2	77	87.0	65

HOUSATONIC RIVER.

Date.	Gage height.	Color.	Turbidity.	Alkalinity.	Hardness.	Discharge in second-feet.
1901.						
Oct. 29	4.05	19.0	3	103	103.0	935
Nov. 13	4.83	25.0	4	102	106.0	1,860
Nov. 23	4.10	21.0	5	100	105.0	980
Dec. 28	5.16	14.0	6	91	97.0	2,420
1902.						
Jan. 11	5.00	13.0	5	89	92.0	2,145
Feb. 14	[a] 8.30	20.0	5	96	103.0	8,000
Mar. 18	7.63	24.0	....	53	60.0	8,277
May 3	6.10	20.0	11	78	86.0	4,459
June 22	4.70	24.0	4	89	92.0	1,530
June 23	4.50	18.0	3	92	94.0	1,177
June 25	4.30	14.0	3	93	95.0	1,070

[a] Backwater.

Turbidity, color, alkalinity, and hardness of streams—Continued.

HOUSATONIC RIVER—Continued.

Date.	Gage height.	Color.	Turbid-ity.	Alkalin-ity.	Hard-ness.	Discharge in second-feet.
1902.						
June 26	4.30	15.0	2	94	95.0	1,070
July 2	4.60	18.0	3	90	90.0	1,400
July 4	4.70	20.0	6	91	93.0	1,530
July 6	4.50	16.0	2	93	93.0	1,177
July 8	5.00	22.0	3	91	94.0	2,145
July 15	3.90	14.0	5	85	101.0	750
July 18	3.90	18.0	7	95	98.0	750
July 22	6.70	34.0	22	63	75.0	5,119
July 25	5.60	30.0	12	73	82.0	3,050
July 29	4.90	26.0	7	88	91.0	1,800
Aug. 1	4.80	35.0	4	88	94.0	1,650
Aug. 5	4.20	14.0	4	102	109.0	983
Aug. 8	4.50	14.0	2	102	107.0	1,177
Aug. 12	5.20	32.0	5	73	83.0	2,300
Aug. 15	4.50	31.0	3	85	86.0	1,177
Aug. 19	3.70	11.0	3	96	106.0	---- -----
Aug. 22	3.90	11.0	2	96	99.0	750
Aug. 26	3.90	11.0	4	103	107.0	750
Aug. 29	3.90	10.0	3	96	104.0	750
Sept. 2	3.60	10.0	2	98	113.0	640
Sept. 5	3.60	9.0	1	104	110.0	640
Sept. 9	3.40	10.0	1	105	109.0	490
Sept. 12	3.90	13.0	2	97	104.0	750

Though the number of observations is not sufficient to give accurate curves, the results as shown in the tables have been plotted in Pls. IX, XI, XII, and XIII[a] and tentative curves drawn showing the relation of these qualities to the discharge of the stream. In the curves representing alkalinity and hardness the relation seems to be well marked. The diagrams show the relative hardness of the various streams, also ratio of decrease in hardness as the discharge increases. The regularity of the points enables one to prophesy with fair precision the alkalinity or hardness that might be expected at intermediate discharges. The turbidity and color are, as might be expected, far more irregular. It would not be expected that during a rapidly rising flood we should find the same turbidity as at the time of general high water. The

[a] Since the diagrams were plotted many more observations have been obtained and are included in these tables. The diagrams have not been changed, as they are only intended to be suggestive.

effect, too, of a local shower on one tributary may affect the quality of the water much more than the same increase of water from another tributary, so that in an exhaustive study of a large river the effect of floods on each tributary is important, and should be studied rather than the river as a whole. Most of the tributaries of the streams under consideration are short, and storms would usually cover a large part of the drainage basin.

It is not considered that results have been obtained that are final upon these points, so that their publication is in the nature of a progress report. Measurements are being continued, and it is hoped that better curves can be constructed later. The curves representing turbidity and color are merely suggestions. It was not intended that the color curves of the Catskill and Tenmile should turn so far to the left at the upper part.

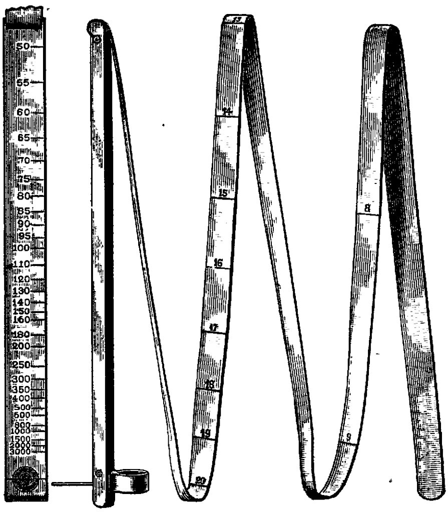


FIG. 8.—New folding turbidity stick.

GAGE HEIGHTS AND DISCHARGE MEASUREMENTS.

In the following tables are given the mean daily gage heights during the years 1901 and 1902 at the stations established upon the Catskill, Esopus, Rondout, and Fishkill creeks, and Wallkill, Tenmile, and Housatonic rivers.

Following these tables are records of current-meter discharge measurements on these streams. These observations and measurements are being continued.

Mean daily gage height of Catskill Creek at South Cairo, N. Y., for 1901.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	------	2.55	2.92	2.8	2.7	2.65
2	------	2.6	3.0	2.75	2.7	2.65
3	------	2.55	3.22	2.7	2.65	2.65
4	2.75	2.4	3.27	2.7	2.67	3.3
5	2.9	2.4	3.05	2.67	2.67	3.3
6	3.3	2.5	2.92	2.67	2.65	3.32
7	3.6	3.35	2.87	2.62	2.7	3.32
8	3.63	3.05	2.9	2.65	2.7	3.3
9	3.35	2.87	2.87	2.6	2.65	3.35
10	3.07	2.8	2.82	2.65	2.65	5.35
11	3.53	2.77	2.8	2.6	2.65	4.62
12	3.45	2.65	2.75	2.6	2.67	4.45
13	3.23	2.55	2.77	2.65	2.8	3.95
14	3.0	2.5	2.72	2.8	3.02	6.95
15	2.85	2.5	2.7	3.1	2.85	12.8
16	2.9	2.5	2.75	3.15	2.82	5.6
17	3.85	2.4	2.82	3.02	2.77	5.0
18	3.78	2.52	2.97	2.97	2.75	4.4
19	4.35	2.62	2.97	2.9	2.75	4.0
20	3.58	2.67	2.82	2.85	2.75	3.85
21	3.17	2.75	2.8	2.82	2.75	3.9
22	2.67	3.05	2.8	2.8	2.75	4.0
23	2.95	3.22	2.77	2.8	2.7	4.0
24	3.0	3.45	2.72	2.8	2.7	4.07
25	3.02	3.55	2.67	2.8	2.7	3.45
26	2.82	3.2	2.65	2.8	2.7	3.4
27	2.7	2.95	2.65	2.75	2.65	3.4
28	2.7	2.8	2.7	2.75	2.65	3.5
29	2.72	2.7	2.8	2.75	2.65	3.85
30	2.65	2.65	2.82	2.7	2.65	4.5
31	2.6	2.6	------	2.7	------	4.4

Mean daily gage height of Catskill Creek at South Cairo, N. Y., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	------	4.30	11.70	5.35	4.10	2.95	3.48	4.50	2.90	6.18	4.30	3.60
2	------	5.05	9.68	5.88	3.95	2.88	3.28	5.58	2.83	5.63	4.15	3.63
3	------	5.20	6.70	4.95	3.93	2.80	3.13	4.38	2.75	5.20	4.05	3.80
4	------	4.45	6.80	4.88	3.88	2.83	3.10	4.13	2.73	4.80	3.95	4.18
5	4.40	4.40	6.35	4.90	3.83	2.88	3.08	3.85	2.73	4.60	3.90	4.00
6	4.20	4.40	5.40	4.65	3.78	2.88	4.45	4.45	2.70	4.53	3.83	4.00
7	4.05	4.30	4.10	4.40	3.73	2.85	4.20	4.20	2.73	4.40	3.77	3.98
8	4.80	4.25	4.10	4.60	3.70	2.90	3.48	3.93	2.78	4.23	3.73	3.80
9	3.70	4.20	4.30	11.65	3.60	2.80	3.80	3.80	2.90	4.05	3.65	3.70
10	3.55	4.25	5.20	8.25	3.50	2.75	3.65	3.65	3.68	3.90	3.55	4.05
11	3.40	4.40	5.75	6.98	3.40	2.70	3.60	3.55	3.55	3.93	3.50	4.40
12	3.30	4.50	9.10	6.48	3.30	2.65	3.55	3.55	3.28	5.08	3.55	4.13
13	3.30	4.70	9.20	5.50	3.28	2.78	2.95	3.45	3.40	4.60	3.63	4.00
14	3.30	4.95	7.50	4.95	3.23	2.75	2.80	3.15	3.53	4.25	3.53	4.00
15	3.20	3.10	5.45	4.78	3.20	2.70	2.80	3.20	3.35	4.15	3.50	3.95
16	3.30	3.20	7.40	4.58	3.05	2.75	2.75	3.15	3.18	4.25	3.40	4.53
17	3.20	3.40	9.43	4.35	3.00	2.90	2.70	3.05	3.05	3.93	3.40	6.35
18	3.00	3.50	6.85	4.25	2.95	2.88	2.65	2.93	2.95	3.83	3.33	5.43
19	2.90	3.60	4.15	4.20	2.90	2.78	2.70	3.05	2.98	3.80	3.30	5.00
20	2.90	3.80	4.50	4.20	2.95	2.85	4.40	3.10	3.25	3.83	3.28	4.80
21	3.10	3.80	4.00	4.13	2.95	2.80	7.25	3.03	3.48	3.73	3.30	6.65
22	9.85	3.80	4.55	4.10	2.83	2.80	6.50	2.98	3.58	3.73	3.20	8.48
23	5.90	3.50	5.58	4.03	2.78	2.80	6.53	2.93	3.18	3.60	3.20	6.70
24	4.80	3.20	5.48	3.95	2.90	2.78	6.18	2.83	3.10	3.63	3.15	5.13
25	4.40	3.40	5.05	3.90	2.95	2.70	7.08	2.75	3.25	3.60	3.20	4.85
26	4.03	3.50	4.93	3.80	2.85	2.68	7.85	2.70	3.58	3.50	3.30	6.65
27	3.85	4.83	4.83	3.83	3.10	2.65	4.05	2.70	4.35	3.55	3.85	4.35
28	3.58	9.15	5.08	3.73	3.33	2.60	4.20	2.73	a4.70	5.90	4.13	4.20
29	3.70	------	5.73	3.95	3.25	2.80	4.40	2.85	9.95	5.30	3.80	4.13
30	4.25	------	5.93	4.10	3.13	3.88	4.38	2.98	7.20	4.70	3.63	3.95
31	4.30	------	5.43	------	3.00	------	4.25	3.08	------	4.45	------	3.85

a 12 o'clock midnight, 16.1.

Mean daily gage height of Esopus Creek, at Kingston, N. Y., for 1901.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	------	3.97	6.47	4.52	4.62	4.6	17	4.05	4.37	5.0	4.47	4.3	10.55
2	------	3.95	6.3	4.62	4.52	4.52	18	4.05	4.54	5.27	4.42	4.37	9.05
3	------	3.9	6.67	4.7	4.35	4.77	19	4.6	4.5	5.07	4.6	4.52	8.1
4	------	4.95	6.27	4.52	4.37	5.45	20	4.15	4.77	5.35	4.77	4.5	8.0
5	4.3	3.95	5.8	4.42	4.55	4.62	21	4.1	5.95	5.17	4.77	4.47	7.75
6	4.35	3.7	5.57	4.3	4.47	4.67	22	3.9	6.62	4.77	4.67	4.52	7.2
7	4.3	3.95	5.42	4.47	4.57	4.72	23	4.05	5.92	4.92	4.67	4.45	6.85
8	4.4	7.0	5.02	4.57	4.47	4.65	24	4.0	7.35	4.77	4.62	4.52	6.7
9	4.4	5.72	5.17	4.5	4.32	------	25	3.9	7.67	4.5	4.62	4.62	6.5
10	4.25	5.17	4.95	4.52	4.32	5.6	26	3.97	6.52	4.37	4.52	4.6	6.35
11	4.25	5.05	5.02	4.47	4.45	11.5	27	3.92	6.02	4.5	4.42	4.57	6.25
12	4.3	4.87	4.87	4.4	4.57	9.72	28	3.85	5.87	4.72	4.45	4.77	6.0
13	4.3	4.72	4.9	4.5	4.6	7.35	29	3.72	5.72	4.45	4.57	5.45	7.55
14	4.2	4.6	4.87	4.52	4.45	8.12	30	4.2	5.45	4.42	4.47	4.52	11.65
15	3.95	4.42	4.72	4.57	4.37	21.37	31	4.25	5.22	------	4.6	------	9.45
16	4.2	4.42	4.75	4.65	4.43	15.2							

Mean daily gage height of Esopus Creek at Kingston, N. Y., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.20	7.25	12.10	9.35	8.95	4.85	6.38	7.09	4.45	13.38	7.28	5.90
2	10.35	7.45	16.82	8.69	8.18	4.83	6.19	7.95	4.48	11.68	6.75	5.70
3	9.95	9.35	15.75	8.05	7.78	4.76	6.00	7.10	4.43	10.10	5.83	6.19
4	8.40	7.72	11.07	7.64	7.70	4.83	6.40	6.90	4.33	9.50	6.55	6.43
5	7.65	7.52	9.45	7.33	7.43	4.70	5.99	6.53	4.38	8.60	6.55	6.33
6	7.30	7.16	8.95	7.03	7.11	4.73	6.19	7.08	4.33	9.64	6.25	6.18
7	6.95	6.70	7.90	7.18	6.98	4.55	6.16	6.90	4.38	8.68	6.47	6.35
8	6.65	6.47	7.68	7.28	6.74	4.63	6.03	3.43	4.38	8.18	6.35	6.60
9	6.50	6.14	8.85	13.10	6.55	4.63	5.80	6.18	4.38	7.85	6.13	6.45
10	6.40	6.25	9.20	13.86	6.40	4.68	5.58	5.88	7.68	7.40	6.00	6.00
11	6.35	5.94	9.05	11.60	6.23	4.58	5.50	5.83	6.00	7.15	7.85	6.35
12	5.88	5.88	9.80	10.22	6.10	4.45	5.34	6.25	5.49	9.10	7.95	6.55
13	6.00	5.77	11.85	9.41	5.96	4.53	5.15	5.73	5.53	8.47	5.85	6.35
14	5.93	5.60	11.82	8.78	5.88	4.58	5.05	5.58	6.18	8.00	5.78	6.40
15	5.60	5.58	9.98	8.25	5.70	4.40	4.98	5.38	5.85	7.60	5.73	6.43
16	5.58	5.53	9.33	7.90	5.70	4.46	4.99	5.30	5.53	7.33	5.63	6.65
17	5.59	5.63	a18.28	7.58	5.50	4.78	4.89	5.08	5.30	7.15	5.60	16.20
18	5.30	5.39	13.10	7.35	5.33	4.94	4.80	5.10	5.13	6.95	5.60	12.86
19	5.50	5.45	10.13	7.10	5.38	4.63	4.78	4.98	5.08	6.75	5.54	11.00
20	5.37	5.30	9.20	6.93	5.39	4.60	6.88	4.98	5.30	6.73	5.46	9.95
21	4.95	5.35	8.62	6.80	5.28	4.81	10.00	4.88	6.88	6.47	5.45	8.55
22	12.73	5.36	8.25	6.78	5.13	5.55	9.50	4.85	6.28	6.30	5.38	15.60
23	10.88	5.30	8.20	6.93	5.03	5.13	9.28	4.78	5.88	6.20	5.36	12.80
24	8.88	5.36	7.87	6.88	5.00	4.93	8.38	4.65	5.68	6.13	5.36	10.40
25	8.00	5.39	7.63	6.58	4.88	4.81	8.58	4.70	5.68	6.30	5.20	9.35
26	7.53	6.45	7.43	6.36	5.20	4.93	8.68	4.65	7.00	5.87	5.30	8.70
27	8.63	9.30	7.28	6.35	5.20	5.15	8.01	4.55	10.35	5.78	6.00	8.28
28	8.08	9.37	7.17	6.20	5.58	4.84	7.75	4.65	9.48	7.83	6.60	8.75
29	7.72	------	11.65	5.98	5.25	4.81	7.19	4.70	b22.43	8.35	6.10	9.10
30	7.82	------	12.55	9.81	5.03	7.10	7.68	4.60	17.35	7.75	5.88	8.97
31	7.48	------	10.45	------	5.03	------	7.35	4.63	------	7.50	------	8.05

a Highest water at 1.30 p.m., 25.25. b Highest water at 1.30 p.m., 18.30.

Mean daily gage height of Rondout Creek at Rosendale, N. Y., for 1901.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	7.57	7.62	7.26	6.5	6.55	17	6.3	6.5	6.67	7.1	6.55	8.95
2	......	5.5	7.95	6.85	6.5	6.4	18	6.85	6.75	7.05	7.0	6.55	8.04
3	......	6.3	7.8	6.95	6.5	6.5	19	6.55	7.0	6.85	6.9	6.55	7.77
4	......	6.25	7.61	6.8	6.45	6.85	20	6.48	6.95	6.65	6.8	6.5	7.55
5	......	6.17	7.42	6.7	6.4	6.87	21	6.47	8.75	6.55	6.72	6.4	7.55
6	......	6.35	6.97	6.62	6.4	6.85	22	6.37	8.15	6.52	6.7	6.35	7.57
7	......	9.75	6.87	6.55	6.4	6.92	23	6.4	7.5	6.47	6.7	6.4	7.95
8	6.5	7.35	6.77	6.55	6.4	7.0	24	6.35	9.0	6.42	6.6	6.5	7.75
9	6.4	6.92	6.67	6.52	6.4	7.2	25	6.35	9.4	6.4	6.6	7.6	7.22
10	6.25	6.62	6.6	6.45	6.4	9.2	26	6.3	8.1	6.35	6.6	7.25	7.12
11	6.2	7.17	6.6	6.42	6.37	9.25	27	6.47	7.47	6.32	6.6	6.97	7.0
12	6.25	7.42	6.65	6.42	6.45	8.22	28	6.42	7.15	6.3	6.65	6.87	7.35
13	6.3	6.87	6.72	6.5	6.95	7.75	29	6.37	6.95	7.05	6.5	6.8	9.1
14	6.33	6.55	6.57	7.25	6.8	8.97	30	6.67	7.42	7.41	6.5	6.8	12.12
15	6.3	6.50	6.5	7.72	6.62	16.75	31	6.72	6.72	......	6.5	......	10.0
16	6.38	6.52	6.62	7.37	6.6	10.6							

Mean daily gage height of Rondout Creek at Rosendale, N. Y., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	8.73	8.98	17.20	8.18	8.25	6.58	7.08	7.70	6.25	10.03	7.25	6.73
2	7.90	8.95	14.23	7.85	7.70	6.48	6.90	8.35	6.20	9.28	7.05	6.70
3	7.90	9.75	12.53	7.58	7.70	6.55	6.98	7.60	6.13	8.43	7.03	6.90
4	7.90	9.35	9.75	7.58	7.75	6.63	7.70	7.28	6.15	7.90	7.00	7.20
5	7.90	9.70	8.70	7.35	7.50	6.48	7.23	7.08	6.10	7.80	6.90	6.88
6	7.83	9.25	8.05	7.25	7.33	6.40	7.13	7.25	6.18	8.78	6.87	6.80
7	7.58	9.00	7.95	7.60	7.28	6.48	7.00	7.33	6.20	8.00	6.95	6.95
8	7.28	8.83	7.65	8.10	7.15	6.45	6.88	7.03	6.20	7.65	6.85	6.98
9	7.13	8.58	9.40	12.28	7.03	6.48	6.85	6.93	6.23	7.38	6.80	6.88
10	7.08	8.05	9.70	11.40	6.93	6.38	6.65	6.83	7.00	7.18	6.78	7.10
11	7.10	8.18	9.30	9.75	6.88	6.30	6.58	6.80	6.58	6.95	6.73	7.08
12	7.35	8.05	9.70	9.15	6.88	6.35	6.53	6.90	6.40	9.75	6.73	7.00
13	6.95	7.98	11.05	8.63	6.83	6.35	6.50	6.80	6.45	8.65	6.73	6.95
14	6.73	7.88	10.15	8.15	6.68	6.38	6.45	6.70	6.68	8.00	6.70	7.15
15	6.83	7.80	9.15	7.85	6.63	6.35	6.35	6.55	6.48	7.57	6.70	7.50
16	6.90	7.65	8.80	7.65	6.70	6.35	6.40	6.58	6.35	7.35	6.70	8.35
17	6.78	7.53	13.10	7.50	6.60	6.50	6.33	6.50	6.25	7.23	6.65	12.95
18	6.70	7.60	9.95	7.38	6.63	6.45	6.30	6.45	6.20	7.07	6.65	10.00
19	6.78	7.35	8.65	7.25	6.60	6.30	6.33	6.40	6.18	7.07	6.68	8.80
20	6.70	7.43	8.25	7.18	6.60	6.43	7.53	6.40	6.25	7.00	6.65	8.30
21	6.73	7.43	8.08	7.10	6.58	6.43	8.93	6.38	6.50	6.95	6.65	8.35
22	14.68	7.40	8.00	7.05	6.50	7.10	9.18	6.48	6.40	6.90	6.65	13.45
23	9.83	7.43	7.88	7.00	6.48	6.70	8.38	6.40	6.23	6.80	6.60	10.58
24	8.35	7.48	7.80	6.90	6.45	6.50	[a]9.94	6.40	6.25	6.80	6.60	9.55
25	7.85	7.55	7.63	6.88	6.40	6.40	10.34	6.33	6.45	6.80	6.55	8.50
26	7.68	8.23	7.45	6.98	6.80	6.43	8.95	6.30	9.40	6.73	6.70	8.10
27	8.95	10.68	7.38	6.95	6.88	6.50	8.23	6.28	9.75	6.63	6.75	8.87
28	7.75	12.10	7.33	6.83	7.20	6.43	7.80	6.25	8.68	9.38	6.90	7.45
29	8.00	......	9.85	6.78	6.85	6.45	7.38	6.33	[b]14.09	8.60	6.88	7.27
30	8.18	......	9.53	9.38	6.60	7.70	7.80	6.30	10.78	7.83	6.80	7.20
31	8.60	......	8.63	......	6.63	......	7.33	6.30	......	7.45	......	7.20

[a] Highest water, 12.65, at 7 p. m. [b] Highest water, 15.6, at 3 p. m.

Estimated diversion from Rondout Creek to Delaware and Hudson Canal, Rosendale, N. Y., 1902, in second-feet.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1				15.5	22.6		24.2	26.0		22.6	22.5	
2				17.7	15.0	25.2	23.8	25.6	25.3	22.4		
3				21.5	24.6	20.8	23.1		22.5	26.1	21.0	
4				22.0		11.6		23.8	24.3	25.8	23.5	
5				17.9	27.6	25.3	24.1	24.5	25.3		21.5	
6					23.1	19.5		22.5	25.8	22.2	23.3	
7				20.4	24.8	21.8	23.1	24.5		23.1	24.2	
8				20.2	24.3		22.7	23.8	25.0	22.4	24.8	
9				18.4	24.6	23.8	24.3	24.0	23.5	21.9		
10				14.3	24.5	35.9	25.3		24.3	22.8		
11				20.7		24.9	26.1	24.0	24.3	22.1		
12				19.2	24.3	33.8	21.8	24.5	25.1			
13					24.1	27.5		24.6	22.2	20.4		
14				25.4	25.0	23.6	25.3	26.0		20.6		
15				25.7	24.1		25.3	24.8	26.5	20.5		
16				24.2	24.5	22.3	24.2	24.5	25.6	19.5		
17				25.1	22.8	22.6	26.0		25.8	19.5		
18				26.1		24.3	25.1	25.5	23.3	19.7		
19				25.6	24.3	23.8	22.7	24.3	24.8			
20					24.6	23.9		23.8	22.0	21.3		
21				25.9	23.1	24.4	23.8	25.1		23.5		
22				26.7	23.6		25.6	25.6	24.3	21.0		
23			15.8	24.1	25.6	22.1	22.8	24.3	23.8	21.2		
24			11.4	23.3	24.3	20.1	20.6		24.0	23.0		
25			12.3	23.4		22.6	19.0	22.8	25.1	20.4		
26			15.3	22.8	21.1	22.8	22.8	22.2	22.8			
27			16.9		28.0	19.8		25.1	22.6	22.8		
28			16.4	27.1	26.5	22.6	25.6	22.5		23.8		
29				25.2	26.3		21.6	25.8	20.3	24.3		
30				25.8	20.7	26.7	23.6	23.0	22.1	23.0		
31			21.8		24.1		26.4			25.0		
Mean				22.5	24.0	23.7	23.8	24.3	24.0	22.2		

Mean daily gage height of Wallkill River at New Paltz, N. Y., for 1901.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1		6.10	9.20	7.45	6.00	6.25	17	6.37	6.75	7.05	7.50	6.25	13.10
2		5.90	9.85	7.25	6.00	6.05	18	7.15	9.25	7.62	7.27	6.05	13.65
3		5.97	9.75	7.15	6.00	6.00	19	7.98	11.15	7.65	7.15	6.15	13.75
4		6.00	9.35	7.00	6.00	6.20	20	7.20	10.15	7.45	6.95	6.35	12.95
5		6.45	8.55	6.95	6.05	6.35	21	6.50	10.25	7.30	6.70	7.30	11.70
6		6.45	8.35	6.85	6.10	6.65	22	6.35	10.25	7.10	6.45	8.10	10.70
7	7.27	12.05	8.05	6.65	6.00	6.60	23	6.25	10.15	6.95	6.32	8.65	10.45
8	7.23	11.25	7.70	6.47	5.95	7.30	24	6.05	9.70	6.82	6.30	8.35	10.15
9	6.93	9.30	7.47	6.35	5.85	10.00	25	6.00	14.30	6.65	6.20	8.10	9.55
10	6.65	9.15	7.45	6.30	5.75	12.30	26	6.00	12.00	6.50	6.12	7.45	9.00
11	6.53	9.10	7.25	6.30	5.65	11.70	27	5.85	11.25	6.35	6.10	6.95	9.25
12	7.33	8.05	7.05	6.20	5.95	10.30	28	5.85	10.60	6.35	6.10	6.85	9.70
13	7.60	7.70	7.15	6.20	6.40	10.05	29	5.85	9.90	6.65	6.10	6.65	11.80
14	7.15	7.15	6.95	6.35	7.00	10.60	30	5.80	9.15	7.25	6.10	6.45	19.35
15	6.85	7.40	6.65	7.50	6.90	13.30	31	5.95			6.50		19.20
16	6.55	7.10	6.75	7.85	6.55	12.85							

Mean daily gage height of Wallkill River at New Paltz, N. Y., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	15.15	8.75	23.53	9.35	10.25	7.50	7.25	9.50	6.10	10.25	8.65	6.80
2	13.25	8.75	23.80	8.95	8.95	7.25	7.15	9.10	6.05	10.85	8.35	6.70
3	12.95	10.65	a24.65	8.65	9.15	7.05	7.50	8.75	6.00	10.15	8.15	7.50
4	12.10	9.70	22.75	8.20	8.85	6.90	7.58	8.60	5.88	9.65	7.95	7.95
5	10.45	9.75	20.25	8.00	8.35	6.55	7.08	8.30	5.78	9.60	7.65	8.10
6	10.70	8.90	15.20	9.70	7.95	6.35	6.78	7.95	5.70	10.10	7.50	8.55
7	10.20	8.15	13.20	7.70	7.50	6.30	6.53	7.85	5.60	9.45	7.50	8.10
8	8.70	7.85	12.70	8.40	7.45	6.25	6.35	7.65	5.50	9.00	7.65	7.70
9	9.15	7.78	14.90	b13.65	7.35	6.30	6.23	7.30	5.50	8.55	7.15	7.70
10	8.85	7.70	16.45	13.50	7.10	6.50	6.10	7.05	6.10	8.40	6.95	7.65
11	8.75	7.55	15.90	12.20	6.80	6.35	6.00	6.90	6.45	8.25	6.75	7.60
12	8.20	7.55	16.10	11.65	6.65	6.30	6.00	6.80	6.30	12.45	6.70	7.60
13	8.05	7.40	17.05	10.65	6.60	6.20	5.90	6.75	6.35	11.90	6.60	7.55
14	8.05	7.35	16.50	9.80	6.55	6.15	5.78	6.68	6.45	10.50	6.60	7.50
15	8.00	7.15	15.00	9.35	6.50	6.10	5.70	6.60	6.25	9.70	6.60	7.50
16	8.00	7.10	14.65	8.65	6.45	6.20	5.70	6.53	6.15	9.35	6.50	7.50
17	7.70	7.20	15.40	8.20	6.35	6.25	5.73	6.43	6.05	9.00	6.50	12.20
18	7.55	7.15	13.75	8.00	6.30	6.15	5.58	6.38	5.95	8.60	6.50	12.25
19	7.50	7.08	11.75	7.85	6.30	6.13	5.55	7.28	5.80	8.60	6.50	12.30
20	7.20	7.00	10.60	7.60	6.30	6.10	6.10	6.20	5.90	8.15	6.50	12.30
21	7.20	7.05	10.30	7.45	6.30	6.13	7.78	6.15	5.90	7.95	6.40	12.95
22	18.50	7.05	10.20	7.35	6.30	6.33	8.65	6.10	5.90	7.65	6.40	19.00
23	17.65	7.10	9.75	7.15	6.25	6.40	7.40	6.05	5.90	7.47	6.65	19.65
24	13.55	7.25	9.60	7.10	6.20	6.35	c11.00	6.10	5.90	7.37	6.30	17.20
25	13.15	7.30	9.45	6.95	6.20	6.20	d14.00	6.05	6.15	7.15	6.30	16.25
26	12.20	7.75	9.00	6.85	6.45	6.20	9.10	6.00	9.65	6.95	6.35	15.30
27	12.85	11.40	8.50	7.00	8.30	6.10	8.50	6.00	12.00	6.85	7.35	14.20
28	12.65	12.75	8.20	6.75	9.20	6.03	7.80	5.95	11.90	11.65	7.35	14.20
29	11.15	......	10.20	6.65	8.40	6.13	7.45	8.25	13.45	11.25	7.10	13.80
30	9.50	......	11.05	e11.75	8.30	7.00	7.45	6.95	10.35	9.45	6.95	12.30
31	9.25	......	9.90	......	7.90	......	8.45	6.40	......	8.95	......	11.75

a Highest water 24.80 at p. m.
b Highest water 14.6 at p. m.
c Highest water 15.4 at 8 p. m.
d Highest water 16.6 at 9 p. m.
e Highest water 12.6 at p. m.

Mean daily gage height of Fishkill Creek at Glenham, N. Y., for 1901.

Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Day.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	......	3.95	4.57	4.05	3.97	3.90	17	3.73	3.85	4.15	4.55	3.95	6.18
2	......	3.82	4.60	3.97	3.95	3.98	18	4.23	5.07	4.22	4.40	3.95	5.53
3	......	3.77	4.47	4.10	3.95	4.05	19	4.00	4.70	4.12	4.32	3.95	5.15
4	......	3.67	4.42	4.10	3.95	4.08	20	3.90	4.40	4.02	4.22	3.95	4.98
5	......	3.65	4.30	4.00	3.90	4.10	21	3.77	4.45	4.02	4.20	3.93	4.78
6	......	3.65	4.15	3.92	3.90	4.25	22	3.70	4.95	4.00	4.15	3.98	4.73
7	......	4.70	4.17	3.90	3.92	4.28	23	3.65	4.62	3.92	4.12	3.90	4.73
8	3.90	5.55	4.10	3.87	3.95	4.18	24	3.65	4.70	3.90	4.10	3.90	4.55
9	3.90	4.77	4.07	3.85	3.90	4.05	25	3.65	6.40	3.87	4.05	4.35	4.60
10	3.80	4.35	4.02	3.85	3.87	4.73	26	3.62	6.55	3.85	4.00	4.33	4.55
11	3.78	4.12	4.05	3.85	3.87	5.33	27	3.60	5.65	3.80	4.00	4.13	4.85
12	3.83	4.07	4.37	3.80	3.92	4.83	28	3.45	5.20	3.87	4.00	4.03	4.15
13	3.80	4.02	4.32	3.80	4.32	4.60	29	3.57	4.85	3.95	4.00	4.00	5.75
14	3.73	3.90	4.15	4.30	4.17	4.68	30	4.35	4.70	4.20	4.00	3.98	8.28
15	3.70	3.90	4.10	4.85	4.05	6.78	31	4.15	4.57	......	3.97	......	7.50
16	3.65	3.82	4.25	4.82	4.00	7.45							

Mean daily gage height of Fishkill Creek, at Glenham, N. Y., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	6.05	5.00	13.00	4.90	5.48	3.83	3.70	3.80	2.90	4.25	4.40	3.70
2	5.65	4.75	10.00	4.78	4.93	3.70	3.53	3.70	2.80	4.20	4.33	3.73
3	5.50	5.63	8.78	4.68	4.70	3.60	3.45	3.60	2.95	4.00	4.20	3.88
4	5.30	5.55	6.70	4.60	4.73	3.70	3.85	3.60	2.73	3.83	4.15	4.03
5	5.18	5.58	5.80	4.53	4.63	3.70	3.60	3.50	2.90	3.83	4.05	3.98
6	4.95	5.28	4.95	4.45	4.45	3.55	3.70	3.43	2.95	4.20	4.03	3.70
7	4.80	5.25	5.05	4.53	4.35	3.50	3.70	3.48	2.90	4.20	4.00	3.70
8	4.70	5.00	5.15	4.63	4.30	3.85	3.55	3.40	2.95	3.93	4.00	3.80
9	4.65	5.18	5.90	5.13	4.20	3.85	3.45	3.40	3.00	3.85	3.93	3.98
10	4.63	5.05	7.75	5.65	4.10	3.75	3.38	3.30	3.33	3.78	3.90	4.05
11	4.60	4.75	6.95	5.53	3.90	3.60	3.40	3.50	3.25	3.70	3.88	3.85
12	4.58	4.80	6.50	5.28	3.98	3.50	3.30	3.85	3.08	4.95	3.88	3.90
13	4.75	4.60	6.70	5.05	3.95	3.40	3.23	3.65	3.30	5.03	3.88	4.05
14	5.00	4.40	6.63	4.90	3.90	3.43	3.20	3.48	3.23	4.08	3.88	4.10
15	4.70	4.33	5.98	4.80	3.90	3.50	3.13	3.40	3.20	4.35	3.80	4.30
16	4.35	4.25	5.65	4.70	3.90	3.50	3.13	3.35	3.15	4.20	3.83	4.40
17	4.28	4.48	6.73	4.60	3.80	3.95	3.10	3.28	3.15	4.80	3.80	6.65
18	4.25	4.38	6.45	4.58	3.70	3.70	3.10	3.20	3.18	4.00	3.70	7.55
19	4.25	4.33	5.70	4.50	3.75	3.50	3.08	3.20	3.00	4.00	3.70	6.50
20	4.18	4.35	5.20	4.40	3.80	3.53	3.20	3.15	3.05	3.95	3.68	5.98
21	4.18	4.38	5.30	4.35	3.83	3.50	4.15	3.10	3.03	3.90	3.63	5.50
22	5.88	4.85	5.23	4.30	3.68	3.75	4.70	3.15	3.15	3.80	3.60	7.75
23	6.55	4.85	5.13	4.23	3.68	3.60	4.65	3.10	3.08	3.80	3.60	8.05
24	5.15	4.90	5.00	4.15	3.60	3.50	4.10	3.10	3.13	3.70	3.63	7.00
25	4.75	4.70	4.85	4.05	3.60	3.40	4.18	3.15	2.95	3.75	3.63	5.95
26	4.63	4.85	4.75	4.05	4.20	3.50	4.10	3.05	3.48	3.73	3.68	5.60
27	5.00	5.88	4.70	4.13	4.15	3.40	4.05	3.00	3.60	3.70	3.95	5.40
28	5.00	7.10	4.55	4.08	4.58	3.30	3.90	3.00	3.60	4.65	3.88	5.05
29	4.95	------	4.85	4.00	4.23	3.35	3.80	2.95	4.80	5.43	3.80	4.93
30	5.05	------	5.40	4.83	4.03	4.08	4.20	2.95	4.75	4.93	3.70	4.90
31	4.95	------	5.05	------	3.90	------	3.95	2.90	------	4.55	------	4.77

Mean daily gage height of Tenmile River at Dover Plains, N. Y., for 1901.

Day.	Sept.	Oct.	Nov.	Dec.	Day.	Sept.	Oct.	Nov.	Dec.
1	------	5.02	4.95	4.65	17	5.00	6.17	5.05	8.15
2	------	4.80	4.90	4.67	18	5.30	5.87	5.90	7.20
3	------	5.00	4.90	4.95	19	5.00	5.62	4.87	6.85
4	------	5.00	4.85	5.50	20	4.85	5.50	4.87	6.35
5	------	4.87	4.87	6.05	21	4.80	5.47	4.85	5.95
6	------	4.85	4.87	5.40	22	4.80	5.40	4,79	5.75
7	------	4.75	4.85	5.02	23	4.70	5.35	4.75	5.92
8	------	4.65	4.80	4.80	24	4.60	5.27	4.75	5.90
9	------	4.65	4.77	4.77	25	4.57	5.20	5.20	5.95
10	------	4.65	4.75	6.35	26	4.50	5.00	5.10	6.40
11	------	4.65	4.67	6.72	27	4.55	5.02	4.90	6.47
12	------	4.65	4.97	6.35	28	4.37	5.05	4.95	6.50
13	------	4.57	5.90	6.12	29	4.77	4.97	4.85	10.70
14	------	6.27	5.50	6.47	30	5.50	4.95	4.72	12.30
15	------	6.82	5.27	11.17	31	------	4.92	------	10.22
16	------	6.42	5.10	9.50					

Mean daily gage height of Tenmile River at Dover Plains, N. Y., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.70	5.40	14.15	6.60	6.95	4.55	4.45	5.10	3.90	5.78	5.75	4.45
2	7.00	6.10	14.10	6.45	6.95	4.50	4.25	4.88	3.83	5.85	5.50	4.48
3	6.95	6.95	[a]11.43	6.25	6.50	4.40	4.35	4.65	3.80	5.43	5.43	4.80
4	6.10	6.08	8.35	5.98	6.20	4.55	5.53	4.63	3.90	5.10	5.33	4.90
5	6.08	5.50	6.95	5.80	6.05	4.48	4.38	4.53	3.83	5.30	5.30	4.73
6	6.15	5.35	5.90	5.90	5.90	4.35	4.60	4.43	3.80	5.85	5.25	4.78
7	6.10	5.10	6.25	6.13	5.75	4.25	4.63	4.65	3.85	5.38	5.10	4.80
8	5.80	5.10	6.25	6.40	5.55	4.48	4.33	4.60	3.88	5.13	5.08	4.85
9	5.65	4.95	8.90	6.80	5.35	4.55	4.38	4.45	3.95	4.90	5.00	5.13
10	5.55	4.90	10.60	7.60	5.23	4.48	4.23	4.43	4.23	4.83	4.93	5.08
11	5.60	5.10	9.15	7.10	4.95	4.30	4.20	5.68	3.95	5.00	4.83	4.85
12	5.55	5.10	8.70	6.60	4.85	4.20	4.10	5.03	3.90	6.10	4.78	4.80
13	5.38	4.80	9.10	6.30	4.85	4.75	4.15	5.95	4.10	6.93	4.83	4.80
14	5.25	6.75	8.40	6.15	4.80	4.70	3.90	4.78	4.23	5.87	4.80	4.93
15	5.25	5.25	7.70	6.10	4.80	4.35	3.88	4.68	4.13	5.63	4.83	5.08
16	4.93	5.15	7.30	5.90	4.75	4.45	4.30	4.23	4.03	5.43	4.73	6.15
17	4.65	5.05	8.15	5.88	4.65	4.65	4.18	4.18	3.88	5.25	4.65	10.47
18	5.05	5.05	7.60	5.68	4.60	4.45	3.88	4.15	3.88	5.15	......	9.13
19	5.10	5.00	6.55	5.58	4.65	4.28	4.03	4.15	4.03	5.27	4.60	8.28
20	5.05	4.85	6.13	5.45	4.68	4.15	4.65	4.18	4.28	5.20	4.53	7.70
21	5.05	4.75	6.10	5.35	4.58	4.40	6.98	4.25	4.33	4.90	4.55	7.74
22	11.95	4.68	6.15	5.23	4.50	4.60	7.15	4.23	4.13	4.80	4.58	11.50
23	8.10	4.40	6.20	5.13	4.40	4.38	6.35	4.10	4.15	4.75	4.55	10.65
24	6.35	4.50	6.25	5.03	4.30	4.33	5.75	4.08	4.08	4.73	4.53	8.58
25	5.80	4.65	6.05	4.95	4.30	4.15	5.68	4.08	4.05	4.65	4.58	7.95
26	5.70	5.83	5.90	4.95	5.05	4.10	5.50	3.98	4.08	4.55	4.70	7.48
27	7.80	8.45	5.85	5.30	5.30	4.05	5.30	3.93	4.65	4.60	4.93	7.05
28	7.45	9.73	7.43	5.25	5.50	4.05	5.40	3.85	6.50	7.05	4.78	......
29	6.55	......	7.60	5.30	5.18	4.10	5.25	3.83	7.75	7.10	4.65	......
30	6.25	......	7.30	7.00	4.80	4.70	5.65	3.80	5.98	6.37	4.33	......
31	5.50	......	6.90	......	4.70	......	5.25	3.85	......	6.00	......	......

[a] Readings on new gage from this date, datum 0.33 above former gage.

Daily gage height of Housatonic River at Gaylordsville, Conn., for 1900.

Day.	Oct.	Nov.	Dec.	Day.	Oct.	Nov.	Dec.
1	......	3.2	4.9	17	......	3.6	......
2	......	3.1	4.6	18	......	3.5	......
3	......	3.1	4.3	19	......	3.6	......
4	......	2.9	4.2	20	......	3.7	......
5	......	3.0	5.6	21	......	4.1	......
6	......	2.9	5.8	22	......	4.0	......
7	......	2.8	5.4	23	2.9	3.9	4.8
8	......	3.2	5.1	24	3.1	3.9	5.1
9	......	3.5	4.9	25	3.2	3.8	4.3
10	......	4.1	4.5	26	3.1	4.6	4.2
11	......	3.9	4.2	27	3.1	5.5	4.1
12	......	3.7	4.2	28	3.1	5.4	4.2
13	......	3.6	4.2	29	3.1	5.1	4.0
14	......	3.7	4.2	30	3.0	4.9	3.9
15	......	3.7	......	31	......	......	4.2
16	......	3.7	......				

Daily gage height of Housatonic River at Gaylordsville, Conn., for 1901.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.40	3.20	3.30	5.30	6.20	6.20	3.60	3.50	4.30	4.30	4.00	4.00
2	4.00	3.30	3.50	5.30	6.20	6.00	3.50	3.70	4.40	4.20	4.20	4.10
3	(a)	3.30	3.60	5.30	6.40	5.70	3.80	3.50	4.70	4.50	4.00	4.20
4	(a)	3.30	3.60	6.10	6.30	5.50	3.90	3.40	4.60	4.60	3.80	4.10
5	(a)	3.10	4.10	6.60	6.00	5.50	3.70	3.30	4.60	4.40	3.70	4.00
6	4.50	3.00	3.90	6.50	5.60	5.20	4.00	3.30	4.40	4.20	4.10	4.00
7	4.50	3.40	3.90	7.30	5.50	5.20	4.00	3.90	4.40	4.00	3.80	3.90
8	4.40	3.50	3.60	8.30	5.30	5.50	3.80	4.80	4.40	3.90	3.80	3.80
9	4.20	3.40	3.50	8.00	5.20	5.50	3.80	4.40	4.00	4.00	3.80	3.90
10	4.40	3.70	7.50	7.80	5.20	5.40	3.80	4.10	3.90	4.00	3.70	5.00
11	4.10	3.50	8.20	7.20	5.70	5.20	3.90	4.00	4.00	3.80	3.50	5.50
12	4.70	3.30	7.50	6.70	6.30	4.90	4.00	3.90	4.20	3.80	3.60	5.90
13	4.00	3.40	6.00	6.50	6.10	4.80	4.00	3.70	4.00	3.80	4.80	5.70
14	3.50	3.70	5.50	6.10	6.00	4.60	3.90	3.70	4.00	5.20	4.90	5.80
15	3.70	3.60	5.60	5.90	5.60	5.20	3.60	3.60	4.00	6.70	4.70	8.90
16	3.80	3.40	5.60	5.90	5.50	4.70	3.50	3.70	4.10	6.00	4.60	8.20
17	4.40	3.40	4.60	5.50	5.30	4.50	3.70	3.60	4.10	5.80	4.50	7.80
18	4.00	3.40	4.60	5.30	5.30	4.20	3.60	3.70	4.70	5.30	4.40	7.50
19	3.50	3.20	4.80	5.20	5.80	4.30	3.60	4.00	4.50	5.10	4.20	6.80
20	3.40	3.30	4.80	5.20	6.20	4.20	3.60	3.80	4.40	4.90	4.30	6.10
21	3.80	3.40	10.00	7.30	6.20	4.10	3.60	4.10	4.20	4.80	4.20	5.60
22	3.60	3.50	8.70	9.30	5.80	4.00	3.50	4.70	4.20	4.60	4.20	5.10
23	3.70	3.40	7.40	8.40	5.80	4.30	3.40	4.80	4.00	4.50	4.10	4.90
24	3.50	3.20	7.10	8.50	5.60	4.70	3.60	4.80	3.80	4.40	4.20	5.20
25	3.60	3.30	6.60	8.80	6.80	4.60	3.60	6.80	3.90	4.30	4.60	5.20
26	3.70	3.00	6.60	7.85	6.70	4.30	3.50	6.70	3.80	4.30	4.80	5.00
27	3.80	3.40	7.20	7.20	6.80	4.20	3.50	5.70	3.80	4.20	4.50	5.30
28	3.70	3.30	6.90	6.90	6.80	4.00	3.50	5.20	3.80	4.00	4.00	5.10
29	3.50	....	6.60	7.00	6.90	4.00	3.50	4.80	3.90	4.00	4.00	6.30
30	3.50	....	6.20	6.40	6.80	3.80	3.40	4.60	4.40	4.30	4.20	9.40
31	3.40	....	5.80	....	6.60	....	3.70	4.40	....	4.10	....	7.60

a Frozen.

Mean daily gage height of Housatonic River at Gaylordsville, Conn., for 1902.

Day.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	7.10	4.90	14.30	6.80	6.80	4.70	4.80	4.80	3.80	5.50	5.50	4.10
2	6.50	4.90	10.80	6.60	6.30	4.40	4.60	4.65	3.55	5.50	5.30	4.15
3	5.90	5.40	9.90	6.80	6.10	4.40	4.40	4.65	3.50	5.25	5.00	4.40
4	5.30	4.90	10.20	5.80	5.90	4.60	4.70	4.45	3.60	5.15	4.95	4.60
5	5.20	4.80	7.80	5.80	5.60	4.90	4.50	4.30	3.65	5.00	4.85	4.60
6	5.30	4.60	6.80	5.50	5.50	4.80	4.50	4.40	3.55	5.15	4.75	4.30
7	5.30	4.50	6.50	5.50	5.50	4.60	4.80	4.60	3.65	5.00	4.65	4.35
8	5.20	4.40	6.80	5.70	5.30	4.60	5.00	4.55	3.50	4.85	4.60	4.30
9	5.30	8.50	6.80	6.10	5.20	4.40	4.70	4.55	3.55	4.70	4.50	3.45
10	5.10	6.80	7.50	6.80	4.90	4.60	4.50	4.45	4.00	4.55	4.35	3.55
11	5.00	7.00	2.20	6.90	5.00	4.50	4.40	4.50	4.00	4.40	4.30	3.70
12	4.90	8.00	7.70	6.80	4.90	4.50	4.30	5.15	3.90	5.30	4.45	3.75
13	4.70	8.80	7.80	6.80	4.90	4.40	4.20	5.00	3.85	5.30	4.40	4.00
14	4.30	8.30	8.00	6.70	4.80	4.70	4.00	4.70	4.10	5.10	4.50	4.05
15	4.50	8.00	7.90	6.20	4.70	4.60	3.90	4.50	4.00	5.00	4.50	4.25
16	4.50	7.10	7.70	5.90	4.60	4.30	4.10	4.35	3.60	4.80	4.40	4.90
17	4.30	6.80	7.90	5.80	4.60	4.50	4.20	4.20	3.70	4.75	4.35	7.90
18	4.20	7.00	7.60	5.60	4.50	4.40	3.90	4.00	3.75	4.60	4.25	7.35
19	4.40	7.50	7.30	5.60	4.40	4.40	3.80	3.80	3.80	4.55	4.30	6.70
20	4.20	7.30	7.00	5.50	4.30	4.40	4.65	4.05	3.85	4.25	4.25	6.35
21	4.50	7.20	6.60	5.20	4.60	4.30	6.00	3.95	4.05	4.30	4.30	6.65
22	8.50	7.20	6.60	5.20	4.40	4.70	6.60	4.05	3.75	4.45	4.20	8.60
23	6.80	6.80	6.10	5.10	4.30	4.50	6.00	4.10	3.60	4.40	4.20	8.40
24	6.30	6.50	5.90	5.10	4.10	4.30	5.70	4.10	3.70	4.45	4.05	7.55
25	5.80	6.80	6.00	5.00	4.20	4.30	5.50	3.95	3.65	4.45	4.15	7.30
26	5.60	7.00	6.00	4.90	4.50	4.30	5.30	3.95	3.85	4.40	4.25	6.90
27	5.90	10.60	5.90	5.00	4.60	4.20	4.95	3.95	4.20	4.30	4.60	6.65
28	5.70	9.00	5.90	5.10	5.30	4.20	4.85	3.95	4.60	5.85	4.50	6.00
29	5.30	......	6.70	5.10	5.20	4.10	5.55	3.90	6.30	6.55	4.40	5.75
30	4.90	......	6.70	6.20	5.00	4.30	5.45	3.90	6.00	6.00	4.25	5.90
31	4.90	......	6.70	......	4.70	......	5.40	3.70	......	5.80	......	5.60

Current-meter discharge measurements of Catskill Creek at South Cairo, N. Y.

Date.	Gage height.	Discharge.	Hydrographer.
1901.	*Feet.*	*Second-feet.*	
Oct. 10	2.58	23.3	Hollister and Schlecht.
Oct. 4	2.70	25.6	W. W. Schlecht.
Nov. 8	2.70	27.6	Do.
Aug. 19	2.70	39.6	Hollister and Place.
Sept. 23	2.74	35.6	W. W. Schlecht.
Nov. 9	2.75	42.3	Do.
July 4	2.75	60.9	Horton and Hollister.
Aug. 1	2.80	47.9	A. E. Place.
Oct. 22	2.82	54.2	W. W. Schlecht.
Sept. 7	2.92	68.8	A. E. Place.
Aug. 9	3.00	81.5	Do.
July 25	3.00	81.9	Do.
Sept. 2	3.00	87	Do.
Aug. 27	3.12	121.4	Do.
July 17	3.50	260.3	Pressey and Place.
July 20	3.60	307.5	A. E. Place.
June 13	2.69	40.6	W. W. Schlecht.
June 24	2.70	43.5	Do.
Aug. 27	2.74	39.4	H. K. Barrows.
Sept. 5	2.79	50	Do.
June 3	2.82	49.5	W. W. Schlecht.
May 23	2.83	51.1	Do.
Sept. 22	3.32	121	P. M. Churchill.
July 9	3.365	113.5	H. K. Barrows.
May 10	3.47	133	W. W. Schlecht.
Aug. 13	3.49	135	H. K. Barrows.
Nov. 7	3.80	235	F. H. Tillinghast.
Dec. 3	3.90	275	Do.
Oct. 10	3.92	242	P. M. Churchill.
Apr. 22	4.06	320.2	W. W. Schlecht.
Aug. 2	5.36	1,005	H. K. Barrows.
July 23	6.11	1,602	Do.
Apr. 11	6.86	2,312	W. W. Schlecht.
Mar. 13	8.66	5,483	Horton and Schlecht.

A measurement made February 27, 1902, with the stream obstructed by ice, showed the discharge 363 second-feet, gage height 4.72. The stream was frozen from bank to bank to a depth of 6 to 8 inches.

Current-meter discharge measurements of Esopus Creek at Kingston, N. Y.

Date.	Gage height.	Discharge.	Hydrographer.
1901.	*Feet.*	*Second-feet.*	
Aug. 5	3.60	39.9	A. E. Place.
July 22	3.80	64.2	Do.
July 18	4.10	144.9	Do.
July 5	4.32	148	Horton and Hollister.
July 19	4.40	172.7	A. E. Place.
Nov. 18	4.45	126.5	W. W. Schlecht.
Sept. 26	4.55	167.8	Do.
Do	4.55	150.4	Do.
Aug. 19	4.60	180.2	Hollister and Place.
Oct. 10	4.62	165.8	W. W. Schlecht.
Do	4.62	188.1	Geo. B. Hollister.
Oct. 8	4.70	178.2	W. W. Schlecht.
Nov. 1	4.74	184.3	Do.
Nov. 14	4.75	195.4	Do.
Sept. 21	4.78	200.3	Do.
Aug. 10	4.85	259.2	A. E. Place.
Nov. 26	5.06	244.7	W. W. Schlecht.
Oct. 3	5.26	329.4	Do.
Sept. 6	5.46	352.2	A. E. Place.
Aug. 29	5.50	364.3	Do.
Oct. 21	5.56	380.8	W. W. Schlecht.
Aug. 8	5.65	396.1	A. E. Place.
Sept. 4	6.11	554.3	Do.
Aug. 27	6.26	728.6	Do.
Oct. 16	6.64	785.2	W. W. Schlecht.
Dec. 19	8.35	1,472	Do.
Dec. 11	11.46	1,720.8	Do.
Dec. 30	12.15	3,989	Do.
1902.			
June 16	4.48	135.8	W. W. Schlecht.
Sept. 4	4.49	133	H. K. Barrows.
Aug. 21	4.94	191	Do.
June 26	5.02	225	W. W. Schlecht.
June 5	5.03	234.5	Do.
July 16	5.13	268.8	H. K. Barrows.
Nov. 22	5.45	272	F. H. Tillinghast.
July 9	5.81	450.4	Barrows and Schlecht.
May 14	5.83	422	W. W. Schlecht.
Sept. 23	5.87	449	P. M. Churchill.

Current-meter discharge measurements of Esopus Creek, etc.—Continued.

Date.	Gage height.	Discharge.	Hydrographer.
1902.	*Feet.*	*Second-feet.*	
Nov. 11	6	416	F. H. Tillinghast.
Aug. 12	6.28	550	H. K. Barrows.
May 24	6.38	[a] 274	W. W. Schlecht.
June 5	6.41	[a] 272	Do.
Nov. 5	6.56	594	F. H. Tillinghast.
Apr. 23	6.94	828.3	W. W. Schlecht.
May 14	7.14	[a] 508	Do.
July 30	7.65	1,155	H. K. Barrows.
July 24	8.11	1,348	Do.
Oct. 4	9.32	1,890	P. M. Churchill.
Mar. 12	9.90	2,843	Horton and Schlecht.
Apr. 30	10.28	2,813	W. W. Schlecht.
Apr. 10	13.37	5,021	Do.
Mar. 1	20.38	[b] 12,620	Do.

[a] Measured at Glasgow Bridge, Glen Eyrie.
[b] Large quantities of floating ice in the stream. Surface velocities used.

The following measurements were also made during the period of ice obstruction by W. W. Schlecht:

February 20: Gage height, 5.38; discharge, 245 second-feet; river partly frozen over. February 15: Gage height, 5.60; discharge, 557 second-feet; river mostly frozen over. February 7: Gage height, 6.83; discharge, 530 second-feet; river partly frozen. September 29, 1.30 p. m., the stream attained a flood stage, giving a reading of 25.25 on the gage.

Current-meter discharge measurements of Rondout Creek at Rosendale, N. Y.

Date.	Gage height.	Discharge.	Hydrographer.
1901.	*Feet.*	*Second-feet.*	
July 18	6.30	118.2	A. E. Place.
Aug. 6	6.40	99.4	Do.
Nov. 7	6.42	138.2	W. W. Schlecht
Sept. 24	6.45	139.6	Do.
Oct. 11	6.47	163.2	Do.
Oct. 11	6.47	201.8	G. B. Hollister.
Nov. 16	6.55	183	W. W. Schlecht.
July 6	6.55	319	Horton and Hollister.
Aug. 15	6.55	225.4	A. E. Place.
Oct. 7	6.60	217.5	W. W. Schlecht.

Current-meter discharge measurements of Rondout Creek, etc.—Continued.

Date.	Gage height.	Discharge.	Hydrographer.
1901.	*Feet.*	*Second-feet.*	
Sept 7	6.90	426.7	A. E. Place.
Aug. 20	6.94	526.4	Hollister and Place.
Oct. 18	7.03	509.9	W. W. Schlecht.
Aug. 28	7.15	644.6	A. E. Place.
Aug. 8	7.50	745.4	Do.
Sept. 4	7.56	836.1	Do.
Dec. 21	7.60	772	W. W. Schlecht.[a]
Sept. 3	7.80	1,200	A. E. Place.
Dec. 12	8	1,490.8	W. W. Schlecht.
Nov. 26	7.21	675.4	Do.
Dec. 30	11.95	5,353	Do.[a]
1902.			
Sept. 25	6.31	167	B. M. Churchill.
July 15	6.33	141.9	H. K. Barrows.
July 18	6.33	137.2	Do.
Aug. 29	6.33	145	Do.
June 6	6.38	163	W. W. Schlecht.
June 20	6.42	166	Do.
Nov. 21	6.55	283.4	F. H. Tillinghast.
Dec. 2	6.70	367	Do.
Apr. 28	6.83	382	W. W. Schlecht.
May 12	6.855	421	Do.
Nov. 4	7.00	570	F. H. Tillinghast.
Aug. 7	7.39	838	H. K. Barrows.
July 29	7.40	888	Do.
Mar. 21	8.07	1,529	W. W. Schlecht.
Mar. 1	17.60	13,936	Do.
Apr. 11	11.78	5,666	Do.

[a] Stream somewhat obstructed by shore ice.

Additional measurements were made by W. W. Schlecht while the river was frozen over, as follows:

February 18, gage height, 7.70; discharge, 342 second-feet. The river was frozen over from bank to bank and slush had collected below the ice.

February 26, gage height, 8.13; discharge, 543 second-feet. Slush below the ice made an unsatisfactory record.

February 26, gage height, 8.43; discharge, 684 second-feet. Ice covered the river from bank to bank and slush had collected underneath.

The Delaware and Hudson Canal has been abandoned in New York State, with the exception of the portion from High Falls feeder on Rondout Creek to tide water, below Eddyville. The gaging station at Rosendale is situated opposite the canal level between locks 6 and 7. The water supply of this level is drawn entirely from Rondout Creek. In order to determine the amount of this diversion during the season of canal navigation, usually from April 1 to December 10, a record has been kept at lock No. 6, or Creek Locks, at the lower end of the Rosendale level. The record includes overflow at by-pass weir, water used for lockage, and flow through paddles in miter gates. There is also a small amount of leakage in the lock walls and gates which has not been determined. The flow in the canal at lock No. 6 added to the flow at the Rosendale station will give the total actual run-off from Rondout Creek above Rosendale. The following tables show the mean monthly and estimated daily diversion during the canal season of 1902. The estimated flow in the canal as recorded in 1901 is as follows:

	Second-feet.
October, 1901	20
November 21, 1901	19

Mean monthly diversion in second-feet to Delaware and Hudson Canal, lock No. 6, near Rosendale, in 1902.

	Second-feet
March [a]	15.70
April	22.45
May	29.98
June	23.67
July	23.78
August	24.33
September	23.99
October	22.23

Current-meter measurements of Wallkill River at New Paltz, N. Y.

Date.	Gage height.	Discharge.	Hydrographer.
1901.	*Feet.*	*Second-feet.*	
Nov. 9	5.94	178	W. W. Schlecht.
July 23	5.20	306	A. E. Place.
Oct. 11	6.30	340	W. W. Schlecht.
Oct. 11	6.30	355	Geo. B. Hollister.
Oct. 24	6.33	333	W. W. Schlecht.
Oct. 9	6.48	398	Do.
Nov. 16	6.50	402	Do.
July 7	7.19	824	Horton and Hollister.
July 8	7.25	842	Do.

[a] March 23 to 31, inclusive.

Current-meter measurements of Wallkill River at New Paltz, N. Y.—Continued.

Date.	Gage height.	Discharge.	Hydrographer.
	Feet.	*Second-feet.*	
1901.			
Oct. 1	7.36	896	W. W. Schlecht.
Nov. 27	7.52	1,022	Do.
Sept. 19	7.73	1,076	Horton, Place, and Schlecht.
Aug. 13	7.85	1,038	A. E. Place.
July 19	8.25	1,243	Do.
Sept. 5	8.90	1,676	Do.
Aug. 31	9.07	1,917	Do.
Aug. 20	10.00	2,729	Hollister and Place.
Aug. 28	10.60	2,982	A. E. Place.
Dec. 11	11.50	3,040	W. W. Schlecht.[a]
Dec. 19	13.70	3,277	Do.[a]
Aug. 7	14.85	7,365	A. E. Place.
1902.			
July 17	5.70	124.3	H. K. Barrows.
Aug. 28	5.86	169	Do.
Sept. 18	5.96	209.5	Barrows and Churchill.
June 19	6.18	295	W. W. Schlecht.
May 21	6.33	344	Do.
June 6	6.40	381	Do.
Nov. 18	6.62	550	F. H. Tillinghast
May 13	6.68	506	W. W. Schlecht.
Aug. 15	6.72	518	H. K. Barrows.
Dec. 2	6.80	626	F. H. Tillinghast.
Apr. 26	6.92	[b] 680	W. W. Schlecht.
Feb. 24	7.33	288	Do.
July 29	7.49	942	H. K. Barrows.
Apr. 21	7.57	[c] 1,028	W. W. Schlecht
Feb. 10	7.78	597	Do.
Nov. 4	7.95	1,165	F. H. Tillinghast.
Aug. 6	7.98	1,150	H. K. Barrows.
May 1	10.264	2,623	W. W. Schlecht.
Apr. 9	13.21	5,354	Do.
Mar. 11	15.93	7,140	Do.

[a] Stream obstructed by ice causing backwater.
[b] Measured through ice 1 foot 6 inches to 2 feet 6 inches in thickness.
[c] Measured through ice 1 foot to 2 feet in thickness.

Current meter measurements of Fishkill Creek, at Glenham, Dutchess County, N. Y.

Date.	Gage height	Discharge.	Hydrographer.
	Feet.	*Second-feet.*	
1901.			
July 24	3.60	60	A. E. Place.
Oct. 12	3.80	97	Geo. B. Hollister.
Nov. 11	3.85	82	W. W. Schlecht.
Aug. 15	3.85	110	A. E. Place.
Sept. 27	3.86	90	W. W. Schlecht.
July 20	3.90	135	A. E. Place.
July 8	3.92	147	Horton and Hollister.
Nov. 20	3.95	114	W. W. Schlecht.
Oct. 5	3.98	126	Do.
Oct. 15	4.05	137	Do.
Sept. 6	4.15	193	A. E. Place.
Sept. 18	4.22	229	Do.
Dec. 24	4.52	315	W. W. Schlecht.
Aug. 21	4.56	342	A. E. Place.
Aug. 30	4.60	325	Do.
Dec. 13	4.62	375	W. W. Schlecht.
Oct. 15	5.10	579	Do.
Dec. 31	7.43	2,210	Do.[a]
1902.			
Aug. 26	3.04	48.5	H. K. Barrows.
July 14	3.18	64.4	Do.
Aug. 11	3.51	115	Do.
Oct. 11	3.71	155	P. M. Churchill.
June 2	3.785	132.3	W. W. Schlecht.
July 28	3.90	200	H. K. Barrows.
June 17	4.00	212.5	W. W. Schlecht.
Nov. 8	4.00	233	F. H. Tillinghast.
Apr. 25	4.03	[b]152.4	W. W. Schlecht.
May 6	4.46	349.5	Do.
Feb. 11	4.87	[c]202.5	Do.
Oct. 30	4.97	697.7	C. C. Covert.
Apr. 12	5.30	772.6	W. W. Schlecht.
Mar. 5	5.79	1,129	Do.

[a] Surface velocity used.

[b] Probably incorrect.

[c] Ice along banks at gaging station, frozen from bank to bank 90 yards below station 2 to 9 inches thick.

Current-meter discharge measurements of Tenmile River at Tabor's bridge, below Dover Plains, N. Y.

Date.	Gage height.	Discharge.	Hydrographer.
1901.	*Feet.*	*Second-feet.*	
Sept. 16	5.27	245.4	A. E. Place.
Sept. 28	4.36	70.3	W. W. Schlecht.
Nov. 11	4.75	121.5	Do.
Nov. 22	4.76	123.4	Do.
Nov. 22	4.76	120.9	Do.
Nov. 6	4.88	140.1	Do.
Oct. 26	5.01	187.6	Do.
Dec. 27	6.54	554	Do.
Oct. 15	7.19	692.8	Do.
Dec. 17	8.41	1,213.4	Do.
1902.			
Sept. 2	3.95	63	H. K. Barrows.
Aug. 19	4.28	100	Do.
June 10	4.45	[a] 158	W. W. Schlecht
Feb. 13	4.67	179	Do.
Aug. 4	4.69	184.8	H. K. Barrows.
Nov. 28	4.80	211.5	F. H. Tillinghast.
Nov. 14	4.87	211	Do.
May 15	4.88	230	W. W. Schlecht.
June 30	4.92	249	Do.
May 28	5.50	380	Do.
Oct. 2	5.80	443	P. M. Churchill.
Apr. 15	6.13	526	W. W. Schlecht.
Apr. 7	6.18	558	Do.
May 2	6.46	640	Do.
July 21	7.18	821	H. K. Barrows.
Mar. 3	10.41	2,386	W. W. Schlecht.

[a] River nearly covered with ice from bank to bank and 1¼ to 2½ inches thick.

Current-meter discharge measurements of Housatonic River at Gaylordsville, Conn.

Date.	Gage height.	Discharge.	Hydrographer.
	Feet.	*Second-feet.*	
1900.			
Oct. 20	3	303	E. G. Paul.
Oct. 24	3.10	370	Do.
Aug. 10	3.25	422	Do.
Aug. 9	3.30	450	Do.
1901.			
Aug. 3	3.50	549.5	A. E. Place.
Sept. 28	3.78	700.8	W. W. Schlecht.
Sept. 13	4	911.7	A. E. Place.
Oct. 29	4.05	951	W. W. Schlecht.
Nov. 23	4.11	965.4	Do.
Nov. 13	4.82	1,863.7	Do.
Dec. 28	5.16	2,250	Do.
1902.			
Sept. 8	3.45	543	H. K. Barrows.
Sept. 19	3.75	640	Barrows and Churchill.
Aug. 20	3.95	835	H. K. Barrows.
Aug. 5	4.28	983	Do.
July 11	4.30	1,159	Do.
Nov. 29	4.40	1,281	F. H. Tillinghast.
June 23	4.46	1,177	W. W. Schlecht.
Nov. 15	4.50	1,356	F. H. Tillinghast.
Oct. 3	5.35	2,133	P. M. Churchill.
May 3	6.10	4,459	W. W. Schlecht.
July 22	6.68	5,119	H. K. Barrows.
Mar. 18	7.63	8,259	W. W. Schlecht.
Mar. 4	9.9	13,601	Do.

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The following papers also relate to this subject: Underground waters of Arkansas Valley in eastern Colorado, by G. K. Gilbert, in Seventeenth Annual, Part II; Preliminary report on artesian waters of a portion of the Dakotas, by N. H. Darton, in Seventeenth Annual, Part II; Water resources of Illinois, by Frank Leverett, in Seventeenth Annual, Part II; Water resources of Indiana and Ohio, by Frank Leverett, in Eighteenth Annual, Part IV; New developments in well boring and irrigation in eastern South Dakota, by N. H. Darton, in Eighteenth Annual, Part IV; Rock waters of Ohio, by Edward Orton, in Nineteenth Annual, Part IV; Artesian well prospects in the Atlantic Coastal Plain region, by N. H. Darton, Bulletin No. 138.

SERIES P—HYDROGRAPHIC PROGRESS REPORTS.

Progress reports may be found in the following publications: For 1888-89, Tenth Annual, Part II; for 1889-90, Eleventh Annual, Part II; for 1890-91, Twelfth Annual, Part II; 1891-92, Thirteenth Annual, Part III; for 1893 and 1894, Bulletin No. 131; for 1895, Bulletin No. 140; for 1896, Eighteenth Annual, Part IV, WS 11; for 1897, Nineteenth Annual, Part IV, WS 15, 16; for 1898, Twentieth Annual, Part IV, WS 27, 28; for 1899, Twenty-first Annual, Part IV, WS 35-39; for 1900, Twenty-second Annual, Part IV, WS 47-52; for 1901, WS 65, 66, 75.

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