THE WORK OF THE WATER RESOURCES BRANCH OF THE UNITED STATES GEOLOGICAL SURVEY IN THE OHIO RIVER VALLEY.

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The Water Resources Branch of the United States Geological Survey was formerly called the Hydrographic Branch, the change in name being made in 1907. The investigation of the water resources of the United States by the United States Geological Survey has been carried on since 1888, funds for this particular work being drawn from the general appropriation of the Geological Survey. The early work was confined to the Western States for use, primarily, in irrigation studies. In 1894 the popular demand for data in regard to the flow of eastern streams for use in power development became so great that Congress made a specific appropriation for stream gaging work and the Water Resources Branch was organized. The first appropriation in 1895 was $12,500; the appropriations have increased as the work has expanded until in 1903 to 1906 it was $200,000 per year; in 1907 it was reduced to $150,000, and in 1908 it was still further reduced to $100,000, and has remained at that figure since. As a result of this reduction in the appropriation the number of gaging stations has been materially decreased and the work very much crippled and embarrassed. Since the reduction in the appropriation many of the States have appropriated money to carry on stream gaging work in cooperation with the United States Geological Survey.

In carrying on the stream gaging work in the United States the country has been divided into districts with a district office located at some central or convenient point. At the present time offices of the Water Resources Branch of the United States Geological Survey are located at Boston, Mass.; Atlanta, Ga.; Newport, Ky.; Albany, N. Y.; Denver, Colo.; Helena, Mont.; Portland, Oreg.; Salt Lake City, Utah, and Los Angeles, Cal. Each office is in charge of a district engineer who is assisted by several aids. It is the duty of each district engineer to select the location of gaging stations, to see that discharge measurements are made at the proper time, that the gage readers are reading the gages honestly; and, at the end of each year prepare the data that have been collected during the year for transmission to Washington, where it is prepared for publication.

The data necessary for determining the yearly flow of any stream at any particular place are a record of the daily stage and measurements of the discharge covering the range in stage of the stream at that place; a gaging station therefore consists essentially of a gage for determining the fluctuations of the stage of a stream and some structure or apparatus from which discharge measurements can be made, usually a bridge or a cable.

The selection of a site for a gaging station is governed largely by the facilities for making discharge measurements and for locating the gage. As a rule stations are located at bridges because the floor of the bridge is a convenient and safe place from which to make measurements of the discharge and because the piers and bridge furnish a suitable and permanent place on which to place a gage. Great care is taken in the selection and equipment of gaging stations for determining discharge by velocity measurements, although in some localities where it is desired to locate stations it is a question of making the best use of existing conditions. An ideal station would be one at which there is a single span bridge at right angles to the current. The stream should be straight for some distance above and below. The current should be free and smooth from eddies or boils at all stages. For best results a good velocity at low water is necessary. The bed of the stream should be smooth and permanent and the banks high and not wooded so that the flood flow shall be confined to one channel and all passing under the bridge with no liability of backwater effect from any cause. Even where the ideal conditions do not exist care and thoroughness in making measurements will give reliable and accurate results. When a suitable bridge can not be found a cable is erected across the stream and measurements are made from a car suspended from the cable. Cable stations are numerous in the West where, on account of sparse population, few bridges have been erected.

Many engineers think that discharge measurements made from bridges where there are several piers in the channel are not accurate on account of the irregular currents near the piers and the effect of the restriction of the channel upon the gage heights. The effect of the piers on the gage is the same while measurements are being made as it is at any other time; the commotion caused by the piers does not affect more than 10 per cent of the total discharge and the velocity near the piers can be determined with errors certainly not greater than 10 to 20 per cent; 20 per cent of 10 per cent is only 2 per cent, which is the maximum error. In actual practise the error from this cause is probably much less as the velocity and location of the edge of the current are determined very carefully.

There are two classes of gages, automatic or self-recording, and nonrecording. Automatic gages are but little used in the work of the survey on account of their cost and the expense of installing them. The gage in general use is the standard chain gage. Whenever possible the ordinary staff gage is used, as it is much easier to maintain and more convenient to read. It is sometimes necessary to erect an inclined staff gage; this type is common at cable stations. The gages are referred to permanent bench marks so that they can be replaced at the same elevation in case they should be destroyed in any way.

The gage is read once or twice each day by some one living nearby, the record being kept by the gage reader in a book furnished for that purpose. By means of weekly reports of the gage heights the district office is kept informed of the stage of the streams and whether or not the gage readers are attending to their work.

There are 3 distinct methods of determining the flow of open channel streams: (1) By determining the slope and cross-section and applying Kutter's formula; (2) By means of a weir or dam; (3) By measurements of the velocity of the current and of the area of the cross-section. The latter method is the one most commonly used in the work of the Water Resources Branch; the other methods are used whenever occasion demands or opportunity presents. The two factors required to determine the discharge of a stream past a section perpendicular to the direction of the current are the area of the cross section, which is obtained by sounding the section, and the mean velocity of flow normal to the section, which is obtained by the use of a current meter.

The Price current meter is now used almost to the exclusion of other types of meters by the United States Geological Survey in the determination of the velocity of flow of water in open channels, as this style of meter is well adapted for use under practically all conditions. Briefly, the meter consists of 6 cups attached to a vertical shaft which revolves, when placed in running water, on a conical, hardened steel point. The revolutions are indicated electrically. The rating, or relation between the velocity of the moving water and the revolutions of the wheel is determined by drawing it through still water for a given distance at different speeds and noting the number of revolutions for each run. From these data a rating table is prepared which gives the velocity in feet per second of moving water for any number of revolutions in any time interval.

In making measurements with a current meter a number of points called "measuring points" are laid off above and in the plane of the measuring section at which observations of depth and velocity are taken. These points are spaced equally for those parts of the section where the flow is uniform and smooth, and are spaced unequally for other parts according to the discretion of the observer. In general, there should be from 20 to 25 measuring points.

The measuring points divide the total cross section into elementary strips, at each end of which observations of the depth and the velocity are made. The discharge of each elementary strip is the product of the average of the depths at the two ends times the width of the strip times the average of the mean velocities at the ends of the strip. The sum of the discharges of the elementary strips is the total discharge of the stream. The mean of the gage height at the beginning and end of the measurement is taken as the gage height of the measurement.

There are two methods most commonly used in determining the mean velocity in a vertical in a stream, the multiple point and single point methods. The two principal multiple point methods in general use are the vertical velocity curve and the 0.2 and 0.8 method.

In the vertical velocity curve method a series of velocity determinations are made in each vertical at regular intervals, usually about 10 to 20 per cent of the depth apart. By plotting these velocities as abscissas and their depths as ordinates and drawing a smooth curve among the resulting points the vertical velocity curve is developed; the mean velocity in the vertical is obtained from this curve. This method of obtaining the mean velocity is probably the best method known, but on account of the length of time required to make a complete measurement it is largely limited to the determination of coefficients for purposes of comparison and to measurements under ice.

In the second multiple point method the meter is held successively at 0.2 and 0.8 depth, and the mean of the velocities at these two points is taken as the mean velocity for the vertical. Numerous observations under a wide range of conditions show that this method gives the mean velocity very closely for both open water and under ice.

The single point method consists in holding the meter either at the depth of the thread of the mean velocity or at an arbitrary depth for which the coefficient for reducing to mean velocity has been determined or must be assumed.

In general practise the thread of mean velocity is considered to be at 0.6 depth and the meter is held at this point in most of the measurements made by the single point method. A large number of vertical velocity curve measurements taken on many streams and under varying conditions show the average coefficient for reducing the velocity obtained at 0.6 depth to mean velocity is practically unity. The variation of the coefficient from unity in individual cases is, however, greater than in the 0.2 and 0.8 method.

In the other principal single point method the meter is held near the surface, usually one foot below, or low enough to be out of the influence of wind or other disturbing influences. This is known as the subsurface method. The coefficient for reducing the velocity taken at the subsurface to the mean has been found to be in general from about 0.85 to 0.95, depending on the stage, velocity, and channel conditions; this method is especially adapted for flood measurements.

At the end of each year the field or base data for the gaging stations, consisting of daily gage heights, discharge measurements, and full notes are assembled in preparation for obtaining the daily flow of the streams at the various points where stations have been maintained. The first step in computing the daily discharge is the construction of a rating table which shows the discharge corresponding to any stage of the stream. The construction of this rating table depends upon the fact that as long as the conditions at or near the gaging station remain constant the discharge is a function of, and increases with, the stage.

All the discharge measurements made at a station are plotted on cross section paper with the discharges in cubic feet per second as abscissas and the gage heights at which the measurements were made as ordinates. A smooth curve is drawn among the resulting points and extended if necessary to cover the range in stage at the station; the area and mean velocity curves are generally plotted on the same sheet as an aid in fixing the location of the discharge curve and in extending the same. After the discharge curve is located a table is prepared with gage heights as one argument and discharge as the other, the discharge for each gage height to tenths or half-tenths being scaled from the discharge curve and entered in the table. From this table the daily discharge is obtained, and from the daily discharge the maximum, minimum, and mean monthly flow is obtained which, with other data, are published in the annual reports. These reports may be obtained by addressing the Director of the United States Geological Survey, at Washington, D. C

[*To be continued.*]