COOPERATIVE PROGRAMS OF THE UNITED STATES GEOLOGICAL SURVEY WITH HIGHWAY DEPARTMENTS

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SYNOPSIS

The United States Geological Survey has as part of its duties the preparation of topographic, geologic, and traffic maps; the study and appraisal of the mineral resources of the nation, including the location and qualitative and quantitative analysis of road-building materials; and the investigation and the reporting of the water resources of the nation. All of these types of investigations are of value to the highway engineer. The water resources work is carried on largely in cooperation with other federal, state, county, and municipal agencies. The cooperation with state and municipal agencies is conducted on a basis whereby the Federal Government pays not exceeding 50 percent of the cost. These investigations are carried on in all 48 States from permanent field offices usually located near the central offices of the State Highway Departments.

The surface-water data collected by the Geological Survey are very useful to highway departments in the economical and safe design of bridge and culvert openings and road grades. These data consist of continuous gaging station records, miscellaneous flood information, and analytical and interpretative reports. Much information has been collected in late years on floods by special means such as slope-area and contracted-opening methods to supplement in a material way the data available at the regular gaging stations.

The Geological Survey at present cooperates directly with eleven State highway departments in water resources work. Among the most constructive and far reaching programs are those carried on in cooperation with Kentucky, South Carolina, and Ohio.

In Kentucky analytical and interpretative studies and reports especially designed for highway problems are included in the cooperative work, along with a general stream-gaging program which includes obtaining data on small watersheds. Flood frequency studies have aided materially in this State in the proper design of waterway structures.

In South Carolina the program is similar to that in Kentucky. In the case of one bridge study recently completed, the data furnished saved a very large part of the total investment in the bridge structure by forming the basis for improvement in design.

The Highway Department in Ohio recently entered into cooperation with the Geological Survey for a comprehensive program tailored to highway needs. It includes gaging stations on small streams, supplementary crest stage gages, rain gages, and provision for obtaining a large amount of special information after the occurrence of large floods. In addition, special studies will be made and the base records and results of analysis published in state reports.

The continued welfare and progress of our country, and their effect on the daily life of every man, woman, and child in the United States, are dependent upon adequate supplies and the wise use of the country's mineral and water resources. Investigations of these all-important natural resources form a principal part of the work of the Geological Survey. The Survey was created March 3, 1879, and was given responsibility for the classification of the public lands and an examination of the geological structure and the mineral resources and products of the national domain. Today, the investigative and engineering activities of the Geological Survey are performed by four branches—the Geologic, Topographic, Water Resources, and Conservation Branches.

In addition to other very important activities such as the study and appraisal of the mineral resources of the nation, the Geologic Branch, by its studies of the availability of suitable road building materials and its examination of proposed road locations, furnishes valuable assistance to the highway builder.

The Topographic Branch produces topographic maps which provide basic information on population distribution and the size of drainage areas and, through the use of contours, give general information on the configuration of the land surface which is such a vital factor in determining the most economical location for proposed roads. As a special project the Topographic Branch is preparing, for the Public Roads Administration, a series of transportation maps for the entire United States. These transportation maps are essentially highway maps on which the classification of the various roads is shown.

The surface water investigations carried on by the Water Resources Branch, with which this paper is principally concerned, are likewise of considerable interest and value to the highway people, especially in connection with records of flood stages and the collection of data needed in the design of bridges and culverts.

The Geological Survey began its water investigational program in 1888; at that time the work was principally in connection with special studies relating to irrigation. Since 1895, successive appropriation bills passed by Congress have carried an item "For gaging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells, and for the preparation of reports upon the best methods of utilizing the water resources."

This work has grown so that now the Geological Survey maintains more than 5,200 stream-gaging stations on important rivers and streams in all parts of the United States. The records obtained at these stations are published each year in the Survey's water-supply papers. The surface water investigations are conducted through 44 major field offices, to which are assigned highly-trained engineering personnel who have become, through their long residence and service, local citizens familiar with local problems and the requirements of their communities. These field offices are in practically every state, usually at the state capital where they are readily accessible to the highway departments and other interested state agencies. In this manner, the field work is accomplished efficiently and the state officials can be freely consulted as to state problems and needs; also, the results as they are obtained may be promptly furnished to the officials.

There are many uses and demands for stream-flow records, especially by those who are concerned with the administration of water rights, those having problems in river hydraulics and hydrology, and in engineering studies related to the design, construction, and operation of hydraulic structures. The list of uses of stream-flow records would include investigations of water supplies for domestic, industrial, livestock, and irrigation requirements; the design of hydroelectric power plants; litigation involving the determination of water rights; and studies of stream pollution, flood control, navigation channels and locks, drainage of agricultural lands, sanitary and storm sewers for urban areas, design of railway and highway bridges, road drainage, and erosion-control structures and practices.

Surface water investigations are conducted in all of the 48 States, Hawaii, and Alaska in cooperation with about 150 state and municipal agencies. Investigations are also done on a repay basis for many federal agencies. Except for the work that is done for federal agencies, such as the Bureau of Reclamation and the Army Engineers, which amounts to about 25 percent of the total, the cost of the water investigational work is shared essentially on a 50-50 basis by the Federal government and the state or municipal agencies.

In the early years of our work there were few, if any, records of stream flow in existence and our efforts were expended in obtaining as wide a spread of information as was possible with the available funds. In recent years, much information has been obtained concerning outstanding droughts and floods; and that information has been published in numerous reports, especially that relating to floods. These reports give the results of many special field investigations and the detailed analyses of the field data. In many areas, this array of data when properly analyzed, and in some cases interpreted for special problems, can be especially useful and valuable to the highway engineer. The use of such data will enable the best design of highway structures such as bridges and culverts, both from an economic and safety standpoint.

One of the important responsibilities of the Geological Survey is to measure the discharge of major floods. It has been our practice, whenever possible, to determine peak discharges at many miscellaneous places in addition to the data obtained at gaging station sites. During floods our engineers work day and night to obtain the data of most interest for highway work—flood discharges. These data are obtained where possible by actual current-meter measurements but frequently, because of the lack of sufficient personnel, difficulty of travel, and other factors, it is necessary to supplement these direct measurements, especially at miscellaneous places, by the use of other methods of determining peak flow. These somewhat indirect methods of measurement are based on surveys made after the floods have passed utilizing factual data, such as high water marks and cross sectional areas. One widely used means of computing peak discharge is by the contracted-opening method; this method requires the measurement of the drop through a section which materially contracts the channel of flow, such as that at a bridge or a culvert. The methods that are used in the contracted-opening computation frequently are verified by the Geological Survey by comparison of computed discharge with that obtained by direct measurement or by other reliable means. These data have been collected by the Survey for many years in connection with the routine measurement of stream flow. We are now tabulating, analyzing, and interpreting those data and putting them to work where they will do the most good—for agencies such as those that highway engineers represent.

The highway engineer is interested in the flow of water through bridge and culvert openings, but he is principally concerned with the adequacy of the opening to pass floods. The Survey is interested in the structure as a discharge measuring device, either directly or as a structure from which a current meter can be operated. Obviously the two interests are parallel and therefore it is only natural that the Geological Survey and the highway departments should cooperate with one another and work hand in hand on such matters.

The Geological Survey at present cooperates directly on a 50-50 cost-sharing basis with 11 state highway departments and indirectly through some other state agency with a number of other such departments. However, a part of that cooperation is for the purpose of supplementing other cooperative programs in the gathering of routine stream-flow records, and to be of the most value it should be broadened somewhat to include the necessary special studies.

Special studies and reports regarding the design of waterway openings under highway structures are a part of the Survey's cooperative program in several states, notably in Kentucky, South Carolina, and Ohio. In a number of other states we have from time to time been called upon to supply basic data for particular bridge problems. The growing recognition by the highway engineer of the soundness of the practice of using actual records of measured discharges in the design of waterway openings has led the Geological Survey to include as part of its investigational activities a program of work especially designed for the solution of some of the hydraulic problems facing the highway engineer. The interest of highway departments varies in different parts of the country, and in each area we attempt to tailor our program to fit local needs.

Drainage structures are rarely designed to discharge the maximum possible flood, as it is usually not economically sound in the case of highway structures to design for such unusual occurrences. In order that the design may be made on a rational basis, something must be known about the expected flood discharges on that stream and the frequency with which such a discharge may be expected to occur. Our long-time discharge records furnish the most reliable means for determining the magnitude and frequency of floods. There is no satisfactory substitute for basic data in the sound design of hydraulic structures. On this score all hydrologists are in agreement.

KENTUCKY

Very recently I was transferred from our district office at Louisville, Ky., where I was in charge of the water resource investigations in that State. Inasmuch as I am well acquainted with the work there, much of which is carried on in cooperation with the Kentucky Department of Highways, I will describe some of the special features of that program as well as those in South Carolina and Ohio, all of which are good examples of what can be done on a cooperative basis by the Geological Survey and State highway departments.

The 80 gaging stations in operation in Kentucky at this time are supported by a number of State and Federal agencies. Thirty-five of those stations were constructed and are operated in cooperation with the Kentucky Department of Highways. They are at strategic locations where they furnish, along with the other gaging stations, good general coverage throughout the State. Some of the gages are on small drainage areas where basic data are all too often inadequate or wholly lacking. In addition, cooperative funds are provided for special investigations at specific bridge sites and for special reports. During the 1947 fiscal year this cooperative program is in the amount of $12,500 on the part of each party.

A mimeographed report entitled "Flood discharges in Kentucky" was prepared in 1942 for distribution to all district and central offices of the Kentucky Department of Highways as a part of the cooperative program with that agency. Data presented in the report include tabulations of flood discharges, a map showing places where flood discharge determinations were made, and graphical presentations of flood discharges and their relative magnitude and frequency.

The curves presented in that report represent the results of analyses of past floods, by means of geographical groupings of the peak discharges of record, in an effort to predict what might be a reasonable expectation for future peak discharges in the state.

The State was divided into seven major drainage basins in order to segregate as far as feasible the areas of like rainfall-runoff characteristics. Enveloping curves of peak discharge were drawn for each of these drainage basins.

The enveloping curves, as shown in the Kentucky report, are smooth curves defining the upper limits of known peak discharge determinations and extending over the range of drainage areas for the particular group of determinations. For each drainage basin subdivision the maximum known discharges of record, in cu ft per sec per sq mi, were plotted as ordinates with the corresponding drainage areas as abiscissas. All determinations for each subdivision were plotted on a single sheet and the enveloping curve was drawn through the points that represent the highest known discharges for the various drainage areas. Thus, the curve defines the discharge for any particular drainage area that has not been exceeded by any known record of discharge within the limits of the basin subdivision.

A series of flood-discharge frequency curves were derived from those gaging stations having continuous records of stage and discharge in excess of ten yr. These curves were extended to include a maximum recurrence interval of 100 yr. The results of these frequency studies were plotted in the same manner as the maximum recorded discharges. In other words, in addition to the maximum recorded discharge, there was also plotted a series of flood discharge rates with different recurrence intervals. On the basis of these plotted results, enveloping curves were constructed to represent probable frequency of floods of certain magnitudes in the basin subdivision. Curves representing flood recurrence intervals of 2, 5, 10, 20, 50, and 100 yr are presented; these curves are really enveloping curves for the period of recurrence they represent. It should be noted that because of the relatively short period of most of the available records the 50- and 100-yr frequency curves were indicated as being unreliable.

Because there were no long-term streamflow records on small streams in Kentucky it was impracticable to extend the curves to include drainage areas of much less than 100 sq mi. It is believed that in a few more years with a continuance of the present program of stream gaging in the State, it may be possible to develop curves for use of the highway department, and other agencies, that will cover drainage-area ranges considerably below 100 sq mi. Furthermore, the additional data that will become available on the larger streams will undoubtedly greatly improve our present knowledge of the larger areas.

The information presented in the Kentucky report was intended to serve as one step in the orderly, efficient, and practical solution of hydraulic problems in connection with channel encroachments such as bridges, road levees, and other structures. It is believed that the flood-frequency curves have been of considerable aid in arriving at sound economic design of highway structures in the State. The report is frequently used as a preliminary guide in the original layout and then, where considered necessary, supplemented by a special report prepared by the Geological Survey which will frequently include additional information such as distribution of velocities, elevation of specific floods, backwater condition and other features that would affect flow condition.

SOUTH CAROLINA

The program in South Carolina is similar in many ways to the one in Kentucky. In general, reports are made as to the adequacy of the waterway openings (structures) after preliminary plans have been made by the highway department. We have been able at times to show that much of the proposed area under a bridge is inefficient in discharge carrying capacity and may be eliminated without causing serious adverse results. Recently a study of a proposed bridge across a wide valley on a coastal stream showed that a 1700-ft trestle across the flood plain could be eliminated and would cause only a small increase in head, less than ¼ ft, through the main channel. A very substantial saving to the highway department resulted.

OHIO

A rather comprehensive program has recently been started on a 50-50 cost sharing basis in cooperation with the Ohio Department of Highways. This program has been designed to cover the range of needs from small culverts to large bridges. Fourteen stream-gaging stations, each equipped with a continuous water-stage recorder, have been established over the state, located so that at least one was situated in each of the 12 highway divisions. These gages are on drainage areas ranging from 0.3 to 10 sq mi, and are divided as to landslopes with four of them on flat-sloped basins, seven on medium, and three on steep-sloped basins. Continuous records of stage and discharge are obtained at these places. In addition to these gages, there are four others that have been in operation for some time, on areas from 1.6 to 14.8 sq mi, that will be used in the program. In each of the above 18 basins there has been installed a recording rain gage. Both the amount and the intensity of rains will be recorded by these gages.

Crest-stage gages have been installed at 12 places on drainage areas of less than 15 sq mi. These gages are of an economical design and consist of a length of 2-in pipe mounted vertically on bridge abutments, trees, or posts, to record the peak stage of each flood. Several such gages have been installed on each of the 12 channels so that the slope of the water surface, or the drop through a bridge or culvert can be measured. These gages will help to determine the crest discharges by use of slope-area or contracted-opening formulas. A recording rain gage is also located in each of these basins.

About 100 additional crest-stage gages are to be installed at sites in other small drainage basins for the purpose of obtaining individual flood heights (only one of these gages will be installed at each location). Discharges corresponding to the peak stages obtained from the crest stage gages can be computed by correlation with discharges measured at nearby gaging stations.

Floods on small streams rise and fall quickly, and therefore many times it will not be possible to make current meter discharge measurements. The gage sites have, therefore, been selected with the expectation that discharges will frequently have to be computed by a indirect method, such as the slope-area or the contracted-opening method, by means of field data obtained after the floods have passed.

Activity will not be confined solely to the areas where the gages are located, but when a major flood occurs on ungaged streams field surveys will be made and maximum discharges computed. All local and unofficial rainfall records that can be located will be obtained. An example of this kind occurred in June 1946, when about 7.0 in. of rain, with 3.5 in. in one hr, fell over a small area near Wooster, and similar but separated rains fell over several other areas. Over 50 bridges were seriously damaged or destroyed. We made 24 indirect discharge measurements, that showed peak rates much higher than ever before measured in these areas, and obtained about 80 rainfall records.

The records obtained from small drainage areas may be used to determine the required size of culvert, and small bridge openings.

There are so many culverts built that it is probably impractical to make a detailed study for each one, but records from such a program as that in Ohio will furnish a means for developing graphs and tables that can be used to determine with acceptable accuracy proper design discharges for practically any stream. Measurements of discharge, rainfall amount and intensities, and topographic features will allow for a more accurate evaluation of widely used methods of design.

Peak discharges have been compiled for all floods above a selected base for all gaging stations in Ohio where a record of 15 yr or more is available, except for those stations seriously affected by artificial storage. A flood frequency analysis has been made for each of these stations. Base records and results of analyses will be published as a state report.

Mr. Tate Dalrymple, who is now spearheading the coordination of the type of investigation in which highway departments are principally interested, will work closely with representatives of the Public Roads Administration in the formulation of policy and the adoption of methods of approach to the highway problems. His paper in this Volume[1] describes somewhat in detail some of the things that may be done with the basic records collected by the Geological Survey in connection with the hydraulic problems such as those often facing the highway engineer. Mr. Carl Izzard, chairman of the Highway Research Board Committee on Surface Drainage of Highways, has already been of considerable help to us in this work.

[1] *The Use of Stream Flow Records in the Design of Bridge Waterways*, p. 163.

REPORT OF COMMITTEE ON ROADSIDE DEVELOPMENT

H. J. NEALE, *Chairman*

SYNOPSIS

The death toll on our highways makes us conscious of the need for increased safety measures. This points up the need for complete highway design with roadbed and roadside in balance in order to build a full measure of safety into the highways of the future. Complete coordinated development of highways and adjacent areas is a site planning problem.

One prominent cause of highway accidents is fatigue. Well designed waysides offer an ideal solution to the fatigue problem. The importance of this should be recognized by designers in order that sites for waysides and turnouts may be selected and acquired in the early stages of highway location.

Where turf is desirable on shoulders it must not be a mask for soft, wet or otherwise unstable soils. Michigan and New York and a number of other States are making tests for the development of turf shoulders designed to support occasional standing vehicles safely in all weather and seasons of the year.

The hazards of earth slides, erosion of slopes, blocking of drainageways, and interference of pole lines and trees stress the need for more liberal right-of-way widths and improved cross section grading and slope protection measures. The use of mulches, including asphalt, sawdust, various grain straws and roadside mowings containing mature seed, and the various methods of holding these in place will be the subject of a project outline for the coming year.

In-service training, short courses, and other university programs will continue to be encouraged to aid in training young engineers and to inform the public regarding latest methods used in the development of complete highways. Complete cooperation of highway staffs is the only path to the common goal of safer highway service to the public.

The increasing toll of deaths on highways indicates the need for increased safety measures. Safer highways require the integrated design and development of roadbed, roadside and adjacent land areas. Increased safety features