DESIGN CRITERIA AND RESEARCH NEEDS

Vernon Hagen, Hydrologic Engineering Branch, U. S. Army Corps of Engineers

•THE OCCURRENCE of an extreme flood event, such as Hurricane Agnes, requires all those involved in flood prevention activities to review procedures and criteria currently in effect.

The degree of protection provided by a flood control project refers to that amount of the flood that can be controlled to essentially nondamaging effects. This can be accomplished by a reservoir reducing the peak flow or by local protection works such as a levee, channel improvement, flood wall, diversion, or combinations of more than one type of work.

One might wonder what the degree of flood protection provided by Corps of Engineers projects has to do with highway design. Well, I am sure most people involved in highway work realize that one of the most critical problems involved in flood protection work is the relocation of highways and streets. The costs associated with raising or replacing bridges, protecting embankments, gating culverts, and other necessary highway costs are often a major portion of the total cost of a flood protection project.

In selecting the degree of protection provided by a project, Congress has generally insisted that the average annual tangible benefits exceed the average annual costs of the project. There are very few exceptions where intangible benefits have been great enough to convince Congress that a benefit-cost ratio less than unity should be permitted. It therefore follows that a major constraint in project formulation is that the benefit-cost ratio be equal to or greater than one.

Because there are not nearly enough federal funds to provide everyone flood protection, it is important that available funds be used where the greatest return can be realized. This return can of course be in the form of either tangible or intangible benefits. In the formulation of Corps flood control projects, it is required that the point of maximum net tangible benefits be established. This is determined by adding increments of flood protection until the benefits of the increment are exactly equal to its costs. The point of optimum economic return thus established is the beginning level for selecting the degree of protection. When intangible benefits are great enough, the degree of protection may be increased to a large flood such as the standard project flood, provided the benefit-cost ratio will permit. In some agricultural areas, intangible benefits are relatively small, and the degree of protection is then usually limited to the economic optimum. There are many items that enter into the intangible considerations when one evaluates how far beyond economic optimum he should go in selecting the degree of protection. One of the more important items is the potential for loss of life when the design flood is exceeded. This potential is related to factors such as the rate of rise in flood levels, type of project design, warning facilities, escape routes, and many others. There is not enough time to go into detailed discussion of project formulation; however, it should not be a casual undertaking.

Should the occurrence of Hurricane Agnes and other severe storms like the Rapid City disaster alter the basic criteria used by the Corps in selecting the degree of protection to be provided by flood control projects? Personally, I do not believe they should. I think the criteria are basically good; however, their application could stand some improvement.

The experience of great damage and loss of life by unusual floods provides a vivid example of the need to consider intangible benefits in project design. Immediately following large floods, local interests have a keen desire to provide a high degree of flood protection or control on development in floodplains. As time passes and memory dims, they become more concerned with project costs or earnings to be gained by

intensive use of the floodplains. Lessons learned from the large floods should be used to adhere more closely to prudent design criteria and should discourage those primarily concerned with maximum economic gain or minimum expenditure.

I have indicated some of my views on formulating the degree of flood protection to be provided and the effect of Agnes on this formulation activity. Now, I would like to comment on the effect of Agnes on some of those hydrologic tools we use in project formulation.

Two hypothetical floods that are of considerable significance to us are called the probable maximum flood and the standard project flood. The probable maximum flood is used to size spillways and heights of major dams built by the Corps. It is defined as the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in a region. The standard project flood is generally used as the upper level of flood protection to be made available by construction works. Its definition is essentially the same as the probable maximum flood except that we substitute the words "reasonably characteristic" in lieu of "reasonably possible" and add a phrase that excludes extremely rare combinations. The standard project flood is usually from 40 to 60 percent of the probable maximum flood in the eastern two-thirds of the United States. The storm rainfall values selected to derive a standard project flood have generally been exceeded by 10 to 15 percent of actual storms experienced within the region.

The hydrometeorological branch of the Weather Service and hydrologic engineers in the Corps have been examining the rainfall characteristics of Agnes. Although results are not complete, initial studies indicate that any changes in probable maximum precipitation or in the generalized criteria for standard project storms would not be appreciable. Agnes was a really extreme storm for some locations and for large areas; however, it did not exceed probable maximum precipitation criteria for the area it covered. There were a few areas where the rainfall exceeded standard project storm values, but this was expected to occur on rare occasions.

In the reevaluation of the Susquehanna River hydrology, the Hydrologic Engineering Center in Davis, California, found that many of the routing characteristics of the basin had to be revised from previous assumptions to reproduce such an extreme flood as Agnes. These changes, of course, resulted in new estimates of standard project flood peaks at some locations. Revisions in peak flow-probability relations have also been developed since Agnes. Although the peak flows of Agnes provided the extreme events at many gauging stations, they were only a partial reason for major changes in frequency curves. Many of the older curves had been developed with less data and were derived by superseded procedures. The recent studies by the Hydrologic Engineering Center involved regional frequency analysis, which should provide better results than single-station studies.

In summary, I do not contemplate any immediate major changes in the Corps's design criteria or hydrologic procedures because of Agnes. However, I anticipate more interest in intangible benefits when project design is formulated in the future.

Research such as that being conducted by Hardison, Reich, and others may provide us with new techniques for improving our hydrologic tools. In addition to flood probability procedures, another important area of hydrologic research is the development of conceptual models of river basins that permit optimum management of reservoir systems and accurate runoff forecasting.

Walter Hofmann, U. S. Geological Survey

•THE Geological Survey does not have construction responsibilities, so I cannot comment too much on design criteria. I would like to make the point, however, that we should continue to strive for improvement in the flood-frequency analysis techniques, and, what is more important, we need to achieve a better degree of uniformity or agreement on the results from the flood-frequency analyses. It behooves all of us in the federal establishment to try to get together and come up with an answer that will eliminate some of the confusion in flood-frequency analyses that results from different

magnitudes of floods being assigned the same frequency. Speaking for the Water Resources Division of the Survey, we are attempting to improve what we do in terms of data collection activities. We are coordinating our activities with the National Weather Service in an attempt to improve not only the data collection side but also the forecasting activities by input from both agencies. This coordination is still in the formative stages, but I am sure improvement will result in both activities.

The last point I wanted to make was in connection with the report on bridge and culvert failures by O'Donnell. Carl Nordin of our Fort Collins office attended the meeting of the Surface Water Drainage Committee in August, and I think the question of bridge failure was raised. At that time, he got the impression that very little would be done to document the failures occurring as the result of the 1972 floods. Apparently, though, there has been considerable documentation. The point I wanted to make is that it would be very helpful if the statistics of bridge failures could be collected on a nationwide basis in a uniform format so that the current design practice could be evaluated and the relative importance of additional research on scour problems, approach design, structural design, bank protection, and the like could be identified. Nordin has suggested that the Geological Survey take the lead in a project to develop this information in cooperation with the state highway departments. If funding permits in fiscal year 1974, we will try to make a start on this, but it will be a bigger job than we can handle with our resources alone. Perhaps it is something that this Surface Water Drainage Committee could take the lead in. Nordin recommended that, for selected floods, the number of bridge failures be determined and classified according to type of failure, e.g., pier scour, approach failures, abutment failures, structural failures from debris or ice buildup, some combination of these, or any other factors deemed significant. There are other statistics that could be compiled at the same time, and we would be glad to work with the Surface Water Drainage Committee to develop the questionnaire.

Frank L. Johnson, Hydraulics Branch, Federal Highway Administration

•WE HAVE HEARD about the 50-year storm quite a bit, and I assume that it is known that we generally design for the 50-year storm. But there is more to it than just that, so I want to quote a portion of an FHWA policy memorandum that most highway departments follow in designing structures.

> All culverts and bridges over streams shall be designed to accommodate floods at least as great as that for a 50-year frequency or the greatest flood of record, whichever is greater . . . with backwater limited to an amount which will not result in damage to upstream property or to the highway . . . . For highways other than those on the Interstate System, the design flood may be less than a 50-year frequency where conditions warrant lower standards. The flood frequency selected for design should be consistent with the magnitude of damage to adjacent property and the importance of the highway.

The word "accommodate" is intended to imply that the design flow will not necessarily pass through the structure. The significance of this is that an underestimate of the design flood does not necessarily mean that the structure will fail if a flood in excess of the estimated flood occurs. Because of the recent rare flood events, and for other reasons, we are currently reexamining these design criteria. In April, the Water Resources Council issued a bulletin, Flood Hazard Evaluation Guidelines for Federal Executive Agencies. It was issued to implement provisions of Executive Order 11296, which requires that to preclude uneconomic, hazardous, or unnecessary use of floodplains requires that the flood hazard be evaluated in the planning of federal or federally aided facilities. In these guidelines, two approaches are identified for purposes of flood hazard evaluation: the plan approach, under which flood hazard areas are delineated and long-range land use regulations are established, and the case approach, under which decisions regarding floodplain usage are made case by case. The case approach is the one that will generally apply to highway designs. These guidelines indicate that the 100-year flood should be used as the basic flood in evaluating the flood hazard and that any encroachment on the floodplain will permit conveyance of the basic

flood without increasing flood heights or velocities to an extent that will cause significant damage to existing or anticipated upstream or downstream development. So, we need to look at the policy under which we are operating to see whether the basic flood concept creates a need for changes in our design criteria.

The executive order goes on to state in another guideline that floods greater or less than the basic flood may be used in the evaluation, as appropriate. So, as a result of the rare events experienced recently and these new guidelines, we have been looking at the policy that I quoted earlier. Tentatively, we have come up with something that is slightly different, not a great deal, but somewhat different, that we think will meet the objectives of the guidelines and comply with the executive order as well as take care of us in the rare flood events. Here is the way it currently reads. (The statement is still in the formative stage and is subject to change.)

> All designs for highways that encroach on flood plains shall permit conveyance of the 100-year flood without significant damage to the highway or other property. All culverts and bridges shall be designed to pass at least the 50-year flood without traffic interruption, except that structures for low traffic volume highways may be designed for recurrence intervals compatible with traffic volumes, construction costs, risk of flood related accidents and costs to repair probable highway damages from floods larger than the design flood.

This is intended to recognize that flood events in excess of the design flood will occur somewhere each year. It is not possible, because of money constraints, to build all structures to pass the biggest flood that might happen in that location. So, the only answer appears to be to build highways so that extensive damage will not occur, either to the highway or to other property. A highway fill can be replaced in short order and at a relatively small cost compared to the time and cost involved in replacing a bridge. The key words in the new policy, as written, were borrowed from the guidelines for flood hazard evaluation: "Any encroachment on the floodplain will permit conveyance of the basic flood." Highways that encroach on floodplains can and should be designed to permit conveyance of floods that exceed the design flood.

Samuel V. Fox, Texas Highway Department

•THERE IS an old advertising adage that goes something like this: "Tell them what you're going to tell them; tell them; and then tell them what you told them," and, by now, if you have not been told about catastrophic floods, there is not much I am going to be able to add. On page 3, Thomas presents maps that show no floods in Texas for 1972. He explained that there were floods that he could not show because time limited taking into account all the significant floods that had occurred in 1972. Herr alluded to the fact that it was difficult to get information out of Texas.

I am afraid that probably our simple way of life sometimes prevents people in the outside world from really knowing what goes on down in Texas, but I want to take this opportunity to quietly report something to you. I think we've done it again! I believe we have set another record in Texas! (You would be disappointed if I did not say that.) We had a "little" flood that occurred on May 11 and 12, 1972, in the Guadalupe River basin between San Antonio and Austin that evidently got covered up. We had rainfall intensities that ranged to more than 10 in. in 1½ hours. There were 16 people killed, and the event possibly yielded a record unit runoff. I know it set a new record in Texas, and how it compares to the record for the rest of the United States I am not sure. From a drainage area of 0.38 square mile, we got a runoff of 2,510 cfs, which translates to a unit discharge of 5,236 cfsm. Please note that we did not lose a single highway or a single bridge. It happened at approximately 11 p.m., and many of the people that were killed were asleep in their homes. For the most part it was just simply a wall of water.

We have been concerned about the catastrophic flood, also referred to as the super flood by the AASHO Task Force on Hydrology and Hydraulics. Those of us on the task force have talked about what kind of guidelines AASHO should include in telling the state hydraulic engineers just what they should do in evaluating these so-called super floods,

maximum events, catastrophic occurrences, or whatever you wish to nickname them. Each highway engineer, if he has been doing his job, has also been concerned. This is nothing new; it just seems to be brought to mind every time one of the real big ones, like Agnes, occurs. But somewhere, for instance in Texas, every single year there is at least one and sometimes several floods that exceed the 50-year flood by more than 2, 3, or 4 times. We have tried, in the past, to avoid analyzing the big flood. Now our thinking is to look the big floods over, to analyze them, and to try to determine, without any thought of really designing for that particular flood occurrence again, what contributions or feedback we can get from a flood that might affect our normal design procedures within the realm of economy.

It has just been in recent years that we have really begun to properly document the big floods. Other authors in this Record have talked about documentation and have shown some excellent documentation. To me it is most important to get out while the flood is occurring, if possible, or very soon after the flood to find out what happened with regard to the highway and the highway structures.

The highway departments now must take a different tack. In dealing with these flood hazards, we have to begin at the time the flood is going on and, immediately after, to listen to what the local citizens have to say to us. They will be in a state of shock; many of them will have just lost their homes; some of them will have just lost their loved ones; they will not have money to fund remedial Corps of Engineer projects. Certainly a lot of the counties do not have enough money to do much good. Emergency relief is not available right there on the spot. The man they can look to is the "ole boy" that holds the highway purse strings, and I am not saying that we have all the money; we just happen to be the men on the job in many of these floods, and there are very few floods that do not involve highways in one form or another. We have to listen to the citizens and try to calm their fears by explaining the effects of highway involvement and our interest in doing what we can and not just tell them this is an occurrence we cannot design for.

Sandahl mentioned blowing the highway to relieve a flooding condition. All of us have thought about this from time to time. Sandahl spoke of blowing the highway if warranted after studying what effects it might have downstream and upstream. I would hope that in all cases of this kind a hydraulic engineer would be involved in the decision. All available expertise should be utilized.

We have lost highways and structures in Texas, and evaluation of these losses points toward two basic causes: drift and scour. We have lost structures from drift in two different ways—one from buildup that blocks the bridge and causes the water to increase in head to the point where it produces a very erosive velocity under the bridge, taking out the foundations. We have also had failures, pretty dramatic failures, from the impact on structures of large drift being carried down by the currents. Scour has taken out roadway embankments, header banks, and bridge foundations.

We are not changing our design criteria to any great extent, and I can say without hesitation that we are not designing the opening to accommodate the catastrophic flood any more now than we ever did. Design, of course, varies depending on the criteria established to define the design boundaries or limits. We are not designing for the catastrophic flood because we do not know what the magnitude of the catastrophic event is going to be. Is the catastrophic flood going to be two times a 50-year flood, five times a 50-year flood, or, as mentioned by other authors in the case of Hurricane Agnes, 62 times a 50-year flood? Hardison said that our goal should be to do the best we can to determine the 50-year flood and its true risk values and, then going from there, to drop the big flood magnitudes as outliers. The 50-year flood represents a sound design boundary because we feel its magnitude is predictable and design results are within the realm of economy.

So, although we have not changed our basic waterway design, we are, through the philosophical approach, realizing that we are encroaching on an existing system when we build a highway across or adjacent to a floodplain and, consequently, must be aware of the effects we impose on that existing system. This seems to be an important message of Executive Order 11296 to which Frank Johnson referred earlier.

One consideration concerning the catastrophic event is the availability of adequate alternate routes. In coastal areas, entire cities can become isolated when all highways serving the area are inundated and impassable. We should not overlook the possibility of providing, where feasible, accessible routes.

All water during the extreme flood does not have to go through the highway structure. We consider relief grades in roadway approaches to bridges that would allow the water, if dammed up at the bridge by drift, to have some type of relief by allowing overtopping of the roadway grade. We also consider raising the low point of the superstructure of the roadway bridge to clear the known high-water datum that has occurred in the past.

We also are becoming more conscious of the classes of dams and levees that are upstream and downstream from structures and what would happen if they failed. Who designed them and how valid the design is become important. Are they flood control structures, water supply structures, or just what?

We need to use in all cases, at least in my opinion, flow-through railing on all hydraulic bridges. This will allow better passage of some drift. Although it is far from a cure, it is better than building a parapet wall of concrete or creating something that will cause the water to run off around the ear wall or wingwall and take out approach slabs and put extreme pressures on the bridge. These are the times when the impact loads from fairly heavy drift have done the most damage.

We need to consider the foundations. I believe it is in South Dakota that they have shied away from the spread footing and now have gone to piling and drill shaft. This is a simple move but nevertheless a move worth taking.

We need to constantly update motorist warning systems. Maintenance people are well aware of what needs to be done when one of these floods occurs to adequately warn the motorist.

That hurriedly covers our current thinking. It is more philosophical than it is an absolute design approach. The research that might be suggested from studying the catastrophic floods is mostly under way and involves two areas of concern: hydrology and risk. The state hydraulic engineer, who is not a hydrologist, has to define, when using something like the Log-Pearson Type III analysis, what to do with outliers that represent catastrophic storms. I was glad to hear Hardison's presentation because he has possibly furnished us a tool to deal with outliers that I am going to study more closely. One thing we need is some way to evaluate whether we throw the outliers out or leave them in for our design.

The second item involving research is risk evaluation, and a pioneer study by Ken Young of Water Resources Engineering, Inc., in cooperation with FHWA, is already under way. They are seeking a better method for evaluating risk, which is really, when we get down to it, the name of the whole game. We have not been losing modern structures built in the last 15 years to the catastrophic floods. Maybe we are just fortunate. I think most of it relates to the fact that we are designing our foundations better. Our structure openings and grade lines are better designed because of the use of better hydraulic and hydrological tools. The bridges that have been lost in the last 15 years have been older structures, some on spread footing and some on timber pile. So we believe, all in all, the highways we are building today are standing the tests of these large unusual events very well. Now all we have to do is just fit our design philosophy into the whole system of things, and I think we will be on the road to success.

Brian M. Reich, Pennsylvania State University

•THE ONE THING about being the last man is that most things worth saying have already been said. Perhaps returning to the actual title of this session will allow us to come up with something on current design criteria and research needs. So I want to talk mainly about building a bridge between research and methods that can be applied by designers. There is an information gap, extension gap as our agricultural friends call it, between the results of research that has been done in various agencies or at universities and methods we see applied in engineering practice. It is quite understandable that there should be some sort of a gap here. There should be a providing period of these new

ideas. We should not just pick up every new idea and run with it; so we expect a certain amount of this information gap. There are, however, some specific things that I think have gone on a little too long, which are particularly pertinent in designing highway bridges.

First, let us address the topic of risk, which has been mentioned often today. I am glad to see that almost every one of the panelists discussed the needs for more research, particularly research in flood-frequency analysis. There are certainly quite a lot of people studying this subject today. Figure 1 shows a flood-frequency curve of the Susquehanna River at Harrisburg. The dots represent the observed floods, the highest one, of course, being the 1972 Agnes flood. The second largest is the 1936 flood, which was previously considered the record flood. The series of annual maximum river records comprises the 82 dots. We consider ourselves extremely lucky if a river record is so long. Various curves have been mathematically fitted. The dotted straight line is the Gumbel flood-frequency curve, classically mentioned in introductory textbooks. The Log-Pearson Type III, which was proposed by the Water Resources Council, is shown with the calculated coefficient of skewness of the logs, CSL = 0.670. Suggestions have been made by some to regionalize the skew or arbitrarily take it as zero and to recompute the Log-Pearson Type III curve. The data can be fitted rather well with the Log Gumbel Curve, which simply requires taking logs of the floods before applying the Gumbel technique. This approach, also known as the Frechet distribution, was recently used by the Institute of Hydrology at Wallington, England, to apply to a regional station year analysis of floods all over Great Britain. Mr. Alexandria in Australia, who spent his life on flood-frequency distributions, favors the Log Gumbel technique very highly. There are other stations whose curves suggest that this is a good distribution, but I am not going to suggest that the solution is a simple change. Data shown in Figure 2 for 73 years of record upstream on the same river suggest that the Gumbel method is more suitable. Together they illustrate that there is plenty of scope for more research in this area of flood frequency. It is, of course, basic to all drainage design problems.

Secondly either of these figures illustrates another point concerning the risk that dominates our concern of Agnes. On both of the figures I have introduced three scales in addition to the normal return period scale on the bottom. These scales show the percentage chance of exceeding a flood in certain period of years—one for a 50-year period, another 25 years, and the other 10 years. If we look, for instance, to the 100-year value we see that there is a 39 percent chance that that flood will be exceeded in the next 50 years. Other chances are associated with 10 continuous years. Various "return period" floods have different percentages for different design lifetimes.

Another factor that we should give attention to is that some of the theoreticians are pointing out that we should not be working with annual series of floods anymore. We started to work with annual series of floods for ease of punching just one number per year into a desk calculator. But partial-duration series, or methods that include more than one flood each year, hold good promise for improved results. Now that we have computers we can handle a lot of information, and we might be turning our attention toward analyzing more than simply the annual series of floods. There are some data banks at the moment that do give in very convenient form on magnetic tape just annual maximum flood series. We might well be thinking about future research and examine whether we really need partial-duration series or some other basic data and prepare data banks containing that information.

In conclusion, the obvious lesson can be drawn that there seems to be a lot of money put forth for flood relief. We saw the terrible mess that had to be cleaned up after Agnes, which involved a fantastic amount of money, the same amount of money that could build a tunnel under the English channel to France. When it comes to an emergency, we suddenly manage to spend money. Maybe we should be spending a small share of this money on the very matter of research that each panelist has raised. If we invested a very small percentage of these damage funds in research, I do believe our designs would improve and future generations would not have to cough up the huge sums of relief money as at present.

Figure 1. Flood-frequency curve for Susquehanna River.

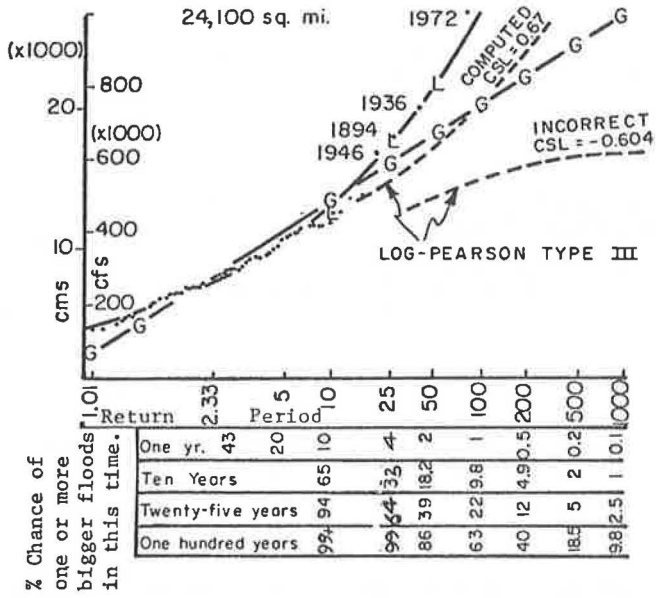
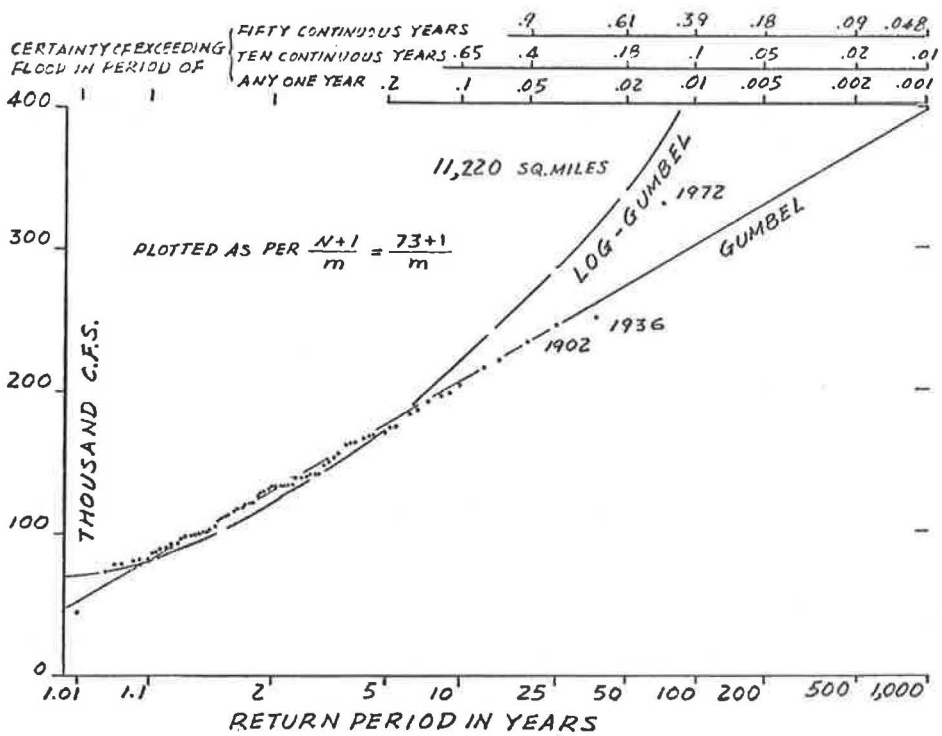


Figure 2. 73-year flood-frequency curve for Susquehanna River.



INFORMAL DISCUSSION

Question

The Weather Service has had a program of broadcasting tornado warnings in the midwest particularly. Lately, they have started announcing flash flood warnings in this area. Is this a program used nationally for, say, hurricanes such as Agnes?

Miller

Yes, the Weather Service has an expanding program in this area. We are developing more expertise all the time. Recently, we have issued flash flood alarms and flash flood warnings. The whole thing is tied up in our ability to more accurately predict precipitation in quantitative amounts. Reaching perfection in this is a long way down the road. We are concentrating in the area where the probability of having flash floods is greatest.

Question

To what extent are automatic flood warning systems being installed—for instance, automatic devices in remote areas that could be placed upstream to give warning that a flood is likely to occur?

Miller

This is part of the flash flood program. There are such automatic devices available. Most of these are put in with the cooperation of the local community. There are a few in, but I do not know exactly where they are located. There must be a cooperative program; they are put in upstream and monitored in police stations and fire houses.

Question

In connection with the rebuilding of these bridges, has there been any change in the hydrologic design, that is, in the amount of water that a bridge can accommodate, or has any change been made in design as a result of the flood?

Bowser

Not directly. Criteria to determine the amount of water reaching a bridge site were changed in 1970.

Question

There are a number of dams on the Susquehanna River. Are these an advantage or a disadvantage to bridges?

Bowser

I am not directly familiar with information to answer that question but, according to the newspaper accounts, lives and property damage were saved because of these dams.

Comment

Where there were completed major dams such as on the Allegheny River in western New York State, which is in the Ohio River watershed, there were tremendous reductions in damage, especially on the Genessee River south of Rochester.

Comment

I would like to mention that most water supply or power dams being kept full cannot do very much to reduce flood flow. In Connecticut, a new dam was to take 3 years to fill. It was filled during Hurricane Diane, and, incidentally, it prevented quite a bit of damage downstream.

Comment

The Kaw Reservoir on the North Carolina-Virginia border reduced the 1972 flood on the Roanoke River in North Carolina; otherwise it would have equaled the 1940 flood, a maximum of record. This dam prevented the flood from getting out of its channel banks.

Question

Were the through lanes on the Interstate System in Pennsylvania closed? If so, for how long?

Bowser

I do not believe that there was any stretch in the Harrisburg area that was closed. However, the state police and National Guard did restrict traffic for 2 or 3 days, principally from going downtown.

Comment

We really need more data in order to determine 50-year floods. Needed, too, are better methods to calculate flood magnitudes and frequencies. Washington should provide the climate to get various local, state, and federal agencies to combine their resources in proportion to their needs so a data base can be provided. We tried this in Montana, but we did not have much success. When the Bureau of Reclamation or the Forest Service or other agencies in the government were asked to work with the Federal Highway Administration and the state highway department to finance the project, we found that it depended on the local administrator's interest rather than on a need to accomplish a common goal. It also depended on timing of each agency's budget, when it is made up and when it is passed by Congress. Therefore, I do not think that it is impossible at the local level to get a program or an agreement in which funds can be combined. I do believe, however, that, if all concerned agencies of the federal government could meet to set the goal and priority, then the local people could get together to determine the best method to accomplish the objectives in their region. It seems that hydrologic regions, and not necessarily state lines, should determine the geographic areas. In this way, we could combine the best efforts in the Corps of Engineers, the Bureau of Reclamation, the U. S. Geological Survey, state highway agencies, and the Federal Highway Administration as well as other interested groups. If we can combine the efforts and talents of these people, then the necessary data base, as well as the best methods for determining magnitude and frequencies of floods, can be developed, and properly designed hydraulic structures will result. What I said is not so much a question as a statement, but in essence it is. If anyone wants to comment on it, I would appreciate being able to report back to Montana that there may or may not be this possibility.

Question

I wanted to raise the same question myself. To rephrase it, what are the chances for interagency cooperation on hydrologic research in order that we can do the job with the least amount of money and combine our efforts to do a better job?

Hofmann

First of all, I think there is quite a bit of this being done although it may not be so apparent or so extensive as it should be. Through the Water Resources Council, or other coordinating groups in Washington, and through direct communication, I think there is a good start for the coordination of activities. Speaking as a federal bureaucrat, the problems associated with the type of coordination you have in mind, of actually integrating the activities at the field level, are tremendous. Each agency has its own mission, and they do not like to see other agencies encroach on that particular mission. And then there are the problems of budgeting. Each agency, because of the unique nature of its mission, has its own priorities, and the individual agency's priorities may

differ. The Geological Survey, as its funds are constrained, may decide that the collection of frequency data for small drainage areas is of less priority than the collection of water data on the major river systems of the United States because of the environmental push that the nation is going through. So it is a question of individual agencies selecting priorities, and these may not mesh. So, in answer to your question, I do not see much chance for real improvement in terms of integrated activities at the field level among all of the agencies. I think a more promising action would be to integrate program activities in some fashion and then assign these to specific agencies to carry out in the field, which is more or less what is being done.

Question

With so many agencies collecting water resources data of one type or another, how can the potential user of the data find out what is available?

Hofmann

Well, we are starting a program called the National Water Data Exchange (NAWDEX), by which we are trying to make all water resources data available nationwide from one central location. NAWDEX will not necessarily store all the water information in this one system, but this system will serve as a linking mechanism for data that may be stored in the California Water Resources Department, Water Resources Institutes, EPA, the Corps of Engineers, or the Geological Survey. The concept is that NAWDEX will be the central point where anyone who is interested in water data in a certain locality can go to find out what is available and where to obtain it. NAWDEX is being funded at a very minimal level during this fiscal year. We asked for $2 or $3 million and received $100,000.

Comment

Somebody pointed out that each federal agency has a mission, and perhaps we do not see beyond the end of our nose sometimes. The approach New Jersey used was to call everybody together and say, "We have to live with all you federal agencies, so let's get together and get some kind of common approach and agree on how we're going to operate." I think this is a good approach because the state is going to have to live with the decision so possibly they can act as the coordinating agency to get the federal agencies together and maybe agree on an approach for that state.

Comment

Minnesota has taken that approach. The highway departments and the Federal Highway Administration are putting a lot of money into hydraulic and hydrologic research. Probably whatever we can contribute combined with other agencies as a pool could be used in a little bit better manner and, it is hoped, could provide us with more basic information for the design of facilities.

Comment

Although I agree with the complexity of the problems, I do not think that that is going to be the solution. We have been faced many times in the highway departments and in other agencies where national priorities could not be determined at the local level.