FLOOD HAZARD NEWS

Vol. 7, No. 1

June 1977

WAS THE BIG THOMPSON STORM AN EXTREMELY UNUSUAL ONE?

by V. A. KOELZER

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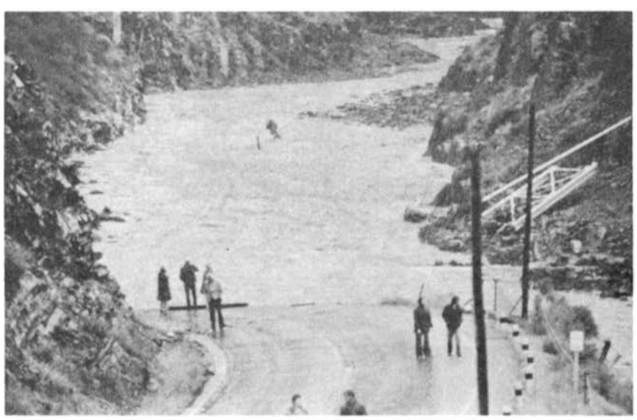
The Big Thompson flood of last year was a disaster. The Nation's record on avoiding such disasters is not totally good. Despite about 9 billion dollars spent on flood control dams and levees throughout the U.S. since 1900, the records are clear that flood damages are greater today than they were before any flood control works were built. This is with all historic damages converted to 1976 dollars—it is not simply a matter of inflation. This has happened because of a failure in flood plain management—for example, a mistaken belief that, when flood control works are built or when zoning is provided, to protect against a 100-year flood, people can move into a flood plain and be totally safe. Engineers know this is not true and yet somehow we are failing to get the message across.

In the Big Thompson situation, we engineers knew intuitively—even though we might not have been commissioned to make specific engineering studies—that the potential for disaster existed. Yet, this knowledge has not been adequately conveyed to the general public in a manner that would allow it to take the proper precautions. To me this is a failure, just as much as the Teton Dam failure in Idaho, even though it is an infinitely more complex problem and many besides engineers are involved.



The end of Highway 34 at the Narrows.

But the first step in the solution of a problem is in knowing that it exists—and there lies the engineer's most important role. We know from studies of storms in Colorado that a number of storms greater than the Big Thompson storm have occurred. We know also that these storms were not operating to maximum efficiency when they occurred and, therefore, that even greater storms are possible. We know further that it is possible for the engineer and meteorologist to analyze what adjustment in size of storm might be necessary if those storms were considered as having occurred over the Big Thompson Canyon instead of where they did occur.

If this engineering and scientific knowledge is so generally known, why wasn't there more publicity on the potential? Maybe it is because all of us, engineer and layman alike, tend to be lulled by the fact that these floods are, indeed, rare events. Or maybe it is because engineers tend to say that, once having given the facts to the planner, or the zoning board, or the homeowner, or the political entity that may be involved, we can wash our hands of it. Or maybe we just don't want to frighten people. But perhaps we should frighten people (making them aware is a more polite term). Until engineers, along with planners, politicians, zoning boards, etc. are able to get the message across, they must at least share in what the writer considers to be the big failure in flood plain management.

Before describing the historic precipitation events that lead one to conclude that the Big Thompson flood was not extremely unusual, it would be helpful to make a few elementary comments about probabilities. The reader, undoubtedly, has heard that the Big Thompson flood was a 100-year flood, or perhaps, a 200-year flood. Some believe that this means that a 100-year flood will not occur again for 100 or 200 years. Nothing could be further from the truth. Another flood of the same magnitude has just as much a chance of occurring next year as in any other year in the next 100 years. Floods are essentially random events, much like flipping a coin. If one flips a coin nine times and it shows heads each time, there are still even odds that it will show heads the next flip.

As a part of this same picture, one of the professional trials a hydrologic engineer faces is the man who says, "I have lived on this river for 50 years and it never has been as high as you say it can go; it is senseless to say that such a flood could occur." Actually, the fact that floods have not occurred within one's memory is no guarantee whatever. While we can make good engineering analyses which show the potential of flooding that may be present, what we do not know is how to determine *when*, within any given period (say, 100 years) the highest flood will happen. For example, in the 327 years of record on the Seine River in France, the highest flood occurred in only the 9th year of record. On the Tiber

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River in Rome, records have existed for almost 2,400 years, yet the highest flood did not occur until the 2,000th year. The Connecticut River at Hartford, Connecticut had 300 years of record prior to 1936, when a flood 8½ feet higher than any previous flood occurred. This was followed, only two years later, by a flood 6 feet higher than any prior to 1936. Closer to home, the Republican River east of the Colorado-Kansas line had had a maximum discharge of only 25,000 cfs prior to 1935, but in 1935 a flood of 250,000 cfs occurred—an increase of ten times!

An isohyetal map of the storm causing the Big Thompson flood is shown in Figure 1. Most of this rain is reported to have occurred within 3 hours. Maximum measured precipitation was 11.5 inches near Glen Comfort, with a considerable area being subjected to rainfall in excess of 8 inches. The resulting flood at the mouth of the Big Thompson Canyon was about 4 times the size of the largest flood that had occurred previously in 50 years of record.

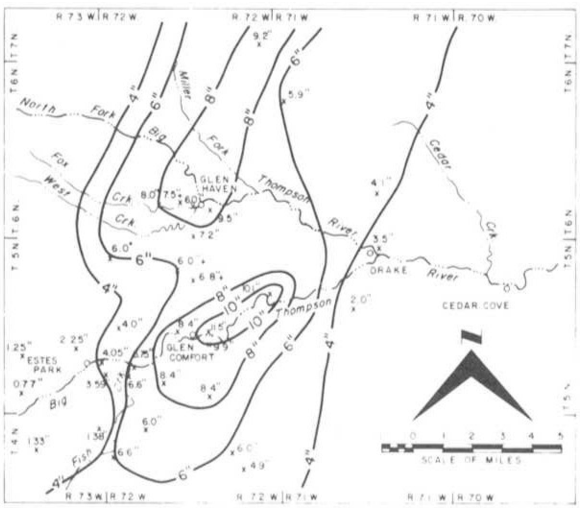

Figure 1—Preliminary Rainfall Map for Big Thompson Flood (most of rain in 3 hours) — Analysis by NWS.

The meteorological situation for the Big Thompson flood was very similar to a flood in 1972 at Rapid City, South Dakota. There was an east-west front with a band of moist air north of the front and strong easterly winds. The dewpoint was above 70, which is an indication of a heavy charge of precipitable water in the atmosphere.

Meteorologists can use data from large historical storms to estimate the maximum amount of precipitation which they believe could occur in any given area at any given time of the year. This is known as "maximizing" historical storms. In making these calculations, they use the values of dewpoint, wind velocity, orientation, and elevation which existed for the historical storm and then, by considering the most critical of these parameters that might conceivably exist, convert the observed precipitation values to "maximized" values. This might result in "maximizing factors" as much as 3 to 4 times an observed storm. While not highly precise, if repeated for a number of observed storms, it can give a range of the potential that exists for storms larger than historical ones.

Studies of this type have been made throughout the State of Colorado. They indicate quite clearly that a potential does, in fact, exist for rainfall considerably larger than that which occurred in 1976 on the Big Thompson. Figure 2 shows a map of the Colorado area of the probable maximum 24-hour precipitation that has been estimated by the National Weather Service, for different portions of the State. It will be noted that the maximum potential for the Big Thompson area over a 10-square mile area is estimated to be in the order of 24-26 inches, almost 2.5 times the 1976 occurrence!

The previously mentioned flood of May, 1935 on the Republican River resulted from a storm in which 24 inches of rainfall occurred within 24 hours at one storm's center. Another center of 24 inches occurred southeast of Denver in the headwaters of Bijou Creek, causing excessive flooding on that stream. At the time of the 1935 storm, no one in the area believed that the Republican River flood could occur because it was ten times larger than any that previously had occurred. However, one does not need to search too hard to find many people in that area now who are quite aware of what happened in 1935 and are wary of it happening again.

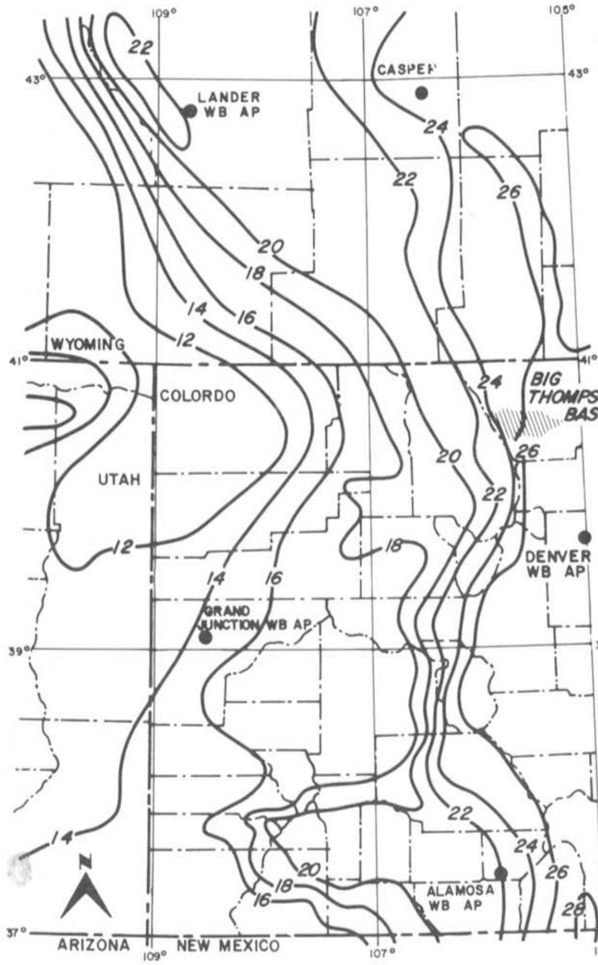

Figure 2—Probable Maximum 24-Hour Precipitation for 10 Square Miles.

A storm of June 17, 1954, which occurred northeast of Colorado Springs, had centers of 10, 12, and 14 inches. The storm caused excessive flooding throughout Bijou Creek, which runs from southeast of Denver to near Fort Morgan. The preceding day a storm had occurred between Castle Rock and Colorado Springs, with three storm centers of equal magnitude to that of June 17, causing heavy flood damage in Plum Creek and the Denver area. When these storms were maximized, centers of 21.5 inches resulted.

In 1969, a huge storm occurred over Buckhorn Creek (a tributary to the Big Thompson) and on the St. Vrain. Occurrences of 12 inches were measured on the Buck-

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FLOOD PLAIN MANAGEMENT
Developing a Program

by BILL DeGROOT

CHIEF, FLOOD PLAIN MANAGEMENT PROGRAM

With the addition of Ben Urbonas to the District's staff as chief of master planning, we have been able to spend more time on some of the more "non-traditional" methods of flood loss management, including warning systems and notification of flood plain occupants. Efforts in both these areas are now underway and are summarized below. As more results are obtained, they will be reported in future issues of *Flood Hazard News*.

The District's initial effort in early warning planning is a pilot study of Boulder Creek. The results of this study will help determine the feasibility of providing warning systems throughout the District. The study effort is broken into several elements. The University of Colorado Institute of Behavioral Science is completing two reports under the direction of Dr. Gilbert White. Eve Gruntfest has analyzed the behavior patterns of people during the Big Thompson flood. Her objective was to recommend actions other communities can take to lessen the effects of a similar flood. Tom Downing has looked specifically at the Boulder Creek situation to determine who would be affected by a flood on Boulder Creek and how the desired response to flood warnings could be obtained.

Leonard Rice Consulting Water Engineers has had the task of evaluating various methods of detecting a flood early enough to allow evacuation of the flood hazard area. Hydrology for this portion of the study was provided by the Omaha District, Corps of Engineers.

A workshop was held on May 13, 1977 to discuss drafts of the three reports and to make recommendations to the District. Approximately 50 people representing federal, state and local agencies, city and county government, the media, and private citizens participated in the workshop. Also included in the day-long session was a simulated flood on Boulder Creek, during which the National Weather Service, Boulder County Sheriff, Boulder Police Chief and representatives from other action agencies outlined actions they would take in response to given hydrologic conditions. The simulation was very useful in demonstrating the many problems to be overcome in the design of a complete warning system from detection through evacuation.

The three study reports are now being finalized and will be presented to the District. We will then consolidate the reports into a plan or plans to be presented to Boulder and Boulder County for consideration for implementation. The study results will also be utilized to assist other local governments with their warning systems.

Another product of the study will be a report entitled "Warning for Flash Floods in Front Range Communities." This report, to be prepared by the Institute of Behavioral Science, will contain basic information which can be utilized by front range communities to develop their warning systems.

On November 18, 1976, the District's Board of Directors adopted a resolution directing the Executive Director to annually notify all occupants of identified flood hazard areas which have been designated by the Colorado Water Conservation Board. The procedure which has been developed consists of mailing a brochure to each occupant of each flood hazard area.

A separate brochure is being developed for each drainageway. The brochure contains a map of the flood hazard area and tells the reader how the flood hazard area was defined and where more information may be obtained. It also suggests the following actions:

1. Know the flood hazard exists.
2. Plan escape routes to high ground.
3. Buy flood insurance.
4. During times of heavy rainfall, monitor the level of water in the drainageway. Also, stay tuned to radio or television for possible flood warnings.
5. Evacuate the flood hazard area in times of impending flood.

A mailing list for each flood plain is developed by driving the flood plain and recording all the addresses on the flood hazard area delineation maps. The compilation of these address lists is a very time-consuming process. However, once the lists are completed, it will be quite easy to mail the brochures in future years.

It is our hope that this effort will result in a more informed response to the flood hazard by the occupants of the flood plains.

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horn. When this storm was maximized, it resulted in an estimated 31 inches of rainfall in 24 hours in a center over the St. Vrain, almost three times the maximum observed in the 1976 Big Thompson.

The above cited occurrences are only a few of the major storms that have occurred in Colorado and nearby states. Meteorologists tell us that it is valid to assume that these storms could occur in other locations, with appropriate adjustments for some of the parameters mentioned previously.

Based on this historical evidence, it is clear that the Big Thompson flood of 1976, while unusual, was by no means unprecedented. The evidence is also clear that the precipitation which caused the Big Thompson flood could just as easily have happened on the Poudre, the St. Vrain, Boulder Creek, Clear Creek, or the South Platte River. It is distressing to hear a layman, in an important position, make misleading statements concerning such possibilities. For example, I recently heard, over a Fort Collins Radio station, a leading local political figure state that the flood potential of the Poudre is not as great as it was on the Big Thompson. Such statements have no scientific basis and only tend to lull people in to a false feeling of security.

To emphasize the point, the question is not whether a large flood such as the Big Thompson flood can occur in the canyons of any of these rivers, but *when* will the inevitable happen? Perhaps not in my lifetime or that of the readers, but it will happen, and it has just as much chance of occurring in 1978 as in 2078.

The engineer, the planner, the politician, the environmentalist, and the public service groups must all marshall their forces to continually make the public aware of this flood potentital. This must be followed by measures aimed at mitigation of consequences when the inevitable floods occur. Together, these steps represent the basic need in flood prone areas—flood plain management.

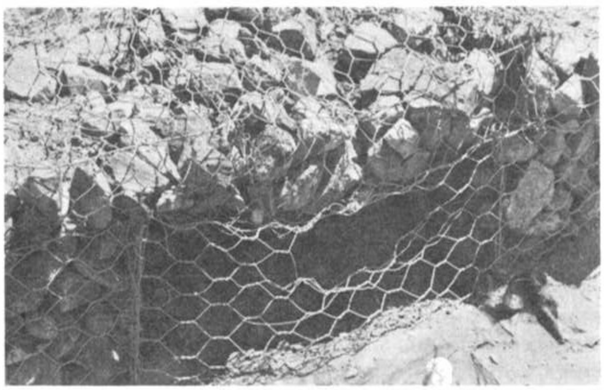
Design and Construction Notes

by BRIAN S. KOLSTAD
Chief, Design and Construction Program

The number of District construction projects continues to increase. The following is an update of these activities:

Sanderson Gulch. The second phase in Denver is currently being advertised for bids with bid opening scheduled for July 1, 1977. This will complete the work in Denver. The third and final phase in Lakewood will probably be advertised for bids in July.

The first phase in Denver has been complete for about one year, and has experienced some problems. In certain areas, the gabion check dams and drop-structures are being subjected to vandalism to the point of possibly rendering the structures inadequate. Rocks are being removed from the wire baskets and thrown into the gulch. In one structure alone, several baskets stand empty. Maintaining these structures will be expensive and may require grouting the rocks, which tends to defeat some of the advantages of gabions. The designer needs to consider the location of structures as it relates to possible vandalism and design accordingly.



An example of vandalism to gabions.

Weir Gulch. Three phases are in various stages of construction in Denver and Lakewood. Schedule VI at 9th Street and Bryant Avenue has just been completed (May 31, 1977). The project was designed as a combination flood control and recreation facility (See *Flood Hazard News,* June, 1976) and was constructed in cooperation with the Platte River Development Committee.

Schedule II in Denver is nearing completion. This Schedule, from Perry Street to Alameda Avenue began in October, 1976. Schedule III in Lakewood began in April, 1977 and is well underway. At the current rate of progress, the contractor should be complete by August or September. The next portion of Weir Gulch, Schedule III in Denver from Hooker Street to Perry Street, should begin construction by late Summer.

Holly Dam. This project has been held up for two years due to difficulties in obtaining the needed right-of-way. In April of this year, the land was finally transferred to the District. One remaining obstacle is what to do with an existing sewer line which runs through the project area. If this problem can be resolved, the dam could be constructed yet this year.

Leetsdale Storm Sewer. The State Highway Department is coordinating the construction of a storm sewer in conjunction with improvements to Leetsdale Drive in southeast Denver. The State, the City of Denver, and the District are funding the project which is nearing completion.

Weir Gulch Park (Schedule VI)

Globeville Storm Sewer Project. Phase I of this project which was completed at the end of May, included several storm sewers in north Denver, detention ponds and open channel work. One interesting part of the project was the pre-cast culvert work at a railroad crossing. This is the third time the District has used pre-cast culverts which have reduced the down time of the transportation system being crossed.

Sloans Lake Outfall. Denver is currently completing construction on parallel sanitary sewers and storm sewers near 17th Avenue and Decatur Street between Mile High Stadium and McNichols Arena. (The District's participation is limited to the storm sewer.)

Lena Gulch at 32nd Avenue. Another project coordinated by the State Highway Department is in Wheat Ridge. It includes a double box culvert and channel work associated with the widening of 32nd Avenue. This project was completed by mid-June and will serve as a pilot project for the remaining portion of Lena Gulch, which is scheduled for final design this year.

Maple Grove Reservoir. Another project nearing completion on Lena Gulch is in the improvement of the spillway on Consolidated Mutual Water Company's Maple Grove Reservoir. Two fabridams are being installed on top of a concrete spillway. The fabridams will control the water level in the reservoir and will provide some flood protection for floods up to the 100-year event. For larger floods, the fabridams will deflate, thereby increasing the spillway capacity and protecting the embankment from possible collapse. Preliminary testing will be conducted in June, with final testing scheduled to take place during the next major storm.

Niver Channel. A second phase of channel work has reecntly been completed on Niver Creek. The channel work corrected a constriction at the Explorador Calle bridge and ties into the channel previously completed in 1975.

Niver Detention. This project includes a detention dam at I-25 and 88th Avenue and a road embankment west of I-25 at about 86th Avenue extended. The design is complete and will be advertised for bids as soon as right-of-way is acquired, probably in August or September.

This has been a busy year. The total project costs of those listed above are estimated to be $9,141,000 with the District's participation estimated to be $3,365,000.

The design for Cherry Creek is essentially complete and we are awaiting news from the Corps of Engineers

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Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

ADDITION TO STAFF

The District was fortunate to add Mr. Ben Urbonas to the staff in September, 1976. Ben has assumed responsibility for the District's master planning program. He came to the District from Blatchley Associates, Denver consulting engineers. In addition to the planning program, Ben also has assumed responsibility for the District's rainfall/runoff and water quality data collection and analysis programs with the U.S. Geological Survey.

With the addition of Ben, District activities are divided into three primary areas. In addition to the planning program headed by Ben, there is the flood plain management program, headed by Bill DeGroot, and the construction and maintenance program, headed by Brian Kolstad.

Ben has jumped right into the problems at hand and has the planning program well under control. The addition of Ben has added considerably to the District's capabilities.

WE HAVE MOVED

In September of 1976, the District moved its offices from the Silco Building at 181 East 56th Avenue, to the Diamond Hill Office Complex located near the intersection of Speer Boulevard and the Valley Highway in Denver. Our new address is: 2480 West 26th Avenue, Suite 156-B, Denver, Colorado 80211. The new location at Diamond Hill has worked out well, particularly with regard to its central location in terms of the District's activities.

STORMWATER DATA COLLECTION AND ANALYSIS CONFERENCE

I served on the conference committee for an Engineering Foundation Conference held in Easton, Maryland in December, 1976. The conference was co-sponsored by the U.S. Geological Survey and the Urban Water Resources Research Council of the American Society of Civil Engineers (ASCE). Other members of the conference committee included James Biesecker, Colorado District Chief of the USGS, as chairman; Dave Dawdy of Dames & Moore; and Murray McPherson, Director, ASCE Urban Water Resources Research Program.

The conference resulted in a *Guide for Collection, Analysis and Use of Urban Stormwater Data*, published by the American Society of Civil Engineers. Participants of the conference were provided a complete draft of the Guidelines report when they arrived at Easton. The conferees re-wrote the Guidelines during the week-long conference. Mr. William M. Alley authored the draft and edited the final version. For more information on this report, see the article "Urban Stormwater Field Data" elsewhere in this issue.

CONFERENCE ON FLOOD PROOFING HELD

I was co-chairman of an Engineering Foundation Conference on Flood Proofing and Flood Plain Management held at the Asilomar in Pacific Grove, California in March, 1977. A co-sponsor of this conference was the Urban Water Resources Research Council of ASCE. The other co-chairman for the conference was Tom Lee of Minnesota. Tom passed away in December, 1976 and he was greatly missed at the conference. Without Tom's initiation and foresight, the conference would never have been held.

Earl Jones of HUD's Federal Housing Administration came to our rescue and put together an excellent program. Earl and Merwin Dougal, Director of the Iowa State Water Resources Research Institute, are working together to compile a conference proceedings. We are hoping to publish the proceedings through ASCE.

The conference was attended by approximately 100 persons who all contributed to a productive and successful week.

MAINTENANCE FINANCING

Legislation was introduced before the Colorado General Assembly this year to increase the District's mill levy by up to 0.4 mills for the purpose of financing the maintenance of drainage and flood control facilities. The bill was introduced into the Senate by Senator Schieffelin of Jefferson County. Representative Paul Swalm of Arapahoe County agreed to sponsor the bill in the House.

The District presently relies on local governments to operate and maintain drainage facilities that are partly funded by District funds. These facilities are multi-jurisdictional in nature, requiring consistent maintenance criteria throughout the entire drainageway. Local governments are generally faced with too little money for too many demands. Consequently, the maintenance of drainage facilities is in some cases not accomplished or is not accomplished adequately.

The purpose of the legislation was to provide the District with funds so that it could contract with local entities to insure the maintenance of completed facilities in accordance with standard criteria. The funds could also have been used to acquire right-of-way for undeveloped flood plains and for their subsequent maintenance.

Unfortunately, the legislation was killed by the Senate's Local Government Committee. The maintenance problems will not go away, however, and another attempt to pass the required legislation will most likely be made in future legislative sessions.

COMMENTS ON URBAN STORMWATER QUALITY

A great deal of attention has recently been focused on urban stormwater quality because of Section 208 of PL 92-500 (1972 Amendments to the Federal Water Pollution Control Act). Section 208 of the Act provides for 100% Federal financing of the development of regional water quality plans. The Act specifies that urban stormwater quality programs will be addressed.

A dilemma faced, however, is the lack of adequate basic data to define the problem and to evaluate solutions. It is my opinion that it will not be possible to define stormwater pollution problems and to evaluate solutions in the current 208 planning process. Without an adequate data base, it will just simply not be possible

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to recommend solutions that require substantial public commitment and funds.

Unfortunately, to date there has been no Federal effort towards the development of a national urban stormwater data collection and analysis program. In the absence of a Federal effort, it will be necessary for each metropolitan area in the United States to develop its own data collection and analysis program. This will be no easy or inexpensive task. Very few people appreciate the complexities involved with the urban stormwater quality problem. Urban hydrologists are still struggling with the urban rainfall/runoff process, and the addition of quality complicates the problem tremendously.

To put it simply, the rainfall/runoff/quality process is not adequately understood. There are indications that water coming from some storm sewers is polluted, but there is little information extant to indicate from where this pollution originates. The rainfall/runoff/quality process must be understood before we will be able to intelligently address the problem.

This dilemma has been recognized in at least one 208 Study. In Chicago, 208 monies are financing a $1.6 million data collection program. This provides for installation of the program only and does not include funds for continuing analysis. This is the relative type of expenditure that will have to be made by most metropolitan areas, if they are to successfully address the urban storm runoff pollution question.

APWA DRAINAGE CONFERENCE HELD IN DENVER

Ben Urbonas and I had the opportunity to participate in an American Public Works Association (APWA) Workshop on Urban Drainage, held in Denver in April, 1977. The thrust of our remarks was the urban stormwater runoff pollution problem and how to address it. We presented what we consider to be a rational approach to the urban storm runoff problem, which included the following steps:

1. Identification and evaluation of problem.
2. Exploration of alternative solutions.
3. Analysis of most attractive alternatives.
4. Alternative selection.
5. Preliminary design.
6. Detailed design and implementation.
7. Operation and maintenance.

It is important to note that the time frame for such a process is from 10 - 20 years. We tried to impress upon the conferees that a basic element of such an approach is a data collection and analysis program. This is absolutely necessary if success is to be achieved.

NATIONAL FLOOD INSURANCE PROGRAM UNDER ATTACK IN THE U.S. CONGRESS

The House of Representatives recently passed amendments in the Housing Act of 1977 which would seriously weaken the National Flood Insurance Program. These amendments would: 1) repeal the prohibition against Federally regulated lenders making loans in identified flood hazard areas in communities not participating in the flood insurance program (Section 202) (b); 2) change the definition of "substantial improvements" from 50% to 80% of pre-improvement value; 3) require lenders to inform borrowers in flood hazard areas that they will not be eligible for flood disaster aid in the event of flood damage; and 4) deny Federal disaster assistance to communities which fail to participate in the program.

Legislation in the Senate, S. 1408, would similarly repeal Section 202(b) and deny Federal disaster assistance to communities not participating in the program. Another provision of S. 1408 would require an analysis of the benefits and costs of the program for each community.

The National Flood Insurance Program presently stipulates that any Federally insured lending institution require the purchase of flood insurance prior to the issuance of a loan for any property located in a defined flood hazard area. This provision, known as Section 202(b), provides the muscle and is the heart of the National Flood Insurance Program. In my opinion, the flood insurance program will be rendered essentially ineffective if Section 202(b) is eliminated.

One of the benefits of the insurance program is the requirement for local entities to regulate and manage flood plains. It makes sense that development in flood plains should be managed. However, pressure at the local level by those that wish to optimize the development of their flood plain lands can be severe. Without the Federal incentive as provided in Section 202(b), it may not be possible for many local communities to withstand the pressures of the owners of flood plain lands.

Because of the serious adverse nature of the House passed amendment, and S. 1408 now in the Senate, it is recommended that people concerned contact their Congressional representatives. Congressional oversight hearings on the National Flood Insurance Program are scheduled for September, 1977. In your contacts with your Congressional representatives, you might suggest that they resist any changes in the present makeup of the program until the oversight hearings are complete. We feel that the appropriate time to consider any changes in the program is at the conclusion of the hearings after proponents and opponents of the program have had the opportunity to present their cases.

Flood insurance plays a vital role in flood plain management. The emasculation of the flood insurance program will only serve to reduce the effectiveness of all our efforts in this regard.

Why Worry About Floods During A Drought?

The above question is being asked quite often as the drought in Colorado persists. The following quote from the May 3, 1977 edition of the *Rocky Mountain News* may provide an answer to the question.

> Drought was no longer the problem for farmers along Highway 85 in Weld County Monday. Heavy rains and hailstorms Sunday leveled crops, washed newly planted seeds out of the ground, flooded bridges and houses and left huge lakes of water in fields prepared for irrigation. In Ault, 11 miles north of Greeley, up to five inches of rain and hail pounded the ground in less than an hour Sunday afternoon. Damage to roads and bridges in the county was estimated Monday to be at least $750,000.

The lesson is this. Heavy rainfall and resulting flooding can occur during a period of drought.

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on our application for a 404 Permit. Denver has applied for Public Works funds to do the construction.

Other projects scheduled for design this year are: Boulder Creek at 75th Street bridge in Boulder County; Lena Gulch in Wheat Ridge; Westerly Creek in Denver, and Aurora; Van Bibber Creek in Arvada; Hidden Lake in Adams County; and SJCD in Jefferson and Arapahoe Counties.

PLANNING NOTES

by BEN URBONAS
Chief, Master Planning Program

COLORADO URBAN HYDROGRAPH PROCEDURE REVISIONS

Major drainageway and local drainage facilities planning processes utilize a variety of state-of-the-art engineering and economic tools to find cost effective solutions. The cornerstone of the analytical process is hydrology. The runoff estimates serve as the basis for all hydraulic and economic analyses that follow.

To improve the reliability of the hydrologic tools within the District, the UD&FCD has been a cooperative partner with the USGS in collecting rainfall and runoff data at approximately 30 different locations in the District. Some of the data collected between 1968 and 1972 was used to revise the Colorado Urban Hydrograph Procedure (CUHP) in May of 1975. At that time, the data base lacked information from basins having low percentages of impervious area. To compensate for this shortcoming, data from other parts of the country was also used. Although the resulting relationship for the time coefficient C_t as a function of imperviousness appeared to be reasonable at that time, it later became evident that the new procedure gives excessively large values of C_t when imperviousness in the basin is below 20 percent. Since most of the District's planning and design efforts were for basins having imperviousness greater than 20%, this shortcoming was not immediately noticed or considered too serious.

To correct the CUHP, the local data used in the 1975 revision was scrutinized. After discarding all of the data from other parts of the country, it was possible to revise the C_t vs Ia curve (Figure 4-2 in the *Urban Storm Drainage Criteria Manual*) for the range of imperviousness between 0% and 25%. Figure 1 presents the revised C_t vs Ia curve and will be sent to all current Manual holders. It is recommended that the heavy line on this figure be used until further improvements can be made to the CUHP. The District is formulating a program to analyze all of the rainfall and runoff data collected so far and to continue this analysis through 1980. If the analysis of this large data base so indicates, the CUHP will be updated on a more permanent basis around 1981.

The other area of CUHP requiring immediate attention is the slope correction procedure. The use of the slope correction procedure in the *Urban Storm Drainage Criteria Manual* is very subjective and there is a general lack of consistency in its use. The local data used for the 1975 revision was not analyzed to determine a trend of how the basin slope affects the estimate of Ct, even though the data came from basins having main channel slopes between 0.5 to 3.6, percent, with all but four of the 18 basins used having slopes between 1.0 and 2.5 percent.

After studying the works of several investigators, it is believed that the slope of the basin does have an effect on the value of C_t. Also, it was concluded that standardization of the slope correction procedure is essential to achieve consistency of results within the District. Recognizing that the CUHP was "calibrated" using data from basins with the majority of them having slopes between 1.0 and 2.5 percent, the following slope correction procedure for C_t is recommended at this time:

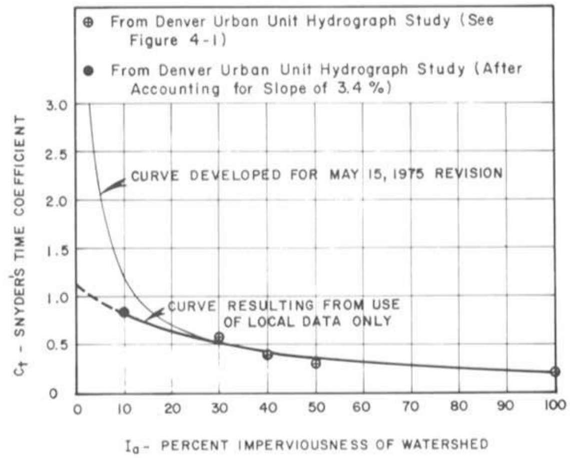

Figure 1—Relationship between Ct and Imperviousness.

$C_t = C_{t_o}$; for $1.0\% \leq S \leq 2.5\%$

$C_t = C_{t_o} S^{-0.2}$; for $S < 1\%$

$C_t = 1.2\, C_{t_o} S^{-0.2}$; for $S > 2.5\%$

Where, C_t = corrected value of time coefficient;

C_{t} = value of C_t from Figure 1;

S = Basin slope along the major drainageway, in percent.

To find Cp that also accounts for slope, use the corrected value of C_t whenever using Figure 4-3 of the *Drainage Criteria Manual*.

We also recognize the need to improve the Manual's procedure which modifies the flow estimates due to the degree of storm sewering and main channel improvements in a drainage basin. The effects of improved storm drain systems have been recognized by many investigators, but it is difficult to objectively quantify them. An effort is underway to develop more objective guidelines that will account for the effects of drainage system improvements within a given drainage basin.

BENEFIT-COST MANUAL TO BE PUBLISHED

The District, in the summer of 1977, will publish a manual titled, *Methodology for Evaluation of Feasibility of Multi-jurisdictional Urban Drainage and Flood Control Projects*. The price for this manual has not yet been set, but should be around $5.00. Copies of the manual may be reserved by calling or writing Mrs. Trudy Nash at the District.

Joe Shoemaker points out improvements on the Platte River Greenway during a field trip by the Board of Directors.

Hydraulic Design of Curb-Opening Inlets

by Carl F. Izzard, Consulting Engineer
Arlington, Virginia

This paper presents a graphical solution for standard curb-opening inlet design and is based on a re-analysis of the original experimental data for full-scale inlets reported by Karaki and Hawnie, Colorado State University, 1961. It gives results similar to the charts developed by Bauer and Woo presented in *Hydraulic Engineering Circular No. 12, Drainage of Highway Pavements,* Federal Highway Administration, 1969. The latter charts were reproduced in the section of Storm Inlets of the *Urban Storm Drainage Criteria Manual.* The graphical solution presented here has the advantage of being applicable to any grade (S), cross-slope (Sx), roughness coefficient (n) and flow spread (T), while giving a direct reading from a single chart.

The standard curb-opening inlet is illustrated by Figure 1 and is defined as having a gutter depression apron W feet wide at the inlet opening which extends W feet upstream and downstream from the opening, has a depression depth (a) equal to W/12 feet at the curb face, and a curb opening height (h) of at least 0.5 feet. The graph as presented by Figure 2 is based on a depression apron width (W) equal to 2 feet. The pavement cross-section is straight to the curb face; however, a parabolic street section can also be analyzed using an effective flow spread as will be discussed later. The entire length of the inlet opening must be free of any obstruction.

An example in dotted lines illustrates the use of Figure 2. The depth of flow, dw, in the street section at the point W (2 feet from the curb face) is the starting point.

1. Enter with dw = Sx (T - 2) feet at top of Figure 2.
2. Follow vertically down to a line representing Mannings n, normally 0.016.
3. Move horizontally across to longitudinal slope S.
4. Follow vertically down to flow spread T; this establishes a horizonal line for the example at hand.
5. *If Qi/Q is given,* enter with Qi/Q (Upper right), follow horizontally across to line A, or line for Sx, whichever is intersected first.
6. Move vertically down to lower margin (where Qi/Q = 0.1) and then diagonally to intersection with line from Step 4.
7. Follow vertically down to find the required length of inlet Li.
8. The horizontal line in Step 4 can be extended to line L3 to find the needed curb opening to achieve 100% interception; from intersection with line L3, move vertically down to inlet length for that case.
9. *If length of inlet is given,* enter with that length, move vertically up to horizontal line established in Step 4, then diagonally to Qi/Q = 0.1, then vertically to Sx or line A and horizontally across to find Qi/Q.

The cost curve in the lower right-hand quadrant is inserted to illustrate how costs may be estimated. This curve happens to be based on 1973 contract prices for Virginia State Highway Department curb-opening inlets. This curve can be useful in consideration of alternate criteria for T and Sx. It will be found that total street inlet costs increase greatly for cross-slopes less than 0.03 ft/ft, and when attempting to maintain a flow spread of less than 10 feet.

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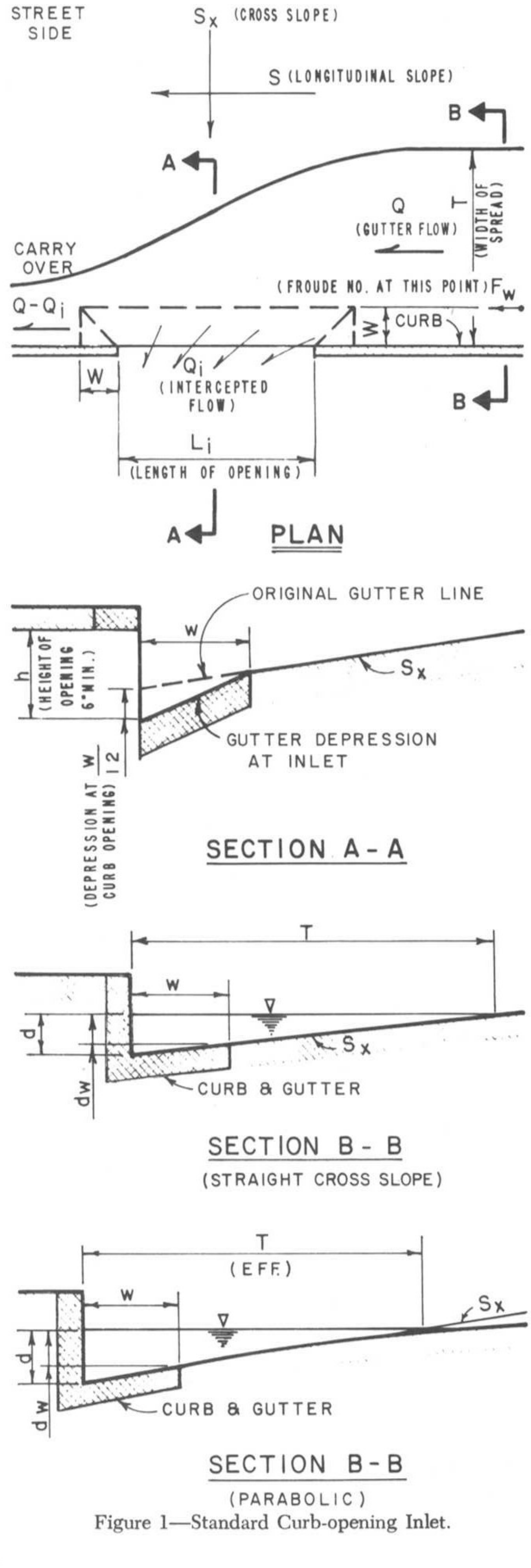


Figure 1—Standard Curb-opening Inlet.

Figure 2—Standard Curb-opening Inlet Chart.

W = 2 ft.

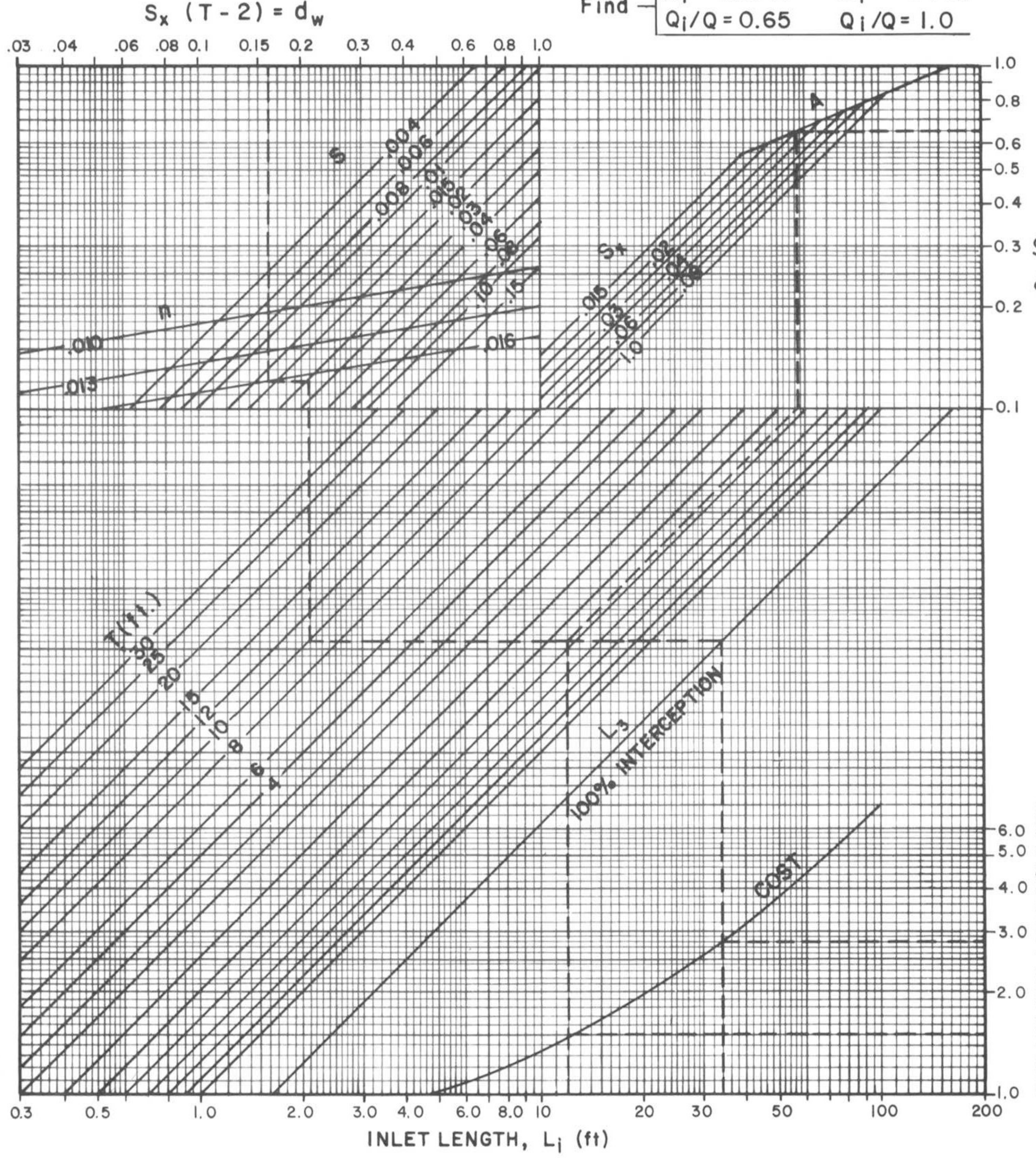
a = 2 in.

h = 6 in.

EXAMPLE

Given — S_x = 0.02 ft/ft; T = 10 ft.; S = 0.03 ft/ft

Find — L_i = 11.8 ft, Q_i/Q = 0.65; L_i = 34 ft., Q_i/Q = 1.0



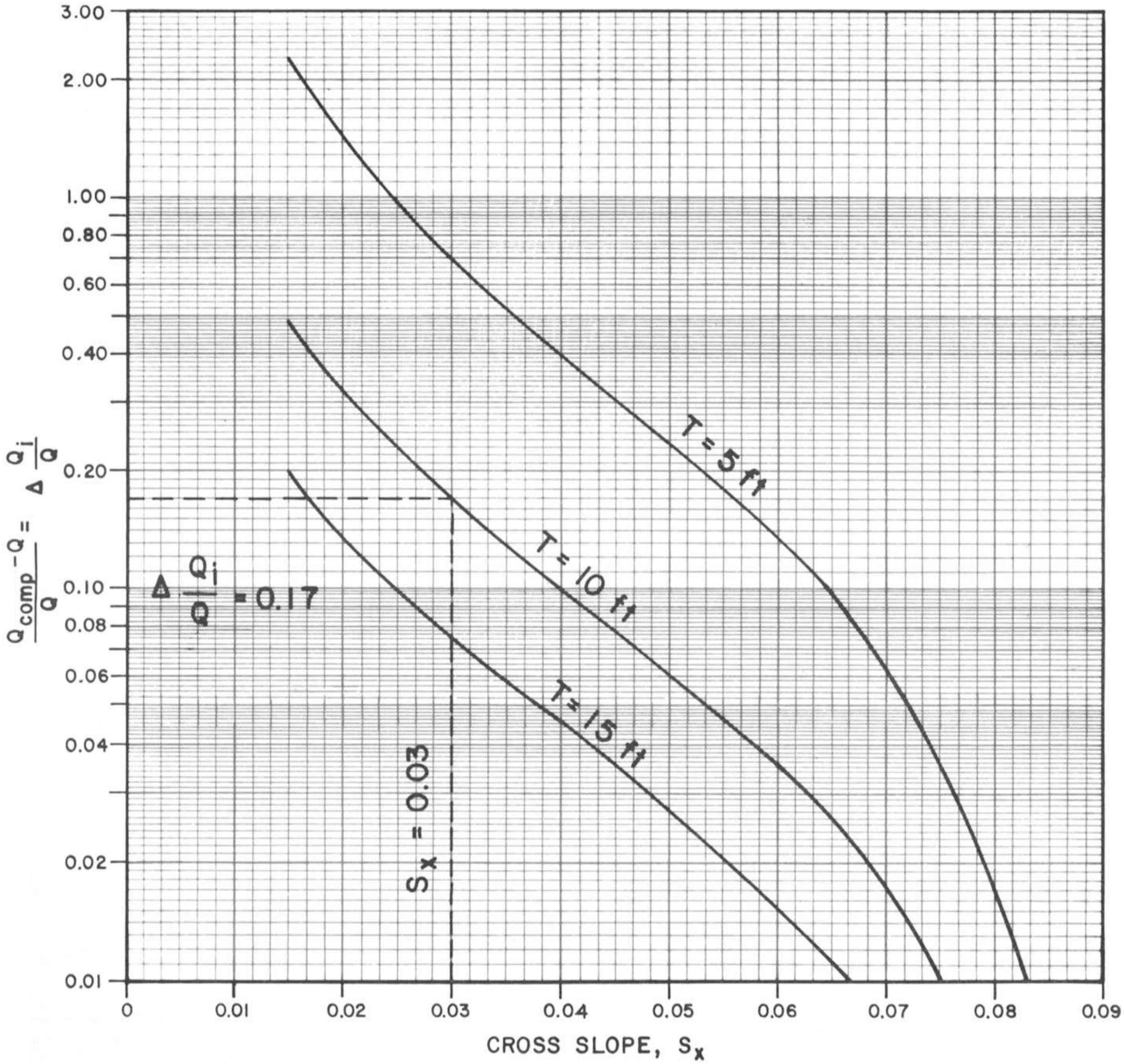


Figure 3—Increase in Interception of Compound Street Section for W = 2 ft. and Gutter Cross-slope = 1:12.

(Continued from Page Eight)

As illustrated in the example, the length of inlet decreases markedly when Oi/Q is taken less than 1.0. If a slight increase in spread (T) is tolerable for successive inlets, the carry-over flow added to the runoff from the intervening watershed increases the interception ratio. Consequently, by the third inlet, all the intervening flow is intercepted. Cost savings can be substantial, even when the last inlet is sized to pick up the total flow.

It has been assumed in the foregoing that the user has access to a method of computing flow spread (T) for a given flow (Q) in the approach street section, such as the "Nomograph for Flow in Triangular Channels," which is reproduced in the *Urban Storm Drainage Criteria Manual.*

There have been no tests on inlets placed on a street section where the gutter has a steeper cross-slope than the pavement. A method of estimating the increase in interception capacity due to the increased flow in such a compound section is suggested here. When the gutter slopes more steeply than the pavement, an increase in gutter flow results. If the gutter has the same width as the inlet depression, it is reasonable to assume the increased increment in gutter flow will be intercepted by the inlet. Using the method outlined in the "Nomograph for Flow in Triangular Channels" mentioned above, Figure 3 has been computed to give the relative increase in total flow for various cross-slopes and values of T. Figure 3 is based on a gutter 2 feet wide with a cross slope of 1:12.

To use Figure 3, first estimate inlet interception flow Qi for the given inlet using the method previously described. Knowing Sx and T, read Qi/Q on the ordinate scale, and multiply it by the previously estimated Q to obtain the increase in the interception to be added to the original Qi.

Experimental data on operation of curb opening inlets on parabolic sections is also lacking. However, an equivalent straight section can be calculated which closely approximates the parabolic section, having the same depth at the curb and the same street flow Q. Again, it is assumed that the designer has a conveyance curve Q/S1/2 for the parabolic section similar to Figure 28 in *Hydraulic Engineering Circular No. 12.* From this curve, Q is found for a given depth of flow at the curb and street grade, or vice-versa.

To compute the equivalent straight cross-slope section and flow spread, first solve for cross-slope using an equation for flow in a triangular channel using Q, n, d, and S from the parabolic section:

$$S_x = \frac{0.56d^{8/3} S^{1/2}}{nQ}$$

Then compute flow spread T = d/Sx. Using the equivalent cross-slope and flow spread, proceed to Figure 2 to determine the curb-opening inlet design.

Westerly Creek—August 1, 1976

Looking downstream from 19th Avenue

At 19th Avenue and Beeler

Montview Park

A multi-jurisdictional problem

Urban Stormwater Field Data

The Urban Drainage and Flood Control District would like to bring attention to a recent ASCE publication entitled, *Guide for the Collection, Analysis and Use of Urban Stormwater Data.* This publication is the product of a recent Engineering Foundation Conference cosponsored by the Urban Water Resources Research Council of the American Society of Civil Engineers and the U.S. Geological Survey. A draft of the report was authored by Bill Alley with the support of the Urban Drainage and Flood Control District and intensely reviewed during the week-long conference by the conference participants. Bill then edited the final version.

The report responds to the ever-increasing need for more field data, the fact that local governments are essentially on their own for collection of this data, and the lack of guidelines for acquiring field data. A very definite need exists for more field data, particularly urban runoff quality data. In fact, any true indication of the urban runoff quality "problem" hinges on the proper collection of local field data.

The report suggests an integrated approach of data collection, analysis and use rather than the all too frequent case of waiting until data collection has been completed and then deciding how the data are to be analyzed and used. Five separate but interdependent topics are discussed: data utilization, data analysis, network planning and design, instrumentation, and data collection.

The report reminds the reader that a first consideration in establishing a stormwater data collection program is the use to which the data will be put.

Four aspects of data utilization which have so far been largely neglected in urban stormwater data-collection programs are then discussed. These are the transferability of information to ungaged/unsampled catchments, the relationship of urban runoff to receiving water bodies, the determination of event probabilities, and the evaluation of urban-runoff control strategies.

After determining how the data are to be utilized, a second consideration in developing a stormwater data collection program is the manner in which data will be analyzed and how this affects the setup of the data collection program. The report emphasizes that data should be reduced and analyzed in some manner (at least a comparison of hyetographs, hydrographs and pollutographs as soon as possible after they have been collected. A failure to reduce data to a usuable form as soon as possible after their collection can reduce the efficiency of the data collection program and result in actual loss of data from burial in files. Likewise, promptly analyzed field data can reveal faulty operation and maintenance of equipment or complications of the catchment which could remain undetected for long periods of time. Prompt analysis of data is also necessary to reconsider the sampling frequency and whether the data being collected are the data wanted. In fact, model analysis prior to any data collection using best estimates of model parameters and a few typical rainstorms, can be a valuable guide in network design and can allow early familiarization and debugging of models well before approaching deadlines.

The discussion of data analysis centers on model analysis, but other types of data analysis are included. It is emphasized that the selection of models to be used, if any, depends upon the objectives and constraints of the data collection program. Certain urban-runoff problems (e.g., heavy metals and coliform) are too complex to model quantitatively at the present time and are best assessed through qualitative descriptive approaches. Guidelines for model selection and an overview of some of the existing models of significance are given. Model calibration and verification is discussed as a function of the quality of the data used, the structure of the mathematical model, the criteria used for goodness-of-fit, and the method of fitting the model to the data. Points of emphasis are that a good fit during model calibration does not mean good subsequent prediction and that model verification should be performed with a set of data separate from that used in model calibration. Model limitations are also discussed.

After data analysis, network planning and design is discussed. Within any set of budgetary and time constraints, there may be numerous sampling strategies that can be used to satisfy the objectives of the policy maker. Definition of the efficiency of each of these feasible strategies is the key to good practice in technical network design. Network planning and design should emphasize the concepts of "representative samples" and "transferability" of collected data to ungaged/unsampled sites. Important "trade-off" evaluations must be made between the choice of data types, the number of catchments to be gaged/sampled, the density of instruments on each catchment, the frequency of gaging/sampling at each site. A catchment inventory should be performed in order to select catchments for gaging/sampling that provide a "representative sample" of the hydrologic, geographic, terrestrial, and cultural characteristics of the project area. Factors which should be considered in selecting catchments for instrumentation include land-use, drainage type, size, physical catchment characteristics, availability and suitability of gaging/sampling sites, vandalism, and land rights.

In the section on instrumentation, rain gages, flow gages, water-quality samplers, and recorders are each discussed as well as instrument maintenance and instrument costs. The selection of instrument type will depend on site characteristics and program objectives. At the present time, the most recommended devices for flow measurement are weirs and flumes at outfalls or open channels, Palmer-Bowlus flumes at sewer pipes where full-pipe flow does not occur or is of no interest, and a hybrid flume of the U.S. Geological Survey or University of Illinois type where both open-channel and full-pipe flows are of interest. The selection of secondary instruments for collecting water stage or pressure differential data is also a function of the application. In general, a float, blubber, or acoustic sensor is used. Among the most important considerations in selecting and using an automatic sampler are position of the intake(s) in the flow stream, intake velocity, line velocity, line size, sample gathering device, sample type, reliability of the control system, and site selection. The recorder and its timer are very important in the data collection process — poorly recorded or time-distorted information are of little or no value. Recording may be performed on-site or at a central location. Recording may be achieved by strip chart, punched paper tape or magnetic tape. The advantages and disadvantages of each are discussed. Because of the short life of most gaging/sampling programs, it is extremely important that every reasonable step be taken to inspect and maintain the equipment. Periodic preventative maintenance, a local-resident observer, sufficient spare parts, knowledgeable maintenance and repair personnel, and equipment schematics and manuals are important aspects of good equipment maintenance.

Some of the practical considerations of collecting

(Continued on Page Thirteen)

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meteorological data, flow data, water-quality data, and ancillary data are discussed in the final chapter. Meteorological data which might be of interest include rainfall, snow, wind, solar radiation, evaporation, and temperature data, and atmospheric fallout. Collection of reliable flow data is a difficult and sometimes costly operation. In selecting, establishing and operating flow stations, four essential elements must be considered—(1) development of a stage-discharge measurement, (2) verification on a periodic basis of the stage-discharge measurement, (3) the interval at which data are recorded, and (4) the time synchronization of flow data and rainfall data (and water-quality data, if they are collected).

The water-quality parameters that are measured in a sampling program will vary with the location and purpose of the sampling program. Analytical costs are very high. Therefore, only those data which will help answer the question(s) of interest should be collected. Preliminary manual sampling for initial characteristics of the run-off can be invaluable for determining parameters to include in the sampling program. Analyses should be performed in a qualified laboratory which has and follows a quality assurance program. The collection of data from receiving water bodies and from street surfaces will sometimes be desirable. Ancillary data which might be of interest include a physical description of the catchment, environmental practices data, and miscellaneous data. Consideration should be given, to the extent practicable, to future data needs as well as present data needs.

The above described report may be obtained from the American Society of Civil Engineers, 345 East 47th Street, New York, New York 10017. The cost is $2.50 for members and $5.00 for non-members.

The siphon from Big Thompson Project was washed downstream.

Debris marks the path of the Big Thompson flood.

MEET THE NEW BOARD MEMBERS

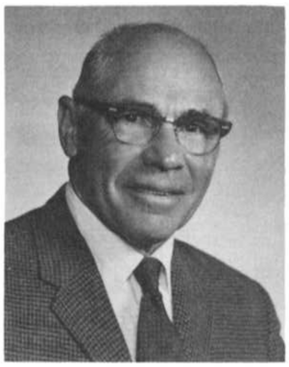
DAVID A. DAY

Professional Engineer

Mr. Day is one of the two professional engineer members of the Board. He is presently Senior Staff Civil Engineer for Stearns-Roger. Prior to joining Stearns-Roger in 1974, he served as Chairman and Professor, Civil Engineering Department and Dean of the College of Engineering at the University of Denver.

Mr. Day received his B.C.E. from Cornell and his M.S. and Ph.D. from the University of Illinois at Urbana. He has been very active in professional organizations including the American Society of Civil Engineers, National Society of Professional Engineers, and Professional Engineers of Colorado.

Mr. Day and his wife, Mary, have four daughters and one son.



W. G. DUNCAN

Commissioner, Douglas County

Mr. Duncan was born in Red Lodge, Montana and raised in Colorado. He holds a degree in Veterinary Medicine from Colorado State University. He is a member of the National Audubon Society, Defenders of Wild Life, and a Life Member of the National Cowboy Hall of Fame and Western Heritage Center. He spent 15 years with the U.S.D.A. and 17 years in large animal practice.

Commissioner Duncan is retired and lives with his wife, Gertrude, on a ranch at Sadalia.

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