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POTENTIAL EFFECTIVENESS OF DETENTION POLICIES

by Ben Urbonas, Chief, Master Planning Program; and Mark W. Glidden, Wright Water Engineers

This article is a condensation of a paper which was to be presented at the 1983 Southwest Stormwater Symposium at Texas A & M. Unfortunately the Thanksgiving snow storm prevented Ben Urbonas from attending the symposium to present the paper.

This article is a follow-up to a preliminary article concerning the District's detention study which was published in the December, 1981, Flood Hazard News. A copy of the full paper is available upon request.

INTRODUCTION

This paper will address primarily the *potential effectiveness* of on-site detention policies requiring control of storm runoff peak flows. The basis for the discussion, conclusions and recommendations are the studies conducted by the Urban Drainage and Flood Control District utilizing hydrologic information for the Denver area. Similar results may be obtained in other regions; however, it will require local investigations, using local data base, to identify the potential effectiveness of local detention policies in other regions.

BACKGROUND

The basic policy that most frequently guides the development of stormwater detention ordinances and design standards is the control of stormwater runoff peak discharges. The peak flow, after development, is required not to exceed what would have occurred from the same storm under conditions existing prior to development (1). In the Denver area, the most commonly used policy among the various local general purpose governments is to limit the 100-year peak flow after development to the pre-developed 100-year peak flow. However, there are several communities that require control of two recurrence frequencies such as 2-year and 100-year, 5-year and 100-year or 10-year and 100-year events.

References (2) through (10) discuss earlier model studies of on-site detention and the use of the design storm in sizing drainage facilities.

POLICY AND POTENTIAL EFFECTIVENESS

The objective of the Denver study reported herein was to assess the *potential effectiveness* of on-site detention by estimating how much on-site detention can reduce the peak flows along major drainageways. As stated earlier, many local governments require on-site detention; however, little work has been done to assess the effectiveness of on-site detention in controlling flows along major drainageways. The primary interest of the Urban Drainage and Flood Control District (District) is in the flooding along the "major drainageways". Thus, it was logical for the District to investigate the potential effectiveness of on-site detention policies in controlling flood levels along such drainageways.

Denver Area Setting

A study conducted by the District used an actual Denver area watershed as a study basin. The study watershed had an area of 7.85 square miles, a watershed length of 6.4 miles with an average watershed slope of 0.015. It was estimated that 1.9 percent of its area was impervious before land developement began. After full development, the watershed area is projected to be 38 percent impervious.

Runoff was modeled using 2-hour design storms for the 2-, 10-, and 100-year recurrence frequencies. These design storms were developed for the Denver area using the rainfall-runoff data collected by U.S.G.S. since 1970 and the long term Denver Raingage record collected since 1896. Modeling was done using stationary storms and storms that moved across the watershed at six miles per hour upstream and downstream. In addition, runoff was modeled using three recorded rainstorms under the stationary and moving storm scenarios. Although the results reported in this paper are for the stationary design storm scenarios, the effects of stormwater detention on each storm scenario were found to be similar. Namely, if a reduction in peak flow was calculated with detention for the stationary storm scenario, then a similar reduction was also observed for a moving storm scenario when compared against the undetained moving storm condition.

Because the modeling was for a 7.85 square mile watershed, conclusions of this study should not be extrapolated much beyond 10 square mile watersheds. This seems like a severe limitation; however, many of the observed rainstorms in the semi-arid climates have a rather limited footprint where the intense rainfall occurs. Thus, controlling runoff from 10 square mile or lesser watersheds may be very beneficial for flood control purposes in semi-arid climates.

The study watershed was subdivided into 56 sub-catchments and 52 channel segments. After calibration, runoff was modeled using the various storm scenarios for the undeveloped and the urbanized land use conditions. The model was then modified to include 28 randomly located detention ponds. The ponds intercepted 91 percent of the total area with runoff from 9 percent of the area being undetained. Each pond was sized on the basis of the hydrographs calculated for the pre- and post-developed conditions.

The hydraulic characteristics of each pond's outlet were designed assuming that the outlet functioned as an orifice until the design control volume was filled. At that point the ponds were assumed to overflow and the overflow was controlled by a broad-crested weir. On the basis of trends observed in several individual designs, the outlet discharge versus storage volume relationship was reduced to a non-dimensional form for all ponds. This expedited the design of a large number of ponds under a variety of desired control conditions. The details of how this was done are included in the full paper.

Results And Observations

Many of the results of the District's random detention study can be found

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PLANNING OF THE SOUTH PLATTE RIVER

by Ben Urbonas

The South Platte River, the granddaddy of them all, is the only waterway in the Denver area to be called a river. It is a river that, until recently, has been abused and neglected by man. In the last 10 years, the people of this region have discovered what an asset they have in their own back yard and have begun to reclaim it. Under the leadership of Denver's Platte River Development Committee and Denver's Department of Health and Hospitals a metamorphosis began. Where junk strewn banks once lined the river, we now have trails and parks; where barriers across the river were a hazard to anyone attempting to boat on it, there now exists an excellent urban boating stream; where uncontrolled discharges of raw sewage and industrial pollutants once poisoned its waters, the Colorado Division of Wildlife is now able to regularly stock the river for the enjoyment of inner-city fishermen.

In 1983 the District initiated a comprehensive master planning effort for 40 miles of the South Platte River between Chatfield Reservoir and the City of Brighton. Although much has been accomplished already on the River, a comprehensive master plan was still needed to define long term goals for the river. The work began with a contract to study the river's erosion and stability problems and a final report for this study was completed in November. Also a contract was let to prepare new topographic mapping and a consultant was hired to perform the master planning studies.

The planning studies began in October and are scheduled to be completed in early 1985. During this period, the consultant will develop an updated 100-year floodplain through the City of Denver, identify flood control options between Oxford Avenue and the City of Brighton, investigate the recreation needs and potential along the entire 40 miles being studied and explore the long term management needs for the river within the District's boundaries. The study is first and foremost a flood control and stream stability study. However, the flood control options will have to recognize all of the other uses of the river such as recreation, fisheries, wildlife, irrigation water, domestic water supply, and as the receiving body of water for wastewater effluent. In that respect, the study is comprehensive and goes beyond the typical scope of flood control master planning studies in the past.

A very important element of this effort is to seek public comment. The District and its consultants believe the final master plan must reflect what the public wants to happen to the river over the next generation. The plan will serve as a long term roadmap for the river's development and the decisions made today will eventually result in a lasting long term character of the South Platte River within the Denver metropolitan region. Everyone is encouraged to forward their written comments to the District. Also, if you want to receive a newsletter concerning the study, forward your requests to Ben Urbonas at the Urban Drainage and Flood Control District.

DISTRICT PROJECT WINS AWARDS

The Upper Sloans Lake Storm Drainage Facilities construction project was recognized by the Denver Regional Council of Governments' Local Government Innovations Awards Program in March, 1983. The project; a cooperative effort between the District, Denver, Edgewater and Lakewood; won the first place award for cooperative service delivery.

The project consisted of approximately 3950 feet of grass-lined open channel with trickle channel and concrete maintenance trail, four road crossings and four drop structures. The channel starts at Sloans Lake in Denver and winds its way west through Lakewood and Edgewater.

The construction contractor, Schmidt-Tiago, received the Contractor of the Year award from the Colorado Chapter of the American Public Works Association. The most outstanding feature of Schmidt-Tiago's work was the installation of a quadruple 7'x5' precast concrete box culvert crossing of Sheridan Boulevard over one weekend.

Bob Hoffmaster, Chief of Design and Construction was the project manager.

DRAINAGEWAY VEGETATION STUDY

The District is presently under contract with a private consulting firm to prepare a drainageway vegetation study. Grass-lined open channels form the bulk of the drainageways within the District and since maintenance of vegetation in grass-lined channels is an integral part of the District's Maintenance Program, the District deemed it necessary to re-evaluate and update our present vegetation criteria. The primary emphasis of the study will cover topics such as seed bed and soil preparation, soil types, native grass seed types, planting and mulching methods, timing of planting, weed control, fertilizer and routine maintenance of drainageway vegetation. The study will include alternatives to native grasses such as nonturf plants and "hardscape" materials, i.e., riprap and interlocking concrete blocks.

The study will also investigate other aspects of the District's vegetation management procedures such as site construction guidelines, maintenance standards, erosion control methods and construction inspection procedures. The finished product, which will be done in January, 1984, will provide a sound vegetation program from which the District can expect consistent results. It will also be a valuable source of information to which consultants and other agencies could refer in developing seeding specifications for a specific site or in developing their own set of standards and procedures.

NEWS NOTE

Papers Published and/or Presented by District Staff in 1983

DeGroot, W.G.; Tucker, L.S.; Urbonas, B.R.; "Elements Of A Comprehensive Floodplain Management Program"; ASCE Annual Convention, Houston, Texas; October, 1983.

Urbonas, B.R.; "Flood Control Channels and Levees"; Flood Plain Management Workshop; Beaver Creek, Colorado; September, 1983.

Urbonas, B.R., "Effectiveness Of A Stormwater Management Program"; Pennsylvania State University Stormwater Symposium '83; May, 1983.

Urbonas, B.R., "Potential Effectiveness Of Detention Policies"; Southwest Urban Stormwater Symposium; Texas A & M University; November, 1983.

Hunter, M.R.; Tucker, L.S.; "Contract Maintenance For Drainage and Flood Control Facilities"; APWA Reporter; June, 1983.

Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

Annual Update On Federal Water Resource Legislation

1983 has been an interesting but frustrating year with regard to Federal water resources activities. On the plus side, both House and Senate Water Resource Subcommittees have prepared omnibus water resource development authorization bills. In the House, Representative Bob Roe (D-NJ) put together a comprehensive bill, HR 3678, that passed the House Public Works Committee in August 1983 by a 49 to 0 margin. HR 3678, containing 304 pages, is the most comprehensive water resources bill to come before the Congress in many years. Highlights of HR 3678 relating to flood control include:

1. Project Authorization. Over 200 flood control, water supply, shore protection, and navigation projects are authorized.
2. A revised cost sharing policy. The Bill provides that non-Federal interests pay cost of lands, easements, and rights-of-way. If these costs are less than 25% of the total project cost, the difference must be paid in cash over fifteen years. If they are more than 25% up to a maximum of 30%, non-Federal interests pay all right-of-way costs. If over 30% the Federal Government pays the excess. This policy applies not only to projects authorized by the Bill, but to all projects previously authorized but not yet under construction. In addition, the Corps may not give priority to projects where the sponsor agrees to a greater Federal share.
3. Local cost sharing of feasibility studies. Feasibility studies are to be cost shared at a level of 25% non-Federal and 75% Federal with up to one-half of the non-Federal share eligible as in-kind services. The 25% non-Federal share is to be credited toward project construction costs.
4. Assessment of nation's flood problems. The Chief of the Corps of Engineers is directed to undertake an assessment of the nature and extent of the nation's flood problems with particular emphasis on the urban areas.
5. Elimination of the 800 CFS rule. In preparing feasibility studies, the Corps is directed to consider and evaluate measures to reduce or eliminate damages from flooding without regard to frequency of flooding, drainage area, and amount of runoff. Current Corps regulations require that the 10-year flow be equal or greater than 800 CFS if it is to be of Federal interest and to be studied by the Corps.
6. Credits for local construction. The Bill authorizes local interests to proceed with construction of a project with non-Federal funds and receive a credit against the non-Federal share if a project is subsequently authorized.
7. Reduction of long-time for project authorization. The Corps is directed to study and evaluate measures necessary to increase its capacity to plan and construct projects on an expedited basis.
8. Increase in project limitations. The Bill increases the project limit for small flood control projects per Section 205 to $7.5 million, to $750,000 for Section 14 Emergency Stream Bank Erosion, to $4 million for Section 105 Small River and Harbor Improvement Projects, to $3 million for Beach Restoration and Protection, and to $4 million for Clearing and Snagging.
9. Establishment of a national board on water resources policy. The Bill would establish a seven member national board on water resources policy consisting of the Secretaries of Interior, Agriculture, Army; the Administrator of EPA; two members recommended by Congress and a chairman appointed by the President and confirmed by the Senate. The Board would recommend water resources policies to the President and Congress and assist in interagency coordination.

On the Senate side, the Senate Sub-Committee on Water Resources, chaired by Senator James Abnor (R-SD) has passed S 1739, the Water Resources Development Act of 1983. The Bill authorizes 116 projects for flood control, navigation, shore protection, and hydroelectric power. In the area of cost sharing, the Senate Bill requires non-Federal interests to pay 35% of the cost of a flood control project with 5% being payable in cash during construction. The ten title bill was reported out by full Senate Environment and Public Works Committee on November 8, 1983 just prior to the Congress's holiday recess.

While the Senate Bill does not include all the features of the House Bill, it too is a comprehensive bill. This is the first time that Congress has come forward with new cost sharing policies. The Senate Bill comes the closest to the Administration's cost sharing policy and it would seem that the House, Senate and the Administration are close enough that a compromise on cost sharing could be reached. Agreement between Congress and the Administration on cost sharing policy would be a significant step forward.

On the negative side, there was no water resource authorization bill passed during 1983. Neither of the two omnibus bills, S 1739 or HR 3678, will be considered by the full House or Senate until the 1984 Congressional session. The bills are important from the standpoint of the policy issues involved. If neither bill is passed, Congress will have again set aside any decision regarding the direction of Federal water resources activities. I also feel that if neither of these bills is passed, it may be awhile before the House and Senate Water Resources Subcommittees try it again. In the meantime, Federal water resource policy will continue to flounder.

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(Tucker. . . Continued from page 3)

Financial Feasibility Analysis

The District's primary source of revenues for construction is a 0.4 mill levy that generates approximately $3.5 million of revenue per year. This has served well to address some of the serious flooding problems in the Denver Metro region, but it is far below the annual needs.

In a joint effort with the City of Littleton and Arapahoe County, the District is looking at the feasibility of financing drainage capital improvements through a Special Improvement District approach. Special improvement districts have been around a long time and there is nothing new about them. The problem with special improvement districts for drainage projects has been that those being flooded are relatively few in number while the cost of the improvements are relatively high, making it difficult for those directly benefiting to pay for the improvements. Since all properties located in a drainage basin that have constructed impervious surfaces contribute additional waters to the downstream properties than what occurred historically, these upstream landowners must somehow be made to contribute to the solution of the downstream drainage problems.

An approach that has been gaining in popularity is a drainage fee that is based on the amount of water that is contributed by a property to the downstream drainage facility, as well as the location of the property in terms of flooding problems. To my knowledge, however, a special improvement district has not been created wherein **all** properties in a basin are assessed. The main criteria in an assessment district is that properties must benefit in amount at least equal to the level of the assessment. Colorado statutes provide that one of the benefits of a drainage project is the handling of drainage waters from upstream property owners. We are therefore looking at the possibility of assessing all properties in an identified drainage basin an amount that will be related to the amount they contribute to the drainage system.

A study effort has just recently been initiated for a specific basin, Slaughterhouse Gulch, and many facts are yet to be determined before the feasibility can be evaluated. Several methods of allocating costs will be explored. The basin is fully developed and is about two square miles in size, consisting of a mix of residential, commercial, and multi-family areas.

If the effort is successful, it may provide us a way to finance capital improvements in basins where the cost of improvements are far in excess of available funding. We should be available to report to you our findings in the 1984 issue of *Flood Hazard News*.

Maintenance Legislation

The District's Maintenance Program is financed by a 0.4 mill levy that generates approximately $3.5 million per year. In 1979 the Legislature authorized the District to levy the 0.4 mill for the years 1981, 1982 and 1983. In 1983 the Legislature removed the time limitation and the District now has the authority to levy 0.4 mills for maintenance that is unlimited in terms of time.

This has important ramifications in the sense that we can now make long term commitments to maintenance. Up until the Legislature removed the time restrictions in 1983, we did not know if we would be in a position to continue the maintenance of facilities in 1984 and beyond. The facilities can now be built with some assurance that there will be funds available for their continued maintenance.

Prior to the time when the District had monies available for maintenance, we relied on local governments to maintain major drainageway facilities. Drainage maintenance never seems to be a high priority and the maintenance provided by local governments was spotty at best. The District now has a sound financial basis for planning and administration (0.1 mill), for construction (0.4 mill), and maintenance (0.4 mill). Now all that remains is getting the job done.

RECENT PLANNING PROGRAM ACTIVITIES

by Ben Urbonas Chief, Master Planning Program

A revised riprap section of the Urban Storm Drainage Criteria Manual was distributed to all manual owners as was promised in the last issue of *Flood Hazard News*. Since then, draft revisions of the "Rainfall", "Colorado Urban Hydrograph", "Effective Rainfall for CUHP", and "Rational Method" sections were distributed to a number of consulting engineers and local governments for review and comment. These sections will be reexamined and revised as needed once all of the comments have been evaluated. The final version of these sections will be printed and distributed early in 1984.

Seven major drainageway studies were underway and three were completed in 1983. We expect to start four to seven new master plan studies in 1984. The exact number will depend on the cost of these studies and the budget limits. At this time the backlog of requests from local governments far exceeds available funds. The accompanying table summarizes the current and anticipated planning activities of the District.

STATUS OF PLANNING PROJECTS

PROJECT	COMPLETED 1983	UNDERWAY	PLANNED FOR 1984
Brantner Gulch	*		
Tucker Gulch & Kenney's Run	*		
Upper Slaughterhouse Gulch	*		
Boulder & Adjacent County		*	
Boulder Cr/S. Boulder Cr. Confl.		*	
Henry's Lake Basin		*	
Lower Ralston & Van Bibber Cr.		*	
Sand Creek		*	
Sheridan Outfall		*	
South Platte River		*	
Lafayette Criteria Update			*
Adams County Urban Areas			*
Direct Flow 0056 & 4100			*
Columbine Valley/Littleton/Bow Mar			*
Arapahoe County Criteria			*
Jefferson County Airport			*
Broomfield NE			*
Boulder County Gunbarrel Area			*

DESIGN AND CONSTRUCTION NOTES

B.H. Hoffmaster
Chief, Design and Construction Program

A unique project was undertaken during the year. The Boulder County Justice Center is located within the Boulder Creek 100-year floodplain. Their concern about the Emergency Control Center, which is located in the basement, being flooded prompted the County, as a part of the expansion of the jail facilities, to flood proof the building including a flood wall along the creek side and 6th Street and some grading to direct flood waters away from the building. The District is joining the County to construct the flood wall. Henningson, Durham and Richardson, Inc. of Denver, is designing the facilities including the wall. A portion of the wall is incorporated into the building expansion. Construction is expected in 1984. The construction cost will amount to $342,700.

Relief is coming to the properties along First Avenue Tributary to Weir Gulch in the City and County of Denver. Denver Wastewater Management Division designed a box culvert storm drain from Weir Gulch to Sheridan Boulevard. The project is now under construction.

The District cooperated with the City of Englewood on the construction of a detention facility for off-channel storage along Little Dry Creek (Arapahoe Co.). The construction of this facility by Palasades Construction Company called for cooperation between Englewood, the District and the Englewood School District. The construction is nearing the end. The facility will skim off peaks of flood flows and reduce flooding in the Cinderella City Shopping Center.

A 171 feet long box culvert was designed and built in the City of Boulder along Boulder Slough. The project separates flood flows from an irrigation ditch and provides adequate capacity to reduce flooding in the immediate area.

Goldsmith Gulch detention facility at Union in the Denver Technological Center is another unique project. The project, a cooperative effort between the District, the City and County of Denver and the Goldsmith Metropolitan District, involves flood control, park development, street drainage, and water main construction as a package. The detention facility and channelization upstream and downstream is in park land that the Goldsmith Metropolitan District is providing for the City. The two drop structures are designed to be functional for both park and hydraulic purposes. The structures are stepped with concrete blocks scattered around the surface for easy pedestrian access.

Little's Creek, Schedules II and III, in Littleton are now complete. These schedules are located between Santa Fe Drive and Prince Street, a length of approximately 1410 feet. The project consists of vertical walls beginning from caissons, three traffic bridges, a pedestrian bridge and four drop structures. Included in the project was a 48 inch storm drain below the channel to drain a railroad depression now being constructed in Littleton. Little's Creek will pass over the railroad depression through a flume and drop structure to the channel. The drop structure was recently constructed under Colorado Highway Department contracts, then covered with fill material and a shoo-fly for the Denver Rio Grande Western Railroad built over the top to carry railroad traffic while the railroad depression is constructed. Below the 48 inch storm drain is an 18 inch line to drain water from behind the retaining walls.

The last phase of Westerly Creek, Schedule IV, is being constructed and will be completed by May, 1984. The completion of this phase will provide flood protection for a 10 year frequency storm for the reach from Kelly Road Dam at Lowry Air Force Base to Stapleton Airport. This last phase extends from near 13th Avenue to 11th Avenue in Denver.

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdictions	Status
Boulder Co. Justice Center Floodwall	Boulder County	80% Complete
Boulder Slough Culvert	City of Boulder	Complete
Goldsmith Gulch Detention at Union	Denver	Complete
Lafayette Drainage #4	Lafayette	90% Complete
Little Dry Creek (ADCO)	Westminster Adams County	Complete 30% Complete
South Jefferson County	Arapahoe County, Nevada Ditch Company, Last Chance Ditch Co.	95% Complete
Upper Sloans Lake Schedule II	Edgewater, Lakewood	Begin Nov. 1983
Weir Gulch First Avenue Tributary	Denver	Complete

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Participating Jurisdictions	Cost	Status
Boulder Co. Justice Center Floodwall	Boulder County	$ 400,200	Start Spring 1984
Boulder Slough Culvert	City of Boulder	130,900(e)	Complete
Broomfield Basin 3207	Broomfield	114,600	Complete
Goldsmith Gulch Dentention at Union	Denver	1,553,500(e)	20% Complete
Hidden Lake	Adams County	1,335,000	70% Complete
Lena Gulch Schedule III	Wheat Ridge	964,200	Start 11/83
Little Dry Creek Detention & Channel	Englewood	3,500,000	90% Complete
Little's Creek Schedule II & III	Littleton	2,112,000	Complete
Weir Gulch First Avenue Tributary	Denver	1,249,000	60% Complete
Westerly Creek Schedule III Schedule IV	Denver Denver	1,209,000 660,000	Complete 90% Complete
West 52nd Avenue West of Sheridan	Denver	303,000	Complete

MEET THE NEW BOARD MEMBERS

FEDERICO PEÑA
Mayor,
City and County of Denver

Federico Peña was elected Mayor of the City & County of Denver in June, 1983 and was inaugurated as its 37th Mayor on July 1, 1983.

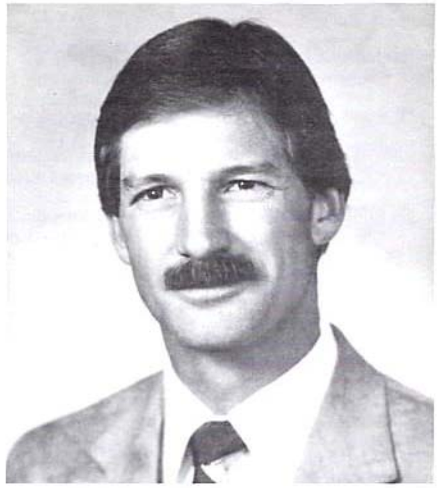
Federico Peña was born in Loredo, Texas on March 15, 1947, and is a graduate of St. Joseph's Academy in Brownsville, where he was raised, and of the University of Texas at Austin where he received his undergraduate and law degrees. He has lived in Denver since 1973.

In 1978 Federico Peña was elected to the Colorado House of Representatives where he served two terms. He was elected House Democratic leader in 1981, and served on the Judiciary, Finance, Legal Services, and Rules Committees as well as the Legislative Council.

Federico Peña has been a licensed attorney for ten years and is a partner in the law firm of Peña and Peña in Denver. He is a member of the Colorado and Denver Bar Associations, is a member of the State Board of Law Examiners and has been associated with the Harvard Center for Law and Education.

Federico Peña was rated among the top ten legislators by the Denver Post. He was selected as the "Outstanding House Democratic Legislator." He has received the American Jewish Committee's "Award of Appreciation" and earned the Colorado Coalition for Persons with Diabilities "Grateful Appreciation Award."

His civic activities include involvement in the Sloan's Lake Citizen Association; the Front Range Project Coordinating Council; the Jefferson, Highlands and Sunnyside Neighborhood Association; and the Rocky Flats Blue Ribbon Citizens Committee. He is a board member of the American Lung Association and KCFR Public Radio.



ROBERT H. BROOKS
Commissioner, Arapahoe County

Robert H. Brooks, 36, was selected to fill the unexpired term of Arapahoe County Commissioner on September 20, 1982. The Arapahoe County Republican Vacancy Committee also picked Brooks to be the Republican Commissioner candidate for election on November 2nd, when he was elected to a full term.

Commissioner Brooks is a self employed construction consultant. He was previously the Director of Construction Services for the Colorado Contractors Association, Inc. Brooks was City Manager in Monte Vista, Colorado from 1974 to 1976 and served as Administration Assistant for the City of Abilene, Texas from 1971 to 1974.

Brooks is a 1964 graduate of Abilene High School, has a BBA from McMury College and an MBA from Abilene Christian University. A former member of the Abilene Jaycees, Brooks is presently president of the Aurora Rotary Club.

An active Republican, Brooks was an Arapahoe County District Captain and a member of the County Republican Executive Committee.

Brooks served in the U.S. Navy from 1968-1970. He and his wife, Jan and daughter Brittany, live in Aurora.

GEORGE HOVORKA
Mayor, City of Westminster

George Hovorka was first elected to the Westminster City Council in 1973. He served as Mayor Pro Tem from 1975 to 1983. He was elected Mayor on November 7, 1983.

Mayor Hovorka graduated from Regis High in 1949 and received a Bachelor of Science degree from Regis College and a Master of Arts degree from Denver University. He has been the principal at Gregory Hill Elementary School in Adams County School District 50 since 1961.

Hovorka has been active in Holy Trinity Church and Men's Club, the Salvation Army and Drug and Alcohol Resource Effort; and has also coached softball and soccer. He and his wife Jackie have six children.

DISTRICT STAFF IN LEADERSHIP ROLES

Members of the District's staff have been honored by their selection to important leadership positions within the profession. Executive Director L. Scott Tucker is Vice President of the Water Resources Institute of the American Public Works Association, and recently completed a term of office as President of the National Association of Urban Flood Management Agencies.

Ben Urbonas; Chief Master Planning Program; has been elected Chairman of the American Society of Civil Engineers (ASCE) Urban Water Resources Research Council. Ben has also been chairing the ASCE Task Committee on Stormwater Detention Outlet Structures.

DESIGN NOTES

Supplement to Flood Hazard News (December, 1983)

FLOOD CONTROL CHANNELS AND LEVEES

by Ben Urbonas, Chief, Master Planning Program

INTRODUCTION

Floodplain management is designed to prevent flooding damages to new structures within the 100-year floodplain limits of major drainageways. As land develops, the individual property owners often want to reduce the floodplain limits through channelization so that more land can be used to construct new residences, apartments, offices or industrial structures. It is the responsibility of the floodplain managers and local government officials to recognize that the channels and reserved floodplains will become a part of the community infrastructure. That is, the new facilities will have to be maintained and operated forever at the local community level. It is an awesome responsibility and a burden that is being accepted on behalf of the local residents and the community revenue base. Because of this, it is incumbant on those that review and approve channelization projects to insist that quality design and construction be provided. Anything less than that can be considered to be irresponsible.

There are many texts, technical reports and manuals to guide engineers in the design of major drainageway channels. The purpose of this paper is not to provide detailed design guidance. Instead, it will summarize some thoughts and concepts of what has been observed to work and not work whenever channelization of drainageways has occurred.

DESIGN FREQUENCY

Selecting the design recurrence frequency for a channel is, in part, an economic decision. The options range from virtually undisturbed 100-year floodplain to providing formal channels for any recurrence frequency from 2-year through, and in excess of, 100-year. The decision is arrived at by evaluating the costs and benefits of each option and balancing these against the goals and objectives of the individual tract of land and the community in which it is located. Where land costs are very high, the option that reduces the residual floodplain, namely the 100-year channel, is often selected. Where land costs are less, or open space credits are made available to the developer, the smaller improvements can be more economical. The final decision should be based on economic analysis and on the local floodplain management and community development goals, objectives, and regulations.

Design for levees, where permitted, should be sufficient to protect against the very large, infrequent floods. In the writer's opinion, levees are the least desirable means of modifying existing floodplains and should be employed only where flood damage potential to already existing structures is present. Levees should be avoided as a means of modifying undeveloped floodplains so that new development could be located in the "reclaimed" areas. Locating new developments behind a levee below the 100-year flood profile only invites eventual disaster when the levee fails, is overtopped by a larger flood, or is breached by any other natural or man-made cause.

CHANNELS

Man-made flood control channels can take a variety of shapes and can be stabilized by a number of different materials. The District's *Urban Storm Drainage Criteria Manual* (USDCM) provides guidance in the design of various types of channels, and everyone is encouraged to become familiar with its content. However, considerable experience has been gained in how different channels work since the manual has been published, and this paper will attempt to share some thoughts that the reader may find useful.

Grass Lined Channels

Regardless of the type of channel being designed, long term integrity, ease of maintenance and safety are the prime concerns in design. The USDCM provides basic depth and velocity criteria for grass lined channels under major flow conditions. Namely, no additional protection is needed if the following conditions are satisfied:

Erosion Resistant Soil

Max. Velocity	Max. Depth
7 fps	5 ft

Erosive Soil

Max. Velocity	Max. Depth
5 fps	5 ft

Froude Number is less than 0.8

What do these criteria really mean? First, the velocity and depth limits are for the normal depth flow condition; namely, they apply when the flow is not slowed down by any backwater effects from culverts, bridges, flow checks, transitions, etc. Second, the Manning's roughness used to calculate the velocity should be chosen from the low end of the range for this type of a channel. Third, the Manning's n used to calculate depth should be chosen from the high end of the range for this type of a channel. Fourth, the velocity and depth limits have to be applied using the 100-year flow, even if a lesser design is chosen. Fifth, some channel damage will probably occur during the 100-year discharge; that is, there is little if any safety factor. Sixth, these criteria are not appropriate in mountain and foothill streams that have large cobble bed loads.

These criteria were carefully chosen as a balance between stability, economics, aesthetics and safety. It does not mean that faster flowing or deeper channel sections should not be built. All it means is, if a designer wishes to exceed these criteria, he or she needs to provide other types of channel lining and/or develop adequate sedimentation and erosion analysis that proves channel stability will be maintained under the site specific soil conditions.

A trapezoidal grass lined channel by itself will be a severe maintenance burden unless additional features are provided. Obviously, drop structures will be needed to control the channel velocities. However, discussion of drop structures is a topic in itself and is not included in this paper.

One of the most important items of an urban channel is the control of trickle and/or low flows. Unless a low flow and/or trickle channel is provided, the channel bottom becomes permanently soggy and cannot be easily maintained. Uncontrolled growth in the channel bottom accelerates the entrapment of sediments which over a period will cause a reduction in the channel conveyance section. Thus, low flow and trickle channels facilitate channel maintenance and help preserve the design hydraulic conveyance of the channel bottom.

Trickle channels are not practical when the channel is through sandy soils or is to convey flows for an extended period of time. Under these conditions, a low flow channel, preferably having riprap lined banks, is more practical in confining and controlling the frequently occurring flows. By confining the low flows to a smaller part of the total section, maintenance requirements are reduced and the life of the total section is prolonged. It is suggested the low flow section be designed to handle approximately a 2-year flow, thereby insuring that the larger section will have an opportunity to "rest" and stabilize itself so that it can resist damage during the less frequent, larger events.

In addition to drops and trickle channels, the designer must pay particular attention at channel bends, confluences and transitions. If the bends have shorter radii than recommended in the USDCM, we suggest they be hardened with riprap. The riprap should be extended at least one curve length downstream of the point at which the bend becomes tangent to a straight channel section again.

Perennial streams and their floodplains are best left alone since all of them have a history of changing their course and meander locations with time. It is a natural phenomenon and there are many examples where attempts to channelize or straighten such streams have resulted in costly failures. Never-the-less there are times when a shifting stream needs to be stabilized. When that is the case, try to work with the stream's natural meander pattern. Whenever possible, try to only armor the outsides of meanders and the riffle/crossing of the stream between meanders. When armoring the outside banks, take into account local and general scour and bury rock into the stream bed so that it will not be underscoured.

Such an armoring approach on perennial streams preserves their natural appearance and aquatic habitat. Also, it often requires less riprap and fewer drop structures than are required by straightening out a stream. Although there are exceptions, the more a floodplain is encroached upon, the more bank protection and drop structures are required to keep it stable. Once the stream is sufficiently encrouched upon, its banks need continuous protection and the drop structures have to be spaced close to each other to maintain stability. The South Platte River through Denver and the proposed U.S. Corps of Engineers' channelization through Englewood are very good examples of totally confined sections in perennial streams.

Concrete Lined Channels

Concrete lined channels, when built properly, are expensive and have a cost advantage over grass lined channels only where the right-of-way is limited or is very expensive. To minimize their cross-section, concrete channels are usually designed to operate in a supercritical flow regime. Because flow is very unstable and unpredictable between Froude Number 0.7 and 1.3 it is suggested that designs in this range be avoided. If a design in this range is unavoidable, then the freeboard should be calculated assuming the channel can operate at either a Froude Number of 0.7 or 1.3. The condition requiring the larger channel section should be used. This recommendation is not arbitrary, since flows within this range of Froude Numbers have been observed to shift from supercritical to subcritical and back to supercritical flow regime for no apparent reason.

Forces on concrete liners carrying supercritical flow can be very large and there are many examples of liner failure. The exact nature and location of such forces are virtually impossible to predict and the design of the liner has to attempt to prevent or minimize such forces. The velocities in a channel are best limited to 20 to 25 feet per second. Although it is possible to design channels for higher velocities, the liner's integrity is severely endangered from erosion and cavitation and the local energy, pressure, and momentum perturbations. After all, at 25 feet per second the velocity head alone is almost ten feet. Just visualize what ten foot waves can do and what structures are needed to protect against their forces and you will have a correct impression of the forces involved.

To protect concrete liners from differential pressures, granular bedding (not filter cloth) and subdrains must be installed before the concrete liner is poured. In addition, to guard against localized forces, the concrete liners of supercritical channels need to be 6- to 7-inches thick and continuously reinforced in the longitudinal and transverse directions. If the lined section is designed for less than the 100-year flow, protect the concrete liner and adjacent earthen section with riprap against excessive damage when the concrete section's capacity is exceeded. Overbank erosion can be a problem and this writer has personally inspected two concrete channels that failed completely due to overtopping of the liner.

The advantages of a concrete lined channel include reduced right-of-way and reduced annual maintenance. The disadvantages include: 1) very high hazard potential (need security fencing), 2) failures are extremely expensive to repair, 3) requires ongoing maintenance to clean and seal joints and cracks in the liner, and 4) aesthetics are less pleasant than other types of channels.

Riprap Lined Channels

Riprap is an excellent channel liner whenever the velocities and depths begin to exceed the recommended maximums for grass lined channels. It permits steeper banks, which can reduce right-of-way requirements, and is not too expensive to repair if localized failures occur. Riprap can be designed to control moderately high velocities, provided the flows are subcritical. Although riprap can be designed to handle supercritical flow, the rates of failure increase dramatically and the USDCM recommends that riprap be used to line channels only for flows having a Froude Number of 0.8 or less.

The majority of the observed failures in riprap channel liners can be attributed to a failure in the bedding. Bedding is particularly susceptible to scour at channel bends, transitions and drops. The high failure rate attributed to bedding implies that much greater care is needed in the design and construction of riprap bedding than it obviously receives.

In recent years, filter cloth has gained wide acceptance as a substitute for granular bedding. Unfortunately, it has not turned out to be the answer to all problems. In addition to other problems, it often suffers from lack of adequate field control during installation. In addition, laboratory and field evidence suggest that soils can liquify under cloth when channel velocities are high. Therefore, if filter cloth is used as a part of riprap bedding, it is recommended that, as a minimum, the USDCM guidelines be followed and a

Native grass-lined channel with riprap lined low flow channel in sandy soil. This is Meadowwood Channel in Aurora.

Native grass-lined channel with concrete trickle channel and maintenance trail. This is Sanderson Gulch in Denver.

Niver Creek, a riprap lined channel in Adams County.

Entrance to Weir Gulch concrete channel in Denver.

granular bedding cover be installed over the cloth.

The second most common cause of riprap liner failure can be attributed to lack of quality control during construction. Problems include improperly installed bedding, undersized rock, and improper gradation of rock. For the riprap liner to work properly, all of these items must be installed as specified. Therefore it is good practice to have the person designing the riprap liner participate in the inspection and quality control during construction as well.

Maintenance of riprap is extremely important. Riprap liners have to be repaired whenever localized failures have occurred. The channel's integrity depends on the entire liner providing protection, and spot failures can lead to widespread failures if not repaired. There are examples of catastrophic failures that could have been prevented if the riprap liner damage was repaired immediately after the flood causing the failure had occurred. In one instance, a major interstate bridge in Arizona collapsed and loss of life occurred because riprap liner damaged a year earlier was not repaired. When the next flood occurred, the weakened area expanded and an entire bridge abutment failed.

Chances are very good the bedding, rock size and gradation **will not** be up to specification when constructed. This seems to be very common and is particularly a problem when large rock sizes are specified. A designer should keep this in mind and compensate for such shortcomings when designing the liner.

Gabion Lined Channels

Gabion or wire enclosed rock liner is an excellent material when constructed properly and is used in areas of the channel section that are not exposed to frequent flows. The USDCM provides good guidance for the use of gabions and recommends its use for flows having a Froude Number of 0.8 or less. Gabion baskets are susceptible to damage from scour, corrosion and vandalism. Most failures that were observed were in areas where the baskets were exposed to sustained or frequent flows at drop structures and toes of channel linings.

Bedding and construction quality control problems are very similar to those experienced for riprap. Baskets need to be thoroughly packed with rock. Lack of proper packing is common and results in settling of the rock, voids in baskets, poor bank protection, and very costly repairs. As with riprap, aggressive quality control during construction is needed to avoid such problems.

Other Channel Linings

There is a variety of new products on the market promising to provide good protection at savings in cost. Obviously, these products have to demonstrate some success to gain acceptance; however, there is a recent trend to use some of these products well beyond their true capability. Although initial cost savings are demonstrated, we engineers and designers have to remember that the true cost to society and it's citizens has to also include the costs of long term operation and maintenance. Often the price of an inexpensive initial fix is passed on to the local tax base for repairs or reconstruction in the future.

As an example, there is a new fibrous plastic mat product on the market that is very effective in protecting earthen surfaces from sheet flow. Ultimately grass grows through the matting and results in reinforced turf. However, some designers, probably encouraged by product vendors, have been specifying this material as a substitute for riprap or gabions.

Dissipation of kinetic energy and exchange of momentum requires mass and the ability of the liner to transfer the hydraulic forces to the earth mass underneath. The plastic mat provides bank protection only up to a point. As flow depth, velocity and duration increase, the likelihood for bank failure also increases. Where failure has been observed, the failure itself suggests that the soil under the mat had liquified and washed out. Such failure was recently observed along Cherry Creek in Denver where flow velocities were estimated at less than 6 feet per second. Therefore, extreme caution is suggested in how and where such materials are used since subsequent repairs are very costly.

Another type of channel liner, not seen very often in the Rocky Mountain Region, is made of interlocking porous concrete slabs. This liner material does provide considerable mass that is not available in the fibrous plastic mat materials. Although direct experience of its use is lacking in this region, it does look promising provided the same Froude Number (i.e. less than 0.8) limits are applied for its use as is used for riprap. To avoid soil liquification and/or excessive uplift forces, free draining granular bedding is recommended for this type of liner. Granular bedding is particularly needed where flow direction is being changed or where flow is accelerating or decelerating (i.e. upstream, through, and downstream of bends, transitions, culverts, bridges, drop structures and confluences with other channels).

LEVEES

Although levees have been used in the past in many parts of the United States, they should be viewed as a "last resort" item in floodplain management. Levees are in fact dams and should be viewed by the designer as dams. Namely, a designer needs to address all the technical and safety related issues normally associated with dams such as seepage control and cutoffs, armoring against water action, and the effects on properties if the levee is overtopped or breached.

There is considerable controversy in using levees to modify the 100-year floodplain, particularly for new development. There is considerable risk in using levees to narrow a floodplain for the purpose of developing lands behind them. Should the levee fail, for any reason, the damages in the newly developed, low lying areas can be catastrophic.

Levees are a valid technique for reducing the flooding potential in flood prone areas that are already developed. It is best if they are used sparingly and selectively and only when there is no other affordable option to mitigate flooding damages.

Once constructed, levees should receive the highest level of attention and maintenance. Any weaknesses or damage to a levee has to be repaired immediately so that it can protect against the next flood without the danger of failure.

If they are to be built, adequate freeboard must be provided. Conservative freeboard is needed to protect not only against the danger from 100-year floods but also as a safety factor against any deficiencies in hydraulic calculations or unforseen loss in channel capacities. One only needs to read a newspaper each spring to be reminded of the flood damages that are possible to properties "protected" by levees. In this writer's opinion, one cannot be overconservative when using levees to modify floodplains.

SUMMARY

There are a number of ways to channelize flow. The decision of what type of channel will be used is largely economic. However, factors such as community goals, recreational needs, politics, environmental concerns, etc. often affect the decisions. This paper attempts to describe some of the technical and practical concerns a designer needs to consider when selecting or designing a channel lining. Many of these are based on the District's experience and the writer's own personal experience in hydraulics over the last 17 years. Hopefully, the reader will find the discussions in this paper useful when considering different types of channels for floodplain management.

Recently dedicated Little's Creek channel in Littleton. Channel consists of concrete walls, grass bottom, trickle channel and maintenance trail.

CONTRACTING FOR RESTORATION MAINTENANCE

by Mark Hunter, Chief, Maintenance Program

INTRODUCTION

Each year the Maintenance Program of the Urban Drainage and Flood Control District has done more and more work in the category called restoration maintenance. This type of work involves rehabilitating and restoring portions of drainageways that have deteriorated but it does not require the assistance of a consulting engineer to design the work. Typical individual restoration projects range in price from $1000 to $40,000. In 1982 each restoration "individual project" was submitted to three contractors for proposals to determine the best and most reasonable price to get the work done. This procedure led to a lot of administrative time in contacting contractors, meeting them at the job site, and being sure all the contractors understood the job as intended and submitted proposals on an equal basis. Because of the increasing amount of restoration work and the time required to contract for this work in 1982, we developed a new approach to contracting for restoration work in 1983. The desired results from the new approach are to maintain reasonable costs, to give us quicker response time from contractors when we call on them to do restoration work, and to lessen the administrative work to accomplish restoration maintenance.

METHOD OF SELECTION

In late 1982 the Maintenance Department solicited written proposals from 29 contractors who had done work for us before or had expressed an interest in doing work for us. In our request for proposals from the contractors we asked them to address the following items:

1. Availability to do work on a 48 hour basis.
2. Work experience and background doing drainageway maintenance and restoration.
3. Labor and wage rates.
4. Equipment rates.

As a result of our request for proposals, nineteen contractors submitted letters describing their company and addressing the questions above. All five staff members of the Maintenance Department reviewed the proposals and ranked the contractors. The ranking revealed that there were five contractors at the top of the ratings. Those five contractors were interviewed to discuss in more detail the restoration work that the District would be doing in 1983. The interviews consisted of a short presentation by each contractor followed by the District asking a set list of questions and then several minutes of open questions and answers. As a result of the interviews, three contractors were selected to do restoration work in 1983.

CONTRACTING PROCEDURE

The paragraphs below define some of the unique features and requirements of the restoration contract for 1983:

1. Each "individual project" done under the restoration contract will be authorized through a change order. Each change order will define the work, the justification for the work, the extent of the work to be done, and the value of the work authorized.
2. Where possible, all work will be accomplished and paid for by negotiating unit prices. The other options available are lump sum negotiated price and time and materials.
3. As mentioned in No. 1 above, all work under this contract will be authorized by change orders. Therefore, at the beginning of the contract, there is no set contract amount. Maintenance staff will assign restoration "individual projects" to the three contractors based on the following criteria:
   a. Where it is applicable, "individual projects" will be assigned based on the contractor that will have the shortest move in and set up time.
   b. Projects will be assigned in a manner so that at the end of the year the total contract amounts for each of the three contractors are as equal as possible.
   c. Try to take advantage of the contractor's work expertise and experience.
4. A Performance and Payment Bond of $50,000 will accompany each of the contracts. This bond will not be specific to any single "individual project" done by the contractor but will run for the life of the contract and be written in favor of the District.
5. No retainage shall be held on those "individual projects" for which a contractor will submit only a single pay request. If work on an "individual project" spans two or more pay periods, we will hold ten percent retainage through the initial pay periods and will release it in accordance with the contract upon completion of that "individual project". Retainage shall not accrue during the life of the contract. It will accrue only on a project by project basis.
6. In the interest of administrative efficiency, it was decided that we would advertise for final payment only those "individual projects" where the contractor purchased more than $20,000 worth of materials or supplies, rental equipment or subcontractor services. Below that level, based on the professional selection process used to select the three contractors, the District will assume the risk of not advertising for final payment for "individual projects". At the end of each year, before closing out each of the three contracts, the District will publish a general final payment advertisement covering all the "individual projects" performed under each of the contracts.
7. A staff decision was made to forego requiring lien wavers for each "individual project". The opinion was that we had protection under the bond discussed in No. 4 above, the advertisement for large projects discussed in No. 6 above, and the strong termination clause mentioned below.
8. The termination section of the contract was firmly written to provide protection to the District and to allow it flexibility in accomplishing the work in a manner that best suits the District.
9. If a contractor does any work inadequately or performs any activity that does not meet with the satisfaction of the District, the District should promptly notify the contractor in writing of their displeasure and, if applicable, define what measures should be taken to correct the deficiency.

(Continued on page 8)

(Maintenance . . . Continued from page 7)

FUTURE RESTORATION WORK

To implement the same contracting procedure in 1984 we will take the following steps:

1. We will solicit proposals from our current contractors, potential restoration contractors we received proposals from in 1983, and new contractors who have expressed an interest in doing restoration work for the District. Our request to the Contractor will specifically ask them to supply the following information:

   a. Wage rates,

   b. Equipment rates,

   c. Move-in, move-out and standby rates for equipment,

   d. Drainage construction experience,

   e. Past performance and productivity,

   f. Response time and availability,

   g. References.

2. Once the closing date for return of proposals has passed, we will review and rank each one based on the following factors:

   a. Cost—labor and equipment,

   b. Experience,

   c. Performance—past and potential.

   A rating system will be used to weigh these factors. A system being considered is described below. This system may be revised as the process is finalized.

   Cost will be rated on a scale from 0 to 15. To establish the cost rating we will develop a hypothetical "individual project". Based on this project, we will list the number of hours of time needed for a variety of equipment and manpower. Using each contractor's wage and equipment rates we will then develop a total project cost for each contractor. Using a cost curve developed for that hypothetical project we will then assign a rating number to each contractor and place that number in the matrix shown below. The cost curve will be set up so that a lower cost for the hypothetical project will result in a higher rating.

   Experience will be rated on a scale from 0 to 10. We will look for experience specifically in construction and rehabilitation of channels and drainageways. Past work with low flow channels, bank shaping, riprap placement and wet conditions is very important to our program. The better the experience the higher the rating.

   Performance will also be rated on a scale from 0 to 10. (This means cost will be the most important single item considered in ranking the contractors). A high rating for performance will depend on endorsements from references, short response time for emergency calls, a good range of medium size equipment capable of working efficiently in drainageways, willingness to do labor intensive work and a good understanding of the function and characteristics of a drainageway. The better the performance the higher the rating.

   The accompanying table is an example of the ranking matrix that will be used to rate each contractor.

3. Based on this ranking contractors A, B, and C are the three most qualified. From this point there are two directions that can be taken.

   a. If contractors A, B, & C are also the contractors currently under contract to perform restoration work for the District, the selection process needs to go no further. The basis for this is that we already have at least one year of experience with the current contractors and if they rank the highest during the review of the proposals, we believe we have then satisfied the needs of competitive contracting and have determined which contractors are best qualified for this work. We will then contract with contractors A, B, and C for 1984 as described in Step 4 below.

   b. If any or all of Contractors A, B, or C are not working for the District under the current year's restoration contract, the next step in the selection process will be to interview the five or six contractors that ranked highest during the review of the proposals. the interview process will consist of a short presentation by the contractor, discussion regarding several prepared questions from the District, a short period of open questions and answers, and then closing statements. This process will keep the five or six contractors on an equal basis. It is not necessary that any or all of the current restoration contractors be within the group of five or six interviewed. The three contractors ranked highest after the interviews will be offered a restoration contract for 1984 as described in Step 4. This process will also be used if we ever wish to increase the number of contractors doing restoration work for us.

4. The contract form to be used in 1984 will be essentially the same as the one used in 1983. The highlights of the restoration contract are described above under "Contracting Procedure".

Any process used in contracting for work to be done for the District must be fair to the contractors, the District staff, and to the taxpaying public. In addition to being fair to all parties this contracting procedure results in high District productivity, high quality construction and a well maintained system of urban drainageways.

	Rating Range	Contractors A	B	C	D	E
Cost	0-15	9	7	13	11	7
Experience	0-10	8	9	6	3	5
Performance	0-10	8	6	9	5	6
Total		25	22	28	19	18

(**Detention**. . .Continued from page 1)

in the Thesis by Mark Glidden (12). What follows is a series of five figures (i.e. Figures 1,2,3,4, and 5) summarizing the generalized trends identified by the random detention modeling study. Each figure relates the size of the watershed to the non-dimensional peak flow. The non-dimensionalized peak flow was obtained by dividing the actual peak flow by its respective flow from the undeveloped watershed. Therefore, a value of "one" on the ordinate represents no change from the undeveloped condition and a value of "two" represents an increase in peak flows by a factor of two from the undeveloped condition. Figure 1 shows the estimated trends in peak flows along the major drainageways without on-site detention and Figures 2 through 4 show the trends when different on-site detention designs are used.

Figures 1 through 5 reveal the following trends for the soil and meteorological conditions modeled by the District's study:

1. The 2-year random detention pond design was effective in controlling the 2-year peak flows at individual pond sites only. As the number of ponds increased with an increasing tributary area, the 2-year design rapidly diminished in effectiveness. This trend is attributed to the fact that the 2-year storm volume increased many fold after development and, although the peaks were controlled at the individual sites, the resulting flat peaked outlet hydrographs from the ponds added directly as the flows progressed downstream. In contrast, prior to development the individual tributary hydrographs had small volumes and were out of phase with each other. The 2-year design somewhat reduced the 10-year and the 100-year storm runoff peaks when compared to the undetained condition.
2. The 10-year random detention pond designs were relatively effective in limiting runoff peaks along the major drainageways from the 10-year storms and were also somewhat effective in reducing the 100-year storm peaks. It was virtually ineffective in controlling the 2-year design storm runoff peaks.
3. The 100-year design was effective in controlling the 100-year peaks but was virtually ineffective in controlling the 2- and 10-year storms.
4. The combination 10- and 100-year control design was effective in controlling the 10- and 100-year storm runoff, but was ineffective in controlling the 2-year storm runoff peaks. The two-frequency control design looked to be more effective in controlling the two design storms than the individual 10- or 100-year frequency designs were in controlling their respective individual recurrence runoff peaks.

The results of the District's study seem to verify some of the conclusions of other investigators (4). The one surprise, although predictable, was that the 2-year design was not very effective in controlling peak flows along the major drainageways from the smaller storms. It does not mean that the 2-year design is ineffective for individual sites and may be more effective than the study results indicate if the spatial distributions of the smaller storms are considered. Additional work is needed to quantify realistic spatial storm patterns before the 2-year detention design effectiveness can be judged.

SIMPLIFIED CRITERIA EFFECTIVENESS

General

As a follow-up to the study of the *potential effectiveness* of detention policies for the Denver area, the District investigated the possibility of using simplified detention design criteria. Of great concern to designers is that simplified detention requirements take away the "creativity" in design and may result in detention sizing that is inappropriate for an individual site. These concerns are very valid. On the other hand, simple regionalized detention sizing requirements do offer advantages to the developer, the design engineer and the local government official that has to review large numbers of designs.

Although simplified detention requirements may not permit "optimization" for each on-site detention facility, they offer the advantages of simplicity, uniformity and, from land developers' perspective, equal treatment. In other words, all developments know early on what the detention volumes and areas will have to be. It is also clear to everyone that all similar developments will be treated the same way. For these

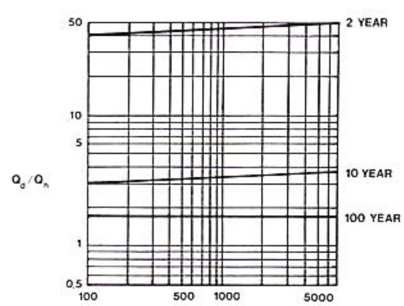


FIGURE 1 :URBAN RUNOFF TRENDS WITHOUT DETENTION

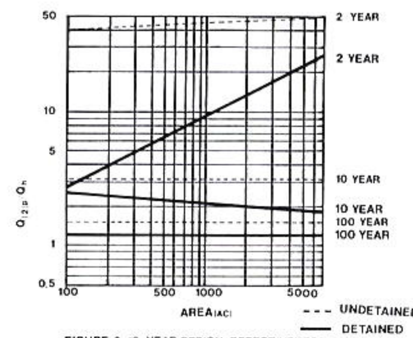


FIGURE 2 :2-YEAR DESIGN EFFECTIVENESS

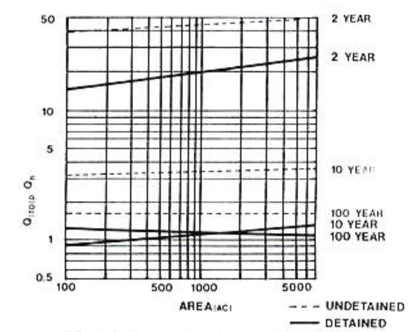


FIGURE 3 :10-YEAR DESIGN EFFECTIVENESS

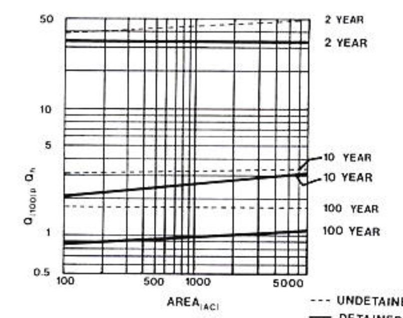


FIGURE 4 :100-YEAR DESIGN EFFECTIVENESS

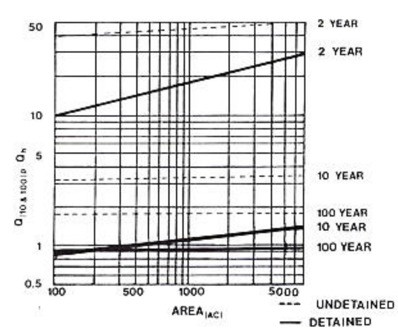


FIGURE 5 :10-& 100-YEAR COMBINATION DESIGN EFFECTIVENESS

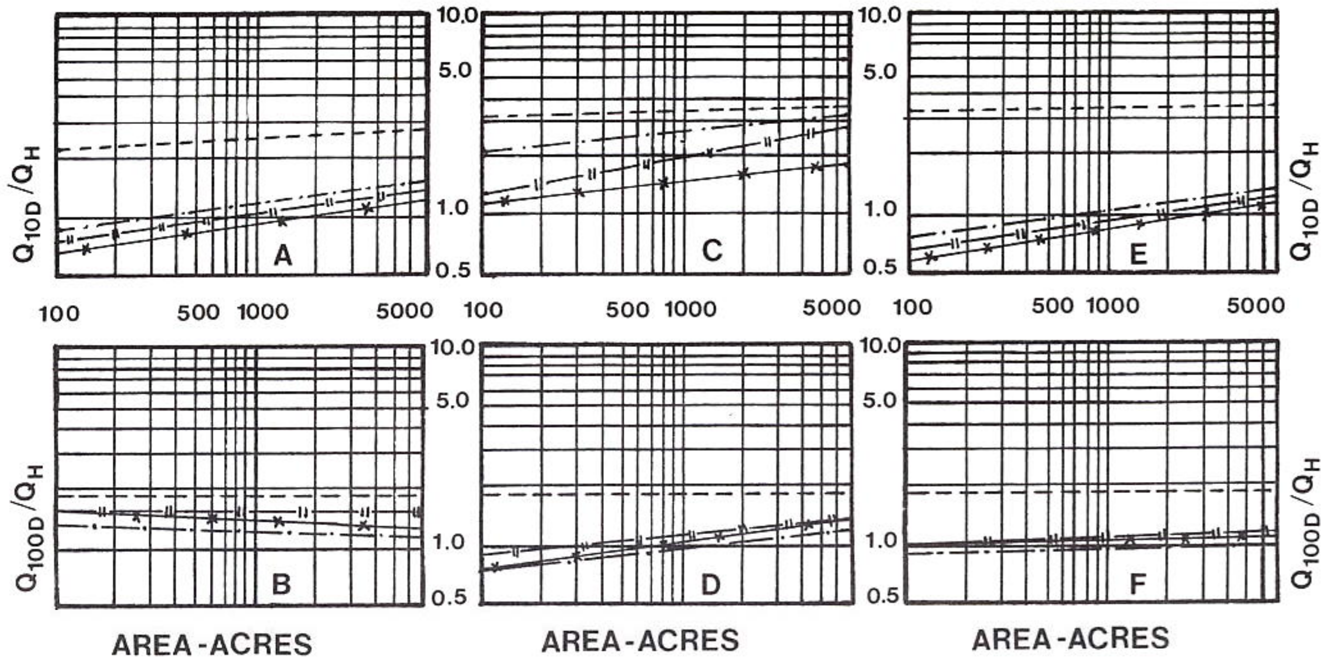


FIGURE 6

a) Effects of 10-year detention design on 10-year design storm peak.
b) Effects of 10-year detention design on 100-year design storm peak.
c) Effects of 100-year detention design on 10-year design storm peak.
d) Effects of 100-year detention design on 100-year design storm peak.
e) Effects of 10- and 100-year detention design on 10-year design storm peak.
f) Effects of 10- and 100-year detention design on 100-year design storm peak.

LEGEND

— — 39% impervious basin without detention
—·— 39% impervious basin with rigorous detention sizing
—x— 39% impervious basin with simplified detention sizing
—ıı— 78% impervious basin with simplified detention sizing

reasons, regionalized simple detention design criteria deserve to be considered by stormwater management professionals. A decision if they should be promulgated or rejected should then be made based on each community's needs, capabilities and political factors.

Scrutinizing the results of the earlier modeling effort revealed simplified trends in estimating undeveloped runoff and detention control volume.

After three trials, a set of simplified design equations were developed that produced peak flow trends along major drainageways similar to the ones obtained using a rigorous analysis of each detention site. The details of how this was done are included in the full paper.

Observations

The peak flow results obtained with detention ponds sized using the simplified equations were reduced to a non-dimensional form and are depicted in Figures 6 a through f. These figures reveal the following trends:

1. The 10-year and 100-year designs based on the simplified equations controlled their respective peak flows along the major drainageways almost as well as the rigorous individual design scenarios.
2. The 10-year simplified design was less effective in controlling the 100-year peak storm flows than the rigorous 10-year design scenario.
3. The 100-year simplified design was more effective in controlling the 10-year peak storm flows than the rigorous 100-year design scenario.
4. The combined 10-year and 100-year simplified design was equivalent to the rigorous combined 10-year and 100-year design in controlling both recurrance storm flow peaks.

Although the peak flow trends along the major drainageways were duplicated very well by the simplified design equations, there were a number of ponds in the system that overflowed. All ponds have the potential for overflowing since a storm larger than it was designed to control can and will occur. Thus, an infrequent overflow by itself should not constitute a faulty design. It is up to the designer to insure that when an overflow occurs, property damages are not increased. Namely, a safe overflow path, free of structures, has to be provided for every detention pond regardless of control frequency design.

DESIGN ACCURACY AND EFFECTIVENESS

Citations concerning urban design storms are numerous and have been tabulated by the Design Storm Task Committee of the Urban Water Resources Research Council into an Annotated Bibliography (13) which can be obtained upon request from ASCE. The mere fact that design storms or their substitutes are used as input in the sizing of detention basins, leaves a lot of room for argument as to the design accuracy or detention pond effectiveness. Although the questioning has merit and should not stop if technology is to move forward, it should not paralyze the designer into an endless analysis process. In the authors' opinion, it is important that the designer recognize the limitations in the accuracy of the rainfall input and move forward to design what are considered reasonably sized facilities in line with current state-of-the-art technology and practice.

Unlike many other fields of engineering, the statistics of hydrologic data have very wide bounds of design confidence. As an example, a 1980 USGS document (14) provides regression equations and techniques for estimating flood peaks, volumes, and hydrographs on small streams in South Dakota. The range in the standard error of estimate is as much as +152 and −60 percent for the flood peaks and +136 and −58 percent for the runoff volumes. Such uncertainties, as an example, in structural analysis would be considered intolerable and would be dealt with through the use of very large safety factors. On the other hand, drainage and flood control engineers work with these kind of uncertainties all the time whether they know it or not. Thus, whenever we discuss accuracy or effectiveness, we need to remind ourselves of the randomness of the physical phenomenon which is involved, and the fact that the data that was used in developing all of the commonly available surface runoff calculating techniques is broadly scattered.

INSTITUTIONAL CONSTRAINTS

In their discussion, Jones and Jones (15) point out that many communities mandated misuse of detention ponding with resultant waste of land and economic resources. They encourage communities to avoid arbitrary specification of single recurrence probability in their ordinances. Instead communities need to reexamine their selected design basis and attempt to arrive at a design basis that is demonstratably cost-effective. Too often either the extreme rare event or the small frequent event are the basis for local requirement, which, when applied uniformly and without regard to the effects downstream, can lead to either local drainage and erosion problems or to flooding problems. They went on to say,

> "It follows that design of detention pond outlet works often should have a multi-probability basis: (a) for frequent low flow conditions; (b) for the detention design discharge condition; and (c) for the extreme runoff (emergency spillway) condition."

The District's study revealed that even though the smaller storms may be the pond design criteria, the increased runoff volume resulting from urbanization virtually precludes design of on-site ponds that can effectively control peak flows along downstream drainageways. This mandates that downstream drainage facilities cannot arbitrarily be sized to accommodate flow from historic or undeveloped watershed only on the basis of "on-site" detention policy. It is incumbent on communities to also examine the detention requirements for each site, when detention is required, to insure that pond releases will not create hazards or damages to downstream properties. Requiring on-site detention is not an assurance that the drainage needs of the community and of the new development are satisfied. Communities and developers need to recognize that detention, when used, is only one element of a total formalized (or natural) drainage system and cannot be treated haphazardly. Thus, institutional arrangements in communities are just as important as sound design practices. In other words, communities need an institutional structure that insures sound design, and that the required detention ponds fit the system and are not used just to pacify local regulatory requirements.

Beyond this, an institutional structure is needed to insure that detention ponds are properly constructed and maintained for as long as they are a part of the community's drainage system. Assessing the potential hydraulic effectiveness of a detention ordinance or policy without knowledge of the local governments staff capability, implementation practices and maintenance practices is like trying to weigh candy with only one-half of a balance scale. Even though the product looks attractive, it is not possible to kow how much there is. If there is an emerging theme among the stormwater management professionals, it is that more often than not such institutional structures are not in place, are inadequate, or are under funded. Thus, the *true effectiveness* of detention systems or policies cannot be assessed without knowledge of how policy requirements translate into physical facilities and how these facilities will continue to function over the many years they are expected to operate.

CONCLUSIONS

The effectiveness of on-site detention ponds was addressed from the quantity and institutional aspects. The model study of random on-site detention in one Denver area watershed has indicated the following:

1) When ponds are designed to control the peak flow from a single recurrence event, the effectiveness of the system in controlling flow rates along major drainageways is limited only to that single design event.
2) Ponds designed to control peak flows of two separate recurrence frequency events appear to be effective in controlling flow rates along major drainageways for a range of flows and also appear to be more effective in controlling the two individual design events.
3) Designs intended to control frequent events (e.g. 2-years) are effective in controlling the frequent event immediately downstream of each pond only. Control of frequent events appears to be less and less effective along the major drainageways as more and more ponds contribute to the system.
4) It appears feasible to develop simplified regional on-site detention sizing requirements. Ponds sized using such requirements have the potential of controlling peak flows rates along major drainageways just as effectively as ponds sized using rigorous, flood routed, design procedures.

Finally, the effectiveness of random on-site detention policies is also constrained by the institutional structure that can insure adequate design, proper construction and long term operation and maintenance of detention facilities. Without knowing how effective the institutional structure is in providing and maintaining adequate facilities, we need to view the foregoing conclusions as representing only the *potential effectiveness* of detention policies. The assessment of the actual effectiveness of random on-site detention will require studies beyond those conducted to date.

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MEET THE NEW BOARD MEMBERS

RICH FERDINANDSEN

Commissioner, Jefferson County

Rich Ferdinandsen was appointed to fill an unexpired term of Jefferson County Commissioner in April, 1983. Prior to his appointment he was very active in Republican politics, serving as a District Captain as well as campaign coordinator or campaign manager for various local, state and national candidates.

Commissioner Ferdinandsen graduated from Denver East High School and received a BA in Economics from the University of Colorado at Boulder in 1969. Prior to his appointment as Commissioner he was Assistant Director, Colorado Division of Parks and Outdoor Recreation.

Ferdinandsen is a little league football coach and scoutmaster and is a member of the National Association of Parks and Recreation and the Colorado Parks and Recreation Association. He served in the Marine Corps from 1960-64. He and his wife Grace live in Arvada. They have two children.

FLOOD HAZARD NEWS
Bill DeGroot,
Editor

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