URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

FLOOD HAZARD NEWS

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Field Evaluation of a Stormwater Sand Filter

by
Ben R. Urbonas, John T. Doerfer and L. Scott Tucker

Introduction

The July, 1996 issue of the *APWA Reporter* had an article summarizing the findings of a two year effort to test a sand filter as a structural BMP (Urbonas, et. al., 1996). At this time an expanded discussion on this topic is presented and readers' comments are solicited by the authors.

The use of media filter basins, mostly sand filters, for stormwater quality enhancement was first reported by Wanielista et al. (1981) and Veenhuis *et al.* (1988). Since then the use of filters has expanded, with most uses reported in the State of Delaware, the Washington DC area, Alexandria, VA and the Austin, Texas area (Anderson *et. al.*, undated; Bell *et. al.*, 1996; Chang *et. al.*, 1990; City of Austin, 1988; Harper and Herr, 1992; Shaver and Baldwin, 1991; Trung *et. al.*, 1993). Recently filter media such as peat, compost and geotextiles have also been tried (Farham and Noonan, 1998; Galli, 1990; Stewart, 1992). Some designs, such as in the City of Austin, are defined by local criteria, including an ingenious sand filter inlet suggested by Shaver and Baldwin. In many designs, a detention basin is often provided upstream of the filter to capture the runoff and even out the flow through the filter.

It is evident that sand and other media filters are gaining popularity in the United States as stormwater BMPs. While the literature contains reports about their ability to remove pollutants, very little has been reported in the literature on their long-term hydraulic performance.

Field Testing Program

Since 1994 the Urban Drainage and Flood Control District, in cooperation with the City of Lakewood, has been conducting field and laboratory investigations about water quality enhancement and hydraulic performance of stormwater sand filters. The District supported the laboratory testing by one of its student interns of a number of different sand gradations (Neufeld, 1996). This resulted in the selection of concrete sand (ASTM C-33 Mix) as providing the best balance between constituent removals and hydraulic conductivity. This sand mix was then field tested in Lakewood, CO. ASTM C-33 sand is a commonly available gradation of sand and appears to be used today at many of the existing stormwater filters reported in the literature.

The water quality performance characteristics of the District's test sand filter were found to be comparable to those reported in the literature, especially for total suspended solids (TSS) (EPA, 1983; Veenhuis, 1989; City of Austin, 1990). However, this was true only for the fraction of the runoff that actually flowed through the filter. This is not true for all of the runoff that by-passed the filter. Early in the field test program the sand filter began to quickly lose hydraulic conductivity. This led the authors to conclude that, unless there is substantial detention volume upstream of sand filters that will capture and slowly release stormwater, or the sand filter is much larger or it is sized to be in balance with the available stormwater capture volume upstream of it, much of the runoff will either by-pass the filter or cause large and prolonged ponding areas on the land surfaces adjacent to the filter.

Findings

The Figure shows the test filter's unit hydraulic flow-through rate (feet per hour per square foot of sand filter) degrades as the total TSS removed by each square foot of the filter's surface accumulates over the test season. Immediately after the filter was installed, its flow-through rate was in excess of 3-feet per hour. This diminished to less than 0.075 feet per hour as 0.4 to 0.6 pounds of TSS per square foot of filter area accumulated on its surface (0.4 lb./sq.ft. of TSS accumulation equals approximately 1/16 inch layer). The final flow-through rate of 0.05 feet per hour (0.006 gpm/sq.ft.), which in the test facility was reached after only a few storms, is approximately equal to one-tenth to one-fifth of the design rate recommended by several local stormwater BMP criteria manuals that permit or require sand filters as BMPs. The rapid reduction in flow-through rate is a "red flag" about the use of this practice today. Clearly, hydraulic design questions need to be better answered before this type of BMP is recommended by District for use.

During the 1995 summer season of operation, over one half of all runoff events exceeded the combined capacity of the filter and the upstream surcharge volume of the test facility to "capture" the storm's entire runoff. This resulted in a TSS removal rate during the

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1996 Professional Activities of District Staff

Scott Tucker, Executive Director

*Chaired program on Stormwater Management at National Association of Flood and Stormwater Management Agencies (NAFSMA) annual conference, in San Diego in October.
*Member of Board of Directors and Chairman of the Stormwater Management Committee of NAFSMA.
*Member of the Stormwater Phase II Advisory Subcommittee, formed pursuant to the Federal Advisory Committee Act to assist in developing the Phase II stormwater program.
*Speaker on "Urban Runoff - A Pollutant or a Resource?" at the Colorado Nonpoint Source Water Quality Conference in Longmont, CO in September.
*Speaker on "The Evolving Urban Flood Control Role" at the 1966 South Platte Forum in Northglenn, CO in October.
*Speaker on "Environmental Permitting for Drainage and Flood Control Projects" at American Society of Civil Engineers Colorado Chapter Water Resources Technical Group in Denver, CO in February.
*Participated in Water Environment Federation and American Bar Association Clean Water Act satellite conference as panelist on Wet Weather Issues session, in Washington, DC in January.
*Speaker on "Why Counties Need to Know About Stormwater" at Environment, Energy and Land Use Steering Committee of the National Association of Counties in St. Louis, MO in November.
*Participant in "Cross Currents" discussion on managing increased levels of urban runoff in Water Policy Report, May 22nd issue.

Bill DeGroot, Chief, Floodplain Management Program

*Chair of the Floodplain Management Committee of the National Association of Flood and Stormwater Management Agencies (NAFSMA), and chaired a session on Floodplain Management Issues at NAFSMA's annual meeting in San Diego in Oct.
*Member of an Association of State Floodplain Managers committee evaluating Community Rating System Activity 450 Stormwater Management for FEMA's Community Rating Task Force.

Kevin Stewart, Project Engineer, Floodplain Management Program

*Chairman of National Hydrologic Warning Council representing the Southwestern Association of ALERT Systems (SAAS).
*Member of the Colorado Natural Hazards Mitigation Council's Dam Safety and Warning Subcommittee.
*Speaker at ALERT Users Group annual conference in Ventura, CA in May and SAAS conference in Baton Rouge, LA in Nov.
*Reviewer for National Research Council (NRC) concerning NRC National Weather Service (NWS) Modernization Committee report: *Toward A New National Weather Service: Assessment of Hydrologic and Hydrometeorological Operations and Services.*
*Appointed to Customer Advisory Panel on selected NWS modernization activities at March workshop in Silver Spring, Maryland.
*Instructor at US Army Corps of Engineers HEC training course on Flood Warning-Preparedness Programs in Davis, CA in April.
*Presented paper on "Evolution of Local Flood Warning Systems" at Big Thompson Flood 20th Anniversary Symposium in Fort Collins in July.

Ben Urbonas, Chief, Master Planning & South Platte River Programs

*Accepted an invitation by the French NOVATECH 98 organizing committee to serve as a member of that conference's scientific group responsible for the evaluation of abstracts and the selection of conference papers.
*Principal co-investigator (Eric Strecker principal co-investigator) of an EPA funded ASCE effort to develop protocols for a Nationwide BMP Evaluation Protocols.
*Co-authoring a paper with Ian Lawrence of Australia, Jiri Marsalek of Canada and Brian Ellis of Great Britain on *Review of Stormwater Detention and BMPs* to be published in a special volume of the *Journal of the International Association of Hydrologic Research.*
*Participated by invitation in a June 13-14, 1996 *Wet Weather Research Protocols Workshop* in Baltimore, MD sponsored by Water Environment Research Foundation.
*Organized and chaired a session on *Watershed Development Effects in Arid and Semi-Arid Regions* at the Engineering Foundation Conference on *Effects of Watershed Development and Management of Aquatic Ecosystems*, Snowbird, UT, August, 1995.
*Continues to Chair the *Urban Gauging Networks Committee* of the Urban Water Resources Research Council of ASCE.
*Co-chair, chapter principal editor and a contributing author of a joint Water Environment Federation and American Society of Civil Engineers *Stormwater Quality Management Manual of Practice*. Expected publication release late 1996 or early 1997. Participated by invitation at a Water Environment Federation's training seminar on the MOP in October, 1996.
*Co-author, James C.Y. Guo, Ph.D. lead author, of a paper published in the ASCE *Journal of Water Resources and Planning and Management*, titled "Maximized Detention Volume Determined by Runoff Capture Ratio," January/February, 1996.
*Lead author, Larry Roesner, Ph.D. and James C.Y. Guo, Ph.D. co-authors, of a paper titled "Hydrology for Optimal Sizing of Urban Runoff Treatment Control Systems," published in the *Water Quality International Journal*, January/February, 1996.
*Lead author, John T. Doerfer and L. Scott Tucker co-authors, of a paper titled "Stormwater Sand Filtration, A Solution or a Problem?" published in the *APWA Reporter*, July, 1996.
*Contributed to an effort by the International Association for Water Quality to develop an international *Urban Drainage Glossary* which will be published in 1998 in English, French, German and Japanese.

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Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

District Overview

The Urban Drainage and Flood Control District is now in its 28th year of activity, and 1996 has been another active year as one can see from the various articles in this newsletter. The District has five areas of program activity consisting of the Master Planning Program, Design and Construction Program, Maintenance Program, Floodplain Management Program, and the South Platte River Program. There are six counties located within the District and 32 incorporated jurisdictions. The District works with all of these local governments in its five program areas. Our approach is to enter into partnership arrangements with the local governments both in terms of funding projects as well as managing and developing the actual work. Most District projects are multi-jurisdictional and we work very closely with the local governments.

The five program areas are mutually supportive and interdependent. Master Planning is important because it sets a basis for future work in a watershed. In undeveloped portions of a watershed it provides guidance as development occurs. In developed parts of a watershed where there may be flooding problems it provides recommendations for addressing those problems. The Design and Construction Program is the basic implementing activity of the District. In order for a project to be addressed it must be a part of an approved master plan. Also, not all projects need to be structural. For example, a recent project with the City of Arvada included the acquisition of approximately 100 mobile homes located in the Ralston Creek floodplain. The mobile homes have all been relocated and the floodplain and creek will be restored.

Maintenance can never be neglected and is a critical component of a long-term program. The policy of the District is not to own drainage and flood control facilities which are instead owned by local governments. Therefore, the District's Maintenance Program is oriented towards providing maintenance assistance to the local governments. Maintenance includes routine work consisting of trash and debris pick-up and mowing, restoration work which includes bank stabilization and erosion control, and rehabilitative projects which are larger in nature and include projects such as large grade control structures. Maintenance is critical even in drainageways that have been left alone by development. We find erosion begins to occur as a watershed n area urbanizes and this needs to be addressed as well as trash and debris pick-up and control.

Our Floodplain Management Program is oriented more toward the non-structural arena. Important functions in this program include the review of proposed developments that will impact the floodplain. This is important if we are to prevent unwise development in floodplain areas. Another important function in the Floodplain Management Program is flood forecasting and warning. The District has developed a general flood warning activity for the entire District area as well as specific warning plans for watersheds with high potential for loss of life and heavy property damage.

While the South Platte River is not a very big river by many standards, its the biggest river we have in the Denver metropolitan area. As such we have a program that addresses the specific needs along the 40 miles of the South Platte River that run through the District. There is a dedicated funding source which enables the District to plan for the future, implement improvements along the South Platte River, and maintain the river on a regular basis. All of these program activities are important and it is a case where the sum of the parts add up to more than the total of the individual components.

Stormwater Issues

Last year I discussed the establishment of a federal advisory committee by EPA to advise them on how to address Phase II storm water discharges. This committee was created pursuant to the Federal Advisory Committee Act and is called the Phase II FACA Committee.

In the way of background, Phase I stormwater sources are being addressed through the National Pollutant Discharge Elimination System (NPDES) permits. Phase I stormwater discharges include cities over 100,000 population and most large industrial sites. Anything that is not in Phase I is considered to be a Phase II stormwater source. This includes potentially seven million sites ranging from incorporated jurisdictions and counties less than 100,000 in population to a myriad of small and light industrial and commercial sites.

The Phase II FACA Committee is comprised of approximately 35 individuals representing different interest groups including industry, environmental, state, tribal, federal, cities, and counties. The charge of the committee was to reach a consensus recommendation regarding how EPA should address the task of regulating Phase II stormwater discharges. EPA is on a tight schedule and has to have a proposed regulation ready for publication by September, 1997. In order for EPA to meet that deadline and all the internal reviews including the Office of Management and Budget, they needed recommendations from the FACA Committee by August, 1996. The committee was unable to reach a consensus recommendation by that time so EPA by necessity started writing the regulation. EPA did consider and utilize the committee input as they developed their proposed regulations. The Phase II FACA Committee role is now to react to EPA proposals and to provide input as EPA develops the

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Design and Construction Notes

By
David W. Lloyd, P.E.
Chief, Design and Construction Program

In 1996 the design and construction program committed over $5.1 million to design and construction projects. Most of this funding has gone toward construction as well as initiation of several new design projects.

Three separate construction contracts totaling over $7 million were completed this year for the Goldsmith Gulch Flood Control Project. This project first began in 1986, when the District and the City and County of Denver started preliminary design engineering. After a lengthy public involvement process, agreement on the plan to remove over one hundred homes and businesses from the 100-year floodplain was reached in early 1994. The three contracts were awarded for construction in 1995 and completed this past summer. All three contracts, although very complex and disruptive to the neighborhoods and traffic, were very ably administered by Steve Bello, Project Engineer for Denver's Wastewater Management Division. Our hats are off to Steve and his inspectors, Greg Gasner and Rick Zimmat, for their tireless efforts in keeping these contracts on course and in keeping the neighborhood groups well informed.

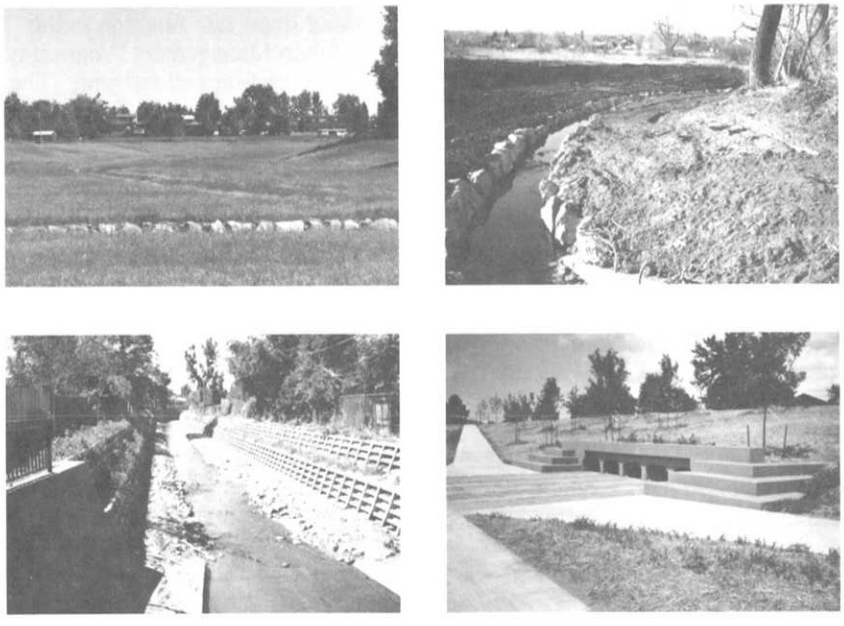
Another project which has been many years in development is the Dutch Creek project in the Town of Columbine Valley. This project originally started in 1985. Agreement was finally reached in 1995 as to the scope of the improvements and the project was bid. Bids were rejected due to the cost being greater than funds available. A few design modifications were made in 1996, the project rebid and construction is now underway with project completion anticipated in the spring of 1997. The project consists of open channel improvements through the Columbine Valley Country Club and a bridge replacement at Fairway Lane. The project will remove over 50 homes from the 100-year flood plain.

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdiction(s)	Status
Drainageway A	Louisville	95% Complete
Ralston/Leyden Feasibility	Arvada, Corps of Engineers	On hold
Van Bibber Final Design	Arvada, Corps of Engineers	40% Complete
Eastlake No. 3	Thornton	50% Complete
Goose Creek Phase 3	Boulder	5% Complete
Cherry Creek Drop @ Iliff	Arapahoe County	Complete
Lakewood Gulch	Denver	95% Complete
Tom Frost Detention	Broomfield	95% Complete
Little Dry Creek Phase C	Westminster	70% Complete
Little Dry Creek RR Crossings	Adams County	90% Complete
Lone Tree Creek Detention	Arapahoe County	Complete
Jewell Wetland Detention	Aurora	60% Complete
Littles Creek	Littleton, Arapahoe County	10% Complete
Willow Creek	Arapahoe County	20% Complete
Weaver Creek at Simms	Jefferson County	Complete
Pleasant View Trib. to Lena	Jefferson County	25% Complete

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Jurisdiction(s)	Cost	Status
Goldsmith Gulch Phases 1, 2, 3	Denver	$10,100,000	Complete
Granby/Sable	Aurora	752,000	Complete
Chateaux Beaumar	Littleton	350,000	Complete
I-25/46th & Pecos	Denver	600,000	40% Complete
Dutch Creek	Columbine Valley	1,240,000	60% Complete
Lena Gulch Schedule V	Wheat Ridge	585,000	90% Complete
Lena Gulch - 20th & Winfield	Lakewood	140,000	Complete
Irondale 80th Ave. Detention	Adams County	655,000	Complete
Marston Lake North	Denver	525,000	Complete
Gregory Canyon Cr. @ Willowbrook	Boulder	200,000	Complete
Knox Outfall	Arapahoe County, Denver	559,000	Complete
Lower Ralston Cr.	Arvada	2,670,000	90% Complete
West Evans Ave. Phase 1	Denver	638,000	Complete
Mushroom Farm Detention	Westminster	450,000	Complete
Valverde Outfall	Denver	475,000	Complete
Bear Canyon Cr. - Mohawk	Boulder	400,000	Complete
Dry Gulch - 15th/Kipling Detention	Lakewood	1,600,000	Complete



Upper Left - Kipling Pond on Dry Gulch, Upper Right -Lena Gulch Schd. V, Lower Left- Goldsmith Gulch at Mexico, Lower Right - Goldsmith Gulch inlet structure to off-line detention facility at Iliff.

A number of design projects were initiated this past year. One of the more interesting projects is the design of improvements at the Jewell Avenue wetland site. This proposed detention pond site was purchased in cooperation with the City of Aurora and the Trust for Public Land. Citizens for Aurora Jewell Wetland, a local neighborhood group, has been very active in the purchase of the property and in the design of the recommended improvements at the site. Since public input was going to be a critical issue in the design of these facilities, Aurora and the District selected a landscape architecture consultant for the design of the improvements. Due to the local interest in preserving the site for its wildlife habitat and as a unique natural area, the project team includes the curator for the Butterfly Pavilion and Insect Center as well as a wildlife consultant. Construction is anticipated in 1997.

The beginning of design for the next phase of Goose Creek extending from 30th Street to Valmont in the City of Boulder began in 1996. Design and right-of-way acquisition will be completed in 1997 with construction to start sometime in 1998. This phase of the work, much like the two previous phases, appears to be very complex due to the difficult right-of-way and utility constraints.

This past year the Design and Construction Program initiated a study for preparation of an update to the District's "Storm Sewer Pipe Materials Technical Memorandum" dated April, 1987. This is a joint project with the Cities of Lakewood, Westminster, Golden, Brighton, Denver, Aurora, and Boulder; the Counties of Arapahoe and Douglas and the Colorado Department of Transportation. The purpose of the study is to define limits as to when different pipe materials should be used as well as provide recommendations for installation of the different pipe materials. This study should be completed and available in early 1997.

First Municipal Stormwater Permits Issued in Colorado

by John Doerfer

The first municipal stormwater permits in Colorado were issued on May 10, 1996, by the Water Quality Control Division, Colorado Department of Public Health and Environment to the Cities of Denver, Aurora, and Lakewood. The cities spent 2 1/2 years and a combined total of $2,000,000 to prepare their permit applications, which were submitted in November, 1992.

The permit requirements consist of five management programs:

Construction Sites. The cities will implement an erosion and sediment control program that includes guidance on BMPs for use at construction sites, review and approval of plans, inspections, and training programs for staff and construction site operators.

Commercial/Residential Areas. New developments will be required to address stormwater quality and incorporate BMPs as part of the plan review and approval process. All municipally-owned detention facilities, drainageways, and storm sewer inlets are required to be cleaned periodically, and existing structural controls need to be evaluated as to the feasibility of retrofitting for water quality purposes. Public street maintenance practices such as sanding, sweeping, and weed control must be examined and modified as necessary to enhance water quality.

Illicit Discharges. Programs to prevent and investigate illicit discharges will be continued, or developed if not in place, including enforcement of existing ordinances, removal of illicit connections, sampling of outfalls, response to accidental spills, and seepage of sanitary sewers into storm sewers. Other required programs include public education on proper disposal of used oil and household toxic materials, and establishing a hotline for reporting of illegal dumping.

Industrial Facilities. A program has to be developed to monitor and control pollutants in stormwater from municipal landfills; hazardous waste treatment, disposal, and recovery facilities; industrial facilities that use or store certain amounts of toxic chemicals on site or are of particular concern to the city. The cities need to identify priorities and procedures for inspections and establishing and implementing control measures.

Municipal Facilities. The cities are directed to identify, develop, and implement stormwater management plans for facilities they own such as vehicle maintenance, asphalt and concrete batch plants, solid-waste transfer stations, sand/salt stockpiles, snow dumps, and sweeper wastes.

It is apparent there are a number of activities that must be accomplished by the cities to remain in compliance with their permit. A progress report and permit fee must be submitted annually by each city upon issuance of the permits. Public education and stormwater monitoring programs will be developed by the three cities as an early action in the upcoming year. Existing city programs are no longer discretionary. The permits are effective for an initial period of five years and must be renewed.

Call for papers NOVATECH 98

Every three years the French hold an international conference on the topic of urban stormwater technology. It is a major conference where one can learn much about the research and technology development in this field by the French and by others throughout the world. The next one, NOVATECH 98, will take place in late spring or late summer of 1998. The formal call for papers is available through Ben Urbonas and asks the authors to address any of the following: alternative technologies for stormwater management, control of combined stormwater/ wastewater effluent quality under wet-weather conditions, strategies and considerations for stormwater management at the city or town scale, and new design and management tools.

Of particular interest are the topics of physical modeling of original and innovative systems, non-traditional approaches to urban storm drainage, and techniques and tools for stormwater management in developing countries.

MAINTENANCE PROGRAM ACTIVITIES

by
Mark R. Hunter, P.E.
Chief, Maintenance Program

Routine Maintenance

Through the routine program $490,000 was spent in 1996 for mowing and debris pickups on approximately 210 different sections of drainageways within the District boundaries. This equates to a total of nearly 100 miles of drainageways in the Denver area that were given routine maintenance.

Some of the drainageways we maintain are quite urbanized with adjacent homes, streets, and improved parks. In recent years we have responded to numerous requests to increase the number of mowings we do per year in the more urbanized areas. Other drainageways we maintain are more rural in character. On portions of some of these more rural drainageways we have taken the opportunity to reduce or eliminate our mowing activities. This has been done to encourage habitat and leave a more natural character in the corridor.

Restoration Maintenance

In 1996 the restoration program completed $1.02 million of work. Restoration projects typically address isolated drainage problems where the solution involves small scale construction. Seventy-eight individual activities were completed during the year.

Lena Gulch discharges into **Clear Creek** on the east side of Kipling Street at 41st Avenue in Wheat Ridge. The final 300 feet of Lena Gulch is parallel to and lower than the Clear Creek channel. Through natural forces Clear Creek captured or took over that 300 feet of Lena Gulch. The result was that Clear Creek abandoned a portion of its previous channel and its water flowed in the captured portion of Lena Gulch along with the water of Lena Gulch. This was certainly a natural process, but in an urban area the results were undesirable. Clear Creek water backed up approximately 500 feet above the capture point in the Lena Gulch

STATUS OF MAINTENANCE REHABILITATION PROJECT

Project	Jurisdiction	Cost		Status
ADAMS COUNTY				
Grange Hall Creek-east of Irma	Northglenn	design	$20,000	90%
detention pond repairs		const.	150,000	delayed
Niver Creek-Pecos to Zuni	Thornton	design	61,289	100%
erosion repair		const.	304,717	100%
Westerly Creek-north of Montview	Aurora	design	48,743	100%
replace pipe with channel		const.	200,000	0%
Niver Creek-S.Platte to Steele St.	Adams County	design	by others	20%
replace pipes, repair channel		const.	192,500	0%
ARAPAHOE COUNTY				
Big Dry Creek-Nobles Rd. Trib	Arapahoe Co.	design	$74,653	100%
east of University		const.	212,345	100%
Greenwood Gulch-east of Holly	Greenwood Village	design	12,861	40%
erosion repair		const.	250,000	0%
Little Dry Ck.-West of Colorado	Arapahoe County	design	45,000	5%
drops and channel repair		const.	next year	0%
West Harvard Gulch	Englewood	design	52,664	95%
pipe replacement		const.	536,753	0%
W. Toll Gate Ck.-Delaney Farm	Aurora	design	30,000	0%
north of Alameda		const.	275,000	0%
BOULDER COUNTY				
Coal Creek	Superior	design	by others	postponed
at 2nd Avenue		const.	$15,000	postponed
Fourmile Canyon Creek	Boulder	design	35,680	95%
west of Broadway at Lee Hill		const.	175,000	delayed
South Boulder Creek	Boulder	design	19,085	95%
n.e. of Valmont and 55th		const.	125,000	delayed
DENVER COUNTY				
Bear Creek	Denver	design	$49,610	20%
Raleigh to Sheridan		const.	200,000	0%
Cherry Ck - Babi Yar	Denver	design	34,865	95%
drops, bank repair		const.	135,000	delayed
Goldsmith Gulch	Denver	design	67,189	30%
Bible Park low flow channel		const.	next year	0%
Goldsmith Gulch	Denver	design	50,000	0%
Cook Park low flow channel		const.	150,000	delayed
Lakewood Gulch-Federal to Knox	Denver	design	78,432	100%
Channel repair		const.	375,000	0%-phase 3
Montbello Drainage (w/city)	Denver	design	by others	100%
Concrete channel repair		const.	35,530	100%
Montbello Drainage-along 51st	Denver	design	34,309	100%
Concrete channel repair		const.	135,875	100%
South Platte River	Denver	design	43,868	95%
Westside trib.		const.	next year	delayed
Weir Gulch	Denver	design	by others	60%
Barnum Park detention		const.	87,000	0%
DOUGLAS COUNTY				
Cherry Creek-	Parker	design	by others	95%
trail and bridge		const.	$26,000	0%
East Dad Clark Gulch	Douglas Co.	design	52,498	100%
improve existing drop		const.	149,734	10%
Sulphur Gulch	Parker	design	by others	0%
repair trail embankment		const.	30,000	0%
JEFFERSON COUNTY				
Airport Creek	Westminster	design	$93,438	100%
Eaton and 112th		const.	441,946	100%
Lakewood Gulch-Tributary F	Jefferson Co.	design	18,737	80%
Green Mtn. drainage		const.	80,000	0%
McIntyre Gulch	Lakewood	design	25,000	0%
west of Holland St.		const.	next year	0%

channel. A pedestrian bridge was occasionally under water. Mosquitoes were more common and uncontrolled vegetation was evident. The Lena Gulch trickle channel was completely submerged under a 50 foot wide pool of slow-moving water.

In early 1996 the maintenance program regraded part of the confluence area to put Clear Creek back in its channel. We also cleaned the sediment out of the Lena Gulch trickle channel and tilled and revegetated the area that had been under water. Our efforts were short lived. With the spring runoff in 1996 Clear Creek recaptured Lena Gulch and the pool of slow-moving water returned.

We continue to spend money to treat the symptoms of this natural process. At the same time we are approaching the appropriate parties to put together a project to solve the larger problem of stabilizing the channel of Clear Creek.

Rehabilitation Maintenance

Twenty-seven projects were at various stages of design or construction during 1996. Those projects are listed in the accompanying table titled "STATUS OF MAINTENANCE REHABILITATION PROJECTS". Rehabilitation projects usually take the form of consultant-designed repairs that are intended to address severe problems that have occurred on a previously improved drainageway. By the end of 1996 the District will have spent about $2,826,000 on rehabilitative design and construction for the year. A few of the unique projects are discussed below.

Since we reported on it last year our project on **Westerly Creek** immediately south of the Stapleton Airport site in Aurora has been on hold due to right-of-way considerations. The good news is that the right-of-way issues have been resolved and the project is now out for bid. The project still calls for replacing a collapsing 60" pipe with an open channel. This small project area will ultimately be part of the Westerly Creek "green" corridor serving the neighborhoods around the old Stapleton Airport.

Deteriorated and collapsing pipes under a road in Adams County have given us the opportunity to repair portions of **Niver Creek** near the South Platte River. By cooperating with Adams County in funding the project the deteriorated pipes which now carry Niver Creek will be replaced with a bridge and an open channel. An adjacent section of the creek will also be rehabilitated. It will be widened and given more accessible side slopes. If enough land can be acquired the county is also considering expanding the Niver Creek trail-head park.

We have another project this year that calls for replacing an existing pipe system with an open channel grass-lined drainageway. **West Harvard Gulch** flows through a linear park in Englewood on the west side of the South Platte River. Base flows and small storm events are carried in a 60" pipe that runs beneath the park. The pipe is badly deteriorated. The 2600 linear feet of pipe will be removed and replaced by a new open channel and two drop structures. Once construction is completed all runoff will flow on the surface through the linear park.

In last year's *Flood Hazard News* we reported that a landscape architect was the prime consultant for a project on **Airport Creek** at 112th Avenue and Harlan Street in Westminster. Construction has now been completed on this project to correct localized aggradation and degradation. The wide drainageway corridor permitted the consultant to take advantage of the gently graded open space to design the drainage repairs and incorporate some aesthetic features.

The heavy spring runoff in 1995 severely damaged a drop structure and about 100 feet of gabion bank protection on **Lena Gulch.** The site is downstream from the Consolidated Mutual water treatment plant at 27th Avenue in Lakewood. Construction of a new grouted boulder drop structure and adjacent features has recently been completed. Rebuilding this facility was possible because of the cooperation of the City of Lakewood, the City of Wheat Ridge, Consolidated Mutual Water Company, the capital and maintenance programs of the District, and the adjacent property owner.

Bible Park is located on **Goldsmith Gulch** between Yale Avenue and Dartmouth Avenue in Denver. Within Bible Park the drainageway flows through an area of natural grassed and volunteer trees and shrubs. Through this area the low flow channel for Goldsmith Gulch has eroded into a vertical-sided channel ranging from three to ten feet deep. The design process is well under way with representatives from nearby neighborhoods, the Denver parks department, the consultant and the District maintenance program

Airport Creek after completion of the rehabilitation project.

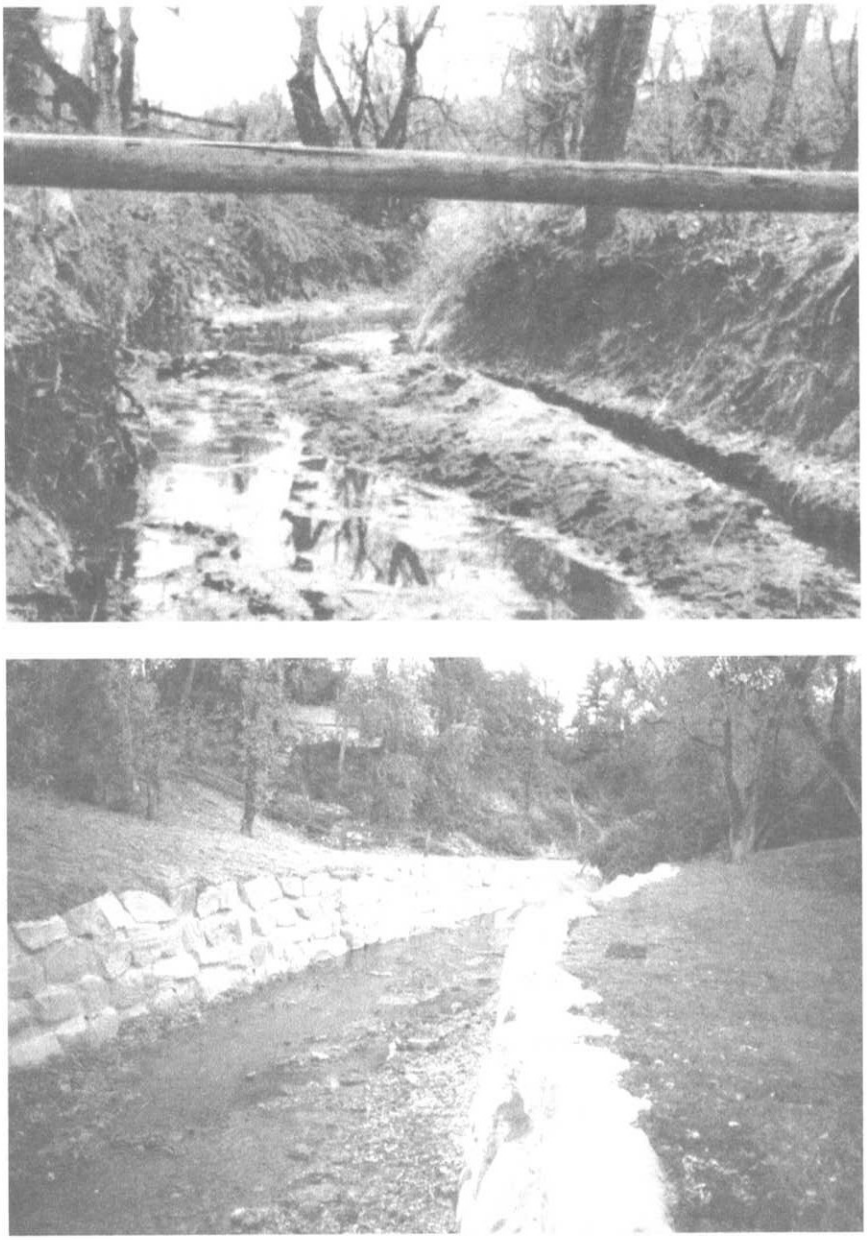
contributing to the partnership. The goal of the project is to repair the erosion damage to the channel and, at the same time, to make the gulch a more accessible and aesthetic component of the natural area of the park.

Cook Park is also on **Goldsmith Gulch** and is one and one-half miles downstream from Bible Park. It is in the City of Denver and is immediately east of Monaco Parkway where Goldsmith Gulch joins Cherry Creek. The erosion in the low flow channel in Cook Park has created a steep-sided channel that is three to six feet deep. Although this is not as severe as in Bible Park the setting in Cook Park is an improved blue-grass multi-use area. This dictates that the channel configuration for Goldsmith Gulch be rehabilitated to be less of a threat to existing facilities such as pedestrian bridges and play areas. It also means that visitor safety and convenience will be a component of the design. The design for this project has just begun. As with Bible Park, the design of maintenance repairs to Goldsmith Gulch through Cook Park will incorporate the contributions of the neighborhood representatives and the participating government departments.

Barnum Lake on **Weir Gulch** at Federal Boulevard and 6th Avenue has filled in with so much sediment over the years that it now has an average water depth of nine inches. The lake serves primarily as a natural habitat area and a stormwater detention pond. By its location it inevitably serves as a sediment trap. The Denver Parks Department is designing a project to remove the accumulated sediment and restore the lake to an attractive wildlife habitat. Plans also include nature trails and fishing stations on the banks of the lake. The maintenance program can participate in this project at two levels. Any sediment that is within the stormwater detention volume of the lake qualifies for maintenance of a flood control facility. The maintenance program can fully fund the removal of sediment that occupies some of the designed detention volume. Any sediment that is trapped within the permanent pool of the lake does not impact detention volume but does serve to improve the quality of the stormwater in Weir Gulch. The maintenance program will fund a part of the removal of this portion of the sediment recognizing that improved water quality is a long-term benefit to the function of the drainageway.

Another District Award

The District, Wright Water Engineers, and L & M Enterprises received a Certificate of Recognition from the International Erosion Control Association for a project on Lena Gulch downstream of Youngfield Street. The project had been nominated for an Environmental Excellence Award in the Design Category. The project consisted of 1500 lineal feet of boulder walls and riprap stabilized channel bottom featuring several unique landscape accents; a grouted boulder drop structure with stilling basin, tree protection designs, and a modified wall section to allow for pedestrian access to the channel bottom. Congratulations to David Bennetts from the District, Wright Water, and L&M Enterprises.



Before and after views of the award winning Lena Gulch project.

Floodplain Management Program Notes

by
Bill DeGroot, P.E.
Chief, Floodplain Management Program

FEMA strikes again

As of October 1st FEMA is charging local governments fees for processing LOMRs for locally funded flood control projects. Not only do you not get so much as one point of CRS credit for reducing the flood hazard within your community, but now you also have to pay FEMA for the privilege of having them recognize your efforts.

We now get to pay our consultants to prepare requests for LOMRs and we get to pay FEMA's consultants to pick them apart. It's great for everybody but the taxpayer. What's also shabby is that the excuse FEMA has always used for not giving CRS credit for structural flood control projects is that you get your FIRM changed instead.

Humbug!

Rapid City Revisited

I received a voice mail the other day from one of my favorite college professors, Don Thorson. Don, who is retired now, taught in the civil engineering department at South Dakota School of Mines and Technology in Rapid City, SD; where I earned my two degrees. As you know, Rapid City suffered a devastating flood in 1972. Following the flood, a major part of the recovery effort involved acquiring the 100-year floodplain and converting it to flood compatible uses, primarily parks and open space.

Recently a developer proposed to buy 15.5 acres of the publicly owned floodplain, which included a soccer field, for construction of a grocery store. The issue was placed on the ballot, where it failed by 57.4% to 42.6%.

Don is now working with a group of people in Rapid City who are trying to figure out a way to avoid this kind of proposal in the future. He asked me if we were aware of any methods which would assure once and for all that floodplain lands, once acquired, could not be given up for development later on. After thinking about it for a while I had to concede that I wasn't aware of any better way to protect publicly owned land in these situations than to require a vote of the people. There is no way to absolutely lock in a decision that cannot be changed. Even the U. S. Constitution can be changed.

According to the *Rapid City Journal*, "A sampling of city voters showed that while many voted because of the flood issues, many cast their votes to preserve the soccer field there or because they prefer parks to stores." Although this was apparently not a scientific survey, it seems to indicate that the winning combination came from voters who had different reasons for voting no. Some people were concerned about the flood hazard while others voted to preserve parks and/or a soccer field. This is perhaps a good example of the value of multiple use of flood hazard areas. The combination of constituencies won, whereas a single purpose flood hazard argument may not have fared as well.

The fact that a community that has suffered such an enormous tragedy so recently could seriously consider (42.6%) allowing development of that floodplain should remind all of us floodplain managers that we have to be constantly vigilant to these kinds of proposals, and we have to keep the public informed of the reasons why this is not an appropriate action to take. This is a battle that we will have to fight over and over again, and it will probably never be totally won.

New Development Continues

The development boom continued in 1996. I don't try to keep track of the total number of referrals we review annually, but I know 1996 continued the recent busy trend.

The District's maintenance eligibility program once again processed a large number of projects. We reviewed 204 projects for some aspect of maintenance eligibility, most of them on more than one occasion. Boyle Engineering Corporation has observed construction for us again in 1996, and makes recommendations regarding acceptance of constructed projects for District maintenance eligibility. We expect to close out approximately 44 projects this year. Boyle currently has 41 sites under observation with more projects in the pipeline and more proposals coming in the door every day.

NAFSMA Committee

I continue to chair the floodplain management committee of the National Association of Flood and Stormwater Management Agencies (NAFSMA). I anticipate an increased level of activity in Washington working on issues of interest to NAFSMA member agencies.

I'm always open to ideas, suggestions and concerns regarding what goes on at the Federal level and how it affects local governments' floodplain management efforts, so if you have any thoughts you may feel are worthy of NAFSMA consideration, feel free to send them my way.

Community Rating System

Earlier this year I served on a committee for the Association of State Floodplain Managers (ASFPM) which performed a technical review of the Community Rating System (CRS) Activity 450, Stormwater Management at the request of FEMA's Community Rating Task Force. I guess that committee chair Dave Carlton wanted to assure that the committee would have divergent viewpoints represented when he invited me to participate.

The committee's final report was submitted to ASFPM in September. It will be a while before it works its way through the process and any of the recommended changes are implemented

What do they really mean?

We want to build a flood control channel and "reclaim the floodplain." Did you claim it before the drainageway came along?

The floodplain encroaches on the proposed plat. Perhaps you mean the proposed plat encroaches into the floodplain?

We want to restore the natural channel. No you don't. It was a dry deeply incised gulch once upon a time. Perhaps you mean that you want to enhance the channel?

FLOOD WARNING & PREPAREDNESS

by
Kevin G. Stewart, Project Engineer
Floodplain Management Program

ALERT System Usage Increases

The District's ALERT base station logged more than 3500 connections in 1996. This base is one of eight currently used within the District's Flash Flood Prediction Program (F2P2). Four other base stations located in Aurora, Boulder and Denver also have modems which are routinely accessed. In addition, Aurora provides ALERT data via their Internet home page.

The District provides its local government partners and certain other cooperators with free access to the base station. In addition to ALERT data displays from 130 gaging stations (113 rain gages, 62 water level sensors and 8 weather stations), a full suite of weather products is available including watches, warnings and advisories from the National Weather Service; and heavy precipitation outlooks, quantitative precipitation forecasts and internal message status reports from the F2P2 meteorologist, Henz Meteorological Services. Recent system enhancements have contributed to the increased usage by allowing remote users to more easily interpret data using graphics communication software. Warning areas can be displayed using shaded maps. Emergency managers will find tools like these increasingly useful in directing early public safety actions.

Dedicated phone lines were added to the District base station in 1996 to accommodate KCNC-Channel 4 and KMGH-Channel 7, the Evergreen Fire Protection District (FPD) and the National Center for Atmospheric Research (NCAR). With no direct cost to the District, ALERT system access was approved by recognizing the public safety contributions each of these organizations provide. The media lines were used by weather news teams headed by Larry Green at KCNC and Pam Daale at KMGH. An excellent working relationship has developed from this interaction and the viewers were well served. The Evergreen FPD logged daily calls to obtain ALERT data from two weather stations. This, along with other weather data, was used to develop a more representative fire weather reporting system for the Jefferson County mountains. The additional stations permitted dividing the county into three regions to better assist fire districts with their activities.

NCAR's dedicated access to the ALERT system was devoted to Doppler radar research through the summer months. Their study dealt with improving radar precipitation estimates using Doppler radar technology. ALERT rain data was used to help validate their models and identify deficiencies

Local Data Acquisition & Dissemination

The District's ongoing weather information dissemination project with NOAA's Forecast Systems Laboratory (FSL) has evolved in 1996 to include a surveillance component and a LAN link ALERT data ingest. This project is serving as a model and testing ground for how NWS offices will interact with emergency managers and other local agencies in the future.

Loss of Mesonet

The Program for Regional Observing and Forecasting Systems (PROFS) at NOAA's Environmental Research Laboratories (ERL) in Boulder recently discontinued a 22-station mesoscale network (or Mesonet) of weather stations which has been operating in northeast Colorado since the mid-1980s. This system has been available to the F2P2 and many others at no charge and its loss will be felt. For flash flood forecasting the Mesonet allowed meteorologists to observe changing weather conditions every 5 minutes; display wind fields and convergence lines; identify moisture sources; plot vertical profiles of temperature, wind and moisture up to mountain top levels; and predict storm development and movement.

The District is taking some steps in 1997 to offset this loss by relocating ALERT weather stations in Boulder County and cooperating with Douglas County to develop three new sites there. The District is also planning to evaluate which Mesonet sites have proven to be most useful for flash flood prediction over the past decade and may consider replacing a few of these stations with ALERT equipment. ERL also has an ongoing project which may eventually lead to a cooperative of data providers contributing weather information to be assimilated in a common database and shared among the contributors.

Buffalo Creek Fire/Flood

Between 10 and 11 PM on July 12, a 30-foot wall of water roared down the North Fork South Platte River causing two deaths and damages exceeding $5 million. The flood resulted from a thunderstorm beginning at approximately 9:40 PM which produced an estimated 2 to 3.5-inches of rain within 30 to 90 minutes over a 10 to 30 square mile area. Sand Draw and the lower portion of Buffalo Creek, both running through the small Jefferson County community of Buffalo Creek, were hard hit. Estimated peak discharges (17,000 cfs maximum) exceeded FEMA's 100-year flood estimates by 10 to 20 times.

The storm was centered over a steep-sloped fire-scorched area just south of Buffalo Creek. A 13,000-acre forest fire, which occurred less than two months prior to the flood, clearly contributed to the flood's destruction. The intense fire significantly changed the runoff characteristics of the watershed by causing not only a near total loss of vegetation but also by altering the physical, chemical, and biological properties of the soil, producing "hydrophobic" conditions. Essentially the watershed became the hydrologic equivalent of a parking lot.

Other Info

The F2P2 activated a record number of 51 days this year. The program has been serving the District since 1979.

During 1996 the ALERT network measured one-hour rainfall amounts exceeding an inch on eight days. The station at Morrison reported the heaviest amount with of 2.32" on Sept. 11. Even though we experienced a very active season, all flooding that occurred within the District this year may be categorized as nuisance events.

Design of Low Tailwater Riprap Basins for Storm Sewer Pipe Outlets

by
Michael A. Stevens, Consultant
Ben Urbonas, Urban Drainage & Flood Control District

Introduction

The *Major Drainage* chapter of Volume 2 of the Urban Storm Drainage Criteria Manual, (USDCM) of the Urban Drainage and Flood Control District provides guidance for the design of scour protection downstream of culvert outlets. This guidance was intended for culvert crossings of major drainageway channels and assumed that the culvert is in line with the channel. It also assumed there was significant tailwater that partially inundated the culvert's outlet. This guidance does not work for storm sewer pipes discharging into open drainageways when the flow depth in the drainageway provides a low tailwater at the pipe's outlet. Thus, when tailwater is low, scour protection at the outlet of a storm sewer has to be designed differently than for culverts crossing major drainageways. For storm sewer outlets, low tailwater is defined when:

$$y_t \le \frac{D}{3} \quad \text{or} \quad y_t \le \frac{H}{3}$$

in which: y_t = depth of tailwater at the time the pipe is discharging its design flow, in feet; D = the diameter of a circular pipe, in feet; H = the height of a rectangular pipe, in feet.

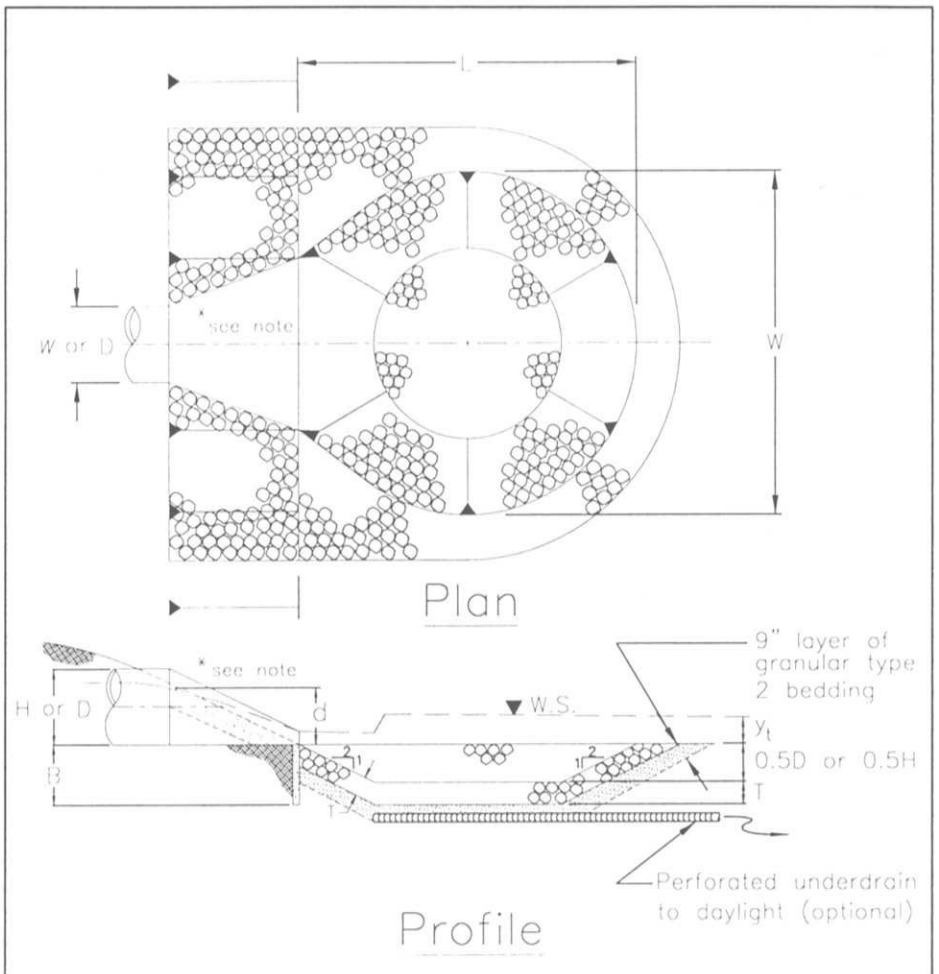
,Stevens (1969) reported on a series of studies describing the scour geometry in riprap located at pipe outlets. Quantifiable relationships were found between flow depth and velocity at the outlet, the scour hole geometry, and the rock size. Figure 1 describes the geometry of a pre-shaped scour hole downstream of a pipe fitted with a flared end section. Refer to this figure when reading the rest of this article.

Finding Flow Depth and Velocity at Storm Sewer Pipe Outlets

The first step in the design of a scour protection basin at the outlet of a storm sewer is to find the depth and velocity of flow at the outlet. Pipe-full flow can be found using *Manning's* equation and the pipe-full velocity can be found using the *Continuity* equation. Namely,

$$Q_{full} = \frac{1.49}{n} \cdot A_{full} \cdot \left(R_{full}\right)^{2/3} \cdot S_o^{1/2}$$

in which: Q_{full} = Pipe full discharge at its slope, in cubic feet per second; n = Manning's n for the pipe full depth; A_{full} = Cross-sectional area of the pipe, in square feet; S_o = Longitudinal slope of the pipe, in feet per foot; R = Hydraulic Radius of the pipe flowing full, in feet with



Note: For rectangular conduits use a standard design for a headwall with wingwalls, paved bottom between the wingwalls, with an end cutoff wall extending to a minimum depth equal to B

Figure 1: Low tailwater basin at pipe outlets

$R_{full} = D/4$ for circular pipes,

$R_{full} = A_{full}/(2H + 2w)$ for rectangular pipes, where w = width of a rectangular conduit, all in feet. Then,

$$V_{full} = Q_{full} / A_{full}$$

in which: V_{full} = Flow velocity of the pipe flowing full, in feet per second.

The normal depth of flow, d, and the velocity at that depth in a conduit can be found with the aid of Figure 2. Using the known design discharge, Q, and the calculated pipe-full discharge, Q_{full}, enter Figure 2 with the value of Q/Q_{full} and find d/D for a circular pipe or d/H for a rectangular pipe.

Compare the value of this d/D (or d/H) with that obtained from Figure 3 using the Froude parameter, namely,

$$Q/D^{2.5} \quad \text{or} \quad Q/(w \cdot H^{1.5})$$

Choose the smaller of the two d/D (or d/H) ratios to calculate the flow depth at the end of the pipe, namely,

$$d = D \cdot \left(d/D\right)$$

or

$$d = H \cdot \left(d/H\right)$$

Again enter Figure 2 using the smaller d/D (or d/H) ratio to find the A/A_{full} ratio. Use this to calculate the area of flow at the end of the pipe, namely,

$$A = \left(A/A_{full}\right) \cdot A_{full}$$

in which : A = Area of the design flow in the end of the pipe, in square feet. Finally,

$$V = Q/A$$

in which: V = Design flow velocity at the pipe outlet, in feet per second.

Finding the Appropriate Riprap Size

Use Figure 4 to find the size and type of the riprap to use in the scour protection basin downstream of the pipe outlet [i.e., HG (grouted H), H, M or L]. First, calculate the riprap sizing design parameter, P_d, namely,

$$P_d = \left(V^2 + g \cdot d\right)^{1/2}$$

in which: g = acceleration due to gravity, 32.2 feet per second per second.

When the riprap sizing design parameter indicates conditions that place the design above the Type H riprap line in Figure 4, use HG, or larger, grouted rock. An alternative to a grouted or loose riprap basin is to use the standard Bureau of Reclamation Basin VI, a reinforced concrete impact structure, to dissipate the energy in the flow at the outlet of the pipe.

After the riprap size has been selected, the minimum thickness of the riprap layer, T in feet, in the basin is set at

$$T = 1.75 \cdot D_{50}$$

in which: D_{50} = the median size of the riprap (see Table 1).

Table 1. Median (D_{50}) Rock Size of Urban Drainage District Riprap.

Riprap Type	Median Size (Inches)
L	9
M	12
H & HG	18

Finding the Basin Length

The minimum length of the basin, L in Figure 1, is defined as being the greater of the following lengths:

For circular pipe,

$$L = 4\,D \quad \text{or} \quad L = (D)^{1/2} \cdot \frac{V}{2}$$

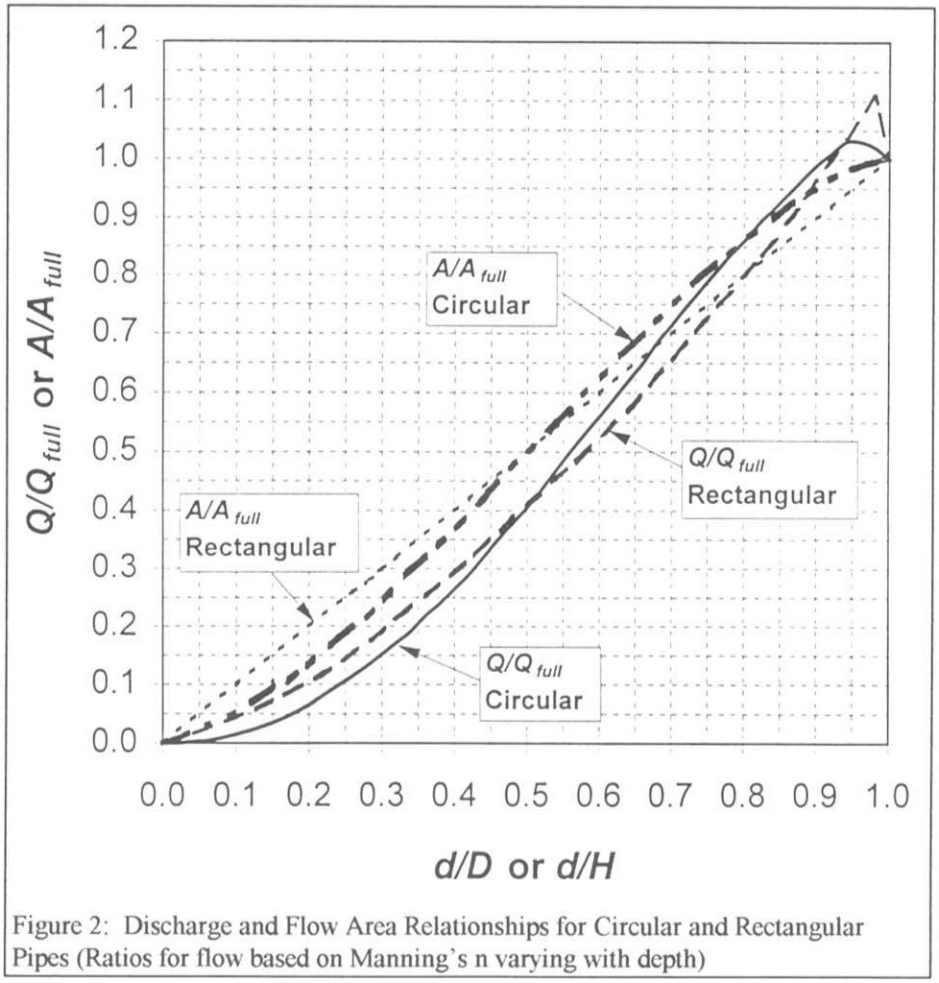


Figure 2: Discharge and Flow Area Relationships for Circular and Rectangular Pipes (Ratios for flow based on Manning's n varying with depth)

For rectangular pipe,

$$L = 4\,H \text{ or } L = (H)^{1/2} \cdot \frac{V}{2}$$

Finding the Basin Width

The minimum width, W, of the basin downstream of the pipe's flared end section is set at:

For circular pipes:

$$W = 4\,D$$

For rectangular pipe:

$$W = w + 4H$$

Other Design Requirements

- All slopes in the preshaped riprapped basin are 2H to 1V.
- Provide pipe joint fasteners and a structural concrete cutoff wall at the end of the flared end section for a circular pipe, or a headwall with wing walls and a paved bottom between the walls, both with a cutoff wall that extends down to a depth of

  $$B = \frac{D}{2} + T \text{ or } B = \frac{H}{2} + T$$

- The riprap must be extended up the outlet embankment's slope to the mid-pipe level.

Examples

Example 1 - Circular pipe on a relatively flat slope.

Given:
Design flow, Q = 90 cfs;
Tailwater depth, y_t = 1.0 feet
Pipe Diameter D = 4.0 feet;
Slope S = 0.005 ft/ft
Manning's n = 0.013

Step 1. Determine if method is applicable: $y_t < D/3$; namely, low tailwater.

Step 2. Calculate the capacity of the pipe flowing full: Q_{full} = 102 cfs is found using the Manning's Equation.

Step 3. Using the Q/Q_{full} = 0.88 ratio, Figure 2 gives d/D = 0.82 for a circular pipe.

Step 4. Calculate: $Q/D^{2.5}$ = 2.81. Use this in Figure 3 to find d/D = 0.57.

Step 5. Since the smaller of the two d/D ratios is 0.57, use it to calculate depth, d, at the outlet and then in Figure 2 to find the ratio for A/A_{full} = 0.59.

$d = (d/D) \cdot D = 0.57 \cdot 4.0 = 2.28$ feet

Step 6. Using the A/A_{full} = 0.59 ratio, calculate flow area and velocity at the end of the pipe:

$A = (A/A_{full}) \cdot A_{full} = (0.59) \cdot (\pi \cdot 2.0^2)$ = 7.41 square feet

$V = (Q/A) = (90) / (7.41) = 12.1$ feet per second

Step 7. Calculate the riprap sizing design parameter, P_d, and use it in Figure 4 to find the appropriate riprap size:

$$P_d = \left(V^2 + g \cdot d\right)^{1/2}$$

$= (12.1^2 + 32.2 \cdot 2.28)^{1/2} = 14.8$;

Use Type L Riprap

Step 8. Calculate the minimum thickness of the riprap layer for D_{50} = 9 inches:

$T = 1.75 \cdot 9.0 = 15.75$ inches

Use T = 16 inches.

Step 9. Find the length of the basin, namely the greater of the following two lengths:

$L = (D^{1/2}) \cdot (V/2) = 4^{1/2} \cdot (12.1 / 2) =$ 12.1 feet

$L = (d/D) \cdot D = 4 \cdot 4 =$ **16 feet**
(Greater of the two: **use this value.**)

Step 10. Find the width of the riprap basin:

$W = 4 \cdot D = 4 \cdot 4 =$ **16 feet**

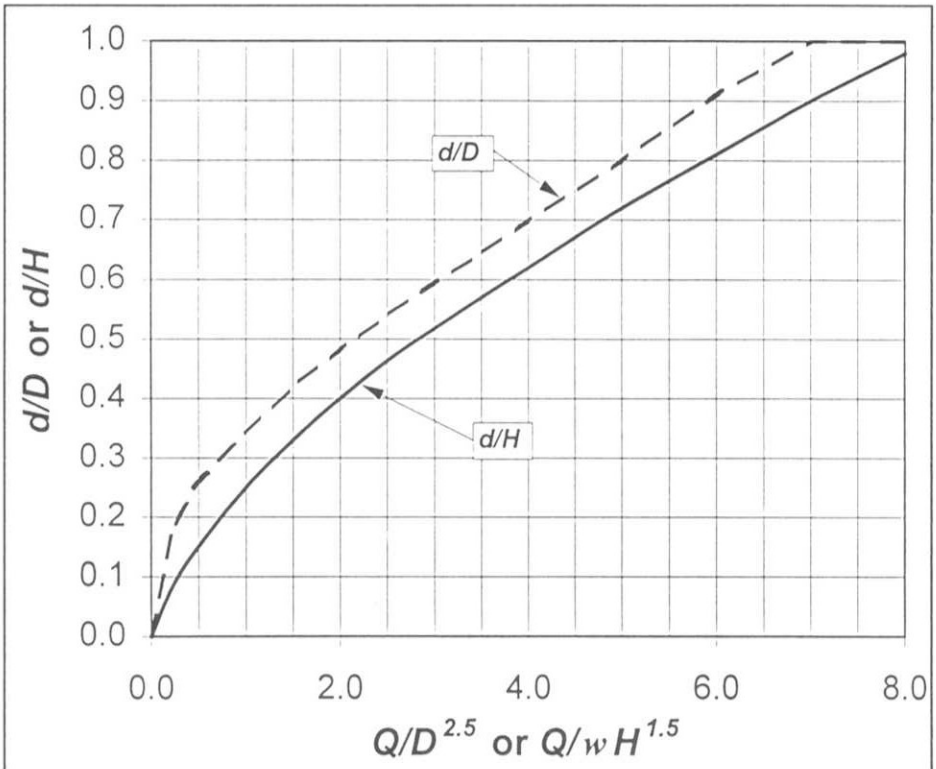


Figure 3: Brink Depth for Horizontal Pipe Outlets

Example 2 - Rectangular pipe on a fairly steep slope.

Given:
Design flow $Q = 300$ cfs;
Tailwater depth $y_t = 1.0$ feet
Box Height $H = 4.0$ feet,
Width $w = 5.0$ feet
Slope $S = 0.05$ ft/ft;
Manning's $n = 0.013$

Step 1. Determine if method is applicable: $y_t < H/3$; namely, low tailwater.

Step 2. Calculate the capacity of the pipe flowing full:

$Q_{full} = 426$ cfs is found using the Manning's Equation.

Step 3. Using the $Q/Q_{full} = 0.70$ ratio, Figure 2 gives the ratio $d/H = 0.73$.

Step 4. Calculate $Q/wH^{1.5} = 7.50$ and use this in Figure 3 to find $d/H = 0.94$.

Step 5. Since the smaller of the two d/H ratios is 0.73, use it to find the depth, d, at the outlet and in Figure 2 to find the ratio of $A/A_{full} = 0.73$.

$d = 0.73 \cdot 4.0 = 2.92$ feet

Step 6. Using $A/A_{full} = 0.73$ ratio, calculate the flow area and velocity at the end of the pipe:

$A = A/A_{full} \cdot A_{full} = (0.73) \cdot (4 \cdot 5) =$ 14.6 square feet

$V = Q/A = (300) / (14.6) = 20.5$ feet per second

Step 7. Calculate the riprap sizing design parameter, P_d, and use it in Figure 4 find the appropriate riprap size:

$P_d = (20.5^2 + 32.2 \cdot 2.92)^{1/2} = 22.7$;
Use Type M Riprap

Step 8. Calculate the minimum thickness of the riprap layer for $D_{50} =$ 12 inches:

$T = 1.75 \cdot 12.0 =$ **21 inches**.

Step 9. Find the length of the basin, namely the greater of the following two lengths:

$L = 4 \cdot H = 16$ feet

$L = (H^{1/2}) \cdot (V/2) = 4^{1/2} \cdot (20.5 / 2) =$ **20.5 feet (use this length)**

Step 10. Find the width of the riprap basin:

$W = w + 4H = 5 + 4 \cdot 4 =$ **21 feet**

Acknowledgments

The authors express their appreciation to Bill DeGroot and Bryan Kohlenberg, Urban Drainage and Flood Control District and Besharah Najjar, Adams County Engineering Department for their review and suggestions; to Bryan for the preparation of the design examples; and to Ken McKenzie and Vince Vigil, the District's student interns for the preparation of the graphics.

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The information on circular pipes in Table 2 was taken from: Chow, Ven Te (1959). *Open-channel Hydraulics.* McGraw-Hill Book Company, Inc., New York, page 135.

The information on brink depth for mild slopes and size of riprap is taken from: Stevens, M.A., (1969). *Scour In Riprap At Culvert Outlets.* Ph.D. dissertation, Civil Engineering Department, Colorado State University, Ft. Collins, Colorado.

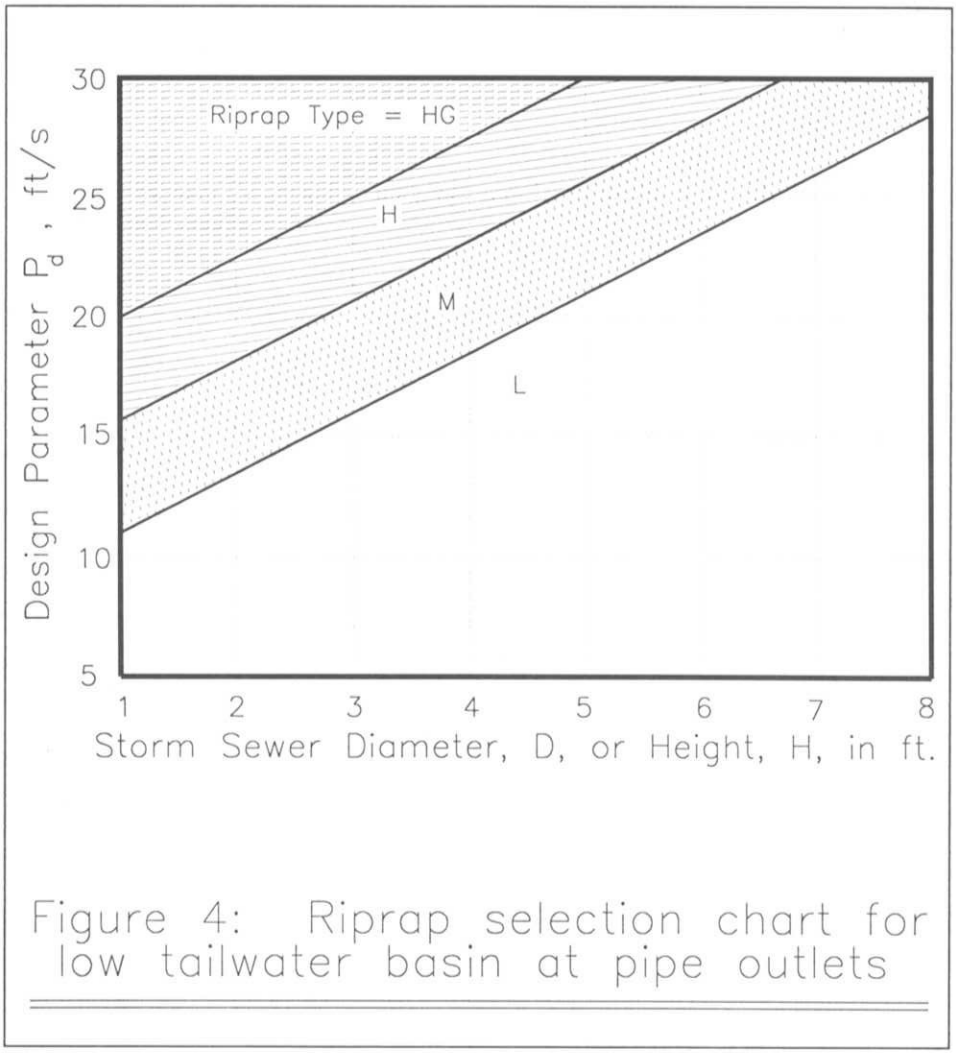

Figure 4: Riprap selection chart for low tailwater basin at pipe outlets

Tucker (Continued from page 3)

regulation and guidelines.

The current recommendation being considered and debated would define Phase II municipalities as an incorporated place, county or other governmental entity located in an urbanized area and not already required to get a municipal separate storm sewer permit under Phase I of the NPDES stormwater program. In addition, any other incorporated place, county or governmental entity can be designated by the permitting authority which will either be a state or EPA. An urbanized area, by definition, consists of 50,000 or more population. It could be one town of over 50,000 or it could be several smaller towns combined that are over 50,000 in population. EPA's draft proposal would require all municipalities in urbanized areas to develop a minimum stormwater program consisting of public involvement/education and outreach on stormwater impacts, illicit connection and discharge detection and elimination, construction site sediment and erosion control, post-construction stormwater management in new development and re-development, and pollution prevention/good housekeeping of municipal operations. Municipalities that fall under the permit requirements will have to either apply for an individual permit or seek coverage under a general permit if one is available in the state. EPA's proposal would simplify the application process vis a vis Phase I applications.

The big picture is that EPA expects that first round municipal permits will be issued by the year 2002 with municipalities implementing the five minimum measures discussed above. Second round permits would be issued about five years later in the year 2007. Permits might be stepped up in terms of requirements of municipalities depending on whether or not water quality standards were being achieved. Third round permits would be issued about 2012. Again, requirements might be stepped up even further depending on compliance with water quality standards.

The EPA is looking at watershed management approaches to help determine what needs to be done in the future. At this point in time the process known as Total Maximum Daily Load Analysis (TMDL) is undergoing a great deal of change and scrutiny. Current law requires that wherever a water body is not meeting its designated use the state must conduct a TMDL study that identifies the source of the pollutants causing the problem, identifies potential solutions, and allocates the responsibility to reduce pollutant loads. The studies are very complex to develop at this point in time and EPA has created another FACA to recommend how they might approach the TMDL issue. The bottom line is that more emphasis will be directed toward watershed analysis which would include evaluating the contribution of point and non-point sources to receiving waters. This means that municipal stormwater discharges will be involved along with the classic point source contributors such as treatment plants and non-point contributors such as the farming community.

There is a lot of popular support for clean water and municipalities along with industries are aware of this and are willing to implement programs that are reasonable in nature. However, as the future unfolds and the screws continue to be tightened there might be a point where that support starts to crack. Time will tell.

An emerging issue is one of controlling the rate and volume of stormwater runoff through the NPDES permit system. Some on the FACA committee have indicated they feel that impervious surfaces in urban areas should be limited to 10 to 15 per cent and that runoff volumes should be limited to no more than a 15 or 20 per cent increase over historical values. So far, the NPDES program has been limited to control and regulation of stormwater quality and not quantity. Putting the regulation and control of stormwater quantity under the NPDES regulatory program would put the federal government directly in the land use regulation business. Local governments for many years have been requiring detention to reduce the impact of stormwater flows, but the notion of putting this under federal control is of great concern. The FACA committees have yet to fully debate this difficult issue.

DISTRICT & DRCOG AGREE TO PREPARE A CONSTRUCTION ACTIVITIES MANAGEMENT TRAINING VIDEO

By Ben Urbonas

In May of 1996, the Denver Regional Council of Governments (DRCOG) entered into an agreement with the State of Colorado Department of Public Health and Environment to prepare a training video for the installation and maintenance of storm water Best Management Practices (BMPs) associated with construction activities. This is being funded by a pass-through Section 319 EPA grant.

The Urban Drainage and Flood Control District (District) sees this as an opportunity to develop valuable educational materials and to work with another regional agency that also deals with urban growth issues and their effect on local receiving waters. As a result, the District has entered into an agreement with DRCOG to providing a substantial portion of the local match needed for this project and to work with its staff to produce this training video. The Colorado Department of Transportation (CDOT) has also expressed an interest in this project and we hope will join this effort by contributing their professional video production support and the use of some of their construction sites for filming. We also hope that some of the local government and private parties will join this effort by providing access to construction activities for filming.

The Video will be professionally scripted and produced. DRCOG will set up an advisory committee with expertise in construction, education, erosion control, and other relevant areas. When finished the footage will include guidance on the proper selection, design, installation, inspection and maintenance procedures of these BMPs, consistent with District and CDOT criteria and with the needs of this region. It will supplement the current training activities by the Red Rocks Community College and others, and will make erosion control technology more accessible to everyone in Colorado.

PLANNING PROGRAM ACTIVITIES

by
Ben Urbonas
Chief, Master Planning Program

Planning Projects

The table "Status Of Planning Projects" lists the projects that were under way or completed in 1996 and the ones we hope to begin in 1997. We will begin the consultant selection process for the 1997 projects as soon as the funding agreements are executed between the District and each project's local sponsors. This is expected to occur anytime between February and November.

Only one of the ongoing planning projects was completed in 1996, although we came close to completing three more. Westerly Creek Upstream of Havana now has the distinction of being the longest ongoing planning project the District has ever had. It has been under way since 1990 and is an example of a project that gets stalled because of changes in staff, changes in policies and direction, and for many other reasons as it moves forward. However, this is atypical and we try very hard to move these projects forward as rapidly as possible. Typically a master plan is completed within one to two years.

STATUS OF PLANNING PROJECTS

Project	Sponsor(s)	Consultant	Status
Westerly Creek U. S. of Havana	Aurora	Merrick	Completed in 1996
Niver, Brantner & Grange Hall Cr. Updates	Thornton & Adams Co.	Kiowa	90% Complete
Arapahoe & Magpie Gulches	Golden & Jefferson Co.	WRC Engineering	98% Complete
Big Dry Cr. (ARAPCO) Update	Arapahoe Co., Douglas Co., Greenwood Village, Englewood, Littleton	WRC Engineering	95% Complete
Willow/Little Willow Cr.	Douglas Co.	Greenhorne & O'Mara, Inc.	40% Complete
Brighton Basin	Brighton & Adams Co.	WRC Engineering	25% Complete
Cherry Creek - Reservoir to County Line	Arapahoe Co. & Cherry Cr. Water Quality Authority	n/a	Mapping under way.
East Henry's Lake Trib. to Bear Creek	Denver, Lakewood & Jefferson Co.	n/a	Mapping done Select Engineer
City of Englewood OSP	Englewood	n/a	Mapping under way.
Pleasantview Area OSP	Jefferson Co. & Lakewood	Turner Collie & Braden, Inc.	15% Complete
Lower Box Elder Cr. OSP	Adams Co.	n/a	Scheduled for 1997
Areas SE of 54th & Pecos Trib to SPR	Denver & Adams Co.	n/a	Scheduled for 1997
Misc. Big Dry Cr. & Slaughterhouse Gulch Outfalls	Arapahoe Co., Greenwood Village	n/a	Scheduled for 1997
Broomfield & Vicinity MP Updates	Broomfield, Westminster	n/a	Scheduled for 1997
Quincy Reservoir Watershed Outfall Plan	Aurora	n/a/	Scheduled for 1997
Sulphur & Tallman Gulches Outfall Plan	Douglas Co., Parker	n/a	Scheduled for 1997

Technology Transfer & Education

Erosion Control Training

In our last issue I mentioned that Red Rocks Community College is offering training and certification (the latter for Colorado Department of Transportation) in stormwater quality management during construction activities. Contact Scott Olson at Red Rocks for information: telephone 988-6160, X-282). This training program was originally started in cooperation and sponsorship by the Colorado Department of Transportation and the District. We encourage all municipal officials, consultants and construction contractors to take this class and to obtain the CDOT certification.

Erosion Control Video

The District has entered into an agreement with the Denver Regional Council of Governments (DRCOG) to develop a training video for the selection, design, installation and maintenance of stormwater quality management activities and facilities during construction. DRCOG has received a Section 319 grant from EPA through the Colorado Department of Health and Environment (CDOHE) for this project and the District is contributing a significant portion of the local match. We are exited about this project and hope to have a video addressing the conditions faced during construction in Colorado, especially within its semi-arid regions.

Software

The District and *Computer Software Library, Inc.*, the District's software distribution agent, cooperated to upgrade the District's hydrologic software. *CUHPFPC* and *UDSWM386* are expanded and updated versions of earlier software. *CUHPFPC* now provides for an option to account for the effects of hydraulically unconnected impervious areas and *UDSWM386* has corrected some of the problems reported by users and has been expanded to handle gutter/pipe numbers of up to 1900. Both have been compiled using the Microsoft FORTRAN Power Station 32 bit compiler. Both programs have undergone considerable testing and are now available through *Computer Software Library, Inc.* P.O. Box 27517, Denver, CO, 80227, Tel. 303-947-3413, FAX 303-985-8882.

Stormwater NPDES Activities

New EPA Initiatives

There is very little new to report on this topic. The Clean Water Act stalled in Congress and did not see daylight in 1996. No one can predict if it will move forward in 1997. However, EPA in August issued *Interim Permit Approach for Water Quality-Based Effluent Limitations in Storm Water Permits.* In a nutshell, the policy states: "The interim permit approach uses best management practices (BMPs) in first-round storm water permits, and expanded or better-tailored BMPs in subsequent permits, where necessary, to provide for attainment of water quality standards." It also states that each permit should include a monitoring

program to gather the "necessary information" to determine if such standards are being met and if "adjustments" need to be made to the municipality's BMP program. In other words, the beat goes on as the relentless march towards the mandate of end of pipe standards moves forward. What does this mean to municipalities and its local taxpayers? A very expensive mandated program unless the law is modified!

On September 30th, EPA issued a *Storm Water Phase II Draft Preliminary Concept Paper*. This document is the first formal step leading toward Federal regulations that will define the permits and their requirements for municipalities having less than 100,000 residents and for Phase II industrial/commercial sites. It is a complex document, stressing the need for state implemented general storm water discharge permits (although individual permits can be issued) that contain a number of required practices. This draft suggests that all municipalities located in metropolitan areas with 50,000 residents be covered by these permits. If you would like a copy of this document, call Dena at our office. We encourage all municipal officials to become involved in EPA's process to promulgate these regulations.

Denver, Aurora, Lakewood Receive Stormwater Discharge Permits

The three largest cities in the Denver area submitted their Part 2 Permit Applications to the State of Colorado in November, 1992. Their permits were issued in May, 1996. They contain specific provisions in how, by whom, and when certain urban activities, such as street sweeping, inlet cleaning, maintenance of detention basins, etc. will be performed. These activities, required by the permits, will take precedence over others for the cities to not be in violation of their provisions.

These permits also require the three cities to develop a wet weather monitoring program that supports the State's and DRCOG's Total Daily Maximum Load (TMDL) plan development and ongoing activities. The District has entered into agreements with these three cities to assist them to comply with the wet weather monitoring requirements and the development of the certain public education materials.

Arapahoe County Phase 1 Application

In 1995, Arapahoe County was notified by the state that it now has an urban area population of over 100,000 and this put them into the Phase 1 category for municipal stormwater NPDES permitting. The District is assisting the county as it begins to prepare Part 1 of its application. If we think that the other three applicants had complicated institutional issues, we have seen nothing yet. The county has to address a number of metropolitan, water and sanitation and other special districts that have stormwater responsibilities. In addition, part of the county is also within the Cherry Creek Basin Water Quality Authority. Who will ultimately be responsible for each entity's performance will require agreements between all concerned.

For the most part the county is taking advantage of the protocols developed by the Joint Task Force (which included Arapahoe County) when the initial permit application requirements were being defined for the three cities that now have received their permits.

Offer of Assistance

Should your city or county (i.e., if within the District's service area) decide to begin any work preparing information that will lead toward a permit application, or is taking an initiative to develop its own stormwater quality management program, or simply wants to develop a stormwater system inventory, call us. We can provide you with advice, a fully developed set of consistent protocols, and data management tools that will help you with these goals.

DISTRICT SUPPORTS ASCE IN AN EFFORT TO DEFINE BMP PARAMETERS FOR EPA

Although there are many ongoing efforts in the United States to compile and evaluate performance data about structural stormwater best management practices (i.e., BMPs), there is no known authoritative nationwide quantitative evaluation of these practices. At the same time there appears to be a dearth of field data that permits quantitative evaluation of non-structural BMPs. This was discussed in much detail at the 1994 Engineering Foundation Conference on *Stormwater NPDES Monitoring Needs* by Ben Urbonas. This conference was co-sponsored by the Environmental Protection Agency (EPA), the American Society of Civil Engineers (ASCE) Urban Water Resources Research Council (UWRRC) and the American Public Works Association.

As a follow up, in 1995 EPA contracted with ASCE to have UWRRC take the lead in the development of BMP effectiveness data screening and evaluation protocols, and named Ben Urbonas of the District and Eric Strecker of Woodward Clyde as the principal investigators for this effort. ASCE in turn signed an agreement with the District for Ben's portion of the work. Eric worked on identifying the sources of available data, including data that is not readily available in literature or in EPA data bases.

Ben has turned over to EPA a list of recommended parameters and constituents needed to qualify any BMP data set for inclusion in a nationwide data base, yet to be developed, for BMP evaluation purposes. Eric, with Ben's input is currently developing recommendations on how to evaluate available data to produce quantifiable results that will help with the selection, analysis and design of various BMPs, regardless of their location in the United States. All work was reviewed by an advisory panel of 30 professionals from a variety of organizations in the United States and Canada.

Sand Filter **(From page 1)**

summer monitoring season of less than 15% after all the flow by-pass volume was accounted for. This compares poorly with the more than 85% TSS removal rates reported in the literature, and confirmed by District's field tests, for that portion of the runoff that actually flowed through the filter.

Flow bypasses were anticipated in the design of this test installation because it was designed to be "stressed" in order to more quickly reveal how much maintenance a sand filter BMP would need. The rate at which it sealed and lost hydraulic conductivity was a surprise however. Clearly, if these findings can be extrapolated to other installations, three concerns emerge: (1) there probably is a need for an aggressive maintenance program to keep such filters operational, (2) the filters probably need to be sized larger than most current design recommendations suggest, and/or (3) the filters need formal stormwater capture volume basin upstream (Urbonas and Ruzzo, 1986; City of Austin, 1988) that balance the filters' flow-through rates with the population of storms for which the filters are being designed. Any of these have significant economic and operational consequences. We suggest all of these be considered whenever sand filters or other stormwater quality BMPs are being selected.

A recent report by Bell *et. al.* (1996), in his very extensive report on the performance of sand filters in the Alexandria, VA area, also reported on some bypasses of flow around filters, but he did not address the fraction of the total annual runoff that bypassed them. Bell's group primarily field tested the Delaware filter that was originally suggested by Shaver and Baldwin. Their findings suggested a longer clogging period than was found by the authors although their data were insufficient to judge if the clogging *rates* were similar. It is not surprising that the Delaware filters did not clog as rapidly as the Denver test suggest since they were much larger in proportion to the tributary impervious area, had larger storage volumes above the filters, and the inflow at their test sites had much lower average event mean concentrations (EMC) of TSS than were found at the test site in the Denver area (60mg/l vs. 400 mg/l). This suggests that adequately sized filters, ones that are sized with maintenance frequency, the average annual runoff and its average EMC of TSS in mind, can have acceptable performance for more that one season. However, the three basic points about filter maintenance and design made earlier cannot be forgotten whenever media filters are considered for use.

Commentary on Findings

Clearly, filters can be popular BMPs where land area is at a premium, but they need regular maintenance to keep working. It is important to recognize that a media filter, once clogged, will drain at very slow rates (i.e., falling head of approximately 0.5 inches per hour) and stormwater will either pond upstream of the filter of bypass it. Either condition is unacceptable. In the first case the ponding water may be a nuisance or create dangerous situations. In the latter, only a fraction of the stormwater that arrives at the filter actually receives the treatment efficiencies reported for media filters.

To compensate for this potential problem it is necessary to properly size the filters for the expected maintenance cycle that matches both the average annual runoff volume and the average annual EMC of TSS in its runoff. If the filter cannot be made large enough to pass through the design event without backing up water when it is partially clogged, provide sufficient stormwater capture detention volume upstream that is in balance with the filter's clogged flow-through rate. Making the filter larger will reduce its needed maintenance frequency. Also, remember that media filters, without upstream detention, have no effect on stormwater runoff flow rates. As a result, they have do not attenuate the increases in runoff rates that result when land urbanizes.

When a media filter is located within an underground vault, such as a water quality inlet, it is out-of-sight-and-out-of-mind and is likely to not receive the needed maintenance attention of a visible surface facility. As a result, regular inspection programs are a must. Otherwise there is nothing to insure that the filter will continue to operate properly.

Sand filter inlets suggested by Shaver and Baldwin and by City of Austin, while effective, are expensive to construct. Above ground filter basins can be more expensive to build than simple extended detention basins. It has been argued that media filters are most likely to be used where land costs are very high. However, comparisons made by the authors of filter basins designed with clogging and minimal maintenance in mind against the detention basins and retention ponds revealed that filter basins often require similar land areas to construct as do extended detention basins. If this is the case, and recent findings suggest it is, the life cycle costs of functional media filters may actually be more than those of extended detention basins.

Acknowledgments

The authors acknowledge the help of Richard Ommert, engineering student intern with the District and Curtis Neufeld, formerly an engineering student intern with the District and now a project engineer with Greenhorne and O'Mara. Their hard work and dedication in collecting and analyzing the field data is much appreciated. The cooperation and assistance of Jerry Goldman and Jay Hutchinson of the City of Lakewood are also acknowledged. Without their help, the installation, maintenance and testing of this facility would not have been possible.

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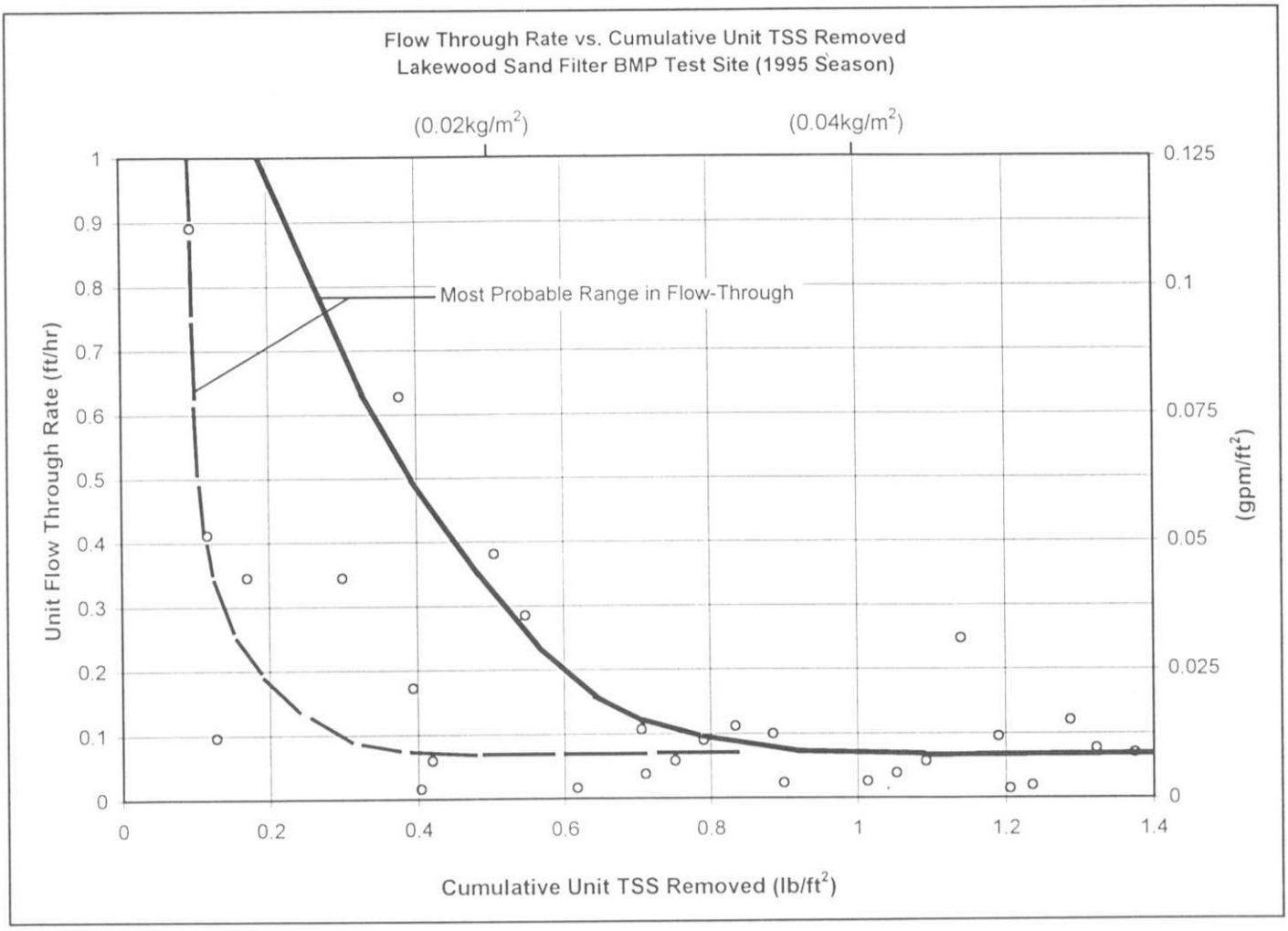


South Platte River Program Notes

by
Ben Urbonas, P.E., Chief
and
Bryan W. Kohlenberg, P.E., Project Engineer
South Platte River Program

Local Initiatives Along the Platte

City and County of Denver

Last year the City and County of Denver launched a major South Platte River initiative. The Mayor set up a special commission with a diverse membership representing a variety of federal, state and local organizations with interests in technical, neighborhood redevelopment, political, fiscal, environmental and other issues. The commission is supported by a number of working groups that are addressing minimum river flows for a fishery and in-river recreation, trails and recreation along the river, water quality, wildlife, local flora and fauna, rafting and kayaking, aquatic habitat, open space needs, river stability, etc. As a result, these working groups and the commission are looking at the river and its potential from a holistic perspective. One of the outcomes of this effort is that Great Outdoors Colorado (GOCO) has awarded Denver a $6,000,000 grant for river parks and river habitat improvements.

The District is encouraged by this attention to the river and is working with Denver to implement some of the suggested improvements. Our primary involvement is in areas that address the river's stability, maintenance access, channel maintenance, flood control and related river improvements. All of the projects that we now fund or develop with Denver or other communities try to address all of the issues listed above as being addressed by Denver's South Platte River Commission.

Adams County

In 1995, Adams County also began a comprehensive look at the South Platte River corridor as a resource. In recent years urban development has resulted in pressures on the remaining open space resources along the river. Using a grant from GOCO the county constituted a steering committee consisting of county and city elected officials and "partners" work groups represented by a variety of interests, not unsimilar to what was done by Denver. The county also hired a consultant to inventory open space resource and recreational needs of the county and of various cities within the county. Using this information the consultant will work with the steering committee and the partners work groups to develop a plan for the acquisition and preservation of these resources. The District is represented on the partners group and is cooperating with the county to develop their South Platte River plan.

City of Littleton

Along the southern end of the South Platte River within the District, the City of Littleton and South Suburban Parks and Recreation District are working together to improve the river for rafting, kayaking and fish migration. The District was asked to assist with the installation of a boat and fish passage chute just downstream of Highway C-470. This is the site of a major sanitary sewer crossing that has been helping to control the river bottom from head cutting upstream.

Over the years the South Platte River channel bottom has incised downward, leaving this sewer line's encasement exposed. A five to six foot vertical drop had developed downstream of this line. This situation made safe boat passage impossible and eliminated the possibility for fish migration upstream.

The District had an interest to buttress the sewer line in order to stabilize the river from further degradation. We worked with the owners of the sewer line, City of Littleton and South Suburban Parks and Recreation District to install a partially grouted large boulder sloping buttress downstream of the sewer line. Since access was along property owned by the US Army Corps of Engineers, the Corps was asked to expedite needed permits. The Corps cooperated and expedited the issuance of all needed permits for this project.

The project was designed and constructed to provide for boater passage and fish migration. To help with this function, the City of Littleton provided the services of an expert in fisheries habitats to help us properly align the low flow chute for maximum habitat enhancement. During construction care was taken not to disturb healthy stands of sandbar willow on the east bank and to revegetate and restore all disturbed areas with indigenous grass and shrub species. See the before and after photographs of the site accompanying this article.

Maintenance Activities

Routine Maintenance

In 1996, the South Platte River routine maintenance included an *equivalent* of 58 miles of trail edge mowing, tree trimming and pruning along 9 miles of the river trail, and trash and debris pickup and removal along 158 miles of the river. Over 50 truckloads of trash and debris were removed and taken to a landfill. These quantities do not include the trash picked up by local government personnel, volunteer groups, or the trash removed from trash receptacles maintained by park personnel along all recreational trails.

Although this type of routine maintenance often is not highly visible and often is not noticed or recognized by the public, without it the South Platte River corridor within the District would have an entirely different "look" and "feel." This type of maintenance we believe to be essential to provide the public with a more pleasant experience whenever visiting the many trail and pocket park facilities that now exist along the 41 miles of the South Platte River between Chatfield Reservoir and the Weld/Adams County line.

Restoration Maintenance

The restoration maintenance program continued to repair erosion damage along the combined recreation and maintenance trail; repair the trail and maintenance access bridges; cut and remove large numbers of dead elm trees in Adams County (Franklin Street to the Sand Creek confluence) which were the victims of a Dutch Elm Disease epidemic in 1992-93; restore a

damaged water diversion structure's boat chute; and stabilize, rehabilitate, and revegetate approximately 1500 feet of river banks in the City of Brighton and in Adams County.

The largest restoration maintenance project in 1996 was the aforementioned sewer line buttressing project just downstream of Highway C-470 in Littleton's South Platte Park. A total of $210,000 was spent to design and construct this boulder buttress structure. Littleton and the owners of the sewer contributed $50,000 to help fund this much needed project. South Suburban Parks and Recreation District also contributed their time and organized volunteers to assist with the revegetation efforts - Thanks to all! We are pleased to say this project has received favorable comments from many who have seen it.

A second restoration project now under construction is a stretch of the west bank just north of 160th Avenue in the City of Brighton. The city recently acquired this property that contains a wonderful cottonwood grove in a relatively undisturbed natural area along the river. The river bank was undermined over the last few years, with many of the large trees now in danger of being lost. The District will rehabilitate and stabilize this bank and then revegetate it with indigenous riparian and dry land species.

Other restoration maintenance projects completed in 1996 include the reconstruction of approximately 50 feet of concrete maintenance access trail, which also serves as a recreational trail, at a large storm sewer outfall in north Denver; and the rehabilitation of a damaged boat chute and its maintenance access bench at the Overland Park Golf Course water diversion structure upstream of Florida Avenue.

This year we were pleased to work with young people from *Fresh Start, Inc.*, a not-for-profit organization that works with what some call "high-risk youth." Their goal is to help the young people become motivated, capable, self-sufficient individuals. Under the guidance of D. Grover, Dan Lee, and the District staff, approximately 10 students formulated a revegetation site plan for the installation of wetland plants in and around a large storm sewer outfall at Arizona Avenue in Denver. The District provided the needed topsoil and plants while the students provided ingenuity, enthusiasm, hard-work, fun and a job well done. Unfortunately, some of the plants were washed out by high runoff before solid root growth could develop. We look forward to working with this organization again in 1997.

Cooperative Projects With Private Property Owners

Miles Project

We have now completed the construction of this project that was started in 1995. Readers may recall last year we described how the U. S. Environmental Agency (EPA) issued to Mr. Miles an Administrative Order to remove unauthorized fill from his river bank property. Under the watchful eye of the EPA the District-hired contractor removed over 500 cubic yards of trash and debris, including broken asphalt, railroad track rails, tires, construction debris, and approximately 70 cubic yards of asbestos cement pipe. The latter required special removal and disposal procedures. It had been rumored that a car body or two might be found, but no such luck!

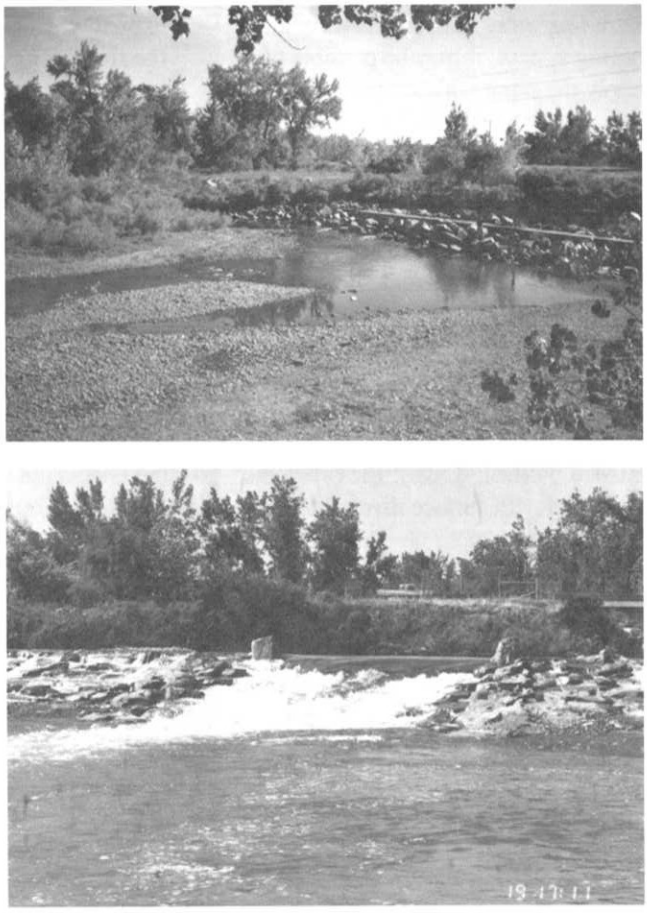
The newly restored bank is stabilized with buried riprap and revegetated with native grass and willows. See the photographs showing the before-and-after views of this project. Soon after completion and before vegetation could establish roots, a 5-year flood flow of approximately 7,500 cfs occurred. This flow exposed much of the buried riprap and contributed to the mortality rate of the live staked willows. Next year we plan to revegetate this area again.

Cooley Gravel Project

The Cooley Gravel Cooperative Project north of 88th Avenue started in 1995 and is now 70 percent complete. This project installed one more sloping boulder river bottom degradation check structure. Cooley Gravel is providing the labor and equipment while the District is paying for the materials. The remaining bank rehabilitation work should be completed early in 1997.

Rogers Project

In exchange for a perpetual river flowage and maintenance access easement, the District is now participating in the bank stabilization and rehabilitation of 1,100 feet of river bank on the property owned by Mr. and Mrs. Jack Rogers. This west river bank project is located just upstream of East 168th Avenue in Adams County. When



C470 utility crossing before and after.

completed, this project will arrest active bank erosion that threatens to breach the existing berm between the river and an adjacent active sand and gravel operation. This work should also arrest abutment erosion at the 168th Avenue bridge. All work will be complete in spring of 1997.

Capital Improvement Projects

Upper Central Platte Valley Project

During the last two years we have been cooperating with the City and County of Denver to develop and design the Upper Central Platte Valley Project. Since we last reported on this, an understanding has been reached with the Public Service Company of Colorado (PSCo), the owners of the Zuni Electric and Steam Generating Plant, to have its cooling system eventually converted to a closed loop recirculating system. When this is done, only 10% of the currently diverted water will need to be diverted. This will permit a change in the way cooling water is diverted from the river.

Since a recirculation system needs much less water than a pass-through cooling system, it may be possible to supply the plant with an infiltration gallery instead of a surface diversion system. If this proves to be feasible, the advantages are profound. First, all surface diversion structures disappear. Second, the options for river rehabilitation expand and allow for a more "natural" appearance and habitat alternatives. Third, there are more options available for integrating fish habitat, rafting, kayaking, other recreation uses and aesthetics into the finished product. Lastly, the problems associated with surface diversions, such as the presence of sediment and floatables in the water, disappear.

The District and its consultant are now testing a prototype section of an infiltration gallery installed in the river bottom upstream of the Zuni plant. We expect to "stress test" this section under conditions that exceed what an operational gallery would encounter. At the end of the test we want to have no doubts that the recommended design will work. The testing will take place over the next 12 months, but we hope to have sufficient data to determine if this option is feasible within the next six months. The second six months of testing will be used to improve the final design and to fortify our confidence in this facility. There is no room for failure. The power generating plant has to have a reliable source of cooling water when it operates, bottom line!

Globeville Area Project

The other capital project we wrote about last year is located in the Globeville neighborhood in north Denver. Phase I of the project is now under construction. It covers 2,000 feet of the South Platte River. Although flood control is one of the primary reasons for this project, the improvements also focus on river bank rehabilitation and on improvements to a recreational trail, aquatic and terrestrial habitat, and on community access to the river. The design of Phase II, encompassing 5,000 feet of the river upstream of Phase I, is under way. We expect construction of Phase II to begin in October of 1997.

The funding for the final phase of this project, which is immediately downstream of Phase I, has yet to be secured. Denver and the District are exploring various ways to fund it. It is the key phase for flood protection. Without it the upstream two phases will not have sufficient capacity to protect the Globeville neighborhood and some of Adams County immediately downstream. At $6,000,000 it is also the most expensive and complex element of the entire project. Nevertheless, we hope to have it under construction within the next two to three years as well.

Once the project is fully completed, approximately 300 acres of inner-city existing residential, industrial and commercial area will be removed from the 100-year regulatory floodplain. In addition, 7,000 feet of the river's channel will have been rehabilitated; and a recreational trail separated from traffic and connected to the Adams County's trail system, and the community's access to the river and the environment for this old neighborhood of Denver will be significantly improved.

Other News

We have now completed the removal of infected dead Siberian Elm trees along the South Platte River through Denver and southern Adams County. Since this work was started in August of 1995, a total of about 1,500 trees have been cut and chipped.

The District and Denver Parks and Recreation Department have entered into an agreement to fund the replacement of two rapidly deteriorating timber pedestrian/ maintenance access bridges spanning the river. Over the next three to five years we hope to work with Denver to replace the deteriorating timber bridges that are still in service. The new steel bridges will require less maintenance and be much easier to use by maintenance equipment operators due to wider decks. They will also permit bikers, roller bladers and hikers to use these crossings with less conflict.

Before and after views of Miles' river bank rehabilitation maintenance project.

Professional Activities (Continued from page 2)

John Doerfer, Project Hydrologist, Master Planning Program

*Chairman of the Stormwater Quality Committee, Colorado Association of Stormwater and Floodplain Managers (CASFM).
*Chairman of Awards Committee, 1996 CASFM Annual Conference.
*"Stormwater Sand Filtration: A Solution or a Problem?" co-authored with Ben R. Urbonas and L. Scott Tucker, APWA Reporter, July, 1996.
*"Incorporating Water Quality into Drainageway and Watershed Plans," presented at the 1996 CASFM Annual Conference in Vail in September.
*Invited Speaker on stormwater master planning principles, Landscape Architecture program at UCD in Denver in November.

Mark Hunter, Chief, Maintenance Program

*Member of International Erosion Control Association (IECA) standards committee on riprap, standards committee on articulating blocks, and the by-laws committee.
*Secretary of the Steering Committee for the IECA-Mountain States Chapter.
*Panel member for the review and evaluation of proposed testing protocol for articulated concrete block, a Colorado State University project for the U.S. Army Corps of Engineers.

Mike Sarmento, Engineering Inspector, Maintenance Program

*Attended APWA Construction Inspection School in November.
*Attended ASCE Wetlands and 404 Permitting Seminar in November.

Paul Hindman, Project Engineer, Design and Construction Program

*Treasurer of the Colorado Chapter of APWA.
*Vice-Chairman of the Water Resources Committee of the Colorado Chapter of APWA.
*Speaker on drainageway construction at the APWA Construction Inspection School in October.
*Race director for the 2nd annual APWA Bike and Run for Education.

News Briefs

We're on the Web

As we go to press the District is on the verge of getting on the Web. We have a home page under design, which will be at: www.udfcd.org, and a bunch of e-mail addresses including:
Scott Tucker: lst@udfcd.org
Ben Urbonas: burbonas@udfcd.org
Dave Lloyd: dwl@udfcd.org
Bill DeGroot: bdegroot@udfcd.org
Kevin Stewart: kstewart@udfcd.org
Mark Hunter: mhhunter@udfcd.org

On our home page we hope to have some basic information about the District and the latest issue of *Flood Hazard News* (with color photos). If all goes well we may expand to include electronic files, like hydrology models, and our monument information.

District Wins Accounting Award

For the eighth year in a row the District has received a "Certificate of Achievement for Excellence in Financial Reporting" from the Government Finance Officers Association of the United States and Canada. The certificate is presented to government units whose comprehensive annual financial reports achieve the highest standards in government accounting and financial reporting. Congratulations to Frank Dobbins, Chief of Finance and Accounting, for continuing this string of awards.

Projects Win Awards

Three projects which were sponsored in part by the Urban Drainage and Flood Control District won "Colorado's Best of 1996" awards from the Colorado Association of Stormwater and Floodplain Managers at its annual conference in Vail in September. The Outstanding Project of the Year was the Goose Creek flood control channel designed by Greenhorne & O'Mara, Inc. and funded by the City of Boulder and the District.

Stormwater Management Planning for Stapleton Redevelopment, sponsored by the District and the City and County of Denver, and completed by McLaughlin Water Engineers, Ltd. and Wenk Associates, won an Honor Award for Outstanding Achievement.

Also winning an Honor Award was South Platte River Improvements - Confluence Park, sponsored by Denver and the District and designed by McLaughlin Water Engineers, Ltd. This project was featured in the cover story of the 1995 *Flood Hazard News*.

Bidtabs Program

The District has been utilizing and distributing the Bidtabs Program for seven years. It is continuously updated by the Design and Construction Program. The Bidtabs data contains bid unit price information on 113 District projects, and continues to grow.

This program is now widely distributed to consulting firms, contractors, and state and local government agencies, upon their request. Once you have requested the program, your name will be added to the Bidtabs User List, which allows you to receive any updated information.

The Bidtab information has been a very useful tool in estimating construction projects. The program can be run from DOS or Windows in a DOS shell. By March, the program will be provided in a Windows version. For more information contact Laura Garcia or Paul Hindman at (303) 455-6277.

Fifteen Years of Maintenance Costs

The maintenance program has completed its compilation of urban drainageway maintenance costs (first reported in *Flood Hazard News* last year). The result is a data base that can be used to show actual drainageway maintenance costs over the last 15 years for a variety of drainageway types.

Work records were analyzed going back to the beginning of the program in 1981. The types of maintenance work include mowing and debris pickups, local erosion repair, and major channel reconstruction. It should be noted that the mowing and debris pickups we do are on natural grass channels only. All our drainageway maintenance work is carried out through contracts with private contractors and consultants.

The data base can be sorted in a variety of formats depending on the information that is desired.

At the end of each year's drainageway maintenance activities we will add that year's cost information to the data base. As the period of time covered by the data base expands the output will become more representative of the cost of long term drainageway maintenance.

Please feel free to call Mark Hunter at 303-455-6277 or fax 303-455-7880 to review the results from this data base. Questions regarding specific drainageway types and cross-sections are welcome.

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
2480 West 26th Ave. #156-B
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