FLOOD CONTROL DISTRICT-69-URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

FLOOD HAZARD NEWS

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SOUTH PLATTE RIVER PROGRAM

By L. Scott Tucker, Executive Director
Ben Urbonas, Chief, South Platte River Program

STATE AUTHORIZES NEW PROGRAM

During the 1986 session the Colorado Legislature amended the District's statute to include authority for the District's Board to levy up to 0.1 mill for the South Platte River Program. This legislative act was signed by Governor Lamm in time for the Board to commence the program in January of 1987 with a budget of approximately $900,000. This program, like other District activities, is being implemented through contract services for maintenance, engineering, land acquisition, design and construction.

PROGRAM GOALS AND OBJECTIVES

In adopting a policy for the operation of the South Platte River Program, the Board defined the following goals and objectives:

I. Create a Special Revenue Fund — South Platte River.

The Board established a Special Revenue Fund for the South Platte River program. Monies for capital improvements will be allocated on an annual basis for projects in Arapahoe, Douglas, Jefferson, Denver, and Adams Counties. The allocations will be based on:

- timing of projects,
- availability of matching funds,
- relative need and priority of improvement,
- compatibility with the master plan, and
- distribution of funds to various counties.

Unlike the Capital Improvements Program and the Maintenance Program, no rigid formula was established for the allocation of funds to various counties. The Board recognizes that the South Platte River is a regional drainageway for all stormwater, regardless of its origin. All communities contribute drainage to this river and it is important that the problems resulting from this be addressed on an as-needed basis.

II. Cost Sharing of Capital Improvements.

Because of the river's regional nature, the Board decided that the District could increase its share of such projects. It established a goal that when funds are available the local share of capital projects could be as low as 25 percent. The board also recognized that the funds available are limited and that local governments or other parties may have to provide a share that exceeds the 25 percent minimum.

III. Adopt an Annual Work Program.

The Board will adopt an annual work program for the South Platte River that will generally include one or more of the following activities:

- maintenance activities,
- design and construction of improvements, recommended in the master plan,
- maintenance access acquisition, for both sides of river,
- stabilization of banks, and
- other activities as approved by the Board.

IV. River Maintenance.

The Board anticipates allocation of a portion of the South Platte River Fund toward maintenance of the river. Unlike capital projects, the District will contribute 100 percent toward such maintenance activities. Two types of maintenance will be provided.

- *Routine maintenance* will include general housekeeping such as trash and debris removal, mowing of grass and weeds adjacent to the maintenance/biker/hiker trails, minor erosion repair, and clearing and snagging of large debris in the river channel.
- *Restorative Maintenance* is to include repairing damages to maintenance trails, check structures and banks, and the fortification of facilities threatened by erosion and undermining.

FIRST YEAR'S EXPERIENCE

The South Platte River Program was started in January of 1987. The program responsibilities were assigned to Ben Urbonas, who now heads both the Master Planning Program and the South Platte River Program. In addition, Barbara Evans joined the District staff to work in both programs. After the first 10 months the South Platte River Program is well under way.

So far, one nearly completed capital improvement project is under way, a major drop structure at 88th Avenue; and an agreement has been signed with the City of Littleton to assist them with the construction of a new Belleview Avenue bridge. Also, agreement has been reached to replace a portion of the maintenance trail between 8th and 13th Avenues.

This year the District funded routine maintenance activities for almost 20 miles of the river. Routine maintenance activities were limited

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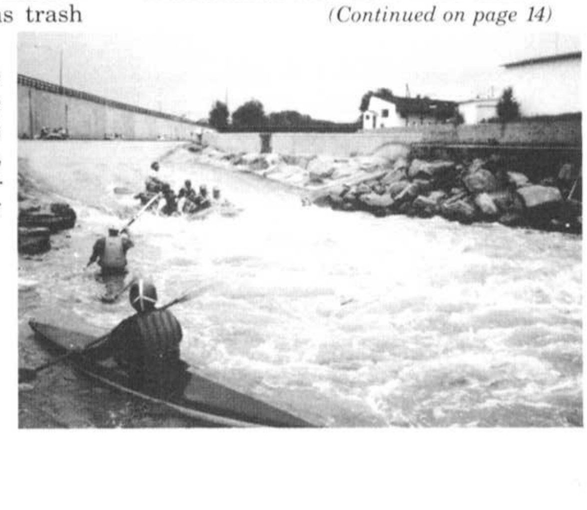

White water rafting in the middle of Denver on the South Platte River. This boat chute, which was added to an existing dam, made the river safer while lowering the upstream 100-year water surface profile.

Staff Members Become Authors

Urban Drainage & Flood Control District staff are heavily involved with preparation of the American Society of Civil Engineers forthcoming *Manual of Practice for the Design and Construction of Storm Drainage Systems.* Scott Tucker is authoring Chapter II of the book on "Regulatory and Legal Considerations." Mark Hunter is preparing text on maintenance of open channels, closed conduits and local drainage facilities. Kevin Stewart provides insight into risk assessment, early flood warning systems and the need to look beyond the 100-year design standard. Paul Hindman and David Lloyd have coauthored an excellent chapter on construction methods. Finally, Ben Urbonas will serve a major role as one of the principal editors of the *Manual of Practice* and is currently serving as a liaison between the Task Committee that is preparing the *Manual of Practice* and the sponsoring entity, ASCE's Urban Water Resources Research Council. The manual could be published as early as late 1988.

— Jonathan E. Jones,
***Manual of Practice* Editor**

CUHPE/PC PROGRAM INPUT FILE BUILDER

A new program was recently developed by Dan Norick, a student intern currently working for the Urban Drainage and Flood Control District. The program is available free of charge to all registered CUHPE/PC program owners. In the future it will be distributed along with any new CUHPE/PC programs ordered through our distributing agent, Dr. Guo. It is called CUHP-INP, is designed to assist the user in preparing and editing input files, and is fully menu driven.

Dan did an excellent job in writing the program; however, it is being distributed on "as is" basis. Neither Dan or the District warrantees this program. You will be provided a copy on the condition that you assume all risks associated with its use. *If you own the CUHPE/PC program and want to get a copy of CUHP-INP, send Dan a formatted blank 5¹/₄-inch diskette and a preaddressed stamped envelope.* Do not come to our offices to get a copy, but allow two to three weeks for delivery. All requests should be addressed to:

Dan Norick
Urban Drainage and Flood Control District
2480 W. 26th Avenue; Suite 156-B
Denver, CO 80211

Professional Activities of District Staff

Scott Tucker was a member of the judging panel for the Consulting Engineers Council Engineering Excellence awards in January.

Scott Tucker was a speaker at the 21st annual Water Pollution Control Federation Governmental Affairs Seminar in Washington, D.C. in March.

Ben Urbonas presented a lecture on "Practical Considerations in Storm Sewer Design" at a short course on storm sewer design given by the University of Colorado at Denver in May.

Kevin Stewart presented "Planning for the Inevitable — Urban Flash Flood Warning Programs in the Denver Metropolitan Area" at the 1987 Association of State Floodplain Managers conference in Seattle, WA, in June.

B.H. Hoffmaster was session chairman for an October Short Course on Soil-Cement Bank Protection sponsored by the Portland Cement Association, Geotechnical Group of the Colorado Section of ASCE, the City of Aurora and the District.

Scott Tucker, Ben Urbonas, Kevin Stewart and Bill DeGroot participated in the Colorado Urban Conservation Symposium in March.

Scott Tucker participated in a workshop on Use of Natural Hazards Research Results at The George Washington University in Washington, D.C. in June.

Paul Hindman is currently Vice-Chairman of the Water Resources Group of the Colorado Section of ASCE.

Ben Urbonas co-authored a paper with Professor James C.Y. Guo describing the District's newly released software program UDSEWER. Dr. Guo presented the paper at a stormwater modeler's conference held in Denver in April.

Scott Tucker chaired a session on Stormwater Permit Program at a conference of the Association of Metropolitan Sewerage Agencies in New Orleans in May.

Bill DeGroot was a discussant at the 1987 Workshop on Hazards Research and Applications at the University of Colorado in Boulder in July.

Scott Tucker chaired a panel discussion on Municipal Separate Storm Sewer Permit Regulations at the annual meeting of the National Association of Urban Flood Management Agencies in Washington in October.

Ben Urbonas was invited to describe Denver area and Colorado activities in drainage and stormwater quality at a Best Management Practices Symposium sponsored by the State of Maryland in August.

Scott Tucker was moderator for a session on Floods, Stormwater, and Dam Safety at the Colorado Water Engineering and Management Conference in Fort Collins in January.

NEW STAFF MEMBER

We are pleased to welcome Barbara Evans to the District's staff as a project engineer. Barbara is a registered professional engineer who is providing valuable help to the Master Planning and South Platte River Programs. She has a degree from the University of Colorado—Boulder in Environmental, Population and Organismic Biology which she has supplemented with numerous courses in civil engineering. Most of her postgraduate education has been in the areas of geotechnical, hydraulics and hydrology; and she expects to receive her MSCE in "the not too distant future." Barbara comes to us with considerable experience in consulting and public works engineering. We are delighted that she has joined us and look forward to working with her.

DISTRICT WINS AWARD

The Urban Drainage and Flood Control District has received a "Friend Award" from the National Association of County Park and Recreation Officials (an affiliate of the National Association of Counties). The award was given "In recognition of outstanding accomplishment in the field of parks and recreation."

The District was nominated by Roger Scott and Crtystal Gray from Adams County for its work in integrating park and recreation elements into its South Platte River master plan.

FOREIGN VISITORS

Again, we were visited by guests from Europe who had heard of the fine drainage and flood control work being done in the Denver area. Bengt Persson and Peter Stahre of Malmo, Sweden Utilities Department spent a day with us in September. They stopped here on their way to the APWA Convention in Chicago.

Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

The Haunting Spector of the Clean Water Act Amendments

One of the topics I have discussed in past *Flood Hazard News* issues has been the attempt of EPA to develop a program of regulating municipal separate stormwater discharges. The process continues and it is still one of importance to urban areas. Enough has happened since the last *Flood Hazard News* was published in December 1986, that it warrants further attention.

Congress passed Clean Water Act Amendment legislation late in the 1986 session. The amendments would have modified the requirements for obtaining permits for municipal separate storm sewer discharges. The President vetoed that legislation and the issue was dead for that session of Congress. However, the first bill to come out of the 1987 Congressional hopper was HR1 which included the same amendments to the Clean Water Act previously vetoed by the President. The President again vetoed the bill, but this time Congress overrode the veto and the bill became law on February 4, 1987. Title 4, Section 405 of HR1, on municipal and industrial stormwater discharges, sets forth new marching orders for a permitting process. While the new requirements are less onerous than previously required, municipal areas are none-the-less exposed to a permitting process where all the financial risk and exposure is at the local government level.

First, what does the new law require? Permits will be required for stormwater discharges from municipal separate storm sewer systems serving populations of 100,000 or more. Stormwater systems serving less than 100,000 do not have to worry about permits until October, 1992. With regard to the larger municipal systems EPA has until February 4, 1989, to establish regulations setting forth the permit application requirements for municipal separate storm sewer systems serving populations of 250,000 or more. Applications for permits for such discharges have to be submitted by February 4, 1990. By February 4, 1991, the EPA or the state, as the case may be, must issue or deny such permit applications. All permits shall provide for compliance no later than three years after the date of issuance of a permit. For municipal separate storm sewer systems serving populations from 100,000 to 250,000, the time table is two years following that for the systems greater than 250,000.

EPA is now in the process of writing regulations pursuant to the directive set forth in Section 405 of HR1. Provisions of Section 405 that will impact the writing of those regulations are as follows. Section 405 provides that discharges from municipal storm sewers may be issued on a system or jurisdiction wide basis. Previous legislation required the issuance of individual permits for each storm sewer outlet. An important requirement is that any permits for discharges from municipal separate storm sewers shall "require controls to reduce the discharge of pollutants to the maximum extent practicable including management practices, control techniques and system, design and engineering methods and such other provisions as the administrator or state determines appropriate for the control of such pollutants." This portion of the Act opens up the possibility that EPA may require local governments to initiate stormwater control measures. The cost of any such measures will be entirely borne by local governments. Until EPA writes regulations and until the permit requirements are actually seen it will be difficult to determine what kind of impact this will have on local governments. There is cause to worry, however, when EPA is setting the standards and local governments will have to pay for meeting those standards.

In addition, permits for discharges from municipal separate storm sewers shall include a requirement to effectively prohibit non-stormwater discharges illicit connections, into the storm sewers. This mandate by Congress to eliminate non-stormwaters into our storm sewers makes a lot of sense and should be done with or without the federal mandate.

It is difficult to know what the eventual impact will be of the municipal separate storm sewer permitting process on local governments. It is safe to say that local governments will be required to bear the burden of whatever cost is involved in applying for permits and then meeting the requirements set forth in the permits that are issued. Also, it is another intrusion into the activities of local government affairs by the federal government. Either EPA or the state acting in lieu of EPA, will be in the position of requiring local governments to take actions dealing with stormwater discharges regardless of whether the local government feels such actions are necessary and regardless of what the cost to local governments will be for meeting those permit requirements. A frightening thought indeed.

Proposed regulations will be published by EPA, probably by the summer of 1988. There will be a public comment period and in order to comply with the requirements of Section 405 EPA should issue final regulations by February 4, 1988. I strongly urge all local governments to carefully review the proposed regulations and provide comment to EPA on any concerns they may have.

The Role of UDFCD in the Area of Stormwater Quality

The push from Congress for municipal governments to address municipal separate storm sewer discharges has caused the Urban Drainage District to look more closely at its role in dealing with stormwater quality problems. The present enabling legislation of the District does not include any mention of stormwater quality. When the District was created in 1969 stormwater quality was not an issue and the entire focus of the organization was on drainage and flood control. With the increasing concern with stormwater quality and the inter-relationship between stormwater quality and stormwater quantity, the role of the District is becoming an issue. Our current thinking is that as long as we have no legislative authority and as long as we have no funding capability to address stormwater quality problems, the District will take no formal role in the stormwater quality area. We will, however, monitor the stormwater quality situation very carefully, keep the Board of

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PUBLIC-PRIVATE COOPERATION ON THE SOUTH PLATTE RIVER

by Ben Urbonas
Chief, South Platte River Program

River Degradation Problem Develops

During spring floods of 1984 and 1985 the South Platte River experienced severe degradation downstream of 88th Avenue in Adams County. This river degradation was caused by many factors which included reduced river bottom sediment movement caused by the construction of Chatfield, Cherry Creek and Bear Creek dams upstream of Denver; added urbanization in the upstream areas, in-stream gravel mining in the South Platte River, sand mining operations in the Sand Creek bed and many other factors. Also, during the 1984 spring snowmelt period, a gravel pit berm owned by Cooley Gravel Company located downstream of 88th Avenue was eroded away and the river changed its course to flow through this pit, which further accelerated the degradation.

All of this river bottom degradation was endangering the stability of the 88th Avenue bridge, a 16-inch Public Service Company gas line and several major water lines owned by the City of Thornton. In addition, river banks in this reach were being undermined and eroded away on several public and private properties, including land owned by American Continental Corporation, a land development group, and Cooley Gravel Company.

Cooperative Project is Funded

As a result of mutual concerns, the City of Thornton, Cooley Gravel, Public Service Company, Adams County and the District agreed to fund the design and construction of a major drop structure just downstream of 88th Avenue to arrest the continuing river degradation. Cooley Gravel Company also volunteered to regrade and stabilize the most critical reaches of the river banks and to install two rock river bottom checks, all located on their property.

The project, including engineering, cost approximately $600,000. The District was able, at that time, to contribute 75% of the costs; however, much of the credit has to go to the four local sponsors. The entire project would not have been possible without their support, financial commitments and encouragement. Although not one of the "official" sponsors, American Continental Company contributed some of the right-of-way to the City of Thornton. Their timely and expeditious contribution permitted the completion of this project during 1987.

Additional Efforts by a Gravel Company

While construction of the drop structure was underway, Cooley Gravel Company completed the river stabilization activities they agreed to do. Special thanks and recognition goes to Cooley for not only living up to their commitments 110%, but for completing one of the best gravel and river bank reclamation projects that I have observed. It was a real pleasure working with Paul Gesso, Rick Mergens and Tom Ballard on the construction of the drop structure and on their reclamation project. It is efforts such as these that we want to applaud and recognize. We hope that they continue their activities and good and responsible work along the South Platte River.

The drop structure consists of a grouted boulder section at a 10:1 slope (left) and a boat chute (right).

Final Wrapup

The basic work has been completed. What remains is the revegetation and landscaping of the drop structure construction site and Cooley's reclamation site. It is planned to reseed the disturbed areas around the drop structure in March of 1988 and to plant riparian species of trees and shrubs on the river banks before summer of 1988. Cooley has indicated they will also be planting a variety of trees and shrubs as part of their reclamation plan. In two or three years these activities will result in a scenic, environmentally enhanced and relatively stable reach of the river. Similar private-public sector cooperation will be pursued by the District.

THE WALLS OF CHERRY CREEK

by Mark R. Hunter,
Chief, Maintenance Program

Denver's story began in 1858 with the discovery of gold in the sand of Cherry Creek. Within a few months the sparkle of rich gold deposits in the mountains 25 miles to the west drew the prospectors and miners away from Denver. This left Denver to become the transportation and commerce hub for the region. Even then the people of Denver had a love-hate affair with the creek that flowed through the middle of their settlement. On one hand, pioneer Denver historian Jerome Smilely labelled it as "a nuisance, a blight and an abomination . . . it is a standing menace to life and property." On the other hand, the communities on each side of Cherry Creek put their buildings so close to the creek bed that the vigilant Indians warned them that the great waters would come and sweep them all away.

In 1864, only six years after Denver was settled Cherry Creek delivered its first recorded major flood. It flooded again in 1876, and again in 1885. Each time it tore out bridges, destroyed homes and businesses and flooded the railroad depots. Each time the level of flood protection that had been built proved painfully inadequate.

It wasn't until an era of civic improvements and beautification was initiated in 1904 by newly elected Mayor of Denver Robert Speer that significant effort was made to improve the safety and flood protection on Cherry Creek.

The year 1907 brought the first construction of reinforced vertical concrete walls on both sides of Cherry Creek. The reach between Colfax Avenue and Broadway was improved with about 9145 linear feet (total of both sides) of wall. Mr. Daniel McQuaid (Colorado Professional Engineer #157), who was General Foreman for construction, has documented that the project was not without its own difficulties as a 3,000 cfs flow on July 10, 1907, washed out forms and some recently completed wall sections. The concrete walls are 80 feet apart and 10 feet tall. According to Mr. McQuaid the footings for the walls are built on two parallel rows of wooden piles four feet apart. The piles were placed every 12 feet and are about 16 feet long. They were driven using horse operated pile drivers.

In 1908 the reach upstream from

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SPECIFICATIONS FOR ROCK AND GROUT USED IN GROUTED RIPRAP

by
Mark Hunter, Chief Maintenance Program and Paul Hindman, Project Engineer

Grouted Riprap

Riprap, a graded mixture of rock, is one of the most common materials used for erosion protection in open channel drainageways. Dumped riprap, also known as non-grouted riprap, is widely accepted as an adequate erosion protection product in situations where channel side slopes are less than 2 to 1 (horizontal to vertical) and when stream velocities are low enough to not initiate rock movement. In cases where the design parameters are more severe, grouted riprap may provide the best protection. In general terms, grouted riprap is made by filling the voids of dumped riprap with grout.

Construction Techniques

Several years of constructing grouted riprap have given insight into dealing with many of the typical problems that accompany grouted riprap. It also has provided the opportunity to try new materials and applications when appropriate. Below is a review of many useful techiques:

1. Vibration — This can solve many of the problems inherent in grouted riprap. It can speed up production by insuring uniform grout penetration into the whole rock mass. It can also overcome some of the drawbacks created by pump hoses that are too large, grout slump that is too low, or a riprap gradation that has too many fines. Vibrator technique is the same as for structural concrete. Vibration can be the most important step in constructing grouted riprap.
2. Fractured rock faces — The more jagged and rough the rock the better the grout adhesion. River-rounded boulders and cobbles simply don't have the "tooth" required for good grout bonding. Smooth-faced riprap could contribute to rocks popping out of the matrix or to shrinkage cracks at the rock faces.
3. Curing compound — Proper application of this type of product is as important to the integrity of grouted riprap as it is to any other concrete product. To achieve the needed workability, grout mix has a high water-cement ratio. This dilutes the cement paste which can lead to a more permeable, less durable grouted riprap. Proper and complete curing of the grout will help the most in terms of allowing the cement grains to hydrate completely to form a less permeable mass. This is especially relevant for grouted riprap since it can be subject to many wet/dry and freeze/thaw cycles in a year.
4. Fiber reinforcement — This recent innovation holds great promise as reinforcement in grout mixes. It has been used in grouted riprap where it reduced the shrinkage cracking and provided improved flow and workability. In recent pours of less than 100 cubic yards the added cost for fiber reinforcement has been in the range of six to eight dollars per cubic yard.
5. Grout coloring — Adding powdered dyes to the grout mix is very easy. This produces an integrally colored grout which can add subtle contrast to a grouted riprap facility. Difficulties can occur when trying to keep the grout color uniform for several truckloads.
6. Washing the grout — The grout will adhere to the rock much better if the rock has been sprayed with water. This will wet the rock surface so the rock won't draw hydration water out of the grout. It will also dislodge debris and gravel fines that are clinging to the rock.
7. Aesthetics — Good-looking grouted riprap is achievable. When done properly the grout won't be obvious until one looks closely at the facility. Ideally, the grout is pumped into the rock voids so that the voids fill from the bottom up. This requires the right kind of grout pump and hose and a rock gradation that has a low percentage of small material. These items are detailed below in the specifications.

   The voids in the rock should be filled to a level that leaves the rock exposed above the grout. This depth of penetration needs to be considered in the design of the structure. To increase the amount of visible rock the contractor can tilt-up occasional rocks by hand so more rock surface is visible. As the grouting operation moves along rocks can also be hand placed in open areas to reduce expanses of grout. These techniques require additional labor and are likely to be used only with smaller rock gradations.

   If the grouting operation obscures too many of the rocks with grout it may be necessary for the contractor to sand blast or use muriatic acid to remove grout from the rock surfaces that are to be visible. Both these techniques have environmental drawbacks and must be used with proper care.

   Another technique that requires some additional labor but results in a more attractive grouted rock is to have a laborer use a small sturdy broom or a gloved hand to smooth the wet grout. This quickly improves the appearance of the grout from that of dumped concrete to a look of finished mortar work.
8. Bedding — Requirements for bedding should be investigated and will be site specific dependant upon existing soils and the uses of the grouted riprap. In certain cases it may be appropriate to eliminate the use of bedding. For specific criteria and gradation specifications refer to the *Urban Storm Drainage Criteria Manual (USDCM)*.
9. Weep holes — Relief of uplift forces may be required for projects involving channelization or relatively long erosion protection lengths. Groundwater levels, seepage paths and uplift forces should be considered in specifying weep hole spacing. See "Placement Specifications" below for information on weep holes.

Recent Variation

Several recent projects have been built using a grouted riprap layer that was only one rock thick. Most of the installations were drop structures or stilling basins below drop structures. This variation required a rock specification different from those defined below in that the riprap was not a graded material but was a one-sized boulder. The following advantages were enjoyed during these projects:

1. Specification — The rock size specification is simple: a single size boulder with a single set of dimension tolerances. Boulders aren't easy for the quarries to produce and haul, but they are simpler to specify and it is easier for all parties involved to visually determine if a rock falls outside the specification. Since it involves a single size rock, segregation during the many stages of rock handling is far less of a problem than with a graded riprap.
2. Grout penetration — A one-rock-thick layer of boulders with no fines or small rocks allows large void volumes that extend to the bottom of the rock layer. This allows a little more latitude in grout handling hoses and equipment. It also eases the task of achieving full depth grout penetration.
3. Inspection — Simple field measurements will determine if the size specification is being met. It is not nearly so easy with graded rip-

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Grout *(cont. from page 5)*

rap. Likewise, grout penetration is easier to verify.

4. Aesthetics — As mentioned above under Construction Techniques grouted riprap can be a relatively attractive installation if built properly. A layer of grouted boulders can be particularly attractive since the grout operation is straightforward and the large rocks permit a higher percentage of the rock surfaces to be left visible.

Rock Specification for Grouted Riprap

In order to achieve some of the benefits discussed in this article one must use a gradation of rock that is different from that for dumped riprap. The rock types listed below are labelled MG, HG, and VHG to indicate their specific designation for grouted riprap. These correspond to the riprap specifications in the *USDCM* for Types M, H, and VH. The "G" suffix indicates that the smaller sizes of rock have been eliminated from the gradation to improve grout penetration. Dumped riprap installations are still limited to Types VL, L, M, H, and VH. It is recommended that riprap smaller than Type MG not be grouted. Such a gradation of rock would be too small to allow proper grout penetration and could easily end up looking like poor concrete when work is complete. The theory behind the "G" rock sizing is based on a rock layer which is a minimum of one rock thick and a maximum of two rocks thick. The intent is to insure that void chambers in the rock layer are still large enough to allow easy grouting.

General Specifications

1. All concrete will have a 28-day compressive strength equal to 2000 PSI.
2. One yard of concrete shall have a minimum of six (6) sack cementitious material.
3. Type II cement shall be used. A maximum of 25% fly ash may be subsituted for the cementitious material.
4. The aggregate shall be comprised of 70% natural sand (fines) and 30% 3/8-inch rock (coarse).
5. The slump shall be equal to 7" ± 2".
6. Air entrainment shall be 7½% ± 1½%.
7. To control shrinkage and cracking 1.5 pounds of Fibermesh, or equivalent, shall be used per yard of concrete.

Material Specifications

All materials shall be in accordance with ACI 301, paragraphs as listed, unless amended or superceded by requirements of the following items. Also, all laboratory testing shall be performed by an approved testing laboratory and all field testing shall be performed by a certified technician.

1. All cementitious material (ACE 301 2.1). Use of one brand and type of cement shall be used throughout the course of the project. Portland cement shall be used, ASTM C150, Type II. Fly ash shall be ASTM C618 Type C or F. Class F must be used when the surrounding soil has a high sulfate content.
2. In general, below are listed only the Admixtures (ACI 3012.2) to be used, unless specified otherwise by the design engineer. When specified, listed below are the specifications to follow:
   A. Air entraining agents shall conform to ASTM C260 and shall be added or specified in ACI 301 3.4.1.
   B. Water reducing admixtures Type A shall conform to ASTM C494.
   C. High range water reducing admixture (superplasticizer) shall conform to ASTM C494.
3. All aggregate (ACI 301 2.4) shall be obtained from the same source (quarry) throughout the length of the project. Both fine and coarse aggregates shall meet the requirements of ASTM C-33.
4. All grout shall have a minimum 28-day compressive strength (ACI 301 3.2) of 2000 PSI.
5. The durability (ACI 301 3.4) shall be obtained by air entrainment of 7½% ± 1½%.
6. The slump (7" ± 2") shall be in accordance with ACI 301 3.5.

Placement Specifications

In general all placement of concrete grout shall be in conformance with "Specifications for structural concrete for Building" ACI 301-84 unless amended by the requirements contained herein.

1. All grout shall be delivered by means of a low pressure (less than 10 psi) grout pump using a 2" diameter nozzle.
2. Full depth penetration of the grout into the riprap shall be required. To achieve this a pencil vibrator is to be used.
3. The top six inches of the rock layer or the top ¼ of the rock layer, whichever is greater, shall be left exposed.
4. After placement all exposed rocks shall be cleaned with a wet broom.
5. All grout between rocks shall be finished with a broom finish.
6. Weep holes constructed of 1½" or 2" PVC pipe shall be installed when required by design engineer. Groundwater levels, seepage paths and uplift forces should be considered in specifying weep hole spacing. In all other cases a spacing of 10 feet to 15 feet should be sufficient, making sure weep holes at a minimum are installed at the toe of the slopes. The PVC pipe shall be cut flush with the surrounding grout. To alleviate plugging, the PVC pipe should be pushed into the bedding or if bedding is not required under the rock layer the PVC pipe shall be wrapped in a coarse geotextile fabric filled with 1½" rock.
7. All grout shall be sprayed with a clear liquid membrane curing compound as specified in ASTM C309.
8. The following environmental requirements shall be adhered to when placing the grout:
   A. Cold Weather Placement: When depositing concrete after the first frost or when the mean daily temperatures are below 40 degrees F., follow recommendations of ACI 306. Maintain concrete temperature at a minimum of 55 degrees F. for sections having a thickness of less than 12 in., or 50 degrees F. for sections having a thickness of 12 in. or greater, for not less than 72 hours after depositing. Do not place concrete without approval of the design engineer on days when temperature at 9:00 a.m. is below 30 degrees F. No grout is to be

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CLASSIFICATION AND GRADATION OF ROCK FOR GROUTED RIPRAP*

Riprap Designation	% Smaller Than Given Size By Weight	Intermediate Rock Dimension (Inches)
Type MG	70-100	21
	50-70	18
	0-5	12
Type HG	100	30
	50-70	24
	0-5	18
Type VHG	100	42
	50- 70	33
	0-5	24

*All other riprap properties, as specified in USDCM, shall remain unchanged

RECENT PLANNING PROGRAM ACTIVITIES

by Ben Urbonas, Chief, Master Planning Program

PLANNING PROJECTS

The master planning activity remained strong during 1987 and is expected to continue this pace in 1988. We have summarized this in the table titled "STATUS OF PLANNING PROJECTS." We appreciate the continued support of this program by the various local governments and the fine work by the many consultants helping us to plan for the future.

TECHNOLOGY TRANSFER

We were delighted to participate in a short course on the design of storm sewers which was offered by the University of Colorado at Denver. The course was attended by approximately 20 people who, among other topics, were introduced to a new storm sewer design program, namely UDSEWER, by Dr. James Guo. Dr. Guo is continuing to develop new courses in the field of urban drainage and plans to offer one on advanced uses of the District's three computer programs (i.e., CUHPE/PC, UDSWM2-PC, and UDSEWER) sometime this winter. For further information call his office at 556-2831 or his answering service at 798-4936.

At Earl Shaver's State of Maryland Department of the Environment, I had the pleasure of attending a three day conference on stormwater quality Best Management Practices. I was asked to describe storm drainage management activities in the Denver area and Colorado. It became very clear to me that the problems being faced by the Chesapeake Bay states are very different from those we see here. Where our main concern is to protect against floods, they have an added dimension of protecting the Bay from water quality degradation. Although stormwater quality has been identified as an issue of concern by Colorado for Cherry Creek Reservoir and Dillon Lake, we have not observed widespread impacts on the classified uses of our receiving waters. Chesapeake Bay on the other hand has been impacted by various wastewater dischargers and stormwater runoff. Its continued use as a major commercial and recreational fishery is at risk and all of the states draining into it have agreed to clean it up. It was not an easy or an inexpensive decision to make, but I sensed a commitment to get the job done.

SOFTWARE

The new storm sewer design program described in the last issue of *Flood Hazard News* was released earlier this year. It is available for $85.00 through Dr. Guo (his phone numbers are listed above), along with the District's other programs. This price will be maintained for several more months, after which prices for all of the District's programs will be increased. The District has subsidized the development and distribution of these programs to help all local governments and consultants acquire them. It was done to help standardize the approach to hydrology calculations in our area. We feel this purpose has been served, and that the distribution of these programs in the future will have to be more self supporting. We hope you understand and will continue to support our efforts in software development and distribution.

STATUS OF PLANNING PROJECTS

PROJECT	LOCAL SPONSOR	CONSULTANT	STATUS
Boulder & Adjacent County	Boulder, Boulder County	Greenhorne & O'Mara, Inc.	Completed in 1987
Big Dry Creek (ADCO)	Westminster, Broomfield, Adams, Jefferson, Airport	Muller Engineering Company, Inc.	Completed in 1987
Gunbarrel Area	Boulder Co., Boulder	Boyle Engineers	90% Complete
Thornton Criteria	Thornton	WRC Engineers, Inc.	In Review by City
Jefferson Co. Criteria	Jefferson Co.	WRC Engineers, Inc.	Criteria Adopted in 1987
Adams Co. Criteria	Adams Co.	WRC Engineers, Inc.	In Review by County
City of Boulder Criteria	Boulder	WRC Engineers, Inc.	In Review by City
Westminster Criteria	Westminster	WRC Engineers, Inc.	In Review by City
Littleton Criteria	Littleton	WRC Engineers, Inc.	Adopted by Littleton in 1987
Lone Tree, Windmill, Dove Creeks	Arapahoe Co.	WRC Engineers, Inc.	Completed in 1987
Bear & Mt. Vernon Creeks	Morrison, Lakewood, Jefferson Co.	n/a	Selecting Consultant
Cottonwood Creek-Arap. Co.	Arapahoe County	HCE, Inc.	70% Complete
Dry Creek (ADCO) - North	Thornton, Adams Co.	n/a	Waiting for Local Funding
52nd & Pecos to S. Platte & Clear Creek	Adams Co.	Hydro-Triad, Ltd.	30% Complete
First, Second, Third Cr. Hydrology	Adams, Aurora, Brighton, Denver, Commerce City	n/a	Selecting Consultant
Storm Sewer Pipe Criteria	Littleton & Arapahoe County	Wright Water Engineers, Inc.	Completed in 1987
Grange Hall Creek Dam	Northglenn	WRC Engineers, Inc.	Completed in 1987
Clear Creek Update	Adams County	David J. Love & Assoc.	10% Complete
Leyden Dam Feasibility Study	Arvada & Farmers Highline Canal & Irrigation Co.	n/a	Negotiating With Sponsors
Little Dry Creek (ArapCo) Stability Planning	Arapahoe County	n/a	Begin in 1988
Piney Creek and Tribs. Stability Planning	Arapahoe County	n/a	Begin in 1988
Lafayette Outfall Update	City of Lafayette	n/a	Negotiating with Sponsor
Kelcevik Gulch Outfall Update	Adams County & Westminster	n/a	Negotiating with Sponsors
Lee Gulch Outfall Planning	Arapahoe County & Littleton	McLaughlin Water Engineers, Ltd.	Completed in 1987

DESIGN AND CONSTRUCTION NOTES

B.H. Hoffmaster
Chief, Design and Construction Program

The year 1987 saw the completion of many projects and the start of construction of several more projects. The projects are listed in the accompanying tables, "Status of District Design Projects" and "Status of District Construction Projects." The design projects were completed under District management in cooperation with other public agencies. The construction projects were generally managed by the local sponsor.

The District undertakes capital improvements in cooperation with another public agency. Each year the Five-Year Plan is reviewed, updated and approved. The Five-Year Plan sets forth the design and construction program. In the development of the plan, each city and county located in the District is consulted regarding needs in their jurisdiction and on the availability of local matching funds, since the local sponsor(s) must provide at least fifty percent of the cost. The next step after the adoption of the Five-Year Plan and the annual budget is authorization of the project by the District's Board of Directors and entering into agreements with the local agency. Through this process, since the Colorado Legislature authorized the District's construction program in 1973, the District has expended or committed, as its share of capital improvement projects, approximately $37 million. During the year 1987 the District expects to expend or commit through the District and/or local agencies $14.9 million, of which the District's share will be $5.6 million or 38 percent.

While funding is important to the construction of drainage and flood control projects, perhaps the District's greatest influence is on the design standards used. The *Urban Storm Drainage Criteria Manual* is the basis of the designs. However, since most of the District's capital improvement program involves correcting mistakes of the past, the District finds it must deviate from the manual at times because of limited right-of-way for the improvements. The District, however, holds the engineer and local agencies to the manual as closely as possible.

An example of this is the Goldsmith Gulch Project, Cherry Creek to Dartmouth. This design will require an exception to open channel depth and velocity criteria. Channel capacity in a grass lined channel to meet the design flows can only be obtained with values that exceed those contained in the manual. However, in the

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdiction(s)	Status
Basin 3207	Broomfield	Complete
Countryside Creek (Tributary to Big Dry Creek (ADCO)	Jefferson County School District	Complete
Depew St. Basin—Schedule I —Schedule II	Lakewood	Complete 30% Complete
Dutch Creek	Columbine Valley	75% Complete
Goldsmith Gulch—Cherry Creek to Dartmouth	Denver	30% Complete
Goldsmith Gulch—Hampden to Quincy	Denver	Complete
Kenney's Run—East Branch	Golden	75% Complete
Lafayette Drainageway #7	Lafayette	Complete
Little Dry Creek (ARAP)	Cherry Hills Village	Complete
Little Dry Creek (ADCO)	Adams County Westminster	Complete
Louisville Drainageway D	Louisville	Complete
Marston Lake North Schedule II	Denver	Complete
Slaughterhouse Gulch Schedule I (Grant Detention)	Arapahoe County Littleton	Complete
South Jefferson County Drainages	Arapahoe County Last Chance Ditch Company Nevada Ditch Company	50% Complete
Upper Sloans Lake Schedule IV	Denver Lakewood	90% Complete
Westerly Creek Detention	Denver U.S. Army Corps of Engineers Aurora	50% Complete

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Participating Jurisdiction(s)	Cost	Status
Countryside Creek Tributary to Big Dry Creek (ADCO)	Jefferson County School District	$ 350,000	Complete
Big Dry Cr. (ARAP)	Greenwood Village	$ 209,100	Complete
Goldsmith Gulch Hampden to Quincy	Denver	$ 622,000	30% Complete
Goose Cr., Wonderland Cr. Boulder Slough	City of Boulder	$1,852,000	Complete
Lafayette Drainageway #7	Lafayette	$ 54,000	Complete
Little Dry Creek (ADCO) Schedule B2	Westminster	$1,495,900	Complete
Little Dry Creek, Broadway to Clarkson	Englewood	$2,871,100	95% Complete
Little Dry Creek, Clarkson to Belleview	Cherry Hills Village	$ 73,000	Complete
Louisville Drainageway D	Louisville	$ 398,300	Complete
Marston Lake North—Schedule I	Denver	$1,609,200	Complete
Massey Draw North	Jefferson County	$ 600	50% Complete
Parker/Mexico	Arapahoe County	$1,536,900	Complete
Upper Sloans Lake Schedule II	Edgewater Lakewood	$2,007,700	95% Complete
Sand Creek—Schedule I	Aurora	$3,805,700	60% Complete
Sand Creek @ 49th Avenue	Commerce City	$ 528,800	Complete

STUDY OF STORM SEWER PIPE MATERIALS

Dr. Ronald L. Rossmiller, Principal, Wright Water Engineers
Patricia Flood, Senior Project Engineer, Wright Water Engineers
Ben Urbonas, Chief, Master Planning Program, Urban Drainage and Flood Control District

INTRODUCTION

During the development of storm drainage design and technical criteria for Arapahoe County and the city of Littleton, it became apparent that there was little, or no, technical basis for selecting storm sewer pipe manufactured from materials other than reinforced concrete. Because of many years of favorable experience and reliability, reinforced concrete pipe became the material of choice for storm sewers.

Unlike culverts, storm sewers run for miles under city streets and their repair or replacement in expensive and disruptive to the community. As a result, city and county engineers were reluctant to switch to other materials until they were convinced that these new materials would provide at least an equivalent service life.

Thus, at the request of Arapahoe County and City of Littleton, the Urban Drainage and Flood Control District (UDFCD) agreed to enter into a co-operative project to study the feasibility of using storm sewers manufactured from various materials. The project sponsors jointly selected the firm of Wright Water Engineers (WWE) to collect and evaluate technical information, present their findings for consideration, make recommendations, and develop draft technical criteria for pipe materials selected for use by the project sponsors. The work at WWE was performed by Patricia Flood under the guidance of Ronald L. Rossmiller and Kenneth R. Wright.

Recognizing the complexity of the issues surrounding the selection of pipe materials and the development of technical criteria, the sponsors established a Technical Advisory Committee (TAC). This committee included not only representatives from each of the project sponsors, but also experienced engineers from several municipalities in the Denver area and the Colorado Department of Highways (CDOH).

The committee members included Ben Urbonas and Bob Hoffmaster, UDFCD; David Peterson and Bill Rothenmeyer, Arapahoe County; Joe Barsoom, City of Denver; O. Robert Deeds and Fred Bromberger, City of Aurora; Jerry Goldman, City of Lakewood; and Delbert H. Roupp, CDOH. We wish to acknowledge their contributions. Their interest, active participation, and valuable input added tremendous value and credibility to the study and to its published results.

FACT FINDING

Contact of Private and Public Organizations. As the project got underway, the TAC and the consultant jointly identified trade associations, manufacturers, and suppliers of storm sewer pipe materials. These were contacted by the consultant for information regarding their products. Concurrently, an independent literature search was conducted and various state and local government agencies were contacted for information regarding their practices in evaluating and selecting pipe materials and design criteria.

Survey of Municipal Practices. A questionnaire was sent to 66 communities in the Midwestern and Western United States and Front Range Colorado. It contained questions about storm sewers being used, soil/environmental conditions, maintenance, and rehabilitation methods. Completed questionnaires were received from 39 of these communities consisting of a fair representation of cities, counties, and state agencies. The types of storm sewers used, by responses and not by the quantity used, were as follows: 97% reinforced concrete, 54% corrugated steel, 41% bituminous coated corrugated steel, 36% corrugated aluminum, 28% PVC, 13% asbestos bonded bituminous lined CSP, 13% polyethelene, 10% ABS, 10% cast in place concrete, 8% concrete lined CSP, and 2% to 5% for other types of pipe.

The concerns the various respondents had relating to mechanical, chemical, and soil/pipes reactions broke down as follows: 65% were concerned about high groundwater, 50% about steep gradients, 47% about alkaline soils, 47% about freeze-thaw, 38% about acid soils, 26% about chlorides, 26% about sediment bedload abrasion, 24% about sulphates, 21% about alternate wetting and drying soils, 15% about aggressive water quality, 6% about expansive soils, and 6% about low soil cover.

Of those that responded to this question, the estimated average design life for storm sewers ranged from 52 years for off-road installations to 60 years for primary roads. At the same time, pipe maintenance most often included the following: removal of sediment, root penetration, abrasion of inverts, structural deterioration, repair of interior coating, joint repair, and collapsed pipe. Although two-thirds of the respondents have had to replace or restore deteriorated storm sewer pipe, only a third of them have a periodic storm sewer inspection program. Also, only 10% of the respondents performed life cycle cost analysis before selecting pipe materials.

DESIGN LIFE EVALUATION

There are many aspects to selecting the project design life for a storm sewer installation. First, the TAC evaluated the questionnaire responses. The average project design life used by all of the respondents was 58 years; however, these answers ranged from 20 to 100 years.

After lengthy discussion, the TAC selected a project design life of 100 years as the basis for life cycle cost analysis. In making this selection, the TAC weighed heavily the disruptive nature to the community of storm sewer replacement projects, their high cost, and the difficulty municipalities have in securing funds for such projects.

Once the project design life was selected, the consultant was able to begin life cycle cost analysis. This analysis considered the project design life or economic study period, pipe material service life, initial cost of installed sewer, bonding interest rates (i), inflation rates (I), replacement cost at end of service life, number of replacements needed within the project design life, and the residual value of a specific pipe material at the end of the project design life. Routine maintenance costs were not included in this comparison.

Within the formula for life cycle

cost is the term (1+I)/(1+i) which will generally have a value less than one. This term is the inflation/interest ratio. The rate of interest and rate of inflation are interrelated because of federal monetary and fiscal policies. The life cycle analyses in the study were performed for inflation/interest differentials from zero to five percent to test the sensitivity of the rates on the analyses. A three percent differential was used in the final analyses because the average differential in the last twenty years has been about three percent.

RESULTS

Reinforced concrete pipe (RCP) enjoys wide acceptance as a storm sewer pipe material while corrugated metal pipes (CMP), both steel and aluminum, have been widely used for culverts. In order to evaluate CMP, two alternatives were used in the life cycle cost analyses.

1. Use a material service life with the wall thickness necessary to meet structural requirements which includes stiffness for handling and installation. This material service life is generally much less than for RCP.
2. Thicken the wall of the CMP so that its service life is about equal to that of RCP.

The results indicated that it is more economical to use alternative 2, to thicken the wall of the CMP for increased durability as opposed to replacing the CMP more often.

Initially, corrugated steel pipe (CSP) was assigned a service life of 30 years. Additional investigations of the effects of deicing compounds on chloride concentrations in the soil and water indicated that the concentrations are in excess of those recommended for CSP, thus having the tendency for reducing the service life of CSP.

Additionally, inspections of DSP used for storm sewers in Colorado in both environmentally hostile and neutral environments indicated that, based on the condition of the pipe and its length in service, the service life of CSP could be less than 30 to 35 years. For these reasons, service lives for CSP of 25 and 30 years were also used in the life cycle cost for a sensitivity analysis.

The economic life cycle cost ratios presented in Table 1 are based upon an interest rate of seven percent and an inflation rate of four percent. Reinforced concrete pipe was assigned a ratio of 1.00 since it had the lowest life cycle cost. Clearly, the true economic life cycle cost is not the initial installation cost. This fact is very important to recognize since our public works dollars keep shrinking, yet our infrastructure replacement costs keep increasing.

It is estimated that solid wall PVC standard dimension ratio (SDR-35) and profile wall PVC (pipe stiffness 46 psi) are roughly equivalent to reinforced concrete pipe in terms of service life. However, the maximum diameters of these materials available at this time are 27-inch and 36-inch, respectively, which limits their use.

Also, SDR-51 PVC and profile wall PVC (pipe stiffness 10 psi) are available. These lesser stiffness products are recommended on an experimental basis only until more experience with these products is gained.

The values listed in Table 1 are shown in graphical form in Figure 1. An average value of Manning's "n" is listed in Table 3 for each selected pipe material because the size of pipe, and therefore cost, is affected by the roughness factor. An allowance for aging and resistance at poor joints should be included as a part of the roughness factor. The life cycle cost analysis should consider the hydraulic efficiencies of various pipe materials.

MATERIAL SELECTION FACTORS

Successful selection of a pipe material for a storm sewer system involves not only an evaluation of hydraulics, pipe loading, and strength requirements, but also installation procedures, environmental durability, maintenance concerns, and availability of rehabilitation methods.

Hydraulics. The hydraulics may also have an effect on the material longevity or structural stability. It should be noted that a smoother pipe material is not always a better pipe material. In some cases the velocity needs to be reduced to lower the energy grade line and/or to lower the sediment carrying capacity of the storm sewer.

Structural Design. Buried conduits may be classified into two general categories: rigid and flexible. Reinforced concrete pipe is a rigid pipe while the other pipe materials evaluated in the study are flexible. For a rigid pipe, the load increases with the square of the trench width. For flexible pipes, the load increases linearly with the trench width.

Bouyancy. In areas of high groundwater, the bouyancy or flotation of the pipe should be analyzed. The combined weight of the pipe and the backfill directly over the pipe should be greater than the weight of the water displaced. Methods used to prevent flotation include: increased wall thickness, concrete collars, pipes strapped to piles or concrete anchors,

TABLE 1
SERVICE LIFE AND LIFE CYCLE COST RATIOS FOR VARIOUS MATERIALS

Material	Service Life in Years	Life Cycle Cost Ratio
Reinforced concrete pipe	60	1.00
Profile wall PVC (Series 46)**	50	1.10
Bituminous coated corrugated steel	60(35)*	1.15
pipe with thickened wall	60(30)*	1.15
Corrugated steel pipe, uncoated	60(30)*	1.15
with thickened wall	60(25)*	1.15
Solid wall PVC (SDR-35)**	50	1.16
Uncoated corrugated aluminum pipe with thickened wall	60	1.18
Profile wall PVC (Series 10)	35	1.29
Corrugated aluminum pipe	35	1.40
Bituminous coated corrugated steel pipe	35	1.41
Corrugated steel pipe	30	1.54
Fiber bonded corrugated steel pipe with thickened wall	60(45)*	1.55
Bituminous coated corrugated steel pipe	30	1.58
Fiber bonded corrugated steel pipe	45	1.60
Fiber bonded corrugated steel pipe with thickened wall	60(40)*	1.61
Fiber bonded corrugated steel pipe	40	1.72
Fiber bonded corrugated steel pipe with thickened wall	60(30)*	1.73
Corrugated steel pipe	25	1.77
Profile wall polyethylene	35	1.82

*Number in parentheses is material service life prior to wall thickening
**Limited size availability

and additional backfill.

Installation. For a storm sewer to provide satisfactory structural performance, it is absolutely necessary that the design loads be greater than or equal to the installation loads.

A good pipe installation requires: 1) careful handling of the pipe, 2) a width of excavation sufficient to allow access for compaction equipment but not so wide that additional earth loads are imposed on the pipe, 3) stable foundation material, 4) uniform bedding, 5) adequate haunch support, and 6) uniform initial backfill.

Handling. Rough handling can damage, chip, or crack pipe and/or its protective coatings. The damaged area is then exposed to several environmental stresses.

Trench Width. The earth load acting on a pipe increases in proportion to the trench width. During construction, a wider trench width may become necessary due to unstable soils, utility conflicts, or other field conditions. The engineer should be cognizant of the field conditions and at the same time the contractor must be aware of the importance of trench width. If the design trench width is exceeded, then the use of a higher strength pipe or improved bedding class may be required. A trench can be too wide, but it also can be too narrow to allow satisfactory compaction of haunches. Generally, a minimum width of the pipe outside diameter plus three feet is recommended.

Foundation. In the event that rock or unstable material is found at the trench bottom, the trench will require over excavation. The foundation material should be well graded crushed rock having a maximum sieve size of ¾-inch. A soft or unstable foundation will allow uneven settlement which could lead to pipe fracture. A hard rock foundation will cause a point load at the pipe invert inducing stress in the pipe which again could cause pipe fracture.

Bedding. Good bedding provides uniform support of the pipe and insures that the soil or bedding material does not flow into the pipe if cracks or holes develop in the pipe wall. This is particularly important, in fact critical, for flexible wall pipes such as aluminum pipe. The bedding material should be well-graded sand and crushed gravel having good interlocking characteristics and gradation to insure that in-situ soils do not migrate into it or the pipe.

Haunch Support. The purpose of haunching is to provide uniform support over the bottom of the pipe. Poor haunching causes a point load at the pipe invert which has contributed to some pipe failures.

Initial Backfill. The initial backfill provides the side support for the pipe. For rigid pipes, the soil does not contribute support, but it is still important to have uniform bedding and sidefill to avoid concentrated point loads. Flexible pipes derive strength from the side support of the backfill; therefore, the initial backfill is much more critical for flexible pipes than for rigid pipes.

As a result, it is recommended that the initial backfill for flexible pipe be granular bedding material as described above. Additional inspection effort is required for flexible pipes to insure that the bedding and initial backfill are placed properly. The height of the initial backfill extends twelve inches above the top of the pipe.

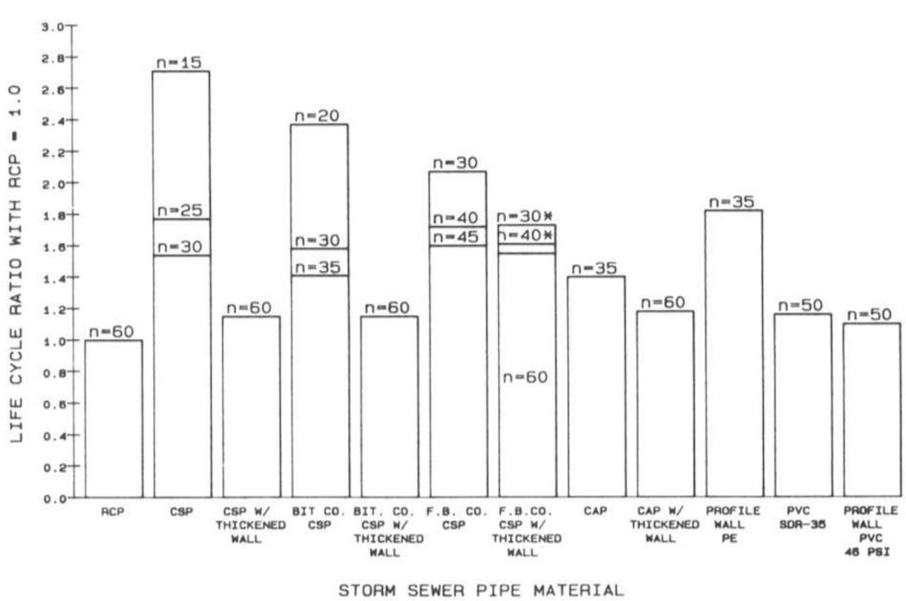
Final Backfill. The requirement for final backfill is determined by the use of the ground surface. Pipe trenches outside of the roadway should be compacted in successive layers not to exceed twelve inches thick to ninety percent standard proctor density. Trenches within the roadway should be compacted in accordance with AASHTO T-99 or T-180 as noted in Table 2.

Durability. Durability is a measure of a pipe material's ability to meet the project design life requirements. Materials vary in their ability to satisfactorily perform under different environmental conditions. The durability factors which are of concern are discussed in the consultant's Technical Memorandum. The parameters involved include soil/water pH, resistivity, sulfate levels, chloride levels, and abrasion.

Freeze-Thaw. In a narrow trench, if the frost heave expansion forces are greater in the trench than in the trench sides, the load on the pipe will be increased. In installations where frost heave may be a problem, i.e., shallow cover and pipe above frost line, it is recommended that the trench be backfilled with granular material.

Utility Corridor. Storm sewers are generally installed in utility corridors. During installation of other utilities, a storm sewer pipe material may be damaged or the lateral earth support for a flexible pipe may be diminished. The potential for this future disturbance should be considered when selecting a pipe material.

FIGURE 1
LIFE CYCLE COSTS FOR VARYING SERVICE LIFE
WITH PROJECT LIFE REQUIREMENT OF 100 YEARS
INTEREST/INFLATION DIFFERENTIAL = 3%



*Service Life 60 Years with Base-Life of 30 and 40 Years as Indicated

MATERIALS SELECTED FOR FURTHER STUDY

Based upon the above evaluation of materials with their relative life cycle costs, the following are recommended at this time for storm sewer pipes when used with the guidelines provided in the Technical Criteria. The use guidelines for these materials are listed in Table 3.

1. Reinforced concrete pipe
2. Corrugated aluminum pipe with thickened wall
3. Solid wall PVC (SDR-35)
4. Profile wall PVC (46 psi)

SUMMARY

A study has been performed to determine the types of pipe materials which can be recommended for use as storm sewers. The project sponsors were the UDFCD, Arapahoe County, and the City of Littleton. A TAC was composed of representatives of the sponsors and representatives from the City of Aurora, City and County of Denver Wastewater Management Division, City of Lakewood, and the CDOH.

A Technical Memorandum was prepared for the TAC containing thirteen different pipe materials for their consideration. This was done by compiling data from numerous sources. The initial step was to contact trade associations, manufacturers, and suppliers of pipe materials for information on their products. Concurrently, an independent literature search was conducted.

Additionally, a survey of storm sewer pipe material practices was made of Colorado Front Range metropolitan areas and communities and counties in the Midwest to Western United States. The survey requested information on material types, soil/environment conditions, maintenance, and rehabilitation methods.

On the basis of the information presented in the Technical Memorandum, the TAC recommended the following four pipe materials be considered for use as storm sewers at this time. It is also recommended that studies such as this be continued to develop information on viable alternative pipe materials for use as storm sewers.

1. Reinforced concrete pipe
2. Corrugated aluminum pipe with thickened walls
3. Solid wall PVC (SDR-35)
4. Profile wall PVC (46 psi)

Information on these four pipe materials were then summarized in a set of Technical Criteria. The criteria also contain information on pipe slope, soil and water use guidelines, structural design, installation, backfill and compaction, and inspection and testing.

TABLE 2
RELATIVE COMPACTIONS REQUIRED WITHIN ROADWAYS FOR VARIOUS SOILS

Soil Classification (AASHTOM 145)	AASHTO T99 Minimum Relative Compaction, %	AASHTO T180 Minimum Relative Compaction, %
A-1	100	95
A-3	100	95
A-2-4	100	95
A-2-5	100	95
All others	95	90

TABLE 3
PIPE MATERIAL USE GUIDELINES

Item	RCP		Thickened CAP	Profile Wall PVC	Solid Wall PVC
Manning's n — Max. Cap. & Min. Vel.	.013		Varies	.011	.011
— Max. Vel.	.011		Varies	.009	.009
Minor storm vel. (fps)	20		12	15	15
Size availability, pipe diameter (inches)	12 to 144		12 to 120	12 to 36	12 to 27
Soil testing required?	Yes, if requested by city/county		Yes	No	No
Soil guidelines	Type II Cement	Type V Cement			
Soil — Ph	5-9	5-9+	5-9	N.A.	N.A.
— Cl (% Max.)	1.00	1.50	1.50		
— SO_4 (% max.)	0.20	1.50	1.00		
— Resistivity (ohms-cm)	—	—	>1,500		

analysis that the engineer makes, the District must be assured that the future maintenance cost will not be significant and that the variance will not endanger life and/or property.

The design of this particular project has created considerable public interest. In order to reduce the downstream requirements for structural improvements the engineer, Sellards & Grigg, Inc., recommends approximately 400 acre-feet of flood water detention in Bible Park at Yale between Monaco and Quebec in Denver. After the construction of side-channel storage as well as two on-line reservoirs, the park would be returned to its original condition. The residents around the park are concerned about the park use being disrupted for a year and the inconvenience of the construction to the neighborhood.

In Broomfield another set of problems developed concerning wet lands in relation to the construction of two detention dams. The detention would offer protection on Basin 3207 in Broomfield. Immediately below the detention are several subdivisions with very inadequate drainage facilities. The detention will be provided by reconstruction of an existing irrigation pond to increase capacity and improve the safety of the structure, and construction of a new detention pond immediately downstream of the existing pond. There are concerns about the existing wetlands. The design incorporates these wetlands into the project. The toe drain for the upper detention is designed to direct any seepage into a wetland area. Design of this project has been by Sellards & Grigg, Inc.

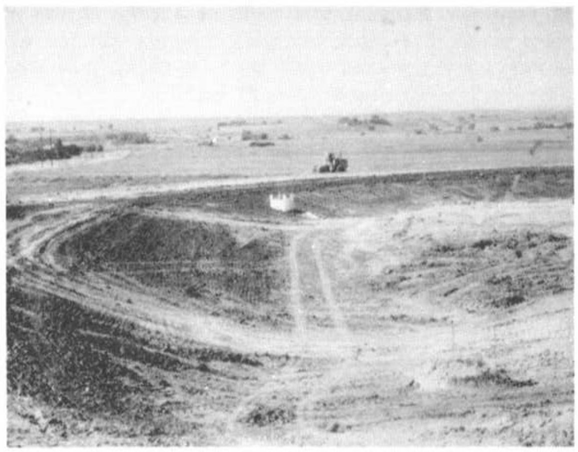
Dutch Creek in the Town of Columbine Valley presents a unique design problem since it requires the blending of the flood control project into a golf course. Dutch Creek flows through the Columbine Country Club where championship golf has been played. Any channel work must be compatible with the course. The need for the work is to prevent flooding of adjacent homes. The design engineer, David J. Love and Associates, has presented some interesting ideas for the town and club to consider.

The District, in cooperation with Aurora and Denver, have had Simons, Li and Associates designing an interim detention facility for Westerly Creek on Lowry Air Force Base; however, Congress has now authorized the design and construction of the Westerly Creek Dam on the base. The U.S. Army Corps of Engineers has completed a "General Design Memorandum" and the relocation of utilities is expected in the spring of 1988. When the construction of the detention is complete, it will open up the upstream area so that adequate drainage can be provided.

A detention pond was constructed in Louisville on Drainageway D during the past year. The capacity of the detention is 40 acre-feet and allows a design outflow for the 100-year event of 200 cubic feet per second. The peak inflow to the detention is approximately 880 cubic feet per second. This discharge will not exceed the capacity of the channel downstream through a residential area. The detention is created by an earthen embankment along the east and south sides that is approximately 13 feet in height. The City of Louisville expects to incorporate the detention facility into a future park. The design engineer was Centennial Engineering, Inc. and the construction contractor was L&M Enterprises, Inc.

Marston Lake North, Phase 1 channel, located in the southwest part of Denver has been completed by Lillard and Clark Construction Co. WRC Engineers, Inc. designed the facility. The channel extended from the Pinehurst Country Club, across Quincy Avenue and upstream to Marston Lake. The Denver Water Department requested that Phase 2, which extends upstream to Old Wadsworth Boulevard, be redesigned and the Marston Lake embankment be moved southward to provide for an earthen grass lined channel. There was also a need by the

(Continued on page 15)



Embankment construction for Drainageway D detention pond in Louisville.

Little Dry Creek construction in Englewood. A grass lined channel with boulder sided trickle channel.

Little Dry Creek construction in Westminster. Limited right-of-way forced a concrete lined channel in order to provide 100-year flood protection.

LENA GULCH FLOOD EXPERIENCE 1987

by Kevin G. Stewart, Project Engineer

Introduction

The December, 1986, issue of *Flood Hazard News* featured an article describing the flood detection network and warning plan for Lena Gulch which had just completed its first full season of operation. The primary emphasis of the 1986 article was the installation and operation of the automated rain and stream gage "ALERT" network. The article described, in some detail, the components which make up the detection network; discussed meteorological support requirements and real-time applications; and identified the critical elements of the flood warning plan.

In the article's closing statements it was noted that since the project was implemented, Lena Gulch had not experienced an emergency situation and that no significant rainfall had occurred. By the end of the 1987 flood season it had become clear that installing rain and streams gages would not prove to be an effective means of discouraging rain from falling as it had seemed in 1986. This article presents the Lena Gulch flood events of 1987 and reviews the detection and evaluation, the warning dissemination, and the emergency responses which resulted.

Location

The Lena Gulch drainage basin is located in central Jefferson County and drains approximately 13.8 square miles at its confluence with Clear Creek near Kipling Street. The Lena Gulch headwaters are located in the Apex Gulch area of Lookout Mountain. Apex Gulch and Jackson Gulch join to form Lena Gulch just below Heritage Square near the intersection of U.S. Highway 40 and State Highway 93. Numerous developed areas downstream from this point are considered highly flood prone. Lena Gulch flooding will impact numerous major highways and arterial streets in addition to developed areas within unincorporated Jefferson County and the Cities of Golden, Lakewood and Wheat Ridge.

One major water supply reservoir (Maple Grove Reservoir), which is owned and operated by The Consolidated Mutual Water Company, is located in the lower portion of the watershed (drainage area = 10 sq. mi.). The dam and reservoir are located near West 27th Avenue and Youngfield Street in Lakewood. Improvements to the dam and spillway were completed in 1977 to comply with the dam safety requirements of the State Engineer. These improvements included the installation of two Fabridams on the spillway crest which are operated in a manner to protect the dam from failure in the event of floods exceeding the 100-year magnitude. The Urban Drainage and Flood Control District (UDFCD) participated in the construction of one of these Fabridams as part of a major channel improvement project through the City of Wheat Ridge. The downstream flood control improvements, totaling more than $5,000,000 in construction costs, rely heavily on the flood control benefit provided by Maple Grove Reservoir. Should automatic or inadvertent Fabridam deflation occur in a severe emergency, discharges well in excess of downstream channel capacity can be expected with the loss-of-life potential being extremely high.

The flood detection network for Lena Gulch consists of nine automated gages (6-rain and 3-stream) and two "ALERT" base stations. Figure 1 is a computerized map showing the Lena Gulch rain gage network and total rainfall amounts for the 1987 flood season (April 15 through Sept. 15). The remainder of this article describes the key flooding events which took place in 1987, and the operational activities which occurred.

Summary of Key 1987 Rainfall Events

Five rainfall events were recorded during the 1987 flood season where total rainfall amounts exceeded one-inch. The accompanying table summarizes these events:

LENA GULCH RECORDED RAINFALL 1987

(Total Precip. > 1.0")

Date(s)	Gaging Location	Total Rain	Storm Duration	Peak 15-min Intensity
May 2-3	Jeffco Fairgrounds	1.26"	1.5 days	0.12"
May 19	Maple Grove Res.	1.20"	3.5 hours	0.20"
Jun 8	Jeffco Fairgrounds	2.24"	2 hours	0.78"
Jun 18	Maple Grove Res.	1.26"	30 mins.	0.98"
Jun 29	Jeffco Fairgrounds	2.02"	12 hours	0.24"

Of the five events listed above, the events of June 8 and June 18 caused significant runoff resulting in flood damages to private property in Golden, Lakewood and unincorporated Jefferson County. The event of June 29 stands out as the largest general upslope rain of the season where total rainfall accumulations of 2.40" were recorded over a 2.5 day period. These three events are discussed in more detail in the following paragraphs:

Event of 8 June, 1987

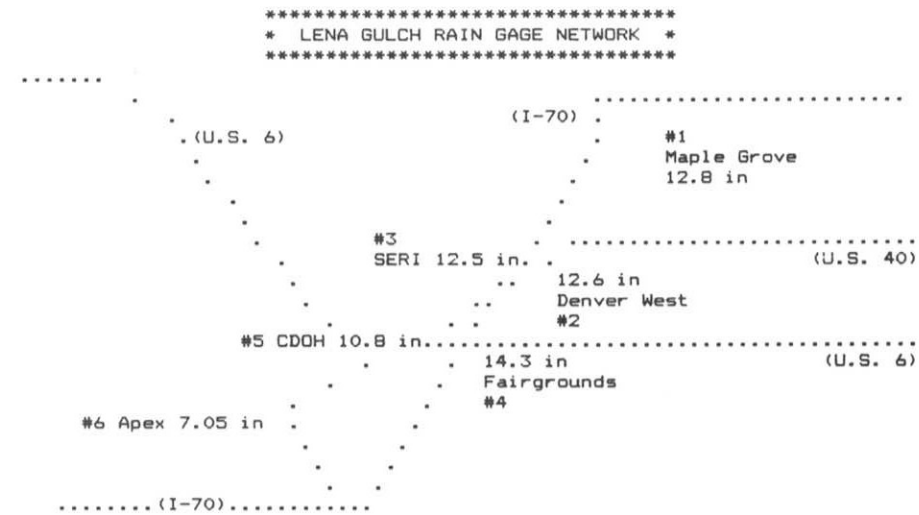
This heavy rainfall event occurred during the evening hours between 8:00 and 10:30 PM. This storm caused the most severe flooding of the 1987 flood season. Significant flooding was reported within Lakewood, Golden and unincorporated Jefferson County. Heavy damages to residential property were reported immediately upstream of the West 20th Avenue crossing of Lena Gulch and a portion of West 20th Avenue was washed out forcing a street closure. The Consolidated Mutual Water Company played a key role in responding to this emergency situation by sending spotters with radios into the upper basin to monitor upstream flooding and by assisting Lakewood Police with the closure of West 20th Avenue. Consolidated also maintained close contact with the Wheat Ridge Police Department concerning the status of Maple Grove Reservoir with respect to projected spillway flows and Fabridam operations.

Other flooding occurred within the upper portion of the basin forcing evacuations at two mobile home parks. A third park was impacted at 13th Avenue and Isabell Street near Camp George West where street overtopping occurred. The Golden and Pleasant View Fire Departments responded to these problem areas after being notified by the Jefferson County Sheriff's Department. Serious street flooding was also reported at a number of other locations. The improved channel and in-stream detention facilities at the Denver West Office Park appeared to have functioned properly during the event. Other than normal clean-up activities, no other damages were reported at Denver West.

Downstream of Denver West, between Arbutus and Youngfield Streets, no major damages were reported. UDFCD channel maintenance efforts over the past few years were credited at minimizing damages within this reach. The channel through this reach has been estimated to have a 10-year capacity due to rehabilitative maintenance projects completed by the District. The event of June 8 was estimated to have a return period of approximately 5 years.

No damages were sustained downstream of Maple Grove Reservoir. Only minor spillway flows were recorded.

FIGURE 1



Values for Map # 1: 154 days 9/15/87 24:00 [APRIL 15 - SEPTEMBER 15, 1987]

BROKEN RECORD SUMMARY: Gage #2 Inactive 6/23 through 6/27
Gage #5 Inactive 8/21 through 9/1
Gage #6 Inactive 4/15 through 6/12

Storm Summary:

- With the exception of a trace of rainfall which occurred at approximately 7:00 PM, the beginning time of the storm was 8:05 PM with the first significant amounts of rain being reported by the Maple Grove rain gage.
- Pre-determined alarm levels (0.5"/hr.) were exceeded at approximately 8:30 PM at Maple Grove. At that time, only a trace of rain had been reported from the Denver West gage and the upper basin gages had not reported any rainfall.
- By 9:00 PM the rainfall had ceased at the Maple Grove gage and radar showed the storm moving to the southwest into the upper basin. This was confirmed by rain gage reports.
- At 9:10 PM the rainfall intensity began increasing in the upper basin with 0.72" of rain falling within the next 20 minutes at the CDOH gage near the intersection of U.S. Highways 6 and 40.
- From 9:30 PM on, all gages were reporting rainfall. Peak intensities occurred at the Jefferson County Fairgrounds and at Denver West at 10:00 and 10:15 PM respectively. The maximum peak intensity reported by the flood detection network was at the Denver West gage where 0.75" fell within a 15 minute period between 10:05 and 10:20 PM.
- The storm appeared to have ended by 10:40 PM with the last traces of rain reporting in by 10:55 PM.

Flood Summary:

- Serious flooding was being reported in the upper portion of the basin by 10:30 PM forcing mobile home park evacuations.
- A peak discharge of 700 cfs was reported by the Nolte gage between Youngfield Street and West 20th Avenue at 11:00 PM.
- The level of Maple Grove Reservoir peaked shortly after midnight. The flooding caused the reservoir to rise 2.1-feet resulting in a water surface 2.5-feet above the normal operating level.
- Spillway flows were estimated to be between 50 and 60 cfs.

The peak 2-hour rainfall intensity of 2.04" was reported by the fairgrounds gage. This 2-hour amount corresponds to a precipitation frequency somewhat greater than a 10-year event according to NOAA Atlas data. The peak 5-, 10-, 15-, 30- and 60-minute intensities were estimated to have return periods of 3- to 6-years. The peak inflow to Maple Grove Reservoir (700 cfs at the Nolte gage) was approximately 40 percent of the 10-year flood estimated for the 1975 Lena Gulch Master Plan. The flood frequency for the main stem of Lena Gulch downstream of Denver West was estimated to be a 5-year event.

Prior to the evening event, meteorological forecasts were made of the flooding potential for that day. At 9:42 AM, Henz Kelly and Associates (HKA), private meteorological service under contract to the District, notified UDFCD of the potential for "Messages" to be issued later in the day. At approximately 2:20 PM, internal alert messages (MESSAGE 1, TYPE 2s) were issued for all District counties effective from 4:00 PM through 11:00 PM. These messages warned of the potential for flash flooding of intersections, low-lying areas and small streams. The forecast called for peak rainfall intensities of 1.5" in 30 minutes with total 3-hour rainfall amounts of 1.0" to 2.5" possible. Pea-sized hail was also forecast. An "Update Message" was issued to Jefferson County at 8:42 PM notifying them that Lena Gulch might be affected.

Numerous other exchanges occurred between the various emergency response groups during the event. The storm was also being monitored by the National Weather Service (NWS) but was determined to not be of a magnitude to warrant issuing a Flash Flood Watch or Warning. NWS criteria is based upon regional responsibility for monitoring weather for the entire Front Range of Colorado. The Denver Weather Service Forecast Office (WSFO) is located at Stapleton International Airport.

Event of 18 June, 1987

The event of June 18 was reported to have caused flood damage at isolated locations but was not nearly as severe as the June 8 event. At least one private residence upstream of West 20th Avenue received water in the basement as a result of this storm. The flood waters rose to within 1- or 2-feet of overtopping West 20th Avenue again but the culvert remained free of blockage and was capable of handling the runoff.

Rainfall first reported from the upper basin gages at about 4:10 PM. The lower portion of the basin began reporting rainfall approximately 20-minutes later. The storm tracked generally from west to east across the basin and lasted only 30-minutes at any one point. Peak rainfall intensities were reported by the rain gage at the Maple Grove Treatment Plant. The frequency was estimated to be a 10-year event or slightly greater for intensities of 5-, 10- and 15-minutes. From a basin wide perspective, 30-minute rainfall totals were estimated to be between a 2- and 5-year frequency.

A peak inflow to Maple Grove Reservoir of approximately 460 cfs was reported by the Nolte stage gage at 5:41 PM. This discharge magnitude and time was forecast with reasonable accuracy by District staff assisting with operations at HKA. Knowledge gained from the June 8 event along with available decision aids proved effective in forecasting the flood peak. The flood peak forecast was made at about 4:45 PM which allowed District staff time to drive to the flooding

(Continued on page 12)

Lena (cont. from page 11)

scene with camera ready. The accompanying two photographs were taken 5 minutes apart near Arbutus Street at 5:30 and 5:35 PM.:

At 1:03 PM, three hours prior to rainfall, UDFCD received an electronic mail message from HKA indicating that "MESSAGE 1, TYPE 2s" were issued for all District counties calling for fast moving thunderstorms capable of producing 1- to 2-inches of rain in 30-minutes. The valid time for Jefferson County was from 1:30 to 9:00 PM. District staff assistance was requested by HKA to assist with Lena Gulch flood forecasting.

Event of 29 June, 1987

The event of June 29 is recognized as the largest upslope rainfall of the 1987 flood season. This event was carefully monitored with the primary concern being the high level of Maple Grove Reservoir as a result of a very wet month. Should a thunderstorm have moved into the basin, significant spillway flows could have been expected and upstream flooding would likely have been worse than that experienced on June 8. The major portion of the rainfall fell within a 12-hour period with slightly more than 2-inches reporting in from the fairgrounds gage. A peak discharge of approximately 210 cfs was reported by the Nolte gage at 1:03 PM. Discharges in excess of 100 cfs continued to flow into Maple Grove Reservoir for a 9.5-hour period between 12:10 and 9:40 PM.

Lessons Learned from the 1987 Experience

The storm events of June 8 and June 18, 1987, illustrate how rapid runoff occurs from small urban watersheds like Lena Gulch. These events also illustrate the importance of accurate meteorological forecasting well in advance of rainfall. Short duration intense rain storms, such as the June 8 event, are difficult to forecast, particularly where the scale of forecasting is on a watershed basis. The techniques employed for this level of forecasting are referred to as "mesoscale" forecasting and the probability of false alarms increases as the forecast area decreases.

The use of real-time data proved extremely helpful in projecting peak flows, times and reservoir level increases. The events of 1987 will be used to improve decision aids and adjust hydrologic models to better reflect actual basin runoff responses. Critical rainfall depths, durations and intensities will be identified for various problem areas within the Lena Gulch basin.

Tributaries to Lena Gulch produced

Lena Gulch 5:30 PM

Lena Gulch 5:35 PM

some of the worst flooding in the upper basin and decision aids for their respective problem areas are needed. It should be noted that significant flooding problems can occur along tributaries without causing any major problems along the main stem as illustrated by the June 18 event. These scenarios need to be recognized so that appropriate emergency responses can occur.

The 1987 experience called attention to the continual need for improved communications. The proper information must be communicated in a timely manner if the warning plan is expected to have any chance of succeeding. Dispatch operators are not well versed in the areas of meteorology and hydrology and care must be taken to make sure that the correct communication occurs and critical messages are not delayed. Training programs or periodic contacts are needed to help assure that individuals on duty will understand the importance of relaying weather related information to all emergency response groups within the specified communications network.

The lessons learned from the Lena Gulch flooding experience of 1987 will allow refined flood forecasting techniques to be applied to other problem areas within the District. Simplified decision aids are needed so that meteorologic forecasts can be properly interpreted and related to specific problem areas. A refined communications network should be investigated and the idea of establishing a focal point for emergency operation decisions and communications dissemination should be explored. The use of computer mail has been suggested and should be strongly considered for implementation in 1988.

The following emergency response organizations should be given a special recognition for their efforts in handling the 1987 Lena Gulch flooding situations:

- Jefferson County Sheriff's Department
- Jefferson County Office of Emergency Preparedness
- Golden Police Department
- Lakewood Police Department
- Wheat Ridge Police Department
- The Consolidated Mutual Water Company
- Golden Fire Department
- Pleasant View Fire Protection District

Grout (cont. from page 6)

placed on snow, ice or frozen material.

B. Hot Weather Placement: When depositing concrete in hot weather, follow recommendations of ACI 305. The temperature of concrete at time of placement shall not exceed 90 degrees F. Grout shall be protected to prevent rapid drying. Finishing and curing shall start as soon as possible. When the air temperature is expected to exceed 90 degrees F., the Contractor shall obtain approval from the design engineer of the procedures to be used in protecting, depositing, finishing, and curing the concrete. The specified water reducing retarding admixture may be used upon approval of the design engineer. The use of continuous wetting or fog sprays may be required by the engineer for 24 hours after depositing or the work may be restricted to evenings or nights, especially in times of low humidity.

The authors would like to thank Ms. Robbie Zephrin of EMK Consultants, Inc., Mr. Ron Coburn of Rocky Mountain Ready-Mix Concrete, Inc. and Mr. Kevin Stewart, UDFCD, for their contributions and support.

SOUTH PLATTE RIVER GENERAL 404 PERMIT

by Barbara L. Evans, Project Engineer

Before the Urban Drainage and Flood Control District can undertake many of its projects, coordination with the U.S. Army Corps of Engineers is essential. By federal dictate, a Section 404 Permit must be issued by the Corps of Engineers for any dredge and fill activities in the "Waters of the United States." The South Platte River and its tributaries are "Waters of the United States," with most channel construction and some channel maintenance work undertaken by the District requiring a Section 404 Permit.

Riprap installation is done frequently to protect the river banks along the South Platte. Each location that is riprapped needs an individual Section 404 Permit, so if ten locations require repair, the District must apply for ten separate Section 404 Permits. These ten applications then must be processed and approved by the Corps of Engineers before any work begins. This process of applying for separate permits for similar projects takes a lot of time and generates a large amount of paperwork. Also, in emergencies the District cannot wait the typical four month processing period to acquire a permit before stabilizing an area when utilities, roadways, or other facilities are being jeopardized.

In an effort to expedite this permit process, the District staff decided to pursue a General Permit from the Corps of Engineers for activities in the South Platte River. To accomplish this, the firm of Wright Water Engineers, Inc. was hired to assist in the preparation of an application for a General Permit. In addition to riprap bank protection, the application included the following structures that also would be installed repeatedly: 1) bottom degradation check structures; 2) rock groins; and 3) scour protection for existing river crossings.

Bottom degradation check structures are constructed of riprap which lines the entire width of the river channel for 25 to 300 feet along the length of the river. The riprap is continued up the banks of the channel for a height of 5 to 10 feet. These structures stabilize the bottom of the river and are installed at the master plan river invert elevation identified for the South Platte River. These check structures are essential in arresting general river bed degradation and in assuring the long-term stability of the river.

Rock groins are composed of a large mass of dumped riprap, and they direct flows away from an eroding riverbank. Several groins must be installed together in series to provide the needed protection. Groins (or jetties) have been used for bank stabilization on many rivers in the United States and for erosion protection along ocean fronts. We expect that there may be areas along the river where they will be used.

Scour protection at existing utility crossings consists of large riprap/boulders in the scour hole that normally forms on the downstream side of a crossing. The need for this protection is two-fold: First, it helps to protect the utility from being undermined and extends its life. Second, scour holes downstream from river crossings can form strong undertows (or "keepers") which can trap anyone who enters the scour hole. By filling the scour holes with riprap, these undertows can be reduced significantly, and safety to the public can be improved.

The process of obtaining a Section 404 Permit is fairly lengthy, with a routine application involving a minimum of a 30-day Public Notice period. The entire process, if there are no objections, takes about four months before a permit is issued. If, however, an objection is filed, this period can extend almost indefinitely, depending on the issues raised. The Corps encourages "pre-application consultations" with the applicant to iron out details. The key to successfully acquiring a Section 404 Permit is to confer with the Corps and affected local, state, and federal agencies before submitting an application.

Dave Mehan of Wright Water Engineers did an excellent job in arranging for the pre-application conferences with the Corps of Engineers, the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the Colorado Division of Wildlife, the South Suburban Parks and Recreation District, and the Greenway Foundation. Nevertheless, the process of working out the fine points of the language on the permit application with the local representatives of EPA and the U.S. Fish and Wildlife Service took six weeks. The consensus permit application was submitted to the Corps of Engineers on July 31, 1987.

After the District receives a General Permit, there will be conditions that will have to be satisfied before any project can begin. For example, a 30-day written notice to the Corps, describing each project in detail, will be required. Each project may not begin until it is authorized in writing by the Corps. Even though the details of the project are in full agreement with the details of the General Permit, the Corps of Engineers may place additional conditions on the project or could even deny it. The General Permit will be limited to a five-year period.

In spite of these stipulations, which are many, the General Permit still could save time and reduce the paperwork that would accompany multiple applications. At this writing, the Public Notice period is over, and the District is waiting to hear from the Corps on the status of the General Permit application. We hope that it will be approved so the District can proceed with restorative maintenance on the South Platte River, using local funds to solve local problems, in a more efficient and timely manner.

Walls *(cont. from page 4)*

Broadway to Downing was built and in 1911 walls were built from Colfax downstream to Blake Street. Those walls are also 80 feet apart and 10 feet tall. With these walls in place the design capacity of Cherry Creek from Downing to Blake was 10,000 cfs.

Cherry Creek took its turn next as heavy rains on July 14, 1912, generated flooding with a peak flow of 11,000 to 15,000 cfs. Coupled with several pool-forming weirs across Cherry Creek which reduced the capacity to 5,500 cfs much of lower downtown (particularly below Blake Street) was flooded. Water was three feet deep in Union Station and about 1,600 feet of existing concrete wall was destroyed. The Cherry Creek Flood Commission was established shortly after this flood. It developed many recommendations to reduce the potential for future flooding. A political convulsion shook Denver at this time and the only Commission recommendation that was implemented was to extend the concrete walls downstream from Blake Street to the confluence with the South Platte River. These walls were built 12 feet tall and 88 feet apart and were completed in 1915.

At this point more than three miles of Cherry Creek through the heart of Denver were restrained by concrete walls. The accumulated construction cost to this point, including right-of-way acquisition and parallel street construction, was $880,556. A chapter in the efforts to control Cherry Creek closed with the completion of the walls. It would take the flood of 1933 and the subsequent realization that a flood control dam upstream of the City was necessary before the people of Denver would be motivated to renew their love-hate relationship with Cherry Creek.

South Platte *(cont. from page 1)*

to those reaches of the river for which public access is available. Restorative maintenance is getting off to a slow start because Section 404 permits are needed to repair bank erosion or to install any facilities that would stabilize the river from degradation, the banks from erosion or various crossings from damage. To reduce the time required for obtaining a permit, the District has applied for a general restorative maintenance permit (read the article by Barbara Evans for details of what this involved). Applications for several individual restorative maintenance projects have also been submitted. Restorative maintenance work will begin in earnest once the permits are obtained from the Corps of Engineers.

Much has been learned about the South Platte River and its needs during this first year of the new program. Although, when compared to the $60,000,000 estimate for master plan recommended improvements, the annual budget of approximately $900,000 appears small. However, the establishment of this program is expected to achieve much more than the budget implies. The mere fact that the District now has a focused activity on the river permits the District to act much more in a proactive fashion than before. As an example, the District was able to work out understandings with several parties ready to begin mining gravel in or adjacent to the South Platte River channel. As a result, the District anticipates entering into agreements with gravel mining companies for several cooperative projects during 1988. These cooperative projects will begin cleaning up river banks, protect them from erosion and will install river bottom degradation checks.

To facilitate the new program, a facilities inventory for approximately 19 miles of the river was developed in 1987. In 1988 this inventory will be completed for the remainder of the river between Chatfield Dam and Baseline Road. The inventory, prepared for the District by Wright Water Engineers, Inc., consists of a computerized data base, location maps and many photo slides. It provides information on the location of bridges, other structures, trails, storm sewer outfalls and utilities. Eventually capital costs and maintenance costs will be added to the inventory system to keep track of where the funds are being spent and how much various activities are costing to build and maintain.

WHAT NEXT?

In 1988 the objective is to continue the efforts begun during 1987. Construction of the trail replacement between 8th and 13th Avenues is also expected to begin in 1988 as well as the detailed investigations of flood control options for the Central Platte Valley and for an area north of the Franklin Street bridge. All of these activities will require financial participation by the local governments. The General 404 Permit will have been issued and a more orderly flow of restorative maintenance activities should result. It is also hoped that cooperative projects with several property owners to stabilize or rebuild eroded river banks can begin. It promises to be an active year and more will be learned about the river. The needs far exceed available funds and the District will be attempting to develop techniques that will allow more to be accomplished with limited funds. We will report to you in future issues of *Flood Hazard News* what has been learned and accomplished.

Tucker Talk *(cont. from page 3)*

Directors appraised accordingly, and be ready to recommend changes in direction to the Board should that become appropriate. In the meantime we will not discourage the use of drainage and flood control facilities for improving stormwater quality, detention facilities being a prime example. However, at this point the District can not take a responsibility for maintenance of the stormwater quality portion of the facility nor can it require that a stormwater quality function be included as a part of a flood control or drainage facility.

Quantity and quality are inextricably linked and it is difficult to separate out the quality from the quantity and treat them as separate issues. However, it is also difficult to make institutional changes on a regional basis when the problem and what to do about it are so poorly understood.

Assessed Valuation Nearly Doubles

The Colorado state legislature has required that assessed valuations be updated to current values. For 1987, assessed valuations were updated from 1977 levels to 1984 levels. This has resulted in a significant change in the assessed valuations in the Denver metropolitan area. In 1986 the assessed valuations for the Urban Drainage and Flood Control District was $9,197,042,142. This has increased by about 98% to $18,180,608,075. This does not mean a similar increase in property tax revenues, however. The General Assembly limited the increase in property tax revenues from 1987 to 1988 to 5.5% plus an additional amount for new construction. Consequently, the mill levies for the District's four funds will decrease by approximately 50%. Based on the budgets adopted by the Board the mill levy for the General Fund will be reduced from 0.1 mill to 0.053 mill, the Construction Program from 0.4 mill to 0.209 mill and the Maintenance Program mill levy from 0.4 mill to 0.203 mill. The mill levy for the South Platte River Program will be reduced from 0.1 mill to 0.054 mill.

The total mill levy for the District, except in Boulder County, will be 0.518 mill which has a small impact on the individual taxpayer. For example, the property tax for a home valued at $150,000 would be $13.98. The property tax for a home valued at $100,000 would be $9.32.

District Boundaries

The Urban Drainage and Flood Control District has been considering the possibility of enlarging its existing boundaries. The annexations of Aurora to the east have extended beyond existing District boundaries at Powhatan Road. Also, the City of Parker has incorporated since the creation of the Urban Drainage and Flood Control District and its boundaries extend to the south beyond existing District boundaries. Parker also is considering annexations of additional lands to the south of the District. In a report prepared for the Board of Directors, Board member and Arapahoe County Commissioner Bob Brooks recommended that the District consider approaching the legislature to extend its boundaries in those areas where projected urban growth is to be expected. This possibility will be discussed by the Board in future weeks and months. There are other ways to annex new territories into the Urban Drainage and Flood Control District but it was the conclusion in the report by Commissioner Brooks that a legislative change in the boundaries would provide the most logical and workable change in District boundaries.

Interlocking cellular concrete block erosion protection was installed in West Harvard Gulch under the direction of project engineer Frank Rosso. Once vegetation is established it will be difficult to see the concrete.

Aurora and District Build "Wetland"

by Dave Lloyd, Project Engineer

It wasn't long ago that when drainage engineers developed a project, one of the main objectives was the adequate drainage of lowland areas otherwise referred to as wetlands. With the emergence of the National Clean Water Act and the U.S. Army Corps of Engineers 404 requirements, one of the main objectives of drainage projects has become the protection of wetlands. Where at one time we may have drained the swamp, it appears now we may be building them.

In August of 1984, the City of Aurora and the District entered into an agreement to design drainage and flood control improvements for a portion of Sand Creek extending from approximately 3,000 feet downstream of Peoria Street to approximately 1,500 feet upstream of Colfax Avenue. In September of 1984, the City and District selected Greenhorne & O'Mara, an engineering consulting firm, to design the proposed channel improvements. The first phase of work, which is currently under construction, consisted of channel improvements from the confluence of Toll Gate Creek and Sand Creek to approximately 450 feet upstream of Sable Boulevard.

During the course of the design it became apparent that mitigation of wetlands lost to construction would have to be addressed as part of the 404 Permit process. In November of 1985, Thorne Ecological Institute, an environmental consulting firm under subcontract to Greenhorne & O'Mara, began the preparation of a mitigation plan to be submitted as part of the 404 Permit Application for the first phase of construction. It was determined that the first phase of construction would impact 8.1 acres of wetlands.

The mitigation plan was completed in March of 1986 and involved two distinct areas of mitigation. It was decided that a portion of the improved channel bottom would be dedicated to the restoration of existing wetlands between the channel banks and the low flow channel. It was determined that this would mitigate approximately 4.7 acres of wetlands consisting of three-square grasses, cattails and wetland shrubs (willows and snowberry). The second area of mitigation was designated to take place off-site in Four Star Park, a 67-acre unimproved park site owned by the City of Aurora. Four Star Park is located along Sand Creek to the south of Smith Road at Laredo Street.

In August of 1986, William Wenk Associates, a landscape architectural firm, in cooperation with Thorne Ecological Institute, both under subcontract to Greenhorne & O'Mara, commenced final design of the Four Star Park improvements. The plan called for the mitigation of 3.4 acres of wetland herbs (aquatics and emergents), shrubs and trees. The park site, an abandoned sand and gravel operation, had been left in its natural state, and turned into an illegal trash dump strewn with automobile parts, 55-gallon drums, abandoned construction equipment, and even its very own railroad car.

Randall & Blake, Inc. was awarded the contract for the construction of improvements to Four Star Park in January, 1987. The main items of work included approximately 23,000 cubic yards of excavation for the purposes of expanding and tying together three existing ponds at the park site and

A view of the Four Star Park wetland.

lowering ground levels such that wetland grasses and shrubs could be sustained by groundwater. Approximately 3,000 tubers of arrowhead, burr reed, and cattails were planted as well as 600 wetland shrubs consisting of American Plum, Choke Cherry, Elderberry, Golden Current, Snowberry and Wood Rose. Approximately 300 trees were planted in the park, as were approximately 16,000 nursery grown willows. Also, 100 willow pads (3′ × 8′) were transplanted from the bottom of Sand Creek to the park. In order to sustain groundwater levels at their existing level, a temporary drop structure was constructed in Sand Creek to retard the gradual degradation of the creek bottom and subsequently reducing groundwater levels in the Park. Construction and plantings were completed in May, 1987, at a cost of $145,000.

The City of Aurora has plans to include a trail through the park, blinds for observing animals, and signs explaining the area's delicate aquatic habitat. Four Star Park stands to become a very unique setting in the midst of what eventually will become a mass of warehouses and light industry.

Design *(cont. from page 9)*

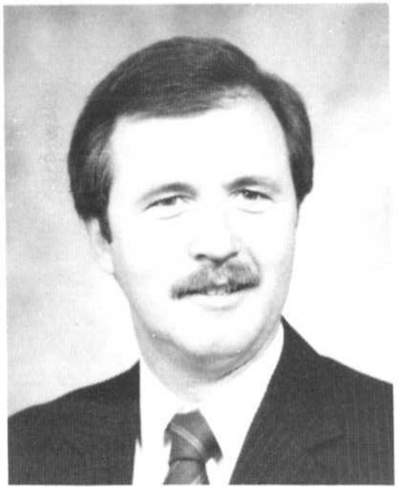
Water Department to improve the embankment structurally.

The connecting link in the Upper Sloans Lake Project is now under construction. This phase of the project extends from Ingalls Street and 20th Avenue to Reed Street and 25th Avenue. When this phase is completed, an improved storm drain system will have been constructed from Sloan's Lake to 26th Avenue and Wadsworth Boulevard. The contractor is Trainor Construction Company and the design engineer is URS Corporation. The project included placement of reinforced concrete pipe ranging in size from 48 to 90 inches in diameter. A detention facility was constructed on the Jefferson High School athletic fields in Edgewater. A requirement of the Jefferson County School District was that the work had to be done during the summer and the fields be available for the fall classes. Work at the detention pond included constructing a 48 inch pipe across the field, embankment, retaining walls, spillway and some grading. The work was completed with resodding the weekend before school started in the fall.

A construction contract let by Aurora to Randall and Blake, Inc., started this spring for the Sand Creek Project from the confluence of Sand Creek and Toll Gate Creek to east of Chambers Road. The project was designed by Greenhorne & O'Mara, Inc. This project requires the placement of approximately 32,000 cubic yards of soil cement. The soil cement was used in place of riprap for bank protection. The bid schedule included alternate bids for soil cement and a riprap channel. The soil cement channel was the least cost. Included in the construction are three sheet pile drop structures faced with pre-cast architecturally designed panels.

Placing soil cement in Sand Creek.

MEET THE NEW BOARD MEMBERS



JOHN P. STONE

Commissioner, Jefferson County

John Stone was elected to the Board of County Commissioners in November, 1986, and began his first term in office in January, 1987. Prior to his election he spent 13 years with the Lakewood Department of Public Safety as a Crime Scene Investigator. For five years before that he was a Police Officer in Palo Alto, California.

Commissioner Stone has an Associate of Arts in Law Enforcement from De Anza College; and a Bachelor of Science in Law Enforcement and Business Management from Metropolitan State College.

In the past Mr. Stone has served as a Director of the Bancroft Fire Protection District and Vice Chairman of the International Police Officers Association. He helped found the Colorado Law Enforcement Rodeo Association and the Lakewood Regional High School Rodeo Team.

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