FLOOD HAZARD NEWS

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# DRAINAGEWAY EROSION IN SEMI-ARID URBANIZING AREAS

by Ben Urbonas
Chief, Master Planning and Maintenance Programs

## INTRODUCTION

The District has always been aware of the problem of erosion of major drainageway channels, both natural and man made. We also recognized a trend towards *increased* deterioration of these drainageways when the tributary watersheds urbanized. However, the magnitude of the problem was not fully realized until the District became directly involved in maintenance activities in 1979. Immediately our awareness of erosion damages to drainway facilities increased. Design criteria limiting channel velocities were supposed to prevent severe erosion problems. However, erosion damage was evident everywhere. We started to recognize the shortcomings of how the District's design criteria was being applied. All the emphasis was being placed on controlling the velocities for the infrequent 100-year flood and no attention was given towards controlling erosion from the frequently occurring storms (i.e. 2-year return or less.).

Figures 1 through 4 illustrate some of the erosion problems that are commonly found. For some of these problems, such as erosion at storm sewer outlets, the causes are obvious and can be controlled with paved rundowns similar to the one shown in Figure 5. However, what causes general stream degradation is not always so obvious. Failure to understand the erosion processes and the means to control these processes continues to contribute to major drainageway erosion problems in the urbanizing Denver metropolitan area. There is a need to increase awareness of these problems, and their potential solutions, before comprehensive programs can be undertaken by local governments and industry to control them.

## EROSION PROCESSES

Erosion and sediment transport in a waterway is difficult to quantify, although the state of the art in this field of engineering has progressed over the past 20 years to where reasonable quantitative predictions can be made. Unfortunately, there is a limited number of individuals that understand the technology and can use it accurately. As a result, we often have to rely on a conceptual understanding of the problems and what is needed to prevent them in the future.

Waterway erosion and sediment transport is affected by many factors such as bed slope, discharge, depth, velocity, sediment load, soil type, vegetative cover, etc. The stability of a waterway is a delicate balance between these factors. Disturb or change one and all the others readjust to establish a new state of equilibrium. For instance, an increase in stream slope because of stream straightening and rechannelization will often be accompanied by stream bed meandering, degradation and readjustment to a new, stable slope. Also, an increase in flow will be accompanied by an adjustment to stream slope and degradation. On the other hand, an increase in a sediment load from lands undergoing development will cause the waterway to aggrade.

(Continued on page 2)

Figure 1—Degradation on Toll Gate Creek tributary in Aurora.

Figure 2—Erosion and degradation on Bear Creek in Boulder.

Figure 3—Degradation on Little Dry Creek in Arapahoe County.

Figure 4—Erosion at storm sewer outlet.

## EROSION (Continued)

Figuure 5—Paved rundown to trickle channel.

The process of aggradation is often indicated by culvert and bridge silting and results in the loss of waterway capacity to carry floods.

It is an established fact, supported by data, that surface runoff is increased by urbanization. The amount of increase depends on climate, the size of the storms, and the predevelopment land condition. Figure 6 illustrates the statistical shift of peak flows for a 100-acre parcel of land when its land use changes from native grassland to single family residential development. This shift is representative of an area located in the District having soils classified by SCS and Hydrologic Soils Groups C and D (fair to poor drainage). The shift is even more dramatic for better draining soils such as Hydrologic Soil Groups A and B.

If you examine Figure 6 you will notice a 2-year peak flow from the site after urbanization had a 10-year return frequency before urbanization. For runoff events smaller than the 2-year event, the ratio of post-urbanization to pre-urbanization peaks increases to infinity as the storms become smaller and smaller. On the other hand, the ratio in peak flows may be less than two for the 100-year event. Similar shifts in the volume of surface runoff also occur with urbanization.

An increase in the flow peaks, volumes and their frequency of occurrence causes a drainageway to accommodate itself to the increase. Erosion, degradation, and increased channel meandering will result. The physical processes involved are natural and have been in existence from the very beginning of time. When man's activities cause one of the variables in the stream stability balance to be altered (i.e. flow), the others readjust until a new balance is reached.

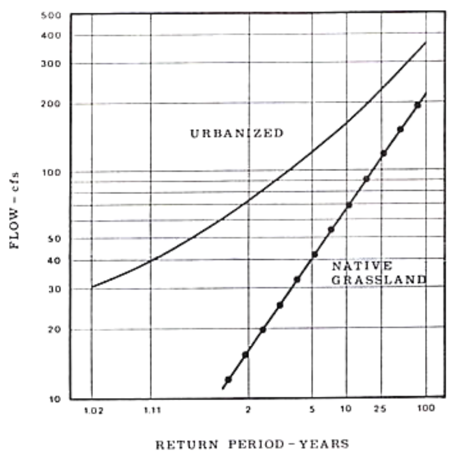
Detention is often used to control the peak flow from urban areas. Some have suggested the use of on-site detention as a solution for erosion control. Unfortunately, detention does not reduce the runoff volume. It merely reduces the peak flow by extending the duration of flow. This increase in volume and duration of runoff causes degradation of the stream bed in the waterways that had virtually no flow for most of the time prior to urbanization. This is not to say that detention does not help urban drainage and flood control; however its net effect on controlling erosion needs to be questioned and studied further.

### NEED FOR CONTROL MEASURES

Both man-made and natural channels in urbanizing areas will experience erosion and degradation unless the natural processes are checked. The District has encouraged the preservation of 100-year flood plains or the construction of grass-lined open channels as development occurs. These options have many flood control advantages; however, the erosion problems along these types of drainageways must be controlled. One method of control is revegetation and adequate mulching. In our climate, it is difficult and expensive to revegetate an area with native grasses. However, it must be done, or weeds will take over. Erosion resistant vegetative cover of native grasses becomes extremely difficult to establish once weeds take hold, and in the meantime, the drainageway banks are susceptible to erosion damage.

Figure 6

CHANGE IN PEAK FLOWS
100 ACRE SINGLE FAMILY RESIDENTIAL SITE




Another means of control is to adjust the effective channel slope by providing drop structures and/or low flow erosion checks. Figure 7 depicts how a channel profile will typically degrade. Without any erosion checks, it will seek a slope that is stable under the new hydrologic flow regime. Erosion checks provide a stable slope while controlling soil loss. A rule of thumb used in preliminary design is to space low flow checks using a longitudinal slope of 0.4 to 0.5 percent and one to two feet of stream bed degradation at each check. The check structures have to be sufficiently protected from underscour damage.

Drop structures act as checks for major flows and low flows. They are oftentimes massive in size and expensive to build. However, without them, an urban drainageway would be very unstable. Figure 8 is a photograph of a drop structure built on Sanderson Gulch by the District and controls

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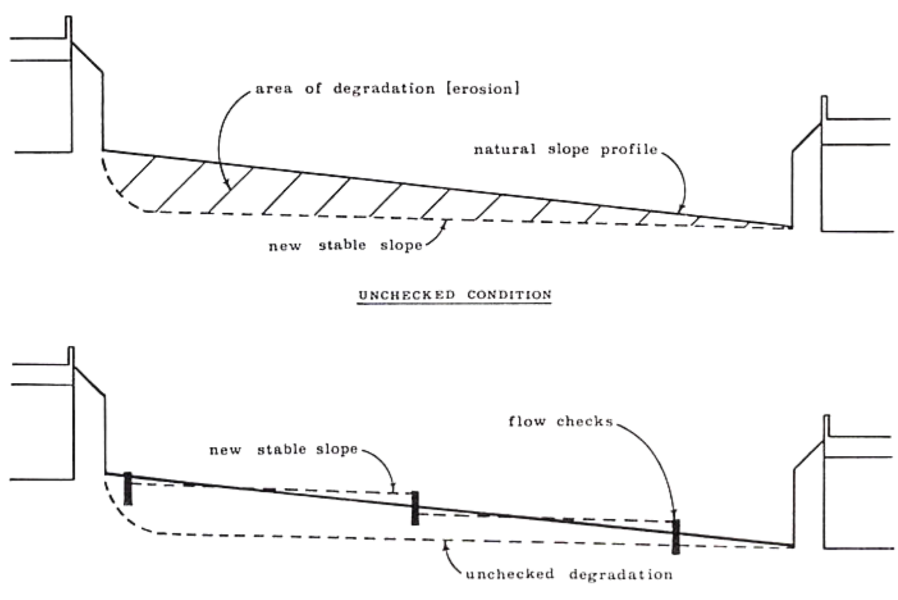
Figure 7

**STREAM DEGRADATION CONTROL IN URBAN AREAS**



# Tucker-Talk

by L. Scott Tucker

*Timely Comment from the District's Executive Director*

## After Studying It—Then What?

The Urban Drainage and Flood Control District is fortunate to have a small but stable revenue for the construction of drainage and flood control facilities. Since drainage and flood control is the only District responsibility, there is no competition for funds between patching streets, building more parks, repairing roads and bridges, hiring more policemen, etc. Our major problem is stretching that relatively small amount of revenue over a relatively large area with many problems. To illustrate, as of January, 1980, 31 major drainageway master plans had been completed and 6 were underway. Approximately $300,000,000 of needed improvements have been identified in those master plans. Needless to say, we will not run out of work for some time based on the District's annual construction revenue of $2,500,000.

The approximately $300,000,000 of identified needs address only major drainageways. It is my guess that needed storm drainage improvements probably exceed $300,000,000 by several times when the whole Denver metropolitan area is considered.

One source of funding drainage improvements that has not been fully explored is drainage fees. The concept of a fee is that a charge is made based on the provision of a service or for the use of a facility. In the case of drainage, the fee would be related to the use of the drainage facility by the tributary properties.

Some entities in Colorado have drainage development fees, most notably Arvada and Colorado Springs. Communities that have general drainage fees include Boulder, Denver and Aurora. Denver just passed an ordinance this year authorizing them to collect a fee with the first revenues being generated in 1981.

One concept that has not been tried, to my knowledge, is the charging of a drainage fee in a specific basin to finance specific improvements. This concept could be used to finance major drainageway improvements by spreading the costs to all property owners in the basin. If the cost of a drainage fee could be held to the $5 per month or $60 per year range, for an equivalent single-family dwelling unit, I think the concept would be viable.

A fee of $60 per year, given an 8% interest rate and a ten year payback period would raise an initial amount of $400.00. If there were 5,000 equivalent single-family residences in a basin, then 5,000 × $400, or $2,000,000, could be raised via a revenue bond.

Governmental financing in general seems to be going in the direction of user charges. Drainage and flood control at the local level could very likely head that way as well.

## The Coming Together of a Total Drainage and Flood Control Program

The Colorado Legislature in 1979 authorized the District to levy up to 0.4 mills for the maintenance and preservation of floodways and floodplains. Funds from this mill levy authorization will first become available in 1981.

Since the passage of the maintenance levy authorization, the District has been in the process of developing a maintenance effort. The maintenance capability brings together a total program of activities for the District.

The District has been involved in major drainageway master planning since 1980, when the Weir/Sanderson Gulch Master Plan was initiated. All master plans have been completed in cooperation with local governments, and over $2,000,000 have been spent in this regard. The need for major drainageway planning is diminishing, and emphasis in the future will shift toward subbasin planning and total basin planning.

Just studying the problem, however, does not solve it. The Legislature recognized this dilemma, and in 1973 authorized the district to levy up to 0.4 mills for construction of drainage and flood control facilities. As of January, 1980, approximately $25,000,000 of projects have been committed with the District's share being in excess of $9,000,000.

In 1973, the District also initiated an active floodplain management program. The District's floodplain management program emphasizes nonstructural activities, including flood hazard area delineation, floodplain regulation, flood warning planning and implementation, development review, floodplain occupant notification, flood insurance coordination, and flood hazard information dissemination.

The provision of a maintenance capability provides an important missing link in the District's capabilities. The maintenance of facilities is critical to insure the adequate performance of a facility over a long period of time. There is one slight hitch, however: the Legislature authorized the maintenance levy only for the years 1981, 1982 and 1983. It could only be a three-year program unless the Legislature extends or removes the time limitation.

## Flooding Below Water Storage Dams—A Curious Dilemma

As the Denver metro area and other portions of the State of Colorado develop and urbanize, the problem of flooding below dams increases. A striking example in the Denver metro area is Maple Grove Reservoir on Lena Gulch. Another problem that surfaced this year was in Silverthorne below Dillon Dam and Reservoir.

Maple Grove Dam and Reservoir is located at 27th and Youngfield in Lakewood. The facility, built in 1957, is owned and operated by the Consolidated Mutual Water Company for the purpose of water storage. In addition to water storage the earthen dam incidentally provides limited flood control on Lena Gulch.

When the Maple Grove Dam was completed in 1957, there were virtually no residences on the floodplain immediately downstream of the facility. Now the floodplain is significantly developed. Also, increased urbanization has increased peak flows, which has increased the flooding problem.

While the dam and reservoir provides some dampening of flood peaks, there are discharges over the emergency spillway at the 10-year frequency and above. While the dam *appears* to provide protection to residents located downstream of the facility, the possibility of flooding still remains. Also aggravating the problem is a lack of an adequate channel from the dam downstream to the confluence of Lena Gulch with Clear Creek.

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## TUCKER TALK (Continued)

Residences and businesses located along Lena Gulch are still occasionally flooded. The residents along the creek look at the dam and the potential flood storage, and want Consolidated Mutual to provide more flood protection. The water company, on the other hand, wants as much water storage as possible, to ensure adequate water supplies.

Who is responsible? Development below the dam in its present form should have never occurred. The apparent protection offered by a water supply reservoir, and in some cases, flood protection dams as well, should be seriously evaluated before development is allowed to proceed below the spillway of the dam. Legislation should be considered that will give local governments the authority to control development in areas located below the spillways of dams.

The second situation mentioned is the town of Silverthorne located on the Blue River below Dillon Dam. Dillon Dam is owned by the Denver Water Board, and is for the purpose of storing water for the Denver metro region.

1979-80 was a good snow year, and the reservoir filled rapidly during May and June. As the water surface began to rise, the Water Board began to let more and more water out of the dam. Water Department officials warned residents of Silverthorne that heavy winter snows would mean higher than normal runoff, and possible flooding. They also advised the residents of Silverthorne to move their mobile homes from along the banks of the river to higher ground, but Silverthorne officials responded by buying sandbags and urging the residents to purchase flood insurance.

The Water Board cooperated with Silverthorne to the extent possible by increasing the flow out of the dam to be in excess of the inflow while at the same time being consistent with downstream capacity.

When the snowmelt period was over, the flooding problems in Silverthorne were minimal. However, it was close, and the threat demonstrated the potential problem. Dillon Reservoir was not constructed as a flood control facility. Development below Dillon Reservoir should have been controlled in recognition of that fact. Development was not controlled properly and now there is a potential flooding problem. Who is responsible? Again, this situation points out the need for legislation which will authorize local governments to control development below reservoirs much more carefully than they have in the past.

## Stormwater Detention—Pain or Panacea?

Urbanization tends to increase the peak discharge and volume of runoff for a given rainfall event compared to natural conditions. This phenomenon is generally accepted and has been rather conclusively demonstrated. The effect on peak flows can be as much as 2 to 6 times for smaller rainfall events, with less effect for higher intensity storms. In the Denver region, some of the District's rainfall/runoff stations located on totally undeveloped basins, never recorded runoff. Similar basins in developed areas recorded runoff after every rainfall event of any significance.

This phenomenon has been recognized by the District in the delineation of floodplains and the planning and design of facilities. The hydrology used by the District in floodplain delineation and flood control planning and design is based on developed basin conditions.

It can be argued that developers should detain the flows so as not to increase downstream flows over historic rates. Intuitively this is a great idea, but how does it really work? Small, on-site detention facilities randomly scattered throughout a community are what result when each developer is required to install a detention facility to control runoff from his development.

Without careful thought and design these random ponds can be ineffective or even harmful. Some local governments in Colorado require only that 100-year peak discharges be maintained at pre-development levels. The frequent events oftentimes pass right on through the ponds. Thus, the downstream properties see increased flows and increased drainage problems with every significant rainfall. These routine events are the ones that give local governments the most problems on an annual basis.

Another problem is that these ponds are seldom designed to retain the increased volumes which result from urbanization. The increased volumes, combined with changes in peaking times caused by the ponds, can actually result in the same or even larger discharges in the major drainageway, thus defeating one of the major reasons for requiring on-site detention. Again, design criteria is critical.

Another concern is that of assuring the long term effectiveness of the detention ponds. They must be checked to assure that they have been built in accordance with approved plans. They must also be monitored periodically to assure that they are properly maintained.

To make detention truly effective, a community should estimate what the potential effects of detention are on downstream flows and develop basinwide and communitywide plans accordingly. Design parameters can be varied in the planning stage to determine optimum criteria. The District has been working with Lafayette to develop a drainage master plan in which detention will play an important role. However careful consideration was given to detention criteria and requirements to determine and insure its effectiveness. Detention can be used to lessen peaks downstream but downstream facilities will still be needed.

In essence random on-site stormwater detention can be a pain or it can be an asset. To be an asset, design criteria must be carefully considered, design of proposed facilities carefully reviewed, and a program of future maintenance to ensure proper operation must be developed. If these steps are not taken, on-site random stormwater detention may end up to be a pain instead of a panacea.

## MEET THE NEW BOARD MEMBERS

### EUGENE L. OTIS
*Mayor, City of Englewood*

Mayor Otis retired in 1979 from the General Accounting Office after a career as a management analyst/auditor. Shortly thereafter he was elected to the Englewood City Council and selected by his fellow council members to be Mayor. He has lived in Englewood for 29 years.

Mayor Otis has been active in the United Methodist Church, serving as church treasurer, assistant lay leader, President of Methodist Men and Sunday School teacher. He is also a member of the El Jebel and Englewood Shrine clubs. He and his wife Ruth have three children.

# EXPERIENCE GAINED IN MAINTENANCE PROGRAM

*An interesting aspect of the new drainageway maintenance program being implemented by the District comes to light in our inventory program, where the District hires consulting engineers to review a drainageway in detail, identify maintenance problem areas, and estimate costs to bring the drainageway up to an acceptable maintenance standard. Many examples of designs—both good and bad—are noticed in the field. The experience gained in reviewing actual field performance of improvements to drainageways give the District's maintenance engineers valuable insight as to how future improvements can be designed, and how present maintenance activities can be performed. The following two articles, written by the District's maintenance engineers, relate their observations and experiences in two important areas; low flow crossings and revegetation.*

## REVEGETATION FOR EROSION CONTROL

*By Steve Hogoboom*
*Maintenance Engineer*

The most common and serious problem encountered in the District's inventory of drainage facility maintenance needs was erosion of channel bottoms and sides and dam embankments. Three general types of erosion were encountered: 1. Sheet flow erosion—Caused by flows that enter the drainageway system from lands that are directly connected to the main channel; 2. Local flow erosion—Caused by flows that have been concentrated in areas not directly connected to the main channel and transported to the main channel via pipes or street systems; 3. Main channel erosion—Caused by flows that have been collected from local systems and are being transported in the major channel to the final receiving waters. Some of these problem areas require structural solutions (drop structures, riprap, etc.) but many others can be protected by establishing a good vegetative cover.

The establishment of vegetation is difficult because of our semi-arid climate and because many of our drainageways have poor soil characteristics when it comes to revegetation. It is for these reasons that the District has emphasized the use of regionally adapted drought resistant perennial grasses for revegetation.

The perennial grasses exhibit many characteristics that make them favorable for use in and along drainageways, the most important of which is their resistance to the types of erosion commonly experienced. This resistance is achieved through a diversified and dense root structure. A cross-section of a group of grass plants shows that the root system commonly extends 12" deep and the shorter roots are so dense and intertwined that it is only with difficulty that they can be torn apart. Another major reason for the use of perennial grasses is their adaptability to varying climatic conditions, soil texture, and chemical conditions.

All of the drainageway projects that were constructed with the District's assistance have used locally adapted perennial grasses that require only natural moisture. The techniques of seeding and seed mixtures experienced to date have yielded mixed results. Yet, once established, these grasses have proven to be erosion resistant and the attendant maintenance costs have been reasonable.

The sequence required to plant the seed mixture is basic and has been used for over a century by dry land farmers in this region. In order of their respective operations they are as follows: Soil preparation, fertilization, seeding and mulching. Each of these operations has been closely observed by the District over the past years and subtle refinements in these operations have been developed and used, resulting in greater success.

The goal of soil preparation is to establish a firm and uniform seed bed. No effort should be spared in the establishment of this seed bed. If the soils encountered are clayey, with clods, reworking of the soils many times with a ripper and a chain harrow is required. If the embankments of the channel or dam have been compacted under controlled conditions to extreme degrees, it may be necessary to import topsoils in order to establish the seed bed. It has been found in observing many miles of streams and gulches in the sandy soils of eastern Arapahoe County that the import of special material is necessary to temper the natural state of the soils in order to provide a more cohesive seed bed. It is not easy to determine when the seed bed is ready for fertilization; advice from your local Soil Conservation Service agent may be necessary.

Fertilization is necessary to assure that nutrients are available for the new grasses when they need the artificial stimulation. Soil samples should be secured from the areas to be seeded and tested by a recognized soil testing firm

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## LOW FLOW CROSSING STRUCTURES

*by Mike Dungan*
*Maintenance Engineer*

Low flow crossing structures are often used to allow maintenance and hiker-biker trails to cross low flow trickle channels. These low flow crossings, although indispensible in our urban settings, have some design and maintenance problems that require attention.

For instance, many crossings we have seen become easily plugged with debris common to an urban area. A crossing of this nature must have periodic maintenance in order to perform its intended function. Another frequently observed situation requiring maintenance is the silting in of small pipes used to convey runoff under the trails. Small pipes can be almost impossible to clean by hand without the aid of expensive sewer jetting equipment. These low flow crossings are also susceptible to overtopping at frequent intervals. For this reason, erosion protection must be provided downstream of all low flow crossings.

Many low flow crossings are constructed using one or more pipes in the low flow area of the channel, with an asphalt or concrete trail over the top. Other types of crossings in use include timber and formed concrete structures. Each of the crossings has advantages and disadvantages which are unique to their design. The problems associated with pipe crossings have been covered previously. Concrete structures have a higher initial cost but are usually more permanent structures. Careful attention must be paid to protection from downstream erosion and side cutting around the structure. Crossings made of timber or other floatable materials have the potential of creating a flooding problem because, upon failure, they can float downstream and obstruct major channel crossings. This can result in raised levels during flooding and increased flood damages. Timber crossings can be designed as breakaway structures with the main deck attached to an aircraft cable and anchored to a suitable foundation to prevent the crossing from becoming a downstream flow obstruction.

It is recommended that low flow crossings be designed to prevent overtopping or significant backwater from approximately the one-year event. Too frequent overtoppings can cause undue erosion and possible failure of the struc-

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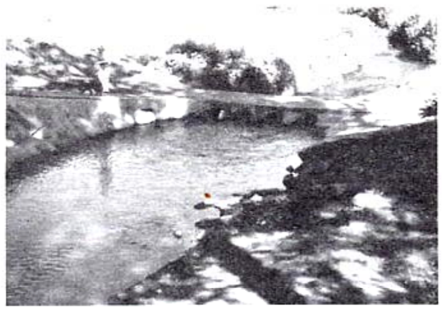
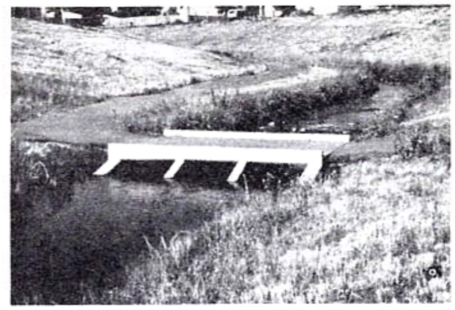
## LOW FLOW (Continued)

ture. In addition, frequent overtopping reduces availability for use by the public. Depending on velocities, needed erosion protection could be provided by vegetation, riprap, or any of a number of commerically available erosion control mats. When considering overtopping it is easy to see why the entire low flow crossing structure must be made of erosion resistant material. A crossing that needs frequent replacement would not be acceptable as far as use or maintenance is concerned.

Pipes used for crossings need to be designed with adequate slopes to keep sediment flushed through the structure. Also, the downstream channel must be kept clear to prevent a high tailwater condition at the pipe outlet. To improve on the inlet capacity of pipes the use of standard flared end sections or transitions is recommended.



Pipe low flow crossing on Ralston Creek in Arvada



Concrete low flow crossing on Sanderson Gulch in Denver

The preceeding paragraphs have explained qualitatively how some problems concerning low flow crossings affect their usefulness. Experience gained from in-place observations of these structures suggests they should be designed and constructed with the same sound design and good engineering practice that larger structures command.

## REVEGETATION (Continued)

to determine specific chemicals required and their rates of application. The District has found that applying pelletized fertilizer has given better results than liquid fertilizer. Liquid fertilizer leaches from the root zone too fast for the small grass plants to use the nutrients. A light chain harrowing of the spread fertilizer is suggested in order to mix the pellets with the soil.

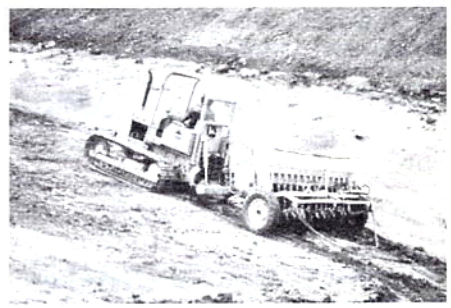
The design of the seed mix should be undertaken by an expert familiar with the specific conditions of the site. The District has adopted as a standard a mix that contains both native and introduced seed species. This standard mix must be adjusted for every case. The key to a mix that yields an established stand of grass rests on its adaptability to the site. A detailed site survey of undisturbed grasslands near the disturbed site to determine what grasses are well established in the undisturbed areas will increase the chances of success. Consultation with the Soil Conservation Service or the County Extension Agent is the best first step in seed mix design.

A key concept in seeding has sometimes been forgotten in this era of high technology. That is, the seed must be placed in contact with its best suited environment, the soil. The technique that best accomplishes this operation is seeding with a grass drill. The District has used several contractors that have specially adapted grass drills that can and will seed slopes as steep as 2:1. In extreme cases the use of hydraulic seeding equipment is necessary. However, the necessity of the seed to be in contact with the soil should not be forgotten. Do not accept a combined hydro-seed/mulch operation. Pay the extra cost of two distinct hydraulic operations: first have the seed sprayed on using only a couple of bags of mulch in the tank to meter its application and assure uniform coverage; and second, have the mulch sprayed on.

Of particular importance is the time of year when seeding should be done. The District's specification for seeding only rarely includes watering of the newly seeded areas; and, because of this, seeding can only be accomplished from March 15 to April 15 and September 1 to September 15. However, with a requirement for watering of the newly seeded areas until establishment, this time restriction can be lifted. In general, the District has found that grasses can be established without irrigation and the best time to seed is in the fall. By seeding in the fall the seeds and new plants can utilize moisture from late spring snows.

Mulching is required to aid in moisture retainage on slopes and to limit erosion until the seed has germinated and small plants are established. The District has found that chopped straw blown onto the area being seeded and then crimped yields the best stands of grass. However, for steep slopes and those with southern exposures, wood fiber mulches applied by hydraulic methods have yielded acceptable stands of grass.

The continued maintenance of newly seeded areas for three or four years is essential for the establishment of an erosion resistant cover. Maintenance includes mowing (3 times a year), fertilization (once a year) and weed spraying (once or twice a year).



Seeding with a grass drill.

Rows of grass seeded with a drill.

In summary, seeding is an operation which appears simple yet is very complex. In order for a seeding operation to be successful, the selection of a contractor following the steps listed above, a good erosion resistant vegetative cover can be established.

## Status of Planning and Maintenance Programs

By Ben Urbonas
Chief, Master Planning
and Maintenance Programs

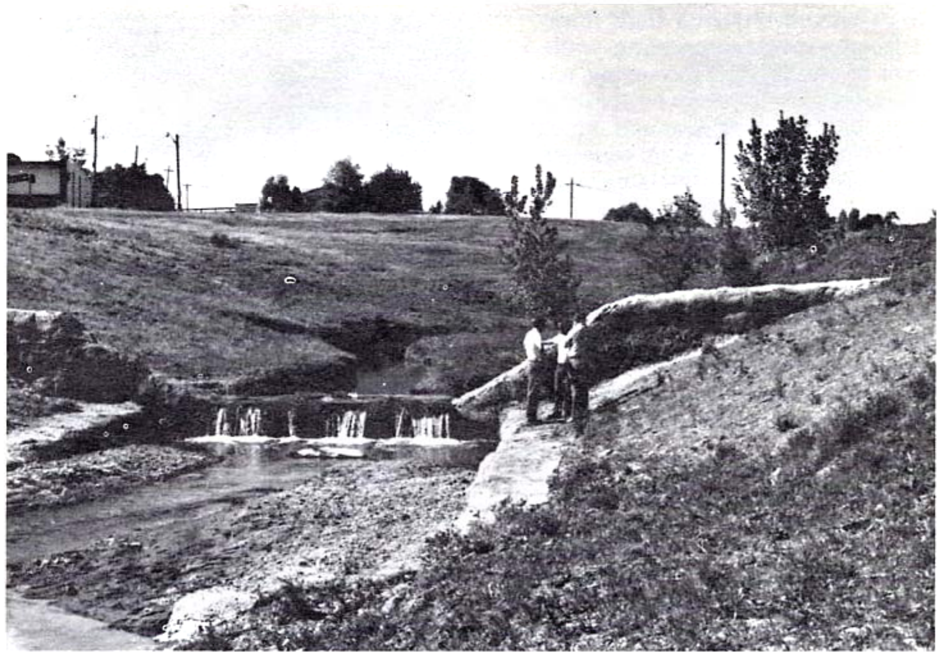
During 1979 the Colorado General Assembly authorized the Urban Drainage and Flood Control District to levy, during 1981, 1982 and 1983, up to 0.4 mills for the maintenance and preservation of floodplains and floodways. The District's Board of Directors felt that the District should know the nature and extent of the maintenance problems and needs and should have some experience in performing maintenance activities prior to establishing the 1981 maintenance mill levy.

As a first step in defining maintenance problems and needs, Distict staff members met with officials from most of the 34 local governments within the District to determine their perception of maintenance needs within their jurisdictions. Following these meetings, engineering consultants were retained to conduct reconnaissance surveys of maintenance needs in each of the six counties within the District. These studies have been completed and results, along with the local official input, are being used to develop the 1981 maintenance program.

To gain experience in performing maintenance the board of Directors allocated some of the District's 1980 capital construction funds to a limited maintenance effort. Two maintenance engineers were hired to implement the maintenance effort. Steve Hogoboom became a full time staff member in January of 1979, at a time when the District began to assist local governments with the maintenance of drainageway facilities owned or improved with District financial assistance. Mike Dungan was hired in January of 1980. During 1980 the two of them will have handled 12 to 15 maintenance contracts in the six counties totalling approximately $600,000.

I was assigned the responsibility for the overall maintenance program. This is in addition to the responsibility for the master planning program and new technology development projects. Because the maintenance program is in its formative stages and does not have a full time program manager, the time spent on it had to come from the master planning activities. As a result, the number of new master planning projects during 1980 was reduced. We expect the number of new planning projects to increase in 1981.

The nature of planning projects in which the District will participate is changing. For years we have concentrated only on the major drainageway problems. By now, the majority of the drainageways with flooding problems have either been master planned or a flood hazard area delineation report has been published. Also, the District has had requests from local governments to assist with the planning of drainageway facilities on a basinwide or community basis. Last year we started our first multi-jurisdictional drainageway planning study that looked at the total subbasin needs. The study was limited to the planning of an "arterial" system of drainageways such as major interceptors, outfall channels and detention facilities. We see a shift towards this type of planning in the future. At the same time we want to limit the District's participation to the planning of multi-jurisdictional drainage problems. Anyone having a need for this type of planning assistance should contact the District. More than likely we will enter into this type of project on a first-come, first-served basis.



Past issues of Flood Hazard News have outlined problems the District has experienced with gabion structures. One solution the District has tried is to grout the entire structure with brown colored grout. This structure is on Weir Gulch in Denver.

**TALK TO US!**

What topic would you like to see in the next issue of

**FLOOD HAZARD NEWS?**

## MEET THE NEW BOARD MEMBERS

### BONNIE ALLISON
*Mayor, City of Edgewater*

Mayor Allison is a Colorado native and 30-year resident of Edgewater. She was elected Councilwoman in 1975 and Mayor in 1977 and 1979.

Mayor Allison received her A.A. degree from Community College of Denver in 1977. She is presently serving on Governor Lamm's Front Range Project and the Governor's Conference on Aging. She is also active in the Colorado Municipal League, Jeffco Governments and Jeffco Mental Health. She married her high school sweetheart and they have two grown children and one grandchild.

channel velocities during high flows. Note the downstream training walls. Control of frequently reoccurring low flows and trickle flows can be achieved with the use of trickle channels which are often lined with rock or concrete. Use of lined trickle channels prevents channel degradation from the increased low flows. In addition, trickle channels facilitate urban drainageway maintenance and help reduce buildup of sediment whenever land erosion is occurring upstream. Figure 9 is a picture of a trickle channel installation in an Arapahoe County subdivision. It is attractive and controls erosion effectively.

Figure 8—Drop structure on Sanderson Gulch in Denver.

Figure 9—Concrete trickle channel in an Arapahoe County subdivision.

### DISTRICT ACTIVITIES

The District is actively involved in the planning, design, construction and maintenance of major drainageway facilities. At the same time drainageway facilities are being built by private developers in the process of land development throughout the District. In early 1980 the District Board established a policy requiring that the designs of all major drainageway facilities to be built by others be reviewed and approved by the District in order for them to qualify for future District maintenance assistance. We have in the past provided plan review assistance to local governments; however, the new policy increases our involvement in the design review process.

The District also participates in and sponsors seminars related to urban drainage and flood control. Education, technology transfer, and encouraging awareness are activities that the District has always considered important. As a small regional agency we cannot solve all of the drainageway related problems. By increasing awareness, a larger number of public works officials and engineers are realizing the need for stable, multi-purpose, maintainable drainageways. Unless adequately designed and constructed drainageway facilities are provided at the outset, the District and the local multi-purpose governments and their citizens are faced with assuming the continuing problems and expenditures that are inherent in poorly designed and/or built drainageway facilities.

## FLASH FLOOD WARNING EFFORT PROGRESSES

*by Bill DeGroot*
*Chief, Flood Plain Management Program*

The District's involvement in flash flood warning has been moving forward at an accelerated rate. We have developed a two-pronged effort consisting of an area-wide system and individual drainage basin plans.

The goal of the area-wide system is to provide improved meteorological data to all local governments within the District. To do this the District has retained GRD Weather Center, a private meteorological company, to work with the National Weather Service Forecast Office (WSFO). GRD is capable of providing forecasts of potential flooding situations for a specific area (namely sub-areas the District) whereas the large area of responsibility and manpower limitations of the Denver WSFO make such specific area forecasts difficult. Although some coordination problems have occurred, as can be expected with any new effort of this type, this arrangement has worked quite well in only its second year of operation.

GRD provides forecasts of potential flood producing rainfall to one contact in each of the six counties in the District. These contacts, in turn, fan-out the forecasts to the affected local governments within their respective counties. Local acceptance of this program has been very good.

The District has also been working with local governments to develop flood detection networks (rain and stream gages) and flood warning plans for specific drainage basins. The first basin plan to be fully implemented was for Westerly Creek (See *Flood Hazard News*, July, 1978). The system for Boulder Creek is in the process of being installed with completion scheduled for 1981. GRD is also involved in these plans and provides specific forecasts for these basins in addition to the other forecasts discussed above.

Additional planning efforts are underway for the Bear Creek and Lena Gulch drainage basins. The District is available to assist other local governments in the planning of warning systems upon request.

## DISTRICT RECEIVES AWARD

April 20, 1980, was a special day along the South Platte River. On that day the Environmental Protection Agency, Platte River Greenway Foundation and local governments sponsored "Earth Day On The Platte" to celebrate the ten-year anniversary of Earth Day.

As a part of the day's activities the Greenway Foundation presented "Friends of the River" awards to 15 individuals and organizations who had made significant contributions to the revitalization of the South Platte River. The District was pleased to be one of the recipients of this award.

Prior to the Earth Day celebration the District's Board of Directors adopted a resolution which states in part that "... the Board pledges the District's continued support in the development of multi-use urban flood control improvements compatible with the restoration and recreational opportunities provided thus far and to be provided in the future on the South Platte and its tributaries."

Chairman Cathy Reynolds accepts the award from EPA Administrator Roger Williams

# *DESIGN AND CONSTRUCTION NOTES*

*B.H. Hoffmaster*
*Chief, Design and Construction Program*

The District has been busy with design and construction the past year and the future appears to be the same. The two accompanying tables indicate the status of projects now in progress.

At the present time there is a need for a standard set of specifications. Each job now has its own. This causes confusion for the contractors, suppliers and inspectors from job to job. The District is scheduling the development of standard specifications for flood control and drainage projects. This will supplement the already complete contract documents the District has put together.

By the same token, a good all-round specification would be desirable for the region. In many areas where these have been developed, the benefits have been found to outweigh the problems.

There is a continual problem with gabions. One problem reviewed recently was the rock size. The specifications do not set a minimum size and small rock works out of the basket between the mesh. The specifications, in the future, will be modified to specify a minimum size as well as a maximum size.

The District recently entered into an agreement with William Hughes, professor at the University of Colorado, Denver, to develop design standards for riprap channels. The work is about 90% complete and a review indicates that an excellent tool will soon be available to the design engineer.

Utility Coordinating Committees have been meeting around the region to expedite utility and public works projects coordination. Involved in the meetings are the utility agencies, cities, counties, State Highway Department, and special districts. They are performing an excellent clearing house for project conflicts.

## STATUS OF DISTRICT DESIGN PROJECTS

| **Project** | **Participating Jurisdictions** | **Status** |
|---|---|---|
| Westerly Creek Schedules III & IV | Denver | Plans Completed in September 1980 |
| Little Dry Creek (Arapahoe County) | Englewood, Greenwood Village | Plans being completed on channel So. Santa Fe to So Platte River. Feasibility study of Prentice, Berry and Belleview Dams to be completed December 1980 |
| Upper Sloans Lake Schedule II | Lakewood, Edgewater, Denver | In Abeyance pending access to site |
| Harlan Street Storm Drain | Wheat Ridge, Mountain View | Design to be completed by end of 1980 |
| Lena Gulch Schedules II-VI | Wheat Ridge | 95% Completed |
| Hidden Lake | Adams County | Channel Design in review |
| Little's Creek | Littleton | |
| Schedule I | | 80% Complete |
| Schedule II | | 15% Complete |
| Van Bibber Creek Detention Reservoir | Arvada, Jefferson County | In Abeyance pending access to site |
| South Jefferson County Drainage Flow Separation | Arapahoe County, Nevada Ditch Company, Last Chance Ditch Company | 10% Complete |

## STATUS OF DISTRICT CONSTRUCTION PROJECTS

| **Project** | **Participating Jurisdictions** | **Cost** | **Status** |
|---|---|---|---|
| Westerly Creek | | | |
| Schedule I | State of Colorado, Denver, Aurora | $1,087,650 | 95% Complete |
| Schedule II | Aurora | 2,116, 500 | Construction Advertising late 1980 |
| Weir Gulch | | | |
| Schedule III | Denver | 1,652,445 | 98% Complete |
| Schedule IV | Denver | 1,008,949 | Construction started Sep. 1980 |
| Schedule V | Denver | 753,000 | Construction Advertising late 1980 |
| Upper Sloans Lake | | | |
| Schedule I | Denver, Edgewater, Lakewood | 1,363,700 | Construction Advertising by end of 1980 |
| Lena Gulch | | | |
| Schedule I | Wheat Ridge | 989,800 | Advertise September 1980 |
| Brighton Southeast Drainage | Brighton | 135,800 | Construction to be completed Oct. 1980 |
| North Tributary Columbine Knolls | Jefferson County | 181,000 | Construction Completed |

## CONSTRUCTION ON WESTERLY CREEK SCHEDULE I NEARS COMPLETION

Right—Near Stapleton International Airport east-west runway.

Far-right—Looking south from 19th Avenue.

# DESIGN NOTES—TRICKLE CHANNELS

Supplement to Flood Hazard News (September 1980)

*Editor's Note: Beginning with this issue of Flood Hazard News we are including a new removable section called Design Notes. Its purpose is to impart to the reader the experience gained by the District concerning a particular design problem. The initial topic is trickle channels.*

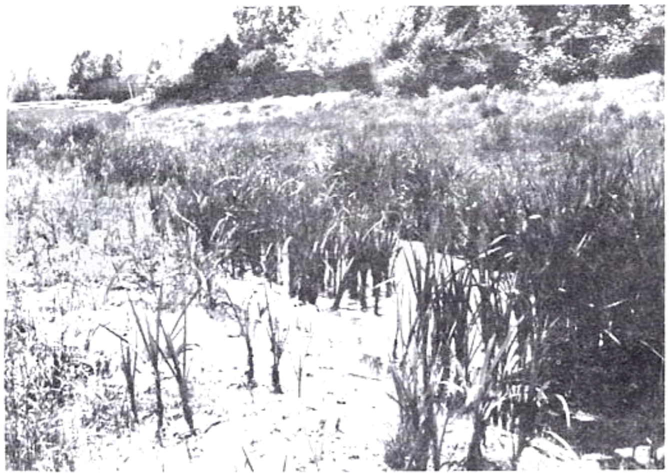


Figure 1—Earth trickle channel on Goldsmith Gulch in Denver

## Introduction

Section 2.3.3., Major Drainage Chapter, *Urban Storm Drainage Criteria Manual* (USDCM), Volume 2, states that, "Trickle channels or underdrain pipes are required on all urban grassed channels." A trickle channel is a small channel located within the major channel. Its purpose is to confine the normal base flows and runoff from minor rainfall events to a small protected area with the following benefits:

1. The remainder of the channel bottom is kept dry and accessible for routine maintenance such as mowing and trash removal,
2. Erosion and meandering caused by constant base flows is controlled,
3. Sediment deposition is controlled by confining the base flows, thus increasing the velocity and sediment transport capability of the base flow.

Grass lined channels have been used extensively in the Denver area by the District, local governments and private parties. Experience has shown that a good trickle channel is an important part of the design of a grass-lined channel. It should be pointed out that trickle channels may not be practical on major rivers or in channels through fine grained sandy soils.

This issue of Design Notes presents and analyzes several types of trickle channels which have been constructed in the Denver area and recommends practices to be followed in future designs.

## Types of Trickle Channels In Use In the Denver Area

The following types of trickle channels, which are in use in the Denver area, will be discussed in this issue:

1. Earth channel,
2. Rock lined channel,
3. Concrete channel,
4. Underground low flow pipe

## Earth Channel

The earth channel is the easiest and least expensive type of trickle channel to design and construct, but it also offers the greatest potential for problems to develop. Figure 1 shows an earth trickle channel in a grass-lined channel section of Goldsmith Gulch. Meandering, deposition and vegetative growth have combined to create a marshy bottom which is all but inaccessible for routine maintenance purposes. Figure 2 shows an earth trickle channel through a park on Big Dry Creek (Arapahoe County). Note the

Figure 2—Earth trickle channel on Big Dry Creek in Arapahoe County

Figure 3—Rocklined trickle channel on Lena Gulch in Wheat Ridge

area that is inaccessible for mowing.

Earth trickle channels are for the most part unacceptable to the District. The exception would be in park areas, such as shown in Figure 2, where a natural look is desired for aesthetic reasons. However, the park owner should be aware of the problems which may develop.

## Rock Lined Channel

Rock lined channels, when properly designed, have the ability to control erosion and they are more aesthetically pleasing than concrete structures. However, they tend to encourage sediment deposition and vegetative growth which decrease the design capacity and increase maintenance problems. They are also subject to vandalism, either by adults who take the rock for their lawns and gardens, or children who displace the rock while playing in the water.

Figure 3 shows a rock lined channel on Lena Gulch at 32nd Avenue. Figure 4 shows the design details of the channel. This channel has sustained discharges of over 400 cfs on three occasions with no discernable damage.

Great care must be taken to insure proper construction of this type of channel. Figure 5 illustrates that erosion damage can occur along a rock lined channel. Note also that vegetation is starting to grow among the rocks. The vegetation will encourage increased deposition and reduced channel capacity.

Properly designed and constructed rock lined trickle channels are acceptable to the District provided they have sufficient capacity to allow for the expected deposition and vegetation problems and also provided the rock size is sufficient (12" or larger) to deter vandalism.

## Concrete Channels

In general concrete trickle channels prevent erosion of the areas they cover, prevent vegetative growth and provide sufficient velocity to minimize deposition. They also allow mowing right up the edge of the concrete. On the negative side they are considered by most people to be less aesthetically pleasing than earth or rock-lined channels.

Concrete channels can be V-shaped, trapezoidal or rectangular. Shallow V-shaped channels have a tendency to suffer severe erosion problems at the interface of the concrete and the grass lined channel bottom. Figure 6 shows the erosion problems encountered on North Sanderson Gulch. This channel has a top width of 4 feet and a depth of 6 inches. This shape allows excessively high velocities to reach the grass areas. The channel on Goldsmith Gulch in Figure 7 has a top width of 6 feet and a depth of one foot. No erosion problems are evident along this channel. The larger dimensions appear to be successful in keeping high velocities away from the grass, although it is unknown if the Goldsmith channel has experienced the high discharges that the North Sanderson channel has.

We do know that the trapezoidal channel on lower Goldsmith Gulch shown in Figure 8 has sustained flows in excess of the major channel capacity with no apparent damage. The design details of this channel are shown in Figure 9.

Rectangular channels have not been used to any great extent to date. The District plans to try a rectangular section on the Hidden Lake outlet channel (Figure 10). Results similar to those experienced with the trapezoidal channel are expected. The rectangular channel can be more aesthetically pleasing than the other concrete sections if the normal base flow is sufficient to cover the entire bottom. Then the only visible concrete would be the walls, or curbs, and the concrete can be tinted to give a more natural color.

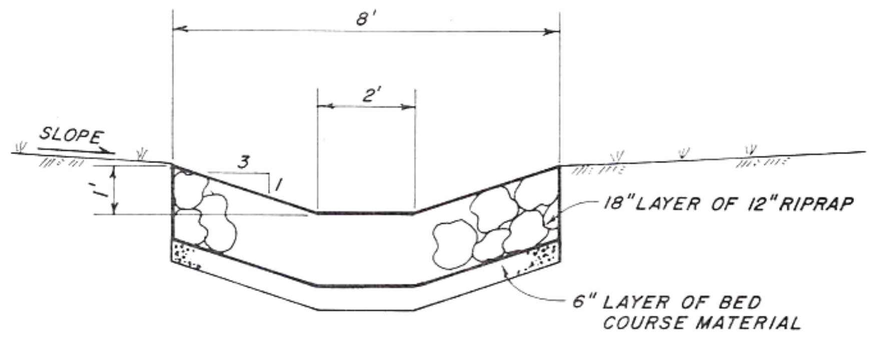



FIGURE 4 - LENA GULCH ROCK LINED TRICKLE CHANNEL DESIGN

Figure 5—Rocklined trickle channel on Goldsmith Gulch in Arapahoe County.

Figure 6—Concrete V-shaped trickle channel on North Sanderson Gulch in Lakewood.

## Combination Channels

In an effort to combine the benefits of the rectangular concrete trickle channel with the aesthetics of the rock lined channel, the District and cooperating local governments will be constructing combination trickle channels on Lena Gulch and Little's Creek as illustrated in Figure 11. The channel design consists of a concrete bottom with rock imbedded in the concrete to form the channel sides. The voids between the rocks will be grouted to prevent the soil behind the rocks from coming in contact with the water and being eroded.

## Underground Low Flow Pipe

Underground low flow pipes can be used when the owner wants to keep the entire channel bottom dry under normal weather conditions. Pipes have been used in at least a few channels in the Denver area with mixed results.

One problem that must be considered is that of insuring that all low flows get to the pipe. Otherwise these flows enter the channel and create the marshy bottom conditions the pipe was supposed to prevent. Another problem is that of clogging. This can be particularly severe when the upstream area is being developed and the low flows are heavily laden with sediment.

Because of these problems, the District generally discourages the use of the underground low flow pipes. However, if they are used they should meet the following criteria:

1. Minimum diameter - 24",
2. Minimum velocity - 3 fps at a depth of ½ the diameter,
3. Design discharge - 0.5% of 100-year design discharge,
4. Provide access manholes at 300'-500' intervals.

## Delivery of Low Flows to the Trickle Channel

For a trickle channel to fully perform its intended function the base flows must be delivered to the channel. Too often the base flows are released at the top of the major channel and allowed to run down the channel slope to the trickle channel (See Figure 12). This can result in erosion damage to the major channel. This water can also damage the trickle channel or collect outside the trickle channel, creating marshy conditions which accelerate damage to the grass channel bottom.

Low flows should be delivered to the trickle channel by either carrying pipes all the way to the trickle channel or providing concrete rundowns similar to that shown in Figure 13.

## Design Considerations

The design of the trickle channel is an important element which should be given the appropriate emphasis in the design process. While certain basic conditions must be met, the final selection of a trickle channel design should reflect the ingenuity of the designer. The basic design considerations are:

Figure 7—Concrete V-shaped trickle channel on Goldsmith Gulch in Arapahoe County.

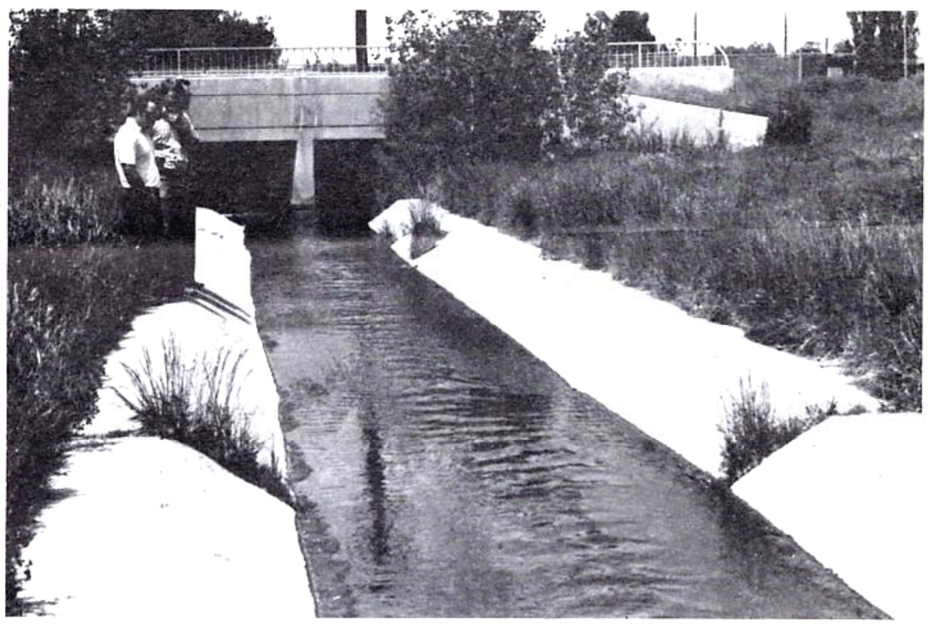


Figure 8—Concrete trapozoidal trickle channel on Goldsmith Gulch in Denver.

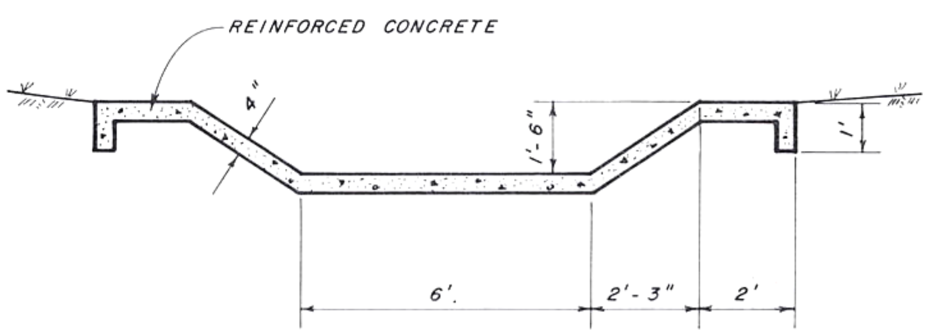



FIGURE 9 - GOLDSMITH GULCH CONCRETE LINED CHANNEL

1. Design discharge—The USDCM calls for a discharge of 0.5 to 1.0 percent of the major (100 year) design flow. If the channel is used to convey irrigation flows these flows should be added in to arrive at the design discharge.

2. Cost—Because of the number of variables no attempt has been made in this publication to compare costs of various channel design. The capital cost of each alternative must be weighed against the annual maintenance costs. This can be a tricky area, particularly when the builder of the channel (i.e., a developer) is different from the entity which will be responsible for maintenance (i.e., a local government or homeowner's association).

3. Aesthetics—The location and intended concurrent uses of the channel can impact the trickle channel design. A channel which is not highly visible or easily accessible will probably not have the aesthetic demands that a greenbelt or park setting would require.

4. Maintenance—The District is very concerned about the ability to perform maintenance of channels at a reasonable cost and level of effort. The trickle channel design must facilitate maintenance of the major channel and not be a problem itself.

## Summary

Trickle channels are an important element in the design of grass lined channels, and they should be given the appropriate amount of attention in the design process. The District prefers the use of rectangular or trapezoidal concrete channels based on observations of trickle channels in use in the Denver metro area. V-shaped concrete and rock-lined channels are also acceptable if the maintenance problems discussed above are properly addressed.

Maintenance is the key. The design with the lowest initial cost may be the most expensive to maintain. The designer and the approval authority should consider both costs in arriving at a final trickle channel design.

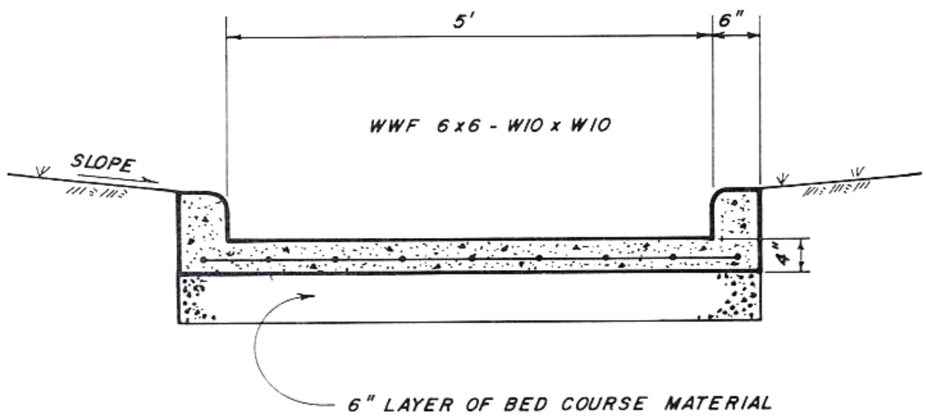



FIGURE 10 - HIDDEN LAKE RECTANGULAR CONCRETE TRICKLE CHANNEL

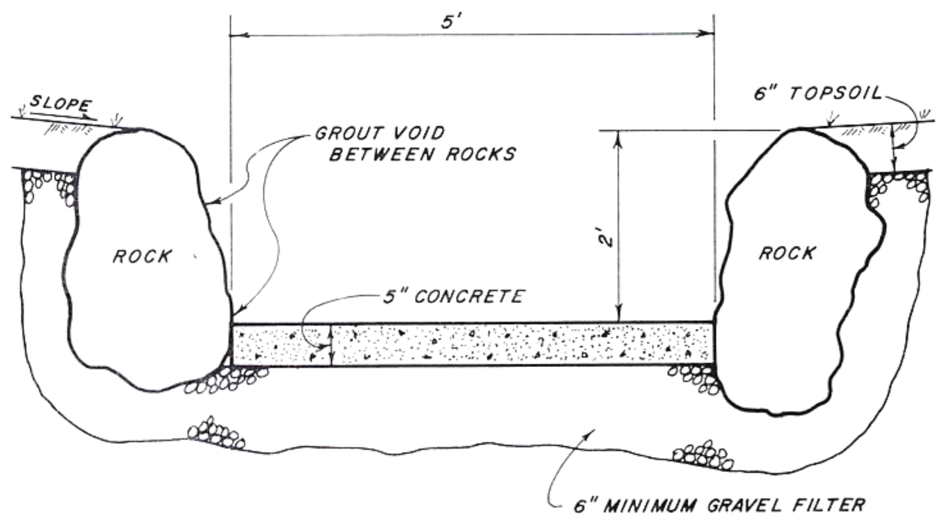



FIGURE 11 - LENA GULCH COMBINATION TRICKLE CHANNEL

Figure 12—Lack of a rundown to the channel invert on Sanderson Gulch in Denver.

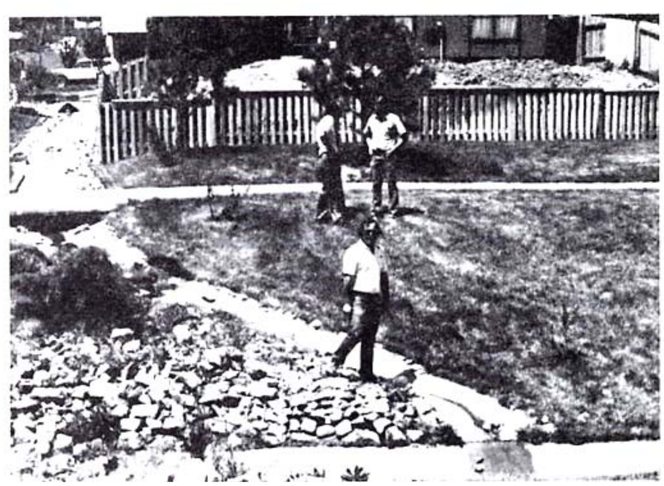


Figure 13—Concrete rundown to the trickle channel.

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