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STORMWATER DETENTION PRACTICES SURVEY

by

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Background

In 1982, the Task Committee on Detention Outlet Structures of the American Society of Civil Engineers surveyed stormwater professional throughout the United States (ASCE; 1985). In 1991 the Urban Drainage & Flood Control District, Denver, Colorado conducted a similar survey. The purpose was to see how the state of practice has changed since the 1982 survey.

The list was expanded and a total of 378 stormwater professionals in United States and Canada, including those surveyd in 1982. They were asked to fill out a four-page questionnaire. The 1991 survey received 135 responses, which broke down by employment group as shown in Figure 1. What follows is a condensed summary, as interpreted by the authors, of the responses received.

Type of Detention Used

Since 1982 there is a trend away from the use of *rooftop detention*, especially among the responding consulting engineer group. At the same time, the use of *parking lots*, *parks* and *open space areas* continue to be commonly used. Separate *retention ponds* and *detention basins* remain the most frequently used type of detention facilities. In 1991, 50% of the respondents reported they considered using *wetland detention basins*. This was not one of the questions asked in 1982, but does apparently reflect a recent trend and an increase in the attention in the use of *wetland basins* as a water quality best management practice.

Performance of Detention Facilities

In both surveys, over 90% of the respondents that *inspect the installation of detention facilities* or *review the design of detention facilities* believe that all detention facilities constructed for the purpose of reducing peak flow rates continue to function several years after their initial construction. On the other hand, only 50% of this same group believe that these facilities functioned as they were originally designed to do. In other words, only 50% of this group believe that detention facilities actually function as designed.

When asked to rate the importance of specific factors in the design of detention facilities, both the 1982 and the 1991 surveys were identical and rated *hydraulic design* as most important. *Peak flow reduction* was ranked second in importance. *Safety* of detention facilities and their *maintainability* were ranked closely behind *hydraulic design* and *peak flow reduction* in importance.

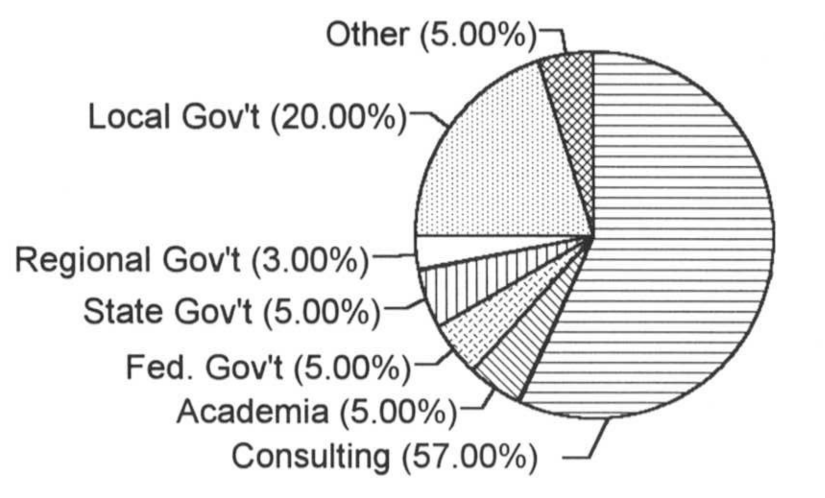

Figure 1. Distribution of Survey Respondents by Employment.

Return Period for Design

The most often analyzed *runoff return periods* for the design of *outlet works* were 10, 25, and 100 years. The percentage of respondents who considered the use of 2, 5, or 10 year outlets increased since 1982 among consultants, but remained unchanged among the government and academic groups.

When asked to rate the importance of *runoff return period* to achieve specific stormwater control goals, the 1991 respondents ranked the 10, 100, and 5 year return periods, respectively, as the three most important ones for use in *drainage design*. The 100, 25, and 10 year return periods were ranked, respectively, as most important for use in *flood control*, while the <2, 2, and 5 year return periods were ranked, respectively, as most important when designing for *water quality enhancement*.

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1993 Professional Activities of District Staff

Scott Tucker, Executive Director

*Participated in review and comment on EPA Options for addressing Phase II stormwater sources, organized by Rensselaerville Institute for EPA, Falls Church, VA in March.
*Testified before House Water Resources Subcommittee of Public Works and Transportation Committee on Reauthorization of the Clean Water Act, Representing National Association of Flood and Stormwater Management Agencies (NAFSMA), Washington, D.C. in April
*Participated in National League of Cities Committee on Energy, Environment and Natural Resources meeting, Provided input on watershed management issues, Scottsdale, AZ in May.
*Guest lecturer at Environmental Science Class, Metro State College, Spring and Fall Semesters, 1993, in Denver.
*"Examples of Implementation of Integrated Solutions - Coordinating Agency Perspective," presented at Colorado Association of Stormwater and Floodplain Managers (CASFM) 1993 Annual Conference, Breckenridge, CO in June.
*Testified before Senate Subcommittee on Clean Water, Fisheries, and Wildlife of the Environment and Public Works Committee on Reauthorization of the Clean Water Act, Representing NAFSMA, Washington, D.C. in July.
*"Emerging Clean Water Act Amendments," Presented at Third Annual Symposium on Stormwater, Water Environment Association of Texas, Dallas, TX in August.
*Chaired program on Stormwater Management at NAFSMA Annual Conference, Cincinnati, OH in October.
*Chapter Delegate for Colorado Chapter of American Public Works Association.

Bill DeGroot, Chief, Floodplain Management Program

*Region 8 Director of the Association of State Floodplain Managers (ASFPM).
*Secretary of the Colorado Natural Hazards Mitigation Foundation.
*Member of the Colorado Natural Hazards Mitigation Council.

Kevin Stewart, Project Engineer, Floodplain Management Program

*"Flash Flood Prediction and Early Warning Programs in the Denver, Colorado Metropolitan Area," co-authored with Scott Tucker, presented at the United States - Republic of China Workshop on Natural Disaster Reduction, Taipei, Taiwan, in June.
*Member of Colorado Natural Hazards Mitigation Council's (CNHMC) Dam Safety and Warning Subcommittee.
*Speaker, workshop instructor and session moderator at the ALERT Users Group annual conference in Pacific Grove California in May and at the Southwestern Association of ALERT Systems annual conference in Houston, Texas in October
*Session moderator and speaker, "Flood Warning Systems in the United States - Organizing and Networking Regional Users Groups and the Formation of a National Advisory Council," Association of State Floodplain Managers annual conference in Atlanta, Georgia in March.
*Instructor, ALERT Base Station Management short courses held in Houston, TX; Phoenix, AZ and San Jose CA.
*"Flash flood Prediction and Early Warning Programs in the Denver, Colorado Metropolitan Area," presented at the 18th annual Natural Hazards Research and Applications Center workshop in Boulder, CO in July.
*Spoke on the Midwest floods at meetings of the Colorado Section of ASCE and CASFM.
*"Early Notification and Flood Warning Dissemination Procedures in the Denver, Colorado Metropolitan Area,"prepared for presentation at the World Conference on Natural Disaster Reduction, Yokohama, Japan in May, 1994.

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

*Chairman, ASCE Urban Water Resources Research Council's Urban Gaging Networks Committee.
*General Chairman for an Engineering Foundation Conference on NPDES related stormwater monitoring needs which will take place August 7-12, 1994 (see announcement on page 14 for more information).
*Elected to the Board of Directors of APWA's Institute for Water Resources.
*Developed and presented a short course on Urban Stormwater Detention and Best Management Practices offered last fall by the Continuing Education Department of the University of Colorado at Denver.
*Member of the control group of the Urban Water Resources Research Council of the ASCE.

John Doerfer, Project Hydrologist, Master Planning Program

*Guest speaker on nonstructural and erosion control BMPs at UCD continuing education course in Denver in October.
*Presented summary of the District's BMP manual and the results of the District's stormwater quality monitoring to the CASFM 1993 Annual Conference, Breckenridge, CO in June.

Mark Hunter, Chief, Maintenance Program

*Member of ASCE Task Committee on Urban Drainage Rehabilitation Programs and Techniques.
*Member of International Erosion Control Association standards committee on riprap ;and articulating blocks.

Paul Hindman, Project Engineer, Design and Construction Program

*Chairman of the Institute of Water Resources of the Colorado Chapter of APWA.

Dave Bennetts, Project Engineer, Maintenance Program

*Speaker at the Clear Creek Watershed Forum II in October.

Tucker-Talk

by L. Scott Tucker

Timely Comment from the District's Executive Director

We're from the Federal Government and We're Here to Fine You

I have discussed the mandate issue and the command and control approach it generates in the last two or three *Flood Hazard News* columns. The issue is of critical concern to local governments and warrants continued attention until changes are made. Mandates have been a way for Congress to shift what they define as problems of national concern to local governments. Local governments have the responsibility of providing basic services to their citizens. Such services include police and fire protection, libraries, park and recreation facilities, streets, roads, and transportation facilities, the homeless problem, etc. Urban areas do not exist for the purpose of making a profit. They do not "enrich" themselves by providing these services, nor do they provide profits to shareholders. It can be argued that since industry produces a product and sells it for a profit, they should not do so at the expense of the environment and they should be required to provide reasonable environmental controls. The same logic should not be extended to local governments. They exist solely for the purpose of providing the infrastructure needed for urban populations to exist.

It is as though the federal government serves a different constituency than local government. Unfortunately the federal government has slowly but surely intruded to a larger and larger extent into the basic affairs of local government. With each new mandate, the local governments have less dollars available to spend on what they consider to be the priority issues.

To be sure, there are environmental problems that need to be addressed. It is a simple fact of life, however, that all problems cannot be addressed simultaneously. Unfortunately the mandate approach does not allow for resources to be directed at priority problems. The command and control system simply requires that the mandates be met regardless of the costs, benefits or impacts. Another fundamental problem is that mandates and the resulting command and control approach is adversarial in nature. Congress defines the mandate; a federal agency promulgates regulations that define how the mandate is to be implemented and enforced; and the regulated community then complies with the mandate under the threat of large fines; and finally, the federal government pursues enforcement actions if local governments do not comply with the mandate.

Another insidious feature of the approach is that Congress has provided a mechanism for citizen suits which empowers the environmental community with enforcement powers. As the various mandates take hold, local governments operate under the continued threat of enforcement either from the federal government or lawsuits from citizen groups. It is very difficult to develop a partnership relationship between local, state and federal governments to address environmental problems under the command and control environment.

We used to chuckle when someone said "We are from the federal government and we are here to help you." Those were the good old days, and perhaps with not so much tongue in cheek, one has to fear the knock on the door when the news is "We are from the federal government and we are here to fine you."

Local governments are starting to become very vocal about unfunded federal mandates. Local officials from cities and counties across the nation are expressing their concern and dissatisfaction with the many unfunded mandates that have been promulgated by Congress.

New Approach Needed

Federal, state and local governments should attempt to develop a true partnership in addressing important national problems. Instead of mandating local governments to solve problems in accordance with burdensome, inefficient and bureaucratic regulations, the federal, state and local governments should work together to define problems, solutions and priorities. The federal government should provide leadership in developing technical solutions and should assist states and local governments in defining how problems can best be addressed at the state and local level. The "one size fits all" approach that mandates and the associated regulations dictate simply do not work. What works in New York City is not appropriate for Denver or Wheat Ridge or Omaha or Phoenix, etc. A true partnership needs to be developed. The federal government, state government and local governments must work together to define the problems and solutions. There needs to be a recognition of and a mechanism to prioritize which problems need to be addressed first with the limited resources that are available. Local governments must be treated as equals in the process of developing solutions to the nation's problems. The current approach cannot, does not and will not allow a true partnership to develop between federal, state and local government. The mandate approach is founded on threats, fears and intimidation and this is not a foundation upon which partnerships can be forged.

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Performance of the Shop Creek Joint Pond-Wetland System

by
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Jay Carlson, Project Engineer, Kiowa Engineering Corporation
Bao Vang, Student Intern, Urban Drainage and Flood Control District

Introduction

Retention ponds, namely ponds with a permanent pool of water and a surcharge detention volume above the permanent pool; and constructed wetlands, are two Best Management Practices (BMPs) that are often used independently to enhance the quality of urban stormwater runoff. Occasionally the use of these two BMPs in a combined system have been reported (USGS, 1986; Strecker et al., 1990). Such a combined system (see Figure 1), consisting of a retention pond followed by a series of wetlands was constructed in 1989 by the Cherry Creek Basin Water Quality Authority (Authority) and City of Aurora, Colorado.

This pond-wetland system receives the runoff from a 550-acre watershed which is mostly covered by a single family residential (with several acres of multi-family residential) land use. There are no commercial or industrial land uses. The total imperviousness of this watershed is approximately 40 percent, of which 75 percent is considered to be hydraulically connected to the surface runoff system.

The Urban Drainage and Flood Control District (District) has been cooperating with the Authority to collect data on this system's performance ever since its installation. Thus far the District and the Authority have collected stormwater and base-flow data during the 1990, 1991 and 1992 rainfall seasons, and we want to acknowledge the Authority for its contribution to this effort. Some of the initial findings on its performance were reported by Kunkle et al (1992). A more detailed, concurrent and subsequent analysis of the data by the District, including the effects of base flows, has provided further insight into this system's performance, one that may affect the conclusions reached earlier.

The retention pond's permanent pool has a volume of 4.8 acre feet. Stated another way, the permanent pool's volume is equal to 0.10 inches of runoff form the entire watershed, or 0.26 inches or runoff from the tributary impervious surfaces. The surcharge detention basin above the permanent pool has a brim-full volume equal to 9.1 acre-feet, namely 0.2 inches of runoff from the entire watershed or 0.5 inches from the impervious surfaces only. Ninety-eight percent (98%) of this brim-full surcharge volume is emptied through an orifice in about 30 hours. This outlet empties a volume equal to 0.1 watershed inches of runoff in 21 hours and a volume equal to 0.05 watershed inches in 13 hours. Whenever stormwater inflow less the volume emptied during the filling period exceeds the available brim-full volume of 9.1 acre-feet, the water flows over the crest of a soil-cement dam, that also serves as an emergency spillway.

A total of 3.5 acres of wetlands are located downstream of the pond and are situated within a very flat and wide channel bottom. The flow velocity in the wetlands downstream of the pond is controlled by six drop structures designed to limit the 100-year flow velocities to less than 3-feet per second. The velocities within the wetlands during the 1-year and smaller storms average less than 0.3 feet per second, providing around two hours of contact time.

Data Collected and Findings

A total of 107 storm runoff events occurred during the three monitoring seasons. Water quality data were collected during 36 of these storms and five separate base flow samples were also taken. All water quality sampling occurred May through September. Ten-minute flow-stage data were recorded April through October. Flow record data were lost for several short periods and the flow volumes for these were estimated using recorded rainfall records. Using all of the data obtained,

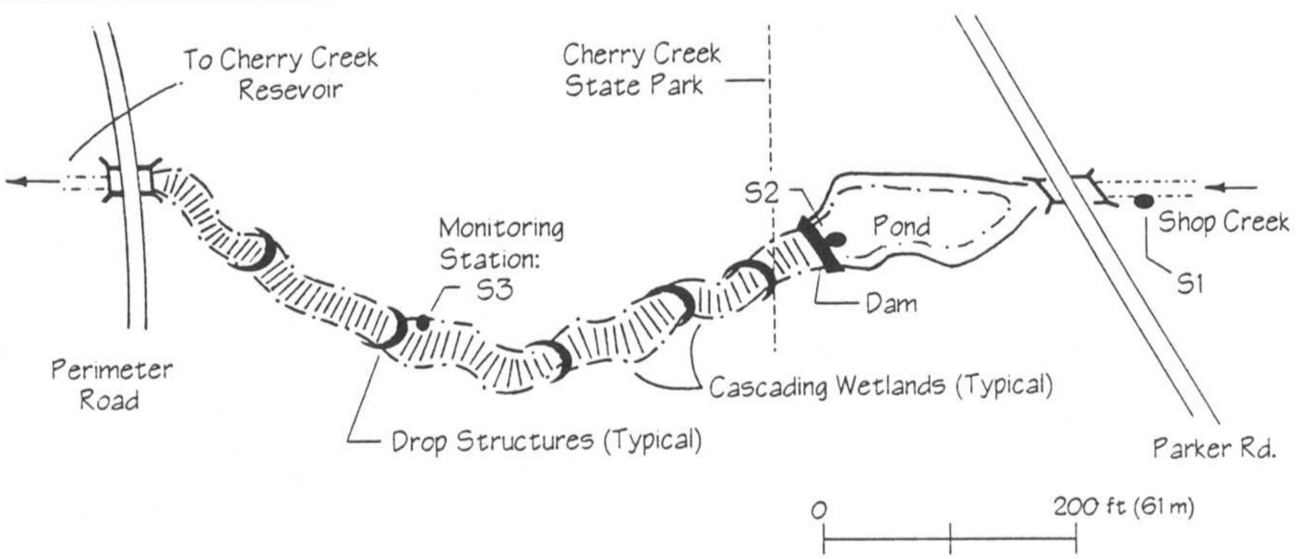

Figure 1. Arrangement of the Pond-Wetland System on Shop Creek.

the following were determined: Event Mean Concentrations (EMCs) for 19 constituents for each of the 36 storms sampled, storm runoff volumes for all recorded events, storm runoff duration periods, the times of all inter-event periods and the daily base-flow volumes. The actual EMC data for the constituents tested for are summarized for all three years in Table 1.

The monitoring season average EMCs for the three years were calculated using the individual storm EMCs. These are listed in Table 2. The monitoring season average EMCs were used to estimate the constituent loads for the 69 recorded storms for which water quality data were not collected. Similarly, constituent loads attributed to base-flows were estimated for these seasons using the concentrations listed in Table 3.

In 1983 EPA reported that no statistically valid relationship could be found between individual storm EMCs and storm runoff volumes. The Shop Creek data also did not reveal a statistically valid relationship between storm runoff volume and constituent EMCs. In addition, an investigation by the authors using average EMCs and flow-weighted EMCs revealed virtually no difference in seasonal load estimates. As a result, all load removal rates reported here were arrived at using numerical, (i.e., not flow-weighted) average EMCs for the events for which data were not available.

Figure 2 presents the statistical distribution of all runoff volumes, storm runoff durations and inter-event times experienced during the three monitoring seasons at the Shop Creek site. The available brim-full surcharge volume of the detention facility was larger than the runoff volume for 89 percent of the recorded runoff events. However, because as the surcharge volume is filled during runoff events, it is also being emptied. As a result, a larger volume than is physically present can be captured within this basin. This resulted in only seven runoff events that overtopped the dam's crest in 1990 through 1992, of which only three events were considered significant, namely, where the outflow rate was more than double that of the maximum outflow rate of the orifice controlled outlet. The other four overtoppings are considered marginal. Thus, 94 percent of all runoff events were totally contained within the water quality surcharge basin and only six percent (6%) of the runoff events resulted in some degree of overtopping of the brim-full volume.

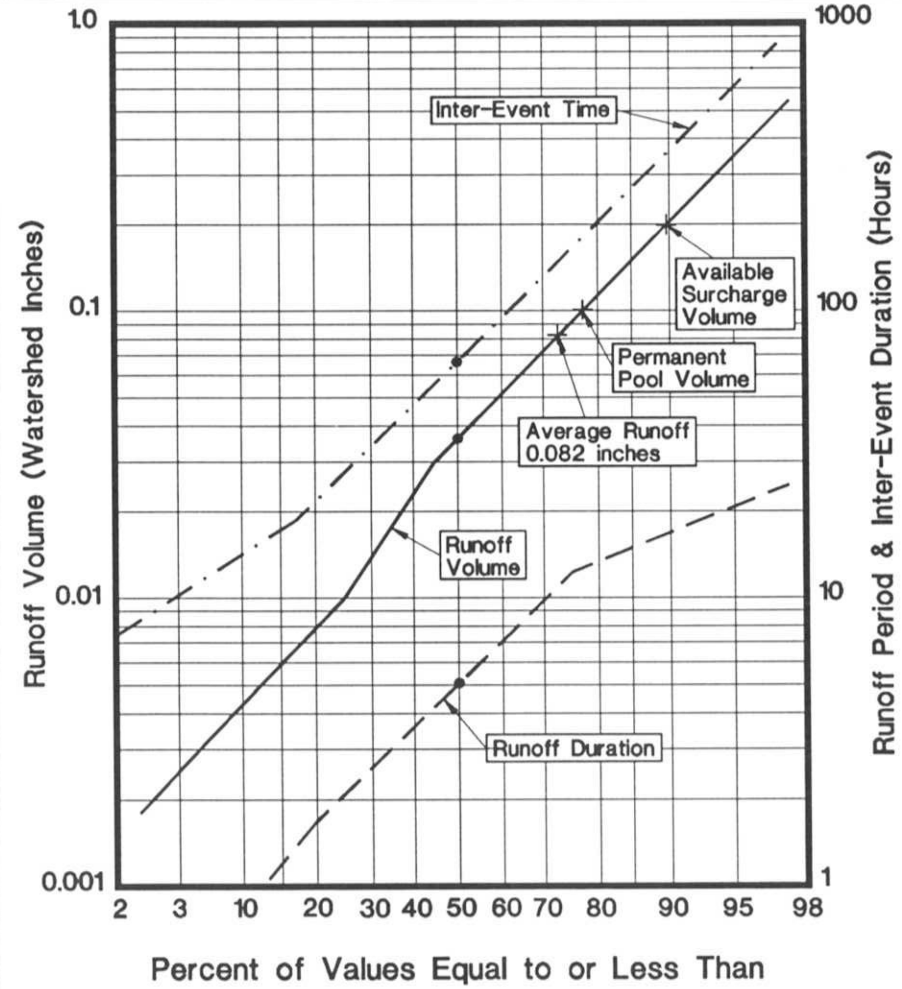

Figure 2. Statistical Distribution of Runoff Volume, Storm Duration and Inter-Event Time Duration.

The brim-full surcharge volume of this installation is slightly larger than the volume currently recommended by the District (UDFCD, 1992) for a retention pond, namely 0.20 watershed inches instead of 0.18 inches recommended. Current recommendations also call for a larger permanent pool volume, namely 0.18 watershed inches instead of the 0.10 inches available. Also, this installation does not have the recommended littoral zone in its permanent pool. Examination of Figure 2 reveals that for the three monitoring seasons, the average runoff event was almost identical to the permanent pool volume of 0.1 inches, which is the stated goal of the UDFCD (1992) criteria. The recorded average runoff event during the three monitoring seasons had 54 percent less volume than the brim-full volume of 0.18 inches recommended by the criteria and emptied out of the basin in 21 hours.

Load Reduction Rates

The monitoring season loads for each constituent were estimated using the 1990-92 data at three separate points in the system. During these two years most of the constituents monitored experienced a positive rate of removal by the system. The exceptions were the removal rates for Total Nitrites and Total Copper. Total Nitrite load increased approximately 117% between the inflow and outflow of the pond-wetland system. Also, while the load for Total Copper increased 12% through the wetlands, it in fact decreased by 6% through the pond-wetland system, the pond providing the removals that resulted in this decrease. Table 3 summarizes the estimated total load removal rates achieved by the pond, the wetlands, and the pond-wetland system over the combined three monitoring seasons.

TABLE 1 Average Storm Runoff EMCs at Three Points in the Pond-Wetland System in 1990 - 1992.

	Pond Inflow			Pond Outflow			Wetland Outflow		
Constituent and Units	**1990**	**1991**	**1992**	**1990**	**1991**	**1992**	**1990**	**1991**	**1992**
Total Phosphorus (μg/l)	533	356	448	267	141	229	229	161	213
Dissolved Phosphorus (μg/l)	264	210	448	188	77	122	156	103	132
Total Ortho Phosphorus (μg/l)	262	142	124	200	54	111	163	60	128
Dissolved Ortho Phosphorus (μg/l)	185	128	61	159	78	60	136	53	80
Total Nitrates (μg/l)	1,220	1,300	1,170	2,320	2,510	2, 080	2,220	2190	2,320
Total Nitrites (μg/l)	82	49	170	107	60	110	103	81	120
Kjeldahl Nitrogen (μg/l)	2,340	n/a	n/a	1,570	n/a	n/a	1,410	n/a	1,870
Total Nitrogen (μg/l)	3,540	n/a	n/a	3,760	n/a	n/a	3,750	n/a	4,070
Total Copper (μg/l)	33	35	41	18	18	16	19	14	13
Dissolved Copper (μg/l)	30	33	60	17	20	n/a	15	12	20
Total Iron (μg/l)	4,830	2,440	3,194	750	550	1,255	620	580	445
Dissolved Iron (μg/l)	880	50	66	110	80	30	110	70	27
Total Manganese (μg/l)	n/a	80	108	n/a	47	60	n/a	50	34
Dissolved Manganese (μg/l)	170	27	24	42	30	30	28	45	13
Dissolved Zinc (μg/l)	71	45	24	32	30	19	28	43	16
Total Zinc (μg/l)	92	98	139	63	41	31	31	45	20
Alkalinity (mg/l)	58	53	55	136	144	114	134	122	147
Chemical Oxygen Demand (mg/l)	88	69	67	48	45	39	30	46	34
Total Suspended Solids (mg/l)	195	102	104	28	17	39	30	47	22

TABLE 2. Average Base-Flow Constituent Concentrations in 1990 - 1992.

	Pond Inflow			Pond Outflow			Wetland Outflow		
Constituent and Units	**1990**	**1991**	**1992**	**1990**	**1991**	**1992**	**1990**	**1991**	**1992**
Total Phosphorus (μg/l)	96	156	74	360	106	104	46	161	63
Dissolved Phosphorus (μg/l)	87	135	63	59	57	26	46	128	44
Total Ortho Phosphorus (μg/l)	78	140	38	64	51	16	22	81	23
Dissolved Ortho Phosphorus (μg/l)	69	128	37	22	51	n/a	21	76	9
Total Nitrates (μg/l)	702	618	810	353	258	340	280	156	223
Total Nitrites (μg/l)	25	15	10	10	145	90	115	135	70
Kjeldahl Nitrogen (μg/l)	80	n/a	100	450	n/a	n/a	85	n/a	110
Total Nitrogen (μg/l)	785	n/a	n/a	815	n/a	n/a	375	n/a	340
Total Copper (μg/l)	20	10	n/a	25	30	n/a	45	18	n/a
Dissolved Copper (μg/l)	n/a	7	5	n/a	22	5	n/a	10	5
Total Iron (μg/l)	65	55	n/a	145	345	n/a	85	100	n/a
Dissolved Iron (μg/l)	25	n/a	10	25	n/a	10	30	n/a	10
Total Manganese (μg/l)	n/a	20	n/a	n/a	35	n/a	n/a	20	n/a
Dissolved Manganese (μg/l)	25	15	20	32	8	5	5	5	5
Dissolved Zinc (μg/l)	20	15	10	12	8	5	5	8	5
Total Zinc (μg/l)	35	15	n/a	25	15	n/a	25	12	n/a
Alkalinity (mg/l)	303	294	306	207	239	220	200	245	204
Chemical Oxygen Demand (mg/l)	16	25	15	108	35	25	27	25	20
Total Suspended Solids (mg/l)	9	10	1	55	20	4	10	6	1

Removal rates reported in Table 3 are presented using two different estimating techniques. One is for estimates of the removal rates achieved during storm events only, the other includes the effects on seasonal loads of the dry weather (i.e., base) flow.

If anything, the actual storm runoff volumes and storm durations recorded during the monitoring seasons were less than predicted by regional long-term simulations at the time the UDFCD (1992) criteria were being developed. On the other hand, the average inter-event time was similar to what was predicted by long-term simulations. In addition, the brim-full surcharge volume drain time for this retention pond is longer than recommended (30 hours vs. 12 hours). The District's basin sizing recommendations are intended to capture at least 70 percent of all runoff events within the available surcharge volume and were developed using runoff simulation for a 40-year precipitation record. It appears that the actual capture rate of 94 percent at this installation during the three monitoring seasons exceeded the stated goal of totally capturing, within the surcharge basin, at least 70 percent of all runoff events. However, a much longer data record is needed to confirm the long term simulations.

Clearly, incorporating the base-flow data into the load analysis had a significant effect on the estimated removal rates by this facility for some of the constituents. For example, the pond was three times more efficient at removing Total Phosphorous and 1.5 times more efficient in removing Total Suspended Solids from storm runoff events during the three monitoring seasons when the effects of base-flow were not considered.

One generalized observation made from the analysis of the results is that the wetland downstream of the retention pond tended to even out the removal rates for most of the monitored constituents. This appears to be true whether the removal rate estimates were based on storm events only or whether the estimates also accounted for base-flow loads. Although this is not the case for all constituents (e.g., Total Iron and Alkalinity), there appears to be a definite benefit in combining these two BMPs in series. However, before we can turn this into a final conclusion, we need to remind ourselves that the load reduction estimates for this installation used only five base-flow samples. If, by chance, this limited data are not representative of actual averages, the base-flow seasonal load estimates reported here are likely to be biased by an amount equivalent to the errors in the monitored constituent averages.

Phosphorous. DRCOG (1982) recommended that 50% of the annual Total Phosphorous load from all non-point runoff sources be removed before it enters the Cherry Creek Reservoir. This was suggested to help achieve an in-reservoir standard of 0.035 mg/l for Total Phosphorus. The 1990-92 data show that, if base-flows are considered, the 45% removal rate achieved during the three monitoring seasons was less than the 50% removal goal. On the other hand, if only the storm-event loads are considered, this goal was met. Even if base-flow is considered, the average 1990-92 monitoring season concentration of total phosphorous leaving the pond-wetland facility was 0.21 mg/l. This is well below the 1.0 mg/l concentration often considered as ordinarily achievable by tertiary wastewater treatment plants for point discharges (Viessman, 1985). Considering the low average EMC leaving this pond-wetland facility, it is unlikely that lower average surface runoff concentrations can be obtained without the introduction of flocculants such as Alum or other chemical-physical treatment processes.

Nitrogen. As suspected, the pond-wetland system provided the least amount of removal for Nitrogen related compounds. In fact, the concentrations of all nitrogen compounds, except total nitrates, increased within the system. Total Nitrate plus Nitrite concentrations leaving the system were 2.4 mg/l while EPA's drinking water standard is 10.0 mg/l (Viessman, 1985). Also, since recent studies of the Cherry Creek Reservoir indicate that the lake may be Nitrogen limited, there appears to be no good reason to reduce these concentrations further. In addition, the average Total Nitrite concentration leaving the systems is only 0.07 mg/l, significantly less than EPA's drinking water standard of 1.0 mg/l (AWWA, 1990).

Metals. Difficulty was encountered in obtaining data for some metals, especially for Lead and Total Manganese. Data records for both were incomplete and data were often missing at one or more of the three sampling sites for many of runoff events. Missing data for Lead during the 1990 and 1991 seasons often resulted because most of the sample analysis results came in below the laboratory detection limits of 10 and 20 mg/l.

The pond-wetland system reduced the loads of most of the monitored metals, with Total Copper being the exception. Including the base-flows in load removal calculations proved to be very important for metals. Many of the calculated averages were different when using storm events only from those obtained after including base-flows in the analysis. For example, during base-flow periods Total Copper increased through the system by an average 115 percent, while for storm-events only the Total Copper loads decreased an average of 57 percent. The net result being an overall load increase of five percent during the three monitoring seasons, or virtually no net removal or increase in Total Copper resulted from the presence of this system. Never the less, it appears that for most constituents the pond and the downstream wetlands supplement each other to provide better removal of metals than was achieved by either facility independently.

Total Suspended Solids. Total Suspended Solids (TSS) as an indicator of BMP effectiveness seems to have evolved over the last 15 to 20 years. As a result, TSS concentrations and loads are of keen interest to most investigators. The Shop Creek retention pond facility removed 78 percent of TSS during storm events. On the other hand, the TSS loads increased 350 percent through the pond during base flow periods. This trend was reversed in the wetlands, where the seasonal TSS load increased 29 percent during storm events and decreased by 80 percent during base flow periods. The net result was an average seasonal load TSS removal rate of 68 percent for the pond-wetland system, with the average TSS concentrations leaving the system being 30 mg/l in 1990, 41 mg/l in 1991 and 22 mg/l in 1992.

We speculate that much of the TSS increase through the pond during base-flow periods is due to algae growth in the pond, while the increase through the wetland channel during storm events is due to resuspension of previously deposited sediment and algae. A wetland channel design that provides somewhat slower flow velocities during runoff events should help address this potential for resuspension. Although no specific objectives were set for the reduction in suspended solids, the average of 68 percent removal by the system should benefit water quality of the downstream reservoir.

Chemical Oxygen Demand. Chemical Oxygen Demand (COD) load was decreased by an average of 35 percent by the pond-wetlands system. The pond effluent during base flow period had 251 percent more COD than the influent, while during storm runoff periods the pond, on the average, removed 44 percent of the influent COD. It is speculated that the COD increases in the pond during the base-flow periods are linked to the TSS increases and are probably the result of algae and micro organism growth in the pond. The wetlands, on the other hand, tended to remove COD during both base-flow and storm runoff periods. This trend implies that adding a littoral zone to this pond, because of the emergent vegetation within this zone, could reduce algae and TSS in the water column during base-flow periods, a premise that deserves further investigation and field testing. The pond-wetland system effluent concentrations during storm events over the three monitoring seasons ranged between 25 and 46 mg/l, a range that is not unusual in stream and lake systems found outside urban areas.

Conclusion

This study shows that detention pond-wetlands systems that are designed for water quality enhancement can provide significant pollutant load reductions for most of the constituents monitored. The exceptions to this observation for the pond-wetland system investigated were total nitrites and total copper, whose concentrations in the water increased through the pond. Significant year-to-year differences were seen in the 1990 through 1992 data.

Because of data variability and for other reasons yet to be determined, it is not possible to clearly identify all of the mechanisms that are actually behind the various constituent removals within the Shop Creek system described here. Many more studies of such facilities are warranted. There is also a need for a systematic approach by all investigators in how the results of various studies are reported. This is needed to permit comparisons of results and the systems studied. Unfortunately, such a system of data exchange is not yet in place.

It is also clear that base-flow, sometimes referred to as dry-weather flow, whenever present, can play a significant role in the annual load removal rates provided by ponds and wetlands. Thus, collecting data on dry-weather flow rates and its quality can be essential to these types of investigations.

References

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TABLE 3. Estimated Average Removal Rates for the Combined 1990 - 1992 Monitoring Seasons

	Percent Removed By					
	Pond		Wetlands		System	
Constituent	Storm Events Only	Storms + Base Flow	Storm Events Only	Storms + Base Flow	Storm Events Only	Storms + Base Flow
Total Phosphorus	49	14	3	36	51	44
Dissolved Phosphorus	48	48	12	-3	54	46
Total Ortho Phosphorus	27	33	10	13	35	42
Dissolved Ortho Phosphorus	19	39	15	5	31	42
Total Nitrates	-85	38	5	21	-76	51
Total Nitrites	-1	-115	-7	-1	-9	-117
Kjeldahl Nitrogen)	32	-137	-1	65	31	18
Total Nitrogen	-12	-6	1	41	19	53
Total Copper	57	18	2	-15	57	6
Dissolved Copper	53	25	-1	20	58	49
Total Iron	75	70	25	32	81	79
Dissolved Iron	77	73	-8	-9	75	71
Total Manganese	40	26	17	25	50	44
Dissolved Manganese	61	50	14	36	66	68
Dissolved Zinc)	34	37	-5	7	30	41
Total Zinc	51	45	31	24	66	58
Alkalinity	-113	10	-5	0	-124	10
Chemical Oxygen Demand	44	-25	21	48	56	35
Total Suspended Solids	78	50	-29	25	72	68

South Platte River Program Notes

by
Barbara Benik, P.E., Project Engineer, and
Ben Urbonas, P.E., Chief
South Platte River Program

Maintenance of South Platte River

In 1993, the South Platte River routine maintenance work included an equivalent of 69 miles of mowing, 8 miles of tree trimming and pruning, and 119 miles of trash and debris pickup and removal. Restoration projects along the river during 1993 included: repair of erosion damage along the maintenance trail, repairs to the trail itself, rehabilitation of a major storm sewer outfall headwall, and approximately 550-feet of bank stabilization and restoration

Cooperative Activities

This year we entered into cooperative project agreements with three property owners. The Miles/White project included approximately 1600-feet of bank cleanup, restoration, revegetation, and stabilization. A 37-acre easement for river channel maintenance access and flowage right-of-way was dedicated to the District through this cooperative project. The Frei project included 300-feet of bank stabilization, restoration, and revegetation and transferred a 3.8-acre easement to the District. The Carlson projects included 1200-feet of bank stabilization restoration and revegetation at two locations. An easement of 1.44 acres was added to the original 63.9 acre area dedicated to the District in 1990.

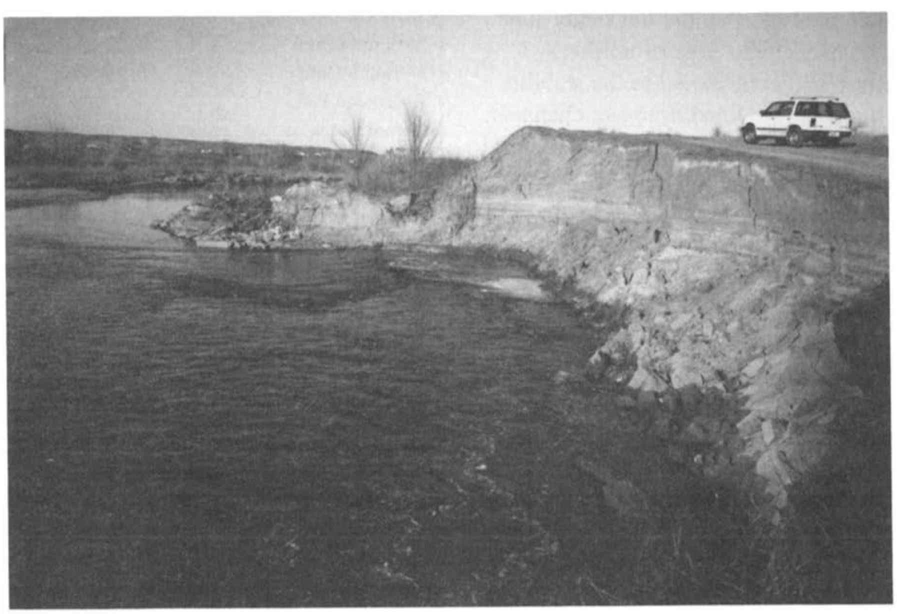
Capital Improvement Activities

The pedestrian/maintenance access bridge at Globeville Landing Park will be replaced in a joint project with the City and County of Denver Parks and Recreation Department in late January, 1994. The structural integrity of the original 8-foot wide glue-laminated bridge became questionable in the last few years, the wooden decking was severely rutted and became unsafe, and the approaches to the bridge were fairly steep. A 12-foot wide Continental Corten steel bridge with a concrete deck will be installed. The existing abutments will remain, but the approaches to the bridge will be modified to ADA standards. Additionally, a long-standing drainage problem will be corrected along the trail at the east approach to the bridge.

Other News

The Colorado Water Conservation Board modified the two drop structures upstream from and at Oxford Avenue to improve boater safety. The original structures had drops that were too high for safe boating, and their narrowness made it difficult for most rafter to maneuver through them.

The City of Englewood plans to construct a check structure immediately upstream from Union Avenue to improve the accuracy of the flow monitoring gauge. Since the river channel has experienced some degradation in this reach, the District will partially fund this structure. This should arrest future river bottom degradation immediately upstream of this check structure. As a side benefit, we expect additional aquatic habitat to develop after this structure is completed sometime in the Spring of 1994.



Two examples of the severe erosion problems being experienced along the South Platte River in Adams County.

MAINTENANCE PROGRAM ACTIVITIES

by

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

Program Direction

As the restoration program has matured over the years we have recognized the benefit from having a consultant do sketch drawings and quantity take-offs for many of our restoration projects. Where maintenance staff used to prepare the sketches and take-offs in the past they now spend more time securing permits and managing our relationship with the local governments and the contractors. This permits us to execute as many or more restoration projects than in the past with a better balance of staff time available for project management.

The increasing use of consultants for restoration is likely to continue. The additional engineering capacity allows us to take better advantage of the competitive process for our construction projects. We will continue to bid more of our restoration projects among the restoration contractors.

Restoration Maintenance

In 1993 the restoration program completed $1.35 million worth of work. About 69 individual projects were completed.

In last year's *Flood Hazard News* article we reported that the sandy soils of the **Montbello** area of northeast Denver had contributed to the stability of the concrete-lined drainage channels. Since that time we have had a structural engineer review the possible causes of the channel-lining failures. A combination of inadequate reinforcement and poorly compacted subgrade and backfill has caused most of the problems. We now recognize that our initial assumption about the original concrete channels was only partially correct. Sandy soils certainly can contribute to channel stability, but only if the soils are properly compacted during construction.

Cherry Creek, between Cherry Street and Holly Street, in the City and County of Denver has a right-of-way width of about 190 feet. Within this cross-section the creek has developed an incised low flow channel that is about

STATUS OF MAINTENANCE REHABILITATION PROJECTS

Project	Jurisdiction(s)	Cost	Status
ADAMS COUNTY			
Middle Branch Hylands	Westminster	design- $56,028	100%
Drops and low flow		const- $250,000	98%-phase 2
ARAPAHOE COUNTY			
Little Dry Creek	Arapahoe Co.	design- $76,590	100%
Erosion repair		const- $192,347	100%-phase 1
Big Dry Creek	Arapahoe Co.	design- $126,980	100%
Branch 2		const- $365,157	30%
W. Toll Gate Creek	Aurora	design-$17,506	100%
Summer Valley Ranch		const- $99,231	100%-phase 3
Lee Gulch	Littleton	design- N/A	N/A
Trail participation		const- $10,000	50%
Lee Gulch	Littleton	design- $52,574	100%
drop and low flow		const- $157,110	100%
West Harvard Gulch	Englewood	design- $25,000	10%
Pipe replacement		const- $200,000	0%
BOULDER COUNTY			
Bear Canyon Creek	Boulder	design- $30,000	75%
drops,bank repair w/city		const- $220,000	0%
Wonderland Creek	Boulder	design- $25,703	95%
Diagonal Hwy.		const- $146,981	cancelled
City Park Drainageway	Broomfield	design- $35,466	100%
park channel repair		const- $197,038	100%-phase 2
Basin D-Lac Amora	Broomfield	design- $45,985	100%
low flow pipe		const- $121,821	100%
Goose Ck-Elmer's 2-mile	Boulder	design- $10,917	50%
trickle channel		const- $100,000	0%
DENVER COUNTY			
Cherry Creek	Denver	design- $29,170	95%
drop structure (Monaco)		const- $150,000	0%
Cherry Creek	Denver	design- $95,605	100%
Drop structures (Holly)		const- $310,496	100%-phase 1
Cherry Creek	Denver	design- $103,389	100%
Creekfront		const- $900,342	100%
Cherry Ck - Babi Yar	Denver	design- $25,000	10%
drops, bank repair		const- $150,000	0%
Cherry Ck - Kennedy	Denver	design- $20,000	cancelled
bank protection		const- $150,000	cancelled
Goldsmith Gulch	Denver	design- $35,000	10%
Rosamond Park		const- $200,000	0%
Harvard Gulch	Denver	design- $75,386	100%
McWilliams Park		const- $201,951	100%
Lakewood Gulch	Denver	design- $29,491	85%
Channel repair		const- $135,000	0%-phase 3
DOUGLAS COUNTY			
East Dad Clark Gulch	Douglas Co.	design- $33,432	100%
drop structures		const- $104,673	100%
JEFFERSON COUNTY			
Little Dry Creek	Arvada	design- $49,518	100%
Harlan to Wadsworth		const- $163,645	100%-phase 1
Little Dry Creek	Arvada	design- $20,082	95%
Wadsworth to Club Crest		const- $150,000	0%-phase 2
Sloan Lake	Edgewater	design- N/A	N/A
Along 20th Ave		const- $45,000	100%
SJCD (So)	Jefferson Co.	design- $38,461	100%
Columbine Knolls South		const- $132,130	90%
SJCD (So)	Jefferson Co.	design- $28,335	75%
Carr to Estes		const- $250,000	0%

20 feet wide by five feet deep. This incised channel was not an immediate threat to the stability of the larger channel, but we recognized that continued erosion within the low flow channel would ultimately cause problems further upstream. We elected to construct two low flow drop structures to stop the on-going low flow channel erosion that has such a damaging cumulative effect. These sloping-riprap structures are located in the low flow channel and do not provide 100-year protection to the full channel.

In 1992 we began the installation of protection to the low flow channel of **Lakewood Gulch** east of Wadsworth. We chose to use boulders to line the edges of the low flow channel to stop the lateral erosion on the creek. In late 1993 we hired a contractor to build another phase of the same type of work on Lakewood Gulch. The character of the work of this new phase is like that of the previous phase because it is similarly situated within a narrow alignment through a residential area.

We are also continuing erosion protection work on **Lena Gulch** north of 32nd Avenue. In this case, rather than continuing to install boulders for low flow channel erosion protection we are building riprap bank protection at select points along the gulch. This option was selected because, in this area, Lena Gulch is not confined within a residential alignment, but is flowing through open space park land.

Indian Creek, south of Chatfield Reservoir, drains the low foothills of western Douglas County. The longitudinal grade of the creek in this reach is greater than one percent. At public road crossings this steep grade is combined with the erosive power generated at the outlet of the culverts. The result is often severe erosion downstream from the road. We typically address these situations with an outlet headwall/drop structure combination. Additional riprap channel protection is necessary downstream to repair and protect the scour hole. These culvert structures have as much to do with transportation as with drainage. For those problems we have repaired we have taken the position that the immediate threat was to the integrity of the channel and that it was therefore appropriate to spend maintenance funds repairing the drainage components of the structure.

Rehabilitation Maintenance

Twenty-six projects were at various levels of design or construction during 1993. Those projects are listed in the accompanying table titled "STATUS OF MAINTENANCE REHABILITATION PROJECTS". Each county had one or more large projects constructed in 1993. By the end of 1993 we will have spent about $2.0 million on rehabilitative design and construction for the year. A few of the unique projects are discussed below.

Grouted Sloping Boulder Drops - 1993 was similar to 1992 in that we built several grouted sloping boulder drop structures. Their versatility and safety are still their leading attributes. The drop structures described in the paragraph below were built with sheet-pile cutoff walls to reduce the flow of groundwater through the structure.

A 15 foot tall drop structure was completed in early 1993 on **East Dad Clark Gulch** in Highlands Ranch in Douglas County. Its immediate purpose was to to provide protection to a wetland and a planned open space area. The long-term goal was to stabilize the channel bottom and prevent the erosion from continuing upstream. Two old drop structures on **Cherry Creek**, one upstream of Cherry Street and the other upstream of Holly Street, were rebuilt in 1993 as grouted sloping boulder drops. Each structure drops the water about nine feet. Another existing drop structure on Cherry Creek, downstream from Monaco Street, is currently being designed and will be constructed in early 1994. These rehabilitated drops on Cherry Creek are consistent with the overall Cherry Creek Stabilization Plan prepared in February, 1991.

In 1993 we completed the third phase of low flow channel repairs to the **Middle Branch of South Hylands Creek** at 101st Avenue and Sheridan in Westminster. The major feature of the project was the boulder edge protection to the low flow channel. In the first two phases of work on this creek the bottom of the low flow channel was built out of cast concrete. For the third phase, the bottom was built from riprap that was then covered with native soil. This change was made as a result of input from the neighborhood association.

Lee Gulch, between Santa Fe Drive and Prince Street in Littleton, was completed this spring. The work included two grouted-boulder drop structures and select bank protection on this 660 foot long reach. The shape of the structures and the size of the individual boulders combined with the natural contours of this part of the creek to result in a particularly attractive drainage project.

SJCD South - As upstream development in Jefferson County has occurred, this drainageway, between Carr Street and Estes Street at Ken Caryl Avenue, has experienced increased base flows and a rapid lowering of the channel invert. Individuals in the neighborhood said they "used to be able to step across the creek". What was a shallow stream flowing through gentle meadows just a few years ago has now become a creek that is reacting to sediment generation and changes in flow due to urbanization. The creek is now a mixture of 10-foot deep pockets of erosion and areas of aggradation that are deflecting the base flows into homeowners' yards. At one specific site the silt and the accompanying vegetation have served to raise the channel invert enough that the creek water now seeks a path through a private backyard. Where the water exits the backyard and returns to the channel it has eroded under the privacy fence and exposed buried utilities. The project is under design and will address the problems through the use of grade control structures and bank protection.

Basin D Outfall tributary to Rock Creek - The western portion of Broomfield overlooks the Rock Creek basin. Basin D Outfall is a short but steep drainageway that carries runoff water from the residential subdivisions at the top of the hill to Rock Creek. Our options on how to solve the erosion problems were limited. Had we built drop structures they would have been literally end to end because the channel has a longitudinal grade of seven percent for two-thirds of its 1200 foot length. Our decision was to install a pipe system to carry the water collected from the residential area through an open space park to Rock Creek.

FLASH FLOOD PREDICTION PROGRAM HIGHLIGHTS

by

Kevin G. Stewart, P.E., Project Engineer, Floodplain Management Program

Communications and Product Dissemination

Ask any experienced emergency manager...what's the weakest link in achieving a successful emergency response?...and almost without exception the answer will be "communications." Past issues of *Flood Hazard News* have discussed many technological and procedural changes which are now integral components of the District's 15-year-old Flash Flood Prediction Program (F2P2). Many of these changes have directly affected the way we communicate today.

The fax has proven itself an extremely useful tool. In 1992, the District's contract meteorologist, Henz Meteorological Services (HMS) made a total of 11,482 program-related fax communications to 43 emergency service and public works agencies in the Denver area. The fax continued to be used extensively in 1993 to disseminate the following F2P2 products:

Message Forms are prepared uniquely for each F2P2 dissemination point with fax capabilities. These computerized forms are similar to those used by 911 dispatchers to document and relay voice communications (i.e. internal alerts, watches, warnings and updates). Whenever possible, messages are faxed to communication centers immediately prior to making the required voice contact. HMS meteorologists verify receipt of the fax, review its contents with the duty dispatcher and answer any questions. The dispatcher then follows internal procedures for relaying the weather information. This process has essentially eliminated the need to write down the specifics of the message and greatly reduced the potential for misunderstanding its meaning and communicating incorrect information.

Heavy Precipitation Outlooks or HPOs are issued daily by 11:00 a.m. When necessary, the HPO is updated by 4:00 p.m. This fax product is also available via the District's dial-up Electronic Bulletin Board (EBB). The EBB has been in operation since 1988, but not all agencies have computers with modems, whereas, most offices do have fax machines.

Internal Message Status (IMS) reports are prepared only when the program is functioning in an alert mode. The IMS is disseminated as soon as possible after F2P2 messages have been issued to required county contact points. This product is also identical to the one available from the EBB. The intent of the IMS is to keep all parties updated concerning the message status for the entire District area. Relative to voice communications, this product has a lower priority and is not relied upon as a means of initial notification of flood potential or warning. When "high-touch" operations are in progress at HMS, it may or may not be possible to update the IMS.

Quantitative Precipitation Forecast (QPF) is another fax disseminated EBB product which contains technical information designed primarily for hydrologists and other technical personnel. It is prepared only for days having a 1.5-inch or greater one hour rainfall potential. The QPF contains probability forecasts of storm duration, rainfall intensity and cumulative amounts for three possible scenarios based on current atmospheric data and predicted short-term changes. The probabilities of occurrence for each storm type are identified for twelve major drainage basins. This QPF product has been used since 1989.

StormTracks (ST) provide an easy-to-understand map showing predicted impact zones, movement, timing, stalling potential and relative size of a storm or multiple storms expected to cross the District. Text is added to summarize conditions and the estimated magnitude of the flood threat. STs are only issued on "Message Days" and are not available on the EBB. Lead times for issuing the ST vary according to flood potential and the availability of current meteorological data. Lead times of 3-hours or more are attempted when the flood potential is very high. For lower flood potentials (10-year or less), lead times of 30- to 60-minutes are generally provided. Updates are issued as the event progresses. The ST may now be the most anticipated and relied-upon product offered by the F2P2.

By the end of the 1992 flood season, the number of fax dissemination points had increased substantially, and timely delivery of fax products posed a concern due to single fax machine limitations. Certain products required 30-minutes or more to transmit to the programmed call list. This bottle-neck was eliminated in 1993 by using a new U.S. West service know as "Broadcast Fax." The 30-minute transmission time was reduced to two minutes by sending a single one-page fax to a central fax number. Once received, the central fax sends the product simultaneously to the District's user list. The delivery status is promptly reported to the fax machine originating the call. The only difficulty encountered was during World Youth Day activities in August. Like the mid-west floods of 1993, this temporary loss of service can be considered a rare event. The 1993 test of Broadcast Fax was judged a success and this service is expected to continue. To control costs, the service will only be used when multiple "priority" communications are appropriate. Daily HPOs and non-critical IMSs and QPFs are not disseminated by this method.

The EBB continues to serve year-round as a excellent way for users to obtain hard-copy weather information. Six phone modems are now available. In 1992, more than 1300 logins were recorded for EBB access alone. As a result of wide-spread fax usage and other system improvements, this figure was reduced to 500 in 1993. The National Weather Service (NWS) does not disseminate weather information by fax, making the EBB still one of the best ways for Denver area emergency managers to obtain NWS text products.

In 1992, the City of Aurora added EBB dissemination capabilities through some innovative programming by staff engineer, Bruce Rindahl. Currently, whenever any EBB weather product is received at the District from either HMS or NWS, the information is automatically relayed via phone modem to five other ALERT base stations in Aurora, Denver, Boulder (2 sites) and at HMS. Audible alarms and flashing color displays accompany this delivery of these weather products.

A fax modem was added to Aurora's ALERT base station in 1992 resulting in the ability to send high resolution graphics, ALERT data, alarm messages, EBB products, and other text files to any fax machine. By the end of 1993, many innovative communication applications had been implemented by Aurora including: digital pager notification of base station alarms; inter-departmental local area network (LAN) linkage between the base station and networked computers running DOS; automated internal EBB dissemination over the LAN; and color graphics display capabilities for LAN terminals.

Even with these useful computerized enhancements, the telephone remains the program's primary means of communication. Ham radio operators are available to assist with backup communications when requested and a cellular phone is also available. The fax and EBB have greatly increased the program's ability to get information to people quickly and have reduced the potential for misunderstandings. Along with the now 4-year-old procedure for issuing "Red Flag" messages, these electronic devices have minimized the number of direct contacts with 911 dispatchers, as recommended by Denver area emergency managers and communications supervisors. But, regardless of how it is accomplished, the "wake-up call" will continue to be relied upon well into the future.

While all these high-tech developments may seem impressive, the potential for communication failure must remain a major concern of the flash flood program. Steps to further minimize this potential will continue through annual flood exercises, increased news media involvement, more rapid dissemination techniques and refinements based on actual experience. Low cost video communications are already being used by some public safety organizations and we know that seeing is believing. Such techniques can be expected to evolve in the future including the delivery and presentation of better high-resolution maps along with other easy-to-interpret products.

Advice from Denver area emergency managers has been relied upon heavily in developing standardized communication procedures for the F2P2 and their high degree of involvement must continue in order to achieve the desired response when "the big flood" occurs. It is interesting to note that although a major flood has not occurred in Denver since 1973, or maybe some would argue 1965, the F2P2 remains one of the most recognized local flood warning programs in the United States. We believe that our perceived success status exists because of the network which has been built and maintained by many committed individuals, organizations (public and private), and local elected officials working as a team and dedicated to protecting the public's safety and welfare.

The 1993 ALERT System

The District-operated ALERT system has been collecting rainfall and stream level data since the Lena Gulch network was installed 1985. This system, which initially consisted of nine remote gaging stations and a single radio repeater, has grown substantially. By Spring of 1994, 139 ALERT stations will be in operation collecting data from more than 200 sensors.

New Installations

Four new ALERT gaging stations were installed in October and November of 1993. These stations will be fully operational by next flood season. Three of the sites are part of the Bear Creek system and the fourth site is located in Brighton. All four stations will report rainfall using standard 1 mm ALERT tipping buckets. The Morrison gage also includes a float shaft encoder for continuous monitoring of water levels in Bear Creek. The three new Bear Creek gaging stations represent the final components of the flood detection network project which began in 1989. The City of Brighton is already considering upgrading their rain gage to full weather station status.

Annual Report Standardized

Since 1990, the District has been preparing comprehensive annual maintenance and progress reports for local government sponsors involved with flood detection networks. Each year special efforts have been made to consolidate required reports into a single publication which includes summaries of ALERT data collected by the District during the previous flood season. While the data reduction task is very time consuming, the benefit of having these reports readily available has been realized. Requests for ALERT data are increasing and the annual report has become a convenient source for fulfilling such requests. The front-end effort of preparing statistical data summaries has reduced staff time in handling requests for information.

The process of preparing the now standardized statistical summaries continues to become easier as software improvements are routinely made. Also, the past three years of work on the entire O&M report has brought us to a comfort level with its format. Due to the size of this document, complete copies are provided only to project sponsors and a few other organizations that actively participate in the F2P2. One copy of the report is available in the District's library for public use.

Emergency Power

Installation and testing of a 10-KW generator was completed last April for the District. This diesel driven unit is located at the District's office building and supplies emergency power to critical equipment on three floors of the building including: two ALERT base stations; radar and satellite receivers and display equipment; weather message fax machine; NOAA Weather Wire; and other components critical to F2P2 operations. The generator also supplies power for the District's Prime Computer, front office lighting and our primary word-processing computers. All computers are provided with individual Uninterruptible Power Supplies.

Radio Paths Re-configured

A dual repeater system for handling all ALERT radio traffic was installed in 1993. Its unique design provides for selectable radio path options should a major system component fail. The two principle repeaters are located at Lookout Mountain west of Golden and at Smoky

Hill in southeast Aurora. Prior to 1993, the Lookout Mountain repeater served the entire ALERT system and represented the weakest radio link.

In a normal configuration, optimum radio paths are utilized which essentially means that data transmissions from remote gaging stations in the eastern portion of the District are repeated by Smoky Hill and the western gage data is handled by the Lookout Mountain repeater. Should one repeater fail, the remaining repeater can be switched to a "pass all" mode and take over operations for the entire system until the failed repeater can be repaired. Should both repeaters fail during an event, which is highly unlikely, most ALERT base stations have dual frequency receivers allowing them to receive data from the remote gages having a direct line-of-sight radio path. This design change has greatly increased system reliability and allows for future system expansion without compromising radio integrity. The system was designed by DIAD, Inc. of Boulder, the District's ALERT system maintenance contractor, and the electronic components were supplied by High Sierra Electronics of Grass Valley, California.

Significant Hydrologic Events

The 1993 flood season was relatively uneventful, particularly in the shadow of the catastrophic mid-west flooding last summer. There were 28 message days in 1993; three in May, seven in June, seven in July, eight in August, and four in September.

The hydrologic records continue to improve as more emphasis is placed on sensor calibrations and routine maintenance. Statistical ALERT data summaries are provided in the annual report for each stream gage in the network. Anyone wanting specific site information should contact the District. The following provides a brief summary of annual peak flows for a few selected stream gages: Ralston Creek at Carr St., June 17, 760 cfs; Van Bibber Cr. at Hwy. 93, June 17, 440 cfs; Westerly Cr. at Montview, Sept. 18, 550 cfs; Harvard Gulch at Logan, July 5, 470 cfs; Goldsmith Gulch at Eastman, June 17, 520 cfs; Toll Gate Cr. at 6th Ave., Sept. 18, 460 cfs; S. Platte River at Dartmouth, June 18, 890 cfs; Cherry Creek at Wazee, July 13, 680 cfs; and Sand Creek at Brighton Rd., Sept. 18, 580 cfs.

Based on these figures and other records, one might think that the most significant hydrologic event for Denver in 1993 was drought. Regarding the future, Denverites must remember that it has been more than 20 years since a flood has caused major wide-spread impacts here, and history tells us that this string of good fortune should not be expected to continue much longer.

NEXRAD Arrives in Denver

On September 3, 1993, a Kavouras RADAC 2100 computer was installed at the District, replacing the RADAC 1000 which has been displaying color radar data for the F2P2 since 1979. The new system also replaces the Vista 500 satellite downlink system which was installed in 1988. This upgrade provides capability to display a variety of high resolution hydro-meteorological products made possible by the nation-wide installation of the WSR-88D radars known as NEXRAD. Denver's NEXRAD radar, located near Watkins, was installed in April of 1993 and was accepted for performance testing by the National Weather Service in May. Full commissioning of this radar is planned for August, 1994.

On November 30, Kavouras installed a data distribution transmitter at the District to allow other users access to radar products via a local phone line. Outside users are responsible for purchasing their own display equipment and making arrangements with Kavouras for data access. The District's decision to act as a communication hub for Kavouras was made to give existing radar users, currently on the District's dedicated phone circuit from Limon, a more affordable option for continuing their radar service. The choice to obtain a RADAC 2100 allowed the District to utilize existing satellite downlink equipment and abandon the expensive long distance phone service which has been in use since 1979. Anyone wishing to connect to the communications hub at the District should contact Dan Modeen with Kavouras, Inc. in Minneapolis at 1-800-328-2278. Existing radar users should contact their Kavouras representative.

ENGINEERING FOUNDATION CONFERENCE ANNOUNCED

A five-day Engineering Foundation conference on "Stormwater NPDES Related Monitoring Needs" will be held August 7-12, 1994, at the Grand Butte Hotel in Crested Butte, Colorado. It is co-sponsored by the Urban Water Resources Research Council of the American Society of Civil Engineers, American Public Works Association, U.S. Environmental Protection Agency, and U.S. Geological Survey. The list of sponsors is expected to expand to also include the Water Environment Federation, American Water Resources Association and the American Institute of Hydrology.

This is a focused conference to explore the needs and technology associated with stormwater monitoring that has to take place under municipal and industrial NPDES stormwater discharge permits. The technology of stormwater monitoring to achieve compliance, runoff characterization, BMP effectiveness and the monitoring needed to define long term trends in receiving waters will be thoroughly examined. Institutional issues, affordability, economics, and what we would like to achieve vs. what is practicably achievable will also be addressed.

It is a fact that stormwater monitoring is very expensive. In addition to the millions of dollars already spent, much more will be spent over the near-term future. This conference will provide a forum for examining where monitoring is at this time and what we, as professionals and as a nation, need to be pursuing and what technology we should be using to achieve the various goals set forth for stormwater in the Clean Water Act and the NPDES regulations.

Because of limited space, attendance will be limited to approximately 120. If you have an interest in this topic and would like to participate in a series of discussions with some of the leading experts in this field, request early registration forms from the Engineering Foundation by contacting Barbara Hickernell in writing at 345 East 47th Street, New York, NY, 10017, by telphone at 800-541-7016, or via FAX at 212-705-7441.

CHANGES TO SECTION 404 OF THE CLEAN WATER ACT

by Mark R. Hunter, P.E.

The August 25, 1993 edition of the Federal Register presented the final rule documenting changes to the Clean Water Act (CWA) Section 404 regulatory program. These changes became effective on September 25, 1993. The modifications were not extensive. In fact, they were limited to: (1) change of the definition of "discharge of dredged or fill material;" (2) clarification of when the placement of pilings is a discharge of fill material; (3) codification of the current policy that prior converted croplands are not waters of the United States.

This article is limited to a review of the changes to the definition of "discharge of dredged or fill material" and the resulting impact on organizations doing work in the streams and creeks of the region.

The expanded definition of discharge of dredged or fill material includes the clarification that mechanized landclearing, ditching, channelization, and other excavation activities typically result in discharges of dredged or fill material when these activities are performed in waters of the United States. These activities would be regulated under Section 404 of the CWA when the discharge of the dredged or fill material would have the effect of destroying or degrading "waters of the United States."

At this point it is worthwhile to define what it means to destroy or degrade waters of the U.S. Any activity, such as a discharge or redeposition of dredged or fill material, is said to destroy or degrade waters of the U.S. if the activity has more than a "de minimis" (inconsequential) effect on the aquatic area by causing an identifiable adverse effect on any aquatic function.

A definition of the term "waters of the United States" is also worthwhile. As used in Section 404 of the CWA the term waters of the United States means all waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide. This includes all wetlands, lakes, rivers, streams, mudflats, sloughs, prairie potholes, and wet meadows or any other waters which could be used for recreational purposes, fishing, or industrial uses.

Examples which typically would not be considered waters of the U.S. are flows in street curb and gutter, in-pipe flow, temporary overland or sheet flow resulting from rainfall, irrigation ditches, and dry detention areas without wetlands that normally fill and drain only as an immediate result of rainfall.

The reason the above-mentioned excavation activities are being identified as regulated discharges is that the regulatory agencies believed it is virtually impossible to do mechanized landclearing, ditching, channelization or excavation in waters of the United States without causing incidental redeposition of dredged or fill material in the process. This requirement applies no matter how small or temporary the redeposition. Under this final rule a permit is required whenever any incidental redeposition of dredged or fill material would destroy or degrade waters of the U.S.

Some clarification here is appropriate. This updated definition of discharge of dredged or fill material is intended to include soil or sediment that spills or drips from machinery during excavation activities. Such a displacement or redeposit of dredged or fill material can also occur as the excavation equipment moves on or through the soil or sediment being excavated.

There are a few exceptions, but for most of those organizations that have been removing, relocating, or dredging material in streams this legislation will have the effect of regulating virtually all excavation-related activities in the waters of the United States.

The August 25, 1993 final rule leaves intact the portion of the CWA that authorizes the nationwide permits. For example, one of the nationwide permits allows the discharges of dredged or fill material into certain waters of the U.S., including adjacent wetlands, that are located above the five cubic feet per second "headwaters" of the stream. Many of the minor creeks in the western states are above the headwaters. However, this does not mean that work in these creeks would be unregulated. Excavation-related work or the discharge of dredged or fill material in these creeks would still be subject to limitations on the acreage of waters of the U.S. that can be disturbed.

Recognizing that the definition of discharge of dredged or fill material has been expanded the nationwide permit still grants that a discharge activity that is located above the five cubic feet per second headwaters and causes the loss or adverse modification of less than one (1) acre of waters of the U.S., including wetlands, is usually permitted with no further action from the Corps of Engineers required. For discharges of dredged or fill material that impact one to 10 acres of waters of the U.S., including wetlands, the Corps of Engineers must be given proper notification and the applicant may be required to obtain an "individual permit". For areas of more than 10 acres an individual permit from the Corps of Engineers will be required.

The term wetlands means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas.

The CWA is a complex regulation and there are several other conditions that must be followed before work can be done in the waters of the U.S. Check with the local Corps of Engineers office for further information and Section 404 permit requirements.

The goal of this final rule is to ensure that the CWA Section 404 program can effectively protect the aquatic resources from the degradation that can result from unregulated mechanized landclearing, ditching, channelization, and other excavation activities.

PLANNING PROGRAM ACTIVITIES
by
Ben Urbonas
Chief, Master Planning Program

Planning Projects

Again we had a productive year in assisting cities and counties with their major drainageway and outfall systems planning. The table titled "Status Of Planning Projects" lists the projects that were under way in 1993 and the ones we hope to begin in 1994. We will begin consultant selection for the projects scheduled for 1994 as soon as the funding agreements are finalized between the District and local sponsors. It looks like 1994 will be busier than 1993, which was a very active year.

STATUS OF PLANNING PROJECTS

Project	Sponsor(s)	Consultant	Status
Box Elder Creek	Aurora, Arapahoe Co. Adams Co.	CH2MHill	10% Complete
Columbine Basin	Arvada & Wheat Ridge	Muller Engineering	75% Complete
Dry Gulch Update	Lakewood	Muller Engineering	50% Complete
Happy Canyon Creek	Douglas Co. & Arapahoe Co.	Kiowa Engineering	Complete in 1993
Lower Slaughterhouse	Littleton	Boyle Engineering	Completed in 1993
Moon Gulch	Jefferson Co. & Arvada	Kiowa Engineering	50% Complete
Newlin/Baldwin Gulch	Parker, Douglas Co.	Kiowa Engineering	50% Complete
Stapleton Drainage	Denver	McLaughlin Water	5% Complete
Upper Lena Gulch Update	Jefferson Co., Lakewood & Golden	Boyle Engineering	90% Complete
Upper Weir Gulch Update	Lakewood & Jefferson Co.	Kiowa Engineering	98% Complete
Westerly Cr. u/s of Havana	Aurora	Merrick	40% Complete
Arapahoe Gulch	Golden	n/a	Scheduled for 1994
Big Dry Cr. (ARAPCO) Update	Arapahoe Co. Douglas Co., Englewood, Greenwood Village	n/a	Scheduled for 1994
Coal Creek	Superior	n/a	Scheduled for 1994
Louisville Update	Louisville, Boulder Co.	n/a	Scheduled for 1994
Thornton-wide	Thornton	n/a	Scheduled for 1994
Weaver Creek Tr.	Jefferson Co.	n/a	Scheduled for 1994

Technology Transfer

Since we began distributing Volume 3 of the *Urban Storm Drainage Criteria Manual* in November, 1993, over 550 copies have been distributed throughout the United States and Canada. We have received many compliments about its concise treatment of the topic, and the clear and well defined technical guidance that it provides to the user. A copy may be purchased by sending a check for $43.50, including $3.50 for postage, made out to the Urban Drainage and Flood Control District. This price includes updates for the next five years.

Over the next two years we hope to install and test several structural practices, some of which have not yet been included in this document. Once field testing has show us how to size and design cost effective structures, they will be added to Volume 3.

Also in 1993, the Environmental Compliance Technology Department of the Red Rocks Community College gave several training sessions for stormwater management and erosion control technology to use during construction. So far the demand for this training did not come up to what we expected when we (i.e., the District and the Colorado Department of Transportation) approached Red Rocks to develop and to offer this type of training on an ongoing basis. We hope that the attendance for this excellent short course will pick up. If it does not, its availability may be scaled back and this type of training may not be available on a regular schedule for the near-term. It seems to us that there is a big need for such training, especially when we observe how erosion control (or lack of it) is occurring in the field. If you have an interest in attending (we encourage that consultants and construction personnel responsible for erosion control attend), or would like to have this training provided within your own organization, call Scott Olson at 988-6160, X-282 for a schedule.

Software

We have begun a low level activity within the District to examine the CUHP software. Two items are of interest to us at this time, namely, developing a capability to account for rainfall losses when the sub-watershed has reduced levels of directly connected impervious area, and developing a menu-driven user interface to input and edit the basin parameters. We will report to CUHP software owners of any progress that is made in 1994.

Stormwater NPDES Activities

As a follow-up to the NPDES separate stormwater permit applications submitted by Denver, Lakewood and Aurora, the Colorado Water Quality Control Division (CWQCD) in November of 1993 sent draft permits to each city to begin discussions on their conditions. It now appears that the three largest cities in the Denver metropolitan area will be operating under a stormwater discharge permit sometime in 1994. We are very interested in seeing how this arrangement will change the way municipalities conduct their stormwater system management and allocate their resources. We will probably be able to report in our next issue on what regulatory conditions the smaller municipalities will have to face in the future, based on the final permit conditions issued to these three cities.

In 1992 we began holding regular meetings with the Phase II municipalities (i.e., with populations less than 100,000). These meetings continued at a reduced pace in 1993 and provided many cities and counties an opportunity to keep up with the current status of federal and state regulations, share experiences in how to prepare for future permit applications and to exchange information about stormwater quality management activities on an informal basis. We will continue to sponsor these meetings and invite all cities and counties in Colorado to send a representative to these meetings. In 1994 we expect to hold three or four meetings unless there are regulatory or legislative changes that will need more concentrated attention. Call John Doerfer of our office to place yourself on the list and to find out when the next meeting will take place. Everyone is welcome to attend.

SURVEY (From page 1)

Water Quality Enhancement

Contrary to the expectations of the authors, the percentage of respondents who considered *water quality enhancement* in their design *decreased* since 1982 among consultants and academia and remained unchanged among government officials. This downward trend is difficult to explain, especially in light of recent federal government's activities in stormwater quality.

Another interesting trend since 1982 was that only 33 percent of the respondents to the 1991 survey considered *modifying existing detention* facilities to provide *water quality enhancement* (this question was not asked in the 1982 survey). This low percentage may indicate a bias against this practice. It is also possible that many experienced professionals do not believe that existing facilities can be easily modified.

When asked to rank what they consider most important when designing detention facilities or reviewing their designs, *water quality* was ranked relatively low, with only *wildlife habitat* being ranked lower. As in 1982, the 1991 survey showed that *water quality* is still given only limited consideration in the design of detention facilities. There does appear to be, however, an increasing awareness of water quality issues since the 1982 survey.

The respondents ranked the following factors in order of perceived effectiveness when for *water quality enhancement*:

1. Hydraulic design,
2. Detention/retention residence time,
3. Routine maintenance, and
4. Major maintenance/reconstruction.

When asked to rate specific changes that are needed to the traditional hydraulic and hydrologic design practices typically used in the past for flood control to now also provide *water quality enhancement*, the 1991 respondents listed the following three in their order of perceived importance:

1. Reduction of the outlet size,
2. Elongation of the distance between the inlet and the outlet, and
3. Design to control runoff from a range of storm runoff events.

Safety

The respondents to the 1991 survey rated *safety* high, only somewhat less importance than *hydraulic function* and *peak-flow reduction*. This was similar to the 1982 survey. The design factors that were considered most important for improving *safety* were flat side-slopes and shallow water depths. Its location and local public opinion were also noted as being important in determining how much concerns for safety are an issue.

Other *safety-related* factors that were mentioned by the respondents were: ice buildup, multiple storm detention, and maintenance. These were listed by several respondents only as specific concerns without any explanation. As a result it is difficult to form an opinion as to their general applicability.

Aesthetics

The *use of natural materials* was considered to be most important for help achieve *aesthetic* design, followed by *consultation with a landscape architect*. Other items listed, in order of perceived importance, were: *providing park and play areas*, *providing wildlife habitat* and the *use of colored concrete*.

The category of *aesthetics* had a large number of write-in responses. Among the ideas offered were the following: the use of basins without permanent pools, the use of natural land forms, meandering channels, water fountains, beaches, irregular configurations, native/natural vegetation, and mosquito control. The large number of written comments on this question show that stormwater professional have a variety of ideas in how to improve the appearance (i.e., aesthetics) of urban stormwater detention facilities.

In 1982 *aesthetics* was ranked as the least important factor in the design of detention facilities. This perception remained virtually unchanged in 1991, but was ranked higher than *wildlife habitat* as a design consideration. The low ranking of *aesthetics* in this survey may not indicate its true place in the design of detention facilities. It may merely indicate, however, that designers and engineers are more concerned about the hydrologic and hydraulic function and in the physical safety of detention facilities. *Aesthetics* is probably treated, or perceived, by engineers as an added element to the "actual design." Namely, the first of a designer of public facilities is to design for structural integrity, physical function and safety. Visual aspects and other functions probably enter the designer's mind only after the most structural functions are adequately dealt with.

Summary

The 1982 and 1991 survey results show that stormwater detention design practice and attitudes changed little in last ten years. Although still not considered much by the respondents, there appears to be in the increased awareness of water quality issues. It will be interesting to observe how this awareness translates into a state of practice over the next ten years.

Bibliography

ASCE, *Stormwater Detention Outlet Control Structures*, prepared by the Task Committee of the Am. Soc. of Civil Engrs., New York NY, 1985.

Current BIDTABS data is now available

BIDTABS is a program that has been in use for four years to catalog and continuously update bid prices as they are submitted for District projects. The BIDTABS program is easy to use, with a menu-driven format, and can be used with IBM PC compatibles.

A copy of the BIDTABS program and a set of instructions on its use, or just the updated data files if you already have the program, can be obtained by sending a formatted 1.4 Mb 3-1/4" or 1.2 Mb 5-1/2" floppy disk to the attention of Paul Hindman at the District.

Reflections on 20-years as a floodplain manager

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

Introduction

As I approach my twentieth anniversary as a floodplain manager, I have been reflecting on how I got into this business, what we have been able to accomplish and where we are today.

How I Got Here

On June 10, 1972, I awoke to the news that my old college town, Rapid City, SD, had been devestated by a flash flood on Rapid Creek. At the time I was working in the San Francisco Bay Area as a construction engineer for Shell Oil Co., but I had an appointment for later that week with my former department head at South Dakota School of Mines and Technology (SDSM&T) to see about a graduate teaching assistantship. I decided to make the trip and hope that things would work out.

When I arrived in Rapid City the extent of the destruction was amazed me. The fraternity house where I had lived for three years, which was located about half a block from Rapid Creek, had been heavily damaged. A number of my fraternity brothers had spent the night of the flood on the roof. I remember thinking that when I lived there I had never thought about a possible flood.

I got the assistantship, and with the help of the GI Bill, I went back to school to work on my MS in Civil Engineering. Living in Rapid City during the planning and implementation of the recovery effort had an impact on me, as did the fact that all of my professors were working on documentation of the flood and/or on the recovery effort. The more I was exposed to the flood impacts and the recovery effort the more I became interested in a career in floodplain management.

One of my responsibilities as a teaching assistant was to staff a short course on drainage. One of the experts brought in as an instructor was Ken Wright from Denver. Later, when I began searching for a job I sent Ken my resume. He gave it to Scott Tucker at the District who was looking for a floodplain manager to fill a newly created position. He invited me to Denver for an interview, offered me the job, and I began work on January 31, 1974.

What We Have Accomplished

The District's Board of Directors had already made a number of policy decisions which would prove valuable. Perhaps the most important was to recognize that the floodplains along 75% of the major drainageways in the Denver metro area were still undeveloped and that a two-pronged approach of fixing past mistakes while preventing new mistakes in these undeveloped floodplains would be the best way to go. That led to the creation of the floodplain management position I was hired to fill.

Twenty years later the Denver metro area's population has grown from about 1.25 million to two million people. Along with the population growth has come the homes, shopping areas and work places for these additional 750,000 people. Still, on January 1, 1994, I can state with certainty that there are fewer structures located in identified 100-year floodplains now than there were on January 1, 1974.

There are still many structures in flood hazard areas, and the potential for significant flood disasters still exists, but the trend has been in the right direction. This is a tribute to many people, including the elected officials of the 35 cities and counties within the District, their staffs, and many interested citizens.

The District's remedial effort includes master planning to determine the best solutions to the existing problems, a design and construction program to implement the master planned remedial projects and a maintenance program to preserve the functional integrity of the facilities.

The District has been involved in the construction of more than $125 million in drainage and flood control facilities. These facilities include on-line and off-line detention facilities, grass lined-channels, rock-lined channels, trapazoidal and rectangular concrete channels, concrete wall-grass bottom channels, and soil cement side-wetland bottom channels. We even built a few conduits, although that's not our favorite option. One thing every project had in common: the local government sponsors wanted the facility enough to pay at least half the costs and sometimes more. I also must recognize the construction of two major flood control dams by the Corps of Engineers.

The preventive effort includes an aggressive flood hazard area delineation program in which we have gotten out ahead of development and delineated 100's of miles of 100-year floodplains before the developers get there. It includes floodplain regulations and other land use controls adopted by local governments to prevent unwise development in those floodplains. It includes a drainage criteria manual widely used by the local governments.

We review proposed developments and offer comments to local governments. We work with local governments to develop drainage master plans to guide growth in newly developing areas. We tell every developer that our prefered option is to leave the floodplain alone; set it aside for open space, wild life habitat and/or recreation. If they won't do that, they do have the option to fill the fringe areas of the floodplain or build a channel to reduce the size of the floodplain. We can't stop them from doing that, so long as they "deal with" the 100-year flood.

We have our maintenance eligibility program in which facilities built by others (developers and local governments) can be made eligible for our maintenance assistance if they follow our criteria and our eligibility procedures. Through this process we try to get the floodplain, or channel, dedicated to the local government. We also require a maintenance access trail which can usually be used as a recreation trail as well. We also try to discourage attempts to put drainageways in underground conduits by stating that, by definition, conduits are not eligible for District maintenance assistance.

Finally, we recognized that it would still be many years and many dollars ($500 million +) before all the problems could be "fixed." We therefore developed a substantial flood detection and warning system throughout the metro area, and we put together an effort in which we now annually mail an informational brochure to every structure in every defined floodplain warning of the flood hazard and suggesting actions individuals can take to reduce their potential flood losses.

I think it is important to note that almost every detention facility we have constructed has a recreation, open space or habitat function in addition to flood cotrol. Many of the channels we have built, and developers have built, have become recreation corridors. Many floodplains set aside by developers are now assets to the neighborhoods.

Role of the NFIP

I have lived with the National Flood Insurance Program (NFIP) for my entire career, and there have certainly been ups and downs.

The NFIP requirement that local governments adopt and enforce floodplain regulations in return for making affordable flood insurance available within the community definitely helped us in our efforts to assure that our local governments adopt and enforce floodplain regulations and make flood insurance available to their citizens. We were also able to "piggy back" on a number of flood insurance studies to define additional miles of 100-year floodplains to our level of detail.

However, the NFIP also gave us a number of problems. Chief among them was the NFIP's insistance on using existing basin conditions to develop flood insurance study (FIS) hydrology whereas we used projected future development in our hydrology. We were planning for the future and wanted to manage the floodplains accordingly. NFIP said that the insurance program could only charge premium rates based on the current hazard. But, at the same time the NFIP was a de facto land use management program and the Flood Insurance Rate Maps (FIRMs) were actually encouraging development that would be included within the future 100-year floodplain. We spent an enormous amount of time trying to ensure consistency between our maps and the FIRMs, with mixed results.

Later on we found that the Federal Emergency Management Agency (FEMA), which had assumed management of the NFIP, was actually encouraging our local governments to relax provisions of their floodplain regulations which exceeded FEMA minimum standards. Then, after our local governments went to the minimum standards, FEMA introduced the Community Rating System in which they give reduced premiums to communities that do more than the FEMA minimums.

We have always had trouble getting FEMA to revise the FIRMs to recognize our remedial projects. Without going into all the gory details suffice it to say that we find it difficult to understand why it can take upwards of 24 months to get FEMA's consultants in Virginia to accept the work of our consultants in Denver.

While all of this has been going on, the number of structures insured under the NFIP has been low. After 20 years of a mandatory insurance purchase requirement, only 15 % of the structures in identified floodplains in Colorado are covered. The recent floods in the Midwest have again exposed the failure of the NFIP in this regard. The Denver area is equally vulnerable to major uninsured losses as a result of FEMA's inability to enforce the mandatory purchase requirements.

Where We Are Going?

Most floodplains are delineated, and on a FIRM, and we are moving ahead on the same two fronts. On the preventive side, we are continuing our past efforts. Any significant changes will come only if the federal government makes dramatic changes that will dictate a response on our part. On the remedial side we continue to plug away at about $8 million in projects per year.

I am concerned about the negative impact of federal agencies on remedial measures like dams and enlarged channels. As federal regulators have become more intrusive in local government decisions it has become more difficult and expensive to build a remedial project or maintain an existing one. There are now instances where we have to meet up to six requirements: a floodplain development permit from the local government, a 404 Permit from the Corps of Engineers, a construction stormwater discharge permit from the Colorado Department of Health (CDH), a construction dewatering permit from the CDH, a Conditional Letter of Map Revision from FEMA, and a survey for an endangered orchid. Only after all these requirements are met are we allowed to build a project, or maintain a facility, which provides flood protection for people.

Now we have additional concepts to be concerned about: multi-objective management (MOM), watershed management, and "natural and beneficial values," all of which are motherhood and apple pie concepts, but which promise more federal government regulations, more unfunded mandates, and more interference in the ability of local governments to run their own affairs.

I don't have a problem with these concepts in newly developing areas, as indicated above in describing our approach to preventing new problems. However, I do have a problem when miniscule wetlands and orchid surveys get in the way of flood protection for people in already urbanized areas, and I don't see it getting any better.

Some Final Thoughts

When I look back on the last 20 years I feel pretty good about what all of us at the District, working with many other individuals and agencies, have been able to do to fix existing problems while preventing new ones from being created. We've taken several thousand structures out of the floodplain, and kept countless new structures from being put in the floodplain. Along the way we have played a part in developing a substantial recreational resource in the form of multi-use facilities.

I would like nothing more than to continue to work on this record of accomplishment. However, as FEMA continues to be difficult to deal with; and as MOM, watershed management and "natural and beneficial values" become entrenched in federal law and regulations; we can expect more federal intrusion into the local decision making process. I also see the limited financial resources of local governments being diverted from projects which help people to projects required solely to meet federal stormwater quality regulations. This will make it harder for us to protect our citizens from existing flood hazards.

On a more positive note, the basic concept of floodplain management is well known and accepted by the staffs and elected officials of our local governments. Perhaps as important, many of the developers in the Denver area recognize the value of staying out of the floodplain and using it as an amenity for their developments. For these reasons I see continued success on the preventive side of the District's efforts. That is my continuing goal.

DESIGN AND CONSTRUCTION NOTES

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

Nineteen Ninety-three was a year of construction starts for projects which had been on hold for various reasons but mostly awaiting right-of-way or funding.

The District and City of Arvada recently cooperated in the construction of major improvements to Hays Lake Dam (also known as Oberon Lake #1). The dam, which is owned by the Oberon Water Company, is an earth fill structure used for water supply purposes. In 1982 the District and Arvada cooperated in the preparation of a master plan for Hays Lake which recommended modifications to the spillway to allow for detention storage needed to supplement the downstream outfall system.

In 1985, the Office of the State Engineer ordered the Oberon Water Company to provide an acceptable spillway or breach the dam. The alternative of breaching the dam was not well received by yet a fourth party involved in the project, the Denver and Rio Grande Western Railroad (DRGWR). A main line of DRGWR traverses the crest of the Hays Lake Dam embankment.

In 1990, the District, City of Arvada, Oberon Water Company and the Denver and Rio Grande Western Railroad entered into an agreement for the design and construction of the improvements needed to provide a safe and functional dam. Construction of those improvements was completed earlier this year. The majority of the work consisted of jacking a large diameter conduit, which will now serve as the main spillway and outlet works, through the embankment. A complex intake structure was required to allow for a low level outlet works, release of irrigation flows and the passage of storm flows.

Two projects went into construction this year in unincorporated Jefferson County. The Lena Gulch crossing at Isabell Street finally got underway in September as did the SJCD South at Kendall project. Both of these projects will relieve frequent flooding of these two streets which has been a problem for Jefferson County over several years.

Another project which has been designed for several years, finally got it's start in March of this year. That project is the next phase of Goose Creek in the City of Boulder. This phase of construction consists of major channel improvements between Foothills Parkway and 30th Street and includes new cross drainage structures at 30th Street and the Burlington Northern Railroad. Completion of this $2.7 million project is expected sometime in the spring of 1994. The project will eliminate a large area of 100-year floodplain through this commercial area in Boulder.

The final phase of construction on Upper Slaughterhouse Gulch in Littleton began this fall and is expected to be completed in the spring of 1994. This is the third and final phase of construction on Upper Slaughterhouse Gulch in the city and will provide some much needed relief to a frequently flooded residential area along the gulch from Broadway downstream to Powers Park.

The North Branch of Sloan Lake Project was completed this past year. This was the second of two phases of construction on the North Branch which serves to provide much needed drainage and flood control to a large residential area within Edgewater and Wheat Ridge. Improvements consisted primarily of over 9,000 l.f. of large diameter storm sewer capable of handling the 5-year event.

This past year also saw the start of several design projects. Final design of the lower reaches of Goldsmith Gulch from Iliff to Cherry Creek was initiated this fall. Final plans and specifications should be ready in the spring of 1994 for construction of the estimated $3.0 million in improvements.

Redesign of the lower reach of Little Dry Creek (ADCO) was recently completed. The new design will allow for the discharge of flow from Little Dry into an existing borrow pit recently purchased by Adams County and the

(Continued on page 23)

STATUS OF DISTRICT DESIGN PROJECTS

Project	Participating Jurisdiction(s)	Status
Lower Goldsmith Gulch	Denver	5% Complete
Little Dry - Clear Cr. to 64th	Adams County	Complete
Marston Lake North	Denver	Complete
Ralston / Leyden Feasibility	Arvada, Corps of Engineers	85% Complete
Van Bibber Feasibility	Arvada, Corps of Engineers	95 % Complete
Clear Creek @ 52nd Avenue	Denver	95% Complete
Irondale -Dahlia/80th Ave.	Adams County, Commerce City	Prelim. - 50% Complete
Happy Canyon Creek	Arapahoe County	60% Complete
Lonetree, Windmill, Dove	Arapahoe County	Prelim. - 95% Complete
Sanderson @ Green Gables	Jefferson County, Lakewood	5% Complete
Niver Creek Trib. M	Federal Heights	Preliminary - Complete
Bear Canyon Creek	Boulder	50% Complete
Knox Court Outfall	Arapahoe County	5% Complete

STATUS OF DISTRICT CONSTRUCTION PROJECTS

Project	Jurisdiction(s)	Cost	Status
Brighton North Outfall	Brighton	$650,000	Complete
Granby / Sable	Aurora	752,000	40% Complete
Huron Street Outfall	Adams County	2,078,000	Complete
I-25 / 40th & Inca	Denver	1,900,000	Complete
North Branch Sloan Lake	Edgewater, Wheat Ridge	2,128,000	95% Complete
Prentice @ Holly	Greenwood Village	250,000	Complete
Big Dry Cr. @ Orchard	Greenwood Village	150,000	90% Complete
Goose Creek	Boulder	2,700,000	50% Complete
Drainageway No. 4	Lafayette	300,000	5% Complete
Four Square Mile - Westerly	Arapahoe Co., Aurora	1,035,000	Complete
Hays Lake Dam	Arvada	210,000	Complete
Lena @ Isabell	Jefferson County	405,000	50% Complete
Meadowlark Drainage	Westminster	665,000	75% Complete
SJCD @ Kendall	Jefferson County	370,000	85% Complete
Sand Creek- Buckley/Colfax	Aurora	1,000,000	5% Complete
17th & Ulster	Denver	730,000	Complete
Slaughterhouse Gulch	Littleton	725,000	20% Complete
Spring Creek	Arapahoe County	360,000	95% Complete
Dry Gulch	Lakewood	1,500,000	80% Complete

STORMWATER QUALITY CHARACTERIZATION IN THE DENVER METROPOLITAN AREA

by

John T. Doerfer, Project Hydrologist and Ben Urbonas, P.E., Chief, Master Planning Program

Introduction

During the past two years, the District and the cities of Denver, Aurora, and Lakewood jointly funded a monitoring program to characterize stormwater quality in the Denver metropolitan area. Rainfall, runoff, and water-quality data were collected from urban watersheds typical of industrial, commercial, and residential land use. This monitoring was done to comply with Environmental Protection Agency (EPA) regulations that require the three cities to obtain municipal stormwater discharge permits under the National Pollutant Discharge Elimination System (NPDES). The joint approach used to prepare the three municipal stormwater permit applications was discussed in previous issues of *Flood Hazard News*.

A similar stormwater monitoring program occurred in the Denver metropolitan area in 1980 and 1981 as part of EPA's Nationwide Urban Runoff Program (NURP). The NURP study in Denver was one of 28 funded by EPA under a grant received by the Denver Regional Council of Governments (DRCOG). In addition to commercial and residential sites, an undeveloped watershed was monitored in the DRCOG study.

Similar data-collection techniques and laboratory analytical procedures used in both monitoring programs allow a comparison to be made of stormwater quality over the 12-year period. Results are presented and discussed along with characteristic values of stormwater quality considered to be representative of the Denver metropolitan area.

Characterization Method

The underlying assumption used by some stormwater professionals is that stormwater quality can be characterized by association with the predominant land use of the watershed. This implies that unmonitored areas can be characterized based on monitored areas of similar land use. It is important to note, however, that in the NURP study no statistically significant differences were found in average concentrations between land uses (EPA, 1983).

Monitoring Sites. A total of nine sites were monitored in 1980-1981. These included one undeveloped, four residential, one commercial, one mixed commercial/residential, and two sites below retention ponds. An average of eleven storm runoff events were sampled at each of the monitoring sites. A description of each watershed is provided in Gibbs (1981).

A total of eight sites were monitored in 1992-1993. These included two residential, three commercial, and three industrial sites. Three storm runoff events were sampled at each site. A description of each watershed is provided in the joint appendix to the three permit applications (UDFCD, 1992). Criteria used in site selection are discussed in Doerfer and Urbonas (1992).

Monitoring Methods. The U.S. Geological Survey (USGS) collected data in both programs through cooperative agreements with project sponsors. Raingages were installed in each watershed, along with flumes in storm sewers and automated-sampling equipment for discharge monitoring. Two existing streamflow gaging stations were used as sampling sites in 1992-1993. Rainfall and runoff data were recorded at 5-minute intervals and used to actuate the sampler pump at the beginning of a runoff event. Field data and manual grab samples were collected as necessary for specific analyses.

Sample collection in 1980-1981 used the technique known as discrete sampling where a number of individual samples are taken at intervals during a runoff event and each are analysed separately. In 1992-1993, a flow-weighted composite sample was prepared for laboratory analysis by collecting multiple samples during the event and combining these in proportion to the flow at the time each was taken. Ellis *et al.* (1984) found the two methods to produce similar event mean concentrations (EMCs). Analysis of flow-weighted composite samples is less expensive, and provides a direct measure of the average water-quality conditions during a runoff event (ie. EMCs).

Laboratory Analysis. Samples were analysed for as many as 150 constituents. These included the general categories of suspended solids, nutrients, oxygen-demanding substances, coliform bacteria, trace metals, and organic compounds such as pesticides and polychlorinated biphenyls (PCBs).

Laboratory analyses were performed at the USGS National Water Quality Laboratory in Arvada for most constituents. In 1981, Rocky Mountain Analytical Laboratory analysed organic compounds for seven runoff events. In 1992, USGS analysed organic compounds for 24 runoff events. Analytical methods, detection limits, and quality control provisions were similar for both labs and adhered to EPA protocols.

During 1993, the District collected samples at the eight sites for 5-day biochemical oxygen demand (BOD5) and chemical oxygen demand (COD). These samples were analysed by the Denver Wastewater Management Division and the Metro Wastewater Reclamation District. The City of Aurora and a private laboratory were also used to test the variability of BOD5 and COD results produced by different laboratories.

Results and Discussion

Monitoring data collected in the Denver NURP project were published in two reports by USGS (Gibbs, 1981; Gibbs and Doerfer, 1982). EMCs were calculated from these data and published by DRCOG (1983a). Results from the 1992-1993 monitoring were published by UDFCD (1992).

Land-Use Averages. Table 1 presents a comparison of EMCs for commercial and residential land use for several constituents monitored in both programs. These were obtained by flow-weight averaging all EMCs at a site, and then arithmetically averaging the EMCs from all sites of similar land use.

Table 1. Comparison of Commercial and Residential EMCs for Several Constituents Monitored in 1980-1981 and 1992-1993

		Commercial		Residential	
Constituent	**Units**	**80-81**	**92-93**	**80-81**	**92-93**
Total Suspended Solids	(mg/L)	251	165	226	325
Total Nitrogen	(mg/L)	3.0	3.9	3.2	4.7
Total Nitrate + Nitrite	(mg/L)	0.80	1.4	0.61	0.92
Total Phosphorus	(mg/L)	0.46	0.34	0.61	0.87
Dissolved Phosphorus	(mg/L)	0.15	0.15	0.22	0.24
Copper, Total Recoverable)	(ug/L	27	81	28	31
Lead, Total Recoverable	(ug/L)	200	59	190	53
Zinc, Total Recoverable	(ug/L)	220	290	180	180

Review of Table 1 shows that stormwater EMCs over the 12-year period have remained similar, with the exception of lead that has decreased by about a factor of three to four. The differences in average EMCs between the two monitoring periods as shown in Table 1 are much smaller than the variability in data observed between individual storm runoff events used to find the average EMCs.

With the exception of lead, data from both periods were combined to develop representative EMCs for commercial and residential land uses. EMCs for constituents not listed in Table 1 and required for characterizing stormwater quality in municipal permit applications were developed using 1992-1993 data.

Table 2 presents representative EMCs for four general land-use categories in the Denver metropolitan area. EMCs for undeveloped land in Table 2 were taken from DRCOG (1983b). Industrial land-use EMCs in Table 2 represent the 1992-1993 data averages.

Organic Compounds. Stormwater samples were analysed in 1981 and 1992 for 112 organic compounds that can be detected at levels of parts-per-billion. A fair amount of consistency was found in compounds detected in both 1981 and 1992 although different watersheds were monitored in the two programs.

Of 29 volatile compounds, five were found at or near the detection limit. Toluene, a combustion product of petroleum, was found in nearly every sample analysed. Chloroform, tetrachloroethylene, and 1,1,1-trichloroethylene (cleaning solvents) were found at commercial sites during 1981 and 1992. Ethylbenzene, not previously detected in 1981, was found at one industrial site only in 1992.

Of eleven acid-soluble compounds, three were detected in both 1981 and 1992. These included phenol (associated with petroleum), pentachlorophenol (a wood preservative), and 2,4-dichlorophenol (associated with pesticides). Six other acid-soluble compounds were found in one sample at one commercial site in 1992.

Of 46 base/neutral-soluble compounds analysed, a total of four were detected in 1981 and ten in 1992. Two found in 1981 were not detected again in 1992. Naphthalene (a fuel or solvent) was found in residential areas in both programs. Two compounds that are plasticizers were detected in most samples. The additional compounds detected in 1992 are polycyclic aromatic hydrocarbons (PAHs) related to petroleum use or petroleum-combustion byproducts. The PAHs were found primarily at industrial and commercial sites.

Pesticides were detected in runoff from the three urban land-use categories. Lindane was found at residential and commercial sites in both programs. Dieldrin was detected at an industrial site. Of the 24 samples in 1992, two types of PCB were detected--one at a commercial site and another at an industrial site.

Conclusion

Stormwater quality was monitored in the Denver area during 1980-1981 and 1992-1993. Between these two periods, similar average concentrations of total suspended solids, nutrients, copper and zinc were found in runoff from commercial and residential areas. Lead was found to have decreased by a factor of about four. There was consistency in the types and numbers of organic compounds detected in runoff during both periods.

Average concentrations of selected constituents that characterize stormwater quality in the Denver area were developed for four land-use categories: industrial, commercial, residential and undeveloped land. In using these results, it should be recognized that only a small number of storms and limited number of watersheds were monitored overall, and that stormwater quality is highly variable during the course of a runoff event and from one storm to another within a particular watershed.

Table 2. Land-Use Average Event Mean Concentrations in the Denver Metropolitan Area

Constituent	Units	Industrial	Commercial	Residential	Undeveloped
Total Suspended Solids	(mg/L)	399	225	240	400
Total Dissolved Solids	(mg/L)	58	129	119	678
Biochemical Oxygen Demand	(mg/L)	29	33	17	4
Chemical Oxygen Demand	(mg/L)	232	173	95	72
Total Nitrogen	(mg/L)	2.7	3.3	3.4	3.4
Total Kjeldahl Nitrogen	(mg/L)	1.8	2.3	2.7	2.9
Nitrate plus Nitrite	(mg/L)	0.91	0.96	0.65	0.50
Total Phosphorus	(mg/L)	0.43	0.42	0.65	0.40
Dissolved Phosphorus	(mg/L)	0.20	0.15	0.22	0.10
Cadmium, Total Recoverable	(ug/L)	3	1	0.0	0
Copper, Total Recoverable	(ug/L)	84	43	29	40
Lead, Total Recoverable	(ug/L)	130	59	53	100
Zinc, Total Recoverable	(ug/L)	520	240	180	100

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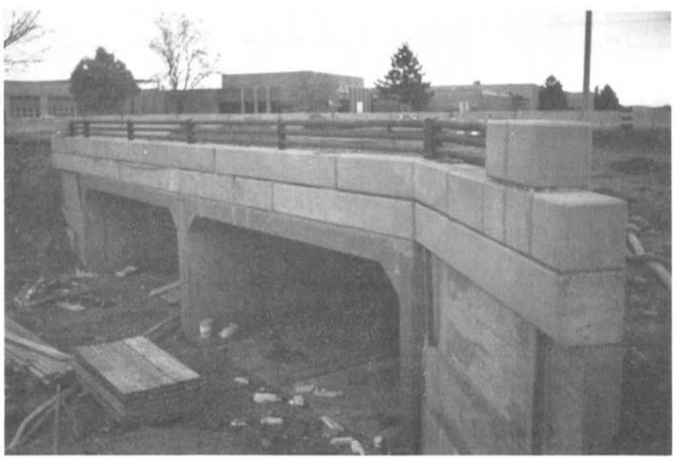
Construct (from page 20)

District. The existing 7 acre body of water will allow for the temporary storage of storm flows from Little Dry and hopefully provide some much needed water quality benefits. Flow will discharge from the borrow pit through small diameter outlet conduits with the larger flows to go through a grass lined spillway into the adjacent Clear Creek.

The District and City of Lakewood have plans to design improvements to Dry Gulch in the area of 15th and Kipling. Part of this project will include detention storage on a site which has a certain degree of historical significance to the City. The challenge of incorporating the needed detention storage at this location will make this a very interesting project. We expect the design work to commence sometime around January 1st.

After years of mental anguish, successfully alienating every right-of-way agent within the District's boundaries and driving off at least four student interns (including one to seminary), we are now complete in our efforts to research and document right-of-way in which the District has participated over the years. The information is now readily available and maintained on a data base as well as hard copies on file.



Goose Creek crossing of 30th St. in Boulder.

Grade control strucure on Spring Creek in Arapahoe Co.

Tucker (from page 3)

Urban Drainage and Flood Control District Enters Its 25th Year

In June of 1994 the Urban Drainage and Flood Control District will be completing its 25th year. It was in June of 1969 that the Colorado State Legislature created the District with the adoption of the Urban Drainage and Flood Control Act. The first 25 years have seen significant changes take place. The District has developed active master planning, floodplain management, construction, maintenance, and South Platte River programs and much has been accomplished. The basic approach has been to work in partnership with the cities and counties of the District to define drainage and flood control problems and solutions, in the implementation of mitigation or preventive projects, and to assist in the maintenance of drainage and flood control facilities. It is hard to believe that 25 years have passed so quickly.

I once thought 25 years was an eternity; not so, not so. The next 25-year period will end in the year 2019, which perhaps now could be seen as just around the corner. The first 25 years has seen the District progress from a new fledgling organization to one with developed programs and approaches. The next 25 years will also see many changes as the Denver metropolitan community wrestles with how to best address the provision of basic services to the area. I am certain the District will play as vital a role in the Denver metropolitan community in the next 25 years as it has in the first quarter century of its existence.

District Awards

For the fifth year in a row the District has received a "Certificate of Achievement for Excellence in Financial Reporting" from the Government Finance Officers Association of the United States and Canada. The certificate is presented to government units whose comprehensive annual financial reports achieve the highest standards in government accounting and financial reporting.

Congratulations to Frank Dobbins and Darla Schulz, the District's finance and accounting team.

The District was involved in two projects which received awards from the Colorado Association of Stormwater and Floodplain Managers.

The District received the "Honor Award for Outstanding Achievement in the Field of Stormwater Management" for completion of *Urban Storm Drainage Criteria Manual, Volume 3, Best Management Practices*. Congrats to Ben Urbonas and John Doerfer and their consultants CH2M-Hill and Kiowa Engineering Corporation.

The City and County of Denver received the "Honor Award for Outstanding Achievement in the Field of Floodplain Management" for the Lakewood Gulch & Dry Gulch park and flood control project. Congratulations to Dave Lloyd and Paul Hindman from the District, Joe Magers and Isaac Jiron at Denver Wastewater Management Division and consultants Greenhorne & O'Mara, Inc. and Wenk Associates.

FLOOD HAZARD NEWS
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