

FLASH FLOOD PREDICTION PROGRAM & RELATED ACTIVITIES

by
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1991 PROGRAM CHANGES APPLAUDED

This past year represents the 13th operational season of the District's Flash Flood Prediction Program (F2P2). Weather forecasting was provided by Henz Meteorological Services (HMS) for the second consecutive year. The continued success of this program can be largely attributed to the dedicated involvement of many public safety and public works officials from the six-county Denver metropolitan area that the District serves. Efforts to improve services continue by soliciting input from key individuals directly involved with emergency services planning, coordination and operations.

In last year's issue of *Flood Hazard News*, two articles were devoted to describing the evolution of F2P2 communications, recent program changes and the need for further refinements. The main problem identified in 1990 involved a practice of issuing "Thunderstorm Advisories" or TA's to 911 dispatchers. These TA's were generally considered non-emergency weather information and were issued quite frequently, resulting in what was then termed "information overload." On March 14, 1991, a meeting was held by the District to address the issues raised during 1990 and obtain approval from emergency managers concerning 1991 operations. This meeting resulted in implementing the following changes:

1. The practice of issuing TA's was discontinued.
2. Forecasts concerning possible thunderstorm activity, having either no or very low flood potential, would only be available via Electronic Bulletin Board (EBB) or fax. Associated severe weather may be mentioned in this written communication but not used as criteria for contacting dispatchers.
3. Unless the potential for flash flooding exists, dispatchers will not be contacted by the F2P2 meteorologist. The National Weather Service (NWS) is responsible for disseminating all severe weather information.
4. A uniform policy of issuing "Red Flag" messages would be implemented for flash flood predictions or flood related information requiring priority handling by dispatchers.

5. Improved message forms for verbal communications were distributed to all F2P2 contact points.

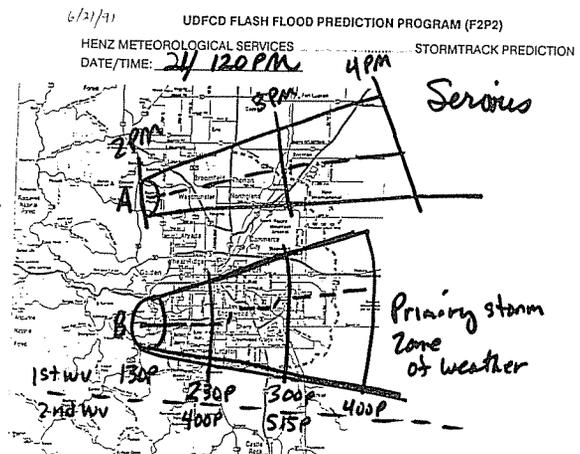
As the 1991 flood season progressed, there were many opportunities to review, critique and further refine internal procedures. By the end of the season, nearly everyone had developed a new level of confidence and comfort with the F2P2. On October 10, the District conducted a program review meeting which was attended by 26 officials from various local government agencies as well as representatives from HMS and NWS. The following feedback was received at that meeting and during the year:

1. The response to fax communications was extremely positive. While internal procedures differed somewhat between the various jurisdictions, the consensus was unanimous that this type of communication should continue.
2. Perhaps the highest compliments related to HMS's storm-track predictions which are presented using an area map and disseminated via fax. Since the fax has become a standard piece of equipment in many offices, the majority of F2P2 contact agencies were able to obtain this product and

considered it very helpful. A number of the users gave specific examples concerning the accuracy and timeliness of the storm-track predictions. This product was first introduced in 1990 and is now considered a standard F2P2 product with the user base rapidly increasing.

3. On some "Message Days" HMS took the initiative to fax completed message forms to certain 911 dispatch points prior to placing the required phone call. The content of the message would be reviewed with the dispatcher to make sure all information was clearly understood. The dispatcher would subsequently initiate the message fanout according to internal procedures. In commenting, Jefferson County Communications stated: "We love the fax... We get so busy that a lot of times we don't have time to sit and take all the message information down by hand, so the fax is wonderful. The information is more accurate and our dissemination is much easier." Douglas County echoed this statement by saying that the use of the fax has 100-percent eliminated the communication problems which were common in past years.

A reduced example of a fax map showing two storm tracks (A and B) for June 21, 1991. Note that the times of arrival of each wave are given on the map, and in the case of Track B, two sets of wave times are given.



- A: 1-2 Severe R_s with street/stream flooding. Hail to 1.5"
 - B: 2 waves of 7-storms 130P → 530P
 1. Serious severe weather & rain threat
 2. Urban street + stream flooding threat > 50%
 3. LARGE HAIL 1-2" may clog drains
- Henz

4. The uniform Red Flag procedure worked well. Arvada Police requested during the season that only Red Flag messages that affect Arvada be communicated directly to their dispatch. All other messages are received in a timely manner from Jefferson County Communications. It was agreed that this practice should also be implemented for Wheat Ridge and Lakewood Police in 1992.

5. There was a consensus that the information and services provided by the National Weather Service this past year was the best ever. The cooperation between NWS and HMS also received very favorable review.

While the positive comments were many, there is always room for improvement. Concern was expressed about the Limon radar being out-of-service at critical times and the future availability and cost of radar data when Limon is replaced by the NEXRAD radar. Problems with internal communications still exist in some places and more education is needed regarding the meaning of certain message code numbers and Red Flags. Further clarification and definition is needed on when Red Flags should be issued and to whom. Certain jurisdictions continue to struggle over message fan-out procedures and are being asked to address complaints about too much "unnecessary" weather information over the network at undesirable times. One example given by volunteer fire districts involved a NWS Flash Flood Watch issued at 4:00 a.m. with the watch not being effective until much later in the day.

Efforts to improve forecasting techniques will never end and with every event there is a new lesson to learn. But all considered, the main message delivered by emergency service personnel was: **KEEP UP THE GOOD WORK.**

The District appreciates the candid comments received from the many dedicated emergency managers, communications personnel, first responders, public works and public safety staff, department heads and elected officials. The high level of commitment exhibited by these individuals is critical to the success of the Flash Flood Prediction Program and we applaud your efforts.

SIGNIFICANT STORM EVENTS

As mentioned in the preceding article, there were many opportunities this past year to gain experience and evaluate the new procedures. During 1991 it seems that everyone in the

District had at least one turn in dealing with heavy precipitation and some type of flooding problem. Also, other severe weather such as hail, lightning, high winds and tornados frequently accompanied many of the thunderstorms. While the number of occurrences were many, none of these events resulted in what would be categorized as a "major flood." The following days highlight some of the more notable events of 1991:

May 16: The Thursday 11:00 a.m. Heavy Precipitation Outlook (HPO) noted that a general overnight rainfall of 0.75 to 1.50" had occurred. Minor thunderstorms with small hail and low flood potential were predicted for later in the day. By 3:30 p.m. the HPO was updated calling for a 60 to 80-percent chance of a thundershower producing 0.35" to 0.75" in 60-minutes. No internal alerts (MESSAGE 1) were issued since the quantitative forecast fell below message level criteria.

In Jefferson County the heaviest measured rainfall occurred between 7:00 and 9:00 p.m. The automated flood detection network (ALERT system) for Lena Gulch measured a peak rainfall amount of 0.63" in one hour at the Fairgrounds gage. Small hail of sufficient quantity to attract the attention of television news reports accompanied this storm. After presenting their headline report on the weather, Channel 2 News' reporter Steve Sonders gave an excellent cover story on the subject of flooding in Colorado. The report included interviews with District and HMS staff, video of past flood events and mention of the technology used in the F2P2 (e.g. ALERT system, radar and satellite).

While this event is considered at the low end of the "significant events" this year, it was the first storm of the flood season to gain wide media attention. It should be noted that the ALERT system also measured heavy

rainfall along the foothills between Golden and Boulder.

Annual peaks were measured on this day at the following gage sites:
- Jeffco/Van Bibber Creek at Highway 93 (8:12 p.m.)
- Denver/Harvard Gulch at Logan Street (3:03 a.m.)

June 1: On this Saturday morning at 10:15 a.m., the NWS issued a Flash Flood Watch effective until midnight for the entire northeast portion of Colorado including the mountains. The HMS quantitative forecast at noon noted that the prime time for activity in the District would be between 2:00 and 9:00 p.m. and locally heavy rainfall of 1.5" to 2.0" lasting 30 to 60 minutes was likely. The possibility of one-inch diameter hail was also mentioned.

Thunderstorms began developing in the mountains west of the District by 12:30 p.m. By 3:20 p.m., heavy rainfall was reported in the foothills of southern Jefferson and western Douglas Counties. Shortly after 3:30, the action in the District began, resulting in flood problems which lasted well into the evening. Jefferson, Boulder and Adams Counties were the primary areas impacted. Hail and tornados accompanied the storms.

The heaviest reported rainfall of 3.2" in 55 minutes occurred in Lakewood south of Green Mountain. Flooding in Denver was documented at Pinehurst Country Club along Marston Lake North Drainage where Sheridan Blvd. overtopped near Ft. Logan National Cemetery. Significant flooding was also reported along Dutch Creek through Columbine Valley resulting in damages to the golf course (i.e. destroyed bridges, bank erosion, etc.). The District was provided with excellent home videos of flooding along these two streams.

As this storm system moved

The June 1 flooding on Dutch Creek caused major channel erosion and the loss of golf cart bridges on Columbine Valley Country Club.



northward into the Lena Gulch basin (4:10 p.m.), the amount of hail increased, thereby lessening the rainfall somewhat. This aggravated problems in some areas like the Pleasant View Mobile Home Park near Golden and reduced the flood potential for areas downstream such as Lakewood. Even though Lakewood benefited from the hail, one Lakewood homeowner was damaged by Lena Gulch floodwaters as the peak came very close to overtopping West 20th Avenue.

Significant rainfall and runoff was also measured in Wheat Ridge and Arvada. Ralston Creek at Carr Street recorded the second highest peak discharge of the year.

The City of Boulder received its heaviest rainfall of 1991 on this day with the Justice Center ALERT gage reporting a total amount of 1.93". The storm in Boulder County was separate from the event described above with the heaviest rains occurring between 1:00 and 2:30 p.m. Flooding was reported in the City of Boulder along most of the northern or left-bank tributaries to Boulder Creek. The lower reaches of Boulder Creek in Boulder County also flooded.

Flooding was of a sufficient magnitude to prompt the NWS to issue a Flash Flood Warning at 5:20 p.m. for persons in extreme western Adams and Northern Jefferson Counties. This warning was effective until 7:15 p.m. for the entire northwest Denver metro area. Lena Gulch, Ralston Creek and Clear Creek were mentioned specifically in the warning message.

Annual peaks were measured by the ALERT system on this day at the following gage sites:

- Lakewood/Lena Gulch at Maple Grove Reservoir (7:59 p.m.)
- Lakewood/Lena Gulch near Youngfield Street (5:54 p.m.)
- Wheat Ridge/Upper Sloan Detention Basin near 26th and Wadsworth (5:21 p.m.)
- Arvada/Ralston Creek at Simms Street (5:14 p.m.)
- Broomfield/Basin 3207, Pond 6 near 10th and Main (11:08 p.m.)
- Louisville/Drainageway 'D' Detention Basin near McCaslin Blvd. and Via Appia Drive (6:23 p.m.)
- Thornton/Niver Creek Detention Basin at 88th and I-25 (7:18 p.m.)
- Denver/South Platte River near Dartmouth (8:41 p.m.)

June 2: The next day, at 4:45 a.m., the NWS issued another Flash Flood Watch effective from noon to midnight. The HMS assessment at

11:15 p.m. indicated a 60- to 90-percent probability of locally heavy rainfall (1.0" to 1.5"/60 min.) with a risk of severe weather. The prime time for activity was forecast between 3:00 and 9:00 p.m. While the forecast precipitation amounts would not generally be considered a dangerous flood potential, the saturated condition resulting from the storms on June 1 caused reason for concern. Also, an NWS Flood Warning remained in effect for the South Platte River north of Ft. Lupton.

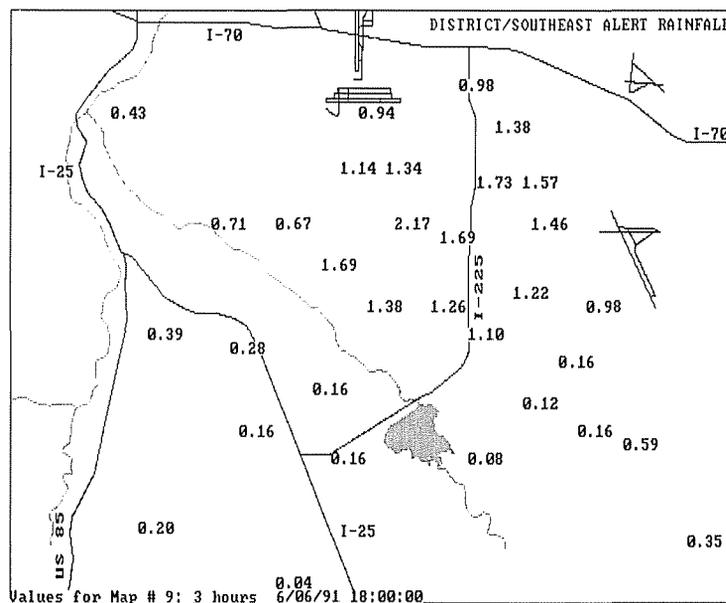
Beginning at 4:50 p.m., an isolated thunderstorm dumped nearly 1" of rain on Goldsmith Gulch north of the Denver Tech Center. A rapid rate of rise measured at the Eastman Ave. ALERT stream gage (Tamarac Square in Denver) prompting the NWS to issue a Flash Flood Warning for Goldsmith Gulch at 5:50 p.m. The peak discharge at Eastman occurred at 5:30 p.m. and downstream of this point, Dartmouth Ave. was overtopped and the upstream embankment of the Highline Canal was breached. Emergency services and public works officials from Denver were advised throughout the day and on location during the flood to prevent citizens from entering the hazard area. No other problems were reported other than normal street flooding.

Goldsmith Gulch seemed to be a favored target for flooding this year particularly at Dartmouth Ave. This event was not the largest event of the year for Goldsmith Gulch.

June 6: It seems like nearly

every year, the first week in June is a good one to watch where flash floods are concerned. On this Thursday, it was definitely Aurora's turn. At 4:40 a.m., the NWS issued another early-bird Flash Flood Watch effective until 9:00 p.m. for the entire front range of Colorado below elevation 8000 feet. The 11:00 a.m. HMS bulletin indicated a 40- to 60-percent chance for a 1.5" to 2.0"/60 to 90-minute rainfall with the prime threat period between 2:00 and 8:00 p.m. Shortly after noon, the NWS issued a Tornado Watch which included the Denver metro area. At 2:15 p.m., radar showed a developing thunderstorm northwest of Parker moving toward Aurora at 15 to 20 mph. HMS estimated that this storm was capable of producing 1.5"/hour rains. At 3:00, the NWS reported strong thunderstorms developing in northeast Park County and heading toward southern Jefferson County at 20 mph. At about this same time, Aurora began receiving its first measurable rainfall. At 3:35, the NWS issued a Tornado Warning for western Adams and extreme southwestern Weld Counties which included the town of Brighton. By 4:05, heavy rainfall was reported in the metro area and between 4:05 and 5:00 the Westerly Creek and Toll Gate Creek basins in Aurora were hit hard.

The ALERT system measured a peak rainfall of 2.17" which fell over a 2-hour period at Expo Park in Aurora (Alameda and Havana). Numerous reports of flooding were received on that day but the primary



Three hour rainfall depths for Southeast Denver on June 6.

disruption involved traffic. News media coverage was extensive.

What typically goes unnoticed during events like this are the emergency preparedness and response actions by local governments. The City of Aurora deserves special recognition for their role on June 6. Many agencies were coordinating operations prior to, during and after the storm. Public works supervisors were dispatched to known problem areas as early as 3:30 p.m., prior to the occurrence of heavy rainfall. Both public works and public safety officials carefully monitored weather information throughout the day and as the storm began, the ALERT system was utilized to guide field operations. The detailed chronology of events kept by the city provides an excellent example of how communities can achieve a well-coordinated proactive response to an urban flash flood.

While this event was relatively big, the flooding cannot be categorized as major. The storm drainage systems worked well with the exception of a few known problem areas like the intersection of Alameda and Havana. The event was classified as a 5- to 10-year frequency runoff and no flood control facilities exceeded their capacity. The Expo Park detention basin came within six-inches of overtopping its spillway and flowing onto Alameda. The ALERT water level sensor at Expo Park proved itself a very useful tool in recognizing when the threat was over.

Annual peaks were measured by the ALERT system on this day at the following gage sites:

- Denver and Aurora/All Westerly Creek stations (between 5:00 and 8:00 p.m.)
- Aurora/Toll Gate Creek at 6th Ave. (5:24 p.m.)
- Aurora/West Toll Gate Creek near Yale Ave. (5:06 p.m.)
- Aurora/East Toll Gate Creek at Buckley Rd. (5:44 p.m.)
- Aurora/Granby Ditch at 6th Ave. (6:46 p.m.)
- Aurora/Sable Ditch at 18th Ave. (4:38 p.m.)
- Aurora/Sand Creek at Sand Creek Park downstream of I-225 (7:04 p.m.)
- Commerce City/Sand Creek at Brighton Blvd (8:20 p.m.)

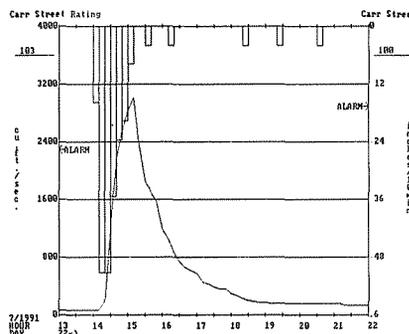
June 21: On this Friday, the first day of summer, at 11:15 a.m., the HMS outlook identified a potentially serious situation developing by mid-afternoon with rainfall amounts of up to 3" possible with intensities of 1" to 1.5"/30min accompanied by severe weather. The HPO also indicated that

internal alerts (MESSAGE 1's) would be issued after the lunch hour. At 12:40 p.m., the NWS issued a Severe Thunderstorm Watch for the Denver area effective until 8:00 p.m. At 1:15 p.m, HMS issued the internal alerts forecasting a "very serious severe weather and urban flooding threat" with the prime time being from 2:00 to 6:00 p.m. At 1:50 p.m., the NWS issued a Flash Flood Watch and shortly after that, a Severe Thunderstorm Warning was issued for a storm over southwest Denver moving northeast at 10 mph.

The afternoon storms did not turn out to be big rain producers but the NWS did issue a Tornado Warning for the Denver metro area at 3:02 p.m. At 5:00, the NWS cancelled the Flash Flood Watch and HMS downgraded the alert status to MESSAGE 1's and extended those messages to 8:00 p.m. The heavy rains did finally arrive that evening with an inch or more occurring at a number of locations. The railroad underpass at 38th and Fox Street flooded, submerging cars and forcing rescue workers to use scuba gear to search for victims. Fortunately, all motorists had escaped their vehicles and no one was seriously injured.

The annual peak was measured by the ALERT system on Cherry Creek at Wazee St. in Denver at 11:31 p.m.

The above discussions should give the reader a good idea about the type of flood season we had in 1991 and how forecast services and technology are used in the District's Flash Flood Prediction Program. F2P2 messages were issued for 40 days between April 15 and September 15 with "message level rainfall" verifying on 35 of those days. While it is not practicable to describe all of the 1991 events in a short newsletter, the following days are also worthy of mention:



July 12: Downtown Golden experienced heavy rainfall and localized street flooding on this Friday afternoon. Emergency crews also responded to Lena Gulch flooding at the Mountainside Estates mobile home park at U.S. Highway 6 and Mount Vernon Road. At 5:10 p.m., the annual peak was measured by the ALERT system at this location

July 20: Denver received most of the action on this Saturday. The heaviest rainfall measured by the ALERT system was in the Goldsmith Gulch, Harvard Gulch and lower Cherry Creek basins. An elderly woman was rescued from her car after attempting to cross Goldsmith Gulch on Dartmouth Ave. Annual peaks were measured by the ALERT system on this day at the following gage sites:

- Denver/Harvard Gulch at Jackson St. (4:57 p.m.)
- Denver/Cherry Creek at Steele St. (5:55 p.m.)

July 22: This Monday afternoon, it was Arvada's turn once again. The Arvada Fire Protection District evacuated the Valley Mobile Manor trailer park along Ralston Creek near 56th and Sheridan. Denver was also involved with rescue operations along Lakewood Gulch where three children narrowly escaped drowning. The weather forecast services (HMS and NWS) were relied upon extensively by both public safety and public works agencies. Local decision making also made effective use of ALERT data. This was another model day on how emergency operations can be successfully coordinated. Annual peaks were measured by the ALERT system at the following gage sites:

- Arvada/Ralston Creek at Carr St. (3:11 p.m.)
- Arvada/Leyden Creek below Simms St. (2:34 p.m.)
- Arvada/Van Bibber Creek at 58th and Miller (2:22 p.m.)



Flooding at Valley Mobile Manor mobile home park on July 22 and a combined hydrograph and hyetograph for that flood at Carr Street upstream.

July 25: Between 3:00 and 4:00 p.m., the official Denver rain gage at the National Weather Service office near Stapleton International Airport received its second highest hourly rainfall of record (1.86" in 46 minutes). Flooding problems along I-70 brought traffic to a standstill.

August 2: The annual peak was measured by the ALERT system on Goldsmith Gulch at Eastman Ave. in Denver at 6:31 p.m. Dartmouth Avenue was once again closed to traffic.

August 3: Annual peaks were measured by the ALERT system on this day at the following gage sites:
- Arapahoe County/Englewood Dam (1:13 p.m.)
- Arapahoe County/Holly Dam (11:31 a.m.)

Readers interested in more specific rainfall or streamflow data from the ALERT system for any of the above days should contact Kevin Stewart at 455-6277.

AURORA BENEFITS FROM CREATIVE ALTERNATIVE USES FOR ALERT

The City of Aurora has integrated water resources data from Colorado's GOES satellite-linked monitoring system into the ALERT database. This has provided the City with quick and easy access to important streamflow information which they use to manage their water rights program and diversion operations. Because of this data integration, on at least one occasion this past summer, the City was able to divert runoff water (valued at \$5,000) from a single thunderstorm to storage facilities and verify that the action was within their water rights allocation. Without real-time data, an operation of this type would be extremely difficult to accomplish. Certain State Water Commissioners have also recognized the value of Aurora's ALERT data integration and now routinely access the Base Station to obtain statistical reports.

In addition to capturing water which would otherwise be lost downstream, the Aurora Parks Department utilizes rainfall and weather data from the ALERT system and other sources in continuing efforts to conserve water. Also, the Denver Water Department has completed its third season of using ALERT data to help provide metro-wide ET ratings for their lawn irrigation conservation program.

FLOOD EXERCISES LEAD TO NEW LEVELS OF COOPERATION

Whenever the District becomes involved with installing an ALERT system, a key element of the project is the development of a basin-specific Flood Warning Plan. The cooperating local governments and agencies execute an agreement which is automatically renewed annually for a period of 50 years. The intent of this 50-year term is to commit the parties to an on-going maintenance program. In addition to maintaining the field equipment and other technology, the warning plans are updated and exercised annually. The District and local governments have been doing this since the first warning plan was written for Westerly Creek in 1977.

In recent years, more and more agencies have become increasingly involved with this process. Many individuals are now evaluating ALERT data, working directly with meteorologists and other professionals, and making their own assessments of potential flood emergencies. Public works agencies have taken a more active role in emergency preparedness and field operations. New relationships are developing between public safety and public works officials which require continual adjustment, practice and education in learning how to work together effectively. The District, through its annual flood exercises, has recognized the importance of these relationships and wants to encourage further growth.

Certain jurisdictions, like Denver and Aurora, have developed emergency operations plans which designate a specific public works official as the "Incident Commander" in the event of a flood emergency. Consequently, those designated individuals must become very familiar with how public safety agencies function. Such a role is anything but routine for an individual who may have an engineering and/or public administration background.

To help meet the need for education in this area, the District works closely with public safety and public works officials in designing appropriate flood exercises. From the District's perspective, three areas require special attention in a pre-emergency mode: 1) communications, 2) technical evaluation of data and 3) decision making. Once an Emergency Operations Center (EOC) is activated, many other factors also become critical and are included in designing a comprehensive exercise.

In recognizing these complexities, certain exercises this past year were broken into two parts. The first part involved primarily the technical evaluation and decision making components in which participants would take input from the meteorologist and other data sources, such as ALERT, and make decisions on how to advise public safety or request an EOC activation. The goal here is to learn how to communicate and mobilize personnel before an emergency situation develops. Also, technical personnel receive training on how to use the ALERT Base Station and interpret data with the assistance of exercise software developed for the District. Training of this type can take place at any time and does not need to involve all EOC agencies.

The second part of the exercise, which may occur on a separate day, involves a fully operational EOC with emphasis placed on communications between field personnel and the EOC, and between the agencies at the EOC. All exercises are followed by a critique and emergency plans are revised according to the lessons learned.

It has been the District's experience that the participants take these practices very seriously and much gets accomplished. The cross-training that takes place at the exercise is critical if we are to have any reasonable assurance of conducting a successful response when a flash flood emergency occurs.

THE LONG RANGE FORECAST

The Flash Flood Prediction Program will continue to serve the Denver metropolitan area and seek guidance from the many dedicated individuals involved. The ALERT system, which currently collects data from 120 remote stations, will increase in size with new systems being projected in Jefferson, Arapahoe and Douglas Counties. Boulder County is planning for additional weather stations to aid in fire support and flash flood forecasting. The Bear Creek system will be completed in 1992. Radar will become a topic of increased interest as the National Weather Service moves closer to its planned installation of the NEXRAD Doppler Radar for Denver. And finally, the BIG FLOOD will occur, but don't ask me about where and when, I'm only an engineer. Given the experience this past year, I am willing to predict that this community will be anticipating it and ready to respond when it does happen.

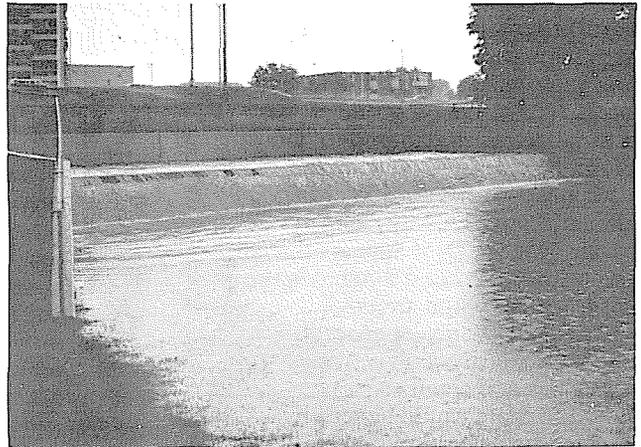
Photo Page - Flood Control Projects In Action

Everyone in the flood management business likes to see his or her project or facility in action, or at least see the high water marks following a flood event. We have had the

opportunity this year to photograph a number of flood events or the immediate aftermaths of events, and several of those photographs are presented below.



Kelly Road Dam, normally dry, on Westerly Creek on June 6, 1991.



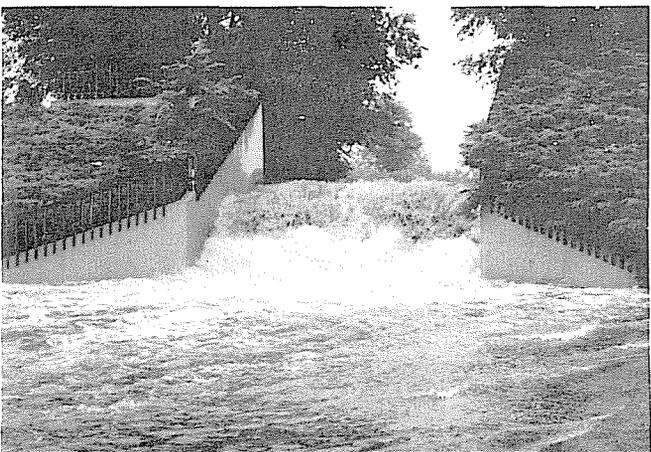
The side channel spillway into the off-line detention at Veterans Park in Denver on July 20, 1991.



Expo Park on Westerly Creek in Aurora on June 6, 1991. Detention in a park. Note the ball field back stops in the center of the picture and the ALERT gage standpipe in the right foreground.



High water line on a grass lined channel on Westerly Creek in Montview Park in Aurora from the June 6, 1991, event.



A baffle chute drop structure on Harvard Gulch in Harvard Gulch Park in Denver on July 20, 1991.



A park in Arvada along Ralston Creek in Arvada on July 22, 1991. Parks in floodplains are excellent uses of flood hazard areas.