FLASH FLOOD PREDICTION PROGRAM & RELATED ACTIVITIES

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NEW METEOROLOGICAL SUPPORT SERVICE

The 1990 meteorological support contract for the District's Flash Flood Prediction Program (F2P2) was awarded to Henz Meteorological Services (HMS) of Denver. HMS offices are located in Suite 310-B of the Diamond Hill Office Complex at 2480 West 26th Avenue. For the previous seven years, the program was served by the firm of Henz Kelly and Associates (HKA) and prior to that, by GRD Weather Center, Inc. The program has now completed 12 years of serving Denver area emergency managers.

John Henz, President of HMS, has participated in the F2P2 since its beginning in 1979. Frank Robitaille is the most recent member to the team, having joined HMS in June. Frank has extensive background in atmospheric research having worked for the National Center for Atmospheric Research (NCAR) in Boulder from 1967 to 1975 and for the Alberta Research Council in Edmonton, Alberta, Canada from 1975 until January of 1989. Frank returned to Colorado in February of 1989 after accepting employment with a meteorological instrument manufacturer located in Boulder. The District appreciates the new perspectives and experience that Frank brought to the program.

PROGRAM CHANGES REVEAL NEED TO FURTHER STREAMLINE COMMUNICATIONS

With the support of emergency managers from the six-county Denver area, the F2P2 operations were changed substantially this past year. These changes were made in response to a user survey completed following the 1989 flood season. The new operational procedures were designed to simplify communications for dispatchers and other individuals less familiar with the program's message codes and technical terms. While this new approach generally worked well, other problems surfaced which require further attention.

In prior years, three message levels were used to prompt various responses. For example, a MESSAGE 1 indicated that the potential for a flash flood exists and that appropriate preparedness actions should be taken. A MESSAGE 1 was considered advisory in nature and not intended for public dissemination. A MESSAGE 2 was previously used to relay a National Weather Service (NWS) flash flood "watch" to local governments and add any specific information of concern. Similarly, a MESSAGE 3 was used to relay a NWS flash flood "warning."

While the three-message code format was not overly complex, the procedures used for issuing these messages did open the door for misinterpretation. For example, a MESSAGE 1 would be issued using supplemental number codes to indicate the type of flooding expected. Any one or combination of four flooding type codes would commonly be used by the meteorologist. A MESSAGE 1, TYPE 2 would mean that flash flooding of small streams and streets is possible. Another type code was used for "large streams" and still other codes for slow-rise flood predictions. If none of the flooding type codes applied, the meteorologist would issue a TYPE 5 code and indicate the expected flooding source. It was not uncommon for a MESSAGE 1, TYPE 2 to be interpreted as a MESSAGE 2 and consequently prompt an improper response. Also, the difference between "large" and "small" streams was not always clear to the user.

Without changing the basic three-message approach for initiating a "Ready-Set-Go" response, the dual number codes for MESSAGE 1 were eliminated for 1990 and new, more descriptive fill-in-the-blank forms were distributed to users. When communicating with a dispatcher, the meteorologist would indicate the most likely areas to be impacted by flooding with specific form check-offs provided for: mountain canyon streams; urban streams; and urban streets, intersections & low-lying areas. Also, the potential risk to life and property would be categorized as either low, moderate or high depending on the magnitude and probability of the flood prediction.

It was further specified that a MESSAGE 1 would only be issued when the rainfall prediction or quantitative precipitation forecast (QPF) called for 1-inch of rain or more to fall within a one hour period or when the predicted intensity exceeded a 5-year frequency (i.e. 0.5" within 10 to 15 minutes). Considerable judgement was required by the meteorologist on when to and when not to issue a MESSAGE 1.

In addition, another advisory message was developed to address "garden variety" thunderstorms capable of producing only minor nuisance flooding. The issuance of a THUNDERSTORM ADVISORY or TA would not normally warrant an alert level response, but supplemental information was sometimes included concerning the possibility of severe weather. TA's were frequently issued and, due to their typically low danger threshold, generally recognized as non-emergency information. Consequently, TA's received low priority for message fanout. It was this program change that contributed the most to an information overload problem which, in some instances, resulted in a casual manner of handling information that turned out to be more important then expected. In 1990, TA's were issued on 78 days of the 167 days that the program operated. Communications that occurred preceding the July 11 hail storm probably best illustrate this problem.

The hail storm, which began in northern Boulder County around noon and moved south-southeast through the center of the metropolitan area over the next three hours, caused more than one-half billion dollars in property damage and sent 49 people, mostly kids, to area hospitals due to injuries received while enjoying Elitch Gardens amusement park. TA's were issued to all counties between 12:15 and 12:30 p.m. calling for severe thunderstorms with 1-2" diameter hail, 60 mph winds, 0.50-0.75" of rain lasting 30 minutes and active cloud-to-ground lightning. Boulder County was issued a MESSAGE 1. A number of key public safety officials never received this communication before the hail storm hit. The storm reached Elitch Gardens at about 2:30 p.m. This weather situation did not pose a flood threat but there is no question that this storm was dangerous.

The pre-1990 procedures also restricted the meteorologist's ability to upgrade the message code to a higher response level unless the NWS would first issue a flash flood watch or warning. To resolve this, it was agreed that the meteorologist should have the flexibility to issue a MESSAGE 2 or

MESSAGE 3 should conditions warrant. In defining such conditions, the term "life-threatening flood" would be used and the appropriate message level determined by either a high probability or imminent threat of occurrence. Also, should the NWS issue a flash flood watch or warning, the appropriate message would continue to be relayed as in the past.

Additionally, three new activities were tested in 1990: 1) a video tape archive program to record Limon radar data for all significant events; 2) a storm track FAX map program to enhance the bulletin board QPF product by providing spatial and timing information in an easy-to-understand format; and 3) a prediction evaluation program to assess the timeliness and accuracy of the various forecast products.

Using FAX communications has proven to be an effective means of disseminating weather information. Once received, certain users redistribute the FAX products to other users in their fanout network which may include ten or more additional contact points. Standard bulletin board products (i.e. daily outlooks, message status reports and QPF summaries) were also distributed by FAX at the request of participating public safety and public works agencies. Considering the favorable response this past year, it is likely the FAX service will be continued.

EMERGENCY MANAGERS HELP SHAPE PROGRAM

By the end of the 1990 flood season it was clear that more communication refinements were needed. It was also clear that the program should not attempt to provide any specialized services dealing with other types of severe weather (i.e. tornados, hail, micro-burst winds, lightning, etc.). Originally, the idea of providing supplemental forecast information was rationalized by recognizing that a high percentage of heavy precipitation events are accompanied by other forms of severe weather. Advisories and warnings of severe weather are routinely issued by the NWS and broadcast to the public by the electronic news media. It was never intended for F2P2 users to rely on the District's program for this information.

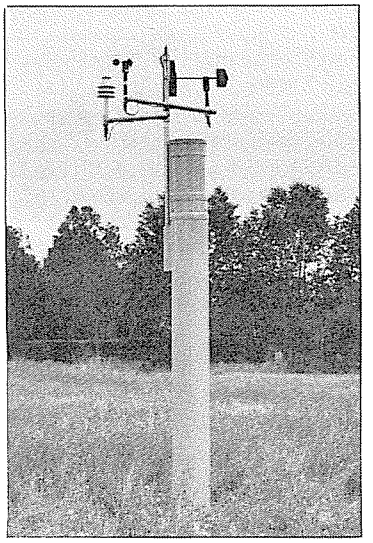
To avoid contributing to information overload at emergency communication centers, the practice of issuing TA's will likely be discontinued. The focus of the program meteorologist will be to predict heavy precipitation and flood potential as originally intended and the decision to communicate weather information will not be complicated by considering the threat of severe weather. The protocol for handling other message types should not be impacted by this change.

Under the leadership of Captain Warren Lumpkin, Deputy Director of Emergency Management for the City of Aurora, an advisory group comprised of Denver area emergency managers was formed to recommend further program improvements, including the adoption of a uniform policy of issuing "Red Flag" messages. This practice was originally adopted by Denver and Arvada in implementing flood warning plans for Westerly Creek and Ralston Creek. The intent of the Red Flag message is to notify dispatchers that this information requires immediate attention. The procedure has proven to be an effective means of quickly getting critical weather information to key decision makers. Further direction is also being given concerning the use of the weather bulletin board and other written communications. The District greatly appreciates the high level of interest and expertise that Captain Lumpkin and his colleagues offer. With positive change being driven by the user, it is our belief that the program will have a much greater chance for success when the next flood disaster occurs.

ALERT SYSTEM EXPANSION & IMPROVEMENTS CONTINUE

New automated rain and stage gages continue to be added to the District's ALERT system. Weather stations were also introduced to the system for the first time in January of 1990. The first ALERT weather station was installed at the Quincy Reservoir water treatment plant in Aurora as part of an early flood detection and warning project for the Toll Gate Creek basin. Two new weather stations will soon be installed in the foothills of Ralston Creek and Bear Creek.

The weather station at Quincy Reservoir is event driven and measures precipitation, wind speed and direction, relative humidity, temperature, barometric pressure and solar radiation. Weather stations provide valuable information for use in flash flood prediction before it rains and also encourage many multi-purpose uses. For example, the City of Aurora uses ALERT data in a major effort to conserve water. By incorporating the use of weather data from various sources with a new



Alert Weather Station

irrigation control system, the Parks Division estimates that a 12.5 percent annual savings can be achieved. The Denver Water Department also routinely uses data from the District's ALERT system for specifying ET lawn watering amounts for the entire Denver metro area. Real-time weather data is useful for assessing forest fire danger, managing fire fighting activities, evaluating air quality, directing emergency operations for hazardous material incidents, and many other applications.

New ALERT stations were added this past year to the Ralston Creek, Toll Gate Creek, District Wide and South Platte Networks. The Master Planning Program also installed an ALERT rain gage at a stormwater quality monitoring site on Shop Creek along Parker Road near Cherry Creek Reservoir. With today's technology, it is feasible to add water quality sensors to ALERT stations but, thus far, the District has not attempted any adaptations of this type.

Shaft encoders and ALERT transmitters were retrofitted at two existing USGS gaging stations on the South Platte River and Cherry Creek. Unfortunately, a programming error on the transmitter logic board caused erroneous data to be collected for these two sites. This problem was extremely difficult to isolate, but now is finally being corrected by the manufacturer. Land owner permission to install approximately 12 new stations for the Bear Creek flood detection network is in the process of being secured.

The ALERT system status table on the following page shows the total number stations in operation as of September 30, 1990. The table also

summarizes the type and number of sensors currently reporting data. The transmitters at most of the existing stations have been configured to conveniently add more sensors. For example, many of the stations which currently report only rainfall could be easily upgraded in the future to full weather station status.

As the ALERT system grows in size, new capabilities and improvements at the base stations are also evolving. Independent ALERT base stations are currently operating at the District, HMS, the City of Aurora, the Boulder County Sheriff's Department, The Consolidated Mutual Water Company in Lakewood and at the U.S. Bureau of Reclamation. The National Weather Service collects ALERT data at NOAA's research facilities in Boulder where data processing and display capabilities are being integrated in the design of a future hydro-meteorological workstation for use by NWS forecasters.

The District is continuing to improve the graphical interface for displaying ALERT data. As new graphical products are developed, user interpretation of the data will become more simplified and the decision making process greatly enhanced. The City of Aurora has incorporated the use of a large wall map board interface which, through the use of colored lights, continually shows where rainfall is occurring and which gages have exceeded alarm levels. Many other enhancements will continue to evolve, particularly as more users gain experience using the system.

CURRENT ALERT SYSTEM STATUS:

Network	Stations	Precip	Stage	Weather	
District Wide	9	8	9		
S. Platte & MP	4	3	3		
Lena Gulch	9	6	3		
Ralston Creek	11	10	8		
Westerly Creek	10	10	5		
Toll Gate Creek	11	11	8	5	
Goldsmith/Harvard	5	5	4		
Boulder County	53	41	12		
TOTALS	112	(94)	+ (52)	+ (5)	= 151 SENSORS

ALERT UPGRADE IN PROGRESS FOR BOULDER COUNTY

Boulder County's aging STORRM (Sheriff's Telemetry Operated Rainfall and River Monitor) system, which has been successfully used by the Sheriff's Department for more than ten years, is nearing the end of its useful life. This system provides for real-time displays of rainfall, stream stage, alarm levels, and system status information using data collected by the existing ALERT network located in the mountains. The computer software developed by the County also incorporates a hydrologic model for Boulder Creek and a basin average rainfall mapping routine.

The District is cooperating with Boulder County on a major upgrade to this system. The current plan is to install two ALERT computers modelled after the District's system and run the STORRM system concurrently. The new ALERT computers will eventually replace the outdated system, but until a comfort level can be established and existing capabilities either duplicated or replaced, it was felt that a parallel operation would minimize disruption of a well-run flood warning program.

COMPLEXITIES IN PREDICTING MOUNTAIN CANYON FLASH FLOODS

In March of 1990, a report entitled: Simplified Mountain Canyon Flash Flood Guidance for Boulder Creek was completed by George V. Sabol Consulting Engineers, Inc. This study included the development of a hydrologic model for Boulder Creek using the Corps of Engineers' HEC-1 computer program. Since existing rainfall/runoff data for Boulder Creek was considered inadequate to perform valid model calibration, various model runs were compared with accepted design hydrographs and the result having the "best fit" was used for further analysis.

The Sabol report also presented historical storm reconstitutions for three major events: the Big Thompson Canyon flash flood of July 31, 1976; the Cheyenne, Wyoming flood of August 1, 1985; and the Masonville, Colorado flood of September 10, 1938. These storms were meteorologically transposed over the Boulder Creek watershed for further hydrologic investigation. The meteorologic portion of this study was completed by HMS.

The selected unit hydrograph procedure for the fifteen Boulder Creek sub-basins was based on mountain hydrology research completed by the U.S. Bureau of Reclamation for Buckhorn Creek near Masonville, Colorado. The runoff sensitivity of various infiltration algorithms and antecedent conditions was evaluated. Then, using the selected model, each of the three major historical storms were analyzed. In all cases, the resulting peak discharge at the Canyon Mouth exceeded the 100-year discharge. The following table summarizes the results of this analysis:

STORM	DISCHARGE
100-year	9,700 cfs
Big Thompson	45,500 cfs
Cheyenne	33,800 cfs
Masonville	15,800 cfs

It should be noted that the adopted 100-year discharge for Boulder Creek is 11,600 cfs. After comparing the calculated hydrograph shapes, runoff volumes and timing factors with the design hydrograph developed by the Corps of Engineers, the hydrograph having a peak discharge of 9,700 cfs was selected. Boulder Creek historians may also recall that an earlier study by the Corps produced a 100-year discharge of 7,400 cfs. Additional model adjustments could have been made to force the peak discharge closer to the accepted design discharge, but this was not the focus of this project.

Subsequent calculations were made to develop a graph for estimating peak discharge at the Canyon Mouth for various antecedent conditions as a function of the maximum average 1-hour rainfall for an estimated 10 square mile storm area. While this approach may seem overly simplistic, the goal here was to develop a reasonable basis for recognizing when critical rainfall thresholds are exceeded or when quantitative precipitation forecasts warrant special attention. The transferability of this flash flood guidance to other mountain watersheds was also an objective.

The Boulder Creek hydrologic model will eventually interface with the ALERT database and be used for estimating flood magnitudes and arrival times during actual events. It is hoped that this study will prompt

future investigations to further refine flash flood prediction techniques for mountain streams. Users of such information should recognize the complex nature of forecasting spatial and temporal rainfall from both meteorologic and hydrologic perspectives, and given that knowledge, exercise care in directing emergency operations.

DENVER HOSTS ALERT CONFERENCE

The Third Annual Conference of the Southwestern Association of ALERT Systems (SAAS) was held in Denver last September at the Hotel Denver-Downtown. Sixty-two people attended the conference from many parts of the United States, and one foreign guest from Stockholm, Sweden received special recognition. Twenty four speakers presented information on a variety of topics including: NWS modernization and training programs, system maintenance and lightning protection, alternative uses for ALERT, local flood warning programs, social science research, hydrologic radio frequencies, new software developments and applications, and many other interesting subjects. Equipment vendors were provided the opportunity to make formal presentations and display their products. A special workshop was held on hydro-meteorology for flash flood forecasting and field trips were conducted to the District's F2P2 and the NWS Forecast Office at Stapleton International Airport. By all accounts, the conference was a success and the District is pleased to have had the opportunity to host the event.

Associate membership in SAAS is open to anyone interested in the use of real-time environmental monitoring systems. Active or voting membership is currently limited to ALERT users from the states of Arizona, Arkansas, Colorado, Kansas, Louisiana, New Mexico, Oklahoma and Texas. For more information concerning SAAS and member benefits, contact Kevin Stewart at 303-455-6277.

HYDROLOGIC RADIO FREQUENCIES AT RISK

ALERT users need to be aware that the future of their programs could be dramatically impacted by pending Congressional legislation and regulatory changes currently being considered by the Department of Commerce. On November 14, Kevin Stewart attended a meeting of the Interdepartment Radio Advisory Committee (IRAC) in Washington, D.C. along with Mr. Philip Holland of the Santa Barbara County Flood Control District in California. Mr. Holland represented the ALERT Users Group which includes nine western states and Mr. Stewart represented the eight states comprising the Southwestern Association of ALERT Systems. A subsequent meeting was also held with the Honorable Janice Obuchowski, Assistant Secretary of Commerce for Communications Information. Ms. Obuchowski was extremely knowledgeable and sensitive to the issue and welcomed the opportunity to hear our concerns and develop a better understanding of our needs. There is no question that this issue is of major importance to all agencies and businesses that use any type of radio communications.

IRAC consists of representatives from 22 federal agencies, each competing for their fair share of the radio frequency spectrum. Problems of current congested use and future commercial needs have forced IRAC to look at narrow-banding alternatives to increase the number of available frequencies. Also, a bill has been introduced in Congress which, if signed into law, would effectively remove 200 Mhz from the spectrum currently allocated for federal government users. Hydrologic radio frequencies, both UHF and VHF, are classified as federal uses. ALERT systems fall into this category through the sponsorship of the National Weather Service.

A good working relationship has been established with the National Telecommunications and Information Administration (NTIA). NTIA regulates the federal spectrum and is essentially the counterpart to the better known Federal Communications Commission (FCC) which regulates all commercial uses of the spectrum. Both ALERT users groups intend to maintain this level of cooperation with NTIA and keep members informed on when specific actions are needed on their part. It has been suggested that ALERT users contact their Congressional Representatives to express concern and offer support.

WEATHER BULLETIN BOARD NOW A YEAR-ROUND OPERATION

For the second consecutive year, the National Weather Service will make available to District Bulletin Board users certain public forecast products including special weather statements, winter storm warnings and other weather advisories and information routinely issued over NOAA weather wire and weather radio.

The bulletin board was also used recently by the Boulder County Sheriff's Department to obtain weather forecasts in support of intense fire fighting operations that lasted for three days just north of the Boulder city limits. The Olde Stage Road Forest Fire, which destroyed ten homes and burned more than 2200 acres, was declared a disaster by Governor Romer. HMS provided the fire weather forecast services at the County's request.

The District is pleased to be able to serve the community in this way and will continue to keep the bulletin board operational during the non-flood season (September 16 through April 14) provided that its use not be relied upon exclusively for emergency services. Use of this system requires a computer and phone modem and access is limited to government agencies. The bulletin board is currently a one-way communications tool requiring the user to initiate the phone call. Any qualified agency can obtain user access information by contacting Kevin Stewart at 303-455-6277.

Floodplain Management Conference Comes To Denver

The 15th Annual Conference of the Association of State Floodplain Managers, Inc. will be held June 10-14, 1991, in Denver. The conference will be hosted by the Colorado Water Conservation Board (CWCB), Urban Draiange and Flood Control District, University of Colorado at Colorado Springs (UC-CS), and Colorado Association of Stormwater and Floodplain Managers (CASFM).

The conference will be held at the Hyatt Regency Denver. The Conference Director is Bill Stanton (CWCB) and the Program Chair is Eve Gruntfest (UC-CS). This will be the premier floodplain management conference in 1991, and Colorado floodplain managers who are members of CASFM will have the opportunity to attend this conference at a significantly reduced registration fee.

For more information concerning the conference contact Bill Stanton at (303) 866-3441. For information on membership in CASFM contact Bill DeGroot at (303) 455-6277.