



THE 1995 FLASH FLOOD PREDICTION  
PROGRAM  
(F2P2) ANNUAL OPERATIONS REPORT

HMS REPORT No. 96-3

Submitted to  
Urban Drainage & Flood Control District  
Denver, Colorado

by

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## 1.0 Introduction

Urban Drainage & Flood Control District (**UDFCD or District**) has funded a Flash Flood Prediction Program (F2P2) since May 1979. The F2P2 was established as a response to the disastrous Big Thompson Flash Flood of July 31, 1976 in Larimer County. The F2P2 contracts for the value-added weather forecasts of a Private Meteorological Service (PMS) to augment the traditional forecast services of the National Weather Service (NWS) for the six county District region.

The forecast area supported is shown in Figure 1 and includes over 60 per cent of Colorado's population in roughly a 1600 square mile area. Terrain in the region varies from the rolling populated prairies of Arapahoe and Adams Counties to highly urbanized Denver County to the rugged plains-foothills-mountain interfaces of Jefferson, Boulder and Douglas Counties.

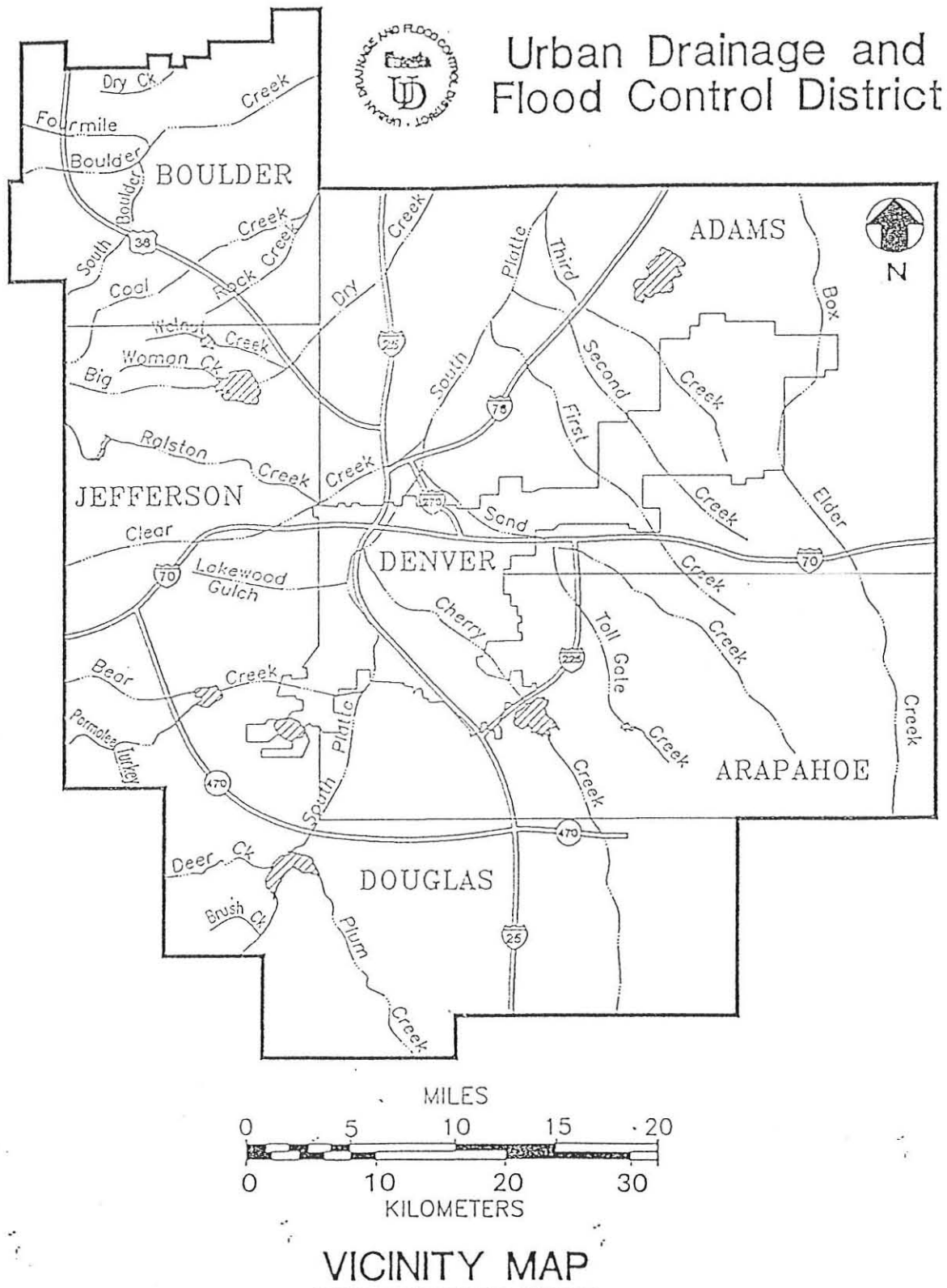
**Henz Meteorological Services (HMS)** of Denver was selected as the 1995 F2P2 Private Meteorological Service. HMS provided similar services for the 1990 - 1994 F2P2's. HMS forecast services were provided by **John Henz, Bryan Rappolt and Frank Robitaille** during the 1995 season. Significant communications improvements were made by **Robert Hirsekorn** the business manager of HMS. One meteorological intern, **Lisa Morrison**, was employed in the F2P2 from September 1 to 18 to assist the HMS meteorologists. She had 1 year experience as National Weather Service meteorological intern in Wisconsin and is familiar with using NEXRAD products to issue NWS Nowcasts of severe weather. Lisa has been retained and promoted to a full-time HMS meteorologist.

## 2.0 1995 Operational Season

The F2P2 season began on 15 April 1995 and continued through 15 September 1995 for **154 operational days**. **An additional operations day was declared on September 18, 1995**. Normal operational hours were from 0700L to 2200L and covered **2,322 hours**. Overnight and/or early morning operations conducted during the period from 1000PM to 700AM added an **additional 193 hours** of support time for a total of **2,515 hours of F2P2 activity**. The overnight hours were especially active during late May into mid-June and again in August and September. A trend toward more active overnight periods has now been evidenced since 1992.

The F2P2 required a continuous Metwatch of the District for the entire period using radar, satellite, conventional surface and upper air observations and local ALERT and mesonet networks. These observations were used to prepare predictions and specialized F2P2 products which included: daily **Heavy Precipitation Outlooks (HPO)**, **MESSAGE 1, 2, 3 and 4's**, **Message updates**, **Quantitative Precipitation Forecasts (QPF)** and **StormTraks**.

Figure 1: Urban Drainage and Flood Control District



### 3.0 1995 F2P2 Operational Product Production

The F2P2 is designed to offer a supplementary weather information source concerning heavy precipitation, urban flooding and flash flooding threat to the six participating District Counties and the cities within those counties. Additionally direct basin specific support is rendered to the seven District basin warning plans. Five specific F2P2 products exist in addition to voice support. These products are **Heavy Precipitation Outlooks (HPO), Message 1, 2, 3 and 4's, Internal Message Status's (IMS), Quantitative Precipitation Forecasts (QPF) and HMS StormTrak Predictions.**

During the 1995 season HMS produced the following quantities of the F2P2 Products:

- **HPO's: 8,778 routine HPO faxes** to the 26 primary HPO reception points
- **MESSAGES: 303 Message 1 and 2 faxes,**
- **IMS's: 2,302 IMS faxes,**
- **QPF's: 250 QPF faxes and**
- **StormTraks: 3,354 StormTrak faxes.**

These products were delivered via fax to participating agencies. The majority of the faxes were sent on either the HMS Communications fax machine or the internal fax card on the HMS F2P2 Communications workstation. Additional use was made of the US West Broadcast Fax service network to send F2P2 products such as StormTraks and IMS's.

While fax service dominated the "hard copy" F2P2 products significant electronic copy service was provided to the F2P2 via the District's Electronic Bulletin Board (**EBB**). All HPO, IMS and QPF products were sent to the District EBB for either re-dissemination or dial-in customer support. HMS sent **446 HPO products, 136 IMS's and 25 QPF** products through the District's EBB. The on-demand access of the EBB products to decision-makers using home computer systems is a desirable aspect of the EBB service.

HMS logged over **2,900 storm-related telephone interactions** during the program, emphasizing the **strong technical "touch"** of the program in the local community. HMS installed three dedicated telephone lines: two for voice and one for fax and data communication in its redesigned weather center. These three lines and US West's Broadcast Fax were adequate to handle the volume of communications generated during peak storm periods. Clearly the F2P2 summer program has a more far reaching extent in the Denver metro area than the numbers alone would indicate.

## 4.0 1995 F2P2 Operational Verification and Evaluation

HMS has changed "the look" of this year's F2P2 report to focus on an evaluation of the support given to the F2P2 users. This section of the report will evaluate the monthly and location support rendered in a two table format. Appendix A is attached to this report and it contains the traditional annual comparisons of the F2P2 1979 to the 1995 statistics. Note that Table A-1 in this appendix contains the individual daily Messages and their verifications for the entire 1995 season. References will be made to appendix tables at times. Tables 1 and 2 summarize the 1995 operational support evaluation.

### 4.1 Message 1 and Message 2 Monthly Evaluations

The communication of flash flooding or urban flooding potential to F2P2 users through the issuance of Message 1's is one of the primary program objectives. An overview of the monthly issuance and verification of Message 1's and Message 2's activity during the 1995 F2P2 season is shown in Table 1. Note that the **months of June, July and August** were almost uniformly active with over a third of the days with Message 1's (M-1's). M-1 rain events occurred on 34 of the 41 Message days for an 83 percent verification on a District basis. The 34 days with verified M-1 events were the second highest (tie with 1982) since the program began in 1979 and were exceeded only by 40 event days in 1987.

Two minor urban flooding events occurred without active Message 1's issuance. One M-1 level event occurred on August 14, 1995 in extreme southeastern portion of the District in Arapahoe County for which a Message 1 was not issued but needed. The other occurred on July 15, 1995 in Arvada. A lack of surface mesonet observations in Douglas County on August 14th may have contributed to this forecast failure. A review of the event indicates that a more persistent and thorough Metwatch might have identified the storm's potential in time for M-1 issuance. The July 15th storm is discussed in detail later in this report.

A total of 283 M-1's were issued on the 41 M-1 days with monthly accuracy varying from a high of 83% accuracy in May to a low of 35 percent accuracy in August. **The overall accuracy of 55 percent is at the five year average** ( See Table A-4). The M-1 product identifies days with the potential for heavy rain production ( 1 inch or more per hour) from thunderstorms. Thunderstorms occurred in the District on all but 4 of the 41 M-1 days. It is the HMS goal to improve the overall M-1 individual Message verification to 65 percent or better for the season. HMS achieved this goal in May and June of 1995. **HMS believes that the Message 1 issuance provided very accurate notice to F2P2 users of locally heavy rain and urban flooding potential which assisted emergency operations.**



Table 1

Month	M-1 Days	M-1 Day Hits	M-1's	M-1 Hits	% Hits	Events Missed	RF's	RF Hits	% RF Hits	M-2 Days	M-2 Day Hits	M-2's	M-2 Hits	% M-2 Hits
April	0	0	0	0	0	0	0	0	0%	0	0	0	0	0%
May	5	5	29	24	83%	0	15	12	80%	1	0	10	0	0%
June	11	11	78	52	67%	0	35	29	83%	2	2	20	11	55%
July	10	8	74	41	55%	0	47	32	68%	0	0	0	0	0%
August	11	7	68	24	35%	1	40	22	55%	0	0	0	0	0%
September	4	3	34	16	47%	0	19	14	74%	0	0	0	0	0%
TOTALS	41	34	283	157	55%	1	156	109	70%	3	2	30	11	37%

= 6/28/95 M1/M2 day--Both M-1's and M-2's issued and verified

Table 2: HMS Message 1 and M-1 Red Flag Verification Evaluation  
(No M-2's Counted, Source Table A-1)

Group	M-1's	M-1 Hits	RF's	RF Hits	Accuracy		% RF M-1's
					M-1	RF	
BOCO	30	11	7	6	37%	86%	23%
JEFFCO	37	21	16	13	57%	81%	43%
ARAPCO	33	27	19	17	82%	89%	58%
DOUGCO	34	20	16	13	59%	81%	47%
DENCO	31	21	18	15	68%	83%	58%
ADCO	32	18	16	12	56%	75%	50%
Tot Cnty	197	118	92	76	60%	83%	47%
AUR	31	16	15	10	52%	67%	48%
LAK	18	12	17	12	67%	71%	94%
WHT	18	8	17	8	44%	47%	94%
ARV	19	5	17	4	26%	24%	89%
Tot Cities	86	41	66	34	48%	52%	77%
TOTALS	283	159	158	110	56%	70%	56%

M-1 Goal = 65% RF Goal = 90%

While the overall M-1 verification was quite good, the M-1, Red Flag product showed its second year of lowered verification. HMS issues M-1 Red Flags when a thunderstorm is considered imminent and capable of producing 1.00 inch or more rainfall in 30 minutes. **The HMS Red Flag goal is a 90 percent verification rate. All monthly Red Flag statistics fell below this goal with the July and August statistics especially disturbing.** A more detailed evaluation of this problem will be presented when Table 2 and the County/City support is evaluated.

Note that Message 2's were issued for three days in May and June when the National Weather Service issued Flash Flood Watches for the entire District.. HMS concurrence with the NWS Watches occurred on the two days which verified. Only 37 percent of the NWS individual M-2's verified on the three M-2 days. Note that on June 28 both Message 1's and Message 2's were issued and were verified separately. The excessive Spring 1995 rainfall of May and June left local soil conditions frequently saturated necessitating the Flash Flood watches issued. **The 67 percent verification rate of these NWS Flash Flood Watches exceeds the NWS national average of about 35 percent and underscores the synergistic results we can achieve when cooperating with the NWS.**

#### 4.2 County and City Message Verification and Evaluation

This section of the report focuses on the evaluation of the M-1's issued to specific counties and cities in an effort to identify the support rendered and identify areas that need improvement. Table 2 presents the results of this evaluation for each of the six counties and four cities.

On the county level **above average M-1 verification was achieved in Arapahoe (82%) and Denver Counties (68%)** while **below average** verification was noted only in **Boulder County ( 37%)** compared to the overall 60 percent county M-1 verification. The HMS M-1 goal is 65 percent accuracy and the two above average statistics show encouraging progress was made. On the other hand **the low Boulder verification rate is hard to explain** especially when compared to the Red Flag verifications. Slightly below average verification was also noted in Jefferson County. Both counties are in storm genesis areas which shorten lead-times and may lead to forecaster over-prediction rates.

In contrast, the Boulder County **Red Flag verification** of 86 percent was topped only by Arapahoe County's 89 percent verification. So, while the Boulder County M-1's verified only about one in three, Boulder Red Flags verified almost nine out of ten. The HMS goal is 90 percent verification of Red Flags. Thus the overall county verification rate of 82 percent fell short by a little. **In general, the County M-1's and Red Flag verifications appeared to be on track with goals.**



Unfortunately the city level verification showed a much lower level of verification results. Before discussing the city statistics, it is important to note that the only Message 1's issued directly to Lakewood, Wheat Ridge and Arvada are Red Flagged M-1's. This support was requested by the cities involved to reduce the number of "mediocre Fred" storms prompting Message 1's for the rest of Jefferson County. Aurora is grouped with the cities but receives its Message support like the counties. It receives both Message 1's and M-1 red Flags.

Note that the Red Flag statistics for each city fell well below the 90 percent verification goal. **It is especially disturbing to see the less than 50 percent verifications in Wheat Ridge (47%) and Arvada (23%).** What is even more surprising was the fact, that while only M-1, Red Flags are to be issued to Arvada, Wheat Ridge and Lakewood, four non-Red Flagged M-1's were issued to them. These facts suggested a misunderstanding on the operational use of Message 1's existed among the HMS meteorologists. It prompted an intense post-season review of Red Flag policy in the F2P2 with the District.

HMS made a concerted effort to discuss the Red Flag problem with the District during the months of October to December. The philosophy, use and criteria of Red Flags was discussed individually and collectively with each forecaster. It is hoped that the misunderstandings on Red Flag use have been cleared up and will not be repeated. **Twenty-one of city Red Flag "busts" came on Message days with no thunderstorms imminent to the city Red Flagged.** Had procedure been understood on these four days, the verification statistics would have been about 85 percent or near the County level statistics. **We believe that the problem has been addressed and will not be repeated. The HMS Forecast Team is on track and on the same page as the District once again.**

## **5.0 Significant 1995 Storms**

The 1995 F2P2 season was slow to start as cold, upslope weather systems spread copious general rains over the District from mid-April through mid-May. Along with the rainfall and snowfall came very cool temperatures which delayed the start of the thunderstorm season. Once the season started on May 16th, it remained active each month through mid-September. Message 1's were issued on 6 days in May, 12 days in June, 10 days in July, 11 days in August and 4 days in September. Of these 43 Message days 35 days experienced some form of urban, stream or flash flooding. These figures are **well above the 17 year F2P2 average** of 34 Message days and 28 flooding days.

Despite the high frequency of event days, the 1995 F2P2 season was uneventful with no major flash flooding events occurring. **Most of the storms were quick-hitting "front-end dumpers" of less than 30 minutes duration**

**and less than 1.00 inch of rainfall.** However, notable storm exceptions were experienced on May 16-17, June 2nd to 8th, July 13-19 and September 9 - 10th. These **storm periods** featured multiple storms and are summarized below:

**May 16 to 17** A strong spring storm brought general rains and embedded thunderstorms to the entire District from 1000PM on the 16th through 300PM on the 17th. General rainfall of 1.50" to 2.50" was noted in all counties with east Boulder, east Jefferson, north Douglas and western Arapahoe Counties receiving the heaviest amounts. Snowfall at elevations above 6,000 feet on the 17th eased a critical snowmelt runoff flooding potential.

**June 2 to 8** A seven day barrage of storms brought local cloudbursts with small hail to the entire District. These storms occurred during a period of heavy snowmelt runoff which prompted the NWS to issue a Flash Flood watch on the 3rd which verified.

**June 4** The storms were especially heavy on June 4 when 30 - 45 minute rainfall rates exceeded 3.00 inches/hour on the south side during the afternoon hours of 3:00PM to 6:00PM. The rainfall produced flash flooding in portions of southwest Denver, east-central Jefferson and northwest Arapahoe Counties.

**July 13 to 19:** Waves of heavy thunderstorms formed on Palmer Divide and Jefferson County foothills and moved across the District producing numerous reports of urban street and small stream flooding in all counties. The storms were especially strong late on the 15th with most District counties and cities receiving Red Flags for verified storm events.

**Sept. 9-10** Rapidly forming thunderstorms formed both days along convergence lines in Jefferson and Denver Counties. The storms dropped very heavy rainfall estimated by radar to reach 1.50 inches in less than an hour. Urban street flooding was reported throughout the District.

Two storms, one on June 4th in southwestern Denver County and the other on July 15th, were especially notable. The June 4th storm was the heaviest thunderstorm rainfall producer of the 1995 F2P2 season. Radar-estimated rainfalls of 2.00 to almost 4.00 inches in 45 to 90 minutes over southwest Denver County. were derived for the June 4th storm, called the Marston Lake Storm, using a new HMS radar-rainfall product to derive the storm rainfall.

While a Message 1 had been issued for storm-affected portions of Denver, eastern Jefferson and western Arapahoe Counties, communications problems with Denver County EOC slowed awareness of the problem within the city. The Red Flag for the storm was delayed in its receipt and slowed response in Denver. Similar problems were not experienced in Jefferson and Arapahoe Counties.

The **“Saturday night special” storm of July 15th** was also affected by “a Murphy forecast yo-yo”. HMS issued Message 1’s to cover storm formation during the late morning hours. After consultation with and encouragement from the National Weather Service, HMS unfortunately decided to cancel the M-1’s. About 90 minutes after the M-1 cancellation, the storm exploded over Arvada. HMS quickly identified the need for and re-issued M-1, Red Flags with 30-60 minute lead-times throughout the downstream portions of the District for all but Arvada. The re-issued M-1’s did their job well but the Arvada portion of the storm contributed a **“black eye”** for HMS with their Arvada support agencies.

**In response to both of these storm incidents, HMS has decided to staff with two meteorologists when M-1’s are valid instead of one person. The added staffing will assist in forecaster decision-making, communications and customer support.**

## **6.0 Concerns and Recommendations**

HMS utilizes this portion of the report to identify important operational developments, operational problem areas and matters of concern which became apparent during the operational season. HMS will present pertinent comments in each of these categories.

### **Doppler radar**

The most significant operational development of 1995 was the full season availability of the National Weather Service WSR-88D (NEXRAD doppler) radar for the 1995 F2P2 season. The WSR-88D’s close proximity to the District provided excellent radar coverage of the entire District and the mountains to the west. The District-provided Kavouras RADAC 2100 allowed operational access to a full suite of new radar products. **The new WSR-88D products significantly enhanced the ability of HMS meteorologists to issue and verify Message 1’s..** The NEXRAD offers excellent coverage of all city areas and allows detailed storm and post-storm evaluation of heavy rainfall rates. As experienced is gained new HMS doppler-based forecast techniques are expected to benefit the F2P2 program.

## Mesonet

HMS relies **very heavily on the existing 20-station ERL Mesonet and the limited District Weather Detection Network (WDN)** for its ability to **provide basin specific flash flood prediction**. Since 1993 HMS has used three key short range forecast techniques based on the Mesonet:

1. The **Quantitative Convective Precipitation Potential (QCP2)** links surface observations of temperature, dew point and winds to the HMS Convective Storm Model to produce basin-specific QPF's.
2. The **Denver Cyclone model** makes use of the observed occurrence of severe weather and heavy rainfall in the different quadrants of the Denver Cyclone to assist in issuing Message 1's and assigning probabilities to the QPF products, and finally,
3. The **Me(so)und** technique allows an estimation of the changes in the vertical profile of temperature and moisture in the atmosphere from the surface to about 15,000 feet to assist in thunderstorm and QPF prediction. This technique makes use of elevation differences in Mesonet sites to construct a sounding of the atmosphere.

All three techniques have been reported in professional papers and operationally tested. **The ERL Mesonet will lose funding after the 1996 F2P2 and its loss has cast a shadow over the future use of these techniques in the District F2P2..** The existing District Weather Detection Network ( WDN ) is expected to grow to 10 stations by 1997 F2P2 but the number of stations will be only half of the existing Mesonet. **The expected loss of the Mesonet could significantly degrade the short term, basin-specific QPF forecasting capability.**

## Training

In its 1994 F2P2 season report HMS noted a continuing need for training of both dispatchers and other emergency response personnel in the understanding and utilization of F2P2 products within Flood Warning Plans and in emergency situations. HMS suggested that the District consider the development of a year-round F2P2 which focuses on user understanding of F2P2 products and their utility in flood warning programs continued to be a concern. **HMS concurs with the District viewpoint that a year-round F2P2 is not needed at this time.** However HMS feels strongly that training is a very necessary component of a successful flash flood warning program which needs more attention.



HMS suggests that the District considers funding a three month pre-operations period (PRE-OPS) from mid-January to mid-April. The PRE-OPS could have the following objectives:

1. Providing direct person-to-person PMS contact with dispatchers and decision-makers
2. Training County and FDN dispatchers and emergency response agencies in the use of PMS forecast products and
3. Exercising existing flood warning plans, and making suggestions on how they can be improved.

HMS acknowledges that there may be other ways to address the training issues and will cooperate with the District as requested. HMS feels that the personal contact is needed to keep emergency response agencies motivated and able to respond in case of a major urban or foothills flash flood. An effort to visit communications/dispatch centers in Spring 1996 will be discussed with the District when it is considered appropriate.

### Recommendations

HMS offers the following recommendations for consideration by the District in 1996:

1. HMS recommends that the District consider funding a pre-operational period ( PRE-OPS) which enhances user training and exercises flood warning plans. HMS will submit a proposal for such a program to the District by May 1996 with a proposed budget for possible 1997 F2P2 implementation.
2. HMS recommends that the UDFCD consider future funding of the unsolicited Mesonet evaluation and design proposal submitted by HMS to insure an operational mesonet presence which does not lead to degraded basin-specific QPF and Message prediction capability in 1997. The anticipated impact of the loss of the ERL Mesonet after the 1996 F2P2 on F2P2 operations needs to be quantitatively addressed. \$10K
3. HMS recommends that the District consider participating the planned 20th Anniversary activities of the 1976 Big Thompson Flash Flood which prompted the formation of the District's Flash Flood Prediction Program (F2P2).

APPENIX A  
SUPPLEMENTARY ANNUAL VERIFICATIONS



**Table A-1: MESSAGE DAYS FOR THE 1995 FLASH FLOOD PREDICTION PROGRAM**

DATE	FORMS ISSUED						MESSAGE VERIFICATION BY DISTRICT, COUNTY, AND CITY										
	HPO	M1	M2	M3	IMS	QPF	DISTRICT	BOCO	JEFFCO	ARAPCO	DOUGCO	DENCO	ADCO	AUR	LAK	WHT	ARVADA
5/16/95	X	X			X		5/16/95	X	X	X	X						
5/17/95	X	X			X		5/17/95	R	R	R	R	R			R	R	R
5/20/95	X	X			X		5/20/95		X		X						
5/26/95	X	X			X		5/26/95		X	X	X		X	X			
5/29/95	X	X			X	X	5/29/95	X	R	R	X	R	R	X	R	R	R
5/30/95	X		X		X	X	5/30/95	N	N	N	N	N	N	N	N	N	N
6/2/95	X	X			X		6/2/95	R	X	X	X	R	R	X	R	R	
6/3/95	X		X		X	X	6/3/95	N	N	N	N	N	N	N	N	N	N
6/4/95	X	X			X	X	6/4/95	X	R	R	X	R	X	R	R	R	R
6/6/95	X	X			X		6/6/95	X									
6/7/95	X	X			X		6/7/95	R	R	X	X	X	R	X			R
6/8/95	X	X			X		6/8/95	X	X	X	X	X	X	X			
6/17/95	X	X			X	X	6/17/95	R	R	R	R	R	X	R	R	R	R
6/22/95	X	X			X		6/22/95		X	R	R		X	R			
6/23/95	X	X			X		6/23/95		X			X	X	X			
6/24/95	X	X			X		6/24/95			X		X	X	X			
6/28/95	X	X	X		X	X	6/28/95	X/N	X/N	X/N	X/N	X/N	X/N	X/N	R/N	R/N	R/N
6/30/95	X	X			X	X	6/30/95	X	X	R	X	R	R	R	X	X	X
7/1/95	X	X			X	X	7/1/95	X	X	X	X	X	X	X			
7/13/95	X	X			X		7/13/95		R			X	R		R	R	R
7/14/95	X	X			X	X	7/14/95	X	R	R	R	R	R	R	R	R	R
7/15/95	X	X			X	X	7/15/95	X	R	X	R	X	X	R	R	R	X*
7/16/95	X	X			X	X	7/16/95	X	R	R	R	R		X			
7/17/95	X	X			X	X	7/17/95		R	R	X	R	R	X	R	R	R

X = HMS ISSUED

R=RED FLAG

N=NWS ISSUED

= HIT

EM1=MISSED M1 DAY

**Table A-1: MESSAGE DAYS FOR THE 1995 FLASH FLOOD PREDICTION PROGRAM**

DATE	FORMS ISSUED						MESSAGE VERIFICATION BY DISTRICT, COUNTY, AND CITY										
	HPO	M1	M2	M3	IMS	QPF	DISTRICT	BOCO	JEFFCO	ARAPCO	DOUGCO	DENCO	ADCO	AUR	LAK	WHT	ARVADA
7/18/95	X	X			X	X	7/18/95	X	X		X		X				
7/19/95	X	X			X		7/19/95	X	X	R	R	R	R	R	R	R	R
7/29/95	X	X			X		7/29/95					X	X				
7/30/95	X	X			X		7/30/95	R	R	R	R	R	R	R	R	R	R
8/9/95	X	X			X		8/9/95			X	X			X			
8/11/95	X	X			X		8/11/95	X	R	R	R	R	R	R	R	R	R
8/12/95	X	X			X	X	8/12/95	X	R	R	R	R	R	R	R	R	R
8/14/95							8/14/95			EM1							
8/18/95	X	X			X		8/18/95	R	R	R	R	R		R	R	R	R
8/19/95	X	X			X	X	8/19/95	X	X	X	X	X	X	X			
8/20/95	X	X			X	X	8/20/95	X	X	R	R	R	R	R			R
8/21/95	X	X			X	X	8/21/95	X	X	R	R	X	R	R			
8/22/95	X	X			X	X	8/22/95	X	X	X	X	X	X	X			
8/23/95	X	X			X	X	8/23/95		X	R	R		R				
8/24/95	X	X			X	X	8/24/95		X								
8/26/95	X	X			X	X	8/26/95	X	X								
9/3/95	X	X			X	X	9/3/95	X	X	X	X	X	X	X			
9/9/95	X	X			X	X	9/9/95	R	R	R	R	R	R	R	R	R	R
9/10/95	X	X			X	X	9/10/95	X	R	R	R	R	R	R	R	R	R
9/18/95	X	X			X	X	9/18/95	X	X	X	X	X	X	X			
TOTAL:	43	41	3	0	43	25	43	32	39	35	36	33	34	33	20	20	21

X = HMS ISSUED

R=RED FLAG

N=NWS ISSUED

= HIT

EM1=MISSED M1 DAY

**Table A-2**

**UDFCD F2P2 DISTRICT-WIDE MESSAGE 1 DAY VERIFICATION  
1979 - 1995**

	Year	Message 1 Days	Verified Hits	Verified Misses	Not Forecasted	Percent Accuracy	False Alarm %	Probability of Detection
GRD Weather Center (District Era)	1979	26	17	9	3	65%	35%	85%
	1980	35	23	12	0	66%	34%	100%
	1981	40	31	9	0	78%	23%	100%
	1982	42	34	8	0	81%	19%	100%
Henz, Kelly & Associates (County Era)	1983	37	32	5	0	86%	14%	100%
	1984	38	32	6	0	84%	16%	100%
	1985	28	25	3	0	89%	11%	100%
	1986	35	30	5	1	86%	14%	97%
	1987	47	40	7	0	85%	15%	100%
	1988	28	24	4	0	86%	14%	100%
	1989	31	26	5	0	84%	16%	100%
	1990	30	26	4	2	87%	13%	93%
Henz Meteorological Services (Red Flag Era)	1991	42	31	11	0	74%	26%	100%
	1992	29	25	4	0	86%	14%	100%
	1993	28	25	3	0	89%	11%	100%
	1994	26	24	2	0	92%	8%	100%
	1995	43	35	8	1	81%	19%	97%
	Total District Era	143	105	38	3	73%	27%	97.2%
	Total County Era	244	209	35	1	86%	14%	99.5%
	Total Red Flag Era	198	166	32	3	84%	16%	98.2%
	Total	585	480	105	7	82%	18%	98.6%

**Message Day** = Issuance of a Message 1: Stream or Urban Flooding Forecast anywhere  
in District usually due to 1"/hour or more

**Hit** = Verification of Message in issued County

**Miss** = No verifications

**Table A-3: Annual Verification Comparison for UDFCD (District)**

Year	M-Days	Hits	Misses	Percent Accuracy	Percent False Alarm	Probability of Detection	Total M-1's	Hits	Misses	Percent Accuracy
1991	42	31	11	74%	26%	100%	293	155	138	53%
1992	29	25	4	86%	14%	100%	143	81	62	57%
1993	28	25	3	89%	11%	100%	123	66	57	54%
1994	26	24	2	92%	8%	100%	153	86	67	56%
1995	43	35	8	81%	19%	98%	283	159	124	56%
Tot	168	140	28	83%	17%	99%	995	547	448	55%
AVG	34	28	6	82%	18%	99%	199	109	90	55%

**Table A-4: County / City Message-1 Verification**

	Total County and City			County Verification			City Verification		
Year	Number of M-1's	Hits	Percent Hit	County M-1's	Hits	Percent Hit	City M-1's	Hits	Percent Hit
1991	293	155	53%	185	98	53%	108	57	53%
1992	143	81	57%	109	66	61%	34	15	44%
1993	123	66	54%	100	60	60%	23	6	26%
1994	153	86	56%	112	70	63%	41	16	39%
1995	283	159	56%	197	118	60%	86	41	48%
Total	995	547	55%	703	412	59%	292	135	46%

**Table A-5: Red Flagged M-1's (RF)**

Year	Total M-1's	RF's	RF Hits	Percent RF Hits	Percent RF's	County RF's	County RF Hits	% County RF Hits	City RF's	City RF Hits	% City RF Hits
1991	293	171	156	91%	58%	N/A	N/A	N/A	N/A	N/A	N/A
1992	143	85	81	95%	59%	69	66	96%	16	15	94%
1993	123	12	12	100%	10%	8	8	100%	2	2	100%
1994	153	67	47	70%	44%	38	32	84%	29	15	52%
1995	283	159	110	69%	56%	92	76	83%	66	34	52%
Tot	995	494	406	82%	50%	207	182	88%	113	66	58%