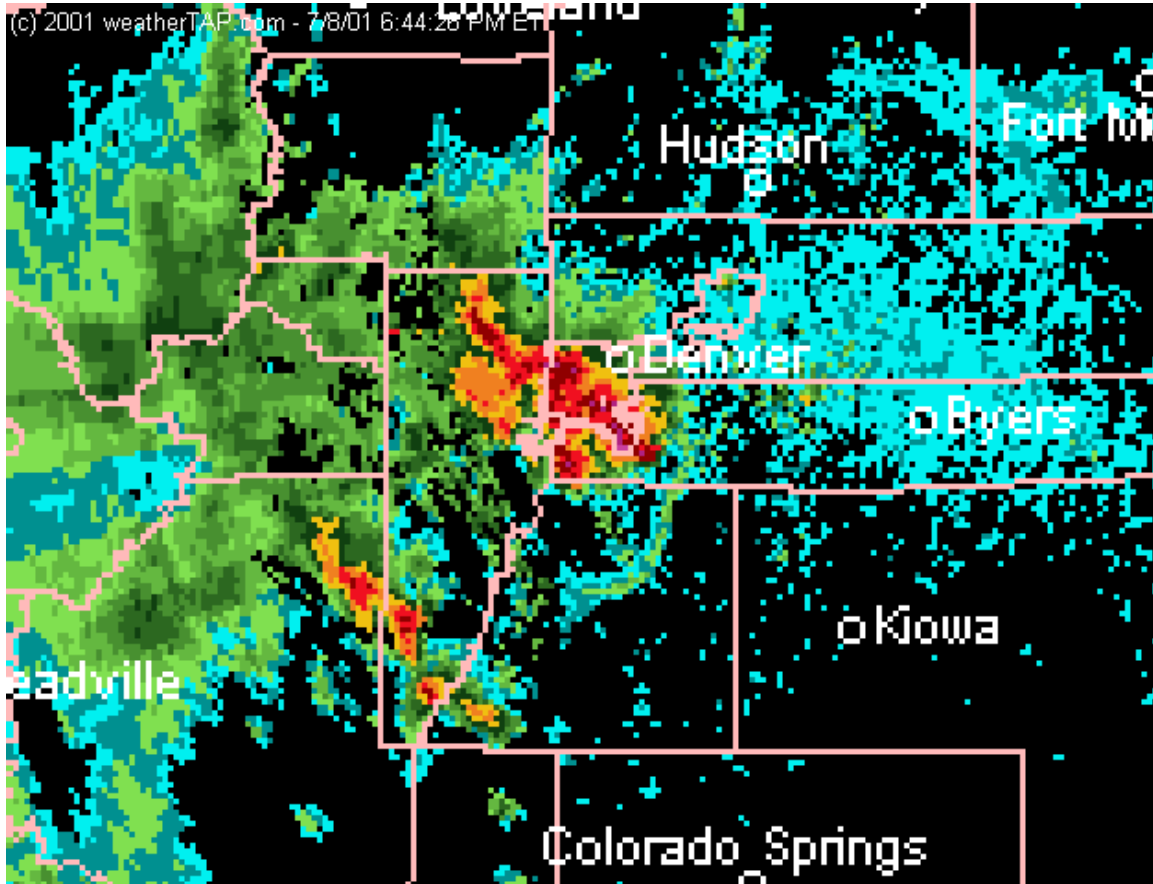


# 2001 UDFCD FLASH FLOOD PREDICTION PROGRAM ANNUAL REPORT



The July 8, 2001 Cherry Creek Arts Festival Storm radar reflectivity, 445PM.

**HDR Engineering, Inc**  
**Hydro-Meteorological Services**  
**303 East 17<sup>th</sup> Avenue, Suite 300**  
**Denver Colorado 80203**

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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 District contracts the unique, basin-/storm-specific 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 District forecast area supported is shown in **Figure 1** and includes over 60 percent of Colorado's population. The District is approximately 1,600 square miles and the forecast area is about 3,000 square miles. Terrain in the forecast area 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. The population in this area has increased ~21 percent in the period of 1991 to 2000 and prediction service requests have increased noticeably in the past three years in Boulder, Douglas and Arapahoe Counties.

**HDR Weather Services (HDR)** of Denver was selected as the 2001 F2P2 Private Meteorological Service. HDR Engineering's Hydro-Meteorological Services provided the private meteorological support for the first time. HDR forecast meteorologists Bryan Rappolt and John Henz provided the F2P2 forecast services with assistance of Dan Henz, meteorological technician. Bryan and John have over two decades of combined F2P2 experience gained at Henz Meteorological Services.

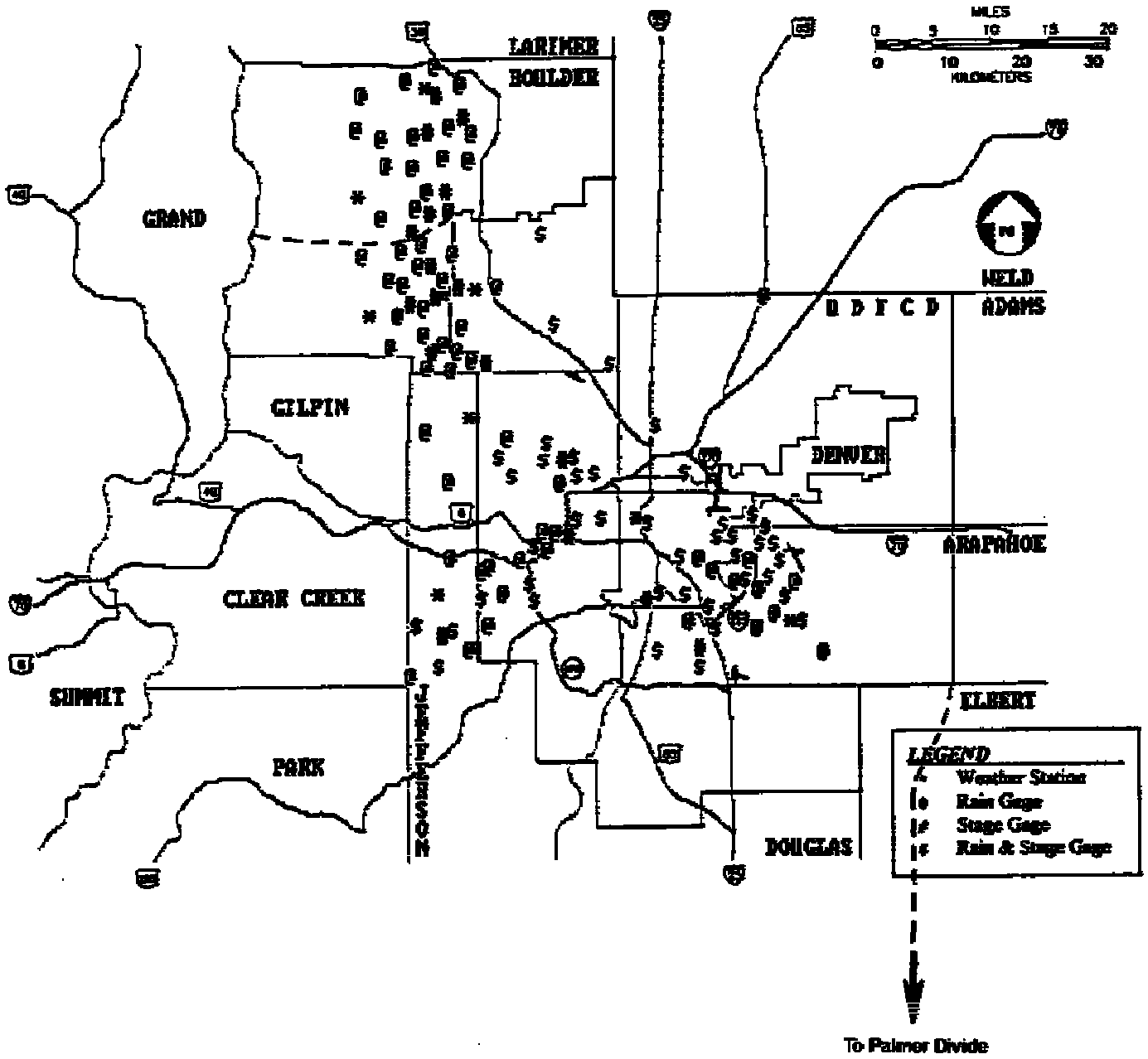
## 2.0 2001 Operational Season

The F2P2 season began on 15 April 2001 and continued through 15 September 2001 for 154 operational days. Normal operational hours were from 0700L to 2200L and covered 2,322 hours. During the period from 1000PM to 1200AM HDR meteorologists added an additional 76 hours of support time as storms in eastern Adams, eastern Arapahoe and northern Douglas Counties persisted over newly populated areas near Denver International Airport, Parker and eastern Aurora. Overnight forecasting from midnight to 700 AM added an additional 369 hours for a total of 2,691 hours of F2P2 operations. This sixteen per cent increase in operational hours past 1000PM was due to the extremely active thunderstorm period from 1 July to 15 August 2001.

The F2P2 required a continuous Metwatch of the District for the entire period using the NWS WSR-88D Doppler radar, satellite, conventional surface and upper air observations and local ALERT and weather station networks. These observations were used by HDR meteorologists to prepare in-house analyses, predictions and specialized F2P2 products.

The products included daily Heavy Precipitation Outlooks (HPO), MESSAGE 1, 2, 3 and 4's, Message updates, Quantitative Precipitation Forecasts (QPF) and StormTraks. The HPO's were issued at least once daily to describe the potential for heavy precipitation in each of the District counties. Messages were issued on those days when the potential of heavy rainfall capable of producing some form of flooding in the District or a portion of the District was deemed possible. QPF's and Storm Traks were issued on Message days to provide additional weather support to the F2P2 user community.

Figure 1 The District and F2P2 Forecast Area



### 3.0 2001 F2P2 Operational Product Production

The F2P2 is designed to offer a unique, basin-specific weather information source concerning heavy precipitation, urban flooding and flash flooding threats to the six participating District Counties and the cities within those counties. Direct support is rendered to the District basin-specific warning plans identified below:

1. **Boulder Creek Flood Warning Plan**, which serves Boulder/South Boulder Creeks in Boulder County, which impacts the City of Boulder and portions of un-incorporated Boulder County.
2. **Lena Gulch Flood Warning Plan**, which serves the Lena Gulch Basin and impacts Jefferson County, Golden, Lakewood and Wheat Ridge.
3. **Goldsmith/Harvard Gulch Flood Warning Plan** which impacts south-central Denver.
4. **Westerly Creek Flood Warning Plan**, which impacts eastern Denver and western Aurora.
5. **Toll Gate Creeks Flood Warning Plan**, which impacts central and southern Aurora.
6. **Ralston Creek Flood Warning Plan**, which impacts Arvada and Jefferson County.
7. **Bear Creek Flood Warning Plan**, which impacts southern Lakewood, the Town of Morrison and Portions of central Jefferson County.

Five specific F2P2 products exist as expert-to-user support. These products are Heavy Precipitation Outlooks (HPO), Messages, Internal Message Status's (IMS), Quantitative Precipitation Forecasts (QPF) and HDR Storm Trak predictions. During the 2001 season HDR delivered the following quantities of the identified F2P2 Fax Products:

**Table 1 2001 F2P2 Production Summary**

Product	Number issued*
Heavy Precipitation Outlook (HPO)	336
Message Forms and Updates	284
Internal Message Status (IMS) statements	126
Basin-Specific Quantitative Precipitation Forecasts	23
StormTraks	117
<b>Total</b>	<b>886</b>

- NOTE: In order to compare to previous years take number issued times the number of Broadcast Fax recipients

These products were delivered via Qwest Broadcast Fax until June 27 when it was replaced by the Internet-based Expedite Broadcast fax service. The new Expedite service provided extremely reliable service. An informal survey conducted in August suggested that Message Day products were delivered in about 5 minutes less time with Expedite compared to Qwest in 2000.

All HPO, IMS and QPF products were sent to the District Alert System Web and the HDR F2P2 Web pages. HDR sent 336 HPO products, 126 IMS and 23 QPF products on the Internet.

The on-demand access of the Web Page products to decision-makers using office and home computer systems is a desirable asset of the Web Page service. HDR logged over 1,800 storm-related telephone interactions during the program, emphasizing the strong technical "touch" of the program in the local community. HDR used three dedicated telephone lines: two for voice and one

for fax products. These three lines were adequate to handle the volume of communications generated during peak storm periods. User input indicates that the quality of the faxed StormTraks has improved sufficiently to supplant event verbal “hand-holding” to some degree. Users indicated a strong interest in the StormTrak product migrating to the District Alert System Web page.

#### 4.0 2001 F2P2 Operational Verification

The primary service rendered by the F2P2 to participating local governments and associated emergency response agencies is the issuance of value-added weather forecasts of flash flooding potential, urban and stream flooding, and locally heavy rainfall. HDR indicates the potential for these events in a series of products issued directly to the users by phone, fax and Web Page. The definition of each Message is given below in **Table 2**.

**Table 2 Message Definitions used in the District Flash Flood Prediction Program (F2P2)**

##### **MESSAGE 1** (*Internal Alert*)

A Message 1 is an advisory Message meant to inform key people in local emergency response community that weather conditions are such that flood producing storms could develop later in the day. It is issued after forecast discussions between HDR and National Weather Service (NWS). The advisory is preceded by the statement, “THIS IS A RED FLAG MESSAGE”, when HDR deems priority handling by communications dispatchers is required.

##### **MESSAGE 2** (*Flash Flood Watch*)

This Message indicates that a Flash Flood Watch has been issued by the NWS and/or HDR feels that the risk is high that a life-threatening flood may occur later in the day. This Message requires priority handling by communications dispatchers.

##### **MESSAGE 3** (*Flash Flood Warning*)

This Message indicates that a Flash Flood Warning has been issued by the NWS and/or HDR feels that the risk is high that a life-threatening flood is imminent. This Message requires priority handling by communications dispatchers.

##### **MESSAGE UPDATE**

This Message is used by HDR to provide additional information to any of the above Messages on the developing weather situation. For example, this Message has been used to narrow a NWS Watch or Warning area, as more information becomes available or to provide more site-specific information during an event. If HDR feels that this Message requires priority handling by a communications dispatcher, it is preceded by the statement, “THIS IS A RED FLAG MESSAGE”.

##### **MESSAGE 4** (*All Clear*)

This Message cancels the flood potential status. HDR issues it after consultation with NWS and other entities involved with direct HDR communications.

The issuance of F2P2 Messages is quantitatively linked to both the rainfall potential of the weather events and the response of the District basins to the rainfall. **Table 3** shows the criteria for Message issuance based on both the rainfall potential and the anticipated response of the District basin.

**Table 3 UDFCD Flash Flood Prediction Program Message Criteria**

**UDFCD FLASH FLOOD PREDICTION PROGRAM  
MESSAGE CRITERIA**

<b>Message 1:</b>	Issued primarily to alert local governments to the threat of nuisance flooding of streets and low lying areas due to thunderstorm rainfall when storm total rainfall is 0.50" - 1.00" in one hour or less. When rainfall is 1.00" to < 3.00" in one to three hours, urban street and stream flooding becomes a significant problem. M-1 lead-times of >1 hour are desirable.
<b>Message 1 Rainfall Intensity Criteria:</b>	<p><b>Any of the forecast rainfall intensities below prompt a Message 1 issuance</b></p> <p><b>1.00"/ 60 minutes</b></p> <p><b>0.75"/ 30 minutes</b></p> <p><b>0.50"/ 10 minutes</b></p>
<b>Message 1: RED FLAG</b>	Issued to identify storm events, which fall just short of producing life-threatening rainfall, but produce a significant impact on street runoff.
<b>RED FLAG Rainfall intensity:</b>	Rainfall rates are predicted or observed to <b>exceed 1.00"/30 minutes and</b> the storm is considered <b>imminent</b> .
<b>Message 2:</b>	Issued to local governments when the threat of potential life threatening flooding is predicted or the NWS issues a Flash Flood Watch. An HDR-generated M-2 is the equivalent of a Flash Flood Watch. M-2 lead-times of several hours are desirable.
<b>M-2 Rainfall intensity criteria:</b>	<b>&gt;3.00"/hour or a lower value based on mutual discussion between NWS, District and HDR due to antecedent rainfall impacts on soil saturation and/or runoff characteristics.</b>
<b>Message 3:</b>	Issued to local governments whenever a life-threatening flash flood is imminent or the NWS issues a Flash Flood Warning. M-3's are issued in accordance with basin-specific warning plans if available or at the discretion of the meteorologist.

## 4.1 Message Verification

The verification of the Messages issued by the District's F2P2 is presented in **Table 4**. This year's verification is presented in a simplified verification scheme that embodies common sense. A Message day is defined as any day from 15 April to 15 September on which a Message 1, Message 2 or Message 3 is issued based on the criteria presented in **Table 3**. Messages were issued on 42 days during the 2001 F2P2. The next column shows the number of Message days on which rainfall events were observed which met or exceeded the Message criteria described in **Table 3**. In 2001 there were 39 days on which events occurred and met the Message criteria. The HDR forecasts of a Message day were correct 93 percent of the time.

Individual Messages are issued to counties and cities located within the District as shown in **Figure 1**. Typically, more than one Message is issued on a Message day. A total of 284 Messages were issued on the 42 Message days or an average of about 7 Messages per Message day. The next column shows the number of individual Messages that verified with a rainfall event meeting the criteria in **Table 3**. Approximately 64 percent of the individual Messages verified. This value demonstrates **above average** skill for the 2001 F2P2 compared to the 23-year F2P2 statistics.

Message issuance is used to alert the District users that the potential exists for street flooding or flash flooding rainfall. The operational period runs 154 days from 15 April to 15 September. HDR meteorologists correctly identified that heavy rainfall would not occur on 112 of the 115 days when heavy rainfall was not observed. On the days a Message was issued, heavy rainfall was observed over 90 percent of the time in the District and in almost 2 out of 3 of the counties alerted with Messages.

**Table 4: Monthly Message Verification for the 2001 F2P2 Operational Season**

Month	District-Wide Message Days	District-Wide Message Days That Verified	Local Government Messages Issued	Local Government Messages That Verified	Percent of Local Government Messages Verifying
April	0	0	0	0	N/A
May	7	7	42	37	88%
June	6	5	42	21	50%
July	16	15	109	76	70%
August	11	11	77	43	56%
September	2	1	14	5	36%
<b>Total</b>	<b>42</b>	<b>39</b>	<b>284</b>	<b>182</b>	<b>64%</b>

Messages were issued on 42 days which tied for the 5<sup>th</sup> highest number of Forecast Message days in the 23-year history of the F2P2. The 39 District-Wide Message days that verified is the third highest number observed in the past 23 years. Sixty-four percent of the 284 Messages verified which was about 7 percent above the 23-year average. The 182 verified Message events was ***the third highest number recorded since the F2P2 began in 1979 and almost two and a half times (229%) more than observed in 2000!***



If storm rainfall intensities are sufficient to create serious street flooding or flash flooding, the District PMS issues either a Message Red Flag or a Message 3, Flash Flood Warning. A Red Flag was issued 76 times and verified 75 times for a 99 percent verification rate. The improvement in Red Flag (RF) verification marks the sixth straight year of 98 percent verification or better. The Red Flag has proved to be one of the most reliable products of the F2P2.

Flash Flood Watches or Message 2's were issued on 13 days in 2001. This is the highest number of Message 2 days since the F2P2 began in 1979. Of the 13 Flash Flood Watch days forecast, ten verified and set another record. HDR and the NWS concurred on all Flash Flood Watch days except for July 8, 2001. On this day, HDR issued a Message 2 without NWS concurrence at about 1040AM. July 8, 2001 proved to be one of the heaviest rain and flash flood days of the summer.

A Message 3(*Flash Flood Warning or Flood Warning*) was issued by the National Weather Service for 3 storm days: July 8, July 10 and July 13. In each case, HDR called affected communities and informed them of weather factors. Close coordination between NWS and HDR meteorologists on storm days kept both organizations "on the same page" most days to the public's benefit. All M-3's verified, though the event on July 10<sup>th</sup> was a marginal flooding event.

Two flash flood warnings were issued on July 8<sup>th</sup> for portions of Denver and Arapahoe Counties as severe flash flooding was reported on Harvard Gulch, Goldsmith Gulch and on Cherry Creek. Additionally, flash flooding was reported in portions of western Aurora and on numerous portions of I-25. In addition to the flash flooding, the severe thunderstorms produced numerous reports of large hail to 1.25 inches in diameter and damaging winds gusts of 60-70mph in Denver and Englewood.

The flash flood warning issued on July 10<sup>th</sup> was handled equally well by Message Red Flags and constituted a minor flash flood event. Peak rainfall reached about 1.00" to 1.50" in 30-45 minutes in portions of western Lakewood and Morrison. No reports of serious or life threatening flooding were reported. While District suggested threshold criteria for a flash flood warning were not met, National Weather Service criteria were.

On July 13<sup>th</sup> severe street flooding developed in northern portions of Arvada. This rapidly developing event in Arvada was well handled by swift, co-coordinated actions by District staff reporting from the scene, the HDR operational meteorologist and the staff NWS meteorologist serving the program. Reported rainfall reached about 1.30" in 30 minutes, however, radar estimates of 2.00" to 3.50" in 45 minutes were made during the event. Phone communication during the event with the Arvada police dispatchers resulted in a high degree of reliance on HDR advice provided to the shift supervisors, the National Weather Service duty forecasters and the Jefferson County dispatchers.

A second nasty flooding event occurred the next afternoon on July 14 when a strong storm formed over the northwestern Jefferson County foothills. The storm produced damaging hail north of Golden and over Rocky Flats and then dropped up to 3.7 inches of rain in western Adams County and Thornton. While a flash flood warning was not issued, numerous Message 1, Red Flags were issued for portions of southeastern Boulder County, northeastern Jefferson County, western Adams County and Denver International Airport.

## 4.2 County Message Verification and Service Evaluation

Each of the Messages issued in the F2P2 is released to a specific county or city dispatcher in which the flooding potential has been forecast. Some of the Messages are issued for a portion of a county while others are issued for a specific basin supported by a Flood Detection Network (FDN). A Message indicates to the user that the potential exists for a flooding event later during the day. A **Red Flagged Message indicates that a flooding event is imminent**. In other words, the Red Flag means rapid information dissemination and response action is needed.

A County Message is verified as a "hit" only if a rain/flooding event meeting the Message criteria in **Table 3** occurs in the District portion of that county or in the drainage area of a stream flowing into the District. **Table 5** below summarizes the results of the 2001 F2P2 verification by jurisdiction.

**Table 5: County Message Verification for the 2001 F2P2 Operational Season**

Group	Message Issued	Message Hits	% M Hits	Red Flags	RF Hits	% RF Hits	% RF M-1's	Events Missed	Event<10min Lead
<b>County</b>									
<b>Arapahoe</b>	41	28	68	10	10	100	24	0	0
<b>Adams</b>	41	31	76	8	8	100	20	0	0
<b>Douglas</b>	40	26	65	8	8	100	20	0	0
<b>Boulder</b>	40	21	53	7	7	100	18	0	0
<b>Jefferson</b>	40	26	65	7	7	100	18	0	0
<b>Aurora</b>	41	23	56	10	10	100	24	0	0
<b>Denver</b>	41	27	66	13	12	92	32	0	0
<b>TOTAL</b>	<b>284</b>	<b>182</b>	<b>64</b>	<b>63</b>	<b>62</b>	<b>98</b>	<b>22</b>	<b>0</b>	<b>0</b>
<b>Red Flags</b>									
<b>Arvada</b>	N/A	N/A	N/A	6	6	100	100	0	0
<b>Lakewood</b>	N/A	N/A	N/A	3	3	100	100	0	0
<b>Wheat Ridge</b>	N/A	N/A	N/A	4	4	100	100	0	0
<b>TOTAL</b>	N/A	N/A	N/A	13	13	100	100	0	0

Verification for the City of Aurora was added to the County statistics because Aurora is a primary notification point. The Red Flag support cities receive Message notification from the appropriate County dispatchers and Message Red Flags from the HDR meteorologist in 2001. Messages and Message Red Flags are designed to support both unique District flood-warning plans associated with Flood Detection Networks (FDN) and other portions of District counties and cities that do not have a flood detection network.

***The 2001 F2P2 was the third most active operational season on record!*** The 182 verified Message events and 62 verified Red Flag events underscore just how active the period was. These values are both twice the number recorded during the 2000 F2P2. The high verification rates for both the Messages and Red Flags in 2001 support a highly accurate level of forecasting provided to the F2P2 community of users. Verification of each Message provides a means of assessing the accuracy of the support given to the District emergency response community.

Consistency was noted in the accuracy of most County Messages issued during 2001 as about two out of three Messages verified. The highest degree of Message accuracy as enjoyed by western Adams County where about three out of four Messages verified. Ninety-eight percent of the 2001 Message Red Flags verified indicating users could rely on F2P2 Red Flags. Each Red Flag had at least a 30+ minute lead-time.

Message verifications for Aurora and Boulder County were about 5-8 percent less accurate than in the other counties. It is possible that the relatively small aerial extent of southeastern Boulder County in the District and the limited number of verifying rain gauges may have contributed to a lower verification rate. Aurora simply had a “fortunate summer” and was missed by the big storm events when cooler air near the surface managed to keep the air stable over Aurora.

## 5.0 Significant 2001 Storms: Return of the Deluge

The 2001 F2P2 season set several records for storm activity. The following F2P2 records were observed in 2001:

1. **Third highest number of verified Message days:** 39 days
2. **Second highest Message day forecast accuracy:** 93%
3. **Most number of Message 2 or Flash Flood Watch days:** 13 days
4. **Most verified number of Message 2 days:** 10 days
5. ***The 186 verified Message events were the 2<sup>nd</sup> highest recorded.***
6. ***The 75 verified Message Red Flags were the 2<sup>nd</sup> highest number recorded.***

These records underscore the sharp contrast between the relatively “storm-less” 2000 season when only 22 Message days were observed and the very active 2001 season. The nastiest stretch of storms occurred between July 5<sup>th</sup> and August 15<sup>th</sup> when Message event days verified on 25 of the 42 days or 60% of the days.

Eleven straight Message issuance days occurred from July 5<sup>th</sup> –15<sup>th</sup> setting a record for most consecutive days of Message issuance. Verifying flash flooding events occurred on all days but July 9<sup>th</sup> when thunderstorms occurred around the District but gave it a “day of rest”.

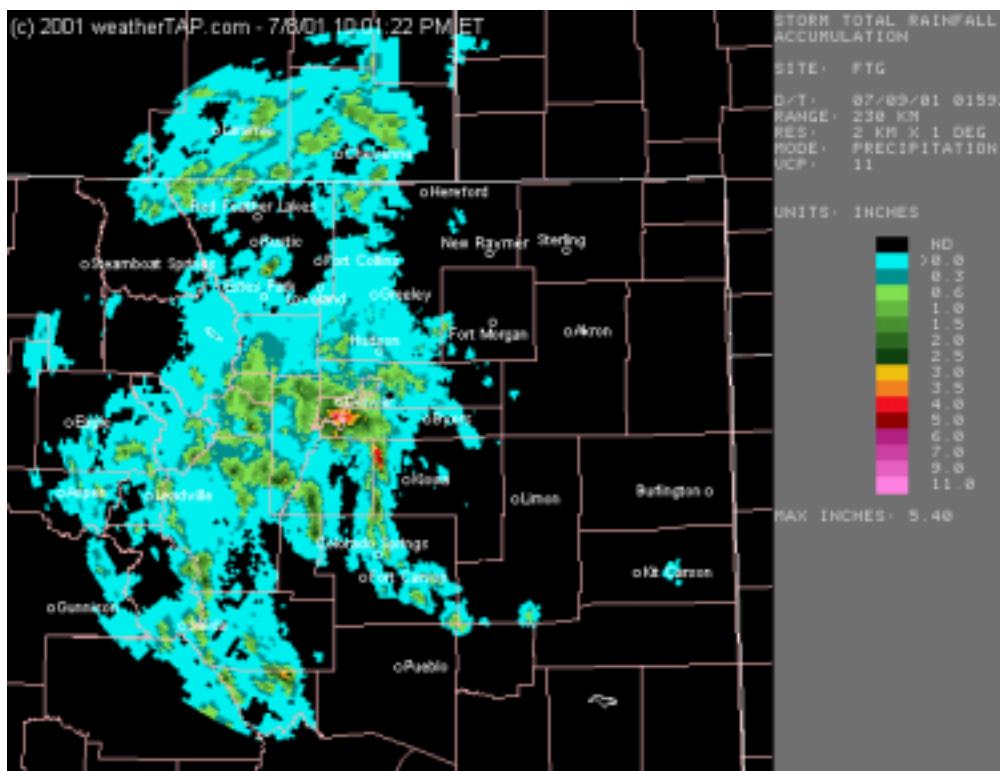
The extraordinary storm days or periods of days in the 2001 F2P2 are listed below:

1. **May 3-5:** Three days of steady general rain saturated soils along the Front Range and produced minor flooding problems. The third day of the steady upslope general rain brought 1.00” –2.00” amounts and numerous reports of minor street flooding.
2. **July 56:** Fast-moving front-end dumper storms dropped up to 1.85” of windy rain on the rush hour in Aurora in less than an hour. These storms heralded the start of a 45 day siege of monsoon storms.



**Figure 2 Cars driving in bumper deep water near Cherry Creek Mall on July 8, 2001.**  
*(Photo courtesy Channel 9 News)*

3. **July 8:** Serious street and urban stream flash flooding deluged the Cherry Creek Arts Festival in Denver between 400PM and 600PM. Flash flooding was observed on Harvard Gulch where 0.67"/5 min and 2.48" in an hour were observed. This multi-cell storm had formed earlier over Littleton where it produced serious street flooding. As this storm dissipated a Denver Cyclone formed over Cherry Hills that produced flooding rains over Goldsmith Gulch, Aurora and on Cherry Creek. Additional reports of flash flooding were noted on I-25 and in Centennial and Englewood.

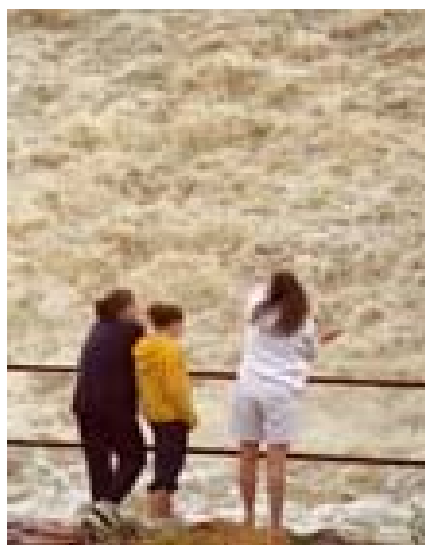


**Figure 3 NWS WSR-88D radar-estimated rainfall for July 8, 2001**

4. July 10: A fast developing storm formed over the central Jefferson County foothills and dropped almost 1.50" of rain in 35 minutes while another foothills storm hit Evergreen with 1.00" to 2.00" in less than an hour and small hail. These dual foothills storms were the strongest to hit the foothills in 2001.
5. July 13: Dual "Friday the 13<sup>th</sup>" storms deluged Arvada and Aurora. Radar-estimated rainfall of 2.00"-3.50" was noted in northern Arvada and an observed 1.73" in less than an hour caused heavy runoff in the Toll Gate Creeks and Sand Creek in Aurora. Figures 4(left) and 5(right) below show storm flooding in Aurora.



**Figure 4 Shopping center parking lot flooding due to clogged storm drains.**  
*(Photo courtesy Channel 9 News)*



**Figure 5 Toll Gate Creek roars in the aftermath of the Aurora cloudbursts.**  
*(Photo courtesy Channel 9 News)*

6. **July 14:** A long track multi-cell storm complex developed over the northwestern Jefferson County foothills about 300PM. The storm produced severe weather in the form of damaging hail and high winds across the foothills north of Golden, Rocky Flats, Broomfield and west-central Adams County. Thornton was hit hard by an estimated 3.7 inches of street flooding rainfall. High winds and heavy rainfall produced street flooding problems in northern Aurora, Barr Lake and at Denver International Airport.
7. **July 23:** A highly localized storm terrorized rush hour traffic around the Denver Tech Center with funnel clouds, hail, winds and 1.26"/25 minutes of rain that slowed travel on I-25 and I-225.
8. **August 9:** The "final" big storm day of the 2001 F2P2 as the Boulder and Jefferson County foothills were hit with four active storms dropping more than 1.00" in 30 minutes or less. The heaviest rainfall was noted on Morrison (1.61"), Turkey Creek (1.50") and South Boulder Creek (1.34"). Very active lightning accompanied the rain.

The storms identified above as the most significant events of the 2001 F2P2 were chosen by John Henz and Bryan Rappolt, HDR operational meteorologists, and Kevin Stewart of the District. While other storms may have produced more lightning, hail, tornadoes or wind, the storms above were the key flooding events of the 2001 F2P2. Each storm developed intense localized rainfall that produced flooding urban runoffs.

Very heavy rainfall, active lightning and high winds characterized the storms of 2001. It should be noted that the Cherry Creek Art Festival/Harvard Gulch storm of July 8<sup>th</sup> formed in a very similar manner to the August 17<sup>th</sup> storm of 2000 that killed a Denver firefighter. Another similar storm occurred on July 19, 1985, when a storm produced over 4.00" rains in portions of Denver and Aurora and closed I-25 for two days due to a combination of hail accumulation clogging drains and heavy rainfall. Each of these storms shared the following common characteristics:

1. A Denver Cyclone developed just to the east of the main storm updraft and enhanced the flow of moist low-level air into the storm. The DC circulation was closed with about 10-20mph of inflow air.
2. The amount of moisture in the air exceeded 1.20 inches with deep monsoon influences.
3. A monsoon disturbance was observed to the south on morning satellite photos at levels near 10,000 feet that did not show up on conventional upper air analyses. The disturbance intensified as it moved north of Palmer Divide and off the Jefferson County foothills. The July 8, 2001 disturbance was especially intense and developed a closed 20-30mph circulation in the Jefferson County and Douglas County foothills complex.
4. Upper level winds from 10,000 feet to 30,000 feet were relatively light from the south to south-southeast at 10-20mph with a large mass of sinking sub-tropical air over Oklahoma. This warm air helped pre-storm temperatures climb into the 90s while "capping" the air's latent energy as dew points hovered in the 50's on both occasions.

5. The storm complex formed within the 30 minutes after the critical surface temperature needed to break the cap was reached. It is interesting to note that the cap break temperature is determined by the Squaw Peak temperature plus 35F.
6. On July 8<sup>th</sup> the cooling of the Squaw Peak temperature reduced the needed "cap-breaker" surface temperature as foothills storms "cooled the cap temperature". Similar "cap cooling" occurred on August 17, 2000 and July 19, 1985.

It is hoped that these observations will gradually be added to others and produce a repeatable methodology of forecasting these rapidly developing storms systems that produce intense surface rainfall and serious flash flooding.

The challenging forecasting events described above were dealt with operationally by three members of the HDR Hydro-Meteorological Services Group: **John Henz**, Senior Meteorologist and Project Manager; **Bryan Rappolt**, Project Meteorologist who performed the majority of the F2P2 forecasting shifts and **Dan Henz**, meteorological intern from the University of Arizona. Dan is a Colorado native, enrolled in the University of Arizona's undergraduate atmospheric science program and is the son of John Henz. The meteorological success of the program is a reflection of their dedication.

## **6.0 Recommendations**

HDR 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.

### **Mesonet**

HDR meteorologists have been very pleased with continued upgrading of weather station coverage by the District during the 2001 F2P2. A full season of use of the weather station site on Squaw Peak vastly improved HDR capability to issue basin-specific products such as QPF and StormTraks and to anticipate the onset of heavy rainfall due to the breaking of a convective inversion. The new Urban Farm station installation was too late in the season to develop an opinion of its value.

HDR supports installation of new weather stations at DIA and Aurora Reservoir or Heritage Eagle Bend Golf Course in the east District to address the expanding population base and the installation of a new flood detection network in the southwestern corner of the District where a "data-void area" has existed. Additional stations in Weld County or eastern Arapahoe and Adams Counties would help with timing the arrival and the temperature/moisture content of thunderstorm outflow boundaries.

### **Use of the Expedite Internet-based Broadcast Fax service**

HDR has embraced the new Internet based fax delivery system and highly recommends it be used again next year. While HDR encountered some early problems with system use, it provided reliable, fast and easy to use broadcast fax capabilities. HDR strongly recommends that the District maintain this account for the 2002 F2P2.

## **Use of Denver message paging system**

HDR recommends that the District expand the use of paging information system to key F2P2 users as was done in the communications test with Denver EOC and Wastewater Management. The system was easy to use, required little time to implement and provided efficient, accurate text information within the Denver F2P2 user community.

## **The time has come to shift from the RADAC 2100 system to the Storm Sentry system**

The existing RADAC 2100 monitor is well over 7 years old and began dying during the latter part of the 2001 F2P2. Its diminished picture display began to affect late season operations. Rather than replace this expensive unit, HDR recommends that the District shift operational reliance on the PC-based Storm Sentry system. The Storm Sentry system was run in tandem with the RADAC 2100 during the latter half of the 2001 F2P2. Storm Sentry allows ingest and use of both the standard and the GIS-based Kavouras radar data displays. Additionally lightning data is accessible.

HDR recommends that the Storm Sentry system be enhanced to support dual monitor display with two 21" color monitors to allow simultaneous display of radar and lightning data for the 2002 F2P2.

## **Flood Warning Plans**

HDR will begin to actively approach the cities and counties served by the F2P2 to develop GIS-enhanced Flood Warning Response Plan that can be used in concert with existing District plans and information.

## **GIS-based Hydrologic basin information and display of F2P2 QPF, Message and StormTrak products would greatly assist program service to the F2P2 emergency response community**

Three significant improvements to the F2P2 could be realized if GIS were embraced as both the display and database platform of choice for the F2P2 over the next 10 years. The improvements are:

1. Enhanced basin-specific warning capability by displaying the radar data over the basins with access to the hydrologic responses of the basin.
2. Development of enhanced basin-specific quantitative precipitation forecasts linked to both basin scenario modeling and observed basin flood detection network observations
3. Development of real-time radar-rainfall monitoring of basin rainfall and floodplain inundation zones impacts as storms move cross the basins.

Future flood warning response plan initiatives are strongly leaning in the direction of GIS as the key database and display component. HDR recommends that the District provides the 2002 Private Meteorological Service with a GIS database of the basin characteristics for each of the basins with flood detection networks and warning plans, GIS-based radar data for use with the basin data base and the ability to issue Message, QPF and StormTrak products in the GIS format and display such on the Internet.



**Table B-1**  
**UDFCD F2P2 DISTRICT-WIDE MESSAGE 1 DAY ONLY VERIFICATION**  
**1979 - 2001**

	Message 1	Verified	Verified	Not	Percent	False	Probability	
	Days	Hits	Misses	Forecasted	Accuracy	Alarm %	of Detection	
<b>GRD</b> "District" Era	1979	26	17	9	3	<b>65%</b>	<b>35%</b>	85%
	1980	35	23	<b>12</b>	0	66%	34%	100%
	1981	40	31	9	0	78%	23%	100%
	1982	42	34	8	0	81%	19%	100%
<b>HKA</b> "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%
<b>HMS</b> "Basin" Era	1990	30	26	4	2	87%	13%	93%
	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	<b>2</b>	0	92%	8%	100%
	1995	43	35	8	1	81%	19%	97%
	1996	<b>52</b>	<b>41</b>	11	0	79%	21%	100%
	1997	40	38	<b>2</b>	1	<b>95%</b>	<b>5%</b>	97%
	1998	34	28	6	0	82%	18%	100%
	1999	45	37	8	0	82%	18%	100%
	2000	23	19	4	1	83%	17%	95%
<b>HDR</b>	<b>2001</b>	<b>42</b>	<b>39</b>	<b>3</b>	<b>0</b>	<b>95%</b>	<b>5%</b>	<b>100%</b>
	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	433	369	64	5	85%	15%	98.5%
	Total	820	683	137	9	83%	17%	98.6%
	23 Year Average	36	30	6	0.4	83%	17%	98.6%

**Message 1 Day** = Forecast potential of urban/stream flooding due to predicted rain rates of >1.00"/hr

**Hit** = Observation of flooding or >1.00"/hr

**Miss** Non-observation of >1"/hr



#	Date	Arapco	Adco	Boco	Denco	Dougco	Jeffco	Aurora	Red Flags	WhtRg	Lak	Arv	Arapco	Adco	Boco	Denco	Dougco	Jeffco	Aurora
30	8/1	M-2/1 HIT	M-2/1 HIT	M-2/1 MISS	M-2/1 HIT	M-2/1 MISS	M-2/1 HIT	M-2/1 MISS					HIT	HIT		HIT		HIT	
31	8/2	M-2 HIT	M-2 MISS	M-2 MISS	M-2 HIT-DIA	M-2 HIT	M-2 MISS	M-2 HIT								HIT-DIA	HIT		HIT
32	8/6	HIT	HIT	M-2 MISS	HIT	M-2 MISS	M-2 MISS	HIT					HIT	HIT	HIT	HIT	HIT	HIT	HIT
33	8/7	MISS	HIT	M-2/1 MISS	MISS	M-2/1 MISS	M-2/1 MISS	MISS											
34	8/8	HIT	MISS	HIT	MISS	HIT	HIT	HIT											HIT
35	8/9	MISS	MISS	M-1/2 HIT	MISS	M-1/2 HIT	M-1/2 HIT	MISS		HIT	HIT	HIT			HIT			HIT	
36	8/13	HIT	HIT	MISS	HIT	HIT	HIT	HIT					HIT			HIT	HIT		HIT
37	8/14	MISS	HIT	HIT	MISS	HIT	HIT	MISS											
38	8/15	MISS	HIT	HIT	HIT	MISS	HIT	MISS											
39	8/22	MISS	HIT	MISS	MISS	HIT	HIT	MISS											
40	8/30	HIT	MISS	HIT	HIT	HIT	MISS	HIT								DIA-HIT			
41	9/14	HIT	HIT	HIT	HIT	MISS	HIT	MISS											
42	9/15	MISS	MISS	MISS	MISS	MISS	MISS	MISS											
<b>Hit/Total</b>		<b>28/41</b>	<b>31/41</b>	<b>21/40</b>	<b>27/41</b>	<b>26/40</b>	<b>26/40</b>	<b>23/41</b>		<b>4/4</b>	<b>3/3</b>	<b>6/6</b>	<b>10/10</b>	<b>8/8</b>	<b>7/7</b>	<b>12/13</b>	<b>8/8</b>	<b>7/7</b>	<b>10/10</b>
<b>% Hit</b>		<b>68</b>	<b>76</b>	<b>50</b>	<b>66</b>	<b>65</b>	<b>65</b>	<b>56</b>		<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>	<b>92</b>	<b>100</b>	<b>100</b>	<b>100</b>

MESSAGE DAY HITS: 39 OF 42 = 93%

MESSAGE 1 RED FLAG DAY HITS 13 OF 13 = 100%

CITY AND COUNTY RED FLAG HITS 75 OF 76 = 99%

COUNTY WIDE MESSAGE HITS: 181 OF 284 = 64 %

COUNTY WIDE MESSAGE HITS ON NON-BUST DAYS: 181 OF 263 = 69 %

UN FORECASTED EVENTS = 0