Photograph courtesy of Dann Cinaca.

2010
UDFCD FLASH FLOOD PREDICTION PROGRAM - ANNUAL REPORT

Submitted by
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303-927-6522

DRAFT

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1.0 Introduction

The Urban Drainage and Flood Control District (District or UDFCD) has used the forecasting and notification services of a private sector meteorologist for the Flash Flood Prediction Program (F2P2) since 1979. The services of a Private Meteorological Service (PMS) supplement the forecast and warning services of the National Weather Service (NWS) in Boulder, Colorado for the seven-county District area. This is the 32nd year the UDFCD has funded the F2P2.

The UDFCD forecast area supported by the PMS is shown in Figure 1 and contains a population of approximately 2.8 million people. The forecast area of approximately 3,000 square miles includes the upper basin areas of watercourses that flow into the District. Terrain in the forecast area varies in elevation of around 5,000 feet above sea level to as high as 10,500 feet above sea level.

A team comprised of Genesis Weather Solutions, a Highlands Ranch, Colorado based company and Skyview Weather, a Castle Rock, Colorado based company was selected as the 2010 PMS.

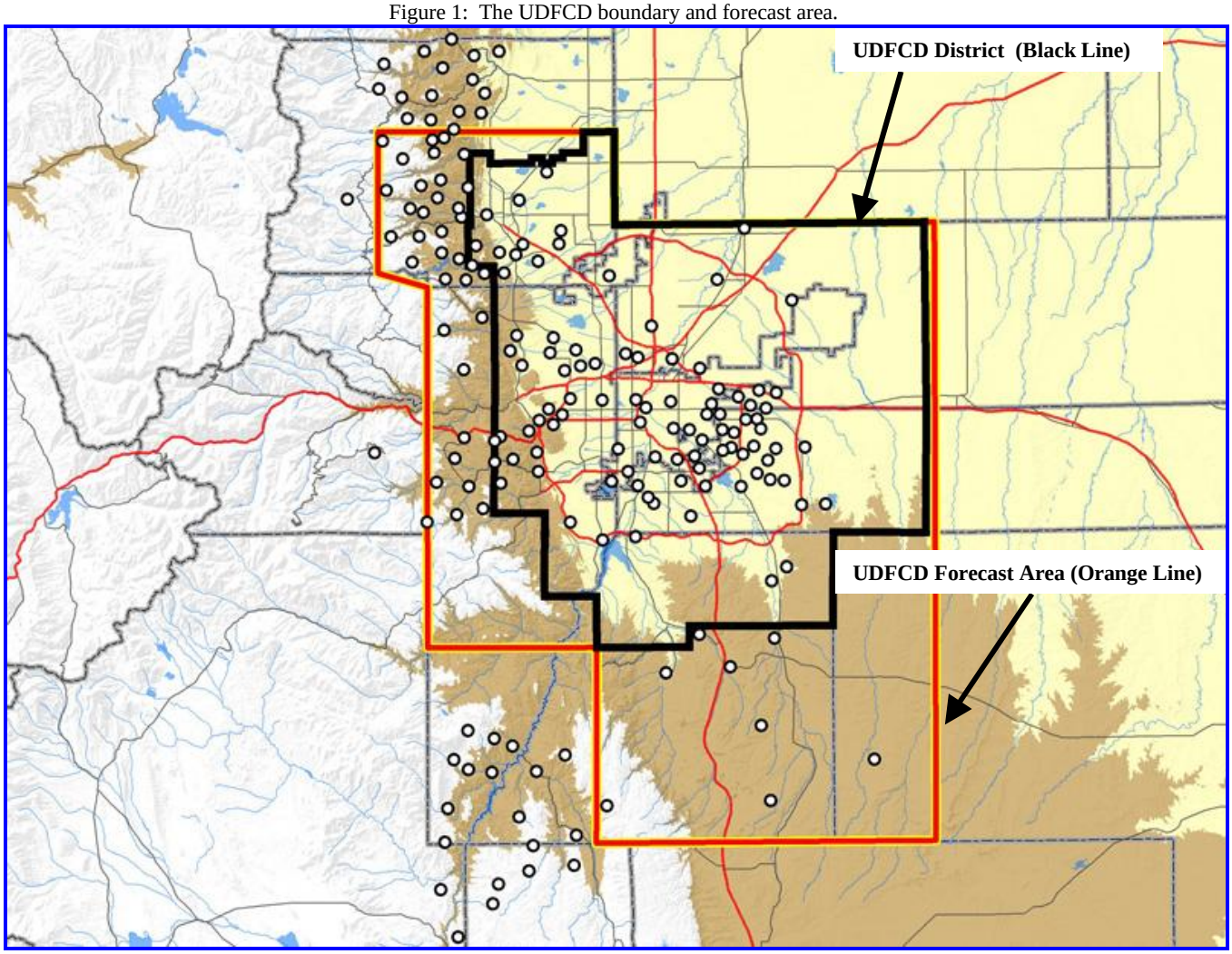
Weather prediction personnel Bryan Rappolt, Tim Tonge, Brad Simmons, Chris Anderson and Daryl Brynda provided the F2P2 prediction and notification services. Bryan Rappolt was as the Project Manager and Chief Operational Meteorologist.

Bryan Rappolt worked his 17th season on the F2P2 while Tim Tonge worked his 5th, Brad Simmons his 4th, Chris Anderson his 3rd and Daryl Brynda his 1st season.

2.0 2010 Operational Season

The 2010 F2P2 season began on April 15, 2010 and concluded on September 15; 2010 for a total of 154 operational days. Normal operational hours were from 7:00 AM to 10:00 PM. A total of **1219** man-hours were expended by the PMS providing support of the F2P2 during normal operational hours. During the time period from 10:00 PM to 7:00 AM the PMS provided an additional **211** man-hours of operational support.

Figure 1: The UDFCD boundary and forecast area.



3.0 2010 Operational Products

The F2P2 is designed to provide rainfall prediction and notification services of urban flooding and flash flooding threats to the seven District counties and the cities and towns within those counties. Direct support is provided to the District basin-specific flood warning plans, which include the Westerly Creek, Boulder Creek, Toll Gate Creek, Lena Gulch, Ralston Creek, Goldsmith/Harvard Gulch, and the Bear Creek drainage basins.

Five specific F2P2 products were produced by the PMS. The products included the Heavy Precipitation Outlook (HPO), the Internal Message Status (IMS), the Quantitative Precipitation Forecast (QPF), Storm Track (ST), and Messages. Table 1 provides a description of the first 4 products and Table 2 provides a description of Messages. Table 3 depicts the number of F2P2 products that were produced and the number of communication contacts made or received by the PMS in 2010.

Table 1. F2P2 product descriptions.

Heavy Precipitation Outlook (HPO)/Internal Message Statement (IMS). This HPO is available by 11:00 AM every day during our primary flood season as noted above. It provides a weather forecast for the District with emphasis on possible rainfall amounts and where storms are most likely to occur. When flood potentials threaten the District, the HPO will be revised and renamed "Internal Message Status" or IMS. This report will indicate the message status for each primary contact point within the District. The contact points include the counties of Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas and Jefferson, and the City of Aurora.

Quantitative Precipitation Forecast (QPF). This text product is only available on days when the rainfall potential exceeds 1.5 inches in one-hour or less. The QPF product contains more basin-specific information than the HPO or IMS, and requires some knowledge of the regional major drainage basins, streams and associated flood hazards that impact the District. Storm types, expected rainfall totals, storm duration, peak intensities and associated probabilities of occurrence are presented in this forecast product.

Storm Track (ST). This combination map/text product is a short lead-time forecast showing where a storm has formed or is forming, the approximate size of the storm(s), the direction (or track) of the storm(s), and the estimated arrival times along the forecast track(s). This is probably the most-anticipated hard copy product of the F2P2, but keep in mind that generally it is only available within an hour or less of storm impact. Also, the Storm Track is not prepared for storms that do not pose a flood threat.

All of the above products were produced and delivered to F2P2 participants using the UDFCD F2P2 Internet based Product Generator Interface (PGI). All F2P2 products were made available on the PGI in both html and pdf format.

Voice communication is the principal method of disseminating information within the F2P2. Three hundred and thirty (**330**) telephone contacts were made to F2P2 communication points by the PMS.

Table 2: Message definitions.

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT FLASH FLOOD PREDICTION PROGRAM (F2P2) MESSAGE DEFINITIONS

MESSAGE 1 ***(Street Flood Advisory)***

This advisory message is to inform key people that weather conditions are such that "nuisance" or low impact flooding could develop later in the day. Streets, low-lying areas, normally dry gulches, small urban streams, and recreational trails located along small drainage channels are areas most likely to be affected. Mud/debris flows and rockslides are the primary concern for the mountains and foothills. It will be issued by PMS after consultations with NWS. If PMS considers the threat imminent, the message will be identified as a **RED FLOOD ALERT (RFA)**.

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

This advisory message is to inform key people that either a Flash Flood Watch has been issued by NWS or PMS believes that weather conditions are such that a life-threatening flash flood may occur later in the day. Significant stream flooding and property damage is possible. PMS will add any additional information that is available.

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

This warning message will be issued to inform key people that a Flash Flood Warning has been issued by NWS or PMS feels that a life-threatening flash flood is imminent. Significant stream flooding and property damage is expected. PMS will add any additional information that is available. This warning message should be disseminated as quickly as possible.

MESSAGE UPDATE

This message will be used by PMS to update any of the previous messages. For example, this message can be used to narrow a watch or warning area as more information becomes available, or to provide more site-specific data and direction during an event. If PMS believes that "nuisance" level flooding is imminent, the message will be identified as an **RFA** (see MESSAGE 1 above).

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

This message cancels the flood potential status. It is issued by PMS after consultation with NWS and other entities involved with direct PMS communications.

SUPPLEMENTAL: F2P2 messages are used to notify local governments of potential (MESSAGE 1 and 2) and imminent (MESSAGE 3 and **RFA**) flood threats. All F2P2 messages are designed for internal use and not intended for the general public. Standard message forms are completed by the meteorologist and sent by fax or email to designated communication fan-out points prior to making contact by telephone. Each county warning point or designated recipient follows their respective protocol for subsequent dissemination of messages.

An **RFA** is used when PMS believes that a "nuisance" flooding rainstorm is imminent and expected to primarily impact streets, low-lying areas, creek-side trails, etc. This type of flooding is generally considered a low risk to life and property. When a MESSAGE 2 is in effect, **RFA** may be used with a MESSAGE UPDATE to indicate imminent low impact flooding that does not warrant a MESSAGE 3. When a MESSAGE 3 is in effect, **RFA** may be used with a MESSAGE UPDATE when an approaching storm is expected to cause low impact flooding outside the warning area. Due to the short lead-time nature of the **RFA**, it should be disseminated as quickly as possible.

For Boulder County only, MESSAGE letters **A, B, C and D** are used to avoid confusion with operational "MODE" Numbers 1-4. All other jurisdictions use MESSAGE numbers **1, 2, 3 and 4** respectively.

ABBREVIATIONS: NWS...National Weather Service PMS...Private Meteorological Service

Table 3: 2010 product/communication summary.

Product/Communication	**Number**
Heavy Precipitation Outlook (HPO)	165
Messages and Red Flood Alerts	257
Internal Message Status (IMS)	91
Basin-Specific Quantitative Precipitation Forecasts (QPF)	35
Storm Tracks (ST)	108
PMS Initiated Telephone Contacts	330
F2P2 Participant Initiated Telephone Contacts	22
Total	**1,008**

One hundred sixty five (**165**) emails identifying daily Message potential were disseminated to F2P2 participants.

4.0 2010 Message Statistics

The primary service provided to F2P2 participants is early prediction and notification of the potential for flash flooding, urban and small stream flooding, and locally heavy rainfall events that can initiate nuisance flooding. The PMS indicated the potential for these events in a series of products issued to F2P2 participants by phone, facsimile, email and Internet.

4.1 Message Verification

A Message day is defined as any day in which a Message 1, Message 2 or Message 3 is issued based on the criteria depicted in Table 4. Messages were issued on **36** days during the 2010 F2P2 between April 15, 2010 and September 15, 2010. Of the **36** Message days **33** days had Message 1's or a combination of Message 1's and Message 2's. There were **3** days where only Message 2's were issued. Of the **33** Message 1 days **30** of these days had at least one Message verify, based on the criteria listed in Table 4. The result was a **91%** verification rate of Message 1 days on a District-wide basis.

Table 5 depicts the number of Message 1 days and the number of Message 1's issued and verified for each month of the 2010 F2P2.

Table 4: Message Criteria.

Message 1 "Nuisance Flood Advisory" Criteria (Boulder County Message A)
• **Message-1** (Street or gutter flooding): **0.50"/10 minutes or 1.00"/60 minutes**
• **Message-1** (Significant urban street and stream flooding): **1.00 to <3.00"/ 60 minutes**
• **Red Flood Alert**: Rainfall intensity: **0.50"/10 minutes or 1.00"/60 min AND occurrence is imminent**
Message 2 Flash Flood Watch Criteria (Boulder County Message B)
• Option A: National Weather Service issues a Flash Flood Watch affecting the District
• Option B: PMS predicts rainfall that will equal/exceed **3.00"/hour (No NWS Flash Flood Watch exists)**
Message 3 Flash Flood Warning Criteria (Boulder County Message C)
• Option A: National Weather Service issues a Flash Flood Warning affecting the District
• Option B: PMS issues a Flash Flood Warning for a specific District river/stream/drainageway **(No NWS Flash Flood Warning exists)**
Message 4 (Boulder County Message D)
• Message 4 ("All Clear") is issued whenever Messages are rescinded before their expiration time.

There was **1** "nearby hit" days where a Message 1 was issued for a portion of the District and Message level rainfall was not observed within the District; however Message level rainfall was observed within the "nearby hit" zone (Figure 1) outside of the District. Including "near hit' days in the Message 1 day statistics, results in a **94%** verification rate of Message 1 level rainfall being observed within or near the District on the **33** Message 1 days.

Of the **33** Message 1 days, **31** of the days had Message level rainfall observed within either the forecast area or nearby the forecast area.

There were **2** days (June 10, and June 27) where Message 1 level rainfall was observed within a portion of the District and a Message 1 was issued with short lead-time (< 30 minutes).

There were **0** days where Message 1 level rainfall was observed within a portion of the District and no Message 1 was issued by the PMS for that location.

There were **0** days where a Message 1 was issued for a portion of the District, the Message 1 was rescinded and then re-issued due a renewed threat of Message 1 level rainfall.

Table 5: Monthly Message 1 verification.

Month	Number of Message 1 Days	Verified Message 1 Days	Verifying Message 1 Days	Message 1's Issued	Verified Message 1's	Verified Message 1's
April	2	2	100%	14	14	100%
May	3	3	100%	21	12	57%
June	7	5	71%	53	26	49%
July	13	12	92%	96	57	59%
August	8	8	100%	55	40	73%
September	0	0	N/A	0	0	N/A
Total	**33**	**30**	**91%**	**239**	**149**	**62%**

A Red Flood Alert was issued when the PMS felt that there is a 90% or greater probability that Message 1 level rainfall would be observed within a portion of the District. There were a total of **18** Red Flood Alert days, of which **18** of these Red Flood Alert days verified somewhere within the District; resulting in a verification rate of **100%**.

There were **7** NWS issued Flash Flood Watch and Flood Watch days and subsequently there were **7** Message 2 days. There were **3** NWS issued Flood Watches issued for Boulder County due to the potential for flooding due to a combination of snowmelt and accumulating rainfall.

The NWS in Boulder issued **0** Flash Flood Warnings for the District.

4.2 County/City Message Statistics

Each Message issued within the F2P2 is disseminated to a primary contact point in which flooding potential has been predicted. The counties and cities that receive Messages are listed in Table 6.

A Message is verified as a "hit" when a rainfall event meeting the Message criteria depicted in Table 4 is observed in the District-portion of that City/County or in the drainage area of a watercourse that flows into the jurisdiction. Table 6 contains the results of the Message 1 verification on a City/County basis.

Verification of Message 1's issued for the City of Aurora and Denver International Airport (DIA) are included in the County statistics because Aurora is a primary contact point and Denver County is segmented into two sections which includes the City and County of Denver and northeast Denver County, DIA. The cities of Arvada, Lakewood and Wheat Ridge receive Message 1 notifications from Jefferson County dispatch, but also receive Red Flood Alerts, Message 2's and Message 3's directly from the PMS.

Table 6: County/City Message 1 Verification.

Primary Message Contact Points	Message 1's Issued	Message 1 Hits	Message 1 Hits	Red Flood Alerts Issued	Red Flood Alert Hits	Message Red Flood Alert Hits	Events Missed	Event < 30 min Lead Time
Adams	27	20	74%	21	21	100%	0	1
Arapahoe	29	20	69%	13	13	100%	0	0
Aurora	29	19	66%	13	13	100%	0	0
Boulder	28	18	64%	6	6	100%	0	0
Broomfield	23	9	39%	4	3	75%	0	0
Denver	24	15	63%	3	3	100%	0	0
DIA	23	12	52%	10	10	100%	0	0
Douglas	27	16	59%	10	10	100%	0	1
Jefferson	29	20	69%	7	7	100%	0	0
TOTAL	**239**	**149**	**62%**	**87**	**86**	**99%**	**0**	**2**
Red Flood Alert Contact Points	**Message 1's Issued**	**Message 1 Hits**	**Message 1 Hits**	**Red Flood Alerts Issued**	**Red Flood Alert Hits**	**Message Red Flood Alert Hits**	**Events Missed**	**Event < 30 min Lead Time**
Arvada	N/A	N/A	N/A	2	2	100%	0	0
Lakewood	N/A	N/A	N/A	2	2	100%	0	0
Wheat Ridge	N/A	N/A	N/A	3	3	100%	0	0
TOTAL	**N/A**	**N/A**	**N/A**	**7**	**7**	**100%**	**0**	**0**
GRAND TOTAL	**239**	**149**	**62%**	**94**	**93**	**99%**	**0**	**2**

A total of **239** Message 1's were issued to the 8 primary contact points within the District. Of the **239** Message 1's that were issued, **149** verified, resulting in a verification rate of **62 %**. Adams County had the highest verification rate, **74 %**, while Broomfield County had the lowest verification rate, **39 %**.

A total of **94** Red Flood Alerts were issued. Of the **94** Red Flood Alerts issued, **93** of them verified, resulting in a verification rate of **99 %**.

The PMS prepared a cloud–to-ground lightning table that covered the forecast period of April 15, 2010 through September 15, 2010. Archived cloud–to-ground lightning data was reviewed for each of the 154 operational days of the F2P2. The table shows that of the 154 days, **71** of the days (**46%** of the total days) cloud–to-ground lightning was observed within or near the District. Of the **71** "thunderstorm days" within the District **51%** of the days had Messages issued for them.

5.0 Notable Weather Events

The 2010 F2P2 season was more or less normal with respect to the number of thunderstorms, Message days and severe weather that was observed within the District. Some of the notable weather events observed during the 2010 F2P2 are described below:

May 26th: Multiple severe thunderstorms produce heavy rainfall and large hail across the northern portion of the District. The combination of accumulating hail (Figure 2) and short duration heavy rainfall resulted in flooding of streets and low lying areas across the northern Denver Metropolitan area. Property damage due the hail was approximately 70 million dollars.

Figure 2: CDOT plows hail from a roadway in Thornton, Colorado on May 26th, 2010. (Courtesy of Tony Laubach).

July 4, 2010: An upper level storm system brought unseasonably cool and very wet weather to the District on Independence Day. Multiple thunderstorms produce heavy rainfall across the entire District with the highest rainfall amounts observed in the Cities of Aurora, Centennial and Parker. Rainfall amounts ranged from 0.50" to as much as 2.50". The widespread rainfall and cool temperatures put a damper on most fireworks displays. The active weather resulted in 20 Red Flood Alerts to be issued along with 10 Storm Tracks.

August 9th: A slow moving thunderstorm produced heavy rainfall of 1.00 to 1.50”” in 15-25 minutes across northeast Jefferson County and western Adams County. Significant street flooding resulted (Figure 3) across portions of Arvada and Westminster.

Figure 3: Street flooding at 80th and Chase in Arvada, Colorado on August 9, 2010. (Courtesy of Tony Laubach).

6.0 Recommendations

Storm Track

It is recommended that the GIS-based stormtrack application used to produce Storm Track products within the program be upgraded. Currently it is rather cumbersome to add text, shapes and lines, which are all used to create the product. It is felt that the current application could be improved in how text, shapes and lines are added to the product, allowing the user to produce and disseminate the Storm Track product in a more efficient and timelier manor.