2015
UDFCD FLASH FLOOD PREDICTION PROGRAM - ANNUAL REPORT

Submitted by
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303-927-6522

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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 37th 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 Colorado based company and Skyview Weather, a Colorado based company was selected as the 2015 PMS.

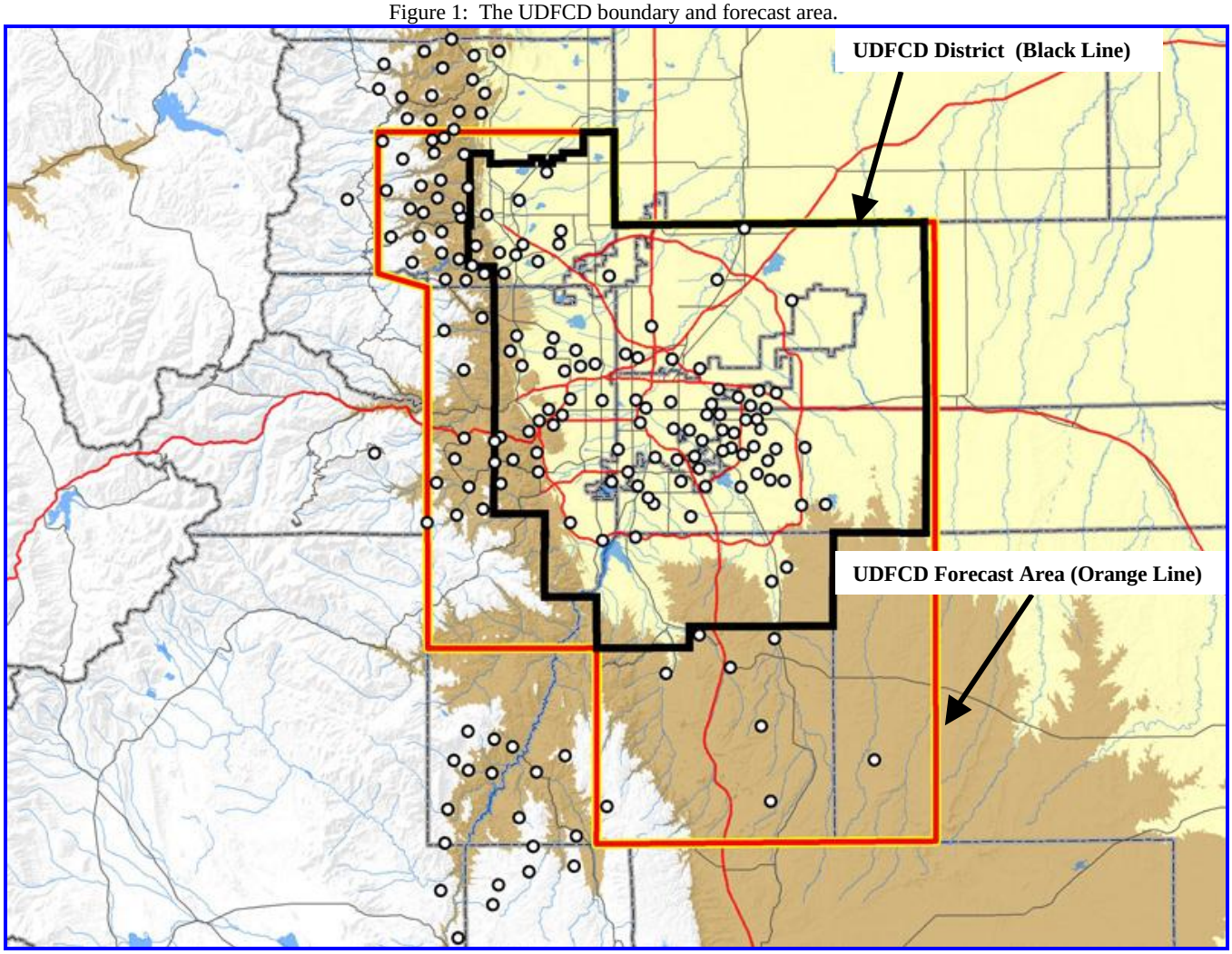
Weather prediction personnel Bryan Rappolt, Tim Tonge, Brad Simmons, Alan Smith, and Andrew Muniz, provided the F2P2 prediction and notification services. Bryan Rappolt was the Project Manager and Chief Operational Meteorologist for the program.

Bryan Rappolt worked his 22nd season on the F2P2 while Tim Tonge worked his 10th, Brad Simmons his 9th, Alan Smith his 3rd and Andrew Muniz his 2nd season.

2.0 2015 Operational Season

The 2015 F2P2 season began on May 1st, 2015 and concluded on September 30th, 2015 for a total of **152** operational days. The operational period was changed this year to start on May 1st, 2015 and ended on September 30th, 2015. Although routine daily forecast service did not begin until May 1st, the PMS was prepared to issue messages between April 15th and April 30th. In the past the season began April 15th and ended on September 15th. Normal operational hours were from 700 am to 1000 pm. A total of **1663** man-hours were expended by the PMS providing support of the F2P2 during normal operational hours. During the time period from 1000 pm to 700 am the PMS provided an additional **311** man-hours of operational support.

Figure 1: The UDFCD boundary and forecast area.



3.0 2015 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 four 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 2015.

Table 1. F2P2 product descriptions.

Heavy Precipitation Outlook (HPO)/Internal Message Statement (IMS). This HPO is available by 1100 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 one of the most-anticipated products 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, with exception of the Storm Track product which is only available in PDF format.

Voice communication is the principal method of disseminating information within the F2P2. Two hundred thirty six (**236**) telephone contacts were made to F2P2 communication points by the PMS in 2015.

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

MESSAGE 1 (*Street Flooding Potential*)

This message is to inform key people that weather conditions are such that low impact street flooding may occur later in the day. Streets, low-lying areas, normally dry gulches, small urban streams, and recreational trails located along streams are areas most likely to be affected. Mud, debris and rock slides are the primary concern in the mountains and foothills. This product is comparable to a **NWS Hazardous Weather Outlook** concerning heavy rainfall.

MESSAGE 1 (Low Impact Flooding)

This message informs key people that low impact flooding is either imminent or occurring. Streets, low-lying areas, normally dry gulches, small urban streams, and recreational trails located along streams are areas most likely to be affected. Mud, debris and rock slides are the primary concern in the mountains and foothills. This product is comparable to a **NWS Flood Advisory**.

MESSAGE 2 (*Flash Flood Watch*)

This message is to inform key people that a Flash Flood Watch has been issued by NWS indicating 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 available.

MESSAGE 3 (*Flash Flood Warning*)

This 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 or occurring. Significant stream flooding and property damage is expected. PMS will add any additional information 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.

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 (MESSAGES 1-Street Flooding Potential and MESSAGE 2) and imminent (MESSAGE 1- Low Impact Flooding and MESSAGE 3) flood threats. All F2P2 messages are designed for internal use and not intended for the general public. Standard message forms completed by the meteorologist are sent by fax or email to designated communication fan-out points prior to making contact by telephone. Each county warning point or designated recipient should follow their respective protocol for subsequent dissemination of messages.*

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

Table 2: Message definitions

Table 3: 2015 product/communication summary.

Product/Communication	**Number**
Heavy Precipitation Outlook (HPO)	168
Messages and LIF's	787
Internal Message Status (IMS)	128
Basin-Specific Quantitative Precipitation Forecasts (QPF)	47
Storm Tracks (ST)	97
PMS Initiated Telephone Contacts	236
F2P2 Participant Initiated Telephone Contacts	68
Total	**1,531**

Three hundred thirty-two (**332**) short message service (SMS) emails identifying Message potential were disseminated to F2P2 participants.

4.0 2015 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 low impact 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 **62** days during the 2015 F2P2 between May 1st and September 30th. There were **3** days of the **62** Message days where only Message 2's were issued. There were **2** days of the **62** Message days where a combination of Message 2's and Message 1's were issued for portions of the District. Thirteen (**13**) Message 3's were issued on 5 different days. There was a **100%** verification rate of Message days on a District-wide basis.

Table 5 depicts the number of Message days and the number of Messages issued and verified for each month of the 2015 F2P2.

Table 4: Message Criteria.

Message 1 "Low Impact Flood Advisory" Criteria
• **Message-1** (Street or gutter flooding): **0.5"/10 minutes or 1"/60 minutes**
• **Message-1** (Significant urban street and stream flooding): **1" to <3"/ 60 minutes**
• **Low Impact Flooding (LIF)**: Rainfall intensity: **0.5"/10 minutes or 1"/60 min AND occurrence is imminent**
Message 2 Flash Flood Watch Criteria
• Option A: National Weather Service issues a Flash Flood Watch affecting the District
• Option B: PMS predicts rainfall that will equal/exceed **3"/hour (No NWS Flash Flood Watch exists)**
Message 3 Flash Flood Warning Criteria
• 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
• Message 4 ("All Clear") is issued whenever Messages are rescinded before their expiration time.

Table 5: Monthly Message verification.

Month	Number of Message Days	Verified Message Days	% Verifying Message Days	Messages Issued	Verified Messages	% Verified Messages
May	**16**	**16**	**100%**	**153**	**116**	**76%**
June	**18**	**18**	**100%**	**159**	**112**	**70%**
July	**14**	**14**	**100%**	**131**	**79**	**60%**
August	**13**	**13**	**100%**	**111**	**55**	**50%**
September	**1**	**1**	**100%**	**10**	**5**	**50%**
Total	**62**	**62**	**100%**	**564**	**367**	**65%**

There was **2** days (August 10th and September 29th) where Message 1 level rainfall was observed within a portion of the District and no Message was issued. On these 2 days Message 1's were issued after a rainfall rate alarms were activated, resulting in zero lead-time for the jurisdiction experiencing the heavy rainfall.

The **62** Message days observed is the highest number of Message days in the 37 year history of the F2P2. The second highest number of Message days observed in a season is **61**, which occurred in 2014.

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 verification on a City and County basis.

A Low Impact Flood (LIF) product is issued when the PMS felt that there is a **90%** or greater probability that Message level rainfall would be observed within a portion of the District. There were a total of **31** LIF days, of which all **31** of these LIF days verified; resulting in a verification rate of **100%**.

Verification of Messages 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 Four Mile burn area was added as a new forecast zone due to its high potential for flooding from minimal rainfall caused by a wildfire in the fall of 2010.

The cities of Arvada, Lakewood and Wheat Ridge receive Message 1 notifications from Jefferson County dispatch, but also receive LIFs, Message 2's and Message 3's directly from the PMS.

Table 6: County/City Message Verification.

Primary Message Contact Points	Messages Issued	Message Hits	% Message Hits	LIFS Issued	LIF Hits	% LIF Hits	Events Missed	Event < 30 min Lead Time
Adams	**57**	**44**	**77%**	**22**	**22**	**100%**	**0**	**0**
Arapahoe	**59**	**38**	**64%**	**24**	**24**	**100%**	**0**	**1**
Aurora	**59**	**37**	**63%**	**24**	**24**	**100%**	**0**	**1**
Boulder	**54**	**28**	**52%**	**12**	**12**	**100%**	**0**	**0**
Broomfield	**51**	**17**	**33%**	**12**	**12**	**100%**	**0**	**0**
Denver	**55**	**36**	**66%**	**22**	**22**	**100%**	**0**	**1**
DIA	**55**	**36**	**66%**	**16**	**16**	**100%**	**0**	**0**
Douglas	**61**	**49**	**80%**	**17**	**17**	**100%**	**0**	**0**
Jefferson	**61**	**47**	**77%**	**17**	**17**	**100%**	**0**	**1**
Four Mile Burn	**52**	**35**	**67%**	**10**	**10**	**100%**	**0**	**0**
TOTAL	**564**	**367**	**65%**	**176**	**176**	**100%**	**0**	**4**
LIF Contact Points	**Messages Issued**	**Message Hits**	**% Message Hits**	**LIFS Issued**	**LIF Hits**	**% LIF Hits**	**Events Missed**	**Event < 30 min Lead Time**
Arvada	N/A	N/A	N/A	**10**	**10**	**100%**	**0**	**0**
Lakewood	N/A	N/A	N/A	**12**	**12**	**100%**	**0**	**1**
Wheat Ridge	N/A	N/A	N/A	**10**	**10**	**100%**	**0**	**1**
TOTAL	**N/A**	**N/A**	**N/A**	**32**	**32**	**100%**	**0**	**2**
GRAND TOTAL	**564**	**367**		**208**	**208**	**100%**	**0**	**6**

A total of **564** Messages were issued within the District. Of the **564** Messages that were issued, **367** Messages verified, resulting in a verification rate of **65%**. Douglas County had the highest verification rate, **80%**, while Broomfield County had the lowest verification rate, **33%**.

A total of **208** LIF's were issued. Of the **208** LIF's issued, **208** of the LIF's verified, resulting in a verification rate of **100%**.

The PMS identified cloud–to-ground lightning days that covered the forecast period of May 1st, 2015 through September 30th, 2015. A cloud–to-ground lightning day was identified as any day that a thunderstorm cell produced cloud to ground lightning within the District. Archived cloud–to-ground lightning data was reviewed for each of the **152** operational days of the F2P2. Of the **152** operational days, **103** of the days (**67%** of the total days) cloud–to-ground lightning was observed within the District. Of the **103** "thunderstorm days" within the District, **60%** of the days had Messages issued.

5.0 Notable Weather Events

The 2015 F2P2 season was well above normal in the number of thunderstorms (103 thunderstorm days from May 1st through September 30th) and Message-days but no "signature" flood events occurred other than sustained high flows along the Platte River due to an unusually wet May and June. There were however, many days where heavy rainfall initiated significant urban flooding and low scale flash flooding of District watercourses. Below are a summary of some of these days.

May 4th and 5th: A large and slow moving upper level low pressure system would impact the District with heavy rain both days as the system slowly moved through the state. Rainfall totals of 2-4 inches were observed across portions of the District over the two day period. The heavy rain combined with snowmelt to initiate flooding on many District watercourses. Upper limit stream gauge alarms were activated on twelve different watercourses across the District.

Figure 2: Flooding on the South Platte River at Confluence Park on May 5th, 2015.

June 11th: Slow moving, strong thunderstorms moved through potions of the District during the afternoon and evening hours on June 11th initiating heavy rain and flooding across the central portion of the District. Message 3's and Flash Flood Warnings were issued for Douglas and Arapahoe Counties including the City of Aurora. Rainfall amounts ranged from 2-3.5 inches across the Flash Flood warned area.

Upper limit stream gauge alarms were activated on eight different watercourses across the District. Rainfall rate alarms were activated on fourteen ALERT rain gauges.

June 24th: Slow moving, strong and severe thunderstorms impacted the District during the afternoon and evening hours on June 24th producing excessive runoff and flooding for the central portion of the District. Message 3's and Flash Flood Warnings were issued for Adams, Arapahoe and Denver Counties including the City of Aurora. Rainfall amounts ranged from 1-4 inches. The South Platte River at 19th Street recorded the 5th highest peak on record during from this event.

Upper limit stream gauge alarms were activated on nine different watercourses across the District. Rainfall rate alarms were activated on twenty-six ALERT rain gauges.

Figure 3: Severe urban flooding in Denver County on June 24th, 2015.

August 10th: Deep low level moisture was in place due to thunderstorm outflow boundaries that that pushed through overnight. An area of thunderstorms developed over the central portion of the District and moved slowly to the southeast. Training thunderstorm cells moved over western Arapahoe County and northern Douglas County. Message 3's and Flash Flood Warnings was issued for western Arapahoe County and northern Douglas County. Rainfall amounts ranged from 2-4 inches across the Flash Flood warned area.