

**2016**  
**UDFCD FLASH FLOOD PREDICTION**  
**PROGRAM - ANNUAL REPORT**

**Submitted by**  
**Skyview Weather**



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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 38<sup>th</sup> 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.

Skyview Weather, a Colorado based company was selected as the 2016 PMS.

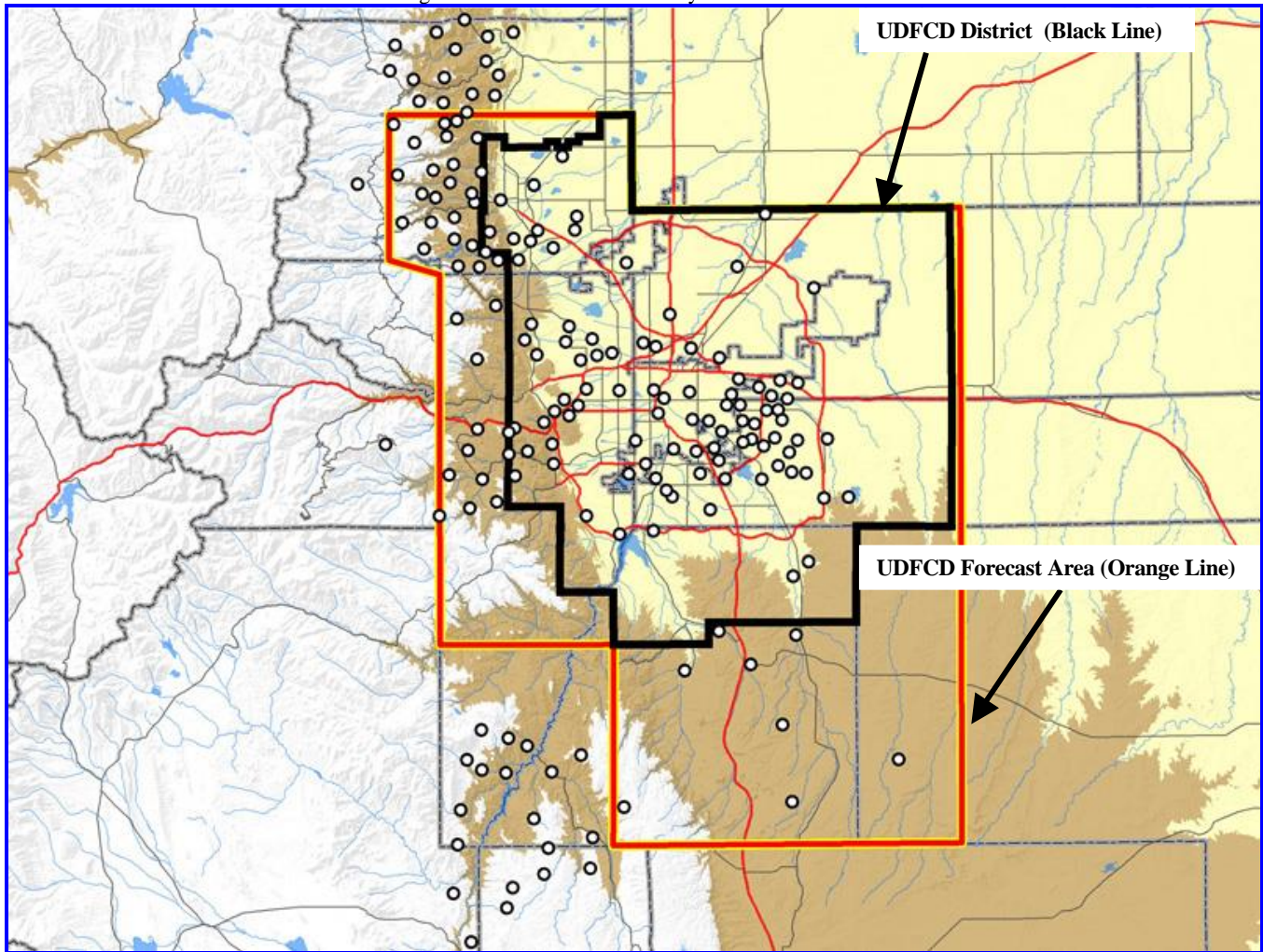
Weather prediction personnel Tim Tonge, Brad Simmons, Alan Smith, Bryan Rappolt, Justin Brooks, Nick Barlow and Ryan Matoush provided the F2P2 prediction and notification services. Brad Simmons was the Project Manager for the program.

Bryan Rappolt worked his 23<sup>rd</sup> season on the F2P2 while Tim Tonge worked his 11<sup>th</sup>, Brad Simmons his 10<sup>th</sup>, Alan Smith his 4<sup>th</sup> season. It was the first year working the program for Justin Brooks, Nick Barlow and Ryan Matoush.

## 2.0 2016 Operational Season

The 2016 F2P2 season began on May 1<sup>st</sup>, 2016 and concluded on September 30<sup>th</sup>, 2016 for a total of **152** operational days. Although routine daily forecast service did not begin until May 1<sup>st</sup>, the PMS was prepared to issue messages between April 15<sup>th</sup> and April 30<sup>th</sup>. Normal operational hours were from 700 am to 1000 pm. A total of **1542** 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 **81** man-hours of operational support.

Figure 1: The UDFCD boundary and forecast area.



### 3.0 2016 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 2016.

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 of 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 and nineteen (219) telephone contacts were made to F2P2 communication points by the PMS in 2016.



## 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: 2016 product/communication summary.

<b>Product/Communication</b>	<b>Number</b>
Heavy Precipitation Outlook (HPO)	175
Messages and LIF's	408
Internal Message Status (IMS)	117
Basin-Specific Quantitative Precipitation Forecasts (QPF)	26
Storm Tracks (ST)	91
PMS Initiated Telephone Contacts	219
F2P2 Participant Initiated Telephone Contacts	7
<b>Total</b>	<b>1043</b>

#### **4.0 2016 Message Statistics**

The primary services provided to F2P2 participants include 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 **42** days during the 2016 F2P2 between May 1<sup>st</sup> and September 30<sup>th</sup>. There was **1** day of the **42** Message days where only Message 2's were issued. There was **1** day of the **42** Message days where a combination of Message 2's and Message 1's were issued for portions of the District. Seven (**7**) Message 3's were issued on **2** different days. There was a **98%** 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 2016 F2P2.

Table 4: Message Criteria.

<b>Message 1 “Low Impact Flood Advisory” Criteria</b>
<ul style="list-style-type: none"> <li>• <b>Message-1</b> (Street or gutter flooding): <b>0.5"/10 minutes or 1"/60 minutes</b></li> <li>• <b>Message-1</b> (Significant urban street and stream flooding): <b>1” to &lt;3”/ 60 minutes</b></li> <li>• <b>Low Impact Flooding (LIF)</b>: Rainfall intensity: <b>0.5"/10 minutes or 1"/60 min AND occurrence is imminent</b></li> </ul>
<b>Message 2 Flash Flood Watch Criteria</b>
<ul style="list-style-type: none"> <li>• Option A: National Weather Service issues a Flash Flood Watch affecting the District</li> <li>• Option B: PMS predicts rainfall that will equal/exceed <b>3"/hour (No NWS Flash Flood Watch exists)</b></li> </ul>
<b>Message 3 Flash Flood Warning Criteria</b>
<ul style="list-style-type: none"> <li>• Option A: National Weather Service issues a Flash Flood Warning affecting the District</li> <li>• Option B: PMS issues a Flash Flood Warning for a specific District river/stream/drainageway (<b>No NWS Flash Flood Warning exists</b>)</li> </ul>
<b>Message 4</b>
<ul style="list-style-type: none"> <li>• Message 4 (“All Clear”) is issued whenever Messages are rescinded before their expiration time.</li> </ul>

Table 5: Monthly Message verification.

<b>Month</b>	<b>Number of Message Days</b>	<b>Verified Message Days</b>	<b>% Verifying Message Days</b>	<b>Messages Issued</b>	<b>Verified Messages</b>	<b>% Verified Messages</b>
<b>May</b>	<b>6</b>	<b>6</b>	<b>100%</b>	<b>51</b>	<b>38</b>	<b>75%</b>
<b>June</b>	<b>13</b>	<b>13</b>	<b>100%</b>	<b>92</b>	<b>51</b>	<b>55%</b>
<b>July</b>	<b>10</b>	<b>9</b>	<b>90%</b>	<b>82</b>	<b>52</b>	<b>63%</b>
<b>August</b>	<b>11</b>	<b>11</b>	<b>100%</b>	<b>88</b>	<b>41</b>	<b>47%</b>
<b>September</b>	<b>2</b>	<b>2</b>	<b>100%</b>	<b>6</b>	<b>3</b>	<b>50%</b>
<b>Total</b>	<b>42</b>	<b>41</b>	<b>98%</b>	<b>319</b>	<b>185</b>	<b>58%</b>

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

The **42** Message days observed is above average for the number of Message days in the 38-year history of the F2P2. The average number of Message days over the 38-year history of the F2P2 is **37**.



## 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 was a total of **17** LIF days, of which all **17** 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	30	20	67%	9	9	100%	0	0
Arapahoe	33	19	58%	10	10	100%	0	0
Aurora	31	14	45%	8	8	100%	0	0
Boulder	32	16	50%	6	6	100%	0	0
Broomfield	28	9	32%	4	2	50%	0	0
Denver	31	17	55%	7	7	100%	0	0
DIA	30	20	67%	6	6	100%	0	0
Douglas	38	28	74%	10	10	100%	0	0
Jefferson	38	30	79%	10	10	100%	0	0
Four Mile Burn	28	12	43%	6	6	100%	0	0
<b>TOTAL</b>	<b>319</b>	<b>185</b>	<b>58%</b>	<b>72</b>	<b>70</b>	<b>97%</b>	<b>0</b>	<b>0</b>
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	5	5	100%	0	0
Lakewood	N/A	N/A	N/A	6	6	100%	0	0
Wheat Ridge	N/A	N/A	N/A	6	6	100%	0	0
<b>TOTAL</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>17</b>	<b>17</b>	<b>100%</b>	<b>0</b>	<b>0</b>
<b>GRAND TOTAL</b>	<b>319</b>	<b>185</b>	<b>58%</b>	<b>89</b>	<b>87</b>	<b>98%</b>	<b>0</b>	<b>0</b>

A total of **319** Messages were issued within the District. Of the **319** Messages that were issued, **185** Messages verified, resulting in a verification rate of **58%**. Jefferson County had the highest verification rate, **79%**, while Broomfield County had the lowest verification rate, **32%**.

A total of **89** LIF's were issued. Of the **89** LIF's issued, **87** of the LIF's verified, resulting in a verification rate of **98%**.

The PMS identified cloud-to-ground lightning days that covered the forecast period of May 1<sup>st</sup>, 2016 through September 30<sup>th</sup>, 2016. A cloud-to-ground lightning day was identified as any day that a thunderstorm cell produced cloud to ground lightning or multiple cloud-to-cloud strikes within the District forecast area. Archived cloud-to-ground/cloud-to-cloud lightning data was reviewed for each of the **152** operational days of the F2P2. Of the **152** operational days, **100** of the days (**66%** of the total days) cloud-to-ground lightning or multiple cloud-to-cloud lightning strikes were observed within the District. Of the **100** "thunderstorm days" within the District forecast area, **42%** of the days had Messages issued.

## **5.0 Notable Weather Events**

The 2016 F2P2 season was slightly above normal in Message days, but no "signature" flood events occurred. However, there were several days in which heavy rainfall initiated significant urban flooding over portions of the District and low-scale flash flooding of District watercourses. Below is a summary of some of these days.

**June 6<sup>th</sup>:** Increasing moisture through the day in combination with daytime heating and an upper level disturbance initiated multiple strong to severe thunderstorms across the District. Thunderstorms produced heavy rainfall, accumulating hail, and gusty winds in excess of 50mph, resulting in 9 severe thunderstorm warnings issued by the NWS and 2 aerial flood advisories. Multiple rain alarms were triggered with 1" to nearly 3" of rain reported in the District, with the heaviest amounts over Douglas County in the Highlands Ranch area and along the Weld/Adams County line from Brighton to roughly Lochbuie.

**June 13<sup>th</sup>:** A trough of low pressure moving across Colorado, combined with abundant low level moisture resulting in multiple rounds of strong to severe thunderstorms across the District. Thunderstorms would favor western, southern, and eastern areas, producing large hail, heavy rainfall, and gusty winds, resulting in 4 severe thunderstorm warnings, 1 tornado warning, and 1 aerial flood advisory issued by the NWS. Multiple rainfall alarms were triggered with the heaviest rainfall occurring over Northeast Douglas County, where amounts of 1" to 2.5" occurred. Heavy rains also occurred over portions of Central Jefferson County and Eastern Adams and Arapahoe Counties (just east of C-470) where amounts ranged from 0.5-1.3".

**July 19<sup>th</sup>:** Monsoonal moisture streamed into the District from the southwest with PW values between 1.1-1.2", fueling a strong, slow-moving thunderstorm that produced heavy rainfall over a large area of the Denver metro area south of I-70 during the late afternoon and early evening hours. Rainfall rates were around 1" in 15-20 minutes under the heaviest downpours, with observed rainfall amounts topping out in the 1.3-1.6" range from UDFCD gauges and CoCoRaHs weather spotters, but some areas may have had up to 2" in West Arapahoe and South Denver Counties. This storm prompted a NWS Flash Flood Warning for Denver and Arapahoe Counties, along with a small portion of Adams County.

**August 30<sup>th</sup>:** Moisture increased across NE Colorado as a weakening upper level low pressure system tracked across the area, and an outflow boundary from northeast plains convection initiated strong, slow-moving thunderstorms across much of the District during the evening hours, initially east of I-25, but

eventually expanding westward. Very slow to stationary storm motions resulted in prolonged periods of moderate to heavy rainfall. The heaviest rains were observed over Jefferson, Boulder, Adams, Denver, and Arapahoe Counties, with higher end totals of 1-2” or more, and an isolated area west of Boulder where a 3” UDFCD gauge hit was measured. The stronger cells produced NWS Flash Flood Warnings for small portions of Adams and Boulder Counties, and numerous aerial flood advisories were also issued by the NWS for other counties.