



**2017**  
**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 39<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.

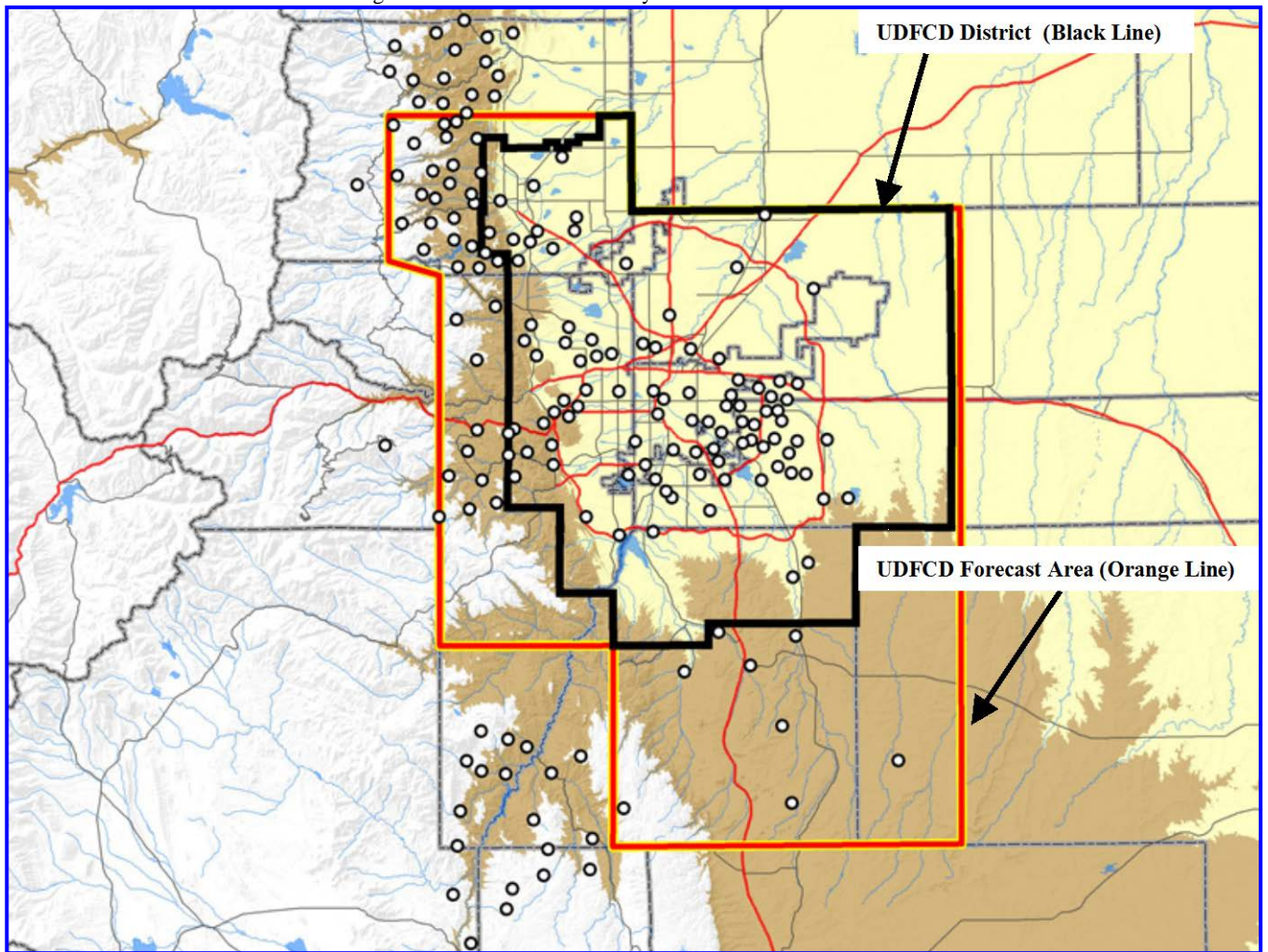
Skyview Weather, a Colorado based company was selected as the 2017 PMS.

Weather prediction personnel Tim Tonge, Brad Simmons, Alan Smith, Nick Barlow and Justin Brooks provided the F2P2 prediction and notification services. Brad Simmons was the Project Manager for the program. Tim Tonge worked his 12<sup>th</sup>, Brad Simmons his 11<sup>th</sup> season, Alan Smith his 5<sup>th</sup> season, Nick Barlow his 2<sup>nd</sup> season, and Justin Brooks his 2<sup>nd</sup> season.

## 2.0 2017 Operational Season

The 2017 F2P2 season began on May 1<sup>st</sup>, 2017 and concluded on September 30<sup>th</sup>, 2017 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 7:00 am to 10:00 pm. A total of **1703** 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 **57** man-hours of operational support.

Figure 1: The UDFCD boundary and forecast area.



### 3.0 2017 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 2017.

Table 1. F2P2 product descriptions.

**Heavy Precipitation Outlook (HPO)/Internal Message Status (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 continues to be the principal method of disseminating information within the F2P2 once LIF updates are issued. Email and ham-radio communication are secondary and tertiary forms of communication and are not logged at this time. Two hundred and nineteen (219) telephone contacts were made to F2P2 communication points by the PMS in 2017.



## 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: 2017 product/communication summary.

<b>Product/Communication</b>	<b>Number</b>
Heavy Precipitation Outlook (HPO)	170
Messages and LIF's	356
Internal Message Status (IMS)	113
Basin-Specific Quantitative Precipitation Forecasts (QPF)	25
Storm Tracks (ST)	52
PMS Initiated Telephone Contacts	127
F2P2 Participant Initiated Telephone Contacts	5
Non Message Emails and Ham Radio Interactions are NOT Included	NA
<b>Total</b>	<b>848</b>

#### **4.0 2017 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, SMS text message, facsimile, email and Internet.

##### **4.1 Message Verification**

A Message period is defined as any time period in which a Message 1, Message 2 or Message 3 is issued based on the criteria depicted in Table 4. Messages were issued on 40 days during the 2017 F2P2 season between May 1<sup>st</sup> and September 30<sup>th</sup>. On 8/3 Message 1's were issued two times in one day, which resulted in two separate Message Periods, and a total of **41** Message periods during the season. There was **1** period of the **40** Message periods where a combination of Message 2's and Message 1's were issued for portions of the District (Arapahoe, Douglas and Jefferson Counties on 7/29). Only 1 Message 3 was issued for Douglas County on 7/26. There was a **98%** verification rate of Message periods on a District-wide basis where at least 1 of the 7 Counties experienced message level rainfall.

Table 5 depicts the number of Message periods and the number of Messages issued and verified for each month of the 2017 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.

Month	Number of Message Periods	Verified Message Periods	% Verifying Message Periods	Messages Issued	Verified Messages	% Verified Messages
May	6	6	100%	42	35	83%
June	6	6	100%	45	32	71%
July	14	14	100%	88	53	60%
August	13	12	92%	83	56	67%
September	2	2	100%	12	3	25%
<b>Total</b>	<b>41</b>	<b>40</b>	<b>98%</b>	<b>270</b>	<b>179</b>	<b>66%</b>

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

The **41** Message periods observed is slightly above the 38-year average for the number of Message periods in the history of the F2P2, which is **37** periods. However, the 40 Message periods observed is slightly below average for the 2007-2017 timeframe in which Skyview’s records are available, which is **43** Message periods.

Table 6: Total Number of Message Periods Compared to Average.

Month	May	June	July	August	September	Total
<b>2017</b>	<b>6</b>	<b>6</b>	<b>14</b>	<b>13</b>	<b>2</b>	<b>41</b>
<b>2007-2017 Average</b>	<b>5.8</b>	<b>9.0</b>	<b>14.1</b>	<b>11.7</b>	<b>2.7</b>	<b>43.4</b>



## 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 **20** LIF periods, of which **19** of these LIF periods verified; resulting in a verification rate of **95%**.

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 continues to be its own forecast zone due to its higher potential for flooding from less intense 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 7: 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	35	22	63%	14	12	86%	0	2
Arapahoe	38	26	68%	15	14	93%	0	3
Aurora	37	24	65%	10	9	90%	0	1
Boulder	27	15	56%	3	3	100%	0	0
<b>Four Mile Burn</b>	27	8	30%	1	1	100%	0	0
Broomfield	25	9	36%	3	3	100%	0	0
Denver	36	20	56%	10	9	90%	0	0
<b>DIA</b>	36	15	42%	5	2	40%	0	0
Douglas	39	36	92%	13	13	100%	0	1
Jefferson	33	29	88%	6	6	100%	0	1
<b>TOTAL</b>	<b>333</b>	<b>204</b>	<b>61%</b>	<b>80</b>	<b>72</b>	<b>90%</b>	<b>0</b>	<b>8</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	2	1	50%	0	1
Lakewood	N/A	N/A	N/A	2	2	100%	0	0
Wheat Ridge	N/A	N/A	N/A	2	1	50%	0	1
<b>TOTAL</b>	<b>N/A</b>	<b>N/A</b>	<b>N/A</b>	<b>6</b>	<b>4</b>	<b>67%</b>	<b>0</b>	<b>2</b>
<b>GRAND TOTAL</b>	<b>333</b>	<b>203</b>	<b>61%</b>	<b>86</b>	<b>76</b>	<b>88%</b>	<b>0</b>	<b>10</b>

A total of **333** Messages were issued within the District. Of the **333** Messages that were issued, **204** Messages verified, resulting in a verification rate of **61%**. Douglas County had the highest verification rate, **92%**, while the Four Mile Burn Area had the lowest verification rate, **30%** due largely to its relatively small forecast area.

A total of **86** LIF’s were issued. Of the **86** LIF’s issued, **76** of the LIF’s verified, resulting in a verification rate of **88%**. There were total of **10** events over **5** separate periods in which Message 1’s were issued with a short lead time of 30 minutes or less.

The PMS identified **104** cloud-to-ground (CG) lightning days that covered the forecast period of May 1<sup>st</sup>, 2017 through September 30<sup>th</sup>, 2017. A lightning day is identified as any day that a thunderstorm cell produced a cloud to ground lightning strike within the forecast District boundary or multiple cloud-to cloud (CC) strikes. Archived CG and CC lightning data was reviewed for each of the **152** operational days in 2017. Of the **152** operational days in 2017, 104 of these days, or **68%** of the total days, CG lightning was observed or multiple CC lightning strikes were observed within the forecast District. This was higher than the 2008-2017 annual average of 92 lightning days. Of the **104** “thunderstorm days” within the forecast District, **37%** of days had Messages issued. Jefferson County had the highest number of lightning days with **86** total. July had the highest monthly total of **29** lightning days.

Table 8: UDFCD Lightning Statistics for period May1-September 30

County	2017 Lightning Days	Percent of Total Days w/Lightning	2008-2017 Average Lightning Days	Highest Yearly Total 2008-2017
Adams	59	39%	54.8	69 (2016)
Arapahoe	59	39%	52.3	70 (2015)
Boulder	72	47%	63.7	76 (2015)
Broomfield	37	24%	36.9	51 (2014)
Denver	45	30%	46.0	62 (2015)
Douglas	85	56%	73.0	87 (2014)
Jefferson	86	57%	77.2	92 (2009)
<b>Total</b>	<b>104</b>	<b>68%</b>	<b>92.4</b>	<b>108 (2009)</b>

## 5.0 Notable Weather Events

The 2017 F2P2 season was slightly above the long-term average in Message periods, but no “major” flood events occurred. However, there were several days in which heavy rainfall initiated significant urban flooding over portions of the District and low impact flash flooding of District watercourses. Just south of the District, significant rainfall fell in El Paso County during the month of July, which was the 10<sup>th</sup> wettest month on record in Colorado Springs, and the 3<sup>rd</sup> wettest July on record. But if we only look at the airport data from 1948 to current, July 2017 would have been the wettest July on record in Colorado Springs and 6<sup>th</sup> wettest month on record. The heavier rains from the summer monsoon were nearby just not over the District. The most memorable storm of the season for many was the May 8<sup>th</sup> hail storm that caused major damage over parts of Jefferson, Denver and Adams Counties and became the costliest hail storm in not only Denver history but the entire US ahead of the July 11, 1990 storm at 1.4 billion dollars! Below is a meteorological summary of the more notable days of 2017.

**May 8<sup>th</sup>:** A slow-moving trough of low pressure over the southwestern United States directed unseasonably high moisture levels into NE Colorado. A surface cold front arrived on the morning of May 8<sup>th</sup>, setting the stage for widespread thunderstorm activity, heavy rainfall, and severe weather. Dew points increased into the



upper 40s to low 50s by afternoon, with integrated moisture levels between 0.75-0.80". Showers and thunderstorms initiated over the foothills and Palmer Divide by noon, gradually increasing in coverage and intensity over the next 2-3 hours. A severe thunderstorm developed over the Jefferson County foothills shortly after 2:00 PM, tracking NNE onto lower elevations of the District. This storm produced widespread heavy rainfall over the northern and central portions of the District, along with severe hail up to 2.5" in diameter. Numerous alarms for rainfall  $\geq 0.50''/10\text{min}$  were triggered in the Denver, Westminster,

and Henderson areas. Thunderstorm activity continued into the early-evening hours, producing moderate to locally-heavy rainfall totals near Golden, and also over portions of Douglas and Arapahoe Counties.

(Photo Courtesy of Banjo Billy's Bus Tours).

**July 20<sup>th</sup>:** High pressure anchored SE of Colorado allowed deep monsoonal moisture to stream N out of the Desert Southwest, setting the stage for scattered, slow-moving thunderstorms during the afternoon and evening. Strong, nearly-stationary thunderstorms developed over the foothills of central Jefferson County around 1:00 PM. These storms produced heavy rainfall  $\geq 0.50''/10\text{min}$  W of Evergreen, but were slow to propagate E onto lower elevations. A cluster of strong storms then developed over the Rampart Range of Douglas and Jefferson Counties by mid-afternoon, which moved slowly NE onto lower elevations of the District. The National Weather Service issued a Severe Thunderstorm Warning for the cluster, due to severe-level hail and damaging winds. Additional storm activity was noted over portions of Adams and Arapahoe Counties, producing heavy rainfall over S Aurora near Cherry Creek Reservoir, and also just S of DIA. Rainfall alarms were triggered for rainfall  $\geq 0.50''/10\text{min}$  and also 1.16"/hour at the Shop Creek gauge in S Aurora. Weak thunderstorm activity continued over the central and southern portions of the District through 9:00 PM, but total rainfall remained below 0.20" with these storms.

**July 26<sup>th</sup>:** Favorable placement of upper-level features allowed monsoonal moisture to stream N into Colorado on Wednesday July 26<sup>th</sup>. A cold front slipped through the District the previous evening, turning winds upslope against the Front Range, and transporting significant surface moisture over the area. Thunderstorms producing heavy rainfall developed during the mid-afternoon hours over the foothills of Jefferson and Douglas Counties. These storms tracked slowly SE onto lower elevations by early evening. Additional storm development over eastern portions of the District back-built W towards the foothills, as training of thunderstorms cells produced heavy rainfall over the same areas for 1-2 hours. The National Weather Service issued a Flash Flood Warning for NE Douglas County, indicating 2.5" rainfall in about 40 minutes near Franktown. Heavy thunderstorm activity continued to fill in over Douglas County, prompting issuance of a second Flash Flood Warning for the majority of the county, including portions of the District. Spotter reports and gauge data indicated 30-60 minute rainfall totals of 1.5-2.5" near Castle Rock. However, heavy rainfall was also recorded further N. Rainfall of 0.25-0.59" was recorded at several Boulder County gauges, while areas of Littleton and S Aurora reported one-hour rainfall totals of 0.98" and 0.71", respectively. Of note, the 6:00 PM (00z) radiosonde sounding at KDNR recorded 1.36" precipitable water (PW). This is the highest PW ever recorded on the climate record for a July 27<sup>th</sup> 00z sounding (6pm July 26<sup>th</sup>).