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2011
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 33rd 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 2011 PMS.

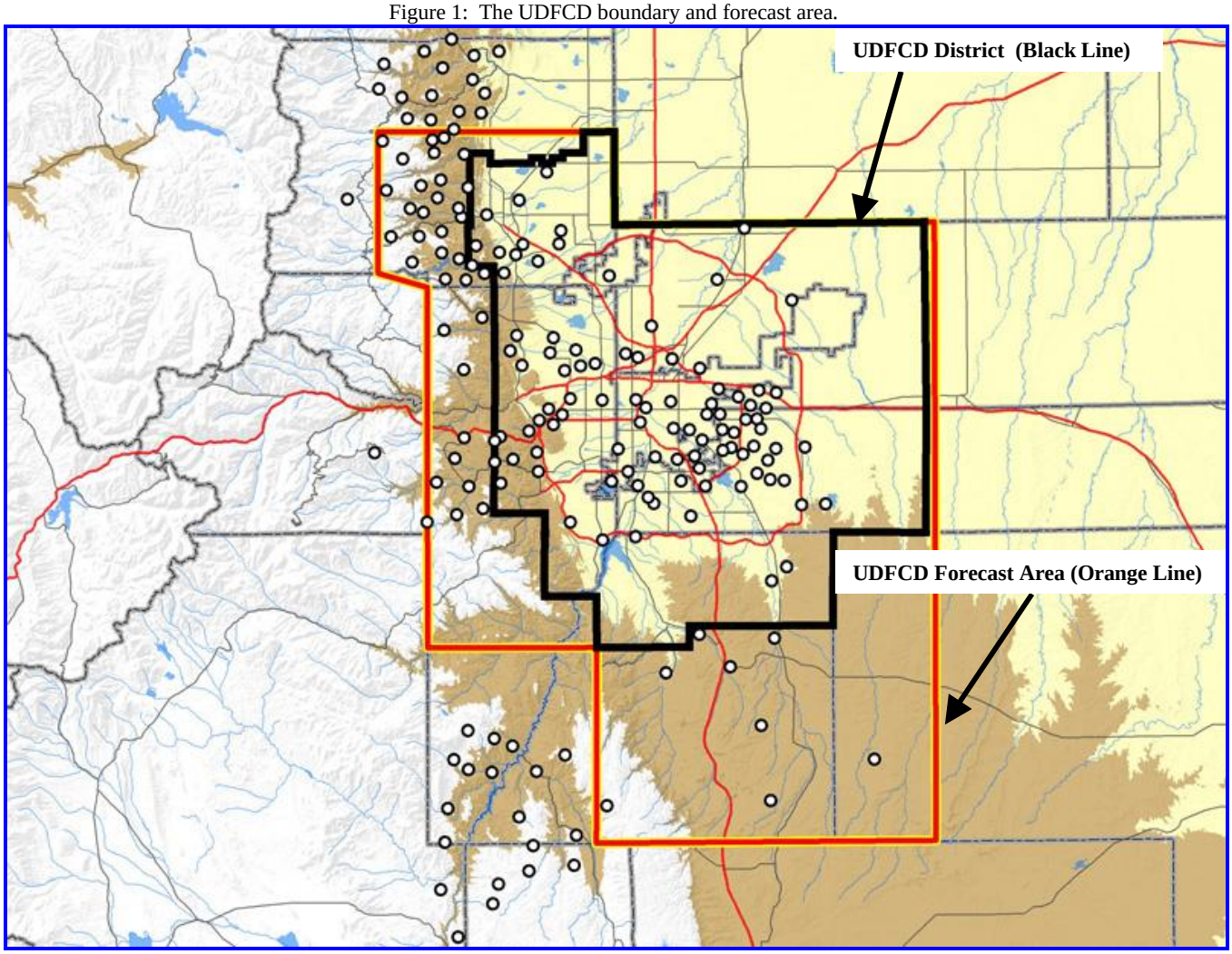
Weather prediction personnel Bryan Rappolt, Tim Tonge, Brad Simmons, Chris Anderson and Matt Jones provided the F2P2 prediction and notification services. Bryan Rappolt was as the Project Manager and Chief Operational Meteorologist.

Bryan Rappolt worked his 18th season on the F2P2 while Tim Tonge worked his 6th, Brad Simmons his 5th, Chris Anderson his 4rd and Matt Jones his 1st season.

2.0 2011 Operational Season

The 2011 F2P2 season began on April 15, 2011 and concluded on September 15; 2011 for a total of 154 operational days. Normal operational hours were from 7:00 AM to 10:00 PM. A total of **1503** 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 **265** man-hours of operational support.

Figure 1: The UDFCD boundary and forecast area.



3.0 2011 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 2011.

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. Five hundred and twenty-four (**524**) 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.

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

Table 3: 2011 product/communication summary.

Product/Communication	**Number**
Heavy Precipitation Outlook (HPO)	163
Messages and Red Flood Alerts	442
Internal Message Status (IMS)	107
Basin-Specific Quantitative Precipitation Forecasts (QPF)	32
Storm Tracks (ST)	104
PMS Initiated Telephone Contacts	524
F2P2 Participant Initiated Telephone Contacts	88
Total	**1,460**

One hundred sixty five (**163**) emails identifying daily Message potential were disseminated to F2P2 participants.

4.0 2011 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 **40** days during the 2011 F2P2 between April 15, 2011 and September 15, 2011. Of the **40** Message days **38** days had Message 1's or a combination of Message 1's and Message 2's. There were **2** days where only Message 2's were issued. Of the **38** Message 1 days **34** of these days had at least one Message verify, based on the criteria listed in Table 4. The result was an **89%** 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 2011 F2P2.

Table 4: Message Criteria.

Message 1 "Nuisance Flood Advisory" Criteria
• **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
• 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
• 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.

There was **2** "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 **95%** verification rate of Message 1 level rainfall being observed within or near the District on the **38** Message 1 days.

Of the **38** Message 1 days, **36** of the days had Message level rainfall observed within either the forecast area or nearby the forecast area.

There was **1** day (July 26) 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	**0**	**0**	**N/A**	**0**	**0**	**N/A**
May	**5**	**5**	**100%**	**40**	**24**	**60%**
June	**6**	**5**	**83%**	**50**	**34**	**68%**
July	**18**	**15**	**83%**	**125**	**73**	**58%**
August	**7**	**7**	**100%**	**41**	**22**	**51%**
September	**2**	**2**	**100%**	**8**	**8**	**100%**
Total	**38**	**34**	**89%**	**264**	**161**	**61%**

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 **17** Red Flood Alert days, of which **17** of these Red Flood Alert days verified somewhere within the District; resulting in a verification rate of **100%**.

There were **8** NWS issued Flash Flood Watch and Flood Watch days and subsequently there were **8** Message 2 days. There were **5** NWS issued Flash Flood Watches issued for only the Four Mile burn area in Boulder County due to the potential for flooding due to the post-fire hydrologic conditions.

The NWS in Boulder issued **10** Flash Flood Warnings on **5** different days for portions of the District. Five of the 10 Flash Flood Warnings were issued for the Four Mile burn area in Boulder. Subsequently there were 10 Message 3's issued for portions of 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 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 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	**28**	**18**	**64%**	**15**	**15**	**100%**	**0**	**0**
Arapahoe	**25**	**15**	**60%**	**12**	**12**	**100%**	**0**	**0**
Aurora	**24**	**14**	**58%**	**11**	**11**	**100%**	**0**	**0**
Boulder	**30**	**17**	**57%**	**5**	**4**	**80%**	**0**	**0**
Broomfield	**22**	**10**	**45%**	**4**	**3**	**75%**	**0**	**0**
Denver	**24**	**13**	**54%**	**11**	**10**	**91%**	**0**	**0**
DIA	**23**	**14**	**61%**	**6**	**5**	**83%**	**0**	**0**
Douglas	**31**	**27**	**87%**	**12**	**12**	**100%**	**0**	**0**
Jefferson	**29**	**21**	**72%**	**11**	**11**	**100%**	**0**	**1**
Four Mile	**28**	**12**	**43%**	**3**	**2**	**67%**	**0**	**0**
TOTAL	**264**	**161**	**61%**	**90**	**85**	**94%**	**0**	**1**
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	**6**	**6**	**100%**	**0**	**1**
Lakewood	N/A	N/A	N/A	**9**	**9**	**100%**	**0**	**0**
Wheat Ridge	N/A	N/A	N/A	**9**	**9**	**100%**	**0**	**0**
TOTAL	**N/A**	**N/A**	**N/A**					
GRAND TOTAL	**264**	**161**	**61%**	**114**	**109**	**96%**	**0**	**2**

A total of **264** Message 1's were issued to the 8 primary contact points within the District. Of the **264** Message 1's that were issued, **161** Messages verified, resulting in a verification rate of **61%**. Douglas County had the highest verification rate, **87%**, while the Four Mile burn area had the lowest verification rate, **43%**.

A total of **114** Red Flood Alerts were issued. Of the **114** Red Flood Alerts issued, **109** of them verified, resulting in a verification rate of **96%**.

The PMS prepared a cloud–to-ground lightning table that covered the forecast period of April 15, 2011 through September 15, 2011. Archived cloud–to-ground lightning data was reviewed for each of the 154 operational days of the F2P2. Of the 154 operational days, **83** of the days (**54%** of the total days) cloud–to-ground lightning was observed within or near the District. Of the **83** "thunderstorm days" within the District **48%** of the days had Messages issued for them.

5.0 Notable Weather Events

The 2011 F2P2 season was above normal with respect to the number of thunderstorms, Message days and flooding that was observed within the District. Some of the notable weather events observed during the 2011 F2P2 are described below:

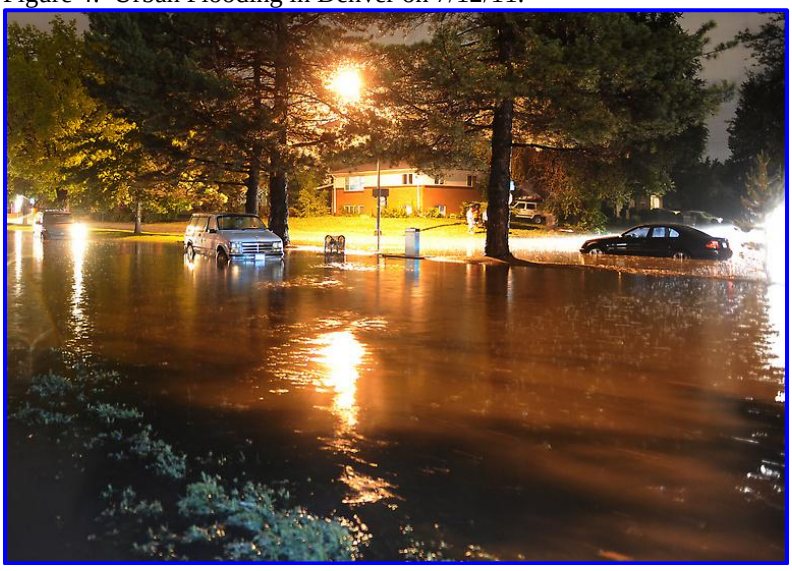
July 7th: A large thunderstorm complex developed over the District producing severe weather, very heavy rainfall and significant street and urban flooding in Denver County (Figure 2), southwest Adams County, northeast Jefferson County, southern Boulder County, and northwest Arapahoe County. The National Weather Service issued a Flash Flood Warning due to the significant urban flooding that was observed in Denver County and northwest Arapahoe County. In addition significant mud slides and debris flows were observed across portions of the Four Mile burn area (Figure 3) in Boulder County.

Figure 2: Urban Flooding in Denver on 7/7/11.

Figure 3: Flooding within the Four Mile burn area on 7/7/11.

July 12th, 2011: Multiple thunderstorms tracked across the central and north central portion of the District producing severe weather, heavy rainfall and street and urban flooding (Figure 4) across a good portion of the Denver Metropolitan area.

Figure 4: Urban Flooding in Denver on 7/12/11.



July 13th: A slow moving thunderstorm produced heavy rainfall across the Four Mile burn area in Boulder County. Significant mud slides and debris flows were observed (Figure 5) as well as significant rises on Four Mile Creek and Boulder Creek. In addition, significant urban and street flooding was experienced across a large portion of the District.

Figure 5: Flooding within the Four Mile burn area on 7/13/11.

6.0 Recommendations

Storm Track Product

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.