Information Services and Flood Warning Program

Kevin Stewart, PE, Program Manager

UDFCD's IS/FW program continued to strengthen services in 2016. Highlights this year include early flood detection enhancements for Thornton; an improved high-resolution precipitation forecast tool; better web map services; E-records management and processing upgrades; and planning for future IT security and growth.

New rain/stream gage on Big Dry Creek at Thorncreek Golf Course in Thornton

Julia Bailey is in her seventh year at the District where she manages the OnBase™ project, directs internal GIS activities, improves web map capabilities, and continues to make E-documents easier to find. She also assists with UDFCD's Internet and satellite data communications connected with the flood warning program. Be sure to read Julia's article in this issue of *Flood Hazard News* to learn about recent developments and planning activities that she leads.

Derrick Schauer is UDFCD's network administer and is entering his tenth year of full-time employment. IT systems security and continuity of operations remain high priorities for Derrick as well as website administration. As E-records and E-accounting practices continue to evolve, IT grows increasing critical to daily operations at the District.

2016 Flood Season Recap

After three record-breaking years for tallying the number of days with flood potential, UDFCD's flood warning program finally had a slight reprieve with the threat day count for 2016 being just slightly above normal. The flood problems were also considerably less than preceding years.

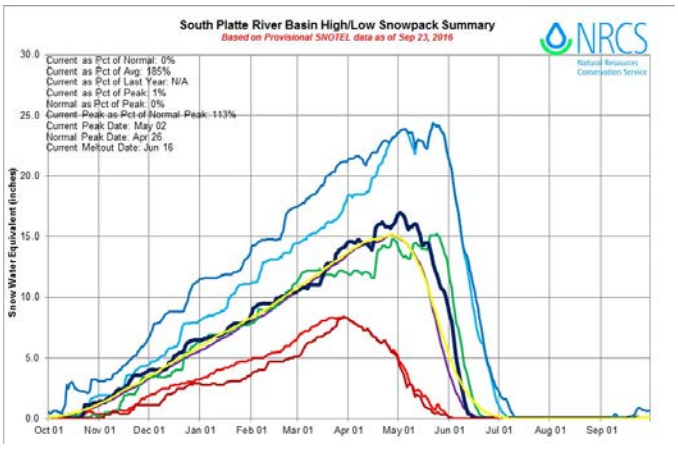
This past year the ALERT System generated rainfall rate alarms on only 21 days compared to 31 the previous year. The following table pinpoints the specific alarm dates for 2016 and designates the days that the National Weather Service issued flash flood watches and warnings.

42 days with flood potential in 2016

May	7, 10, 16, 24, 26, 31	6
June	6, 7, 9, 12, 13, 19, 20, 23, 24, 25, 28, 29, 30	13
July	1, 2, 8, 15, 18, 19, 20, 22, 24, 28	10
August	2, 3, 6, 7, 8, 16, 18, 19, 25, 29, 30	11
Sept	1, 3	2

Red dates are when automated rain gauges exceeded alarm thresholds. Yellow highlighted dates indicate heavy rainfall only affected areas outside UDFCD's main area of concern such as the Hayman Burn Area in SW Douglas County and watersheds in northern Boulder County. Blue boxes are when a NWS flash flood watch was the highest threat level reached and red designates a flash flood warning.

Only one ALERT rain gauge measured over 3 inches in 24-hours during 2016. This occurred on August 30 at the Betasso Filter Plant in Boulder County during an intense thunderstorm that lasted about 80 minutes. Radar precipitation estimates suggest that the Denver region may have experienced as many as four other days (May 26, June 6, 13 & 20) with rainfall totals nearing the 3-inch mark while no CoCoRaHS observations in the region exceeded this threshold. A storm summary table is available that lists peak rain totals for every day in 2016 having flood potential.



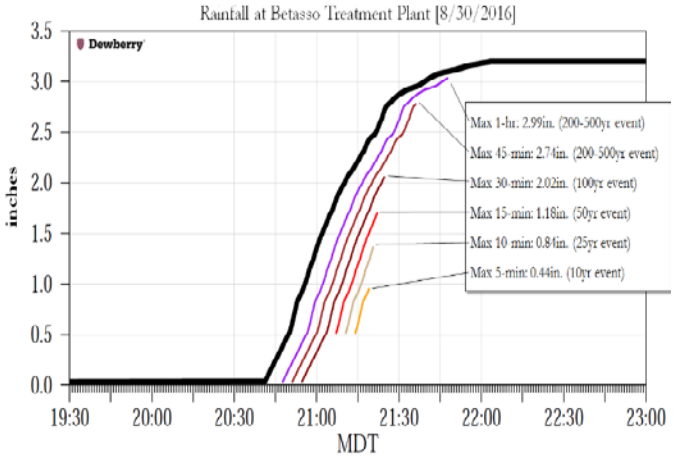
The 2016 snowpack for the South Platte River basin (*dark blue line above*) tracked close to average (*yellow line*) providing northeast Colorado farmers with another good water year. Cooler than normal temperatures in May delayed runoff slightly, but this did not result in any unusual flooding being reported.

Cherry Creek flooding near Speer Blvd. and Stout Street on June 24, 2015

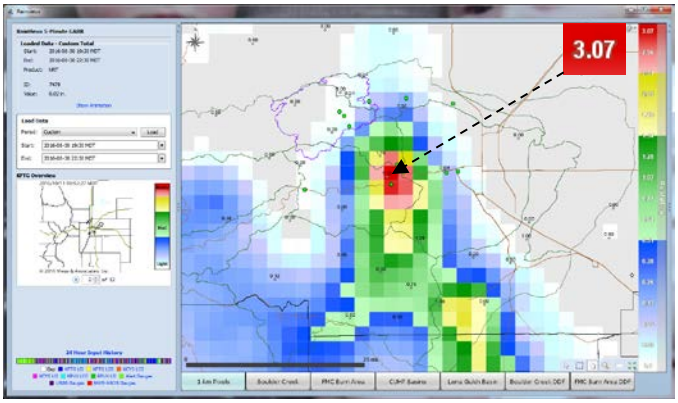
CORRECTION: Last year's *Flood Hazard News* reported a peak discharge of 2,000 cfs for the June 24, 2015 event on Cherry Creek through downtown Denver. Subsequent reviews suggested that the actual peak was considerably higher. The USGS agreed and recently updated their stage/discharge rating with the corresponding revised flood peak of 3,350 cfs.

Rainfall Exceeds 100-Year Return Period Yet Again

In 2015, three days recorded rainfall intensities that exceeded the 100-year threshold (*1% AEP-annual exceedance probability*) according to NOAA Atlas 14. This past year only one day achieved this "rare" status—that day being Tuesday, **August 30, 2016**. The ALERT rain gage at the Betasso Water Treatment Plant in Boulder County recorded a storm rainfall total of 3.15" between 8:40PM and 10PM. The maximum 30-, 45- and 60-minute intensities exceeded the 1% AEP values for that location. The plot below suggests that the maximum rainfall return period (*or frequency*) was between a 200 and 500-year event. Due to the small footprint of that storm, the impacts from the runoff were minimal, attracting little attention.



Cumulative rainfall plot of August 30, 2016 storm with corresponding NOAA-14 precipitation frequency values



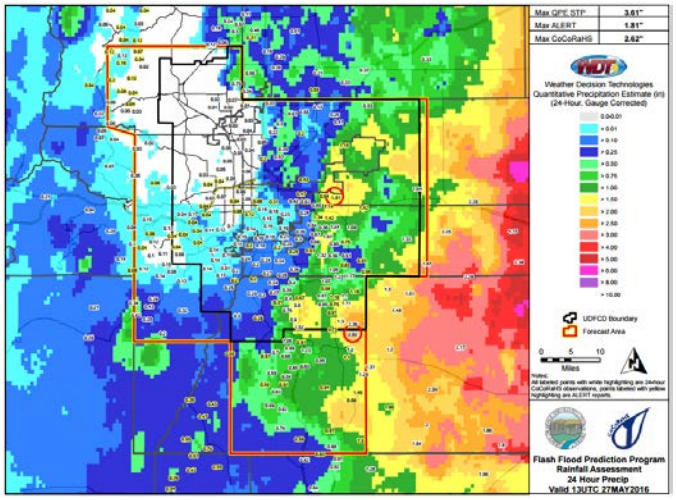
Gage Adjusted Radar Rainfall (GARR) estimates for the August 30, 2016 storm located over Boulder Creek about 2 miles west of Boulder

Other Noteworthy Events of 2016

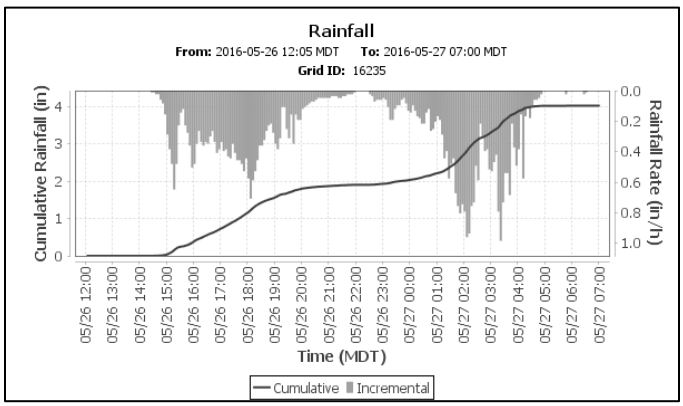
This past year the Denver region experienced 28 days with daily rainfall exceeding one-inch. The following dates characterize the more significant happenings:

Saturday, **May 7** was the first 'Message Day' of the year delivering short-lived heavy rainfall during the early afternoon hours. Due to the fast storm movement, rain accumulations remained low *(< 1-inch*) resulting in some minor street flooding. High winds and hail accompanied some storms with one tornado warning being issued for central Arapahoe County and NW Elbert County at 1:29 PM.

Thursday PM to Friday AM, **May 26-27** brought 24-hour rain totals close to 3 inches near the eastern District border with rain intensities on the low side. It is remarkable that no alarms occurred from any of the 203 rain gages in the ALERT network. Areas further east may have received over 6 inches of rain according to some radar estimates (*see map below*). A CoCoRaHS observer near Deer Trail in eastern Arapahoe County reported 4.58 inches, a 50- to 100-year event according to NOAA Atlas 14. The time series plot below the map is from a radar-precipitation grid point in Elbert County. It shows precisely when the rain fell as well as the storm's intensity in 5-minute increments.



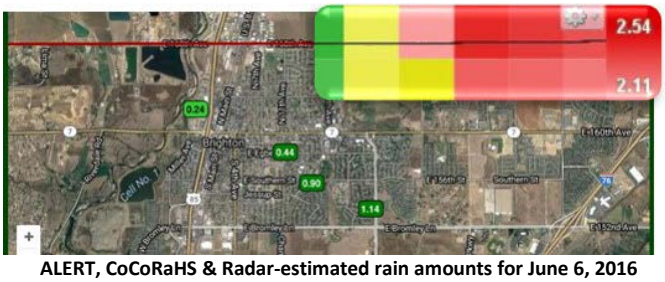
24-hour radar-rainfall estimates and rain gauge totals for May 26-27, 2016



Time-series plot of 5-minute radar-rainfall estimates

On Monday, **June 6,** the primary target was Highlands Ranch in northern Douglas County where rainfall amounts approached 3-inches from two waves of storm activity in the late afternoon and late evening hours. The ALERT gage on Big Dry Creek at the Heritage Regional Park recorded a rainfall total of 2.44" with bursts occurring from 4:30 to 5:50PM and from 11:30PM to 12:15AM with a maximum 10-minute intensity of 4.0 in/hr at 5:05PM. A nearby CoCoRaHS observer reported the maximum 24-hour amount for the day of 2.81 inches. The most intense rainfall measurement occurred further north at a new ALERT station along Weir Gulch in Denver where the rain total there was just under an inch with a 5-minute downpour at 5:16PM averaging an impressive 7.1 inches per hour. The streamgage at that location measured its high water maximum for the year at 5:30PM with a 3.8-foot rise occurring in just 15 minutes and a corresponding flow rate change from 2 cfs to about 300 cfs.

The ALERT streamgage on Big Dry Creek at Heritage Regional Park came within 0.04-feet of tying a previous high water record set in 2012 with the creek rising nearly 10-feet in just over an hour and cresting at 6PM with a peak flow of 830 cfs. Coincidentally, the 2012 storm also occurred on D-Day (June 6) of that year. The station has only been in operation since June of 2011.



ALERT, CoCoRaHS & Radar-estimated rain amounts for June 6, 2016

Another heavy downpour on June 6 occurred near Brighton reminding us once again that our "dense" network of rain gages do not catch everything that happens. Gerald Blackler with Enginuity Engineering Solutions was asked by the City of Brighton to analyze this storm in detail. According to radar-rainfall estimates, this event produced nearly 2.5-inches in less than 2-hours while nearby rain gages measured far less. The engineer's report contains other interesting information including a video of their 2D rainfall/runoff model to visualize the flooding.

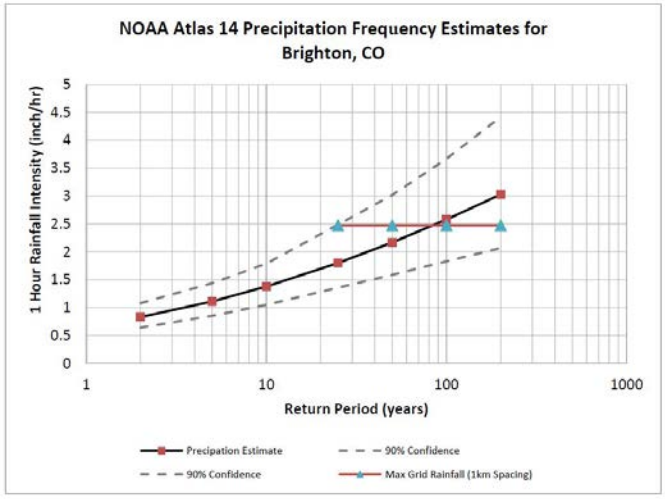


Figure from Enginuity report on Brighton event of June 6, 2016

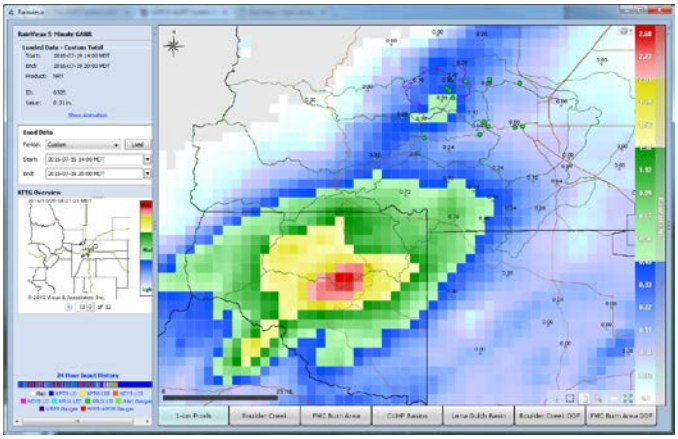
One week later on Monday, **June 13,** rainfall again approached the 2.5-inch threshold with the highest totals occurring in Parker. The Lakewood and Morrison areas of Jefferson County also experience rain amounts close to 2 inches. Large hail, heavy rainfall and gusty winds accompanied the storms.

Maple Grove Reservoir on Lena Gulch in Lakewood reached its spill level just after midnight and continued overflowing for 3 days. The spillway flows were small however and no flooding resulted.

Tuesday, **June 28**, brought hail and very intense rainfall to the central part of the metro area with peak rainfall rates approaching the 6 inch-per-hour mark in downtown Denver around 6:45PM, while storm totals remained on the low side—less than 2 inches. Similar rain intensities also occurred a short time earlier in Arvada and Wheat Ridge. High water maximums for the year were set this day for Ralston, Leyden and Van Bibber Creeks in Arvada; on Little Dry Creek in Adams County; and on Lakewood Gulch, Cherry Creek and the South Platte River in Denver. A video of Ralston Creek was shot at the crest of the "flood" in Hoskinson Park along Brooks Drive near the Carr Street crossing.

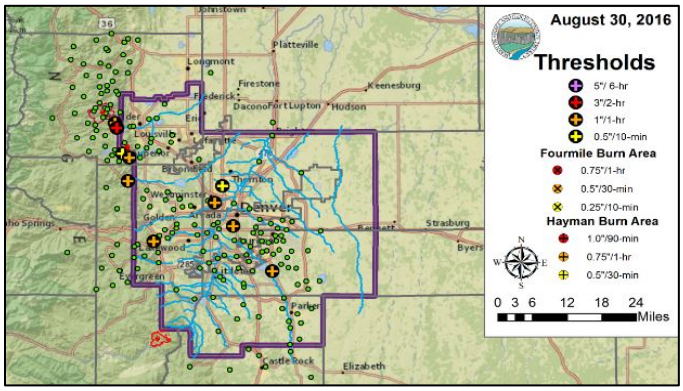
Ralston Creek near Carr Street at 7:50PM on June 28, 2016

After an extended 2-week period of unusually dry weather and rising fire danger, the Colorado monsoon—that normally debuts around Independence Day—finally arrived on July 17 with heavy rainfall in eastern Adams County prompting the NWS to issue a flash flood warning while the metro area continued its dry spell. The following day more intense storms began threatening the District on the east and south sides but once again with little consequence. By Tuesday, **July 19,** the urban landscape began feeling the monsoon when intense downpours dropped 1 to 1.5 inches just south of downtown Denver with peak rain rates exceeding 5 inches/hour. A number of stage gauges recorded their annual maximums of this day on Harvard Gulch, Sanderson Gulch, Cherry Creek, the South Platte River, and a few other locations. Another interesting observation this day was the large storm that occurred in the mountains over Gilpin County that produced over 2.5 inches according to radar rainfall estimates. Fortunately, this storm missed the Fourmile Burn Area (*fire in 2010*) while the little rain that did fall there caused the highest flow of the year from the FMBA, albeit small.



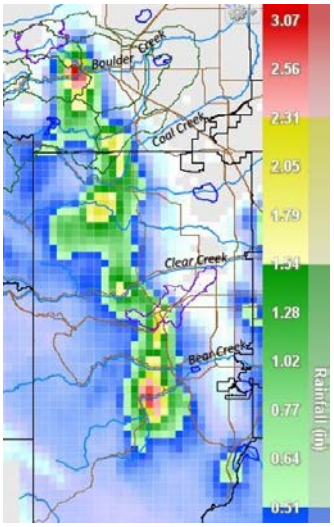
July 19, 2016 rainstorm over Gilpin County

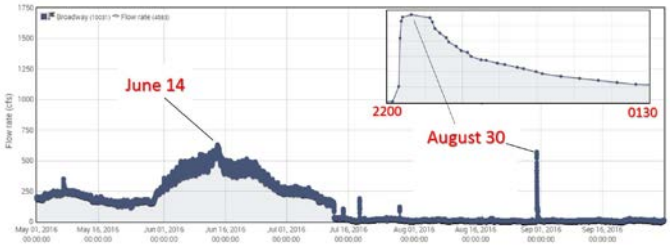
The cloudburst during the evening hours of Tuesday, **August 30** has the illustrious honor of being the year's most unusual event, with one point in Boulder County having a return period between 200 and 500-years according to NOAA-14 (*see previous discussion and data plot for the Betasso Filter Plant ALERT gage*).



Rainfall Rate Alarms for August 30, 2016

While the point rainfall from this storm is statistically rare, it did not result in the maximum peak flow of the year on Boulder Creek due to its small footprint. That record was set on June 14 from seasonal mountain snowmelt *(see plot below),* plus a little help from a much smaller rainstorm than what happened on August 30. The 8/30 runoff is remarkable, however, especially when comparing the storm runoff to the extended two-week high water period in June. Both flow peaks were nearly identical but the August event caused Boulder Creek to rise from 5 cfs to over 500 cfs in just 15 minutes. Compared to the "September-to- Remember" flood of 2013, this Boulder Creek peak was quite small (*the 2013 peak was about 5,000 cfs*), but the 8/30 event does clearly illustrate why flash floods are so dangerous, happening quickly, sometimes with little or no warning.





Boulder Creek flows at Boulder from May 1 to September 30, 2016

Fortunately, an early warning issued for this mini flash flood gave first responders in Boulder plenty of lead-time and the rapid rise occurred during a less busy time of day, just after 10PM. Prior to this the first rain alarm from the Betasso Filter Plant occurred at 8:50PM. Next an automated streamgage in the canyon just west of Boulder detected a 500 cfs increase between 9PM and 9:35PM prompting the NWS to issue their flash flood warning at 9:25PM. Earlier notifications concerning the heavy rain threat went out before 6PM. The earliest indication of a more serious flood potential may have been the QPFMAX product at 12:38PM (*see later discussion*) suggesting that 1-hour rainfall amounts could reach the 2.5-inch threshold during the evening hours. As it was in 2013, emergency managers in Boulder were once again ready well ahead of what ensued this day.

Meteorological Support

UDFCD's Flash Flood Prediction Program, a.k.a. F2P2, operates from April 15 through September 30 in close partnership with the National Weather Service, focusing primarily on intense rainfall events that threaten local

jurisdictions within the District. This long-running program has been serving the region since 1979.

Skyview Weather provided the flood prediction and notification services for 2016. Forecast products include daily heavy precipitation outlooks, quantitative precipitation forecasts (QPF), storm track maps, and jurisdiction-specific 'messages' concerning flood threats (see example below). Skyview's president Tim Tonge has participated in the program for the past 11 years. Project manager Brad Simmons is a 10-year veteran of the F2P2. Bryan Rapport, a 23-year veteran with Genesis Weather Solutions, served as Skyview's senior operational and consulting meteorologist. Other meteorological support staff included 4-year veteran Alan Smith along with Justin Brooks, Nick Barlow and Ryan Matoush, who all just completed their rookie season of flood forecasting for the F2P2.

Sent: Tuesday, August 30, 2016 7:52 PM
To: message-jefferson-sms@lists.udfcd.org
Subject: M-1 Low Impact Flooding Update

Heavy Rainfall Likely for Jefferson County from Current to 915 PM
http://udfcd.org/gmap

An annual report and a complete archive of F2P2 products are available.

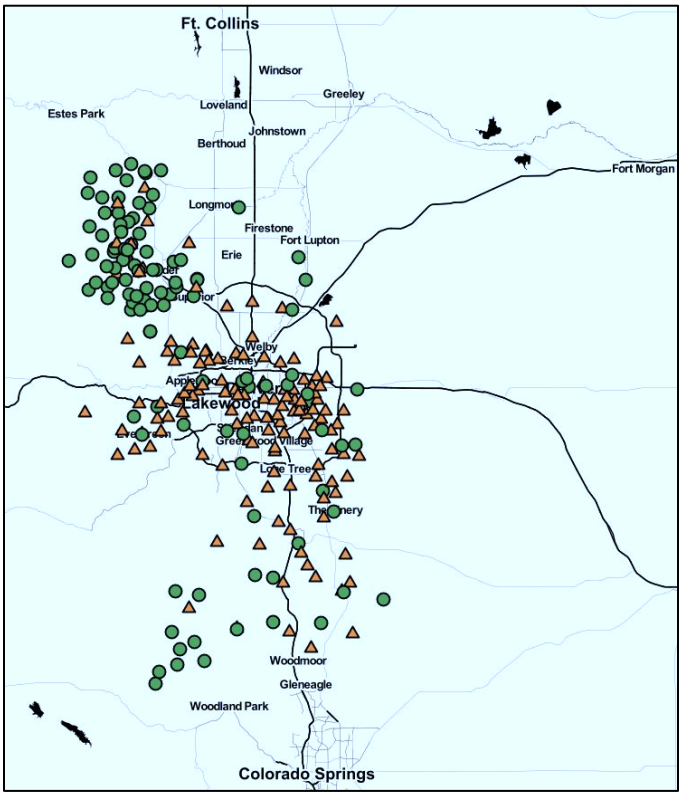
CoCoRaHS Update

UDFCD has been a proud sponsor of the Community Collaborative Rain, Hail & Snow Network, a.k.a. CoCoRaHS, since 2001. This large network of about 21,000 volunteer observers covers all 50 states, Canada, Puerto Rico, the U.S. Virgin Islands and the Bahamas—just added in 2016. Funding of CoCoRaHS currently relies on sponsorships and contributions by individuals. Consequently, this unique non-profit organization continues to seek new financial partners. To donate or to become a volunteer observer visit the CoCoRaHS website.

ALERT System News

Weir Gulch at Julian Street in Denver

The ALERT system operated by UDFCD covers an extensive regional area with 232 gaging stations that monitor rainfall, water levels and weather conditions in real-time. Two new stations installed in January of 2017 will measure rainfall and water levels on Big Dry Creek at the Thorncreek Golf Course and on Brantner Gulch near Quebec Street this coming year. Both stations are located in the City of Thornton. Last March, Denver had a new gaging station installed on Weir Gulch at Julian Street to monitor both rainfall and streamflow.

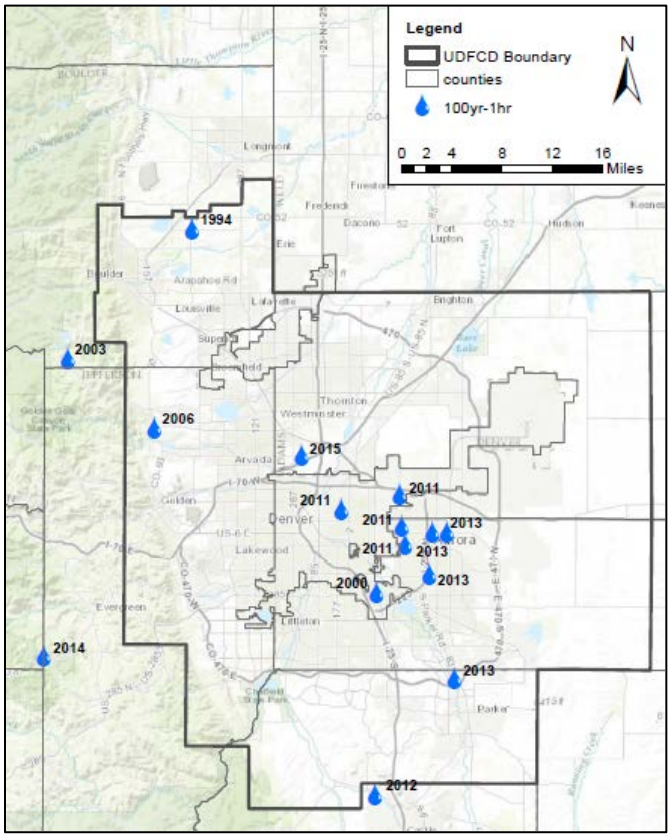


2016 ALERT System Coverage

OneRain and Water & Earth Technologies (WET) provided routine preventative maintenance and unscheduled repair services for 2016, enabling successfully data collection of 13.1 million ALERT data reports. The Resources box at end of this article contains links to annual reports and other pertinent documents.

A MS-Excel™ workbook is available that summaries the annual peaks and maximums for the period of record for every ALERT streamgage in the network including discontinued stations and those temporarily out-of-service. The corresponding data includes the date, time, gage height/stage and flow rate. Appropriate notes are also included as cell-specific comments where data is missing, questionable, or supplemented by other measurements.

Similarly, monthly rainfall data is analyzed and tabulated using Excel to provide summaries for various peak rainfall periods ranging from 5-minutes to 24-hours. The data at the top of the each worksheet represents the maximums for each month. Highlighted cells indicate that a pre-defined alarm threshold was exceeded for the respective time period. Subsequent analysis permits comparison with NOAA-14 intensity/duration/frequency (IDF) values for each gaging station location. A recent long-term records analysis by WET lead to the production of the following map that shows the location and corresponding year when 1-hour rainfall measurements exceeded the 100-year (1% AEP) threshold.

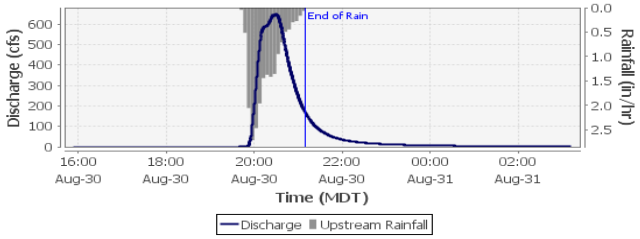


Locations and corresponding years when a 1-hour rainfall event exceeded the 100-year (1% annual chance) threshold

UDFCD supports two primary websites that provide access to ALERT data. OneRain maintains the public website linked to from UDFCD's flood safety page. Links to the F2P2 and Twitter websites are also on this page. The 'alert5' website is the starting point for most flood warning program partner agencies.

Real-Time Hydromodel Experience from 2016

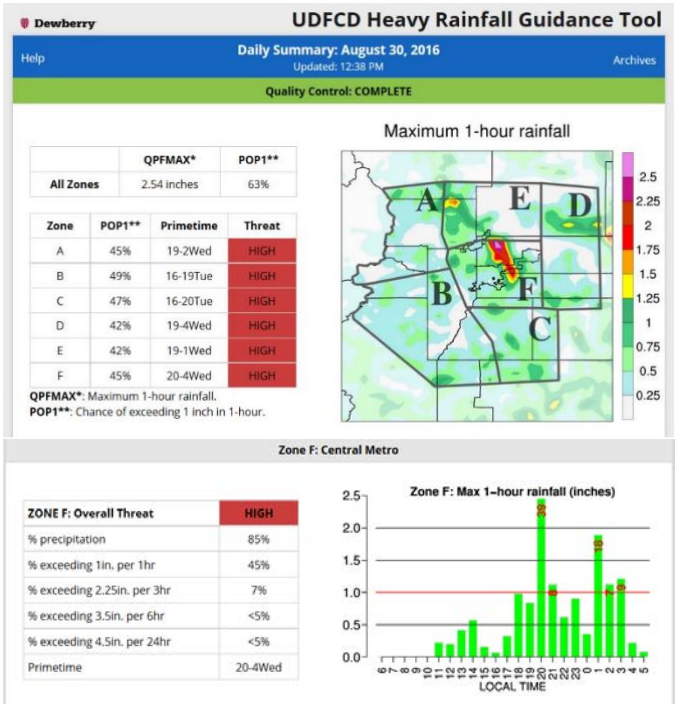
This past flood season provided few opportunities to evaluate RT-hydromodel performance. One good occasion was **August 30** when Lena Gulch in Jefferson County recorded its annual peak from a storm in the foothills near Golden where just over 2-inches of rain fell in about 90-minutes. This storm was less intense than the Boulder County storm that same day (*see previous discussion*), but the runoff response was impressive and good lessons were learned about the complexities of running hydromodels in real-time. A detailed report by Vieux, Inc. exposes some of the challenges.



Vflo hydromodel output near Heritage Square in Golden

High-Resolution QPF Enhancements

In 2015, Dewberry built a web-based precipitation forecast tool for UDFCD to address four crucial questions regarding potential flood threats from heavy rainfall: 1) timing, 2) location, 3) intensity and 4) confidence. The tool, named "QPFMAX", relies on an ensemble of high-resolution weather models that directly simulates thunderstorm rainfall. The original 2015 operational version used raw model data. In 2016, a technical memo documenting 2015 performance noted, among other things, that a noticeable "overconfidence" bias existed where predicted heavy rainfall had a higher probability than the observations implied. Thus, a significant processing step added in 2016 reduced this bias. A recent report prepared by Dewberry describes the performance of QPFMAX (v.2) during 2016 and comments on the potential for future refinement.



QPFMAX from August 30, 2016

In closing, the 2016 flood season was thankfully a year of low impact flooding for UDFCD but as usual, flood forecasting continues to be a challenging experience that provides many learning opportunities for us all. Please share your ideas on how we may better serve your needs knowing that future floods are certain to come.

Resources

A complete archive of daily forecasts, flood threat notifications, storm track predictions, storm summary maps, and other products are available at the F2P2 website. A MS-Excel workbook containing annual and record stream levels and peak flows measured by the ALERT System along with detailed annual reports concerning ALERT System maintenance activities and F2P2 operations are also available.