Information Services and Flood Warning Program Notes

Kevin Stewart, PE, Program Manager

Last year's *Flood Hazard News* article devoted considerable Copy to evolving flood concerns resulting from the 2010 Fourmile Canyon Fire that started on Labor Day (September 6) and destroyed 169 homes in the Gold Hill area west of Boulder. Those concerns proved valid when a destructive life-threatening flash flood struck on July 13. Read on to learn how community flood preparedness efforts saved lives in the Fourmile Burn Area, and some specifics about this and other big rain events from the 2011 flood season.

When it concerns IT matters at the District, Derrick Schauer has the conn and forecasts "clear sailing" for 2012. District LAN servers were replaced in 2011, electronic records and files are secure, and our website www.udfcd.org is well-maintained. Priorities are now focused on file structure and records management as we look ahead.

Julia Bailey is the District's Information Services Engineer and gatekeeper for our Internet-accessible publications and associated data. She also oversees District GIS activities and facilitates related staff training needs. Julia is principally responsible for the EDM "Electronic Data Management" mapping interface that has become a very popular means of acquiring information from the District. The link to this valuable service is easy to find on the District homepage. Be sure to read Julia's article in this newsletter about recent changes to the EDM.

This year the IS/FWP had the pleasure of welcoming a new engineering student intern from Colorado State University, Rebecca West. Becky quickly adapted to the flood video archive project that has been underway for a number of years. She also used her talents to help us improve our online streamflow statistical summaries from over 20 years of data collection activities. Becky anticipates receiving her B.S. degree in Civil Engineering in 2012.

2011 Flood Season Recap

This past flood season had an above average number of threat days. To some extent this resulted from the elevated risk associated with the Fourmile Burn Area (FMBA). While July 7 was probably the most notable rainfall event in the District, July 13 received far more attention due to the number of lives threatened and homes damaged by flooding in the mountains of Boulder County less than three miles west of the District boundary.

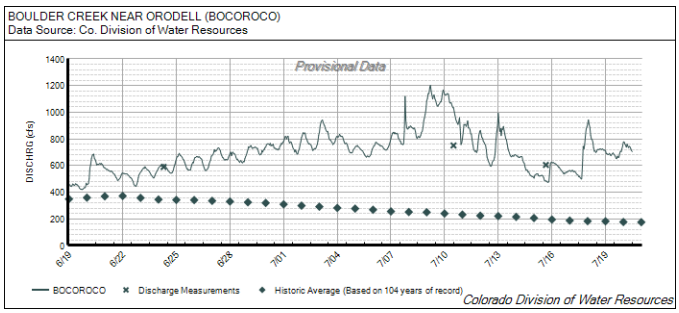
The ALERT system triggered rainfall rate alarms on 34 days between 15 April and 15 September in 2011 compared to only 17 days the previous year. Specific alarm dates are shown in red in the table below. A few alarm dates are not reflected in the table such as April 25, May 12,13&19 and September 6&7. Most of these alarms occurred from the low alarm threshold settings (¼" per hour) for rain gages in or near the FMBA. Some of the April and May alarms resulted from snow accumulating in the 12-inch diameter collector funnels and forming a frozen obstruction. When the snow melts, the "ice dams" eventually give-way causing the tipping bucket gage to falsely measure high rain rates under clear skies. The alarms on April 25 are an example of this phenomenon. On other "non-threat" days, short-duration intense storms caused a few of the FMBA gages to exceed their quarter-inch thresholds without consequence. On September 6 and 7, debris movement was reported in the FMBA without prior notice of the potential threat. This illustrates just how sensitive fresh burn areas can be to small frequently occurring rains.

Twenty-four hour precipitation totals exceeded 3" on three days in 2011 (May 11 & 18 and July 7). Nine other days (Jun19; Jul8,11,12,13&14; Aug20; Sep2&14) had rain totals ranging from 2 to 3 inches with July 13 resulting in the greatest damage from just over an inch of rain. A storm summary table and corresponding maps are available for each day listed below.

41 days with flood potential in 2011

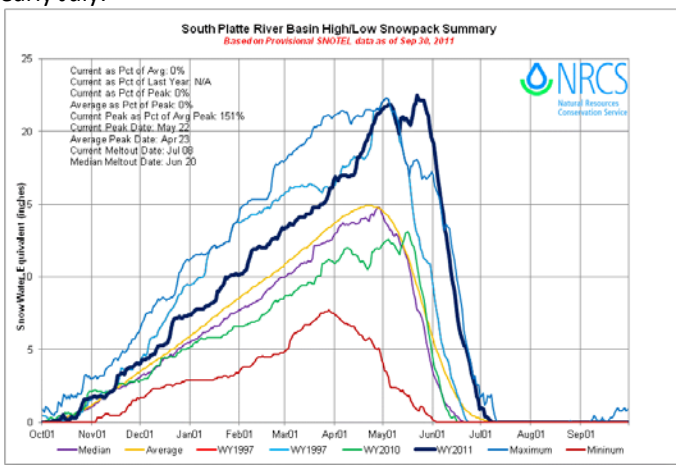
May	**11**, **18**, **20**, 23, 24	5
June	11, 13, **17**, **19**, **20**, 30	6
July	2, 5, **6**, **7**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, 15, **16**, **17**, 18, **19**, **26**, 27, 31	19
August	**2**, **3**, **4**, **14**, **16**, **20**, 21, 29	8
September	**2**, **14**, **15**	3

Red dates are days when rainfall measured by automated gages exceeded alarm thresholds. Yellow highlighted dates indicate that heavy rainfall measurements only affected areas outside the District's main area of concern, i.e. Hayman Burn Area in Douglas and Jefferson Counties, and the St. Vrain Creek basin in northern Boulder County. Blue boxes designate NWS flash flood watches that affected the District and red boxes designate flash flood warnings.



The 2011 Snowpack

This was an unusually late runoff season with melting snow from the mountains affecting Colorado streamflows well into July. The plot above shows data from the Boulder Creek streamgage near Orodell with records that date back 104 years. Note the difference between the 104-year averages from mid-June to mid-July. When the Fourmile Creek flash flood occurred on July 13, the runoff from snowmelt was as least three times its normal rate. The plot below shows that the South Platte River basin held on to its snowpack through late May into early June, then the runoff became aggressive, nearly matching the maximum recorded event. Consequently, streams like Boulder Creek were flowing well above normal when the monsoon rains arrived in early July.



Boulder County Main Events

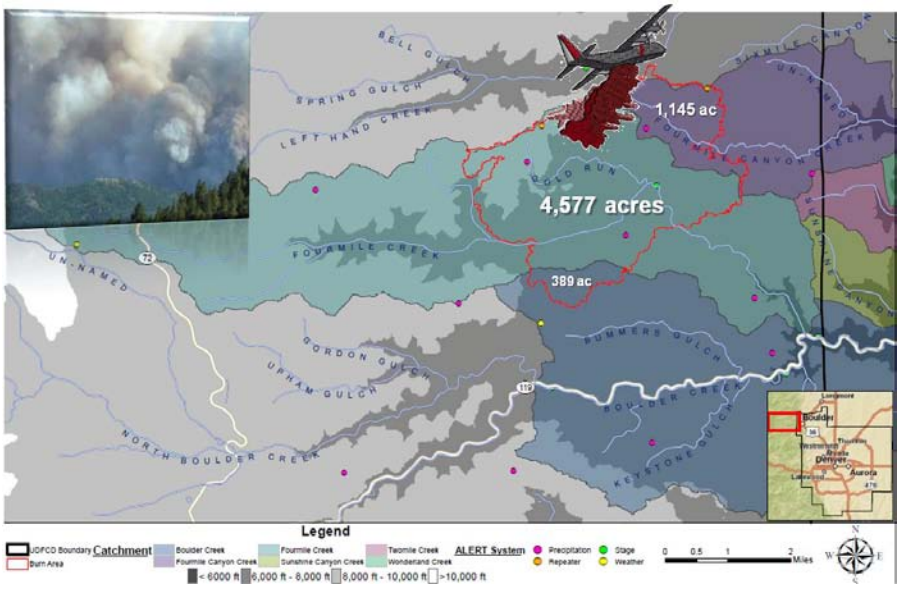
In describing Boulder County's 2011 flood season, this recap begins in mid-January when dire predictions were being made concerning the elevated flash flood threat posed by the Fourmile Burn Area (FMBA). While there was general agreement that the risk was extremely high for those living in or traveling through the FMBA during a heavy summer downpour, opinions varied widely with respect to how such a relatively small burn area of less than 6,200 acres could seriously threaten the City of Boulder. To help answer this question a number of hydrologic studies were quickly completed and as expected, the results differed (see table). However, all models did indicate that a short duration rainstorm of 2-inches or more over the FMBA could certainly cause problems in Boulder along Boulder Creek. It was also suggested that Fourmile Canyon Creek on the north side of Boulder may actually pose a greater threat.

1-HR PCP	Vieux	LRE	WWE	UCD
0.5"	880	150	200	550
0.75"	1,600	460	470	900
1.0"	2,400	890	820	1,400
1.25"	3,300	1,400	1,200	1,800
1.5"	4,300	2,000	1,800	2,200
1.75"	5,300	2,600	2,800	2,700
2.0"	6,300	3,300	3,800	3,200
2.5"	8,400	4,600	5,900	4,300
3.0"	10,500	6,100	7,500	5,600

Peak discharge estimates in CFS from runoff models for the 4,577-acre burn area portion of the Fourmile Creek watershed.

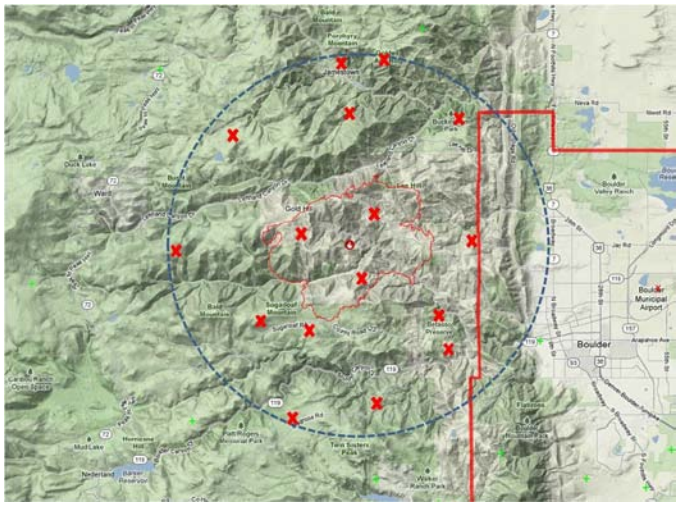
To provide some context for the numbers in the table, paleoflood investigations conducted by Bob Jarrett of the USGS suggested that the Fourmile Creek minor flood events of 1995 and 2003, with estimated peaks of less than 500 cfs, were likely the largest floods experienced by this area in at least the past 75 years. The Boulder Creek flood of 1969, the largest in recent memory, resulted from four days of moderate intensity rainfall in the mountains that exceeded 9 inches at the Boulder Hydroelectric Plant and produced a peak flow on May 7 through Boulder of 2,500 to 3,000 cfs. The May 30, 1894 flood is the historic flood of record for this area, caused extensive damage along Boulder Creek and Fourmile Creek, and generated an estimated peak through Boulder of 12,000 cfs. Paleoflood studies of the 1894 event revealed that most of the rain-driven runoff came from the 25 square mile Fourmile Creek watershed and that Boulder Creek above the Fourmile Creek confluence showed little geologic evidence of high flows.

A post-fire threat assessment was conducted to evaluate potential impacts for a range of rainfall intensities. A flood hazard inventory for Fourmile Creek and Gold Run suggested that flow rates as small as 100 cfs could overtop and potentially wash-out many private drive crossings, and that larger capacity road crossings like Colorado Highway 119 could handle no more than 2,000 cfs prior to overtopping, and that as many as 80 structures were at risk with approximately 20 of those—mostly private homes—potentially threatened by flow rates of less than 1,500 cfs.



The National Weather Service made use of these investigations, advice from the USGS, and their own past experience with post-wildfire Colorado floods like Hayman and Buffalo Creek to establish initial criteria for issuing public advisories, watches and warnings. With a high danger for mud, rock and debris slides, a very low ¼-inch per hour rain rate was established as the advisory threshold for road problems and minor flooding. The warning threshold for flash flooding in the FMBA was set for one hour rainfalls exceeding ½-inch. For the City of Boulder more rain would be required to cause a serious threat and therefore, the initial warning threshold for the City was set for an hourly amount of 1.5 inches. Prior to the fire, less than 2 inches of rain in the mountains would not likely have posed any serious flooding threat.

ALERT rainfall alarm rates were adjusted accordingly for automated gages located in and near the FMBA (see map). The District also cooperated with the USGS to reestablish two streamgage sites on Fourmile Creek near Crisman (Logan Mill Road) and at Orodell (Boulder Mountain Lodge) with satellite telemetry. The owners of the lodge also provided the utility connection that enabled installation of a live video webcam.



Map showing location of 16 automated rain gages within 5 miles of the burn area center. Alarm thresholds set at 0.25"/hr, 0.5"/hr and 0.75"/hr.

Two rainfall/runoff models for Boulder Creek were developed for real-time operations and adjusted to reflect the post-fire conditions. Both models extended their flood routing calculations to the Boulder city limits at the mouth of Boulder Canyon, but questions remained concerning their reliability because no runoff measurements existed at this point in time to calibrate the models. The Colorado Water Conservation Board provided the funding that helped make these technical accomplishments possible. The flood forecasters and response agencies were now reasonably prepared for the 2011 flood season.

With the technical resources in place and the research/study results in hand, emergency management officials, fire districts and other agencies in Boulder County undertook a major public education effort to prepare people for what might happen. These measures proved life-saving by July when the summer monsoon rains arrived. Convincing people that the threat was real was not an easy task, and many living in the FMBA still likely have some doubts about the magnitude of the threat. Doomsday predictions seldom convince people of high danger. Many public safety and public works officials, subject matter experts, and public information professionals deserve commendations for their services in 2011 as the following recaps will reveal.

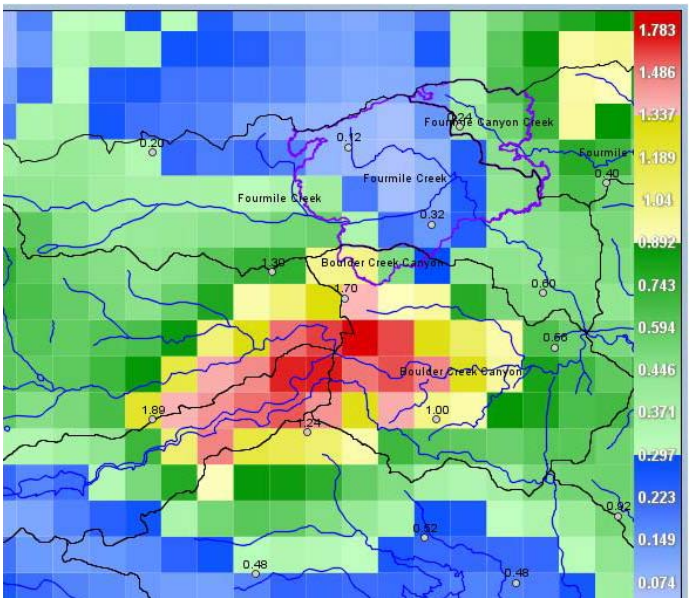
Wednesday, **May 11** was the first heavy rain threat of the 2011 flood season. Because of the reduced advisory and warning rainfall thresholds for the FMBA, the NWS issued a flash flood watch for this area. Emergency managers and response agencies were leaning forward as officials staffed the Boulder EOC preparing for the worst. At 8:58 AM, the Boulder Office of Emergency Management's director Mike Chard used their new Everbridge emergency notification system for the first time to activate weather spotters in the FMBA. Five volunteers responded immediately. The observed precipitation that day was a mixture of snow and rain with totals for the day approaching 2-inches in the lower elevations. In the FMBA most of the precip fell as snow, essentially eliminating the flood threat. Rainfall rate alarms from the FMBA occurred over the next two days due to melting snow that accumulated in the 12-inch diameter collector funnels.

One week later on **May 18** the NWS issued their second flash flood watch for the FMBA with similar results. This event did involve more rain than snow compared to the week prior but the rainfall intensities in the FMBA stayed below serious thresholds. Runoff from the event was observed by spotters but no damages were reported. Some heavier rain on the plains produced 24 hour totals approaching 3 inches with radar estimates exceeding 3 inches. Severe weather accompanied storm activity east of Boulder with tornado warnings being issued for northwest Adams County and eastern Broomfield.

This Father's Day Sunday, **June 19**, produced a too-close-for-comfort late evening event that took aim at the FMBA and missed. The rainfall total for the Magnolia gage within the 5-mile radius was 0.94 inches. The gage also measured a peak 10-minute intensity that exceeded 3 in/hr at 10:46 PM. A small stream flood advisory was issued for the FMBA by the NWS at 11 pm, but measured rainfall totals over the burn area were only between 0.2 and 0.3-inches with no problems to report aside from a power outage.

Tuesday, **July 5** began a 15-day string of flash flood threat days for the District. The summer monsoon had officially arrived. The heavy rain potential was recognized early in the day by the NWS when they issued their 7:59 am flash flood watch for the FMBA. Later that morning the watch area was expanded to include the entire District. The day proved uneventful with 24-hour rainfall amounts not exceeding ½"

anywhere in the 7-county area served by the District. A flash flood watch was issued again for the FMBA the following day, **July 6**. Heavy rainfall was observed in northern Douglas County and northeast of DIA, but for Boulder County this day was another no show.

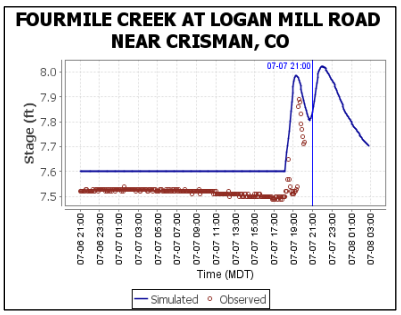


Radar-rainfall estimates between 5-8 pm, July 7

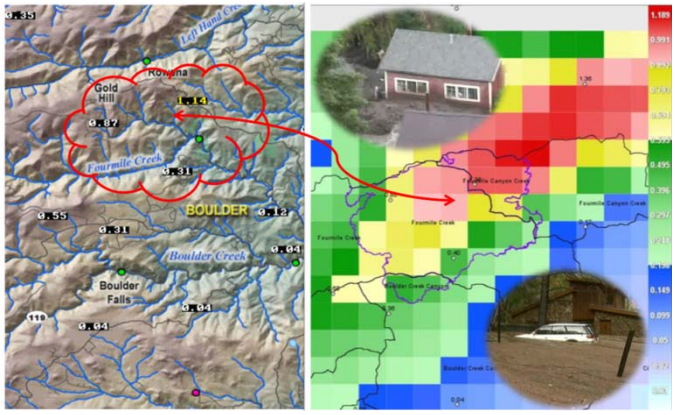
The NWS morning forecast models for Thursday, **July 7**, indicated a lower threat level than the prior two days. Therefore, a flash flood watch was not issued. By late afternoon a small amount of rain fell over the FMBA causing a 100-yard wide by 4-foot deep debris/rock/mud slide, forcing the closure of Fourmile Canyon Drive near Emerson Gulch where the 2010 fire started. The burn area rain was on the northern edge of a much larger storm cell that prompted the NWS to issue a flash flood warning for the FMBA at 6:19 pm as it approached (see above map). Fortunately the intense portion of the storm missed its target. Had the storm cell in Boulder County centered over the FMBA, the impacts in the burn area and downstream through Boulder would have been devastating. July 7 held its status as the largest heavy rainfall day of the year in the District (see later discussion).

July 7 also caused the biggest rain-related impact to the FMBA to date and it certainly drew considerable media attention. It is interesting to note just how low the rain measurements were, ranging from only 0.12 to 0.35 inches. To the south and southwest rainfall amounts in the Sugarloaf and Nederland areas totaled 1.73" and 2.01" respectively. One observer in the FMBA near Long Gulch did provide a report of 0.96" in 16-minutes. The Fourmile Creek gage at Logan Mill Road measured a rapid half-foot rise that was of little consequence. The largest rainfall measurements exceeded 3-inches in Denver and Aurora, and the ALERT system logged 117 rainfall rate alarms from 44 locations.

The first operational test of the real-time Vflo™ model showed promising results. The simulated hydrograph in the figure shows that the model predicted a 0.3-foot rise in stream level at about the right time. An observed rise of 0.4 feet was measured by the streamgage.



As of 7:50 pm, the WebEOC status board indicated no reports of any infrastructure damage other than road debris blockage in the FMBA, no homes impacted, electricity and phones working. The event summary also noted that people did evacuate to high ground with no injuries reported. Weather spotters were activated by officials at 6:13 pm. Prior to this, emergency management officials were leaning forward preparing for possible problems. The first District notification of a potential threat occurred at 12:13 pm when a Street Flood Advisory was issued indicating that strong and possible severe thunderstorms could produce 0.6" to 1.6" of rainfall in 10-30 minutes with up to 2.25" in 45-90 minutes possible. The prime time for flooding was from 2 to 7 pm. This forecast affected all 7 counties within the District.



Rainfall totals from the ALERT system and Radar estimates of rainfall that caused the flash flood of July 13, 2011

The flash flood of **July 13** will not be soon forgotten by FMBA residents, first responders, emergency managers, and many other county and city officials. A flash flood warning for the FMBA was issued at 6:17 pm. At 8:08 pm the warning was extended to include Boulder Canyon west of Boulder. Four-foot surges in water levels on Fourmile Creek were observed and publically reported. Sirens were sounded in Boulder at 8:17 pm and people reacted, some properly while others could have done better. At 8:37 pm the NWS issued a flood advisory (not a warning) that included the City of Boulder. Boulder Creek and Fourmile Canyon Creek on the north side presented concerns. Fortunately the impacts in the City of Boulder were minimal with Boulder Creek rising

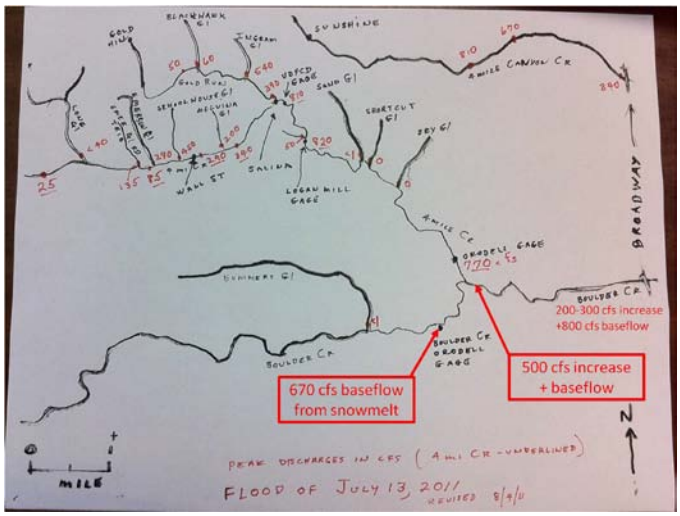
less than a foot and Fourmile Canyon Creek keeping within its flood channel for the most part with some basement damage reported.

Following are examples of some reports received from the field:

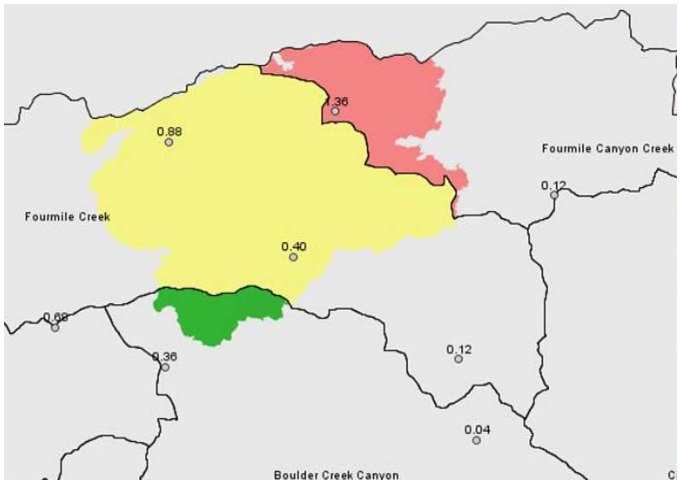
- 12 people stranded behind a washed out road were found safe.
- Lots of debris and rock on roads.
- Cars trapped between mud and trees.
- Sheriff Deputies saw debris flows and water over roads.
- Bridges and roads washed out.
- Large debris being carried by Fourmile Creek.
- At least 10 private properties, including some homes, were damaged.
- 4 people were treated for exposure and minor injuries at Gold Hill after being rescued. They were covered head-to-toe with mud.
- A fire department vehicle in route to a rescue was washing off Gold Run Road by raging floodwaters. Damages to the vehicle totaled $1,500. No one was hurt.
- Walls of water 6' to 10' high were observed by fire and Sheriff Department officials at a number of locations in both the Fourmile Creek and Fourmile Canyon Creek drainages. Ingram Gulch was one of those locations.
- Surprisingly slow movement of "walls of water" was observed.

From the perspective of an engineer or hydrologist, the following data-driven timeline for July 13 may be of interest:

5:24pm first message concerning FMBA heavy rain threat
5:53pm NWS issues small stream flood advisory for FMBA
6:06pm first ¼" rainfall rate alarm within 5 miles of FMBA
6:15pm first ¼" rain alarm in FMBA at Gold Hill
6:17pm **NWS issues flash flood warning for FMBA**
6:22pm ¼" rain alarm in FMBA at Sunshine
6:28pm first ½" rain alarm at Gold Hill
6:33pm ½" rain alarm at Sunshine
6:47pm first ¾" rain alarm at Gold Hill
6:50pm ¾" rain alarm at Sunshine
6:54pm Fourmile Creek at Salina gage detects small rise
6:55pm 1" rain alarm at Sunshine
7:05pm FM Creek at Logan Mill Road gage detects rise
7:20pm FM Creek at Logan Mill peaks showing 4' rise.
Actual peak time was later estimated to have occurred at 7:17pm and 0.8' higher than the 7:20 pm measurement.
8:00pm FM Creek at Orodell gage measures 2' increase compared to the reading 5 minutes earlier. Boulder Creek flow rate 670 cfs from snowmelt.
8:04pm Boulder Creek gage downstream of Fourmile Creek detects small rise.
8:05pm FM Creek at Orodell crests showing a total stream level rise of just under 3' in the past 10 minutes.
Rise at this location captured nicely by the live webcam.
8:11pm Boulder Creek peaks downstream of FM Creek after rising 1.2 feet in 7 minutes, corresponding to a 500 cfs increase in streamflow.
8:15pm Boulder Creek near the public library is flowing at about 800 cfs, well above average due to late mountain snowmelt runoff. At this point in time Boulder Creek levels through Boulder have not been affected by Fourmile Creek, the confluence of which is located approximately 2 miles upstream.
8:17pm **Sirens sounded in Boulder**
8:30pm Boulder Creek at Boulder measures a 0.2-foot rise from the prior 8:15pm reading.
8:45pm The Boulder Creek library gage peaks, showing only a 0.4-foot rise since 8pm and corresponding to a flow rate increase of just over 200 cfs.
Since the gage only reports every 15 minutes, it is likely that the actual increase was slightly higher. Another streamgage located a short distance downstream below Broadway measured a discharge increase of 260 cfs and a rise of 0.5 feet between 8:12 and 8:42pm.

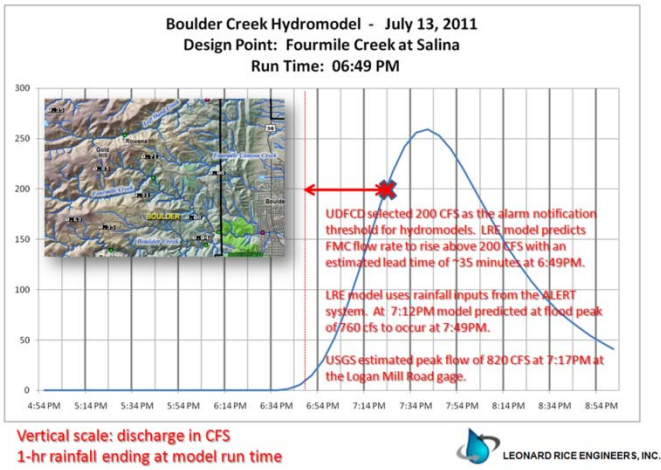


Drawing by Bob Jarrett with USGS showing peak discharge estimates for July 13 from field surveys. Additional added text pertains to Boulder Creek streamgage measurements. Note the 540 CFS estimate for Ingram Gulch, which drains ~400 acres. The Sunshine ALERT rain gage is located at the top of this drainage.



Colors represent Radar estimates of average rainfall over the FMBA by watershed thru 9PM. The yellow area (Fourmile Creek drainage) reflects an average rainfall of 0.7". The red area (Fourmile Canyon Creek drainage) reflects an average of 1.2". The green area (Bummers Gulch drainage) averaged 0.5". The numbers are ALERT rain gage totals. Sunshine measured the highest amount of 1.36".

Note that Fourmile Canyon Creek (FMC^2) and Fourmile Creek/Boulder Creek behaved similarly. Both had flood peaks of approximately 800 cfs immediately downstream of the FMBA—both streams attenuated their flood peaks by more than 50% before reaching the City—and at the Broadway crossings, both streams (Boulder Creek & FMC^2) experienced flow increases of 300 cfs, more or less. Unlike Boulder Creek, there are no historic gage records for FMC^2 but from historic accounts it is very likely that this was the largest flood seen here in many decades. The paleoflood evidence gathered by Bob Jarrett further supports this opinion.



By July 13, the jury was still out concerning how trustworthy the real-time hydrologic models would prove to be due to a lack of runoff data to validate the models. The Vflo™ model mentioned previously (see July 7) performed well at predicting the timing of the flood, but the model overestimated flood peaks on Fourmile Creek by 50%. The Vflo™ timing accuracy may have resulted from using Radar-estimated rainfall with the physics-based model. The LRE model is a unit graph-based lumped parameter model that uses rainfall inputs estimated from the ALERT rain gage data. This model did an excellent job of predicting peak flows (see above figure), but was a little slow in estimating flood arrival times. Using the data collected on July 13, both models will be recalibrated for 2012 operations. Training on the use of these models is still needed and user interface improvements are also anticipated.

Situational awareness throughout the event was good, but forecasting flood impacts was somewhat problematic. The July 13 event certainly gave everyone involved a much clearer picture about what can be expected from just over an inch of rain in one hour over the burn area. The data collected from this event provides forecasters the opportunity to refine warning decision thresholds and gives modelers valuable calibration information to make more accurate and timely flood predictions. A "hot wash" debriefing was held the following morning and action items were identified to further improve the system. During the July 14 debrief, a flash flood watch was received and EOC operations began again.

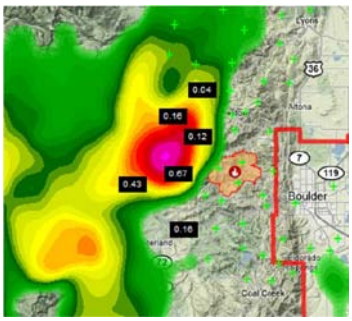
In hindsight, the siren sounding in Boulder may not have been necessary but that action did provide a unique opportunity to assess the public's response to the warning. This experience may help save lives in the future.

Many YouTube videos are available of this flood and its impacts. The District has also archived many local news broadcasts of the event. Two of these can be watched from the District's UD-Tube website.

Similar to July 7, the threat of heavy rain for July 13 was not nearly as great as the days leading up to it. There was no flash flood watch in effect, but the NWS did issue a small stream flood advisory for the FMBA concerning low impact flooding. Although the early forecast threat was considered low, emergency service personnel did not let their guard down and many can be thankful that they did not. Also, the focused and repetitive public education efforts leading up to the flood by mountain fire departments, emergency managers, public information experts, other local officials, and the news media played a huge role in saving lives. No lives were lost on July 13. Now that's a success story!

For the next 6 days Boulder officials continued leaning forward and monitoring conditions from the EOC. Heavy rainfall on Thursday, **July 14** resulted in another flash flood warning for the FMBA, this time with far less consequence as rainfall amounts over the burn area totaled less than half the prior day's rain. One storm south of the BA did measure ½" in 10 minutes around 5PM.

The next FMBA flash flood warning happened on Saturday, **July 16** at 3:46 pm, and like the 14th with nothing serious occurring.



The next day, **July 17**, produced another too-close-for-comfort storm that brushed the west side of the FMBA, resulting in a flash flood warning for Nederland and Eldora at 3:44 pm. Doppler radar estimated that up to 2" of rain had fallen in the past 30 minutes. Again, the FMBA was not impacted.

Two days later on Tuesday, **July 19**, the EOC remained staffed for the 15th consecutive day and once again heavy rains fell very near the FMBA with the ALERT gage at Twin Sisters measuring a ¾" per hour rate at 3:57 pm and accumulating 0.91" from a localized storm. The NWS issued a flash flood watch at 11:13 am for a large area in northeast Colorado above 6,000 feet. They later issued their final FMBA flash flood warning of the year in Boulder County at 3:27 pm. The burn area only received a trace of rain from this event. Another fortunate miss!

The remainder of July, August and September were relatively uneventful for Boulder County officials and most of the FMBA residents. Some debris movement in the Ingram Gulch area was observed from rain showers occurring over **September 6 and 7.** At least one home was affected by a mudslide around 3AM on the 7th. No watches or warnings were in effect for this event. It's hard to catch them all.

With the District's flood season operations ending on September 15, it seemed fitting that another final round of moderately intense rainfall would again occur in the FMBA. Low level ¼"/hr alarms began within the 5-mile radius at 7:17 pm on Wednesday, **September 14**, with the "adios" alarm occurring at 1:01 am on the 15th. The first email alert message from the Vflo™ hydromodel—a new procedure implemented after July 13—was received by EOC officials indicating a predicted flow of 211 cfs at 06727410 (USGS Logan Mill streamgage) at 2011/09/15 00:35:00 MDT. Fourmile Creek, however, ignored this prediction and flowed at normal levels throughout the night.

Main Events Elsewhere in the District

Arvada's biggest rainstorm of the year occurred on the afternoon of Wednesday, **May 18**. Annual high water measurements were recorded on Ralston Creek and Leyden Creek between 1PM and 2PM. Maximum rainfall totals exceeded 2-inches in Arvada and along the I-25 corridor east of Broomfield where Radar estimates exceeded 3-inches.

As pointed out previously in the Boulder County recap, Thursday, **July 7** was the District's biggest rain day of 2011. This was the 3rd day of the summer monsoon season, which arrived on July 5 with the NWS issuing a flash flood watch for the entire District and nothing much happening. On July 7 the rainstorms finally did appear with many flash flood and severe thunderstorm warnings being issued, affecting Adams, Arapahoe, Boulder, Denver and Jefferson Counties. The map on the following page shows the extent of measurements made by the ALERT system and volunteer CoCoRaHS observers. The largest storm totals exceeded 3-inches in the Westerly Creek basin located in Denver and Aurora. Many other rain gages recorded amounts over 2-inches. The EMWIN-Denver Regional system delivered 81 separate NWS products to subscribers. Denver officials reported that storm sewer manholes popped their covers at over 50 locations.

Annual peak flows were recorded for Van Bibber Creek in Arvada; Westerly Creek in Denver and Aurora; Toll Gate Creek, Sable Ditch and Granby Ditch in Aurora; and Sand Creek in Commerce City where the peak flow exceeded 7,500 cfs at 8:07 pm, setting a new record for that gaging station.

Big Dry Creek in Westminster was running well above normal from yesterday's downpour when additional heavy rains fell on Friday, **July 8**, causing the creek to experience its highest flow in recent years—quickly rising over 3.5 feet and setting a new record peak, its highest since 1987. The storm that caused this was localized with maximum rainfall amounts approaching 2.5 inches. Intense rainfall was measured in Broomfield, Thornton and Westminster.

Tuesday, **July 12** was another area-wide rain day for the District. Annual peaks were measured in Denver on Cherry Creek, Lakewood Gulch, Sanderson Gulch, and the South Platte River. The Sanderson Gulch and Lakewood Gulch stream gages set new records. While the rain totals in the District were mostly under 2-inches, a large nearby storm in Elbert County had reports of rainfall exceeding 5 inches. ALERT rain alarm thresholds were exceeded at 23 stations.

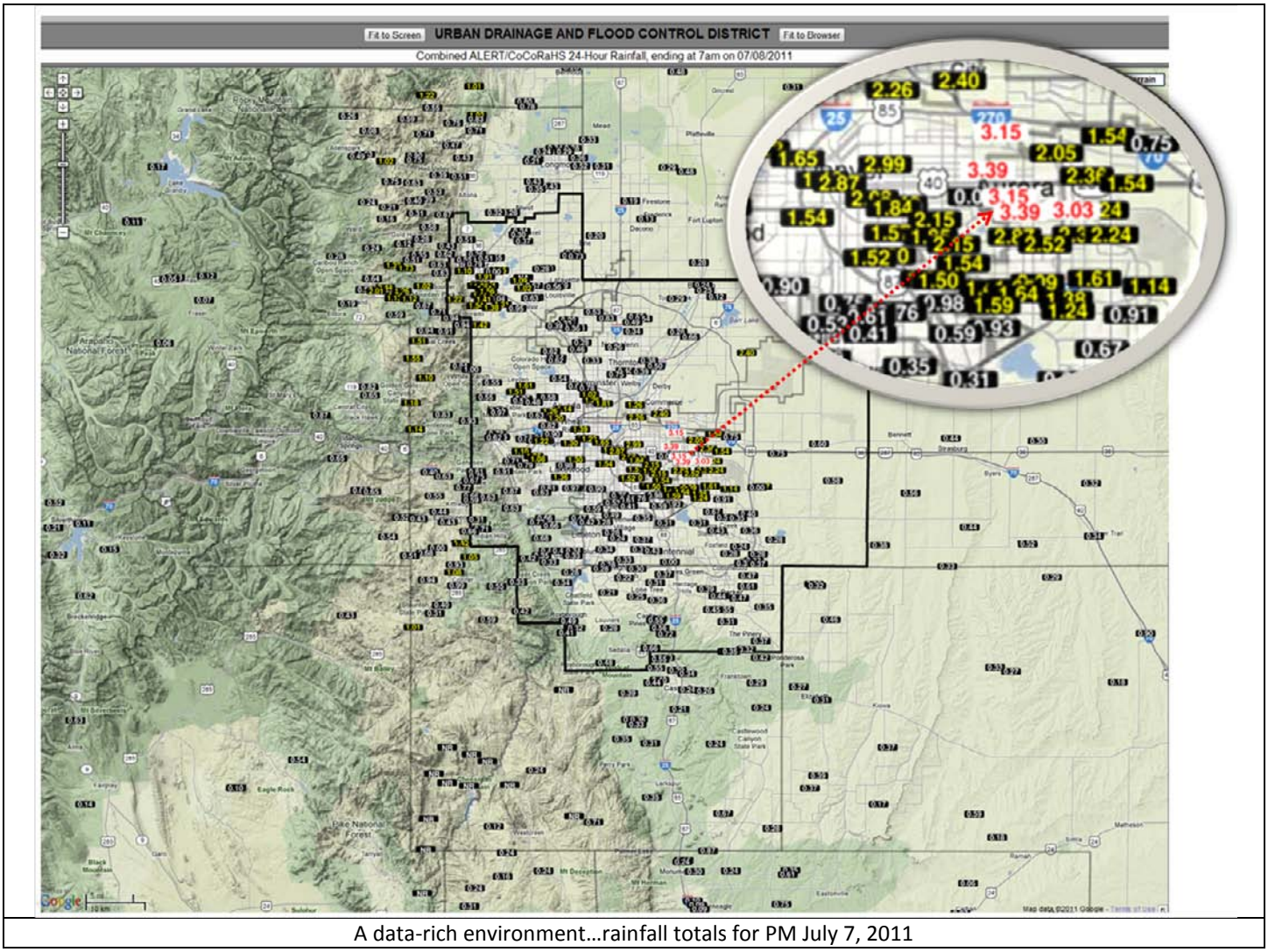
While most of the attention this day, **July 13**, was focused on the Fourmile Burn Area in Boulder County and the flash flood warning issued by the City of Boulder, a few other locations deserve honorable mention. Besides Boulder Creek and Fourmile Creek, annual streamflow peaks occurred also on Goldsmith Gulch in Denver; West Toll Gate Creek in Aurora; Lena Gulch in Jefferson County, Golden and Lakewood; the South Platte River in Adams County; and on Sulphur Gulch in Parker.

This Thursday, **July 14,** ended in tragedy when an Aurora teenager fell into Toll Gate Creek near its confluence with Sand Creek. The creek was flowing above normal but well below flood levels from rains over the past 3 days when the accident happened. The heavy rainfall this day occurred to the west in Denver and Arapahoe Counties where annual peaks were recorded for Harvard Gulch and Goldsmith Gulch at Iliff Ave. in Denver; and at Powers Parks on Slaughterhouse Gulch in Littleton between 3:00 and 3:30 pm.

Tuesday, **August 2** was the last flash flood watch day for the District, which ended without incident. The rest of the month remained very dry in the District. After what happened in July, we certainly deserved a break.

Hayman Flood Threat Nine Years Later

The Hayman Burn Area in southwest Douglas County experienced another debris-loaded flash flood on this Friday afternoon, **July 29**. The NWS issued a small stream flood advisory for this area at 3:54 pm. Trained weather spotters reported 1.2-inches of rain, consistent with Radar-estimated amounts. While flood damages were minimal, an impressive amount of debris once again accompanied the storm runoff as shown in the August 1 photo provided by the USGS. It is interesting to note that this type of impact is still occurring from such a small rainfall event so long after the 2002 fire that burned over 138,000 acres. Should those living in the Fourmile Burn Area in Boulder County expect the same?



A data-rich environment…rainfall totals for PM July 7, 2011

Early Flood Prediction and Notification Services

Meteorological support was provided by Genesis Weather Solutions in partnership with Skyview Weather for the fifth consecutive year. This program provides District local governments with early predictions of potential and imminent flood threats along with a variety of related forecast products like daily heavy precipitation outlooks, area-specific quantitative precipitation forecasts (QPF), and storm track maps. Project manager and chief meteorologist Bryan Rappolt completed his 18th year of service. Bryan's Skyview partners included lead forecaster Brad Simmons, met-techs Chris Anderson and Daryl Brynda, with Skyview's President Tim Tonge providing backup from his business location and forecast center in Castle Rock. This District program was established after the deadly 1976 Big Thompson Canyon flash flood and has served the Denver/Boulder metropolitan area for the past 33 years.

The Flash Flood Prediction Program, a.k.a. F2P2, operates from 15 April through 15 September in close partnership with the National Weather Service Forecast Office in Boulder. The F2P2 forecasts and early notifications focus primarily on heavy rain threats over approximately 3,000 square miles covering the District and watersheds upstream. During the mountain snowmelt runoff season from late spring to early summer, local governments are also kept advised concerning stream conditions and how those high flows increase the flood potential when heavy rain threatens. F2P2 notifications concerning high reservoir releases by the Tri-Lakes Office of the U.S. Army Corps of Engineers from Chatfield, Cherry Creek and Bear Creek dams are also disseminated to affected jurisdictions downstream.

F2P2 products and services were evaluated for the fifth consecutive year by Judy Peratt of JP Consulting, located in Windsor. Judy is a former emergency management director that served Jefferson County for many years. This face-to-face interview process has helped the District learn details about what works well and what could use improvement from an end-user perspective. The District greatly appreciates the valuable time taken by all the participating local officials representing emergency management, communications, public works and emergency services.

Some program changes are likely for 2012. The term "Red Flood Alert" (RFA) has long been used in the F2P2 to notify local governments when low impact flooding is likely. This product is similar to a Flash Flood Warning (F2P2 Message 3)

that is used to warn of imminent threats to life and property. The once "familiar" code now confuses many users, especially those who are new to the program. As more people gain access to this information, keeping users educated about code words becomes problematic. For example, the RFA can easily be confused with the NWS Red Flag Warning that pertains to fire weather conditions. Also, local jurisdictions commonly use colors to designate emergency status or threat levels that correspond to specific operational procedures. Using RFA as an add-on or update to a previous message is also at times misleading. One remedy suggested during Judy's interviews is to make the RFA a stand-alone message. Another good idea is to change its name to something with clear meaning, i.e. use plain language. The Boulder Office of Emergency Management has offered to assist the District with designing an acceptable alternative for 2012 by bringing together key stakeholders to share their experiences from last summer. The Fourmile Burn Area threat may be the perfect test-bed for a new F2P2 messaging procedure. If the changes can pass this test, the change should be widely accepted by others. The District is excited about this unique opportunity to greatly improve public safety communications.

Visit f2p2.udfcd.org for more information about the F2P2 products and services.

CoCoRaHS Update

Thirteen years ago this past June 17, three high school students in Fort Collins launched the first "CoCoRaHS" website. This innovative idea was a positive response to the deadly flash flood the struck that community in July of 1997. Today the Community Collaborative Rain, Hail and Snow Network is active in all 50 states and holds the distinction of being the largest provider of daily precipitation observations in the country. In December the province of Manitoba became the first Canadian community to join.

Efforts were underway in this year by the CoCoRaHS team to gear-up for a school-based outreach program in 2012 for the Denver area. Their plans entail developing a special web resource page that includes lesson plans for elementary, middle school and high school teachers.

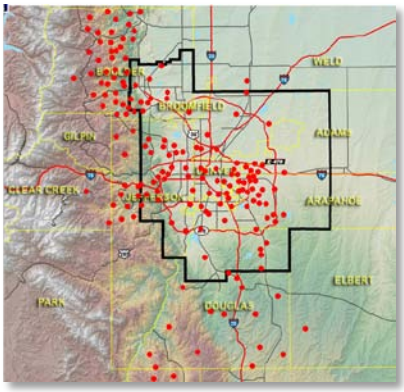
The District has been a sponsor of CoCoRaHS for over a decade and routinely makes use of this valuable data. The past 5 years of web-posted storm summary maps are a good example. Please consider becoming a CoCoRaHS observer today by signing up at www.cocorahs.org.

EMWIN-Denver Regional Update

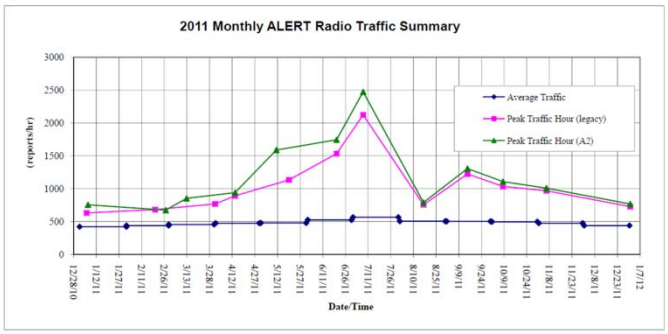
The Emergency Managers Weather Information Network continues to provide northeast Colorado communities with timely NWS weather warnings and advisories. The District currently hosts the subscription-based email service for this regional system. EMWIN-DR is guided by a steering committee chaired by Rick Newman with the Adams County Office of Emergency Management. In 2011 the web-based EAS (Emergency Alert System) activation request procedure was completed, thus providing local government officials with a simple and secure way to notify the public concerning non-weather emergencies. All EAS activation requests are verified by the NWS before alerting the public.

ALERT System News

New gaging station on Happy Canyon Creek at I-25 in Douglas County.

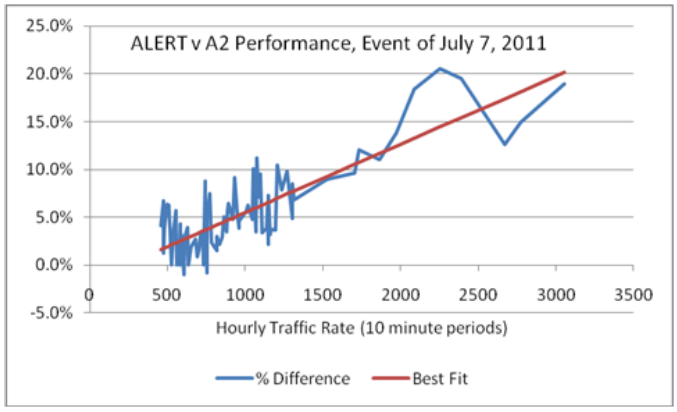


The ALERT system currently collects data from 214 gaging stations that host 191 rain gages, 103 stream gages and 25 full weather stations. The gauging network experienced some rearrangement and growth in 2011. On the District's south side, Douglas County installed two new combination rain/steam gages on East Cherry Creek at Russellville Road and on East Plum Creek at Columbine Open Space. They also relocated eight stations from the Hayman burn area and added stream level sensors to four of those stations on Happy Canyon Creek at North Surrey Ridge, Newlin Gulch at Jordan Road in Parker, Tallman Gulch at Tallman Park near Parker, and on Big Dry Creek at Highland Heritage Regional Park near Lone Tree. One of the relocated Hayman stations at Bingham Lake Park was upgraded to full weather station status. In the northwest portion of the District a new rain/stream gage was installed on South Boulder Creek at South Boulder Road by City of Boulder Open Space and Mountain Parks.



OneRain and Water & Earth Technologies provided preventative maintenance and repair services for 2011, enabling the District to process over 4.2 million ALERT messages and more than double that amount when counting the ALERT2™ data stream. During the storm activity of July 7

the peak traffic rate briefly exceeded 3,000 reports per hour between 5:10 and 5:20 PM.



For the second consecutive year, ALERT2™ vs. ALERT legacy comparisons revealed that the newly developed A2 protocol consistently outperforms its predecessor. The legacy protocol that was first deployed in California in the mid-1970's continues to prove its value, especially for smaller gauging networks. However, when networks become as large as the District's, data collection reliability starts to degrade. Consequently, the District is prepared to take the next logical step in 2012 toward full A2 implementation by upgrading existing ALERT repeater sites to enable both receiving and rebroadcasting the enhanced protocol.

In 2011 the District began testing another new way to relay data from a radio path challenged ALERT rain gage in Douglas County—the Rampart Range Road station near Roxborough Park. The Sutron Corporation voluntarily provided the telemetry that utilizes 66 Low Earth Orbit Iridium satellites. Although the gaging station appears to perform very well, a few surface-based communication bugs still need be resolved. We are confident that systems like this offer affordable options when radio repeater networks prove inadequate.

The District has arrived at a critical crossroads in its support of existing ALERT data collection platforms commonly referred to as base stations. These base stations are comprised of radio reception and data decoding equipment that connect to aging PCs that run an operating system called QNX and proprietary software known as NovaStar. There are six locations in Denver, Douglas County, Lakewood and Boulder that currently host the QNX/NS-4 base stations and most of these sites have been operating continuously since Y2K…remember that event? These platforms also host webserver software, enabling users to access the real-time data from any desktop/notebook computer or any other smart device with Internet browsing capability. After 12 years of success using this aging technology, the time has arrived for a more sustainable approach to be implemented.

In 2012 the District will upgrade two base stations using the latest available NovaStar software and a more widely-accepted Linux operating system. Plans include developing a second receive site not at Diamond Hill (the District's office building) with failover capabilities in the event Diamond Hill somehow becomes disabled. A third site running a different software package known as Contrail Web is also being considered. With this hardened base station network design in place, the proliferation of base stations that currently exists will be much less desirable or necessary for backup data access. The new architecture will also greatly simplify database maintenance activities and reduce associated costs.

The updated equipment will provide new opportunities to consolidate useful data from other non-ALERT sources such as the satellite-monitored streamgages operated by the USGS and the Colorado Division of Water Resources (DWR). With respect to flash floods and effective use of real-time data—one stop shopping, data display familiarity, early threat recognition, longer lead times, and simplified decision support are highly desired attributes that can be difficult to achieve at times and even harder to fully satisfy every user's wishes. The District remains committed to reaching these long term goals and will do so with the help of our many partner agencies.

Speaking of partner agencies, the City of Boulder IT and Public Works departments implemented at creative way to educate the public about streamflow by linking smart phones to real-time water level measurements while observing high flows on Boulder Creek from an unusually late spring runoff. A free QR "Quick Response" Code reader app is all that's required to access the corresponding streamgage URL. B-smart signs were attached to Muni and Library footbridges over Boulder Creek near Broadway, to the flash flood area warning signs in Peach Park, and to the DWR streamgage located between 9th Street and Broadway. Credit goes to Leslie Labrecque, Jody Jacobsen, Kurt Bauer, Bob Harberg and Kip White for making this innovative idea a reality. Now if someone can just find a way to keep people from taking these nifty green signs.

Resources

A complete archive of daily forecasts, flood threat notifications, storm track predictions, storm summary maps, and other products can be found at f2p2.udfcd.org. See www.udfcd.org/FWP/ALERT/wl/annual_peaks.xlsx for an up-to-date table of annual and record water level/streamflow peaks measured by the ALERT system. For detailed operation and maintenance reports visit:
www.udfcd.org/FWP/ALERT_Reports/ and
www.udfcd.org/FWP/F2P2_Reports/

The preceding is an excerpt from the 2011 edition of Flood Hazard News. For the full version of the newsletter see: www.udfcd.org/downloads/pdf/fhn/fhn2011/FHN_2011.pdf