Understanding Extremes

(December 2007)

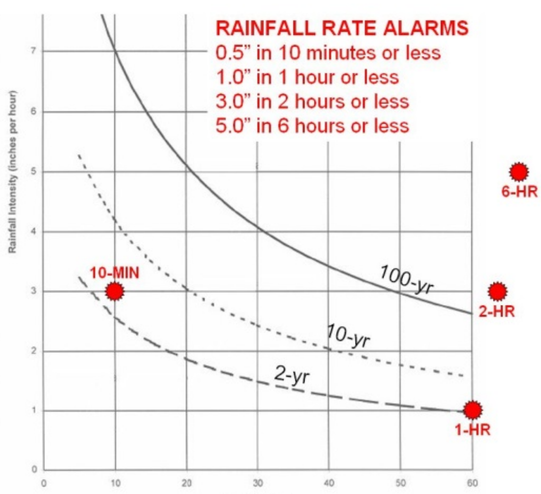
It seems like every time a heavy downpour results in flooding, inquiring minds want to know how big the flood was in terms of its frequency or its likelihood of happening again. Most floods that we experience on an annual basis are relatively small in magnitude, as compared to the 100-year (1% annual chance) flood that most people relate to and believe they understand.

The news media frequently looks for some authority to confirm that a flood or rainstorm was a 2, 5, 10, 50, 100, or 500-year event, or an anomaly of greater magnitude. Since rainfall data is more readily available than streamflow, these measurements are commonly used to estimate a return period that news reporters convey to the public. For example, one TV news report about the May 14 “flash flood” on Lakewood Gulch stated that this event was a 50-year flood. If the truth be told, it wasn’t even close. However, a nearby ALERT rain gage did measure a very short intense burst that approached the 50-year (2% annual chance) magnitude. To equate this to a 50-year flood on Lakewood Gulch is completely misleading, but it happens all too often. By the end of 2007, the Lakewood Gulch stream gage at 10th Avenue in Denver measured three other events of equal magnitude.

Another common misunderstanding is the likelihood of experiencing a so-called “rare” rainfall event. When return periods are used to describe large rainstorms, it leaves the impression that such events happen infrequently. But the truth is, big rains happen every year in a region as large as the District, even events as “unusual” as the 100-year. This defies rational thinking for most people and consequently, trying to explain this to a news reporter may not have the desired outcome. How is it possible that a rainfall event that only has a 1% annual chance of occurring in your neighborhood is almost certain to happen every year somewhere in or near the community in which you live? In attempting to answer this challenging question, consider the following:

Year	Days	Points
2007	17	53
2006	13	45
2005	10	38
2004	18	61
2003	13	**70**
2002	8	17
2001	14	57
2000	7	34
1999	**20**	62

District ALERT Base Station alarm summary



Colorado’s State Climatologist has stated that in a typical year, it is not unusual for Colorado to experience between 100 and 150 precipitation events that exceed the 100-year mark. The above figure supports this statement with a look at nine years of rainfall alarms from the District’s ALERT system. The table shows that 2003 had the largest number of gage point alarms (70) while 1999 had the greatest number of alarm days (20). The graph shows the corresponding return periods for the rainfall rate alarm thresholds used by the District. At the very least, an alarm indicates that a 2-year rainfall event has been exceeded. A closer inspection of the data reveals that a majority of these storms actually exceed the 5-year threshold, suggesting that the metro Denver region averages between 10 and 15 days a year of intense rainfall capable of at least causing minor flooding.

Experience has also shown that significant flooding occurs every year from one or more of these events while disastrous floods are, fortunately, few and far between.

So, how can this information help us begin to correct some of the continuing myths about extreme events? Here are some suggestions:

1. When describing flood magnitudes to the public, relate the subject event to a past flood whenever possible.
2. Use terms most people can correctly relate to like *"the floodwaters rose 3 feet in less than 10 minutes"* or *"the roadway was overtopping by 2 feet of water."*
3. Avoid mentioning peak discharge. Lay people seldom understand flow rate units of CFS, CMS or GPM.
4. When pressed to estimate a return period, consider relating the event in question to the 100-year flood as a fraction or multiple, or state that the water level rose to within 4 feet of the 100-year flood or exceeded the 100-year flood by some known amount at a specific location.
5. Never equate flood frequency with an observed rainfall intensity and corresponding return period, unless you are talking about a flood that occurred in a parking lot with a person that understands exactly what you are talking about.

Events like Hurricane Katrina and worldwide debates over climate change have made us all very sensitive to weather extremes and their potential catastrophic impacts. As engineers and subject experts on floods, we should first educate ourselves about extreme events and then work with communication professionals to more effectively educate others about the true risk of flooding and what individuals and families can do to protect themselves.

The above article was authored by Kevin Stewart and published in the 2007 issue of Flood Hazard News, the annual newsletter of the Urban Drainage and Flood Control District in Denver, Colorado, USA.

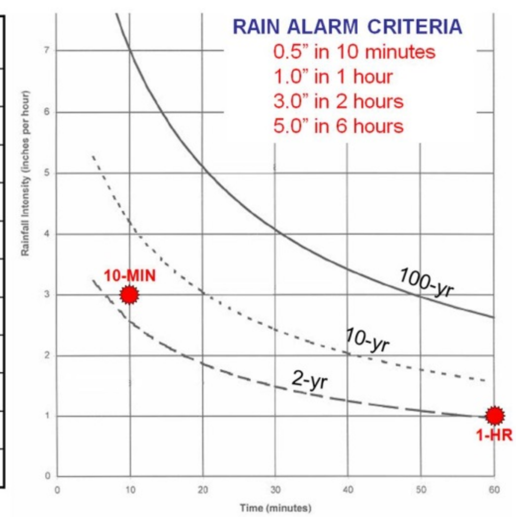
Extremes Revisited

(December 2009)

Have you ever heard someone say – "What if the worst happens and we have a 100-year flood?" I wonder how many people think this way. I suspect that that number is quite large but I know of no research that supports this opinion. A more disturbing question might be…how many professional engineers, floodplain managers and stormwater authorities would agree that the 100-year flood is the worst thing they can imagine? I hope that number is very small, but I have my concerns that the truth might be disappointing.

FEMA, ASFPM, NAFSMA, ASCE, USACOE along with other federal agencies and organizations have recently been seeking answers to questions like this. Katrina's impact has been a major motivating factor, but since that 2005 hurricane a number of other flood events have caused further concern. The National Flood Insurance Program (NFIP) fund is in the red and FEMA wants a better way to address the problem than just continuing along the same unsustainable path.

Year	Alarm Days	Gage Points
2009	32	151
2008	6	42
2007	17	53
2006	13	45
2005	10	38
2004	18	61
2003	13	70
2002	8	17
2001	14	57
2000	7	34
1999	20	62



In the 2007 edition of *Flood Hazard News,* an article entitled *"Understanding Extremes"* pointed out that alleged rare events actually happen quite often, and data from the District's ALERT System was used to illustrate this truth. Given the two unusual flood seasons that followed, it seemed like this might be a good time to refresh the 2007 table/chart and keep the dialog going about what really constitutes an extreme event and how we—the so-called flood experts—should communicate our understanding about flood risks when talking with others.

The table shows how 2009 crushed earlier alarm records that date back to 1986. Only the last decade of statistics are provided because, over the years, the ALERT rain gage network coverage has increased substantially thus skewing the comparison. For example, the Hayman network did not come on line until 2003. Regardless, it is fair to conclude that while 2009 is not considered a big flood year; it definitely produced a high number of heavy rain events with intensities exceeding the 2-year frequency.

As floodplain managers and designers of major drainage and flood control facilities we tend to stay focused on engineering design thresholds and in doing so, we talk a lot about that single event. We attempt to communicate flood risk in terms of frequency or probability, e.g. 100-year or 1% annual chance. Sometimes we try to describe the 100-year flood's likelihood over a longer period of time like 30 years—the term of a typical home mortgage—as having a one-in-four chance of occurring. While we may well understand what we are saying, our non-technical audience may not fully appreciate how this affects them personally.

Consider this…Knowledge of local flood history can be extremely helpful when trying to make a connection with people and gain their trust. People like to hear and tell stories about past floods. Let others tell their stories whenever the opportunity presents itself. After a short journey through the past, it may be much easier to discuss flood risk in ways people can better comprehend.

Bear Creek flood levels in Morrison between Market Street and Mount Vernon Street downstream of the Mount Vernon Creek confluence. The "Historical Flood High Water Mark" depicts the level of the September 2, 1938 flood.

Sometimes flood history is lacking for a specific location. In this situation remember that extreme floods have certainly occurred somewhere nearby. One good example is the Morrison flood of 1938. That particular flood exceeded the 100-year design flood on Bear Creek through downtown Morrison, but the most noteworthy fact that sticks in my mind is that Bear Creek was not the main source of flooding; rather it was the Mount Vernon Creek tributary that peaked at twice its 100-year discharge. The cause of the 1938 flood is another useful fact to point out—it resulted from a very intense rainstorm that dropped nearly 8-inches of rain at its core, while the design rainfall used for calculating the 100-year flood is less than 3-inches. As engineers we should own up to the fact that even our best flood control projects and land use management practices will fail to protect when too much rain falls.

Catastrophic flooding from events like Hurricane Katrina and worse will occur in the future, but not in the District—right? That's what we would like to believe but most of us know better. As engineers, acclaimed as "experts" on floods, we should continue to educate ourselves about extreme events and find better ways to more effectively inform others about the true risk of flooding and what individuals and families can do to protect themselves.

The above article was authored by Kevin Stewart and published in the 2009 issue of Flood Hazard News, the annual newsletter of the Urban Drainage and Flood Control District in Denver, Colorado, USA.

Extreme Rains <u>Not</u> Required

(December 2010)

How likely are flood-producing rainstorms really? Three years ago a small magnitude flood on Lakewood Gulch in Denver claimed the life of a child. It was this tragic event that prompted this author to begin writing about what we believe we have learned about rain frequency and flood frequency from more than 20 years of measuring rainfall and streamflow. In 2009 after the busiest year of flood threats in over 30 years, the question of extreme rainfall and floods was revisited and suggestions were made concerning how subject matter experts might better communicate truths about floods. This year the FMC Fire in Boulder County created yet another opportunity to take a much closer look at flood risk with respect to alleged "infrequent" rainstorms.

Rather than rambling on try to prove my case beyond reasonable doubt, I've decided that this year I will simply draw some final conclusions and leave the following opinions and supporting evidence open to peer review and critique:

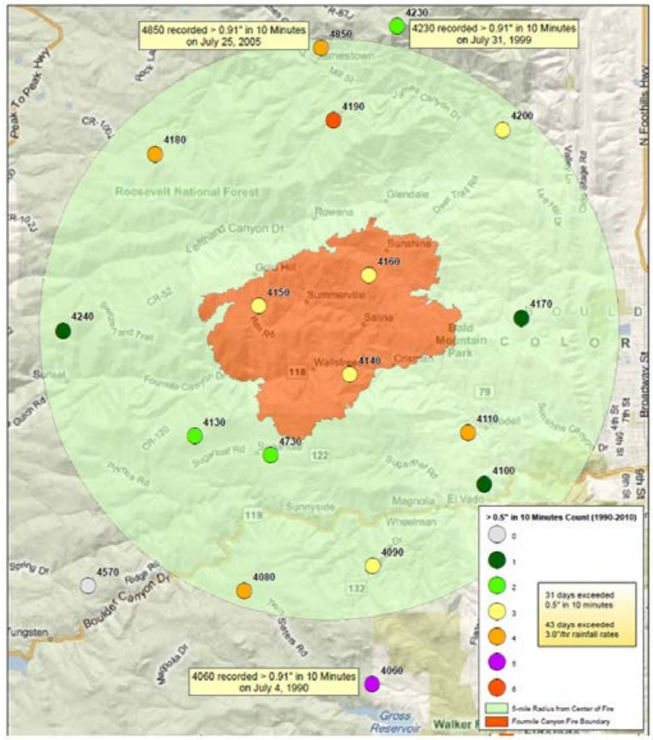
1. Big floods happen (support: many historic flood accounts for this region dating back to the 1860's)
2. Big rains happen often (read 2007 & 2009 issues of *Flood Hazard News* and preceding text)
3. Big rains do not always cause big floods (see past 20+ annual issues of *Flood Hazard News*)
4. Rainfall of a given magnitude, normally expressed as annual probability of occurrence or return period, never causes a like-magnitude flood on the receiving stream (*Supplemental: This author has neither witnessed nor read an account of a flood with these characteristics*).
5. Small floods can be deadly (e.g. Lakewood Gulch 2007)
6. Big floods occur in dry years (e.g. Big Thompson 1976 and Cherry Creek at Denver 2008)
7. Small rains can cause big floods (e.g. Hayman, Buffalo Cr)

Point No. 7 is something that concerns many people involved with and affected by the FMC-BA. The question inquiring minds want answered is: how much rain is needed (over how small of an area in what time period) to seriously threaten lives and properties downstream? For Fourmile Creek residents the answer is fairly certain…it will not take much and such an event it highly likely in the next few years. For the City of Boulder the question is the same but the answer is more difficult and steps are currently being taken to find some answers soon. Until then we will trust what we have learned from Hayman and Buffalo Creek.

The following table and figure provide a revealing historical look at rainfall measured within a 5-mile radius of the center of the FMA-BA over the past 21-years. With 1/4-inch of rain in 1-hour currently being considered a serious threat by the experts, hopefully you can make your own decision about the likelihood of occurrence.

Number of 30-Minute Duration Storms Exceeding:

	0.25"	0.5"	0.75"	1.0"	1.25"	1.5"
1990	18	14	3	2	1	0
1991	25	9	3	2	1	0
1992	18	2	0	0	0	0
1993	20	4	0	0	0	0
1994	27	8	1	0	0	0
1995	22	4	0	0	0	0
1996	23	8	2	0	0	0
1997	27	9	1	0	0	0
1998	22	9	3	1	0	0
1999	35	16	5	3	0	0
2000	12	2	0	0	0	0
2001	27	7	2	0	0	0
2002	13	3	1	0	0	0
2003	16	6	3	1	1	1
2004	13	8	0	0	0	0
2005	9	3	1	1	1	0
2006	2	1	1	1	0	0
2007	9	4	2	2	0	0
2008	1	0	0	0	0	0
2009	5	0	0	0	0	0
2010	5	2	0	0	0	0
TOTALS:	**349**	**119**	**28**	**13**	**4**	**1**



Green circle represents a 5-mile radius from the centroid of the Fourmile Burn Area in Boulder County.

Concerning Boulder's near future, we highly recommend that everyone affected prepare for the worst and hope that the worst does not happen.

The above article was authored by Kevin Stewart and published in the 2010 issue of Flood Hazard News, the annual newsletter of the Urban Drainage and Flood Control District in Denver, Colorado, USA.

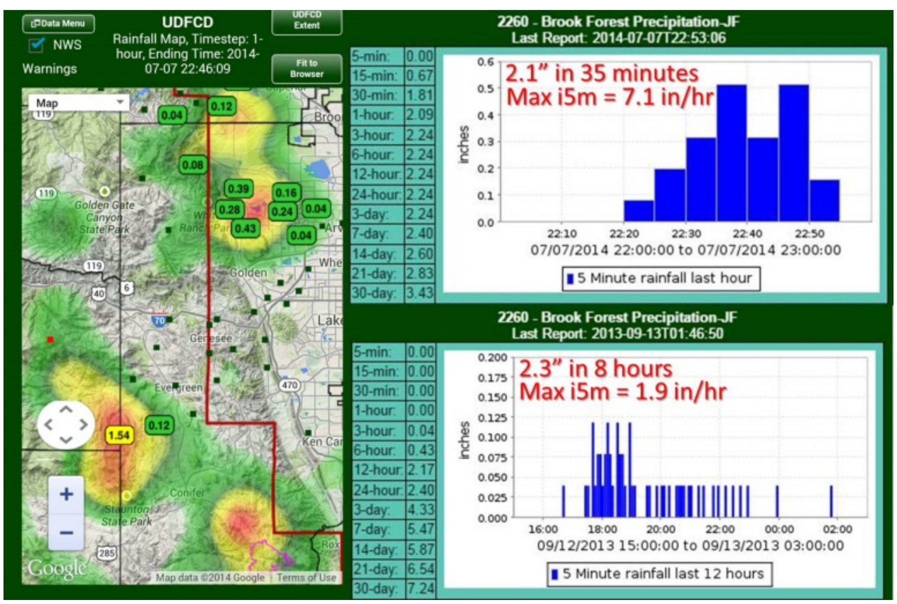
Understanding Extremes—Part IV

(January 2015)

Seven years ago I wrote a short opinion piece about the frequency of so-called extreme rainstorms, and what it takes to cause an equally rare flood. Two years later I expanded on those ideas by suggesting some ways that subject matter experts could more effectively talk with people about flood risk. Then, after the 2010 Labor Day Fourmile Canyon Wildfire in Boulder County, I took a third shot at this subject with a slightly different twist inspired by an elevated flood risk caused by the fire, and the very high likelihood that a dangerous flash flood would severely impact this area in the next few years. As it turned out, the floods did come and the property damage was extreme, but thankfully, no lives were lost.

The Colorado STR (September-To-Remember) floods of 2013 created many opportunities to continue this conversation in Colorado and across the Nation. This year's STP-13 cover story by Wright Water Engineers explains well how an extreme 1/1000 annual chance rainfall can cause flood magnitudes far less extreme. A small localized flood this past July in the Jefferson County foothills spurred this writer to share one "final" real-world example.

The STR-13 rains brought nearly 7.5 inches to the mountain community of Brook Forest over a 7-day period. Brook Forest is located along Cub Creek south of Evergreen. Cub Creek flows into Bear Creek just downstream of Evergreen Lake. An intense thunderstorm occurred on July 7 (*read 2014 Flood Hazard News article for further discussion & video—at 5:20 point in 9News clip*) that dropped a mere 2.1 inches of rain. Yet, as one resident reported, the flooding that occurred was more severe than the STR-13 event. How can this be?



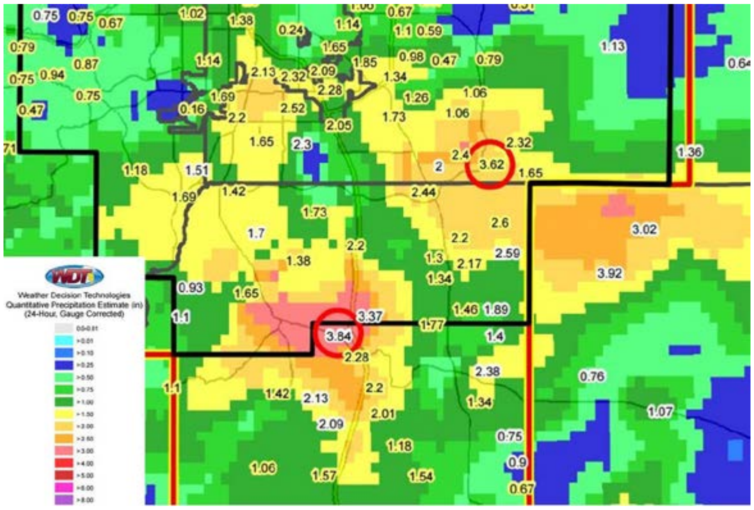
The figure above compares the 2013 and 2014 events. Both events generated about the same amount of rain, but the 2014 storm did so in just over 30 minutes while the STR-13 storm took much longer. Rainfall intensity once again was the primary factor affecting the flood's impact, not the amount or the storm's return period. Rainfall frequency never equals flood frequency in real events.

The above article was authored by Kevin Stewart and published in the 2014 issue of Flood Hazard News, the annual newsletter of the Urban Drainage and Flood Control District in Denver, Colorado, USA.

Rain Measurements Exceeding 1% IDF Thresholds

(December 2015)

This writer has, on more than one occasion, alleged that the Denver/Boulder area experiences at least one rain event every year that exceeds the 1% chance (100-year) threshold defined by point precipitation frequency estimates for the region, commonly referred to in hydrologic engineering design practice as intensity-duration-frequency (IDF) curves. In 2015, three days recorded rainfall intensities reaching this "rare" status according to NOAA Atlas 14.



On Thursday, **June 11** between 5 PM and 6 PM, a rain gage in Douglas County near the intersection of U.S. 85 and Happy Canyon Road measured rainfall that exceeded 100-yr intensities for time periods of 5, 10, 15 and 30 minutes. The first rainfall rate alarm tripped at 5:27 PM and the maximum measured 5-minute intensity was 9.9 in/hr. The comparable NOAA 100-yr value at this location is 8.8 in/hr. This was the most intense rainfall recorded by the ALERT system in 2015. It may also be worth noting that this particular rain gage (2.28" storm total) was not located in the area where the largest 24-hour rain amounts occurred according to the storm summary map.

On Wednesday, **June 24** the second most intense rainfall of the 2015 flood season was recorded at the gage near the Holly/Alameda intersection in Denver with almost 1.2 inches in 10 minutes (7.1 in/hr) at 5:05 PM and a total of 2.2 inches from the 1-hour duration storm. Another rain gage near the I-70/Havana Street interchange also topped the 1% intensity threshold at 5:15 PM.

An isolated storm along the I-76 corridor in Jefferson and Adams counties around 6:30 PM on Thursday, **July 9** produced rain amounts approaching 3 inches. A rain gage near the Pecos Street interchange caught 2.91 inches over a 90-minute period and exceeded 2.5 inches in 60 minutes, making this measurement the maximum 1-hour total for 2015. The 100-year 1-hour NOAA value for this location is 2.4 inches.

The above newsletter excerpt authored by Kevin Stewart was published in the 2015 issue of Flood Hazard News, the annual newsletter of the Urban Drainage and Flood Control District in Denver, Colorado.

Other Related Resources

1. 2016 issue of Flood Hazard News…see page 11 discussion entitled: ***"Rainfall Exceeds 100-Year Return Period Yet Again"*** concerning the rainstorm of August 30, 2016.

2. 2017 issue of Flood Hazard News…see page 44 discussion entitled: "***Rainfall Surpasses 100-Year Threshold***" concerning the rainstorm of July 26, 2017.

3. The 'alert5' Resources webpage under the Flood History section/Special Topics