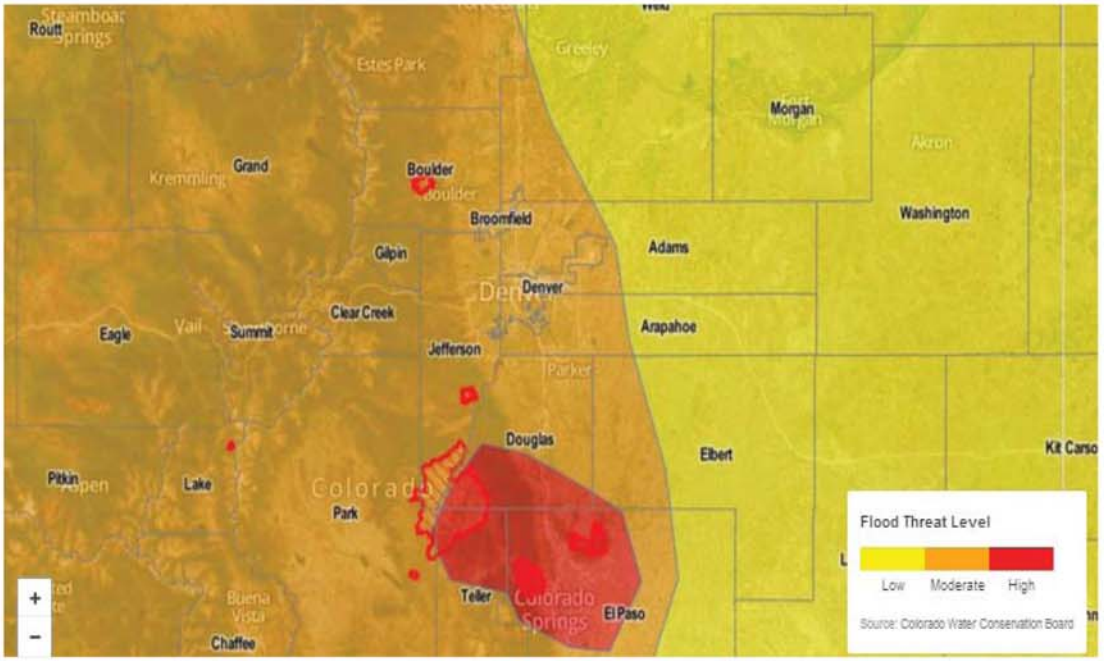
Dewberry

ARCHITECTS ENGINEERS CONSULTANTS



2013 Colorado Flood Threat Bulletin Final Report

Colorado Water Conservation Board

SUBMITTED BY:

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Contents

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2013 Colorado Flood Threat Bulletin

Final Report

INTRODUCTION

Colorado is threatened seasonally by different forms of flooding including ice jams, flash floods, spring snowmelt and river flooding. Causes of this flooding vary with the season and include abnormal periods of hot weather during the spring snowmelt, severe thunderstorms and general storms during the spring and monsoon thunderstorms during the summer and early fall. This project is design to provide Colorado emergency managers and first responders with a daily county-specific assessment of flood and flash flooding threat in their county.

In 2012, another competitive award was made to Dewberry. As in previous years, the program runs from May 1 through September 30 and requires the daily issuance of flood threat bulletin describing the flood threat in Colorado and the issuance of a 15-day Flood Threat Outlook to identify periods of locally heavy rainfall and conversely the development of drought conditions due to lack of precipitation. Meteorologists John Henz, Brad Workman and Robert Rahrs developed all of the FTB forecasts. The forecasts were made available on web page: www.coloradofloodthreat.com.

Daily Flood Threat Bulletin

The Daily Flood Threat Bulletin (Daily FTB) is designed for daily issuance during the contract period by 11:00 AM. The FTB outlines the daily threat of flooding across the State, the nature of the threat and the time period in which the threat of flooding would be the greatest in County-specific manner. Additional information includes a characterization of the threat of attendant severe weather (tornadoes, high winds, hail) and the probability of most likely thunderstorm hourly rainfall rates and/or amounts.

The threat of flooding is conveyed to the user community through the use of graphics and text. The graphical component to the product includes a map of the State of Colorado with county boundaries and a color coded threat to succinctly illustrate the range of flooding threats across Colorado. The evolution of this presentation to a more communicative graphical form enhanced the spatial and temporal threat areas visualization.

The spatial coverage of the threat was available by clicking on a threat icon at the top of the page. The resulting graphic showed the areas of highest threat and a forecasted approximation of the temporal distribution associated with the type of thunderstorm/general storm system forecast. The spatial threat graphic is issued to users on days of high threat or when the National Weather Service issues either Flash Flood or Flood Watches.

Flood Threat Outlook

The second product is a bi-weekly Flood Threat Outlook (FTO) issued to address the 7 to 15 day threat of flooding across the state on Mondays and Thursdays by 300PM. This product addresses both the extended threat of flooding and a precipitation outlook by river basin.

Flood Threat Outlook

For 2013, Dewberry provided a continuation of the STP service through use of an ArcWeb software and website/database package led by Stu Geiger and the Dewberry GIS experts. The STP presented rainfall coverage by merging NWS WSR-88D Storm Total Precipitation products from Boulder, Grand Junction, Puebloe, Cheyenne and Goodand sites with CoCoRahs data into the mapping function so that point-by-point comparisons of the STP/observed data can be assessed.

FTB PERFORMANCE METRICS

Dewberry will provide several performance metrics related to both the forecasting of the flood threat and the delivery of the forecasts. The Table below shows both the final year to date number of Flood Threat

Bulletins provided, the percent of FTB's provided by Colorado-based meteorologists (John Henz, Brad Workman and Rob Rahrs) and the number of all products, FTB's, FTO's and STP's provided on time. In each case Dewberry met the CWCB-established metrics.

Table 1: Product delivery performance for 2013 Flood Threat Bulletin products.

Product	Total Products	Products on Time	Percent on Time
STP	156	149	96%
FTB	156	138	88%
FTO	47	34	72%
Total	**359**	**321**	**89%**

FORECAST METRICS

The daily FTB flood threat forecasts were verified on their ability to both identify days when flood treats were realized and the approximate location of the predicted flooding. An objective set of verification observations were used to determine forecast verification. Here are the rules and information sources used to verify the forecast by Dewberry:

1. Primary verification sources were the National Weather Service (NWS) reports of flash flooding and/or severe weather, CoCoRahs precipitation reports, NWS precipitation reports, Storm Total Precipitation fields from NWS WSR-88D Doppler radars and verifications of flash flooding in the Urban Drainage & Flood Control District's Flash Flood Prediction Program.
2. A flash flood day was declared when reports of flash flooding were received, WSR-88D STP exceeded 1.25 inch or surface rainfall amounts exceeded 1.25 inch. On severe weather days a report of hail and/or a tornado and rainfall over 0.50 inch/15-30 min indicated a flooding threat.
3. A forecast was declared a hit when observed flooding events occurred in the predicted flood threat area. A miss was declared whenever no flooding events occurred in the forecast area or occurred outside the forecast area.

Appendix A contains the daily forecast observations used for verification. Table 2 shows a monthly breakdown of the daily forecasts made for the 2013 FTB season. Four categories of daily forecast verification are presented:

1. No flood forecast and no flood observed
2. No flood forecast and flooding observed
3. Flooding forecast/flooding observed
4. Flooding forecast and no flooding observed

Table 2: Forecast metrics by month for the 2013 forecasting period.

Forecast / Observed	May	June	July	August	September	**Total**
No Flood / No Flood	23	18	4	4	8	**57**
No Flood / Flood	2	4	2	1	4	**13**
Flood / Flood	4	8	21	21	18	**72**
Flood / No Flood	2	0	4	5	0	**11**
Total	**31**	**30**	**31**	**31**	**30**	**153**

Table 3: Forecast metrics by type of forecast for the 2013 forecasting period.			
	Forecast Flood Day	Forecast No Flood Day	**Total**
Observed Flood Day	72 (a)	13 (b)	**85**
Observed No Flood Day	11 (c)	57 (d)	**68**
Total	**83**	**70**	**153**

Each category is self-explanatory and will be used to discuss the forecast accuracy and efficiency. Note the high number of non-flooding days in May and June compared to the high number of flooding days during the monsoon season of July to September. While the serious flooding in September garnered most of the headlines, more flooding days were observed in July and August.

Note that 85 flooding days occurred in 2013 season compared to 64 days. An evaluation of the forecast "flood day goodness" can be determined by combining the total column in Table 2 and presenting it in a more standard evaluation matrix in Table 3.

The overall FTB accuracy can be calculated by adding number of correct forecasts (a + d = 129) and dividing by number of forecasts 153 or 84.3 percent which is comparable to the 86.2 percent of 2012 season. The probability that a flooding day is forecast correctly is determined by dividing the number of correct flood days forecast (72) by the number of flood days observed (85) or 84.7 percent which is close to last year's 84 percent. These accuracy values are well above the normal goals of 70 percent.

Additionally the false alarm rate of flood day forecasts is only 13.3 percent (72/83) or well below the goal of less than 25 percent. The 2012 flash alarm rate was 17.5 percent which suggests that progress is being made at improving the forecasts.

CHARACTERIZATION OF FORECAST PERIOD WEATHER

Colorado was hit by one of the worst flooding events since the 1976 Big Thompson Flash Flood in 1976 and comparable to the spatial coverage by not the duration of the September 1938 floods caused by the passage of a decaying sub-tropical disturbance. Dewberry is preparing a separate report that outlines the September 2013 flooding events that dominated a very wet storm season in 2013. Figure 1 shows the number of daily observation of over 1.00 inch of rain observed

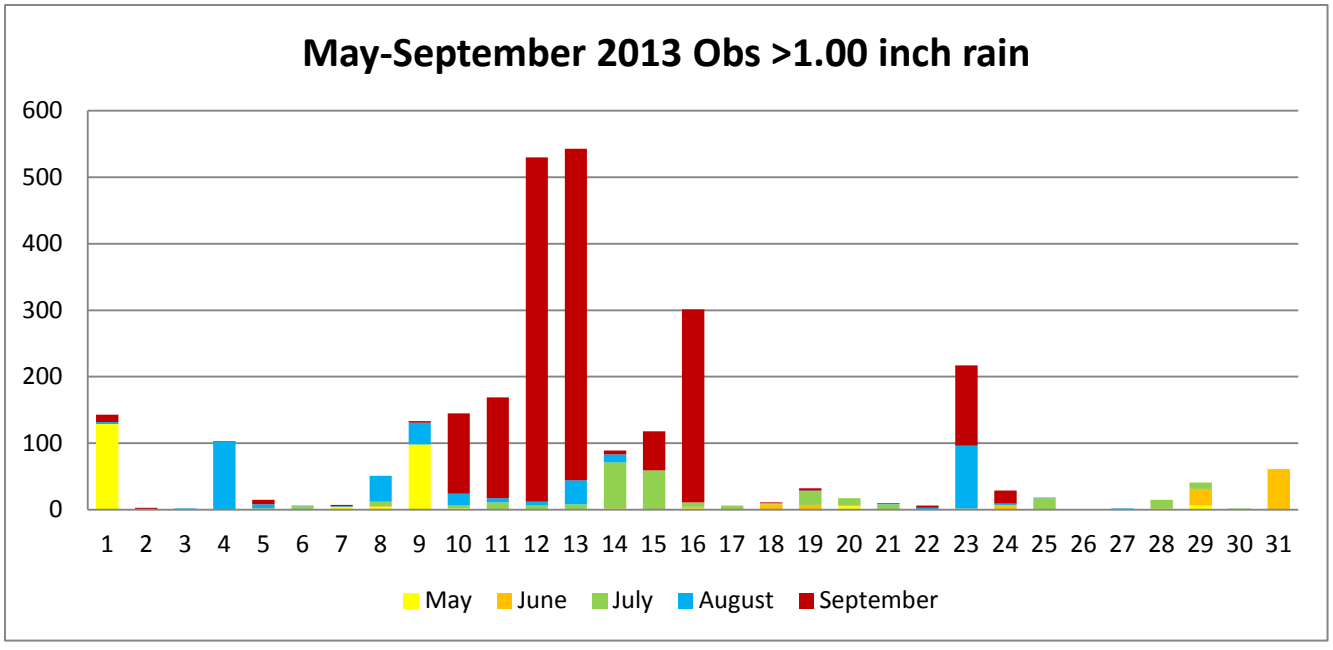


Figure 1 - Number of CoCoRAHS 24 hour rainfall totals observed by 700AM for May to September 2013 by day of the month.

in the Colorado CoCoRAHS network from May 1 to September 30. The September floods occurred from September 10th to 16th with the 48 hours of September 11 to early on September 13 the peak of the rainfall with over 500 reports of rainfall over the state exceeding 1.00 inch.

Figure 2 shows the peak 24 hour rainfall observed within the CoCoRAHS network from May 1 to September 30. Reports of 3.00 inches of rain or more were noted in each month. July and September reported the most daily observations above 3.00 inches on a daily basis. However the peak daily observations of 8.00 - 9.00 inches on September 12 and 13 were extraordinary. Dewberry's Flood Threat bulletins issued on September 10 to 16 issued moderate to high flash flooding and flooding forecasts for the Front Range from Fort Collins to Colorado Springs and on occasion the eastern plains in the South Platte River valley as the flood peak moved downstream during the flood event.

WEBSITE AND SOCIAL MEDIA

During the midst of the September floods, we identified an opportunity to expand the outreach of the Colorado FTB and inform the public at large regarding ongoing flood threats. The unique opportunity was identified as a Twitter account with which to provide updates on meteorological conditions. Twitter is largely known as a social media platform built to distribute information quickly and effectively to a large audience. The ability to drive content and viewership through a Twitter account can be exponential depending upon the number of "retweets" and "followers" that an account may accrue.

During the beginning stages of this flooding event, Sam Miller, a Web Content Specialist for Dewberry, set up a Twitter account meant to be a conglomerate of information, not only from our Flood Threat Bulletin, but also from news stations, emergency managers, CDOT, etc. The Twitter account (@COFloodUpdates) was set up to be a "one-stop shop" of sorts for flooding

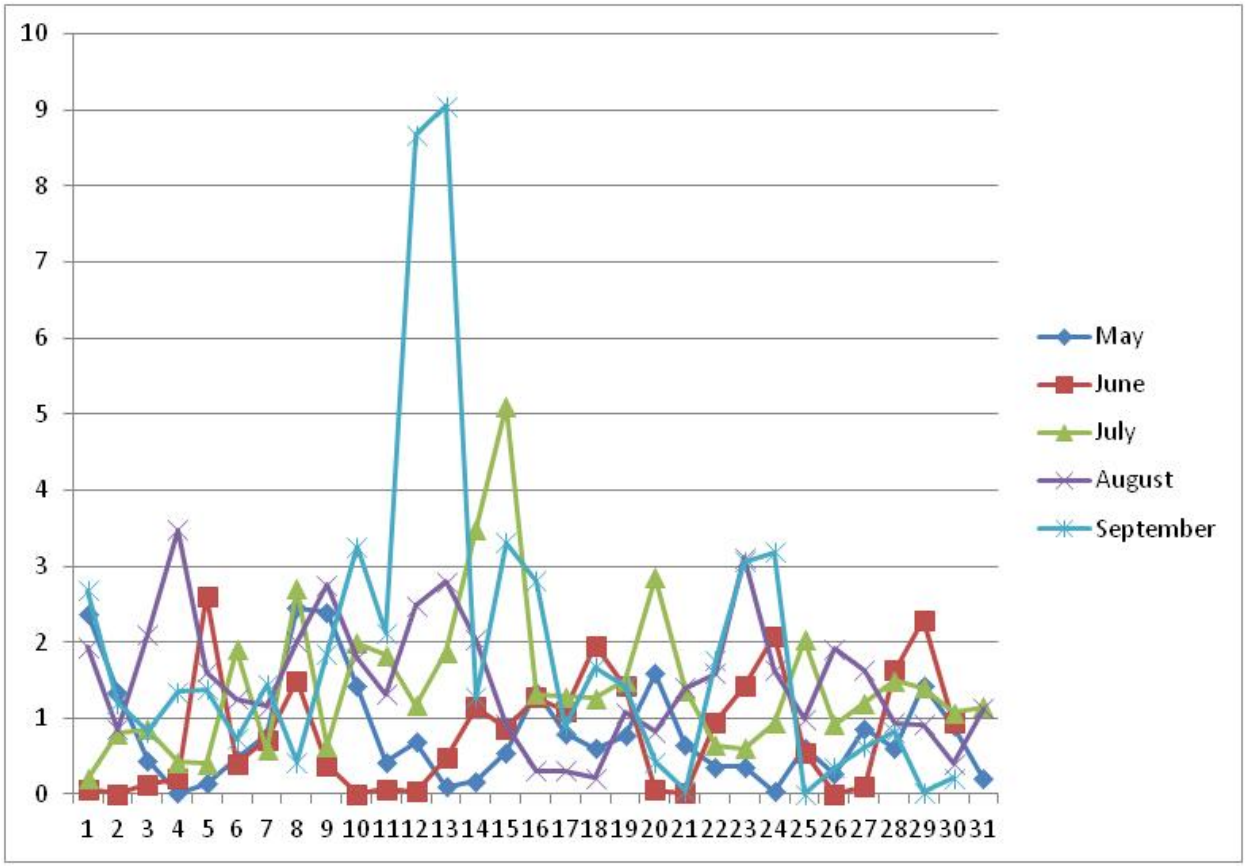


Figure 2 - Peak CoCoRAHS 24 hour rainfall totals observed by 700AM for May to September 2013 by the day of the month.

information. The following, brief "timeline" will highlight milestones of the Twitter account:

- *9/12/13, 12:00 PM MDT*
  Third-party Twitter Account, @COFloodUpdates was created

- *9/13/13, 2:10 PM MDT*
  Huffington Post Green features @COFloodUpdates content in an article.

- *9/16/13, 6:24 AM MDT*
  Total "click-throughs" to FTB site via direct link in Tweets reaches116

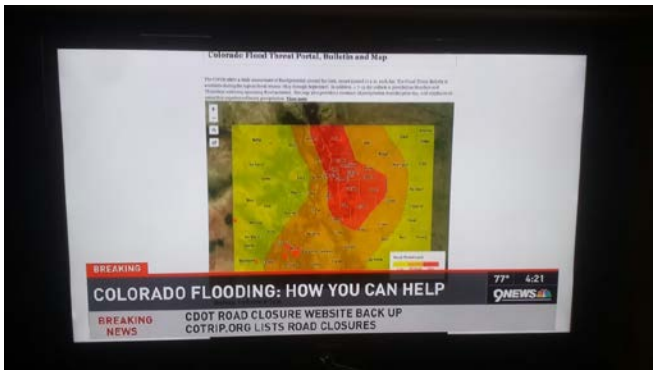
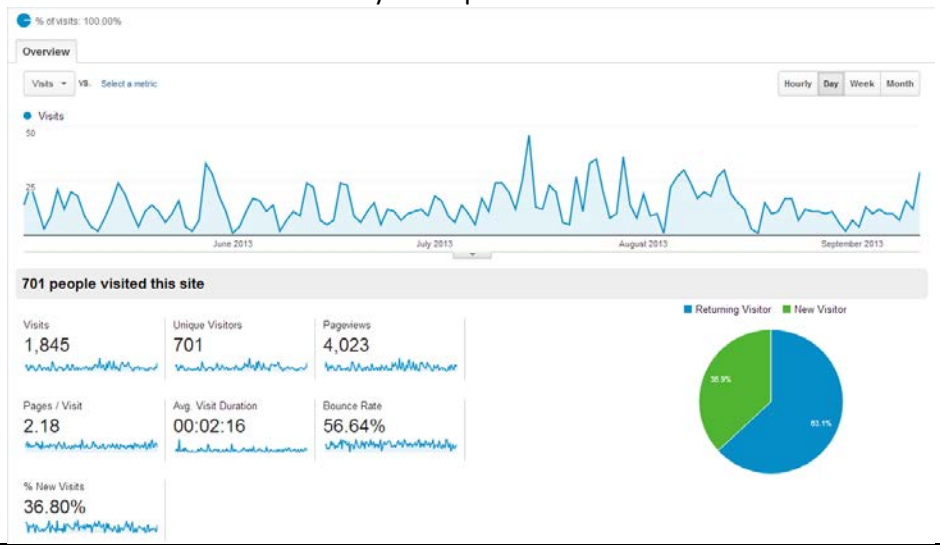


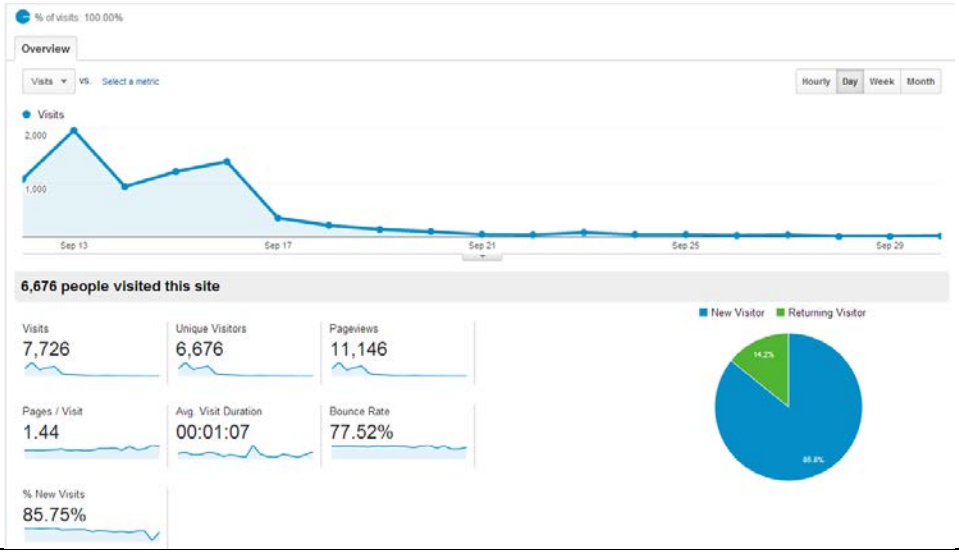
Figure 3 - Screen capture of KUSA, Channel 9 airing the FTB forecast flood threat on September 12, 2013.

Figure 4 – Total Viewership statistics for the Flood Threat Bulletin, May through September 2013.

May 1 – September 11



September 12 – September 30



Google Analytics was utilized to find proof of successfully driving FTB traffic using the Twitter account (Figure 4). Before the introduction of the Twitter account (May 1 – Sept. 11) the FTB website had only received 1,845 visits from 701 unique visitors. Comparatively, after the Twitter account was utilized (Sept. 12 – Sept. 30), the FTB website received 7,726 visits from 6,676 unique visitors. In just 18 days, the FTB websites traffic had increased tremendously and the FTB was able to reach a wider audience. Part of the success, though, must be attributed to the Flood Threat Bulletin being featured on a NBC 9News television broadcast (Figure 3).

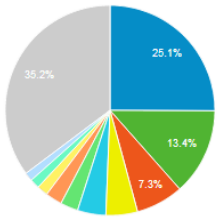
Using the demographics portion of the analytics, it was found that extensive visits to the FTB website occurred from outside the state of Colorado. As expected due to the increase of visitors mentioned above, the visits from countries outside the USA increased as well. Visits from other countries increased more than ten-fold from every country in the Top 10. Canada, for example, produced 4 visitors to the FTB website from May 1 to Sept. 11; after the creation of the Twitter account on Sept. 12, 87 visits occurred. While this increase cannot be exclusively attributed to the creation of the Twitter account, the use of the social media platform likely played a large role.

Visits from states outside of Colorado increased after the creation of the Twitter account, as well. For example, California went from 18 visits during the time period of May 1 – Sept. 11 to 434 visits from Sept. 12 – Sept. 30. All states within the Top 10 of total number of visits were above 100 visits. This points to not only a local interest, but a general national interest as well. It is not out of the realm of possibility that the retweets that the Twitter account received drove a substantial

Figure 5 – Colorado-based viewership for the Flood Threat Bulletin, May-September, 2013.

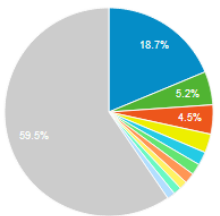
May 1 – September 11

City	Visits	Visits	Contribution to total: Visits
	1,831 % of Total: 99.24% (1,845)	1,831 % of Total: 99.24% (1,845)	
1. Denver	459	25.07%	
2. Castle Rock	245	13.38%	
3. Parker	134	7.32%	
4. Colorado Springs	89	4.86%	
5. Loveland	80	4.37%	
6. Fort Collins	50	2.73%	
7. Webb City	47	2.57%	
8. Durango	31	1.69%	
9. Boulder	27	1.47%	
10. (not set)	24	1.31%	



September 12 – September 30

City	Visits	Visits	Contribution to total: Visits
	7,315 % of Total: 94.68% (7,726)	7,315 % of Total: 94.68% (7,726)	
1. Denver	1,369	18.71%	
2. Boulder	379	5.18%	
3. Fort Collins	331	4.52%	
4. Longmont	213	2.91%	
5. Colorado Springs	151	2.06%	
6. Lakewood	127	1.74%	
7. Aurora	118	1.61%	
8. Washington	91	1.24%	
9. Greeley	90	1.23%	
10. Loveland	90	1.23%	



portion of the increased national interest.

Probably the most unsurprising demographic statistics collected was the increase in visits from cities within Colorado (Figure 5). 27 visits came from Boulder between May 1 and Sept. 11; comparatively, for the time period of Sept. 12 – Sept. 30, folks in Boulder visited the FTB website 379 times. Boulder went from totaling 1.47% of all visits to 5.18%. Some of the locations most affected by the flooding event jumped into the Top 10 of cities, including Fort Collins, Greeley, and Aurora. Furthermore, using the demographics of visits by city, it was determined that the FTB website is being read across the state, and not just the major urban areas along the Front Range.

Appendix A – Verification Worksheets

2013 CWCB FTB Verification Notes

May		FTB FCST	# >1.00in	Max	FF= 1,2,3	Severe	UDFCD M
✓	1		129	2.38	Upslope		
	2		1	1.35	upslope		
	3		0	0.45			
	4		0	0.02			
	5		0	0.14			
	6		0	0.47			
miss	7		4	0.78			
Hit	8	Moderate	4	2.45	Miss 2	Hail	1
Hit	9	Low	98	2.4	hit 2		
	10		2	1.42	hit 1		
	11		0	0.43		Hail	
	12		0	0.69			
	13		0	0.1			
	14		0	0.17			
Hit	15	Low		0.55			1
	16		2	1.35	Hit 1	Hail	
miss	17	Low	0	0.8			
Hit	18	Low	0	0.6		Hail	
	19		0	0.77	multiday		
	20		5	1.59	multiday		
	21		0	0.65			
	22		0	0.36			
miss	23	Low	0	0.36			
	24		0	0.04		Hail	
	25		0	0.61		Hail	
	26		0	0.27			
	27		0	0.87		Hail	
miss	28		0	0.6		Hail	
	29		6	1.43	miss 1	Hail	1
	30		0	0.9			
	31		0	0.2			
June							
	1		0	0.07			
	2		0	0			
	3		0	0.13		Hail	
Hit	4	Low		0.2		Hail	1
	5		2	2.61	Hit 2		
	6		0	0.4			
Hit	7	Low	0	0.72		Hail	
	8		1	1.5	Hit 1		
	9		0	0.38			
	10		0	0			
	11		0	0.07			
	12		0	0.04			
	13		0	0.48		Hail	
	14		1	1.15	1		

Blanks = Correct No Forecast
- multi day before forecast

Green = ≥ 2.00 in

- 2.45" (Localized)

DAY

23 No Hits

Hit
- (8) - mod
- (9) - Low
- (15) - Low
- 18 - Low

miss
- (7) 4 > 1" 2.45"
- 23 0
- (28) 6 > 1" 1.43" + hail

missed 2 days > 1"
1 day > 2"

Hit 4 days

June

18 no day hits

Hit 15	Low	0	0.87		Hail	1	
Hit 16	Low	2	1.27	hit 1			
miss 17		1	1.1	hit 1	Hail		
Hit 18	Moderate	8	1.96	miss 1	Hail	1	
19		7	1.42	Hit 1			
20			0.06				
21		0	0.02		Hail		
Hit 22	Low	0	0.95		Hail		
miss 23		1	1.42	Hit 1	Hail	1	
24		7	2.08	miss 2			
25		0	0.55				
26		0	0				
miss 27		0	0.1				
miss 28		2	1.63	1	Hail	1	
Hit 29	Low	25	2.29	2	Hail		
Hit 30	Moderate	1	0.94	Hit		1	✓
July							
Hit 1	Low	0	0.83 ~~0.2~~		FlashFlood	—waldo Canyon	
miss 2	Low	0	hit 0.8		Hail		
miss 3	Low	0	miss 0.86				
4		0	0.43				
Hit 5	Low	0	0.4		FlashFlood		
miss 6	Low	5	hit 1.9	Green 1			
hit 7	Low	0	miss 0.58				
8		7	hit 2.7	Green 2			
miss 9		0	0.63				
Hit 10	Moderate	4	1.99	miss 2	FlashFlood	1	
Hit 11	Moderate	11	1.83	hit 1		1	
Hit 12	High	6	1.17	hit 1	FlashFlood	2	
Hit 13	High	8	1.87	hit 1	FlashFlood	2	
Hit 14	High	69	3.49	hit 3	FlashFlood	1	
Hit 15	High	58	5.1	hit 3		1	
Hit 16	Low	7	1.32	1			
Hit 17	Low	5	1.29	1	FlashFlood		
Hit 18	Moderate	1	1.26	1	FlashFlood	1	
Hit 19	High	21	1.49	1	FlashFlood		
Hit 20	Moderate	11	2.85	2	FlashFlood	1	
Hit 21	Low	8	1.37	1	Hail		
miss 22	Low	0	0.65				
23		1	0.6				
Hit 24	Moderate	0	0.94		Hail		
Hit 25	Moderate	17	2.03	2	FlashFlood	1	
Hit 26	Low	0	0.92				
Hit 27	Moderate	1	1.2	1		1	
Hit 28	Moderate	13	1.5	1			
Hit 29	Moderate	10	1.4	1	Hail		

Hit
- 4 - Low
- 7 - Low
- 15 Low
- 16 - Low
- 22 Low
- 29 Low
- 30 Low
- 18 - Mod

8

Miss
- 23. 7 > 1" 2.08
- 27. 2 > 1" 1.63"
- 28. 25 > 1" 2.29"
- 17. 1.96"

4

Hit
- 1 - Low
- 5 - Low
- 7 - Low (2.77")
- 10 Mod
- 11 Mod
- 12 High
- 13 High
- 14 High
- 15 High
- 16 Low
- 17 Low
- 18 Mod
- 19 High
- 20 Mod
- 21 Low
- 24 Mod
- 25 Mod
- 26 Low
- 27 Mod
- 28 Mod
- 29 Mod

21

Miss
- 2 - Low 0
- 3 - Low 0
- 6 - Low 0
- 9 - 4 > 1" 1.99
- 22 - Low 0
- 31 3 > 1" 1.94 FF

6

4 no days hit

	30		1	1.08	1		
Miss	31		1	1.15	1	FlashFlood	
August							
Miss	1	Moderate	3	1.94	Miss 1		1
	2		0	0.85			
Hit	3	High	2	2.1	2	FlashFlood	1
	4	Moderate	101	3.48	3	FlashFlood	1
	5	Low	6	1.61	1		1
	6	Moderate	1	1.25	1		
	7	High	1	1.16	1	FF	
	8	Low	39	2.01	2	FF	1
	9	Low	33	2.75	2	FlashFlood	1
	10	Moderate	18	1.79	1	FlashFlood	1
	11	Low	6	1.32	1		
	12	High	6	2.48	2		1
Hit	13	High	36	2.8	2		
miss	14	Low	12	2.03	2	FlashFlood	
	15		0	0.92			
	16		0	0.31			
	17		0	0.31			
Hit	18	Low		0.21		FlashFlood	1
miss	19	Low	1	1.08	1		
Hit	20	Low	0	0.82			
Hit	21	Low	1	1.4	1		1
hit	22	Moderate	3	1.59	1	FlashFlood	1
hit	23	Moderate	94	3.11	3	FlashFlood	1
hit	24	Moderate	2	1.63	1		
Hit	25	High	1	0.99	1		
Hit	26	High	9	1.92	1		
hit	27	Moderate	5	1.63	1	FlashFlood	
miss	28	Low	0	0.94			
miss	29	Low	0	0.92			
	30		0	0.4			
	31	Low	2	2.00 ~~1.13~~	1		
September							
Hit	1	Moderate	11	2.68	2	FF	
Hit	2	Low	2	1.2	1	FF	
Hit	3	Low	0	0.82			
Hit	4	Low	1	1.35	1	FF	1
Hit	5	Low	7	1.38	1	FF	1
miss	6		0	0.73			
Hit	7	Low	2	1.44	1	FF hit	
Hit	8	Moderate	0	0.43			
Hit	9	Moderate	2	1.85	1	FF	1
Hit	10	High	121	3.26	3	FF	1
Hit	11	High	142	2.13	2	FF	1
Hit	12	High	518	8.67	3	FF	3

-2.1" ob taken at 530PM Aug 3

Hit
3 - High
4 mod
5 Low
6 - mod
7 High
8 Low (2.75)
9 Low
10 - mod
11 Low (2.48)
12 High
13 High
18 Low
20 Low
21 Low
22 - mod
23 - mod
24 - mod
25 - High
26 - High
27 mod
31 Low (2.68")

21

Miss
1 - mod 0
14 - low .92"
19 - low .82
28 - low .92
29 - low .4
30 - 0 2.00"

6

4 today hit

Hit
1 - mod
2 - low
3 low
4 - Low
5 - low
7 Low
8 mod
9 Mod
10 High
11 High
12 High
13 High
14 - Mod
15, 16, 17 High
18 Low
22 High

18

Miss
6 - 0 1.44"
19 - 0 1.42
21 0 3.71"
1.76
23 0 3.8

4

10 No hits

Hit	13	High	499	9.05	3	FF	3	
Hit	14	Moderate	6	1.28	1	FF	3	
Hit	15	High	59	3.31	3	FF	1	
Hit	16	High	290	2.81	2	FF		
Hit	17	High	0	0.9		FF		
Hit	18	Low	1	1.67	1	FF		
miss	19		3	1.42	1	FF		
	20		0	0.43				
miss	21		0	0.05				
Hit	22	High	3	1.76	1	FF		
miss	23	miss	191	3.06	3	FF		
	24		20	3.18	3	FF early >11AM		~NE Comm Co
	25		0	0.01				
	26		0	0.35				
	27		0	0.62				
	28		0	0.82				
	29		0	0.03				
	30		0	0.22				