Memo

March 30, 2015

To: Ward Bauscher, Engineering Project Manager, City of Boulder Public Works - Utilities

From: Jeff Brislawn, Hazard Mitigation Lead/Associate

CC: Joel McGuire, Project Manager

Ref: Flood Mitigation Master Plan Bear Canyon Creek

Re: Phase 1: Flood Loss Estimation Technical Memorandum

This report summarizes a study that estimated the building damage impacts from flooding on existing development in three stream reaches along Bear Creek in the City of Boulder, Colorado. The results and additional details on the methods follow in this technical memorandum.

Modeled Flood Losses

Background

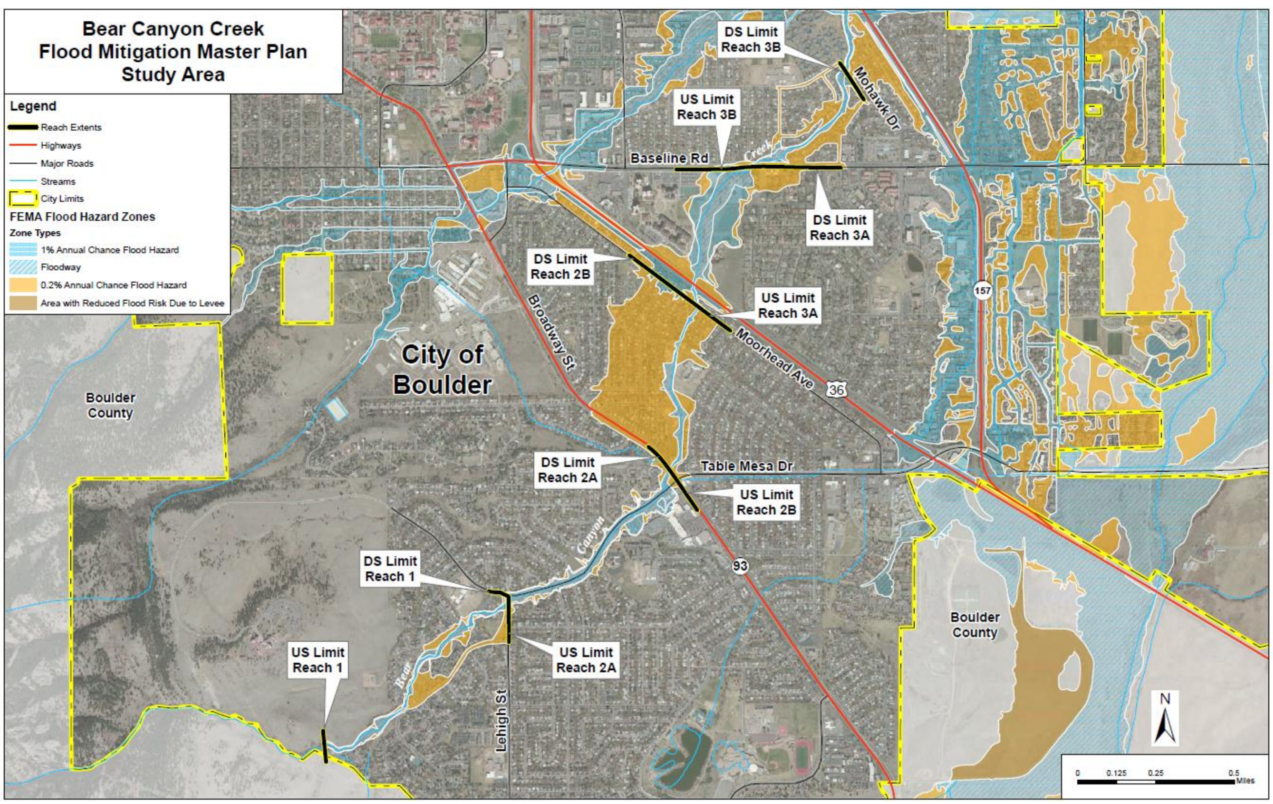
Hazus-MH, FEMA's GIS-based natural hazard loss estimation tool, was initially used to perform a flood loss estimation within the reaches. Site-specific building information for each of the study areas was provided by the FEMA Region VIII via the City. Inspection of the databased revealed that the building dataset was missing point locations for several buildings within the 100 or 500 year floodplain. At least 452 points were missing, including one of the Bear Canyon townhomes that was flooded in 2013. Amec Foster Wheeler staff identified the missing parcels and City staff was able to assist with developing point data for these parcels and populate 8 columns of attributes to match up to the FEMA point data. We also developed additional points so that individual condos/townhomes and business were represented in the model. Many of these were represented by one point for large commercial parcels such as the Table Mesa Shopping Center. Additionally, the provided attribute data needed additional processing steps to prepare it for import into Hazus, including adding content value, estimated first floor height based on building type, and latitude longitude.

The second input into the model was a depth grid, which is a grid-based GIS file that indicates the depth of flooding at a particular grid cell. Flood depth grid data provided by FEMA was limited to the effective 100 year (1% annual chance) return period. The building data was formatted and imported into the Hazus regions for loss analysis using the 100 year FEMA depth grid. Default reports to display Hazus results do not work well with user-defined data, so the loss data needed to be aggregated outside of Hazus in a spreadsheet. QC of the results revealed that the depth damage curves were not being applied appropriately by Hazus and thus the loss estimation was underestimated. This is a known bug in Hazus. In order to fix this we had to use a spreadsheet developed for a previous project as a work around to ensure that the appropriate depth damage curve was being applied.

On February 25 the City provided an email that suggested the FEMA Benefit Cost Analysis (BCA) methodology should be used instead of Hazus for a more comprehensive and accurate loss analysis. The BCA module also uses Army Corp of Engineers (Corp) - developed depth damage curves as opposed to the National Flood Insurance Program – Flood Insurance Administration curves in Hazus. The Corp curves are considered more appropriate and are also used by UDFCD in master planning studies. Subsequent conversations with the City suggested we should use the Corp curves and consider doing a 'planning level' benefit cost analysis to assist with alternative selection.

Further analysis of the 2013 flood event damage data and flood extent (including GIS and YouTube video information) revealed that losses outside of the 100 year flood plain occurred in the Martin Acres reach between Broadway and US 36. These losses were due to split flows near the Table Mesa – Broadway intersection that diverted flows down streets and into the neighborhood and flooded homes in the 500 year floodplain. From this analysis it became clear that the area between Broadway and US 36 (Martin Acres) that was previously excluded from the scope needed to be included, as improvements in reach 2 could benefit this area. A similar conclusion was reached for the area downstream of reach 3 north of Baseline Rd. Additional building data was collected in these areas for analysis.

The following figure displays the study area and the limits of the 3 reaches and sub-reaches analyzed.



Loss Estimation Methodology

The methodology utilized shifted from Hazus-based to an initial planning-level BC analysis. A spreadsheet provided by FEMA was used to aggregate building loss information. This was developed by FEMA for input of detailed structure information into the FEMA BCA tool for drainage projects. Amec

Foster Wheeler used this spreadsheet tool moving forward. The spreadsheet was modified to include depth damage curves for commercial properties as these properties are present in the study area.

This method utilizes estimated first floor heights based on the following building relationships from the Hazus technical manual.

Table 3.11 Default Floor Heights Above Grade to Top of Finished Floor (Riverine)

ID	Foundation Type	Pre-FIRM	Post-FIRM
1	Pile	7 ft	8 ft
2	Pier (or post and beam)	5 ft	6 ft
3	Solid Wall	7 ft	8 ft
4	Basement (or Garden Level)	4ft	4 ft[1]
5	Crawlspace	3 ft	4 ft
6	Fill	2 ft	2 ft
7	Slab	1 ft	1 ft[1]

Source Data: Expert Opinion

Notes:

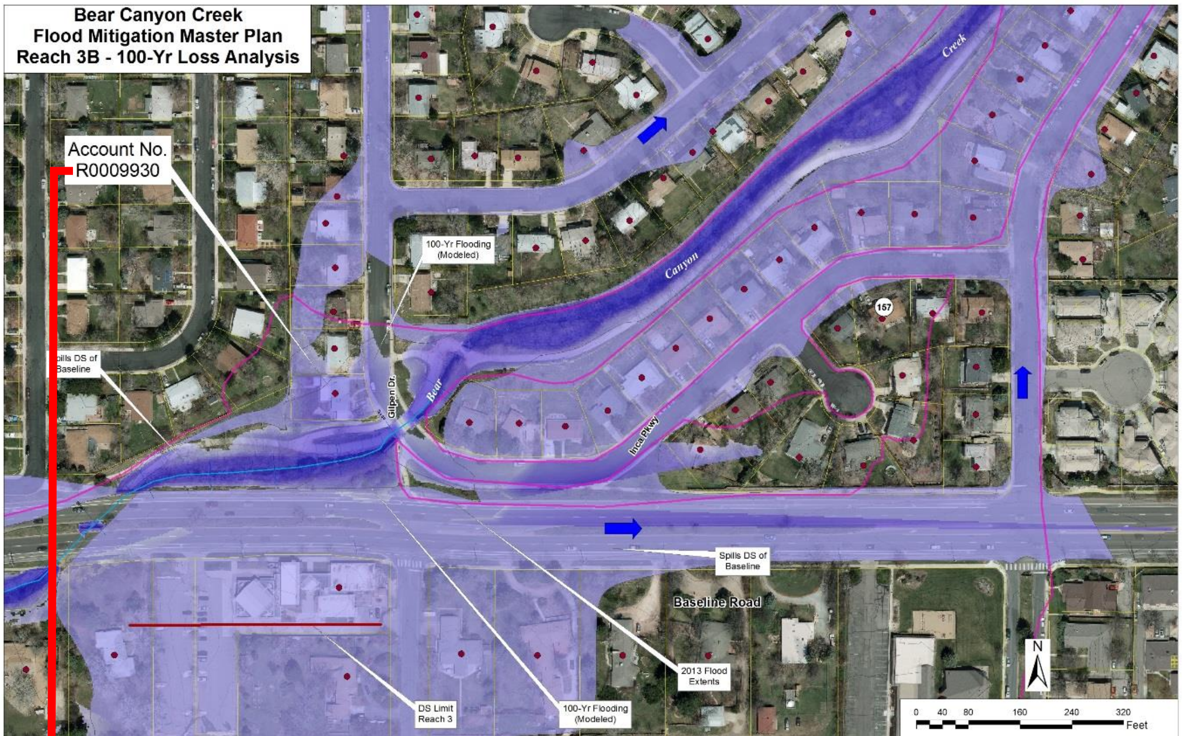
1 Typically not allowed, but may exist

Source: Hazus Riverine Flood Technical Manual

The majority of the structures in the watershed are Pre-FIRM (constructed prior to the adoption of the first Flood Insurance Rate Map on July 17, 1978) residential structures with a mix of slab and basements. A grant-level BC analysis would require additional analysis, possibly including surveyed first floor elevations or analysis of LiDAR data to refine the estimate of these. A grant-level BCA may also require gathering additional benefit information to produce a benefit cost ratio of 1 or greater.

A best available information model was developed to produce the 10-year flood (10% annual chance), 50-year flood (2% annual chance), 100-year flood (1% annual chance), and 500-year flood (0.2% annual chance) events. Due to the complex nature of the flooding source, certain assumptions had to be made in the modeling process. Overtopping occurs at several major crossings, most notably Broadway Street and Baseline Road. Spills from these areas become hydraulically disconnected from the main channel, flow overland through streets and neighborhoods and then rejoin the floodplain downstream. Boundaries for these flows were manually delineated in the original FHAD study, and digitized as part of the current DFIRM. For the purposes of this analysis, areas outside of the main AE zone, yet within the 500-year floodplain were assumed to have a flooding depth of 2 feet for the 500-Yr analysis, 1 foot for the 100-Yr analysis, and zero for the 50-Yr analysis. These areas were joined to the calculated depth grid for areas within the main AE Zone for each corresponding recurrence interval.

The building point layer was overlaid onto each depth grid in GIS and a spatial join was performed to determine the depth of flooding at each structure for each return period. The tabular database was incorporated into the modified BCA spreadsheet to perform the loss calculations. Depth damage functions in the BCA spreadsheet were applied to create a detailed loss estimate for buildings in the reaches for the various flood events. The following figure is a snapshot from reach 3B that illustrates the depth grid and flooded structures and how depth values were used in the spreadsheet to calculate building damage, based on depth-damage curves within the spreadsheet tabs.



2	DB Key	Structure Data						Valuation				Flood Risk				100 year Return Interval					
3																		Total 100 yr Damages $			6,885,564.44
4	Structure ID	Occupancy	Building Type	Foundation	Stories	Year Built	Flood Class	Total Square Footage	Building Value	Content Value	Total BRV	Ground Elevation (NAVD88)	First Floor Height	Flood Zone	Reach	Bldg DDF Damage	Content DDF Damage	Displacement DDF (Days)	Bldg Damages	Content Damages	Damages
504	R0009781	RE	1 STORY - RA	CONCRETE	1	1965	B1SNB	2854	$ 147,100.00	$ 73,550.00	$ 220,650	5284.09	1 ft	50 YEAR FLO	3B	2.5%	2.4%	0 DAYS	$ 3,677.50	$ 1,765.20	$ 5,443
505	R0009808	RE	BI-LEVEL	CONCRETE	2	1965	B2SYB	0	$ 165,200.00	$ 82,600.00	$ 247,800	5298.78	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
506	R0009818	RE	1 STORY - RA	CONCRETE	1	1966	B1SNB	0	$ 141,900.00	$ 70,950.00	$ 212,850	5287.22	1 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
507	R0009827	RE	BI-LEVEL	CONCRETE	2	1966	B2SYB	0	$ 166,400.00	$ 83,200.00	$ 249,600	5294.29	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
508	R0009895	RE	BI-LEVEL	CONCRETE	2	1966	B2SYB	0	$ 214,000.00	$ 107,000.00	$ 321,000	5295.43	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
509	R0009919	RE	BI-LEVEL	CONCRETE	1	1966	B1SYB	0	$ 173,300.00	$ 86,650.00	$ 259,950	5291.46	4 ft	0.2 PCT ANN	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
510	R0009923	R	BI-LEVEL	CONCRETE	2	1966	B2SYB	0	$ 172,100.00	$ 86,050.00	$ 258,150	5291.71	4 ft	0.2 PCT ANN	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
511	R0009930	RES1	SPLIT LEVEL	CONCRETE	1	1964	B1SYB	3206	$ 198,900.00	$ 99,450.00	$ 298,350	5305.74	4 ft	50 YEAR FLO	3B	13.8%	10.5%	0 DAYS	$ 27,448.20	$ 10,442.25	$ 37,890
512	R0009956	RES1	1 STORY - RA	CONCRETE	1	1965	B1SYB	3368	$ 181,400.00	$ 90,700.00	$ 272,100	5300.18	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
513	R0009982	RES1	SPLIT LEVEL	CONCRETE	1	1966	B1SYB	2325	$ 168,600.00	$ 84,300.00	$ 252,900	5292.00	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
514	R0010068	RES1	SPLIT LEVEL	CONCRETE	1	1966	B1SYB	2597	$ 164,400.00	$ 82,200.00	$ 246,600	5298.30	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -
515	R0010106	RES1	BI-LEVEL	CONCRETE	1	1966	B1SYB	0	$ 174,100.00	$ 87,050.00	$ 261,150	5290.15	4 ft	0	3B	0.0%	0.0%	0 DAYS	$ -	$ -	$ -

Results

Results of the analyses are presented in the following table, which is followed by a discussion of the results by reach.

1002 Walnut Street
Boulder, CO 80302
Tel (303) 443-7839
www.amecfw.com

Table 1 Estimated Flood Loss by Stream Reach

Return Period	Structures Damaged	Building Damage	Contents Damage	Total Damages	Displacement Days
Reach 1; US Study Limit to Lehigh					
500-year Flood	35	$ 816,208	$ 330,054	$ 1,146,262	0 Days
100-Year Flood		$ -	$ -	$ -	0 Days
50-Year Flood		$ -	$ -	$ -	0 Days
Reach 2A; Lehigh to Broadway					
500-year Flood	20	$ 722,622	$ 386,778	$ 1,109,400	315 Days
100-Year Flood	11	$ 252,533	$ 67,119	$ 319,652	0 Days
50-Year Flood		$ -	$ -	$ -	0 Days
Reach 2B; Broadway to Moorhead					
500-year Flood	143	$ 5,738,407	$ 1,717,123	$ 7,455,529	7560 Days
100-Year Flood	117	$ 4,006,369	$ 1,139,296	$ 5,145,664	4455 Days
50-Year Flood		$ -	$ -	$ -	0 Days
Reach 3A; Moorhead to Baseline					
500-year Flood	144	$ 4,918,883	$ 1,781,786	$ 6,700,668	2070 Days
100-Year Flood	43	$ 991,125	$ 302,847	$ 1,293,972	90 Days
50-Year Flood	7	$ 249,852	$ 79,161	$ 329,013	180 Days
Reach 3B; Baseline to DS Study Limit					
500-year Flood	70	$ 1,700,570	$ 624,577	$ 2,325,147	540 Days
100-Year Flood	5	$ 93,737	$ 32,540	$ 126,276	0 Days
50-Year Flood	1	$ 3,913	$ 1,878	$ 5,791	0 Days
Total Damages for Study Area by Return Period					
500-year Flood	412	$ 13,896,690	$ 4,840,317	$ 18,737,006	10485 Days
100-Year Flood	176	$ 5,343,763	$ 1,541,801	$ 6,885,564	4545 Days
50-Year Flood	8	$ 253,765	$ 81,039	$ 334,804	180 Days

The table displays losses by stream reach and sub-reach for the 50, 100, and 500 year flood events. There was no risk of structure flooding to the 10 year event risk within any reach, thus no losses are shown. All reaches have risk to the 100 and 500 year events. Only reach 3 has risk to the 50 year event. Total damages across all reaches for the 50 year event is estimated at $335,000; the 100 year and 500 year total estimated damages are $6.9M and $18.7M respectively.

Reach 1 has the lowest risk to flooding of the 3 reaches and does not result in flood loss from the 100 year event. The 500-year event affects 35 residential structures, with a total damage of $1.1M. While there is no modeled risk to the more frequent interval floods, it should be noted that debris and culvert blockage during the 2013 flood (estimated to be a 25 year event) caused flooding in the 500 year floodplain in this reach.

Reach 2A and 2B has the most buildings of the three reaches, including the most commercial structures. The commercial structures are associated with the Table Mesa Shopping Center at the intersection of Table Mesa and Broadway. This area has the greatest risk from the 100 and 500 year floods. The majority of this damage is associated with reach 2B east of Broadway. The 100 year flood analysis results in less than $400k in damages between Lehigh and Broadway in reach 2A, and $1.1M associated with the 500 year event.

Reach 3A and 3B has 213 residential structures and a church at risk to flooding. This reach is the only reach to have some risk to the more frequent 50 year flood event (8 structures total). Reach 3A has substantial risk to the 500 year flood event.

Income Related Losses and Debris Generation Estimates
Hazus has utility in estimating Income related losses and debris (building related as opposed to soil and woody debris), and these losses were calculated based on the Census block based inventory associated with a Level 1 Hazus flood run, but utilizing the user-defined depth grids. These losses were modeled to capture additional losses due to business interruption and debris estimates. Income related losses include a one-time flood disruption cost, rental income losses, and capital income losses. A single Hazus study area was created to encompass all three reaches. Total income losses were estimated at $130,000 for the 100 year and $146,000 for the 500 year event. Debris generation was estimated at 1,150 tons for the 100 year and 1,303 tons for the 500 year event. These values, in addition to the structure loss estimates previously discussed, can be used as a baseline for comparison as flood mitigation alternatives are modeled in future phases of the project.