records at ten USGS gaging stations located in the upper St. Vrain Creek and Big Thompson River basins (Reference 77).

The hydrologic analyses for Bullhead Gulch and Prince Tributary (East and West Branches) were based on modeling performed for UDFCD by Advanced Sciences, Inc. (ASI), for Lafayette and Louisville (Reference 84). Stream data were not available for Bullhead Gulch, and Prince Tributary (East and West Branches); therefore, rainfall-runoff analysis was used to determine flood discharges. The procedure used to determine the 10-, 2-, and 1-percent annual chance discharges involved the following three computer programs: Hydrocad (Reference 92), CUHPE/PC (Reference 86), and UDSWM2-PC (Reference 93). The Hydrocad program was used to digitize the sub-basin area, soil type, land use and drainage flow path information. Individual storm hydrographs were developed by CUHPE using the data from Hydrocad along with user input for rainfall depth and depression losses for pervious and impervious areas. These hydrographs were then routed and combined using the SWMM computer program. The rainfall depths were taken from the Boulder County Storm Drainage Criteria manual (Reference 87). TEA modified the hydrology by ASI to include additional storage facilities. Only facilities, which communities agreed to operate and maintain for flood control, were considered. TEA also adjusted percent impervious values to approximate existing conditions, and development proposed by the Town of Erie Master Plan (Reference 88).

For Fourmile Creek, the discharge probability relationships were determined using the EPA's SWMM computer model (Reference 94). The model was calibrated using data collected from the flood hydrograph of May 1973 for the uncontrolled area of Cherry Creek located downstream from Cherry Creek Dam. Rainfall input for the model was derived from the NOAA Atlas for Colorado (Reference 33). Values for the 0.2-percent-annual-chance storm were extrapolated.

City of Boulder

For South Boulder Creek, the hydrologic information was taken from the South Boulder Creek Climatology and Hydrology Summary Report (Reference 101). Much of the South Boulder Creek watershed lies above Eldorado Springs; however, important tributary flows from the Viele Channel and Bear Canyon Creek basins are generated in the lower part of the watershed. That, in combination with the dynamic nature of the MIKE FLOOD simulation, resulted in a departure from the standard of practice for input of runoff hydrographs.

The City of Boulder, Colorado, has been identified as having one of the largest potentials for loss of life to flash flooding within Colorado. Boulder is lined to the west by a series of foothills canyons that drain into the City. The three primary foothills watersheds from north to south include Four Mile Creek, Boulder Creek and South Boulder Creek. Numerous smaller tributaries flow into these three main streams. Each of these streams is a source for flash flooding and flooding within the City and the adjacent foothills. The hydro-climatological study focuses on South Boulder Creek.

The lower basin is flat with a northeast-southwest orientation with most of the basin's elevation below 6,000 feet. The lower basin ends abruptly at the Flatiron's interface. The middle basin shows a distinct southeast to northwest orientation with elevations rising from almost 6,000 feet to over 9,000-10,000 feet along the basin's north and south boundaries. This portion of the basin extends one to two miles west of Gross Reservoir. The upper portion of the basin faces an almost due east-west orientation and extends from about 8,500 feet to over 13,000 feet along the Continental Divide.

The South Boulder Creek basin is unusual among those in the Denver/Boulder metropolitan area. It is one of the few that extends up to the continental divide and flows through a highly urbanized metropolitan area. As such, the hydrologic response of the basin is not easily characterized by conventional approaches. The citizens of Boulder recognized this when they suggested that a new and different approach was necessary to fully understand the flood hazard along South Boulder Creek. The study was commissioned to develop the most scientifically defensible floodplain delineation using state of the art hydrologic tools balanced against a careful investigation of the recorded and physical record of floods within the basin.

To accomplish this objective, the City developed a hydrologic evaluation that was built upon several different approaches. The approach employs a comprehensive computer model to simulate basin response under a variety of conditions. In this way, the approach is similar to many other studies used in the area. However, the level of attention given to assuring that the model reflects basin conditions accurately is well beyond that of conventional flood studies. Further, the study relies heavily on several other approaches to estimate peak flood flows. These other methodologies lack the flexibility necessary to evaluate flood hazard at several places within the watershed and under various conditions; however, they offer estimates that are based on physical observations of flood in the watershed. These provide an important point against which the computer model can be measured and offer data that can be used to improve the ability of the computer model to replicate actual watershed conditions.

Finally, this study departs from traditional studies in one other important way: it comprehensively incorporates the impacts of floodplain storage in the floodplain delineation process. The simulation of floodplain storage in a watershed such as South Boulder Creek is important, but extremely difficult to do. Most studies do include large flood control facilities or other impoundments such as Gross Reservoir that may affect peak flow. These have been incorporated herein. However, the simulation of ponding behind roadway and railroad embankments, the storage seen in broad floodplains through agricultural or open space areas, or the diversion of flows into irrigation ditches is seldom included in studies of this nature. The effort is extreme and the data is often lacking. This study does incorporate these effects as part of the detailed floodplain hydraulic simulations where ponding and backwater impacts are included.

Together, the level of effort made to assure that the hydrologic computer model represents real watershed responses, along with the incorporation of the effects of floodplain storage, make this study one that represents a scientifically defensible approach with higher resolution, detail and verification than any other study devoted to South Boulder Creek.

Discharges for Bear Canyon Creek, Elmers Twomile Creek, Fourmile Canyon Creek, Goose Creek, Skunk Creek, Twomile Canyon Creek, and Wonderland Creek were taken from the Flood Hazard Area Delineation report for Boulder and Adjacent County

Drainageways (Reference 25). Because no stream gage data are available for the study streams through Boulder, a rainfall-runoff analysis was conducted on the watersheds to determine the flood discharges. This was accomplished by using the UDFCD CUHP-B rainfall-runoff computer program to develop the storm hydrographs (Reference 26) and the USACE HEC-1 computer program for the stream and reservoir routings (Reference 27). For the analysis, basin characteristics of the watershed, as well as rainfall amounts based on the selected recurrence intervals, are used to compute flood hydrographs for various design points in the basin. All stream and reservoir routings were accomplished using the Modified Puls Method.

The 0.2-percent-annual-chance runoff values for various locations along each stream were extrapolated from the discharge-frequency curves.

A more detailed description of the input variables for the CUHP-B and the HEC-1 rainfall-runoff analysis, as well as the CUHP-B computer output and the summary of the final HEC-1 computer output, is located in a technical addendum to this FIS report (Reference 28).

Town of Erie

The peak discharges for the 10-, 2-, 1-, and 0.2-percent annual chance floods for Coal Creek were developed by the SCS in a report entitled "Flood Hazard Analyses, Coal Creek and Rock Creek, Boulder and Weld Counties, Colorado" (Reference 18). The SCS used synthetic rainfall-runoff procedures, as described in the SCS National Engineering Handbook (Reference 32), and the TR-20 computer program for flood routing (Reference 35) to establish the selected discharges along the stream.

The hydrologic analyses for Bullhead Gulch and Prince Tributary (East and West Branches) were based on modeling performed for UDFCD by Advanced Sciences, Inc. (ASI), for Lafayette and Louisville (Reference 84). Stream data were not available for Bullhead Gulch, and Prince Tributary (East and West Branches); therefore, rainfall-runoff analysis was used to determine flood discharges. The procedure used to determine the 10-, 2-, and 1-percent annual chance discharges involved the following three computer programs: Hydrocad (Reference 92), CUHPE/PC (Reference 86), and UDSWM2-PC (Reference 93). The Hydrocad program was used to digitize the sub-basin area, soil type, land use and drainage flow path information. Individual storm hydrographs were developed by CUHPE using the data from Hydrocad along with user input for rainfall depth and depression losses for pervious and impervious areas. These hydrographs were then routed and combined using the SWMM computer program. The rainfall depths were taken from the Boulder County Storm Drainage Criteria manual (Reference 87). TEA modified the hydrology by ASI to include additional storage facilities. Only facilities, which communities agreed to operate and maintain for flood control, were considered. TEA also adjusted percent impervious values to approximate existing conditions, and development proposed by the Town of Erie Master Plan (Reference 88).

Town of Jamestown

Discharges for James Creek and the downstream portion of Little James Creek through Jamestown were taken from a USACE report (Reference 30). Technical Manual No. 1, developed by the USGS (Reference 31), was used to obtain peak discharges on the upstream portion of Little James Creek and Balarat Creek.

City of Lafayette and Town of Superior

Hydrologic data for flooding sources affecting Lafayette and Superior are based on the data generated for the October 1976 study of Coal Creek and Rock Creek, performed by the SCS (Reference 18). Since there are no stream flow records for Coal Creek and Rock Creek, the SCS used synthetic rainfall-runoff procedures to determine the flows for various frequency storms. Analyses were based on storm duration of 24 hours, Type II, and IIA distribution, as described in the SCS National Engineering Handbook, Section 4 (Reference 32). The amount of rainfall was obtained from the precipitation frequency atlas (Reference 33), and a real adjustment was applied to convert the point precipitation values to average precipitation over the watershed area. The studies were conducted using runoff computations based on information regarding the type and location of existing and planned land use provided by the SCS (Reference 19). Hydrologic soil cover complexes and associated Runoff Curve Numbers were extracted from the SCS reports (Reference 15) and field checked. Values of 10-, 2-, 1-, and 0.2-percent annual chance peak discharges were obtained using the SCS computer programs WSP2 and TR20 (References 34 and 35).

City of Longmont

Frequency-discharge data for two of the streams studied in detail in Longmont are based on information published in USACE Flood Plain Information reports for Lefthand and St. Vrain Creeks (References 7 and 8). The 1-percent annual chance flood discharges on Lefthand Creek and St. Vrain Creek are 4,250 cfs and 10,200 cfs, respectively. The 0.2-percent annual chance flood discharges for these two streams equal the discharges for the standard project floods as published in the Flood Plain Information reports (References 7 and 8). These relationships are based on a Log-Pearson Type II analysis of peak runoff data recorded at gages on St. Vrain Creek near Lyons and Platteville (Reference 36). The years of record vary from 79 years at the Lyons gage to 47 years at the Platteville gage.

Discharge-frequency relationships for Spring Gulch were computed using the USACE HEC-1 Flood Hydrograph Package (Reference 37). Synthetic flood hydrographs computed by this method reflect the effects of characteristics of the basin: precipitation, ground cover, slope, drainage area, and other physical characteristics of the drainage basin. Where available, hydrologic data were compared with other studies completed in the area (References 38 and 39). The effects of detention storage near State Highway 66 and at Long Peak Dam on Spring Gulch were studied (Reference 38) and found to be insignificant for the magnitude of the floods considered in the study. That portion of the Spring Gulch Basin located north and east of Terry Lake is considered to be contained completely by Terry Lake.

Rainfall data for the synthetic hydrologic analysis were taken from a rainfall/runoff information report (Reference 40). The discharges computed using the HEC-1 program were verified using the Plains Region equations developed by the USGS (Reference 31). Peak discharges were also verified by the SCS runoff prediction method (Reference 41).

Discharges for the 0.2-percent annual chance floods of all streams were checked by straight-line extrapolation of frequencies previously determined using the procedure of the

USGS (References 9 and 10), and compared to the USACE Standard Project Flood data when available.

The 10-, 2-, 1-, and 0.2-percent annual chance peak discharges for Dry Creek No. 1, Dry Creek No. 1 (Old Channel), Clover Basin Tributary, and Steele Lakes Tributary were taken from the Floodplain Information and Flood Control and Drainage Plan for Dry Creek No. 1 (Reference 3). Discharge-frequency relationships were developed using the EPA's SWMM computer program (Reference 94). Rainfall data used in the SWMM model was obtained from the NOAA Atlas 2, Volume III, Colorado, 1973 (Reference 33). Rainfall infiltration rates were estimated using the "Boulder County Soil Survey" (Reference 15). In the SWMM model floods were routed through five of the reservoirs to account for their effect on peak flows.

The major portion of the Dry Creek No. 1 Basin is located outside the limits of the study area. Runoff from this area contributing to peak discharges within the study reach is limited by the Burlington Northern and Santa Fe Railway, which diverts most of the upstream runoff north to St. Vrain Creek.

Discharges for Lefthand Creek North Overflow Channel and Lefthand Creek South Overflow Channel were determined by the USACE HEC-2 water surface profiles program (Reference 45) during a new hydraulic analysis along Lefthand Creek.

The hydrologic analyses for this study were revised to include information presented in floodplain information reports for Lefthand Creek, Dry Creek No. 1, and St. Vrain Creek (References 1 through 4) and in the LOMR dated May 14, 1999 for Lefthand Creek North Overflow Channel and Lefthand Creek South Overflow Channel.

Town of Lyons

The Lyons stream flow gage, located on the left bank of St. Vrain Creek 0.4 mile downstream from the confluence of North St. Vrain Creek and South St. Vrain Creek, has been in operation since 1895. The flows recorded are partly regulated by small diversions above the gage station. Significant peak flood discharges and stages recorded during this period are presented in Table 2 (Reference 42).

Table 2 – Historic Flood Peak Discharges and Stages at Lyons Gage, St. Vrain Creek

Date	Stage (feet)	Maximum Discharge (cfs)
July 30, 1919	7.90	9,400
June 22, 1941	8.06	10,500
August 3, 1951	5.37	3,920

This report is based upon data generated for the June 1972 and September 1972 studies of Lower and Upper St. Vrain Creek by the USACE (References 8 and 43).

The discharge-frequency relationships in the St. Vrain Creek Basin at Lyons were based on a statistical analysis of the stream gaging records of the St. Vrain Creek at Lyons.

Synthetic unit hydrographs were developed for the St. Vrain Creek Basin and its subdrainage basins of North St. Vrain Creek and South St. Vrain Creek to help define the flow characteristics within the basin. The hydrographs were used for stream routing through Button Rock Dam to Lyons, and downstream from Lyons to determine the discharges throughout the length of the stream.

Town of Nederland
A continuous record of flows at the USGS Nederland gage, located on Middle Boulder Creek, is available from 1907 to the present. Significant peak flood discharges and stages during the period from 1945 to 1975 are presented in Table 3. Flow measurements prior to 1945 could not be verified as being either average daily measurements or daily peak measurements. Following U.S. Water Resources Council Bulletin 17 (Reference 44), discharge-frequency relationships in the Middle Boulder Creek Basin were determined by statistical analysis of the stream gaging records of Middle Boulder Creek at Nederland, using 32 years of record and a weighted skew coefficient of -0.252.

Table 3 – Historic Flood Peak Discharges and Stages at Nederland (Recorded on Middle Boulder Creek)

Year	Date	Stage (feet)	Maximum Discharge (cfs)
1949	June 13, 1949	4.66	674
1951	June 18, 1951	4.75	800
1953	June 13, 1953	3.98	730
1957	June 29, 1957	4.25	745
1965	July 24, 1965	4.25	640

For North Beaver Creek, peak discharges for the respective frequencies were determined using USGS Technical Manual No. 1 (Reference 31).

The procedure outlined in Technical Manual No. 1 was also used to develop peak discharges at various locations in the Middle Boulder Creek Basin and its subdrainage basin of North Beaver Creek to help define the flow characteristics within both basins.

Peak discharge-drainage area relationships for streams studied in detail are shown in Table 4.

Table 4 - Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Arapahoe Avenue Overflow					
At Foothills Parkway (47th Street)	--[1]	--[1]	--[1]	1,500	--[1]
At 30th Street	--[1]	--[1]	--[1]	4,200	--[1]
At 28th Street	--[1]	--[1]	--[1]	3,500	--[1]
Arapahoe Avenue Spill Flow					
Approximately 800 feet downstream of the divergence from Gregory Canyon Creek	--[1]	323	975	1,209	2,149
Balarat Creek					
At Upstream Limit of Detailed Study	0.5	30	150	270	760
Bear Canyon Creek					
At Confluence with Boulder Creek	8.24	2,050	3,762	4,880	7,500
At Confluence of Skunk Creek	5.35	1,170	2,360	3,070	5,100
At Baseline Road	4.96	1,110	2,352	2,930	5,000
At U.S. Highway 36	4.34	820	1,780	2,210	3,850
At Broadway	4.08	680	1,512	1,930	3,400
At Upstream Limit of Detailed Study	3.71	480	1,190	1,600	3,000
Boulder Creek					
At Confluence with Fourmile Canyon Creek	--[1]	3,650	10,100	14,400	29,600
At Valmont Drive	--[1]	3,450	9,200	13,000	23,000
At 28th Street	--[1]	2,200	7,800	8,000	20,600
At County Road 54	--[1]	350	1,560	2,340	4,770
Boulder Creek (Right Bank Overflow)					
Approximately 800 feet Upstream of Foothills Parkway	--[1]	--[1]	1,609	2,523	11,469
Bullhead Gulch					
Just Upstream of Confluence with Boulder Creek	8.85	1,421	1,300	4,532	6,109

[1] Data Not Available

Table 4 – Summary of Discharges (Continued)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Bullhead Gulch (continued)					
Just Downstream of Confluence of Prince Tributary	8.16	1,474	3,581	4,772	6,275
Just Upstream of Confluence of Prince Tributary	5.61	683	1,935	2,639	3,474
Just Downstream of Confluence of Indian Peaks	2.14	374	970	1,333	1,811
Just Upstream of Confluence of Indian Peaks	1.59	190	532	760	1,251
At Upstream Limit of Detailed Study	0.64	294	575	774	1,041
Clover Basin Tributary					
At 75th Street	--[1]	178	400	495	854
Coal Creek					
Near Erie Municipal Airport	68.61	5,970	9,670	11,850	17,860
At Union Pacific Railroad near Erie	76.86	6,160	10,020	12,250	18,340
At Briggs Street	77.48	6,160	10,040	12,280	18,380
At Confluence of Rock Creek	59.3	5,120	8,740	10,640	15,920
At a Point 65,250 feet above Mouth	37.6	2,860	3,620	4,250	6,260
At Burlington Northern and Santa Fe Railway	36.3	2,330	3,490	4,120	6,170
At U.S. Highway 287	35.6	2,370	3,480	4,110	6,160
At a Point 70,350 feet above Mouth	33.7	2,230	3,420	4,040	6,060
At Denver-Boulder Turnpike	27.9	1,740	3,070	3,820	6,030
At McCaslin Boulevard	26.7	1,400	2,980	3,770	5,990
Dry Creek					
At Confluence with Dry Creek No. 2 Ditch Split Flow	--[1]	--[1]	--[1]	4,030	--[1]
At Downstream Limit of Detailed Study	--[1]	--[1]	--[1]	6,630	--[1]
Dry Creek No. 1					
Just Upstream of Steele Lakes Tributary	--[1]	271	674	987	1,812
Just Upstream of the Confluence of Clover Basin Tributary	--[1]	568	1,268	1,726	3,112
Just Upstream of State Highway 119	--[1]	340	845	1,170	2,127

[1] Data Not Available

Table 4 – Summary of Discharges (Continued)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Dry Creek No. 1 (Old Channel)					
Just Downstream of State Highway 119	--[1]	260	330	350	415
Just Upstream of the confluence with St. Vrain Creek	--[1]	320	627	802	1,199
Dry Creek No. 2					
At North 107th Street	--[1]	900	1,900	2,600	4,295
Dry Creek No. 2 Ditch Split Flow					
Just Upstream of the Confluence with Dry Creek	--[1]	0	2,680	4,030	8,850
At Upstream Limit of Study	--[1]	0	100	300	800
Dry Creek No. 3					
Just Downstream of Arapahoe Road	13.6	--[1]	--[1]	1,300	--[1]
Elmers Twomile Creek					
At Confluence with Goose Creek	0.54	373	681	883	1,500
At Iris Avenue	0.32	249	508	630	1,010
At Upstream Limit of Detailed Study	0.13	160	315	384	520
Fourmile Canyon Creek					
At Confluence with Boulder Creek	10.03	119	366	500	1,020
At Longmont Diagonal	9.09	913	2,396	3,336	6,800
At 28th Street	8.60	865	2,566	3,468	6,800
At Broadway	7.92	735	2,662	3,581	6,900
At Upstream Limit of Detailed Study	3.93	350	1,170	1,750	4,000
Fourmile Creek Left Bank Overflow					
At Downstream Limit of Detailed Study	--[1]	715	2,071	2,862	5,780
Fourmile Creek Right Bank Overflow					
At Violet Avenue	--[1]	2	1,319	2,054	4,998

[1] Data Not Available

Table 4 – Summary of Discharges (Continued)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Fourmile Creek					
At Confluence with Boulder Creek	25.0	1,420	4,440	6,230	11,640
Goose Creek					
At Confluence with Boulder Creek	5.46	2,865	5,065	6,315	9,325
At Confluence of Elmers Twomile Creek	3.63	1,050	2,100	2,680	4,300
At Confluence of Twomile Canyon Creek	1.32	670	1,270	1,590	2,400
At 19th Street	1.28	700	1,320	1,600	2,450
At Upstream Limit of Detailed Study	0.48	260	520	620	1,000
Gregory Canyon Creek					
At Marine Street	2.29	673	1,672	2,092	3,700
Downstream of College Avenue	--[1]	600	1,504	1,900	3,300
At Upstream Limit of Detailed Study	1.56	400	1,060	1,450	2,600
Highway 93 Split Flow					
At Downstream Limit	--[1]	0	600	1,660	5,000
At Upstream Limit	--[1]	0	2,580	3,850	7,750
James Creek					
At Cross Section A	14.5	355	2,180	3,930	10,880
At Main Street Bridge	12.2	300	1,785	3,205	8,850
At Confluence of Little James Creek	12.1	300	1,760	3,160	8,725
At Upstream Limit of Detailed Study	8.9	200	1,190	2,140	6,010
Lefthand Creek					
At Confluence with St. Vrain Creek	72.0	520	2,480	4,610	10,320
Lefthand Creek (North Overflow Channel)					
At Divergence from Lefthand Creek	--[1]	--[1]	--[1]	333	--[1]
At Confluence with Lefthand Creek	--[1]	--[1]	--[1]	333	--[1]

[1] Data Not Available

Table 4 -- Summary of Discharges (Continued)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Lefthand Creek (South Overflow Channel)					
At Divergence from Lefthand Creek	--[1]	--[1]	--[1]	472	--[1]
At Confluence with Lefthand Creek (North Overflow Channel)	--[1]	--[1]	--[1]	798	--[1]
Little James Creek					
At Confluence with James Creek	2.8	130	650	1,160	3,220
At Confluence of Balarat Creek	2.25	130	650	1,160	3,220
Little James Creek (continued)					
At Upstream Limit of Detailed Study	1.8	109	544	970	2,690
Little Thompson River					
At Larimer-Weld County Line	--[1]	2,800	5,500	7,200	12,800
Middle Boulder Creek					
At Cross Section A	36.3	693	884	960	1,130
At Cross Section G	29.9	596	760	825	971
Middle St. Vrain Creek					
At Confluence with South St. Vrain Creek	32.4	590	1,430	2,000	4,070
North Beaver Creek					
At Cross Section A	5.3	74	117	135	185
At Cross Section T	5.0	70	112	129	178
North Goose Creek					
At Confluence with Goose Creek	--[1]	3,865	3,865	3,865	6,075
North St. Vrain Creek					
At Confluence with St. Vrain Creek and South St. Vrain Creek	125.0	1,000	2,850	4,310	10,630

[1] Data Not Available

Table 4 – Summary of Discharges (Continued)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Prince Tributary[1]					
Just Downstream of Confluence with Bullhead Gulch	8.16	--[2]	--[2]	4,772	--[2]
Just Upstream of Confluence with Bullhead Gulch	2.55	--[2]	--[2]	2,130	--[2]
At Upstream Limit of Detailed Study	0.58	--[2]	--[2]	423	--[2]
Rock Creek					
At Confluence with Coal Creek	21.6	2,870	5,350	6,690	10,240
Rock Creek (continued)					
At 2,400 feet Upstream of Confluence with Coal Creek	21.5	2,900	5,400	6,710	10,270
At South 120th Street	21.3	2,910	5,410	6,740	10,310
At 16,450 feet Upstream of Confluence with Coal Creek	18.7	2,900	5,360	6,640	10,050
At Denver-Boulder Turnpike	9.3	1,256	3,229	4,520	9,176
At McCaslin Boulevard	4.9	594	1,800	2,717	7,000
At Upstream Limit of Detailed Study	4.1	504	1,587	2,396	6,182
St. Vrain Creek					
At Boulder-Weld County Line	351.0	5,520	10,950	14,850	28,670
At 85th Street	241.0	3,160	6,890	9,580	19,680
Just Downstream of the Confluence of North St. Vrain Creek and South St. Vrain Creek	211.0	2,040	6,670	8,880	20,260
St. Vrain Creek (Vicinity of Lyons)					
At Second Avenue	219.0	2,040	5,570	8,880	20,260
Skunk Creek					
At Confluence with Bear Canyon Creek	2.83	980	1,830	2,230	3,500
At Madison Avenue	2.43	920	1,580	1,870	2,650
At U.S. Highway 36	2.08	650	1,130	1,350	1,900
At Broadway	1.36	210	520	710	1,320

[1] Separate Data for East and West Branches Not Available
[2] Data Not Available

Table 4 – Summary of Discharges (Continued)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
Skunk Creek (continued)					
At Upstream Limit of Detailed Study	1.20	180	460	640	1,200
South Boulder Creek					
Near Eldorado Springs	--[1]	1,310	2,640	4,340	7,400
At State Highway 93	--[1]	1,450	3,270	6,200	9,950
At US Highway 36	--[1]	1,300	3,530	7,240	11,640
At Baseline Road	--[1]	1,390	3,050	5,610	9,210
At Confluence with Boulder Creek	--[1]	1,570	3,180	4,980	7,750
Spring Gulch					
At Confluence with St. Vrain Creek	--[1]	1,950	3,150	3,650	4,200
Steele Lakes Tributary					
At 75th Street	--[1]	494	1,165	1,512	2,428
Twomile Canyon Creek					
At Confluence with Goose Creek	2.9	360	840	1,120	2,000
At Broadway	1.68	210	675	890	1,800
At Upstream Limit of Detailed Study	1.40	210	540	710	1,430
Wonderland Creek[2]					
At Confluence with North Goose Creek	1.91	607	1,419	2,107	4,620
At 28th Street	1.35	404	1,032	1,484	3,799
At Broadway	0.85	205	415	531	1,600
At Upstream Limit of Detailed Study	0.38	92	192	253	860

[1] Data Not Available
[2] Includes Flow Diversions From Fourmile Canyon Creek

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the Flood Insurance Rate Map (FIRM) represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data table in the FIS report. Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS report in conjunction with the data shown on the FIRM.

Hydraulic data from the various engineering reports discussed in Section 7.0 have been used extensively for the revised study of Boulder County.

The hydraulic analyses for the flooding sources studied by approximate methods were based upon data derived from the sources used to establish the peak discharges for these streams.

Boulder County (Unincorporated Areas)
Hydraulic analysis data for Boulder Creek, Arapahoe Avenue Overflow, and Boulder Creek (Right Bank Overflow) are based on information published in the Flood Hazard Area Delineation for Boulder Creek report (Reference 60). The WSELs for the 10-, 2-, 1-, and 0.2-percent annual chance flood events were computed using the USACE HEC-2 Water Surface Profile program (Reference 45). Starting WSELs were obtained from the Omaha District USACE.

Cross section data used in the analysis was obtained photogrammetrically by digitizing sections marked on the aerial photography flown in April 1981 (Reference 98). All bridge cross sections were field surveyed to obtain elevation data and geometry.

Manning's "n" values were estimated by field inspection of the study area. The roughness values for the main channels ranged from 0.035 to 0.065, and for the overbanks from 0.04 to 0.20.

The hydraulic analysis for Dry Creek No. 2 Ditch Split Flow and Highway 93 Split Flow was completed using the USACE HEC-2 step-backwater program (Reference 45). Starting WSELs were based on a study by Simons, Li and Associates, Inc. (Reference 63) as well as bridge rating curves for the C&S Railroad crossing developed by Leonard Rice Consulting Water Engineers, Inc. (Reference 91).

Manning's "n" values were evaluated using a published paper by Jarrett (1984) entitled "Hydraulics of High Gradient Streams" as a guide. The roughness values for the main channels ranged from 0.045 to 0.085, and for the overbanks from 0.05 to 0.10.

Water-surface profiles for the 10-, 2-, 1-, and 0.2-percent annual chance floods for South St. Vrain Creek and Middle St. Vrain Creek were developed using the USACE HEC-2 step backwater computer program (Reference 45).

Cross sections were digitized from topographic maps (Reference 99). The cross sections for above and below bridges and culverts were field-surveyed at close intervals to account for the backwater effects of these structures.

Manning's "n" values were assigned based on field inspection of the floodplain areas. The roughness values for the main channels ranged from 0.030 to 0.040, and for the overbanks from 0.040 to 0.060.

For Bullhead Gulch and Prince Tributary (East and West Branches), the water-surface profiles for the 10-, 2-, 1-, and 0.2-percent annual chance floods were calculated using the USACE HEC-2 water surface computer model (Reference 45). The 10- and 1-percent annual chance starting WSELs for Bullhead Gulch were estimated using the slope area method. The starting WSELs for Prince Tributary (East and West Branches) were based on the backwater flood elevation at the time to peak.

The cross sections were digitized from aerial photography. All major culverts and bridges were field inspected and measured.

Manning's "n" values ranged from 0.035 to 0.045 in the channel areas and 0.04 to 0.45 in the overbank areas.

Water-surface profiles for the 10-, 2-, 1-, and 0.2-percent annual chance floods for Fourmile Creek were developed using the USACE HEC-2 step backwater computer program (Reference 45). Starting WSELs were obtained by assuming that the Colorado Highway 119 bridge was blocked for the 2-, 1-, and 0.2-percent annual chance floods, but open for the 10-percent-annual-chance flood. Flow over the roadway for the 2-, 1-, and 0.2-percent annual chance floods were determined by weir computations. Flow through the bridge for the 10-percent annual chance flood was determined by pipe flow computations.

Cross section data used in the analysis was obtained photogrammetrically from the aerial photography flown October 26, 1977 (Reference 100). Bridge data was supplied by USACE and Boulder County.

Manning's "n" values ranged from 0.065 to 0.080 in the channel. A roughness value of 0.080 was used in the overbank areas.

City of Boulder
A comprehensive computer model, MIKE FLOOD, was developed to simulate the movement of flood flows along the South Boulder Creek channel and floodplain. MIKE FLOOD is a computer model that represents the total floodplain with a one-dimensional representation of major channel liked to a two-dimensional representation of overbank floodplain areas.

The upstream portion of the South Boulder Creek hydraulic model, from Eldorado Springs to approximately 2100 feet upstream of Highway 93 can be classified as a confined channel. This section of South Boulder Creek, where there is a clearly defined flow path, was modeled using MIKE FLOOD with a one-dimensional only setting; meaning the one-dimensional model was not coupled to a two-dimensional floodplain in this reach. For the downstream portion of the South Boulder Creek hydraulic model, the flow paths are less well defined having multiple flow splits and highly braided flows. In this area MIKE FLOOD was fully implemented, coupling the one-dimensional model to the two-dimensional model. Approximately 2100 feet upstream of Highway 93, the one-dimensional only model interfaces with the fully coupled domain.

In the one-dimensional channels, a Manning's n-value of 0.067 was applied in the upper reaches of South Boulder Creek, from the headwaters through the mouth of the canyon where South Boulder Creek exits onto the plains. In these upstream reaches, the channel is confined, and the bed material can be classified as large cobbles and boulders. At the canyon mouth, South Boulder Creek transitions for the mountainous channelized streambed to a channel that flows through the plains. In these downstream reaches, South Boulder Creek has a flatter profile, and the streambed is characterized by cobbles with dirt banks. In these reaches, both the channel and geologic floodplain are well defined. For the lower reaches of South Boulder Creek, from where South Boulder Creek exits the canyon through the confluence with Boulder Creek, a Manning's n-value of 0.045 was applied. With the predominance of undeveloped land during calibration of the 1969 flood event, a constant Manning's resistance value was deemed to be appropriate in the floodplain areas. The calibrated resistance value, Manning n=0.06, represents the base Manning's number in the floodplain. Because the level of development in the South Boulder Creek drainage basin was relatively low during the 1969 flood event, the calibrated base resistance value represents the floodplain resistance due to surface due to surface irregularities and vegetative cover, in undeveloped areas.

In areas that remain largely unaltered from the 1969 flood event, the base Manning's "n" roughness value of 0.06 will be applied. In areas where development or disturbance of the land warrants, a higher Manning's "n" resistance value of 0.08 will be applied. The increase in the Manning's "n" value resulting from obstruction and increased vegetation was determined from two reference papers, the "USGS Water Supply Paper 2339", and the "Computed Roughness Coefficients for Skunk Creek above Interstate 17, Maricopa County, Arizona". The USGS Water Supply paper was used to determine an appropriate increase in the floodplain roughness, and the Skunk Creek paper was used to verify the increase in floodplain resistance was reasonable.

In addition to the higher roughness value for developed land, the two-dimensional flow model in MIKE FLOOD, internally adjusts friction losses as a function of depth. The algorithm used computes losses based on bed shear stress. This computation results in losses that increase geometrically as a function of decreasing flow depth. For more detailed information, please see the MIKE 21 User Guide (M21HD.pdf file includes as referenced in Appendix A), Section 6.2, Bed Resistance, on page 48.

The hydraulic analyses for Bear Canyon Creek, Elmers Twomile Creek, Fourmile Canyon Creek, Goose Creek, Skunk Creek, Twomile Canyon Creek, and Wonderland Creek were taken from the Flood Hazard Area Delineation report for Boulder and Adjacent County Drainageways (Reference 25). For these streams studied, the WSELs of floods of the selected recurrence intervals were computed using the USACE HEC-2 step-backwater computer program (Reference 45).

Cross sections used in the backwater analyses for the streams were developed photogrammetrically using aerial photography flown in October 1981 (Reference 46). All bridges, dams, and culverts were field surveyed to obtain elevation data and geometry.

Roughness factors (Manning's "n") used in the hydraulic computations for the detailed-study streams were chosen by engineering judgment and based on field observations of the flooding sources and floodplain areas. Roughness values for the main channel of the detailed-study streams ranged from 0.020 to 0.100; floodplain roughness values ranged from 0.040 to 0.130.

Starting WSELs were determined by the slope-area method, critical depth, or elevations at confluences if the timing of the peaks coincided.

The hydraulic analyses for this study were based on partially obstructed flow, as defined by Boulder and FEMA through field inspection. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Town of Erie

Water-surface elevations (WSELs) for floods of the selected recurrence intervals of Coal Creek were computed using the USACE HEC-2 step backwater computer program (Reference 45).

Cross-section data for Coal Creek in the area north of the UPRR were obtained photogrammetrically from topographic maps (Reference 96). Field measurements were taken by the SCS to obtain elevation data and structural geometry of all bridges and culverts.

Manning's "n" for Coal Creek, north of the UPRR, were determined by the SCS through field inspections. The roughness values range from 0.085 to 0.120 for the channel and overbank areas.

Manning's "n" for Coal Creek, south of the UPRR, were determined by WRC (Reference 69). The roughness values range from 0.075 in the channel to 0.055 in the overbank areas.

For Bullhead Gulch and Prince Tributary (East and West Branches), the Water-surface profiles for the 10-, 2-, 1-, and 0.2-percent annual chance floods were calculated using the USACE HEC-2 water surface computer model (Reference 45). The 10- and 1-percent annual chance starting WSELs for Bullhead Gulch were estimated using the slope area method. The starting WSELs for Prince Tributary (East and West Branches) were based on the backwater flood elevation at the time to peak.

The cross sections were digitized from aerial photography. All major culverts and bridges were field inspected and measured.

Manning's "n" values for Bullhead Gulch and Prince Tributary (East and West Branches) ranged from 0.035 to 0.045 in the channel areas and 0.04 to 0.45 in the overbank areas.

Town of Jamestown

The results obtained from the HEC-2 computer model for James Creek, Little James Creek, and Balarat Creek were verified by comparing them to ground photographs of the 1969 flood through Jamestown.

Cross sections were obtained by field measurements. Bridges in this study were analyzed using a blockage criteria dependent upon bridge construction and water depth. Concrete and steel bridges were assumed unobstructed until the upstream WSEL reached the bridge "low steel" elevation, at which time the bridge was assumed fully obstructed. Wooden bridge decks were assumed destroyed due to debris. This type of bridge was assumed unobstructed at all discharges with wingwalls and abutments in place but the deck removed. Head losses at fully obstructed bridges were determined by weir computations. Unobstructed bridge losses were computed by using the normal bridge routine in HEC-2.

Manning's "n" values were estimated by field investigation using a paper by V.V. Golubtstov (Reference 47). The roughness values for the main channels ranged from 0.030 to 0.750, and for the overbanks from 0.060 to 0.100. WSELs for James Creek were started at normal depth. WSELs for Little James Creek and Balarat Creek were started at their respective confluence elevations resulting from coincident discharges.

City of Lafayette and Town of Superior

The water surface elevations for the selected recurrence intervals on Coal Creek and Rock Creek were computed using HEC-2 (Reference 45). The starting WSELs for Coal Creek were obtained from the report by Hurst and Associates, Inc. (Reference 90). The starting WSELs for Rock Creek were obtained using a rating curve generated with the Federal Highway Administration (FHA) HY-8 hydraulic computer program for culvert analysis that was adjusted for bend losses.

The hydraulic analysis for Coal Creek is complicated by three flow splits that occur at the Community and Coal Creek Ditch crossings and at the abandoned railroad embankment upstream of Second Avenue. No Coal Creek flow is assumed to be conveyed in the ditches. However, the diversion structures in the creek, and the ditch banks, cause portions of the Coal Creek flow to leave the creek, follow the ditch banks, and overtop the ditch banks further downstream to return to the creek. The ditches potentially divert and spill flows along their length, but other than the impact of the ditch banks described above, ditch spilling and flooding is not modeled or shown on the FIRM. The flow splits for the ditches and the railroad are modeled using the HEC-2 split flow routine.

Manning's "n" values used in the hydraulic computations for the detailed study of Coal Creek were taken from the data generated in the SCS report (Reference 18). On Coal Creek, roughness values for the main channel ranged from 0.09 to 0.11. Overbank roughness values ranged from 0.07 to 0.09. The roughness values appear high. However, they should be used for all future LOMRs in order to be consistent with the SCS hydrology calculations. Roughness factors used in the hydraulic computation for the detailed study of Rock Creek were chosen by engineering judgment and based on field observations (Reference 85). On Rock Creek, roughness values for the main channel ranged from 0.035 to 0.08. Overbank roughness values ranged from 0.03 to 0.085. Manning's roughness values at structures ranged from 0.013 to 0.03.

Cross section data for Coal Creek and Rock Creek were taken from photography and mapping of the study area. Base mapping for Rock and Coal Creeks was compiled by CH2M Hill, for ASI and TEA, at a scale of 1:2,400 from December 1994 aerial photography. Modifications to the base mapping were made by Taggart Engineering Associates, Inc. (TEA) to incorporate structures to be built by April 1997 (Reference 89). Information for the modification was obtained from design drawings prepared by individual consulting firms. All existing bridges and culverts were field surveyed to obtain elevation data and structural geometry.

City of Longmont
WSELs of floods of the selected recurrence intervals were computed through the use of the USACE HEC-2 water-surface profiles computer program (Reference 45). Starting WSELs for Lefthand Creek and Spring Gulch correspond to the computed WSELs for the St. Vrain Creek at the confluence of the two streams.

The flooding in Loomiller Basin is in the form of sheet runoff, in which velocities are low, in depths less than 1.0 foot.

Detailed cross section data for St. Vrain Creek were obtained from the USACE and supplemented with additional cross sections taken from maps at a scale of 1:4,800, with a contour interval of 2 feet, also prepared by the USACE (Reference 6). Detailed cross sections for Lefthand Creek, and Spring Gulch were field surveyed in September 1975. The cross sections were located at close intervals above and below bridges and culverts in order to accurately compute backwater effects at these structures. USGS topographic mapping enlarged to a scale of 1:6,000, with a contour interval of 10 feet, was used to supplement field-survey data (Reference 48).

Manning's "n" values for these computations were assigned on the basis of field inspection of the floodplain areas and engineering judgment. Bridge geometry and elevation information was obtained from the Colorado State Highway Department and Longmont, when available, and measured in the field.

The hydraulic analyses for Dry Creek No. 1, Dry Creek No. 1 (Old Channel), Clover Basin Tributary, and Steele Lakes Tributary were taken from the Floodplain Information and Flood Control and Drainage Plan for Dry Creek No. 1 (Reference 3). The WSELs for the 10-, 2-, 1-, and 0.2-percent annual chance floods were computed using the USACE HEC-2 step backwater computer program (Reference 45). Starting WSELs for Dry Creek No. 1 correspond to the computed WSELs for the St. Vrain Creek at the confluence.

Cross sections were digitized from aerial photography flown March 24, 1979 and provided by the Colorado Water Conservation Board (Reference 97). The City of Longmont conducted field surveys to provide information related to the first floor elevations of all improvements made in the floodplain. Additional field surveys were conducted to obtain bridge and culvert geometry and to verify the computed limits of flooding.

Manning's "n" values were estimated from two separate field investigations. The roughness values ranged from 0.030 to 0.060 for the main channels and from 0.040 to 0.070 for the overbank areas.

For Lefthand Creek North Overflow Channel and Lefthand Creek South Overflow Channel, the water-surface profiles for the 1-percent annual chance flood were calculated using the USACE HEC-2 water surface computer model (Reference 45). The cross sections were determined from field and aerial sources. The starting WSELs for Lefthand Creek North Overflow Channel were determined by the slope/area method. The starting WSELs for Lefthand Creek South Overflow Channel were obtained from the combined flow of the Lefthand Creek North Overflow Channel and the study reach. Manning's "n" values for both channels were 0.03 for the main channels and 0.03 for the overbank areas.

The hydraulic analyses for this study were revised to include information presented in floodplain information reports for Lefthand Creek, Dry Creek No. 1, and St. Vrain Creek (References 1 through 4) and in the LOMR issued on May 14, 1999 for Lefthand Creek North Overflow Channel and Lefthand Creek South Overflow Channel.

Town of Lyons

For St. Vrain Creek (Vicinity of Lyons) through the Lyons area, the analyses used field conditions represented by bridge and valley cross sections surveyed in 1971. Water-surface profiles were determined from backwater computations employing the Standard Step Method (Reference 45). Starting WSELs were taken from the USACE report concerning St. Vrain Creek (References 8 and 43).

The roughness coefficients used in the study were determined by field survey and ranged from 0.045 to 0.055 for the main channels, and from 0.060 to 0.100 for the overbank. Head losses at bridges were computed using data published by the U.S. Department of Transportation (Reference 49).

Town of Nederland

Water-surface profiles for the 10-, 2-, 1-, and 0.2-percent annual chance floods for Middle Boulder Creek and North Beaver Creek through Nederland were developed using the SCS WSP2 computer program (Reference 34). Starting WSELs were determined using stream slope at the starting valley cross sections.

Cross section data were obtained by field measurements. All bridges, culverts, and other structures were surveyed to obtain elevation data and structural geometry.

Roughness coefficients were estimated by field investigation and from pictures of each stream and its respective floodplain using USGS Water-Supply Paper 1849 (Reference 50), *Open Channel Hydraulics*, by Ven Te Chow (Reference 51), and *Handbook of Applied*

Hydraulics, by Davis and Sorenson (Reference 52). The roughness values for the main channels ranged from 0.040 to 0.075, depending on the locations. The roughness coefficients for the floodplain ranged from 0.016 to 0.160.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the FIRM (Exhibit 2).

The hydraulic analyses for this study were based on unobstructed flow, unless otherwise noted. The flood elevations shown on the Flood Profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

3.3 Vertical Datum

All FIS reports and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum in use for newly created or revised FIS reports and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD29). With the finalization of the North American Vertical Datum of 1988 (NAVD88), many FIS reports and FIRMs are being prepared using the NAVD88 as the referenced vertical datum.

All flood elevations shown in this FIS report and on the FIRM are referenced to NAVD88. Elevation Reference Marks (ERMs) shown on the FIRM represent those used during the preparation of this and previous FIS reports. Users should be aware that these ERM elevations may have changed since the publication of this FIS report. To obtain up-to-date elevation information on National Geodetic Survey (NGS) ERMs shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov. Map users should seek verification of non-NGS ERM monument elevations when using these elevations for construction or floodplain management purposes. It is important to note that adjacent communities may be referenced to NGVD. This may result in differences in Base Flood Elevations (BFEs) across the corporate limits between communities.

For this revision, a vertical datum conversion was completed for each studied reach. The range of conversion factors was prohibitively high; therefore, a standard conversion factor was not applied for the entire community. The Profile Panel and FDT conversion from NGVD29 to NAVD88 was carried out in accordance to the procedure outlined in the FEMA document Map Modernization – Guidelines and Specifications for Flood Hazard Mapping Partners Appendix B: Guidance for Converting to the North American Vertical Datum of 1988.

Using the multiple conversion factor approach, an average conversion factor for each flooding source was developed by establishing separate conversion factors at the upstream end, at the downstream end and at an intermediate point of the studied reach. From this data, the average conversion factors for each reach were developed. In some cases, it was necessary to divide each reach into multiple sections in order for the maximum offset from the average conversion factor to be less than or equal to 0.25 feet.

A separate elevation datum conversion was performed for the part of Coal Creek within the corporate limits of the Town of Erie. The latest revision of the FIS report and FIRMs for the Town of Erie dated December 2004 were incorporated into this study (Reference 95). All elevations are now referenced to the NAVD using a datum conversion factor of 3.0 feet (NAVD = NGVD + 3.0).

South Boulder Creek, 55th Street Split Flow, Dry Creek Ditch No. 2, and West Valley Split Flow did not require a datum conversion since the new study was performed in NAVD88.

For more information on NAVD88, see the FEMA publication entitled *Converting the National Flood Insurance Program to the North American Vertical Datum of 1988* (FEMA, June 1992), or contact the Vertical Network Branch, National Geodetic Survey, Coast and Geodetic Survey, National Oceanic and Atmospheric Administration, Rockville, Maryland 20910 (Internet address http://www.ngs.noaa.gov).

Temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with the FIS report and FIRM for this community. Interested individuals may contact FEMA to access this data.

Conversion factors for each studied reach are shown in Table 5.

Table 5 – Datum Conversion Factors

Stream/Reach	Average Conversion	Beginning Station	End Station
Arapahoe Avenue Overflow	3.2	Entire Reach	
Arapahoe Avenue Spill Flow	3.4	Entire Reach	
Balarat Creek	4.1	Entire Reach	
Bear Canyon Creek	3.3	Entire Reach	
Boulder Creek	4.2	Uppermost Point of Reach	Approx. 160,000' Upstream of Confluence
	3.7	Approx. 160,000' Upstream of Confluence	Confluence w/ Fourmile Creek
	3.3	Confluence w/ Fourmile Creek	E. County Line Road
Boulder Creek High School Overflow	3.3	Entire Reach	

Stream/Reach	Average Conversion	Beginning Station	End Station
Boulder Creek (Right Bank Overflow)	3.2	Entire Reach	
Bullhead Gulch	3.1	Entire Reach	
Canyon Boulevard Overflow	3.3	Entire Reach	
Clover Basin Tributary	3.2	Entire Reach	
Coal Creek	3.3	Entire Reach Except for Portion within Erie	
Coal Creek (Erie)	3.0	Portion of Reach that is within Erie	
Dry Creek	3.2	Entire Reach	
Dry Creek No. 1	3.2	Entire Reach	
Dry Creek No. 1 (Old Channel)	3.2	Entire Reach	
Dry Creek No. 2	3.2	Entire Reach	
Dry Creek No.2 Ditch Split Flow	3.2	Entire Reach	
Dry Creek No. 3	3.1	Entire Reach	
Elmers Twomile Creek	3.3	Entire Reach	
Fourmile Canyon Creek	3.3	Entire Reach	
Fourmile Creek	4.6	Uppermost Point of Reach	Eldorado Dr. & Artesian Rd
	4.2	Eldorado Dr. & Artesian Rd	At Baseline Road
	3.8	At Baseline Road	Confluence w/ Boulder Creek
Goose Creek	3.3	Entire Reach	
Gregory Canyon Creek	3.4	Entire Reach	
Highway 93 Split Flow	3.3	Entire Reach	
James Creek	4.4	Just Upstream of Confluence w/ Little James Creek	Approx. 2200' Upstream of Confluence w/ Little James Creek
	3.9	Confluence w/ Lefthand Creek	Just Downstream of Confluence w/ Little James Creek
Lefthand Creek	4.7	Uppermost Point of Reach	Just Downstream of Lefthand Canyon Dr & Sawmill Rd

Stream/Reach	Average Conversion	Beginning Station	End Station
	4.3	Just Downstream of Lefthand Canyon Dr & Sawmill Rd	Just Downstream of Lick Skillet Gulch
	3.8	Just Downstream of Lick Skillet Gulch	Just Downstream of James Creek
	3.4	Just Downstream of James Creek	At Confluence w/ St. Vrain Creek
Lefthand Creek North Overflow Channel	3.2	Entire Reach	
Lefthand Creek South Overflow Channel	3.2	Entire Reach	
Little James Creek	4.1	Entire Reach	
Little Thompson River	3.3	Entire Reach	
Middle Boulder Creek	4.5	Entire Reach	
Middle St. Vrain Creek	4.6	Uppermost Point of Reach	Approx. 33,000' Upstream of Confluence South St. Vrain Creek
	4.2	Approx. 33,000' Upstream of Confluence South St. Vrain Creek	Confluence w/ South St. Vrain Creek
North Beaver Creek	4.5	Entire Reach	
North Goose Creek	3.2	Entire Reach	
North St. Vrain Creek	3.5	Entire Reach	
Prince Tributary, East Branch	3.1	Entire Reach	
Prince Tributary, West Branch	3.1	Entire Reach	
Rock Creek	3.2	Entire Reach	
St. Vrain Creek	3.2	Entire Reach	
St. Vrain Creek (Vicinity of Lyons)	3.3	Entire Reach	
Skunk Creek	3.3	Entire Reach	

Stream/Reach	Average Conversion	Beginning Station	End Station
South St. Vrain Creek	4.6	Uppermost Point of Reach	Approx. 79,000' Upstream of Confluence w/ St. Vrain Creek
	4.1	Approx. 79,000' Upstream of Confluence w/ St. Vrain Creek	Approx. 36,000' Upstream of Confluence w/ St. Vrain Creek
	3.6	Approx. 36,000' US of Confluence w/ St. Vrain Creek	Confluence w/ St. Vrain Creek
Spring Gulch	3.2	Entire Reach	
Steele Lakes Tributary	3.2	Entire Reach	
Twomile Canyon Creek	3.4	Entire Reach	
Wonderland Creek	3.3	Entire Reach	

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. Therefore, each FIS provides 1-percent annual chance flood elevations and delineations of the 1- and 0.2-percent annual chance floodplain boundaries and 1-percent-annual-chance floodway to assist communities in developing floodplain management measures. This information is presented on the FIRM and in many components of the FIS report, including Flood Profiles and Floodway Data Table. Users should reference the data presented in the FIS report as well as additional information that may be available at the local map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent annual chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent annual chance flood is employed to indicate additional areas of flood risk in the community. For each stream studied by detailed methods, the 1- and 0.2-percent annual chance floodplain boundaries have been delineated using the flood elevations determined at each cross section.

For South Boulder Creek, the 1- and 0.2-percent-annual-chance floodplain boundaries have been delineated using the flood elevations determined with MIKE FLOOD. Between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:1,200, with a contour interval of one foot.

The South Boulder Creek Flood Mapping Study employed the use of MIKE FLOOD, a one-dimensional and two-dimensional linked hydraulic model. Model results for the floodplain provide a detailed grid of four-meter by four-meter pixel cells. All "wetted" grid cells where flood water depths are determined to be more than 0.01 feet are highlighted to reflect the extent of 1-percent-annual-chance flood inundation.

Derived using the MIKE FLOOD grid cell inundation results, an electronic flood zone map was produced and manually enhanced by conducting a detailed visual review. These results are projected in ARC-GIS with the City's 2003 six-inch pixel aerial photography and one-foot topographic contours. The 2003 topography was used to create the digital elevation model (DEM) used in the MIKE FLOOD two-dimensional analysis. This quality assurance review offers a "physical reality check" to process the flood zone mapping.

For Bear Canyon Creek, Elmers Twomile Creek, Fourmile Canyon Creek, Goose Creek, Skunk Creek, Twomile Canyon Creek and Wonderland Creek, the floodplain boundaries between cross sections were interpolated using topographic maps at scale 1:2,400, with contour intervals of 2 feet (Reference 46). For Lefthand Creek and Spring Gulch, the floodplain boundaries between cross sections were interpolated using topographic maps at scale 1:6,000 (enlarged from 1:24,000), with contour intervals of 10 feet (Reference 48). Floodplain boundaries between cross sections for Balarat Creek, James Creek and Little James Creek were interpolated from topographic maps at scale 1:1,200, with contour intervals of 2 feet (Reference 53). The floodplain boundaries for Coal Creek in Erie were interpolated using topographic maps at scale 1:4,800, with contour intervals of 2 feet and 4 feet (Reference 96). For Dry Creek No. 1 and Clover Basin Tributary, the floodplain boundaries between cross sections were interpolated using topographic maps at scale 1:200, with contour intervals of 2 feet (Reference 97). The floodplain boundaries between cross sections for St. Vrain Creek were interpolated using topographic maps at scale 1:4,800, with contour intervals of 2 feet (Reference 6). For Coal Creek and Rock Creek, the floodplain boundaries between cross sections were interpolated using topographic maps at scale 1:4,800, with contour intervals of 4 feet (Reference 57). For Coal Creek and Rock Creek in Lafayette, the floodplain boundaries between cross sections were interpolated using topographic maps at scale 1:4,800, with contour intervals of 4 feet (Reference 54). The floodplain boundaries for North Beaver and Middle Boulder Creeks were interpolated using topographic maps at scale 1:4,800, with contour intervals of forty feet (Reference 56). For St. Vrain, North St. Vrain and South St. Vrain Creeks in Lyons, the floodplain boundaries were interpolated using topographic maps at scale 1:6,000, with contour intervals of forty feet (Reference 55).

Floodplain boundaries in other portions of Boulder County have been revised to include boundary information shown on topographic work maps included with the reports referenced in Section 7.0.

The 1-percent annual chance floodplain boundaries for Anderson Ditch, David's Draw, Little Dry Creek, and Viele Channel, studied by approximate methods, were taken from the previous FIRM for the City of Boulder (Reference 58).

The 1-percent annual chance floodplain boundaries for Gregory Creek, Bluebell Canyon Creek, Kings Gulch, Sunshine Gulch, upper reaches of Bear Canyon Creek, and Skunk

Canyon Creek, were taken from the Boulder and Adjacent County Drainageways - Flood Hazard Area Delineation prepared by G&O (Reference 25).

Approximate 1-percent annual chance floodplain boundaries in some portions of the study area were taken directly from the Flood Hazard Boundary Map for the Town of Nederland (Reference 59).

The 1- and 0.2-percent annual chance floodplain boundaries are shown on the FIRM. On this map, the 1-percent annual chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AH, AO, and AE); and the 0.2-percent annual chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent annual chance floodplain boundaries are close together, only the 1-percent annual chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the 1-percent annual chance floodplain boundary is shown on the FIRM.

4.2 Floodways

Encroachment on flood plains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent annual chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent annual chance flood can be carried without substantial increases in flood heights. Minimum Federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this study are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this FIS report and the FIRM were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations have been tabulated for selected cross sections (Table 6). In cases where the floodway and 1-percent annual chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

The area between the floodway and 1-percent annual chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent annual chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 1.

Floodway computations are performed to assess the impact of floodplain encroachment on the water level and the energy gradient during a flooding event. Traditional floodway computations performed with one-dimensional hydraulic models are performed by manipulating user-defined cross-sections by inserting encroachment stations, thus encroaching the cross-sectional area and causing a rise in water level as a result. Typically, this process is performed iteratively until a specified rise in water level has been achieved. Because the simulation of flooding events for South Boulder Creek is being performed with MIKE FLOOD, a dynamically coupled one-dimensional and two-dimensional model, the floodway computations must be performed using a non-traditional approach. It is impossible to simply encroach the user specified cross-sections in the one-dimensional portion of the model. Encroaching only the user specified cross-sections would simply give rise to additional spillage onto the two-dimensional floodplain and the desired rise in water level along a defined floodway would not be observed.

Given the fully developed conditions in the west valley of South Boulder Creek and that no clearly defined west valley channel exists, a single designated floodway along the main South Boulder Creek corridor was modeled. All flow splits were eliminated, confining flow to the designated floodway, by full encroachments into the two-dimensional model topography. In addition to modifying the two-dimensional topography to confine flooding to the main channel of South Boulder Creek, all one-dimensional structures not located on the South Boulder Creek main stem were removed from the model.

The resulting water levels of the floodway computations were compared with the water surface elevations from the floodplain model to determine what level of increase occurs. If more than a 0.5-foot rise in water surface elevations within city boundaries and a 1-foot rise in water surface elevations in unincorporated areas occurs ,the floodway was defined as the entire floodplain in the east valley main creek corridor, and an assessment of the need to consider a floodway in the west valley should be made.

No floodway has been computed for Arapahoe Avenue Overflow, Boulder Creek (Right Bank Overflow), Boulder Creek (Reference 61), and Dry Creek. However, Boulder and the UDFCD regulate a floodway that is more restrictive than the floodway required by FEMA. Contact the City of Boulder or UDFCD for this floodway information

No floodway is shown for Lefthand or South St. Vrain Creeks in Longmont as a result of the latest analyses of these drainages. Also, no floodway is shown for Bullhead Gulch, Dry Creek No. 2, Dry Creek No. 2 Ditch Split Flow, Dry Creek No. 3, Fourmile Creek, Highway 93 Split Flow, Lefthand Creek (North and South Overflow Channels), Little Thompson River, Middle St. Vrain, Price Tributary (East and West Branches), South Boulder Creek, St. Vrain Creek and Steele Lakes Tributary.

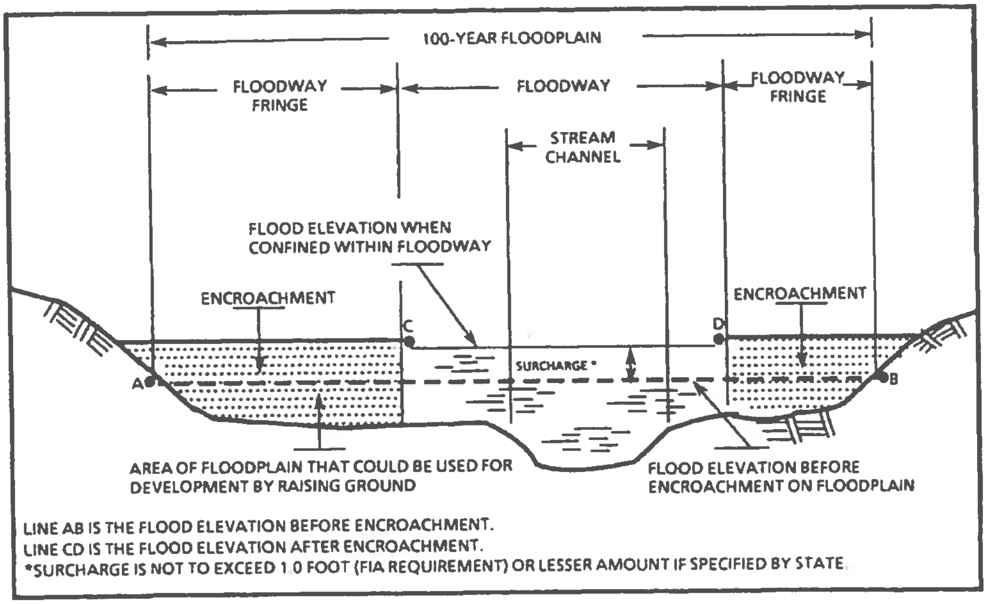

Figure 1 – Floodway Schematic

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
NORTH ST. VRAIN CREEK								
A	1,530	157	511	8.4	5,338.1	5,338.1	5,338.1	0.0
B	2,550	60	331	13.0	5,347.0	5,347.0	5,347.0	0.0
C	3,500	202	612	7.0	5,359.9	5,359.9	5,359.9	0.0
D	5,090	98	361	12.0	5,373.6	5,373.6	5,373.6	0.0
E	6,103	93	516	8.4	5,381.9	5,381.9	5,382.0	0.1
F	8,721	115	436	9.9	5,404.3	5,404.3	5,404.6	0.3
G	9,616	113	458	9.4	5,414.6	5,414.6	5,415.3	0.7
H	10,346	53	327	13.2	5,423.1	5,423.1	5,423.1	0.0

[1]Feet above confluence with St. Vrain Creek and South St. Vrain Creek

TABLE 6

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO
AND INCORPORATED AREAS

FLOODWAY DATA

NORTH ST. VRAIN CREEK

FLOODING SOURCE		FLOODWAY			1-PERCENT-ANNUAL-CHANCE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY (FEET NAVD)	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY (FEET NAVD)	INCREASE (FEET)
ST. VRAIN CREEK (VICINITY OF LYONS)								
A	166,708	205	936	9.5	5,267.8	5,267.8	5,267.8	0.0
B	167,408	166	817	10.9	5,273.3	5,273.3	5,274.3	1.0
C	167,828	220	973	9.1	5,277.4	5,277.4	5,278.3	0.9
D	168,708	608	2,052	4.3	5,281.6	5,281.6	5,282.5	0.9
E	169,848	500	1,283	6.9	5,290.3	5,290.3	5,290.6	0.3
F	170,278	226	904	9.8	5,296.5	5,296.5	5,296.8	0.3
G	170,688	251	1,262	7.0	5,299.3	5,299.3	5,300.3	1.0
H	171,603	320	1,117	8.0	5,305.9	5,305.9	5,306.0	0.1
I	172,378	624	1,511	5.9	5,311.4	5,311.4	5,311.4	0.0
J	173,167	597	3,032	2.9	5,319.8	5,319.8	5,319.9	0.1

[1]Feet above mouth

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO
AND INCORPORATED AREAS

FLOODWAY DATA

ST. VRAIN CREEK (VICINITY OF LYONS)

TABLE 6