Skunk Creek, Bluebell Canyon Creek, and King's Gulch

Request for Physical Map Revision (PMR)

Prepared for:

City of Boulder
Public Works Department - Utilities Division
1739 Broadway, 2nd Floor
Boulder, Colorado 80302
303.441.3200

Prepared by:

8100 South Akron Street, Suite 300
Centennial, CO 80112
303.221.0802
(Job No. 14-008-SBK)

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1.0 Introduction

1.1 Purpose of Study

This request for a Physical Map Revision (PMR) is being submitted to update the Skunk Creek, Bluebell Canyon Creek, and King's Gulch floodplains and floodways. This study, commissioned by the City of Boulder includes Skunk Creek from downstream of the Anderson Ditch in Green Mountain Cemetery to the confluence with Bear Canyon Creek (approximately 2.2 mi), Bluebell Canyon Creek from the City limit to the confluence with Skunk Creek (approximately 1.5 mi), and King's Gulch from the City limit to the confluence with Skunk Creek (approximately 0.8 mi).

The revised study includes recent structural improvements at the box culverts and pedestrian crossings at Broadway and 27th Way, a previously unstudied (by detailed methods) crossing at King Avenue, and updated topographic mapping. New 100-year road box culverts with pedestrian trails were built by the City at Broadway in 1999 and at 27th Way in 2006 (Love & Associates Floodplain Development Permits, 1999 and 2006).

The Skunk Creek effective study is detailed from the downstream limit to the downstream face of King Avenue. The Skunk Creek effective study is approximate upstream of the downstream face of King Avenue. The Bluebell Canyon Creek and King's Gulch effective studies are approximate studies. This study models the entire study area using detailed methods. Multiple spills from the main channel are included in the hydraulic analysis and mapping which were not previously shown on the Flood Insurance Rate Map (FIRM).

1.2 Authority and Acknowledgement

This document provides the information necessary to fulfill the requirements of 44CFR 65.3, Parts 60, 65 and 72 in requesting a Letter of Map Change (LOMC) as a PMR for Skunk Creek, Bluebell Canyon Creek, and King's Gulch within the City. The study was performed under a contract between ICON Engineering and the City of Boulder and includes hydraulic modeling of the 10-, 25-, 50-, 100-, and 500-year return period events and delineation of the associated floodplains and conveyance zones (0.5 ft rise floodway). Design parameters and hydraulic modeling techniques have been reviewed and approved by the City.

Portions of the study area are within the jurisdiction of the University of Colorado at Boulder (State of Colorado) and the U.S. Department of Commerce (USDC Boulder Labs at 325 Broadway).

1.3 Base Information

The regulatory studies for Skunk Creek, Bluebell Canyon Creek, and King's Gulch are described in *Flood Hazard Area Delineation (FHAD), Boulder and Adjacent County Drainageways* (Greenhorne and O'Mara, 1987). The regulatory floodplain for the study area is delineated on FIRM panels: 08013C0557J, 08013C0394J and 08013C0413J (FEMA, December 18, 2012) Skunk Creek hydrology and hydraulics were also documented in the Boulder County Flood Insurance Study (FIS) (FEMA, 2002).

Topographic and planimetric information required for the study was obtained from aerial topographic maps at 1-foot contour intervals prepared by Merrick & Company and flown during the spring of 2003 (Datum: Horizontal – NAD 83, Colorado State Plane Coordinates, Vertical – NAVD 88) supplemented by Light Detection and Ranging (LIDAR) mapping captured by Merrick in January 2004 in the densely vegetated floodplain areas. Field survey data for structures and cross sections was obtained by Boulder Land Consultants (BLC, 2007, 2008, 2010 and 2011). Certified field survey is located in Appendix 6. Utility information, including storm and sanitary sewer lines was acquired from the COB GIS department and last updated on 7/30/11.

The Skunk Creek regulatory (effective) models are on the NGVD 29 vertical datum. A conversion factor was obtained using Corpscon 6.0.1 to convert the cross sectional geometry for comparison to this detailed study from NGVD 29 to NAVD 88 (USACE, 2004). The conversion equation is shown below.

NGVD 29 + 3.28-ft = NAVD 88 (Skunk Creek: U/S Limit – U/S Face 27th Way
NGVD 29 + 3.23-ft = NAVD 88 (Skunk Creek: D/S Face 27th Way - Confluence)

The hydraulic analysis for the revised study was completed using HEC-RAS version 4.1.0 developed by the U.S. Army Corps of Engineers (USACE, 2010).

At the time of this study, the new University of Colorado Systems Biotechnology Building was under construction on the parcel bounded by Colorado Avenue, Discovery Drive, 33rd Street, and 35th Street. The Bid Package grading plans dated 11/3/2010 were used to model cross sectional geometry on this parcel.

2.0 Study Area

2.1 Scope of Study

This PMR Request includes a detailed hydraulic analysis of the 10-, 50-, 100- and 500-year flood events through the study reach using HEC-RAS modeling and updated topography. The 25-yr hydrologic profile was developed for the City as part of this study and 25-yr water surface elevations were determined. The study reach is comprised of public, commercial, single family residential, and multi-family residential areas. The revised study includes the new Skunk Creek structures and pedestrian underpasses at Broadway and 27th Way.

The study area is located in a portion of Sections 32 and 33, Township 1 North, Range 70 West and a portion of Sections 5 and 6, Township 1 South, Range 70 West. The study reach is entirely within the City of Boulder (Figure 1).

2.2 Community Description

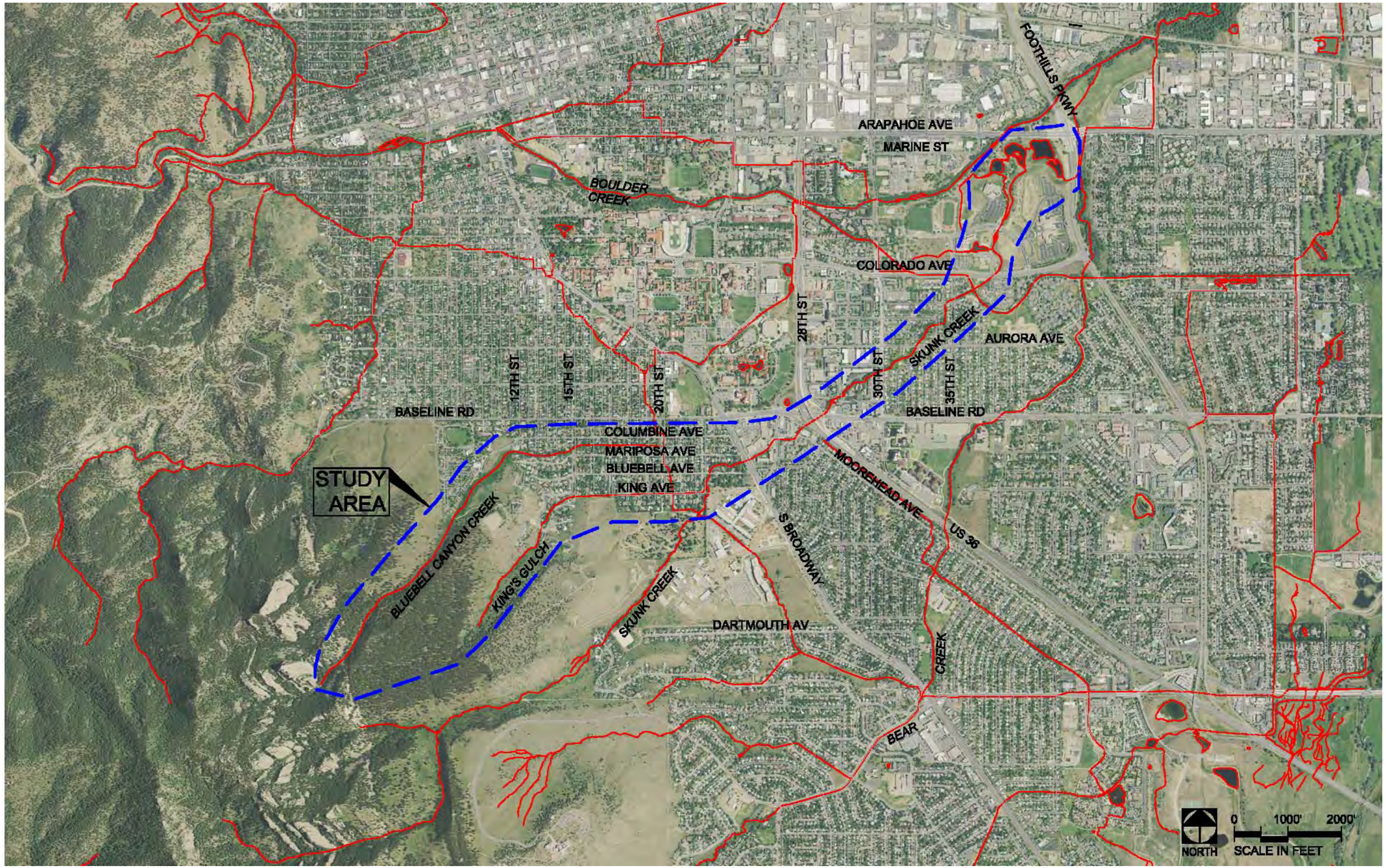
The City of Boulder is located in central Boulder County northwest of Denver and on the east side of the Rocky Mountains in Colorado. The City, with an estimated population of 103,000, encompasses approximately 24 square miles of moderately steep, rolling terrain. The underlying geologic formation consists of an alluvial floodplain extending from the base of the Front Range of the Rocky Mountains eastward. The climate is relatively dry and averages approximately 18.3 inches of precipitation per year. The average elevation is 5,344 feet and ranges from about 5,150 to 8,500 feet.

The upslope areas are covered with a variety of rock outcroppings, thin residual soils on bedrock, and thicker debris, alluvium, and slope wash deposits and are vegetated with grasses, trees, and shrubs. Deeper soils and wetland vegetation are found on alluvial deposits adjacent to streams. The City includes residential and commercial development and open space.

2.3 Principal Flooding Problems

The principal cause of flooding problems is intense, localized thunderstorms combined with a drainage infrastructure of insufficient capacity to handle large events. In addition to the overbank flows generated during a 100-year flooding event, the steep terrain and alluvial physiography of the watershed contributes to flash flooding which is forced out of the channel by undersized culverts under major roadways, allowing flows to travel down side streets and creating local areas of shallow flooding.

Figure 1 – Project Location Map



2.4 Project Description

Culvert structures on Skunk Creek at Broadway and 27th Way were replaced in recent years. A 6-ft x 6-ft concrete box structure at Broadway was replaced with a 22-ft wide x 8-ft tall concrete box structure (dimensions do not include the low flow channel which also runs through the new box). A double 10-ft x 6-ft concrete box at 27th Way was replaced with a new 20-ft x 7.4-ft reinforced concrete box (dimensions do not include low flow channel which also runs through box). Both structures were designed to convey the 100-year flood event without overtopping. Low water pedestrian crossings were built downstream of the Broadway box culvert and upstream of 27th Way box culvert.

A redevelopment project was also constructed on the U.S. Department of Commerce (USDC) Boulder Labs property at 325 Broadway in 2008. The site was surveyed upon completion of the project and post-project topography is used for this study. The project included installation of storm sewer, an underground detention vault, a detention pond, parking lot expansion, roadway resurfacing, fill, and regrading. Project mapping incorporates the post construction topography.

Various other projects involving infill and redevelopment have taken place with the study area and have been addressed with LOMR's. This study incorporates these areas into the revised model with new project mapping.

3.0 Engineering Methods

3.1.0 Hydrology

The effective hydrology as defined in the FIS and used in the FHAD effective hydraulic model (Greenhorne & O'mara, 1987) was used for this analysis. The FHAD did not include the 25 or 500-yr profile. These events were interpolated using a frequency analysis chart and the flow values given in the FHAD for the 2-year to 100-year flow profiles. The frequency chart is included in Appendix 2. Flows in intermediate reaches were determined from the flow profile (Figure 9 in the FHAD) and included in Appendix 2. Note that it was necessary to break these flows down further at junctions and reaches where flows left or returned. This will be discussed in greater detail in Section 3.2.

3.1.1 Bluebell Canyon Creek

Peak discharges for Bluebell Canyon Creek are given in Table 1 and shown graphically in Figure 2. Figure 3 shows the FHAD Design Points (DP's) for the project area. The effective hydrology for Bluebell Canyon Creek as defined in the FHAD at these DP's is shown as bold values in the table.

Table 1 – Peak Discharge Summary for Bluebell Canyon Creek (cfs)

FHAD DP	Flow Change ID	River Station ID	Flow Change Location	Recurrence Interval				
				10-year	25-year	50-year	100-year	500-year
	1	7631	Upstream Study Limit	60	95	170	230	50
211		**5485**		**60**	95	**170**	**230**	50
	2	3917	20th Street	180	256	350	420	660
	3	2622		270	373	500	590	870
212	**4**	**14545**	**Broadway**	**360**	480	**630**	**740**	1010

Figure 2 – Discharge Profiles

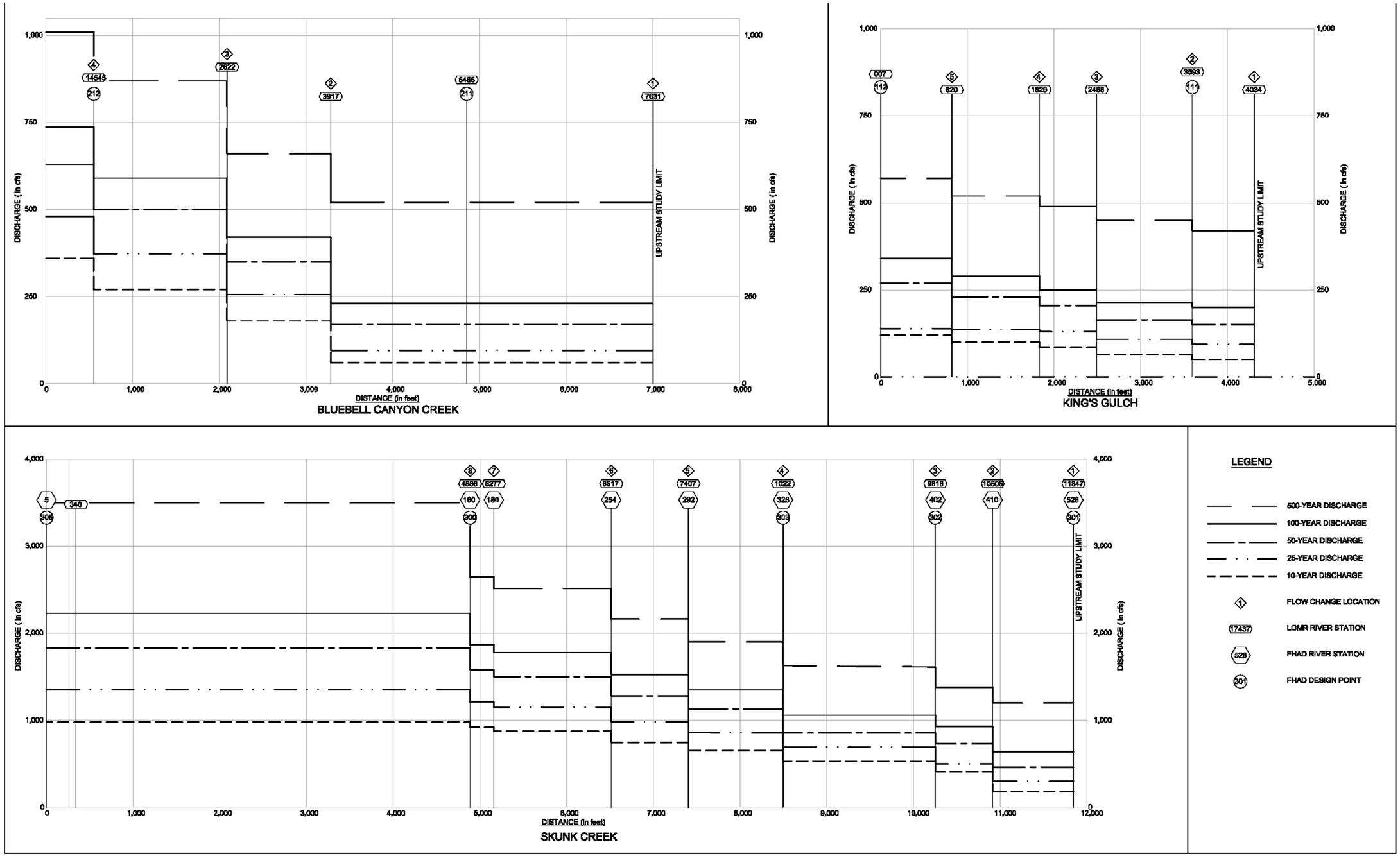
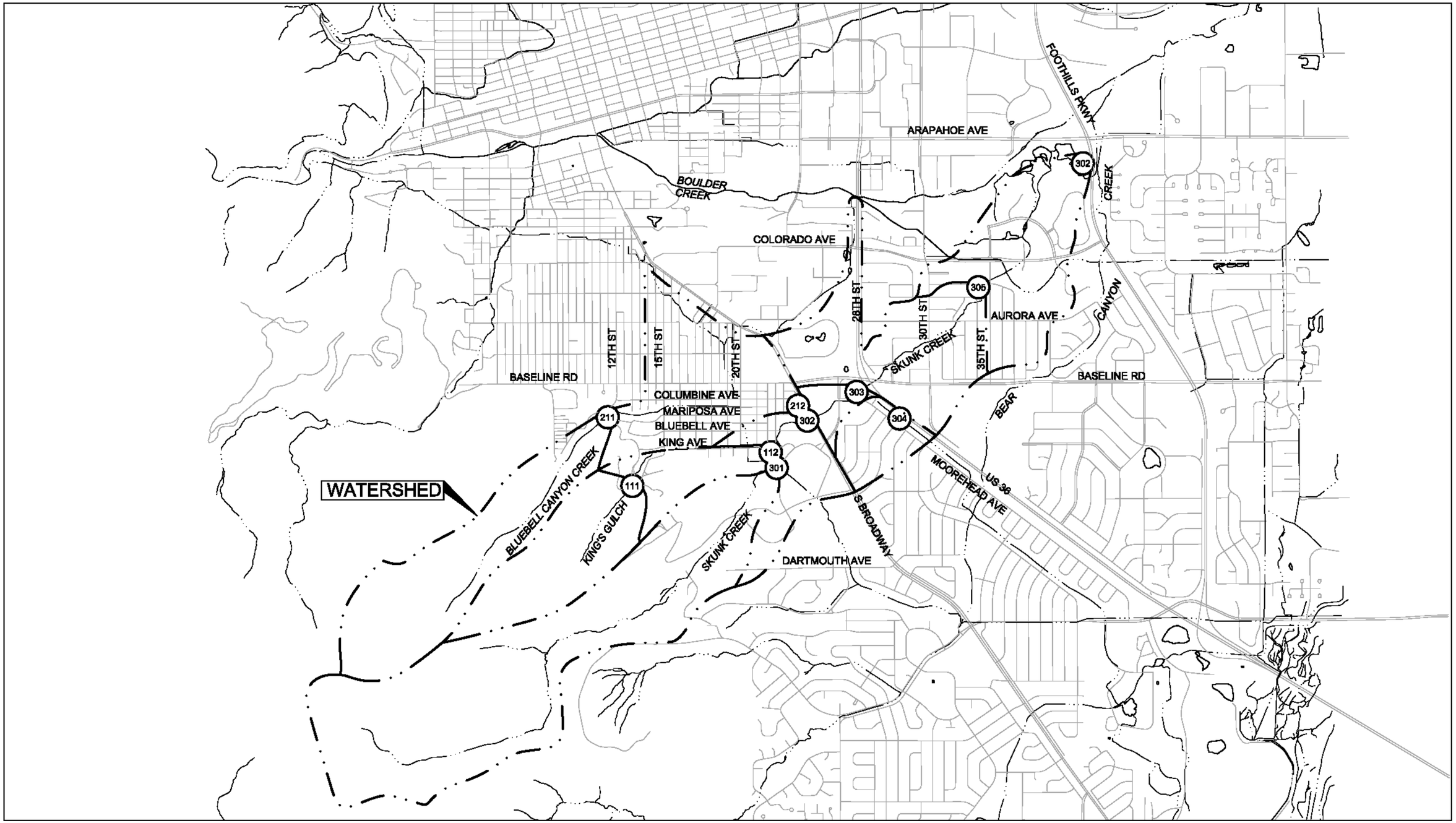


Figure 3 – FHAD Design Points



3.1.2 King's Gulch

Peak discharges for King's Gulch are given in Table 2. The bold values in the table are flow values included in the FHAD. Flows in intermediate reaches were determined from the flow profile from Figure 11 in the FHAD and included in Appendix 2.

Table 2 – Peak Discharge Summary for King's Gulch (cfs)

FHAD DP	Flow Change ID	River Station ID	Flow Change Location	Recurrence Interval				
				10-year	25-year	50-year	100-year	500-year
	1	4034	Upstream Study Limit	50	94	150	200	420
111	**2**	**3593**	**Bellevue Drive**	**64**	108	**164**	**214**	450
	3	2488	15th Street	85	130	205	250	490
	4	1829	17th Street	100	136	230	290	520
	5	820	20th Street	120	139	269	340	570
112	**-**	**0001**	**Confluence with Skunk Creek**	**120**	139	**269**	**340**	570

3.1.3 Skunk Creek

The FIS gives the flow values on Skunk Creek at five different design points. The revised model breaks down the flow inputs into smaller increments with flow increases at eight different design points. The revised model flow values were used between the five major design points defined in the FIS in order to insure continuity in the hydraulic model due to the numerous split flows.

Peak discharges for Skunk Creek are given in Table 3. The bold values in Table 3 are values included in the FIS. The other intermediate values are taken from the effective hydrology. Flows which spill to Bear Creek were subtracted from the 100-year profile in the effective hydraulic model between US Highway 36 and 30th Street. No flows are subtracted in the revised model.

The hydrology used in the effective hydraulic model is in some places inconsistent with the hydrology given in the 1987 FHAD and the 2002 FIS for the reach upstream of Broadway by up to 10%. Generally, the flow rates from the FIS are slightly less than those in the effective hydraulic model in places where the two differ. For example, for the reach from upstream of section 402 (effective)/10095 (revised) to the upstream limit the 100-year flow rate is 640 cfs in the FIS and 675 cfs in the effective model. A corrected effective model was completed for Skunk Creek which corrects the effective model hydrology to match the 2002 FIS & FHAD hydrology.

The spills and residual flows from Bluebell and Kings enter the Skunk Creek main stem at multiple locations on Baseline and along Broadway. In order to assimilate these flows into the Skunk Creek model, a hydrologic adjustment factor was developed to honor FHAD DP 303 at the Highway 36 interchange. Since the FHAD hydrology for Skunk Creek indicates a lower peak flow at design point (DP) 303 than the sum of Bluebell (DP 212) and Kings (DP 112), these flows were distributed into the Skunk Creek model using a ratio of 1.0 – {[DP112+DP212] / DP302}, or 66% for the 100-year event and similarly for the 10, 25, 50 and 500-year profiles (see Appendix 3).

Table 3 – Peak Discharge Summary for Skunk Creek (cfs)

FHAD DP	Flow Change ID	River Station ID	Flow Change Location	Recurrence Interval				
				10-year	25-year	50-year	100-year	500-year
301	**1**	**11437**	**Upstream Study Limit**	**180**	299	**460**	**640**	1200
302	**3**	**9818**	**Confluence with Bluebell Canyon Creek**	**529**	693	**854**	**1270**	1612
303	**4**	**1022**	**Upstream of US-36**	**650**	860	**1130**	**1350**	1900
	5	7407	Upstream of 29th Street	745	981	1280	1525	2165
	6	6517	Upstream of 30th Street	875	1150	1500	1,780	2515
	7	5277	Upstream of Euclid Avenue	920	1212	1580	1870	2650
305	**8**	**4886**	**Upstream of Madison Avenue**	**980**	**1354**	**1830**	**2230**	**3500**

3.2.0 Hydraulic Analysis – Bluebell Canyon Creek and King's Gulch

The hydraulic analysis for this study was performed using HEC-RAS version 4.1.0. Hydraulic modeling included analysis of the 10-yr, 25-yr, 50-yr, 100-yr, and 500-yr flow profiles. The hydraulic modeling also includes a 0.5-ft rise conveyance zone (or floodway) model and high hazard zone analysis.

The proposed existing conditions models for Bluebell Canyon Creek, King's Gulch and Skunk Creek all together consists of 66 reaches, 32 junctions, 578 cross sections, 18 culverts and 8 bridges broken down into two separate projects. Within each project, separate geometry and flow files were developed for each profile due to the variable capacity of the drainage network and limitations of the model. Some junctions and lateral structures which were coded in to model the 100-year event would not converge at lower discharges (KINGS-20th, BLUEBELL-20th), and additional lateral structures were required to model

the 500-year event (Skunk – 2551, 2601, 2651, 2701). Each of these combinations of geometry and flow were saved as separate plans within their respective project file.

The separate geometry files contain identical cross section and reach data. Variables for each plan (discharge profile) include boundary conditions, optimization or addition of lateral structures, and inclusion or deletion of junctions. Five (5) plans for each model were developed for the system. Appendix 8 contains electronic files for all hydraulic models.

Geometry files were developed from the project CAD base file utilizing a digital terrain model compiled from the mapping source cited earlier. This information was brought into the hydraulic model using the GIS data import feature in HEC-RAS. Reaches and junctions for the Skunk Creek model were organized using a dendritic hierarchy starting from the downstream limit (Figures 4-7). The main channel reaches were numbered 1.000, 2.000, etc. while the main tributaries were numbered 1.100, 1.200 and minor tribs 1.110, 1.120, etc. Junctions were numbered according to the downstream reach. The Bluebell-Kings model was organized by street name and number as it is mainly centered on the residential neighborhood to the south of Baseline and to the west of Broadway.

In order to keep track of ongoing results and input variables, including split flows, junction balance, bridges and culverts, model topology, and overall continuity, a graphical database was developed to combine tabular output from HEC-RAS with plan data, providing a visual representation of the model results. Tables were exported from HEC-RAS, including Standard Table 1, Lateral Structures, Bridges and Culverts, as well as starting flows and optimization data for the lateral structures and input into an Excel spreadsheet. Plan graphics were also exported and placed in a separate “Schematic” tab in the spreadsheet, and cells were created within the schematic to relate the database from the tables in order to display results graphically, make additional calculations, and to provide links to other model result databases. Exhibits have been made from this spreadsheet for each model and can be found in Appendix 3.

Figure 4 – Reach Designations

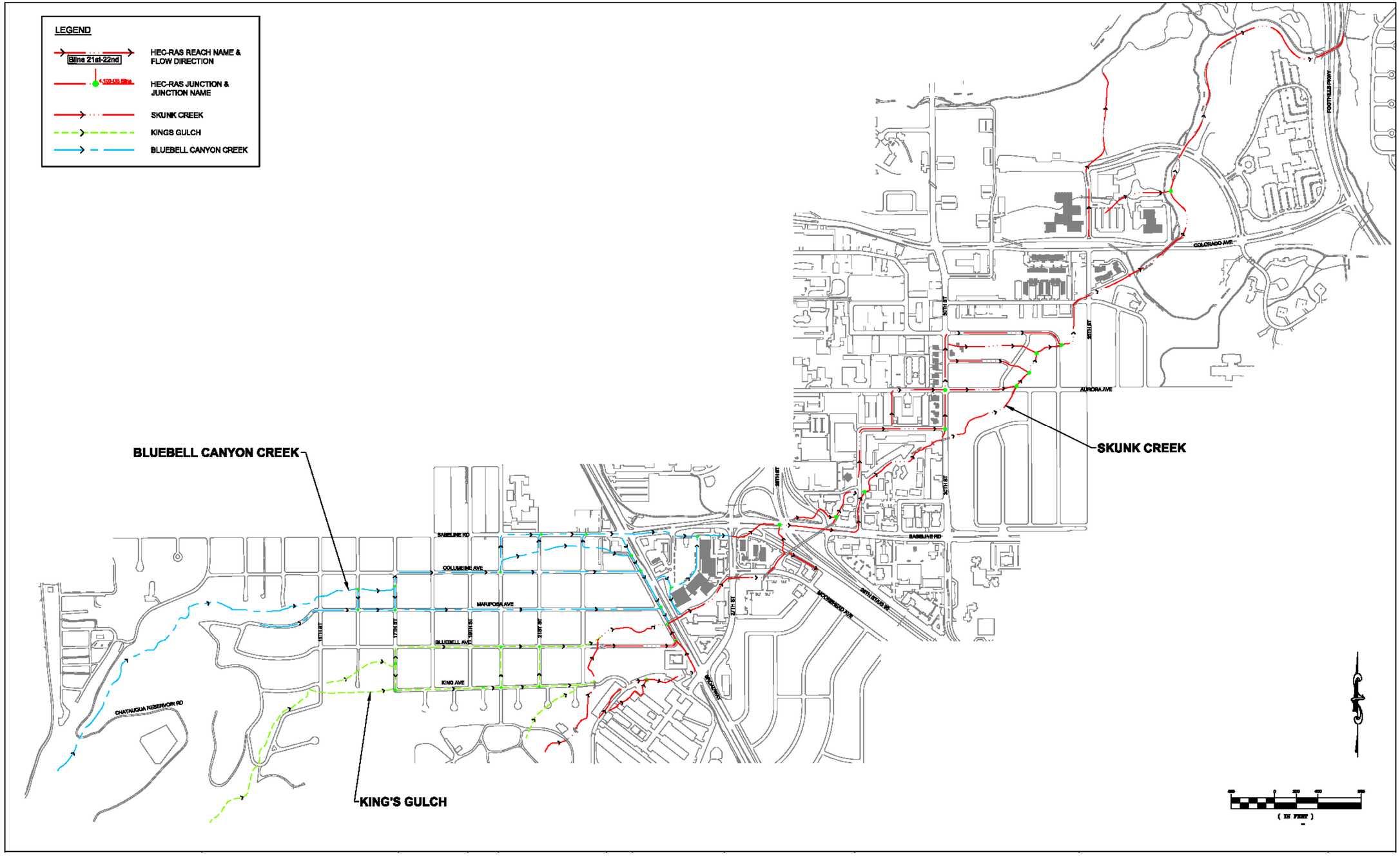


Figure 5 – Reach Designations (Upper)

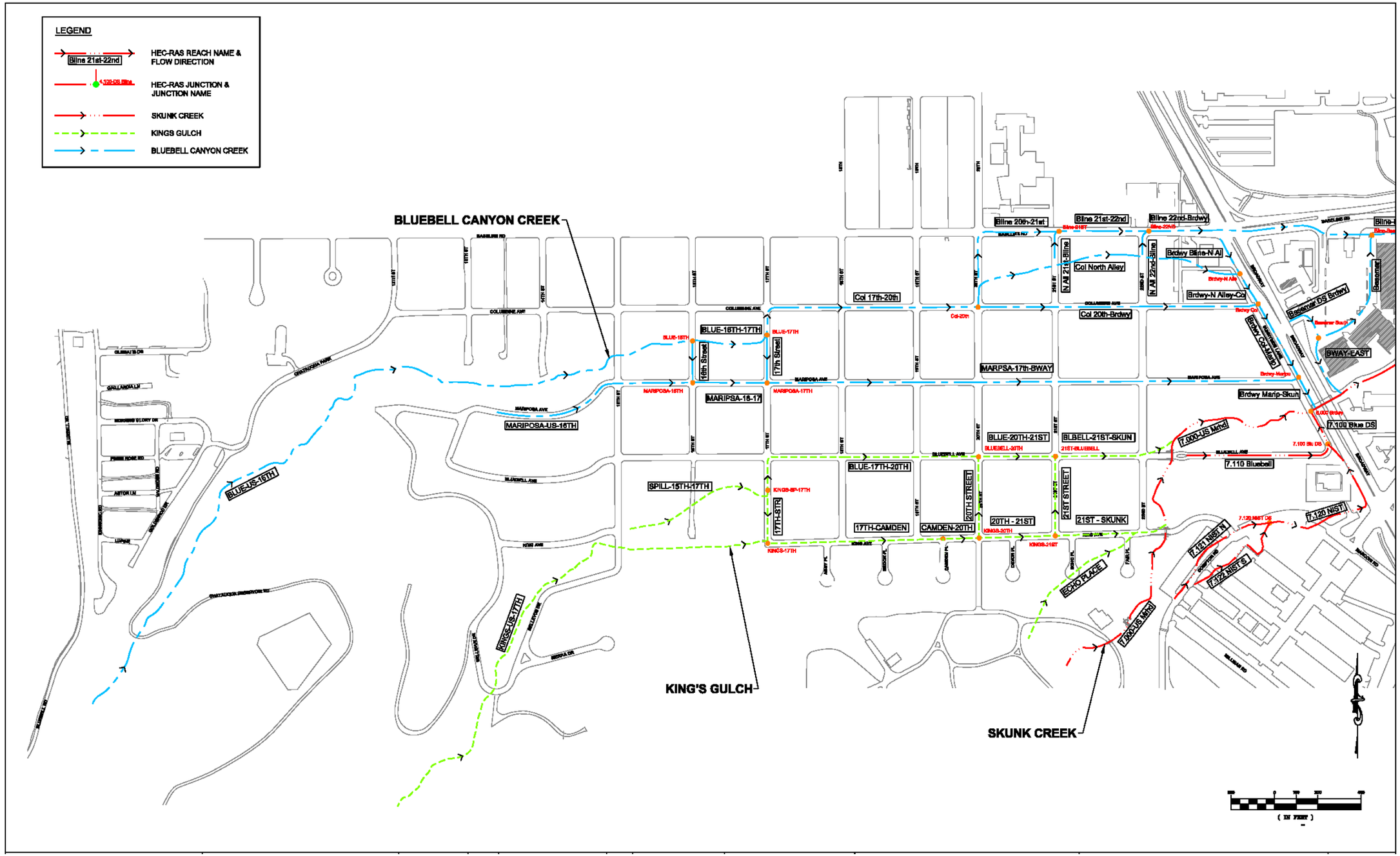


Figure 6 – Reach Designations (Middle)

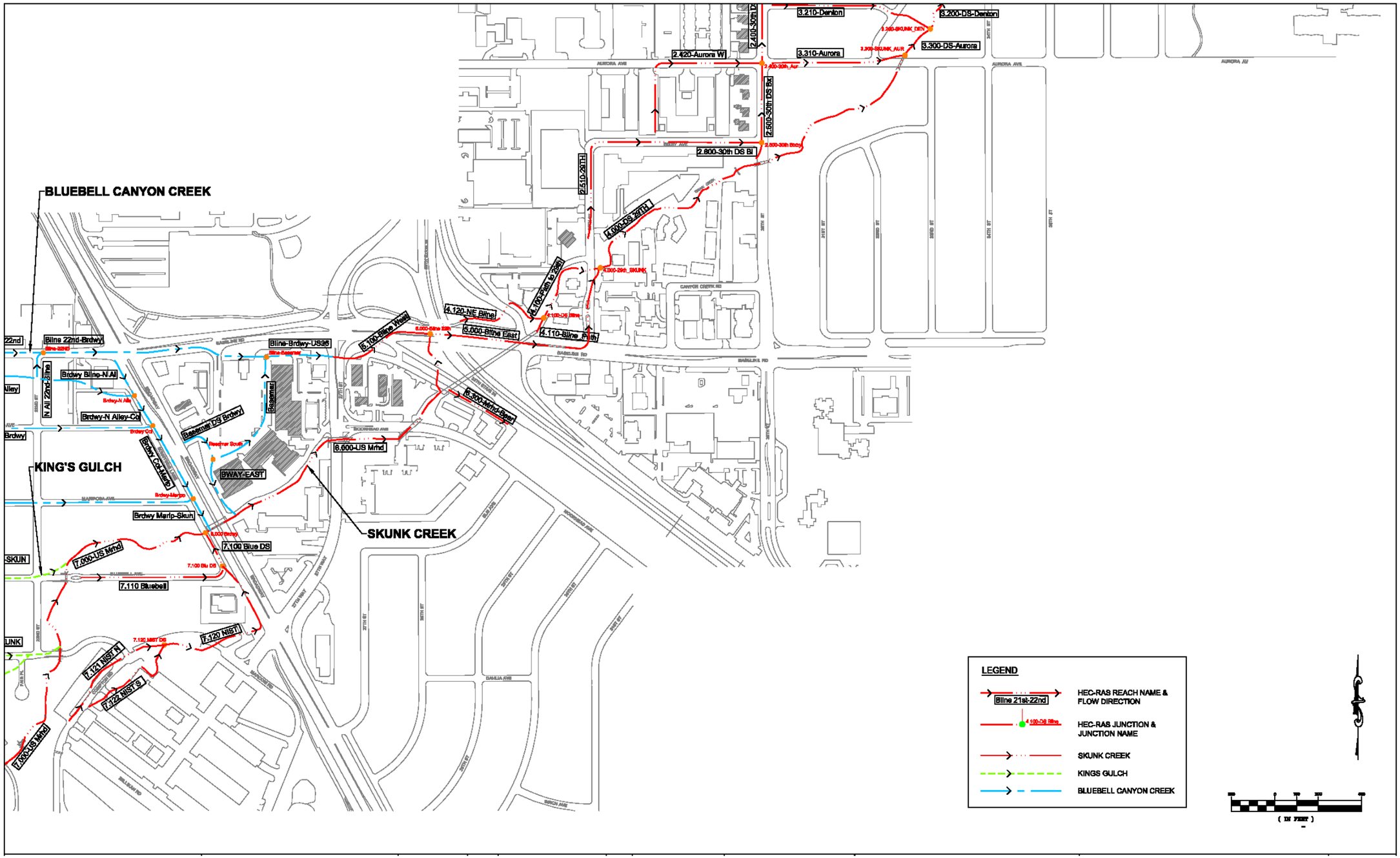
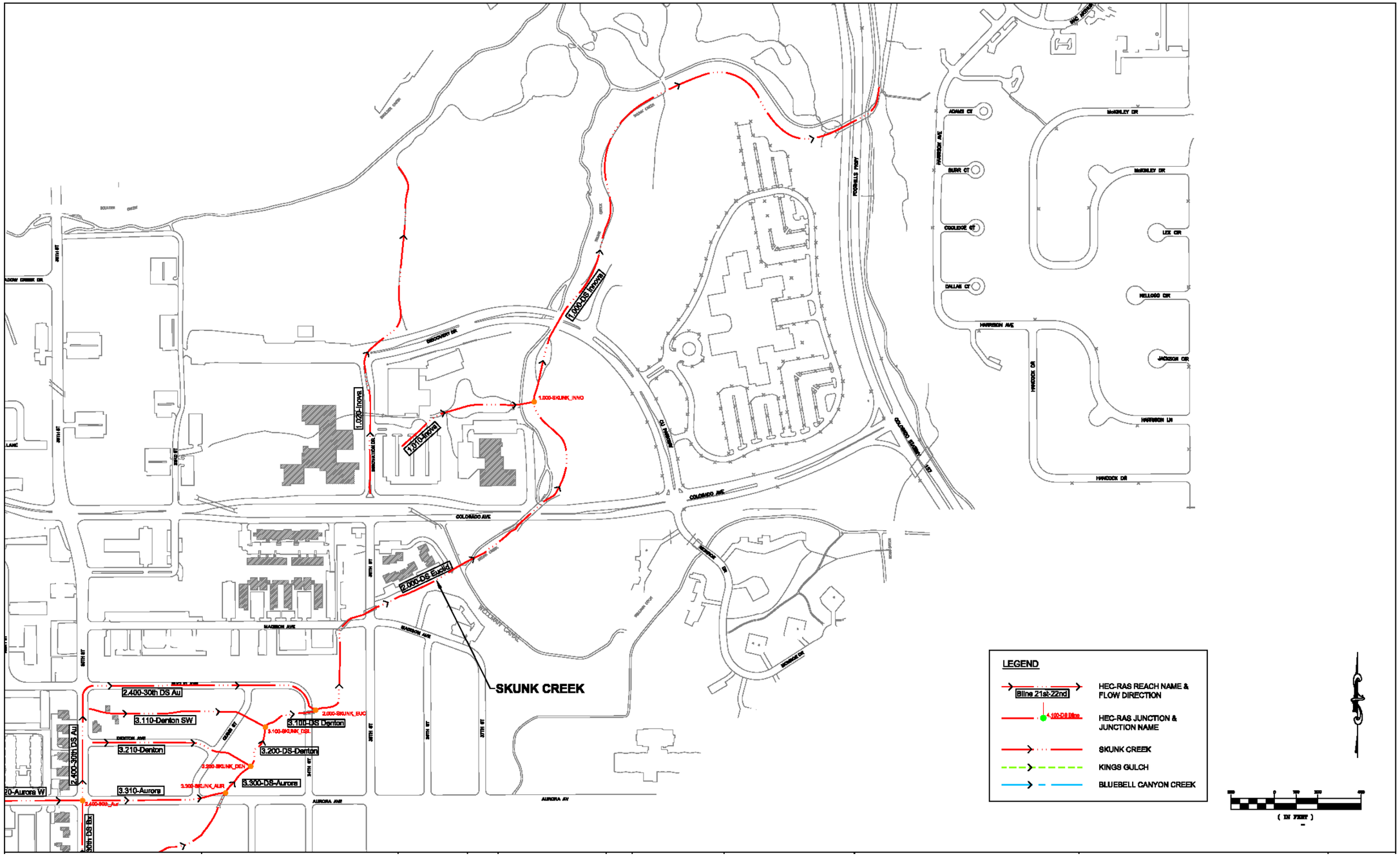


Figure 7 – Reach Designations (Lower)



The use of junctions in particular proved challenging for the scope of this modeling effort. These are locations where two or more streams (or reaches) either come together or split apart. Junctions were used to model street intersections where sheet flow through neighborhoods is conveyed primarily by the street cross section, and either converges with flows from a cross street or diverges where the cross street has less flow and a lower energy grade. This condition sometimes changed for different profiles depending on hydraulic conditions upstream or downstream. For example, while culvert discharge varies with headwater, it is relatively constant in comparison to the magnitude of difference in flows for different profiles. So, a culvert which may have re-directed a substantial portion of the flow to another reach in the 10 or 25 year event may only direct a fraction of the total flow in the 500 year event, causing a junction downstream of the culvert to change from a divergence zone where these culvert flows exceeded the capacity of the intersection to a convergence zone in higher flows where the culvert now only re-directs a fraction of the total flows and the bypass now exceeds the capacity of the intersection but from a different direction. This will be discussed in more detail on a case by case basis.

Junctions along King Avenue, Columbine and Broadway in the Bluebell-Kings model and on 28th and 30th Streets in the Skunk model which converged for the 100-year event failed to converge for other profiles. Typically, HEC-RAS will add flows from two different reaches automatically and maintain continuity, even with multiple junctions. However with many junctions and extensive split flows being subtracted from one reach and added to another, the model began to have convergence issues. This problem was worked around by first noting the flows into or out of the junction for a run which converged or at least came close, eliminating the junction and then manually balancing the flows while maintaining continuity until a reasonable energy grade differential was established. This typically required multiple iterations to balance the flow over the entire network. An example of this is the Brdwy-Col junction in the Bluebell-Kings model, where flows from Baseline, North Alley, Columbine Avenue and Mariposa mix back and forth in the neighborhood west of Broadway, then converge onto Sunnyside Lane adjacent to Broadway. The model failed to add the flows at this junction from upstream reaches properly, so flows were input manually taking into consideration the overall distribution of flows being lost along Baseline and the Kings and Skunk Creek systems.

Lateral structures were used extensively in the project to model flows leaving hydraulically connected areas. These flows were either added to the same reach downstream, an adjacent reach, a downstream junction, or in some cases allowed to leave the model completely and then added back in manually at another point in the model. Typically these were modeled as broad crested weir embankments with a 5 foot top width, which is an average crest width for lawn areas between residences and office buildings, using a typical weir coefficient of 2.6. Weir geometry was coded from the digital terrain model, with the length

corresponding to the bounding cross sections. The weir coefficient was varied where the weir crest occurred along the crown of a roadway or the highpoint of a sidewalk to a maximum of 2.8, and lowered to 2.4 where high backwater occurred. Rating curves were also used to model flows lost at street intersections and selected culverts. These rating curves were calculated using external hydraulic modeling software based on physical data compiled from the survey information and incorporated into the CAD base. Details for these can be found in Appendix 3, and are discussed on a reach by reach basis where they are used.

A detailed accounting was maintained utilizing the above mentioned graphical database in order to maintain continuity. This was accomplished by noting flows leaving a reach along a line of hydraulically connected lateral structures and summing the lost flows. Typically these flows were returned to another reach downstream or adjacent internally by utilizing the return flow option in HEC-RAS. In many cases, there were additional areas where flows were lost at a different point in the reach or in the one immediately downstream. In some cases these flows were eliminated from the model completely in order to facilitate convergence or add to the flow table in a separate model. The graphical database was used to sum these flows at strategic locations in order to insure that continuity was maintained.

3.2.1 Hydraulic Modeling (Bluebell Canyon Creek and King's Gulch)

The effective floodplains from the 1987 FHAD for Bluebell Canyon Creek and King's Gulch are approximate Zone A floodplains. No detailed effective models were developed for these streams. The proposed existing conditions model for both Bluebell Canyon Creek and King's Gulch is combined in one hydraulic model named Bluebell-Kings.prj and consists of 37 reaches, 19 junctions, 274 cross sections, 3 culverts and no bridges. Much of the flow in both streams spills from the main channel upon entering the residential area downstream of 15th Street and proceeds through the neighborhood as sheet flow down streets and through yards and alleys. Flow splits and spills are modeled through a network of junctions and lateral weirs within the combined Bluebell Canyon Creek and King's Gulch model. A discussion of the results can be found later in this report. The hydraulic models for Bluebell Canyon Creek and King's Gulch are located in Appendix 3. The floodplain work maps can be found in Appendix 4.

3.2.2 Boundary Conditions (Bluebell Canyon Creek and King's Gulch)

The downstream limits of Bluebell Canyon Creek flows are located at 1) section 14050 just south east of the intersection of Mariposa Avenue and Sunnyside Lane near the upstream face of box culvert at Skunk Creek and Broadway, 2) section 0097 near the downstream face of the box culvert at Skunk Creek and

Broadway, and 3) section 101.72 on Baseline Avenue just west of 27th Street. The starting water surface elevation at these locations is based critical depth at section 14050 (1), normal depth with slopes of 0.8%, at section 0097 (2) and normal depth with a slope of 3.72% at section 101.72 (3).

King's Gulch flows into Skunk Creek near King Avenue and 22nd Street and just east of Bluebell Avenue and 22nd Street. The starting water surface elevations on King's Gulch at the confluences with Skunk Creek are based on the 10-yr water surface elevation in Skunk Creek. The starting water surface elevation for all profiles on King Gulch at section 001 at King Avenue and 22nd Street is 5417.33. This elevation is equal to the Skunk Creek 10-yr water surface elevation at section 10978. The starting water surface elevation for all profiles on Kings Gulch near Bluebell Avenue and 22nd Street is 5403.23. This elevation is equal to the Skunk Creek 10-yr water surface elevation at section 10505.

3.2.3 Roughness Coefficients (Bluebell Canyon Creek and King's Gulch)

Roughness coefficients for Bluebell Canyon Creek and King's Gulch were developed from field inspection and aerial images. Photographic documentation for Bluebell Canyon Creek and King's Gulch was completed in the winter of 2010. Roughness coefficients at representative hydraulic cross section are included in table format in Appendix 3.

3.2.4 Hydraulic Structures (Bluebell Canyon Creek and King's Gulch)

The hydraulic structures present on Bluebell Canyon Creek and King's Gulch are listed in Table 4. There is one structure on Bluebell Canyon Creek at the Enchanted Mesa Trail and four small structures on King's Gulch. The blockages used in modeling each of these structures are also included in Table 4 and compared to the blockages assumed in the FHAD. Any change in blockage values from the FHAD are explained and justified in the far right column.

3.2.5 Obstructions (Bluebell Canyon Creek and King's Gulch)

Generally, single-family residential structures along Bluebell Canyon Creek and King's Gulch were modeled using a sufficiently high roughness coefficient and were not modeled as blocked obstructions. There are several commercial buildings in the Basemar shopping center as well as large multi-family structures just west of Broadway and south of Baseline Road which were modeled as blocked obstructions. In addition to these large structures, single-family residential structures at 1498 King Avenue, 485 Sunnyside Lane, and 2118

Baseline Road which obstruct a majority of cross sectional flow area were also modeled as obstructions.

Table 4 - Bluebell Canyon Creek and King's Gulch Hydraulic Structure Blockages

Structure Location	FHAD Blockage (%)	Revised Blockage (%)	Railing	Type of Railing and Modeling Method	Structure Description	Justification for Modified Blockage
Bluebell Canyon Creek						
Enchanted Mesa Trail	n/a	50	No	n/a	Semi-circular stone and concrete culvert Span = 12.5 ft Rise = 6.25 ft	n/a
King's Gulch						
Bellevue Drive	50	50	No	n/a	4 ft diameter RCP	n/a
Private Drive at 260 and 1425 Bellevue	25	25	No	n/a	4 ft diameter RCP	n/a
15th Street and adjacent to 1498 King Avenue	25	100	Yes	Residential fence modeled as 100% obstructed	2.5 ft diameter RCP Ties into storm sewer and discharges to gabion lined channel	Blockage increased because storm sewer system assumed full during 10-year events and greater
17th Street (outlet is located east of 22nd Street at Skunk Creek)	25	100	Yes	This storm sewer main is not included in the hydraulic model and is assumed 100% blocked	2 ft diameter RCP with drop inlet	Pipe acts as storm sewer main and is assumed full during 10-year events and greater

3.2.6 Conveyance Zone Modeling

There are currently are no effective Floodway (conveyance) zones within the Bluebell and Kings Gulch floodplains.

Hydraulic modeling was completed to define the City's ½-ft rise conveyance zone which is equivalent to, but more stringent than FEMA's 1-ft rise floodway. The conveyance zone was modeled using the equal encroachment methodologies within HEC-RAS.

Conveyance zones were calculated for all reaches except: Basemar DS Brdwy, BWAY-EAST and Basemar.

In the Conveyance Model, the Base Profile condition was established from the 100-year Floodplain Model and the Conveyance Profile maintained identical discharges with the following exceptions. The Conveyance Profile discharges were reduced to zero in the reaches for which Conveyance zones were not calculated (Basemar DS Brdwy, BWAY-EAST and Basemar) and the Conveyance Profile discharges were modified in adjacent reaches (6.000-US Mrhd, Bline-Brdwy-US36, 5.10-BlineWest) to maintain flow continuity.

In some locations the conveyance encroachment locations were optimized to locate the conveyance zone within the public right-of-way along streets or avoid structures. In the vicinity of some of the reach junctions, engineering judgment was used to modify the conveyance zone delineation to more realistically join and transition between conveyance zones in adjacent reaches.

The conveyance model output indicates no surcharges greater than 0.5-ft and no negative surcharges, except in the three reaches for which conveyance zones were not calculated.

3.3.0 Hydraulic Analysis – Skunk Creek

3.3.1 Hydraulic Modeling (Skunk Creek)

The revised model for Skunk creek is named SkunkCreek.prj and consists of 29 reaches, 13 junctions, 304 cross sections, 15 culverts and 8 bridges. The upper reaches of Skunk Creek lie in the same physiographic area as Bluebell Canyon and Kings Gulch, running parallel with them in the upper watershed. While timing differences will occur in the larger Skunk Creek watershed, it was assumed that these differences are insignificant for the purposes of performing a steady state analysis of both systems. Based on this assumption, flows from the Bluebell-Kings model utilizing the watershed adjustment factor described above were used as input to the Skunk Creek model. These flows were added at

appropriate points as noted on the Hydraulic Summary exhibit for Skunk Creek. A discussion of the results can be found later in this report. The hydraulic models for Bluebell Canyon Creek and King's Gulch are located in Appendix 3. The floodplain work maps can be found in Appendix 4.

3.3.2 Boundary Conditions (Skunk Creek)

Skunk Creek has been modeled to the upstream face of the culvert at Foothills Highway, just upstream of Bear Creek where it joins the Boulder Creek floodplain. At this time, models for both Bear Creek and Boulder creek have been completed but not accepted by FEMA. The starting water surface elevation at this point is based on normal depth with a slope of 0.5%. Two other reaches, reach 1.020 Innova and 6.300-Mrhd Bear were started with slopes of 0.8% and 0.01% respectively.

3.3.3 Roughness Coefficients (Skunk Creek)

Skunk Creek roughness coefficients at each hydraulic cross section are included in table format in Appendix 3. For the Skunk Creek main channel, deviation from the effective roughness coefficients is documented and justified. For spill reaches not included in the effective model, the newly developed roughness coefficients are justified in the tables in Appendix 3. Roughness coefficients for Skunk Creek were developed from field inspection and aerial images. Photographic documentation of Skunk Creek was completed in the April 2007, July 2008, March 2009, and the winter of 2010. Photographs of Skunk Creek are included in Appendix 3.

3.3.4 Hydraulic Structures (Skunk Creek)

Debris blockage at bridges and culverts was determined based on historical data, use of engineering judgment, and close coordination with City of Boulder staff. For bridges, blockage was modeled by adjusting the low chord elevation to achieve the appropriate blocked flow area. Culvert blockages were modeled with an equivalent area pipe or box culvert to account for the reduction of flow area by blockage.

The hydraulic structures present on Skunk Creek and their associated modeled blockages are listed in Table 5. Revised condition blockages in Table 5 are compared to the blockages assumed in the FHAD. Any change in blockage values from the FHAD are explained and justified in the far right column. There are 24 hydraulic structures on Skunk Creek included in the proposed existing conditions model.

Table 5 – Skunk Creek Hydraulic Structure Blockages

Structure Location	FHAD Blockage (%)	Revised Model Blockage (%)	Railing/ Guardrail Present	Type of Railing and Modeling Method	Structure Description	Justification for Modified Blockage
SKUNK CREEK						
King Avenue	50	50	Yes	One longitudinal tubular metal bar with three tubular posts. Assumed railing obstructs 50% of length of headwall (4.5').	1 cell culvert 7'w x 3'H	N/A
Private Drive - 322 22nd	40	40	Yes	One longitudinal metal plate with vertical and diagonal posts. Assumed railing obstructs flow for width of 10' over main channel.	Rise over channel invert 5.4'H; Deck width = 31.35'W	N/A
Private Drive - 2200 Bluebell	40	40	Yes	One longitudinal post with 3-4 vertical posts. Assumed railing obstructs flow for width of 10' over main channel (~50% railing blockage).	Rise over channel invert 5.3'H; Deck width = 23.6'W	N/A
Bluebell Avenue	30	30	Yes	Two longitudinal tubular metal bars with three tubular posts. Assumed railing obstructs 50% of length of headwall (3.75').	1 cell culvert 6'w x 4.5'H	N/A
Broadway	30	10	No	Metal railing on top of headwall with glass/plastic cover. Broadway is not overtopped, so there is no impact from railing blockage.	1 cell culvert 22'w x 8'H.	Possible debris blockage from moderate upstream channel vegetation, but the structure is wide relative to others on Skunk Creek and was designed to pass the 100-yr event with freeboard. (Per discussions with the City, this blockage is modified from the previous restudy of upper Skunk Creek which used 0%.)
Footbridge	30	N/A	N/A		Structure was removed with reconstruction of Broadway underpass.	N/A
Low Water Trail crossing d/s of B-way	N/A	100	No		5'W x 2.2'H	Small opening could easily become plugged with debris.
Low Water Trail crossing u/s of 27th Way	N/A	100	No		12'W x 4'H RCBC. See as-builts pg. 70.	Small opening could easily become plugged with debris.

Structure Location	FHAD Blockage (%)	Revised Model Blockage (%)	Railing/ Guardrail Present	Type of Railing and Modeling Method	Structure Description	Justification for Modified Blockage
SKUNK CREEK						
27th Way	0	10	Yes	Three longitudinal metal bars with multiple vertical posts. Railing was 100% blocked 27th Way is not overtopped so there is no impact from railing blockage.	1 cell culvert 20'w x 8'H.	Possible debris blockage from moderate u/s channel vegetation, but structure is wide relative to others on Skunk and was designed to pass the 100-yr event with freeboard. (Per discussions with the City, blockage is modified from previous restudy of upper Skunk Creek which used 0%.)
Moorhead Avenue	0	15	Yes	Tubular metal railing. 2 longitudinal bars, multiple vertical bars spaced approximately every 4-ft. Assumed railing obstructs 50% of length of headwall (11.5').	2 cell culvert 10'w x 5.8'H	Possible debris blockage from channel vegetation and trees.
US 36/28th St. On Ramp South of Baseline	N/A	15	Yes		1 cell culvert 14'W x 7.5'H; Blockage created by sump condition on outlet side of box. Actual modeled blockage resulting from sump condition = 34%.	Limited debris blockage possible from Skunk Creek main channel and upstream parking area.
US 36	0	30	No	This structure analyzed for capacity in separate model.	U/S 2 cell culvert 6'w x 4'H	Moderate vegetation with mature trees in channel and parking lots north and south of the channel could contribute to debris blockage during a flood.
US 36/28th St. On Ramp North of Baseline	N/A	5	Yes	Guardrail. Box is in sump condition. Actual blockage after accounting for sump is 56%.	1 cell culvert 14'w x 7.1'H	No significant sources of upstream debris.
Low Water Trail Crossing	N/A	75	No		1 cell culvert 14.7w x 3.4'; Unstable solution (profiles cross) when 100% blockage used.	Small opening could easily become plugged with debris, but opening is larger than low flow crossings at Broadway and 27th Way. Less debris sources because it's located immediately downstream of US36 culvert outlet.
Pedestrian Bridge	30	30	Yes	Timber railing, 2 longitudinal, 4 vertical, paneled fence over upstream wing walls. Assumed railing obstructs 75% of length of headwall and wing walls (32').	Bridge opening 14.8'w x 3.7'H.	N/A

Structure Location	FHAD Blockage (%)	Revised Model Blockage (%)	Railing/ Guardrail Present	Type of Railing and Modeling Method	Structure Description	Justification for Modified Blockage
SKUNK CREEK						
29th Street	10	10	No	Assume no railing blockage, no separate railing for 29th Street box, pedestrian bridge railing serves 29th Street.	2 cell culvert 7'w x 4'H; Most of the debris at this location would be captured by the pedestrian bridge located immediately upstream.	N/A
Covered Pedestrian Bridge	30	30	Yes	Bridge is covered with wooden paneling. Assumed 100% blockage of paneled area	Connects day care center to basketball court.	N/A
30th Street	30	30	Yes	Tubular metal railing with 3 longitudinal bars and multiple vertical posts. Railing extends along wing walls and stone retaining wall upstream. Assume railing above headwall is 100% blocked.	1 cell culvert 8'w x 6'H	N/A
Arrowood Park Pedestrian Bridge	30	30	Yes	Wire mesh railing. Assume 100% blocked.	Bridge opening ~32.95'W x 5.3'H(max)	N/A
Aurora Avenue	10	20	Yes	8 longitudinal metal bars, multiple vertical metal bars. Assume railing above headwall and wing walls is 100% obstructed.	1 cell culvert 8'w x 6'H	Dense vegetation, but upstream residential density is less than at 34th, Madison, and 35th Streets.
34th Street	20	20	Yes	2 longitudinal bars, 3 vertical bars. Assumed railing obstructs 50% of length of headwall (7').	2 cell culvert 6'w x 3.5'H	
Madison Avenue - East Cell	30	30	Yes	3 longitudinal bars, multiple horizontal bars. Assume railing obstructs 75% of length of headwall (14.2').	2 cell culvert 6'w x 4'H	West cell does not appear more obstructed than the east cell.
Madison Avenue - West Cell	100	30	Yes			
35th Street	50	30	Yes	2 longitudinal bars, 4 vertical bars. Assumed railing obstructs 50% of length of headwall (7.6').	2 cell culvert 6'w x 4'H	Stream channel appears mostly smooth with minimal debris accumulation.
Wellman Canal	N/A	100	No		2' diameter RCP	Backwater effects would submerge pipe outlet during 10-yr and greater storm events.

Structure Location	FHAD Blockage (%)	Revised Model Blockage (%)	Railing/ Guardrail Present	Type of Railing and Modeling Method	Structure Description	Justification for Modified Blockage
SKUNK CREEK						
Colorado Avenue	0	5	Yes	2 longitudinal rails, 5 vertical bars. Assume railing obstructs 50% of length of headwall (17.5')	2 cell culvert; bike path box = 9.9'w x 7.3'H. Stream box = 9.9'w x 8.2'h	Some limited blockage potential from upstream vegetation. Only limited potential for residential debris accumulation upstream of this crossing. Much of the debris in Skunk Creek will be caught at the Wellman Canal upstream of Colorado Avenue. This structure is wide relative to most others on Skunk Creek and was designed to pass the 100-yr event.
Discovery Drive	0	5	Yes	P/C Concrete Fascia Panels Assumed 100% blocked across entire width.	45' span bridge with pedestrian trail beneath	

Capacity for two hydraulic structures on Skunk Creek was determined in separate HY-8 hydraulic models. The capacity of the double box culvert at Hwy 36 was determined in HY-8 due to the multiple split flow paths which occur just upstream of the inlet to the Hwy 36 structure. At this location, flow splits to the southeast parallel to Hwy 36 and toward Bear Canyon Creek, to the northeast through the pedestrian underpass at the Eastbound Hwy 36 on-ramp, and to the north toward Baseline. Due to the complexity of the flow splits just upstream of the Hwy 36 culvert inlet, model convergence could not be achieved with the Hwy 36 culvert included in the HEC-RAS model. Therefore, HY-8 was used to develop a structure rating table for use on a lateral structure in the HEC-RAS model representing the Hwy 36 structure. Discharges leaving the model at the lateral structure are added back to the model just downstream of the Hwy 36 outlet. The HY-8 model file is named US36_CULVERT&BASELINE-PED-BOX.HY8 and is located in Appendix 3.

The pedestrian underpass box at Baseline Road was also modeled in HY-8. A small spill from Baseline Road toward this underpass box occurs near Baseline and the northbound Hwy 36 exit ramp. The analysis shows this box has more than adequate capacity to return the Baseline spill flow to the main channel of Skunk Creek. The HY-8 model file is named US36_CULVERT&BASELINE-PED-BOX.HY8 and is located in Appendix 3.

3.3.5 Obstructions (Skunk Creek)

Generally, cross sections on Skunk Creek were set up to abut structures or single-family residential structures were modeled using a sufficiently high roughness coefficient and were not modeled as blocked obstructions. There are several large apartment and commercial buildings within the 29th Street spill reach, upstream of Colorado Avenue, and within the University of Colorado Research Park (CURP). These large structures were modeled as blocked obstructions and are hatched in the floodplain work maps. Single-family residential structures on the west side of 30th Street between Skunk Creek and Euclid Avenue were also modeled as blocked obstructions because they blocked a large portion of cross sectional flow area.

3.3.6 Conveyance Zone Modeling

The effective floodway zone within the Skunk Creek floodplain is currently defined in accordance with FEMA's 1-ft rise criteria.

Subsequent to the approval of the regulatory study in 1987, the City of Boulder now enforces a 0.5-ft rise floodway (conveyance) zone for use within the City

limits. The City's ½-ft rise conveyance zone is equivalent to, but more stringent than FEMA's 1-ft rise floodway.

Hydraulic modeling was completed to define the City's ½-ft rise conveyance zone. The conveyance zone was modeled using the equal encroachment methodologies within HEC-RAS.

Conveyance zones were calculated for all reaches.

In the Conveyance Model, the Base Profile condition was established from the 100-year Floodplain Model and the Conveyance Profile maintained identical discharges.

In some locations the conveyance encroachment locations were optimized to locate the conveyance zone within the public right-of-way along streets or avoid structures. In the vicinity of some of the reach junctions, engineering judgment was used to modify the conveyance zone delineation to more realistically join and transition between conveyance zones in adjacent reaches.

The conveyance model output indicates no surcharges greater than 0.5-ft and no negative surcharges.

3.4.0 Effective Hydraulic Model

The effective model (Skun.dat) completed in HEC-2 was used as a starting point for this study. The upstream limit of the Effective Model is at cross section 450 at the downstream face of King Avenue. Skun.dat is the Effective model for the detailed portion of the effective Skunk Creek floodplain.

The FHAD analysis included a second HEC-2 model (Skunk.dat) for the approximate reach of Skunk Creek from the downstream face of King Avenue to the ponds just west of the Kohler Reservoir storage tank and south of Green Mountain Cemetery. This hydraulic model was not approved or adopted by FEMA and the floodplain through this reach was defined by FEMA as an approximate floodplain.

3.5.0 Existing Conditions Hydraulic Model Results

Significant water surface elevation changes and flood hazard delineation are noted as a result of the revised floodplain analysis. These differences are due to changes within the study area including new development, re-development, channel improvements and drainage course alterations over the last 25 years. Some of these alterations to the drainage system have been documented

through the FEMA LOMR process, however a full understanding of the implications of these changes has not been possible without looking at the system as a whole. New topographic data and as-built surveys in conjunction with updated modeling methods have allowed the refinement of the main channel hydraulics enabling the identification of previously undetected spill reaches.

The revised floodplain and floodway delineations are presented on the floodplain work maps in Appendix 4. The current regulatory delineation has also been shown in order to compare the two. Refer to the Hydraulic Summary Schematic for each model, Appendix 3 for clarification of the following reach by reach discussion which follows.

3.5.1 Bluebell Canyon Creek and King's Gulch

Significant water surface elevation changes resulted from the revised floodplain analysis. These changes are due to detailed analysis of previously approximated floodplains, tracing lateral spills, and updated culvert modeling.

Bluebell Canyon Creek from the upstream limit to 20th Street
Along Bluebell Canyon Creek, the hydraulic structure at Enchanted Mesa Trail passes the 100-year event but overtops during the 500-yr event. The floodplain is generally contained to the steep channel upstream of 15th Street. There is a 500-yr spill from the main channel to the south along Mariposa Avenue just upstream of 15th Street. At 15th Street, the defined channel abruptly ends and sheet flows proceed down Mariposa Avenue and through the residential parcels between Mariposa Avenue and Columbine Avenue. A network of junctions at 16th and 17th streets distributes this split, with 80% of flows going north and east down Columbine. At 17th Street, sheet flows continue along the Mariposa Avenue and Columbine Avenue flow paths to 20th Street.

Baseline Spills
A significant portion of the Bluebell Canyon 100-year flows are diverted to the north at 20th Street due to the crossing of the Anderson Ditch. A flow split junction was used to model this diversion at Columbine and 20th. Flow splits require an initial estimate of the split, and will then generally converge once it is close. At this point, approximately 95% of the flows in Columbine are diverted north and into the alley between the houses lining Baseline and Columbine (reach Col North Alley). Some of this flow diversion runs on down 20th Street to the north and out into Baseline, which was modeled with a rating curve set up to calculate normal flow in the 20th Street cross section based on the water surface in the street. Much of the flows in the north alley then spill through the houses onto Baseline Road, where they are lost to the north towards Broadway. These flows were subtracted from the model along this reach, but were assumed to return at the US-36 interchange in the Skunk Creek model.

Broadway and Baseline

At Broadway, Bluebell Canyon Creek flows split, proceeding east across Broadway down Baseline, south down Sunnyside Lane and north along Broadway. This area was modeled again with rating curves for the Broadway roadway section, with the main reach going east down Baseline. Flows lost along Baseline upstream of this area to the north, north on Broadway at the intersection and east down Baseline were summed and added to the Skunk Creek model in reach 5.100-Bline West. Approximately 25% of the flows in Baseline travel south down Broadway from the intersection toward Skunk Creek at Broadway, with a portion spilling across Broadway into the Basemar shopping center. In the Basemar shopping center, a portion of the flows are returned to Skunk Creek between commercial buildings. The remaining flows in Basemar rejoin Baseline along the north end of the shopping center and are returned to the Skunk Creek model at the US-36 interchange.

Broadway to Skunk Creek

The remaining flows traveling south down Broadway are joined by flows from Columbine, Mariposa and Bluebell at junctions in Sunnyside Lane. As stated earlier, these junctions converged for some profiles, while others required manual balancing of flows into and out of the junction to maintain overall continuity. In particular, junction Brdwy-Col at the intersection of Sunnyside Lane and Columbine would not balance with the addition of flows required to satisfy the hydrologic model. For example, the 100-year discharge at DP 212 is 737 cfs (see Bluebell-Kings Hydraulic Summary Schematic, Appendix 3). Taking into account the 353 cfs which has been removed from the model at this point (219 + 6 north down Broadway, 81 down Baseline + 46 coming back out of Basemar Shopping center) and the 172 cfs in Sunnyside Lane (27 in Broadway, 138 from north alley and 7 left in Columbine) this means 737 – (353+172) = 212 cfs would need to be added at this junction to satisfy the hydrology of DP 212. However the model would not converge under these flow conditions, and so an iterative process was used to determine a reasonable balance. It was found that by reducing this flow by 23 cfs to 189 cfs (flow table, section 14545, reach Brdway Col-Marip) the model would balance. A similar ratio was applied to achieve convergence with the other profiles at this point.

Kings Gulch from the upstream limit to 20th Street

On King's Gulch, the hydraulic structures at Bellevue Drive, 260 Bellevue Drive, 1425 Bellevue Drive, and 1498 King Avenue are overtopped by the 10-yr event. Upstream of 15th Street, the 100-year floodplain is generally confined to the steep main channel. The 500-yr floodplain upstream of 15th Street includes Bellevue Drive from 15th Street to the Bellevue Drive culvert pipe. Downstream of 15th Street, King Avenue flows split at multiple locations and are modeled by junctions at 17th Street, 20th and 21st Streets. Some flows enter the small channel between 15th Street and 17th Street while the remaining flow proceeds

through the residential parcels between the small channel and Bluebell Avenue. At 17th Street, all Kings Gulch flows are forced across the street and become sheet flow down King Avenue and Bluebell Avenue. Cross street flow from King Avenue to Bluebell Avenue occurs at 20th Street and 21st Street.

Kings Gulch from 20th Street to 22nd Avenue
A series of junctions connect flows between Bluebell and King Avenues below 20th Street, and most of the flows migrate from King back to Bluebell. The hydraulic connectivity between Bluebell Canyon Creek and King's Gulch at the intersection of Mariposa Avenue and 22nd Street is modeled with embankment weirs. In the vicinity of this intersection, approximately 90 cfs from the Bluebell Canyon Creek floodplain spills into the King's Gulch floodplain prior to entering Skunk Creek.

Bluebell and Kings at the confluence with Skunk Creek
Flows from King and Bluebell Avenues (approximately 400 cfs) enter Skunk Creek just downstream of 22nd Avenue. Flows from Baseline Columbine and Mariposa, which have combined along Broadway traveling south in Sunnyside Lane enter Skunk Creek just above the Broadway culvert. A portion of the Bluebell Canyon flows enter Skunk Creek below Broadway through driveway and pedestrian paths in the Basemar Shopping Center. A significant portion of flows from Bluebell Canyon travel down Baseline on the north side of the drainage catchment, or are assumed to rejoin Skunk Creek at the Highway 36 interchange.

Spill reaches were previously detected on both streams above 15th Street, as floodwaters cascading down the narrow drainage ways are forced out of the historic paths due to insufficient capacity in the drainage infrastructure. For the purposes of this study, the entire drainage infrastructure was assumed to be full or completely blocked upstream of Broadway. The Effective model traced these flows down the east-west network of streets, King Avenue, Bluebell Avenue, Mariposa and Columbine, and delineated the neighborhoods as shallow flooding. This study refined the previous analysis, utilizing lateral weirs and junctions and tracked the spills on Kings at 16th and 17th, distributing them between Kings and Mariposa. Junctions between 20th and 21st Streets show the final distribution of flows as they enter the Skunk Creek main stem.

3.5.2 Skunk Creek

Significant water surface elevation changes result from the revised floodplain analysis. These changes are due to updated topographic data, use of the updated modeling methods, replacement of the culverts at Broadway and 27th Way with 100-year structures, and the analysis of previously untraced spill reaches.

The revised floodplain and floodway delineations are indicated on the floodplain work maps in Appendix 4. New profiles have been developed and are included as exhibits.

Upstream limit to King Avenue

The hydraulic model of Skunk Creek begins immediately upstream of the Anderson Ditch in Green Mountain Cemetery. The 100-year floodplain is approximately 350 wide at this point as the previous study shows the flows spilled out across the left overbank area. The Skunk Creek model confirms this providing good correlation with the extents of the flooded area matching to within 15 feet. The spilled flows in the left overbank do not return to the channel but flow through the neighborhood on the eastern end of King Avenue, where the return to the Skunk Creek channel as part of the King's Gulch flows.

Some of the flows remaining in the channel are forced out of the banks again at King Avenue, Bluebell Avenue, and two private drives in between. Two lateral structures with an embankment weir along the right hand bank (LS 10900 and 11400) were coded in to determine the magnitude of these flows which travel across the USDC NIST facility immediately to the east. A separate model of this area was originally created to assess the extents of flooding across the site and was later incorporated into the main model.

The USDC NIST spill reach is a newly designated portion of the Skunk Creek floodplain. The spill was detected through the use of detailed study methods and updated topography. A USDC project completed in 2008 placed fill along the east bank of Skunk Creek in this area. The project included a new detention pond located just east of lateral weir 10900. A berm was constructed along the east and north sides of the detention pond. For purposes of the hydraulic analysis, pre-project ground surface elevations were used to define lateral weir 10900. The berm is not treated as a levee and it is assumed the berm will be washed out during the base flood.

The USDC project also placed approximately 1-ft of fill along lateral weir 11400 and through the parking lot east of lateral weir 11400. The fill area and parking lot is approximately 200-ft wide. Post-project grades were used to define 11400. Following site visits, the fill area was assumed to be a landform and it is not expected to be washed out by the base flood.

These lateral structures converged for the 100-year event flows, but failed to converge with subsequent profiles. In order to determine flow inputs for the NIST reach for the 25, 50 and 500 year event, the 100-year discharge along the laterals was prorated along the length of the right bank from lateral structure 11400 down through cross section 10581 at Bluebell Avenue. There was no spill during the 10 year, and thus no flow in the NIST reach for this profile.

Flows are also input to the Skunk Creek model from the Bluebell-Kings model along this reach. These flows were adjusted for hydrologic effects as discussed earlier and added at appropriate points above Broadway. Residual flows from the Kings Gulch are added at sections 10978 and 10505. Residual flow from Bluebell Canyon traveling down Broadway is input at section 9842, and flows from NIST are input at section 9818. A detailed accounting of this can be found on the Hydraulic Summary exhibit.

King Avenue to Broadway

The 100-year floodplain is generally narrowed through the residential neighborhood between Broadway and King Avenue, with the most notable narrowing on the north side of Skunk Creek between the Bluebell Avenue culvert and Broadway. Water surface elevations decrease significantly upstream and downstream of the new structure at Broadway. The new Broadway structure passes the 100-year and 500-year flood events without overtopping the roadway. Six residential structures are removed from the 100-year floodplain in this reach. The 100-yr spill flow and a portion of the 500-year spill flow reenter the Skunk Creek main channel just upstream of Broadway.

Broadway to 27th Way

The 27th Way structure, included in the effective model, was overtopped during the 100-year event resulting in spill flows north along 27th Way to Baseline Road. The City of Boulder replaced the 27th Way culvert and constructed channel improvements between 27th Way and Broadway in approximately 2006. The improvements were designed to convey the 100-year event without over topping 27th Way and eliminated the spill flows along 27th Way. A City of Boulder Floodplain Development Permit was completed for these improvements (Floodplain Development Permit Application for the Replacement of the 27th Way Culvert over Skunk Creek, Love & Associates, Inc., 2006) which showed the improvements caused no rise in floodplain water surface elevations. A LOMR was not completed for these improvements.

The Broadway structure, included in the effective model, was overtopped during the 100-year event resulting in spill flows north along Broadway and east to the Basemar Shopping Center. The City of Boulder replaced the Broadway culvert in approximately 1999. The improvements were designed to convey the 500-year event without overtopping Broadway and eliminated the spill flows to Broadway and the Basemar Shopping Center. A City of Boulder Floodplain Development Permit was completed for these improvements (Floodplain Development Permit Application for the Replacement of the Broadway Culvert over Skunk Creek, Love & Associates, Inc., 1999.) which showed the improvements caused no rise in floodplain water surface elevations. A LOMR was not completed for these improvements.

27th Way to Hwy-36

A newly constructed floodwall between Moorhead and 27th way contains flows within the channel. Note that the total flow in the Skunk Creek main stem has been reduced along this reach due to the spill upstream of Broadway along Baseline as discussed earlier. Previously, in the effective model, FHAD hydrology had indicated all of the flows from Bluebell, Kings and Skunk converged upstream of Moorhead, and the curved culvert under Moorhead was overtopped, with a significant portion traveling south into the Bear Creek drainage. The results of this analysis show that with the flow leaving Baseline to the north above Broadway, the Moorhead Culvert is actually capable of passing the 100-year discharge. (Note that the flows leaving Baseline Road above Broadway are assumed to rejoin the floodplain at the Highway 36 interchange).

Flows from the Bluebell-Kings model which spill through and around the Basemar Shopping Center were added to the Skunk Creek model at locations immediately below Broadway (section 9638), upstream of 27th Way (section 9111) and into reach 5.100 on Baseline immediately above the US 36 interchange.

Downstream of Moorhead Avenue, a deep gabion lined channel directs flows to a box culvert under US Highway 36. This double 6'x2.8' culvert has insufficient capacity to convey the 100-year event, even with 10 to 12 feet of headwater. This headwater pools up behind the culvert, spilling into the parking lot of the Baseline Shopping Center directly adjacent to the north, and south down an alley along the southbound ramp to US 36. Lateral structures were coded along the northern perimeter of the shopping center to define flows lost from this pool onto Baseline directly above the highway interchange. Lost flows from the Bluebell-Kings model along Baseline to the west of Broadway are assumed to be added above the US 36 interchange at section 1548, increasing the water surface along Baseline, which in turn reduces the amount of flow lost from these lateral structures.

The deeper pool caused by this condition causes the gabion lined channel above the US 36 culvert to overtop the right bank, forcing more flow to the south in the alley along the southbound ramp toward Bear Canyon Creek. Approximately 334 cfs will be lost to the south, however, these flows were assumed to stay in the system and were added back in downstream of the outfall of the US 36 culvert. Due to the complex nature of the flow interactions above and below the US 36 interchange, the culvert routine in HEC-RAS would not converge. A rating curve was developed for the culvert using the FHWA program HY-8 (Appendix 3) and input as a lateral structure with flows returning downstream into reach 4.110 – Bline Path. This also failed to converge. Finally, a lateral structure with the rating curve was used to define the flow in the culvert based on headwater at section 8489 and the flow was removed from the model but added back in along with the Bear Canyon flows at section 7950, which is the outfall of the US 36

culvert at the pedestrian path crossing. A detail of this area including the rating curve calculations and flow summary can be found in the Hydraulic Summary exhibit.

US Highway 36 to 29th Street

The flow balance upstream of the US 36 interchange was achieved by iteratively assigning values in the flow table at section 1022 (DP 303) until the overall discharge between reach 5.000 Bline-East (Baseline through the underpass), reach 6.000 US-Moorhead (the US 36 double box culvert and the pedestrian underpass through the SB on ramp) and reach 6.300 Mrhd-Bear (flows lost to Bear Canyon which are assumed to be re-introduced below US 36) summed to the published FHAD value of 1,350 cfs. Of this, approximately half of the flow travels down Baseline through the underpass, spilling to the left into the infield area of the NB on ramp through a pedestrian culvert and to the southeast infield area immediately adjacent to the NB off ramp, which also runs through a pedestrian culvert. Some residual flows travel on eastward down Baseline. The two pedestrian culverts discharge to the outfall of the US 36 double box culvert, affecting the tail water thus the discharge in the culvert. The flow balance in this area was also manually balanced in order to achieve continuity, adding approximately 10% to achieve an interpolated FHAD hydrology value of 1,525 cfs at section 7407.

A gabion lined channel downstream of this area collects Skunk Creek flows but is blocked above 29th Street by a commercial structure built in a pond formed by an irrigation dam immediately to the west of 29th. This structure is supported by concrete piers above the permanent pool which are inundated during the 100-year event. The piers were represented in section 7642 by raising the manning's n value to 0.15. This condition, coupled with the dam forces flood flows around and on to the 28th Street Frontage Road, where lateral structures on 29th Street show flows running north down 29th Street, east back into Skunk Creek, and south around the apartment complex located immediately downstream of 29th.

29th and 30th Street Spill Reaches

Spill flows down 29th travel along the streets down to Bixby and north to Aurora Avenue. The effective model assumed that flows were lost along this reach. A more detailed analysis of this split flow indicates that 95% of flows stay in the main channel or flood fringe down to 30th Street, where an undersized culvert forces 35% of flows out of the channel and into the neighborhood bounded by 30th, Madison and 35th Street before finding their way back to the main channel of Skunk Creek through a series of junctions. Some flows are eventually lost to the north near Aurora and 30th, however they are minimal and were added back in downstream.

Flows through these reaches are highly variable for profiles other than the 100-year. Variations in flows lost at lateral structures, the capacity of culverts and the

ability of steep street sections to convey large flows back to the main channel result in street profiles showing large flows for one event and very little for others. For the purposes of this study, all flows were assumed to return to the main channel or flood fringe at Madison Avenue, which is FHAD DP 305.

Colorado at 35th Street

Between Euclid and Madison, the floodplain narrows to 350-400 feet, and the full 100-year flow is confined at depths of 2-3 feet and velocities of 2 feet per second. Culverts at Madison Avenue and 35th Streets force flows out of the floodplain to the north along 35th Street toward Colorado Avenue. Downstream of this area, the Wellman Canal cuts across and obliterates the Skunk Creek channel, resulting in still more flows lost north toward Colorado Avenue and the CU Research Park. Several attempts were made to model this area with separate reaches and lateral structures, with the result that the model failed to converge. These models were compared to one another and used to compile an energy grade surface of the floodplain between Colorado and Madison Avenues. This surface was then contoured, and the resulting isolines of energy grade were used to strike new cross sections for the entire area. The resulting single reach model run was checked against the multi-reach runs and found to agree well in terms of flow distribution, depth and velocity.

The flows in the left overbank overtop Colorado Avenue. Approximately 25% of these flows cross Colorado Avenue and into Innovation Drive, traveling down Innovation adjacent to the new CU Biotech building, still under construction. Grading around the building forms the left side of the roadway section, while the right bank of this section opens into a parking lot. Lateral weirs were used to define flows leaving Innovation Drive along this reach which are then collected in a channel running in front of the CU LASP Building. Much of this flow returns to Skunk Creek at Discovery Drive, however approximately 165 cfs rejoins the Boulder Creek floodplain in a swale across Potts Field to the north.

Wellman Canal

The Wellman Canal represents a significant obstruction to Skunk Creek as there is no drainage infrastructure to carry it across. Assuming the canal is flowing full, the capacity is limited by a low point along the left bank as it bends to the southeast away from limits the capacity while the canal is flowing full, however immediately south of the Skunk Creek crossing the canal actually has significantly greater capacity. During a flood event on Skunk Creek, the water surface created as Skunk Creek flows over the canal will allow for a diversion of flows to the southeast. These flows were assumed to go into storage due to backwater from Foothills Highway and were returned to Skunk Creek above Colorado Avenue.

Colorado Avenue to Foothills

The bridge at Colorado Avenue constricts the remaining flows in Skunk Creek at this point, forcing some water east along Colorado Avenue towards the intersection with Monroe and Discovery Drives. These flows will be shallow and will return to the Skunk Creek channel as the peak recedes.

A flood channel was constructed in the late 1980's to convey Skunk Creek flows from Colorado Avenue through the CU Research Park to Foothills Hwy. Below Colorado Avenue, flows which have overtopped the roadway are returned with a spill collection channel on the right hand bank. Just below the CU Center for Astrophysics, a majority of the flows lost above Colorado Avenue which travel north down Innovation Drive are returned to the main channel by way of the flood channel and pond which runs west to east in front of the LASP Center.

Above Discovery Drive, the flood channel does not have the capacity to contain the headwater required to force the 100-year flows through the culvert, and backs up onto both overbank areas. The 500-year floodplain spills at this point to the east across Innovation Drive and returns to the Skunk Creek channel downstream.

Below Discovery Drive, flows will overtop the channel along the north (left) bank and mix with Boulder Creek flood flows before the remainder passes under the culvert at Foothills Parkway and into the Bear Creek channel. Embankment weirs were coded along this area to model the spill using a weir coefficient of 2.4 to reflect high backwater in the left overbank (Boulder Creek floodplain). More than half of the flow in the Skunk Creek channel is lost into the convergence zone above Arapahoe and Foothills Highway along this reach.

4.0 Floodplain Management Applications

The PMR process is being used to provide a more accurate definition of the flood conditions on Skunk Creek, Bluebell Canyon Creek, and King's Gulch in the City of Boulder. This study uses updated topographic data and hydraulic modeling methods and incorporates structural improvements at Broadway and 27th Way. The City regulates the 100-year and 500-year floodplains and a 0.5-ft rise floodway through the NFIP. The City also regulates the High Hazard Zone (HHZ), a zone where depth and velocity are used to determine 100-year flood hazards to public health and safety. The HHZ determined for this creek will not be submitted to FEMA as a part of this LOMR.

The City, with assistance from the UDFCD, maintains the channel and floodplain of Skunk Creek, Bluebell Canyon Creek, and King's Gulch. The City periodically inspects the channel and road crossings.

5.0 Conclusions

The PMr process is being used to provide a better definition of existing flood conditions along Skunk Creek, Bluebell Canyon Creek, and King's Gulch. Its purpose is to update the FIRM using more accurate topographic information, updated methodology, and inclusion of structural improvements. The FEMA forms required for this PMR are located in Appendix 1.

6.0 References

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Appendix 1 –
FEMA Forms

Appendix 2 – Hydrology

FLOOD HAZARD AREA DELINEATION

CITY OF BOULDER

BOULDER AND ADJACENT COUNTY DRAINAGEWAYS

MAY 1987

Prepared For:
URBAN DRAINAGE and FLOOD CONTROL DISTRICT
The CITY OF BOULDER
BOULDER COUNTY, COLORADO

Prepared By:
GREENHORNE & O'MARA, INC.
Consulting Engineers
Denver, Colorado

Flood water surface elevations and floodplain boundaries are often revised by road and bridge construction, floodplain development, flood control improvements, or natural process. Prior to utilization of this report for planning or design purposes, the user is advised to contact the Urban Drainage and Flood Control District, the City of Boulder, and Boulder County to determine if the information in this report has been amended.

BASIN DESCRIPTIONS

The major drainage basin and sub-basin boundaries along with their respective drainage areas, are shown on Sheets 2 and 3 in the Appendix. A description of each basin is presented below.

Bear Canyon Creek

Bear Canyon Creek drainage basin is the southernmost region of the study area. Its overall length is about 5 miles. The source of the creek is near Kossler Lake. The drainage basin is rugged, steep and narrow as the creek drains Boulder Mountain and its surrounding areas. As it leaves the Foothills, the creek flows to the south of the National Center for Atmospheric Research.

Near Table Mesa Drive and Lehigh Street the basin enters residential and commercially developed areas. As the stream crosses the southern line of the City of Boulder, the basin remains highly developed. North of the Empson Ditch, the basin is again undeveloped. The slope of the land is gradual, and the vegetation is dense with native grasses and weeds.

The stream channel within the upstream reaches of the Bear Canyon Creek drainage basin reflects the characteristics of the basin. The creek bed at Bear Mountain Drive and Wildwood Road is very rocky with 10 to 12 foot banks, with 3:1 side slopes. As the channel enters the developed reaches of the basin, it becomes more defined. From Table Mesa Drive and Ithaca to Table Mesa Drive and Broadway, there are several drop structures and culverts. The stream channel is grasslined approximately six feet wide with 2:1 side slopes. As the creek approaches its confluence with Boulder Creek, the channel becomes wide and shallow.

Skunk Canyon Creek

The Skunk Canyon Creek drainage basin originates in the Flatirons southwest of Boulder and drains to the northeast a distance of about 2 miles. The undeveloped portion of the basin which exists in the mountains is steep, narrow and rocky. As the drainage enters and crosses the Boulder City limits, the basin becomes less steep in slope, and wider. Skunk Creek flows into Bear Canyon Creek 2000 feet south of the confluence of Bear Canyon Creek and Boulder Creek.

Skunk Canyon Creek flows notheast from the Flatirons past Kohler Reservoir. The stream channel is 10 to 12 feet high and very rocky. Stream banks rise from the channel at 2:1 side slopes. Downstream, the creet flows through Green Mountain Cemetery. The Creek banks within this reach are grass or rip-rapped, and range in height from 2 to 5 feet. The width of the channel ranges from 5 to 10 feet. As the creek leaves the cemetery, it crosses the Anderson Extension Ditch.

Northeast of the ditch, the creek approaches developed residential and commercial areas. The creek crosses Highway 36 at Baseline Road. Within the developed areas of the basin the channel is natural with 4 foot banks at approximately a 2:1 side slope. The channel reflects the basin conditions as it approaches its confluence with Bear Creek. Under a smaller gradient, the channel is wide and shallow.

Bluebell Canyon Creek

Bluebell Canyon Creek also drains east from the Boulder Flatirons. The overall length of the basin is about 1.8 miles. Approximately half of this distance is within Bluebell Canyon, which is undeveloped. In this portion of the basin, the channel is steep, rocky and well defined. The lower half of the basin is located in fully developed residential areas. Again, the drainage channel is all but obliterated by development. The channel enters this portion of the basin at 15th Street. A small ditch carries trickle flows eastward along the backyard property lines between Mariposa and Columbine Avenues. The drainage flows directly into the Anderson Extension Ditch at 20th Street. During a storm event, the creek

will overflow the ditch and sheet flow west through properties with the water eventually draining into Skunk Creek.

Kings Gulch

The Kings Gulch drainage basin starts in the Boulder Flatirons and drains eastward from the mountains to lower-lying residential areas which start around 15th Street. From 15th Street to the stream's confluence at 22nd Street near King Avenue, the grade of the land is moderately steep. The basin is fully developed as a residential area. As such, the natural drainage channel is obliterated.

Gregory Canyon Creek

The Gregory Canyon Creek drainage basin is steep, narrow, and approximately 1.9 miles long in its upstream and undeveloped section. The drainage starts near Green Mountain and continues northeastward towards the Boulder City limits. The drainage traverses fully developed residential areas between Baseline and Arapahoe Road along 9th Street for a distance of about 1 mile. The creek eventually empties into Boulder Creek north of 9th Street and Arapahoe Avenue.

The channel within the upstream portion of the basin mirrors basin conditions. It is steep, rocky, and narrow. The downstream section of the channel through the developed areas is open and relatively steep in grade. Within the developed areas there are numerous road crossings. The channel within this section is narrow with steep banks at several locations. Deciduous vegetation borders and overhangs the channels.

Sunshine Canyon Creek

The Sunshine Canyon Creek drainage basin has its source in the mountains west of Boulder. The drainage runs from the mountains to Boulder Creek south of Canyon Boulevard at 3rd Street, an approximate distance of 2.2 miles. The majority of the basin exists in the mountains under undeveloped conditions. This portion of the basin is very steep, rocky, narrow and approximately 1.6 miles long. The basin enters the city limits near Memorial Hospital. It then turns to the south, and parallels 4th Street along a steep grade to Boulder Creek. The drainage basin within the city limits is fully developed. A small tributary about 0.5 miles long enters the main Sunshine Canyon Creek drainage basin at Memorial Hospital. This tributary drains the area directly north of the hospital. The entire basin of this tributary is undeveloped.

The channel within the undeveloped section of the basin is rocky, steep and narrow. The channel within the developed section is well defined, steep and narrow.

Goose Creek

The Goose Creek drainageway originates one block north of 9th Street and Alpine through overland flow drainage of an area of approximately 200 acres. This area naturally drains to the east side of North Boulder Park. From here floodwaters enter Balsam Street from 9th Street. There is no stream visible within this portion of the drainage basin. The stream appears at 19th Street and Tyler Road, which is one block north of Alpine Avenue.

The drainage basin between North Boulder Park and the Boulder and Whiterocks Ditch has a moderate slope and is situated in developed residential areas. The stream bed within this area is very well-defined with heavy growth adjacent to the channel. The width of the channel within this section is as large as 25 feet with 6- to 15-foot high channel walls. The stream runs south of and parallel to Edgewood Drive. Homes border the stream along its length within this section.

Under non-flood conditions, Goose Creek flows into the Boulder and Whiterocks Ditch. During a flood event, floodwaters traverse the ditch. The basin area east of the Boulder and Whiterocks Ditch is largely developed by a variety of commercial business. The channel through this area has been largely obliterated with development. Culverts under Foothills Parkway flows directly into two improved channels downstream for approximately 0.8 miles before joining again at a sediment pond just above the confluence with Boulder Creek.

- Fourmile Creek
- Wonderland Creek
- Twomile Creek
- Elmer's Twomile Creek
- Goose Creek
- Bear Canyon Creek *
- Skunk Creek **

* Bear Canyon Creek from Boulder Creek to Yale Road.
** Skunk Creek from Bear Creek to King Avenue.

The floodplain information for the additional streams and stream reaches listed below was completed as part of this study.

- Bluebell Canyon Creek
- King's Gulch
- Gregory Creek
- Sunshine Canyon Creek
- Bear Canyon Creek *
- Skunk Creek **

* Bear Canyon Creek upstream of Yale Road.
** Skunk Creek upstream of King Avenue.

Hydrologic Analyses

Historic stream flow measurements were not available for any of the streams under study, and hence, hydrologic modelling was used to develop frequency discharge information. The Colorado Urban Hydrograph Procedure (CUHP), (Reference 2,3), was used to determine the runoff hydrographs for each sub-basin. Basins and sub-basins used in the analysis are shown on Figures 1 and 2. These hydrographs were then lagged and routed through the basin using the HEC-1 computer model (Reference 4) to account for stream travel times and flow attenuation due to channel or reservoir storage.

The CUHP model was used to develop hydrology for future basin conditions along each drainageway. An investigation was completed by the MSM/SP Group to compare existing vs full development hydrology. The results of this study showed that the increase in discharges and associated water surface elevations for full development was relatively small. Representatives of the City of Boulder, the Urban Drainage and Flood Control District and the Federal Emergency Management Agency reviewed the information and agreed that the use of future condition hydrology was appropriate for the Flood Insurance Study as well as this study.

Frequency discharges were developed for each of the drainageways for the 2-, 5-, 10-, 50-, and 100-year storm events. The CUHP model was used to calculate the 10-, 50-, and 100-year events for each stream included in the Flood Insurance Study (Fourmile Creek, Wonderland Creek, Twomile Creek, Elmer's Twomile Creek, Goose Creek, Bear Canyon Creek, and Skunk Creek). The 2-year and 5-year discharges for these streams were determined by extrapolating the modelled discharge information downward on a log probability graph. Frequency discharges for the 2-, 5-, 10-, 50-, and 100-year events for the remaining streams (King's Gulch, Bluebell Canyon Creek, Gregory Creek, and Sunshine Canyon Creek) were all calculated using the CUHP method.

Rainfall data was developed based on the revised guidelines dated September 15th, 1982, set forth in the Urban Storm Drainage Criteria Manual. Rainfall depths presented in these guidelines were obtained from the Precipitation Frequency Atlas of the Western United States (Reference 5). The total rainfall depths for the flood events analyzed for each drainageway included in this study are presented in Table 2.

TABLE 2

Rainfall Depths (Inches) / 1-Hour Duration

Basin	2-Year	5-Year	10-Year	50-Year	100-Year
Kings Gulch	1.00	1.41	1.70	2.30	2.65
Bluebell Canyon Creek	0.94	1.35	1.65	2.25	2.55
Gregory Creek	0.95	1.36	1.63	2.28	2.58
Sunshine Canyon Creek	0.94	1.35	1.62	2.25	2.55
Skunk Creek	*N/A	*N/A	1.65	2.25	2.55
Bear Canyon Creek	*N/A	*N/A	1.65	2.25	2.50
Elmer's Twomile Creek	*N/A	*N/A	1.70	2.35	2.65
Goose Creek	*N/A	*N/A	1.70	2.30	2.55
Wonderland Creek	*N/A	*N/A	1.60	2.25	2.50
Fourmile Canyon Creek (Upper Basin)	*N/A	*N/A	1.65	2.30	2.55
Fourmile Canyon Creek (Lower Basin)	*N/A	*N/A	1.70	2.35	2.65
Twomile Canyon Creek (Upper Basin)	*N/A	*N/A	1.60	2.20	2.45
Twomile Canyon Creek (Lower Basin)	*N/A	*N/A	1.70	2.30	2.65

*(N/A) The 2-year and 5-year events for these streams were extrapolated.

The 1-hour duration rainfall obtained from the NOAA Atlas is distributed into a 2-hour design storm for use with the CUHP program. The desired 2-hour storm duration is calculated for each recurrence frequency by multiplying each time increment by the percentages as shown in Table 3. The resulting 2-hour storm depth is comparable to the 2-hour depth found in the NOAA Atlas.

TABLE 3

Design Storm Distributions of 1-Hour NOAA Atlas Depths

Time	Percent of NOAA Rainfall Atlas Depth				
Minutes	2-Year	5-Year	10-Year	50-Year	100-Year
5	2.0	2.0	2.0	1.3	1.0
10	4.0	3.7	3.7	3.5	3.0
15	8.4	8.7	8.2	5.0	4.6
20	16.0	15.3	15.0	8.0	8.0
25	25.0	25.0	25.0	15.0	14.0
30	14.0	13.0	12.0	25.0	25.0
35	6.3	5.8	5.6	12.0	14.0
40	5.0	4.4	4.3	8.0	8.0
45	3.0	3.6	3.8	5.0	6.2
50	3.0	3.6	3.2	5.0	5.0
55	3.0	3.0	3.2	3.2	4.0
60	3.0	3.0	3.2	3.2	4.0
65	3.0	3.0	3.2	3.2	4.0
70	2.0	3.0	3.2	2.4	2.0
75	2.0	2.5	3.2	2.4	2.0
80	2.0	2.2	2.5	1.8	1.2
85	2.0	2.2	1.9	1.8	1.2
90	2.0	2.2	1.9	1.4	1.2
95	2.0	2.2	1.9	1.4	1.2
100	2.0	1.5	1.9	1.4	1.2
105	2.0	1.5	1.9	1.4	1.2
110	2.0	1.5	1.9	1.4	1.2
115	1.0	1.5	1.7	1.4	1.2
120	1.0	1.3	1.3	1.4	1.2
Totals	**15.7**	**115.7**	**115.7**	**115.6**	**115.6**

The Colorado Urban Hydrograph Procedure was completed utilizing the computerized model (CUHPB) as currently approved by the Urban Drainage and Flood Control District. The basin parameters required as input into the CUHPB model include the Basin Area (A), basin length along the flow path (L), length to centroid

TABLE 5

CUHPB Basin Parameters

* Sub-Basin Designation	AREA (mi2)	Basin Length (mi)	L_{ca} (mi)	%I	C_t*	C_p	Pervious Depression (Inches)	Impervious Depression (Inches)	Initial Infl. (In/Hr)	Decay Rate (per sec.)	Final Infl. Rate (In/Hr)
Twomile Canyon Creek											
601	1.40	2.41	1.35	7.0	0.33	0.32	0.50	0.10	3.0	0.0018	0.5
602	0.28	0.86	0.51	25.0	0.19	0.30	0.40	0.10	4.0	0.0018	0.6
603	0.51	1.48	0.76	41.0	0.22	0.48	0.40	0.10	4.0	0.0018	0.6
Goose Creek											
701	0.48	1.52	0.59	27.0	0.20	0.34	0.40	0.10	3.0	0.0018	0.5
702	0.80	1.44	0.66	42.0	0.23	0.52	0.40	0.10	4.0	0.0018	0.6
703	0.04	0.52	0.28	28.0	0.16	0.24	0.50	0.10	3.0	0.0018	0.5
704	0.12	0.66	0.21	41.0	0.18	0.39	0.40	0.10	3.0	0.0018	0.5
705	0.62	1.57	0.76	64.0	0.25	0.66	0.40	0.10	3.0	0.0018	0.5
706	0.69	1.63	0.80	53.0	0.27	0.59	0.40	0.10	3.0	0.0018	0.5
Wonderland Creek											
801	0.38	0.72	0.38	11.0	0.22	0.26	0.50	0.10	3.0	0.0018	0.5
802	0.47	1.21	0.57	16.0	0.23	0.27	0.50	0.10	3.0	0.0018	0.5
803	0.29	0.88	0.57	30.0	0.23	0.34	0.40	0.10	4.0	0.0018	0.6
804	0.21	0.81	0.47	36.0	0.21	0.38	0.40	0.10	3.0	0.0018	0.5
805	0.24	1.14	0.43	31.0	0.25	0.33	0.40	0.10	3.0	0.0018	0.5
806	0.32	1.42	0.76	10.0	0.37	0.25	0.50	0.10	3.0	0.0018	0.5
Fourmile Canyon Creek											
901	3.93	4.17	1.37	5.0	0.39	0.38	0.50	0.10	3.0	0.0018	0.5
902	3.28	3.08	1.18	6.0	0.35	0.37	0.50	0.10	3.0	0.0018	0.5
903	0.71	1.10	0.49	15.0	0.22	0.29	0.50	0.10	3.0	0.0018	0.5
904	0.68	1.89	1.02	41.0	0.27	0.50	0.40	0.10	4.0	0.0018	0.6
905	0.49	1.25	0.49	12.0	0.31	0.27	0.50	0.10	3.0	0.0018	0.5
906	0.94	2.50	1.21	13.0	0.42	0.30	0.50	0.10	3.0	0.0018	0.5
Skunk Creek											
301	0.88	2.79	1.40	8.0	0.34	0.30	0.50	0.10	3.0	0.0018	0.5
302	0.16	0.99	0.23	51.0	0.14	0.45	0.40	0.10	4.0	0.0018	0.6
303	0.04	0.26	0.16	78.0	0.11	6.48	0.40	0.10	4.0	0.0018	0.6
304	0.11	0.38	0.19	50.0	0.12	0.43	0.40	0.10	4.0	0.0018	0.6
305	0.35	1.33	0.51	6.0	0.23	0.57	0.40	0.10	3.0	0.0018	0.5
306	0.29	1.00	0.53	22.0	0.27	0.28	0.50	0.10	3.0	0.0018	0.5

* Design Points for each sub-basin designation are shown on Figures 1 and 2, respectively.

TABLE 5

CUHPB Basin Parameters

*Sub-Basin Designation	AREA (mi2)	Basin Length (mi)	L_{ca} (mi)	%I	C_t*	Cp	Pervious Depression (Inches)	Impervious Depression (Inches)	Initial Infl. (In/Hr)	Decay Rate (per sec.)	Final Infl. Rate (In/Hr)
King's Gulch											
K1	0.23	1.00	0.44	5.0	0.26	0.24	0.50	0.10	3.0	0.0018	0.5
K2	0.09	0.57	0.38	35.0	0.32	0.15	0.40	0.10	3.0	0.0018	0.5
Bluebell Canyon Creek											
B1	0.40	1.55	0.95	5.0	0.30	0.26	0.50	0.10	3.0	0.0018	0.5
B2	0.28	0.88	0.35	46.0	0.14	0.47	0.40	0.10	3.0	0.0018	0.5
Gregory Creek											
G1	1.16	1.61	0.87	5.0	0.34	0.30	0.50	0.10	3.0	0.0018	0.5
G2	0.40	0.93	0.45	5.0	0.29	0.24	0.50	0.10	3.0	0.0018	0.5
G3	0.73	1.20	0.72	33.0	0.42	0.19	0.40	0.10	3.0	0.0018	0.5
Sunshine Canyon Creek											
S1	1.13	2.56	0.95	.5	0.33	0.33	0.50	0.10	3.0	0.0018	0.5
S2	0.30	0.91	0.46	5.0	0.27	0.24	0.50	0.10	3.0	0.0018	0.5
S3	0.29	0.91	0.40	5.0	0.27	0.28	0.50	0.10	3.0	0.0018	0.5
S4	0.10	0.47	0.40	43.0	0.39	0.13	0.40	0.10	3.0	0.0018	0.5
Bear Canyon Creek											
401	2.84	4.43	2.05	7.0	0.40	0.34	0.50	0.10	3.0	0.0018	0.5
402	0.87	1.59	0.76	27.0	0.22	0.37	0.50	0.10	4.0	0.0018	0.6
403	0.37	1.10	0.68	53.0	0.20	0.54	0.40	0.10	4.0	0.0018	0.6
404	0.26	0.83	0.57	42.0	0.24	0.43	0.40	0.10	4.0	0.0018	0.6
405	0.37	1.04	0.38	28.0	0.18	0.33	0.40	0.10	4.0	0.0018	0.6
406	0.18	0.64	0.27	40.0	0.19	0.40	0.40	0.10	4.0	0.0018	0.6
407	0.07	0.47	0.25	20.0	0.21	0.22	0.50	0.10	3.0	0.0018	0.5
408	0.39	1.74	0.95	32.0	0.31	0.32	0.40	0.10	3.0	0.0018	0.5
409	0.06	0.38	0.27	5.0	0.31	0.19	0.50	0.10	3.0	0.0018	0.5
Elmer's Twomile											
501	0.12	0.52	0.25	30.0	0.16	0.30	0.40	0.10	3.0	0.0018	0.5
502	0.19	0.72	0.22	36.0	0.18	0.37	0.40	0.10	3.0	0.0018	0.5
503	0.21	1.06	0.64	47.0	0.23	0.44	0.40	0.10	3.0	0.0018	0.5

* Design Points for each sub-basin designation are shown on Figures 1 and 2, respectively.

through the various channel reaches. The Modified Puls Method for channel routing was chosen using typical stream cross-sections for developing normal depth storage/discharge relationships.

The only major transbasin diversion modelled in the Flood Insurance Studies was the Broadway diversion of Fourmile to Wonderland. In this diversion, 400 cfs was taken from Fourmile Creek and added to Wonderland. The Fourmile discharges were not reduced since improvements may eliminate the diversion in the future.

Irrigation ditches cross each of the drainageways at various locations. In many cases, siphons, aqueducts, or pipes are used at the crossings. However, Goose, Elmer's Twomile, and Bluebell Canyon Creeks discharge directly into ditches. For this hydrologic analysis, it was assumed that the ditches would be full to capacity while crossing the basins, and storm runoff was therefore assumed to flow directly across the irrigation ditches.

Table 6 presents a summary of all peak discharge results. Discharge profiles for the streams are shown in Figures 6 through 11. Typical flood hydrographs are shown in Figure 12.

Hydraulics

The water surface profiles for all streams under study were computed using the HEC-2 computer model (Reference 8). Cross section information for streams completed as part of the Flood Insurance Studies was obtained using photogrammetric techniques, by utilizing digitized sections from the aerial photography used to prepare the two foot contour mapping. Cross sections for streams analyzed under this study were taken directly from the two foot contour mapping.

Geometric measurements and invert elevations for bridge and culvert crossings were obtained in the field as required. Photographs were taken of each crossing and a sketch of the crossing was prepared showing appropriate dimensions. This material is on file as back up information to the project. During these field investigations, estimates of roughness coefficients, i.e. Mannings "n" values, were also noted.

Hydraulic runs were completed for the 10-year, 50-year, 100-year, and 500-year events for streams analyzed in the Flood Insurance Study. Hydraulic runs were completed for the 2-year, 5-year, 10-year, 50-year and 100-year events for stream analyzed in this study. However, only the 10-year and 100-year water surface profiles are reported in this study.

In addition, a floodway was computed for all streams under study. This floodway is based on the City of Boulder criteria allowing for no more than a one-half foot rise in the water surface elevation with encroachment during the 100-year event, and no encroachment in areas where velocities exceed 2 feet per second or depths exceed 2 feet.

The floodplains for the 100-year event were then delineated on the topographic mapping using the computed water surface profile. The floodplains and water surface profiles are presented on Sheets 1 through 31.

Culvert or bridge blockage was considered at each crossing structure. The degree of blockage was determined by field inspection by the City of Boulder Staff. Table 7 presents the estimate of blockage at major crossings for the drainageways included in this study.

FLOODPLAIN DESCRIPTIONS

The extent of flooding in overbank areas varies throughout each study reach. A description of the 100-year floodplain for each of the eleven streams follows.

Bear Canyon Creek

The upstream portion of Bear Canyon Creek experiences shallow flooding. From the upstream study limit to Lehigh Street, the floodplain ranges in width from 50 to 150 feet. Although the area is fairly well developed, flood damage to properties is light, as the floodplain is narrow and buildings are usually not located close to the stream channel. Three buildings are affected by the floodplain within this section of the creek.

TABLE 6

SUMMARY OF PEAK DISCHARGE

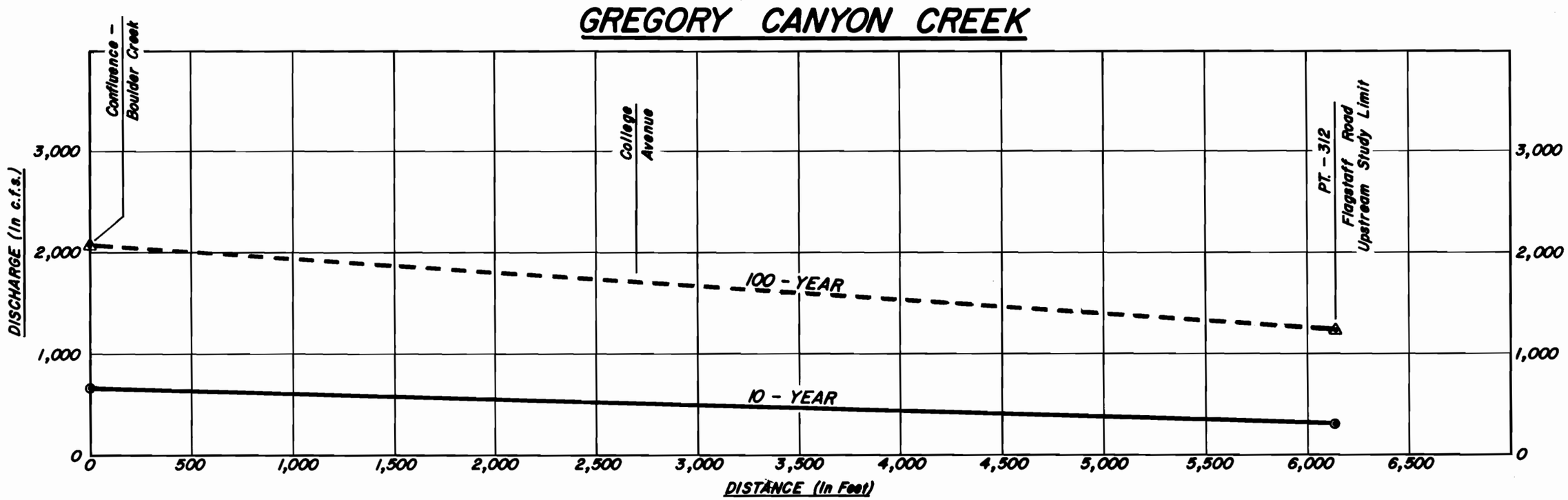
Design Point	Flooding Source	Drainage Area (sq mi)	Peak Discharges (cfs) 2-Yr	5-Yr	10-Yr	50-Yr	100-Yr
	BEAR CANYON CREEK - (Figure 2)						
409	Confluence - Boulder Creek	8.24	720	1415	2050	3762	4880
408	Confluence - Skunk Creek	5.35	355	780	1170	2360	3070
407	Baseline Road	4.96	330	740	1110	2352	2930
404	U.S. 36	4.34	240	540	820	1780	2210
403	Broadway	4.08	140	440	680	1512	1930
402	Yale Road	3.71	110	290	480	1190	1600
401	500' u/s of Lehigh	2.84	68	180	307	791	1063
	SKUNK CANYON CREEK - (Figure 2)						
306	Confluence - Bear Creek	2.83	350	700	980	1830	2230
305	Madison Avenue	2.43	340	690	920	1580	1870
303	U.S. 36	2.08	270	480	650	1130	1350
302	Broadway	1.36	47	125	210	520	710
301	Anderson Ditch	1.20	39	105	180	460	640
	BLUEBELL CANYON CREEK - (Figure 2)						
211	Chautauqua Park	0.40	6	31	63	168	227
212	Confluence with Skunk Creek	0.68	139	247	360	627	737
	KING'S GULCH - (Figure 1)						
111	Design Point	0.23	6	32	64	164	214
112	Confluence with Skunk Creek	0.32	41	82	132	292	373
	GREGORY CREEK - (Figure 2)						
311	0.4 mi. u/s Flagstaff Road	1.16	22	117	229	659	890
312	Flagstaff Road	1.56	30	163	321	932	1239
313	Confluence with Boulder Creek	2.29	161	435	673	1672	2092
	SUNSHINE CANYON CREEK - (Figure 1)						
411	Confluence w/Sunshine Creek Tributary	1.13	17	89	169	538	678
412	Design Point d/s of Memorial Hospital	1.72	27	139	266	869	1103
414	Confluence with Boulder Creek	1.82	45	155	286	914	1159
	SUNSHINE CANYON TRIB. - (Figure 1)						
414	Confluence with Sunshine Canyon Creek	0.29	10	26	51	161	200
	GOOSE CREEK - (Figure 1)						
706	Confluence - Boulder Creek	5.46	650	1260	1740	3300	4180
705	Colorado & Southern Railroad	4.77	520	1040	1520	2960	3761
704	Confluence - Elmer's Twomile	3.63	340	710	1050	2100	2680
703	Confluence - Twomile Canyon	1.32	240	470	670	1270	1590
702	19th Street	1.28	260	500	700	1320	1600
701	Upstream Study Limit	.48	90	183	260	520	620
	TWOMILE CANYON CREEK - (Figure 1)						
603	Confluence - Goose Creek	2.19	110	255	360	840	1120
602	Broadway	1.68	48	138	210	675	890
601	Upstream Study Limit (Maxwell Reservoir)	1.40	40	112	210	540	710
	ELMER'S TWOMILE - (Figure 2)						
503	Confluence - Goose Creek	0.52	84	190	280	630	790
502	Iris Avenue	0.31	93	185	270	510	610
501	Upstream Study Limit	0.12	40	78	110	210	250

TABLE 7

ESTIMATED BLOCKAGE AT MAJOR DRAINAGE STRUCTURES

DRAINAGEWAY	LOCATION	% BLOCKAGE
Bear Canyon Creek		
	Wildwood	40
	Boiler Pipe Culvert	100
	Footbridge	30
	Lehigh	75
	All Table Mesa Drive Culverts	50
	Security Bank	0
	Broadway	75
	2 Footbridges	20
	Martin	50
	Moorhead	20
	Turnpike	0
	Bike Bridge	0
	Church Culvert	30
	Baseline	50
	Gilpin	10
	Mohawk	0
	Low Flow Crossing at Wellman	100
	47th	0
	Arapahoe	30
Skunk Creek		
	King	50
	Driveway	40
	Driveway	40
	Bluebell	30
	Broadway	30
	Footbridge	30
	27th	0
	Moorhead U.S. 36	0

DRAINAGEWAY	LOCATION	% BLOCKAGE
Skunk Creek		
	U.S. 36	0
	Baseline	0
	29th	10
	Pedestrian Bridge	30
	30th	30
	Footbridge	30
	Aurora	10
	34th	20
	Madison (East Cell)	30
	(West Cell)	100
	Skunk/35th	50
	Colorado	0
	47th Parkway	0
Bluebell Canyon Creek		
	15th Street	0
	16th Street	100
	17th Street	100
	18th Street	100
	19th Street	100
	20th Street	100
King's Gulch		
	Bellevue Drive	50
	Driveway	25
	15th Street	25
	17th Street	25


GREGORY CANYON CREEK
Confluence - Boulder Creek
College Avenue
PT. - 312
Flagstaff Road
Upstream Study Limit
100 - YEAR
10 - YEAR
DISCHARGE (In c.f.s.)
DISTANCE (In Feet)
0
1,000
2,000
3,000
500
1,500
2,500
3,500
4,000
4,500
5,000
5,500
6,000
6,500

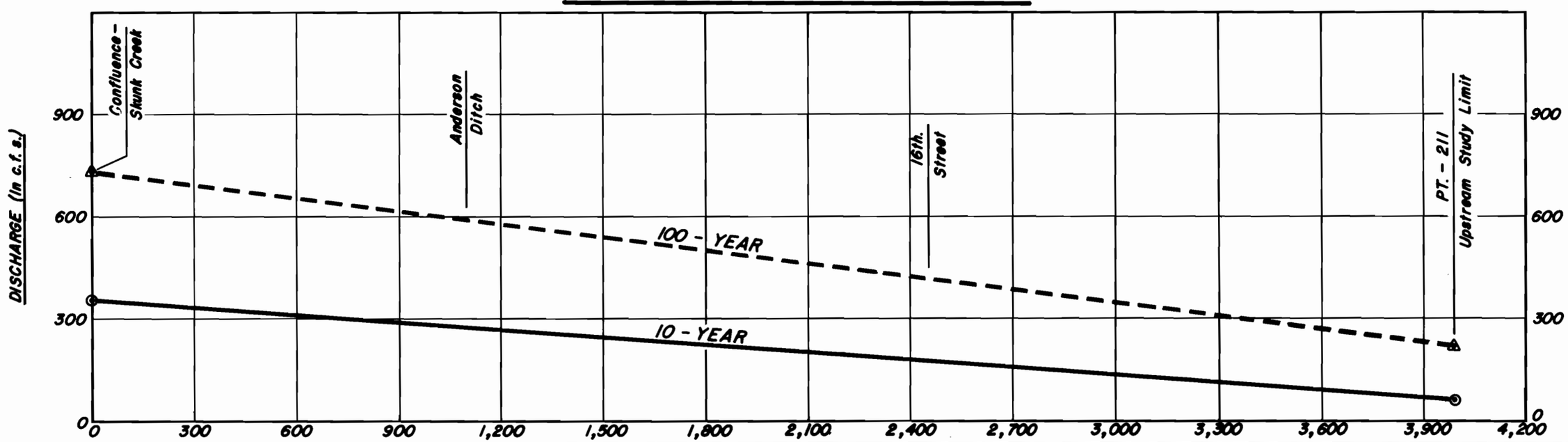
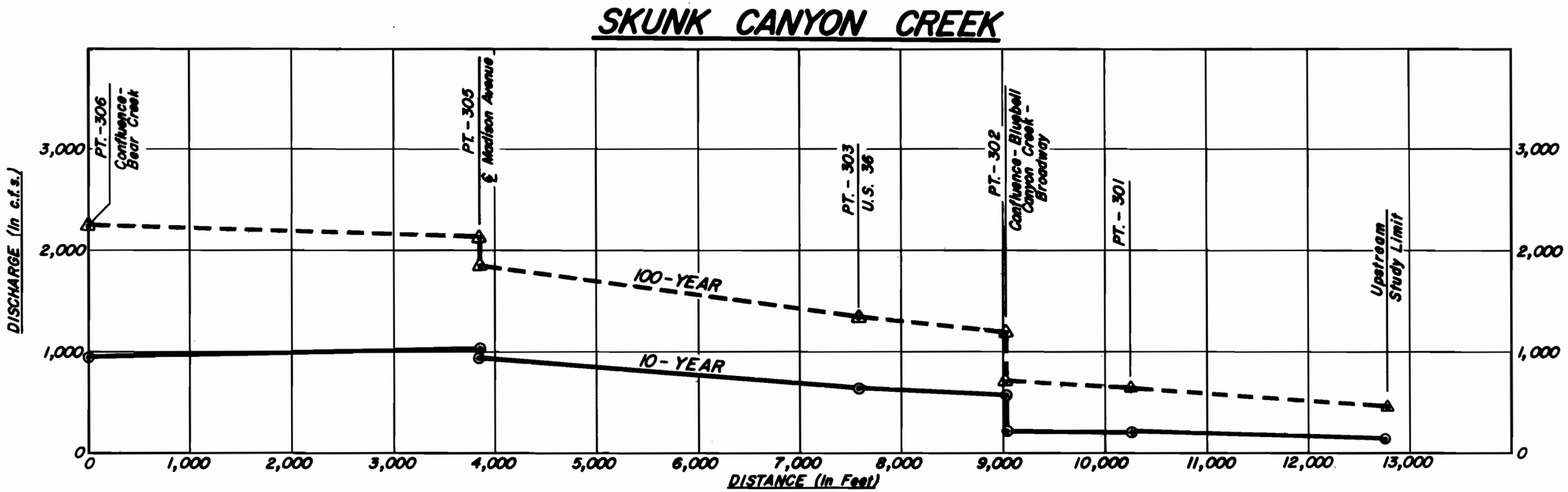

BLUEBELL CANYON CREEK
Confluence - Skunk Creek
Anderson Ditch
16th. Street
PT. - 211
Upstream Study Limit
100 - YEAR
10 - YEAR
DISCHARGE (In c.f.s.)
0
300
600
900
1,200
1,500
1,800
2,100
2,400
2,700
3,000
3,300
3,600
3,900
4,200

Figure 9


SKUNK CANYON CREEK
DISCHARGE (In c.f.s.)
DISTANCE (In Feet)
PT.-306 Confluence-Bear Creek
PT.-305 ℄ Madison Avenue
PT.-303 U.S. 36
PT.-302 Confluence-Bluebell Canyon Creek-Broadway
PT.-301
Upstream Study Limit
100-YEAR
10-YEAR
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000

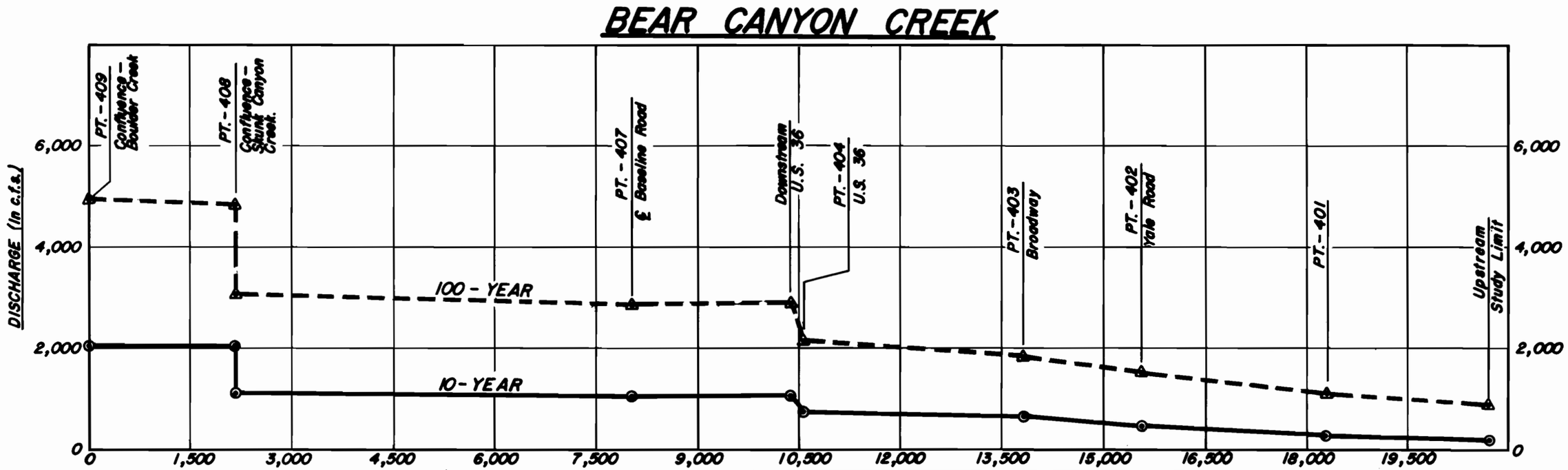

BEAR CANYON CREEK
DISCHARGE (In c.f.s.)
PT.-409 Confluence-Boulder Creek
PT.-408 Confluence-Skunk Canyon Creek.
PT.-407 ℄ Baseline Road
Downstream U.S. 36
PT.-404 U.S. 36
PT.-403 Broadway
PT.-402 Yale Road
PT.-401
Upstream Study Limit
100-YEAR
10-YEAR
0
1,500
3,000
4,500
6,000
7,500
9,000
10,500
12,000
13,500
15,000
16,500
18,000
19,500

Figure 10

KINGS GULCH

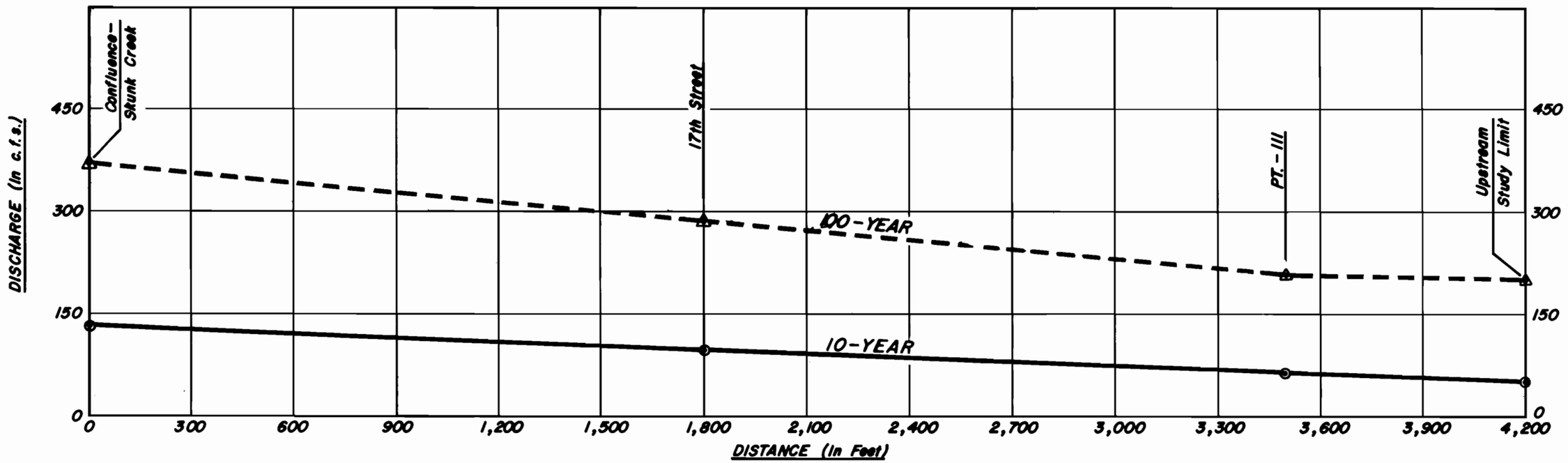


Figure 11

Between Lehigh Street and Broadway, the floodplain generally follows the exterior boundaries of Table Mesa Drive. The floodplain widens at cross streets with Table Mesa. This is caused by the culverts built for those streets. As the creek approaches Broadway, the floodplain becomes wider. Downstream from Gillaspie Drive, the floodplain extends eastward as the terrain starts to flatten out. Commercial development also increases in this area. The floodplain crosses approximately 450 feet of Broadway. Again damages are not heavy, as only 2 buildings are within the floodplain.

Downstream from Broadway, the wide floodplain intersects Eastman Avenue on the west side of the stream. Eastman conveys its water to 35th Street, and 35th Street carries the water down to Martin Drive. Between Martin Drive and Highway 36, a continuous floodplain boundary lies to the east of the creek. This boundary is 250 feet east of the creek at Martin Drive. It follows along the western half of Chase Circle and returns very close to the creek at Moorhead Avenue. The floodplain on the west side of the creek between Martin Drive and Highway 36 is not continuous. Three-fourths of the area west of the creek and between Martin and Berkeley Avenue is not flooded. Immediately downstream from this area, a residential area which is built around Berkeley Avenue is flooded. Twenty homes are effected by the floodplain in this area.

Downstream of Highway 36 broad, shallow flooding occurs to Baseline Road. The floodplain approaches 1300 feet in width at its widest point. Only a commercial building is located within the floodplain near Baseline Road. North of Baseline Road, the floodplain becomes narrow as the creek's channel is larger and street flow occurs along Gilpin Drive.

The floodplain is narrow along the creek bed and Gilpin Drive, leaving most of the area between the creek and the street dry. Floodwaters from Gilpin Drive flow onto Inca Parkway and then onto Mohawk Drive. A large amount of property damage occurs as a result of this flooding pattern. Twenty-two residential buildings incur shallow flooding.

From Mohawk Drive to the creek's confluence with Boulder Creek, the floodplain ranges from being narrow to very extensive. The width of the floodplain is influenced by Skunk Creek, which flows into Bear Creek approximately 530 feet south of Arapahoe Road. The floodplain is a fairly uniform 75 feet in width for 750 feet downstream of Mohawk Drive. As the stream approaches Foothills Parkway and the Skunk Creek floodplain, the Bear Creek floodplain widens on the west side of the creek. On the east side of the creek, the floodplain extends to within 100 feet of Hancock Drive near Foothills Parkway. The flood profiles and floodplain delineation immediately upstream of Arapahoe have been revised to reflect the installation of larger culverts by the Highway Department and overbank grading by a developer. North of Arapahoe Road to the creek's confluence with Boulder Creek, a broad area is flooded to approximately 1 foot of depth. The widest area of the floodplain extends approximately 200 feet on the east side of the creek. Property damage is light in this downstream portion of the creek, as only 3 small buildings are within the floodplain.

Skunk Creek

The floodplain upstream from the Kings Gulch confluence with Skunk Creek ranges from narrow and confined in steep channel banks to wide where overland shallow flooding occurs within Green Mountain Cemetery. Street flooding occurs near the upstream study limit.

The floodplain maintains a fairly uniform width of about 200 feet as it enters Green Mountain Cemetery. However, about halfway through the cemetery, the land slopes off to the north. This results in shallow overland flooding which flows northward from the cemetery. Some of the flow returns to the floodplain while the rest of the flow enters Kings Avenue east of 21st Street. North of the Kings Gulch confluence with Skunk Creek, the floodplain is approximately 1700 feet wide. This width is maintained as the floodplain crosses Broadway. Property damages are moderately heavy in this area as 27 buildings are flooded.

Between Broadway and 30th Streets, the floodplain ranges from 1700 feet to 100 feet. The floodplain is restricted as it passes through large culverts, notably, the culverts at U.S. 36 and Baseline Road. Some street flow occurs down 29th Street to Bixby. All of the water returns to the channel. Property damage remains moderately heavy upstream of U.S. 36, but becomes light downstream of U.S. 36. From 30th Street where the floodplain is 500 feet wide, to Colorado Avenue where the floodplain is 2000 feet wide, a large amount of property damage

occurs. More than 75 residential and commercial buildings are flooded. Colorado Avenue intercepts the floodwaters and conducts them eastward. This decreases the width of the floodplain. Downstream of Colorado Avenue, a broad floodplain occurs near the creek's confluence with Bear Creek. Although the floodplain is at places more than 1500 feet wide, a small amount of damage results as this is a very sparsely developed area.

Bluebell Canyon Creek

The Bluebell Canyon Creek Floodplain is narrow and well confined in its upstream reaches and is dominated by the street pattern over its lower reaches. From the upstream study limit to 15th Street, the floodplain is narrow (about 50 feet wide) within Bluebell Canyon.

Downstream, from 15th Street to the creek's confluence with Skunk Creek, the floodplain is basically determined through shallow street flooding. Mariposa Avenue conveys floodwaters to Broadway. At 20th Street, floodwaters travel northward and then eastward on Baseline Road. Twenty-first Street is also flooded between Columbine and Baseline. Flood damage is generally light within the street flooding area. However, approximately 12 buildings are affected by overland flooding between 15th and 19th Streets.

Kings Gulch

Kings Gulch has a flooding pattern similar to Bluebell Canyon Creek. A narrow floodplain exists in the mountainous upstream portions of the basin. Approximately 800 feet downstream of the upstream study limit overland flooding occurs eastward from the storm channel. Floodwaters travel down East Belleview Drive to 15th Street. Two buildings are flooded. At 15th Street, the floodplain is 200 feet wide.

From 15th Street, floodwaters flow down King Avenue to Skunk Creek. Between 15th and 17th Streets, overland flow affects 7 buildings. At 17th Street, the floodplain is 450 feet wide. Overland shallow flooding covers the half block area between 17th and 18th Streets. Floodwaters reach Bluebell Avenue and travel to Skunk Creek. Property damage to the downstream sections of the basins is very light.

Gregory Creek

The floodplain for Gregory Canyon Creek is significantly affected by the streets within the drainage basin. Street flow occurs when the floodplain intersects a street and floodwaters are then carried off down the street.

The floodplain is basically narrow between the upstream study limit and College Avenue. However, street flow results in shallow flooding in areas along Baseline Road, Willow Street (north and south of the creek), Gilbert Street and Rose Hill Drive. The streets generally do not overflow onto adjacent areas. Property damage is moderate within this section of the creek as 13 residential buildings are flooded.

Between College Avenue and the stream's confluence with Boulder Creek the floodplain becomes wider and continues to be affected by street flows. The floodplain is 300 feet wide between College and Pleasant Avenues. Rose Hill Drive conveys floodwaters across Arapahoe Road and into Boulder Creek. As the floodplain intersects Pleasant Avenue on the east side of the creek, floodwaters travel eastward along the street and overflow the street creating a shallow flooding zone between Pleasant Avenue and University Avenue. Floodwaters reach 9th Street and travel northward on 9th Street north of University Avenue. The floodplain downstream of Arapahoe Avenue is approximately 400 feet wide. Property damage within this downstream portion of the creek is heavy. More than 50 residential and commercial buildings are flooded.

Sunshine Canyon Gulch and Sunshine Canyon Tributary

The upstream floodplain of Sunshine Canyon Gulch and its tributary are very similar. This portion of the stream flows from the upstream study limit to Sunshine Canyon Road near Memorial Hospital. Both floodplains are narrow and follow the creek beds within their steep channels. Damage is very light within the floodplain as few buildings are present within the upstream reaches.

The floodplain between Sunshine Canyon Road and Spruce Street, range in width from less than 50 feet, near Sunshine Canyon Road, to more than 300 feet at Spruce Street. Eight buildings are flooded north of Spruce Street. Shallow

FLOOD HAZARD AREA DELINEATION

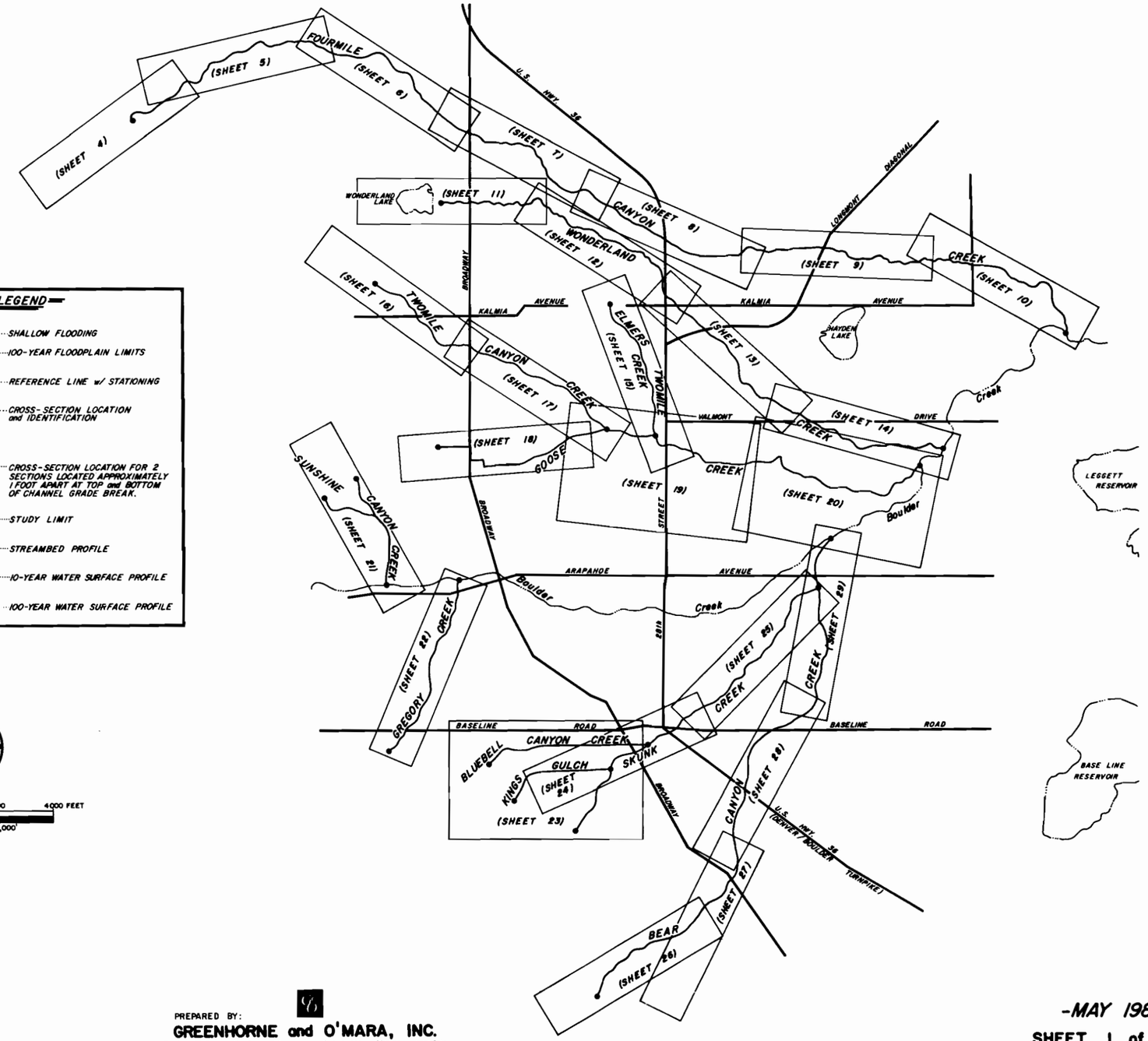
CITY OF BOULDER & ADJACENT COUNTY DRAINAGEWAYS

INDEX TO SHEETS

SHEET NO.	TITLE
1	COVER & INDEX SHEET
2	DRAINAGE BASINS/NORTH
3	DRAINAGE BASINS/SOUTH
4	FOURMILE PLAN & PROFILE (Sta. 380+00 To Sta. 401+00)
5	FOURMILE PLAN & PROFILE (Sta. 321+00 To Sta. 380+00)
6	FOURMILE PLAN & PROFILE (Sta. 261+00 To Sta. 321+00)
7	FOURMILE PLAN & PROFILE (Sta. 199+00 To Sta. 261+00)
8	FOURMILE PLAN & PROFILE (Sta. 135+00 To Sta. 199+00)
9	FOURMILE PLAN & PROFILE (Sta. 70+00 To Sta. 135+00)
10	FOURMILE PLAN & PROFILE (Sta. 0+00 To Sta. 70+00)
11	WONDERLAND PLAN & PROFILE (Sta. 186+00 To Sta. 217+50)
12	WONDERLAND PLAN & PROFILE (Sta. 114+00 To Sta. 186+00)
13	WONDERLAND PLAN & PROFILE (Sta. 60+00 To Sta. 114+00)
14	WONDERLAND PLAN & PROFILE (Sta. 0+00 To Sta. 60+00)
15	ELMERS TWOMILE PLAN & PROFILE (Sta. 0+00 To Sta 51+85)
16	TWOMILE PLAN & PROFILE (Sta. 57+00 To Sta. 104+00)
17	TWOMILE PLAN & PROFILE (Sta. 0+00 To Sta. 57+00)
18	GOOSE PLAN & PROFILE (Sta. 141+00 To Sta. 194+00)
19	GOOSE PLAN (Sta. 75+00 To Sta. 141+00)
20	GOOSE PLAN (Sta. 0+00 To Sta. 75+00)
21	SUNSHINE PLAN & PROFILE (Sta. 0+00 To Sta. 50+00)
22	GREGORY PLAN & PROFILE (Sta. 0+00 To Sta. 65+00)
23	SKUNK PLAN (Sta. 97+00 To Sta. 128+00) BLUEBELL PLAN (Sta. 13+00 To Upstream Study Limit) KINGS PLAN (Sta 0+00 To Uptream Study Limit)
24	SKUNK PLAN & PROFILE (Sta. 63+00 To Sta. 97+00) BLUEBELL PLAN (Sta. 0+00 to Sta. 13+00)
25	SKUNK PLAN & PROFILE (Sta. 0+00 To Sta. 63+00)
26	BEAR PLAN & PROFILE (Sta. 158+00 To Sta. 207+00)
27	BEAR PLAN & PROFILE (Sta. 126+00 To Sta. 158+00)
28	BEAR PLAN & PROFILE (Sta. 66+00 to Sta. 126+00)
29	BEAR PLAN & PROFILE (Sta. 0+00 To Sta. 66+00)
30	GOOSE PROFILE (Sta. 0+00 To Sta. 141+00)
31	BLUEBELL PROFILE (From 15th St. To Upstream Study Limit) KINGS PROFILE (From 15 St. To Upstream Study Limit) SKUNK PROFILE (Sta. 97+00 To Sta. 128+00) SUNSHINE TRIBUTARY PROFILE (Sta. 0+00 To Sta. 17+00)

LEGEND

- SHALLOW FLOODING
- 100-YEAR FLOODPLAIN LIMITS
- 10+00 — REFERENCE LINE w/ STATIONING
- 10 — CROSS-SECTION LOCATION and IDENTIFICATION
- 12 / 13 OR 15 / 16 — CROSS-SECTION LOCATION FOR 2 SECTIONS LOCATED APPROXIMATELY 1 FOOT APART AT TOP and BOTTOM OF CHANNEL GRADE BREAK.
- STUDY LIMIT
- STREAMBED PROFILE
- 10-YEAR WATER SURFACE PROFILE
- 100-YEAR WATER SURFACE PROFILE



NOTE:

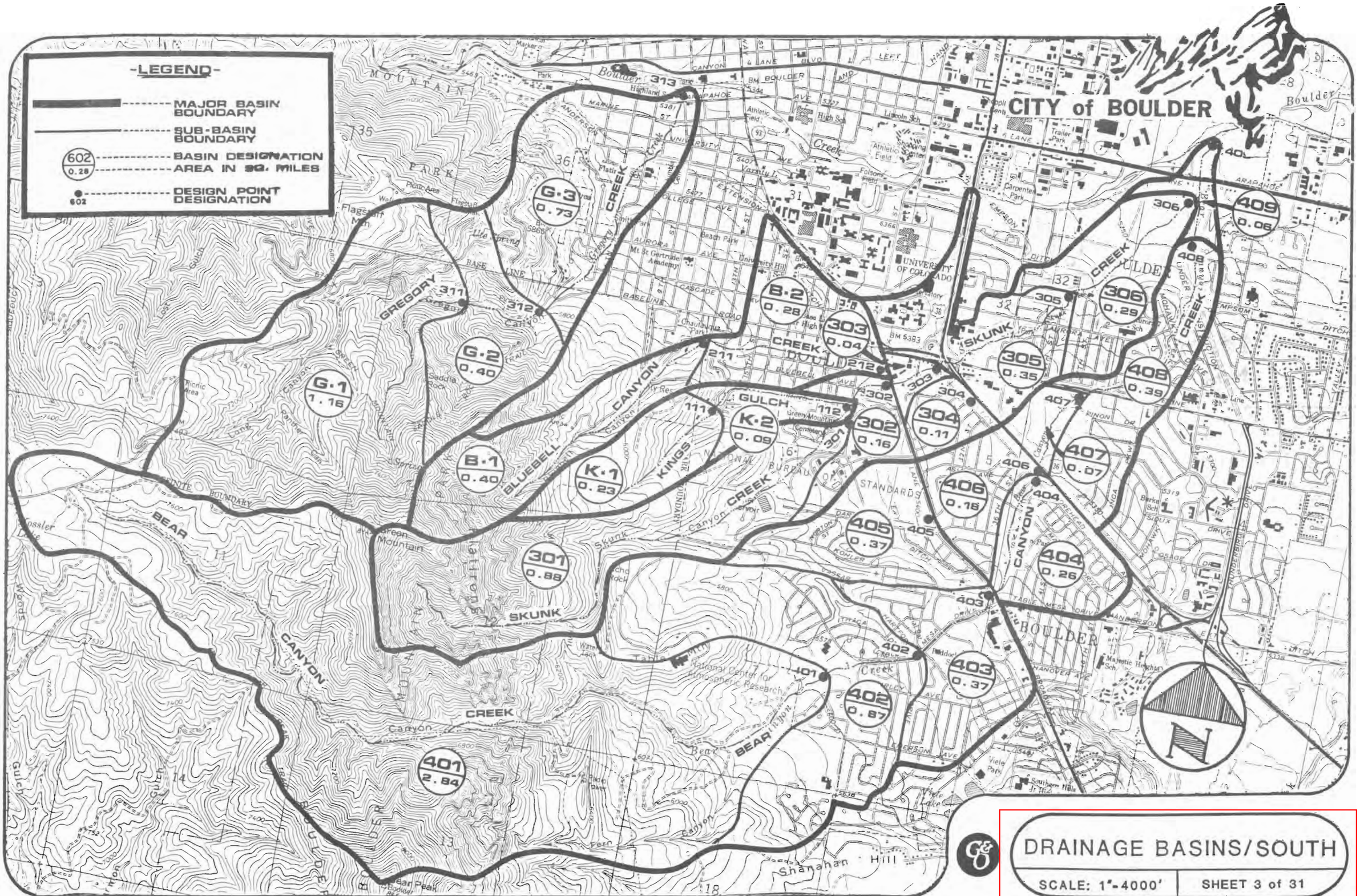
FLOOD WATER SURFACE ELEVATIONS AND FLOOD PLAIN BOUNDARIES ARE OFTEN REVISED BY ROAD AND BRIDGE CONSTRUCTION, FLOOD PLAIN DEVELOPMENT, FLOOD CONTROL, IMPROVEMENTS, OR NATURAL PROCESS PRIOR TO UTILIZATION OF THIS REPORT FOR PLANNING OR DESIGN PURPOSES. THE USER IS ADVISED TO CONTACT THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT TO DETERMINE IF THE INFORMATION IN THIS REPORT HAS BEEN AMENDED.

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER - BOULDER COUNTY

PREPARED BY:
GREENHORNE and O'MARA, INC.
Engineers · Architects · Planners · Surveyors · Photogrammetrists
3131 South Vaughn Way · Suite 228 · Aurora, Colorado 80014 · (303) 755-9000

-MAY 1987-

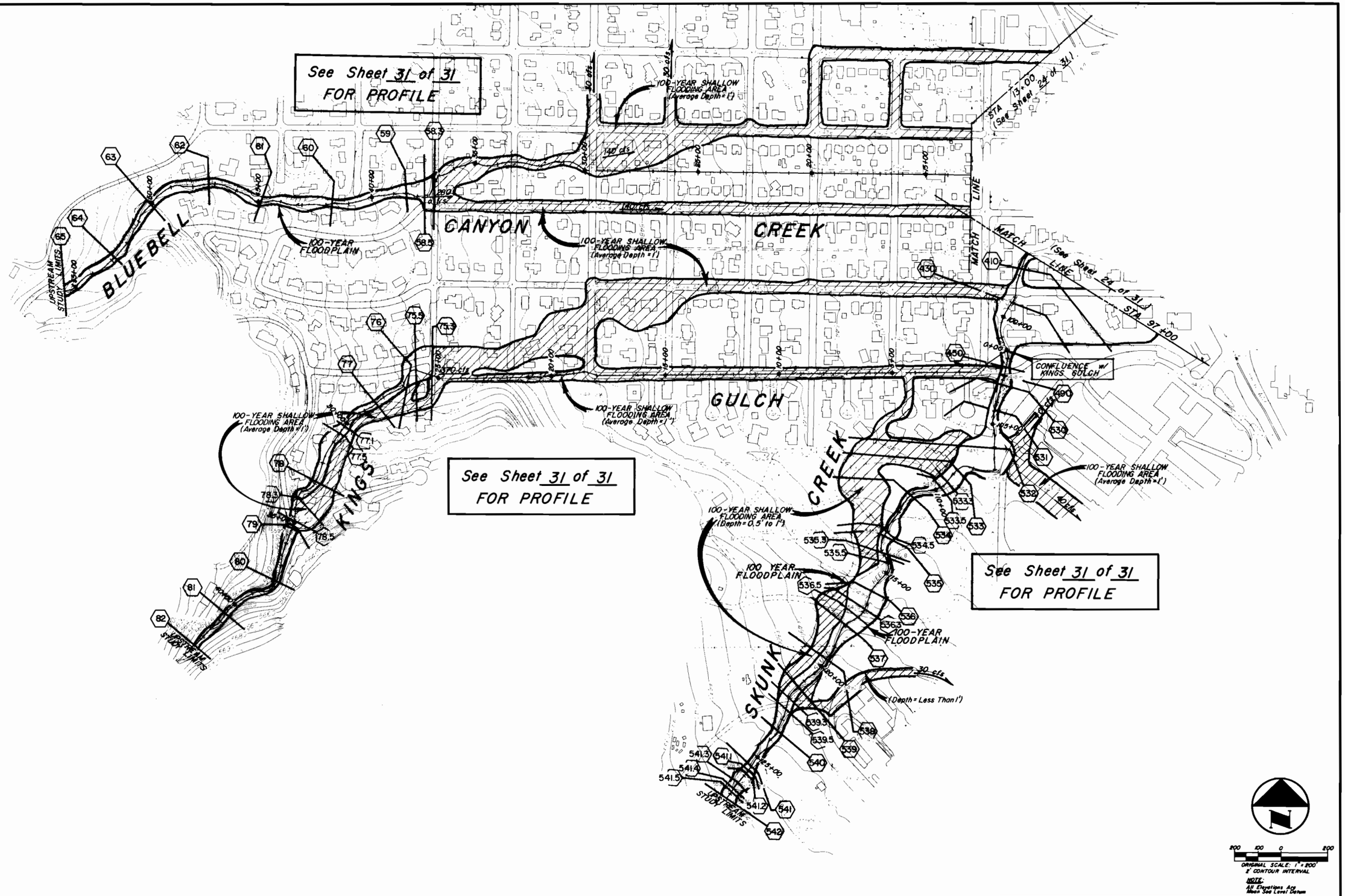
SHEET 1 of 31



DRAINAGE BASINS/SOUTH

SCALE: 1"=4000'

SHEET 3 of 31



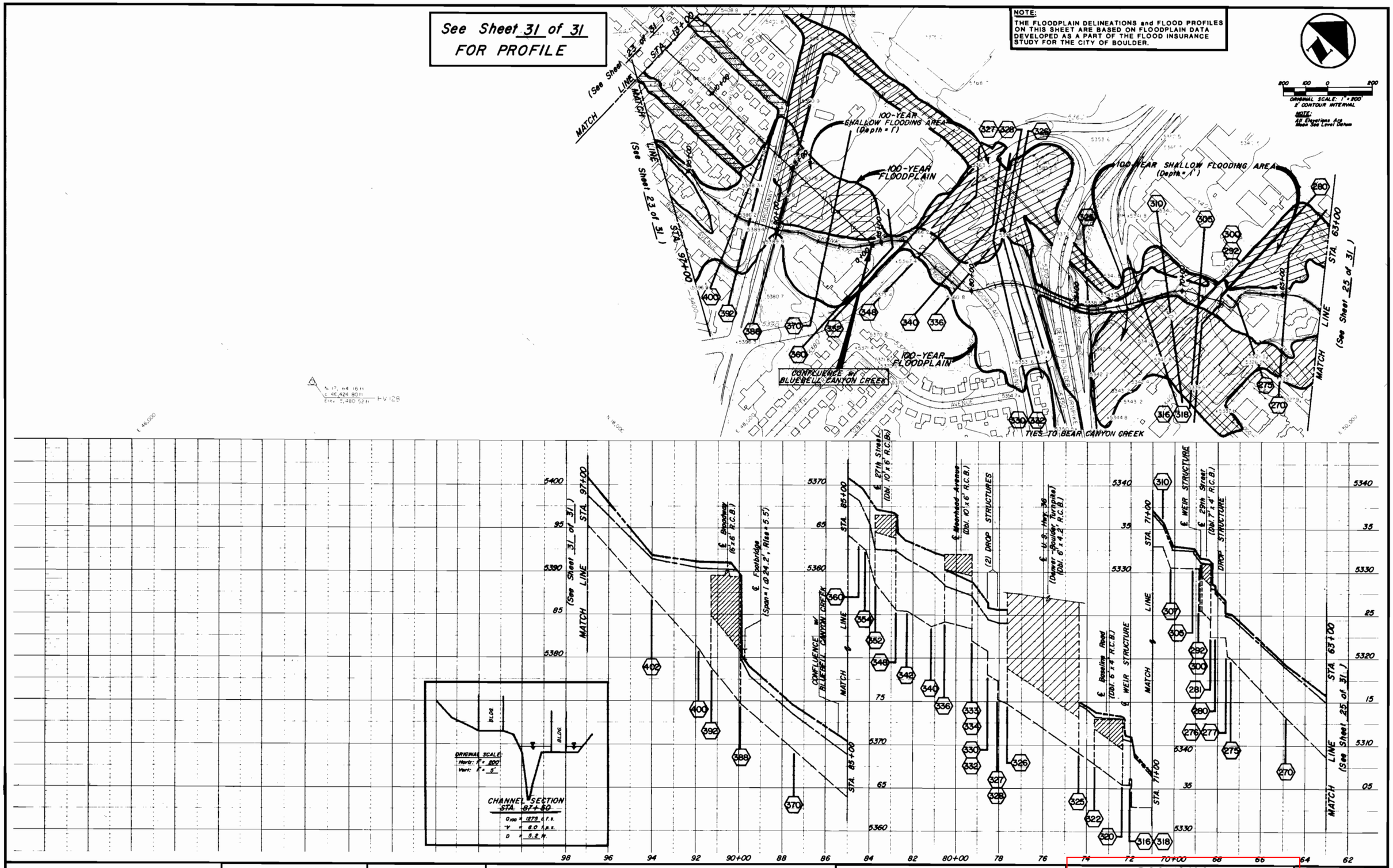
NOTE:
All Elevations Are Above Sea Level Datum

ORIGINAL SCALE: 1" = 200'
2' CONTOUR INTERVAL

GREENHORNE and O'MARA, INC. Engineers · Architects · Planners · Surveyors · Photogrammetrists 1325 South Colorado Boulevard · Suite 405 · Denver, Colorado 80222 · (303) 758-5250	Ground Control Survey By: MSM CONSULTANTS, INC. Aerial Photography By: GENGE AERIAL SURVEYS Topographic Mapping By: GENGE AERIAL SURVEYS Contour Interval: 2' Date Flown: OCTOBER 10, 1981	Designed By: MKP Date: 6/84 Drawn By: CDS Date: 9/84 Checked By: RLL Date: 9/84 Revised By: ____ Date: ____	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT CITY OF BOULDER - BOULDER COUNTY	FLOOD HAZARD AREA DELINEATION CITY of BOULDER and ADJACENT COUNTY DRAINAGEWAYS	BLUEBELL CANYON CREEK KINGS GULCH SKUNK CREEK	JOB NO. 0680-FHD-415 SHEET 23 OF 31

See Sheet 31 of 31
FOR PROFILE

NOTE:
THE FLOODPLAIN DELINEATIONS and FLOOD PROFILES ON THIS SHEET ARE BASED ON FLOODPLAIN DATA DEVELOPED AS A PART OF THE FLOOD INSURANCE STUDY FOR THE CITY OF BOULDER.



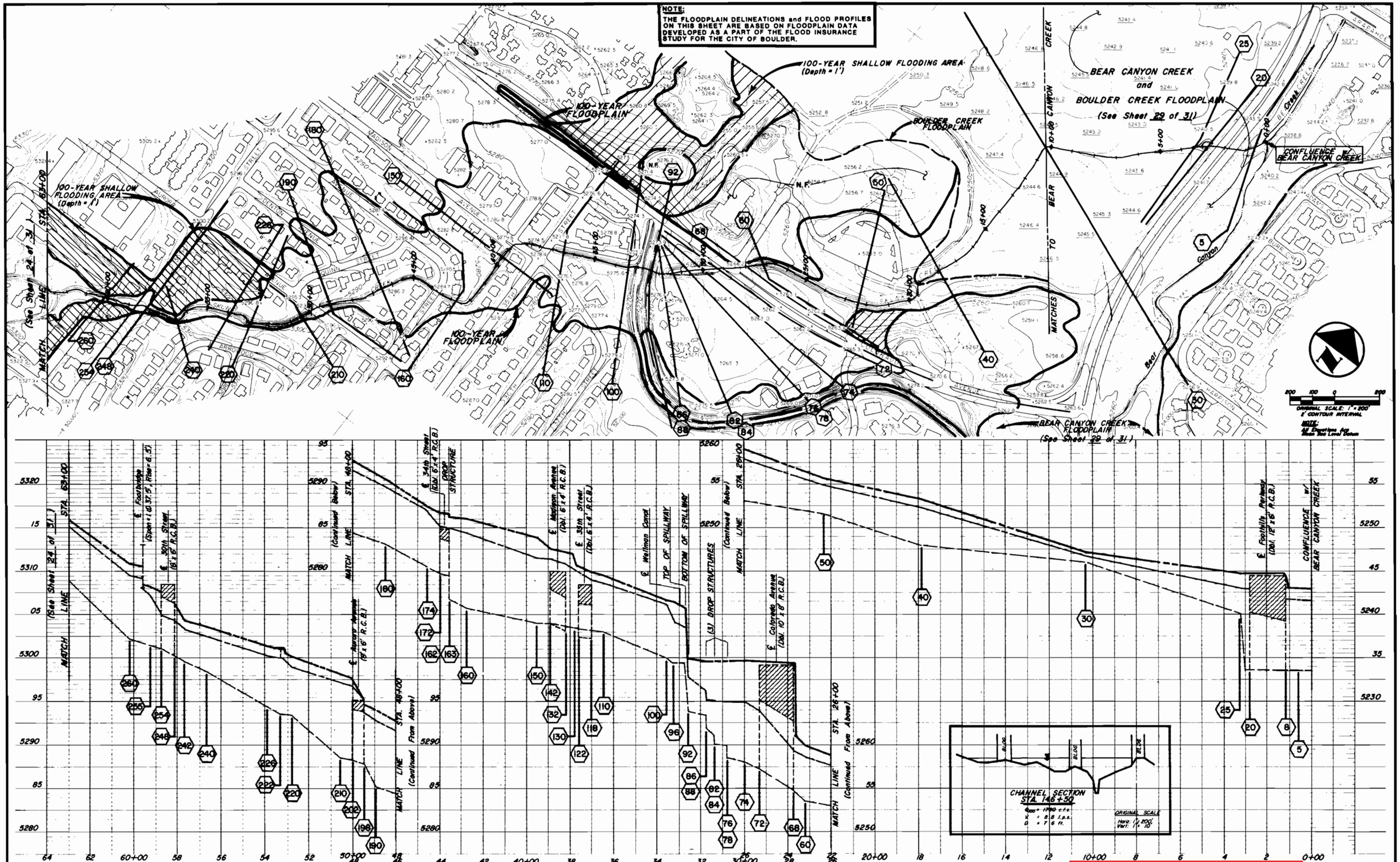
GREENHORNE and O'MARA, INC. Engineers · Architects · Planners · Surveyors · Photogrammetrists. 1325 South Colorado Boulevard · Suite 405 · Denver, Colorado 80222 · (303) 758-5250	Ground Control Survey By: MSM CONSULTANTS, INC. Aerial Photography By: GENGE AERIAL SURVEYS. Topographic Mapping By: GENGE AERIAL SURVEYS. Contour Interval: 2' Date Flown: OCTOBER 10, 1981	Designed By: ____ Date: ____ Drawn By: CDS Date: 4/84 Checked By: RLL Date: 4/84 Revised By: ____ Date: ____	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT CITY OF BOULDER – BOULDER COUNTY

FLOOD HAZARD AREA DELINEATION
CITY of BOULDER
and
ADJACENT COUNTY DRAINAGEWAYS

SKUNK CREEK
(STA. 63+00 TO STA. 97+00)

JOB NO. 0680-FHD-415
SHEET 24 OF 31

NOTE:
THE FLOODPLAIN DELINEATIONS and FLOOD PROFILES ON THIS SHEET ARE BASED ON FLOODPLAIN DATA DEVELOPED AS A PART OF THE FLOOD INSURANCE STUDY FOR THE CITY OF BOULDER.

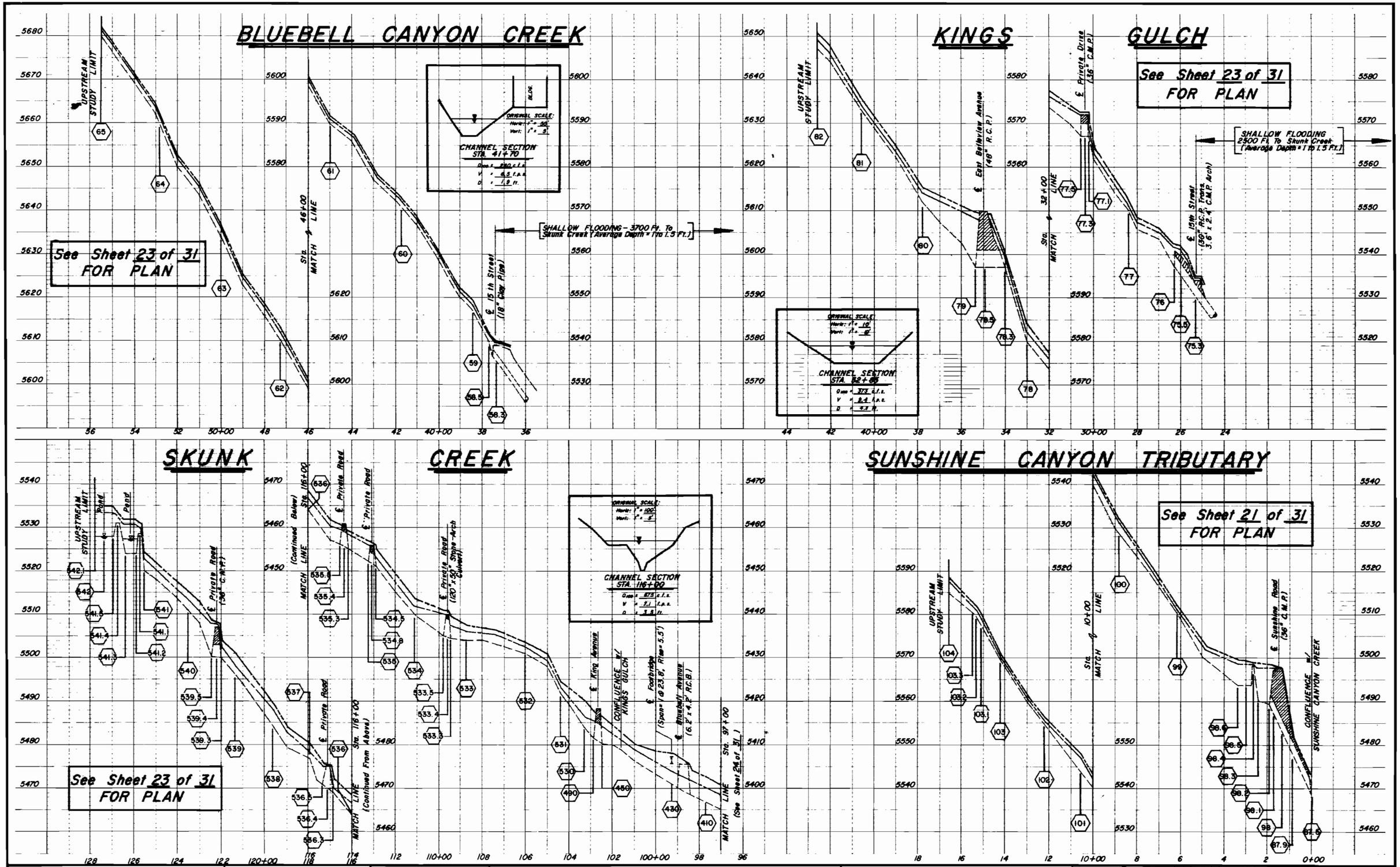


GREENHORNE and O'MARA, INC. Engineers · Architects · Planners · Surveyors · Photogrammetrists 1325 South Colorado Boulevard · Suite 405 · Denver, Colorado 80222 · (303) 758-5250	Ground Control Survey By: MSM CONSULTANTS, INC. Aerial Photography By: GENGE AERIAL SURVEYS Topographic Mapping By: GENGE AERIAL SURVEYS Contour Interval: 2' Date Flown: OCTOBER 10, 1981	Designed By: ____ Date: ____ Drawn By: DPS Date: 1/84 Checked By: RLL Date: 1/84 Revised By: ____ Date: ____	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT CITY OF BOULDER – BOULDER COUNTY

FLOOD HAZARD AREA DELINEATION
CITY of BOULDER and ADJACENT COUNTY DRAINAGEWAYS

SKUNK CREEK
(STA. 0+00 TO STA. 63+00)

JOB NO. 0680-FHD-415
SHEET 25 OF 31



GREENHORNE and O'MARA, INC. Engineers · Architects · Planners · Surveyors · Photogrammetrists 1325 South Colorado Boulevard · Suite 405 · Denver, Colorado 80222 · (303) 758-5250	Ground Control Survey By: MSM CONSULTANTS, INC. Aerial Photography By: GENGE AERIAL SURVEYS Topographic Mapping By: GENGE AERIAL SURVEYS Contour Interval: 2' Date Flown: OCTOBER 10, 1981	Designed By: NRP Date: 6/84 Drawn By: DDS Date: 9/84 Checked By: RCL Date: 9/84 Revised By: ____ Date ____	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT CITY OF BOULDER - BOULDER COUNTY	**FLOOD HAZARD AREA DELINEATION** CITY of BOULDER and ADJACENT COUNTY DRAINAGEWAYS

BLUEBELL CANYON CREEK
KINGS GULCH · SKUNK CREEK
SUNSHINE CANYON TRIBUTARY

JOB NO. 0680-FHD-415
SHEET 31
OF 31

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
CONFLUENCE WITH BEAR CANYON CREEK		0+00								
	5	0+60	2225	5233.6	5243.0	(2)	670	225	925	5243.0
FOOTHILLS PARKWAY										
	20	2+80	2225	5233.6	5244.8	(2)	675	460	1135	5244.8
	25	3+20	2225	5240.0	5244.8	(2)	675	425	1100	5244.8
	30	10+30	2225	5246.0	5247.6	(2)	300	565	865	5247.2
	40	17+80	2225	5248.0	5253.0	420	135	135	270	5253.3
	50	22+30	2225	5251.5	5255.8	660	350	25	375	5255.7
	60	27+20	2225	5253.5	5259.9	630	25	30	55	5259.9
COLORADO AVENUE		28+50								
BOTTOM OF SPILLWAY	92	32+60	2225	5263.8	5269.9	530	15	25	40	5269.2
WELLMAN CANAL		33+00								
	100	33+60	2225	5270.0	5276.6	605	325	220	545	5276.6
	110	36+50	2225	5273.0	5279.5	685	325	220	545	5279.5
35th STREET		37+30								
MADISON AVENUE		38+55								
	150	39+50	2225	5274.0	5283.9	560	210	185	395	5283.9
	160	42+70	1875	5275.7	5286.0	535	290	15	305	5286.2
34th STREET		43+75								

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.
(2) INFLUENCED BY FLOODING FROM BOULDER AND BEAR CREEKS. REFER TO MAP SHEET.

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
	180	46+50	1780	5283.2	5290.7	820	200	250	450	5290.8
	190	48+90	1780	5285.2	5294.1	735	215	365	580	5294.2
AURORA AVENUE		49+75								
	210	50+60	1780	5288.6	5297.9	675	140	20	160	5297.9
	220	52+80	1690	5293.5	5300.2	310	140	15	155	5300.2
	226	53+90	1690	5294.5	5301.3	380	120	30	150	5301.3
	240	56+70	1690	5298.5	5303.6	285	270	15	285	5303.6
	248	58+10	1690	5300.3	5306.9	490	200	15	215	5307.0
30th STREET		58+40								
	260	60+20	899	5302.2	5310.8	260	35	15	50	5310.8
	270	64+90	819	5313.3	5320.5	775	25	50	75	5320.5
	280	68+10	819	5322.5	5329.9	610	75	20	95	5329.9
29th STREET		68+50								
WEIR		68+80								
	305	69+20	744	5330.5	5332.7	595	90	60	150	5332.7
	310	70+50	744	5333.0	5335.6	680	35	60	95	5335.7
WEIR	316	72+00	744	5333.0	5340.8	540	85	20	105	5340.8
	318	72+00	744	5336.0	5340.8	540	85	20	105	5340.8

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.
(2) INFLUENCED BY FLOODING FROM BOULDER AND BEAR CREEKS. REFER TO MAP SHEET.

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
BASELINE ROAD		73+10								
	325	74+10	674	5339.2	5345.0	570	20	75	95	5345.0
U.S. HIGHWAY 36		76+05								
DROP STRUCTURE	330	78+50	1350	5348.0	5357.9	1010	35	395	430	5357.9
DROP STRUCTURE	332	78+50	1350	5350.8	5357.6	1010	35	395	430	5357.6
MOORHEAD AVENUE		79+95								
	340	81+20	1350	5353.7	5362.6	655	40	45	85	5362.6
	348	82+80	1350	5355.5	5364.4	570	55	25	80	5364.4
27th STREET		83+80								
	360	84+50	1275	5363.3	5369.6	410	20	170	190	5369.7
CONFLUENCE WITH BLUEBELL CANYON CREEK		85+40								
	370	87+50	1275	5369.5	5374.7	630	20	265	285	5374.7
	388	89+90	1275	5374.3	5380.2	850	265	20	285	5380.2
BROADWAY		90+60								
	400	91+80	1275	5381.0	5391.1	580	205	225	430	5391.1
	410	97+80	675	5397.3	5402.9	535	15	25	40	5402.9
	430	99+25	675	5399.3	5408.2	360	30	30	60	5408.2
KING AVENUE	450	102+40	675	5410.5	5416.6	30	15	15	30	5416.6

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.
(2) INFLUENCED BY FLOODING FROM BOULDER AND BEAR CREEKS. REFER TO MAP SHEET.

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
	490	102+80	675	5411.5	5419.0	50	20	30	50	5418.0
	530	103+20	675	5414.0	5420.3	65	20	45	65	5420.3
	531	104+35	675	5422.0	5424.6	25	10	15	25	5424.6
	532	106+05	675	5431.0	5433.5	215	45	55	100	5433.5
	533	108+75	675	5433.7	5437.3	80	20	30	50	5437.3
	533.3	109+40	675	5434.5	5439.3	100	45	50	95	5439.3
	533.5	109+80	675	5435.0	5441.2	70	35	35	70	5441.2
	534	111+20	675	5440.0	5443.4	40	20	20	40	5443.4
	534.5	113+00	675	5451.0	5454.7	215	165	50	215	5454.7
CEMETERY ROAD 2	535	113+25	675	5451.0	5456.9	185	140	45	185	5456.9
	535.3	114+10	675	5455.0	5459.0	145	130	15	145	5459.0
CEMETERY ROAD 3	535.5	114+45	675	5455.5	5460.8	160	140	20	160	5460.8
	536	116+00	675	5465.0	5468.5	175	100	75	175	5468.5
	536.3	116+90	675	5469.0	5472.4	215	150	65	215	5472.4
CEMETERY ROAD 4	536.5	117+35	675	5471.0	5475.9	220	165	55	220	5475.9
	537	117+95	675	5477.0	5480.3	230	165	65	230	5480.3
	538	119+65	675	5485.0	5489.5	115	20	15	35	5489.5
	539	121+35	675	5496.0	5501.5	225	20	10	30	5500.7

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.
(2) INFLUENCED BY FLOODING FROM BOULDER AND BEAR CREEKS. REFER TO MAP SHEET.

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
	539.3	112+00	675	5500.0	5504.0	130	15	20	35	5504.3
	539.5	122+52	675	5500.0	5508.5	75	25	20	45	5508.5
	540	123+50	675	5511.0	5515.1	50	30	20	50	5515.1
	541	125+45	675	5520.0	5524.1	40	20	20	40	5524.1
	541.1	125+65	675	5528.5	5530.9	70	30	40	70	5530.9
	541.2	125+85	675	5524.0	5531.7	85	35	50	85	5531.7
	541.3	126+40	675	5524.0	5531.7	80	35	45	80	5531.7
	541.4	126+75	675	5531.0	5533.6	70	35	35	70	5533.6
	541.5	126+90	675	5528.0	5534.6	70	35	35	70	5534.6
	542	127+25	675	5531.0	5534.7	75	30	45	75	5534.7

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.
(2) INFLUENCED BY FLOODING FROM BOULDER AND BEAR CREEKS. REFER TO MAP SHEET.

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
15th STREET	58.3	37+00	269	5539.0	5540.1	165	35	130	165	5540.5
	58.5	37+60	280	5540.0	5541.7	145	75	70	145	5541.7
	59.0	38+50	280	5547.0	5549.0	75	55	20	75	5549.1
	60.0	41+75	280	5571.0	5572.9	35	20	15	35	5572.9
	61.0	44+90	280	5590.0	5591.7	40	25	15	40	5591.8
	62.0	47+30	280	2610.0	2612.9	30	15	15	30	5612.9
	63.0	50+10	280	5634.0	5636.0	35	15	20	35	5636.0
	64.0	52+80	280	5660.0	5662.2	40	25	15	40	5662.2
	65.0	55+50	280	5680.0	5682.0	40	15	25	40	5682.0

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.

FLOODING SOURCE				FLOODPLAIN DATA			FLOODWAY DATA			
IDENTIFICATION	CROSS-SECTION	STATION	100-YR. DISCHARGE (c.f.s.)	STREAM BED ELEVATION (m.s.l.)	100-YR. FLOOD ELEVATION (m.s.l.)	100-YR. WIDTH (Feet)	FLOODWAY WIDTH (1) LEFT (Feet)	RIGHT (Feet)	TOTAL (Feet)	FLOODWAY ELEVATION (m.s.l.)
15th STREET	75.3	25+30	339	5533.9	5534.7	270	125	12	137	5535.2
	75.5	26+00	339	5540.0	5541.9	270	40	25	65	5541.9
	76.0	26+30	373	5538.0	5542.5	265	40	15	55	5542.5
	77.0	28+50	373	5550.0	5552.6	100	10	10	20	5552.6
	77.1	30+20	373	5567.0	5569.9	75	14	10	24	5569.9
	77.5	30+60	373	5566.8	5573.1	105	45	25	70	5574.0
	78.0	32+90	373	5580.0	5584.1	110	12	12	24	5584.1
	78.3	34+05	373	5597.0	5600.9	160	10	12	22	5600.9
BELLEVUE AVENUE	78.5	34+90	373	5597.5	5609.6	115	15	43	58	5609.7
	79.0	35+25	373	5598.0	5609.9	60	30	20	50	5610.0
	80.0	37+70	373	5612.0	5615.7	25	10	10	20	5615.7
	81.0	40+55	373	5633.0	5635.9	40	12	14	26	5636.0
U/S STUDY LIMIT	82.0	42+50	373	5647.0	5650.8	30	6	15	21	5651.1

NOTES:

(1) FLOODWAY WIDTHS MEASURED LOOKING DOWNSTREAM.

FLOOD INSURANCE STUDY

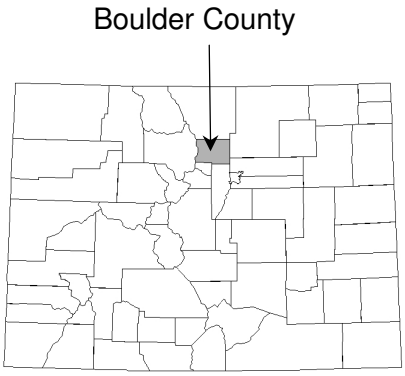
VOLUME 1 OF 4

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

Community Name	*Community Number*
BOULDER, CITY OF	080024
BOULDER COUNTY (UNINCORPORATED AREAS)	080023
ERIE, TOWN OF	080181
JAMESTOWN, TOWN OF	080216
LAFAYETTE, CITY OF	080026
LONGMONT, CITY OF	080027
LOUSIVILLE, CITY OF	085076
LYONS, TOWN OF	080029
NEDERLAND, TOWN OF	080255
SUPERIOR, TOWN OF	080203
*WARD, TOWN OF	080292

* No Special Flood Hazard Areas Identified



Revised: December 18, 2012

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
08013CV001B

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

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	

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)
SKUNK CREEK								
A	1,020	103	304	6.6	5,247.1	5,247.1	5,247.1	0.0
B	2,020	126	375	5.9	5,254.9	5,254.9	5,254.9	0.0
C	2,721	148	593	3.8	5,259.8	5,259.8	5,260.2	0.4
D	3,637	100	759	2.9	5,273.1	5,273.1	5,273.3	0.2
E	3,913	218	497	4.5	5,279.9	5,279.9	5,280.7	0.8
F	4,218	310	783	2.8	5,282.8	5,282.8	5,283.7	0.9
G	4,518	190	455	4.9	5,287.2	5,287.2	5,287.4	0.2
H	4,848	287	1,025	1.8	5,289.3	5,289.3	5,289.8	0.5
I	5,223	196	538	3.3	5,294.0	5,294.0	5,295.0	1.0
J	5,468	190	318	5.6	5,297.4	5,297.4	5,297.8	0.5
K	5,618	150	326	5.5	5,301.2	5,301.2	5,301.2	0.0
L	6,233	670	541	3.1	5,306.9	5,306.9	5,307.3	0.4
M	6,588	43	456	3.5	5,319.3	5,319.3	5,319.6	0.3
N	7,058	65	178	8.6	5,323.8	5,323.8	5,323.8	0.0
O	7,633	52	150	9.6	5,340.2	5,340.2	5,340.2	0.0
P	7,978	37	133	5.1	5,347.8	5,347.8	5,348.0	0.2
Q	8,428	38	211	6.4	5,359.4	5,359.4	5,359.8	0.4
R	8,698	68	296	4.6	5,365.6	5,365.6	5,365.8	0.2
S	9,018	49	187	6.8	5,372.9	5,372.9	5,373.0	0.1
T	9,318	79	257	5.0	5,378.0	5,378.0	5,378.4	0.4
U	9,753	420	1,471	0.9	5,394.4	5,394.4	5,394.7	0.3
V	10,338	40	127	5.3	5,406.2	5,406.2	5,406.2	0.0
W	10,758	22	86	7.9	5,418.1	5,418.1	5,418.2	0.1

[1]Feet above confluence with Bear Canyon Creek

TABLE 6

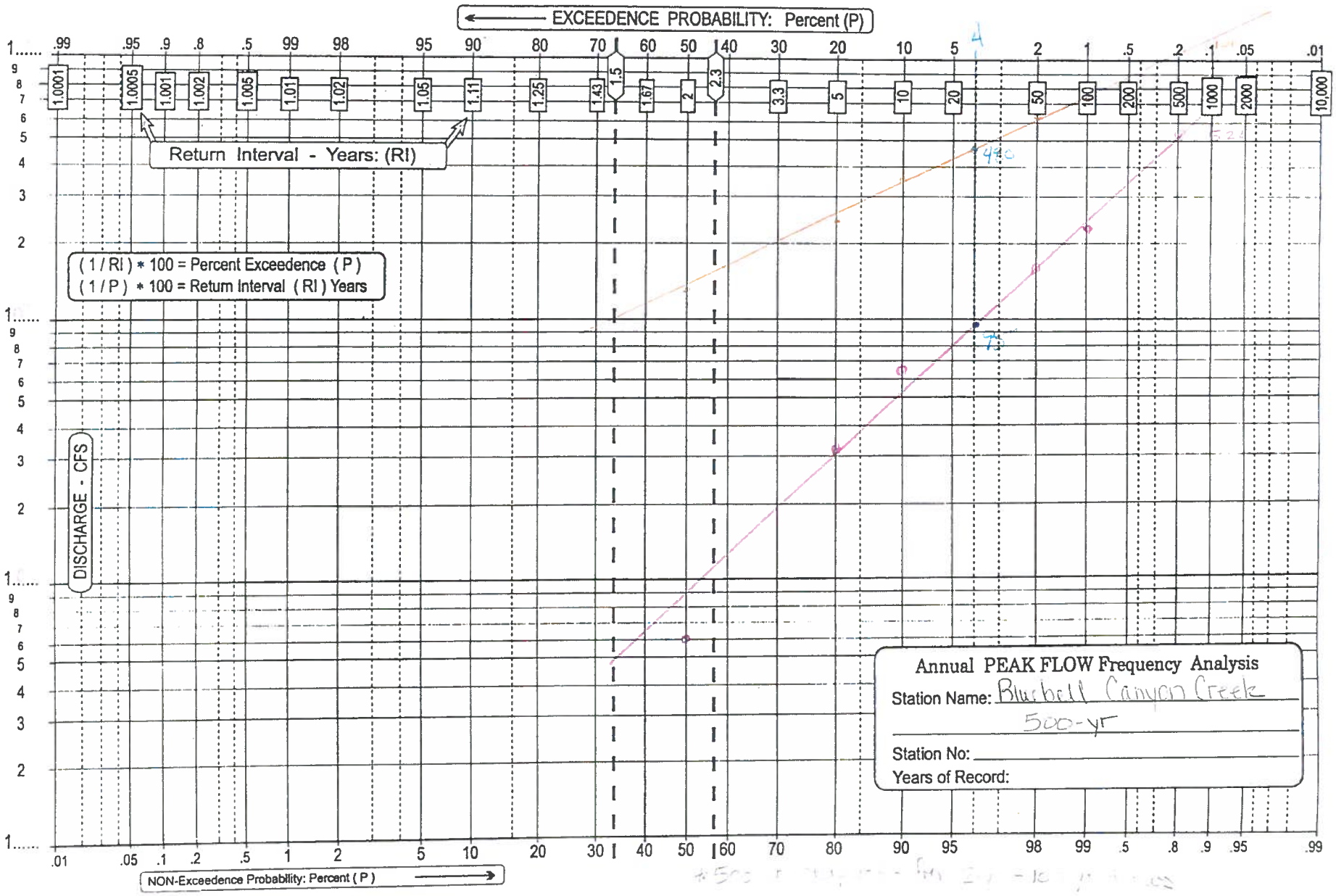
FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO
AND INCORPORATED AREAS

FLOODWAY DATA

SKUNK CREEK

25-yr (cfs)
520
75
480



* Intermediate flows btw. DS PAs 211 & 212 defined using this figure

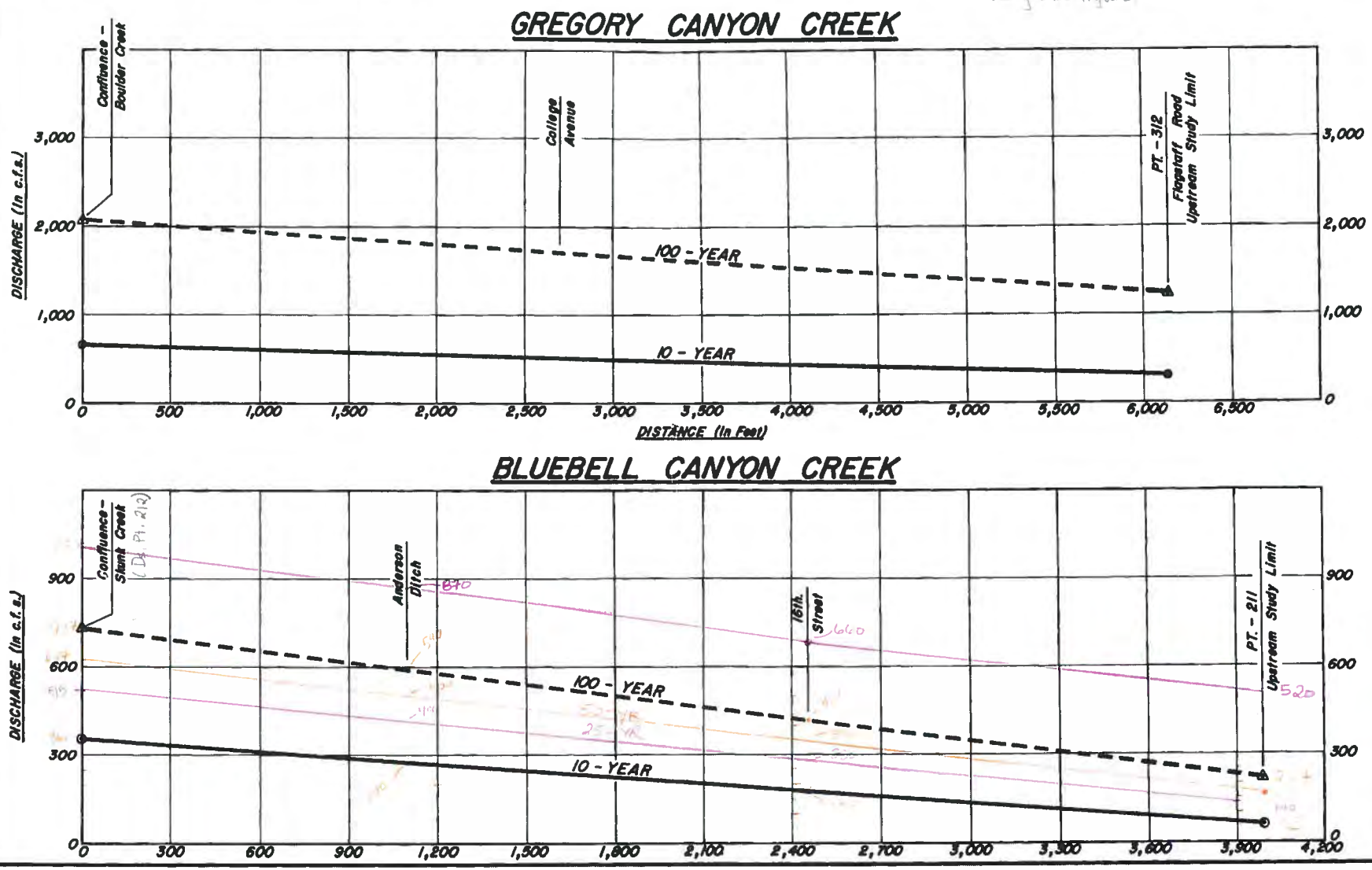
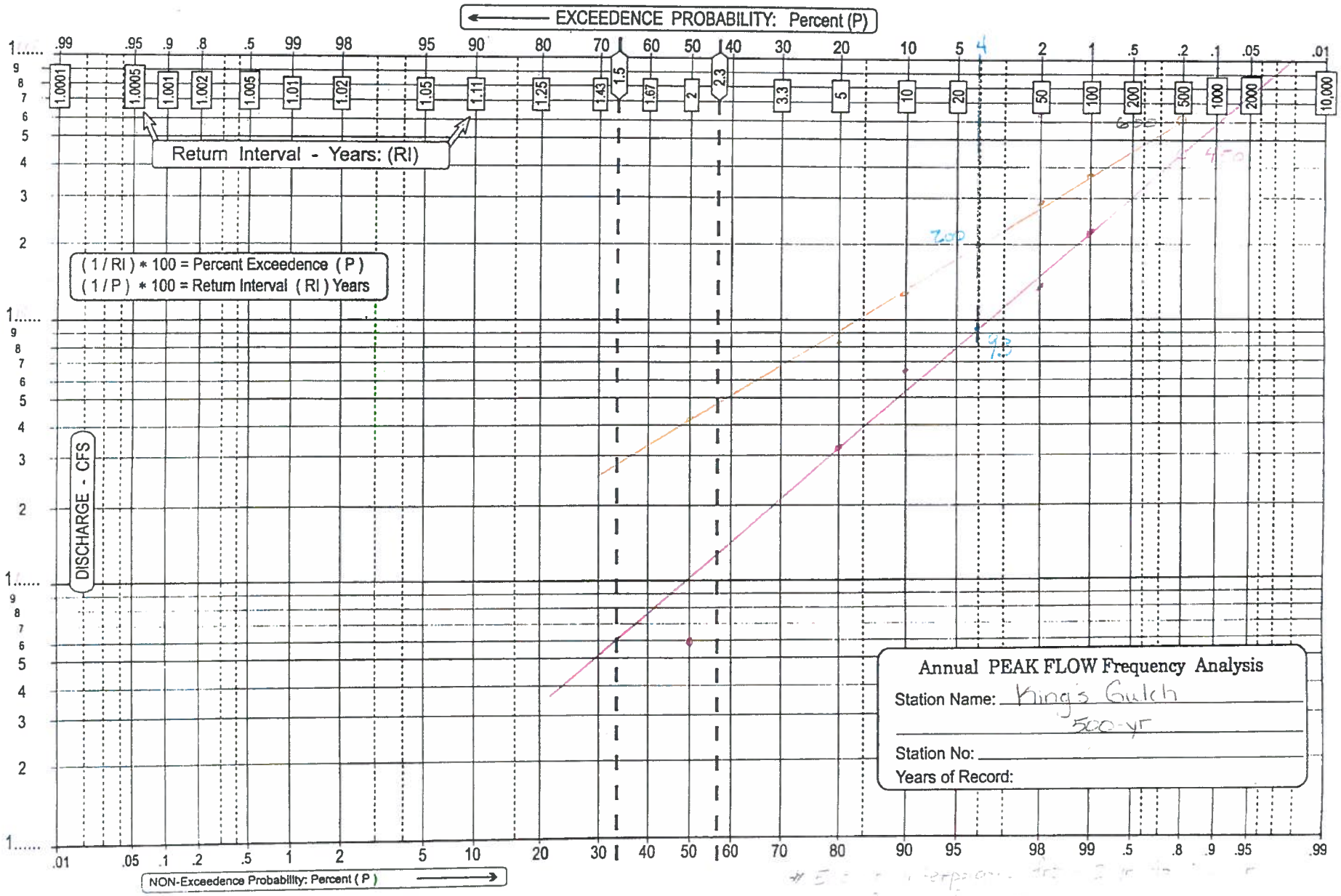


Figure 9


EXCEEDENCE PROBABILITY: Percent (P)
Return Interval - Years: (RI)
(1 / RI) * 100 = Percent Exceedence (P)
(1 / P) * 100 = Return Interval (RI) Years
DISCHARGE - CFS
NON-Exceedence Probability: Percent (P)
Annual PEAK FLOW Frequency Analysis
Station Name: Kings Gulch
500-yr
Station No:
Years of Record:

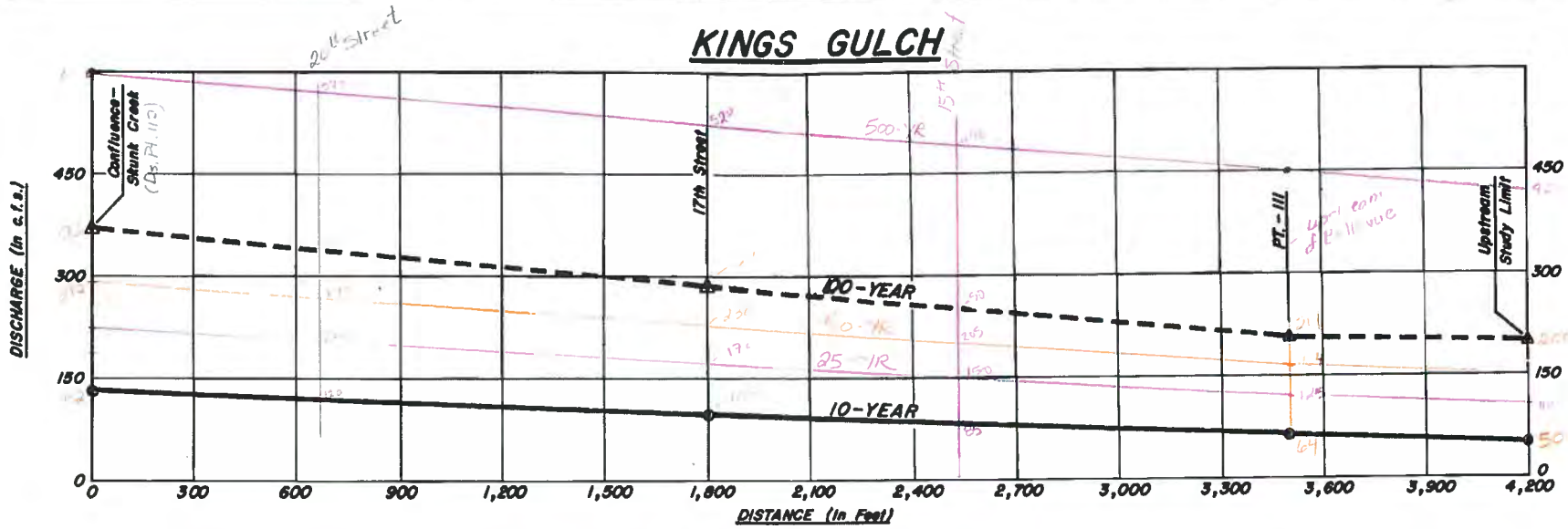

KINGS GULCH
DISCHARGE (In c.f.s.)
DISTANCE (In Feet)
Confluence-Skunk Creek
17th Street
PT. - III
Upstream Study Limit
100-YEAR
10-YEAR
0
150
300
450
0
300
600
900
1,200
1,500
1,800
2,100
2,400
2,700
3,000
3,300
3,600
3,900
4,200

Figure 11

Appendix 3 –
Hydraulic Modeling

Christie Coleman, P.E., CFM
1739 Broadway
Boulder, CO 80306

REF: 10-002A – Bluebell Canyon Creek, King's Gulch, and Skunk Creek Floodplain Restudy – Structure Blockage Assumptions

Dear Christie:

The floodplain restudy of Bluebell Canyon Creek, King's Gulch, and Skunk Creek includes a total of 29 hydraulic structures. A site-specific methodology was used to assign blockage values to each structure. First, the regulatory blockages were researched to identify the historically regulated blockages. Seven of the structures included in the restudy were not included in the regulatory Flood Hazard Area Delineation (FHAD) study. Then, each structure was inspected in the field and photographed. The land use characteristics upstream of each structure were noted including the level of vegetation, urban uses, residential uses, and potential for erosion. This information was used to assign a unique blockage value to each structure based on the structure type and size, presence or absence of upstream debris sources, and presence or absence of upstream structures which may intercept debris flow.

Blockages will be modeled by lowering the low chord of box culverts or bridges and by decreasing the diameter of culvert pipes. Where low flow channels exist through a box culvert, the low flow channel will be blocked first and then the low chord will be lowered to achieve the prescribed blockage. Handrails and guardrails at each structure were inspected individually and a handrail/guardrail blockage from 50% to 100% was assigned to each.

A comparison table is attached which shows the regulatory and proposed restudy blockages with justification for modifications to the regulatory blockages. A photo inventory of each structure is also attached for your use in reviewing the proposed blockage values.

Please contact us with any questions or comments. We are excited to be progressing with this study.

Sincerely,

Brianna L. Wallace

Brianna Wallace, P.E., CFM

Belt Collins West, Ltd. | 4909 Pearl East Circle, Suite 300 | Boulder, CO 80301-6100 USA
Tel: 303.442.4588 | Fax: 303.786.8026 | www.beltcollins.com | west@beltcollinswest.com

Belt Collins West is an Equal Opportunity Employer

Bluebell Canyon Creek, King's Gulch, and Skunk Creek Floodplain Modeling
Structure Blockage Assumptions
September 14, 2010

Structure Location	FHAD Blockage (%)	Revised Model Blockage (%)	Railing/Guardrail Obstructed	Type of Railing	Structure Description/Comments	Justification for Modified Blockage
BLUEBELL CANYON CREEK						
Enchanted Mesa Trail	N/A	50	N/A		semi-circular stone and concrete culvert, span = 12.5', rise = 6.25'	
KING'S GULCH						
Bellevue Drive	50	50	N/A	Back of sidewalk = top of road = 5612.65	4' diameter RCP	
Private Drive at 260 and 1425 Bellevue	25	25	N/A	Top of headwall = 5575.85	4' diameter CMP	
15th Street and adjacent to 1498 King Avenue	25	100	Yes	Residential Fence.	2.5' diameter RCP which ties into storm sewer and discharges to gabion channel	Blockage increased because storm sewer system assumed full during 10-yr events and greater.
17th Street (outlet is located east of 22nd Street at Skunk Creek)	25	100	N/A	Top of headwall = 5496.35	2' diameter RCP with drop inlet	Pipe acts as storm sewer main and is assumed full during 10-yr events and greater.
SKUNK CREEK						
King	50	50	Yes (50%)	One longitudinal tubular metal bar with three tubular posts. Assumed railing obstructs 50% of length of headwall (4.5').	1 cell culvert 7'w x 3'H	
Private Drive - 322 22nd	40	40	Yes (~50%)	One longitudinal metal plate with vertical and diagonal posts. Assumed railing obstructs flow for width of 10' over main channel.	rise over channel invert 5.4'H; deck width = 31.35'W	
Private Drive - 2200 Bluebell	40	40	Yes (~50%)	One longitudinal post with 3-4 vertical posts. Assumed railing obstructs flow for width of 10' over main channel.	rise over channel invert 5.3'H; deck width = 23.6'W	
Bluebell	30	30	Yes (50%)	Two longitudinal tubular metal bars with three tubular posts. Assumed railing obstructs 50% of length of headwall (3.75').	1 cell culvert 6'w x 4.5'H	
Broadway	30	10	N/A	Metal railing on top of headwall with glass/plastic cover. Broadway is not overtopped, so there is no impact from railing blockage.	1 cell culvert 22'w x 8'H.	Possible debris blockage from moderate upstream channel vegetation, but the structure is wide relative to others on Skunk Creek and was designed to pass the 100-yr event with freeboard. (Per discussions with the City, this blockage is modified from the previous restudy of upper Skunk Creek which used 0%.)
Footbridge	30	N/A			Structure was removed with reconstruction of Broadway underpass.	
Low Water Trail crossing d/s of B-way	N/A	100	N/A		5'W x 2.2'H	Small opening could easily become plugged with debris.
Low Water Trail crossing u/s of 27th Way	N/A	100	N/A		12'W x 4'H RCBC. See as-builts pg. 70.	Small opening could easily become plugged with debris.
27th Way	0	10	Yes (100%)	Three longitudinal metal bars with multiple vertical posts. 27th Way is not overtopped so there is no impact from railing blockage.	1 cell culvert 20'w x 8'H.	Possible debris blockage from moderate u/s channel vegetation, but structure is wide relative to others on Skunk and was designed to pass the 100-yr event with freeboard. (Per discussions with the City, blockage is modified from previous restudy of upper Skunk Creek which used 0%.)
Moorhead Avenue	0	15	Yes (50%)	approximatley every 4-ft. Assumed railing obstructs 50% of length of headwall (11.5').	2 cell culvert 10'w x 5.8'H	Possible debris blockage from channel vegetation and trees.
US 36/28th St. On Ramp South of Baseline	N/A	15	Yes		1 cell culvert 14'W x 7.5'H; Blockage created by sump condition on outlet side of box. Actual modeled blockage resulting from sump condition = 34%.	Limited debris blockage possible from Skunk Creek main channel and upstream parking area.

US 36	0	30	N/A	This structure analyzed for capacity in separate model. Elevation given is top of riprap gabion wall elevation.	U/S 2 cell culvert 6'w x 4'H	north and south of the channel could contribute to debris blockage during a flood.
US 36/28th St. On Ramp North of Baseline	N/A	5	Yes	Guardrail. Box is in sump condition. Actual blockage after accounting for sump is 56%.	1 cell culvert 14'w x 7.1'H	No significant sources of upstream debris.
Low Water Trail Crossing	N/A	75	N/A		1 cell culvert 14.7w x 3.4'; Unstable solution (profiles cross) when 100% blockage used.	Small opening could easily become plugged with debris, but opening is larger than low flow crossings at Broadway and 27th Way. Less debris sources because it's located immediately downstream of US36 culvert outlet.
Pedestrian Bridge	30	30	Yes	Timber railing, 2 longitudinal, 4 vertical, paneled fence over upstream wingwalls. Assumed railing obstructs 75% of length of headwall and wingwalls (32').	bridge opening 14.8'w x 3.7'H.	
29th	10	10	No	Assume no railing blockage, no separate railing for 29th Street box, pedestrian bridge railing serves 29th Street.	at this location would be captured by the pedestrian bridge located immediately	
30th Street	30	30	Yes	Tubular metal railing with 3 longitudinal bars and multiple vertical posts. Railing extends along wingwalls and stone retaining wall upstream. Assume railing above headwall is 100% blocked.	1 cell culvert 8'w x 6'H	
Arrowood Park Pedestrian Bridge	30	30	Yes (100%)	Wire mesh railing. Assume 100% blocked.	bridge opening ~32.95'W x 5.3'H(max)	
Aurora Avenue	10	20	Yes (100%)	8 longitudnal metal bars, multiple vertical metal bars. Assume railing above headwall and wingwalls is 100% obstructed.	1 cell culvert 8'w x 6'H	Dense vegetation, but upstream residential density is less than at 34th, Madison, and 35th Streets.
34th Street	20	20	Yes (50%)	2 longitudnal bars, 3 vertical bars. Assumed railing obstructs 50% of length of headwall (7').	2 cell culvert 6'w x 3.5'H	
Madison Avenue - East Cell	30	30	Yes (75%)	3 longitudnal bars, multiple horizontal bars. Assume railing obstructs 75% of length of headwall (14.2').	2 cell culvert 6'w x 4'H	
Madison Avenue - West Cell	100	30	Yes (75%)			West cell does not appear more obstructed than the east cell.
35th Street	50	30	Yes (50%)	2 longitudnal bars, 4 vertical bars. Assumed railing obstructs 50% of length of headwall (7.6').	2 cell culvert 6'w x 4'H	Stream channel appears mostly smooth with minimal debris accumulation.
Wellman Canal	N/A	100	N/A		2' diameter RCP	Backwater effects would submerge pipe outlet during 10-yr and greater storm events.
Colorado Avenue	0	5	Yes (50%)	2 longitudnal rails, 5 vertical bars. Assume railing obstructs 50% of length of headwall (17.5')	2 cell culvert; bike path box = 9.9'w x 7.3'H. Stream box = 9.9'w x 8.2'h	Some limited blockage potential from upstream vegetation. Only limited potential for residential debris accumulation upstream of this crossing. Much of the debris in Skunk Creek will be caught at the Wellman Canal upstream of Colorado Avenue. This structure is wide relative to most others on Skunk Creek and was designed to pass the 100-yr event.

Enchanted Mesa Trail at Bluebell Canyon Creek
Semi-circular stone and concrete culvert, span = 12.5', rise = 6.25'
Not modeled in FHAD. Restudy blockage = 50%.

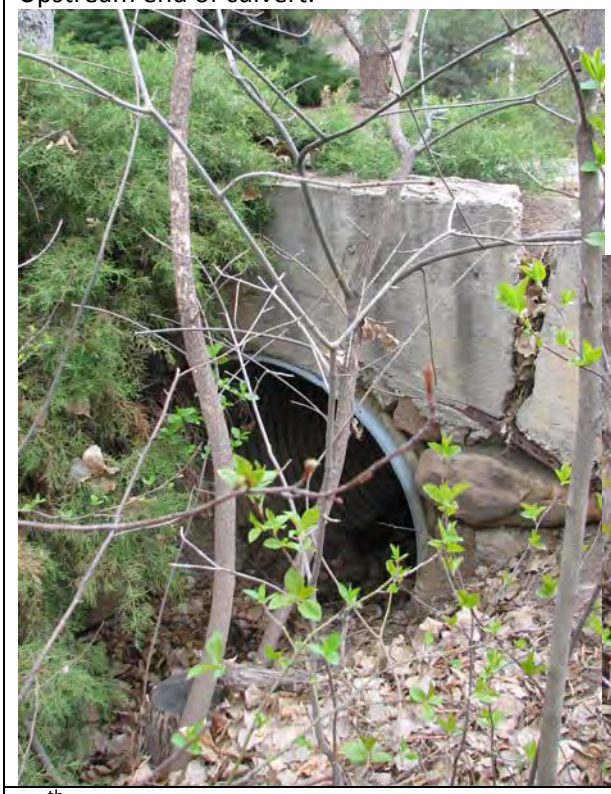
Bellevue Drive at King's Gulch
4' diameter RCP
FHAD Blockage = 50%, Restudy Blockage = 50%

Upstream end of culvert.

Downstream end of culvert.

Private Drive for 260 and 1425 Bellevue Drive at King's Gulch
4' diameter CMP
FHAD Blockage = 25%, Restudy Blockage = 25%

Upstream end of culvert.



Downstream end of culvert.

15th Street at King's Gulch and adjacent to 1498 King Avenue
2.5' diameter RCP
FHAD Blockage = 25%, Restudy Blockage = 100%

Upstream end of culvert.

Downstream end of culvert.

17th Street at King's Gulch
2' diameter RCP with drop inlet
FHAD Blockage = 25%, Restudy Blockage = 100%

Upstream end of pipe.

Downstream end of pipe.

Colorado Avenue at Skunk Creek looking downstream
2 cell culvert 10'W x 8'H.
FHAD blockage = 0%, Restudy blockage = 5%

Wellman Canal at Skunk Creek looking north.
Intake and overflow structure with 2’ culvert under canal.
FHAD blockage = N/A. Restudy blockage of 2’ culvert under canal = 100%

35th Street at Skunk Creek looking downstream.
2 cell culvert 6’W x 4'H
FHAD blockage = 50%. Restudy Assumed blockage = 30%

Madison Avenue at Skunk Creek looking downstream.
2 cell culvert 6'W x 4'H
FHAD blockage = 100% west cell, 30% east cell. Restudy blockage = 30%

34th Street at Skunk Creek looking downstream.
2 cell culvert 6'W x 3.5'H
FHAD blockage = 20%. Restudy blockage = 20%

Aurora Avenue at Skunk Creek looking downstream.
1 cell culvert 8’W x 6'H
FHAD blockage = 10%. Restudy blockage = 20%

Foot bridge at Skunk Creek looking downstream.
Bridge opening ~32.95'W x 5.3'H(max)
FHAD blockage = 30%. Restudy blockage = 30%

30th Street at Skunk Creek looking downstream.
1 cell culvert 8'W x 6'H
FHAD blockage = 30%. Restudy blockage = 30%

29th Street at Skunk Creek looking downstream.
Pedestrian Bridge 14.8'W x 3.7'H
FHAD blockage = 30%. Restudy blockage = 30%
2 cell culvert 7'W x 4'H
FHAD blockage = 10%. Restudy blockage = 10%

Low Water Trail Crossing downstream of Baseline
Open Area 14.7'W x 1.3 to 3.5'H
FHAD blockage = N/A. Restudy blockage = 100%

Upstream end.

Downstream end.

US 36/28th St. On Ramp North of Baseline
1 cell box culvert 14'W x 7.1'H
FHAD Blockage = N/A, Restudy blockage = 5%
Looking upstream.

Service Road, pipe under US 36 with outlet d/s of Baseline.
2 cell culvert 6'W x 4'H
FHAD blockage = 0%. Restudy blockage = 30%
Upstream end of box culvert.

US36/28th Street On-Ramp South of Baseline looking east.
1 cell culvert 14'W x 7.5'H
FHAD blockage = N/A Restudy blockage = 15%

Moorehead Avenue looking downstream.
2 cell culvert 10'W x 6'H
FHAD blockage = 0%. Restudy blockage = 15%

27th Way at Skunk Creek looking upstream.
1 cell 20'W x 8'H
FHAD Blockage = 0%, Restudy Blockage = 10%
Low Water Trail Crossing Downstream of Broadway – FHAD Blockage = N/A, Restudy Blockage = 100%

Broadway at Skunk Creek looking at downstream face and low flow channel.
1 cell culvert 22'w x 8'H.
Broadway Box Culvert - FHAD Blockage = 30%, Restudy Blockage = 10%
Low Water Trail Crossing Downstream of Broadway – FHAD Blockage = N/A, Restudy Blockage = 100%

Bluebell Avenue at Skunk Creek
1 cell culvert 6'w x 3.2'H
FHAD Blockage = 30%, Restudy Blockage = 30%

Downstream of Bluebell Avenue.

Upstream face of Bluebell Avenue.

Private Drive at 2200 Bluebell Avenue
Bridge opening 10'w x 3.9'H
FHAD Blockage = 40%, Restudy Blockage = 40%

Downstream face

Bridge Deck

Private Drive at 322 22nd Street
bridge opening 10'w x 2.7'H
FHAD Blockage = 40%, Restudy Blockage = 40%

Bridge deck

Upstream face

King's Avenue at Skunk Creek
1 cell culvert 7'w x 1.5'H
FHAD Blockage = 50%, Restudy Blockage = 50%

Downstream face

Looking upstream

HY-8 Culvert Analysis Report

Baseline Pedestrian Culvert

Table 1 - Summary of Culvert Flows at Crossing: BASELINE-PED-BOX

Headwater Elevation (ft)	Total Discharge (cfs)	BASELINE-PED-BOX Discharge (cfs)	Roadway Discharge (cfs)	Iterations
44.69	0.00	0.00	0.00	1
44.84	16.26	16.26	0.00	1
44.84	32.52	32.52	0.00	1
44.85	48.78	48.78	0.00	1
44.85	65.04	65.04	0.00	1
44.86	81.30	81.30	0.00	1
44.87	97.56	97.56	0.00	1
44.89	113.82	113.82	0.00	1
44.75	130.08	130.08	0.00	1
44.77	146.34	146.34	0.00	1
44.78	162.60	162.60	0.00	1
47.00	797.08	797.08	0.00	Overtopping

Rating Curve Plot for Crossing: BASELINE-PED-BOX

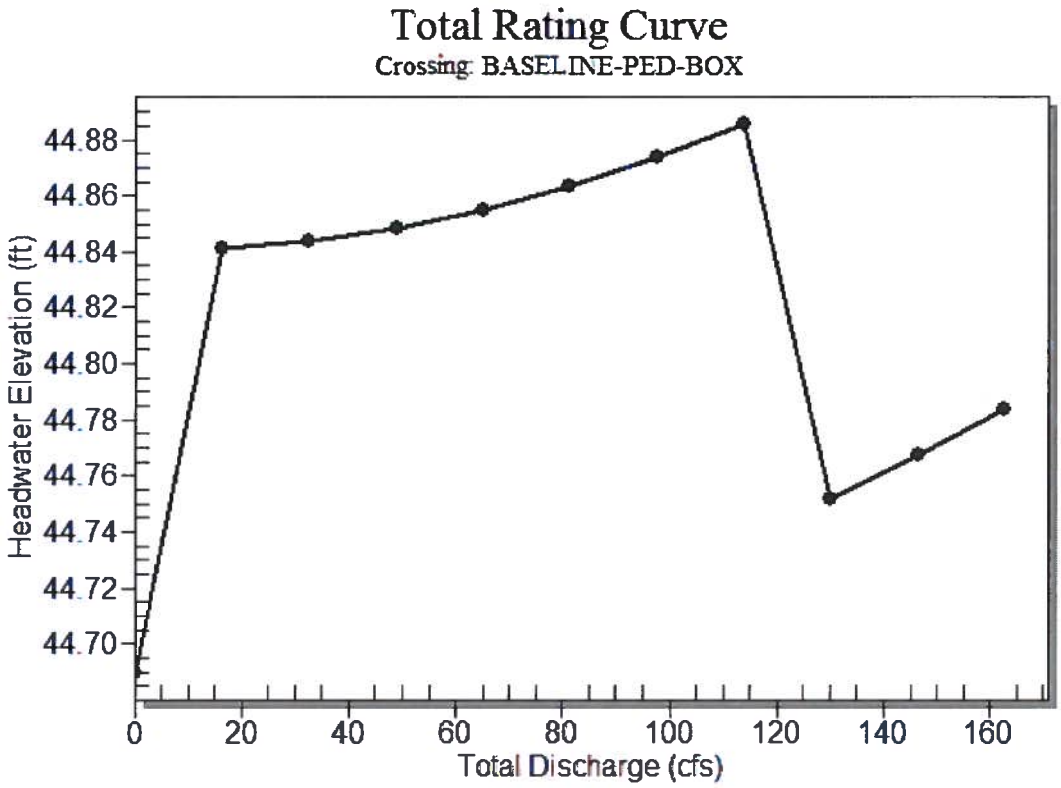


Table 2 - Culvert Summary Table: BASELINE-PED-BOX

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	44.69	0.000	5.690	0-NF	0.000	0.000	0.000	6.590	0.000	0.000
16.26	16.26	44.84	0.794	5.841	1-S1t	0.153	0.348	6.590	6.590	0.176	0.000
32.52	32.52	44.84	1.023	5.844	1-S1t	0.306	0.552	6.590	6.590	0.352	0.000
48.78	48.78	44.85	1.252	5.848	1-S1t	0.459	0.724	6.590	6.590	0.529	0.000
65.04	65.04	44.85	1.499	5.855	1-S1t	0.611	0.877	6.590	6.590	0.705	0.000
81.30	81.30	44.86	1.746	5.863	1-S1t	0.764	1.018	6.590	6.590	0.881	0.000
97.56	97.56	44.87	1.973	5.874	1-S1t	0.859	1.149	6.590	6.590	1.057	0.000
113.82	113.82	44.89	2.184	5.886	1-S1t	0.937	1.274	6.590	6.590	1.234	0.000
130.08	130.08	44.75	2.382	5.752	1-S1t	1.014	1.392	6.590	6.590	1.410	0.000
146.34	146.34	44.77	2.570	5.767	1-S1t	1.092	1.506	6.590	6.590	1.586	0.000
162.60	162.60	44.78	2.751	5.784	1-S1t	1.169	1.615	6.590	6.590	1.762	0.000

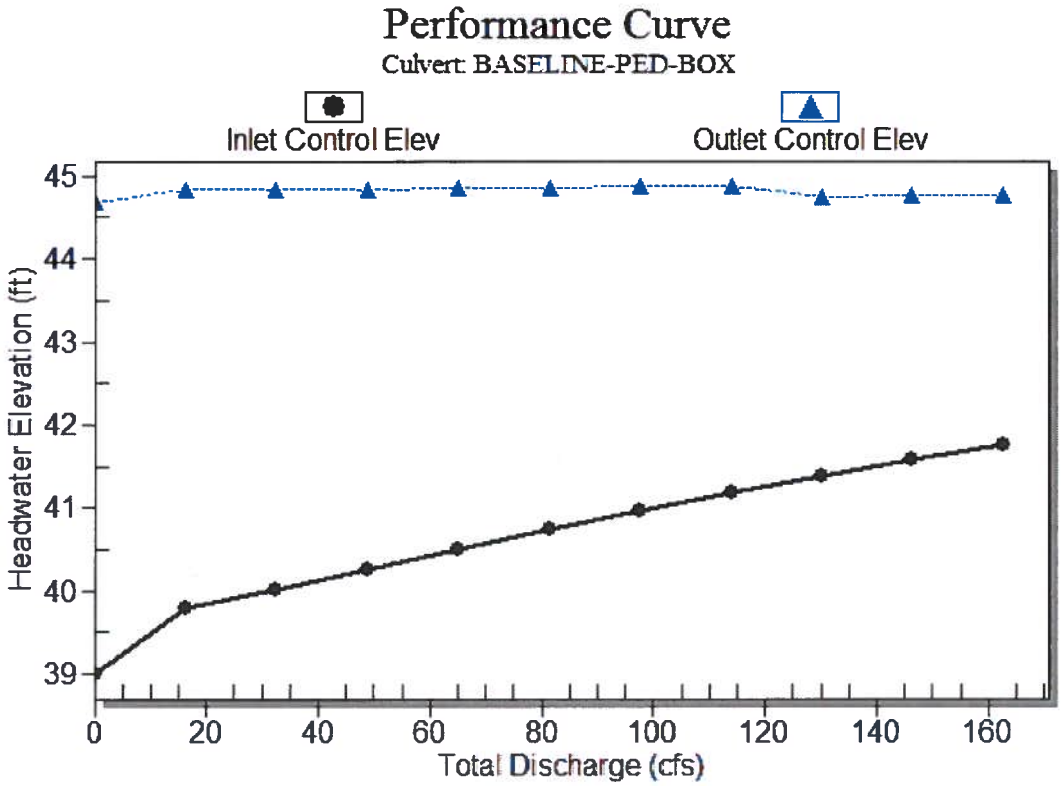
****

Inlet Elevation (invert): 39.00 ft, Outlet Elevation (invert): 38.10 ft

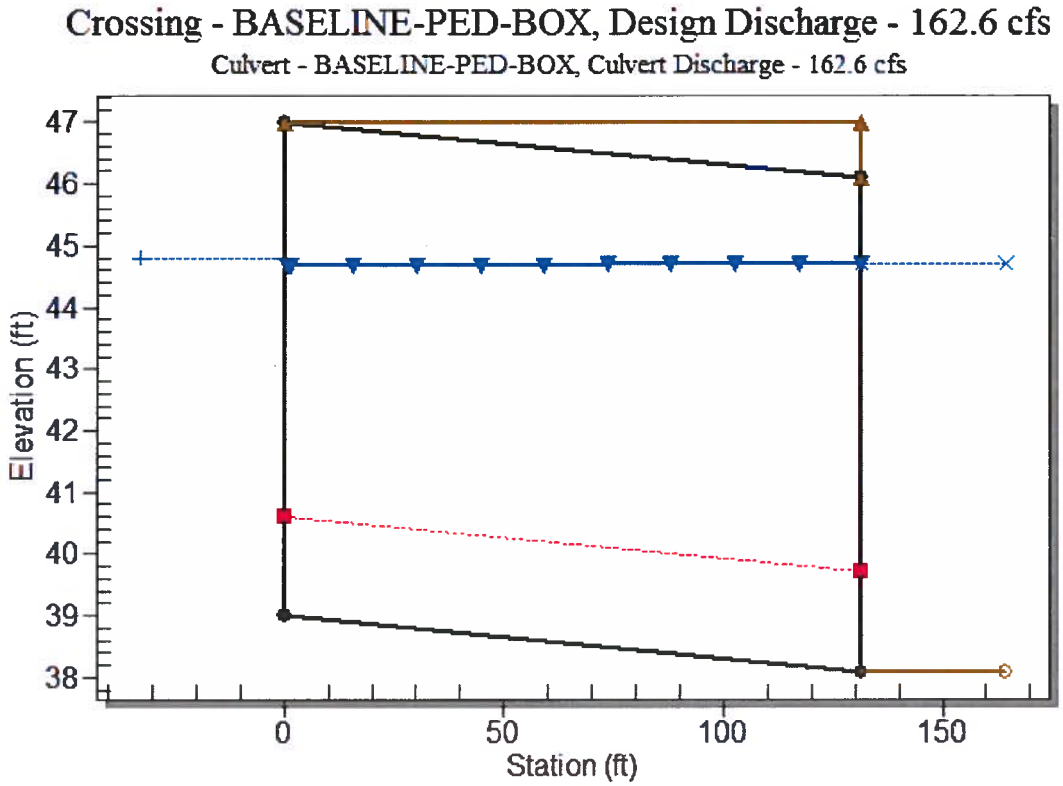
Culvert Length: 131.50 ft, Culvert Slope: 0.0068

****

Culvert Performance Curve Plot: BASELINE-PED-BOX



Water Surface Profile Plot for Culvert: BASELINE-PED-BOX



Site Data - BASELINE-PED-BOX

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 39.00 ft

Outlet Station: 131.50 ft

Outlet Elevation: 38.10 ft

Number of Barrels: 1

Culvert Data Summary - BASELINE-PED-BOX

Barrel Shape: Concrete Box

Barrel Span: 14.00 ft

Barrel Rise: 8.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: BASELINE-PED-BOX)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
0.00	44.69	6.59
16.26	44.69	6.59
32.52	44.69	6.59
48.78	44.69	6.59
65.04	44.69	6.59
81.30	44.69	6.59
97.56	44.69	6.59
113.82	44.69	6.59
130.08	44.69	6.59
146.34	44.69	6.59
162.60	44.69	6.59

Tailwater Channel Data - BASELINE-PED-BOX

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 44.69 ft

Roadway Data for Crossing: BASELINE-PED-BOX

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 47.00 ft

Roadway Surface: Paved

Roadway Top Width: 131.50 ft

HY-8 Culvert Analysis Report

Hwy 36 Culvert

Table 1 - Summary of Culvert Flows at Crossing: US 36

Headwater Elevation (ft)	Total Discharge (cfs)	US 36 DOUBLE BOX CULVERT Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5348.70	0.00	0.00	0.00	1
5350.49	75.00	75.00	0.00	1
5351.55	150.00	150.00	0.00	1
5352.66	225.00	225.00	0.00	1
5354.07	300.00	300.00	0.00	1
5355.90	375.00	375.00	0.00	1
5358.27	450.00	450.00	0.00	1
5360.19	500.00	500.00	0.00	1
5361.05	600.00	520.89	79.07	4
5361.38	675.00	528.69	146.14	4
5361.67	750.00	535.36	214.53	4
5360.40	505.14	505.14	0.00	Overtopping

Rating Curve Plot for Crossing: US 36

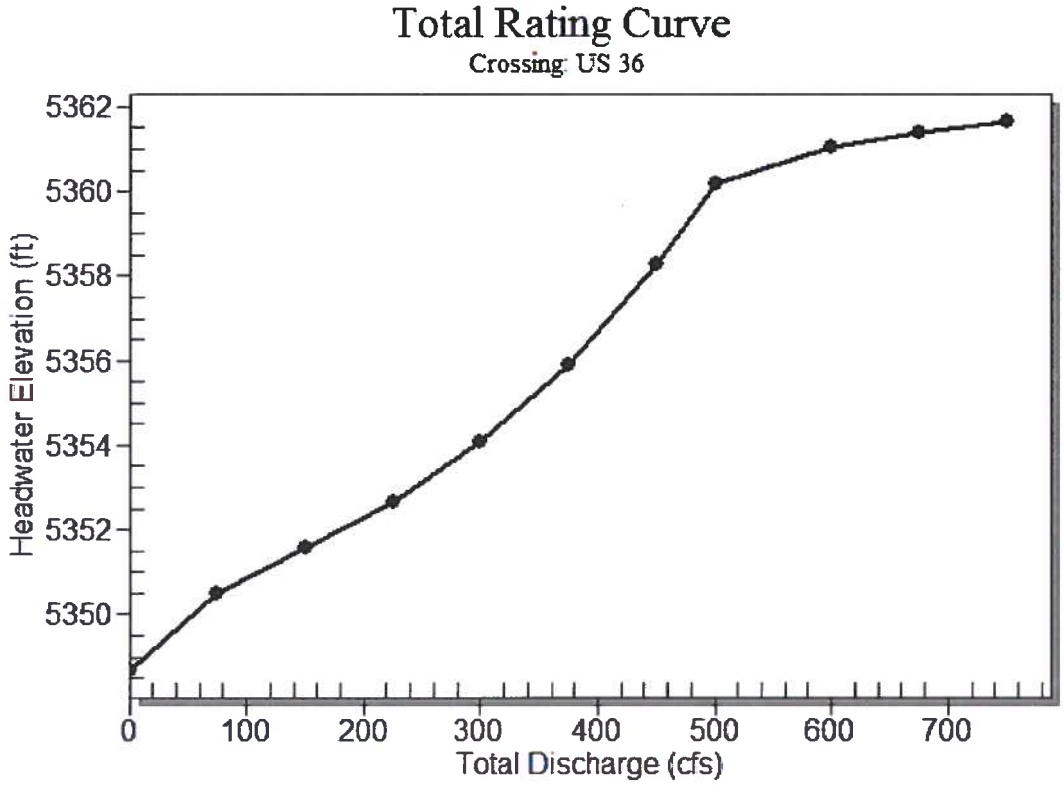


Table 2 - Culvert Summary Table: US 36 DOUBLE BOX CULVERT

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	5348.70	0.000	0.0*	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
75.00	75.00	5350.49	1.791	0.0*	1-S2n	0.628	1.069	0.629	2.916	9.940	1.914
150.00	150.00	5351.55	2.853	0.0*	5-S2n	0.994	1.697	0.996	3.545	12.555	2.478
225.00	225.00	5352.66	3.959	0.0*	5-S2n	1.309	2.223	1.313	4.089	14.278	2.810
300.00	300.00	5354.07	5.368	0.0*	5-S2n	1.598	2.693	1.602	4.605	15.603	2.980
375.00	375.00	5355.90	7.198	1.668	6-FFc	1.870	2.800	1.873	4.959	16.682	3.239
450.00	450.00	5358.27	9.574	5.328	6-FFc	2.130	2.800	2.133	5.287	17.581	3.465
500.00	500.00	5360.19	11.491	8.138	6-FFc	2.299	2.800	2.316	5.495	17.991	3.602
600.00	520.89	5361.05	12.352	9.400	6-FFc	2.368	2.800	2.369	5.890	18.323	3.849
675.00	528.69	5361.38	12.682	9.884	6-FFc	2.394	2.800	2.415	6.248	18.243	3.931
750.00	535.36	5361.67	12.969	10.661	4-FFf	2.416	2.800	2.419	6.628	18.443	3.939

* theoretical depth is impractical. Depth reported is corrected.

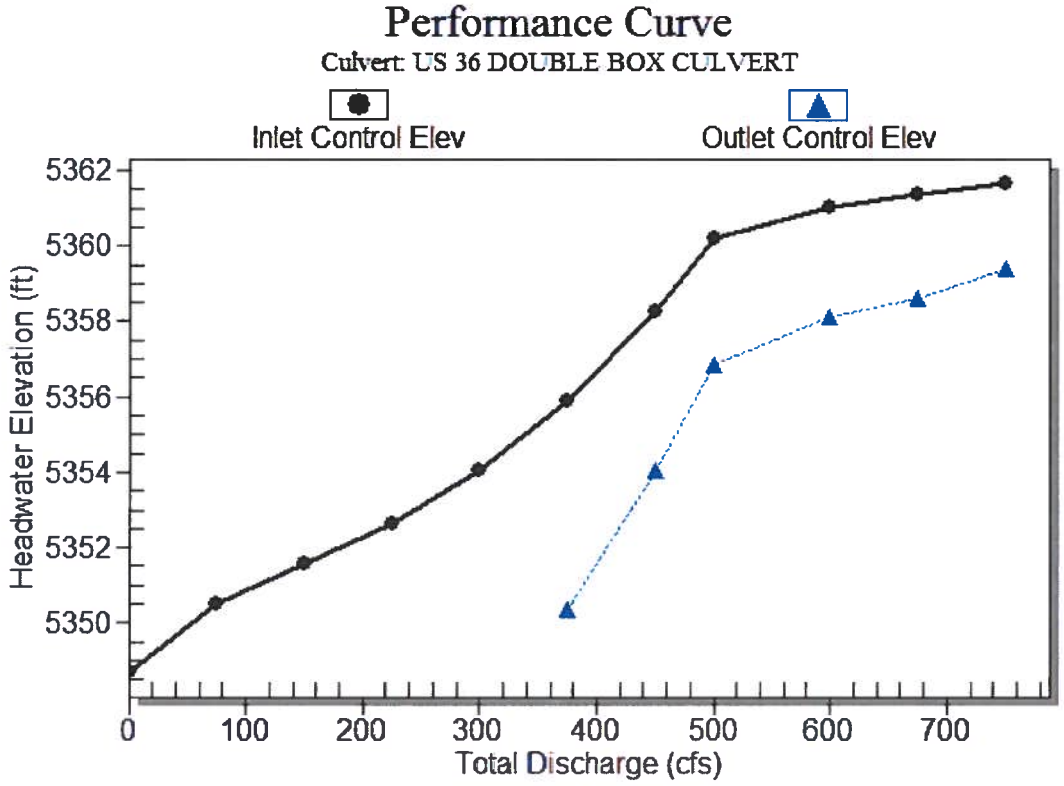
****

Inlet Elevation (invert): 5348.70 ft, Outlet Elevation (invert): 5339.25 ft

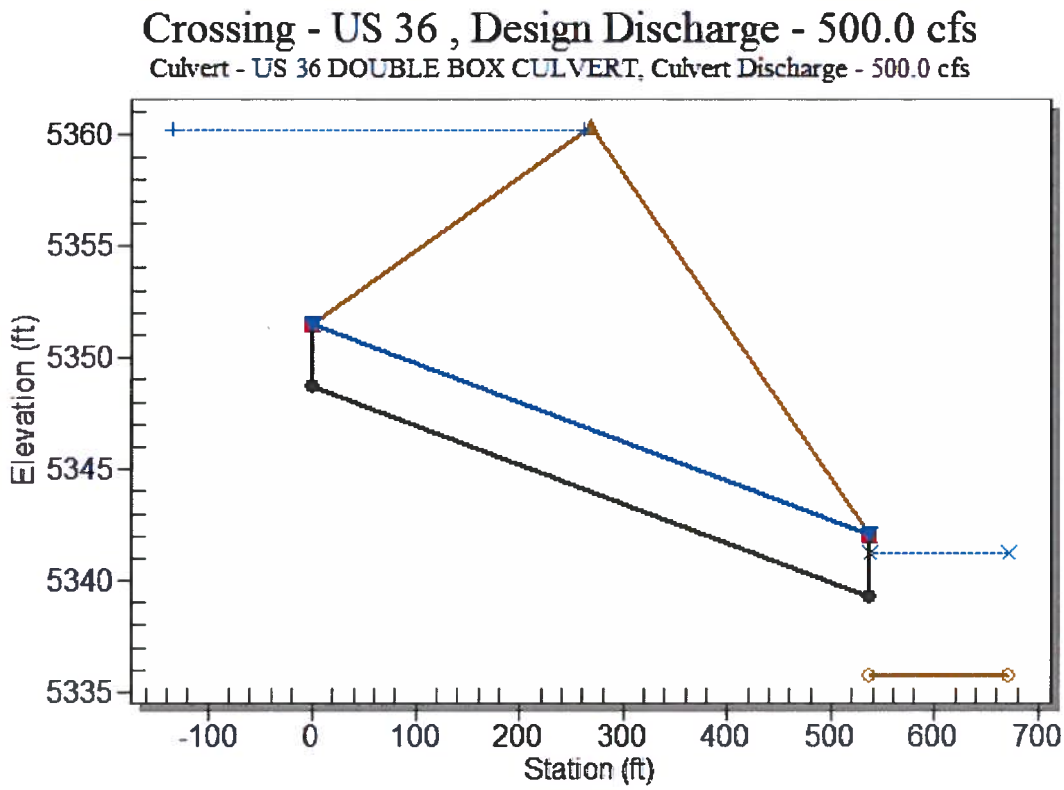
Culvert Length: 537.08 ft, Culvert Slope: 0.0176

****

Culvert Performance Curve Plot: US 36 DOUBLE BOX CULVERT



Water Surface Profile Plot for Culvert: US 36 DOUBLE BOX CULVERT



Site Data - US 36 DOUBLE BOX CULVERT

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 5348.70 ft

Outlet Station: 537.00 ft

Outlet Elevation: 5339.25 ft

Number of Barrels: 2

Culvert Data Summary - US 36 DOUBLE BOX CULVERT

Barrel Shape: Concrete Box

Barrel Span: 6.00 ft

Barrel Rise: 2.80 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: US 36)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	5335.78	0.00	0.00	0.00	0.00
75.00	5338.70	2.92	1.91	1.82	0.31
150.00	5339.33	3.55	2.48	2.21	0.33
225.00	5339.87	4.09	2.81	2.55	0.34
300.00	5340.38	4.60	2.98	2.87	0.34
375.00	5340.74	4.96	3.24	3.09	0.35
450.00	5341.07	5.29	3.46	3.30	0.35
500.00	5341.28	5.50	3.60	3.43	0.35
600.00	5341.67	5.89	3.85	3.68	0.36
675.00	5342.03	6.25	3.93	3.90	0.36
750.00	5342.41	6.63	3.94	4.14	0.36

Tailwater Channel Data - US 36

Tailwater Channel Option: Irregular Channel

Roadway Data for Crossing: US 36

Roadway Profile Shape: Constant Roadway Elevation

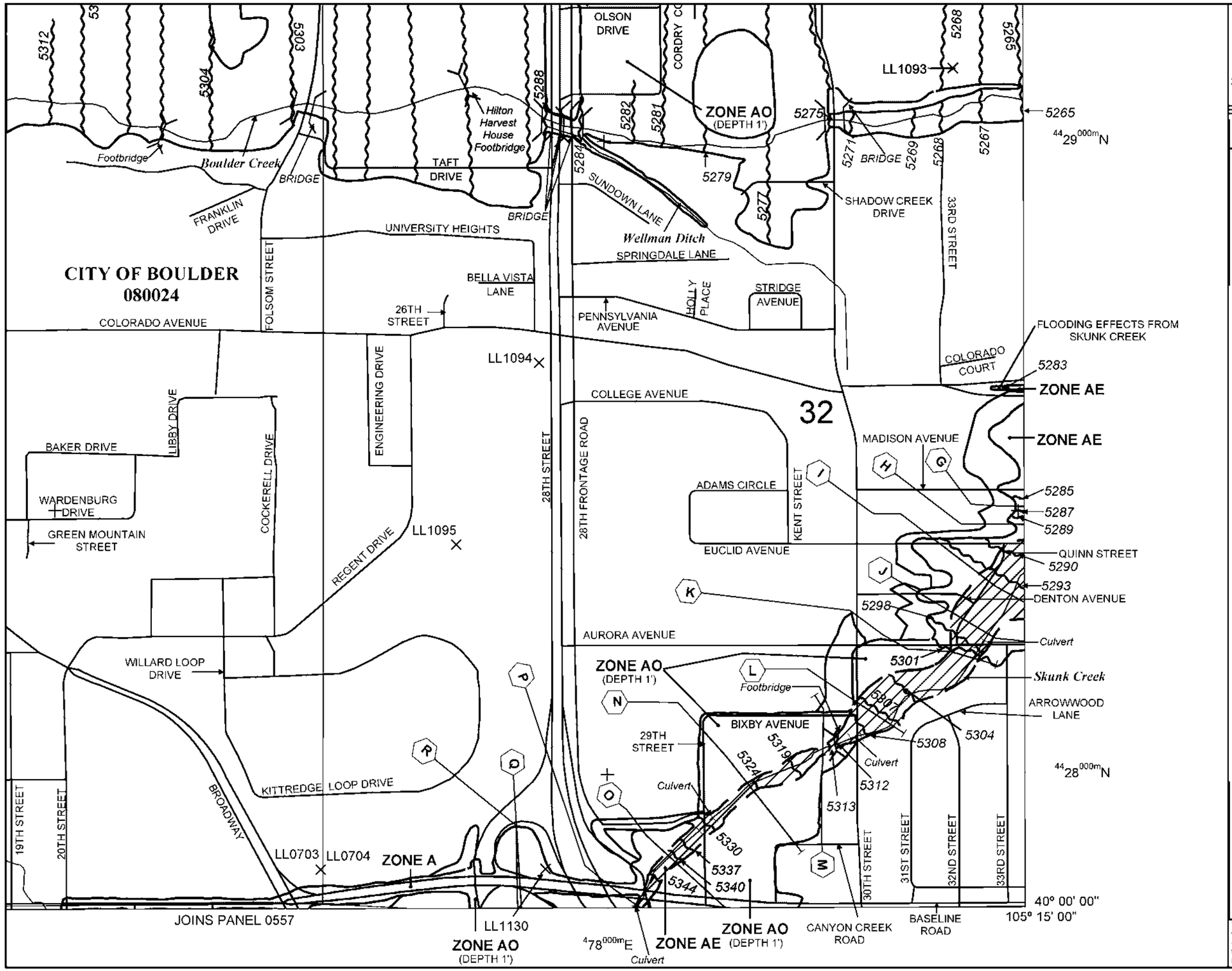
Crest Length: 50.00 ft

Crest Elevation: 5360.40 ft

Coefficient of Discharge: 3.0000

Roadway Top Width: 1.00 ft

Appendix 4-
Floodplain Workmaps and Profiles



MAP SCALE 1" = 500'

250 0 500 1000 FEET

METER

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0394J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 394 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER CITY OF	080024	0394	J

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08013C0394J

MAP REVISED
DECEMBER 18, 2012

Federal Emergency Management Agency

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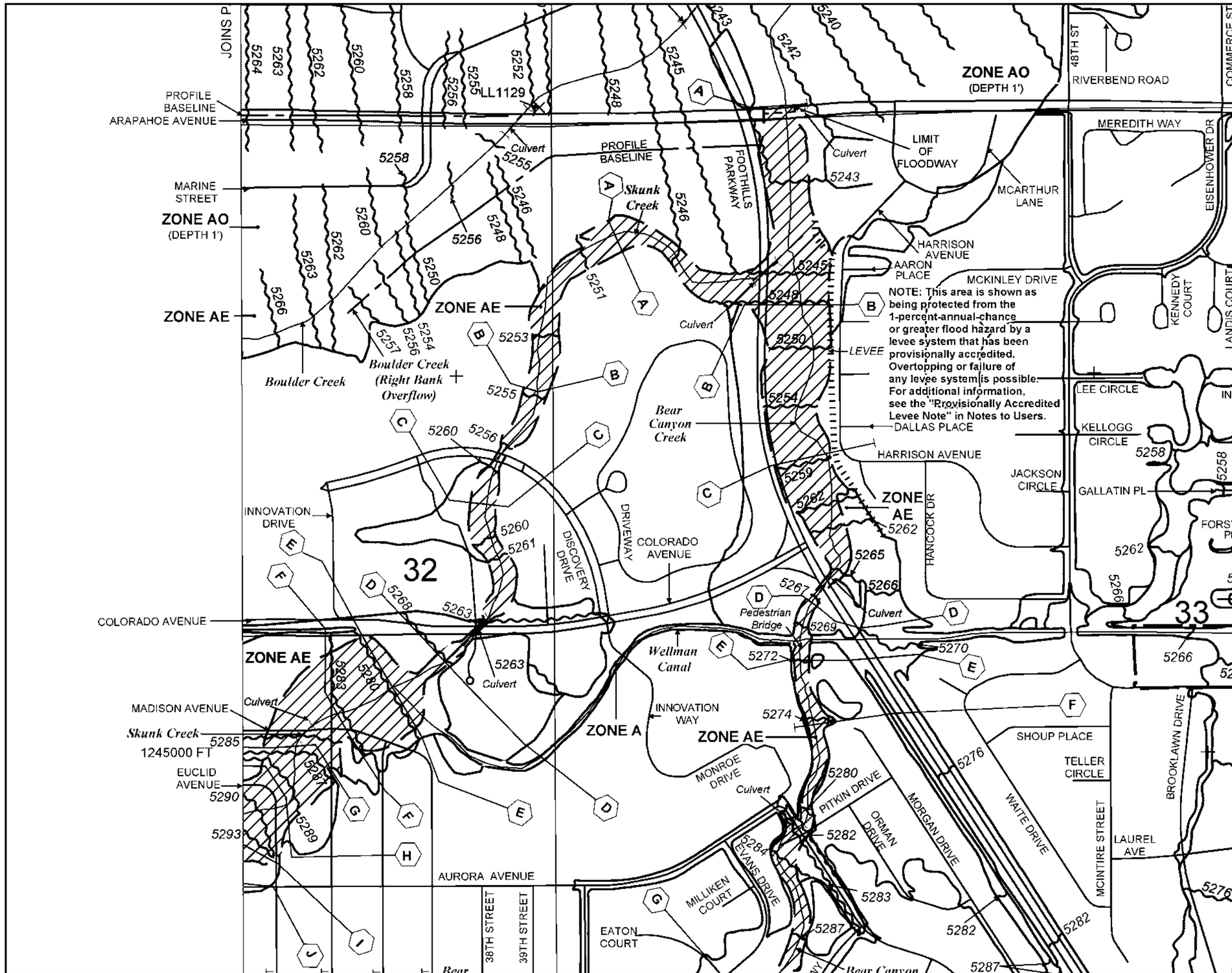

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NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0413J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 413 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER, CITY OF	080024	0413	J
BOULDER COUNTY	080023	0413	J

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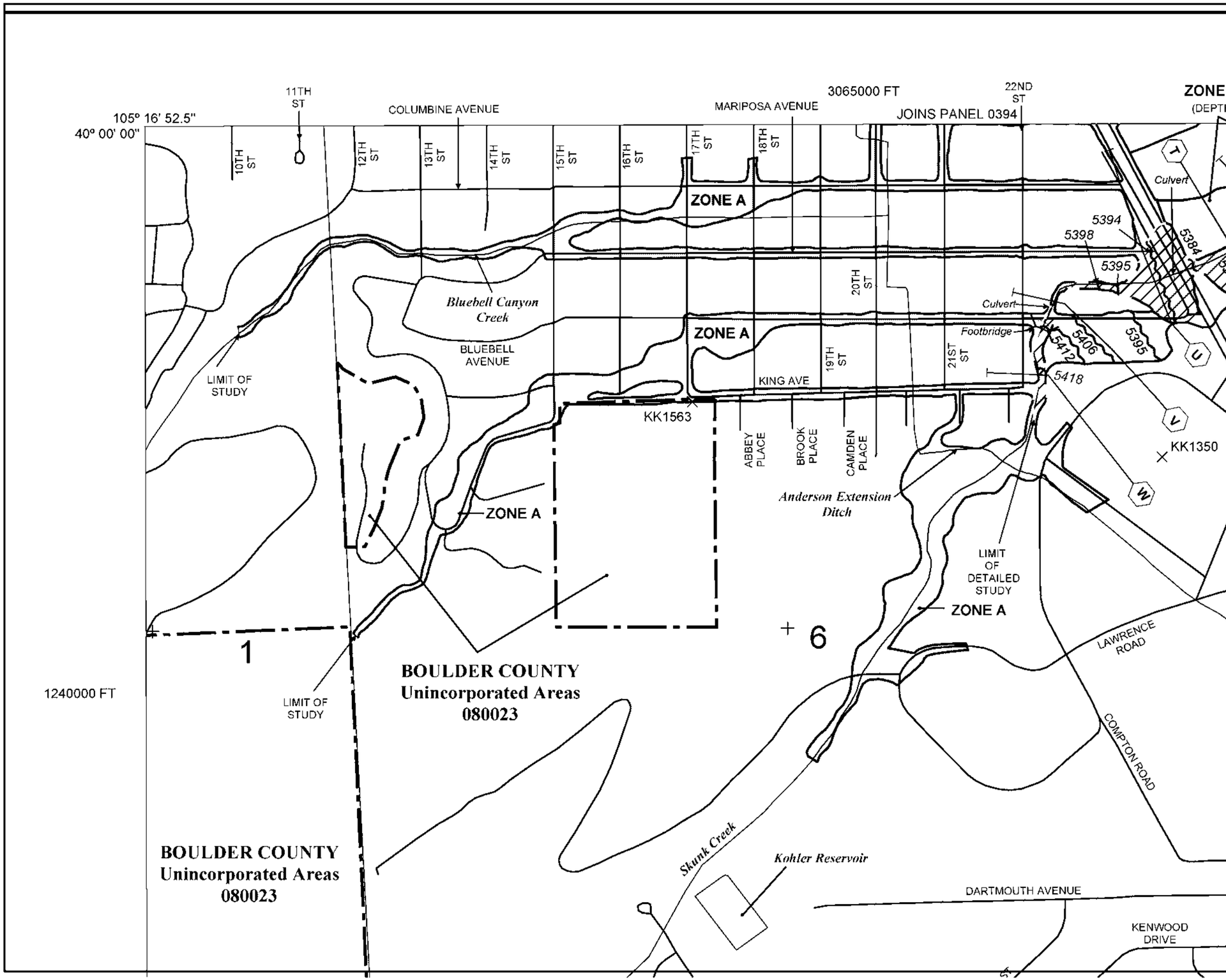

MAP SCALE 1" = 500'

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METER

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NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0557J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 557 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER, CITY OF	080024	0557	J
BOULDER COUNTY	080023	0557	J

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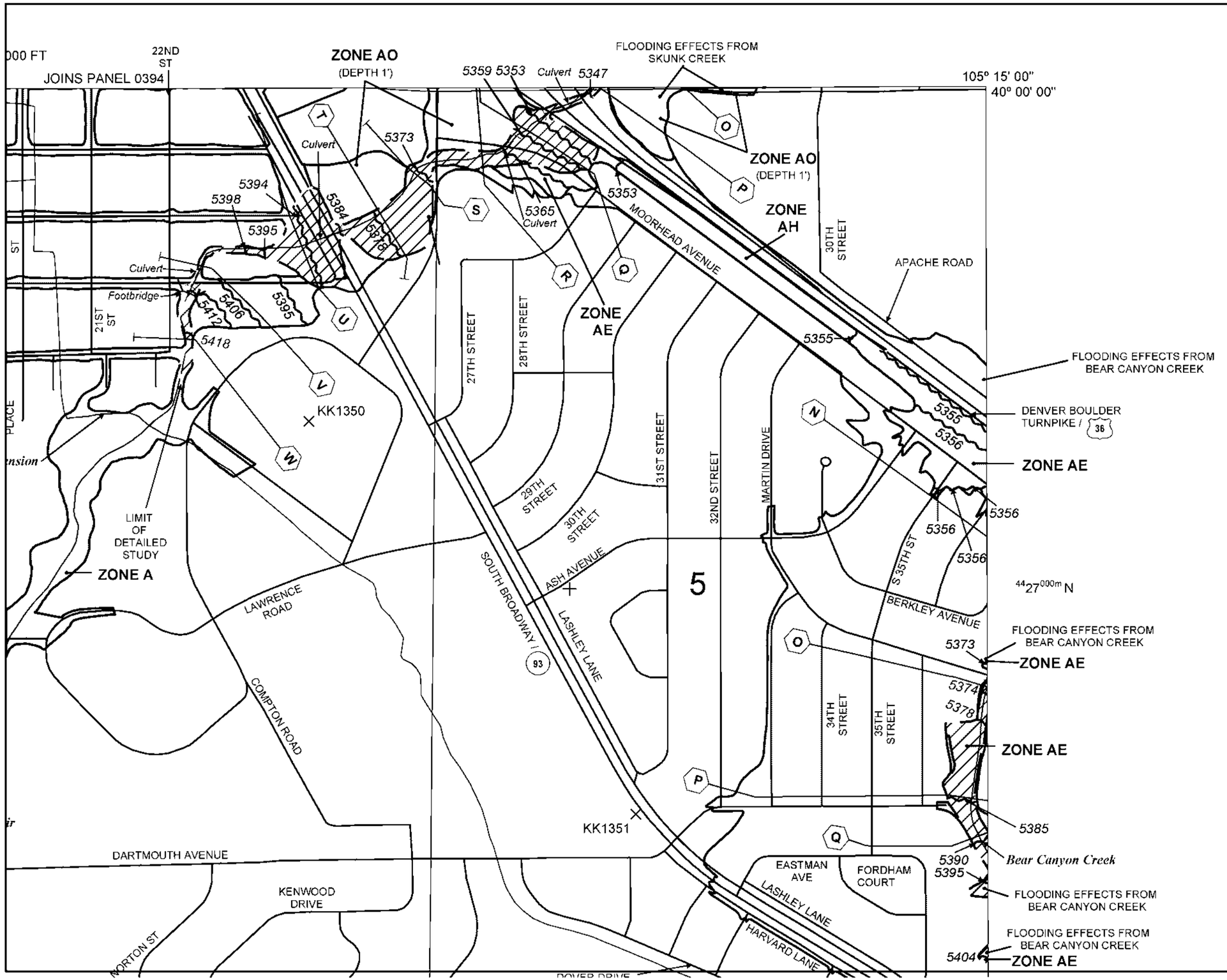

MAP SCALE 1" = 500'

250 0 500 1000 FEET

METER

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0557J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 557 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER, CITY OF	080024	0557	J
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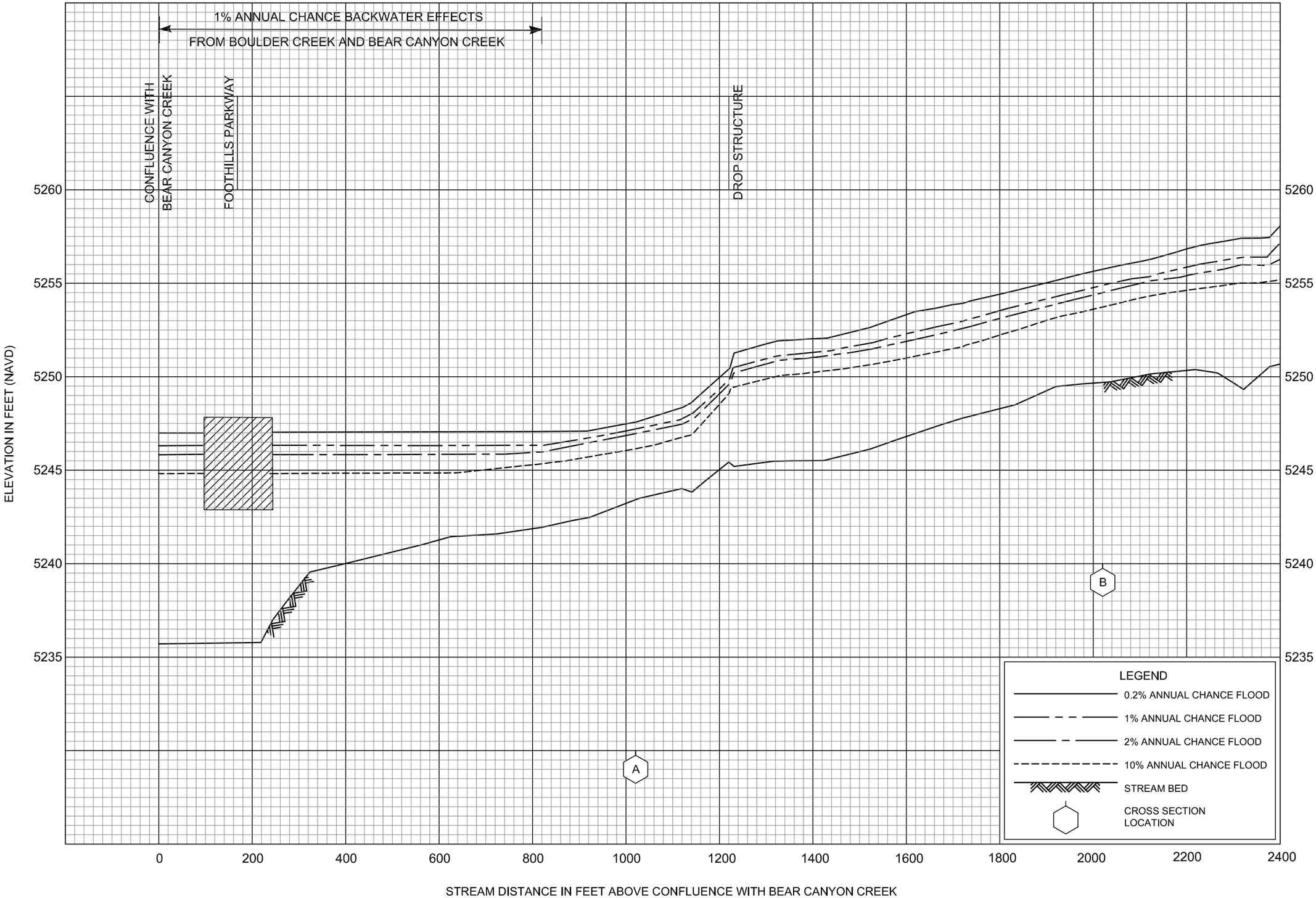


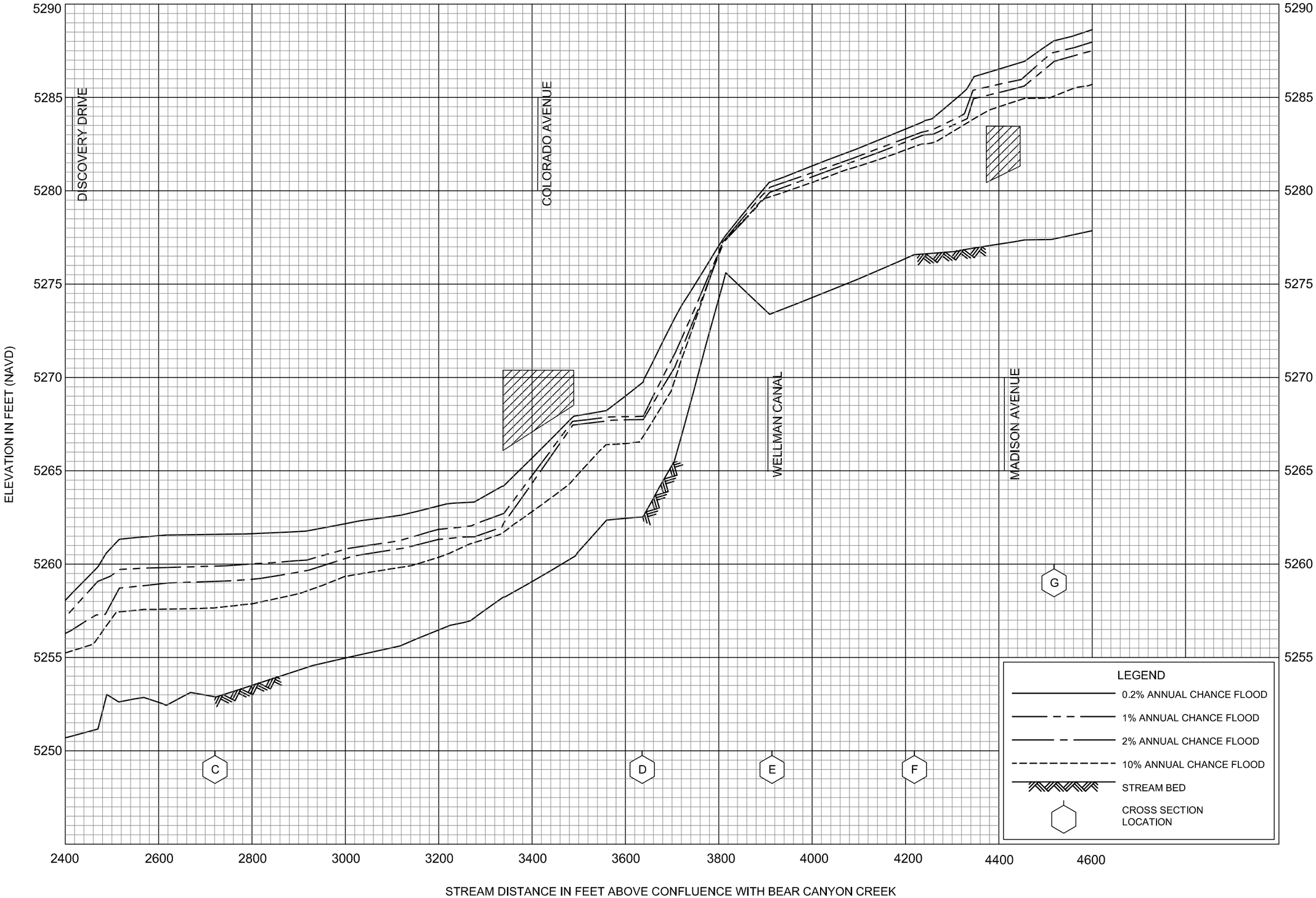
FLOOD PROFILES

SKUNK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO

AND INCORPORATED AREAS



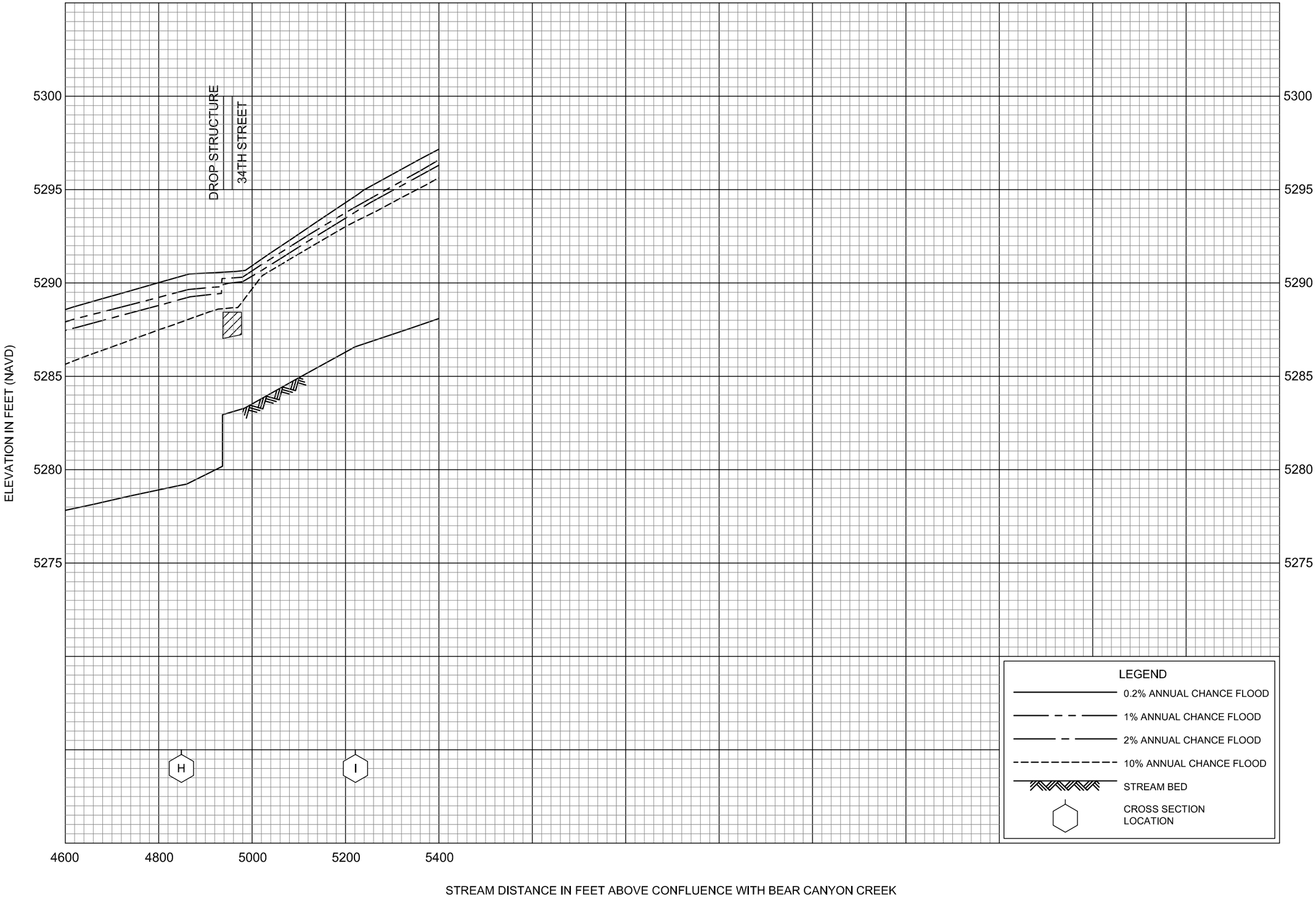
FLOOD PROFILES

SKUNK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO

AND INCORPORATED AREAS



FLOOD PROFILES

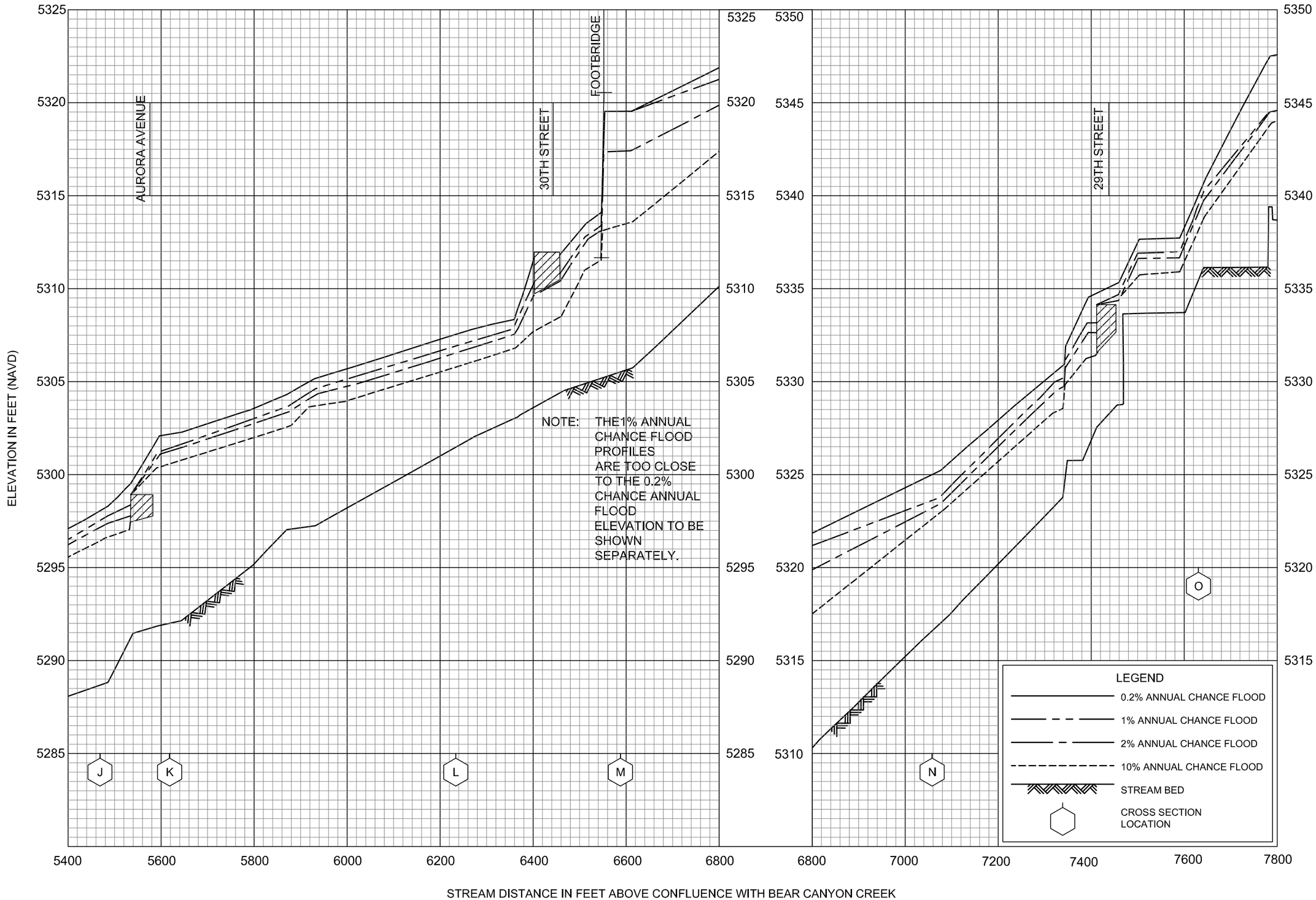
SKUNK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO

AND INCORPORATED AREAS

300P



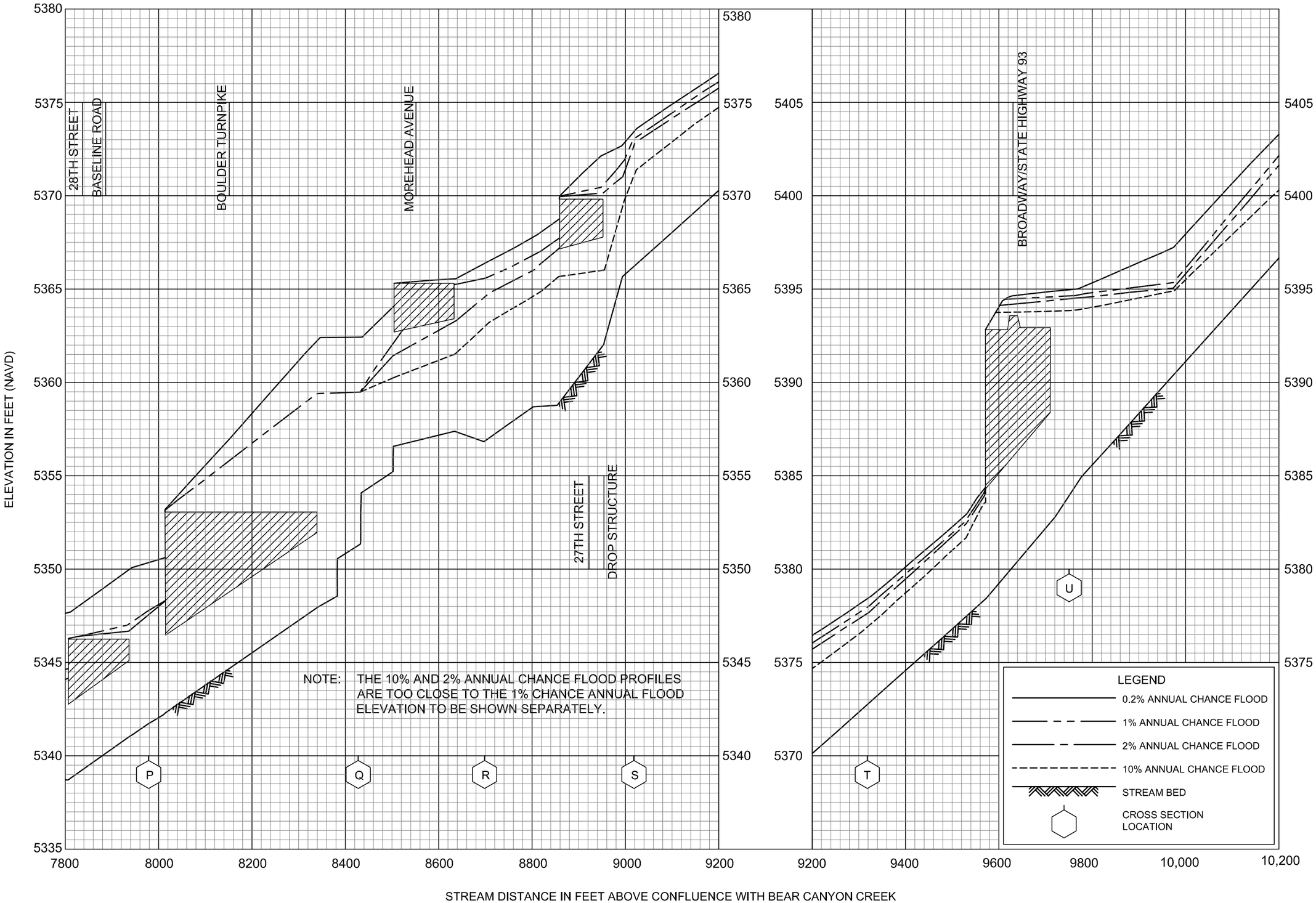
FLOOD PROFILES

SKUNK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO

AND INCORPORATED AREAS



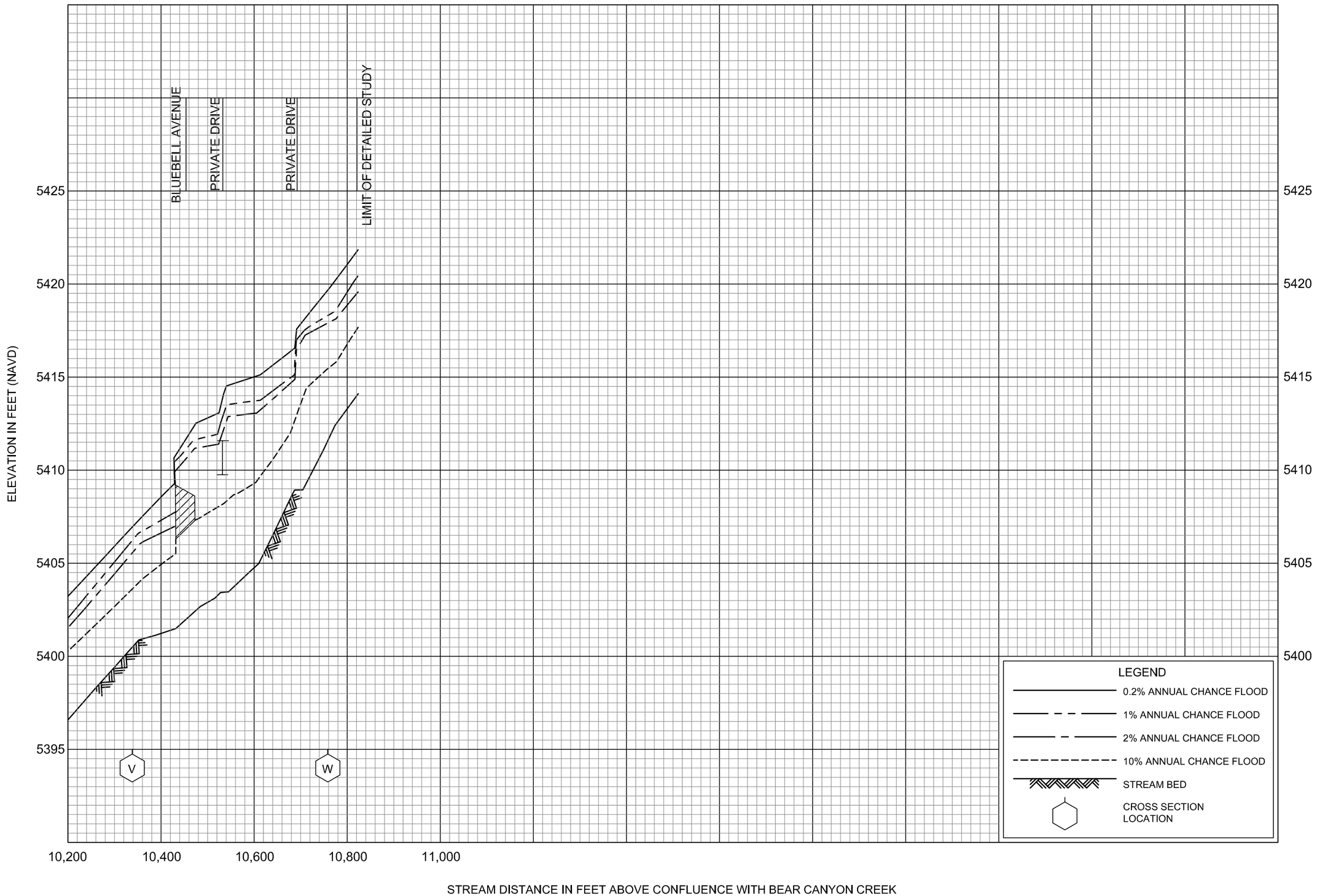
FLOOD PROFILES

SKUNK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO

AND INCORPORATED AREAS



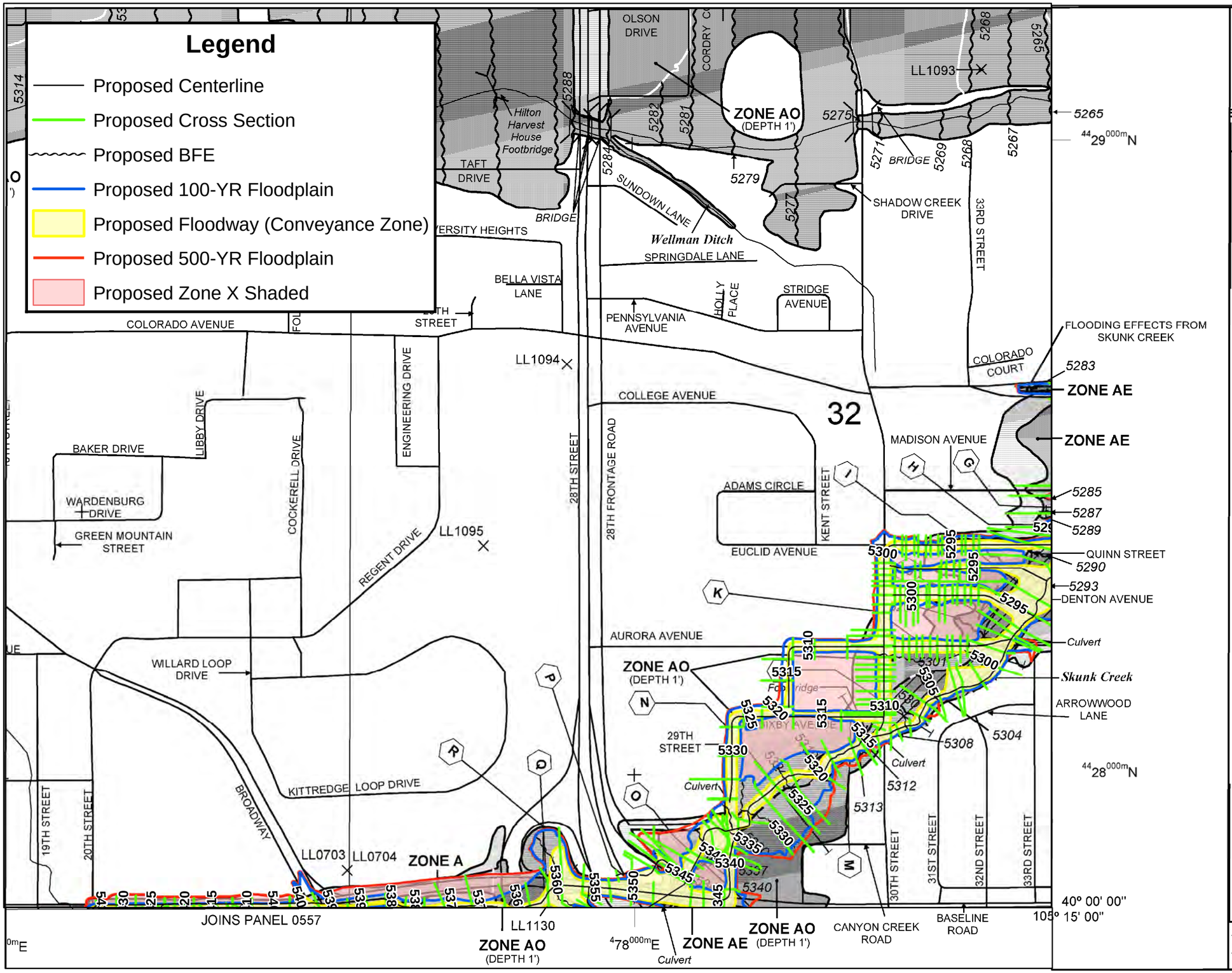
FLOOD PROFILES

SKUNK CREEK

FEDERAL EMERGENCY MANAGEMENT AGENCY

BOULDER COUNTY, CO

AND INCORPORATED AREAS



MAP SCALE 1" = 500'

250 0 500 1000 FEET

METER

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0394J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 394 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER, CITY OF	080024	0394	J

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08013C0394J

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DECEMBER 18, 2012

Federal Emergency Management Agency

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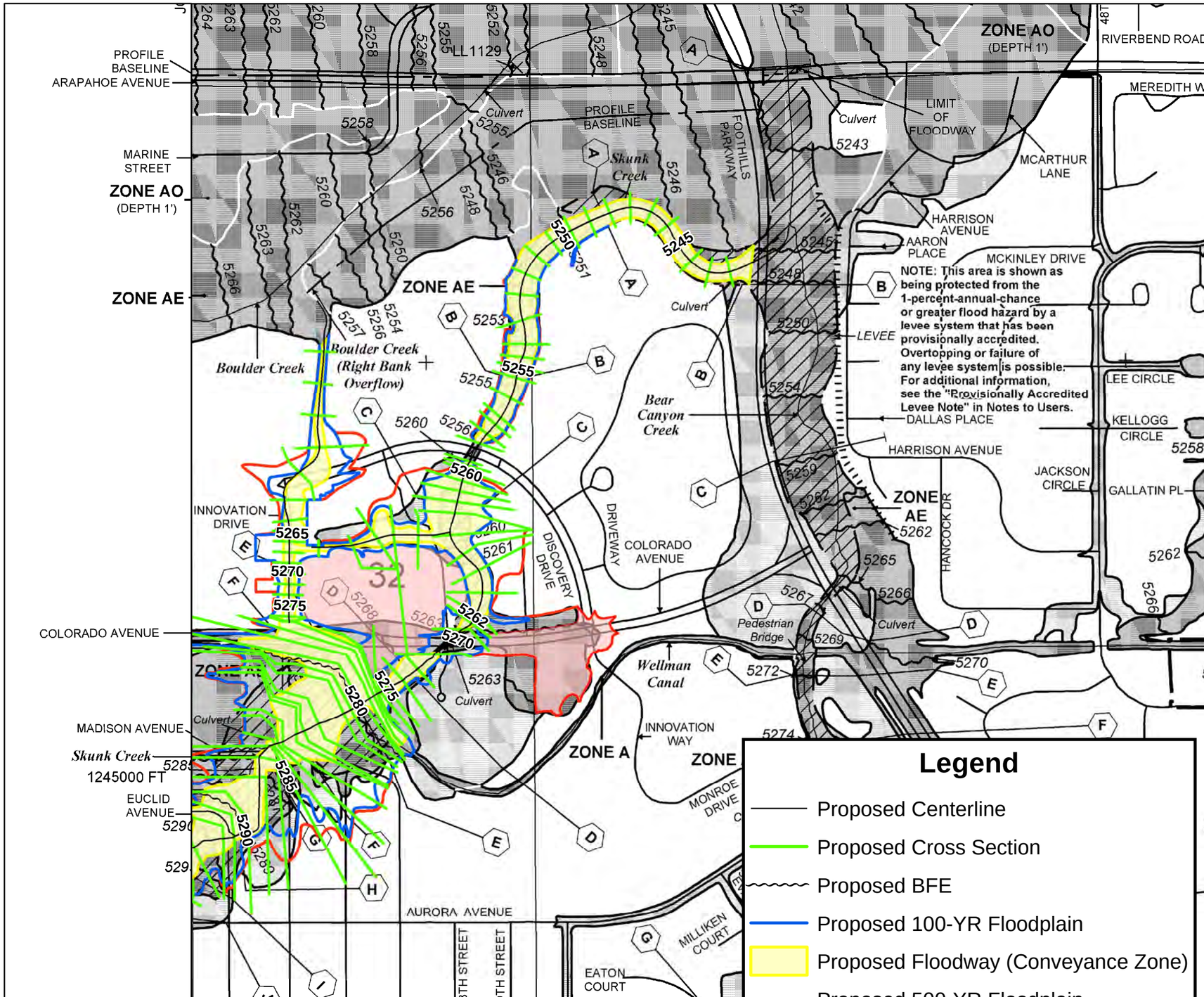

Legend

- Proposed Centerline
- Proposed Cross Section
- Proposed BFE
- Proposed 100-YR Floodplain
- Proposed Floodway (Conveyance Zone)
- Proposed 500-YR Floodplain
- Proposed Zone X Shaded

MAP SCALE 1" = 500'

250 0 500 1000 FEET

METER

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NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0413J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 413 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER, CITY OF	060024	0413	J
BOULDER COUNTY	060023	0413	J

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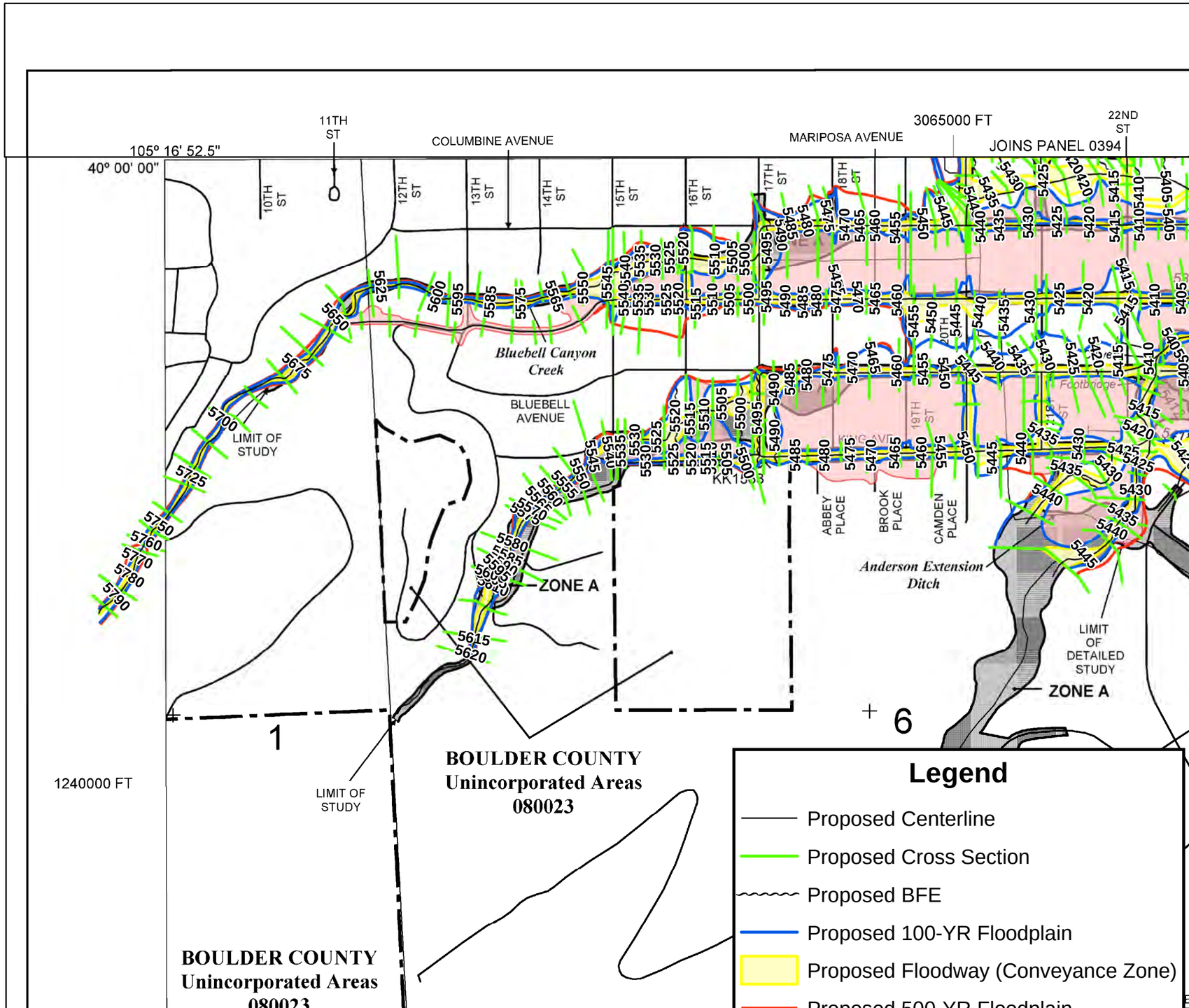

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- Proposed BFE
- Proposed 100-YR Floodplain
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MAP SCALE 1" = 500'

250 0 500 1000 FEET

METER

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NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0557J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 557 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BOULDER, CITY OF	080024	0557	J
BOULDER COUNTY	080023	0557	J

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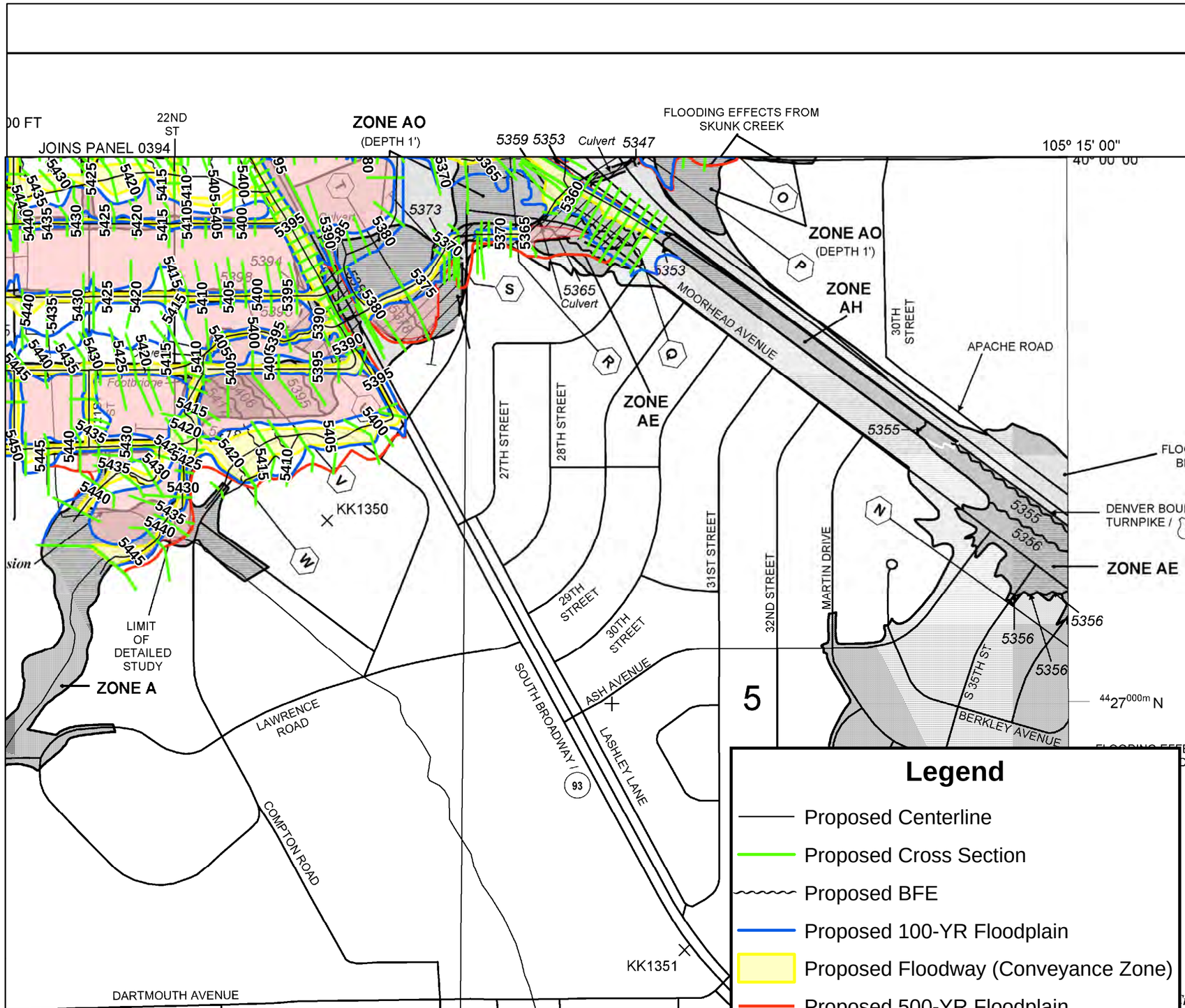

Legend

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MAP SCALE 1" = 500'

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METER

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NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0557J

FIRM

FLOOD INSURANCE RATE MAP

BOULDER COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 557 OF 615

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

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Appendix 5 –
Floodplain Comparison Tables

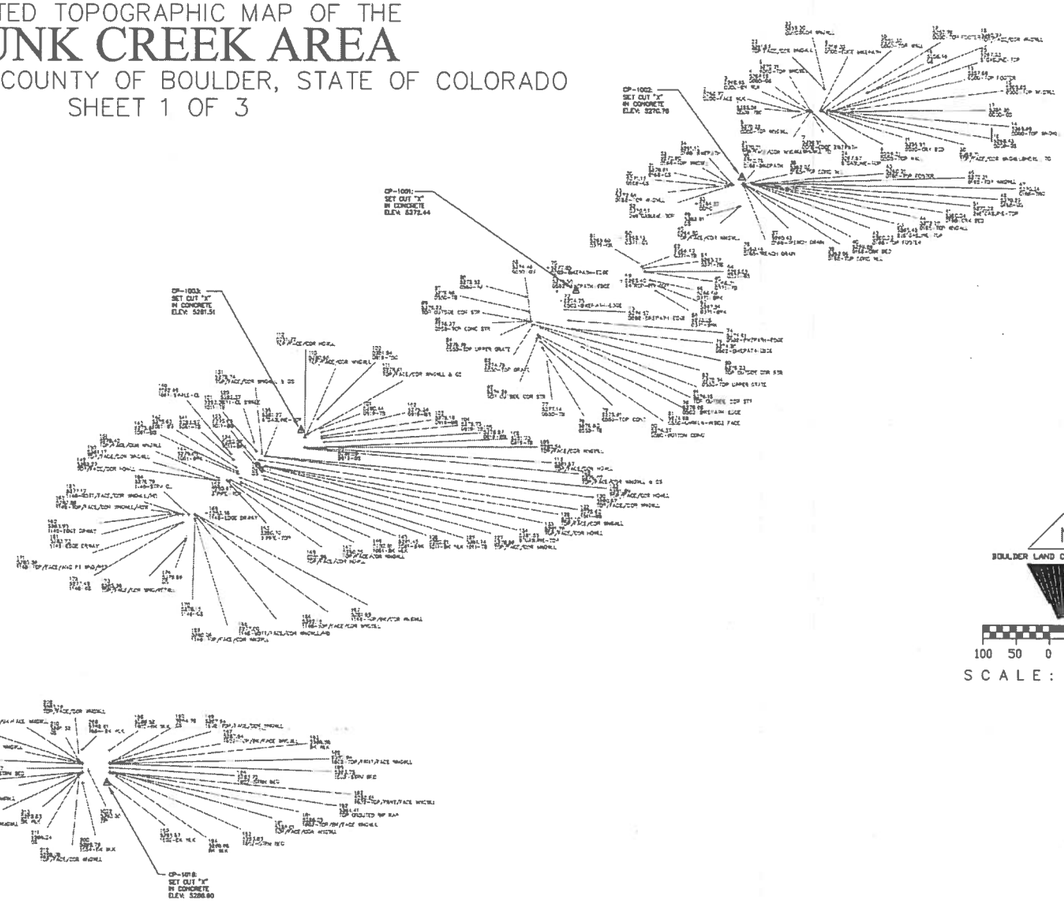
Appendix 6 –
Certified As-Built Plans and Survey

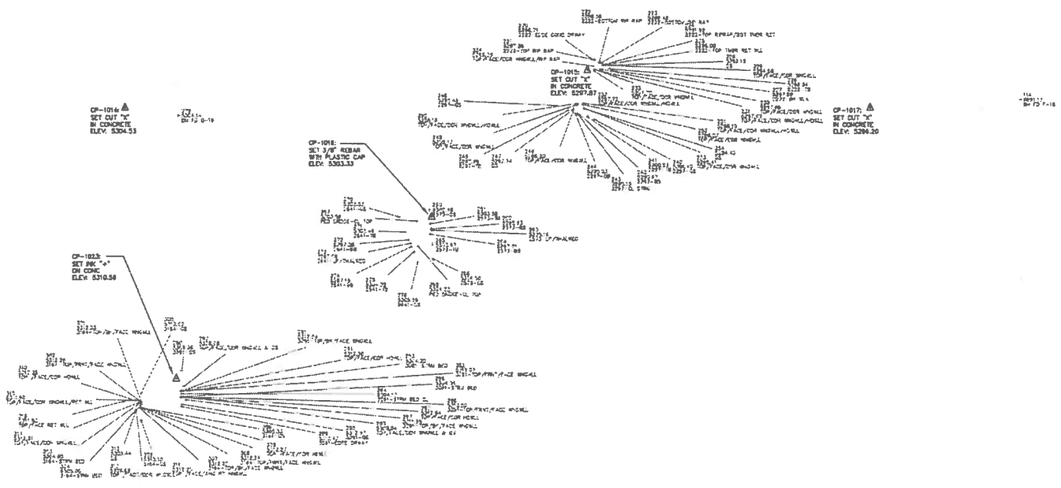
A LIMITED TOPOGRAPHIC MAP OF THE

SKUNK CREEK AREA

CITY OF BOULDER, COUNTY OF BOULDER, STATE OF COLORADO

SHEET 1 OF 3





NOTES

1. THIS MAP DOES NOT REPRESENT A BOUNDARY SURVEY OR TITLE SEARCH PERFORMED BY BOULDER LAND CONSULTANTS, INC. THERE MAY EXIST EASEMENTS AND/OR OTHER ENCUMBRANCES AFFECTING THE SUBJECT PROPERTIES THAT ARE NOT SHOWN HEREON.
2. HORIZONTAL INFORMATION SHOWN HEREON IS BASED ON U.S. STATE PLANE COORDINATES NAD 1983 (2007), COLORADO ZONE 501 NORTH. PROJECT COMBINED SCALE FACTOR IS 0.99971290.
3. PRIMARY BENCHMARK FOR VERTICAL INFORMATION SHOWN HEREON IS NATIONAL GEODETIC SURVEY FIRST ORDER, CLASS II BENCH MARK "J 440" (PID KK1563). ELEVATION: 5492.60', NAVD88 DATUM.
4. NO UNDERGROUND UTILITIES WERE SURVEYED NOR ARE ANY SHOWN HEREON.
5. CERTIFICATION DEFINED: THE USE OF THE WORDS "CERTIFY" OR "CERTIFICATION" BY A REGISTERED PROFESSIONAL LAND SURVEYOR CONSTITUTES AN EXPRESSION OF PROFESSIONAL OPINION REGARDING THE FACTS AND FINDINGS WHICH ARE THE SUBJECT OF THE CERTIFICATION, AND DOES NOT CONSTITUTE A WARRANTY OR GUARANTY, EITHER EXPRESSED OR IMPLIED. THE CERTIFICATION SHOWN HEREON EXTENDS ONLY TO THOSE PARTIES SPECIFICALLY MENTIONED THEREIN (PER COLORADO STATE BOARD RULE 6.2.2).
6. IN ACCORDANCE WITH C.R.S. 13-80-105: NOTICE: ACCORDING TO COLORADO LAW YOU MUST COMMENCE ANY LEGAL ACTION BASED UPON ANY DEFECT IN THIS SURVEY WITHIN THREE YEARS AFTER YOU FIRST DISCOVER SUCH DEFECT. IN NO EVENT MAY ANY ACTION BASED UPON ANY DEFECT IN THIS SURVEY BE COMMENCED MORE THAN TEN YEARS FROM THE DATE OF THE CERTIFICATION SHOWN HEREON.

SURVEYOR'S CERTIFICATION

I, JASON EMERY, HEREBY CERTIFY TO BELT COLLINS WEST, LTD. THAT, SUBJECT TO THE NOTES SHOWN HEREON, THIS LIMITED TOPOGRAPHIC MAP WAS BASED ON A FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION, AND THAT THIS LIMITED TOPOGRAPHIC MAP ACCURATELY DEPICTS THE RESULTS OF SAID SURVEY, AND THAT THIS MAP DOES NOT REPRESENT A LAND SURVEY PLAT OR BOUNDARY SURVEY OF THE SUBJECT PROPERTY. DATE OF FIELD WORK: ARIL THROUGH MAY 2010.

COLORADO REGISTERED PROFESSIONAL ENGINEER 34 JASON EMERY

MAY 17, 2010

JASON EMERY
COLORADO REGISTERED PROFESSIONAL
LAND SURVEYOR NO. 20034

N

BOULDER LAND CONSULTANTS, INC.

100 50 0 50 100 150

SCALE: 1" = 100'

THIS MAP WAS PREPARED BY

BOULDER LAND CONSULTANTS, INC.

5690 VALMONT RD. BOULDER, CO 80301
(303) 443-3618
www.BLCsurveyors.com

DRAWING: 100018_SITE_CER.dwg
B.C.: INC. PROJECT NO. 06318

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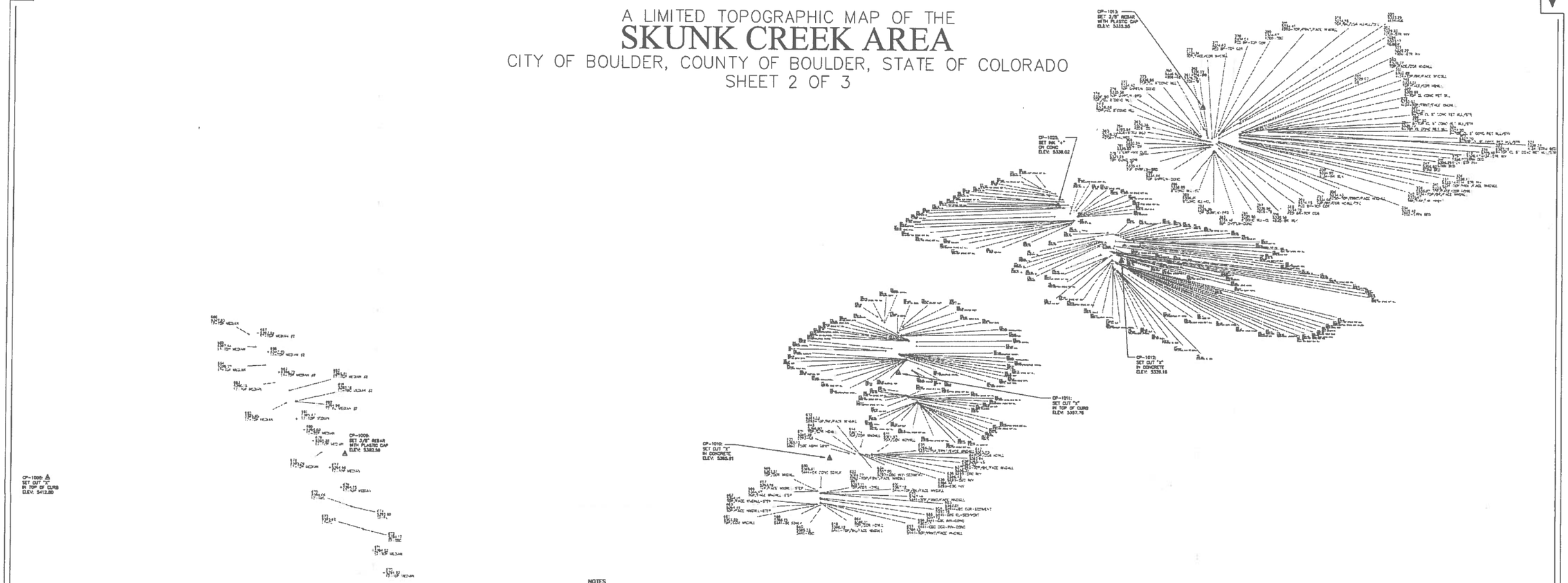
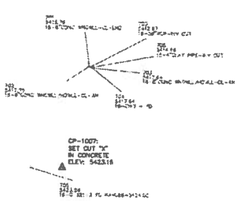
A LIMITED TOPOGRAPHIC MAP OF THE

SKUNK CREEK AREA

CITY OF BOULDER, COUNTY OF BOULDER, STATE OF COLORADO

SHEET 2 OF 3





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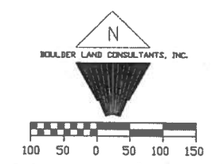
2. HORIZONTAL INFORMATION SHOWN HEREON IS BASED ON U.S. STATE PLANE COORDINATES NAD 1983 (2007), COLORADO ZONE 501 NORTH. PROJECT COMBINED SCALE FACTOR IS 0.99971290.
3. PRIMARY BENCHMARK FOR VERTICAL INFORMATION SHOWN HEREON IS NATIONAL GEODETIC SURVEY FIRST ORDER, CLASS II BENCH MARK "J 440" (PID KK1563). ELEVATION: 5492.60', NAVD88 DATUM.
4. NO UNDERGROUND UTILITIES WERE SURVEYED NOR ARE ANY SHOWN HEREON.
5. CERTIFICATION DEFINED: THE USE OF THE WORDS "CERTIFY" OR "CERTIFICATION" BY A REGISTERED PROFESSIONAL LAND SURVEYOR CONSTITUTES AN EXPRESSION OF PROFESSIONAL OPINION REGARDING THE FACTS AND FINDINGS WHICH ARE THE SUBJECT OF THE CERTIFICATION, AND DOES NOT CONSTITUTE A WARRANTY OR GUARANTY, EITHER EXPRESSED OR IMPLIED. THE CERTIFICATION SHOWN HEREON EXTENDS ONLY TO THOSE PARTIES SPECIFICALLY MENTIONED THEREIN (PER COLORADO STATE BOARD RULE 6.2.2).
6. IN ACCORDANCE WITH C.R.S. 13-80-105:
   NOTICE: ACCORDING TO COLORADO LAW YOU MUST COMMENCE ANY LEGAL ACTION BASED UPON ANY DEFECT IN THIS SURVEY WITHIN THREE YEARS AFTER YOU FIRST DISCOVER SUCH DEFECT. IN NO EVENT MAY ANY ACTION BASED UPON ANY DEFECT IN THIS SURVEY BE COMMENCED MORE THAN TEN YEARS FROM THE DATE OF THE CERTIFICATION SHOWN HEREON.

SURVEYOR'S CERTIFICATION

I, JASON EMERY, HEREBY CERTIFY TO BELT COLLINS WEST, LTD. THAT, SUBJECT TO THE NOTES SHOWN HEREON, THIS LIMITED TOPOGRAPHIC MAP WAS BASED ON A FIELD SURVEY PERFORMED UNDER MY DIRECT SUPERVISION, AND THAT THIS LIMITED TOPOGRAPHIC MAP ACCURATELY DEPICTS THE RESULTS OF SAID SURVEY, AND THAT THIS MAP DOES NOT REPRESENT A LAND SURVEY PLAT OR BOUNDARY SURVEY OF THE SUBJECT PROPERTY. DATE OF FIELD WORK: APRIL 29 THROUGH MAY 3, 2010.

JASON EMERY
COLORADO REGISTERED PROFESSIONAL
LAND SURVEYOR (PLS) 20134

MAY 17, 2010



THIS MAP WAS PREPARED BY

BOULDER LAND CONSULTANTS, INC.
5690 VALMONT RD. BOULDER, CO 80301
(303) 443-3616
www.BLCsurveyors.com

DRAWING "06010t1_SPC_CERT_2of3.dwg"
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A LIMITED TOPOGRAPHIC MAP OF THE

SKUNK CREEK AREA

CITY OF BOULDER, COUNTY OF BOULDER, STATE OF COLORADO

SHEET 3 OF 3

NOTES

1. THIS MAP DOES NOT REPRESENT A BOUNDARY SURVEY OR TITLE SEARCH PERFORMED BY BOULDER LAND CONSULTANTS, INC. THERE MAY EXIST EASEMENTS AND/OR OTHER ENCUMBRANCES AFFECTING THE SUBJECT PROPERTIES THAT ARE NOT SHOWN HEREON.
2. HORIZONTAL INFORMATION SHOWN HEREON IS BASED ON U.S. STATE PLANE COORDINATES NAD 1983 (2007), COLORADO ZONE 501 NORTH. PROJECT COMBINED SCALE FACTOR IS 0.99971290.
3. PRIMARY BENCHMARK FOR VERTICAL INFORMATION SHOWN HEREON IS NATIONAL GEODETIC SURVEY FIRST ORDER, CLASS II BENCH MARK "J 440" (PID KK1583). ELEVATION: 5492.60', NAVD88 DATUM.
4. NO UNDERGROUND UTILITIES WERE SURVEYED NOR ARE ANY SHOWN HEREON.
5. CERTIFICATION DEFINED: THE USE OF THE WORDS "CERTIFY" OR "CERTIFICATION" BY A REGISTERED PROFESSIONAL LAND SURVEYOR CONSTITUTES AN EXPRESSION OF PROFESSIONAL OPINION REGARDING THE FACTS AND FINDINGS WHICH ARE THE SUBJECT OF THE CERTIFICATION, AND DOES NOT CONSTITUTE A WARRANTY OR GUARANTY, EITHER EXPRESSED OR IMPLIED. THE CERTIFICATION SHOWN HEREON EXTENDS ONLY TO THOSE PARTIES SPECIFICALLY MENTIONED THEREIN (PER COLORADO STATE BOARD RULE 6.2.2).
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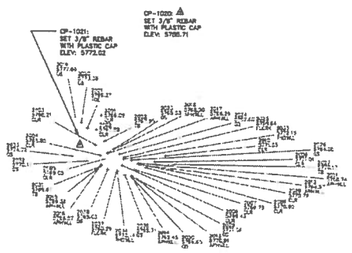
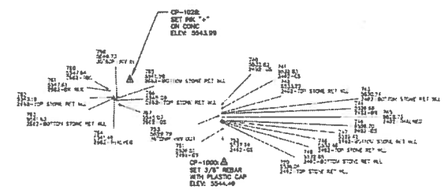
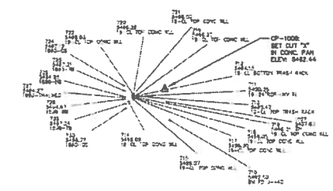
COLORADO REGISTERED PROFESSIONAL LAND SURVEYOR NO. 20104

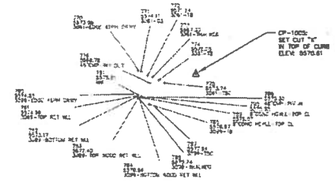
MAY 17, 2010

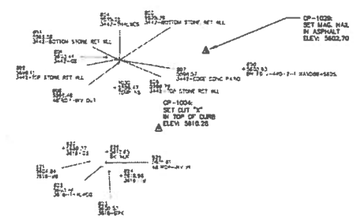
JASON EMERY
COLORADO REGISTERED PROFESSIONAL
LAND SURVEYOR NO. 20104

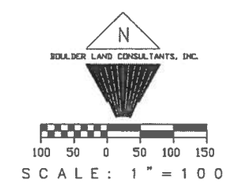












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Appendix 7 –
Public Process Documentation

Appendix 8 –
Electronic Data Files