HYDROLOGY VERIFICATION REPORT
FOR
BOULDER CREEK

Prepared for:

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I. INTRODUCTION

1.1 Background

In 2008, the City of Boulder contracted with Anderson Consulting Engineers, Inc. (ACE) to conduct a floodplain study for Boulder Creek from east of the city to the mouth of Boulder Canyon. Current regulatory flood hazard information for Boulder Creek was originally defined in 1977 by a U.S. Army Corps of Engineers (USACE) study. The reach between 6th Street and 17th Street was revised pursuant to a Letter of Map Revision (LOMR) completed for the City in 1994. The current floodplain study is intended to revise the regulatory flood hazard information along Boulder Creek, through the City of Boulder, in order to reflect existing conditions along the stream corridor and within the adjacent floodplain, including the flood mitigation benefits of a number of projects completed by the City along Boulder Creek. The floodplain study also seeks to update the hydraulic model for the creek using state-of-the-art tools and techniques.

The original intent of the City was to continue to utilize the 1977 USACE hydrology as the basis for the current hydraulic modeling effort. However, prior to finalizing this decision, the City requested an evaluation of the USACE hydrology in order to determine whether or not using the 1977 hydrology was appropriate given current modeling techniques and currently available data.

1.2 Purpose of Study

The purpose of the current hydrologic study is to evaluate the 1977 USACE hydrologic model and resulting discharges, in an effort to determine whether or not a revised hydrologic modeling effort would be justified prior to conducting the new floodplain study. Accordingly, the current hydrologic study included the preparation of a duplicate hydrologic model, review and evaluation of physical modeling parameters and rainfall hyetographs, and correlation of the 1977 hydrologic modeling results to stream gage data and regional regression equations.

All available hydrologic models pertaining the 1977 Boulder Creek study were obtained from the USACE Omaha District. The hydrologic models that are currently available constitute only a portion of the total number of models originally developed by the USACE for Boulder Creek. Consequently, this evaluation included special treatment of the models, as discussed in the following sections.

Additional sources were investigated for the Boulder Creek hydrologic models. Neither the City of Boulder nor the Urban Drainage and Flood Control District had copies of the Boulder Creek hydrologic models in their archives. A data request was made to the FEMA library to obtain all available hydrologic and hydraulic models and documentation. FEMA did not have copies of any of the Boulder Creek hydrologic models.

II. U.S. ARMY CORPS OF ENGINEERS HYDROLOGIC MODELS

2.1 General Model Information

Detailed documentation of the 1977 U.S. Army Corps of Engineers (USACE) hydrologic model of the Boulder Creek watershed is relatively limited. General modeling information and modeling results are summarized in "Water and Related Land Resources Management Study," [USACE, 1977]. An apparently unpublished report by the USACE entitled, "Review Report, Boulder Creek" [undated] includes some detailed information associated with the hydrologic modeling effort. As provided by the USACE Omaha District, this report is included in its entirety in Appendix A.

Numerous hydrologic models were provided by the USACE, but only three of the models represent detailed modeling of the Boulder Creek watershed; these models encompass the portion of the watershed upstream of the confluence with South Boulder Creek. A model was provided for South Boulder Creek; however, the downstream terminus of that model is located approximately 5 miles upstream of Eldorado Springs, leaving a gap in the model that corresponds to roughly 13 river miles down to the confluence with Boulder Creek. A listing of all models provided by the USACE is included in Appendix B.

With respect to the Boulder Creek models provided by the USACE, the 4-percent annual chance (25-year) event is analyzed in two models, one each for the lower basin and upper basin. The lower basin model extends from upstream of South Boulder Creek into the lower portion of Boulder Canyon, while the upper basin model covers the portion of the watershed from below the Fourmile Creek confluence upstream to the basin divide. A 0.2-percent annual chance (500-year) model for the upper portion of the basin was also provided by the USACE.

Subbasin maps provided by the USACE showing the upper and lower portions of the watershed are provided in Appendix B as Figures B1 through B4. Close review of these maps indicated that an area in the lower portion of the upper basin is not covered by the version of the subbasin maps provided by the USACE. Correlation of the maps to the hydrologic model revealed that the subbasins missing from the maps are included in the model. This was confirmed by verifying that the area of the subbasins in the model that are otherwise not shown on the maps is equal to the subbasin area that is missing on the maps.

The USACE subbasin maps were geo-rectified to real-world coordinates by correlating features on the subbasin maps to those shown on rectified USGS quadrangle maps of the area. Figure 2.1 is the resulting map, using the USGS quad maps as a base, showing the location of the Boulder Creek watershed and the area covered by the lower and upper hydrologic models. Using the subbasin maps and the USACE hydrologic model of the lower basin for the 4-percent annual chance event, a hydrologic model schematic was developed for the lower basin; this model schematic is included in Appendix B as Figure B5.

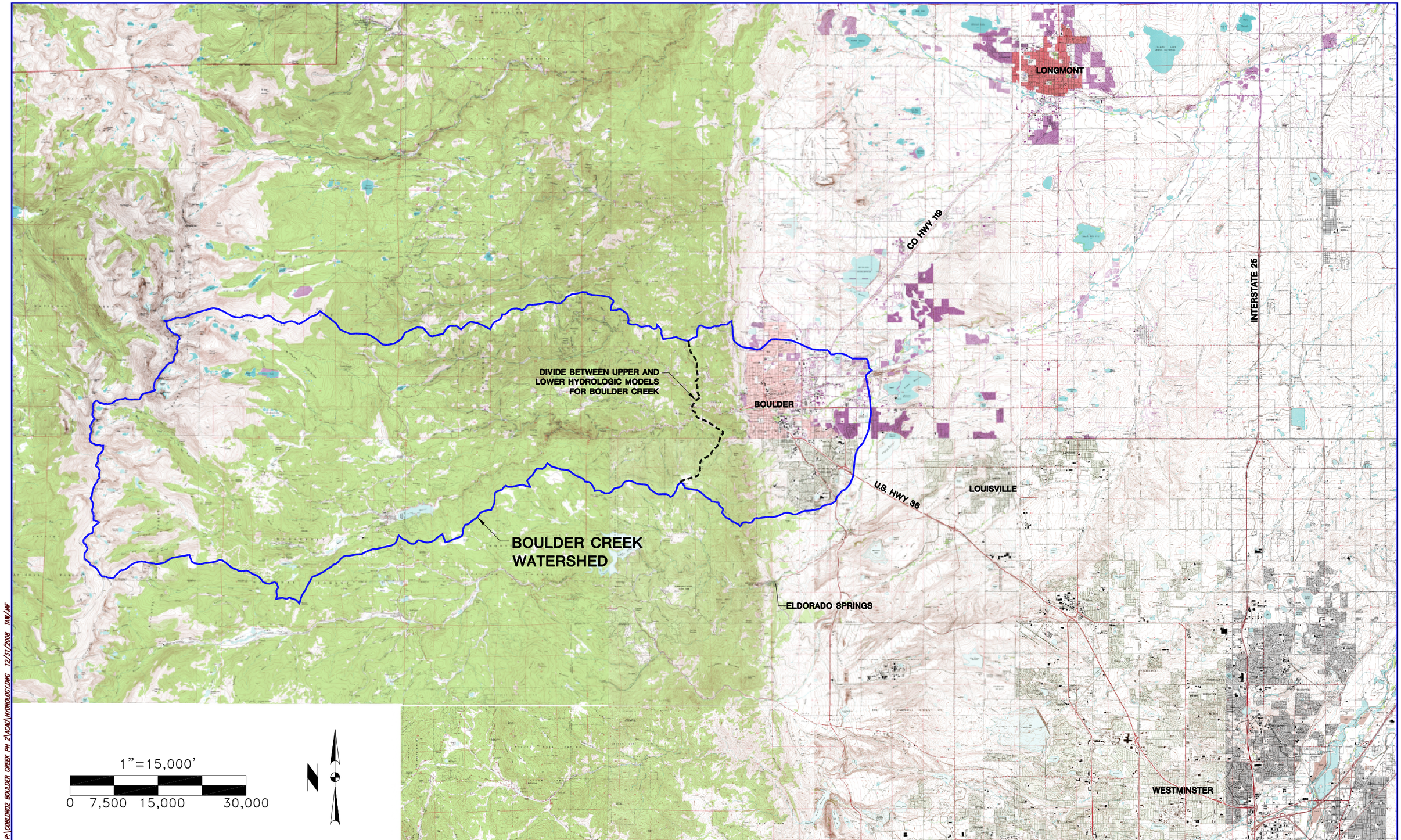

Figure 2.1 Boulder Creek Watershed, USACE Hydrologic Models

2.2 USACE Modeling Methodology

Information provided in the USACE report provides insight into the 1977 modeling effort, but in some cases data in the report conflict with the parameters used in the hydrologic models. Based on a combination of information contained in the report and the parameters indicated in the models, a number of scenarios were investigated (as documented in Chapter III) in an effort to produce a duplicate effective hydrologic model for Boulder Creek.

Hydrologic modeling by the USACE was conducted using an early version of the Runoff Block of the EPA Storm Water Management Model. Consequently, the rainfall-runoff transformation is accomplished using kinematic wave routing theory. Both the source code and executable version of the SWMM model utilized by the USACE in 1977 was provided by the USACE Omaha District. The files representing the 4-percent annual chance hydrologic models provided by the USACE were executed using the older SWMM model, as well as a newer version of the Runoff Block from the EPA Storm Water Management Model (UDSWM2-PC). The results of the analyses conducting using the two models were virtually identical (agreeing to within approximately 1 percent), confirming that the model utilized in 1977 is compatible with a nearly identical hydrologic model that is approved by FEMA for use within the Urban Drainage and Flood Control District (UDFCD).

Lacking documentation of the SWMM model used by the USACE, in many instances UDSWM2-PC or another surrogate SWMM model was used for the current analyses. This occurred particularly when an analysis required the addition of non-routing nodes, as the older SWMM model handles non-routing nodes somewhat differently than the newer UDSWM2-PC model. A third model (MODSWMM) was often used in place of UDSWM2-PC due its ease of use. MODSWMM was developed by Mr. Ted Combs of Longmont. This model simply uses the UDSWM2-PC computational algorithm but includes a data preprocessor with a Windows™ interface, allows the insertion of comment cards in the data input file, provides computational error flags and messages when necessary, and organizes the model output to facilitate review and evaluation. Modeling results from MODSWMM have been demonstrated on many occasions to be virtually identical to those produced by UDSWM2-PC.

With respect to conveyance routing along Boulder Creek, in the upper portion of the basin the USACE applied the kinematic wave method by utilizing conveyance routing within the older SWMM model. However, for conveyance routing along Boulder Creek in the lower portion of the basin, the USACE used an “unsteady flow routing program developed by the Missouri River Division.” The USACE provided source code and an executable version of a model called “Harders Hydraulic Flood Routing Model” which presumably performed dispersion wave flood routing along lower Boulder Creek. An input data file was also provided by the USACE for the Harders model, but documentation and user instructions were not included. As concluded in Chapter IV, it was determined that it was not necessary to apply the Harders routing model as part of the current study.

2.3 Available Rainfall Hyetographs

The USACE SWMM files for the lower and upper portions of the Boulder Creek watershed utilized a total of five rainfall hyetographs, apparently in order to accommodate the variation in rainfall potential along the east-west axis of the watershed. The subbasins located within each of the five rainfall zones were identified on the USACE subbasin maps. A watershed map showing the five rainfall zones defined by the USACE is provided as Figure 2.2. Also shown on this map are the 1-percent annual chance (100-year), 6-hour isohyets digitized from NOAA Atlas 2, "Precipitation-Frequency Atlas of the Western United States, Volume III – Colorado," [1973], excerpts of which are provided in Appendix B. Rainfall depths from this NOAA atlas were utilized by the USACE to define rainfall hyetographs for the hydrologic models.

For the current study, an average point rainfall depth associated with the 1-percent annual chance, 6-hour event was defined for each of the five rainfall zones. This was accomplished using an area-weighted averaging procedure available within ESRI's GIS-based Spatial Analyst software. The point rainfall values for each of the five rainfall zones are provided in Appendix B. Also shown in the appendix are rainfall depths that have been area reduced by 13 percent; corresponding to an area reduction factor of 0.87 specified in NOAA Atlas 2 for a watershed area of 158 square-miles. This is the area encompassed by the Boulder Creek watershed, as indicated in the USACE hydrologic models, upstream of the confluence with South Boulder Creek.

The 1-percent annual chance rainfall hyetographs utilized by the USACE are no longer available, making it incumbent on the current project to develop these hyetographs for use in the SWMM models. The only complete hydrologic models provided by the USACE for both upper and lower basins correspond to the 4-percent annual chance event. These hyetographs utilize 1-hour time increments following the pattern of a modified version of the USACE 6-hour Standard Project Storm, having been adapted by using what is termed by the USACE as the Southwestern Division Criteria. Interestingly, the USACE hydrologic model for the 0.2-percent annual chance, which covers all or part of the upper basin, used a variation of the 6-hour Southwestern Division Criteria Standard Project Storm which consists of twelve 30-minute time increments. This hyetograph pattern is documented in the USACE document, "Review Report, Boulder Creek."

2.4 Effective Discharge Profiles

Effective discharges along Boulder Creek were defined based on data contained in the original effective HEC-2 model documented in the "Boulder Creek Flood Hazard Area Delineation Report," [Muller Engineering, 1983]. A discharge profile was defined for each of the 10-percent, 2-percent, 1-percent and 0.2-percent annual chance of occurrence events (10-year, 50-year, 100-year and 500-year events). In addition, the discharge profile associated with the 4-percent annual chance of occurrence event (25-year event) was defined based on a log-probability interpolation of the discharges defined in the HEC-2 model. The resulting discharge profiles are provided in Table 2.1. Backup information associated with defining the effective discharge profiles is included in Appendix C.

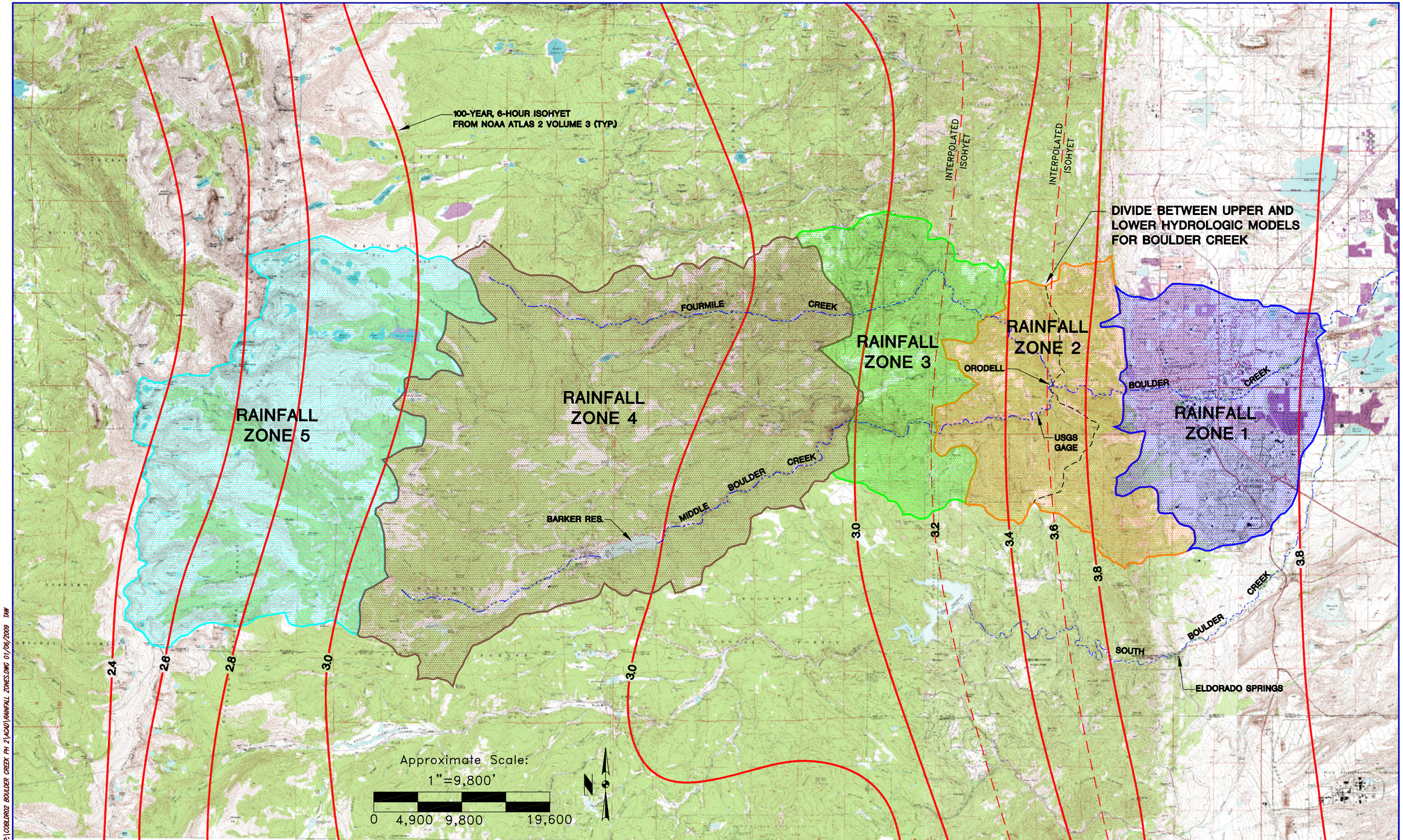

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Figure 2.2 Boulder Creek Watershed, USACE Rainfall Zone Delineation

Table 2.1 Effective Discharge Profiles for Boulder Creek.

Cross Section ID (1983 FHAD)	Peak Discharge (cfs)					Approximate Location
	10-Percent Annual Chance (10-Year)	4-Percent Annual Chance (25-Year)	2-Percent Annual Chance (50-Year)	1-Percent Annual Chance (100-Year)	0.2-Percent Annual Chance (500-Year)	
77	2,000	5,580	7,950	11,650	21,200	U/S Study Limit
73.1	2,000	5,690	8,100	11,950	21,600	
64.1	2,200	5,830	8,100	12,150	22,100	6th Street
58	2,200	5,810	8,100	12,100	22,100	9th Street
55	2,200	5,800	8,100	12,000	21,400	Broadway
47	2,200	5,790	8,100	11,950	21,400	
43	2,200	5,780	8,100	11,900	21,400	17th Street
38	2,200	5,670	7,800	11,750	20,600	24th Street
33	2,200	5,620	7,800	11,500	20,600	
26	2,200	5,560	7,800	11,200	19,800	
21	2,200	5,550	7,800	11,150	19,800	
14	3,000	6,200	8,200	11,800	21,200	Bear Creek Confl.
11	3,000	6,200	8,200	11,800	20,700	BN Railroad
7	3,600	7,070	9,300	13,050	23,000	
9180	3,450	6,760	8,400	13,050	18,600	55th Street
128	3,450	7,040	9,400	13,300	27,200	Valmont (new)
118	3,500	7,070	9,400	13,300	27,200	
116	3,400	7,010	9,400	13,300	27,200	

III. HYDROLOGIC MODELING

3.1 Initial Hydrologic Modeling Effort

Rainfall hyetographs for the 1-percent annual chance event were initially prepared using the hyetograph pattern defined for the 4-percent annual chance event, coupled with the area reduced 1-percent annual chance rainfall depths identified in Appendix B. Inserting these rainfall hyetographs into the hydrologic models for the upper and lower basins, 1-percent annual chance discharges were estimated along Boulder Creek. However, the resulting discharges near the canyon mouth were significantly lower than the 1-percent annual chance discharges utilized in the regulatory hydraulic model.

A second set of rainfall hyetographs was prepared for the 1-percent annual chance event utilizing the alternate rainfall pattern, represented in the 0.2-percent annual chance model, using a 30-minute time increment. The rainfall hyetographs for the five rainfall zones are provided in Appendix B. The discharges near the canyon mouth resulting from application of the hydrologic models were still lower than the 1-percent annual chance discharges used in the regulatory hydraulic model. However, rather than being less than half of the regulatory discharges (as was the case when the 60-minute rainfall increments were used), the computed discharges were within approximately 14 percent of the regulatory values.

The discharges resulting from these two hydrologic modeling efforts are summarized in Table 3.1, as Scenario No. 1 and Scenario No. 2, respectively. Discharges shown in the first row of the table are the effective 1-percent annual chance flows taken from the effective hydraulic (HEC-2) model. Since the USACE SWMM model for the lower basin did not include conveyance routing along Boulder Creek, for this phase of the analysis the hydrographs arising from the lower basin tributaries were simply combined on a time step-by-time step basis, analogous to using non-routing nodes. Consequently, the discharges provided in the table for locations downstream of 9th Street are over estimates due to the lack of accounting for attenuation of the flood peak along lower Boulder Creek. For the purposes of the hydrologic modeling documented in this chapter, comparison of modeling discharges to effective discharges is limited to the locations both near the canyon mouth and near the upstream crossing of Arapahoe Avenue.

3.2 Refinement of the Hydrologic Models

In an effort to create duplicate effective hydrologic models for the upper and lower basins, and recognizing that the 1-percent annual chance discharges arising from the analysis of the first two scenarios under-estimated the effective discharges, further efforts were made to refine the hydrologic models. This effort was conducted with the recognition that parameters in the hydrologic models

Table 3.1. Boulder Creek 1-Percent Annual Chance (100-Year) Discharges, Without Flood Routing Along Lower Boulder Creek.

Scenario	Filenames	1-Percent Annual Chance Discharge (cfs) at the Location Indicated						
		Orodell Gage 102.1 sq. mi. (CE 253)	Canyon Mouth 131.3 sq. mi. (CE 23, 93 & 94)	U/S Crossing of Arapahoe Ave 133.4 sq. mi. (CE 23 & 93-95)	9th Street 135.6 sq. mi. (CE 23 & 93-96)	U/S of BNRR 145.8 sq. mi. (CE 23 & 93-97)	U/S of Valmont 157.4 sq. mi. (CE 23 & 93-98)	U/S of S. Boulder Cr. 158.1 sq. mi. (CE 23 & 93-99)
Effec.	Original Effective HEC-2 Model	N/A	11,650	11,950	12,100	11,800	13,300	13,300
1	Upper Basin: UPBDR100 Lower Basin: LWBDR100	5,230	5,260	5,410	5,540	8,980	11,850	12,060
2	Upper Basin: UBDR100H Lower Basin: LBDR100H	5,910	9,980	10,230	10,430	13,700	16,650	16,850
3	Upper Basin: UBDR10HA Lower Basin: LBDR10HA	5,970	10,130	10,410	10,630	14,220	17,240	17,450
4	Upper Basin: UBDR10HA Lower Basin: LBDR10HB	5,970	10,130	10,410	10,630	14,450	17,680	17,900
5	Upper Basin: UBDR10HC Lower Basin: LBDR10HC	8,830	16,570	17,140	17,690	22,380	25,760	25,980
6	Upper Basin: UBDR10HD Lower Basin: LBDR10HD	5,980	10,120	10,390	10,600	13,980	17,010	17,210
7	Upper Basin: UBDR10HZ Lower Basin: LBDR10HZ	6,550	11,410	11,740	12,000	16,060	19,360	19,580
8	Upper Basin: UBDR10HY Lower Basin: LBDR10HY	5,890	10,070	10,380	10,650	15,230	18,600	18,830
9	Upper Basin: UBDR10HX Lower Basin: LBDR10HX	5,920	10,160	10,490	10,780	15,490	18,850	19,080
10	Upper Basin: UBDR10HW Lower Basin: LBDR10HW	5,930	10,260	10,620	11,000	15,810	19,180	19,410
11	Upper Basin: UBDR10HV Lower Basin: LBDR10HV	6,050	10,430	10,750	11,010	15,240	18,380	18,590
12	Upper Basin: UBDR10HT Lower Basin: LBDR10HT	6,270	10,910	11,260	11,540	15,870	19,080	19,300

provided by the USACE did not consistently correspond to information included in the USACE report and that these models may not represent the final work product produced by the USACE in 1977.

The first phase of the effort to refine the hydrologic models focused on parameters other than the rainfall hyetographs. For these initial analyses, the rainfall hyetographs based on 30-minute time increments (as described in the previous section) were utilized.

Reviewing the USACE subbasin maps, it appears that the 1977 modeling effort was conducted with a high level of detail that would likely not be exceeded using modern modeling techniques. The typical size of the subbasins defined in the USACE study appears to be reasonable for the size of the watershed and the terrain. However, the current model refinement effort did include perturbing numerous modeling parameters in both the upper and lower basin models; this including the surface storage on both pervious and impervious surfaces, infiltration rates, and the computational time interval. Details associated with the parameters and values used in these analyses are provided in Appendix D. The discharges resulting from these analyses are summarized in Table 3.1, as Scenario Nos. 3, 4, 5 and 6.

At the conclusion of this phase of the analysis, it was judged that the modeling parameters associated with Scenario No. 3 best represented the original intent of the USACE hydrologic models while also being compatible with expected physical conditions in the watershed. For Scenario No. 3, the following changes were made to the 25-year models provided by the USACE:

(a) 30-minute increment rainfall hyetographs associated with the 1-percent annual chance event replaced the 60-minute increment, 4-percent annual chance rainfall hyetographs;

(b) surface storage depths of 0.2 inches for the impervious portions of both the upper basin and the upper portion of the lower basin were modified to 0.05 inches, commensurate with the surface storage values documented in the USACE report for " the mountain portion of the basin;" and

(c) lacking direction with respect to the following parameters in the USACE report, surface storage depths of 0.2 inches and 0.18 inches for the impervious and pervious areas within the lower portion of the lower basin, respectively, were changed to 0.062 inches and 0.184 inches, in accordance with current default surface storage parameters in UDSWM2-PC.

Even with utilizing the revised physical parameters in the hydrologic models, resulting discharges near the mouth of the canyon were 12 to 13 percent lower than the effective discharges at that location.

The second phase of this effort focused on the rainfall depths utilized to generate the rainfall hyetographs used in the models. Scenario No. 7 simply considered increasing the rainfall depth in each of the five rainfall zones by 5 percent. As indicated in Table 3.1, this brought the computed 1-percent annual chance discharges near the mouth of the canyon into close agreement (within approximately 2 percent) of the effective discharges. While these results were encouraging, an across-the-board increase in rainfall depth of 5 percent could not readily be justified.

It was recognized that the USACE would have relied on manual methods for defining the average rainfall depths for each of the five rainfall zones, rather than the GIS tools utilized initially for the current study. Consequently, 100-year rainfall depths were recalculated by manually computing area-weighted averages using the isohyetal map provided in Figure 2.2. These rainfall depths, along with the recalculated 1-percent annual chance rainfall hyetographs are provided in Appendix D. The discharges resulting from the hydrologic modeling conducted using the manually estimated rainfall depths are shown in Table 3.1, as Scenario No. 8. Near the canyon mouth, the computed discharges were approximately 13 to 14 percent lower than the effective values.

Considering the small scale of the isohyetal maps available in NOAA Atlas 2 (1 inch is approximately equal to 32 miles) relative to the size of the watershed (approximately 8 miles north-south and 25 miles east-west), along with the density of the isohyets in the vicinity of the Boulder Creek watershed (as shown in the map excerpt from the NOAA atlas provided in Appendix D), it is possible that the USACE used less precise values than those computed for the current study. Various rounding schemes were attempted, as described in detail in Appendix D. The results of utilizing the various rainfall hyetographs in the hydrologic models are summarized Table 3.1, as Scenario Nos. 9, 10, 11 and 12. Reviewing the results of these analyses, it was determined that Scenario No. 12 provided the closest estimate of the effective 1-percent annual chance discharges. It was also judged that the rainfall depths used to generate the rainfall hyetographs for this scenario were values that could have possibly been utilized by the USACE in the original study. The rainfall depths and rainfall hyetographs used for Scenario No. 12 are provided in Table 3.2.

Table 3.2 Summary of Rainfall Depths and Hyetographs Used in the Scenario No. 13 Hydrologic Model.

Condition or Time (min) / % of Total Rainfall	Rainfall Depth (inches) for the Given Rainfall Zone				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Point Rainfall, 100-Yr, 6-Hr Storm	3.8	3.61	3.11	3.0	2.78
Area-Reduced Rainfall, Rounded up to Nearest 0.1 inches (Scenario #13)	3.4	3.2	2.8	2.7	2.5
Rainfall Hyetographs, USACE Standard Project Storm, Southwestern Division Criteria					
30 min. / 2%	0.136	0.128	0.112	0.108	0.100
60 min. / 4%	0.272	0.256	0.224	0.216	0.200
90 min. / 4%	0.272	0.256	0.224	0.216	0.200
120 min. / 5%	0.340	0.320	0.280	0.270	0.250
150 min. / 9%	0.612	0.576	0.504	0.486	0.450
180 min. / 10%	0.680	0.640	0.560	0.540	0.500
210 min. / 40%	2.720	2.560	2.240	2.160	2.000
240 min. / 10%	0.680	0.640	0.560	0.540	0.500
270 min. / 6%	0.408	0.384	0.336	0.324	0.300
300 min. / 4%	0.272	0.256	0.224	0.216	0.200
330 min. / 4%	0.272	0.256	0.224	0.216	0.200
360 min. / 2%	0.136	0.128	0.112	0.108	0.100

The 1-percent annual chance discharges estimated using the hydrologic models associated with Scenario No. 12 are within approximately 6 percent of the effective discharges near the mouth of the canyon. Consequently, the Scenario No. 12 hydrologic models are considered to be reasonable representations of the duplicate effective hydrologic models for the Boulder Creek watershed, for the areas upstream of the canyon mouth. All hydrologic models (input and output files) developed for Scenario Nos. 1 through 12 are provided on the CD-ROM included with this report, along with the three applicable USACE models (input files only).

IV. CONVEYANCE ROUTING THROUGH THE LOWER BOULDER CREEK BASIN

As mentioned previously, the USACE hydrologic (SWMM) model of the lower Boulder Creek basin did not consider flood routing along the creek. Rather, for lower Boulder Creek the USACE used a diffusion routing model apparently called the Harders model. The current study attempted to closely replicate the results of the USACE diffusion routing effort by adding conveyance elements into the lower basin SWMM model, thereby accomplishing conveyance routing along lower Boulder Creek using the kinematic wave algorithm inherent in SWMM.

Locations of the six tributary inflows along lower Boulder Creek were identified using the USACE subbasin maps; these are shown on the annotated map included in Appendix E as Figure E1. Due to the relatively close proximity of the confluences of the two upstream tributaries with Boulder Creek, a stream conveyance element was not identified between those two tributaries. In addition, the downstream-most tributary is defined in the USACE model as entering Boulder Creek at the downstream limit of the study. Consequently, four stream routing conveyance elements were defined and incorporated into the final hydrologic model for the lower basin, as defined in the previous chapter; that is, the model associated with Scenario No. 12. In addition, an inflow hydrograph to the lower basin was defined for the 1-percent annual chance event based on the upper basin hydrologic modeling results also associated with Scenario No. 12.

The lower basin schematic previously presented in Figure B5 (Appendix B) shows the conveyance elements, inflow hydrograph, and non-routing nodes added to the lower basin model to support upper basin inflows and conveyance routing within the SWMM model along Boulder Creek. Using the hydraulic model being prepared by ACE for the current floodplain study for Boulder Creek, a cross section was selected within each routing reach that is representative of the typical channel and overbank condition for each reach. Cross sectional geometry was defined based on the HEC-RAS model geometry for each of the four selected cross sections. Roughness coefficients were defined as approximate averages for each reach, while the reach lengths and channel slopes were determined based on reach-wide data taken from the HEC-RAS model. Detailed information concerning the definition of the conveyance routing elements is provided in Appendix E.

Hydrologic modeling Scenario No. 13 is identical to Scenario No. 12 with the exception that the lower basin model includes the inflow hydrograph from the upper basin (from Scenario No. 12) and the four conveyance routing elements along Boulder Creek. The conveyance routing elements span from nearly the canyon mouth downstream to near the confluence with South Boulder Creek. The computed discharges resulting from Scenario No. 13 are summarized in Table 4.1. As shown in the table, the discharges computed using the Scenario Nos. 12 and 13 hydrologic models agree with the 1-percent annual chance discharges from the effective hydraulic model to within ±6.5 percent. Consequently, the Scenario No. 12 hydrologic model for the upper basin and the Scenario No. 13 hydrologic model for the lower basin are considered to be reasonable representations of duplicate effective hydrologic models for the Boulder Creek watershed, for the areas upstream of the confluence with South Boulder Creek.

Table 4.1 Boulder Creek 1-Percent Annual Chance Discharges, With Flood Routing Along Lower Boulder Creek.

Scenario	Filenames	1-Percent Annual Chance Discharge (cfs) at the Location Indicated (Percent Difference Relative to Effective)					
		Canyon Mouth 131.3 sq. mi. (CE 23, 93 & 94)	U/S Crossing of Arapahoe Ave. 133.4 sq. mi. (CE 23 & 93-95)	9th Street 135.6 sq. mi. (CE 23 & 93-96)	U/S of BNRR 145.8 sq. mi. (CE 23 & 93-97)	U/S of Valmont 157.4 sq. mi. (CE 23 & 93-98)	U/S of S. Boulder Cr. 158.1 sq. mi. (CE 23 & 93-99)
Effec.	Effective HEC-2 Model	11,650	11,950	12,100	11,800	13,300	13,300
13	Upper Basin: UBDR10HT Lower Basin: LBDR10HS	10,910 (-6.4%)	11,170 (-6.5%)	11,430 (-5.5%)	11,550 (-2.0%)	13,400 (+0.8%)	13,470 (+1.3%)

Input and output files associated with the hydrologic model that represents Scenario No. 13 are provided on the CD-ROM included with this report.

V. CORRELATION OF MODELING RESULTS TO STREAM GAGE DATA AND REGRESSION EQUATIONS

In an effort to assess the appropriateness of the discharges utilized in the effective hydraulic model for Boulder Creek, an evaluation was conducted to estimate 1-percent annual chance discharges along Boulder Creek based on U.S. Geological Survey (USGS) stream gage data, as well as regional regression equations.

The only USGS stream gage on Boulder Creek near the current floodplain study reach (through the City of Boulder) is the Orodell gage which is located more than 2.5 river miles upstream of the canyon mouth. This gage is located below Barker Reservoir, which can substantially impact flood peaks by offering significant detention storage of storm runoff depending on the water level in the reservoir at the time a storm event occurs. A flood flow frequency analysis of stream gage data that is influenced by upstream controls is not strictly valid. However, in an effort to evaluate general trends, just such an analysis was attempted using the USGS PEAKFQ computer program; this software automates Bulletin 17B procedures for conducting flood flow frequency analyses. This analysis is documented in Appendix F. The results of this analysis indicate that the modeled 1-percent annual chance discharge near the Orodell gage is higher than the estimate by the statistical evaluation of the gaged stream flows, as would be expected given the upstream control imposed by the reservoir. However, specific results of this analysis are not valid due to the influence of the reservoir of flood flow peaks.

In an attempt to validate the effective 1-percent annual chance discharges along Boulder Creek, regression equations developed by the USGS were applied to the study area based on data extracted from the USACE hydrologic models. Given that most of the watershed contributing runoff to the study reach is located in the foothills and mountains of the north-central Front Range of Colorado, the USGS regression equation for the Mountain Region was first applied. However, the regression equation results indicated that this likely was not the appropriate relationship to be used in this case. This analysis is provided in Appendix F.

Reviewing the USGS map (included in Appendix F) that defines regional boundaries and shows the locations of the gaging stations used in developing the regression equations, it became clear that relative to the mountains along the Front Range, the spatial locations of several gaging stations used in developing the Plains Region regression equations are similar to the Boulder Creek study reach. In fact, four of these gaging stations are located relatively close to Boulder Creek; these include: (a) Clear Creek near Golden; (b) Bear Creek at Morrison; (c) Turkey Creek near Morrison; and (d) North Fork South Platte River at South Platte. Consequently, the USGS regression equation for the Plains Region was used to the estimate 1-percent annual chance discharges at three locations along Boulder Creek. This analysis is documented in Appendix F, with the results summarized in Table 5.1.

With an average standard error of prediction of 96 percent, the Plains Region equations have generally resulted in unreliable estimates of 1-percent annual chance discharges in northeastern Colorado. However, with many of the gages used in developing these equations being located in relatively close proximity to mountainous areas, in this case the Plains Region estimates agree well with

effective 1-percent annual chance discharges for Boulder Creek, particularly near the canyon mouth and upstream of the confluence with South Boulder Creek. With the Orodell gage being located entirely in a mountainous area, correlation of the two flows at that location would not necessarily be expected.

Table 5.1 Summary of Regional Regression Equation Result and Comparison With Effective Discharges.

Location	Area (sq. mi.)	Effective Discharge (cfs)	USGS Plains Region Equation		CWCB SPL-3 Subregion Eqn	
			Q_{100} (cfs)	% Error Qeff. vs Q_{100}	Q_{100} (cfs)	% Error Qeff. vs Q_{100}
Boulder Creek at Orodell Gage	102.1	6,270[a]	9,870	–36.5	9,530	–34.2
Boulder Creek near the Canyon Mouth	131.3	11,650[b]	10,880	+7.1	10,930	+6.6
Boulder Creek u/s of S. Boulder Cr.	158.1	13,300[b]	11,700	+13.7	12,100	+9.9

[a] Discharge taken from the SWMM model for Scenario No. 12.
[b] Discharge taken from the original effective HEC-2 model.

Regional regression equations were not defined by the Colorado Water Conservation Board (CWCB) for streams within the UDFCD. However, the CWCB Central Foothills Subregion (SPL-3), within the South Platte River Basin, encompasses the upper portion of the Boulder Creek watershed downstream nearly to the canyon mouth. Reference is made to the CWCB subregion map included in Appendix F. Therefore, the CWCB SPL-3 regression equation was used to estimate 1-percent annual chance discharges for Boulder Creek. This analysis is documented in Appendix F, with the results summarized in Table 5.1.

At the Orodell gage, the 1-percent annual chance discharge produced by the duplicate effective hydrologic model is 34 percent lower than the CWCB estimate. This value does not fall within the regression equation's standard error of estimate of 23 percent. However, near the canyon mouth and upstream of South Boulder Creek (roughly bracketing the current floodplain study reach), the CWCB regression estimates agree relatively closely with the 1-percent annual chance discharges utilized in the effective hydraulic model.

VI. SUMMARY AND CONCLUSIONS

This study included an evaluation of the effective hydrologic model, along with the preparation of a duplicate effective hydrologic model. Through both of these processes it was concluded that the level of detail incorporated into the 1977 USACE hydrologic model appeared to at least meet, if not exceed, typical hydrologic modeling techniques currently employed in the industry. Although a detailed evaluation was not conducted of each parameter used in the model, the hydrologic modeling parameters utilized in the duplicate effective hydrologic model appear to be in general agreement with typical modeling parameters currently used in this geographic area.

It was determined that using technically-based rainfall depths for the watershed, along with standard rainfall hyetographs and physically-based conveyance routing elements through the lower basin, an accurate duplicate effective hydrologic model could be created. It was demonstrated that this duplicate effective model will generate 1-percent annual chance discharges along Boulder Creek that agree reasonably closely with discharges used in the original effective hydraulic model. These discharges agree to within 7 percent through the extreme upper portion of the floodplain study reach, and within 2 percent through the remaining portion of the study reach. In addition, the effective 1-percent annual chance discharges agree closely with discharge estimates produced by application of both USGS and CWCB regional regression equations for the area.

Consequently, it appears that the 1-percent annual chance discharges produced by the 1977 USACE study, and currently used as the effective discharges for purposes of flood regulation by the City of Boulder and FEMA, are reasonable and appropriate for conducting the current floodplain study.

VII. REFERENCES

Colorado Department of Natural Resources, Colorado Water Conservation Board, Flood Protection Program, "Guidelines for Determining 100-Year Flows for Approximate Floodplains in Colorado," Version 6.0, Denver, Colorado, June 2004.

Dodson and Associates, Inc., "ProHEC1 Program Documentation Plus," Version 4.0 User's Manual, April 1991, revised June 1995.

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U.S. Geological Survey, "Analysis of the Magnitude and Frequency of Floods in Colorado," Water Resources Investigations Report 99-4190, Denver, Colorado, 2000.

U.S. Water Resources Council, "Guidelines for Determining Flood-Flow Frequency," Bulletin No. 17B of the Hydrology Committee, Washington, D.C., September 1981.

APPENDIX A

USACE REVIEW REPORT, BOULDER CREEK

REVIEW REPORT
BOULDER CREEK

1. INTRODUCTION. This report presents the results of hydrologic studies recently completed on Boulder Creek, Colorado, in connection with the Metropolitan Denver Urban Studies. These studies have resulted in the revision of hydrologic relationships presented in Volume II, Flood Plain Information (FPI) Boulder Metropolitan Region, August 1969. A description of the 1969 study results and discussion of the updated studies is presented in the following paragraphs.

2. PREVIOUS STUDIES.

a. Discharge Probability. The Boulder Creek basin discharge probability values presented in the FPI report cited above were developed by applying statistical parameters computed from the South Boulder Creek at Eldorado Springs and Boulder Creek at Orodell gaging records to a regional standard deviate (K) distribution. This regional "K" distribution was developed in 1967 from seven long-record mountain stream gaging stations having a combined record of 473 years. The resulting 100-year discharges published in the FPI report were 7,400 cubic feet per second for Boulder Creek at Boulder, and 10,800 cubic feet per second for Boulder Creek below the confluence of South Boulder Creek.

b. Standard Project Flood. The standard project flood developed for the Boulder Creek FPI studies was based on an extrapolation of the standard project storm data presented in EM 1110-2-1411 and adjusted for the mountain barrier effect. The standard project flood runoff was determined by applying

a loss rate equal to 1 inch per hour to the standard project storm. Unit hydrographs developed for Boulder Creek at Boulder and South Boulder Creek at Boulder from regional unit graph studies of mountain tributaries to the South Platte River were used to convert this runoff to standard project flood hydrographs at Boulder. The resulting standard project flood peak discharges as published in the FPI report were 15,800 cubic feet per second for Boulder Creek at Boulder, and 21,000 cubic feet per second for Boulder Creek below the mouth of South Boulder Creek.

3. UPDATED STUDY.

a. General. The updated hydrologic studies for Boulder Creek were based on a surface water runoff model of the Boulder Creek basin using the Surface Water Management Model (SWMM) developed by EPA. This model was used to develop flows for major tributaries along Boulder Creek from the west edge of Boulder to the mouth. The resulting tributary flows were routed through the Boulder Creek flood plain using the unsteady flow routing program developed by Missouri River Division. A discussion of the important details of the study are presented in the following paragraphs. Historical stream gaging records were used to check the results obtained with the surface water runoff model.

b. Surface Water Runoff Model.

(1) General. The runoff model for the Boulder Creek basin was developed from geophysical information obtained from an AMS map and a reconnaissance trip into the basin. Selection of the hydraulic and hydrologic parameters that correspond to these physical features were based on sensitivity and calibration studies in conjunction with values obtained from past studies of mountain tributaries in the South Platte Basin. Some of the more significant parameters are discussed in detail below.

(2) Overland Flow Roughness. An overland flow roughness coefficient of "n" = 0.12 was used instead of the default value of "n" = 0.25. The selection was based on the results of calibration studies of the 1973 flood on lower Cherry Creek which indicated that the model was sensitive to the size of the subarea breakdown used in the analysis. These calibration studies also revealed that variation due to subarea size could be compensated by adjusting the overland flow "n". An overland "n" value of 0.12 relates to subareas ranging in size from three-fourths to one square mile.

(3) Detention Storage. The model results were quite sensitive to variation in the detention storage in the mountain region. Considering the steep slopes that exist in the mountains, it is doubtful that the average detention storage figure could ever approach the default value of 1.84. Therefore, a nominal figure of 0.5 was selected for the mountain portion of the basin.

(4) Channel and Overbank Roughness. Channel and overbank "n" values were varied from .06 to .09 depending on the amount of boulders, vegetation and buildings that were present at the selected observation sites during the reconnaissance inspection. The model was quite sensitive to variations in the assumed values of "n", therefore, guidance was solicited from the Hydraulics Section and from MRD in making the final selection in each of the typical areas.

(5) Rainfall. Rainfall values for the Boulder Creek basin were obtained from NOAA's Atlas 2, Volume 3, published for the State of Colorado in 1973. Rainfall durations of 1, 3 and 6 hours were studied in order to test the

model sensitivity to rainfall duration. Variations in the rainfall data from the NOAA Atlas were such that five hyetographs were required to delineate the average amounts over the basin accurately. Depth-area adjustments were based on 155 square miles for Boulder Creek to the mouth of South Boulder and 440 square miles for Boulder Creek at the mouth. Expected probability adjustments to the rainfall were made on equivalent rainfall record length of 48 years. Time distribution of the rainfall was based on a rainfall intensity-duration study of hourly rainfall values at 13 recorder stations in the South Platte River Basin. Further refinement to 30-minute durations was based on information presented in Civil Works Bulletin 52-8 for standard project storm rainfall. These results are shown in Table 1 for the rainfall durations studied.

TABLE 1
RAINFALL DISTRIBUTION

Rainfall Duration (hours)	30 Minute Increments (% of Total)		Rainfall Duration (hours)	30 Minute Increments (% of Total)		Rainfall Duration (hours)	30 Minute Increments (% of Total)	
1	1st	20	3	1st	4	6	1st	2
	2nd	80		2nd	8		2nd	4
				3rd	19		3rd	4
				4th	50		4th	5
				5th	11		5th	9
				6th	8		6th	10
							7th	40
							8th	10
							9th	6
							10th	4
							11th	4
							12th	2

AVG. RAINFALL PROVIDED BY W. STARRY ON 4/17/81

FOUR MILE	BOULDER
500 - 4.3"	500 - 3.8"
100 - 3.2"	100 - 2.8"
50 - 2.8"	50 - 2.5"
10 - 1.9"	10 - 1.7"

Flood peaks computed from the model were somewhat sensitive to the rainfall duration selected. Although the 3-hour storm produced the critical peak discharge, the 6-hour duration storm was selected as the most

representative of conditions to be expected in the Boulder Creek basin. This selection was based on our judgement that areal coverage for short duration storms such as the 3-hour over a basin of 155 square miles in mountainous terrain would not be as likely to occur as indicated by the depth-area relationships presented in the NOAA Atlas. It is recognized that high intensity short duration storms do occur over small portions of the Boulder Creek basin and sharp high peaks result from these events. It is our judgment, however, that the effect of these events is highly localized because of the small volumes associated with them. Since our study effort was more basin-wide in approach, it was felt that the longer duration rainfall results would be more appropriate.

c. Unsteady Flow Routing. It was apparent from the field reconnaissance of Boulder Creek that flows downstream from the mouth of the canyon would be affected by overbank storage. Therefore, MRD's version of the unsteady flow routing technique was used to route flood hydrographs downstream from the west edge of Boulder to the mouth of Boulder Creek. Hydraulic characteristics of the channel and flood plain for use in the routings were taken from several sources depending on location. In the reach from the mouth

of the Canyon to Valmont Road, the conveyance information was obtained from a recent backwater study using surveyed sections. Pertinent data for the reach from Valmont Road to the mouth of Coal Creek were taken from studies completed for the Flood Plain Information Report. The conveyance data for the last reach to the mouth was based on trial and error routings of 1938 event recorded at Orodell and the mouth.

d. Discharge Profiles. Profiles for the 500, 100, 50, 25 and 10-year peak discharges are shown on attachment 1. These data are the results of our computer runs using the SWMM program in conjunction with MRD's unsteady flow routing model.

e. 100-Year Flood Hydrographs. The hydrographs showing the time distribution of flow for the 100-year event on Boulder Creek are shown on attachments 2 & 3. The variation in the runoff volume occurring in these hydrographs is due to a change in depth-area relationships and different rates of runoff caused by impervious condition in the Boulder area.

f. 500-Year Flood. Standard project storm criteria presented in EM 1110-2-1411 have not been defined for the mountain regions of the Boulder Creek basin; therefore, the 500-year flood was selected to represent the major flood potential in Boulder. This flood was determined by extrapolating on semi-log paper the 100-year rainfall obtained from the NOAA Atlas previously discussed.

g. +.05 Error Limit. A discharge corresponding to the .05 error limit of the 100-year rainfall was developed to provide a discharge that can be used in planning and design studies for sensitivity comparisons. The discharge profile for this analysis is shown on attachment 1.

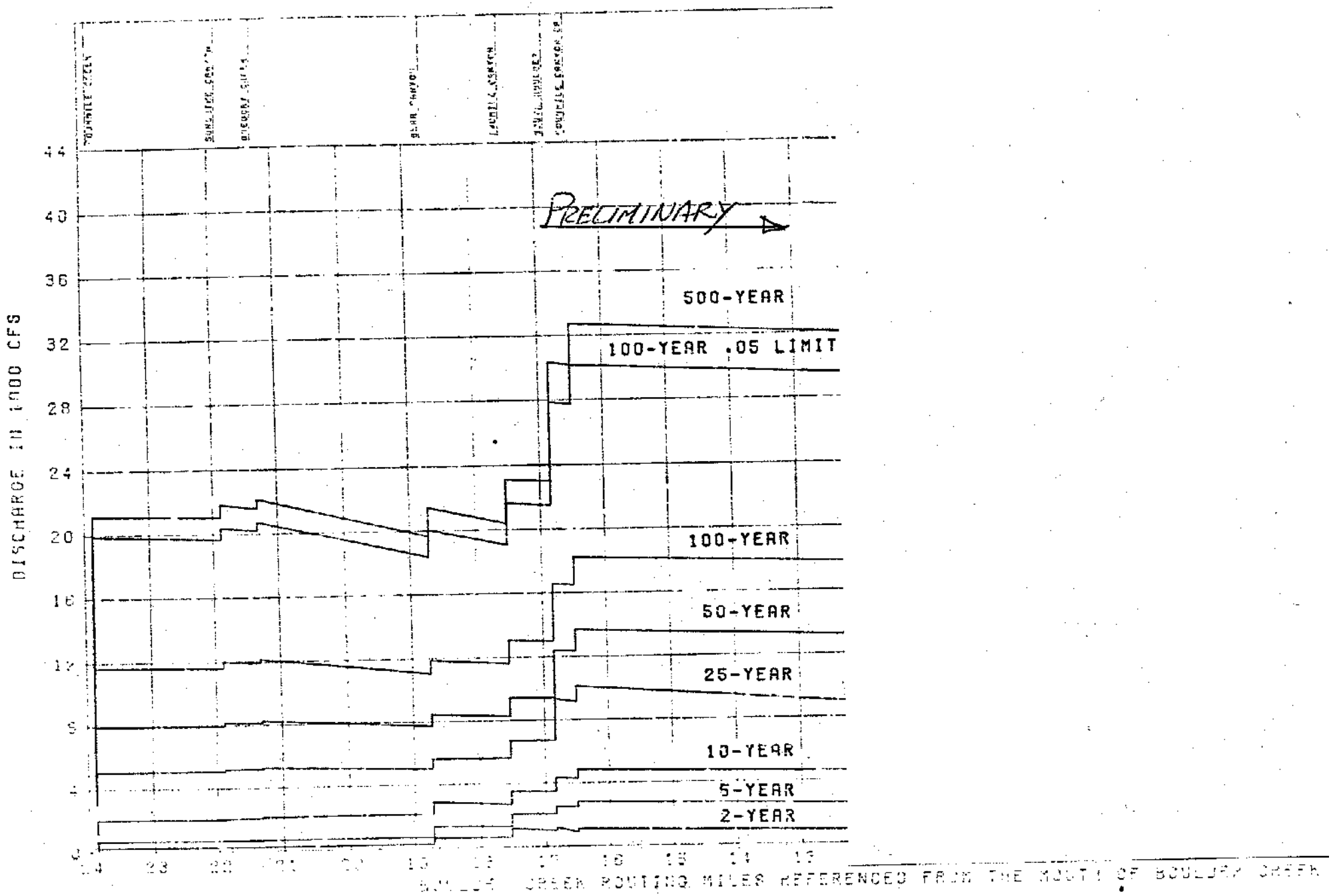
4. GAGING STATION COMPARISONS.

a. Boulder Creek at Boulder. The fragmentary discharge record for Boulder Creek at Boulder (located 1-1/2 miles downstream from Fourmile Creek) which was started in 1889 and discontinued in 1909 was selected as the key station for Model calibration. Although this station has a relatively short period of record, it is at a location that has experienced rather severe floods prior to its establishment and after it was discontinued. In each case a discharge estimate is available. The events involved are 1894 with a discharge estimate ranging from 9,000 cubic feet per second to 13,000 cubic feet per second, 1914 with a discharge estimate of 5,000 cubic feet per second, and 1969 with a discharge estimate of 3,000 cubic feet per second. The results obtained from these data using a Weibull plotting position analysis were compared with the Model results and are shown on attachment 4.

b. Boulder Creek near Orodell and South Boulder Creek at Eldorado Springs. Comparisons similar to those shown above were made at the gaging stations located on Boulder Creek near Orodell and South Boulder Creek at Eldorado Springs. The record lengths at these stations are 67 years and 76 years respectively. These data were run under the old guidelines and therefore are plotted according to the median plotting positions. The results are shown on attachments 5 and 6.

5. REGIONAL STUDY. A discharge probability curve was developed at the old Boulder Creek at Boulder gage site using criteria presented in Technical Manual #1 (1976), prepared by the Colorado Water Conservation Board in cooperation with the U.S.G.S. This study relates discharge to drainage area below 7,500 feet. These results are shown on attachment 4 for comparison purposes.

6. DISCUSSION. The peak discharges developed in this study for the 100-year event are substantially higher than previously published by our office. This study indicates 1 percent discharges through Boulder vary from 11,000 c.f.s. to 12,000 c.f.s. as compared to a value of 7,400 c.f.s. for this reach from the earlier study. Below the South Boulder Creek confluence these figures are 16,500 cubic feet per second and 11,000 cubic feet per second respectively. In reviewing our July 1969 correspondence with the USGS concerning Boulder Creek, their estimate of the 1 percent discharge in Boulder was 11,000 cubic feet per second. This value was predicated on the 1894 flood peak which had discharge estimates ranging from 9,000 cubic feet per second to 13,000 cubic feet per second at Boulder. Considering the recent flood (1 August 1976) on the Big Thompson River and the peak discharge estimates of the 1894 flood on Boulder Creek, the 1 percent discharges determined from the new studies seem to provide a more realistic representation of the flood potential in the Boulder Creek basin than was indicated by the earlier studies made by our office.


PRELIMINARY
500-YEAR
100-YEAR .05 LIMIT
100-YEAR
50-YEAR
25-YEAR
10-YEAR
5-YEAR
2-YEAR
DISCHARGE IN 1000 CFS
40
36
32
28
24
20
16
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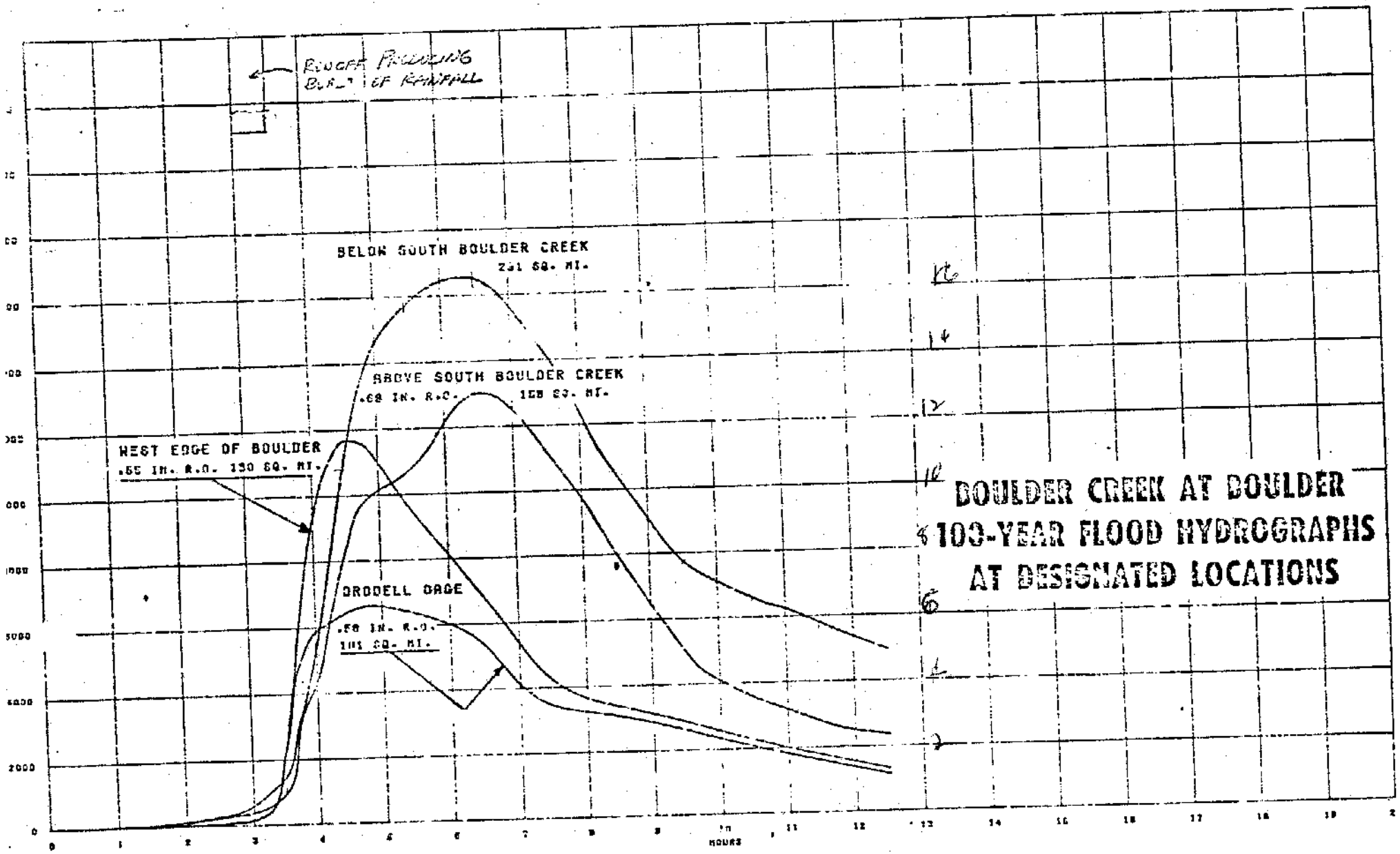
4
0
CREEK ROUTING MILES REFERENCED FROM THE MOUTH OF BOULDER CREEK



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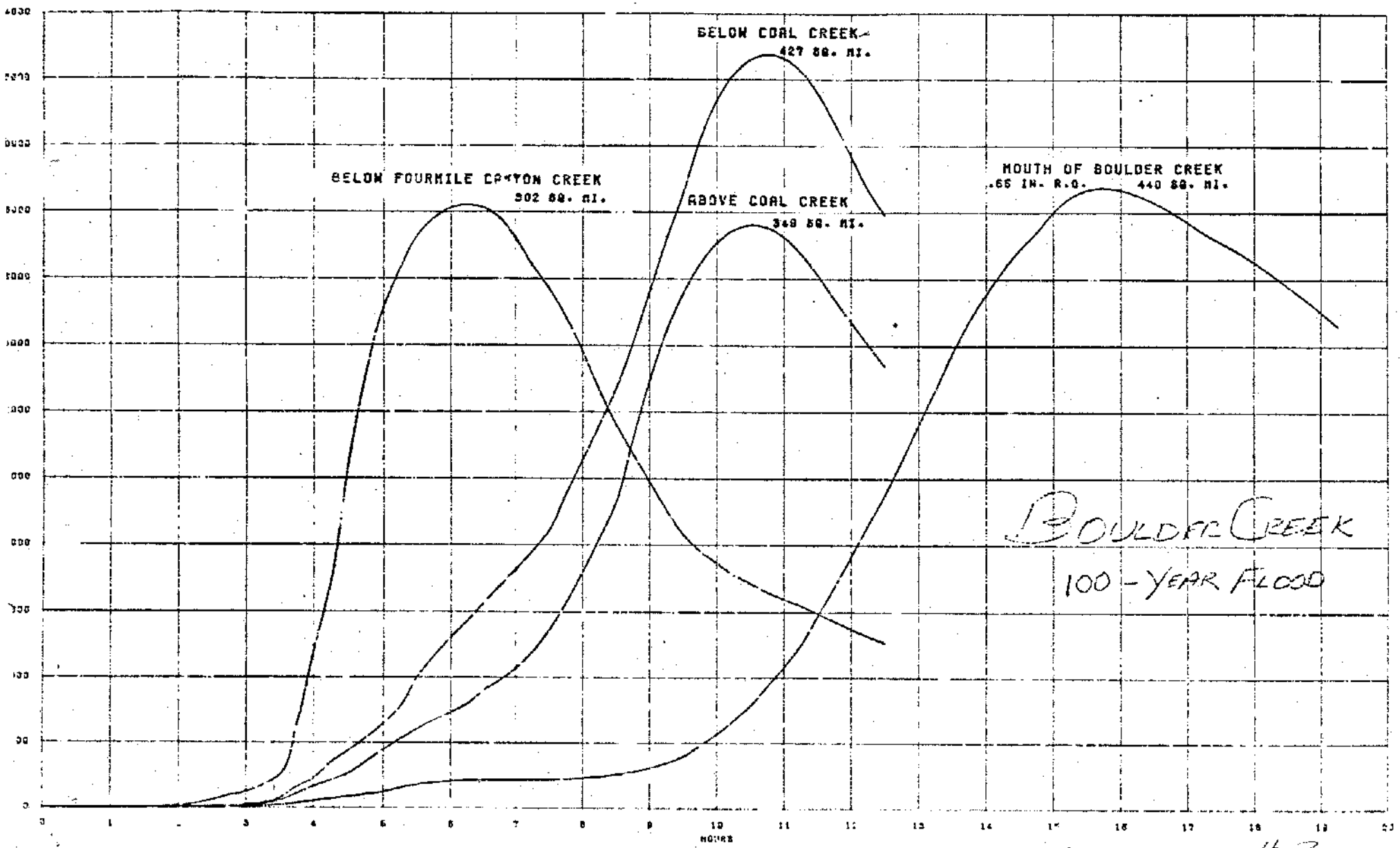
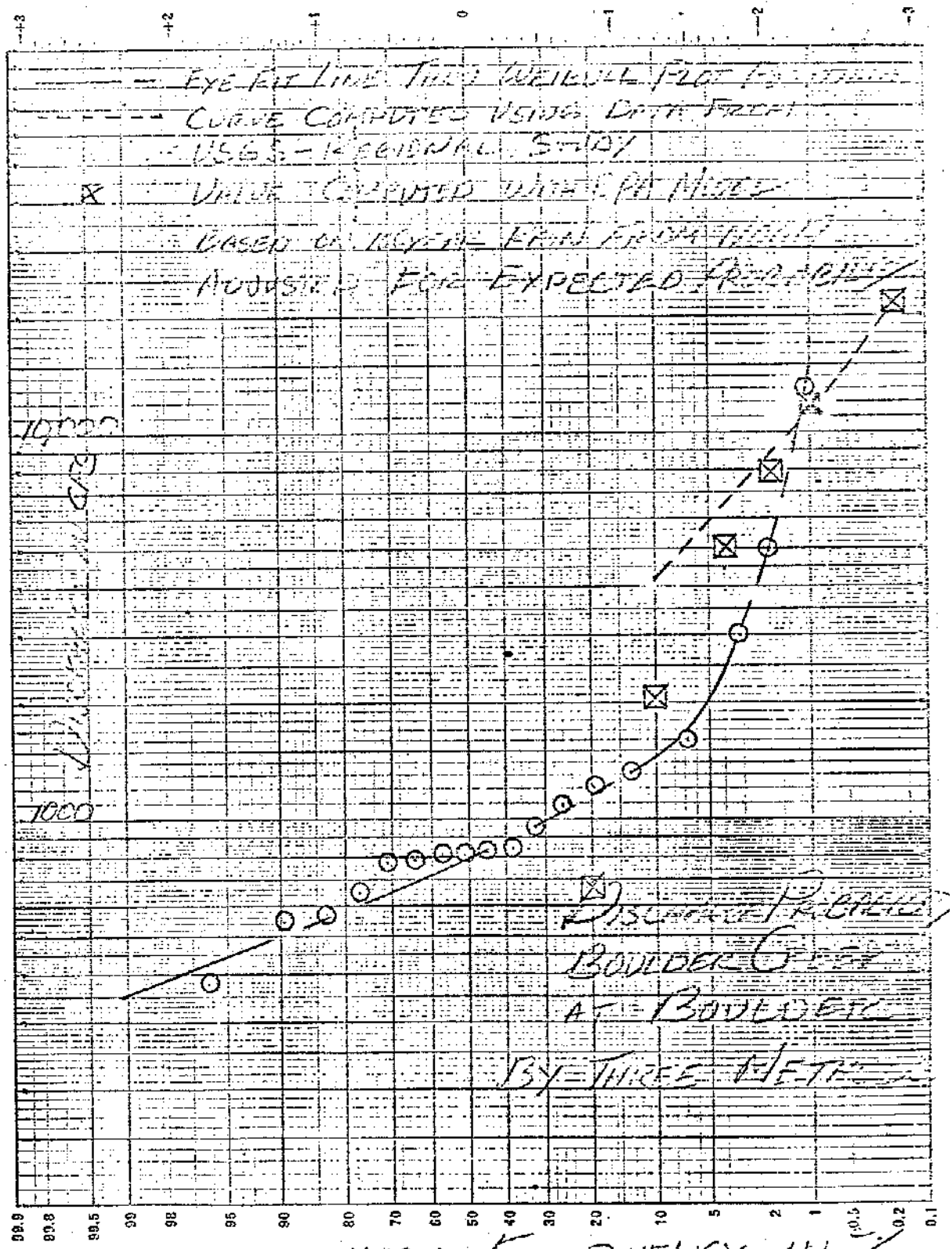


BOULDER CREEK
100-YEAR FLOOD

ATTACHMENT #3



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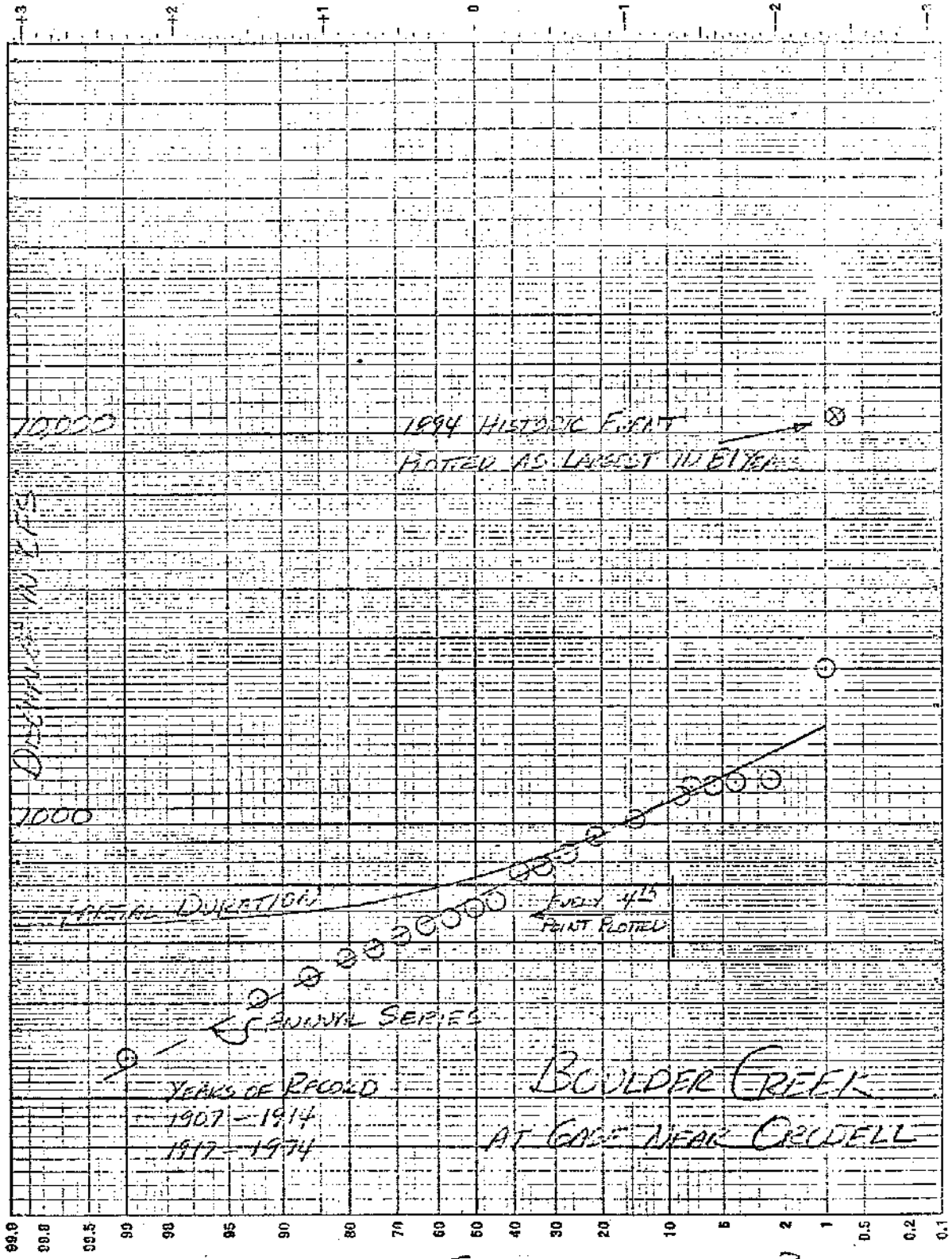

EXCEEDENCE FREQUENCY IN %

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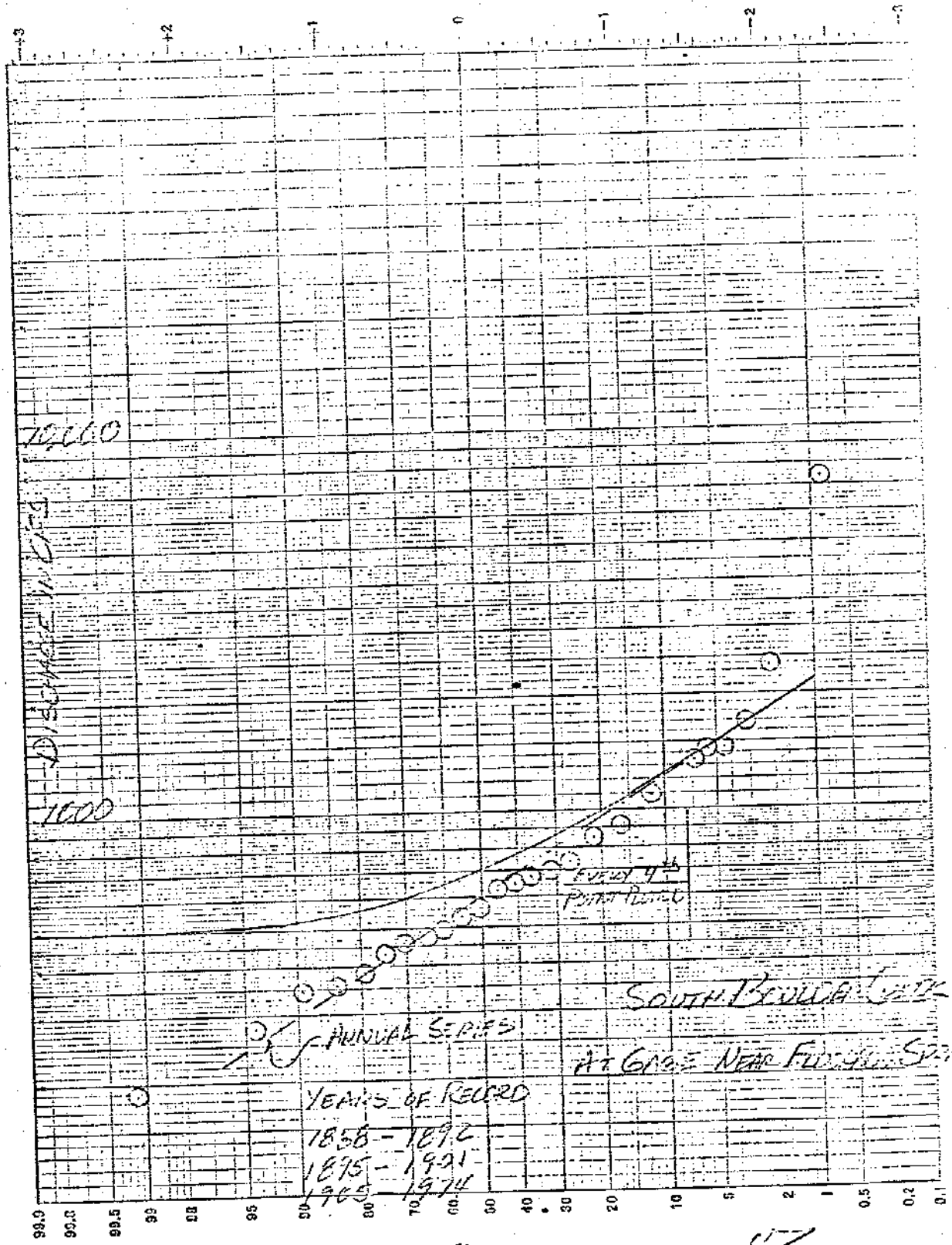

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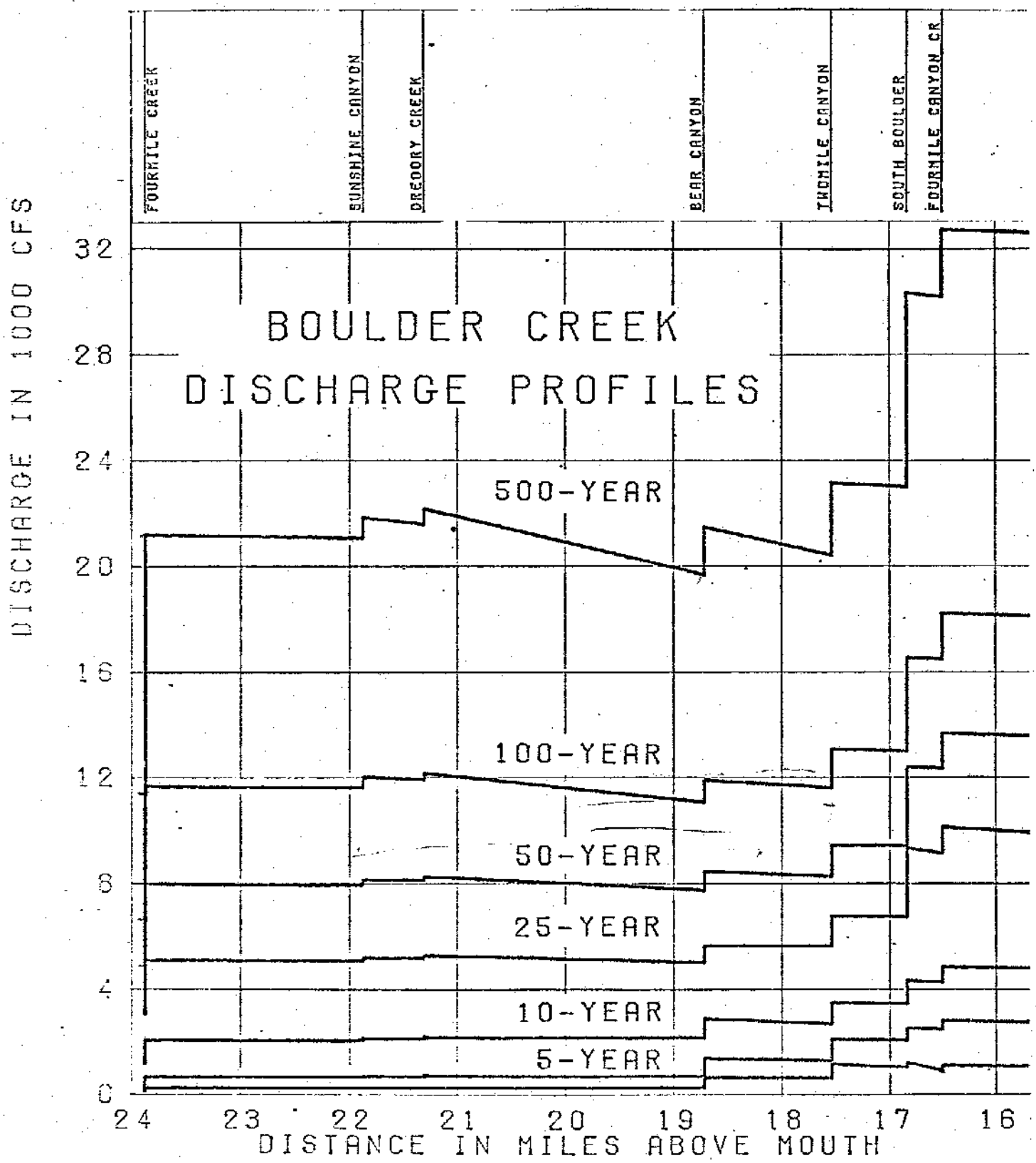
BOULDER CREEK
DISCHARGE PROFILES
FOURMILE CREEK
SUNSHINE CANYON
GREGORY CREEK
BEAR CANYON
TWOMILE CANYON
SOUTH BOULDER
FOURMILE CANYON CR
500-YEAR
100-YEAR
50-YEAR
25-YEAR
10-YEAR
5-YEAR
DISCHARGE IN 1000 CFS
0
4
8
12
16
20
24
28
32
24
23
22
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20
19
18
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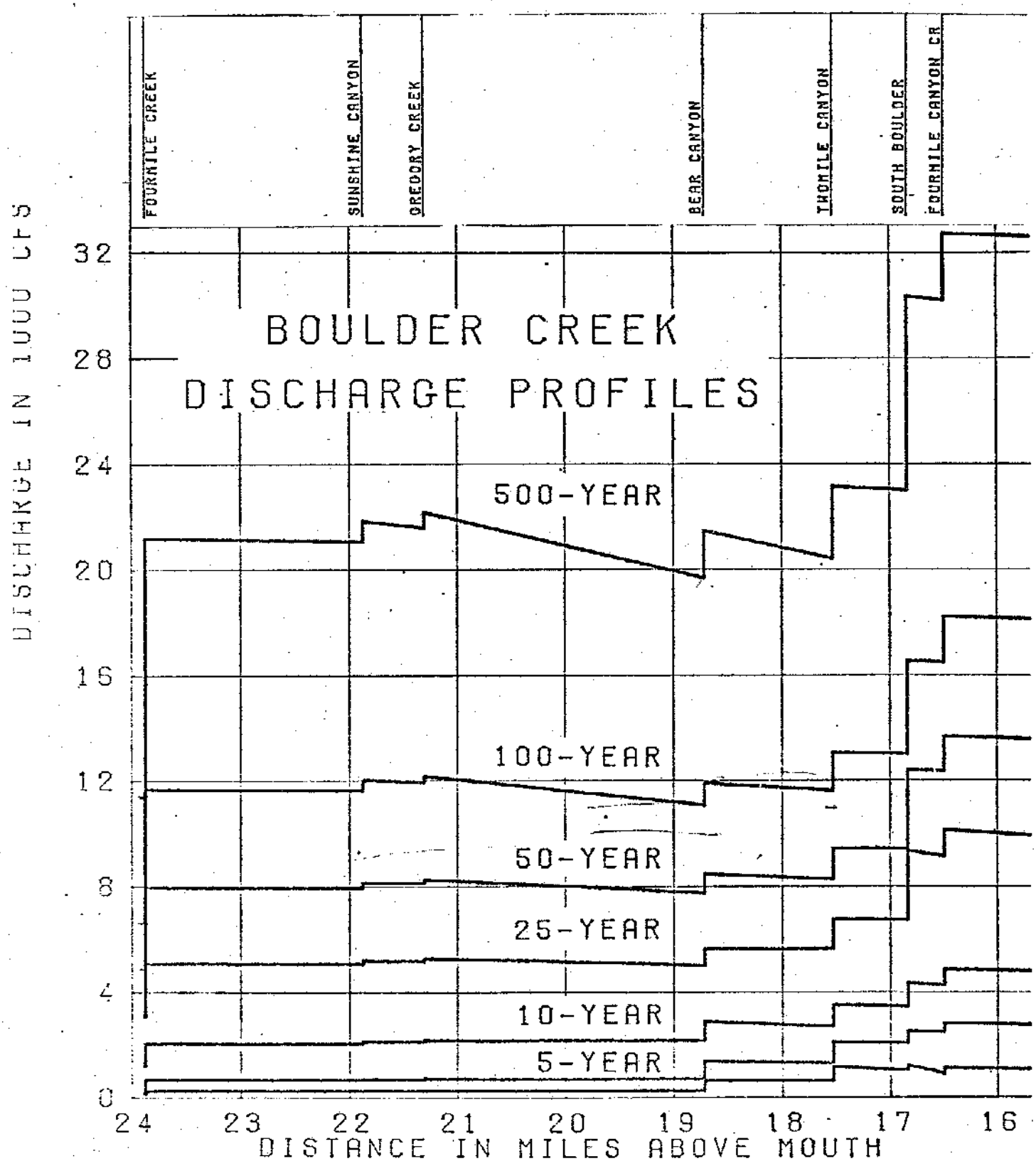
16
DISTANCE IN MILES ABOVE MOUTH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DISCHARGE PROFILES
FOURMILE CREEK
SUNSHINE CANYON
GREGORY CREEK
BEAR CANYON
TWOMILE CANYON
SOUTH BOULDER
FOURMILE CANYON CR
500-YEAR
100-YEAR
50-YEAR
25-YEAR
10-YEAR
5-YEAR
DISCHARGE IN 1000 CFS
0
4
8
12
16
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24
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32
24
23
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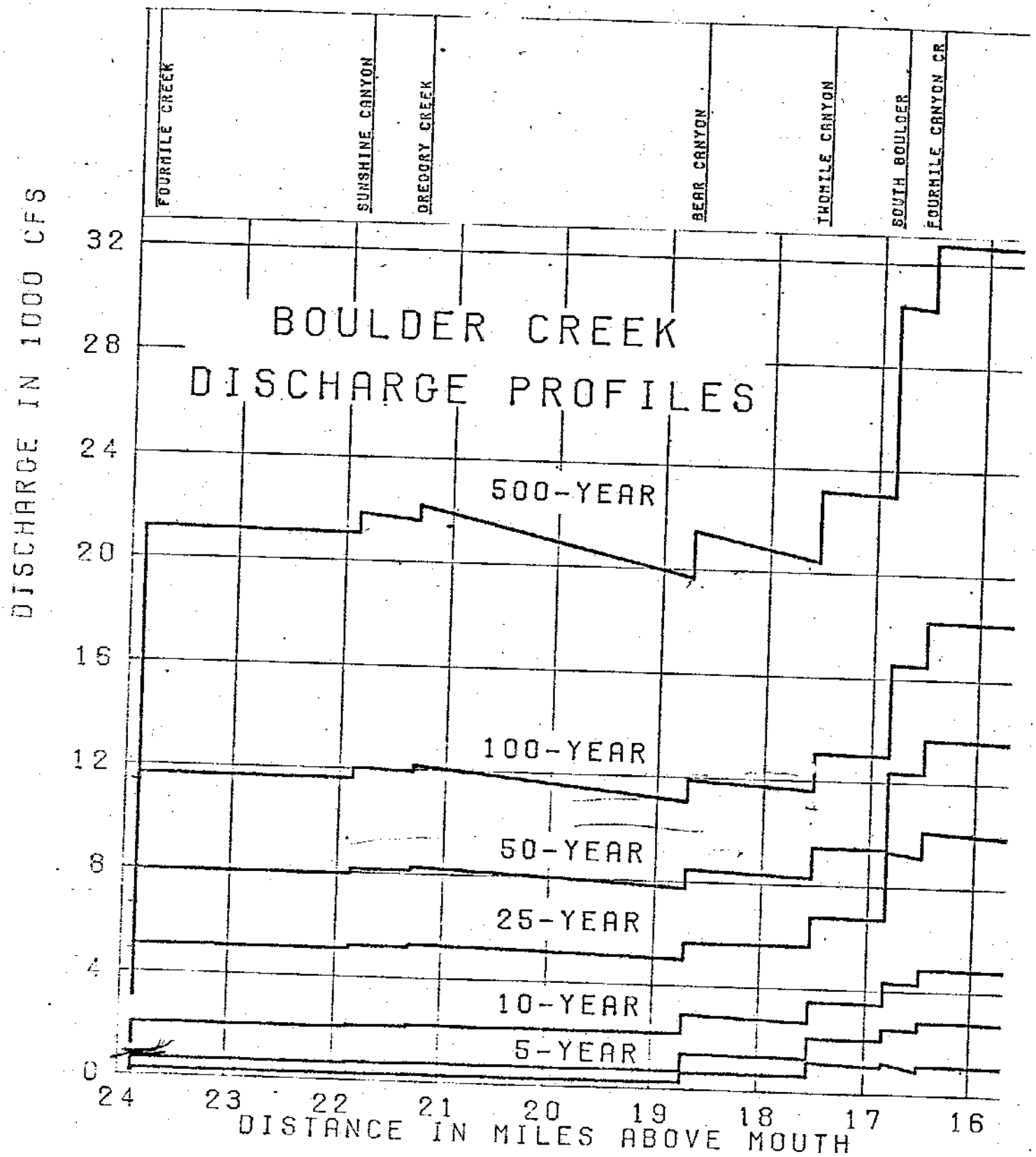
DISTANCE IN MILES ABOVE MOUTH


BOULDER CREEK
DISCHARGE PROFILES
FOURMILE CREEK
SUNSHINE CANYON
GREGORY CREEK
BEAR CANYON
TWOMILE CANYON
SOUTH BOULDER
FOURMILE CANYON CR
500-YEAR
100-YEAR
50-YEAR
25-YEAR
10-YEAR
5-YEAR
DISCHARGE IN 1000 CFS
0
4
8
12
16
20
24
28
32
24
23
22
21
20
19
18
17
16
DISTANCE IN MILES ABOVE MOUTH

APPENDIX B
USACE HYDROLOGIC MODEL INFORMATION AND RAINFALL HYETOGRAPHS

ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number COBLDR02	Page 1 Of 2
Owner-Project BOULDER CREEK FLOODPLAIN MAPPING	By GJK	Date 10/13/2008
Subject USACE 1977 HYDROLOGY	Checked By	Date

AVAILABLE DATA

- SUBBASIN MAPS FROM USACE; HAND DRAFTED, APPEAR TO BE IN-PROGRESS WORK PRODUCT, NOT FINAL; S. BOULDER CREEK COVERAGE IS INCOMPLETE
- "REVIEW REPORT, BOULDER CREEK," [USACE] PROVIDING BRIEF DOCUMENTATION OF THE BOULDER CREEK HYDROLOGY STUDY
- SWMM FILES: ALL FILES PROVIDED BY USACE ARE SUMMARIZED ON ATTACHED SHEET; THE PERTINENT FILES ARE AS FOLLOWS:
  - QEPABLDR & QEPAUPBC -- APPEAR TO BE COMPLETE FILES FOR 'LOWER' & 'UPPER' BOULDER CREEK, RESPECTIVELY; 'LOWER' IS BELOW ORODELL GAGE TO U/S OF SOUTH BOULDER CREEK; 'UPPER' IS U/S OF ORODELL GAGE; 25-YR RAINFALL W/ 1-HR HYETOGRAPH INCREMENTS
  - QUPBOULD -- PARTIAL BASIN FILE; 500-YR RAINFALL W/ 30-MIN. HYETOGRAPH INCREMENTS
  - INPUT FILES REFERENCE A VARIETY OF BASIN AREAS USED FOR AREAL REDUCTION OF POINT RAINFALL DEPTHS; 924 SQ. MI. IS REFERENCED MOST OFTEN
- HARDER ROUTING FILES: ALL FILES PROVIDED BY USACE ARE SUMMARIZED ON ATTACHED SHEET; IT IS DIFFICULT TO TELL WHICH FILE(S) ARE MOST APPLICABLE DUE TO THE LACK OF CORRELATION TO MAPPING; FILE 'QBLDR4' MAY BE THE MOST APPLICABLE TO BOULDER CREEK U/S OF SOUTH BOULDER CREEK

RAINFALL HYETOGRAPHS

- THE SWMM FILES INDICATED THE USE OF FIVE DIFFERENT RAINFALL HYETOGRAPHS CORRESPONDING TO FIVE REGIONS OF THE BOULDER CR WATERSHED

- THESE REGIONS WERE IDENTIFIED ON THE SUBBASIN MAPS AND TRANSLATED TO REAL WORLD COORDINATES

- THE AVERAGE 6-HOUR, 100-YEAR RAINFALL DEPTH FOR EACH REGION WAS ESTIMATED FROM THE "PRECIPITATION-FREQUENCY ATLAS OF THE WESTERN UNITED STATES, VOLUME III - COLORADO," [NOAA ATLAS 2] USING AN AREA-WEIGHTED AVERAGING PROCEDURE WITHIN ESRI'S SPATIAL ANALYST SOFTWARE

ZONE*	AVERAGE POINT 6HR, 100-YR RAINFALL DEPTH (INCHES)	AREA-REDUCED 100-YR, 6HR RAINFALL DEPTH -- 158 SQ.MI.** (INCHES)
1	3.82	3.32
2	3.46	3.01
3	3.04	2.64
4	3.05	2.65
5	2.73	2.38

* SEE ATTACHED FIGURE FOR ZONES
** 87% OF POINT RAINFALL; FROM NOAA ATLAS 2, FIG. 14

- THE RAINFALL HYETOGRAPHS USED BY THE USACE ARE UNCERTAIN. THE ONLY APPARENTLY COMPLETE MODELS AVAILABLE (25-YR MODELS) UTILIZE 1-HR HYETOGRAPH INCREMENTS WITH A PATTERN THAT FOLLOWS THE USACE 6-HOUR STANDARD PROJECT STORM, SPECIFICALLY UTILIZING THE SOUTHWESTERN DIVISION CRITERIA (WHICH IS A VARIATION OF THE STANDARD SPS DISTRIBUTION). HOWEVER, INITIAL ANALYSES COMPLETED USING THAT DISTRIBUTION, ALONG WITH AREAL REDUCED DEPTHS CITED ABOVE, YIELDED 100-YR DISCHARGES SIGNIFICANTLY LOWER THAN THOSE USED IN THE EFFECTIVE HYDRAULIC MODEL

- THE INCOMPLETE 500-YR HYDROLOGIC MODELS UTILIZE A VARIATION OF THE 6-HR SPS SWD HYETOGRAPH WHICH CONSISTS OF 12 30-MINUTE TIME INCREMENTS. THIS RAINFALL PATTERN IS SHOWN IN THE USACE "REVIEW REPORT."

Rainfall Hyetograph Calculator for Boulder Creek									
USACE Rainfall Distribution			Boulder Creek	Area-Reduced 100-Yr, 6-Hr		Area-Reduced 100-Yr, 6-Hr Rainfall Hyetographs			
Time	Rainfall Depth		Rainfall Zone	Rainfall Depth		Rainfall Intensity (inches/hour)			
(min)	(% of total)		(by USACE)	(inches)		Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
30	2		1	3.32		0.133	0.120	0.106	0.106	0.095
60	4		2	3.01		0.266	0.241	0.211	0.212	0.190
90	4		3	2.64		0.266	0.241	0.211	0.212	0.190
120	5		4	2.65		0.332	0.301	0.264	0.265	0.238
150	9		5	2.38		0.598	0.542	0.475	0.477	0.428
180	10					0.664	0.602	0.528	0.530	0.476
210	40					2.656	2.408	2.112	2.120	1.904
240	10					0.664	0.602	0.528	0.530	0.476
270	6					0.398	0.361	0.317	0.318	0.286
300	4					0.266	0.241	0.211	0.212	0.190
330	4					0.266	0.241	0.211	0.212	0.190
360	2					0.133	0.120	0.106	0.106	0.095
Total	100									

SWMM INPUT FILES

File Name	Title Cards
Boulder Creek:	
QEPABLDR	BOULDER CREEK AT BOULDER, COLO. 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPALBT1	LOWER BOULDER CREEK TRIBUTARIES (EPALBT1) WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPALBT2	LOWER BOULDER CREEK TRIBUTARIES (LBT2) WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPAUBT	UPPER BOULDER TRIBS WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPAUPBC	BOULDER CREEK ABOVE CONFLUENCE WITH SOUTH BOULDER CREEK 1-HR RF INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH AREA FOR 924 SQ. MI.
QUPAUBT	UPPER BOULDER TRIBS 25%, 25% RAINFALL DISTRIBUTION 500 YEAR, 6 HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 440 SQ. MI.
QUPBOULD	BOULDER CREEK ABOVE FOURMILE CREEK DEPTH-AREA FOR 101 SQ. MI. 500 YEAR, 6 HOUR RAIN WITH EXPECTED PROBABILITY
Others:	
QPABHG	BULLHEAD GULCH WITH 1-HOUR RAINFALL INTERVALS 25-YEAR 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPACC	COAL CREEK WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPACC1	DRY CREEK 25 YEAR, 6 HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 127 SQ. MI.
QEPADC	DRY CREEK WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPAR4CC	REVISED FOURMILE CANYON CREEK WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPALHC	LEFT-HAND CREEK, THE SLOUGH, AND STREAM 309 WITH 1-HOUR RF INTERVALS 100-YR 6-HR WITH EX. PROB. AND 211 SQ. MI. D-A .15 DETN 7% IMP. .5 PL INFIL
QEPALHCU	LEFT-HAND CREEK, THE SLOUGH, AND STREAM 309 WITH 1-HR RF INTERVALS YR 2000 URBANIZATION 10-YR 6-HR WITH EX. PROB. 924 SQ. MI. D-A ONLY, .15 DETN 7% IMP. .5 PL INFIL
QEPALHCX	LEFT-HAND CREEK, THE SLOUGH, AND STREAM 309 WITH 1-HR RF INTERVALS YR 2000 URBANIZATION 10-YR 6-HR WITH EX. PROB. 924 SQ. MI. D-A ONLY, .15 DETN 7% IMP. .5 PL INFIL
QUPLEFT	LEFT-HAND CREEK ABOVE JAMES CREEK .4 IN. PERV. DETN. 1 IN/HR INFILTRATION 10-YR 3-HR WITH EX. PROB. AND 21.65 SQ. MI. D-A 15-MIN RF INTERVALS
QEPASOBC	SOUTH BOULDER CREEK WITH 1-HOUR RAINFALL INTERVALS 25-YEAR, 6-HOUR WITH EXPECTED PROBABILITY AND DEPTH-AREA FOR 924 SQ. MI.
QEPANSSV	SO. ST. VRAIN AND NO. ST. VRAIN WITH BUTTONROCK DAM 1-HOUR RAINFALL INTERVALS 10-YR 6-HR WITH EX. PROB. AND 211 SQ. MI. D-A .15 IN. DETN 7% IMPERVIOUS
QEPAVR1	ST. VRAIN CREEK BELOW BOULDER CREEK WITH 1-HOUR RAINFALL INTERVALS 500-YR 6-HR WITH EX. PROB., D-A FOR 924 SQ. MI., .5 INFIL, .1 DETN
QEPAVR2U	LOWER ST. VRAIN CRK ABOVE BOULDER CRK W/O LEFT-HAND CRK AND THE SLOUGH 1-HOUR RF INTERVALS 10-YR 6-HR EX. PROB., 924 SQ. MI. D-A, .5 INFIL., .1 DETN YR 2000 URBANIZATION

HARDER ROUTING PROGRAM INPUT FILES

File Name	Title Card
QBLDR1	BOULDER CREEK 100 YR 6 HR BOULDER AND SO BOULDER ONLY 440 SQ MI D-A .6K 1 MI REACHES
QBLDR2	BOULDER CREEK 127 SQ MI D-A .3 DETENTION .6 K 1 MI REACHES
QBLDR3	BOULDER CREEK LOWER AREA ONLY DEPTH-AREA FOR 343 SQ MI 1-HOUR RAINFALL INTERVALS
QBLDR4	BOUDLER CREEK ABOVE SOUTH BOULDER 10-YR 6-HR 150D-A .8 K .5 MI REACHES
QBOULDER	BOULDER CREEK (ENTIRE AREA) 100-YR 6-HR 440 SQ. MI. D-A .8K .5 MI REACHES

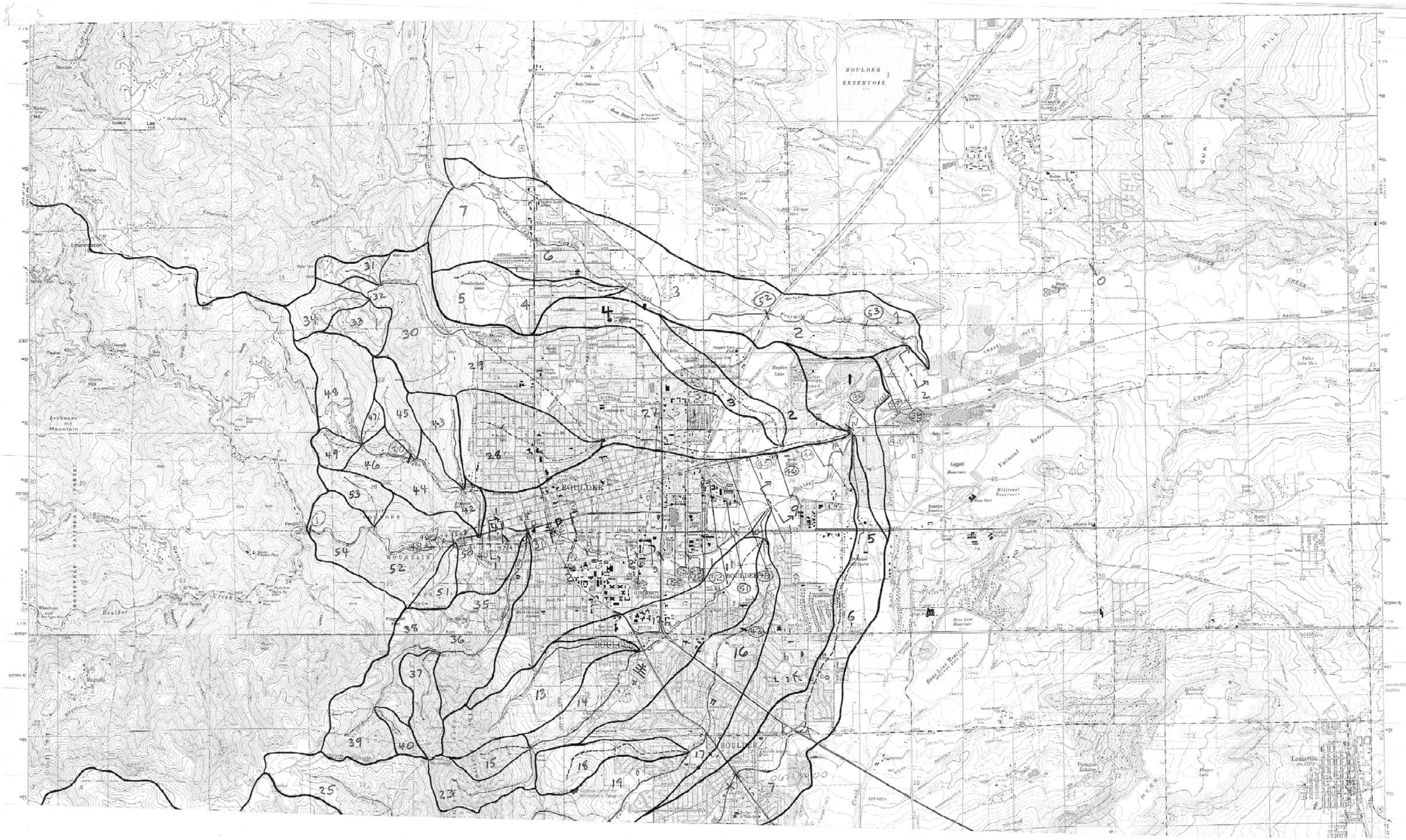


Figure B1. Lower Boulder Creek Subbasin Map, North, USACE 1977 Hydrologic Study

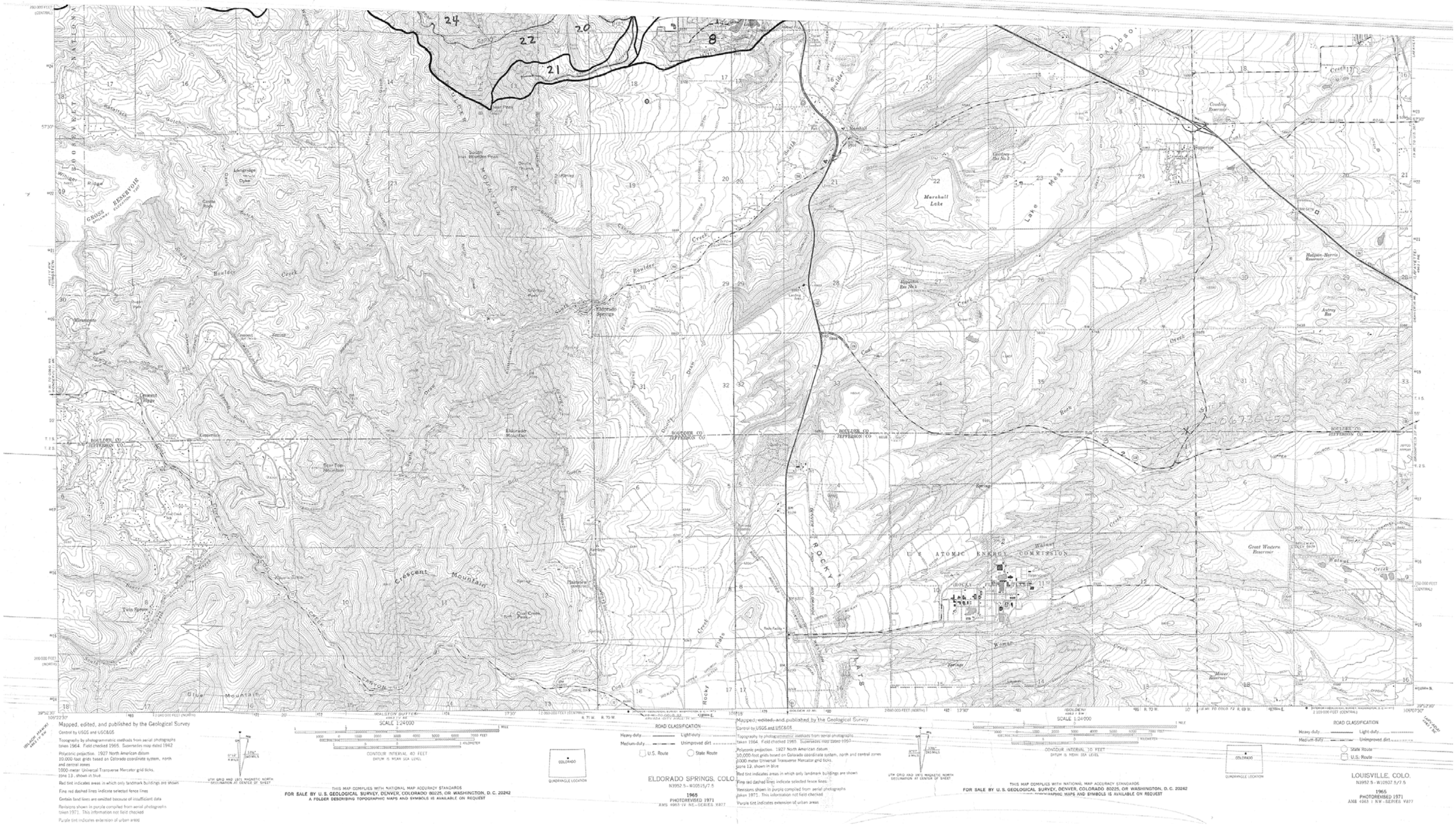


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Figure B2. Lower Boulder Creek Subbasin Map, South, USACE 1977 Hydrologic Study

Figure B3. Upper Boulder Creek Subbasin Map, West, USACE 1977 Hydrologic Study

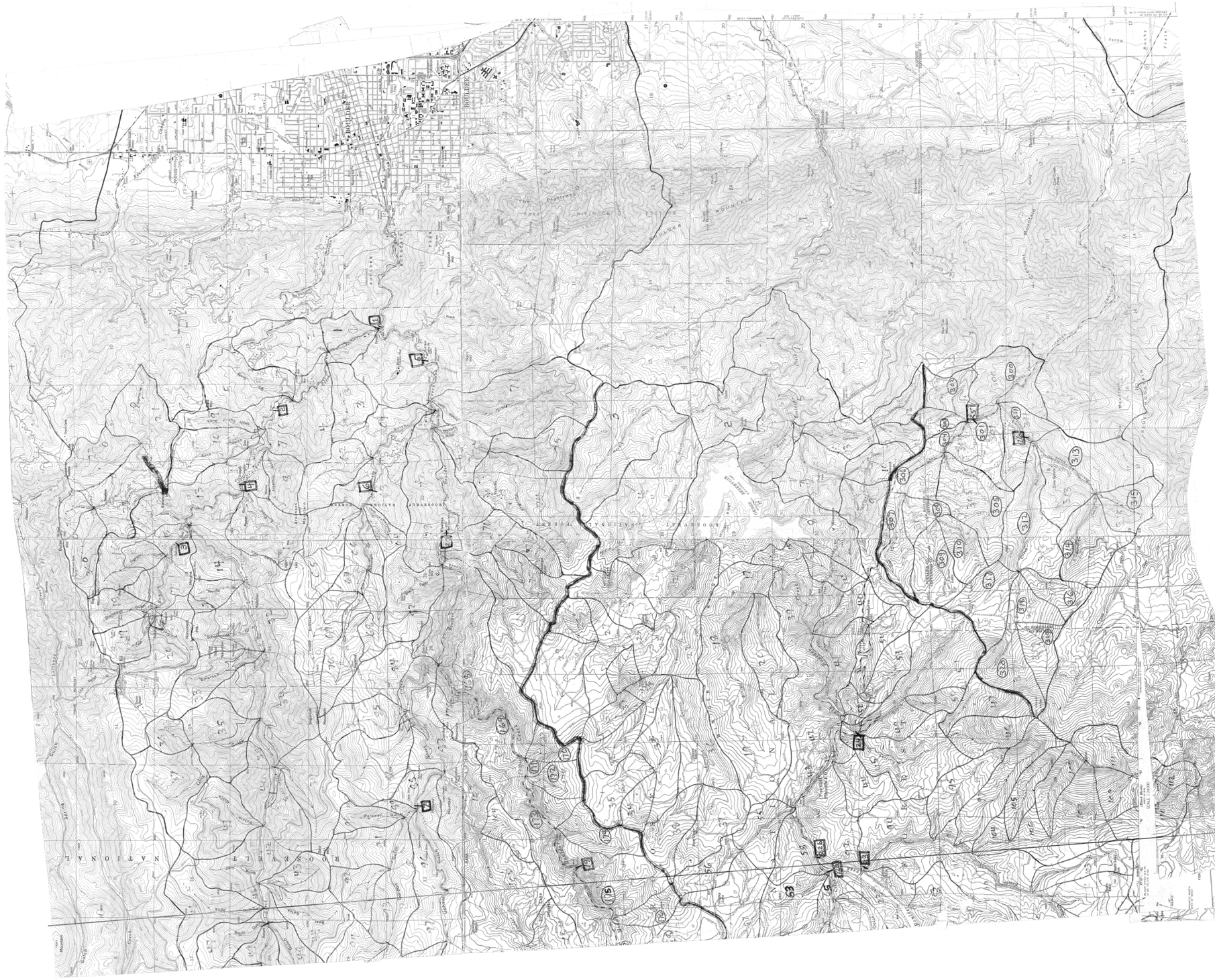


Figure B4. Upper Boulder Creek Subbasin Map, East, USACE 1977 Hydrologic Study

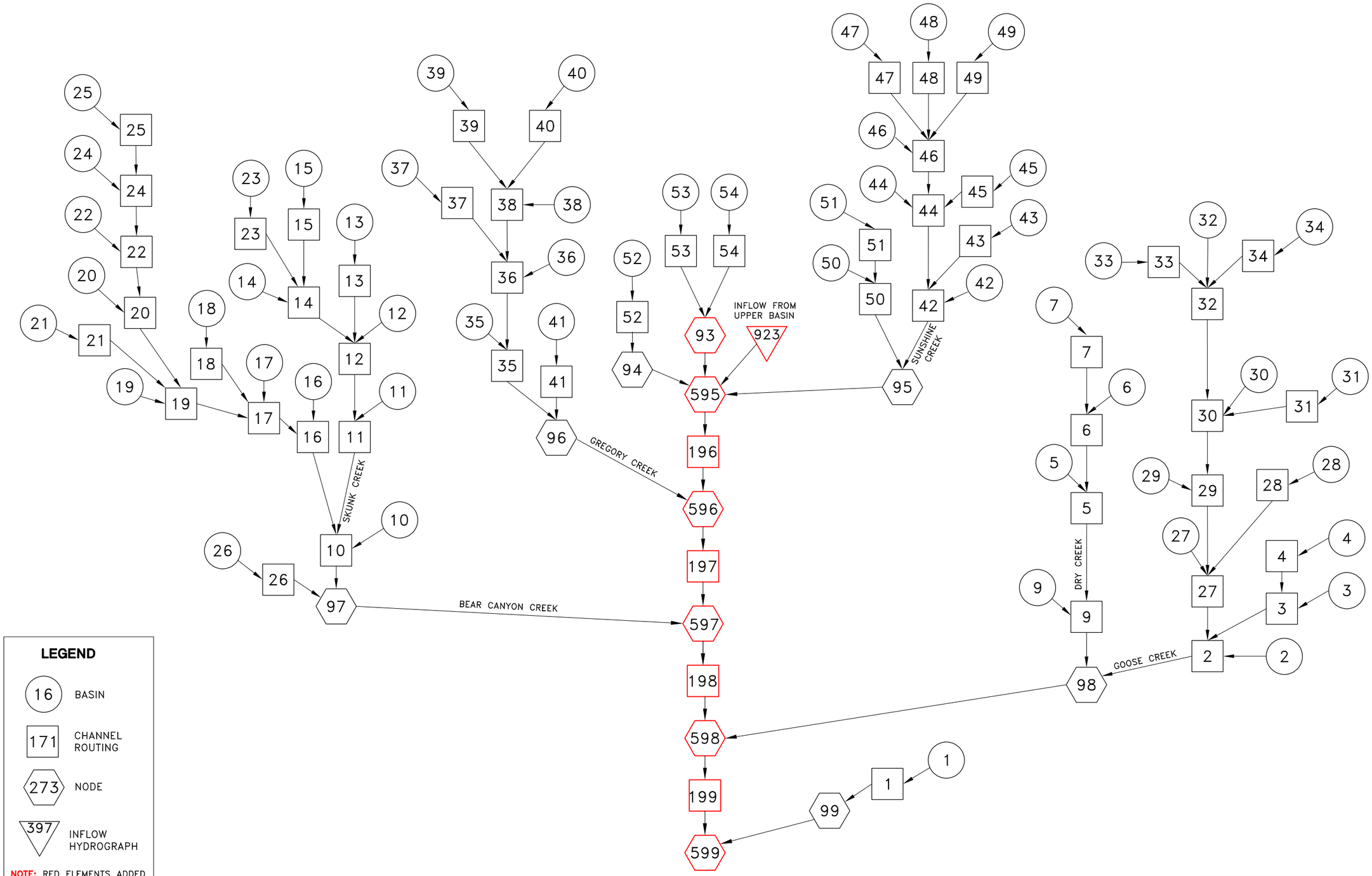


Figure B5 Lower Boulder Creek Basin, Hydrologic Model Schematic

P:\COBLDR02 BOULDER CREEK PH 2\SWMM HYDROLOGY.DWG 01/07/2009 TAW

A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

NOAA ATLAS 2

Precipitation-Frequency Atlas of the Western United States

J. F. Miller, R. H. Frederick, and R. J. Tracey

Volume III–Colorado

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

National Weather Service

Silver Spring, Md.
1973

Interpretation of Results

Season of Occurrence

The maps in this Atlas are based upon data for the entire year. In certain sections of the West, precipitation is highly seasonal. Thus, rainy season precipitation-frequency values approach the annual values. In sections where the greatest annual *n*-hour precipitation amount may be observed in any season, seasonal precipitation-frequency maps would differ from those presented in this Atlas. In no case could the seasonal value be greater than the annual value. However, the seasonal values would be a certain percent of the annual values, with the percent varying according to the frequency of large storms during the season under investigation. Generalizations about the seasonal distribution of large storms can be obtained from ESSA, *U.S. Weather Bureau Technical Paper* No. 57 (Environmental Science Services Administration, Weather Bureau, 1966). Currently, there is no convenient manner of applying this knowledge to the maps of this Atlas, other than subjectively.

Within Vs. Among Storms

Data for the various duration maps and diagrams in this Atlas were determined independently; that is, there was no requirement that the maximum 6- or 1-hr amount for a particular year be included within the maximum 24-hr amount for that year. The maps, therefore, represent an "among" storm distribution. In regions where winter-type storms predominate, the 6-hr value for a particular return period would more closely approximate the 6-hr value within the 24-hr storm for the same return period than would generally be the case in regions where convective storms predominate. In a study for the United States east of the Mississippi River, Miller (1971) showed that the ratio between the 2-yr 1-hr value computed from the maximum 1-hr amount within the 24-hr maximum and the 2-yr 1-hr value computed using maximum 1-hr amounts varied between 0.52 and 0.91. Studies have not been undertaken of this relation in the West, but a wide range in such ratios and similar ratios for the 6-hr duration could be expected.

Point Probabilities

The maps in this Atlas are derived from and depict point probabilities; the data points are independent of each other. Precipitation over a region is variable, even in large general area storms; neighboring stations do not necessarily experience maximum annual amounts from the same storm. Thus, the individual points on these maps express individual probabilities. That a point within a particular watershed may receive an amount equal to or greater than its 50- or 100-yr value on a particular day does not affect probabilities for any other point within that watershed. A second point within the watershed may experience an amount equal to or greater than its 50- or 100-yr value within the same storm or on the next day, within the next week or at any other time.

Areal Analysis

A value read from an isopluvial map in this Atlas is the value for that point and the amount for that particular duration which will be equaled or exceeded, on the average, once during the period indicated on the individual map. In hydrologic design, engineers are more concerned with the average depth of precipitation over an area than with the depth at a particular point. Depth-area curves were developed to meet this need. The depth-area curve is an attempt to relate the average of all point values for a given duration and frequency within a basin to the average depth over the basin for the same duration and frequency.

Generally, there are two types of depth-area relations. The first is the storm-centered relation; that is, the maximum precipitation occurring when the storm is centered on the area affected (fig. 13). The second type is the geographically fixed-area relation where the area is fixed and the storm is either centered over it or is displaced so only a portion of the storm affects the area (fig. 13). We can say that storm-centered rainfall data represent profiles of discrete storms, whereas the fixed-area data are statistical averages in which the maximum point values frequently come from different storms. At times, the maximum areal value for the network is from a storm that does not produce maximum point amounts. Each type of depth-area relation is useful, but each must be applied to appropriate data. Generally, the storm-centered relations are used for preparing estimates of probable maximum precipitation, while the geographically fixed relations are used for studies of precipitation-frequency values for basins.

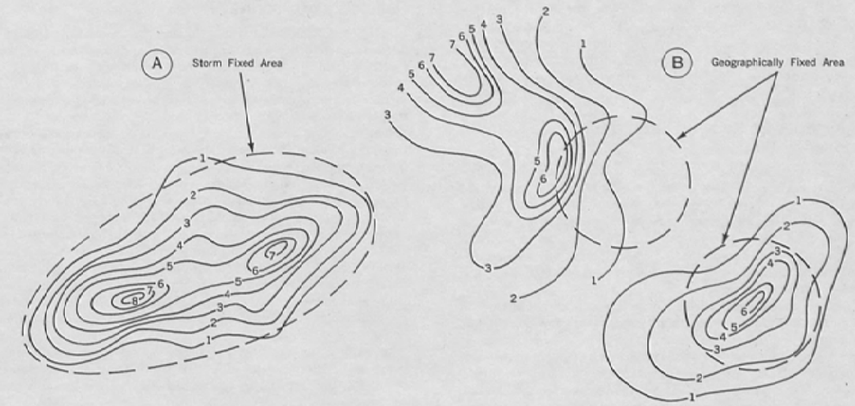
Dense networks of precipitation gages are required to furnish basic data used in developing depth-area relations for fixed areas. The criteria used in selecting dense networks for the determination of areal precipitation-frequencies by the National Weather Service have been:

1. A network should be composed entirely of recording gages. The use of nonrecording gages may greatly increase the number and density of stations within a network, but it involves the construction of mass curves and introduces additional subjectivity. Nonrecording gages are read at various hours, usually early morning, late afternoon, or midnight. Because of conflicting activities, a cooperative observer may not always be able to read his precipitation gage at the exact hour specified. In these cases, the exact time of the observation may not be available, so it is hard to relate the reported amounts to those of surrounding stations with the precision required for development of depth-area relations.
2. A minimum length of record should be established to ensure a reasonable estimate of the 2-yr areal precipitation.
3. Gage locations and exposures should remain consistent during the period of record analyzed.
4. Gages should be located so that there is at least one gage located within each 100 square-mile area.

The average depth-area curves in this Atlas (fig. 14) are for fixed areas and were developed from dense networks meeting the above criteria. The curves were first prepared for an earlier study (U.S. Weather Bureau 1957–60) and have since been rechecked against longer record data; no changes were needed. Application of these curves must be consistent with the manner in which they were developed. The following steps are used:

1. Estimate point values from a grid of many points over the basin of interest for the duration and return period required.
2. Compute an average of the point values obtained in step 1.
3. Use figure 14 to obtain an areal reduction factor required for the precipitation duration and size of area under consideration.
4. Multiply the average value obtained in step 2 by the ratio obtained in step 3. The value obtained in this step provides the areal value for the basin of interest for the duration and return period under consideration.

Figure 13. *Examples of (A) isohyetal pattern centered over basin as would be the case for storm-centered depth-area curves and (B) two possible occurrences of isohyetal patterns over a geographically fixed area as would be the case in development of curves for a geographically fixed area.*



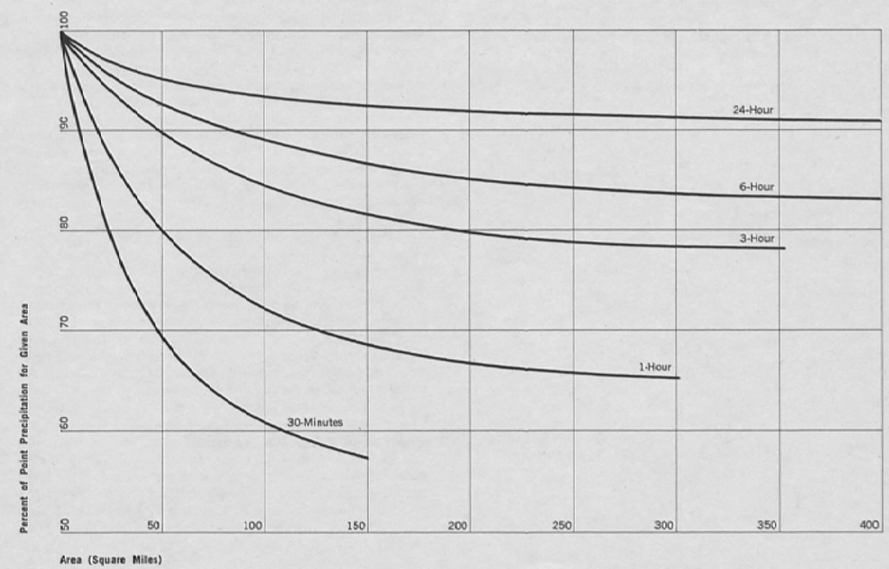
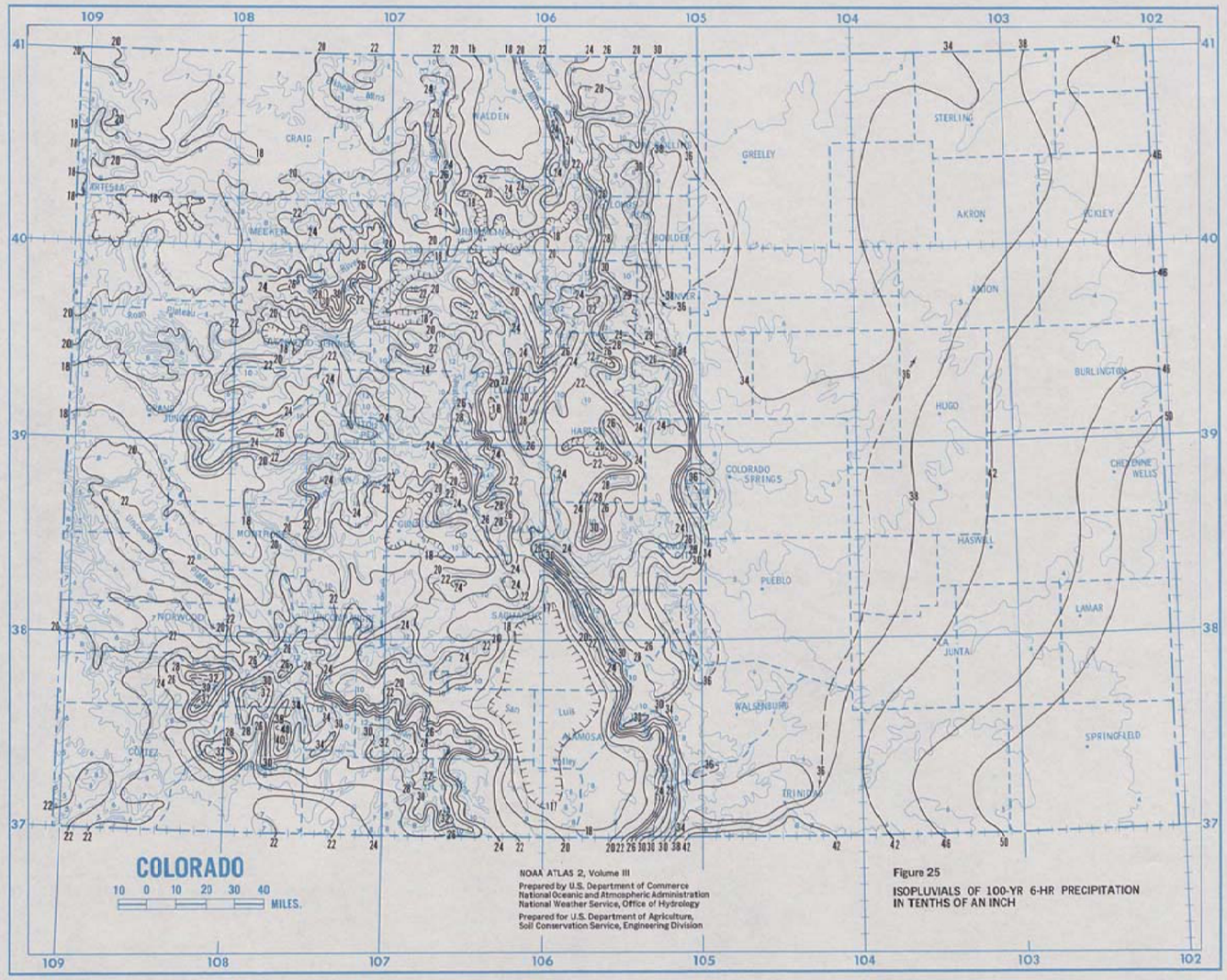


Figure 14. *Depth-Area curves.*


COLORADO
10 0 10 20 30 40
MILES.
NOAA ATLAS 2, Volume III
Prepared by U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service, Office of Hydrology
Prepared for U.S. Department of Agriculture,
Soil Conservation Service, Engineering Division
Figure 25
ISOPLUVIALS OF 100-YR 6-HR PRECIPITATION
IN TENTHS OF AN INCH
CRAIG
HALDEN
GREELEY
STERLING
AKRON
ATKIN
BURLINGTON
HUGO
COLORADO SPRINGS
CHEYENNE WELLS
HASWELL
PUEBLO
LAMAR
LA JUNTA
WALSENBURG
SPRINGFIELD
TRINIDAD
CORTEZ
NORWOOD
MONTROSE
MEEKER
BOULDER
DENVER

APPENDIX C

EFFECTIVE DISCHARGE INFORMATION

ANDERSON CONSULTING ENGINEERS, INC
Civil • Water Resources • Environmental

Project Number	Page Of
COBLDR02	1 2
By	**Date**
AMH	6/16/08
Checked By	**Date**

Owner-Project: Boulder Creek

Subject: Steady State Discharge Profile

⇒ Discharge Profile Based on the Boulder Creek FHAD [Muller Engineering, 1983]

Cross Section ID	Peak Discharge (cfs) 10-Year	25-Year*	50-Year	100-Year	500-Year	**Location (Approx.)
77	2,000	5,580	7,950	11,650	21,200	Upstream Study Limit
73.1	2,000	5,690	8,100	11,950	21,600	
64.1	2,200	5,830	8,100	12,150	22,100	6th Street
58	2,200	5,810	8,100	12,100	22,100	9th Street
55	2,200	5,800	8,100	12,000	21,400	Broadway
47	2,200	5,790	8,100	11,950	21,400	
43	2,200	5,780	8,100	11,900	21,400	17th Street
38	2,200	5,670	7,800	11,750	20,600	24th Street
33	2,200	5,620	7,800	11,500	20,600	
~~32~~	~~2,200~~		~~7,800~~	~~11,500~~	~~20,600~~ No Change	~~28th Street~~
26	2,200	5,560	7,800	11,200	19,800	
~~23~~	~~2,200~~		~~7,800~~	~~11,200~~	~~19,800~~ No Change	
21	2,200	5,550	7,800	11,150	19,800	
~~20~~	~~2,200~~		~~7,800~~	~~11,150~~	~~19,800~~ No Change	
~~17~~	~~2,200~~		~~7,800~~	~~11,150~~	~~19,800~~ No Change	Foothills
14	3,000	6,200	8,200	11,800	21,200	Bear Creek
11	3,000	6,200	8,200	11,800	20,700	Railroad
7	3,600	7,070	9,300	13,050	23,000	
9180	3,450	6,760	8,400	13,050	18,600	55th
128	3,450	7,040	9,400	13,300	27,200	Valmont (New)
118	3,500	7,070	9,400	13,300	27,200	
116	3,400	7,010	9,400	13,300	27,200	

* 25-Year Discharges based on a log fit equation for the 10-, 50-, 100-, and 500-Year Events (Rounded to 10 cfs)
** Location descriptions are approximate. SEE PDF's for locations

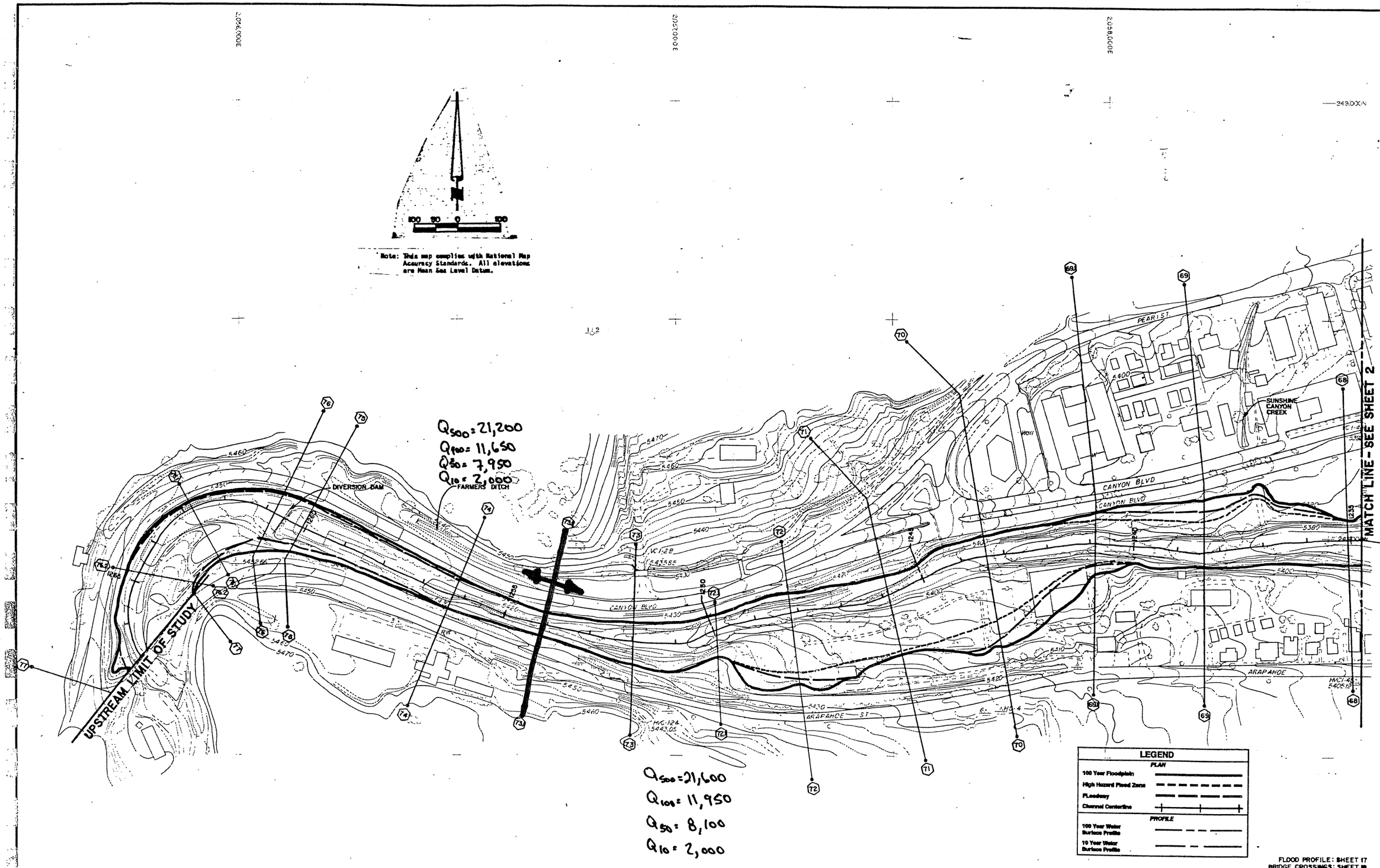
ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number COBLDR02	Page 2 Of 2
Owner-Project Boulder Creek	By AMH	Date 6/16/08
Subject Steady State Discharge Profile	Checked By	Date

=> 25-Year Discharge Calculations based on a log fit equation of the 10, 50, 100 and 500 year storms.

$$\Rightarrow Y = B * \ln(X) + A \quad (X = 25\text{ year})$$

Cross Section ID	Equation* B	A	Y ← 25 year discharge
77	-4921.04	12405.50	5583
73.1	-5026.76	12654.64	5686
64.1	-5109.89	12908.45	5825
58	-5107.70	12895.19	5814
55	-4929.82	12633.54	5799
47	-4927.62	12620.28	5789
43	-4925.43	12607.02	5779
38	-4733.74	12278.09	5666
33	-4722.76	12161.78	5615
26	-4511.32	11813.50	5559
21	-4569.12	11800.24	5549
14	-4668.80	12668.08	6196
11	-4544.88	12500.14	6200
7	-4972.80	13960.94	7067
9180	-3959.00	12247.08	6759
128	-6057.50	15436.87	7039
118	-6045.11	15445.07	7065
116	-6069.89	15428.66	7014

* Equation Coefficients determined using Grapher version 6.0.17



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REIDS AERIAL MAPPING
CONTOUR INTERVAL: 2'
DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-0340

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOOD PLAIN: 1266+80 TO 1234+80

SHEET 1 OF 19
MEC JOB NO. 8130

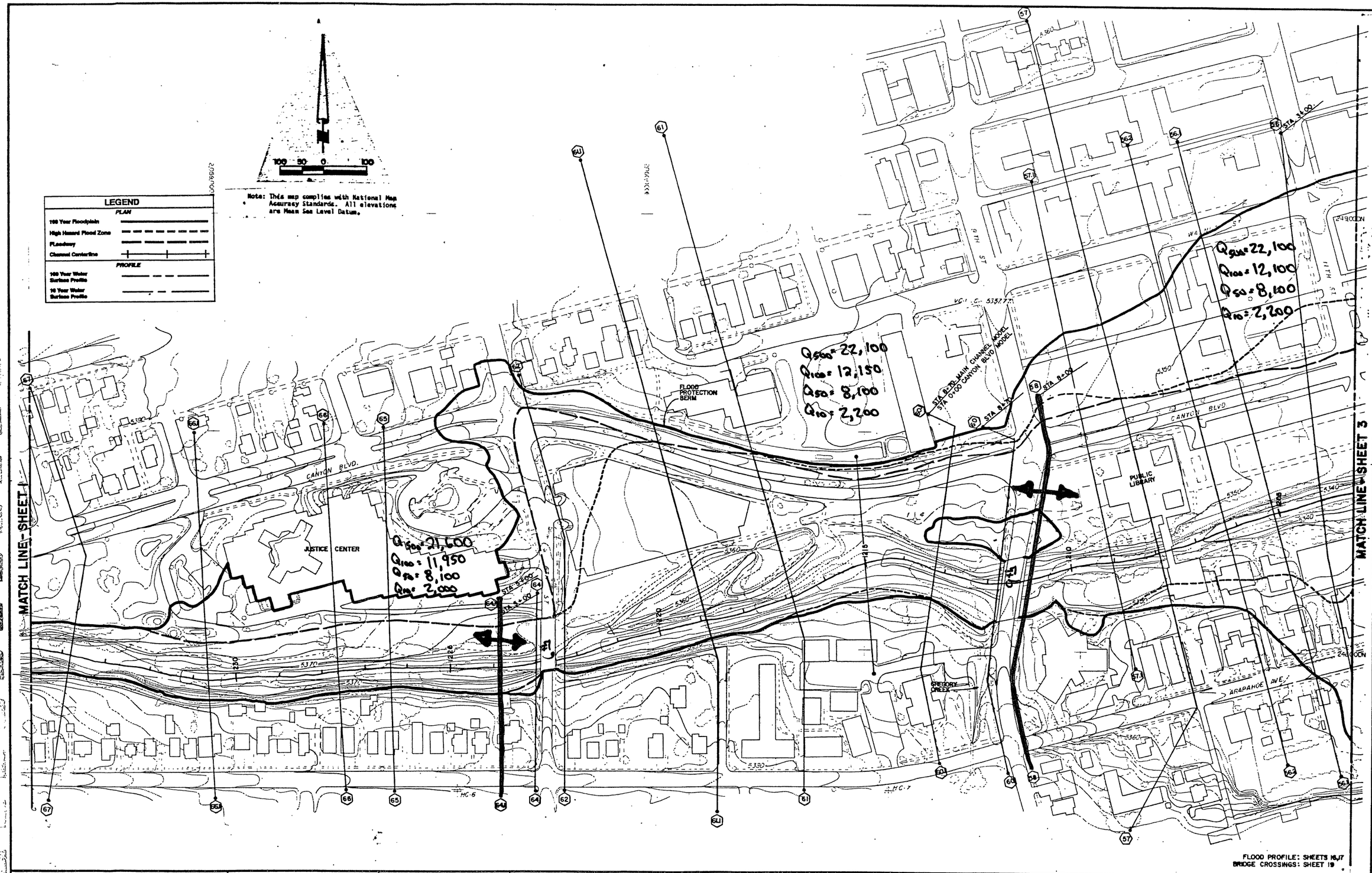
David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3435

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR.

REVISIONS
No. DATE
1 4-88 REMOVE 5 YRS FLOODWAY



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2' DATE FLOWN 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-9349

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOOD PLAIN: 1234+80 TO 1203+20

SHEET 2 OF 19
MEC JOB NO. 8130

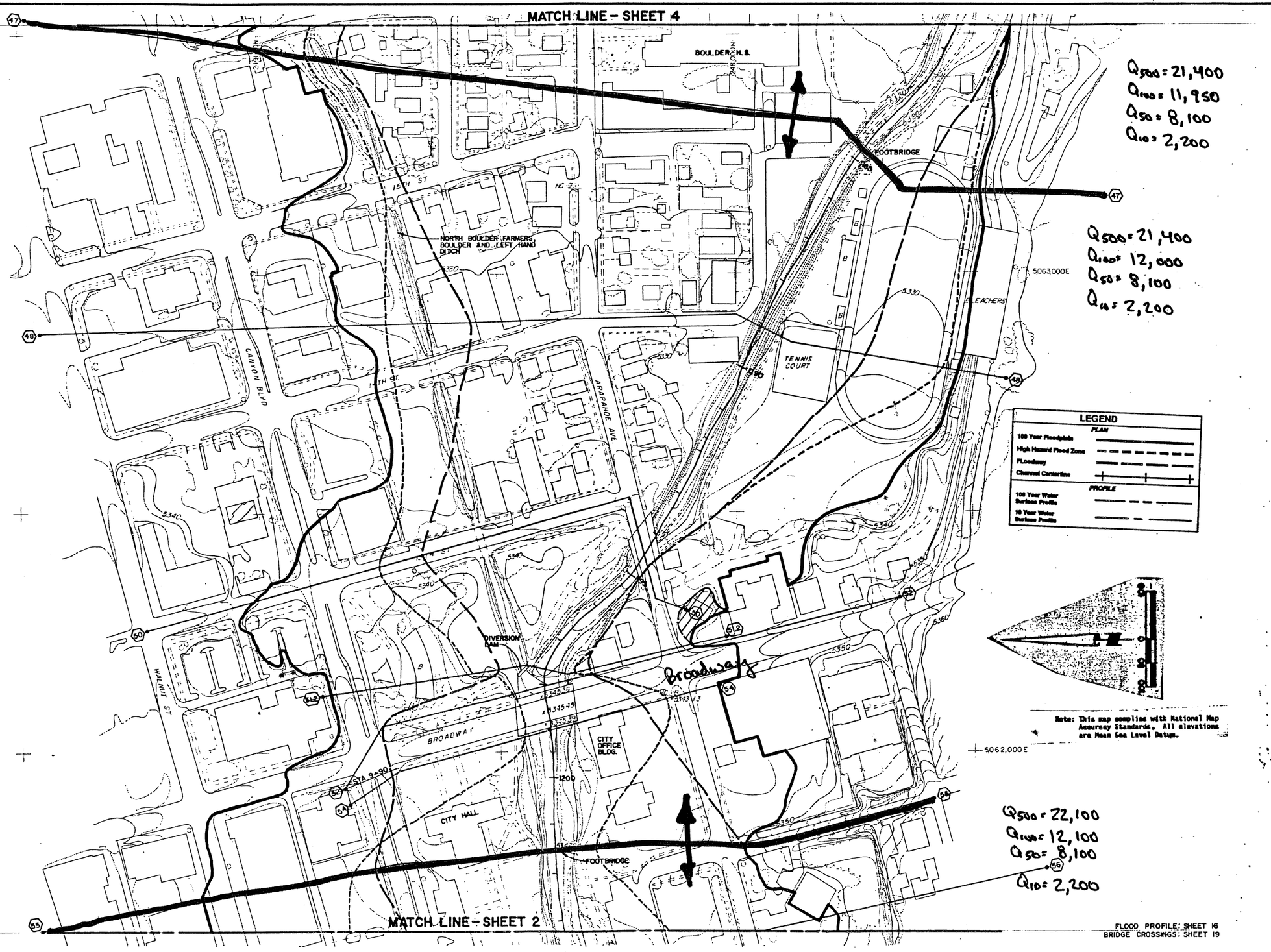
David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR.

REVISIONS
No. DATE
1 4/88 REMOVE 0.5FT FLOODWAY



GROUND CONTROL SURVEY BY: MULLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2'
DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-9340

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOOD PLAIN: 1203+20 TO 1181+40

SHEET 3 OF 19
MEC JOB NO. 8130

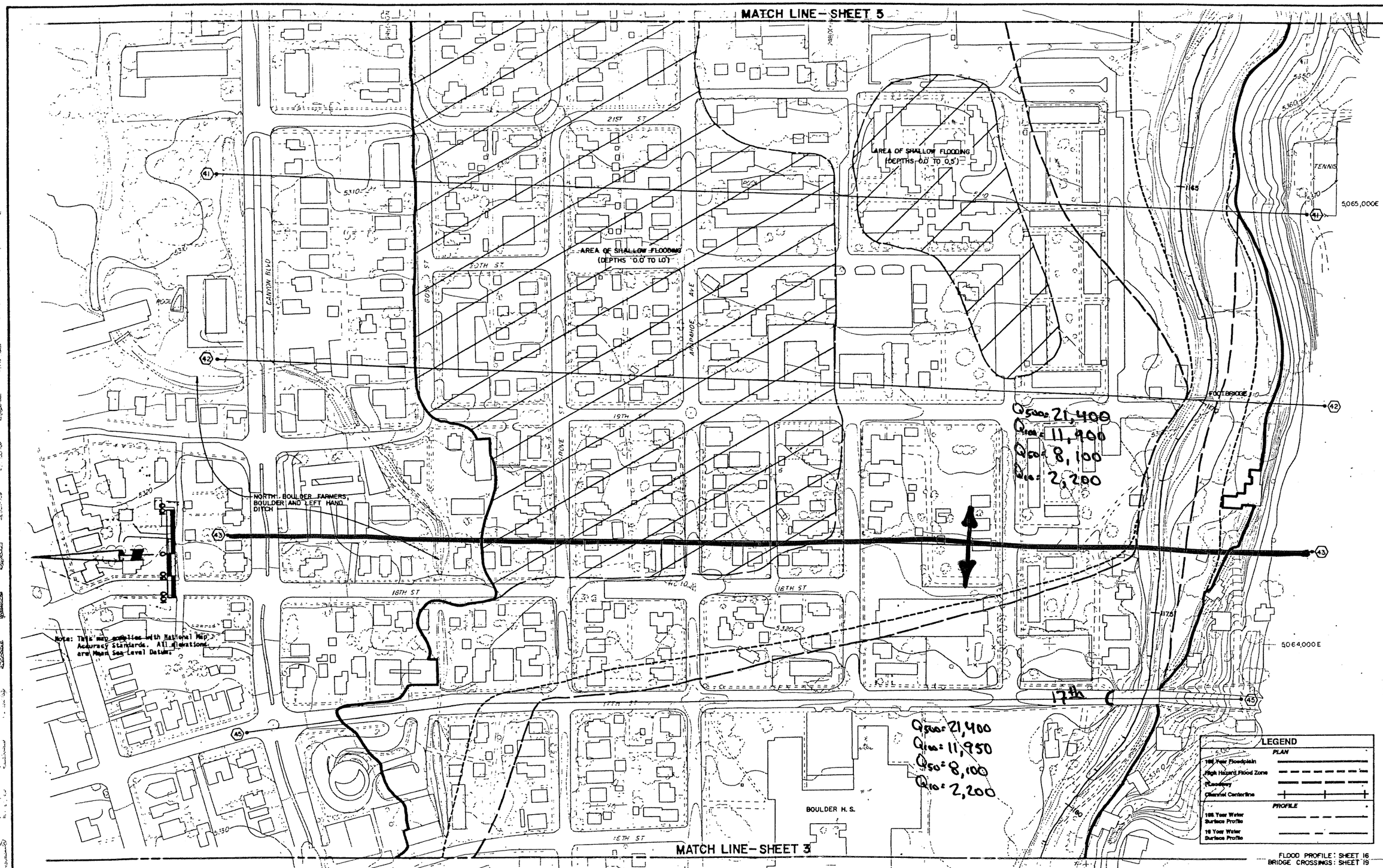
David J. Love & Associates, Inc.
2995 Centergreen Court South – Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR.

REVISIONS
No. DATE
1 4/88 REMOVE 0.5 FTR FLOODWAY



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2' DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80213
(303) 232-4040

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOOD PLAIN: 1181+40 TO 1161+10

SHEET 4 OF 19
MEC JOB NO. 8130

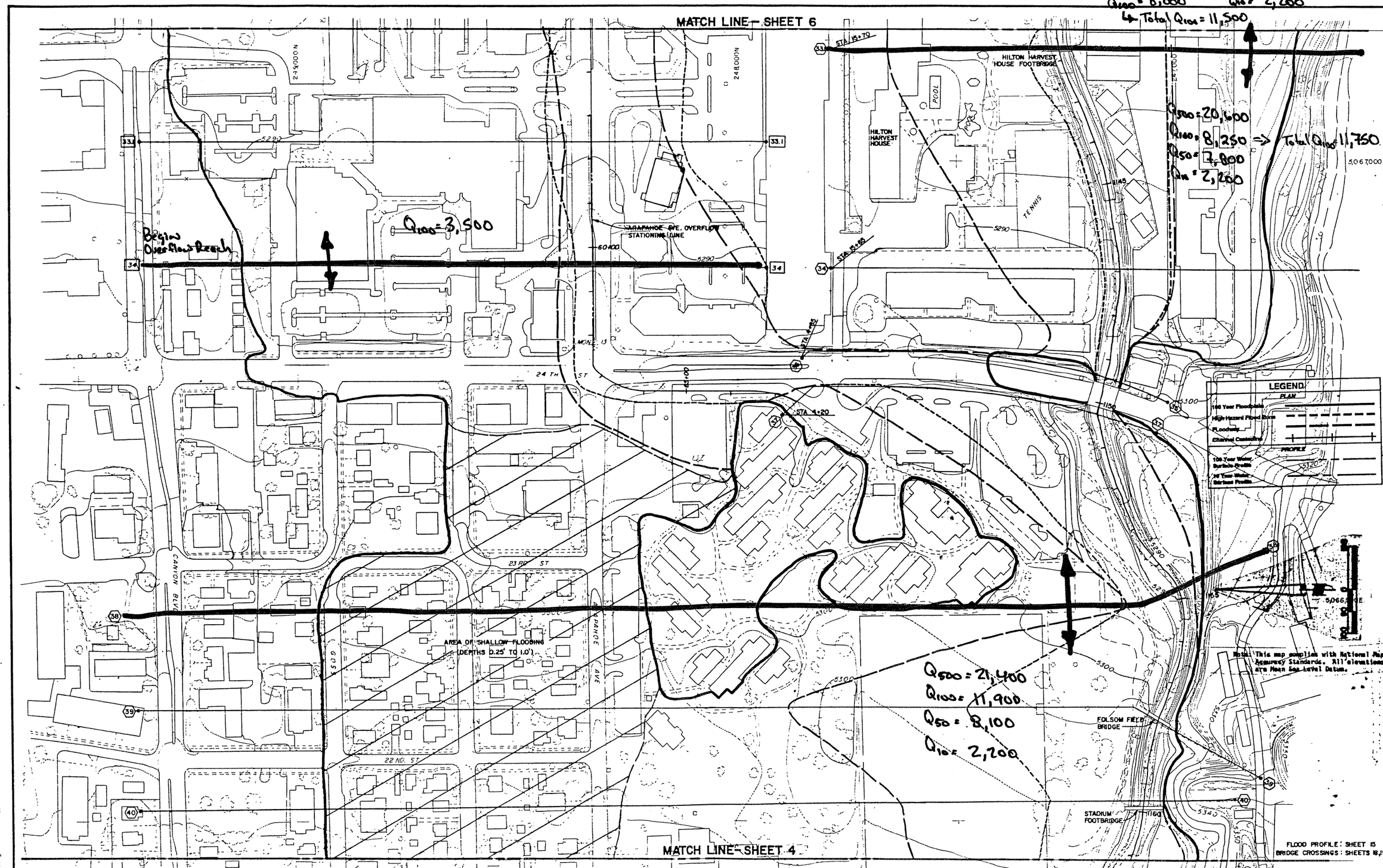
David J. Love & Associates, Inc.
2995 Centergreen Court South – Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR.

REVISIONS
No. DATE
1 4/88 REVISED 100 YR FLOODWAY



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REIDS AERIAL MAPPING
CONTOUR INTERVAL: 2' DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-9349

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOOD PLAIN = 1161+10 TO 1141+30
ARAPAHOE AVE. = 63+00 TO 55+00

SHEET 5 OF 19
MEC JOB NO. 8130

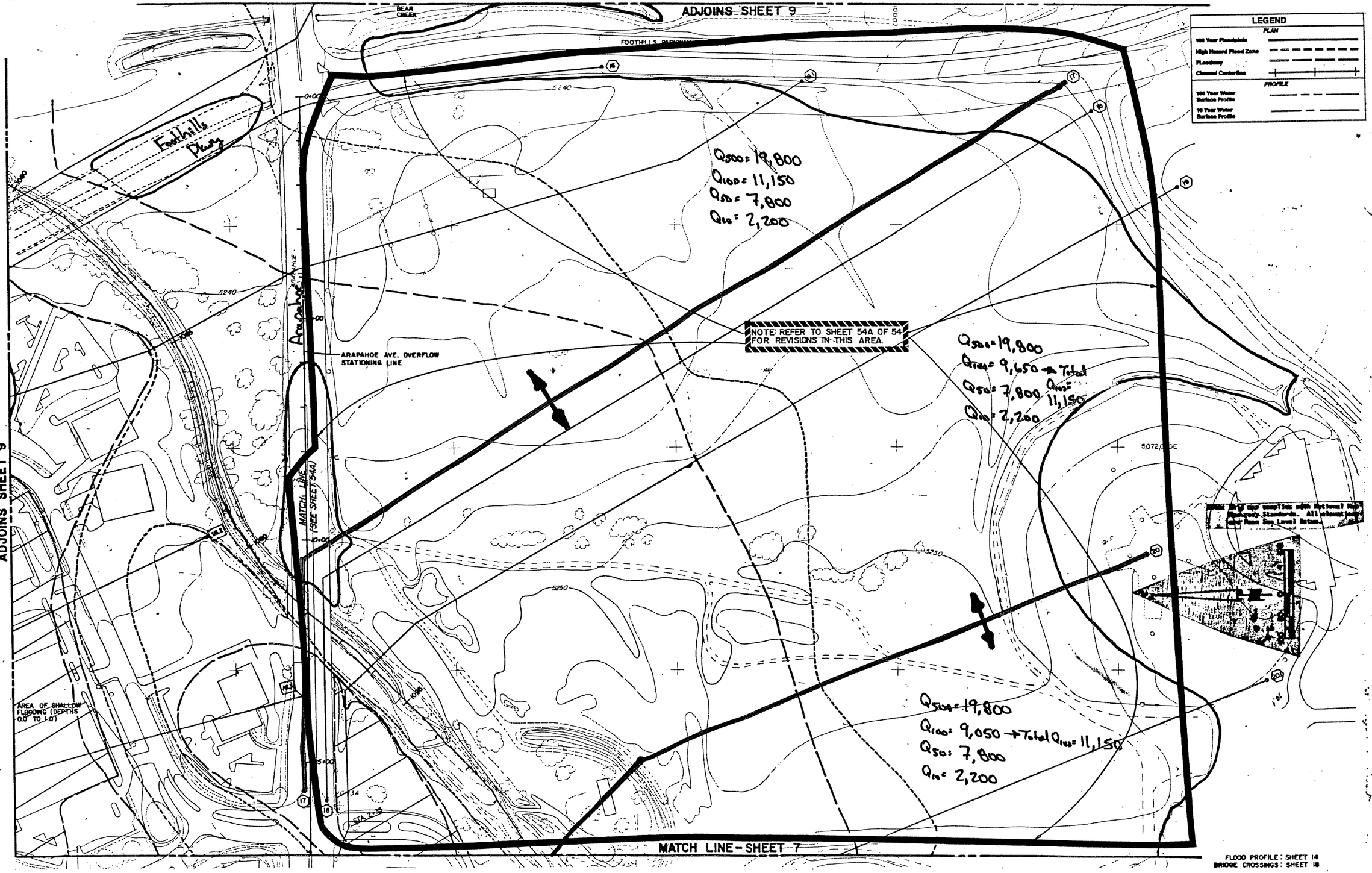
No.	DATE	REVISIONS
1	4/88	REMOVES FPR FLOODWAY
2	4/89	REVISE HIGH HAZARD ZONE, 34.33.1

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR. DJL

David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REIDS AERIAL MAPPING
CONTOUR INTERVAL: 2'
DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1498 VANCE ST., SUITE 200
LAKEWOOD, COLORADO 80213
(303) 235-7040

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOODPLAIN: 1099+60 TO 1080+00
ARAPAHOE AVE.: 17+10 TO 0+00

SHEET 8 OF 19
MEC JOB NO. 8130

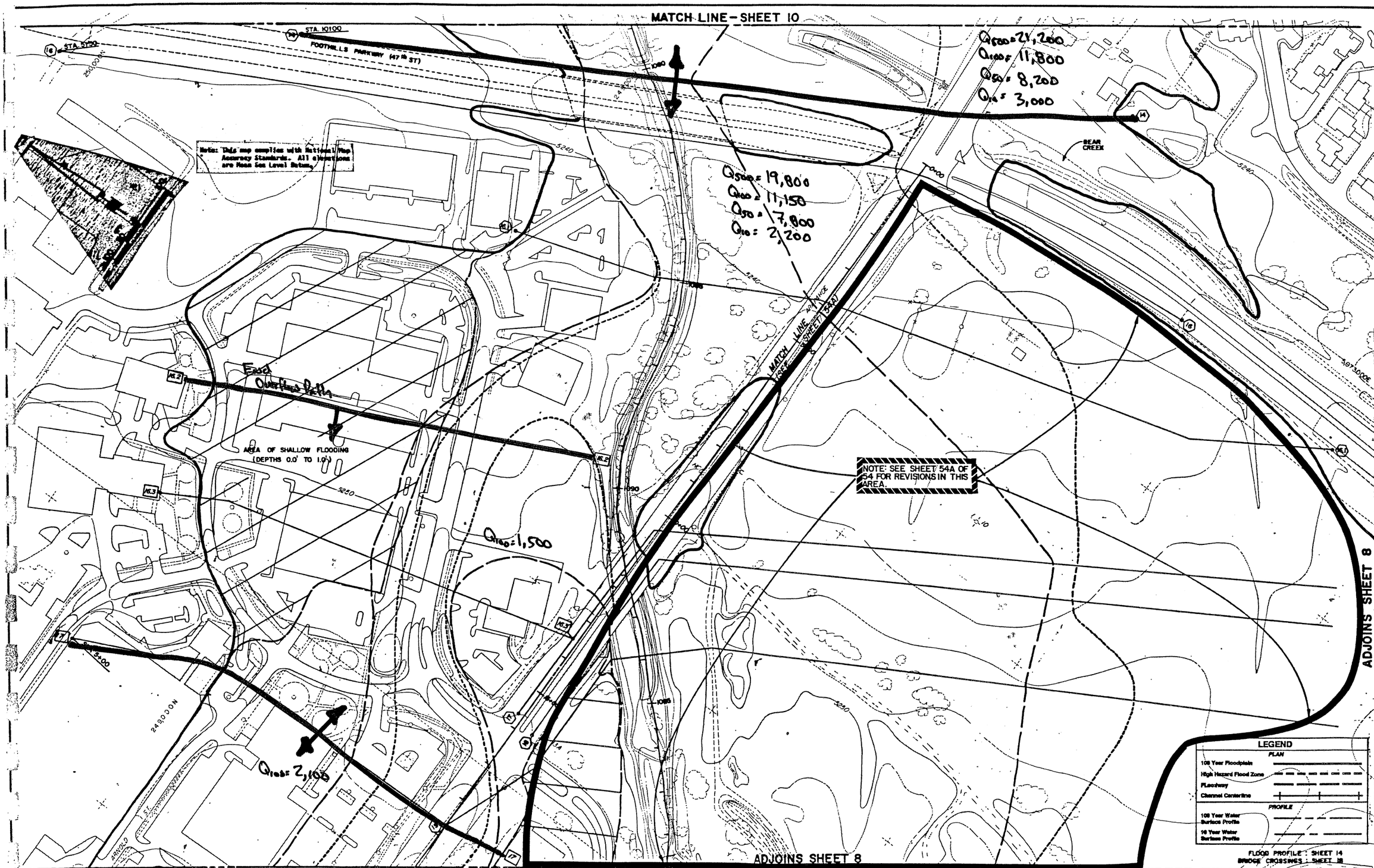
David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR '88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR.

REVISIONS:
MODIFY FHZ FLOODWAY
RE: ALL GOV. REA. PARK



GROUND CONTROL SURVEY BY: MULLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REIDS AERIAL MAPPING
CONTOUR INTERVAL: 2'
DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1439 VANCE ST., SUITE 208
LAKEWOOD, COLORADO 80215
(303) 233-1049

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOODPLAIN: 109+80 TO 107+80
ARAPAHOE AVE.: 19+90 TO 0+00

SHEET 9 OF 19
MEC JOB NO. 8130

SHEET 10 OF 54

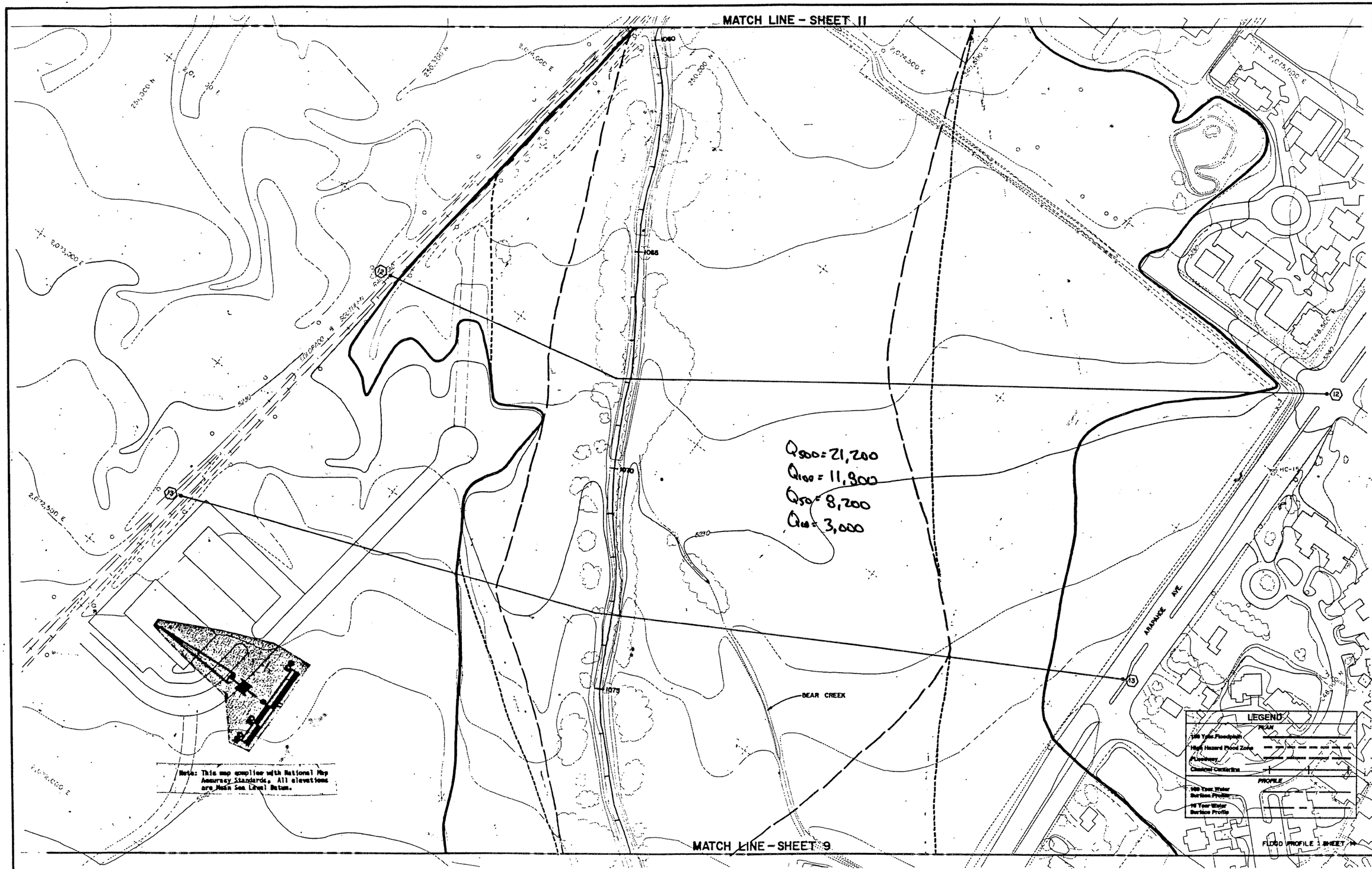
David J. Love & Associates, Inc.
2995 Centergreen Court South – Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR. DJL

REVISIONS
DWG. PER RECOMWAY
VE. AT CAL. BR. PARK



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2' DATE FLOWN 4-23-81

MUELLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 233-9340

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOOD PLAIN : 1078+80 TO 1069+70

SHEET 10 OF 19
MEC JOB NO. 8130

David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

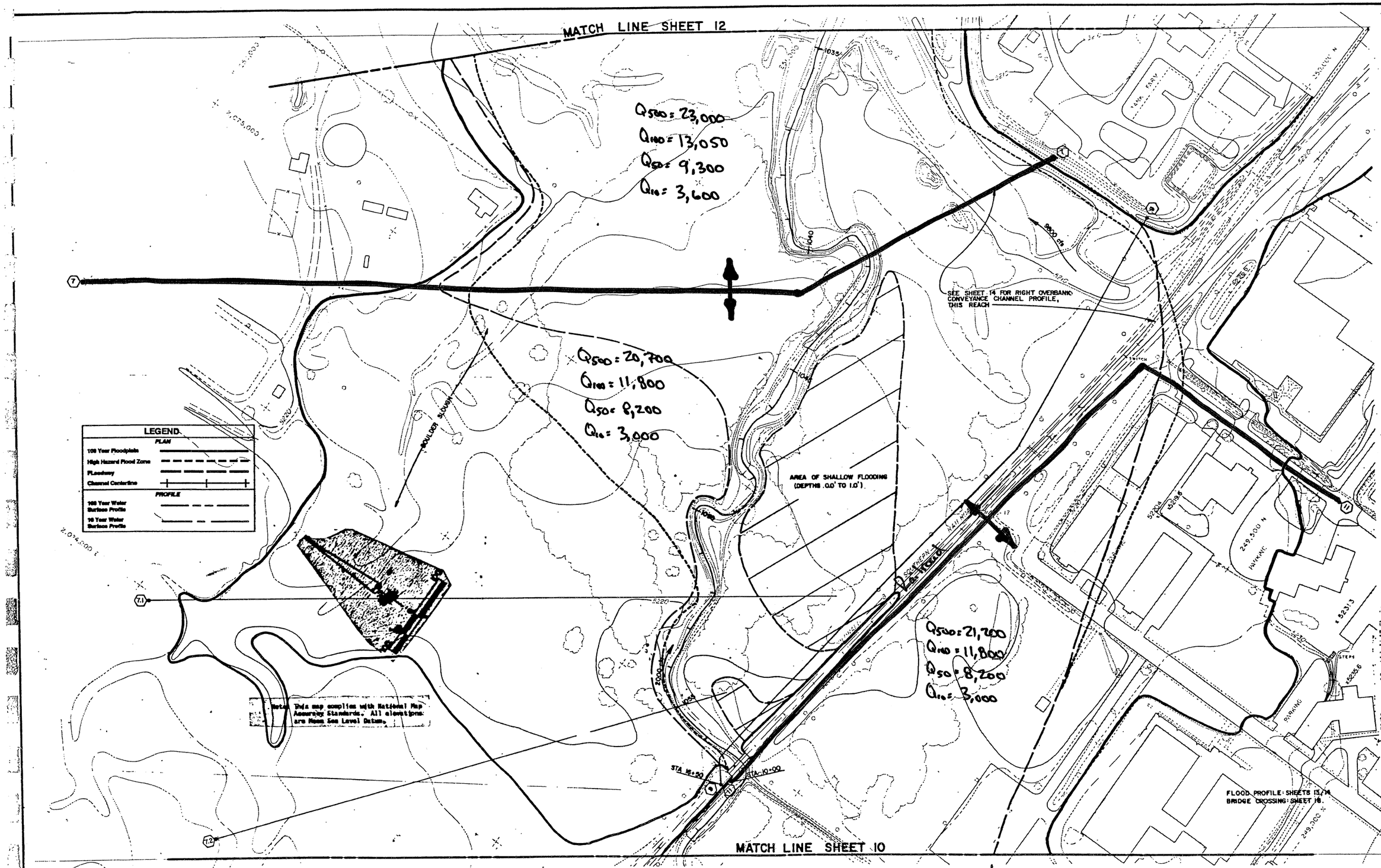
DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LCC
CHECK DJL
APPR.

REVISIONS

No.	DATE	
1	4/88	REMOVED PPR FLOODWAY



GROUND CONTROL SURVEY BY: MULLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REIDS AERIAL MAPPING
CONTOUR INTERVAL: 2' DATE FLOWN 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1438 VANCE ST., SUITE 208
LAKEWOOD, COLORADO 80215
(303) 232-8949

DESIGNED	KGS, BLE	DATE	
DRAWN	JDM, JHK	DATE	7/82
CHECKED	LAM	DATE	12/82
REVISED		DATE	

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOODPLAIN: 1069+70 TO 1034+60

SHEET 11 OF 19
MEC JOB NO. 8130

SHEET 12 OF 54

David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN	CSB		
DRAWN	LCC		
CHECK	DJL		

No.	DATE	REVISIONS	APPR.
1	4/88	REVISE FWY. FLOODWAY	DJL
2	4/88	REVISE FLOODWAY, 8-7	

DOWNSTREAM LIMIT OF STUDY

FLOODPLAIN LIMITS EXTEND TO ELEVATION 5199.6

9180

1015

9530

NOT IN 100 YR FLOODPLAIN

1020

1025

1030

10000

BOULDER SLOUGH

10220

10370

10600

FEE DRIVE

5210

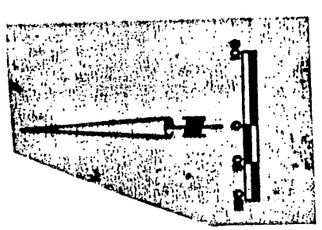
$Q_{500} = 23,000$

$Q_{100} = 13,050$

$Q_{50} = 9,300$

$Q_{10} = 3,600$

MATCH LINE SHEET 11



Note: This map complies with National Map Accuracy Standards. All elevations are Mean Sea Level Datum.

LEGEND

PLAN

- 100 Year Floodplain
- High Hazard Flood Zone
- Floodway
- Channel Centerline

PROFILE

- 100 Year Water Surface Profile
- 10 Year Water Surface Profile

FLOOD PROFILE : SHEETS 13,14
BRIDGE CROSSINGS : SHEET 18

GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2'
DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-9240

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOODPLAIN: 1040+60 TO 1011+00

SHEET 12 OF 19
MEC JOB NO. 8130

David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

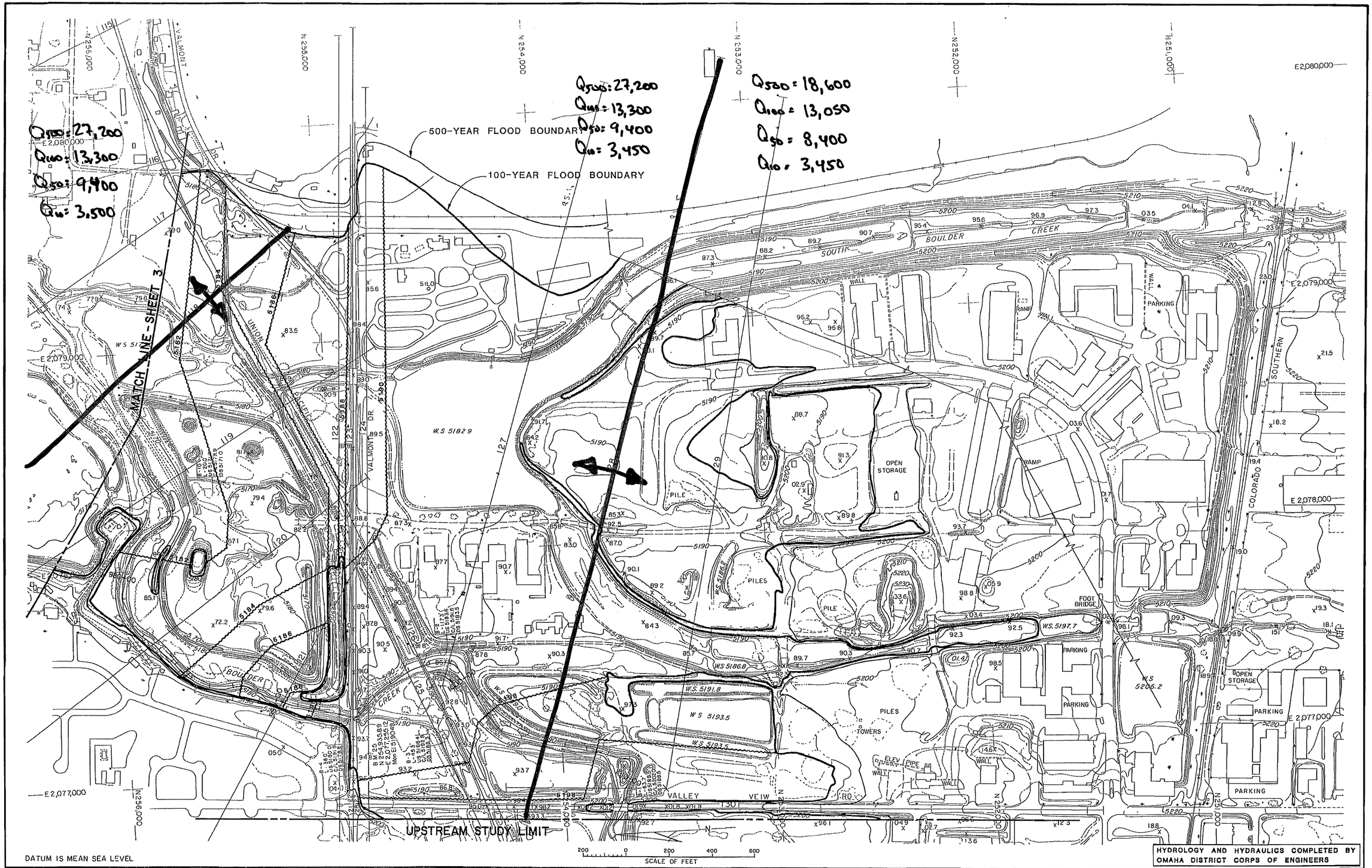
DATE 1 MAR 88
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN CSB
DRAWN LDC
CHECK DJL
APPR.

REVISIONS

No.	DATE	
1	4/88	REMOVED FWA FLOODWAY



HYDROLOGY AND HYDRAULICS COMPLETED BY OMAHA DISTRICT CORPS OF ENGINEERS

GROUND CONTROL SURVEY; AERIAL PHOTOGRAPHY; TOPOGRAPHIC MAPPING BY CONTOUR INTERVAL= 2 FEET

DELTA AERIAL SURVEYS, INC.

DATE FLOWN 4/29/79

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1410 VANCE ST., SUITE 203
LAKEWOOD, COLORADO 80215
(303) 232-0340

DESIGNED	COE	DATE	
DRAWN	JHK, JDM	DATE	1/83
CHECKED	KOS, LAM	DATE	1/83
REVISED		DATE	

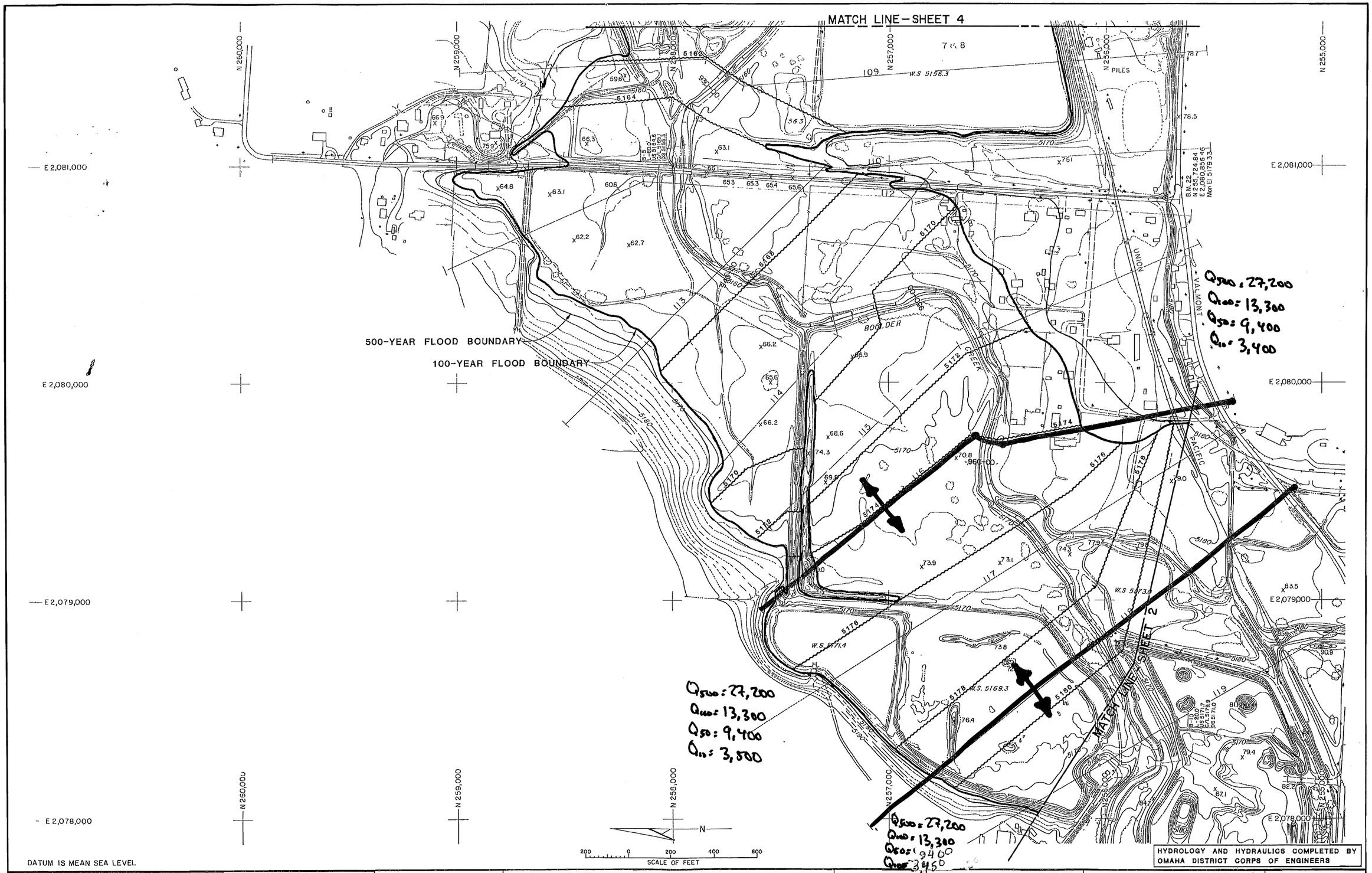
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
COLORADO WATER CONSERVATION BOARD
BOULDER COUNTY

FLOOD HAZARD AREA DELINEATION
LOWER BOULDER CREEK

FLOODPLAIN MAP
STA 1012+00 TO 972+10

SHEET 2 OF 23

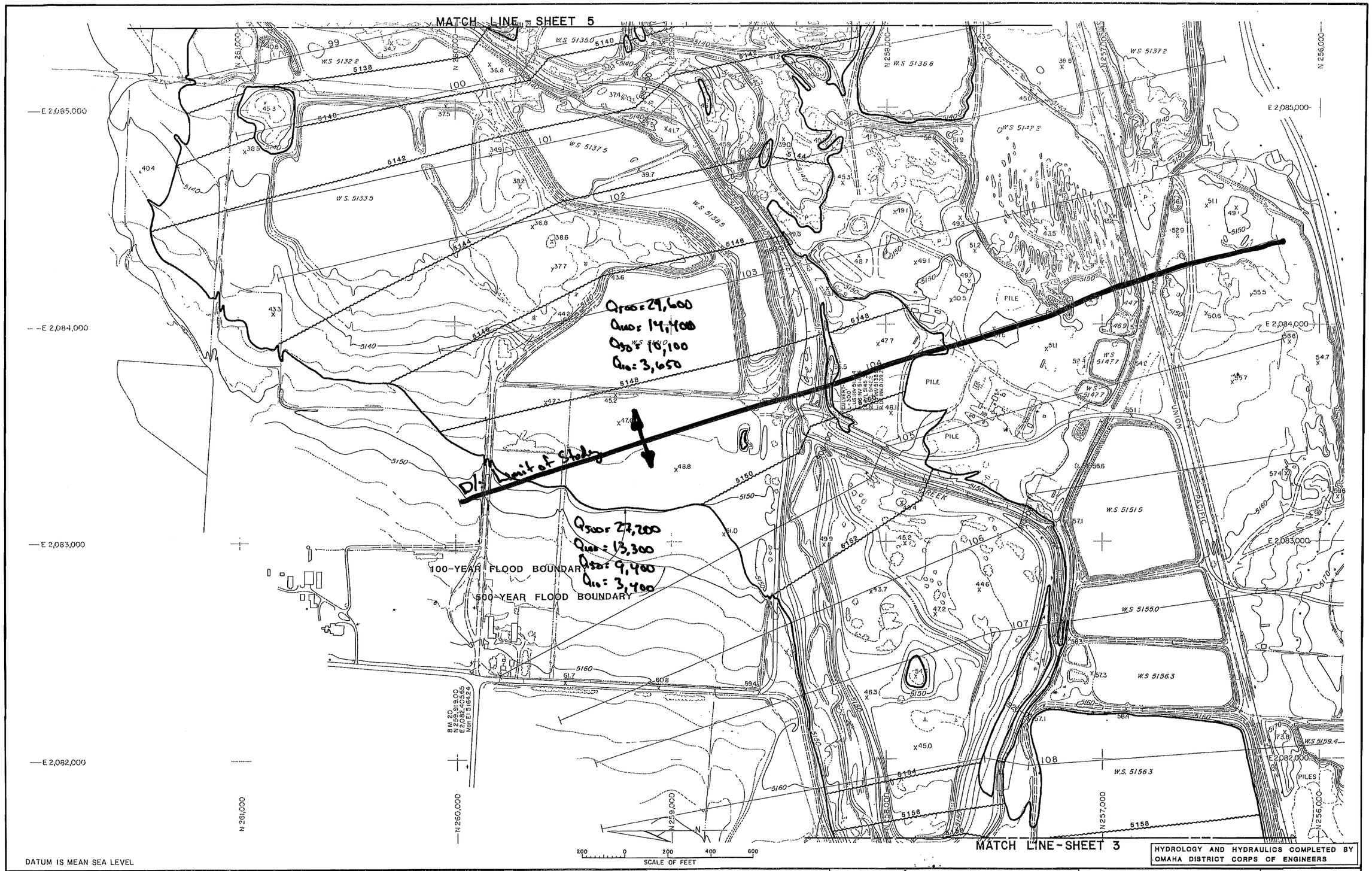
MEC JOB NO. 8218



DATUM IS MEAN SEA LEVEL

HYDROLOGY AND HYDRAULICS COMPLETED BY OMAHA DISTRICT CORPS OF ENGINEERS

GROUND CONTROL SURVEY; AERIAL PHOTOGRAPHY; TOPOGRAPHIC MAPPING BY CONTOUR INTERVAL: 2 FEET	DELTA AERIAL SURVEYS, INC. DATE FLOWN 4/29/79	MULLER ENGINEERING COMPANY, INC. CONSULTING ENGINEERS 1410 VANCE ST., SUITE 203 LAKEWOOD, COLORADO 80215 (303) 232-0340	DESIGNED COE DATE DRAWN JHK, JDM DATE 1/83 CHECKED KGS, LAM DATE 1/83 REVISED DATE	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT COLORADO WATER CONSERVATION BOARD BOULDER COUNTY	FLOOD HAZARD AREA DELINEATION LOWER BOULDER CREEK	FLOODPLAIN MAP STA 972+10 TO 926+00	SHEET 3 OF 23 MEC JOB NO. 8218



HYDROLOGY AND HYDRAULICS COMPLETED BY OMAHA DISTRICT CORPS OF ENGINEERS

GROUND CONTROL SURVEY; AERIAL PHOTOGRAPHY; TOPOGRAPHIC MAPPING BY CONTOUR INTERVAL = 2 FEET	DELTA AERIAL SURVEYS, INC. DATE FLOWN 4/29/79	MULLER ENGINEERING COMPANY, INC. CONSULTING ENGINEERS 1410 VANCE ST., SUITE 203 LAKEWOOD, COLORADO 80215 (303) 232-9340	DESIGNED COE DATE ___ DRAWN JHK, JDM DATE 1/83 CHECKED KGS, LAM DATE 1/83 REVISED ___ DATE ___	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT COLORADO WATER CONSERVATION BOARD BOULDER COUNTY	FLOOD HAZARD AREA DELINEATION LOWER BOULDER CREEK	FLOODPLAIN MAP STA 926+00 TO 870+90

SHEET 4 OF 23

MEC JOB NO. 8218

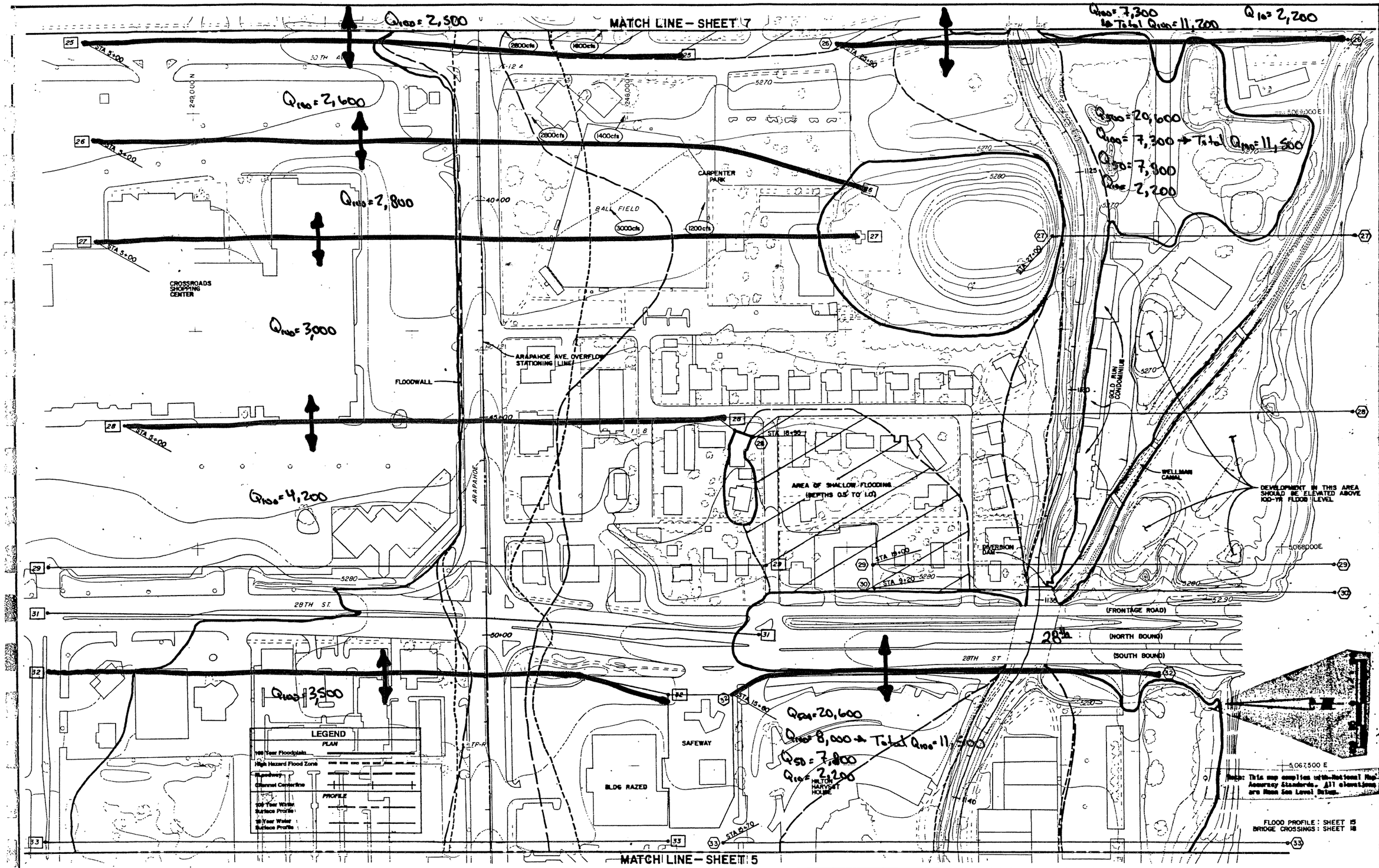
DATUM IS MEAN SEA LEVEL

HYDROLOGY AND HYDRAULICS COMPLETED BY OMAHA DISTRICT CORPS OF ENGINEERS

GROUND CONTROL SURVEY; AERIAL PHOTOGRAPHY; TOPOGRAPHIC MAPPING BY CONTOUR INTERVAL= 2 FEET	DELTA AERIAL SURVEYS, INC. DATE FLOWN 4/29/79	MULLER ENGINEERING COMPANY, INC. CONSULTING ENGINEERS 1410 VANCE ST., SUITE 203 LAKEWOOD, COLORADO 80215 (303) 232-9340	DESIGNED COE DATE ___ DRAWN JHK, JDM DATE 1/83 CHECKED KGS, LAM DATE 1/83 REVISED ___ DATE ___	URBAN DRAINAGE AND FLOOD CONTROL DISTRICT COLORADO WATER CONSERVATION BOARD BOULDER COUNTY	FLOOD HAZARD AREA DELINEATION LOWER BOULDER CREEK	FLOODPLAIN MAP STA 870+90 TO 819+80

SHEET 5 OF 23

MEC JOB NO. 8218



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2' DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1438 VANCE ST., SUITE 308
LAKEWOOD, COLORADO 80215
(303) 232-4940

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOODPLAIN # 1141+30 TO 1121+30
ARAPAHOE AVE. 55+00 TO 36+10

SHEET 6 OF 19
MEC JOB NO. 8130

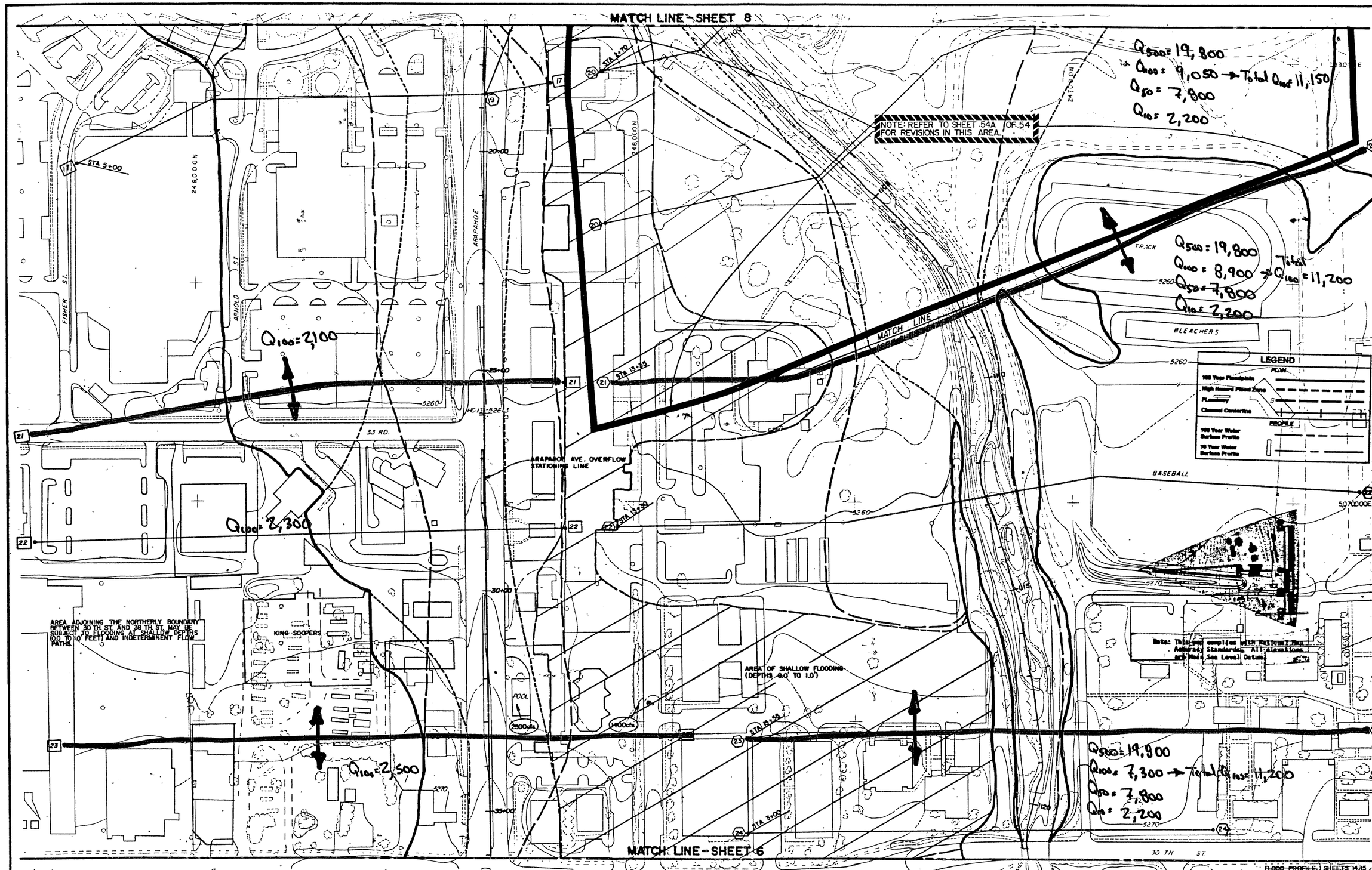
HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

David J. Love & Associates, Inc.
2995 Centergreen Court South – Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 88
PROJECT NO. 8722B

DESIGN CSB
DRAWN LCC
CHECK DJL

No.	DATE	REVISIONS	APPR.
1	4/88	REMOVED FPR FLOODWAY	DJL
2	4/89	REVISE HIGH HAZARD ZONE, 33	



GROUND CONTROL SURVEY BY: MILLER & ERNSTSEN ASSOC.
AERIAL PHOTOGRAPHY BY: SCHARF AND ASSOC. INC.
TOPOGRAPHIC MAPPING BY: REDS AERIAL MAPPING
CONTOUR INTERVAL: 2'
DATE FLOWN: 4-23-81

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS
1438 VANCE ST., SUITE 200
LAKEWOOD, COLORADO 80215
(303) 233-9340

DESIGNED KGS, BLE DATE
DRAWN JHK, JDM DATE 7/82
CHECKED LAM DATE 12/82
REVISED DATE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT
CITY OF BOULDER

FLOOD HAZARD AREA DELINEATION
BOULDER CREEK

BOULDER CREEK
FLOODPLAIN: 1121+30 TO 1099+60
ARAPAHOE AVE.: 36+10 TO 17+10

SHEET 7 OF 19
MEC JOB NO. 8130

David J. Love & Associates, Inc.
2995 Centergreen Court South - Suite C
Boulder, Colorado 80301 (303) 440-3439

DATE 1 MAR 85
PROJECT No. 8722B

HIGH HAZARD FLOOD ZONE
0.5' RISE FLOODWAY
CITY OF BOULDER

DESIGN GSB
DRAWN LCC
CHECK DJL
APPR. DJL

No.	DATE	REVISIONS
1	4/88	REVISED & PRE FLOODWAY
2	4/88	REVISE AT CU. RES. PARK

SHEET 8 OF 54

APPENDIX D

HYDROLOGIC MODELING SENSITIVITY ANALYSIS AND CALIBRATION

ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number LOBLDR02	Page 1 Of 5
Owner-Project BOULDER CREEK FLOODPLAIN MAPPING	By GJK	Date 11/14/2008
Subject HYDROLOGIC MODELING SENSITIVITY ANALYSIS	Checked By	Date

THE 100-YEAR PEAK DISCHARGE ESTIMATED BY SWMM AT THE CANYON MOUTH (AND D/S TO 9TH STREET) IS APPROXIMATELY 14% LOWER THAN THE 100-YEAR DISCHARGES USED IN THE USACE HEC-2 MODEL. IN A CONTINUING EFFORT TO CONFIRM THE EFFECTIVE HYDROLOGY, A SENSITIVITY ANALYSIS WAS CONDUCTED TO ASSESS THE PROBABILITY THAT THE SWMM MODEL PROVIDED BY THE USACE (AS DESCRIBED PREVIOUSLY) MAY HAVE BEEN USED, PERHAPS IN A SLIGHTLY MODIFIED FORM, TO PRODUCE THE EFFECTIVE 100-YEAR DISCHARGES.

SURFACE STORAGE #1 (FILES: UBDR10HA & LBDR10HA)

THE S.S. PARAMETERS IN THE USACE AND THE DESCRIPTION IN THE USACE WRITE-UP TOGETHER BROUGHT INTO QUESTION THE APPROPRIATE S.S. VALUES FOR BOULDER CREEK. THE S.S.|IMPERV FOR THE UPPER BASIN, AS WELL AS THE S.S.|IMPERV & S.S.|PERV FOR THE UPPER PORTION OF THE LOWER BASIN, WERE ALL SET EQUAL TO 0.05 IN.; THE USACE-DOCUMENTED VALUE FOR "THE MOUNTAIN PORTION OF THE BASIN." S.S. VALUES FOR BOTH IMPERVIOUS AND PERVIOUS AREAS IN THE LOWER PORTION OF THE LOWER BASIN WERE SET TO THE PRESENT DAY DEFAULTS IN SWMM OF 0.062 IN. AND 0.184 IN., RESPECTIVELY. IN THE MODEL PROVIDED S.S.|IMPERV. WAS SET TO BE GREATER THAN S.S.|PERV. IN THE LPLB; USING THE DEFAULTS RECTIFIED THIS DISPARITY.

RESULT: Q_{100} INCREASED BY 1.5 TO 2.0% BETWEEN CANYON MOUTH & 9TH AVE. Q_{100} IS LOWER BY 12% TO 13% COMPARED TO HEC-2 DISCHARGES

SURFACE STORAGE #2 (FILES: UBDR10HA & LBDR10HB)

S.S.|IMPERV & SS|PERV IN THE LPLB WERE BOTH CHANGED TO 0.5 IN. TO REFLECT THE VALUES USED IN THE UB & UPLB.

RESULT: NO CHANGE IN Q_{100} BETWEEN CANYON MOUTH & 9TH AVE. AND THE MODIFIED S.S. VALUES ARE NOT NECESSARILY PHYSICALLY-BASED.

INFILTRATION RATE (FILES: UBDR10HC & LBDR10HC)

IN THE UB AND THE UPLB, THE CONSTANT INFILTRATION RATE WAS CHANGED TO 0.5 IN/HR COMMENSURATE WITH THE INFILTRATION RATE USED IN THE LPLB.

RESULT: Q_{100} INCREASED BY 64% TO 66% BETWEEN CANYON MOUTH & 9TH AVE. AND THE MODIFIED INFILTRATION RATES ARE NECESSILY SUPPORTED BY SOILS CONDITIONS.

COMPUTATIONAL TIME INTERVAL (FILES: UBDR10HD & LBDR10HD)

FOR THIS ANALYSIS, ALL S.S. VALUES AND INFILTRATION RATES WERE REVERTED BACK TO THOSE USED IN FILES UBDR10HA & LBDR10HA. THE PARAMETERS USED IN THOSE MODELS FOLLOW THE USACE WRITE-UP, WHILE ALSO APPEARING TO BE THE MOST PHYSICALLY REASONABLE.

THE COMPUTATIONAL TIME INTERVAL WAS CHANGED FROM 5 MIN. TO 1 MIN. IN THE CURRENT VERSION OF SWMM, USE OF A 5 MIN. TIME INTERVAL WILL OCCASIONALLY MISS THE PEAK DISCHARGE BY A FEW PERCENT, OR MORE.

RESULT: MINIMAL CHANGE IN Q_{100} BETWEEN CANYON MOUTH & 9TH AVE. REVERT BACK TO 5 MIN. INTERVAL FOR ALL REMAINING ANALYSES.

THE REMAINING SENSITIVITY ANALYSES FOCUSED ON PRECIPITATION AND RAINFALL HYETOGRAPHS, USING THE UBDR10HA & LBDR10HA MODELS AS A BASIS.

ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number COBLDR02	Page 3 Of 5
Owner-Project	By GJL	Date 11/14/2008
Subject HYDROLOGIC MODELING SENSITIVITY ANALYSIS	Checked By	Date

PRECIPITATION #1 (FILES: UBDR10HZ & LBDR10HZ)

IN AN EFFORT TO CHECK THE SENSITIVITY OF THE SWMM MODEL TO RAINFALL DEPTH AND INTENSITY, ALL 100-YR RAINFALL DEPTHS WERE INCREASED BY 5%.

RESULT: Q_{100} INCREASED BY 13% TO 15% BETWEEN CANYON MOUTH AND 9TH AVE. (AS COMPARED TO THE "...HA" RESULTS). Q_{100} IS WITHIN 2% OF THE HEC-2 DISCHARGES BETWEEN THE CANYON MOUTH AND 9TH AVE.

PRECIPITATION #2 (FILES: UBDR10HY & LBDR10HY)

RECOGNIZING THAT THE USACE WOULD HAVE LIKELY RELIED ON MANUAL MEANS FOR DEFINING AVERAGE RAINFALL FOR EACH OF THE FIVE ZONES (RATHER THAN GIS TOOLS), 100-YEAR RAINFALL DEPTHS WERE DETERMINED BY AREA AVERAGE USING A MAP THAT OVERLAID NOAA'S ISOHYETS ON THE BASIN AND RAINFALL ZONE MAP. CONSIDERED ON A ZONE-BY-ZONE BASIS FOR THE FIVE RAINFALL ZONES, COMPARED TO THE RAINFALL DEPTHS DETERMINED BY GIS THE DEPTHS COMPUTED USING MANUAL METHODS RANGED FROM BEING 2% LOWER TO 4% HIGHER.

RESULT: Q_{100} INCREASED BY UP TO 2% BETWEEN CANYON MOUTH AND 9TH AVE. (AS COMPARED TO THE "...HA" RESULTS). NOTE: Q_{100} AT CANYON MOUTH ACTUALLY LOWER BY <1%

PRECIPITATION #3 (FILES: UBDR10HX & LBDR10HX)

THE MANUALLY-COMPUTED RAINFALL DEPTHS WERE ROUNDED UP TO THE NEAREST 0.05 IN. THEN AREA REDUCED TO 87%.

RESULTS: Q_{100} INCREASED BY ABOUT 100CFS, OR NEARLY 1%, COMPARED TO "...HY" RESULTS.

PRECIPITATION #4 (FILES: UBDR10HW & LBDR10HW)

THE MANUALLY-COMPUTED RAINFALL DEPTHS WERE ROUNDED UP TO THE NEAREST 0.10 IN. THEN AREA REDUCED TO 87%.

RESULTS: Q_{100} INCREASED BY ABOUT 200 CFS TO 400 CFS, COMPARED TO "...HY" RESULTS.

PRECIPITATION #5 (FILES: UBDR10HV & LBDR10HV)

THE MANUALLY-COMPUTED RAINFALL DEPTHS WERE AREA REDUCED TO 87% THEN ROUNDED UP TO THE NEAREST 0.05 IN.

RESULTS: Q_{100} INCREASED BY 360 CFS TO 370 CFS, COMPARED TO "...HY" RESULTS.
Q_{100} IS LOWER THAN HEC-2 DISCHARGES BETWEEN THE CANYON MOUTH & 9TH AVE. BY 9% - 10%.

PRECIPITATION #6 (FILES: UBDR10HT & LBDR10HT)

THE MANUALLY-COMPUTED RAINFALL DEPTHS WERE AREA REDUCED TO 87% THEN ROUNDED UP TO THE NEAREST 0.10 IN.

RESULT: Q_{100} INCREASED BY 840 CFS TO 890 CFS, OR ABOUT 8%, COMPARED TO "...HY" RESULTS.
Q_{100} IS LOWER THAN HEC-2 DISCHARGES BETWEEN THE CANYON MOUTH & 9TH AVE. BY 5% - 6%.

THIS METHOD FOR DEFINING RAINFALL DEPTH APPEARS REASONABLE GIVEN THE MAPPING TECHNIQUES AVAILABLE IN THE 1970S AND THE SMALL SCALE OF THE NOAA ISOPLUVIAL MAPS.

RAINFALL DEPTHS BY MANUAL AVERAGE

- REFERENCING THE RAINFALL ZONE MAP, THE 100-YR, 6-HR RAINFALL DEPTH FOR RAINFALL ZONES 1 & 4 CAN BE REPRESENTED WITH 3.8 INCHES AND 3.0 INCHES, RESPECTIVELY
- RAINFALL ZONES 2, 3 & 5 WERE SUBDIVIDED TO DEFINE THE AREA OF INFLUENCE ASSOCIATED WITH EACH ISOHYET; THESE ZONES ARE SHOWN ON THE ATTACHED RAINFALL ZONE SUBREGION MAP

RAINFALL ZONE SUBREGION	ISOHYET (IN.)	AREA (AC)
2.1	3.2	679.3
2.2	3.4	3,431.5
2.3	3.6	2,752.6
2.4	3.8	5,462.1
3.1	3.0	4,844.2
3.2	3.2	4,758.3
3.3	3.4	506.1
5.1	2.4	2,463.0
5.2	2.6	6,215.7
5.3	2.8	8,926.3
5.4	3.0	8,273.9

RAINFALL ZONE	100-YR, 6-HR POINT RAINFALL DEPTH (IN.)	100-YR, 6-HR AREA REDUCED RAINFALL DEPTH[b] (IN.)
1	3.8	3.31
2	3.61[a]	3.14
3	3.11[a]	2.71
4	3.0	2.61
5	2.78[a]	2.42

[a] COMPUTED BY AREA-WEIGHTING OF THE VALUES LISTED ABOVE

[b] REDUCED TO 87% OF POINT RAINFALL VALUES

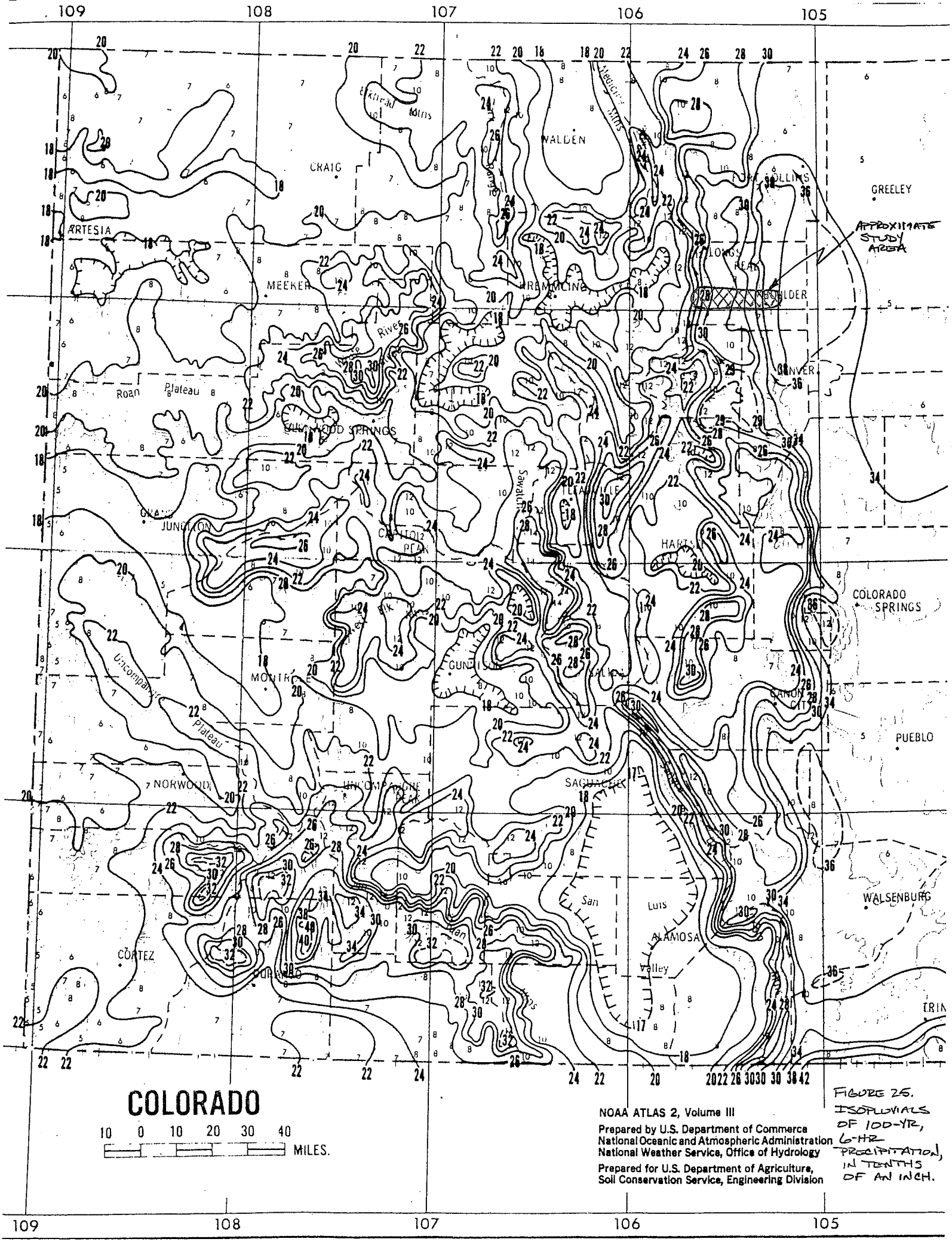


FIGURE 25. ISOPLUVIALS OF 100-YR, 6-HR PRECIPITATION, IN TENTHS OF AN INCH.

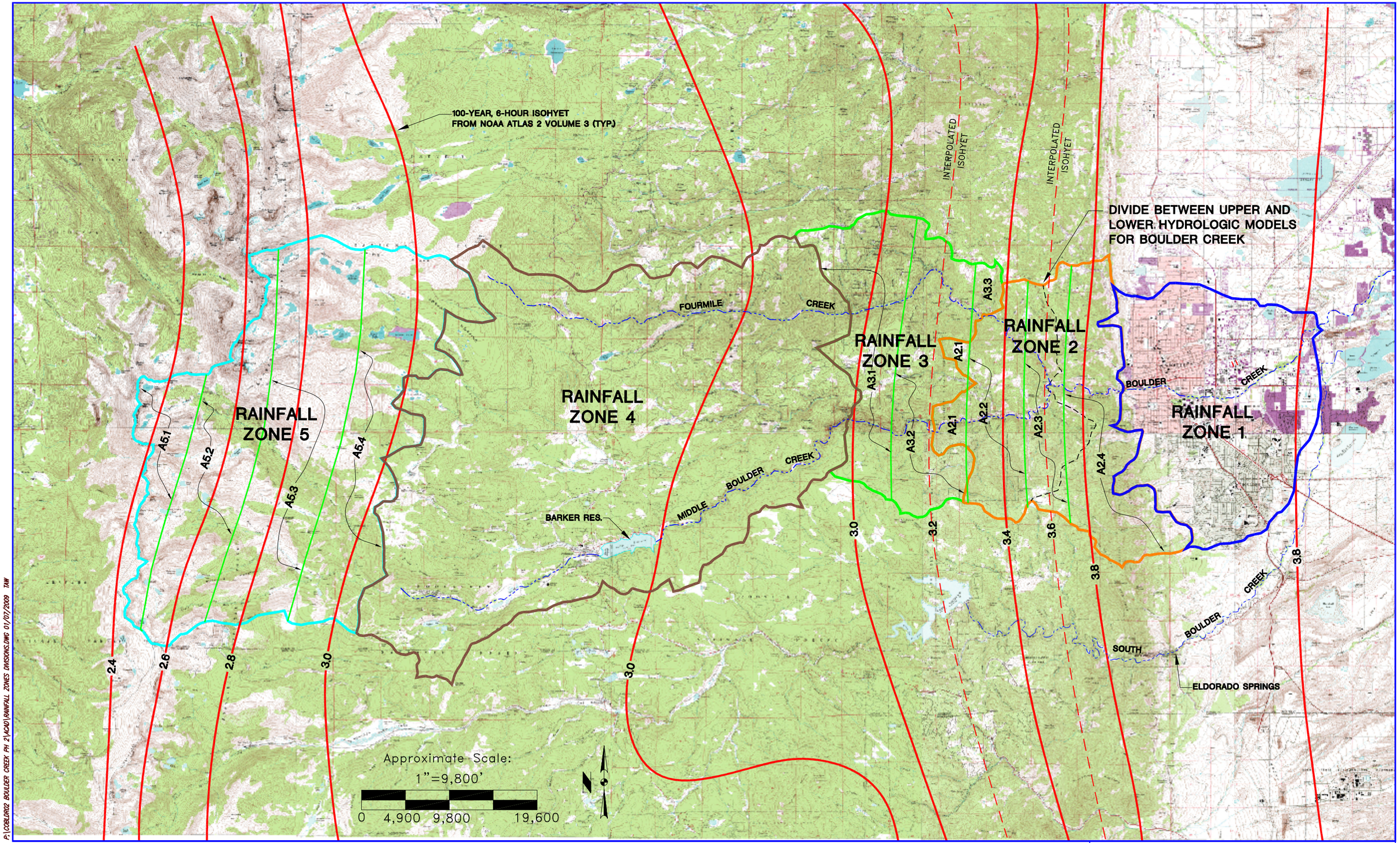


Figure D1 Boulder Creek Watershed, Rainfall Zone Subregions

P:\COBLDR02 BOULDER CREEK PH 2\ACAD\RAINFALL ZONES DIVISIONS.DWG 01/07/2009 TAW

Rainfall Hyetograph Calculator for Boulder Creek

USACE Rainfall Distribution Time (min)	Rainfall Depth (% of total)
30	2
60	4
90	4
120	5
150	9
180	10
210	40
240	10
270	6
300	4
330	4
360	2
Total	100

SCENARIO NOS. 1 - 6

Boulder Creek Rainfall Zone (by USACE)	Area-Reduced 100-Yr, 6-Hr Rainfall Depth (inches)
1	3.32
2	3.01
3	2.64
4	2.65
5	2.38

SCENARIO NO. 7

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Increased 5% (inches)
1	3.49
2	3.16
3	2.77
4	2.78
5	2.50

NOT USED

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Increased 10% (inches)
1	3.65
2	3.31
3	2.90
4	2.92
5	2.62

SCENARIO NO. 8

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Manual Averaging (inches)
1	3.31
2	3.14
3	2.71
4	2.61
5	2.42

SCENARIO NO. 9

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Manual Avg (round up 0.05) (inches)
1	3.31
2	3.18
3	2.74
4	2.61
5	2.44

SCENARIO NO. 10

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Manual Avg (round up 0.1) (inches)
1	3.31
2	3.22
3	2.78
4	2.61
5	2.44

SCENARIO NO. 11

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Manual Averaging (A) (inches)
1	3.35
2	3.15
3	2.75
4	2.65
5	2.45

SCENARIO NO. 12

Boulder Creek Rainfall Zone (by USACE)	100-Yr, 6-Hr Rainfall Depth Manual Averaging (B) (inches)
1	3.40
2	3.20
3	2.80
4	2.70
5	2.50

(A) rounding up to nearest 0.05 after area reducing
(B) rounding up to nearest 0.10 after area reducing

Area-Reduced 100-Yr, 6-Hr Rainfall Hyetographs Rainfall Intensity (inches/hour)					100-Yr, 6-Hr Rainfall Hyetographs Increased 5% Rainfall Intensity (inches/hour)					100-Yr, 6-Hr Rainfall Hyetographs Increased 10% Rainfall Intensity (inches/hour)					100-Yr, 6-Hr Rainfall Hyetographs Manual Average Rainfall Intensity (inches/hour)				
Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0.133	0.120	0.106	0.106	0.095	0.139	0.126	0.111	0.111	0.100	0.146	0.132	0.116	0.117	0.105	0.132	0.126	0.108	0.104	0.097
0.266	0.241	0.211	0.212	0.190	0.279	0.253	0.222	0.223	0.200	0.292	0.265	0.232	0.233	0.209	0.265	0.251	0.217	0.209	0.194
0.266	0.241	0.211	0.212	0.190	0.279	0.253	0.222	0.223	0.200	0.292	0.265	0.232	0.233	0.209	0.265	0.251	0.217	0.209	0.194
0.332	0.301	0.264	0.265	0.238	0.349	0.316	0.277	0.278	0.250	0.365	0.331	0.290	0.292	0.262	0.331	0.314	0.271	0.261	0.242
0.598	0.542	0.475	0.477	0.428	0.627	0.569	0.499	0.501	0.450	0.657	0.596	0.523	0.525	0.471	0.596	0.565	0.488	0.470	0.436
0.664	0.602	0.528	0.530	0.476	0.697	0.632	0.554	0.557	0.500	0.730	0.662	0.581	0.583	0.524	0.662	0.628	0.542	0.522	0.484
2.656	2.408	2.112	2.120	1.904	2.789	2.528	2.218	2.226	1.999	2.922	2.649	2.323	2.332	2.094	2.648	2.512	2.168	2.088	1.936
0.664	0.602	0.528	0.530	0.476	0.697	0.632	0.554	0.557	0.500	0.730	0.662	0.581	0.583	0.524	0.662	0.628	0.542	0.522	0.484
0.398	0.361	0.317	0.318	0.286	0.418	0.379	0.333	0.334	0.300	0.438	0.397	0.348	0.350	0.314	0.397	0.377	0.325	0.313	0.290
0.266	0.241	0.211	0.212	0.190	0.279	0.253	0.222	0.223	0.200	0.292	0.265	0.232	0.233	0.209	0.265	0.251	0.217	0.209	0.194
0.266	0.241	0.211	0.212	0.190	0.279	0.253	0.222	0.223	0.200	0.292	0.265	0.232	0.233	0.209	0.265	0.251	0.217	0.209	0.194
0.133	0.120	0.106	0.106	0.095	0.139	0.126	0.111	0.111	0.100	0.146	0.132	0.116	0.117	0.105	0.132	0.126	0.108	0.104	0.097

(round up 0.05)

100-Yr, 6-Hr Rainfall Hyetographs Mnl Avg

Rainfall Intensity (inches/hour)

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0.132	0.127	0.110	0.104	0.098
0.265	0.254	0.219	0.209	0.195
0.265	0.254	0.219	0.209	0.195
0.331	0.318	0.274	0.261	0.244
0.596	0.572	0.493	0.470	0.439
0.662	0.636	0.548	0.522	0.488
2.648	2.544	2.192	2.088	1.952
0.662	0.636	0.548	0.522	0.488
0.397	0.382	0.329	0.313	0.293
0.265	0.254	0.219	0.209	0.195
0.265	0.254	0.219	0.209	0.195
0.132	0.127	0.110	0.104	0.098

(round up 0.10)

100-Yr, 6-Hr Rainfall Hyetographs Mnl Avg

Rainfall Intensity (inches/hour)

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0.132	0.129	0.111	0.104	0.098
0.265	0.258	0.222	0.209	0.195
0.265	0.258	0.222	0.209	0.195
0.331	0.322	0.278	0.261	0.244
0.596	0.580	0.500	0.470	0.439
0.662	0.644	0.556	0.522	0.488
2.648	2.576	2.224	2.088	1.952
0.662	0.644	0.556	0.522	0.488
0.397	0.386	0.334	0.313	0.293
0.265	0.258	0.222	0.209	0.195
0.265	0.258	0.222	0.209	0.195
0.132	0.129	0.111	0.104	0.098

(round up 0.05 after area reduction)

100-Yr, 6-Hr Rainfall Hyetographs Mnl Avg

Rainfall Intensity (inches/hour)

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0.134	0.126	0.110	0.106	0.098
0.268	0.252	0.220	0.212	0.196
0.268	0.252	0.220	0.212	0.196
0.335	0.315	0.275	0.265	0.245
0.603	0.567	0.495	0.477	0.441
0.670	0.630	0.550	0.530	0.490
2.680	2.520	2.200	2.120	1.960
0.670	0.630	0.550	0.530	0.490
0.402	0.378	0.330	0.318	0.294
0.268	0.252	0.220	0.212	0.196
0.268	0.252	0.220	0.212	0.196
0.134	0.126	0.110	0.106	0.098

(round up 0.10 after area reduction)

100-Yr, 6-Hr Rainfall Hyetographs Mnl Avg

Rainfall Intensity (inches/hour)

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
0.136	0.128	0.112	0.108	0.100
0.272	0.256	0.224	0.216	0.200
0.272	0.256	0.224	0.216	0.200
0.340	0.320	0.280	0.270	0.250
0.612	0.576	0.504	0.486	0.450
0.680	0.640	0.560	0.540	0.500
2.720	2.560	2.240	2.160	2.000
0.680	0.640	0.560	0.540	0.500
0.408	0.384	0.336	0.324	0.300
0.272	0.256	0.224	0.216	0.200
0.272	0.256	0.224	0.216	0.200
0.136	0.128	0.112	0.108	0.100

Table D1. Hydrologic Modeling Parameters for the Various Scenarios, Without Flood Routing Along Lower Boulder Creek.

Scenario	Filenames	Rainfall Hyetograph Time Increments (minutes)	Computational Time Interval (minutes)	Roughness Coefficient (Manning's n value)						Surface Storage (inches)						Infiltration Rate (inches/hour)					
				Upper Basin		Upper Portion of Lower Basin		Lower Portion of Lower Basin		Upper Basin		Upper Portion of Lower Basin		Lower Portion of Lower Basin		Upper Basin		Upper Portion of Lower Basin		Lower Portion of Lower Basin	
				Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Initial	Final	Initial	Final	Initial	Final
1	Upper Basin: UPBDR100[a] Lower Basin: LWBDR100[a]	60	5	0.013	0.12	0.013	0.12	0.013	0.12	0.2	0.05	0.20	0.18	0.20	0.18	1.0	1.0	1.0	1.0	0.5	0.5
2	Upper Basin: UBDR100H Lower Basin: LBDR100H	30[b]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.2	0.05	0.20	0.18	0.20	0.18	1.0	1.0	1.0	1.0	0.5	0.5
3	Upper Basin: UBDR10HA Lower Basin: LBDR10HA	30	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05[c]	0.05	0.05[c]	0.05[c]	0.062[d]	0.184[d]	1.0	1.0	1.0	1.0	0.5	0.5
4	Upper Basin: UBDR10HA Lower Basin: LBDR10HB	30	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.05[c]	0.05[c]	1.0	1.0	1.0	1.0	0.5	0.5
5	Upper Basin: UBDR10HC Lower Basin: LBDR10HC	30	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.5	0.5	0.5	0.5
6	Upper Basin: UBDR10HD Lower Basin: LBDR10HD	30	1	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
7	Upper Basin: UBDR10HZ Lower Basin: LBDR10HZ	30 (intensities increased 5%)	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
8	Upper Basin: UBDR10HY Lower Basin: LBDR10HY	30 (intensities by manual average)	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
9	Upper Basin: UBDR10HX Lower Basin: LBDR10HX	30 (intensities by man. avg. round up 0.05 pre.)[e]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
10	Upper Basin: UBDR10HW Lower Basin: LBDR10HW	30 (intensities by man. avg. round up 0.10 pre.)[f]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
11	Upper Basin: UBDR10HV Lower Basin: LBDR10HV	30 (intensities by man. avg. round up 0.05 post.)[g]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
12	Upper Basin: UBDR10HT Lower Basin: LBDR10HT	30 (intensities by man. avg. round up 0.10 post.)[h]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5

Notes: Values shown in red indicate changes from the preceding scenario; except for Scenario #6 where the red values indicate changes from Scenario #3.

[a] Parameter values and hyetograph time increments were taken from USACE 25-year model.

[b] Rainfall pattern documented in USACE report; rainfall depths determined from NOAA Atlas 2, Volume 3.

[c] Surface storage value for "the mountain portion of the basin" as documented in USACE report.

[d] Current default surface storage values in UD-SWM2PC.

[e] Rainfall intensities determined by manual averaging techniques, rounded up to the nearest 0.05 inches, then area reduced to 87%.

[f] Rainfall intensities determined by manual averaging techniques, rounded up to the nearest 0.10 inches, then area reduced to 87%.

[g] Rainfall intensities determined by manual averaging techniques, area reduced to 87%, then rounded up to the nearest 0.05 inches.

[h] Rainfall intensities determined by manual averaging techniques, area reduced to 87%, then rounded up to the nearest 0.10 inches.

APPENDIX E

LOWER BASIN CONVEYANCE ROUTING ALONG BOULDER CREEK

ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number COBLDR#2	Page 1 Of 3
Owner-Project BOULDER CREEK FLOODPLAIN MAPPING	By GJL	Date 11/21/2008
Subject LOWER BASIN STREAM ROUTING USING SWMM	Checked By	Date

- THE SWMM MODELS PROVIDED BY THE USACE DID NOT INCLUDE CONVEYANCE ELEMENTS TO REPRESENT STREAMFLOW ROUTING
- STREAM ROUTING WAS ACCOMPLISHED BY THE USACE USING A SEPARATE DIFFUSION ROUTING MODEL
- THE USACE SWMM MODEL FOR THE LOWER BASIN WAS CONVERTED TO THE PRESENT-DAY SWMM MODEL FORMAT AND RE-ANALYZED USING MODSWMM (UD-SWMM COULD HAVE BEEN USED BUT MODSWMM WAS UTILIZED TO TAKE ADVANTAGE OF THE MORE CONVENIENT OUTPUT FORMAT); RESULTS OF THE MODSWMM MODEL AGREE WITH THOSE DETERMINED BY THE ORIGINAL USACE MODEL TO WITHIN ABOUT 1%
- LOCATIONS OF THE TRIBUTARY INFLOWS CORRESPONDING TO SWMM NODES 94-99 WERE IDENTIFIED USING THE USACE'S SWMM MODEL AND BASIN MAP; THESE LOCATIONS ARE SHOWN IN THE ATTACHED FIGURE AND IDENTIFIED AS FOLLOWS:

NODE	LOCATION
94	NEAR U/S CROSSING OF ARAPAHOE AVE.
95	D/S OF ARAPAHOE AVE. CROSSING, NEAR 3RD ST.
96	AT 9TH STREET
97	U/S OF BARR (D/S OF BEAR CANYON CR. CONFLUENCE)
98	AT VALMONT RD.
99	U/S OF S. BOULDER CREEK CONFLUENCE

- DUE TO THE CLOSE PROXIMITY OF NODES 94 & 95 TO EACH OTHER, CONVEYENCE ELEMENT ROUTING FOR THIS ANALYSIS BEGINS AT NODE 95

CONVEYANCE ELEMENT 196 (3RD STREET TO 9TH STREET)

BOULDER CR. FROM NODE 95 TO NODE 96
BOUNDING HEC-RAS XSECS 34040 & 31689
REPRESENTATIVE XSEC 33036

LENGTH = 34,040 − 31,689 ≅ 2,350 FT

$$\text{SLOPE} = \frac{5379 - 5350}{34{,}040 - 31{,}689} \cong 0.012 \text{ FT/FT}$$

LOW FLOW: BW ≅ 60 FT $SS|_L \cong 6.5H:1V$ $SS|_R \cong 2.7H:1V$ $\eta = 0.055$ $D_{MAX} \cong 5$ FT

HIGH FLOW: BW ≅ 100 FT $SS|_L \cong 24H:1V$ $SS|_R \cong 1.9H:1V$ $\eta \cong 0.045$ $D_{MAX} = 10$ FT

AN APPROX. AVERAGE (TYPICAL)

CONVEYANCE ELEMENT 197 (9TH STREET TO BEAR CANYON CR.)

BOULDER CR. FROM NODE 96 TO NODE 97
BOUNDING HEC-RAS XSECS 31632 & 17485
REPRESENTATIVE XSEC 24831

LENGTH = 31,632 − 17,485 ≅ 14,150 FT

$$\text{SLOPE} = \frac{5349 - 5231}{31632 - 17485} \cong 0.008 \text{ FT/FT}$$

LOW FLOW: BW ≅ 30 FT $SS|_L \cong 2H:1V$ $SS|_R \cong 5H:1V$ $\eta = 0.040$ $D_{MAX} \cong 7$ FT

APPROX. AVERAGE

HIGH FLOW: BW ≅ 120 FT $SS|_L \cong 270H:1V$ $SS|_R \cong 110H:1V$ $\eta \cong 0.040$ $D_{MAX} = 10$ FT

ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number COBLDR02	Page 3 Of 3
Owner-Project	By GTK	Date 11/21/2008
Subject LOWER BASIN STREAM ROUTING USING SWMM	Checked By	Date

CONVEYANCE ELEMENT 198 (BEAR CANYON CR. TO VALMONT)

BOULDER CR. FROM NODE 97 TO NODE 98
BOUNDING HEC-RAS XSECS 17485 & 10369
REPRESENTATIVE XSEC 17164

LENGTH = 17485 − 10369 ≅ 7,100 FT

$$\text{SLOPE} = \frac{5230.66 - 5185.40}{17485 - 10369} = 0.006 \text{ FT/FT}$$

LOW FLOW: BW ≅ 30 FT LSS ≅ 4H:1V RSS ≅ 3H:1V η = 0.055 D_{MAX} ≅ 3 FT

HIGH FLOW: BW ≅ 830 FT LSS ≅ 120H:1V RSS ≅ 13H:1V η ≅ 0.050 D_{MAX} = 10 FT

CONVEYANCE ELEMENT 199 (VALMONT TO U/S OF S. BOULDER CR.)

BOULDER CR. FROM NODE 98 TO NODE 99
BOUNDING HEC-RAS XSECS 10293 & 6974
REPRESENTATIVE XSEC 9050

LENGTH = 10293 − 6974 ≅ 3,300 FT

$$\text{SLOPE} = \frac{5185.3 - 5168.0}{10293 - 6974} = 0.005 \text{ FT/FT}$$

LOW FLOW: BW ≅ 60 FT LSS ≅ 4.5H:1V RSS ≅ 3H:1V η = 0.060 D_{MAX} ≅ 4 FT

HIGH FLOW: BW ≅ 400 FT LSS ≅ 4.61H:1V RSS ≅ 1.5H:1V η = 0.065 D_{MAX} = 10 FT

Figure E1. Lower Boulder Creek Subbasin Map with Tributary Locations.

Table E1. Hydrologic Modeling Parameters for the Various Scenarios, With Flood Routing Along Lower Boulder Creek for Scenario No. 13.

Scenario	Filenames	Rainfall Hyetograph Time Increments (minutes)	Computational Time Interval (minutes)	Roughness Coefficient (Manning's n value)						Surface Storage (inches)						Infiltration Rate (inches/hour)					
				Upper Basin		Upper Portion of Lower Basin		Lower Portion of Lower Basin		Upper Basin		Upper Portion of Lower Basin		Lower Portion of Lower Basin		Upper Basin		Upper Portion of Lower Basin		Lower Portion of Lower Basin	
				Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Imperv.	Perv.	Initial	Final	Initial	Final	Initial	Final
1	Upper Basin: UPBDR100[a] Lower Basin: LWBDR100[a]	60	5	0.013	0.12	0.013	0.12	0.013	0.12	0.2	0.05	0.20	0.18	0.20	0.18	1.0	1.0	1.0	1.0	0.5	0.5
2	Upper Basin: UBDR100H Lower Basin: LBDR100H	30[b]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.2	0.05	0.20	0.18	0.20	0.18	1.0	1.0	1.0	1.0	0.5	0.5
3	Upper Basin: UBDR10HA Lower Basin: LBDR10HA	30	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05[c]	0.05	0.05[c]	0.05[c]	0.062[d]	0.184[d]	1.0	1.0	1.0	1.0	0.5	0.5
4	Upper Basin: UBDR10HA Lower Basin: LBDR10HB	30	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.05[c]	0.05[c]	1.0	1.0	1.0	1.0	0.5	0.5
5	Upper Basin: UBDR10HC Lower Basin: LBDR10HC	30	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.5	0.5	0.5	0.5	0.5	0.5
6	Upper Basin: UBDR10HD Lower Basin: LBDR10HD	30	1	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
7	Upper Basin: UBDR10HZ Lower Basin: LBDR10HZ	30 (intensities increased 5%)	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
8	Upper Basin: UBDR10HY Lower Basin: LBDR10HY	30 (intensities by manual average)	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
9	Upper Basin: UBDR10HX Lower Basin: LBDR10HX	30 (intensities by man. avg. round up 0.05 pre.)[e]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
10	Upper Basin: UBDR10HW Lower Basin: LBDR10HW	30 (intensities by man. avg. round up 0.10 pre.)[f]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
11	Upper Basin: UBDR10HV Lower Basin: LBDR10HV	30 (intensities by man. avg. round up 0.05 post.)[g]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
12	Upper Basin: UBDR10HT Lower Basin: LBDR10HT	30 (intensities by man. avg. round up 0.10 post.)[h]	5	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5
13	Upper Basin: UBDR10HT Lower Basin: LBDR10HS	30	5 (channel routing, lower basin)[i]	0.013	0.12	0.013	0.12	0.013	0.12	0.05	0.05	0.05	0.05	0.062	0.184	1.0	1.0	1.0	1.0	0.5	0.5

Notes: Values shown in red indicate changes from the preceding scenario; except for Scenario #6 where the red values indicate changes from Scenario #3.

[a] Parameter values and hyetograph time increments were taken from USACE 25-year model.

[b] Rainfall pattern documented in USACE report; rainfall depths determined from NOAA Atlas 2, Volume 3.

[c] Surface storage value for "the mountain portion of the basin" as documented in USACE report.

[d] Current default surface storage values in UD-SWM2PC.

[e] Rainfall intensities determined by manual averaging techniques, rounded up to the nearest 0.05 inches, then area reduced to 87%.

[f] Rainfall intensities determined by manual averaging techniques, rounded up to the nearest 0.10 inches, then area reduced to 87%.

[g] Rainfall intensities determined by manual averaging techniques, area reduced to 87%, then rounded up to the nearest 0.05 inches.

[h] Rainfall intensities determined by manual averaging techniques, area reduced to 87%, then rounded up to the nearest 0.10 inches.

[i] Inflow hydrograph added from upper basin and channel flows routed through the lower basin using SWMM.

APPENDIX F

STREAM GAGE AND REGRESSION EQUATION EVALUATION

ANDERSON CONSULTING ENGINEERS, INC *Civil • Water Resources • Environmental*	Project Number COBLDR02	Page 1 Of 4
Owner-Project BOULDER CREEK FLOODPLAIN MAPPING	By BJK	Date 11/17/2008
Subject STREAM GAGE AND REGRESSION EQUATION EVALUATION	Checked By	Date

STREAM GAGE EVALUATION

USGS PEAK STREAMFLOW DATA WAS OBTAINED FOR THE BOULDER CREEK NEAR ORODELL, CO GAGE. EXCEPT FOR 1914 & 1915, THE RECORD IS CONTINUOUS FROM 1907 TO 1995. FLOWS AT THIS GAGE ARE HIGHLY CONTROLLED BY BARKER RESERVOIR, AND HAVE BEEN OVER THE ENTIRE PERIOD OF RECORD. HOWEVER, THE STREAMFLOW DATA PROVIDE AT LEAST A LIMITED BASIS OF COMPARISON TO THE HYDROLOGIC MODELING RESULTS FOR THE UPPER PORTION OF THE BOULDER CREEK WATERSHED.

THE HIGHEST MEASURED DISCHARGE BETWEEN 1907 & 1995 WAS 2,500 CFS.

APPLYING THE USGS PEAKFQ COMPUTER PROGRAM, BASED ON BULLETIN 17-B PROCEDURES, THE "EXPECTED PROBABILITY" ESTIMATE FOR THE 100-YEAR FLOW IS 1,789 CFS.

APPLICATION OF PEAKFQ TO ESTIMATE THE 100-YEAR DISCHARGE IS NOT STRICTLY APPROPRIATE DUE TO THE STORAGE EFFECTS OF BARKER RESERVOIR. THE MEASURED FLOW AT THE ORODELL GAGE IS A FUNCTION OF NOT ONLY THE RAINFALL INTENSITY & DURATION AND RAINFALL-RUNOFF TRANSFORMATION, BUT ALSO THE STORAGE AVAILABLE IN BARKER RESERVOIR FOR CAPTURING RUNOFF. FOR REGULATORY PURPOSES, THE HYDROLOGIC MODEL MUST ASSUME THAT THE RESERVOIR IS FULL TO THE LOWEST UNCONTROLLED OUTLET. IT IS ASSUMED THAT THE USACE MODEL FOLLOWS THIS CONVENTION, AS DETAILED MODELING INFORMATION FOR THE RESERVOIR WAS NOT PROVIDED BY THE USACE. COMPARING THE STREAM GAGE DATA TO THE MODELING RESULTS, THE TYPICAL RESERVOIR OPERATION CLEARLY DOES NOT SUPPORT A POOL LEVEL EQUAL TO THE EMERGENCY SPILLWAY. WITH A SURFACE AREA OF APPROXIMATELY 200 ACRES, BARKER RESERVOIR WOULD BE CAPABLE OF SIGNIFICANT ATTENUATION OF THE PEAK RUNOFF FROM THE ROUGHLY 39-SQ. MI. CONTRIBUTING BASIN. IN FACT, IT APPEARS THAT THE USACE MODEL ASSUMED A FULL RESERVOIR TO THE CREST OF THE EMERGENCY SPILLWAY (WHICH BASED ON THE MODEL DATA SEEMS TO BE APPROXIMATELY 175 FT LONG) WITH THE MODEL TAKING A PEAK INFLOW OF 3,260 CFS AND ATTENUATING IT TO 2,050 CFS IN THE 100-YEAR SIMULATION.

RESULTS: THE MODELED 100-YEAR DISCHARGE AT ORODELL IS GREATER THAN THAT WHICH WOULD BE SUPPORTED BY THE GAGE DATA AT THAT LOCATION. THIS RESULT WOULD BE EXPECTED DUE TO THE EFFECT OF BARKER RESERVOIR. HOWEVER, IF THE MAGNITUDE OF THE DISCREPANCY IN MODELED & GAGED FLOWS IS A CONCERN.

USGS REGRESSION EQUATIONS

– REFERENCE: "ANALYSIS OF THE MAGNITUDE AND FREQUENCY OF FLOODS IN COLORADO," WATER-RESOURCES INVESTIGATIONS REPORT 99-4190, U.S. GEOLOGICAL SURVEY, DENVER, CO, 2000

MOUNTAIN REGION 100-YEAR EQUATION:

$$Q_{100} = 39.5\,A^{0.706}\,(S+1.0)^{1.577}\;;$$

A ≡ DRAINAGE AREA (SQ. MI.)
S ≡ MEAN DRAINAGE BASIN SLOPE (FT/FT)

LOCATION	AREA (SQ. MI.)[a]	MEAN DRAINAGE BASIN SLOPE (FT/FT)[b]	Q_{100} (CFS)
BOULDER CREEK AT ORODELL GAGE	102.1	0.316	1,600 (6,270)[c]
BOULDER CREEK AT CANYON MOUTH	131.3	0.326	1,930 (11,650)[d]
BOULDER CREEK U/S S. BOULDER CR. CONFL.	158.1	0.298	2,130 (13,300)[d]

[a] FROM USACE SWMM MODELS
[b] AREA-WEIGHTED AVERAGE FROM USACE SWMM MODEL DATA
[c] FROM SWMM MODEL UBDR1ΦHT
[d] FROM EFFECTIVE HEC-2 MODEL

EVEN WITH AN AVERAGE STANDARD ERROR OF PREDICTION OF 44%, THOSE ESTIMATES ARE ONLY ABOUT 1/4 TO 1/3 OF THE 100-YEAR DISCHARGE PREDICTED BY THE HYDROLOGIC MODEL (UBDR1ΦHT). THE REGRESSION EQUATIONS SHOULD PROVIDE FLOW ESTIMATES ASSUMING UNCONTROLLED WATERSHED CONDITIONS. HOWEVER, THE 1,600 CFS ESTIMATE AT THE ORODELL GAGE IS ROUGHLY COMMENSURATE W/ THE PEAK FQ RESULTS BASED ON THE CONTROLLED FLOWS AT THAT LOCATION. ALTHOUGH THE UPPER PORTION OF THE BOULDER CREEK WATERSHED IS CLEARLY MOUNTAINOUS, IT APPEARS AS THE USGS MOUNTAIN REGION REGRESSION EQUATIONS MAY NOT APPLY TO THIS CASE.

USGS REGRESSION EQUATIONS (CONTINUED)

FOUR OF THE GAGING STATIONS USED BY THE USGS TO DEFINE REGRESSION EQUATIONS FOR THE PLAINS REGION ARE LOCATED RELATIVELY CLOSE TO BOULDER CREEK (NOS. 11, 13, 14 & 18 SHOWN ON THE ATTACHED MAP). THOSE GAGING STATIONS ARE: (a) CLEAR CREEK NEAR GOLDEN; (b) BEAR CREEK AT MORRISON; (c) TURKEY CREEK NEAR MORRISON, AND (d) NORTH FORK SOUTH PLATTE RIVER AT SOUTH PLATTE. THE CONTRIBUTING WATERSHED AT EACH OF THESE LOCATIONS IS MOUNTAINOUS, SIMILAR TO MOST OF THE BOULDER CREEK WATERSHED. THEREFORE, THE PLAINS REGION REGRESSION EQUATIONS MAY ACTUALLY APPLY TO BOULDER CREEK.

PLAINS REGION 100-YEAR EQUATION:

$$Q_{100} = 1640\ A^{0.388}; \quad A = \text{DRAINAGE AREA (SQ. MI.)}$$

LOCATION	AREA (SQ. MI.)	Q_{100} (CFS)	EFFECTIVE Q_{100} (CFS)
BOULDER CREEK AT ORODELL GAGE	102.1	9,870	6,270[a]
BOULDER CREEK AT CANYON MOUTH	131.3	10,880	11,650[b]
BOULDER CREEK U/S S. BOULDER CR. CONFL.	158.1	11,700	13,300[b]

[a] FROM SWMM MODEL UBDR10HT
[b] FROM EFFECTIVE HEC-2 MODEL

WITH AN AVERAGE STANDARD ERROR OF PREDICTION OF 96%, THE PLAINS REGION EQUATIONS HAVE BEEN NOTORIOUSLY UNRELIABLE. HOWEVER, WITH MANY OF THE GAGES USED IN DEVELOPING THESE EQUATIONS BEING LOCATED IN CLOSE PROXIMITY TO MOUNTAINOUS AREAS (SEE ALSO NOS. 38, 39, 41 & 42), THE PLAINS REGION EQUATION RESULTS AGREE WELL WITH THE HYDROLOGIC MODELING RESULTS, PARTICULARLY AT THE CANYON MOUTH AND UPSTREAM OF THE SOUTH BOULDER CREEK CONFLUENCE.

CWCB REGRESSION EQUATIONS

REGRESSION EQUATIONS WERE NOT DEFINED BY THE CWCB FOR STREAMS WITHIN THE UDFCD. THE CWCB CENTRAL FOOTHILLS SUBREGION WITHIN THE SOUTH PLATTE RIVER BASIN (SPL-3) INCLUDES THE UPPER BOULDER CREEK WATERSHED DOWNSTREAM NEARLY TO THE CANYON MOUTH. THEREFORE, THE SPL-3 REGRESSION EQUATION WAS USED FOR THIS COMPARISON.

SPL-3 100-YEAR EQUATION:

$$Q_{100} = 762.4 A^{0.546} \quad ; \quad A \equiv \text{DRAINAGE AREA (SQ. MI.)}$$

LOCATION	AREA (SQ. MI.)	Q_{100} (CFS)	EFFECTIVE Q_{100} (CFS)
BOULDER CREEK AT ORODELL GAGE	102.1	9,530	6,270[a]
BOULDER CREEK AT CANYON MOUTH	131.3	10,930	11,650[b]
BOULDER CREEK U/S S. BOULDER CR. CONFL.	158.1	12,100	13,300[b]

[a] FROM SWMM MODEL UBDR10HT

[b] FROM EFFECTIVE HEC-2 MODEL

THE 100-YR DISCHARGE AT THE ORODELL GAGE PRODUCED BY THE HYDROLOGIC MODEL IS 34% LOWER THAN THE CWCB ESTIMATE. THIS IS NOT WITHIN THE STANDARD ERROR OF ESTIMATE OF 23%. HOWEVER, THE HYDROLOGIC MODEL RESULTS AND THE 100-YR DISCHARGE ESTIMATES FROM THE CWCB EQUATION AGREE CLOSELY, WITHIN 6% AND 10%, RESPECTIVELY, AT THE CANYON MOUTH AND UPSTREAM OF SOUTH BOULDER CREEK.

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Peak Streamflow for the Nation

USGS 06727000 BOULDER CREEK NEAR ORODELL, CO.

Available data for this site Surface-water: Peak streamflow GO

Boulder County, Colorado
Hydrologic Unit Code 10190005
Latitude 40°00'23", Longitude 105°19'49" NAD27
Drainage area 102 square miles
Gage datum 5,826.00 feet above sea level NGVD29

Output formats

- Table
- Graph
- Tab-separated file
- peakfq (watstore) format
- Reselect output format

Water Year	Date	Gage Height (feet)	Stream-flow (cfs)
1888	Jun. 19, 1888		350[6,7]
1907	Jul. 01, 1907		840[2,6]
1908	Jun. 17, 1908		465[2,6]
1909	Jun. 20, 1909		875[2,6]
1910	Jul. 28, 1910		324[6]
1911	Jun. 14, 1911		469[6]
1912	Jul. 30, 1912		880[6]
1913	Jun. 02, 1913		366[6]
1916	Jun. 29, 1916		458[6]
1917	Jun. 25, 1917	3.23	545[6]
1918	Jun. 22, 1918	3.74	812[6]
1919	Aug. 03, 1919	4.60	1,300[6]
1920	Jun. 10, 1920	3.34	436[6]
1921	Jun. 06, 1921	4.31	2,500[6]
1922	Jun. 16, 1922	2.95	554[6]
1923	Jun. 15, 1923	3.58	983[6]
1924	Jun. 14, 1924	3.42	926[6]
1925	Jun. 24, 1925	2.87	374[6]
1926	Jun. 08, 1926	3.62	929[6]
1927	Jun. 11, 1927	3.30	672[6]
1928	Jun. 02, 1928	3.42	767[6]
1952	Jun. 07, 1952	3.96	1,180[6]
1953	Jun. 11, 1953	3.64	786[6]
1954	May 20, 1954	3.07	374[6]
1955	Jun. 26, 1955	3.21	436[6]
1956	May 23, 1956	3.50	588[6]
1957	Jun. 29, 1957	3.87	1,010[6]
1958	Jun. 06, 1958	3.75	855[6]
1959	Jun. 21, 1959	3.41	602[6]
1960	Jun. 16, 1960	3.66	776[6]
1961	Jun. 20, 1961	3.53	634[6]
1962	Jul. 01, 1962	3.42	546[6]
1963	Jun. 16, 1963	3.03	328[6]
1964	Jun. 29, 1964	2.96	299[6]
1965	Jul. 24, 1965	4.01	1,190[6]
1966	May 26, 1966	2.84	251[6]
1967	Jun. 23, 1967	3.32	594[6]
1968	Jun. 23, 1968	3.21	406[6]
1969	May 07, 1969	4.07	1,220[6]
1970	May 25, 1970	3.53	634[6]
1971	Jun. 19, 1971	3.67	753[6]
1972	Jun. 06, 1972	3.23	360[6]

1929	Jun. 22, 1929	3.17	548[6]	1973	Jun. 14, 1973	3.58	610[6]
1930	Jun. 14, 1930	3.08	490[6]	1974	Jun. 21, 1974	3.39	488[6]
1931	May 28, 1931	3.25	535[6]	1975	Jul. 03, 1975	3.35	460[6]
1932	Jun. 26, 1932	3.27	550[6]	1976	Aug. 03, 1976	2.96	249[6]
1933	Jun. 12, 1933	3.39	480[6]	1977	Jun. 09, 1977	3.04	290[6]
1934	May 31, 1934	2.96	576[6]	1978	Jun. 25, 1978	3.54	608[6]
1935	Jun. 15, 1935	3.62	1,060[6]	1979	Jul. 01, 1979	3.52	582[6]
1936	Jun. 19, 1936	3.27	626[6]	1980	Jul. 02, 1980	3.57	599[6]
1937	Jun. 25, 1937	3.10	455[6]	1981	Jun. 04, 1981	2.94	240[6]
1938	Jun. 22, 1938	3.53	802[6]	1982	Jul. 02, 1982	3.43	510[6]
1939	May 31, 1939	3.01	425[6]	1983	Jun. 28, 1983	3.77	830[6]
1940	Sep. 21, 1940	3.15	490[6]	1984	Jul. 02, 1984	3.52	566[6]
1941	Jun. 21, 1941	3.86	1,120[6]	1985	Jun. 10, 1985	3.38	454[6]
1942	Jun. 12, 1942	3.52	793[6]	1986	Jun. 20, 1986	3.56	617[6]
1943	Jun. 30, 1943	3.34	634[6]	1987	Jun. 10, 1987	3.26	416[6]
1944	Jun. 22, 1944	3.27	578[6]	1988	Jun. 22, 1988	3.29	440[6]
1945	Jun. 26, 1945	3.32	617[6]	1989	Jul. 30, 1989	2.81[2]	208[6]
1946	Jun. 18, 1946	3.12	469[6]	1990	Jun. 12, 1990	3.33	489[6]
1947	Jun. 21, 1947	4.00	1,290[6]	1991	Jun. 18, 1991	3.27	428[6]
1948	Jun. 07, 1948	3.40	712[6]	1992	May 21, 1992	2.98	266[6]
1949	Jun. 06, 1949	3.70	965[6]	1993	Jun. 18, 1993	3.27	428[6]
1950	Jun. 16, 1950	3.26	518[6]	1994	Jun. 02, 1994	3.05	285[6]
1951	Jun. 21, 1951	3.93	1,220[6]	1995	Jun. 21, 1995	3.64[2]	830[6]

Peak Gage-Height Qualification Codes.

- 2 -- Gage height not the maximum for the year

Peak Streamflow Qualification Codes.

- 2 -- Discharge is an Estimate
- 6 -- Discharge affected by Regulation or Diversion
- 7 -- Discharge is an Historic Peak

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Geographic Area: United States GO

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Peak Streamflow for the Nation

USGS 06727000 BOULDER CREEK NEAR ORODELL, CO.

Available data for this site Surface-water: Peak streamflow GO

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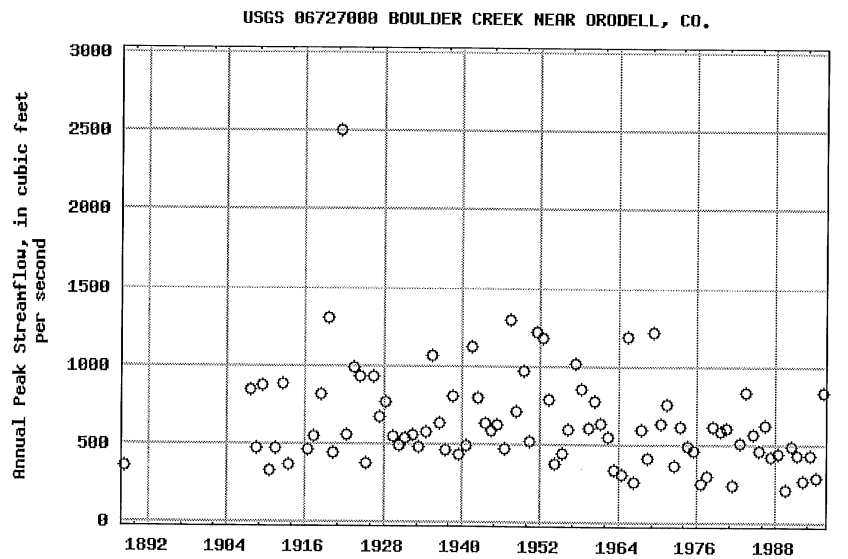

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1.93 1.86 nadww01

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1
  Program PeakFq          U. S. GEOLOGICAL SURVEY              Seq.000.000
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
  05/06/2005          following Bulletin 17-B Guidelines       10/16/2008 12:25

                         --- PROCESSING OPTIONS ---

                      Plot option         = None
                      Basin char output   = None
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  - P:\COBLDR02.1_BOULDER CREEK
HYDROLOGY\HYDROLOGY_SECOND PHASE\ORODELLDATANO6.TXT
                         specifications - PKFQWPSF.TMP

                      Output file(s):
                         main - P:\COBLDR02.1_BOULDER CREEK HYDROLOGY\HYDROLOGY_SECOND
PHASE\ORODELLDATANO6.PRT

1


  Program PeakFq          U. S. GEOLOGICAL SURVEY              Seq.001.001
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            Station - 06727000  BOULDER CREEK NEAR ORODELL, CO.


                 I N P U T   D A T A   S U M M A R Y

               Number of peaks in record            =       88
               Peaks not used in analysis           =        1
               Systematic peaks in analysis         =       87
               Historic peaks in analysis           =        0
               Years of historic record             =        0
               Generalized skew                     =   -0.186
                    Standard error                  =    0.550
                    Mean Square error               =    0.303
               Skew option                          =   WEIGHTED
               Gage base discharge                  =      0.0
               User supplied high outlier threshold =   --
               User supplied low outlier criterion  =   --
               Plotting position parameter          =     0.00


  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********

  **WCF109W-PEAKS WITH MINUS-FLAGGED DISCHARGES WERE BYPASSED.        1
  **WCF113W-NUMBER OF SYSTEMATIC PEAKS HAS BEEN REDUCED TO NSYS =   87
    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                    0.0
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.             153.1
    WCF162I-SYSTEMATIC PEAKS EXCEEDED HIGH-OUTLIER CRITERION.   1     2209.5
    WCF002J-CALCS COMPLETED.  RETURN CODE =  2
1


  Program PeakFq          U. S. GEOLOGICAL SURVEY              Seq.001.002
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
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ORODELLDATAN06.PRT

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	2.7647	0.1952	0.229
BULL.17B ESTIMATE	0.0	1.0000	2.7647	0.1952	0.149

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	194.7	201.4	189.1	162.9	224.6
0.9900	214.8	220.7	209.9	182.0	245.7
0.9500	283.2	286.3	280.0	247.9	316.2
0.9000	329.5	331.0	327.1	293.2	363.7
0.8000	397.3	396.8	395.8	359.7	433.6
0.6667	475.0	472.9	474.3	435.4	515.0
0.5000	575.2	571.8	575.2	530.9	622.9
0.4292	623.4	619.7	623.7	575.9	676.3
0.2000	846.0	844.1	849.5	775.4	934.0
0.1000	1042.0	1045.0	1050.0	942.7	1173.0
0.0400	1307.0	1322.0	1327.0	1162.0	1508.0
0.0200	1517.0	1545.0	1550.0	1331.0	1782.0
0.0100	1738.0	1784.0	1789.0	1506.0	2077.0
0.0050	1971.0	2038.0	2046.0	1687.0	2394.0
0.0020	2300.0	2404.0	2418.0	1939.0	2851.0

1

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Ver. 5.0 Beta 8
05/06/2005

U. S. GEOLOGICAL SURVEY
Annual peak flow frequency analysis
following Bulletin 17-B Guidelines

Seq.001.003
Run Date / Time
10/16/2008 12:25

Station - 06727000 BOULDER CREEK NEAR ORODELL, CO.

I N P U T D A T A L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1888	-350.0	H	1952	1180.0	
1907	840.0		1953	786.0	
1908	465.0		1954	374.0	
1909	875.0		1955	436.0	
1910	324.0		1956	588.0	
1911	469.0		1957	1010.0	
1912	880.0		1958	855.0	
1913	366.0		1959	602.0	
1916	458.0		1960	776.0	
1917	545.0		1961	634.0	
1918	812.0		1962	546.0	
1919	1300.0		1963	328.0	
1920	436.0		1964	299.0	
1921	2500.0		1965	1190.0	
1922	554.0		1966	251.0	
1923	983.0		1967	594.0	
1924	926.0		1968	406.0	
1925	374.0		1969	1220.0	
1926	929.0		1970	634.0	
1927	672.0		1971	753.0	
1928	767.0		1972	360.0	
1929	548.0		1973	610.0	

1930	490.0	1974	488.0
1931	535.0	1975	460.0
1932	550.0	1976	249.0
1933	480.0	1977	290.0
1934	576.0	1978	608.0
1935	1060.0	1979	582.0
1936	626.0	1980	599.0
1937	455.0	1981	240.0
1938	802.0	1982	510.0
1939	425.0	1983	830.0
1940	490.0	1984	566.0
1941	1120.0	1985	454.0
1942	793.0	1986	617.0
1943	634.0	1987	416.0
1944	578.0	1988	440.0
1945	617.0	1989	208.0
1946	469.0	1990	489.0
1947	1290.0	1991	428.0
1948	712.0	1992	266.0
1949	965.0	1993	428.0
1950	518.0	1994	285.0
1951	1220.0	1995	830.0

Explanation of peak discharge qualification codes

PEAKFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq
Ver. 5.0 Beta 8
05/06/2005

U. S. GEOLOGICAL SURVEY
Annual peak flow frequency analysis
following Bulletin 17-B Guidelines

Seq.001.004
Run Date / Time
10/16/2008 12:25

Station - 06727000 BOULDER CREEK NEAR ORODELL, CO.

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
1921	2500.0	0.0114	0.0114
1919	1300.0	0.0227	0.0227
1947	1290.0	0.0341	0.0341
1951	1220.0	0.0455	0.0455
1969	1220.0	0.0568	0.0568
1965	1190.0	0.0682	0.0682
1952	1180.0	0.0795	0.0795
1941	1120.0	0.0909	0.0909
1935	1060.0	0.1023	0.1023
1957	1010.0	0.1136	0.1136
1923	983.0	0.1250	0.1250
1949	965.0	0.1364	0.1364
1926	929.0	0.1477	0.1477

1924	926.0	0.1591	0.1591
1912	880.0	0.1705	0.1705
1909	875.0	0.1818	0.1818
1958	855.0	0.1932	0.1932
1907	840.0	0.2045	0.2045
1983	830.0	0.2159	0.2159
1995	830.0	0.2273	0.2273
1918	812.0	0.2386	0.2386
1938	802.0	0.2500	0.2500
1942	793.0	0.2614	0.2614
1953	786.0	0.2727	0.2727
1960	776.0	0.2841	0.2841
1928	767.0	0.2955	0.2955
1971	753.0	0.3068	0.3068
1948	712.0	0.3182	0.3182
1927	672.0	0.3295	0.3295
1943	634.0	0.3409	0.3409
1961	634.0	0.3523	0.3523
1970	634.0	0.3636	0.3636
1936	626.0	0.3750	0.3750
1945	617.0	0.3864	0.3864
1986	617.0	0.3977	0.3977
1973	610.0	0.4091	0.4091
1978	608.0	0.4205	0.4205
1959	602.0	0.4318	0.4318
1980	599.0	0.4432	0.4432
1967	594.0	0.4545	0.4545
1956	588.0	0.4659	0.4659
1979	582.0	0.4773	0.4773
1944	578.0	0.4886	0.4886
1934	576.0	0.5000	0.5000
1984	566.0	0.5114	0.5114
1922	554.0	0.5227	0.5227
1932	550.0	0.5341	0.5341
1929	548.0	0.5455	0.5455
1962	546.0	0.5568	0.5568
1917	545.0	0.5682	0.5682
1931	535.0	0.5795	0.5795
1950	518.0	0.5909	0.5909
1982	510.0	0.6023	0.6023
1930	490.0	0.6136	0.6136
1940	490.0	0.6250	0.6250
1990	489.0	0.6364	0.6364
1974	488.0	0.6477	0.6477
1933	480.0	0.6591	0.6591
1911	469.0	0.6705	0.6705
1946	469.0	0.6818	0.6818
1908	465.0	0.6932	0.6932
1975	460.0	0.7045	0.7045
1916	458.0	0.7159	0.7159
1937	455.0	0.7273	0.7273
1985	454.0	0.7386	0.7386
1988	440.0	0.7500	0.7500
1920	436.0	0.7614	0.7614
1955	436.0	0.7727	0.7727
1991	428.0	0.7841	0.7841
1993	428.0	0.7955	0.7955
1939	425.0	0.8068	0.8068
1987	416.0	0.8182	0.8182
1968	406.0	0.8295	0.8295
1925	374.0	0.8409	0.8409
1954	374.0	0.8523	0.8523
1913	366.0	0.8636	0.8636
1972	360.0	0.8750	0.8750
1963	328.0	0.8864	0.8864
1910	324.0	0.8977	0.8977
1964	299.0	0.9091	0.9091
1977	290.0	0.9205	0.9205
1994	285.0	0.9318	0.9318
1992	266.0	0.9432	0.9432

```
      1966          251.0          0.9545          0.9545
      1976          249.0          0.9659          0.9659
      1981          240.0          0.9773          0.9773
      1989          208.0          0.9886          0.9886
      1888         -350.0            --              --
1


 End PEAKFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      88

Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4,  or *.)
(2, 4, and * records are ignored.)

 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:  06727000       USGS BOULDER CREEK NEAR ORODELL, C


 For the station below, the following records were ignored:

 FINISHED PROCESSING STATION:
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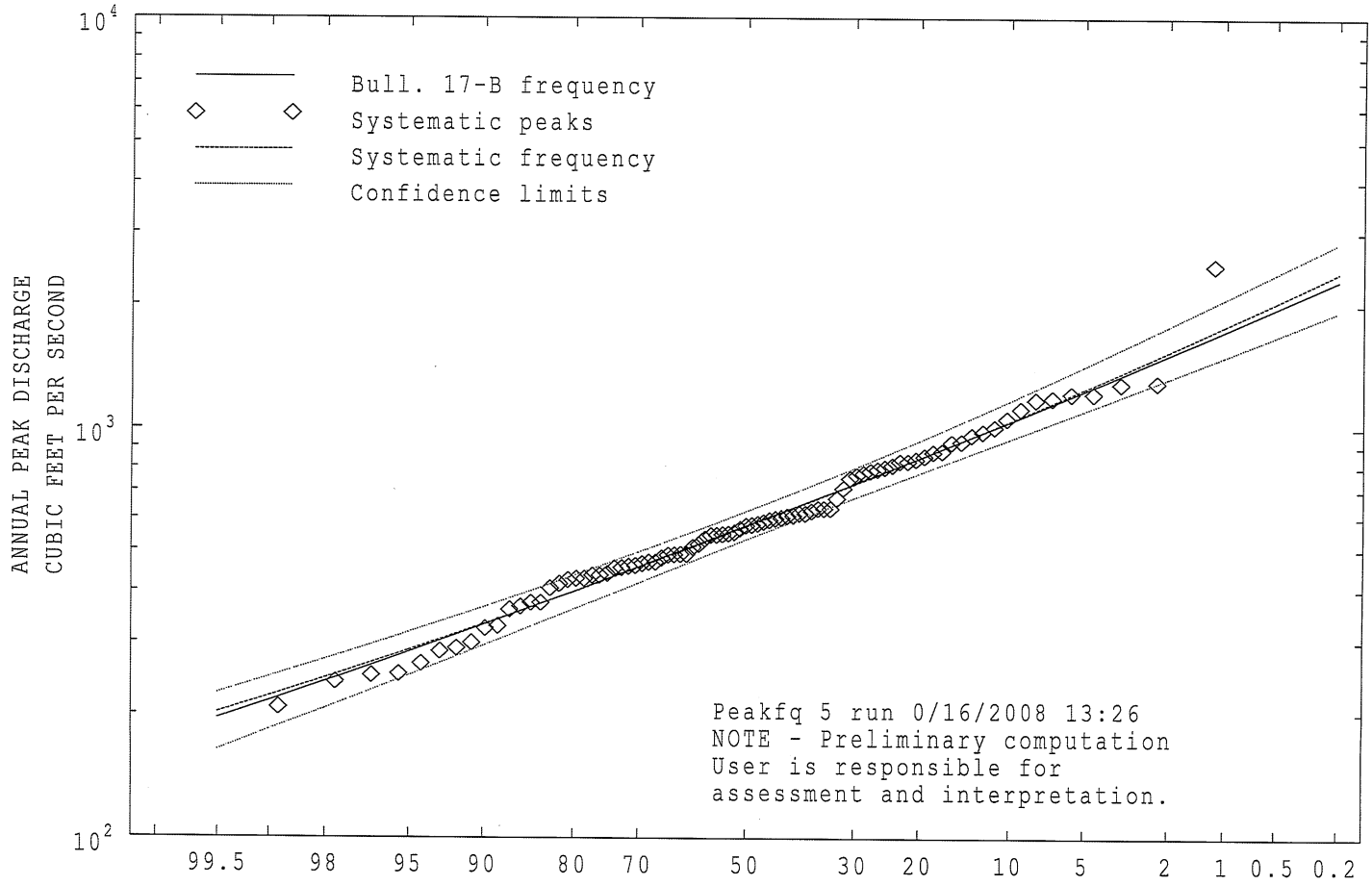

Station - 06727000 BOULDER CREEK NEAR ORODELL, CO.

Analysis of the Magnitude and Frequency of Floods in Colorado

By J.E. Vaill

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 99–4190

Prepared in cooperation with the
COLORADO DEPARTMENT OF TRANSPORTATION
and the BUREAU OF LAND MANAGEMENT

Denver, Colorado
2000

Table 1. Regional flood-frequency equations, Colorado

[*Q*, discharge, in cubic feet per second; *A*, drainage area, in square miles; *P*, mean annual precipitation, in inches; *S*, mean drainage-basin slope, in foot per foot]

Recurrence interval, in years	Regression equation	Standard error of the model, in percent	Average standard error of prediction, in percent
Mountain region			
2	$Q = 11.0\ (A)^{0.663}\ (S + 1.0)^{3.465}$	58.5	59.6
5	$Q = 17.9\ (A)^{0.677}\ (S + 1.0)^{2.739}$	47.7	48.6
10	$Q = 23.0\ (A)^{0.685}\ (S + 1.0)^{2.364}$	43.7	44.6
25	$Q = 29.4\ (A)^{0.695}\ (S + 1.0)^{2.004}$	41.4	42.3
50	$Q = 34.5\ (A)^{0.700}\ (S + 1.0)^{1.768}$	41.4	42.3
100	$Q = 39.5\ (A)^{0.706}\ (S + 1.0)^{1.577}$	42.4	43.4
200	$Q = 44.6\ (A)^{0.710}\ (S + 1.0)^{1.408}$	44.2	45.2
500	$Q = 51.5\ (A)^{0.715}\ (S + 1.0)^{1.209}$	47.5	48.6
Rio Grande region			
2	$Q = 0.03\ (A)^{0.979}\ (P)^{1.615}$	77.7	82.6
5	$Q = 0.12\ (A)^{0.940}\ (P)^{1.384}$	64.0	67.9
10	$Q = 0.25\ (A)^{0.914}\ (P)^{1.277}$	58.2	89.1
25	$Q = 0.52\ (A)^{0.884}\ (P)^{1.117}$	53.4	56.8
50	$Q = 0.81\ (A)^{0.864}\ (P)^{1.121}$	51.2	54.5
100	$Q = 1.19\ (A)^{0.846}\ (P)^{1.074}$	49.9	53.3
200	$Q = 1.67\ (A)^{0.828}\ (P)^{1.036}$	49.5	52.9
500	$Q = 2.48\ (A)^{0.808}\ (P)^{0.995}$	50.0	53.6
Southwest region			
2	$Q = 28.7\ (A)^{0.699}$	85.0	87.3
5	$Q = 50.5\ (A)^{0.693}$	74.1	76.1
10	$Q = 66.0\ (A)^{0.697}$	71.4	73.4
25	$Q = 86.3\ (A)^{0.704}$	71.2	73.4
50	$Q = 102.0\ (A)^{0.709}$	72.8	75.0
100	$Q = 118.4\ (A)^{0.715}$	75.6	78.0
200	$Q = 135.5\ (A)^{0.720}$	79.1	81.7
500	$Q = 159.4\ (A)^{0.728}$	85.0	87.9
Northwest region			
2	$Q = 0.39\ (A)^{0.684}\ (P)^{1.304}$	82.6	85.6
5	$Q = 2.84\ (A)^{0.674}\ (P)^{0.833}$	71.5	74.0
10	$Q = 7.56\ (A)^{0.671}\ (P)^{0.601}$	68.5	70.9
25	$Q = 20.6\ (A)^{0.669}\ (P)^{0.362}$	67.1	69.7
50	$Q = 38.8\ (A)^{0.667}\ (P)^{0.210}$	67.2	69.8
100	$Q = 104.7\ (A)^{0.624}$	75.0	76.7
200	$Q = 118.5\ (A)^{0.624}$	77.8	79.6
500	$Q = 137.6\ (A)^{0.623}$	83.1	85.1
Plains region			
2	$Q = 39.0\ (A)^{0.486}$	233.7	258.5
5	$Q = 195.8\ (A)^{0.399}$	204.2	223.8
10	$Q = 364.6\ (A)^{0.400}$	212.4	233.7
25	$Q = 725.3\ (A)^{0.395}$	231.8	256.2
50	$Q = 1116\ (A)^{0.392}$	249.5	278.3
100	$Q = 1640\ (A)^{0.388}$	267.3	300.0
200	$Q = 2324\ (A)^{0.385}$	284.5	321.3
500	$Q = 3534\ (A)^{0.380}$	305.8	347.9

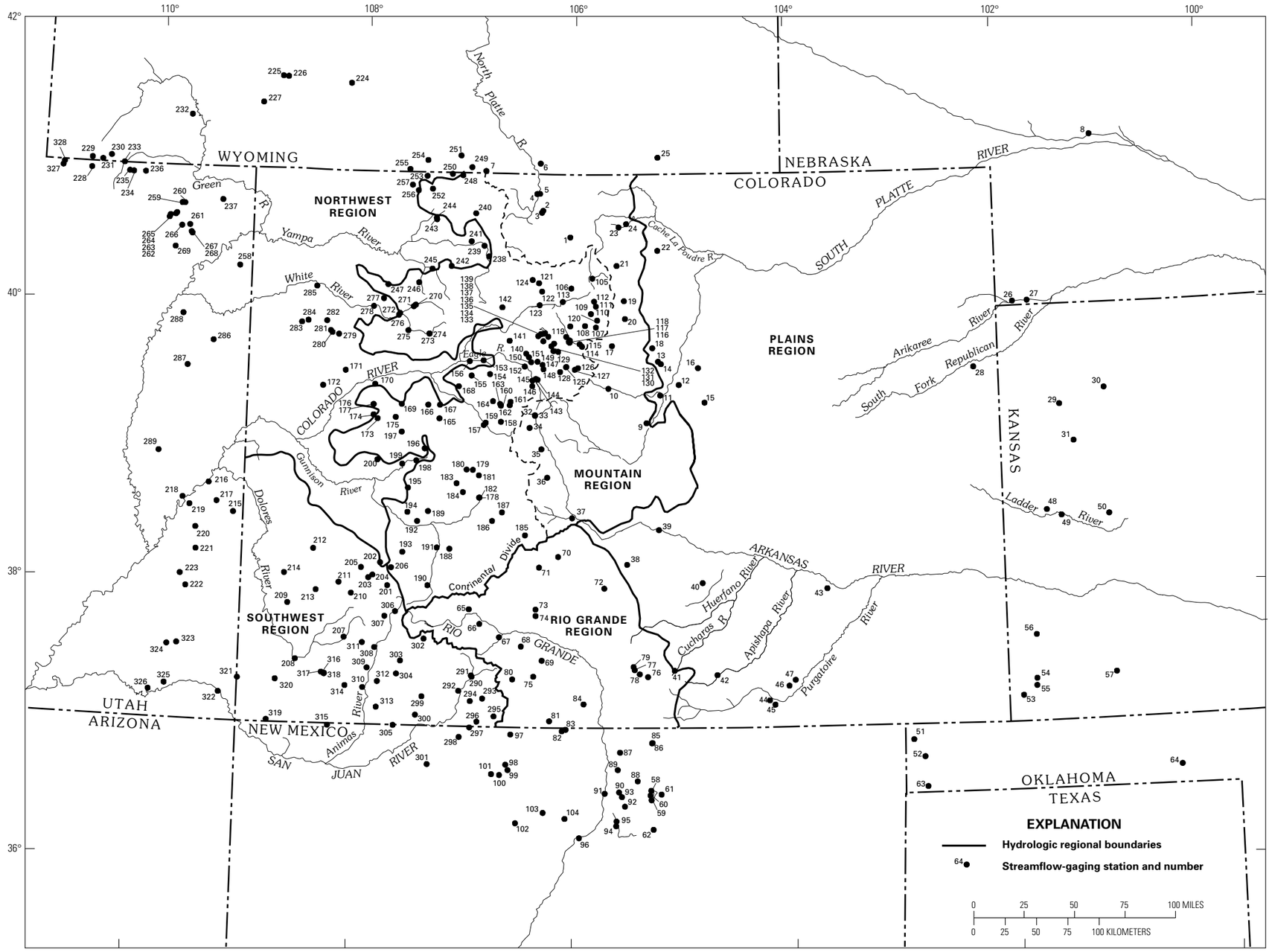

Figure 1. Boundaries of hydrologic regions and location of streamflow-gaging stations in Colorado and adjacent States.

Guidelines For Determining 100-Year Flood Flows For Approximate Floodplains in Colorado

Version 6.0

Prepared by:
Thomas W. Browning, Colorado Water Conservation Board
In cooperation with the Colorado Flood Hydrology Advisory Committee

Department of Natural Resources
Colorado Water Conservation Board
Flood Protection Program
1313 Sherman Street, Room 721
Denver, Colorado 80203
www.cwcb.state.co.us

June 2004

The equation for subregion SPL-1 is:

$$\mathbf{Q = 707.9(A)^{.654}}$$

Where:

A = Drainage Area, square miles (2<A<1090)
Q = 100 year peak flow, cfs

SPL-2: SOUTHERN FOOTHILLS SUBREGION

This subregion includes stream reaches in the southern foothills area of the South Platte River basin. The streams in this subregion may have part of their *drainage basins* above an elevation of 7500' MSL, but this subregion only includes *stream reaches* that are downstream of (below) the 7500' elevation limit. The subregion is bounded as follows:

- On the south by the South Platte River-Arkansas River basin divide;
- On the east by the Kiowa Creek-West Bijou Creek basin divide;
- And on the east by the Kiowa Creek-Comanche Creek basin divide (to the south of Elbert);
- And on the east by the Box Elder Creek-Kiowa Creek basin divide (to the north of Elbert);
- On the north by the southern boundary of the Urban Drainage and Flood Control District; and
- On the west by an elevation line that is generally 7500'

The regression equation for this subregion is only valid for natural tributary streams that have drainage areas between 1 mi^2 and 170 mi^2. A detailed study or other hydrologic analysis must be performed for projects involving streams with drainage areas that fall outside of the applicable range.

The equation for subregion SPL-2 is:

$$\mathbf{Q = 1005.5(A)^{.638}}$$

Where:

A = Drainage Area, square miles (1<A<170)
Q = 100 year peak flow, cfs

SPL-3: CENTRAL FOOTHILLS SUBREGION

This subregion includes stream reaches in the central foothills area of the South Platte River basin that are located to the west of the western boundary of the Urban Drainage and Flood Control District. The streams in this subregion may have part of their *drainage basins* above an elevation of 7500' MSL, but this subregion only includes *stream reaches* that are downstream of (below) the 7500' elevation limit. The subregion is bounded as follows:

- On the south by an elevation line that is generally 7500';
- On the east by the western boundary of the Urban Drainage and Flood Control District;
- On the north by the Lefthand Creek-St. Vrain Creek basin divide;
- On the west by an elevation line that is generally 7500'

The regression equation for this subregion is only valid for natural tributary streams that have drainage areas between 1 mi^2 and 175 mi^2. A detailed study or other hydrologic analysis must be performed for projects involving streams within the Urban Drainage and Flood Control District and streams with drainage areas that fall outside of the applicable range.

The equation for subregion SPL-3 is:

$$\mathbf{Q = 762.4(A)^{.546}}$$

Where:

A = Drainage Area, square miles (1<A<175)
Q = 100 year peak flow, cfs

SPL-4: NORTHERN FOOTHILLS SUBREGION

This subregion includes stream reaches in the northern foothills area of the South Platte River basin. The streams in this subregion may have part of their *drainage basins* above an elevation of 7500' MSL, but this subregion only includes *stream reaches* that are downstream of (below) the 7500' elevation limit. The subregion is bounded as follows:

- On the south by the northern boundary of the Urban Drainage and Flood Control District;
- On the southeast by the South Platte River mainstem between the northern boundary of the Urban Drainage and Flood Control District and the town of Dent;
- On the east by an arc that passes through the following three locations:
    1. The town of Dent
    2. The town of Bracewell
    3. The confluence of Owl Creek and Lone Tree Creek
- On the northeast by the Owl Creek-Lone Tree Creek basin divide;
- On the north by the Colorado-Wyoming state line;
- On the west by an elevation line that is generally 7500'

The regression equation for this subregion is only valid for natural tributary streams that have drainage areas between 1 mi^2 and 445 mi^2. The mainstems of the South Platte River, Cache La Poudre River below Poudre Park, Big Thompson River below Drake,, and St. Vrain Creek below Lyons are all exempt from this subregion. The incorporated areas of Fort Collins are also exempt from this subregion. A detailed study or other hydrologic analysis must be performed for projects involving those streams and streams with drainage areas that fall outside of the applicable range.

The equation for subregion SPL-4 is:

South Platte River Basin
Regression Analysis Summary

Sub-region Name	Sub-region Description	Regression Equation	# of Data Points	Min. D.A.	Max. D.A.	R Squared (Regression Correlation)	Std Error of Estimate
SPL-1	*Eastern Plains*	$Q = 707.9(A)^{.654}$	17	2	1090	.920	34%
SPL-2	*Southern Foothills*	$Q = 1005.5(A)^{.638}$	29	1	170	.968	18%
SPL-3	*Central Foothills*	$Q = 762.4(A)^{.546}$	67	1	175	.927	23%
SPL-4	*Northern Foothills*	$Q = 800.8(A)^{.478}$	81	1	445	.756	48%
SPL-5	*Mountains*	$Q = 39.4(A)^{.776}$	27	2	480	.938	29%

The following stream reaches and geographic areas are exempt from the South Platte River Basin ***Guidelines:***

- South Platte River mainstem
- St. Vrain Creek mainstem below Lyons
- Big Thompson River mainstem below Drake
- Cache La Poudre River mainstem below Poudre Park
- South Park
- Urban Drainage and Flood Control District
- City of Fort Collins incorporated areas
- Town of Wellington
- Blackhawk and Central City incorporated areas
- Other areas where the local government prefers to use their own drainage criteria in lieu of the ***Guidelines***

State of Colorado

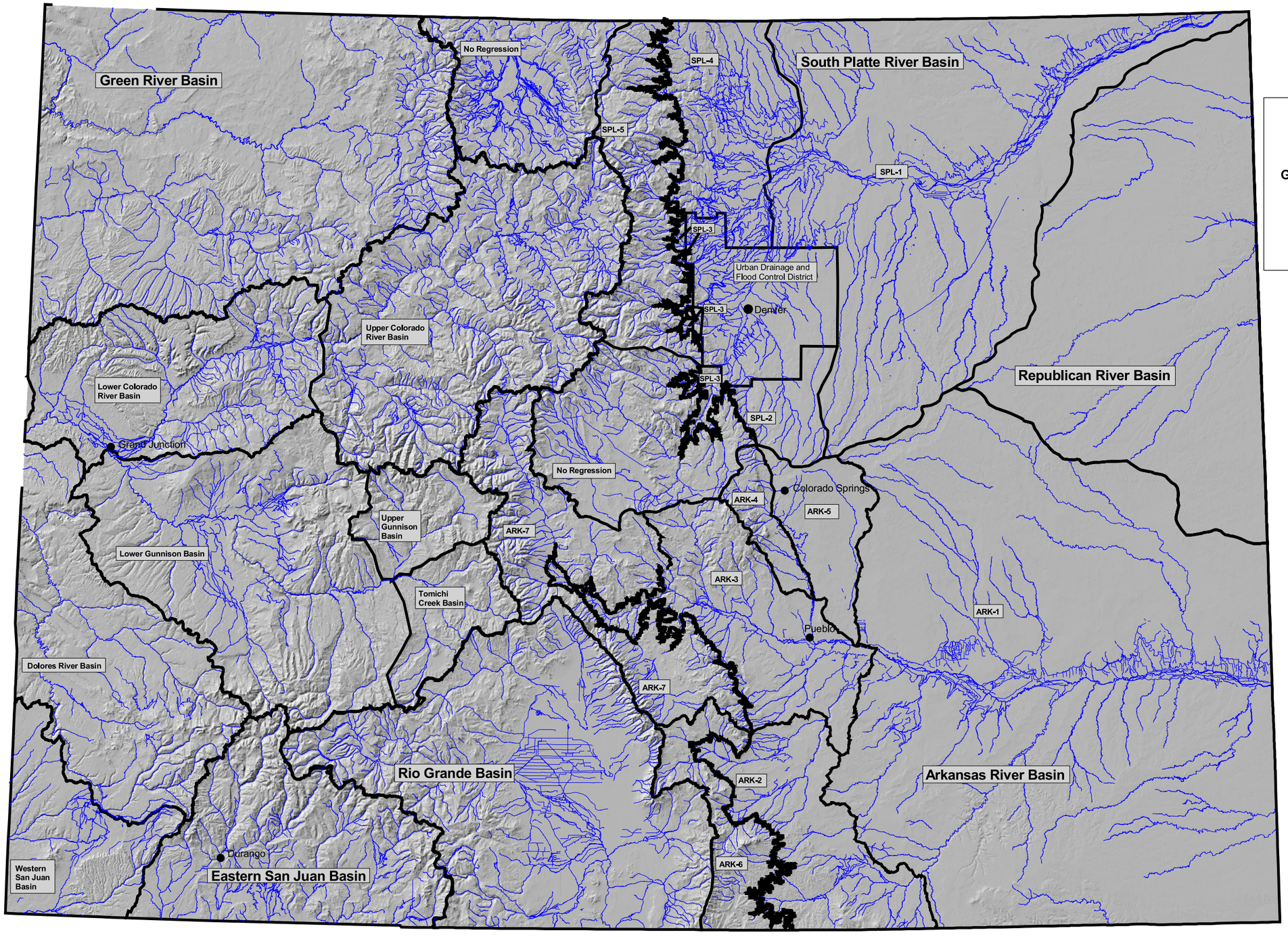

Figure 1.0

GUIDELINES FOR DETERMINING 100-YEAR FLOOD FLOWS FOR APPROXIMATE FLOODPLAINS IN COLORADO

Hydrologic Regions and Subregions

2004