Upper Goose Creek and Twomile Canyon Creek Flood Mapping Study Update

Hydrology Verification Report

Prepared for:

City of Boulder
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(Job No. 11-022-TGF)

December 9, 2011
Revised: February 16, 2012

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SECTION 1: INTRODUCTION

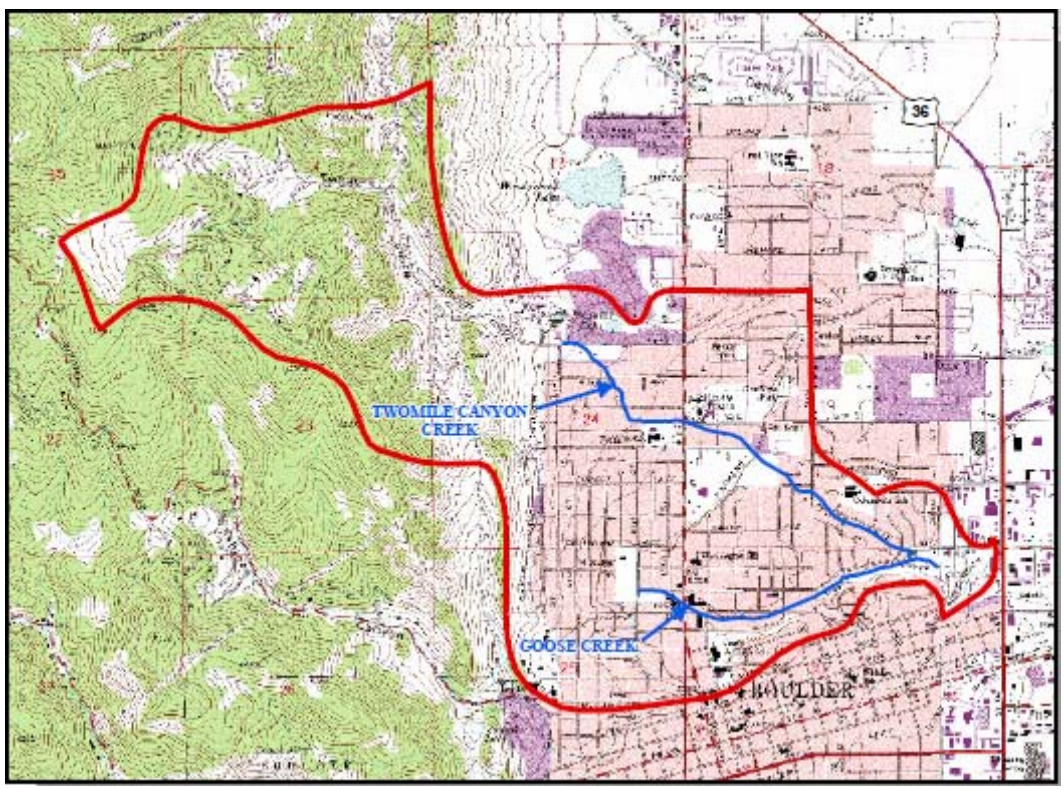
1.1 Purpose

ICON Engineering, Inc. has been placed under contract by the City of Boulder (COB) to prepare a Hydrology Verification Report for the Twomile Canyon Creek and Upper Goose Creek watersheds. The purpose of this report is to assess the effective hydrology for use in the current Flood Mapping Study Update. This report also documents the development of Duplicate Effective and Corrected Effective Conditions hydrologic modeling for use along Upper Goose and Twomile Canyon Creeks. Methodology and calculations are presented for the 5-, 10-, 25-, 50-, 100-, and 500-year storm events.

1.2 Project Area

Twomile Canyon Creek and Upper Goose Creek are located on the northwest side of the City of Boulder. The project area is bounded on the north by the Fourmile Canyon Creek drainage basin, on the east by Folsom Street, on the south by North Street and Balsam Drive, and on the west by the Sunshine Canyon Creek drainage basin. A vicinity map for the Twomile Canyon Creek and Upper Goose Creek study area is shown in Figure 1.

Figure 1 – Vicinity Map



1.3 Background

Hydrologic information for Twomile Canyon Creek and Upper Goose Creek was previously included as part of the May 1987 Flood Hazard Area Delineation (1987 FHAD) for Boulder and Adjacent County Drainageways. The 1987 FHAD was prepared by Greenhorne & O'Mara, Inc. The hydrologic and hydraulic information presented in the 1987 FHAD was originally prepared by the MSM/SP Group (Greiner Engineering Services) as part of the original Flood Insurance Study update. In the 1987 FHAD, hydrology was presented for the 10-, 50-, and 100-year events. Equivalent discharges are shown in the 2002 Flood Insurance Study (2002 FIS), which also presented 500-year discharges. Excerpts from the 1987 FHAD and 2002 FIS are included in Appendix A. Table 1.1 below includes the Effective Conditions drainage areas and associated discharges as developed by the 1987 FHAD and 2002 FIS.

Table 1.1 – Effective Conditions Discharge Summary

			Effective Conditions (1987 FHAD / 2002 FIS)			
Location	**SWMM Element**	**Effective DA (sq. mi.)**	**10-Year (cfs)**	**50-Year (cfs)**	**100-Year (cfs)**	**500-Year (cfs)**
Twomile Canyon Creek						
Linden Avenue	JUNCT_601	1.40	210	540	710	1430
North Broadway Street	JUNCT_602	1.68	210	675	890	1800
Confluence with Goose Creek	JUNCT_603	2.19	360	840	1120	2000
Goose Creek						
Balsam Avenue	JUNCT_701	0.48	260	520	620	1000
19th Street	JUNCT_702	1.28	700	1320	1600	2450
Upstream of Confluence with Twomile Creek	JUNCT_703	1.32	670	1270	1590	2400
Downstream of Folsom Street	JUNCT_704	3.63	1050	2100	2680	4300

A data request was made to the Federal Emergency Management Agency (FEMA) to obtain the technical hydrologic information from the MSM/SP Group study. No information was available from FEMA regarding project hydrology. A similar request was made to the Urban Drainage and Flood Control District (UDFCD). Limited hydrologic technical information was available through the District. This information generally consisted of area, length, centroid length, slope, imperviousness, Ct values, and Cp values for each sub-basin used in the analysis. Copies of the input or output files for Colorado Unit Hydrograph Procedure (CUHP) and hydrologic routing models were not available through the UDFCD. The technical backup information provided by UDFCD is included in Appendix A.

1.4 Methodology and Approach

Preliminary results regarding the hydrology verification were presented to project sponsors during a progress meeting on October 19, 2011. During this meeting, the effective discharges were reviewed and compared to results from DRAFT duplicate effective modeling. At that time, the effective discharges were also compared to discharges computed from regional regression equations.

Based on discussions during the progress meeting, both the project sponsors and ICON Engineering agreed to duplicate the effective hydrology with current software (CUHP version 1.3.3 and EPA Storm Water Management Model (SWMM) version 5.0) and calibrate the hydrology through adjustment to the Cp factor to correlate with the Effective Conditions information.

Calibration to the Effective Conditions hydrology was selected based on the fact that the Effective Conditions 100-year discharges compared within approximately 20% to the Duplicate Effective Conditions 100-year model developed using the current software versions identified above. In addition, the decision was further supported on a favorable comparison between the Effective Conditions 100-year discharge and the 100-year regional regression discharge at the downstream end of the watershed, where the regression equations was closest to its recommended application range.

It was also decided that following calibration, the hydrologic sub-basins would be further refined to reflect existing imperviousness in fully developed areas. Future land use would be assumed outside of the fully developed areas, in similar fashion to what was completed for the Effective Conditions information. Sub-basins would also be refined to reflect anticipated flow paths and as required to match previous hydrologic and hydraulic studies completed for Elmer's Twomile Canyon Creek and the associated Letters of Map Revisions (LOMRs). Finally, during the project meeting, it was discussed and agreed to not further pursue discretization of the hydrologic sub-basins, in order to avoid increased discharges resulting from the sub-division of the effective sub-basins in accordance with the District's recommendations for calibration.

Meeting Minutes with figures and tables from the DRAFT duplicate effective and Updated Existing Conditions modeling are provided in Appendix H.

SECTION 2: DRAINAGE BASINS

2.1 Effective and Duplicate Effective Conditions Drainage Basins

The original drainage basin map from the 1987 FHAD is included in Appendix A. From this map, drainage basins 601, 602, and 603 are tributary to Twomile Canyon Creek and drainage basins 701, 702, 703, and 704 are tributary to Upper Goose Creek upstream of Folsom Street. These drainage basins and the associated drainage basin parameters provided in the 1987 FHAD, and from the UDFCD, were used to duplicate the existing hydrology, as discussed in Section 4.0 of this report. The Effective Conditions drainage basins are illustrated on current mapping in Figure 2. Drainage basin areas are compared in Table 2.1 below. Differences in basin area between the Effective Conditions and the Duplicate Effective Conditions can be attributed to digitizing of the original basins from the 1987 FHAD map.

Table 2.1 – Drainage Basin Areas

	Drainage Basin Area (mi^2)		
Basin	**1987FHAD Effective Conditions**	**Duplicate Effective Conditions**	**Corrected Effective Conditions**
601	1.40	1.38	1.38
602	0.28	0.28	0.21
603	0.51	0.56	0.36
701	0.48	0.43	0.43
702	0.80	0.86	0.98
703	0.04	0.07	0.07
704	0.12	0.12	0.12
Total	**3.63**	**3.70**	**3.55**

2.2 Corrected Effective Conditions Drainage Basins

The Effective Conditions drainage basins were taken directly from the 1987 FHAD, as discussed above. Three adjustments to the Effective Conditions drainage basin areas were completed to develop the Corrected Effective Conditions drainage basins. The resulting drainage basin areas for the Corrected Effective Conditions are included in Table 2.1 above.

First, discharges to the west of Broadway in the Effective Conditions drainage basin 603 are anticipated to encounter the roadway embankment, turn south, and continue flowing on the west side of Broadway southward, as opposed to overtopping the roadway as indicated by the Effective Conditions drainage basin delineation. Based on this anticipated behavior, basin 603 was adjusted to reflect only the drainage area east of Broadway. The original portion of basin 603 located west of Broadway was incorporated into basin 602.

Second, an approximately 90 acre portion of basin 603 was determined to be tributary to Elmer's Twomile Canyon Creek due to a low point along 19th Street, as noted in a January 3, 2006 ASCG memorandum to the City of Boulder (see Appendix I). This 90 acre portion of basin 603 was incorporated into the Elmer's Twomile Canyon Creek drainage project and subsequent Letter of Map Revision (LOMR) for case no. 10-08-0754P. For the Corrected Effective Conditions, basin 603 has been revised to remove this portion of basin 603.

Third, basin 702 was enlarged to include an area of the effective drainage basin 602 located just south of the Twomile Canyon Creek channel. Upon review of the project mapping, it was determined that surface flows in this area will travel southeast and ultimately flow towards Goose Creek, not Twomile Canyon Creek as originally identified in the 1987 FHAD.

The Corrected Effective Conditions drainage basins are illustrated in Figure 3.

In addition to the changes in drainage basin delineation, the Corrected Effective Conditions drainage basins were also updated to reflect the actual percent impervious values of the drainage basin and anticipated future development. Impervious surface area data was provided by the City of Boulder, in GIS format, and was used to calculate the overall percent impervious value for each drainage basin.

In general, the existing project area reflects fully development conditions, consistent with the future development conditions defined in the 1987 FHAD. An exception to the current development conditions is a small area located in the southwest corner of drainage basin 702, just north of the Sanitas Wellness Center. According to the City of Boulder, this currently undeveloped parcel has recently been sold and is planned to be developed into single family residential housing. Based on this expected land use change, this portion of drainage basin 702 was considered to be 40% impervious in order to complete the Corrected Effective Conditions impervious calculations for drainage basin 702.

Additionally, open space and sparse development within the County areas, west of the City limits and the City's impervious data, was assumed to have a 5% impervious value, reflecting the current forestry land use designation by the County. The 5% impervious value used for open space and sparse development is the same impervious value used for open space areas in the 1987 FHAD.

Table 2.2 identifies the 1987 FHAD Effective Conditions impervious values, the Corrected Effective Conditions impervious values based on the revisions described above, and difference between the two conditions.

Table 2.2 – Drainage Basin Imperviousness

Basin	% Impervious		
	1987 FHAD Effective Conditions	Corrected Effective Conditions	% Difference
601	7.0	6.1	-13%
602	25.0	30.1	20%
603	41.0	40.7	-1%
701	27.0	25.3	-6%
702	42.0	41.5	-1%
703	28.0	33.8	21%
704	41.0	48.2	18%

SECTION 3: DESIGN RAINFALL

Design rainfall depth values for the 10-, 50-, and 100-year hydrologic models were taken directly from the 1987 FHAD Technical Appendix information. These rainfall depth values were then used to extrapolate the 500-year rainfall depth value based on a logarithmic trend line. The 5- and 25-year rainfall depths for the Corrected Effective Conditions were derived from the UDFCD Storm Drainage Criteria Manual Volume 1(USDCM) rainfall depth, duration, and frequency maps (figures RA-2 and RA-4). The 5- and 25-year rainfall depths derived from the UDFCD figures were compared to values calculated from the logarithmic trend line, and were found to compare very well with a maximum deviation of 3%. The logarithmic trend line formulas and comparison information are included in Appendix I.

Table 3.1 below includes the 1-hour rainfall depths for all drainage basins in the project area. Please note that the rainfall depth table in the 1987 FHAD report text only provides limited rainfall depth information. The 1987 FHAD Technical Appendix information provided by the UDFCD included sub-basin specific rainfall values that are not reflected in the FHAD report table. Excerpts from the 1987 FHAD Technical Appendix showing the 10-, 50-, and 100-year 1-hour rainfall depth values are included in Appendix A.

The City of Boulder's Design and Construction Standards also provide rainfall intensity values for use within the City's jurisdiction. These rainfall values compare very well to those developed for this study and have been added to the bottom of Table 3.1 for reference; however for this study the sub-basin specific rainfall values have continued to be used for consistency with the Effective Conditions discharges. The City of Boulder rainfall values in Table 3.1 have been shown for documentation purposes only and have not been used in the Corrected Effective Conditions discharge development.

Table 3.1 – 1-Hour Rainfall Depths

	1-Hour Rainfall (in)					
Basin	**5-YR**	**10-YR**	**25-YR**	**50-YR**	**100-YR**	**500-YR**
601	1.35	1.60	1.95	2.20	2.45	3.05
602	1.38	1.65	2.02	2.30	2.55	3.19
603	1.40	1.70	2.05	2.30	2.65	3.27
701	1.35	1.65	2.00	2.30	2.55	3.19
702	1.39	1.70	2.02	2.30	2.60	3.21
703	1.41	1.70	2.06	2.30	2.65	3.27
704	1.42	1.70	2.08	2.40	2.65	3.34
COB	1.37	1.79	2.05	2.24	2.49	n/a

SECTION 4.0: HYDROGRAPH DEVELOPMENT AND ROUTING

4.1 Duplicate Effective Conditions Hydrograph Development

The 1987 FHAD drainage basin parameters, including basin area, basin length, distance to centroid, and percent impervious for the 10-, 50-, 100-, and 500-year events were imputed into the current version of CUHP in an effort to duplicate the Effective Conditions discharges. CUHP then calculated the Cp and Ct values and produced a corresponding hydrograph. The Duplicate Effective Conditions hydrograph results were then routed in EPA SWMM 5.0 (SWMM) to compute the Duplicate Effective Conditions discharges. The Duplicate Effective Conditions CUHP input and output files are included in Appendix B.

4.2 Hydrograph Routing

In order to route the CUHP hydrographs, a simplified SWMM model was developed for the project area. Routing element lengths, channel/conveyance properties, and Manning's 'n' values were estimated from the project mapping and field reconnaissance photographs. Adjustments to the Manning's 'n' values were made using guidance from the USDCM. The routing schematics are shown on Figures 2 and 3. The SWMM input and output information for the Duplicate Effective Conditions is included in Appendix C. The resulting Duplicate Effective Conditions discharges are summarized and compared to the Effective Conditions discharges in Table 4.1.

Table 4.1 - Duplicate Effective Conditions Discharge Summary and Comparison

			Effective Conditions (1987 FHAD / 2002 FIS)				Duplicate Effective Conditions (CUHP/SWMM, Cp & Ct from CUHP)							
Location	SWMM Element	Effective DA (sq. mi.)	10-Year (cfs)	50-Year (cfs)	100-Year (cfs)	500-Year (cfs)	10-Year (cfs)	% Diff.	50-Year (cfs)	% Diff.	100-Year (cfs)	% Diff.	500-Year (cfs)	% Diff.
Twomile Canyon Creek														
Linden Avenue	JUNCT_601	1.40	210	540	710	1430	194	-8%	549	2%	717	1%	1021	-29%
North Broadway Street	JUNCT_602	1.68	210	675	890	1800	251	20%	692	3%	903	1%	1290	-28%
Confluence with Goose Creek	JUNCT_603	2.19	360	840	1120	2000	440	22%	1037	23%	1370	22%	1922	-4%
Goose Creek														
Balsam Avenue	JUNCT_701	0.48	260	520	620	1000	236	-9%	479	-8%	574	-7%	780	-22%
19th Street	JUNCT_702	1.28	700	1320	1600	2450	772	10%	1488	13%	1813	13%	2429	-1%
Upstream of Confluence with Twomile Creek	JUNCT_703	1.32	670	1270	1590	2400	745	11%	1470	16%	1801	13%	2422	1%
Downstream of Folsom Street	JUNCT_704	3.63	1050	2100	2680	4300	1214	16%	2537	21%	3176	19%	4348	1%

4.3 Hydrograph Calibration

As shown in Table 4.1, the Duplicate Effective Conditions discharge values compare within approximately 20% of the Effective Conditions discharge information. As noted in Section 1.3 of this report, calibration to the Effective Conditions hydrology was pursued. In an effort to correlate the Duplicate Effective Conditions discharges to the Effective Conditions discharges, the model was calibrated by adjusting the peaking coefficient (Cp) value in CUHP. Calibration was completed following recommendations in the October 19th meeting as well as UDFCD calibration methodology. The 100-year event was used as the basis for the calibration. Individual Cp adjustment factors (multipliers to the original CUHP Cp values) were determined for each sub-basin in order to best correlate between the Duplicate Effective Conditions and the Calibrated Duplicate Effective Conditions 100-year discharges. The Cp factors are shown in Table 4.2. These same Cp factors were then applied to the Cp values for 10-, 50-, and 500-year return intervals. The resulting Calibrated Duplicate Effective Conditions discharges are shown in Table 4.3.

Table 4.2 – Calibration Factors

Basin	Calibration Factor
601	1.00
602	0.65
603	0.20
701	1.10
702	0.70
703	0.90
704	0.70

Table 4.3 - Calibrated Duplicate Effective Conditions Discharge Summary and Comparison

			Effective Conditions (1987 FHAD / 2002 FIS)				Calibrated Duplicate Effective Conditions[1] (CUHP/SWMM)							
Location	SWMM Element	Effective DA (sq. mi.)	10-Year (cfs)	50-Year (cfs)	100-Year (cfs)	500-Year (cfs)	10-Year (cfs)	% Diff.	50-Year (cfs)	% Diff.	100-Year (cfs)	% Diff.	500-Year (cfs)	% Diff.
Twomile Canyon Creek														
Linden Avenue	JUNCT_601	1.40	210	540	710	1430	194	-8%	549	2%	717	1%	1021	-29%
North Broadway Street	JUNCT_602	1.68	210	675	890	1800	254	21%	690	2%	898	1%	1280	-29%
Confluence with Goose Creek	JUNCT_603	2.19	360	840	1120	2000	346	-4%	863	3%	1122	0%	1581	-21%
Goose Creek														
Balsam Avenue	JUNCT_701	0.48	260	520	620	1000	255	-2%	515	-1%	616	-1%	836	-16%
19th Street	JUNCT_702	1.28	700	1320	1600	2450	676	-3%	1317	0%	1602	0%	2147	-12%
Upstream of Confluence with Twomile Creek	JUNCT_703	1.32	670	1270	1590	2400	658	-2%	1306	3%	1600	1%	2150	-10%
Downstream of Folsom Street	JUNCT_704	3.63	1050	2100	2680	4300	931	-11%	2040	-3%	2572	-4%	3533	-18%

[1] Calibrated Duplicate Effective Conditions (100-Year only) have been calibrated to approximate the Effective Conditons by adjusting the Cp coefficient. The 10-, 50-, and 500-year values use the claibrated Cp factor as developed for the 100-year calibration

The results of the Cp factor calibration correlated well for the 10-, 50-, and 100-year events; however, the calibration efforts had an adverse effect on the 500-year discharges. Given that the Duplicate Effective Conditions CUHP/SWMM modeling of the 500-year event initially compared better to the Effective Conditions discharges at the lower end of each drainage, it was determined that the best course of action for the 500-year Corrected Effective Conditions was to use the original (i.e. non-calibrated) Cp factors.

The Calibrated Duplicate Effective Conditions CUHP input and output are included in Appendix D. Calibrated Duplicate Effective Conditions SWMM modeling is included in Appendix E.

4.4 Corrected Effective Conditions Hydrograph Routing

The Corrected Effective Conditions sub-basin parameters and percent impervious values, as discussed in Section 2.2 of this report, were updated in CUHP for all return intervals. Additionally, original Cp values from CUHP were adjusted based on the Cp factors determined by the hydrograph calibration efforts for each basin for the 5-, 10-, 25-, 50-, and 100-year return intervals. The 500-year return interval used the non-calibrated Cp factors as calculated by CUHP. Corrected Effective Conditions hydrographs were routed using SWMM. The resulting Corrected Effective Conditions discharges are provided in Table 4.4.

The Corrected Effective Conditions CUHP input and output are included in Appendix F. Corrected Effective Conditions SWMM modeling is included in Appendix G.

Table 4.4 - Corrected Effective Conditions Discharge Summary and Comparison

			Effective Conditions (1987 FHAD / 2002 FIS)				Corrected Effective Conditions[1]											
Location	SWMM Element	Effective DA (sq. mi.)	10-Year (cfs)	50-Year (cfs)	100-Year (cfs)	500-Year (cfs)	Corrected Effective DA (sq. mi.)	% Diff.	5-Year (cfs)	10-Year (cfs)	% Diff.	25-Year (cfs)	50-Year (cfs)	% Diff.	100-Year (cfs)	% Diff.	500-Year[2] (cfs)	% Diff.
Twomile Canyon Creek																		
Linden Avenue	JUNCT_601	1.40	210	540	710	1430	1.38	-1%	91	186	-11%	415	533	-1%	699	-2%	997	-30%
North Broadway Street	JUNCT_602	1.68	210	675	890	1800	1.59	-5%	123	235	12%	501	643	-5%	838	-6%	1187	-34%
Confluence with Goose Creek	JUNCT_603	2.19	360	840	1120	2000	1.95	-11%	173	307	-15%	613	779	-7%	1014	-9%	1572	-21%
Goose Creek																		
Balsam Avenue	JUNCT_701	0.48	260	520	620	1000	0.43	-10%	141	212	-18%	347	434	-17%	521	-16%	661	-34%
19th Street	JUNCT_702	1.28	700	1320	1600	2450	1.41	10%	499	733	5%	1160	1426	8%	1741	9%	2706	10%
Upstream of Confluence with Twomile Creek	JUNCT_703	1.32	670	1270	1590	2400	1.48	12%	498	733	9%	1179	1451	14%	1785	12%	2760	15%
Downstream of Folsom Street	JUNCT_704	3.63	1050	2100	2680	4300	3.55	-2%	645	964	-8%	1669	2080	-1%	2624	-2%	4275	-1%

[1] Corrected Effective Conditions reflect revised % impervious values per COB data, and drainage basin adjustments (see report text)
[2] The 500-year Corrected Effective Conditions discharges reflect non-calibrated Cp values

SECTION 5.0: DISCHARGE COMPARISONS

The Corrected Effective Conditions discharges as shown in Table 4.4 reflect discharges that have been developed as a result of CUHP calibration to the Effective Conditions discharges, in addition to sub-basin and impervious changes within the Twomile Canyon Creek and Goose Creek drainage basins. As concluded in the October 19, 2011 progress meeting, this discharge development methodology was selected by the project sponsors and engineer.

To further validate this hydrology methodology, the Corrected Effective Conditions discharges were compared to both regional regression equation discharges and discharge values previously developed for similar drainage basins along the Front Range. Report sections 5.1 and 5.2 below provide analysis of these comparisons.

5.1 Comparison to Regional Regression Equations

The United States Geological Survey's (USGS) Analysis of the Magnitude and Frequency of Floods in Colorado (Water Resources Investigations Report 99-4190) was used as the basis for the regional regression equations. Pertinent excerpts from this report are included in Appendix I. Per the report, the western boundary of the Plains Region coincides with a line along elevation 7,500 in the South Platte River basin. The high point within the Twomile Canyon Creek drainage basin is at an elevation of approximately 7,000. Based on this physical property of the Twomile Creek drainage basin, the plains regional regression equations were used to calculate discharges.

Table 5.1 compares the regional regression discharges to the Corrected Effective Conditions discharges. As shown in Table 5.1, the correlation between the regional regression equation discharges and the Corrected Effective Conditions discharges is poor with the single exception to the downstream most design point on Goose Creek. As noted in the regional regression equation report, the limitations and accuracy of the regional regression equations may not be valid for drainage basins that have been altered by urban development or for drainage basins that have independent variables outside of the range used to develop the equation. In this case the independent variable is drainage basin size, which the report lists the range of values at 5.5 to 988 square miles. The downstream most design point in this study only has a tributary are of 3.55 square miles. For these reasons the regional regression equation discharges are not considered accurate enough to provide any substantial comparison to the Corrected Effective Condition discharges; however, the regional regression equations do generally provide validation for the 100-year discharge at the downstream end, where the basin size is closest to the parameters used in the regional regression equation development.

Table 5.1 - Regional Regression Equation Discharge Summary and Comparison

		Regional Regression Equation Discharge[1]						Corrected Effective Conditions											
Location	Corrected Effective DA (sq. mi.)	5-Year (cfs)	10-Year (cfs)	25-Year (cfs)	50-Year (cfs)	100-Year (cfs)	500-Year (cfs)	5-Year (cfs)	% Diff.	10-Year (cfs)	% Diff.	25-Year (cfs)	% Diff.	50-Year (cfs)	% Diff.	100-Year (cfs)	% Diff.	500-Year (cfs)	% Diff.
Twomile Canyon Creek																			
Linden Avenue	1.38	223	415	824	1266	1858	3994	91	-59%	186	-55%	415	-50%	533	-58%	699	-62%	997	-75%
North Broadway Street	1.59	236	439	871	1338	1963	4215	123	-48%	235	-46%	501	-42%	643	-52%	838	-57%	1187	-72%
Confluence with Goose Creek	1.95	256	476	944	1450	2125	4555	173	-32%	307	-36%	613	-35%	779	-46%	1014	-52%	1572	-65%
Goose Creek																			
Balsam Avenue	0.43	140	260	520	802	1182	2564	141	1%	212	-19%	347	-33%	434	-46%	521	-56%	661	-74%
19th Street	1.41	225	418	831	1277	1874	4027	499	122%	733	75%	1160	40%	1426	12%	1741	-7%	2706	-33%
Upstream of Confluence with Twomile Creek	1.48	229	427	847	1301	1909	4102	498	118%	733	72%	1179	39%	1451	11%	1785	-7%	2760	-33%
Downstream of Folsom Street	3.55	325	605	1196	1834	2681	5719	645	99%	964	59%	1669	40%	2080	13%	2624	-2%	4275	-25%

[1] Regional regression equations utilize the "plains" region equations. See Appendix I for regional regression backgorund information.

5.2 Comparison to Similar Front Range Drainage Basins

In addition to the comparison to USGS regional regression equations, the Corrected Effective Conditions were also compared to several other similar Front Range drainage basins.

The Boulder and Jefferson County Flood Insurance Study (FIS) reports were reviewed for drainage basins that had similar drainage basin characteristics as the design points along Twomile Canyon Creek and Goose Creek. Specifically, the FIS studies were reviewed for watersheds that initiated in the foothills and had similar basin area size and development levels. Discharges from Apex Gulch, Lena Gulch, Cressmans Gulch and West Fork of Kenney's Run in Jefferson County, in addition to Rock Creek in Boulder County, were used for discharge comparisons.

As shown in Table 5.2, the correlation between the Corrected Effective Conditions and the similar Front Range drainage basins are reasonable when considering an undeveloped basin. Both the Apex Gulch and Cressmans Gulch discharges correlate well to the 601 design point (see Figure 3) when considering the differences in basin area.

Locating drainage basins with a similar proportion of undeveloped and developed areas to Twomile Canyon Creek and Goose Creek was more difficult. Rock Creek, Lena Gulch, and West Fork of Kenneys Run were selected for comparisons. As shown by Table 5.2, the discharge comparison was not as strong as for the undeveloped drainage basin comparison due to the varying levels of development; however, reasonable correlation was made for the 704 design point. It should be noted that all three of these drainage basins have a lesser percentage of the drainage basin that is developed compared to Twomile Canyon Creek and Upper Goose Creek, thus validating the slightly lower discharges along these drainageways.

Table 5.2 - Similar Front Range Drainage Basins Discharge Summary and Comparison

	Similar Front Range Drainage Basins		Corrected Effective Conditions	
Drainage Basin	**Drainage Area (sq. mi.)**	**100-Year (cfs)**	**Corrected Effective DA (sq. mi.)**	**100-Year (cfs)**
Undeveloped Basin (Junction_601 Equivalent)				
Apex Gulch	1.47	830	1.38	699
Cressmans Gulch	1.48	710	1.38	699
Developed Basin (Junction_704 Equivalent)				
Rock Creek	4.10	2396	3.55	2624
Lena Gulch	3.68	2200	3.55	2624
West Fork Kenneys Run	3.43	2010	3.55	2624

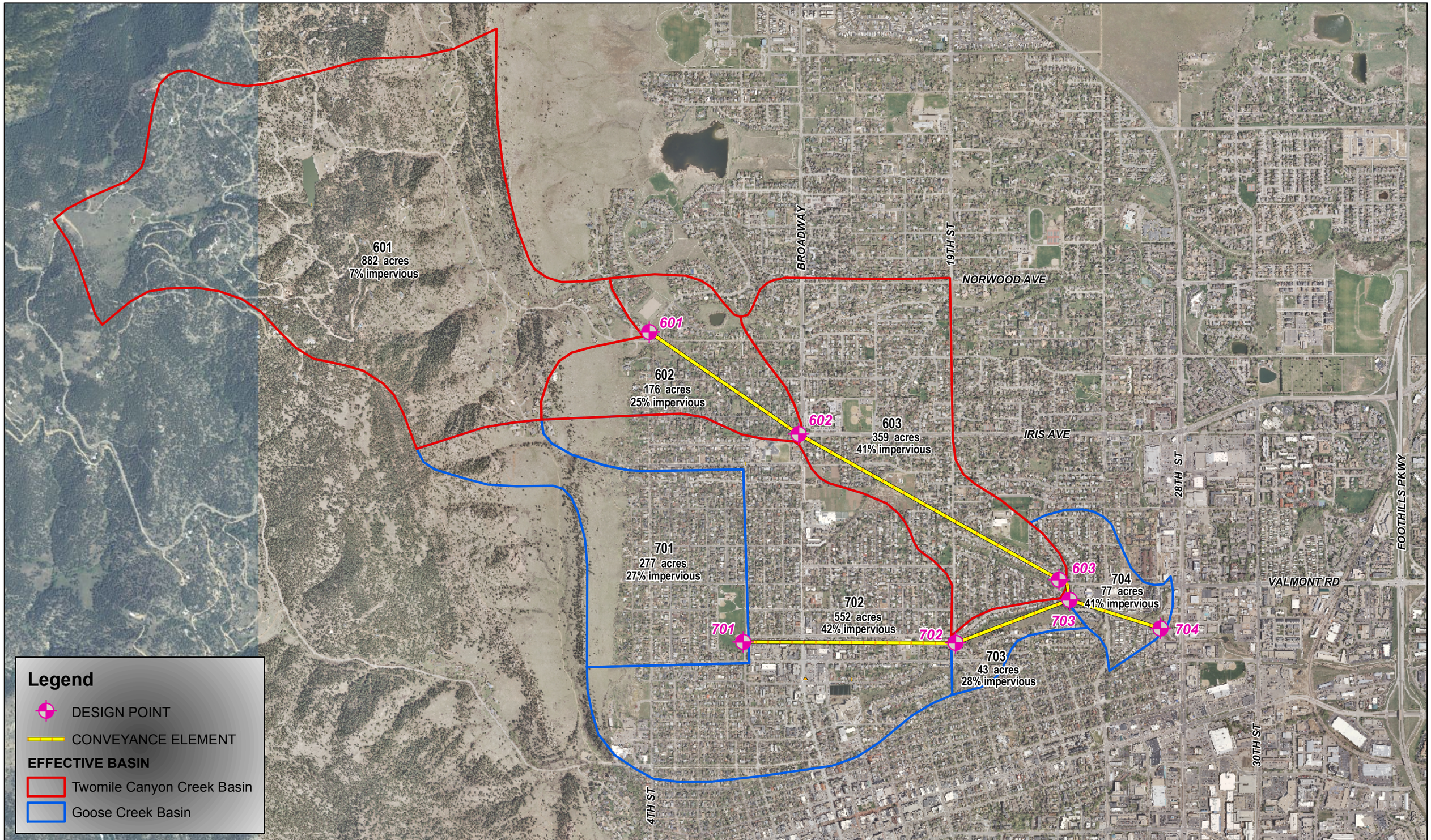
SECTION 6.0: RECOMMENDED DISCHARGES

Based on the hydrologic analysis presented in this report and discussions with project sponsors, the Corrected Effective Conditions discharges, following the calibration efforts, are recommended for the Upper Goose Creek and Twomile Canyon Creek flood mapping study update. These recommended discharges are presented in Table 6.1. We believe that the use of the Corrected Effective discharges are further supported by the comparisons to the regional regression equations and comparisons with other similar Front Range drainage basins for use in the Upper Goose Creek and Twomile Canyon Creek Flood Mapping Study Update.

These discharges will be incorporated into the hydraulic analysis at locations corresponding to the design point locations as shown in Figure 3. However, it should be noted that future detailed hydraulic modeling of the project area may modify discharge application locations and volumes as a result of shallow flooding and split flow behavior within the watersheds.

Table 6.1 - Recommended Discharges

Location	SWMM Element	Drainage Basin Area (sq. mi.)	5-Year (cfs)	10-Year (cfs)	25-Year (cfs)	50-Year (cfs)	100-Year (cfs)	500-Year (cfs)
Twomile Canyon Creek								
Linden Avenue	JUNCT_601	1.38	91	186	415	533	699	997
North Broadway Street	JUNCT_602	1.59	123	235	501	643	838	1187
Confluence with Goose Creek	JUNCT_603	1.95	173	307	613	779	1014	1572
Goose Creek								
Balsam Avenue	JUNCT_701	0.43	141	212	347	434	521	661
19th Street	JUNCT_702	1.41	499	733	1160	1426	1741	2706
Upstream of Confluence with Twomile Creek	JUNCT_703	1.48	498	733	1179	1451	1785	2760
Downstream of Folsom Street	JUNCT_704	3.55	645	964	1669	2080	2624	4275



ICON ENGINEERING, INC.

Upper Goose Creek and Twomile Canyon Creek Flood Mapping Study Update - Hydrology Verification Report
Figure 2 - Effective Conditions Sub-basins

1 inch = 1,500 feet

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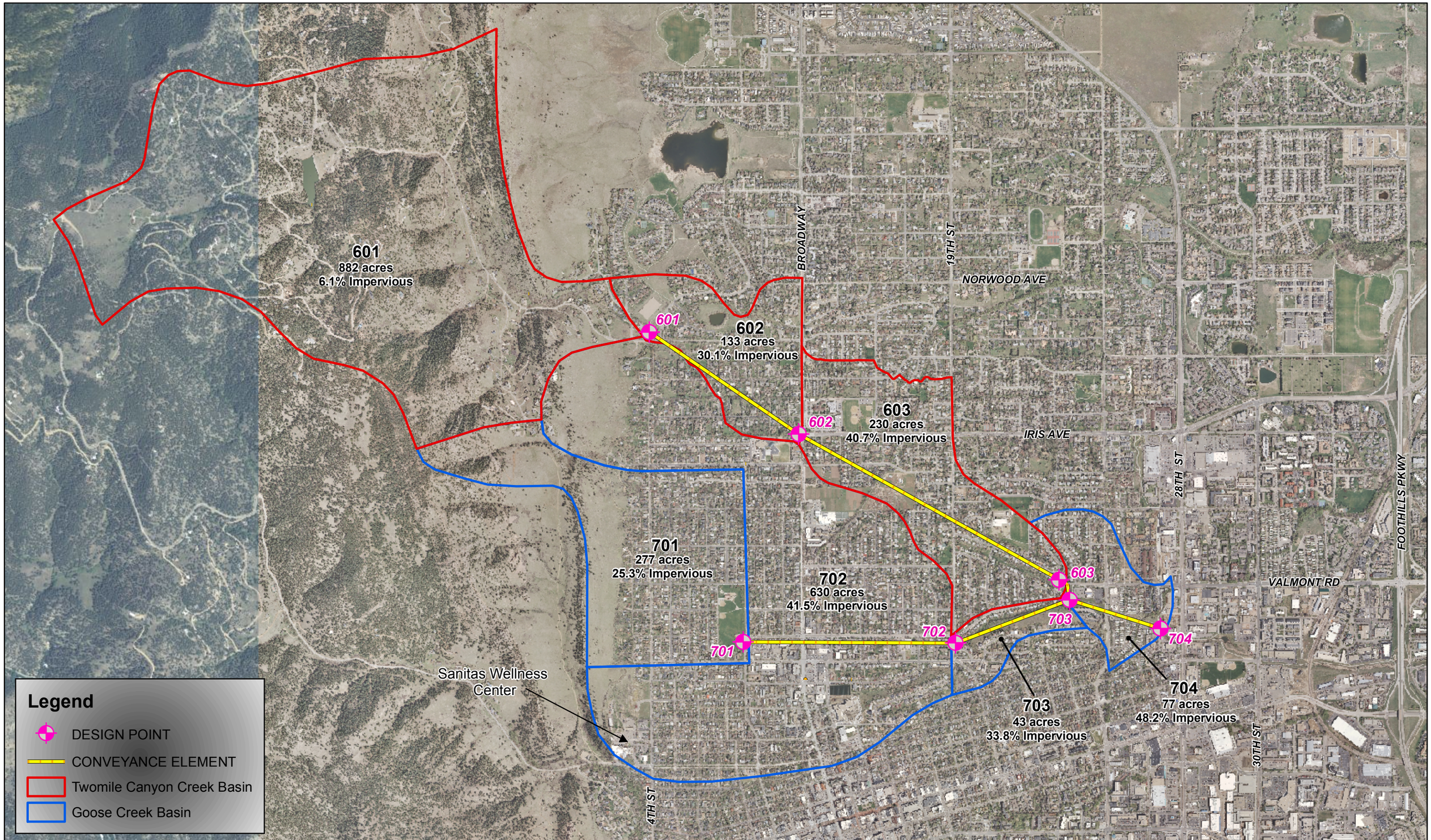


ICON ENGINEERING, INC.

Upper Goose Creek and Twomile Canyon Creek Flood Mapping Study Update - Hydrology Verification Report
Figure 3 - Corrected Effective Conditions Sub-Basins

1 inch = 1,500 feet

N

SECTION 7.0: REFERENCES

1. Greenhorne & O'mara Inc., Flood Hazard Area Delineation – Boulder and Adjacent County Drainageways, May 1987.

2. Urban Drainage and Flood Control District, Colorado Unit Hydrograph Procedure (CUHP) 2005 (v 1.3.3), February 2010.

3. United States Environmental Protection Agency, EPA Storm Water Management Model (SWMM) (v 5.0, Build 5.0.018), November 2009.

4. Urban Drainage and Flood Control District, Urban Storm Drainage Criteria Manual – Volume 1, April 2008.

5. ASCG Incorporated, Memorandum – Elmer's Two Mile Creek Hydrology Review and Analysis – Revised to Include Additional 90 Acre Tributary Area, January 3, 2006.

6. United States Geological Survey, Analysis of the Magnitude and Frequency of Floods in Colorado, 2000.

7. Federal Emergency Management Agency, Flood Insurance Study – Boulder County, Colorado and Incorporated Areas, October 4, 2002.

8. Federal Emergency Management Agency, Flood Insurance Study – Jefferson County, Colorado and Incorporated Areas, June 17, 2003.

Appendix A –
Effective Information
(1987 FHAD and 2002 FIS Excerpts)

FLOOD HAZARD AREA DELINEATION

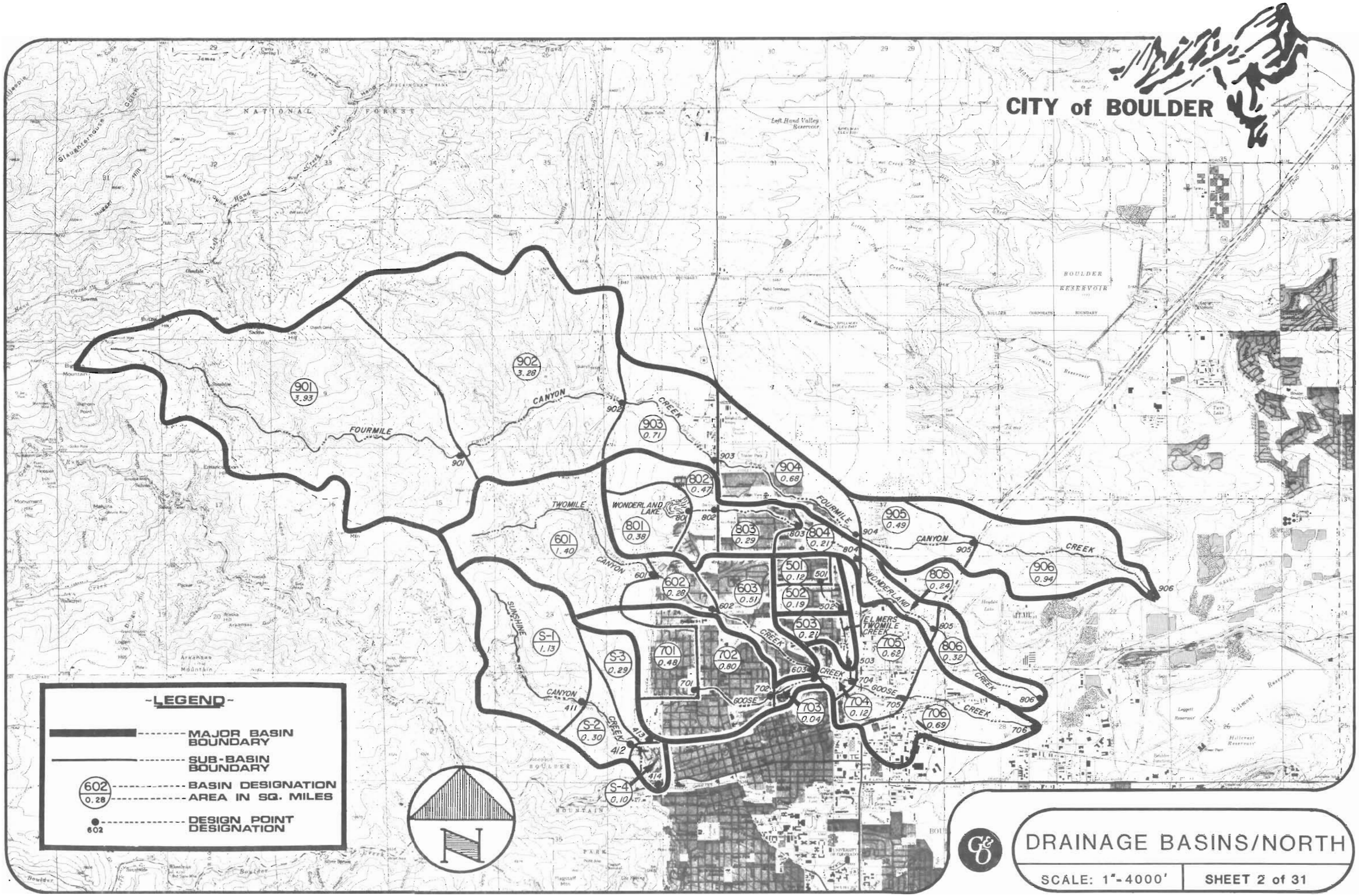
CITY OF BOULDER

BOULDER AND ADJACENT COUNTY DRAINAGEWAYS

MAY 1987

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

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


CITY of BOULDER
NATIONAL FOREST
Left Hand Valley Reservoir
BOULDER RESERVOIR
FOURMILE CANYON CREEK
TWOMILE CANYON CREEK
WONDERLAND LAKE
WONDERLAND
ELMERS TWOMILE CREEK
GOOSE CREEK
SUNSHINE CANYON CREEK
901 3.93
902 3.28
903 0.71
904 0.68
905 0.49
906 0.94
801 0.38
802 0.47
803 0.29
804 0.21
805 0.24
806 0.32
601 1.40
602 0.28
603 0.51
501 0.12
502 0.19
503 0.21
701 0.48
702 0.80
703 0.04
704 0.12
705 0.62
706 0.69
S-1 1.13
S-2 0.30
S-3 0.29
S-4 0.10
LEGEND
MAJOR BASIN BOUNDARY
SUB-BASIN BOUNDARY
602 0.28
BASIN DESIGNATION
AREA IN SQ. MILES
602
DESIGN POINT DESIGNATION
N
DRAINAGE BASINS/NORTH
SCALE: 1"-4000'
SHEET 2 of 31

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

Kings Gulch

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

Gregory Canyon Creek

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

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

Sunshine Canyon Creek

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

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

Goose Creek

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

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

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

Twomile Canyon Creek

Twomile Canyon Creek starts in the mountains west of Boulder near Pine Brook Hill Fire Station. About one mile downstream, the stream channel becomes undefined west of Broadway. The overall study reach is estimated to be 3 miles. The drainage basin of the upstream reach is narrow, steep and rocky. The channel is two to three feet wide and well defined with steep banks. There are rocks and heavy vegetation within the channel which restrict the capacity.

Approximately 1500 feet downstream the drainage basin becomes much wider between steep mountains. The creek remains highly vegetated, but becomes much wider through this section as it enters a pond east of Spring Valley Road Reservoir. Downstream the creek enters the City of Boulder southwest of Maxwell Reservoir. As the stream continues downstream, the drainageway becomes less steep and broader. This change coincides with an increase in urbanization over the middle sections of the basin.

To the west of the intersection of Broadway with Iris, the rocky creek bed is approximately three to four feet wide. East of this intersection the basin is broad and gentle in slope with the channel completely overgrown with heavy grasses. The drainage enters Goose Creek at Floral Avenue south of Valmont.

Elmer's Twomile Creek

Elmer's Twomile Creek drainage basin is located between Wonderland and Twomile Creek Basins, and is tributary to Goose Creek.

This creek originates west of Kalmia Avenue and Folsom. A short reach of the channel is concrete lined and bound by riprap. A natural earthen channel runs through Parkside Park, west of Folsom. The drainageway of this reach is approximately five feet wide and completely covered with vegetation. Beyond the park, the channel widens and remains heavily vegetated as it passes by the Whispering Pines condominium complex. The creek crosses Iris and passes through a series of 3 detention ponds behind the K-Mart and then crosses Glenwood Drive and Valmont. Under normal conditions, the creek flows into Boulder and Whiterocks Drainage Ditch south of the Goose Creek confluence with the same ditch. During flood conditions, the creek overflows the ditch and flows into Goose Creek.

Wonderland Creek

The Wonderland Creek drainage basin flows from Wonderland Lake and drains into Boulder Creek 4000 feet southeast of the Boulder Airport. The overall basin length is estimated to be 3.6 miles. The basin east of Wonderland Lake is very broad. Vegetation within this section consists of dense grasses with few trees. The drainage basin is developed within the Boulder City limits. East of Folsom, the drainage basin again becomes broad, and land development is more sparse. This broad and grassy basin pattern continues across 28th Street. As the basin drains eastward, it passes through Aspen Grove Subdivision. There are several high density developments from this point to Valmont Road. The remainder of the basin to the southeast is undeveloped.

As the stream leaves Wonderland Lake, the stream bed is narrow, approximately 3 to 4 feet wide. The creek banks are low, approximately 1 to 3 feet high. The stream flows through the Wildwood Solar Homes complex. The stream is narrow but well defined within this area. Southeast of the complex, the channel becomes grassy, with small rocks on the stream bottom. Banks are generally 4 feet high, with stone or rip-rapped embankments of up to 10 feet at street crossings. Further downstream in lower lying areas, the channel is laden with small stones, silt, and clay. Ponding occurs south of Iris Avenue at 47th Street. The subsequent outflow has created a channel approximately 12 to 15 feet wide. South of Valmont, regrading has taken place which allows most of the flows in excess of the channel capacity to spill into the improved North Goose Creek channel.

Fourmile Canyon Creek

The upstream drainage basin of Fourmile Canyon Creek originates near Sunshine Saddle in steep and rocky terrain. The basin is narrow in the foothills, but becomes less steep and wide as the drainageway extends to the east. The overall length of the basin is estimated to be 6.5 miles. The creek empties into Boulder Creek 3000 feet north of Valmont Butte.

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

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

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

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

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

Hydrologic Analyses

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

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

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

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

Note: Rainfall depths used in the CUHP models were taken directly from the technical appendix of the 1987 FHAD which provide sub-basin specific rainfall depths that vary from this table.

TABLE 2

Rainfall Depths (Inches) / 1-Hour Duration

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

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

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

TABLE 3

Design Storm Distributions of 1-Hour NOAA Atlas Depths

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

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

of the basin (Lca), percent of impervious cover, coefficient reflecting time to peak (Ct), and coefficient related to the peak rate of runoff (Cp).

Basin areas, basin and channel slopes, and lengths of flow paths were measured on the U.S. Geological Survey's 7.5 Minute Quadrangle mapping, and supplemental information was taken as needed from the topographic mapping (Reference 5) as provided by UD&FCD (Reference 6). Actual basin slopes were adjusted for use in determining the coefficient reflecting time to peak (Ct) for use with the most current data determined by the Urban Drainage and Flood Control District (Figure 3). Values of Ct and Cp were also determined from this latest version of CUHP and were taken from Figures 4 and 5. The coefficients for Ct were adjusted for use in the computer program. The equation used to convert Ct to *Ct is as follows.

$$*C_t = C_t \frac{LL_{ca}^{.18}}{So^{.24}}$$

Based upon a new equation for time to peak:

$$t_p = C_t \frac{LL_{ca}^{.48}}{So}$$

In addition, the unit peak of the unit hydrograph is defined by:

$$q_p = \frac{640C_p}{t_p}$$

In which q_p = peak rate of runoff in cfs per square mile.

C_p = Coefficient related to peak rate of runoff.

Once q_p is determined, the peak of the unit hydrograph for the basin is computed by:

$$Q_p = q_p A$$

In which Q_p = peak of the unit hydrograph in cfs.

A = area of basin in square miles.

Finally, the value for C_p was determined using the equation:

$$C_p = PC_tA^{0.15}$$

Where P = peaking parameter from Figure 5.

C_t = Coefficient from Figure 4

A = basin area in square miles.

The impervious cover was determined by first identifying land uses throughout each of the basins from planning and zoning maps of the City and County of Boulder. Typical values for the percentage of impervious area for each land use were then assigned and a weighted impervious area was computed for each land use. Impervious percentages used in the CUHPB model are shown in Table 4.

TABLE 4

Impervious Percentages

Land Use	Percent Impervious
Downtown Business Area, Shopping Centers, etc.	95 - 100
Residential Dense	50 - 70
Residential Normal	35 - 50
Residential, Large Lots	20 - 40
Scattered Mountain Development, Parks, Greenbelts, Open Space, Undeveloped Areas	0 - 10

Rainfall losses due to infiltration and depression storage are also input parameters to the CUHPB model. Infiltration rates were taken from the Urban Storm Drainage Criteria Manual revised guidelines and are based on soils classified by the Soil Conservation Service (Reference 7). The infiltration rates used for the analysis ranged from 3.0 to 4.0 inches/hour initial and from .015 to 0.6 inches/hour final, with a decay coefficient of 0.0018. Depression storage values ranged from 0.4 to 0.5 inches for pervious areas and were 0.1 inch for impervious areas.

The drainage basin and channel input data parameters for the 11 drainageways are summarized in Table 5.

Stream routing for each of the sub-basins was completed using the U.S. Army Corps of Engineers HEC-1 Flood Hydrograph Computer Model. For this analysis, the storm hydrographs computed by the CUHPB were input into the HEC-1 Model and routed

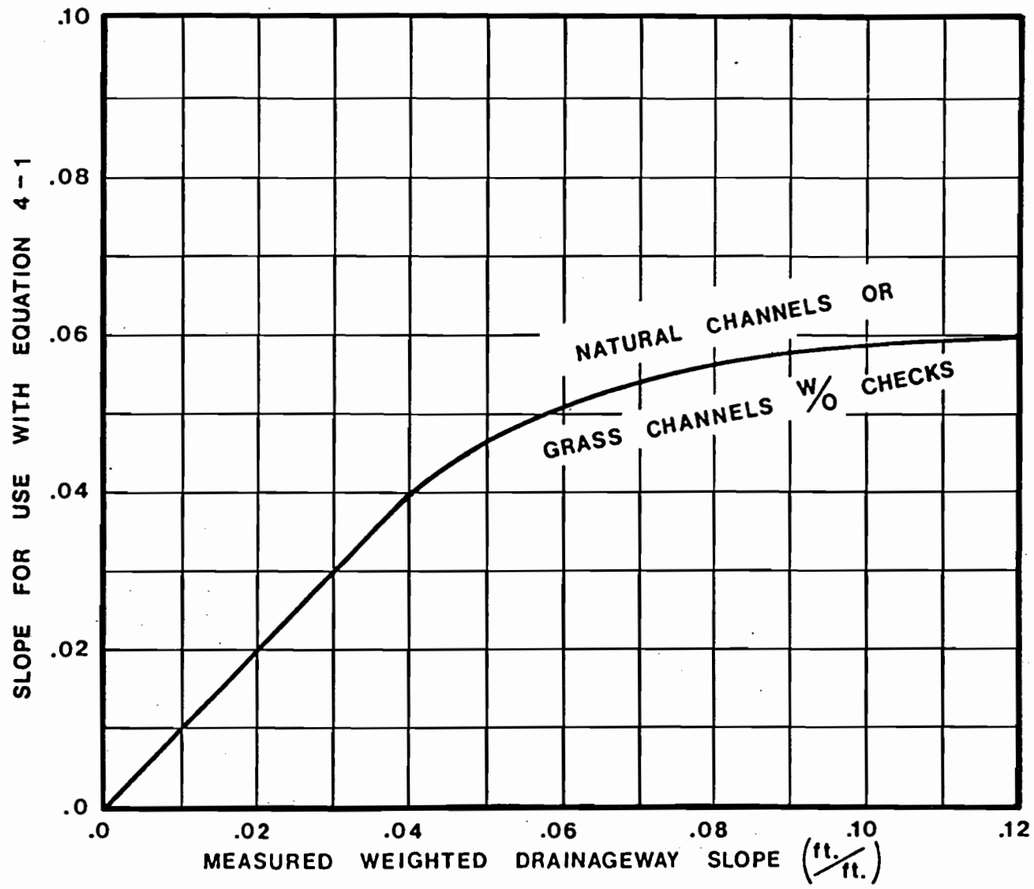


FIGURE 4 - 1. SLOPE CORRECTION FOR NATURAL DRAINAGEWAYS

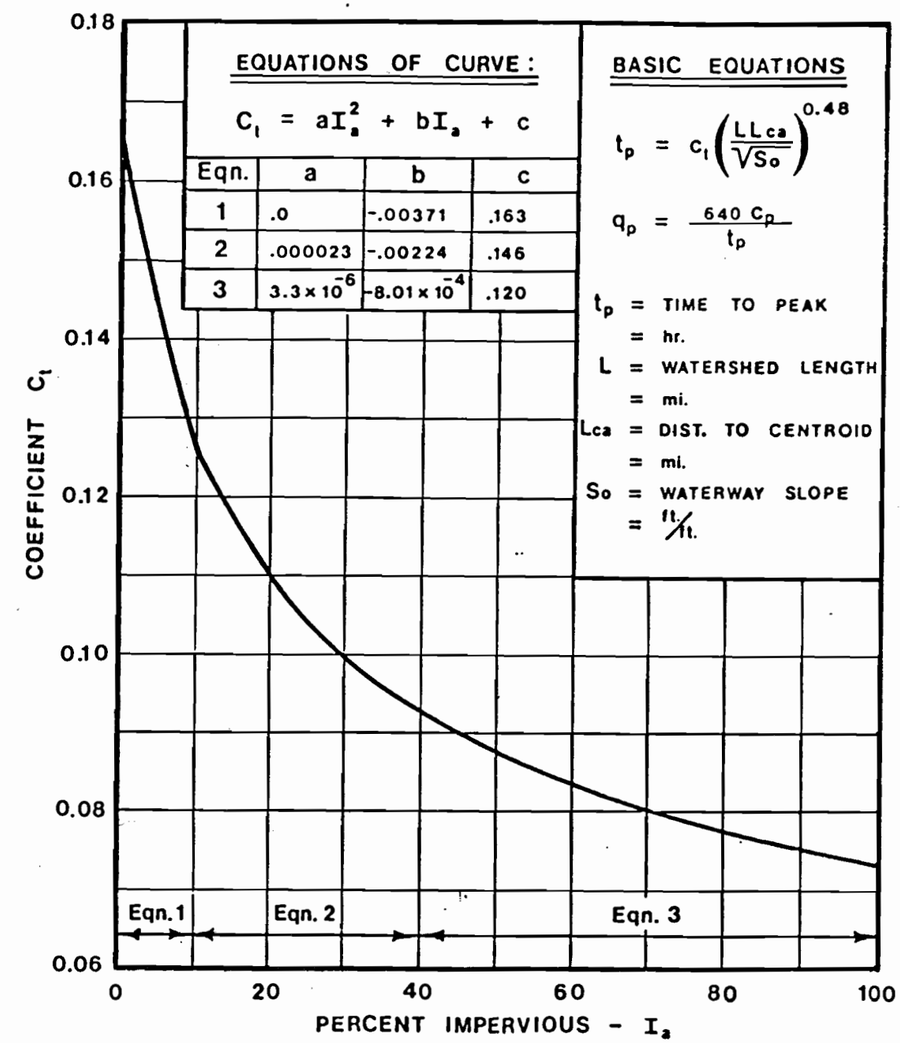


FIGURE 4-2. RELATIONSHIP BETWEEN C_t & IMPERVIOUSNESS

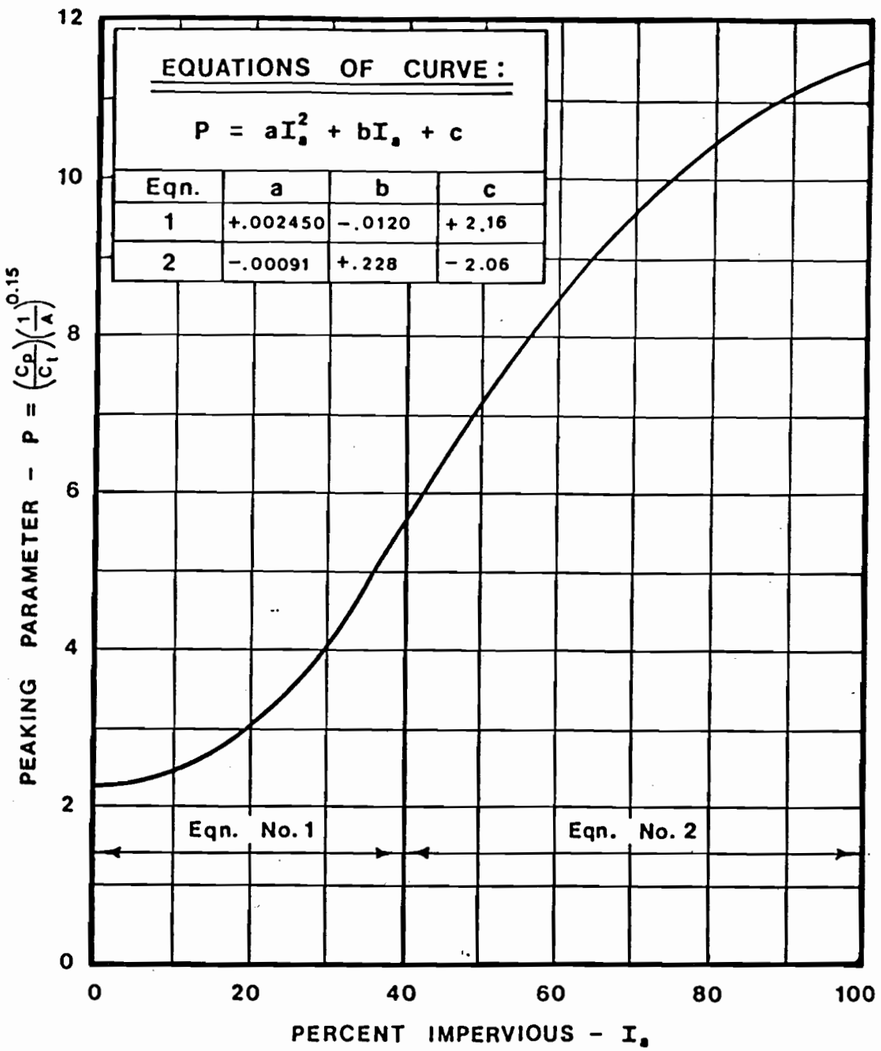


FIGURE 4-3. RELATIONSHIP BETWEEN PEAKING PARAMETER AND IMPERVIOUSNESS

FIGURE 5

TABLE 5

CUHPB Basin Parameters

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

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

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

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

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

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

Hydraulics

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

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

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

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

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

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

FLOODPLAIN DESCRIPTIONS

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

Bear Canyon Creek

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

TABLE 6

SUMMARY OF PEAK DISCHARGE

Design Point	Flooding Source	Drainage Area (sq mi)	Peak Discharges (cfs) 2-Yr	5-Yr	10-Yr	50-Yr	100-Yr
	BEAR CANYON CREEK - (Figure 2)						
409	Confluence - Boulder Creek	8.24	720	1415	2050	3762	4880
408	Confluence - Skunk Creek	5.35	355	780	1170	2360	3070
407	Baseline Road	4.96	330	740	1110	2352	2930
404	U.S. 36	4.34	240	540	820	1780	2210
403	Broadway	4.08	140	440	680	1512	1930
402	Yale Road	3.71	110	290	480	1190	1600
401	500' u/s of Lehigh	2.84	68	180	307	791	1063
	SKUNK CANYON CREEK - (Figure 2)						
306	Confluence - Bear Creek	2.83	350	700	980	1830	2230
305	Madison Avenue	2.43	340	690	920	1580	1870
303	U.S. 36	2.08	270	480	650	1130	1350
302	Broadway	1.36	47	125	210	520	710
301	Anderson Ditch	1.20	39	105	180	460	640
	BLUEBELL CANYON CREEK - (Figure 2)						
211	Chautauqua Park	0.40	6	31	63	168	227
212	Confluence with Skunk Creek	0.68	139	247	360	627	737
	KING'S GULCH - (Figure 1)						
111	Design Point	0.23	6	32	64	164	214
112	Confluence with Skunk Creek	0.32	41	82	132	292	373
	GREGORY CREEK - (Figure 2)						
311	0.4 mi. u/s Flagstaff Road	1.16	22	117	229	659	890
312	Flagstaff Road	1.56	30	163	321	932	1239
313	Confluence with Boulder Creek	2.29	161	435	673	1672	2092

Design Point	Flooding Source	Drainage Area (sq mi)	Peak Discharges (cfs) 2-Yr	5-Yr	10-Yr	50-Yr	100-Yr
	SUNSHINE CANYON CREEK - (Figure 1)						
411	Confluence w/Sunshine Creek Tributary	1.13	17	89	169	538	678
412	Design Point d/s of Memorial Hospital	1.72	27	139	266	869	1103
414	Confluence with Boulder Creek	1.82	45	155	286	914	1159
	SUNSHINE CANYON TRIB. - (Figure 1)						
414	Confluence with Sunshine Canyon Creek	0.29	10	26	51	161	200
	GOOSE CREEK - (Figure 1)						
706	Confluence - Boulder Creek	5.46	650	1260	1740	3300	4180
705	Colorado & Southern Railroad	4.77	520	1040	1520	2960	3761
704	Confluence - Elmer's Twomile	3.63	340	710	1050	2100	2680
703	Confluence - Twomile Canyon	1.32	240	470	670	1270	1590
702	19th Street	1.28	260	500	700	1320	1600
701	Upstream Study Limit	.48	90	183	260	520	620
	TWOMILE CANYON CREEK - (Figure 1)						
603	Confluence - Goose Creek	2.19	110	255	360	840	1120
602	Broadway	1.68	48	138	210	675	890
601	Upstream Study Limit (Maxwell Reservoir)	1.40	40	112	210	540	710
	ELMER'S TWOMILE - (Figure 2)						
503	Confluence - Goose Creek	0.52	84	190	280	630	790
502	Iris Avenue	0.31	93	185	270	510	610
501	Upstream Study Limit	0.12	40	78	110	210	250

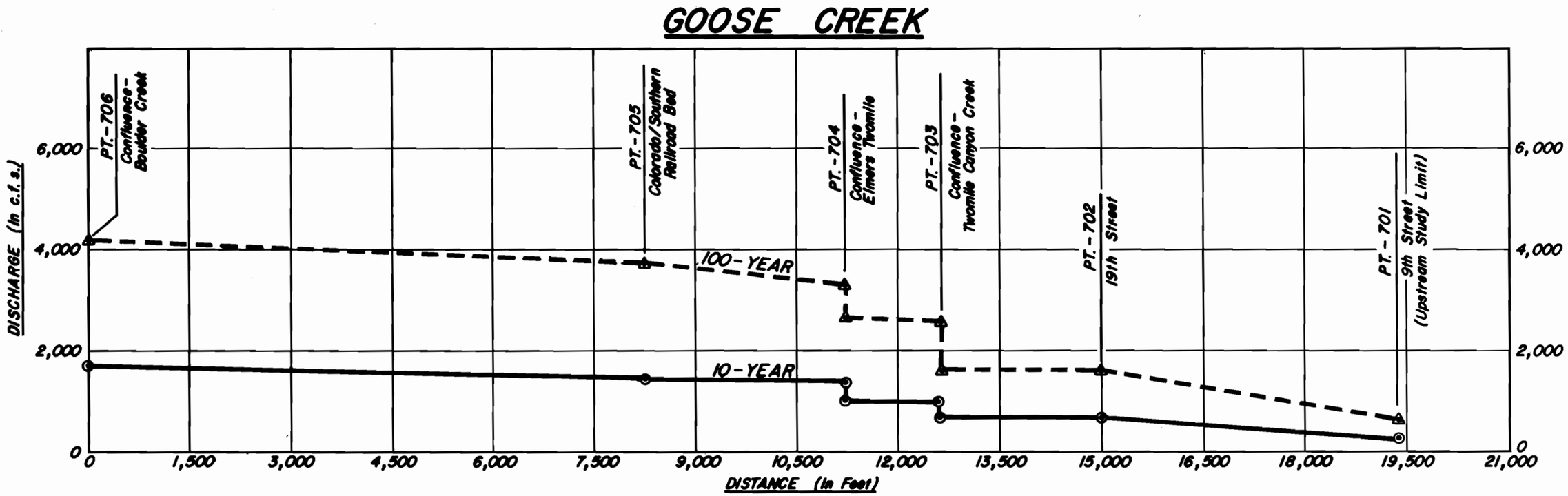
TABLE 7

CONTINUED

DRAINAGEWAY	LOCATION	% BLOCKAGE
Gregory Canyon Creek		
	Flagstaff	0
	Driveway	100
	Driveway	50
	Footbridge	N/A
	Willowbrook Drive	50
	Aurora Avenue	50
	Euclid Avenue	50
	College Avenue	50
	Pennsylvania	50
	Rose Hill Drive	50
	Ditch Crossing	50
	Pleasant Avenue	50
	University Avenue	50
	8th Street	50
	Marine Street	50
	Alley	50
	Arapahoe Avenue	50
	Footbridge	50
Sunshine Canyon Creek		
	Sunshine Canyon Road	50
	Spruce Street	25
	Pearl Street	0
	Canyon Boulevard	0
Goose Creek		
	Pipes at 19th	100
	26th	30
	Bridge in Trailer Court	30
	Trailer Court	30

DRAINAGEWAY	LOCATION	% BLOCKAGE
Twomile Creek		
	3rd Street	100
	Wonderland Hill Avenue	100
	Linden Avenue	100
	Kalmia Avenue	100
	Juniper Avenue	100
	Broadway	100
	13th Street	*
	14th Street	*
	Hawthorne Avenue	*
	Garland Avenue	*
	19th Street	*
	Floral Drive	*
	Edgewood Drive	*
Elmer's Twomile Creek		
	Kalmia	0
	Footbridge in Park	
	26th	100
	Juniper (Twin Trees)	100
	Iris (33")	50
	Valmont	0
	Glenwood	0

* Twomile Creek is not defined in the Lower Reaches. Therefore culvert crossings were not considered in this area.


GOOSE CREEK
DISCHARGE (in c.f.s.)
DISTANCE (in Feet)
PT.-706 Confluence-Boulder Creek
PT.-705 Colorado/Southern Railroad Bed
PT.-704 Confluence-Elmers Twomile
PT.-703 Confluence-Twomile Canyon Creek
PT.-702 19th Street
PT.-701 9th Street (Upstream Study Limit)
100-YEAR
10-YEAR
0
2,000
4,000
6,000
0
1,500
3,000
4,500
6,000
7,500
9,000
10,500
12,000
13,500
15,000
16,500
18,000
19,500
21,000

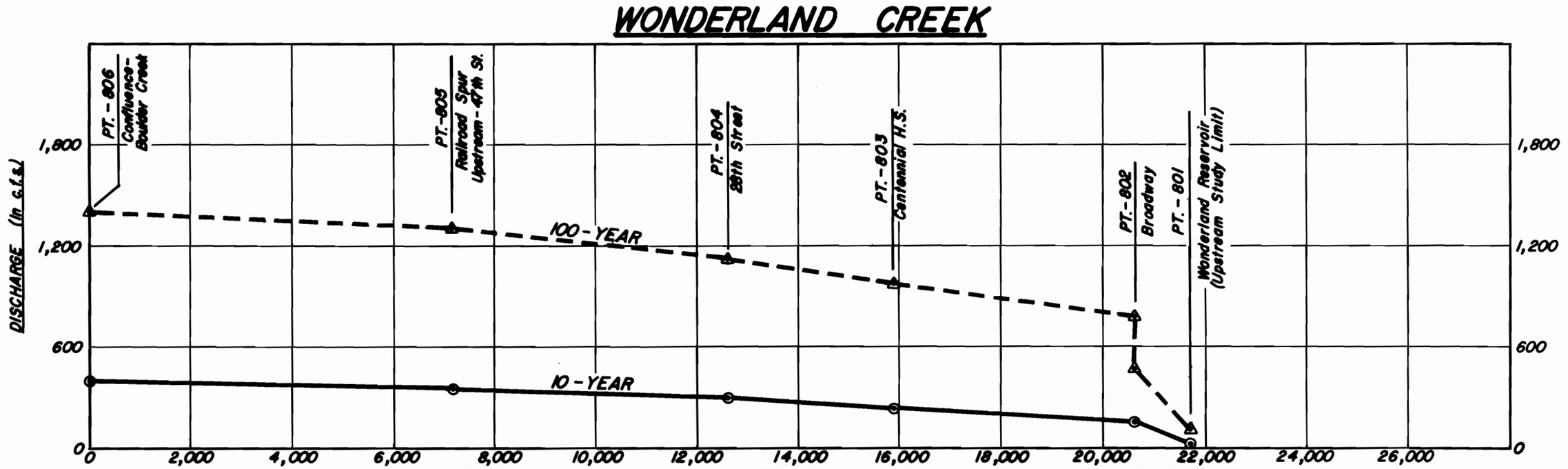
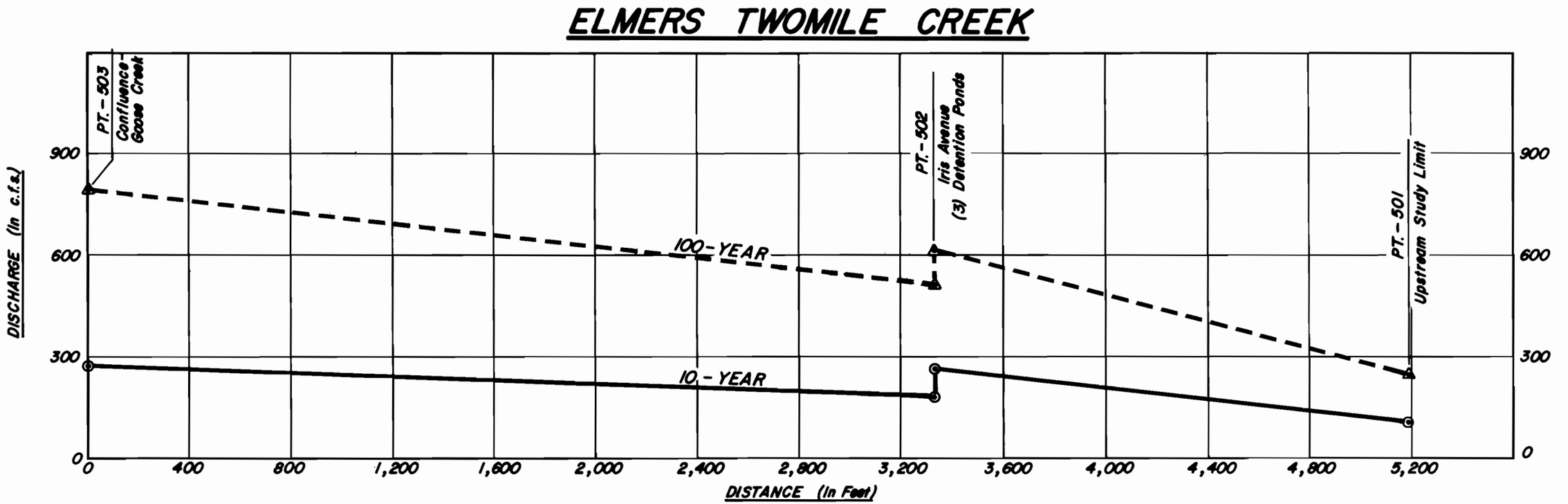

WONDERLAND CREEK
DISCHARGE (in c.f.s.)
PT.-806 Confluence-Boulder Creek
PT.-805 Railroad Spur Upstream-47th St.
PT.-804 28th Street
PT.-803 Centennial H.S.
PT.-802 Broadway
PT.-801 Wonderland Reservoir (Upstream Study Limit)
100-YEAR
10-YEAR
0
600
1,200
1,800
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000

Figure 7


ELMERS TWOMILE CREEK
PT.-503
Confluence-Goose Creek
PT.-502
Iris Avenue (3) Detention Ponds
PT.-501
Upstream Study Limit
100-YEAR
10-YEAR
DISCHARGE (In c.f.s.)
DISTANCE (In Feet)
0
300
600
900
0
400
800
1,200
1,600
2,000
2,400
2,800
3,200
3,600
4,000
4,400
4,800
5,200

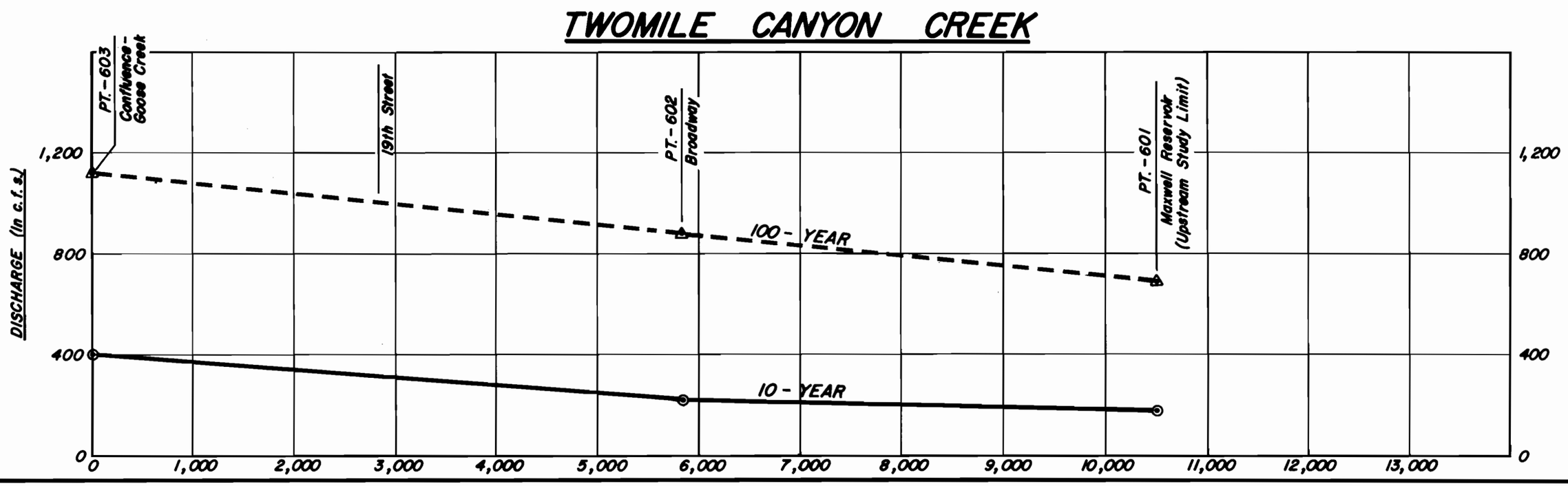

TWOMILE CANYON CREEK
PT.-603
Confluence-Goose Creek
19th Street
PT.-602
Broadway
PT.-601
Maxwell Reservoir (Upstream Study Limit)
100-YEAR
10-YEAR
DISCHARGE (In c.f.s.)
0
400
800
1,200
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000
13,000

Figure 8

Obtained 9/6/96
from UDFCD

Return when not
needed

MAJOR DRAINAGEWAY PLANNING

BOULDER AND ADJACENT COUNTY DRAINAGEWAYS

PHASE "B"
MAY 1987

TECHNICAL ADDENDUM

Greenhorne and O'Mara, Inc.
Denver, Colorado

MSM CONSULTANTS, INC. DENVER, COLORADO

By JPD Date 5/18/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By ___ Date ___ CUHP-B DATA TABLE Job No. 4834916

BASIN DESIGNATION	AREA (mi^2)	BASIN LENGTH (mi)	L_{CA} (mi)	% I	C_t	C_p	PERVIOUS DEPRESSION (IN.)	IMPERVIOUS DEPRESSION (IN)	INITIAL INFL. RATE (IN/HR)	DECAY RATE (1/SEC.)	FINAL INFL RATE (IN/HR
601	1.40	2.41	1.35	7.0	0.33	0.32	0.5	0.1	3.0	.0018	0.5
602	0.28	0.86	0.51	25.0	0.19	0.30	0.4		4.0		0.6
603	0.51	1.48	0.76	41.0	0.22	0.48	0.4		4.0		0.6
701	0.48	1.52	0.59	27.0	0.20	0.34	0.4	0.1	3.0	.0018	0.5
702	0.80	1.44	0.66	42.0	0.23	0.52	0.4		4.0		0.6
703	0.04	0.52	0.28	28.0	0.16	0.24	0.5		3.0		0.5
704	0.12	0.66	0.21	41.0	0.18	0.39	0.4		3.0		0.5
705	0.62	1.57	0.76	64.0	0.25	0.66	0.4		3.0		0.5
706	0.69	1.63	0.80	53.0	0.27	0.59	0.4		3.0		0.5
801	0.38	0.72	0.38	11.0	0.22	0.26	0.5	0.1	3.0	.0018	0.5
802	0.47	1.21	0.57	16.0	0.23	0.27	0.5		3.0		0.5
803	0.29	0.88	0.57	30.0	0.23	0.34	0.4		4.0		0.6
804	0.21	0.81	0.47	36.0	0.21	0.38	0.4		3.0		0.5
805	0.24	1.14	0.43	31.0	0.25	0.33	0.4		3.0		0.5
806	0.32	1.42	0.76	10.0	0.37	0.25	0.5		3.0		0.5
901	3.93	4.17	1.37	5.0	0.39	0.38	0.5	0.1	3.0	.0018	0.5
902	3.28	3.08	1.18	6.0	0.35	0.37	0.5		3.0		0.5
903	0.71	1.10	0.49	15.0	0.22	0.29	0.5		3.0		0.5
904	0.68	1.89	1.02	41.0	0.27	0.50	0.4		4.0		0.6
905	0.49	1.25	0.49	12.0	0.31	0.27	0.5		3.0		0.5
906	0.94	2.50	1.21	13.0	0.42	0.30	0.5		3.0		0.5

MSM CONSULTANTS, INC. DENVER, COLORADO

By TED Date 5/12/82 PROJECT BOULDER F.I.S. Sheet No. ____ of ____

Checked By RC Date 5/13/82 RAINFALL DEPTH CALCULATIONS FOR 10-YEAR STORM - 1 HOUR Job No. 4834916

	BASIN NUMBERS		AVERAGE RAINFALL (INCHES)
0	501		1.70
0	502 & 503		1.70
0	601	$\frac{90(1.5) + 786(1.6)}{876} = 1.59$	1.60
0	602	$\frac{96(1.6) + 106(1.7)}{202} = 1.65$	1.65
0	603		1.70
0	701	$\frac{169(1.6) + 139(1.7)}{308} = 1.65$	1.65
0	702	$\frac{55(1.6) + 459(1.7)}{514} = 1.69$	1.70
0	703		1.70
0	704		1.70
0	705		1.70
0	706	$\frac{149(1.75) + 292(1.70)}{441} = 1.72$	1.70
0	801	$\frac{51(1.7) + 193(1.6)}{244} = 1.62$	1.60
0	802	$\frac{119(1.6) + 366(1.7)}{485} = 1.68$	1.70 1.65
0	803 4		1.70
0	804 5		1.70
0	805	$\frac{67(1.7) + 137(1.75)}{204}$	1.75
0	901		1.50
0	902	$\frac{1362(1.6) + 737(1.5)}{2099} = 1.56$	1.55
0	903	$\frac{243(1.6) + 209(1.7)}{452} = 1.65$	1.65
0	904		1.70
	905		1.70
	906		1.75

cont'd

MSM CONSULTANTS, INC. DENVER, COLORADO

By TED Date 5/12/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By RC Date 5/14/82 RAINFALL DEPTH CALCULATIONS FOR 50-YEAR STORM — 1 HOUR Job No. 4834916

BASIN NUMBERS		AVERAGE RAINFALL (INCHES)
501	$\frac{44(2.3)+34(2.4)}{78} = 2.34$	2.35
502 & 503	$\frac{95(2.3)+158(2.4)}{253} = 2.36$	2.35
601		2.20
602	$\frac{20(2.2)+182(2.3)}{202} = 2.29$	2.30
603		2.30
701	$\frac{60(2.2)+248(2.3)}{308} = 2.28$	2.30
702		2.30 ok ~~2.35~~
703		2.30 2.35
704		2.40 2.35
705		2.40
706		2.40
801	$\frac{71(2.2)+173(2.3)}{244} = 2.27$	2.25
802	$\frac{49(2.2)+436(2.3)}{485} = 2.29$	2.30
803	$\frac{49(2.3)+84(2.4)}{133} = 2.36$	2.30 2.35
804		2.40
805		2.40
901	$\frac{133(2.2)+2384(2.1)}{2517} = 2.11$	2.10
902	$\frac{413(2.1)+1686(2.2)}{2099} = 2.18$	2.20
903	$\frac{74(2.2)+378(2.3)}{452} = 2.28$	2.30
904	$\frac{331(2.3)+102(2.4)}{433} = 2.32$	~~2.34~~ 2.30
905		2.40
906		2.40

MSM CONSULTANTS, INC. DENVER, COLORADO

By TED Date 5/12/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By RC Date 5/14/82 RAINFALL DEPTH CALCULATIONS FOR 100-YEAR STORM - 1 HOUR Job No. 49349 16

BASIN NUMBERS		AVERAGE RAINFALL (INCHES)
501		2.65
502 & 503		2.65
601	$\frac{287(2.5)+589(2.4)}{876} = 2.43$	2.45
602	$\frac{101(2.5)+101(2.6)}{202} = 2.55$	2.55
603	$\frac{134(2.6)+195(2.65)}{329} = 2.63$	2.65
701	$\frac{168(2.5)+140(2.6)}{303} = 2.55$	2.55
702	$\frac{76(2.5)+83(2.65)+355(2.6)}{514} = 2.59$	2.60
703		2.65
704		2.65
705		2.65
706	$\frac{140(2.7)+301(2.65)}{441} = 2.67$	2.65
801	$\frac{44(2.6)+200(2.5)}{244} = 2.52$	2.50
802	$\frac{120(2.5)+104(2.65)+261(2.6)}{485} = 2.59$	2.60 ~~2.55~~ 2.65
803		2.65
804		2.65
805	$\frac{23(2.65)+181(2.7)}{204} = 2.69$	2.70
901		
902	$\frac{329(2.5)+1770(2.4)}{2099} = 2.42$	2.40
903	$\frac{253(2.5)+199(2.6)}{452} = 2.54$	2.55
904	$\frac{156(2.6)+277(2.65)}{433} = 2.63$	2.65
905	$\frac{188(2.65)+122(2.7)}{310} = 2.67$	2.65
906		2.70

MSM CONSULTANTS, INC. DENVER, COLORADO

By DLM Date 5/10/82 PROJECT Boulder FIS Sheet No. ___ of ___

Checked By RPK Date 5/13/82 BASIN 601 Job No. 4834916

Twomile Sub basin

Area = 898 Ac. / 1.40 mi²

Length = 12,750' / 2.41 mi.

L_{ca} Centroid Length = 7,150 / 1.35 mi.

S_o Waterway Slope = 5.9 % ✓

% Impervious = 7%

cm-5-17

✓ C_t = 0.136

✓ $C_{t(Program)}$ = 0.332

✓ P = 2.2

✓ C_p = 0.315

MSM CONSULTANTS, INC. DENVER, COLORADO

By DLM Date 5/10/82 PROJECT Boulder FC Sheet No. ___ of ___

Checked By BPK Date 5/13/82 BASIN 602 Job No. 4836916

Twomile Sub basin T2

	Area	180. AC. / 0.28 mi²
	Length	4550' / 0.86 mi.
L_{CA}	Centroid Length	2,700' / 0.51 mi
S_o	Waterway Slope	5.0%
	% Impervious	25.0%

✓ $C_t = 0.105$ CIM - 5-18

✓ $C_{t(Program)} = 0.186$

✓ $P = 3.5$

✓ $C_p = 0.304$

MSM CONSULTANTS, INC. DENVER, COLORADO

By DLM Date 5/10/82 PROJECT Boulder Flr Sheet No. ___ of ___

Checked By RPK Date 5/13/82 BASIN 603 Job No. 4834916

Two mile Sub-basin T3

Area	329 Ac. / 0.51 mi²
Length	7800' / 1.48 miles
Centroid Length	4000' / 0.76 mi.
Waterway Slope	3.1%
% Impervious	41%

$C_t = 0.093$ ✓

$C_{t\,(Program)} = 0.219$ ✓

✓ JPD 5/17/82

$P = 5.7$ ✓

$C_p = 0.479$ ✓

MSM CONSULTANTS, INC. DENVER, COLORADO

By RC Date 5/7/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By RPK Date 5/13/82 GOOSE CREEK Job No. 4834916

BASIN 701

AREA = 308 ac = 0.48 mi^2

L = 8000 ft = 1.52 mi.

$S_1 = \frac{6800 - 5600}{8000 - 4000} = 30\% \Rightarrow 6.0\%$

$S_2 = \frac{5600 - 5395}{4000 - 0} = 5.1\% \Rightarrow 4.6\%$

$S_o = \frac{4000(6.0) + 4000(4.6)}{8000} = 5.3\%$ /

L_{CA} = 3100 ft. = 0.59 mi.

% Impervious = 27%

$C_t = 0.103$ ✓

$C_{t(Program)} = 0.204$ ✓

✓ JPD 5/17/82

$P = 3.7$ ✓

$C_p = 0.341$ ✓

MSM CONSULTANTS, INC. DENVER, COLORADO

By RC Date 5/7/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By RPK Date 5/13/82 GOOSE CREEK Job No. 4834916

BASIN 702

AREA = 514 ac = 0.80 mi^2

$L = 7600\ ft = 1.44\ mi.$

$S_1 = \frac{5800-5440}{7600-6400} = 30\ \% \Rightarrow S = 6\%$

$S_2 = \frac{5440-5340}{6400-0} = 1.6\%$

$S_o = \cancel{1.5\%}\ \frac{1200(6)+6400(1.6)}{7600} = 2.3\%$

$L_{CA} = 3500\ ft. = 0.66\ mi.$

% Impervious = 42%

$C_t = 0.092$ ✓

$C_{t(Program)} = 0.225$ ✓ ✓ JPD 5/17/82

$P = 5.8$ ✓

$C_p = 0.516$ ✓

MSM CONSULTANTS, I[illegible]. DENVER, COLORADO

By RC Date 5/7/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By RPK Date 5/13/82 GOOSE CREEK Job No. 4834916

BASIN 703

AREA = 26 ac = .04 mi^2

$L = \cancel{2300}\ 2750\ ft = \cancel{0.44}\ 0.52\ mi.$

$S_1 = \frac{5400 - 5360}{2750 - 1850} = 4.4\% \Rightarrow S_1 = 4.3\%$

$S_2 = \frac{5360 - 5306}{1850 - 0} = 2.9\%$

$S_o = \frac{900(4.3) + 1850(2.9)}{2750} = 3.4\%$ /

$L_{CA} = 1500\ ft. = 0.28\ mi.$

% Impervious = 28%

$C_t = 0.102$ ✓

$C_{t\,(Program)} = 0.162$ ✓ ✓ JPD 5/17/82

$P = 3.8$ ✓

$C_p = 0.239$ ✓

MSM CONSULTANTS, INC. DENVER, COLORADO

By RC Date 5/7/82 PROJECT BOULDER F.I.S. Sheet No. ___ of ___

Checked By RPK Date 5/13/82 GOOSE CREEK Job No. 4834916

BASIN 704

AREA = 77 ac = 0.12 mi^2

L = 3500 ft = 0.66 mi.

$S = \frac{5345 - 5290}{3500 - 0} = 1.6\%$

S_o = 1.6% ✓

L_{CA} = 1100 ft. = 0.21 mi.

% Impervious = 41%

C_t = 0.093 ✓

$C_{t(Program)}$ = 0.176 ✓

✓ JPD 5/17/82

P = 5.7 ✓

C_p = 0.386 ✓

FLOOD INSURANCE STUDY

BOULDER COUNTY, COLORADO
AND INCORPORATED AREAS
VOLUME 1 OF 5

08013CV001

COMMUNITY NAME	COMMUNITY NUMBER
BOULDER,CITY OF	080024
BOULDER COUNTY,CO UNINCORPORATED AREAS	080023
JAMESTOWN,TOWN OF	080216
LAFAYETTE,CITY OF	080026
LONGMONT,CITY OF	080027
LOUISVILLE,CITY OF	085076
LYONS,TOWN OF	080029
NEDERLAND,TOWN OF	080255
SUPERIOR,TOWN OF	080203
WARD, TOWN OF	080292*

* NON-FLOOD PRONE COMMUNITIES

REVISED: OCTOBER 4, 2002

Federal Emergency Management Agency

and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed methods affecting the community.

Hydrologic data from the various engineering reports discussed in Section 7.0 have been used extensively for the revised study of Boulder County, including peak discharges and starting water-surface elevations.

Because no stream gage data are available for the study streams through the City of Boulder, a rainfall-runoff analysis was conducted on the watersheds to determine the flood discharges. This was accomplished by using the UDFCD CUHP-B rainfall-runoff computer program to develop the storm hydrographs (Reference 27) and the USACE HEC-1 computer program for the stream and reservoir routings (Reference 28). For the analysis, basin characteristics of the watershed, as well as rainfall amounts based on the selected recurrence intervals, are used to compute flood hydrographs for various design points in the basin. All stream and reservoir routings were accomplished using the Modified Puls Method.

The 500-year storm runoff values for various locations along each stream were extrapolated from the discharge-frequency curves.

A more detailed description of the input variables for the CUHP-B and the HEC-1 rainfall-runoff analysis, as well as the CUHP-B computer output and the summary of the final HEC-1 computer output, are located in a technical addendum to this Flood Insurance Study (Reference 29).

Peak discharges for Gregory Creek, Bluebell Canyon Creek, Kings Gulch, Viele Channel, Anderson Channel, and Davids Draw were taken from reports prepared by Wright-McLaughlin Engineers (References 17 and 30) as part of a plan to manage the city's storm drainage.

Discharges for James Creek and the downstream portion of Little James Creek through the Town of Jamestown were taken from a USACE report (Reference 31). Technical Manual No. 1, developed by the

USGS (Reference 32), was used to obtain peak discharges on the upstream portion of Little James Creek and Unnamed Tributary to Little James Creek.

Hydrologic data for flooding sources affecting the City of Lafayette and the Town of Superior are based on the data generated for the October 1976 study of Coal Creek and Rock Creek, performed by the SCS (Reference 19). Since there are no stream flow records for Coal Creek and Rock Creek, the SCS used synthetic rainfall-runoff procedures to determine the flows for various frequency storms. Analyses were based on a storm duration of 24 hours, Type II and IIA distribution, as described in the SCS National Engineering Handbook, Section 4 (Reference 33). The amount of rainfall was obtained from the precipitation frequency atlas (Reference 34), and areal adjustment was applied to convert the point precipitation values to average precipitation over the watershed area. The studies were conducted using runoff computations based on information regarding the type and location of existing and planned land use provided by the SCS (Reference 5). Hydrologic soil cover complexes and associated Runoff Curve Numbers were extracted from the SCS reports (Reference 14) and field checked. Values of 10-, 50-, 100-, and 500-year peak discharges were obtained using the SCS computer programs WSP2 and TR20 (References 35 and 36, respectively).

Frequency-discharge data for two of the streams studied in detail in the City of Longmont are based on information published in USACE Flood Plain Information reports for Lefthand and St. Vrain Creeks (References 7 and 8, respectively). The 100-year flood discharges on Lefthand Creek and St. Vrain Creek are 4,250 cfs and 10,200 cfs, respectively. The 500-year flood discharges for these two streams equal the discharges for the standard project floods as published in the Flood Plain Information reports (References 7 and 8). These relationships are based on a Log-Pearson Type III analysis of peak runoff data recorded at gages on St. Vrain Creek near Lyons and Platteville, Colorado (Reference 37). The years of record vary from 79 years at the Lyons gage to 47 years at the Platteville gage.

Discharge-frequency relationships for Dry Creek No. 1 and Spring Gulch were computed using the USACE HEC-1 Flood Hydrograph Package (Reference 38). Synthetic flood hyrographs computed by this method reflect the effects of characteristics of the basin: precipitation, ground cover, slope, drainage area, and other physical characteristics of the drainage basin. Where available, hydrologic data were compared with other studies completed in the area (References 39 and 40). The effects of detention storage near State Highway 66 and at Long Peak Dam on Spring Gulch were studied (Reference 39) and found to be insignificant for the magnitude of the floods considered in the study. That portion of the Spring Gulch Basin located north and east of Terry Lake is considered to be containted completely by Terry Lake.

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

Rainfall data for the synthetic hydrologic analysis were taken from a rainfall/runoff information report (Reference 41). The discharges computed using the HEC-1 program were verified using the Plains Region equations developed by the USGS (Reference 32). Peak discharges were also verified by the SCS runoff prediction method (Reference 42).

Discharges for the 500-year floods of all streams were checked by straight-line extrapolation of frequencies previously determined using the procedure of the USGS (References 9 and 10), and compared to the USACE Standard Project Flood data when available. The hydrologic analyses for this study were revised to include information presented in floodplain information reports for Lefthand Creek, Dry Creek No. 1, and St. Vrain Creek (References 1 through 4).

The Lyons streamflow gage, located on the left bank of St. Vrain Creek 0.4 mile downstream from the confluence of North St. Vrain Creek and South St. Vrain Creek, has been in operation since 1895. The flows recorded are partly regulated by small diversions above the gage station. Significant peak flood discharges and stages recorded during this period are presented in Table 2 (Reference 43).

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

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

This report is based upon data generated for the June 1972 and September 1972 studies of Lower and Upper St. Vrain Creek by the USACE (References 8 and 44, respectively).

The discharge-frequency relationships in the St. Vrain Creek basin at the Town of Lyons were based on a statistical analysis of the stream gaging records of the St. Vrain Creek at Lyons. Synthetic unit hydrographs were developed for the St. Vrain Creek basin and its subdrainage basins of North St. Vrain Creek and South St. Vrain Creek to help define the flow characteristics within the basin. The hydrographs were used for stream routing through Button Rock Dam to Lyons, and downstream from Lyons to determine the discharges throughout the length of the stream.

A continuous record of flows at the USGS Nederland gage, located on Middle Boulder Creek, is available from 1907 to the present. Significant peak flood discharges and stages during the period from 1945 to 1975 are presented in Table 3. Flow measurements prior to 1945 could not be verified as being either average daily measurements or daily peak measurements. Following U.S. Water Resources Council Bulletin 17, (Reference 45), discharge-frequency relationships in the Middle Boulder Creek Basin were determined by statistical analysis of the stream gaging records of Middle Boulder Creek at Nederland, using 32 years of record and a weighted skew coefficient of -0.252.

For North Beaver Creek, peak discharges for the respective frequencies were determined using USGS Technical Manual No. 1 (Reference 32).

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

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

Year	Date	Stage Feet	Maximum Discharge Cubic Feet per Second
1949	June 13, 1949	4.66	674
1951	June 18, 1951	4.75	800
1953	June 13, 1953	3.98	730
1957	June 29, 1957	4.25	745
1965	July 24, 1965	4.25	640

Peak discharge-drainage area relationships for all flooding sources studied by detailed methods are shown in Table 4.

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals.

For flooding sources studied by detailed methods as part of the previous Flood Insurance Study for the unincorporated areas of Boulder County, hydraulic analyses were developed from the various engineering discussed in Section 7.0, and have been incorporated into this study of Boulder County.

Table 4. Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
Elmers Twomile Creek					
At Confluence With Goose Creek	0.52	280	630	790	1,450
At Iris Avenue	0.31	270	510	610	990
At Upstream Limit of Detailed Study	0.12	110	210	250	400
Fourmile Creek					
At Mouth	25.0	1,420	4,440	6,230	11,640
Fourmile Canyon Creek					
At Confluence With Boulder Creek	10.03	920	2,890	3,960	8,900
At Longmont Diagonal	9.09	1,050	2,805	3,930	7,600
At 28th Street	8.60	1,000	2,850	3,920	8,200
At Broadway	7.92	830	2,530	3,520	7,600
At Upstream Limit of Detailed Study	3.93	350	1,170	1,750	4,000
Gay Reservoir Channel					
At Confluence With Big Dry Creek	2.60	915	1,525	1,820	2,650
Gay Reservoir Channel North Tributary					
Above Confluence With City Park Channel	--[1]	225	370	440	640
Goose Creek					
At Confluence With Boulder Creek	5.46	2,865	5,065	6,315	9,325
At Confluence With Elmers Twomile Creek	3.63	1,050	2,100	2,680	4,300
At Confluence With Twomile Canyon Creek	1.32	670	1,270	1,590	2,400
At 19th Street	1.28	700	1,320	1,600	2,450
At Upstream Limit of Detailed Study	0.48	260	520	620	1,000
Indian Peaks					
Upstream Bullhead Confluence	0.49	--[1]	--[1]	447	--[1]
At 95th Culvert	0.43	--[1]	--[1]	419	--[1]
At Upstream Limit of Detailed Study	0.18	--[1]	--[1]	163	--[1]
North Goose Creek					
At Confluence With Goose Creek	--[1]	3,865	3,865	3,865	6,075

--[1]Data Not Available
--[2]Split Flow From Goose Creek

Table 4. Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
North Beaver Creek					
At Cross Section A	5.3	74	117	135	185
At Cross Section T	5.0	70	112	129	178
Prince Tributary					
Below Bullhead Confluence	8.16	--[1]	--[1]	4,772	--[1]
Above Bullhead Confluence	2.55	--[1]	--[1]	2,130	--[1]
At Upstream Limit of Detailed Study	0.58	--[1]	--[1]	423	--[1]
Rock Creek					
At Confluence With Coal Creek	21.6	2,870	5,350	6,690	10,240
At Downstream Corporate Limits	21.5	2,900	5,400	6,710	10,270
At South 120th Street	21.3	2,910	5,410	6,740	10,310
At Upstream Corporate Limits	18.7	2,900	5,360	6,640	10,050
At Denver-Boulder Turnpike	9.3	1,256	3,229	4,520	9,176
At McCaslin Boulevard	4.9	594	1,800	2,717	7,000
At Upstream Limit of Detailed Study	4.1	504	1,587	2,396	6,182
Skunk Creek					
At Confluence With Bear Canyon Creek	2.83	980	1,830	2,230	3,500
At Madison Avenue	2.43	920	1,580	1,870	2,650
At U.S. Highway 36	2.08	650	1,130	1,350	1,900
At Broadway	1.36	210	520	710	1,320
At Upstream Limit of Detailed Study	1.20	180	460	640	1,200
St. Vrain Creek (Vicinity of Longmont)					
At Mouth	924.0	5,350	12,120	16,520	40,080
St. Vrain Creek (Vicinity of Lyons)					
At Second Avenue	219.0	2,070	6,000	10,200	36,000
Twomile Creek					
At Confluence With Goose Creek	2.9	360	840	1,120	2,000
At Broadway	1.68	210	675	890	1,800
At Upstream Limit of Detailed Study	1.40	210	540	710	1,430

Appendix B –
Duplicate Effective CUHP Input/Output

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	10 160	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	5.47		0.143		0.143		0.325
602	3	10 165	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	22.14		0.108		0.108		0.275
603	3	10 170	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	38.82		0.094		0.094		0.456
701	3	10 165_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	24.12		0.105		0.105		0.311
702	3	10 170_702	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	39.82		0.093		0.093		0.502
703	3	10 170_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	25.19		0.104		0.184		0.219
704	3	10 170_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	38.82		0.094		0.118		0.367

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.143	0.325	71.4	18.15	37.2	12.83	30.3	588	3,252,480	0.40	1,315,725	67.0	194	1,315,728
602		0.108	0.275	25.3	5.66	13.2	4.00	9.4	332	650,496	0.64	418,120	37.0	135	418,118
603		0.094	0.456	23.5	8.21	12.2	5.49	14.2	652	1,184,832	0.92	1,088,840	39.0	346	1,088,775
701		0.105	0.311	30.5	7.58	15.9	5.36	12.6	472	1,115,136	0.79	882,342	41.0	236	882,312
702		0.093	0.502	21.0	7.35	10.9	4.92	14.0	1,142	1,858,560	0.93	1,734,426	39.0	595	1,734,108
703		0.184	0.219	35.0	6.20	18.2	4.38	10.3	34	92,928	0.78	72,673	41.0	16	72,669
704		0.118	0.367	15.7	4.72	8.2	3.34	7.9	230	278,784	1.02	283,963	33.0	115	283,955

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	50 220	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	5.84		0.141		0.141		0.323
602	3	50 230	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	22.88		0.107		0.107		0.279
603	3	50 230_603	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.32		0.093		0.093		0.463
701	3	50 230_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	24.86		0.105		0.105		0.316
702	3	50 230_702	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	40.32		0.093		0.093		0.509
703	3	50 230_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	25.86		0.103		0.182		0.223
704	3	50 240_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	39.38		0.093		0.117		0.373

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.141	0.323	71.2	17.98	37.0	12.70	30.0	589	3,252,480	1.06	3,444,776	70.0	549	3,444,776
602		0.107	0.279	24.8	5.61	12.9	3.97	9.4	339	650,496	1.36	882,234	42.0	294	882,236
603		0.093	0.463	23.1	8.07	12.0	5.40	14.2	663	1,184,832	1.58	1,873,114	44.0	633	1,873,033
701		0.105	0.316	29.8	7.53	15.5	5.32	12.5	484	1,115,136	1.50	1,672,776	46.0	479	1,672,755
702		0.093	0.509	20.7	7.24	10.8	4.84	14.0	1,160	1,858,560	1.60	2,964,476	44.0	1,076	2,964,172
703		0.182	0.223	34.3	6.16	17.8	4.36	10.3	35	92,928	1.44	133,872	47.0	34	133,867
704		0.117	0.373	15.4	4.71	8.0	3.33	7.8	234	278,784	1.78	496,847	38.0	208	496,880

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	100 245	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	5.95		0.141		0.141		0.322
602	3	100 255	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	23.07		0.107		0.107		0.281
603	3	100 265	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.52		0.093		0.093		0.465
701	3	100 255_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	25.05		0.104		0.104		0.317
702	3	100 260	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	40.50		0.093		0.093		0.511
703	3	100 265_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	26.12		0.103		0.182		0.224
704	3	100 265_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	39.52		0.093		0.117		0.375

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.141	0.322	71.2	17.93	37.0	12.67	29.9	590	3,252,480	1.38	4,490,438	72.0	717	4,490,413
602		0.107	0.281	24.6	5.60	12.8	3.96	9.3	341	650,496	1.67	1,085,569	43.0	355	1,085,513
603		0.093	0.465	22.9	8.02	11.9	5.36	14.1	668	1,184,832	1.99	2,355,977	45.0	792	2,355,854
701		0.104	0.317	29.6	7.51	15.4	5.31	12.5	487	1,115,136	1.81	2,020,681	46.0	574	2,020,692
702		0.093	0.511	20.6	7.21	10.7	4.82	14.0	1,166	1,858,560	1.95	3,624,203	44.0	1,308	3,623,861
703		0.182	0.224	34.0	6.15	17.7	4.34	10.2	35	92,928	1.86	172,485	47.0	43	172,481
704		0.117	0.375	15.3	4.71	8.0	3.33	7.8	235	278,784	2.09	581,615	38.0	243	581,666

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	100 245	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	6.14		0.140		0.140		0.321
602	3	100 255	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	23.43		0.106		0.106		0.283
603	3	100 265	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.78		0.093		0.093		0.469
701	3	100 255_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	25.42		0.104		0.104		0.320
702	3	100 260	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	40.76		0.093		0.093		0.514
703	3	100 265_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	26.45		0.103		0.181		0.226
704	3	100 265_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	39.80		0.093		0.117		0.378

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.140	0.321	71.1	17.84	37.0	12.61	29.7	591	3,252,480	1.99	6,481,835	71.0	1,021	6,481,712
602		0.106	0.283	24.3	5.58	12.6	3.94	9.3	345	650,496	2.33	1,514,620	42.0	489	1,514,416
603		0.093	0.469	22.7	7.95	11.8	5.32	14.1	673	1,184,832	2.64	3,127,666	45.0	1,043	3,127,546
701		0.104	0.320	29.2	7.49	15.2	5.29	12.5	492	1,115,136	2.48	2,765,325	46.0	780	2,765,338
702		0.093	0.514	20.4	7.16	10.6	4.78	13.9	1,174	1,858,560	2.59	4,814,884	44.0	1,723	4,814,466
703		0.181	0.226	33.6	6.13	17.5	4.33	10.2	36	92,928	2.50	232,710	47.0	58	232,707
704		0.117	0.378	15.2	4.70	7.9	3.32	7.8	237	278,784	2.82	784,970	38.0	326	785,027

Appendix C –
Duplicate Effective SWMM Input/Output

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	128.402	41.842
External Outflow	126.737	41.299
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	2.470	0.805
Continuity Error (%)	-0.627	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	1.51	2.19	5580.19	0 01:54
602	JUNCTION	1.47	2.18	5447.18	0 02:07
603	JUNCTION	0.31	0.48	5315.48	0 01:48
703	JUNCTION	1.44	3.74	5314.74	0 01:09
702	JUNCTION	1.41	3.78	5343.78	0 01:01
701	JUNCTION	0.20	0.57	5382.57	0 00:54
703a	JUNCTION	3.36	6.35	5317.35	0 01:08
704	OUTFALL	3.31	6.34	5287.34	0 01:13

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	96.00	96.00	0 01:54	8.328	8.326
602	JUNCTION	93.33	129.50	0 01:39	3.128	11.213
603	JUNCTION	190.07	279.79	0 01:01	8.145	19.131
703	JUNCTION	19.53	466.80	0 01:09	0.544	20.217
702	JUNCTION	313.39	464.96	0 01:01	12.973	19.623
701	JUNCTION	154.68	154.68	0 00:54	6.600	6.600
703a	JUNCTION	0.00	740.29	0 01:08	0.000	39.348
704	OUTFALL	89.65	779.54	0 01:12	2.124	41.296

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	262.55	779.54	41.296
System	97.23	262.55	779.54	41.296

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	95.58	0	02:07	3.84	0.01	0.11
102	CONDUIT	128.90	0	01:48	7.67	0.00	0.02
103	DUMMY	279.79	0	01:01			
201	CONDUIT	151.76	0	01:02	6.04	0.00	0.03
202	CONDUIT	454.21	0	01:09	3.54	0.03	0.19
203	CONDUIT	736.57	0	01:13	4.87	0.06	0.32
703	DUMMY	466.80	0	01:09			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Dec 08 09:42:51 2011
Analysis ended on: Thu Dec 08 09:42:52 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	128.402	41.842
External Outflow	126.737	41.299
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	2.470	0.805
Continuity Error (%)	-0.627	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	1.51	2.19	5580.19	0 01:54
602	JUNCTION	1.47	2.18	5447.18	0 02:07
603	JUNCTION	0.31	0.48	5315.48	0 01:48
703	JUNCTION	1.44	3.74	5314.74	0 01:09
702	JUNCTION	1.41	3.78	5343.78	0 01:01
701	JUNCTION	0.20	0.57	5382.57	0 00:54
703a	JUNCTION	3.36	6.35	5317.35	0 01:08
704	OUTFALL	3.31	6.34	5287.34	0 01:13

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	96.00	96.00	0 01:54	8.328	8.326
602	JUNCTION	93.33	129.50	0 01:39	3.128	11.213
603	JUNCTION	190.07	279.79	0 01:01	8.145	19.131
703	JUNCTION	19.53	466.80	0 01:09	0.544	20.217
702	JUNCTION	313.39	464.96	0 01:01	12.973	19.623
701	JUNCTION	154.68	154.68	0 00:54	6.600	6.600
703a	JUNCTION	0.00	740.29	0 01:08	0.000	39.348
704	OUTFALL	89.65	779.54	0 01:12	2.124	41.296

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	262.55	779.54	41.296
System	97.23	262.55	779.54	41.296

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	95.58	0 02:07	3.84	0.01	0.11
102	CONDUIT	128.90	0 01:48	7.67	0.00	0.02
103	DUMMY	279.79	0 01:01			
201	CONDUIT	151.76	0 01:02	6.04	0.00	0.03
202	CONDUIT	454.21	0 01:09	3.54	0.03	0.19
203	CONDUIT	736.57	0 01:13	4.87	0.06	0.32
703	DUMMY	466.80	0 01:09			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Dec 08 09:47:08 2011
Analysis ended on: Thu Dec 08 09:47:08 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	313.057	102.014
External Outflow	308.548	100.545
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	5.483	1.787
Continuity Error (%)	-0.311	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.66	3.87	5581.87	0 01:53
602	JUNCTION	2.60	3.86	5448.86	0 02:02
603	JUNCTION	0.61	0.96	5315.96	0 01:46
703	JUNCTION	2.06	5.74	5316.74	0 01:14
702	JUNCTION	2.04	5.78	5345.78	0 01:07
701	JUNCTION	0.32	0.95	5382.95	0 01:01
703a	JUNCTION	4.97	9.35	5320.35	0 01:14
704	OUTFALL	4.89	9.34	5290.34	0 01:18

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	336.04	336.04	0 01:53	28.409	28.400
602	JUNCTION	250.94	430.07	0 01:40	8.120	35.915
603	JUNCTION	452.70	778.97	0 01:20	17.623	52.995
703	JUNCTION	49.53	1121.91	0 01:13	1.290	43.632
702	JUNCTION	720.83	1101.34	0 01:07	27.108	42.281
701	JUNCTION	383.58	383.58	0 01:01	15.115	15.115
703a	JUNCTION	0.00	1896.42	0 01:14	0.000	96.626
704	OUTFALL	191.23	1988.06	0 01:16	4.350	100.537

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	637.38	1988.06	100.537
System	97.50	637.38	1988.06	100.537

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	335.14	0 02:02	5.27	0.02	0.19
102	CONDUIT	429.24	0 01:46	11.38	0.00	0.05
103	DUMMY	778.97	0 01:20			
201	CONDUIT	380.63	0 01:06	8.18	0.00	0.05
202	CONDUIT	1088.42	0 01:14	4.46	0.06	0.29
203	CONDUIT	1891.96	0 01:18	6.15	0.15	0.47
703	DUMMY	1121.91	0 01:13			

****
Conduit Surcharge Summary
****

Conduit	Hours Full: Both Ends	Hours Full: Upstream	Hours Full: Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Wed Oct 26 15:01:50 2011
Analysis ended on: Wed Oct 26 15:01:50 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	133.045	43.355
External Outflow	133.877	43.626
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.441	0.144
Continuity Error (%)	-0.957	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	1.41	3.03	5581.03	0 01:07
602	JUNCTION	1.46	3.01	5448.01	0 01:18
603	JUNCTION	0.32	0.71	5315.71	0 01:20
703	JUNCTION	1.25	4.73	5315.73	0 00:50
702	JUNCTION	1.19	4.87	5344.87	0 00:42
701	JUNCTION	0.17	0.72	5382.72	0 00:41
703a	JUNCTION	3.06	7.66	5318.66	0 00:49
704	OUTFALL	3.05	7.63	5288.63	0 00:53

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	194.17	194.17	0 01:07	9.841	9.841
602	JUNCTION	135.20	251.07	0 01:11	3.128	13.028
603	JUNCTION	346.27	440.22	0 00:42	8.144	21.194
703	JUNCTION	16.42	745.23	0 00:50	0.544	20.322
702	JUNCTION	595.39	772.08	0 00:42	12.971	19.642
701	JUNCTION	236.10	236.10	0 00:41	6.600	6.600
703a	JUNCTION	0.00	1164.27	0 00:49	0.000	41.516
704	OUTFALL	115.11	1213.53	0 00:53	2.124	43.623

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	277.32	1213.53	43.623
System	97.23	277.32	1213.53	43.623

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	190.94	0	01:18	4.60	0.01	0.15
102	CONDUIT	249.54	0	01:20	9.64	0.00	0.04
103	DUMMY	440.22	0	00:42			
201	CONDUIT	224.62	0	00:48	6.96	0.00	0.03
202	CONDUIT	729.92	0	00:50	4.10	0.04	0.24
203	CONDUIT	1152.56	0	00:53	5.46	0.09	0.38
703	DUMMY	745.23	0	00:50			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Wed Oct 26 16:12:22 2011
Analysis ended on: Wed Oct 26 16:12:22 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	263.252	85.784
External Outflow	264.046	86.043
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.540	0.176
Continuity Error (%)	-0.507	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.17	4.78	5582.78	0 01:10
602	JUNCTION	2.24	4.76	5449.76	0 01:18
603	JUNCTION	0.52	1.24	5316.24	0 01:17
703	JUNCTION	1.58	6.56	5317.56	0 00:53
702	JUNCTION	1.53	6.66	5346.66	0 00:46
701	JUNCTION	0.24	1.08	5383.08	0 00:46
703a	JUNCTION	4.08	10.33	5321.33	0 00:55
704	OUTFALL	4.07	10.32	5291.32	0 00:59

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	548.51	548.51	0 01:10	25.766	25.766
602	JUNCTION	294.11	692.37	0 01:11	6.599	32.469
603	JUNCTION	633.34	1036.71	0 01:07	14.010	46.498
703	JUNCTION	33.59	1469.73	0 00:53	1.001	35.860
702	JUNCTION	1076.41	1488.32	0 00:46	22.172	34.747
701	JUNCTION	478.98	478.98	0 00:46	12.512	12.512
703a	JUNCTION	0.00	2429.19	0 00:55	0.000	82.357
704	OUTFALL	208.41	2536.86	0 00:58	3.717	86.037

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	545.40	2536.86	86.037
System	97.50	545.40	2536.86	86.037

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	543.13	0	01:18	6.03	0.03	0.24
102	CONDUIT	688.59	0	01:17	13.24	0.00	0.06
103	DUMMY	1036.71	0	01:07			
201	CONDUIT	466.36	0	00:51	8.80	0.00	0.05
202	CONDUIT	1437.48	0	00:53	4.87	0.08	0.33
203	CONDUIT	2419.43	0	00:59	6.56	0.19	0.52
703	DUMMY	1469.73	0	00:53			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Dec 08 09:52:42 2011
Analysis ended on: Thu Dec 08 09:52:42 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	328.969	107.200
External Outflow	329.854	107.488
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.565	0.184
Continuity Error (%)	-0.441	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.45	5.36	5583.36	0 01:12
602	JUNCTION	2.51	5.34	5450.34	0 01:19
603	JUNCTION	0.60	1.43	5316.43	0 01:17
703	JUNCTION	1.71	7.20	5318.20	0 00:53
702	JUNCTION	1.65	7.31	5347.31	0 00:47
701	JUNCTION	0.27	1.19	5383.19	0 00:46
703a	JUNCTION	4.47	11.31	5322.31	0 00:56
704	OUTFALL	4.46	11.30	5292.30	0 01:00

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	717.11	717.11	0 01:12	33.588	33.588
602	JUNCTION	354.84	903.40	0 01:11	8.120	41.824
603	JUNCTION	792.29	1369.93	0 01:08	17.622	59.468
703	JUNCTION	43.24	1801.08	0 00:53	1.290	43.701
702	JUNCTION	1307.55	1813.19	0 00:47	27.106	42.291
701	JUNCTION	574.17	574.17	0 00:46	15.115	15.115
703a	JUNCTION	0.00	3041.73	0 00:56	0.000	103.169
704	OUTFALL	243.27	3175.60	0 00:58	4.351	107.480

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	681.32	3175.60	107.480
System	97.50	681.32	3175.60	107.480

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	711.29	0 01:19	6.44	0.04	0.27
102	CONDUIT	898.87	0 01:17	14.33	0.00	0.07
103	DUMMY	1369.93	0 01:08			
201	CONDUIT	562.18	0 00:52	9.32	0.00	0.06
202	CONDUIT	1759.22	0 00:53	5.11	0.10	0.36
203	CONDUIT	3033.63	0 01:00	6.93	0.24	0.56
703	DUMMY	1801.08	0 00:53			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Dec 08 09:54:17 2011
Analysis ended on: Thu Dec 08 09:54:17 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	452.718	147.525
External Outflow	453.633	147.823
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.639	0.208
Continuity Error (%)	-0.343	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.89	6.22	5584.22	0 01:11
602	JUNCTION	2.96	6.21	5451.21	0 01:18
603	JUNCTION	0.73	1.72	5316.72	0 01:15
703	JUNCTION	1.96	8.26	5319.26	0 00:52
702	JUNCTION	1.91	8.36	5348.36	0 00:46
701	JUNCTION	0.32	1.41	5383.41	0 00:46
703a	JUNCTION	5.12	12.82	5323.82	0 00:55
704	OUTFALL	5.10	12.81	5293.81	0 00:58

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	1020.62	1020.62	0 01:11	48.483	48.483
602	JUNCTION	488.84	1289.79	0 01:10	11.328	59.946
603	JUNCTION	1043.25	1922.32	0 01:07	23.394	83.354
703	JUNCTION	58.17	2421.84	0 00:52	1.741	58.634
702	JUNCTION	1722.61	2429.04	0 00:46	36.012	56.768
701	JUNCTION	780.15	780.15	0 00:46	20.685	20.685
703a	JUNCTION	0.00	4162.28	0 00:55	0.000	141.988
704	OUTFALL	326.06	4347.75	0 00:57	5.872	147.812

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.78	934.33	4347.75	147.812
System	97.78	934.33	4347.75	147.812

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	1014.17	0	01:18	7.02	0.05	0.31
102	CONDUIT	1284.62	0	01:15	15.89	0.00	0.09
103	DUMMY	1922.32	0	01:07			
201	CONDUIT	767.61	0	00:51	10.26	0.00	0.07
202	CONDUIT	2365.35	0	00:52	5.51	0.13	0.41
203	CONDUIT	4153.22	0	00:58	7.49	0.32	0.64
703	DUMMY	2421.84	0	00:52			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Oct 27 13:07:43 2011
Analysis ended on: Thu Oct 27 13:07:43 2011

Appendix D –
Calibrated CUHP Input/Output

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	10 160	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	5.47		0.143		0.143	0.325364881	0.325
602	3	10 165	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	22.14		0.108		0.108	0.178993328	0.179
603	3	10 170	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	38.82		0.094		0.094	0.091236355	0.091
701	3	10 165_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	24.12		0.105		0.105	0.342127767	0.342
702	3	10 170_702	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	39.82		0.093		0.093	0.351515083	0.352
703	3	10 170_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	25.19		0.104		0.184	0.197404038	0.197
704	3	10 170_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	38.82		0.094		0.118	0.257026339	0.257

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.143	0.325	71.4	18.15	37.2	12.83	30.3	588	3,252,480	0.40	1,315,725	67.0	194	1,315,728
602		0.108	0.179	39.0	5.66	20.3	4.00	9.4	216	650,496	0.64	418,120	41.0	95	418,121
603		0.094	0.091	117.3	8.52	61.0	6.02	14.2	130	1,184,832	0.92	1,088,840	77.0	94	1,088,837
701		0.105	0.342	27.7	7.58	14.4	5.36	12.6	519	1,115,136	0.79	882,342	40.0	255	882,327
702		0.093	0.352	30.0	8.40	15.6	5.94	14.0	800	1,858,560	0.93	1,734,426	41.0	453	1,734,424
703		0.184	0.197	38.9	6.20	20.2	4.38	10.3	31	92,928	0.78	72,673	43.0	15	72,669
704		0.118	0.257	22.4	4.72	11.6	3.34	7.9	161	278,784	1.02	283,963	35.0	89	283,951

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	50 220	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	5.84		0.141		0.141	0.323073444	0.323
602	3	50 230	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	22.88		0.107		0.107	0.181661329	0.182
603	3	50 230_603	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.32		0.093		0.093	0.092548255	0.093
701	3	50 230_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	24.86		0.105		0.105	0.347672708	0.348
702	3	50 230_702	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	40.32		0.093		0.093	0.356225697	0.356
703	3	50 230_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	25.86		0.103		0.182	0.200376587	0.200
704	3	50 240_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	39.38		0.093		0.117	0.261184078	0.261

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.141	0.323	71.2	17.98	37.0	12.70	30.0	589	3,252,480	1.06	3,444,776	70.0	549	3,444,776
602		0.107	0.182	38.1	5.61	19.8	3.97	9.4	221	650,496	1.36	882,234	47.0	212	882,219
603		0.093	0.093	115.3	8.50	60.0	6.00	14.2	133	1,184,832	1.58	1,873,114	71.0	178	1,873,105
701		0.105	0.348	27.1	7.53	14.1	5.32	12.5	532	1,115,136	1.50	1,672,776	45.0	515	1,672,755
702		0.093	0.356	29.6	8.38	15.4	5.93	14.0	812	1,858,560	1.60	2,964,476	46.0	833	2,964,443
703		0.182	0.200	38.1	6.16	19.8	4.36	10.3	31	92,928	1.44	133,872	48.0	31	133,869
704		0.117	0.261	22.0	4.71	11.4	3.33	7.8	164	278,784	1.78	496,847	40.0	164	496,783

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	100 245	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	5.95		0.141		0.141	0.322433066	0.322
602	3	100 255	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	23.07		0.107		0.107	0.182376812	0.182
603	3	100 265	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.52		0.093		0.093	0.09307497	0.093
701	3	100 255_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	25.05		0.104		0.104	0.349155854	0.349
702	3	100 260	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	40.50		0.093		0.093	0.357560026	0.358
703	3	100 265_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	26.12		0.103		0.182	0.201570045	0.202
704	3	100 265_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	39.52		0.093		0.117	0.26220599	0.262

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.141	0.322	71.2	17.93	37.0	12.67	29.9	590	3,252,480	1.38	4,490,438	72.0	717	4,490,413
602		0.107	0.182	37.8	5.60	19.7	3.96	9.3	222	650,496	1.67	1,085,569	48.0	259	1,085,553
603		0.093	0.093	114.6	8.49	59.6	6.00	14.1	134	1,184,832	1.99	2,355,977	72.0	232	2,355,971
701		0.104	0.349	26.9	7.51	14.0	5.31	12.5	535	1,115,136	1.81	2,020,681	45.0	616	2,020,576
702		0.093	0.358	29.4	8.38	15.3	5.92	14.0	816	1,858,560	1.95	3,624,203	47.0	1,016	3,624,072
703		0.182	0.202	37.8	6.15	19.6	4.34	10.2	32	92,928	1.86	172,485	49.0	40	172,482
704		0.117	0.262	21.9	4.71	11.4	3.33	7.8	165	278,784	2.09	581,615	41.0	192	581,538

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	100 245	1.4	1.35	2.41	0.059	7	0.5	0.1	3	0.0018	0.5	0		0.14		0.07	6.14		0.140		0.140	0.321307774	0.321
602	3	100 255	0.28	0.51	0.86	0.05	25	0.4	0.1	4	0.0018	0.6	0		0.50		0.15	23.43		0.106		0.106	0.183755397	0.184
603	3	100 265	0.51	0.76	1.48	0.031	41	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.78		0.093		0.093	0.09376056	0.094
701	3	100 255_701	0.48	0.59	1.52	0.053	27	0.4	0.1	3	0.0018	0.5	0		0.54		0.16	25.42		0.104		0.104	0.352009504	0.352
702	3	100 260	0.8	0.66	1.44	0.023	42	0.4	0.1	4	0.0018	0.6	0		0.81		0.21	40.76		0.093		0.093	0.359558703	0.360
703	3	100 265_703	0.04	0.28	0.52	0.034	28	0.5	0.1	3	0.0018	0.5	0		0.56		0.16	26.45		0.103		0.181	0.20312331	0.203
704	3	100 265_704	0.12	0.21	0.66	0.016	41	0.4	0.1	3	0.0018	0.5	0		0.81		0.20	39.80		0.093		0.117	0.264315046	0.264

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.140	0.321	71.1	17.84	37.0	12.61	29.7	591	3,252,480	1.99	6,481,835	71.0	1,021	6,481,712
602		0.106	0.184	37.4	5.58	19.5	3.94	9.3	225	650,496	2.33	1,514,620	47.0	357	1,514,599
603		0.093	0.094	113.6	8.48	59.1	5.99	14.1	135	1,184,832	2.64	3,127,666	72.0	308	3,127,657
701		0.104	0.352	26.6	7.49	13.8	5.29	12.5	542	1,115,136	2.48	2,765,325	45.0	836	2,765,070
702		0.093	0.360	29.2	8.36	15.2	5.91	13.9	822	1,858,560	2.59	4,814,884	46.0	1,340	4,814,605
703		0.181	0.203	37.4	6.13	19.4	4.33	10.2	32	92,928	2.50	232,710	48.0	54	232,705
704		0.117	0.264	21.7	4.70	11.3	3.32	7.8	166	278,784	2.82	784,970	40.0	258	784,903

Appendix E –
Calibrated SWMM Input/Output

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	131.859	42.968
External Outflow	132.328	43.121
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.690	0.225
Continuity Error (%)	-0.879	

****
Highest Flow Instability Indexes
****
Link 201 (1)
Link 202 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	1.41	3.03	5581.03	0 01:07
602	JUNCTION	1.45	3.01	5448.01	0 01:18
603	JUNCTION	0.32	0.71	5315.71	0 01:22
703	JUNCTION	1.27	4.45	5315.45	0 00:52
702	JUNCTION	1.22	4.56	5344.56	0 00:44
701	JUNCTION	0.17	0.75	5382.75	0 00:40
703a	JUNCTION	3.30	6.83	5317.83	0 00:58
704	OUTFALL	3.26	6.82	5287.82	0 01:03

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	194.17	194.17	0 01:07	9.841	9.841
602	JUNCTION	94.97	253.54	0 01:15	3.128	13.028
603	JUNCTION	94.25	345.77	0 01:22	7.757	20.795
703	JUNCTION	15.10	657.68	0 00:52	0.544	20.312
702	JUNCTION	453.15	676.18	0 00:44	12.973	19.646
701	JUNCTION	255.17	255.17	0 00:40	6.600	6.600
703a	JUNCTION	0.00	882.74	0 00:58	0.000	41.107
704	OUTFALL	88.91	930.56	0 01:02	2.124	43.118

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	274.12	930.56	43.118
System	97.23	274.12	930.56	43.118

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	190.94	0	01:18	4.60	0.01	0.15
102	CONDUIT	251.99	0	01:22	9.67	0.00	0.04
103	DUMMY	345.77	0	01:22			
201	CONDUIT	241.27	0	00:47	7.15	0.00	0.04
202	CONDUIT	643.66	0	00:52	3.94	0.04	0.22
203	CONDUIT	879.64	0	01:03	5.08	0.07	0.34
703	DUMMY	657.68	0	00:52			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Upstream	Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Oct 27 09:00:54 2011
Analysis ended on: Thu Oct 27 09:00:54 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	261.393	85.179
External Outflow	261.709	85.282
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.913	0.297
Continuity Error (%)	-0.470	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.17	4.78	5582.78	0 01:10
602	JUNCTION	2.23	4.76	5449.76	0 01:18
603	JUNCTION	0.52	1.24	5316.24	0 01:20
703	JUNCTION	1.61	6.20	5317.20	0 00:56
702	JUNCTION	1.56	6.29	5346.29	0 00:48
701	JUNCTION	0.23	1.12	5383.12	0 00:45
703a	JUNCTION	4.36	9.45	5320.45	0 01:04
704	OUTFALL	4.31	9.44	5290.44	0 01:08

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	548.51	548.51	0 01:10	25.766	25.766
602	JUNCTION	212.11	690.27	0 01:15	6.599	32.468
603	JUNCTION	177.65	862.68	0 01:20	13.406	45.885
703	JUNCTION	31.01	1305.71	0 00:56	1.001	35.848
702	JUNCTION	832.87	1317.34	0 00:48	22.174	34.749
701	JUNCTION	514.85	514.85	0 00:45	12.512	12.512
703a	JUNCTION	0.00	1947.09	0 01:04	0.000	81.733
704	OUTFALL	164.36	2040.11	0 01:06	3.716	85.276

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	540.59	2040.11	85.276
System	97.50	540.59	2040.11	85.276

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	543.13	0	01:18	6.03	0.03	0.24
102	CONDUIT	687.63	0	01:20	13.25	0.00	0.06
103	DUMMY	862.68	0	01:20			
201	CONDUIT	499.31	0	00:50	9.01	0.00	0.06
202	CONDUIT	1276.11	0	00:56	4.71	0.07	0.31
203	CONDUIT	1942.85	0	01:08	6.20	0.15	0.47
703	DUMMY	1305.71	0	00:56			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Oct 27 10:24:42 2011
Analysis ended on: Thu Oct 27 10:24:42 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	326.734	106.471
External Outflow	327.068	106.580
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	1.010	0.329
Continuity Error (%)	-0.411	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.45	5.36	5583.36	0 01:12
602	JUNCTION	2.51	5.34	5450.34	0 01:19
603	JUNCTION	0.60	1.43	5316.43	0 01:20
703	JUNCTION	1.75	6.81	5317.81	0 00:56
702	JUNCTION	1.70	6.90	5346.90	0 00:48
701	JUNCTION	0.26	1.24	5383.24	0 00:45
703a	JUNCTION	4.79	10.38	5321.38	0 01:06
704	OUTFALL	4.74	10.38	5291.38	0 01:10

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	717.11	717.11	0 01:12	33.588	33.588
602	JUNCTION	259.01	898.26	0 01:15	8.120	41.824
603	JUNCTION	231.60	1122.22	0 01:20	16.897	58.733
703	JUNCTION	40.03	1599.79	0 00:56	1.290	43.688
702	JUNCTION	1016.10	1602.33	0 00:48	27.108	42.291
701	JUNCTION	615.76	615.76	0 00:45	15.114	15.114
703a	JUNCTION	0.00	2457.36	0 01:06	0.000	102.422
704	OUTFALL	191.84	2571.69	0 01:08	4.350	106.572

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	675.59	2571.69	106.572
System	97.50	675.59	2571.69	106.572

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	711.29	0	01:19	6.44	0.04	0.27
102	CONDUIT	895.29	0	01:20	14.33	0.00	0.07
103	DUMMY	1122.22	0	01:20			
201	CONDUIT	601.08	0	00:51	9.54	0.00	0.06
202	CONDUIT	1561.22	0	00:56	4.94	0.09	0.34
203	CONDUIT	2454.78	0	01:10	6.57	0.19	0.52
703	DUMMY	1599.79	0	00:56			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Dec 08 10:01:47 2011
Analysis ended on: Thu Dec 08 10:01:47 2011

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.018)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****
Flow Units ..... CFS
Process Models:
  Rainfall/Runoff ..... NO
  Snowmelt ..... NO
  Groundwater ..... NO
  Flow Routing ..... YES
  Ponding Allowed ..... NO
  Water Quality ..... NO
Flow Routing Method ..... KINWAVE
Starting Date OCT-05-2011 00:00:00
Ending Date OCT-05-2011 06:00:00
Antecedent Dry Days 0.0
Report Time Step 00:15:00
Routing Time Step ..... 30.00 sec

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	449.884	146.601
External Outflow	450.149	146.688
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	1.188	0.387
Continuity Error (%)	-0.323	

****
Highest Flow Instability Indexes
****
Link 201 (1)
Link 202 (1)

****
Routing Time Step Summary
****
Minimum Time Step : 30.00 sec
Average Time Step : 30.00 sec
Maximum Time Step : 30.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.89	6.22	5584.22	0 01:11
602	JUNCTION	2.95	6.21	5451.21	0 01:18
603	JUNCTION	0.73	1.72	5316.72	0 01:19
703	JUNCTION	2.01	7.82	5318.82	0 00:54
702	JUNCTION	1.96	7.90	5347.90	0 00:48
701	JUNCTION	0.31	1.47	5383.47	0 00:45
703a	JUNCTION	5.47	11.79	5322.79	0 01:05
704	OUTFALL	5.42	11.78	5292.78	0 01:08

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	1020.62	1020.62	0 01:11	48.483	48.483
602	JUNCTION	357.29	1279.99	0 01:14	11.329	59.947
603	JUNCTION	307.79	1580.52	0 01:18	22.475	82.429
703	JUNCTION	53.88	2150.30	0 00:54	1.741	58.619
702	JUNCTION	1339.70	2146.85	0 00:48	36.013	56.768
701	JUNCTION	836.20	836.20	0 00:45	20.683	20.683
703a	JUNCTION	0.00	3373.09	0 01:05	0.000	141.048
704	OUTFALL	257.83	3532.84	0 01:06	5.871	146.677

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.78	927.19	3532.84	146.677
System	97.78	927.19	3532.84	146.677

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days	hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	1014.17	0	01:18	7.02	0.05	0.31
102	CONDUIT	1276.71	0	01:19	15.87	0.00	0.09
103	DUMMY	1580.52	0	01:18			
201	CONDUIT	820.62	0	00:50	10.49	0.00	0.07
202	CONDUIT	2098.06	0	00:54	5.33	0.12	0.39
203	CONDUIT	3369.65	0	01:08	7.11	0.26	0.59
703	DUMMY	2150.30	0	00:54			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Upstream	Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Oct 27 11:56:22 2011
Analysis ended on: Thu Oct 27 11:56:22 2011

Appendix F –
Corrected Effective Conditions CUHP Input/Output

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	10 160	1.38	1.35	2.41	0.059	6.1	0.5	0.1	3	0.0018	0.5	0		0.12		0.06	4.53		0.146		0.146	0.330763406	0.331
602	3	10 165	0.21	0.51	0.86	0.05	30.1	0.4	0.1	4	0.0018	0.6	0		0.60		0.17	26.76		0.103		0.108	0.189497357	0.189
603	3	10 170	0.36	0.57	1.14	0.031	40.7	0.4	0.1	4	0.0018	0.6	0		0.80		0.20	38.13		0.094		0.094	0.084938647	0.085
701	3	10 165_701	0.43	0.59	1.52	0.053	25.3	0.4	0.1	3	0.0018	0.5	0		0.51		0.15	21.90		0.108		0.108	0.321479971	0.321
702	3	10 170_702	0.98	0.66	1.44	0.023	41.5	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	38.92		0.094		0.094	0.353224703	0.353
703	3	10 170_703	0.07	0.28	0.52	0.034	33.8	0.5	0.1	3	0.0018	0.5	0		0.68		0.18	30.68		0.099		0.147	0.244833453	0.245
704	3	10 170_704	0.12	0.21	0.66	0.016	48.2	0.4	0.1	3	0.0018	0.5	0		0.84		0.22	45.76		0.090		0.113	0.297290871	0.297

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.146	0.331	72.0	18.59	37.4	13.13	31.0	575	3,206,016	0.18	572,760	66.0	91	572,757
602		0.108	0.189	37.0	5.68	19.2	4.01	9.5	170	487,872	0.49	240,094	40.0	56	240,093
603		0.094	0.085	97.1	6.64	50.5	4.69	11.1	111	836,352	0.65	543,707	62.0	54	543,708
701		0.108	0.321	30.2	7.77	15.7	5.49	12.9	427	998,976	0.49	488,402	41.0	141	488,395
702		0.094	0.353	30.0	8.44	15.6	5.96	14.1	980	2,276,736	0.65	1,483,904	41.0	393	1,483,903
703		0.147	0.245	25.1	5.01	13.0	3.54	8.4	84	162,624	0.58	94,261	37.0	28	94,255
704		0.113	0.297	18.6	4.56	9.7	3.22	7.6	193	278,784	0.83	231,850	34.0	83	231,810

Corrected Effective 10-yr Input

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	10 160	1.38	1.35	2.41	0.059	6.1	0.5	0.1	3	0.0018	0.5	0		0.12		0.06	4.74		0.145		0.145	0.329340418	0.329
602	3	10 165	0.21	0.51	0.86	0.05	30.1	0.4	0.1	4	0.0018	0.6	0		0.60		0.17	27.24		0.102		0.108	0.191617897	0.192
603	3	10 170	0.36	0.57	1.14	0.031	40.7	0.4	0.1	4	0.0018	0.6	0		0.80		0.20	38.52		0.094		0.094	0.085860393	0.086
701	3	10 165_701	0.43	0.59	1.52	0.053	25.3	0.4	0.1	3	0.0018	0.5	0		0.51		0.15	22.44		0.107		0.107	0.324952838	0.325
702	3	10 170_702	0.98	0.66	1.44	0.023	41.5	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.32		0.093		0.093	0.357236508	0.357
703	3	10 170_703	0.07	0.28	0.52	0.034	33.8	0.5	0.1	3	0.0018	0.5	0		0.68		0.18	31.14		0.099		0.146	0.247727486	0.248
704	3	10 170_704	0.12	0.21	0.66	0.016	48.2	0.4	0.1	3	0.0018	0.5	0		0.84		0.22	46.10		0.090		0.113	0.298990061	0.299

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.145	0.329	71.9	18.49	37.4	13.07	30.8	576	3,206,016	0.39	1,260,593	68.0	186	1,260,580
602		0.108	0.192	36.4	5.65	18.9	3.99	9.4	173	487,872	0.71	348,252	40.0	81	348,250
603		0.094	0.086	95.9	6.62	49.9	4.68	11.0	113	836,352	0.91	765,025	64.0	77	765,027
701		0.107	0.325	29.7	7.72	15.5	5.46	12.9	434	998,976	0.77	769,346	41.0	212	769,307
702		0.093	0.357	29.6	8.42	15.4	5.95	14.0	993	2,276,736	0.93	2,108,473	41.0	558	2,108,455
703		0.146	0.248	24.7	5.00	12.8	3.53	8.3	85	162,624	0.86	139,989	37.0	40	139,982
704		0.113	0.299	18.5	4.55	9.6	3.22	7.6	195	278,784	1.11	309,395	34.0	108	309,334

Corrected Effective 25-yr Input

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	50 220	1.38	1.35	2.41	0.059	6.1	0.5	0.1	3	0.0018	0.5	0		0.12		0.06	4.96		0.145		0.145	0.327916033	0.328
602	3	50 230	0.21	0.51	0.86	0.05	30.1	0.4	0.1	4	0.0018	0.6	0		0.60		0.17	27.70		0.102		0.107	0.193757059	0.194
603	3	50 230_603	0.36	0.57	1.14	0.031	40.7	0.4	0.1	4	0.0018	0.6	0		0.80		0.20	38.84		0.094		0.094	0.086651942	0.087
701	3	50 230_701	0.43	0.59	1.52	0.053	25.3	0.4	0.1	3	0.0018	0.5	0		0.51		0.15	22.89		0.107		0.107	0.327925887	0.328
702	3	50 230_702	0.98	0.66	1.44	0.023	41.5	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.62		0.093		0.093	0.360305249	0.360
703	3	50 230_703	0.07	0.28	0.52	0.034	33.8	0.5	0.1	3	0.0018	0.5	0		0.68		0.18	31.55		0.098		0.146	0.250368817	0.250
704	3	50 240_704	0.12	0.21	0.66	0.016	48.2	0.4	0.1	3	0.0018	0.5	0		0.84		0.22	46.43		0.090		0.113	0.300647954	0.301

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.145	0.328	71.8	18.39	37.3	12.99	30.6	576	3,206,016	0.80	2,575,622	71.0	415	2,575,581
602		0.107	0.194	35.8	5.63	18.6	3.98	9.4	176	487,872	1.15	561,078	46.0	141	561,062
603		0.094	0.087	94.9	6.61	49.3	4.67	11.0	114	836,352	1.33	1,109,170	65.0	123	1,109,173
701		0.107	0.328	29.3	7.68	15.2	5.43	12.8	440	998,976	1.17	1,173,566	46.0	347	1,173,559
702		0.093	0.360	29.3	8.41	15.2	5.94	14.0	1,003	2,276,736	1.31	2,977,594	46.0	849	2,977,498
703		0.146	0.250	24.3	4.98	12.7	3.52	8.3	86	162,624	1.27	207,055	42.0	65	207,052
704		0.113	0.301	18.4	4.54	9.6	3.21	7.6	196	278,784	1.54	428,815	39.0	157	428,772

Corrected Effective 50-yr Input

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	50 220	1.38	1.35	2.41	0.059	6.1	0.5	0.1	3	0.0018	0.5	0		0.12		0.06	5.07		0.144		0.144	0.327158625	0.327
602	3	50 230	0.21	0.51	0.86	0.05	30.1	0.4	0.1	4	0.0018	0.6	0		0.60		0.17	27.97		0.101		0.107	0.19498532	0.195
603	3	50 230_603	0.36	0.57	1.14	0.031	40.7	0.4	0.1	4	0.0018	0.6	0		0.80		0.20	39.02		0.094		0.094	0.087091781	0.087
701	3	50 230_701	0.43	0.59	1.52	0.053	25.3	0.4	0.1	3	0.0018	0.5	0		0.51		0.15	23.17		0.106		0.106	0.329866401	0.330
702	3	50 230_702	0.98	0.66	1.44	0.023	41.5	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	39.82		0.093		0.093	0.362394057	0.362
703	3	50 230_703	0.07	0.28	0.52	0.034	33.8	0.5	0.1	3	0.0018	0.5	0		0.68		0.18	31.76		0.098		0.145	0.251736247	0.252
704	3	50 240_704	0.12	0.21	0.66	0.016	48.2	0.4	0.1	3	0.0018	0.5	0		0.84		0.22	46.64		0.090		0.113	0.301676484	0.302

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.144	0.327	71.8	18.33	37.3	12.96	30.6	577	3,206,016	1.05	3,358,712	71.0	533	3,358,671
602		0.107	0.195	35.5	5.62	18.5	3.97	9.4	177	487,872	1.43	696,254	46.0	174	696,238
603		0.094	0.087	94.3	6.61	49.0	4.67	11.0	115	836,352	1.58	1,318,654	66.0	147	1,318,658
701		0.106	0.330	29.1	7.66	15.1	5.41	12.8	444	998,976	1.48	1,477,251	45.0	434	1,477,257
702		0.093	0.362	29.1	8.40	15.1	5.94	14.0	1,010	2,276,736	1.59	3,615,397	46.0	1,029	3,615,223
703		0.145	0.252	24.2	4.97	12.6	3.51	8.3	87	162,624	1.52	247,094	42.0	78	247,091
704		0.113	0.302	18.3	4.54	9.5	3.21	7.6	197	278,784	1.87	522,455	39.0	191	522,404

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	100 245	1.38	1.35	2.41	0.059	6.1	0.5	0.1	3	0.0018	0.5	0		0.12		0.06	5.17		0.144		0.144	0.326547304	0.327
602	3	100 255	0.21	0.51	0.86	0.05	30.1	0.4	0.1	4	0.0018	0.6	0		0.60		0.17	28.16		0.101		0.107	0.195884028	0.196
603	3	100 265	0.36	0.57	1.14	0.031	40.7	0.4	0.1	4	0.0018	0.6	0		0.80		0.20	39.22		0.094		0.094	0.087586188	0.088
701	3	100 255_701	0.43	0.59	1.52	0.053	25.3	0.4	0.1	3	0.0018	0.5	0		0.51		0.15	23.36		0.106		0.106	0.331183472	0.331
702	3	100 260	0.98	0.66	1.44	0.023	41.5	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	40.00		0.093		0.093	0.364198539	0.364
703	3	100 265_703	0.07	0.28	0.52	0.034	33.8	0.5	0.1	3	0.0018	0.5	0		0.68		0.18	32.01		0.098		0.145	0.253341885	0.253
704	3	100 265_704	0.12	0.21	0.66	0.016	48.2	0.4	0.1	3	0.0018	0.5	0		0.84		0.22	46.77		0.090		0.113	0.302322188	0.302

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.144	0.327	71.7	18.29	37.3	12.93	30.5	577	3,206,016	1.37	4,391,587	72.0	699	4,391,554
602		0.107	0.196	35.3	5.61	18.3	3.96	9.3	179	487,872	1.74	847,290	47.0	210	847,282
603		0.094	0.088	93.7	6.60	48.7	4.67	11.0	115	836,352	1.98	1,659,604	68.0	192	1,659,596
701		0.106	0.331	28.9	7.64	15.0	5.40	12.7	447	998,976	1.79	1,789,921	46.0	521	1,789,861
702		0.093	0.364	28.9	8.40	15.1	5.93	14.0	1,016	2,276,736	1.94	4,424,104	47.0	1,256	4,423,886
703		0.145	0.253	24.0	4.96	12.5	3.51	8.3	88	162,624	1.93	314,231	42.0	99	314,221
704		0.113	0.302	18.2	4.53	9.5	3.20	7.6	197	278,784	2.17	606,128	39.0	222	606,055

Basin Management
This sheet is used to enter the subcatchment parameters. The user may use all of Excel's cut and paste functions to build the model. The user may also use the Basin management sheet to enter subcatchments one at a time. The user should avoid entering values in columns where the heading is green.

The possible values for print modes are:
1 Catchment Summary Pages
2 Summary and Unit Hydrograph
3 Summary, Unit Hydrograph, and Storm Hydrograph

								Maximum Depression Storage (Watershed in)		Infiltration				Directly Connected Impervious Fraction (Decimal)		Receiving Receiving Fraction (Decimal)			C_T		C_t		C_p	
Catchment Name	Print Mode	Raingage	Area (mi^2)	Distance to Centroid (mi)	Length (mi)	Slope (ft/ft)	Percent Imperviousness	Pervious	Impervious	Initial Rate (in/hr)	Horton's Decay Coefficient (1/seconds)	Final Rate (in/hr)	DCIA Level	Override	Used	Override	Used	Effective Imperviousness (Percent)	Override	Used	Override	Used	Override	Used
601	3	100 245	1.38	1.35	2.41	0.059	6.1	0.5	0.1	3	0.0018	0.5	0		0.12		0.06	5.34		0.143		0.143		0.325
602	3	100 255	0.21	0.51	0.86	0.05	30.1	0.4	0.1	4	0.0018	0.6	0		0.60		0.17	28.52		0.101		0.106		0.304
603	3	100 265	0.36	0.57	1.14	0.031	40.7	0.4	0.1	4	0.0018	0.6	0		0.80		0.20	39.48		0.093		0.093		0.441
701	3	100 255_701	0.43	0.59	1.52	0.053	25.3	0.4	0.1	3	0.0018	0.5	0		0.51		0.15	23.73		0.106		0.106		0.303
702	3	100 260	0.98	0.66	1.44	0.023	41.5	0.4	0.1	4	0.0018	0.6	0		0.81		0.20	40.26		0.093		0.093		0.524
703	3	100 265_703	0.07	0.28	0.52	0.034	33.8	0.5	0.1	3	0.0018	0.5	0		0.68		0.18	32.33		0.098		0.145		0.284
704	3	100 265_704	0.12	0.21	0.66	0.016	48.2	0.4	0.1	3	0.0018	0.5	0		0.84		0.22	47.05		0.090		0.112		0.434

Summary of Unit Hydrograph Parameters Used By Program and Calculated Results (Version 1.3.3)

		Unit Hydrograph Parameters and Results									Excess Precip.		Storm Hydrograph		
Catchment Name/ID	User Comment for Catchment	Ct	Cp	W50 (min.)	W50 Before Peak	W75 (min.)	W75 Before Peak	Time to Peak (min.)	Peak (cfs)	Volume (c.f)	Excess (inches)	Excess (c.f.)	Time to Peak (min.)	Peak Flow (cfs)	Total Volume (c.f.)
601		0.143	0.325	71.7	18.21	37.3	12.87	30.4	578	3,206,016	1.98	6,351,550	72.0	997	6,351,530
602		0.106	0.304	22.6	5.59	11.8	3.95	9.3	278	487,872	2.40	1,170,968	42.0	392	1,170,907
603		0.093	0.441	18.6	6.50	9.7	4.35	11.0	581	836,352	2.64	2,204,174	41.0	831	2,204,124
701		0.106	0.303	31.4	7.62	16.3	5.38	12.7	411	998,976	2.46	2,455,877	47.0	661	2,455,862
702		0.093	0.524	20.1	7.04	10.5	4.70	14.0	1,463	2,276,736	2.58	5,881,996	44.0	2,131	5,881,542
703		0.145	0.284	21.3	4.95	11.1	3.50	8.3	98	162,624	2.58	420,171	41.0	142	420,142
704		0.112	0.434	12.7	4.44	6.6	2.97	7.5	284	278,784	2.91	810,664	37.0	368	810,638

Appendix G –
Corrected Effective Conditions SWMM Input/Output

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ OCT-05-2011 00:00:00
Ending Date .............. OCT-05-2011 06:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec
```

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	83.753	27.292
External Outflow	84.308	27.473
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.419	0.136
Continuity Error (%)	-1.163	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****

```
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
```

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	0.93	2.14	5580.14	0 01:06
602	JUNCTION	0.97	2.10	5447.10	0 01:19
603	JUNCTION	0.20	0.47	5315.47	0 01:25
703	JUNCTION	1.11	3.83	5314.83	0 00:53
702	JUNCTION	1.06	3.92	5343.92	0 00:44
701	JUNCTION	0.12	0.54	5382.54	0 00:41
703a	JUNCTION	2.60	5.85	5316.85	0 00:55
704	OUTFALL	2.58	5.83	5286.83	0 01:01

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	91.49	91.49	0 01:06	4.284	4.284
602	JUNCTION	56.20	123.41	0 01:16	1.796	6.118
603	JUNCTION	54.31	172.93	0 01:24	4.019	10.147
703	JUNCTION	27.68	497.98	0 00:53	0.705	15.638
702	JUNCTION	392.82	499.40	0 00:44	11.100	14.811
701	JUNCTION	141.03	141.03	0 00:41	3.653	3.653
703a	JUNCTION	0.00	607.67	0 00:55	0.000	25.785
704	OUTFALL	83.46	644.70	0 01:00	1.734	27.471

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	174.64	644.70	27.471

System	97.23	174.64	644.70	27.471

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	88.29	0 01:19	3.84	0.00	0.10
102	CONDUIT	121.79	0 01:25	7.63	0.00	0.02
103	DUMMY	172.93	0 01:24			
201	CONDUIT	131.18	0 00:50	5.81	0.00	0.03
202	CONDUIT	476.26	0 00:53	3.63	0.03	0.19
203	CONDUIT	603.24	0 01:01	4.63	0.05	0.29
703	DUMMY	497.98	0 00:53			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Fri Feb 10 09:02:09 2012
Analysis ended on: Fri Feb 10 09:02:09 2012

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ OCT-05-2011 00:00:00
Ending Date .............. OCT-05-2011 06:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec
```

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	130.686	42.586
External Outflow	131.291	42.783
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.547	0.178
Continuity Error (%)	-0.882	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****

```
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
```

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	1.38	2.97	5580.97	0 01:08
602	JUNCTION	1.43	2.95	5447.95	0 01:19
603	JUNCTION	0.30	0.68	5315.68	0 01:23
703	JUNCTION	1.34	4.64	5315.64	0 00:52
702	JUNCTION	1.29	4.74	5344.74	0 00:43
701	JUNCTION	0.16	0.68	5382.68	0 00:41
703a	JUNCTION	3.20	6.93	5317.93	0 00:56
704	OUTFALL	3.17	6.92	5287.92	0 01:01

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	186.18	186.18	0 01:08	9.429	9.429
602	JUNCTION	81.22	234.88	0 01:16	2.605	12.091
603	JUNCTION	76.51	307.14	0 01:22	5.663	17.758
703	JUNCTION	40.31	732.84	0 00:51	1.047	22.774
702	JUNCTION	558.19	732.50	0 00:43	15.771	21.596
701	JUNCTION	212.09	212.09	0 00:41	5.754	5.754
703a	JUNCTION	0.00	913.28	0 00:56	0.000	40.532
704	OUTFALL	108.37	964.16	0 01:00	2.314	42.780

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	271.97	964.16	42.780

System	97.23	271.97	964.16	42.780

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	183.09	0 01:19	4.56	0.01	0.15
102	CONDUIT	233.25	0 01:23	9.43	0.00	0.03
103	DUMMY	307.14	0 01:22			
201	CONDUIT	200.43	0 00:48	6.71	0.00	0.03
202	CONDUIT	700.99	0 00:52	4.03	0.04	0.23
203	CONDUIT	909.71	0 01:01	5.13	0.07	0.35
703	DUMMY	732.84	0 00:51			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Fri Feb 10 09:11:10 2012
Analysis ended on: Fri Feb 10 09:11:10 2012

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ OCT-05-2011 00:00:00
Ending Date .............. OCT-05-2011 06:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec
```

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	207.139	67.499
External Outflow	207.657	67.668
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.635	0.207
Continuity Error (%)	-0.556	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****

```
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
```

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	1.90	4.24	5582.24	0 01:11
602	JUNCTION	1.96	4.22	5449.22	0 01:19
603	JUNCTION	0.44	1.04	5316.04	0 01:23
703	JUNCTION	1.54	5.84	5316.84	0 00:56
702	JUNCTION	1.49	5.92	5345.92	0 00:49
701	JUNCTION	0.19	0.90	5382.90	0 00:46
703a	JUNCTION	3.86	8.71	5319.71	0 01:03
704	OUTFALL	3.83	8.70	5289.70	0 01:07

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	414.63	414.63	0 01:11	19.265	19.265
602	JUNCTION	140.87	500.79	0 01:16	4.197	23.550
603	JUNCTION	123.43	613.26	0 01:21	8.227	31.779
703	JUNCTION	65.26	1179.33	0 00:56	1.549	32.767
702	JUNCTION	848.68	1159.56	0 00:49	22.272	31.115
701	JUNCTION	346.78	346.78	0 00:46	8.778	8.778
703a	JUNCTION	0.00	1593.14	0 01:03	0.000	64.546
704	OUTFALL	157.39	1669.03	0 01:06	3.207	67.663

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.23	430.15	1669.03	67.663

System	97.23	430.15	1669.03	67.663

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	409.62	0 01:19	5.63	0.02	0.21
102	CONDUIT	498.21	0 01:23	12.03	0.00	0.05
103	DUMMY	613.26	0 01:21			
201	CONDUIT	334.90	0 00:53	7.93	0.00	0.04
202	CONDUIT	1125.39	0 00:56	4.56	0.06	0.29
203	CONDUIT	1589.17	0 01:07	5.90	0.12	0.43
703	DUMMY	1179.33	0 00:56			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Fri Feb 10 09:13:15 2012
Analysis ended on: Fri Feb 10 09:13:15 2012

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ OCT-05-2011 00:00:00
Ending Date .............. OCT-05-2011 06:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec
```

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	257.687	83.971
External Outflow	258.214	84.143
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.696	0.227
Continuity Error (%)	-0.475	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****

```
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
```

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.15	4.73	5582.73	0 01:11
602	JUNCTION	2.21	4.71	5449.71	0 01:19
603	JUNCTION	0.50	1.19	5316.19	0 01:22
703	JUNCTION	1.70	6.44	5317.44	0 00:55
702	JUNCTION	1.64	6.53	5346.53	0 00:48
701	JUNCTION	0.22	1.02	5383.02	0 00:45
703a	JUNCTION	4.24	9.53	5320.53	0 01:03
704	OUTFALL	4.20	9.52	5290.52	0 01:06

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	533.48	533.48	0 01:11	25.122	25.122
602	JUNCTION	173.56	643.31	0 01:16	5.208	30.431
603	JUNCTION	147.07	779.11	0 01:20	9.788	40.216
703	JUNCTION	77.98	1450.82	0 00:55	1.848	40.113
702	JUNCTION	1029.04	1425.98	0 00:48	27.042	38.160
701	JUNCTION	433.89	433.89	0 00:45	11.050	11.050
703a	JUNCTION	0.00	1985.88	0 01:03	0.000	80.329
704	OUTFALL	191.11	2080.22	0 01:05	3.908	84.137

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	533.36	2080.22	84.137

System	97.50	533.36	2080.22	84.137

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	528.21	0 01:19	5.99	0.03	0.23
102	CONDUIT	640.59	0 01:22	12.98	0.00	0.06
103	DUMMY	779.11	0 01:20			
201	CONDUIT	420.99	0 00:52	8.53	0.00	0.05
202	CONDUIT	1385.70	0 00:55	4.81	0.08	0.32
203	CONDUIT	1981.21	0 01:06	6.23	0.15	0.48
703	DUMMY	1450.82	0 00:55			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Fri Feb 10 09:15:29 2012
Analysis ended on: Fri Feb 10 09:15:29 2012

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ OCT-05-2011 00:00:00
Ending Date .............. OCT-05-2011 06:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec
```

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	321.873	104.887
External Outflow	322.456	105.077
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.748	0.244
Continuity Error (%)	-0.414	

****
Highest Flow Instability Indexes
****

Link 201 (1)
Link 202 (1)

****
Routing Time Step Summary
****

```
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
```

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min
601	JUNCTION	2.43	5.30	5583.30	0 01:12
602	JUNCTION	2.49	5.29	5450.29	0 01:19
603	JUNCTION	0.58	1.37	5316.37	0 01:22
703	JUNCTION	1.84	7.09	5318.09	0 00:55
702	JUNCTION	1.79	7.17	5347.17	0 00:48
701	JUNCTION	0.24	1.13	5383.13	0 00:46
703a	JUNCTION	4.65	10.47	5321.47	0 01:05
704	OUTFALL	4.62	10.46	5291.46	0 01:08

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	699.02	699.02	0 01:12	32.848	32.848
602	JUNCTION	210.07	837.82	0 01:16	6.338	39.300
603	JUNCTION	191.81	1014.38	0 01:20	12.332	51.630
703	JUNCTION	98.60	1784.79	0 00:55	2.350	49.017
702	JUNCTION	1256.37	1740.61	0 00:48	33.091	46.553
701	JUNCTION	520.74	520.74	0 00:46	13.388	13.388
703a	JUNCTION	0.00	2506.47	0 01:05	0.000	100.647
704	OUTFALL	221.90	2624.21	0 01:07	4.533	105.069

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.50	666.05	2624.21	105.069

System	97.50	666.05	2624.21	105.069

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	693.34	0 01:19	6.40	0.04	0.26
102	CONDUIT	834.80	0 01:22	14.04	0.00	0.07
103	DUMMY	1014.38	0 01:20			
201	CONDUIT	508.45	0 00:52	9.04	0.00	0.06
202	CONDUIT	1700.27	0 00:55	5.05	0.09	0.35
203	CONDUIT	2503.35	0 01:08	6.60	0.19	0.52
703	DUMMY	1784.79	0 00:55			

****
Conduit Surcharge Summary
****

Conduit	Hours Full: Both Ends	Hours Full: Upstream	Hours Full: Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Fri Feb 10 09:17:36 2012
Analysis ended on: Fri Feb 10 09:17:36 2012

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.022)

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options
****

```
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ OCT-05-2011 00:00:00
Ending Date .............. OCT-05-2011 06:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:15:00
Routing Time Step ........ 30.00 sec
```

WARNING 04: minimum elevation drop used for Conduit 703

********** Flow Routing Continuity **********	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	442.928	144.335
External Outflow	443.811	144.622
Internal Outflow	0.000	0.000
Storage Losses	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.659	0.215
Continuity Error (%)	-0.348	

****
Highest Flow Instability Indexes
****
Link 201 (1)

****
Routing Time Step Summary
****

```
Minimum Time Step           :    30.00 sec
Average Time Step           :    30.00 sec
Maximum Time Step           :    30.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
```

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	hr:min
601	JUNCTION	2.87	6.16	5584.16	0	01:12
602	JUNCTION	2.94	6.14	5451.14	0	01:18
603	JUNCTION	0.71	1.65	5316.65	0	01:18
703	JUNCTION	2.06	8.68	5319.68	0	00:52
702	JUNCTION	2.00	8.78	5348.78	0	00:46
701	JUNCTION	0.30	1.29	5383.29	0	00:47
703a	JUNCTION	5.10	12.73	5323.73	0	00:54
704	OUTFALL	5.08	12.72	5293.72	0	00:57

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days	hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal
601	JUNCTION	996.65	996.65	0	01:12	47.509	47.509
602	JUNCTION	392.13	1187.47	0	01:12	8.758	56.399
603	JUNCTION	831.40	1571.53	0	01:10	16.487	72.881
703	JUNCTION	141.65	2759.53	0	00:52	3.143	65.716
702	JUNCTION	2131.22	2705.58	0	00:46	43.994	62.439
701	JUNCTION	660.58	660.58	0	00:47	18.370	18.370
703a	JUNCTION	0.00	4089.85	0	00:54	0.000	138.597
704	OUTFALL	368.37	4275.05	0	00:56	6.064	144.612

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Outfall Loading Summary
****

Outfall Node	Flow Freq. Pcnt.	Avg. Flow CFS	Max. Flow CFS	Total Volume 10^6 gal
704	97.78	914.10	4275.05	144.612

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum Velocity ft/sec	Max/ Full Flow	Max/ Full Depth
101	CONDUIT	990.37	0 01:18	6.98	0.05	0.31
102	CONDUIT	1184.00	0 01:18	15.53	0.00	0.08
103	DUMMY	1804.30	0 01:08			
201	CONDUIT	650.30	0 00:52	9.74	0.00	0.06
202	CONDUIT	2636.45	0 00:52	5.67	0.15	0.43
203	CONDUIT	4338.01	0 00:57	7.57	0.34	0.65
703	DUMMY	2759.53	0 00:52			

****
Conduit Surcharge Summary
****

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
103	0.01	0.01	0.01	6.01	0.01
703	0.01	0.01	0.01	6.01	0.01

Analysis begun on: Thu Dec 08 11:19:19 2011
Analysis ended on: Thu Dec 08 11:19:19 2011

Appendix H –
Project Progress Meeting Minutes

ICON ENGINEERING, INC.

TWOMILE CANYON CREEK AND GOOSE CREEK
FLOOD STUDY
PROGRESS MEETING
OCTOBER 19, 2011 - 9:30 AM

AGENDA

1. Introductions

2. Purpose and Scope Review

3. Collection of Existing Data
    A. City of Boulder
        i. GIS;
        ii. Twomile FIS (1991 Update; 1993-1994 LOMRs);
        iii. Broadway As-builts;
        iv. Awaiting Goose Creek planning/storm sewer study
    B. FEMA – Data Request
        i. Effective HEC-2 (Portions of Both Creeks)
        ii. No Hydrology
    C. UDFCD –
        i. MDP/FHAD Data
        ii. Technical Backup – CUHP-B Hard Copy; No HEC-1 Routing

4. Survey and Field Documentation
    A. Progress Update
    B. Roadway sections
    C. Field Documentation Report

5. Hydrologic Evaluation
    A. Duplicate Effective CUHP/SWMM
    B. Revised Basins CUHP/SWMM
        i. Rainfall Comparison
        ii. Imperviousness Values / Comparisons
        iii. Topographic deficiencies
    C. Preliminary Results
    D. Recommendations

6. Hydraulic Modeling
    A. Initial Flo-2d Sample Section (Upper Reach of Twomile Canyon Creek)
        i. Grid Size Selection
        ii. Steady Flow Simulation
        iii. Channel / Culvert Elements

7. Schedule

Discharge Summary

				Effective Conditions (1987 FHAD)			Duplicate Effective Conditions (CUHP/SWMM)			Updated Existing Conditions (CUHP/SWMM)			USGS Regression Equations (Plains Region)		
Location	**SWMM Element**	**Effective DA (sq. mi.)**	**Existing DA (sq. mi.)**	**10-Year (cfs)**	**50-Year (cfs)**	**100-Year (cfs)**	**10-Year (cfs)**	**50-Year (cfs)**	**100-Year (cfs)**	**10-Year (cfs)**	**50-Year (cfs)**	**100-Year (cfs)**	**10-Year (cfs)**	**50-Year (cfs)**	**100-Year (cfs)**
Twomile Canyon Creek															
Approximately 4,980 ft Upstream of Linden Drive	JUNCT_301	-	0.45	-	-	-	-	-	-	62	274	350	264	813	1199
Linden Drive	JUNCT_302	-	0.74	-	-	-	-	-	-	133	522	668	322	990	1456
Approximately COB Limits	JUNCT_303	-	1.19	-	-	-	-	-	-	166	699	904	391	1196	1756
Linden Avenue	JUNCT_601	1.40	1.38	210	540	710	158	495	656	205	865	1124	414	1265	1857
North Broadway Street	JUNCT_602	1.68	1.71	210	675	890	218	643	845	296	1122	1463	451	1376	2018
Confluence with Goose Creek	JUNCT_603	2.19	1.96	360	840	1120	408	1007	1316	504	1560	2039	477	1453	2129
Goose Creek															
Balsam Avenue	JUNCT_701	0.48	0.45	260	520	620	202	427	513	184	485	634	264	814	1199
North Broadway Street	JUNCT_402	-	0.66	-	-	-	-	-	-	279	666	857	308	946	1393
Approximately 1,100 ft Downstream of North Broadway Street	JUNCT_404	-	1.02	-	-	-	-	-	-	566	1196	1537	367	1124	1652
19th Street	JUNCT_702	1.28	1.29	700	1320	1600	696	1368	1672	643	1591	2020	404	1235	1812
Upstream Confluence with Twomile Creek	JUNCT_703	1.32	1.36	670	1270	1590	692	1378	1690	653	1629	2074	412	1259	1848
Downstream of Folsom Street	JUNCT_704	3.63	3.44	1050	2100	2680	1151	2445	3057	1228	3070	3988	598	1811	2649

Volume Conservation (ac-ft)	294.6		316.1

Note: the Duplicate Effective Conditions discharges shown here do not exactly match those shown in the Hydrology Verification Report due to minor revisions to the SWMM model completed after the October 19, 2011 progress meeting.

Summary of Rainfall

Update Existing Conditions
Reflecting UDFCD 1-hr Rainfall Depth

Sub-Basin ID	100-year 1-hr Rainfall (in)
601A	2.40
601B	2.45
601C	2.52
601D	2.45
601E	2.50
601F	2.53
602A	2.61
602B	2.59
603A	2.63
603B	2.65
603C	2.65
603D	2.65
603E	2.65
701A	2.60
701B	2.60
702A	2.60
702B	2.62
702C	2.64
702D	2.61
702E	2.64
703	2.64
704	2.66

Rainfall Comparison to Effective Hydrology

Overall Sub-basin	EFFECTIVE 100-year Rainfall (in)	REVISED 100-year Rainfall (in)
601	2.45	2.47
602	2.55	2.60
603	2.65	2.65
701	2.55	2.60
702	2.6	2.63
703	2.65	2.64
704	2.65	2.66

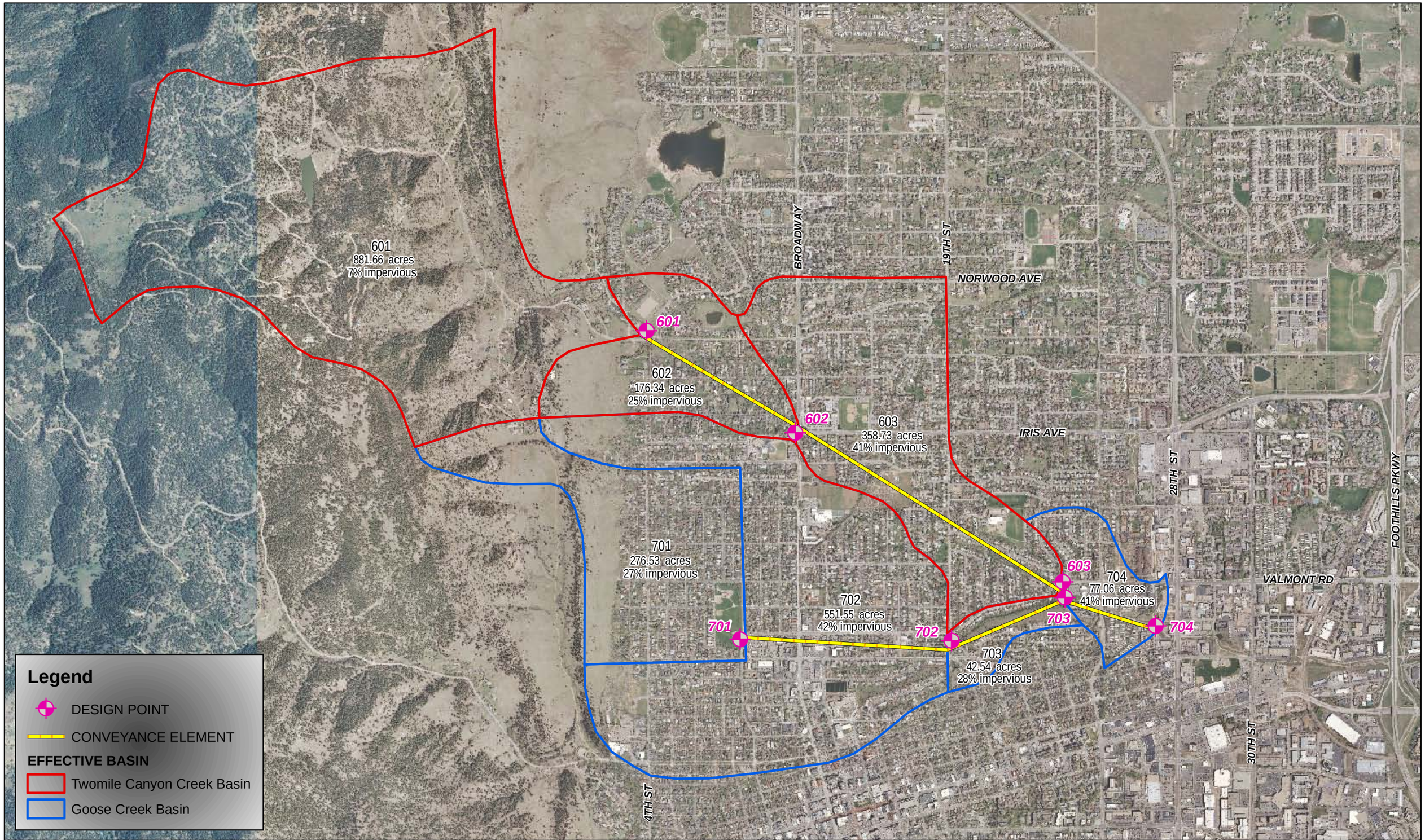
Summary of Sub-basin Imperviousness

Update Existing Conditions
Reflecting Future Conditions Landuse

Sub-Basin ID	FUTURE % Impervious
601A	5.0%
601B	5.0%
601C	9.8%
601D	5.0%
601E	5.0%
601F	8.7%
602A	45.0%
602B	21.6%
603A	32.4%
603B	37.2%
603C	45.3%
603D	42.9%
603E	37.4%
701A	24.2%
701B	31.8%
702A	28.3%
702B	43.7%
702C	45.8%
702D	55.6%
702E	50.8%
703	44.5%
704	58.4%

Imperviousness Comparison to Effective Hydrology

Overall Sub-basin	EFFECTIVE % Impervious	FUTURE % Impervious
601	7	6.2%
602	25	32.3%
603	41	40.3%
701	27	26.9%
702	42	47.0%
703	28	44.5%
704	41	58.4%

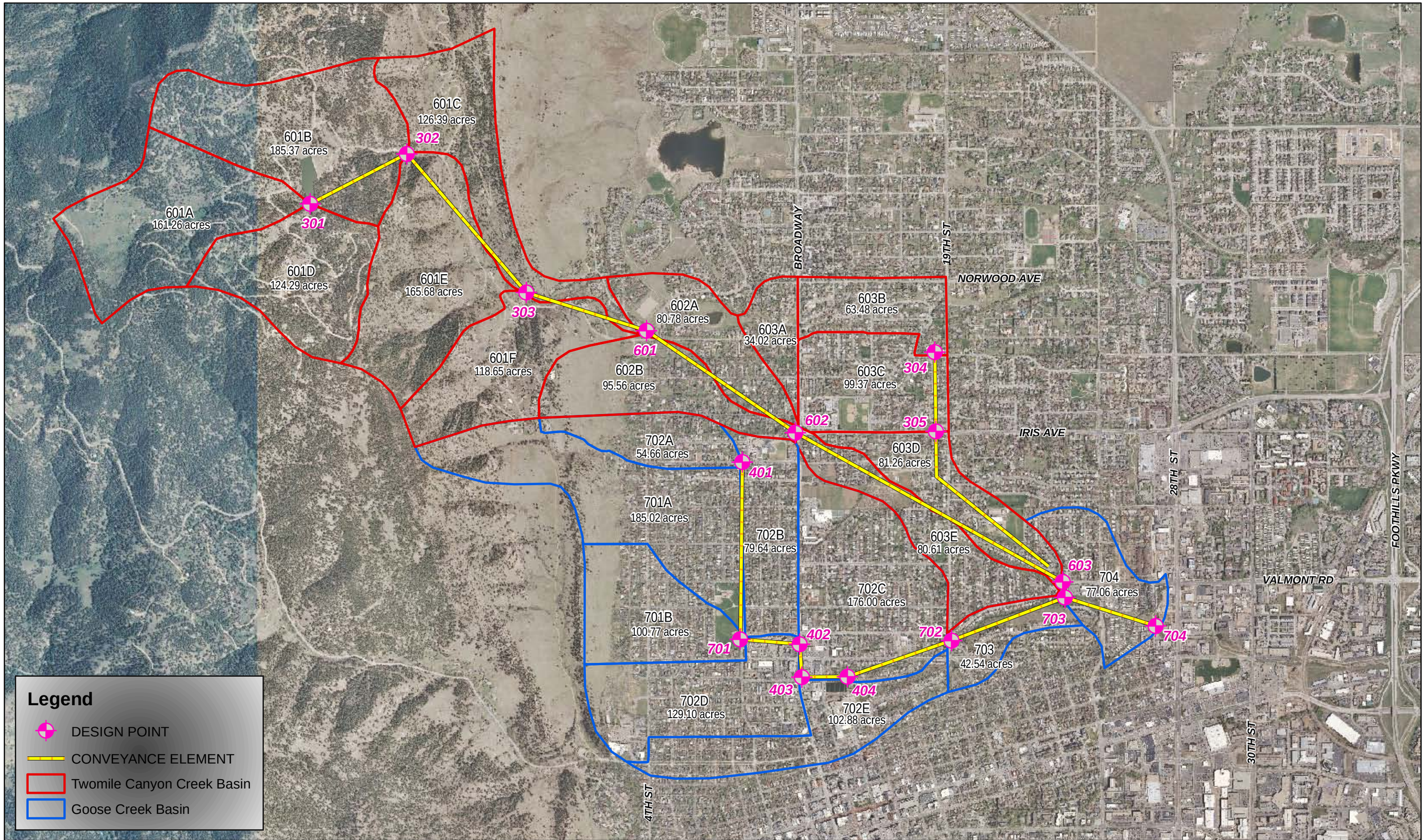


ICON ENGINEERING, INC.

Twomile Canyon and Goose Creeks
Effective Sub-basins

1 inch = 1,500 feet

N

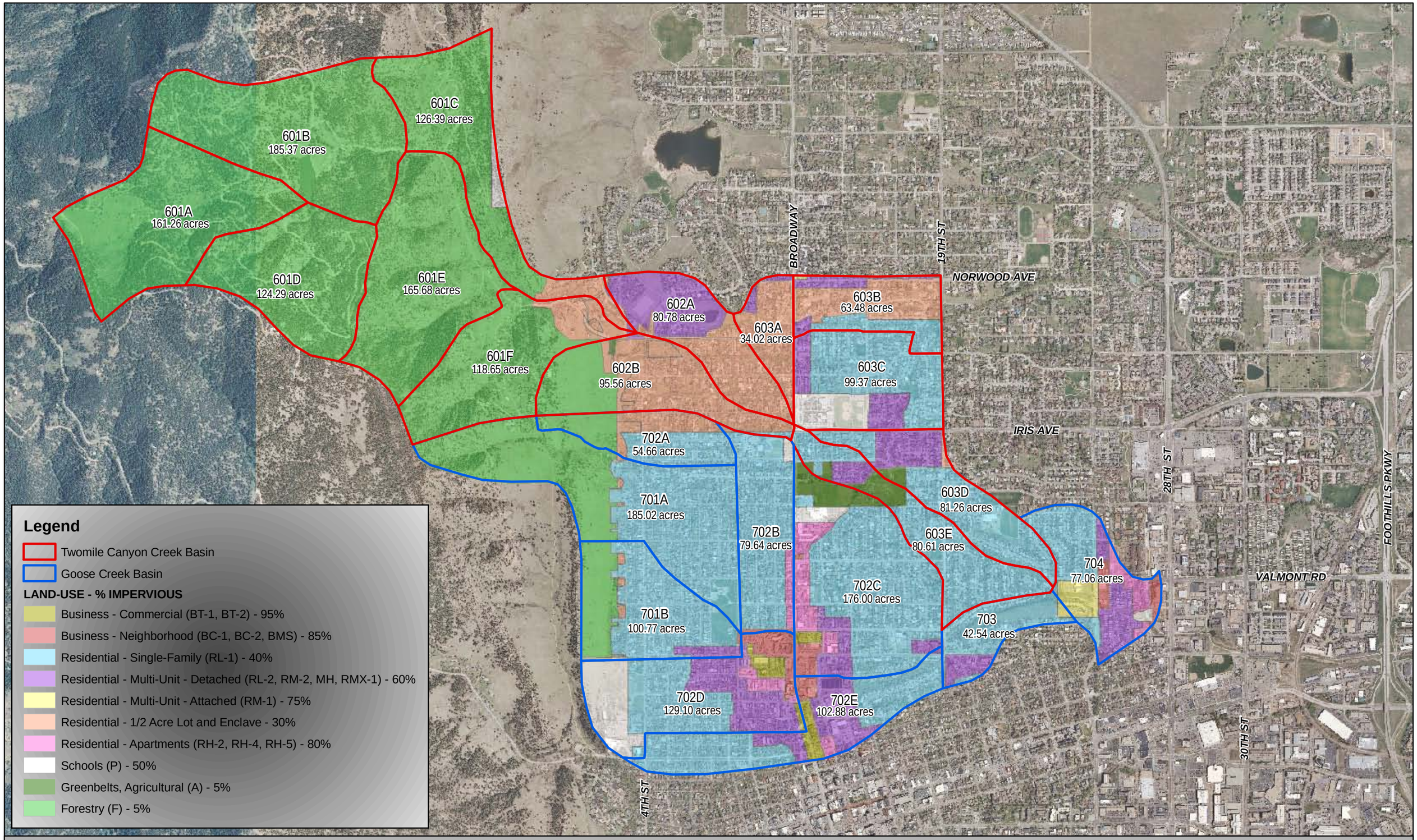


ICON ENGINEERING, INC.

Twomile Canyon and Goose Creeks
CUHP/SWMM Update

1 inch = 1,500 feet

N

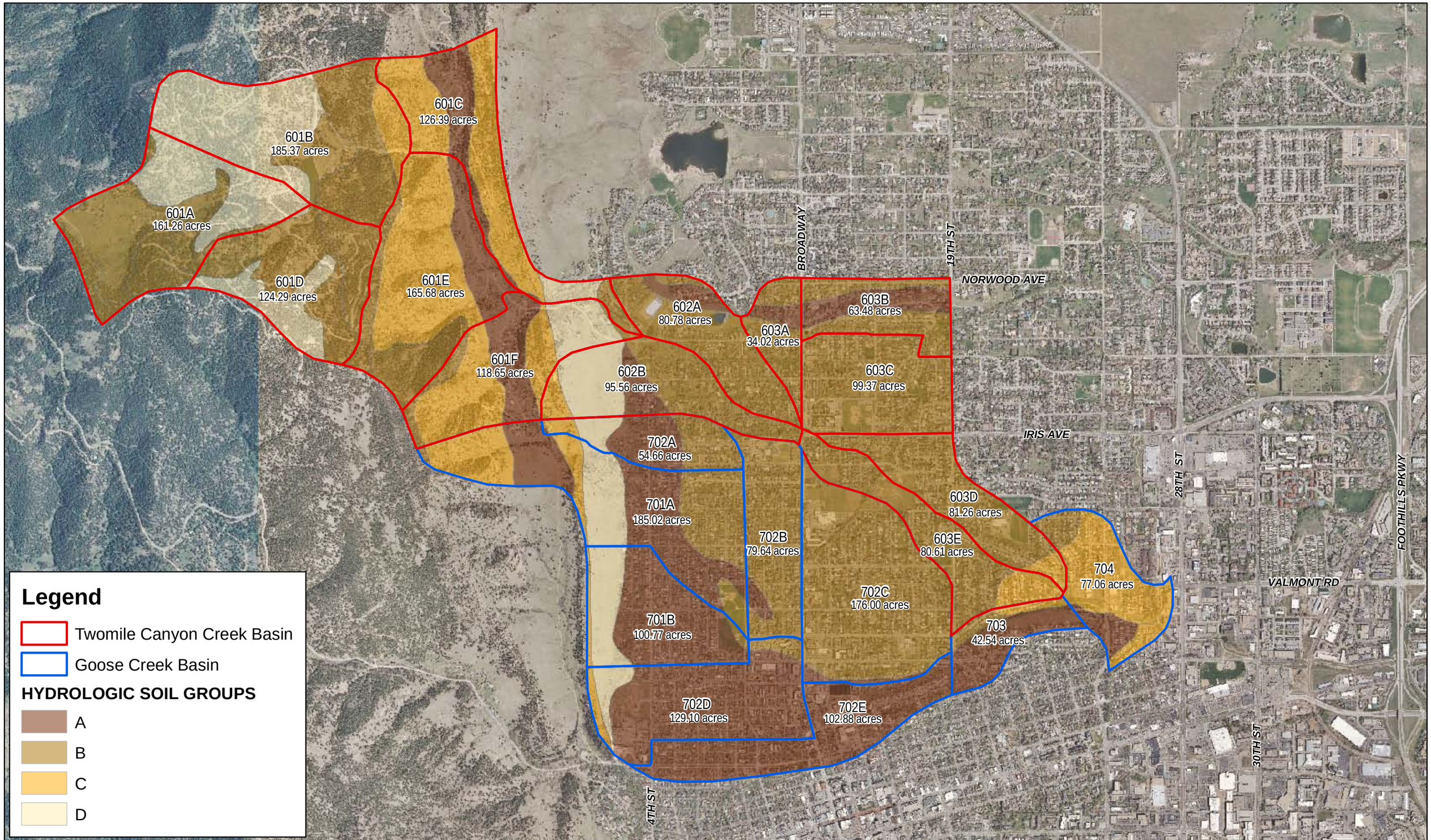


ICON ENGINEERING, INC

Twomile Canyon and Goose Creeks Land-Use

1 inch = 1,500 feet

N



ICON ENGINEERING, INC.

Twomile Canyon and Goose Creeks
Hydrologic Soil Groups

1 inch = 1,500 feet

N

UPPER GOOSE CREEK AND TWOMILE CANYON CREEK
FLOODPLAIN MAPPING STUDY UPDATE
OCTOBER 19, 2011, 9:30AM

MINUTES

Attendees:
Kurt Bauer, City of Boulder
Chris Trice, City of Boulder
Shea Thomas, UDFCD
Craig Jacobson, ICON Engineering
Brian LeDoux, ICON Engineering
Doug Williams, ICON Engineering

1. **Purpose and Scope Review**

   Craig provided a quick review of the purpose and scope of the project. ICON has been tasked with updating the hydrology and hydraulics, and ultimately revising the regulatory flood hazard information (Flood Insurance Study) for Upper Goose Creek and Twomile Canyon Creeks.

   Kurt noted that Anderson Consulting Engineers Inc. is now under contract with the City of Boulder to perform peer review for this project.

2. **Collection of Existing Data**
   - **A. City of Boulder**
     - **i. GIS;** Chris noted that the effective floodplain in the project reach had recently been revised to reflect a projection issue. The preliminary DFRIM data is not correct. Chris will confirm that the flood hazard data on the City's FTP site is up to date.
     - **ii. Twomile FIS (1991 Update; 1993-1994 LOMRs);** It was noted that the LOMRs have been incorporated into the current GIS flood hazard data.
     - **iii. Broadway As-builts;** ICON has obtained the Broadway storm sewer system as-built drawings. It was noted that although the recently constructed storm sewer is large, it flows into the existing system which is limited in capacity.
     - **iv. Awaiting Goose Creek planning/storm sewer study;** This study completed by HDR will be provided by Kurt and will provide capacity information related to the existing storm sewer system on Goose Creek.
     - **v. LiDAR Data;** Chris will look into providing points and breaklines from the LiDAR data for use in the digital terrain model (DTM). Currently ICON has assigned points along elevation contours at regular intervals to develop the DTM. It was noted that LiDAR data may present some issues with FLO2D model development due to the density of elevation data.
   - **B. FEMA – Data Request**
     - **i. Effective HEC-2 (Portions of Both Creeks);** ICON has obtained this information for both Goose Creek and Twomile Canyon Creek. Shea asked if the date of these models were known. The Goose Creek model is dated July 3, 1984, and the most recent Twomile Canyon Creek model is dated November 4, 1994. Craig noted that several LOMRs have been processed in the project area by the UDFCD that were not provided by FEMA.

ii. **Hydrology;** Hydrology information was not available from FEMA.

C. **UDFCD –**

i. **MDP/FHAD Data;** ICON has obtained the MDP/FHAD data from the UDFCD.

ii. **Technical Backup – CUHP-B Hard Copy; No HEC-1 Routing;** ICON will confirm that the technical appendix has been scanned and will return the hard copy back to the UDFCD.

3. **Survey and Field Documentation**

A. **Progress Update;** Craig noted that the surveyors are experiencing canopy cover issues are have been required to move control throughout the survey work. This has resulted in delays; however, the most recent report indicated that the survey work would be completed by the end of this week.

B. **Roadway sections;** Based on field observation of the roadways within the project area, survey data acquisition has been reduced along several of the adjacent roadways. These roadway sections do not have curb and gutter and are not expected to convey significant amounts of flow, rather they are expected to overtop at low points along the roadway crest. If the FLO2D model indicates notable flows traveling along the roadways, additional survey information will be obtained at a later date.

C. **Field Documentation Report;** The field documentation memorandum has been started. The ultimate product will consist of a PDF file that is bookmarked and includes graphical links to the survey and photo information for ease of use. The project sponsors noted that an electronic version of the memorandum is preferred to a hardcopy.

4. **Hydrologic Evaluation**

A. **Duplicate Effective CUHP/SWMM;** Information from the 1987 FHAD was duplicated into current versions of CUHP (1.3.3) and SWMM (5.0). The resulting duplicate effective discharge information is presented in the discharge summary table.

B. **Revised Basins CUHP/SWMM;** Drainage basins were then revised to be on the order of 160 acres or smaller. CUHP and SWMM were revised accordingly.

i. **Rainfall Comparison;** For the updated existing conditions hydrology model, the 1-hr rainfall depths were also revised according to the revised basin location and the corresponding rainfall depth provided by UDFCD criteria. The rainfall map was presented and it was noted that particularly at the upstream end of the Twomile Creek the changes in rainfall values are in close proximity. Using the rainfall depth map, the revised basins were assigned a rainfall depth based on an average depth for each basin. The resulting depths and a comparison to the effective depths are provided in the summary of rainfall table.

ii. **Imperviousness Values / Comparisons;** Land use (Zoning information) was obtained from the City of Boulder and used to develop a future % impervious value for the revised drainage basins. A comparison between the effective and future conditions % impervious values is provided in the summary of sub-basin imperviousness table.

It was noted that the area in basin 702 that is designated as “Schools (P) – 50%” has recently been sold. The southern portion of this area will remain the Sanitas Wellness Center; however, the northern portion has been slated for single family residential structures. Given that this is the only area within the project area that is not yet fully developed, it was determined that the zoning information and the associated % impervious values should not be used as the basis for the future conditions % impervious values. The project sponsors determined that actual impervious surfaces, as available from the City (Chris will provide ICON with the applicable GIS data), could be used in this project.

The % impervious for the proposed single family development area in basin 702 will be estimated in order to develop the % impervious value for sub-basin 702.

iii. **Topographic deficiencies;** Sub-basins 603B and 603C were noted as areas where the effective basins may not be routed correctly as some of the flow may actually discharge to Elmer's Twomile Creek. Currently discharges that are collected on the north east side of Broadway and Iris are conveyed directly east along the north side of Iris and are ultimately discharged into the Farmers Ditch. If surface flows are not caught by the ditch, they will travel south on 19th Street and may turn east at Iris Avenue or continue south. It was noted that Elmer's Twomile had recently undergone improvements and a LOMR based on discharges that do not include sub-basins 603B or 603C. The project sponsors recommended matching the effective basins and routing to Twomile Canyon Creek in anticipation of a future corresponding outfall system.

C. **Preliminary Results;** The results of the updated existing conditions were presented in a discharge summary table. The results indicate an increase in discharge at all design points within the project area.

The USGS regression equation results are also presented in the discharge summary table and compare well to the effective discharges at the downstream design point of Goose Creek. However, upstream design points do not compare well and show a significant increase in discharge. Craig noted that the USGS regression equations have an applicable range starting at 5.5 square miles, which is larger than the entire project area. This may explain the better comparison in the lower project area.

D. **Recommendations;** Shea noted that it is the preference of the UDFCD to not increase discharges as a result of sub-dividing effective drainage basins. Given this directive, it was determined that the duplicate effective CUHP/SWMM models would be calibrated prior to any sub-division of basins. It was also determined that the effective drainage basins should not be sub-divided any more than considered necessary for application of hydrographs along the main channel. ICON will review the need to subdivide basin 602 based on the potential for water in southern portion of the basin to not flow into Twomile Canyon Creek, but rather continue south into the Goose Creek basin.

5. **Hydraulic Modeling**

A. **Initial Flo-2d Sample Section (Upper Reach of Twomile Canyon Creek);** The test section of FLO2D was presented. Input hydrograph conditions, Manning's n values, outflow locations, channels, and culverts were discussed. Floodplain results illustrating the difference between the "with" and "without" channel model runs were shown for reference.

i. **Grid Size Selection;** Currently the grid size is 20' by 20' and was selected to provide better detail along the roadways and channels.

ii. **Steady Flow Simulation;** The current model only considers an input hydrograph that ramps up to 710cfs over the initial hour and runs at this discharge for an additional 1 hour simulating a steady state flow condition and eliminating floodplain storage.

iii. **Channel / Culvert Elements;** The field documentation report will provide recommendations on % blockage for all culverts and bridges. The test model of FLO2D includes culverts at Wonderland Hill Road and Linden Avenue, however, the rating curves for these elements are not refined and have been used only for the purposes of executing the test FLO2D model. Per Kurt's request, the pond upstream of Wonderland Hill Road will be considered full for the FLO2D and HEC-RAS analysis.

iv. **Upstream Tie-in;** Chris noted that a recent LOMR had been completed immediately upstream of the FLO2D test model. The final HEC-RAS hydraulic model will consider this LOMR for it's upstream tie-in.

6. **Schedule**

The hydrology and field documentation report drafts are expected to be completed by mid November. The schedule for peer review was not known, however it is anticipated that the project can move forward and the results of the peer review will be provided in a timely manner.

Action Items:

- City of Boulder will provide ICON with % impervious GIS data reflecting the current existing conditions.
- City of Boulder will provide ICON with the Goose Creek planning / storm sewer study by HDR.
- ICON will complete draft versions of both the hydrology report and field documentation memorandum.

- END OF MEETING--

Minutes prepared by: _____ **2011-10-20**

Brian LeDoux, P.E., CFM Date

ICON Engineering, Inc.

Appendix I –
Referenced Information

ASCG
INCORPORATED
ENGINEERS • ARCHITECTS • SURVEYORS • PLANNERS

MEMORANDUM

Date: Jaunuary 3, 2006

To: Annie Noble, Mark Post

From: Mike Galuzzi, Project Manager MRG
George Slovensky, Project Engineer GS

Re: Elmer's Two Mile Creek Hydrology Review and Analysis – Revised to Include Additional 90 Acre Tributary Area

Introduction

In a memorandum dated November 29, 2005 ASCG provided a review and update of hydrologic modeling for the Elmer's Two Mile Creek basin. In that memorandum it was noted that current 1-foot contour interval topographic mapping indicates that a previously unaccounted for 90 acre area west of 19th Street is tributary to the Elmer's basin. This has subsequently been confirmed by site visits and ground survey information. This memorandum updates the November 29, 2005 analysis to include this additional tributary area. Additionally, revised topography for a detention pond in a recently constructed park on Elmer's Creek has been included in the analysis. Revisions to include the 90 acre basin and new pond topography are documented herein.

Analysis

As described above, an additional 90 acre area west of 19th Street has been identified as tributary to the Elmer's Two Mile Creek basin. In the original 1983 MSM hydrologic analysis, this area was part of Basin 603 and flowed south to Two Mile Canyon Creek and did not enter the Elmer's Two Mile Creek basin. Site visits and ground survey data have confirmed the presence of a low point in 19th Street at Kalmia. This low point is approximately 1.8 feet below a high point located 400 feet to the south on 19th Street and would direct runoff from this area into the Elmer's Two-Mile Creek basin on the east side of 19th Street. CUHP has been utilized to evaluate runoff for the 90 acre area using parameters developed from recent aerial photography and topographic mapping, and UDFCD guidelines contained in the Urban Storm Drainage Criteria Manual. Basin parameters for the new 90 acre tributary area are presented in Table 1 below.

Table 1 – 90 Acre Basin Parameters	Area (sq mi)	Length (mi)	Length to Centroid, (mi)	Percent Imp., (%)	Slope (%)	Ct	Cp	Tp (min)
CUHP 2005/ASCG (Revised)	0.14	0.642	0.3125	49	8	0.249	0.458	40

The peak 100-year discharge from the 90 acre basin computed by CUHP is 236 cfs. The CUHP computed hydrograph was input into the EPA SWMM model and routed to its combination point with Basin 501 at Kalmia and Elmer's Two Mile Creek.

In addition to the new 90 acre basin added to the hydrologic model, revised topography for a park located on Elmer's Two Mile Creek between Iris Avenue and Glenwood Drive has been incorporated. The new topography is the result of a park improvement project designed by Love and Associates. Design topography for the park was obtained from the February 22, 2001 Floodplain Development Permit Application for the project. The park improvements have been constructed and design plans were compared to recent 1-foot contour interval mapping which showed good agreement. SWMM modeling results show that current park topography provides a storage rating curve very similar to values used in the 1983 MSM study and that the changes have little impact on peak flows or ponding elevation. Revised modeling results are summarized in Table 2 below.

Table 2 – Revised Model Routing Results						
	Original FIS		CUHP 2005/ FIS		CUHP 2005/ ASCG (Revised)	
	Qp (cfs)	Tp (min)	Qp (cfs)	Tp (min)	Qp (cfs)	Tp (min)
Kalmia Ave. Basin 501	253	35	181	40	384	45
Iris Ave. Basin 501+502	615	40	558	38	630	45
Valmont Road Basins 501+502+503	789	55	733	54	862	55

Summary

Comparison of the current model (CUHP 2005/ASCG Revised) to the original FIS shows 100-year peak flows are 52 percent higher at Kalmia, 2 percent higher at Iris and 9 percent higher at Valmont Road. We recommend that the City review the hydrologic model results with the UDFCD and decide if the original or revised flows should be used for the updated floodplain mapping study and the design of the Elmer's Two Mile Creek channel improvements.

Prepared in cooperation with the
Colorado Department of Transportation
and the Bureau of Land Management

Analysis of the Magnitude and Frequency of Floods in Colorado

Water-Resources Investigations Report 99–4190

U.S. Department of the Interior
U.S. Geological Survey

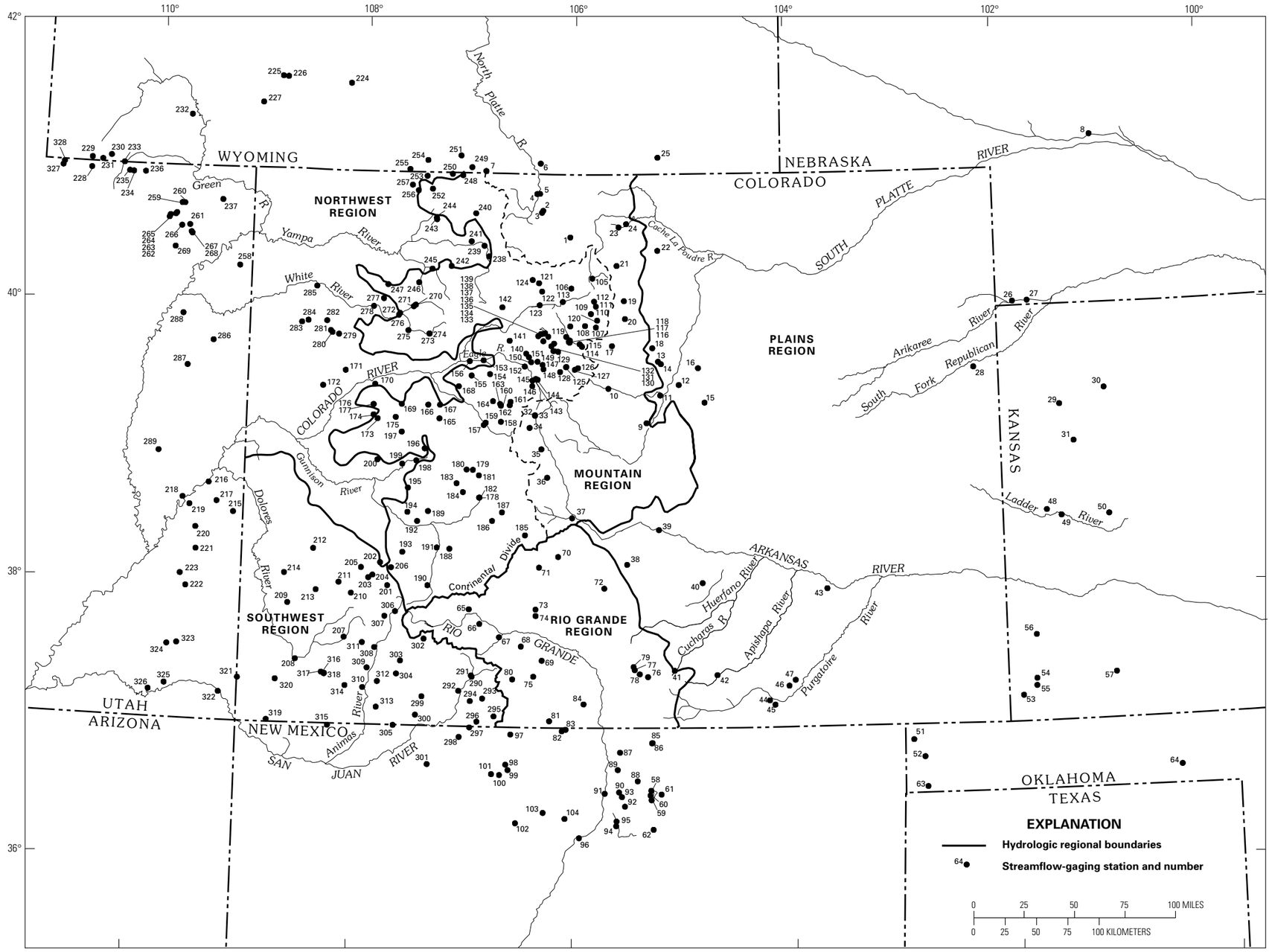


Figure 1. Boundaries of hydrologic regions and location of streamflow-gaging stations in Colorado and adjacent States.

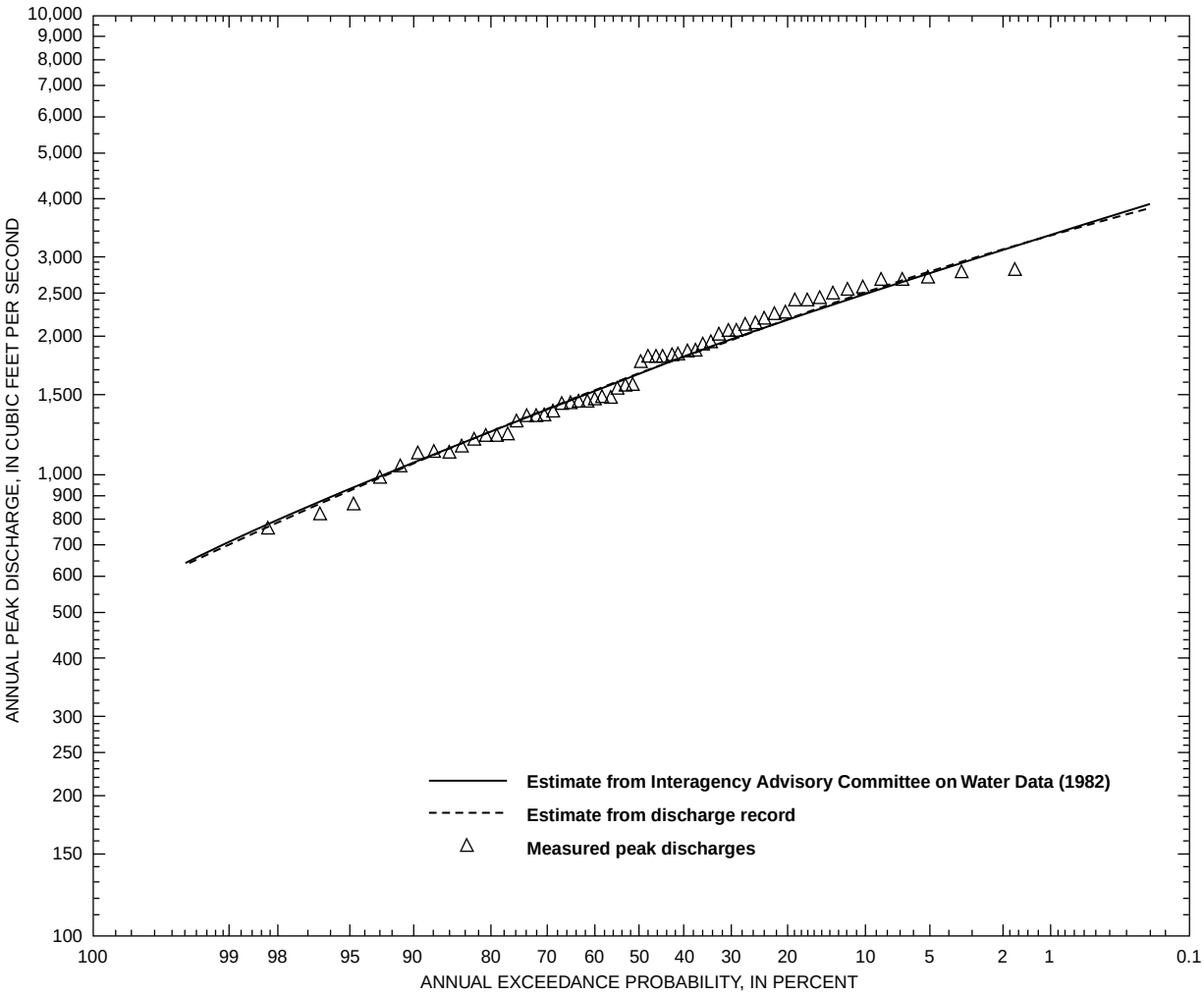


Figure 3. Flood-frequency curve for Lake Fork at Gateview, Colorado.

of the Arkansas drainage basin above 9,000 ft on the eastern slope of the Sangre de Cristo Mountains. Elevations range from about 7,500 to 14,000 ft in the region. The Continental Divide forms a topographic barrier between the mountain and Rio Grande regions and between the Rio Grande and southwest regions. The southwest region includes the San Juan Mountains west of the Continental Divide to the Colorado-Utah State line and south from the 7,500-ft elevation along the north side of the Uncompahgre Plateau. Elevations in the southwest region range from about 5,000 ft near the Colorado-Utah State line to about 14,000 ft near the Continental Divide. The Uncompahgre Plateau forms a major orographic barrier to air masses moving north from the south and southwest. Annual precipitation south of the Uncompahgre Plateau ranges from about 12 to 25 inches and decreases to about 8 inches at lower elevations north of the Uncompahgre Plateau in the northwest region (U.S. Geological Survey, 1984). The northwest region is located north of the 7,500-ft elevation along the north side of the Uncompahgre Plateau and west of the mountain region to the Colorado-Utah State line and the Colorado-Wyoming State line. Elevations in the northwest region range from about 5,000 to 7,500 ft, with the exception of the 8,000- to 9,000-ft Roan Plateau in the central part of the region. The western boundary of the plains region coincides with a line along an elevation of 7,500 ft in the South Platte River Basin, south to a transition zone near the Chaffee-Fremont County line, to a line along an elevation of about 9,000 ft in the Arkansas River Basin. The region extends east to the State lines of Kansas and Nebraska, south to the State lines of New Mexico and Oklahoma, and north to the Colorado-Wyoming State line.

Regression coefficients were estimated by considering the time-sampling error in the streamflow characteristics and the cross correlation between sites. The time-sampling error is associated with the length of record for a gaging station. A gaging station with a short period of record may have a large time-sampling error because the record may not be representative of the actual flood history of the site based on a larger number of years. A short period of record has the possibility of falling within a wet or dry climatic cycle (Thomas and Lindskov, 1983).

Use of the GLS method requires estimates of the cross correlation between streamflows at every pair of sites. Sample estimates of cross correlation based on recorded streamflows from short periods of record are often imprecise. To overcome this problem, the sample correlations were smoothed by relating them to distance between gaging stations using a nonlinear-regression model (Tasker and Stedinger, 1989).

The regression equations that were developed using the GLS method related drainage-basin characteristics to peak discharges by using a weighting matrix to account for the different time-sampling errors and cross correlations of concurrent peak-discharge records of the various gaging stations. The final regression equations developed for each region using GLS, the standard errors of estimate, and the average standard error of prediction are listed in table 1.

Limitations and Accuracy of Regression Equations

The regression equations provide a means for determining flood peaks for selected recurrence intervals for ungaged streams in Colorado. The equations were developed from gaging-station data on streams with little or no regulation in the basin and where significant urban development or other major basin changes have not occurred. Thus, the regression equations may not be valid where regulation is a factor or where a drainage basin has been altered by urban development. The regression equations also will not be valid where unique, localized geologic features affect floods. As with any regression analysis, the regression equations are defined only within the range of the independent variables used. For this study, the range of values of the basin characteristics used is listed in table 2. Extrapolation beyond the range of basin characteristics given may provide unreliable results.

The accuracy of a regression equation generally is assessed in terms of the standard error of estimate and the average standard error of prediction. The standard error of estimate is a measure of how well the observed peak streamflows agree with the regression estimate of the peak streamflows. The largest standard errors of estimate were found in the plains region. The standard errors ranged from 204 to 306 percent. These large errors may be attributed to the sparsity of gaging stations within the streamflow-gaging-station network in this region and the variability of the magnitude of annual peak streamflows. The smallest standard errors of estimate were found in the mountain region where the errors ranged from 41 to 58 percent. Standard errors of estimate and the average standard error of prediction for the regression equations in each hydrologic region are listed in table 1.

The average standard error of prediction at an ungaged site is a measure of the expected accuracy with which the regression equation can estimate a flood of a given recurrence interval. The average standard error of prediction includes errors associated with the regression equation and any time sampling error. The largest average standard errors of prediction were found in the plains region where errors ranged from 89 to 100 percent. The smallest average standard errors of prediction were found in the mountain region where errors ranged from 44 to 52 percent.

ESTIMATING MAGNITUDE OF PEAK DISCHARGES

The regression equations developed for this study are for estimation of peak discharges at ungaged sites. Peak-discharge estimates also are often required at or near gaged sites or at an ungaged site on the same stream as a gaged site. The methods for estimating the magnitude of peak discharges in general are explained in this section.

Gaged Sites

Magnitudes of peak discharges for gaged sites can be estimated using equations defined in this study. Table 3 (in the “Supplemental Data” section at the back of the report) lists the peak discharges from the flood-frequency curve for each gaging station for various recurrence intervals. Once the recurrence

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	61.9
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	$Q = 39.0\ (A)^{0.486}$	234	258
5	$Q = 195.8\ (A)^{0.399}$	204	224
10	$Q = 364.6\ (A)^{0.400}$	212	234
25	$Q = 725.3\ (A)^{0.395}$	232	256
50	$Q = 1116\ (A)^{0.392}$	250	278
100	$Q = 1640\ (A)^{0.388}$	267	300
200	$Q = 2324\ (A)^{0.385}$	284	321
500	$Q = 3534\ (A)^{0.380}$	306	348

interval of interest is selected, a weighted estimate of the peak discharge can be computed for a site using the regression equation for the appropriate region and the peak-discharge value from the flood-frequency curve.

Weighted estimates are used for unregulated streams to reduce the time-sampling error that may occur in a station flood-frequency estimate. This time-sampling error is associated with the length of record for a gaging station. A station with a short period of record may have a large time-sampling error because its record may not be representative of the actual flood history of the site based on a large number of years. The observed period of record has the possibility of falling within a wet or dry climatic cycle. The weighted estimate of flood frequency should be a better indicator of the true value because the regression estimate is an average of the flood histories of many gaging stations over a long period of time (Thomas and Lindskov, 1983).

Table 2. Basin characteristics and the range of values used in the analysis

Basin characteristics	Range of values
Drainage-basin area, in square miles	5.5 to 988.0
Mean annual precipitation, in inches	7.0 to 49.0
Mean drainage-basin elevation, in feet	2.805 to 12,200
Mean drainage-basin slope, in foot per foot	0.081 to 0.562

Sites near Gaging Stations on the Same Stream

Peak discharges for sites near gaging stations on the same stream can be estimated by using a ratio of drainage area for the sites near the ungaged sites and the gaged sites. This method is considered to be reliable when the drainage-area ratio is between about 0.5 and 1.5 and when the two sites have similar drainage-basin and climatic characteristics. If the sites of interest have similar basin and climatic characteristics and meet the drainage-area-ratio requirement, peak discharges can be computed by the following equation:

$$Q_{T(u)} = Q_{T(g)}(A_u/A_g)^x, \qquad (3)$$

where

$Q_{T(u)}$ is the peak discharge, in cubic feet per second, at the ungaged site for T-year recurrence interval;

$Q_{T(g)}$ is the weighted peak discharge, in cubic feet per second, at the gaged site for T-year recurrence interval;

A_u is the drainage area, in square miles, at the ungaged site;

A_g is the drainage area, in square miles, at the gaged site; and

x is the average exponent for drainage area for each flood region as follows:

Flood region	Exponent
Mountains	0.69
Rio Grande	0.88
Southwest	0.71
Northwest	0.64
Plains	0.40

The following is an example calculation to determine the 100-year peak discharge for an ungaged site near a gaged site on the same stream in the mountain region. The drainage area at the ungaged site is given as 350 mi^2 and at the gaged site is 450 mi^2. The weighted discharge for the 100-year peak at the gaged site is given as 11,500 ft^3/s.

1. Check that the drainage area ratio A_u/A_g is between 0.5 and 1.5. That ratio is as follows:

$$A_u/A_g = 350/450 = 0.78$$

which meets the ratio requirement.

2. Compute the discharge at the ungaged site using the specified values in equation 3:

$$Q_{100(u)} = 11,500(350/450)^{0.69} = 9,670 \text{ ft}^3/\text{s}.$$

Ungaged Sites

Peak discharges at ungaged sites can be computed using the appropriate regional equation shown in table 1. For sites on streams that cross regional boundaries, results from more than one of the regional equations need to be weighted as described below.

FLOOD INSURANCE STUDY

BOULDER COUNTY, COLORADO
AND INCORPORATED AREAS
VOLUME 1 OF 5

08013CV001

COMMUNITY NAME	COMMUNITY NUMBER
BOULDER,CITY OF	080024
BOULDER COUNTY,CO UNINCORPORATED AREAS	080023
JAMESTOWN,TOWN OF	080216
LAFAYETTE,CITY OF	080026
LONGMONT,CITY OF	080027
LOUISVILLE,CITY OF	085076
LYONS,TOWN OF	080029
NEDERLAND,TOWN OF	080255
SUPERIOR,TOWN OF	080203
WARD, TOWN OF	080292*

* NON-FLOOD PRONE COMMUNITIES

REVISED: OCTOBER 4, 2002

Federal Emergency Management Agency

and 0.2 percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 100-year flood (1 percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed methods affecting the community.

Hydrologic data from the various engineering reports discussed in Section 7.0 have been used extensively for the revised study of Boulder County, including peak discharges and starting water-surface elevations.

Because no stream gage data are available for the study streams through the City of Boulder, a rainfall-runoff analysis was conducted on the watersheds to determine the flood discharges. This was accomplished by using the UDFCD CUHP-B rainfall-runoff computer program to develop the storm hydrographs (Reference 27) and the USACE HEC-1 computer program for the stream and reservoir routings (Reference 28). For the analysis, basin characteristics of the watershed, as well as rainfall amounts based on the selected recurrence intervals, are used to compute flood hydrographs for various design points in the basin. All stream and reservoir routings were accomplished using the Modified Puls Method.

The 500-year storm runoff values for various locations along each stream were extrapolated from the discharge-frequency curves.

A more detailed description of the input variables for the CUHP-B and the HEC-1 rainfall-runoff analysis, as well as the CUHP-B computer output and the summary of the final HEC-1 computer output, are located in a technical addendum to this Flood Insurance Study (Reference 29).

Peak discharges for Gregory Creek, Bluebell Canyon Creek, Kings Gulch, Viele Channel, Anderson Channel, and Davids Draw were taken from reports prepared by Wright-McLaughlin Engineers (References 17 and 30) as part of a plan to manage the city's storm drainage.

Discharges for James Creek and the downstream portion of Little James Creek through the Town of Jamestown were taken from a USACE report (Reference 31). Technical Manual No. 1, developed by the

Table 4. Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
North Beaver Creek					
At Cross Section A	5.3	74	117	135	185
At Cross Section T	5.0	70	112	129	178
Prince Tributary					
Below Bullhead Confluence	8.16	--[1]	--[1]	4,772	--[1]
Above Bullhead Confluence	2.55	--[1]	--[1]	2,130	--[1]
At Upstream Limit of Detailed Study	0.58	--[1]	--[1]	423	--[1]
Rock Creek					
At Confluence With Coal Creek	21.6	2,870	5,350	6,690	10,240
At Downstream Corporate Limits	21.5	2,900	5,400	6,710	10,270
At South 120th Street	21.3	2,910	5,410	6,740	10,310
At Upstream Corporate Limits	18.7	2,900	5,360	6,640	10,050
At Denver-Boulder Turnpike	9.3	1,256	3,229	4,520	9,176
At McCaslin Boulevard	4.9	594	1,800	2,717	7,000
At Upstream Limit of Detailed Study	4.1	504	1,587	2,396	6,182
Skunk Creek					
At Confluence With Bear Canyon Creek	2.83	980	1,830	2,230	3,500
At Madison Avenue	2.43	920	1,580	1,870	2,650
At U.S. Highway 36	2.08	650	1,130	1,350	1,900
At Broadway	1.36	210	520	710	1,320
At Upstream Limit of Detailed Study	1.20	180	460	640	1,200
St. Vrain Creek (Vicinity of Longmont)					
At Mouth	924.0	5,350	12,120	16,520	40,080
St. Vrain Creek (Vicinity of Lyons)					
At Second Avenue	219.0	2,070	6,000	10,200	36,000
Twomile Creek					
At Confluence With Goose Creek	2.9	360	840	1,120	2,000
At Broadway	1.68	210	675	890	1,800
At Upstream Limit of Detailed Study	1.40	210	540	710	1,430

FLOOD INSURANCE STUDY

JEFFERSON COUNTY, COLORADO

AND INCORPORATED AREAS

VOLUME 1 OF 7

COMMUNITY NAME	COMMUNITY NUMBER
ARVADA, CITY OF	085072
*BOW MAR, CITY OF	080232
EDGEWATER, CITY OF	080089
GOLDEN, CITY OF	080090
*LAKESIDE, TOWN OF	080311
LAKEWOOD, CITY OF	085075
MORRISON, TOWN OF	080092
*MOUNTAIN VIEW, TOWN OF	080254
WESTMINSTER, CITY OF	080008
WHEAT RIDGE, CITY OF	085079
JEFFERSON COUNTY UNINCORPORATED AREAS	080087

*NON-FLOODPRONE COMMUNITIES

JUNE 17, 2003

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER

08059CV001A

Removal of vegetation, sediment deposits, debris, and rocks from the floodways of Bear Creek, Mount Vernon Creek, and Bear Creek Tributary No. 7 would improve flood control, but the problem of the inadequate capacity of the State Highway 8 box culvert would remain.

There are no flood protection works in the City of Westminster on the streams in the areas that were studied. However, two large reservoirs, Standley Lake and Great Western Reservoir, exist at the upstream limits of the study area and provide incidental protection even though they were not designed for flood control storage.

In addition, Ketner and Jackson Lake reservoirs exist within the study area but are primarily used for irrigation purposes and therefore, were not considered as flood protection structures. Westminster has passed zoning ordinances to prohibit construction within floodplains to lessen potential flood damage. The Ketner Reservoir has been renovated to increase its flood storage capacity, thus reducing the downstream flows and floodplains.

3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 100-year flood (1-percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed methods affecting the community.

Jefferson County (Unincorporated Areas)

Detailed discussions of the hydrologic analyses for the streams studied were presented in previous hydrology reports. The hydrologic analyses for Cold Spring, Kerr, Swede, and Switzer Gulches, and the SJCD 6200 North Tributary were discussed in a 1982 hydrology report (Reference 39). The remainder of the streams was discussed in a four-part technical addendum prepared in 1979 (Reference 40).

Discharges for streams with drainage areas greater than 15 square miles were calculated using a log-Pearson Type III frequency analysis (Reference 41). As is typical in Colorado, flood events in the study area comprise two distinct and generally independent populations (i.e., rain and snowmelt floods).

For this reason, it was necessary to analyze the rain and snowmelt events separately. Each type of flood event was assumed to follow log-Pearson Type III distribution. At each of 15 USGS gaging stations with at least 15 years of record, two annual peak flood series were determined, respectively, for the rain events and snowmelt events from streamflow charts. Three statistical parameters, the mean, standard deviation, and skew, which define the log-Pearson Type III distribution, were then computed for each type of flood event. The statistical parameters are intuitively dependent on watershed characteristics and hydrometeorologic conditions in the region. Two basin parameters, drainage area and mean watershed elevation, which most significantly affect the magnitudes of floods, are regarded as independent variables in the discharge predictive regression analyses. The regression equations, including only the significant independent variables for each type of event, were used to compute the flood-frequency curve at any ungaged site, given the drainage area and mean watershed elevation. These two frequency curves, one for rain events and the other for snowmelt events, were then statistically combined to give a composite flood-frequency curve that defines the flood-frequency curve for the ungaged site in question.

Discharges for streams with less than 15 square miles of drainage area were calculated using the Colorado Urban Hydrographic Procedure (CUHP) (Reference 42). The 10-, 50-, and 100-year discharges were calculated directly, whereas the 500-year was estimated by extrapolation. Peak discharges at selected locations in the study area were obtained by routing CUHP flood hydrographs for each subbasin.

Peak discharges for the South Platte River were developed as part of the FIS for Douglas County (Reference 20). In that study, a log-Pearson Type III analysis (Reference 41) was used to calculate the discharges. Streamflow data from USGS stream-gaging stations located at South Platte (Gage No. 06707500) and below Cheesman Lake (Gage No. 06701500) were used in the frequency analysis.

The hydrologic analyses for Lena Gulch upstream of West 6th Avenue, Jackson Gulch, Kenneys Run, and Clear Creek, upstream of the Burlington Northern Railroad were developed as part of the FIS for the City of Golden (Reference 5). In that study, the peak discharges for Clear Creek above the Burlington Northern Railroad were obtained from the USACE, Omaha District (Reference 43). The USACE established peak discharge frequency relationships for floods of 10-, 50-, 100-, and 500-year recurrence intervals. A log-Pearson Type III analysis (Reference 41) was conducted on the discharge records for the Clear Creek USGS stream gages at Golden (1911-76) and Derby (1934-76); however, the statistical parameters computed by these methods were not sufficiently reliable to predict the frequency of extreme events. In lieu of a discharge-frequency analysis, a rainfall-runoff approach was used. The Massachusetts Institute of Technology Catchment Model (Reference 44) was constructed for the 400-square-mile area above the Golden gage, and a storm water management model (Reference 45) was constructed for the 175-square-mile area between the Golden and Derby gages. The rainfall depths used in the analysis were based on data obtained from the 1973 National Oceanic and Atmospheric Administration (NOAA) report,

Table 4. Summary of Discharges

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
Airport Creek					
At confluence with Big Dry Creek	2.39	550	1,250	1,590	2,860
At confluence with North Branch Airport Creek	1.06	350	780	850	1,491
At upstream study limit	0.43	340	690	815	1,348
Apex Gulch					
At confluence with Lena Gulch	1.47	390	680	830	1,250
Bear Creek					
Below Mt. Carbon Dam	239.00	500	1,000	1,000	2,000
Below confluence with Mount Vernon Creek	174.00	2,270	8,410	14,000	41,400
At USGS Gage at Morrison	164.00	2,180	8,140	13,500	39,900
Below confluence with Sawmill gulch	158.00	1,930	6,750	10,800	30,500
Below confluence with Swede Gulch	146.00	1,710	5,850	9,500	25,000
Above confluence with Myers Gulch	139.00	1,600	5,350	8,500	22,500
Above confluence with Troublesome Creek	126.00	1,390	4,500	7,100	17,750
Above confluence with Buffalo Creek	96.00	950	2,780	4,200	9,500
At Western Jefferson County Line	85.00	800	2,250	3,250	7,050
Below confluence with Mount Vernon Creek	174.00	2,270	8,410	14,000	41,400
Above confluence with Mount Vernon Creek USGS Gage No. 067105	164.00	2,180	8,140	13,500	39,900
Bear Creek Tributary No. 1					
At mouth	0.59	145	385	510	980
At upstream limit of detailed study	0.14	45	115	155	285
Bear Creek Tributary No. 2					
At mouth	0.69	100	290	385	670
Bear Creek Tributary No. 3					
At Dedisee Park Road	0.41	120	310	415	760

[1]Data not available

Table 4. Summary of Discharges (Cont'd)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
Buffalo Creek					
At confluence with Sand draw	46.70	370	540	630	840
City Park Channel					
At confluence with Nissen Reservoir Channel	5.68	770	1,300	1,500	2,250
Clear Creek					
Above confluence with Tucker Gulch	403.80	3,470	8,010	12,420	27,430
Below confluence with Tucker Gulch	420.70	3,470	8,480	13,070	28,900
Above confluence with Ralston Creek	455.00	3,710	9,750	14,520	31,000
At Kipling Boulevard	450.00	3,280	9,000	13,470	29,850
At upstream limit of detailed study	325.00	3,280	9,000	13,470	29,850
Cold Spring Gulch					
At mouth	5.07	655	1,630	2,070	4,025
0.40 mile above mouth	4.49	590	1,485	1,885	3,575
1.74 miles above mouth	1.99	285	750	960	1,900
Coon Creek					
At mouth	4.56	1,930	2,620	2,950	3,650
At Bowles Avenue	3.89	1,760	2,350	2,655	3,500
Countryside Creek					
At confluence with Walnut Creek	1.13	300	660	840	1,479
At upstream study limit	0.60	235	520	620	1,090
Cressmans Gulch					
At confluence with Tucker Gulch	1.48	230	510	710	--[1]

[1]Data not available

Table 4. Summary of Discharges (Cont'd)

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
Kerry Gulch					
At mouth	3.95	585	1,395	1,945	3,300
At confluence with Swede Gulch	1.84	310	660	1,040	1,900
At upstream limit of detailed study	0.96	175	460	590	1,180
Lena Gulch					
At U.S. Highway 6	3.68	1,000	1,800	2,200	3,300
At confluence with Apex and Jackson Gulches	2.38	900	1,500	1,810	2,600
Lena Gulch Tributary					
At mouth	0.39	140	285	350	570
Leyden Creek					
At Simms Street	11.80	1,000	2,000	2,500	4,000
Below Leyden Lake	9.00	850	1,150	2,200	3,400
Above Leyden Lake	9.00	1,500	3,000	3,750	6,200
At Foothills Road	4.20	1,300	2,500	3,300	5,400
Lilley Gulch					
At mouth	3.01	1,240	1,660	1,880	2,300
Above confluence with North Branch Lilley Gulch	1.88	1,150	1,540	1,720	2,050
At Simms Road	0.43	380	510	585	700
Little Cub Creek					
At mouth	2.83	300	885	1,180	2,000
Massey Draw Tributary					
At Wadsworth Boulevard	0.99	585	820	920	1,200
At Garrison Road	0.53	370	515	570	700

[1]Data not available

Table 4. Summary of Discharges (Cont'd)

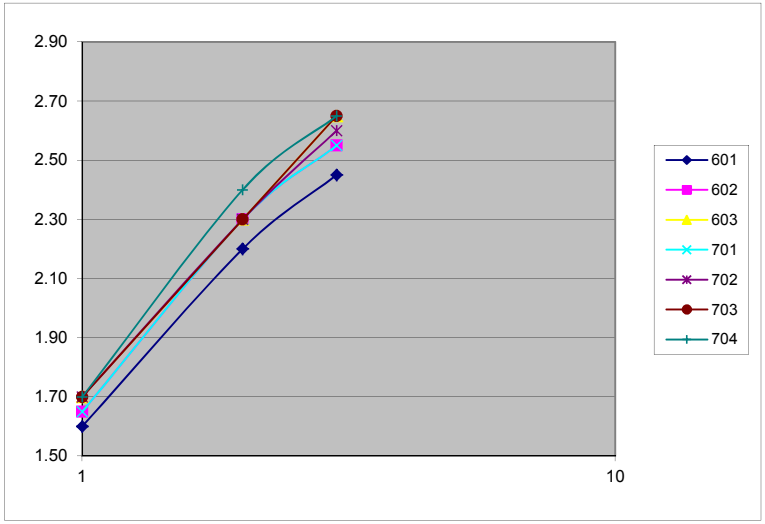
Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharges (Cubic Feet per Second) 10-Year	50-Year	100-Year	500-Year
Weaver Creek					
At West Hampden Avenue	5.11	1,820	2,515	2,820	3,550
At upstream limit of detailed study	1.99	200	285	300	415
West Fork Kenneys Run					
Above 20th Street	3.43	770	1,610	2,010	--[1]
West Fork Kenneys Run Tributary No. 1					
At confluence with West Fork Kenneys Run	1.00	170	460	620	--[1]
West Fork Kenneys Run Tributary No. 2					
At confluence with West Fork Kennys Run	0.36	90	240	330	--[1]
Wilmot Creek					
At mouth	1.73	360	900	1,175	1,850
Above confluence with Wilmot Creek Tributary	0.56	100	285	380	650
Wilmot Creek Tributary					
At mouth	0.61	150	375	490	830
At upstream limit of detailed study	0.26	55	160	215	390

[1]Data not available

Basin	Rainfall[1] (in) 10-YR	50-YR	100-YR	Trend Line	Extrapolated Rainfall (in) 5-YR	25-YR	500-YR
601	1.60	2.20	2.45	y=0.3698Ln(x) + 0.7496	1.34	1.94	3.05
602	1.65	2.30	2.55	y=0.3932Ln(x) + 0.7487	1.38	2.01	3.19
603	1.70	2.30	2.65	y=0.4056Ln(x) + 0.7539	1.41	2.06	3.27
701	1.65	2.30	2.55	y=0.3932Ln(x) + 0.7487	1.38	2.01	3.19
702	1.70	2.30	2.60	y=0.3877Ln(x) + 0.8018	1.43	2.05	3.21
703	1.70	2.30	2.65	y=0.4056Ln(x) + 0.7539	1.41	2.06	3.27
704	1.70	2.40	2.65	y=0.4165Ln(x) + 0.7478	1.42	2.09	3.34

[1]Rainfall values taken from 1987 FHAD Technical Appendix

Rainfall (in) by UDFCD Figures 5-YR	% Diff.	25-YR	% Diff.
1.35	0%	**1.95**	1%
1.38	0%	**2.02**	0%
1.40	0%	**2.05**	0%
1.35	-2%	**2.00**	-1%
1.39	-3%	**2.02**	-1%
1.41	0%	**2.06**	0%
1.42	0%	**2.08**	0%



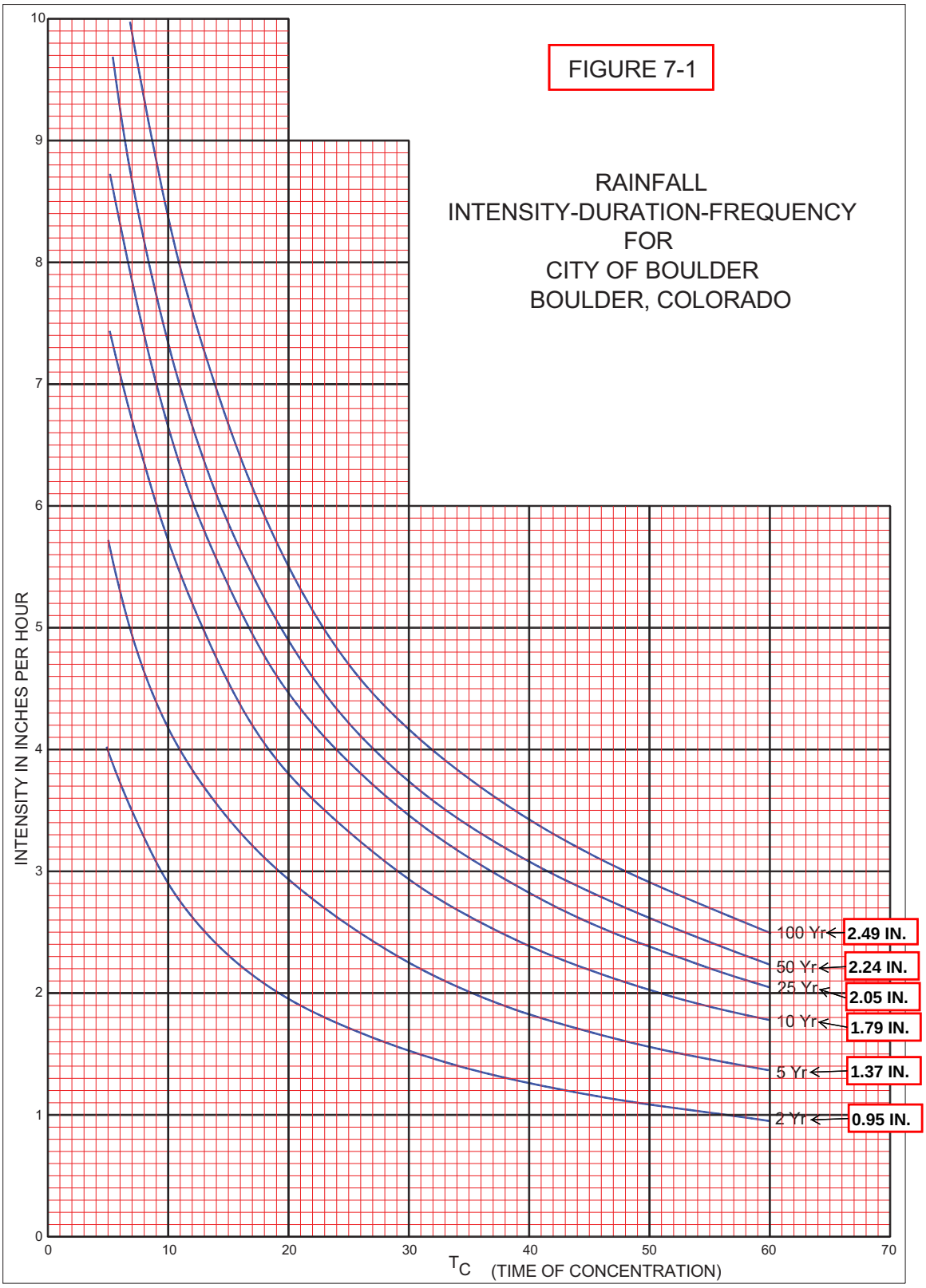


FIGURE 7-1
RAINFALL
INTENSITY-DURATION-FREQUENCY
FOR
CITY OF BOULDER
BOULDER, COLORADO
INTENSITY IN INCHES PER HOUR
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
TC (TIME OF CONCENTRATION)
100 Yr
2.49 IN.
50 Yr
2.24 IN.
25 Yr
2.05 IN.
10 Yr
1.79 IN.
5 Yr
1.37 IN.
2 Yr
0.95 IN.

Appendix J –
Review Comments and Responses

ICON ENGINEERING, INC. 8100 S. Akron Street, Suite 300, Centennial, CO 80112 - Phone (303) 221-0802 / Fax (303)-221-4019

Planning

Design

Management

February 16, 2012

Mr. Kurt Bauer, P.E.
Engineering Project Manager
Department of Public Works / Utilities Division
1739 Broadway, 2nd Floor
Boulder, Colorado 80302

RE: Upper Goose Creek and Twomile Canyon Creek – Flood Mapping Study Update – Hydrology Verification Report Revision

Dear Mr. Bauer,

This letter provides responses to the comments provided by the City of Boulder, the Urban Drainage and Flood Control District and by Anderson Consulting Engineers as part of the peer review regarding the Upper Goose Creek and Twomile Canyon Creek – Flood Mapping Study Update – Hydrology Verification Report, dated December 9, 2011.

City of Boulder Comments:

1. **Please include pertinent information from the October 19, 2011 progress meeting in the main body of the report, including a summary justifying the recommended hydrology approach.**

   Additional information from the October 19, 2011 progress meeting has been incorporated into the main body of the revised Hydrology Verification Report with further justification regarding the recommended discharges.

2. **The unnamed and untitled table presented in Appendix H summarizes peak flows presented during our Oct. 19, 2011 progress meeting. Please provide a title for this table. The values in this table do not match those presented in Table 4.2 of the main report. Please provide a description as to why they differ.**

   The table presented in Appendix H has been titled. The values do not exactly match those presented in Table 4.2 due to minor revisions (mainly changes to the Manning's n value) in the SWMM routing model that were completed after the progress meeting.

3. **The peak flows presented in Table 4.2 of the main report no longer indicate that the duplicate effective model results are within 20% of the effective model results. Please discuss this in the report and present a revised recommendation for hydrology if necessary.**

   The Duplicate Effective model results (those using Cp and Ct as derived from CUHP) have a maximum deviation from the Effective information of 23% for the 10-, 50-, and 100-year information. The 500-year Duplicate Effective model results, which were not presented in the October 19, 2011 progress meeting have a maximum deviation of 29%. At the time of the October 19, 2011 progress meeting, the maximum deviation presented

in the 10-, 50-, and 100-year information was 25%, or 18% if only the 100-year discharges were considered. Given that the Duplicate Effective results are still within the same order of magnitude for deviation from the Effective information, the decision to proceed with calibration of the CUHP remains valid and the ultimate recommendation for hydrology has not been revised. The report has been revised to reflect this information.

4. **A portion of subcatchment 603 is tributary to Elmer's Twomile Canyon Creek. This approximately 90 acres of land should not be included as being tributary to Twomile Canyon Creek. Attached is a memorandum and figure from the recently approved LOMR for Elmer's Twomile Canyon Creek showing this area.**

   The approximate 90 acres that is tributary to Elmer's Twomile Canyon Creek has been removed from sub-basin 603 for the Corrected Effective conditions. Please note that the 90 acres remains included in sub-basin 603 for the purposes of calibration of the CUHP in order to be consistent with the basin size that was used to develop the effective discharges.

5. **The main report (pg 9) references Table 4.1 as presenting duplicate effective hydrograph results. Please check this table number as it does not seem to be correct.**

   This table reference has been corrected.

6. **Please include an analysis and review of up to three Front Range drainageways with similar basin size and development conditions per the project scope of work.**

   An analysis and review of three Front Range drainageways have been included in the revised report.

<u>Urban Drainage and Flood Control District Comments:</u>

1. **Comment refers to the order - prior to calibration? - in which sub-watersheds were further refined to reflect current and future land use and basin imperviousness, as well as sub-watershed boundaries as revised.**

   The sub-basin revisions to reflect changes in basin imperviousness and boundaries were not completed prior to calibration. In order to accurately calibrate the CUHP models to the Effective information, the imperviousness and basin boundaries were left unrevised in order to best match the equivalent Effective conditions properties. Once the calibration to the Effective discharges was completed, changes to the imperviousness and basin boundaries were done so that the Corrected Effective conditions discharges reflected current imperviousness and basin boundaries while using the Cp calibration factor that was determined as a result of calibrating to the Effective discharges.

2. **Comment refers to the mentioning of discharge comparison to regional regression equations and other analysis being excluded from this report.**

   A comparison of the recommended discharges to the regional regression equations and to similar drainage basins has been included in the revised report.

3. **Why not use aerial background for vicinity map?**

   The vicinity map has been revised and only the detail portion is included in the revised report. Aerial imagery was not used for clarity due to the size of area depicted.

4. **Comment refers to the clarity of discussion regarding discharges intersecting the roadway embankment.**

   Additional discussion has been included in the revised report in order to clarify why drainage basin 603 was revised to only include basin area east of Broadway.

5. **Comment requests clarification on which values were used in the 1987 FHAD for open space and sparse development within Boulder County west of the City of Boulder limits.**

   The 5% impervious value used in the report reflects the County's current forestry land use designation. The 1987 FHAD also used 5% impervious for similar open space. The FHAD's 7% impervious value for basin 601 is a result of 82 of the 898 total acres being designated as low density development at 30% impervious. The report has been revised to clarify that the FHAD also used 5% impervious for open space areas.

6. **Comment requests additional clarification for the difference in % impervious for each sub-basin, specifically for sub-basins 703 and 704.**

   As noted in the original report the % impervious values for each sub-basin were updated to reflect the actual percent impervious values based on impervious surface area data provided by the City of Boulder. Two specific areas were also addressed in the text – the future single family residential development north of the Sanitas Wellness Center and areas west of the City's impervious data. The % impervious difference between the FHAD and the Corrected Effective conditions in sub-basins 703 and 704 is directly related to the impervious surface area data used to calculate the % impervious. The FHAD used a combination of open space and high density development compared to this report which used the actual % impervious data as provided by the City of Boulder.

7. **Round basin size to nearest acre or tenth of an acre.**

   Basin sizes have been rounded to the nearest acre.

8. **Label Sanitas Wellness Center.**

   The Sanitas Wellness Center has been labeled.

9. **Comment requests comparison of 5- and 25-year rainfall depths from the UDFCD figures versus the same trendline used to extrapolate the 500-year rainfall depth.**

   The 5- and 25-year rainfall depths from the UDFCD figures are within 3% of the values derived by using the trend line. Additional discussion has been included in the revised report to clarify this comparison. Trend line formulas and a comparison table are included in Appendix I of the revised report.

10. **Comment requests clarification on how rainfall depths were obtained.**

    As noted in the text, the 10-, 50-, and 100-year rainfall depth values were taken directly from the 1987 FHAD information. The 10- and 50-year rainfall excerpts from the FHAD Technical Appendix have been added to Appendix A of the revised report for reference. The 500-year rainfall depth was based on a logarithmic trend line using the 10-, 50-, and 100-year data points. The 5- and 25-year rainfall depths were derived from the UDFCD rainfall figures and compare well to the logarithmic trend line used for the 500-year rainfall depth (see comment no. 9 above).

11. **Comment asks for clarification on decision to use different rainfall depths for each sub-basin and using Boulder's rainfall data after calibration.**

    It is ICON's recommendation that the rainfall depths for each individual sub-basin be used for consistency with the Effective methodology. The City of Boulder rainfall data compares very well to the values used for the individual sub-basins. Additional rainfall background data including the City of Boulder IDF curve has been included in Appendix I.

    Please note that the rainfall depth table in the main 1987 FHAD report text only provides limited rainfall depth information for each drainageway. The 1987 FHAD Technical Appendix includes sub-basin specific rainfall values that are not reflected in the FHAD report table. The sub-basin specific rainfall values from the 1987 FHAD Technical Appendix for the 10-, 50-, and 100-year storms are included in Appendix A.

12. **Comment requests clarification on the need to include the step which used the Ct and Cp values as determined by CUHP.**

    The step which used CUHP to determine the Ct and Cp values was initially completed as a comparison to using the Ct and Cp values directly from the FHAD. As it turned out, the discharges developed using the Ct and Cp values calculated by CUHP compared much better to the effective conditions values relative to the discharge values developed using the 1987 FHAD; therefore this step was included in the report. After discussions with the City of Boulder, the step that used Ct and Cp values from the FHAD information has now

been removed from the report in an effort to add clarity to the Duplicate Effective process.

13. **Comment questions the comparison of the effective discharge with the two duplicate effective discharges (100-year differences tops out at 22%, where the 500-year difference tops out at 29%).**

    The 500-year discharge does have a greater absolute difference as compared to the Effective discharge. However, the large differences in the 500-year discharge occur high in the drainage. At the lower end of each drainageway, (junction 603 and 704) the 500-year is within 4% of the Effective discharge while the 100-year is at a 22% and 19% difference respectively. By focusing on design points near the downstream end of the drainageways, the recommendation to not use the calibration factor for the 500-year was made. This recommendation is reinforced by the fact that the calibrated 500-year discharges continue to have differences on the order of 29% high in the drainage, but also deviate by 21% at junction 603 and by -18% at junction 704. The report has been revised to add clarification to the recommendation to not use calibration for the 500-year event as a result of the positive discharge comparisons at the low end of each drainage.

14. **Comment suggests moving the future drainage basin areas within Table 4.2.**

    Table 4.2 has been revised as a result of general revisions to the Hydrology Verification Report. The “Future DA” title has been revised to “Corrected Effective DA” and the values have been included only in the revised tables that reference the Corrected Effective Conditions discharges.

15. **Comment suggest removing the Duplicate Effective (by FHAD Cp and Ct) from the discharge table.**

    The Duplicate Effective (Cp and Ct by FHAD) discharge information has been removed from the table and in general has been removed from the revised report (see comment no. 12 above).

16. **Comment questions the need for the Duplicate Effective 10-year CUHP input information.**

    The Duplicate Effective CUHP information has been retained in Appendix B for reference to Cp and Ct values.

17. **Comment suggests including only the 100-year SWMM input/output given that nothing changes between return intervals.**

    The SWMM input/output information for all return intervals have been retained in Appendix C for reference to discharge values.

Anderson Consulting Engineers (peer review) Comments:

1. **The scope of work provided by the COB stated that ICON would complete a review of up to three Front Range drainageways with similar basin size and development conditions for discharge comparisons. The scope also stated USGS regional regression equations would be used to compute discharges to be compared to the results of ICON's analysis. ICON acknowledged in their report that "due to the decisions made regarding calibration, comparison to regional regression equations and other analyses completed have been excluded from this report for clarity." Results from the USGS regression equation were provided in the appendix; however, comparisons to similar basins were not included in ICON's report. ICON's regional regression equation results generally did not compare favorably with the recommended discharges computed by ICON using CUHP/EPA-SWMM, with the exception of Goose Creek downstream of Folsom Street. Providing the additional discharge data from similar Front Range watersheds would be beneficial for further evaluating the CUHP/EPASWMM results.**

   The revised report includes additional discharge comparisons with three Front Range Drainage basins and comparisons with regional regression equations.

2. **Limited documentation was included in the appendices concerning an existing condition analysis performed by ICON that sub-divided the effective condition subbasins into "more regularly shaped sub-catchments," another preference of the UDFCD. Results from this analysis were disregarded as "the effective drainage basins should not be sub-divided any more than considered necessary for application of hydrographs along the main channel." This reasoning is valid provided the subbasins are generally hydrologically homogenous and do not result in significant levels of concentrated flow. It appears that the subbasin delineation from ICON's existing condition modeling effort more appropriately defines smaller, homogenous hydrologic units than does the corrected effective condition hydrologic model, which utilizes subbasins that seem to be somewhat larger than appropriate.**

   Per the October 19, 2011 progress meeting, the project sponsors and ICON agreed that additional sub-basin discretization would not be completed in order to avoid increased discharges resulting from the sub-division of the effective sub-basins in accordance with the District's recommendations for calibration.

3. **Attached to this memorandum is a figure that provides an alternative comparison to other regional watershed discharges. The graph has been used by the Federal Emergency Management Agency (FEMA) to assess base flood (i.e., 1-percent annual chance) discharge data versus drainage area for over 40 gaging stations in the Plains Region of Colorado and Kansas, as well as a limited number of gages in New Mexico, Oklahoma, Wyoming, and Nebraska. The corrected effective discharges determined by ICON fall within the approximate data envelope delineated on the graph. However, as compared to a number of Colorado gaging stations with drainage areas less than eight square miles, the corrected effective discharges from the Twomile Canyon Creek analysis at the confluence with Goose**

Creek appear to be somewhat low. The corrected effective discharges from the Goose Creek analysis downstream of Folsom Street appear to more closely reflect the gage data. The graph seems to validate results obtained from the USGS regression equations. It is worth noting that existing condition discharges computed by ICON also fall within the approximate data envelope and compare favorably with the stream gage information from Colorado watersheds of similar drainage area.

Considering the comparative subbasin delineations between the corrective effective and existing condition analyses, along with the more favorable comparison to USGS gaging data and regression equations, consideration should be given to using the existing condition discharges rather than the corrected effective discharges. However, it may be appropriate for this recommendation to be modified or eliminated if a favorable comparison could be demonstrated with discharges from similar Front Range watersheds.

The Hydrology Verification Report has been revised to include comparisons with regional regression equations and similar Front Range watersheds. Based on the reasonable comparisons between both the regional regression equations (at the downstream end of the study reach) and the similar Front Range watershed discharges, the recommendation to proceed with the Corrected Effective Conditions discharges using the calibrated Cp factor for the 5-, 10-, 25-, 50-, and 100-year events was further justified. The 500-year Corrected Effective discharge does not use the calibrated Cp value.

This approach essentially uses the Effective Conditions Discharges (based on the calibration of current software to the Effective Conditions Discharges), but with changes to basin delineation and % impervious necessary to reflect actual conditions (i.e. Corrected Effective Conditions).

The recommended discharges fall within the approximate data envelope as indicated on the figure provided by Anderson Consulting Engineers. Based on this data envelope, the recommended discharges compare favorably with the stream gage information from Colorado watersheds of similar drainage area.

Please let me know if there is any additional information needed to clarify our responses to the above review comments. The revised Hydrology Verification Report has been provided under separate cover.

Sincerely,

Brian LeDoux, P.E., CFM
ICON Engineering, Inc.