URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

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TECHNICAL MEMORANDUM

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SUBJECT: Determination of the Excess Urban Runoff Volume (EURV) for Full Spectrum Detention Design

DATE: Revised December 22, 2016 (March 23, 2015)

The purpose of this memorandum is to document the process used to develop new equations to estimate runoff volumes and the Excess Urban Runoff Volume (EURV) as the basis for full spectrum detention design. Simply put, the EURV is the difference in runoff volume between the developed condition and the undeveloped (i.e., natural) condition. The concept of full spectrum detention is described in the Storage chapter of the *Urban Storm Drainage Criteria Manual* and in other technical papers available for download at www.udfcd.org.

All of the equations developed in this memorandum were based on Colorado Urban Hydrograph Procedure (CUHP 2005, v2.0.0) modeling and one-hour rainfall depths from NOAA Atlas 14 at the Capitol Building in Denver.

The runoff volume equations are only valid for one-hour rainfall depths between 0.83 and 3.14 inches as shown in Table 1. These one-hour rainfall depths were temporally distributed over a two-hour period to create design storms consistent with CUHP protocol for the 2-, 5-, 10-, 25-, 50-, 100, and 500-year return periods.

Table 1: Average one-hour rainfall depth in the Denver region, as a function of probability of occurrence.

Recurrence Interval (Years)	Probability of Occurrence	Rainfall Depth (Inch)
2	0.50	0.83
5	0.20	1.09
10	0.10	1.33
25	0.04	1.69
50	0.02	1.99
100	0.01	2.31
500	0.002	3.14

CUHP was used to evaluate 2,020 subcatchments from recent UDFCD master planning studies. Subcatchments having a width/length ratio, slope, or centroid length outside one standard deviation of the mean of the data set were discarded in order to limit data scatter, leaving 1,203 subcatchments for further evaluation. The CUHP model was run for all 1,203 subcatchments and return periods with the hydrologic parameters listed in Table 2. Watershed characteristics (e.g., size, shape, slope, location of centroid, and imperviousness) were taken directly from the master planning studies. Various combinations of Soil Type (A, B, and C/D) were evaluated for each subcatchment.

Table 2: hydrologic parameters used in the CUHP modeling.

Soil Group	**Historic Impervious Percentage (%)**	**Pervious Depression Storage (inch)**	**Impervious Depression Storage (inch)**	**Initial Infiltration Rate (in/hr)**	**Horton's Decay Coefficient (second^{-1})**	**Final Infiltration Rate (in/hr)**
HSG A	2	0.35	0.1	5.0	0.0070	1.0
HSG B	2	0.35	0.1	4.5	0.0018	0.6
HSG C	2	0.35	0.1	3.0	0.0018	0.5

By performing a multiple regression analysis on the results for the 1,203 CUHP subcatchments, equations were developed for the 2-, 5-, 10-, 25-, 50-, 100- and 500-yr return periods for each hydrologic soil group and combined to provide the following watershed runoff equations:

$$V_{Runoff\_2yr} = P_1A[(0.082I^{1.311})A\% + (0.082I^{1.179})B\% + (0.082I^{1.132})CD\%] \quad (1)$$

$$V_{Runoff\_5yr} = P_1A[(0.084I^{1.285})A\% + (0.084I^{1.098})B\% + (0.082I + 0.003)CD\%] \quad (2)$$

$$V_{Runoff\_10yr} = P_1A[(0.086I^{1.241})A\% + (0.081I + 0.005)B\% + (0.073I + 0.012)CD\%] \quad (3)$$

$$V_{\_Runoff\_25yr} = P_1A[(0.087I^{1.133})A\% + (0.063I + 0.024)B\% + (0.056I + 0.030)CD\%] \quad (4)$$

$$V_{Runoff\_50yr} = P_1A[(0.084I + 0.002)A\% + (0.054I + 0.032)B\% + (0.048I + 0.038)CD\%] \quad (5)$$

$$V_{Runoff\_100yr} = P_1A[(0.077I + 0.010)A\% + (0.046I + 0.041)B\% + (0.040I + 0.047)CD\%] \quad (6)$$

$$V_{Runoff\_500yr} = P_1A[(0.064I + 0.024)A\% + (0.036I + 0.052)B\% + (0.031I + 0.057)CD\%] \quad (7)$$

Where $V_{\#yr}$ is the runoff volume for the given return period (acre-feet), P_1 is the one-hour rainfall depth (inches), A is the contributing watershed area (acres), I is the percentage imperviousness (expressed as a decimal), and *A%*, *B%*, and *CD%* are the percent of each hydraulic soil group (also expressed as a decimal). The CUHP Excel™ workbooks and multiple regression analysis files were saved in an archival folder named "*CUHP_Runoff_Volume_Equations.zip*" in the master planning reference library.

Runoff volume equations 1 through 7 were then used to calculate the EURV as the difference between developed condition runoff volume and historic runoff volume. The developed condition runoff volume was calculated for varying levels of imperviousness from 10 percent up to 100 percent. The historic condition runoff volume was estimated by setting the watershed imperviousness to 2%. The calculated EURV results in watershed inches versus imperviousness for each NRCS hydrologic soil group are shown in Figures 1 through 3.

A power curve was fit to the data set for each return period to develop an equation for the EURV. From Figures 1 through 3 it can be seen that the EURV is not always directly proportional in magnitude to the return period, that is to say that the 100-year EURV is not necessarily greater than the 50-year, the 25-year, or the 10-year EURV. The 10-year EURV was chosen as the representative EURV not because it is the largest, but because it is the most consistent among the three hydrologic soil groups.

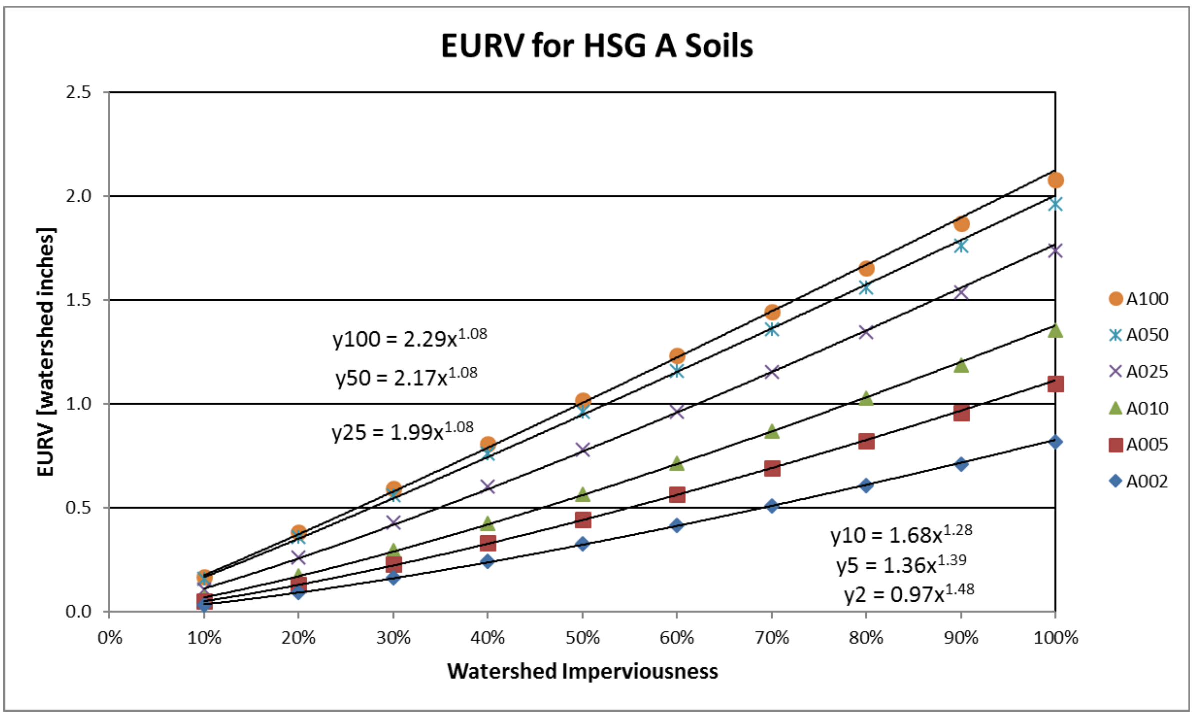

Figure 1: Hydrologic Soil Group A. Plot of EURV represented as the difference between developed condition and historic condition, in units of runoff depth per impervious area.

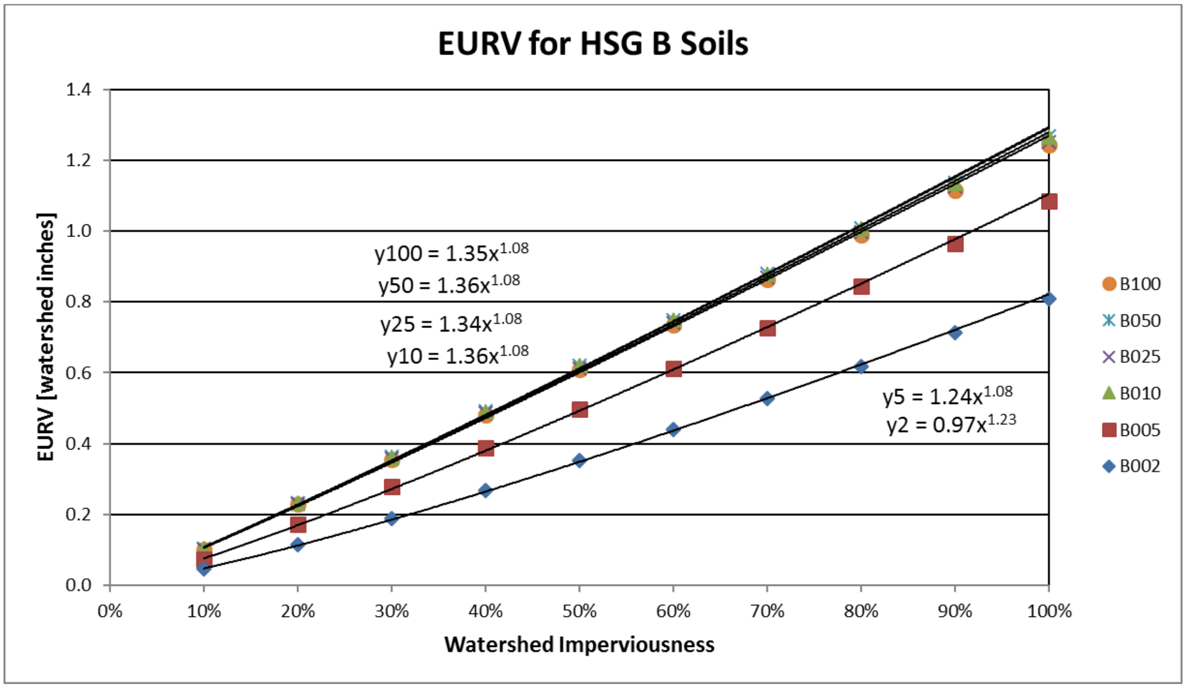

Figure 2: Hydrologic Soil Group B. Plot of EURV represented as the difference between developed condition and historic condition, in units of runoff depth per impervious area.

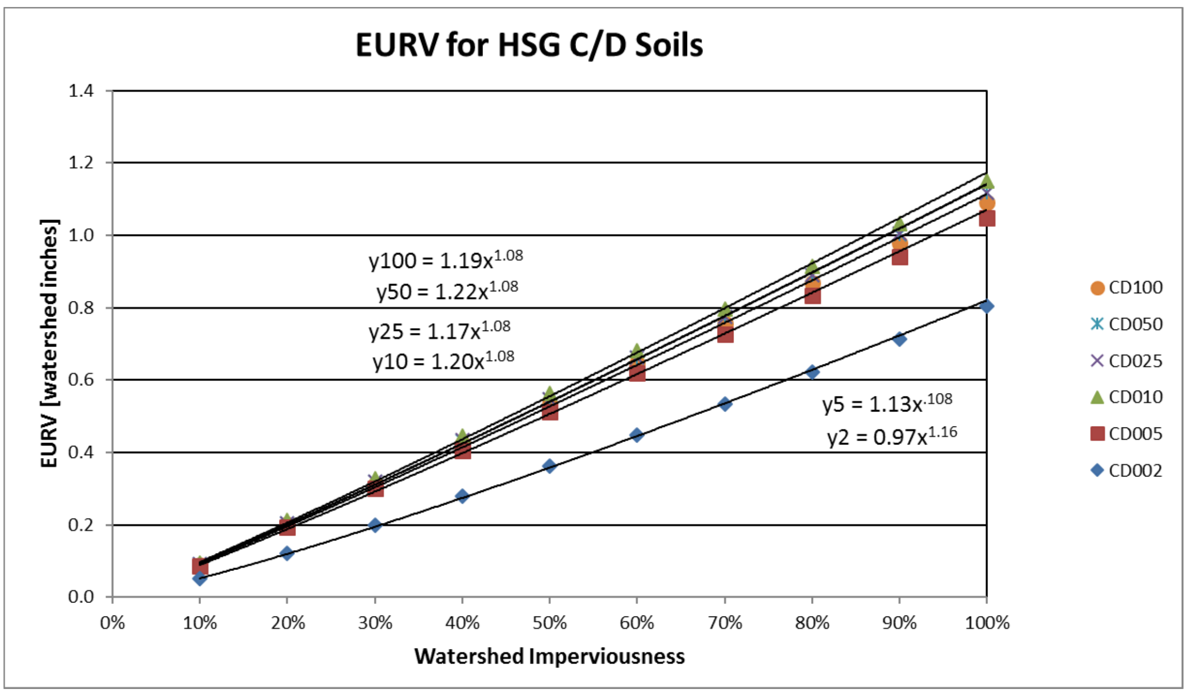

Figure 3: Hydrologic Soil Groups C and D. Plot of EURV represented as the difference between developed condition and historic condition, in units of runoff depth per impervious area.

To calculate the EURV in terms of runoff watershed inches, the resulting three EURV equations for the three representative hydrologic soil groups are:

$$EURV_{HSG\ A} = 1.68(IMP)^{1.28} \tag{8}$$

$$EURV_{HSG\ B} = 1.36(IMP)^{1.08} \tag{9}$$

$$EURV_{HSG\ C/D} = 1.20(IMP)^{1.08} \tag{10}$$

In which *EURV* is the excess urban runoff volume, ***in watershed inches***, and *IMP* is the developed condition imperviousness of the watershed, expressed as a ratio less than 1.

To calculate the EURV in units of acre feet, equations 8 through 10 are written as:

$$EURV_{HSG\ A} = Area * 0.140(IMP)^{1.28} \tag{11}$$

$$EURV_{HSG\ B} = Area * 0.113(IMP)^{1.08} \tag{12}$$

$$EURV_{HSG\ C/D} = Area * 0.100(IMP)^{1.08} \tag{13}$$

In which *EURV* is the excess urban runoff volume, ***in acre feet***, and *IMP* is the developed condition imperviousness of the watershed, expressed as a ratio less than 1. Equations 11 through 13 can then be combined to form equation 14.

$$EURV = Area * [0.140(IMP)^{1.28} * A\% + 0.113(IMP)^{1.08} * B\% + 0.100(IMP)^{1.08}] \tag{14}$$

<u>Example Problem:</u> A 50-acre Denver area watershed is situated on 44% HSG B and 56% HSG C. That portion of the watershed on HSG B soils is 35% impervious, the rest is 45% impervious.

Determine the excess urban runoff volume for this watershed.

Analysis:

$EURV_{HSG\ B} = 50 * 0.44 * 0.113(0.35)^{1.08}$ = 0.80 acre feet;

$EURV_{HSG\ C/D} = 50 * 0.56 * 0.10(0.45)^{1.08}$ = 1.18 acre feet

The excess urban runoff volume is 0.80 + 1.18 acre feet = **1.98 acre feet**.

This could also be calculated as:

$EURV_{HSG\ B} = 1.36(0.35)^{1.08}$ = 0.4377 inches per HSG B watershed area.

$EURV_{HSG\ C/D} = 1.20(0.45)^{1.08}$= 0.5066 inches per HSG C/D watershed area.

$$\left[(EURV_{HSG\ B})(HSG\ B\%) + \left(EURV_{HSG\ C/D}\right)(HSG\ C/D\%)\right]\left(\frac{AREA}{12}\right)$$

(0.4377*0.44 + 0.5066*0.56)(50/12) = **1.98 acre feet**.