SECTION 4.0 – RUNOFF ANALYSIS
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SECTION 4.0 RUNOFF ANALYSIS

4.1 INTRODUCTION

This section presents the criteria and methodology for determining the storm runoff design peaks and volumes to be used in the City of Greeley in the preparation of storm drainage studies, plans, and facility design. Further details and discussion of each of these rainfall/runoff models are presented in the Urban Storm Drainage Criteria Manual (USDCM).

4.2 RATIONAL METHOD

The Rational Method may be utilized for the sizing of storm drains and for determining the amount of runoff from undeveloped areas. The limit of application of the Rational Method is approximately 160 acres. It has been concluded that, for tributary basins in excess of 160 acres, the cost of the drainage works justifies significantly more study, thought, and judgment on the part of the Engineer, than is permitted by the Rational Method. When the urban drainage basin exceeds 160 acres, the CUHP Method represents better practice and should be used.

The procedures for the Rational Method, as explained in the USDCM, Volume 1, Chapter, "Runoff" shall be followed in the preparation of drainage reports and storm drainage facility designs in the City.

Standard forms for the calculation of Time of Concentration and Storm Drainage System Design are provided in Tables 4-1 and 4-2.

4.3 COLORADO URBAN HYDROGRAPH PROCEDURE (CUHP)

The application of the CUHP is required for drainage basins and projects larger than 5 acres. The procedures for the CUHP, as explained in the USDCM, Volume 1, Chapter "Runoff", shall be followed in the preparation of drainage reports and storm drainage facility designs in the City. The design storm events to be used with the CUHP method are presented in Section 3 of these Criteria. Applicable infiltration depths are outlined in Section 3.2 of the USDCM, Volume 1, Chapter "Runoff".

A computer program has been developed to calculate hydrographs using the CUHP Method. This program is available for use on both large mainframe computers and on personal computers. In addition, the personal computer version has an added capability of using CUHP to compute runoff hydrographs for basins as small as 5 acres. For the City, only the personal computer version with the capability to model basins as small as 5 acres shall be allowed. Specific details of the required input for this version are available in the CUHPE/PC Version Users Manual. Both of the computer programs can be obtained by contacting the Urban Storm Drainage and Flood Control District – www.udfcd.org.

The CUHPE/PC computer program was modified to provide the capability of estimating hydrographs for small drainage basins greater than 5 acres. The resulting flood peaks in many cases are generally comparable, but not identical to those estimated by the Rational Formula as specified in the USDCM. To estimate a hydrograph for small basins requires the input of the time of concentration as computed by the Rational Method described in the USDCM. It is often advantageous to generate a storm hydrograph to facilitate the routing of flows through detention facilities or channels.

4.4 STORM FLOW ANALYSIS

When determining the design storm flows, the Engineer shall follow particular criteria and guidelines to assure that minimum design standards and uniformity of drainage solutions are maintained throughout the City. The information presented herein shall be used by the Design Engi-

neer in the development of design storm runoff. Runoff coefficients used for analysis shall be as given in Tables RO-3 and RO-5 of Volume 1, Chapter “Runoff”, of the Urban Storm Drainage Design Criteria Manual (USDCM) latest edition. “C” factors shall be determined per Table RO-5. An acceptable percentage of imperviousness for soils found in the Greeley area typically should be 0 percent as given in Table RO-3.

4.4.1 ON-SITE FLOW ANALYSIS

When analyzing the flood peaks and volumes, the Design Engineer shall use the proposed fully developed land use plan to determine runoff coefficients. In addition, the Engineer shall take into consideration the changes in flow patterns (from the undeveloped site conditions) caused by the proposed street alignments. When evaluating surface flow times, the proposed site grading shall be used to calculate the time of concentration or the CUHP parameters.

4.4.2 OFF-SITE FLOW ANALYSIS

The analysis of off-site runoff is dependent on the development status and whether the tributary off-site area lies within a major drainage way basin as defined in the City of Greeley Comprehensive Drainage Plan. In some cases, credit may be given for detention as defined below.

4.4.3 TRIBUTARY AREA WITHIN A MAJOR DRAINAGE WAY BASIN

Where the off-site area is undeveloped, the runoff shall be calculated assuming a fully developed basin as defined by the City. If this information is not available, then the runoff shall be calculated using the coefficients defined in Table RO-3 and RO-5 of Volume 1, Chapter, “Runoff”, of the USDCM, "Undeveloped Areas - Off-site Flow Analysis." Credit may be allowed for on-site detention in the off-site area as defined in the associated Comprehensive Drainage Plan.

Where the off-site area is fully or partially developed, the storm runoff shall be based upon the existing platted land uses and topographic features. Credit may be allowed for on-site detention in the undeveloped off-site area for any design frequency.

4.4.4 TRIBUTARY AREA NOT WITHIN A MAJOR DRAINAGE WAY BASIN

Where the off-site area is undeveloped, storm runoff shall be calculated assuming a fully developed basin as defined by the City. If this information is not available, then the runoff will be calculated as stated in Section 4.4.3, without credit for on-site detention in the off-site area.

Where the off-site area is fully or partially developed, storm runoff for the developed area shall be based on the existing platted land uses and topographic features. Credit may be allowed for on-site detention in the developed off-site areas provided it has been constructed and accepted by the City. Storm runoff for the undeveloped areas shall be calculated assuming full development as defined by the City. No credit will be given for on-site detention in the undeveloped off-site area.

4.5 CHANNEL ROUTING

Whenever a larger or non-homogeneous watershed is being investigated, it is necessary to segment the watershed into smaller and somewhat homogeneous sub-basins. The storm hydrograph for each sub-basin can then be calculated by the CUHP methodology as explained in the USDCM, Volume 1, Chapter, "Runoff". It is up to the Engineer to route and combine the individual sub-basin hydrographs to calculate a storm hydrograph for the entire watershed. There are several methods commonly used in channel routing that include:

- Direct Translation
- Convex
- Muskingum
- Storage-Discharge (Modified Puls)
- Kinematic Wave
- Diffusion Wave
- Dynamic Wave

The Direct Translation and Convex methods are presented in the USDCM, Volume 1, Chapter, "Runoff". The last three methods are more accurate. Computer programs, such as the EPA Stormwater Management Model (SWMM) which incorporates the Kinematic wave method, are available to route flows through channels, pipes and detention ponds and are recommended for utilization within the City. Of the remaining methods, the Muskingum method is similar to the Convex method and the Storage-Discharge method is less convenient for hand calculations than the Direct Translation or Convex methods. Other computer programs capable of routing flows through stormwater conveyance channels and detention ponds will be reviewed by the City and written approval must be obtained prior to utilization.

STORM DRAINAGE SYSTEM DESIGN
(RATIONAL METHOD PROCEDURE)

CALCULATED BY ______________________ JOB NO. ______________________

DATE ______________________ PROJECT ______________________

CHECKED BY ______________________ DESIGN STORM ______________________

		DIRECT RUNOFF							TOTAL RUNOFF				STREET		PIPE			TRAVEL TIME			
STREET	DESIGN POINT	DESIGN AREA	AREA (AC)	RUNOFF COEFF	tc (MIN.)	CA (AC)	I IN\HR	Q (CFS)	tc (MIN.)	Σ CA (AC)	I IN\HR	Q (CFS)	SLOPE %	STREET FLOW CFS	DESIGN FLOW CFS	SLOPE %	PIPE SIZE	LENGTH (FT)	VELOCITY (FPS)	tt (MIN.)	REMARKS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					

STORM DRAINAGE SYSTEM SYSTEM

TABLE 4-1

City of Greeley Colorado
Great. From the Ground Up.

PUBLIC WORKS DEPARTMENT
STORMWATER MANAGEMENT DIVISION
1001 NINTH AVENUE GREELEY, COLORADO 80631

SCALE: NTS

REVISED MARCH 2007

TIME OF CONCENTRATION

SUB-BASIN DATA			INITIAL/OVERLAND TIME (t_i)			TRAVEL TIME (t_t)				t_C CHECK (URBANIZED BASINS)			FINAL t_C	REMARKS
DESIGN (1)	AREA AC (2)	C_5 (3)	LENGTH FT (4)	SLOPE % (5)	t_i MIN (6)	LENGTH FT (7)	SLOPE % (8)	VEL FPS (9)	t_t MIN (10)	COMP tc (11)	TOTAL LENGTH FT (12)	t_C = (L/180) + 10 MIN (13)	MIN (14)	

SUBDIVISION _____

CALCULATED BY _____ DATE _____

City of Greeley Colorado
Great. From the Ground Up.

TIME OF CONCENTRATION
TABLE 4-2

PUBLIC WORKS DEPARTMENT
STORMWATER MANAGEMENT DIVISION
1001 NINTH AVENUE GREELEY, COLORADO 80631

SCALE: NTS
REVISED MARCH 2007