US-6 over the BNSF Railway Bridge Replacement

Drainage Report (FIR)

Prepared for CDOT Region 6
Project Number: FBR 0062-026 (18202)
December 2011

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Introduction

This report describes the hydrologic and hydraulic analysis conducted for the proposed US-6 over the BNSF Railway bridge replacement. The project is located in Region 6 of the Colorado Department of Transportation (CDOT) and the City and County of Denver (CCD). The project encompasses the US-6 bridge replacement and minor roadway work on US-6.

The project will be part of a larger design/build project and elements of this report and the design may change and will be documented by the design/build team.

Hydrology and Hydraulics

Basin Description

Drainage basins within the project limits were delineated using the project survey and the proposed contours. A high point is located near the bridge and no off site flows enter the project site. The project area drains to existing CDOT and CCD storm drains. Vegetative cover within the project limits consists primarily of native grasses on the roadway embankment. The project is within a FEMA designated floodplain according to FIRM Map Number 0800460182G (November 17, 2005). A floodplain development permit will be required.

Hydrologic criteria for the project are based on The Colorado Department of Transportation Drainage Design Manual (2004). Rainfall data from the City and County of Denver *Storm Drainage Design and Technical Criteria Manual* is utilized to estimate the peak flow rates using the Rational Method.

Determination of Design Discharge

Runoff from approximately 2.4 acres impacting the project area was analyzed. This area is currently divided into 7 proposed sub-basins for a more detailed analysis. In addition, peak flow rates were estimated for two offsite basins draining to the BNSF Railroad under the US-6 bridge. The current study area and sub-basins are shown on the Drainage Map contained in the appendix of this report. The sub-basins were analyzed for 5-year and 100-year flow rates using the Rational Method and the City and County of Denver *Storm Drainage Design and Technical Criteria Manual*.

The proposed bridge generally divides the project into an east and west storm drain system. Basins D (0.24 ac), E (0.26 ac), and F (0.33 ac) are located to the east of the bridge. Inlets have been placed to capture the stormwater generated within these basins and are routed to the existing CCD ditch located just north of US-6. Additional inlets have been placed to intercept nuisance flows along the north edge of US-6. Stormwater generated within these basins is conveyed to Design Point 1 (Q_5 = 3.3 cfs, Q_{100} = 8.0 cfs) via 18” and 24” RCP. A CDS water quality vault located at DP-1 will treat the first 0.5 inch of rainfall prior to release to the existing CCD drainage ditch. Runoff in excess of 0.5 inches will bypass the vault and flow directly to the CCD drainage ditch.

Project runoff west of the BNSF Railway is conveyed to existing CDOT storm drain systems. Basins A (0.13 ac), B (0.49 ac), C (0.48 ac), and G (0.64) continue to discharge to the existing CDOT system located between northbound I-25 and the northbound off ramp. In order to maintain existing drainage patterns to the extent possible, and to limit the number of water quality BMP's required, the inlets will be designed with two outfalls. A smaller pipe will be located at the bottom of the inlet. This will convey the water quality flows to an extended detention basin. A larger pipe will be located in the inlet with a slightly higher invert to convey stormwater in excess of the water quality flows to the existing storm drain. An extended detention basin will treat the Water Quality Capture Volume (WQCV) for Basins A, B, C, and G prior to release to the existing CDOT storm drain systems.

Refer to the Drainage Basin Map located in the appendix of this report for additional information.

Hydraulic Analysis

Runoff from the project areas is collected and conveyed in existing and proposed roadway surfaces, curb and gutter, and 15" to 24" NRCP and RCP to the existing storm drain systems and ultimately to the nearby South Platte River.

Storm Drain and Inlet Design

For the storm sewer sizing done with this study, proposed storm drain pipes were analyzed using Manning's equation. The HGL's will be calculated in the final design process and will be accomplished using StormCAD. Inlets have been sized using UD-Inlet v2.14c. Refer to the appendix of this report for the preliminary hydraulic computations and additional information.

Drainage to BNSF Railroad

The proposedUS-6 improvements will direct project runoff to the existing CDOT and CCD storm drain facilities. The proposed bridge and sidewalk cross slopes will direct stormwater to theUS-6 curb and gutter and the proposed storm drain system, reducing the stormwater entering the BNSF right of way. There is no work proposed in existing Basins OS-1 and OS-2 and the flow rates and drainage patterns will remain as currently constituted. Basin OS-1 (5.8 acres) runoff is conveyed by existing vegetated surfaces to and existing 30" RCP culvert southwest of the proposed bridge replacement. Runoff generated within Basin OS-2 (21.9 acres) is conveyed by existing vegetated and asphalt surfaces, existing curb and gutter, and existing storm drain pipes to an existing 36" RCP southeast of the proposed bridge. A preliminary analysis of the existing culverts shows that they will convey the 5-year flow rates without inundating the BNSF railroad tracks. The area is located in the FEMA 100-year floodplain. The capability of the existing culverts to convey the 100-year peak flow rates was therefore not evaluated. As noted in the *City & County of Denver Storm Drainage Master Plan*, "The existing drainage systems have capacities varying from a 1-year to a 5-year storm event. Rainfall runoff in excess of the storm drain capacity has a history of ponding within the commercial and industrial areas against the railroad and I-25." Basin OS-1

and OS-2 flows combine at an existing manhole to the west of the tracks and are conveyed via a 42" RCP to a concrete lined ditch just north of the proposed bridge.

Post-Construction Water Quality

Post-Construction Water Quality Approach

Compliance with the CDOT MS4 permit requires achievement of 80% removal of the Total Suspended Solids (TSS) from stormwater runoff or 100% of the water quality capture volume. Common practice is to apply various methods (Best Management Practices or BMPs) to achieve this goal. Structural BMPs have been selected based on available land and non-structural BMPs are listed for inclusion in maintenance responsibilities. A separate Water Quality Report has been prepared for this project detailing the post construction BMP's used and the maintenance requirements.

Conclusion

The recommendations proposed in this report are general conformance with the requirements of the CDOT Drainage Manual. The proposed drainage modifications presented in this report convey the developed stormwater flows to acceptable outfalls and treat stormwater quality prior to discharge.

References

- *Urban Storm Drainage Criteria Manual Volumes 1, 2, and 3*; Urban Drainage and Flood Control District; June 2001.
- *Drainage Design Manual*; Colorado Department of Transportation; 2004.
- *Erosion Control and Stormwater Quality Guide*; Colorado Department of Transportation; 2002.

Appendices

Exhibits

- Site Map
- FIRM Map

Hydrology Computations

- Proposed Drainage Basin Calculations

Hydraulic Computations

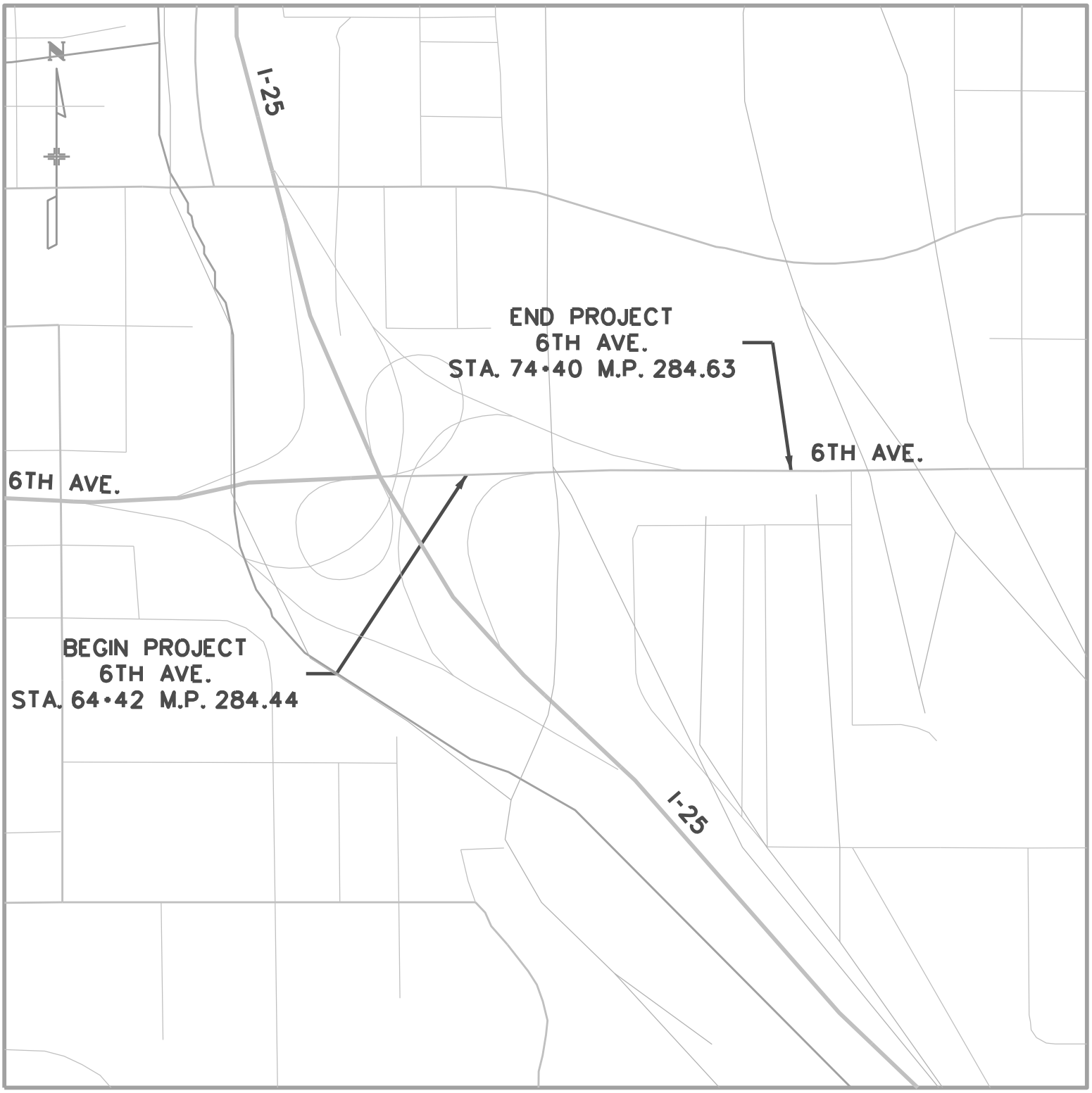
- General Inlet Calculations
- Full Flow Pipe Capacity Calculations

Drainage Maps

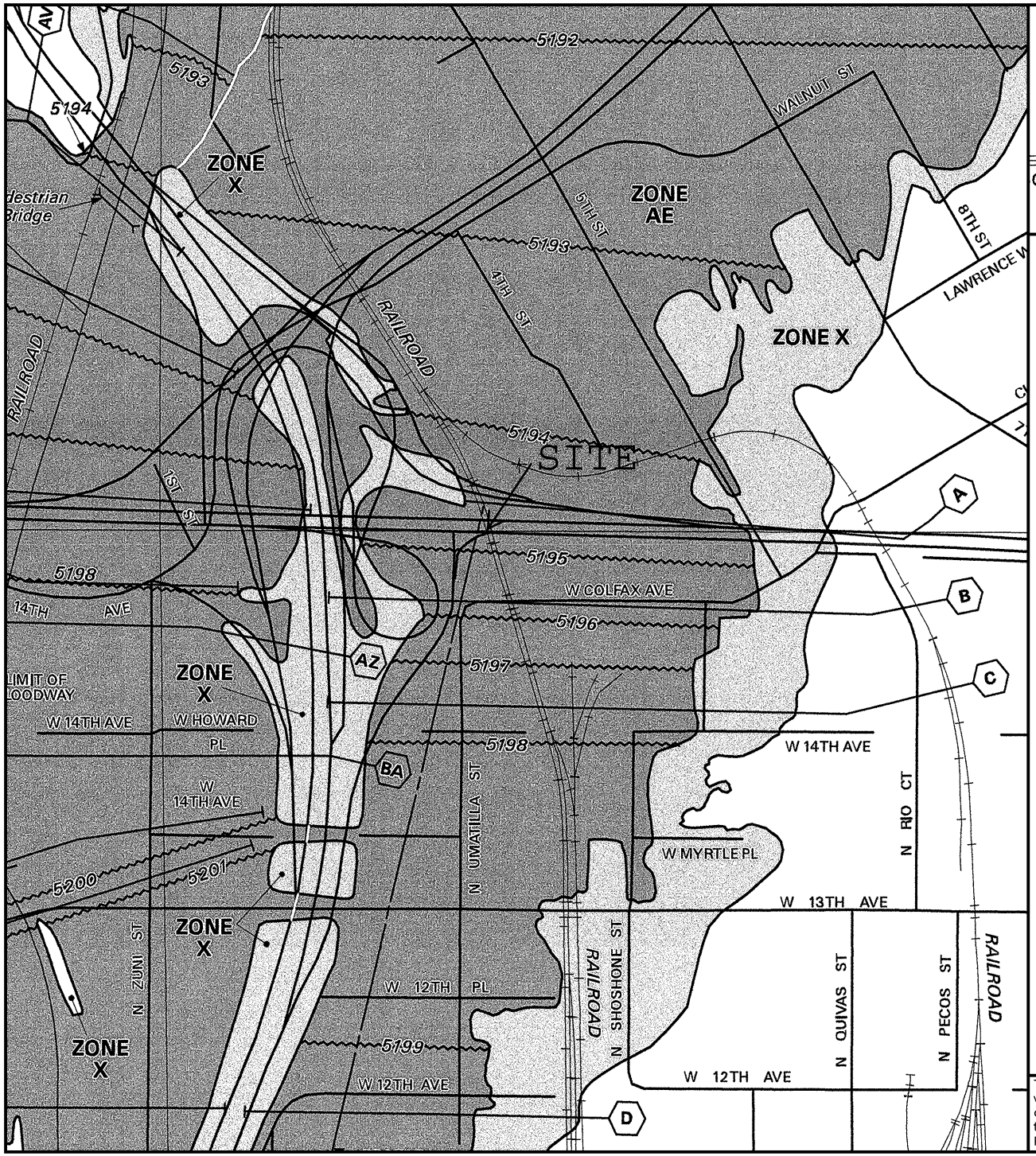
- Drainage Map

Exhibits

- Site Map
- FIRM Map



PROJECT LOCATION MAP



MAP SCALE 1" = 500'

250 0 500 1000 FEET

0 0 150 300 METE

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0182G

FIRM

FLOOD INSURANCE RATE MAP

CITY AND COUNTY OF DENVER, COLORADO

PANEL 182 OF 300

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
DENVER, CITY AND COUNTY OF	080046	0182	G

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

MAP NUMBER
0800460182G

MAP REVISED:
NOVEMBER 17, 2005

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

Hydrology Computations

- Proposed Drainage Basin Calculations

Intensity - Duration - Frequency Curves

	2-Yr	5-Yr	10-Yr	50-Yr	100-Yr
1-Hr Point Rainfall	0.95	1.34	1.55	2.25	2.57

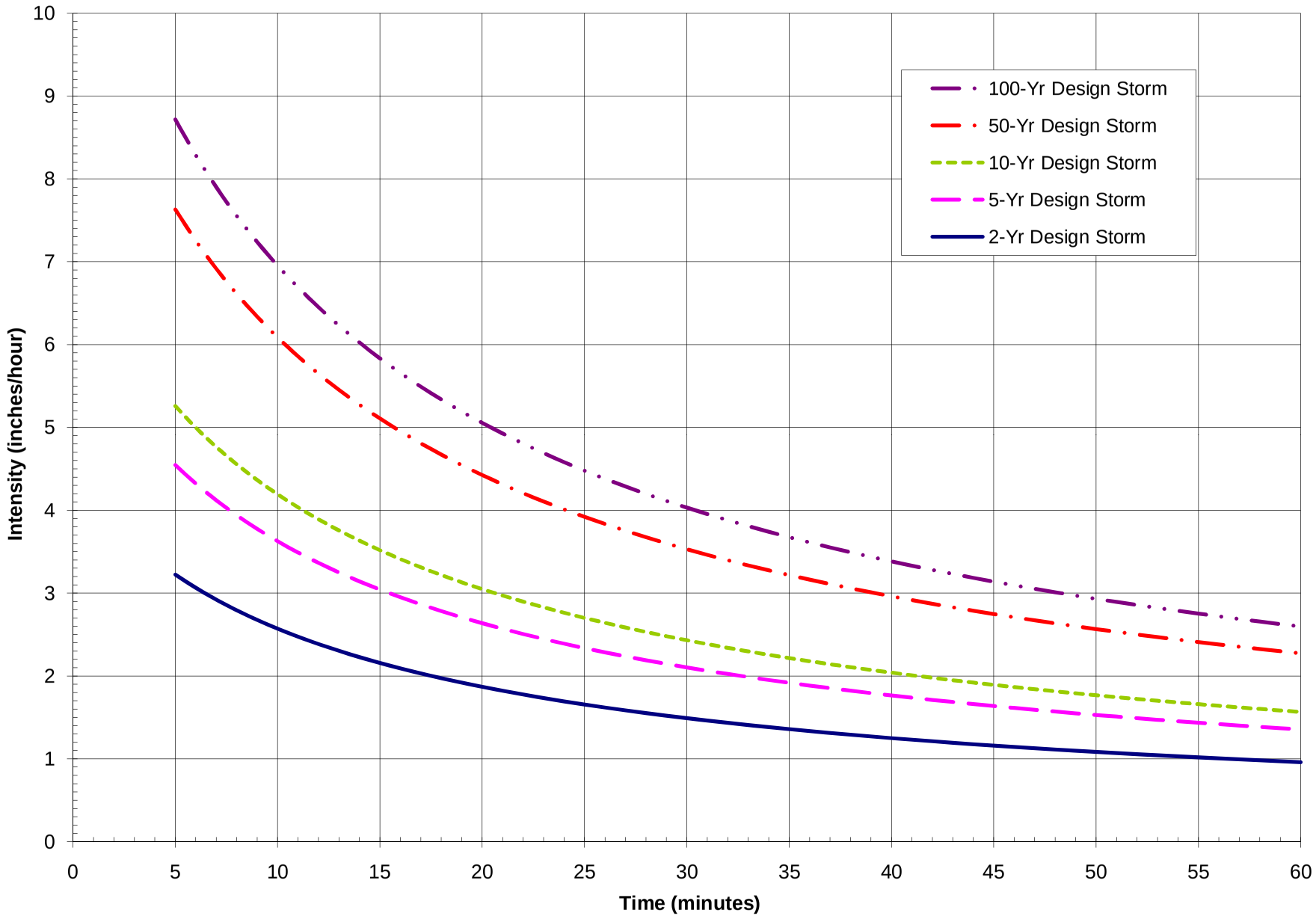
Time (min)	2-Yr Design Storm	5-Yr Design Storm	10-Yr Design Storm	50-Yr Design Storm	100-Yr Design Storm
5	3.22	4.55	5.26	7.63	8.72
6	3.06	4.32	5.00	7.25	8.29
7	2.92	4.12	4.76	6.92	7.90
8	2.79	3.94	4.56	6.61	7.55
9	2.68	3.77	4.37	6.34	7.24
10	2.57	3.63	4.19	6.09	6.95
11	2.47	3.49	4.04	5.86	6.69
12	2.38	3.36	3.89	5.65	6.45
13	2.30	3.25	3.76	5.45	6.23
14	2.23	3.14	3.63	5.27	6.02
15	2.16	3.04	3.52	5.11	5.83
16	2.09	2.95	3.41	4.95	5.66
17	2.03	2.86	3.31	4.81	5.49
18	1.97	2.78	3.22	4.67	5.34
19	1.92	2.71	3.13	4.55	5.19
20	1.87	2.64	3.05	4.43	5.06
21	1.82	2.57	2.97	4.31	4.93
22	1.78	2.51	2.90	4.21	4.81
23	1.73	2.45	2.83	4.11	4.69
24	1.69	2.39	2.76	4.01	4.58
25	1.66	2.34	2.70	3.92	4.48
26	1.62	2.28	2.64	3.84	4.38
27	1.58	2.24	2.59	3.75	4.29
28	1.55	2.19	2.53	3.68	4.20
29	1.52	2.14	2.48	3.60	4.11
30	1.49	2.10	2.43	3.53	4.03
31	1.46	2.06	2.39	3.46	3.95
32	1.43	2.02	2.34	3.40	3.88
33	1.41	1.99	2.30	3.34	3.81
34	1.38	1.95	2.26	3.28	3.74
35	1.36	1.92	2.22	3.22	3.68
36	1.34	1.88	2.18	3.16	3.61
37	1.31	1.85	2.14	3.11	3.55
38	1.29	1.82	2.11	3.06	3.49
39	1.27	1.79	2.07	3.01	3.44
40	1.25	1.76	2.04	2.96	3.38
41	1.23	1.74	2.01	2.92	3.33
42	1.21	1.71	1.98	2.87	3.28

Intensity - Duration - Frequency Curves

	2-Yr	5-Yr	10-Yr	50-Yr	100-Yr
1-Hr Point Rainfall	0.95	1.34	1.55	2.25	2.57

Time (min)	2-Yr Design Storm	5-Yr Design Storm	10-Yr Design Storm	50-Yr Design Storm	100-Yr Design Storm
43	1.19	1.69	1.95	2.83	3.23
44	1.18	1.66	1.92	2.79	3.19
45	1.16	1.64	1.89	2.75	3.14
46	1.14	1.61	1.87	2.71	3.10
47	1.13	1.59	1.84	2.67	3.05
48	1.11	1.57	1.82	2.64	3.01
49	1.10	1.55	1.79	2.60	2.97
50	1.08	1.53	1.77	2.57	2.93
51	1.07	1.51	1.75	2.53	2.89
52	1.06	1.49	1.72	2.50	2.86
53	1.04	1.47	1.70	2.47	2.82
54	1.03	1.45	1.68	2.44	2.79
55	1.02	1.44	1.66	2.41	2.75
56	1.01	1.42	1.64	2.38	2.72
57	0.99	1.40	1.62	2.35	2.69
58	0.98	1.39	1.60	2.33	2.66
59	0.97	1.37	1.58	2.30	2.63
60	0.96	1.35	1.57	2.27	2.60

Intensity-Duration-Frequency Curves
Storm Drainage Design and Technical Criteria Manual



Project Name: 6th Ave over BNSF
Job Number: 11-100-301-02
Subject: Runoff Coefficients
Date: 11/6/2011
By: TDS

COMPOSITE RUNOFF COEFFICIENTS

Global Parameters				
Land Use	% Imp.	C_2	C_5	C_{100}
Roadway	100	0.89	0.90	0.96
Residential-Single Fam	70	0.54	0.58	0.71
Parks/Open Space	7	0.04	0.15	0.50

North System To Barnum

Subbasin	Total Area (acres)	Land Use Area per Sub-Basin							Composite Imperviousness	Composite Runoff Coefficient		
		Roadway		Residential-Single Family		Parks/Open Space		% Check		2-year	5-year	100-year
		Area (sf)	%	Area (sf)	%	Area (sf)	%					
A	0.13	5662	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
B	0.49	21344	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
C	0.48	20909	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
D	0.24	10454	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
E	0.26	11326	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
F	0.33	14375	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
G	0.64	27878	100.0%	0	0.0%	0	0.0%	100.0%	**100.0%**	**0.89**	**0.90**	**0.96**
OS-1	5.80	25000	9.9%	0	0.0%	227648	90.1%	100.0%	**16.2%**	**0.12**	**0.22**	**0.55**
OS-2	21.90	840000	88.1%	0	0.0%	113964	11.9%	100.0%	**88.9%**	**0.79**	**0.81**	**0.91**
Total	**30.27**	**976948.0**	**74.1%**	**0.0**	**0.0%**	**341612.4**	**25.9%**	**100.0%**	**75.9%**	**0.67**	**0.71**	**0.84**

Project Name: 6th Ave over BNSF
Project No: 11-100-301-02
Subject: Runoff Calculations
Date: 11-6-11
Design by: TDS

RUNOFF CALCULATIONS

Subbasin			Area (Ac)	Runoff Coefficient			T_C* (min)	Intensity			Runoff		
				C_2	C_5	C_{100}		2-Yr (in/hr)	5-Yr (in/hr)	100-Yr (in/hr)	2-Yr (cfs)	5-Yr (cfs)	100-Yr (cfs)
A			0.13	0.89	0.90	0.96	5.0	3.22	4.55	8.72	0.4	0.5	1.1
B			0.49	0.89	0.90	0.96	5.0	3.22	4.55	8.72	1.4	2.0	4.1
C			0.48	0.89	0.90	0.96	5.0	3.22	4.55	8.72	1.4	2.0	4.0
D			0.24	0.89	0.90	0.96	5.0	3.22	4.55	8.72	0.7	1.0	2.0
E			0.26	0.89	0.90	0.96	5.0	3.22	4.55	8.72	0.7	1.1	2.2
F			0.33	0.89	0.90	0.96	5.0	3.22	4.55	8.72	0.9	1.3	2.8
G			0.64	0.89	0.90	0.96	5.0	3.22	4.55	8.72	1.8	2.6	5.4
OS-1			5.80	0.12	0.22	0.55	18.3	1.95	2.76	5.29	1.4	3.6	16.7
OS-2			21.90	0.79	0.81	0.91	19.2	1.91	2.70	5.17	33.0	47.8	102.5

Hydraulic Computations

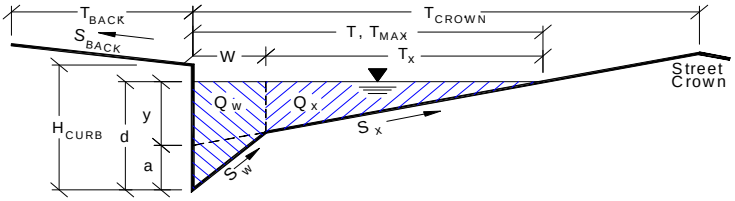
- General Inlet Calculations
- Full Flow Pipe Capacity Calculations

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project: **Pecos Street Bridge Replacement over I-70**

Inlet ID: **5' Type R - On grade**



Gutter Geometry (Enter data in the blue cells)			
Maximum Allowable Width for Spread Behind Curb	T_{BACK} =	0.0	ft
Side Slope Behind Curb (leave blank for no conveyance credit behind curb)	S_{BACK} =		ft. vert. / ft. horiz
Manning's Roughness Behind Curb	n_{BACK} =		
Height of Curb at Gutter Flow Line	H_{CURB} =	6.00	inches
Distance from Curb Face to Street Crown	T_{CROWN} =	16.0	ft
Gutter Depression	a =	2.00	inches
Gutter Width	W =	2.00	ft
Street Transverse Slope	S_X =	0.0200	ft. vert. / ft. horiz
Street Longitudinal Slope - Enter 0 for sump condition	S_O =	0.0100	ft. vert. / ft. horiz
Manning's Roughness for Street Section	n_{STREET} =	0.0180	

		Minor Storm	Major Storm	
Max. Allowable Water Spread for Minor & Major Storm	T_{MAX} =	8.0	12.0	ft
Max. Allowable Depth at Gutter Flow Line for Minor & Major Storm	d_{MAX} =	6.00	6.00	inches
Allow Flow Depth at Street Crown (leave blank for no)				X = yes

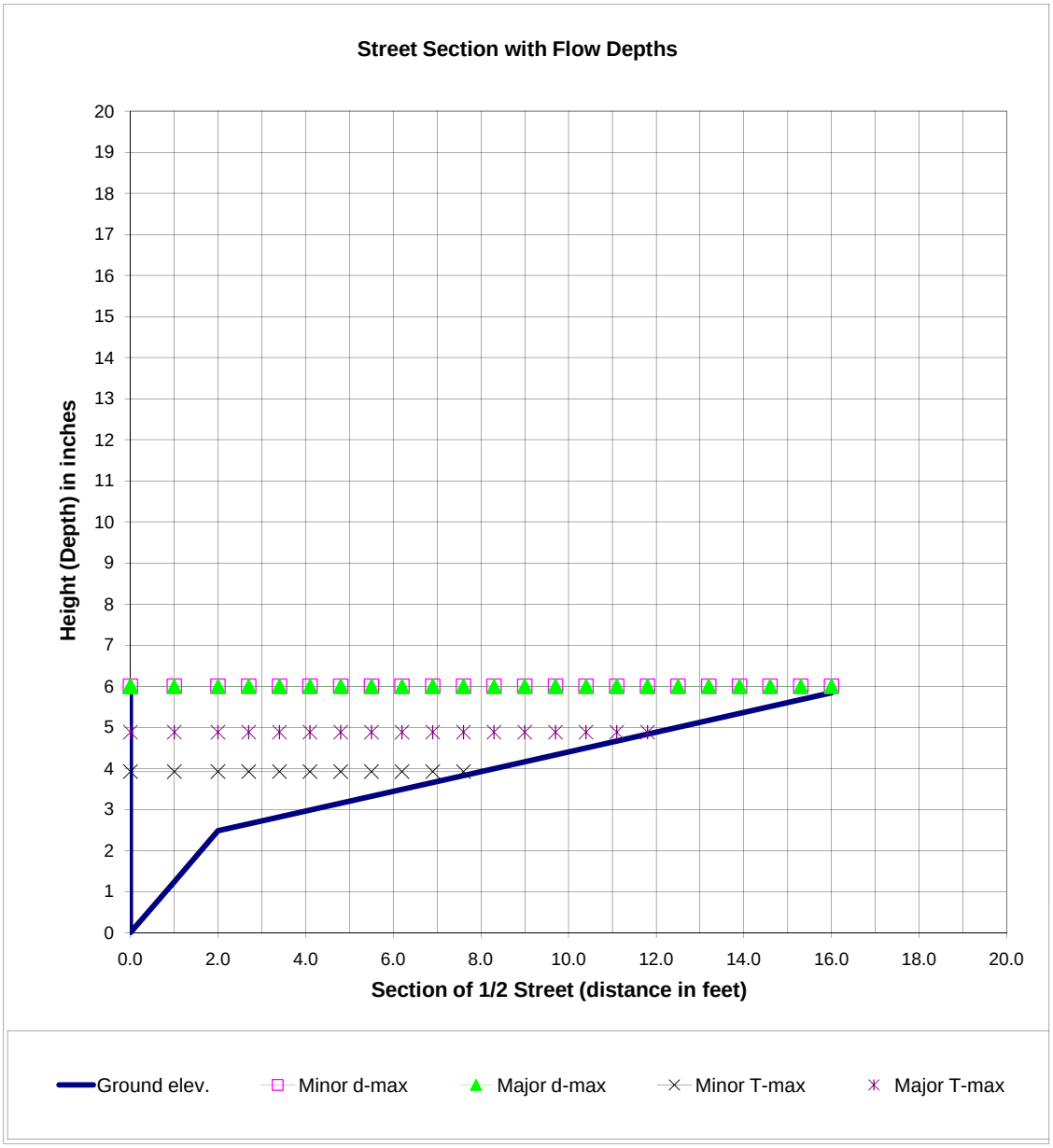
Maximum Gutter Capacity Based On Allowable Water Spread		Minor Storm	Major Storm	
Gutter Cross Slope (Eq. ST-8)	S_W =	0.1033	0.1033	ft/ft
Water Depth without Gutter Depression (Eq. ST-2)	y =	1.92	2.88	inches
Water Depth with a Gutter Depression	d =	3.92	4.88	inches
Allowable Spread for Discharge outside the Gutter Section W (T - W)	T_X =	6.0	10.0	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.722	0.522	
Discharge outside the Gutter Section W, carried in Section T_X	Q_X =	0.5	2.1	cfs
Discharge within the Gutter Section W (Q_T - Q_X)	Q_W =	1.4	2.3	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Maximum Flow Based On Allowable Water Spread	**Q_T =**	**2.0**	**4.4**	**cfs**
Flow Velocity Within the Gutter Section	V =	3.2	3.8	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	1.0	1.6	

Maximum Gutter Capacity Based on Allowable Gutter Depth		Minor Storm	Major Storm	
Theoretical Water Spread	T_{TH} =	16.7	16.7	ft
Theoretical Spread for Discharge outside the Gutter Section W (T - W)	$T_{X\,TH}$ =	14.7	14.7	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.378	0.378	
Theoretical Discharge outside the Gutter Section W, carried in Section $T_{X\,TH}$	$Q_{X\,TH}$ =	5.9	5.9	cfs
Actual Discharge outside the Gutter Section W, (limited by distance T_{CROWN})	Q_X =	5.9	5.9	cfs
Discharge within the Gutter Section W (Q_d - Q_X)	Q_W =	3.6	3.6	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Total Discharge for Major & Minor Storm	**Q =**	**9.5**	**9.5**	**cfs**
Flow Velocity Within the Gutter Section	V =	4.5	4.5	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	2.3	2.3	
Slope-Based Depth Safety Reduction Factor for Major & Minor (d $\geq$ 6") Storm	R =	1.00	1.00	
Max Flow Based on Allow. Gutter Depth (Safety Factor Applied)	**Q_d =**	**9.5**	**9.5**	**cfs**
Resultant Flow Depth at Gutter Flowline (Safety Factor Applied)	d =	6.00	6.00	inches
Resultant Flow Depth at Street Crown (Safety Factor Applied)	d_{CROWN} =	0.16	0.16	inches

		Minor Storm	Major Storm	
Max. Allowable Gutter Capacity Based on Minimum of Q_T or Q_d	**Q_{allow} =**	**2.0**	**4.4**	**cfs**

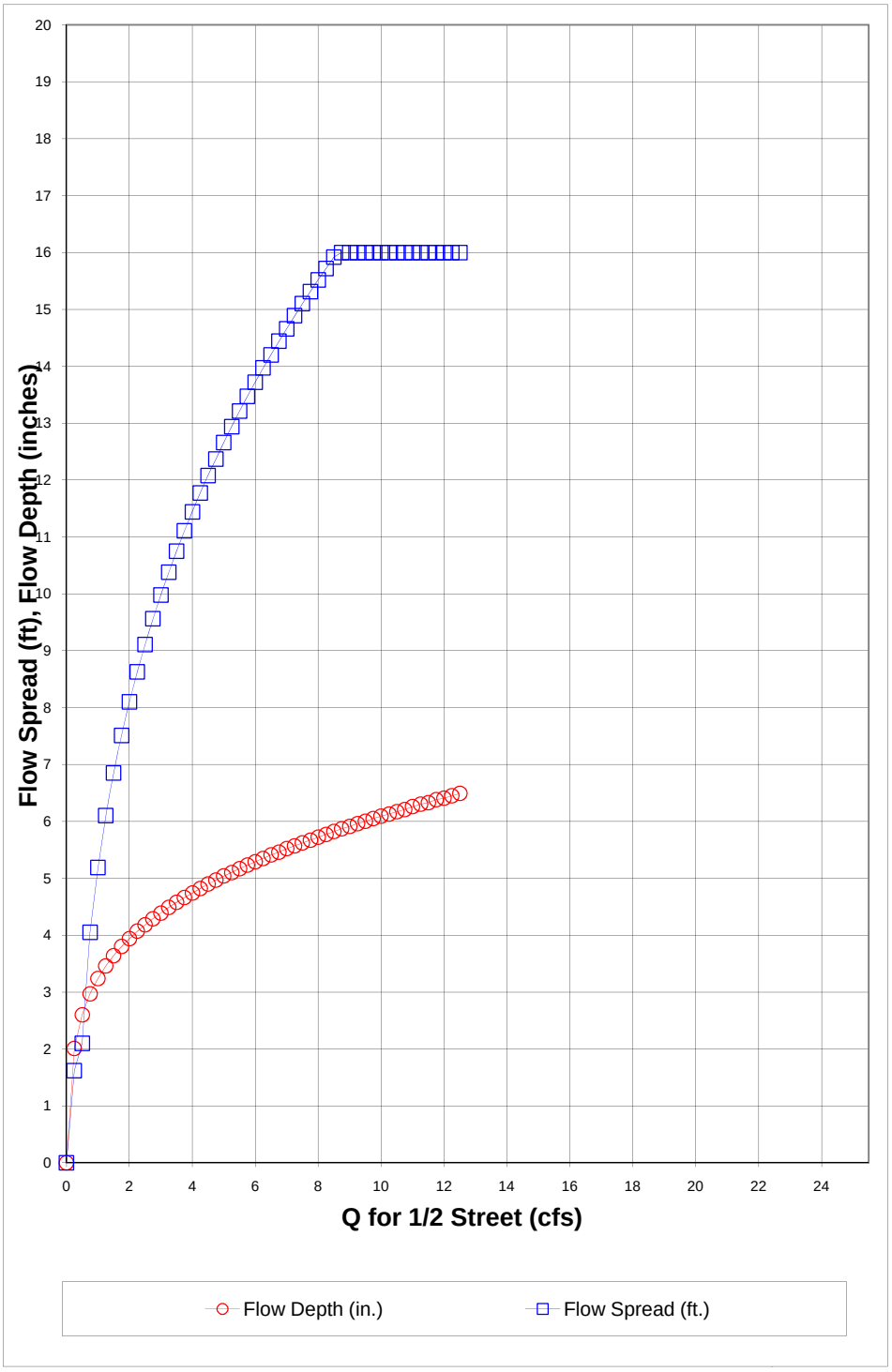
MINOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'

MAJOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'



$$Q_x = \frac{0.56}{n} S_x^{5/3} S_L^{1/2} T_x^{8/3} \qquad E_o = \frac{1}{1 + \dfrac{S_w / S_x}{\left[1 + \dfrac{S_w / S_x}{(T/W) - 1}\right]^{8/3} - 1}}$$

$$Q = \frac{Q_x}{1 - E_o}; \; Q_w = Q - Q_x$$

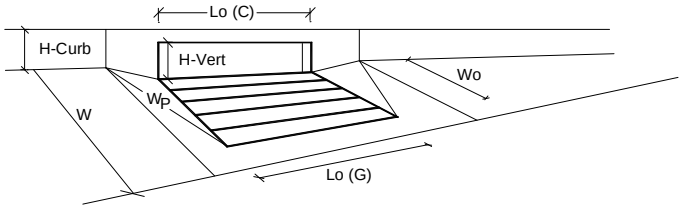


Q for 1/2 Street (cfs)	Flow Depth (in.)	Flow Spread (ft.)
0.00	0.00	0.00
0.25	2.01	1.62
0.50	2.60	2.10
0.75	2.97	4.05
1.00	3.24	5.19
1.25	3.46	6.10
1.50	3.64	6.85
1.75	3.80	7.51
2.00	3.94	8.10
2.25	4.07	8.63
2.50	4.18	9.11
2.75	4.29	9.56
3.00	4.39	9.98
3.25	4.49	10.38
3.50	4.58	10.75
3.75	4.66	11.11
4.00	4.74	11.44
4.25	4.82	11.77
4.50	4.90	12.08
4.75	4.97	12.37
5.00	5.04	12.66
5.25	5.10	12.94
5.50	5.17	13.21
5.75	5.23	13.47
6.00	5.29	13.72
6.25	5.35	13.97
6.50	5.41	14.20
6.75	5.46	14.44
7.00	5.52	14.66
7.25	5.57	14.89
7.50	5.62	15.10
7.75	5.67	15.31
8.00	5.72	15.52
8.25	5.77	15.72
8.50	5.82	15.92
8.75	5.87	16.00
9.00	5.91	16.00
9.25	5.96	16.00
9.50	6.00	16.00
9.75	6.05	16.00
10.00	6.09	16.00
10.25	6.13	16.00
10.50	6.17	16.00
10.75	6.21	16.00
11.00	6.26	16.00
11.25	6.30	16.00
11.50	6.33	16.00
11.75	6.38	16.00
12.00	6.41	16.00
12.25	6.45	16.00
12.50	6.49	16.00

INLET ON A CONTINUOUS GRADE

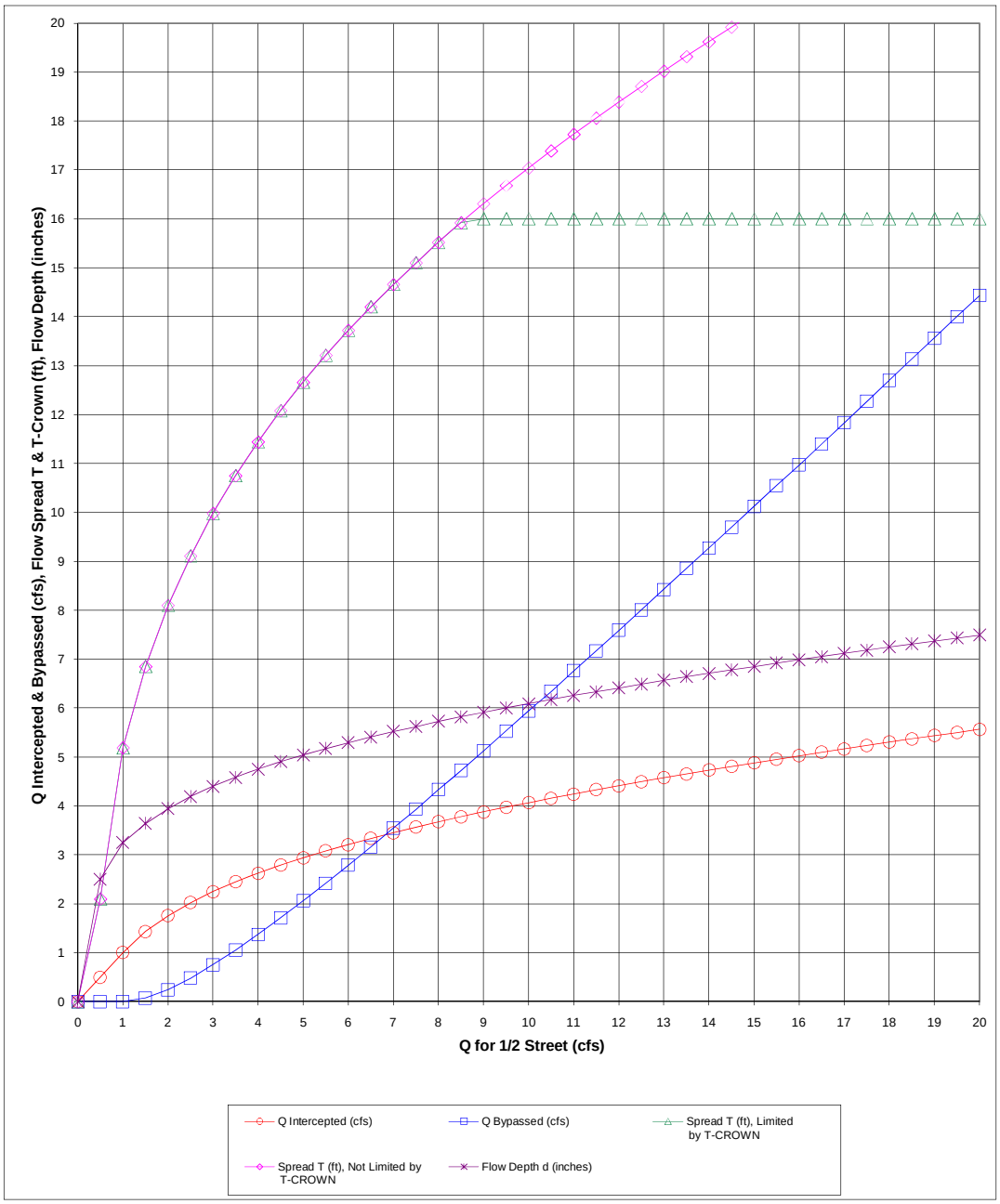
Project: Pecos Street Bridge Replacement over I-70

Inlet ID: 5' Type R - On grade



Design Information (Input)		MINOR	MAJOR	
Type of Inlet	Type =	CDOT Type R Curb Opening		
Local Depression (additional to continuous gutter depression 'a' from 'Q-Allow')	a_{LOCAL} =	3.0	3.0	inches
Total Number of Units in the Inlet (Grate or Curb Opening)	No =	1	1	
Length of a Single Unit Inlet (Grate or Curb Opening)	L_o =	5.00	5.00	ft
Width of a Unit Grate (cannot be greater than W from Q-Allow)	W_o =	N/A	N/A	ft
Clogging Factor for a Single Unit Grate (typical min. value = 0.5)	C_f-G =	N/A	N/A	
Clogging Factor for a Single Unit Curb Opening (typical min. value = 0.1)	C_f-C =	0.10	0.10	
Street Hydraulics: OK - Q < maximum allowable from sheet 'Q-Allow'		MINOR	MAJOR	
Design Discharge for Half of Street (from Sheet *Q-Peak*)	**Q_o =**	**1.00**	**4.00**	**cfs**
Water Spread Width	T =	5.2	11.4	ft
Water Depth at Flowline (outside of local depression)	d =	3.2	4.7	inches
Water Depth at Street Crown (or at T_{MAX})	d_{CROWN} =	0.0	0.0	inches
Ratio of Gutter Flow to Design Flow	E_o =	0.900	0.545	
Discharge outside the Gutter Section W, carried in Section T_x	Q_x =	0.10	1.82	cfs
Discharge within the Gutter Section W	Q_w =	0.90	2.18	cfs
Discharge Behind the Curb Face	Q_{BACK} =	0.00	0.00	cfs
Street Flow Area	A_s =	0.44	1.47	sq ft
Street Flow Velocity	V_s =	2.30	2.72	fps
Water Depth for Design Condition	d_{LOCAL} =	6.2	7.7	inches
Grate Analysis (Calculated)		MINOR	MAJOR	
Total Length of Inlet Grate Opening	L =			ft
Ratio of Grate Flow to Design Flow	$E_{o\text{-}GRATE}$ =			
Under No-Clogging Condition		MINOR	MAJOR	
Minimum Velocity Where Grate Spash-Over Begins	V_o =			fps
Interception Rate of Frontal Flow	R_f =			
Interception Rate of Side Flow	R_x =			
Interception Capacity	Q_i =			cfs
Under Clogging Condition		MINOR	MAJOR	
Clogging Coefficient for Multiple-unit Grate Inlet	GrateCoef =			
Clogging Factor for Multiple-unit Grate Inlet	GrateClog =			
Effective (unclogged) Length of Multiple-unit Grate Inlet	L_e =			ft
Minimum Velocity Where Grate Spash-Over Begins	V_o =			fps
Interception Rate of Frontal Flow	R_f =			
Interception Rate of Side Flow	R_x =			
Actual Interception Capacity	**Q_a =**	**N/A**	**N/A**	**cfs**
Carry-Over Flow = Q_o-Q_a (to be applied to curb opening or next d/s inlet)	**Q_b =**	**N/A**	**N/A**	**cfs**
Curb or Slotted Inlet Opening Analysis (Calculated)		MINOR	MAJOR	
Equivalent Slope S_e (based on grate carry-over)	S_e =	0.2075	0.1336	ft/ft
Required Length L_T to Have 100% Interception	L_T =	4.31	10.05	ft
Under No-Clogging Condition		MINOR	MAJOR	
Effective Length of Curb Opening or Slotted Inlet (minimum of L, L_T)	L =	4.30	5.00	ft
Interception Capacity	Q_i =	1.00	2.84	cfs
Under Clogging Condition		MINOR	MAJOR	
Clogging Coefficient	CurbCoef =	1.00	1.00	
Clogging Factor for Multiple-unit Curb Opening or Slotted Inlet	CurbClog =	0.10	0.10	
Effective (Unclogged) Length	L_e =	4.30	4.50	ft
Actual Interception Capacity	**Q_a =**	**1.00**	**2.63**	**cfs**
Carry-Over Flow = $Q_{b(GRATE)}$-Q_a	**Q_b =**	**0.00**	**1.37**	**cfs**
Summary		MINOR	MAJOR	
Total Inlet Interception Capacity	**Q =**	**1.00**	**2.63**	**cfs**
Total Inlet Carry-Over Flow (flow bypassing inlet)	**Q_b =**	**0.00**	**1.37**	**cfs**
Capture Percentage = Q_a/Q_o =	**C% =**	**100.0**	**65.6**	**%**

Warning 4: Denver No. 16/CDOT Type 13 unit width should be 1.73'.


Q Intercepted & Bypassed (cfs), Flow Spread T & T-Crown (ft), Flow Depth (inches)
Q for 1/2 Street (cfs)
Q Intercepted (cfs)
Q Bypassed (cfs)
Spread T (ft), Limited by T-CROWN
Spread T (ft), Not Limited by T-CROWN
Flow Depth d (inches)

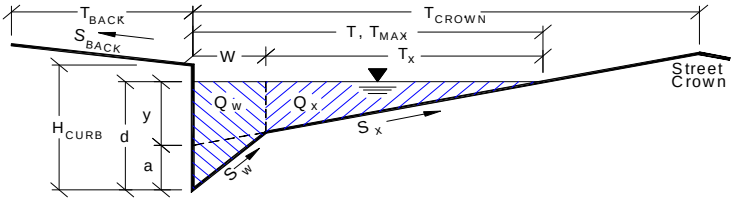
Q for 1/2 Street (cfs)	Q Intercepted (cfs)	Q Bypassed (cfs)	Spread T (ft), Limited by T_{-CROWN}	Spread T (ft), Not Limited by T_{-CROWN}	Flow Depth d (inches)
0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.50	0.00	2.10	2.10	2.50
1.00	1.00	0.00	5.19	5.19	3.25
1.50	1.43	0.07	6.85	6.85	3.64
2.00	1.76	0.24	8.10	8.10	3.94
2.50	2.02	0.48	9.11	9.11	4.19
3.00	2.25	0.75	9.98	9.98	4.40
3.50	2.45	1.05	10.75	10.75	4.58
4.00	2.63	1.37	11.44	11.44	4.75
4.50	2.79	1.71	12.08	12.08	4.90
5.00	2.94	2.06	12.66	12.66	5.04
5.50	3.08	2.42	13.21	13.21	5.17
6.00	3.21	2.79	13.72	13.72	5.29
6.50	3.34	3.16	14.20	14.20	5.41
7.00	3.45	3.55	14.66	14.66	5.52
7.50	3.57	3.93	15.10	15.10	5.62
8.00	3.67	4.33	15.52	15.52	5.73
8.50	3.78	4.72	15.92	15.92	5.82
9.00	3.88	5.12	16.00	16.31	5.91
9.50	3.97	5.53	16.00	16.68	6.00
10.00	4.06	5.94	16.00	17.04	6.09
10.50	4.16	6.34	16.00	17.39	6.17
11.00	4.24	6.76	16.00	17.73	6.26
11.50	4.33	7.17	16.00	18.06	6.33
12.00	4.41	7.59	16.00	18.39	6.41
12.50	4.49	8.01	16.00	18.71	6.49
13.00	4.58	8.42	16.00	19.02	6.57
13.50	4.65	8.85	16.00	19.32	6.64
14.00	4.73	9.27	16.00	19.62	6.71
14.50	4.81	9.69	16.00	19.92	6.78
15.00	4.88	10.12	16.00	20.21	6.85
15.50	4.95	10.55	16.00	20.50	6.92
16.00	5.03	10.97	16.00	20.78	6.99
16.50	5.10	11.40	16.00	21.05	7.05
17.00	5.17	11.83	16.00	21.33	7.12
17.50	5.23	12.27	16.00	21.60	7.18
18.00	5.30	12.70	16.00	21.86	7.25
18.50	5.37	13.13	16.00	22.12	7.31
19.00	5.44	13.56	16.00	22.38	7.37
19.50	5.50	14.00	16.00	22.64	7.43
20.00	5.57	14.43	16.00	22.89	7.49

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project: **Pecos Street Bridge Replacement over I-70**

Inlet ID: **5' Type R - Sump**



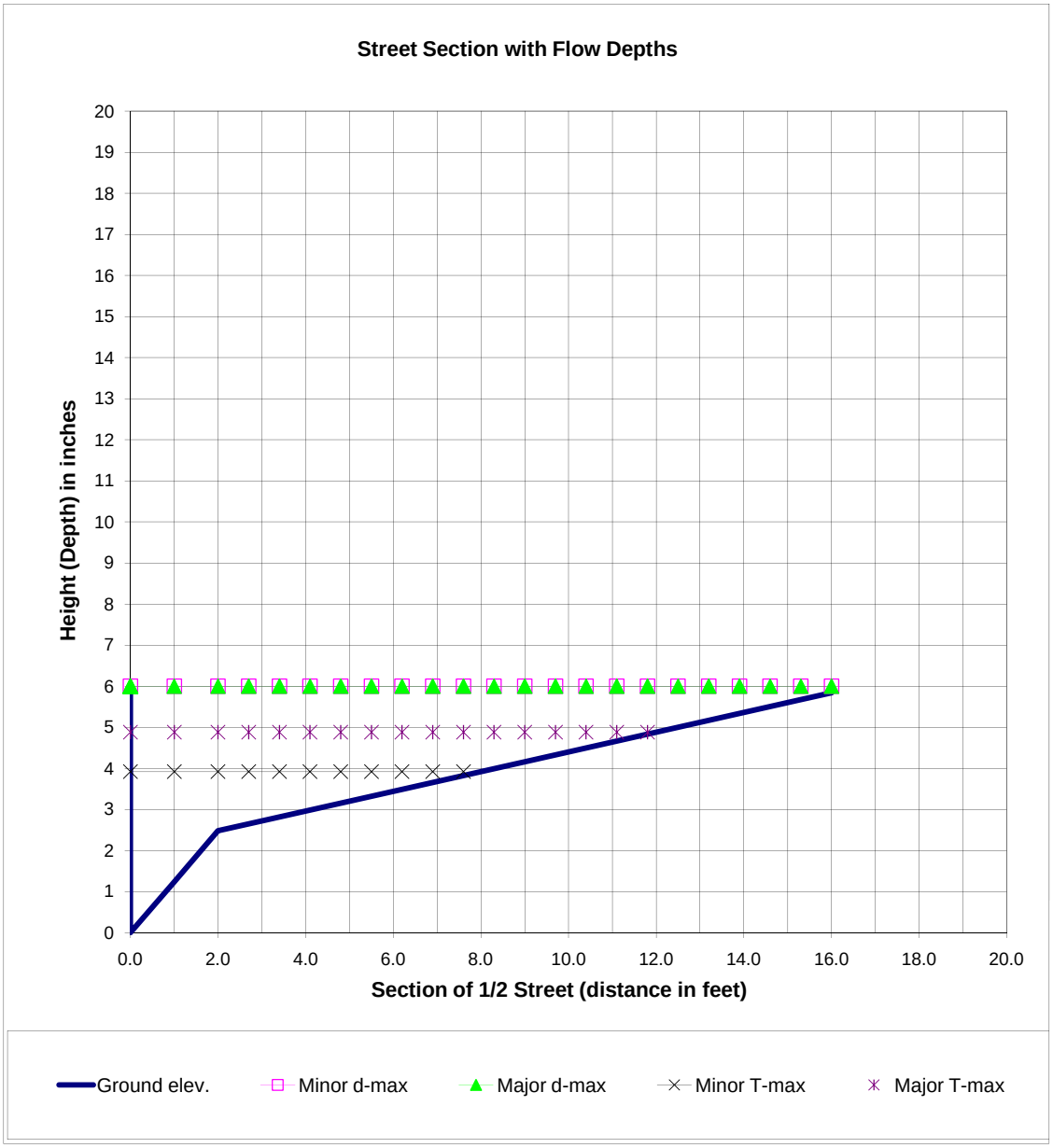
Gutter Geometry (Enter data in the blue cells)				
Maximum Allowable Width for Spread Behind Curb	T_{BACK} =	0.0		ft
Side Slope Behind Curb (leave blank for no conveyance credit behind curb)	S_{BACK} =			ft. vert. / ft. horiz
Manning's Roughness Behind Curb	n_{BACK} =			
Height of Curb at Gutter Flow Line	H_{CURB} =	6.00		inches
Distance from Curb Face to Street Crown	T_{CROWN} =	16.0		ft
Gutter Depression	a =	2.00		inches
Gutter Width	W =	2.00		ft
Street Transverse Slope	S_X =	0.0200		ft. vert. / ft. horiz
Street Longitudinal Slope - Enter 0 for sump condition	S_O =	0.0000		ft. vert. / ft. horiz
Manning's Roughness for Street Section	n_{STREET} =	0.0180		
		Minor Storm	Major Storm	
Max. Allowable Water Spread for Minor & Major Storm	T_{MAX} =	8.0	12.0	ft
Max. Allowable Depth at Gutter Flow Line for Minor & Major Storm	d_{MAX} =	6.00	6.00	inches
Allow Flow Depth at Street Crown (leave blank for no)				X = yes

Maximum Gutter Capacity Based On Allowable Water Spread		Minor Storm	Major Storm	
Gutter Cross Slope (Eq. ST-8)	S_W =	0.1033	0.1033	ft/ft
Water Depth without Gutter Depression (Eq. ST-2)	y =	1.92	2.88	inches
Water Depth with a Gutter Depression	d =	3.92	4.88	inches
Allowable Spread for Discharge outside the Gutter Section W (T - W)	T_X =	6.0	10.0	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.722	0.522	
Discharge outside the Gutter Section W, carried in Section T_X	Q_X =	0.0	0.0	cfs
Discharge within the Gutter Section W (Q_T - Q_X)	Q_W =	0.0	0.0	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Maximum Flow Based On Allowable Water Spread	**Q_T =**	**SUMP**	**SUMP**	**cfs**
Flow Velocity Within the Gutter Section	V =	0.0	0.0	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	0.0	0.0	

Maximum Gutter Capacity Based on Allowable Gutter Depth		Minor Storm	Major Storm	
Theoretical Water Spread	T_{TH} =	16.7	16.7	ft
Theoretical Spread for Discharge outside the Gutter Section W (T - W)	$T_{X\,TH}$ =	14.7	14.7	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.378	0.378	
Theoretical Discharge outside the Gutter Section W, carried in Section $T_{X\,TH}$	$Q_{X\,TH}$ =	0.0	0.0	cfs
Actual Discharge outside the Gutter Section W, (limited by distance T_{CROWN})	Q_X =	0.0	0.0	cfs
Discharge within the Gutter Section W (Q_d - Q_X)	Q_W =	0.0	0.0	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Total Discharge for Major & Minor Storm	**Q =**	**0.0**	**0.0**	**cfs**
Flow Velocity Within the Gutter Section	V =	0.0	0.0	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	0.0	0.0	
Slope-Based Depth Safety Reduction Factor for Major & Minor (d $\geq$ 6") Storm	R =	SUMP	SUMP	
Max Flow Based on Allow. Gutter Depth (Safety Factor Applied)	**Q_d =**	**SUMP**	**SUMP**	**cfs**
Resultant Flow Depth at Gutter Flowline (Safety Factor Applied)	d =			inches
Resultant Flow Depth at Street Crown (Safety Factor Applied)	d_{CROWN} =			inches
		Minor Storm	Major Storm	
Max. Allowable Gutter Capacity Based on Minimum of Q_T or Q_d	**Q_{allow} =**	**SUMP**	**SUMP**	**cfs**

MINOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'

MAJOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'



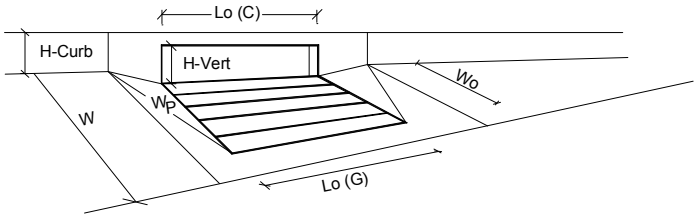
$$Q_x = \frac{0.56}{n} S_x^{5/3} S_L^{1/2} T_x^{8/3} \qquad E_o = \frac{1}{1 + \dfrac{S_w / S_x}{\left[1 + \dfrac{S_w / S_x}{(T/W) - 1}\right]^{8/3} - 1}}$$

$$Q = \frac{Q_x}{1 - E_o}; \; Q_w = Q - Q_x$$

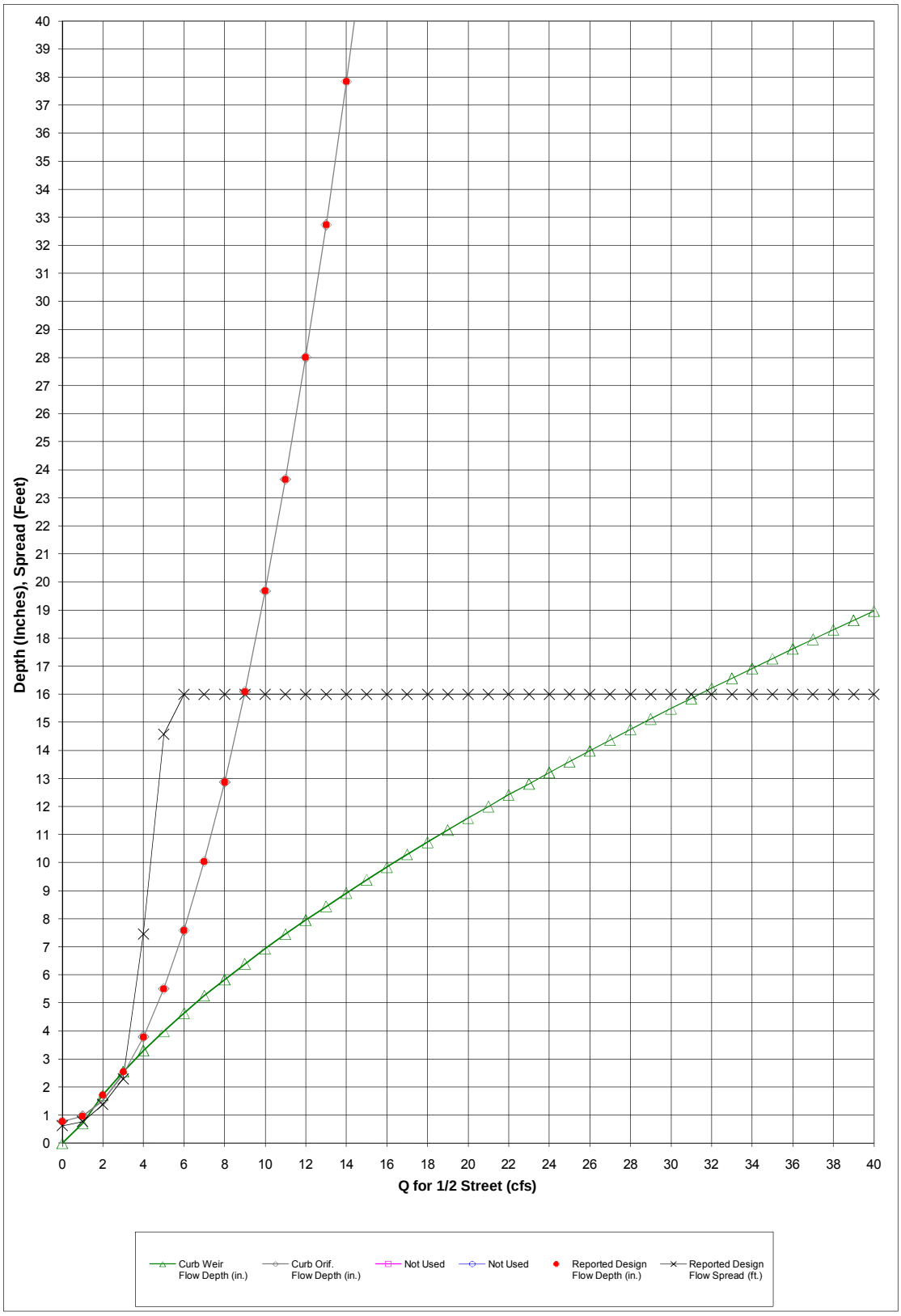
INLET IN A SUMP OR SAG LOCATION

Project = **Pecos Street Bridge Replacement over I-70**

Inlet ID = **5' Type R - Sump**



Design Information (Input)		MINOR	MAJOR	
Type of Inlet	Type =	CDOT Type R Curb Opening		
Local Depression (additional to continuous gutter depression 'a' from 'Q-Allow')	a_{local} =	1.00	1.00	inches
Number of Unit Inlets (Grate or Curb Opening)	No =	1	1	
Grate Information		MINOR	MAJOR	
Length of a Unit Grate	L_o (G) =	N/A	N/A	feet
Width of a Unit Grate	W_o =	N/A	N/A	feet
Area Opening Ratio for a Grate (typical values 0.15-0.90)	A_{ratio} =	N/A	N/A	
Clogging Factor for a Single Grate (typical value 0.50 - 0.70)	C_f (G) =	N/A	N/A	
Grate Weir Coefficient (typical value 3.00)	C_w (G) =	N/A	N/A	
Grate Orifice Coefficient (typical value 0.67)	C_o (G) =	N/A	N/A	
Curb Opening Information		MINOR	MAJOR	
Length of a Unit Curb Opening	L_o (C) =	5.00	5.00	feet
Height of Vertical Curb Opening in Inches	H_{vert} =	4.00	4.00	inches
Height of Curb Orifice Throat in Inches	H_{throat} =	3.95	3.95	inches
Angle of Throat (see USDCM Figure ST-5)	Theta =	63.4	63.4	degrees
Side Width for Depression Pan (typically the gutter width of 2 feet)	W_p =	2.00	2.00	feet
Clogging Factor for a Single Curb Opening (typical value 0.10)	C_f (C) =	0.10	0.10	
Curb Opening Weir Coefficient (typical value 2.30-3.00)	C_w (C) =	2.30	2.30	
Curb Opening Orifice Coefficient (typical value 0.67)	C_o (C) =	0.67	0.67	
Resulting Gutter Flow Depth for Grate Inlet Capacity in a Sump		MINOR	MAJOR	
Clogging Coefficient for Multiple Units	Coef =	N/A	N/A	
Clogging Factor for Multiple Units	Clog =	N/A	N/A	
Grate as a Weir				
Flow Depth at Local Depression without Clogging (0 cfs grate, 1.7 cfs curb)	d_{wi} =	N/A	N/A	inches
This Row Used for Combination Inlets Only	$d_{curb\text{-}un}$ =	N/A	N/A	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 1.7 cfs curb)	d_{wa} =	N/A	N/A	inches
This Row Used for Combination Inlets Only	$d_{curb\text{-}cl}$ =	N/A	N/A	inches
Grate as an Orifice		MINOR	MAJOR	
Flow Depth at Local Depression without Clogging (0 cfs grate, 1.7 cfs curb)	d_{oi} =	N/A	N/A	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 1.7 cfs curb)	d_{oa} =	N/A	N/A	inches
Resulting Gutter Flow Depth Outside of Local Depression	**$d_{a\text{-}Grate}$ =**	**N/A**	**N/A**	**inches**
Resulting Gutter Flow Depth for Curb Opening Inlet Capacity in a Sump		MINOR	MAJOR	
Clogging Coefficient for Multiple Units	Coef =	1.00	1.00	
Clogging Factor for Multiple Units	Clog =	0.10	0.10	
Curb as a Weir, Grate as an Orifice		MINOR	MAJOR	
Flow Depth at Local Depression without Clogging (0 cfs grate, 1.7 cfs curb)	d_{wi} =	2.34	5.42	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 1.7 cfs curb)	d_{wa} =	2.43	5.64	inches
Curb as an Orifice, Grate as an Orifice		MINOR	MAJOR	
Flow Depth at Local Depression without Clogging (0 cfs grate, 1.7 cfs curb)	d_{oi} =	2.21	7.28	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 1.7 cfs curb)	d_{oa} =	2.31	8.58	inches
Resulting Gutter Flow Depth Outside of Local Depression	**$d_{a\text{-}Curb}$ =**	**1.43**	**7.58**	**inches**
Resultant Street Conditions		MINOR	MAJOR	
Total Inlet Length	L =	5.0	5.0	feet
Total Inlet Interception Capacity (Design Discharge from *Q-Peak*)	Q_a =	1.7	6.0	cfs
Resultant Gutter Flow Depth (based on sheet *Q-Allow* geometry)	**d =**	**1.43**	**7.58**	**inches**
Resultant Street Flow Spread (based on sheet *Q-Allow* geometry)	**T =**	**1.2**	**16.0**	**ft. >T-Crown**
Resultant Flow Depth at Street Crown	**d_{CROWN} =**	**0.00**	**1.80**	**inches**


Depth (Inches), Spread (Feet)
Q for 1/2 Street (cfs)
Curb Weir Flow Depth (in.)
Curb Orif. Flow Depth (in.)
Not Used
Not Used
Reported Design Flow Depth (in.)
Reported Design Flow Spread (ft.)

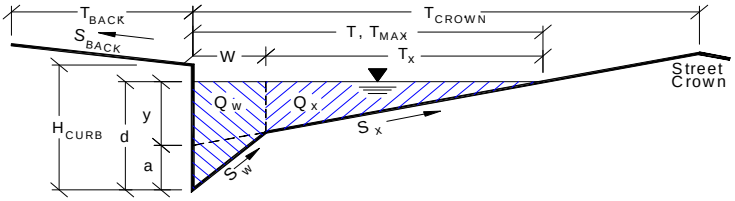
Q Intercepted (cfs)	Curb Weir Flow Depth (in.)	Curb Orif. Flow Depth (in.)	Not Used	Not Used	Reported Design Flow Depth (in.)	Reported Design Flow Spread (ft.)
0.00	0.00	0.77			0.77	0.62
1.00	0.71	0.96			0.96	0.77
2.00	1.71	1.52			1.71	1.38
3.00	2.55	2.47			2.55	2.29
4.00	3.30	3.79			3.79	7.46
5.00	3.99	5.50			5.50	14.58
6.00	4.64	7.58			7.58	16.00
7.00	5.25	10.04			10.04	16.00
8.00	5.83	12.87			12.87	16.00
9.00	6.39	16.09			16.09	16.00
10.00	6.93	19.68			19.68	16.00
11.00	7.45	23.66			23.66	16.00
12.00	7.95	28.01			28.01	16.00
13.00	8.44	32.73			32.73	16.00
14.00	8.92	37.84			37.84	16.00
15.00	9.39	43.33			43.33	16.00
16.00	9.84	49.19			49.19	16.00
17.00	10.29	55.43			55.43	16.00
18.00	10.73	62.06			62.06	16.00
19.00	11.16	69.05			69.05	16.00
20.00	11.58	76.43			76.43	16.00
21.00	12.00	84.19			84.19	16.00
22.00	12.41	92.32			92.32	16.00
23.00	12.81	100.83			100.83	16.00
24.00	13.21	109.72			109.72	16.00
25.00	13.60	118.99			118.99	16.00
26.00	13.99	128.64			128.64	16.00
27.00	14.37	138.67			138.67	16.00
28.00	14.75	149.07			149.07	16.00
29.00	15.12	159.85			159.85	16.00
30.00	15.49	171.01			171.01	16.00
31.00	15.85	182.55			182.55	16.00
32.00	16.21	194.47			194.47	16.00
33.00	16.57	206.76			206.76	16.00
34.00	16.92	219.44			219.44	16.00
35.00	17.27	232.49			232.49	16.00
36.00	17.62	245.92			245.92	16.00
37.00	17.96	259.73			259.73	16.00
38.00	18.30	273.92			273.92	16.00
39.00	18.64	288.48			288.48	16.00
40.00	18.97	303.43			303.43	16.00

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project: **Pecos Street Bridge Replacement over I-70**

Inlet ID: **10' Type R - Sump**



Gutter Geometry (Enter data in the blue cells)				
Maximum Allowable Width for Spread Behind Curb	T_{BACK} =	0.0		ft
Side Slope Behind Curb (leave blank for no conveyance credit behind curb)	S_{BACK} =			ft. vert. / ft. horiz
Manning's Roughness Behind Curb	n_{BACK} =			
Height of Curb at Gutter Flow Line	H_{CURB} =	6.00		inches
Distance from Curb Face to Street Crown	T_{CROWN} =	16.0		ft
Gutter Depression	a =	2.00		inches
Gutter Width	W =	2.00		ft
Street Transverse Slope	S_X =	0.0200		ft. vert. / ft. horiz
Street Longitudinal Slope - Enter 0 for sump condition	S_O =	0.0000		ft. vert. / ft. horiz
Manning's Roughness for Street Section	n_{STREET} =	0.0180		
		Minor Storm	Major Storm	
Max. Allowable Water Spread for Minor & Major Storm	T_{MAX} =	8.0	12.0	ft
Max. Allowable Depth at Gutter Flow Line for Minor & Major Storm	d_{MAX} =	6.00	6.00	inches
Allow Flow Depth at Street Crown (leave blank for no)				X = yes

Maximum Gutter Capacity Based On Allowable Water Spread		Minor Storm	Major Storm	
Gutter Cross Slope (Eq. ST-8)	S_W =	0.1033	0.1033	ft/ft
Water Depth without Gutter Depression (Eq. ST-2)	y =	1.92	2.88	inches
Water Depth with a Gutter Depression	d =	3.92	4.88	inches
Allowable Spread for Discharge outside the Gutter Section W (T - W)	T_X =	6.0	10.0	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.722	0.522	
Discharge outside the Gutter Section W, carried in Section T_X	Q_X =	0.0	0.0	cfs
Discharge within the Gutter Section W (Q_T - Q_X)	Q_W =	0.0	0.0	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Maximum Flow Based On Allowable Water Spread	**Q_T =**	**SUMP**	**SUMP**	**cfs**
Flow Velocity Within the Gutter Section	V =	0.0	0.0	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	0.0	0.0	

Maximum Gutter Capacity Based on Allowable Gutter Depth		Minor Storm	Major Storm	
Theoretical Water Spread	T_{TH} =	16.7	16.7	ft
Theoretical Spread for Discharge outside the Gutter Section W (T - W)	$T_{X\,TH}$ =	14.7	14.7	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.378	0.378	
Theoretical Discharge outside the Gutter Section W, carried in Section $T_{X\,TH}$	$Q_{X\,TH}$ =	0.0	0.0	cfs
Actual Discharge outside the Gutter Section W, (limited by distance T_{CROWN})	Q_X =	0.0	0.0	cfs
Discharge within the Gutter Section W (Q_d - Q_X)	Q_W =	0.0	0.0	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Total Discharge for Major & Minor Storm	**Q =**	**0.0**	**0.0**	**cfs**
Flow Velocity Within the Gutter Section	V =	0.0	0.0	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	0.0	0.0	
Slope-Based Depth Safety Reduction Factor for Major & Minor (d $\geq$ 6") Storm	R =	SUMP	SUMP	
Max Flow Based on Allow. Gutter Depth (Safety Factor Applied)	**Q_d =**	**SUMP**	**SUMP**	**cfs**
Resultant Flow Depth at Gutter Flowline (Safety Factor Applied)	d =			inches
Resultant Flow Depth at Street Crown (Safety Factor Applied)	d_{CROWN} =			inches
		Minor Storm	Major Storm	
Max. Allowable Gutter Capacity Based on Minimum of Q_T or Q_d	**Q_{allow} =**	**SUMP**	**SUMP**	**cfs**

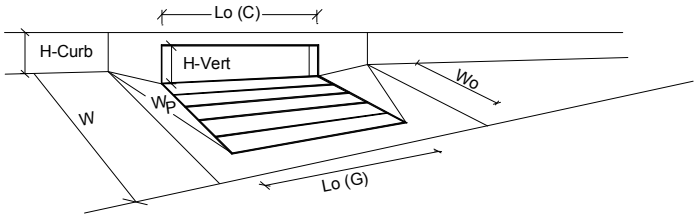
MINOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'

MAJOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'

INLET IN A SUMP OR SAG LOCATION

Project = **Pecos Street Bridge Replacement over I-70**

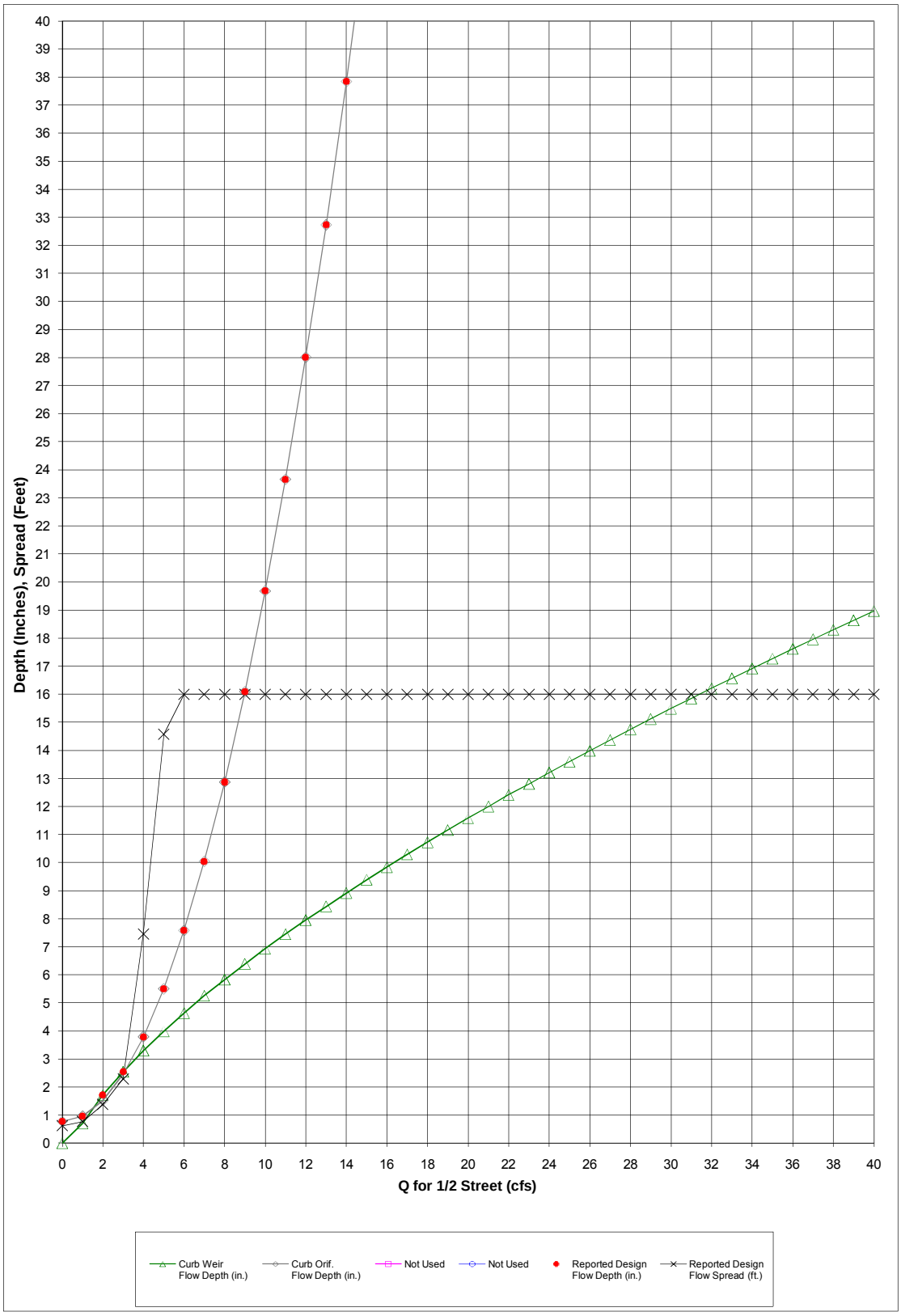
Inlet ID = **10' Type R - Sump**



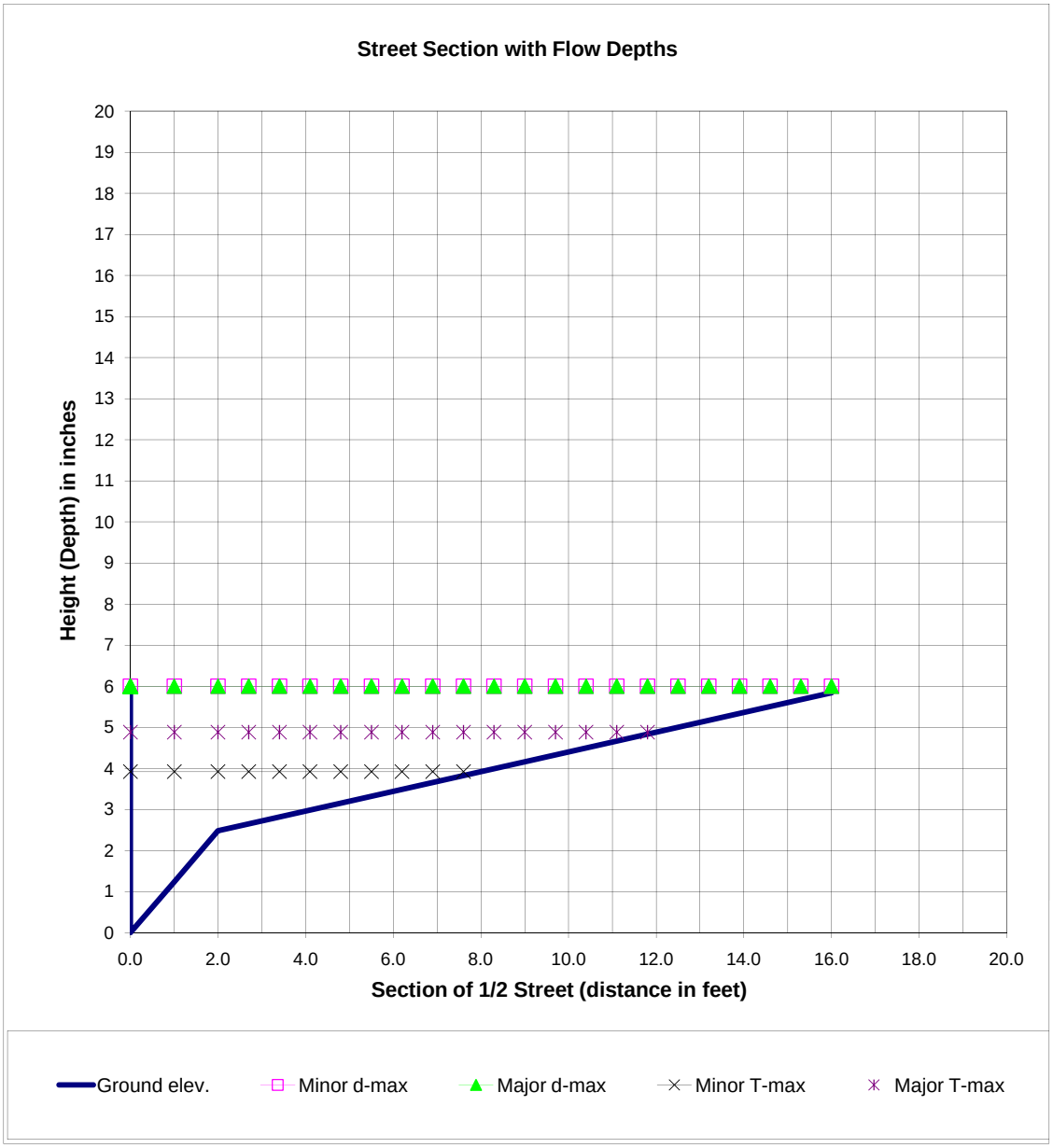
Design Information (Input)		MINOR	MAJOR	
Type of Inlet	Type =	CDOT Type R Curb Opening		
Local Depression (additional to continuous gutter depression 'a' from 'Q-Allow')	a_{local} =	1.00	1.00	inches
Number of Unit Inlets (Grate or Curb Opening)	No =	1	1	
Grate Information		MINOR	MAJOR	
Length of a Unit Grate	L_o (G) =	N/A	N/A	feet
Width of a Unit Grate	W_o =	N/A	N/A	feet
Area Opening Ratio for a Grate (typical values 0.15-0.90)	A_{ratio} =	N/A	N/A	
Clogging Factor for a Single Grate (typical value 0.50 - 0.70)	C_f (G) =	N/A	N/A	
Grate Weir Coefficient (typical value 3.00)	C_w (G) =	N/A	N/A	
Grate Orifice Coefficient (typical value 0.67)	C_o (G) =	N/A	N/A	
Curb Opening Information		MINOR	MAJOR	
Length of a Unit Curb Opening	L_o (C) =	5.00	5.00	feet
Height of Vertical Curb Opening in Inches	H_{vert} =	4.00	4.00	inches
Height of Curb Orifice Throat in Inches	H_{throat} =	3.95	3.95	inches
Angle of Throat (see USDCM Figure ST-5)	Theta =	63.4	63.4	degrees
Side Width for Depression Pan (typically the gutter width of 2 feet)	W_p =	2.00	2.00	feet
Clogging Factor for a Single Curb Opening (typical value 0.10)	C_f (C) =	0.10	0.10	
Curb Opening Weir Coefficient (typical value 2.30-3.00)	C_w (C) =	2.30	2.30	
Curb Opening Orifice Coefficient (typical value 0.67)	C_o (C) =	0.67	0.67	
Resulting Gutter Flow Depth for Grate Inlet Capacity in a Sump		MINOR	MAJOR	
Clogging Coefficient for Multiple Units	Coef =	N/A	N/A	
Clogging Factor for Multiple Units	Clog =	N/A	N/A	
Grate as a Weir				
Flow Depth at Local Depression without Clogging (0 cfs grate, 6 cfs curb)	d_{wi} =	N/A	N/A	inches
This Row Used for Combination Inlets Only	$d_{curb\text{-}un}$ =	N/A	N/A	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 6 cfs curb)	d_{wa} =	N/A	N/A	inches
This Row Used for Combination Inlets Only	$d_{curb\text{-}cl}$ =	N/A	N/A	inches
Grate as an Orifice		MINOR	MAJOR	
Flow Depth at Local Depression without Clogging (0 cfs grate, 6 cfs curb)	d_{oi} =	N/A	N/A	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 6 cfs curb)	d_{oa} =	N/A	N/A	inches
Resulting Gutter Flow Depth Outside of Local Depression	**$d_{a\text{-}Grate}$ =**	**N/A**	**N/A**	**inches**
Resulting Gutter Flow Depth for Curb Opening Inlet Capacity in a Sump		MINOR	MAJOR	
Clogging Coefficient for Multiple Units	Coef =	1.00	1.00	
Clogging Factor for Multiple Units	Clog =	0.10	0.10	
Curb as a Weir, Grate as an Orifice		MINOR	MAJOR	
Flow Depth at Local Depression without Clogging (0 cfs grate, 6 cfs curb)	d_{wi} =	5.42	9.07	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 6 cfs curb)	d_{wa} =	5.64	9.44	inches
Curb as an Orifice, Grate as an Orifice		MINOR	MAJOR	
Flow Depth at Local Depression without Clogging (0 cfs grate, 6 cfs curb)	d_{oi} =	7.28	27.66	inches
Flow Depth at Local Depression with Clogging (0 cfs grate, 6 cfs curb)	d_{oa} =	8.58	33.73	inches
Resulting Gutter Flow Depth Outside of Local Depression	**$d_{a\text{-}Curb}$ =**	**7.58**	**32.73**	**inches**
Resultant Street Conditions		MINOR	MAJOR	
Total Inlet Length	L =	5.0	5.0	feet
Total Inlet Interception Capacity (Design Discharge from *Q-Peak*)	Q_a =	6.0	13.0	cfs
Warning 5 **Resultant Gutter Flow Depth (based on sheet *Q-Allow* geometry)**	**d =**	**7.58**	**32.73**	**inches**
Warning 6 **Resultant Street Flow Spread (based on sheet *Q-Allow* geometry)**	**T =**	**16.0**	**16.0**	**ft. >T-Crown**
Resultant Flow Depth at Street Crown	**d_{CROWN} =**	**1.80**	**26.88**	**inches**

Warning 5: Gutter flow depth is greater than the DEPTH allowed for the MAJOR AND MINOR STORM

Warning 6: Flow spread is greater than that allowed for the MAJOR AND MINOR STORM


Depth (Inches), Spread (Feet)
Q for 1/2 Street (cfs)
Curb Weir Flow Depth (in.)
Curb Orif. Flow Depth (in.)
Not Used
Not Used
Reported Design Flow Depth (in.)
Reported Design Flow Spread (ft.)

Q Intercepted (cfs)	Curb Weir Flow Depth (in.)	Curb Orif. Flow Depth (in.)	Not Used	Not Used	Reported Design Flow Depth (in.)	Reported Design Flow Spread (ft.)
0.00	0.00	0.77			0.77	0.62
1.00	0.71	0.96			0.96	0.77
2.00	1.71	1.52			1.71	1.38
3.00	2.55	2.47			2.55	2.29
4.00	3.30	3.79			3.79	7.46
5.00	3.99	5.50			5.50	14.58
6.00	4.64	7.58			7.58	16.00
7.00	5.25	10.04			10.04	16.00
8.00	5.83	12.87			12.87	16.00
9.00	6.39	16.09			16.09	16.00
10.00	6.93	19.68			19.68	16.00
11.00	7.45	23.66			23.66	16.00
12.00	7.95	28.01			28.01	16.00
13.00	8.44	32.73			32.73	16.00
14.00	8.92	37.84			37.84	16.00
15.00	9.39	43.33			43.33	16.00
16.00	9.84	49.19			49.19	16.00
17.00	10.29	55.43			55.43	16.00
18.00	10.73	62.06			62.06	16.00
19.00	11.16	69.05			69.05	16.00
20.00	11.58	76.43			76.43	16.00
21.00	12.00	84.19			84.19	16.00
22.00	12.41	92.32			92.32	16.00
23.00	12.81	100.83			100.83	16.00
24.00	13.21	109.72			109.72	16.00
25.00	13.60	118.99			118.99	16.00
26.00	13.99	128.64			128.64	16.00
27.00	14.37	138.67			138.67	16.00
28.00	14.75	149.07			149.07	16.00
29.00	15.12	159.85			159.85	16.00
30.00	15.49	171.01			171.01	16.00
31.00	15.85	182.55			182.55	16.00
32.00	16.21	194.47			194.47	16.00
33.00	16.57	206.76			206.76	16.00
34.00	16.92	219.44			219.44	16.00
35.00	17.27	232.49			232.49	16.00
36.00	17.62	245.92			245.92	16.00
37.00	17.96	259.73			259.73	16.00
38.00	18.30	273.92			273.92	16.00
39.00	18.64	288.48			288.48	16.00
40.00	18.97	303.43			303.43	16.00



$$Q_x = \frac{0.56}{n} S_x^{5/3} S_L^{1/2} T_x^{8/3} \qquad E_o = \frac{1}{1 + \dfrac{S_w / S_x}{\left[1 + \dfrac{S_w / S_x}{(T/W) - 1}\right]^{8/3} - 1}}$$

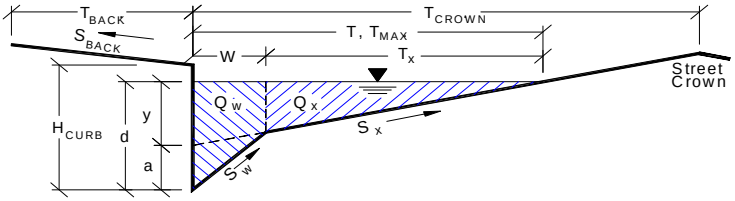
$$Q = \frac{Q_x}{1 - E_o}; \; Q_w = Q - Q_x$$

ALLOWABLE CAPACITY FOR ONE-HALF OF STREET (Minor & Major Storm)

(Based on Regulated Criteria for Maximum Allowable Flow Depth and Spread)

Project: **Pecos Street Bridge Replacement over I-70**

Inlet ID: **Type 13 - On grade**



Gutter Geometry (Enter data in the blue cells)

Maximum Allowable Width for Spread Behind Curb	T_{BACK} =	0.0	ft
Side Slope Behind Curb (leave blank for no conveyance credit behind curb)	S_{BACK} =		ft. vert. / ft. horiz
Manning's Roughness Behind Curb	n_{BACK} =		
Height of Curb at Gutter Flow Line	H_{CURB} =	6.00	inches
Distance from Curb Face to Street Crown	T_{CROWN} =	16.0	ft
Gutter Depression	a =	2.00	inches
Gutter Width	W =	2.00	ft
Street Transverse Slope	S_X =	0.0200	ft. vert. / ft. horiz
Street Longitudinal Slope - Enter 0 for sump condition	S_O =	0.0100	ft. vert. / ft. horiz
Manning's Roughness for Street Section	n_{STREET} =	0.0180	

		Minor Storm	Major Storm	
Max. Allowable Water Spread for Minor & Major Storm	T_{MAX} =	8.0	12.0	ft
Max. Allowable Depth at Gutter Flow Line for Minor & Major Storm	d_{MAX} =	6.00	6.00	inches
Allow Flow Depth at Street Crown (leave blank for no)				X = yes

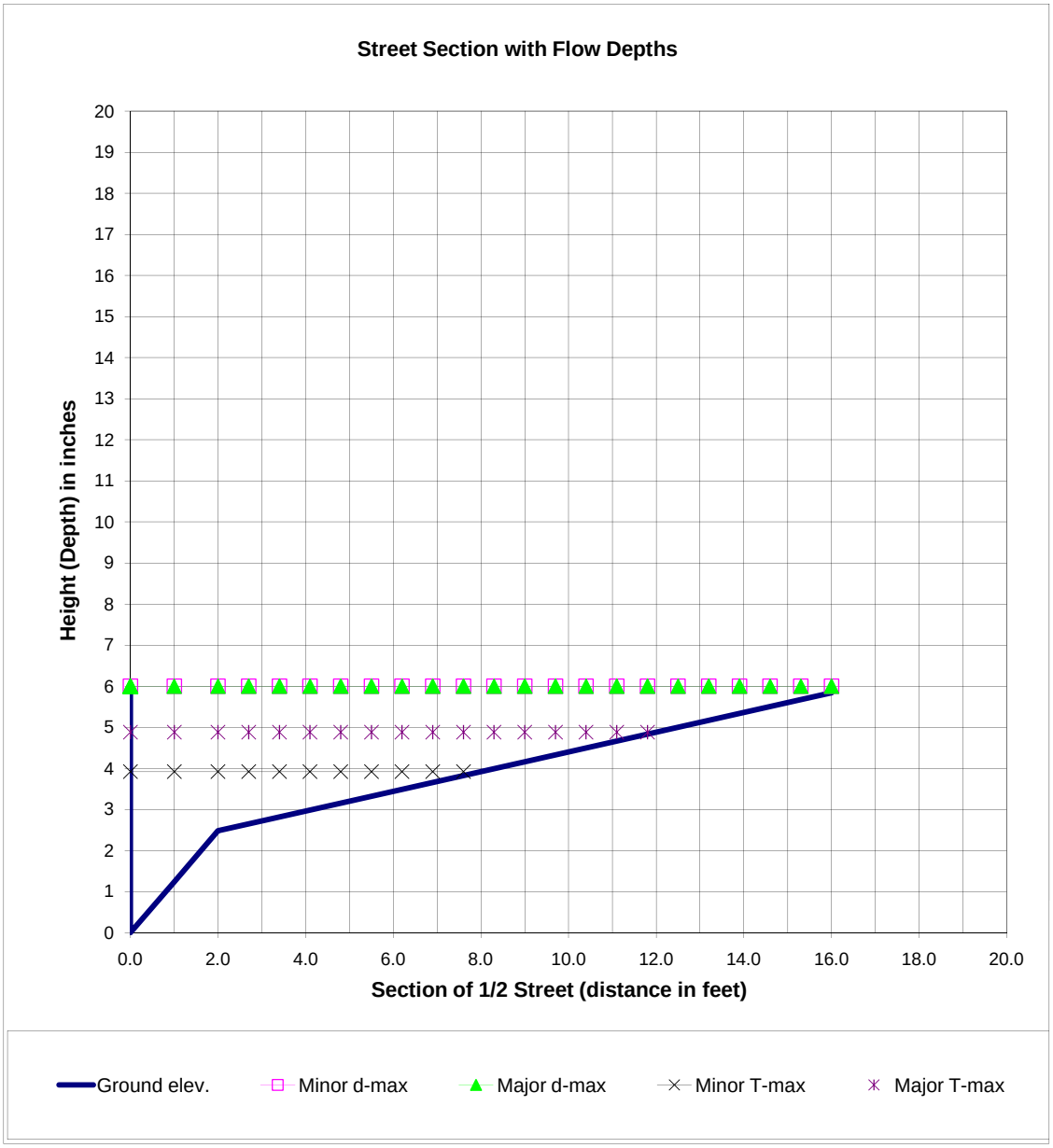
Maximum Gutter Capacity Based On Allowable Water Spread		Minor Storm	Major Storm	
Gutter Cross Slope (Eq. ST-8)	S_W =	0.1033	0.1033	ft/ft
Water Depth without Gutter Depression (Eq. ST-2)	y =	1.92	2.88	inches
Water Depth with a Gutter Depression	d =	3.92	4.88	inches
Allowable Spread for Discharge outside the Gutter Section W (T - W)	T_X =	6.0	10.0	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.722	0.522	
Discharge outside the Gutter Section W, carried in Section T_X	Q_X =	0.5	2.1	cfs
Discharge within the Gutter Section W (Q_T - Q_X)	Q_W =	1.4	2.3	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Maximum Flow Based On Allowable Water Spread	**Q_T =**	**2.0**	**4.4**	**cfs**
Flow Velocity Within the Gutter Section	V =	3.2	3.8	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	1.0	1.6	

Maximum Gutter Capacity Based on Allowable Gutter Depth		Minor Storm	Major Storm	
Theoretical Water Spread	T_{TH} =	16.7	16.7	ft
Theoretical Spread for Discharge outside the Gutter Section W (T - W)	$T_{X\,TH}$ =	14.7	14.7	ft
Gutter Flow to Design Flow Ratio by FHWA HEC-22 method (Eq. ST-7)	E_O =	0.378	0.378	
Theoretical Discharge outside the Gutter Section W, carried in Section $T_{X\,TH}$	$Q_{X\,TH}$ =	5.9	5.9	cfs
Actual Discharge outside the Gutter Section W, (limited by distance T_{CROWN})	Q_X =	5.9	5.9	cfs
Discharge within the Gutter Section W (Q_d - Q_X)	Q_W =	3.6	3.6	cfs
Discharge Behind the Curb (e.g., sidewalk, driveways, & lawns)	Q_{BACK} =	0.0	0.0	cfs
Total Discharge for Major & Minor Storm	**Q =**	**9.5**	**9.5**	**cfs**
Flow Velocity Within the Gutter Section	V =	4.5	4.5	fps
V*d Product: Flow Velocity Times Gutter Flowline Depth	V*d =	2.3	2.3	
Slope-Based Depth Safety Reduction Factor for Major & Minor (d $\geq$ 6") Storm	R =	1.00	1.00	
Max Flow Based on Allow. Gutter Depth (Safety Factor Applied)	**Q_d =**	**9.5**	**9.5**	**cfs**
Resultant Flow Depth at Gutter Flowline (Safety Factor Applied)	d =	6.00	6.00	inches
Resultant Flow Depth at Street Crown (Safety Factor Applied)	d_{CROWN} =	0.16	0.16	inches

		Minor Storm	Major Storm	
Max. Allowable Gutter Capacity Based on Minimum of Q_T or Q_d	**Q_{allow} =**	**2.0**	**4.4**	**cfs**

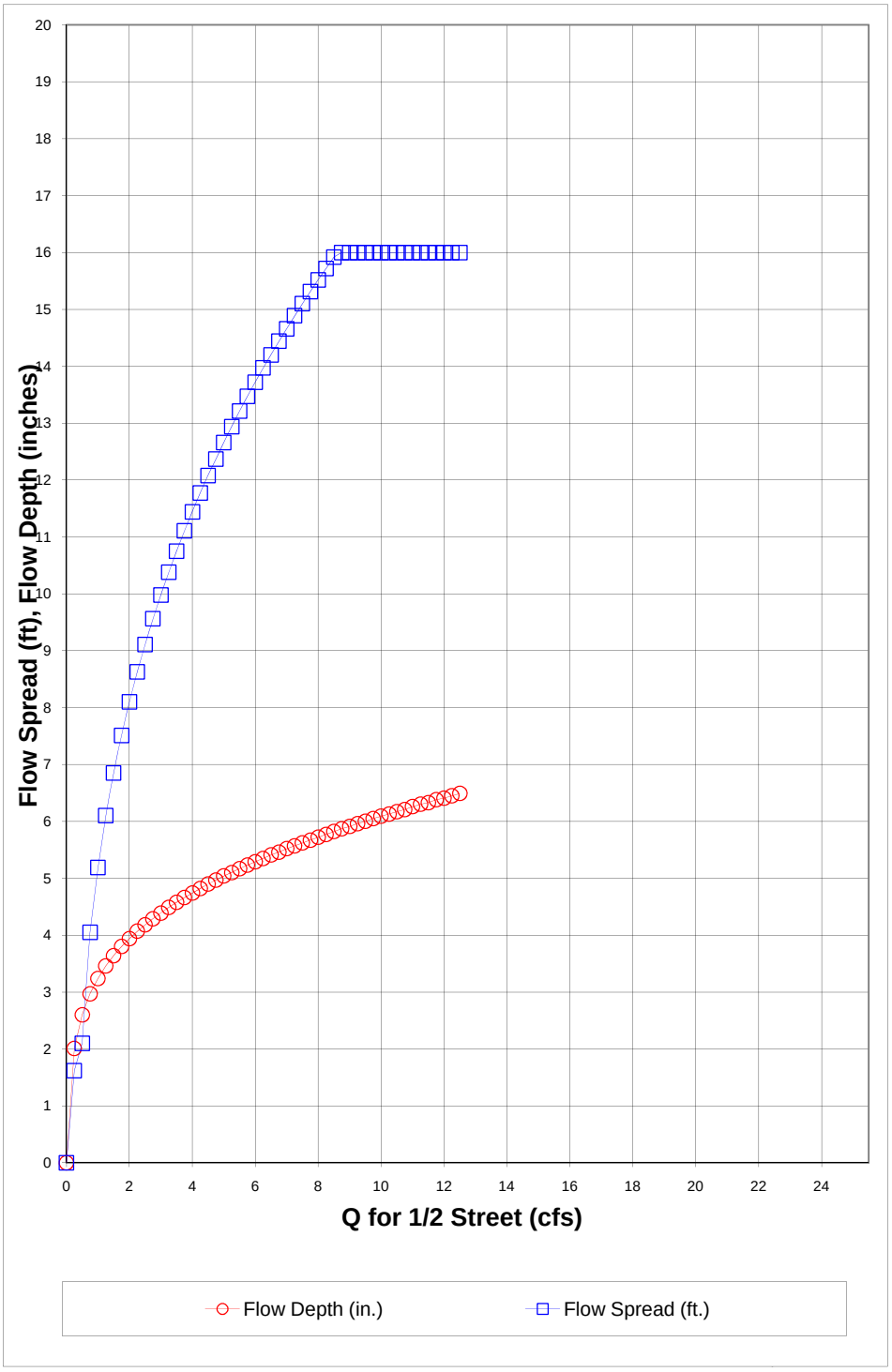
MINOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'

MAJOR STORM max. allowable capacity OK - greater than flow given on sheet 'Q-Peak'



$$Q_x = \frac{0.56}{n} S_x^{5/3} S_L^{1/2} T_x^{8/3} \qquad E_o = \frac{1}{1 + \dfrac{S_w / S_x}{\left[1 + \dfrac{S_w / S_x}{(T/W) - 1}\right]^{8/3} - 1}}$$

$$Q = \frac{Q_x}{1 - E_o}; \; Q_w = Q - Q_x$$

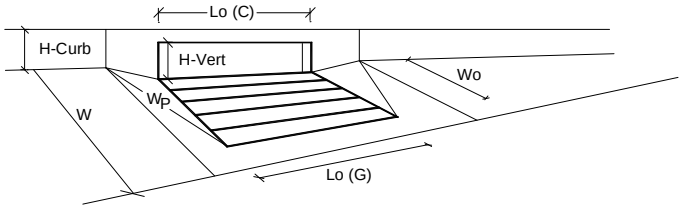


Q for 1/2 Street (cfs)	Flow Depth (in.)	Flow Spread (ft.)
0.00	0.00	0.00
0.25	2.01	1.62
0.50	2.60	2.10
0.75	2.97	4.05
1.00	3.24	5.19
1.25	3.46	6.10
1.50	3.64	6.85
1.75	3.80	7.51
2.00	3.94	8.10
2.25	4.07	8.63
2.50	4.18	9.11
2.75	4.29	9.56
3.00	4.39	9.98
3.25	4.49	10.38
3.50	4.58	10.75
3.75	4.66	11.11
4.00	4.74	11.44
4.25	4.82	11.77
4.50	4.90	12.08
4.75	4.97	12.37
5.00	5.04	12.66
5.25	5.10	12.94
5.50	5.17	13.21
5.75	5.23	13.47
6.00	5.29	13.72
6.25	5.35	13.97
6.50	5.41	14.20
6.75	5.46	14.44
7.00	5.52	14.66
7.25	5.57	14.89
7.50	5.62	15.10
7.75	5.67	15.31
8.00	5.72	15.52
8.25	5.77	15.72
8.50	5.82	15.92
8.75	5.87	16.00
9.00	5.91	16.00
9.25	5.96	16.00
9.50	6.00	16.00
9.75	6.05	16.00
10.00	6.09	16.00
10.25	6.13	16.00
10.50	6.17	16.00
10.75	6.21	16.00
11.00	6.26	16.00
11.25	6.30	16.00
11.50	6.33	16.00
11.75	6.38	16.00
12.00	6.41	16.00
12.25	6.45	16.00
12.50	6.49	16.00

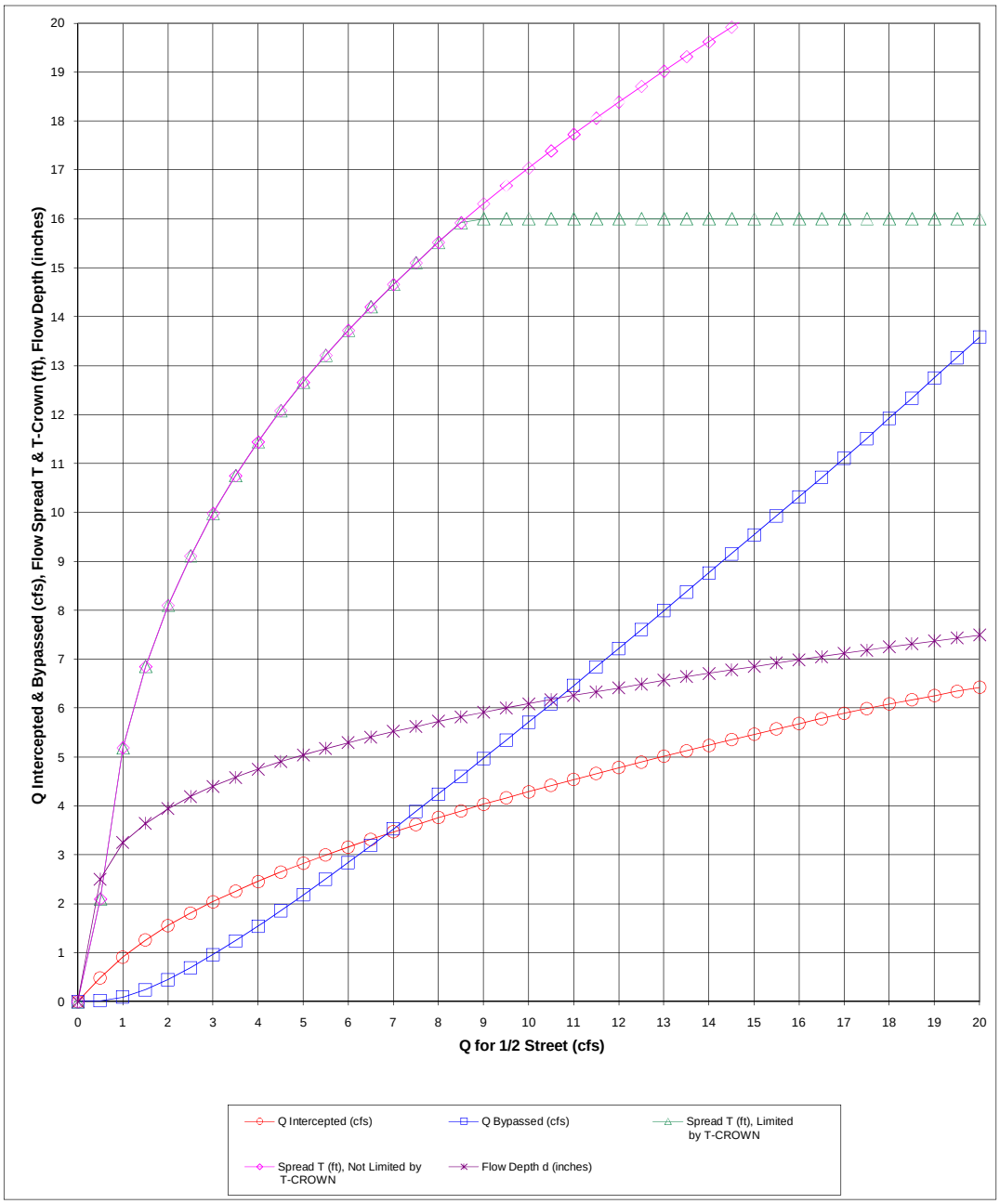
INLET ON A CONTINUOUS GRADE

Project: Pecos Street Bridge Replacement over I-70

Inlet ID: Type 13 - On grade



Design Information (Input)		MINOR	MAJOR	
Type of Inlet	Type =	CDOT/Denver 13 Combination		
Local Depression (additional to continuous gutter depression 'a' from 'Q-Allow')	a_{LOCAL} =	0.0	0.0	inches
Total Number of Units in the Inlet (Grate or Curb Opening)	No =	1	1	
Length of a Single Unit Inlet (Grate or Curb Opening)	L_o =	3.00	3.00	ft
Width of a Unit Grate (cannot be greater than W from Q-Allow)	W_o =	1.73	1.73	ft
Clogging Factor for a Single Unit Grate (typical min. value = 0.5)	C_f-G =	0.50	0.50	
Clogging Factor for a Single Unit Curb Opening (typical min. value = 0.1)	C_f-C =	0.10	0.10	
Street Hydraulics: OK - Q < maximum allowable from sheet 'Q-Allow'		MINOR	MAJOR	
Design Discharge for Half of Street (from Sheet *Q-Peak*)	**Q_o =**	**1.00**	**4.00**	**cfs**
Water Spread Width	T =	5.2	11.4	ft
Water Depth at Flowline (outside of local depression)	d =	3.2	4.7	inches
Water Depth at Street Crown (or at T_{MAX})	d_{CROWN} =	0.0	0.0	inches
Ratio of Gutter Flow to Design Flow	E_o =	0.900	0.545	
Discharge outside the Gutter Section W, carried in Section T_x	Q_x =	0.10	1.82	cfs
Discharge within the Gutter Section W	Q_w =	0.90	2.18	cfs
Discharge Behind the Curb Face	Q_{BACK} =	0.00	0.00	cfs
Street Flow Area	A_s =	0.44	1.47	sq ft
Street Flow Velocity	V_s =	2.30	2.72	fps
Water Depth for Design Condition	d_{LOCAL} =	3.2	4.7	inches
Grate Analysis (Calculated)		MINOR	MAJOR	
Total Length of Inlet Grate Opening	L =	3.00	3.00	ft
Ratio of Grate Flow to Design Flow	$E_{o\text{-}GRATE}$ =	0.843	0.494	
Under No-Clogging Condition		MINOR	MAJOR	
Minimum Velocity Where Grate Spash-Over Begins	V_o =	6.17	6.17	fps
Interception Rate of Frontal Flow	R_f =	1.00	1.00	
Interception Rate of Side Flow	R_x =	0.27	0.22	
Interception Capacity	Q_i =	0.89	2.41	cfs
Under Clogging Condition		MINOR	MAJOR	
Clogging Coefficient for Multiple-unit Grate Inlet	GrateCoef =	1.00	1.00	
Clogging Factor for Multiple-unit Grate Inlet	GrateClog =	0.50	0.50	
Effective (unclogged) Length of Multiple-unit Grate Inlet	L_e =	1.50	1.50	ft
Minimum Velocity Where Grate Spash-Over Begins	V_o =	3.86	3.86	fps
Interception Rate of Frontal Flow	R_f =	1.00	1.00	
Interception Rate of Side Flow	R_x =	0.07	0.05	
Actual Interception Capacity	**Q_a =**	**0.85**	**2.08**	**cfs**
Carry-Over Flow = Q_o-Q_a (to be applied to curb opening or next d/s inlet)	**Q_b =**	**0.15**	**1.92**	**cfs**
Curb or Slotted Inlet Opening Analysis (Calculated)		MINOR	MAJOR	
Equivalent Slope S_e (based on grate carry-over)	S_e =	0.0950	0.0654	ft/ft
Required Length L_T to Have 100% Interception	L_T =	3.07	11.33	ft
Under No-Clogging Condition		MINOR	MAJOR	
Effective Length of Curb Opening or Slotted Inlet (minimum of L, L_T)	L =	3.00	3.00	ft
Interception Capacity	Q_i =	0.07	0.41	cfs
Under Clogging Condition		MINOR	MAJOR	
Clogging Coefficient	CurbCoef =	1.00	1.00	
Clogging Factor for Multiple-unit Curb Opening or Slotted Inlet	CurbClog =	0.10	0.10	
Effective (Unclogged) Length	L_e =	2.70	2.70	ft
Actual Interception Capacity	**Q_a =**	**0.07**	**0.37**	**cfs**
Carry-Over Flow = $Q_{b(GRATE)}$-Q_a	**Q_b =**	**0.07**	**1.55**	**cfs**
Summary		MINOR	MAJOR	
Total Inlet Interception Capacity	**Q =**	**0.93**	**2.45**	**cfs**
Total Inlet Carry-Over Flow (flow bypassing inlet)	**Q_b =**	**0.07**	**1.55**	**cfs**
Capture Percentage = Q_a/Q_o =	**C% =**	**92.6**	**61.4**	**%**


Q Intercepted & Bypassed (cfs), Flow Spread T & T-Crown (ft), Flow Depth (inches)
Q for 1/2 Street (cfs)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Q Intercepted (cfs)
Q Bypassed (cfs)
Spread T (ft), Limited by T-CROWN
Spread T (ft), Not Limited by T-CROWN
Flow Depth d (inches)

Q for 1/2 Street (cfs)	Q Intercepted (cfs)	Q Bypassed (cfs)	Spread T (ft), Limited by T_{-CROWN}	Spread T (ft), Not Limited by T_{-CROWN}	Flow Depth d (inches)
0.00	0.00	0.00	0.00	0.00	0.00
0.50	0.48	0.02	2.10	2.10	2.50
1.00	0.91	0.09	5.19	5.19	3.25
1.50	1.26	0.24	6.85	6.85	3.64
2.00	1.55	0.45	8.10	8.10	3.94
2.50	1.81	0.69	9.11	9.11	4.19
3.00	2.04	0.96	9.98	9.98	4.40
3.50	2.26	1.24	10.75	10.75	4.58
4.00	2.46	1.54	11.44	11.44	4.75
4.50	2.65	1.85	12.08	12.08	4.90
5.00	2.82	2.18	12.66	12.66	5.04
5.50	3.00	2.50	13.21	13.21	5.17
6.00	3.16	2.84	13.72	13.72	5.29
6.50	3.31	3.19	14.20	14.20	5.41
7.00	3.47	3.53	14.66	14.66	5.52
7.50	3.61	3.89	15.10	15.10	5.62
8.00	3.76	4.24	15.52	15.52	5.73
8.50	3.90	4.60	15.92	15.92	5.82
9.00	4.03	4.97	16.00	16.31	5.91
9.50	4.16	5.34	16.00	16.68	6.00
10.00	4.29	5.71	16.00	17.04	6.09
10.50	4.42	6.08	16.00	17.39	6.17
11.00	4.54	6.46	16.00	17.73	6.26
11.50	4.66	6.84	16.00	18.06	6.33
12.00	4.78	7.22	16.00	18.39	6.41
12.50	4.90	7.60	16.00	18.71	6.49
13.00	5.01	7.99	16.00	19.02	6.57
13.50	5.13	8.37	16.00	19.32	6.64
14.00	5.24	8.76	16.00	19.62	6.71
14.50	5.35	9.15	16.00	19.92	6.78
15.00	5.46	9.54	16.00	20.21	6.85
15.50	5.57	9.93	16.00	20.50	6.92
16.00	5.68	10.32	16.00	20.78	6.99
16.50	5.79	10.71	16.00	21.05	7.05
17.00	5.89	11.11	16.00	21.33	7.12
17.50	5.99	11.51	16.00	21.60	7.18
18.00	6.08	11.92	16.00	21.86	7.25
18.50	6.17	12.33	16.00	22.12	7.31
19.00	6.25	12.75	16.00	22.38	7.37
19.50	6.34	13.16	16.00	22.64	7.43
20.00	6.42	13.58	16.00	22.89	7.49

Full Flow Capacity 18" at 0.5%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.00500	ft/ft
Normal Depth	1.50	ft
Diameter	1.50	ft
Discharge	7.43	ft^3/s

Results

Discharge	7.43	ft^3/s
Normal Depth	1.50	ft
Flow Area	1.77	ft^2
Wetted Perimeter	4.71	ft
Hydraulic Radius	0.38	ft
Top Width	0.00	ft
Critical Depth	1.06	ft
Percent Full	100.0	%
Critical Slope	0.00703	ft/ft
Velocity	4.20	ft/s
Velocity Head	0.27	ft
Specific Energy	1.77	ft
Froude Number	0.00	
Maximum Discharge	7.99	ft^3/s
Discharge Full	7.43	ft^3/s
Slope Full	0.00500	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Full Flow Capacity 18" at 0.5%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.50	ft
Critical Depth	1.06	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00703	ft/ft

Full Flow Capacity 24" at 0.5%

Project Description

Friction Method	Manning Formula
Solve For	Full Flow Capacity

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.00500	ft/ft
Normal Depth	2.00	ft
Diameter	2.00	ft
Discharge	16.00	ft^3/s

Results

Discharge	16.00	ft^3/s
Normal Depth	2.00	ft
Flow Area	3.14	ft^2
Wetted Perimeter	6.28	ft
Hydraulic Radius	0.50	ft
Top Width	0.00	ft
Critical Depth	1.44	ft
Percent Full	100.0	%
Critical Slope	0.00662	ft/ft
Velocity	5.09	ft/s
Velocity Head	0.40	ft
Specific Energy	2.40	ft
Froude Number	0.00	
Maximum Discharge	17.21	ft^3/s
Discharge Full	16.00	ft^3/s
Slope Full	0.00500	ft/ft
Flow Type	SubCritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

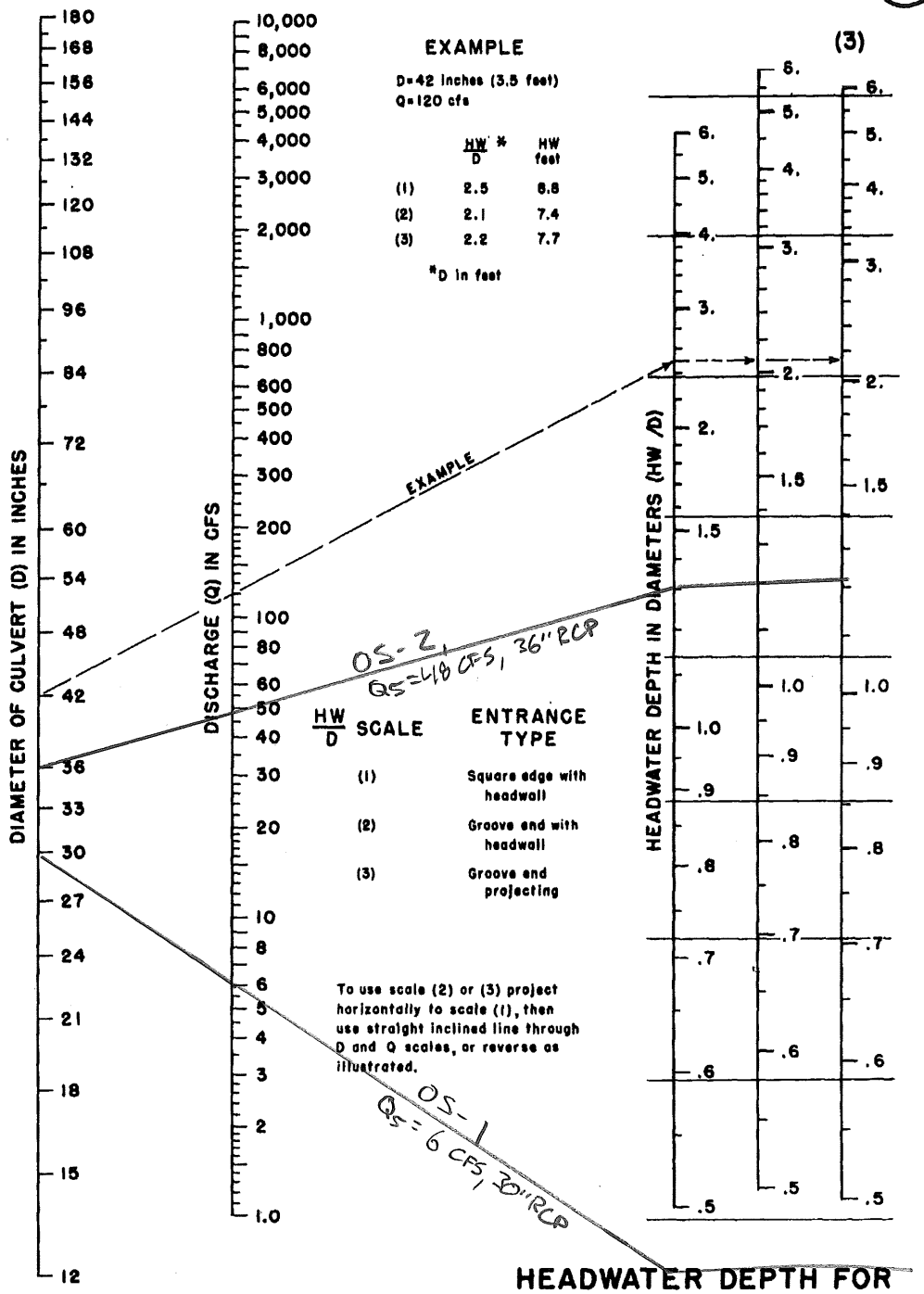
Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Average End Depth Over Rise	0.00	%

Full Flow Capacity 24" at 0.5%

GVF Output Data

Normal Depth Over Rise	100.00	%
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.00	ft
Critical Depth	1.44	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00662	ft/ft

CHART 1B



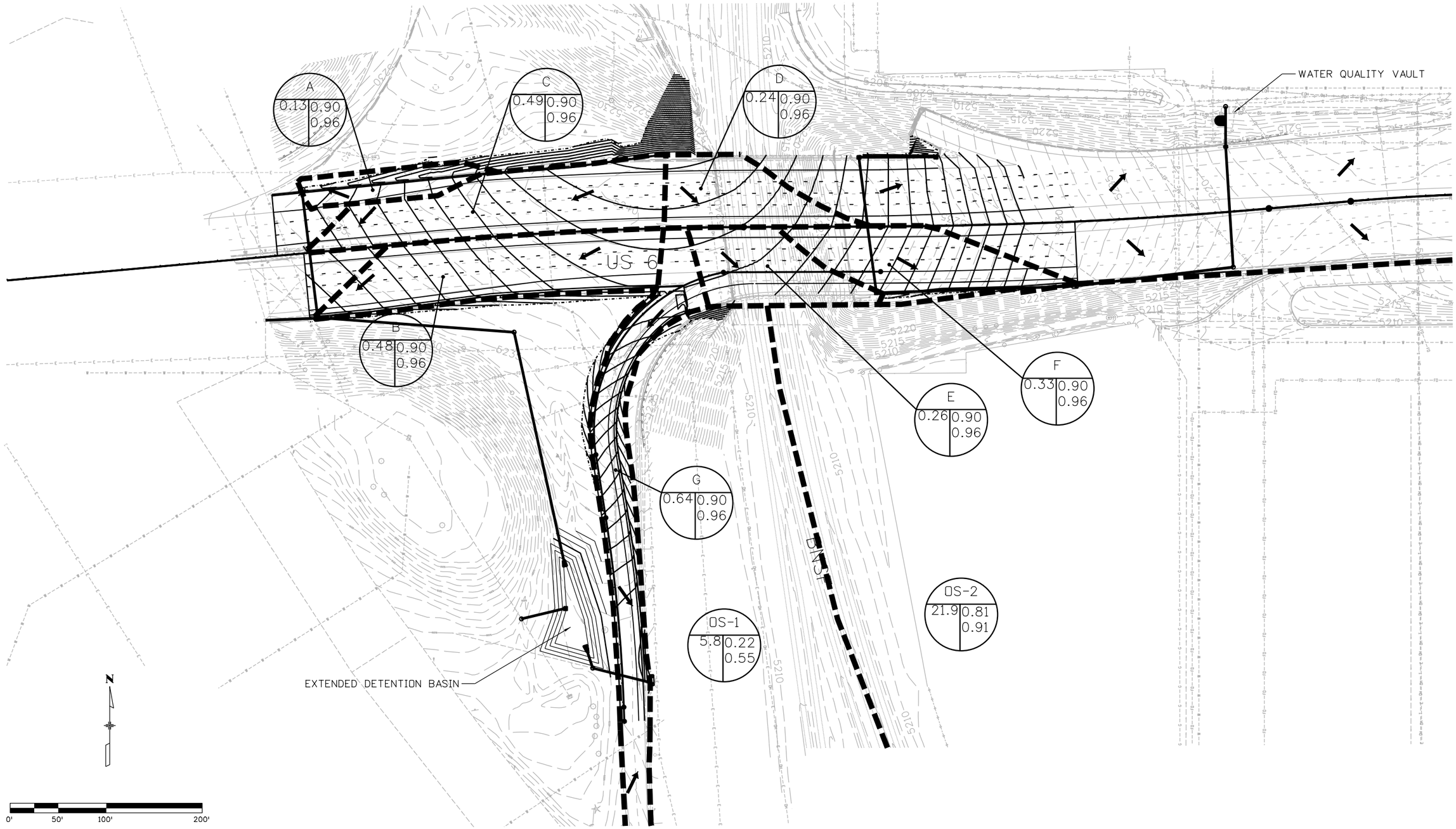
HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

Drainage Maps

- Drainage Map



Print Date: 12/27/2011	Sheet Revisions	Colorado Department of Transportation	As Constructed
File Name: 18202_basinmap.dgn	Date: / Comments / Init.	8833 South Wadsworth Court Littleton, CO 80128 Phone: 303-972-9112 FAX: 303-972-9114	No Revisions:
Horiz. Scale: 1:100 Vert. Scale: As Noted		Region 6 MP	Revised:
Unit Information Unit Leader Initials			Void:

WILSON & COMPANY Engineers & Architects
999 18TH STREET, SUITE 2600
DENVER, CO 80202
PHONE: 303-297-2976
FAX: 303-297-2693

6th AVE OVER BNSF DRAINAGE BASIN MAP

Designer: TDS	Structure Numbers		Project No./Code
Detailer:			FBR 0062-026
Sheet Subset: BASIN MAP	Subset Sheets: 1 of 1		18202
			Sheet Number

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