APPENDIX

D. GUTTER FLOW USING HEC-RAS

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D. GUTTER FLOW USING HEC-RAS

D.1 INTRODUCTION

Gutter flow is a form of open channel flow. Most gutter flow is associated with pavement drainage and storm drain design, and is, therefore, discussed in Storm Drain Design, Chapter 6 of this document. Some situations may warrant a more detailed approach to gutter flow than presented in the Storm Drain Chapter. The gutter flow equation is:

$$Q = \frac{0.56}{n} S_X{}^{5/3} T^{8/3} S^{1/2}$$

where:

Q = Discharge, in ft^3/sec

n = Manning's roughness coefficient

S_X = Cross Slope, in ft/ft

T = Spread, in ft

S = Slope of the energy gradient, in ft/ft

The gutter flow equation is a normal depth equation that can be used in a manner similar to Manning’s Equation. The slope of the energy gradient is the same as the longitudinal slope of the gutter for normal depth of flow in the gutter. The equation cannot be solved if the slope is zero or negative. While zero and negative slope conditions should be avoided when designing a project, you will sometimes encounter these conditions when analyzing existing or retrofit situations.

You can use the HEC-RAS model to analyze open channels with flat or reverse slopes, so HEC-RAS is applicable to analyzing gutter flow with zero or negative slopes. In HEC-RAS, the friction losses between cross sections are estimated using Manning’s Equation. The Manning’s roughness coefficient can be adjusted, in effect, to make HEC-RAS use the gutter flow equation to determine the friction losses.

If the gutter has a typical triangular cross section, such as a gutter against a curb or barrier wall, the area and the hydraulic radius can be solved using the cross slope, S_X, and the spread, T:

$$A = \frac{S_X T^2}{2}$$

$$P \approx T$$

where:

P = Wetted perimeter, in ft

Note that T is an approximation of P when the cross slope is relatively small.

$$R = \frac{A}{P} = \frac{S_X T^2}{2T} = \frac{S_X T}{2}$$

Substituting into Manning's Equation:

$$Q = \frac{1.486}{n}\left(\frac{S_X T^2}{2}\right)\left(\frac{S_X T}{2}\right)^{2/3} S^{1/2} = \frac{1.486}{(2)2^{2/3} n} S_X{}^{5/3} T^{8/3} S^{1/2} = \frac{0.47}{n} S_X{}^{5/3} T^{8/3} S^{1/2}$$

Therefore, Manning's Equation can be manipulated to solve the gutter flow equation if the Manning's roughness coefficient is reduced by a ratio of 0.47/0.56 = 0.84. The roughness value normally used in gutter analysis is 0.016 (see Appendix B, Table B-2). The reduced value that should be used in HEC-RAS is 0.0134 or 0.013.

D.2 EXAMPLE OF GUTTER FLOW USING HEC-RAS

An existing four-lane divided rural highway with zero percent grade will be widened to six lanes by adding lanes in the median. The new inside lanes will slope toward the median. A barrier wall will be erected in the median to prevent cross-over accidents. The inside shoulder will be 12 feet wide with a 0.06 ft/ft cross slope.

The shoulder will not be warped to provide a grade along the barrier wall. Instead, the water collecting against the barrier will be allowed to seek out the nearest inlet despite the flat grade. Pipe will be installed parallel to the barrier wall to connect the inlets. Occasionally, a pipe will be jacked and bored under the existing lanes to outfall the flow from the median storm drain systems. The maximum distance between inlets will be 500 feet. Analyze the maximum spread next to the barrier wall.

D.2.1 Solution

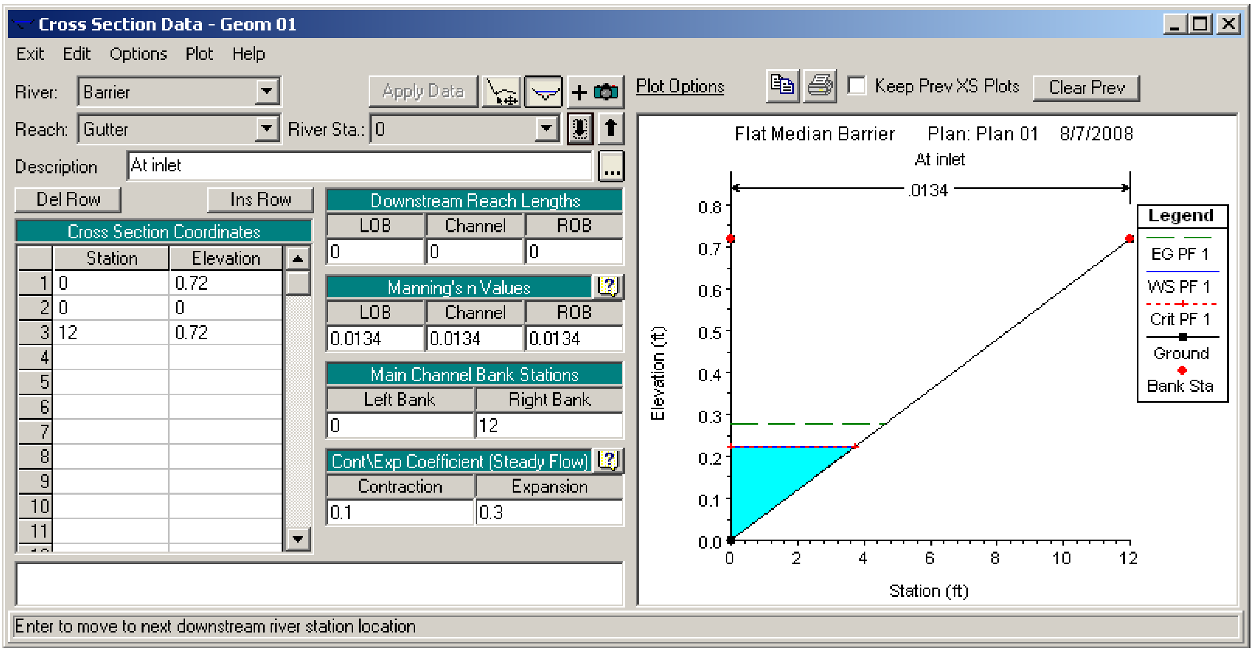
The flow is assumed to divide halfway between the two inlets and flow in both directions. So the flow from one side of the inlet comes from 250 feet away. Table D-1 shows the flow rate at each cross section that will be used in the HEC-RAS analysis. Calculate the flow rates using the rational equation. Calculate the drainage area by multiplying the width of 36 feet by the distance from the midway point between the inlets. The rainfall intensity used is four inches per hour. The runoff coefficient is 0.95.

Table D-1: Discharges

Location (distance from inlet)	**Area (acres)**	**Q (cfs)**
0	0.2066	0.785
1	0.2058	0.782
4	0.2033	0.773
10	0.1983	0.754
25	0.1860	0.707
50	0.1653	0.628
100	0.1240	0.471

The total flow into the inlet is 2 x 0.785 = 1.67 cfs. The capacity chart for a Type D DBI from Appendix I (Inlet Efficiencies) shows that the depth above the inlet is less than 0.1 feet (which is a conservative estimate of the capacity of a barrier wall inlet). This depth will be lower than critical depth, so the profile in HEC-RAS will start at critical depth. Critical depth is not affected by the adjustment to Manning’s “n” because critical depth is independent of the channel roughness.

The geometry of the shoulder next to the barrier wall is entered into HEC-RAS at Station 0, which will be next to the inlet. See Figure D-1, below:



River: Barrier
Reach: Gutter
River Sta.: 0
Description: At inlet

Cross Section Coordinates

	Station	Elevation
1	0	0.72
2	0	0
3	12	0.72
4		
5		
6		
7		
8		
9		
10		
11		

Downstream Reach Lengths

LOB	Channel	ROB
0	0	0

Manning's n Values

LOB	Channel	ROB
0.0134	0.0134	0.0134

Main Channel Bank Stations

Left Bank	Right Bank
0	12

Cont\Exp Coefficient (Steady Flow)

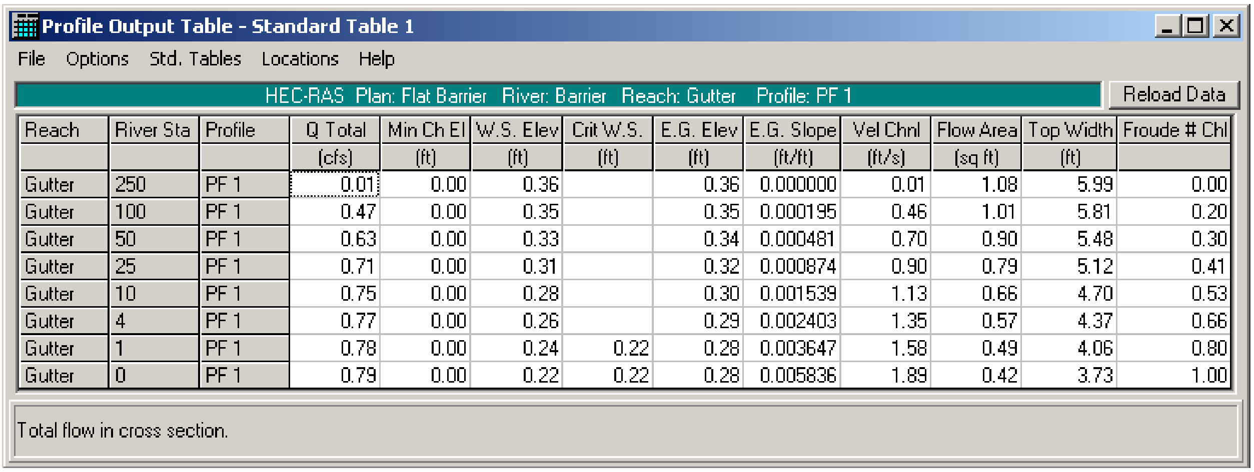
Contraction	Expansion
0.1	0.3

Enter to move to next downstream river station location

Figure D-1: HEC-RAS Input

The geometry is copied to the other desired cross section locations. Since the profile begins at critical depth, the first few cross sections should be located close to each other. The first cross section had to be located only one foot away to avoid a conveyance ratio warning.

The flow data is entered. A flow of 0.01 cfs is entered at Station 250 because HEC-RAS cannot use a value of zero when analyzing Steady State conditions. The downstream boundary condition is set at critical depth. Figure D-2, below, shows the computed profile:



HEC-RAS Plan: Flat Barrier River: Barrier Reach: Gutter Profile: PF 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
Gutter	250	PF 1	0.01	0.00	0.36		0.36	0.000000	0.01	1.08	5.99	0.00
Gutter	100	PF 1	0.47	0.00	0.35		0.35	0.000195	0.46	1.01	5.81	0.20
Gutter	50	PF 1	0.63	0.00	0.33		0.34	0.000481	0.70	0.90	5.48	0.30
Gutter	25	PF 1	0.71	0.00	0.31		0.32	0.000874	0.90	0.79	5.12	0.41
Gutter	10	PF 1	0.75	0.00	0.28		0.30	0.001539	1.13	0.66	4.70	0.53
Gutter	4	PF 1	0.77	0.00	0.26		0.29	0.002403	1.35	0.57	4.37	0.66
Gutter	1	PF 1	0.78	0.00	0.24	0.22	0.28	0.003647	1.58	0.49	4.06	0.80
Gutter	0	PF 1	0.79	0.00	0.22	0.22	0.28	0.005836	1.89	0.42	3.73	1.00

Total flow in cross section.

Figure D-2: Computed Profile

The top width, which is equivalent to the spread, does not exceed six feet. Therefore, the inlets prevent spread onto the travel lanes with a considerable safety factor.

Although spread will not be a problem, nuisance ponding will probably develop since the elevation along the barrier will not be perfectly level. Although this will not be a hazard, silt will collect next to the barrier and may require more maintenance.