218 Attachment 1

Township of Bethlehem
(Part 1, Stormwater Control, of Chapter 218)

Appendix A
Stormwater Runoff Calculations

A.1. Rational Formula. A method of calculating peak rate of runoff is the Rational Formula Q = CIA, in which "Q" is the rate of stormwater flow in cubic feet per second; "C" is a coefficient indicating the degree of imperviousness of the drainage area; "I" is the intensity of rainfall in inches per hour for the particular frequency of storm used; and "A" is the drainage area in acres. This method may be utilized in the design of stormwater inlets and conveyance systems. Neither the Rational Method nor any of its derivatives shall be utilized for design or routing of detention facilities without the specific written authorization of the Township Engineer. The U.S. Soil Conservation Service "Soil-Cover-Complex" method may also be used, as appropriate.

A.2. Values of runoff coefficient "C.". Coefficient "C" values used for the calculation of runoff shall be based on the anticipated ultimate use of the land. Accepted "C" values to be used are as they appear in the chart on the next page.

RUNOFF COEFFICIENT OF THE RATIONAL METHOD: (Q = CIA) BY HYDROLOGICAL SOIL GROUP AND SLOP RANGE [After Rawls et. al., 1981]

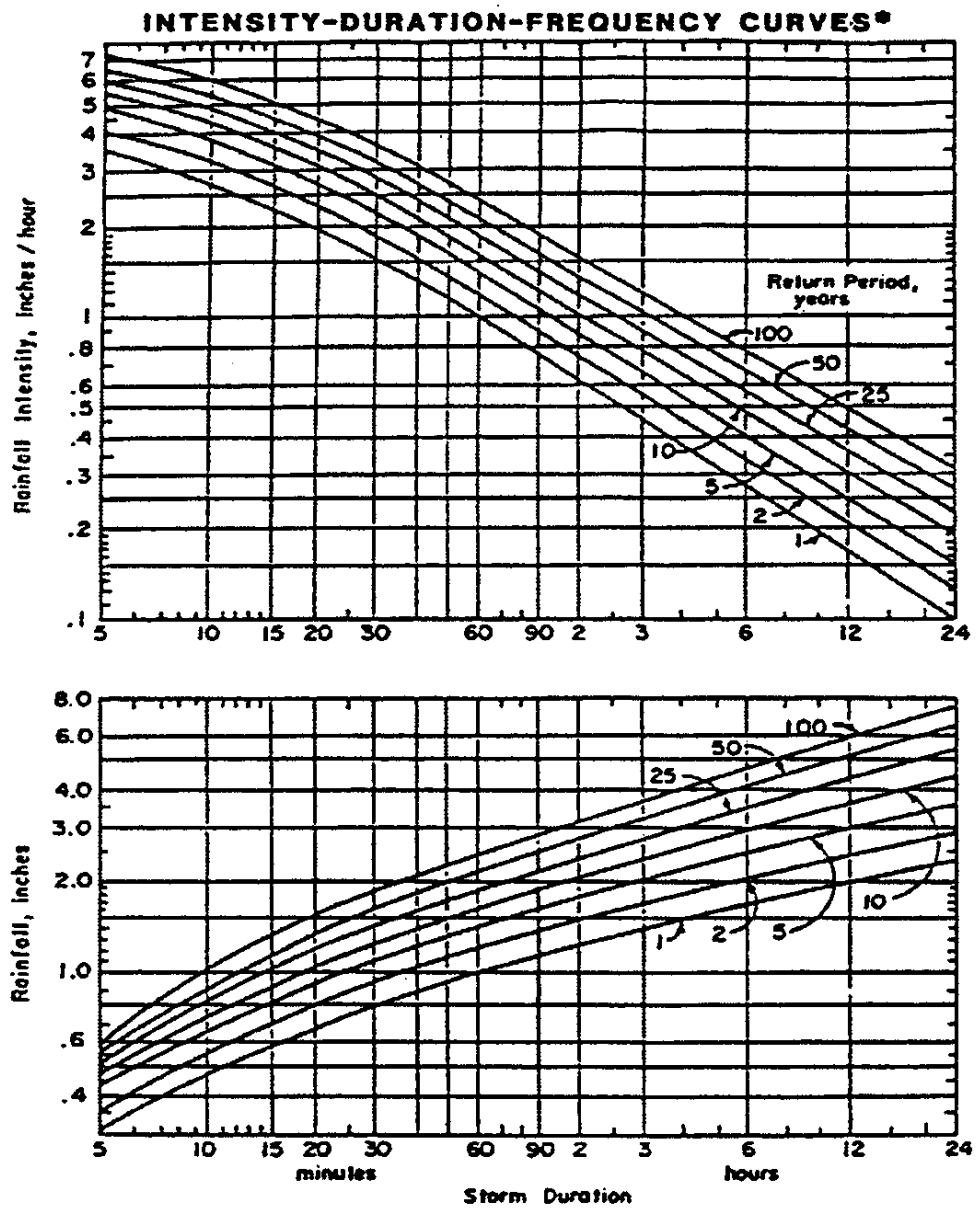
Hydrologic Soil Group	A			B			C			D		
Land Use/Slope	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Cultivated Land	*0.08 **0.14	0.13 0.18	0.16 0.22	0.11 0.16	0.15 0.21	0.21 0.28	0.14 0.20	0.19 0.25	0.26 0.34	0.18 0.24	0.23 0.29	0.31 0.41
Pasture	0.12 0.15	0.20 0.25	0.30 0.37	0.18 0.23	0.28 0.34	0.37 0.45	0.24 0.30	0.34 0.42	0.44 0.52	0.30 0.37	0.40 0.50	0.50 0.62
Meadow	0.10 0.14	0.16 0.22	0.25 0.30	0.14 0.20	0.22 0.28	0.30 0.37	0.20 0.26	0.28 0.35	0.36 0.44	0.24 0.30	0.30 0.40	0.40 0.50
Forest	0.05 0.08	0.08 0.11	0.11 0.14	0.08 0.10	0.11 0.14	0.14 0.18	0.10 0.12	0.13 0.16	0.16 0.20	0.12 0.15	0.16 0.20	0.20 0.25
Resident 1/8 acre lots	0.25 0.33	0.28 0.37	0.31 0.40	0.27 0.35	0.30 0.39	0.35 0.44	0.30 0.38	0.33 0.42	0.38 0.49	0.33 0.41	0.36 0.45	0.42 0.54
1/4 acre lots	0.22 0.30	0.26 0.34	0.39 0.37	0.24 0.33	0.29 0.37	0.33 0.42	0.27 0.36	0.31 0.40	0.36 0.47	0.30 0.38	0.34 0.42	0.40 0.52
1/3 acre lots	0.19 0.28	0.23 0.32	0.26 0.35	0.22 0.30	0.26 0.35	0.30 0.39	0.25 0.33	0.29 0.38	0.34 0.45	0.28 0.36	0.32 0.40	0.39 0.50
1/2 acre lots	0.16 0.25	0.20 0.29	0.24 0.32	0.19 0.28	0.23 0.32	0.28 0.36	0.22 0.31	0.27 0.35	0.32 0.42	0.26 0.34	0.30 0.38	0.37 0.48
1 acre lots	0.14 0.22	0.19 0.26	0.22 0.29	0.17 0.24	0.21 0.28	0.26 0.34	0.20 0.28	0.25 0.32	0.31 0.40	0.24 0.31	0.29 0.35	0.35 0.46
Industrial	0.67 0.85	0.68 0.85	0.68 0.86	0.68 0.85	0.68 0.86	0.69 0.86	0.68 0.86	0.69 0.86	0.69 0.87	0.69 0.86	0.69 0.86	0.69 0.88
Commercial	0.71 0.88	0.71 0.88	0.72 0.89	0.71 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.89	0.72 0.90	0.72 0.89	0.72 0.89	0.72 0.90
Streets	0.70 0.76	0.71 0.77	0.72 0.79	0.71 0.80	0.72 0.82	0.74 0.84	0.72 0.84	0.73 0.85	0.76 0.89	0.73 0.89	0.75 0.91	0.78 0.95
Open Space	0.05 0.11	0.10 0.16	0.14 0.20	0.08 0.14	0.13 0.19	0.19 0.26	0.12 0.18	0.17 0.23	0.24 0.32	0.16 0.22	0.21 0.27	0.28 0.39
Parking	0.85 0.95	0.86 0.96	0.87 0.97	0.85 0.95	0.86 0.96	0.87 0.97	0.85 0.95	0.86 0.96	0.87 0.97	0.85 0.95	0.86 0.96	0.87 0.97

NOTES:

* Runoff coefficients for storm recurrence intervals of less than 25 years.

** Runoff coefficients for storm recurrence intervals of 25 years or more.

A.3. Values of storm intensity "I". The values of "I," in inches per hour, shall be in accordance with the following charts for the area:



Source: Pennsylvania Dept. of Transp. Design Rainfall Curves (1986)

Return Periods	24-Hour Rainfall Depth
2-year	2.88 inches
10-year	4.56 inches
25-year	5.52 inches
100-year	7.68 inches

A.4. Suggested runoff velocities. Suggested runoff velocities for overland flow (and not pipe sizing) are as follows:

Description of Course or Runoff Water	Percent Slope vs. Velocities						
	0-3	4-7	8-10	11-15	16-20	21-25	26-20
Woodland	0.5	1.0	1.5	1.7	2.0	2.7	3.5
Pasture	0.8	1.5	2.2	2.6	3.0	4.1	4.5
Cultivated (row crop)*	1.0	2.0	3.0	3.5	4.0	4.5	5.0
Pavement	5.0	12.0	15.5	18.0	—	—	—
Natural draw not well defined	0.8	2.5	4.0	6.0	—	—	—

* See § 218-18F of Part 1 of Chapter 218, Stormwater Management, of the Code of the Township of Bethlehem.

A.5. Velocity of Flow in Open Channels.

A. The velocity of flow in open channels and in closed drains not under pressure shall be determined by Manning's velocity equation:

$$v: \frac{1{,}486}{n} (a/p)\, 2/3_x\, 1/2$$

v: velocity in feet per second

n: coefficient of roughness

a: cross-section area of structure

p: perimeter of the wetted channel

s: slope in feet per foot

B. The coefficient of roughness "n" shall be as follows, unless otherwise approved by the Township Engineer:

Material/Ground Cover	**Roughness Coefficient ("n")**
Concrete pipe	0.012
Corrugated steel pipe	See table below
Vitrified clay pipe	0.012
Cast iron pip	0.013
Smooth-walled plastic pipe	0.011
Corrugated plastic pipe	0.024
Brick sewer	0.015
Asphalt pavement	0.015
Concrete pavement	0.014
Grass swales	0.04
Earth	0.02
Gravel	0.03
Rock	0.035
Cultivated areas	0.03 to 0.05
Dense brush	0.07 to 0.14
Dense woods with little undergrowth	0.10 to 0.15
Streams:	
– some grass and weeds light brush	0.03 to 0.035
– dense growth of weeds	0.035 to 0.05
– some weeds, heavy brush on banks	0.05 to 0.07

Values of Coefficient of Roughness (n) for Standard Corrugated Steel Pipe (Manning's Formula)							
Corrugations	1 1/2" x 1/4" 8" x 10"		2 2/3" x 1 2/3" 12"	18"	24"	36"	48"
Unpaved	0.013	0.016	0.011	0.014	0.016	0.019	0.020
25% paved					0.015	0.017	0.020
Fully paved					0.012	0.012	0.012

Helical – 3" x 1"

Corrugations	**36"**	**48"**	**54"**	**60"**	**66"**	**72"**
Unpaved	0.021	0.023	0.023	0.024	0.025	0.026
25% paved	0.019	0.020	0.020	0.021	0.022	0.022
Fully paved	0.012	0.012	0.012	0.012	0.013	0.013

A.6. Permissible Stream Velocities in Open Channels. [Amended 6-21-1993 by Ord. No. 6-93]

Material/Cover	**Slop Range %**	**Allowable Velocity (feet/second)**	
		Erosion Resistant Soil	**Easily Eroded Soil**
Kentucky Bluegrass and Fescue	<5	7	5
	5 to 10	6	4
	>10	5	3
Sericea Lespedeza and Weeping Lovegrass and Redtop and Red Fescue	5	3.5	2.5
Grass Mixture and Reed Canarygrass	<5	5	4
	5 to 10	4	3
Annuals and Sundangrass	<5	3.5	2.5

Erosion resistant soil – cohesive (clayey) fine grain soil and course grain soils with a plasticity index of 10 to 40 (CL, CH, SC and GC).

Earth Without Vegetation	**Slope Range %**	**Allowable Velocity (feet/second) With Colloidal**	
		Clear Water	**Silts**
Fine sand, noncolloidal	2	1.50	2.50
Sandy loam, noncolloidal	2	1.75	2.50
Silt loam, noncolloidal	2	2.00	3.00
Alluvial silts, noncolloidal	2	2.00	3.50
Ordinary firm loam	2	2.50	3.50
Stiff clay, very colloidal	2	3.75	5.00
Alluvial clay, colloidal	2	3.75	5.00
Shale and hardpan	2	6.00	6.00
Fine gravel	2	2.50	5.00
Coarse gravel, noncolloidal	2	4.00	6.00
Other:		**Allowable Velocity (feet/second)**	
Bituminous or cement stabilized		6	
Paved channels		10 to 15	

A.7. Calculations. See § 218-18E of Part 1 of Chapter 218, Stormwater Management, of the Code of the Township of Bethlehem.

A.8. Soil-Cover-Complex Values. The values shall apply if the Soil-Cover-Complex Method is used.

Runoff Curve Numbers and Percent Impervious Values*

Cover Description Land Use/Cover Type	Average Percent Impervious Area	Curve Numbers for Hydrological Soil Group			
		A	B	C	D
Open space (lawns, parks, golf courses, cemeteries etc.)					
Good condition (grass cover greater than 75%)		39	61	74	80
Impervious areas					
Pave parking lots, roofs, driveways, etc. (excluding rights-of-way)		98	98	98	98
Streets and roads:					
Paved: curbs and storm sewers (excluding rights-of-way)		98	98	98	98
Paved: open ditches (including rights-of-way)		83	89	92	93

* Source: Soil Conservation Service Technical Release No. 55, Second Edition, June, 1986. The above is not a complete listing of all land use/cover type values. For site conditions significantly different from those provided, refer to the above-referenced SCS publication.

Earth without Vegetation	Slope Range %	Allowable Velocity feet/second			
		Clear Water		With Colloidal Silts	
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (townhouse)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acre	12	46	65	77	82
Wood areas		30	55	70	77

SCS TYPE II RAINFALL DISTRIBUTION