MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

August 14, 2008

TO: Ralph Reznick, Nonpoint Source Unit, WB
Peter Vincent, Nonpoint Source Unit, WB

FROM: Dave Fongers, Hydrologic Studies Unit, LWMD

Dave Fongers

SUBJECT: Small Storm Hydrologic Modeling

Summary

Watershed plans funded by the Nonpoint Source (NPS) program frequently use the Long-Term Hydrologic Impact Assessment (L-THIA) model to estimate pollutant loads. This model, and likely others, compute surface runoff volumes using the runoff curve number technique using continuous modeling of daily rainfalls. The curve number technique was developed to estimate peak flood flows and flood volumes, and was not intended to be used for continuous simulation or computing runoff from small storms. As applied in L-THIA, the modeled runoff from urban areas is likely underestimated relative to agricultural or natural areas. Consequently, calculated pollutant loads from urban areas are likely correspondingly low relative to the agricultural areas.

Technical Discussion

This curve number technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The curve number technique documentation is the NRCS's Part 630 Hydrology National Engineering Handbook (NEH). The technique, as adapted for Michigan, is also described in "Computing Flood Discharges For Small Ungaged Watersheds (Sorrell, 2008).

An assumption of the runoff curve number technique is that the entire watershed contributes runoff. Chapter 10, Section 630-1003 Accuracy, of the NEH states, "The runoff equation generally did reasonably well where the runoff was a substantial fraction of the rainfall, but poorly in cases where the runoff was a small fraction of the rainfall; i.e., the CNs are low or rainfall values are small. Curve numbers were originally developed from annual flood flows from experimental watersheds, and their application to low flows or small flood peak flows is not recommended."

Runoff volumes and flows from smaller events would depend upon the curve number of the portion of the watershed contributing runoff. The watershed is no longer accurately modeled with one weighted-curve number (weighted-CN) for the entire watershed. An improvement is to calculate the runoff from each land cover and soil complex, then sum the runoff volumes. This method is referred to as the weighted Q method in the NEH Chapter 10, which states, "The method of weighted Q always gives the correct result (in terms of the given data), but it requires more work than the weighted-CN method especially when a watershed has many complexes." When every storm, no matter how small, is modeled and the initial abstraction parameter is reset to zero every day, as it is in L-THIA, runoff contributed by directly connected impervious areas (DCIA) during small storms is being missed. If this runoff is underestimated, the pollutants associated with the runoff from pavement are similarly being underestimated.

To illustrate how this can occur, assume a 20-acre residential development on B soil is being modeled. The standard curve number would be 70. Following the curve number method, no runoff would occur from the 20 acres until the rainfall exceeds 0.86 inches, equal to the model parameter termed Initial Abstraction for a curve number of 70. If the 20 acres is 25 percent impervious and is instead modeled as just 5 acres of impervious area with a curve number of 98, runoff would be produced from the impervious area when rainfall exceeds 0.04 inches, equal to the initial abstraction for a curve number of 98. The difference in runoff is illustrated in Figure 1.

Adding the remaining 15-acre area as open space in good condition on B soil, curve number of 61, the pervious 15 acres would contribute runoff only when rainfall exceeds 1.28 inches. This runoff is not shown in Figure 1. It is shown in figure 2, however, which also shows the calculated runoff for all residential development, one-half acre lot size and 25 percent imperviousness, for A through D soil hydrogroups. Similar analyses are shown for industrial land use, 72 percent impervious, and commercial land use, 85 percent impervious, in Figures 4 and 5 respectively. Figures 2 through 4 demonstrate that the two methods yield different results for small storms, but converge toward similar results as storm size increases.

L-THIA uses 30 years of rainfall data to calculate average annual runoff. For simplicity, I performed the analysis for both weighted CN and weighted Q scenarios using one year of data (Michigan Automated Weather Network, East Lansing 2007 daily data). Using a curve number of 70 to represent the entire development, the model calculates 0.59 acre-feet of runoff for the year, meaning only 0.35 inches of rain ran off of the 28.99 inches that fell. Of the 126 days with recorded rainfall, only eight days produce runoff in the model. Modeling the impervious and pervious areas separately, the model calculates 17.65 inches of runoff from the 28.99 inches that fell on the 5 impervious acres. Total runoff is 7.41 acre-feet, or an average for the site of 4.45 inches of runoff. Detailed results are provided in Table 1. Only days with recorded rainfall are shown.

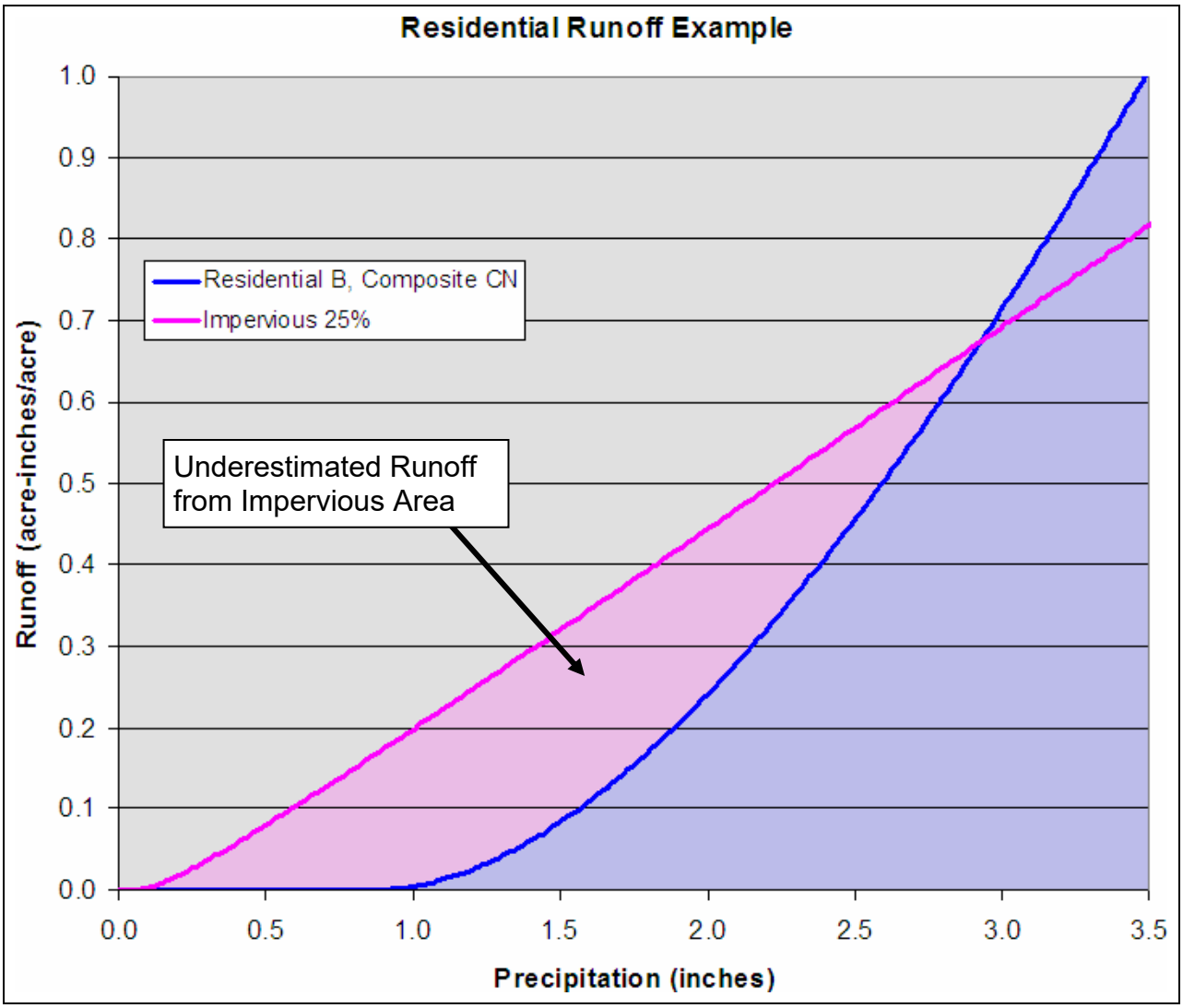

Figure 1: Runoff from an Example Residential Development

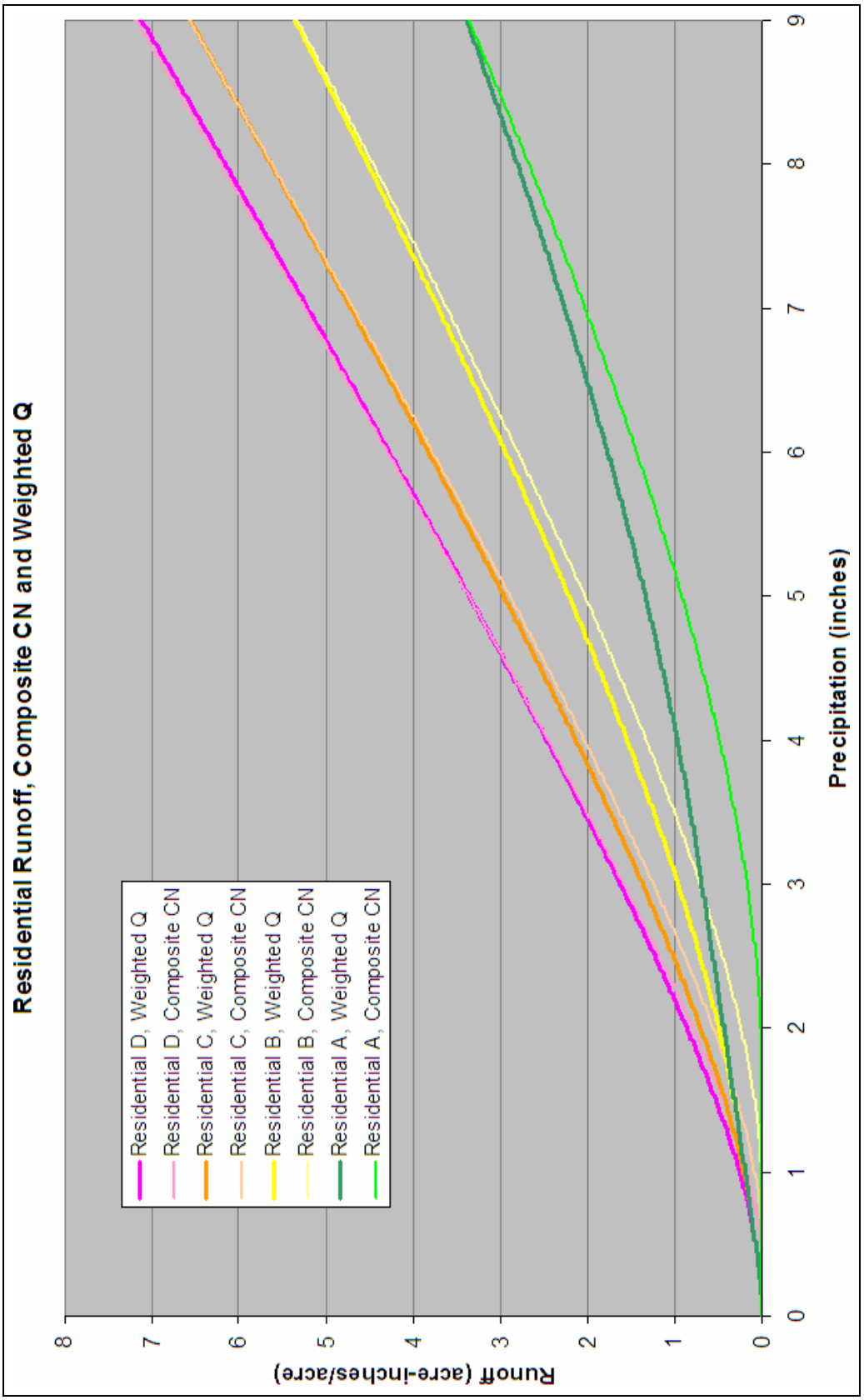

Figure 2: Residential Runoff Comparison

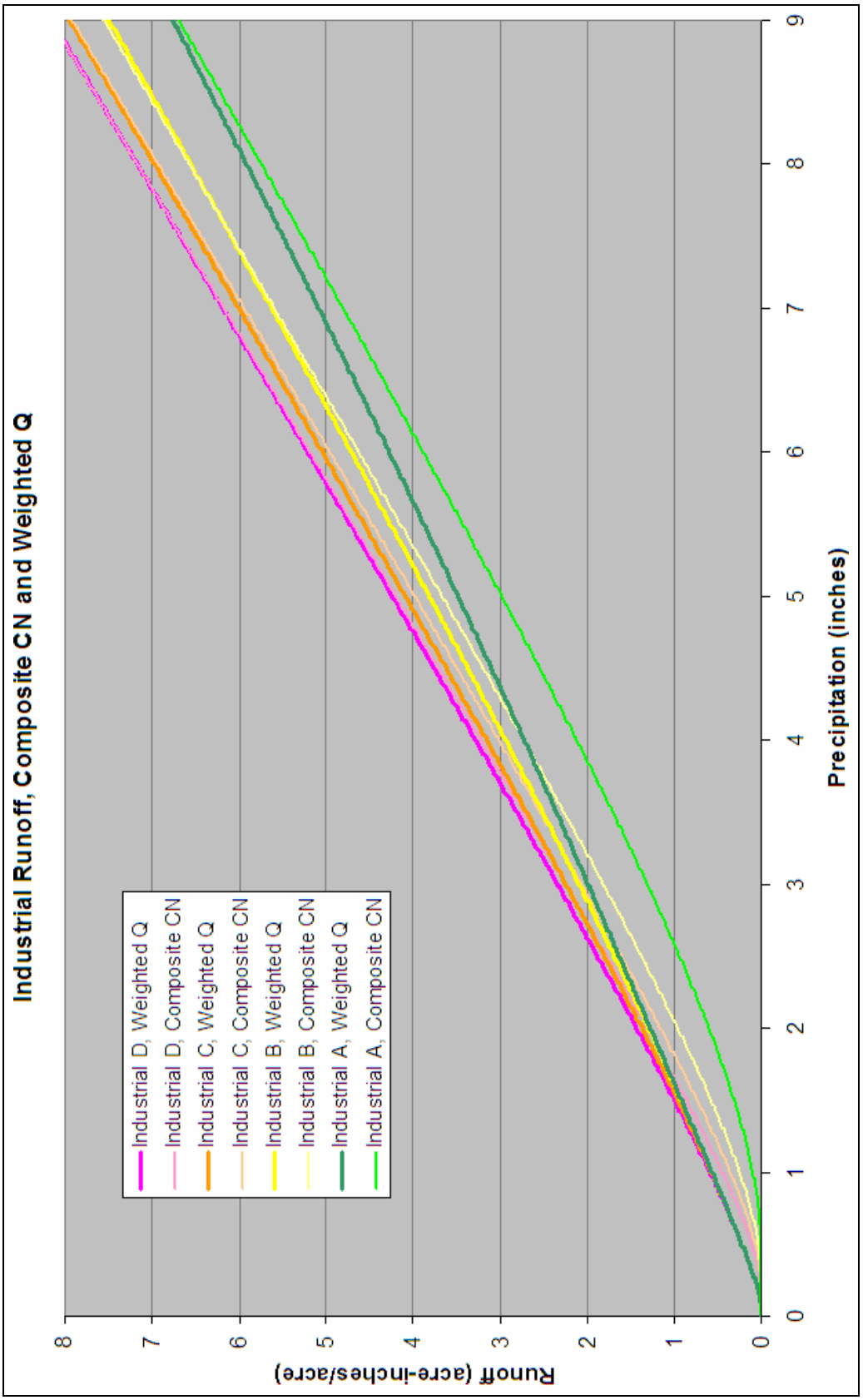

Figure 3: Industrial Runoff Comparison

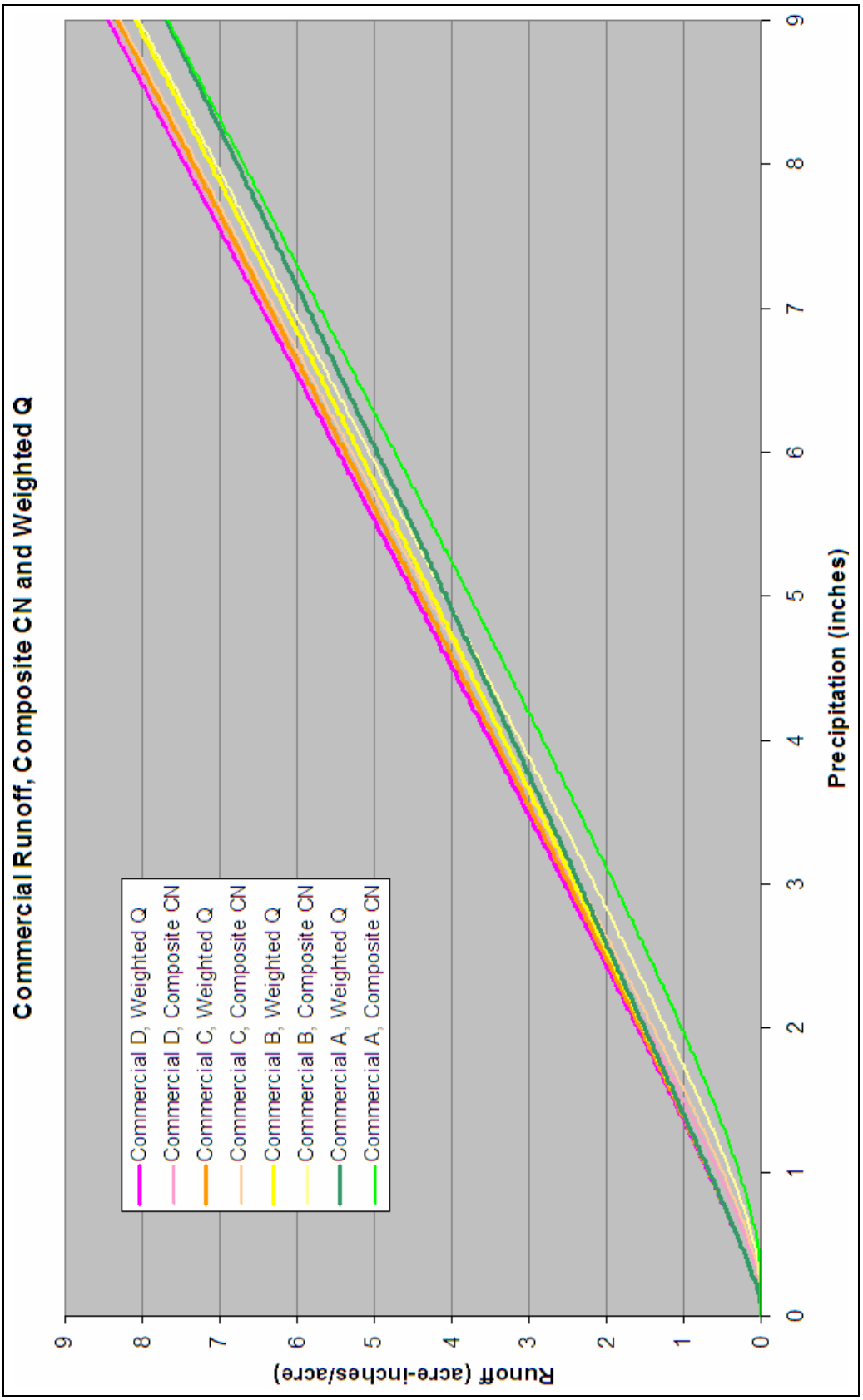

Figure 4: Commercial Runoff Comparison

Table 1: Runoff from an Example Residential Development

Date	Precipitation (inches)	Residential Development, B Soil, 20 Acres					
		20 acre weighted CN = 70		Impervious 5 acres CN = 98		Pervious 15 acres CN = 61	
		Runoff (inches)	Runoff Volume (acre-feet)	Runoff (inches)	Runoff Volume (acre-feet)	Runoff (inches)	Runoff Volume (acre-feet)
1/1/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1/4/2007	0.60	0.00	0.00	0.41	0.26	0.00	0.00
1/5/2007	0.10	0.00	0.00	0.01	0.01	0.00	0.00
1/6/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1/7/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1/8/2007	0.06	0.00	0.00	0.00	0.00	0.00	0.00
1/12/2007	0.25	0.00	0.00	0.11	0.07	0.00	0.00
1/13/2007	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1/14/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
1/16/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
1/17/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1/20/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1/26/2007	0.19	0.00	0.00	0.06	0.04	0.00	0.00
1/27/2007	0.11	0.00	0.00	0.02	0.01	0.00	0.00
2/17/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
2/25/2007	0.08	0.00	0.00	0.01	0.00	0.00	0.00
2/26/2007	0.02	0.00	0.00	0.00	0.00	0.00	0.00
2/27/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
3/1/2007	0.41	0.00	0.00	0.24	0.15	0.00	0.00
3/2/2007	0.06	0.00	0.00	0.00	0.00	0.00	0.00
3/7/2007	0.10	0.00	0.00	0.01	0.01	0.00	0.00
3/9/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
3/10/2007	0.10	0.00	0.00	0.01	0.01	0.00	0.00
3/12/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
3/14/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
3/15/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
3/19/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
3/21/2007	0.31	0.00	0.00	0.15	0.10	0.00	0.00
3/22/2007	0.49	0.00	0.00	0.31	0.20	0.00	0.00
3/25/2007	0.30	0.00	0.00	0.15	0.09	0.00	0.00
3/26/2007	0.16	0.00	0.00	0.04	0.03	0.00	0.00
3/27/2007	0.19	0.00	0.00	0.06	0.04	0.00	0.00
4/1/2007	0.56	0.00	0.00	0.37	0.24	0.00	0.00
4/3/2007	0.09	0.00	0.00	0.01	0.01	0.00	0.00
4/7/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4/10/2007	0.06	0.00	0.00	0.00	0.00	0.00	0.00
4/11/2007	0.58	0.00	0.00	0.39	0.25	0.00	0.00
4/12/2007	0.11	0.00	0.00	0.02	0.01	0.00	0.00
4/25/2007	0.63	0.00	0.00	0.44	0.28	0.00	0.00
4/26/2007	0.42	0.00	0.00	0.25	0.16	0.00	0.00
4/28/2007	0.02	0.00	0.00	0.00	0.00	0.00	0.00
4/30/2007	0.13	0.00	0.00	0.03	0.02	0.00	0.00
5/1/2007	0.42	0.00	0.00	0.25	0.16	0.00	0.00

Date	Precipitation (inches)	Residential Development, B Soil, 20 Acres					
		20 acre weighted CN = 70		Impervious 5 acres CN = 98		Pervious 15 acres CN = 61	
		Runoff (inches)	Runoff Volume (acre-feet)	Runoff (inches)	Runoff Volume (acre-feet)	Runoff (inches)	Runoff Volume (acre-feet)
5/9/2007	0.87	0.00	0.00	0.67	0.42	0.00	0.00
5/10/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
5/15/2007	1.18	0.02	0.04	0.97	0.61	0.00	0.00
5/16/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
5/19/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
5/25/2007	0.13	0.00	0.00	0.03	0.02	0.00	0.00
5/26/2007	0.99	0.00	0.01	0.78	0.49	0.00	0.00
5/27/2007	0.20	0.00	0.00	0.07	0.04	0.00	0.00
6/1/2007	0.25	0.00	0.00	0.11	0.07	0.00	0.00
6/2/2007	0.84	0.00	0.00	0.64	0.40	0.00	0.00
6/3/2007	0.26	0.00	0.00	0.11	0.07	0.00	0.00
6/4/2007	0.30	0.00	0.00	0.15	0.09	0.00	0.00
6/5/2007	0.10	0.00	0.00	0.01	0.01	0.00	0.00
6/19/2007	0.37	0.00	0.00	0.20	0.13	0.00	0.00
6/21/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
6/27/2007	1.38	0.06	0.09	1.16	0.74	0.00	0.00
7/4/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
7/5/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
7/10/2007	0.10	0.00	0.00	0.01	0.01	0.00	0.00
7/14/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
7/17/2007	0.06	0.00	0.00	0.00	0.00	0.00	0.00
7/23/2007	0.14	0.00	0.00	0.03	0.02	0.00	0.00
7/25/2007	0.02	0.00	0.00	0.00	0.00	0.00	0.00
7/26/2007	0.05	0.00	0.00	0.00	0.00	0.00	0.00
7/27/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
8/5/2007	0.18	0.00	0.00	0.06	0.04	0.00	0.00
8/6/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
8/7/2007	0.32	0.00	0.00	0.16	0.10	0.00	0.00
8/9/2007	0.15	0.00	0.00	0.04	0.02	0.00	0.00
8/12/2007	0.06	0.00	0.00	0.00	0.00	0.00	0.00
8/15/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
8/18/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
8/19/2007	0.53	0.00	0.00	0.35	0.22	0.00	0.00
8/20/2007	1.85	0.19	0.31	1.63	1.03	0.05	0.05
8/22/2007	0.31	0.00	0.00	0.15	0.10	0.00	0.00
8/23/2007	0.23	0.00	0.00	0.09	0.06	0.00	0.00
8/24/2007	0.42	0.00	0.00	0.25	0.16	0.00	0.00
8/25/2007	0.04	0.00	0.00	0.00	0.00	0.00	0.00
8/29/2007	1.38	0.06	0.09	1.16	0.74	0.00	0.00
9/7/2007	0.56	0.00	0.00	0.37	0.24	0.00	0.00
9/9/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
9/10/2007	0.42	0.00	0.00	0.25	0.16	0.00	0.00
9/11/2007	0.08	0.00	0.00	0.01	0.00	0.00	0.00
9/14/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00

Date	Precipitation (inches)	Residential Development, B Soil, 20 Acres					
		20 acre weighted CN = 70		Impervious 5 acres CN = 98		Pervious 15 acres CN = 61	
		Runoff (inches)	Runoff Volume (acre-feet)	Runoff (inches)	Runoff Volume (acre-feet)	Runoff (inches)	Runoff Volume (acre-feet)
9/22/2007	0.05	0.00	0.00	0.00	0.00	0.00	0.00
9/25/2007	0.81	0.00	0.00	0.61	0.39	0.00	0.00
9/26/2007	0.11	0.00	0.00	0.02	0.01	0.00	0.00
9/27/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
9/28/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
10/1/2007	1.05	0.01	0.01	0.41	0.17	0.00	0.00
10/2/2007	0.01	0.00	0.00	0.01	0.01	0.00	0.00
10/9/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
10/10/2007	0.11	0.00	0.00	0.00	0.00	0.00	0.00
10/11/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
10/14/2007	0.21	0.00	0.00	0.11	0.04	0.00	0.00
10/16/2007	0.15	0.00	0.00	0.00	0.00	0.00	0.00
10/17/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
10/18/2007	1.06	0.01	0.02	0.00	0.00	0.00	0.00
10/19/2007	0.57	0.00	0.00	0.00	0.00	0.00	0.00
10/20/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
10/22/2007	0.16	0.00	0.00	0.06	0.03	0.00	0.00
10/23/2007	0.34	0.00	0.00	0.02	0.01	0.00	0.00
10/27/2007	0.28	0.00	0.00	0.00	0.00	0.00	0.00
10/31/2007	0.03	0.00	0.00	0.01	0.00	0.00	0.00
11/5/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
11/15/2007	0.02	0.00	0.00	0.00	0.00	0.00	0.00
11/17/2007	0.01	0.00	0.00	0.24	0.10	0.00	0.00
11/20/2007	0.03	0.00	0.00	0.00	0.00	0.00	0.00
11/21/2007	1.03	0.01	0.01	0.01	0.01	0.00	0.00
11/22/2007	0.05	0.00	0.00	0.00	0.00	0.00	0.00
11/23/2007	0.05	0.00	0.00	0.01	0.01	0.00	0.00
11/25/2007	0.01	0.00	0.00	0.00	0.00	0.00	0.00
11/27/2007	0.10	0.00	0.00	0.00	0.00	0.00	0.00
11/28/2007	0.08	0.00	0.00	0.00	0.00	0.00	0.00
12/2/2007	0.59	0.00	0.00	0.00	0.00	0.00	0.00
12/8/2007	0.01	0.00	0.00	0.15	0.06	0.00	0.00
12/10/2007	0.01	0.00	0.00	0.31	0.13	0.00	0.00
12/11/2007	0.38	0.00	0.00	0.15	0.06	0.00	0.00
12/18/2007	0.05	0.00	0.00	0.04	0.02	0.00	0.00
12/23/2007	0.36	0.00	0.00	0.06	0.03	0.00	0.00
12/28/2007	0.13	0.00	0.00	0.37	0.16	0.00	0.00
12/29/2007	0.05	0.00	0.00	0.01	0.00	0.00	0.00
12/31/2007	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Total	28.99	0.35	0.59	17.65	7.35	0.05	0.06

References

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We intend to use the weighted Q method in hydrologic studies for the NPS program that include calculation of runoff from small storms, such as estimations of channel-forming flows, especially if the watershed involves urban areas. Please let me know if you have any comments or questions.

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