DETROIT
Water & Sewerage Department
CITY OF DETROIT

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MEMORANDUM

To: Board of Water Commissioners
From: Debra Pospiech, General Counsel and Chief Administrative Officer
Nikkiya T. Branch, Associate General Counsel

Date: March 28, 2019

Re: DWSD Comment Card re: Solutions for Volume Credit Equation

On March 20, 2019, the BOWC received a comment card from Andre Brooks of ABE Associates, Inc. requesting the solution for the Volume Credit Equation listed on page 4 of *A Guide to Drainage Charge Credits.*

The Board should be aware that late last year, the Stormwater Management Group and DWSD's contractor, TetraTech, spent an inordinate amount of time responding to this question and walking Mr. Brooks through the process on how to solve this equation at great expense to DWSD.

Notwithstanding the above, TetraTech has prepared a detailed response that includes examples on how to solve the equation. It is attached for your review and a copy of the attached will be sent to Mr. Brooks via electronic mail.

What Percent of the Annual Runoff is Retained?

Volume-based drainage charge credits are determined from the average annual volume reductions that result from managing stormwater on-site. The volume credit is calculated as the fraction of average annual runoff volume that is reduced because of implementing stormwater management practices on-site. The equation provided in *A Guide to Drainage Charge Credits* is:

$$Percent\ Volume\ Credit = \frac{Average\ Annual\ Runoff\ Volume\ Retained}{Total\ Average\ Annual\ Runoff\ Volume}$$

But how do you determine the runoff volume and the volume retained on an annual basis?

This document describes two approaches for determining the average annual runoff volume retained. The first approach looks at a long series of individual rain events. The second approach describes how the historical rainfall records were used to fit a regression equation to directly calculate the annual volume retained from a stormwater management practice. Use of the regression equation is the preferred approach for simplicity and consistency reasons. Examples are provided at the end of this document to demonstrate calculating the percent of the annual runoff volume retained.

For the purposes of the drainage charge program we assume that all the rainfall that falls on an impervious surface runs off whereas rainfall on pervious surfaces does not runoff. This means that to convert rainfall to runoff, we can ignore the pervious surfaces and rainfall equals runoff on the impervious surfaces. For example, 1-inch of rainfall on a parking lot will produce 1-inch of runoff.

1.0 INDIVIDUAL RAIN EVENTS APPROACH

Stormwater management practice may be constructed to capture and retain different size rain events. For example, a bioretention could be sized to physically capture and retain the first 0.5 inches of runoff. But the amount of rainfall that occurs at any one time is highly variable. Sometimes it rains just a little, while other times it rains a lot. So, the question is how much of the average annual rainfall is retained. To answer that question, we need to consider all the rain events that occur throughout the year.

Consider the example in Table 1. This example considers ten varying sized rain events (column 2). Column 3 shows how much runoff occurs from the impervious surface. Remember that all the runoff from impervious surfaces is assumed to runoff and none from the pervious surfaces. Columns 4 and 5 assume a stormwater management practice sized to hold the first 0.5 inches of runoff. Column 4 shows how much of the runoff is retained by the stormwater practice whereas column 5 shows how much of the runoff can't be retained and therefore overflows. For example, Event 1 has 0.06 inches of runoff. Since the assumed stormwater practice holds the first 0.5 inches, then all runoff is retained, and none overflows. Contrast that with the 1.73-inch runoff event from Event 6 where the first 0.5-inches of runoff is retained but the remaining 1.23-inches doesn't fit and instead overflows.

Table 1 Example Retention by Stormwater Practice Sized for 0.5-inches

Column 1 Event	Column 2 Rainfall (in)	Column 3 Impervious Runoff (in)	Column 4 Retained Runoff (in)	Column 5 Overflow Runoff (in)
1	0.06	0.06	0.06	0
2	0.26	0.26	0.26	0
3	0.62	0.62	0.50	0.12
4	0.05	0.05	0.05	0

Column 1 Event	Column 2 Rainfall (in)	Column 3 Impervious Runoff (in)	Column 4 Retained Runoff (in)	Column 5 Overflow Runoff (in)
5	0.06	0.06	0.06	0
6	1.73	1.73	0.50	1.23
7	0.18	0.18	0.18	0
8	0.01	0.01	0.01	0
9	0.52	0.52	0.50	0.02
10	0.51	0.51	0.50	0.01
Total	4.00	4.00	2.62	1.38

Based on the data in Table 1 we can calculate what percent of the runoff volume is retained by the stormwater practice sized to capture the first 0.5 inch of runoff. In this case, 65.5% of the runoff was retained due to the presence of the stormwater management practice.

$$Percent\ Retained = \frac{Retained\ Runoff}{Total\ Runoff} = \frac{2.62\ inches}{4.00\ inches} = 65.5\%$$

By taking this same approach and expanding the analysis to include all the rainfall events that occur throughout the year, the percent of annual runoff retained may be calculated which is the same thing as the percent volume credit. Since rainfall amounts varying year to year, at least 10-years of rainfall data is required to come up with average annual values.

Based on historical precipitation records at the Detroit Metropolitan Wayne County Airport, on average there are 127 rainfall events per year. This rainfall information is based on 53.5 years of hourly precipitation data and assumes a minimum of six hours of dry time between rain events. Based on an average of 127 events per year and using at least 10 years of rainfall data, that means the analysis needs to consider approximately 1,270 rainfall events. A spreadsheet approach is well suited for this type of analysis since so many records are required. Figure 1 illustrates a spreadsheet approach to using the individual rain events for 53.5 years of historical records. The approach is the same as described in Table 1 except more rainfall data is used.

Average Annual Rainfall

53.5	Historical Precipitation Record Duration (years)
31.90	Average Annual Rainfall (inches)

Drainage Charge Program Urban Hydrology

1.0	Impervious Surface Runoff Coefficient
0.0	Pervious Surface Runoff Coefficient

GSI Practice

0.50	GSI Retention Volume (in)
22.89	Average Annual Runoff Volume Retained (in)
31.90	Total Average Annual Runoff Volume (in)
71.8%	Percent Volume Credit

Event No.	Start	Rainfall (in)	Impervious Runoff (in)	Retained Runoff (in)	Overflow Runoff (in)
1	10/4/59 17:00	0.06	0.06	0.06	0.00
2	10/5/59 1:00	0.21	0.21	0.21	0.00
3	10/5/59 12:00	0.13	0.13	0.13	0.00
4	10/6/59 2:00	2.11	2.11	0.50	1.61
5	10/7/59 18:00	0.01	0.01	0.01	0.00
6	10/9/59 1:00	0.16	0.16	0.16	0.00

Figure 1 Spreadsheet Approach Using Individual Rain Events

2.0 ANNUAL RUNOFF RETENTION EQUATION

Consider expanding Table 1 to include a range of different retention depths; i.e. 0.25-, 0.50-, 0.75- and 1.0-inches. Table 2 is presented to illustrate the calculation approach but is only based on the ten hypothetical rainfall events. The total runoff retained from a series of rainfall events is calculated and expressed as a percentage. In this example retaining the first 0.25-inches from each rain event results in retaining 40.3% of the rainfall. Similarly retaining the first 0.50-, 0.75- and 1.0-inches results in 65.5%, 75.5% and 81.8% overall retainage.

Table 2 Example Percent Retained Based on Ten Rainfall Events

Event	Rainfall (in)	Impervious Runoff (in)	Retain first 0.25-in		Retain first 0.50-in		Retain first 0.75-in		Retain first 1.00-in	
			Retained Runoff (in)	Overflow Runoff (in)	Retained Runoff (in)	Overflow Runoff (in)	Retained Runoff (in)	Overflow Runoff (in)	Retained Runoff (in)	Overflow Runoff (in)
1	0.06	0.06	0.06	0	0.06	0	0.06	0	0.06	0
2	0.26	0.26	0.25	0.01	0.26	0	0.26	0	0.26	0
3	0.62	0.62	0.25	0.37	0.5	0.12	0.62	0	0.62	0
4	0.05	0.05	0.05	0	0.05	0	0.05	0	0.05	0
5	0.06	0.06	0.06	0	0.06	0	0.06	0	0.06	0
6	1.73	1.73	0.25	1.48	0.5	1.23	0.75	0.98	1	0.73
7	0.18	0.18	0.18	0	0.18	0	0.18	0	0.18	0
8	0.01	0.01	0.01	0	0.01	0	0.01	0	0.01	0
9	0.52	0.52	0.25	0.27	0.5	0.02	0.52	0	0.52	0
10	0.51	0.51	0.25	0.26	0.5	0.01	0.51	0	0.51	0
Total	4.00	4.00	1.61	2.39	2.62	1.38	3.02	0.98	3.27	0.73
Percent Retained			40.3%		65.5%		75.5%		81.8%	

This same process was extended to the full 53.5 years of historical rainfall records in increments of 0.05 inches of retention. The result is shown in Figure 2 as the historical rainfall data symbolized as dots on the graph. A regression equation was fit to the data and is also shown in Figure 2. The derived regression equation is:

$$Average\ Annual\ Percent\ Retained = 1 - 2.5^{-2.5 * Runoff\ Retained}$$

Since the drainage charge program assumes 100% runoff from impervious surfaces and no runoff from the pervious surfaces, the runoff retained is equivalent to the rainfall retained from the impervious surfaces. Also, the volume credit is the average annual percent retained. The equation may be expressed as:

$$Volume\ Credit\ (\%) = 1 - 2.5^{-2.5 * Rainfall\ Retained}$$

This is equation 3 in *A Guide for Credits for Commonly Used Stormwater Management Practices*. The regression equation approach is preferred for simplicity and consistency purposes. The regression equation accomplishes the same thing as analyzing individual rain events over an extended period of records. Table 3 presents tabular retention amounts based on the derived regression equation.

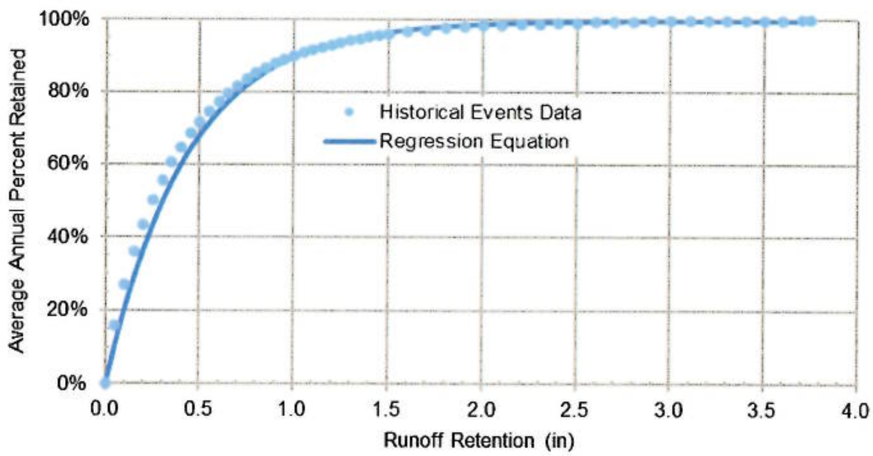

Figure 2 Runoff Retention

Table 3 Runoff Volume Retained based on Historical Rainfall Records

Rainfall Retention per Event (in)	Runoff Retention per Event (in)	Annual Retained Runoff (in)	Annual Overflow Runoff (in)	Percent of Annual Runoff Volume Retained
0.00	0.00	0.00	31.90	0.0%
0.10	0.10	6.53	25.37	20.5%
0.20	0.20	11.73	20.18	36.8%
0.30	0.30	15.86	16.05	49.7%
0.40	0.40	19.14	12.76	60.0%
0.50	0.50	21.76	10.15	68.2%
0.60	0.60	23.83	8.07	74.7%
0.70	0.70	25.49	6.42	79.9%
0.80	0.80	26.80	5.10	84.0%
0.90	0.90	27.85	4.06	87.3%
1.00	1.00	28.68	3.23	89.9%
1.10	1.10	29.34	2.57	92.0%
1.20	1.20	29.86	2.04	93.6%
1.30	1.30	30.28	1.62	94.9%
1.40	1.40	30.61	1.29	96.0%
1.50	1.50	30.88	1.03	96.8%
1.60	1.60	31.09	0.82	97.4%
1.70	1.70	31.26	0.65	98.0%
1.80	1.80	31.39	0.52	98.4%
1.90	1.90	31.49	0.41	98.7%
2.00	2.00	31.58	0.33	99.0%
2.50	2.50	31.80	0.10	99.7%
3.00	3.00	31.87	0.03	99.9%
3.50	3.50	31.89	0.01	100.0%

3.0 EXAMPLES

Two examples are provided to illustrate the percent annual runoff retained calculation and use. Both examples assume the construction of a bioretention practice. The bioretention is assumed to have 3 inches of surface ponding depth overtop of 24 inches of bioretention soil, no underdrain and an infiltration rate in the native soil of 0.20 inches per hour. Also assumed is that the tributary impervious surface drainage area is 10,000 square feet.

Example 1. In this scenario we are assuming that the bioretention is designed first and then the rainfall retention is calculated. The footprint of the bioretention is selected as 1,000 square feet. The equivalent water depth in the bioretention is calculated to be 7.8 inches based on the cross section. Since the bioretention is assumed to have no underdrains, all the water is retained and infiltrated into the soil. The total retention volume provided by the bioretention is calculated to be 650 cubic feet. The retention volume divided by the tributary drainage area yields the equivalent rainfall depth. This is the depth of rainfall that will be retained by the bioretention. We can now apply the regression equation and calculate the average annual volume retained to be 83%.

Tributary Drainage Area	
10,000	Impervious drainage area (sf) *{given}*
GSI Practice – Bioretention (no underdrains)	
1,000	Surface area (sf) *{given}*
3	Surface ponding depth (in) *{given}*
24	Bioretention soil depth (in) *{given}*
7.8	Equivalent water depth (in) assuming 20% effective void ratio in the soil *{3+24*0.20}*
650	Retention volume (cf) *{surface area * equivalent water depth}*
Rainfall Retention	
0.78	Equivalent rainfall depth (in) from tributary drainage area *{retention volume / drainage area}*
83%	Percent of annual runoff retained (i.e. volume credit) *{based on the regression equation}*

Example 2. The second approach starts by selecting the drainage charge credit that is desired and then calculating how big the bioretention needs to be. In this case, let's assume a 90% volume credit is desired. Based on the regression equation to obtain a 90% volume credit the first 1.01 inches of rainfall must be retained. The retention volume required is the rainfall depth times the drainage area or 838 cubic feet. If the bioretention can store an equivalent 7.8 inches of water depth, then the required surface area is 1,289 cubic feet.

Credit Desired	
90%	Target credit desired (which is the same as the percent annual runoff retained) *{given}*
1.01	Equivalent rainfall depth retained (in) *{based on the regression equation}*
Tributary Drainage Area	
10,000	Impervious drainage area (sf) *{given}*
GSI Practice – Bioretention (no underdrains)	
838	Retention volume (cf) required *{equivalent rainfall depth retained * drainage area}*
3	Surface ponding depth (in) *{given}*
24	Bioretention soil depth (in) *{given}*
7.8	Equivalent water depth (in) assuming 20% effective void ratio in the soil *{3+24*0.20}*
1,289	Required bioretention surface area (sf) *{retention volume / equivalent water depth}*

March 20, 2019

Board of Water Commissioners
735 Randolph
Detroit, MI 48226

RE: Solution for Volume Credit Equation

Dear Board of Commissioners,

What is the solution for the Volume Credit Equation listed below? This equation is listed on page 4 under the Drainage Charge Credits tab of the manual. What is the Design Storm Value of the denominator in this equation, is it a 1 Year Storm or 2 Year Storm? The Design Storm was not identified for this equation and the Department has not responded to this question. There is not a solution for this equation in the Credit Manual nor is there a sample problem that informs you of what the Design Storm is for this equation. Knowing the solution to this equation will enable me and others to save our clients/property owners money on the drainage charge design and credits. I have provided a copy of the Peal Flow Volume Credit as a reference.

% Volume Credit = Average Annual Runoff Volume Retained / Total Average Annual Runoff Volume

What is the design storm for this equation?

4 A Guide to Drainage Charge Credits

Equation 8. Detention Peak Flow Credit

Peak Flow Credit = V / V * 100

Volume required for 100 year, 24 hour (Design Storm)

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Additional comments or questions? Email dwsd-publicaffairs@detroitmi.gov or call 313.965.9781.

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