STORMWATER PROGRAM

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Comparison of RUSLE and RUSLE2 to Determine Water Quality Treatment of Vegetated Strips

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Disclaimer:

BIOGRAPHICAL SKETCH

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ABSTRACT

Vegetated strips or biofilter strips provide many benefits to water quality treatment of storm water, including increased infiltration, decreased sedimentation, and decreased erosion. Biofilter strips can be applied on various slopes from 5 to 52% and still provide treatment. Vegetation coverage, however, appears to be the crucial treatment factor.

Typically, the Revised Universal Soil Loss Equation (RUSLE) is used to estimate optimum factors in slope design, including vegetation coverage. RUSLE2 has been introduced as an improved computer-based model which can be applied to disturbed sites in the urban environment. RUSLE2 can be customized for site features using updated soils, climate, cover, and practices information. Factors for urban settings have been determined to allow this model to be applied to construction sites or other disturbed environments, whereas RUSLE is more applicable to rural sites by design.

A two-year monitoring study was performed on biofilter strips adjacent to the highway by the California Department of Transportation (Caltrans). Eight sites with vegetated strips in increasing widths from 1.1 to 13 m from the right-of-way were established. Two to five, 30 m long concrete collection trenches were installed to collect sheet flow passing through the biofilter. Storm water was sampled using automated sampling equipment. Water quality was assessed to determine the optimum width in which treatment occurred over two storm seasons.

Statistical analysis of the water quality data indicated that most of the treatment occurred within approximately 3 m of the right-of-way. Additional biofilter widths greater than 3 m did not provide significantly more treatment. However, treatment effectiveness was affected by percent vegetation cover. It appeared that at least 65% cover was needed to achieve significant pollutant removal. Erosion rates were not originally estimated in the study. Optimum vegetation coverage also needs to be determined.

A comparison of biostrip widths may help assess the optimum treatment design for biostrips. Using RUSLE and RUSLE2 to determine strip width and vegetation coverage can be an effective design tool. It is important to determine whether RUSLE or RUSLE2 provide consistent erosion rates for a particular site. It can then be determined which method is more applicable. This paper provides a case study for using both methods of soil loss prediction to help address the optimum design parameters for water quality treatment of biofilter strips.

Key Words: biofiltration strips; water quality; BMPs; vegetated strips; storm water

INTRODUCTION

Vegetated strips or biofilter strips provide many benefits to the water quality treatment of storm water, including increased infiltration, decreased sedimentation, and decreased erosion. Biofilter strips are widths of vegetation which receive sheet flow of storm water runoff. The vegetation in the strip acts as both a filter and velocity dissipater to allow large sediment particles and pollutants associated with particles to settle and to be removed from the runoff. A large portion of runoff will also be infiltrated into the soil, varying with the antecedent dry period and texture of the soils present. Widespread use of biostrips can be attributed to the broad applications, low cost and low maintenance. Often biostrips are found on slopes and in medians in the highway environment.

There is no definitive determination of appropriate design parameters for the water quality treatment of biofilters. According to research performed by the California Department of Transportation (Caltrans), slopes from 5 to 52% provide significant treatment when compared to highway right-of-way runoff (Caltrans, 2003). Vegetation coverage, however, appears to be the crucial treatment factor in this study.

Typically, the Revised Universal Soil Loss Equation (RUSLE) is used to estimate optimum factors in slope design, including vegetation coverage. RUSLE is designed to estimate rill-interrill erosion. The primary goal of RUSLE is to assist planners, regulators, and others in selecting erosion and sediment control alternatives for a given site. This can be a very important step in the design of a site to assist in minimizing off-site erosion and sedimentation. Once alternative measures are identified, they can be ranked so that the lowest estimated erosion alternative is selected (Foster and Toy, 2003).

RUSLE2 has been introduced as an improved computer-based model which can be applied to disturbed sites in the urban environment. RUSLE2 is maintained and updated by the United States Department of Agriculture-Agricultural Research Service. RUSLE2 can be customized for site features using updated soils, climate, cover, and practices information. Factors for urban settings have been determined to allow this model to be adequately applied to construction sites or other disturbed environments, whereas RUSLE is more applicable to rural sites by design (Foster and Toy, 2003). The computer program allows the user to select from a list of locations, which will incorporate climatic data from that area. Additional information is stored about local soils and vegetation cover systems. RUSLE2 is believed to be more efficient at estimating soil loss from disturbed urban sites than RUSLE.

STUDY DESIGN

A two-year monitoring study was performed on biofilter strips adjacent to the highway. Four sites each were located in northern and southern California to account for climatic, and soil variability (Figure 1). The eight sites had vegetated strips in increasing widths from 1.1 to 13 m from the right-of-way (ROW). Two to five, 30 m long concrete collection trenches were installed to collect sheet flow passing through the biofilters. At a minimum, each site contained a collection trench at ROW and at the furthest point where samples could be collected (Figure 2). If additional space was available, more collection trenches were installed to account for differences in strip width (Caltrans, 2003).

Various soil analyses were performed at each location. Soil texture was determined using laboratory data and the Unified Soil Classification System. Soils were classified as clayey sand, silty sand, and sand, some with large amounts of gravel. Sandy soils found roadside allow storm water infiltration.

Vegetation was not manipulated as part of the study. Collection trenches were installed within the existing vegetation. Care was taken as much as possible not to disturb the vegetation. There was no irrigation used to establish cover. However, the department was instructed to perform regular maintenance on the ROW to determine storm water treatment under normal site conditions. No weeding, fertilizers or herbicides were used as part of the study,unless they were part of the routine maintenance of that particular area. To the maximum extent possible, maintenance records were kept to track activities.

Storm water was sampled using automated sampling equipment. Flow-weighted composite samplers were employed to sample at least eight storms per season when possible. Samplers were prepared prior to predicted storm events. Water quality was assessed to determine the optimum width in which treatment occurred over two storm seasons. Samples were analyzed for water quality parameters such as metals, organics and sediments following the department's storm water monitoring protocols (Caltrans, 2000).

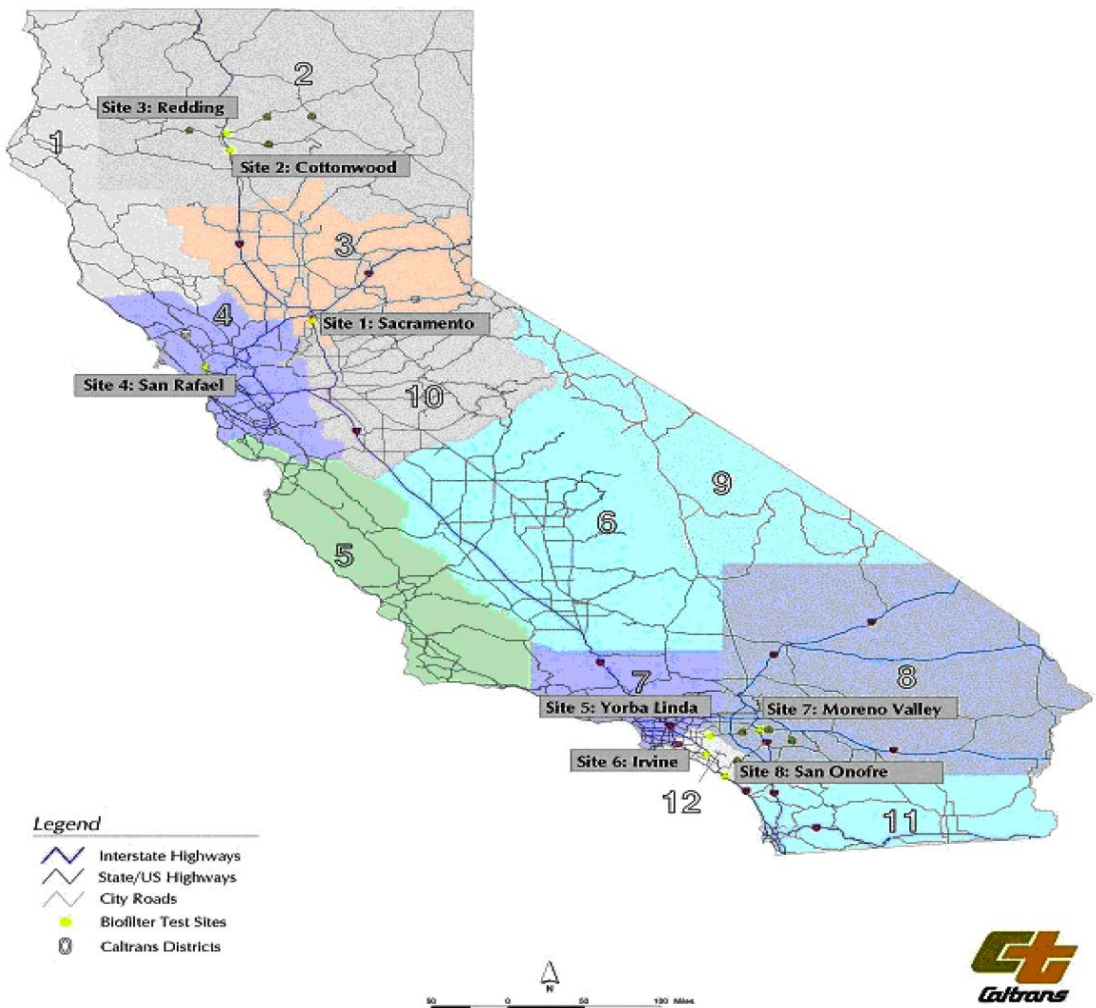

Figure 1 Site locations for biofilter strips.

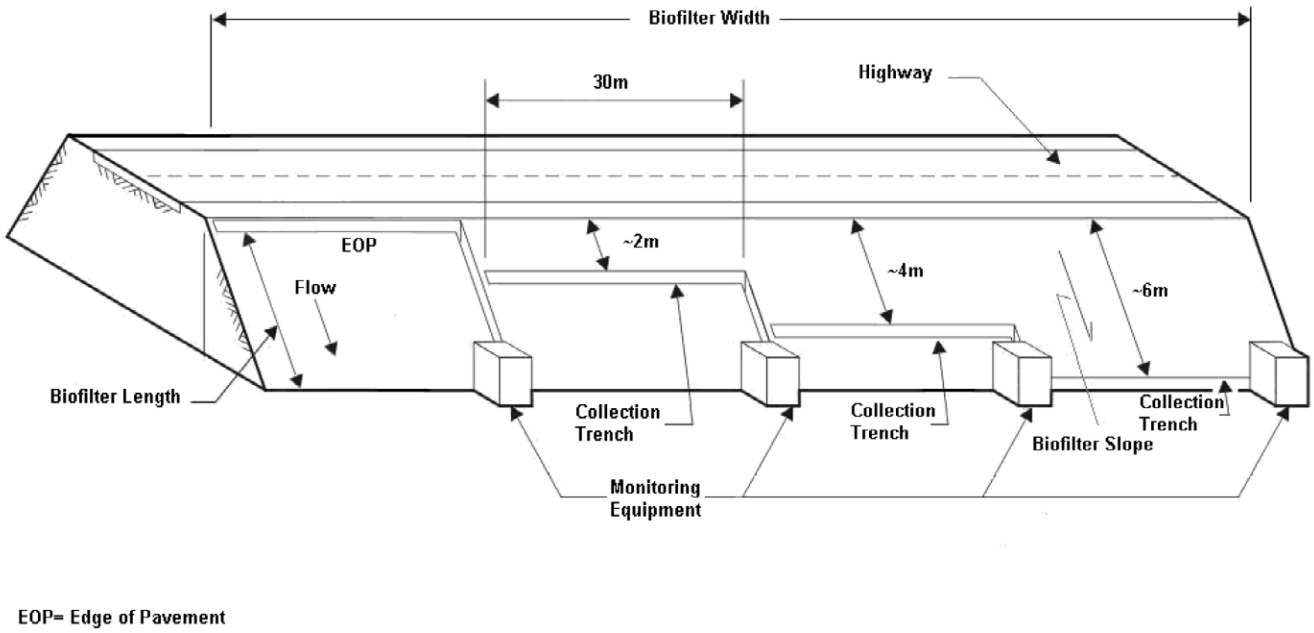

Figure 2 Typical schematic of biofilter strip

Statistical analysis of the water quality data indicated that most of the treatment occurred within approximately 3 to 4 m of the right-of-way. Additional biofilter widths greater than 3 m did not provide significantly more treatment. For example, the average total suspended solids (TSS) concentration was reduced to 25 mg/L, total zinc was reduced to 25 ug/L, and dissolved zinc was reduced to 12 ug/L. Other metals concentrations were reduced to less than 10 ug/L (Scharff et al., 2004). Concentration reductions varied by site and storm. However, treatment effectiveness was affected by percent vegetation cover. It appeared that at least 65% cover was needed to achieve significant pollutant removal. Erosion rates were not measured in the study.

RUSLE AND RUSLE2

Although erosion rates were not measured as part of the original study, they can be estimated. Data on vegetative cover, soils, climate, and slope were collected as part of the original study (Table 1). RUSLE factors were then estimated from the original data set. The R factor was determined using site location information and isoerodent maps. The K factor was estimated using the soil erodibility nomograph. The LS factor was determined using published LS tables with actual slope length and percent slope measurements. The C factor was estimated using the percent cover measured at the site. The P factor was set to emulate a slope that was scraped with a bulldozer up and down the hill, as it would have been upon construction completion. RUSLE was computed using the RUSLE hand computation method for ease of use (IECA, 2002).

Table 1. Biostrip Soils and Vegetation Data.

Site	Gravel (%)	Sand (%)	Silt/Clay (%)	Average Strip Length (m)	Average Strip Length (ft)	Slope (%)	Average Vegetative Cover (%)
Sacramento 1.1 m	51.8	36.9	11.3	1.1	3.6	2	93
Sacramento 4.6 m	31.9	36.5	31.6	4.6	15.1	33	84
Sacramento 6.6 m	32.5	36.5	31	6.6	21.7	33	92
Sacramento 8.4 m	39.2	35.8	25	8.4	27.6	33	90
Cottonwood 9.3 m	44	41.6	14.4	9.3	30.6	52	73
Redding 2.2 m	39.6	48.8	11.6	2.2	7.2	10	80
Redding 4.2 m	47.2	42.5	10.3	4.2	13.8	10	85
Redding 6.2 m	34.7	52.8	12.5	6.2	20.4	10	87
San Rafael 8.3 m	40.6	38.6	20.8	8.3	27.3	50	84
Irvine 3.3 m	24.9	59.9	15.2	3.3	10.9	11	70
Irvine 6 m	16.7	59.5	23.8	6	19.7	11	63
Irvine 13 m	20.1	46.5	33.4	13	42.8	11	62
Yorba Linda 1.9 m	28.1	53.4	18.5	1.9	6.3	14	61
Yorba Linda 4.9 m	25.3	53.5	21.2	4.9	16.1	14	82
Yorba Linda 7.6 m	17.2	60.6	22.2	7.6	25.0	14	74
Yorba Linda 13 m	34.2	49.6	16.2	13	42.8	14	76
Moreno Valley 2.6 m	20.3	61.5	18.2	2.6	8.6	13	3
Moreno Valley 4.9 m	29.7	53	17.3	4.9	16.1	13	16
Moreno Valley 8 m	16.5	59.1	24.4	8	26.3	13	22
Moreno Valley 9.9 m	13.7	70.2	16.1	9.9	32.6	13	18
San Onofre 1.3 m	19	63.8	17.2	1.3	4.3	8	81
San Onofre 5.3 m	27.1	56.8	16.1	5.3	17.4	10	74
San Onofre 9.9 m	21.7	55.7	22.6	9.9	32.6	16	69

Table 2. RUSLE and RUSLE2 Values for Biostrips.

Site	RUSLE R	RUSLE K	RUSLE LS	RUSLE C	RUSLE P	RUSLE t/a/yr	RUSLE2 t/a/yr
Sacramento 1.1 m	40	0.17	0.13	0.07	1.3	0.080	0.073
Sacramento 4.6 m	40	0.17	1.24	0.16	1.3	1.75	0.003
Sacramento 6.6 m	40	0.17	1.7	0.08	1.3	1.20	0.003
Sacramento 8.4 m	40	0.17	1.9	0.1	1.3	1.68	0.003
Cottonwood 9.3 m	60	0.17	2.0	0.27	1.3	7.16	0.004
Redding 2.2 m	80	0.17	0.37	0.2	1.3	1.31	0.010
Redding 4.2 m	80	0.17	0.4	0.15	1.3	1.06	0.001
Redding 6.2 m	80	0.17	0.5	0.13	1.3	1.15	0.001
San Rafael 8.3 m	60	0.17	3.0	0.16	1.3	6.36	0.016
Irvine 3.3 m	40	0.17	0.43	0.3	1.3	1.14	0.0003
Irvine 6 m	40	0.17	0.6	0.37	1.3	1.96	0.0004
Irvine 13 m	40	0.17	0.8	0.38	1.3	2.68	0.0004
Yorba Linda 1.9 m	30	0.17	0.45	0.39	1.3	1.16	0.0004
Yorba Linda 4.9 m	30	0.17	0.59	0.18	1.3	0.70	0.0005
Yorba Linda 7.6 m	30	0.17	0.85	0.26	1.3	1.47	0.0005
Yorba Linda 13 m	30	0.17	1.2	0.24	1.3	1.91	0.0005
Moreno Valley 2.6 m	10	0.17	0.44	0.7	1.3	0.68	3.4
Moreno Valley 4.9 m	10	0.17	0.48	0.84	1.3	0.89	4.0
Moreno Valley 8 m	10	0.17	0.6	0.78	1.3	1.03	5.0
Moreno Valley 9.9 m	10	0.17	0.9	0.82	1.3	1.63	5.6
San Onofre 1.3 m	10	0.17	0.32	0.19	1.3	0.13	0.0003
San Onofre 5.3 m	10	0.17	0.42	0.26	1.3	0.24	0.0003
San Onofre 9.9 m	10	0.17	1.0	0.31	1.3	0.69	0.0005

The following equation was used:

$A = R*K*L*S*C*P$

where:

A = Estimated soil loss in tons per acre per year

R = Rainfall-erosivity factor

K = Soil erodibility factor

L = Slope length factor

S = Slope steepness factor

C = Cover management factor

P = Erosion control practice factor

For comparison, RUSLE2 was used to compute estimated annual soil loss. The most recent version of the computer program, originally created in 1999, was used (Foster and Toy, 2003). Data were selected both from the computer prompted database as well as from the highway study. Both sets of data are presented in Table 2. The data input for RUSLE R and K factors were determined by selecting a location close to the project site from the RUSLE2 database. The LS factor was determined by input of measured slope length and slope. The C factor was determined by selecting the most appropriate vegetation type from the RUSLE2 database. The P factor was determined by selecting contouring up and down a slope, as the site would have been upon completion of construction, similar to the P values for the RUSLE hand computation method.

Although the values of RUSLE and RUSLE2 appear quite different, they are relatively consistent in trend. Since both methods produce an estimated annual average of soil loss and not an absolute value, trends are more important to interpret. Figure 3 represents trends in the data. Moreno Valley, for example shows the same trend for each biostrip. In the planning process, either method would lead the user to choose the 2.6 m strip conditions, since there is the least amount of erosion for that site. It does not matter that one method estimates 0.68 t/A/yr and the other 3.4 t/A/yr. Similar trends exist for each site.

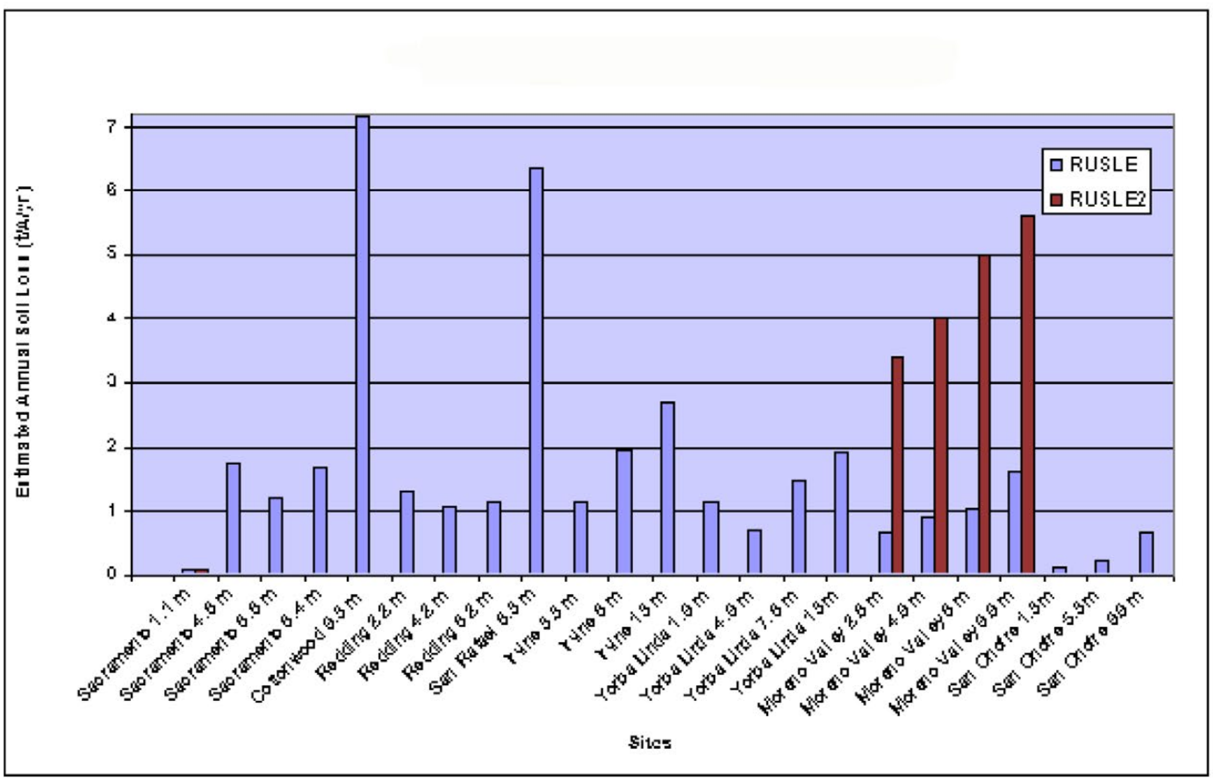

Figure 3. RUSLE and RUSLE2 comparisons.

Differences in the RUSLE A, or estimated soil loss, can be attributed to the values chosen for the RUSLE factors. The hand computation method uses published tables and charts to allow the user to determine the most appropriate values for the factors. The RUSLE2 program is designed to ease use by allowing the user to select from database values in the program. However, these values may not be as accurate. For example, the Irvine site at 13 m has a K factor of 0.55 in the RUSLE2 database, but 0.17 by the hand computation method. This site also has a C factor of 0.00002 in the database, and 0.38 by the hand computation method. It is up to the user to determine the most appropriate RUSLE factor values for the site. It is difficult to determine which method provides a more accurate model without comparison to actual soil loss measurements.

It appears that either RUSLE or RUSLE2 will provide the user with viable alternatives to select practices that minimize site erosion. Both methods are flexible to allow the user to adjust for site information regarding climate, soils, vegetation, and practices. However, RUSLE2 does require familiarity with the computer program, and updates to the database. It also requires the user to assume some geographic uniformity to select a location close to the site, if the site city is not represented in the database. Similar assumptions must be made with regard to vegetation and soils information.

Analyzing the water quality data from the biofilter study reveals that the least amount of potential erosion, and export of particles, occurs within 3 to 4 m of the ROW. Strips larger than 4 m did not appear to reduce erosion significantly more. This is an important finding in the transportation environment where space is often limited. Even in a site only 4 m wide, water quality treatment and erosion loss is minimized. This could be potentially due to the development of concentrated flow with longer slope lengths, or to changes in vegetation coverage. Although it appeared that sites with 65% percent vegetation coverage or more had the most reduction in water quality pollutants (Caltrans, 2003).

CONCLUSION

The use of biofilter strips as water quality treatment best management practices (BMPs) is an important part of storm water management. Even in smaller spaces where larger storm water BMPs may be eliminated, biofilters provide for erosion control and storm water treatment, with minimal cost and maintenance.

According to current research, the most critical part of achieving success is to maximize vegetation coverage. This could be done by putting considerable time into the design of these green BMPs. Both RUSLE and RUSLE2 can be used as tools to help the designer estimate the best alternatives with respect to slope length, slope steepness, climate, vegetation coverage, and erosion control practices. Since RUSLE and RUSLE2 are both designed as relative estimators, either can be used with success. The user should choose the best method to fit the project site. In either case, using estimated soil loss calculators to select conditions for biofilters will help ensure adequate erosion and sediment control and reduce storm water pollution.

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