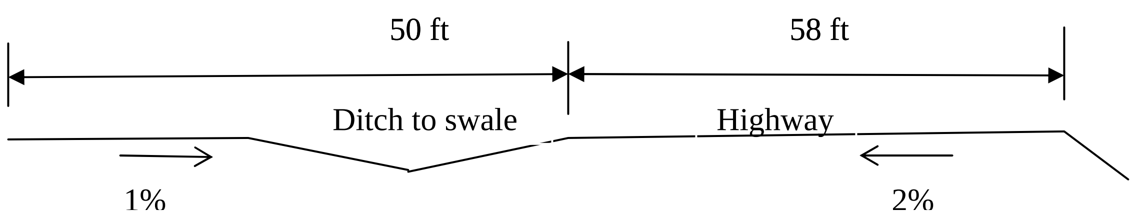
In this example you will learn:

- The design criteria for two different biofiltration swales methods.
- How to design a biofiltration swale by hand and using StormShed.
- How to review output from the History View of StormSHED to verify the design criteria is met.
- How to use the StormSHED calculator to estimate a swale size.

Biofiltration Swale Sample Problem Description

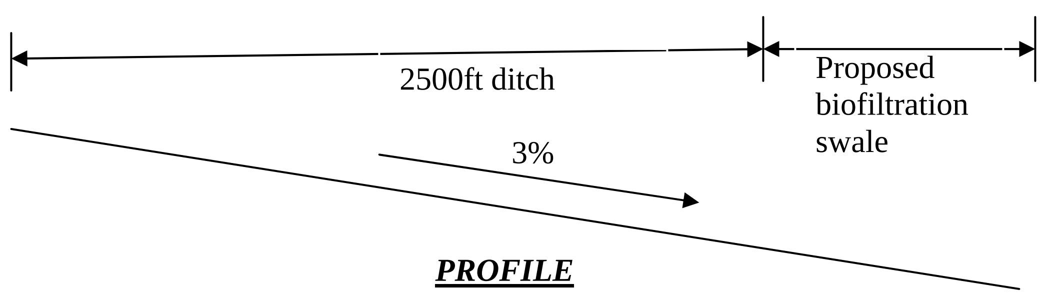
A new highway near the city of Spokane is being constructed. Based on the parameters given below, use the ditch to convey runoff to a biofiltration swale. **Determine the size of the downstream trapezoidal biofiltraion swale** that will provide runoff treatment of the runoff before discharging to a downstream pond for flow control.

- This project will add 58'x 2500' **(3.33 acres)** of roadway.
- The entire roadway is superelevated at a **2% cross slope** toward the outside shoulder with a continuous **3% profile**.
- There are **2.87 acres** of pervious area within WSDOT Right of Way side slopes contributing runoff to the swale **including the swale**.
- The SCS soil type is **Type C** and the ground cover is **primarily forest in fair conditions with a CN of 76**. The average slope of the ground is **1%**.
- For the **time of concentration** on the pervious surfaces, assume the **forested conditions** will be **50 feet** of sheet flow and **2500 feet** of shallow concentrated flow.
- Assume runoff is conveyed to the biofiltration swale via the ditch as shown below.



CROSS SECTION

Figure 1



PROFILE

Figure 2

Introduction to Biofiltration Swales

A Biofiltration Swale is a sloped, vegetation-lined channel designed to remove suspended solids from stormwater. This BMP satisfies the requirements for basic runoff treatment and/or can be used for presettling/pretreatment before an infiltration BMP. Infiltration and flow control are not considered functions of this BMP. The HRM details the design criteria for 3 types of biofiltration swales as described below.

Basic biofiltration swales – The total runoff is directed to the head of the biofiltration swale.

Wet biofiltration swale – A wet biofiltration swale is a variation of a basic biofiltration swale except, the longitudinal slope is slight and due to high ground water elevations the swale usually saturated.

Continuous inflow swale – The runoff enters the swale continuously along the side slopes rather than directly at the head of the swale.

Biofiltration Swale

While there are several procedures for designing biofiltration swales in the HRM, this tutorial will only focus on two and both apply to basic biofiltration swales:

1. The first procedure determines the length based on runoff having a residence time of 9 minutes in the swale and is only recommended for relatively small swales. For this option, we will design the BMP using hand calculations and only use StormSHED to determine the design flow rates Q_{biofil} and Q_{convey}.
2. The second procedure is the same procedure that was in the 1997 HRM method. In this method, there is no residence time requirement; however the length of the swale is set at 200'. To size this swale, only StormShed 3G will be used (no hand calculations).

Sizing Criteria

Biofiltration Swales shall be designed following the guidelines outlined in Section RT.04 of the HRM, Table RT.04.2. Again this tutorial will focus on the Basic Biofiltration Swales, shown in the 2^{nd} column of the table below. In addition to the criteria below, biofiltration swales are sized using the flow rate (Q) from the **6 month short duration**

storm (3 hour storm). The **25 year short duration storm** is then used to verify the freeboard requirements are met.

Table RT.04.2. Biofiltration swale sizing criteria.

Design Parameter	Basic Biofiltration Swale	Wet Biofiltration Swale	Continuous Inflow Biofiltration Swale
Longitudinal slope	0.015–0.050[1] feet per foot	0.015 feet per foot or less	Same as basic swale
Maximum velocity	1 foot per second at Q_{biofil}	Same as basic swale	Same as basic swale
Maximum water depth at Q_{biofil}, y	2 inches if swale mowed frequently; 4 inches if mowed infrequently or inconsistently. For dryland grasses in eastern Washington, set depth to 3 inches.	4 inches	Same as basic swale
Manning coefficient at Q_{biofil}	See Table RT.04.1	Same as basic swale	Same as basic swale
Bed width	2–10 feet[2]	2–25 feet	Same as basic swale
Freeboard height	1 foot for the peak conveyance flow rate (Q_{convey})[3]	Same as basic swale	Same as basic swale
Minimum length	100 feet	Same as basic swale	Same as basic swale
Maximum side slope (for trapezoidal cross section)[4]	3H:1V	Same as basic swale	Same as basic swale

[1] For basic biofiltration swale on slopes less than 1.5%, install an underdrain system (see Figure RT.04.3). Underdrain backfill should be covered by at least 4 inches of amended soil or topsoil. Install the low-flow drain 6 inches deep in the soil (see Figure RT.04.4). For slopes greater than 5%, install energy dissipaters.

[2] Multiple parallel swales can be constructed when the calculated swale bottom width exceeds 10 feet.

[3] Q_{convey} should be based on the design flow rate of the conveyance system downstream of the biofiltration swale. In general, this is the peak $Q_{25\text{-}year}$.

[4] From swale bed to top of water surface at Q_{biofil}.

Biofiltration Calculations Option 1

This tutorial will follow the steps outlined in the HRM section RT.04 to size the swale.

Preliminary Steps (P) - After completing steps 1-4, we will use StormShed to define the basins for the bioswale and calculate the Q.

1. Determine the runoff treatement design flow rate (Q_{biofil}), that is all the runoff that is contributing to the biofiltration swale using the 6 month 3 hour storm.
2. Determine the conveyance flow rate (Q_{convey}), that is all the runoff that is contributing to the biofiltration swale using the 25 year 3 hour storm.
3. Verify the longitudinal slope of the proposed biofiltration swale is within the design parameters (see Table RT.04.1 for criteria). For this example, the longitudinal slope is **3% or s = 0.03** which is within the 1.5%-5% design parameters.
4. Next select a soil and vegetation cover suitable for the biofiltration swale using Table RT.04.1 below. For this example the manning's coefficient is **n = 0.20 or Grass-legume mix on compacted native soil**.

Table RT.04.1. Flow resistance coefficient in basic, wet, and continuous inflow biofiltration swales.

Soil and Cover	Manning's Coefficient
Grass-legume mix on compacted native soil	0.20
Grass-legume mix on lightly compacted, compost-amended[1] soil	0.22
Grass-legume mix on lightly compacted, compost-amended[1] soil with surface roughness features[2]	0.35

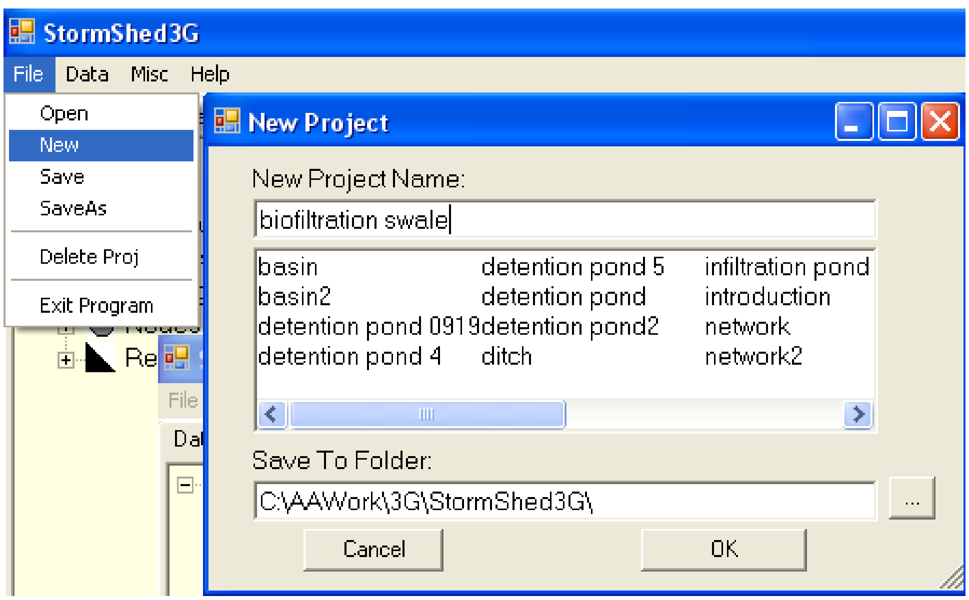
[1] For information on compost-amended soils, refer to Appendix 5A, Section A-2. Note that swales do not require a mulch layer and that compost amendments are incorporated into the soil.

[2] Acceptable surface roughness features are wattle check dams (Std. Spec. 8-01.3(6)D), gravel filter berms (Std. Spec. 8-01.3(9)B), or compost berms (Std. Plan I-14). These features must be placed every 50 feet (or closer) and should not exceed 1.5 feet in height above finished swale bottom. These features must not be used in place of level spreaders or energy dissipaters.

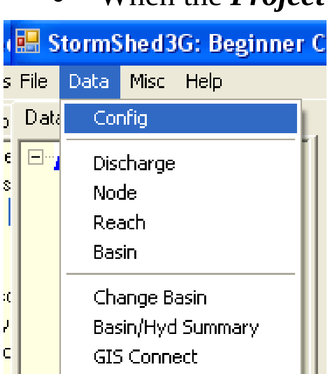
☺ *Next we will go to StormSHED to determine* Q_{biofil}, and Q_{convey}.

Start a new project

The first thing that needs to be done when starting StormSHED is to create a new project.



- Select **File>New** from the main tabs.
- When the ***New Project*** dialog box opens, type in **biofiltration swale** as shown above and then click **OK**.
- When the ***Project Disclaimer*** opens, select the **I Fully Understand** button.

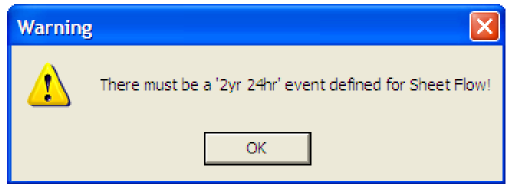


Set Project Defaults

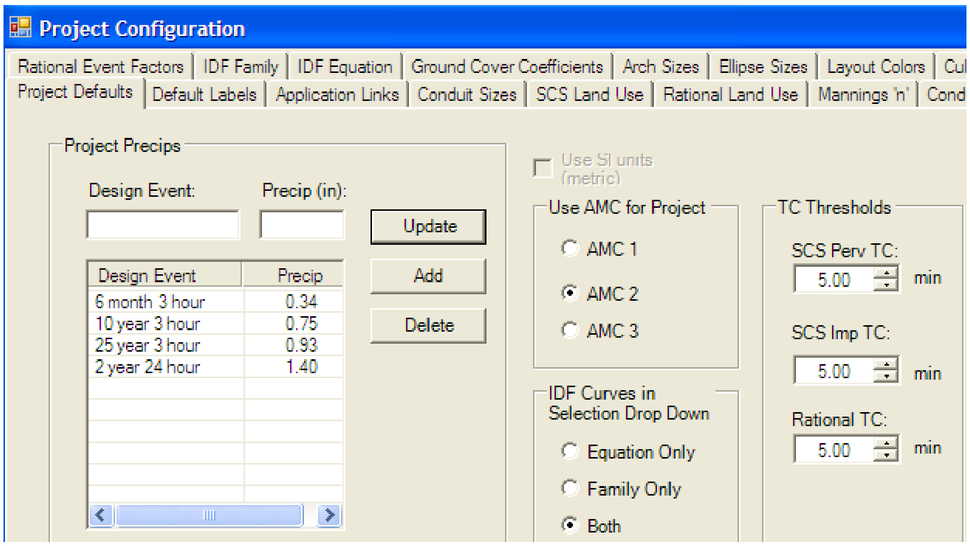
Next set the project defaults.

- Select **Data>Config** from the main menu tabs.

A warning dialog box will open reminding the designer to input a value for the 2 year 24 hour storm StormSHED 3G utilizes TR-55 methodology to calculate travel time and the travel time equation for sheet flow requires the 2 year 24 hour precipitation in the equation.



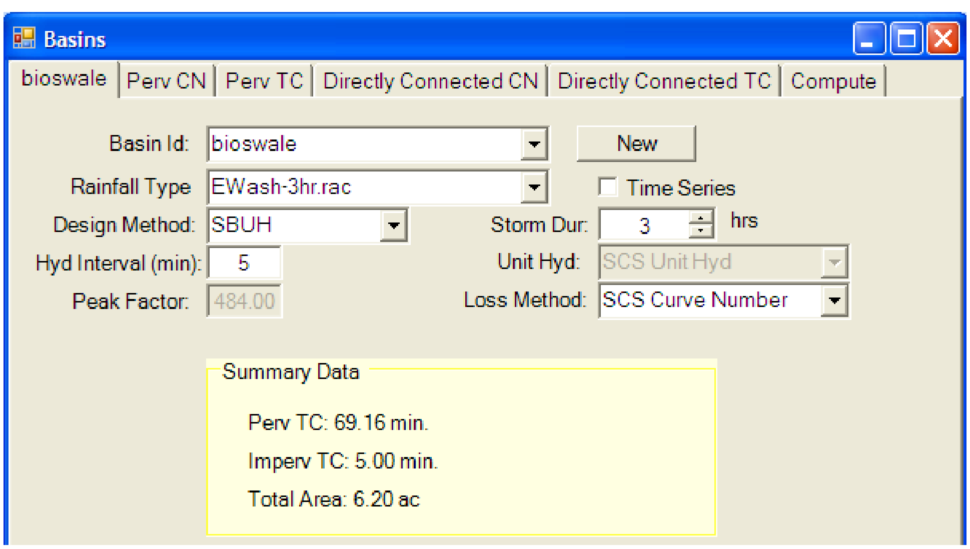
- **<u>Modify</u>** the *Project Precipitation* values as shown below:



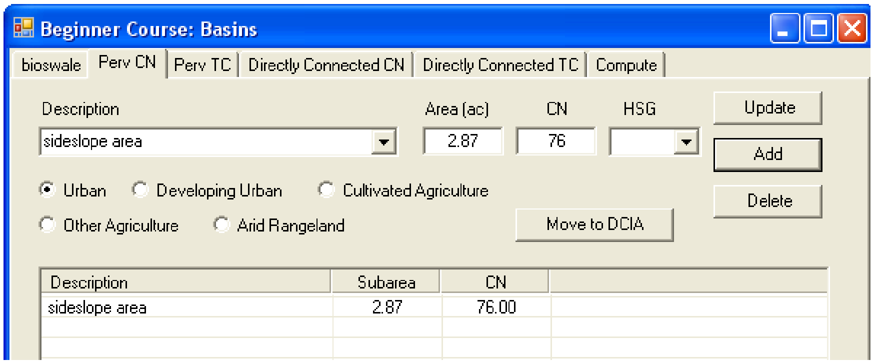
To eliminate the Warning dialog box; type '2 year 24 hour' for the Design Event.

Define Entire Basin (Q_{biofil} and Q_{convey}**)**

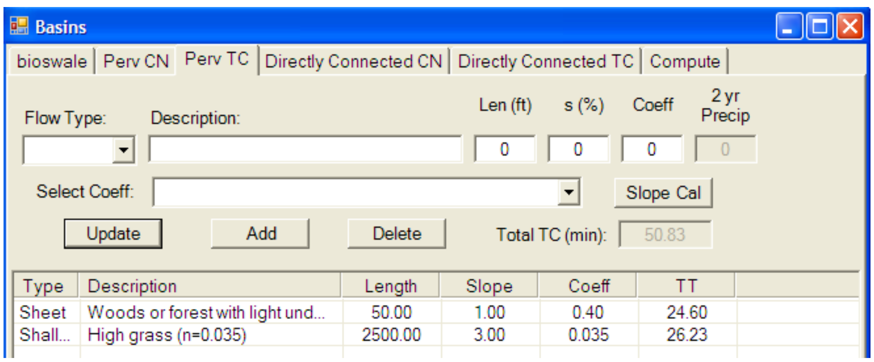
Next, we will create a basin representing all the area contributing the ditch**.** In the tree view, click on the **Basin** plus symbol using the Left Mouse Button. Then double click on the prototype and select new basin and type **bioswale** and **<u>input the data shown below</u>**. Note the interval is changed from 10 minutes to 5 as shown below when using the short duration storm.



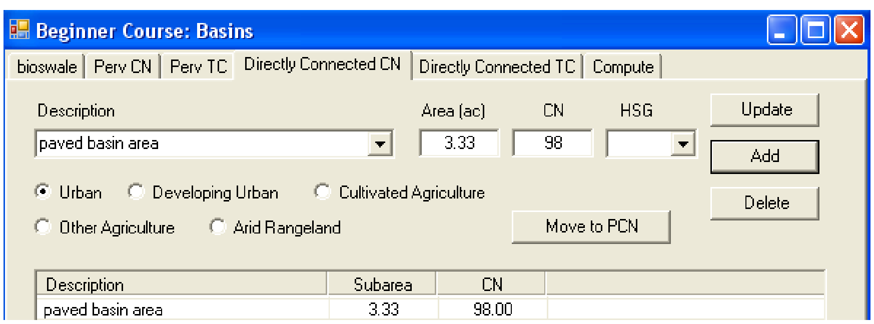
Define the ***Pervious CN*** for the project using the data shown below.



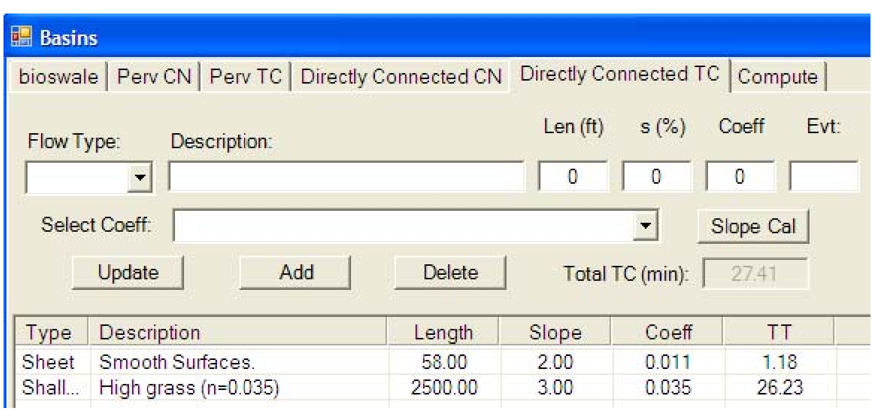
Select the ***Perv TC*** tab and define the flow path for the pervious side slopes area as shown below.



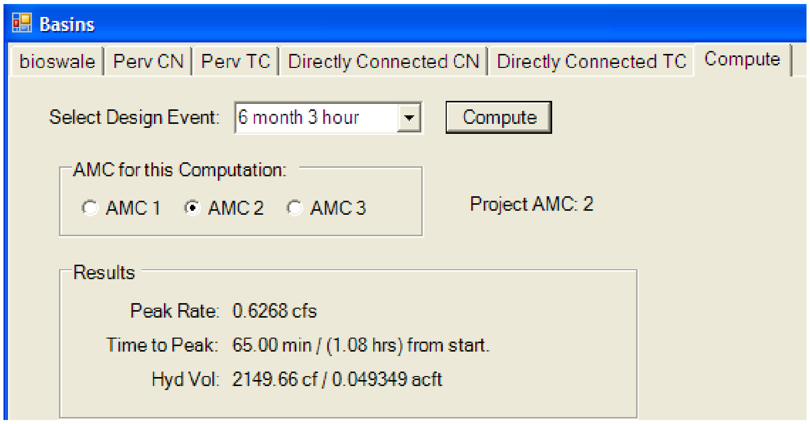
Select the ***Directly Connected CN*** tab and define the impervious basin area (roadway draining toward the ditch) as shown below.



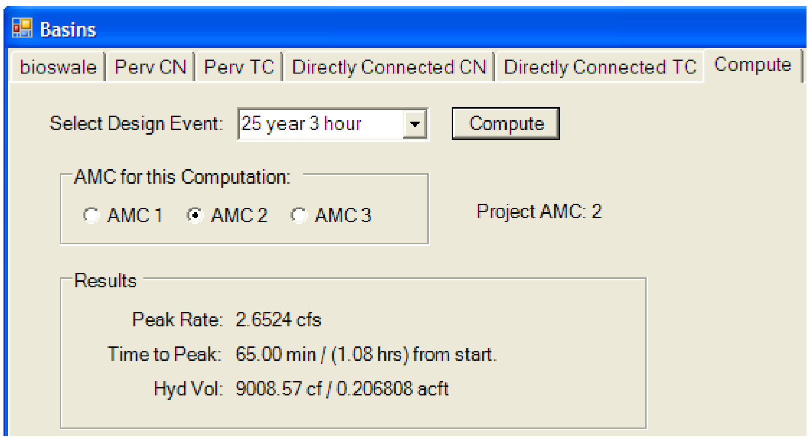
Select the ***Directly Connected TC*** tab and define the flow path off the roadway and through the ditch.



Finally, select the ***Compute*** tab to calculate $\underline{\boldsymbol{Q_{biofil}}}$, for the 6 month 3 hour MRI.



Repeat the process using the 25 year 3 hour short duration storm, $\underline{\mathbf{Q_{convey}}}$, to determine the freeboard depth of the swale.



<u>Design Steps (D)</u>

Now that we have Q_{biofil}, we can move to step D-1 in the biofiltration calculations.

1. From Table RT.04 select a **design depth of flow, y**. Assume we contacted maintenance and were informed the grass would rarely be mowed. Based on this information we will select 4-inches for the grass height.

2. Next **select a swale cross-sectional shape** (trapezoidal is preferred but rectangular or triangular cross-sections can be used if site-specific constraints so dictate). For this example we will use a **trapezoidal shape**.

3. Now we will **determine the required width** of our swale using Manning's equation (RT.04-1):

$$Q_{biofil} = \frac{1.49 A R^{2/3} s^{1/2}}{\mathrm{n}} \qquad \text{(RT.04-1)}$$

where:

Q_{biofi}	=	runoff treatment design flow rate (cfs)
A	=	wetted area (ft^2)
R	=	hydraulic radius (ft)
s	=	longitudinal slope of swale (ft/ft)
n	=	Manning's coefficient (see Table RT.04.1).

To solve for the cross-sectional width of the swale, the HRM offers 3 methods to apply when using equation RT.04.1. **Method 1** has designers substitute A and R for a selected geometry (see Figure RT.04.5) into equation RT.04-1 and then solve for the width. **Method 2** uses nomographs to determine the required width. This example will use **Method 3** as described below:

Method 3:

For a trapezoidal swale that is flowing very shallow (4-inches for this example), the hydraulic radius, *R*, can be set equal to the depth of flow (y) and z is the side slope of the swale. Using this assumption, Manning's equation, and substituting values from Figure RT.04.5, equation RT.04-1 can be rewritten as follows:

$$b = [(nQ_{biofil})/(1.49y^{1.67}s^{0.5})] - zy$$

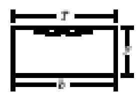
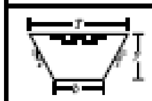
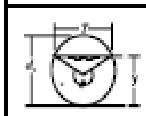
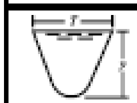
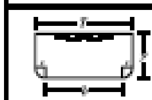
$$b = [((0.2)(0.627))/(1.49(0.33)^{1.67}(0.03)^{0.5})] - 3x0.33$$

b = 2.11 ft

Once a width has been calculated, designers should consult the project engineer to determine a swale width that is constructible.

Note: It is recommended that biofiltration swales with a bottom width greater than 6', have level spreaders installed every 50' of length. If a bottom width of less than 2 feet is calculated, then set bed width to 2 feet.

Figure RT.04.1. Geometric elements of common cross-sections.

Section	Area A	Wetted perimeter P	Hydraulic radius R	Top width W	Hydraulic depth D	Section factor Z
 Rectangle	by	$b + 2y$	$\frac{by}{b+2y}$	b	y	$by^{1.5}$
 Trapezoid	$(b + zy)y$	$b + 2y\sqrt{1+z^2}$	$\frac{(b+zy)y}{b+2y\sqrt{1+z^2}}$	$b + 2zy$	$\frac{(b+zy)y}{b+2zy}$	$\frac{[(b+zy)y]^{1.5}}{\sqrt{b+2zy}}$
 Triangle	zy^2	$2y\sqrt{1+z^2}$	$\frac{zy}{2\sqrt{1+z^2}}$	$2zy$	$^1/_2 y$	$\frac{\sqrt{2}}{2} zy^{2.5}$
 Circle	$^1/_8(\theta - \sin\theta)d_o^2$	$^1/_2 \theta d_o$	$^1/_4\left(1 - \frac{\sin\theta}{\theta}\right)d_o$	$(\sin(^1/_2\theta)d_o)$ or $2\sqrt{y(d_o - y)}$	$^1/_8\left(\frac{\theta - \sin\theta}{\sin {^1/_2}\theta}\right)d_o$	$\frac{\sqrt{2}}{32}\frac{(\theta - \sin\theta)^{1.5}}{(\sin {^1/_2}\theta)^{0.5}} d_o^{2.5}$
 Parabola	$^2/_3 Ty$	$T + \frac{8y^2}{3T}$ *	$\frac{2T^2 y}{3T^2 + 8y^2}$ *	$\frac{3A}{2y}$	$^2/_3 y$	$^2/_9\sqrt{6}Ty^{1.5}$
 Round-cornered Rectangle ($y>r$)	$(\frac{\pi}{2} - 2)r^2 + (b + 2r)y$	$(\pi - 2)r + b + 2y$	$\frac{(\frac{\pi}{2} - 2)r^2 + (b+2r)y}{(\pi - 2)r + b + 2y}$	$b + 2r$	$\frac{(\frac{\pi}{2} - 2)r^2}{(b+2r)} + y$	$\frac{[(\frac{\pi}{2} - 2)r^2 + (b+2r)y]^{1.5}}{\sqrt{b+2y}}$
 Round-bottomed Triangle	$\frac{T^2}{4z} - \frac{r^2}{z}(1 - z\cot^{-1} z)$	$\frac{T}{z}\sqrt{1+z^2} - \frac{2r}{z}(1 - z\cot^{-1} z)$	$\frac{A}{P}$	$2[z(y-r) + r\sqrt{1+z^2}]$	$\frac{A}{T}$	$A\sqrt{\frac{A}{T}}$

*Satisfactory approximation for the interval 0<x≤1, where x=4y/T. When x>1, use the exact expression $P = (^T/_2)\left[\sqrt{1+x^2} + {^1/_x}\ln\left(x + \sqrt{1+x^2}\right)\right]$

4. **Compute the area A** at Q_{biofil} by using the equation for trapezoids from Figure RT.04.5.

   A=(b+yz)y

   A=(2.11+0.33x3)0.33

   A=1.02 sqft

5. Next **verify the velocity** is less than 1 ft/s using equation RT.04-2 below.

   Compute the flow velocity at Q_{biofil}.

$$V_{biofil} = \frac{Q_{biofil}}{A} \qquad \text{(RT.04-2)}$$

   where: V_{biofil} = flow velocity at Q_{biofil} (ft/sec).

$$V_{biofil} = \frac{0.627}{1.02} = 0.61\, ft/s$$

   Since V_{biofil} < 1.0 ft/sec, the width (*b* or *T*) is acceptable. If the V_{biofil} > 1.0 ft/sec the channel width should be increased or investigate ways to reduce Q_{biofil} and then repeat the steps above until $V_{biofil} \leq 1.0$ ft/sec. A velocity greater than 1.0 ft/sec is found to flatten grasses, thus reducing filtration.

10. **Compute the required swale length**, *L* (ft).

   $L = V_{biofil}\, t$

   $L = (0.61\ ft/s)(540)$=329 ft

   This is the length the swale will need to extend beyond the ditch.

11. If there is insufficient space for the biofiltration swale, consider the following solutions:

   - In this example both off site and roadway runoff were used to size the swale. If possible, separate the two flows so the swale is designed to only handle runoff from the roadway.
   - Divide the site drainage into flow to multiple biofiltration swales.
   - Use an infiltration or dispersion BMP upstream of the biofiltration swale to provide lower Q_{biofil}.
   - Alter the design depth of flow, if possible (see Table RT.04.2).
   - Reduce the developed surface area to gain space for the biofiltration swale.
   - Reduce the longitudinal slope by meandering the biofiltration swale.
   - Nest the biofiltration swale within or around another stormwater BMP.

Freeboard Check (FC)

Lastly, a free board check should be performed for the combination of highest expected flow and least vegetation coverage and height. The highest expected flow rate (Q_{convey}) is the design flow rate of the downstream conveyance system to which the swale discharges.

1. From footnote 3 on Figure RT.04.2 Q_{convey} is based on the 25 year short duration storm which was found to be **2.65 cfs**.
2. Select the **lowest possible roughness coefficient** for the biofiltration swale (assume n = 0.03). Since the 25 year storm produces a larger flow rate, the affects of the 25 year storm going through the grass will be less and thus the n value can be reduced to reflect this.
3. Again, **use the implicit equation** $\boldsymbol{AR^{0.67} = Q_{convey}n/(1.49s^{0.5})}$ (Figure RT.04.1) and with a known *b* (or *T*), solve for depth, *y*. Select the lowest *y* that provides a solution. For trapezoidal swales, Figures RT.04.2 and RT.04.3 can be used directly.

   $b = [(nQ_{biofil})/(1.49y^{1.67}s^{0.5})] – zy$

   $2.11 = [(0.03x2.65)/(1.49y^{1.67}(0.03)^{0.5})] – 3y$

   y=0.76ft
4. Ensure that **swale depth exceeds flow depth** at Q_{convey} by a minimum of 1 foot (1 foot minimum freeboard). For this example the depth of the swale should be:

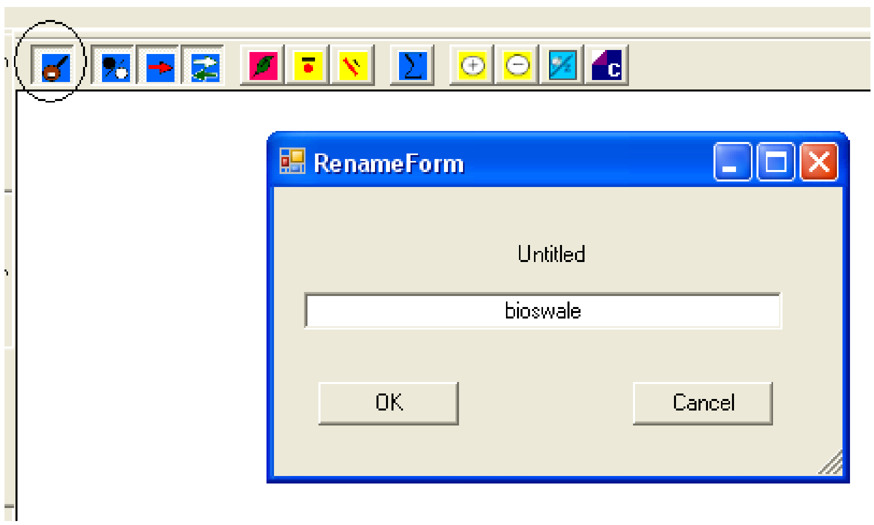
   1'+ 0.76ft = 1.76ft

Biofiltration Swale Option 2

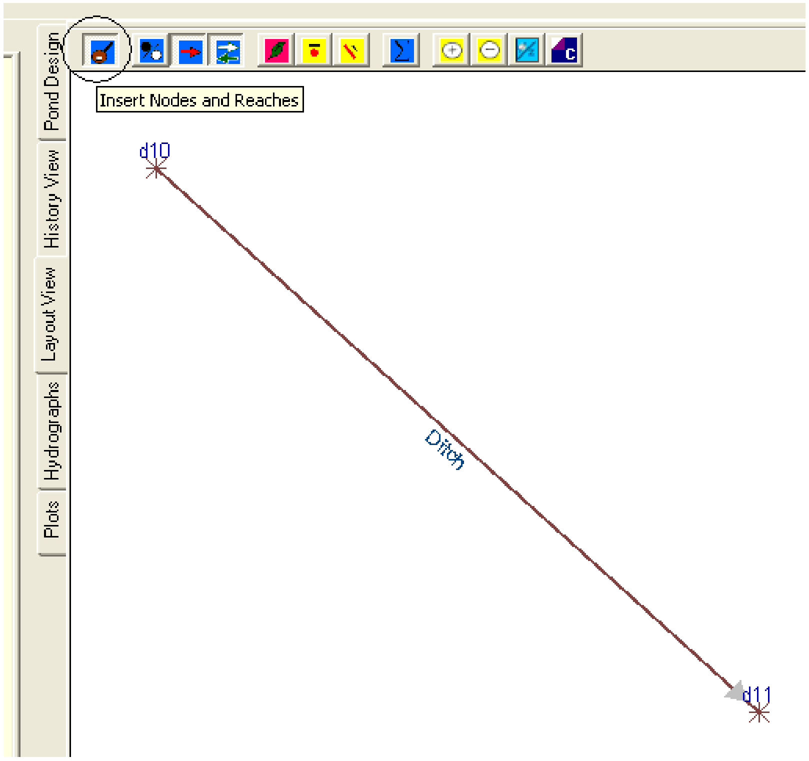
This is the same procedure that was described in the 1997 HRM manual. The difference between this option and option 1 is there is no residence time requirement; instead the swale length is set at 200 feet long. If this procedure were done by hand, all the calculations from the previous section are the same except Design step D-6, the swale length calculation. The design requirements are about the same as described in Table RT.04.2.

Create a Layout

Next we will create a new layout. Select the *Insert Nodes and Reaches* button in the upper left corner of the Layout View toolbar using the right mouse button. A dialog box will open prompting a name before a layout can be created. Type in **bioswale** and select **OK**.



After creating a new layout, select the ***Insert Nodes and Reaches*** button again. Place 2 nodes and one reach by clicking anywhere in the Layout View area with the left mouse button. The structures do not have to be in their exact location and they can be moved later. After the nodes and reach have been placed, toggle off the ***Insert Nodes and Reach button***. Notice the nodes and reaches are assigned the name *Prototype*, the next step is to define each.



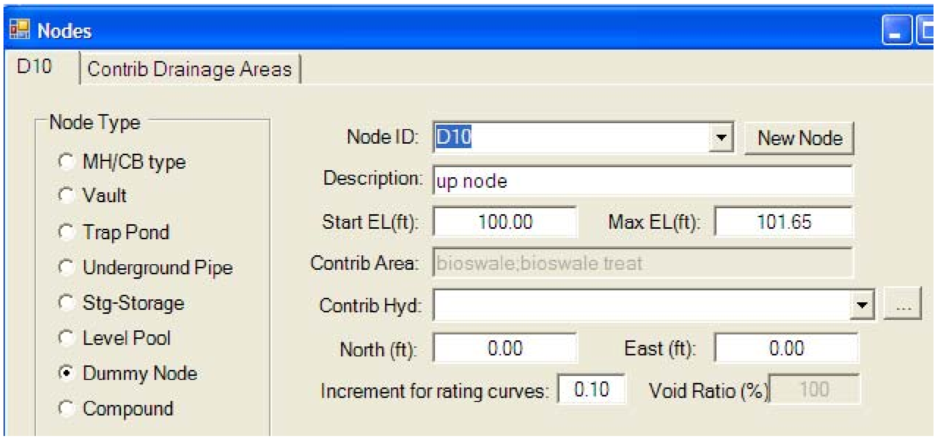
Define the Nodes and Reach

Using the data from the tables below (this is the same information that was given in the initial example problem on the first page of this tutorial), we will define the Nodes and Reaches for the ditch. The basin **bioswale** we created at the beginning of this tutorial will be the contributing drainage area for the upstream node. Both nodes will be defined as a Dummy Node. *Remember every transition in a reach requires a node, in this case the nodes represent the start and end of the ditch.*

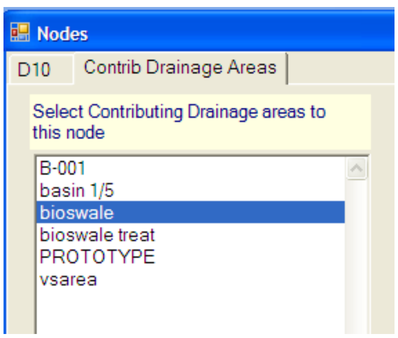
Dummy Node	Outlet Inv El.	Rim El.
D10	100	101.65
D11	94	95.65

Reach	Length	Upstream Inv.	Slope
BS10	200	100	3%

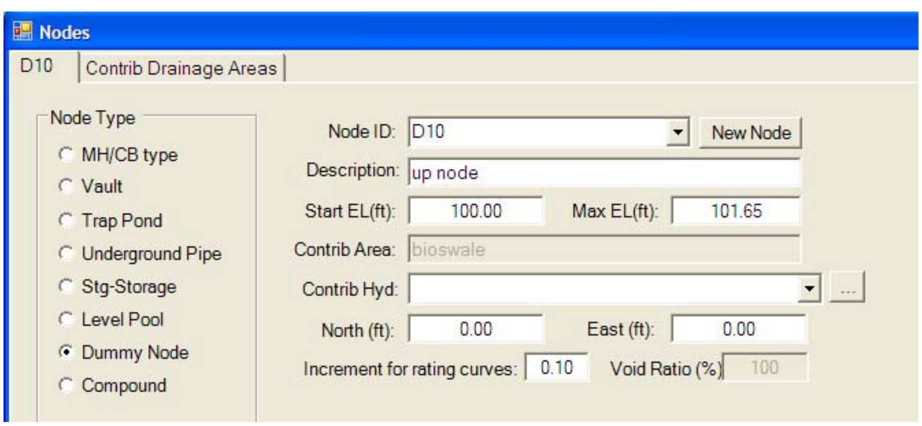
With the left mouse button double click on the first node and define the node with the data shown below.



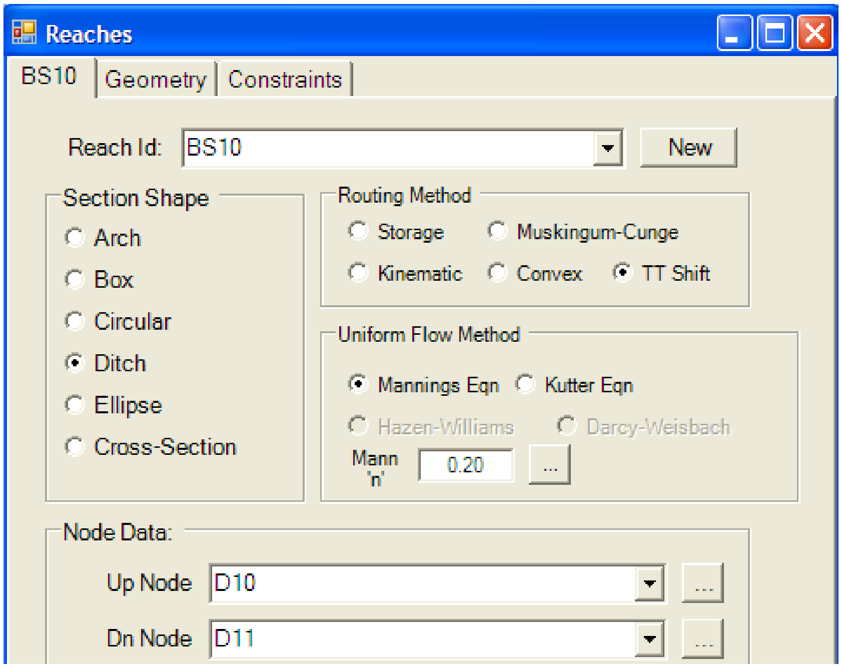
Select the ***Contrib Drainage Areas*** tab and select the **bioswale** basin. Then select the **OK** button to close the dialog box.



Next select double click on the downstream node in the Layout View and input the information as shown below. Click the **OK** button to close the dialog box.

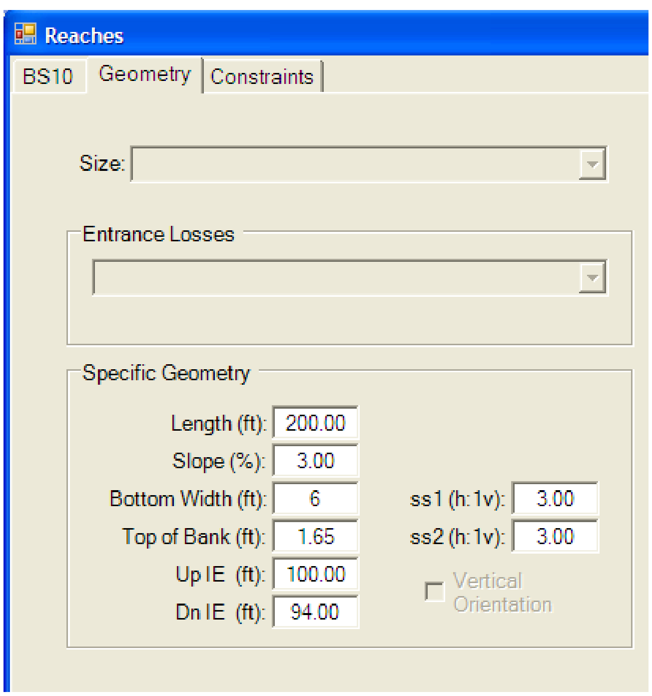


Next we will define the reach by ***double clicking*** on the reach in the layout view with the left mouse button, select the ***New*** button, and name the reach ***BS10*** and select the ***close*** button. Input the remaining data as shown below.



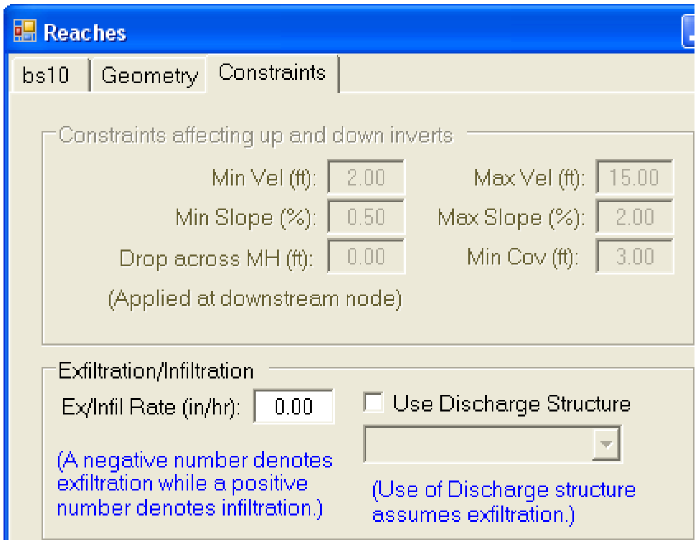
The **<u>TT Shift</u>** option must be selected for sizing biofiltration swales to be consistent with the HRM design criteria. Both the TT Shift routing method and the HRM use manning's equation for all biofiltration swale design.

Next select the ***Geometry*** tab and input the information below. Note that when after apply is hit, the upstream node will be input automatically from the layout.



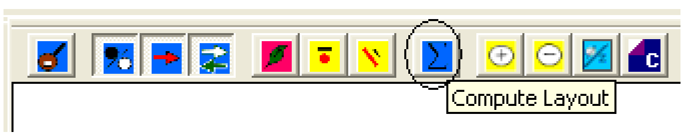
Where did the 6' width come from for the ditch? Determining the width is an iterative process. Start by guessing a width, then compute the layout and see if the design criterion is met. If the velocity and depth are greater than 1ft/sec and 0.33", then make the ditch wider to reduce these values. Also, if the velocity and depth are smaller than required, try reducing the swale width till the values closely match the requirements.

The ***Constraints*** tab is mainly for culverts, the only option that can be modified in ditch design is the **Exfiltration/Infiltration** option. Verify for this application it is **0**.

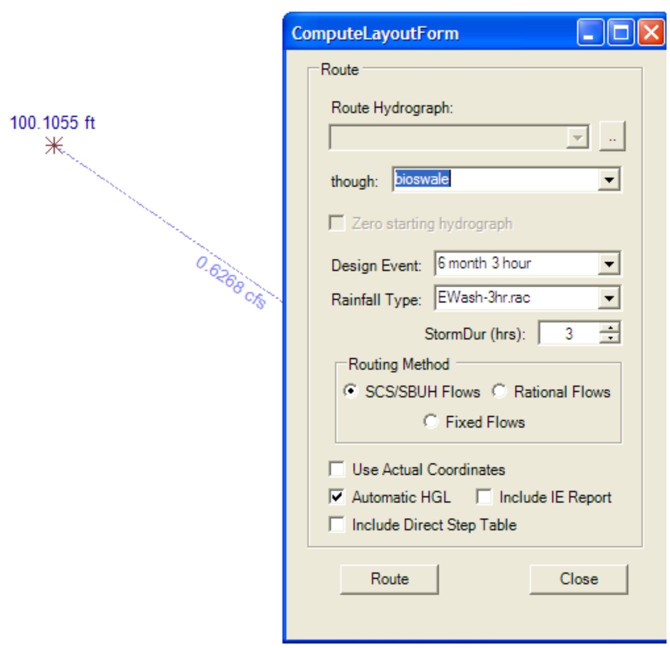


Compute the Layout

Now that the Bioswale Layout is complete, select the **Compute Layout** button on the Layout View Toolbar.



In the Compute Layout Form, input the data as shown below and then select Route. Notice the **Q_{biofil} = 0.6268cfs** appears in the layout view.



View the output

Next select the ***History View*** tab to review all the output data. Remember the information in the History View is not cumulative, so it is important to copy the data before sending anything else to the History View.

- To copy the data to a word document, highlight the information by holding down on the LMB and dragging the mouse of the material to be copied. Next select the **Ctrl and C** buttons at the same time. Open a Word document and select **Ctrl and V** at the same time to paste the data.

The output should appear as shown below:

Appended on: Monday, February 23, 2009 11:59:32 AM
ROUTEHYD [] THRU [bioswale] USING [6 month 3 hour] AND [EWash-3hr.rac] NOTZERO RELATIVE SCS/SBUH

Gravity Analysis using 3 hr duration storm

Reach ID	Area (ac)	Flow (cfs)	Full Q (cfs)	Full ratio	nDepth (ft)	Depth ratio	Size	nVel (ft/s)	fVel (ft/s)	Infil Vol (cf)	CBasin / Hyd
BS10	3.33	0.6268	----	0.00	0.2168	----	Ditch	0.4348	-----	0.00	bioswale

HGL Analysis

From Node	To Node	HG El (ft)	App (ft)	Bend (ft)	Junct Loss (ft)	Adjusted HG El (ft)	Max El (ft)
							94.2168
D10	D11	100.0684	--na--	--na--	--na--	100.0684	101.6500

Conduit Notes

Reach	HW Depth (ft)	HW/D ratio	Q (cfs)	TW Depth (ft)	Dc (ft)	Dn (ft)	Comment
BS10	0.0684	na	0.6268	0.2168	0.0684	0.2168	Direct Step Backwater Calc

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Verify the Design Criteria

When reviewing the History View for the 6 month 3 hour event, there are several things to check.

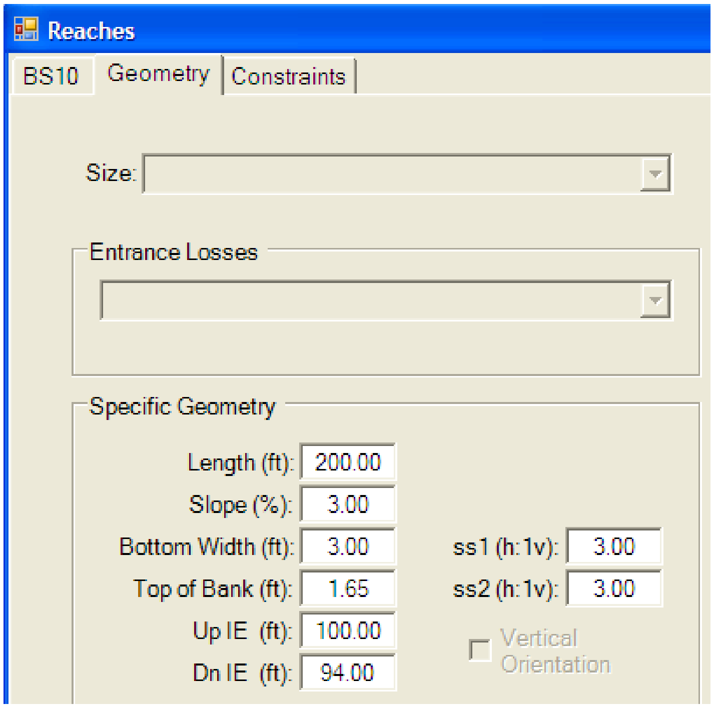
- First verify the depth in the swale is 4" (0.33") or less, by reviewing the 'nDepth' column. For this tutorial the depth is 0.22.
- Next verify the velocity is less than 1 ft/s by reviewing the 'nVel' column. For this tutorial, the velocity is 0.42 ft/s.

Since both the depth and velocity are within an acceptable range, the 6 foot width is also acceptable however since both the depth and velocity are much smaller the width could be reduced. If either had been larger than acceptable, the swale width would need to be increased and the analysis rerun.

Redesign the Bioswale

Since the depth of flow is less than design depth of 4" and the velocity is less than 1 ft/sec, the designer should go back and repeat the process using widths smaller than 6.3'.

- In the Layout View double LMB click on the reach. When the dialog box opens select the ***Geometry*** tab.
- Change the width from **6' to 3'** and then close the dialog box.



- Again select the Compute Layout button on the Layout View toolbar and route the 6 month 3 hour short duration storm through the layout. Then close the dialog box.
- Select the History View tab and output should appear as shown below:

Appended on: Monday, February 23, 2009 11:41:27 AM
ROUTEHYD [] THRU [bioswale] USING [6 month 3 hour] AND [EWash-3hr.rac] NOTZERO RELATIVE SCS/SBUH

Gravity Analysis using 3 hr duration storm

Reach ID	Area (ac)	Flow (cfs)	Full Q (cfs)	Full ratio	nDepth (ft)	Depth ratio	Size	nVel (ft/s)	fVel (ft/s)	Infil Vol (cf)	CBasin / Hyd
BS10	3.33	0.6268	----	0.00	0.313	----	Ditch	0.5084	-----	0.00	bioswale

HGL Analysis

From Node	To Node	HG El (ft)	App (ft)	Bend (ft)	Junct Loss (ft)	Adjusted HG El (ft)	Max El (ft)
							94.313
D10	D11	100.1055	--na--	--na--	--na--	100.1055	101.6500

Conduit Notes

Reach	HW Depth (ft)	HW/D ratio	Q (cfs)	TW Depth (ft)	Dc (ft)	Dn (ft)	Comment
BS10	0.1055	na	0.6268	0.313	0.1055	0.313	Direct Step Backwater Calc

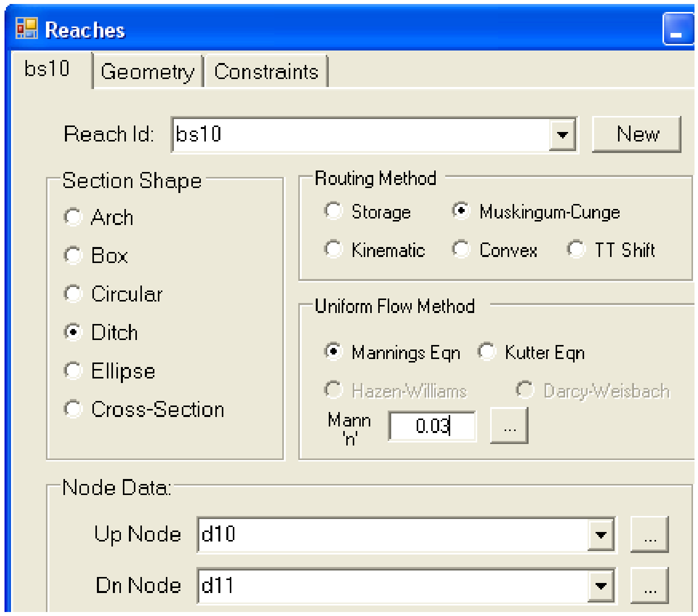
- Since the depth in the ditch is just less than 4" and the velocity is less than 1 ft/sec, this design is acceptable.

Remember the HRM requires all of the runoff travel throught the biofiltration swale for a length of 200'. Since the ditch was designed following the biofiltration swale requirements, designers can receive credit for runoff treatment of runoff in the ditch. However the last 200' of runoff in the ditch will need additional length beyond the ditch to meet the HRM requirements. Consult the HRM and the Region Hydraulic Engineer for additional guidance.

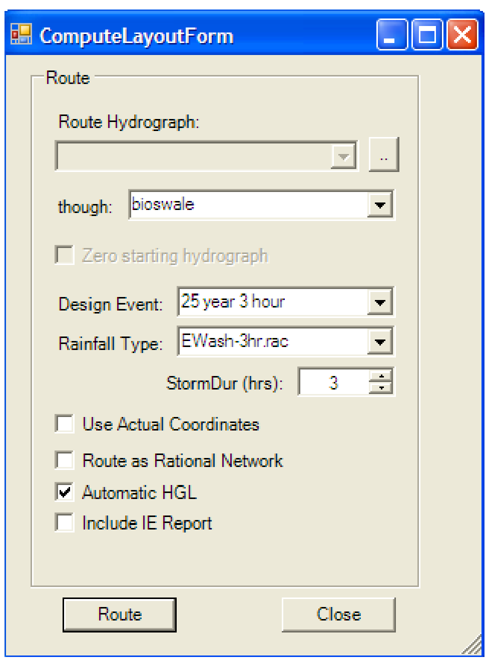
Freeboard Check

Next, we need to go back and change the Manning's n = 0.03 for the 25 year 3 hour. As stated previously in the Free Board Check section, we need to select the **lowest possible roughness coefficient** for the biofiltration swale (assume n = 0.03). This is because the 25 year storm produces a larger flow rate and as a result the vegetation will likely get knocked down producing a smaller effect from the roughness of the vegetation.

- In the layout view, double LMB click on the reach and the dialog box will open.
- Change the Manning's n from **0.2 to 0.03**, then close the dialog box.



- Select the ***Compute Layout*** button from the Layout toolbar and **input the data** as shown below.
- Finally select the **Route** button and then **Close** the dialog box.



- Select the History View tab and the data should appear as shown on the next page. Remember the copy the output to a Word document.

Appended on: Monday, February 23, 2009 12:01:08 PM
ROUTEHYD [] THRU [bioswale] USING [25 year 3 hour] AND [EWash-3hr.rac] NOTZERO RELATIVE SCS/SBUH

Gravity Analysis using 3 hr duration storm

Reach ID	Area (ac)	Flow (cfs)	Full Q (cfs)	Full ratio	nDepth (ft)	Depth ratio	Size	nVel (ft/s)	fVel (ft/s)	Infil Vol (cf)	CBasin / Hyd
BS10	6.20	2.6524	----	0.00	0.2427	----	Ditch	2.9318	-----	0.00	bioswale

HGL Analysis

From Node	To Node	HG El (ft)	App (ft)	Bend (ft)	Junct Loss (ft)	Adjusted HG El (ft)	Max El (ft)
							94.2642
D10	D11	100.2642	--na--	--na--	--na--	100.2642	101.6500

Conduit Notes

Reach	HW Depth (ft)	HW/D ratio	Q (cfs)	TW Depth (ft)	Dc (ft)	Dn (ft)	Comment
BS10	0.2642	na	2.6524	0.2642	0.2642	0.2427	Supercritical flow, dc at up node

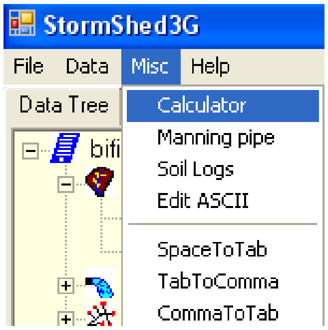
- Lastly, the depth of the swale needs to be a foot above the nDepth (ft). For this tutorial the depth of the swale needs to be 1’+0.24’=1.24’.

Note that the contributing basin Area (ac) in the 2nd column is much larger than it was for the 6 month storm (6.2 compared to 3.33). This is because there was not enough runoff from the pervious surface to generate runoff for the 6 month storm.

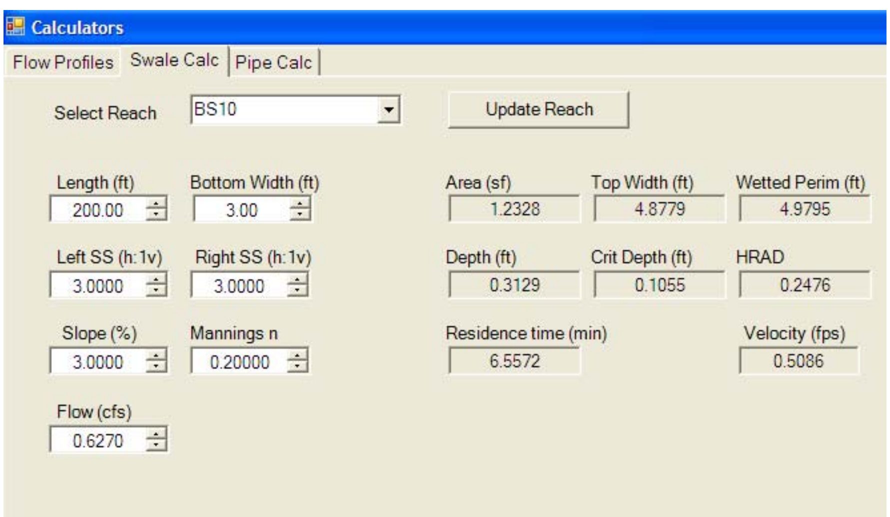
Try this – Use the Calculator to size the Reach

Instead of changing the length in the Reach dialog box, try using the calculator.

- On the main menu toolbar, select **Misc>Calculator** to open the Calculator dialog box.



- From the pulldown menu, select the reach **<u>bs10</u>** and all the data for that reach will appear as shown below.
- **<u>Modify the width</u>** using the Q_{biofil} for the project until the depth and velocity requirement are met.
- Go back to the **<u>Reach dialog box</u>** and input the new width.
- **<u>Route</u>** the 6 month 3 hour storm through the layout and verify the design is correct.



For option 2, ignore the residence time calculation.