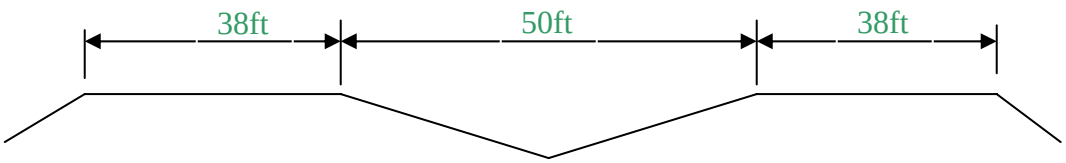
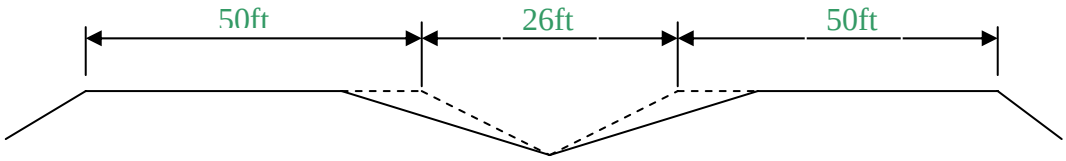
Infiltration Pond Example

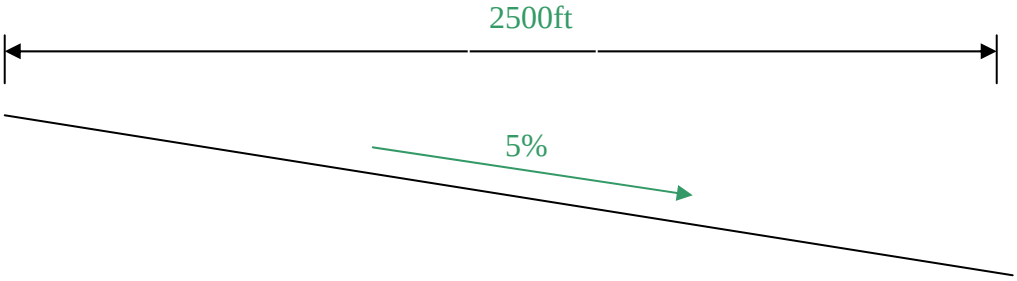
A section of highway near the city of Spokane is to be improved with an additional lane in each direction. The existing configuration consists of two 12-foot lanes with a 6-foot shoulder on one side and an 8-foot shoulder on the other in each direction. The northbound and southbound lanes are separated by an existing 50-foot grassed median. The pavement is sloped towards a "V" shaped median acting as the conveyance system.



There are ditches outside of the lanes preventing off-site drainage from entering the project area. The proposed project will add one 12-foot lane in each direction, while maintaining the current shoulder widths. Both lanes will be added inside of the existing lanes. The cross slope for the roadway is 2% with 4:1 side slopes



Using this information, design an infiltration pond for this 2,500 foot section of roadway that will meet the required release rates of Minimum Requirement 5. The roadway profile is on a continuous 5%.



The soil in the project vicinity has a NRCS identification as Spokane. The median area is grassed with no appreciable amount of brush. The rainfall amounts are noted on the next page.

Infiltration Pond Example

Appendix 4B in the HRM, shows that Spokane soil is rated as NRCS Type B soil. A curve number can also be obtained from Appendix 4B in the eastern Washington section of the HRM. A curve number of 98 should always be used for paved areas andgiven the described conditions of the median, a curve number of 58 should be used.

Calculating the area contributing to the pond being designed indicates that there is a total of **7.23 acres**. The existing roadway configuration has **4.36 acres** of impervious and **2.87 acres** of pervious land contributing flow. After the project is completed, there will be **5.74 acres** of impervious and **1.49 acres** of pervious land contributing flow.

To best analyze this basin for the tri-storm requirement, the designer should define two basins within StormShed, an existing and a developed basin.

Getting Started

Start StormShed and create a new, untitled project using the menu sequence:

- Create a new StormShed project by selecting: *Start/Programs/StormShed/StormShed*
- Create a new project by selecting: *File/New*
- Press the **I Fully Understand** button after reading the disclaimer.

We will immediately save this project under the project name "Widening".

- Select the *File/SaveAs* menu item in the program menu.
- Enter the project name *Widening* in the "File name" input field.
- Press the **Save** button.
- Click in the Tree View to insure that it has focus.

Rainfall Setup

Open the options dialog box by selecting *Data/Option* from the program menu. Using values from the Isopuvials located in Appendix 4A of the HRM, the following rainfalls were determined for Spokane.

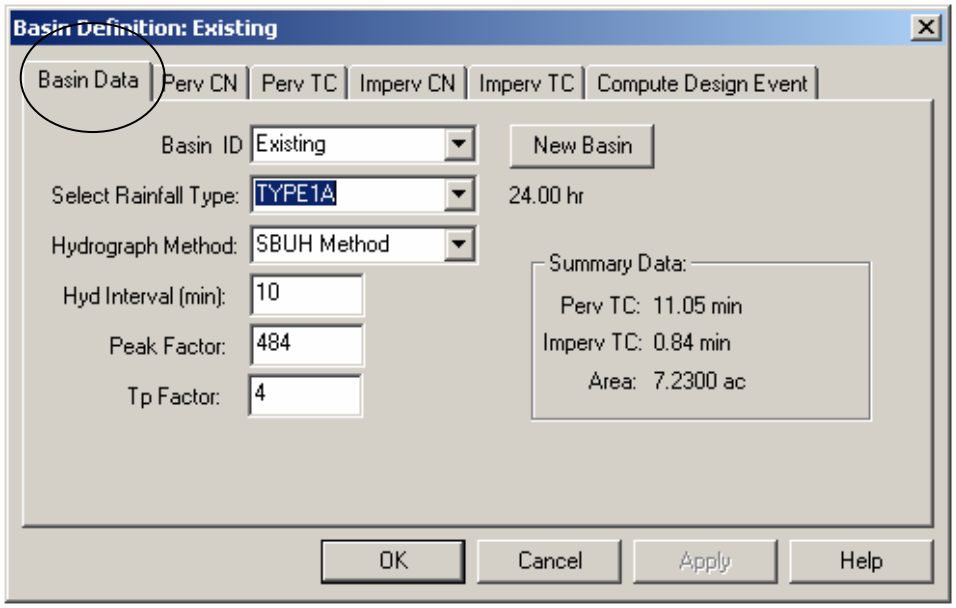
- Change the precipitation for the 2 yr event to 1.4 inches.
- Change the precipitation for the 5 yr event to 1.7 inches
- Change the precipitation for the 10 yr event to 2.0 inches.
- Change the precipitation for the 25 yr event to 2.2 inches.
- Change the precipitation for the 100 yr event to 2.6 inches.
- Change the precipitation for the 6 mo. event to 0.97 inches (Appendix 4D notes that the 6 month storm for Spokane is 0.69*2 yr storm or 1.4*0.69 = 0.97
- Click on the **OK** button to close the "Options" dialog box.

Defining Drainage Areas

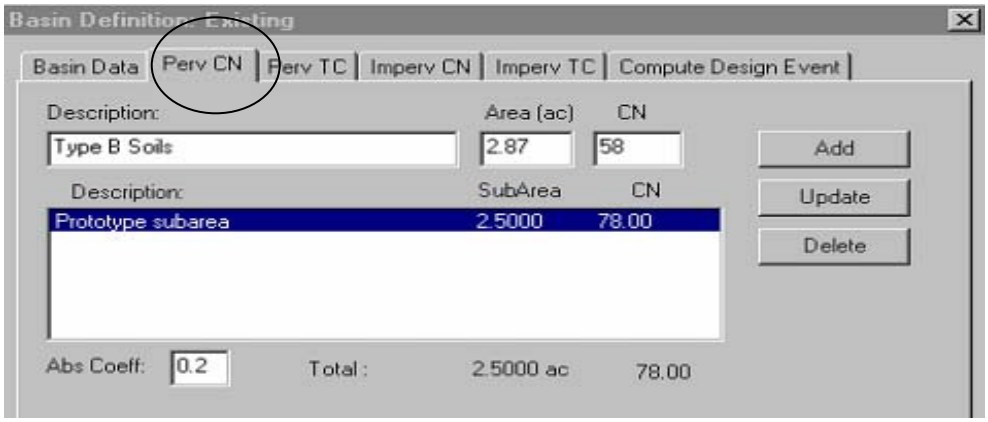
Create Existing Basin

First define the existing drainage area. Always work from left to right going through each TAB.

- Double Click on the "PROTOTYPE" record under the "Basins
- Click on the **New Basin** button
- Modify the AutoLabel Dialog to "*Existing*"
- Press the **OK** button to close the dialog box
- Change the "Rainfall Type" to Type 1A.



- Click on the "Perv CN" tab.
- Click on the "Prototype subarea" line.
- Modify per Figure below

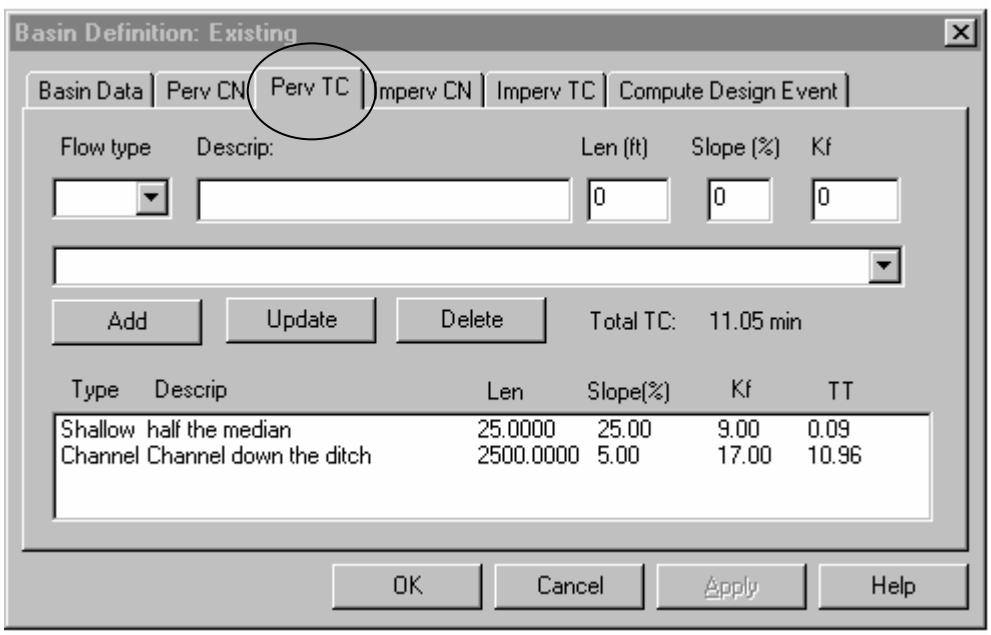


Basin Perv CN

- Click on the **Update** button.
- Make sure the Description in the box below is correct.

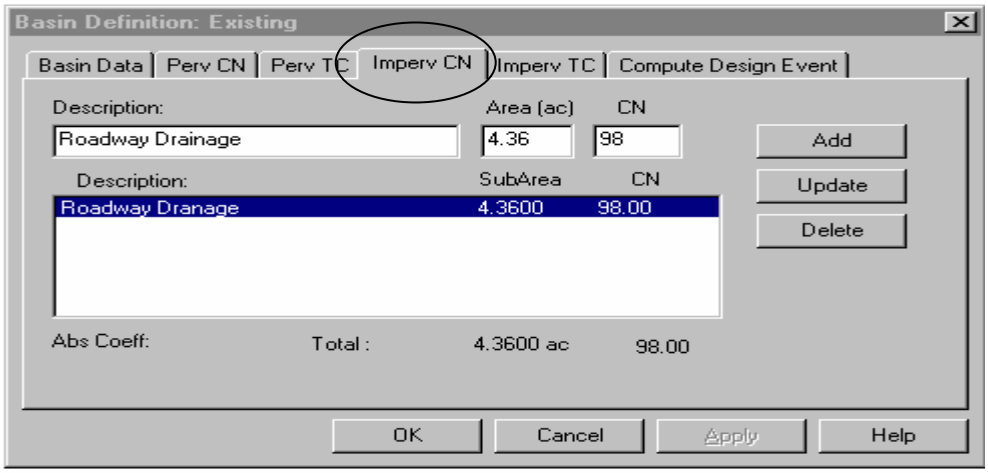
Both the north and south bound lanes drain inward toward the median. Then it drains down the center of the median to the point of analysis.

- Click on the "Perv TC" tab.
- Click on the "*Prototype*.." travel time reach to modify it.
- Make it *Shallow flow*, 25 feet in length with a slope of 25%. For the coefficient, use *High Grass surface* to depict the median.
- Click on the **Update** button.
- Modify the "Flow Type" drop down to *Channel*.
- Change the description to reflect drainage down the ditch.
- Change the length to 2500 feet with a slope of 5%.
- Select *Grass* for the coefficient.
- Press the **Add** button.



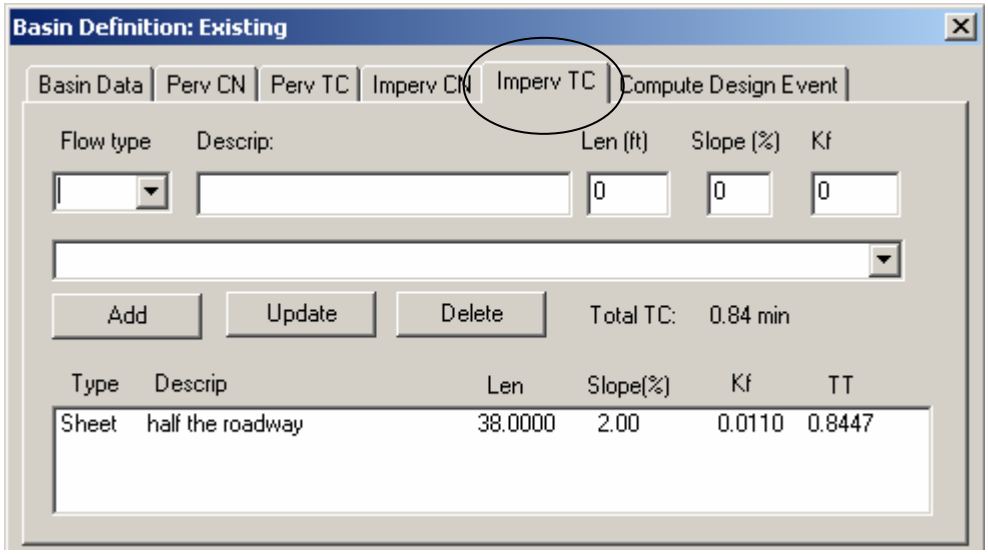
Add the roadway drainage area and CN value of the project site.

- Click on the "Imperv CN" tab.
- Modify per Figure below
- Press the **Add** button.



Modify Basin Imperv CN

Add the Sheet flow shown in the figure below.



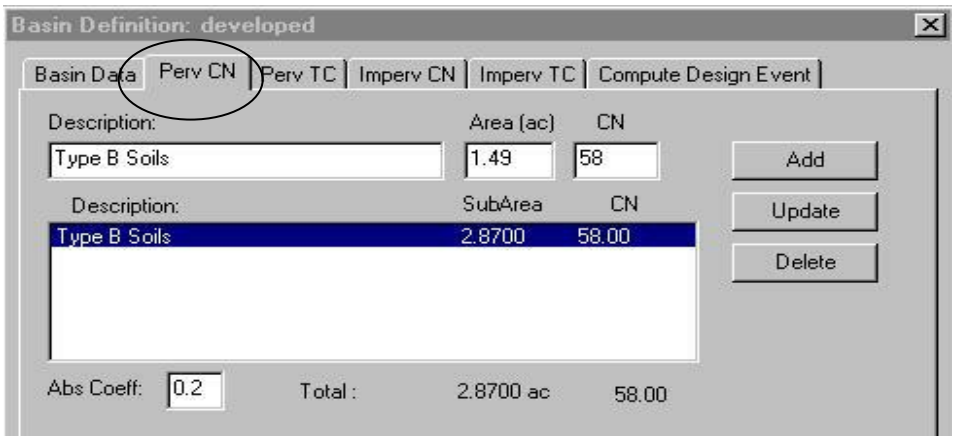
Modify the Imperv TC data

- Click on the "Imperv TC" tab..
- Make it *Sheet flow*, *38 feet* in length with a slope of *2%*. For the coefficient, use *Smooth surface* to depict the roadway
- Click on the **ADD** button

Create Developed Basin

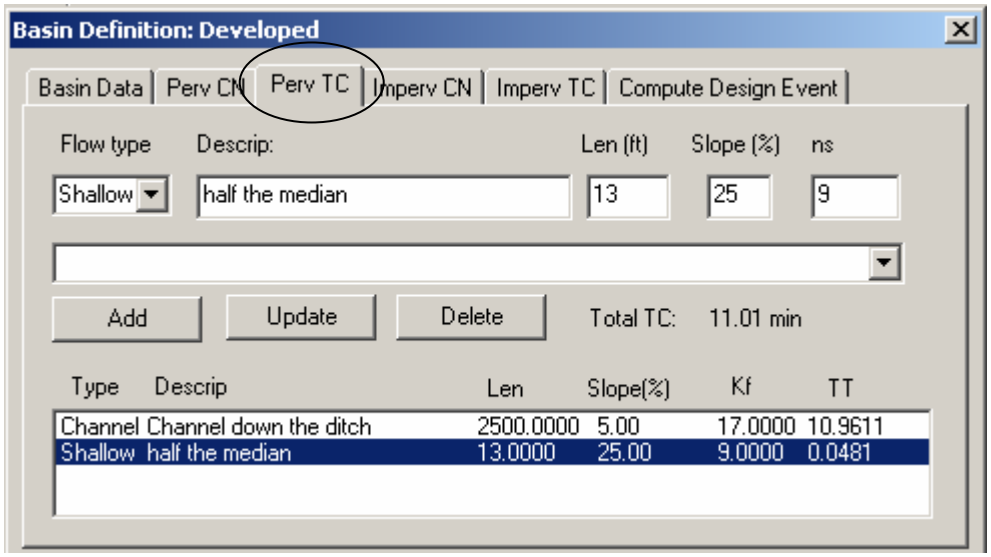
The "Existing" basin can now be used as a template for the developed basin.

- Double click on the "Existing" basin under the "Basins" node in the Tree View.
- Press the **New Basin** button.
- Enter Developed for the Basin ID.
- Press OK to close the "AutoLabel" dialog box.
- Click on the "Perv CN" tab.
- Modify the *Type B soils* area to 1.49 acres.
- Click the **Update** button



Modify Perv CN area for developed conditions

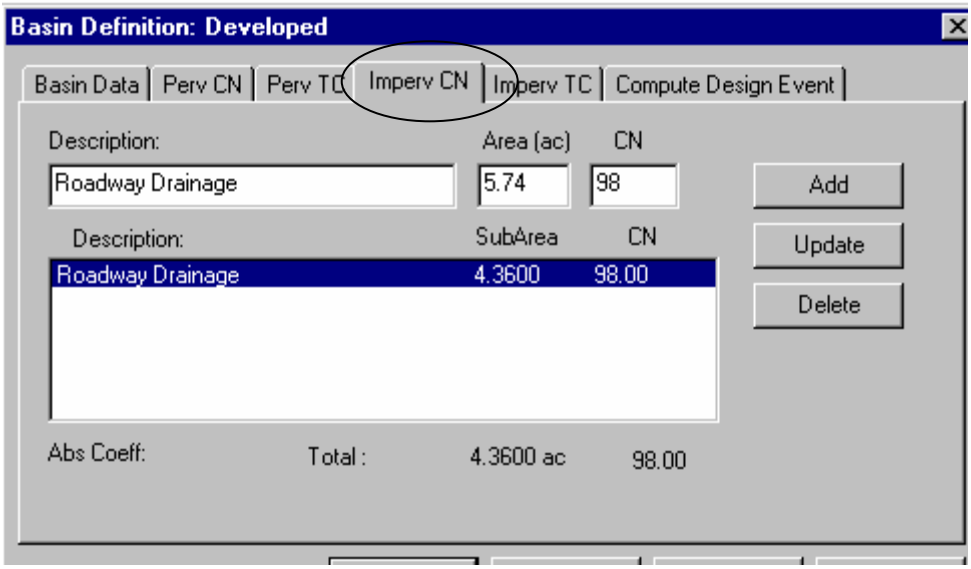
- Click on the "Perv TC" tab
- Modify half the roadway Shallow flow to *13ft*
- Click the **Update** button



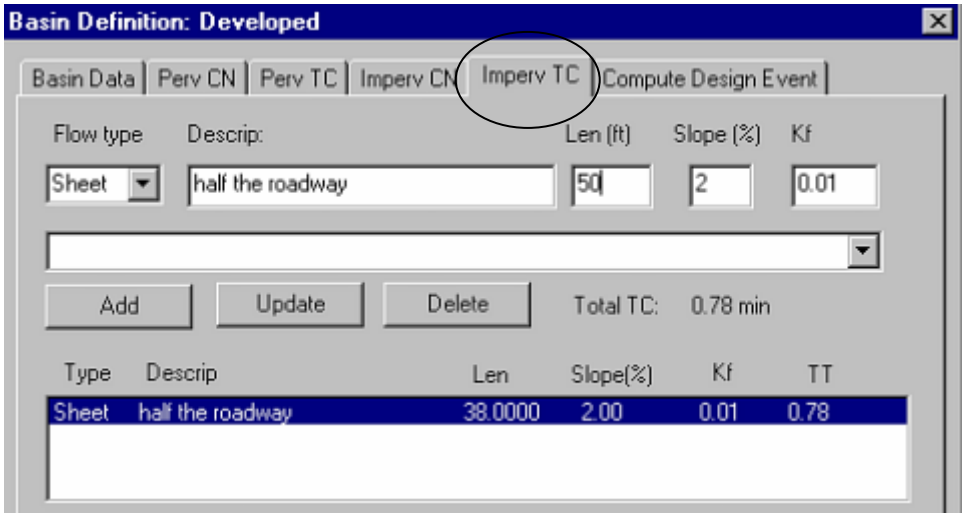
Modify Perv TC for developed conditions

The last step is to modify the Impervious roadway for developed conditions.

- Click on the "Imperv CN" tab.
- Modify the Roadway drainage area to 5.74 acres.
- Click the **Update** button



- Click on the "Imperv TC" tab
- Modify half the roadway Sheet flow to *50ft*
- Click the **Update** button



Modify Imperv Tc data for developed condition

Define a Storage Element (Infiltration Pond)

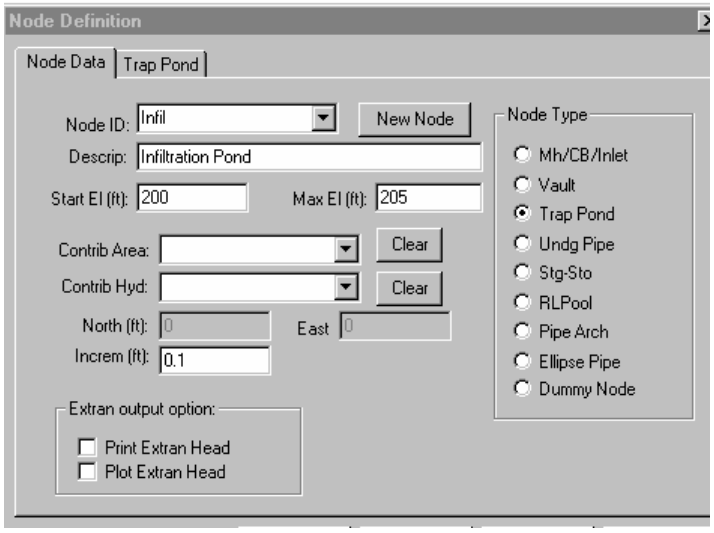
How the design proceeds from this point is dependant on what type of infiltration pond (runoff treatment or flow control) is being designed. For the remainder of this problem we will assume the infiltration pond is being designed for flow control.

> **Flow Control** – An infiltration pond can be a flow control pond if the infiltration rate is greater than 2.4 in/hr. Flow control infiltration ponds can be designed using either the detailed or simplified infiltration approach described in chapter 4 of the 2004 HRM. For this example, they will be designed utilizing the simplified approach. The ponds shall also be designed to empty the 25 year storm in 72 hours with 1' free board.

Define a Storage Element (Infiltration Pond)

Flow Control

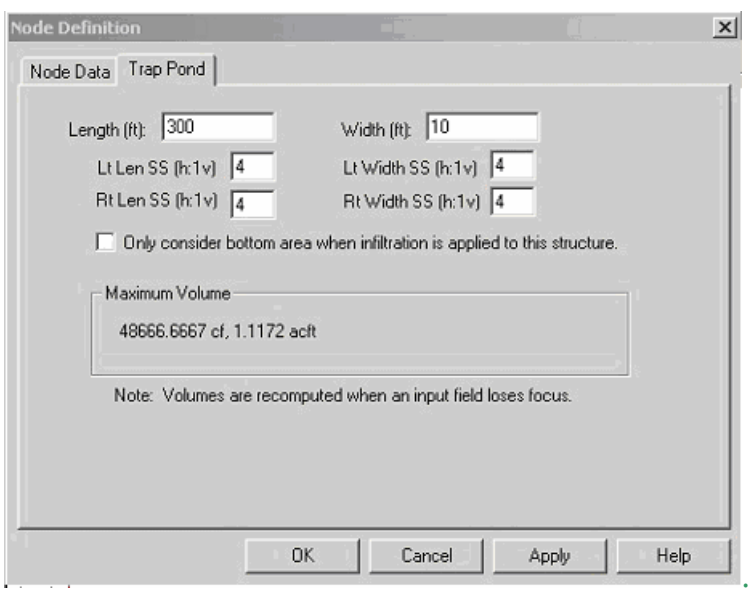
- Double click on the node "PROTOTYPE" record.
- Click on the **New Node** button.
- Change the "AutoLabel" ID to <u>Infil</u>
- Press the **OK** button to close the "AutoLabel" dialog box.
- Change the description to "Infiltration Pond"and the Control Type to Infiltration.
- The Starting Elevation and Max Elevation have not been changed from the previous design and should be <u>200</u> ft and <u>205</u> ft, respectively.



Defining the Infiltration Pond dimension

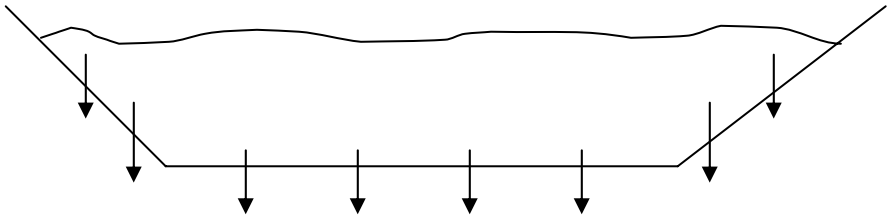
The site selected for the pond can only accommodate a width of 10 feet. The length is the only dimension that can be varied. On a real project, the process would be similar. Once an estimate of the pond volume would be made, the designer would look at the site and find a location that could accommodate the pond. In many cases the pond would be roughed in, and the bottom elevation determined before the data is even placed in the program.

- Click the Trap Pond tab
- Modify the Length to 300ft
- Modify the Width to 10ft
- Modify all the side slopes to 4



If the white box is checked, only the bottom surface would infiltrate requiring a larger pond. WSDOT projects in Eastern Washington can consider infiltration in the bottom and side areas.

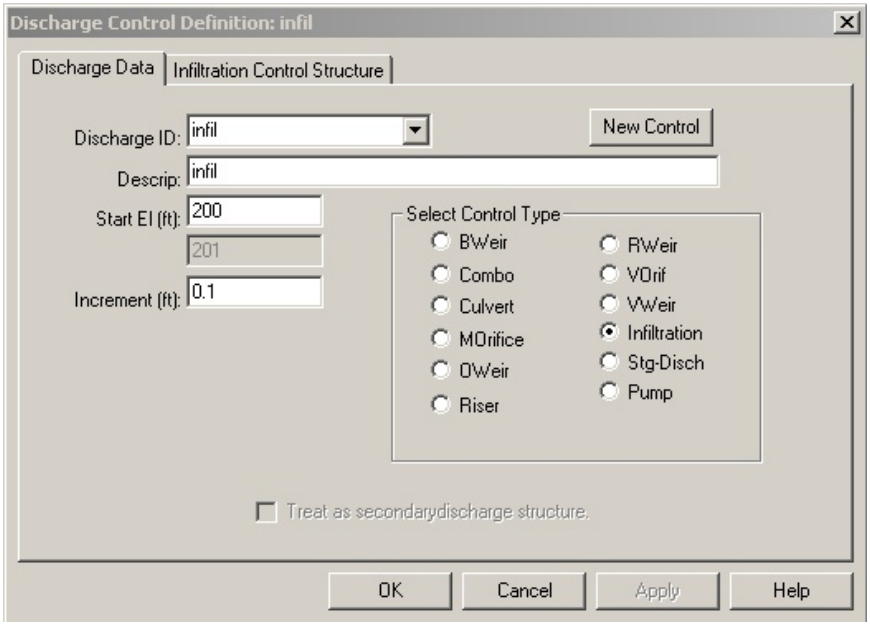
Taking into account the bottom and sideslope surfaces for infiltration



Define a Discharge Control Structure

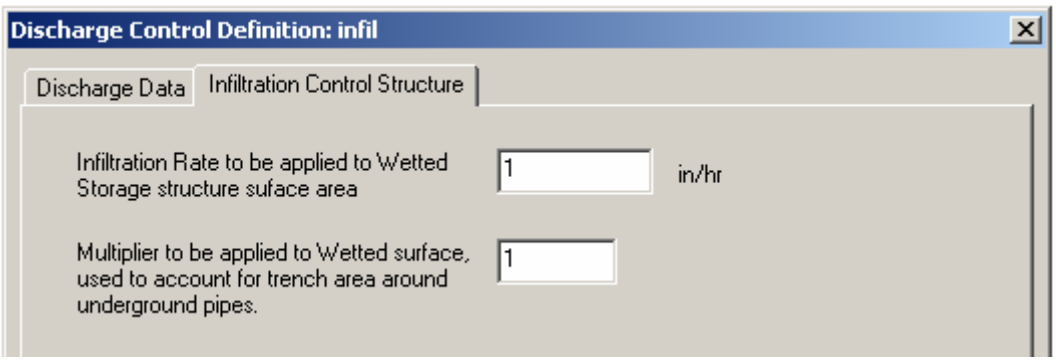
We will select the infiltration radio button as our control structure

- Double click on the PROTOTYPE record found under the "Discharge" node in the Tree View.
- Press the **New Control** button.
- Replace the "AutoLabel" ID with infil.
- Press **OK** to close the "AutoLabel" dialog box.
- Change the Description to "infil".
- Change the "Start El" to 200.



- Click on the "Infiltration Control Structure" tab.

- Change the rate to 1.0 inches/hour. (This rate is based on previously available data from the site. If no data is available, a default rate of 0.5 in/hr should be used.) Once data is available from the lab, the actual infiltration rate can be determined using the procedure described in Section 4-5.21 of the 2004 HRM.
- Press **OK** to close the "Discharge Control Definition" dialog box.

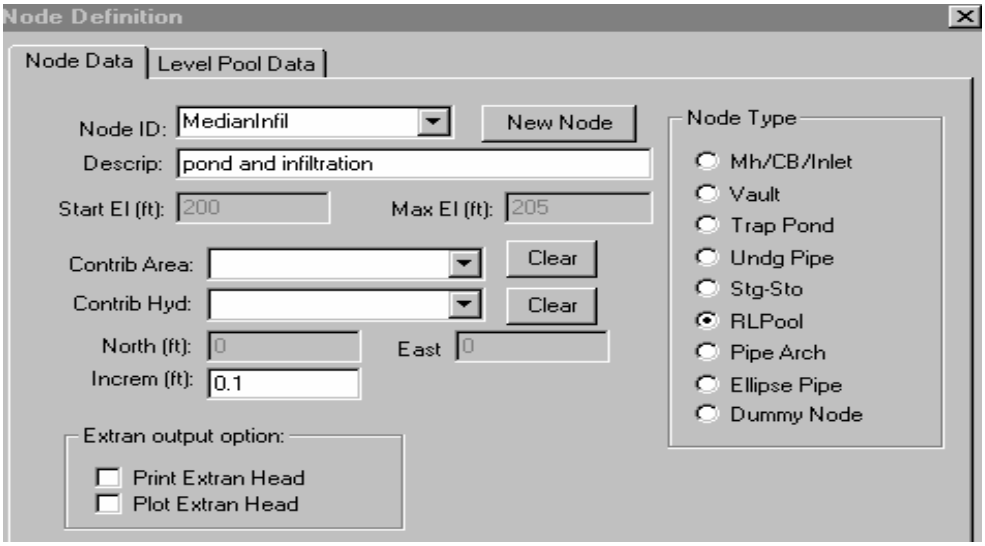


Define the RLPool Node

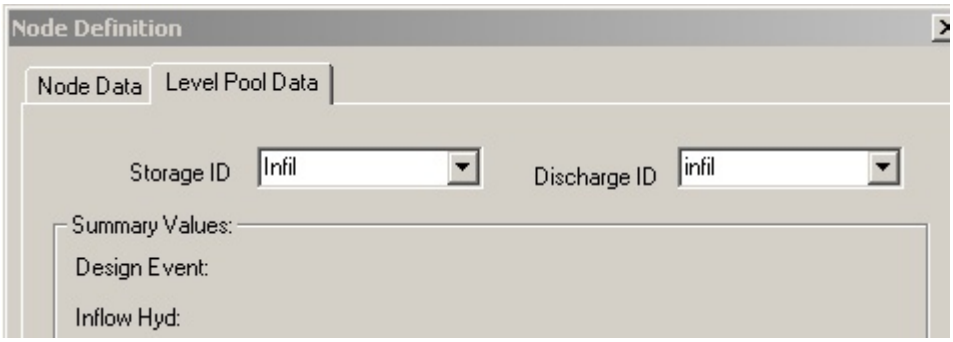
An RLPool node is created to define the storage and discharge structures used in the pond (reservoir) routing

- Double click on the PROTOTYPE node record found under the "Nodes" node in the Tree View.
- Press the **New Node** button.
- Change the "Next Auto ID" to MedianInfil.
- Press the **OK** button to close the "AutoLabel" dialog box.
- Change the "Node Type" to RLPool
- Change the description to pond and infiltration.

  Notice that we have not changed the "Start El" and "Max El".



- Click on the "Level Pool Data" tab.
- From the "Storage ID" drop down, select *infil*.
- From the "Discharge ID" drop down select *infil*.

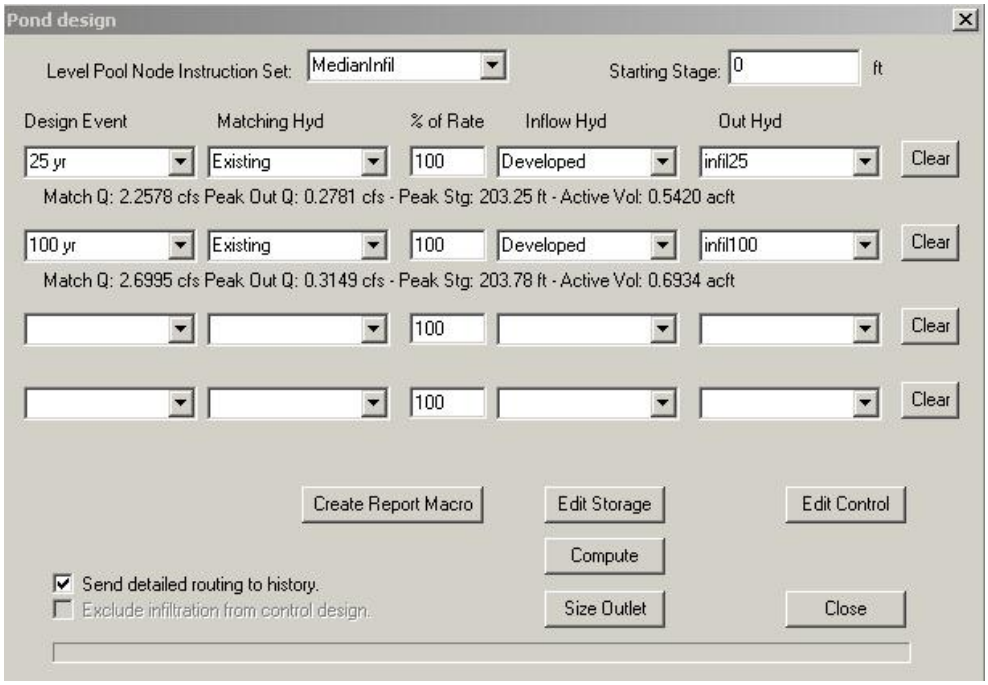


Sizing the Control Structure

- Using the popup menu in the Tree View, open the *Pond Design* dialog box.
- Select *MedianInfil* from the "Level Pool Node Instruction Set" drop down.
- Fill out the pond design dialog box as shown in MedianInfil.

All data in the dialog box is selected from the associated drop downs except for the "Out Hyd" column. This column specifies the ID's for the hydrographs that are routed through the pond. Make sure the 'Send detailed routing to history ' is docked.

Infiltration Pond Example



Results

Since this pond is being designed for flow control, the following requirements apply:

- Infiltrate the 25 year storm in 72 hours (starting after precipitation has ceased).
- 1' of freeboard above the peak level in the pond for the 25 year event.
- The 100 year storm should be checked for damages and flood control.
- The pond depth shall be designed to a desireable depth of 3' minimum and a maximum of 6' (plus a foot for freeboard).

V_{25yr}= 0.5420 acft x 43560 sf = 23610 cf

Q_{out} = 0.2781 cfs

V_{25y}/ Q_{out} = 23610 cf /0.2781 cfs = 24 hours

24 hours – 24 hours = 0 hours <72 hours

Therefore, a pond size of 300'x10' will exceed the freeboard and meet the infiltration requirements. Until more accurate data is available from the lab, this pond size should be used as the preliminary pond size.

Determining the Infiltration Rate

Once data from the lab has been received, see Laboratory Summary on the next page, the infiltration rate can be determined by performing few hand calculations and then utilizing the Infiltration Spreadsheet. This tutorial will first go through the hand calculations required and then proceed to the spreadsheet.

Hand Calculations

In section 4-5.2.1 of the HRM one test hole is required for every 5000 sqft of infiltrating surface in the pond. From Storm Shed, it was estimated that an infiltration pond of 300'x100' or 3000 sqft would be needed for this project site. Therefore only one test hole is required. Two samples were taken at the one test hole one at 14' and then one at 17'. For each depth an infiltration rate will be determined.

1. **Determine the saturated hydraulic conductivity using equation 4-12 in the HRM:**

$$\log_{10}(K_{sat}) = -1.57 + 1.90D_{10} + 0.015D_{60} - 0.013D_{90} - 2.08f_{fines}$$

Where:

D_{10}, D_{60}, D_{90}	=	grain sizes in mm for which 60 to 90 percent of the sample is more fine
f_{fines}	=	fraction of the soil (by weight) that passes the number 200 sieve
K_{sat}	=	saturated hydraulic conductivity in cm/s

Given the lab summary, input D_{10}, D_{60}, D_{90} and the percent fines as shown below for the 14' depth. Since the lab did not print the exact value for D_{90} it will need to be determined using the graph as shown on the following page. For this example it is found to be 0.85 for the test at 14' depth.

$$\log_{10}(K_{sat}) = -1.57 + 1.90(0.096) + 0.015(0.386) - 0.013(0.85) - 2.08(.071)$$

$$\log_{10}(K_{sat}) = -1.54$$

For those who have not used logarithm in a while, the equation above is equivalent to the following:

$$10^{-1.54} = K_{sat}$$

$$K_{sat} = 0.029\frac{cm}{s}$$

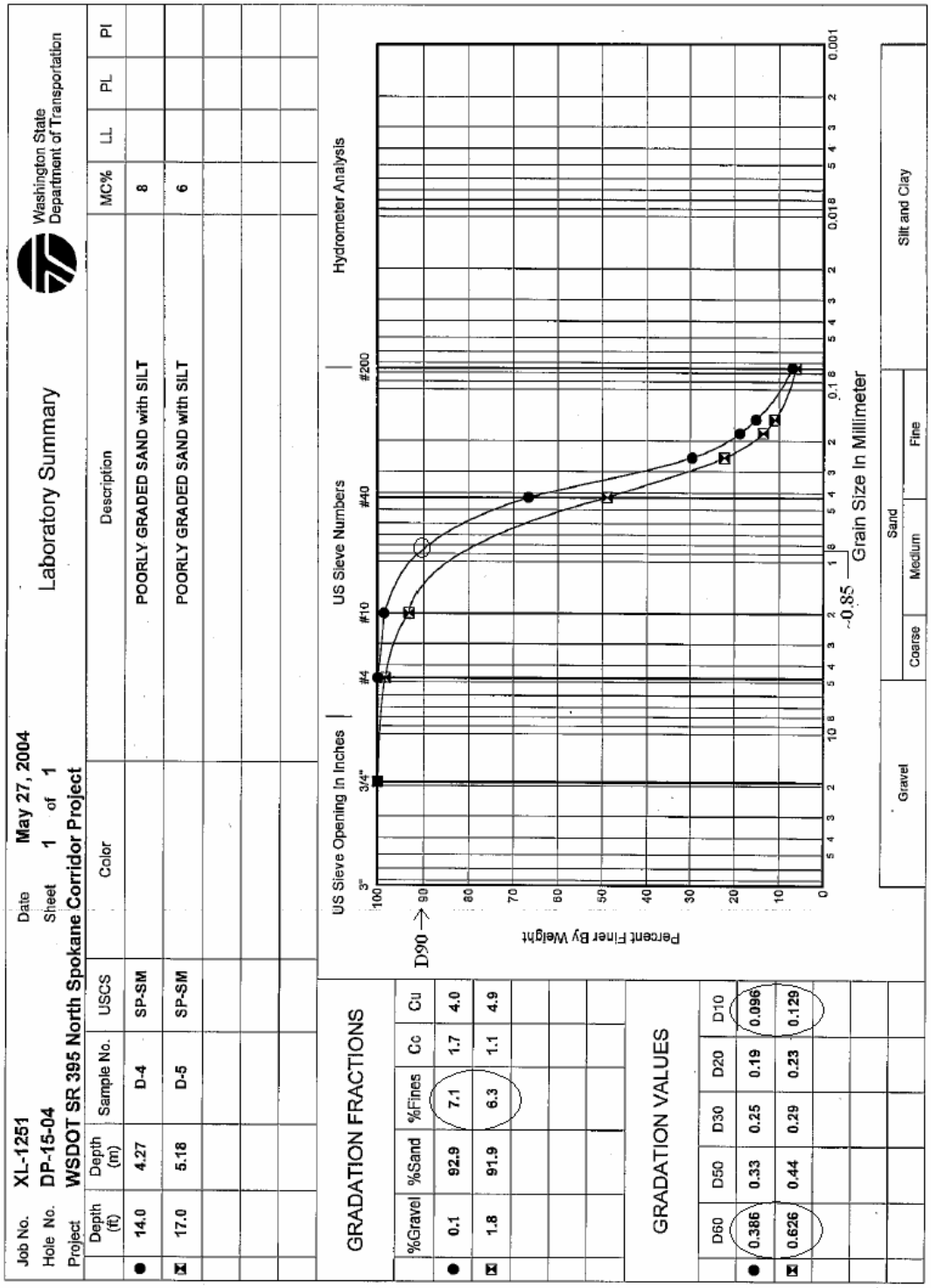
Next convert K_{sat} to inches per hour:

$$K_{sat} = 0.029\frac{cm}{s} \text{ x } \frac{0.394in.}{cm} \text{ x } \frac{60\,sec.}{min.} \text{ x } \frac{60\,min.}{hr} = 40.86\frac{in.}{hr}$$

Next, the process described above was repeated for the 17' sample.

$$K_{sat} = 0.034\frac{cm}{s} \text{ or } 48.5\frac{in}{hr}$$

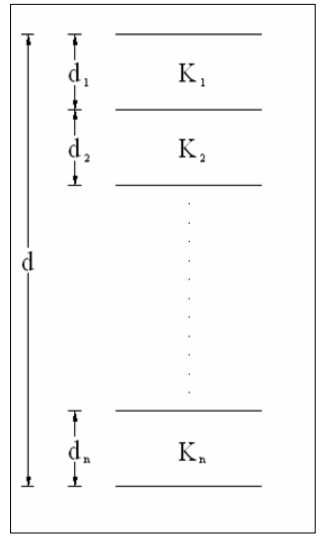
Infiltration Pond Example



2. Determine the effective average saturated hydraulic conductivity:

Since there is more than one saturated hydraulic conductivities for the test hole, the effective average saturated hydraulic conductivity ($K_{equiv.}$) will need to be determined using equation 4-13 from the HRM and the figure below.

$$K_{equiv.} = \frac{d}{\sum \frac{d_i}{K_i}}$$



Where:

$K_{equiv.}$ = average saturated hydraulic conductivity

d = total depth of soil column

d_i = the thickness of layer "i"

K_i = saturated hydraulic conductivity of layer "i"

$$K_{equiv.} = \frac{17}{\sum\left(\frac{14}{40.86} + \frac{3}{48.5}\right)} = 42.0\,\frac{in}{hr}$$

3. Determine the reduction factor to the infiltration rate due to long-term maintenance/performance monitoring or potential for biofouling.

Lastly, before going to the spreadsheet, we need to determine if there are any reductions to the infiltration rate resulting from long-term siltation and biofouling. The degree of long-term maintenance and performance monitoring anticipated, the degree of influent control (performance of presettling ponds, biofiltration swales, etc.) and the potential for siltation, litterfall, moss build up etc. based on the surrounding environment should all be considered. It should be assumed that an average to high degree of maintenance would be performed on these facilities. A low degree of maintenance should only be considered when there is no other option (i.e. access problems).

Using Table 4-11 below we will assume the biofouling in Spokane to be low and the maintenance/monitoring to be average to high yielding a $CF_{silt/bio}$ reduction factor of 0.9.

Table 4-11. Infiltration rate reduction factors to account for biofouling and siltation effects for ponds (Massmann, 2003).

Potential for Biofouling	Degree of Long-Term Maintenance/Performance Monitoring	Infiltration Rate Reduction Factor, $CF_{silt/bio}$
Low	Average to High	0.9
Low	Low	0.6
High	Average to High	0.5
High	Low	0.2

Infiltration Pond Example

Spreadsheet

Given the $K_{equiv.}$ and $CF_{silt/bio}$ calculated above and the size of the pond determined in Storm Shed, the values can now be input into the gray areas on the spreadsheet to determine stage storage discharge relationship. It should be noted that the size of the pond and the infiltration rates are dependant. The process described below is iterative and may take several tries before a final pond size can be reached.

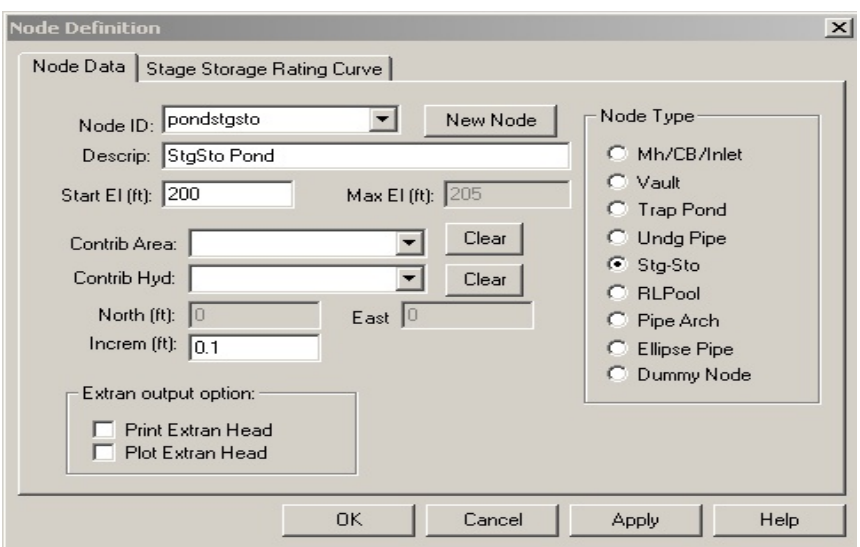
Infiltration Ponds			
Length of Pond Bottom (ft)	300	Width of Pond Bottom (ft)	10
Area of Bottom of Pond (acres)	0.07		
Pond Side Slopes (3:1 typical)	4		

Depth of Pond, D_{pond}	Depth to Water Table, D_{wt}	Hydraulic Conductivity, K_{equiv}	Area of Pond Bottom, A_{pond}	Hydraulic Gradient, i	CF_{H20}	Infiltration Rate, f	Length of Pond	Width of Pond	CF_{aspect}	$CF_{siltbio}$	Adjusted Infiltration Rate, f_{corr}	Infiltration	Pond Volume
Varies 1' to 6'	*Determined by Lab Tests*	*Equation 4-12*	*Determined by designer*	*Equation 4-14*	*Equation 4-15 (1.0 max)*	*Equation 4-16*			*Equation 4-17 (1.4 max)*	*See Table 4-11*	*Equation 4-18*	*converts in/hr to cfs*	*Calculated (or from CAICE)*
(ft)	(ft)	(in/hr)	(Acres)			(in/hr)	(ft)	(ft)			(in/hr)	(cfs)	(ft^3)
0													
1	9	42	0.07	0.05	1.00	2.08	308	18	1.32	0.9	2.48	0.323	4272
2	9	42	0.13	0.05	1.00	2.29	316	26	1.22	0.9	2.52	0.485	11152
3	9	42	0.19	0.06	1.00	2.50	324	34	1.17	0.9	2.64	0.677	20768
4	9	42	0.25	0.06	1.00	2.71	332	42	1.14	0.9	2.78	0.902	33248
5	9	42	0.32	0.07	1.00	2.92	340	50	1.12	0.9	2.93	1.160	48720

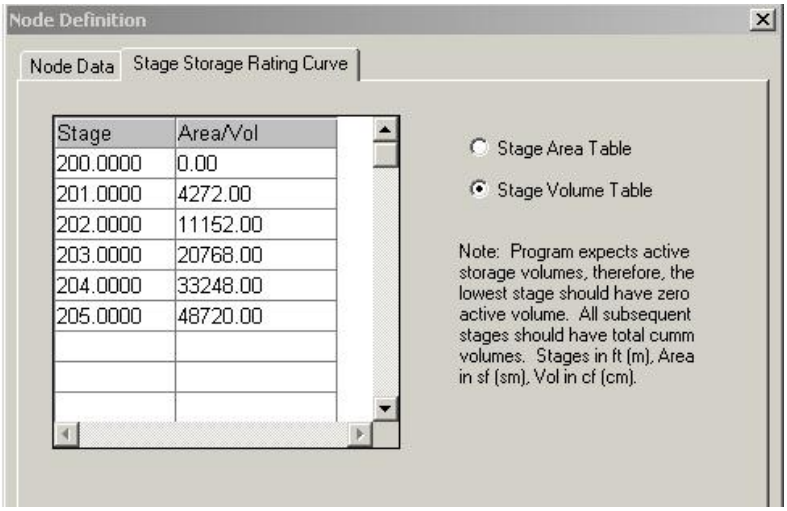
Define a Storage Element

For this project we are looking at different ponds that best fit our site. Our first choice is to design a Stage Storage pond since we have an area that already can be used for a pond with minor work involved.

- Double click on the node "PROTOTYPE" record.
- Click on the **New Node** button.
- Change the "AutoLabel" ID to <u>Pondstgsto</u>.
- Press the **OK** button to close the "AutoLabel" dialog box.
- The Start El is the bottom pond elevation at *<u>200ft</u>*



Defining the Stage Storage Pond

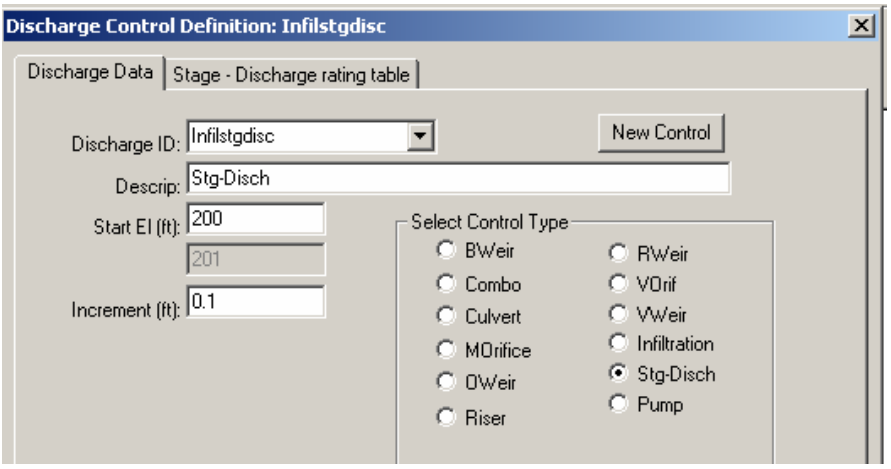


Defining the Stage Storage Pond dimension

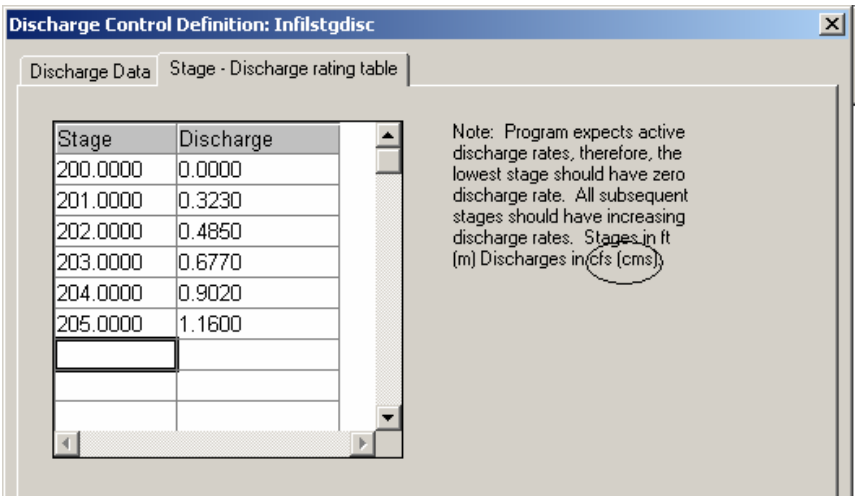
Define a Control Structure

We will start with a multiple orifice control structure and let the program size the orifice diameters.

- Double click on the PROTOTYPE record found under the "Discharge" node in the Tree View.
- Press the **New Control** button.
- Replace the "AutoLabel" ID with InfilStgDisc.
- Press **OK** to close the "AutoLabel" dialog box.
- Change the Control Type to "Stg-Disch".
- Change the "Outlet Elev" to 200.
- Change the "Max Elev" to 205.
- Click on the "Stage-Discharge Rating Table" tab.



- Input the values from the spreadsheet as shown below. ***Note that values need to be in CFS, the infiltration rate has been converted to CFS on the spread sheet in the second to last column.***

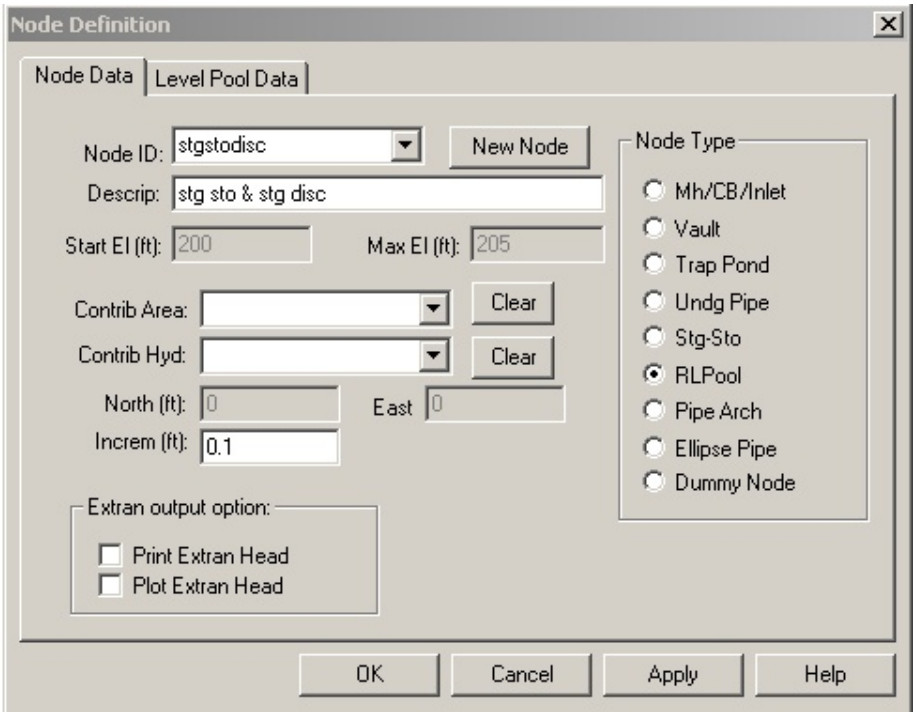


Defining Stage Discharge Control Structure

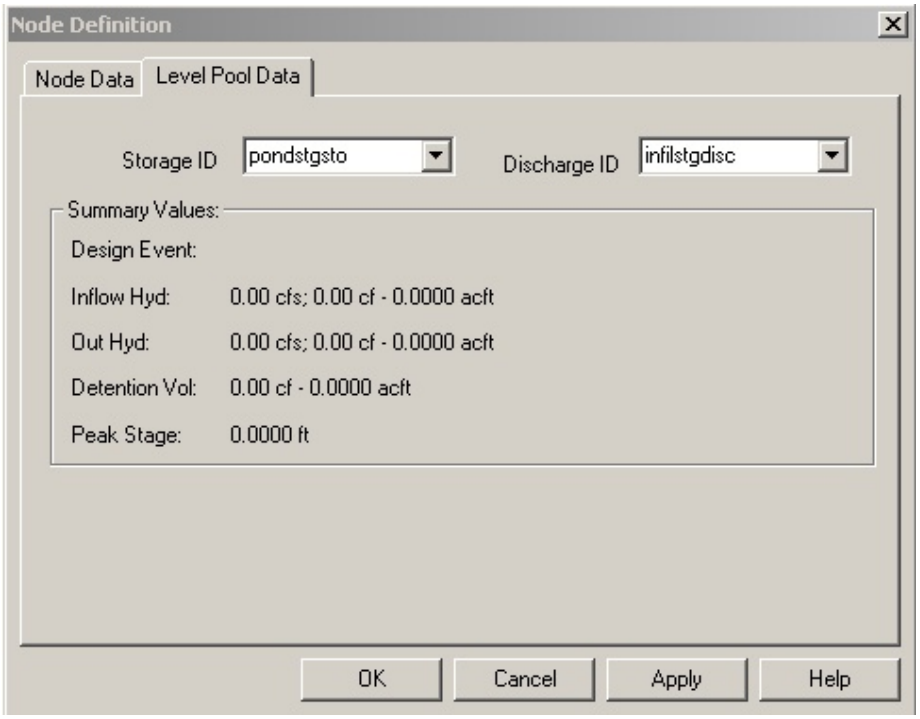
Define the RLPool Node

- Double click on the PROTOTYPE node record found under the "Nodes" node in the Tree View.
- Press the **New Node** button.
- Change the "Next Auto ID" to StgStoDisc.
- Press the **OK** button to close the "AutoLabel" dialog box.
- Change the "Node Type" to RLPool
- Change the description to Stg Sto & Stg Disc.

Notice that we have not changed the "Start El" and "Max El".



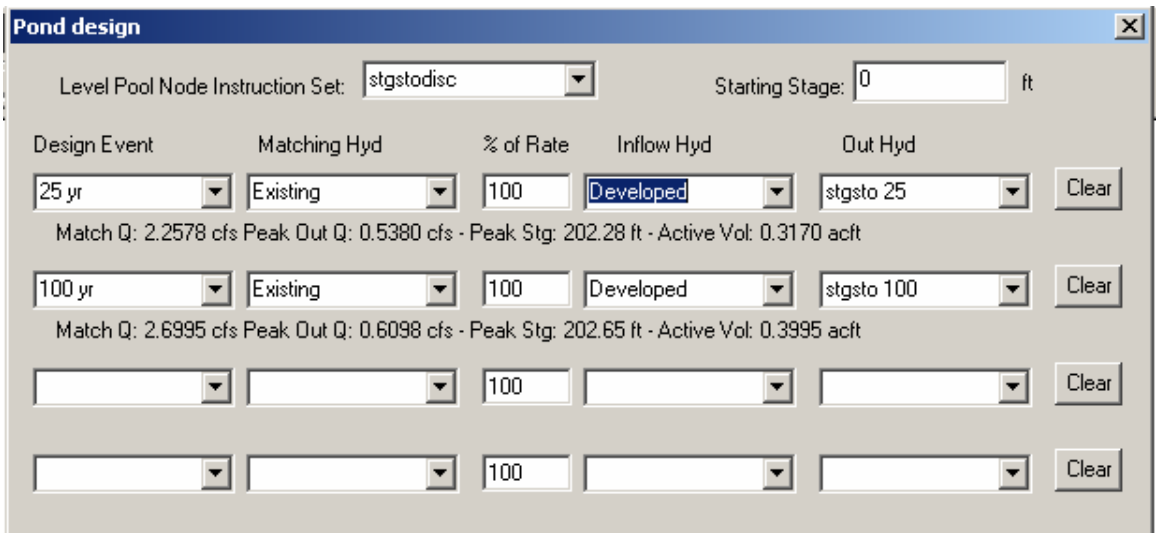
- Click on the “Level Pool Data” tab.
- From the “Storage ID” drop down, select *pondstgsto*.
- From the “Discharge ID” drop down select *infilstgdisc*.
- Click on the “Node Data” tab



Sizing the Control Structure

- Using the popup menu in the Tree View, open the *Pond Design* dialog box.
- Select *Stgstodisc* from the "Level Pool Node Instruction Set" drop down.
- Fill out the pond design dialog box as shown in below.
- Press the **Compute** button.

All data in the dialog box is selected from the associated drop downs except for the "Out Hyd" column. This column specifies the ID's for the hydrographs that are routed through the pond.



From the above Pond Design, it can be noted that the free board criteria is more than exceeded. Next the V/Q relationship is checked to verify the drawdown requirements are met.

V_{25yr}= 0.3170 ac-ft * 43560sf/ac = 13808.5 cft
Q_{out} = 0.538 cfs
V_{25y}/ Q_{out} =13808.5/0.538 = 25666.4 sec = 7 hours < 72 hours

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As noted above the infiltration criterion is also exceeded. Therefore the pond size could be reduced. Remember the infiltration rate is dependant on the pond size, so it is necessary to reduce the pond size in the spreadsheet and in Storm Shed until the criteria is met and the pond size is optimized.

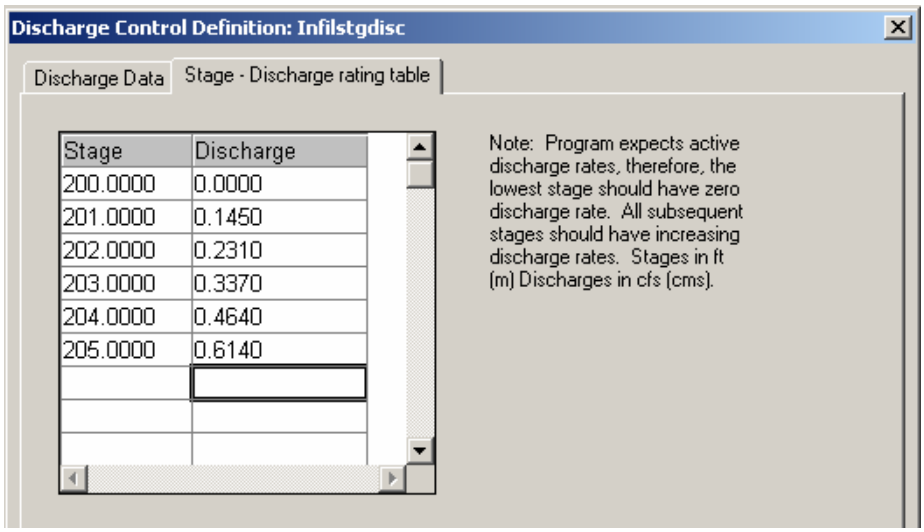
Infiltration Pond Example

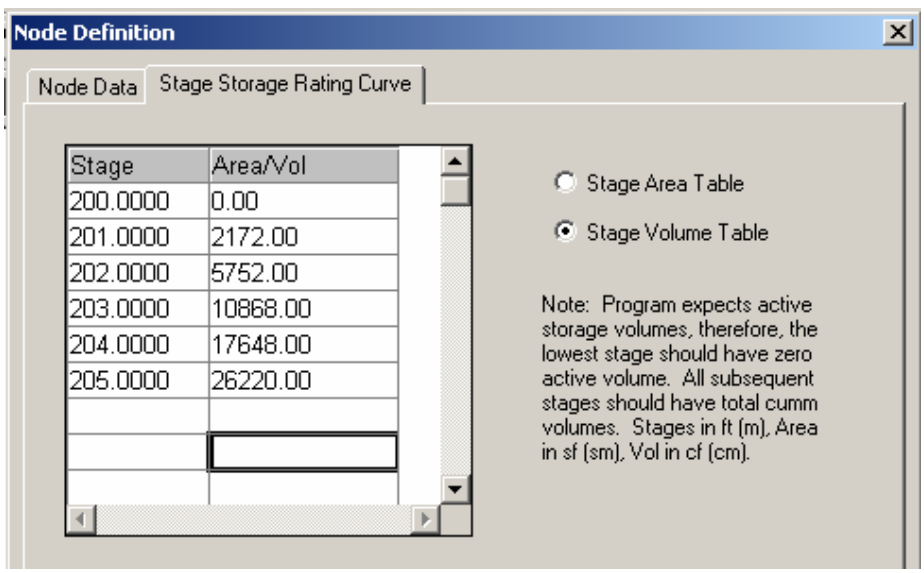
Lets repeat the process with a 150’x10’ pond.

Infiltration Ponds

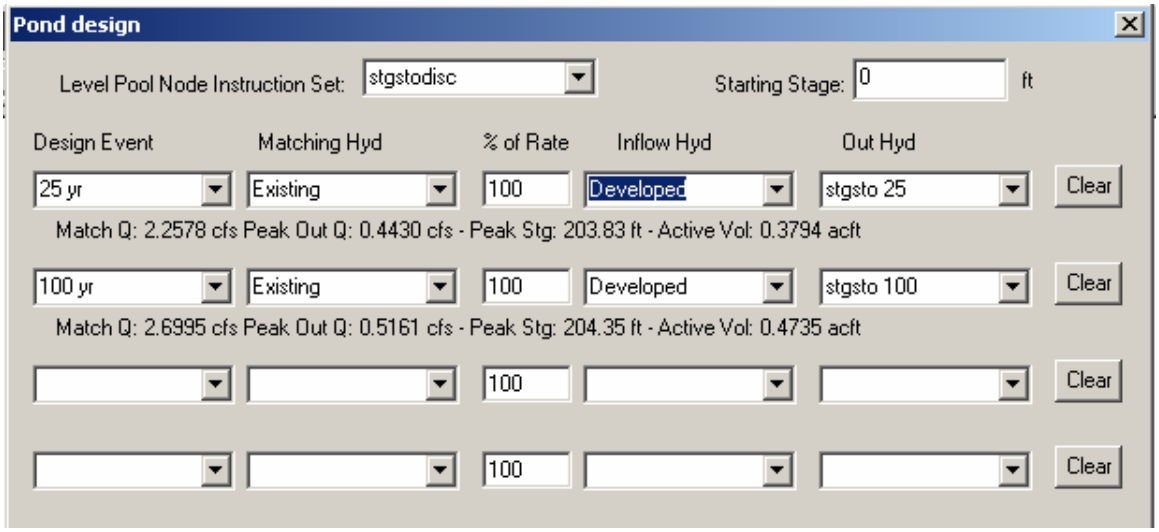
Length of Pond Bottom (ft)	150	**Width of Pond Bottom (ft)**	10
Area of Bottom of Pond (acres)	0.03		
Pond Side Slopes (3:1 typical)	4		

Depth of Pond, D_{pond}	Depth to Water Table, D_{wt}	Hydraulic Conductivity, K_{equiv}	Area of Pond Bottom, A_{pond}	Hydraulic Gradient, i	CF_{size}	Infiltration Rate, f	Length of Pond	Width of Pond	CF_{aspect}	$CF_{siltbblo}$	Adjusted Infiltration Rate, f_{corr}	Infiltration	Pond Volume
Varies 1' to 6'	*Determined by Lab Tests*	*Equation 4-12*	*Determined by designer*	*Equation 4-14*	*Equation 4-15 (1.0 max)*	*Equation 4-16*			*Equation 4-17 (1.4 max)*	*See Table 4-11*	*Equation 4-18*	*converts in/hr to cfs*	*Calculated (or from CAICE)*
(ft)	(ft)	(in/hr)	(Acres)			(in/hr)	(ft)	(ft)			(in/hr)	(cfs)	(ft^3)
0													
1	9	42	0.03	0.05	1.00	2.08	158	18	1.16	0.9	2.17	0.145	2172
2	9	42	0.07	0.05	1.00	2.29	166	26	1.11	0.9	2.29	0.231	5752
3	9	42	0.10	0.06	1.00	2.50	174	34	1.08	0.9	2.44	0.337	10868
4	9	42	0.14	0.06	1.00	2.71	182	42	1.07	0.9	2.60	0.464	17648
5	9	42	0.18	0.07	1.00	2.92	190	50	1.06	0.9	2.77	0.614	26220





Infiltration Pond Example



From the above Pond Design, it can be noted that the freeboard criterion is met with the max pond elevation being Elevation 205. Next the V/Q relationship is checked to verify the drawdown requirements are met.

V_{25yr} = 0.3794 acft * 43560 sf/ac = 16526.7 cft
Q_{out} = 0.4430 cfs
V_{25yr} / Q_{out} = 16526.7 / 0.4430 = 37306.2 sec = 10 hrs < 72 hrs

As noted above, the drawdown requirement has also been met. This pond design is acceptable and could still be reduced in size if needed so long as the 100 year storm did not exceed the 205' elevation and the 72 hour draw down time was met.

In addition to the two criteria listed above, there are other site suitability criteria that must be considered for silting infiltration treatment systems. These criteria are documented in the 2004 HRM Section 4-5.5 and include setback requirements, seepage analysis and control, groundwater protection areas, depth to groundwater, soil infiltration rate, drawdown time, soil physical and chemical suitability for treatment and cold climate and impacts of roadway deicers. When a site investigation reveals that nay of the 8 applicable criteria cannot be met, appropriate mitigation measurers must be implemented so that the infiltration facility will not pose a threat to safety, health, and the environment.