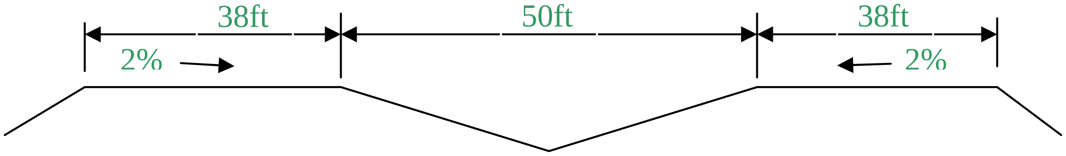
In this example you will:

- Learn more about Flow Control or Minimum Requirement 6 in the Highway Runoff Manual (HRM).
- Review the definition of a Detention Pond as presented in the HRM.
- Create an inflow hydrograph for the detention pond using the hydrograph subtraction command.
- Display the hydrographs.
- Create a stage storage detention pond.
- Model three different outlets including: sizing an orifice, an orifice/weir combo, and a drywell.
- Route a hydrograph through the detention pond using three different outlet structures.

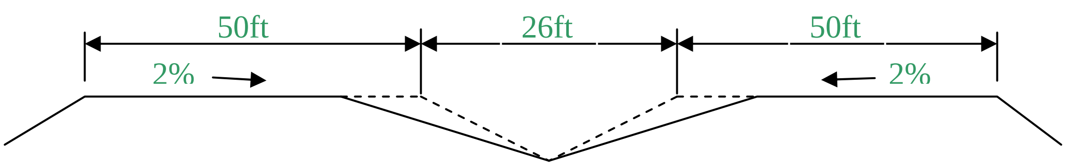
Detention Pond Example

A section of highway near the city of Spokane (Climatic Region 3) is to be improved with an additional lane in each direction. Design a detention pond (BMP FC.03) using the data below, as well as the flow control guidance and design criteria on the following pages.

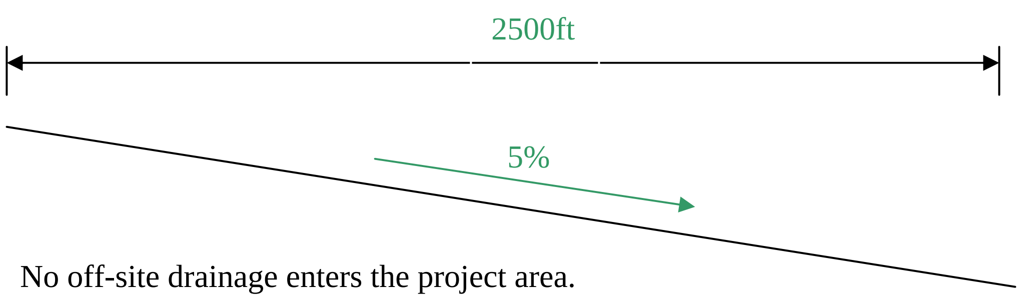
- The existing configuration consists of **two 12-foot lanes** with a **6-foot shoulder** on one side and an **8-foot shoulder** on the other in each direction.
- The north and south bound lanes are separated by a 50-foot grassed median.



- The proposed project will add **one 12-foot lane in each direction** on the inside into the median, while maintaining the current shoulder widths.
- The pavement is **sloped 2%** towards a **"V" shaped median** acting as a conveyance system with **4:1 side slopes**.



- The roadway profile is **2500' long** on a **continuous 5%**.



- No off-site drainage enters the project area.
- The median area is **grassed with no appreciable amount of brush** and the soil in the project vicinity has a NRCS identification as **Spokane**. From the TR55 CN Tables in Appendix 4B in the HRM, Table 4B-1 rates Spokane soils as **Type C.** From Table 4B-3 for EWA, **Meadow cover for type C soils has a CN=71**.
- The **existing** roadway contributes **4.36 acres of impervious** runoff and the **2.87 acres of pervious** runoff.
- The proposed project will contribute **5.74 acres of impervious** surface and **1.49 acres of pervious** runoff.

Flow Control Definition

Flow control is Minimum Requirement 6 in the HRM. Unless an exemption applies (see section 3-3.6 of the HRM), any project that adds 5,000 square feet or more of net-new impervious surfaces in a TDA must provide flow control of stormwater runoff. The objective of flow control is to prevent increases in the erosion rates beyond those characteristics of natural or re-established conditions. The intent is to prevent cumulative future impacts from increased stormwater runoff volumes and flow rates on streams and off WSDOT ROW. Whenever possible, infiltration should be used to provide flow control.

Flow Control Design Guidance

Unless an exception applies, the flow control design criteria for detention facilities, summarized in Table 3-7, should be followed. The goal is to maintain the pre-existing runoff rates at the project location after the proposed project has been constructed. Whenever possible, infiltration should be used to provide flow control. If infiltration is not possible, runoff should be detained in a detention pond and released at the rates shown in Table 3-7.

Table 3-7. Eastern Washington flow control criteria.

Facility Type	Criteria	Model
Detention/combination treatment and detention facilities	Provide storage volume required to match ½ of the 2-year predeveloped peak flow rate and match the predeveloped 25-year peak flow rate, and check the 100-year peak flow for property damage.	Single Event Model (SCS or SBUH) Climatic Regions 1–4 Regional Storm; OR Type 1A Storm for Climatic Regions 2 & 3 only
Infiltration facilities	Size facility to infiltrate the entire volume of the 25-year storm with an overflow, and check the 100-year peak flow for property damage, or infiltrate 100 % of the storm runoff volume.	Single Event Model (SCS or SBUH) Climatic Regions 1–4 Regional Storm; OR Type 1A Storm for Climatic Regions 2 & 3 only

As noted in the **Model** column of **Table 3-7**, the volume from the Regional Storm for Climatic Regions 1–4; OR Type 1A storm for Climatic Regions 2 and 3 should be used to size the detention facility.

In many instances, the 2-year pre-developed flow rate is zero cubic feet per second, or the flow rate is so small that it is impracticable to design a pond to release at the prescribed flow rate from an engineered outlet structure. In these cases, the total post-developed 2-year storm runoff volume must be infiltrated (preferred) or stored in a retention pond for evaporation, and the detention pond designed to release the pre-developed 10- and 25-year flow rates. See BMP FC.03 Detention Pond in Section 5-4.2.3 for pond and release structure design information.

Down Stream Analysis

Any outfall that leaves WSDOT Right of Way is required to have a Down Stream Analysis (DA) as part of the Hydraulics Report. A DA examines the impacts an outfall will on a conveyance system downstream of the project site. Section 4-7 of the Hydraulics Manual provides details of the analysis.

Detention Pond Definition

Detention ponds are open basins that provide live storage volume to enable reduction of stormwater runoff flow rates and allow matching of predeveloped flow durations discharged from a project site. Detention ponds are commonly used for flow control in locations where space is available for above ground facility but where infiltration of runoff is infeasible.

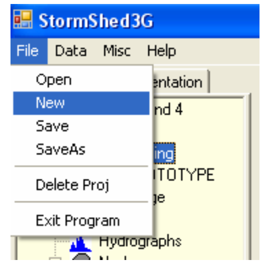
Design Criteria

The following is a summary of section FC.03, Detention Ponds from the HRM.

- Detention ponds are designed to drain completely within 72 after a storm event so that the live storage volume is available for the next storm.
- The pond should with 1’ of freeboard above the 25 year design storm and the designer should verify the 100 year storm does not cause any damage to downstream property.
- Generally the facility is sized by subtracting the existing basin runoff from the proposed basin runoff and using that volume as a starting place to size the pond. This is done so the detention pond contains additional runoff from the proposed basin, while maintaining the runoff conditions from the existing basin.
- Ponds must be a minimum of 5’ from any property line or vegetative buffer and 100’ from any septic tank or drain field.
- The interior of the pond should be hydroseeded up to the 100 year elevation.
- Follow the guidelines in section 5-3.7.1 from the Highway Runoff Manual, to provide maintenance access to the ponds.
- A primary overflow (usually a riser pipe within the outlet control structure) must be provided for the detention pond system to bypass the 100 year developed peak flow. A secondary emergency overflow can be provided as additional protection against overflows should the designer feel that the primary overflow would likely become plugged.

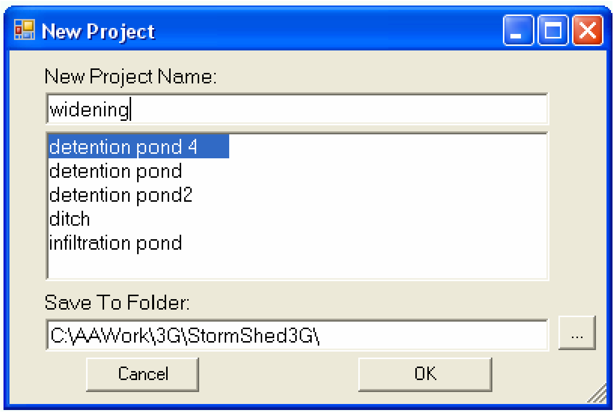
*In addition to the guidelines noted above, designers should review the process for designing flow control facilities in EWA outline in **section 4-4.5** of the HRM. This tutorial was developed using the outline and sections are noted throughout in blue.*

Start a new project



To start a new project in StormSHED, we first need to name a new project.

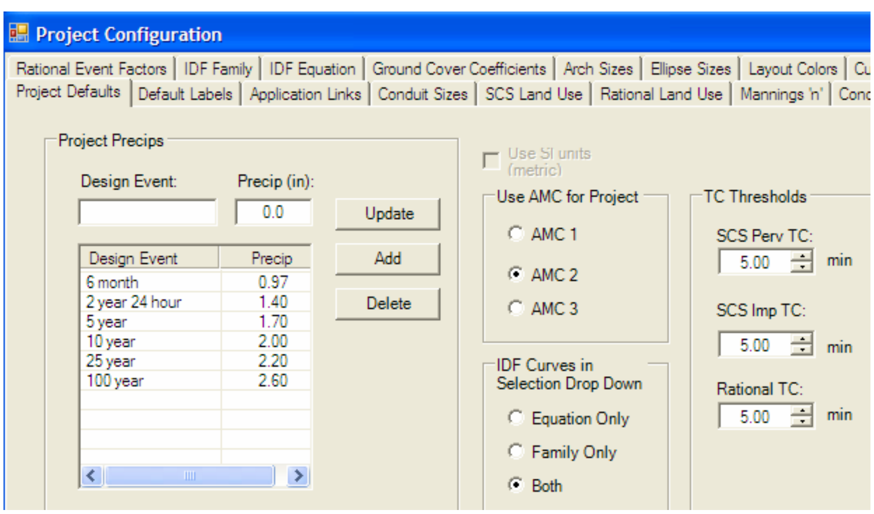
- Open StormShed 3G and select **File>New** from the main toolbar.
- Create a new project by selecting: **File>New**
- Enter the project name <u>**widening**</u> in the New Project Name input field and hit **OK**.



Determine Rainfall Depths

Rainfall Setup

Open the Project Configuration dialog box by selecting **Data>Config** from the program menu. Using the methods described in the **Regional Storm Tutorial**, determine the precipitation values and input as shown below and click on the **Close** button to close the dialog box.



- Change the precipitation for the <u>**2 yr 24 hour**</u> event to <u>**1.4**</u> inches.
- Change the precipitation for the 6 mo. event to <u>**0.97**</u> inches (Appendix 4D notes that the 6 month storm for Spokane is 0.69*2 yr storm or 1.4*0.69 = 0.97)

Determine the predeveloped and postdeveloped time of concentration.

Select the storm hyetograph and analysis time interval.

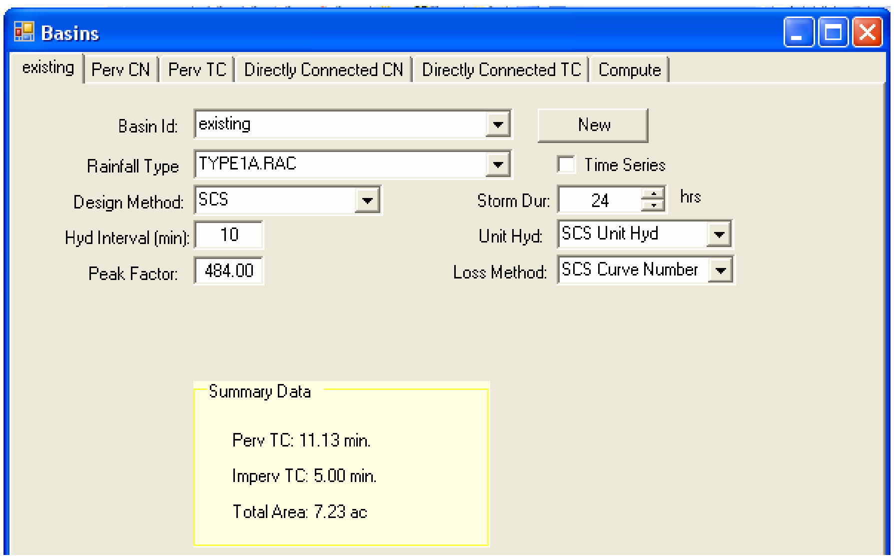
For each TDA input the values in to StormSHED.

Defining Drainage Areas

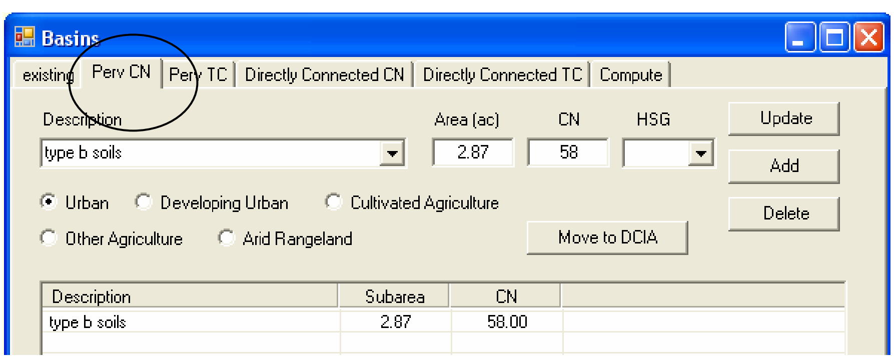
Create Existing Basin

First define the existing drainage area then work from left to right going through the tabs.

- 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

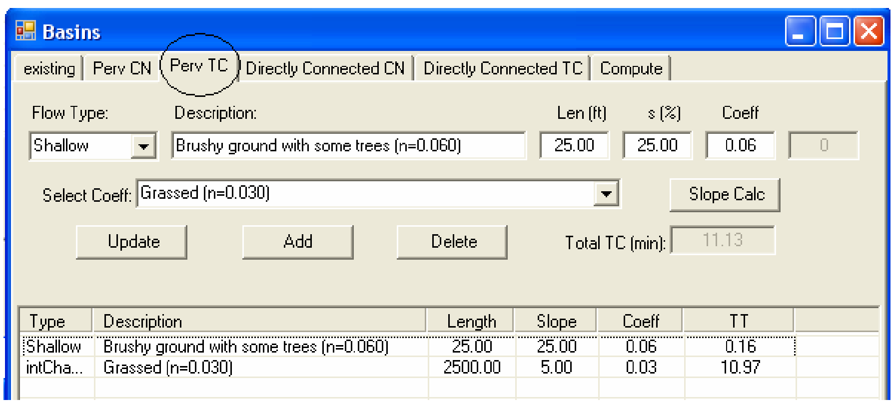


- Click on the **Update** button.

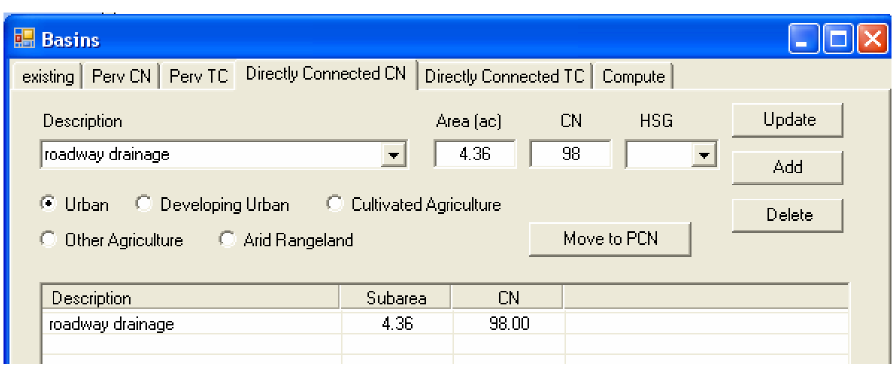
- Delete any default areas that are not used.

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.

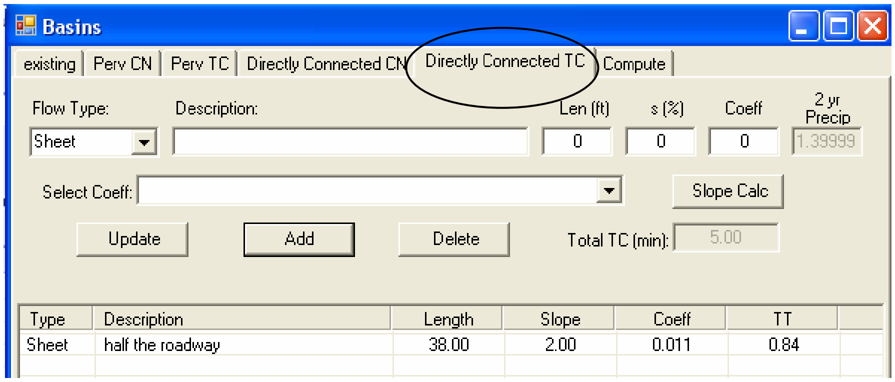
- Click on the "***Perv TC***" tab.
- Click on one of the default travel time reaches to modify it.
- Make it **Shallow flow**, **25 feet** in length with a **slope of 25%**. For the coefficient, use **Short Grass** to depict the median.
- Click on the **Update** button.
- Modify the "***Flow Type***" drop down to **int. Channel**.
- Change the description to **Grassed** reflect drainage down the ditch.
- Change the length to **2500 feet** with a slope of **5%**.
- Select **Grassed** for the coefficient.
- Press the **Add** button.
- Delete any default areas that are not used.



- Add the roadway drainage area and CN value of the project site.
- Click on the "***Directly Connected CN***" tab.
- Modify per Figure below and press the **Add** button.



- Add the Sheet flow shown in the figure below.

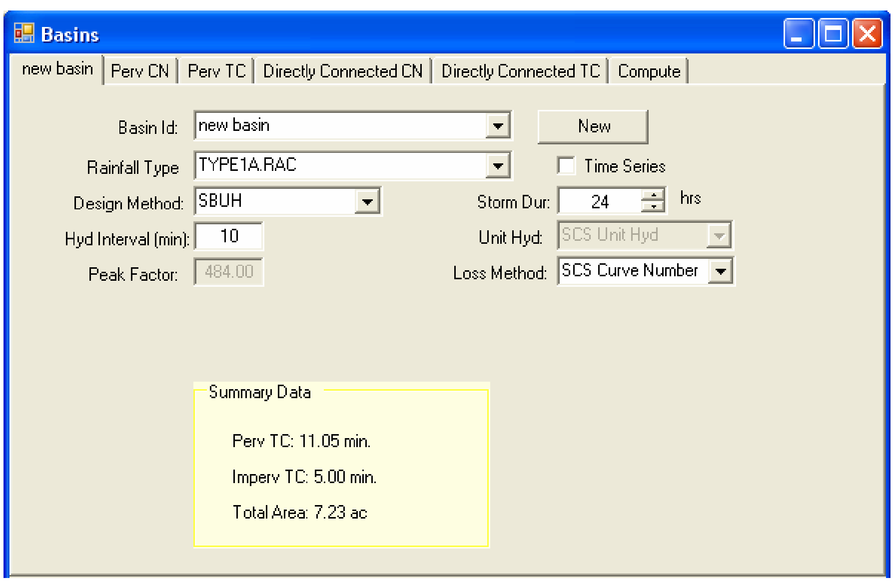


- Click on the "***Directly Connected TC***" tab..
- Make it *Sheet flow*, **38 feet** in length with a slope of **2%**. For the coefficient, use **Smooth surface** to depict the roadway
- Click on the **ADD** button

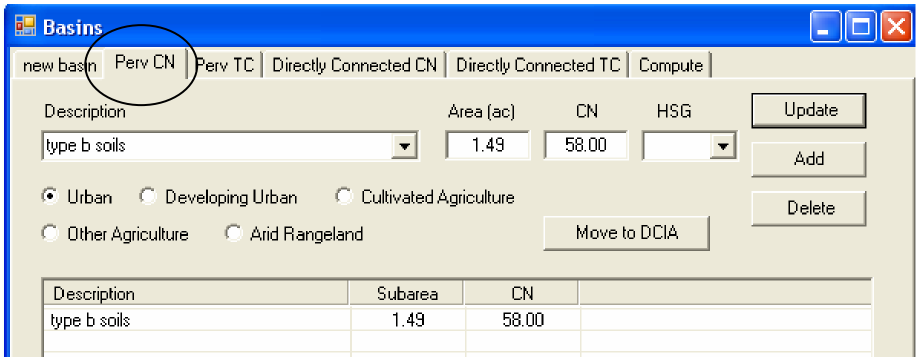
Create Developed Basin

The "Existing" basin can now be used as a template for the developed basin. This will save time, as all the values entered will remain as defaults The designer will only need to modify the numbers that are different.

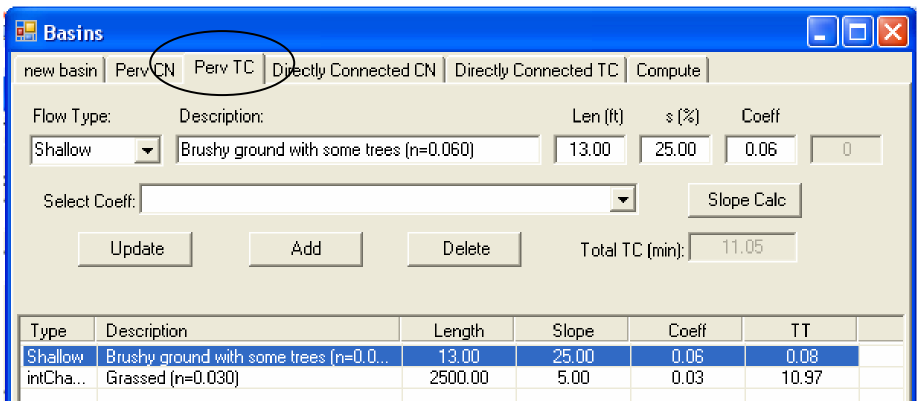
- Double click on the "Existing" basin under the "Basins" node in the Tree View.
- Press the **New Basin** button.
- Enter **new basin** for the Basin ID.



- 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

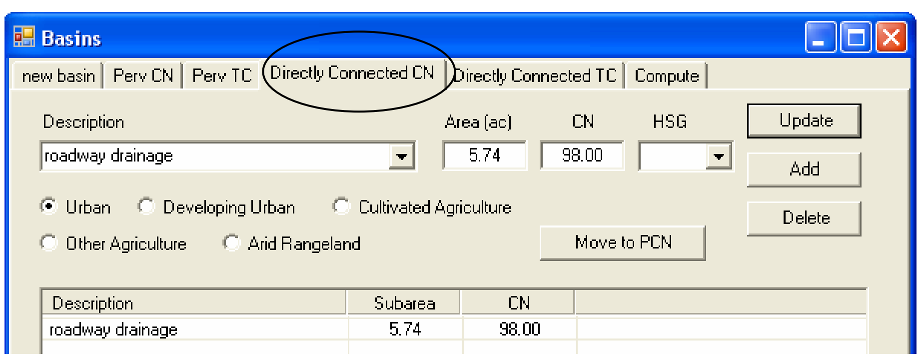


- Click on the “**Perv TC**” tab
- Modify half the roadway Shallow flow to *13ft*
- Click the **Update** button

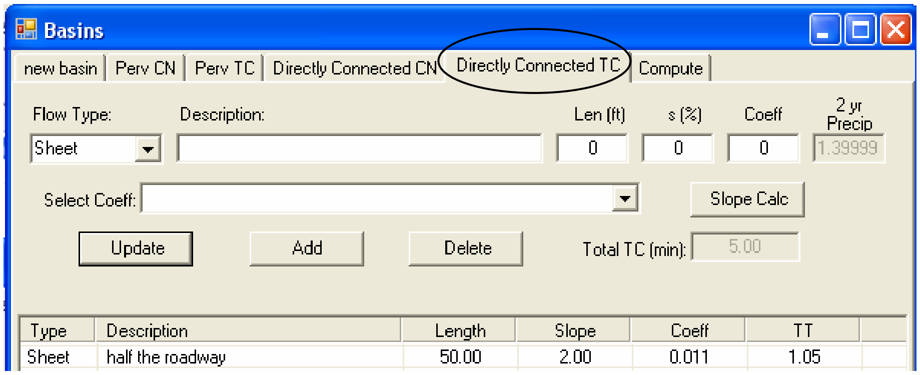


The last step is to modify the impervious roadway for developed conditions.

- Click on the “***Directly Connected CN***” tab.
- Modify the Roadway drainage area to **5.74** acres.
- Click the **Update** button



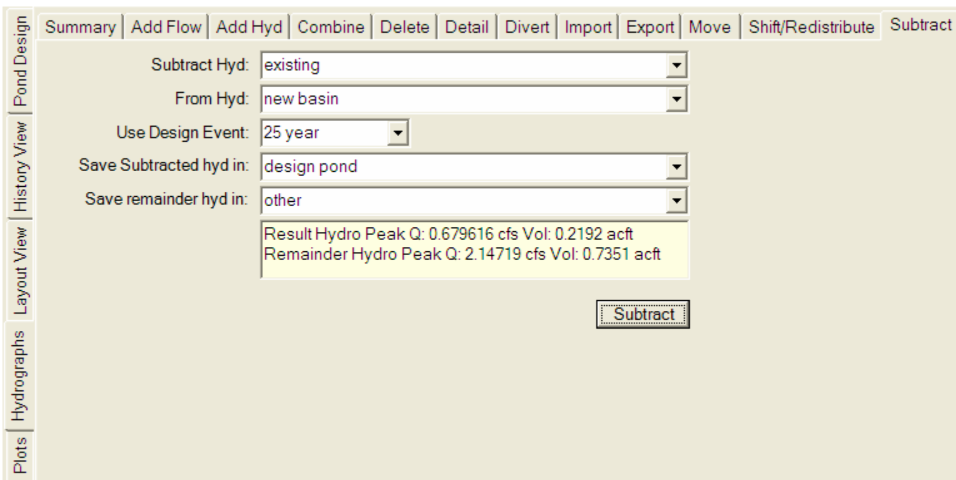
- Click on the “***Directly Connected TC***” tab
- Modify half the roadway Sheet flow to **50ft**
- Click the **Update** button

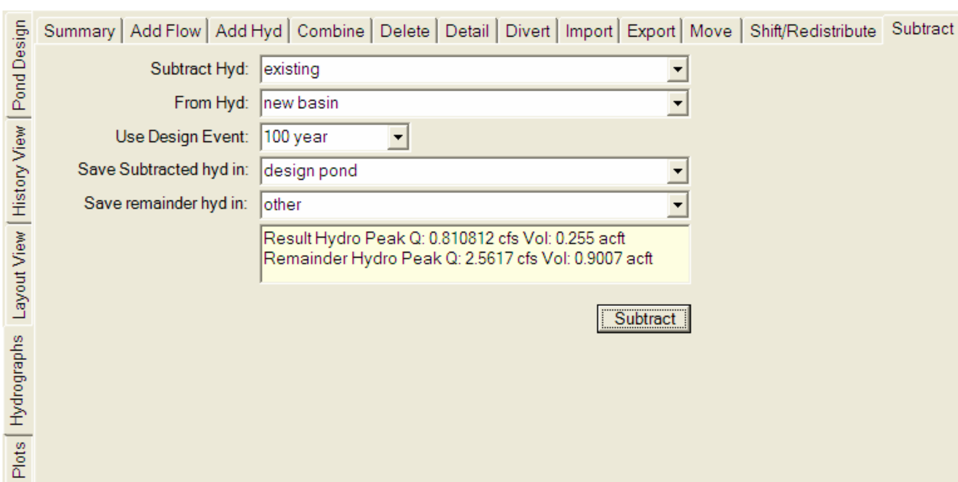


Estimate the Pond Size

We are going to estimate the pond size by subtracting the existing and new basin hydrographs.

- From the Layout View menu, select the tab marked >***Hydrograph*** Click on the "**Subtract**" tab.
- Input the values shown below for the 25 year Design Event and hit Subtract. Repeat using the 100 year Design Event.





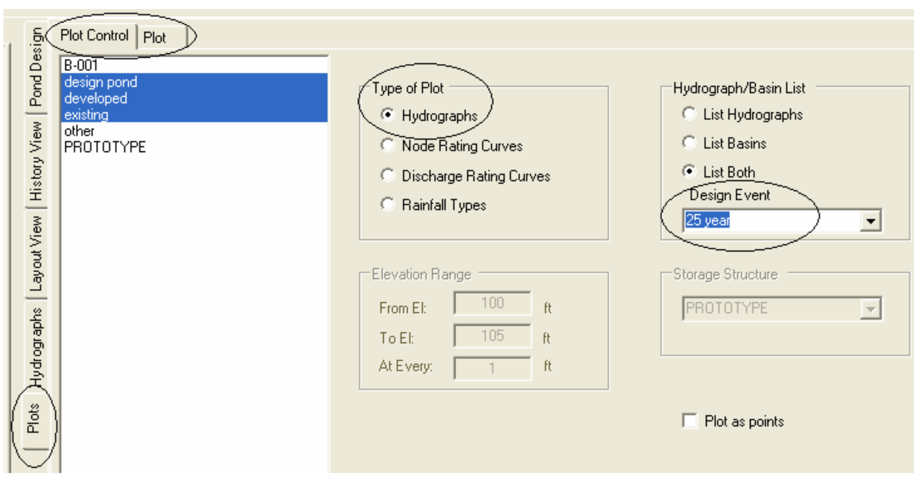
The results are shown in the lower box. We are interested only in the '**Result Hydro Peak Vol**'. **0.22 acft**, which will be used as a starting place to design the pond. The 'Remainder Hydro Peak' is the same as the existing basin or the volume that will be released from the pond (as opposed to the **result hydro peak vol** being contained in the detention pond). A more detailed description of the difference between 'Result' and 'Remainder' is described in the '**Hydrographs in 3G Description**' Section later in this tutorial.

Have StormSHED compute a hydrograph

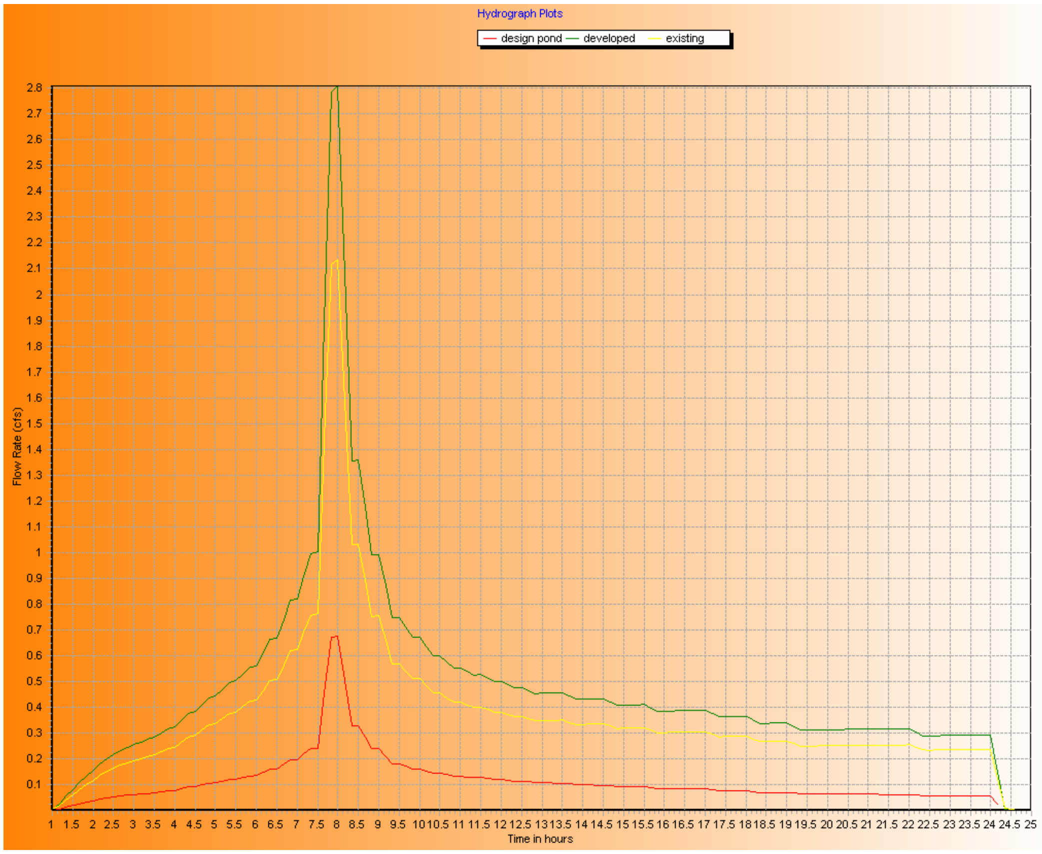
Create a hydrograph

Next we will create a hydrograph given the data we have input into StormSHED so far. Using the subtract function does not create a hydrograph, it only computes the peak Q and volume. To view the hydrograph, follow the directions outlined in the bullet items below:

- To see the hydrograph select the '***Plots'*** tab, located right below the '***Hydrograph***' tab in the Layout View.
- Select the '**design pond**', '**existing**', and '**developed**' (to select all three, hold the control key down and use a single LMB click on each name).
- The *Type of Plot* we want is a **hydrograph**.
- The *Hydrograph/Basin List*, allows the design to only display hydrographs or basins or both in the column on the left side. We want both so, select the **List Both** radio button.
- From the *Design Event* pull down menu, select 25 year.
- Next select the '***Plot***' tab to see the Hydrograph for the options we selected.

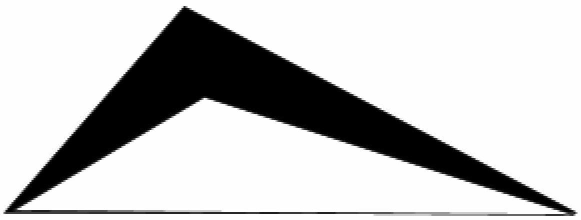


A Hydrograph looking similar to the one below should appear. When the developed hydrograph (green) and the existing hydrograph (yellow) are subtracted, the new hydrograph created is 'design pond' in red (or the area that needs to be stored in the detention pond.



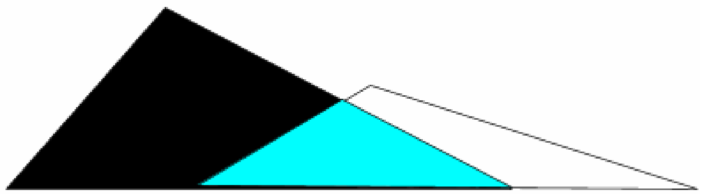
Hydrographs in 3G Description

In the Hydrograph Subtract Tab, there were two names required to save the hydrographs '*Result Hydro Peak*' and '*Remainder Hydro Peak*', this section provides a more detailed explanation of these terms. In the example we were only concerned with the '*Result Hydro Peak*' or the black area shown below, which is the difference between the runoff generated from the existing basin and the runoff generated from the proposed basin. The white area represents the existing basin or the '*Remainder Hydro Peak*'.



Overlap Hydrograph

If the hydrographs were actually offset, they might look like what is shown below. Where the black hydrograph is the developed basin and the combination of the aqua and white is the existing. When the existing is subtracted from the developed, the area shaded in black is the area that is required for storage and the area in aqua is the remainder runoff, from a detention perspective; it is the volume that will theoretically be released from the pond. In this case the sum of the subtracted and remainder hydrographs would have the same volume as the developed hydrograph.



Offset Hydrograph

For the offset hydrograph, the Subtract feature doesn't concern itself with the area in white, it only reports the subtracted area and the remainder area.

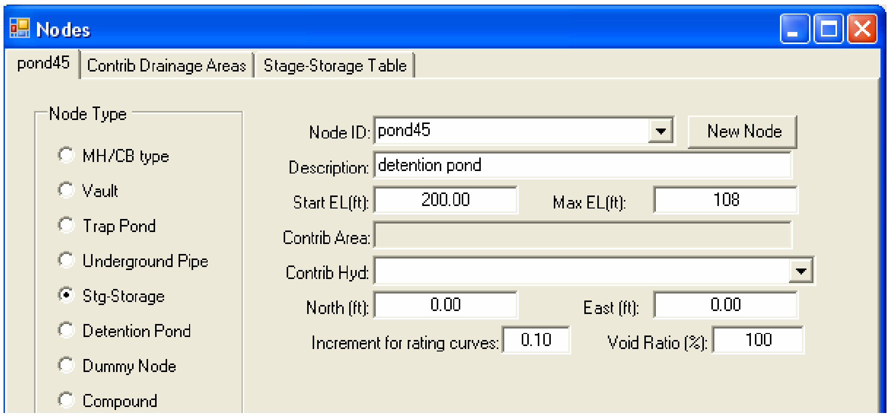
Assume the size of the detention facility

Define a Storage Element

For this project we will be designing a Stage Storage Pond with different outlets. The first-step is to design a Stage Storage pond.

- In the Tree View, double click on the node "*PROTOTYPE*" record.
- Click on the **New Node** button and change the "AutoLabel" ID to **Pond45**.

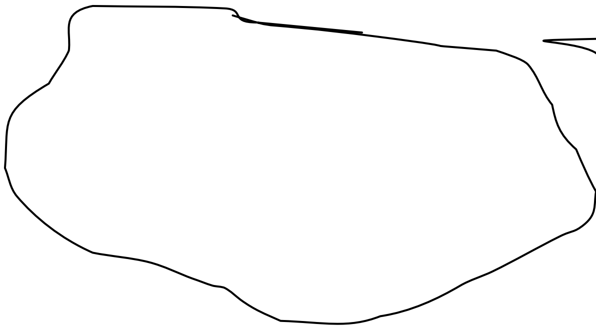
  Press the **OK** button to close the "AutoLabel" dialog box.The *Start El* is the bottom pond elevation, for now leave it at **108ft**., StormSHED 3G will



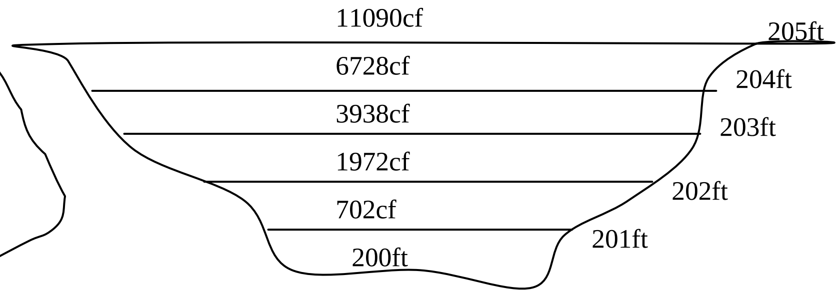
  automatically change these values once the stage-storage table has been created.

On the next page is the detention pond plan and cross sectional views, including staged elevation and volume information.

Plan View of Odd Shape

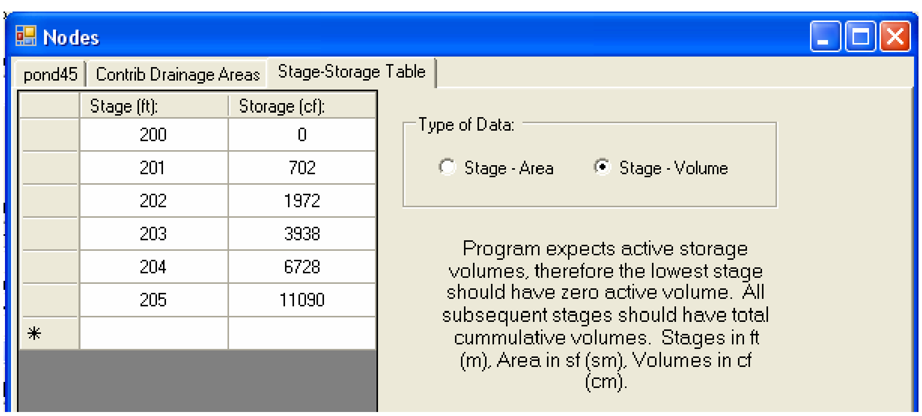


Cross Section View of Odd Shape Pond



The dimensions are selected using the area available for a pond and the volume from the 100 year storm (the subtracted volume from the existing and developed hydrograph) of about **11090 cubic**-feet with a depth of five (5) feet. ***The volume per stage can be calculated using Inroads for odd shape ponds***. On a real project, the designer might use this process when right of way is limited and to try to fit a pond in the space available. Then the odd shape could be input into 3G using a volume per stage as noted above and illustrated on the next page. If space was not limited, the trap pond command could be used till the desired volume was achieved (see the Infiltration example).

- Input the values from InRoads into the ***Stag-Storage Table*** tab as shown below.
- Verify the **Stage-Volume** radio is selected.
- Select the '**pond 45**' tab and note the bottom elevation has automatically changed to **205 feet**.
- Hit '**Ok**' to close the box.



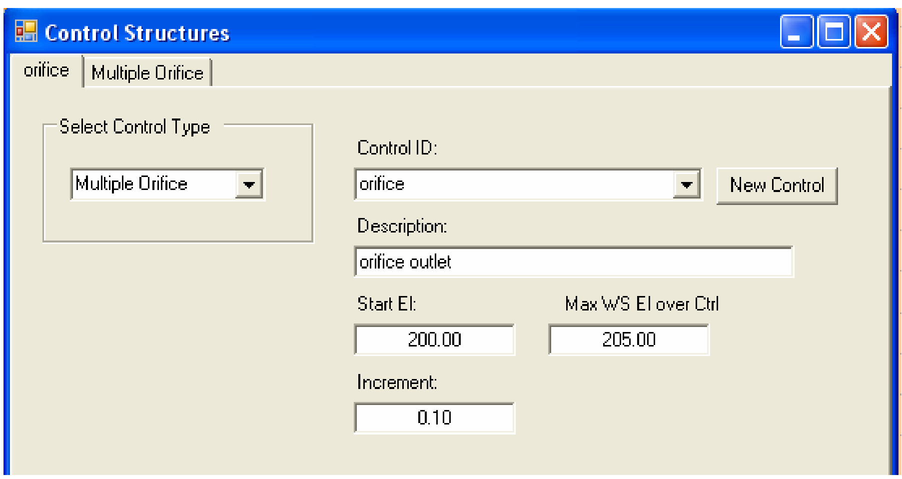
Stage (ft):	Storage (cf):
200	0
201	702
202	1972
203	3938
204	6728
205	11090

Assume the size of the orifice and input into StormSHED (a good estimate is 1 inch diameter orifice per 0.05cfs outflow).

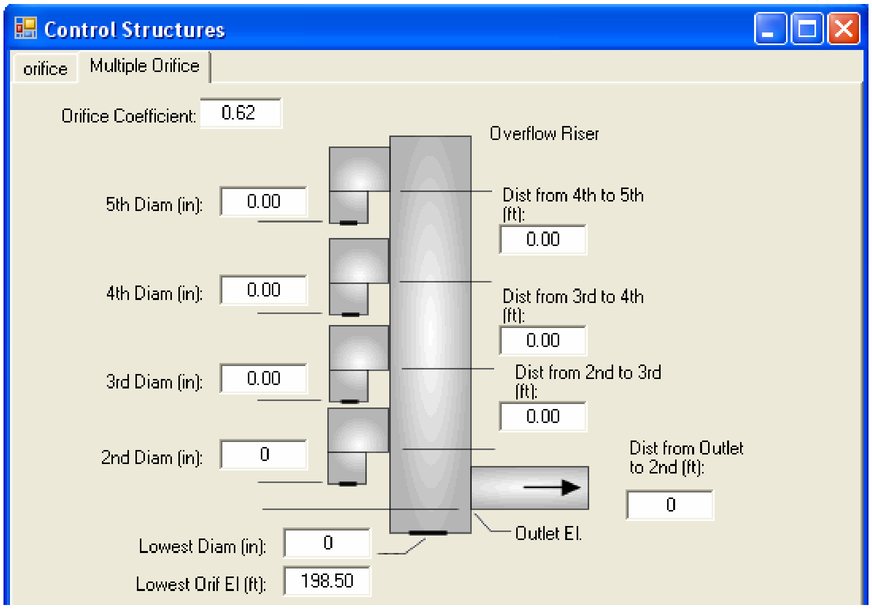
Define a Control Structure - Orifice

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" Control ID with **Orifice**.
- Press **OK** to close the "AutoLabel" dialog box.
- Change the *Control Type* to "**Multiple Orifice**".
- Change the "Outlet Elev" to **200**.
- Change the "Max Elev" to **205**.



- Click on the "***Multiple Orifice***" tab.
- Change the "*Lowest Orif Elev*" to **198.5** feet and then select **CLOSE.**

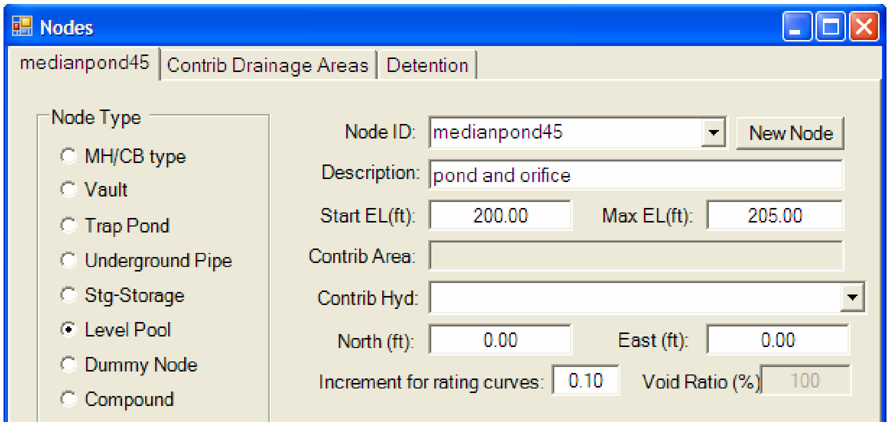


It is assumed that the pond bottom elevation is 200 ft and the maximum depth is five (5) feet above that. The program will size the orifice dimensions, so leave all control dimensions at zero. The lowest orifice elevation is set at 1.5 feet below the outlet elevation; see the Multiple Orifice Structure above. The lowest orifice elevation allows you to physically locate the orifice, but does not affect its discharge rate. For the lowest orifice elevation the discharge is always computed as the head on the outlet. Note that the flow through the other orifices in the multiple orifice structure is based on the driving head from the water surface to the orifice, not the outlet elevation.

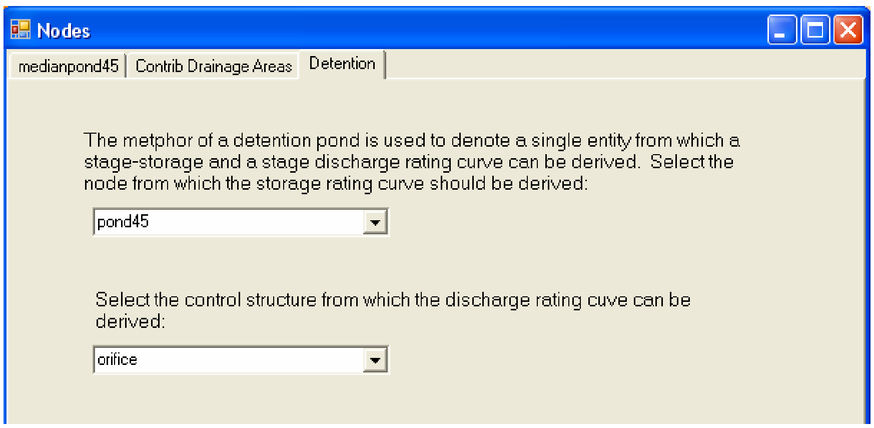
Define the Detention Pond Node

- Double click on the *PROTOTYPE* node record found under the "***Nodes***" category in the Tree View.
- Press the **New Node** button and change the "*Node Auto ID*" to **MedianPond45.**
- Press the **OK** button to close the "AutoLabel" dialog box.
- Change the "*Node Type*" to **Level Pool.**
- Change the description to **pond and orifice**.

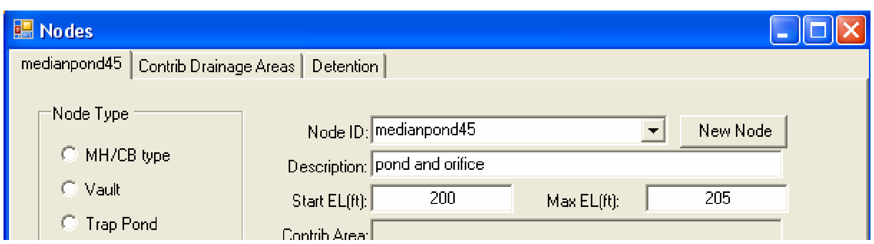
Notice that again, the "*Start El*" and "*Max El*" are not changed, they will change automatically based on the data input into the ***Detention*** tab.



- Select the ***Detention*** tab.
- From the "*Storage ID*" drop down, select **<u>Pond45</u>**.
- From the "*Discharge ID*" drop down select **<u>Orifice</u>**.
- Click back on the "**<u>medianpond45</u>**" tab



Notice that the program automatically updated the *Start* and *Max* elevations.



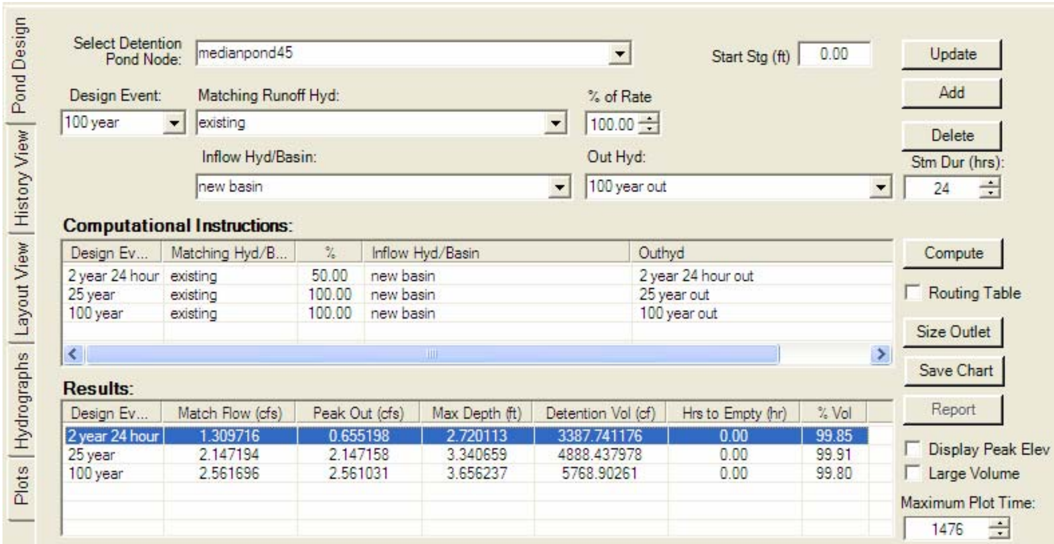
- Click on the **OK** button to close the "***Node***" dialog box.

Sizing the Control Structure

The program will automatically design multiple orifice structures to meet the design requirements.

- Select the ***Pond Design*** tab in the Layout View.
- Using the pull down menus, input the values shown below for the 2, 25, and 100 year design event, selecting the Add button after each input.

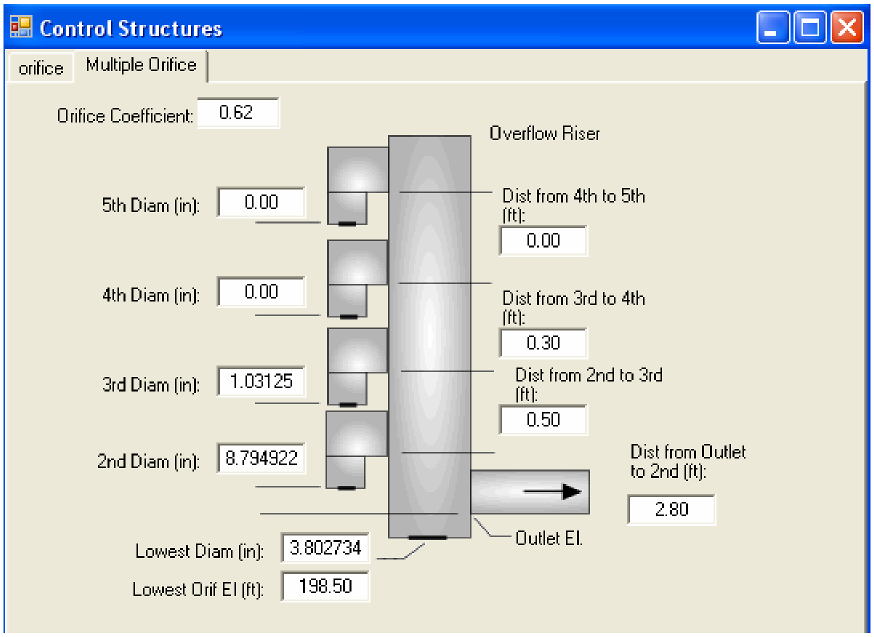
- Note the **2 year** storm should only have **50%** of the rate.
- All data in the dialog box is selected from the associated drop downs except for the "Out Hyd" column. This column specifies the ID's for the hydrographs that are routed through the pond and is automatically named by StormSHED.



- Press the **Size Outlet** button.

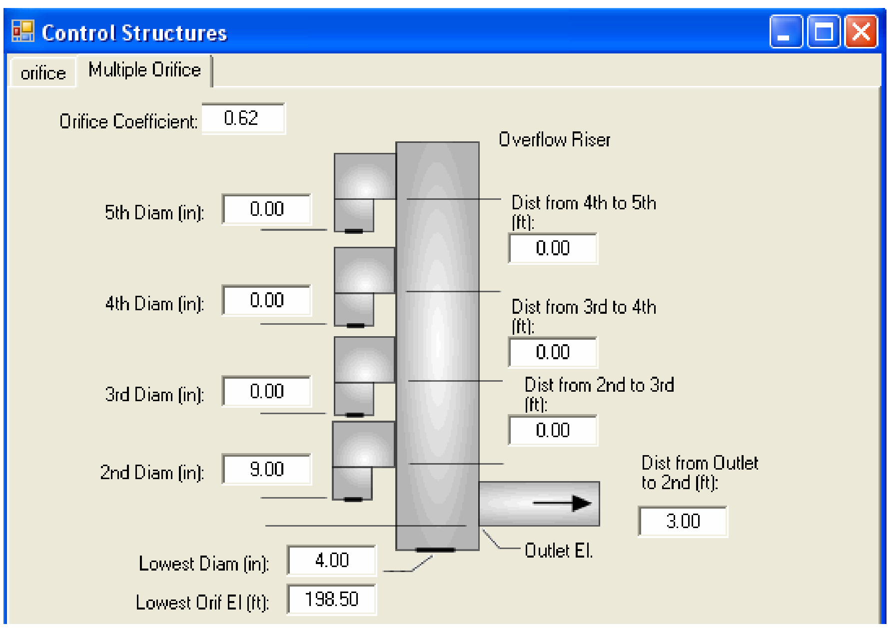
Next we will review the multiple orifice sizes StormSHED selected and see if they are practical and/or constructible.

- Open the Orifice dialog box and select the ***Multiple Orifice*** tab to view the orifice sizes.
- Next, designers need to look at the dimensions StormSHED selected for the orifice and apply engineering judgment. Examine the orifice discharge structure. Note that the lowest orifice is **3.8 inches in diameter** and is located at our input elevation of **198.5 fee**t. The second orifice is **8.44 inches** in diameter and is located a distance of **0.6 feet** from the outlet elevation of **200 feet**, see the multiple orifice diagram on the previous pages. The program uses the standard orifice equation to compute discharges through each orifice.



Designers should change the orifice sizes to something nominal.

- Modify the Multiple Orifice diameters and distances to match as shown below..

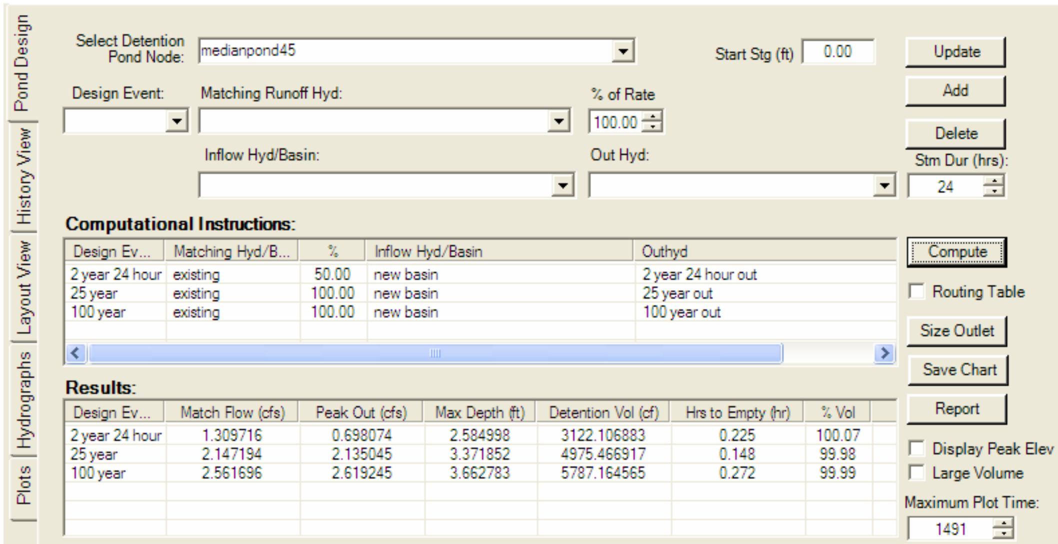


Use the computer model to route the hydrographs through the detention facility and orifice structure.

Adjust the volume and discharge structures and keep running the computer model until the released flows and detention pond design requirements are met.

- Then select **OK** and return to the ***Pond Design*** tab. This time select the **Compute** button. Then we will verify the following:

- The Peak Out Q does not exceed the Match Q for both the 25 and 2 year storm. Note the Match Flow for the 2 year is the full flow and should be multiplied by 50% to verify the Peak Out is not greater.
- There is 1’ of free board above the 25 year pond elevation.
- The 100 year elevation does not exceed the top of pond elevation at 205’.



For the 2-year storm, the Peak Out Q slightly exceeds Match Q. For this tutorial the two numbers are close enough. To reduce the Peak Out Q, designers can change the orifice sizes and spacing and then re-compute the pond design until the Peak Out Q is less or equal to the Match Q.

All the other requirements are met, so this pond size meets the design criteria for flow control and detention ponds.

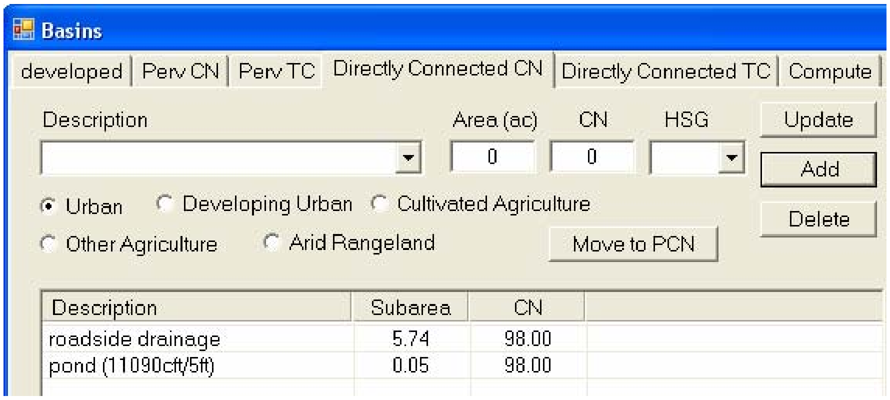
Adjust the basin to include the surface area of the pond

This is a brand new requirement for the next revision (after the 2006 HRM) the upcoming revision to the HRM. The idea is since precipitation falling on the pond will also contribute to the pond volume, it must be included in the analysis as impervious surface. This will take atleast two iterations to properly size the pond: once to estimate the pond size without the pond contributing and a second time to see if the pond size can handle the additional volume for the pond itself.

Modify Developed Basin

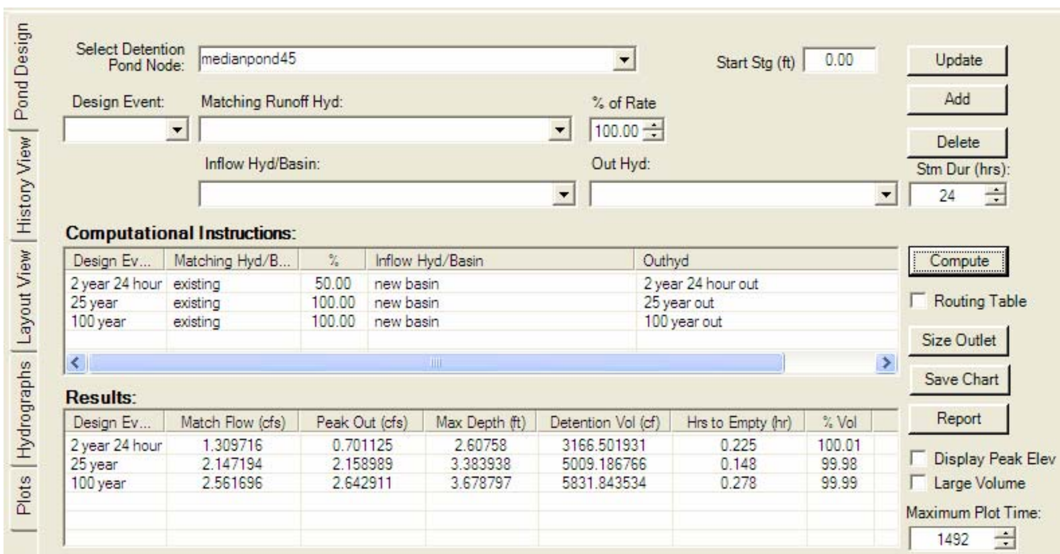
Next we will modify the Developed Basin to include the surface area of the pond.

- Open the basin called **New Basin**.
- Select the ***Directly Connected CN*** tab.



- For the *Description* input **pond (11090cft/5ft)** (converted to acres), **0.05** acres for the *Subarea*, and **98** for the CN.
- Select the **Add** button and close the dialog box.
- Return to the ***Pond Design*** tab and select the **Compute** button.

The results that include the surface area of the pond are shown below.



Check the 100-year release rate, compare to predeveloped conditions, and check for potential property damage.

The pond still meets the flow control requirements and the design criteria for detention ponds, there fore the design is acceptable. The peak discharge rate for the 2 year storm slightly exceeds the 50% requirement. Designers should consider changing the orifice size or spacing to bring this value to 50%.

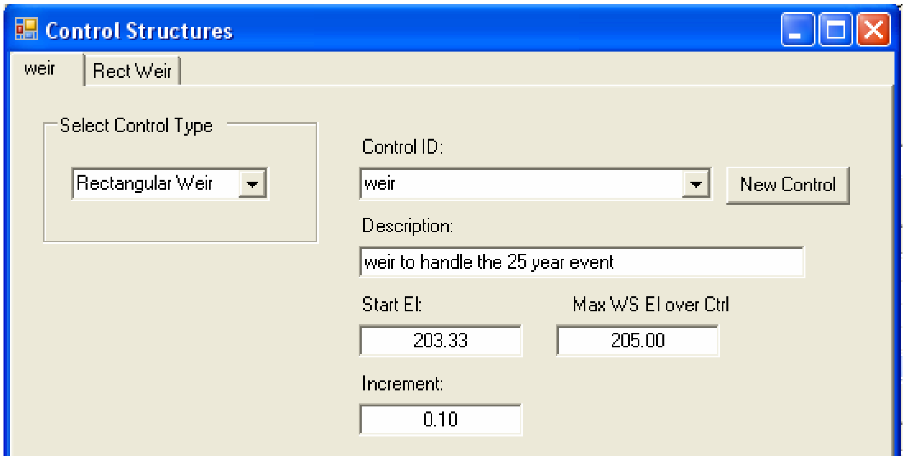
Define a Control Structure – Orifice and Weir Combo

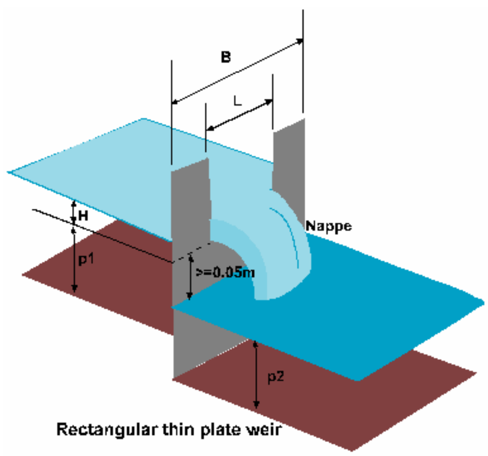
Next we will repeat the process with a weir set at the 25-year elevation from the pond design using the orifices, 203.38 and create a combination discharge structure to recognize both the weir and the orifice.

- Double click on the *PROTOTYPE* under the "***Discharge***" node in the Tree View.

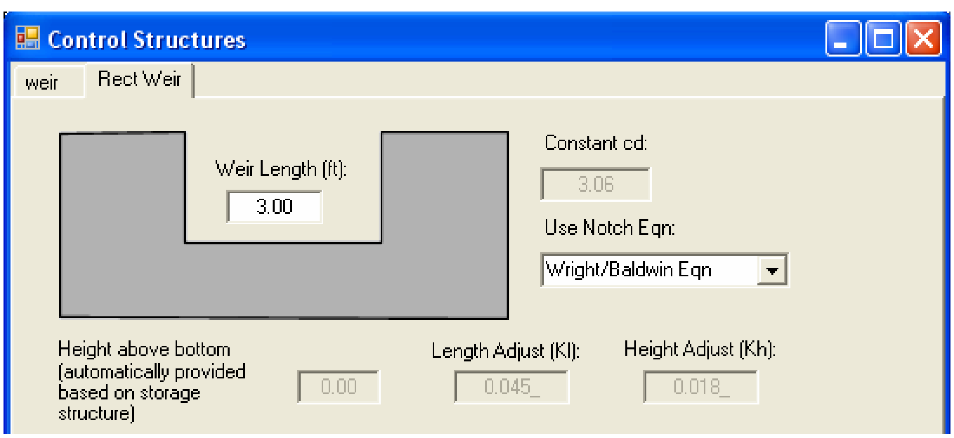
- Click on the **New Control** button and enter **<u>Weir</u>** in the "*AutoLabel*" dialog box.
- Press the **OK** button to close the "*AutoLabel*" dialog box.
- Fill in the remaining data for the weir as shown in below.
- Select the ***Rect Weir*** tab and change the length to **<u>5 feet</u>**.

The weir length is an arbitrary number we are starting with. The program will not size the weir. The only discharge structure that the program will size is the multiple orifices.





Rectangular thin plate weir



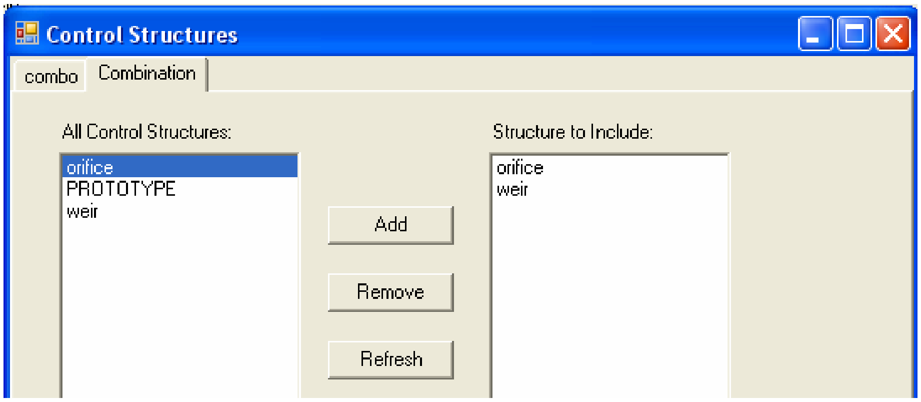
- Click on the **OK** button to close the weir dialog box.

Since we have two discharge structures, we need to create a combination node to model the orifice and the weir.

- Double click on the *PROTOTYPE* node under the "***Discharge***" records again.
- Press the **New Control** button and input **Combo**.
- Press the **OK** button
- Change the *Description* to "**combination discharge structure**"
- Change the "*Control Type*" to **combination**.

Notice that the starting and max elevation input fields have been disabled and the elevations are not correct; this will change once we input the discharge structures.

- Click on the "***Combination***" tab
- Select **Orifice** and then the **Add** button.
- Select **Weir** and then the Add button.



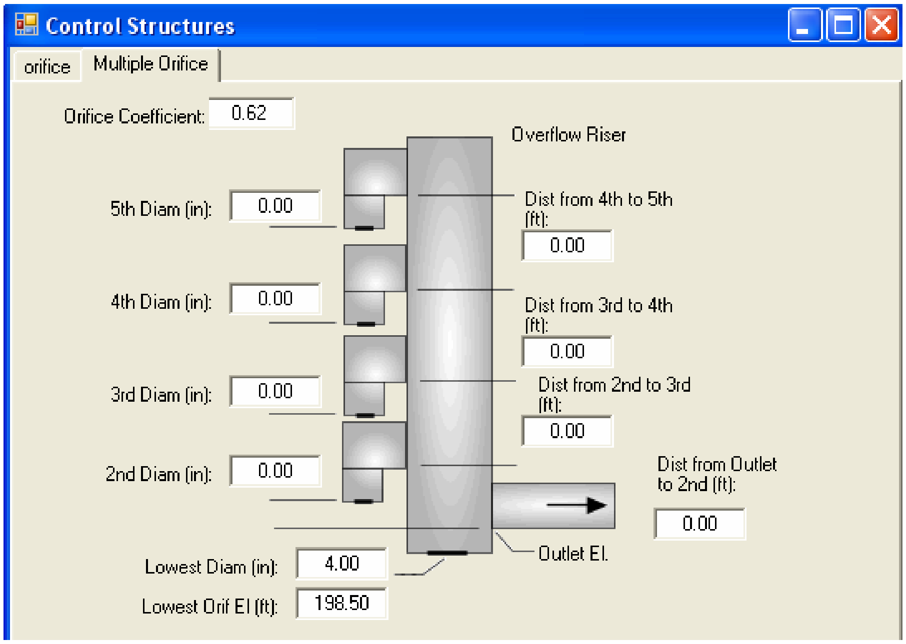
- Click on the "***Combo***" tab.

Notice that StormShed has updated the disabled fields for elevations.

- Press **OK** to close the dialog box.

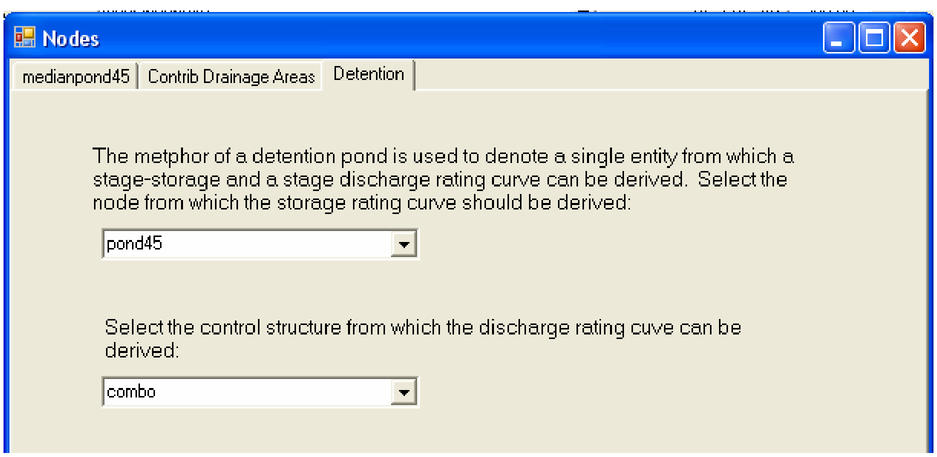
There is more to change. The orifice structures 2nd diameter needs to be deleted, the weir has replaced it.

- Open the "**Orifice**" discharge structure and select the "***Multiple Orifice***" tab.
- **Zero** everything except the "*Lowest Orifice Diameter*" as shown below.
- Press **OK** to close the dialog box.



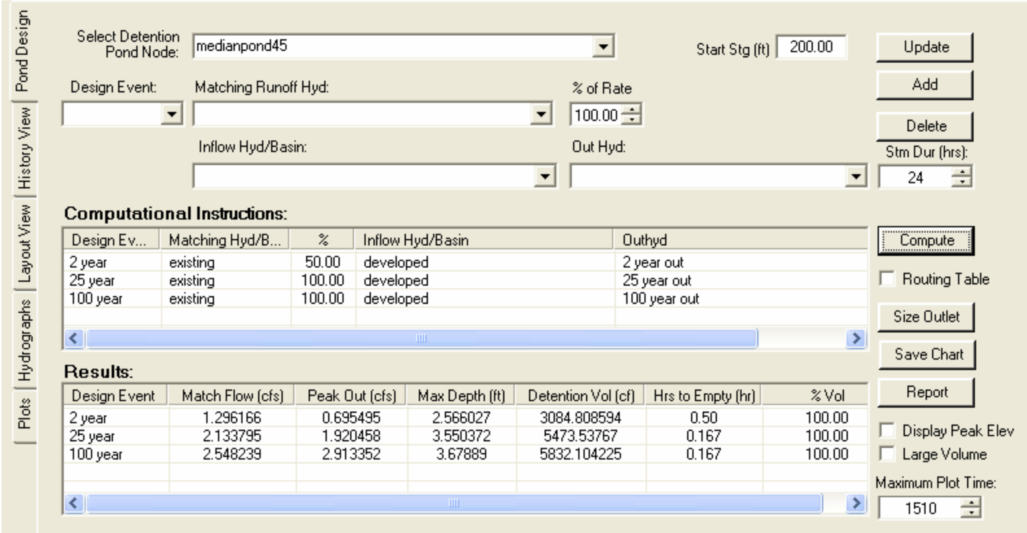
The last step before re-computing the peak pond elevations is to modify the Detention Pond node with the new combination discharge structure.

- Open the "**MedianPond45**" node record and select the "Detention Pond" tab.
- Change the "*Discharge rating curve*" from to **Combo**.
- Press the **OK** button.



- Open the pond design dialog box by clicking the right mouse button in the white space of the tree view.
- Press the **Compute** button.

The "*Size Outlet*" button cannot be used because the discharge structure is no longer just an orifice.



Results

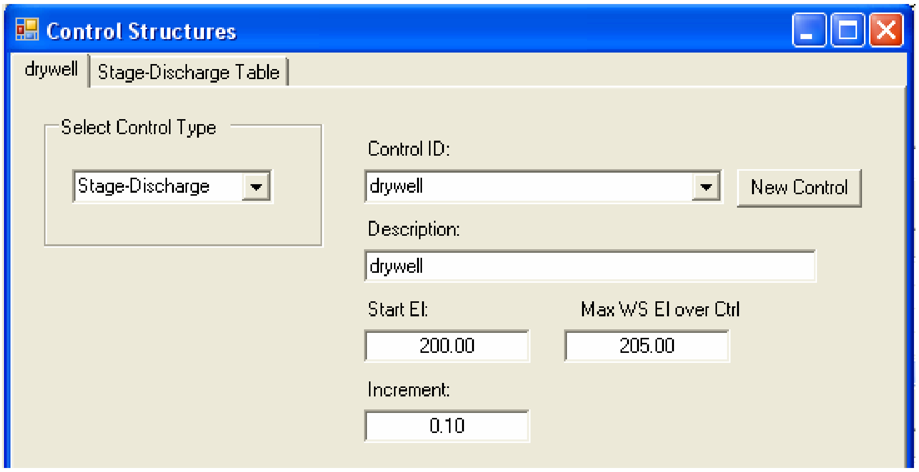
The table above meets all our design requirements. It releases the pre-developed flows and the peak stage in the pond did not go above the maximum proposed elevation, in-fact the designer might consider reducing the pond size making certain the pond does not overtop during the 100 year storm.

If the Peak Out Q had been too high for the 25 year storm, designers could reduce the width of the weir to reduce the flow.

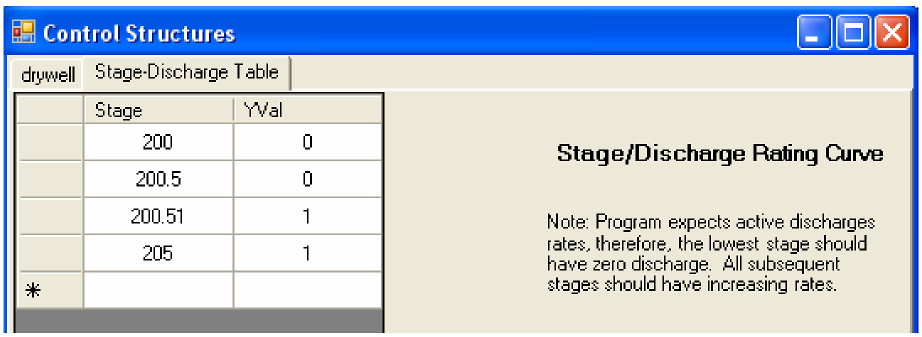
Define a Control Structure – Drywell

The last outlet for our detention pond is a drywell. For this tutorial we will use an discharge of 1 cfs, however the method for determining the discharge from a drywell is changing and we will notify designers how and when to use the new method.

- 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 Drywell.
- Press **OK** to close the "AutoLabel" dialog box.
- Change the Control Type to "stg-disch" or staged discharge.
- Change the "Outlet Elev" to 200.
- Click on the "Stage-Discharge rating table" tab.

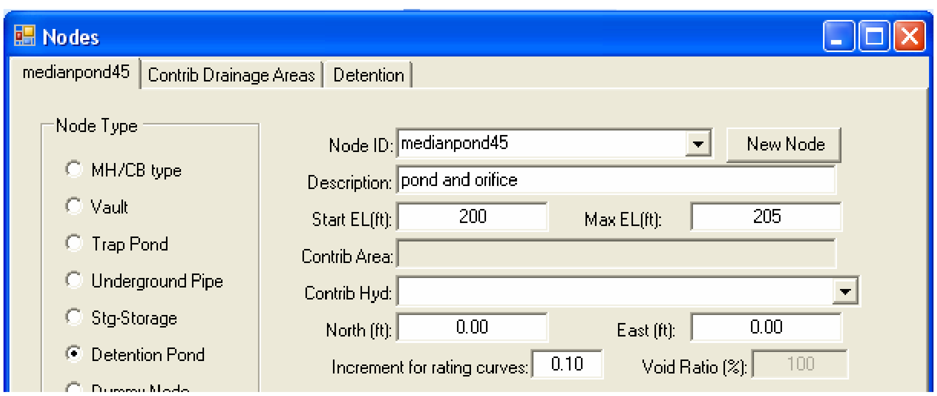


- Change the stage and discharge to match below.
- Press **OK** to close the "Discharge Control Definition" dialog box.

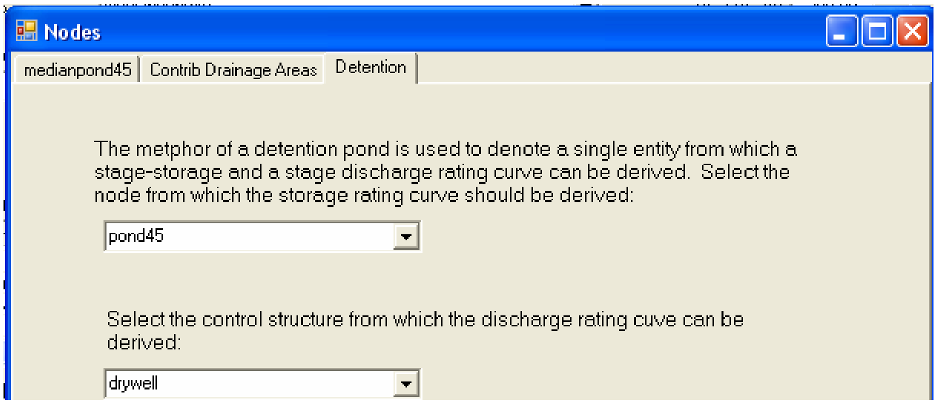


One final step is needed before re-computing peak pond elevations. Modify the *Detention Pond* node with the drywell for the discharge structure.

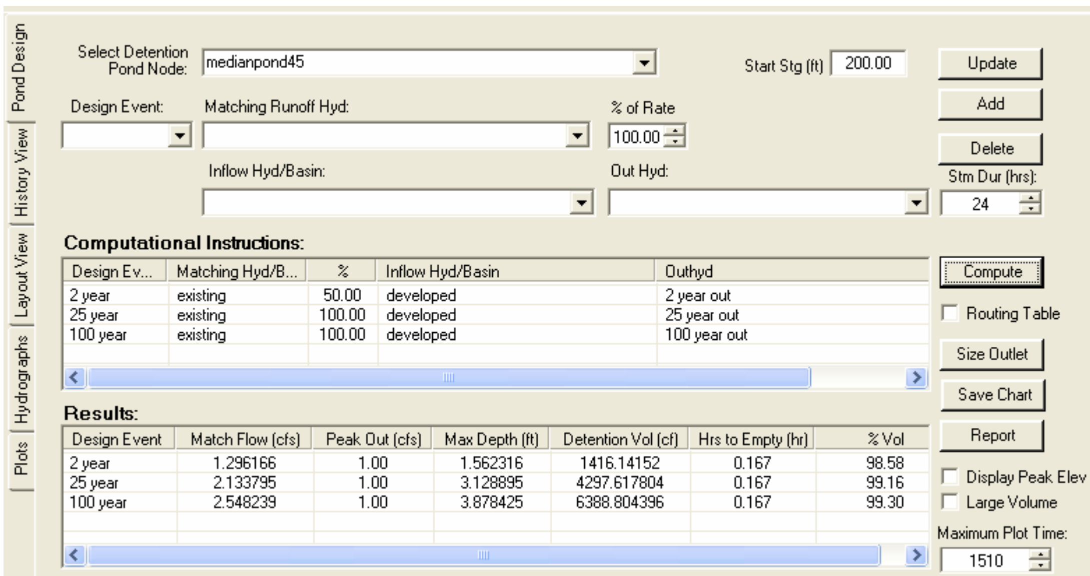
- Open the "**<u>MedianPond45</u>**" node record and select the "***Detention***" tab



- Change the "*Discharge rating curve*" to "**<u>drywell</u>**".
- Press the **OK** button.



- Open the Pond Design tab and press the **Compute** button.



Results

Notice the Peak Out Q for the 2 year storm exceeds the Match Q. This is acceptable because a drywell provides subsurface discharge and in this case the flow control requirement is gone. The only parameter we are concerned with is the Peak Storage and for both the 25 and 100 year storms the Elevation is below the Peak Elevation. In both cases, we exceed the design requirements in-fact the designer could reduce the pond size.