4. Culverts

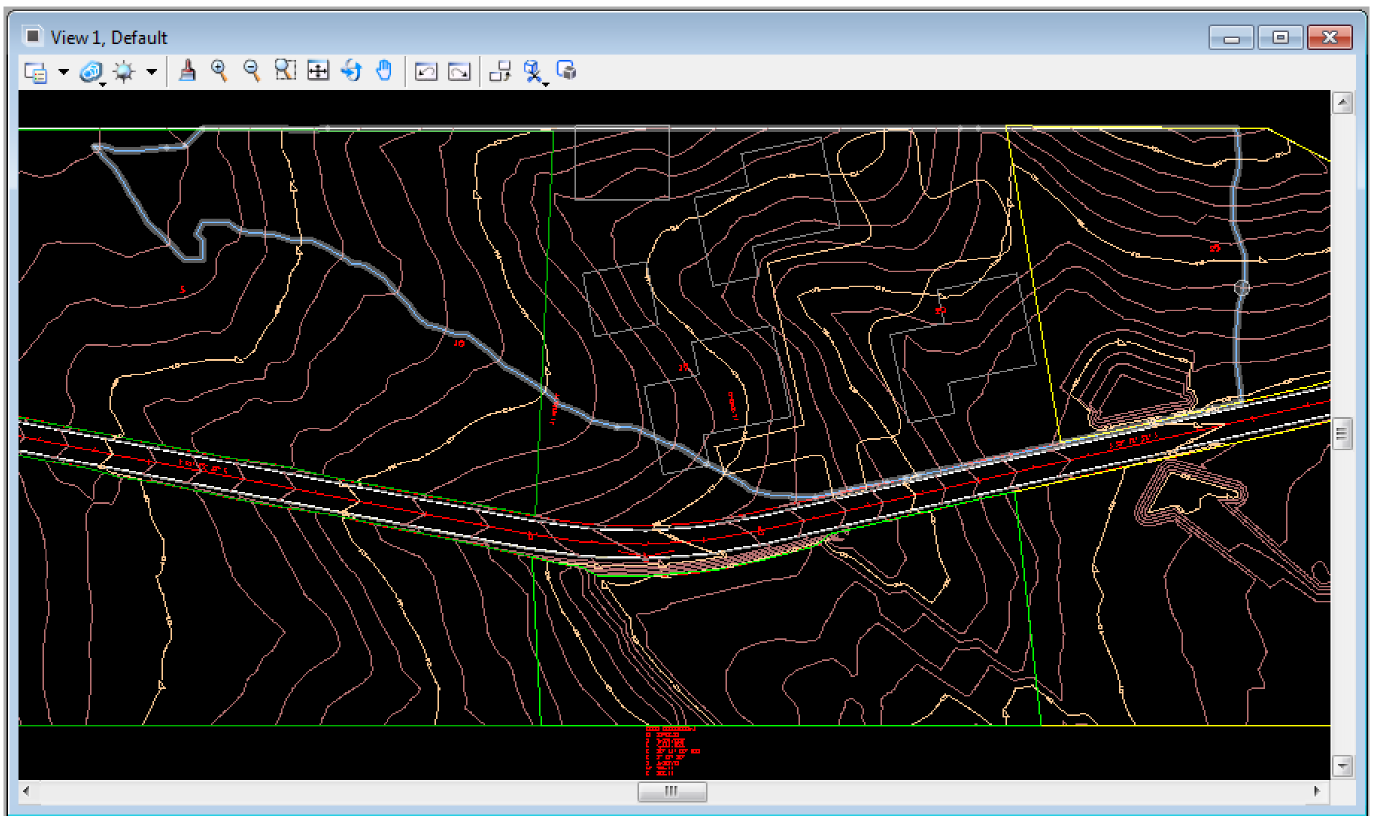
This exercise shows the user how to use the culvert module to design a culvert. The culvert module acts as a standalone component of GEOPAK Drainage, meaning it does not directly interact with Drainage Areas, Nodes, Links or Networks.

4.1 Delineate the Drainage Area

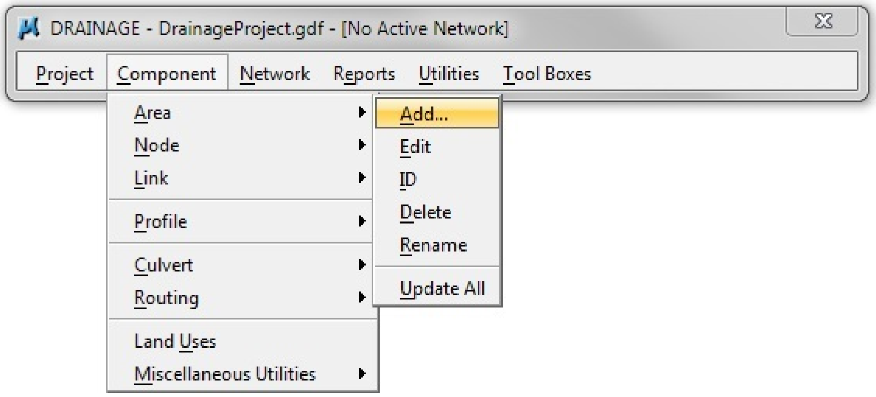
a) Use DTM tool Delineate Watershed to create the drainage area shown below. If necessary, refer back to exercise 3.2 to create the drainage area.

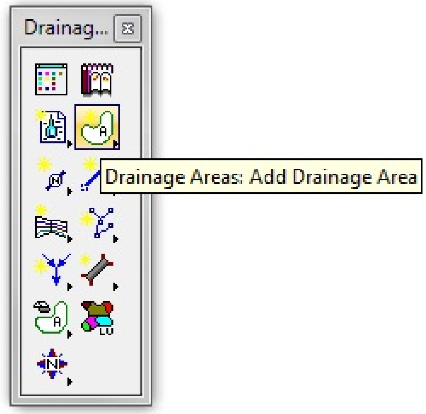
The following shape will be used below as the drainage area for this exercise.

NOTE: The area shown below on level SURVEY - DRAINAGE - Area Shapes extends to the limits of the current TIN file. Inspection of the contours will reveal that the drainage area most likely extends beyond these limits. **Appendix B** will discuss options to approximate the full extent of the drainage area.

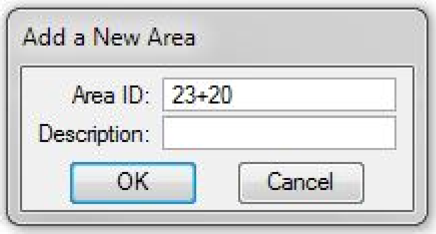


b) From the GEOPAK Drainage menu bar select **Component>Area>Add.**

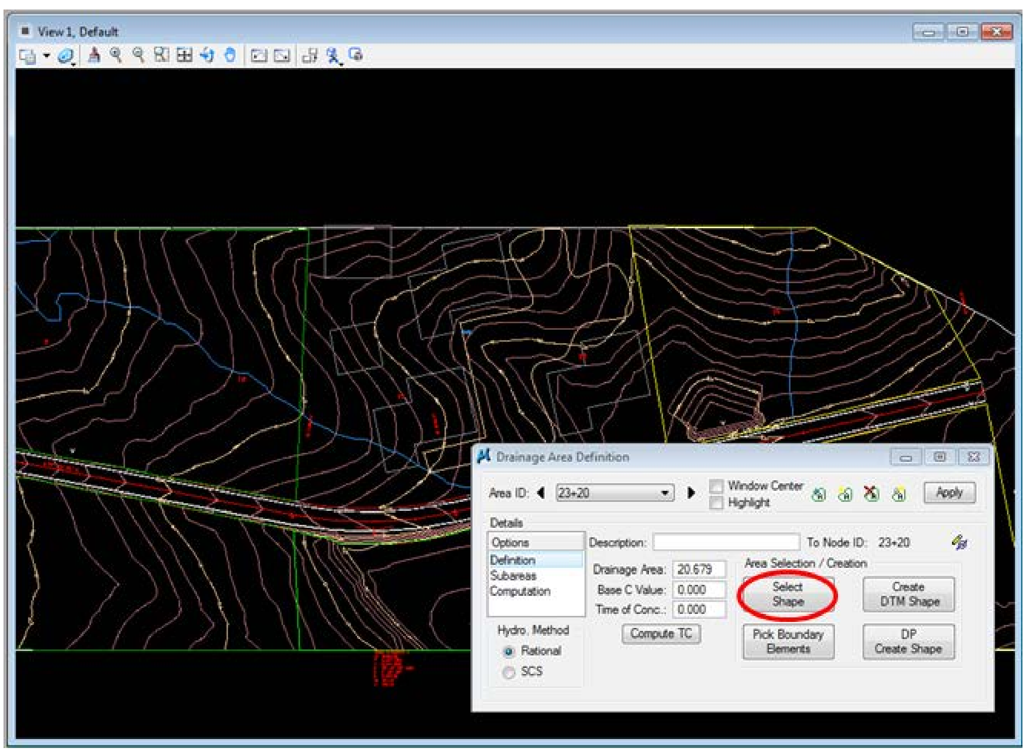




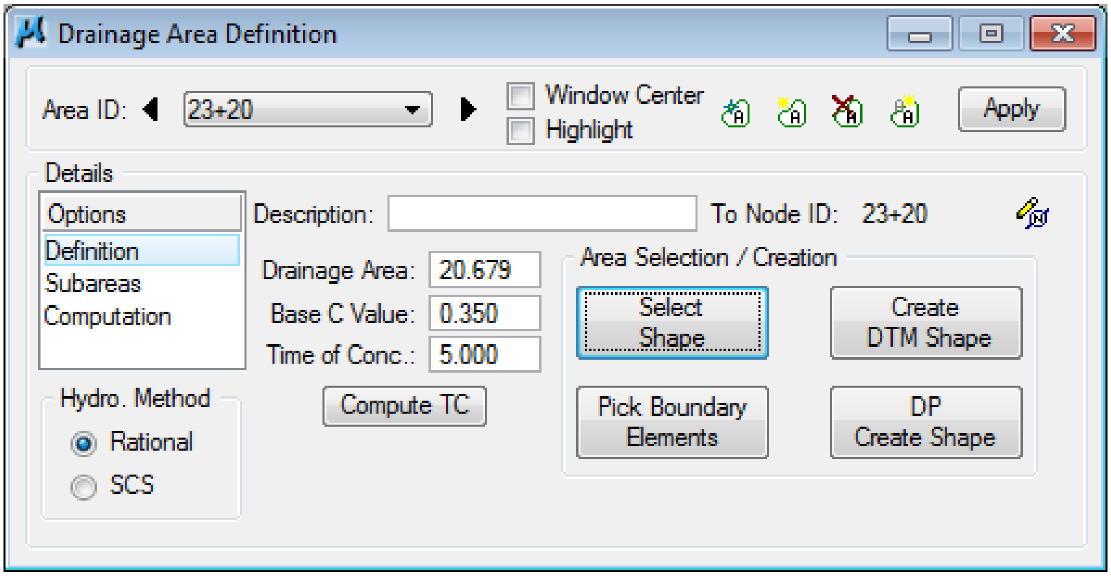
Type in **23+20** for the **Area ID.** Click OK.



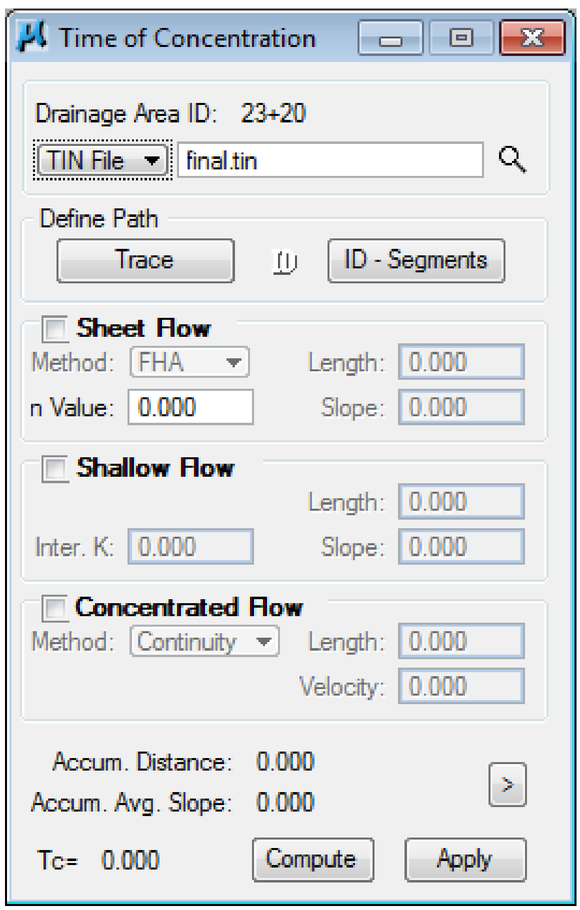
c) Click the Select Shape button. Select and data point to accept the shape shown in the first step. The area is automatically calculated.



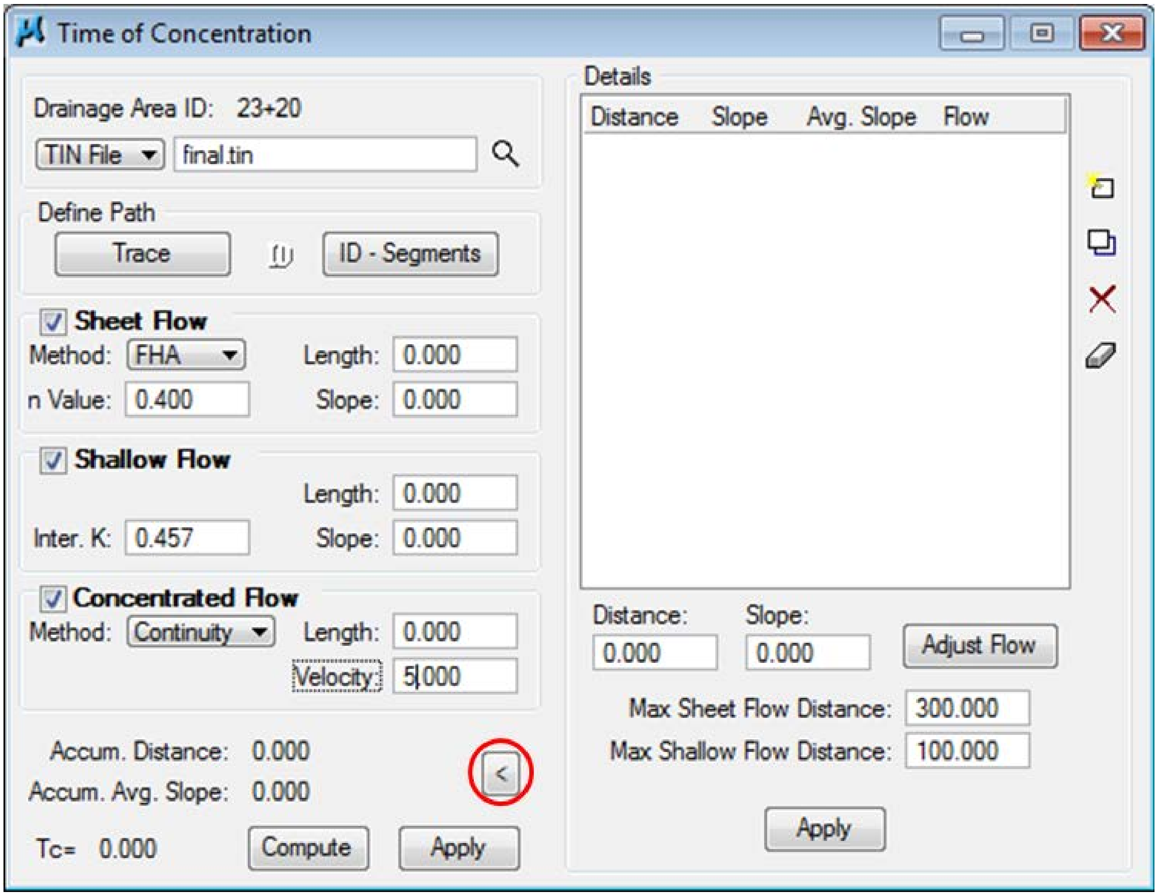
d) Set the **Base C Value** to 0.350 and click on **Compute TC**



When the following Dialog will appears, use the explorer button to select the correct TIN file.



e) Expand window to show details and set Max Sheet Flow Distance to 300’ and Max Shallow Flow Distance to 100’.



Collapse the window, toggle ON Sheet Flow, Shallow Flow and Concentrated Flow and fill in the values as follows:

n Value: 0.400

Inter. K: 0.457

Velocity: 5.000

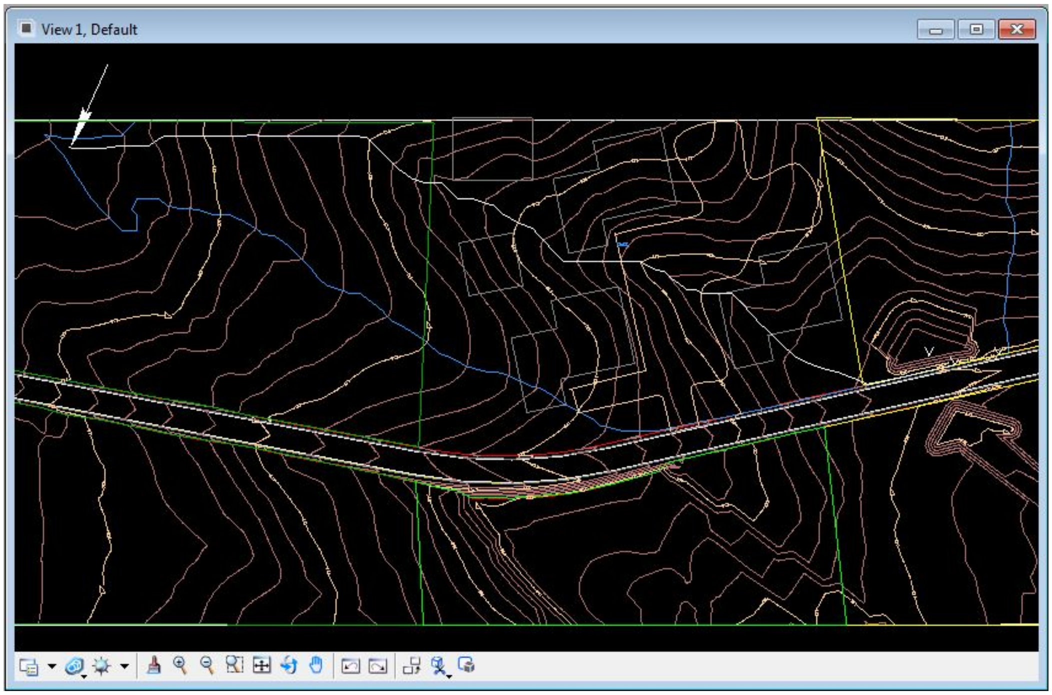
n Values for different surface types are available in the TDOT Drainage Manual, Table 4-3 *Manning’s n Values for Overland Flow*

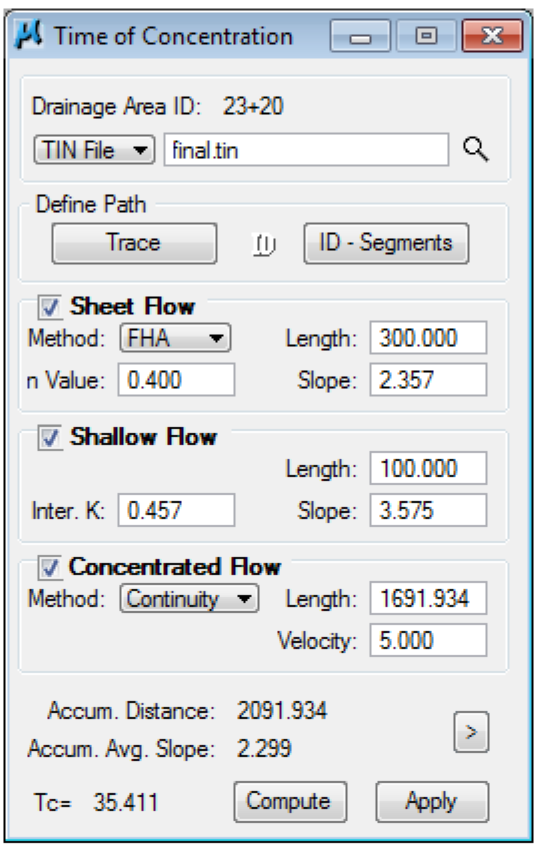
Intercept K values are below:

Land Cover / Flow Regime	**k**
Grassed waterway (shallow concentrated flow)	0.457
Unpaved (shallow concentrated flow)	0.491
Paved area (shallow concentrated flow); small upland gullies	0.619

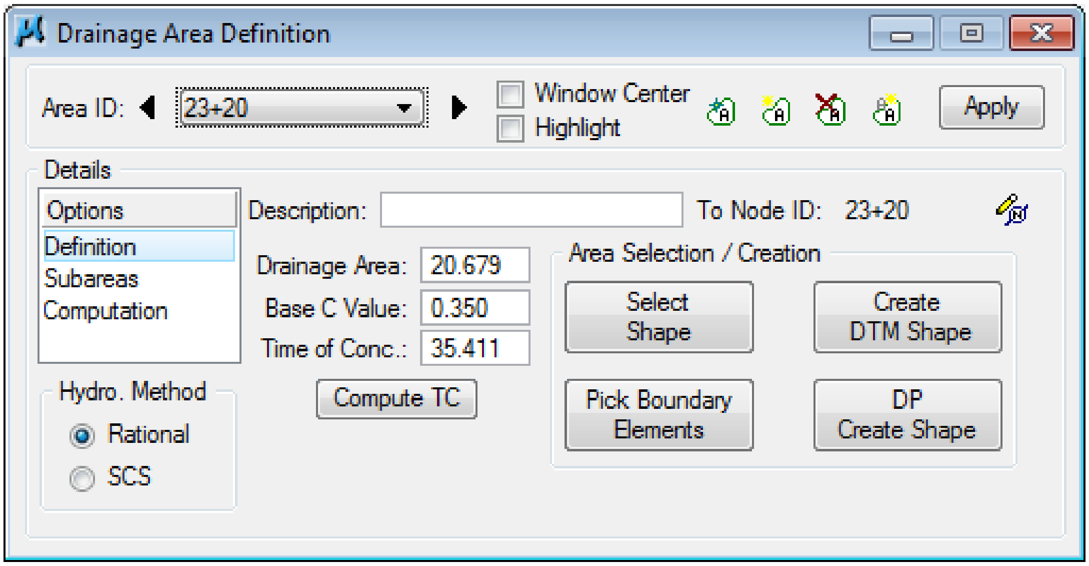
NOTE: See Appendix D for additional Manning's N and Intercept K Values.

f) Click `Trace` and data point at the furthest hydraulic point. Once values are calculated, click `Compute`. Then click `Apply`.





The Drainage Area Definition is now filled out.

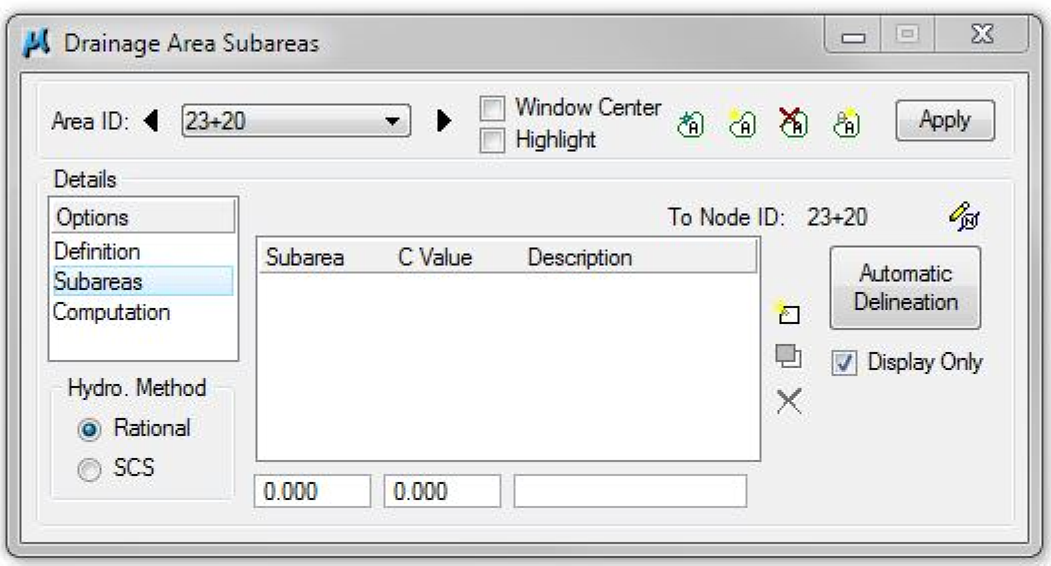


NOTES:
Minimum Time of Concentration is 5 minutes. If computed time is less than **5 minutes** input 5 manually.

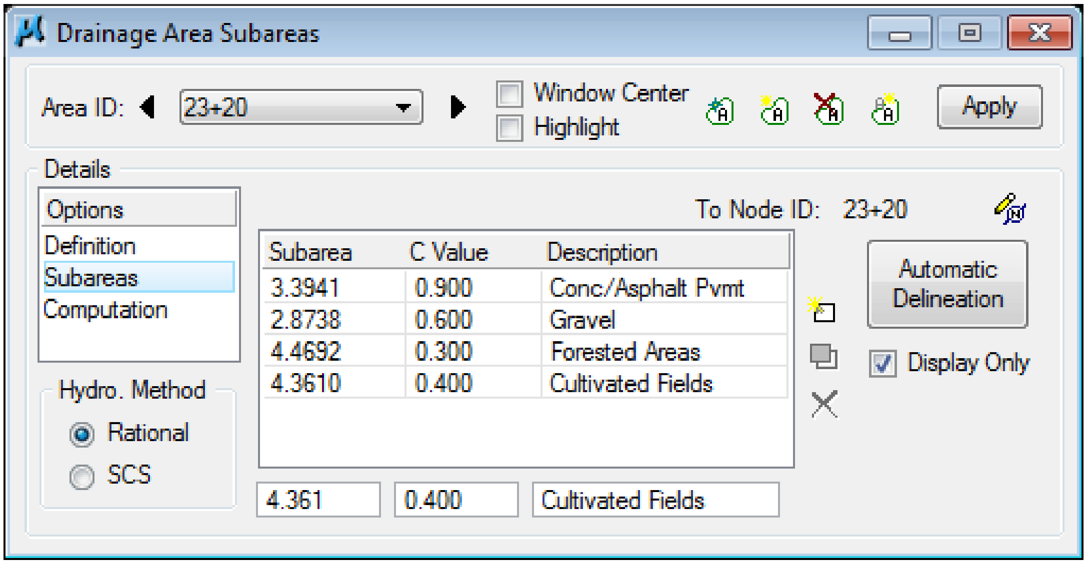
For urban areas adjust maximum sheet flow as required.

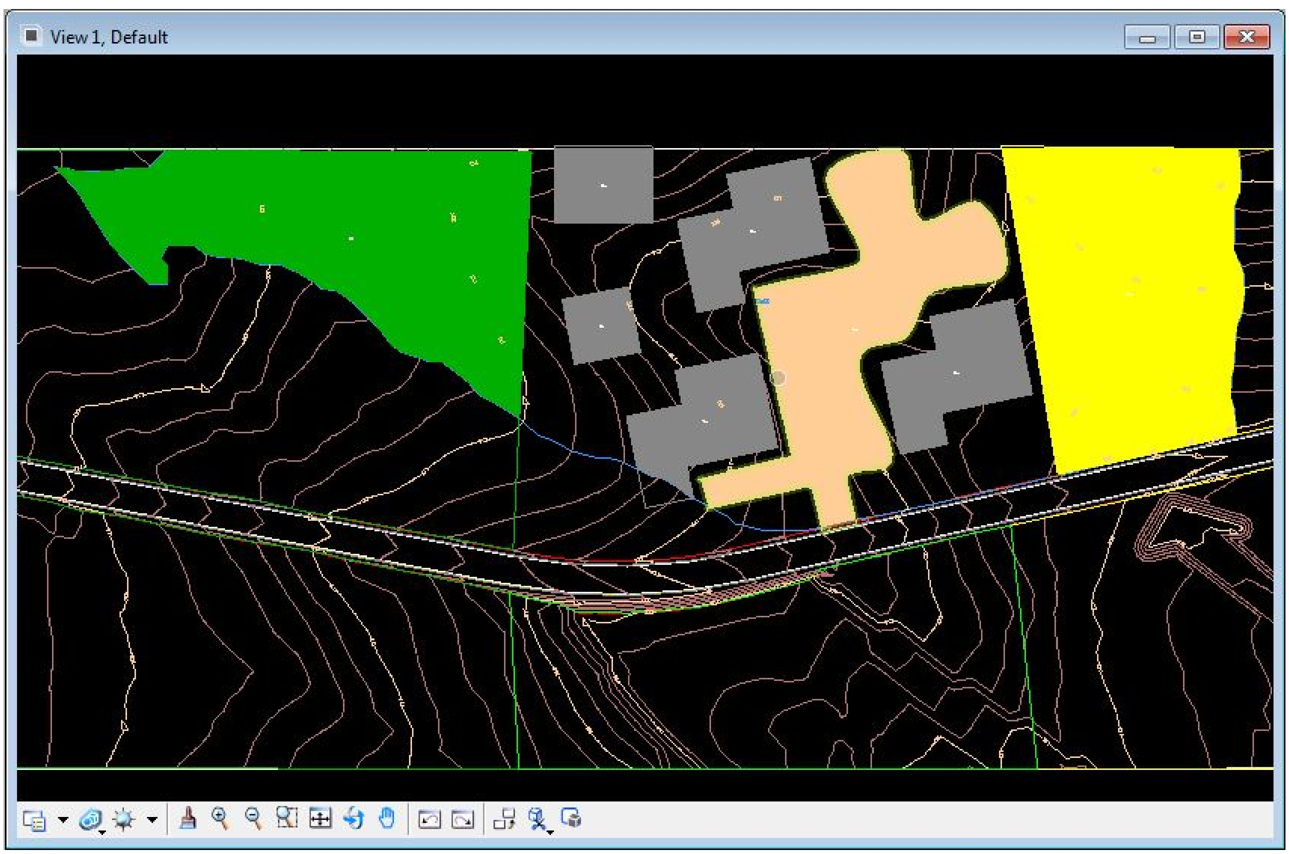
For areas that drain directly from sheet flow to concentrated flow, uncheck the Shallow Flow box. Leaving this box checked and setting it to zero will not allow TC to be calculated correctly.

After the drainage area has been set up, runoff coefficients can be automatically computed with the use of *Land Use Items* from the Drainage Library. Click on **Subareas** in the Details list on the left.



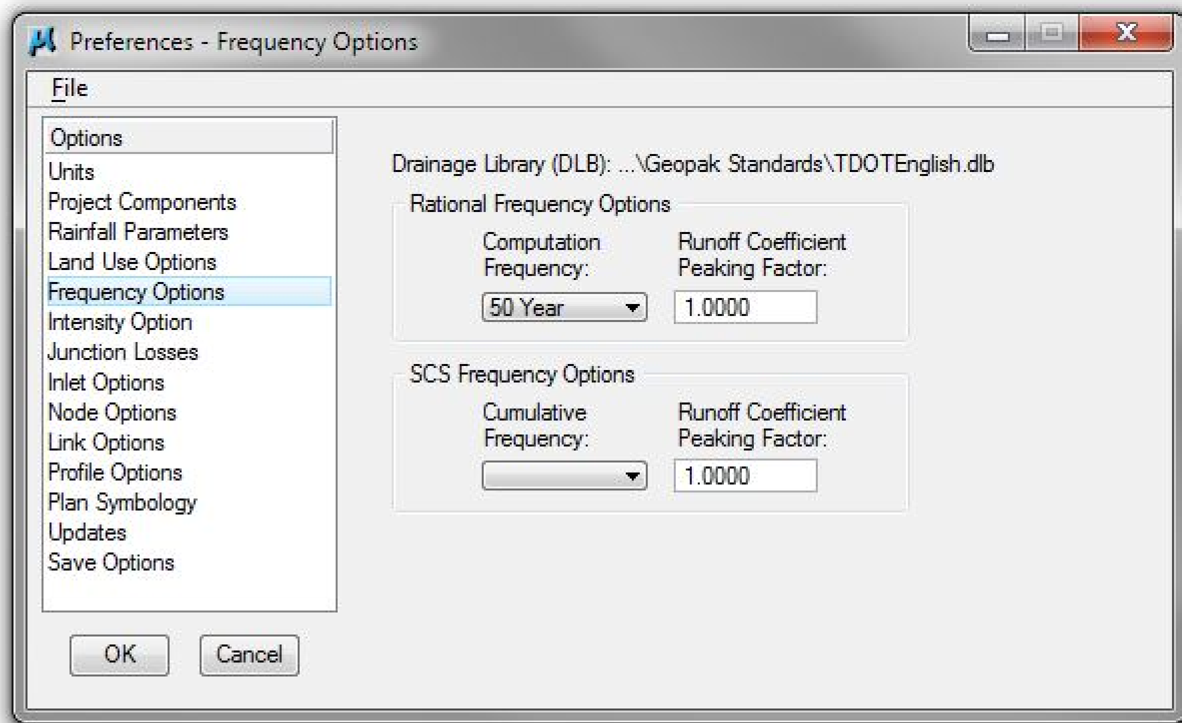
g) Toggle ON **Display Only** and then click the **Automatic Delineation** button. The file is scanned for closed shapes matching the Land Use symbology specified in the Drainage Library (Land Use Tab).



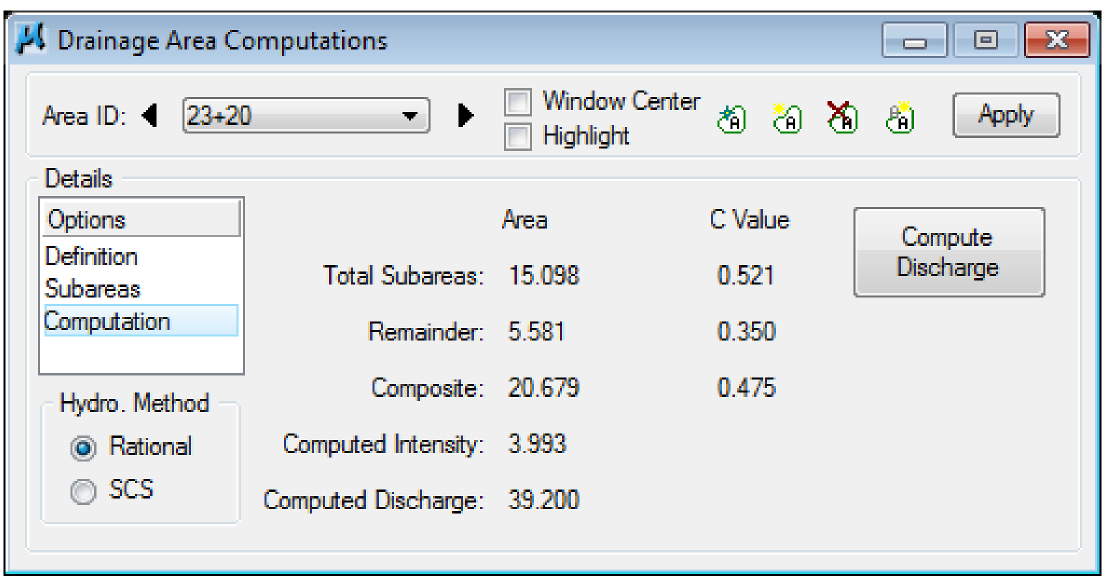


h) Click the **Apply** button to apply the land uses (and their "C" values) to the Drainage Area.

i) We want to compute the discharge for a 50-year storm so if that is not already set; select **Project>Preferences>Frequency Options** and change the Frequency to the 50-year storm. Click the **OK** button to accept the new preference setting.



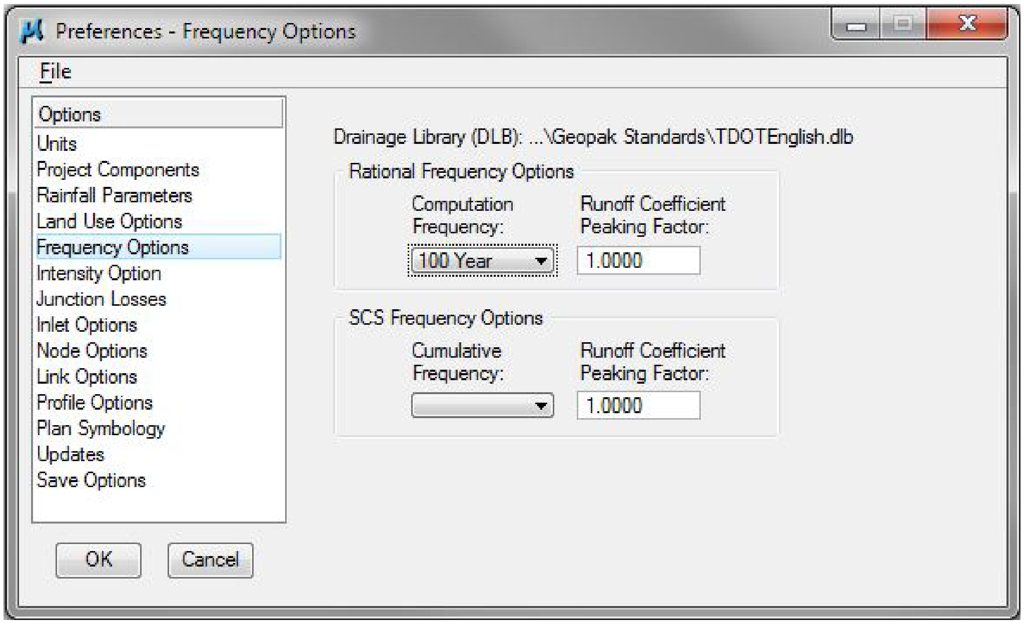
j) Return to the **Drainage Area Computations>Computation** dialog box and click the **Compute Discharge** button:



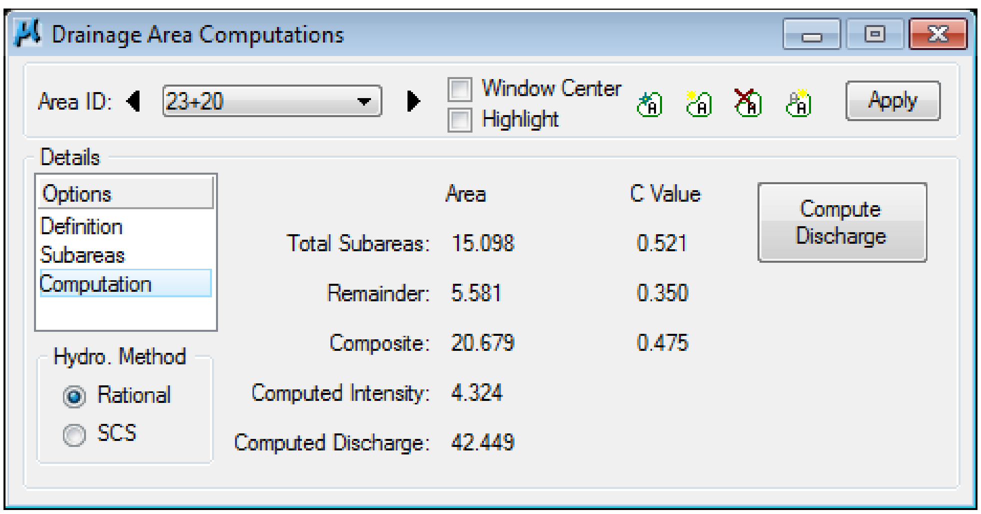
Verify the Computations; then click **Apply** to add the Area to the Project.

k) Jot down the Computed Discharge from the 50-year storm computed in the step above here: ____________

l) Recompute the drainage area discharge for the 100 Year storm. Select **Project>Preferences>Frequency Options** and change the Frequency to the 100 year storm. Click the **OK** button to accept the new preference setting.



m) Return to the Drainage Area Definition dialog box and click the **Compute Discharge** button:



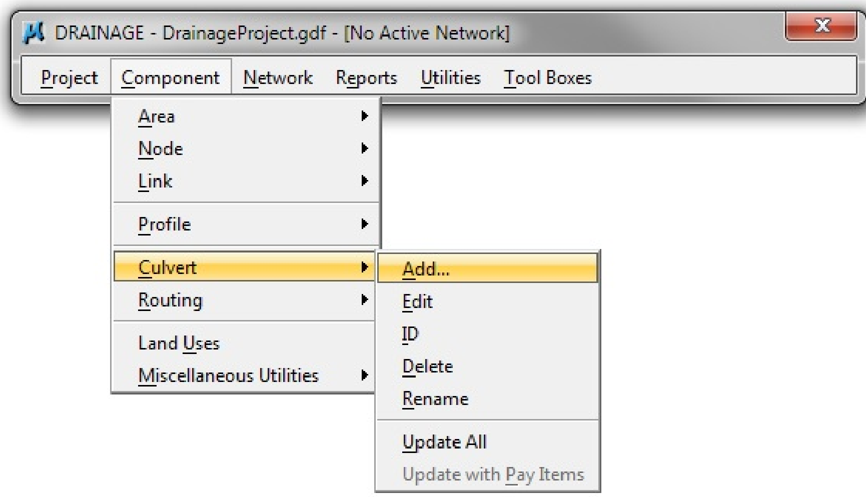
n) Jot down the Computed Discharge from the 100-year storm computed in the step above here: ____________

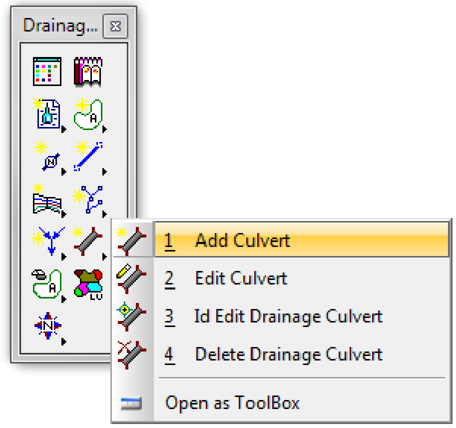
o) Close the **Drainage Area Definition** dialog box.

p) Change the Frequency back to the 50 Year storm

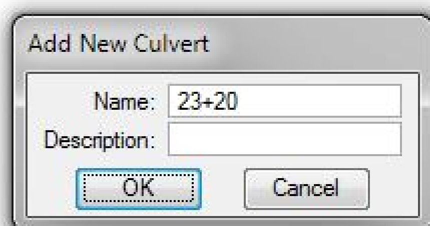
4.2 Design the Culvert

a) From the Drainage main menu, select **Component > Culvert> Add**.

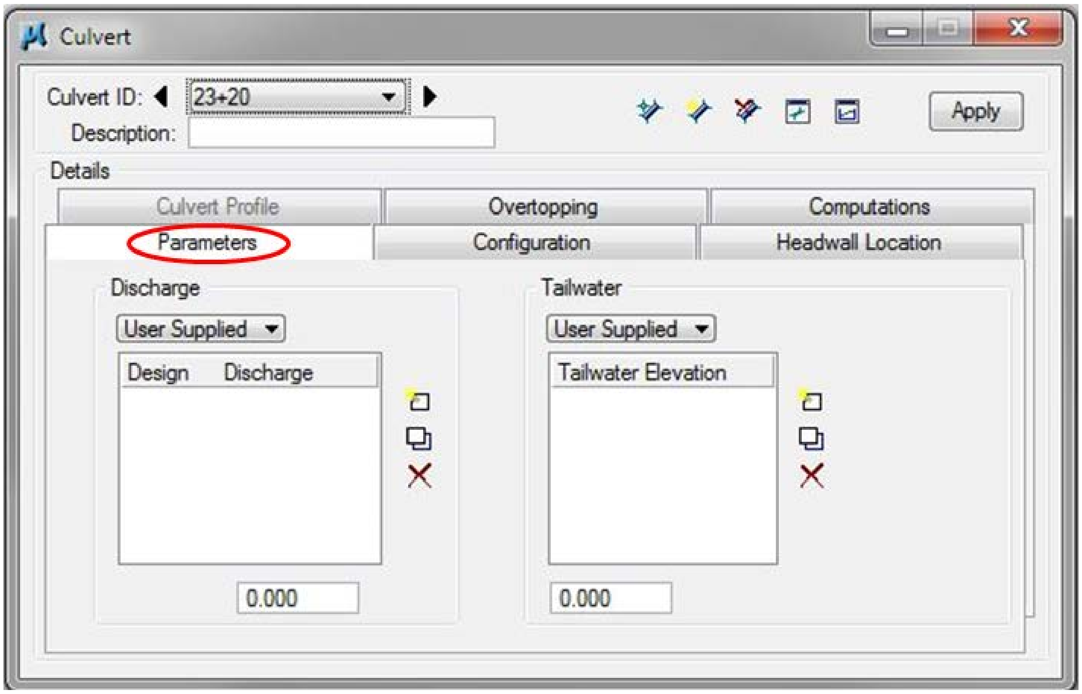




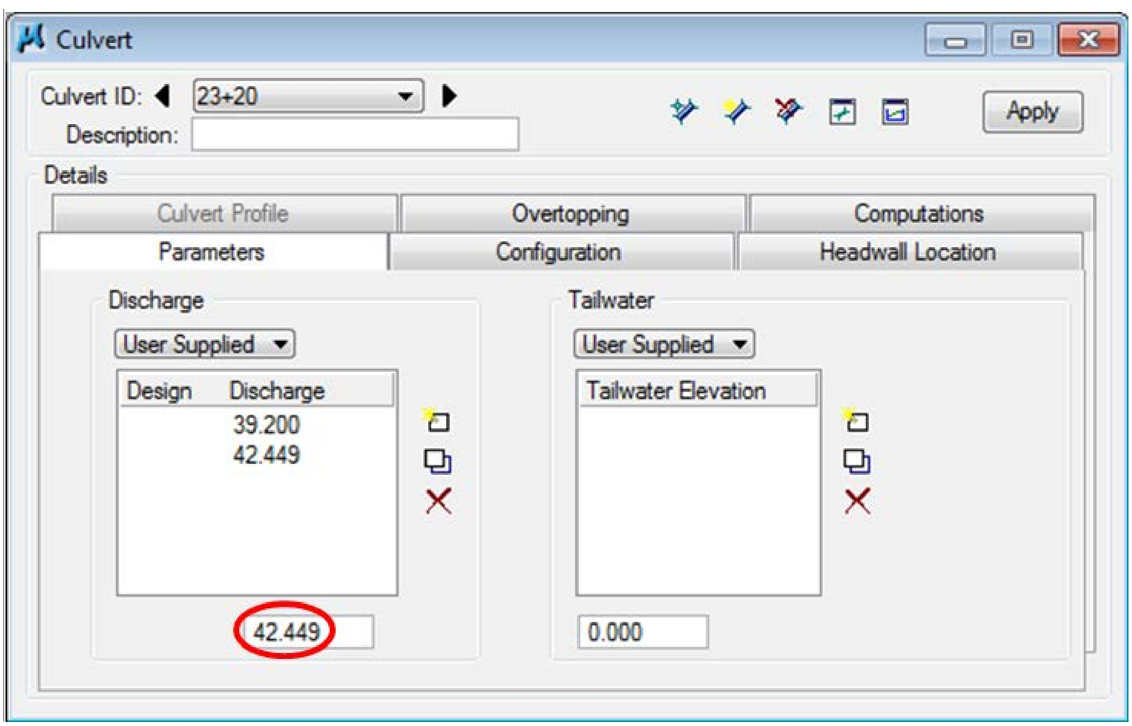
b) Click on the Add button to add a new culvert. Enter the Culvert Name as **23+20** (station of the culvert) and Click **OK**.



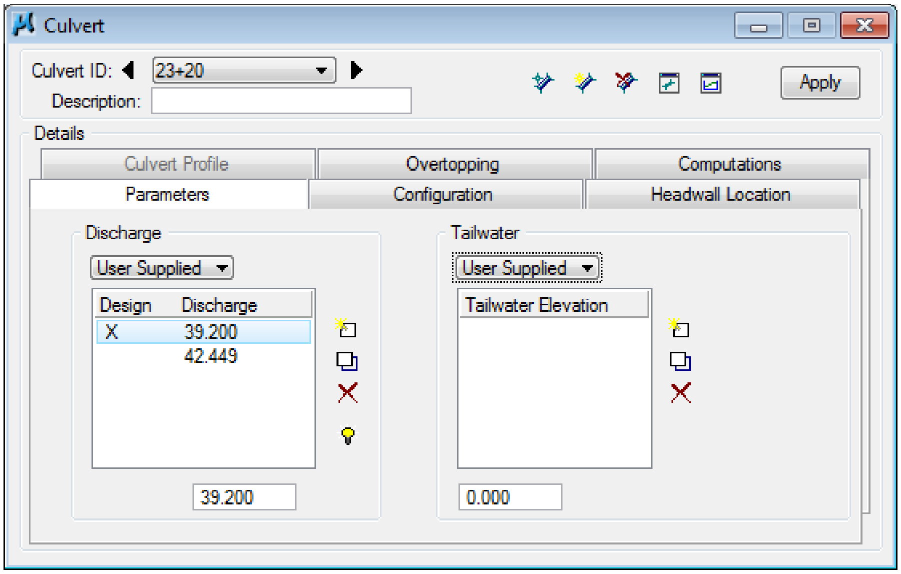
c) The **Culvert** dialog will open as seen below:



d) Enter the culvert discharges from Steps 11 and 14 in the previous exercise. Key-in the discharges in the key-in field and click the **Add List Item** button for each discharge



e) Highlight the 50-yr storm and click **Select Discharge**. This will be the Discharge that the culvert is designed for.

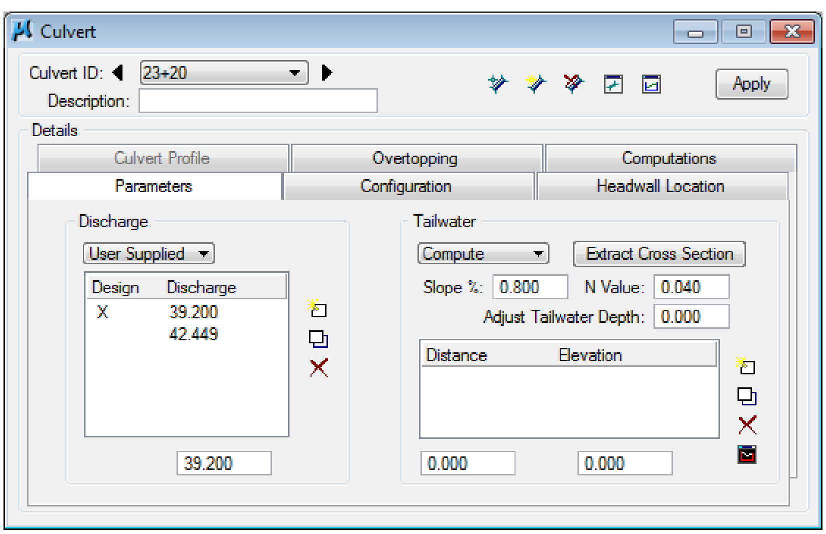


You could also just double **click** to set the desired Design Discharge that the culvert is designed for.

f) Define the tailwater. Set the **Tailwater** option to **Compute** and key-in the slope and N Value.

NOTES:
This slope is the longitudinal slope of the downstream channel. This slope can be determine utilizing the **Analysis** tool: **Height/Slope** located in **Applications>GEOPAK>ROAD>DTM Tools**

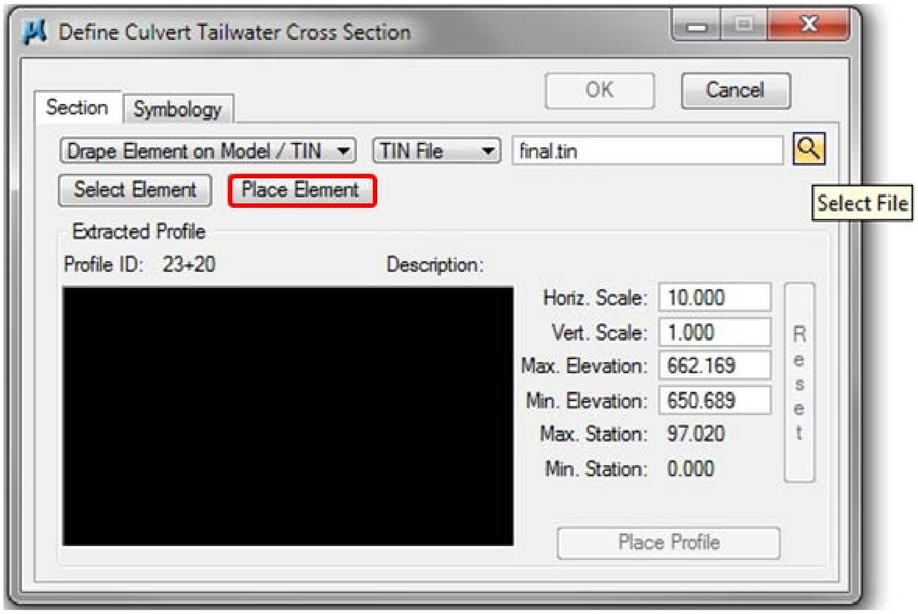
N Values for different surface channels are available in the TDOT Drainage Manual, Table 5A-1 *Values of Roughness* (See Appendix E).



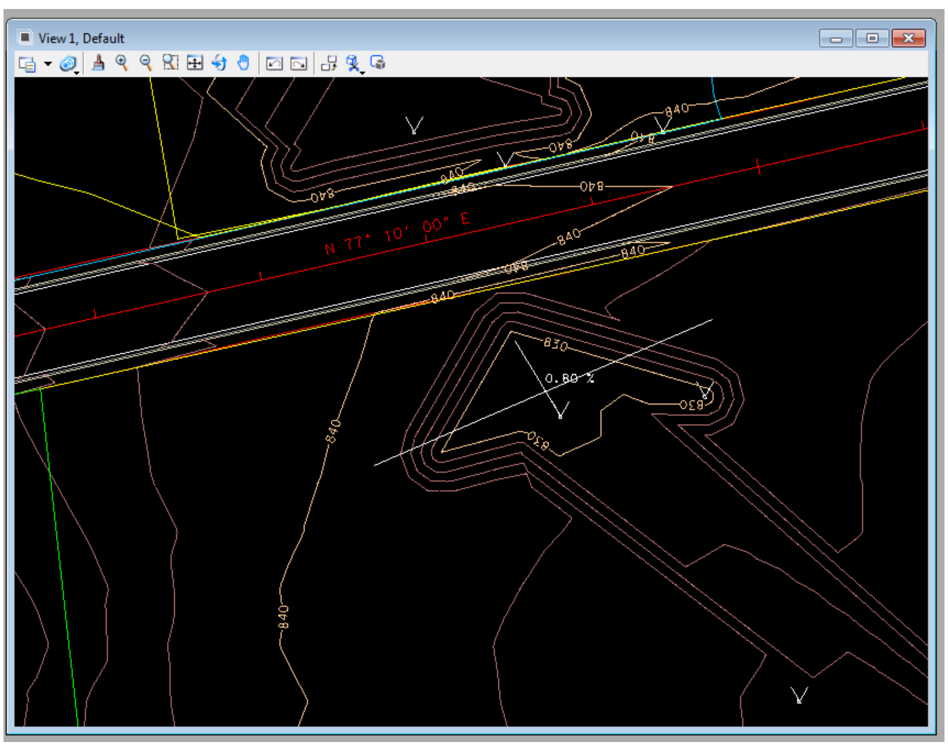
Set the **Slope %** to **0.800** and the **N Value** to **0.040** and click the **Extract Cross Section** button.

g) The **Define Culvert Tailwater Cross Section** dialog will open. Set to **Drape Element on Model/TIN** and **TIN File**.

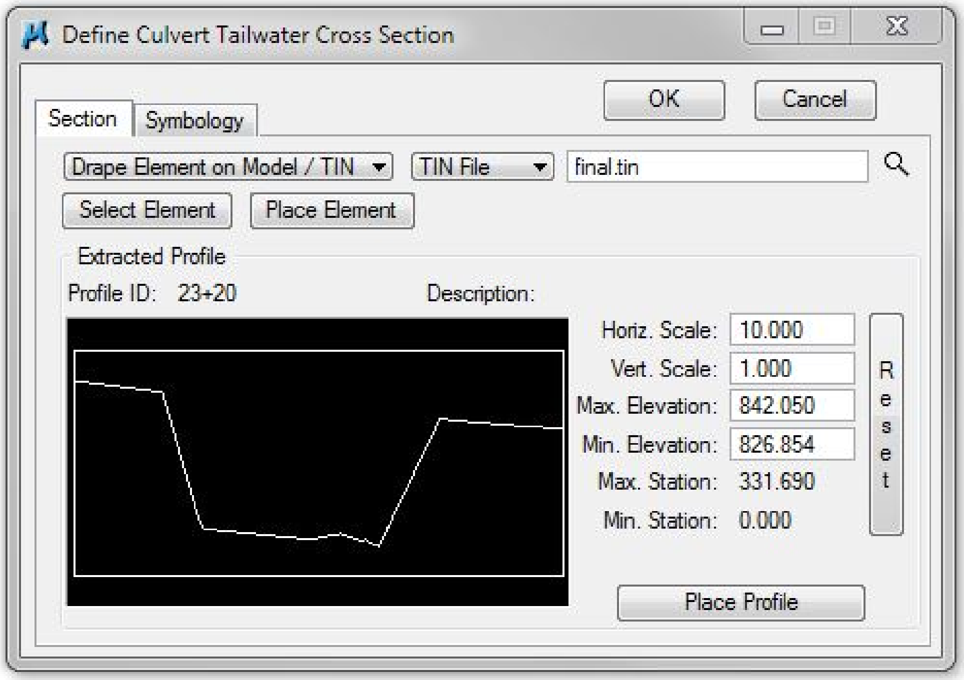
Click on the **Select Files** button and select **final.tin**.



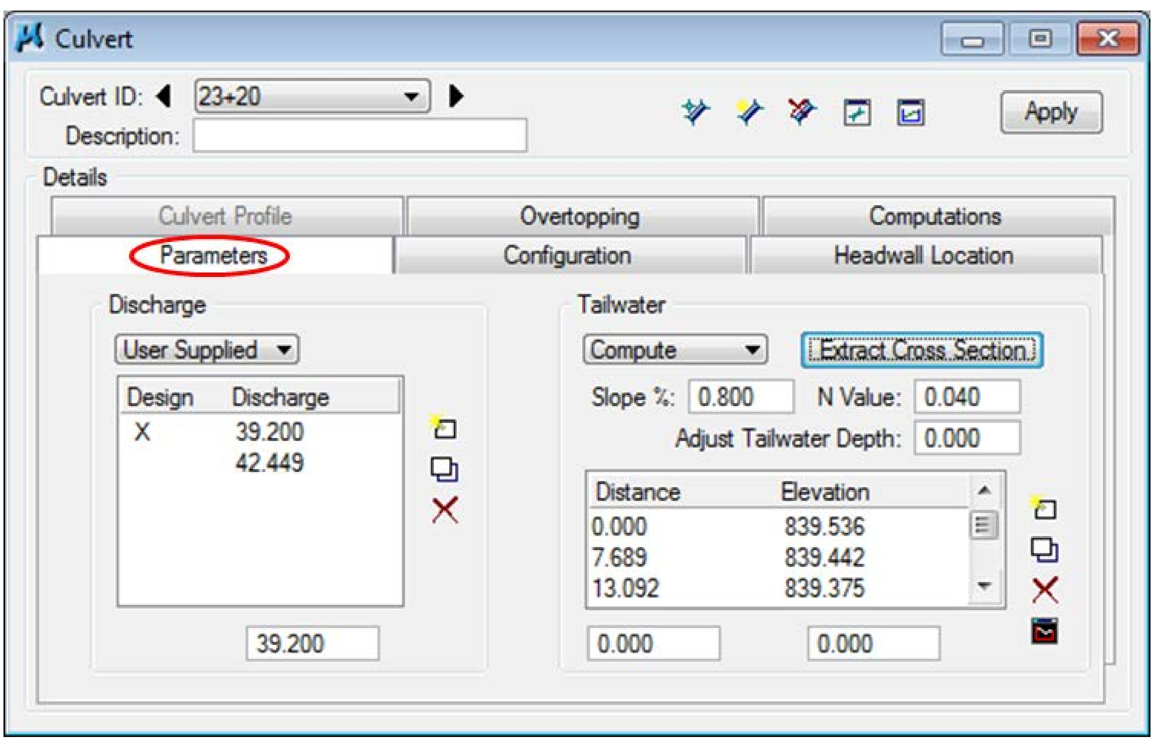
h) Click the Place Element button to locate the postion of the tailwater cross section that is to be extracted (this is notated as the 'Extracted Profile' on the dialog).:



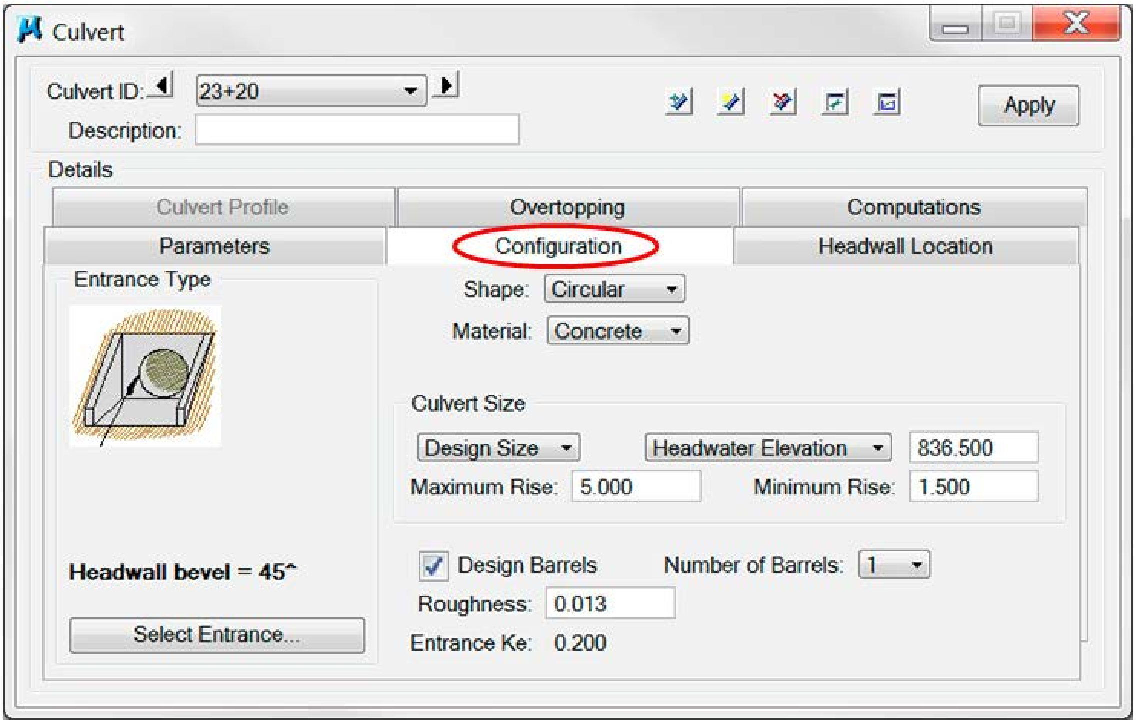
i) The **Define Culvert Tailwater Cross Section** dialog will now contain the profile along the element placed representing the channel cross section at this location.



j) Click the **OK** button and the main culvert dialog will open again. The values for the tailwater section will now be populated.



k) Select the **Configuration** tab to define the type of Culvert. Make settings as listed below.



Shape: Circular
(Culvert Shape: Circle, Box, Ellipse, Etc.)

Material: Concrete
(Culvert Material: Concrete, Steel, Plastic, Etc.)

Headwater Elevation: 836.50
(The maximum elevation the water can reach at the upstream end of the culvert). By default this option is set to Allowable Headwater which uses a height value, click to change to Headwater Elevation.

Maximum Rise: 5.000
(The maximum diameter, height of the culvert)

Minimum Rise: 1.500
(The minimum diameter, height of the culvert)

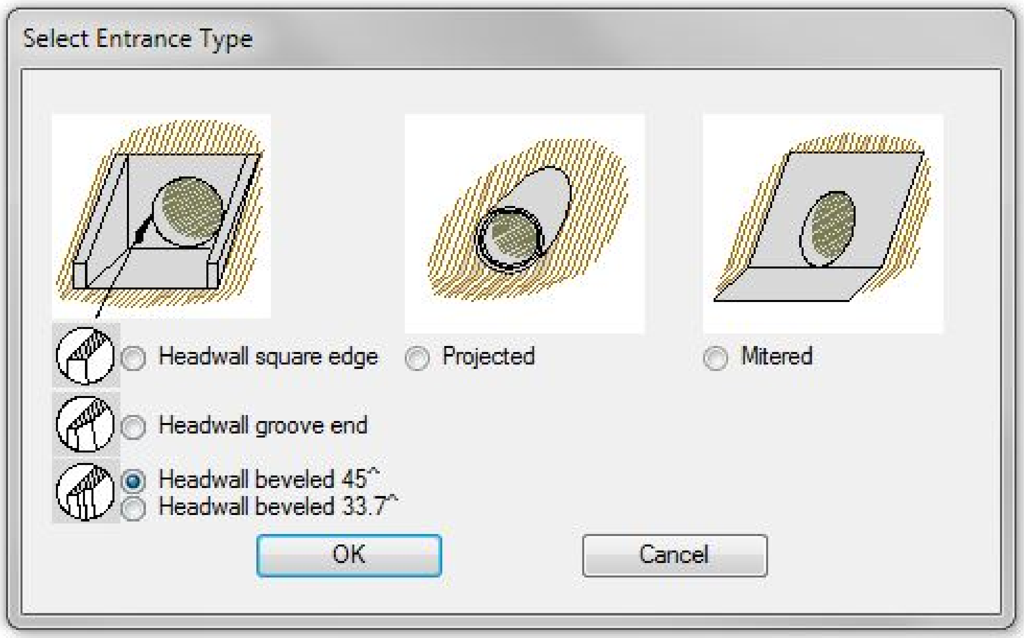
Design Barrels: Toggle ON
(Allows the program to design multiple barrels, if required)

Number of Barrels: 1

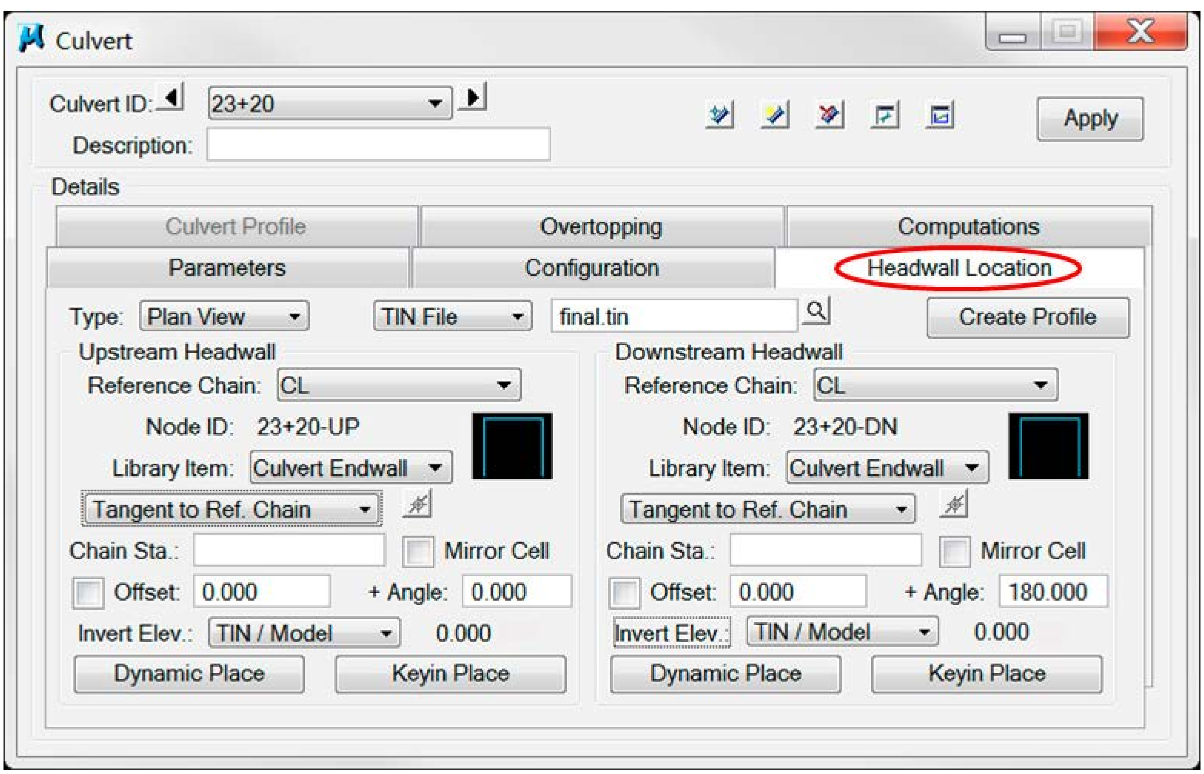
Roughness: 0.013
(Determined by the type of Material, See the TDOT Drainage Manual Section 6.04.2.4.3, *Culvert Roughness Coefficients*)

NOTE: If you know the size of culvert you need beforehand you may set Culvert Size to ‘Library Item’ and pick from the list of defined items.

l) Click **Select Entrance** and select the appropriate entrance condition. The most commonly used for TDOT projects is **Headwall beveled 45^**. Select this condition and click ok. This will automatically set the **Entrance Ke** value.



m) Select the **Headwall Location** tab to define the location of the **Upstream Headwall** and **Downstream Headwall** (nodes). Make settings as listed below.



Type: Plan View

Reference Chain: CL
(Roadway Centerline)

TIN File: final.tin

Library Item: Culvert Endwall

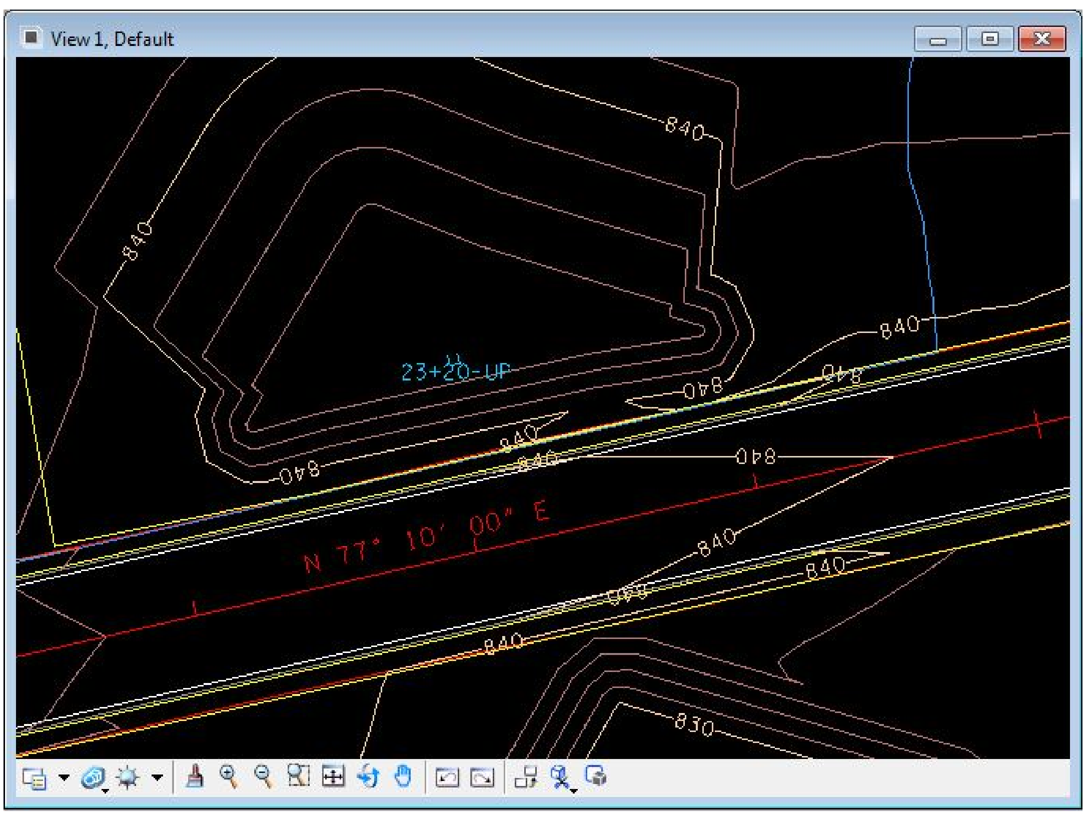
Alignment: Tangent to Ref. Chain

+ Angle.: 0 or 180
(For headwalls parallel to the roadway on the right side use an angle adjustment of 180 and on the left use 0. In this case the upstream is on left so that value should be set to 0.)

NOTE:.Another option is to use Mirror Cell. Set angles to 0 and Toggle ON for headwalls on the right of the roadway and Toggle Off for headwalls on the left of the roadway. Do NOT use Mirror Cell along with Angle Rotations as this adds confusion.

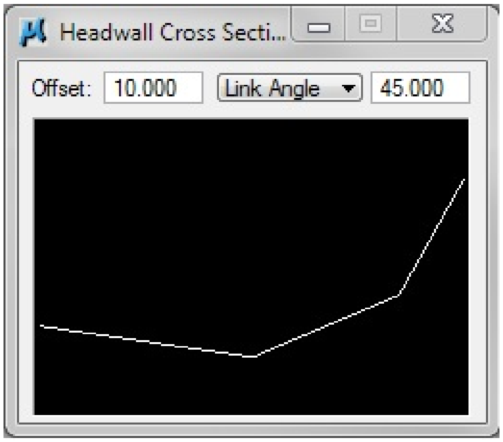
Invert Elev.: TIN / Model
(Reads TIN elevations. Use 'User Supplied' inverts are known or are different than TIN file.)

n) Locate the **Upstream Headwall** by clicking the **Dynamic Place** button and setting the upstream headwall at a location similar to that shown below:



Watch the **Headwall Cross Section** dialog box appear upon mouse-movement. Use this viewer to place the Headwall at the upstream **low point**.

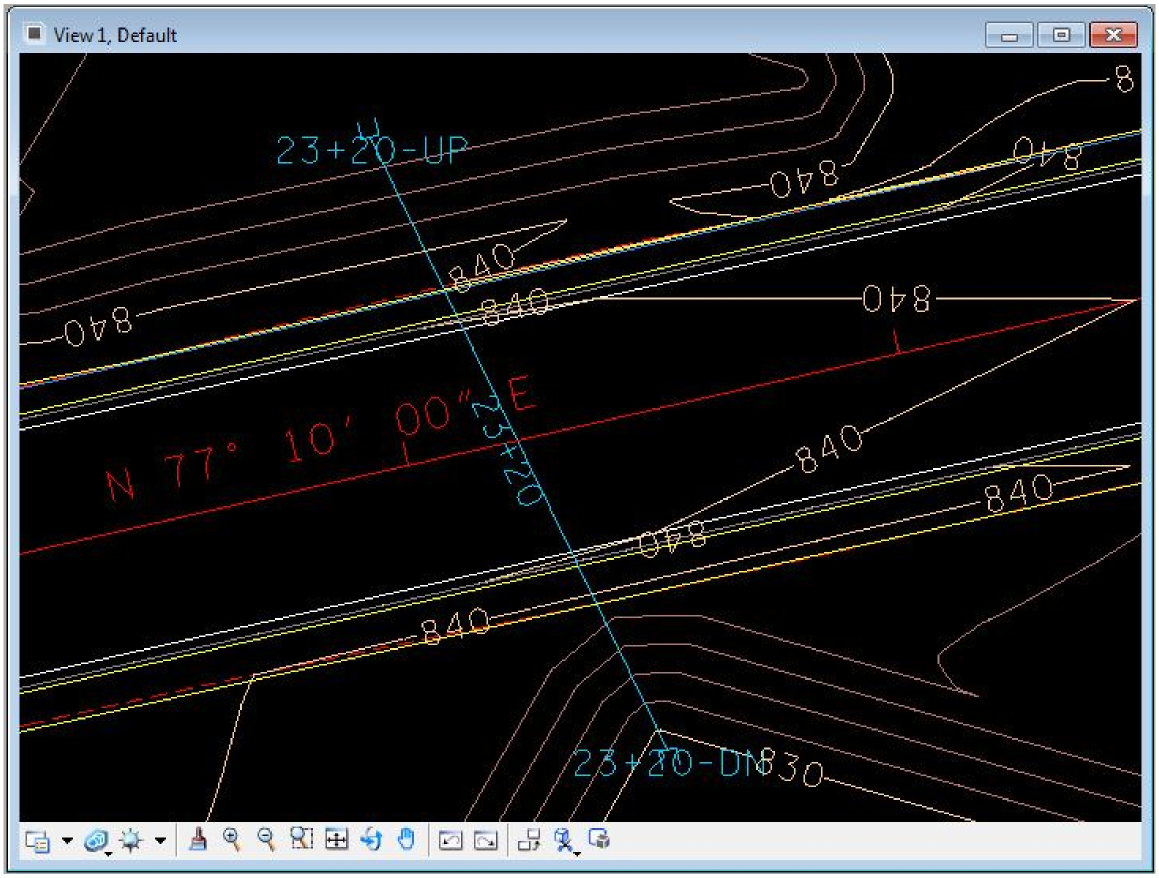
Station and offset values for the headwall location should change dynamically in the dialog as you move your mouse. If not, reset the chain name and try **Dynamic Place** again. It may be necessary to close the tool and reopen.

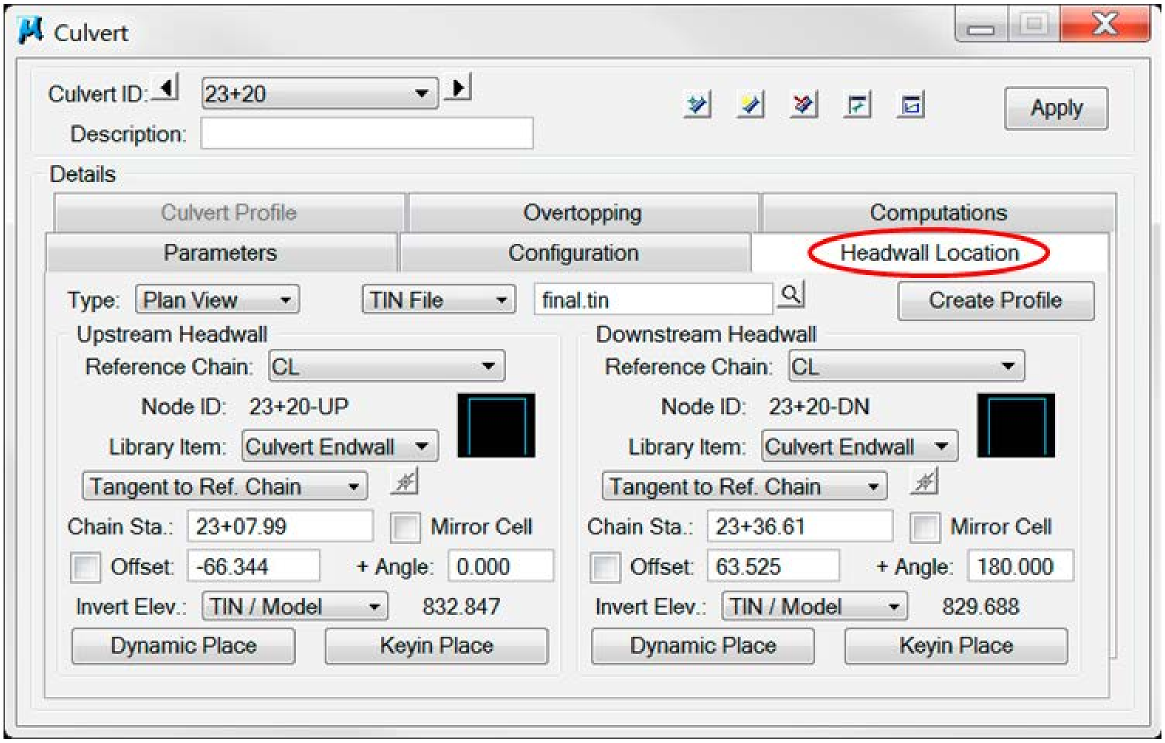


NOTES:
To set the headwall locations for 90 degree cross drains, you can enter the centerline crossing station with a given offset and click the Keyin Place button.

You may wish to utilize the **DTM Tools>Low Point Tool** as discussed in the DTM Tools Section 3 in order to predetermine the low point locations.

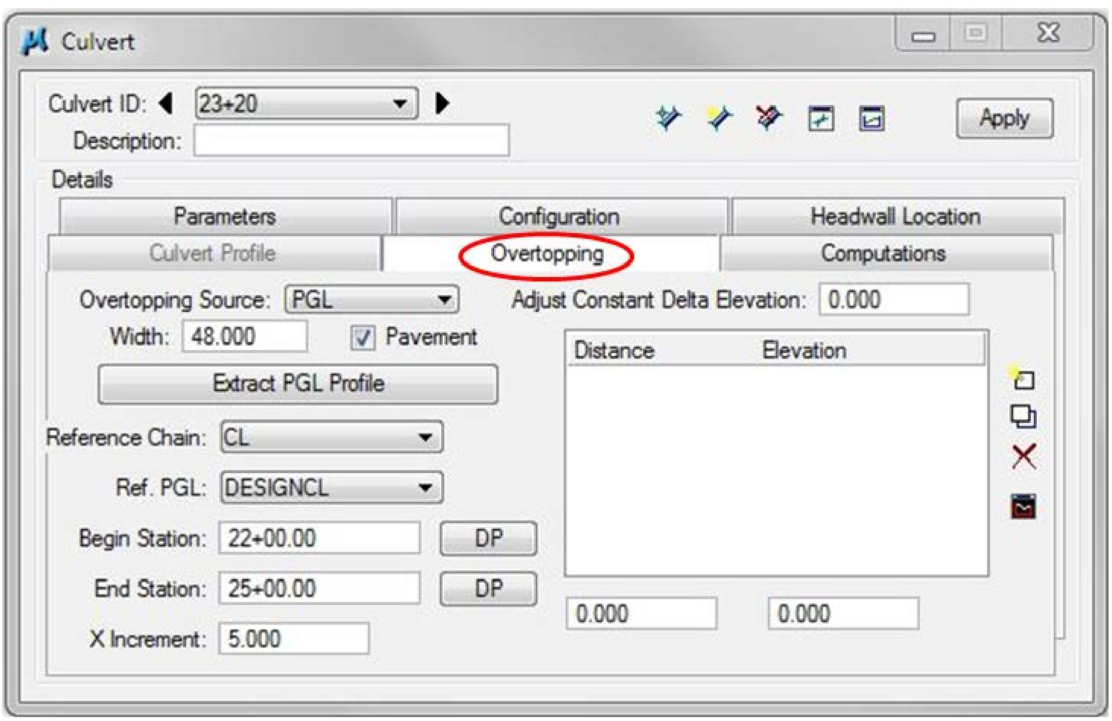
o) Locate the downstream headwall by clicking **Dynamic Place** under the **Downstream Headwall** group.





p) Select the **Overtopping** tab to define the limits of roadway overtopping. Make settings as listed below and click **Extract PGL Profile**.

NOTE: This step is only necessary if your culvert is in a **sag** condition. If you are not in a sag condition you may proceed to **Step 17.**



Overtopping Source: PGL
(This option sets the roadway profile as the controlling surface elevation for overtopping. Other options include 'User Supplied' or constant elevation and 'DTM')

Width: 48.00
(This is the width of your roadway)

Pavement: Toggle ON
(This should be checked unless your road is not paved)

Reference Chain: CL
(Roadway Centerline)

Ref. PGL: DESIGNCL
(Roadway Profile)

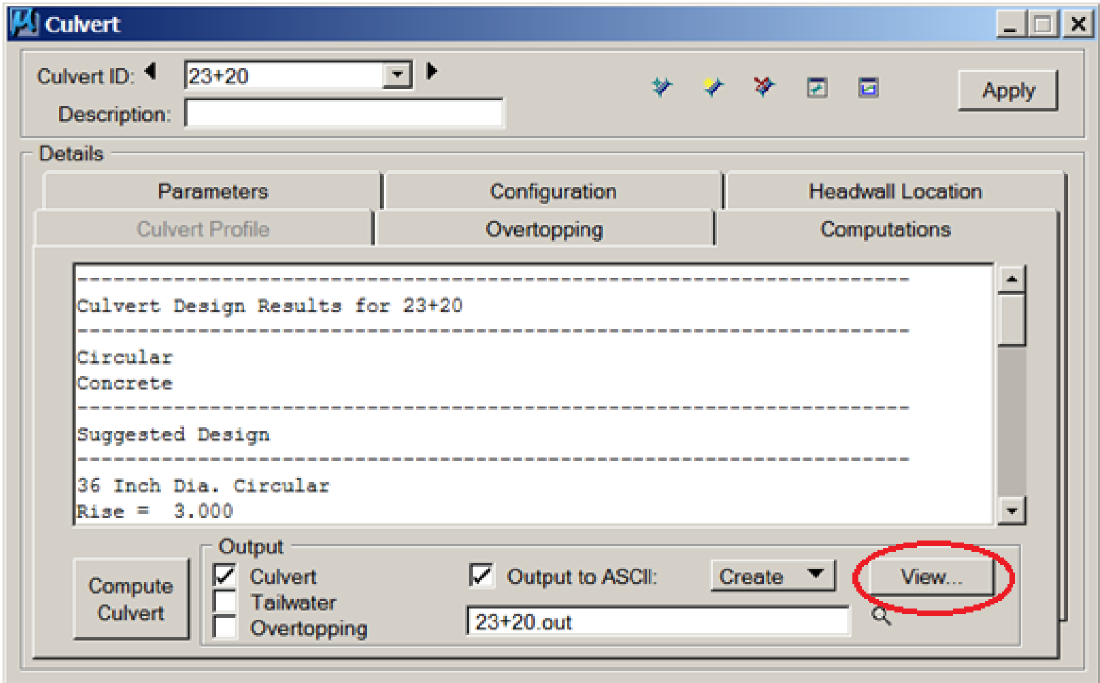
Begin Station: 22+00.00
(Use the **DP** button to select a point before the Culvert.)

End Station: 25+00.00
(Use the **DP** button to select a point after the Culvert.)

X Increment: 5.000
(This may be automatically adjusted depending on the distance between the begin station and end station.)

q) Once the Nodes have been located, and the elevations appropriately calculated, the Culvert can be added to the project. Click the **Apply** button and the culvert will be drawn and labeled according to the symbology in the Preferences.

r) The information to this point is enough to check the culvert computations. Select the **Computations** tab. Toggle on the option to view the **Culvert** calculations. Click the **Compute Culvert** button to perform the calculations.



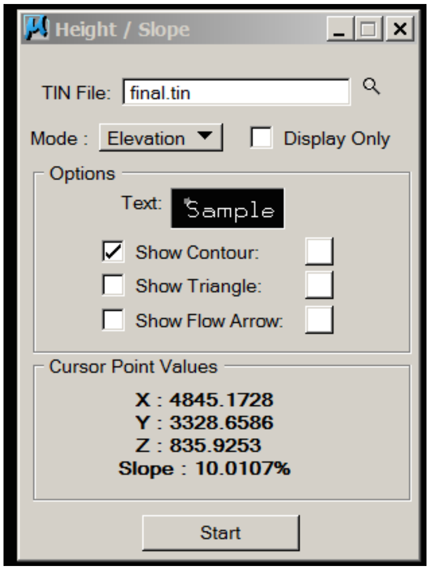
NOTE: You may include Tailwater and Overtopping calculations (if you need them) by toggling ON the option to view them.

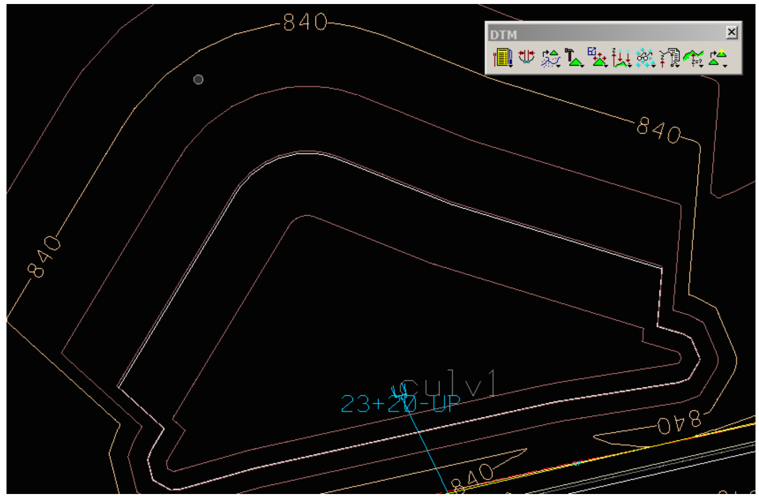
To view the Culvert Design Results, simply press the "View" button on the lower right of the "Culvert" menu to access the output file or you could open the file "23+20.out" from your Project Folder. View and/or print the Culvert Design Results that the Geopak Drainage software has calculated for you. Alternate design options have been found that may be considered.

The report also includes hydraulic computations such as Maximum Head Water Depth and Outlet Velocity for Q50 and Q100 which are helpful in analyzing the culvert design.

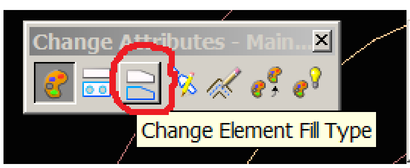
```
----
Culvert     Allow.     MAX      Inlet     Outlet    Tailwater
Discharge     HW        HW        HW        HW         Elev.
---------  --------  --------  --------  ---------  ----------
39.200     836.500   835.926   835.926   835.926   829.770
44.429     836.500   836.240   836.240   836.240   829.800
----------------------------------------------------------------
```

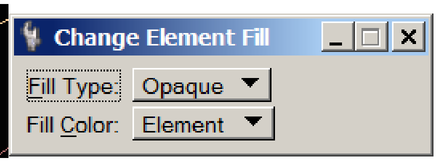
For the 50 year storm, the Head Water Depth is 835.926 ft. Using the DTM Height/Slope tool, a shape may be drawn at that elevation which represents the water surface for this storm event. This is the white shape in the picture below.

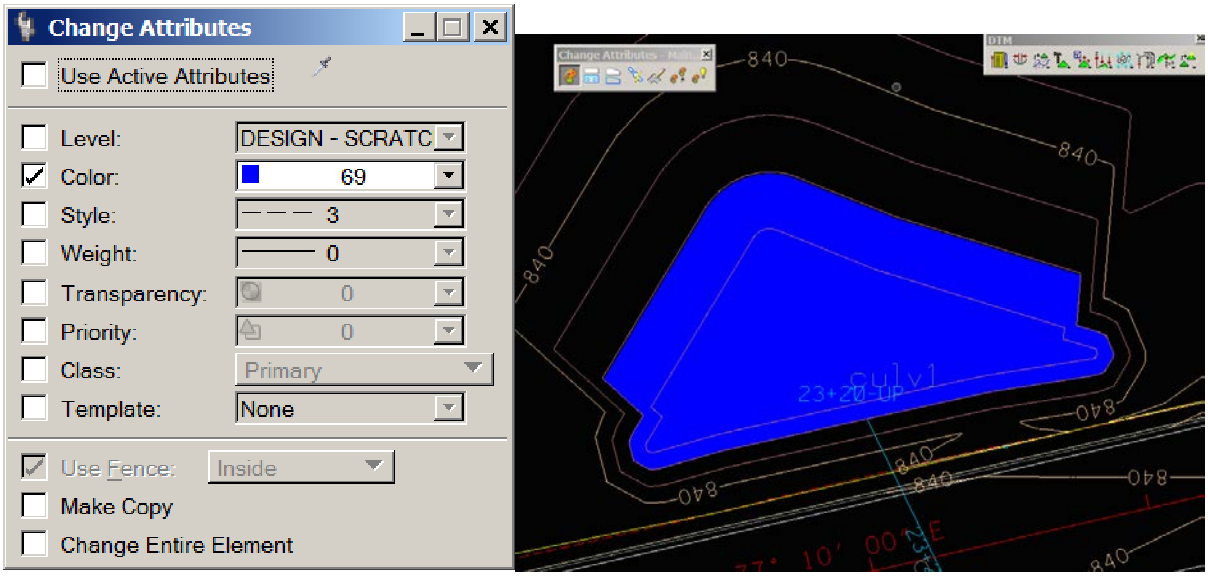




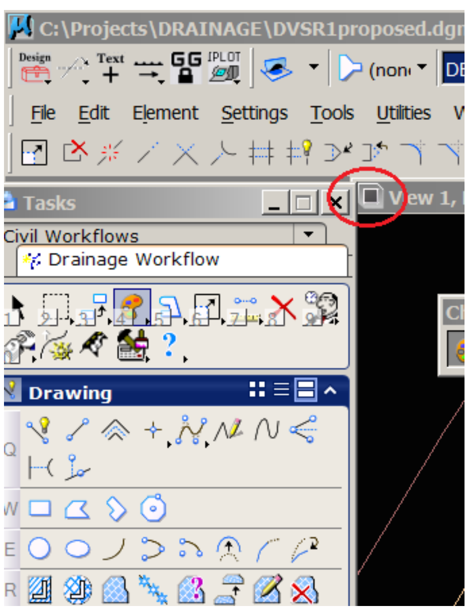
The Microstation Change Element Fill Type tool can be used to illustrate the ponded water for visual analysis. Use the Change Attributes tool to change the color to blue if desired.

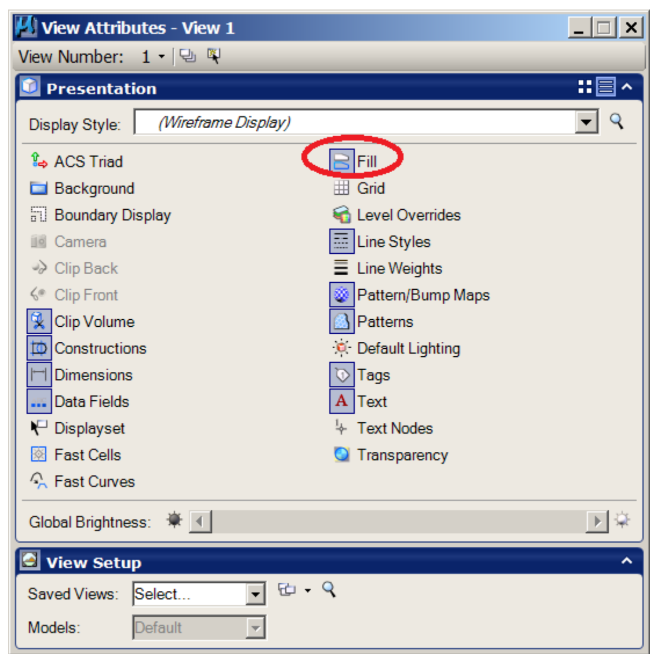




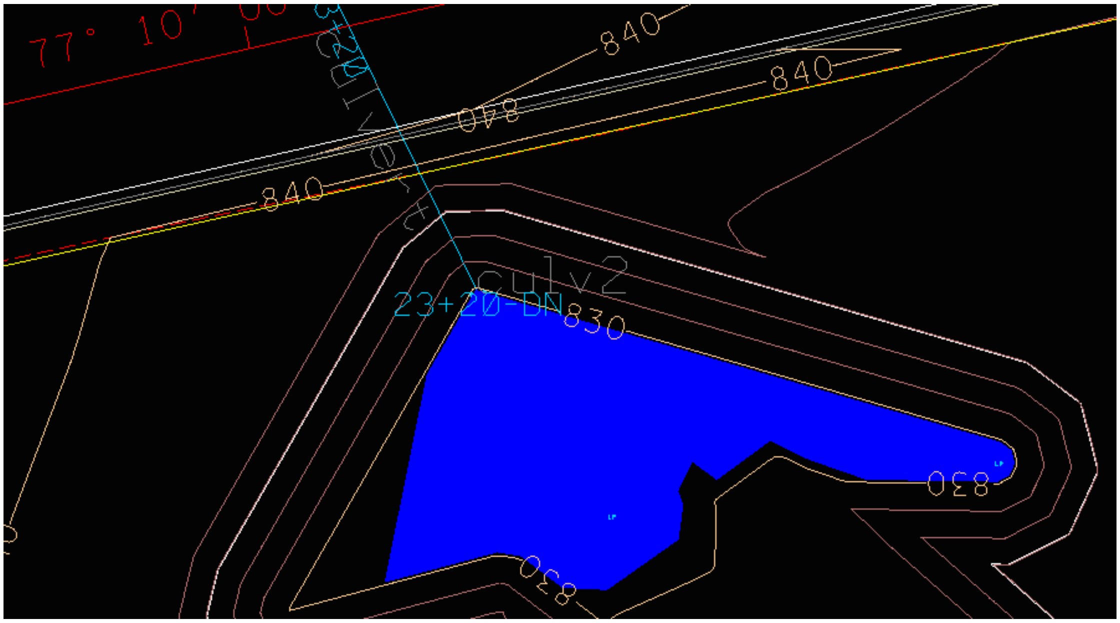


Be sure that your **Fill is toggled On** in the View Attributes menu.





Similarly, a visualization of the Tail Water pond may be created.

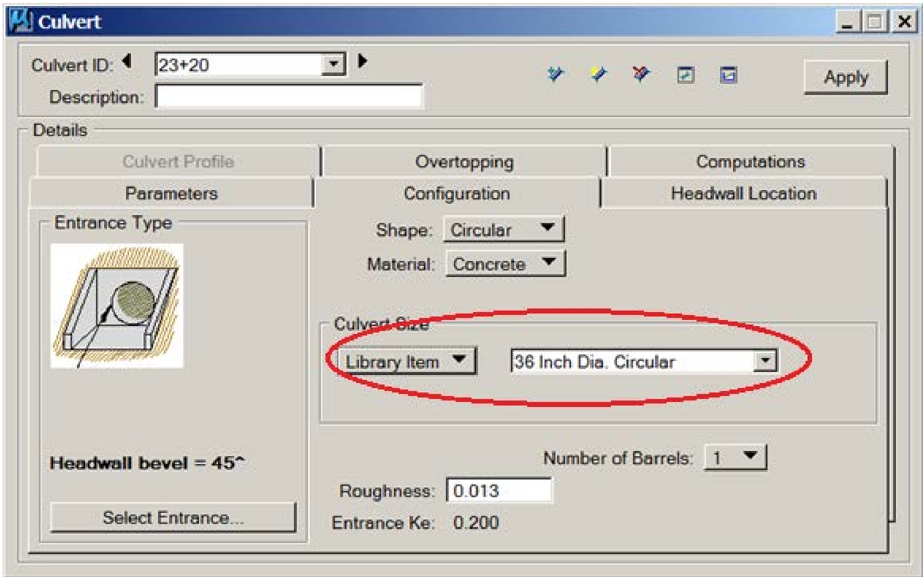


The Drainage Manual states that outlet velocities on Culverts should be based on the 50 year storm. In our file 23+20.out, we see that Geopak Drainage has calculated the Outlet Velocity for the 50 year storm at 13.567 fps.

Culvert Discharge	Outlet Velocity	Uniform Depth	Critical Depth	Critical Slope	Friction Slope
39.200	13.567	1.284	2.038	0.005	0.024
44.429	14.024	1.378	2.172	0.006	0.024

The use of riprap as scour protection at a culvert outlet is discussed in Section 6.04.3.3 of the Drainage Manual. It says that riprap can be used to provide protection at a culvert outfall for velocities between 5 fps and 12 fps. Since our velocity is greater than 12 fps, we would either need to lessen the slope of the culvert, thereby reducing the velocity at the outlet, or we would need to design a stilling basin or some other type of energy dissipator. See the Drainage Manual for guidance.

Before the next step, go back to “Configurations”, change Culvert Size to “Library Item” - 36 Inch Dia Circular. Then, select the Culvert Size drop down and switch it to Design Size and set the Maximum Rise to 3.



4.3 Culvert Profile

At this point, the designer has the pipe size that will be required and can use regular Geopak proposed cross section tools to set up a culvert section to finalize the length & inverts for the cross drain.

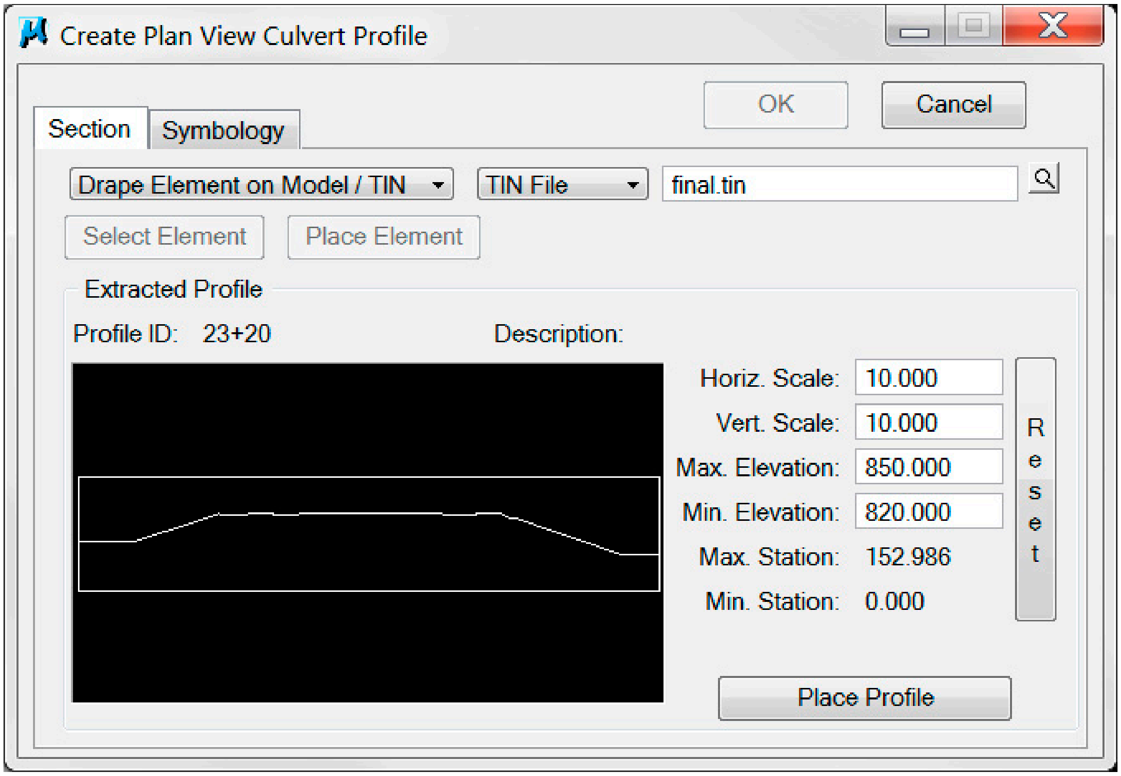
The next several steps illustrate the functionality available through Geopak Drainage to set up a culvert section in profile format along the cross drain.

a) On the **Headwall Location** tab click on **Create Profile** to set up a culvert section and finalize headwall locations. The **Create Plan View Culvert Profile** dialog will open up. Make settings as shown below.

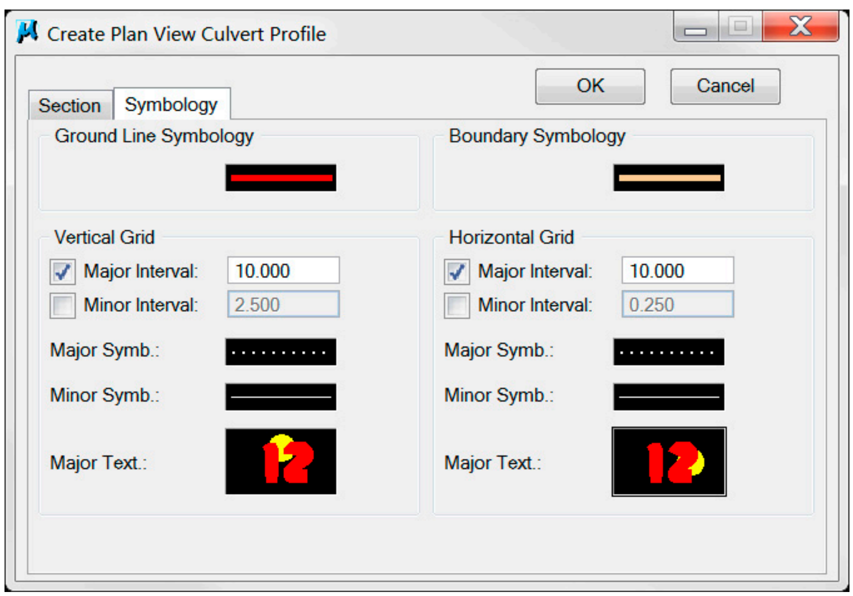
Set **Horiz scale 10** and **Vert scale 10**.

Change **max** and **min** elevations to be the next even 10' up or down.

Use default values for Max and Min station.



b) Click on the **Symbology** tab and make the following settings:



Ground Line Symbology (Proposed Roadway):

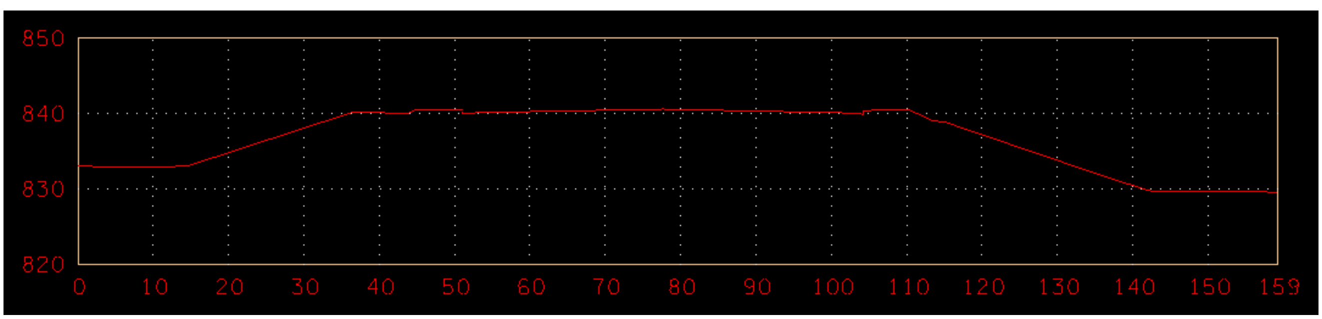
LV= DESIGN - TYPICAL - Finished Grade and Subgrade
CO= 6, Style=0, WT=4

Boundary Symbology:

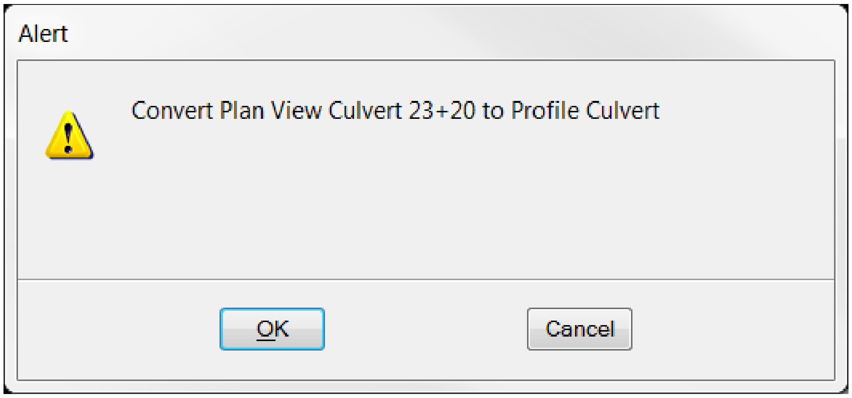
LV= DESIGN – SHEET – Light Grid
CO=2, Style=0, WT=4

Vertical Grid Major Interval:
ON, Value=10
Vertical Grid Minor Interval:
OFF
Vertical Grid Major Symbology:
LV= DESIGN – SHEET – Light Grid
CO=0, Style=1, WT=1
Vertical Major Text:
LV= DESIGN – SHEET – Corner Text
CO=6, WT=10, TH=2, TW=2, FT=LEROYMON(3)
Click the Top Center to set Justification
Horizontal Grid Major Interval:
ON, Value=10
Horizontal Grid Minor interval:
OFF
Horizontal Grid major symbology:
LV= DESIGN – SHEET – Light Grid
CO=0 Style=1 WT=1
Horizontal Major Text:
LV= DESIGN – SHEET – Corner Text
CO=6, WT=10, TH=2, TW=2, FT=LEROYMON(3)
Click the Middle Right to set Justification

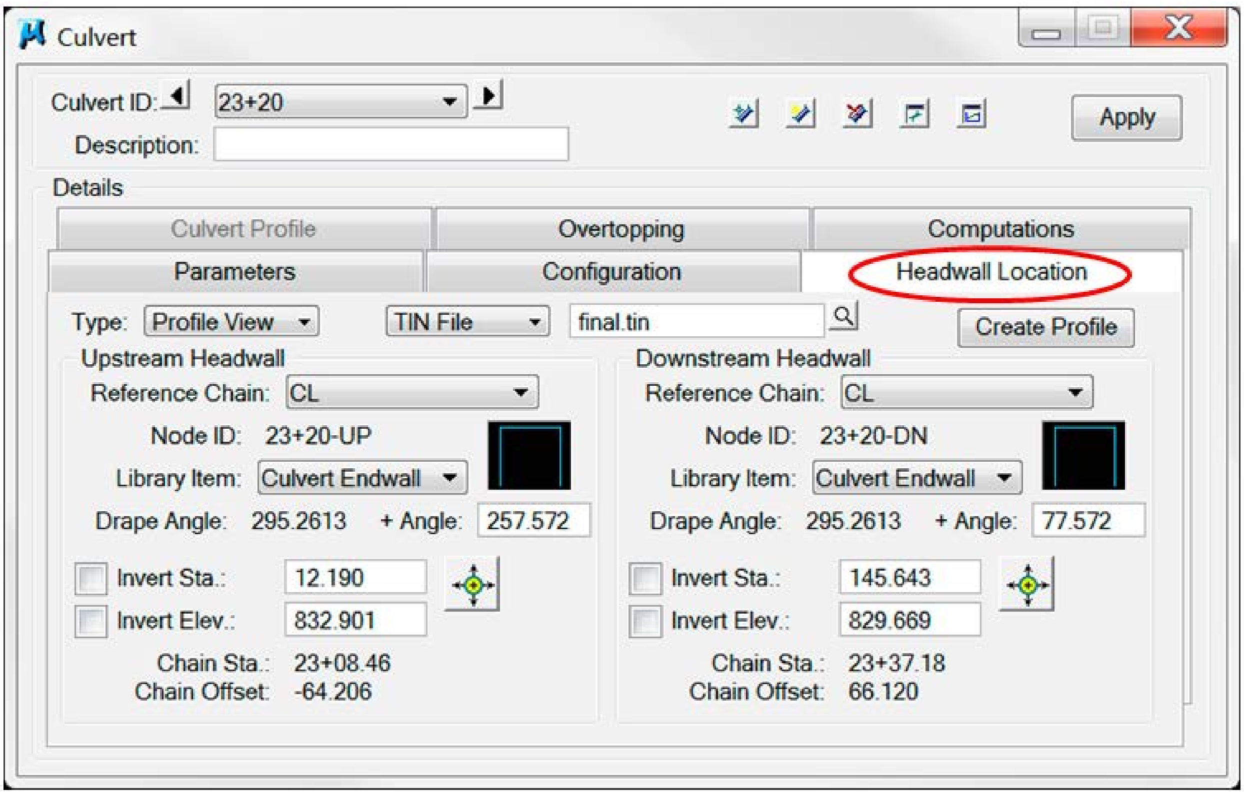
c) Once symbologies are set click on the **Section** tab and click on **Place Profile** in the lower right of the dialog. Culvert Section graphics will appear on the cursor, **Data Point out in the open somewhere to place the graphics**. Click **OK** on **Create Plan View Culvert Profile** dialog to dismiss and reopen the **Culvert Edit** dialog. Click **Apply** to store the culvert information.



d) Now that we have placed our culvert section we can finalize our inlet and outlet locations. On the **Headwall Location** tab change **Type** from Plan View setting to **Profile View**. **When prompted to "Convert Plan View Culvert to Profile Culvert" click OK:**



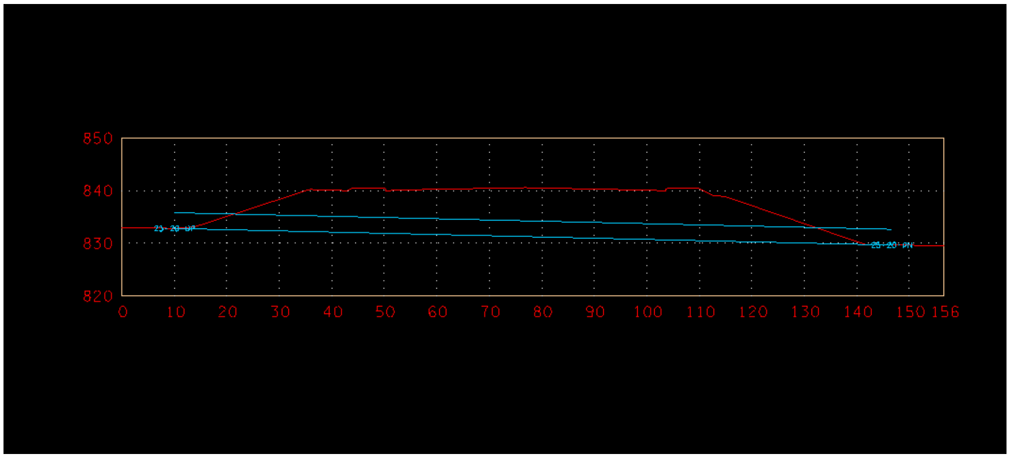
e) The **Headwall location** tab will change to show Profile view controls.



f) Under **Upstream Headwall** controls click **Station DP** button.  Move cursor over culvert section profile near the upstream end of pipe. That end will start dynamically tracking with cursor movement. Relocate inlet so that the upstream invert of the pipe coincides with roadway side slope.

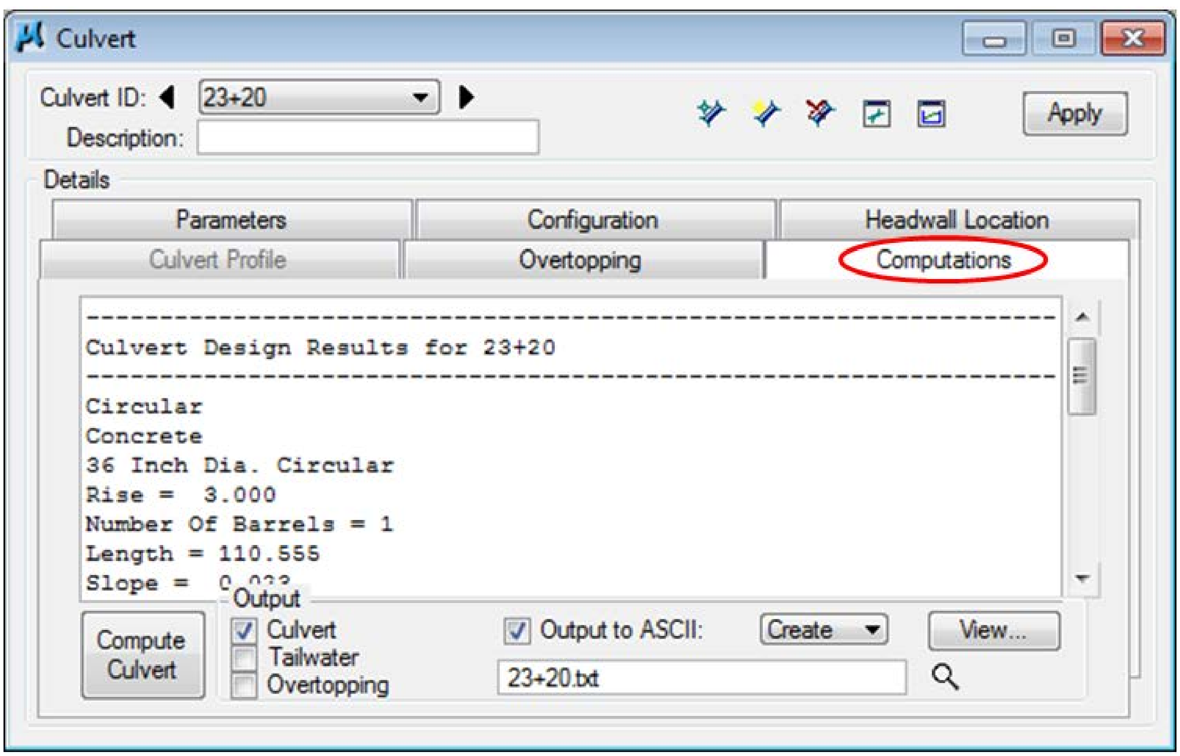
NOTE: This location could be located previously with Microstation commands or calculated and input as values in the Invert Sta. & Invert Elev. Keyin fields.

g) Repeat this procedure on the **Downstream Headwall** by clicking on **Station DP** and locating in culvert section profile.



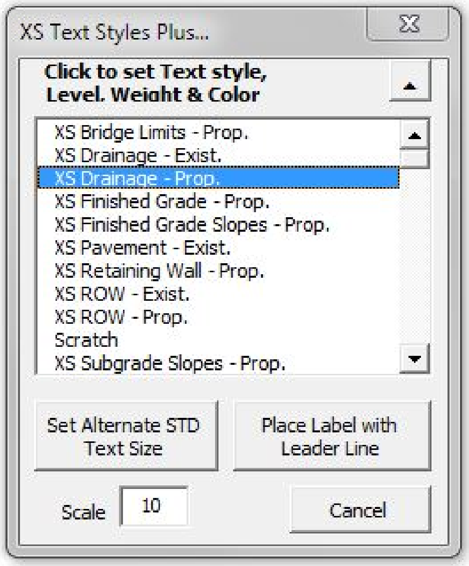
h) Once Headwall locations have been reset click on **Apply** in the upper right corner of the **Culvert Edit** dialog. Now go back to the **Computation** tab and this time before clicking on **Compute Culvert, toggle ON** option for **Output to ASCII**, keyin name **23+20.txt** and set file to **Create** option.

When **Compute Culvert** is clicked the output data in dialog is updated and text output file is created.



i) To place drainage info with culvert section profile :

Set active text settings by going to **TDOT>Cross Sections>XS Text Styles Plus,** set Scale to **10** and select **XS Drainage - Prop.**:



Go to Microstation's **File>Import>Text** and pick the file **23+20.txt** in your project directory. Data Point in the DGN file for placement near the culvert section profile. This data can now be used when filling out TDOT Standard Drainage Data cells or can be edited to show additional data needed with the culvert section.