Roundabout Workshop

Using Civil Geometry

The Roundabout Workshop utilizes some new Civil Geometry tools in GEOPAK along with Roadway Designer and GEOPAK Site tools.

Overview
Chapter 1 – Libraries
Chapter 2 – Working With Civil Geometry
Chapter 3 – Placing the Roundabout
Chapter 4 – Model Setup
Chapter 5 – Corridor Modeling
Chapter 6 - 3D Drive Thru
Class Final Exercise

MoDOT CADD SUPPORT

Overview

This workshop gives the users the ability to use the Bentley Civil Roundabouts application in a hands-on environment.
The Roundabout tool is a rules-based approach that allows intelligence to be preserved in the design, standards to be applied to the roundabout design, and dynamic adjustment to the design.

Prerequisites

- Fluent in MicroStation and a basic understanding of roundabouts is recommended.
- Previous GEOPAK and Roadway Designer classes are recommended.

Objectives

After completing this course, you will be able to:

- Have a basic understanding of the rules based approach as it pertains to design
- Understand the concepts to manipulate your design and save your alternatives
- Understand new Civil Geometry Tools and GEOPAK Site tools
- Manipulate the template to fit your needs

Defining Physical Features

A roundabout is a type of circular intersection, but not all circular intersections can be classified as roundabouts. In fact, there are at least three distinct types of circular Intersections:

- Rotaries are old-style circular intersections common to the United States prior

to the 1960's. Rotaries are characterized by a large diameter, often in excess of 100 m (300 ft). This large diameter typically results in travel speeds within the circulatory roadway that exceed 50 km/h (30 mph). They typically provide little or no horizontal deflection of the paths of through traffic and may even operate according to the traditional "yield-to-the-right" rule, i.e., circulating traffic yields to entering traffic.

- Neighborhood traffic circles are typically built at the intersections of local streets

for reasons of traffic calming and/or aesthetics. The intersection approaches may be uncontrolled or stop-controlled. They do not typically include raised channelization to guide the approaching driver onto the circulatory roadway. At some traffic circles, left-turning movements are allowed to occur to the left of (clockwise around) the central island, potentially conflicting with other circulating traffic.

- Roundabouts are circular intersections with specific design and traffic control

features. These features include yield control of all entering traffic, channelized approaches, and appropriate geometric curvature to ensure that travel speeds on the circulatory roadway are typically less than 50 km/h (30 mph). Thus, roundabouts are a subset of a wide range of circular intersection forms.
To more clearly identify the defining characteristics of a roundabout, consistent definitions for each of the key features, dimensions, and terms are used throughout this guide. Exhibit 1-1 is a drawing of a typical roundabout, annotated to identify the key features. Exhibit 1-2 provides a description of each of the key features.

Description of Key roundabout features

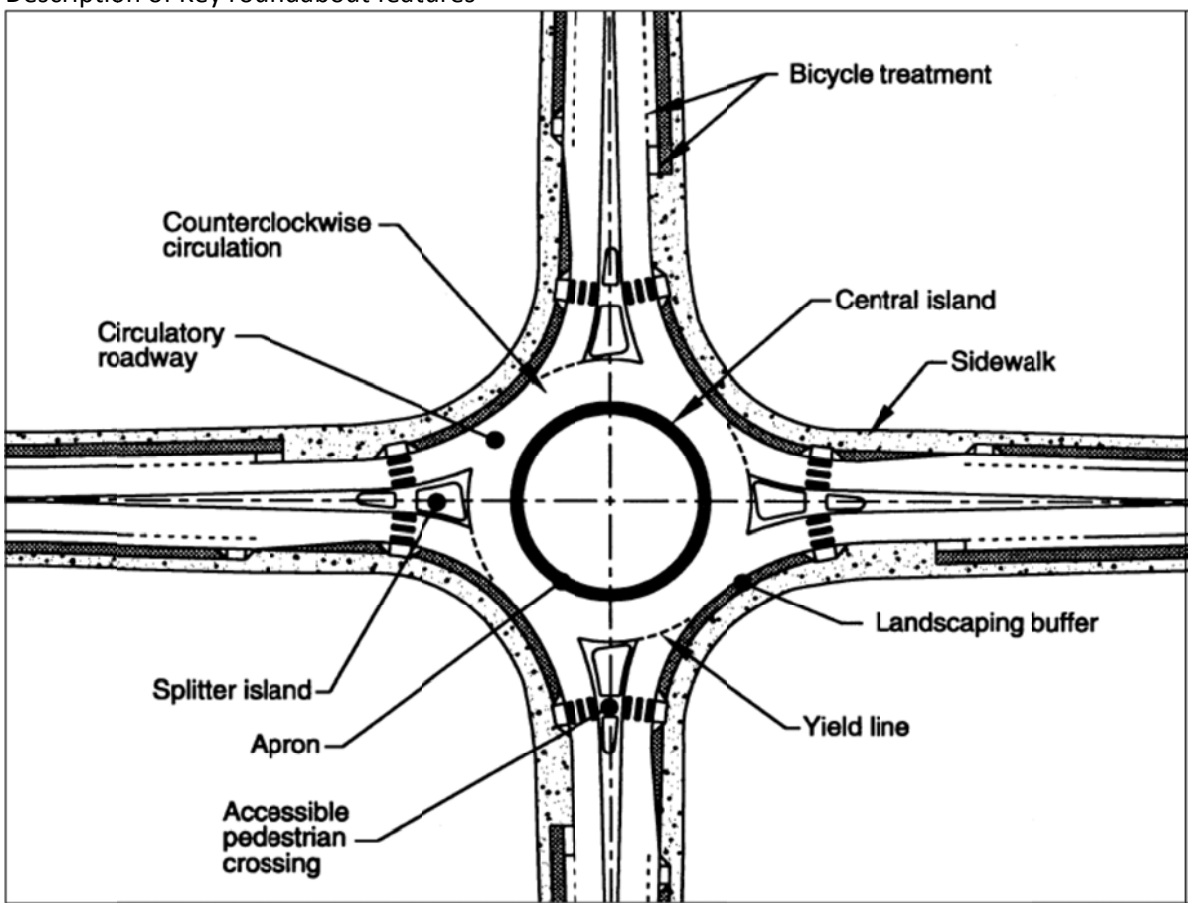
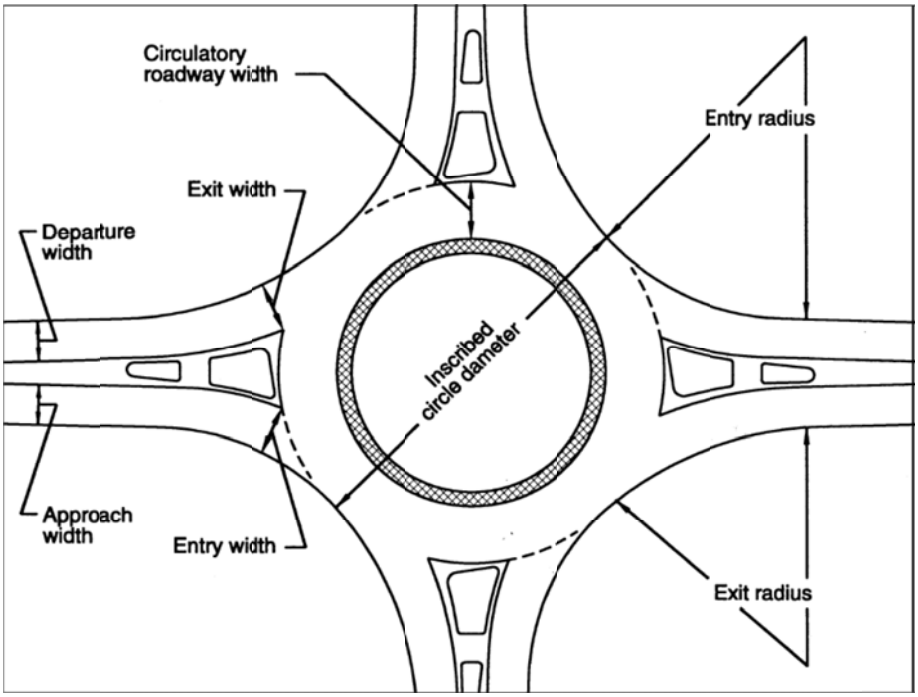


Figure 1 Drawing of key roundabout features

Feature	Description
Central island	The central island is the raised area in the center of a roundabout around which traffic circulates.
Splitter island	A splitter island is a raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow entering traffic, and provide storage space for pedestrians crossing the road in two stages.
Circulatory roadway	The circulatory roadway is the curved path used by vehicles to travel in a counter- clockwise fashion around the central island

Apron	If required on smaller roundabouts to accommodate the wheel tracking of large vehicles, an apron is the mountable portion of the central island adjacent to the circulatory roadway.
Yield line	A yield line is a pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.
Accessible pedestrian crossings	Accessible pedestrian crossings should be provided at all roundabouts. The crossing location is set back from the yield line, and the splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.
Bicycle treatments	Bicycle treatments at roundabouts provide bicyclists the option of traveling through the roundabout either as a vehicle or as a pedestrian, depending on the bicyclist's level of comfort.
Landscaping buffer	Landscaping buffers are provided at most roundabouts to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. Landscaping buffers can also significantly improve the aesthet-ics of the intersection.



Roundabouts: An information Guide – FHWA-RD-00-67, June 2000
http://www.tfhrc.gov/safety/00068.htm

Dimension	Description
Inscribed circle diameter	The inscribed circle diameter is the basic parameter used to define the size of a round- about. It is measured between the outer edges of the circulatory roadway.
Circulatory roadway width	The circulatory roadway width defines the roadway width for vehicle circulation around the central island. It is measured as the width between the outer edge of this roadway and the central island. It does not include the width of any mountable apron, which is defined to be part of the central island.
Approach width	The approach width is the width of the roadway used by approaching traffic upstream of any changes in width associated with the roundabout. The approach width is typically no more than half of the total width of the roadway.
Departure width	The departure width is the width of the roadway used by departing traffic downstream of any changes in width associated with the roundabout. The departure width is typically less than or equal to half of the total width of the roadway
Entry width	The entry width defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle.

Exit width	The exit width defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the exit to the intersection point of the left edge line and the inscribed circle.
Entry radius	The entry radius is the minimum radius of curvature of the outside curb at the entry.
Exit radius	The exit radius is the minimum radius of curvature of the outside curb at the exit.

Chapter-1 Libraries

Creating a Roundabout Library

As discussed earlier Bentley Civil Roundabouts (BCR) uses a library roundabout that is a preset configuration of the roundabout (RAB). A special toolset is available for setting up the RAB.
Before beginning, the user should familiarize themselves with the various parts of the RAB. The prior section outlined the description of these parts as defined by FWHA's manual on roundabout design. When working with BCR you will find this same terminology. Additionally BCR expands on this terminology in order to assign properties to other geometric constraints needed for roundabout design. Below is a list of additional terminology:

Circulatory Crown- Describes the location of crown element if desired in the circulatory area.
Overrun (Apron) - area allowed for overrun in turning radius of circulatory area.
Approach- Consists of the group of geometric features that make up the approaching lane to the RAB.
Deflection Area- The theoretical area used entry and exit to the RAB circulatory area.
Flare- Collection of geometric elements along the outer lane of the RAB used to join adjacent approaches.
The exercise below will guide the user through customizing a delivered library RAB. The customization will involve:

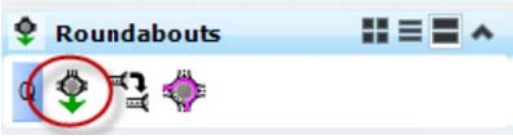
- Selecting a closely related RAB template
- Redefine the geometric components associated to the RAB
- Featurize the geometric components

NOTE: The current version of ProjectWise does not work with Roundabout Libraries. The examples in this manual assume the project is not in ProjectWise, however, it is important that the drawings are placed in ProjectWise when complete.

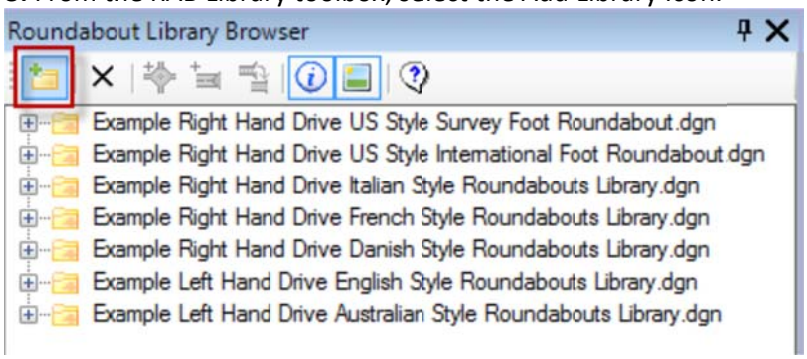
Set Up Roundabout Library

1. Open the File RAB-MODOT.dgn C*:\Data\CH-1Create Library*. (file cannot currently reside in ProjectWise)

2. Open the toolbox "Roundabouts- Library Browser" ... *Tools > Roundabouts>Roundabout Library Browser* or from the task menu



3. From the RAB Library toolbox, select the Add Library Icon.

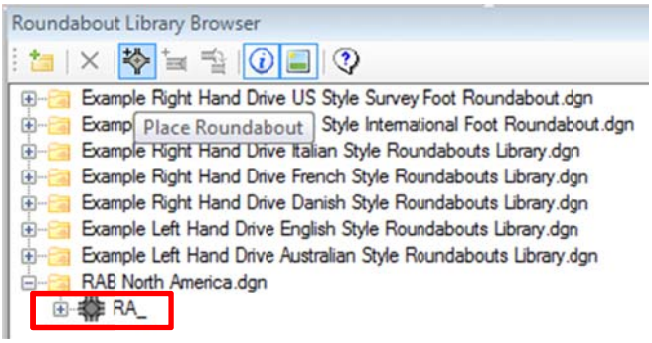


4. Select the RAB North America.dgn. C*:\Data\RoundaboutsII\CH-1Create Library*

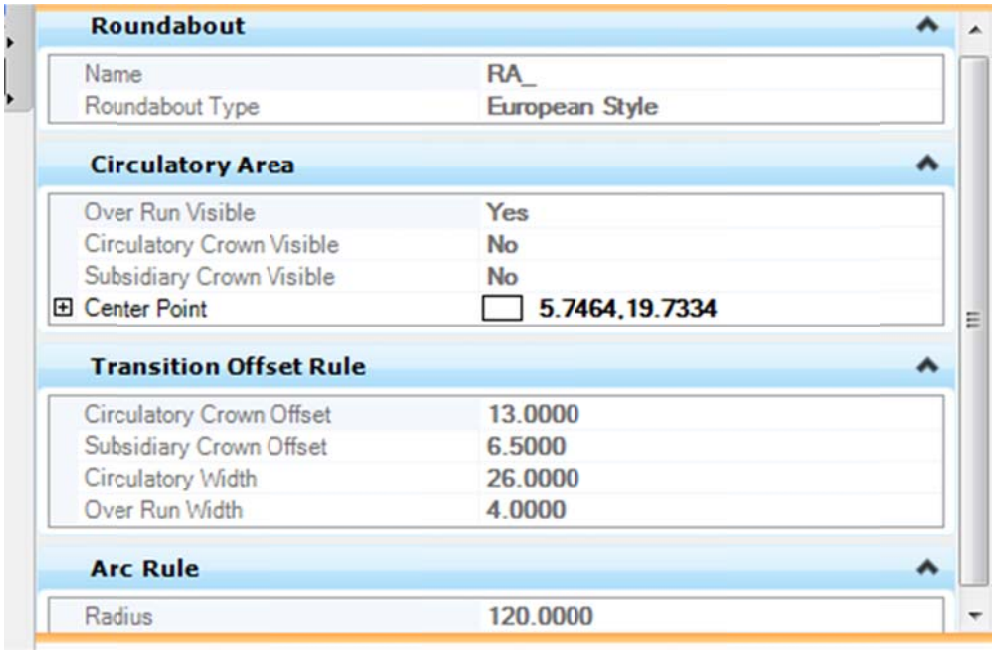
Note *An RAB North America,dgn will now appear in the Roundabout Library Browser*

5. Open the RAB North America Roundabout.

6. Select RA_.

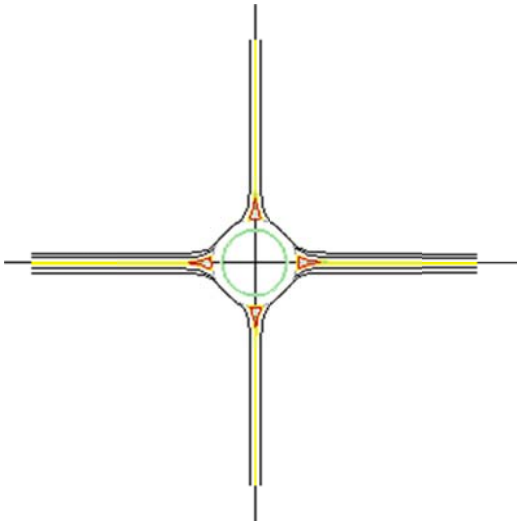


7. Setup the RAB properties.



8. Click the Place Roundabout Tool.

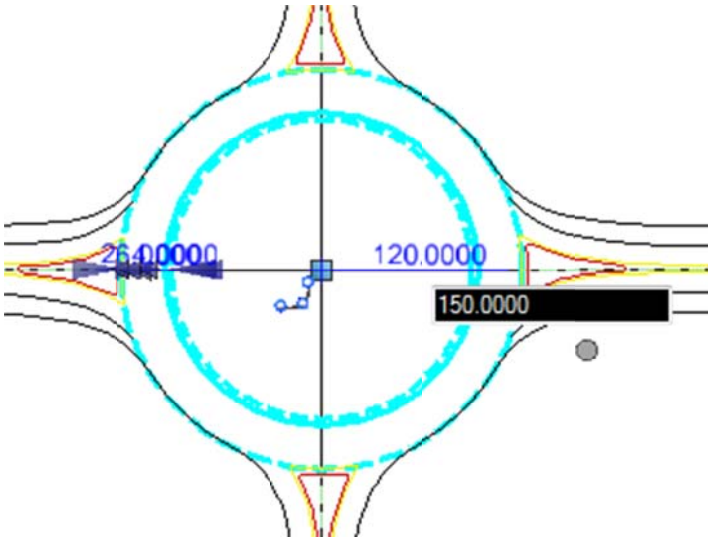
This will place the RAB based on 1 or more legs of the Roundabout. If you select only 1 leg, you will have a roundabout with a single approach created, based on the settings for the approach. An approach will be created for each leg selected. Follow the prompts and select the center point and a RAB will be created. Below a Roundabout has been created selecting 4 legs.



The Library RAB contains the geometric design for a typical RAB. This RAB can be modified by altering any of the features to include additional approaches, customize lanes, circulatory area, and geometry modifications.

Modify Circulatory Area

9. Change the diameter of the RAB circulatory area by selecting any portion of the circulatory area. Change the diameter to 150'. You will see selecting the radius will pull up the Heads Up Display.



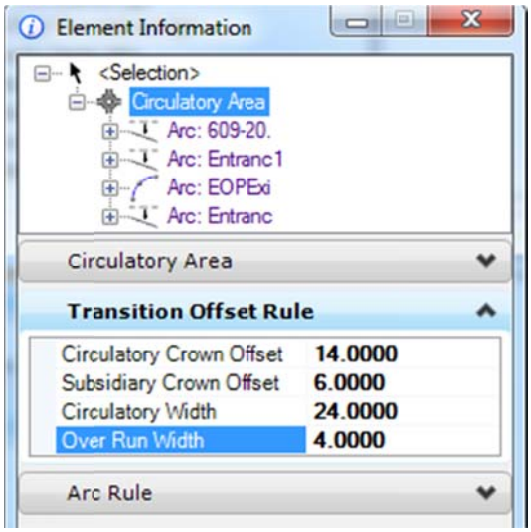
Note *Make the above modification done using the* ***On screen Editing (Heads Up Display)***

Use the MicroStation Element Information tool to change the following:

10. Select the circulatory area.

11. Open the Microstation Element Information dialog .

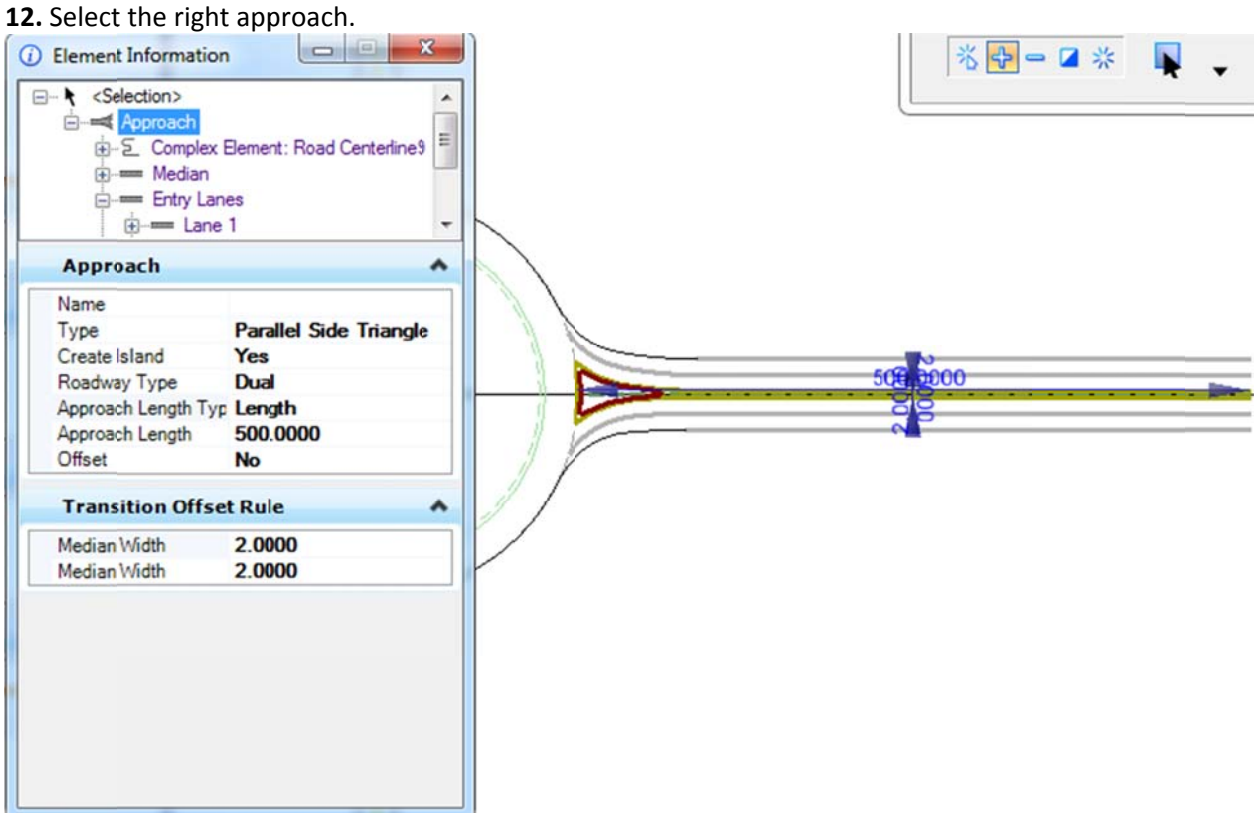
Under the Circulatory Area – Transition Offset Rule, set the following values:



Take time to review the Information available for the different features that make up the Roundabout

Modify Approaches

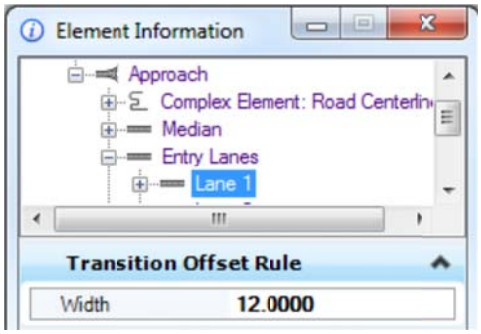
12. Select the right approach.



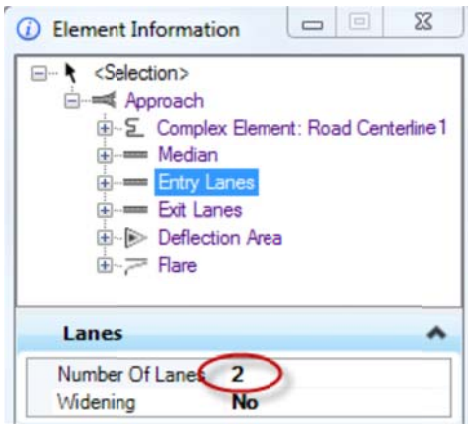
13. Expand the Approach in the element information dialog, expand “Entry Lanes”

14. Highlight Lane1.

15. Set the Lane width to 12'.

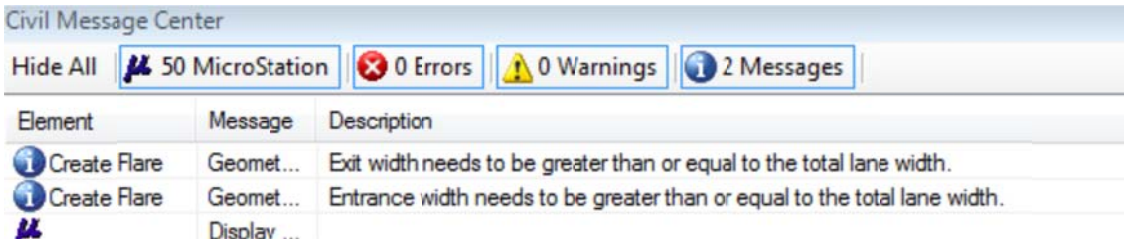


16. Add additional lanes. Set the Number of Entry Lanes to 2.

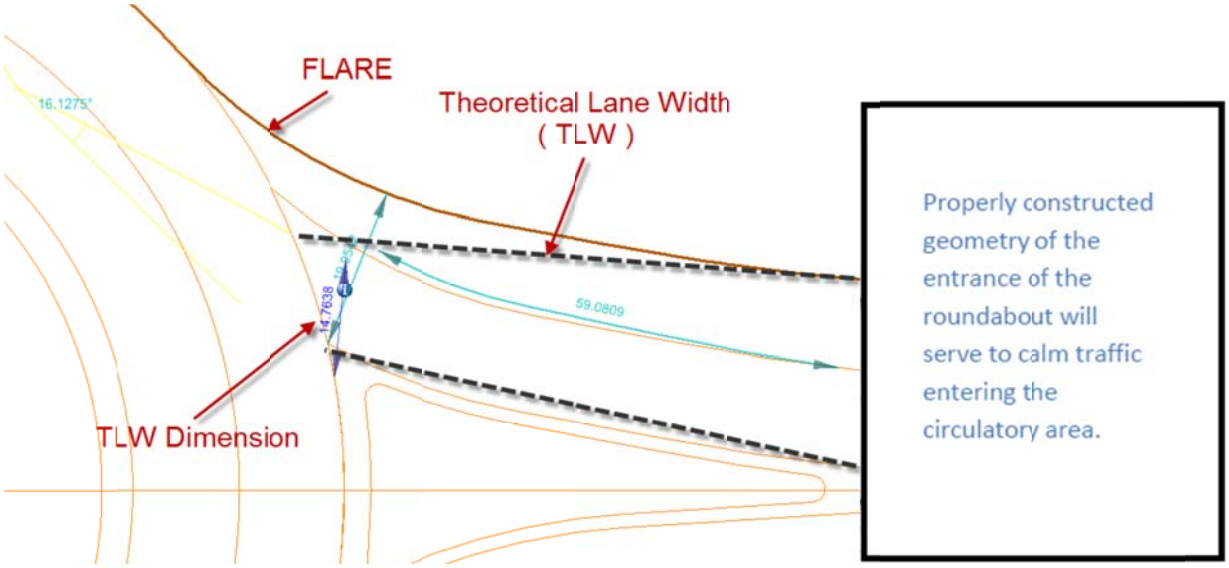


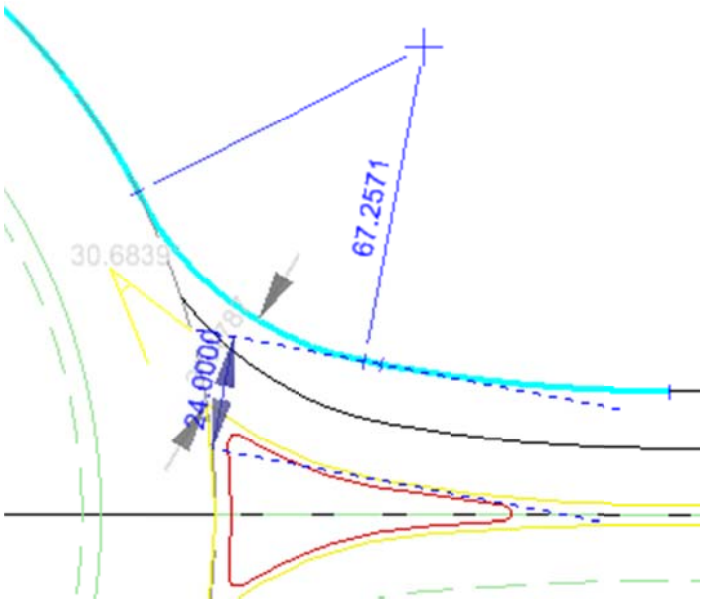
17. Repeat the process for the Exit Lanes, creating 2-12" wide lanes**.**
Experiment with 3 or more lanes.

18. From the Task Menu open the Message Center to view information on the new message alerts. *Tools > Civil Geometry > Message Center.*



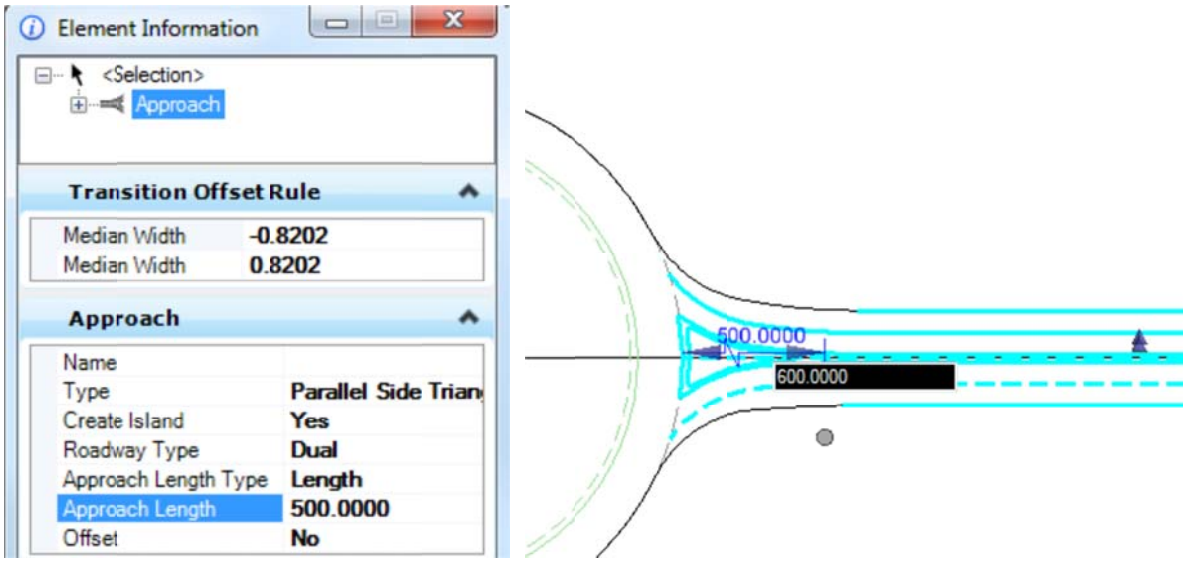
19. Select the entrance "Flare" and zoom to the intersection as shown below. Modify the theoretical lane width to be equal to the combined 2 lane width (12'). Repeat this on the exit lane.



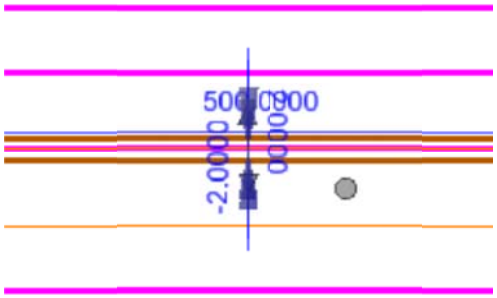


Note *The user will also need to modify the exit lane by selecting the exit flare and editing in the same manner as the entry. Once edited the alerts will disappear.*

20. Modify the length of the right approach by selecting the approach. Change the "**Approach Length Type**" in the element information dialog to "**Length**" this will add an Approach Length field to the information dialog. Enter 600' for the length.

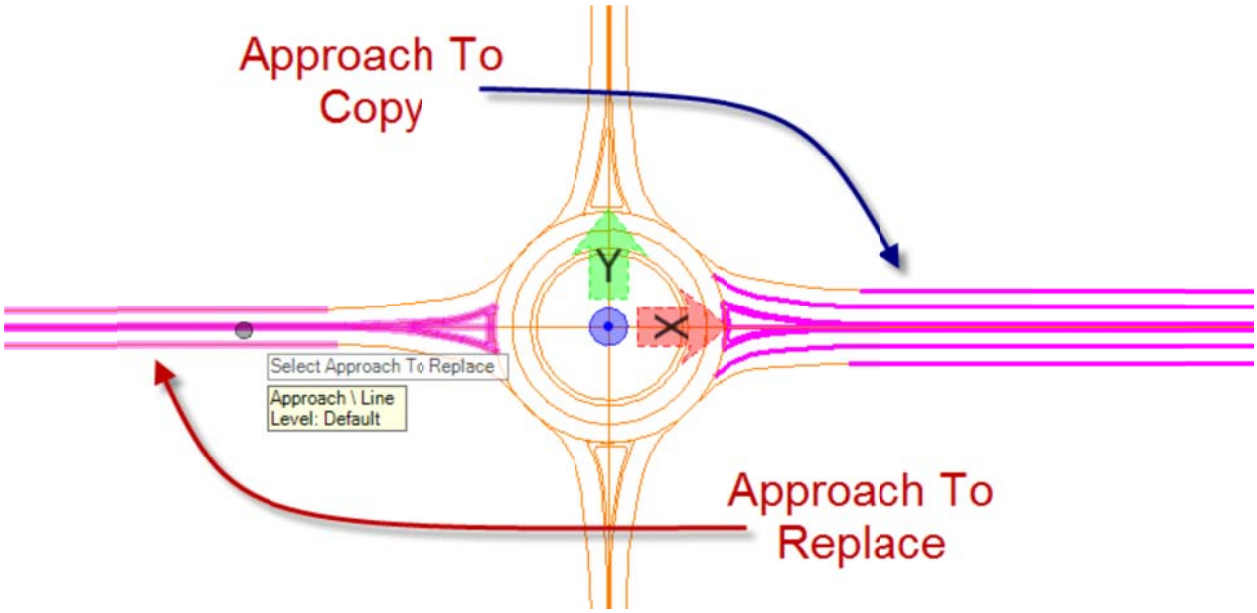


21. Last- Modify the central median Width to 2' by selecting the center of the approach and use the **Heads Up Display** enter 2' for both the entry reserve and exit reserve.



Modify Remaining approaches

22. Modify the "Left" approach using the Replace Approach command. THIS TOOL IS LOCATED UNDER TOOLS>ROUNDABOUTS, OR IN THE TASK MENU FOR ROUNDABOUTS. THIS IS NOT THE TOOL LOCATED IN THE ROUNDABOUTS LIBRARY.



23. Modify the Upper and lower approaches as follows.

a. Change the approach length to 400’.

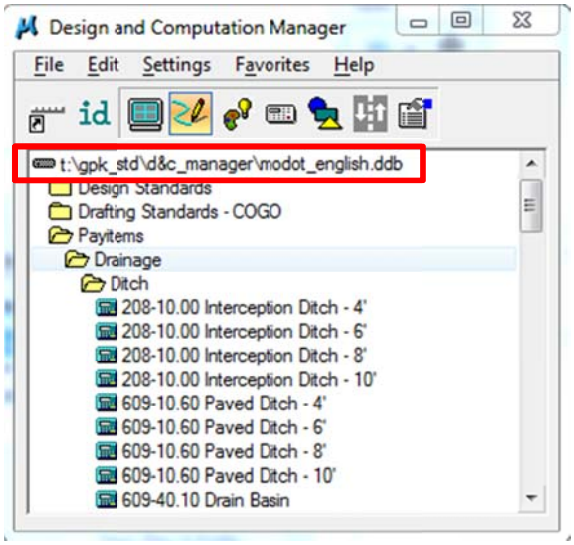
b. Change the Entry and Exit Lane width to 12’.

24. Save and Close your drawing file.

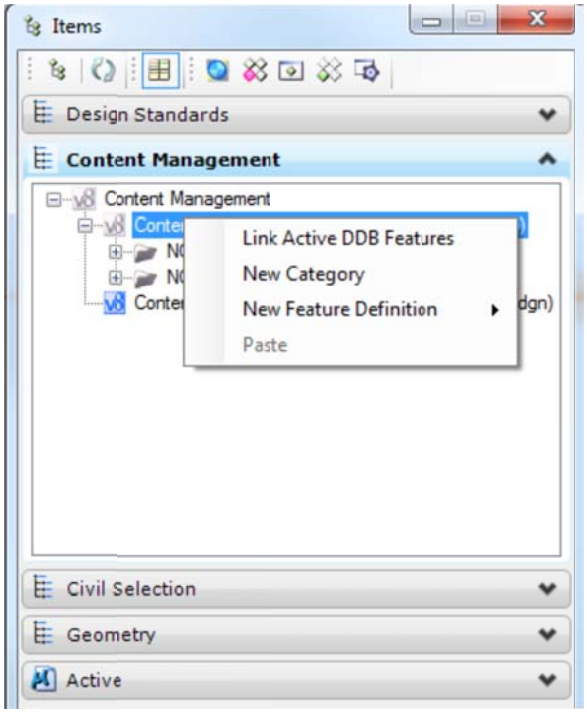
Linking Features Database

Prior to assigning features make sure the Design and Computation Manager has the “Modot_english.ddb” as the items database.

- Activate GEOPAK
- Open Design and Computations Manager



Open the Items Browser on the Primary Tool Bar.



Once imported features with annotation properties can be set to auto annotate. Features used in Hz geometry (IE alignments) can be set for geometry to persists or store in the native Coordinate Geometry database. These attributes are set using the Details panel, accessed through the Item Browser.

The user can assign features to each element comprising the roundabout. Using the now linked DDB, you can assign features to control symbology and assist in quantities calculations.

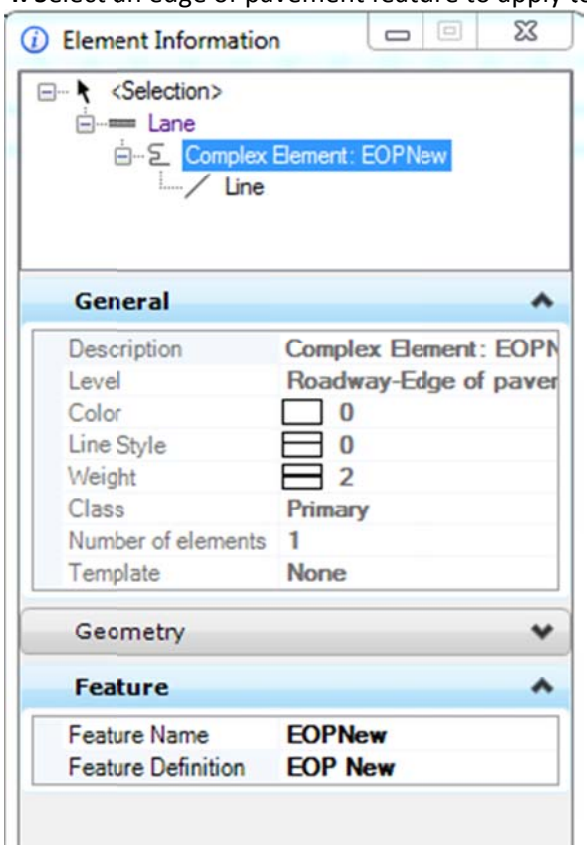
Assigning Features to the RAB

1. Select outer lane of any of the RAB approaches and open element information.

2. Expand the Lane down to the "complex element".

3. Use the Feature section, tag the feature Definition field to expose the list of active features.

4. Select an edge of pavement feature to apply to the outer lane edge.



Assigning features in the library is much more efficient as the features will be automatically passed into the RAB design project.

5. Repeat this process to the various geometric components as time permits.

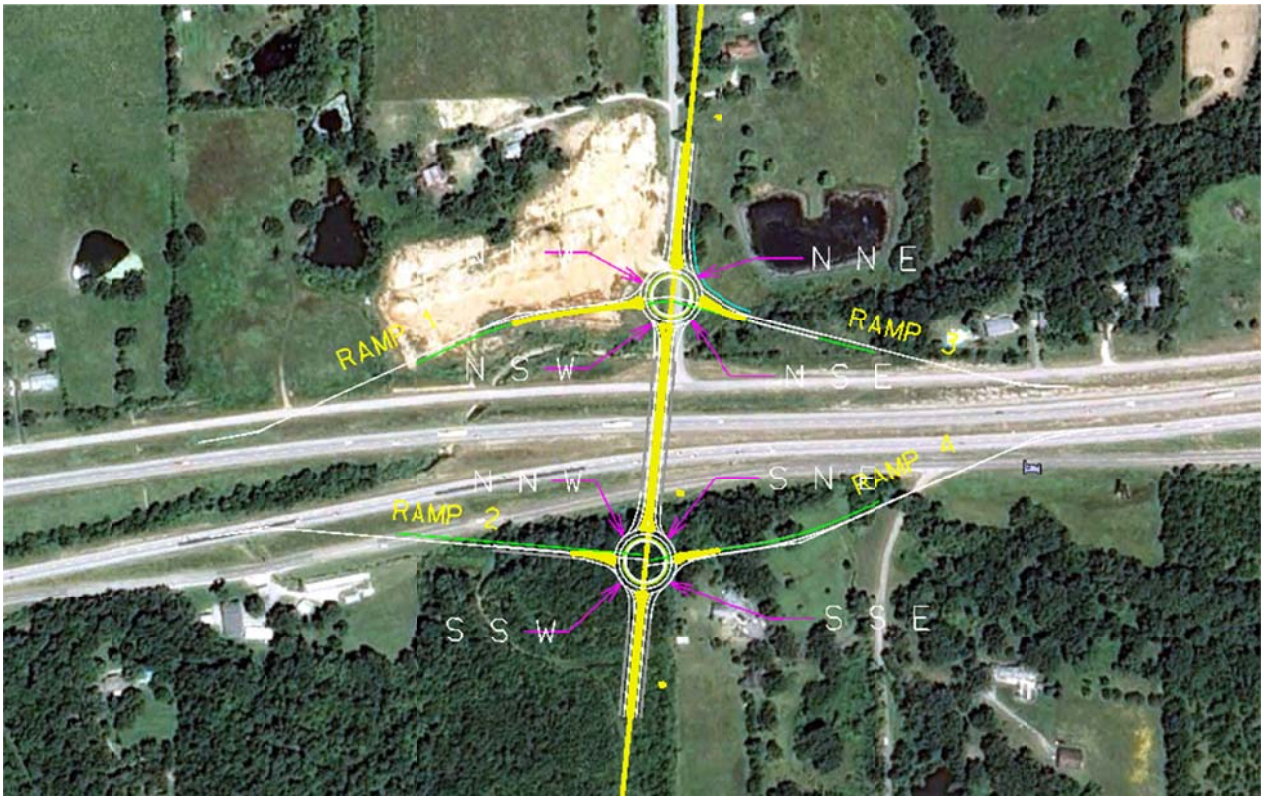
A completed RAB library will be used in the subsequent sections based off the workflow used in this chapter.

Chapter-2 Working With Civil Geometry

Project Overview

The design is a proposed Entrance and Exit ramps along an existing Interstate Hwy. Roundabouts have been planned to complete the intersection and to quickly move the traffic through the top of the ramps.

The project will consist of two-on off ramp exchanges, each with its own roundabout. Additionally the Hwy overpass will require a bridge and an extension of the SR Rt 63. This workshop does not address the compliance of the roadways with all AASHTO standards, nor is it intended to serve in any design aspect. It does attempt to create a realistic design situation and expose the user to a workflow combining Roundabouts, Civil Geometry, GEOPAK Site and Roadway Designer.

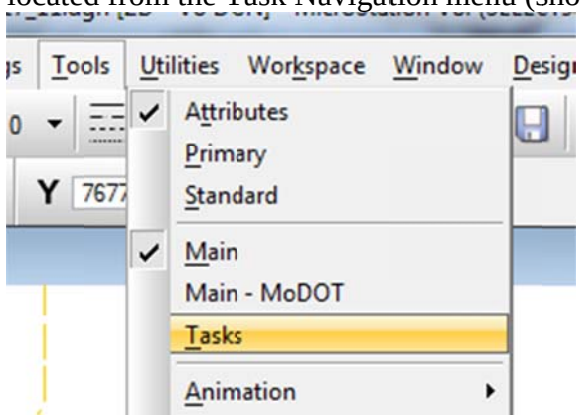


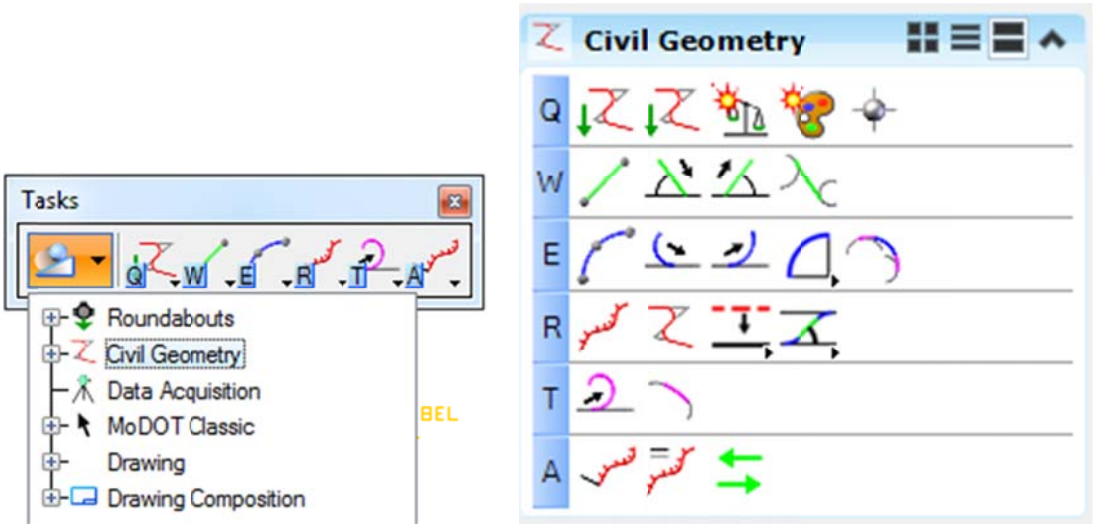
Working with Alignments

As shown in the Diagram the designer will need to create a new alignment for the proposed road and modify the existing road to accommodate the RAB.
The Roundabout tool will work with graphics created from MicroStation, civil application GEOPAK or Bentley Civil Geometry. This workshop will use a combination of stored alignments and alignments created using civil platform geometry. The workflow will consist of the following:

- Import Stored alignments representing "best fit" existing roadway alignments
- Create a new Alignment on the south west side of the main route
- Modify an existing alignment of the road intersecting to the NE of the main route

Bentley Civil tools can be located from the Task Navigation menu (shown below). ***Tools>Tasks***





Additional Tools used with the new Civil Geometry toolset include the message center, Item Browser and the Feature toolbar.

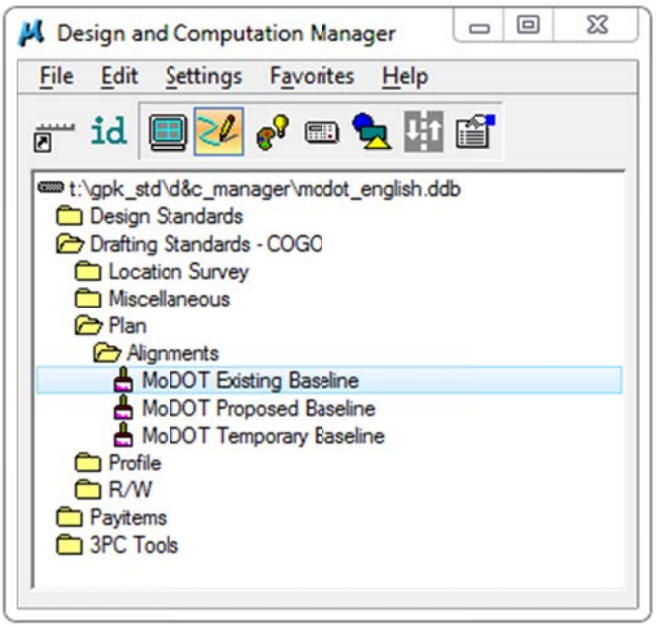
Note *When using Civil Geometry, alignments may reside in a reference file.*

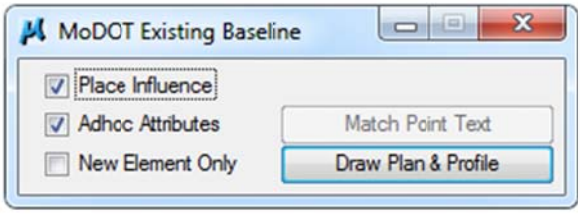
Import Existing Geometry

1. Open the file Geometry_Training.dgn *C:\Data\ J9I2184*. (file cannot currently reside in ProjectWise)
   The drawing will open with the geometry that makes up the ramps and mainline locations along with the background images to show overall location.
2. Locate the Civil Geometry Task bar shown on previous page.
3. Tag the Import Geometry command .

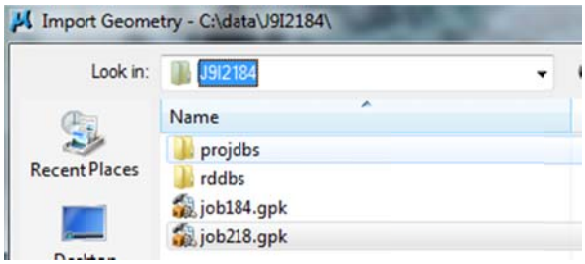
> ***Note*** *For The initial import Projectwise Integration can be used to Navigate to the GPK Located on PW CH2 folder- For subsequent Chapters in the workshop the COGO Preferences will need to be reset to point to the appropriate COGO folder*

4. Set the Design and Computation Manager to MoDOT Existing Base Line, Place Influence.

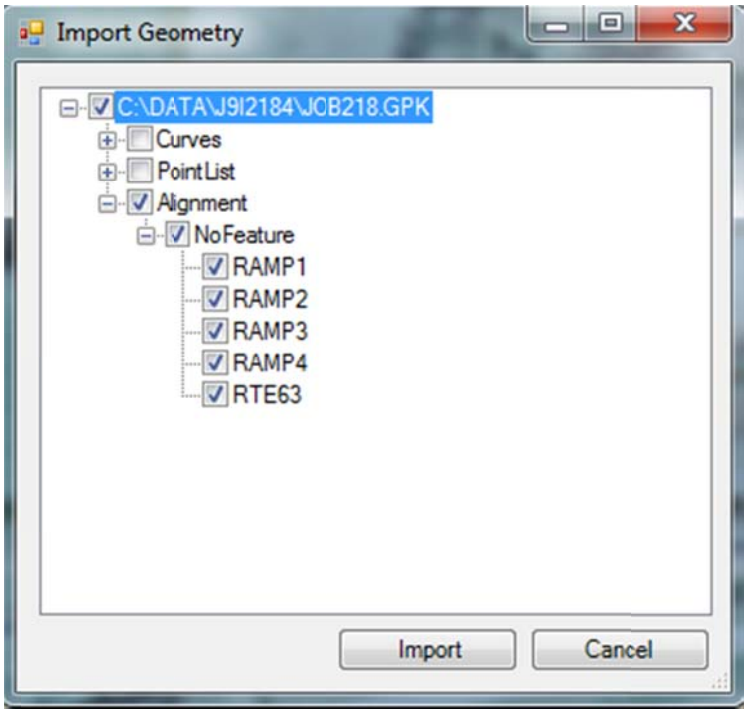




5. Select the GPK. **Job218.gpk**



6. Toggle the Ramp1, Ramp2, Ramp 3, Ramp 4 and RTE63 alignments.

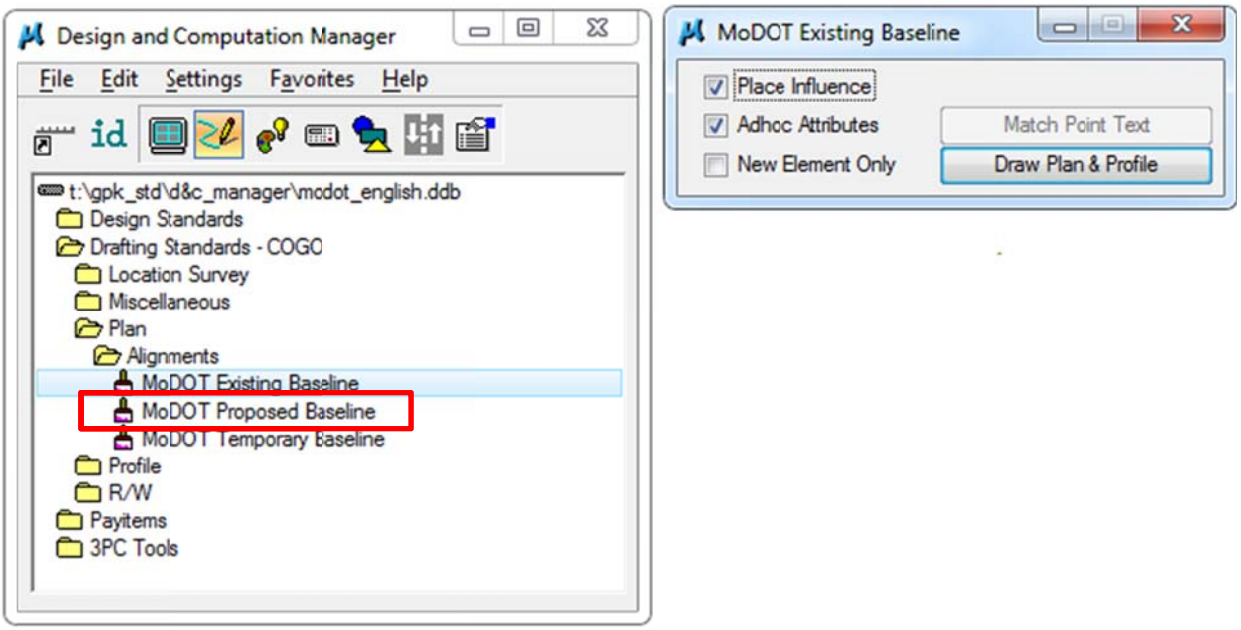


7. Click import from the dialog. This will draw the baseline information into the drawing file along with the correct symbology.
8. Save the drawing file.

Create Hz Alignment using Civil Geometry Tools

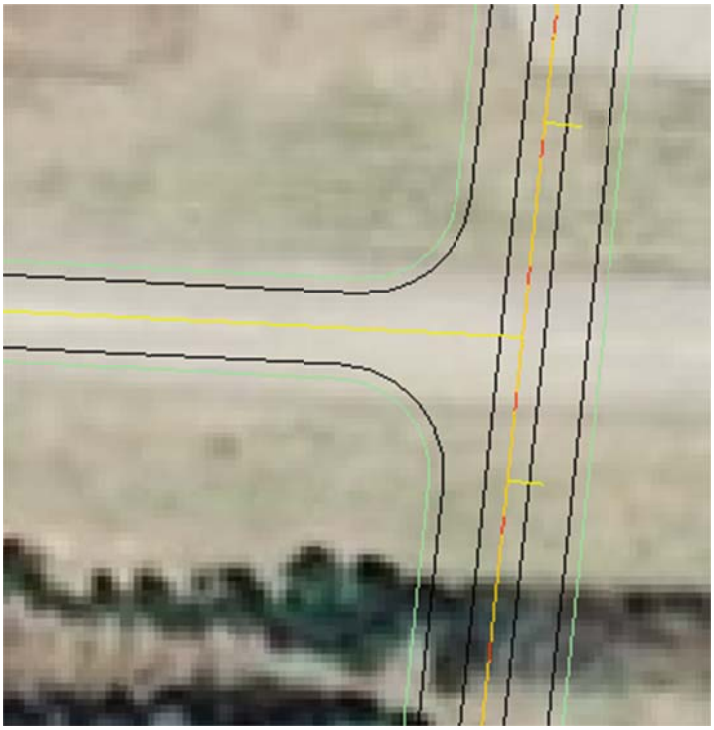
With the existing Geometry in place the designer can begin creating new geometric alignments. We are going to put in the new outer road alignment using Civil Geometry Tools.

9. Open the Design and Computations Manager and place influence on MoDOT Proposed Baseline.

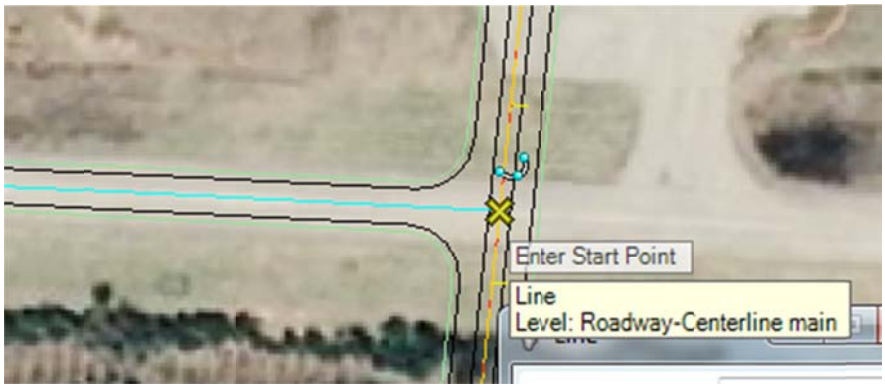


10. Locate and open the Civil Geometry Task menu.

11. Zoom to the intersection of the new outer road and Rte 63 south.

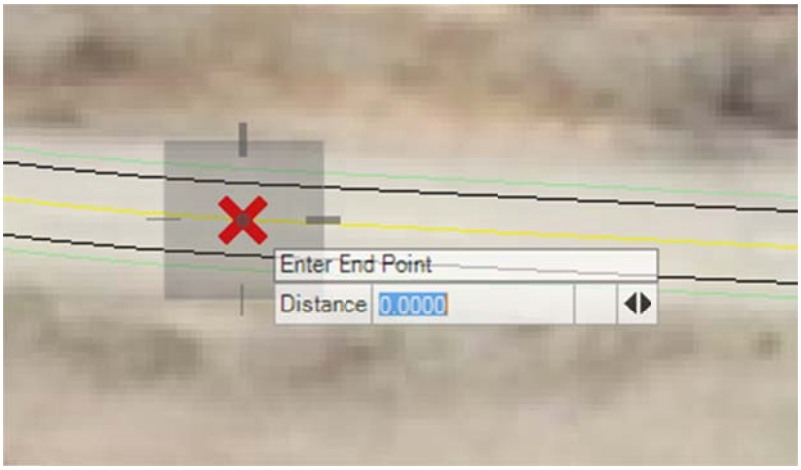


12. Click on the line between points tool located in the Civil Geometry Toolbar.

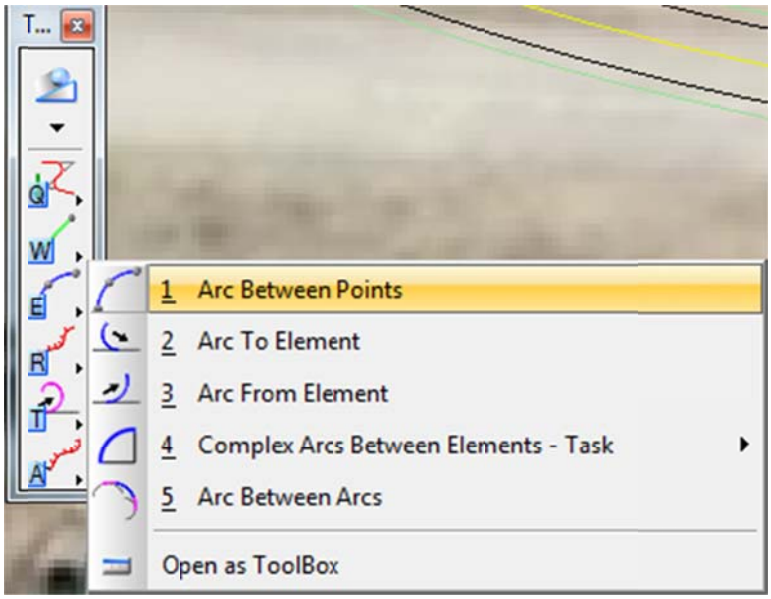


13. Begin with Outer Road start point where it intersects Rte 63 and click a start point shown above.

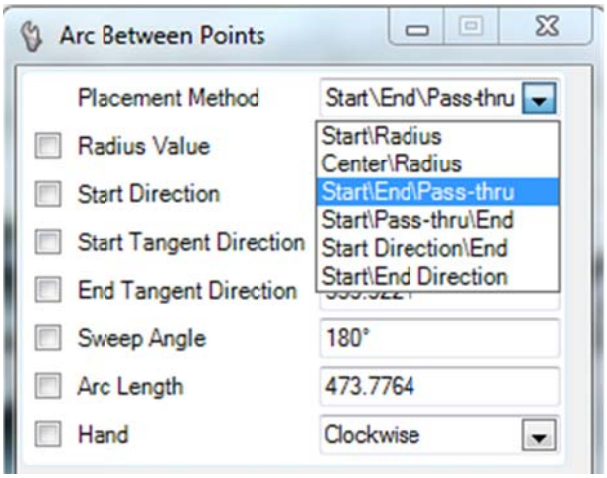
14. Follow the outer road to the west and click the next tangent point



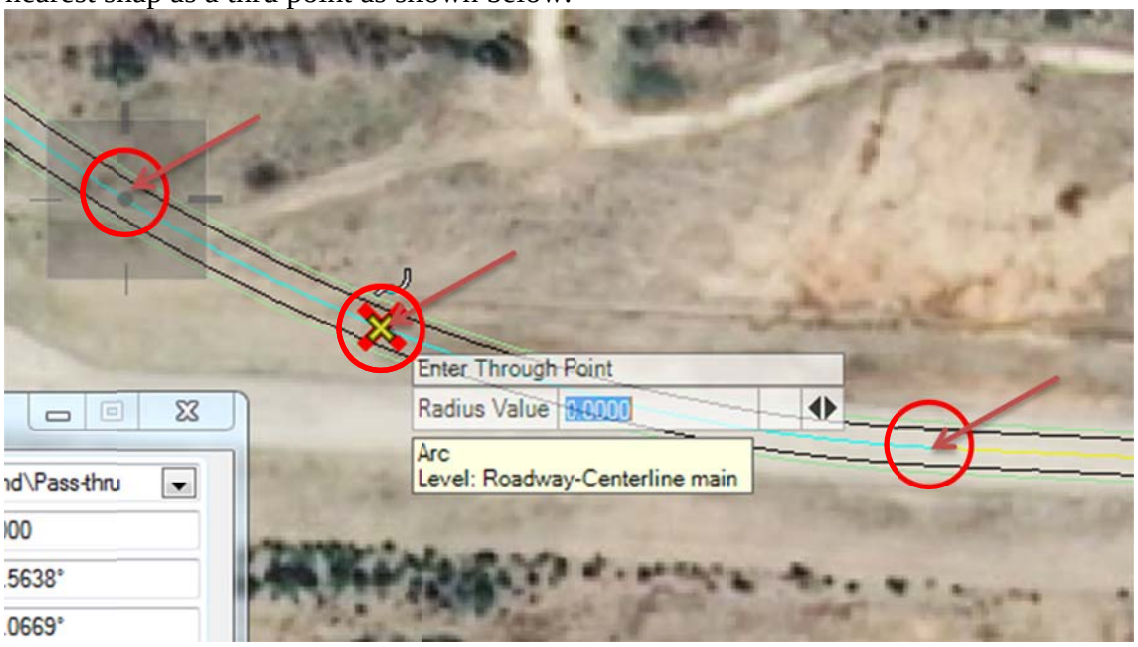
15. Click on the Arc Between Points.



16. Set the dialog Placement Method to Start\End\Pass-thru.



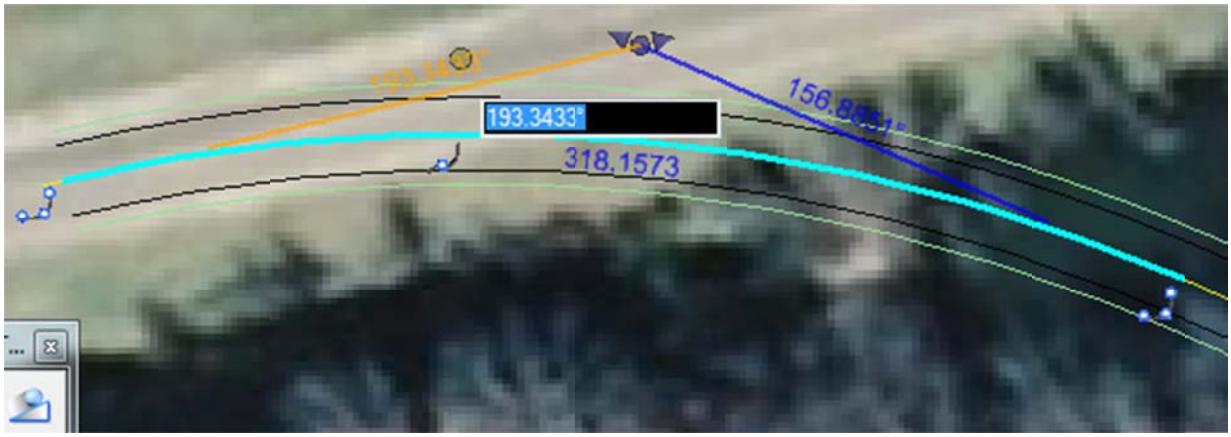
Construct the curve using the start point on the 1.east, the 2.end point on the 3. west using the nearest snap as a thru point as shown below.



17. Using the above methods, complete the rest of the chain.

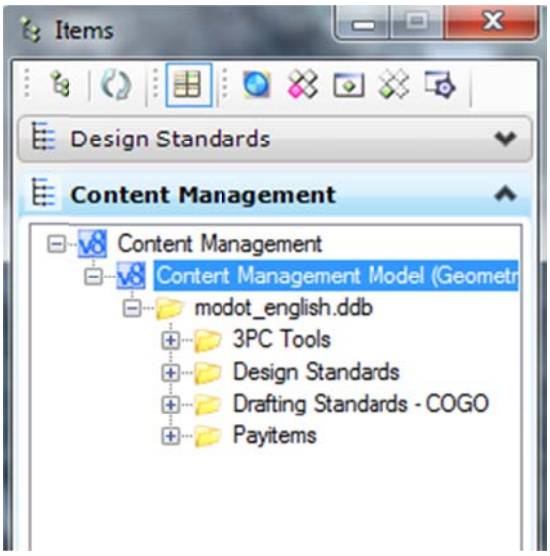
Note	*Use the keyboard arrow keys to change the heads up display options if needed.*

18. Select One of the Arcs created using the Civil Geometry Tools. You will notice that the dimensions show up and can be edited on the heads up display. It also displays where and what type of snap was used to create the arc.



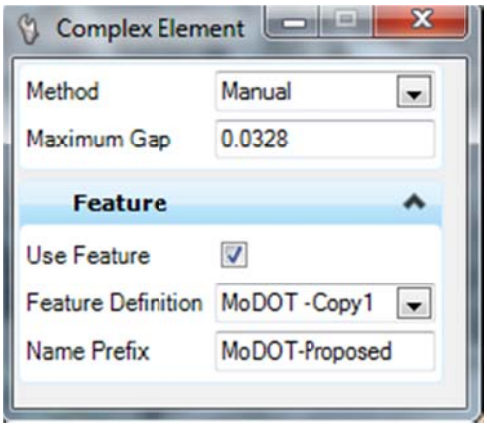
19. Remove your selection and zoom out to where you can see the new alignment for the Outer Road.

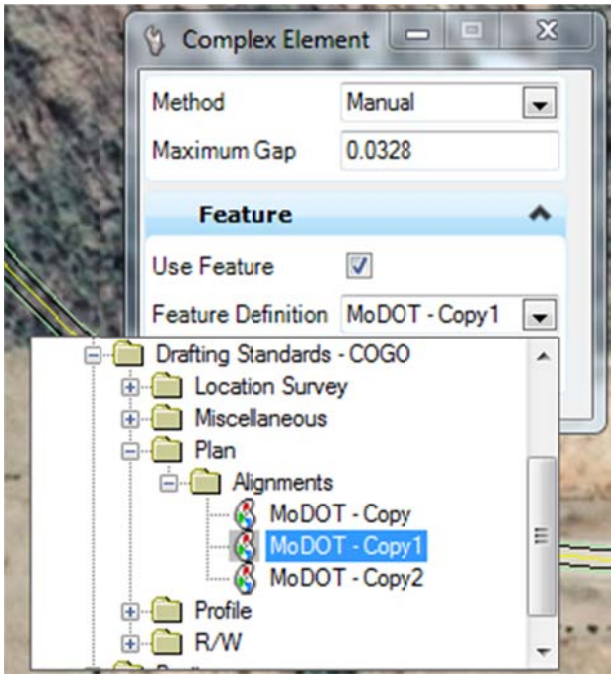
20. Open the Items Browser and check that under Content Management, we are linked to the modot_english.ddb file. If not, we need to right click on Content Management Model and Link Database.



21. Click on the Complex by Element tool in the Civil Geometry Toolbar.

22. Set the method to Manual and Choose the Feature Definition. Set the Feature to "Drafting Standards - COGO>Plan>Alignments>MoDOT-Copy1" and change the Name Prefix to **MoDOT-Proposed**.

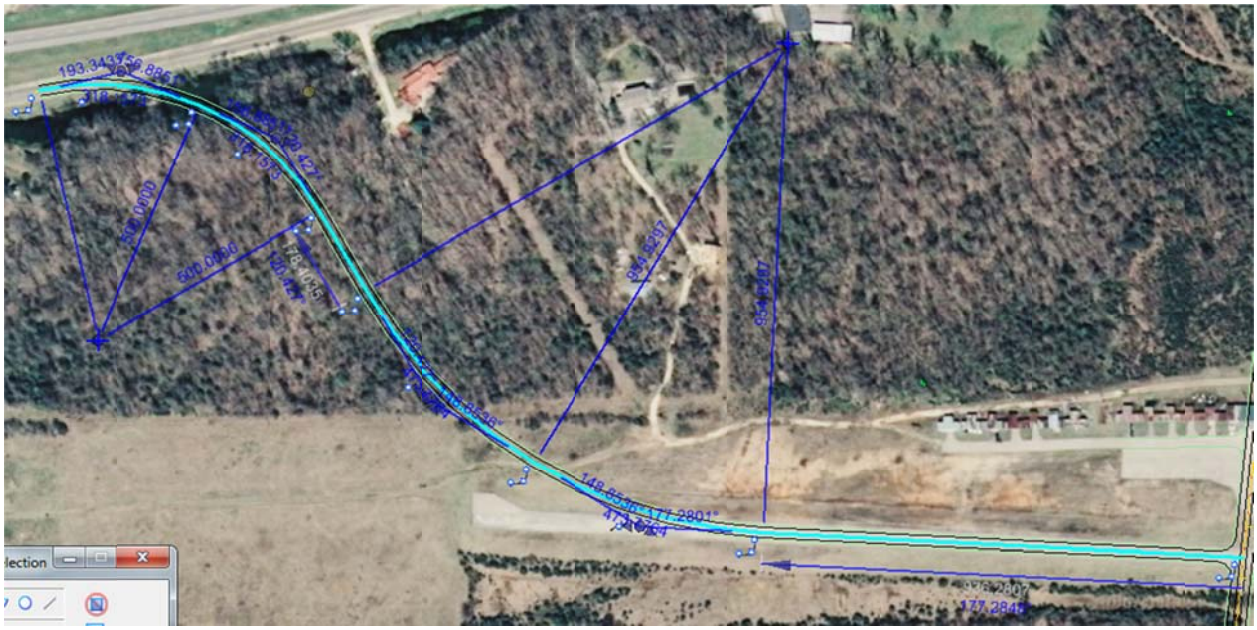




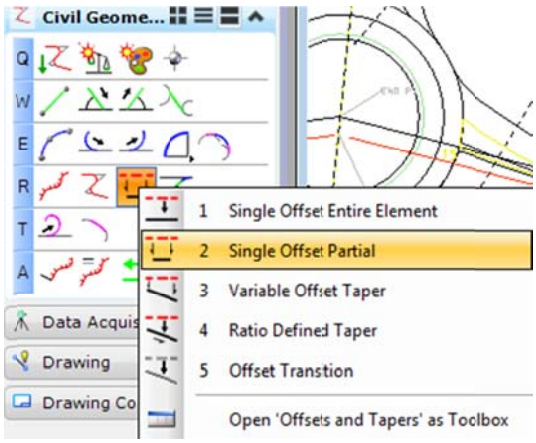
23. Select the east most tangent, be sure the direction of the chain (arrow) points left (west).

24. Select each remaining element in sequence – DP after all elements have been selected.

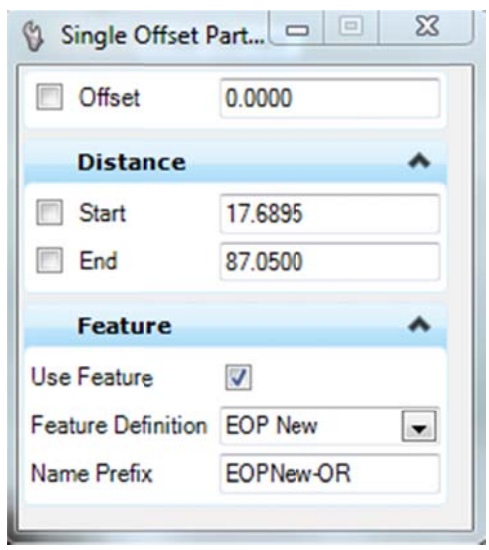
25. Once complete, use the element selection tool to highlight your newly created complex element.



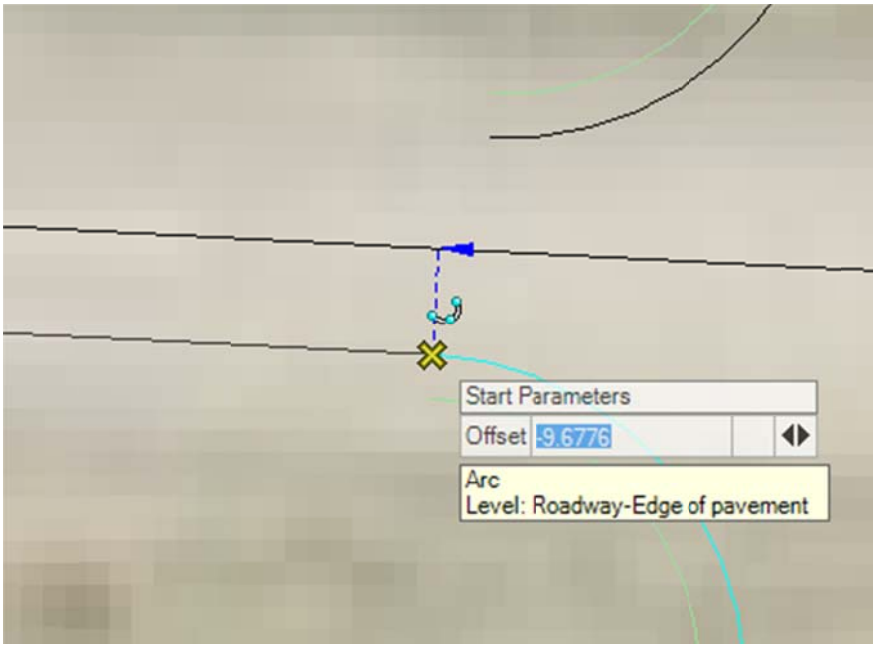
Create the Edges of Pavement and Shoulder Using Civil Geometry



1. Create an offset alignment off the previously created Outer Road alignment from the radius returns on the east and the intersection at the west end to create an EOP see dialog box below for Name Prefix.



2. Click the new OR centerline and for offset, snap to the radius return in the file.



3. Zoom using the mouse wheel to the other end of the alignment and left click just beyond the end of the alignment. The offset will be created.
4. Repeat this step for the other side of the alignment.
5. Create the EOS on either side using the same process, select EOS New Asph for the Feature.
6. Save the file it will be used in later chapters.

Chapter-3 Placing the Roundabout

In this chapter the user will begin working with the previously created RAB Item. With the alignments modified and set up correctly the locating of the library RAB is a simple process. In this section the user will gain an understanding of:

- Library Browser
- Replacing Approach
- Entry Path Curvature Analysis
- In place modifications

Roundabout Library Browser

Open library browser, Used to open the configured listing of available libraries for placement.

Replace approach – Used to replace an existing approach. This tool will allow you to set up parameters once on a single approach and copy these settings to a second approach. More information is available in the "Libraries section" later in the workshop.

Entry Path Curvature Analysis - This tool will allow for the analysis of our design based on the curve path through the roundabout.

Open the message center – Opens message center to reveal all messages, warnings and descriptions.

Show Properties- Exposes the properties of the selected (active) portion of the Roundabout these properties change depending on what geometric element or group of elements is selected.

RAB Horizontal Layout

Select a Roundabout Library

The roundabouts tool uses a library for computing the design. A library is used as a type of seed file specific to Roundabouts. It defines the parameters for the various calculations required for the roundabout design. As we discovered in Chapter1 the seed is a DGN file which contains a simple roundabout design. By using these very same roundabout tools the user has the ability to create or modify libraries, creating "Seed "Roundabouts which contain the parameters used most.

Open the RAB_Training.DGN from the folder C:*Data*\ *J9I2184*. (file cannot currently reside in ProjectWise)

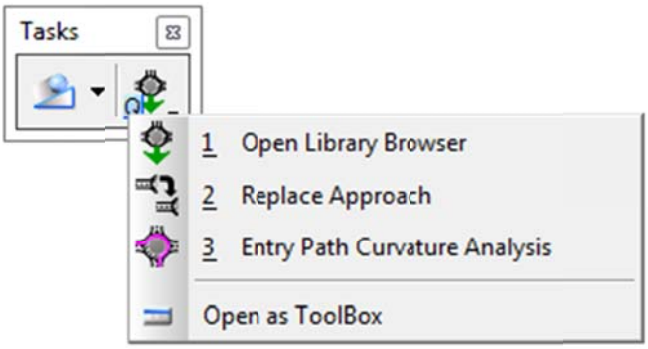
> **Warning:** Verify the Project Preferences COGO Preferences are pointing to the correct folder C:*Data**J9I2184*. (file cannot currently reside in ProjectWise)

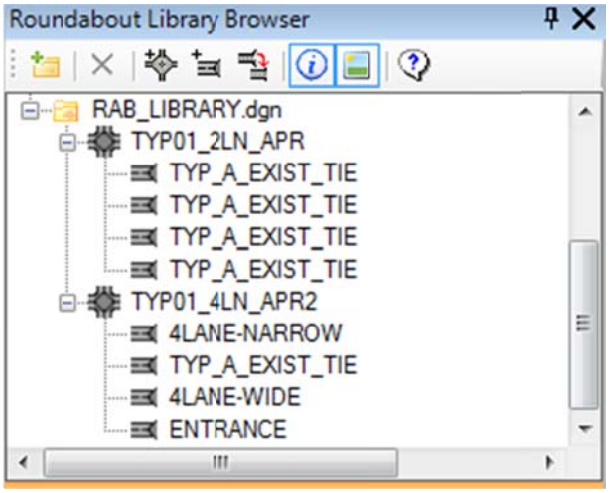
Open the GEOPAK Project

1. Open J9I2184.prj from C:\data directory
2. Open COGO, make sure 218.gpk is being used

Open the Roundabout Library

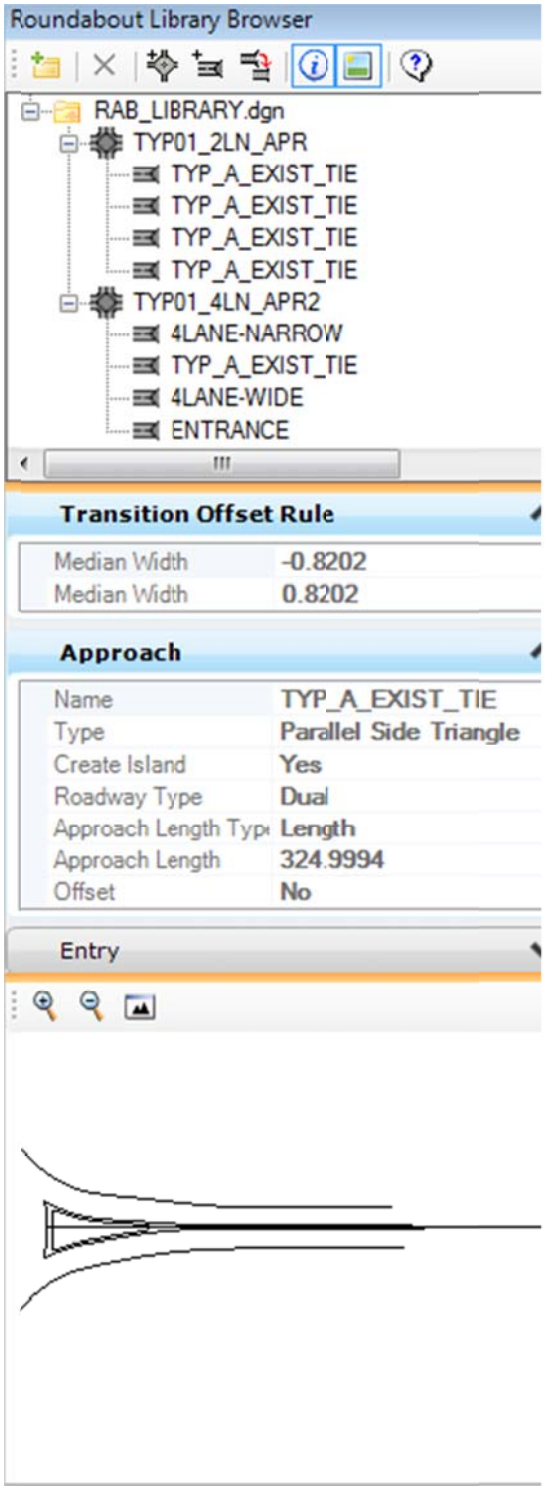
1. Open Create Roundabout task.





2. Click the "Open Library Browser".
   From the Roundabout Library Browser use the "Add" button and add the Library RAB_LIBRARY.dgn from C:*Data**Standards*

3. Expand the RAB _LIBRARY. Highlight any of the approaches. - *Notice the preview updates with the corresponding approach.*



The Civil Library Browser allows the user to review all the features in the selected RAB. By highlighting the different features the user can drill down into the RAB geometric design, each heading revealing different information.
Additionally a preview of the RAB selected is shown on the Bottom Pane.
This browser stacks neatly into the Task Menus and can function as any other Task Menu.

Create the North Roundabout

1. With Type01_2LN_APR roundabout selected in browser, the Place Roundabout button becomes active. Click the button.
2. Select the RTE63 Relief alignment - 2 lane roadway
3. Right Click (Reset Button). Now you are prompted to set the center of the roundabout

> Notice the prompts at the cursor to direct you to what is being asked for input. These are the same prompts that appear in the status bar. In this case the user is prompted to select the reference element (Alignment).

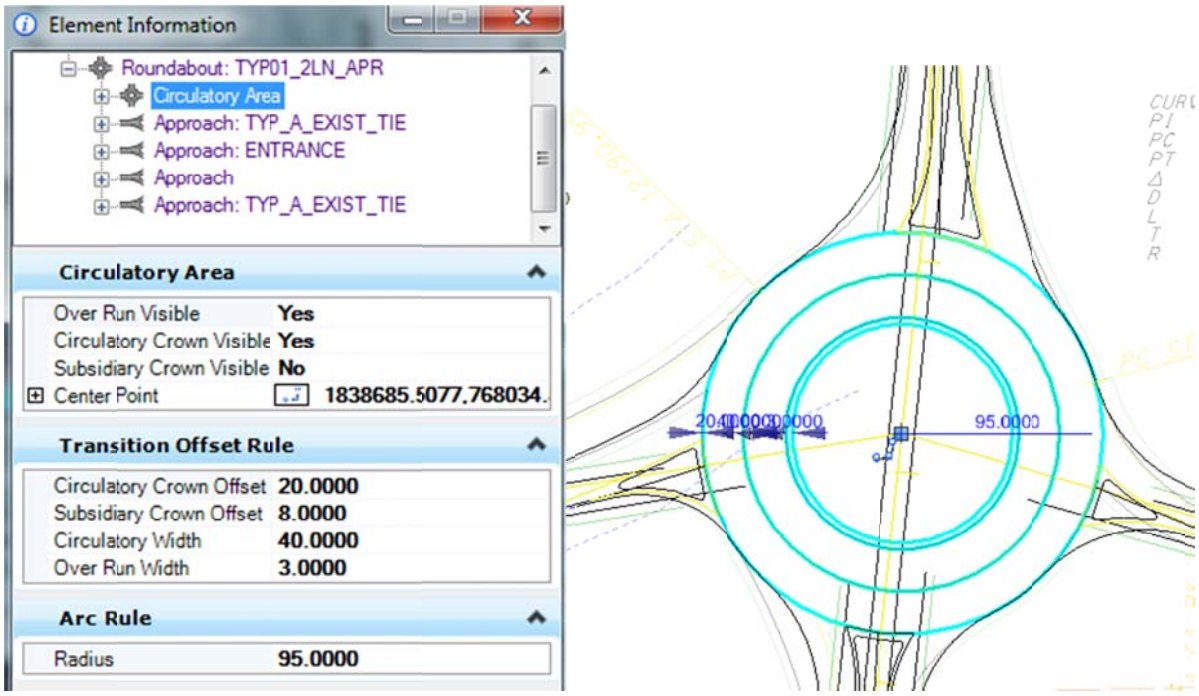
4. Position the RAB center to the intersection of the alignments.

> ***Note*** *Wherever the data point (DP) is placed will be the center of the roundabout. There are certain advantages to using the intersection of the alignments to make the roundabout symmetrical. Additionally, there is no requirement that the alignments must intersect. The only requirement is that each approach alignment must intersect the circulatory area of the traffic circle.*

Change the Center Roundabout Information

1. Select the Center Circle of the Roundabout with the Element Selection tool.

2. Using the Element Information tool, Change the Circulatory area and Arc Rule Radius to match the configuration below.



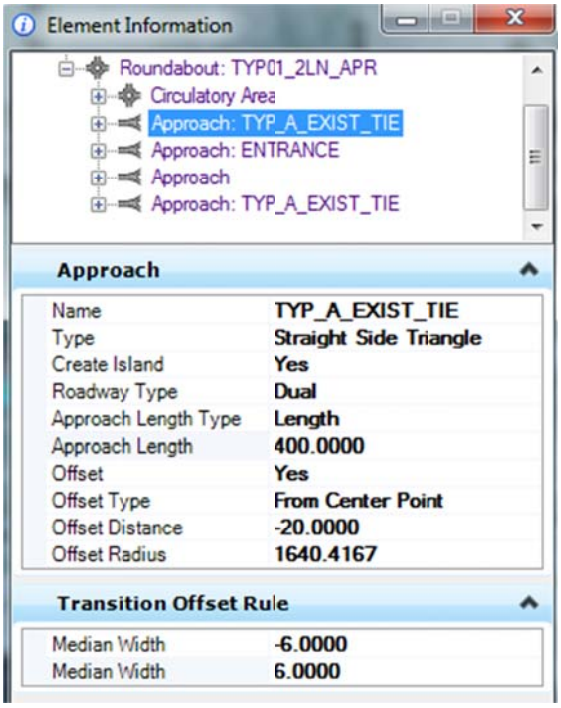
Change the North Approach

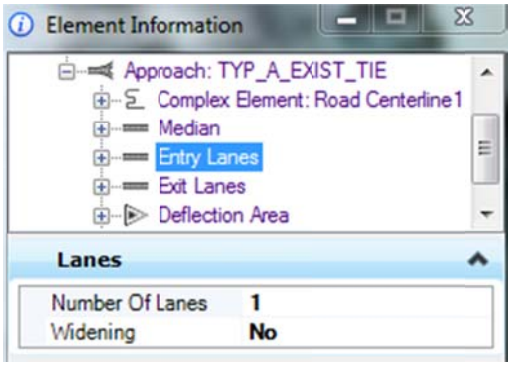
This is a 2 lane roadway with 12' lanes and 6' each side median. We need to modify the north entry and exit geometry to match the existing roadway lines.

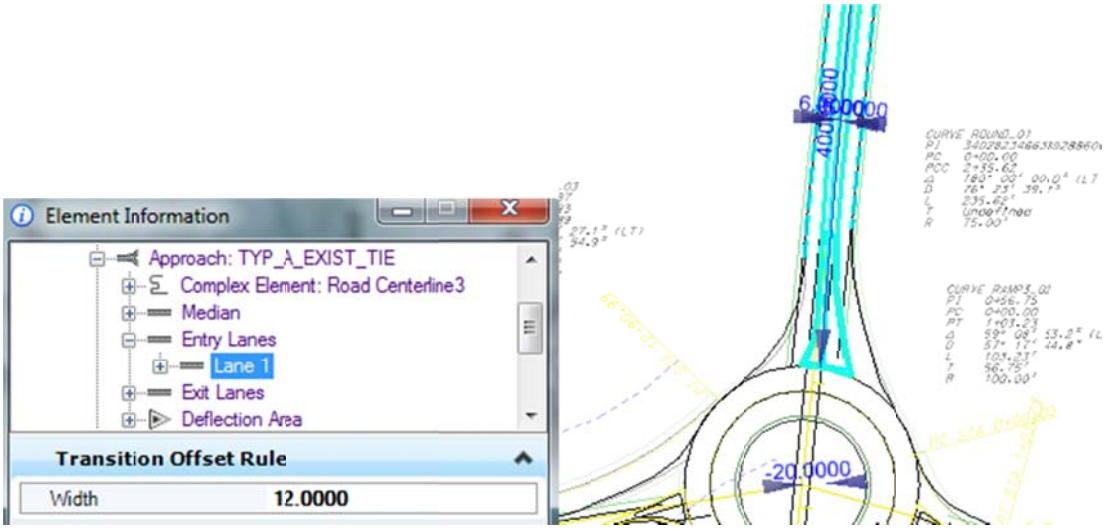
3. Select the North Approach with the Element Selection tool.

4. Use the Information Tool to change the following:

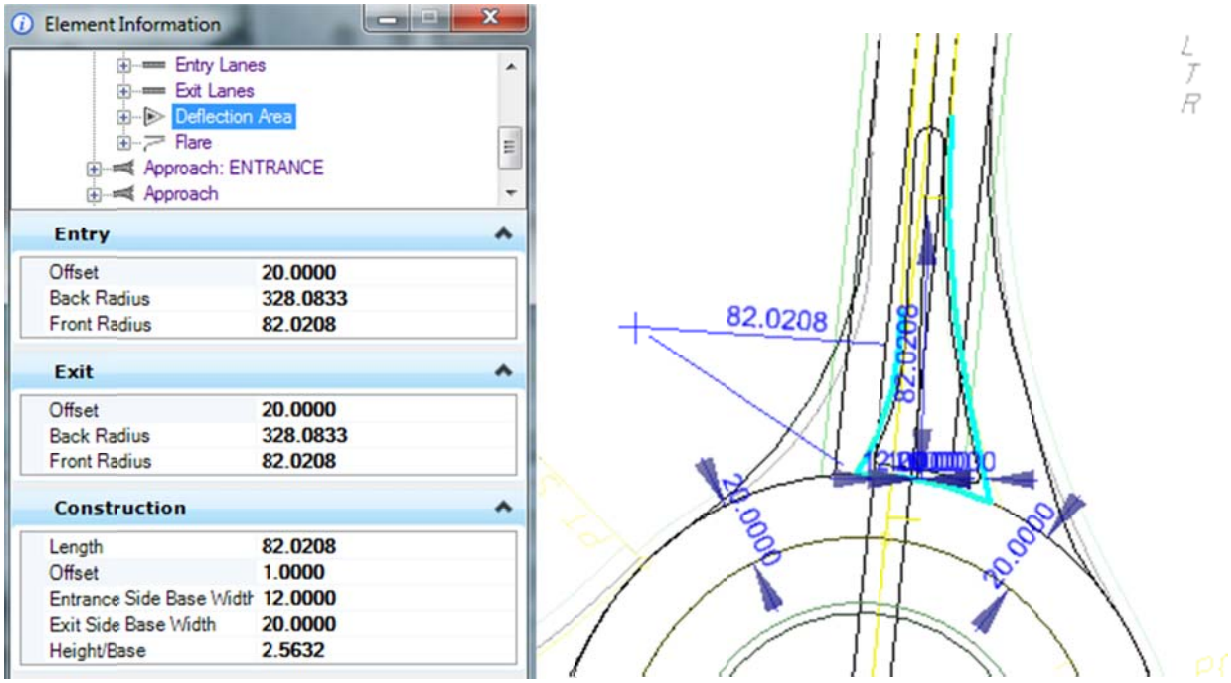
   - Offset the North Approach -20
   - Entry Lanes and exit lanes to 1. And 12' lanes
   - Change the Median width to -6.00 and 6.00 on each side.


Element Information
Roundabout: TYP01_2LN_APR
Circulatory Area
Approach: TYP_A_EXIST_TIE
Approach: ENTRANCE
Approach
Approach: TYP_A_EXIST_TIE
Approach
Name TYP_A_EXIST_TIE
Type Straight Side Triangle
Create Island Yes
Roadway Type Dual
Approach Length Type Length
Approach Length 400.0000
Offset Yes
Offset Type From Center Point
Offset Distance -20.0000
Offset Radius 1640.4167
Transition Offset Rule
Median Width -6.0000
Median Width 6.0000

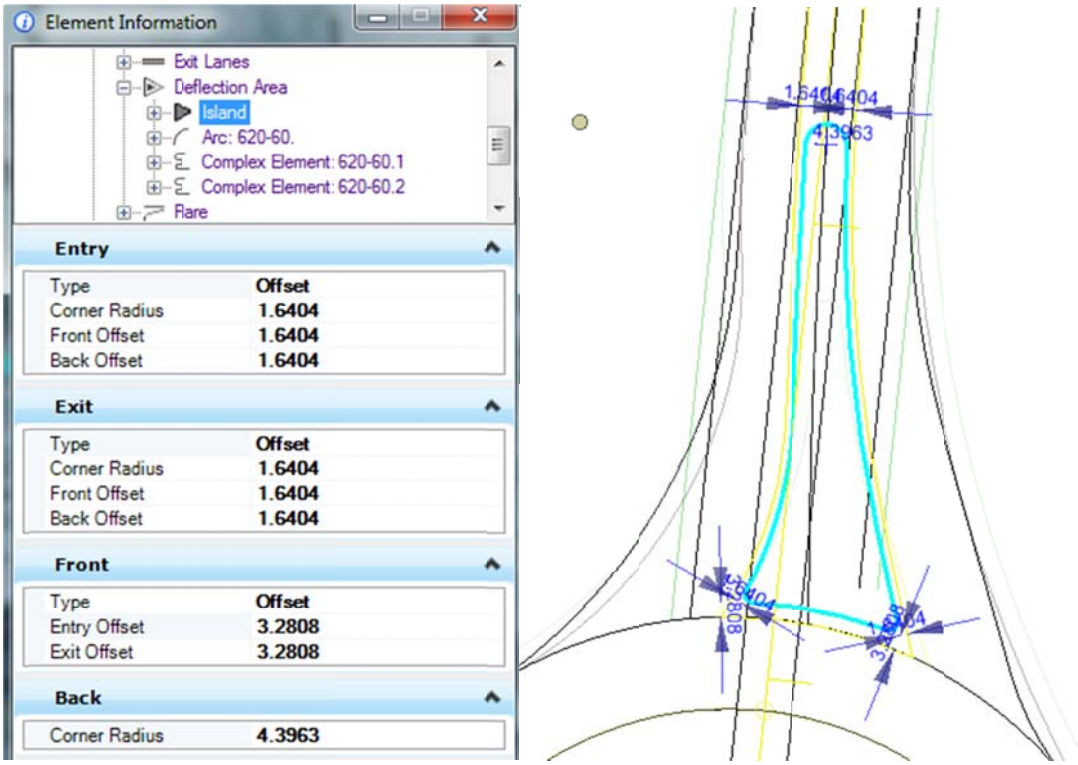

Element Information
Approach: TYP_A_EXIST_TIE
Complex Element: Road Centerline1
Median
Entry Lanes
Exit Lanes
Deflection Area
Lanes
Number Of Lanes 1
Widening No


Element Information
Approach: TYP_A_EXIST_TIE
Complex Element: Road Centerline3
Median
Entry Lanes
Lane 1
Exit Lanes
Deflection Area
Transition Offset Rule
Width 12.0000
-20.0000

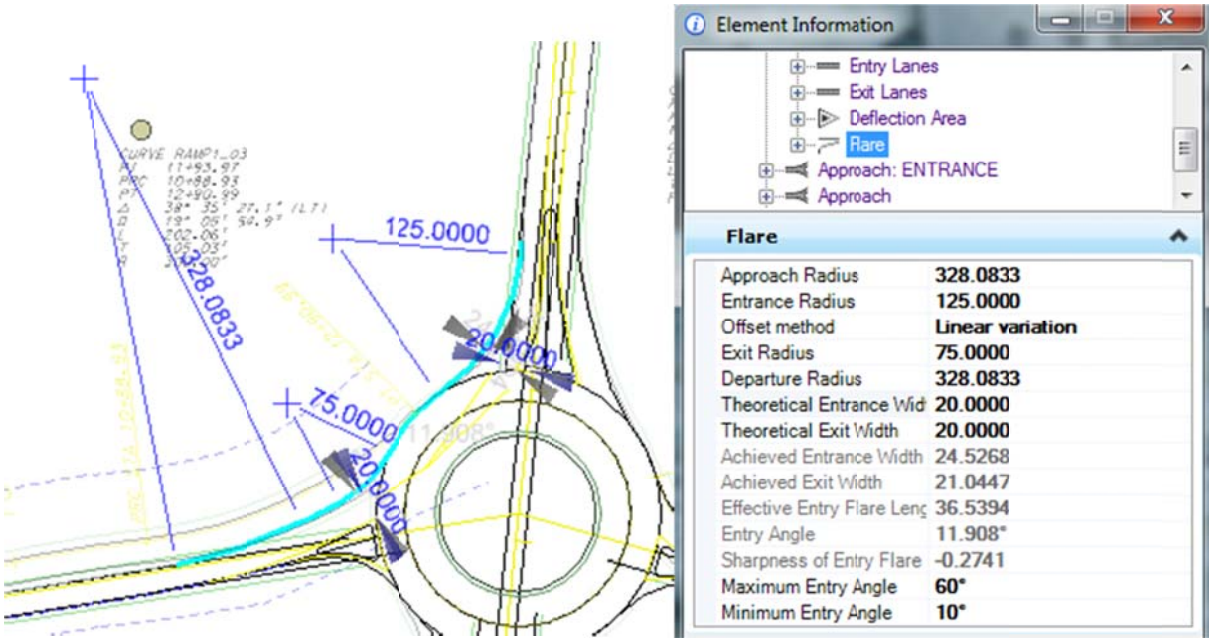
- Modify the Deflection Area using the Element Information tool. Notice which dimensions are affected by changing them in the dialog box.



- Change the Island information for the North Approach.



- Modify the Flares for the roundabout. Use Element Selection to select the flare and Element Information tool to change the information for the West Side Flare.

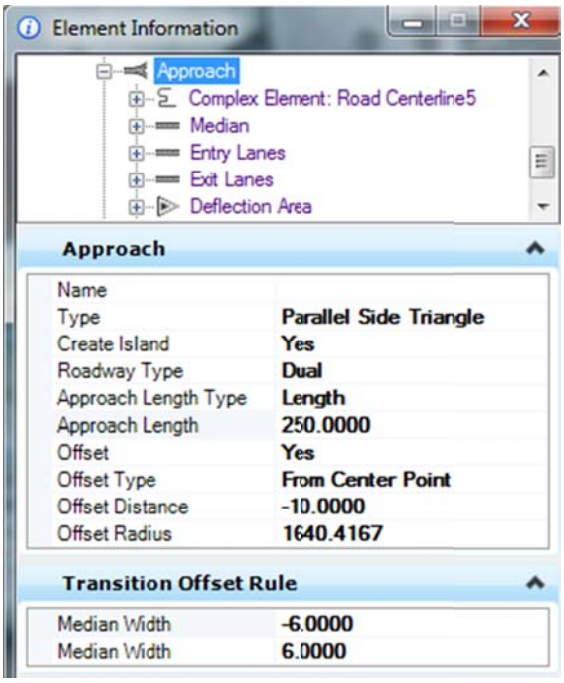


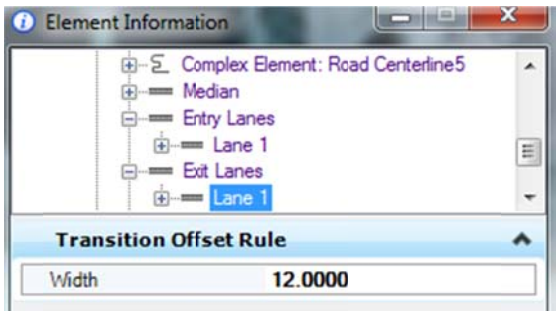
Change the South Approach

This is a 2 lane roadway with 12' lanes and 6' each side median. We need to modify the south entry and exit geometry to match the existing roadway lines as we did the north.

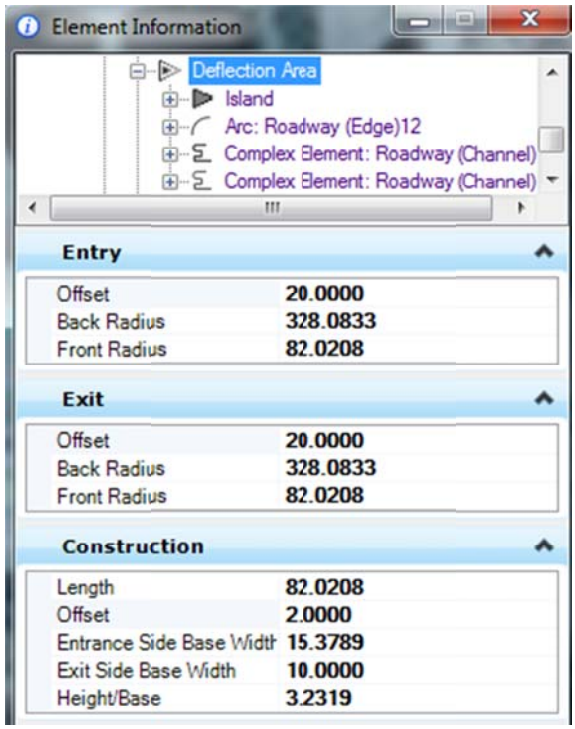
1. Use the same tools and methods to modify the south approach. Set the following parameters for the South Approach.

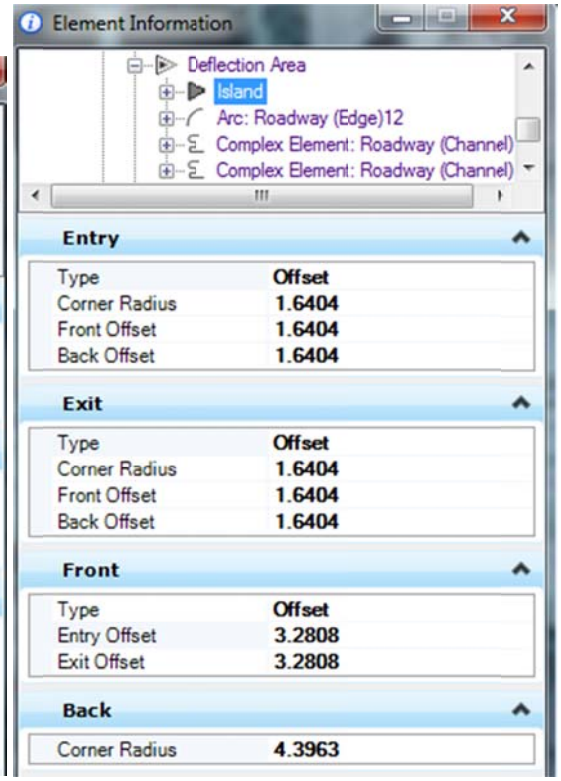
   - North Roundabout South Approach and Entry and Exit lanes (Both 1 lane 12')



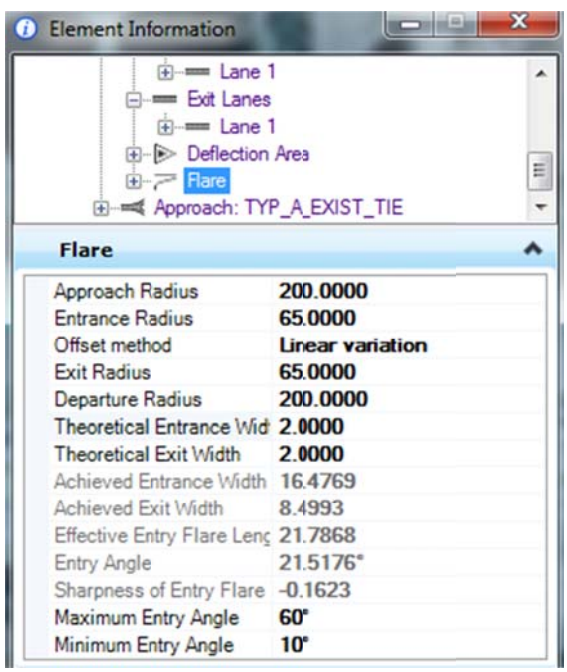


- North Roundabout South Approach Deflection area and Island info



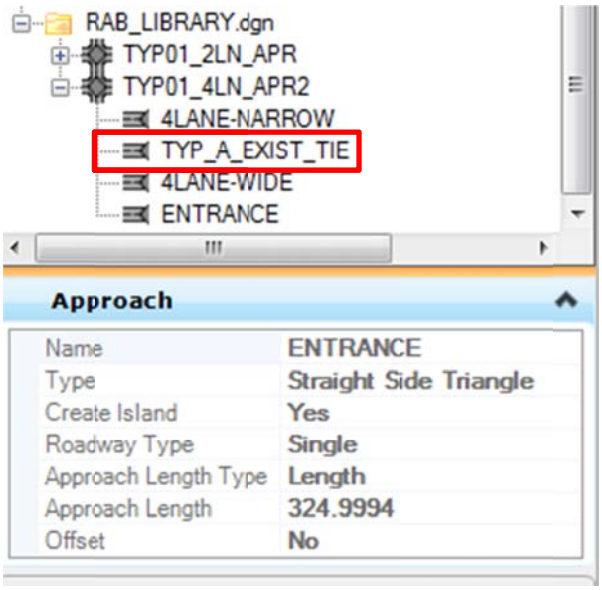


- North Roundabout South Approach Flare



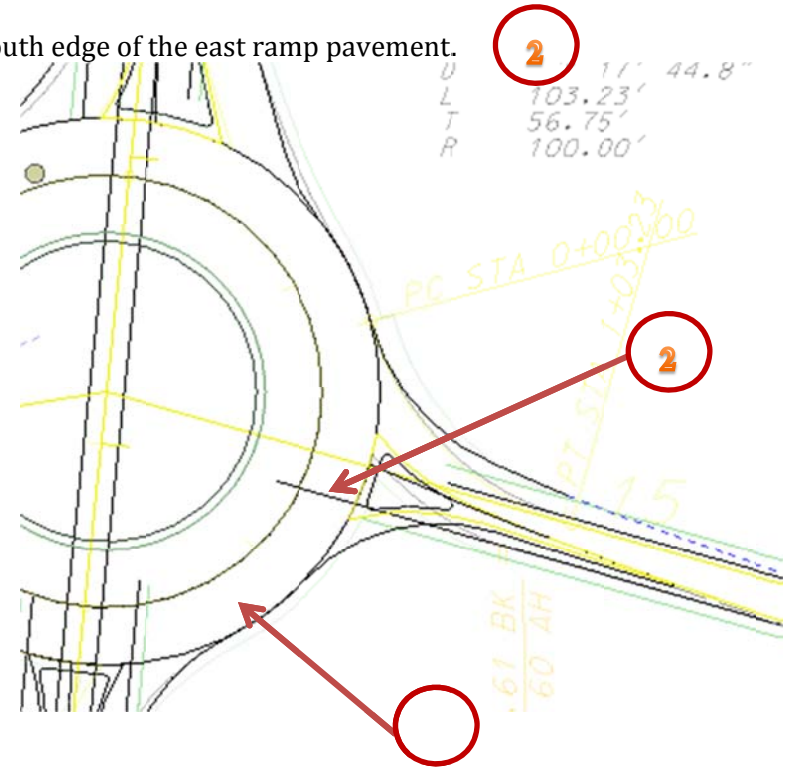
Replace the East Approach Roundabout Ramp Entrance

1. Expand the roundabout library TYP01_4LN_APR2 and select the TYP_A_EXIST_TIE approach.



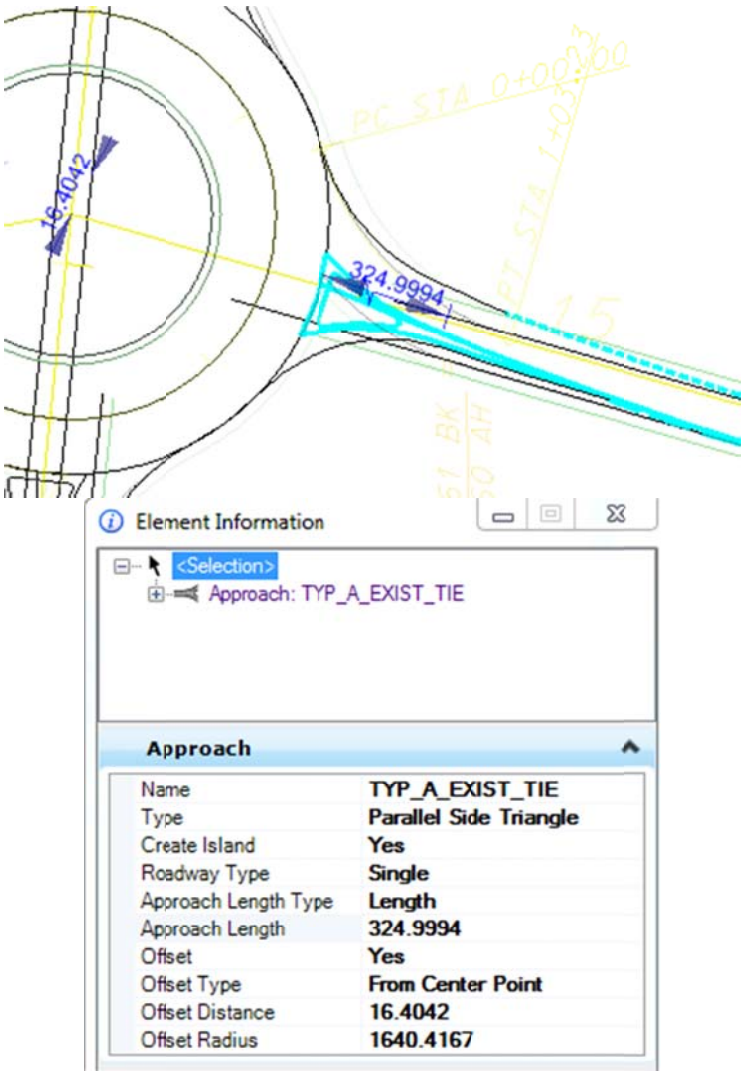
2. Select the Place Approach Icon and select Circulatory area of the roundabout. 1

And the south edge of the east ramp pavement. 2

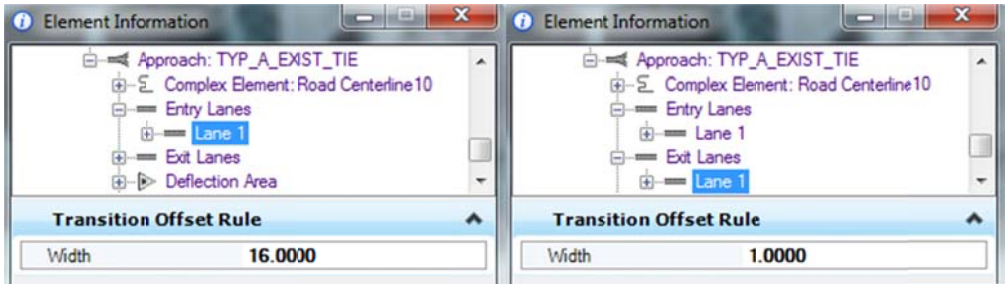


Additional warnings may appear referencing the entry angle. This angle is critical in the geometric design of the RAB. Typical min-max requirements for this angle should range 10° to 60°. The greater the angle the more the speed is reduced for traffic entering the RAB.

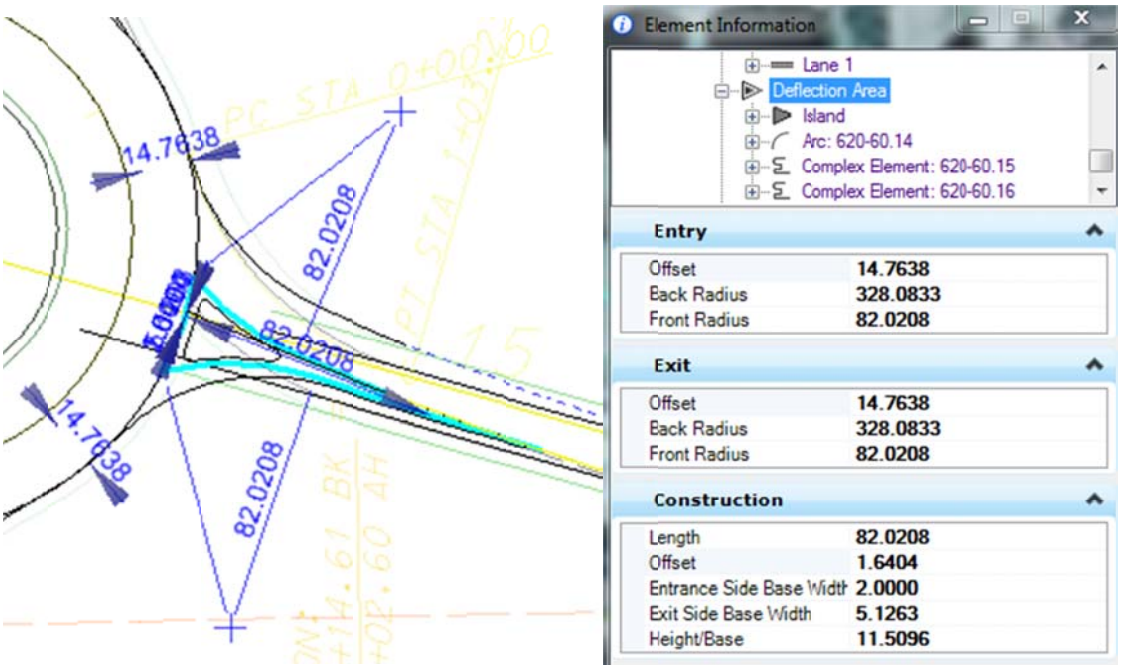
3. Change the approach to match the following dialog. As you change any box, notice the change on the screen.



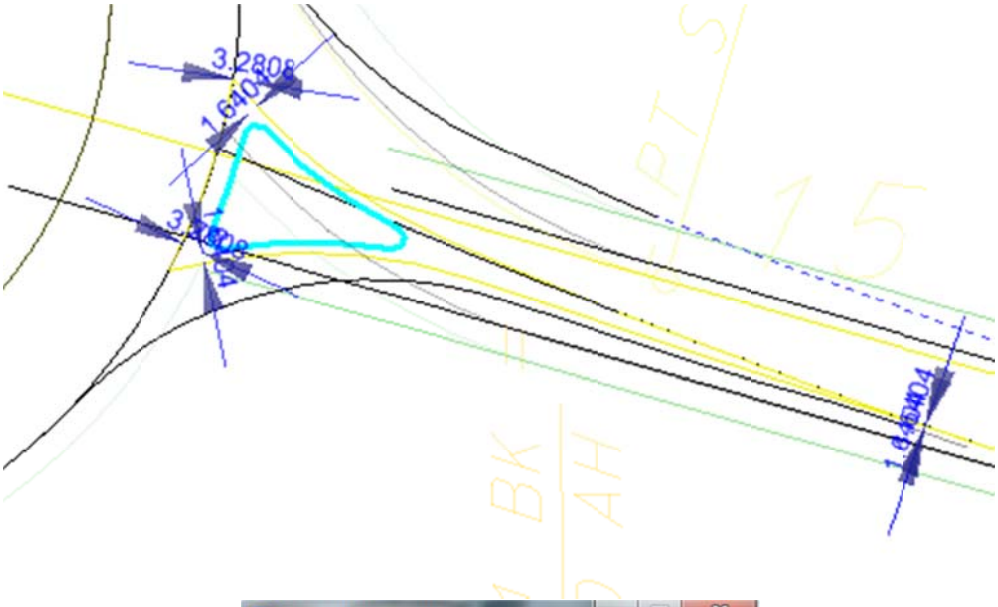
- North Roundabout East Entry Lanes

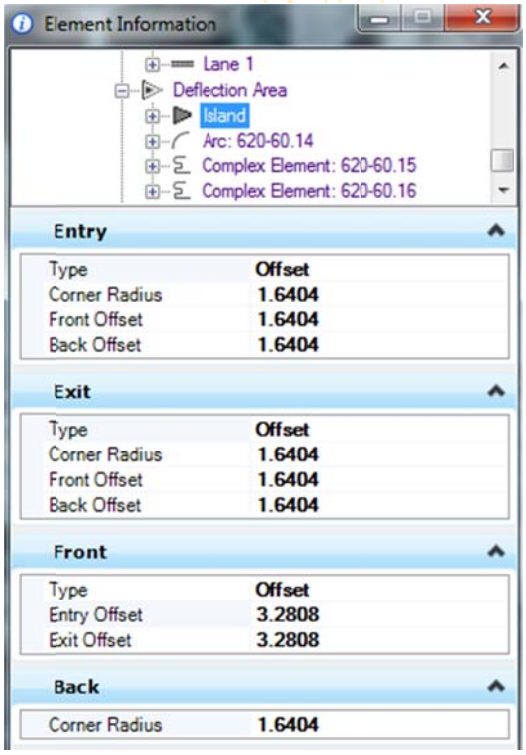


- North Roundabout East Entry Lanes Deflection area

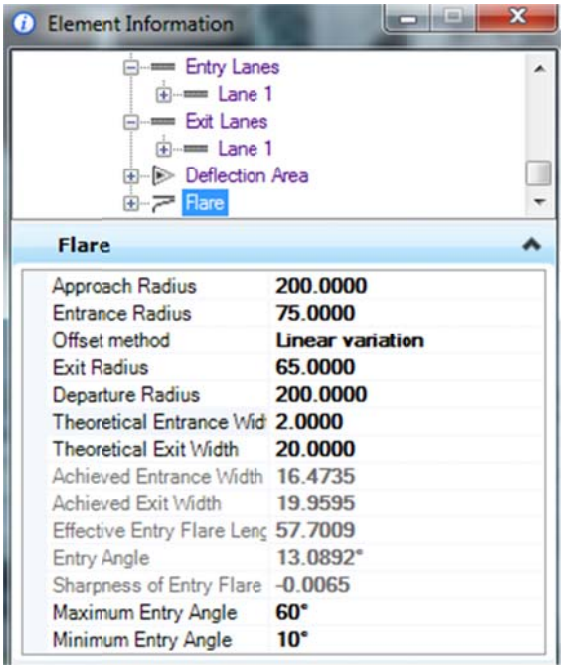


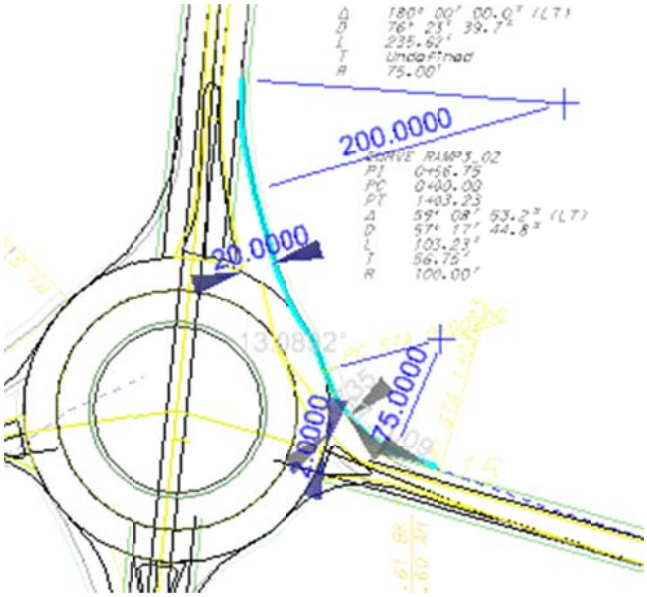
- North Roundabout East Entry Island info





- North Roundabout East Entry Flare

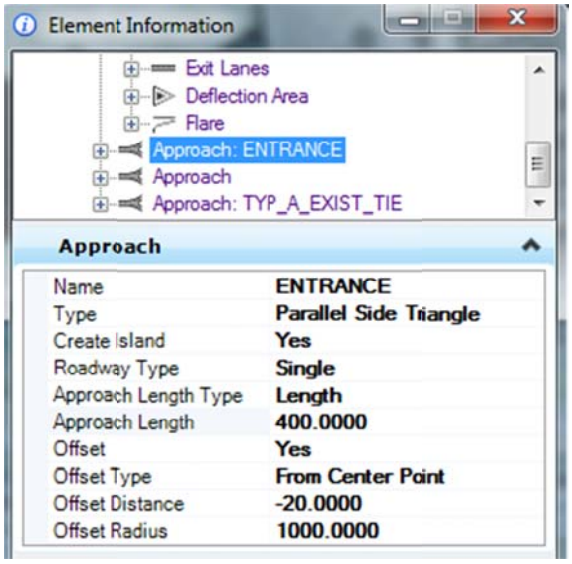


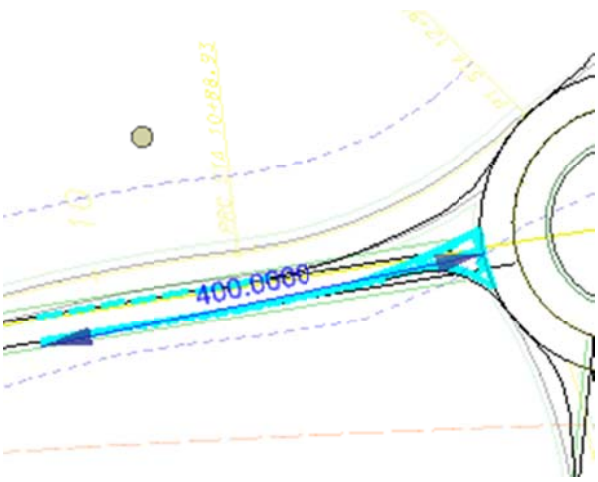


Replace the West Approach Roundabout Ramp Exit

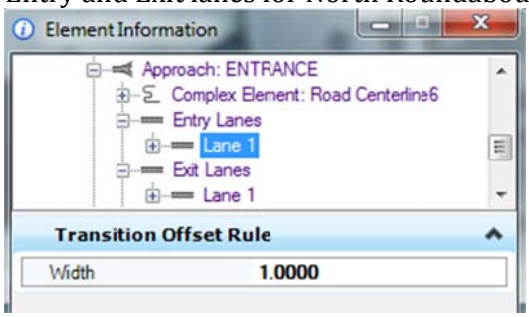
1. Expand the roundabout library TYP01_4LN_APR2 and select the ENTRANCE approach.

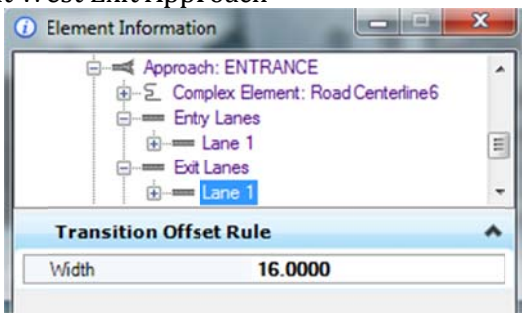
North Roundabout Exit Ramp West Approach



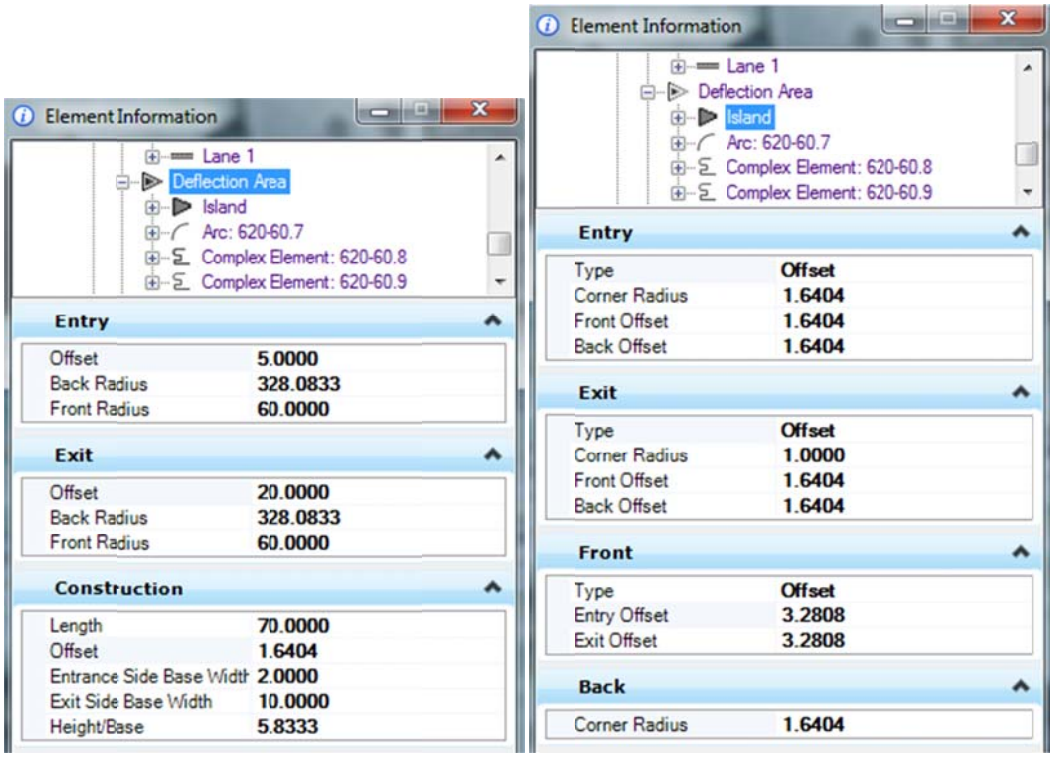


Entry and Exit lanes for North Roundabout West Exit Approach

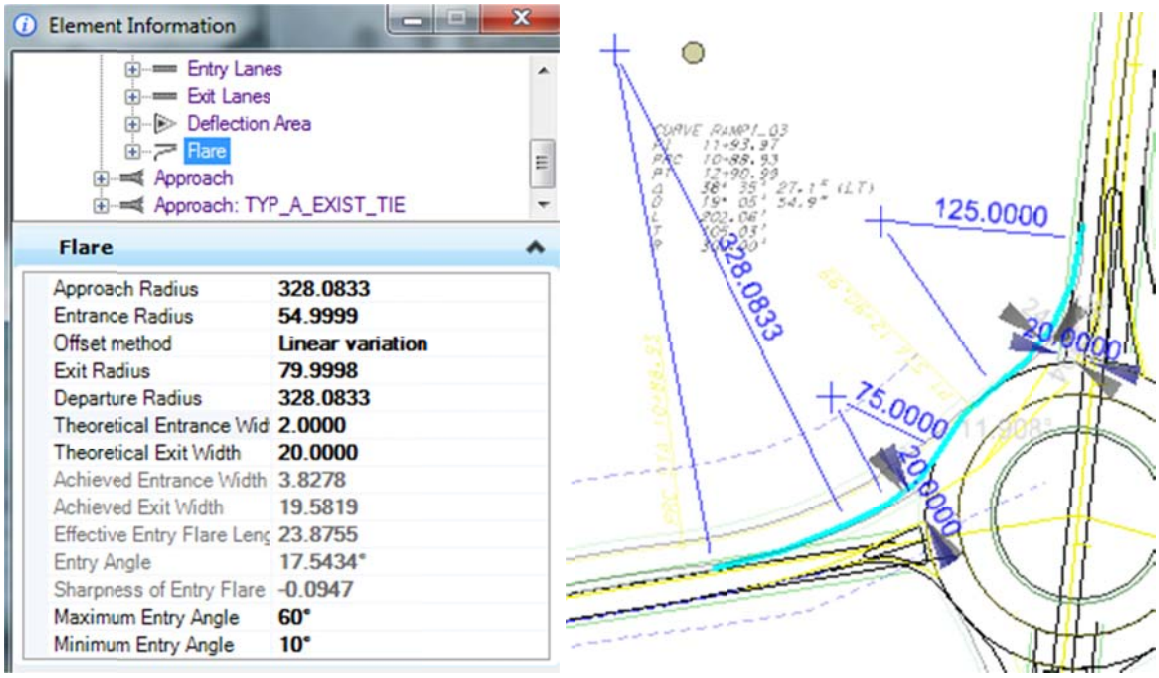




North Roundabout West Exit Deflection area and Island info



North Roundabout West Exit Flare



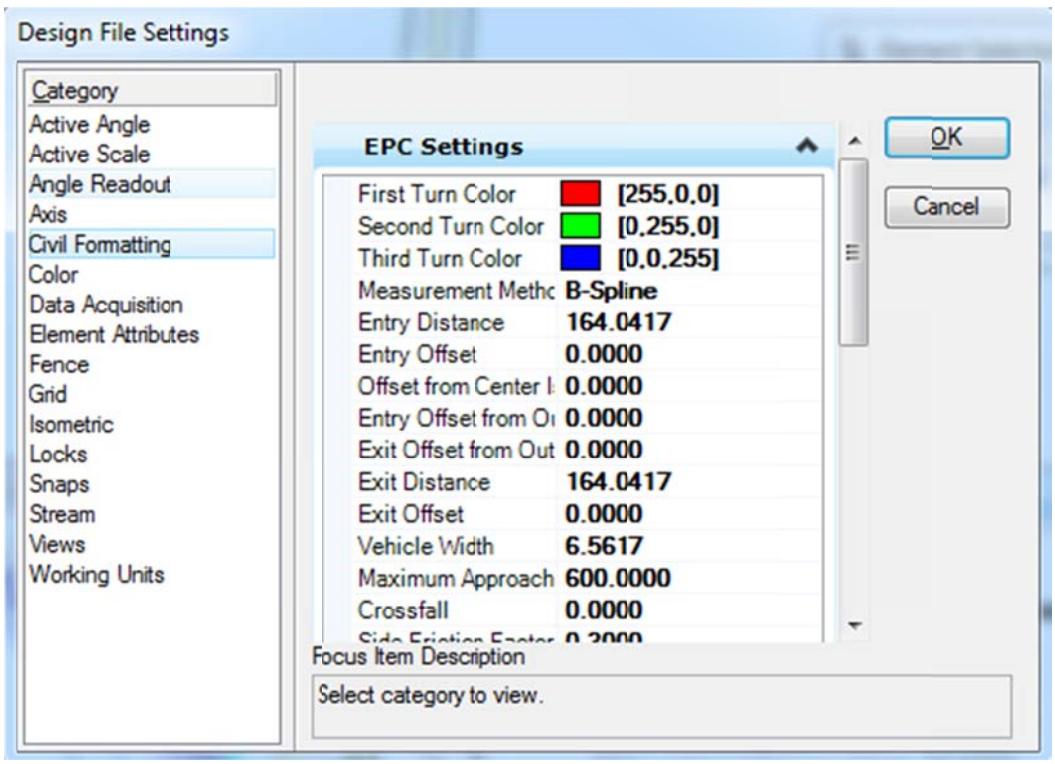
Entry Path Curvature Analysis

Entry path radius is one of the more important determinants of safety at roundabouts. This is a measure of the amount of entry deflection imposed on vehicles at the entry to a roundabout.

> ***Note*** This class is intended to show you how to use the tools to create a good design. It is not intended to teach you the principals and theories of roundabout design.

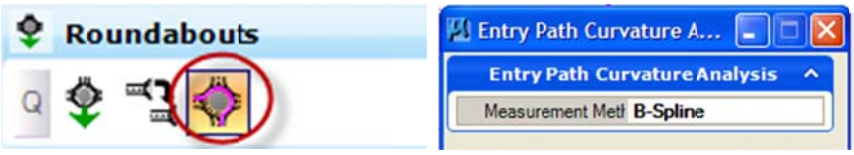
Exercise: Analysis of Design Speed through Roundabout

1. Open the civil formatting dialog *Settings > Design File*.
2. Highlight the Civil Formatting category.

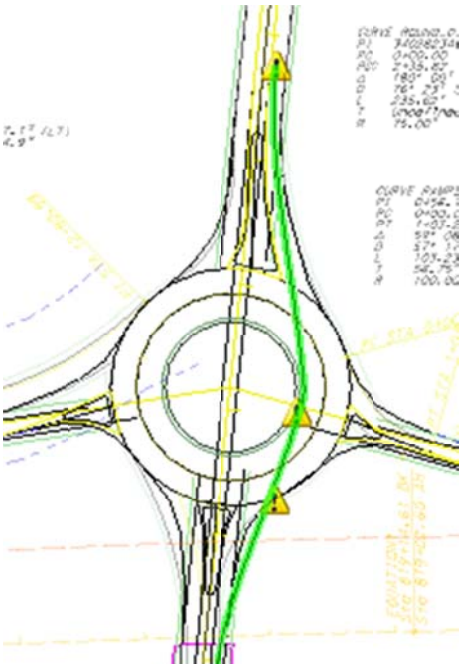


3. Scroll to the bottom and set the “maximum approach” to 600’ and the “design speed units” to MPH.

4. Click on Entry Path Curvature Analysis and select measurement method to B-Spline

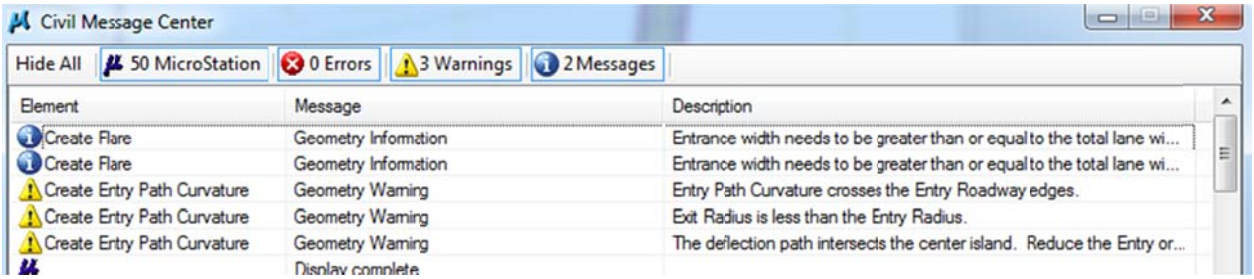


5. Select the South approach first, and then select the North approach. Follow the prompts.



Note	*The vehicle travel path will be drawn and any encroachments on the circle or approaches will be flagged. Review the selections and note if any Alerts or Errors. Check the Message Center and make the necessary adjustments to correct the errors.*

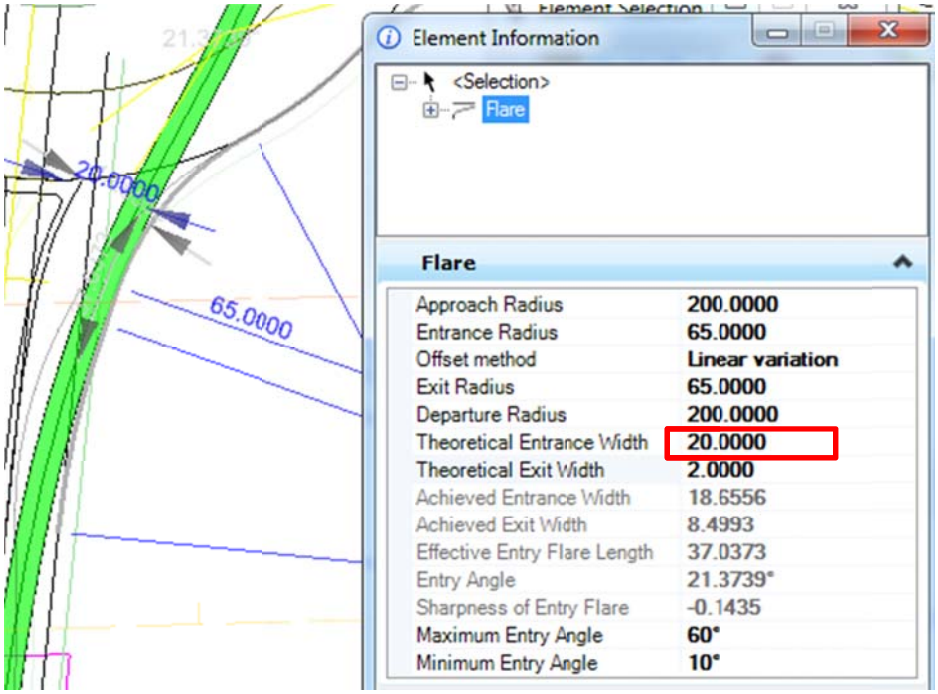
The analysis should result in three warnings and 2 messages.



To correct this, the user will need to modify both the theoretical entrance width on the south approach.

6. Make the following modification:

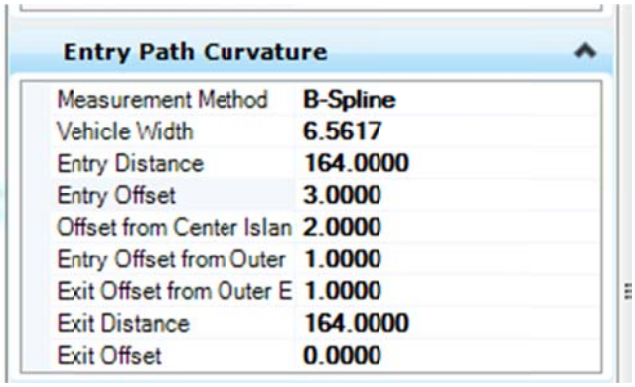
a. On the Flare on the East side of the south approach, change the Theoretial Entrance Width to 20'



7. With the element information dialog open select the entry curve analysis.

a. At this point, the design speed is 33 mph we want to be <25 mph.

b. Reduce the design speed by changing the Entry Path Curvature. By default, the program assumes the driver will hug the centerline with 0' offsets. Change the Entry Path Curvature to match below. What is the design Speed now?



Other modifications to the RAB geometry could be used to remove these warnings such as increasing the exit lane width or increasing the exit curve radius. These modifications would act to allow for increase speed rating when leaving the RAB.

Repeat the previous steps for all approaches.

Note	*Place one Entry Path at a time and resolve any issues you may have before moving to next approach to minimize the number of Alerts you need to adjust.*

When selecting the Roundabout or its Approaches, the designer will see the entry curvature analysis results in addition to the previously seen design data.

Select an Approach and open element information. Review your information on the Calculated Design Speeds for each Approach.

It is easy to see how the dynamic editing capabilities of civil platform can benefit the designer. As we finish this courseware work has begun on the next phase connecting vertical geometry to these dynamic geometric elements.

Summary

You are now able to:

- Identify the parts of a roundabout
- Create a Roundabout Library
- Have a basic understanding of the rules based approach as it pertains to design using the roundabout tool.
- Understand the concepts to manipulate your RAB design.
- Analyze the design with the entry curve analysis tool.

Chapter-4 Model Set Up

RAB Model Overview

In this chapter the user will gain insight into what needs to be completed prior to creating the finished model of the Roundabout. Prior to activating the corridor design tools the vertical geometry (Profiles) of the roadways need to be established. To begin the designer will focus on:

- Establish preliminary grading using DTM tools, Roadway designer tools or GEOPAK Site Modeler
- Establish the profile of the connecting roadways in the area of the RAB
- Create the Circulatory Area Chain (Alignment) and Profile

It is important to first understand the requirements of the project prior to modeling the RAB; in some instances the designer may opt to use GEOPAK Site Modeler. While Site Modeler alone allows for quick modeling of the final surface it does not interact on the same level as the Corridor Modeler. The Model referred to in this workshop will guide the user through the process using the Corridor Modeling tools.

Establish the RAB Rough Grade

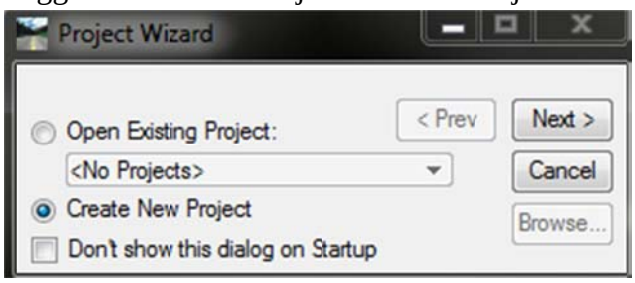
Bentleys Site Modeler is an excellent tool for developing quick, highly adjustable surfaces. In short Site Modeler simply builds TINs. The designer could also opt to create these rough construction surfaces by using other tools such as the DTM tools or roadway designer. For the purpose of the workshop we have opted to use the Site modeler application for the following reason:

- Quickly generates surfaces
- Surfaces can be profiled using the same process as used in GEOPAK Road
- Can be used downstream to complete a finished 3D model of the entire site that is easily updated.

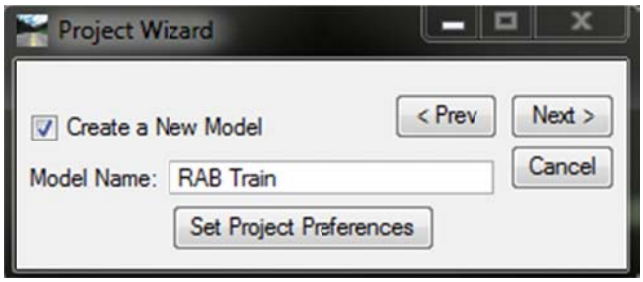
Creating the Modeler Project

With the Horizontal (Chains) in place for Rte 63 and The ramps (1-4)and the profile for the Rte 63 having been established the user can now design a rough grade plane using the PGL as the starting point of the RAB surface.

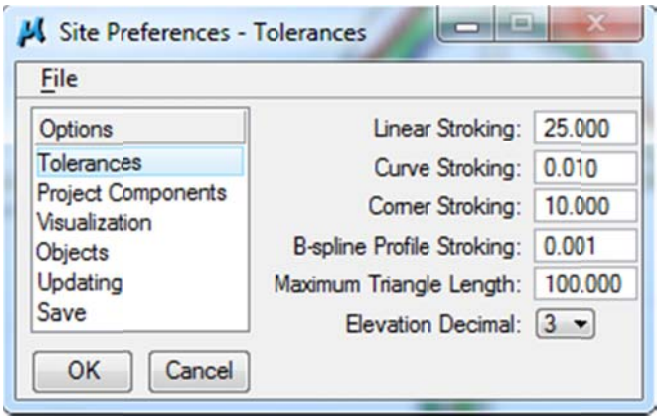
1. Open RAB_Training_Chapter4.dgn from CH4 Folder
2. Open GEOPAK Site *GEOPAK > Site> Site Modeler>Site Modeling*
3. Toggle create New Project from the Project Wizard dialog > Click Next



4. Place in folder C:\Data\J9I2184\ name it "RAB_Training_Chapter4.gsf" > Click next
5. Toggle create a new Model > Enter name RAB Train
6. Click "set Project preferences"



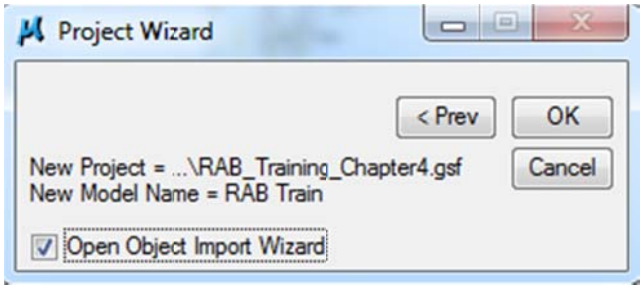
7. Click File> Open> select from the "Standards folder MoDOT_Site.spf



8. Click OK

9. Click Next on the project wizard dialog

10. Toggle "Open Object Import Wizard"

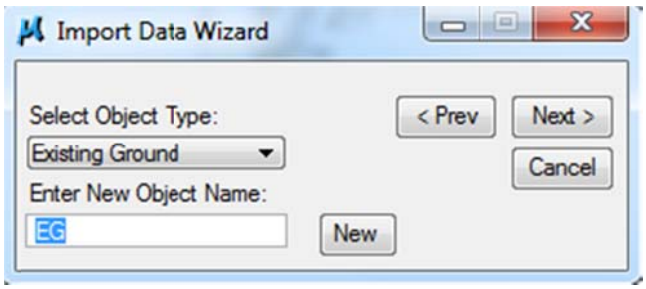


11. Click OK

12. Set the dialog to:

File Type: TIN File
File Name (Browse): C:\Data\J9I2184\J9I2184.tin

13. Click Next- set the dialog as shown below

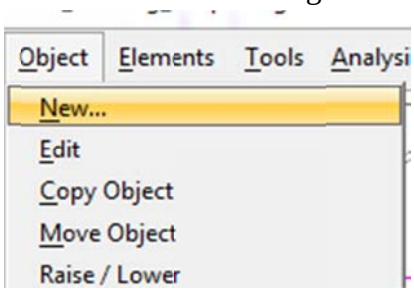


14. Click Next > Toggle ON "Use as Base Object For: Model : RAB Train"

15. Click OK

Create the Construction Object Surface

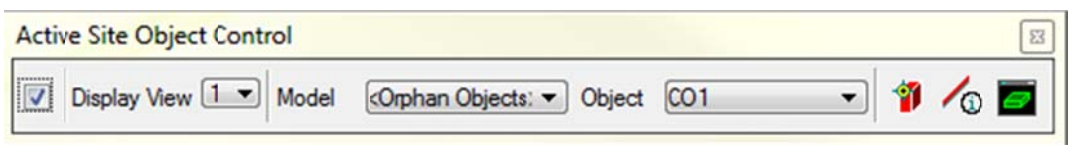
1. From the modeler dialog Create a new Object *modeler Object > New*



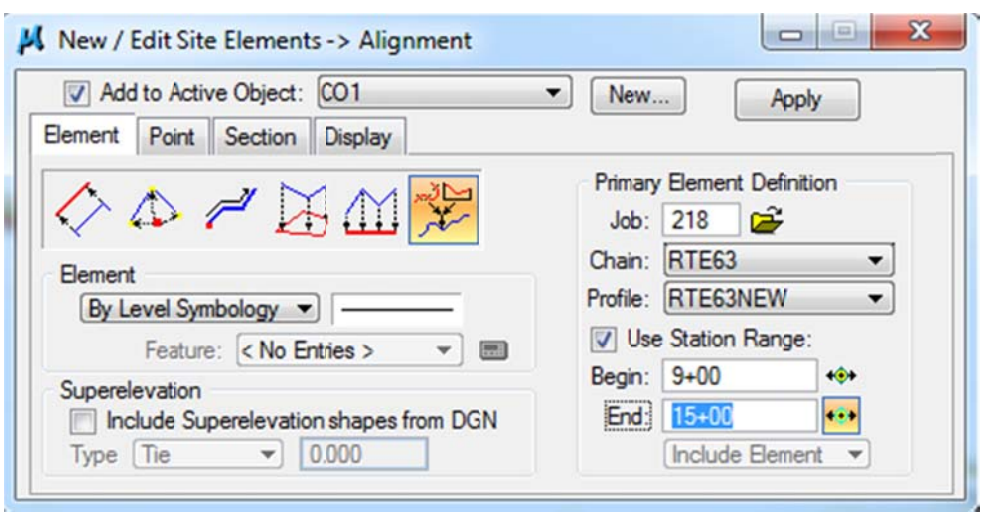
2. Set the dialog
   a. **Type:** Construction
   b. **Object name**: CO1

> ***Note*** *Do not toggle add to active Model- This creates an "Orphan Object" this means the object (an object is simply a surface) will not merge into the Base Object*

3. Click OK... The object should now appear in the Active Site Object Control

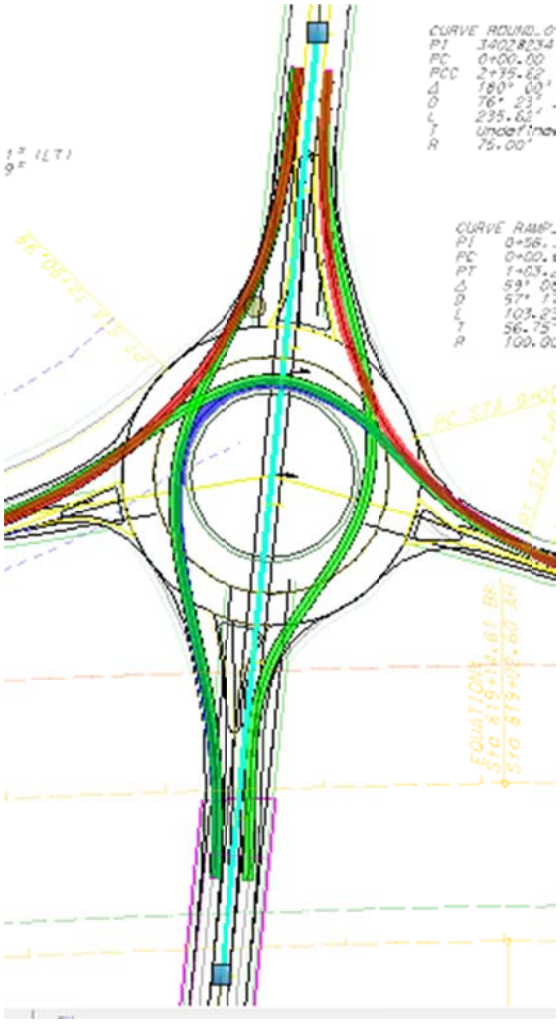


4. Open the Elements New Edit dialog – *Modeler > elements > New/edit*
5. Set the dialog as shown below

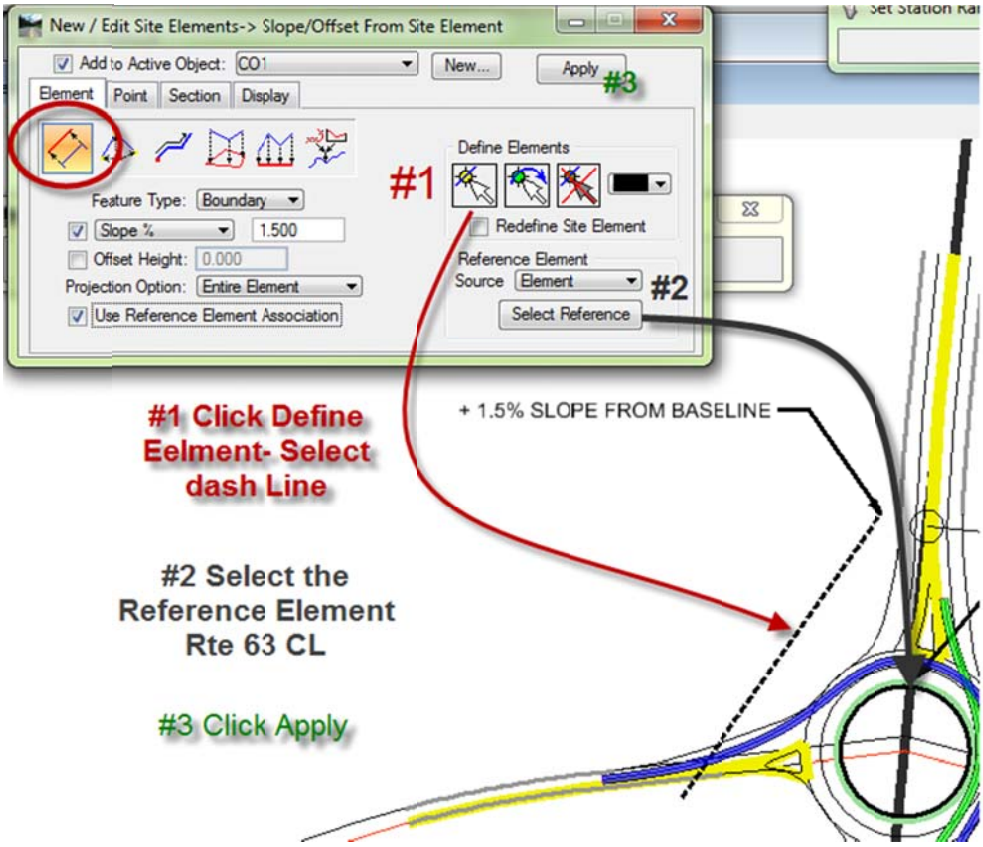


6. Click "Apply"

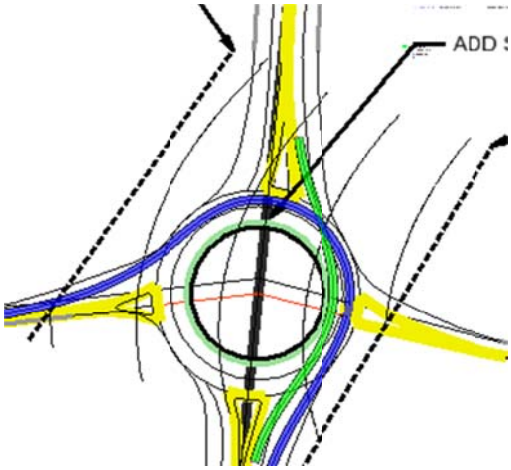
Note	*Once Applied- an element will be created between the station range using the level or feature symbology active on the dialog*



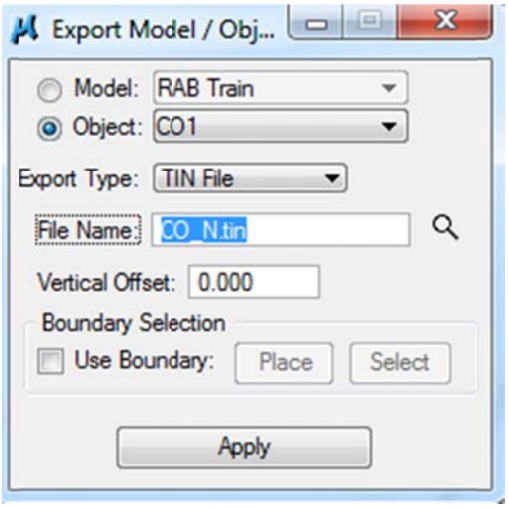
7. Change the command mode on the New / Edit Site Elements Dialog to Slope/ Offset
8. Follow the Diagram below to select the element-select the reference and apply



9. Repeat the process to add the dashed line to the east of Rte 63 at a -1.5% slope



10. Export the newly created CO1 *Modeler > Project > Export> Model/Object*
11. Set the dialog as shown below and click Apply



Creating the Circulatory Alignment

At this point various geometry has been created by placing the RAB the geometry should include:

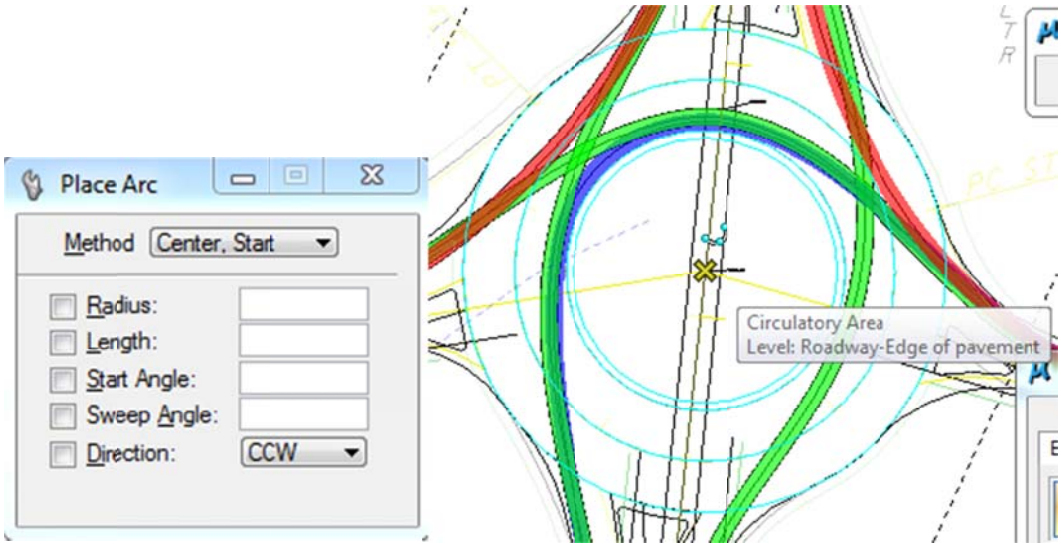
- Circulatory Curves (These will have to be constructed into a Chain)
- 4 Flares- NW, NE, SW, SE

Using the CO1 construction surface as a guide the user can now set the RAB Circulatory Profile

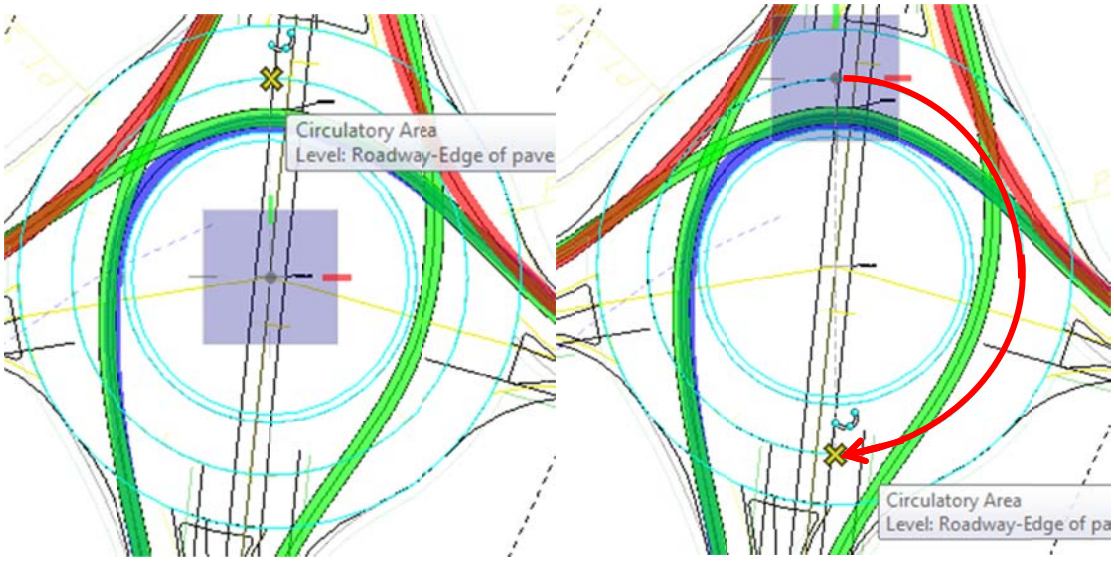
Create the Circulatory Chain / Profile

Currently a chain using a circle does not produce desired results in GEOPAK. So for a chain to work properly, we will create 2 arcs along the Circulatory area of the Roundabout and Store Graphics for the alignment (chain) of the roundabout.

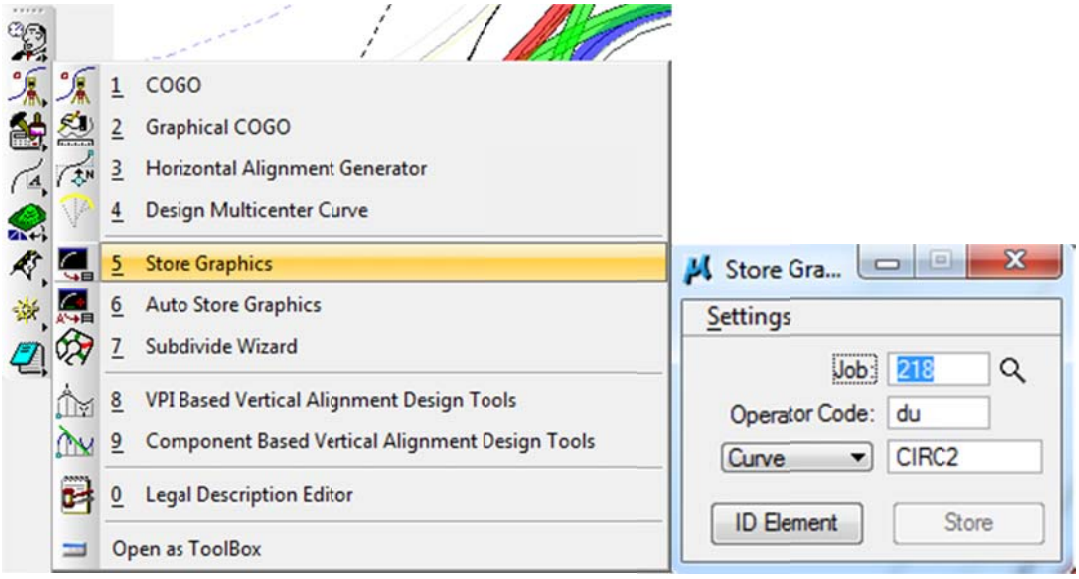
1. Select the Place Arc tool
2. Set Method to Center, Start



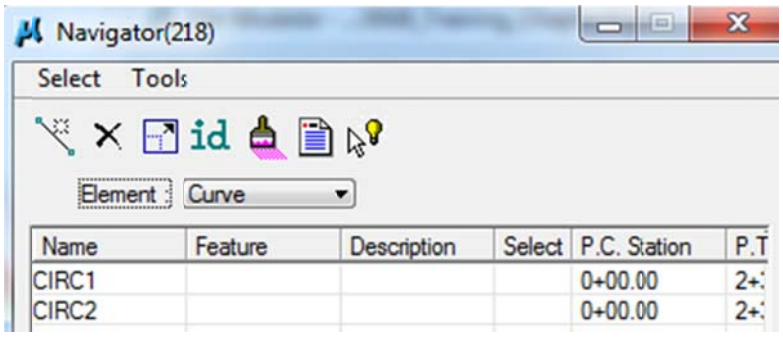
3. Place 2 arcs, using the center of the roundabout and snap points.



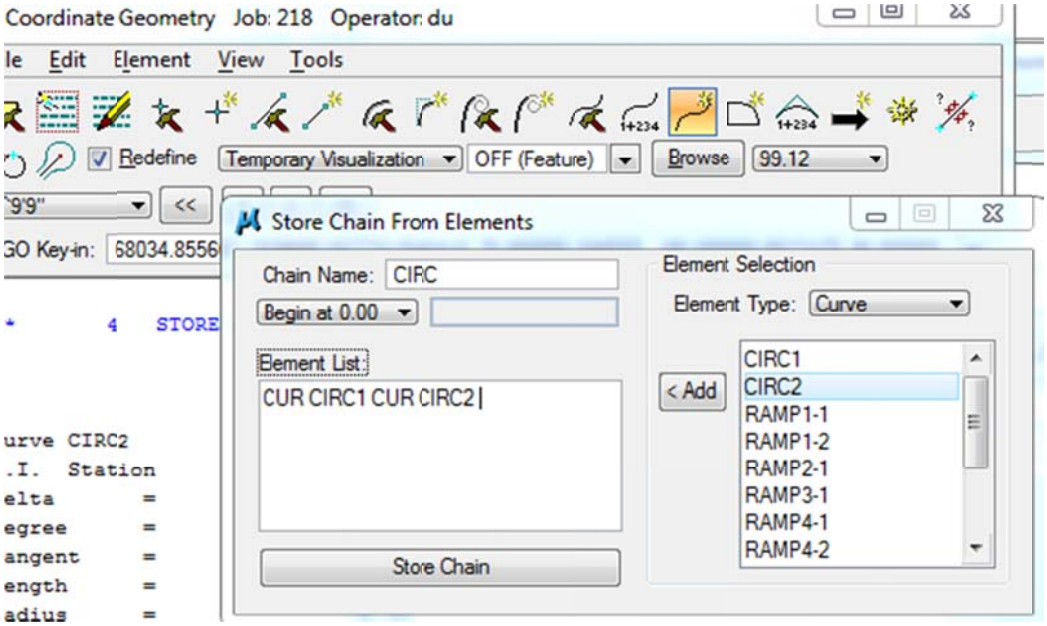
4. Store Graphics of the Arcs created to store curves “CIRC1” and “CIRC2”



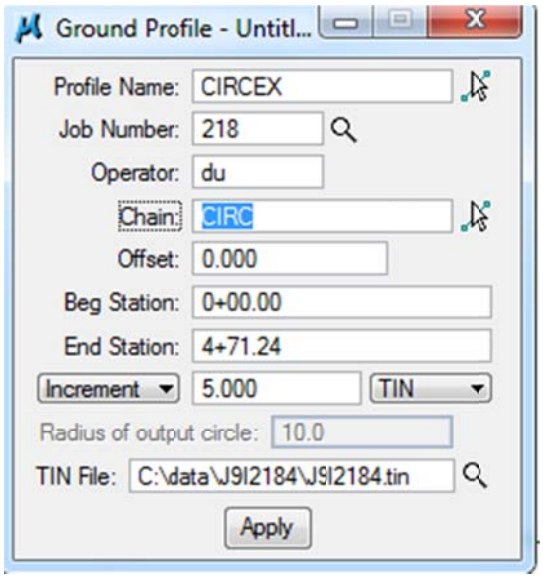
5. ID Element, Select the first arc created and Store the Curve
6. ID Element, Select the second arc created and Store the Curve



7. Open Coordinate Geometry
8. Click Store Chain From Elements
9. Add the two Curves created



10. Click Store Chain "CIRC"
11. Close COGO
12. Open the "Ground Profile" tool- *GEOPAK > Road > Plans Preparation > Ground Profile*
13. Set the Dialog as shown below



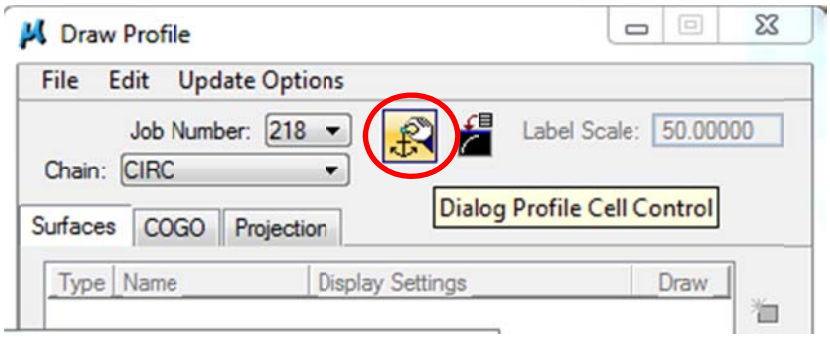
14. Click Apply > Click "OK" to store inp > Click YES to store Profile > Click YES to "Delete Profile String"

15. Close the dialog

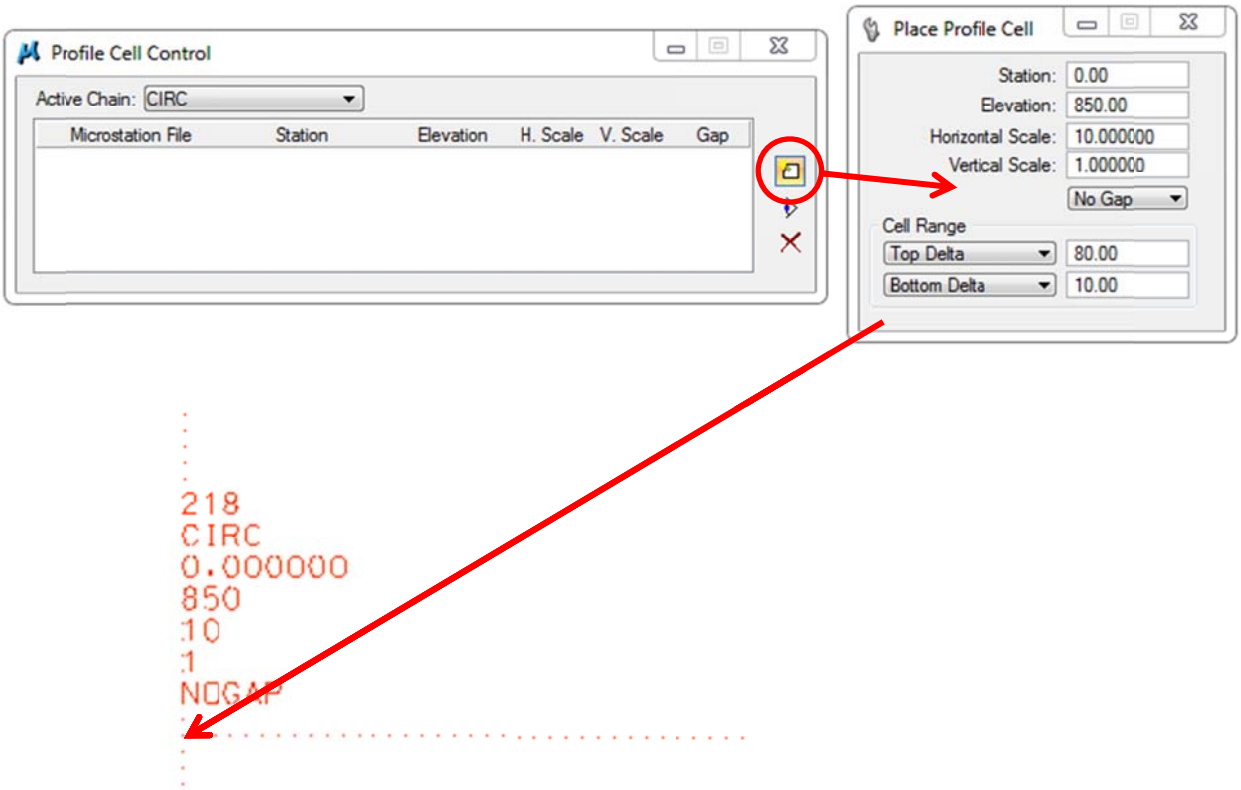
Creating Existing Profile View using GEOPAK Site

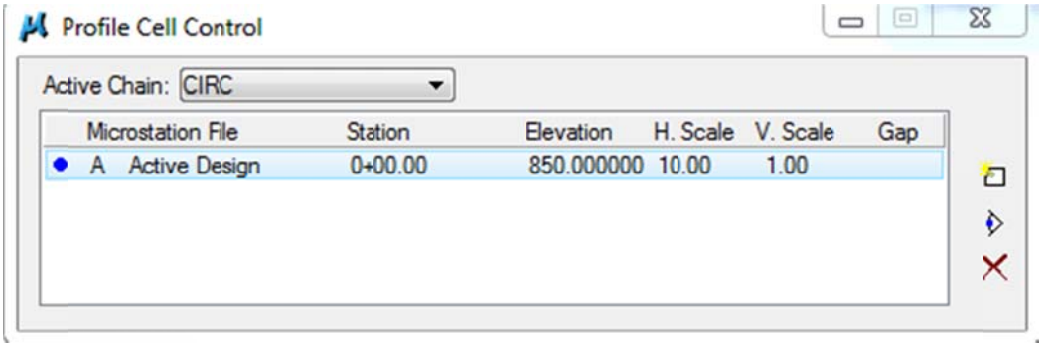
16. Create a profile- modeler > Object > draw profile

17. Place profile Cell- Click the Dialog Place profile Cell



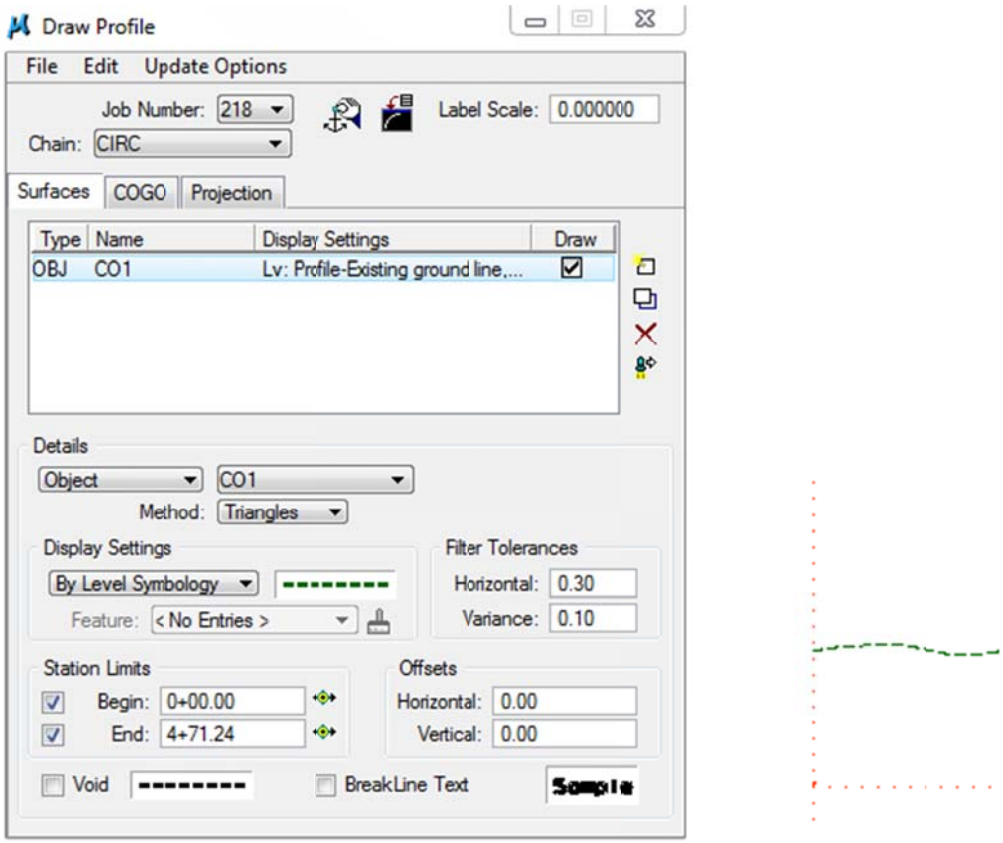
18. From the Profile cell Control dialog follow the steps in the diagram below





19. From the "Draw profile" dialog select the "Surface tab"

20. Set The dialog as shown below – Click "Add" to display the CO1 surface

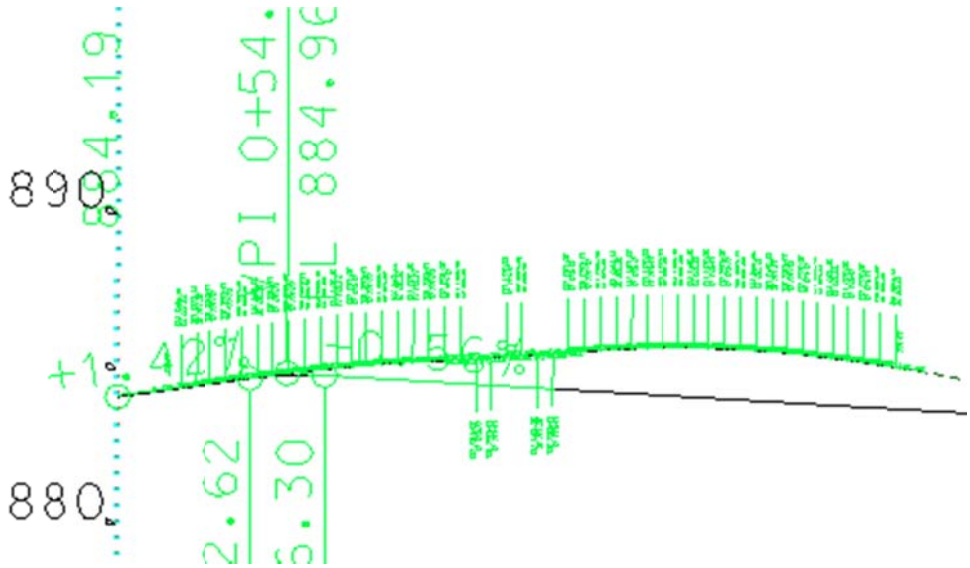


Creating Proposed Profile

21. Repeat the process to create existing ground, This time use the CO_N surface as the Existing ground. This will place the profile for the circle on the desired plane.

Note	Identifying the cell will update the X, Y reference information

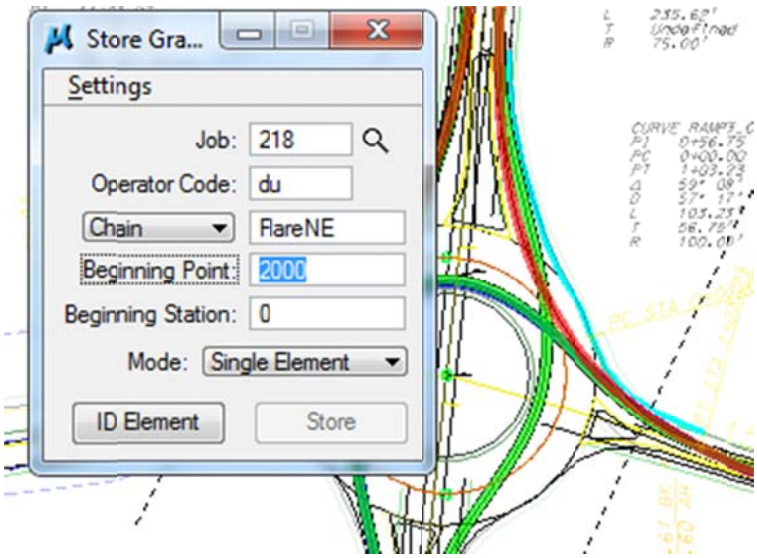
22. Save your profile as CIRCEX2.



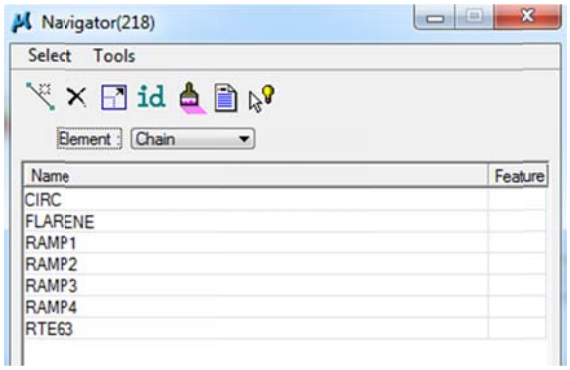
Create the Flare Alignments and Ramp Profiles

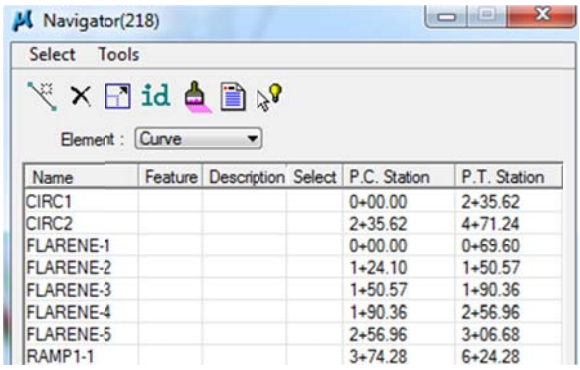
Creating the Flare Alignments

1. Use the MicroStation Create Complex Chain tool
2. Change the method to Manual
3. Select the elements that make up the Flare (leave out any bsplines)
4. Click the Store Graphics tool
5. Set the Dialog box as shown below and ID Element >select the Complex chain created from the North East Flare. This will require you to reset (right click) several times to select the complex chain. Watch the Status bar at the bottom of the screen to make sure you select the Complex Chain and not the Flare. Selecting the Flare will not store the chain.



6. Click the Store button.
7. Repeat this for each Flare on the Roundabout.





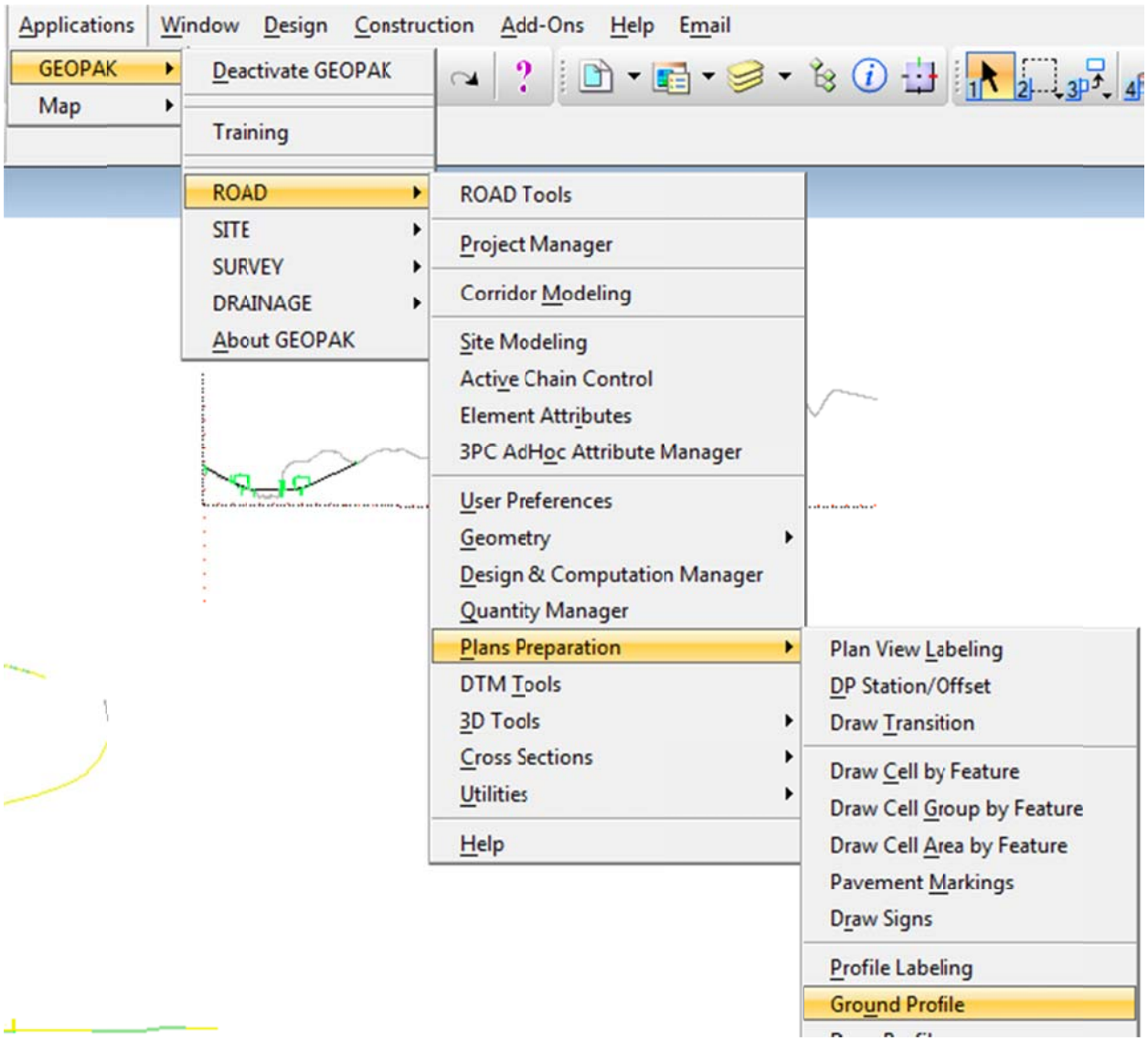
The chain is now stored for FLARENE along with the curves that make up the flare.

Note:
Flares are often made up of bsplines, which GEOPAK may have trouble with. If you continually crash trying to create a flare in this manner, try dropping the complex chain and replacing the bspline with a smartline, then recreating the complex chain. Or when creating the complex chain from the flare, skip the bspline.

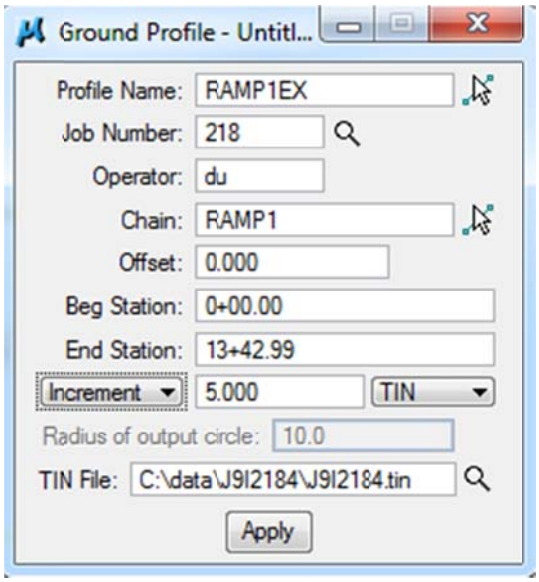
Create Ramp 1 Profiles

Ramp1EX
Ramp1New

1. Open the Ground Profile tool



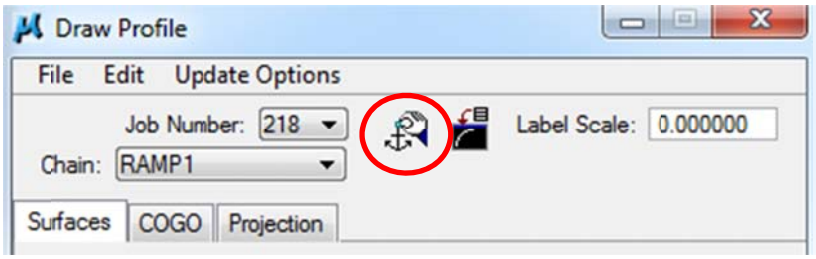
2. Setup the Existing Ground Profile RAMP1EX



3. Click Apply
4. Click OK to store the inp file
5. Click Yes to Store the Profile
6. Click Yes to deleting the 3D string
7. Close the dialog

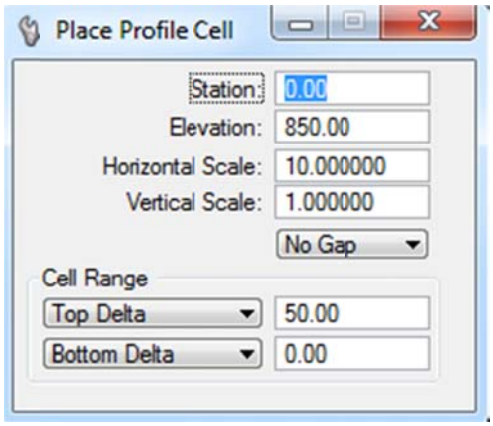
Draw the Profile in to the Drawing

1. Applications> GEOPAK> Road> Plans Preparation> Draw Profile
2. Change the active chain to RAMP1 and click the Dialog Profile Cell Control tool



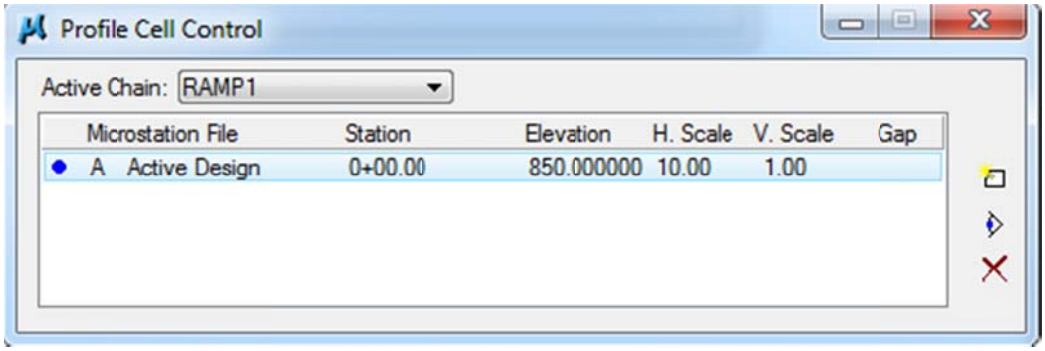
3. In the Profile Cell Control Dialog, choose the add button

4. Set the Place Profile Cell dialog as shown below:

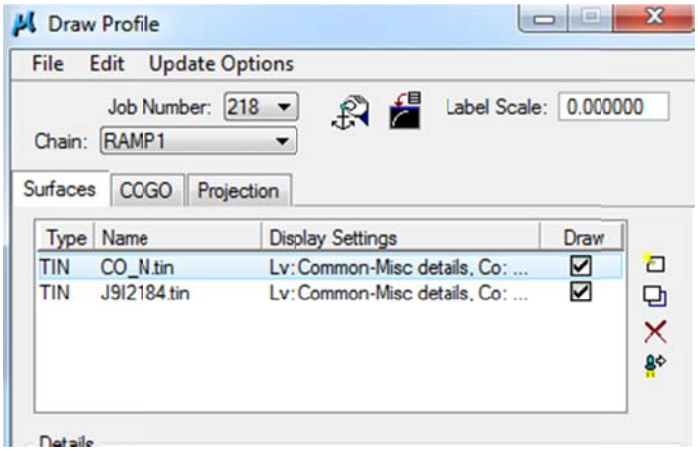


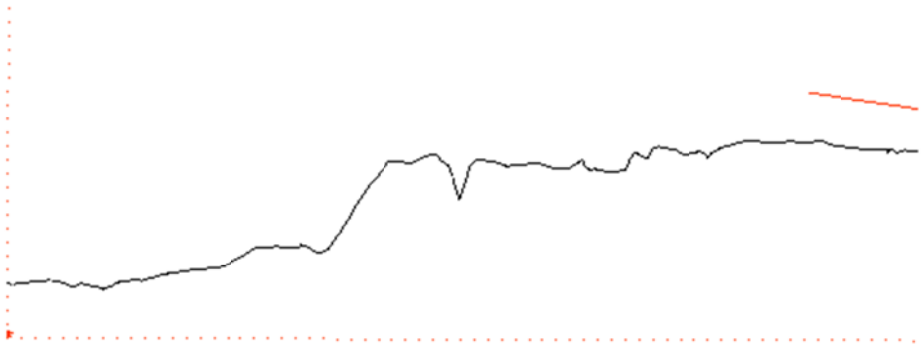
5. Place the profile Cell.

The Cell will show on the screen and in the Profile Cell Control dialog.



6. In the Draw Profile box, add the CO_N.tin and J9I2184.tin on the Surfaces Tab.

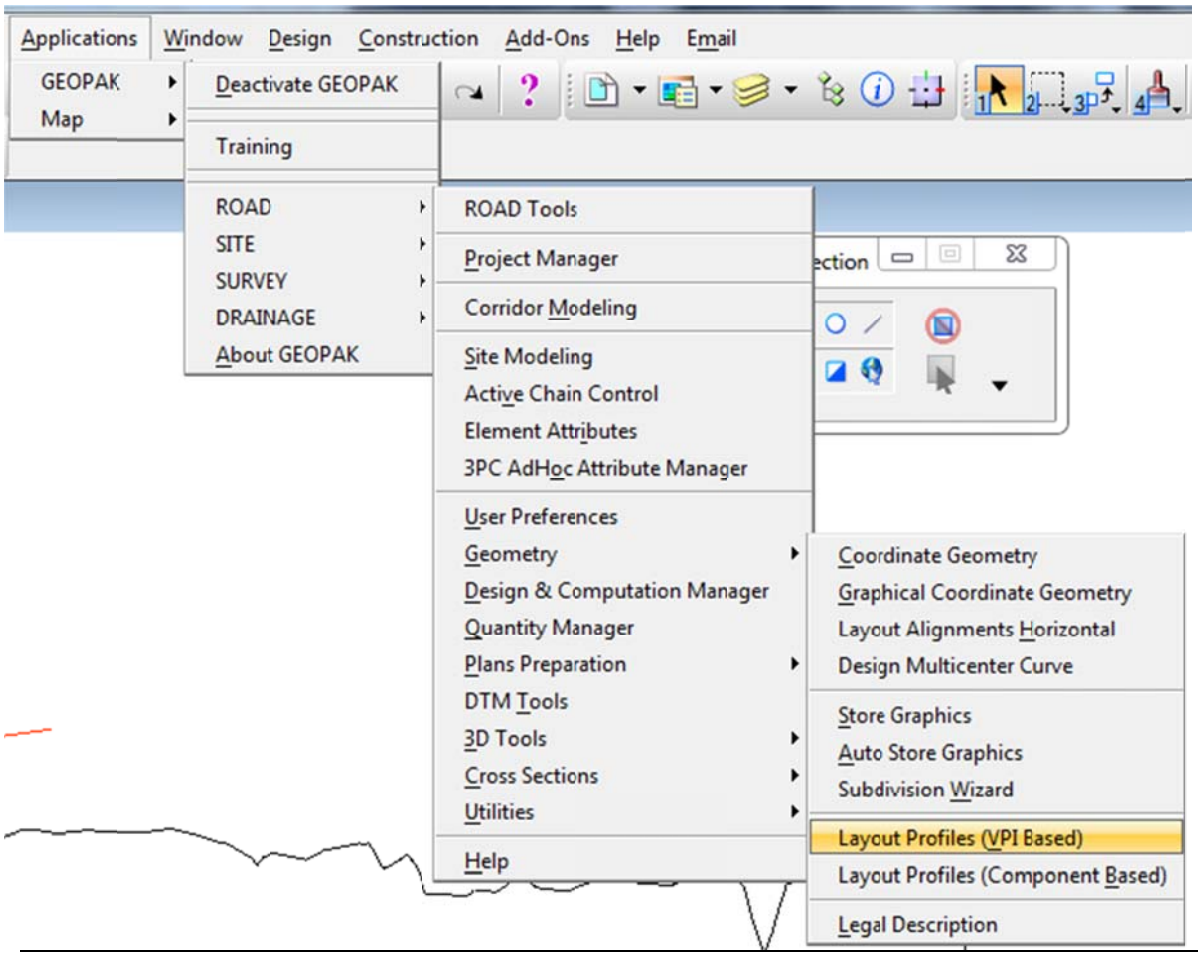




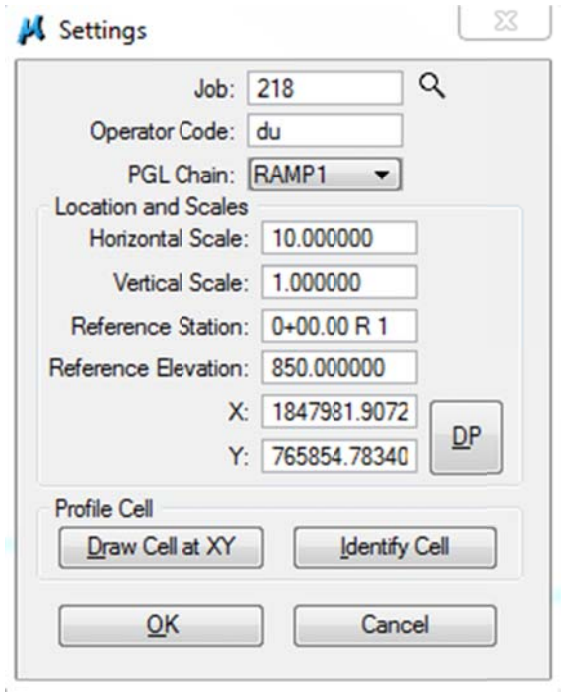
The top line is the Roundabout Surface created by GEOPAK Site. The lower line is RAMP1EX. This could have been drawn in using D&C Manager as well.

Create a New Profile Matching the Roundabout and Existing Elevation

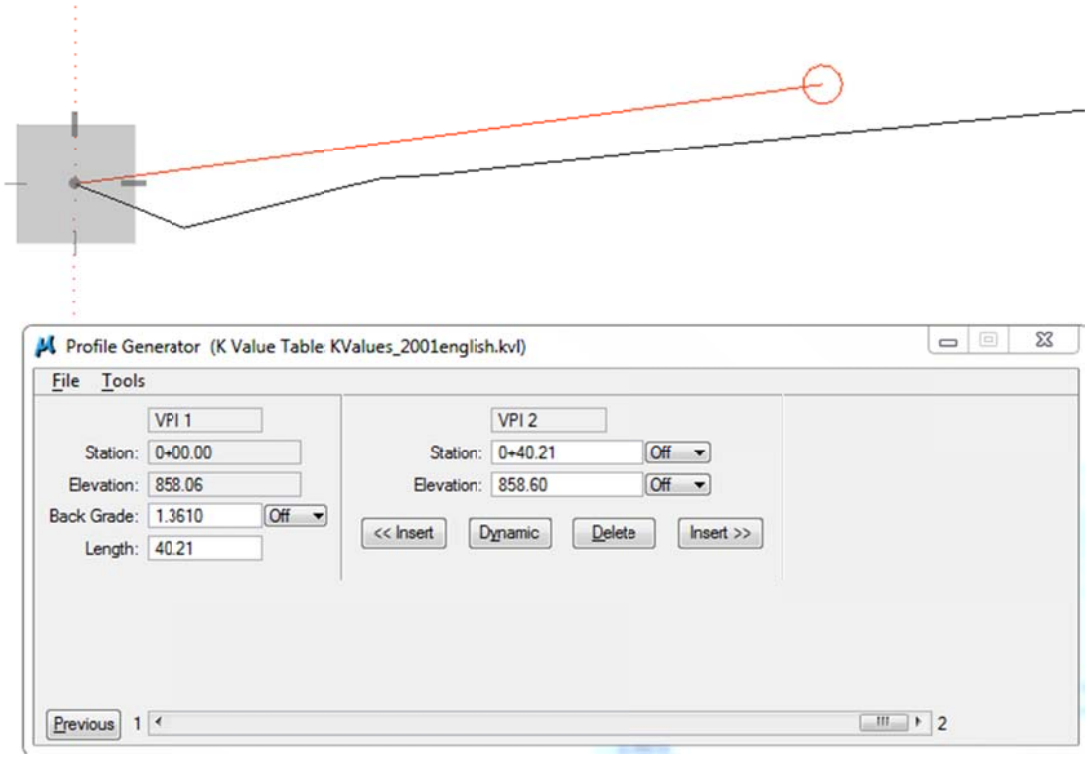
1. Open the Layout Profiles (VPI Based) tool



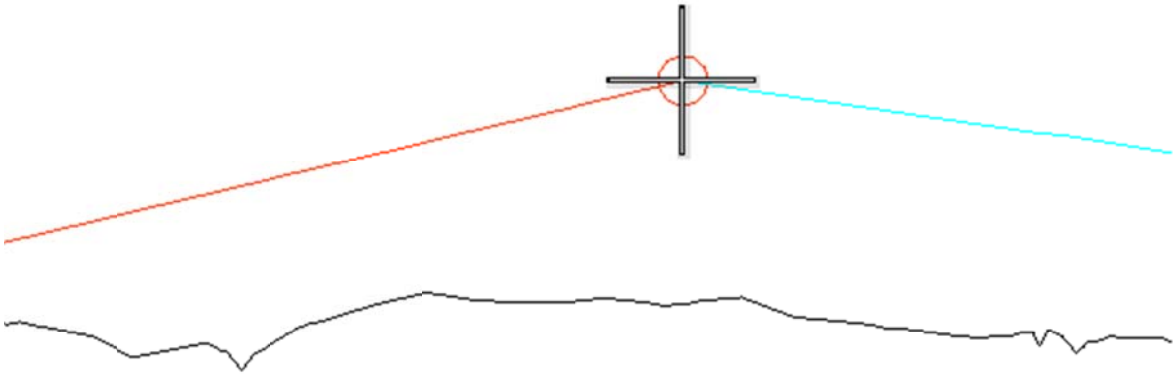
2. Set up the Settings Dialog box, be sure to Identify Cell and select the RAMP1 Cell created earlier.



3. Start the first Station at the beginning of the existing profile (RAMP1EX) line

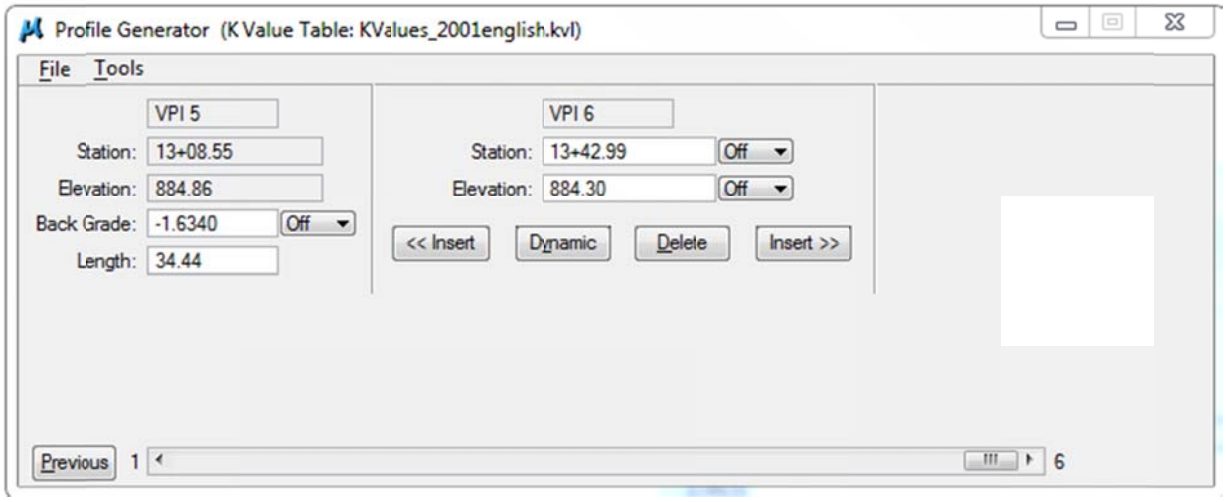


4. Insert the next VPI at the end of the Roundabout Line.



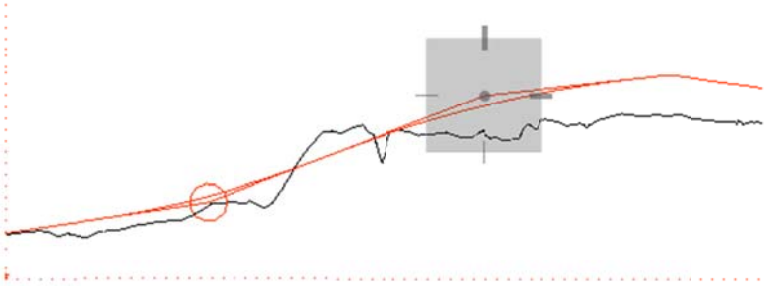
5. Insert more VPI's at the points along the Roundabout Profile line

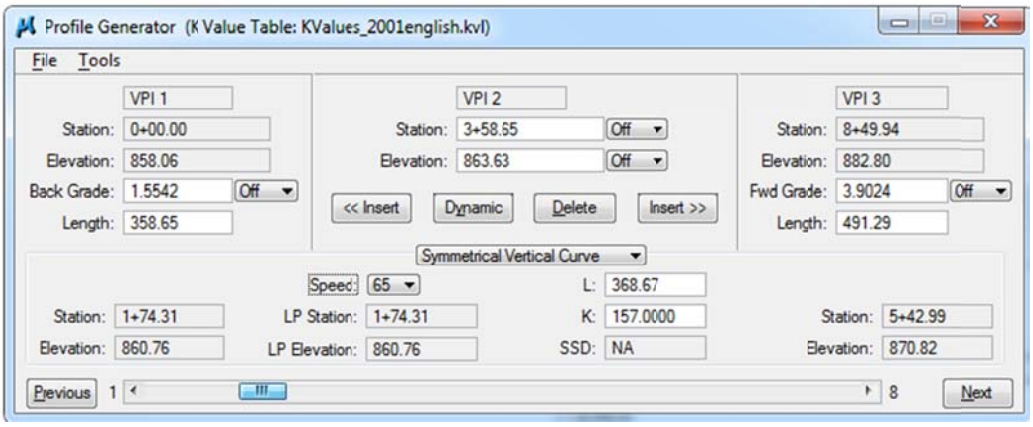
6. The final VPI should be snapped to the far end of the Roundabout Profile Line



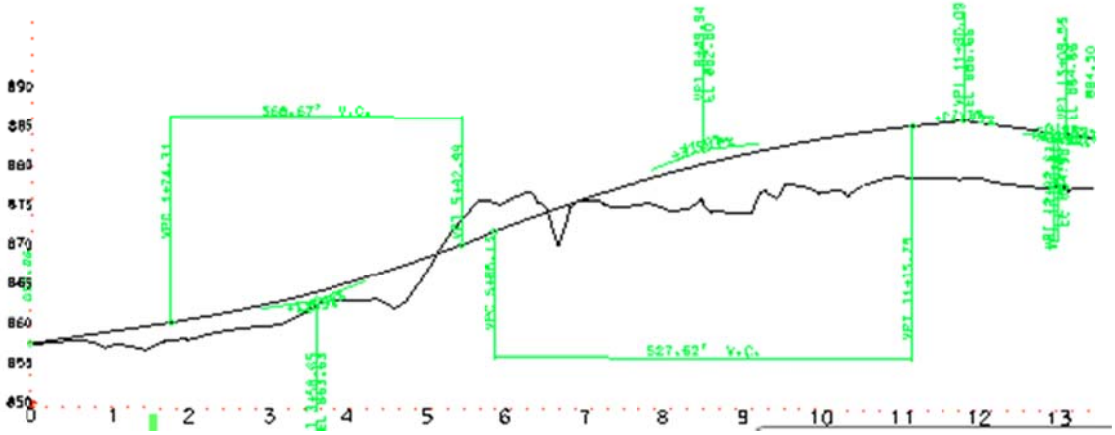
The profile should look similar to the one above.

7. You may now go back and insert any other VPI's you feel necessary.

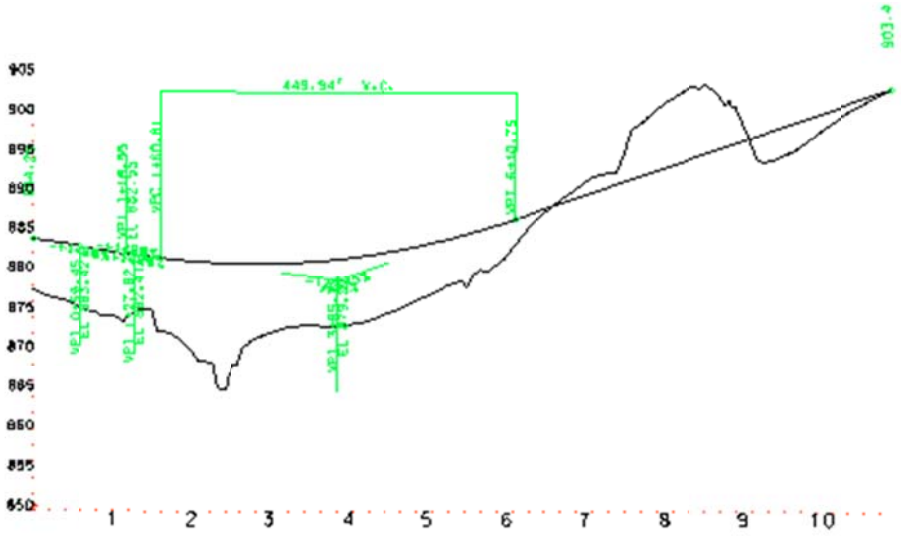




8. Store the profile as RAMP1NEW
9. You may use D&C Manager to place the profile for viewing if you wish



Use this same technique to create RAMP3EX and RAMP3NEW profiles.



Possible RAMP3NEW solution

Chapter-5 Corridor Modeling

Overview

The user will complete the design using previously defined Geometry Chains and Profiles. These include the Road Baseline, RAB Circulatory Area and Flares. In this Chapter emphasis will be placed on:

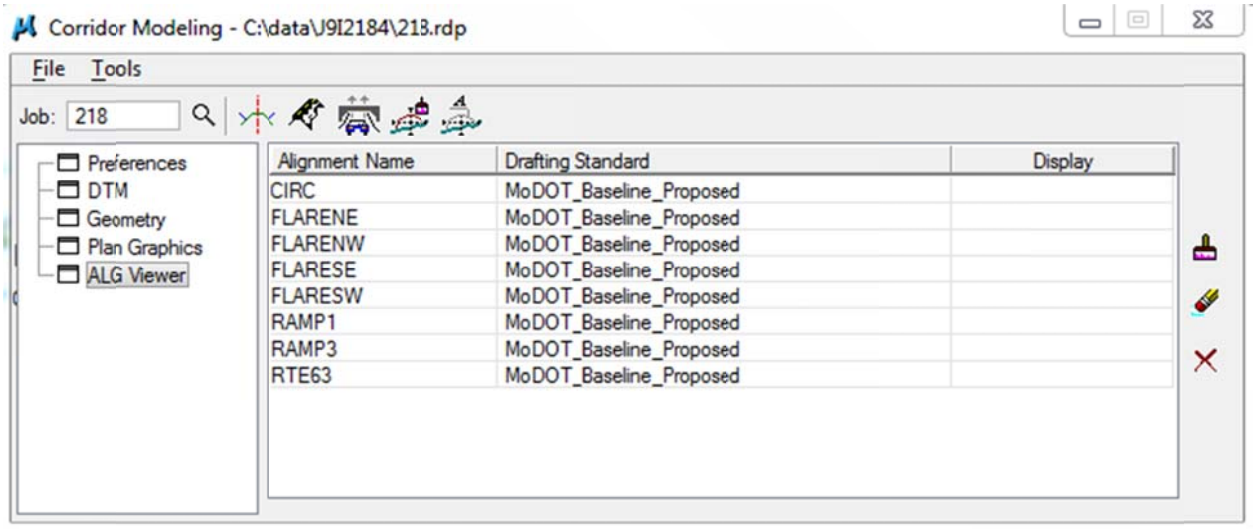
- Adding Multiple corridors to project
- Workflow
- Creating Flare surface
- Creating Flare Profile

Open the Project

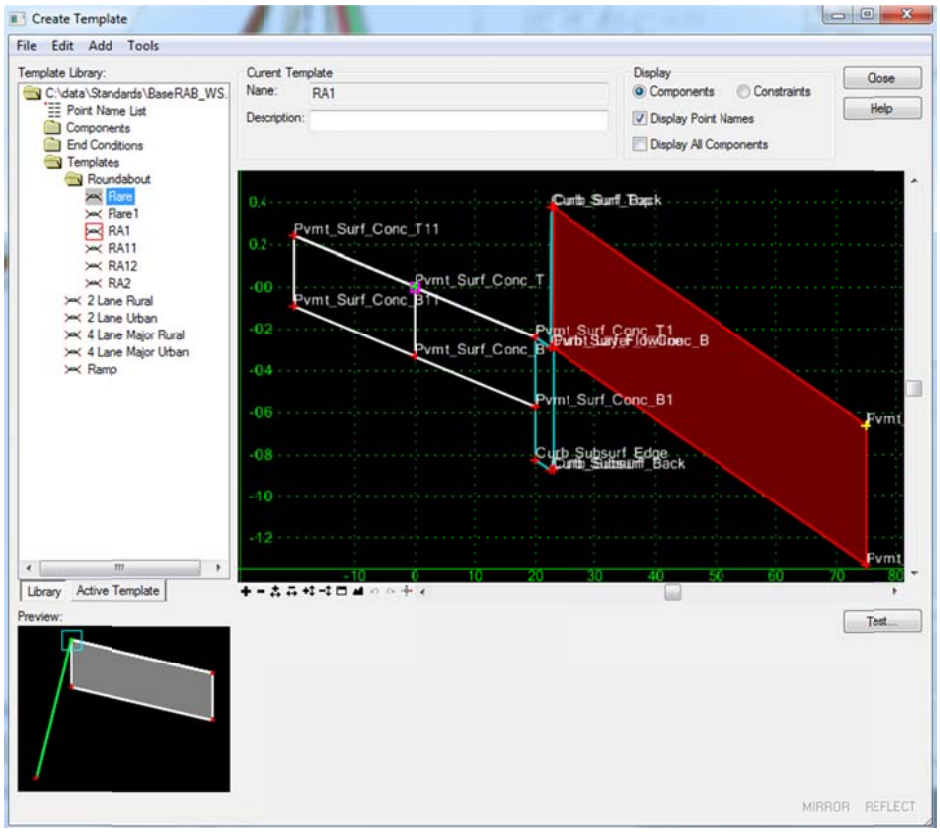
1. Open the RAB_Training_Chapter5.dgn from *C:/data/J9I2184*
2. Open Corridor Modeling – GEOPAK > Road > 3D Tools
3. From the Corridor Modeling dialog load the Road Design Preferences (rdp) File > Load > *C:/data/J9I2184*/218.rdp

   At this time take a minute to review the preferences. The following information has been provided and would be added in the same manner as setting the rdp for a typical corridor project.
   - Template Library = C:/data/Standards/BaseRAB_WS (.itl)
   - DTM = J9I2184.tin and CO_N.tin
   - Geometry = RTE63, FLARENE, FLARENW, FLARESW, FLARESE, RAMP1, RAMP3
   - Plan graphics- At this time no plan graphics have been added.

4. Review the rdp settings



5. Tag "Open create Template"
6. Review the templates – Close Templates



7. Tag “Open Roadway Designer”
8. From the Roadway designer dialog open the CH5_RAB.ird- *File* > *Open*

The ird contains the corridors leading to the RAB Approaches

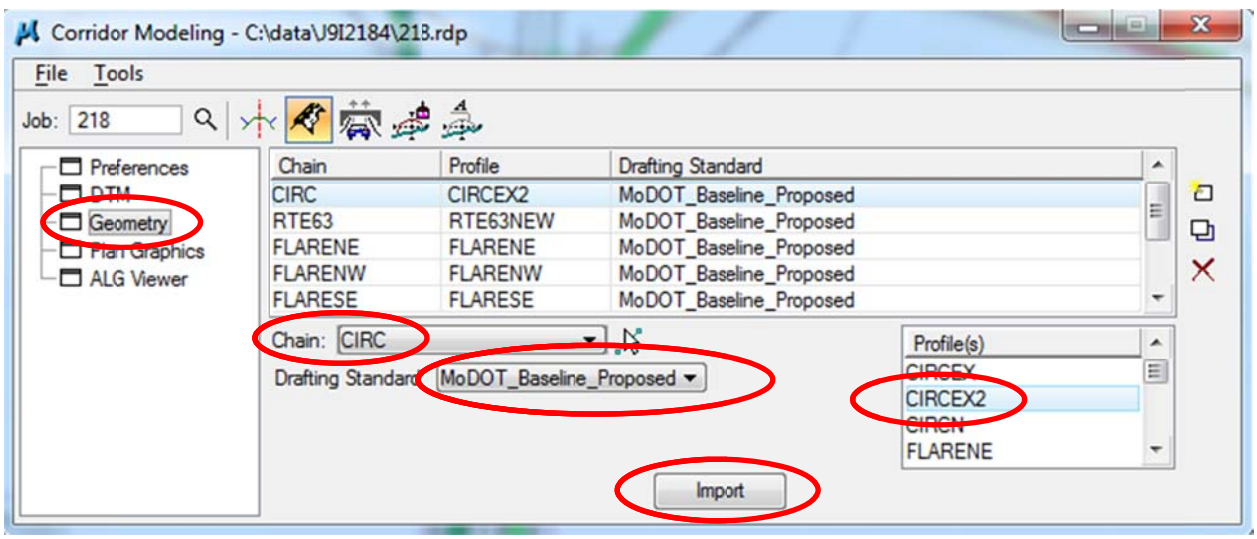
- Ramp1
- Ramp3
- Route 63
- Flares

The workflow to add the RAB corridors is as follows:

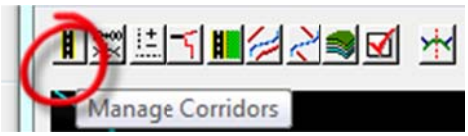
1. **Add the Circulatory area corridor**
2. **Create / edit flare profiles to align with incoming , outgoing, and midpoint corridors**
3. **Use Flare chain profile as baseline for attaching template – create flare corridors**

Add Circulatory Corridor

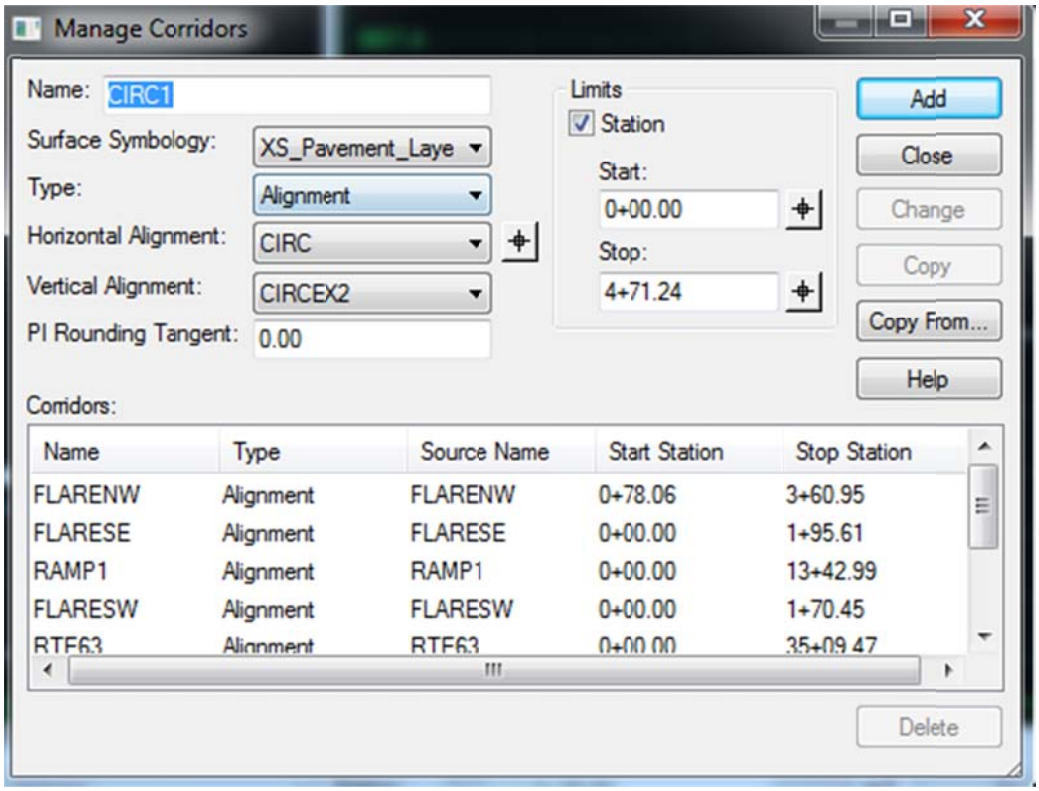
1. Click the Geometry selection on the left of the Corridor Modeling dialog to display all the Geometry that has been imported so far.
2. Change the Chain to CIRC, select the CIRCEX2 from the Profiles and Drafting Standard of MoDOT_Baseline_Proposed.
3. Click Add
4. Click Import to import the CIRC alignment into Roadway Designer.



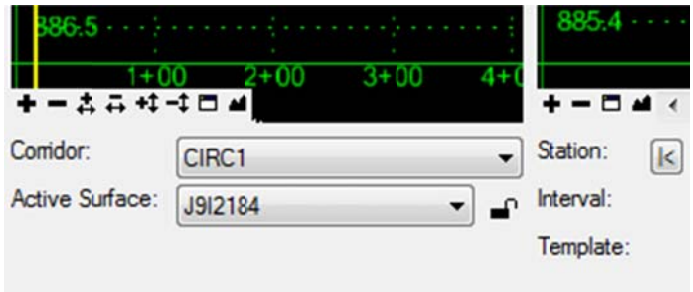
5. Continue with the Roadway Designer Dialog open and the 001_RAB.ird loaded
6. Tag Manage Corridors



7. Set the dialog as shown below

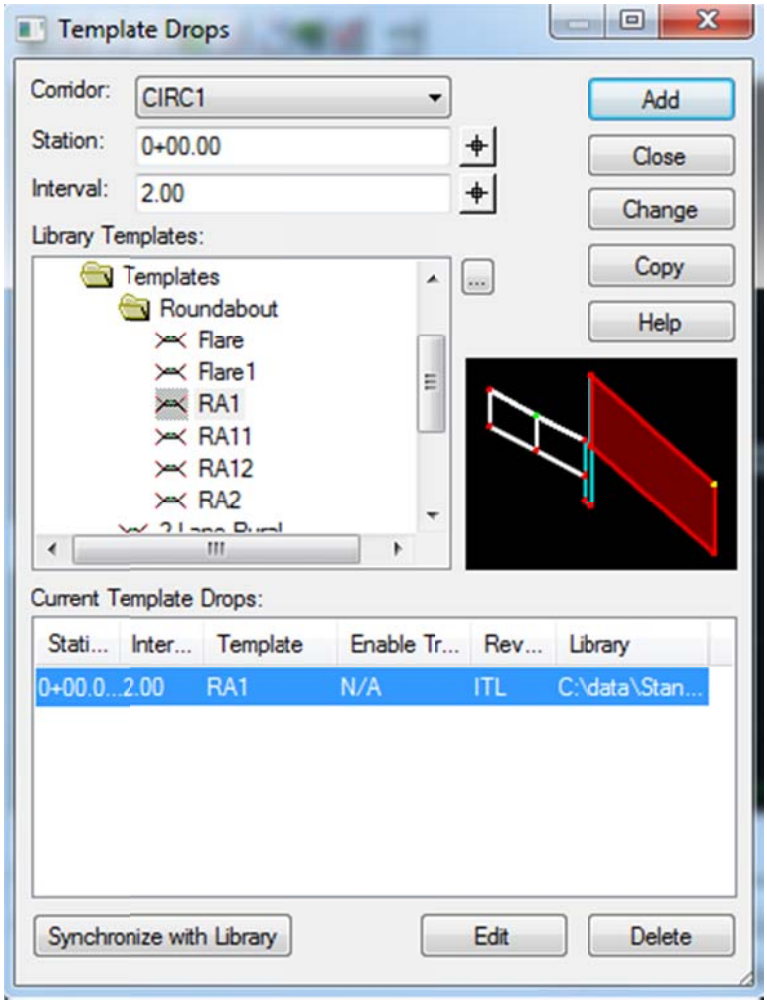


8. Tag the "Add" button and close the dialog – this will add the corridor to the list and set the Roadway designers focus on this Chain



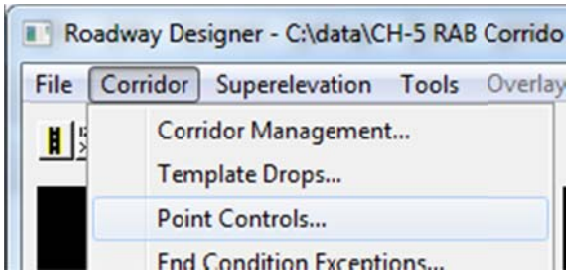
Add template drops

9. Select the Template Drops button (second from left)
10. Set the beginning station to 0+00
11. Set the interval to 2'
12. Select the RA1 template from the library folder

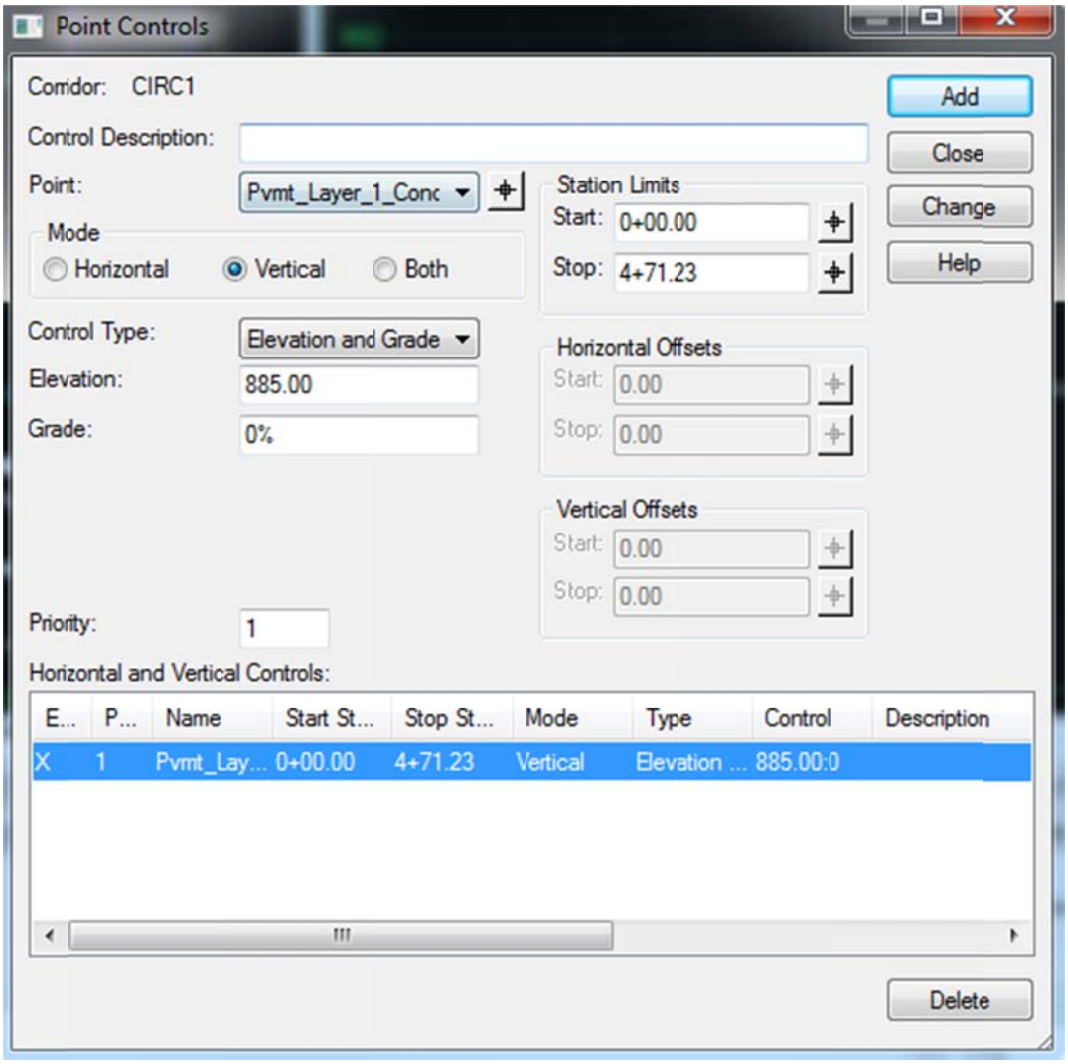


9. Tag Add – and close the dialog

10. Set Point Controls under the Corridor Drop down

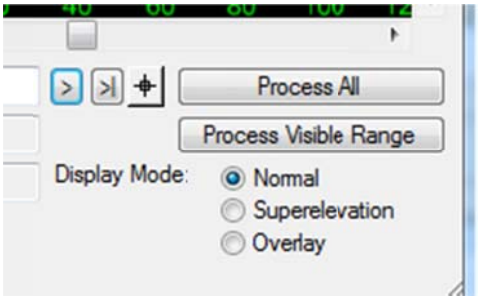


11. Set the point controlling the center of the roundabout to elevation 885

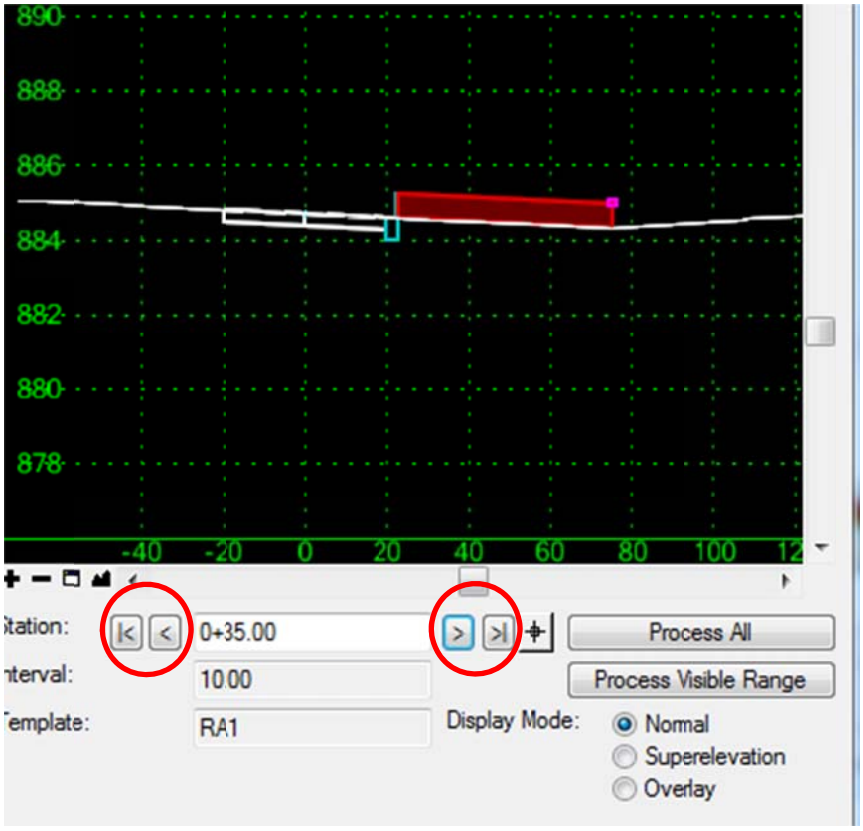


12. Close the Point Controls dialog

13. In the Roadway designer dialog tag "Process All"

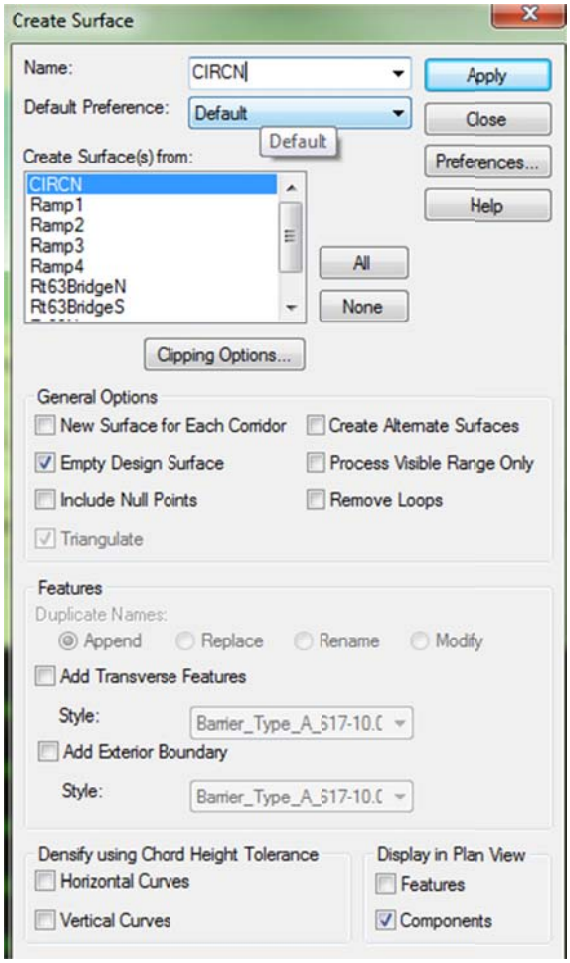


14. Use the station arrows to view the template drops



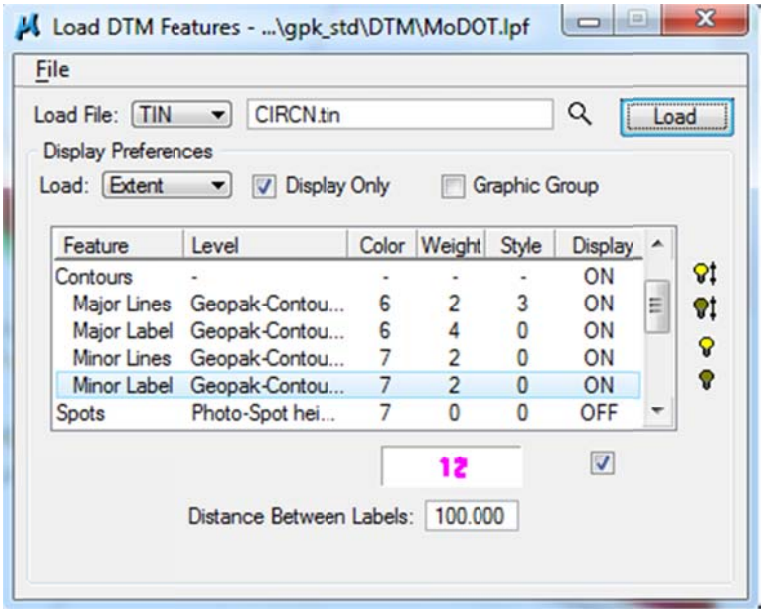
15. From the Roadway Designer Dialog select create Surface

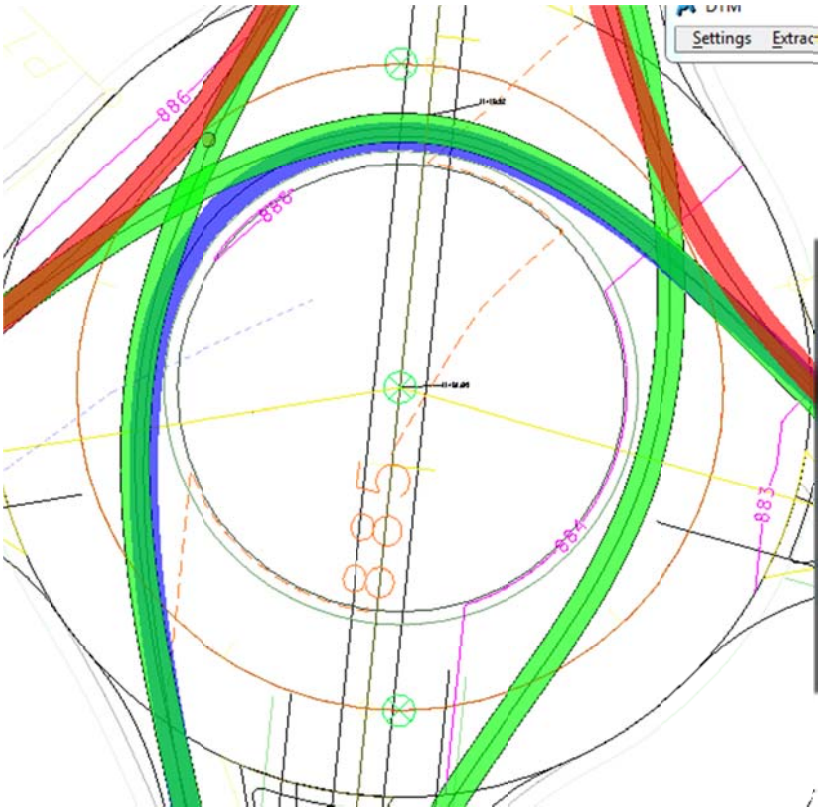
16. Set the display as shown > Click Process



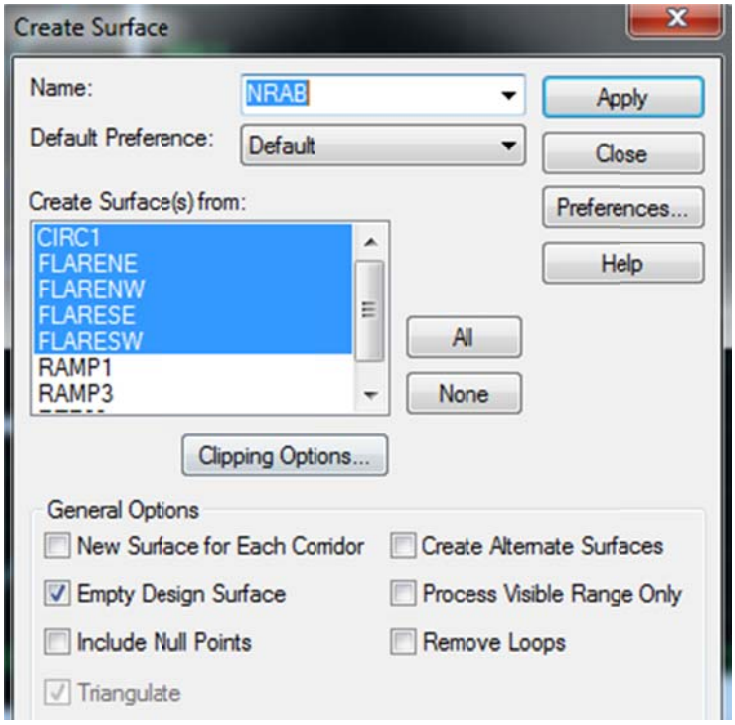
17. Close the reports > close the Create Surface Dialog

18. Review the results and close

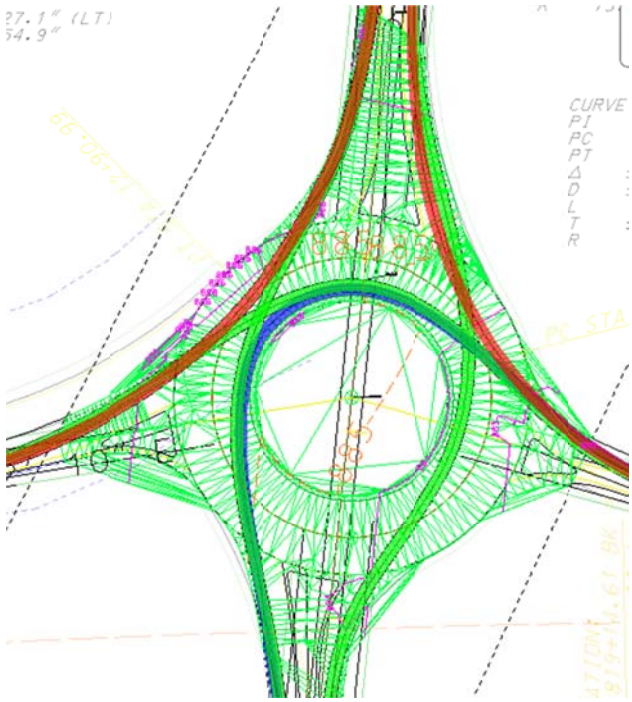


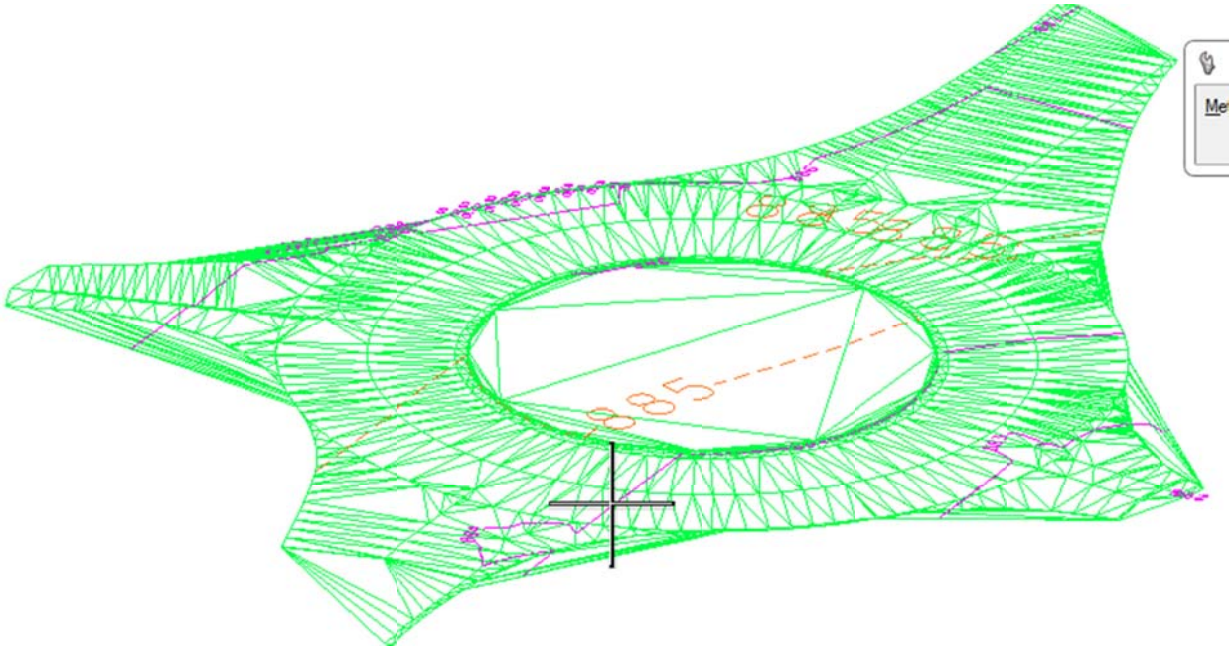


19. The Flares have been created for this class, however, view these to see how they were created. You may also create a Roundabout Surface using the CIRCN circular surface and the Flare corridors.



Utilizing all of these components will give you a surface for your Roundabout as created through the corridors.



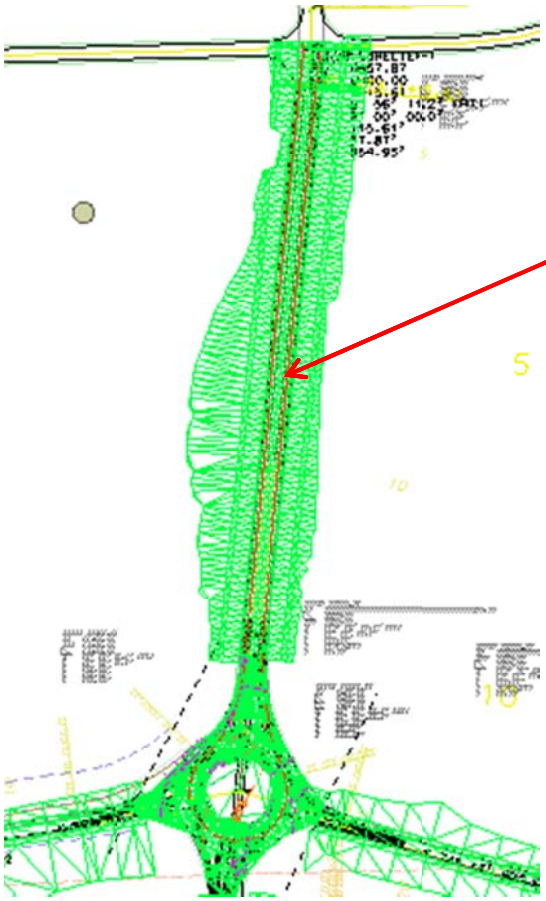


20. Save the Roadway Designer ird file – File > Save

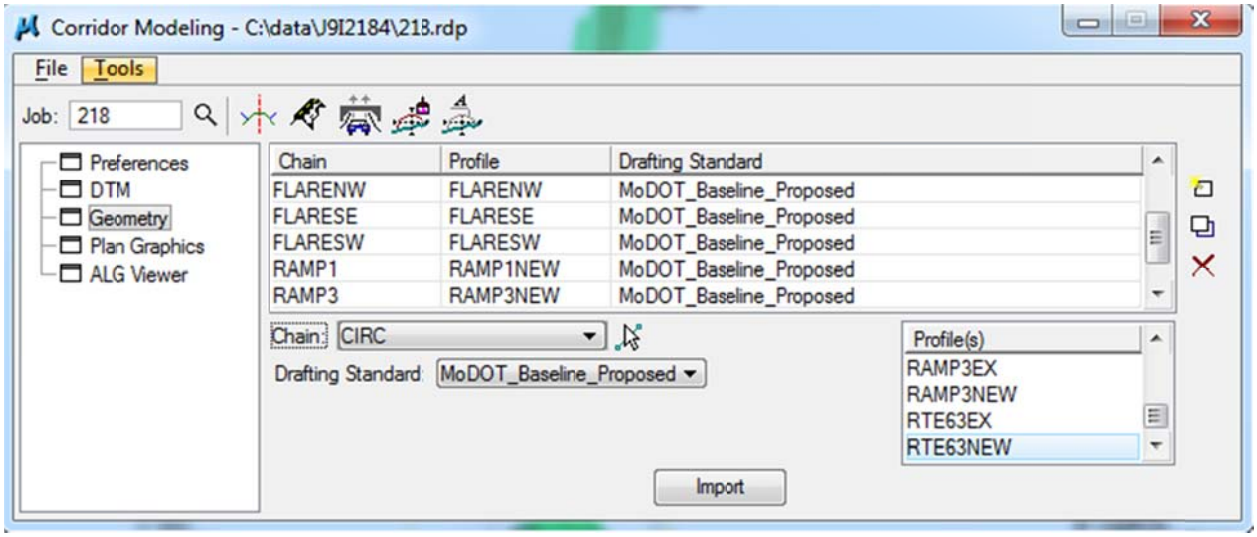
Chapter-6 3D Drive Thru

Displaying in 3D

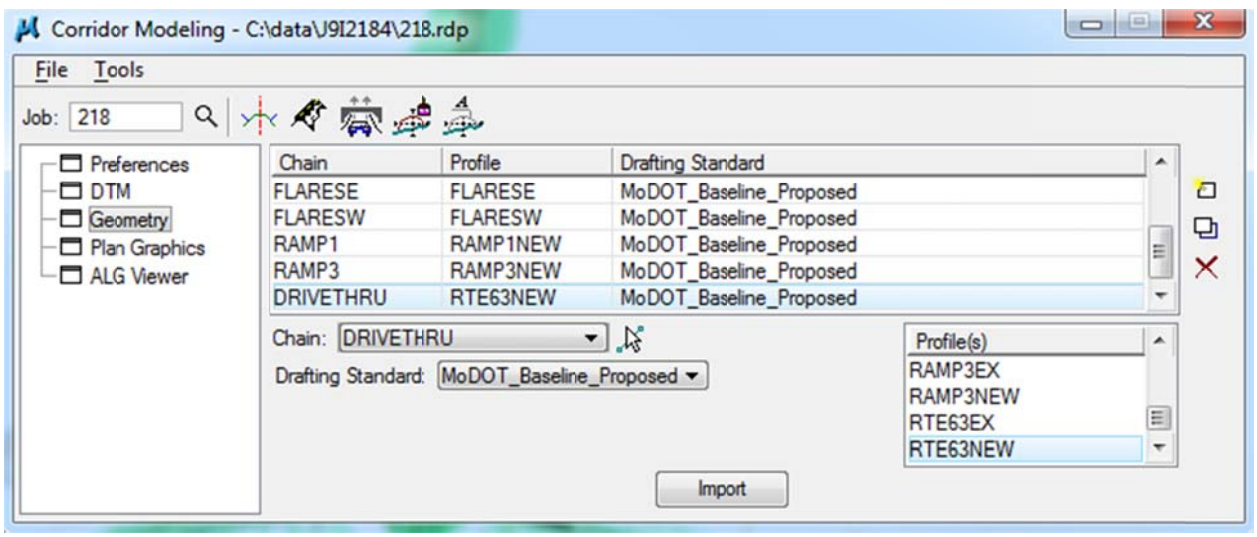
1. Open drawing RAB_Training_Chapter6.dgn this is a 3D drawing to accommodate a drive thru
2. Click on the SmartLine tool, and using snaps, place a complex chain on the mesh that exists representing the different surfaces.



3. Use the Store Graphics tool to Create an alignment named DRIVETHRU using your newly created complex chain.
4. Once the Chain has been created, open Corridor Modeling and Load 218.rdp Applications>GEOPAK>ROAD>3D Tools

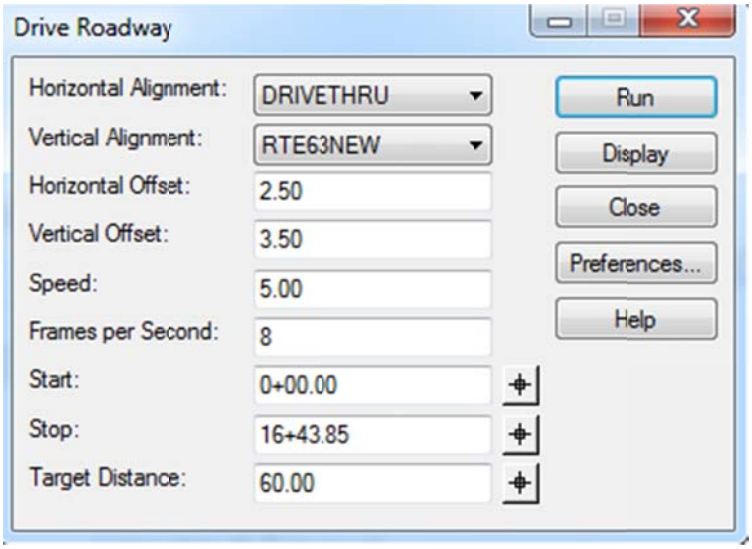


5. Import the new Chain DRIVETHRU into the corridor modeling tool



6. Click on the Drive Thru icon in the Corridor Modeling dialog box

7. Set the dialog box as desired. Yours may look a little different depending on where you drew your chain.

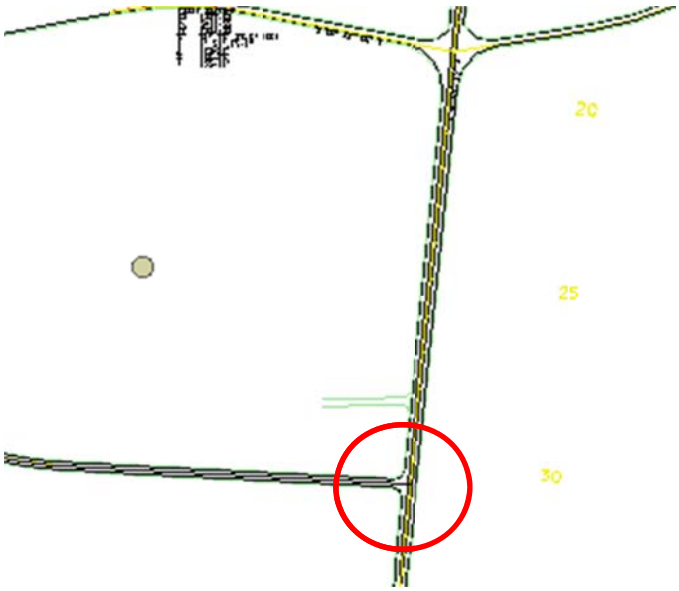


8. Click RUN and watch the drive thru. Did you notice the raised median around the center of the roundabout?
9. Close the dialog and look at other drive thru's as time permits.

Class Final Exercise

What have you learned?

1. Open The Drawing RAB_Training_Class_Exercise.dgn from *C:/data/J9I2184*
2. Zoom to the area where the Outer Road South hits Rte 63



3. Utilizing the templates, roadway designer files and knowledge acquired in this manual, construct a roundabout at this location.
4. Complete as much as you can in the time allotted. At minimum, try to create a roundabout eliminating errors and warnings.
5. If time allows, Create a model for the roundabout circular area.

- Store South Outer Road Chain
- Use 218.gpk
- Use 218.rdp
- Use BaseRAB_WS.itl
- Use RA1 template for Roundabout Circle Template
- Use 2 Lane Rural template for South Outer Road chain
- Use c:/data/standards/RAB_Library.dgn for roundabout library
- Use a 2% slope towards South Outer Roadway in your Site created surface
- Use Flare and Flare1 for templates for your flares
- Create a surface for your circular roundabout and flares
- Export drawing to 3D and attempt to run a drive thru of your roundabout

Appendices

233.3.1.1 Justification for Use

The process of selecting a roundabout as the preferred form of traffic control for a given intersection has three stages. If a roundabout is not "preferred" at any one of these stages, it will cease to be considered as a viable form of traffic control at the given location.

Stage 1: Appropriateness.

The initial stage involves a "broad brush" determination of whether the site is appropriate for a roundabout. Guidance about potentially appropriate and inappropriate sites for the use of roundabouts is available. The site-specific conditions are to be compared to those in the table to determine whether a roundabout merits further consideration.

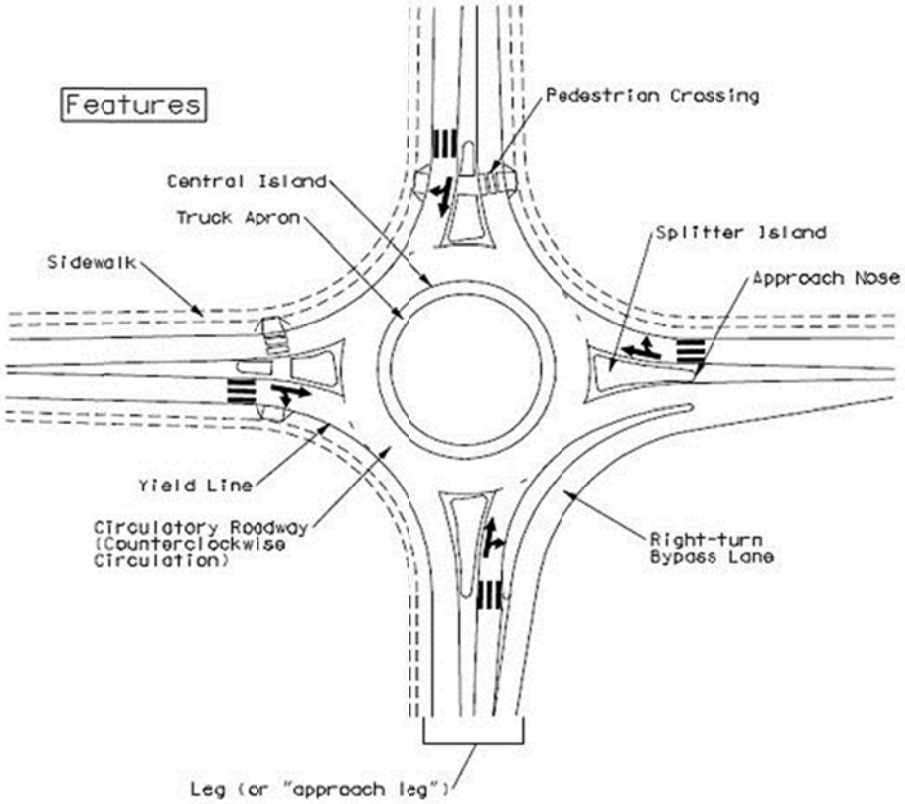
Stage 2: Operational Feasibility.

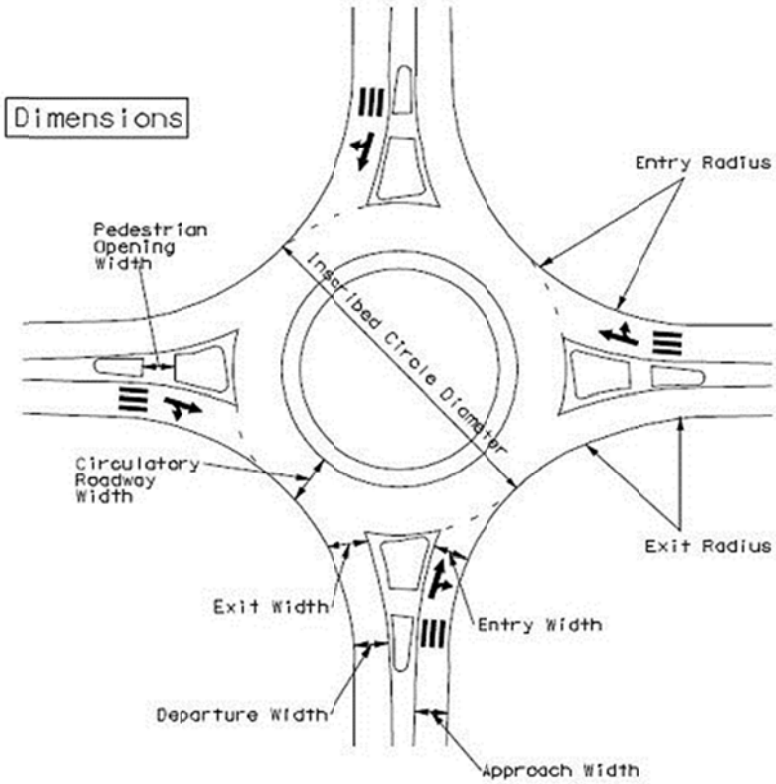
Once a roundabout is determined to be a potentially appropriate form of traffic control, the second stage involves testing to determine if a roundabout can function at an acceptable level of service. A capacity analysis is performed to determine volume-to-capacity (v/c) ratio and basic lane needs. This analysis is based on peak-hour volumes appropriate for local conditions. The analysis is conducted for both Construction Year and Design Year traffic volumes.

Stage 3: Comparative Performance.

Once it is determined a roundabout can function at an acceptable level of service, the final stage compares it's performance to the performance of other potential forms of traffic control (such as signalization) at the given location. The comparison may include, but should not necessarily be limited to: operational performance, construction cost, life-cycle cost, right of way considerations, "reserve capacity" (the ability to accommodate traffic growth), and constructability.

The justification procedure for each roundabout will be documented in a memorandum describing the results of the analysis described performed in the three stages. This memorandum will also summarize the reasons a roundabout was selected as the method of traffic control. The memorandum will be included in the projects conceptual report.


Features
Pedestrian Crossing
Central Island
Truck Apron
Sidewalk
Splitter Island
Approach Nose
Yield Line
Circulatory Roadway (Counterclockwise Circulation)
Right-turn Bypass Lane
Leg (or "approach leg")


Dimensions
Entry Radius
Pedestrian Opening Width
Inscribed Circle Diameter
Circulatory Roadway Width
Exit Radius
Exit Width
Entry Width
Departure Width
Approach Width

233.3.1.2 Operational/capacity analysis

The capacity model described in the Highway Capacity Manual (HCM) will be used as the primary check of a roundabout's capacity. The HCM model applies only to single-lane roundabouts. The model is fundamentally based on gap-acceptance theory. Capacity values are developed for each approach based on peak-hour circulating volumes. Roundabouts will be designed to operate at no more than 85% of capacity. This concept is known as "practical capacity."

Additional analysis is performed to refine the geometric design and provide more information for Stage 1 and 2 of the justification procedure. Operational analysis will use the SIDRA software package. If simulation is desired, the VISSIM software package will be used.

Terminology for Single Lane Roundabout

233.3.1.3 Design criteria

Three fundamental considerations in roundabout design are design speed, capacity, and design vehicle. These parameters result in a series of tradeoffs; while large-diameter roundabouts may provide higher capacity and better truck accommodation, they tend to reduce safety through higher operating speeds. Typical dimensions for a standard four-leg roundabout that satisfies fundamental design criteria are available.

A maximum operating speed of 25 mph should be used. A typical range of 18 to 22 mph is desirable. Speed control at roundabouts is primarily achieved through the deflection of entering vehicles. Operating speeds should be calculated on a move-by-move basis, by drawing the fastest path allowed by the roundabout geometry. The designer develops a speed matrix to illustrate that all speeds have been checked and that operating speeds do not exceed the maximum.

The design of all roundabouts will accommodate a WB-67 design vehicle. In order to keep operating speeds below the allowable maximum, a truck apron may be provided.

Emergency vehicles can generally be accommodated at roundabouts that have been designed for WB-67 design vehicles. Turning paths are checked using AutoTurn software for all allowed movements from each approach, to verify the design vehicle and emergency vehicles can be accommodated.

Transit stops are not to be placed within roundabouts. Transit stops located near roundabouts will include bus turnouts to promote traffic flow and increase safety.

233.3.1.4 Sight Distance

Two categories of sight distance are examined at roundabouts; stopping sight distance and intersection sight distance.

At a minimum, three types of stopping sight distance are checked; approach, circulatory and exit/pedestrian. Methods to measure these values are available. Sight distances are based on a driver eye height of 3.5 ft. and an object height of 2.0 ft.

Two types of intersection sight distance are measured; adjacent entry and circulatory. Methods used to measure these values are also available. Sight distances are based on a driver eye height of 3.5 ft. and an object height of 3.5 ft.

233.3.1.5 Central Island

The central island will be separated from the truck apron by a 6 in. barrier curb. The central island is typically circular in shape. In certain situations, non-circular shapes such as ovals or ellipses can be used. These shapes can be justified for use if irregular approach geometry or an odd number of approaching roadways are at the site. The design of the central island is governed by the operating speed and the design vehicle for the roundabout.

233.3.1.6 Truck Apron

A truck apron is a raised mountable portion of the central island that provides additional circulatory width for large vehicles. A truck apron is to be provided when the central island geometry, as designed to maintain low circulatory speeds, impedes circulation of the design vehicle.

The truck apron is separated from the circulatory roadway by a three-inch mountable curb. The width of the truck apron is the minimum necessary to accommodate the design vehicle. An overly wide apron can confuse drivers by creating a distorted sense of proportion. The width of a typical truck apron is 10 ft.

The truck apron will visually contrast with the circulating roadway. This will delineate the truck apron and discourage motorists from driving on it.

233.3.1.7 Circular Roadway

The width of the circulatory roadway will be the minimum necessary to accommodate the design vehicle. It is equal to the difference between the inscribed circle radius and the central island/truck apron radius. Parking or stopping in the circulatory roadway is prohibited. The outer edge of the circulatory roadway will be a barrier curb (except at openings for entry and exit legs).

233.3.1.8 Splitter Islands

Splitter islands serve two primary functions at a roundabout; physical separation of entering and exiting traffic (consequently reinforcing one-way circulation), and deflection of entering traffic (to control entering speeds). In addition, a splitter island can serve as a pedestrian refuge. Splitter islands will include a barrier curb.

The splitter island geometry is typically asymmetrical. Generally, the entry side provides deflection to slow speeds, while the exit side provides a larger opening to facilitate egress.

The minimum width of a splitter island without a pedestrian crossing is 4 ft.; with a pedestrian crossing, the minimum width (at the crossing) is 6 ft. The pedestrian opening will be 10 ft. wide.

233.3.1.9 Approach Roadway

On approach roadways with a wide median or a two-way left-turn lane (TWLTL), a narrowing of the existing median, to match the splitter island dimensions discussed above, will generally be needed in order to achieve the necessary entry deflection.

Approach roadway legs will include a barrier curb (on the right side) for at least half the length of the splitter island. A typical entry width is 16 ft. (measured curbface to curbface) to allow traffic to bypass a stalled vehicle. The turning path of the design vehicle controls the exit width. A typical exit width is 18 ft.

233.3.1.10 Bypass Lanes

Right-turn "bypass lanes", channelized so vehicles do not enter the roundabout, may be considered on approach roadway legs. Bypass lanes are to be avoided where moderate to high pedestrian or bicycle volumes are anticipated. Pedestrian crossings are discouraged across bypass lanes. Potential applications for which bypass lanes are to be considered (this list is not exhaustive) are:

To reduce the number of vehicles entering the roundabout

If right turns compose more than half of the entry volume, or

If the right-turn volume exceeds 300 vehicles during a single hour

To resolve geometric difficulties

An approach with two existing lanes intersecting a roundabout at which only one circulating lane is needed

An acute angle between adjacent legs

The use of a bypass lane must account for potential weaving and merging needs of traffic. The presence of closely spaced intersections, nearby driveways, and "entrapment" lanes can negatively affect bypass lane operations. These concerns must be thoroughly examined before a bypass lane is included as part of a roundabout.

233.3.1.11 Bicycles and Pedestrians

Bicycle facilities or markings are not provided within the circulating roadway or the central island. If bike lanes are provided on the intersecting roadways, they should be transitioned to off-street facilities sufficiently in advance of the roundabout to avoid introducing additional driver decision points in the roundabout. Bicyclists may choose to enter the roundabout as a vehicle (using the circulatory roadway) or, they may use multi-use facilities if they are provided. Potential bicycle-lane treatments, including bicycle ramps and bicycle platforms are available.

The design of a roundabout will not encourage pedestrian movement within the circulatory roadway or the central island. If crosswalks are determined to be necessary, they are typically located approximately one vehicle length behind the yield line (to allow a pedestrian to cross behind a stopped vehicle), unless it is determined a larger distance is needed to prevent exit queues from backing into the circulatory roadway. Even if sidewalks are not provided, curb cuts and splitter island openings will still be provided at the typical locations in anticipation of future crosswalks. In all cases, pedestrian-related design will conform to the requirements of the Americans with Disabilities Act (ADA).

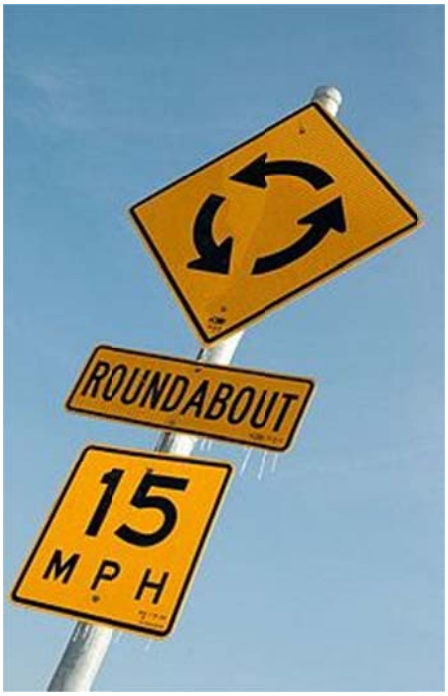
233.3.1.12 Other Issues

Dropping a lane approaching a roundabout is not typical within a distance less than 200 ft., as measured from the downstream end of the lane drop taper.

Ideally, the angles between all adjacent roundabout legs are equal (for example, 90° on a 4-leg roundabout). Maximizing the spacing between legs promotes smooth traffic flow. The designer should attempt to space the approaches so the distance between the extended centerlines of the entry lanes of any two adjacent approaches, measured along the centerline of the circulatory roadway, is at least 50 ft. If reasonable spacing cannot be achieved, careful design consideration is needed to optimize operational characteristics.

Ideally, roundabouts are constructed at level intersections. The maximum approach grade to roundabout is 3%.

It is desirable to provide a -2% cross slope (away from the central island) on the circulatory roadway. A -4% (away from the central island) cross slope on the truck apron is preferred.



233.3.1.13 Signing and Pavement Marking

Typical signing and pavement marking for a roundabout are available. There are three classes of signs that are used in a roundabout. They are:

Regulatory
Warning
Guide

Pavement markings are provided in three areas of the roundabout. They are:
Circulatory roadway
Approach legs
Pedestrian crossings
Specific signing and pavement marking details are also available.

233.3.1.14 Landscaping, Lighting and Drainage

Any landscaping of the roundabout will be located so it does not obstruct sight distance. However, it is generally a good idea to locate landscaping in the center of the central island to create a visible, vertical obstruction that can be seen well in advance. This has the added effect of blocking views between opposing approaches. Landscaping will not attract pedestrians to the center of the roundabout – in fact, low landscaping can be used on the outside of the roundabout (between the sidewalk and the curb) to provide a physical barrier to direct pedestrians toward the crosswalks. The splitter islands are not to be landscaped. Landscaping will not introduce any hazards to the intersection.

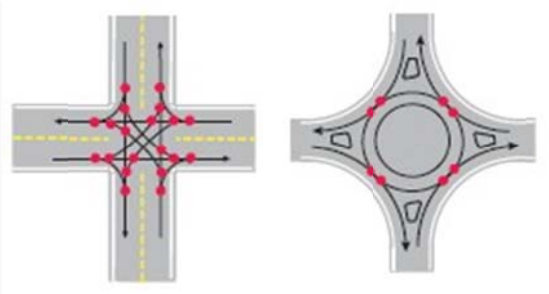


Fig. 233.3.14 Conflict points of signalized intersection (left) and roundabout (right)

Landscaping will be designed for minimal maintenance. If vegetation within the roundabout requires watering, a sprinkler system will be installed.

Lighting intensities at roundabouts will generally conform to MoDOT guidelines for intersection lighting. Key locations to be lit include the splitter island approach noses, all conflict areas where traffic enters the roundabout, and all places where vehicles exit the roundabout. The roundabout will be lit from the outside towards the center. If a 30 ft. luminaire height is used, 8 luminaries are recommended. If a 45 ft. height is used, 4 luminaries are recommended.

Drainage for the roundabout and approach legs will follow MoDOT design criteria. Additional consideration must be given to drainage of the central island.

233.3.1.15 Traffic Control During Construction

The designer must consider the implications of the roundabout's construction on local traffic flow. An initial constructability check, including staging and interim traffic control concepts, is necessary. In accordance with MoDOT policy, the designer will attempt to minimize detours during construction, while maximizing safety and minimizing motorist confusion. Nighttime and off-peak construction activities are encouraged. If the roundabout location is to be "bypassed" during construction, design speeds for the temporary bypass will be similar to those of the completed roundabout, so there is no perceived loss of level of service.

233.3.2 Multi-lane Roundabouts

A multi-lane roundabout is a roundabout with more than one lane on any portion of the circulatory roadway. Unless otherwise specified herein, the guidelines for single-lane roundabouts also apply to multi-lane roundabouts.

One of the most important considerations in multi-lane roundabout design is driver understanding. Every facet of the design must be oriented toward conveying the safe and proper method of driving the roundabout. At a typical two-lane roundabout, the driving rules are:

If you plan to exit less than halfway around, enter the roundabout using the outside lane

If you plan to exit more than halfway around, enter the roundabout using the inside lane

If you plan to exit halfway around, you can enter using either lane

Permitted maneuvers at a typical two-lane roundabout are available. In certain cases deviations from these rules may be necessary. In all cases, expectations must be clearly conveyed to drivers.

In planning roundabouts, it is advisable to consider the differences between short- and long-term needs. If a single-lane roundabout will suffice in the near-term, but a multi-lane roundabout will be needed in the future, the designer will consider constructing a single-lane roundabout with accommodations for a relatively simple conversion to a multi-lane configuration in the future. Examples of such accommodations might include wider splitter islands or a larger initial central island diameter. Particular attention must be paid to the amount of construction necessary to convert a one-lane roundabout to a two-lane configuration, and to the traffic control that would be necessary during such construction. The minimization of operating speeds will continue to be a key design objective.

In all cases, thorough conceptual planning must be completed before design begins. This includes detailed analysis, geometric feasibility assessments, and consideration of user characteristics.

233.3.2.1 Justification for Use

In general, the justification procedures used for single lane roundabouts are also used to justify multi-lane roundabouts. Only the volume-related justifications change: Multi-lane roundabouts may be considered appropriate for intersections with design-year entering peak-hour volumes typically not exceeding 3,700 vehicles (certain treatments, such as bypass lanes, could allow the accommodation of higher volumes.)

For multi-lane roundabouts, the justification process must also consider the nature of motorists in the area of the proposed roundabout (e.g. tourists, trucks, buses, senior drivers).

Multi-lane roundabouts present more complex design issues than those of single-lane roundabouts. They also present a more complex set of decisions to drivers. In recognition of these facts, roundabouts must be designed to minimize the number of circulating lanes to the extent that is operationally feasible. In other words, single-lane circulating roadways are preferred over multi-lane. The most significant point of confusion at a multi-lane roundabout is at the exit, where it may not be clear to motorists who may continue circulating and who may not. Single-lane exits reduce this confusion.

With the above concept in mind, it will often be desirable to consider roundabouts on which only a portion of the circulatory roadway carries multiple lanes. Such roundabouts can be subdivided into two categories:

Instances where an additional "turning" lane is added within the roundabout to facilitate a heavy movement, and

Instances when additional "through" capacity is carried through the roundabout on one street but not another (sometimes referred to as a "2-lane/1-lane" configuration).

Examples from both these categories of partial multi-lane roundabouts are available.

At freeway interchanges with one-way ramps (such as diamond interchanges), the teardrop configuration, which prevents circulating movement in front of one approach, may be used. Although one approach will not be required to yield to circulating traffic, that approach must still be designed to slow entering traffic to the required operating speed. The designer will verify that the elimination of U-turn movements on the teardrop leg will not result in access problems on nearby roadways.

Roundabout dimensions are a function of operating speed and the design vehicle. The roundabout must be large enough to accommodate the design vehicle, but not so large as to encourage excessive speeds. These two parameters are the guiding elements in choosing roundabout dimensions; however, the following dimensions can be used as a general guide. In urban settings, the inscribed circle diameter for a four-leg two-lane roundabout typically ranges from 150 to 180 ft. In rural settings, the inscribed diameter typically ranges from 180 to 200 ft.

Multi-lane roundabouts with more than four legs are extremely complex from a driver's point of view. They present unique challenges in signing and pavement marking. Wherever possible, the use of partial multi-lane configurations is encouraged with roundabouts having five or more legs.

Roundabouts with more than two circulating lanes are discouraged on Missouri state highways, and will be considered a design exception.

233.3.2.2 Capacity Considerations

Many of the operational and capacity considerations of single lane roundabouts also apply to multi-lane roundabouts. However, the Highway Capacity Manual (HCM) does not currently address multi-lane roundabouts, so the SIDRA and VISSIM software packages will be the primary analysis tools. The "practical capacity" used in designing each approach to a multi-lane roundabout will be 75% of the estimated approach capacity. The designer will ensure that the lane-usage assumptions of the analysis are consistent with the proposed operation of the roundabout.

233.3.2.3 Signals

Traffic signals will not be allowed within, or at any exit/entry point of, a roundabouts on MoDOT roadways.

A typical spacing distance between roundabouts and adjacent signalized intersections has not been determined. Instead, the designer must ensure, through operational analysis, adequate distance is available to accommodate 95th-percentile queue lengths between a roundabout and an

adjacent intersection. This includes queues approaching the roundabout as well as queues approaching the adjacent intersection.

233.3.2.4 Operating Speed

A preferred operating speed of 30 mph will be used for multi-lane roundabouts. A typical range of 23 to 27 mph is desirable.

233.3.2.5 Vehicle Path Overlap

Design vehicle requirements for single lane roundabouts also apply to multi-lane roundabouts, with one addition. The designer needs to consider the circulating paths of large vehicles entering the roundabout. At smaller two-lane roundabouts, operators of large vehicles may find it necessary to straddle both circulating lanes. At larger roundabouts, large vehicles may be able to maintain a constant lane. The choice between these two options will affect how turning templates are checked.

For roundabouts where trucks are likely to straddle the circulating lanes, a truck apron is typically not necessary. At roundabouts designed to accommodate two circulating trucks side-by-side, a truck apron may be necessary to keep the circulatory roadway width to a minimum.

It is necessary to avoid "vehicle path overlap" wherever possible during the design of multi-lane roundabouts. On entry, vehicle path overlap most commonly occurs when an entering motorist in the outside lane finds it natural to "drift" toward the inside lane when entering the roundabout. One potential method to discourage vehicle path overlap on entry is to design the entry flare so a tangent can be drawn between the entry lane line and the circulating lane line.

At two-lane roundabout exits, it is necessary to pay attention to lane width and exit radius in order to discourage vehicle path overlap. Vehicle path overlap can occur if the exit radius is so small motorists in the inside lane will tend to "drift" into the outside lane when exiting. A potential method to check for exit overlap is to draw (on a scaled plan) the smoothest continuous connection between the centerline of the circulatory roadway and the centerline of the exiting lanes. If the radius of this connection is less than the radius of the centerline of the circulatory roadway (implying a lower design speed), vehicle path overlap may result. The exit radius and width may need to be adjusted. As with entry path overlap, the exit geometry design is a tradeoff between keeping speeds low enough to maximize pedestrian safety and keeping radii large enough to avoid vehicle path overlap. In cases where path overlap and design speed conflict, minimization of design speeds receives a higher priority.

Although eliminating vehicle path overlap is an important goal, the designer must simultaneously take care to avoid promoting excessive entry speeds. In cases where path overlap and design speed conflict, minimization of design speeds receives a higher priority.

At larger roundabouts, the solutions described above may result in either an excessively sharp entry flare or an excessively wide splitter island. Therefore, it may be difficult to avoid vehicle path overlap.

233.3.2.6 Bypass Lanes

Bypass lanes are a potential method for addressing heavy right-turn movements. A less preferred (due to lower capacity) but acceptable method is to include a dedicated right-turn lane that is not physically separated from the roundabout. If this method is used, the circulatory roadway in that

quadrant of the roundabout will be widened to allow the right-turning vehicles to enter the roundabout simultaneously with adjacent through vehicles on the same approach. This configuration is potentially more confusing than a typical bypass lane configuration, and is only used where necessitated by right-of-way or other physical constraints. Adequate signing and marking must accompany this configuration.

To minimize motorist confusion, single-lane exits are to be considered wherever operationally feasible.

Typically, it is not desirable to require motorists to merge immediately after exiting a two-lane roundabout (via a lane drop). However, in some cases, having two departure lanes may be desirable for roundabout processing capacity, while the basic underlying roadway may only carry one lane per direction. If a lane drop (reduction) is necessary, it will occur a minimum of 200 ft. from the roundabout exit, with a standard merge taper.

233.3.2.7 Signing and Pavement Marking

All the provisions of single lane roundabouts also apply to multi-lane roundabouts, but additional signing is necessary to convey lane usage. The preferred signing method, which uses overhead signage to delineate lane use, is available (also refer to Highway Signing). However, each site must be evaluated on its own merits to determine signage needs. In general, signing for a proposed roundabout will be thoroughly considered at the concept stage, because the effectiveness of a roundabout, even one with excellent geometric design, can be compromised if drivers do not understand how to drive it.

All the provisions used for single lane roundabouts also apply to multi-lane roundabouts, but additional markings are needed to help delineate the circulatory lanes. Typical pavement markings for a multi-lane roundabout are shown in Pavement Marking. Standard Plan 620.00 illustrates standard pavement arrows and placement.

The function of circulatory lane striping is to reinforce permitted movements circulating and exiting the roundabout. In cases of odd geometry or more than four legs, customized modifications to the typical striping pattern may be necessary.

Pavement arrows within the circulatory roadway are not typically used.

Where multiple lanes enter a roundabout, a solid white line will separate the lanes on the approaches. If this line is a continuation of an existing intermittent lane-striping pattern, the conversion to the solid line will occur a minimum of 100 ft. in advance of the yield line.

Similarly, multiple lanes exiting a roundabout will be separated by a solid white line, which will remain solid for a minimum of 100 ft. beyond the roundabout exit.

At conventional multi-lane roundabouts with three or four legs, lane-use arrow markings (supplemented by appropriate signage) may be used on the approaches. If arrows are used, one set of arrows should be located near the yield line, and another set will be located in advance.

All of the pedestrian considerations described for single lane roundabouts also apply to multi-lane roundabouts. However, due to wider approaches and exits, multi-lane roundabouts result in more pedestrian exposure than do single-lane roundabouts. Special care is necessary to maximize pedestrian safety at multi-lane roundabouts. This could include special treatments such as decorative crosswalks, raised crosswalks (which have the added effect of reducing vehicle speeds), or alternative crosswalk locations (further away from the roundabout) that maximize pedestrian visibility and comfort.

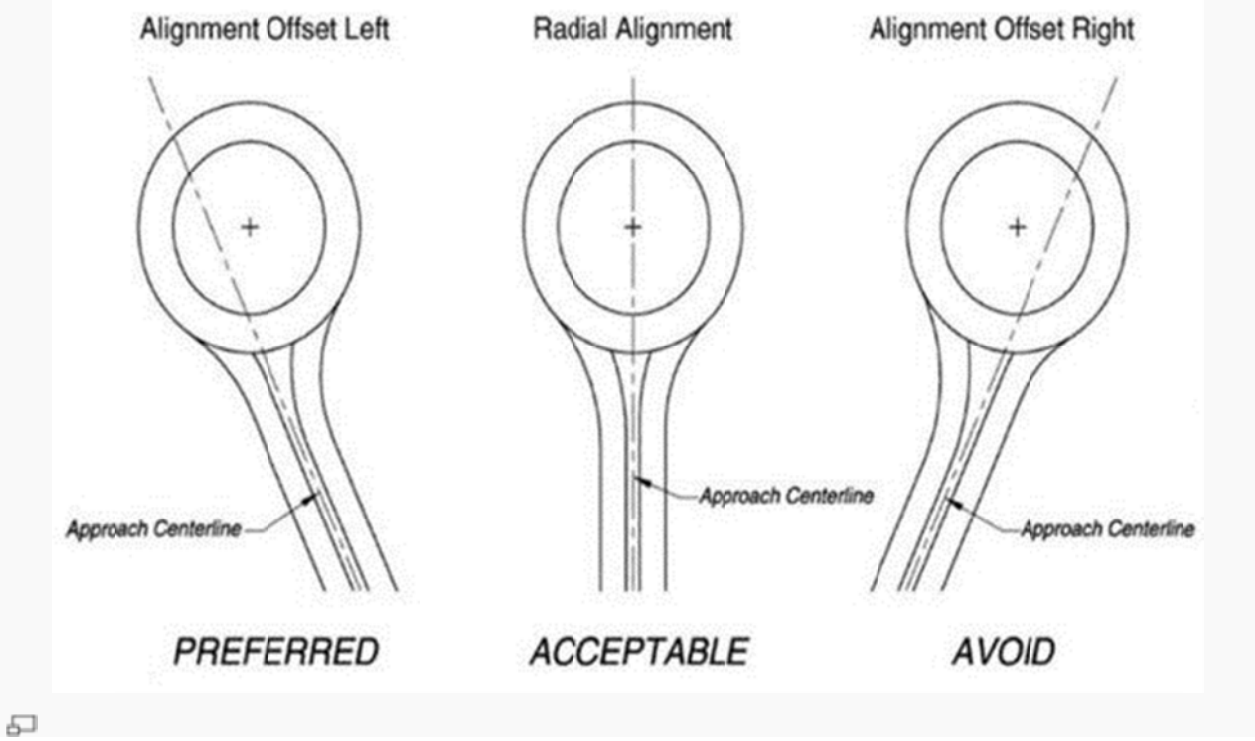
233.3.2.8 Other Issues

In general, while the provisions for single lane roundabouts also apply to multi-lane roundabouts, it may be necessary in certain instances to crown the circulating roadway. One advantage of this approach is it can promote consistency in speeds by superelevating the tighter-radius inner lane and negatively superelevating the higher-radius outer lane. The drainage design becomes more complex since inlets and/or slotted drains will be needed on both the inside and outside edges of the circulatory roadway.

The key lighting locations provided for single lane roundabouts also apply to multi-lane roundabouts: the splitter island approach noses, all conflict areas where traffic enters the roundabout, and all places where vehicles exit the roundabout. At larger roundabouts, the general lighting layout guidelines of may be inadequate; therefore, the designer must check lighting levels to verify adequacy.

Because of the complexity presented to drivers by multi-lane roundabouts, some form of public education program must be considered with each installation especially when multi-lane roundabouts are new to a given area. Safety is increased when motorists are aware of the proper method of driving a multi-lane roundabout.

233.3.3 Deflection



Note Avoid the offset right alignment

Adequate deflection, a horizontal curve in the road that slows approaching traffic, is critical to a proper roundabout design. One of the easiest ways to achieve deflection is to incorporate a left

offset in the design by aiming the approaching road's centerline to the left of the central island's center.

The maximum operating speed should be 25 mph. Bear in mind that drivers often go faster than the models predict. Also, be aware that trucks can experience resonance in a reverse curve. Depending on speed, vehicular shape and distribution of load, it is possible for trucks to roll over at speeds as low as 20 mph.

Whether or not a left offset is selected, the designer should be careful to place the pedestrian crosswalk, if one is present, after the deflection – not in the deflection - so that the traffic is proceeding as slowly as possible when it encounters the crosswalk.

Constructing the roundabout's apron