Beyond Centerline Geometry

This course is for the **2021 Release 1** *version of:*

OpenSite Designer CONNECT Edition

OpenRoads Designer CONNECT Edition

OpenRail Designer CONNECT Edition

About this Practice Workbook...

- This workbook is designed for use in Live instructor-led training and for OnDemand self study. OnDemand videos for this course are available on the *LEARNserver* and through *CONNECT Advisor*.

- This PDF file includes bookmarks providing an overview of the document. Click on a bookmark to quickly jump to any section in the file.

- Both Imperial and Metric files are included in the dataset. Throughout this practice workbook Imperial values are specified first and the metric values second with the metric values enclosed in square brackets.
  For example: *12.0' [3.4m]*.

- This course workbook uses the *Training and Examples* WorkSpace and the *Training-Imperial* or *Training-Metric* WorkSet delivered with the software.

- The terms "Left-click", "Click", "Select" and "Data" are used interchangeably to represent pressing the left mouse button. The terms "Right-click" and "Reset" are also used interchangeably to represent pressing the right mouse button. If your mouse buttons are assigned differently, such as for left-handed use, you will need to adjust accordingly.

Have a Question? Need Help?

If you have questions while taking this course, search in *CONNECT Advisor* for related courses and topics. You can also submit questions to the Civil Design Forum on Bentley Communities where peers and Bentley subject matter experts are available to help.

Edition: **05-01**   Course Level: **Fundamental**

Course Overview

In this course you will learn how to create edge of pavement geometry and learn about rules and relationships that existing between civil geometry elements.
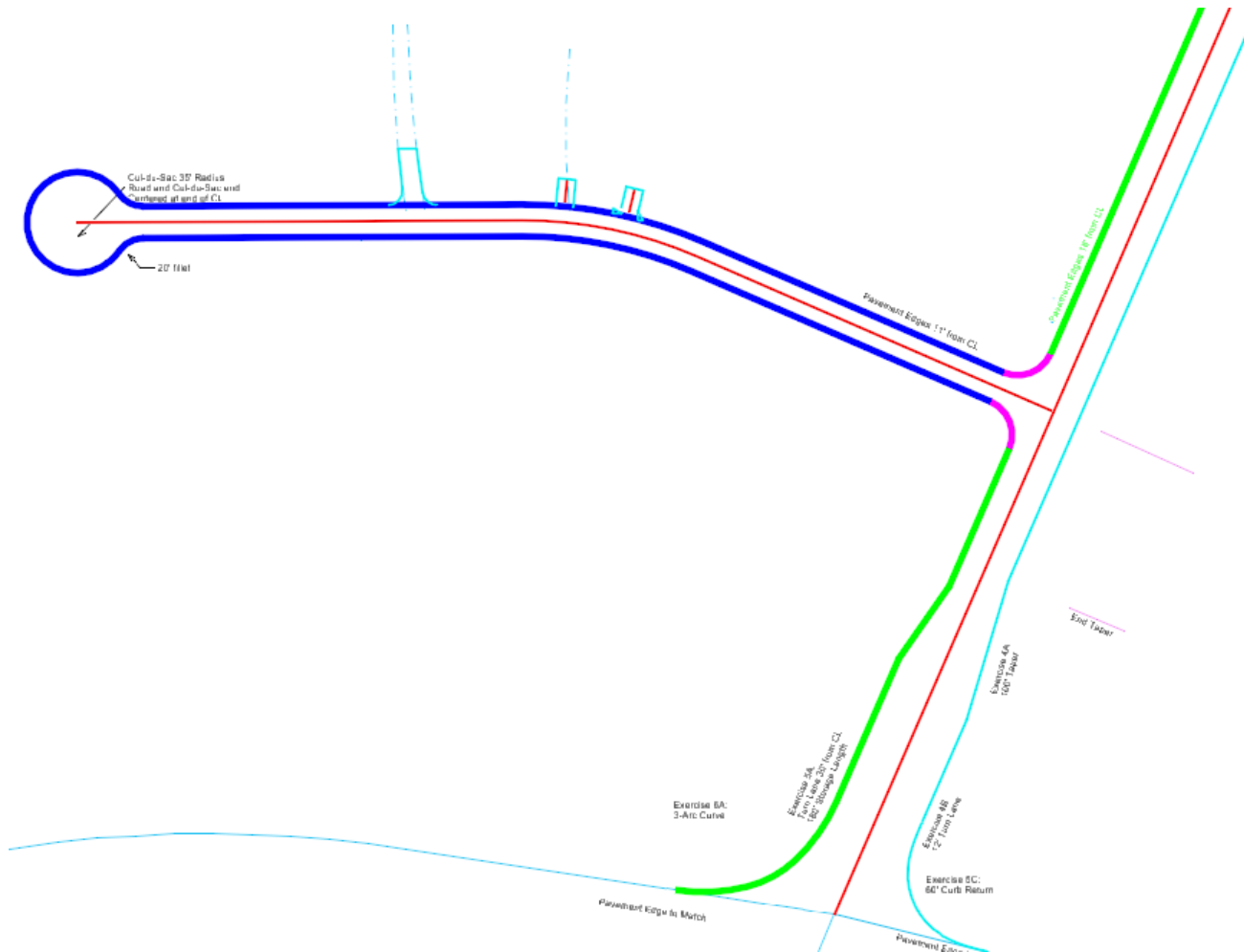
Why is this Class Important? Pavement Edge Geometry is Fundamentally Important.

Everyone understands the importance of baselines to highway or corridor geometry. It's right in the name: it's the base for all the other geometry. Regardless of whether the baseline is the centerline or a different element, most of the horizontal and 3D corridor geometry is directly defined from the baseline.

Everyone understands that roadways are never uniform along their full length. Lanes are added or dropped, shoulders narrowed or widened, medians added or changed.
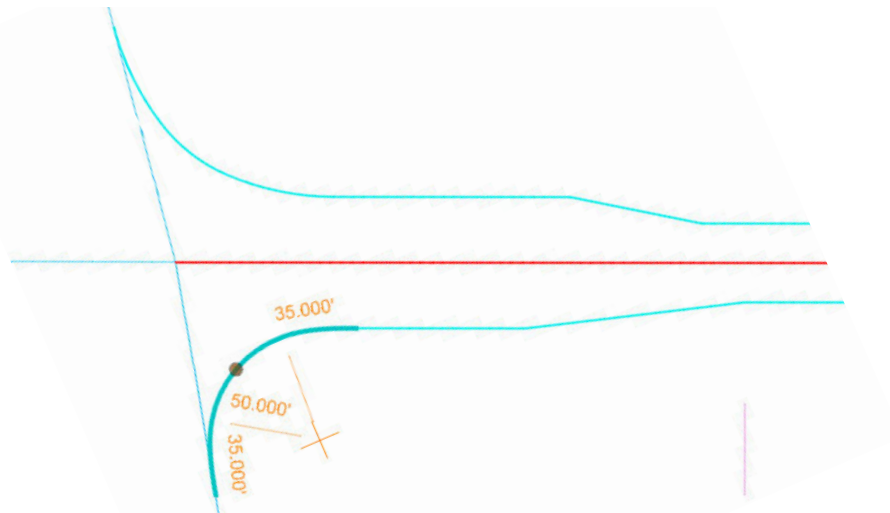
Pavement Edge Geometry is Related to the Baseline

Pavement Edge Geometry can sometimes be independent from the baseline, but is generally dependent on and defined from the corridor baseline. There is an engineering relationship between the baseline and the pavement edges, even when the edges vary.

Consider an edge of pavement in an urban setting. The edge may start two lanes away from the centerline then widen to three lanes wide for a turn lane. After the side road the three lane edge may taper back to two lanes wide. Implicit is two or three lanes *from the baseline*.

Pavement Edges are Critical for Sheets and Modeling

In addition to the general requirement of showing pavement edges on plan sheets, varying pavement edges such as those shown in the image below are generally used as geometric controls for corridors and template points. Rather than having to switch and transition between, say, two-lane and three-lane templates, the baseline and pavement edge features are used to control the width of the road using a single template.

Civil Geometry and Design Intent

In the primitive days of CAD, the software immediately forgot that there was a relationship between the baseline and the pavement edge. A change to the baseline provided no update to the edge. The edge would have to be updated or redrawn manually. Given this inherent re-work, there was a tendency to postpone creation of the edges and other dependent geometry.

The civil geometry tools are a rule based set of geometry tools to create rules and relationships between geometric elements as they are created and edited. Because the civil geometry tools remember and honor the relationships between geometric elements, changes to the baseline automatically update all dependent geometry. We call this honoring the *Design Intent*. There is no waste and, therefore, no reason to defer creation of independent geometry.

Because the civil geometry tools remember and honor relationships, re-work is minimized when the project undergoes its inevitable re-engineering. In the example shown below, when the centerline geometry is moved or changed the edge of pavement geometry and driveway geometry also moves and updates based on the rules and relationships.
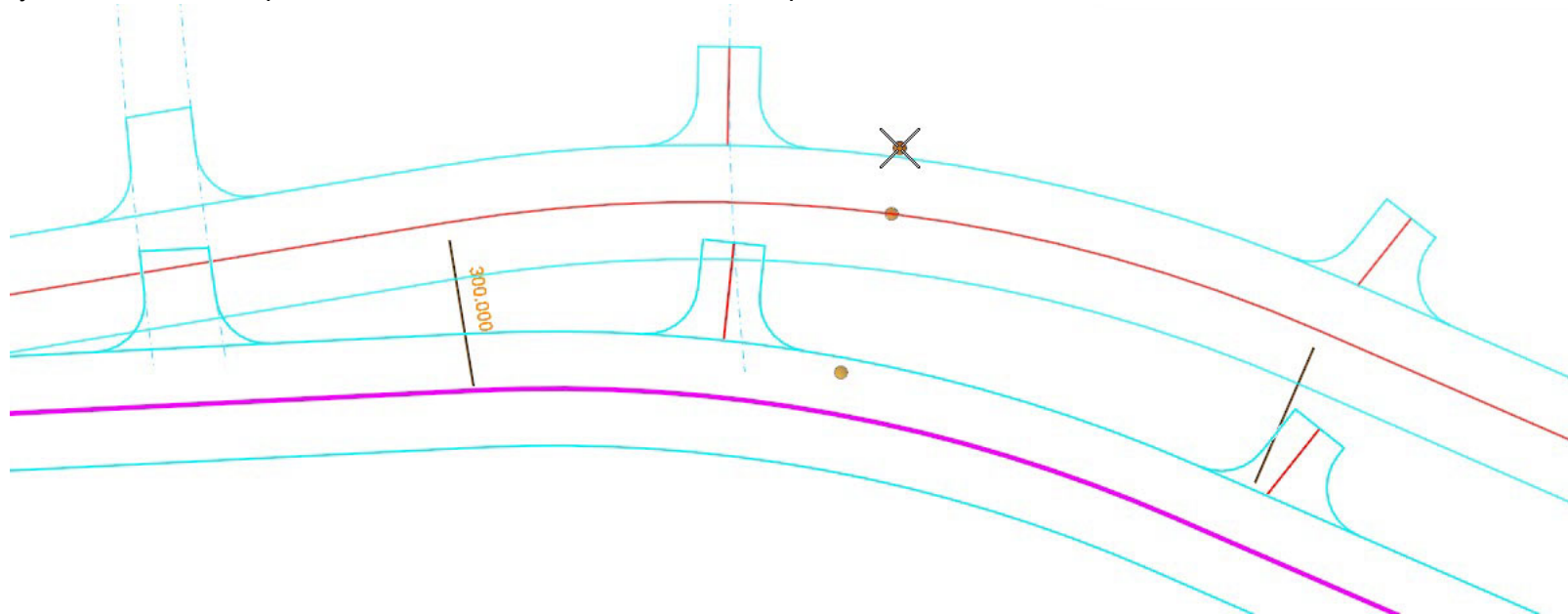
Exercise 1: Civil Geometry Features vs. Plain Graphics

Description

In this exercise we will learn about Civil Geometry Features and how they differ from just plain graphic CAD elements.

Skills Taught

- Reviewing Civil Geometry Features and Plain CAD Graphics

- Rules and Relationships with Civil Geometry Features

- How the software understands geometry

Open the Design File

1. Start the software.

2. Set the Workspace and Workset

   The workspace and workset define standards that are used by the software. The Workspace and Workset used for this training are installed during the software installation.

   a. TySelect **Training and Examples** from the *WorkSpace* drop-down menu.

   b. Select **Training-Imperial** *[Training-Metric]* from the *WorkSet* drop-down menu.

   Open the first file.

   a. Select **Browse**.

   b. Browse to the folder where you unzipped the dataset files and select the file **GraphicsVsFeatures.dgn** *[Metric - GraphicsVsFeatures.dgn].*

   Note: If you get a message stating "Incompatible Civil Data", this is because the training files are "aligned" to OpenSite Designer. Clicking *Yes* will align the file to the software you are using (OpenRoads Designer or OpenRail Designer). This will have zero impact for training. Note that in production, upgrading the file will make the file read-only in OpenSite Designer. Full information is available at *Bentley Communities - Product Realignment*.

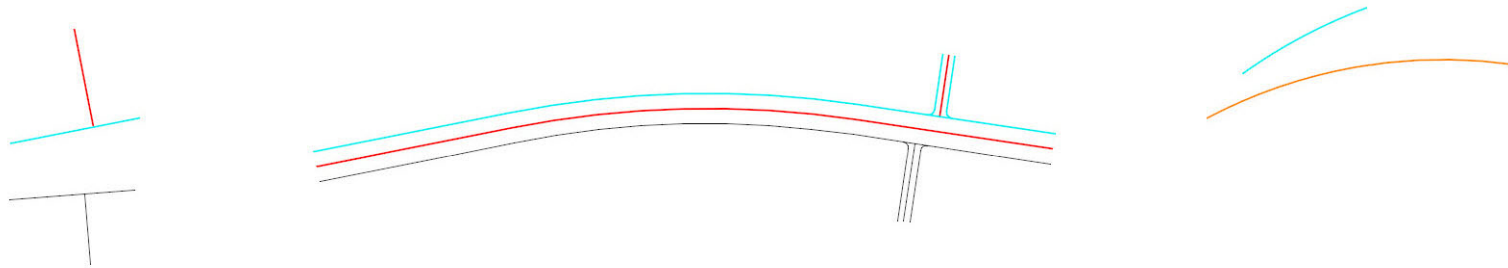DO NOT DISTRIBUTE - Printing for student use is permitted
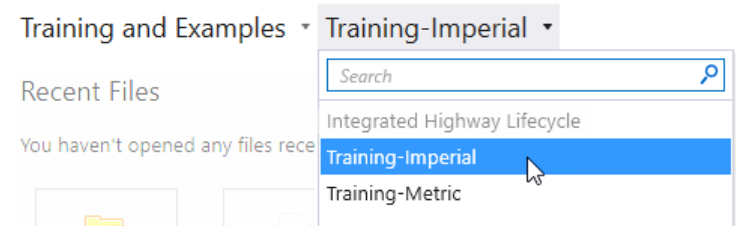
Explore Simple "Tee" Intersection

In this exercise we will demonstrate the fundamental advantage of civil geometry features: intelligent rules and relationships.

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1. Zoom to the *"tee" intersections* on the left portion of the drawing.

North Side (Colored elements) = Civil Geometry Features

CL and South Side (white elements) = CAD-only

The four lines - two tees - at the left of the view illustrate the fundamental advantage of civil geometry features: intelligent rules and relationships.

Both Tees' "side roads" are drawn Perpendicular using the Perpendicular Snap. The difference is the civil geometry side road centerline (red element) "remembers" that it was drawn perpendicular to the "main" line.

2. Using the **Element Selection** tool, adjust the endpoints of the white graphics in the lower intersection. While the lines can be moved independently, they do not remember that they originally had a perpendicular snap relationship. This is how plain graphics behave.

3. Using the **Element Selection** tool, click on the upper *side road* (red element) of the upper intersection. Note the Perpendicular glyph displayed near where the lines intersect.

4. Move any of the endpoints of the blue or red lines civil geometry elements. Note that the lines remain perpendicular. Civil geometry is designed to honor the engineering relationship between elements.
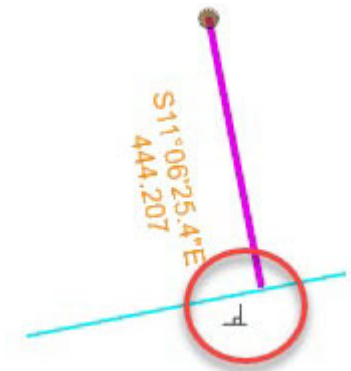
5. Zoom to the *road* in the drawing.

   The mainline pavement edges are offset from a centerline. In this case the centerline and northern edge of pavement are civil geometry features and the southern edge of pavement (while) is a plain graphic element.
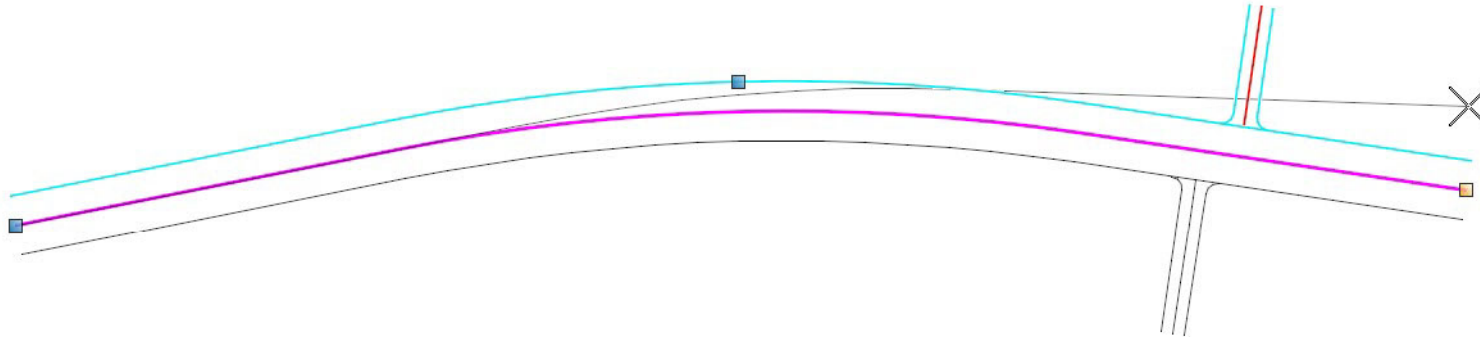
6. Using the **Element Selection** tool, select the curve of the *centerline* (red element).

7. Move the right endpoint of the centerline. What happens?

   The Civil Geometry Features behave in an exemplary Civil Engineering manner by remembering their relationship or design intent. The edge of pavement remains parallel to the centerline and the side road intersection updates to intersect the new edge of pavement. The plain graphics do nothing.
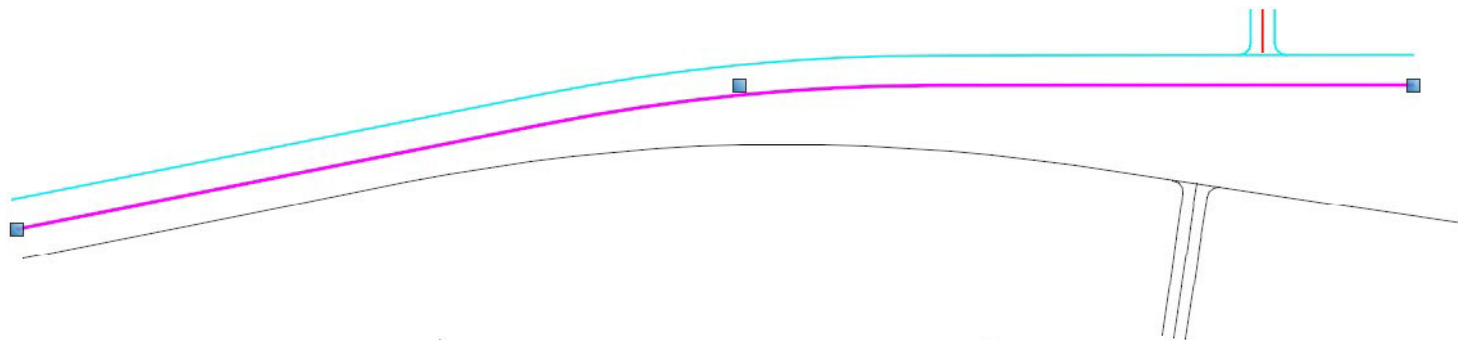
8. Select the centerline of the **south** *side road* and move the south end point to the left.

What Happens?

Other than the point (handle) you moved, nothing happens. No relationships are remembered: they cannot be maintained.

9. Select the centerline of the **north** *side road* and move the end of the north end point to the left.

What Happens?

The Civil Geometry Features all maintain the relationships they were built with (civil geometry remembers the original design intent). The side road centerline slides along and remains perpendicular to the centerline, the edges of the side road remain parallel to their centerline and the arcs remain tangent to their roads.
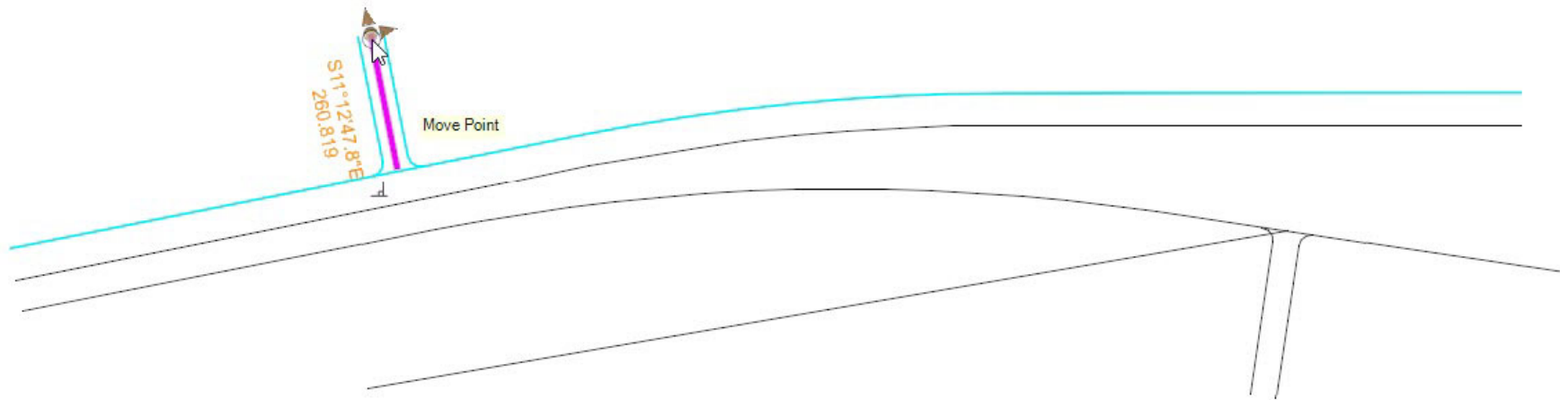
10. Change the Offset to the north Edge of Pavement.

The value of relationships can be changed using the heads up display. For example, text manipulators are used to change values such as Offset distances.

a. Select the **north** *edge of pavement*.

b. Click on the *Offset Text Manipulator* at the midpoint of the element and key in a different offset value.

The Offset may be positive or negative. This is consistent with the engineering standard of negative offsets being to the left of the baseline and positive to the right. This does imply that the reference has a direction. All features do, in fact, have a direction, based on how it was drawn (in most cases). The heads up prompt will provide live readings of station or offset as appropriate.

TIP: There are three offset text manipulators shown along the element. Changing the text manipulator at the midpoint keeps the element parallel. Changing one of the text manipulators near the end of the element results in a taper.

This is the fundamental principle of the civil geometry tools, relationships remain intact and updates are automatic. There are three ways to impart rules/relationships or design intent; Civil Geometry Tools, Snaps, and Civil AccuDraw. In this exercise we experienced the first two. The Civil Geometry Offset tool created a relationship between the centerline and the edge of pavement. A snap created a relationship to keep the side road perpendicular to the edge of pavement.

Note: Two tools were used to create the pavement edges: *Single Offset Entire Element* and *Simple Arc Between Elements*. We will explore these later in this course.

Dissecting a Relationship

Much of what we'll be doing later in this class is placing Offsets and Tapers. Before we do, we'll take a look at one in depth.

1. Zoom to the two features on the right side of the drawing (to the right of the "road").

2. Using the **Element Selection** tool, click on the *Offset Taper* (blue line).

   As with any Civil Geometry Feature, clicking on the taper shows the rules defining it and the manipulators to edit it.

   Note the flexibility in editing from the heads up display.

3. Change the **Offsets** and the **Start** and **End Stations**. Observe how the corresponding values change.

   Tapers are surprisingly complex, largely due to their differing Design Intent: are the Offset values the primary relationship or is the Taper Ratio the primary relationship?

   The heads up display does not indicate which rule was used to create the taper. However, the Properties dialog exposes additional information about the taper as well as editing capabilities that transcend beyond the heads up display.

4. With the Taper selected, click *Home > Primary >* **Properties** to open the *Properties* dialog.
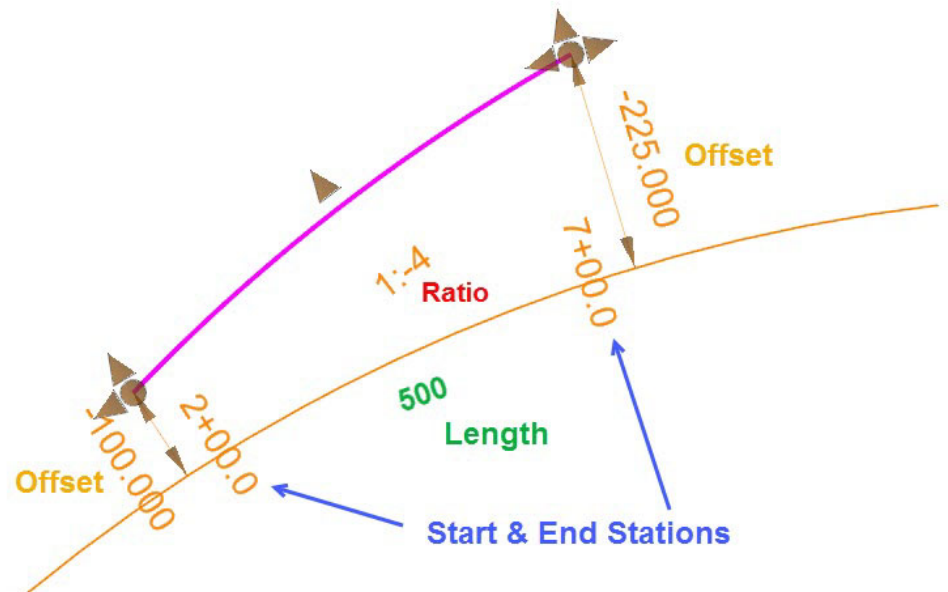
The *Properties* dialog provides another way to edit the feature's geometry. Note that the *Transition Offset Rule* group shown to the right has fields for all the heads up display manipulators (and more).

Among the properties not shown explicitly in the heads up display is *Method*.

5. Expand the **Transition Offset Rule** category.

6. Click on **Method** to see its options:
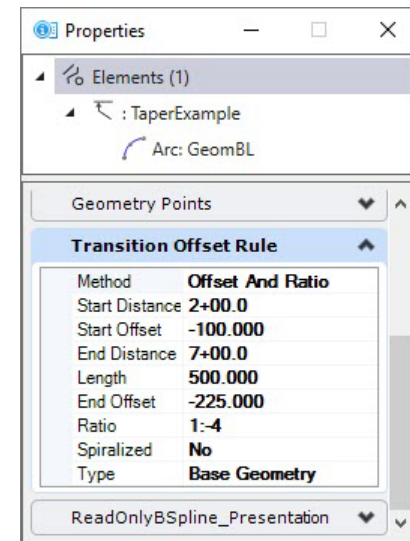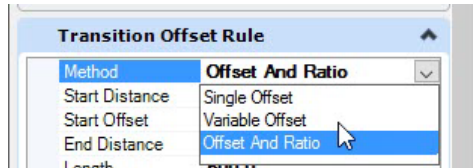
These different represent different relationships/"Design Intent". Is the engineering constrained by the Offset Values, or is the Taper Ratio the overriding requirement?

This indicates the taper's Design Intent is Ratio-dominant.

7. Click on the *Ratio* Text Manipulator and change the value to **1:-5**. Observe what happens.

Like many of the geometry tools, the Offsets and Tapers tools consists of a palette of tools with "overlapping" functionality. Generally one of the tools has all the settings visible and all the prompts enabled. The other tools are streamlined for intent and speed, with some settings preset and some hidden.

- *Single Offset Entire Element* is the simplest. It presets the End Offset equal to the Start Offset, the Start Station locked to the start of the source feature, and the End Station locked to the end of the source feature.

- *Single Offset Partial* unlocks the Start and End Stations, allowing the user to define Starts and Ends different from the source geometry, using keyins (Stations and Lengths) and Snaps. Snaps are valuable because they create relationships to other objects.

- *Variable Offset Taper* and *Ratio Offset Taper* unlocks the Offsets as well. They can provide the same geometry, but reflect a difference in constraint priority: are the Offset Values primary, or is the Taper's Ratio the priority. This will affect the manner in which the geometry is updated when the engineering changes.
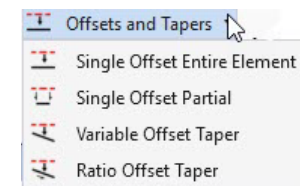
Exercise 2: Create Pavement Edges from Centerlines

Description

In this exercise we will demonstrate the fundamental advantage of Civil Geometry Features: Civil Geometry remembers your design intent.

Skills Taught

- How the software understands geometry

- Feature Definition Toolbar

- Offsets and Tapers

Ensuring Standards

In this exercise, we will be using multiple tools to create Edges of Pavement geometric elements. Using the Feature Definition Toolbar allows a "Set it and Forget It" adherence to standards. We will set the Active Feature Definition to *Road_EdgeOfPavement* and all new features created will be assigned that Feature Definition until we say otherwise.
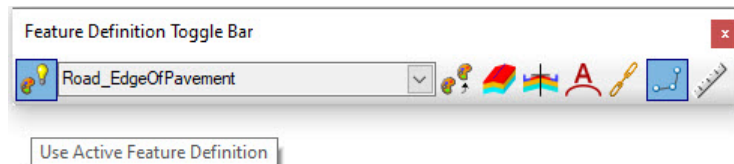
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1. Open **Beyond_CL.dgn** *[Metric - Beyond_CL.dgn]*

   We are going to create pavement edges along the red centerlines.

2. Click *Geometry > General Tools > Standards >* **Feature Definition Toolbar.**

3. In the *Feature Definition* pull-down, select **Linear > Pavement > Road_EdgeOfPavement**.

4. **Enable** the *Use Active Feature Definition* toggle.

5. **Enable** the *Persist Snaps* toggle.

   - When enabled, the Persist Snap rule will be remembered and will be maintained when elements are modified. When disabled, you can snap to place some geometry but the Persist Snap rule will not be remembered. There may be times when this is desirable, but leaving it set, is a good default practice.
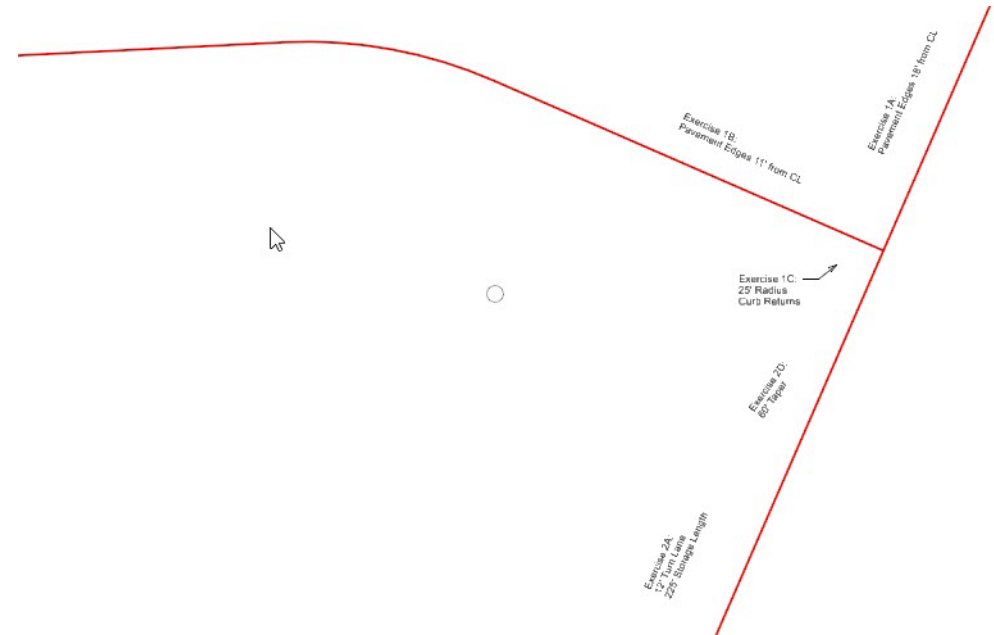
Create Offsets

We will now use the simplest of the Offset tools - Single Offset Entire Feature - to create Pavement Edges **11'** *[3.5m]* from the East-West road and **18'** *[6m]* from the North-South road.

1. Click *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Entire Element.**

   a. Review the Tools Settings dialog. The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

   Consider the Name. Clear explicit Names can be used to provide information to designers and reviewers that may not be apparent from the graphic context. Clear Names are also useful when reviewing the data in tabular mode via the OpenRoads Model Explorer or in Reports.

   Major Features should have clear explicit names. For example, the full Northbound Outside Edge of Pavement of Alden Parkway should have a clear name like AldenPrkwy_NBEoP.

   A complex feature like that is generally made up of a collection of individual elements. The Complex By Element tool is the primary way to group the individual elements into a coherent whole. It provides an opportunity to Name the new complex feature.

   Saving a few seconds by accepting default Names at this point is generally okay, especially if the elements will be made part of a well-named Complex Feature later.

   Names can always be changed via the Properties dialog.
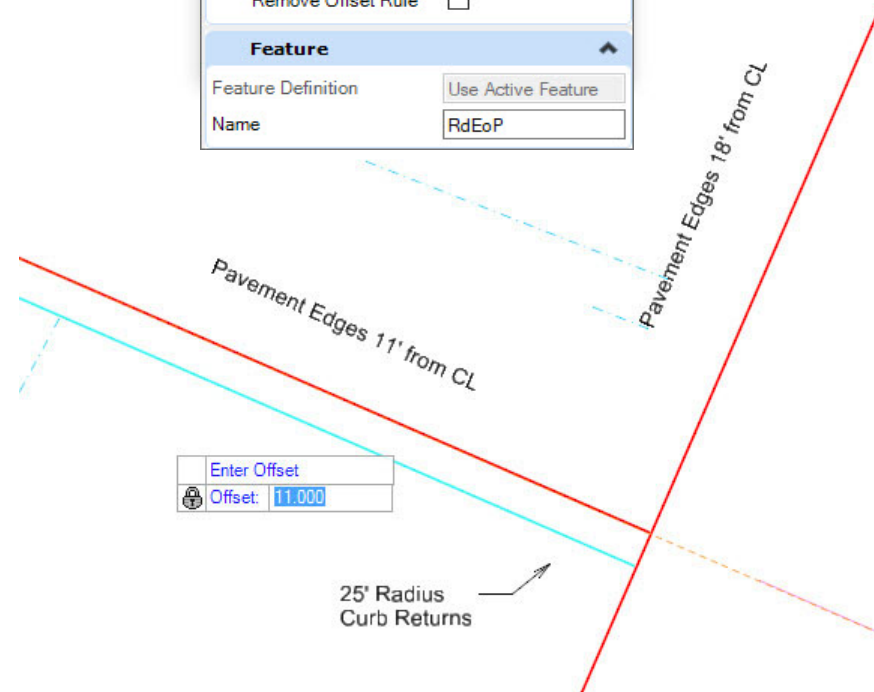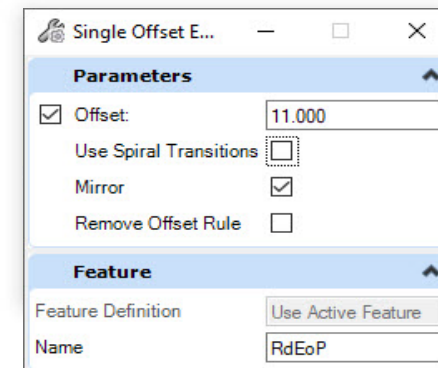
b. **Disable** the *Use Spiral Transitions* option.

This option is used when offsetting a feature with a spiral in it. A true "parallel" spiral is not mathematically possible.

- When Disabled, the result is "closest to parallel" but is a chorded linestring.

- When Enabled, the end points are offset by the exact distance and a new spiral placed between them. Note that this new spiral is not *mathematically* parallel to the original spiral.

Other Settings can be set in the dialog or at the heads up prompts.

2. At the *Locate Element* heads up prompt, click on the curve of the **East-West road centerline**.

Clicking the curve ensures that the entire complexed feature is offset. If you click on the tangent, only the tangent is offset.

3. At the *Enter Offset* prompt, type **11** *[3.5]* and press the **Return** key to lock the value.

4. **Left click** to accept the value.

5. At the *Mirror* prompt, press the **Down Arrow** key until **Yes** is displayed.

Mirror is for speed: it creates an identical feature on the other side of the Reference element, both ruled to the Reference element. It does NOT create any relationship between the two offsets.
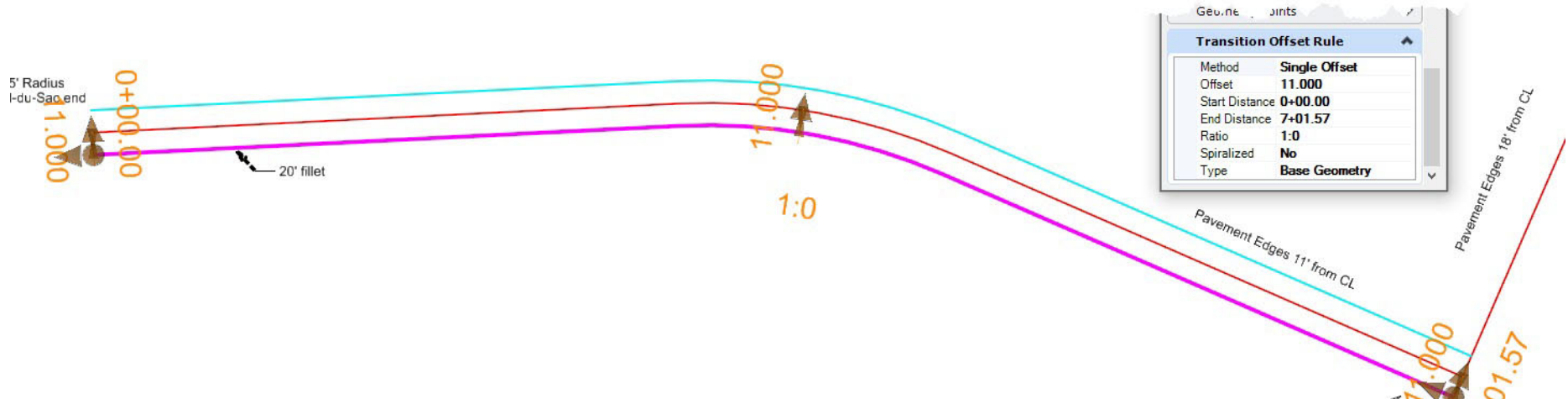
6. Place a **data point (left click)** to place the two offsets.

7. Confirm your Work

   a. Select one of the new pavement edges.

   b. Review the heads up display and the *Properties*. Make changes if necessary.

5' Radius
I-du-Sac end

0+00.00
1.000

20' fillet

11.000

1:0

Transition Offset Rule

Method	Single Offset
Offset	11.000
Start Distance	0+00.00
End Distance	7+01.57
Ratio	1:0
Spiralized	No
Type	Base Geometry

Pavement Edges 11' from CL

Pavement Edges 18' from CL

11.000

01.57

Confirm the Relationships

1. Set undo mark for the current state of the file.

   Before doing something you will likely want to reverse with Undo, a mark can be set in the file marking its current state.

   a. Select **Set Mark** from the Quick Access menu above the ribbon menu.
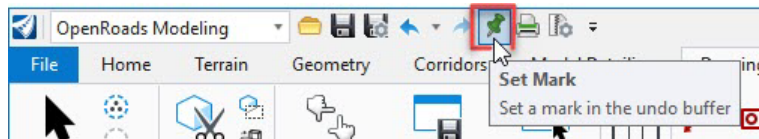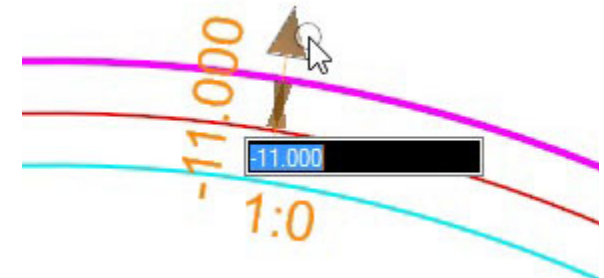

   Note: if the Set Mark tool is not shown in your Quick Access menu, you can Type *Mark* in the Key-in tool.
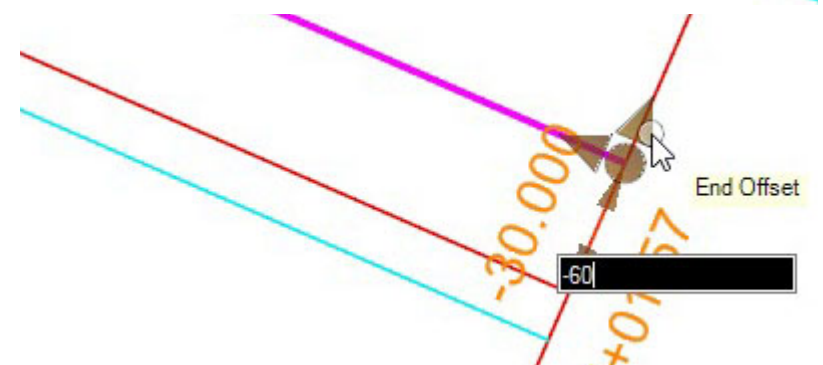
2. Select the **northern edge of pavement**.

3. Change the value of the *middle Offset manipulator*, by either the handle or the text manipulator.

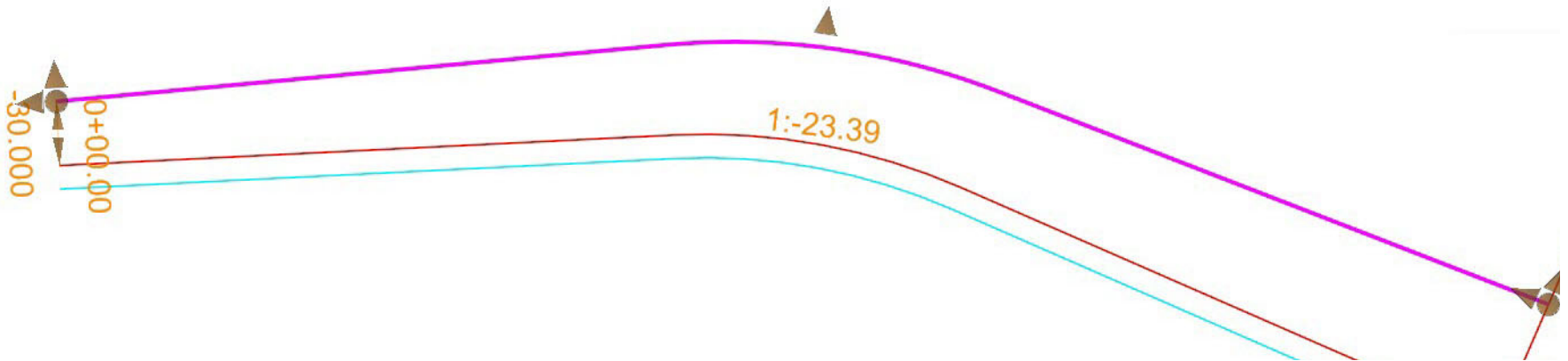   Notice that the Pavement Edge remains parallel (single or constant offset).

4. Change the value of the *end Offset manipulator*, by either the handle or the text manipulator.

   What happens?

Changing a Start or End Offset does not change the Offset at the other end: you get a variable offset taper.


Note that the Taper Text Manipulator is editable: you can "round it off" to an even ratio but of course this will adjust the end offset value.

5. Select the **centerline**.

6. What happens when you move the end point of the centerline of East-West road?

7. Select **Undo to Mark** from the Quick Access menu above the ribbon menu to undo any changes that were made to the centerline or edges of pavement.
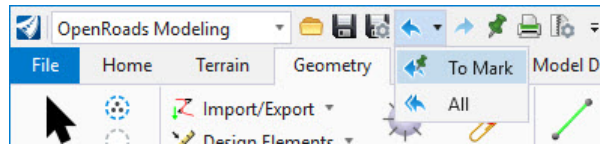
8. Use *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Entire Element** to add pavement edges to the *North-South* road at an **18' *[6m]*** offset.

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Exercise 3: Curb Returns

Description

We now have two roads intersecting at a T. We will now add smart curb returns.

Skills Taught

- Simple Arc Between Elements

Simple Arc Between Elements = Curb Return

1. Zoom to where the two centerlines intersect.

2. Click *Geometry > Horizontal > Arcs > Arc Between Elements >* **Simple Arc**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

3. Place an arc in the north quadrant.

   a. At the *Locate First Element* prompt, click on an **Edge of Pavement**.

   b. At the *Locate Second Element* prompt, click on the other **Edge of Pavement**.

   The *Enter Through Point* is looking for a data point, a snap, or a typed Radius value to locate the curve.

   Given two lines, there are four sectors a arc can occupy. OpenRoads needs to know the sector to place the arc. The next data point will define which sector the arc is placed. If you are using a known Radius, type it in before placing a data point.

   c. Type **25** *[10]* and press the **Return** key to lock the radius value.

   d. Move the cursor to different sides of the intersection and observe the different arcs than can be created. When the correct sector is shown, **click** to select the sector.

   e. At the *Trim/Extend Option* prompt, press the **Down Arrow** key until **Both** is displayed. Both edges of pavement will be trimmed to their intersection with the arc.

   f. **Left click** (data point) to place the arc and trim the edges
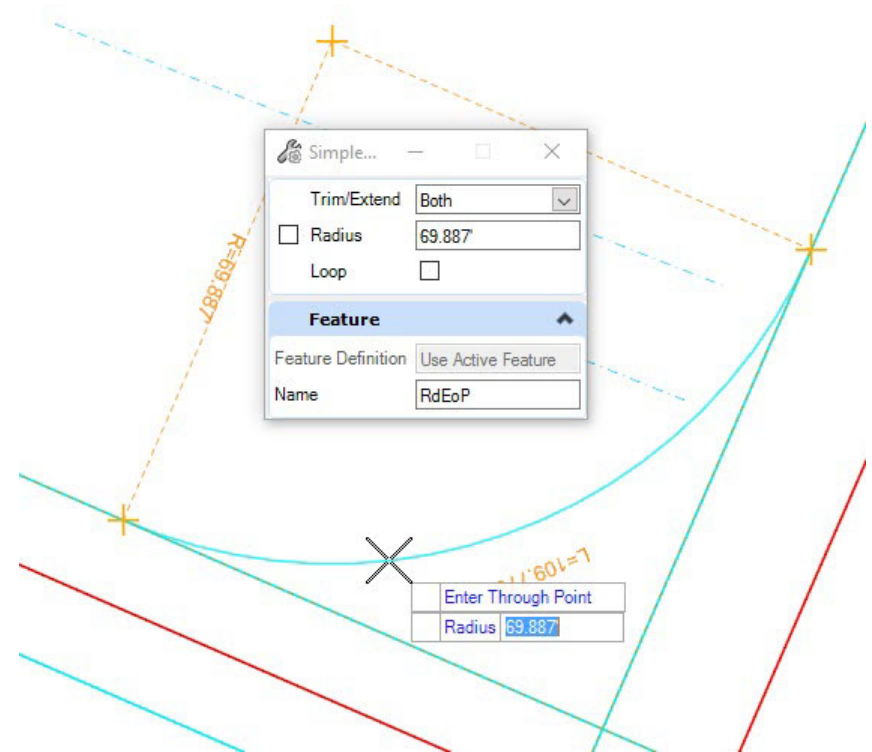
g. Notice that the North-South road edge of pavement has disappeared where it is needed for the other side.

It is actually still there. The software remembers the original element and has created a new *interval* which is a subset of the original element. When we place an arc on the other side of the intersection we will still be able to select the original element.

This is important because the original element was created as an offset to the centerline and we want to maintain that relationship and be able to adjust that offset value if necessary.

4. Place an arc on the south quadrant.

a. At the *Locate First Element* prompt, **click** on the other **East-West** road **Edge of Pavement**.

b. .At the *Locate Second Element* prompt, move the cursor to where the **North-South** road **Edge of Pavement** used to be. **Click** when the edge of pavement highlights.
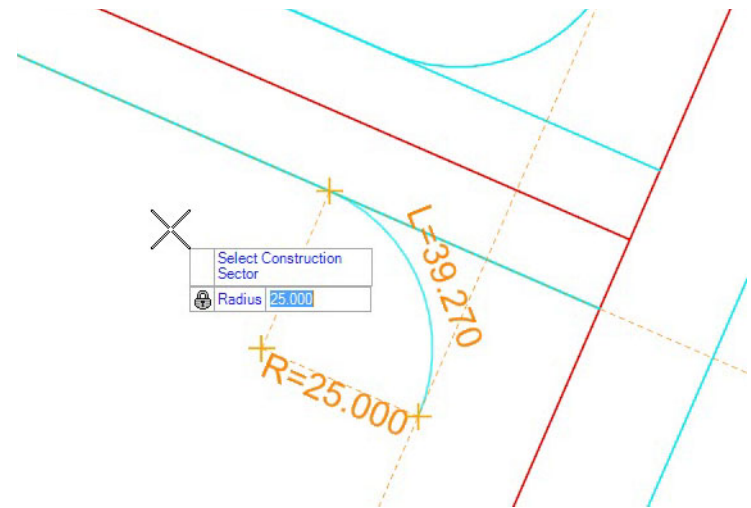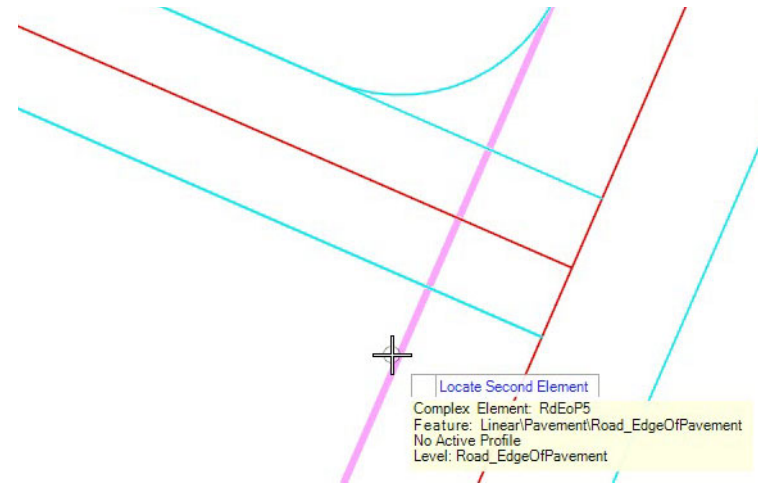
The software remembers the tools last settings. We locked the Radius last time. This time the prompt is *Select Construction Sector*. We can type in a new value if needed. We can also press the *End* key to unlock the Radius and locate a Through Point.

c. At the *Select Construction Sector* prompt, if the radius is still **25'** *[10m]*, simply **click** in the appropriate sector.

d. At the *Trim/Extend Option* prompt, press the **Down Arrow** key until **Both** is displayed

e. Place a data point to place the arc and trim the edges.

Note that the North-South Road Edge of Pavement has reappeared where it is needed for the other side.

Locate Second Element
Complex Element: RdEoP5
Feature: Linear\Pavement\Road_EdgeOfPavement
No Active Profile
Level: Road_EdgeOfPavement

Select Construction Sector
Radius 25.000

L=39.270
R=25.000

5. Review the Interval element by selecting the west edge of pavement south of the intersection.

   As shown in the left image, observe that only the interval element from the arc to the end of the alignment is highlighted in bold. The offset values for the edge of pavement are shown but they are grayed out and cannot be edited. That is because the offsets are to the original edge of pavement. This is an interval derived from the original edge of pavement.

   a. **Right click** while the interval is highlighted. The original element is activated and highlights (see right image). The offset text manipulator fields can now be used to adjust the offset.

   Tip: Selecting a modified element (i.e interval element) and then doing a right click will give you access to the base element..

6. Confirm your Work

   a. Select **Set Mark**.

   b. What happens if a road centerline is moved?

   c. What happens if the pavement edge offsets are changed?

   d. What happens if an arc radius is changed?

   e. Select **Undo to Mark** to undo the confirmation changes.
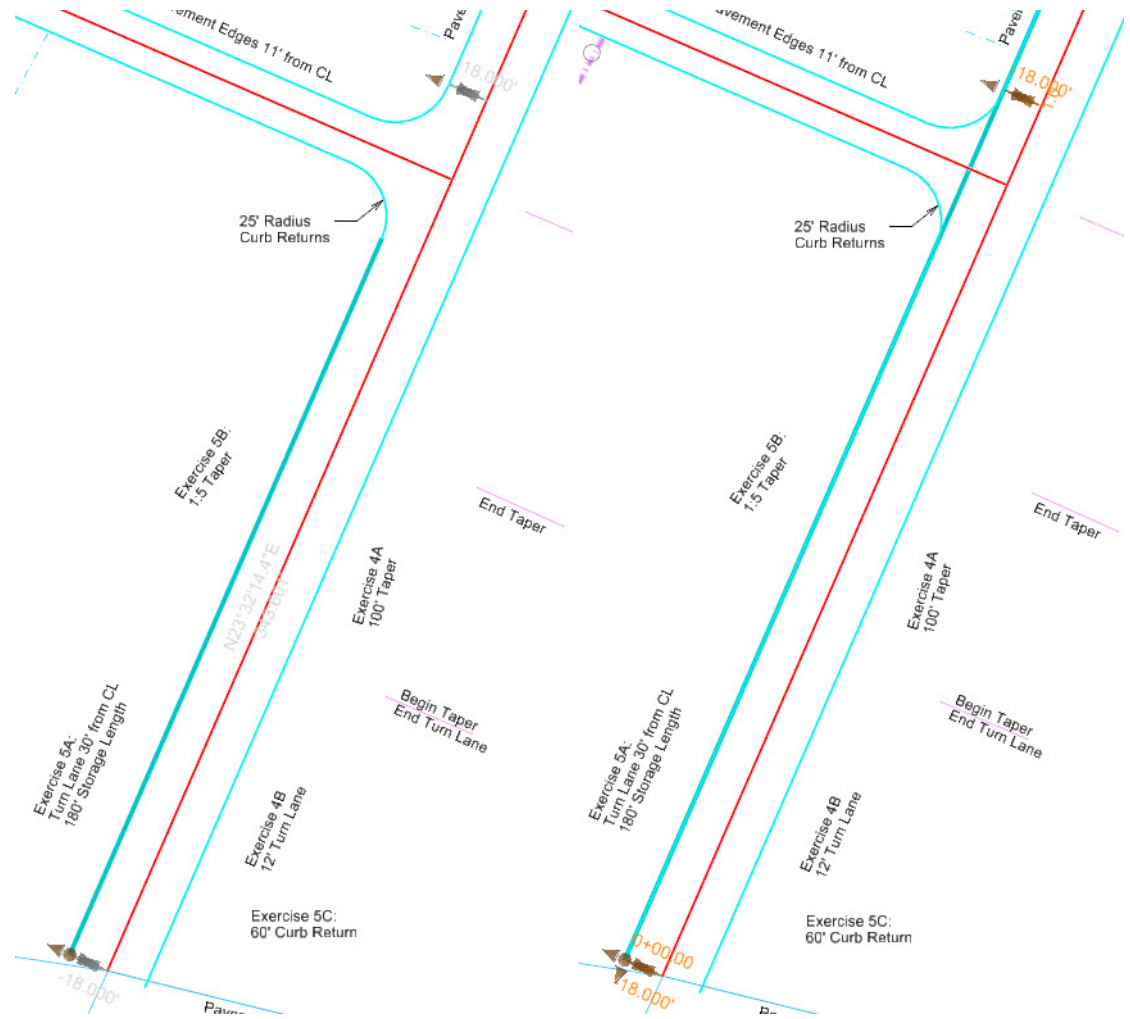
Exercise 4: Turn Lanes - Partial Offsets and Tapers

Description

In this exercise we will add a lane at the south end and then taper that lane back down to zero width at a controlled distance before the intersection. We'll introduce Partial Offsets and Tapers.

Skills Taught

- Single Offset Partial

- Variable Offset Taper

- Ratio Offset Taper

- Turn Lane at an Intersection

Our engineering goal here is to provide a minimum distance between an end of a drop lane taper and the intersection. Cars may make a left turn at the intersection and we want to make sure traffic merging is finished some distance before the intersection.

We could place a "dumb" offset to mark the end of the taper, but using "smart" construction elements allows us to very easily change the buffer length, with all dependent geometry automatically updating.

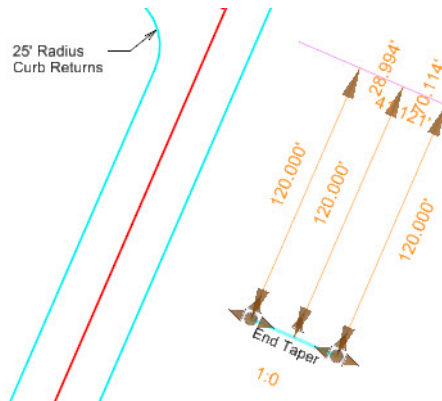We will define the taper end at the station represented by the construction line.

Note that the process is identical to snapping to a "hard point" in a topo file.
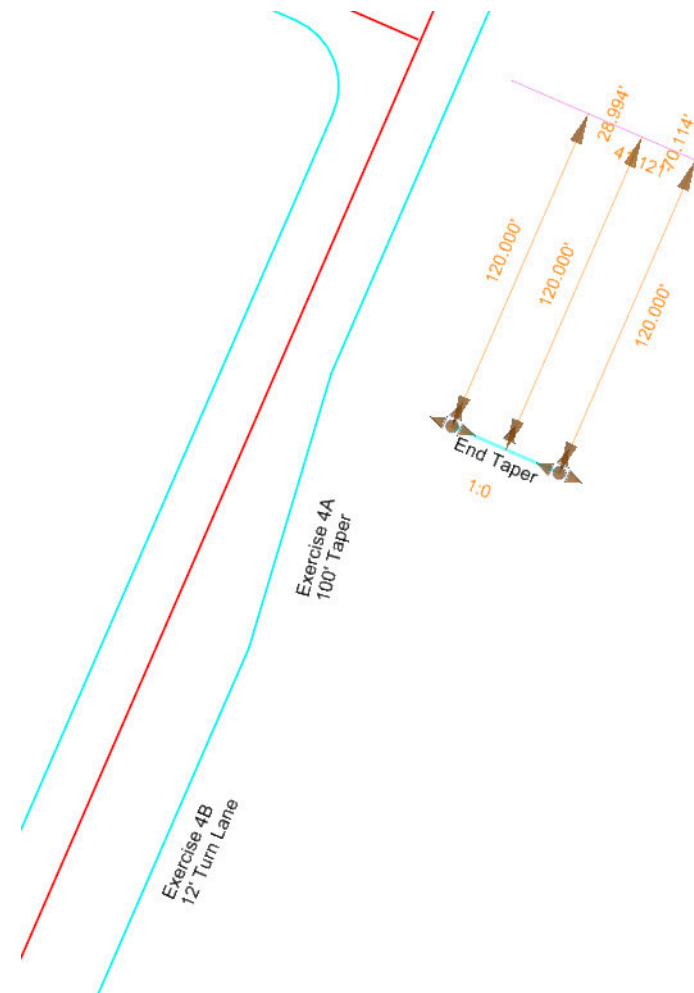
Using Construction Elements

1. Select the line labeled End Taper in the drawing.

This is a construction element that has been defined to be *120' [35m]* from the center of the intersection. We will use this construction element to define where a lane taper ends. By using this construction element to control the position of the taper we can easily adjust the distance between the taper and the intersection.

This is possible because of civil geometry remembers the relationships (design intent) created between elements. It remembers to update dependent features, using the relationships they were created with.

How were the construction elements constructed?

a. The construction line at the intersection is snapped to the centerline of the East-West road and perpendicular to the North-South road. Perpendicular was established using the *Line From Element* tool with a skew angle of 90 degrees. These relationships ensure the line will be at the intersection and perpendicular to the North-South road even if the geometry changes.

b. The construction line labeled *End Taper* was created with the Single Offset Entire Element so it has a relationship to always be parallel to the first line at a specified (and editable) offset distance.

Place the Turn Lane Taper

Tapers can be engineered in many ways. They can be completely dependent on the elements they are between or they can control the position of the ahead feature. It all depends on the engineering requirements - the design intent.

Tapers can be defined where the Start and End Offsets are primary constraints or where the Taper Ratio is the primary constraint. Your design intent depends on the engineering requirements. By picking the corresponding tool, you communicate your Design Intent.

---

1. Select *Geometry > Horizontal > Offsets and Tapers >* **Variable Offset Taper**.

    The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

2. At the *Locate Element* heads up prompt, click the right pavement edge of **North-South Road**.

3. At the *Start Parameters* prompt, you are presented with the Left and Right arrows ◀▶ . These indicate that you have multiple options. Press the **Left** or **Right Arrow** key on the keyboard until the *Start Offset* is visible.

    Whenever you see the double arrows ◀▶ , slow down and use caution. It means you are being prompted for more than one item, and only one item is displayed at a time in the prompt. You will at some point click without checking all the options and get something you don't want. Fortunately, it's easy to fix a mistake via the heads up display or Properties dialog. Undo also works. The Tool Settings dialog shows all options (typically).

4. Type **0** and press the **Return** key to lock the value so that the first end of the taper will begin at the edge of pavement.

    Notice the Padlock icon in the heads up prompt indicating the Start Offset value is locked. Press the **End** key on the keyboard to Unlock a value.

5. Press the **Left** or **Right Arrow** key until *Distance: Start Distance* is visible. Ensure that the *Distance: Start Distance* field is NOT Locked. If necessary, press the **End** key to unlock the value.
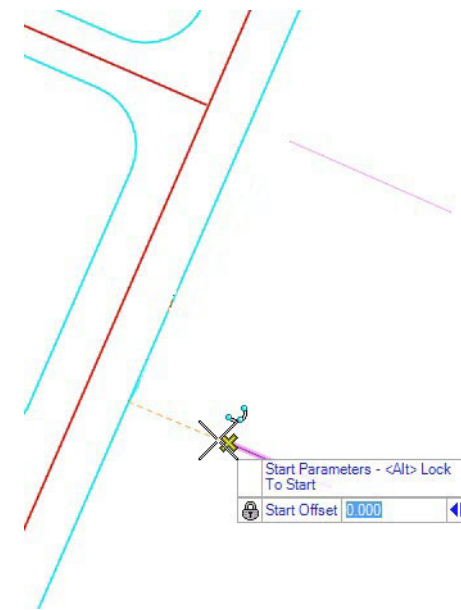
6. **Snap** to the left end of the line labeled *End Taper* in the drawing and **left click** to define the start location of the taper.

   In this situation we are defining this taper in the reverse direction of traffic flow, thus this first point where the taper intersects the edge of pavement is actually the end of the taper in regards to the direction of traffic flow.
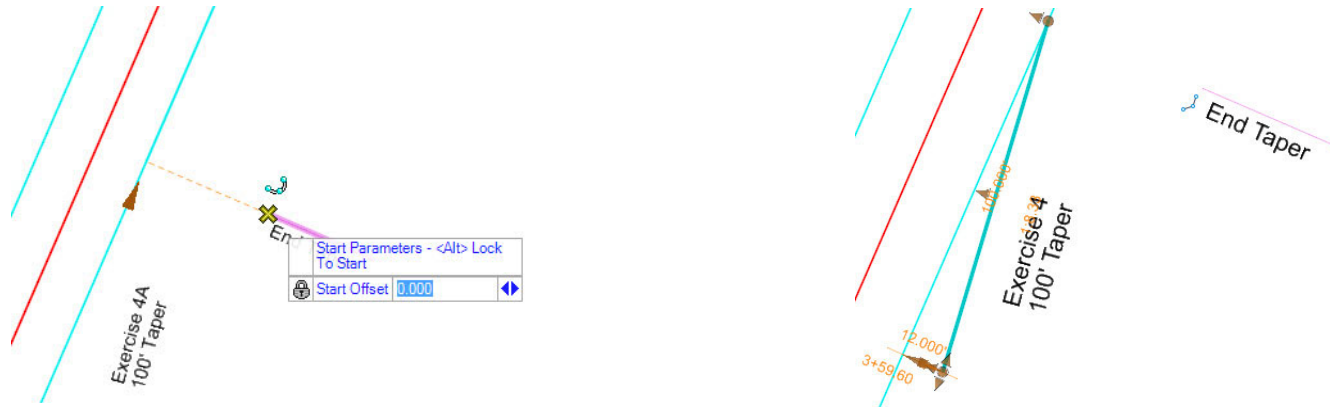
   You are now presented with the *End Parameters* prompt. The Left and Right arrows again indicate that you have multiple options. It is asking for two parameters, but has three options: the *End Offset* and the End Station (via *Distance: End Distance* and *Distance: Length* prompts).

   Note: If you are getting fewer options, you may have an option locked. You can clear it in the Settings dialog.

7. Press the **Left** or **Right Arrow** key to scroll to the *End Offset* field.

8. For *End Offset*, type **12' *[3.6m]*** and press the **Return** key to lock the value.

9. Press the **Left** or **Right Arrow** key to verify that *End Offset and End Distance* are not locked.

10. Press the **Left** or **Right Arrow** key to scroll to the *Distance: End Length* field.

11. For *End Length*, type **100' *[30m]*** and press the **Return** key to lock the value.

   The length could have also been established by snapping to a construction graphic or other civil geometry element.

12. The location of the cursor determines which of multiple taper options will be constructed. Move the cursor *south* of the End Taper construction line and *east* of the edge of pavement to construct the taper in that direction.

13. **Click** to create the taper.

14. At the *Mirror* prompt, press the **Down Arrow** key until **No** is displayed.

15. Place a data point to finish the taper.

16. Confirm your Work

   a. Select **Set Mark**.

   b. Select the taper element.

      Notice the snap glyph near the End Taper construction line showing the relationship the taper has with that element.

   c. What happens if the taper length changes?

   d. What happens if the offset changes?

   e. Select the End Taper construction line.

   f. What happens if the offset from the intersection changes?

   g. Select **Undo to Mark** to undo the confirmation changes.
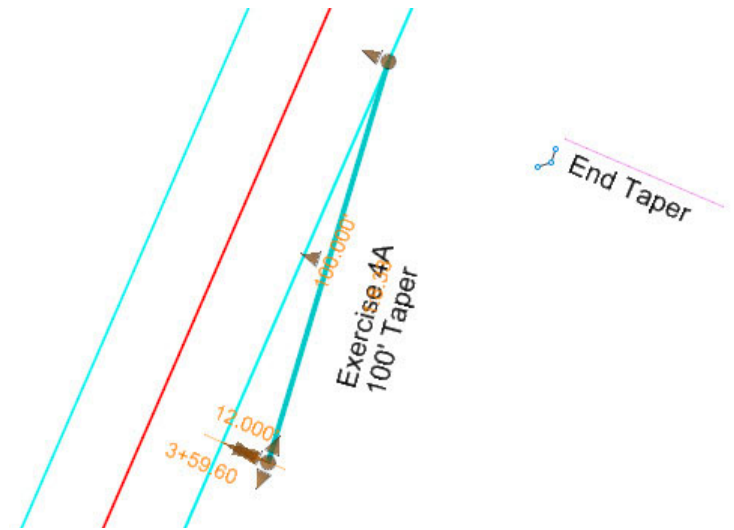
Place the Turn Lane Edge of Pavement

1. Click *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Partial**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

2. At the *Locate Element* heads up prompt, click the **centerline** of **North-South Road**.

   The edge of pavement could have also been used as the reference element. However, the new edge of pavement will eventually replace the original edge of pavement in this area so offsetting from the centerline makes the heads up display a little "cleaner" afterwards.

   Start Parameters is asking you for two things: Start Offset and Start Distance (Station). For this feature, we want the offset and starting position to be related to the taper endpoint rather than keyed in values.

3. At the *Start Parameters* prompt, ensure that the both values are unlocked.

   HINT: Use the arrow keys to cycle through the prompts and the **End** key to clear locks.

4. **Snap** to the end of the south end of the Taper element.

   The pavement edge is linked to the taper and drawn to your cursor at the offset of the taper.

   You are now presented with the *End Parameters* prompt. It is only asking for one item: the End Distance, but it is available in two forms, selectable by the Left and Right arrows ◀▶ : the End Distance (Distance along the reference) or the Length of the offset.

5. Use the **Left** or **Right Arrow** and the **End** key to clear any Locks for both settings.

6. At the *End Parameters* prompt, place a data point near the south end of the road.

   We will place a curb return later, so the exact beginning point is not critical.

   The Offset is locked, only the End Station is ruled to the feature.

7. At the *Mirror* prompt, press the **Down Arrow** key until **No** is displayed.

8. Place a data point to place the turn lane edge.

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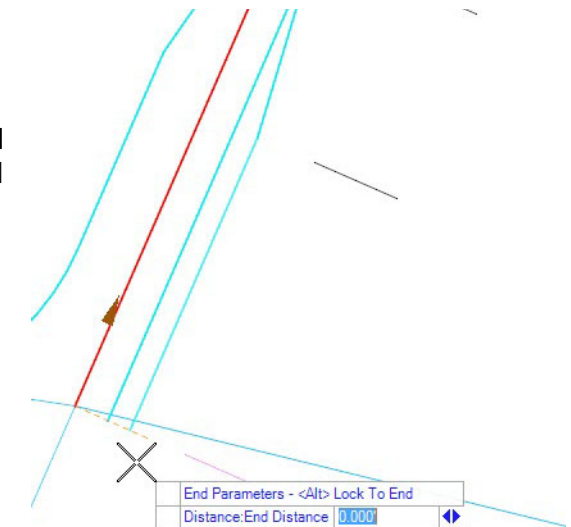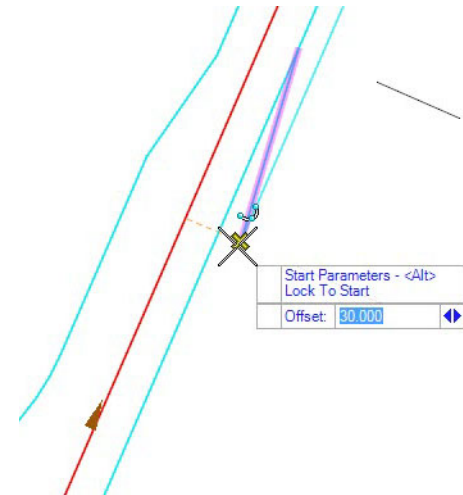
Trim the Original Edge of Pavement

The turn lane and taper represent a new edge of pavement, replacing the original to its interior. We can use "CAD" tools to modify Civil Geometry Features. We'll use Trim to Element here to trim the original pavement edge.

---

1. Select *Drawing > Modify >* **Trim to Element**.

   HINT: This tool is still on the OpenRoads Modeling workflow ribbon, but on a different tab named Drawing.

2. At the *Trim to Element > Identify elements to modify* prompt, click the portion of the North-South road edge of pavement to be kept (the part north of the taper).

3. At the *Trim to Element > Identify cutting element* prompt, click the taper.

4. Explore the Relationships of the Turn Lane and Taper

   a. Set an Undo Mark.

   b. Test the behavior of the geometry when you move and edit things.

   c. Select the taper and notice that the beginning offset is not defined. Remember it is snapped to the edge of turn lane element.

   d. When finished testing the geometry, Undo to the mark.
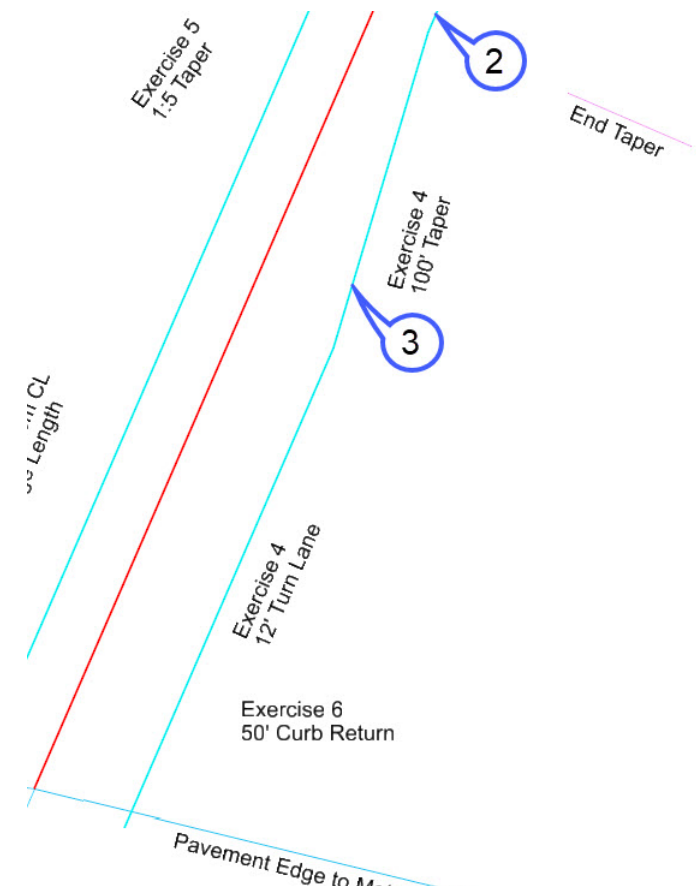
# Exercise 5: Turn Lanes - Offsets and Tapers - Independent

Description

In the previous exercise, we established relationships with existing graphics. Those graphics can represent existing topological features or restrictions on design. You can use graphics such as the construction lines to provide a visual representation of Engineering Criteria. The callout graphics in the previous exercise were essentially that: markers for adjustable lane and taper lengths.

In this exercise, we'll add a turn lane and taper without external references.
We'll use the properties of the features themselves.

Skills Taught

- Single Offset Partial

- Variable Offset Taper

- Ratio Offset Taper

- Turn Lane at an Intersection

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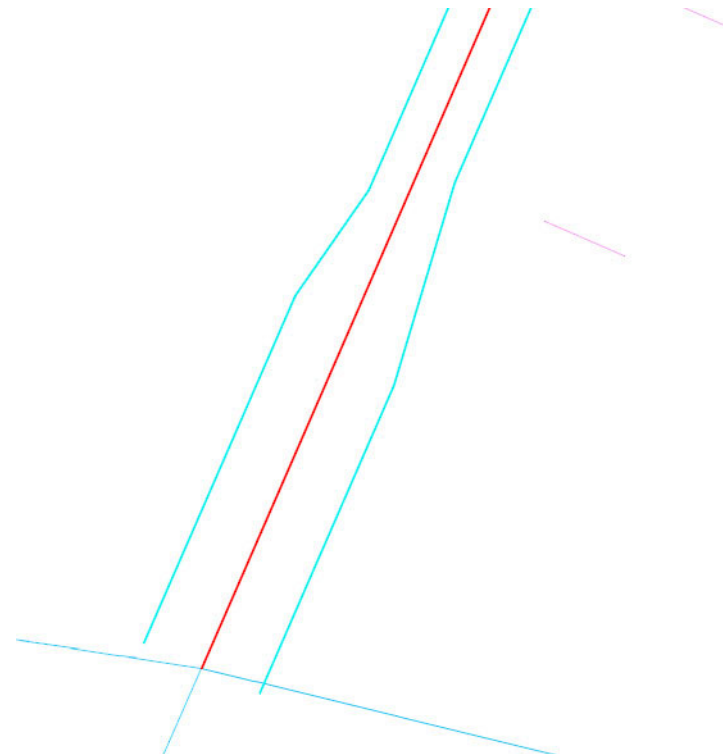
Place the Turn Lane

1. Click *Geometry > Horizontal > Offsets and Tapers > Single Offset Partial*.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

2. At the *Locate Element* heads up prompt, click the **centerline** of **North-South road.**

   The *Start Parameters* prompt is asking you for two things: Start Offset and Start Distance (Station). Make sure both are correct.

3. At the *Start Parameters* prompt, press the **Left** or **Right Arrow** until *Start Offset* is visible.

4. At the *Start Offset* prompt, type **30** *[9]* and press the **Return** key to lock the value.

5. Press the **Left** or **Right Arrow** until the *Distance: Start Distance* prompt appears. Type **0** and press the **Return** key to lock the value to the start (0 distance along) the centerline.

   The *Alt* key can also be used to lock the Offset to the Start of the reference element.

6. **Left click** to accept the Start Parameter values. If the dynamic display is showing you something you don't expect, you might have a value wrong.

   The cursor should now have a line at the given offset extending to it.

   You are now presented with the *End Parameters* prompt. It is only asking for one item: the End Station, but it is available in two forms, selectable by the Left and Right arrows |◀▶ : the *End Station* (Distance along the reference) or the *Length* of the offset.

7. Press the **Left** or **Right Arrow** until *Distance: Length* is visible.

8. When the Display prompts for *Distance: Length*, type **180** *[55]* and press the **Return** key to lock the value.

9. **Left click** to accept the End Parameter values.

10. At the *Mirror* prompt, press the **Down Arrow** key until **No** is displayed.

11. **Left click** to finish placing the southbound turn lane edge.

12. Confirm the expected behavior by selecting the taper and changing the *Length* text manipulator.
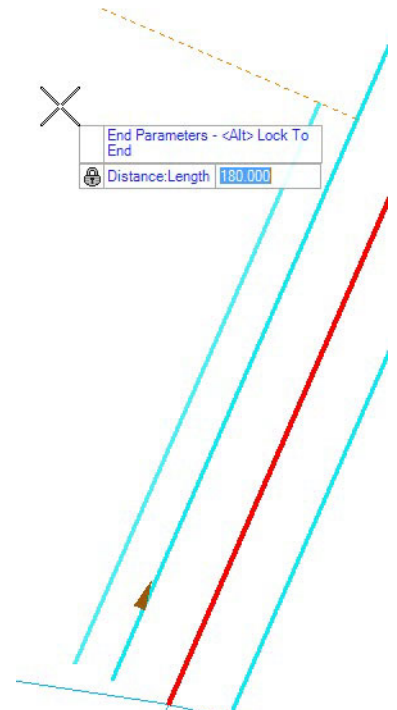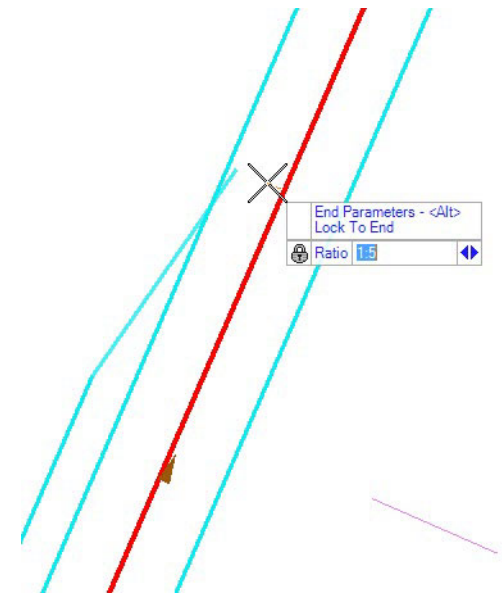
Place the Turn Lane Taper

This time we'll let the length and ratio of the taper determine the end of the taper, rather than a fixed end point like we did on the right side of the road.

1. Click *Geometry > Horizontal > Offsets and Tapers >* **Ratio Offset Taper**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

2. At the *Locate Element* heads up prompt, click the centerline of **North-South road**.

3. At the *Start Parameters* prompt, press the **Left** or **Right Arrow** key a couple of times to make sure that neither the *Start Offset* and *Start Distance* (Station) are locked. The *End* key will unlock a value. We want to have a Snap define our relationship.

4. **Snap** to the north end of the Turn Lane pavement edge created in the previous exercise.

5. You are now presented with the *End Parameters* prompt. The Left and Right arrows ◀▶ indicate that you have multiple options. It is asking for two parameters, but has three options: the *Ratio* and the End Station (via *Distance: End Distance* and *Distance: Length*).

6. Press the **Left** or **Right Arrow** key to scroll to the *Ratio* field.

7. For *Ratio* type **1:5** (plus or minus sign determines the direction of the taper) and press the **Return** key to lock the value.

8. Press the **Left** or **Right Arrow** key to make sure the *Distance* fields are not locked.

9. Place a data point near the original pavement edge. The exact length of the taper is not important as we will be trimming the lines in the next exercise.

10. At the *Mirror* prompt, press the **Down Arrow** key until **No** is displayed.

11. Place a data point to place the taper.

12. Confirm the expected behavior by selecting the taper and looking for the snap glyphs or by moving changing the offset or length of the turn lane.

Trim the Taper and Original Edge of Pavement

The turn lane and taper represent a new edge of pavement, invalidating the original to its interior. We can use "CAD" tools to modify Civil Geometry Features. We'll use *Trim to Intersection* here to trim the taper and the original pavement edge.

1. Click *Drawing > Modify >* **Trim to Intersection**.

   HINT: This tool is still on the OpenRoads Modeling workflow ribbon, but on a different tab named Drawing.

2. At the *Trim to Intersection > Identify first element to modify* prompt, click the original pavement edge *North* of the taper which is the section of the edge of pavement you want to keep.

3. At the *Trim to Intersection > Identify second element to modify* prompt, click on the taper. *south* (part you want to keep) of the intersection.

   If you click in the wrong places, you will cut off the wrong side of an element. Undo and retry.

4. Confirm the modeling.

   a. Set a mark so you can undo after testing the geometry behavior.

   b. Click on the pavement edge north of the taper. Note the Trim glyph.

   c. Click on the taper. Note the Trim glyph.

   d. What happens if you change the new turn lane Offset?

   e. What happens if you change the Taper Ratio?

   > Note: you may need to right-click to enable the Ration text manipulator.

   f. What happens if you change the mainline edge of pavement offset from **18**' *[6m]* to **30**' *[9m]*? Observe the relationships being honored.

   g. Undo to the mark.

The procedure above has two edges, the main lane and the turn lane, both ruled to the centerline. They will both update if the centerlines moves.
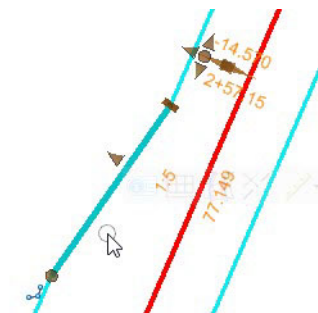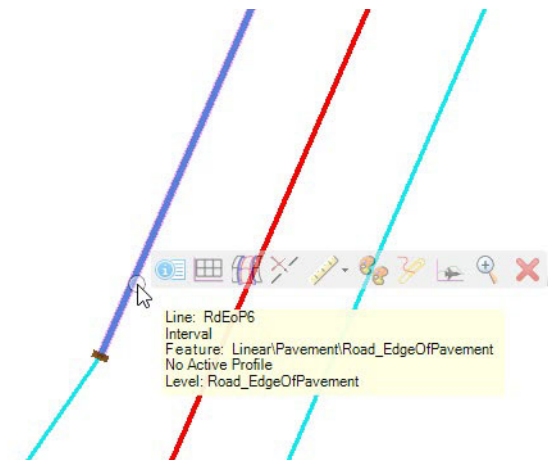
An alternative design would be to rule the turn lane to the main edge. This way the turn lane edge will automatically update if ether or both of the centerline and main lane edge change geometry.

Both methods are valid. The model should be built based on how you want the geometry to update. What is the Design Intent? Which is the primary engineering consideration? Which method will be easier to manage for a large product or with multiple designers over a long period of time? Civil geometry will remember how you build it. The choice is yours.

Exercise 6 - Placing Curb Returns

Description

So far we've created simple single-radius curb returns. Engineering designs often call for geometry more complex than that. The *Arc Between Tools* can handle any requirement.

In this exercise we will add curb returns where the North-South road intersects the ramps.

Skills Taught

- Understanding the Civil Geometry data structure

- Simple Arc

- 3 Center Arc

- Add Spiral Transitions to a Simple Arc

Place a Simple Curb Return

1. Zoom to the south end of the **North-South road**.

2. Click *Geometry > Horizontal > Arcs > Arc Between Elements >* **Simple Arc**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

   The east-west lines are ramp baselines along the their northern pavement edges. We will use these to define the curb return arcs.

3. At the *Locate First Element* prompt, select the eastern **Ramp** edge of pavement.

4. At the *Locate Second Element* prompt, select the **North-South** road edge of pavement.

5. At the *Select Construction Sector* prompt, type **50** *[15]* and press the **Return** key to lock the value.

6. Position the cursor to construct the arc in the correct sector and **left click**.

7. At the *Trim/Extend Option* prompt, press the **Down Arrow** key until *Both* is displayed.

8. Place a **data point** to place the arc and trim the edges.

   Note that the ramp edge is not trimmed. It is in a reference file whose contents cannot be modified.
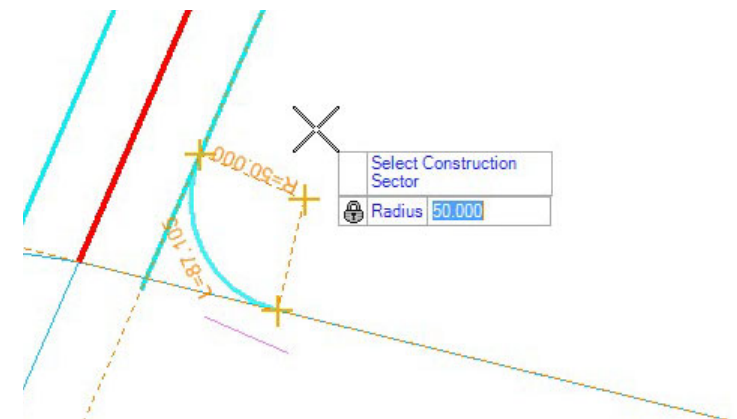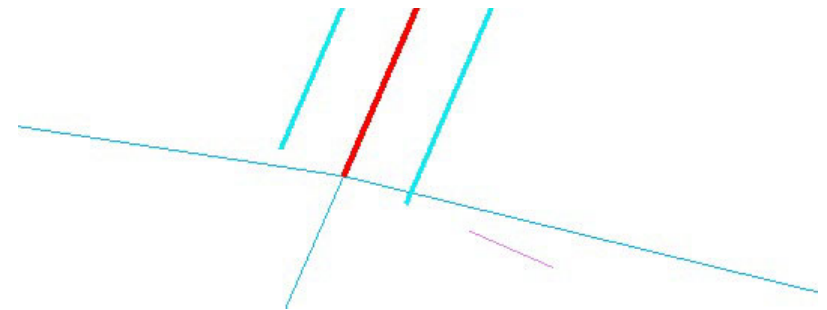
Understanding the Tools

The civil geometry tools are designed to handle even the most complex engineering. The User Interface is designed for simplicity and speed. While there may be 15 variables required to handle the most complex fillet, for a Simple Curve for a fillet only the radius is required. Requiring the user to fill out 15 parameters would be grossly inefficient. Look at the *Arc Between Elements* tools. The menu shows six tools that create different combinations of arcs, spirals, and tapers. While the data structure is exactly the same for all of these, each tool only asks for its required options.

The last tool in the list, *Arc Between Elements*, is the most complete and includes options for forward and back tapers and Back and Ahead transitions including multi-center curves and spiral-curve combinations.
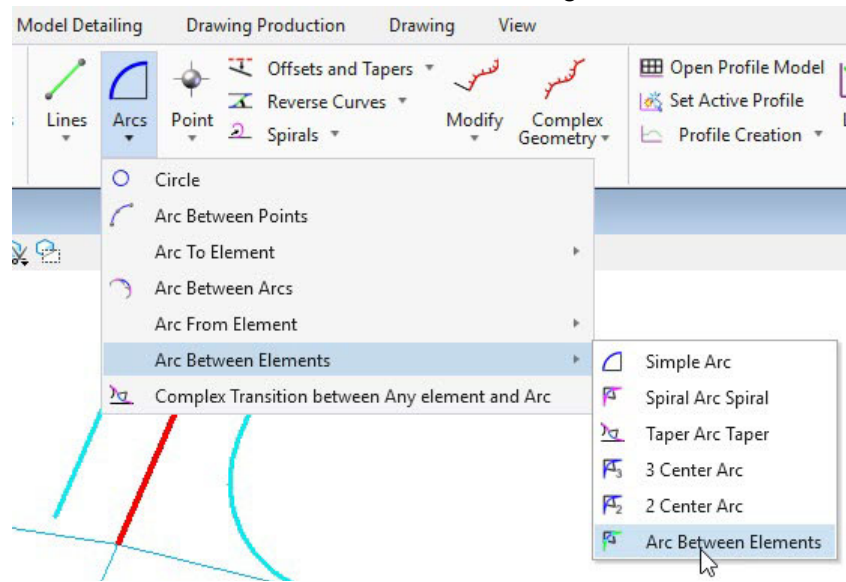
The other tools are essentially the same tool but have some options preset and hidden. For example the *Simple Arc* tool assumes (presets) no tapers and transitions and hides those options. The *Spiral Arc Spiral* tool hides the taper options but shows the transition options and presets them to a spiral type transition.

The important thing to understand is that no matter which tool is used, the arc element created has the same data structure. You can always change ANY of the options in the *Properties* dialog no matter which tool was used to create the arc. For example, if an arc is created with the *Simple Arc* tool and later needs to be changed to a *Spiral-Arc-Spiral* curve, simply open the *Properties* and change the *Back* and or *Ahead Transition* from None to Spiral.
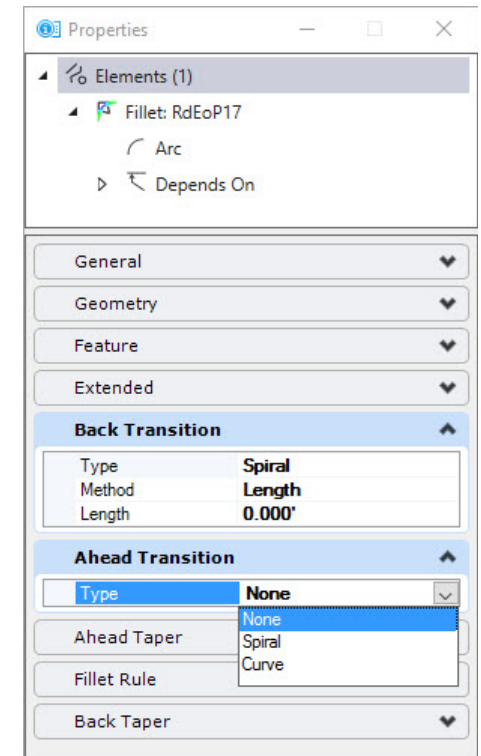
Place A Complex Curb Return

1. Click *Geometry > Horizontal > Arcs > Arc Between Elements >* **3 Center Arc**.

   There are a lot of options with this tool. On tools with many options, setting some or all of them in the Tool Settings dialog may be easier than just using the heads up display. Some settings may not even appear on the heads up prompt and may have to be set in the dialog. The heads up display is designed for the most efficient input of common options. For example with this tool the transition Method option is not shown in the heads up display. If you want to define a transition by deflection angle or offset distance you will need to change that option in the dialog.

   Keep in mind: Like any geometry tool, if you make an input mistake, you can fix the settings in the Properties dialog or use Undo.

2. Use the dialog to set the following:

   - *Trim/Extend* = **Both**

   - *Radius* = **75** *[25]* and **Lock** it

   - *Loop* = **Disabled** (enable this for loop ramp geometry)

   - *Back Transition Type* = **Curve**

   - *Back Transition Method* = **Length**

   - *Back Transition Radius* = **125** *[40]*

   - *Back Transition Length* = **50** *[15]*

   - *Ahead Transition Type* = **Curve**

   - *Ahead Transition Method* = **Length**

   - *Ahead Transition Radius* = **125** *[40]*

   - *Ahead Transition Length* = **50** *[15]*
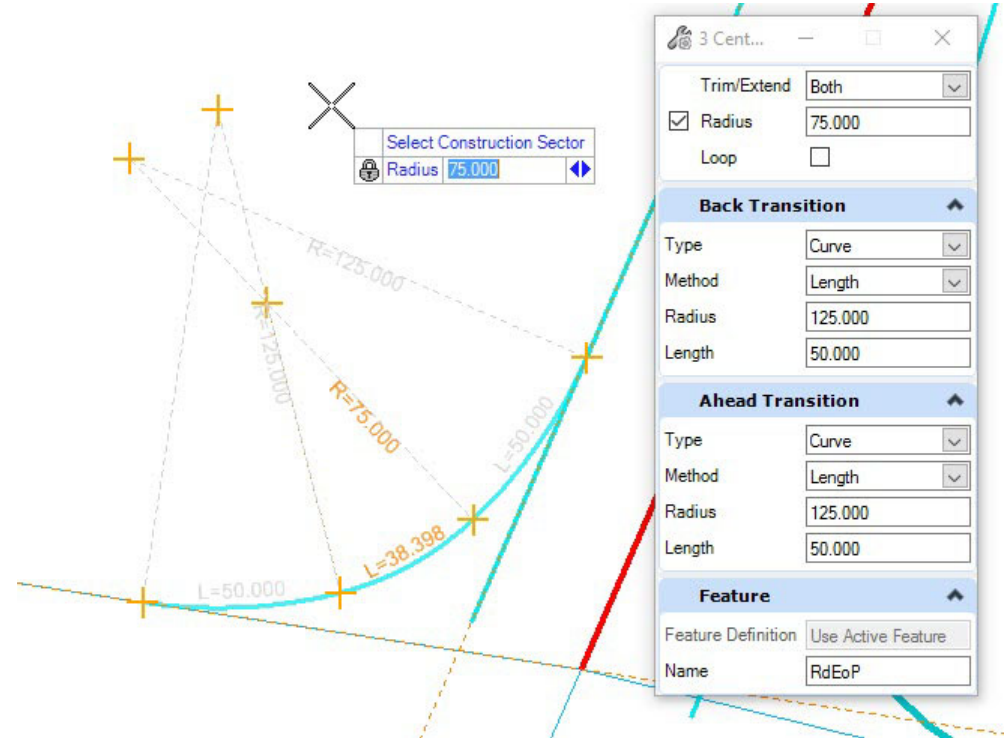
3. At the *Locate First Element* prompt, select the western **Ramp** edge of pavement.

4. At the *Locate Second Element* prompt, select the **North-South road** edge of pavement.

5. At the *Select Construction Sector* prompt, position the cursor to construct the 3-center curve in the correct sector and **left click**.

6. At the *Trim/Extend Option* prompt, press the **Down Arrow** key until *Both* is displayed.
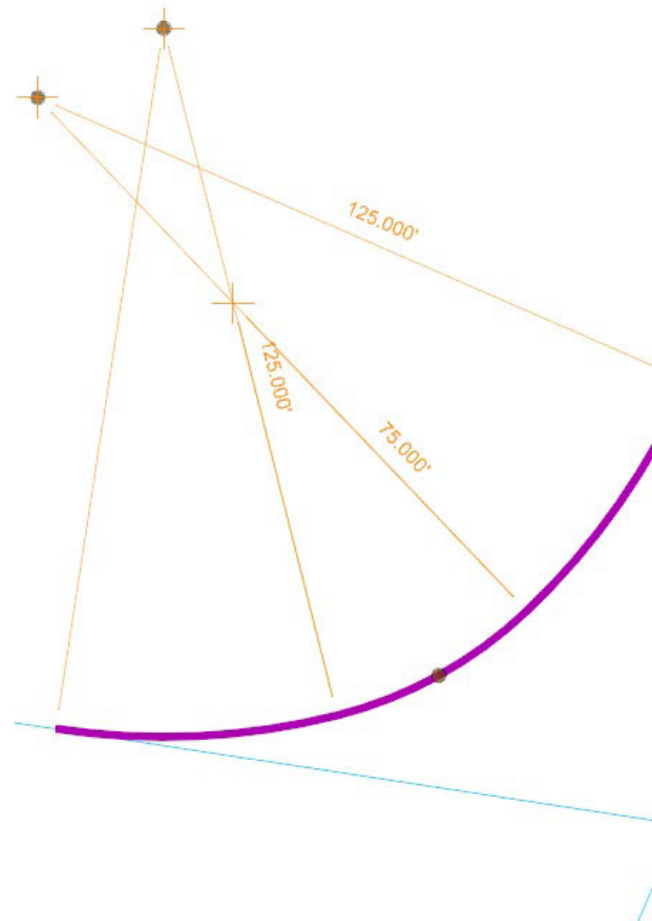
7. Place a data point to create the arc.

   The civil geometry element structure for curves is designed to model the full breadth of engineering needs. Remember that the 3 Center Arc tool is streamlined specialization for the full Arc Between Elements tool. Simple Arc, which only "asks" for Radius, uses the same data structure.

   What this means is that regardless of the tool used, you can edit the curve to any required geometry specification.

   Back and Ahead Transitions can be None, Spiral, Curve, and Arc Ratio. There can be Back and Ahead Offset values. Transition Curves and Spirals can be defined by multiple Methods including length, deflection, offset, A-Value and RL-Value. RL-Value is the radius x length and the A-Value is the square root of the RL value.

8. Review the **Properties** of the just-placed curve.

Add Spiral Transitions to a Simple Arc

1. Review the Properties for the arc on the east side of the intersection.

2. Add a **35' [10m]** spiral to the back and ahead transitions of the arc.

   a. Expand the **Back Transitions** section.

   b. Change the *Type* to **Spiral**.

   c. Set the *Method* to **Length**.

   d. Set the *Length* to **35' [10m]**.

   e. Repeat the steps above to define a **35' [10m]** spiral for the Ahead transition.
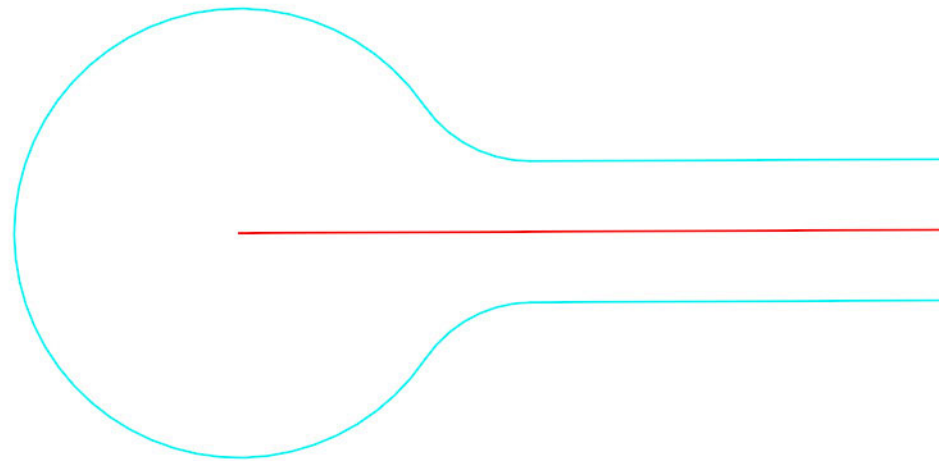
Exercise 7 - Create a Cul-de-Sac

Description

In this exercise you will learn how to create Cul-de-Sac geometry.

Skills Taught
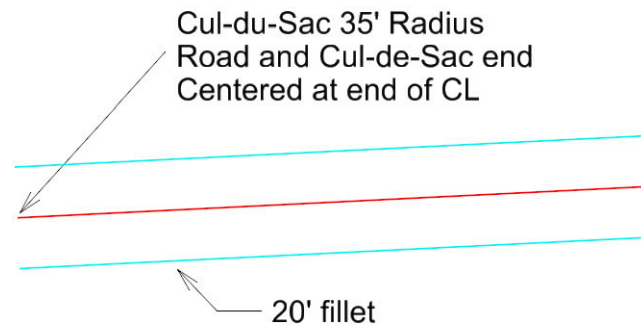
- Place Circle

- Simple Arc Between Elements

Place the Circle Geometry for the Cul-de-Sac

1. Zoom to the west end of East-West road.

2. Select *Geometry > Horizontal > Arcs > **Circle***.

3. At the *Enter Center Point* prompt, **snap** to the west end of the centerline.

Cul-du-Sac 35' Radius
Road and Cul-de-Sac end
Centered at end of CL

20' fillet

4. At the *Enter Through Point* prompt, type **35** *[10]* for the *Radius* and press the **Return** key to lock the value.

5. Place a **data point** anywhere to place the circle.
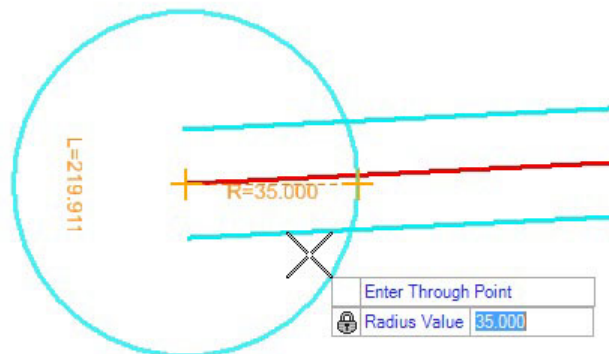
Define Transition from Road to Cul-de-Sac

1. Select *Geometry > Horizontal > Arc Between Elements >* **Simple Arc**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

2. At the *Locate First Element* prompt, click the **circle**.

3. At the *Locate Second Element* prompt, click on the **north Edge of Pavement**.

4. At the *Select Construction Sector* prompt, prompt, type **20** *[7]* and press the **Return** key to lock the value.

5. Position the cursor to construct the arc in the correct sector and **left click**.

6. At the *Trim/Extend Option* prompt, press the **Down Arrow** key until *Both* is displayed.

7. Place a **data point** to place the arc and trim the edges.

8. Repeat the steps above for the southern side of the cul-de-sac.
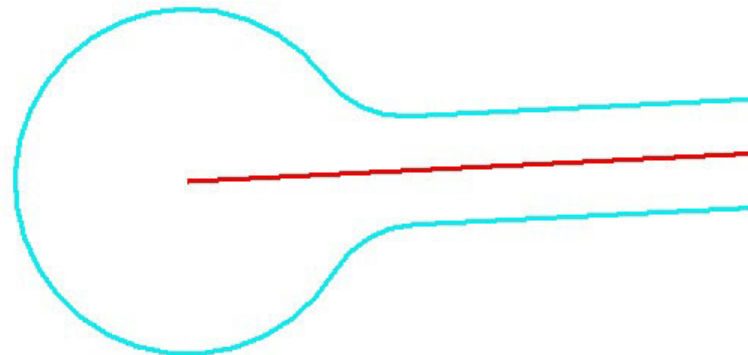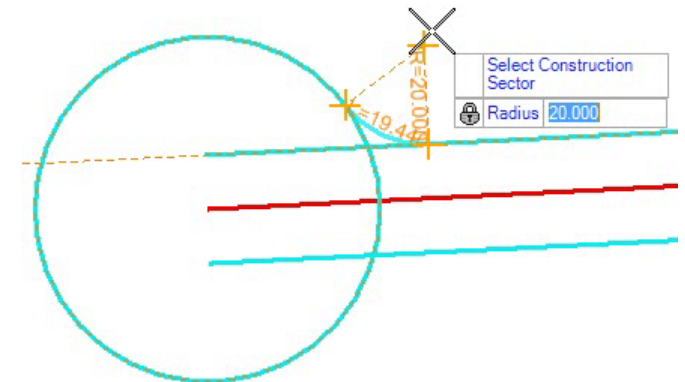
9. What happens if you move the Centerline?

Exercise 8 - Create a Driveway Perpendicular to the Centerline

Description

If you are widening or rehabilitating a road and are obligated to tie into existing driveways, how do you build your driveways? There are a variety of ways. In this exercise, we'll build a driveway that is perpendicular to the road.

Skills Taught

- By Angle From Element to create a line perpendicular to another element

- Single Offset Entire Element

- Simple Arc

- Reinforcing using snap and geometry construction tools to define design intent
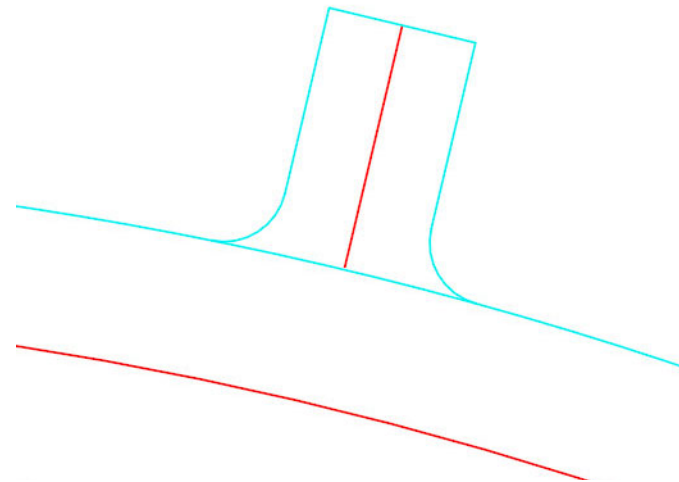
Place the Driveway Centerline

As can be expected, there are several ways to define the driveway centerline. We could use the *Place Line between Points* with a perpendicular snap. We can set the length of the driveway with an offset from the road. We could use Civil AccuDraw to locate the driveway. However, we'll use a tool tailored a little more specifically to our need *Line from Element By > Angle from Element*. It provides a little more control from the centerline element: skew angle and length.

---

1. Zoom to the midpoint of the curve in East-West road.

2. Set the active *Feature Definition* to **Alignment > Geom_Baseline_Driveway** in the *Feature Definition Toolbar*.

3. Select *Geometry > Horizontal > Lines > Line from Element >* **By Angle From Element**.

4. At the *Locate Element* prompt, click on the **north EOP of East-West road**.

5. At the *Enter Start Point* prompt, place a data point near the midpoint of the curve in East-West road. Any nearby location is okay.

6. At the *Enter Skew* prompt, press the **Left** or **Right Arrow** key until *Skew* is displayed. Type **90** and press the **Return** key to lock the value. Click to accept the value.

7. Press the **Left** or **Right Arrow** key again so that *Start Distance* is displayed. Type **0** and press the **Return** key to lock the value.

8. Place a data point to locate the start point.

9. At the *Enter End Distance* prompt, type **-20** *[-6]* and press the **Return** key to lock the value.

10. Place a data point to place the line.

11. Confirm the relationships of the line by clicking on it and reviewing the heads up display. Move the Line by dragging the move point.
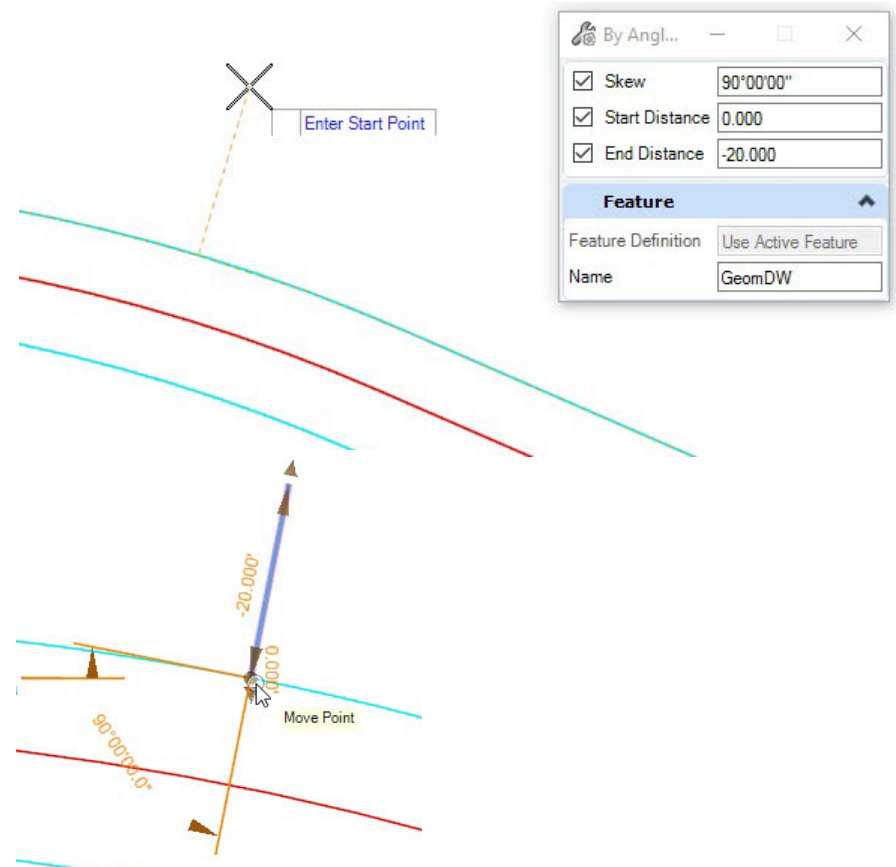
Create the Driveway Edges of Pavement

1. In the *Feature Definition* pull-down, select **Linear > Pavement > Road_EdgeOfPavement**.

2. Click *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Entire Element.**

3. At the *Locate Element* prompt, click on the **driveway centerline**.

    How wide is your driveway? Offset is equal to half this distance.

4. At the *Enter Offset* prompt, type **6** *[2]* and press the **Return** key to lock the value.

5. **Click** to accept the value.

6. At the *Mirror* prompt, press the **Down Arrow** key until **Yes** is displayed.
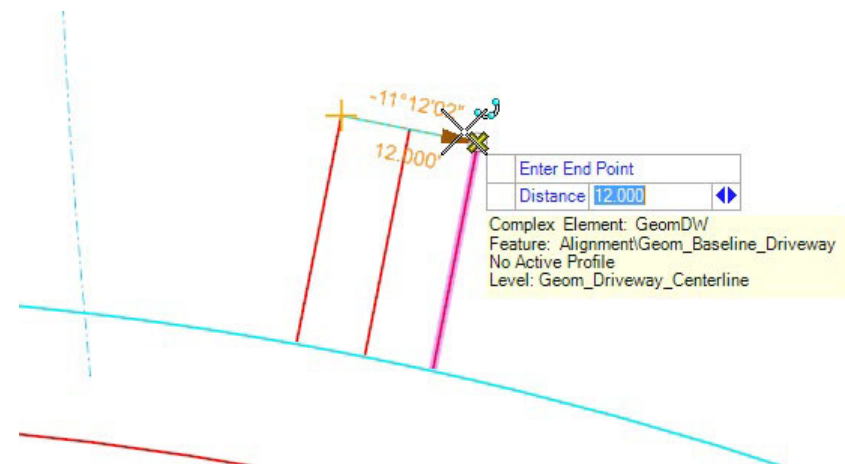
7. Place a data point to place the two offsets.

    Connect the ends. It's a driveway back, so an offset for curves is not necessary.

8. Click *Geometry > Horizontal > Lines >* **Line Between Points**.

9. At the *Enter Start Point* prompt, **snap** to the left back endpoint.

10. At the *Enter End Point* prompt, **snap** to the right back endpoint.

Add the Curb Returns

1. Click *Geometry > Horizontal > Arc Between Elements >* **Simple Arc**.

    The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

2. At the *Locate First Element* prompt, click a **driveway** edge.

3. At the *Locate Second Element* prompt, click on the **East-West road** *edge of pavement*.

4. Set the *Radius* to **5** *[1.5]* and press the **Return** key to lock the value.

5. Position the cursor such that the arc is being created in the correct sector and **click** to place the arc.

    We're going to add curb returns to driveways. We will <u>not</u> trim the road edge of pavement. The Trim/Extend prompt options are Both/None/Back/Ahead. Back means the first element selected, Ahead means the second. Whenever you are trimming only one element, sequence is important. It is a good practice to have a consistent pattern to which element you pick first which is the Back element. If you always pick the side road first, then you always pick Back to trim only the side road. Note that you can always fix the Trim/Extend setting in the Properties dialog.

6. Set the *Trim/Extend* option to **Back**.

7. Place a data point to place the arc and trim the edge.

8. Repeat the process for the other side of the driveway.

9. Experiment with the driveway. You can change the anchor point, skew angle, length, arc radii, etc. All relationships remain intact.
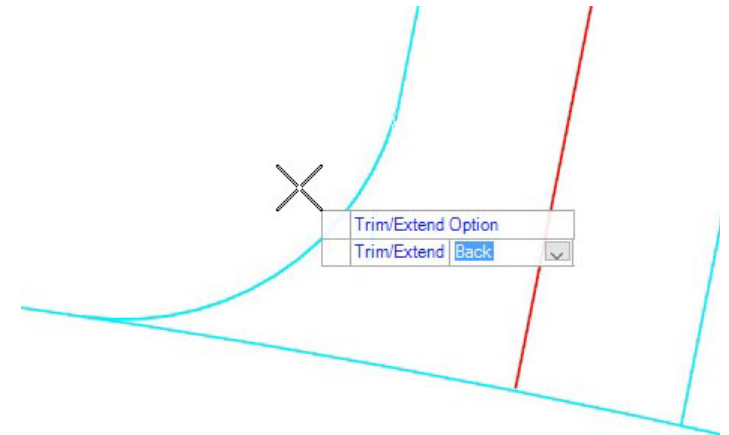
Exercise 9 - Create a Driveway Tied to Existing Driveway Centerline

Description

Here we build a new driveway that is perpendicular to the road and tied to an existing driveway centerline.

Skills Taught

- Single Offset Entire Element

- Single Partial Offset

- Create a line perpendicular to another element using snaps

- Intersection Snap

- Perpendicular Snap

- Trim to Intersection

- Simple Arc

- Reinforcing using snap and geometry construction tools to define design intent
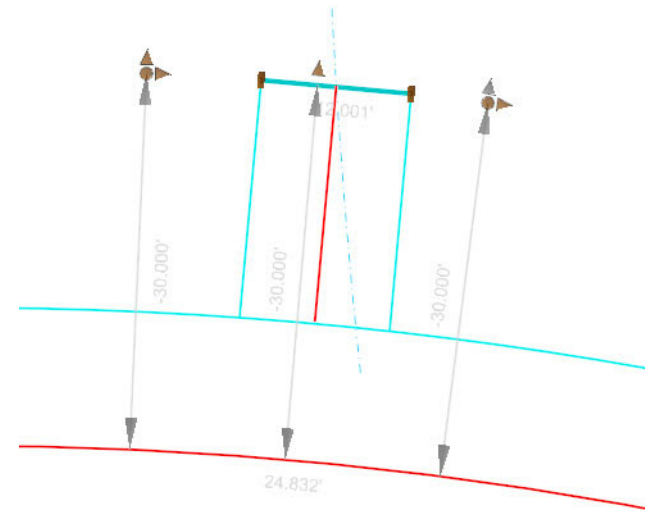
Define the Back of the Driveway

This is the location where the new driveway will intersect the existing driveway.

Two common "backs of driveway" are Right-of-Way lines or offsets from the roadway edge or centerline. We will offset the road centerline in this exercise.

---

1. Zoom to the left end of the curve in East-West road.

2. Select *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Partial**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

3. At the *Locate Element* heads up prompt, click the **centerline** of **East-West road.**

4. Set the *Start Offset* to **30** *[9]* and press the **Return** key to lock the value.

5. Make sure the *Distance: Start Distance* option is not locked.

   You may have to click the **End** key to unlock the Start position.

6. Once you're sure both values are correct, place a data point to the left of the driveway centerline (dash-dot line). Exact position is not required because we will be trimming it to the driveway sides.

7. Make sure that the *End Station* and the *Length* are unlocked.

8. Place a data point to the right of the driveway centerline. Exact position is not required because we will be trimming it to the driveway sides.

9. Set *Mirror* to **No**.

10. Place a data point to place the offset element.
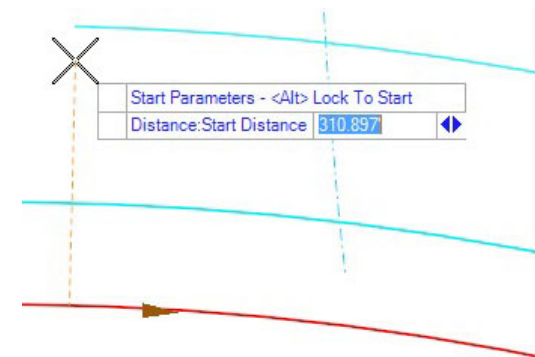
Place the Driveway Centerline Perpendicular to the Road

1. Set the *Feature Definition* to **Alignment > Geom_Baseline_Driveway** in the Feature Definition Toolbar.

2. Click *Geometry > Horizontal > Lines > **Line Between Points***.

3. Left-click on the **Intersection Snap** icon to make it active.

   A single click on the snap icon makes it active for only one snap action and then the active snap reverts to the previously active snap.
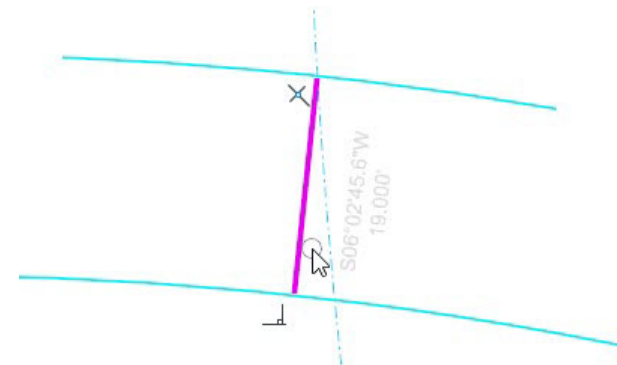
   A double click on the snap icon makes it the new active snap and it will stay active until changed.

4. At the *Enter Start Point* prompt, **snap** to intersection of the existing driveway centerline and the road offset (the driveway back line).
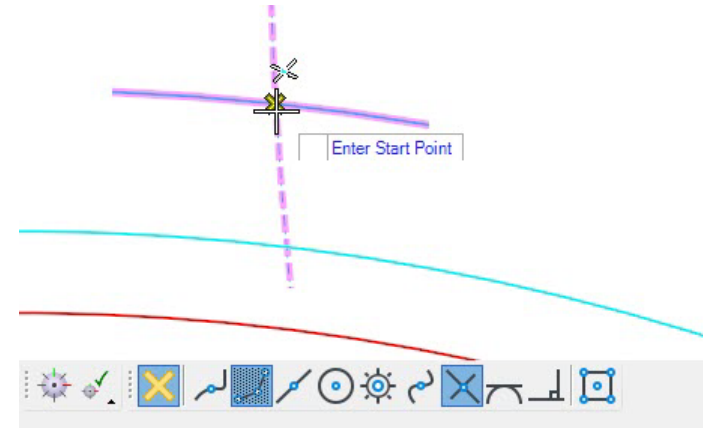
5. Left-click on the **Perpendicular Snap** icon to make it active.

6. At the *Enter End Point* prompt, **snap** to the north edge of pavement.

Place the Driveway Sides

1. In the *Feature Definition* pull-down, select **Linear > Pavement > Road_EdgeOfPavement**.

2. Define edges of the driveway

   a. Place the edges of the driveway using the *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Entire Element** tool.

      - *Offset* = **6** *[2]*

      - *Mirror* = **Yes**

3. Trim the Back Corners

   a. Select *Drawing > Modify >* **Trim to Intersection**.

   b. At the *Identify first element to modify* prompt, **click** the left side of the driveway.

   c. At the *Identify second element to modify* prompt, **click** the back of the driveway.

   d. At the *Identify first element to modify* prompt, **click** the right side of the driveway.
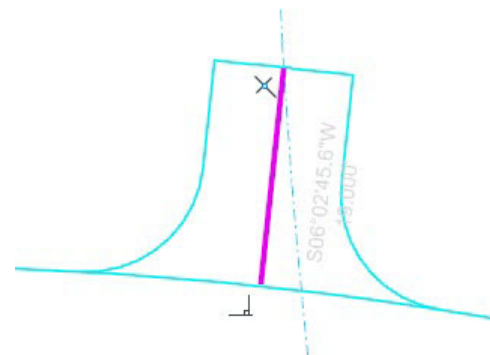
   e. At the *Identify second element to modify* prompt, **click** the back of the driveway.
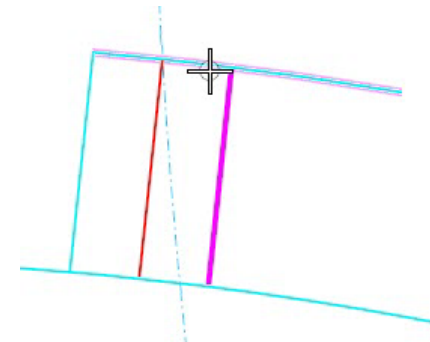
4. Add Arcs to the Driveway

   a. Use the *Geometry > Horizontal > Arc Between Elements >* **Simple Arc** tool to place **5** *[1.5]* radius arcs at the ends of the driveway. Do **NOT** trim the road edge of pavement.

Test the Driveway Geometry

1. Select **Set Mark**.

2. Confirm the rules by clicking on the elements. Note that there is less "flexibility" as the. centerline is constrained by the snaps - to the existing driveway and the perpendicular requirement.

   There is still a lot of adjustments that can be made. The offset of the driveway back can be changed or the road itself can be moved and the relationships still honored.

3. Can you change the offset to the back of the driveway?

   HINT: This is an interval element created when it was trimmed to the driveway sides. Select the element and then right click to get to the base element!

4. You can also remove the Snaps by dragging the appropriate edit handle. Keep in mind that you will lose the relationship of the snap. However, snaps can also be established by dragging an element handle and snapping to a new element.

5. Select **Undo to Mark** to undo the confirmation changes.
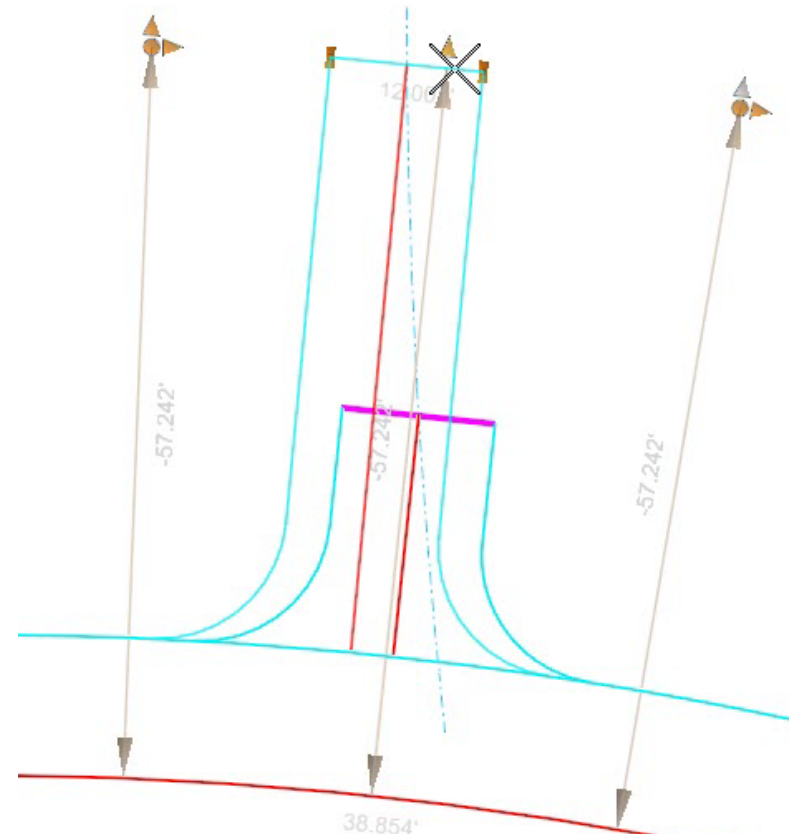
# Exercise 10 - Create a Driveway Matching Existing Driveway Sides

Description

Here we build a new driveway, matching the edges of an existing driveway.

Skills Taught

- Single Offset Entire Element

- Single Partial Offset

- Using a Zero Offset as a copy/match tool

- Trim to Intersection

- Simple Arc

- Reinforcing using snap and geometry construction tools to define design intent.
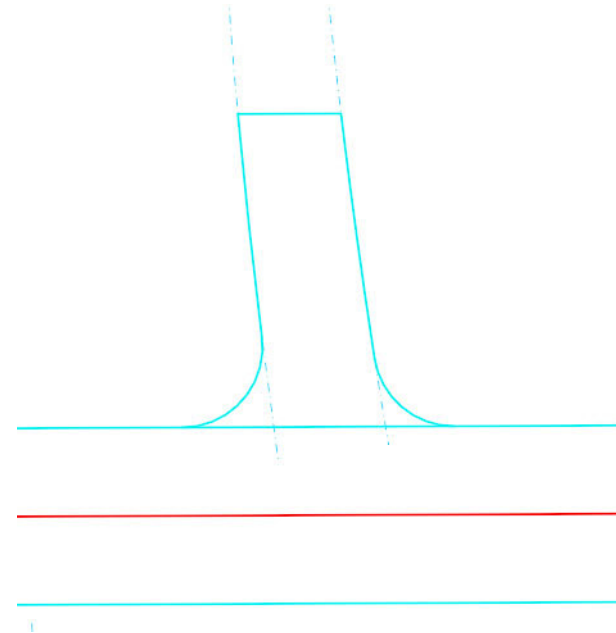
Define the Back of the Driveway

This is the location where the new driveway will intersect the existing driveway.

Instead of defining the back of driveway as an offset from the centerline as we are doing in this exercise, it could also be defined by an existing or proposed right of way line.

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1. Zoom left of the previous driveway where there are two parallel dash-dot lines that represent the edges of an existing driveway.

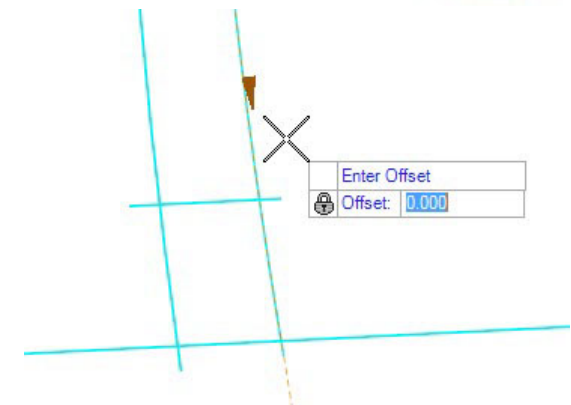2. Define the back of the driveway

   - Use the *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Partial** tool.

   - Define the back of the driveway offset **50'** *[15m]* from the centerline of the road.
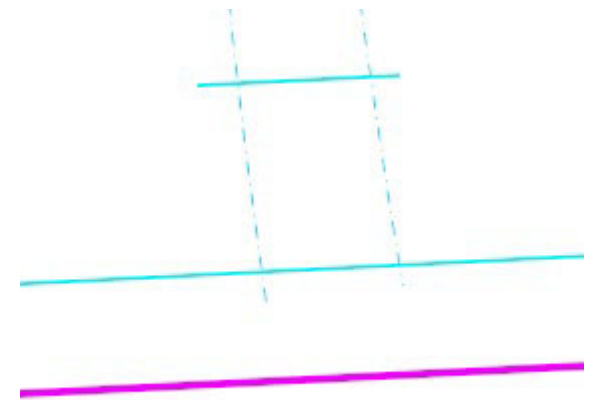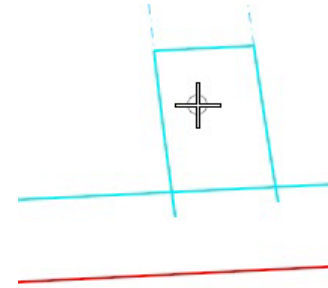
3. Place the sides of the driveway.

   - Use the *Geometry > Horizontal > Offsets and Tapers >* **Single Offset Entire Element** tool.

   - Use an *offset* of **0** to create the new sides of the driveway exactly on top of the existing edges of the driveway.

   - Repeat for both sides of the driveway

4. Trim the back corners of the driveway.

- Use the *Drawing > Modify > ***Trim to Intersection** tool.

- Trim both corners at the back of the driveway.

5. Add the arcs

- Use the *Geometry > Horizontal > Arc Between Elements > ***Simple Arc** tool.

- Add arcs between the driveway and edge of the roadway for both sides of the driveway.

- Use a **5' *[1.5m]*** radius.

- Only trim the edges of the driveway, not the edge of the roadway.
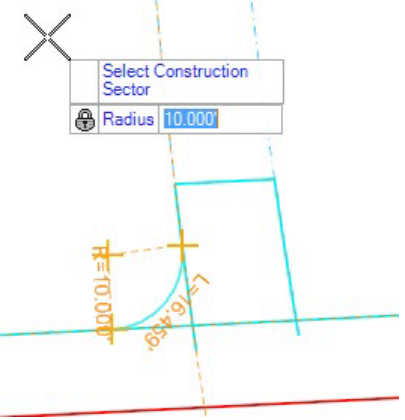
6. Test the driveway.

- Remember to use **Set Mark** and **Undo**!

- What happens if you change the back of driveway offset?

- What happens if you move the road centerline?
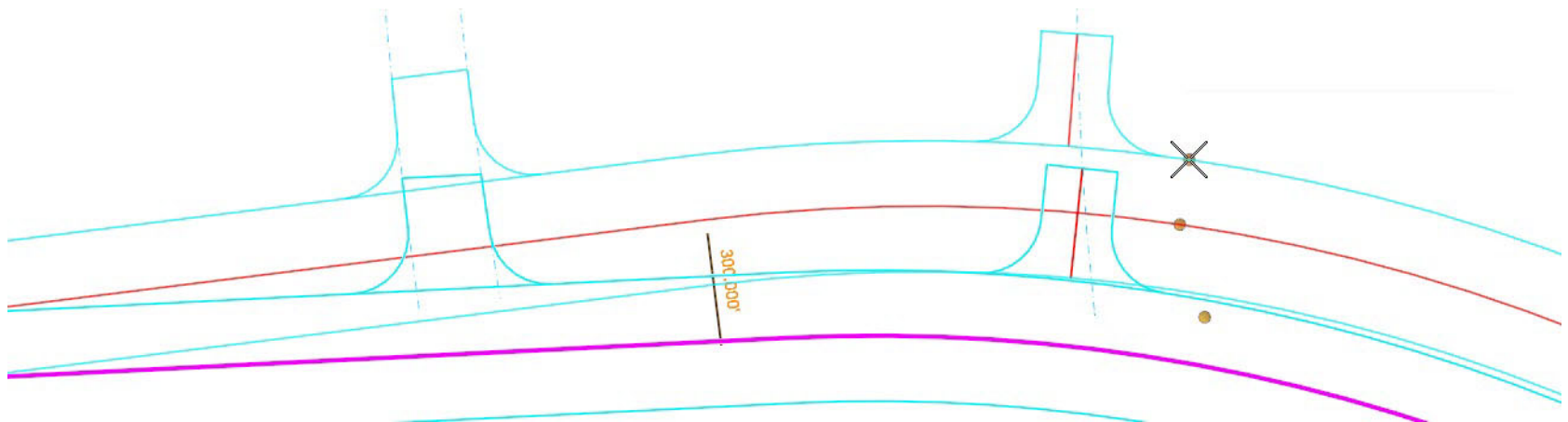
Exercise 11 - Understanding Rules and Relationships

Description

This exercise exercises your ability to change the geometry rules that define design intent relationships.

Skills Taught

- Creating Complex Elements
- Reviewing the Civil Model
- Simplify
- Deactivate Reference Rules
- Deactivate Rules
- Activate Rules
- Remove Rules

Creating Complex Elements

At this point we have wonderful, obedient, well-behaved edges of pavement, all defined by individual elements. They are as powerful as they need to be, but they have one shortcoming: individual elements are not particularly good for data management. Designers generally want to work with the length of a road's edge of pavement, not six little subsections.

The *Complex By Element* tool is used to group individual elements into logical, complex (grouped) elements. It's worth noting that the *Complex By Element* tool conveys no new powers upon the elements, which are as powerful as they can be. *Complex By Element* simply groups them together.

While horizontal work has benefits by Complexing the Geometry, for Profile work it's almost mandatory.

Profiles benefit dramatically from Complexed Horizontal Geometry. Vertical Geometry generally doesn't "stop" because its horizontal path changed from a tangent to a curve.

Complex By Element has two Methods: *Manual* and *Automatic*.

- *Manual* - You click each element in the correct order to add it to the group. Manually selecting which elements to complex together is often required on a complex project and projects with intersecting roadways. We will see why in the following exercises.

- *Automatic* - You click the first element and the software finds the next element and keeps adding elements whose ends are within a specified *Maximum Gap* distance of one another.

Names of the complex elements are important. Rule of Thumb: if it's important enough to complex, it's important enough to name. It only takes a few seconds.
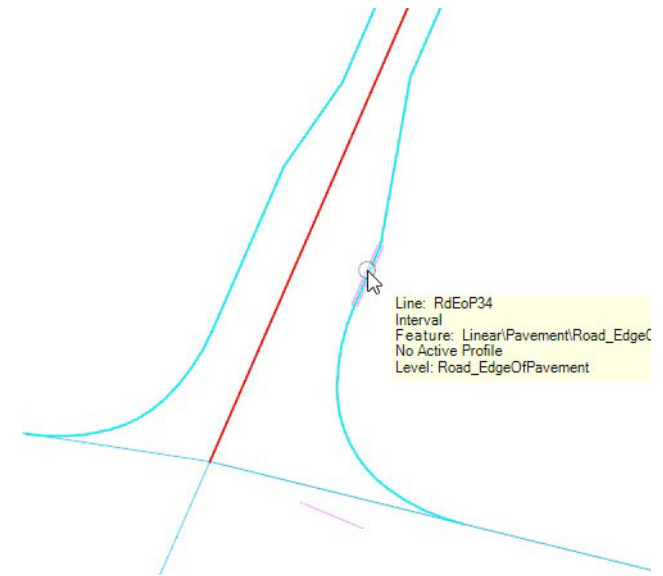
Manually Defining Complex Elements

The task is to group the individual edge of pavement elements along the North-South road.

1. Zoom the drawing so that both the **North-South** and **East-West** roads are visible.

    We will use the manual Complex by Element method in this exercise. If the automatic method is used, the complex element would include all connecting elements (including the intersection curb returns, the East-West road, and the cul-de-sac) shown in purple in the left image below. The manual method allows individual element to be selected and grouped. For the North-South road that should be the elements shown in green in the right image.
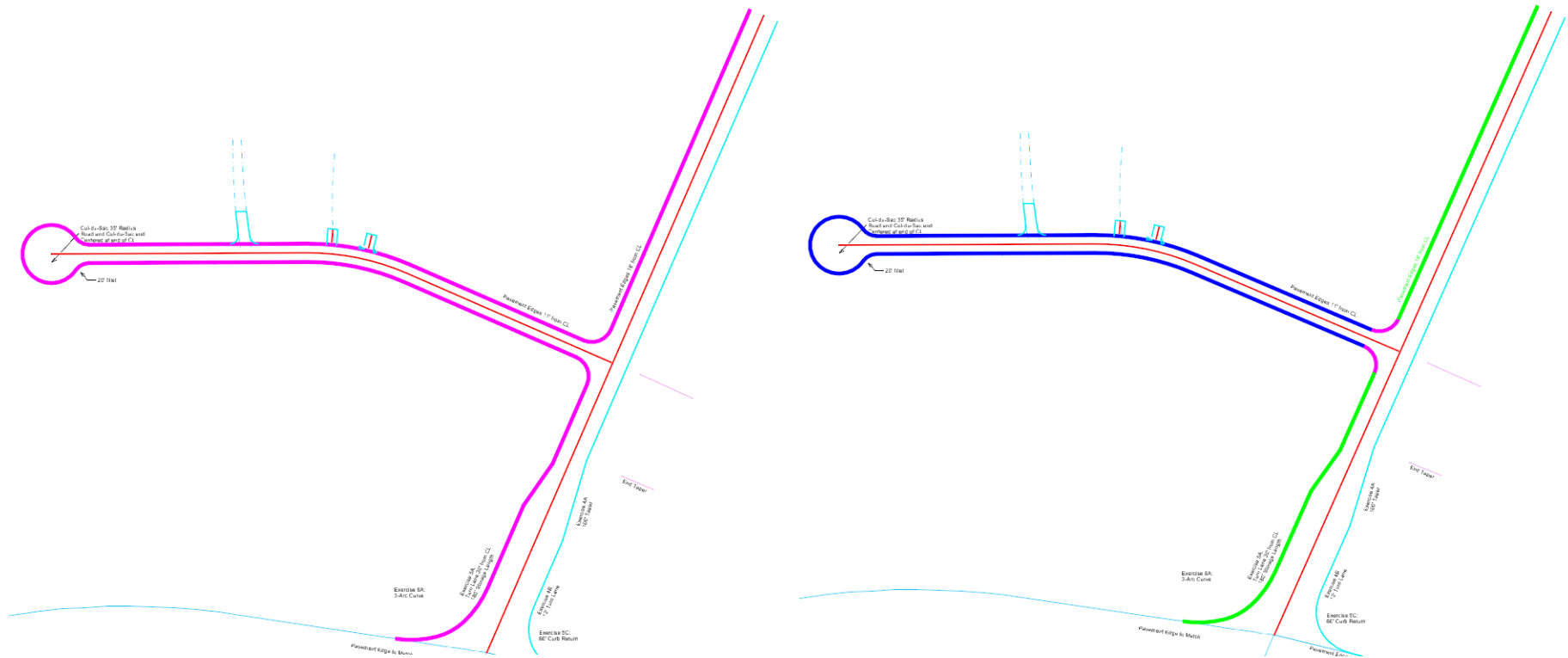
2. Select *Geometry > Horizontal > Complex Geometry > **Complex By Element***.

The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set.

Note that the resulting Complex Feature will be assigned the Feature Definition specified here, overriding the Feature Definition of the individual components, which may be different.

3. Set the *Method* to **Manual**.

4. Set the *Name* to a meaningful name such as: **North-South-Rd_LtEoP**.

5. At the *Locate First Element* prompt, click on the curb return on the southwest corner of North-South road.

Note: The Manual method assumes that the side of element's midpoint that you pick is the Starting side. Direction is determined from your click. The direction is indicated with an arrow.

The tool trusts that you pick the side you intend: it *will* allow a segment to have a direction opposite of an adjacent segment.

6. Make sure that the direction of the selection arrow is pointing toward the north.

7. At the *Locate Next Element* prompt, click the next pavement edge (the turn lane) for the east side of the North-South road.
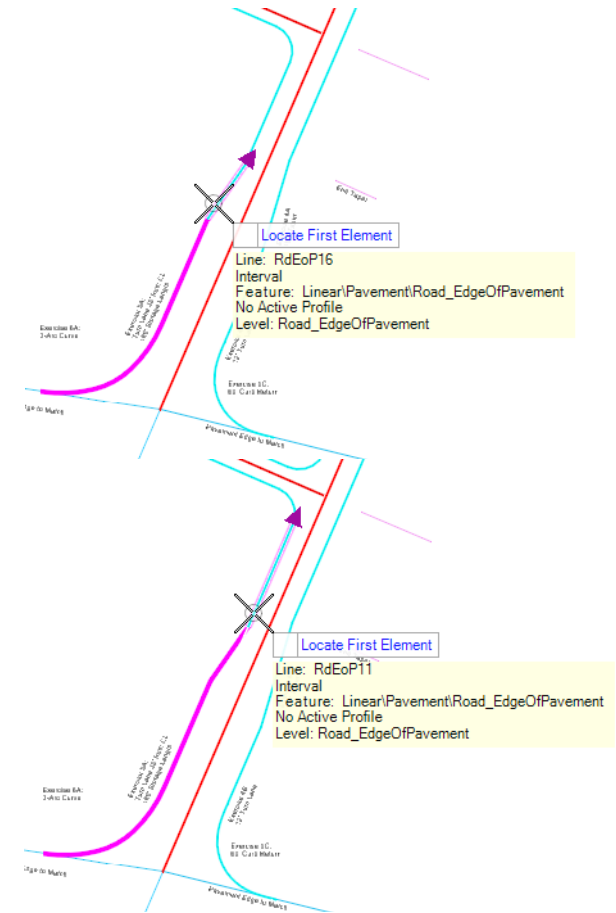
Make sure to pick the element to keep the direction pointed toward the north.
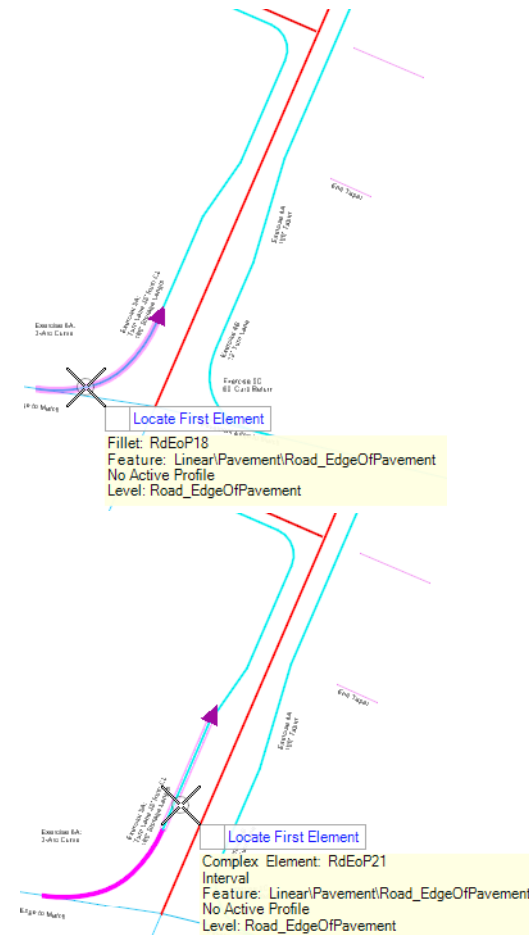
8. At the *Locate Next Element* prompt, click the next pavement edge (the taper) for the east side of the North-South road.

    Make sure to pick the element to keep the direction pointed in the proper direction.

9. At the *Locate Next Element* prompt, click the next pavement edge (the original side of the road) for the east side of the North-South road.

10. Make sure to pick the element to keep the direction pointed toward the north.

11. At the *Locate Next Element* prompt, click the next pavement edge (the original side of the road on the NORTH side of the intersection) for the east side of the North-South road.

   This time we are selecting a non-adjacent element! Complex elements can have gaps. This allows all of the edge of pavement to be grouped in a single element even though it has a gap at the intersection.

   In most modeling situations there would be a match line at the intersection but the match line would be an individual element, not part of the edge of pavement.

   Make sure to pick the element to keep the direction pointed toward the north.

12. After the last element is selected, at the *Locate Next Element* prompts, click away from any element (click nothing). This ends the Complexing and the complex element is created.

13. Select the new complex element and observe the manipulators.

   The manipulators are grayed out because they are for a base element that the selected complex element is dependent upon. Right-click to activate the base element.
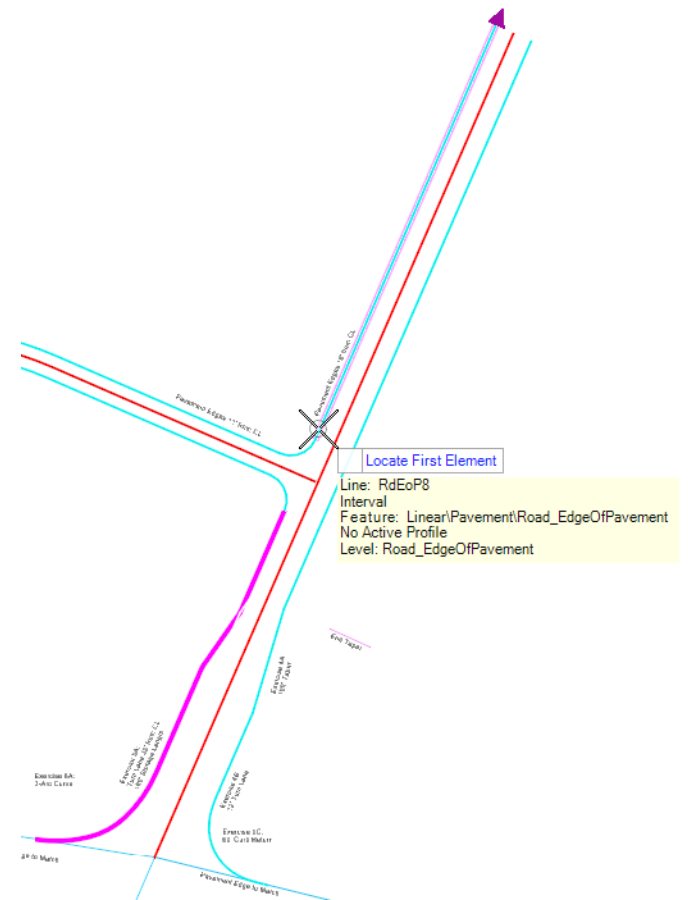
Automatically Defining Complex Elements

1. Select *Geometry > Horizontal > Complex Geometry >* **Complex By Element**.

   The *Feature Definition* should read "**Use Active Feature**". If not, make sure the *Use Active Feature Definition* toggle is set and the active Feature Definition is set to **Road_EdgeOfPavement**.

2. Set the *Method* to **Automatic**.

3. Set the *Name* to a meaningful name such as: **North-South-Rd_RtEoP**.

   Any elements whose endpoints are closer than the **Maximum Gap** distance will be Complexed. If there are multiple elements within the Maximum Gap, you will be prompted to select the "branch" to connect.

4. At the *Locate First Element* prompt, click on the curb return on the southeast corner of North-South road.

   NOTE: The side of element's midpoint that you pick is the starting side and adjoining elements will be located from the opposite end of the element. Direction is determined from your click. The direction is indicated with an arrow.

   OpenRoads will link all the elements within the Maximum Gap limits. It will highlight the elements it will complex.

5. At the *Accept Complex* prompt, left-click to end the complexing and create the complex element.

   The four edge of pavement elements on the right side of the road are complexed into a single element.
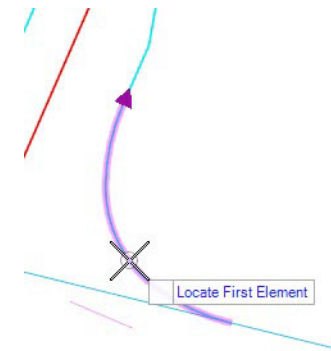
Reviewing the Civil Model

1. Open the *Home > Primary > **Properties*** dialog.

2. Select the right edge of pavement complex element created in the previous exercise.

3. Observe the manipulators.

   Notice that some manipulators are shown in gold/yellow text indicating they can be edited.

   Other manipulators are grayed. These manipulators are for base elements that the selected complex element is dependent upon. Right click to activate the base element and its manipulators become editable.

4. The top section of the properties dialog shows a tree view of the elements that make up this complex element. Explore this element tree.
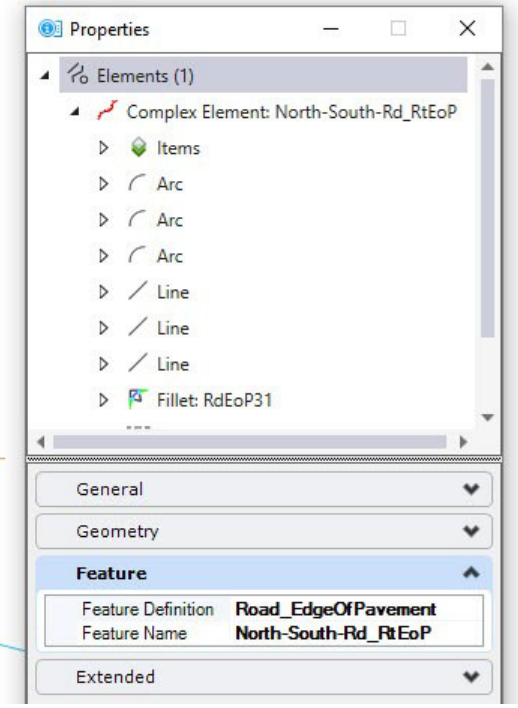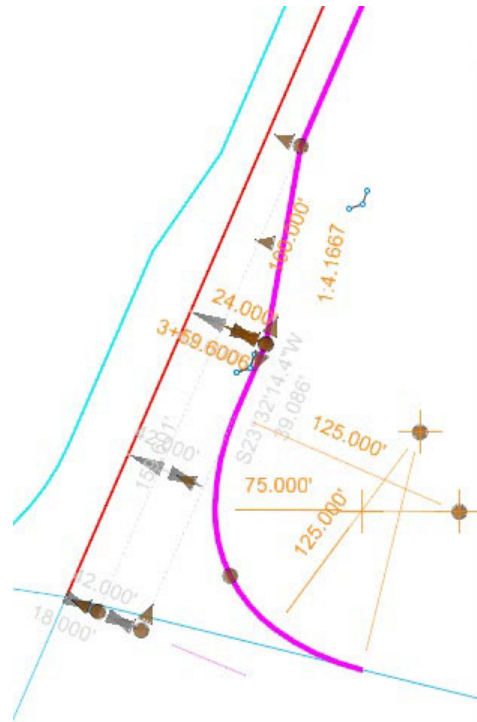
5. Open the *Home > Primary >* **Explorer** dialog.

6. Select the **OpenRoads Model** tab.

7. Expand **OpenRoads Model > Linear Geometry**.

   This is where the linear geometry features are shown grouped by Feature Definition. The Alignment features such as the centerline geometry are in *OpenRoads Model > Alignments*.

8. Expand the **Road_EdgeOfPavement** header.

   All of the simple and complex features that use the *Road_EdgeOfPavement* feature are listed.

9. Expand the **North-South-Rd_RtEoP** Complex Element.

10. Explore the tree structure that defines the ultimate element from all of its dependencies.

    Having a basic understanding of this tree structure which illustrates the relationships between geometry elements is beneficial.

    Notice that there are a number of elements with default naming such as **RdEoP19**. As discussed earlier in the class giving meaningful names to all of these intermediary geometry elements may not be practical. However, the more meaningful naming you can provide the easier it is to understand the geometry when reviewing in the OpenRoads Model and in reports. At a minimum make sure to give your final complex elements meaningful names.
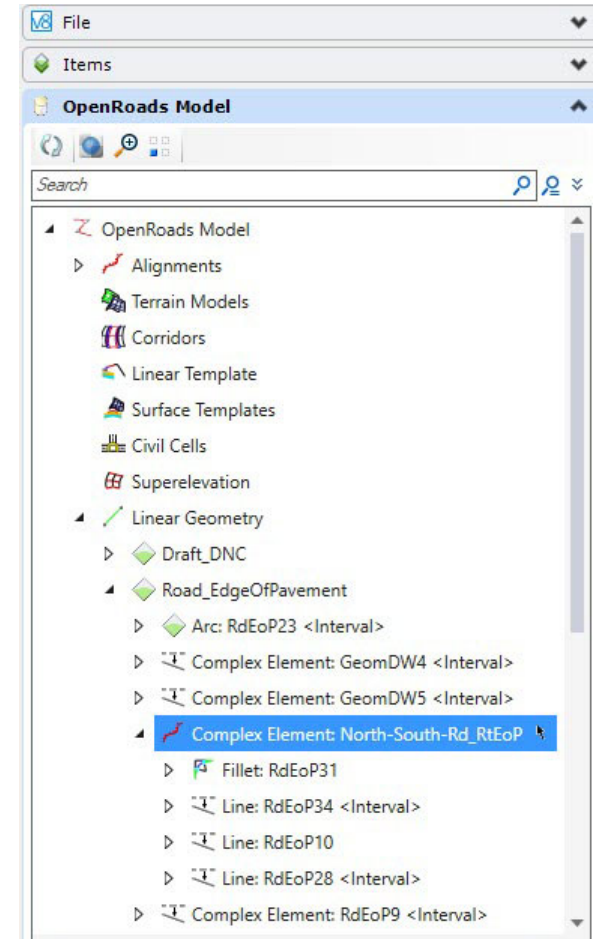
Managing Geometry Rules

We started the class by saying civil geometry is intelligent and contains engineering rules and snaps - the relationships - between elements. Rules always exist but sometimes our needs change and we need to forget some rule here or there, either temporarily or permanently. In this section you will learn how to manage, deactivate and activate civil geometry rules.

1. Zoom to the two crossing lines east of the North-South road.

2. Complete a Line-Arc-Line complex geometry.

   a. Set the active *Feature Definition* to **Alignment > Geom_Baseline**.

   b. Select the *Geometry > Horizontal > Arcs > Arc Between Elements > Simple Arc* tool.

   c. Disable the Radius option.

   d. Following the prompts, identify the first element, second element, and a point that the arc passes through.

   e. Use the *Geometry > Horizontal > Arcs > Complex Geometry> **Complex by Element*** tool to complex the line-arc-line into a single complex element.

3. Review the Complex Element

   a. Select the line-arc-line element created in the previous step.

   b. Review the rules.

      - Observe the direction and length of the tangents are not directly editable. These are base elements.

      - Observe the end points of the lines. Recall there are two tangents that crossed one another.

   c. Move one of the end points and observe how the arc maintains the pass through point.
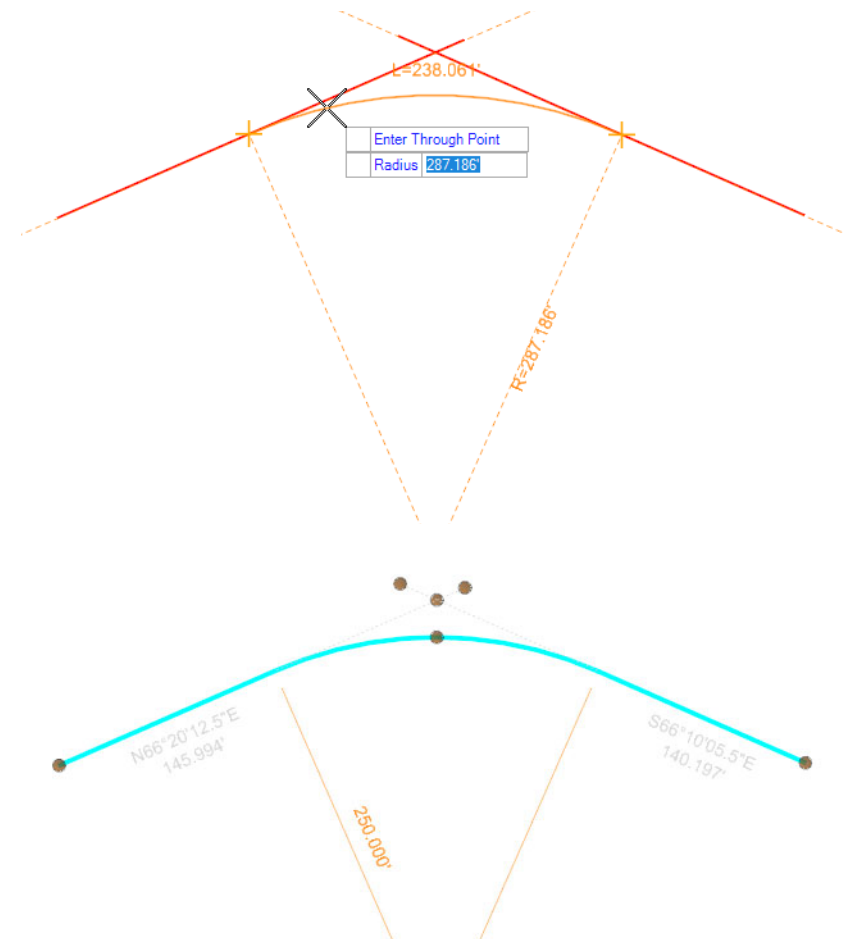
4. Simplify the complex, multi-element geometry

Simplify is a tool that "liberates" a feature from dependency on another feature or features. It maintains "smart" Civil rules, but they are free-standing geometry rules rather then rules that depend on other elements.

A common example is that you may have a ramp with geometry derived from two through lanes. Simplifying the ramp allows you to make intelligent edits not constrained to the through lanes.
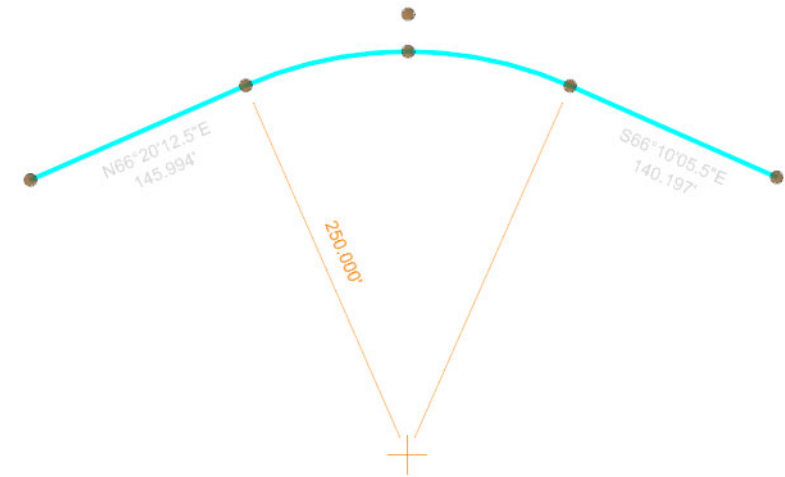
a. Select the *Geometry > Common Tools >* **Simplify Geometry** tool.

b. Select the line-arc-line element.

c. **Right click** (reset) to simplify the element.

d. Set the *Maintain Copy of Base Elements* option to **No**.

e. Select the line-arc-line element to review the rules.

 - Observe that the original crossing line elements are no longer part of the element. The geometry has been simplified to its most basic form. There are two tangents with a common point of intersection.

 - Move one of the end points and observe that the arc now maintains a fixed radius, not the pass through point. Again, the geometry has been simplified to its most basic form.

5. Define edge of pavements

a. Set the active *Feature Definition* to **Linear > Pavement > Road_EdgeOfPavement**.

b. Use the *Geometry > Horizontal > Offsets and Taper >* **Single Offset Entire Element** tool to define edges of pavement **20'** *[6m]* on both sides of the centerline.

c. Select one of the end point of the centerline and verify that the edges of pavement move with the centerline.

DO NOT DISTRIBUTE - Printing for student use is permitted
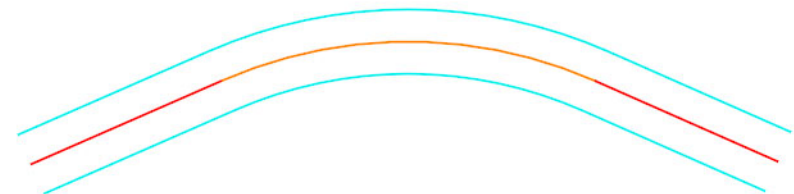
6. Deactivate <u>Reference</u> Rules so that an edge of pavement does not update when the element it depends on changes.

a. Select *Geometry > General Tools > Civil Toggles >* **Deactivate Reference Rules**.

b. Select the southern edge of pavement.

c. **Right click** (reset) to deactivate the rules.

d. Select the southern edge of pavement and notice that the offset manipulators are grayed out because the reference rules (between this element and another reference element) have been disabled.

e. Select the centerline and move one of the end point of the centerline to a new location. Notice that the northern edge of pavement follows but the southern does not because its rule to what it references is deactivated.
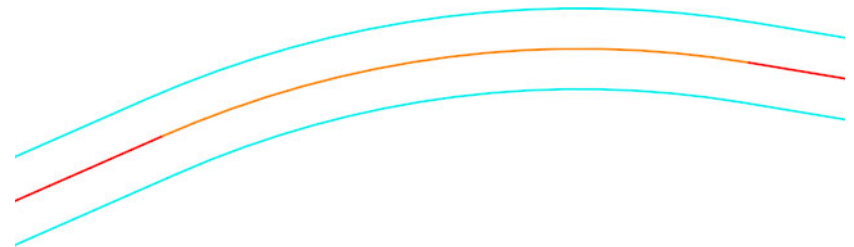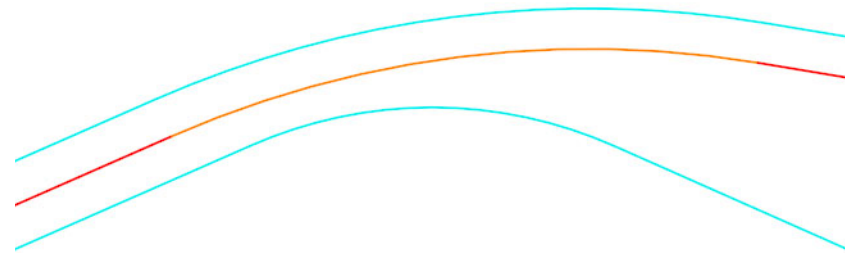
f. Select *Geometry > General Tools > Civil Toggles >* **Activate Rules**.

g. Select the southern edge of pavement.

h. **Right click** (reset) to activate the rules.

As soon as the rule is activated the relationship is evaluated and the geometry heals to once again conform to its rules.

7. Deactivating the Rules (not Reference Rules) on an element essentially makes it a read only element that cannot be changed.
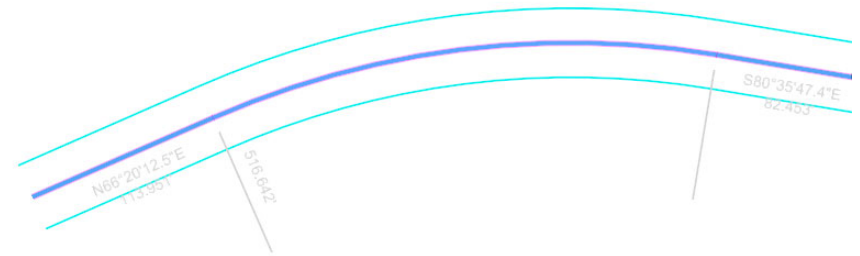
   a. Select *Geometry > General Tools > Civil Toggles >* **Deactivate Rules**.

      Notice the icon is a closed lock. Deactivating the rules *locks* the element so that it cannot be updated.

   b. Select the centerline.

   c. **Right click** (reset) to deactivate the rules.

   d. Select the centerline. Notice that the radius text manipulator is grayed out and the element cannot be edited. Also, there are no manipulators to move the geometry.
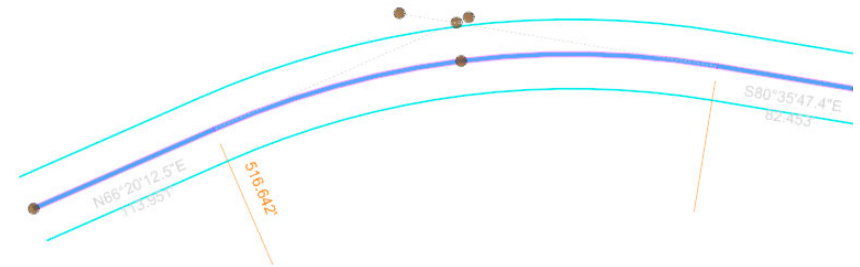
   e. Select *Geometry > General Tools > Civil Toggles >* **Activate Rules**.

      Notice the icon is an open lock. Activating the rules *unlocks* the element so that it can be updated.

   f. Select the centerline.

   g. **Right click** (reset) to activate the rules.

   h. Select the centerline. Notice that the radius manipulator is available to edit the element.

8. Rules can also be completely removed from an element.

   a. Select *Geometry > General Tools > Civil Toggles >* **Remove Rules**.

   b. Select the centerline.

   c. **Right click** (reset) to remove the rules.

   d. Select the centerline. Notice there are no rules. This is essentially a plain cad graphic now. Although it does still have a Feature Definition that defines its appearance and includes it in the OpenRoads model.
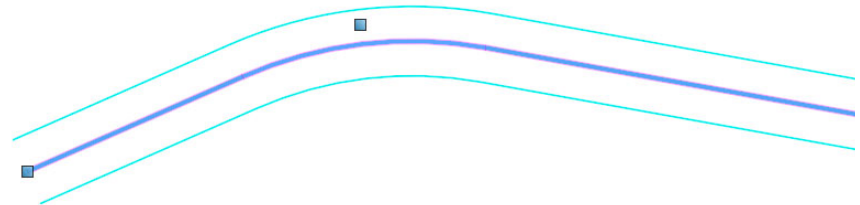
      TIP: Plain graphics can be assigned rules using the *Geometry > General Tools > Design Elements >* **Create Civil Rule Feature** tool.

Skills Assessment

The questions below will test your retention of the skills covered in this course.

1. When placing civil geometry elements rules and relationships are automatically created.

   a. True

   b. False

2. When enabled, the Persist Snap command will create snap rules that will be remembered and maintained when elements are modified.

   a. True

   b. False

3. Using the civil geometry offset tools allows the edge of pavement geometry to be dependent on the centerline geometry so if the centerline geometry changes the edge of pavement geometry automatically updates.

   a. True

   b. False

4. Civil geometry rules can be de-activated or removed at any time.

   a. True

   b. False

5. Which tools can be used to trim civil geometry elements (select all that apply).

   a. Trim To Intersection

   b. Extend Trim to Elements

   c. Trim to Element

   d. Trim Civil Geometry

   e. Trim/Extend option when placing arcs.

Skills Assessment - Answers

The answers to the skills assessment questions are highlighted below.

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1. When placing civil geometry elements rules and relationships are automatically created.

   a. **True**

   b. False

2. When enabled, the *Persist Snap* command will create snap rules that will be remembered and maintained when elements are modified.

   a. **True**

   b. False

3. Using the civil geometry offset tools allows the edge of pavement geometry to be dependent on the centerline geometry so if the centerline geometry changes the edge of pavement geometry automatically updates.

   a. **True**

   b. False

4. Civil geometry rules can be de-activated or removed at any time.

   a. **True**

   b. False

5. Which tools can be used to trim civil geometry elements (select all that apply).

   a. **Trim To Intersection**

   b. Extend Trim to Elements

   c. **Trim to Element**

   d. Trim Civil Geometry

   e. **Trim/Extend** option when placing arcs.

Summary

In this course you learned how to create edge of pavement geometric elements using the civil geometry tools. You have learned about rules and relationships, how to create, review and edit civil geometry elements.