Module 9

Resurfacing Grades

February 2025

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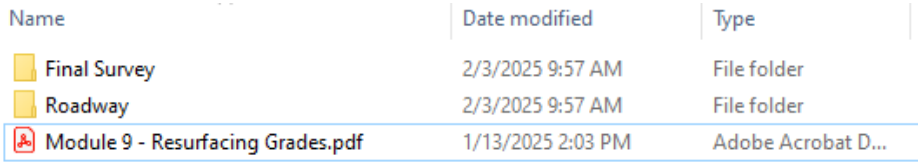
Module 9 – Resurfacing Grades

About this Practice Workbook...

- The Module 09 – Resurfacing Grades.Zip file will be provided for download.
- Exact the zip file to the root C:\
- All files are then automatically extracted here: C:\NCDOT Training\Roadway\Module 09 – Resurfacing Grades
- With these subfolders:



The Module 09 – Resurfacing Grades PDF will also be located here.

- This PDF file includes bookmarks providing an overview of the document. Click on the bookmark to quickly jump to any section in the file. You may have to turn on the bookmark function in your PDF viewer, such as Adobe Reader.

- The dataset used throughout this module uses English units and US Survey Feet.

- Each module is self-contained. You can jump to any module and begin the exercises.

- The ***NCDOT_WorkSets.inp*** on your desktop should be set the following variables:
  - **NCDOT_USE_LOCAL_WORKSETS = L2**
  - **NCDOT_UNIT_TRAINING_WORKSETS = Roadway**
- This module uses the **DOT-US North Carolina** WorkSpace, **Training-RD_R-2635C** WorkSet and **NCDOT_Roadway** Role. It is very important that you select the correct WorkSpace, WorkSet and Role.

- **For more information on setting up workspaces, click here.**

- The tool tips and help were copied from the Bentley Online Help. See this link for the complete list of tools and common usage.
  OpenRoads Designer CE Help (bentley.com)

- NCLUG/NCDOT Bentley ORD Open X presentations from each NCDOT Department:
  NCLUG - 2022 TECH Talks

- **This workbook was written with the release of OpenRoads Designer 2023**
  OpenRoads Designer_Readme (bentley.com)

Table of Contents

Overview

The Resurfacing Grades module provides practical guidance and introduces essential tools to help you develop resurfacing grades effectively. While these tools are valuable, successful roadway design ultimately relies on your engineering judgment and experience.

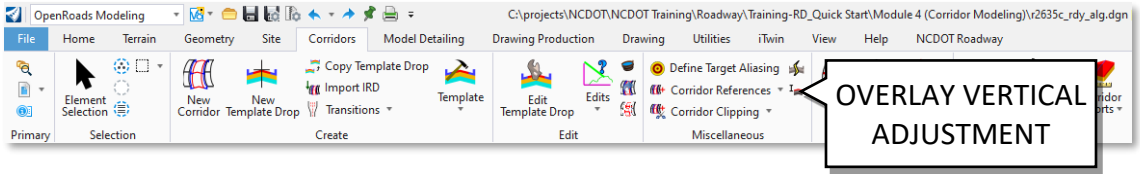
In this module, you will use two key tools: the Overlay Vertical Adjustment Tool to establish a Vertical Control Envelope, and the Best-Fit Profile Tool to create an initial profile that will require refinement. You'll also learn how to leverage ORD reporting features and other methods to streamline your workflow.

By integrating these tools and strategies, you'll be better equipped to apply sound engineering judgment and refine your resurfacing grades to meet specifications.

Key Concepts, Tools, and Terminology

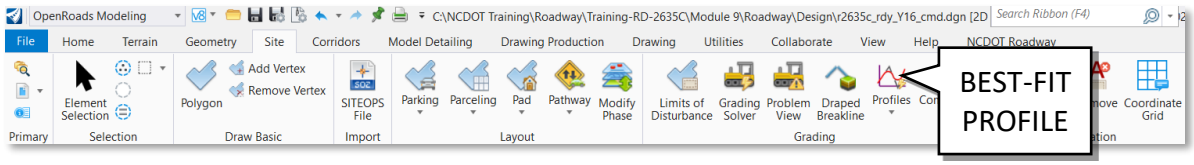
Overlay Vertical Adjustment (OVA) Tool

A tool within OpenRoads Designer is used to create and adjust the vertical alignment for resurfacing projects. It evaluates both the template and existing surfaces to calculate the necessary PGL elevation, minimizing the overlay above or the milling below the surface.



Best-Fit Profile Tool

The Best-Fit Profile tool enables users to create a complex profile that aligns with a selected existing profile, such as generating a new profile that matches an existing ground profile



It is important to clarify that the **Best-Fit Profile** tool located under **(Site > Grading > Profiles > Best-Fit Profile)** is distinct from the similarly named **Define Profile by Best Fit** tool found under **(Geometry > Vertical).** The **Define Profile by Best Fit (Geometry > Vertical)** tool offers limited utility and is not recommended for this purpose.

Resurfacing
The process of adding a new layer of asphalt or concrete over an existing road surface to improve its condition and extend its lifespan.

Profile Grade Line (PGL)
The line representing the elevation of the road's centerline.

Cross Slope
The cross slope refers to the slope of the road surface perpendicular to the direction of travel. In the context of roadway design, it is also known as superelevation.

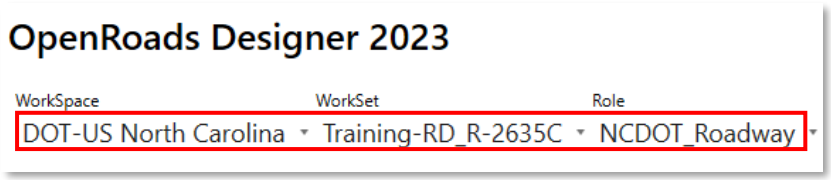
Resurfacing Grade Control Envelope
The Resurfacing Grade Control Envelope is a designated range that ensures the proposed resurfacing grade maintains structural integrity and aligns with existing road conditions. It serves as a guideline for design decisions, ensuring consistency with project standards and minimizing disruption to the underlying pavement.

Exercise 1 - Tools & Techniques for Resurfacing Grade Development

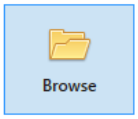
Exercise 1 focuses on the practical application of tools for developing resurfacing grades. You will use the **Overlay Vertical Adjustment** tool to create a **Vertical Control Envelope** and the **Best-Fit Profile** tool to generate an initial profile, which will require further refinement. This exercise primarily concentrates on an **Undivided Facility**, emphasizing hands-on techniques for accurately setting grades with these tools. While many concepts and techniques are applicable to both divided and undivided facilities, there are key differences that must be understood. While this exercise addresses an undivided facility, a subsequent exercise will focus exclusively on divided facilities, highlighting the critical distinctions and how to manage them effectively.

1. **Launch OpenRoads Designer 2023**
   Double-click on the OpenRoads Designer 2023 icon on your desktop to launch OpenRoads Designer.

2. **Set the Workspace and Workset**
   Select **DOT-US North Carolina** from the Workspace menu.
   Select **Training-RD_R-2635C** from the Workset menu.
   Select **NCDOT_Roadway** from the Role menu.

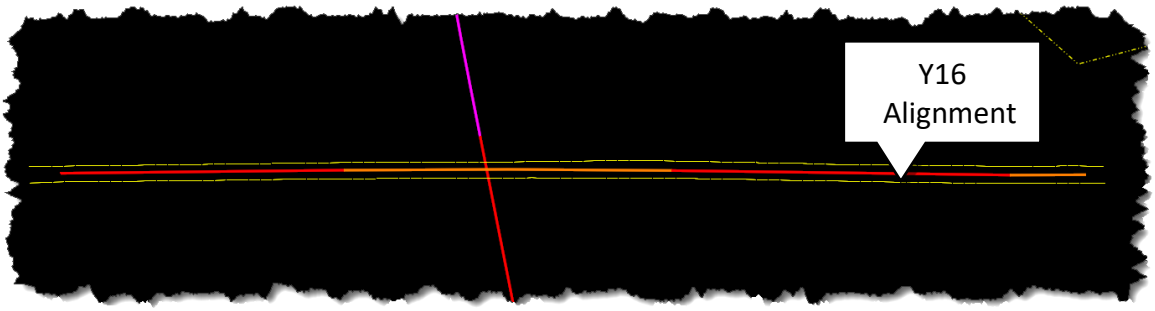


3. **Open the r2635c_rdy_alg.dgn file and zoom in closely to the Y16 Alignment**
   A. Click the **Browse** Button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg.dgn file.



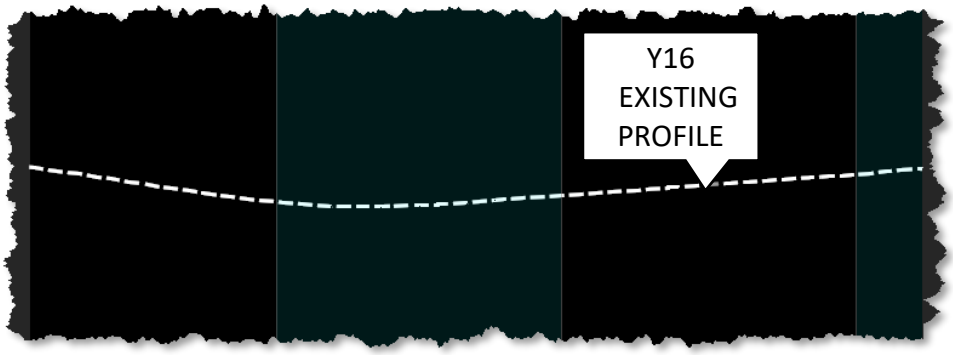
   B. Zoom in near the **Y16 Alignment** as shown below. The **Y16 Alignment** will be used throughout this exercise.

   Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.



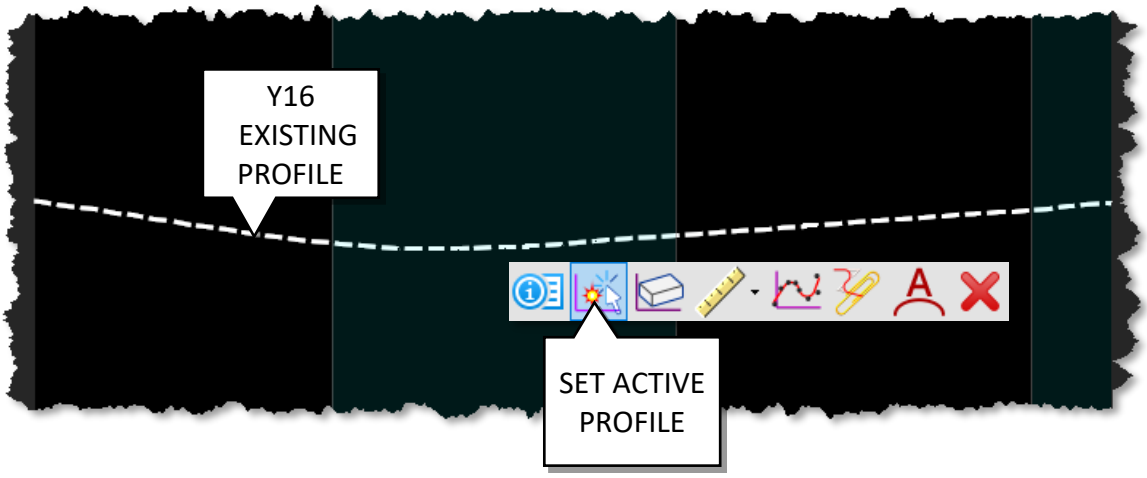
4. **Set the existing ground profile for the Y16 alignment as the active profile.**
   A. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**.

   B. Next, select a view to open when prompted to do so. This will open the **Y16 Profile View** as shown below.

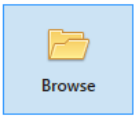


   Note: All existing ground profiles throughout module 9 are based on the R-2635C existing ground terrain model.

C. In the **Y16 Profile View**, left-click on the **Y16 Existing Profile** and pause briefly to display the toolbar as shown below. Next, activate the **Y16 Existing Profile** by selecting the **Set Active Profile** button, as illustrated.

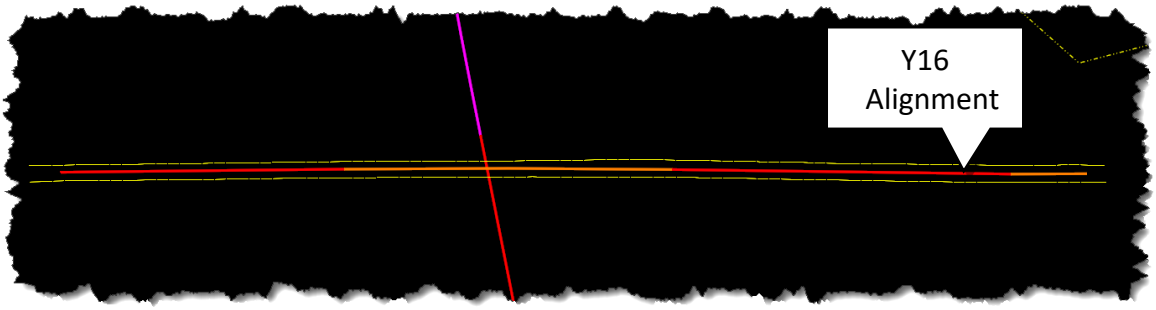


5. Set up a Corridor along the Y16 Alignment



A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder and open the r2635c_rdy_Y16_cmd.dgn file.

B. Zoom in near the **Y16 Alignment** as shown below.

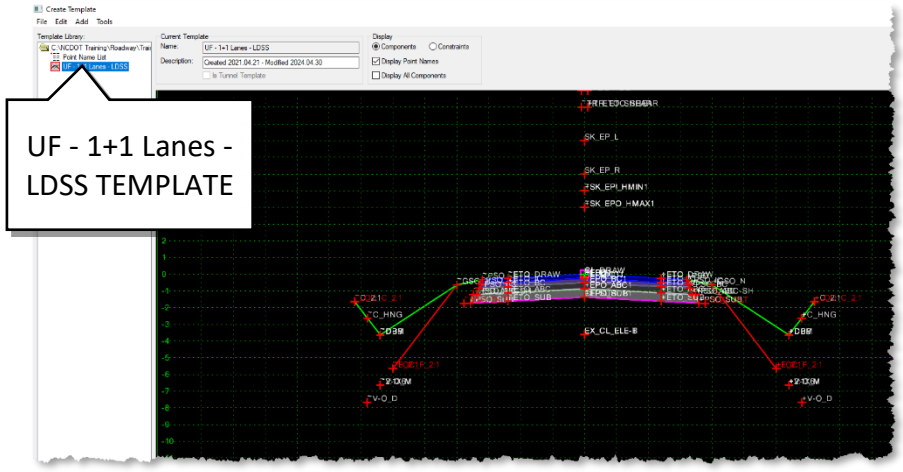


Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

C. Click on the **Create Template** button **(Corridors > Create > Template > Create Template)** to load the **Create Template** dialog.

D. Open the R-2635C (Training)_RDY.itl file located under the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder.

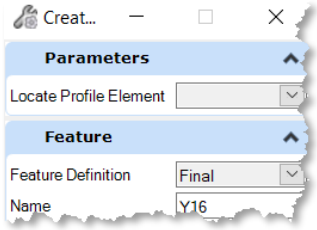
E. Notice the **UF - 1+1 Lanes - LDSS Template** as shown below.



Note: No specific template is required for this exercise. However, it is recommended to choose a template that closely aligns with the intended design, particularly in relation to the pavement and PGL (Proposed Grade Line). Understanding the differences between a divided and undivided facility is crucial in this context. Once you have established a working grade, there is no need to maintain the same template throughout the duration of the project.

F. Close the **Create Template** Dialog. This will set the **R-2635C Template Library** active while working on the **Y16 Corridor**.

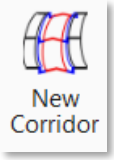
G. Set the following **Parameters** using the **Create Corridor Dialog** and click through the prompts that follow.



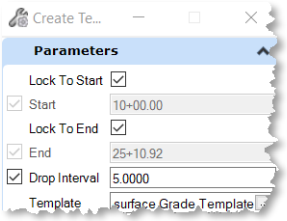
- **Feature Definition** = **Final**
- **Name = Y16**

Note: NCDOT recommends using the "Final" design stage feature definition when utilizing a corridor to develop a grade.

H. Next, click the **New Corridor** button **(Corridors> Create > New Corridor)** and select the **Y16 Alignment** when prompted to **Locate Corridor Baseline** and **Right-Click** to use the **Active Y16 Profile**.



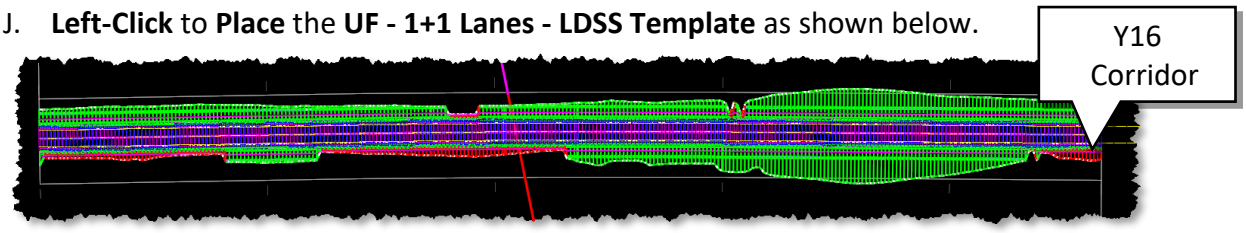
I. This will open the **Create Template Drops Dialog**. Set the following **Parameters** within the **Create Template Drops Dialog**.



- **Start = Lock to Start**
- **End = Lock to End**
- **Drop Interval = 5**
- **Template = UF - 1+1 Lanes - LDSS**

Note: NCDOT recommends using a 5’ drop interval when utilizing a corridor to develop a grade because it will provide very accurate data.

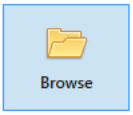
J. **Left-Click** to **Place** the **UF - 1+1 Lanes - LDSS Template** as shown below.



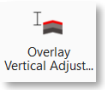
6. Explore and become familiar with the Overlay Vertical Adjustment Tool

Note: Bentley's implementation and explanation of the Overlay Vertical Adjustment tool has introduced unnecessary complexity, as the Backbone Thickness and Minimum Overlay Thickness parameters are effectively interchangeable in determining the final surface elevation. NCDOT recommends setting the Backbone Thickness to 0.0’ and adjusting only the Minimum Overlay Thickness, rather than configuring both. We will provide examples to clarify this.

A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg.dgn file.

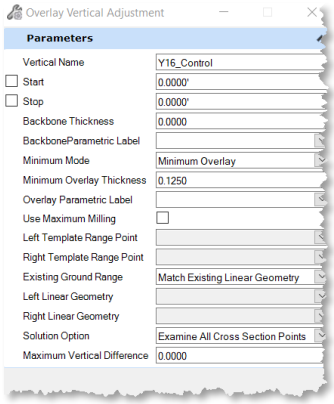


B. Click on the **Overlay Vertical Adjustment** button **(Corridors > Miscellaneous > Overlay Vertical Adjustment)** to load the **Overlay Vertical Adjustment** dialog.



C. Please review the options and parameters within the **Overlay Vertical Adjustmen**t dialog box provided below. This information is provided for reference purposes only. Those interested in fully utilizing this tool are encouraged to take the time to explore and experiment with its features. However, for the purposes of **Module 9 - Resurfacing Grades**, we will focus solely on the elements relevant to this module.

- **Backbone Thickness** - This parameter defines the vertical distance from the **Profile Grade Line (PGL)** to the bottom of the **Backbone** components. It's redundant and can be managed through the **Minimum Overlay Thickness** parameter. To avoid confusion, I recommend setting it to 0 instead (see examples on the following pages for clarity).



- **Minimum Mode**
  - **Minimum Overlay** - When specified, it evaluates the existing surface to find the control point closest to the bottom of the backbone, using that elevation to calculate the centerline elevation.
  - **Minimum Milling** - When specified, the existing surface is evaluated to find the control point farthest from the backbone, and the vertical adjustment is made to align the backbone with that point.

- **Maximum Milling Toggle** - When enabled, it limits the depth of milling to prevent removing too much pavement, ensuring the process follows design specifications.

- **Maximum Vertical Difference** - Generally, this value should remain at 0. If greater than 0.0, the program compares the Adjusted Vertical elevation between stations to ensure the difference does not exceed this value.

- **Minimum Overlay Thickness** - Is the minimum allowable thickness of overlay material that can be applied to the existing surface during vertical adjustment.

- **Solution Option** – Always use the Examine All Cross Section Points option.

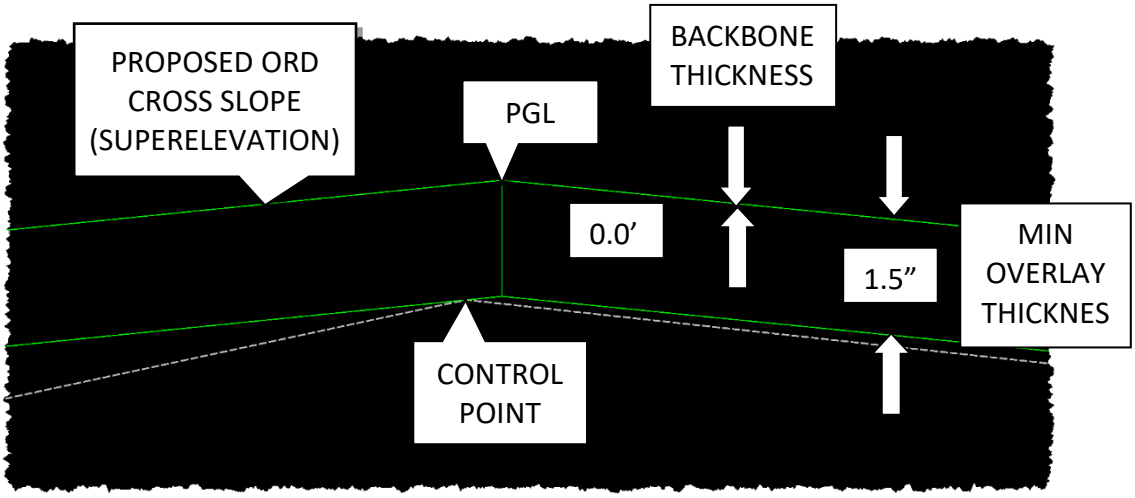
- **Existing Ground Range** – The portion of the existing surface that will be considered for the vertical adjustment. This typically represents existing asphalt. There are a few options to define how this information is provided.

Note: Please refer to the examples on the following pages for more clarity and to provide the necessary context.

D. The following examples demonstrate two parameter variations for the **Overlay Vertical Adjustment** tool using the **Minimum Overlay** method. It is important to note that the **Minimum Overlay Thickness** and **Backbone Thickness** parameters are interchangeable. Therefore, NCDOT recommends setting the **Backbone Thickness** to **0.0'** and adjusting only the **Minimum Overlay Thickness**, rather than configuring both parameters. These examples are provided for clarity and guidance in applying this approach.

Example 1 – Minimum Overlay Method

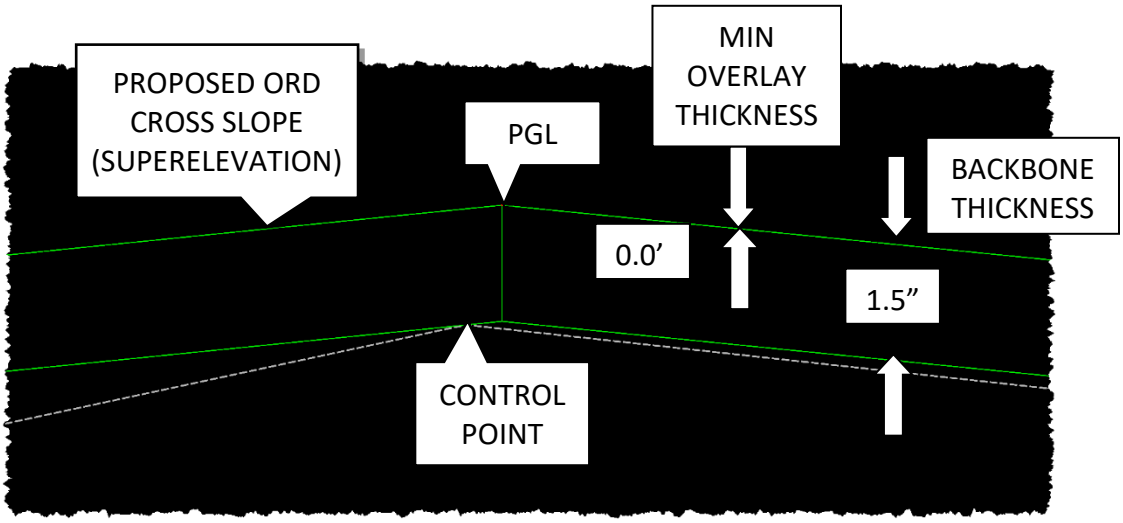
1.5" Minimum Overlay Thickness with Backbone Thickness Value of 0.0'



Note: In the image above, the control point marks where the bottom of the 1.5-inch Minium Overlay Thickness meets the existing asphalt, with the backbone thickness at 0.0' in this example. To determine the PGL (Profile Grade Line), we add the 1.5-inch overlay thickness to the control point's elevation and project the Proposed ORD Cross Slope (superelevation) toward the centerline of the roadway. The superelevation (variable) is applied based on project-specific settings, not template defaults.

Example 2 – Minimum Overlay Method

0.0’ Minimum Overlay Thickness with Backbone Thickness Value of 1.5”

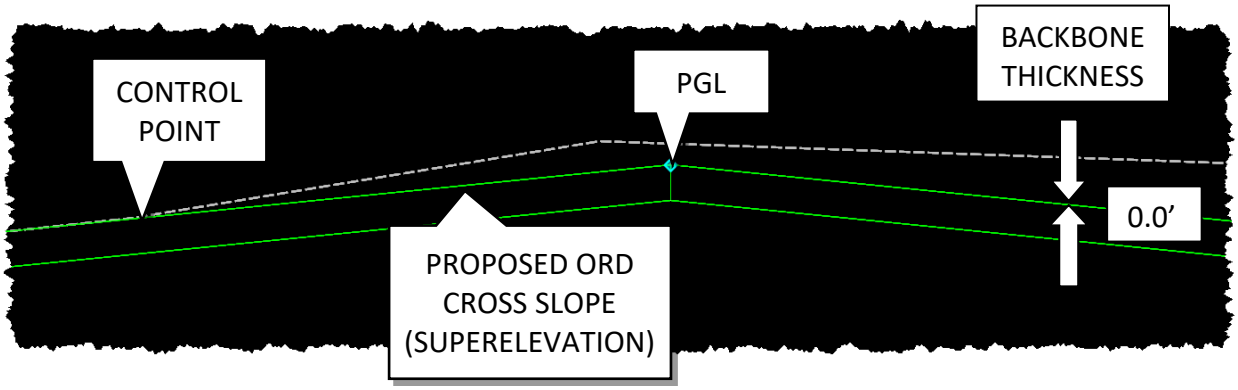


Note: In the image above, the Control Point marks where the bottom of the 1.5-inch Backbone thickness meets the existing asphalt, with the Minimum Overlay Thickness at 0.0’ in this example. To determine the PGL (Profile Grade Line), we add the 1.5-inch Minimum Backbone thickness to the Control Point's elevation and project the Proposed ORD Cross Slope (superelevation) toward the centerline of the roadway. The superelevation (variable) is applied based on project-specific settings, not template defaults.

E. The following examples demonstrate two (2) parameter variations for the **Overlay Vertical Adjustment** tool using the **Minimum Milling** method. Please note that this method will not be utilized in **Module 9** and is provided solely for informational purposes. For those interested in fully exploring this tool, it is encouraged to take the time to review and experiment with its features.

Example 1 - Minimum Milling Method

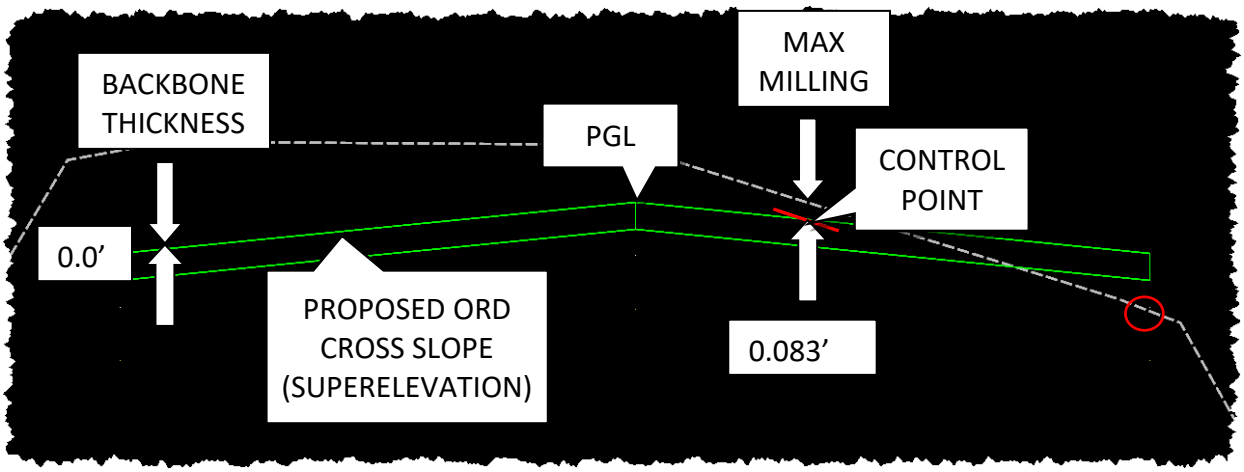
Backbone Thickness Value of 0.0' with the Use Maximum Milling option disabled



Note: In the image above, the Control Point marks the lowest point along the existing asphalt where it meets the bottom of the backbone. To determine the PGL (Profile Grade Line), we project the Proposed ORD Cross Slope (superelevation) from the Control Point toward the centerline of the roadway. The superelevation (variable) is applied based on project-specific settings, not template defaults.

Example 2 - Minimum Milling Method

Backbone Thickness Value of 0.0’ with the Use Maximum Milling option Enabled and a Maximum Milling Thickness of 0.083’ (1-inch)

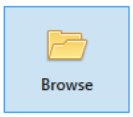


Note: In the image above, the Control Point is marked at the lowest point along the existing asphalt where it meets the bottom of the backbone, which has a thickness of 0.0, and is determined by the Maximum Milling Thickness of 0.083’ (1 inch). Without this specified limit, the Control Point would align with the small red circle, exceeding the allowable milling thickness at that location. Therefore, the Control Point is adjusted to the Maximum Milling Thickness to ensure compliance with specified constraints. To determine the PGL (Profile Grade Line), we project the Proposed ORD Cross Slope (superelevation) from the Control Point toward the centerline of the roadway

F. You may find it helpful to spend additional time exploring the various options within the **Overlay Vertical Adjustment** tool, as it tends to be more complex than necessary for its intended purpose. Familiarizing yourself with its features will help you navigate its functionality more efficiently.

G. Please exit the **Overlay Vertical Adjustment** tool.

7. **Create a Resurfacing Grade Control Envelope for the Y16 Corridor**



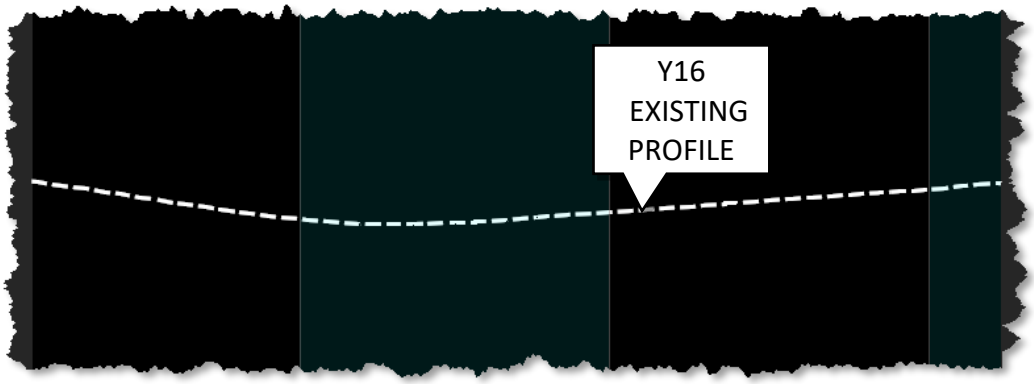
A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg.dgn file.

B. Zoom in near the **Y16 Alignment/Corridor** as shown below.

Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

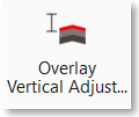
C. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**.

D. Next, select a view to open when prompted. This action will open the **Y16 Profile View**, as illustrated below. At this point, you should have two (2) views open: the **Plan View** and the **Y16 Profile View**.

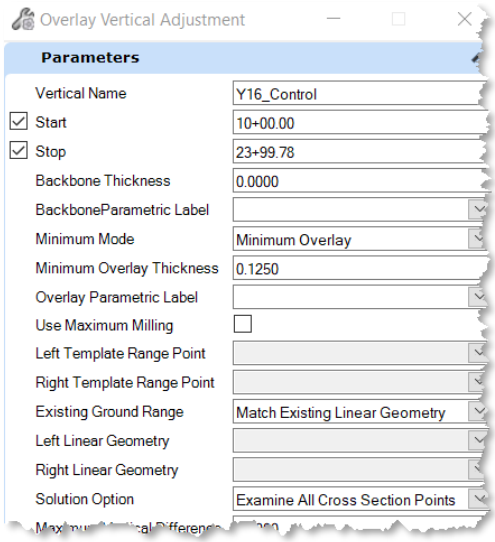


Note: The Profile View needs to be open in order to use the Overlay Vertical Adjustment tool.

E. While keeping the **Y16 Profile View** open, click on the **Overlay Vertical Adjustment** button **(Corridors > Miscellaneous > Overlay Vertical Adjustment)** and select the **Y16 Corridor** from the plan view when prompted to do so.

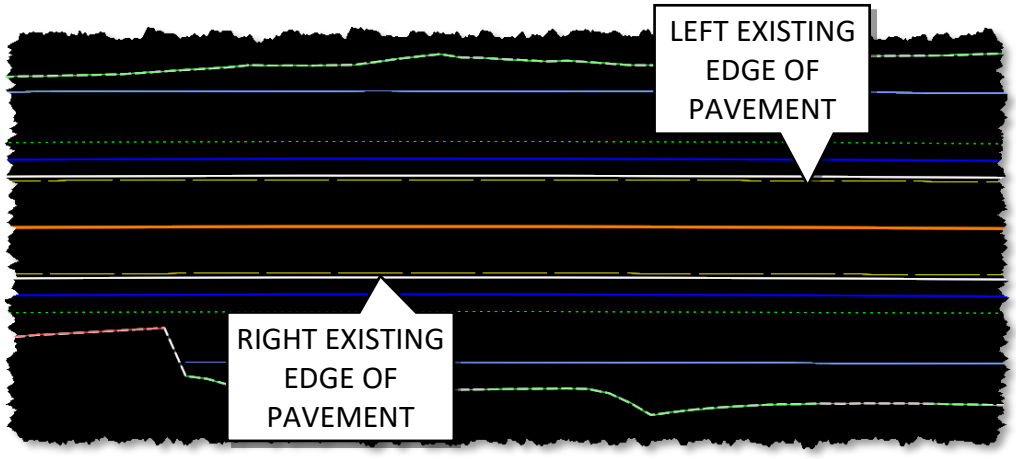


F. This will open the **Overlay Vertical Adjustment** tool. Set the following **Parameters** within the **Overlay Vertical Adjustment** dialog.



- **Vertical Name = Y16_Control**
- **Start = 10+00.00**
- **Stop = 23+99.78**
- **Backbone Thickness = 0.0000**
- **Minimum Mode = Minimum Overlay**
- **Minimum Overlay Thickness = 0.1250**
- **Left Template Range Point = ~ETO**
- **Right Template Range Point = +ETO**
- **Existing Ground Range = Match Existing Linear Geometry**
- **Solution Option = Examine All Cross Section Points**
- **Maximum Vertical Distance = 0.0000**

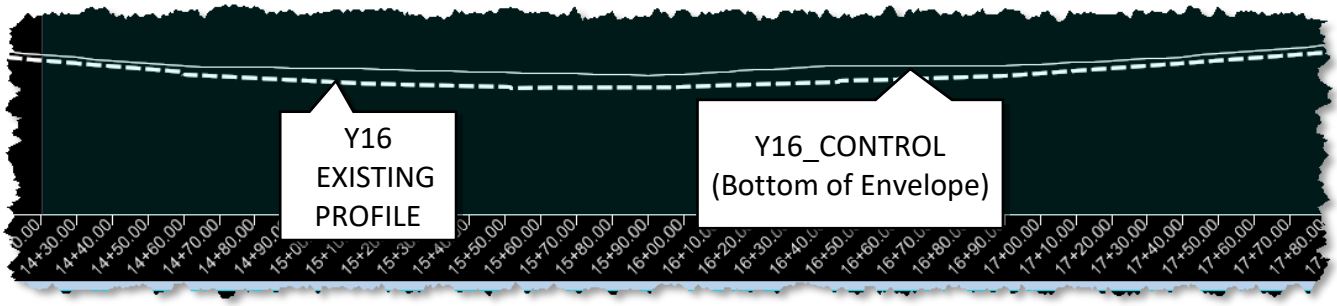
G. After confirming the **Existing Ground Range** parameter and accepting the **Match Existing Linear Geometry** value, you will be prompted to locate the **Left** and **Right Linear Geometry**. At this stage, select the corresponding **Left** and **Right Existing Edge of Pavement** elements, as displayed in the illustration below.



H. Then, continue left-clicking through the remaining prompts until you have completed the process.

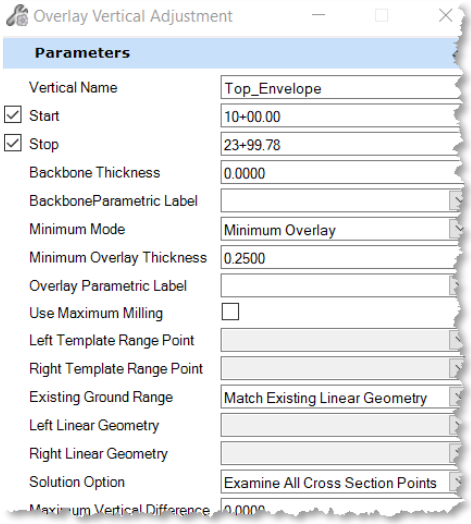
Note: Upon completion of this process, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed.

I. Now, examine the **Y16 Profile View** and notice the newly created white linear **Y16_Control** vertical alignment, located near the existing ground alignment, as illustrated below. This will serve as the **Bottom** of your **Control Envelope**.

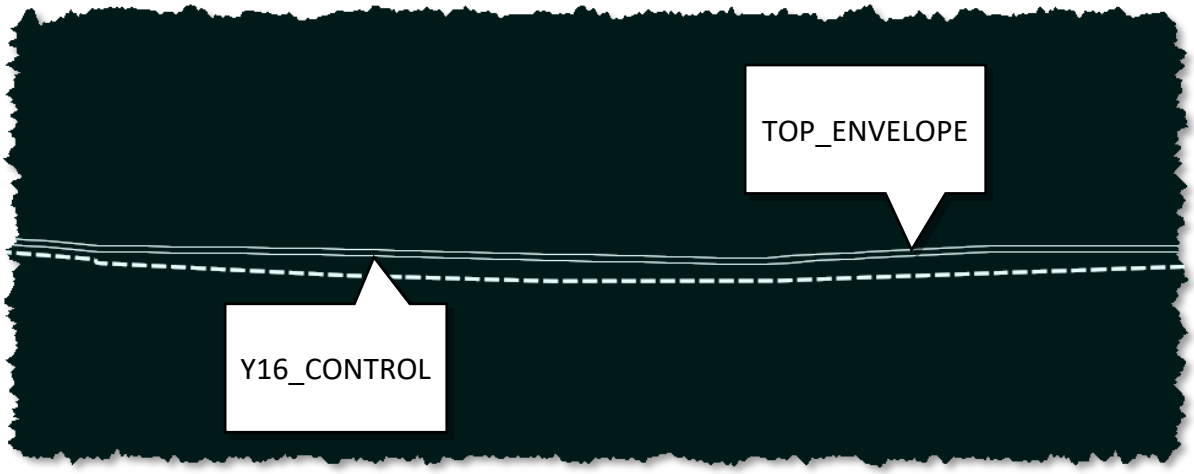


J. Next, we will establish the top of the **Control Envelope** by following the same process used to develop the **Y16_CONTROL** alignment, using the same **Parameters** as before, except with the following two (2) changes.

- **Vertical Name = Top_Envelope**
- **Minimum Overlay Thickness = 0.2500**

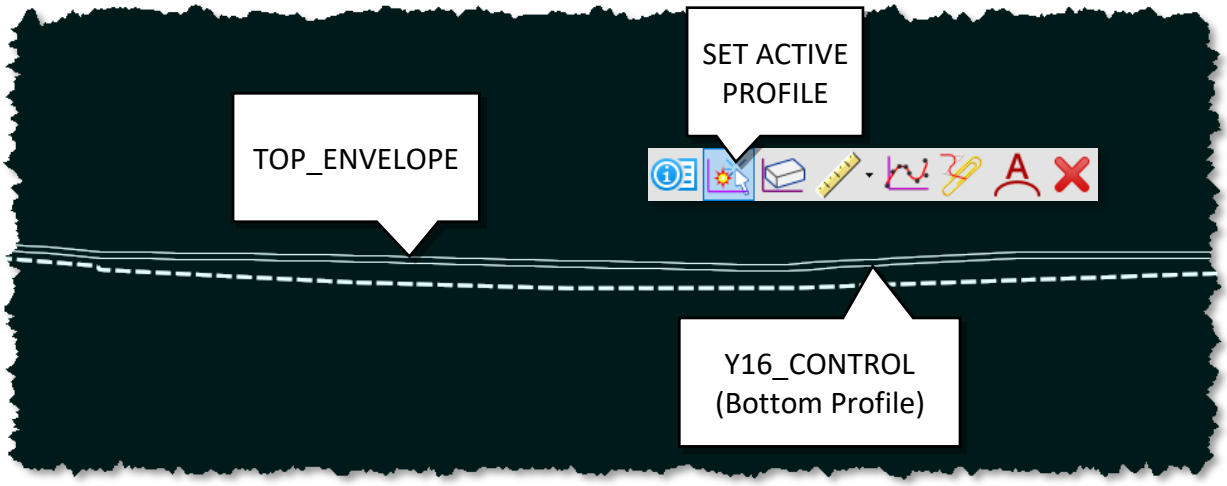


K. Zoom in on the **Profile View**, you'll now see the newly created **Top_Envelope** vertical alignment, positioned **0.125'** (1.5 inches) above the **Y16_Control** alignment. This completes the **Resurfacing Grade Control Envelope**, which was developed based on the design criteria and tailored to the specific needs of the individual project. The purpose of the **Resurfacing Grade Control Envelope** is to establish vertical boundaries for the **Proposed Resurfacing Grade (Y16)**, which will be developed later in this module. The designer should aim to stay as close to the bottom of the envelope as possible without dropping below it to prevent undercutting the existing pavement. Additionally, the designer should avoid exceeding the top of the envelope to minimize wedging.

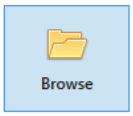


8. Review the Y16 Corridor utilizing the Y16 _Control Vertical Alignment

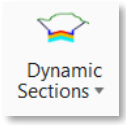
A. Keeping the **Y16 Profile View** open, set the **Y16_Control** (Bottom) vertical alignment active by selecting the **Set Active Profile** button as shown below.



B. After setting the **Y16_Control** vertical alignment active, Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\ Module 9\Roadway**Design** folder and open the r2635c_rdy_Y16_cmd.dgn file to view the **Y16 Corridor,** now utilizing the **Y16_Control** vertical alignment.



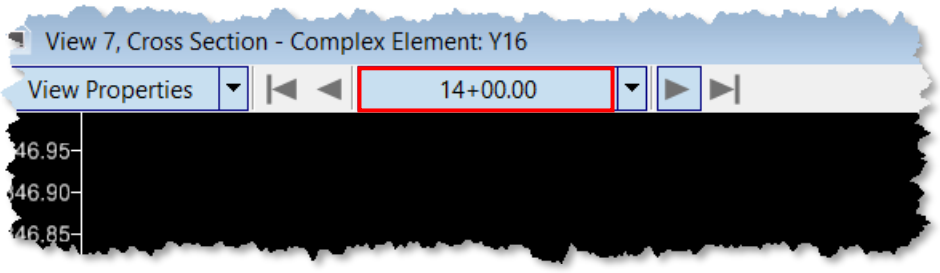
C. Next, click on the **Open Cross Section View** button by navigating to **(Corridors > Review > Dynamic Sections > Open Cross Section View).** When prompted, select the **Y16 Corridor** from the plan view and choose a view to open.



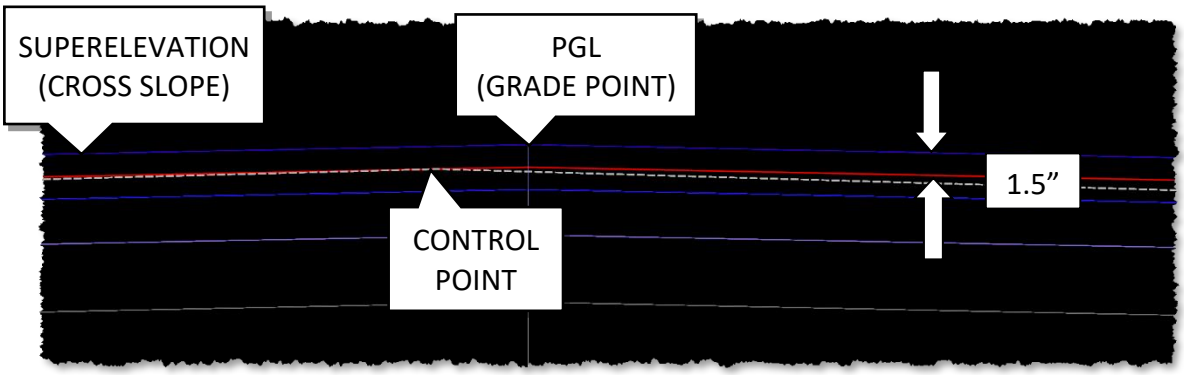
D. Now, scroll through the cross sections and observe the **1.5 inches** of **Surface Course** and the **Grade Point** as you review the sections. You should see that the cross sections are adjusted to be as close as possible to the existing pavement without undercutting it.

Note: Although the Y16 alignment may appear optimal in the cross-section view, it is not feasible in practice because it does not meet NCDOT Standards. It will be used as an initial reference, representing the bottom of the control grade envelope, and will guide the development of a grade that adheres to NCDOT Standards.

E. Then, Key-in station **14+00** using the **Station Key-In** dialog as shown below and zoom in closely to the cross section.



F. In the illustration below, note that the **Overlay Vertical Adjustment** tool establishes the **Grade Point** by maintaining a minimum overlay thickness of **1.5 inches**. It identifies the lowest point **(Control)** that meets this thickness and projects the **Superelevation Cross Slope** from this point to define the **Grade Point**, ensuring that the profile closely follows the existing pavement.

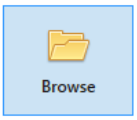


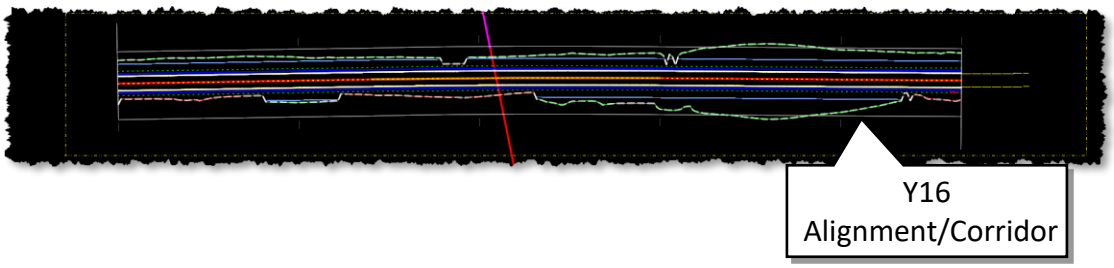
Note: It is important to recognize that the Overlay Vertical Adjustment tool incorporates various parameters in addition to the ones used in this particular excercise. Ultimately, the goal is to develop a proposed PGL elevation that aligns with the pavement design criteria. Multiple combinations of these parameters can yield the same proposed PGL elevation.

9. Use the Y16 Vertical Control Envelope to develop a Best Fit Vertical Profile

Note: A Best-Fit profile is typically a starting point and will require adjustments to align with your design intent and specific needs, applying engineering judgment. The purpose of this module is to demonstrate tools and methods that will assist you throughout the process. If you choose not to use the Best-Fit Vertical Profile option, you may skip this step and proceed to Step 10 to manually develop your profile.

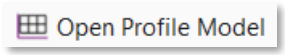
A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg.dgn file.



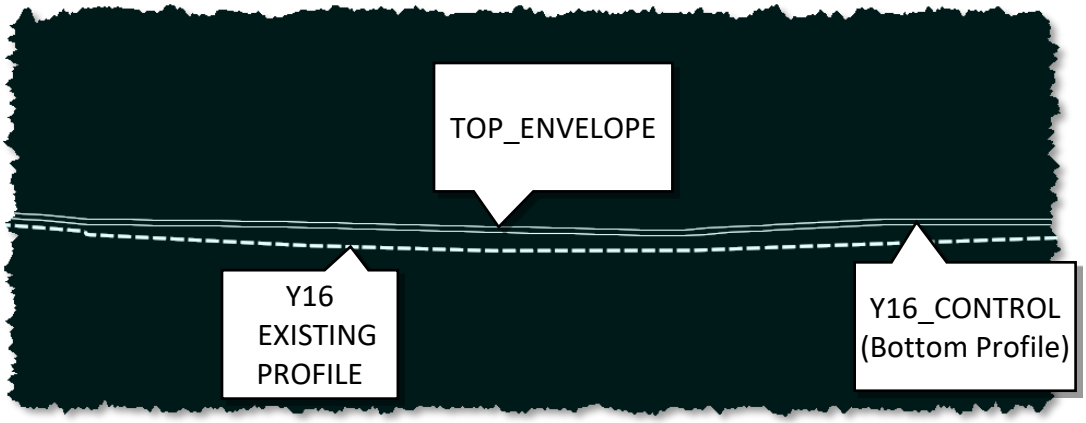


B. Zoom in near the **Y16 Alignment** as shown below.
Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

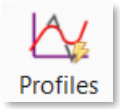
C. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**.



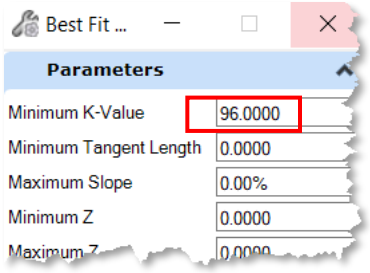
D. Next, select a view to open when prompted. This action will open the **Y16 Profile View**, as illustrated below. At this point, you should have two (2) views open: the **Plan View** and the **Y16 Profile View**.



E. Now, Select the **Best-Fit-Profile** button **(Site > Grading > Profiles > Best-Fit-Profile)** and set the following **Parameters** within the **Best-Fit-Profile** dialog.



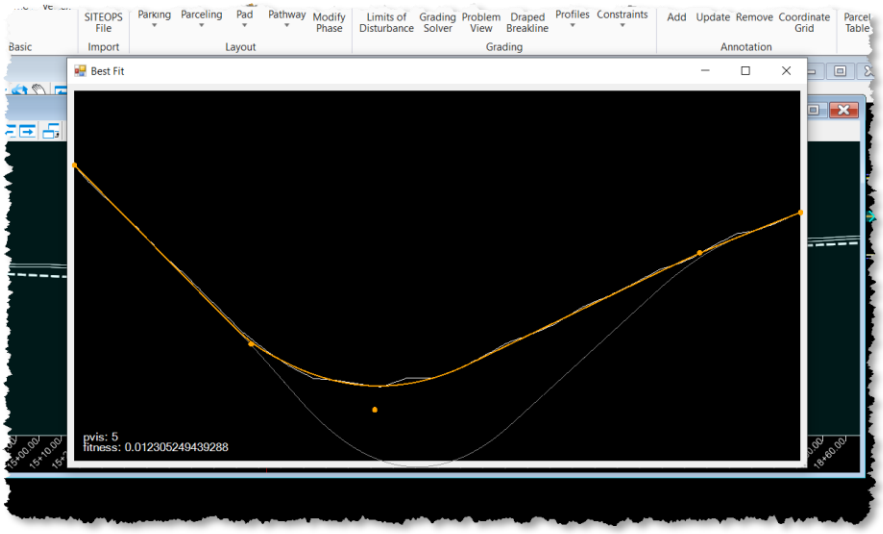
- **Minimum K-Value = 96.0000**
- **Minimum Tangent Length = 0.0000**



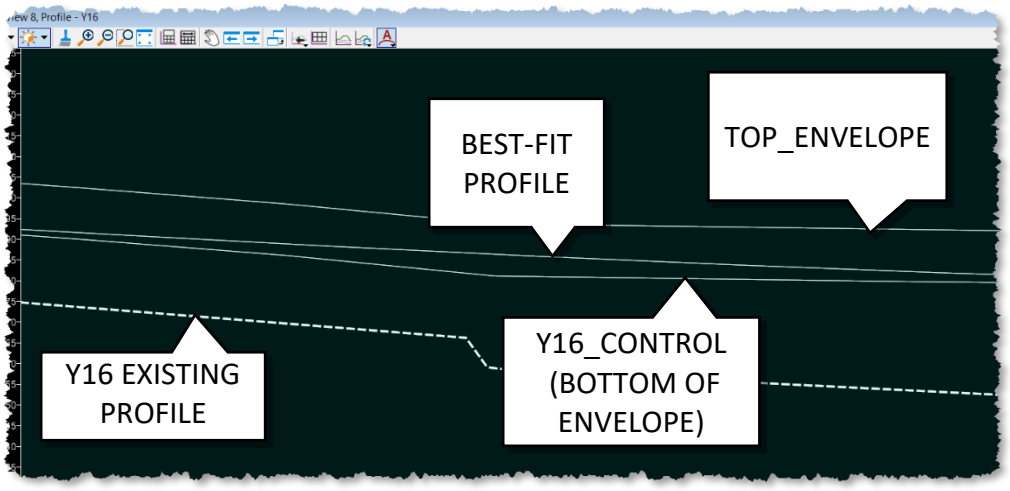
Note: This tool was not specifically designed for this application; because of this, only two parameters are relevant in this context, while the others are disregarded. Additionally, since there is only a single K-value parameter instead of separate values for sag and crest curves, you should select the worst-case scenario of the two based on your design criteria.

F. Then, select the **Y16_Control (Bottom of Envelope)** vertical profile when prompted to locate the element, and then **Left-Click** through the subsequent **Heads-Up Prompts** that follow.

G. This will activate the **Best-Fit** command, swiftly displaying and updating several profile options and variations in orange (see below), creating an animation-like effect as **OpenRoads Designer** develops a **Best-fit** option based on the **Y16_Control** profile. Ultimately, a selection will be made, resulting in the generation of a **Best-Fit** profile.

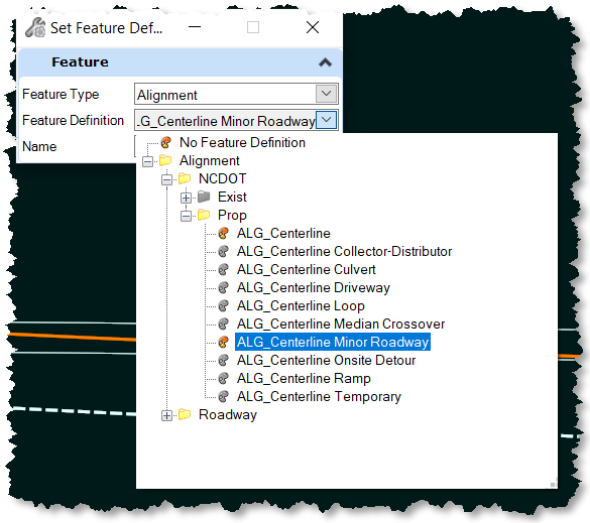


H. Once the **Best-Fit Profile** command is complete, close the **Best-Fit** window. If you zoom in closely on the **Y16_Profile** view, you should see the newly created **Best-Fit** profile, which closely follows the **Y16_Control** profile. This is the profile generated by the **Best-Fit Profile** tool.

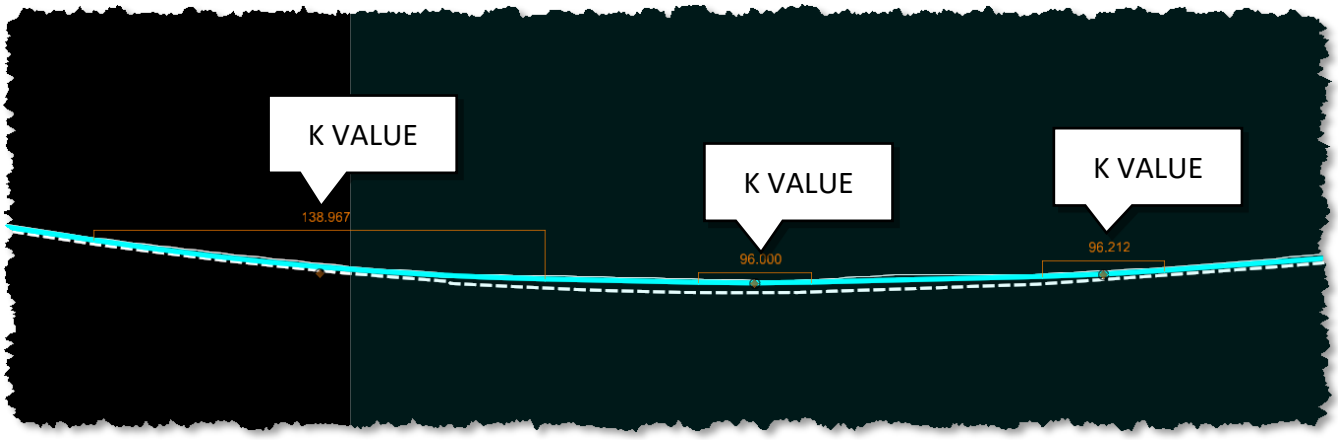


I. Now, select the **Set Feature Definition** button **(Geometry > General Tools > Standards > Set Feature Definition)** and configure the **Parameters** in the **Set Feature Definition** dialog box as outlined below. Then, click on your **Best-Fit** profile to update it with the appropriate **NCDOT Standards** and rename the profile to **Y16**.

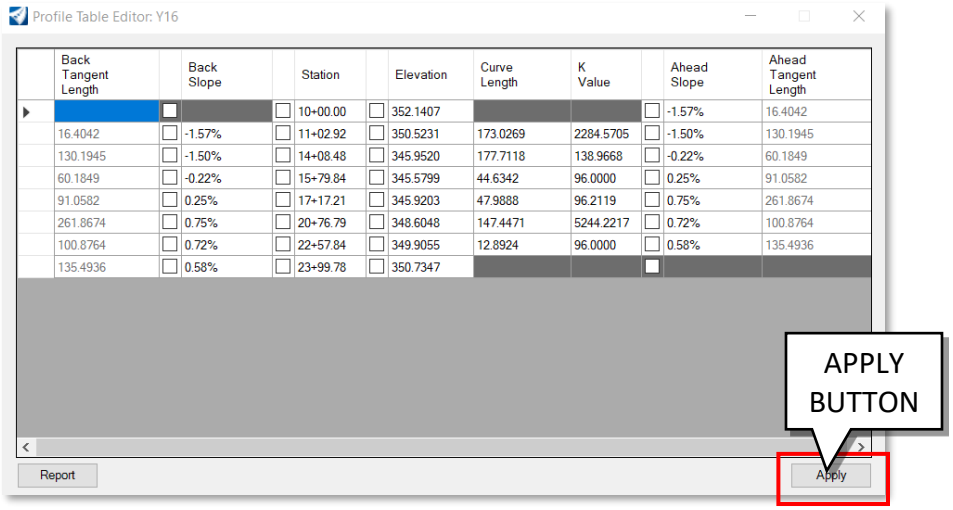
- **Feature Type = Alignment**
- **Feature Definition = ALG_Centerline Minor Roadway**
- **Name = Y16**



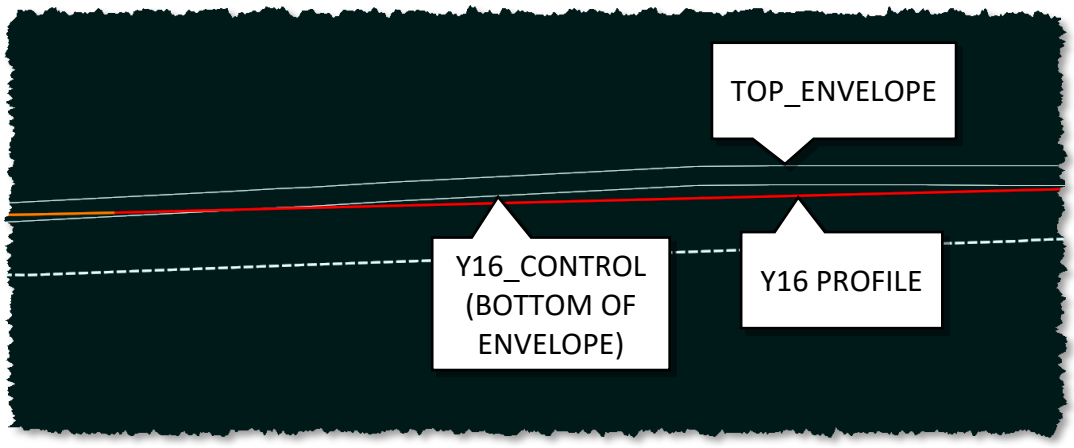
J. Select the **Y16** profile and note that the **Vertical Curves** display only the **K Values**, rather than both the **Curve Lengths** and **K Values**. This occurs due to the functionality of the **Best-Fit Profile** tool.



K. To address this issue and convert your profile into a more manageable format, select the **Table Editor** button **(Geometry > Common Tools > Table Editor)**, select your profile **(Y16)** when prompted to **Locate Alignment**. This will open the **Y16 Profile** within the **Table Editor**. Once the **Y16 Profile** is opened as shown below, click the **Apply** button within the **Table Editor**. This will reformat the profile to function as a standard **VPI** based **OpenRoads Designer** profile.



L. With the **Table Editor** still open, you may notice some clear discrepancies in the **Stationing**, **Slopes**, and **Elevation Readouts**. Additionally, certain portions of the profile do not fall within the **Resurfacing Grade Control Envelope** established in **Step 7**. This is because we aim to align as closely as possible to the **Y16_Control** profile (Bottom of Envelope). While the **Best-Fit Profile** tool provides a good initial approximation, it's not a perfect solution—just a starting point.



M. As you proceed to refine the **Y16 Profile** that was developed using the **Best-Fit Profile** tool. Consider the following tips to guide you through the refinement process.

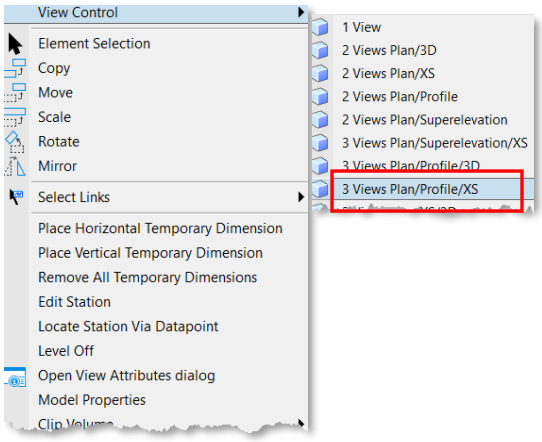
Note: The intent of the Resurfacing Grades Module is to offer general guidance and introduce tools and methods to assist you. It is not intended to teach roadway design, as that requires not only the use of tools but also the application of engineering judgment, which comes with years of experience. When designing your resurfacing grade, it's essential to use your engineering judgment alongside the tools presented in this module. This distinction is crucial to understand.

Refinement Tips for the Y16 Profile:

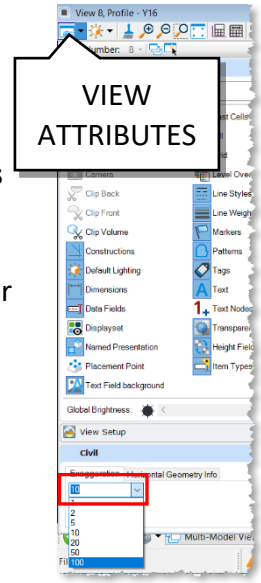
- Refine the stationing by rounding appropriately and adjust the grade and elevation values to two decimal places.

- Adjust the **Y16 Profile** to remain as close to the Resurfacing Grade Control Envelope as possible. It is crucial to understand that if the profile falls below the envelope, it may encroach upon the existing pavement. Conversely, positioning the profile above the envelope will result in excessive elevation, potentially leading to excessive wedging. While a slightly higher profile may be acceptable, it is generally better to be lower unless it results in undercutting the pavement. This is an example of when engineering judgment and a clear understanding of the project's intent are essential.

- Open the **Plan**, **Profile**, and **Cross-Section** views of the **Y16 Corridor** simultaneously for a comprehensive review. **Right-click** in the **Plan view**, select **View Control**, and choose the **3 Views Plan/Profile/XS** setting. The **Cross-Section View** is crucial for spotting details that the **Profile View** may miss, helping you assess variations. Take notes on your observations and adjust the profile as needed.



- Adjust the **Vertical Exaggeration Factor** while fine-tuning your grade to remain close to the bottom of the **Resurfacing Grade Control Envelope**, ensuring that you stay within its limits. Achieving a close alignment with an **Exaggeration Factor** of **100X** indicates a precise adjustment. You can find the **Exaggeration Tool** in the **Profile View** under the **View Attributes Dropdown** in the **Top Left Corner** of the **Profile View**. Once you have established a tight grade at **100X**, switch back to **1X** or **5X** to see the true quality of your grade. This feature is particularly beneficial, as it allows for on-the-fly changes, unlike Geopak, enhancing convenience and ease of use.



- Use the **Profile Insert Curve** tool **(Geometry > Vertical > Modify > Profile Insert Curve)** to add additional **Vertical Curves** if necessary.

- Use the **Delete Vertex** tool **(Drawing > Modify > Delete Vertex)** to delete any Vertical Curves or VPI's if necessary.

- Refer to the **Project Design Criteria** and/or **NCDOT Standards** to define and comply with the **Minimum** and **Maximum Grade** and **K-values**.

- If the existing cross slope does not align with the proposed superelevation, it may lead to excessive wedging on one side of the road. Depending on the specific circumstances and guided by sound engineering judgment as well as an understanding of the project's intent, you may consider adjusting the proposed superelevation to better match the existing conditions.

- Implement standard design practices at both the beginning and end of the resurfacing limits to ensure a smooth and compliant transition between the new and existing pavement, in accordance with **NCDOT Guidelines**.

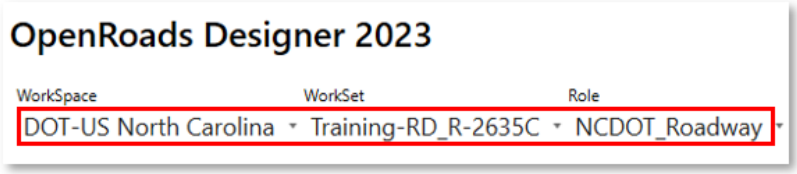
- For additional assistance with vertical geometry, please refer to **Module 4 - Vertical Alignments**.

Exercise 2 - Resurface Grade Tie-in

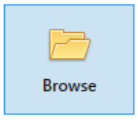
Exercise 2 provides a concise example illustrating how to tie in your grade to the existing pavement. In this example, we will demonstrate how to transition from a proposed grade to an existing grade using a vertical curve to ensure a smooth connection. It is important to recognize that multiple methods may be available for this process. Depending on the specific circumstances, you may encounter limitations that affect your options. In many cases, achieving the desired outcome may require flexibility and compromise. As previously noted, the objective of this module is not to teach you how to engineer or design a resurfacing grade. Rather, the goal of **Module 9** is to familiarize you with the tools within **OpenRoads Designer** that can support your design process. Ultimately, all design decisions should be based on sound engineering judgment and experience.

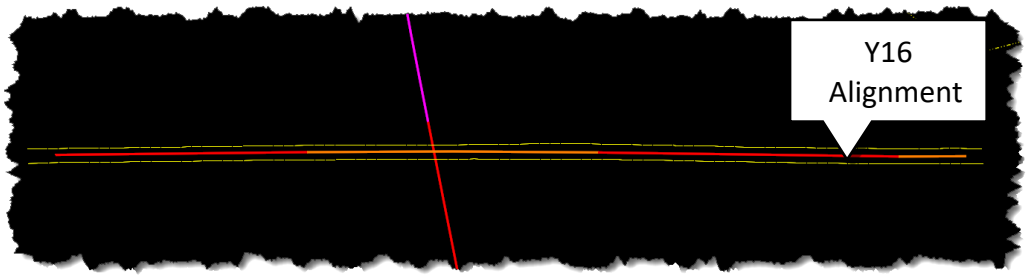
1. **Launch OpenRoads Designer 2023**
   Double-click on the OpenRoads Designer 2023 icon on your desktop to launch OpenRoads Designer.

2. **Set the Workspace and Workset**
   Select **DOT-US North Carolina** from the Workspace menu.
   Select **Training-RD_R-2635C** from the Workset menu.
   Select **NCDOT_Roadway** from the Role menu.

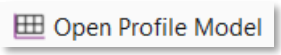


3. **Open the r2635c_rdy_alg_tie-in.dgn file and zoom in closely to the Y16 Alignment**
   A. Click the **Browse** button **(File> Open > Browse)** and path to the Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg_tie-in.dgn file.
   B. Zoom in near the **Y16 Alignment** as shown below. The **Y16 Alignment** will be used throughout this exercise.

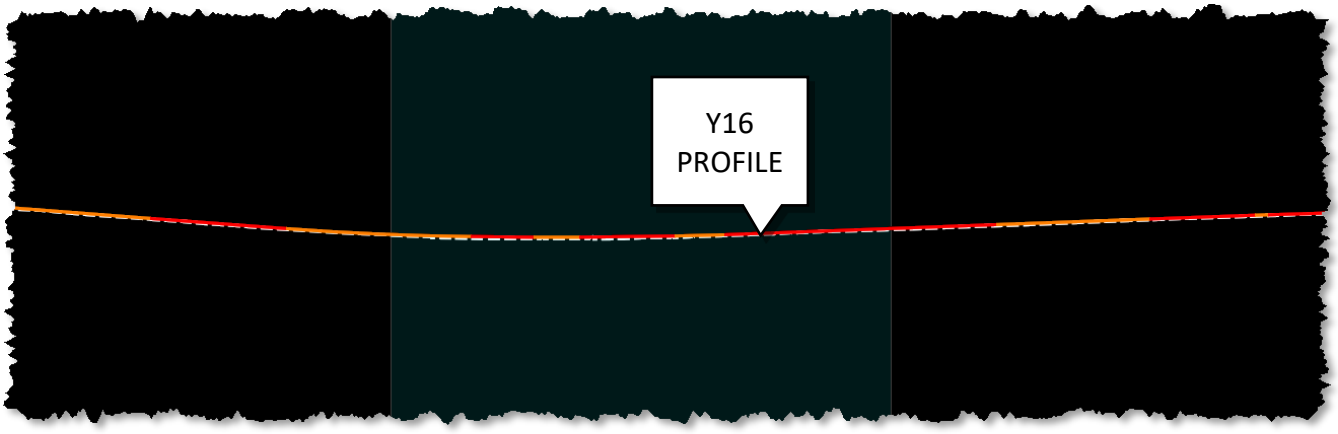




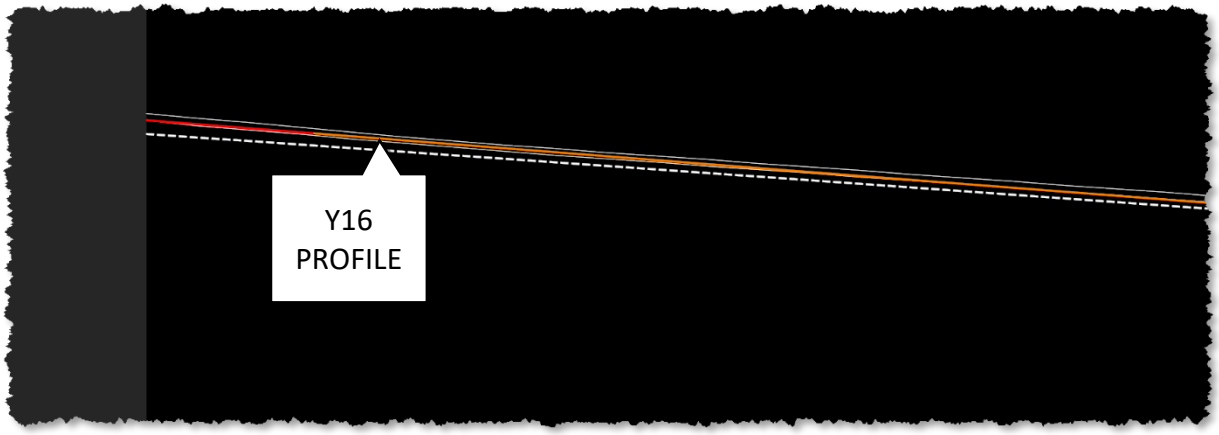
4. **Open the Y16 Profile**
   A. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**.



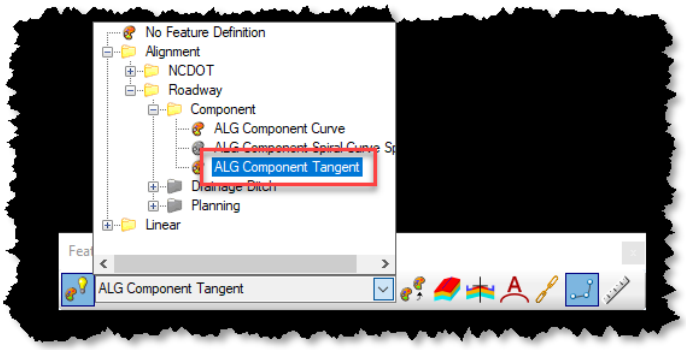
   B. Next, select a view to open when prompted to do so. This will open the **Y16 Profile View** as shown below. Notice the proposed **Y16** Profile does not tie properly to existing.



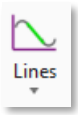
5. **Transition from the proposed Y16 grade to the existing grade using a vertical curve**
   A. Zoom in closely to the beginning of the proposed grade as shown below.

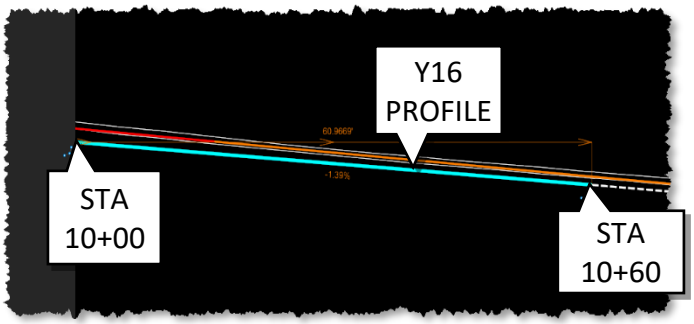


B. Using the Feature **Definition Toggle Bar** set the **Active Feature Definition** to **ALG Component Tangent** **(Alignment > Roadway > Component > ALG Component Tangent)**.

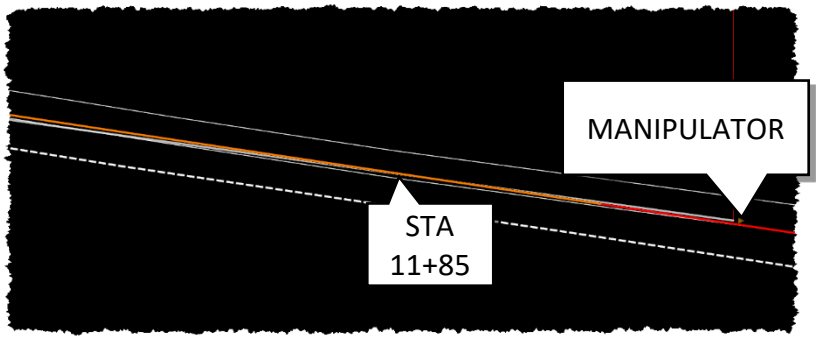


C. Now, using the **Profile Line Between Points** **(Geometry > Vertical > Lines > Profile Line Between Points)** tool, draw a line in snapping to existing from Sta **10+00** to approximetely Sta **10+60** as shown below. This will establish a grade that matches existing at the **Tie-In** location.

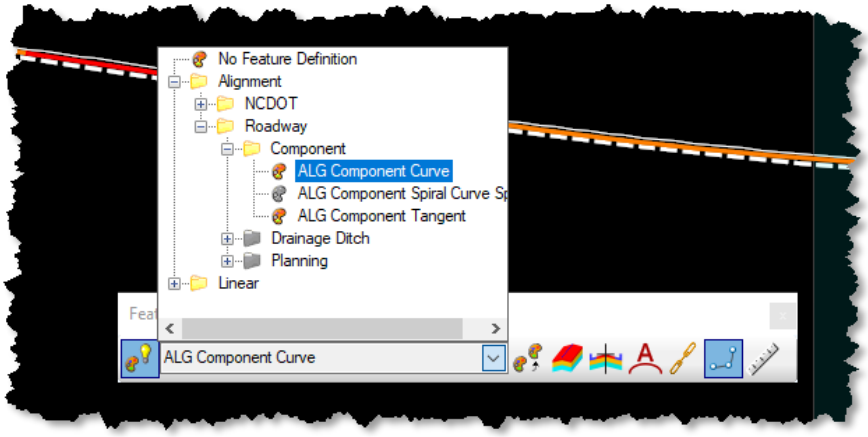




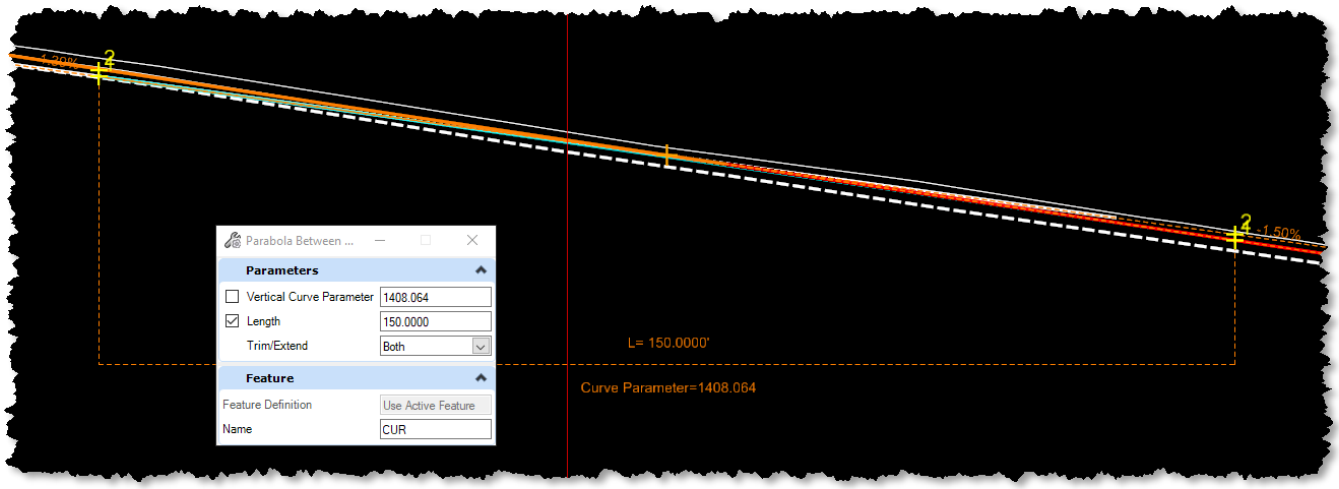
D. Next, click on the vertical line that was drawn in the previous step and use the **Arrow Manipulator** to extend the line out to where it intersects **(approx 11+85)** the proposed grade as shown below. This step is not necessary but can be helpful to understand the proposed geometry while making decisions regarding vertical curve placement.



E. Using the **Feature Definition Toggle Bar** set the **Active Feature Definition** to **ALG Component Curve** **(Alignment > Roadway > Component > ALG Component Curve)**



F. Then, using the **Parabola Between Elements** **(Geometry > Vertical > Curves > Profile Curve Between Elements > Parabola Between Elements)** tool, click on the two (2) **Vertical Tangent Lines**, key-in **150' Curve Length** and place the **Proposed Vertical Curve** as shown below.



G. Again, there a multiple ways to tie profiles back to exisitng conditions. For additional assistance with **Vertical Geometry**, please refer to **Module 4 - Vertical Alignments.**

Exercise 3 – Divided Facilities

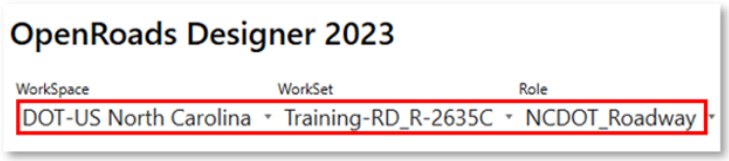
Exercise 3 is focused exclusively on **Divided Facilities**. While many tools, methods, and workflows from **Exercise 1**, which established a resurfacing grade for **Undivided Facilities**, remain applicable, there are notable differences. This exercise will highlight these distinctions and provide comprehensive guidance on making the necessary adjustments to develop a resurfacing grade for a **Divided Facility**. It's important to note that the Overlay Vertical Adjustment tool has specific functional limitations when working with **Divided Roadways**, and much of the focus will be on addressing these limitations. Despite these challenges, the tool remains highly effective when used properly.

1. **Launch OpenRoads Designer 2023**

   Double-click on the OpenRoads Designer 2023 icon on your desktop to launch OpenRoads Designer.

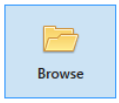
2. **Set the Workspace and Workset**

   Select **DOT-US North Carolina** from the Workspace menu.
   Select **Training-RD_R-2635C)** from the Workset menu.
   Select **NCDOT_Roadway** from the Role menu.

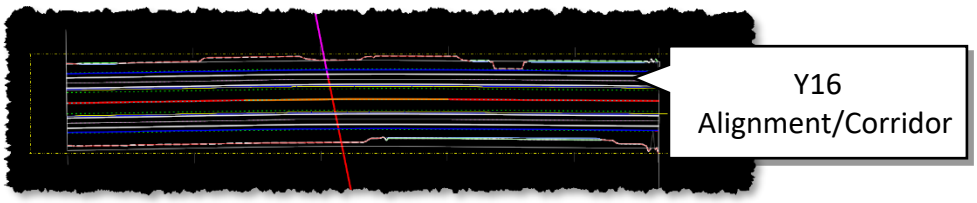


3. **Examine how a divided facility template with a median ditch impacts the operation of the Overlay Vertical Adjustment tool**

   A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg_div_ditch.dgn file.

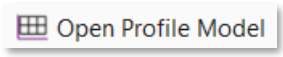


   B. Zoom in near the **Y16 Alignment** and **Corridor** as shown below.

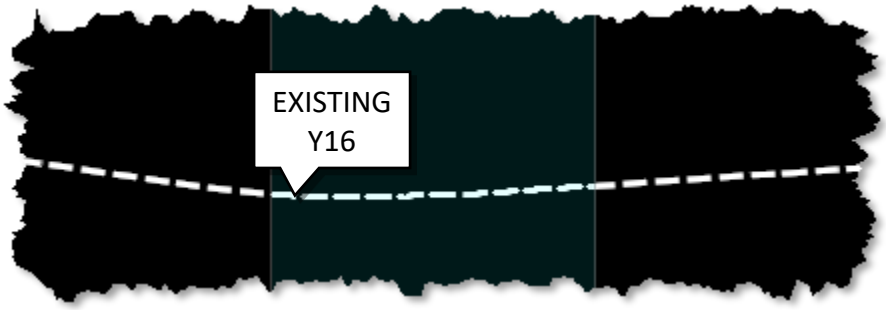


   Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

C. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**.

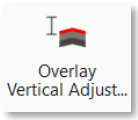


D. Next, select a view to open when prompted to do so. This will open the **Y16 Profile View** as shown below.



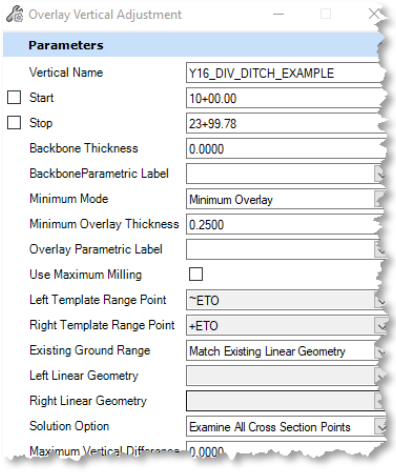
Note: The Y16 Corridor is currently using the existing Y16 profile as shown above.

E. While keeping the **Y16 Profile View** open, click on the **Overlay Vertical Adjustment** button **(Corridors > Miscellaneous > Overlay Vertical Adjustment)** and select the **Y16 Corridor** from the plan view when prompted to do so.

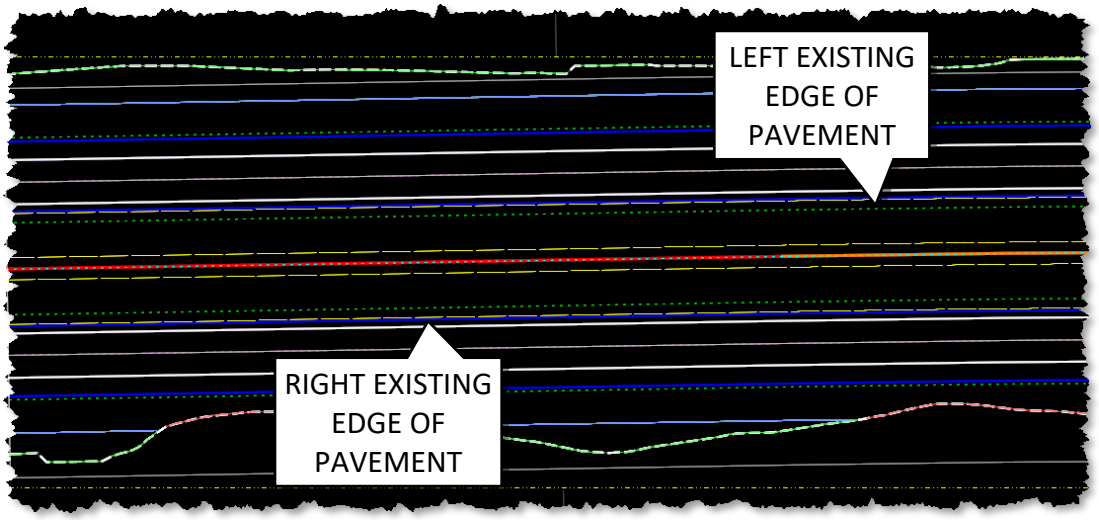


F. This will launch the **Overlay Vertical Adjustment** tool. Set the following **Parameters** within the **Overlay Vertical Adjustment** dialog. Please note the inability to exclude the template median, which is a key issue that will be addressed during this exercise.

- **Vertical Name = Y16_DIV_DITCH_EXAMPLE**
- **Start = 10+00.00**
- **Stop = 23+99.78**
- **Backbone Thickness = 0.0000**
- **Minimum Mode = Minimum Overlay**
- **Minimum Overlay Thickness = 0.2500**
- **Left Template Range Point = ~ETO**
- **Right Template Range Point = +ETO**
- **Existing Ground Range = Match Existing Linear Geometry**
- **Solution Option = Examine All Cross Section Points**
- **Maximum Vertical Distance = 0.0000**



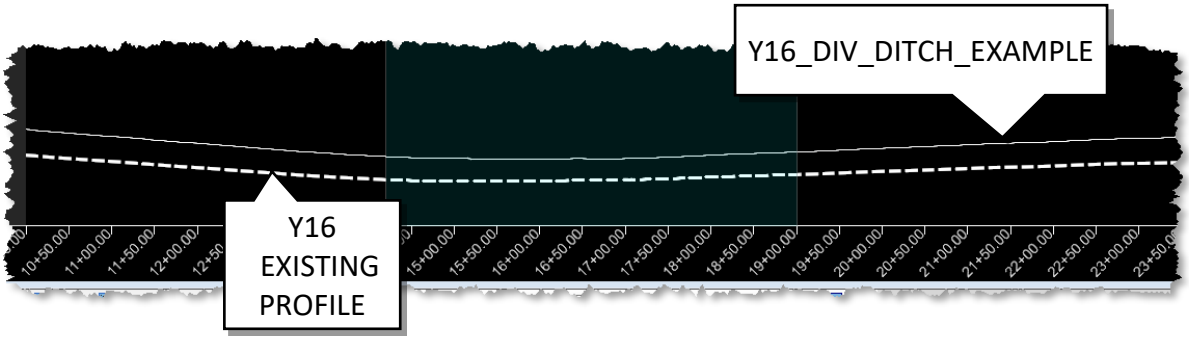
G. After confirming the **Existing Ground Range** parameter and accepting the **Match Existing Linear Geometry** value, you will be prompted to locate the **Left** and **Right Linear Geometry**. At this stage, select the corresponding **Left** and **Right Existing Edge of Pavement** elements, as displayed in the illustration below.



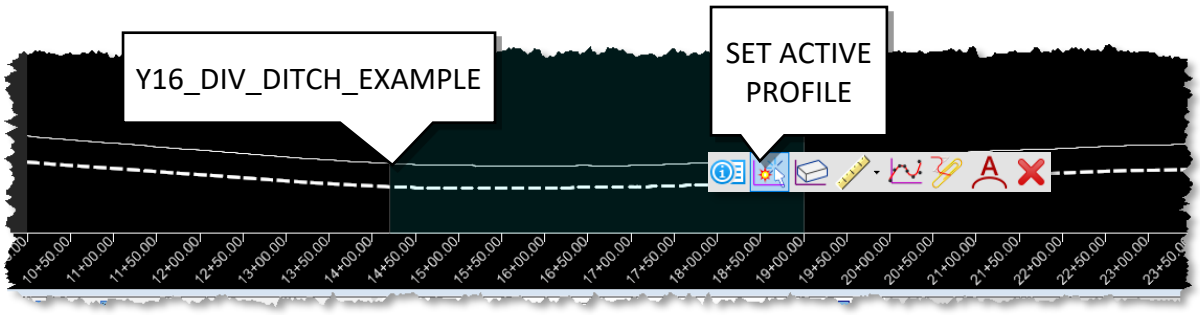
H. Then, continue left-clicking through the remaining prompts until you have completed the process.

Note: Upon completion of this process, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed.

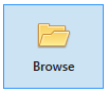
I. Now, examine the **Y16 Profile View** and notice the newly created **Y16_DIV_DITCH_EXAMPLE** vertical alignment, located above the existing ground alignment, as illustrated below.



J. Keeping the **Y16 Profile View** open, set the **Y16_DIV_DITCH_EXAMPLE** vertical profile active by selecting the **Set Active Profile** button as shown below.



K. Now, Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder and open the r2635c_rdy_cmd_div_ditch.dgn file.

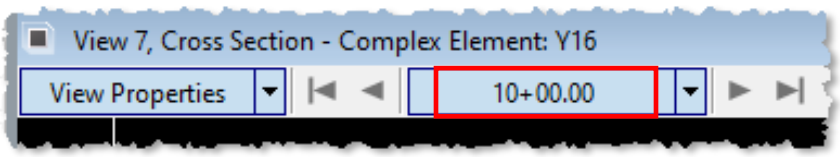


Note: Upon opening the CMD file, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed after setting the newly created Y16_DIV_DITCH_EXAMPLE profile as active in the ALG file.

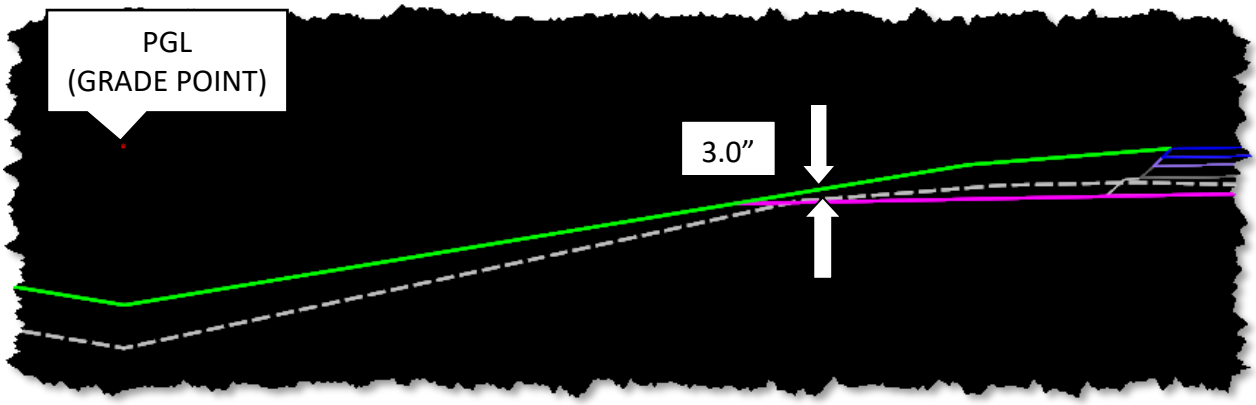
L. Next, click on the **Open Cross Section View** button by navigating to **(Corridors > Review > Dynamic Sections > Open Cross Section View).** When prompted, select the **Y16 Corridor** from the plan view and choose a view to open.

M. Now, scroll through the cross-sections and observe that the **Overlay Vertical Adjustment** tool did not apply the expected adjustments. Instead of minimizing the overlay pavement as intended, the cross-sections appear significantly elevated overall. This outcome was anticipated and intentional, designed to bring awareness to the discrepancy for further review.

N. Let's take a closer look. **Key-in** station **10+00.00** using the **Station Key-In** dialog as shown below and zoom in closely to the cross section.

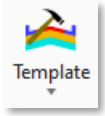


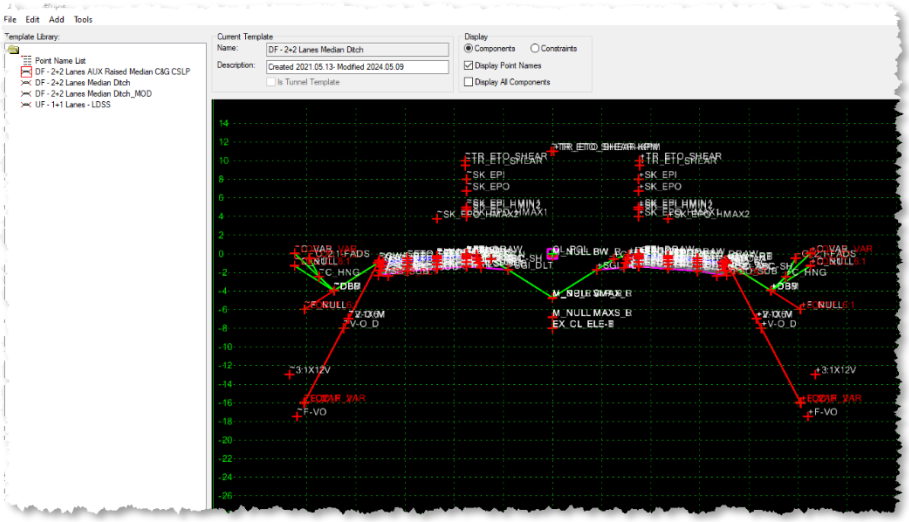
O. Notice that, because the median was not excluded from processing, the **Overlay Vertical Adjustment** tool follows its default logic. It evaluates the existing surface to identify the **Control Point** closest to the bottom of the backbone, then adds an additional **3”** based on the provided input to calculate the **PGL**. However, the tool incorrectly includes the grass median in its calculations, when it should only consider the proposed pavement. As previously mentioned, this is a flaw in the application that we will address.



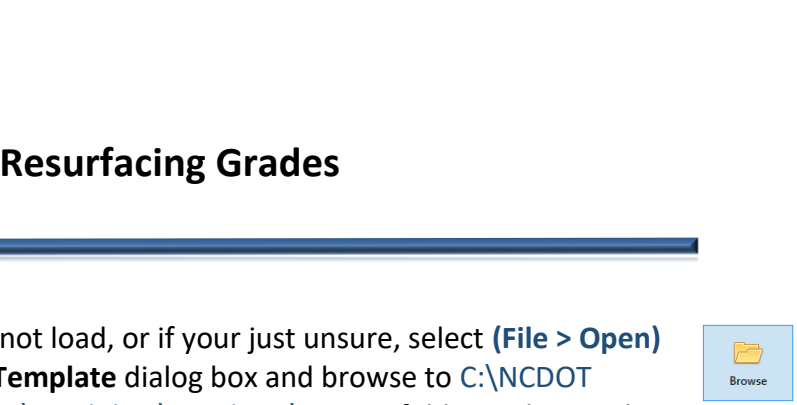
4. Adjust the divided facility median ditch template to ensure compatibility with the Overlay Vertical Adjustment tool, enabling it to function as intended.

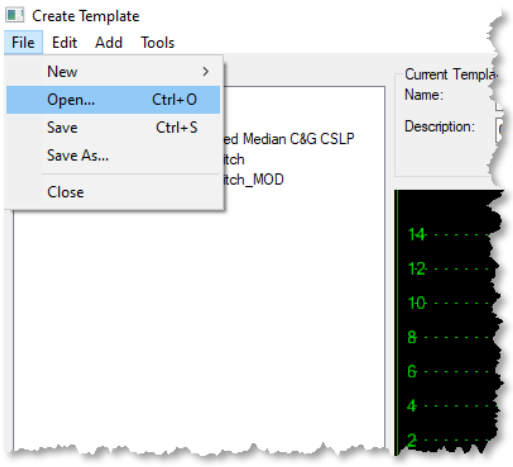
A. Next, click on the **Create Template** button by navigating to **(Corridors > Create > Template > Create Template)**. This should load **R-2635C (Training)_RDY.itl** as shown below.



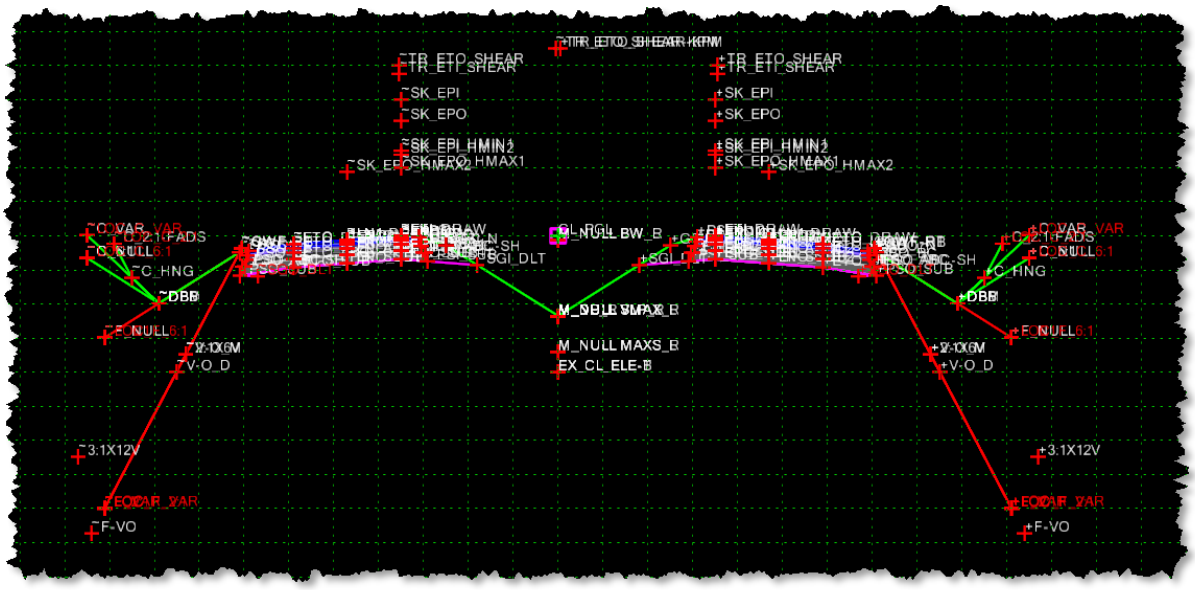


B. If the **R-2635C (Training)_RDY.itl** does not load, or if your just unsure, select **(File > Open)** from the top left corner of the **Create Template** dialog box and browse to C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder and open the R-2635C (Training)_RDY.itl to load it manually.

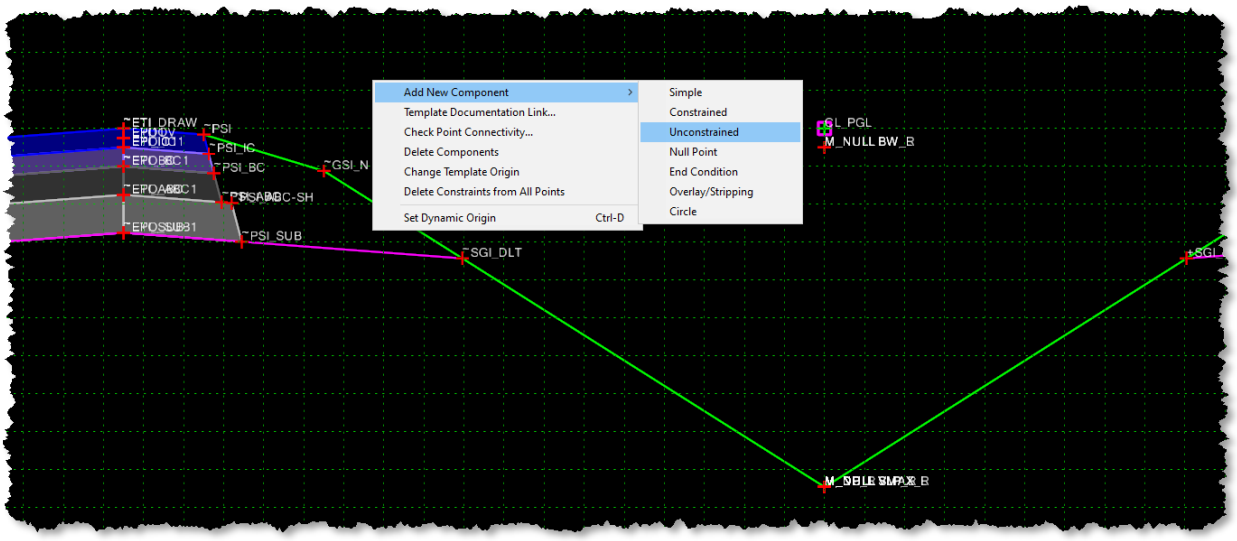




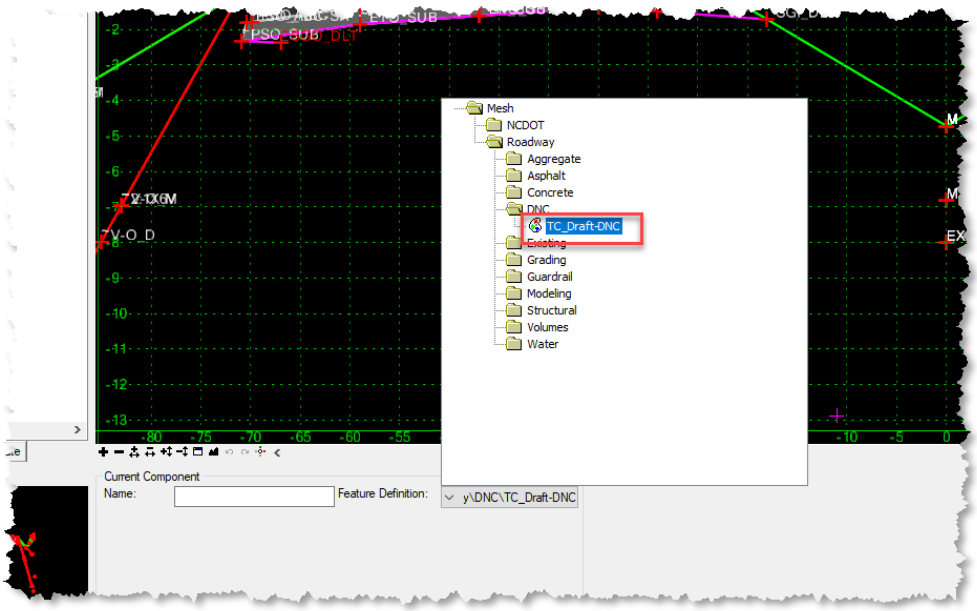
C. Now, double click on the **DF-2+2 Lanes Median Ditch** template to activate it as shown below.



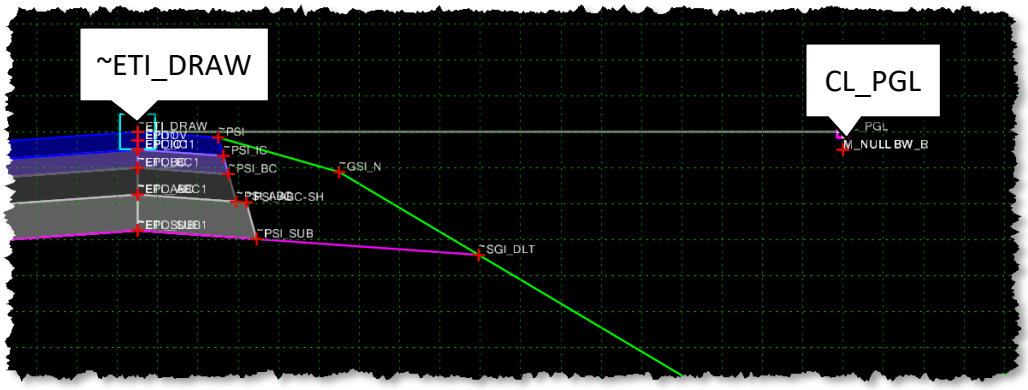
D. Zoom in closely to the median ditch area, then right-click and select **(Add New Component > Unconstrained)** as shown below.



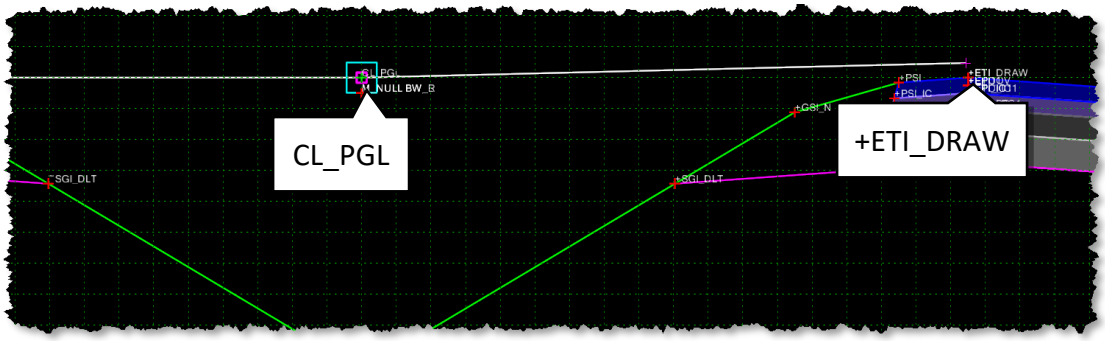
E. Then, set the **Feature Definition** to **TC_Draft-DNC** as shown below.



F. Now, draw a line from the **~ETI_DRAW** point to the **CL_PGL** point, as illustrated below.



G. Then, draw a line from the **CL_PGL** point to the **+ETI_DRAW** point, as illustrated below.

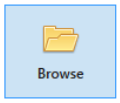


H. In addition to providing the previous steps, I have also included a template called **DF - 2+2 Lanes Median Ditch_MOD** in the R-2635C (Training)_RDY.itl that has already made these changes.

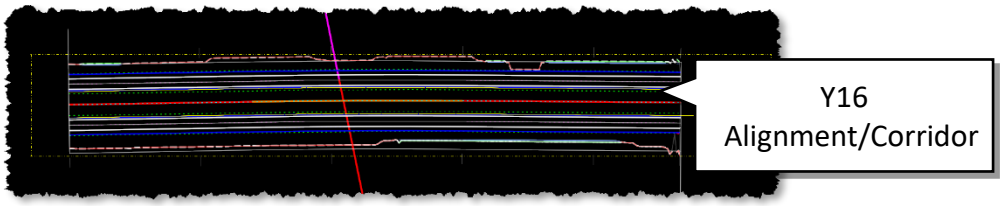
Note: Once the grade has been established, the TC_Draft-DNC lines previously added to the template should be removed.

5. Apply the modified DF-2+2 Lanes Median Ditch Template and see how it impacts the Overlay Vertical Adjustment tool.

A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder and open the r2635c_rdy_cmd_div_ditch.dgn file.



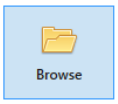
B. Zoom in near the **Y16 Alignment** and **Corridor** as shown below.



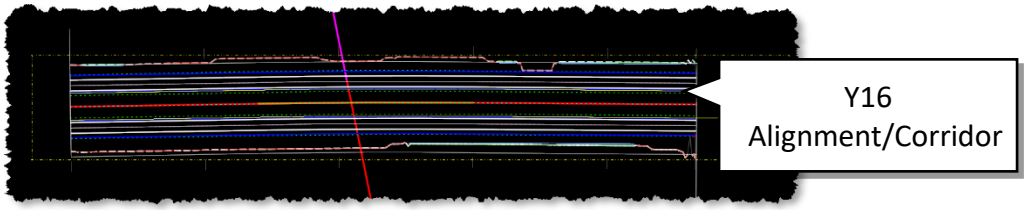
Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

C. Next, click on the **Synchronize Template** button by navigating to **(Corridors > Miscellaneous > Synchronize Template plate)**. This will update the **Y16 Corridor** template to incorporate the changes made in **Step 13**.

D. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg_div_ditch.dgn file.

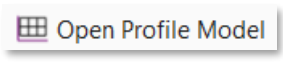


E. Zoom in near the **Y16 Alignment** and **Corridor** as shown below.

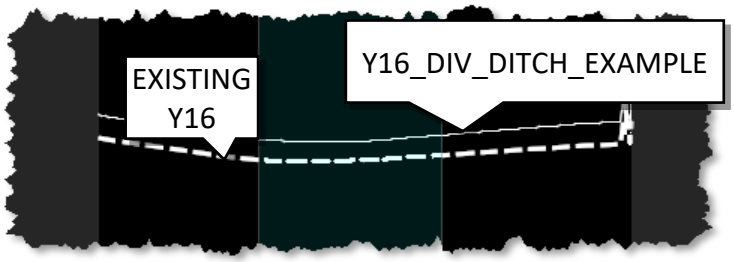


Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

F. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to Locate Plan Element.



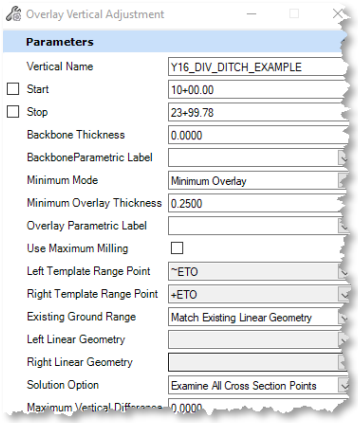
G. Next, select a view to open when prompted to do so. This will open the **Y16 Profile View** as shown below. The **Y16_DIV_DITCH_EXAMPLE** profile is still set to active.



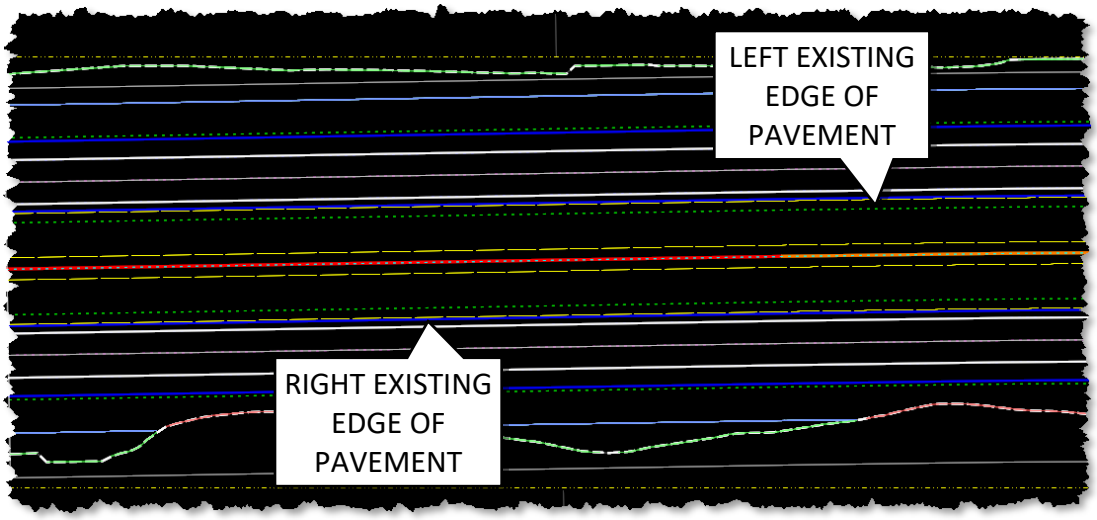
H. While keeping the **Y16 Profile View** open, click on the **Overlay Vertical Adjustment** button **(Corridors > Miscellaneous > Overlay Vertical Adjustment)** and select the **Y16 Corridor** from the plan view when prompted to do so.

I. This will launch the **Overlay Vertical Adjustment** tool. Set the following **Parameters** within the **Overlay Vertical Adjustment** dialog. Please note the inability to exclude the template median, which is a key issue that will be addressed during this exercise.

- **Vertical Name = Y16_DIV_DITCH_EXAMPLE2**
- **Start = 10+00.00**
- **Stop = 23+99.78**
- **Backbone Thickness = 0.0000**
- **Minimum Mode = Minimum Overlay**
- **Minimum Overlay Thickness = 0.2500**
- **Left Template Range Point = ~ETO**
- **Right Template Range Point = +ETO**
- **Existing Ground Range = Match Existing Linear Geometry**
- **Solution Option = Examine All Cross Section Points**
- **Maximum Vertical Distance = 0.0000**



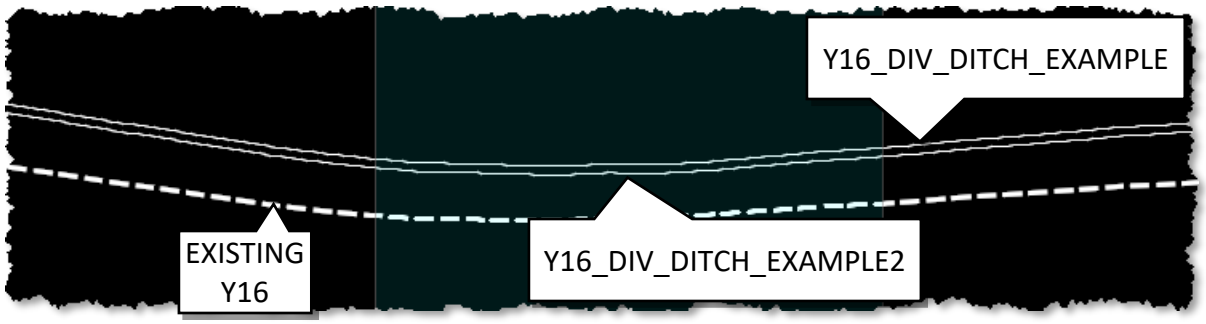
J. After confirming the **Existing Ground Range** parameter and accepting the **Match Existing Linear Geometry** value, you will be prompted to locate the **Left** and **Right Linear Geometry**. At this stage, select the corresponding **Left** and **Right Existing Edge of Pavement** elements, as displayed in the illustration below.



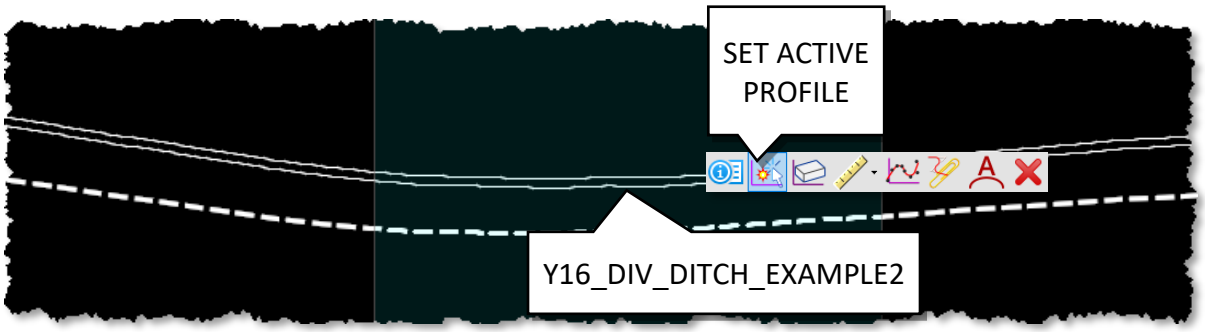
K. Then, continue left-clicking through the remaining prompts until you have completed the process.

Note: Upon completion of this process, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed.

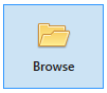
L. Now, examine the **Y16 Profile View** and notice the newly created **Y16_DIV_DITCH_EXAMPLE2** vertical alignment, located in between the **Y16_DIV_DITCH_EXAMPLE** profile and the **Y16** existing ground profile, as illustrated below.



M. Keeping the **Y16 Profile View** open, set the **Y16_DIV_DITCH_EXAMPLE2** vertical profile active by selecting the **Set Active Profile** button as shown below.



N. Now, Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder and open the r2635c_rdy_cmd_div_ditch.dgn file.

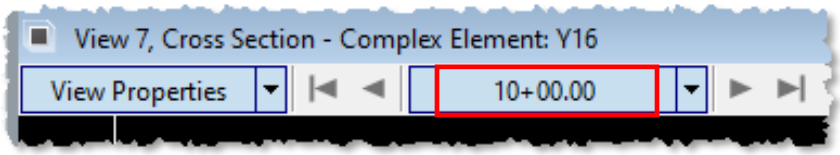


Note: Upon opening the CMD file, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed after setting the newly created Y16_DIV_DITCH_EXAMPLE profile as active in the ALG file.

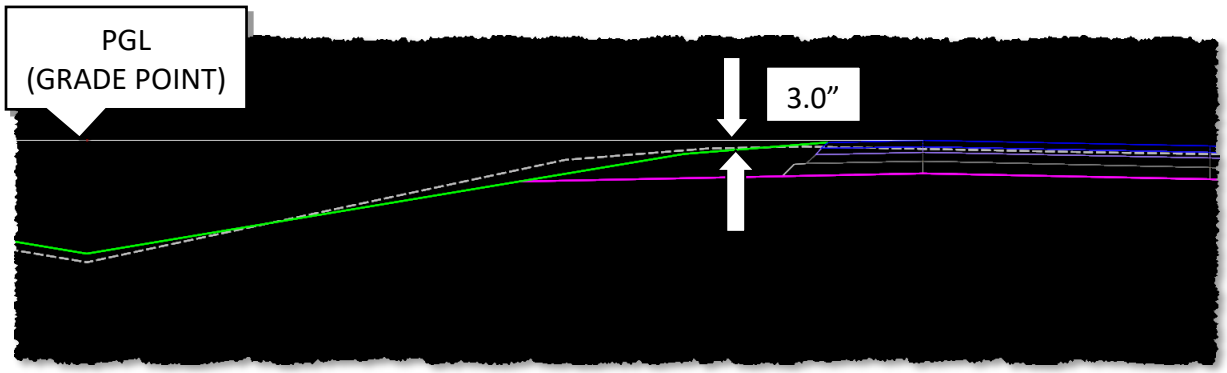
O. Next, click on the **Open Cross Section View** button by navigating to **(Corridors > Review > Dynamic Sections > Open Cross Section View).** When prompted, select the **Y16 Corridor** from the plan view and choose a view to open.

P. Now, scroll through the cross-sections and observe that the **Overlay Vertical Adjustment** tool now works as expected. It minimized the overlay pavement as intended. Exactly how it worked with the undivided facility in **Exercise 1**.

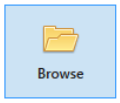
Q. Let's take a closer look. **Key-in** station **10+00.00** using the **Station Key-In** dialog as shown below and zoom in closely to the cross section.



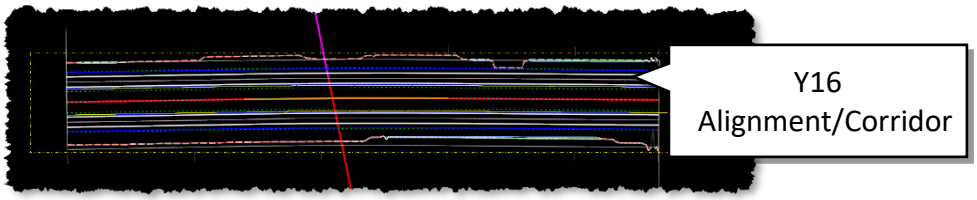
R. It is important to note that, due to the added elements connecting the **PGL** to the **Inside EOT** points, the **Overlay Vertical Adjustment** tool now operates as intended. The median ditch is ignored, and these elements are treated as if they represent the top of pavement. The system then evaluates these elements against the existing surface to identify the **Control Point** closest to the bottom of the backbone, subsequently adding **3"** based on the provided input to calculate the **PGL**. While this is not a perfect solution, it is a highly effective one.



6. **Examine how a divided facility template with a raised median impacts the operation of the Overlay Vertical Adjustment tool**
   A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg_divided.dgn file.



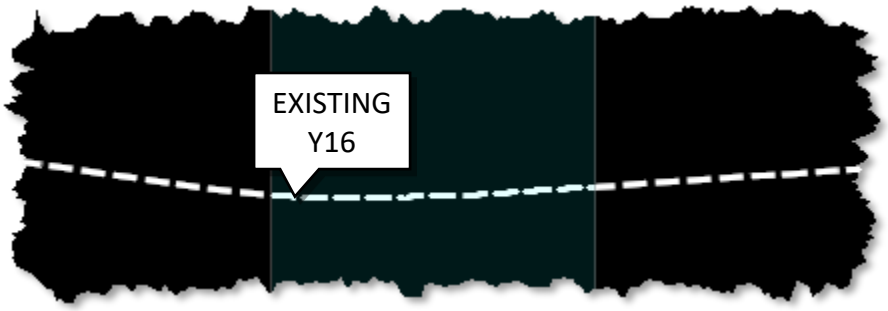
   B. Zoom in near the **Y16 Alignment** and **Corridor** as shown below.



   Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

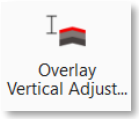
   C. Select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**.

   D. Next, select a view to open when prompted to do so. This will open the **Y16 Profile View** as shown below.



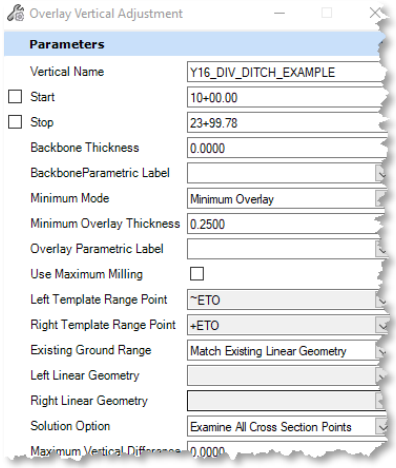
   Note: The Y16 Corridor is currently using the existing Y16 profile as shown above.

   E. While keeping the **Y16 Profile View** open, click on the **Overlay Vertical Adjustment** button **(Corridors > Miscellaneous > Overlay Vertical Adjustment)** and select the **Y16 Corridor** from the plan view when prompted to do so.

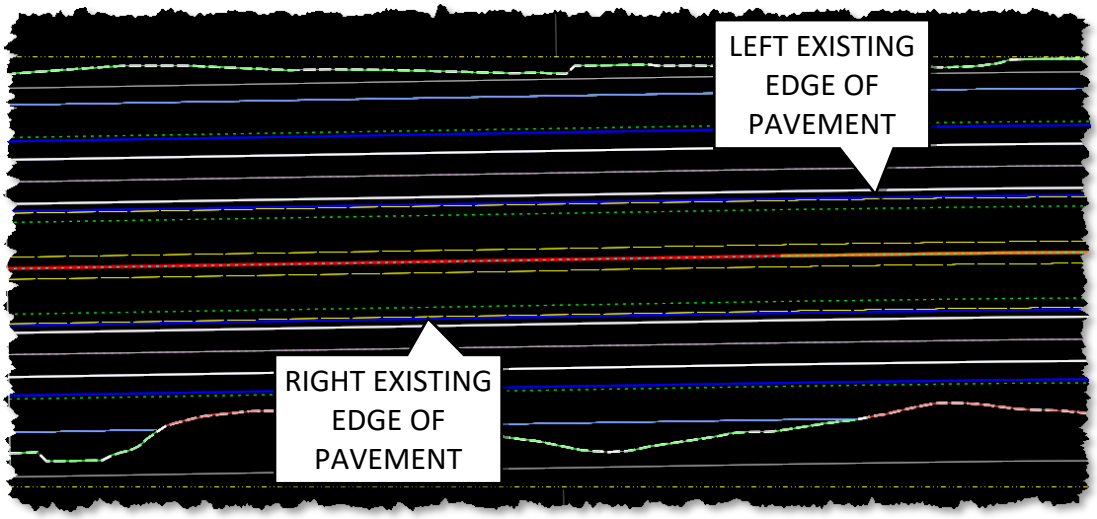


F. This will launch the **Overlay Vertical Adjustment** tool. Set the following **Parameters** within the **Overlay Vertical Adjustment** dialog. Please note the inability to exclude the template median, which is a key issue that will be addressed during this exercise.

- **Vertical Name = Y16_RAISED_MEDIAN_EXAMPLE**
- **Start = 10+00.00**
- **Stop = 23+99.78**
- **Backbone Thickness = 0.0000**
- **Minimum Mode = Minimum Overlay**
- **Minimum Overlay Thickness = 0.2500**
- **Left Template Range Point = ~ETO**
- **Right Template Range Point = +ETO**
- **Existing Ground Range = Match Existing Linear Geometry**
- **Solution Option = Examine All Cross Section Points**
- **Maximum Vertical Distance = 0.0000**



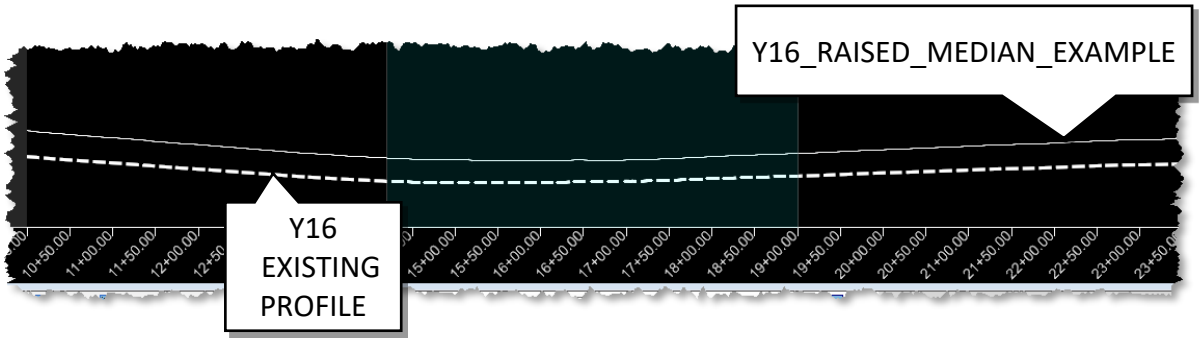
G. After confirming the **Existing Ground Range** parameter and accepting the **Match Existing Linear Geometry** value, you will be prompted to locate the **Left** and **Right Linear Geometry**. At this stage, select the corresponding **Left** and **Right Existing Edge of Pavement** elements, as displayed in the illustration below.



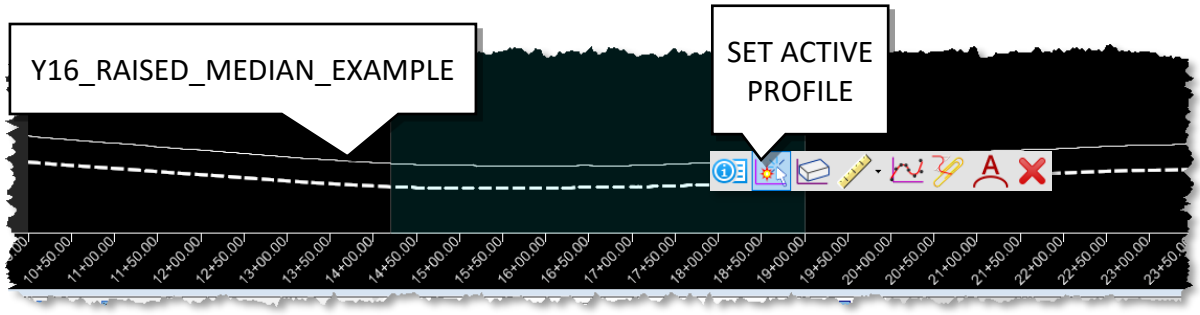
H. Then, continue left-clicking through the remaining prompts until you have completed the process.

Note: Upon completion of this process, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed.

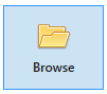
I. Now, examine the **Y16 Profile View** and notice the **Y16_RAISED_MEDIAN_EXAMPLE** vertical alignment, located above the existing ground alignment, as illustrated below.



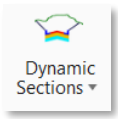
J. Keeping the **Y16 Profile View** open, set the **Y16_RAISED_MEDIAN_EXAMPLE** vertical profile active by selecting the **Set Active Profile** button as shown below.



K. Now, Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Design** folder and open the r2635c_rdy_cmd_divIded_facility.dgn file.



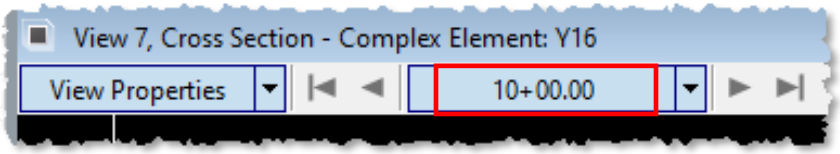
Note: Upon opening the CMD file, a green progress bar will briefly appear in the bottom right corner of your screen, indicating that the corridor has been processed after setting the newly created Y16_RAISED_MEDIAN_EXAMPLE profile as active in the ALG file.



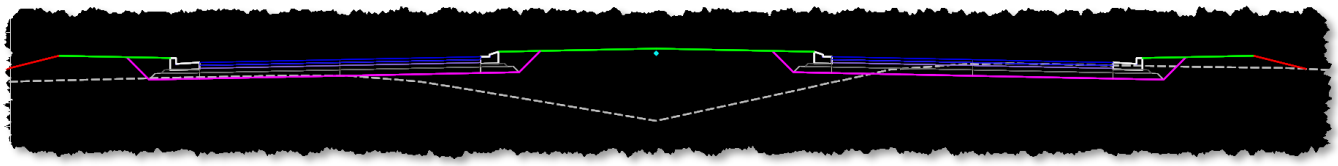
L. Next, click on the **Open Cross Section View** button by navigating to **(Corridors > Review > Dynamic Sections > Open Cross Section View).** When prompted, select the **Y16 Corridor** from the plan view and choose a view to open.

M. Now, scroll through the cross-sections and observe that the **Overlay Vertical Adjustment** tool works as expected. It minimized the overlay pavement as intended. Exactly how it worked with the undivided facility in **Exercise 1**.

N. Let's take a closer look. **Key-in** station **10+00.00** using the **Station Key-In** dialog as shown below and zoom in closely to the cross section.



O. It is important to note that, due to the functionality of the **Overlay Vertical Adjustment** tool, the raised median is essentially disregarded in this process. This occurs because the median does not influence the **Proposed Ground Line (PGL)** in this scenario. Additionally, the raised median is positioned above the proposed pavement, in contrast to the **Median Ditch**, which lies below the proposed pavement. As a result, the **Overlay Vertical Adjustment** tool functions as intended, ignoring the **Raised Median**. This allows the system to assess the **Proposed Pavement** against the **Existing Surface**, identify the **Control Point** closest to the bottom of the backbone, and then apply a **3"** adjustment based on the provided input to calculate the **PGL**.

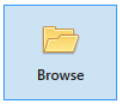


Exercise 4 – Profile Reporting & Proposed Resurfacing Model Review

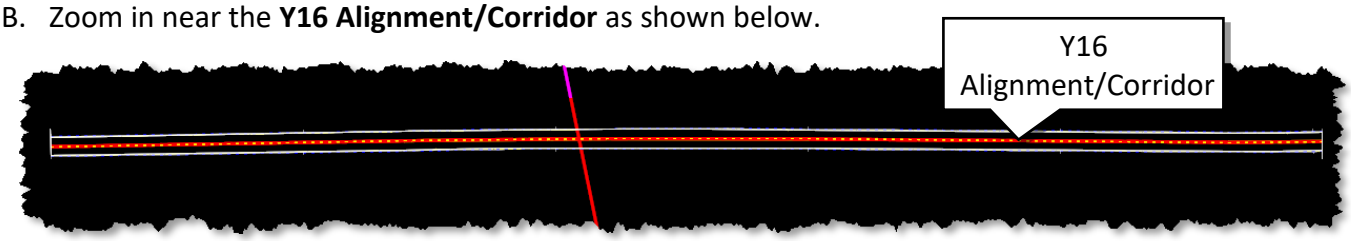
Exercise 4 focuses on methods to check the **Resurfacing Profile** against the **Resurfacing Grade Control Envelope** that was developed in **Exercise 1**.

1. **Generate a report of the Y16 Profile.**

   A. Click the **Browse** button **(File> Open > Browse)** and path to the C:\NCDOT Training\Roadway\Training-RD_R-2635C\Module 9\Roadway**Alignment** folder and open the r2635c_rdy_alg.dgn file.

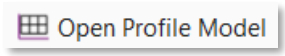


   B. Zoom in near the **Y16 Alignment/Corridor** as shown below.

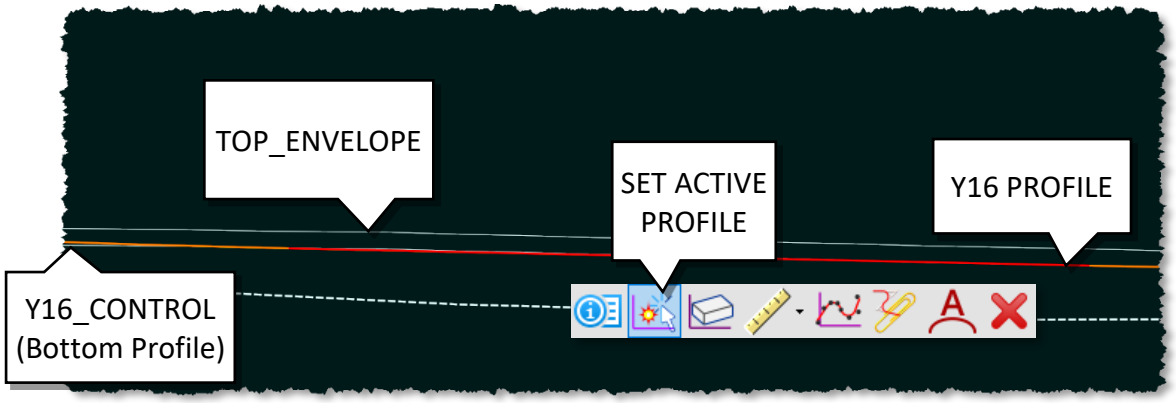


   Note: All reference files that are required for the Resurfacing Grades module have already been attached to the files you will be working in.

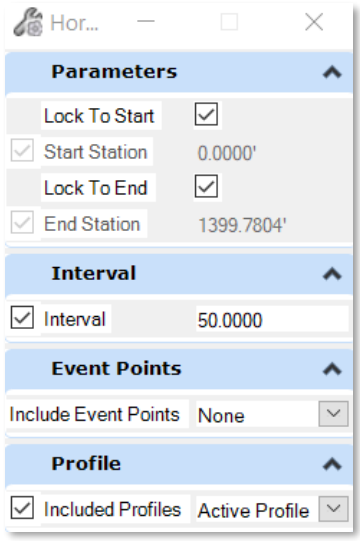
   C. Next, select the **Open Profile Model** button **(Geometry > Vertical > Open Profile Model)** and select the **Y16 Alignment** when prompted to **Locate Plan Element**. Then select a view to open when prompted to do so. This will open the **Y16 Profile View.**



   D. In the **Y16 Profile View**, left-click on the **Y16 Profile** and pause briefly to display the toolbar as shown below. Next, activate the **Y16 Profile** by selecting the **Set Active Profile** button, as illustrated and then close out of the profile view.



E. Next, select the **Horizontal Geometry Report** button **(Home > Model Analysis and Reporting > Reports > Horizontal Geometry Report)** and configure the **Parameters** in the **Horizontal Geometry Report** dialog box as outlined below.

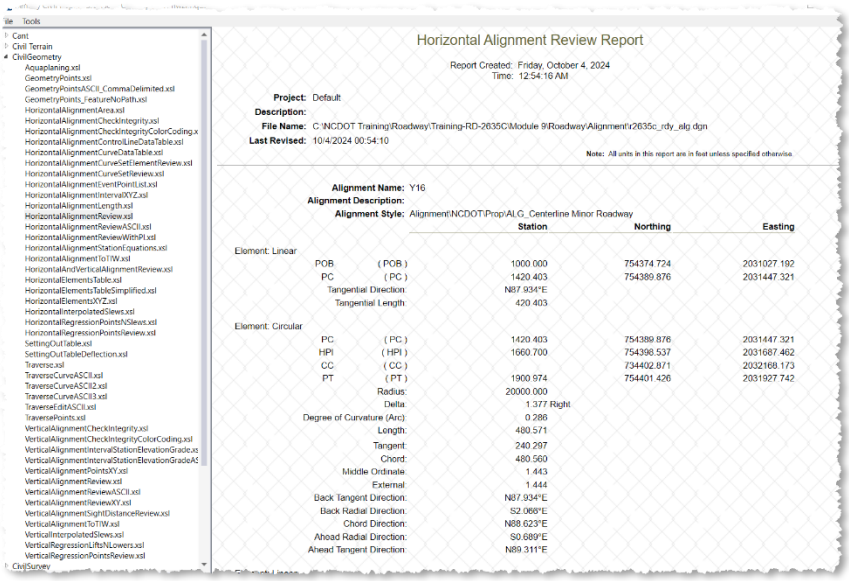


- **Start Station** = **Lock To Start**
- **End Station** = **Lock To End**
- **Interval** = **50.0000**
- **Include Event Points** = **None**
- **Included Profiles** = **Active Profile**

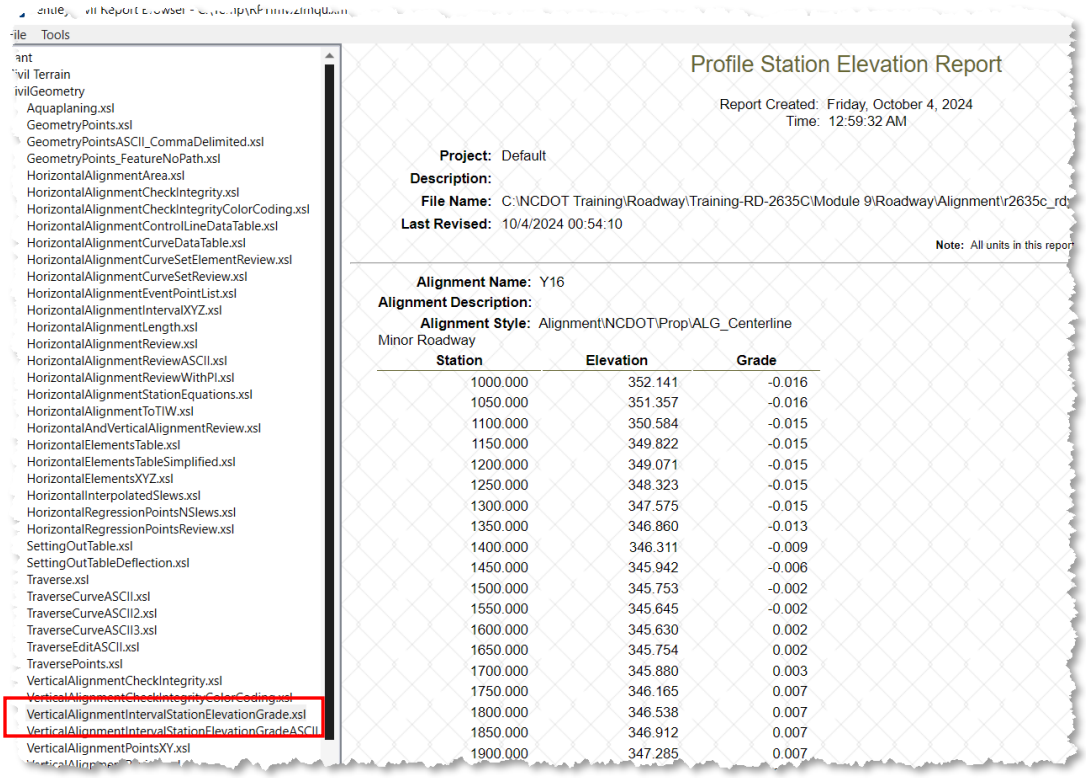
Note: The Interval is used to determine a stationing interval for reporting purposes. This should be set based on the need.

F. Then, select the **Y16 Alignment** when prompted to **Locate First Element** and then **Right-Click** & **Reset to Complete**.

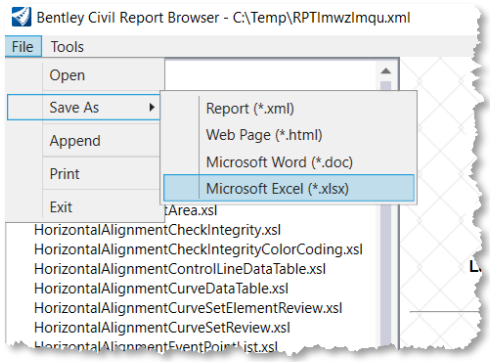
G. Please proceed by clicking through the remaining prompts, which have been pre-populated based on the parameters specified in the **Horizontal Geometry Report** dialog. This action will open the **Bentley Civil Report Browser**, defaulting to the **Horizontal Alignment Review Report**, as illustrated below.



H. Next, please select the **VerticalAlignmentIntervalStationElevationGrade.xsl** from the list on the left side of the **Bentley Civil Report Browser**, as shown below. You will see that the report presents the **Stations** with intervals that correspond to the parameters defined in the **Horizontal Geometry Report** dialog, along with their respective **Elevations**.



I. Finally, Save the report as a Microsoft Excel (.xlsx) file and call it **Y16_Vertical**.



2. **Generate a report on the Top Alignment of the Y16 Resurfacing Vertical Control Envelope, as developed in Exercise 1.**

   A. Please follow the same procedures that were used to generate the Y16 Profile Report.

3. **Generate a report on the Bottom Alignment of the Y16 Resurfacing Vertical Control Envelope, as developed in Exercise 1.**

   A. Please follow the same procedures that were used to generate the Y16 Profile Report.

4. **Compare the three profiles using the Excel reports generated in the previous steps. Assess whether the Y16 profile remains within the envelope boundaries by examining the elevations.**

   A. Copy the **Stationing** and **Elevations** from all three profile reports into a new excel document.

   B. Utilize a formula to evaluate the **Y16 Elevations** for each station against the **Top** and **Bottom Profiles** of the **Envelope**.

   C. If the **Y16 Profile** falls outside the **Envelope Elevation** at a specific station, access the cross-sections to identify the cause. Subsequently, document the reason in the spreadsheet.