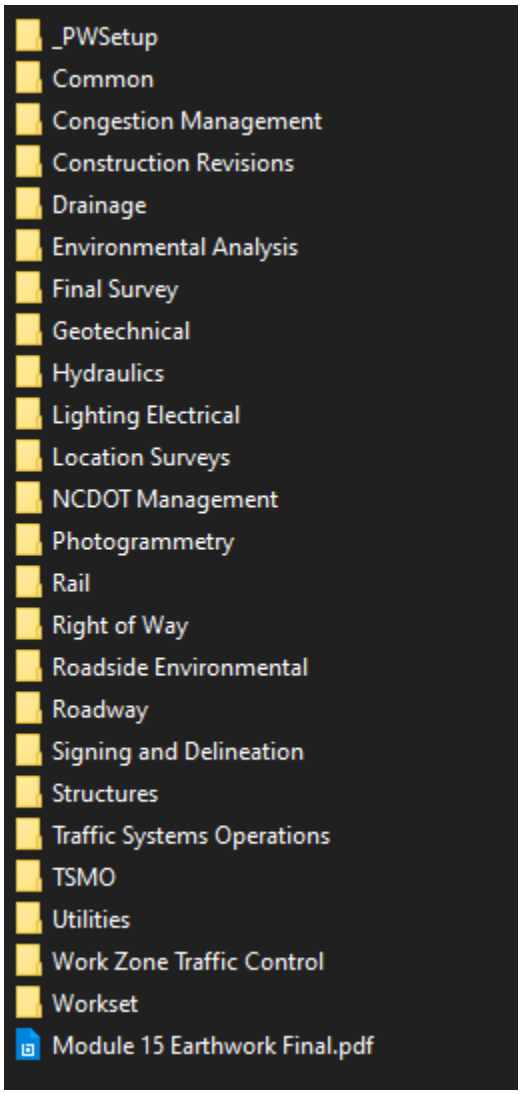
Module 15

Earthwork

2024
OpenRoads Designer 2023

About this Practice Workbook . . . . .

- Module 15 – Earthwork.zip will be provided for download.
- Extract the zip file to the root C:\
- All files are then automatically extracted here:
  C:\NCDOT Training\Roadway\Module 15 - Earthwork
- With these subfolders:



The Module 15 Earthwork 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 in this series is self-contained. You can jump to any section and begin the exercises.

- The ***WorkSpaceSetup CFG*** should be set to the following variables:
  - **NCDOT_USE_LOCAL_WORKSETS = L2**
  - **NCDOT_UNIT_TRAINING_WORKSETS = Roadway**

- This training module uses the **DOT-US North Carolina** WorkSpace, **R-2635C (Training)** WorkSet and **NCDOT_Roadway** Role. It is very important that you select the correct WorkSpace, WorkSet and Role.

- NCLUG / NCDOT Bentley ORD Open X presentations from each NCDOT Department: https://www.nclug.com/

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

Table of Contents

Overview

OpenRoads Designer (ORD) provides new methods for Earthwork Calculations and documentation that will replace the methods used by Geopak. Prismoidal Volumes are now reported by the program and offer a true surface to surface comparison. These volumes will replace the Average End Area method that was utilized with Geopak.

This module will focus on the process of creating the earthwork volumes. This is a straightforward process and should be relatively easy to complete. One of the most important concepts to understand and remember is that this will be a surface-to-surface comparison. That means that the Earthwork Volume will only be as good as the Proposed Model. Errors and omissions in the Proposed Model will be carried to the Earthwork Volume calculation and because this process does not involve Average End Areas the only way to eliminate these errors is to produce a Proposed Model that accurately reflects the roadway design.

This training module does not include any modeling instruction or guidance. The example files in this module include very simple models. This is intentional as the focus of this training module is the steps to compute and report the earthwork volumes. NCDOT has provided additional training modules that give guidance for producing proposed models. This guidance should be followed, and the final model should represent as close as possible the final roadway design.

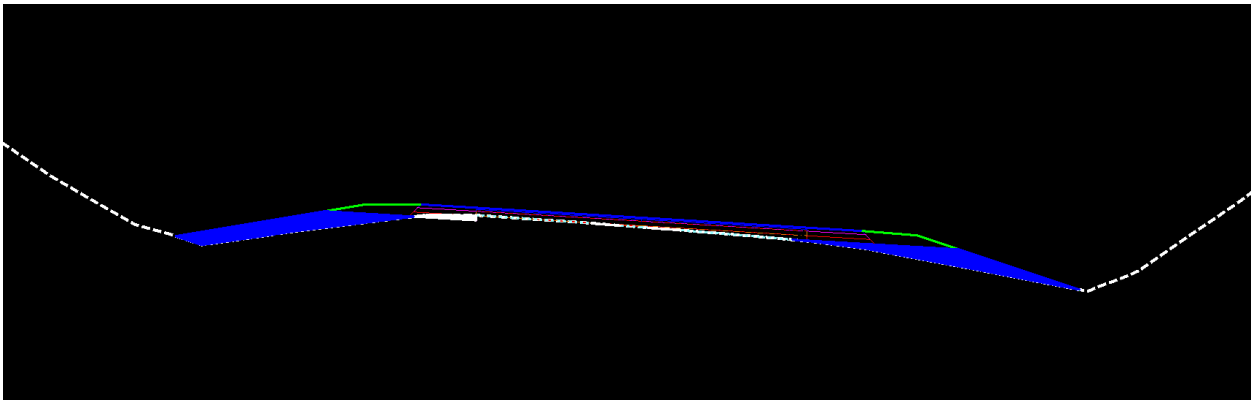
When creating and verifying the earthwork volumes the design and engineer must also verify the proposed roadway model. The necessity to start with a detailed and accurate model cannot be overstated.

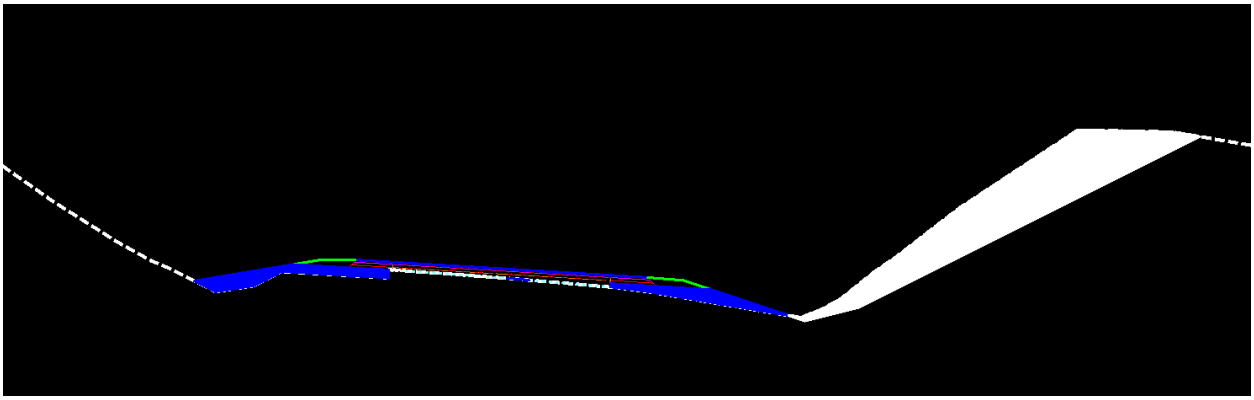
Introduction

Earthwork Calculation completed with OpenRoads Designer will introduce some new terms and concepts. This introduction will give an overview of the new OpenRoads workflow and contrast that with the methods used with Geopak.

The Old Way – Average End Area

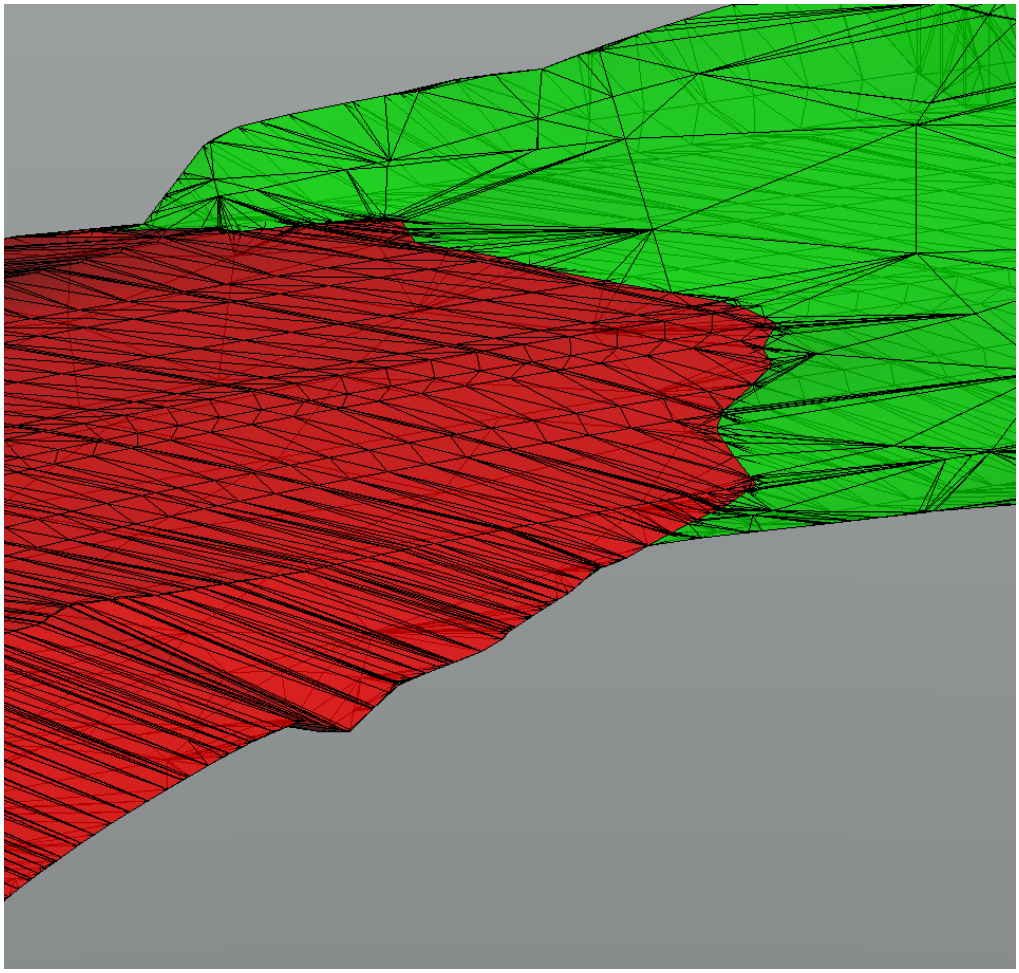
Geopak used the Average End Area method to calculate Earthwork Volumes. This involved measuring the cut and fill areas on two consecutive cross sections, finding the average of those areas, and multiplying the average by the distance between the cross sections. This is shown in the two screen shots below with the familiar blue shape representing fill and the white shape representing cut.





The New Way – Prismoidal Volumes

OpenRoads Designer uses Prismoidal Calculations to determine the earthwork volume. Prismoidal Volume Calculations use a more complicated formula that uses the area of two bounding surfaces and the area midway between these surfaces. In roadway modeling the bounding areas are the triangulated surfaces of the Existing Terrain and Proposed Model and the midway area is calculated based on the tapering sides between the bounding triangular surfaces. This results in a true surface to surface comparison. This in turn results in an improvement in accuracy compared to the Average End Area. The main limitation being the accuracy of the proposed model. The image below shows the cut volumes in green and the fill volumes in red.



Contrast and Compare – Average End Area vs Prismoidal

Prismoidal Volume Calculations will produce a more accurate earthwork volume than Average End Area. Average End Area volumes are reliant on the Average Area of two consecutive cross sections being representative of the design in that section. Some of the things that can affect the accuracy of the Average Areas are:

- Is there a ridge or channel in between the sections that does not show up on either section?
- The cross-section interval density.
- Do the cross sections include the beginning and ending of:
    - Tapers?
    - Alignments?
    - Bridges?
    - Culverts?
    - Horizontal and Vertical Curves?
- How are intersections and other non-typical areas represented in the cross-sections.
- How are break points and shear lines incorporated into the cross-sections.
- Has the cross-section been skewed relative to a baseline?

Some of the benefits of using the Prismoidal Volume Calculation method include:

- It includes any deviations in the existing terrain that are not included on the cross-sections.
- The model is based on drop interval of 5’ set by NCDOT, this is a 10x improvement on the standard 50’ cross section interval.
- Automatically includes tapers, transitions, Begin / End points, key points in the horizontal and vertical geometry.
- Non-typical areas included.
- Break points and shear lines are not required or used.
- Not dependent on Cross Section orientation.

Assuming that the existing ground is accurate the most significant issue that can affect the accuracy of a Prismoidal Volume Calculation is:

- The accuracy of the proposed model. The proposed model must accurately represent the design.

It is critical to review NCDOT guidance on modeling and standards for producing a proposed roadway model.

Prismoidal Volume Calculations are based on the area of each triangle included in the existing terrain model, so they will automatically include all the features; channels, ridge lines, etc. that are in the existing terrain model. Features that would not be included in average end area calculations.

The interval density for earthwork has been set to 5’ as a standard by NCDOT, this will provide a high level of accuracy. The proposed surface will have 10x the accuracy of a standard 50’ cross sections interval. In conjunction with 3D volumes this improves the accuracy of the earthwork volume calculation.

Tapers, transitions, begin/end construction, begin/end bridge stations, horizontal and vertical control points are all included in the model when using the standard NCDOT modeling guidelines and principles. These are features that are not necessarily included in the Average End Area calculation method.

Non-typical areas such as intersections, roundabouts, driveways, grade to drain, bridge abutments etc., are all included when following NCDOT modeling guidelines. These will be modeled as 3D components that will not be affected by a cross-section layout and will be included in the earthwork calculations.

Shear Points and Break Lines are no longer required for Earthwork because earthwork is no longer dependent on the cross-section layout. Y Lines are modeled to the Edge of Travel on L lines. The Prismoidal Volume calculation will include the volume up to the edge of pavement. Cross-Sections are not required to match up in a specific way to generate an accurate Earthwork volume.

Cross sections that shear across areas that are not parallel to the centerline; lane tapers, U-Turn bulbs, intersection corners, gore areas, etc. produce end areas that do not accurately reflect the actual volumes. Using Prismoidal Volumes these areas will be accurately calculated if the proposed model is accurate.

Model Overview

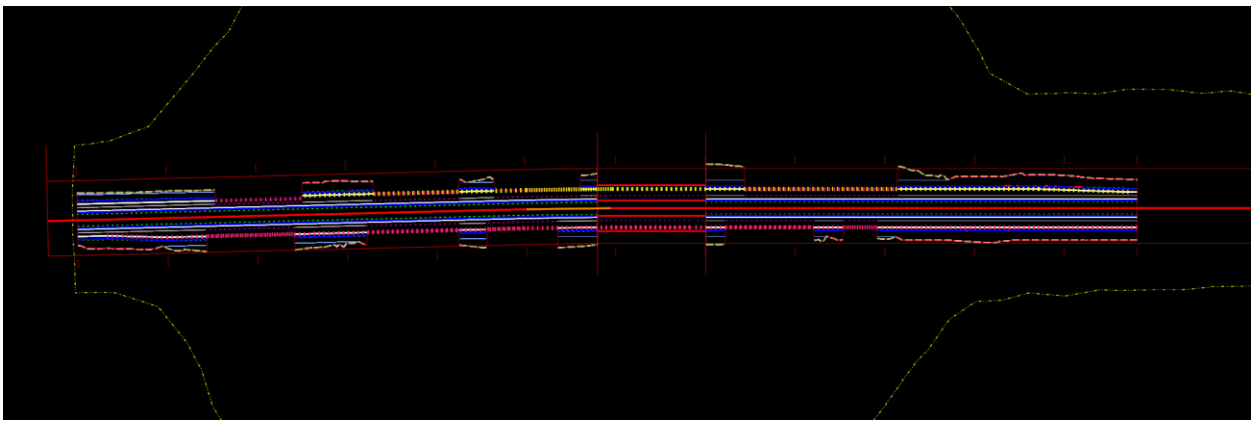
These are a few of the general modeling guidelines that will help produce accurate earthwork volumes. Each project is different, and it is up to the designer to ensure that the model has been developed in a way that accurately reflects the design. The model should be continually refined and become more detailed throughout the design process.

The Prismoidal Volumes will only be as good as the proposed roadway model.

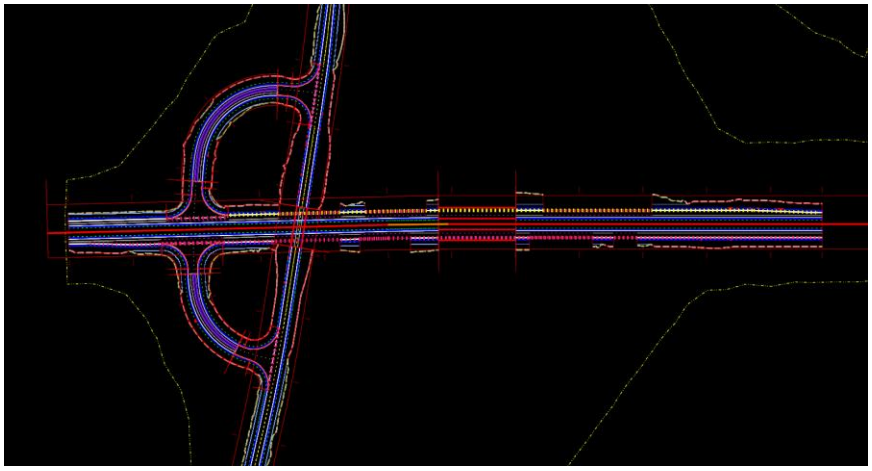
Proposed Corridor Setup

The designer should consider the CMD file setup. Named boundaries can be utilized to separate earthwork volumes, but creating named boundary groups in a file that contains all the corridors may not be feasible. Creating a separate file for each alignment/corridor will be the easiest when only considering the earthwork calculation. If the designer wants to include more than one alignment/corridor in a single CMD file, they should consider how that will impact earthwork calculations.

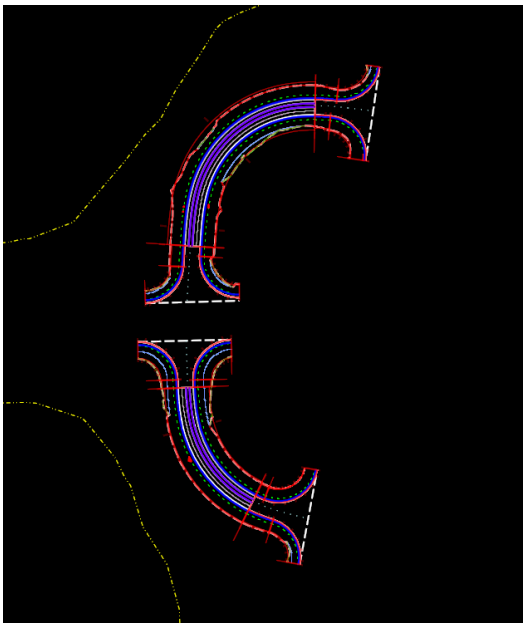
This file contains a single Corridor for Y8 in the R-2635C example file. When computing the earthwork only the corridor in this file will be considered.



If all the corridors are in a single file then the user will have to spend a significant amount of time placing and adjusting named boundaries to separate the earthwork for each alignment.



Including these two corridors in a single file would not result in a significant amount of effort because it would be relatively simple to place two named boundaries around each corridor, since they do not overlap or intersect.

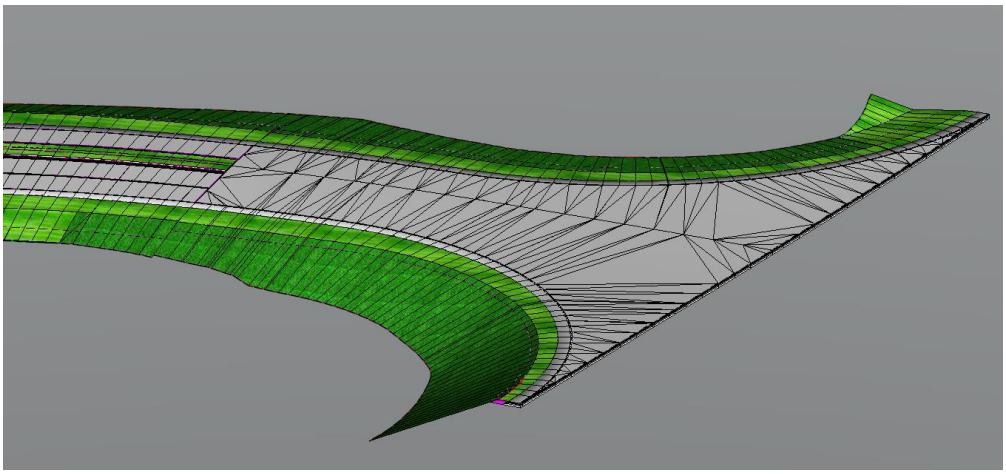


It is easier to make the decisions when setting up the CMD files than it is later in the project when trying to compute earthwork volumes.

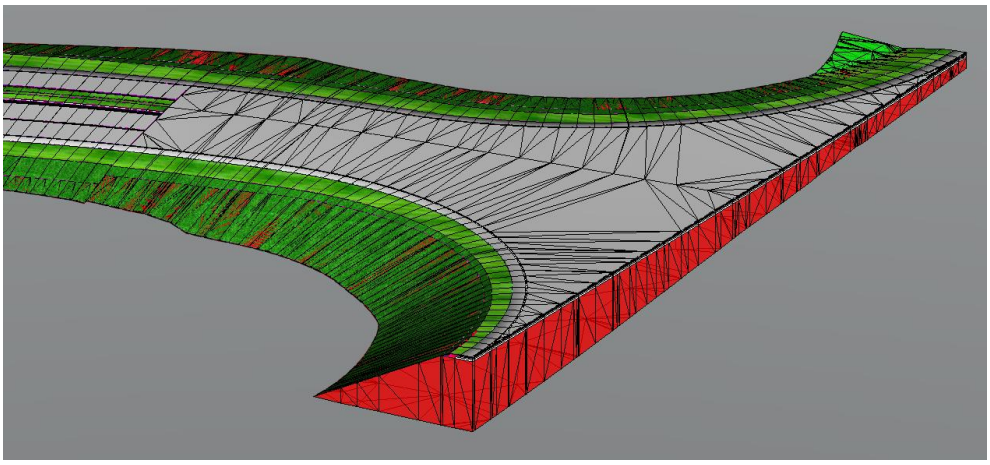
Intersections and Non-Typical Areas

Prismoidal volumes do not rely on cross section areas that match perfectly through intersections or other non-typical areas. Prismoidal volumes do not require Shear Points or Break Lines. Models for non-typical areas should follow NCDOT guidance.

This is an intersection that has been modeled with a combination of design templates, linear templates and surface templates.



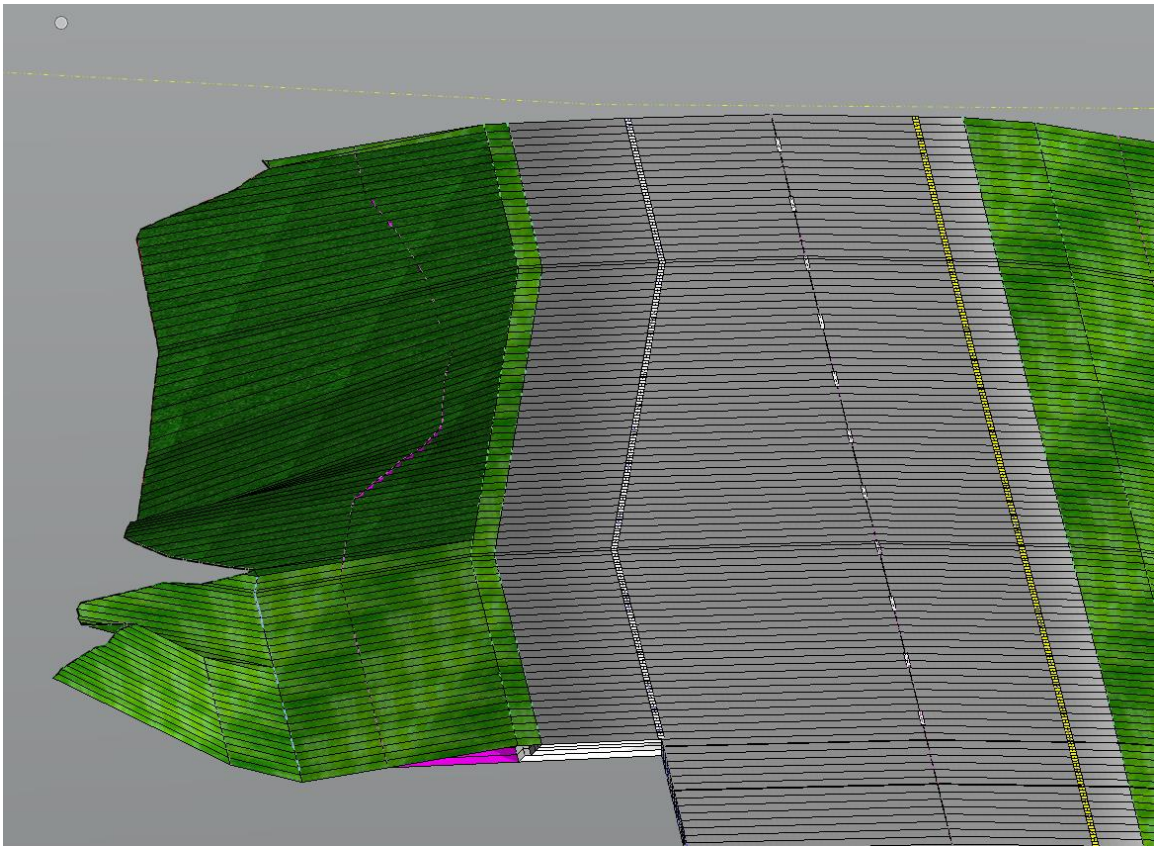
The red volumes show that even though this is a combination of modeling techniques the earthwork volumes will be computed correctly and shear exactly with the EOT on the through roadway.



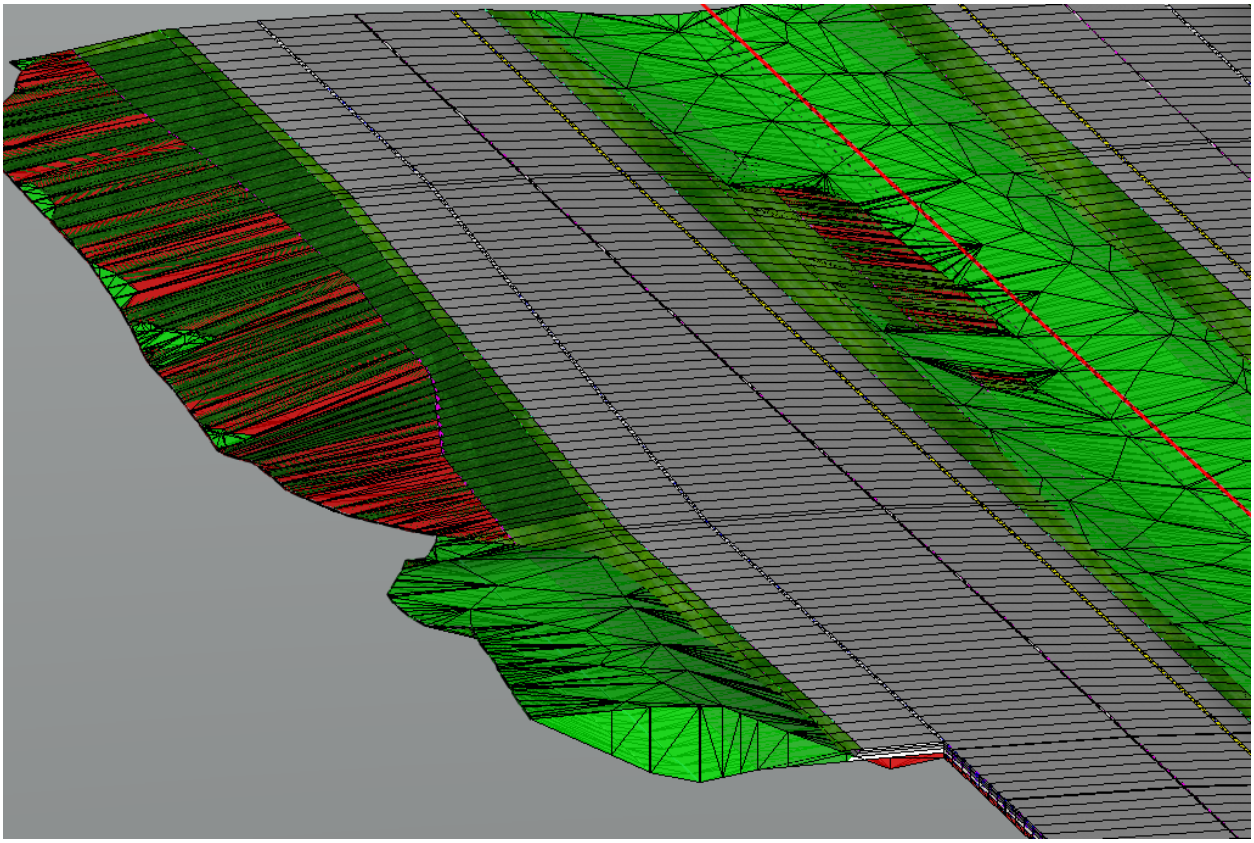
Tapers and Transitions

Pavement and shoulder tapers should be accurately modeled, this includes the use of parametric constraints, point controls, corridor references and key stations. Even if these areas do not show up on cross-sections, they will be included in the Prismoidal Volume

This area shows a turn lane taper that has been added and the right turn lane shearing at an intersection.



When the earthwork volumes are computed they match perfectly with the taper and the shear lines. If this had been done using average end area methods, then it would have required multiple extra cross sections to capture this area accurately. Additionally, if the design had changed then new cross sections would be required at the new taper points. In this case since the model is the design, any changes will be included in a new earthwork calculation.



Earthwork Calculation DGN File

Earthwork calculations will be done in separate DGN files. Intersecting roadways will need separate corridors to keep the earthwork calculation separate. Named boundaries can be used to separate Y lines that do not intersect but the user may still find it easier to create a separate earthwork file for each corridor. These concepts will become clearer when completing the more complex exercises.

The general workflow for computing earthwork volumes:

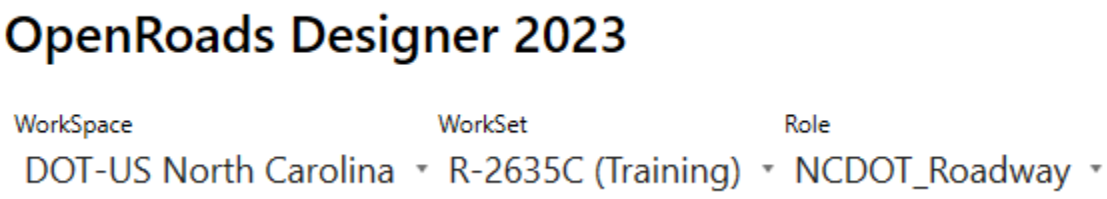
- Create a file using the NCDOT 2D Seed File
- File Naming Convention
  - TIP#_RDY_EAR_Alignment
  - R-2635C_RDY_EAR_Y8.dgn
- Folder location
  - R-2635C\Roadway\Design
- Reference files required
  - Existing Terrain Model
    - Set Active to get Default 3D Model
  - Alignment file
    - Required for advanced earthwork calculations using named boundaries.
  - Proposed Corridor CMD file or files
    - This should include all proposed models needed for the desired earthwork calculation.
      - Proposed Roadway
      - Proposed Special Ditches
      - Non-Typical Areas
- Create Cut and Fill Volumes
- Placed Named Boundaries as required
- Report Earthwork Volumes

Exercise 1 – Simple Earthwork Calculation

In this exercise we will create and report on the Earthwork Volume for an entire project without breaking it up as required for an Earthwork Balance Card. This process could be utilized at the functional or DRPS stage or during design when trying to balance the cut and fill volume.

Start by selecting the OpenRoads Designer 2023 Desktop Icon

The WorkSpace is DOT-US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



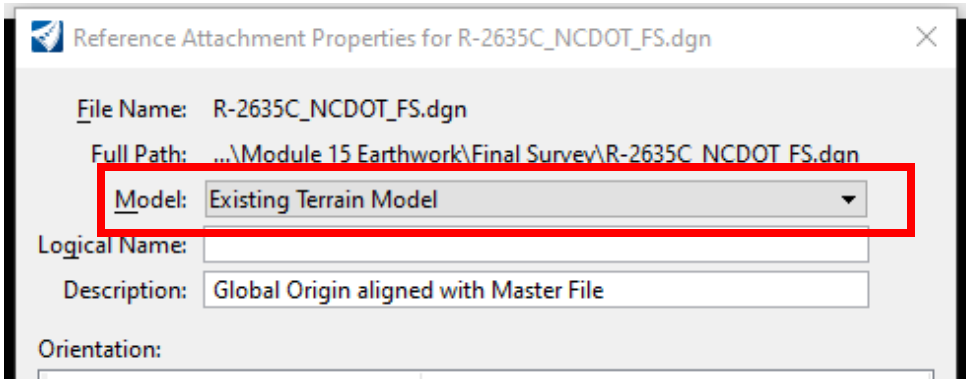
1. Create Earthwork Volumes

A. Create a new DGN file for the Earthwork Calculation

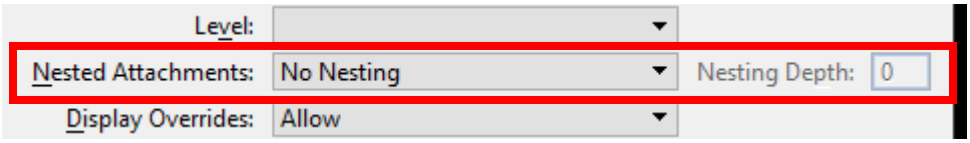
- Filename
  1. R-2635C_RDY_EAR_ALL.dgn
- Folder Location
  1. …\R-2635C\Roadway\Design
- Seed File
  1. Seed2D – English Design.dgn

B. Attach the required reference files:

- Existing Terrain Model
  1. R-2635C\Final Survey\R-2635C_NCDOT_FS.dgn
  2. Attach the Existing Terrain Model in the FS file

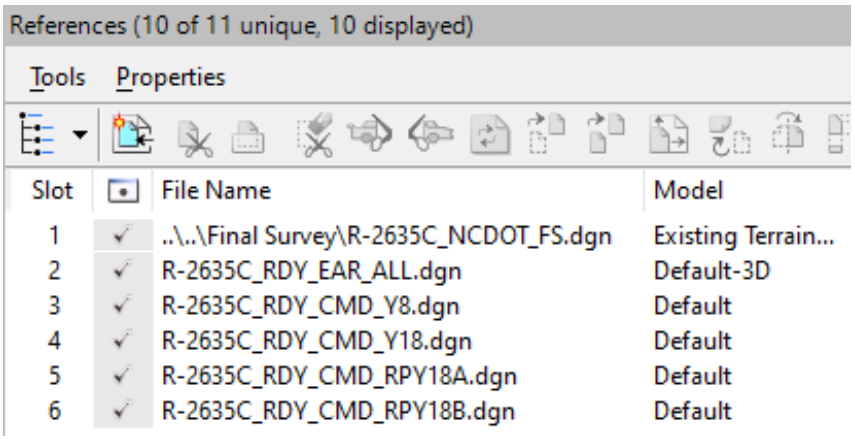


3. When attaching Terrains and Models for use in Earthwork Calculations Live Nesting should be OFF. Live Nesting can result in the program reading multiple surfaces when computing the Earthwork resulting in errors.

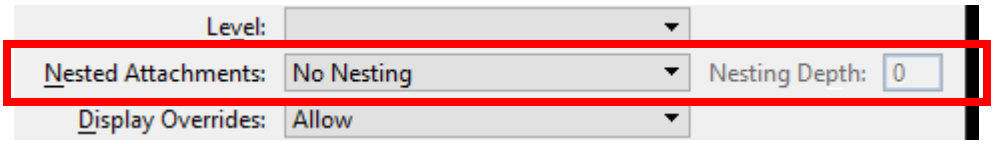


4. Set the Existing Terrain Active to Create the Default 3D Model
5. The 3D model is required to calculate the earthwork

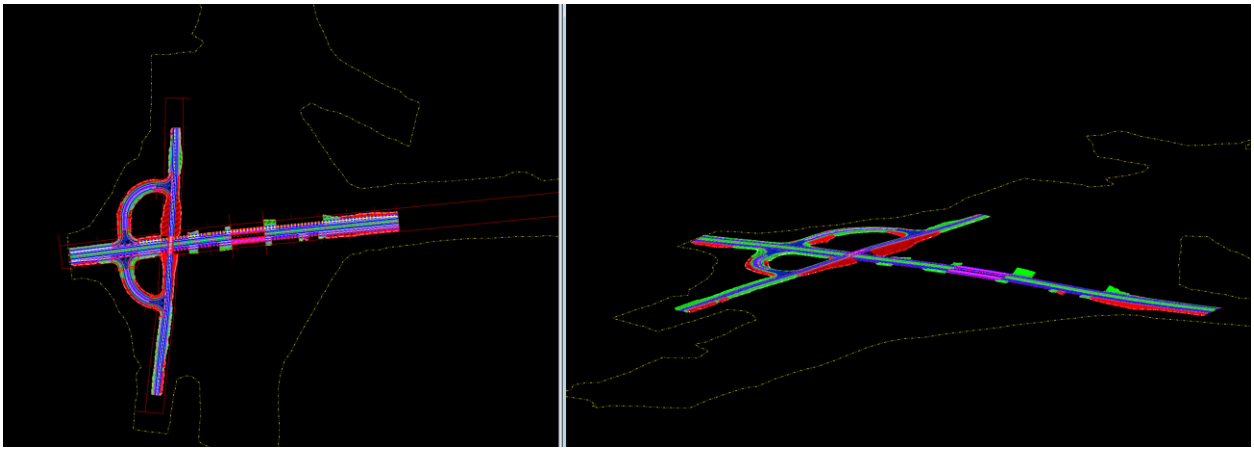
- Proposed CMD Files, this exercise will calculate the total project earthwork volume
  1. R-2635C_RDY_CMD_Y8
  2. R-2635C_RDY_CMD_Y18
  3. R-2635C_RDY_CMD_RPY18A
  4. R-2635C_RDY_CMD_RPY18B
- Note that for this calculation the alignments are not required because there are no Named Boundaries.



- Live Nesting should be OFF for all Files.

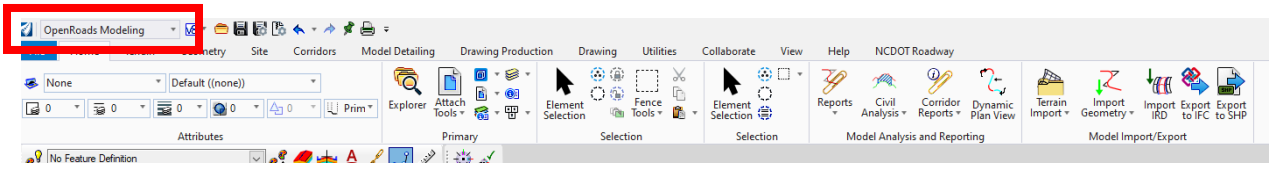


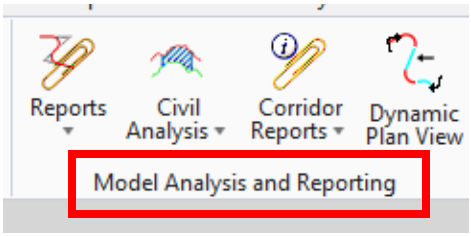
A. Open a view with the Default 3D Model shown. The Default 3D View must be open in order to run the Earthwork Tools.



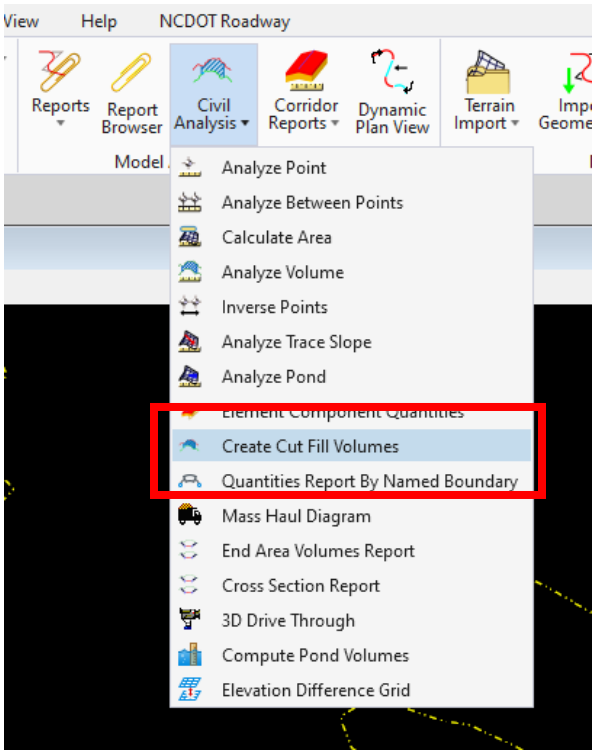
C. Create the 3D Earthwork Volumes

- Use the OpenRoads Modeling workflow.
- On the home Tab find the Model Analysis and Reporting Section.

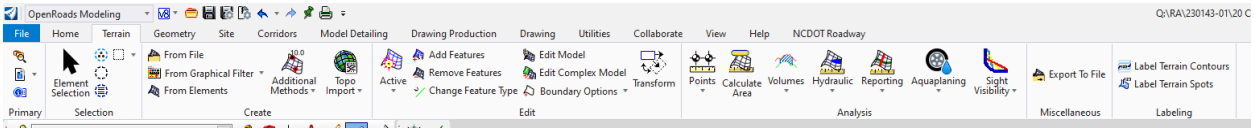


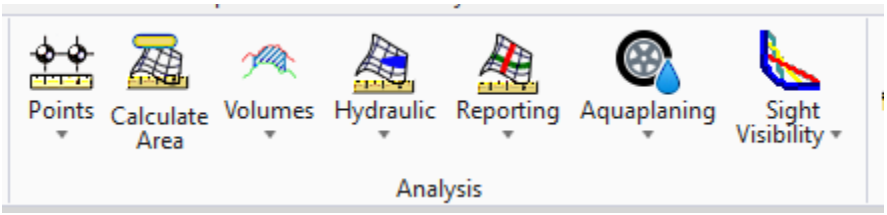


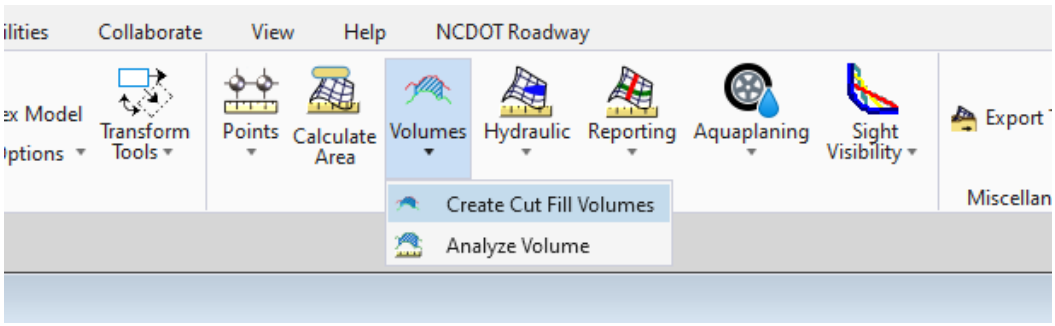
- Under Civil Analysis Find the Create Cut and Fill Volumes Tool.



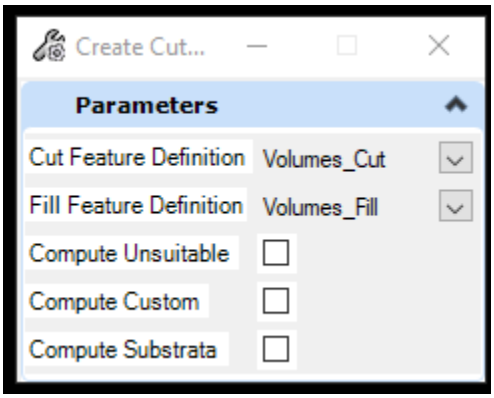
- Note that this same tool is available under the Terrain Tab in the Analysis Section under Volumes



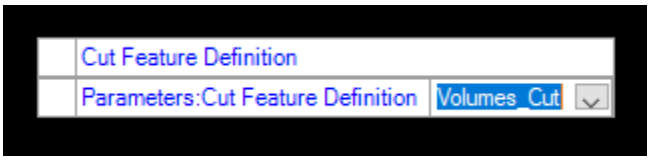




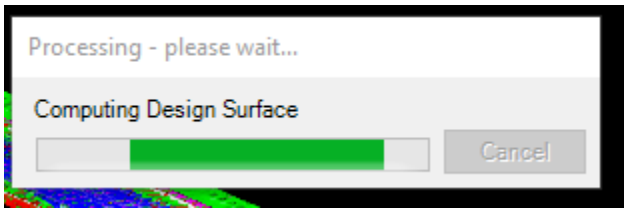
- The dialog Box should be set correctly by Default
  1. Cut Feature Definition = Volumes_Cut
  2. Fill Feature Definition = Volumes_Fill
  3. Compute Unsuitable = Unchecked
  4. Compute Custom = Unchecked
     a. Custom volumes will be used for DDE Calculations and Detour Removal calculations in subsequent examples
  5. Compute Substrata = Unchecked



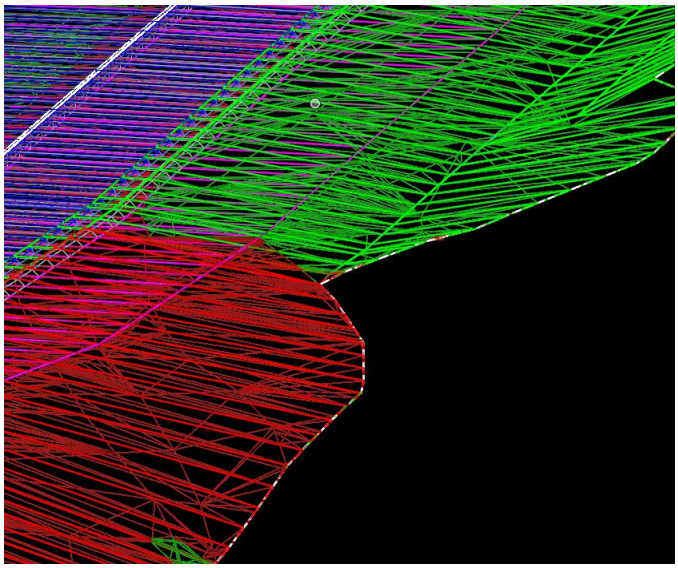
- Left Click for each pop-up window to accept these settings. Left click in any view to start the Earthwork Calculation, the 3D view must be open.



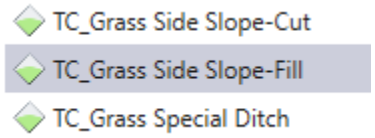
- A processing window should appear.

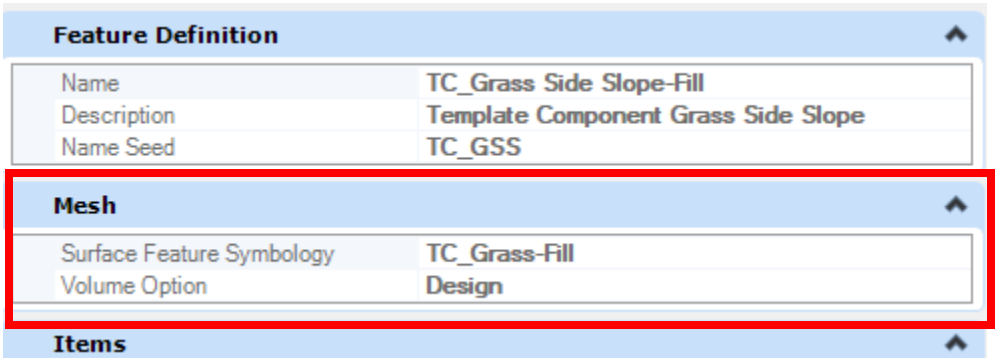


- The Earthwork Volumes will be shown as new triangulated volumes in the 3D view, red will be the fill volume and green will be the cut volume. These are 3D Mesh Volumes.

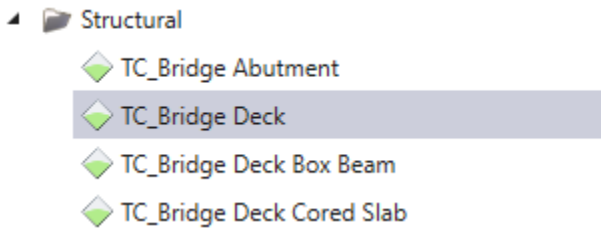


- The Cut and Fill Volumes were determined automatically by the program. Each component of a template is assigned a volume option based on the Feature Definition. For example, in the roadway templates fill slopes are assigned a feature definition of TC_Grass Side Slope-Fill and this feature definition is assigned a volume option of design. Any feature definition that has a volume option set to design will be included in the cut and fill volume calculations. The program can automatically determine which elements represent the top surface and which elements represent the bottom surface out of all the elements that are assigned to a volume option of design.

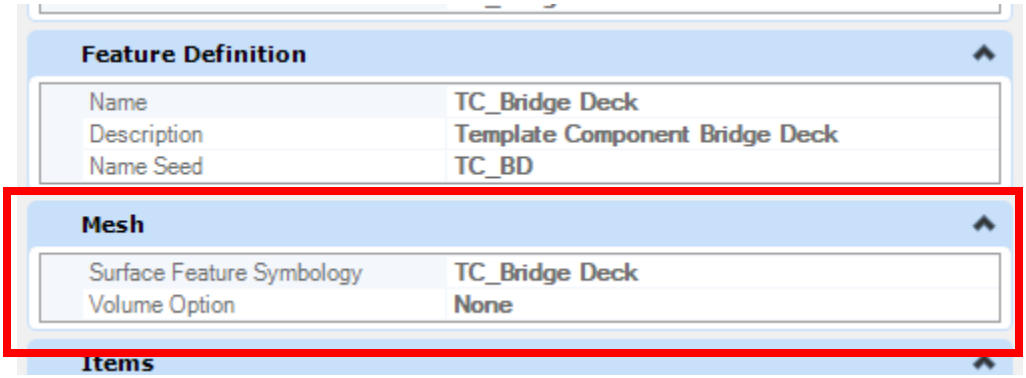




- Bridge components such as the bridge deck are assigned a volume option of none. This means that when the program is determining how to calculate the earthwork cut and fill volumes the bridge deck components in the model will be



ignored.

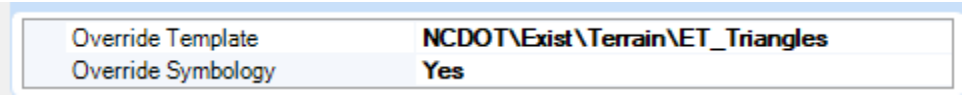


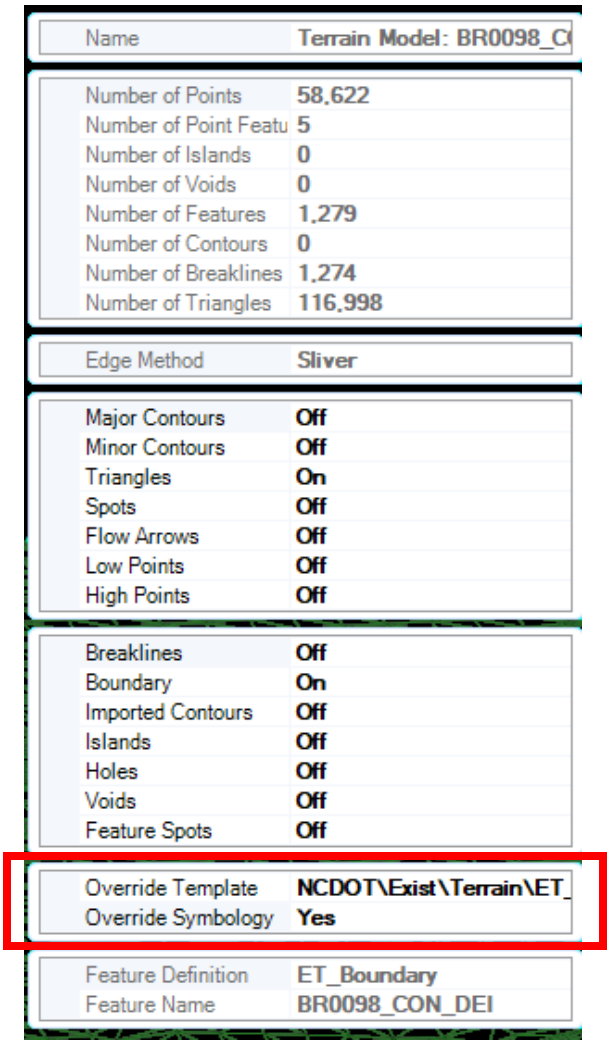
2. Review Volumes for Accuracy - Visually

A. The first step after completing the volumes is to visually review the shapes for Accuracy, this file and these shapes will be part of the required submittal for Earthwork Documentation.

B. To make the review easier setup the 3D Model as Follows.

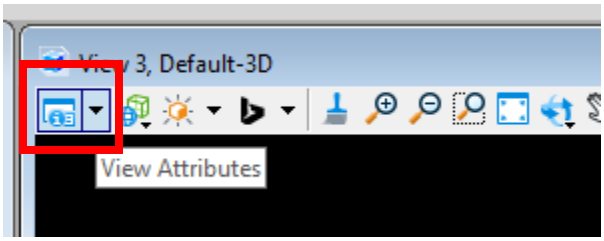
- Set the Existing Terrain Override Template to Yes and Triangles



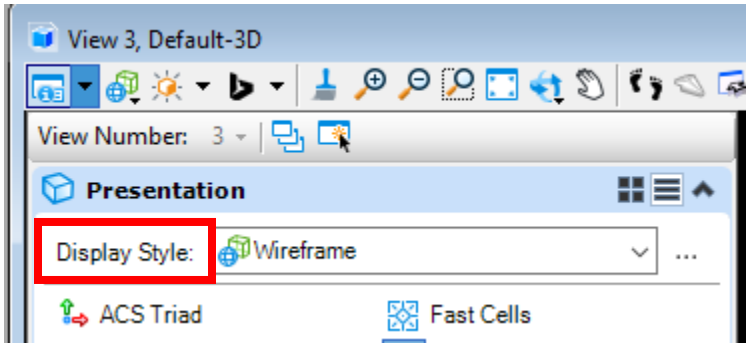


- Turn off the proposed Corridor References.

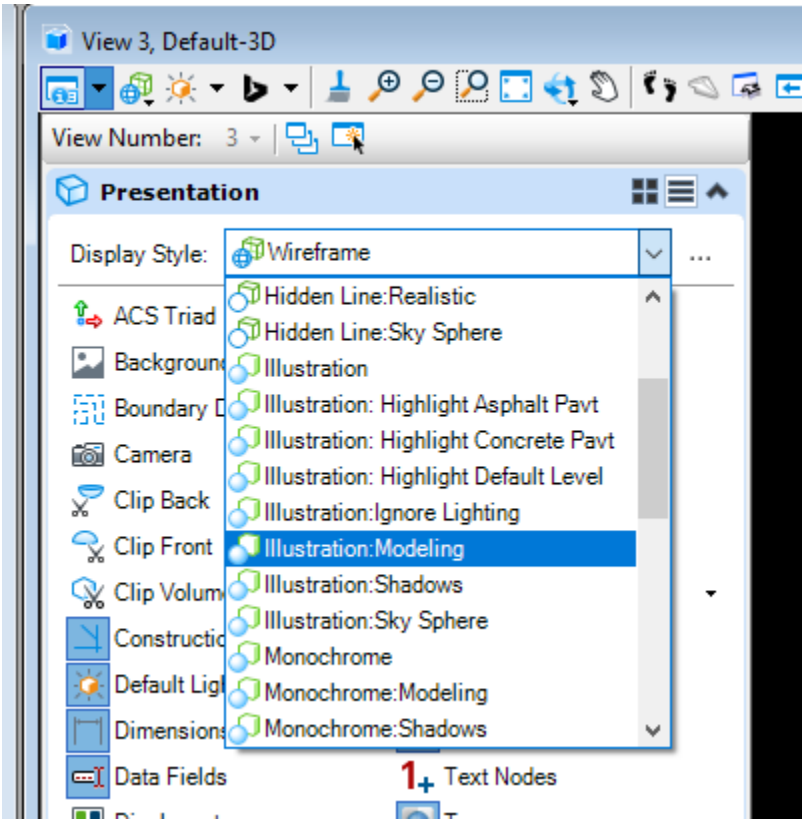
- Set the Display Style to Illustration Modeling.
  1. To do this Look for the View Attribute Icon in the Top Left Corner of the View Window



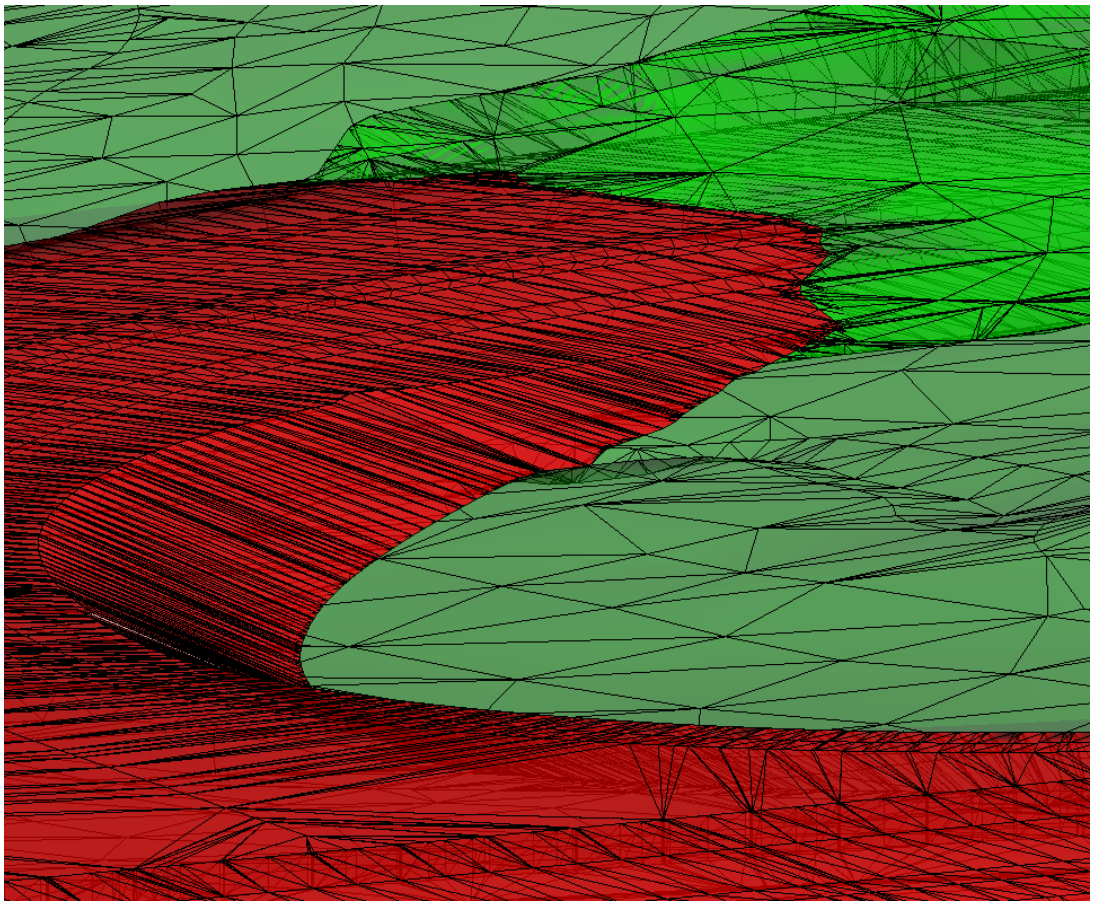
  2. At the top of the Dropdown Menu find the Display Style



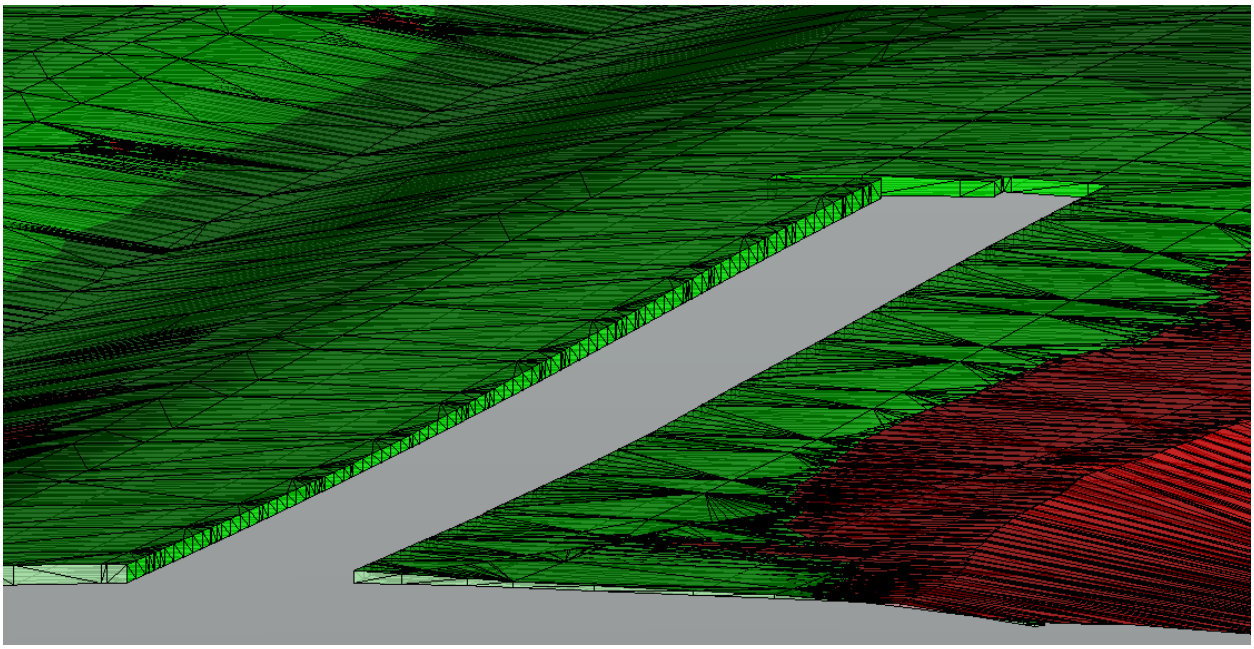
3. This Dropdown Menu contains numerous setting for different display styles, one of the styles that is useful when using 3D views is Illustration modeling.



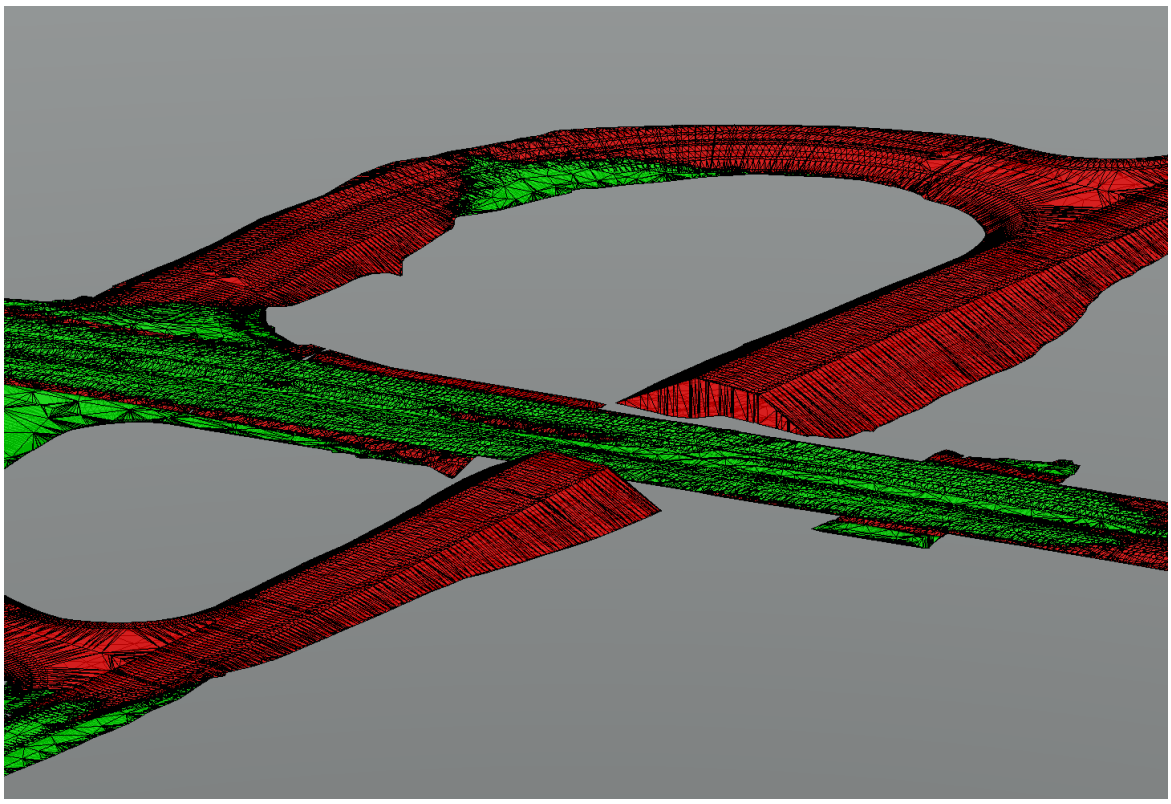
C. In the 3D view, Zoom, Turn and Pan around the DGN to visually verify there are no areas of concern, this would be indicated by the Red or Green Volumes that are obviously not in line with the proposed design. Visually verifying the shapes is one of the easiest and most reliable methods to verify the accuracy of the earthwork.



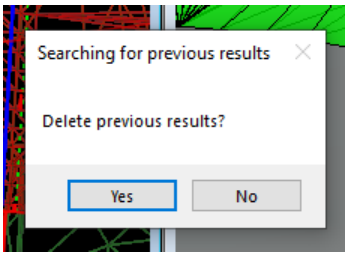
D. This view shows how the earthwork has been ignored in an area of overlay and wedging. Reviewing the 3D view and the volume shapes makes it easy to see how the volumes have been calculated correctly.



D. For these exercises the bridge abutments have been left out and it is very easy to see that these sections are missing from the earthwork calculations. If these abutments were included in the model they would be included in the earthwork calculation.

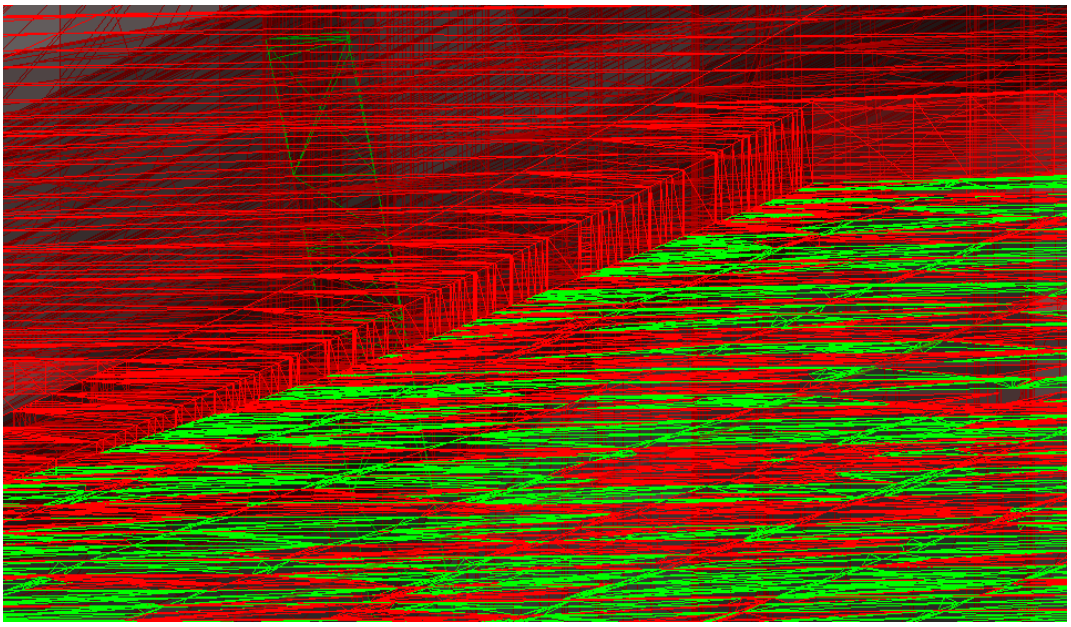


E. At this stage any obvious issues will have to be addressed by revising the proposed model. The Cut and Fill Volume shapes cannot be modified, so any errors need to be corrected in the proposed CMD files and then the Earthwork Shapes will need to be recalculated. The user will be given the option to delete any previous earthwork volumes during subsequent runs.

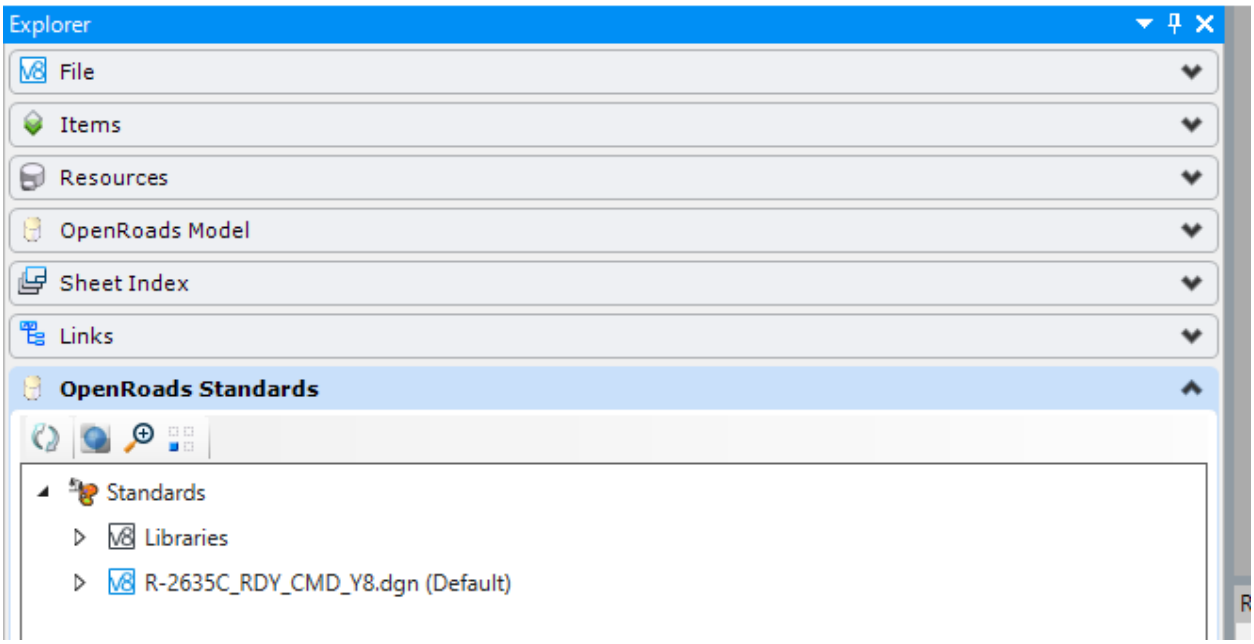


F. ***Note : Older workspace versions and custom templates may experience the following issue with Pavement Wedging areas where earthwork will be computed over the existing pavement. The following is a discussion of the issue and a description of the solution.***

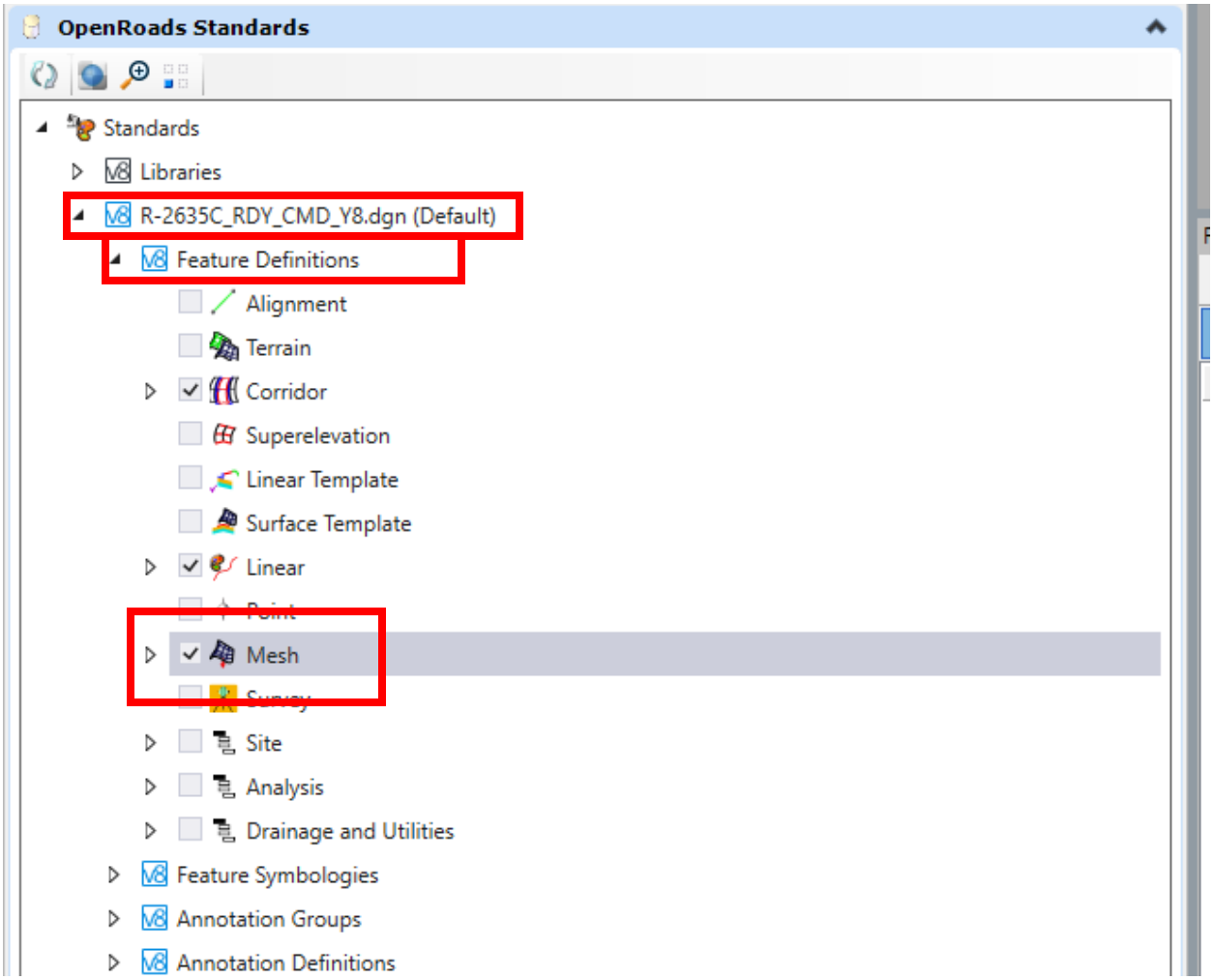
Here we can see an example of a minor discrepancy in the earthwork volumes. In this view we can see where the wedging ends and the full depth pavement begins. This is evident by the ramp up on the outside of the existing pavement shown in red and the numerous red and green areas shown on top of the existing pavement. Although every section and template drop models the wedging depth to perfectly match the existing ground line the Prismoidal Volume uses each existing triangle and each proposed triangle to calculate a volume. Those triangles do not line up exactly with the sections or exactly with each other. That is going to cause these irregularities in the volumes displayed. These are very small volumes and may or may not be considered incidental, but this is an example of how easy it is to visually identify these areas and make a determination on the magnitude of the error and what if anything needs to be done about it.



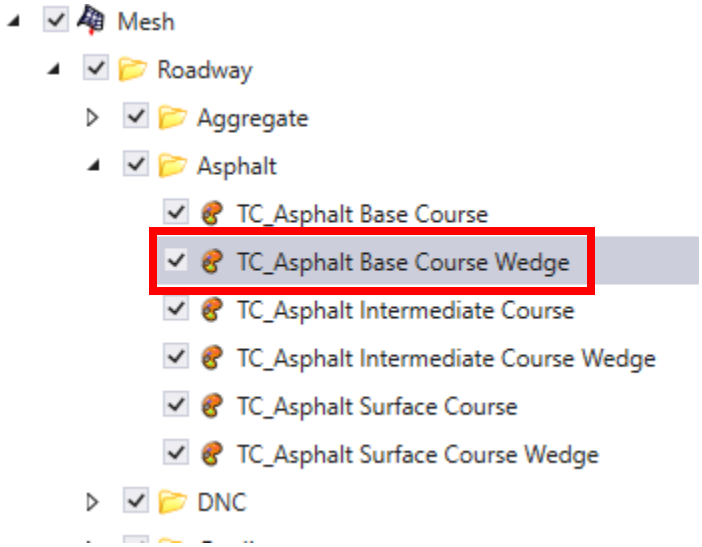
G. This issue with wedging areas needs to be corrected at the template level.
    1. Depending on the workspace version or how the custom templates were put together the wedging component feature definitions may be set to a volume option of DESIGN. This means these components will be used when creating the earthwork volumes.
    2. This needs to be revised and set to ta volume option of NONE. When the feature definition is set to a volume option of NONE these components will be ignored when creating the earthwork volumes.
    3. To set the Feature Definition to none open the corresponding CMD file, in this case R-2635C_RDY_CMD_Y8
    4. In the OpenRoads Explorer Dialog find the OpenRoads Standards Section.



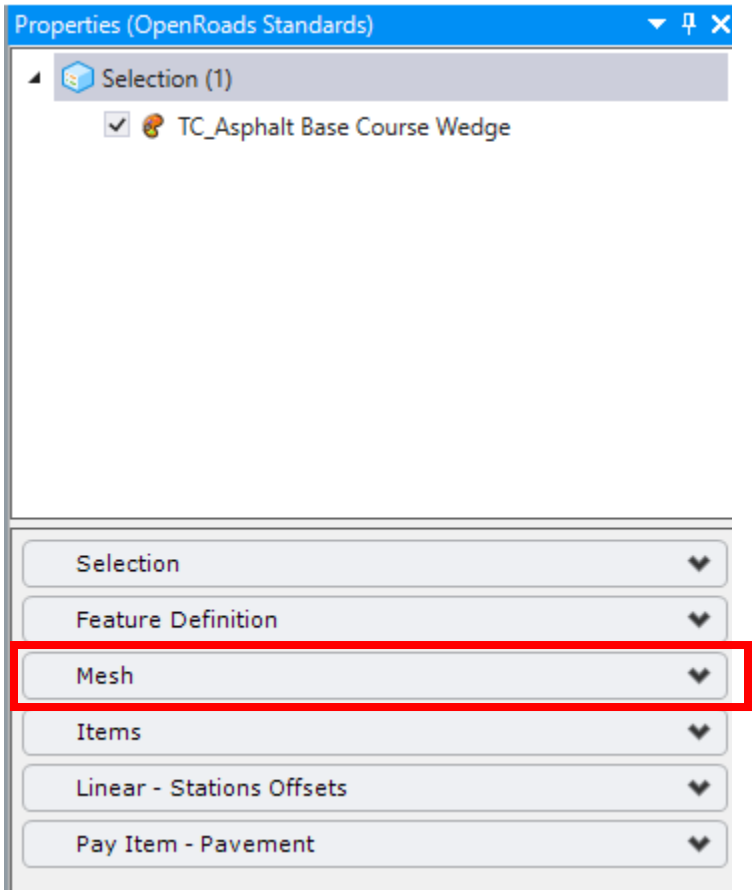
5. Click on the Current Design File → Feature Definitions → Mesh



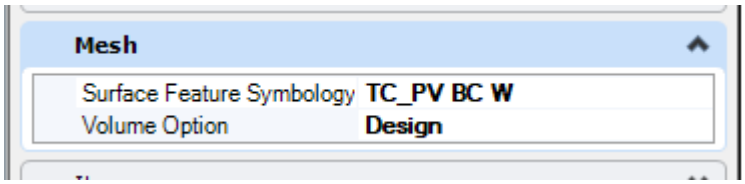
6. Under the Roadway Asphalt Section find the Feature Definition for the TC_Asphalt Base Course Wedge. Note that this matches the template component feature definition that is resulting in the error and the actual feature definition in any custom template may be different.



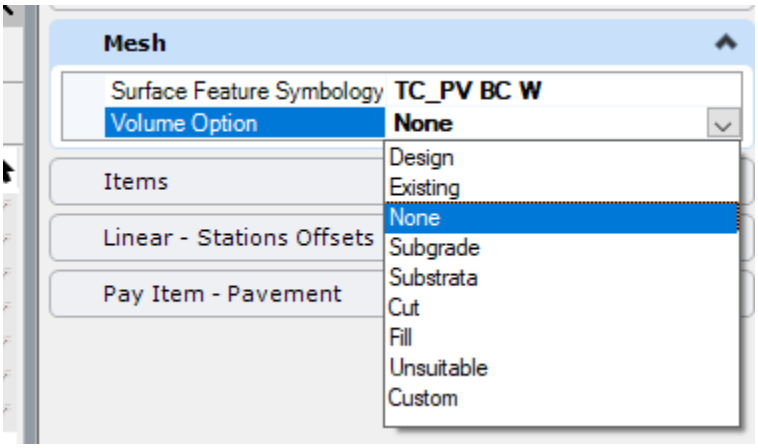
7. In the Properties Dialog find the Mesh section.



8. In this section the Volume Option is shown as Design

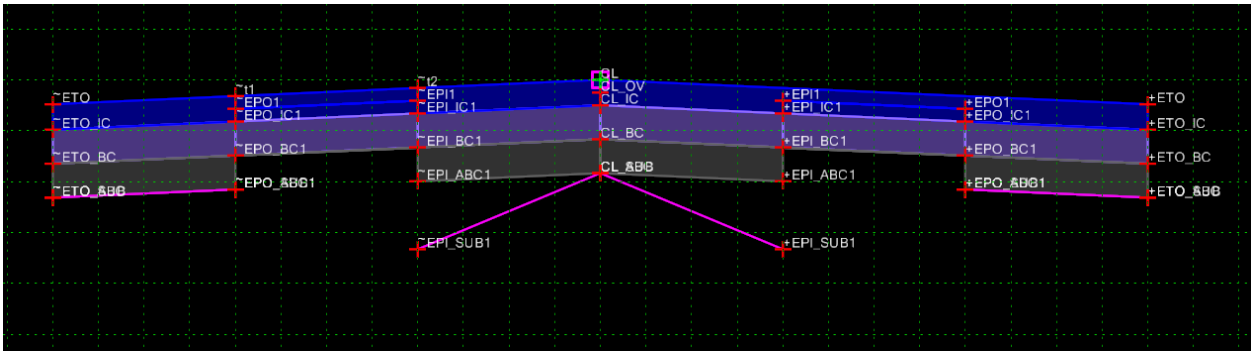


9. Click in the Volume Option box to activate a drop-down list and change this selection to None.

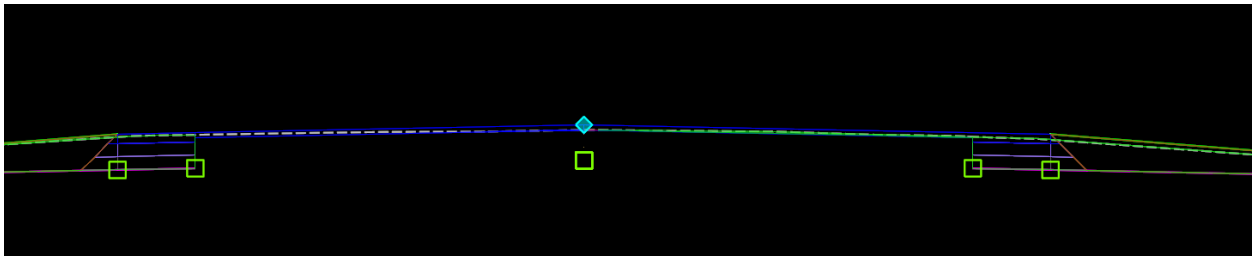


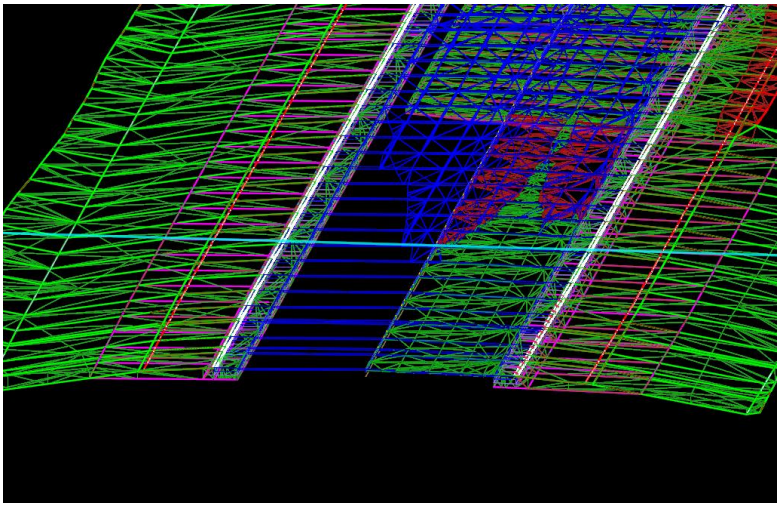
10. Repeat this process for the Intermediate Course Wedge and Surface Course Wedge.
11. Depending on how the template is assembled this may also need to be completed for the Surface Course.
12. If there is one large component that is full depth and minimum resurfacing over wedging. This needs to be split into multiple components or the minimum 1 ½" layer over wedging needs to be removed and surface shown as a single component
13. Alternately all pavement layers could be set to none since there is a subgrade line that would control the earthwork volumes

14. The images below show an example of how this template was modified. The Left Side has been revised and the Right Side was not.



The earthwork is no longer computer under left side wedging.





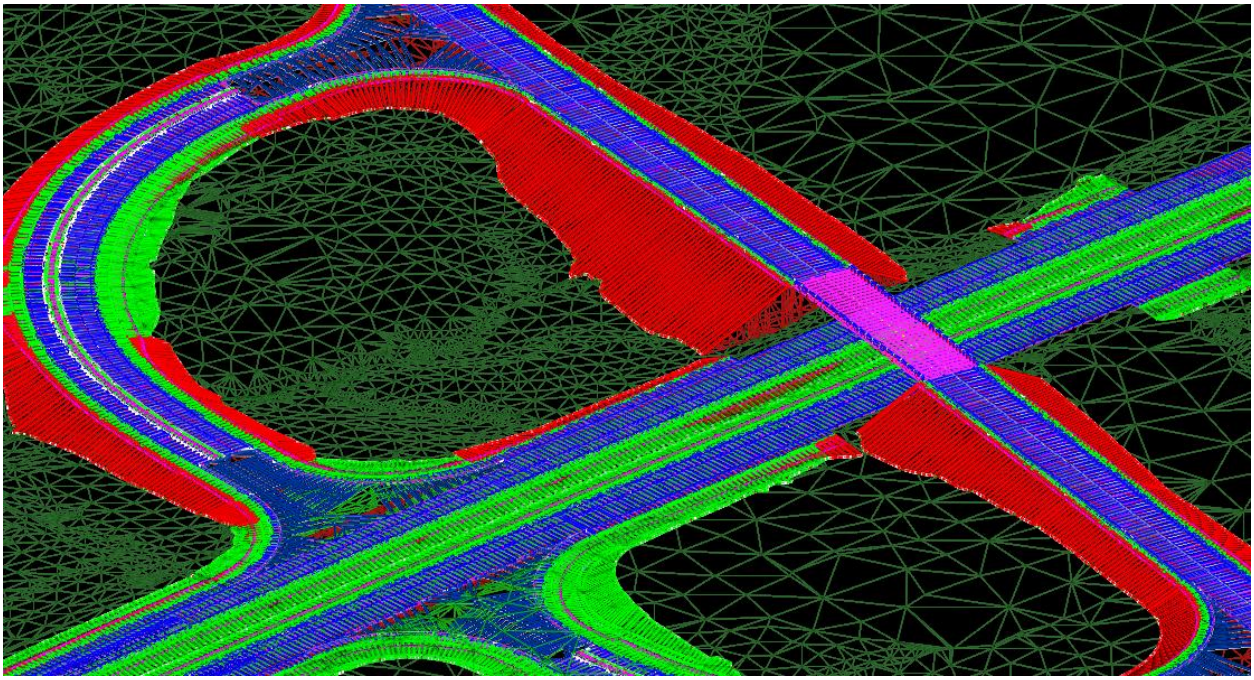
THIS ENDS THE SECTION ON REVISING FEATURE DEFINITIONS TO ELIMINATE EARTHWORK VOLUME ERRORS

3. Review Volumes for Accuracy – Dynamic Sections

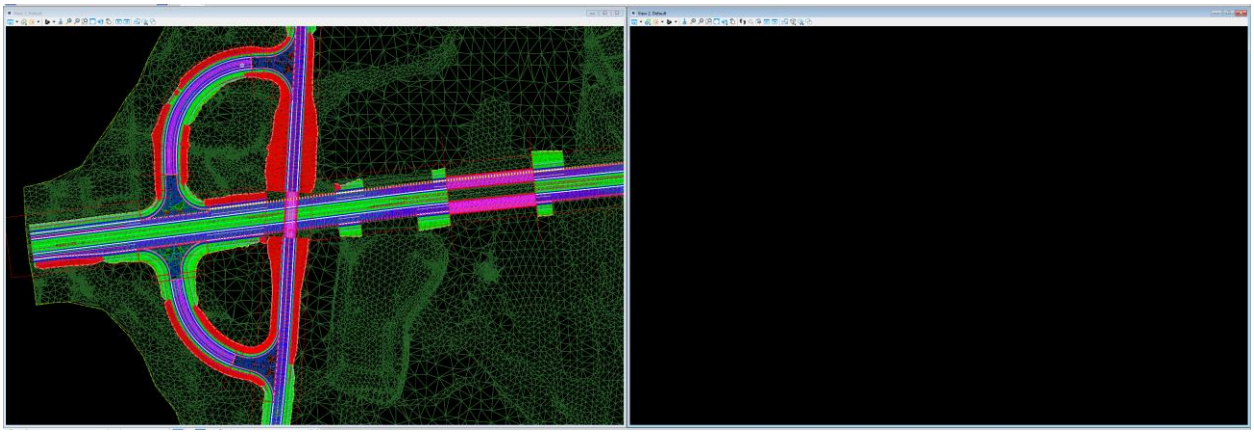
A. After any revisions are made and the proposed shapes look acceptable a more detailed review can be done with the Dynamic Cross Section View.

B. In the 3D Model

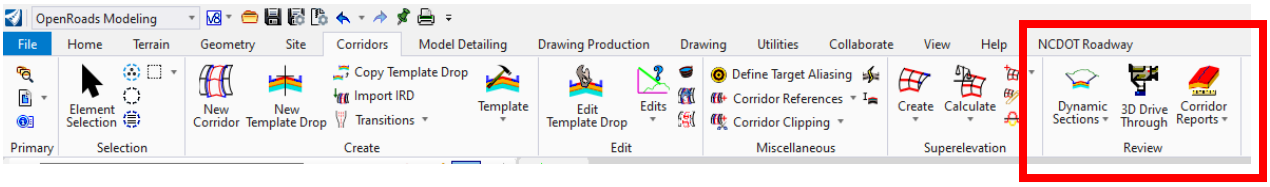
- Set the View Display back to wire frame
- Turn the Proposed Corridor reference files back on.



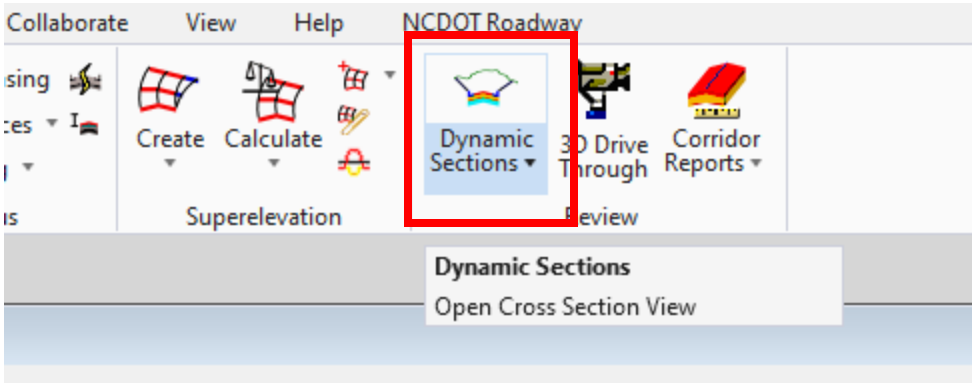
C. Switch Back to the Default 2D Model and open an additional window.



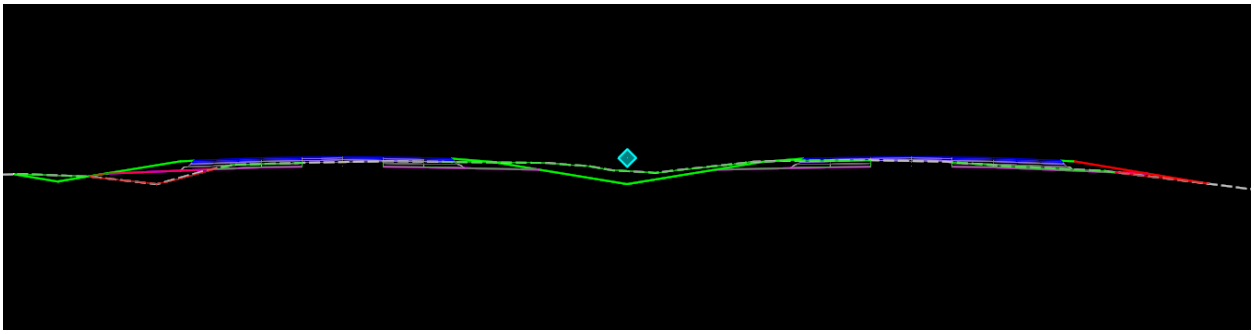
D. Go to the Corridors Tab of the OpenRoads Modeling workflow and the Review Section.



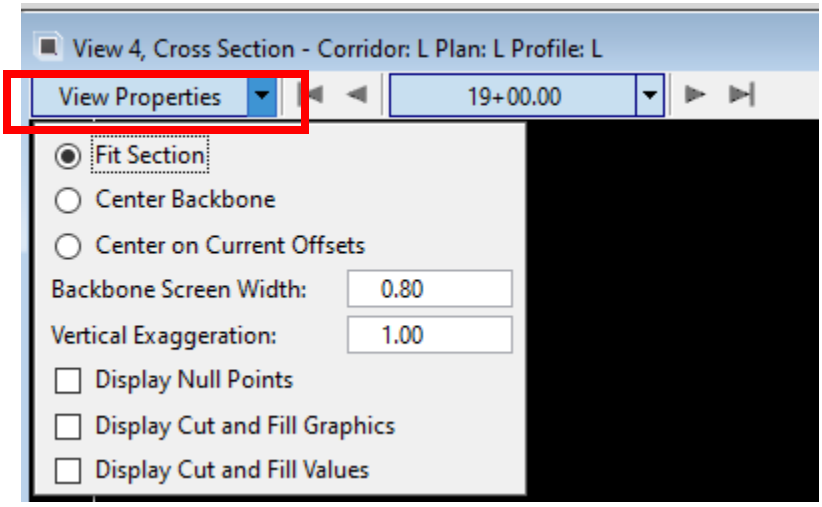
E. Select the Dynamic Sections tool.



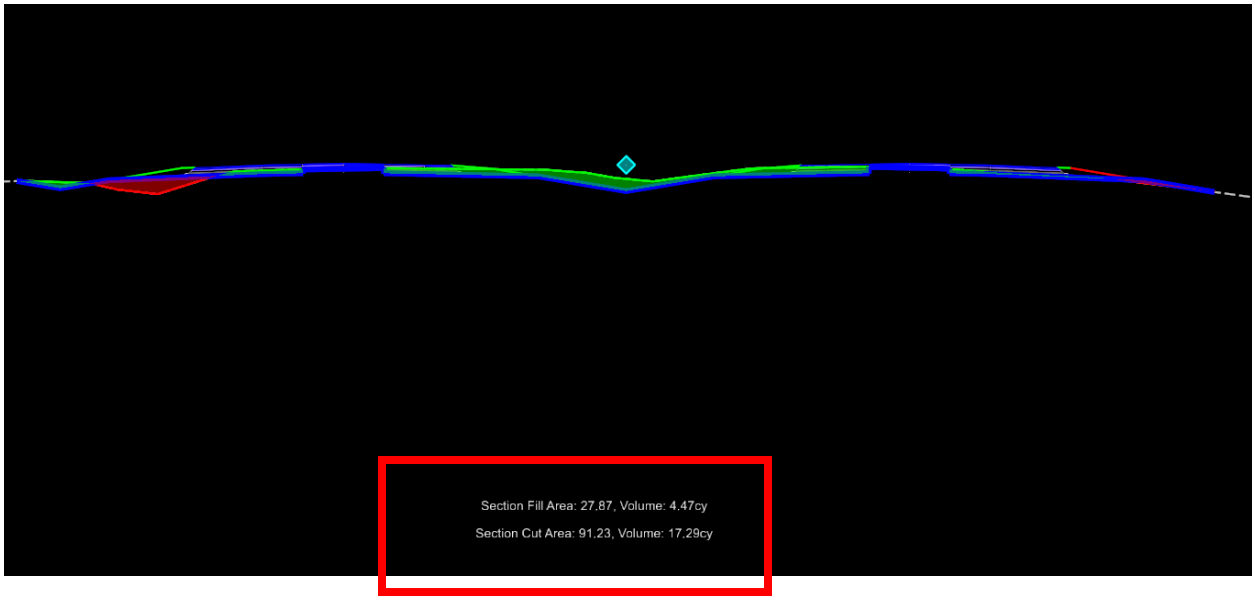
F. Select the Y8 Corridor and click in the open view. Notice the red and green shapes, these are the cut and fill volumes from the Default 3D model.



G. Under View Properties in the Cross Section View, check on Display Cut and Fill Graphics and Display Cut and Fill Values.



H. Now the Cut and Fill Areas will be shaded and the Cut and Fill Area at the section and the volume will be shown below. This is another visual check that should be performed to ensure that the Cut and Fill Volumes from the Default 3D model do match the proposed design.

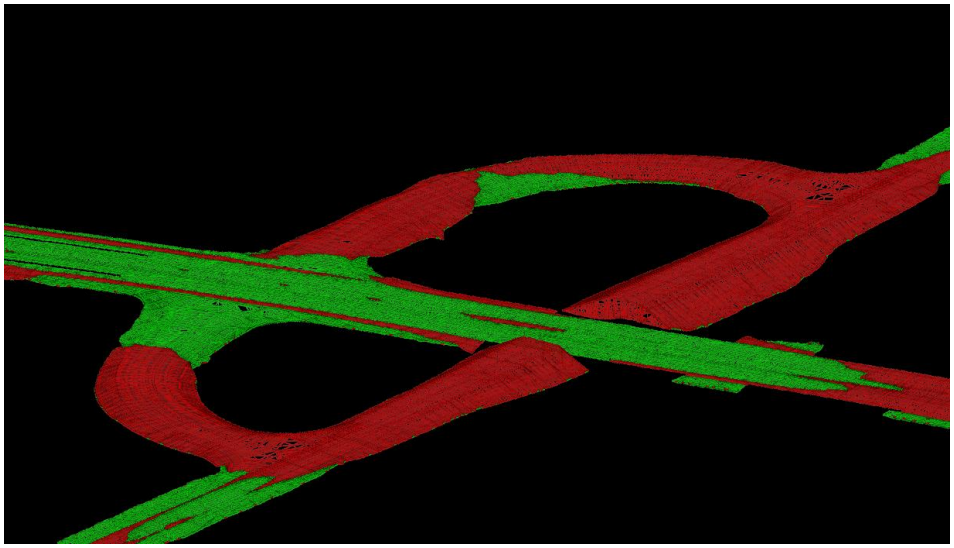


Note that this method will only display the Graphics and Area for the selected corridor, it will not show them for adjacent corridor and linear templates. The areas will be visible but not shaded and the volumes will not display. The volumes and areas in this view are meant as a check of the accuracy of the model.

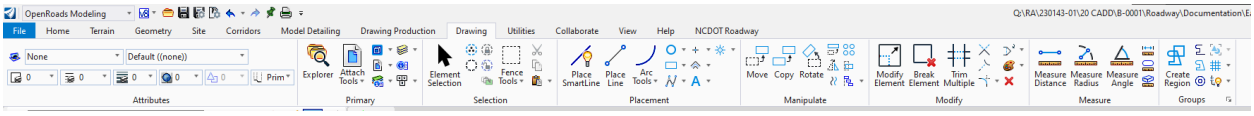
4. Report Earthwork Volumes

A. After the earthwork shapes have been reviewed for accuracies and any errors in the proposed model have been corrected the volumes can be reported out of the program.

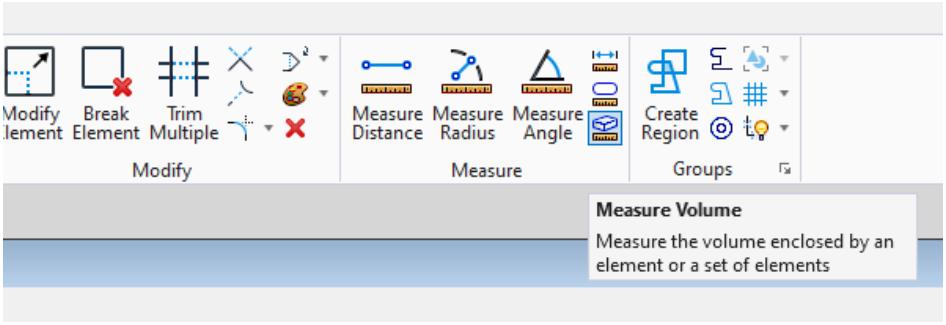
B. The simplest way to get the volumes is to measure directly from the Default 3D Model. Open the Default 3D model and turn off all the references.



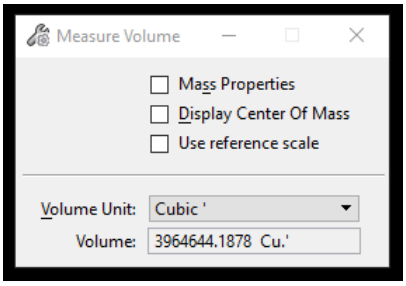
C. Under the Open Road Modeling Workflow switch to the drawing Tab and find the measure section.



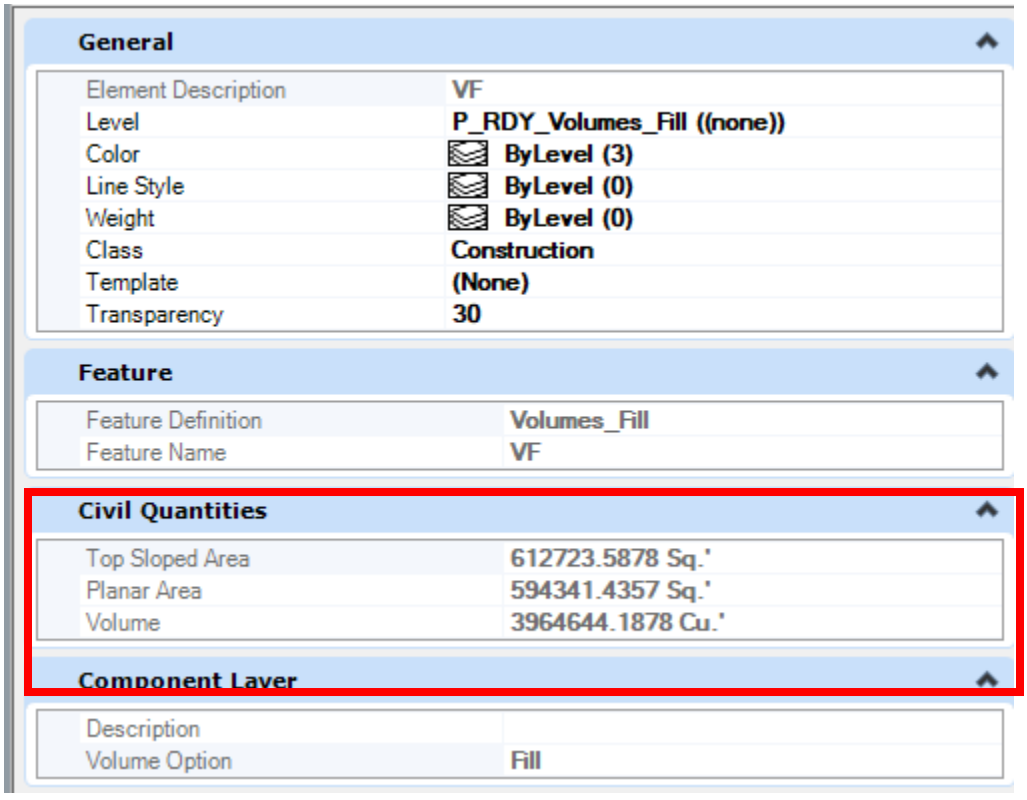
D. Select the Measure Volume tool.



E. Clicking either the Cut or Fill Area will measure the volume of the Prismoidal Shape. The measure will include all the Cut or Fill volume, even volumes that are not connected, so in this example it will be the total Fill or Total Cut volume for the project.

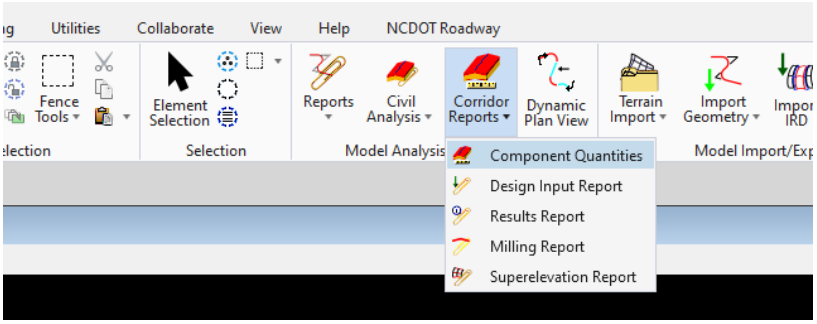


F. Alternately use the Element Selection tool and pick the Cut or Fill Volume. The Volume will be reported in the properties dialog box.



G. The units in both these cases are Cubic Feet.

H. **Caution when using the Component Quantities report located under the Corridor Reports section or the Model Analysis and Reporting tool group.**



This tool utilizes the Average End Area method to determine the volume and surface area of components from the template drops. The volume reported when using component quantities will not match the Prismoidal volume that is measured directly from the volume of the 3D shape

Component Quantities also will only work on a single corridor, it will not provide the total if multiple corridors, linear templates or surface templates are used.

I. This process will provide a quick and simple Earthwork Volume Calculation that is most appropriate for conceptual design iterations and preliminary plans. More detailed Earthwork Calculations will be required for more advanced design submittals. The following exercises will detail the setup required for more detailed earthwork runs but the general process will be the same.

The final section in this module contains guidance on the submittal requirements to NCDOT.

Exercise 2 – Earthwork Using Named Boundaries

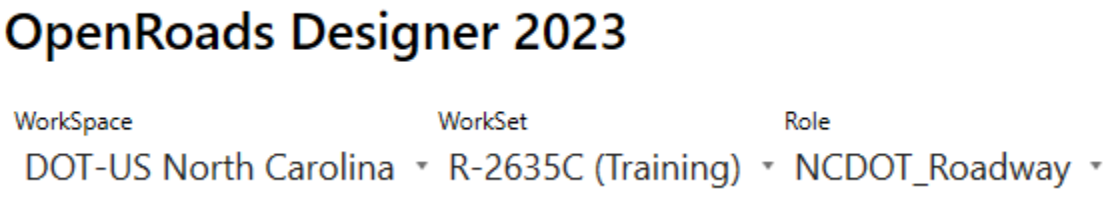
This exercise will provide an example of a more detailed Earthwork Calculation. This Calculation will be completed based on NCDOT guidance and requirements for completing the Earthwork Balance Card. This is the process that would be used later in the design process when the modeling is complete. Detailed areas have been modeled along with any special ditches and grade to drain areas. The process will generally follow the same steps as a simple calculation detailed in the previous section, with the main difference being the inclusion of named boundaries as a way to break out the Earthwork Volumes into sections that meet NCDOT requirements.

The NCDOT Requirements for Earthwork Balance Sheets will be listed in the Roadway Design Manual. Always refer to the Manual for the latest version, the requirements below are based on the May 2024 version and are in Section 15.4.1.1.
Quantity Breakdowns are required as follows:

- Summary points every 3,000 feet.
- Summary Points Begin / End at Each Bridge
- Summary Points Begin / End at Major Intersections
- Summary Points Begin / End at At-Grade Railroad Crossings
- Separate volumes for each alignment
- If required for widening projects: Summaries for Left and Right
- If required for complex projects: Phased with traffic control plan

Start by selecting the OpenRoads Designer 2023 Desktop Icon

The WorkSpace is DOT_US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



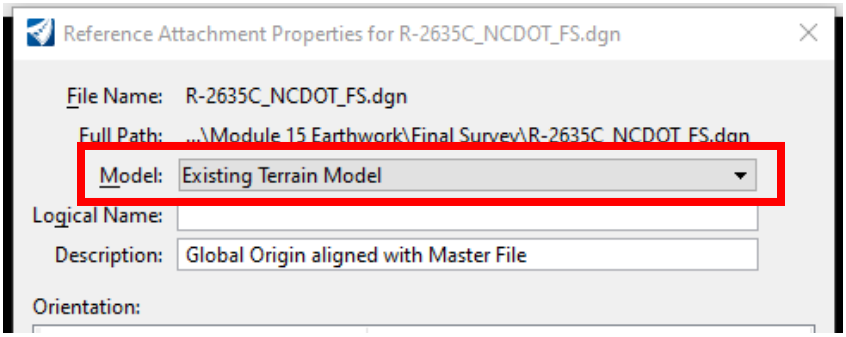
1. Create Earthwork Volumes

A. Create a new DGN file for the Earthwork Calculation. For this exercise we will use Y18 as the example, this alignment has a structure over Y8 and requires a break in the earthwork.

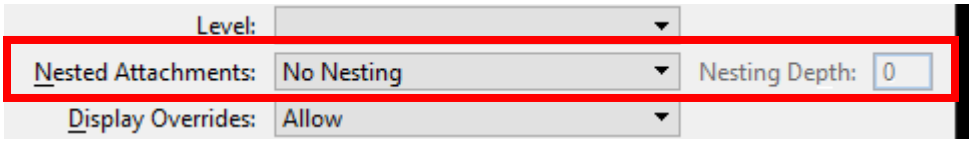
- Filename
  1. R-2635C_RDY_EAR_Y18.dgn
- Folder Location
  1. …\R-2635C\Roadway\Design
- Seed File
  1. Seed2D – English Design.dgn

B. Attach the required reference files:

- Existing Terrain Model – R-2635C_NCDOT_FS
  1. Attach the Existing Terrain Model within the FS file

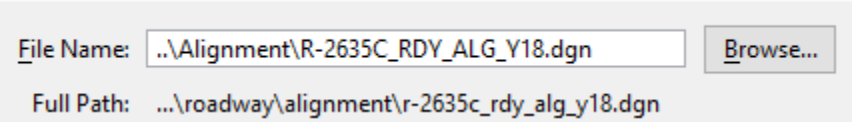


  2. Live Nesting should be OFF.

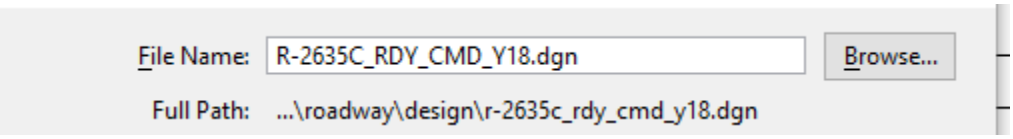


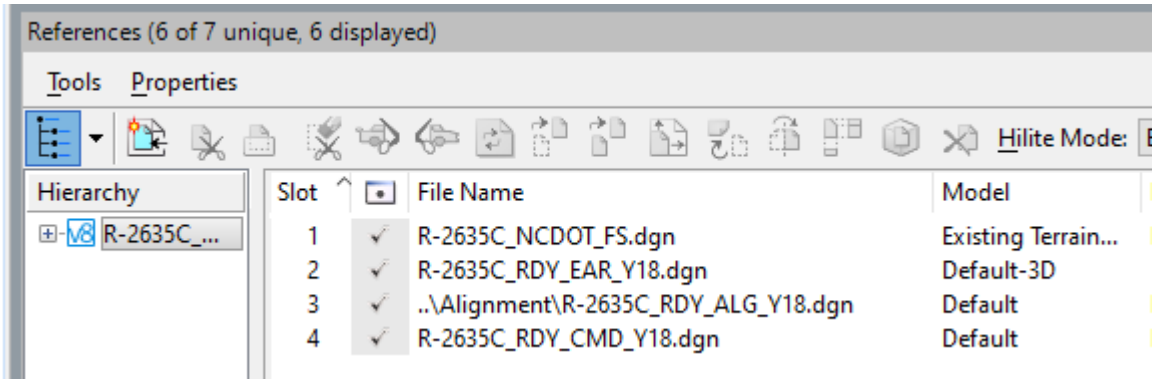
  3. Set Active to Create the Default 3D Model

- Proposed Alignment for the reference corridor
  1. This is required for placing the named boundaries
  2. This is in the Alignment folder under Roadway



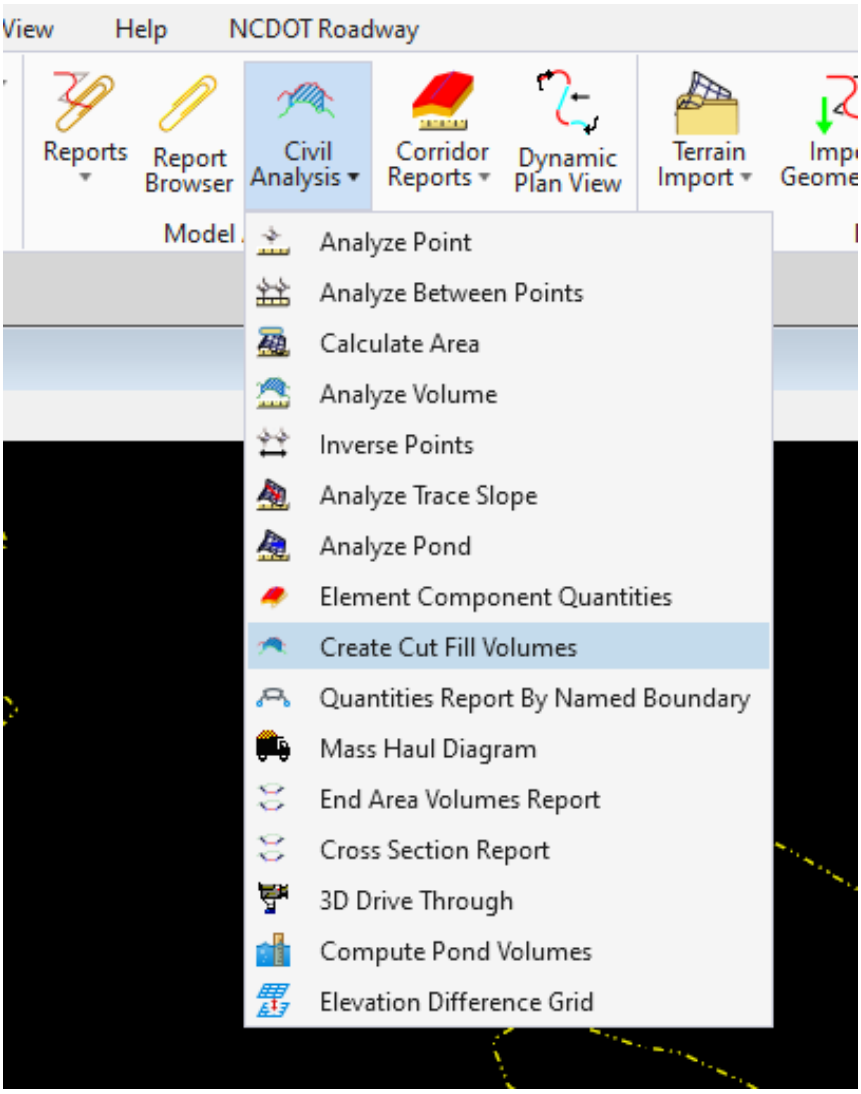
- Proposed CMD File, this exercise will calculate the earthwork volume total for a single Corridor. For more complicated designs include the proposed roadway, any hydraulic models that need to be included, any grade to drain areas or other special areas such as drives or small intersections that will not have a separate line item in the earthwork balance card.



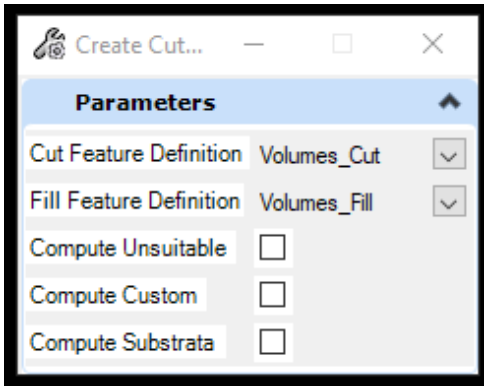


C. Create the 3D Earthwork Volumes

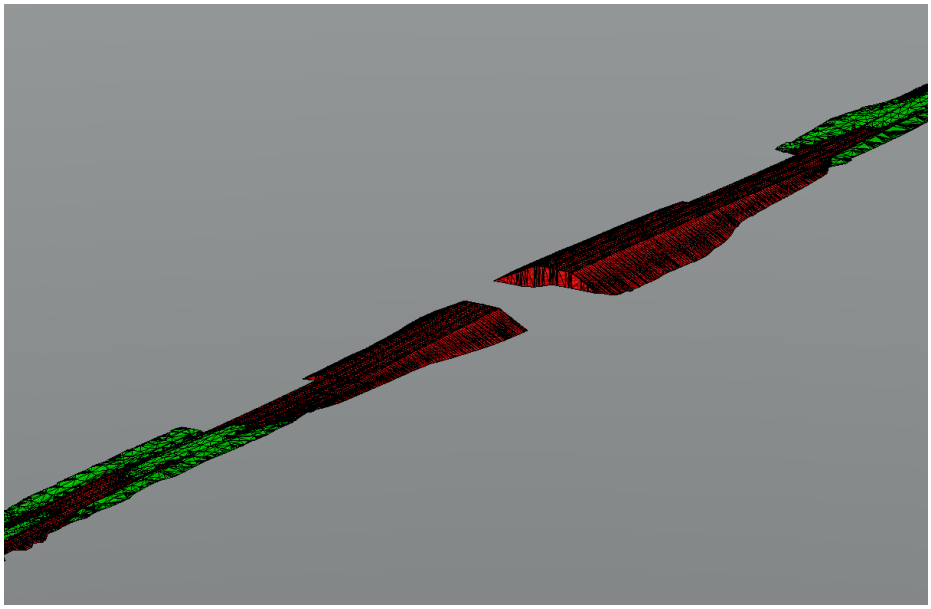
- Create the Cut and Fill Volumes in the Default 3D Model. This is the exact same process used in the previous example
- One View must be open with the Default 3D model.
- Using the OpenRoads Modeling workflow, navigate to the Home Tab and find the Civil Analysis section of the Model Analysis and Reporting tool Group. The drop down has the toll for Create Cut Fill Volumes.



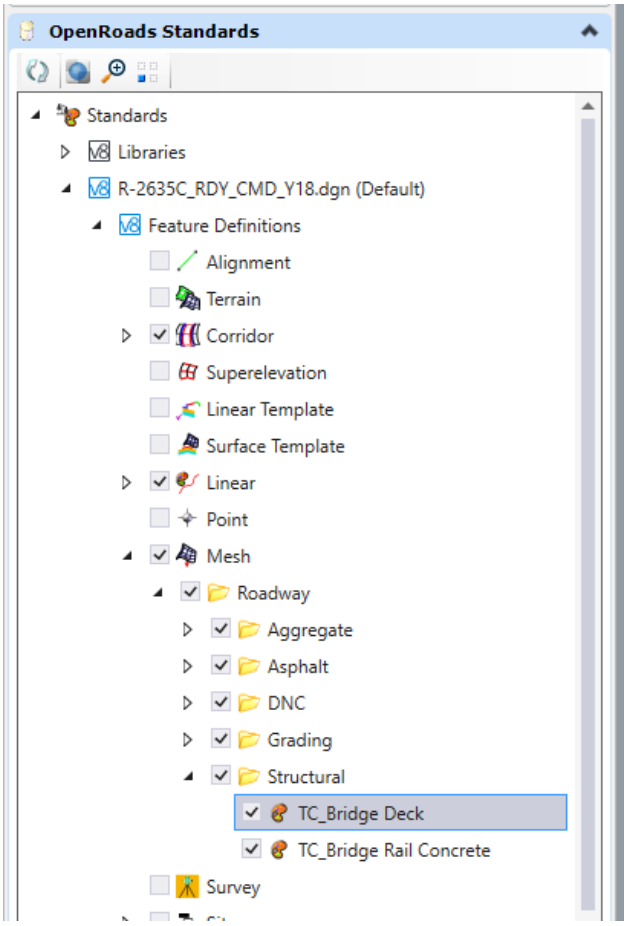
- Set the dialog box with optional computations unchecked.



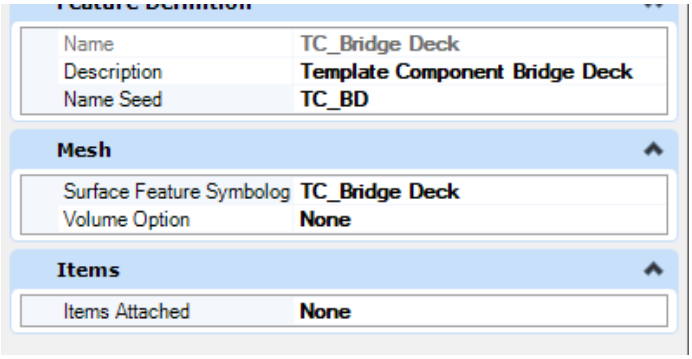
- Left click to accept selections and create the earthwork volumes. There will be Gap at the structures because the Feature Definition for the components in the bridge template is set to a Volume Option of None. This tells the program to ignore these components when computing earthwork. There are also gaps at intersections with the ramp models. With ORD we model the through roadway to the edge of travel and the intersection roadway will be modeled to match the through roadway edge of travel. (Review guidance on detailed modeling for more information on intersection) This is the reason that shear points are no longer a necessity when computing earthwork.



- The volume Option can be seen in the Properties Dialog when selecting the properties for a mesh feature definition. By finding the TC_Bridge Deck Feature Definition in the Open Roads Explorer Dialog

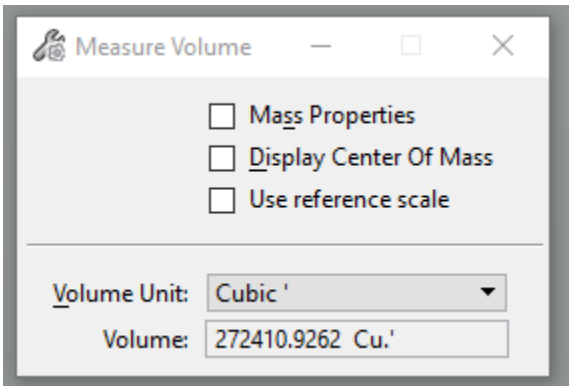


And reviewing the Properties, we see the Volume Option is set to None.

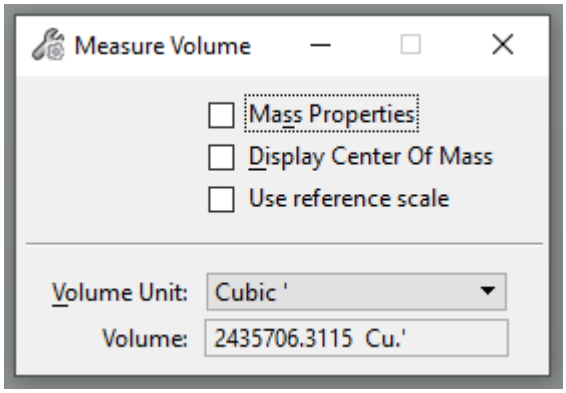


- This process has been the same as the steps required for the simple earthwork calculation. At this point use the various review techniques to verify the earthwork volumes are correct. Using the properties dialog or the Measure Volume Tool can directly measure the 3D volumes in the Default 3D Model.

CUT = 10,089.29 CY



FILL = 90,211.34 CY



Note that the measure volume tool reports the volume in cubic feet not cubic yards and it must be converted.

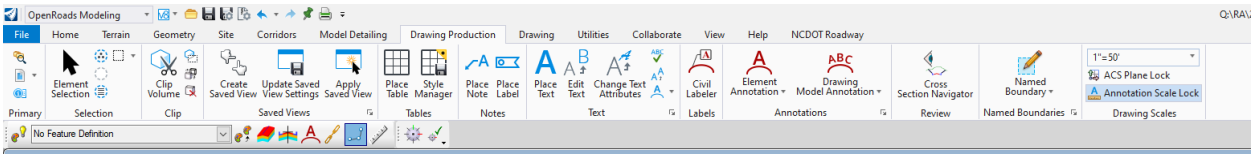
- For reporting the quantities in the earthwork balance card, we will need to split the earthwork into two sections because there is a requirement to break the earthwork for structures. Named Boundaries are required to get the earthwork volumes based the balance card guidelines. The boundary layout will be based on the specific project and should be done according to the NCDOT guidelines and requirements.

2. Place Named Boundaries

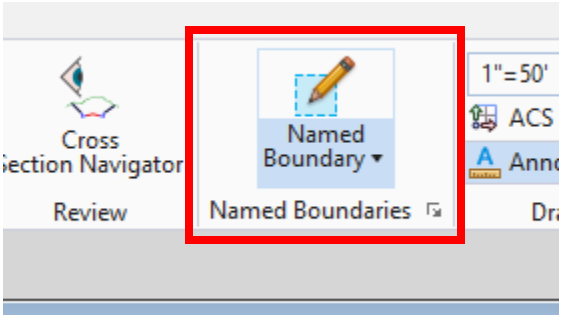
A. Named Boundaries are required to separate the earthwork.

B. The alignment reference file should be ON in the Default model.

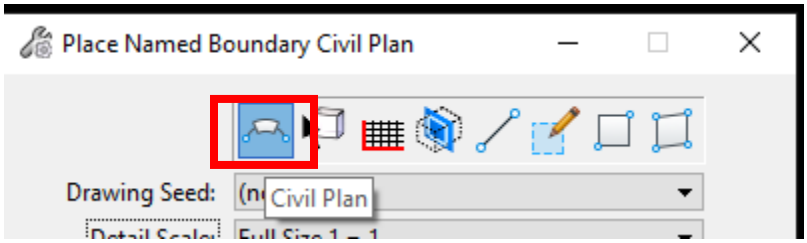
C. Switch to the Drawing Production Tab in the OpenRoads Modeling workflow.



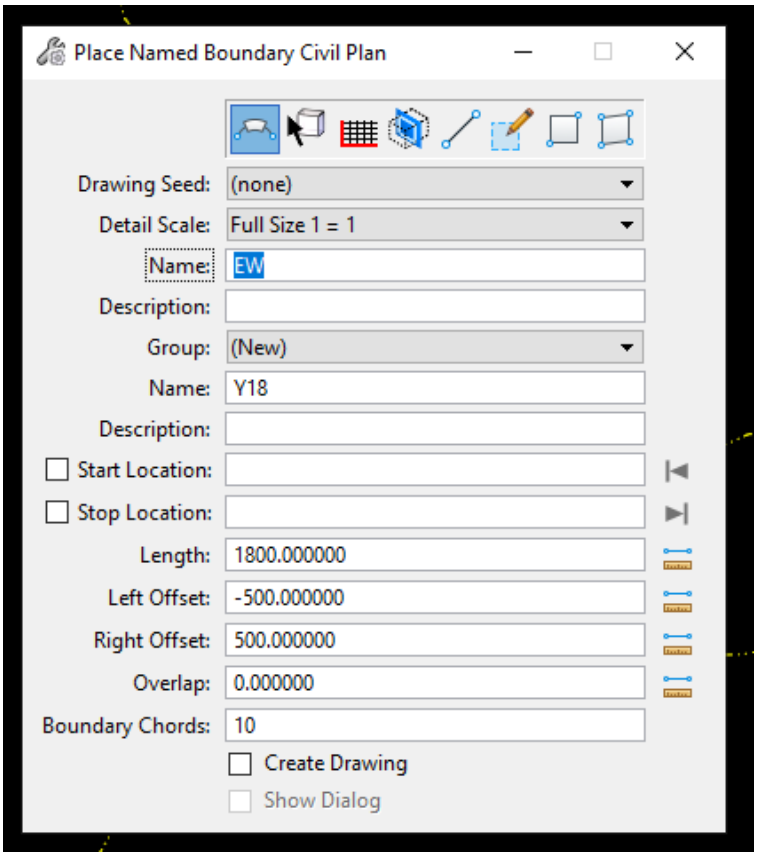
D. Select the named boundary tool.



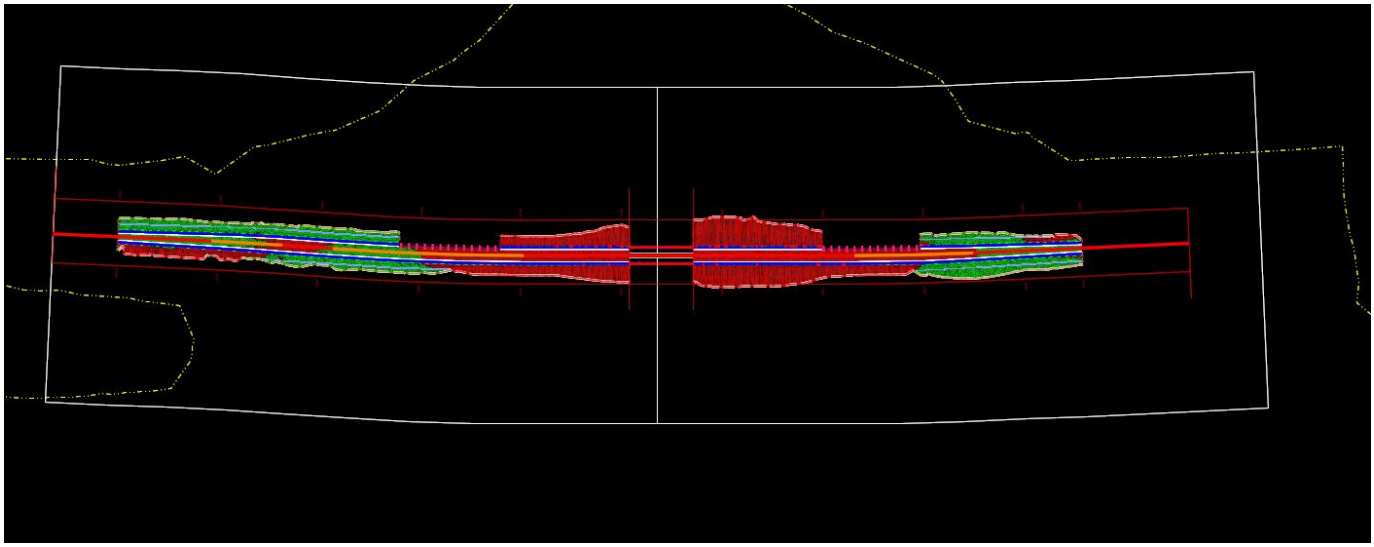
- Select Civil Plan
  1. This could also be done with the 2 points or polygon method.



- Set the dialog box as noted
  1. Drawing Seed – None
  2. Detail Scale – Full Size (This is not critical)
  3. Name – EW
     a. For this example we only have 1 Named Boundary Group and this is not critical, the report will show the end station for each boundary
  4. Group - New
  5. Name –Y18
     a. For this example we only have 1 Named Boundary Group and this is not critical
  6. Length – 1800’ (for this example)
     a. For a long run with no structures or other breaks this could be set to 3000’
     b. For this example, 1800’ places the boundaries in approximately the middle of the bridge
     c. This length will be determined by the designer to place the break in the correct location
  7. Left / Right Offset – 500’
     a. This needs to be large enough to contain the model limits
  8. Overlap – 0
  9. Boundary Chords – 10
     a. This can be adjusted as necessary to contain the model.



- Place the named boundaries
  1. Left click to identify the Y8 alignment as the Path Element
  2. Left click to identify the start station at 10+00.00
  3. Left click to accept the boundary length of 1800’
  4. Left click through the remaining selections to finish the placement of 2 boundaries. The split between the two should be on the structure.
  5. This view is rotated so that Y18 is Horizontal.

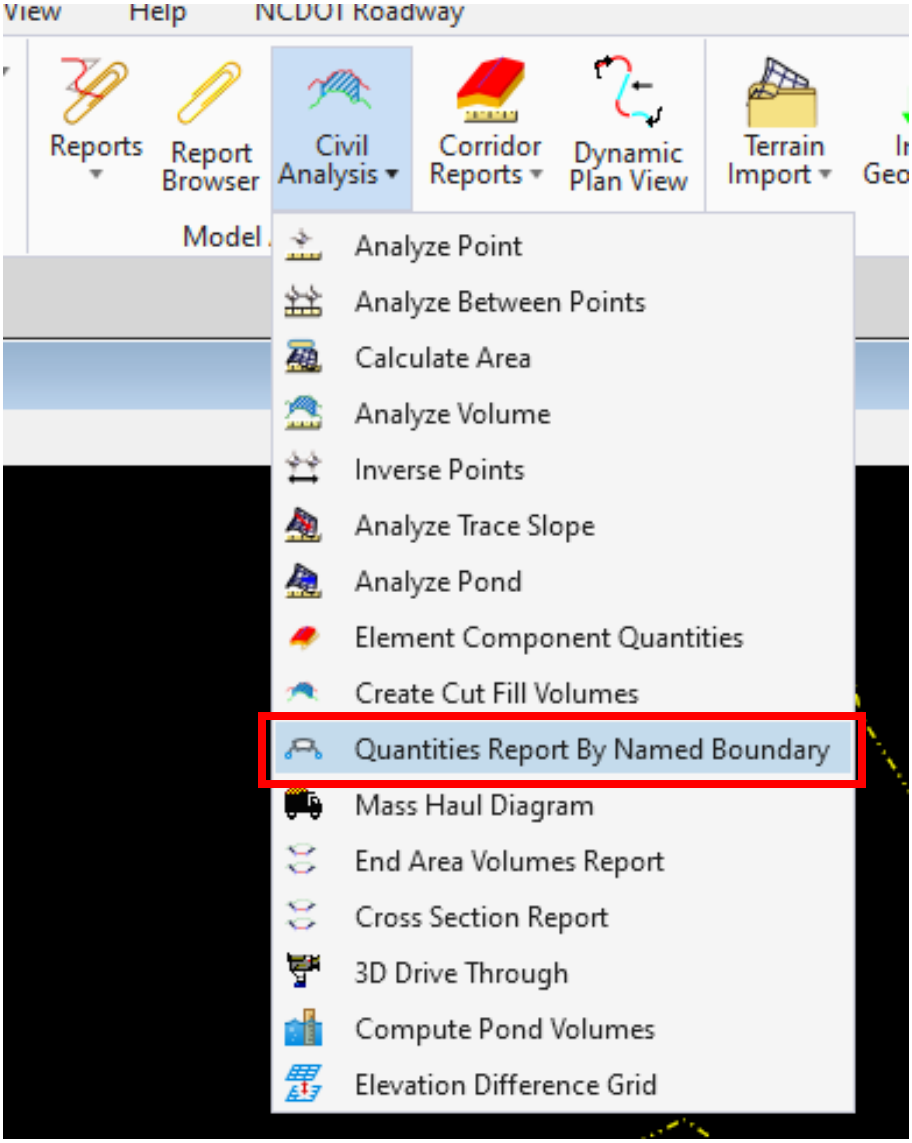


Note that the named boundaries do not have to start and stop at the Begin / End Bridge stations. Because the Bridge is set to a Volume option of None the earthwork volumes will automatically start and stop at the Begin and End stations.

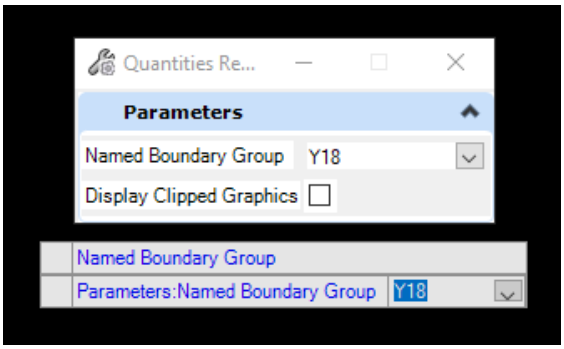
The named boundaries just need to meet somewhere in between the Begin and End bridge.

3. Report Earthwork Volumes

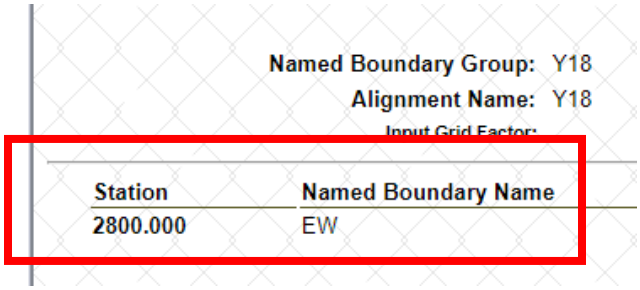
A. Go back to the Home Tab and the Model Analysis and Reporting Tool Group. Under the Civil Analysis dropdown select the Quantities Report by Named Boundary.



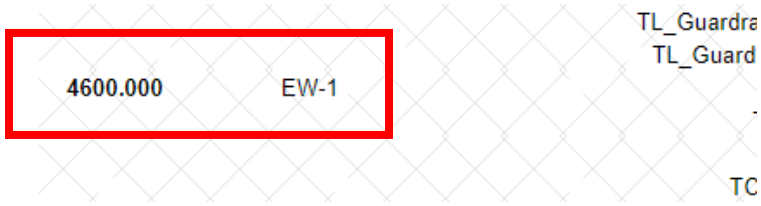
- Select the named boundary group. Display Clipped Graphics should not be checked.



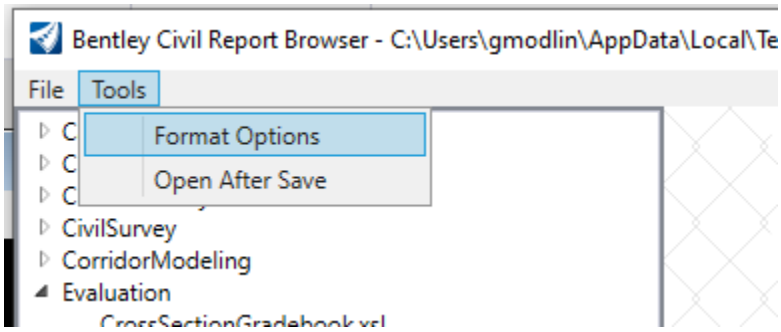
- This generates a report for Each Boundary.
- The End Station and Boundary Name are identified in the left margin of each boundary breakdown.
  1. Station 10+00 to Station 28+00



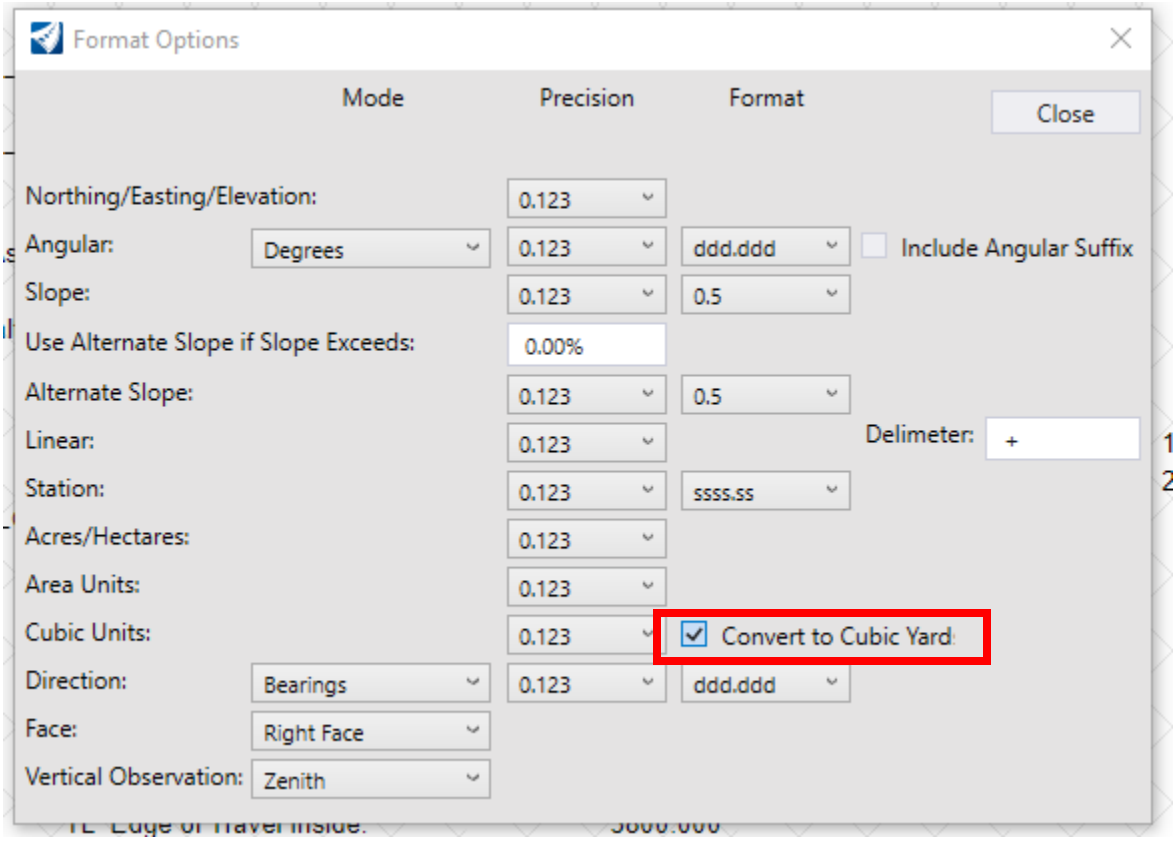
  2. Station 28+00 to Station 46+00



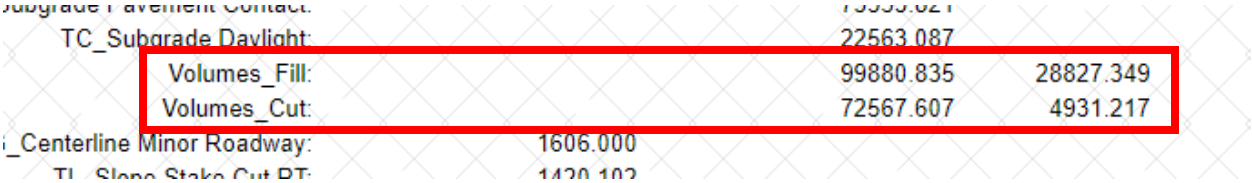
- In the report dialog select Tools and Format Options from the top left.



1. Under Cubic units select Convert to Cubic Yard



- In this report format the Volume is in the last column on the right.
  1. The earthwork volume from Station 10+00 to 28+00



TC_Subgrade Daylight:		22563.087	
Volumes_Fill:		99880.835	28827.349
Volumes_Cut:		72567.607	4931.217
_Centerline Minor Roadway:	1606.000		

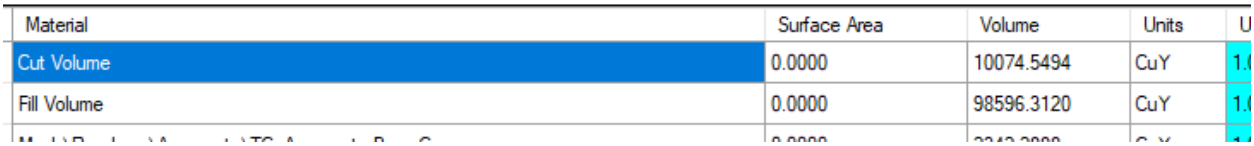
  2. The earthwork Volume from Station 28+00 to 46+00

_Bridge Rail Concrete:		1593.497	23.936
Volumes_Cut:		44402.701	5158.075
Volumes_Fill:		113693.709	61383.995
terline Minor Roadway:	1264.910		

  3. Note that added together these equal the original total of:

     CUT = 10,089.29 CY
     FILL = 90,211.34 CY

B. Compared to the volumes reported from the component quantities tool, the difference in the cut is 0.1% and the difference in fill is 9.3%



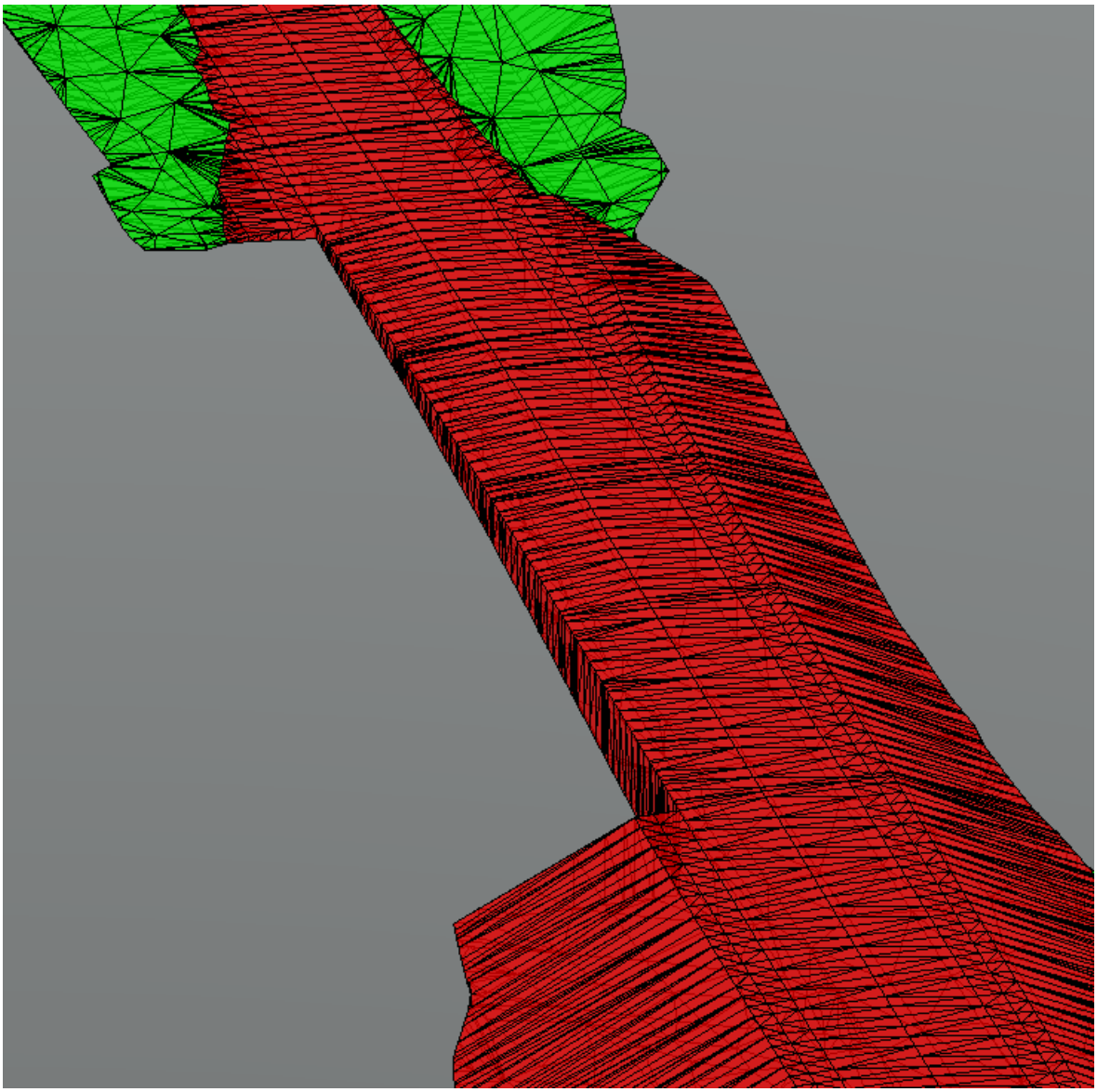
Material	Surface Area	Volume	Units	U
Cut Volume	0.0000	10074.5494	CuY	1.(
Fill Volume	0.0000	98596.3120	CuY	1.(

Component Quantities will always produce different results from the Prismoidal volumes because the average end area only accounts for the area at each cross section. These volumes were relatively close because this is a simple corridor. Depending on project specific situations component quantities can produce large errors. The designer should always be cautious when using component quantities for earthwork volume checks.

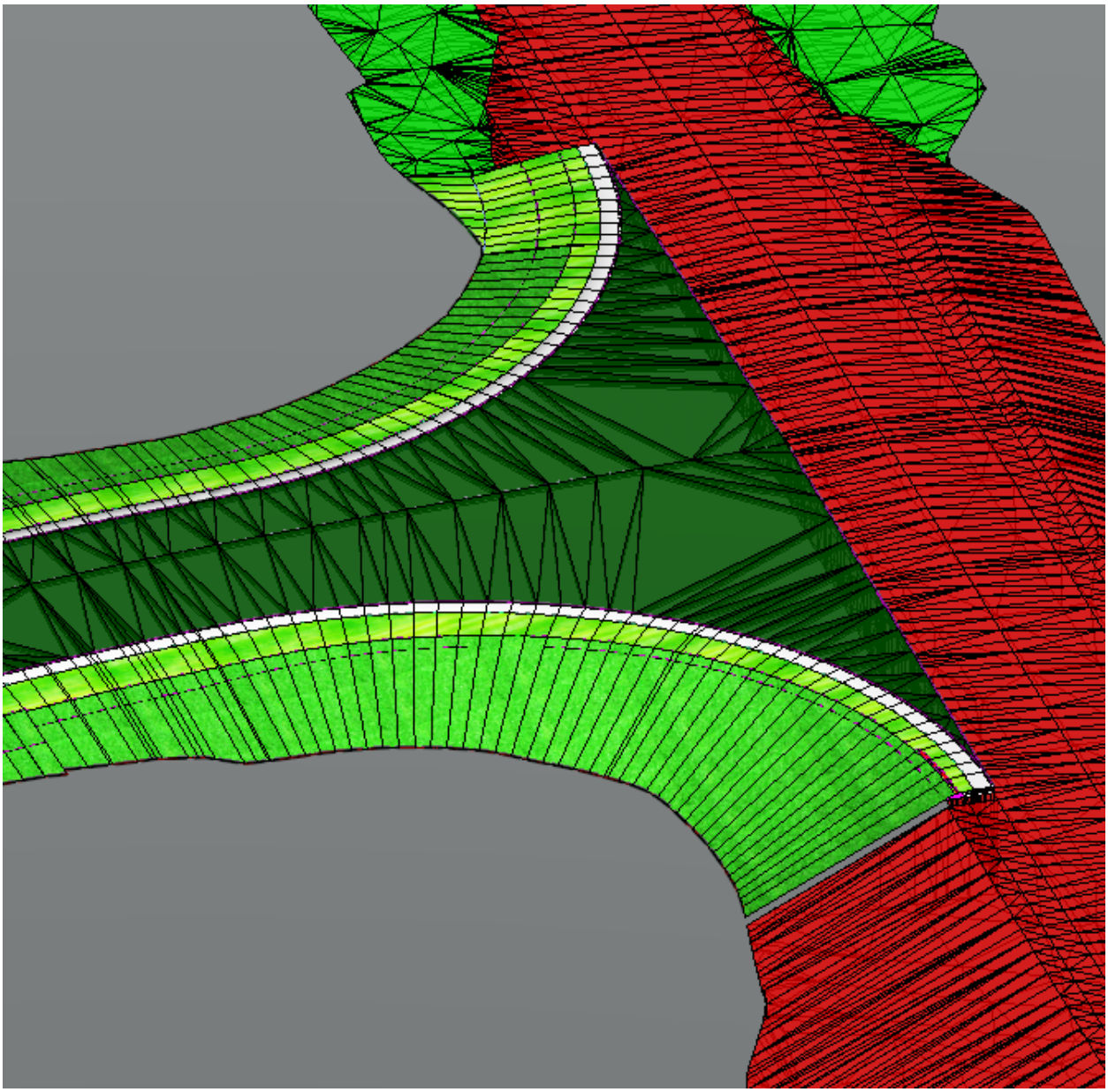
4. Shear Points

A. Shear points are not required for earthwork calculations. Earthwork volumes are determined by what corridors are referenced to the EAR file and can be separated further using Named Boundaries.

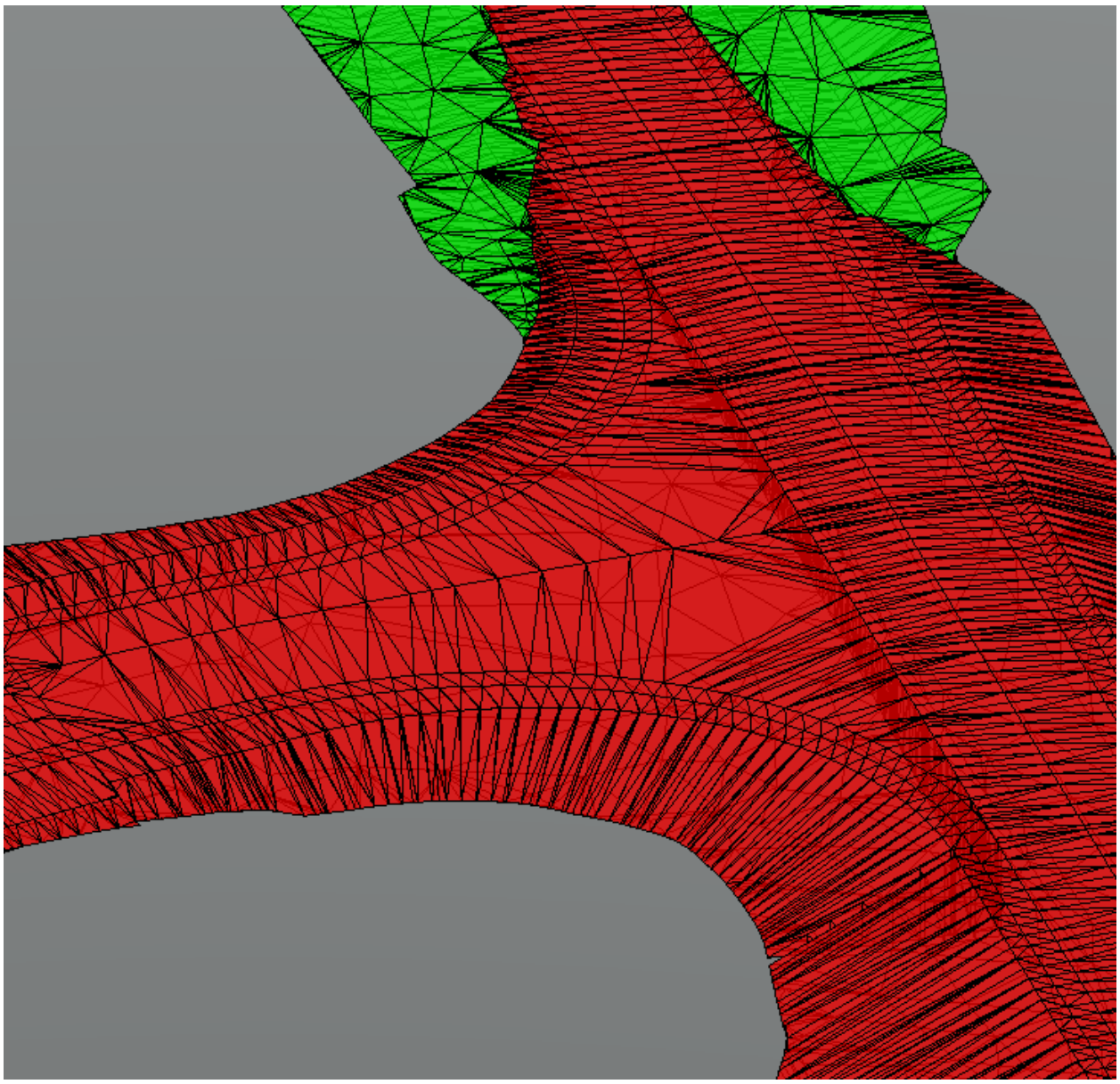
B. This area of the model is where Y18RPA intersects Y18. This area has been excluded from the earthwork calculation for Y18.



C. Using the average end area method the cross sections on Y18 and Y18RPA in this area would have to be laid out very carefully. Break Points and Shear would have been required to accurately compute the earthwork volume, and even then it would have been impossible to eliminate all errors. Using the Prismoidal Earthwork Calculation this area will be included in the Y18RPA Earthwork Volume and will be accurately reported if the intersection is accurately modeled.



D. This is a view of the Y8RPA earthwork shapes matching to the Y8 Earthwork shapes. Also note that this intersection was modeled using Linear and Surface templates and that the earthwork has been computed correctly as evidenced by the red fill shape.



Exercise 3 – Earthwork on Widening Project

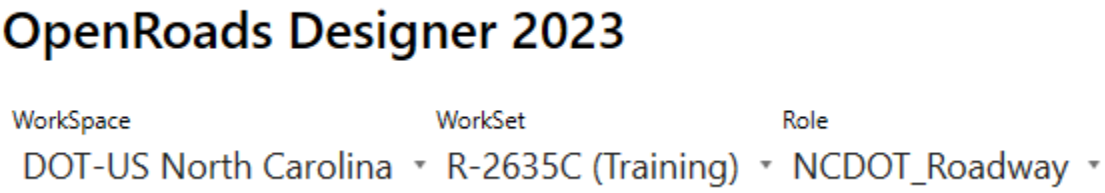
On widening projects, often one requirement will be to split the earthwork up based on the traffic control phasing. That may be left and right or various sections. This can be easily done using Named Boundaries.

Note that named boundaries cannot be used to determine partial vertical construction. If a roadway was going to be raised to an intermediate elevation prior to completion and then raised to the final elevation at a later time and those earthwork numbers needed to be separated, then the designer would need to model the intermediate and final condition.

In the following example we will split the earthwork Left and Right and Break it for a structure, Y8 over L.

Start by selecting the OpenRoads Designer 2023 Desktop Icon

The WorkSpace is DOT_US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



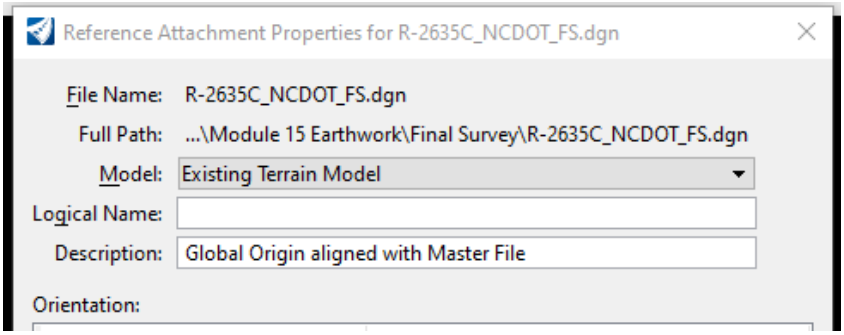
1. Create Earthwork Volumes

A. Create a new DGN file for the Earthwork Calculation. For this exercise we will use Y8 as the example, this alignment has a structure over Y8 and requires a break in the earthwork.

- Filename
  1. R-2635C_RDY_EAR_Y8.dgn
- Folder Location
  1. …\R-2635C\Roadway\Design
- Seed File
  1. Seed2D – English Design.dgn

B. Attach the required reference files:

- Existing Terrain Model – R-2635C_NCDOT_FS
  1. Attach the Existing Terrain Model within the FS file

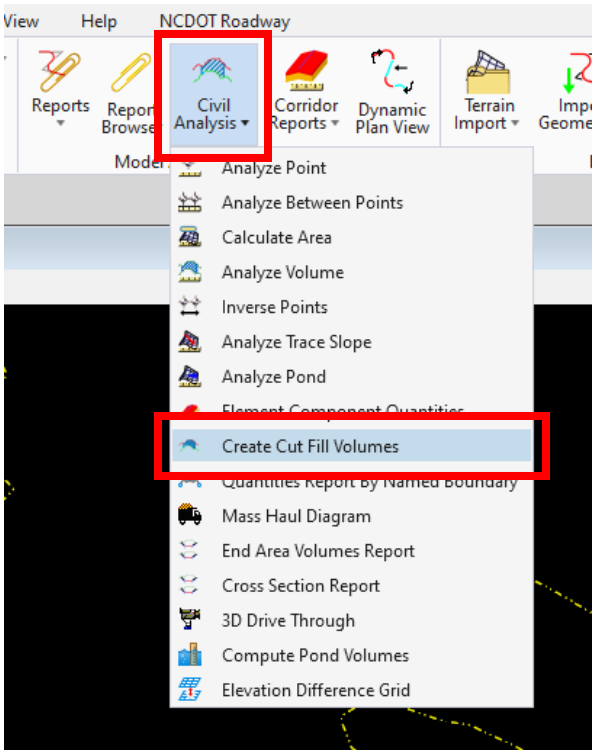


  2. Live Nesting should be OFF.

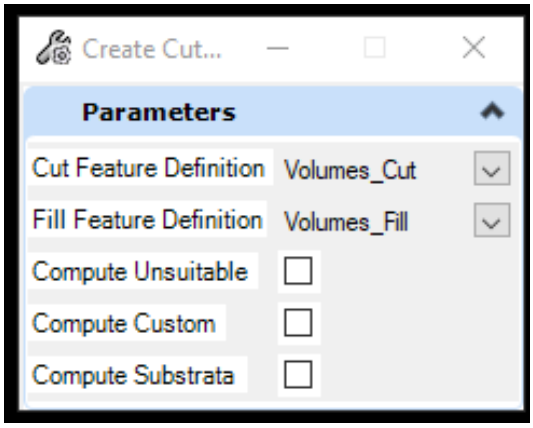
  3. Set Active to Create the Default 3D Model

- Proposed Alignment for the reference corridor
  1. This is required for placing the named boundaries
- Proposed CMD File, this exercise will calculate the earthwork volume total for a single Corridor. For more complicated designs include the proposed roadway, any hydraulic models that need to be included, any grade to drain areas or other special areas such as drives or small intersections that will not have a separate line item in the earthwork balance card.
  1. R-2635C_RDY_CMD_Y8.dgn

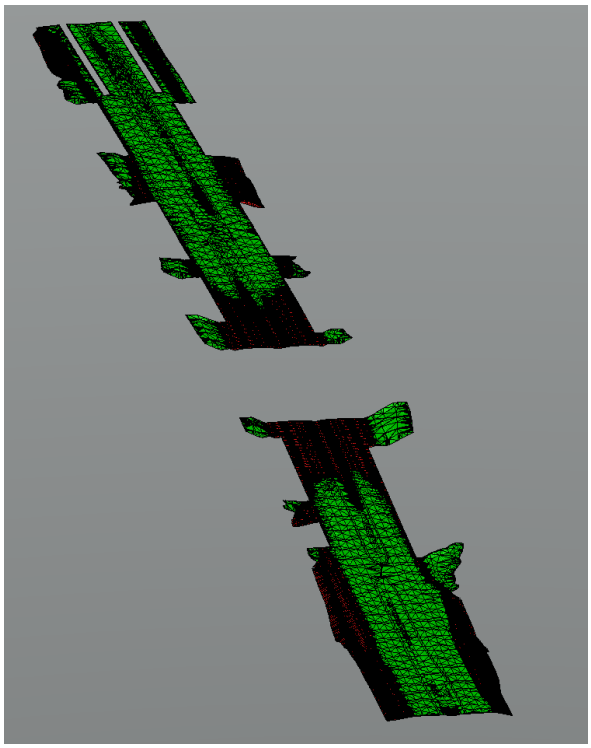
C. Create the Cut and Fill Volumes in the Default 3D Model. This is the exact same process used in the previous example
   - One View must be open with the Default 3D model.
   - Using the OpenRoads Modeling workflow, navigate to the Home Tab and find the Civil Analysis section of the Model Analysis and Reporting tool Group. The drop down has the toll for Create Cut Fill Volumes.



- Set the dialog box with optional computations unchecked.

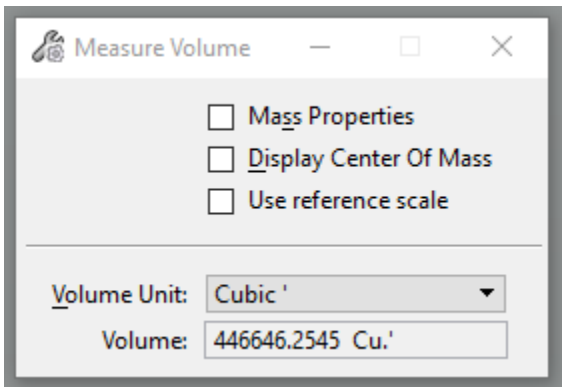


- Left click to accept selections and create the earthwork volumes. Like the previous example there are gaps at intersections and the structure. There are also gaps in the 3D Volumes in areas where wedging has been included in the model. All these areas are ignored for the purpose of the earthwork calculation.

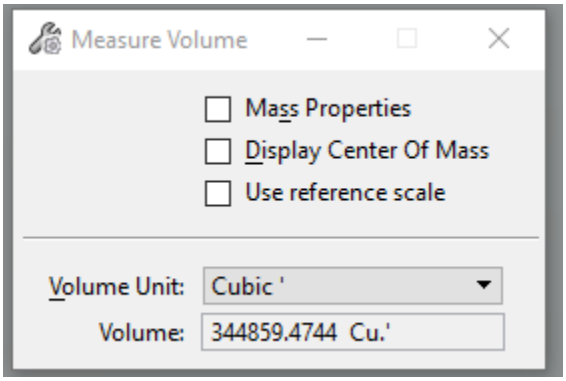


- This process has been the same as the steps required for the simple earthwork calculation. At this point use the various review techniques to verify the earthwork volumes are correct. Using the properties dialog or the Measure Volume Tool can directly measure the 3D volumes in the Default 3D Model.

CUT = 16542.45 CY



FILL = 12,772.57 CY



Note that the measure volume tool reports the volume in cubic feet not cubic yards, and it must be converted.

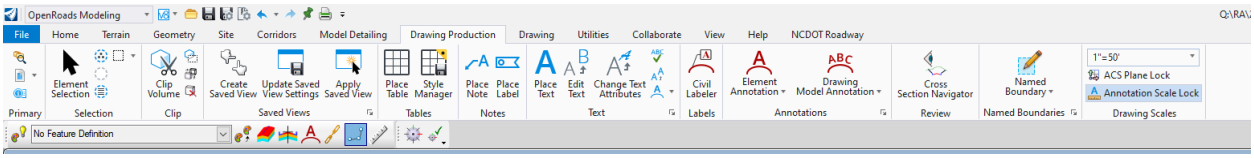
- For reporting the quantities in the Earthwork Balance Card, we will need to split the earthwork into four sections because there is a requirement to break the earthwork for structures and we will be splitting the earthwork for the Left and Right sides of the Alignment. To Accomplish this, we will use named boundaries like the previous example.

2. Place Named Boundaries

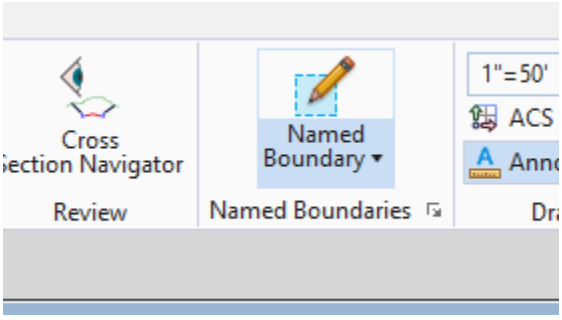
A. Named Boundaries are required to separate the earthwork.

B. The alignment reference file should be ON in the Default model.

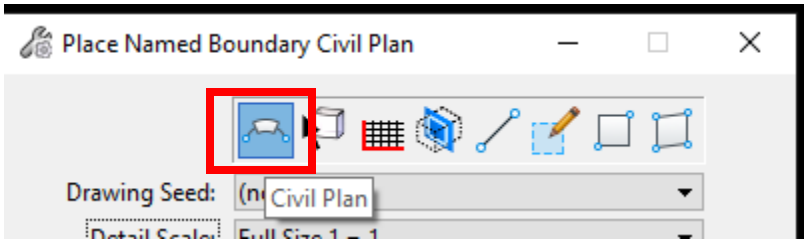
C. Switch to the Drawing Production Tab in the OpenRoads Modeling workflow.



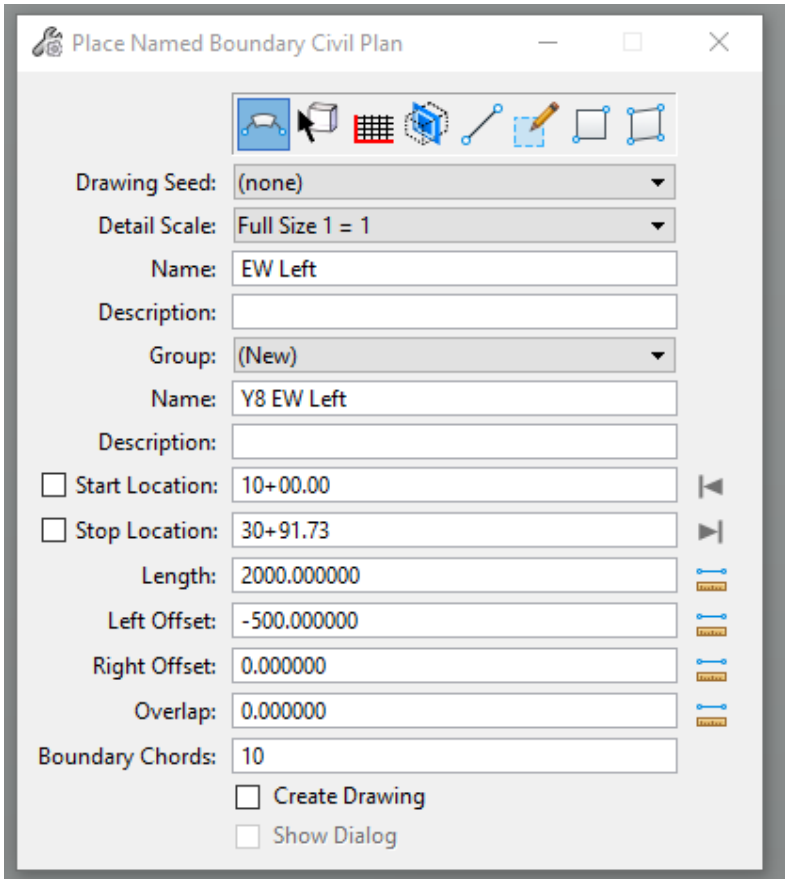
D. Select the named boundary tool.



- Select Civil Plan

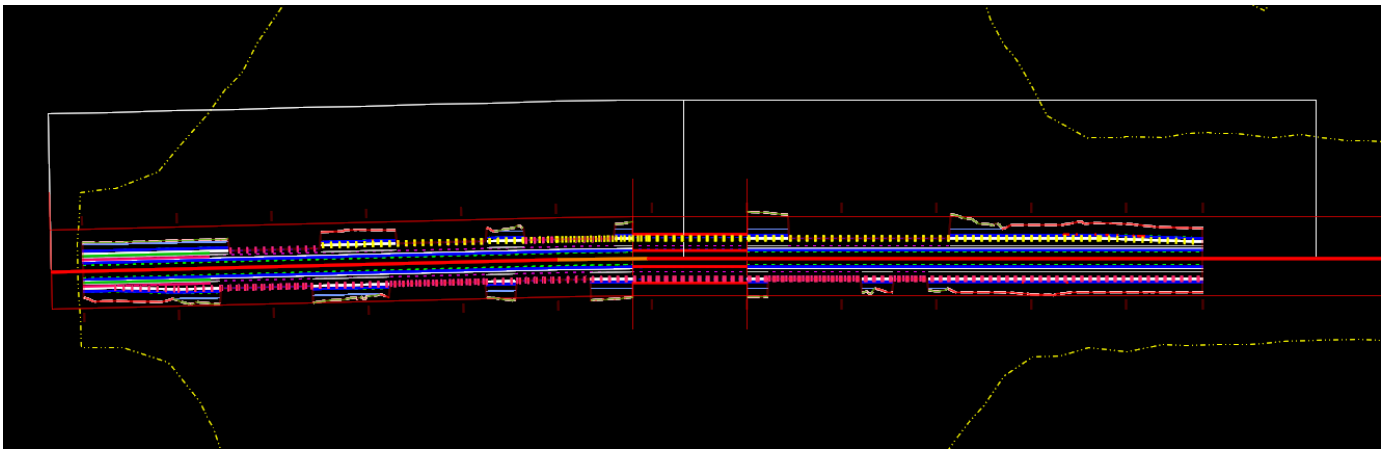


- Set the dialog box as noted
  1. Drawing Seed – None (Not Required - no drawing models will be created)
  2. Detail Scale – Full Size (This is not critical)
  3. Name - EW Left
  4. Group - New
     a. Name – Y8 EW Left
     b. Note that this is changed after selecting the named boundary path
  5. Length – 2000’ (for this example)
  6. Left Offset - -500’
  7. Right Offset – 0’
     a. This will place the right edge of the named boundary on the centerline where we want the split in the earthwork to occur
  8. Overlap – 0
  9. Boundary Chords – 10
     a. This should be adjusted based on the alignment. Alignments with sharp curves may require more boundary curves to match the centerline. Tangent Alignments would not need any boundary chords.

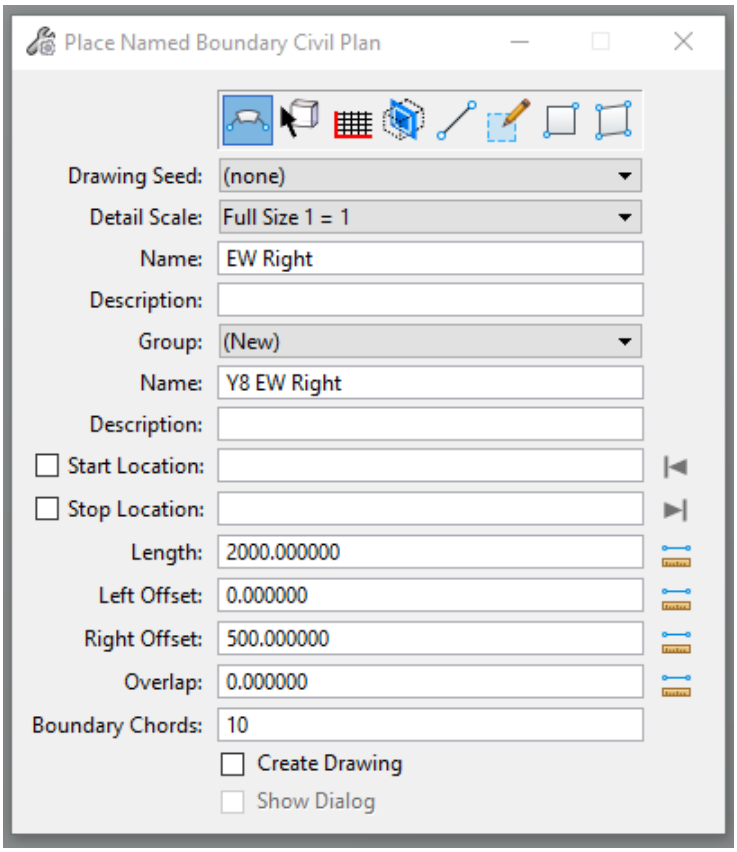


  10. Create Drawing – Checked OFF

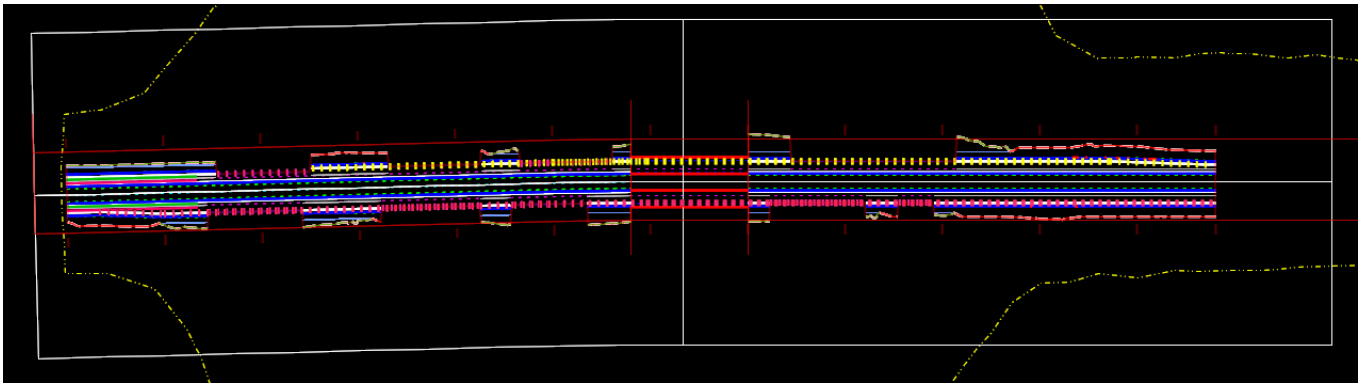
- Place the named boundaries
  1. This should create two boundaries on the left side of the Alignment.
  2. The break in the Boundaries should occur on the structure, the actual location is not critical



- Repeat this process.
  1. Change the name to EW Right
  2. Change the Group Name to Y8 EW Right
  3. Change the Left Offset to 0’
  4. Change the Right Offset to 500’

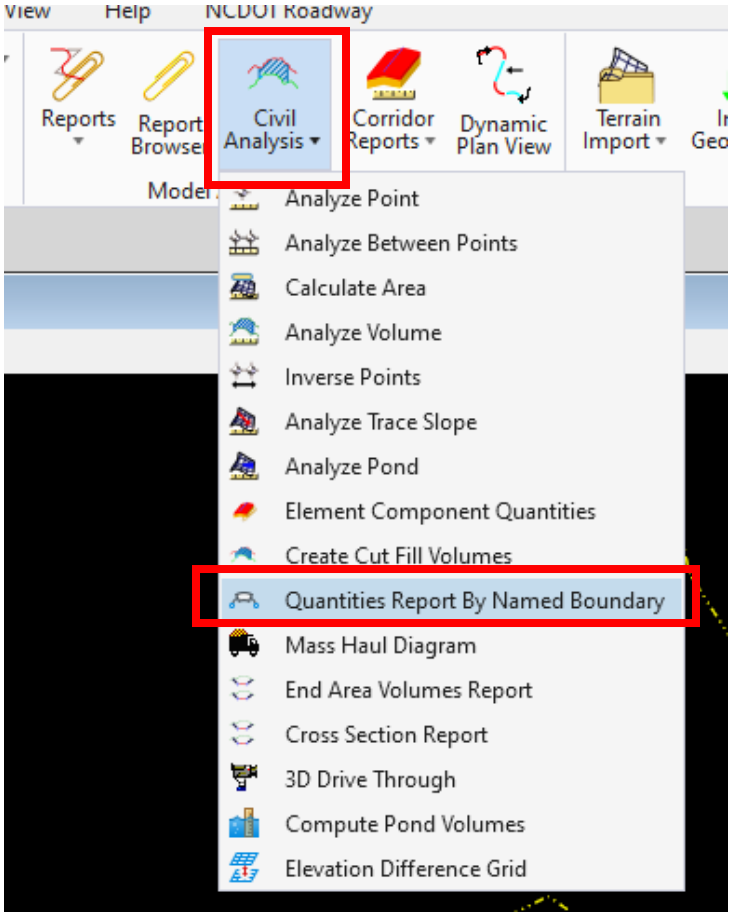


- There should now be 4 named boundaries.
  1. This image has the centerline turned off for clarity.
  2. Note the Named boundaries in this example line up at the same station for the Left and Right side. That is not a requirement. More complex Traffic Control phasing may require the Named Boundaries to break at different stations. If the boundaries cover the entire model and do not overlap the earthwork will be reported correctly.

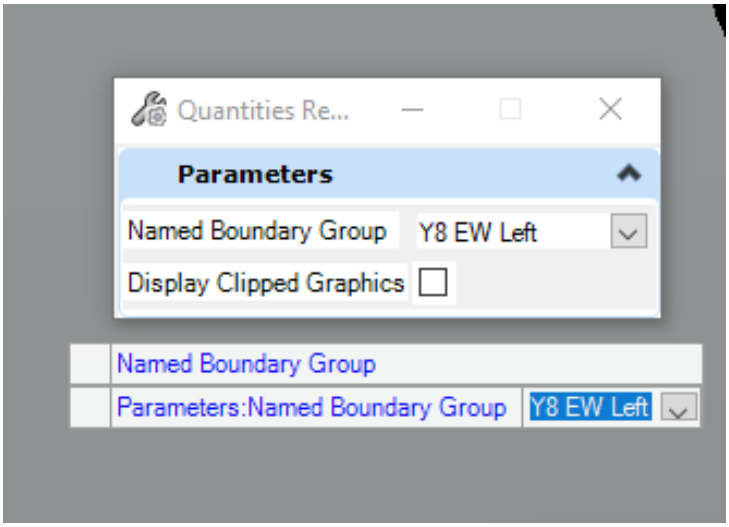


3. Report Earthwork Volumes

A. Go back to the Home Tab and the Model Analysis and Reporting Tool Group. Under the Civil Analysis dropdown select the Quantities Report by Named Boundary.

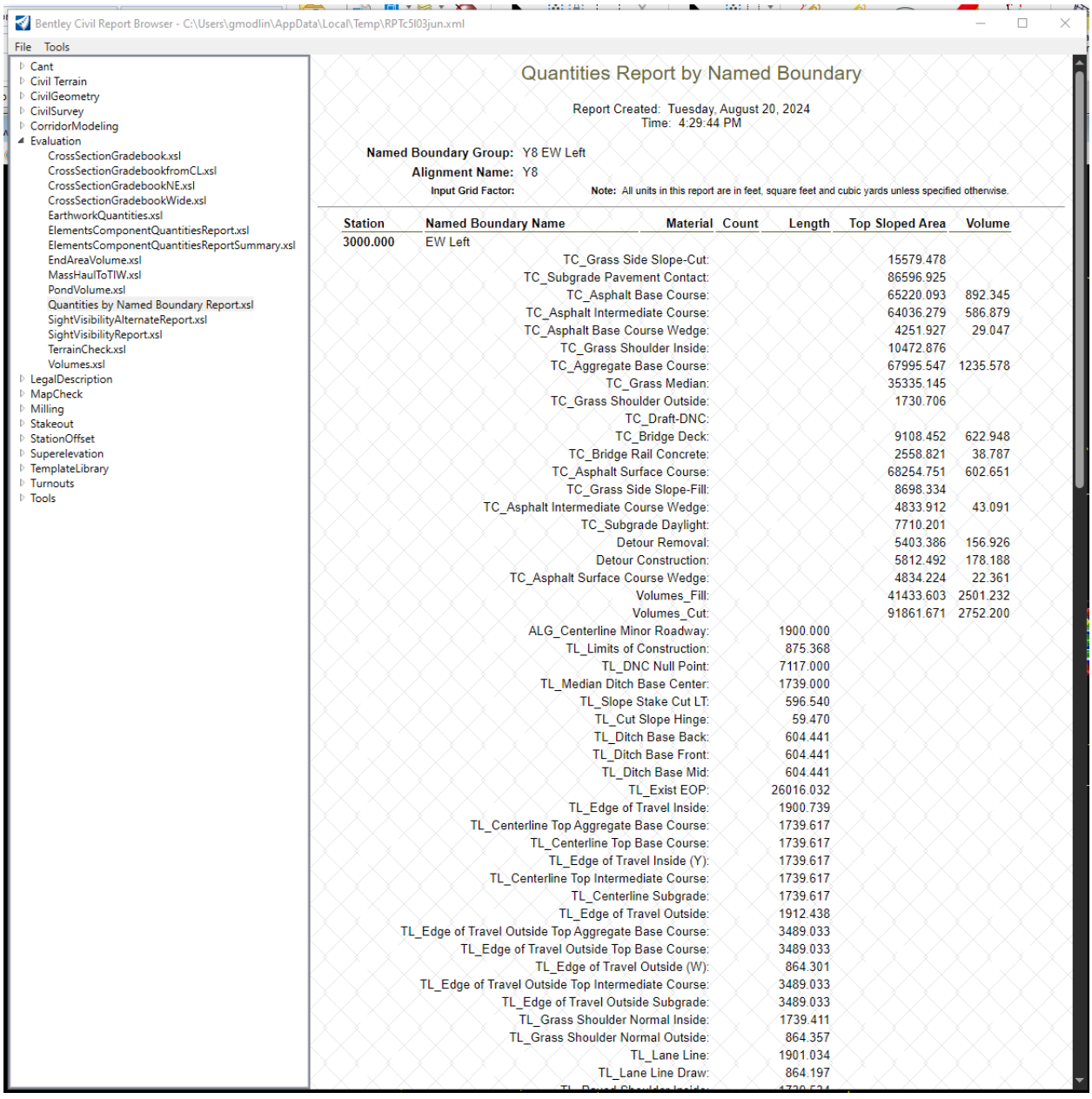


- Select the named boundary group. Display Clipped Graphics should not be checked.

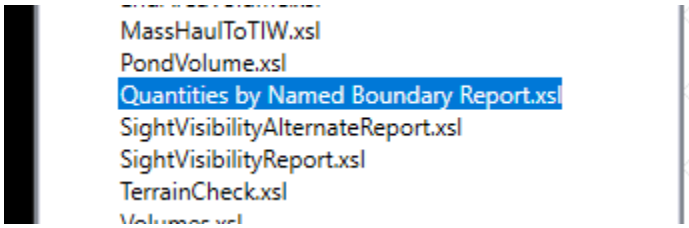


Note that the naming of the boundary in the previous steps is not absolutely critical as long as the user can keep them separate, but is helpful when selecting the correct boundary group and creating reports. As shown in the reporting below it does document the name of Boundary Group so for reporting purposes it may be helpful is the user develops some standard naming convention.

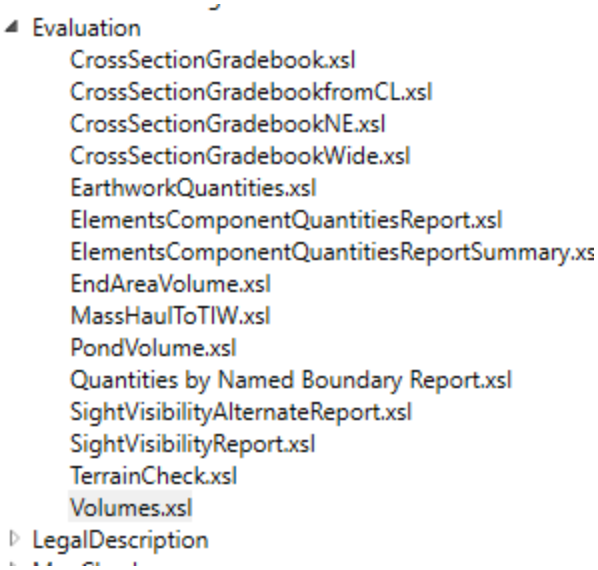
- This generates a report for the Left Side for Each of the Two Boundaries. The Bentley Civil Report Browser will automatically pop up.



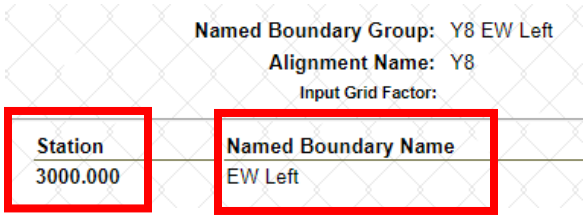
- Because we selected Quantities by Named Boundaries that will be the default selected report.



- The reports are XSL style sheets and only pull out and format information included in the DGN file, there is a long list of reports that pull and format information in various ways that may also be helpful. Additional reports are accessed by simply selecting different XSL files from the list on the left side of the dialog.

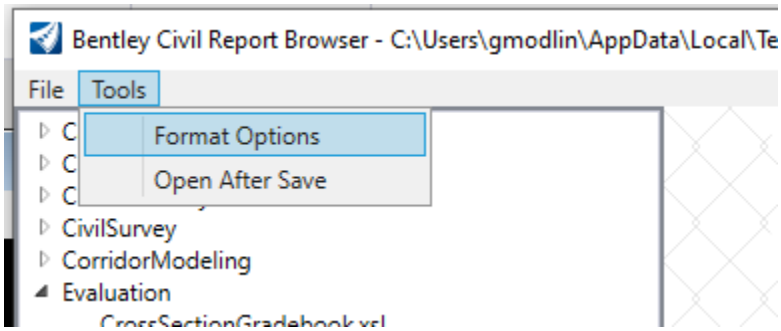


- This view is from the Quantities by Named Boundary Report.xsl. The End Station and Boundary Name are identified in the left margin of each boundary breakdown.
    a. Station 10+00 to Station 30+00

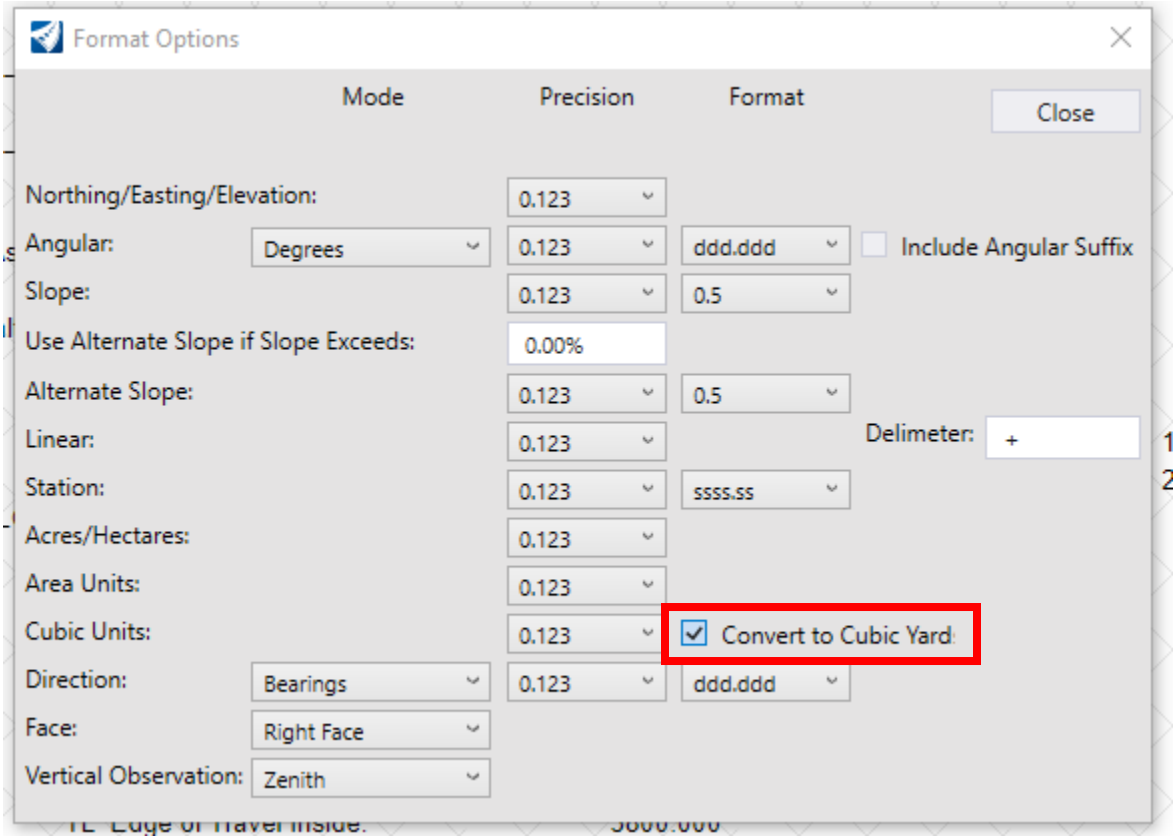


    b. Station 30+00 to Station 50+00

- In the report dialog select Tools and Format Options from the top left.



- Under Cubic units select Convert to Cubic Yard



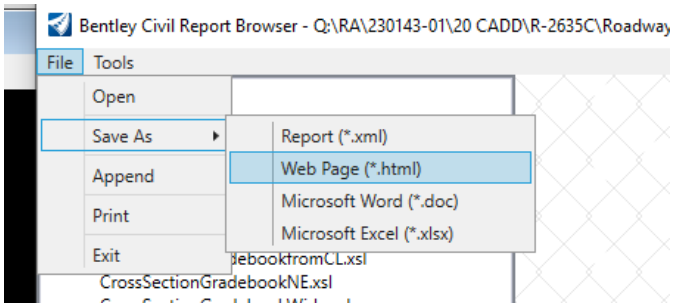
- In this report format the Volume is in the last column on the right.
  1. The earthwork volume from Station 10+00 to 30+00

C_Grass Side Slope-Cut:		15579.478	
Volumes_Fill:		42173.829	2528.517
Volumes_Cut:		91779.735	2770.180
enterline Minor Roadway:	1900.000		

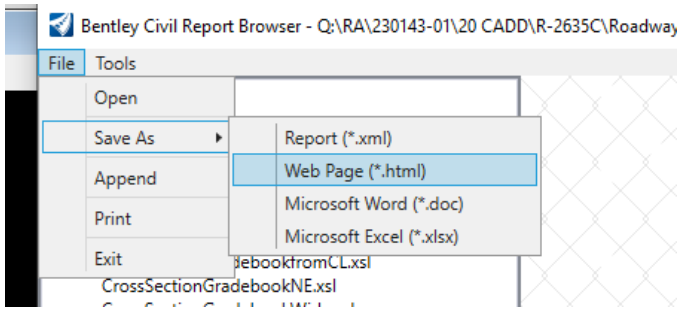
  2. The earthwork Volume from Station 30+00 to 50+00

:_Subgrade Daylight:		5997.849	
Volumes_Cut:		89056.737	5720.279
Volumes_Fill:		51488.835	4452.813
rline Minor Roadway:	1643.000		

- At this step the user should save the report.
  1. In the top left corner of the reports dialog select File → Save As



  2. Select one of the formats for the report. This is based on user preference and what is reported out. For this report that includes quantity totals HTML is probably the most appropriate. Other reports may work better in Word or Excel format.



B. Repeat this process for the boundary elements on the right side – see previous steps for more detail.
   - Select the quantities by named boundary tool
   - Select the boundaries on the right side
   - Review and Save the Report.
     1. For the right side the Earthwork from 10+00 to 30+00 is

e Course Wedge:		4833.912	22.359
Volumes_Fill:		40191.577	1473.394
Volumes_Cut:		106995.405	5429.308
Minor Roadway:	1500.000		

     2. The Earthwork from 30+00 to 50+00 is

ss Shoulder Outside:		2054.107	
Volumes_Cut:		78602.919	2622.902
Volumes_Fill:		59902.721	4317.813
line Minor Roadway:	1643.000		

C. If we add the earthwork from the four named boundaries together we get

   CUT = 16,542.67 Compared to 16,542.45 from the total Volume
   FILL = 12,772.54 Compared to 12,772.57 from the Total Volume

   The small discrepancies can be attributed to the curve in the alignment. Because the Named Boundary uses a chorded curve there is some small areas of overlap at the centerline. These are negligible and could be reduced even further by increasing the number of chords when placing the named boundary. Checking the Total Volume from the named boundary reports against the Total Volume measured directly from the DGN file is a good check that there are no large errors.

Exercise 4 – Earthwork for Hydro Ditch Designs

After the hydraulic design is completed, it will be necessary to incorporate the ditch earthwork volumes into the project totals.

Ditch earthwork is divided in to two categories:

- DDE – Drainage Ditch Excavation
    - Lateral Ditches with a Berm
    - Lateral Ditches where the ditch front slope does not match the roadway fill slope
    - Head and Tail Ditches
- UCE – Unclassified Excavation
    - Special Cut Ditches
    - Lateral Ditches with no Berm and the ditch front slope matches the roadway fill slope.

Note that Berm Ditches are not included in earthwork calculations.

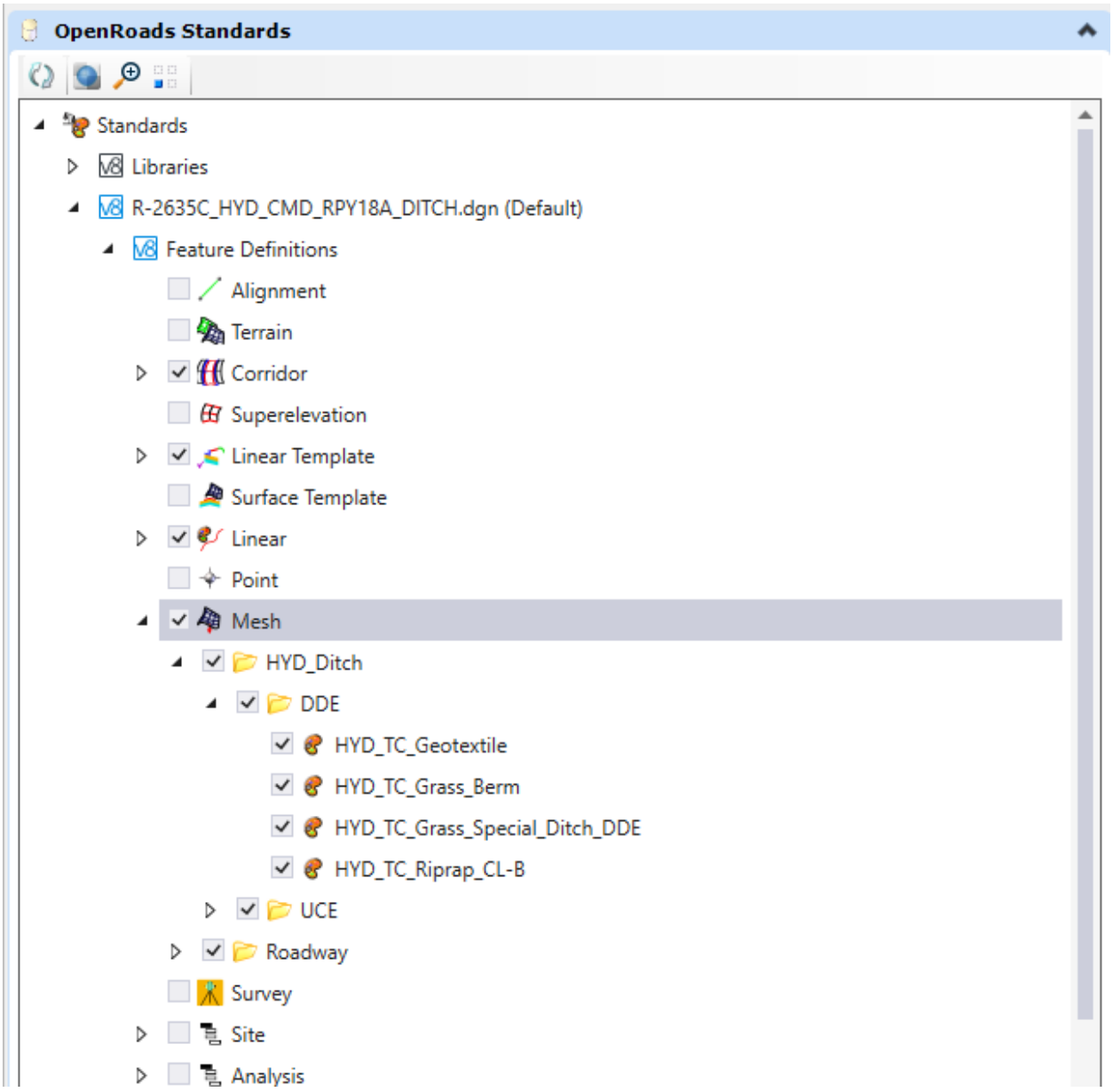
The quantities for DDE and UCE must be computed separately. DDE is a separate pay item and will be documented as a separate quantity. UCE will be incorporated into the roadway earthwork volumes.

The ditch models will be developed with Components and Feature Definitions that will be used to separate them. No additional work should be required to complete the earthwork calculations.

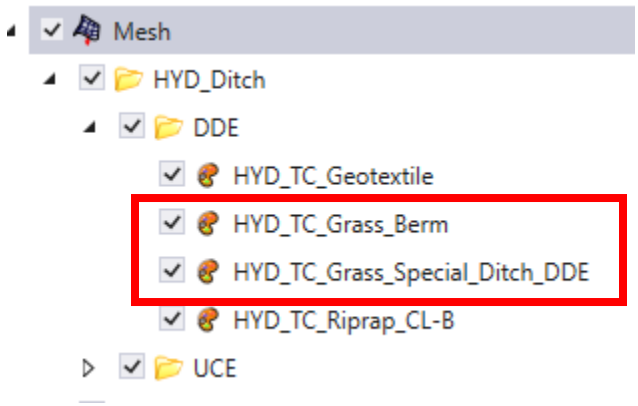
Note : Older workspace versions and custom templates may experience the following issue with Ditch Templates and feature Definitions. The following is a discussion of the issue and a description of the solution.

Ditch feature definitions need to be set up correctly to facilitate the calculation of UCE and DDE earthwork Volumes. The Volume option for DDE ditches should be set to custom. This is the same process used to revise and correct the pavement layer Feature Definitions

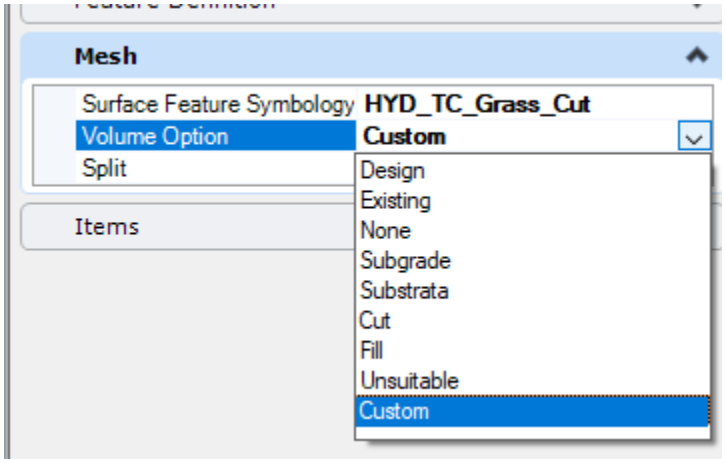
1. Open the DGN file that contains the Ditch Models
2. In the OpenRoads Explorer dialog click on the Current DGN file and go to the Mesh Section under Feature Definitions.



3. Find the Feature Definitions that represent the DDE Earthwork. In this example they are in the DDE folder and labeled HYD_TC_Grass Berm and HYD_TC_Grass_Special_Ditch_DDE.



4. Select these Feature definitions one at a time and in the Properties dialog in the Mesh section set the Volume Option to Custom.

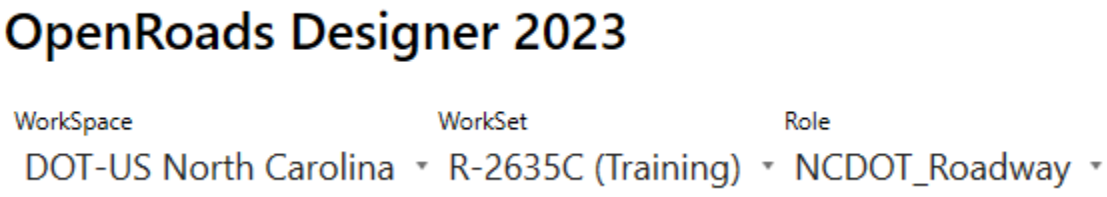


5. This should only be done for the DDE ditches. The UCE ditches should use a volume option of Design.

THIS ENDS THE SECTION ON REVISING FEATURE DEFINITIONS TO CORRECTLY CALCULATE DDE

Start by selecting the OpenRoads Designer 2023 Desktop Icon

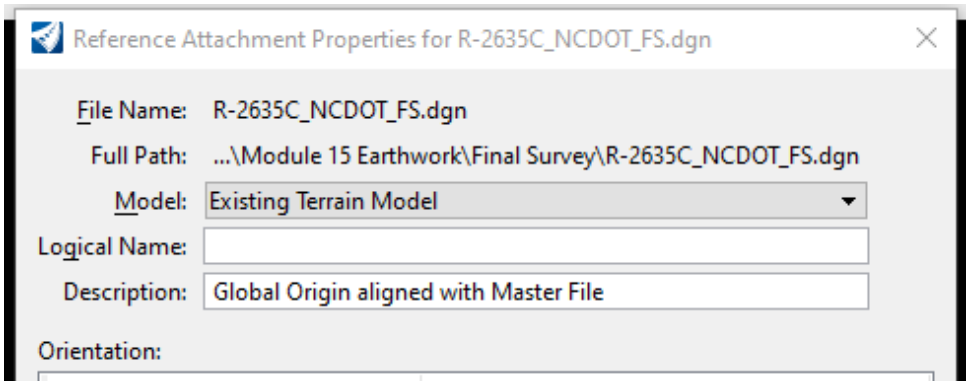
The WorkSpace is DOT_US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



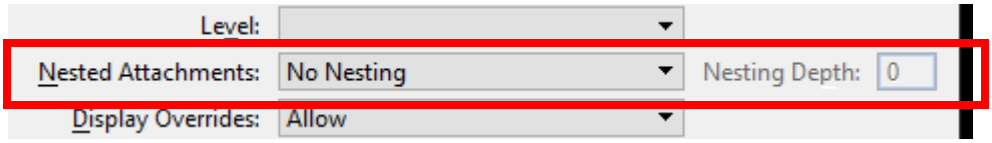
1. Create the Earthwork Volumes

A. The first step will be to compute the UCE and Roadway earthwork together. Create a new DGN file for the Earthwork Calculation. For this exercise we will use RPY18A as the example.

- Filename
  1. R-2635C_RDY_EAR_RPY18A.dgn
- Folder Location
  1. …\R-2635C\Roadway\Design
- Seed File
  1. Seed2D – English Design.dgn
- Attach the required reference files:
  1. Existing Terrain Model – R-2635C_NCDOT_FS
     a. Attach the Existing Terrain Model within the FS file



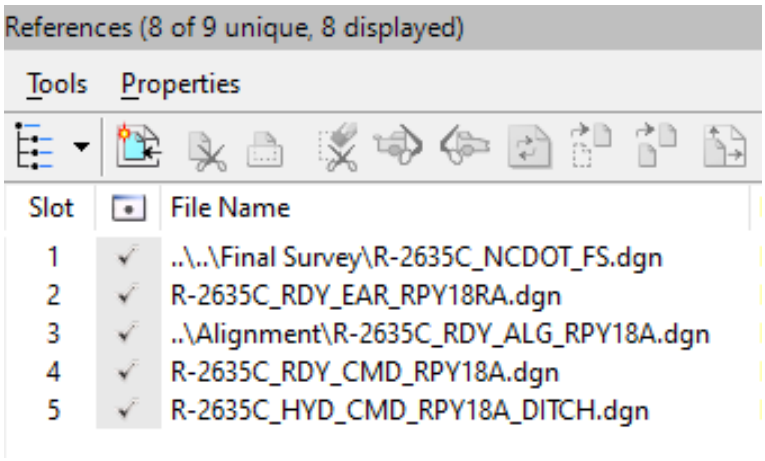
b. Live Nesting should be OFF.



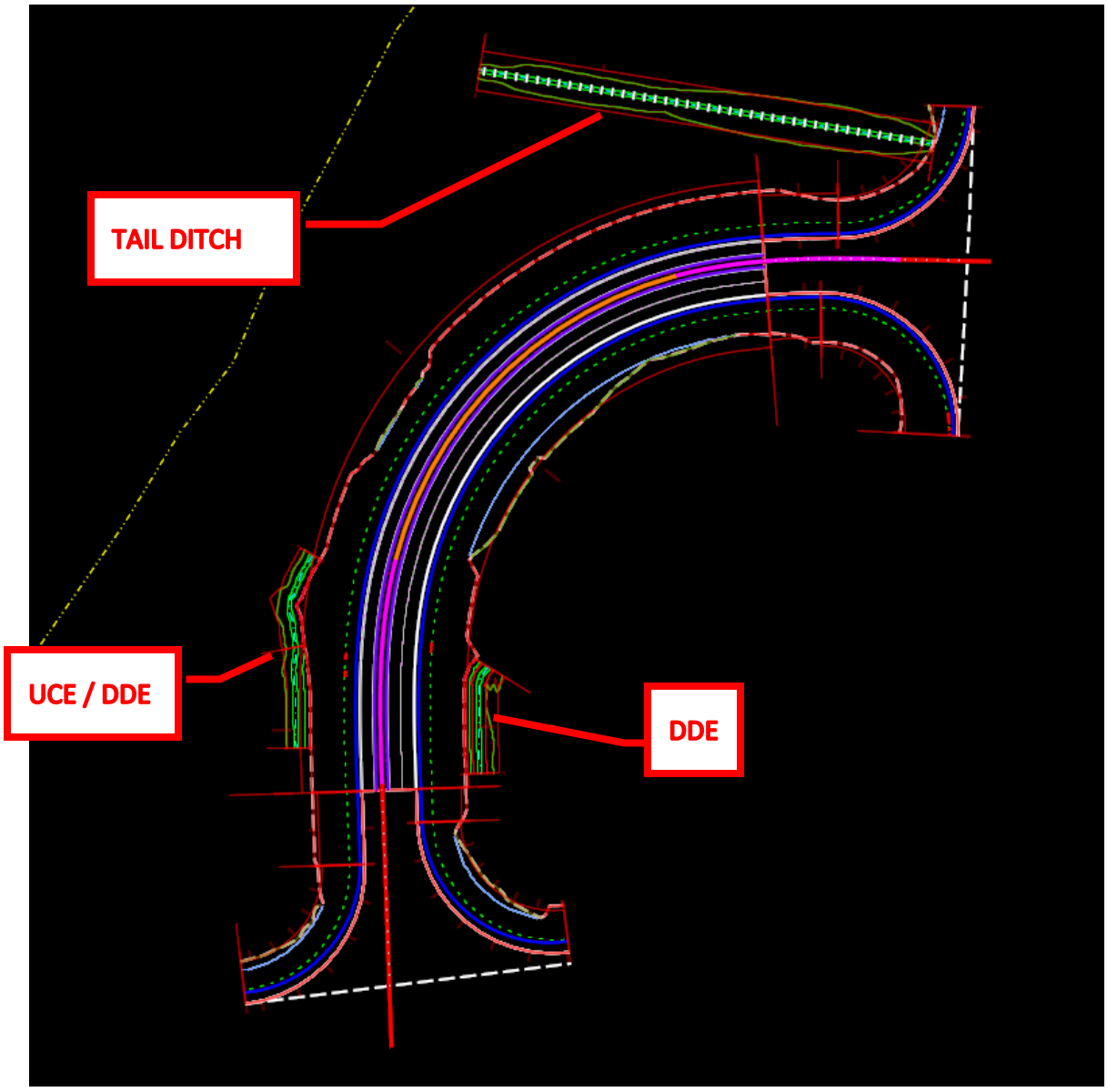
c. Set Active to Create the Default 3D Model

2. Proposed Alignment for the reference corridor
   a. This is not required but is good practice to maintain orientation in the project.

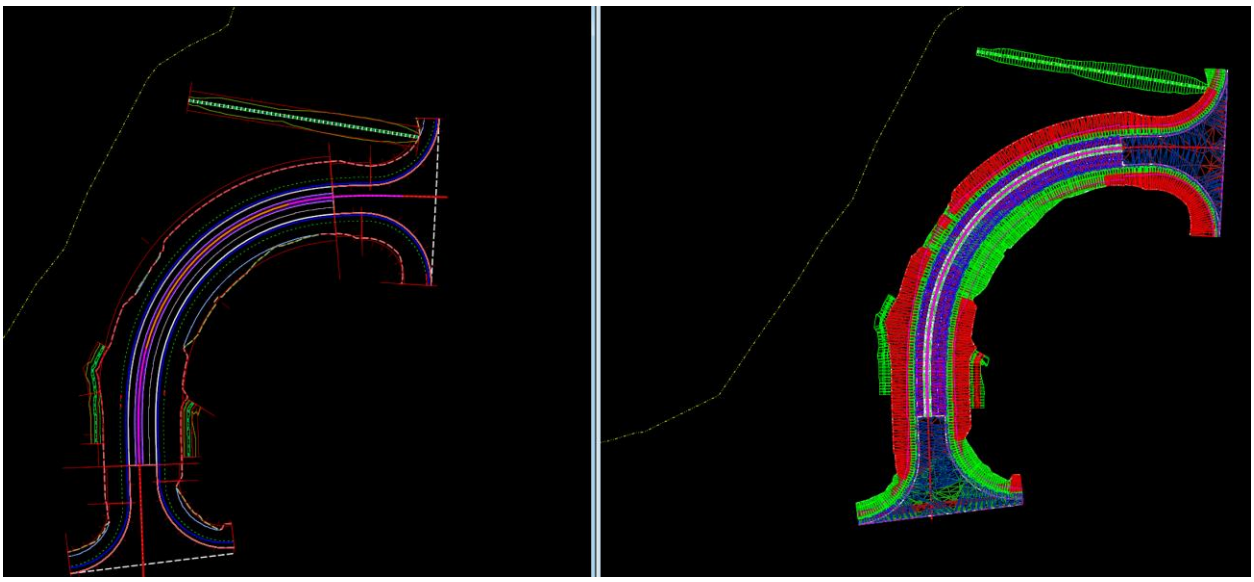
3. Proposed CMD File, this exercise will calculate the earthwork volume total for a single Corridor and the proposed ditches associated with the Y18A alignment.
   a. R-2635C_RDY_CMD_RPY18A.dgn
   b. R-2635C_HYD_CMD_RPY18A_DITCH.dgn



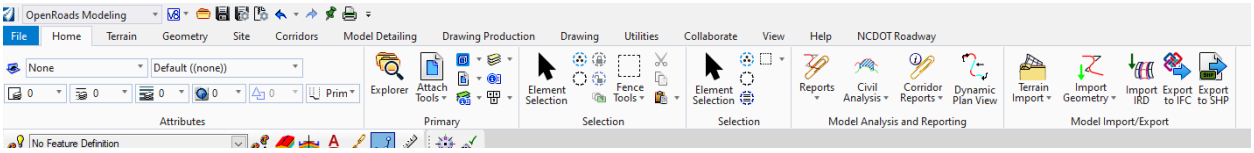
- The default model should look like the image below.
  1. Roadway model with intersections, stationing from top right to bottom left
  2. Proposed Ditch Models
     a. Tail Ditch at the beginning of RPY18A
     b. Lateral Ditch on the right that is partial UCE and Partial DDE
     c. Lateral Ditch on the left that is DDE



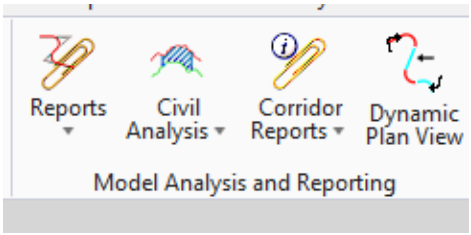
- Open a view with the Default 3D Model shown.



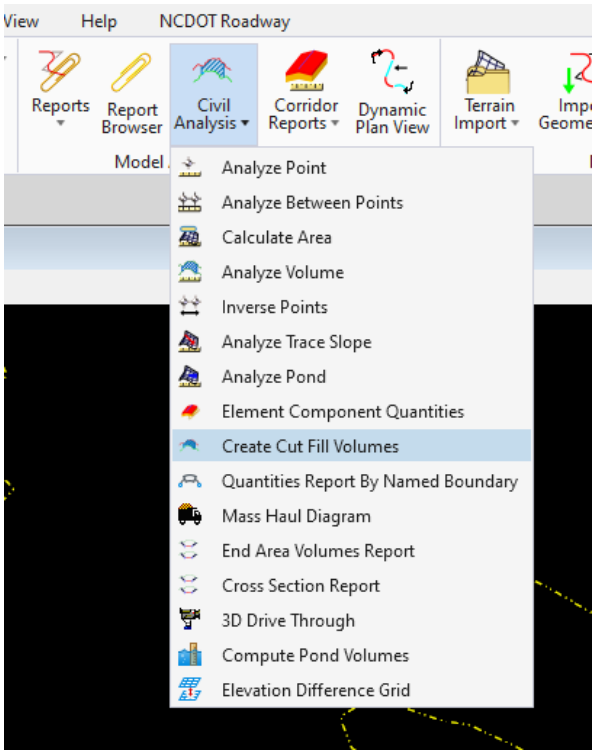
D. Create the Earthwork Volumes. The following workflow is the same steps used in the earthwork calculation in Example 1. Use the OpenRoads Modeling workflow.



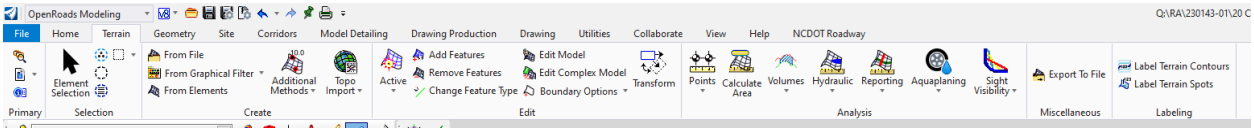
- On the home Tab find the Model Analysis and Reporting Section.

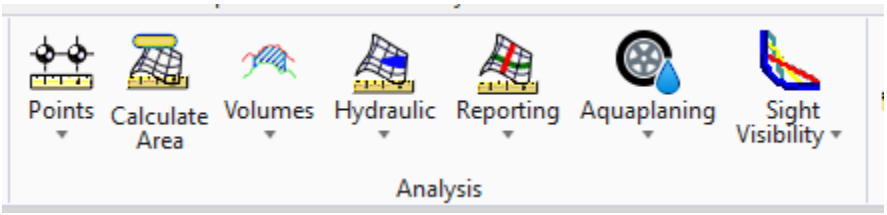


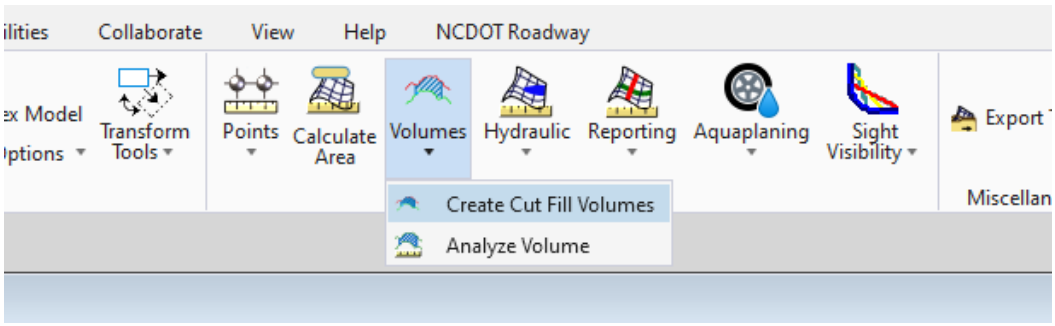
- Under Civil Analysis Find the Create Cut and Fill Volumes Tool.



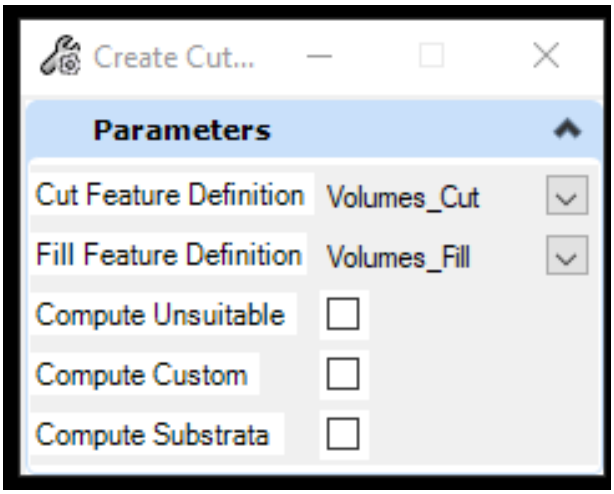
- Note that this same tool is available under the Terrain Tab in the Analysis Section under Volumes



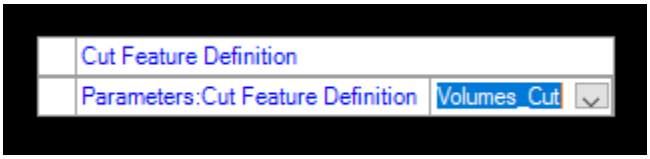




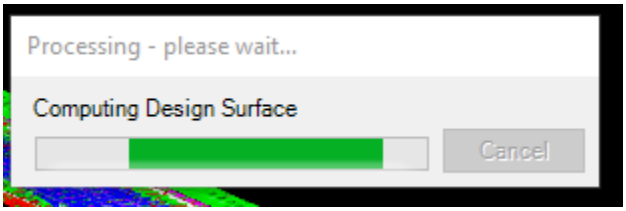
- The dialog Box should be set correctly by Default
  1. Cut Feature Definition = Volumes_Cut
  2. Fill Feature Definition = Volumes_Fill
  3. Compute Unsuitable = Unchecked
  4. Compute Custom = Unchecked
     a. By leaving this unchecked any parts of the model that have components with a volume option set to Custom will not be considered when the earthwork volumes are created. Because the ditch templates include a feature definition for DDE components with the Volume Option set to Custom, those portions of the model will not be included in these earthwork volumes.
  5. Compute Substrata = Unchecked



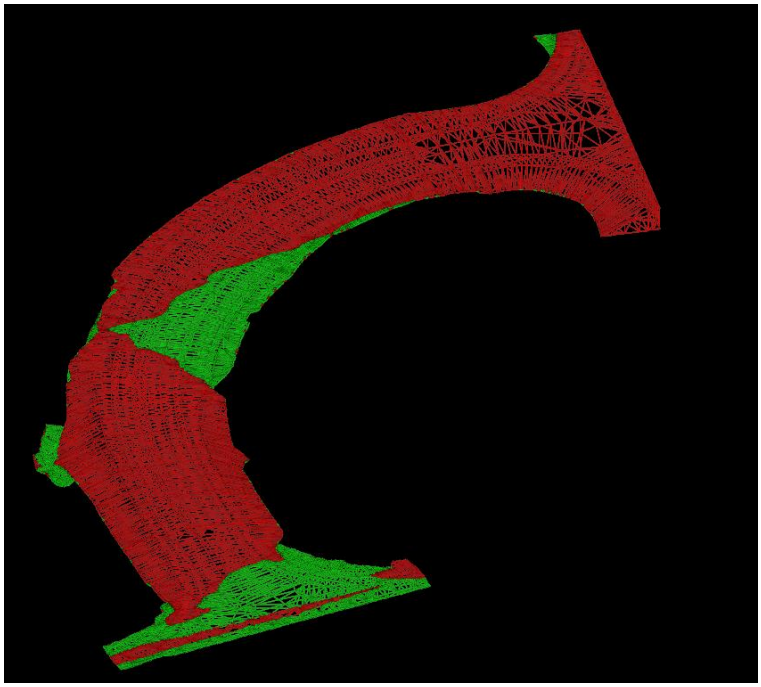
- Left Click for each pop-up window to accept these settings. Left click in any view to start the Earthwork Calculation, the 3D view must be open.



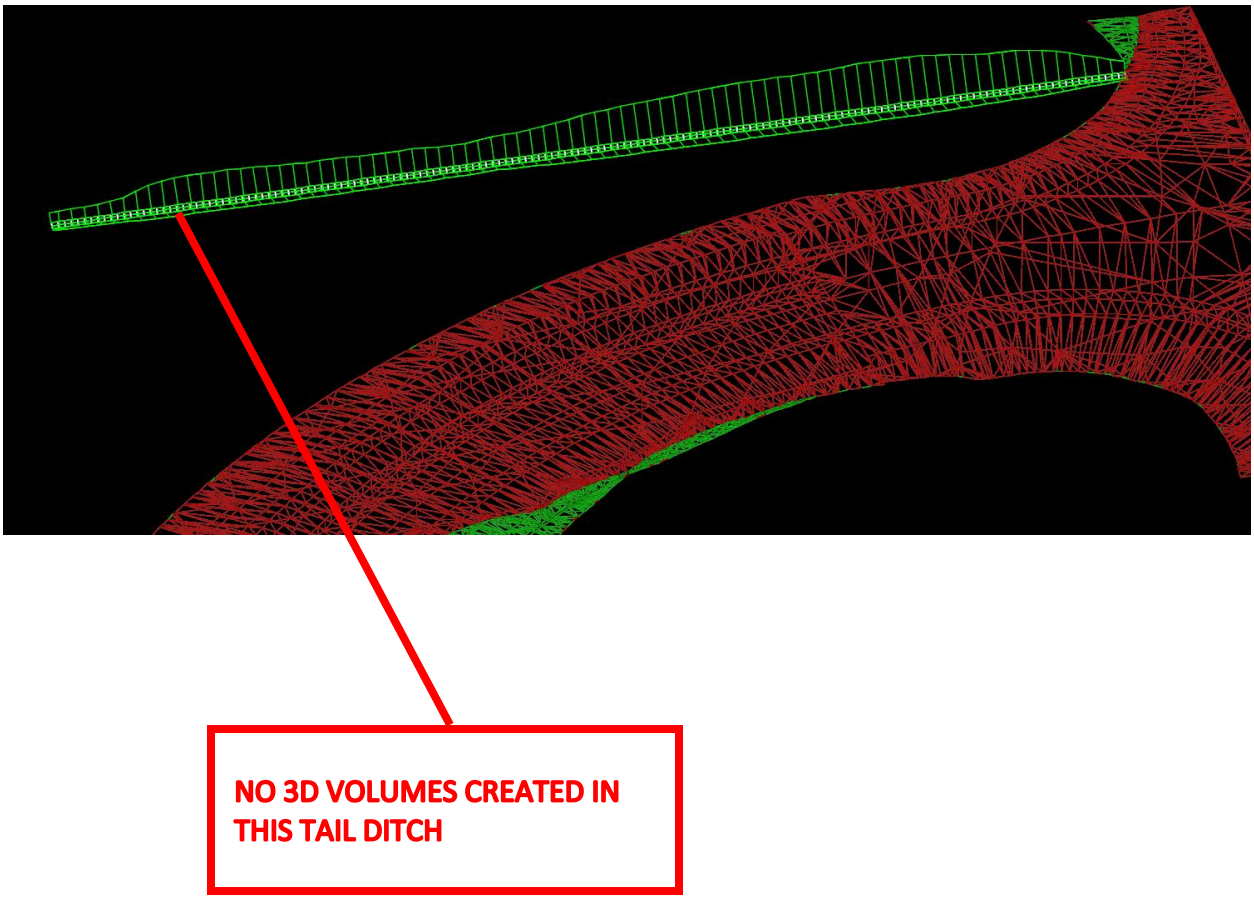
- A processing window should appear.



- The Earthwork Volumes will be shown as new triangulated volumes in the 3D view, red will be fill and green will be cut.

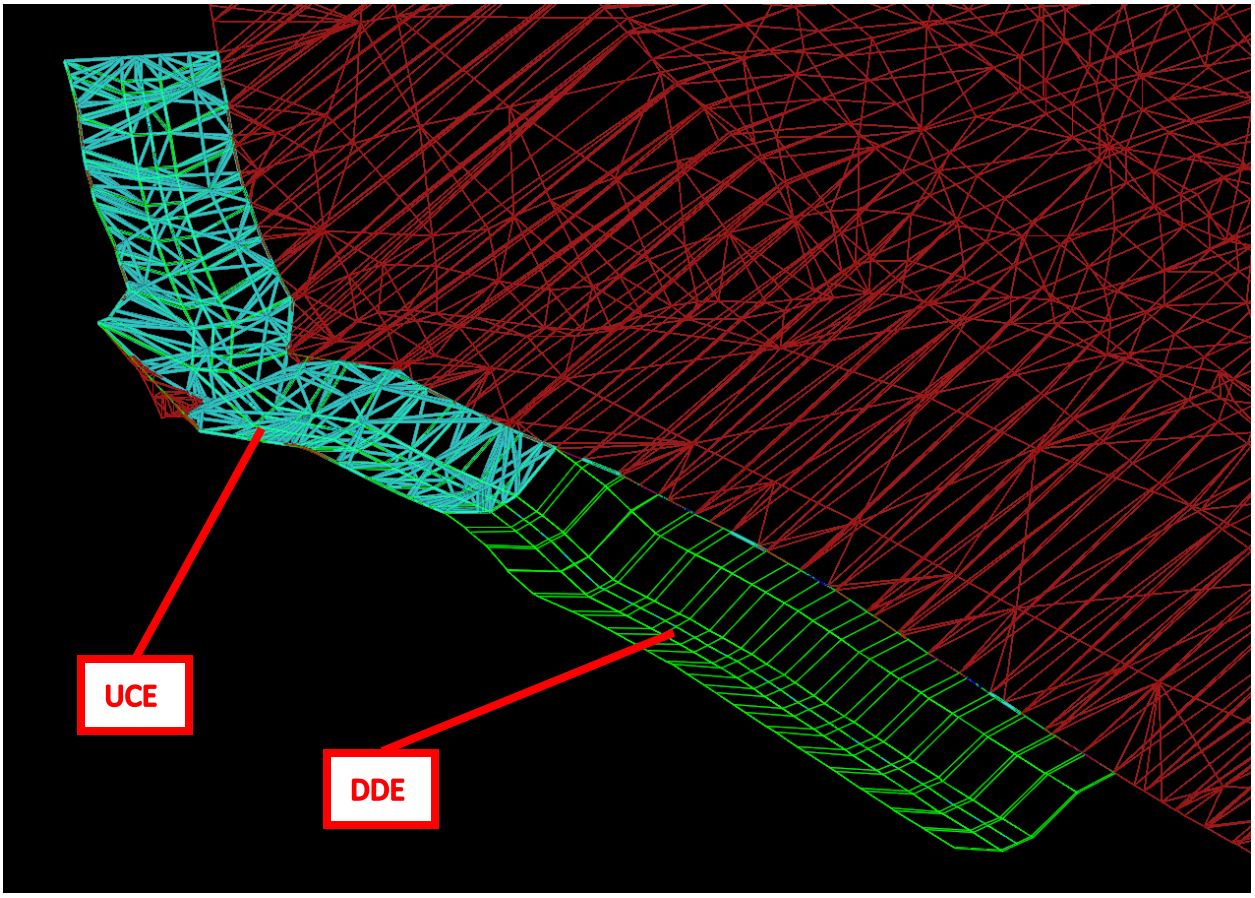


- With the Hydro Ditch Model reference turned on it is easy to see that the tail ditch has not been included in this UCE Earthwork calculation because tail ditches are DDE. When the tail ditch was modeled it used a template with the volume option of the component feature definitions set to None, so that portion of the model was not considered in this earthwork calculation because the Custom option was left unchecked.



- Inspecting the lateral ditch at the end of RPY18A we can see that the UCE portion of the ditch that does not have a berm and has a front slope that matches the roadway front slope was included in the Earthwork Calculation and the DDE portion of the ditch was not included. This is a single corridor but with two template drops, one UCE template and one DDE template.

  The UCE cut volume has been highlighted to show the limits.



- At this point any of the various methods can be used to report and document the earthwork volume.

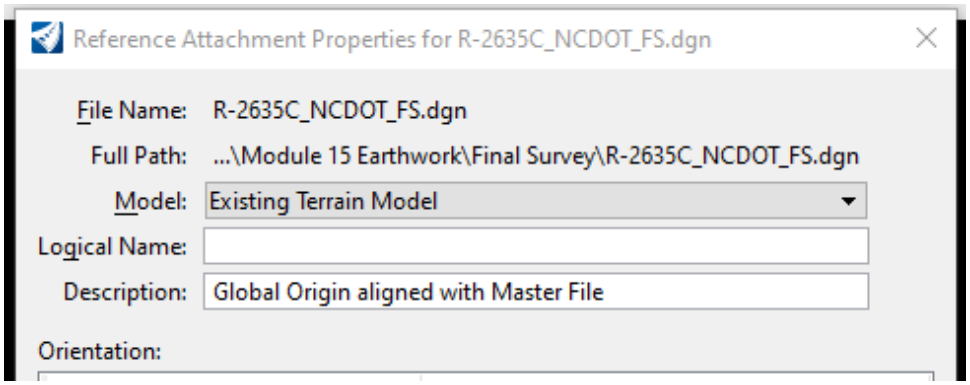
  For this example

  Cut = 1,204 CY
  Fill = 24,477 CY

2. Create the DDE Volumes.

A. Create a new DGN file for the DDE Calculation.

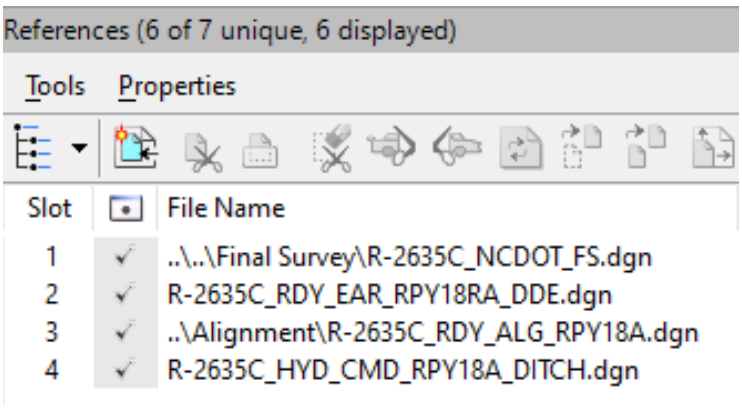
- Filename
  1. R-2635C_RDY_EAR_RPY18A_DDE.dgn
     a. This could be a single file for all DDE throughout a project or multiple files, it would depend on the project complexity and number of ditches.
- Folder Location
  1. …\R-2635C\Roadway\Design
- Seed File
  1. Seed2D – English Design.dgn
- Attach the required reference files:
  1. Existing Terrain Model – R-2635C_NCDOT_FS
     a. Attach the Existing Terrain Model within the FS file



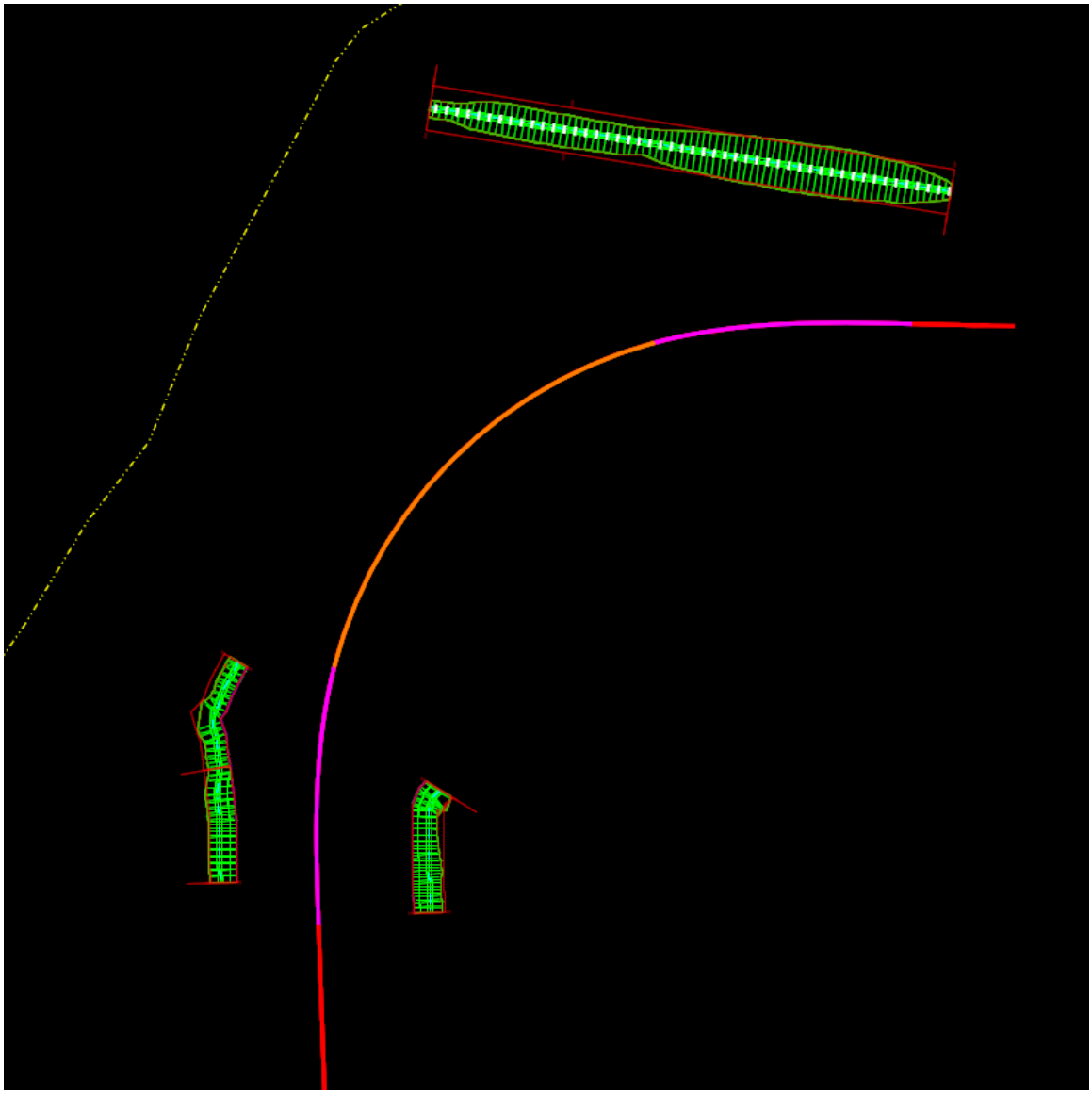
b. Live Nesting should be OFF.

c. Set Active to Create the Default 3D Model

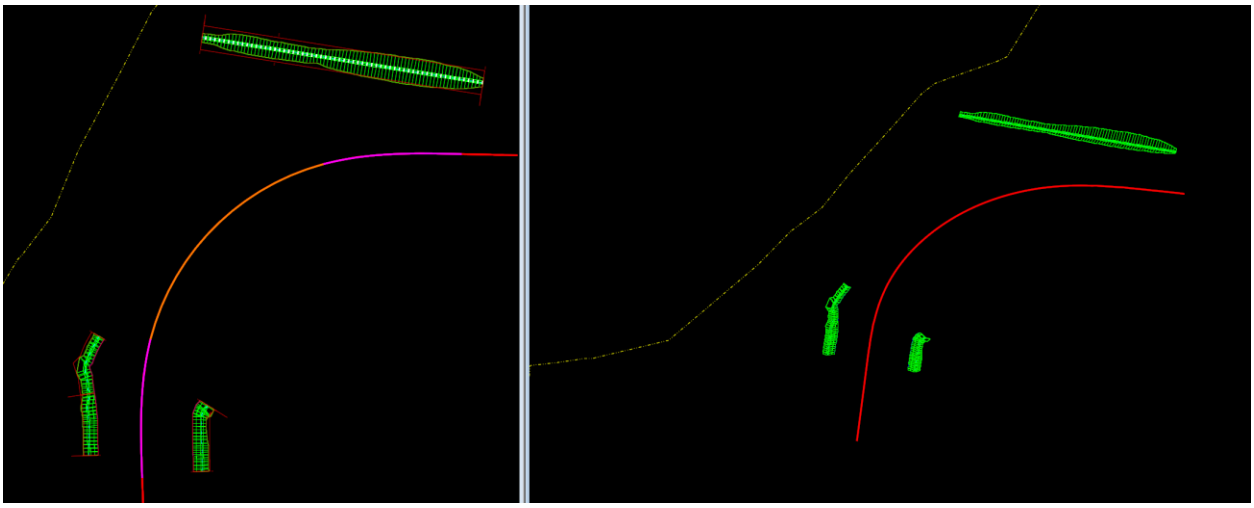
2. Proposed Alignment(s)
   a. This is not required but is good practice to maintain orientation in the project.
   b. For this example, we are only considering the ditches for a single alignment but it may be desirable to reference all alignments.
3. Proposed CMD File, this exercise will calculate the DDE earthwork volumes for the proposed ditches. For this process we do not want any of the roadway models attached. If the roadway models are attached the earthwork volumes will be calculated for those models and it will make it harder to separate the DDE Volumes.
   a. R-2635C_HYD_CMD_RPY18A_DITCH.dgn



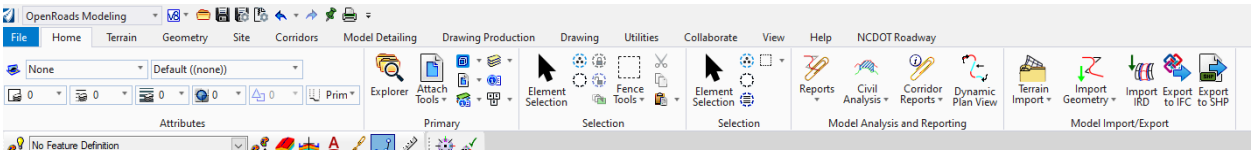
B. The default model should look like the image below
   - Proposed Ditch Models
     1. Tail Ditch at the beginning of RPY18A
     2. Lateral Ditch on the right that is partial UCE and Partial DDE
     3. Lateral Ditch on the left that is DDE



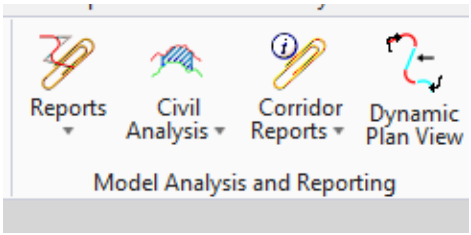
- Open a view with the Default 3D Model shown.



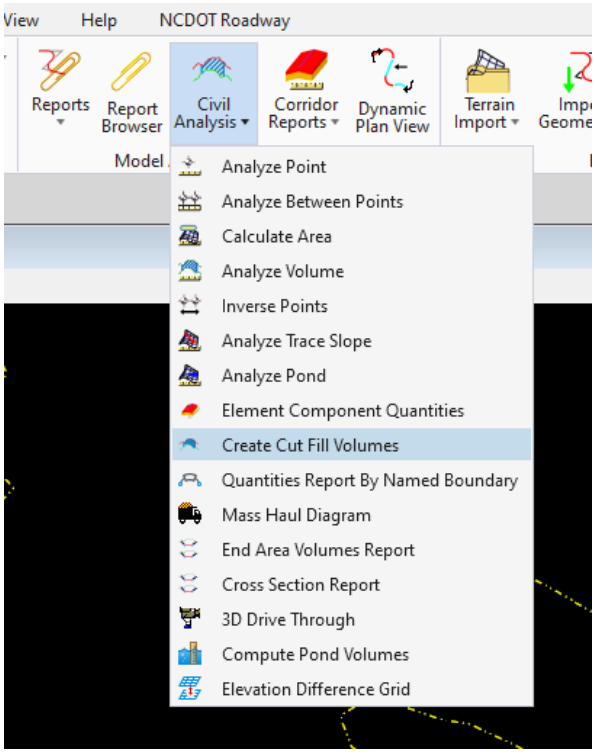
C. The following workflow is the same steps used in the UCE calculation with the change being the Custom Volume Option. Use the OpenRoads Modeling workflow.



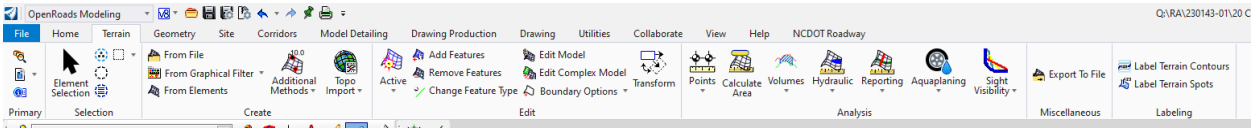
- On the home Tab find the Model Analysis and Reporting Section.

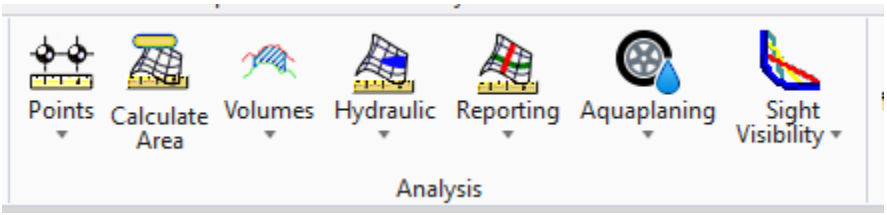


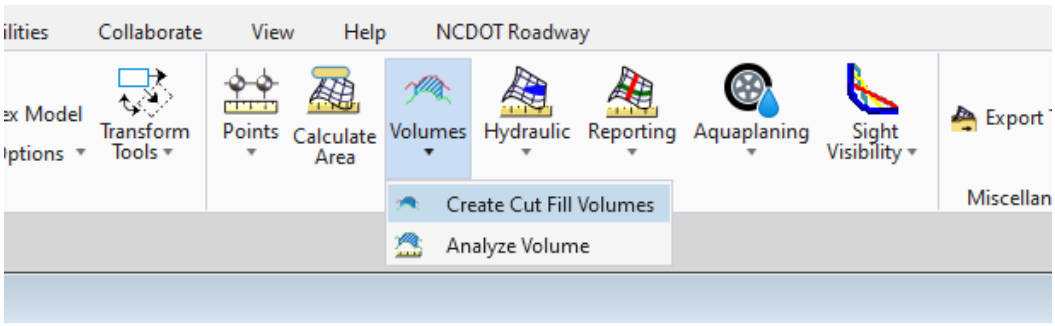
- Under Civil Analysis Find the Create Cut and Fill Volumes Tool.



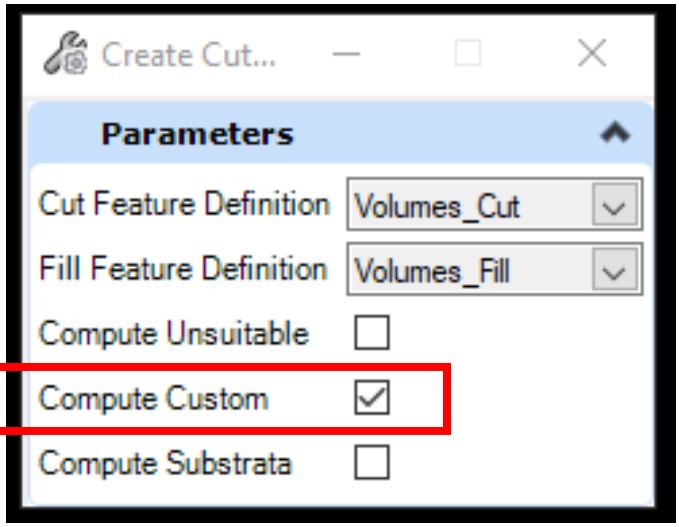
- Note that this same tool is available under the Terrain Tab in the Analysis Section under Volumes



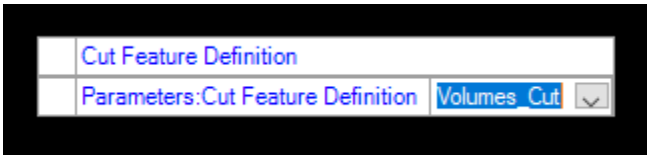




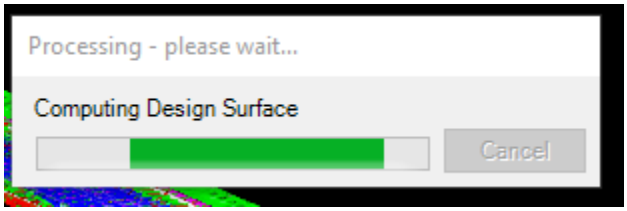
- The dialog Box should be set correctly by Default
  1. Cut Feature Definition = Volumes_Cut
  2. Fill Feature Definition = Volumes_Fill
  3. Compute Unsuitable = Unchecked
  4. Compute Custom = **CHECKED ON**
     a. By checking on the Compute Custom option for this calculation any components that have the volume option set to custom will be reported. Since our DDE Ditch templates use components that have the volume option set to custom they will be reported for this earthwork calculation.
  5. Compute Substrata = Unchecked



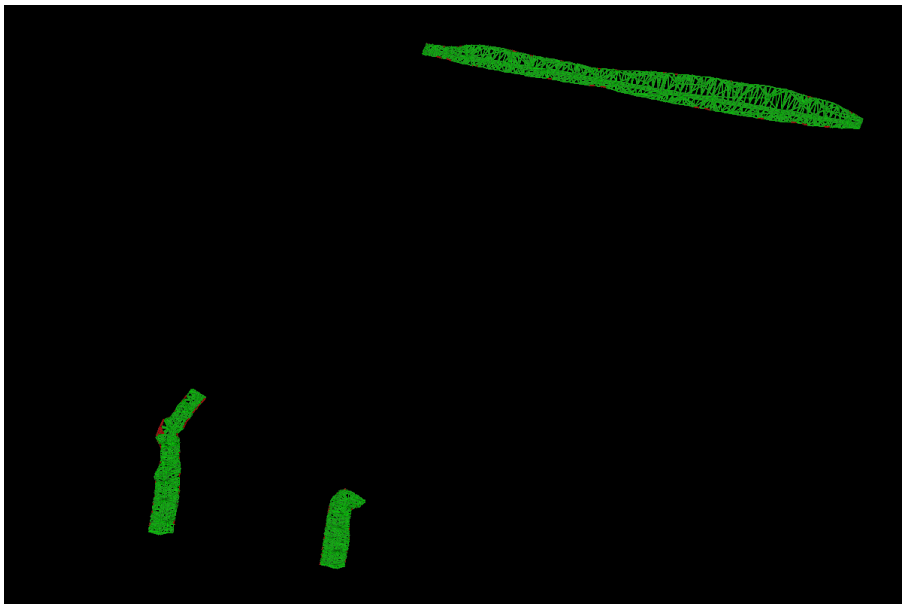
- Left Click for each pop-up window to accept these settings. Left click in any view to start the Earthwork Calculation, the 3D view must be open.



- A processing window should appear.



- The Earthwork Volumes will be shown as new triangulated volumes in the 3D view, red will be fill and green will be cut.
  1. There may be small volumes of fill computed because we are using Prismoidal volumes so all triangles are considered not just the end areas from the cross sections.

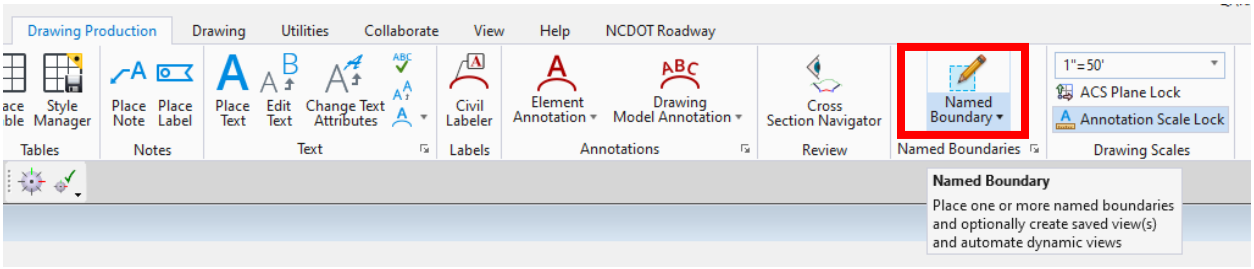


- Note that the UCE and DDE have both been calculated at this stage. We will need to use named boundaries to separate the DDE from the UCE and report only the DDE volumes. Named boundaries will also serve to separate the DDE for each ditch. The DDE volume for each individual ditch is required to be labeled on the plans, and placing the named boundaries will allow volume reporting for each individual ditch.

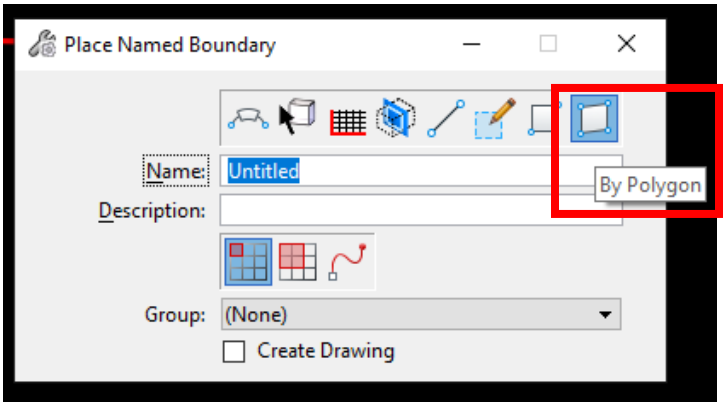
3. Place Named Boundaries

A. Named Boundaries are required to separate the DDE quantities. This is like the process used to separate Earthwork for Station Breaks or Traffic Control requirements.

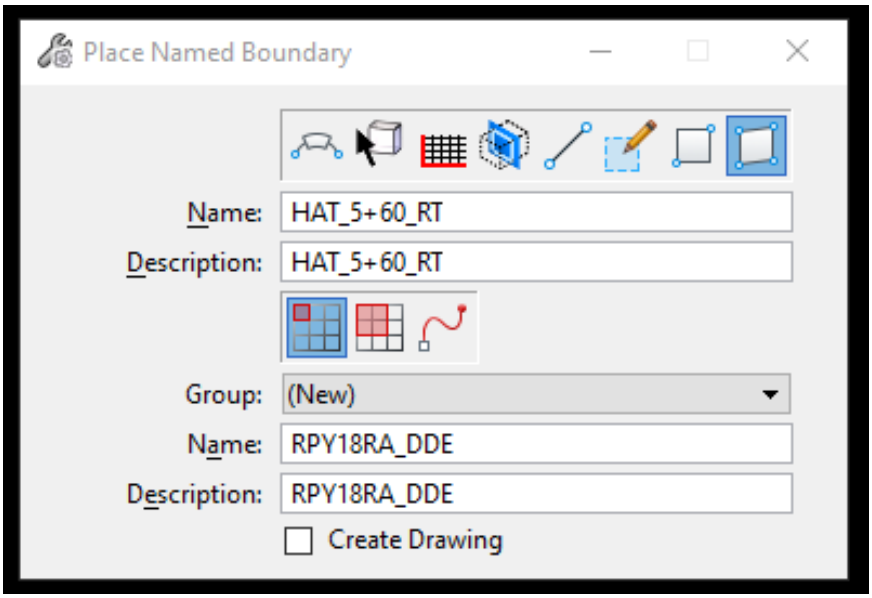
- In the OpenRoads Modeling Workflow go to the Drawing Production Tab and the Named Boundary Group.



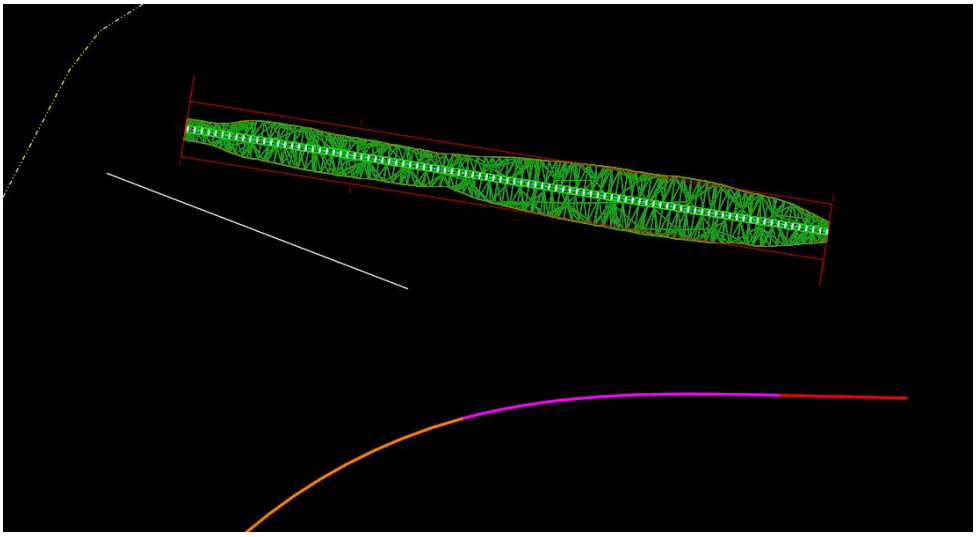
- Select the By Polygon option.



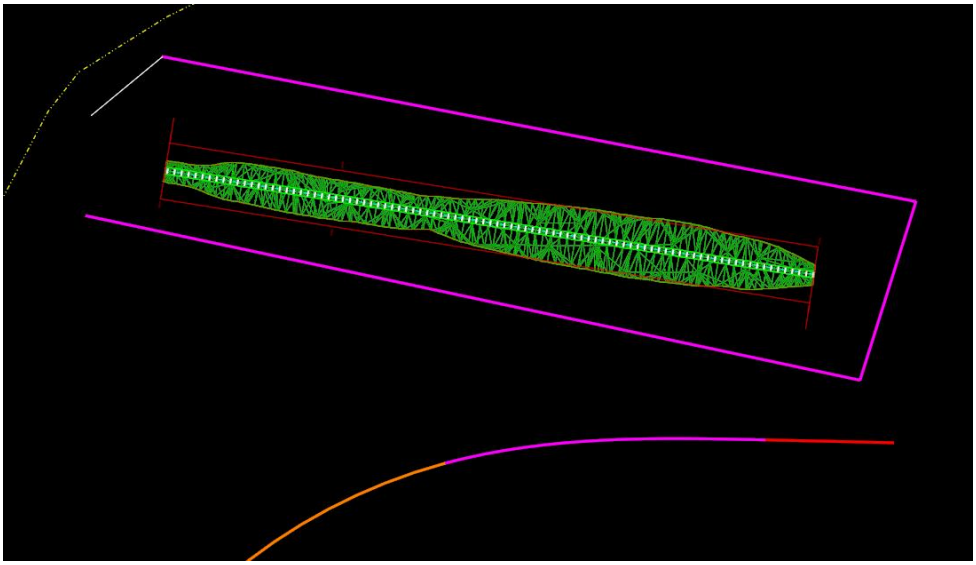
- The first named boundary will go around the tail ditch at Station 5+60 RT.
  1. Set the name and description to HAT_+60_RT
     a. This could be anything that the designer chooses but should allow for this ditch to be identified in the quantity report.
  2. Set the Group to New
  3. Set the name to RPY18RA_DDE
     a. This name should identify the group of ditches that will be in the DDE calculation. If the designer is going to place all the DDE for an entire project into one DGN file this could be the TIP#, i.e. R-2635C_DDE. For this example, the name matches the alignment used as a reference for the ditches. The names aren't critical, but the designer should use a naming convention that allows for identification of the ditches and area of the project included in the earthwork calculation.
  4. Create Drawing should be unchecked.



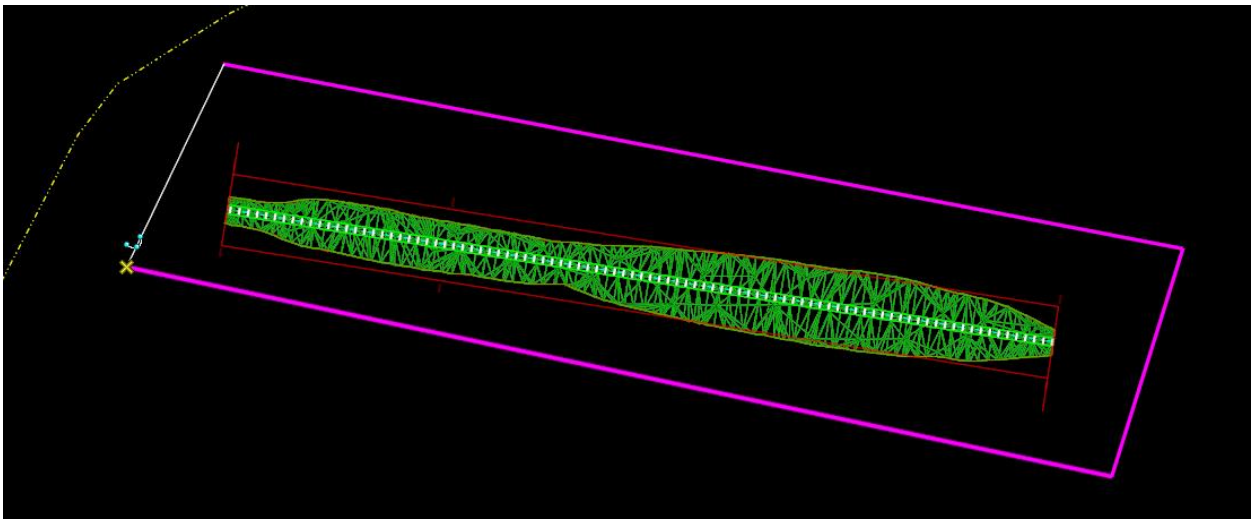
- Place a named boundary around the tail ditch at the beginning of the alignment. The shape of the named boundary is not critical here because this ditch corridor does not cross another corridor and there is nothing adjacent that would affect the quantity report.
  1. Left click to start the shape



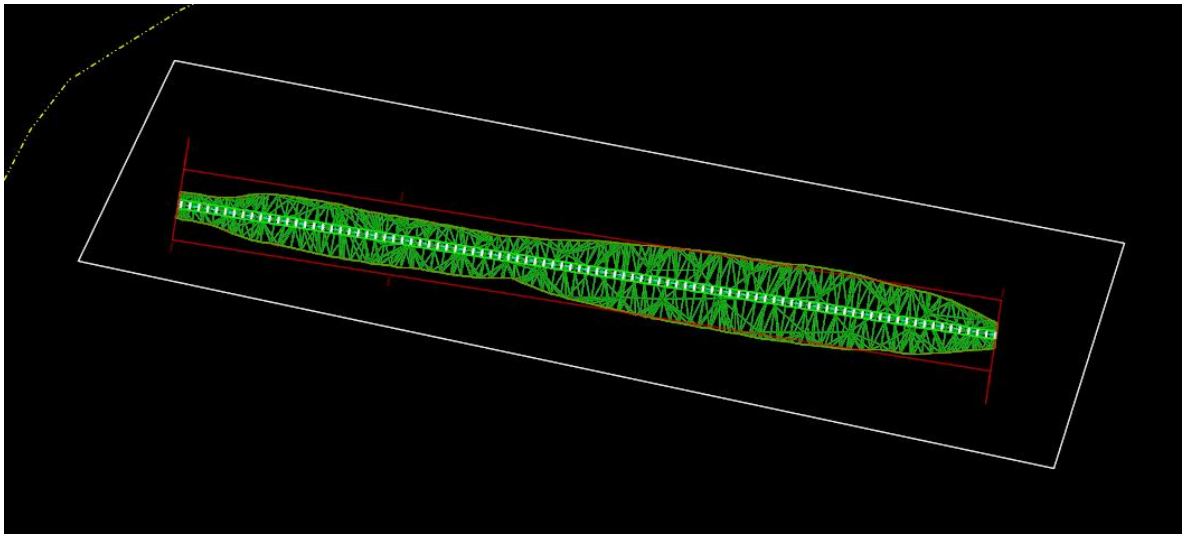
  2. Left click to place additional corners that will enclose the ditch model.



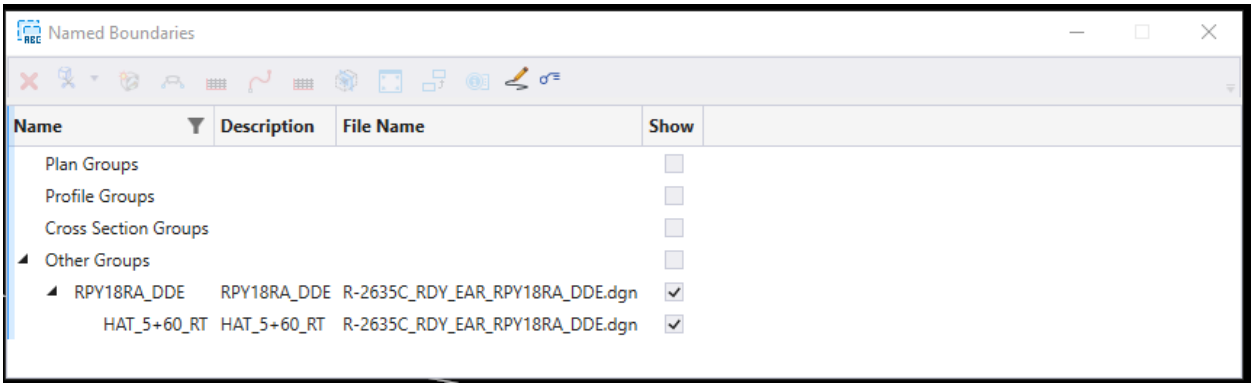
3. Snap to the first point and left click to close the boundary.



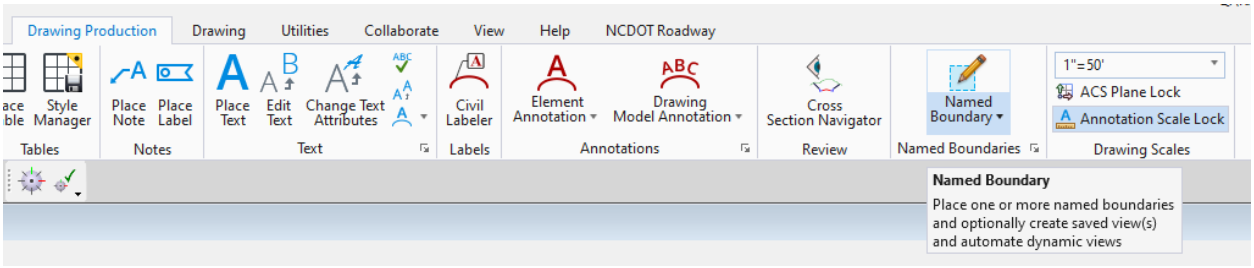
4. Left lick again to accept the named boundary. It should enclose the ditch but the actual shape is not critical.



- Under the Named Boundaries dialog there will be a group for RPY18RA_DDE and a named boundary for HAT_5+60_RT

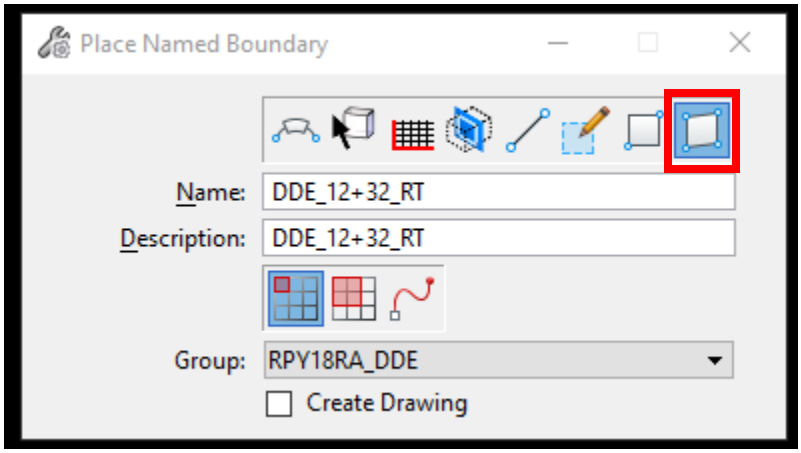


- The next named boundary will be for the DDE ditch at Station 12+32 RT. This ditch is part of a corridor that contains both a UCE ditch and a DDE ditch. In the OpenRoads Modeling Workflow go to the Drawing Production Tab and the Named Boundary Group.

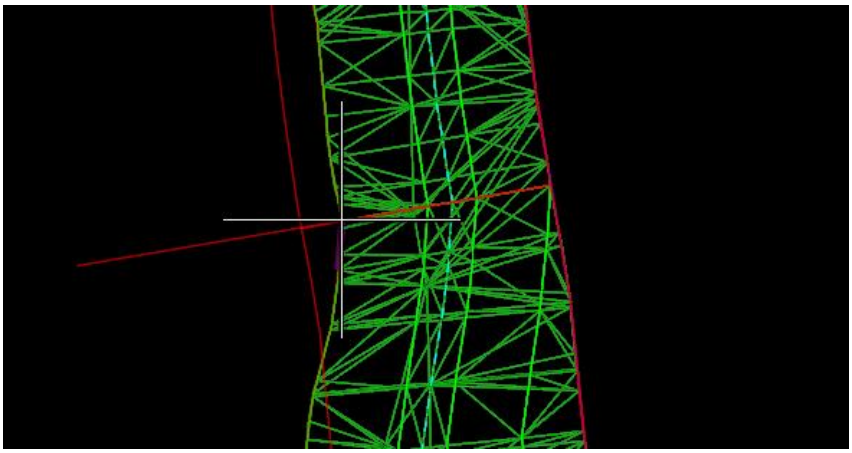


Select the By Polygon option.

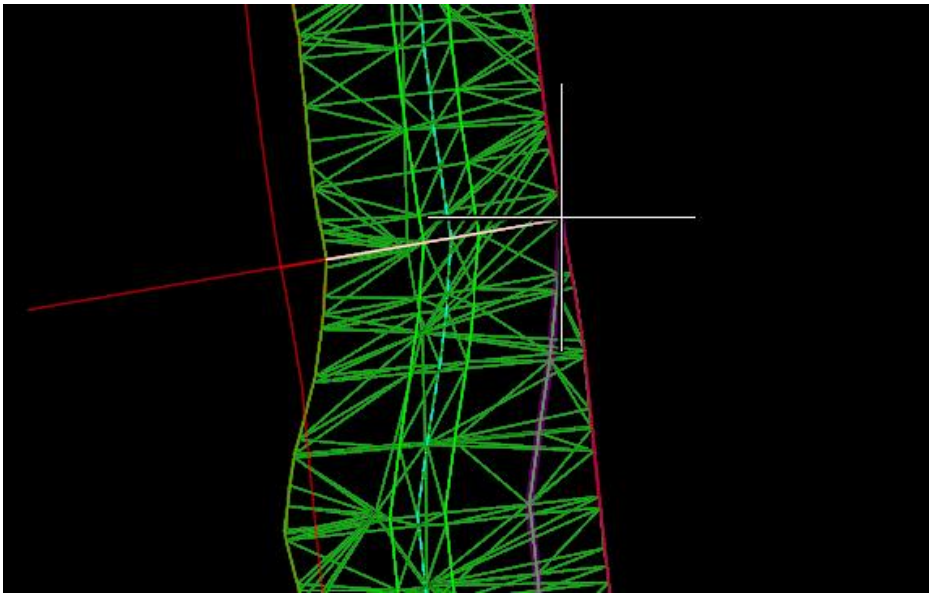
1. Set the name and description to DDE12+32_RT
   a. This could be anything that the designer chooses but should allow for this ditch to be identified in the quantity report.
2. Set the Group to RPY18RA_DDE
   a. This is the previously created group and will add this named boundary to the same group at the HAT Ditch from the previous steps. When the quantities report is created all these boundaries will be in the same report.
3. Create Drawing should be unchecked.



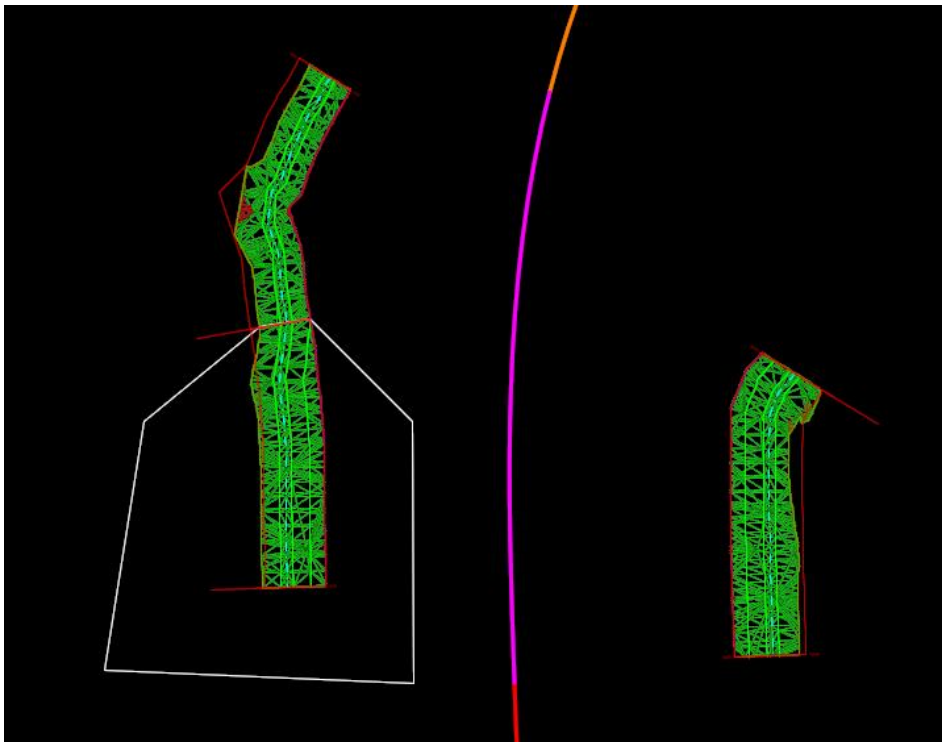
- Place this named boundary to only enclose the region of the model that includes the DDE Ditch
  1. Look for the separation at the template drop and snap to the end of one of the triangles or template lines that separates the UCE and DDE ditch.



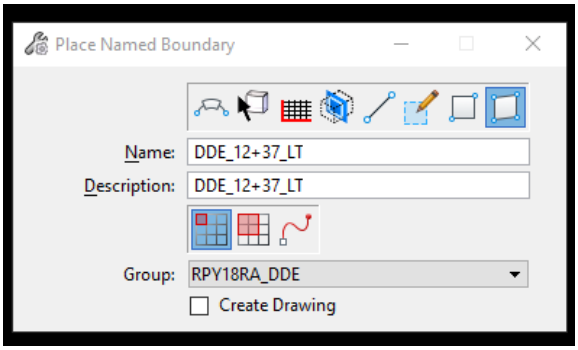
  2. Snap to the point that separates the drops on the opposite side of the ditch.



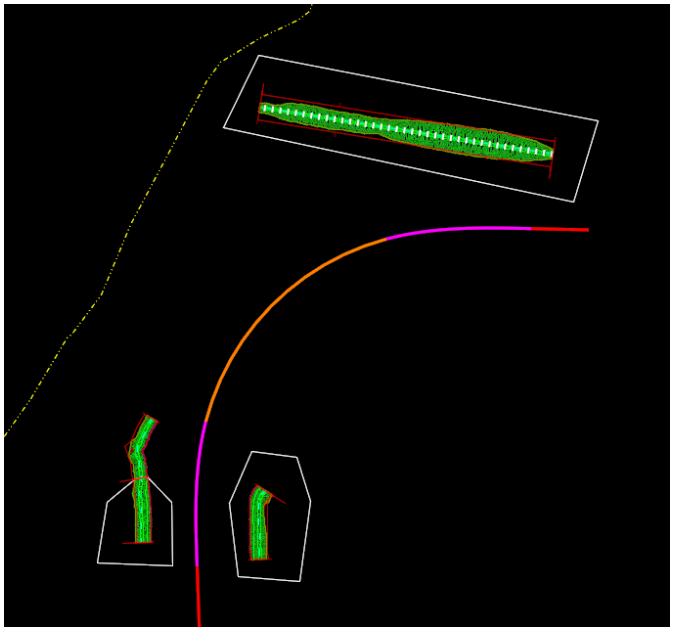
3. Complete the named boundary with the same method used to place the boundary around the HAT ditch in the previous steps. The remaining points are not critical, it is only important that the shape enclose the DDE section of the ditch without crossing any other portions of a model.



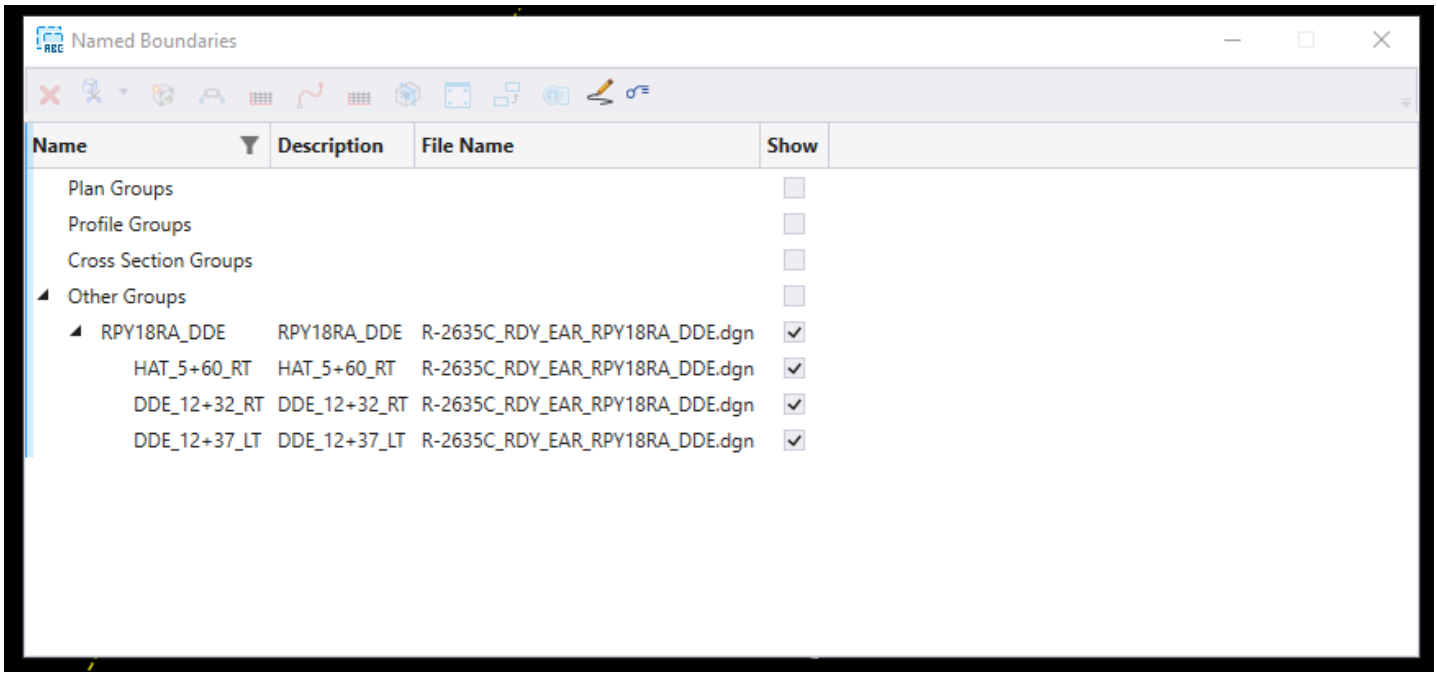
- The last step is to enclose the DDE ditch at Station 12+37 LT. This ditch is entirely DDE, and the shape can be placed with the same method that was used for the HAT ditch previously. Make sure to name the boundary correctly and select the previously created group.



- At this point there should be 3 named boundaries in the drawing. The named boundaries should all enclose a single DDE ditch but not cross any other parts of the model.

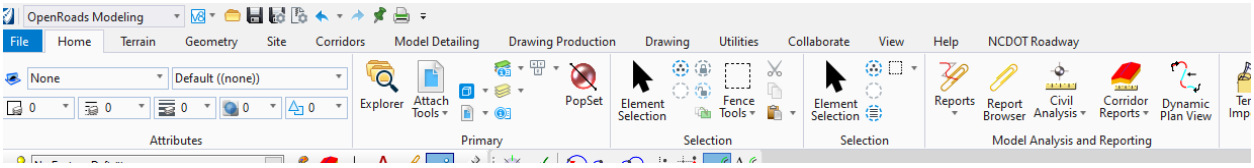


- Reviewing the named boundary dialog should show a single group under the Other Groups Drop Down and 3 named boundaries. These should all be named in a way that allows the designer to determine which named boundary from the report matches to which ditch in the design file.

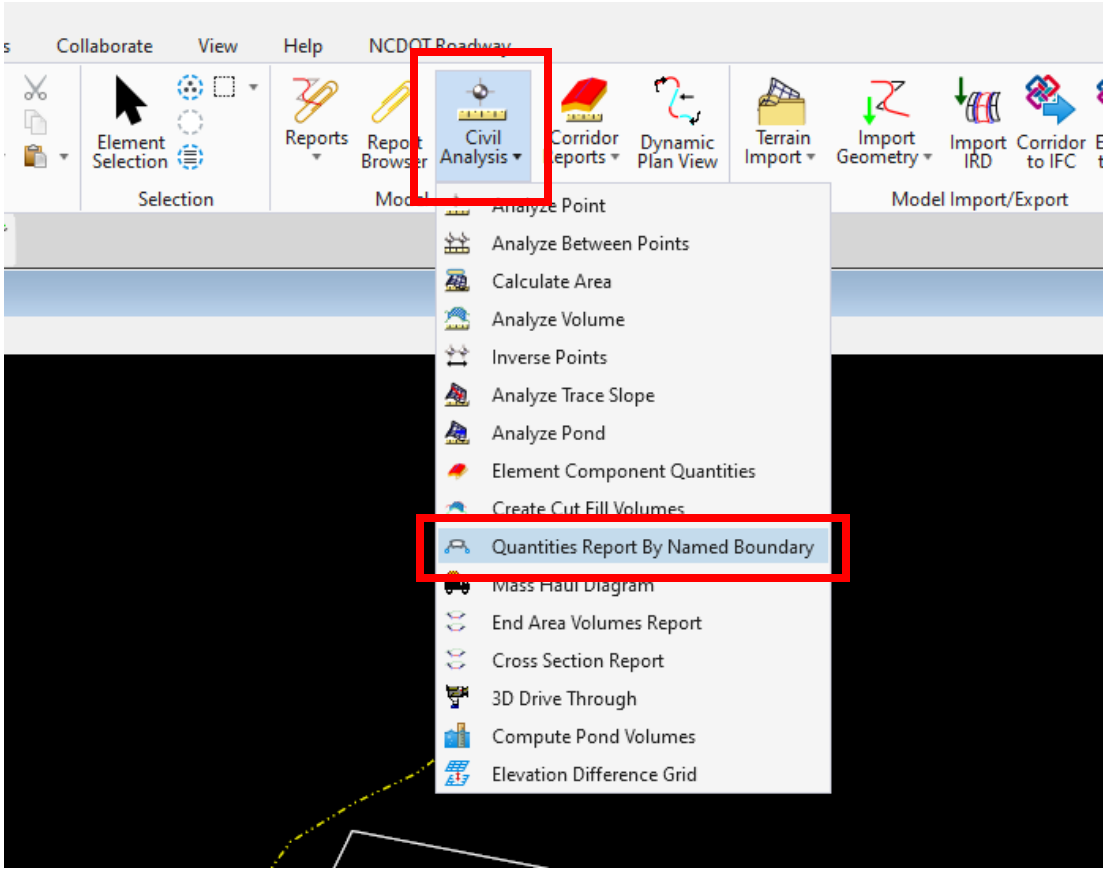


4. Report the DDE quantities

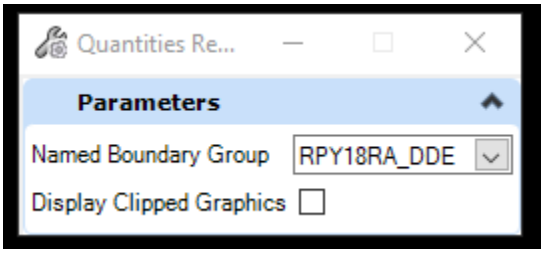
A. Under the OpenRoads Modeling workflow switch to the Hom tab and find the Model Analysis and Reporting section.



- Under Civil Analysis find the Quantities Report by Named Boundary Tool.



- Select the RPY18RA_DDE Named Boundary Group.
  1. Display Clipped Graphics should be checked OFF



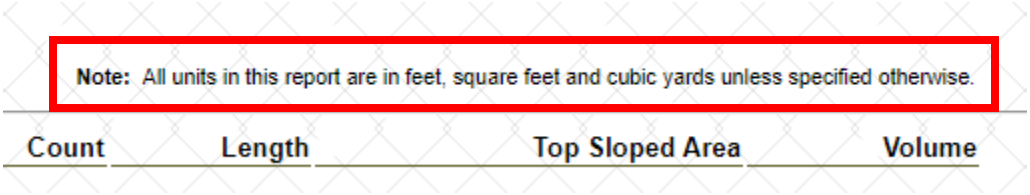
  2. This still generates a quantities report for all the ditches at one time with each one reported in a separate section.

Named Boundary Group: RPY18RA_DDE
Alignment Name:
Input Grid Factor:

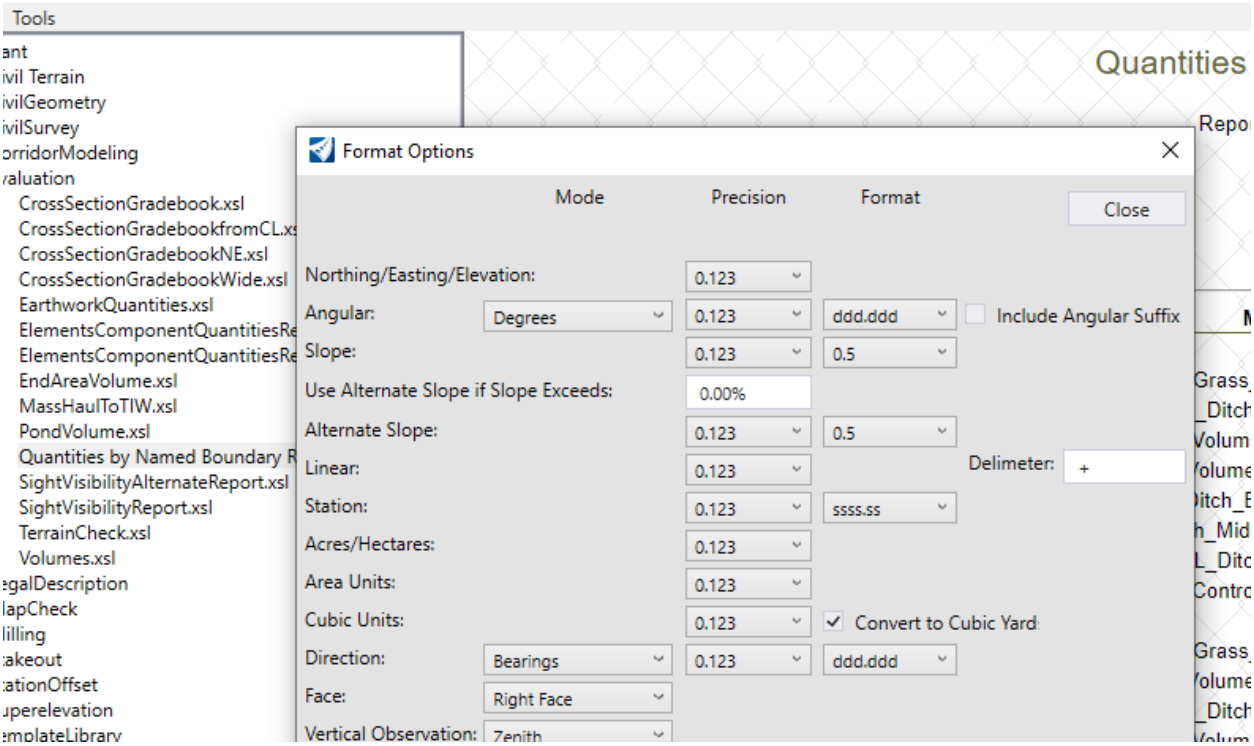
Note: All units in this report are in feet, square feet and cubic yards unless specified otherwise.

Station	Named Boundary Name	Material	Count	Length	Top Sloped Area	Volume
N.A.	DDE_12+37_LT					
		HYD_TC_Grass_Berm:			523.746	
		HYD_TC_Grass_Special_Ditch_DDE:			206.149	
		Volumes_Fill:			6.364	0.006
		Volumes_Cut:			2192.370	143.013
		HYD_TL_Ditch_Bottom:		195.686		
		HYD_TL_Ditch_Middle_LT:		97.372		
		HYD_TL_Ditch_Top:		199.984		
		HYD_TL_Ditch_Control_Line:		105.000		
N.A.	DDE_12+32_RT					
		HYD_TC_Grass_Berm:			401.270	
		Volumes_Cut:			1877.901	122.603
		HYD_TC_Grass_Special_Ditch_DDE:			1608.282	
		Volumes_Fill:			1.038	0.000
		HYD_TL_Ditch_Bottom:		177.958		
		HYD_TL_Ditch_Middle_RT:		88.979		
		HYD_TL_Ditch_Top:		178.121		
		HYD_TL_Ditch_Control_Line:		90.000		
		HYD_TL_Ditch_Middle_LT:				
N.A.	HAT_5+60_RT					
		HYD_TC_Grass_Special_Ditch_DDE:			12621.796	
		Volumes_Fill:			5.889	0.005
		Volumes_Cut:			11492.348	1564.271
		CCE_Target_1:		408.270		
		HYD_TL_Ditch_Bottom:		816.540		
		HYD_TL_Ditch_Middle_Median:		408.270		
		HYD_TL_Ditch_Top:		822.006		
		HYD_TC_Grass_Berm:				
		HYD_TL_Ditch_Middle_RT:				
		HYD_TL_Ditch_Control_Line:				
		HYD_TL_Ditch_Middle_LT:				

- Take note of the report units



- And change them under Tools – Format Options if necessary.



- Note that as a true Prismoidal volume calculation some sections may show a small fill number. This is not unexpected and is likely a result of tying in the ditch to existing ground or a small scour area in the existing ditch that is being filled in.

Named Boundary Name	Material	Count	Length	Top Sloped Area	Volume
DDE_12+37_LT					
	HYD_TC_Grass_Berm:			523.746	
	HYD_TC_Grass_Special_Ditch_DDE:			206.149	
	Volumes_Fill:			6.364	0.006
	Volumes_Cut:			2192.370	143.013
	HYD_TL_Ditch_Bottom:		195.686		

- This report can be saved into various formats for documentation and used to update the ditch labels on the plans. For ditch templates that include Rip Rap and Geotextile those quantities will also be reported here.

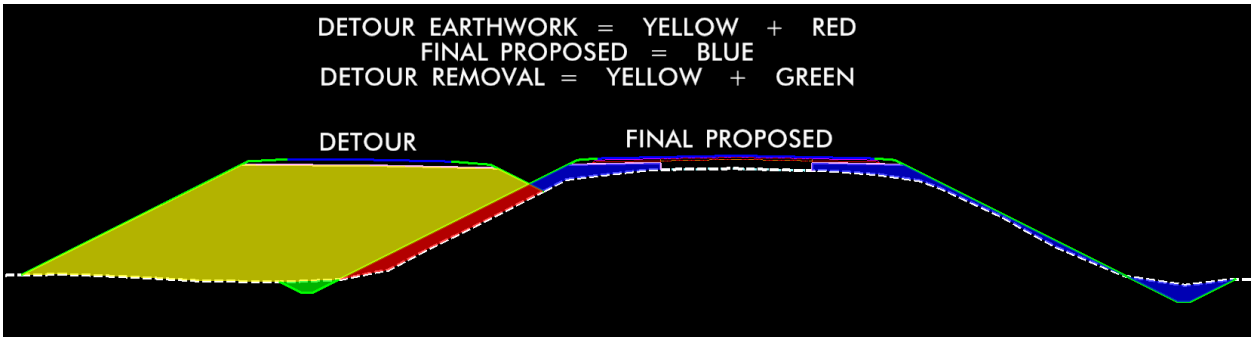
B. The final note on DDE quantities is that if the ditches are revised the same named boundaries can be used to rerun the report, if they enclose the new ditch limits, and generate new quantities very easily. If one of the ditches got longer or shifted out of the named boundary the boundary shape can be adjusted using the standard drafting tools, or a boundary could be deleted from the group and a new boundary added.

Exercise 5 – Earthwork for Project with Onsite Detour

In this exercise we will work through the process of calculating earthwork volumes for a project with an onsite detour. This is a common exercise for bridge replacement projects and in projects where a bridge is replacing an at grade intersection. In these situations, the designer will create a detour model that is based on existing ground and a final proposed model that is based on existing ground, but the earthwork needs to be calculated differently. There will be:

- Earthwork required to build the detour.
  a. Yellow and Red Shapes
- Earthwork required to build the final, excluding the overlap of the detour.
  a. Blue Shape
- Earthwork required to remove the detour, including any additional excavation required and excluding the portion that need to remain for the final.
  a. Yellow and Green Shape

This process will require some special workflows to calculate and report the earthwork volumes correctly.



This is the general workflow for computing earthwork that includes detour removal. Note that the workflow described below will create multiple new files. It is possible to combine the steps into a single file as the user becomes more comfortable with the models that are being created. For simplicity and clarity, the steps in this example have separated.

1. Create Terrains for the Detour Model and the Proposed Final Model

2. Create a complex terrain by merging the Proposed Final Model with the Existing Terrain.

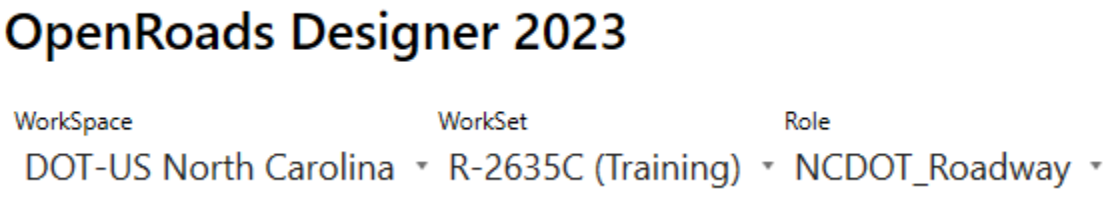
3. Create a complex terrain by merging the Detour Model with the Existing Terrain.

4. Create a Closed Mesh using the Detour Model as the Top Surface and the complex terrain created from the Proposed Final Model and the Existing Terrain as the Bottom Surface (step 2). This will create a volume that represents the yellow and green area in the Detour Removal Schematic. This Closed Mesh can be used by the program to calculate the detour removal volume.

5. Run the earthwork volume calculation using the same steps as the basic calculation using the Proposed Final Model as the proposed grade and the complex terrain created with the Detour Model and the Existing Ground as the existing grade (step 3). With the Custom option selected in the earthwork calculation the Closed Mesh Volumes will be included and the final earthwork including the detour removal will be calculated and reported.

Start by selecting the OpenRoads Designer 2023 Desktop Icon

The WorkSpace is DOT_US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



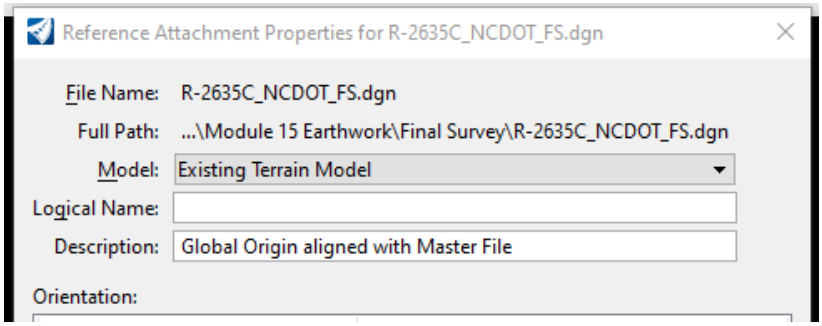
1. Create a Proposed Terrain – Final Roadway and Detour Model

A. The first step is to create proposed terrains for the final roadway model and the detour model. Depending on the complexity of the project and the number of components required for the proposed and detour model, the steps required for this process may vary from the steps shown below. There are also alternate methods that may be more appropriate based on the specific project. The only requirement is a proposed terrain model for the detour and the final roadway.

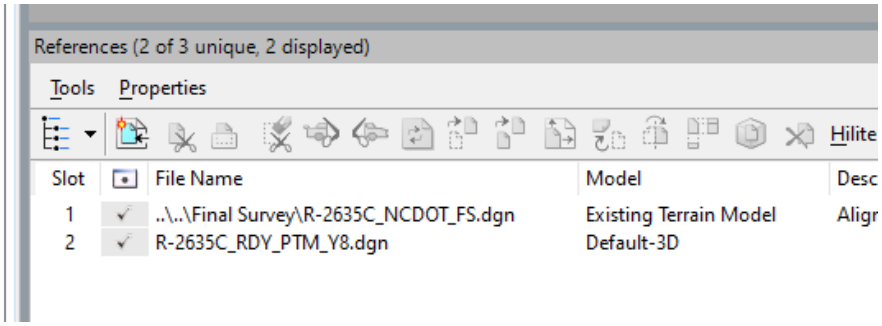
B. Create a terrain from the Y8 Corridor.

- For this example, we will use a graphical filter to create the proposed surface. The Graphical Filter tool uses a filter to select certain 3D elements from the model(s), generally by feature definition. These elements are grouped into various categories such as; boundaries, break lines, voids etc. These elements are then combined into a terrain model. The biggest benefit of using this method is that it can combine multiple corridors, linear templates and detailed areas into a single terrain in one step.

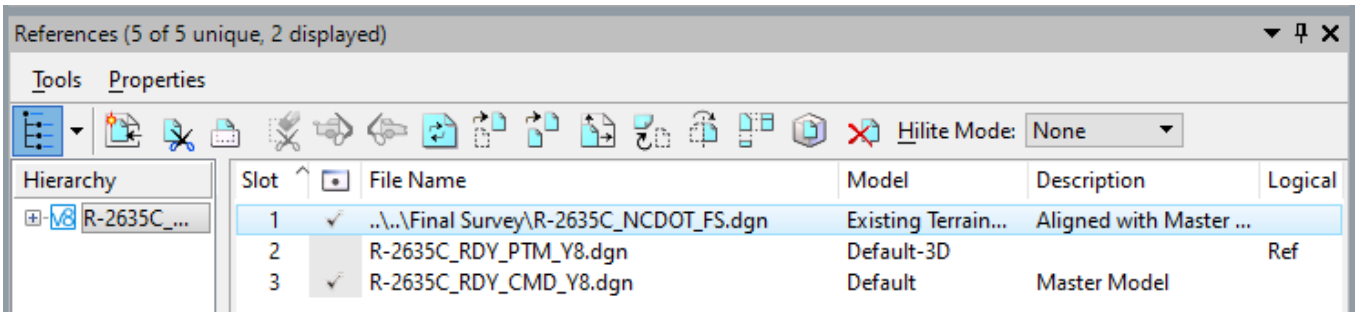
C. Create New DGN File for the proposed final roadway terrain. For this example, we. Create this file in the Roadway\Design folder.
   - Filename
     1. R-2635C_RDY_PTM_Y8.dgn
        a. It is possible to create the proposed terrain in the CMD file, but the recommended workflow is to use separate files. If they are in the same file, the proposed terrain will reprocess every time the corridor is updated.
   - Folder Location
     1. …\R-2635C\Roadway\Design
   - Seed File
     1. Seed2D – English Design.dgn
   - Attach the R-2635C_NCDOT_FS.dgn file selecting the existing terrain model and set the terrain active to generate the Default 3D model.



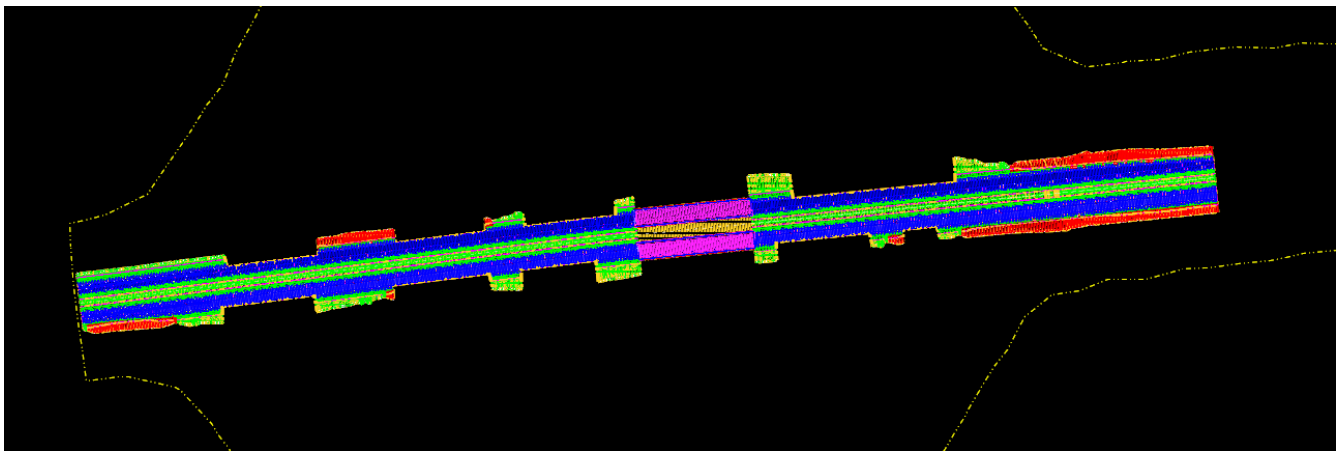
   - Open a view window for and the Default 3D model



D. Attach Proposed Y8 Corridor.
   - When attaching corridor files attach the Default model to the Default model in the current DGN file. This will automatically attach the Default 3D model to the Default 3D model in the current DGN file.
   - Filename
     1. R-2635C_RDY_CMD_Y8.dgn

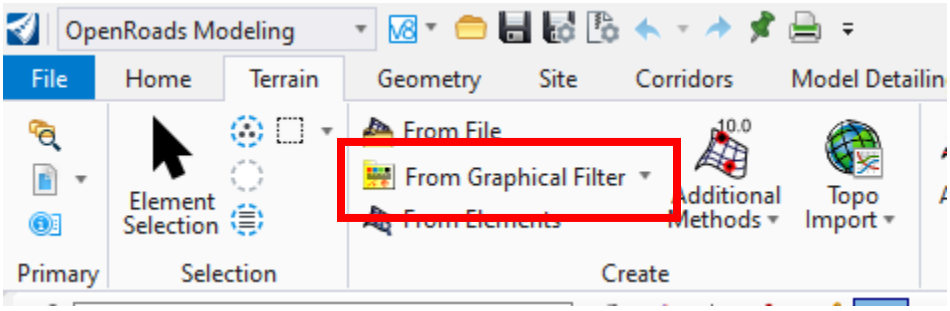


   - For this example, Y8 is a single corridor but if there were areas of detailed modeling that included surface templates, linear templates or separate corridors those should be attached. All the models required for the final proposed condition should be used.

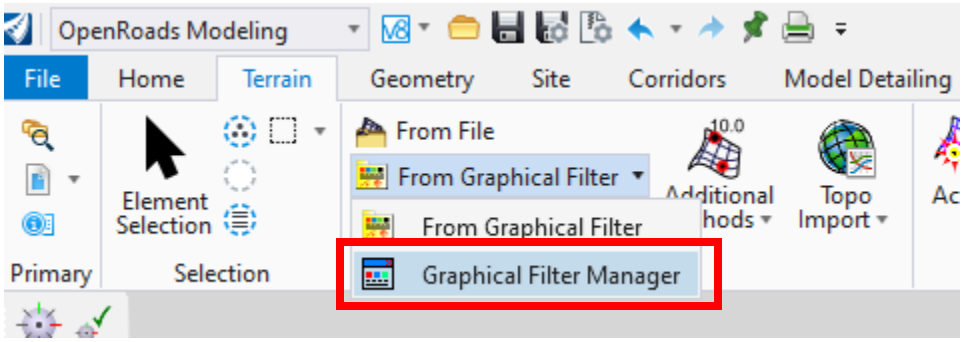


E. Create a Graphical Filter

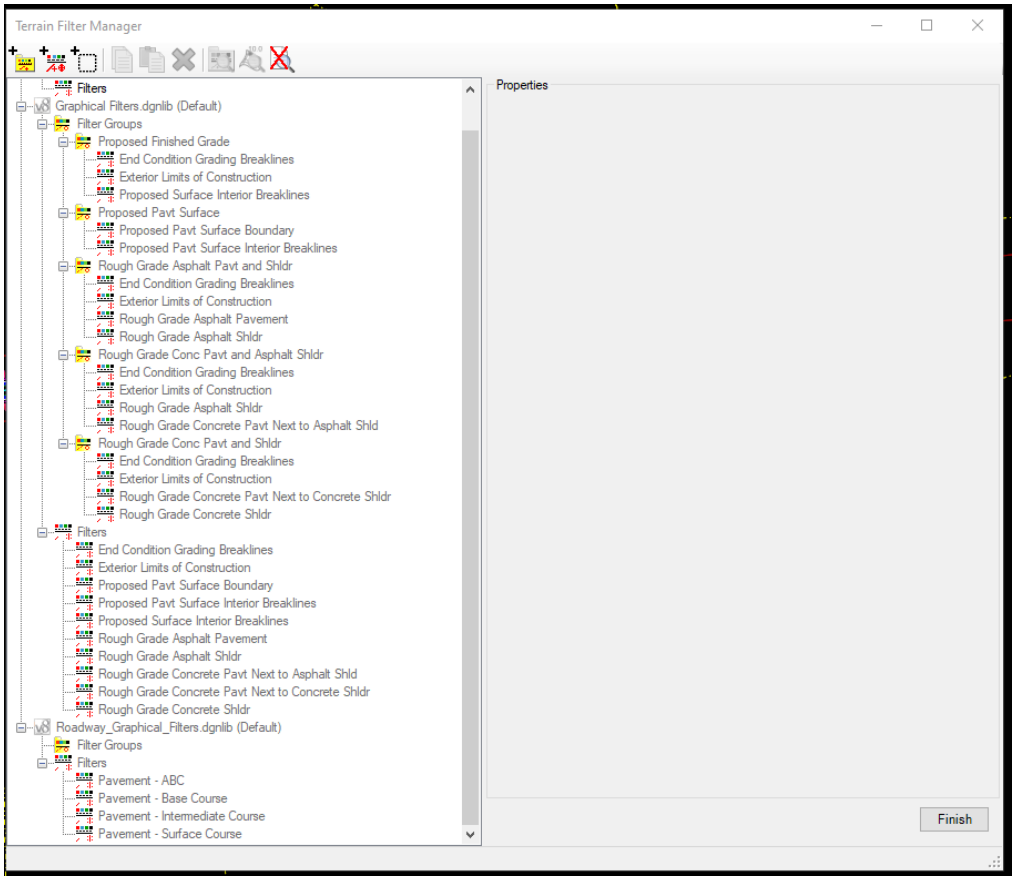
- Graphical Filters for specific projects and templates may or may not be available in the NCDOT Workspaces.
- Creating a Graphical Filter is not difficult and can be accomplished on a project-by-project basis if required. This will also allow for the inclusion of custom feature definitions.
- The Graphical Filter Tool is located in the Terrain Tab in the Create tool Group.



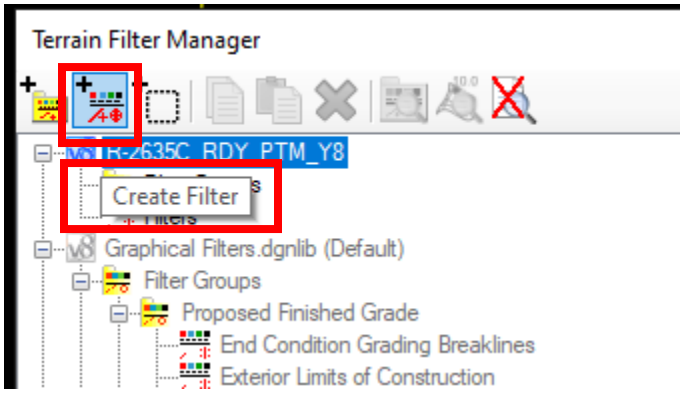
- Select the Graphical Filter Manager from the drop down



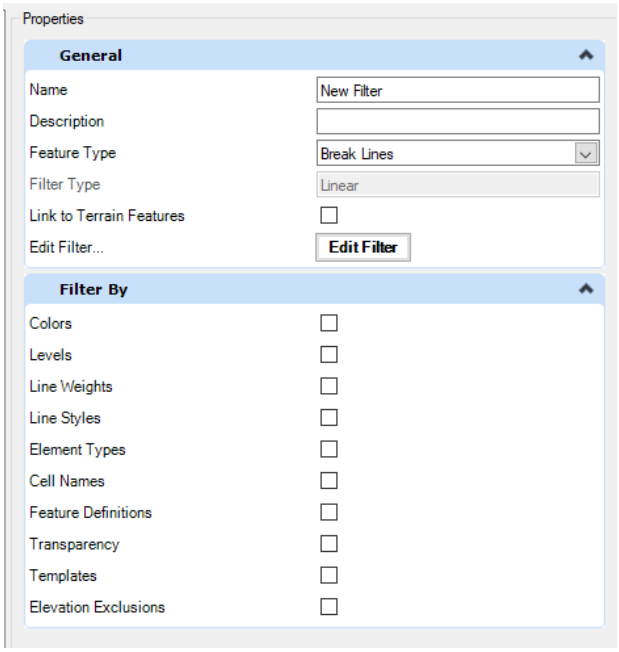
- The dialog includes a list of available Filters and Filter Groups and tools that allow for the creation of new Filters and Filter Groups.



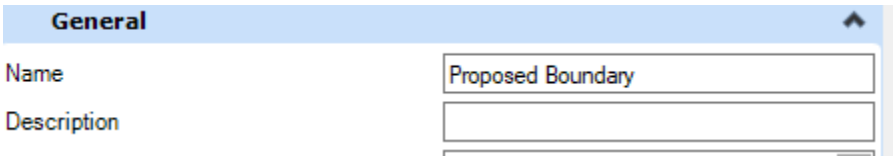
- For this exercise we will create a new Graphical Filter Group that will be used to create the Proposed Terrain
- The first step is to create new Filters. These are used to group elements into specific categories based on how they will be used to create the Terrain model.
- Select the Create Filter tool from the Terrain Filter Manager Dialog.



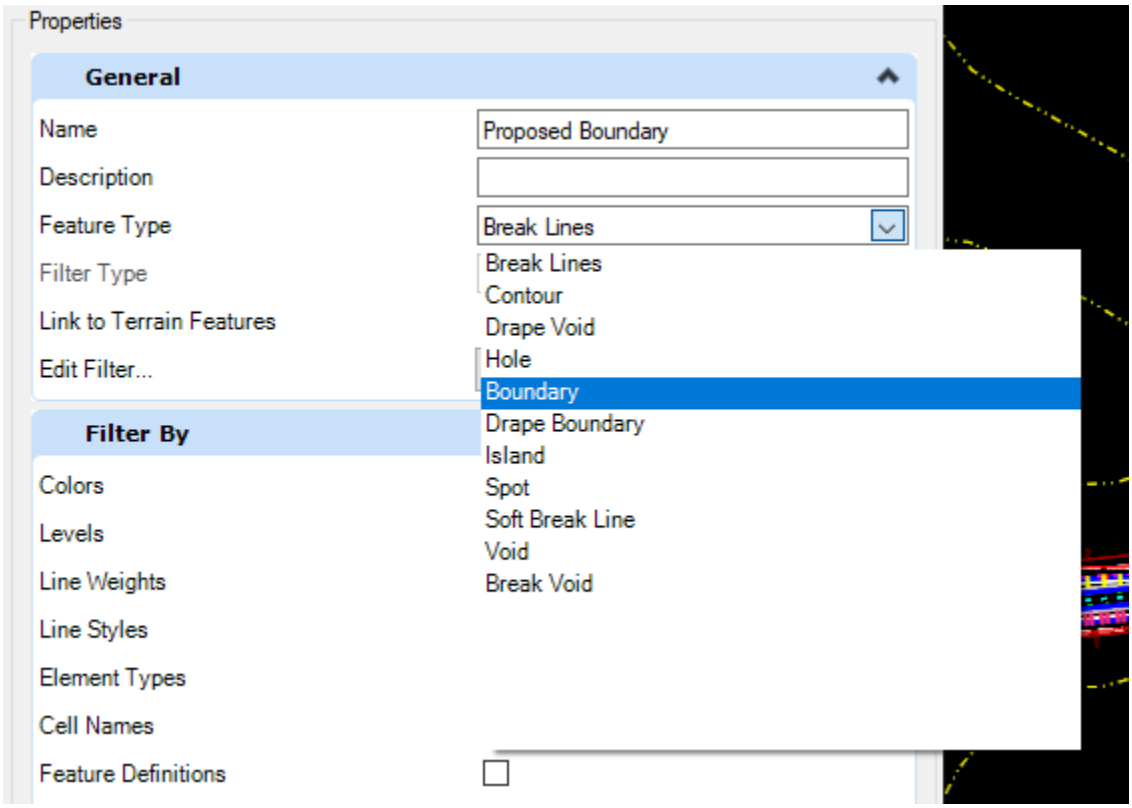
- This will activate the Properties section of the dialog in the right side of the Manager window.



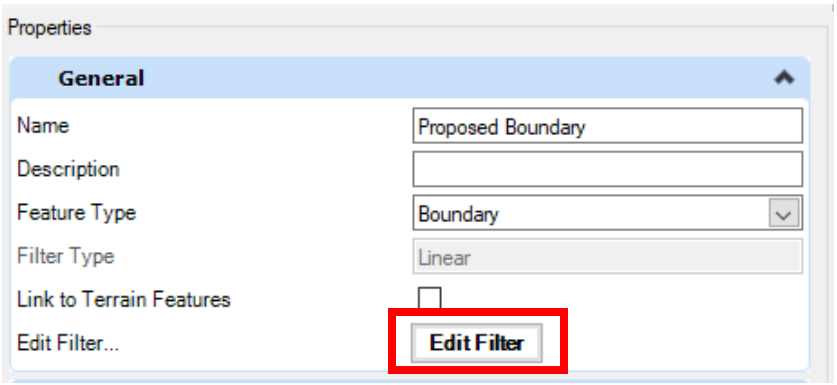
- Set the Name to Proposed Boundary.
- A description can be added but is generally not necessary for simple filters



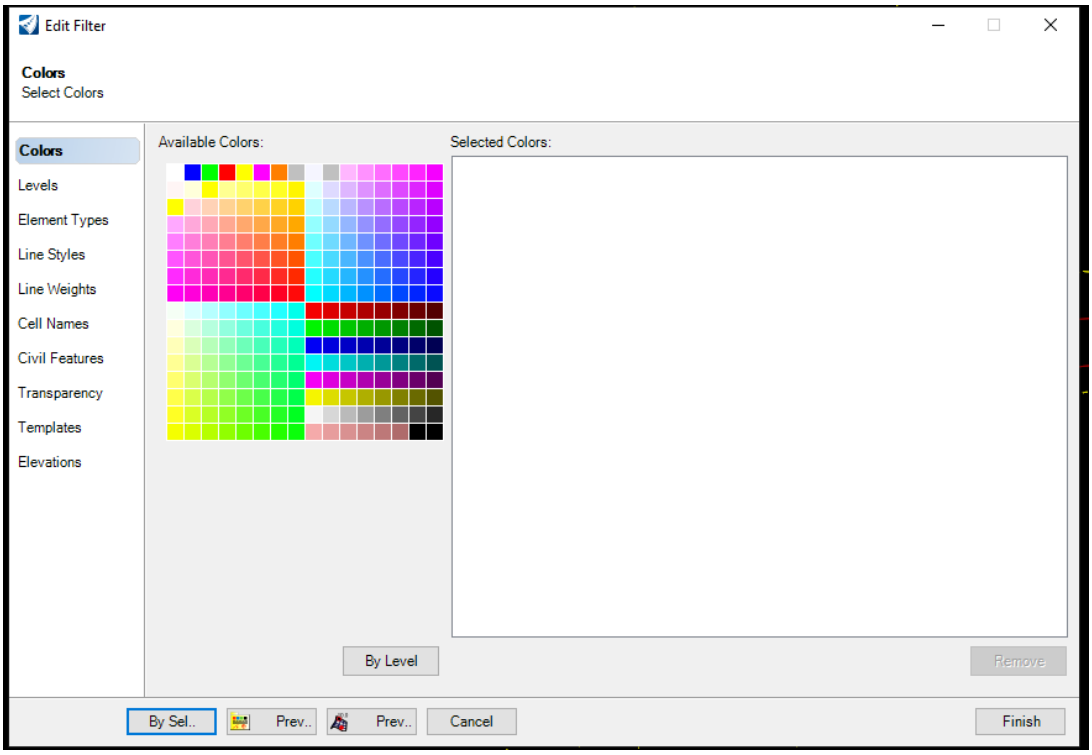
- Set the Feature Type to Boundary. There will be a long list of available features in the drop down. For roadway models we will generally be interested in Boundaries and Break Lines.



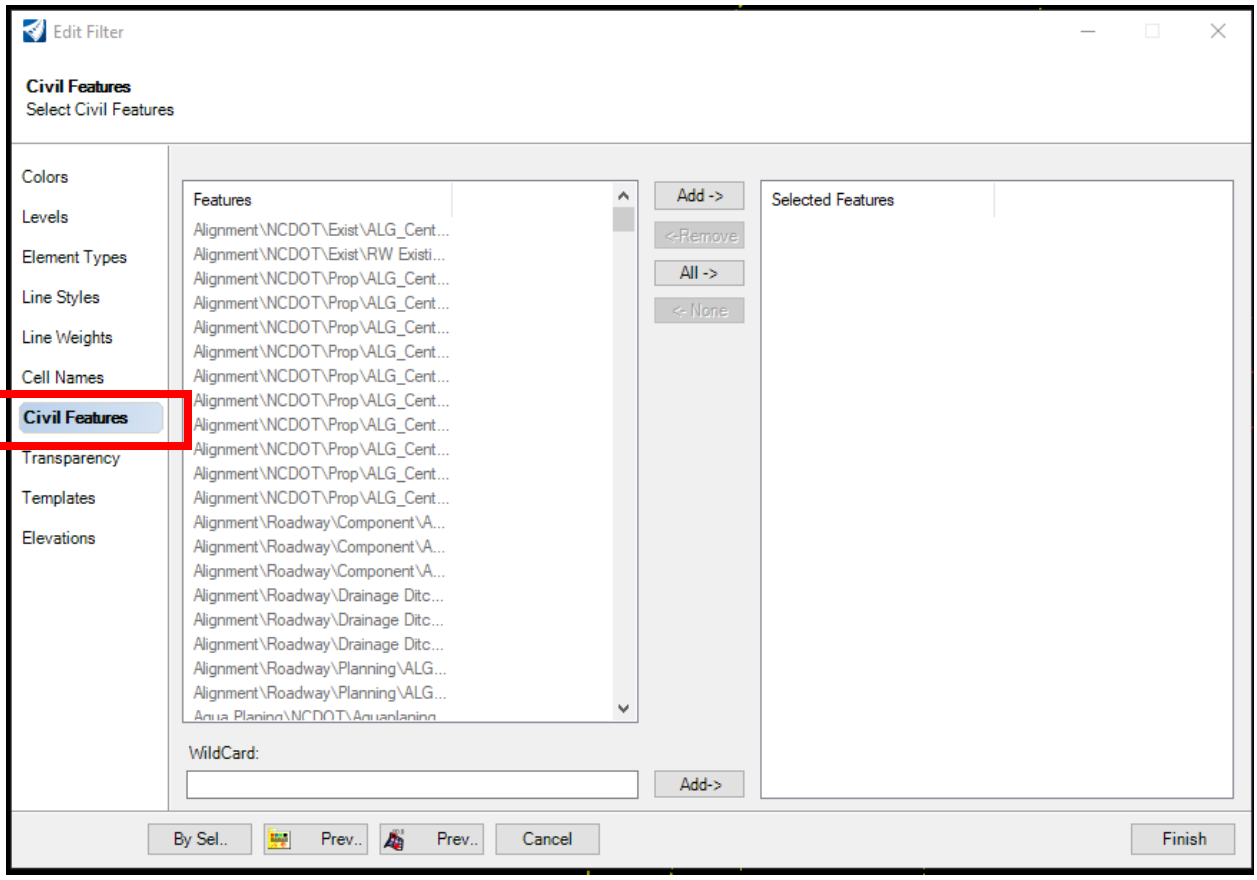
- The General Section for the dialog should match the screen shot below. Now select the Edit Filter button.



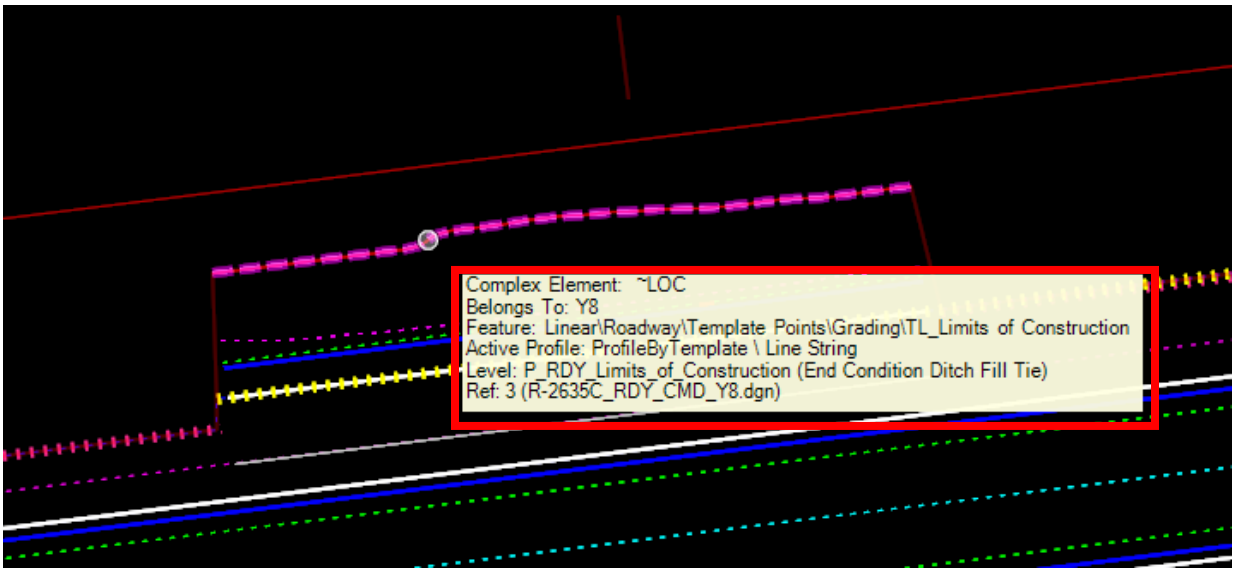
- The Edit Filter command will activate a new dialog that will display all the ways that elements can be selected in the DGN file.



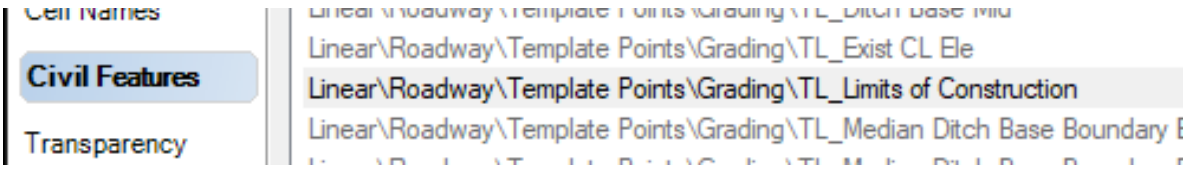
- As a general rule the easiest and most consistent method to creating the filter for roadway models it to use the Civil Features Section. These are the Feature Definition assigned to the points at the Template Level. These feature definitions should be consistent when using the default template library or custom project specific templates. By clicking on the Civil Features Section a list will populate listing all the available features within the workspace. Note that the user will need to be in the correct "Role" to see all the available features, for this exercise it is Roadway but it could be the Roadway-Hydraulic Combination role.



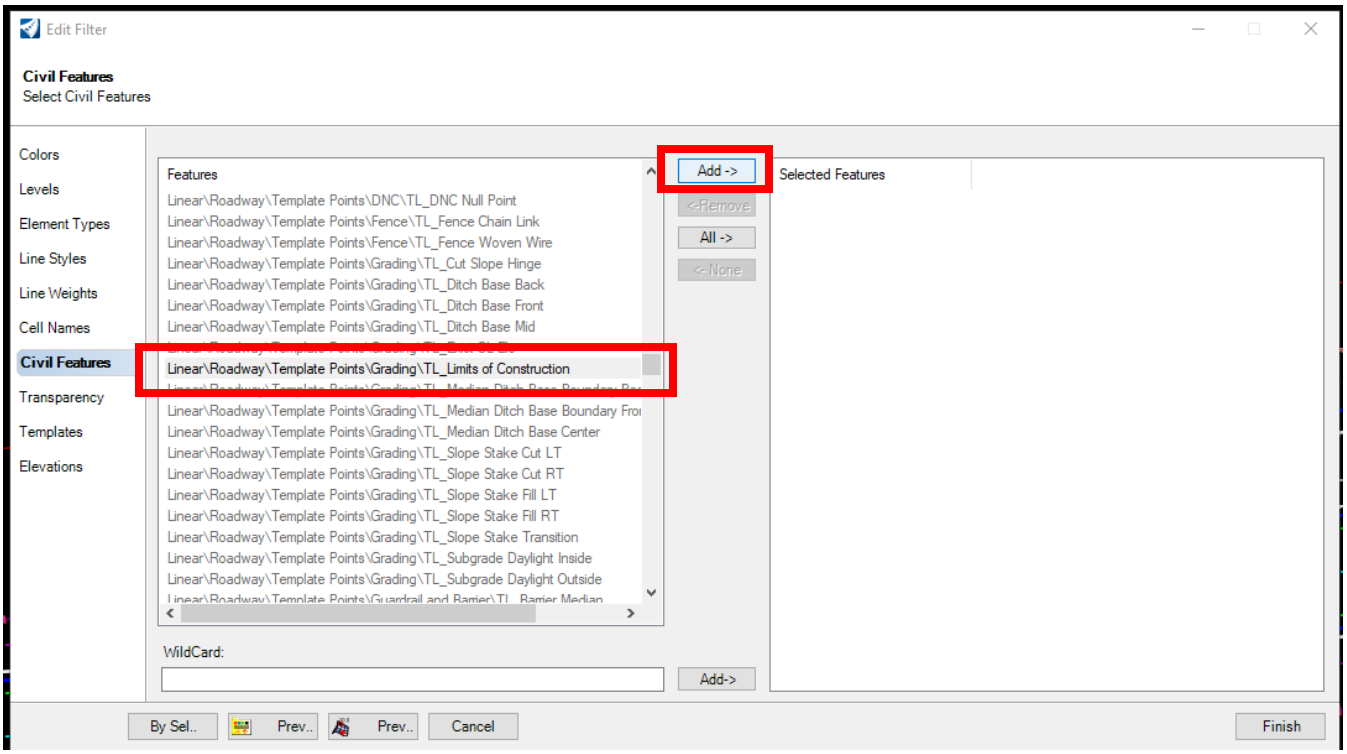
- For this Filter group we want to select the boundary elements. By selecting the boundary of the Roadway Model we can determine the Feature Definition of the boundary element.
  1. TL_Limits of Construction.
- This also shows us the Path where the feature definition is located.
  1. Linear\Roadway\Template Points\Grading\TL_Limits of Construction



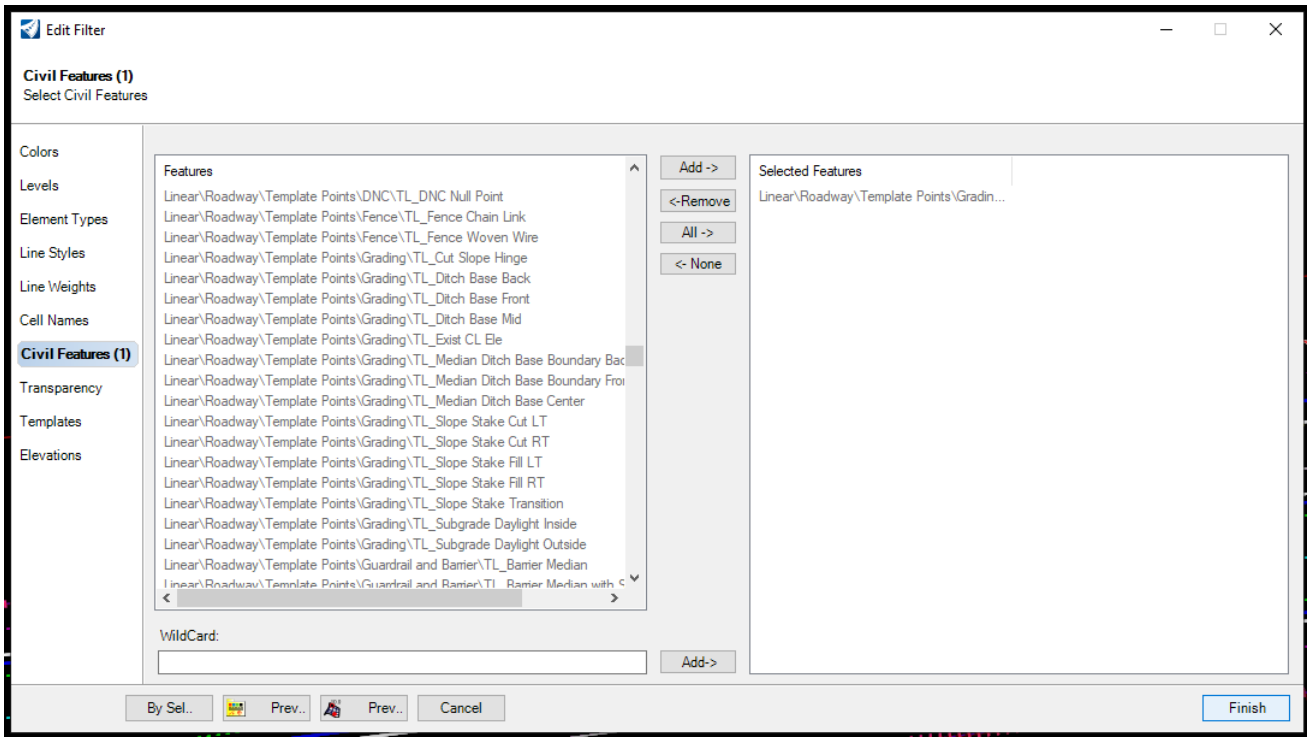
- In the Filter dialog find the matching Feature definition.



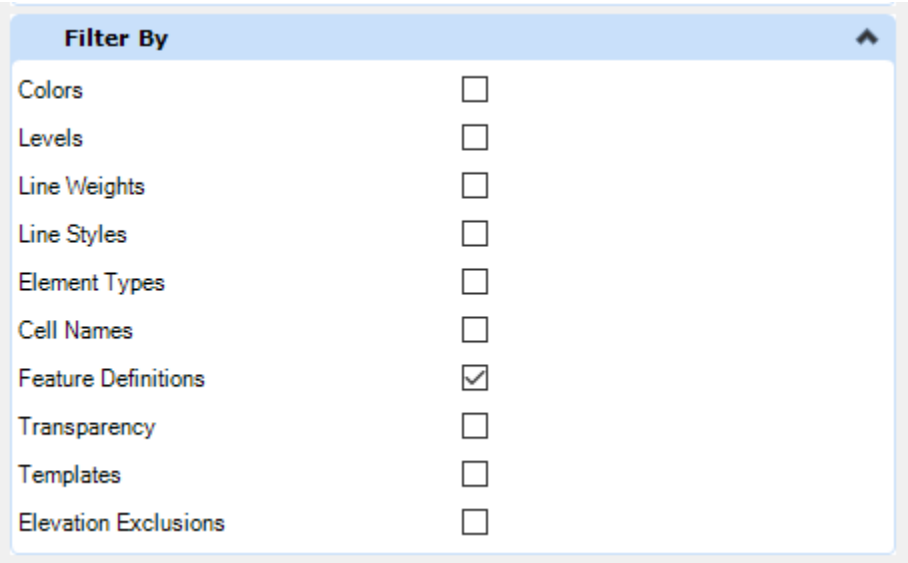
- Select the ADD button in the top middle of the dialog.



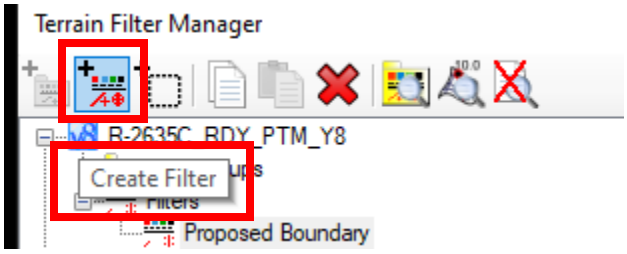
- This will add the feature to the right side of the dialog in the Selected Features pane. Then select FINISH in the bottom right corner of the dialog.



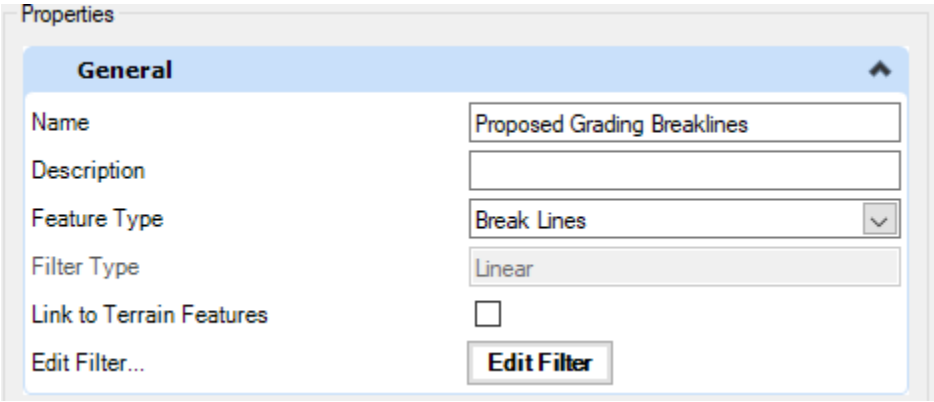
- This will reactive the Terrain Filter Manager. Note that the Feature Definition selection is checked in the Filter By Section indicating that the Filter has been set correctly.



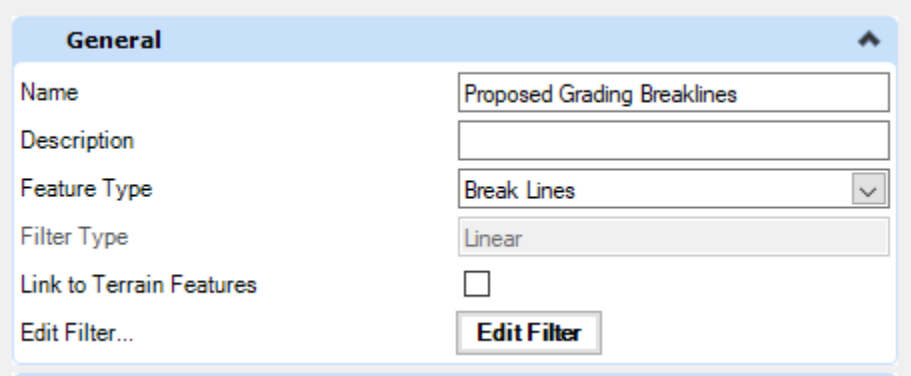
- The next step is to create a Filter for the required Break Lines. Select the New Filter button.



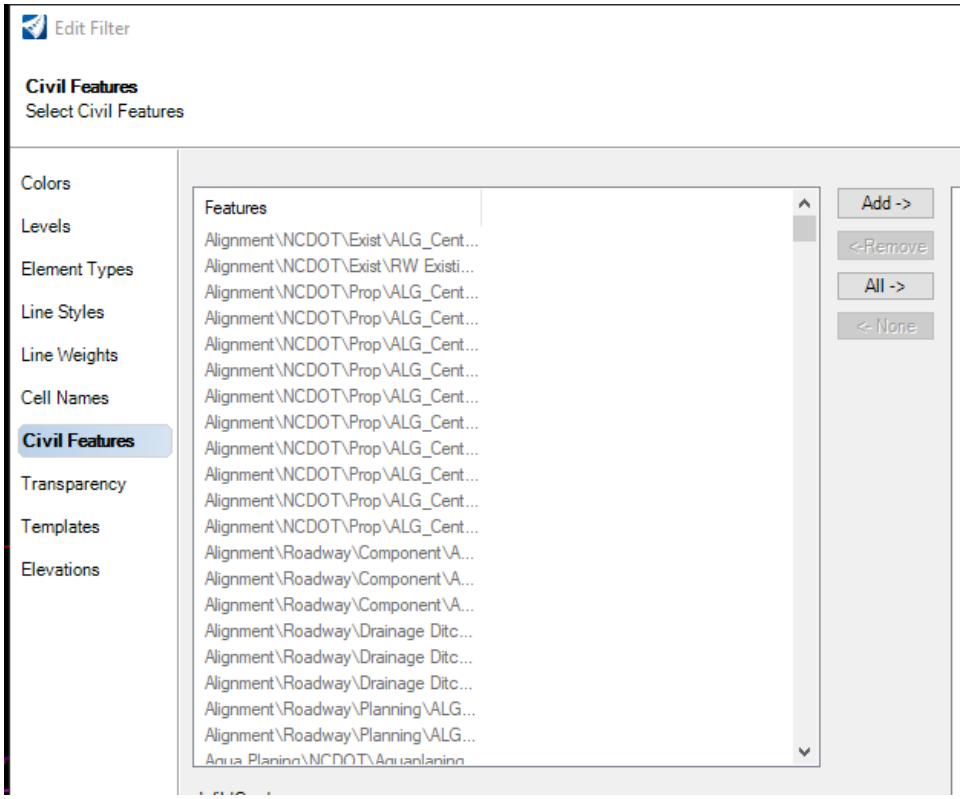
- Set the Filter name to Proposed Grading Break Lines and the Feature Type to Break Lines.



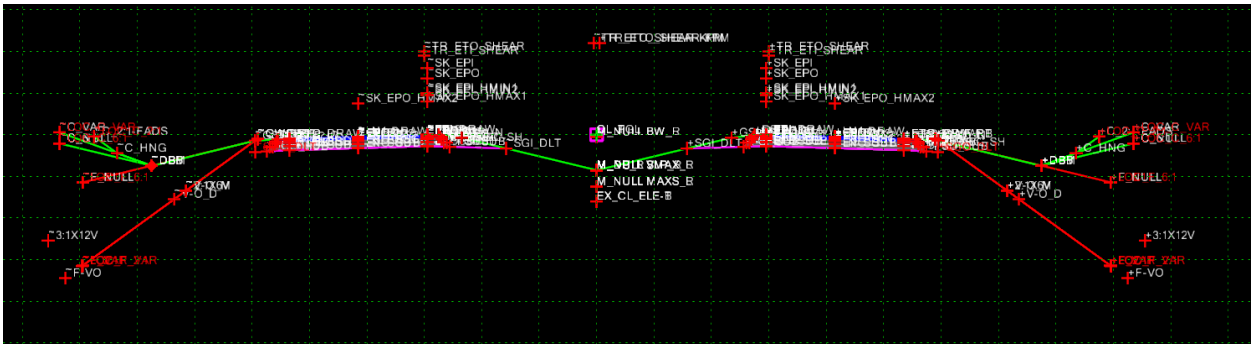
- Select Edit Filter



- Similar to selecting the boundary elements we will select the feature definitions that make up the break lines from the model using the Civil Feature section.



- Another way to determine the required feature definitions for the filter is to review the standard roadway templates. Since the standard templates generally use the same features it is not difficult to select them from the available list.

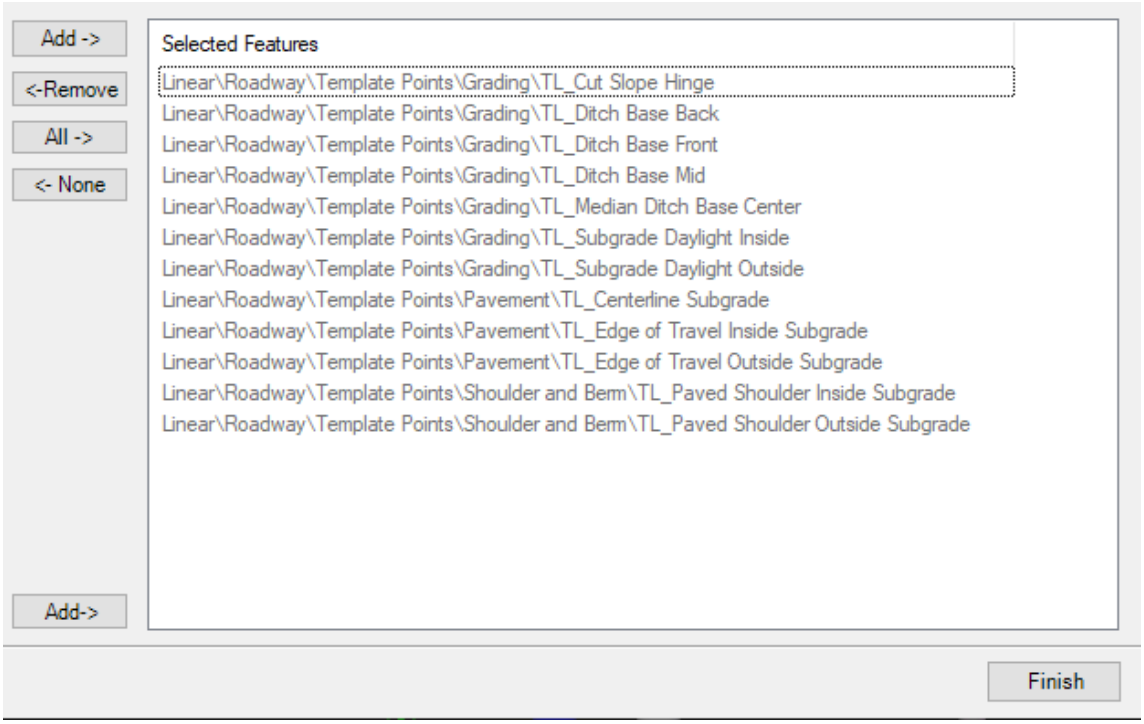


- For the grading surface we want to use any ditch points and the subgrade line. Those feature definitions are all located in the Root Folder
  1. Linear\Roadway\Template Points\:
     a. From the Grading Sub Folder
        i. TL_Cut Slope Hinge
        ii. TL_Ditch Base Back
        iii. TL_Ditch Base Front
        iv. TL_Ditch Base Mid
        v. TL_Median Ditch Base Center
        vi. TL_Subgrade Daylight Inside
        vii. TL_Subgrade Daylight Outside
     b. From the Pavement Sub Folder
        i. TL_Centerline Subgrade
        ii. TL_Edge of Travel Inside Subgrade
        iii. TL_Edge of Travel Outside Subgrade
        iv. TL_Exist EOP
            1. Required for wedging templates with no end conditions
     c. From the Shoulder and Berm Sub Folder
        i. TL_Grass Berm Normal
            1. Required for Curb and Guter Sections
        ii. TL_Grass Berm Widen
            1. Required for Curb and Gutter Sections
        iii. TL_Grass Shoulder Normal Inside
            1. Required for Trench Sections – Omit for Graded Sections
        iv. TL_ Grass Shoulder Normal Outside
            1. Required for Trench Sections – Omit for Graded Sections
        v. TL_Grass Shoulder Widen Inside
            1. Required for Trench Sections – Omit for Graded Sections
        vi. TL_Grass Shoulder Widen Outside
            1. Required for Trench Sections – Omit for Graded Sections
        vii. TL_Paved Shoulder Inside Subgrade
        viii. TL_Paved Shoulder Outside Subgrade

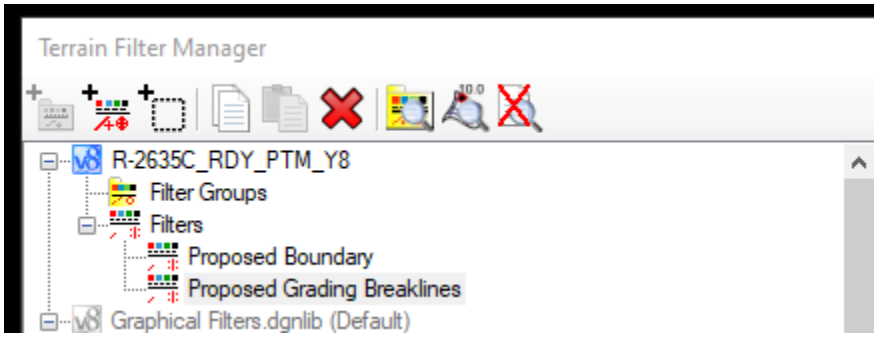
- For this example we are using a Shoulder Section template with a median ditch and a graded section subgrade. Select the following Feature definitions and Add to the Filter list. Then Select Finish.

  Note that by holding down the CTL key multiple Feature Definitions can be selected at one time.

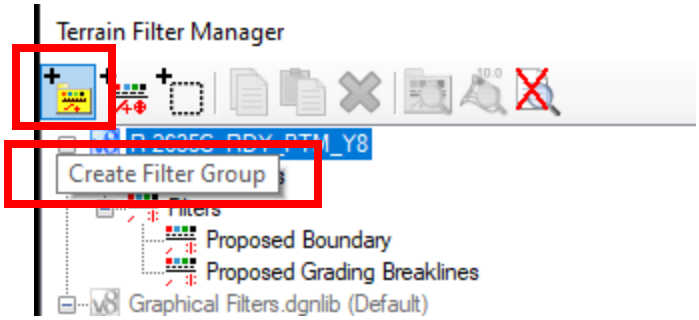
  1. TL_Cut Slope Hinge
  2. TL_Ditch Base Back
  3. TL_Ditch Base Front
  4. TL_Ditch Base Mid
  5. TL_Median Ditch Base Center
  6. TL_Subgrade Daylight Inside
  7. TL_Subgrade Daylight Outside
  8. TL_Centerline Subgrade
  9. TL_Edge of Travel Inside Subgrade
  10. TL_Edge of Travel Outside Subgrade
  11. TL_Paved Shoulder Inside Subgrade
  12. TL_Paved Shoulder Outside Subgrade



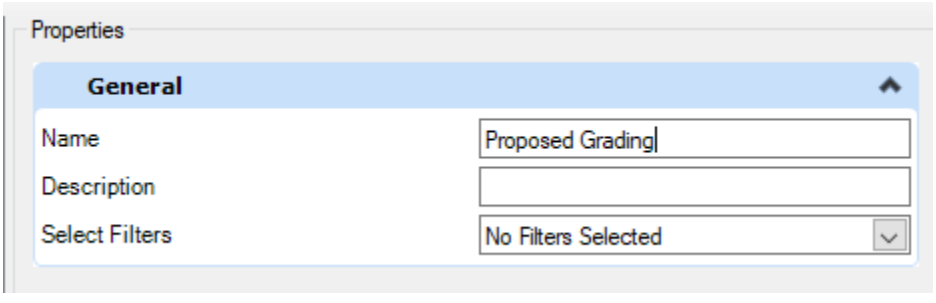
- There will now be 2 filters listed in the Filter Manager Dialog.



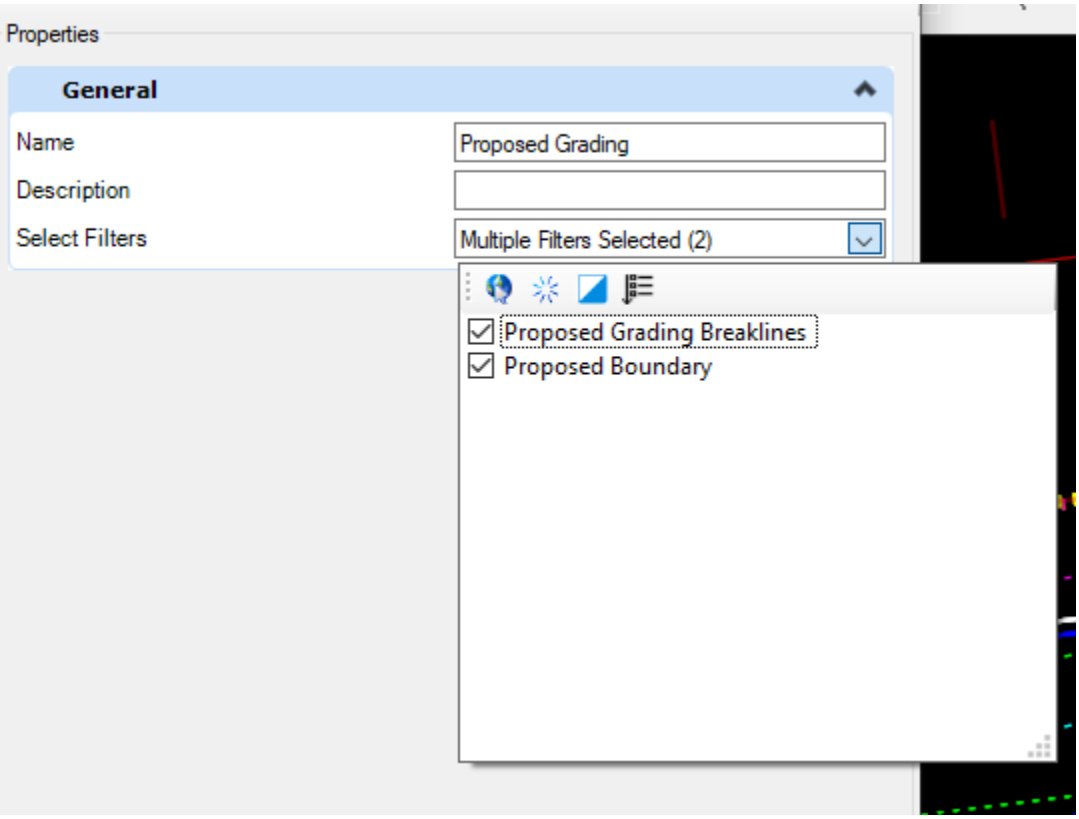
- The next step is to create a Filter Group. This will group multiple filters together into a selection that can be used by the graphical filter dialog to create a terrain model. Highlight the File Name section and select the Create New Filter Group button.



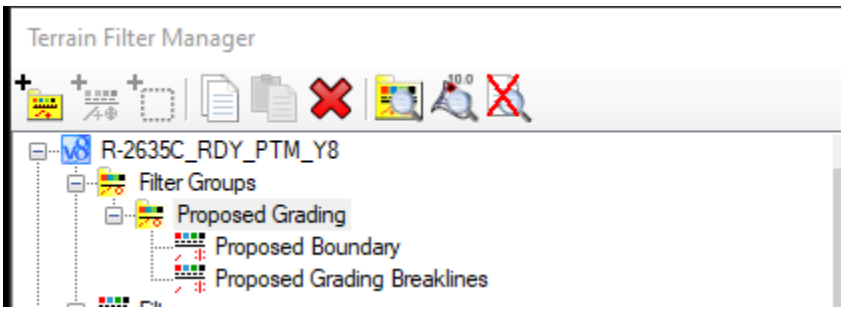
- Set the Filter Naem to Proposed Grading



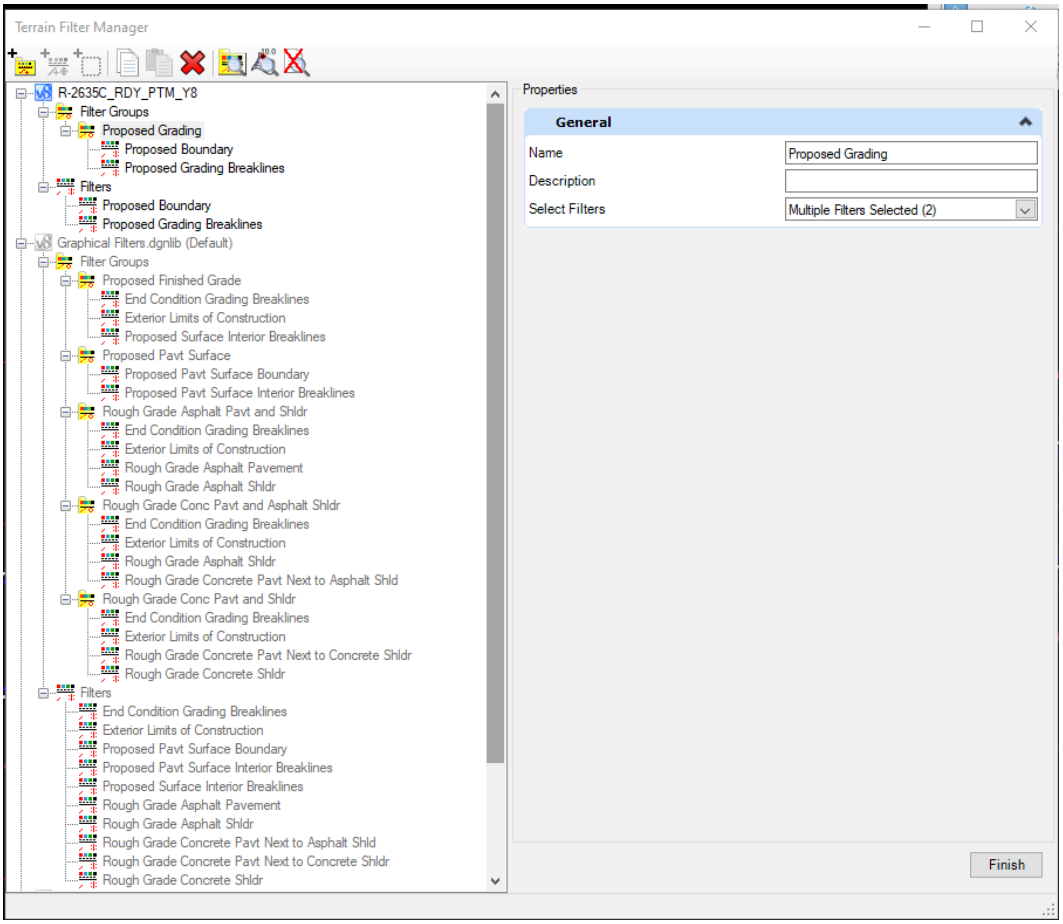
- Under the Select Filters drop down select the previously created Filters
  1. Proposed Grading Break Lines
  2. Proposed Boundary



- The dialog should now show the two Filters listed under the Filter Group

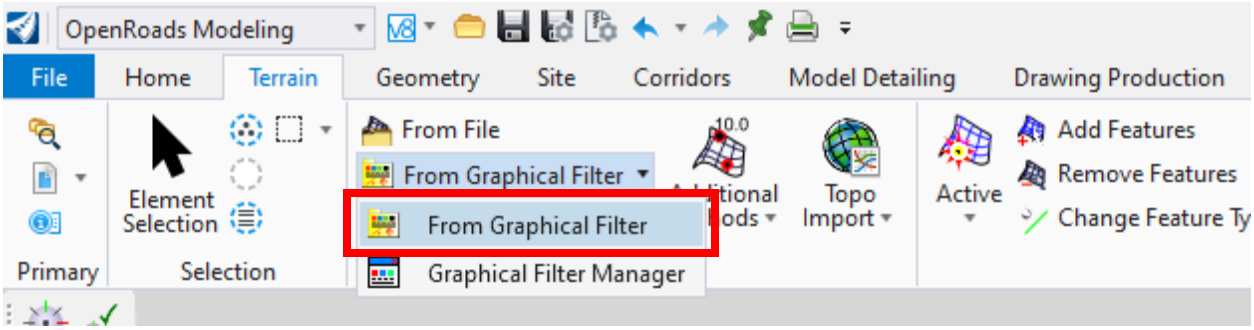


- Select Finish

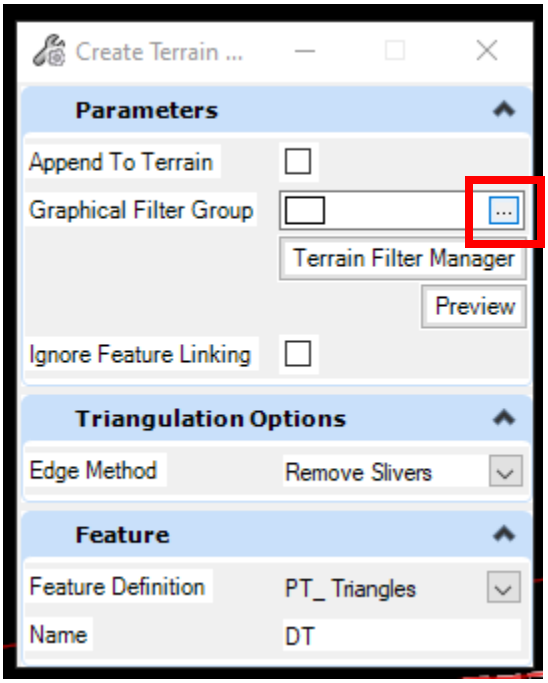


F. Create the Proposed Terrain for Y8

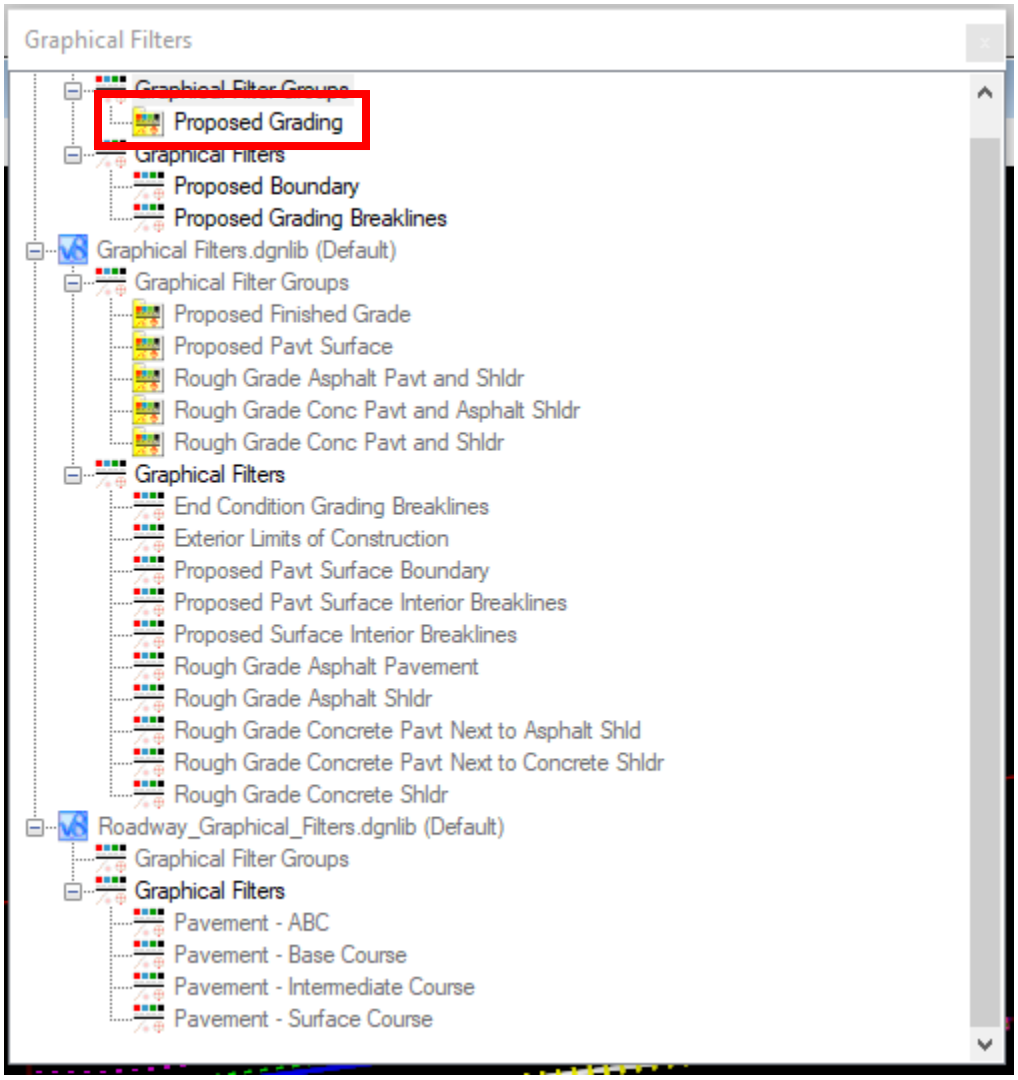
- Go back to the Terrain Tab and select the From Graphical Filter tool.



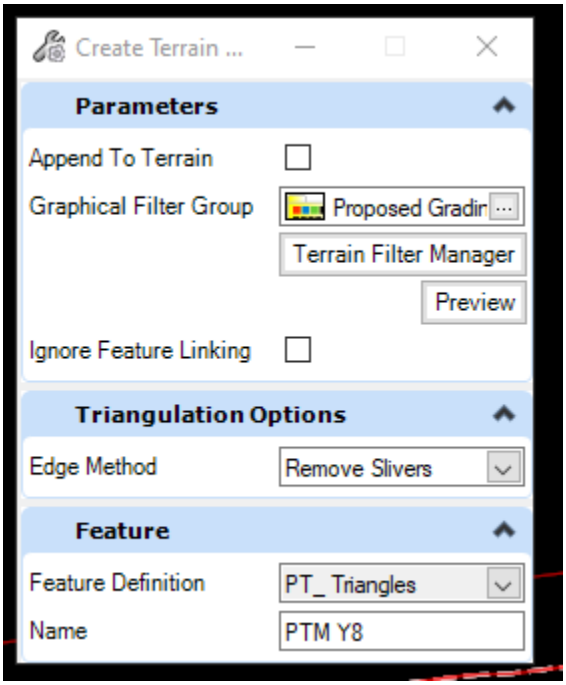
- Click the select icon in the Graphical Filter Group line



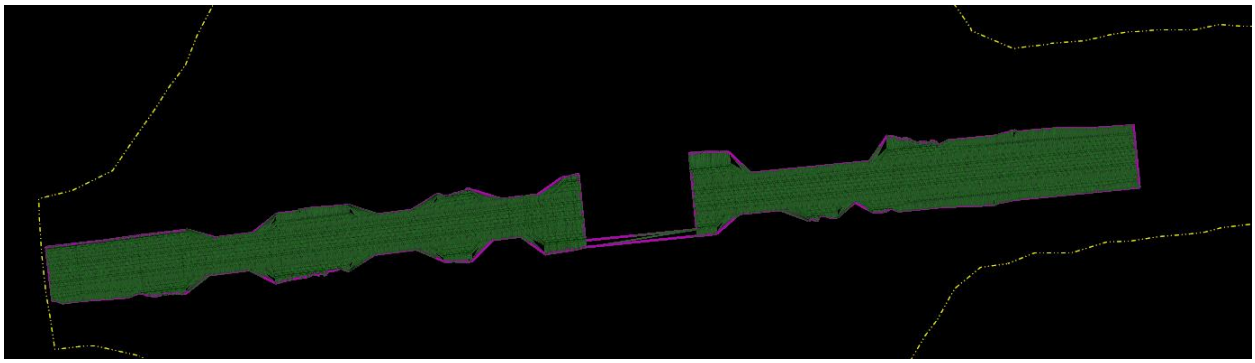
- Select the Proposed Grading Graphical Filter Group



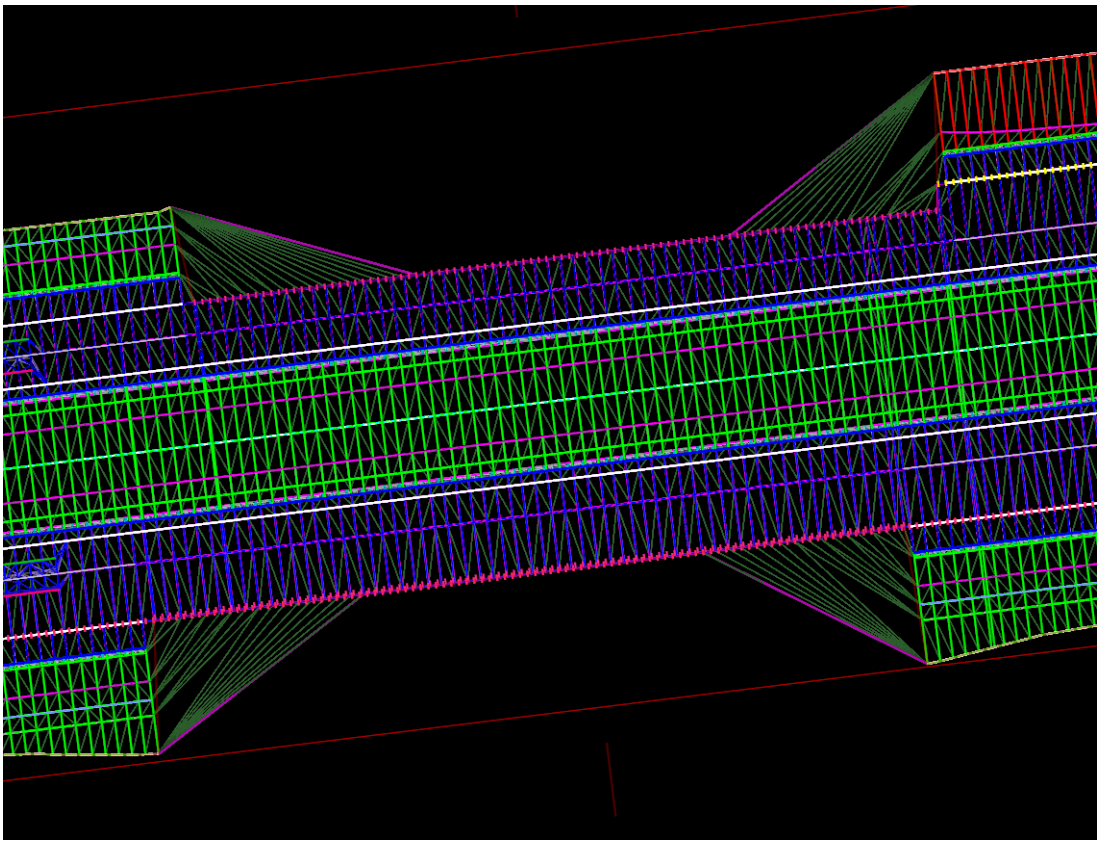
- Set the remaining dialog as follows
  1. Append to Terrain = Unchecked
  2. Edge Method = Remove Slivers
  3. Feature Definition = PT_Traingles
  4. Name = PTM Y8



- Left Click to accept the selections and Create the Proposed Grading Terrain. The Default 3D view should show the proposed triangles and boundary.

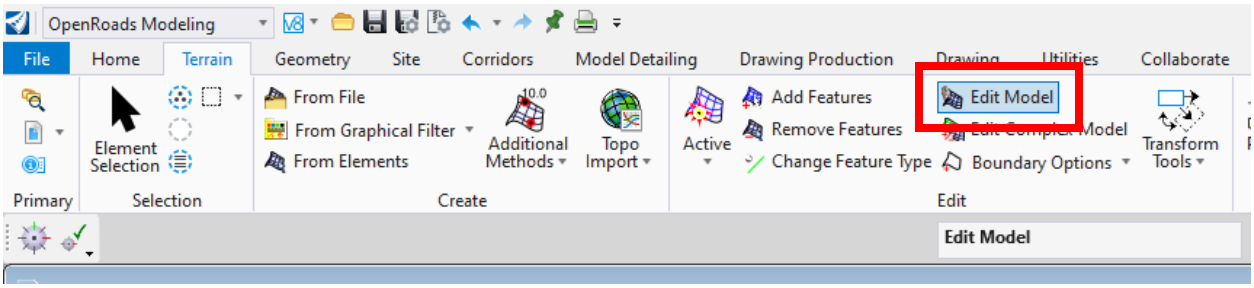


- We can also see the terrain by turning on the Default 3D reference in the Default model.

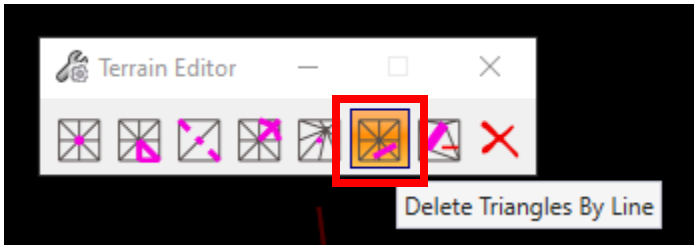


G. Edit the Proposed Terrain

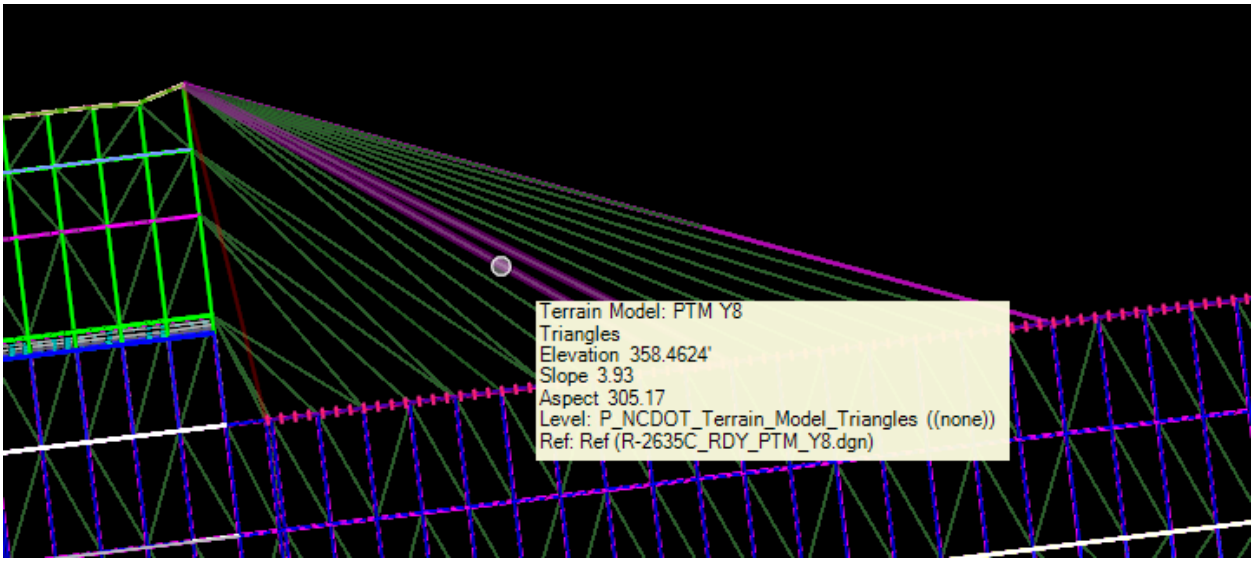
- Notice there are some areas where the terrain has calculated incorrectly, these are areas where the boundary element was not located due to end condition exceptions in the model. These areas are relatively easy to correct. Select the Edit model Tool from the Terrain Tab.



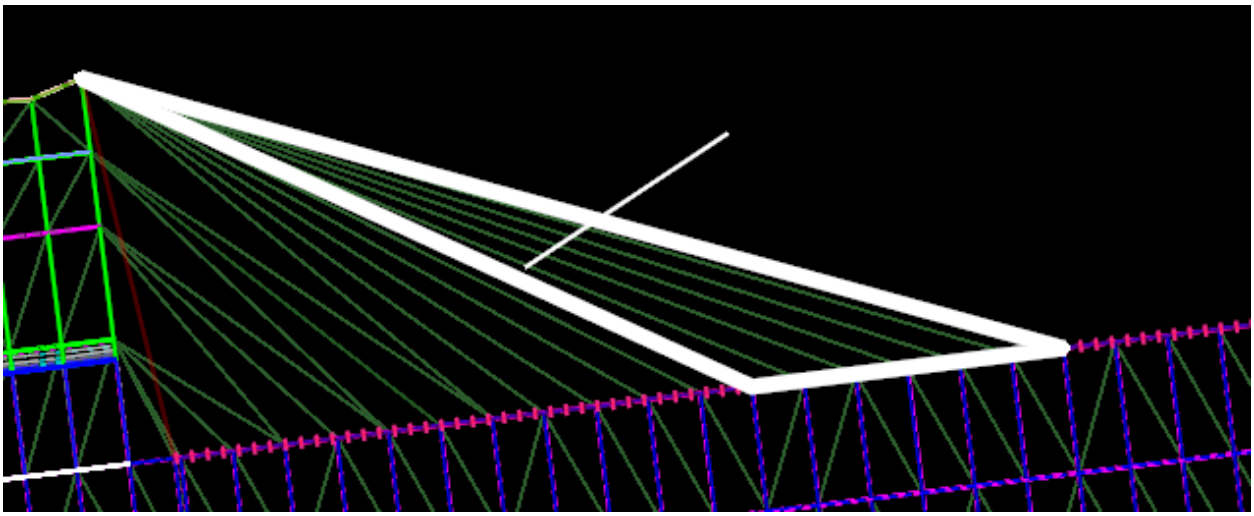
- Select the Delete Triangles by Line tool.



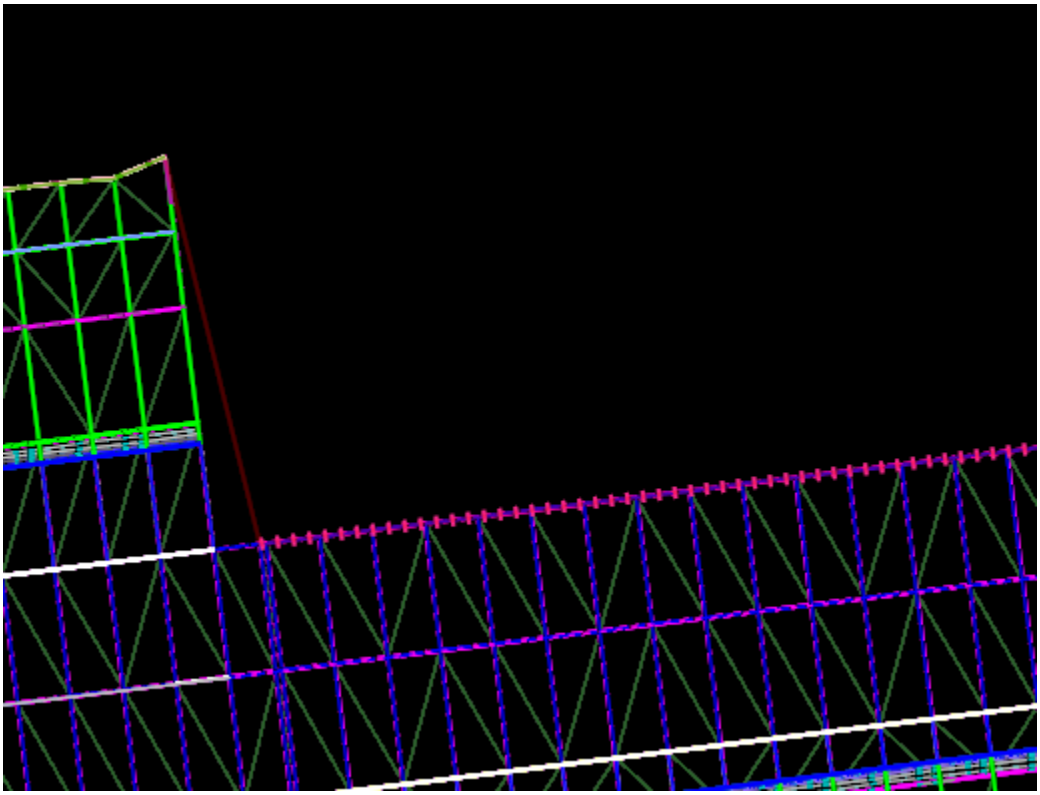
- Left click on the Proposed Terrain, this can be done in the 2D Default Model.



- Left Click on hold down the mouse button to draw a line across the triangles that should be deleted.



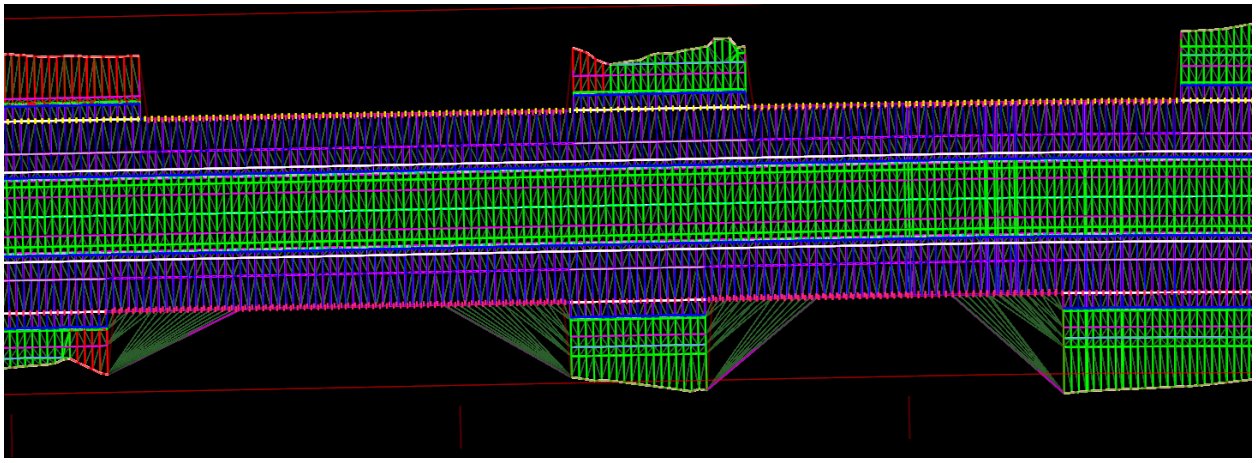
- This will eliminate any triangles that are incorrect.



- Repeat this process until the Terrain has been revised and matches the grading surface of the model.

  Note that this Terrain is going to be used to create a 3D Volume in later steps that represents the detour removal. This terrain is not going to be used for the actual Cut and Fill Earthwork Volumes. This terrain does not need to perfectly match the proposed roadway model everywhere, it only has to match in areas where the proposed roadway model overlaps the proposed detour model. For this example the detour is on the left side of Y8. So, we only need to correct the triangulation in the areas on the left side.

  In this image we can see we have corrected the triangles on the left side of Y8 (top of the image) and disregarded the triangles on the right side of Y8.



2. Create a Proposed Terrain – Detour

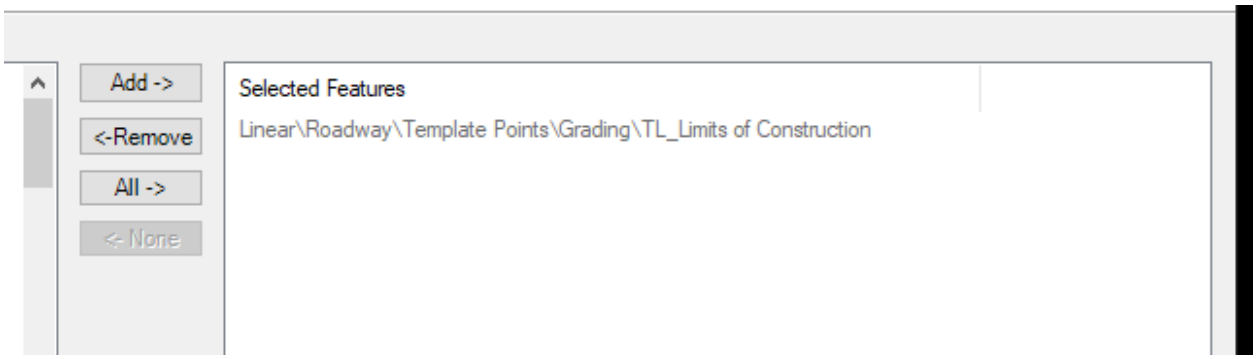
A. This is the exact same process but will use the Detour Model instead of the Proposed Roadway Model.

B. Create a new DGN file for the Detour Terrain

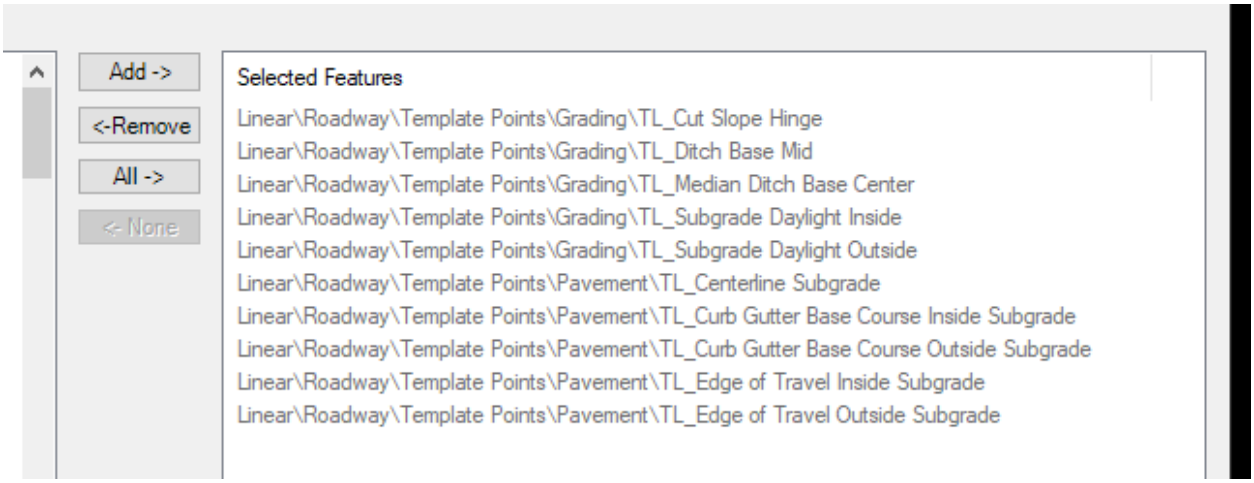
- R-2635C_RDY_PTM_Y8DET.dgn
- Folder Location is Roadway\Design
- Use the 2D Seed File
- Attach the R-2635C_NCDOT_FS.dgn file selecting the existing terrain model and set active
- Attach R-2635C_RDY_CMD_Y8DET.dgn
    1. When attaching corridor files attach the Default model to the Default model in the current DGN file. This will automatically attach the Default 3D model to the Default 3D model in the current DGN file.

C. Create a Graphical Filter

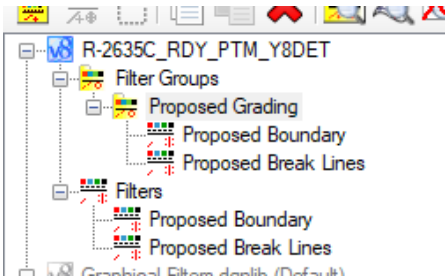
- Using the Graphical Filter Manager
    a. Create a Filter for the Proposed Boundary from the Feature Definition
        i. TL_Limits of Construction



b. Create a Filter for the proposed Break Lines from the Feature Definitions
   i. TL_Cut Slope Hinge
   ii. TL_Ditch Base Back
   iii. TL_Ditch Base Front
   iv. TL_Ditch Base Mid
   v. TL_Median Ditch Base Center
   vi. TL_Subgrade Daylight Inside
   vii. TL_Subgrade Daylight Outside
   viii. TL_Centerline Subgrade
   ix. TL_Edge of Travel Inside Subgrade
   x. TL_Edge of Travel Outside Subgrade
   xi. TL_Paved Shoulder Inside Subgrade
   xii. TL_Paved Shoulder Outside Subgrade

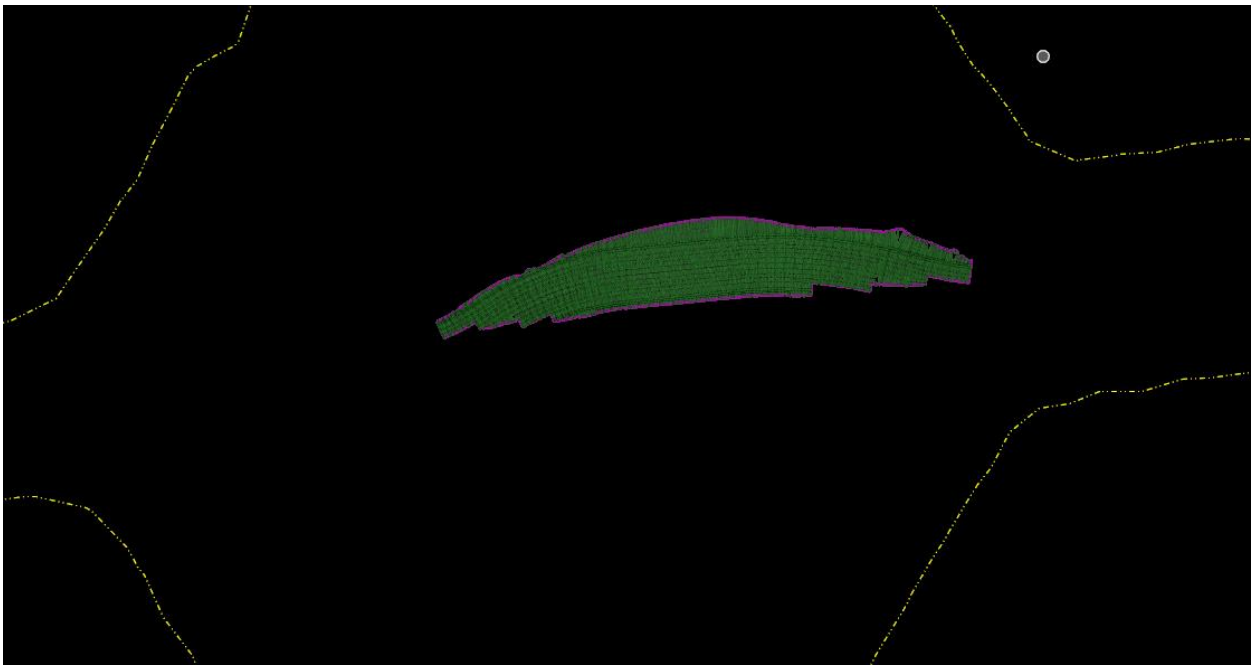


c. Create a Filter Group named proposed Grading from the Filters
   i. Proposed Boundary
   ii. Proposed Break Lines



D. Create the Proposed Terrain for Y8DET
   - Using the From Graphical Filter tool and the Proposed Grading Filter Group create the proposed terrain.
   - Terrain name is PTM Y8DET

E. Edit the Proposed Terrain
   - Using the Edit tools edit the terrain triangles as required
   - For the Detour this is an important step, these triangles must match the model everywhere. This Terrain will be merged with the Existing Terrain and used as the basis for the Cut and Fill volumes for the Final Roadway.



3. Create the Complex Terrain for the Final Roadway

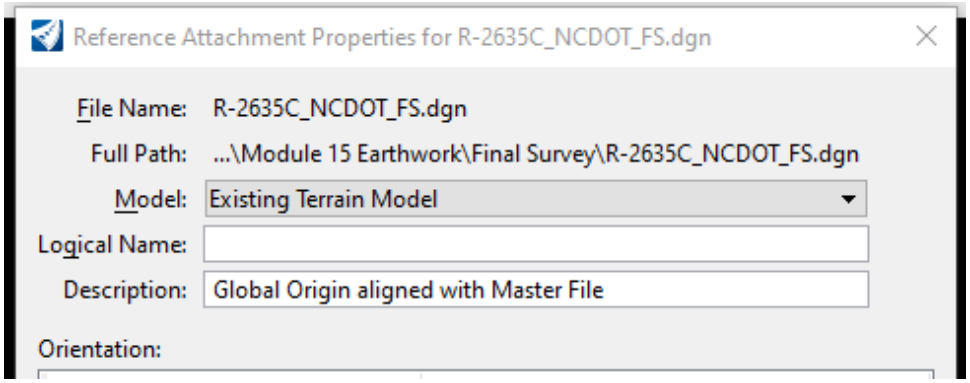
A. A complex terrain is a combination of two different surfaces.

B. This complex terrain in conjunction with the Detour Model will be used to create the 3D Volume that represents the detour removal.

- This volume is represented by the Yellow and Green shape in the Detour Removal Schematic shown on the first page in this section.

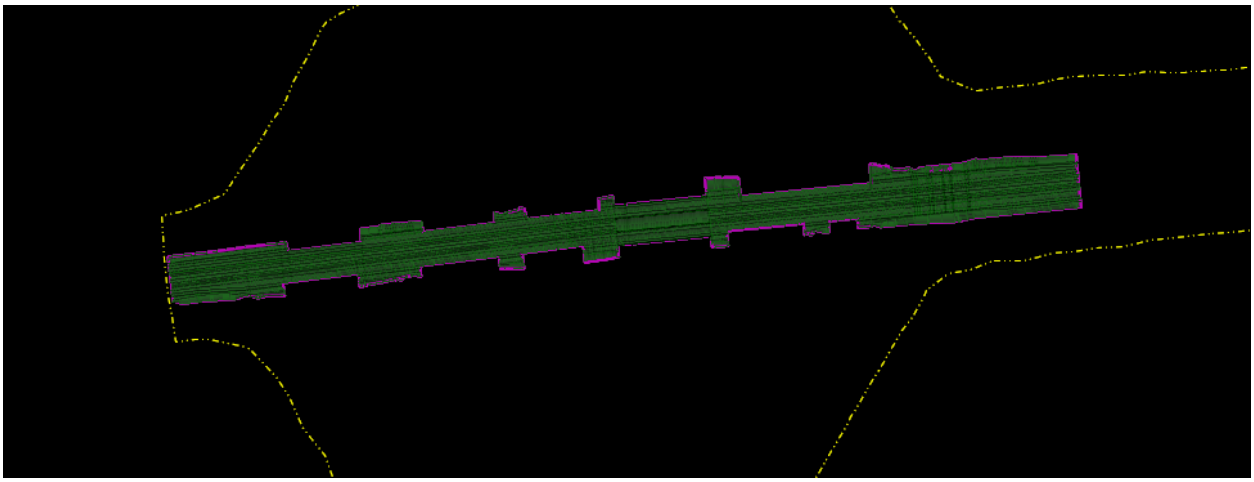
C. Create a new DGN file

- R-2635C_RDY_CTM_Y8.dgn
- Attach R-2635C_NCDOT_FS.dgn using the Existing Terrain model and set it active



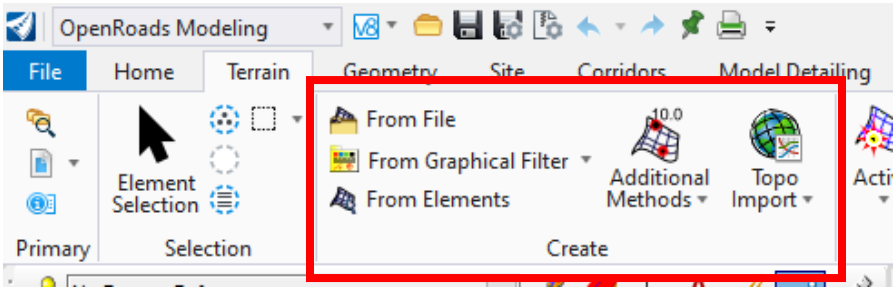
- Live Nesting should be OFF.

- Attach the Proposed Y8 Terrain created in previous steps in the R-2635C_RDY_PTM_Y8.dgn file
  1. When attaching terrain files attach the Default model to the Default model in the current DGN file. This will automatically attach the Default 3D model to the Default 3D model in the current DGN file.

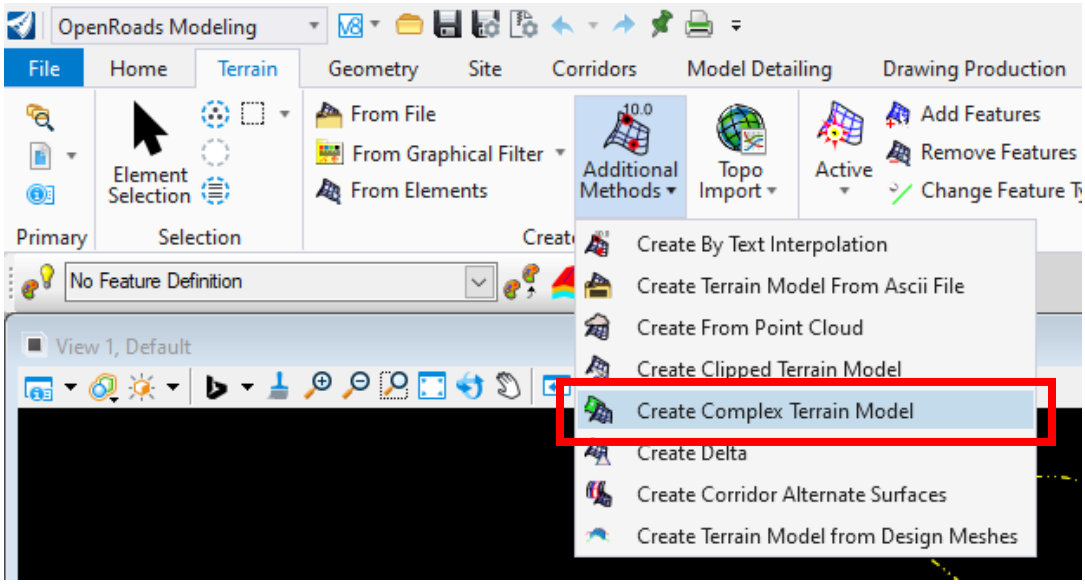


D. Merge the proposed terrain into the existing terrain.

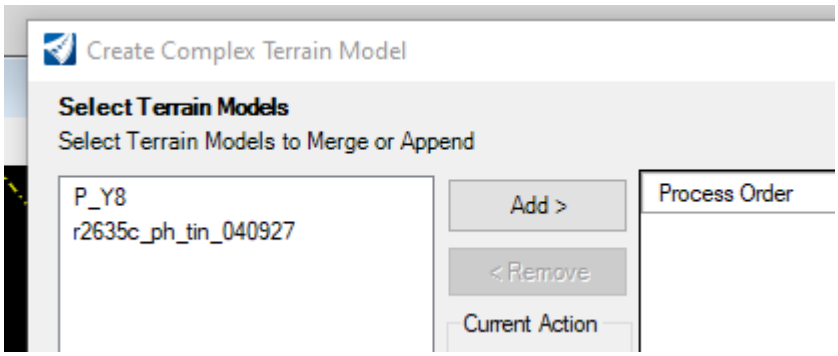
- In the OpenRoads Modeling workflow in the Terrain Tab find the Create Tool Group.



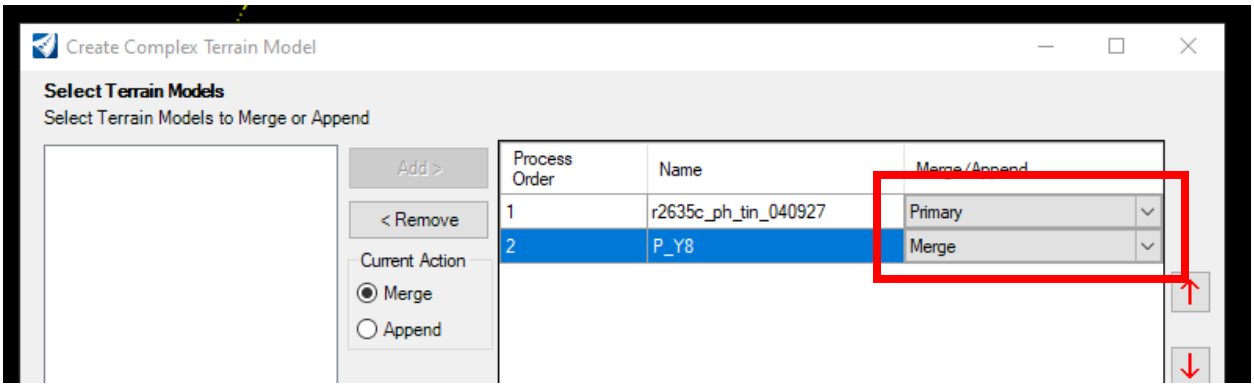
- In the Additional methods drop down find the Create Complex Terrain Model tool.



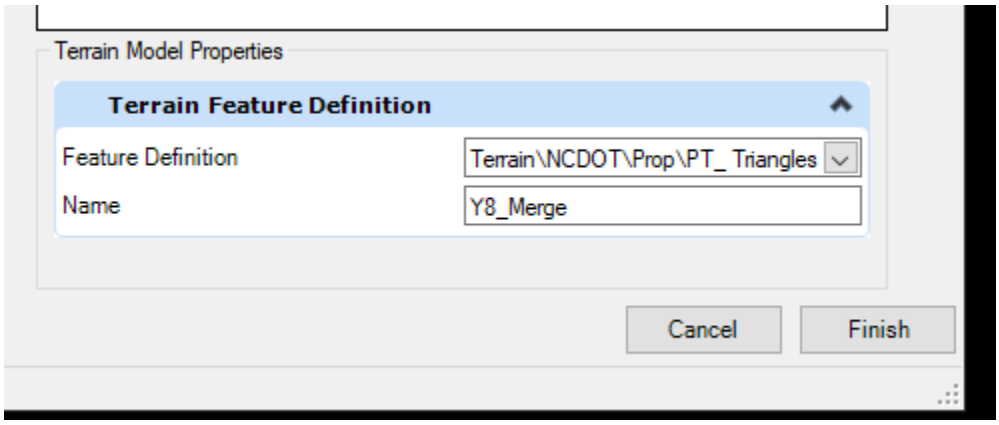
- The dialog should show 2 available Terrains
  1. P_Y8 – Proposed Final Roadway Terrain Created in Previous Steps
  2. r2635c_ph_tin_040927 – the Existing Terrain



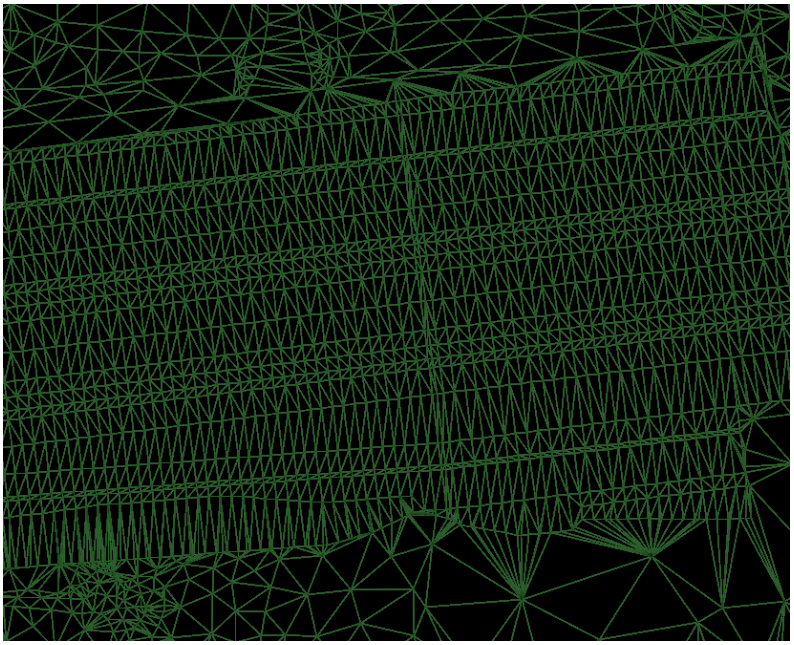
- Select Each Terrain and left click
  1. rR2635c_ph_tin_040927 is the Primary
  2. P_Y8 should be set to Merge



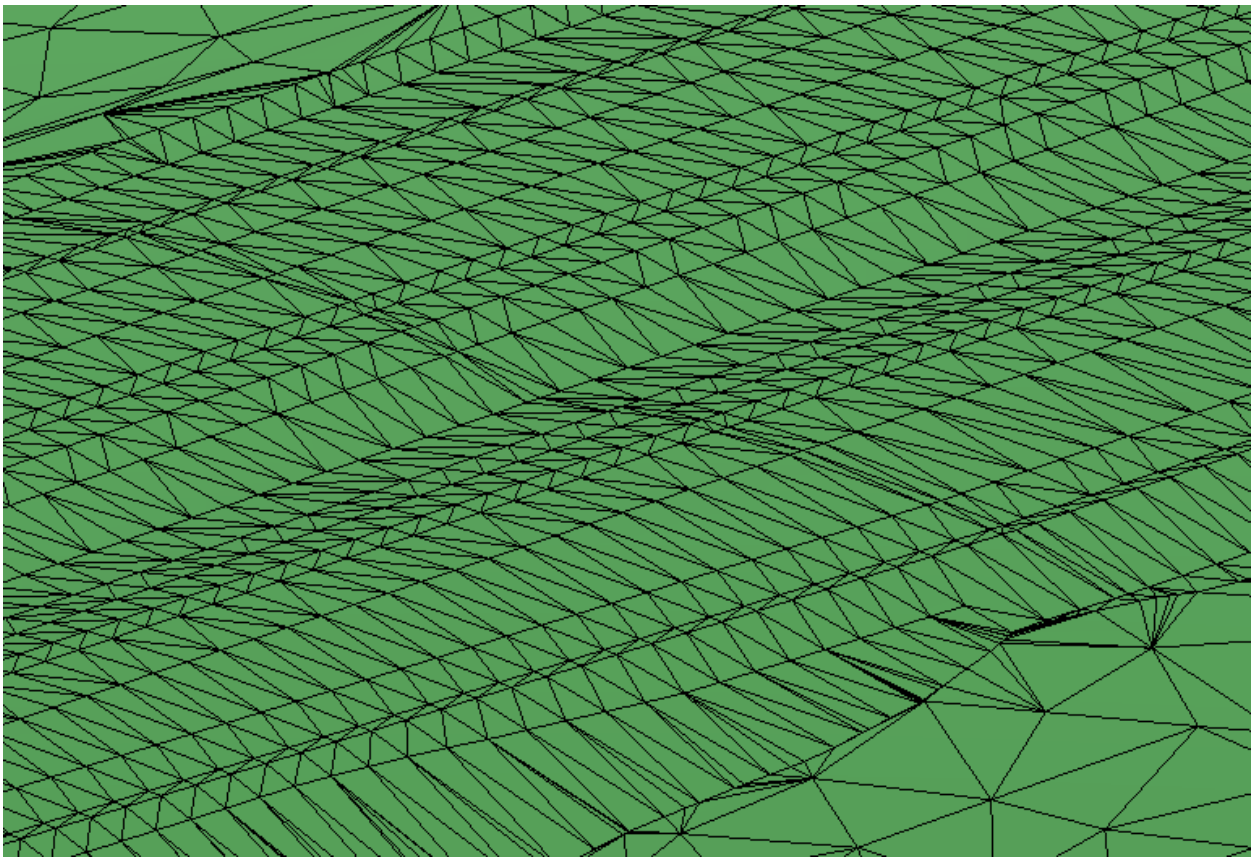
- At the bottom of the dialog set the Feature Definition to PT_Traingles and set the name to Y8_Merge. By using this setting, the existing terrain will effectively be removed and replace by the Proposed Final Roadway terrain in areas where they overlap.



- Left Click Finish. Turn the reference files off, Do Not Detach the files. This will display a newly created Terrain that includes the Proposed Y8 construction merged into the existing ground.



- The 3D view will display the terrain more clearly. The area with the regular pattern of triangles represents the proposed terrain and the area with the irregular pattern represents the existing triangles.

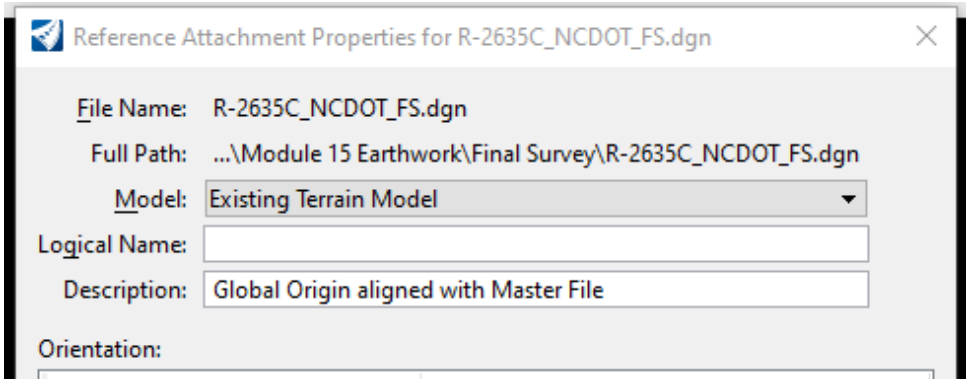


4. Create the Complex Terrain for the Detour

A. This complex terrain will be used as the existing ground when completing the Prismoidal Earthwork calculation. This is required to exclude any previously placed fill or any completed excavation from the Detour construction from being calculated again.

B. Create a new DGN file

- R-2635C_RDY_CTM_Y8DET.dgn
- Attach R-2635C_NCDOT_FS.dgn using the Existing Terrain model and set it active

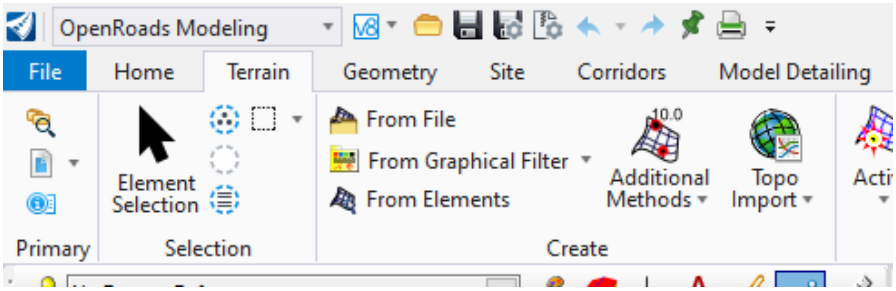


- Live Nesting should be OFF.

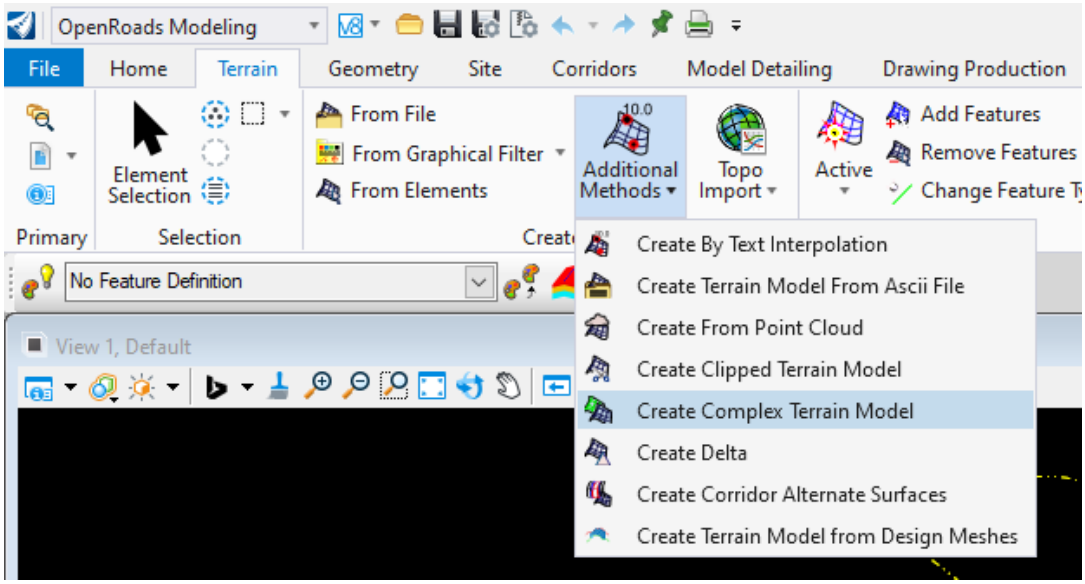
- Attach the Proposed Y8DET Terrain created in previous steps in the R-2635C_RDY_PTM_Y8DET.dgn file.
  1. When attaching terrain files attach the Default model to the Default model in the current DGN file. This will automatically attach the Default 3D model to the Default 3D model in the current DGN file.

E. Merge the proposed terrain into the existing terrain.

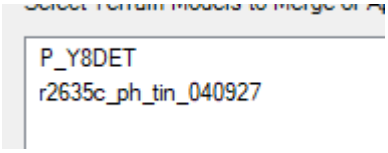
- In the OpenRoads Modeling workflow in the Terrain Tab find the Create Tool Group.



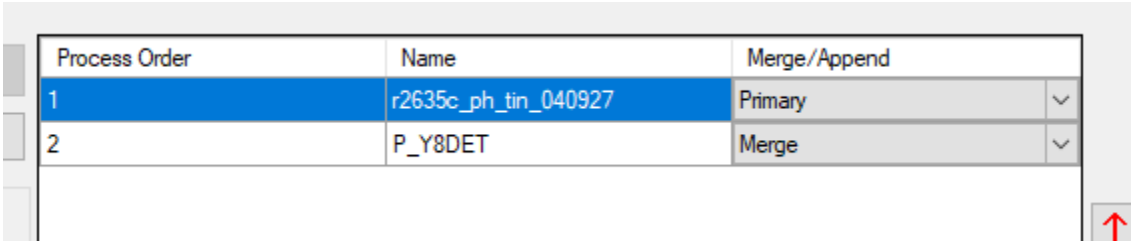
- In the Additional methods drop down find the Create Complex Terrain Model tool.



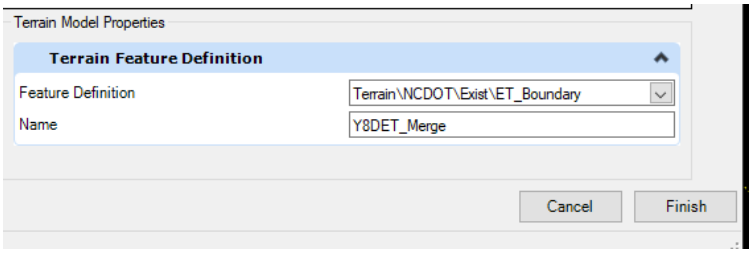
- The dialog should show 2 available Terrains
  1. P_Y8DET – Detour Terrain Created in Previous Steps
  2. r2635c_ph_tin_040927 – the Existing Terrain



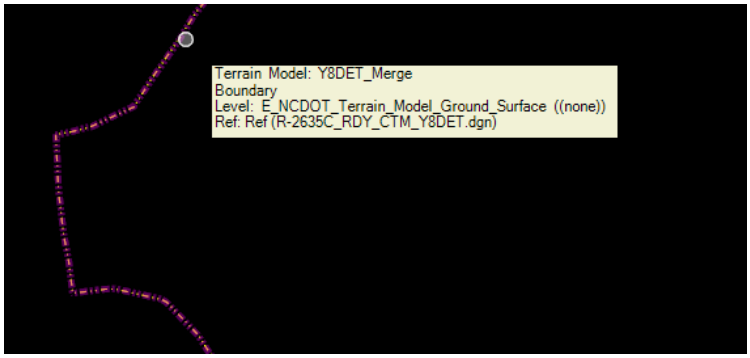
- Select Each Terrain and left click
  1. rR2635c_ph_tin_040927 is the Primary
  2. P_Y8 should be set to Merge



- At the bottom of the dialog set the Feature Definition to ET_Boundary and set the name to Y8DET_Merge. By using this setting, the existing terrain will effectively be removed and replace by the Detour terrain in areas where they overlap.



- It is very important to use the Existing Terrain Feature Definitions. This terrain will be used later as the existing ground for Earthwork Volume calculations. The Existing Terrain Feature Definitions are configured correctly for this use. If the Proposed Terrain Feature Definitions are used the program will not recognize this terrain as existing ground.
- Left Click Finish. Turn the reference files off, Do Not Detach the files. This will display a newly created Terrain that includes the Proposed Y8 construction merged into the existing ground.
- Turning off all reference files and highlighting the boundary will display the Terrain name and verify the merged terrain has been created.



4. Create the Detour Removal Closed Mesh.

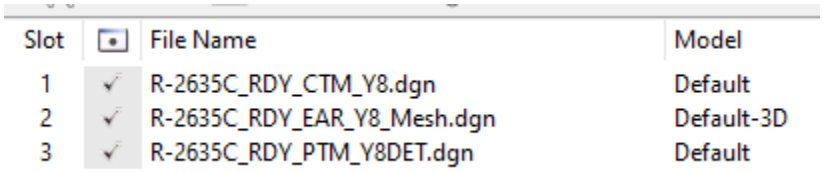
A. This Closed Mesh will represent the amount of detour removal required at the end of a project. It represents previously placed Detour fill volume plus any excavation required during the detour removal for the Final grading.

- This volume is represented by the Yellow and Green shapes in the example figure and must be quantified and shown as removal.
- The work to this point was required to generate the surfaces that will be used to create the earthwork Volumes.
- Closed Meshes are 3D elements that will be used to separate out the Earthwork Volumes.

B. Create a new file for the Closed Mesh Volumes

- R-2635C_RDY_EAR_Y8_Mesh.dgn

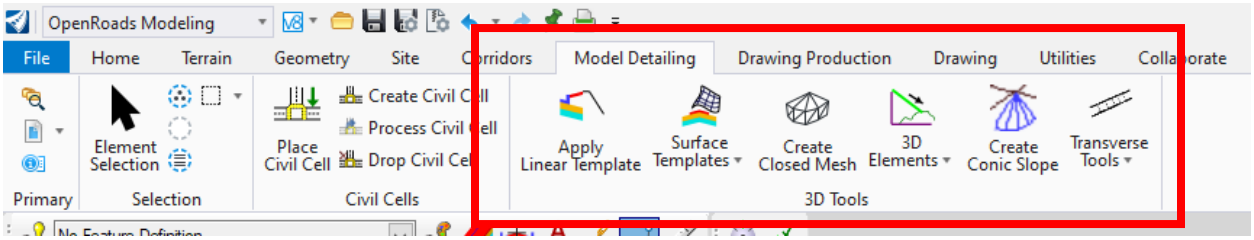
1. Attach the Proposed Final Y8 Complex Terrain R-2635C_RDY_CTM_Y8.dgn and set this file active.
2. Attach the Proposed Y8DET Terrain R-2635C_RDY_PTM_Y8DET.dgn
3. When attaching the terrain files attach the Default model to the Default model in the current DGN file. This will automatically attach the Default 3D model to the Default 3D model in the current DGN file.



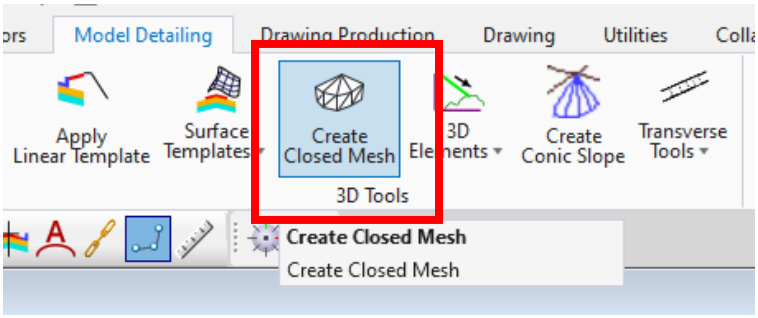
4. Live Nesting should be OFF.

C. Create the Detour Removal Closed Mesh.

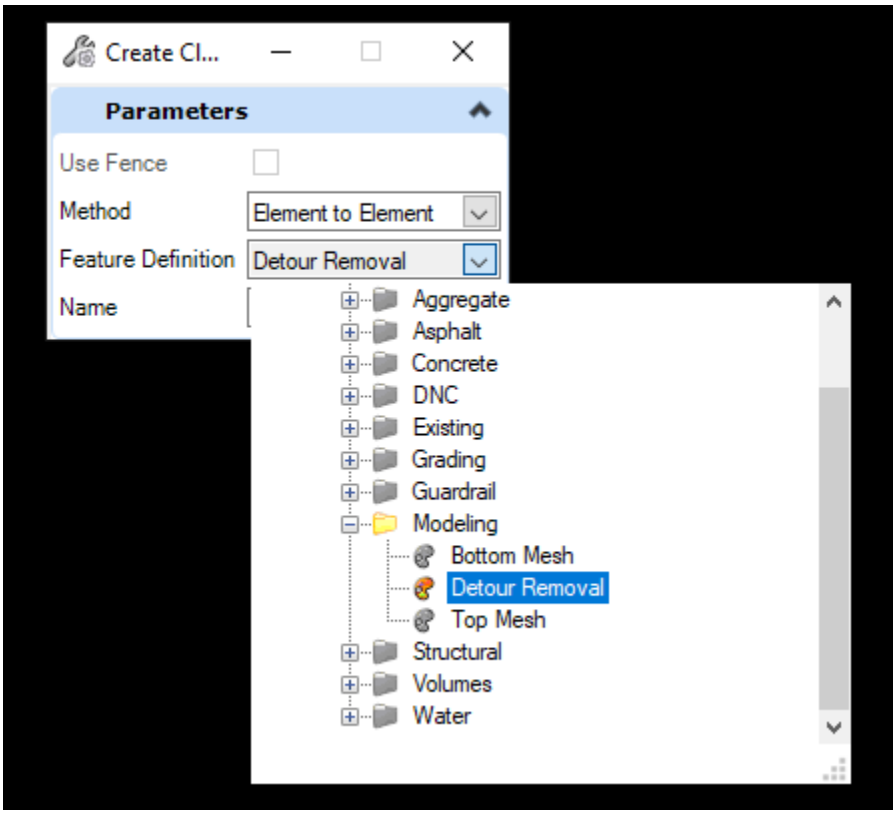
- Switch to the OpenRoads Modeling Workflow and the Model Detailing tab.



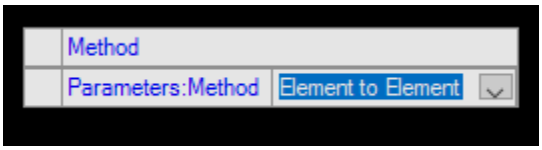
- In the 3D Section select the Create Closed Mesh tool.



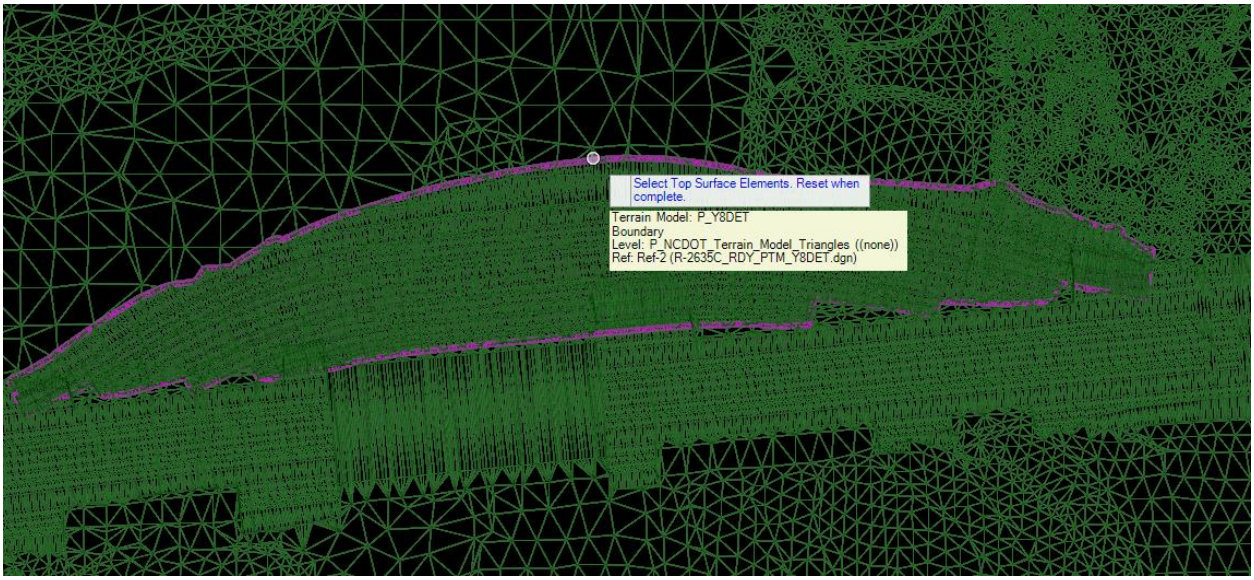
- In the dialog box set
  1. Method to Element to Element
  2. Feature Definition to Detour Removal from the Roadway/Modeling Folder



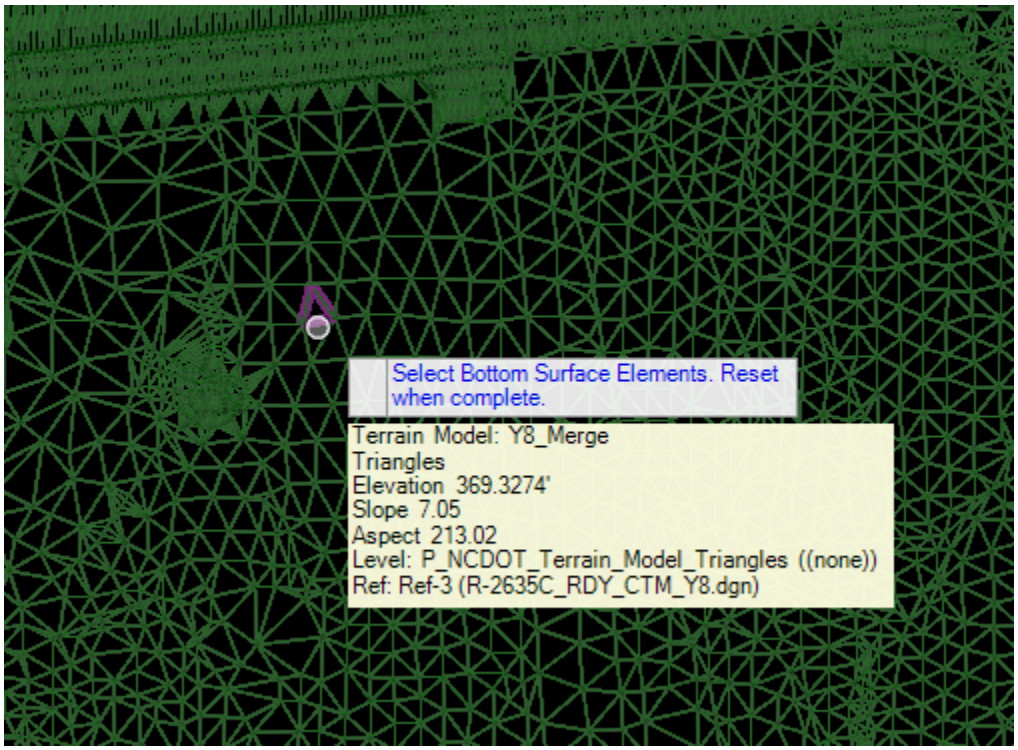
- Left click to verify the Method



- A prompt will appear to select the top surface. Select the proposed detour surface by selecting the boundary element for the detour surface, reset to confirm the selection.

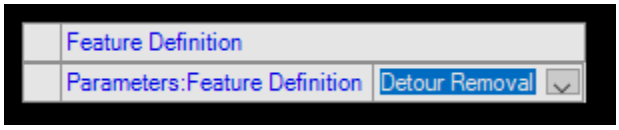


- The prompt will then ask for the bottom surface. Select the complex terrain model that is the Existing and Final Proposed surface merged. Select anywhere on the terrain triangles of the terrain. Reset to confirm the selection.



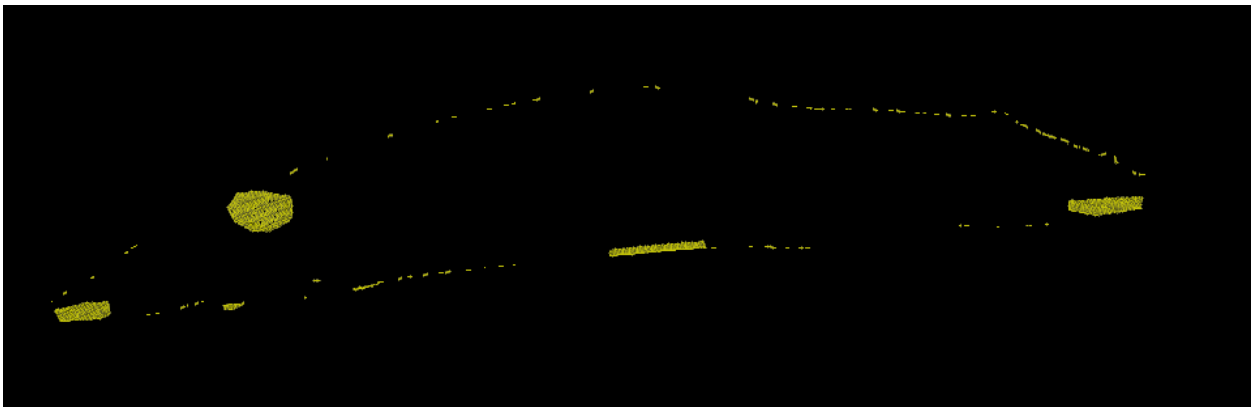
- The prompt will change to ask for Boundary Surface Elements. Because we want to analyze the entire Detour Surface for Earthwork removal reset to skip this selection, it is not required for this workflow.

- Left Click to accept the Feature Definition

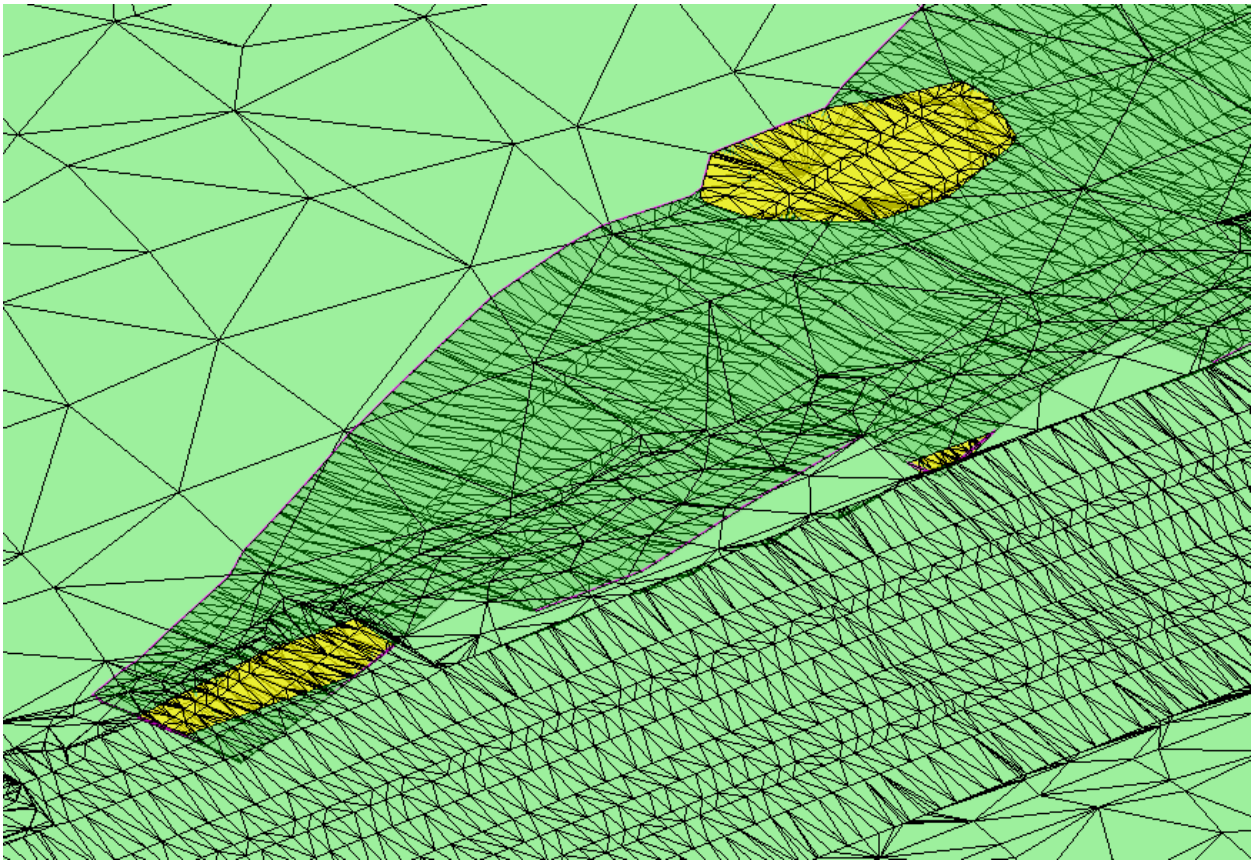


- Left Click – Data Point in the Default 3D model to create the closed mesh.

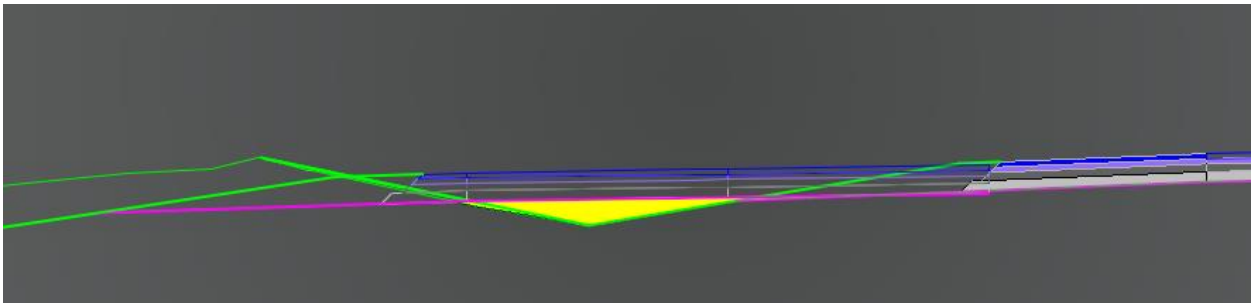
- Turning off the Terrain Model References will reveal a yellow closed 3D mesh.



- This represents the volume of earth placed for the Detour that will be removed after the Final Construction. This is more visible in the Modeling View mode.



- Attaching the corridors and alignment and activating the Dynamic Cross sections also gives a good view of the volume. Here the yellow volume represents the volume of material that will need to be removed for the final construction. This is the dynamic section view at Station 24+75 from the Y8 Corridor.



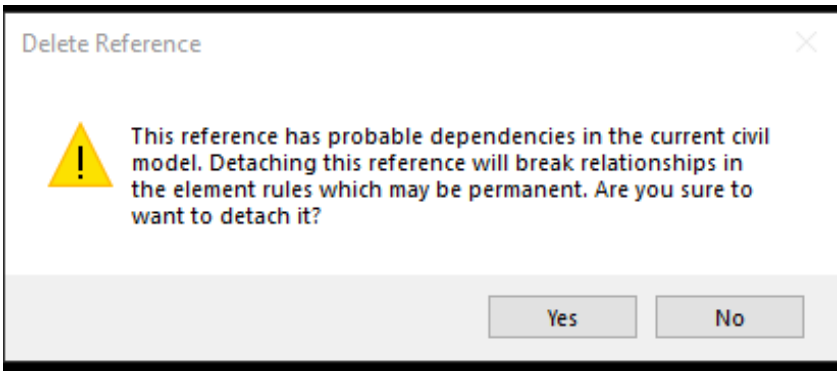
- Note that the example files included with this exercise do not include all the detailed modeling that would be required for a final set of plans. The final construction of Y8 does not necessarily account for the previously removed earth required for the detour construction. A completed project would include more detail, and these areas would be accounted for. These files are only meant to represent the overall workflow.

5. Calculate the Earthwork Volumes.

A. This is the final step in computing the earthwork volumes. This will be the same process used for the basic Earthwork Calculation but will include the detour removal.

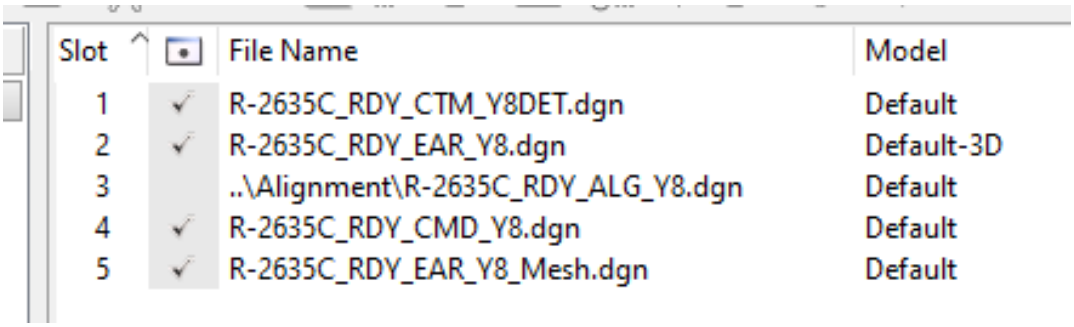
B. Open the Y8 Earthwork File that was created in the first exercise.
- R-2635C_RDY_EAR_Y8.dgn
- This file will have previously created earthwork cut and fill volumes and named boundaries.

C. At this point we need to replace the existing terrain with the complex terrain created by merging the Detour and the Existing Terrain. This will prevent the program from calculating Cut and Fill volumes in areas that were completed during the detour construction phase.
- Detach the existing terrain file
  1. R-2635C_NCDOT_FS.dgn
  2. If a Probable Dependencies error message appear select YES and detach the existing terrain.



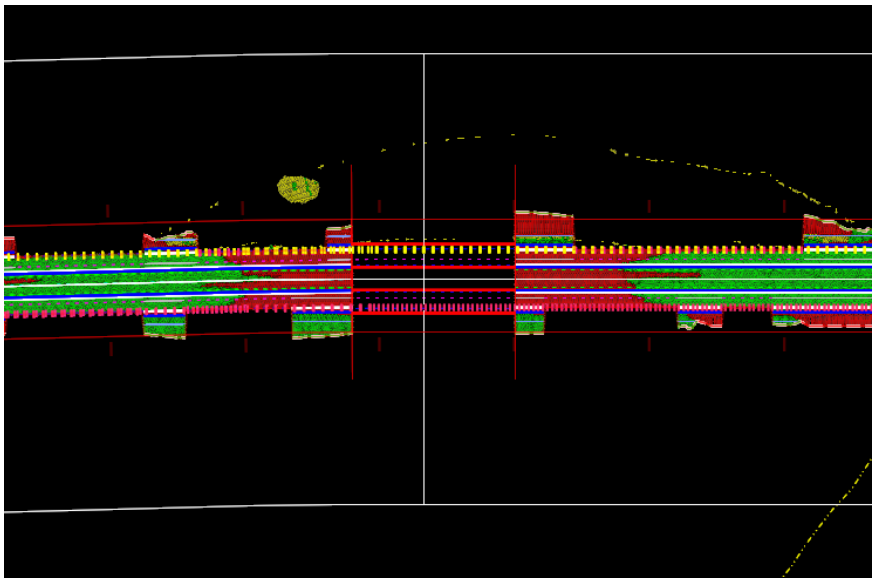
- Attach the Detour Complex Terrian Model
  1. R-2635C_RDY_CTM_Y8DET.dgn
  2. Live Nesting should be OFF
  3. Set this as the Active Terrian

- Attach the Detour Removal mesh file created in previous steps.
  1. R-2635C_RDY_EAR_Y8_MESH.dgn



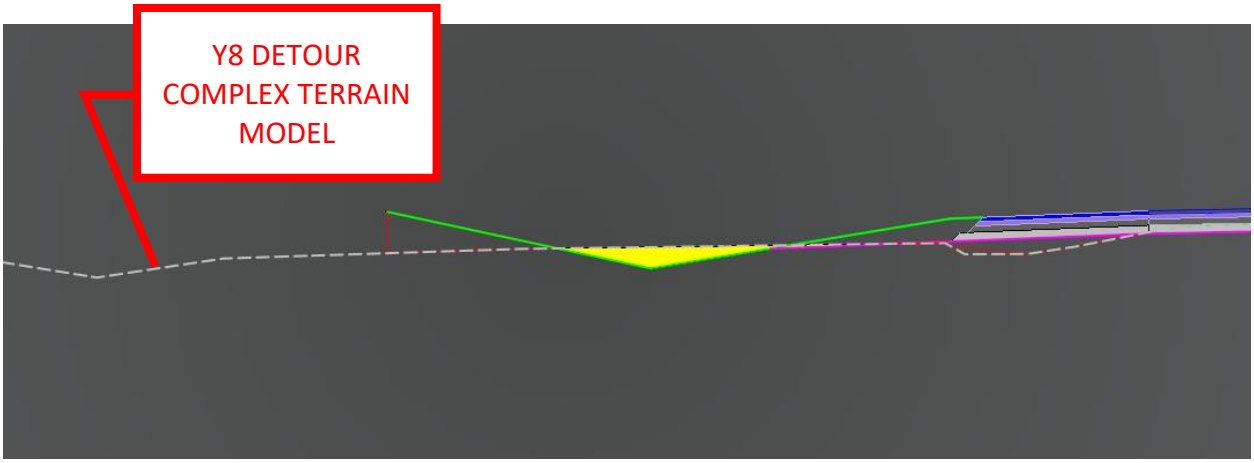
Slot		File Name	Model
1	✓	R-2635C_RDY_CTM_Y8DET.dgn	Default
2	✓	R-2635C_RDY_EAR_Y8.dgn	Default-3D
3		..\Alignment\R-2635C_RDY_ALG_Y8.dgn	Default
4	✓	R-2635C_RDY_CMD_Y8.dgn	Default
5	✓	R-2635C_RDY_EAR_Y8_Mesh.dgn	Default

- These meshes are 3D volumes, the Default 3D reference must be on in the Default view to see the shapes.
- These shapes, shown in yellow, should be enclosed in the previously created named boundaries but if not make any adjustments to the named boundaries using the MicroStation drafting tools.

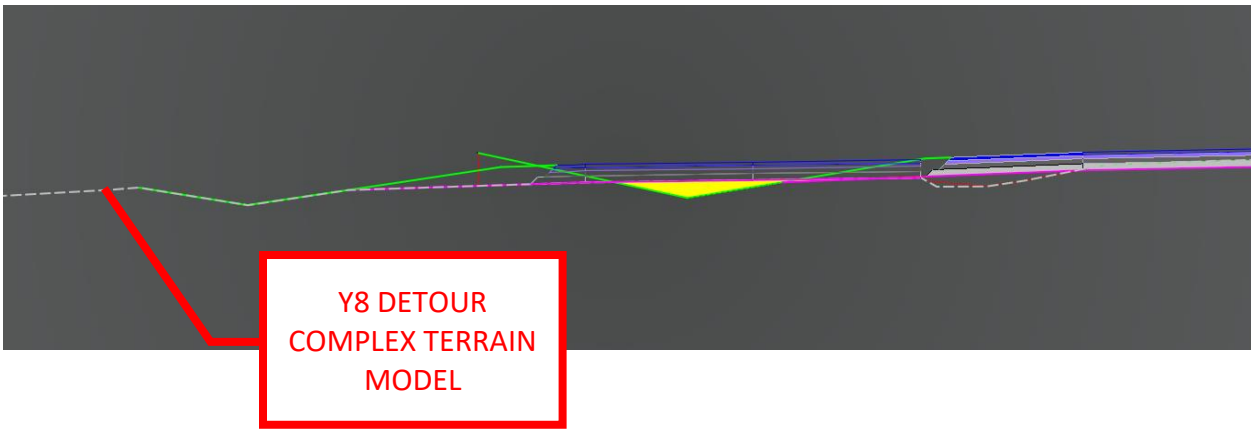


D. This is an image of the cross section at Station 24+80. The Yellow area represents the Detour Removal Volume. This volume will be reported in the quantities report. This volume will also prevent a Cut volume from being Calculated for the Y8 Construction. The area above the yellow volume was excavated previously for the detour construction.

Shown without the Detour Model

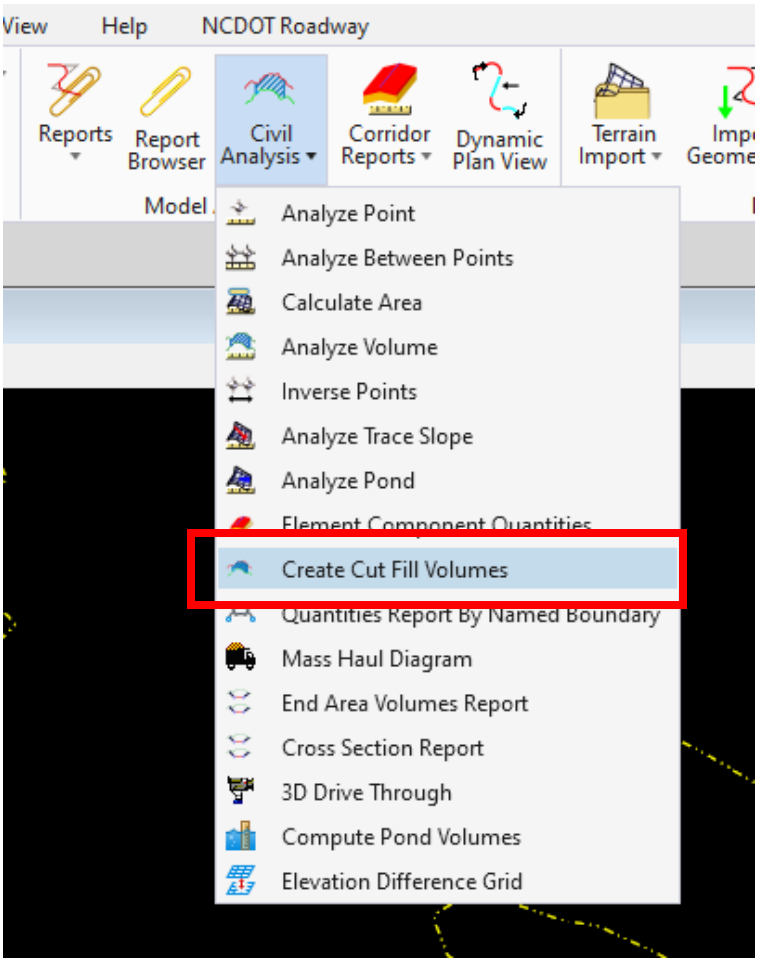


Shown with the Detour Model – Note that the existing ground is represented by the Y8 Detour Complex terrain model.

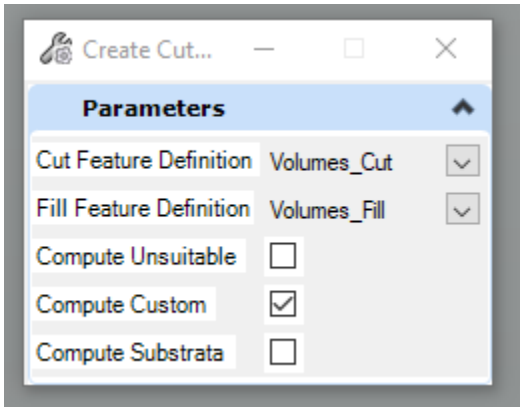


E. Create the Cut and Fill Volumes in the Default 3D Model.

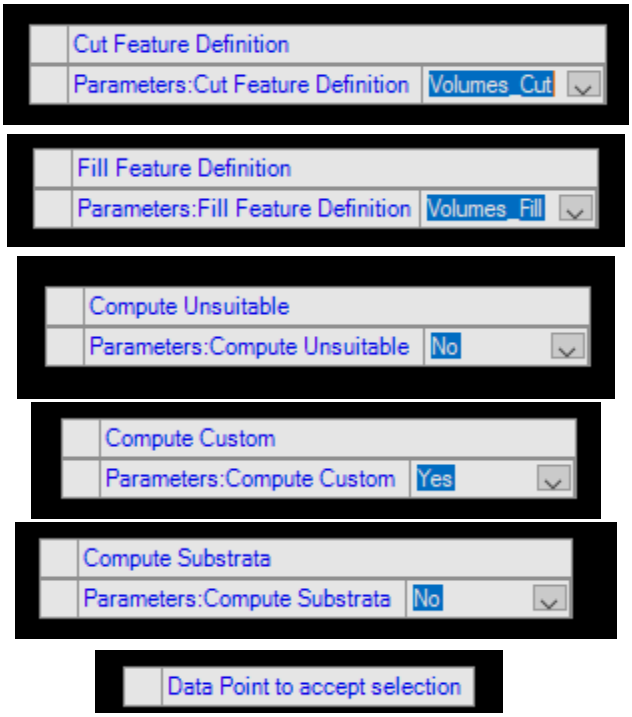
- One View Must be open with the Default 3D Model.
- Using the OpenRoads Modeling workflow, navigate to the Home Tab and find the Civil Analysis section of the Model Analysis and Reporting tool Group and select the tool for Create Cut Fill Volumes.



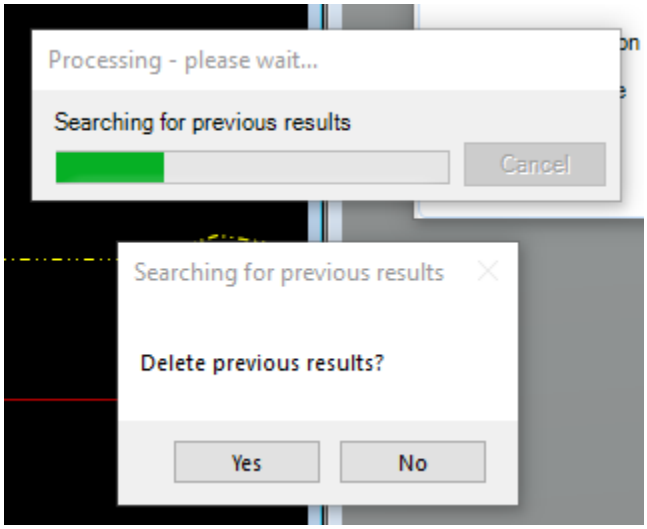
F. Set the dialog box with Compute Custom checked on. By selecting Compute Custom, the Detour Removal Shape will be included in the Earthwork Calculation which will prevent the cut or fill volumes from being computed in areas where there is detour removal.



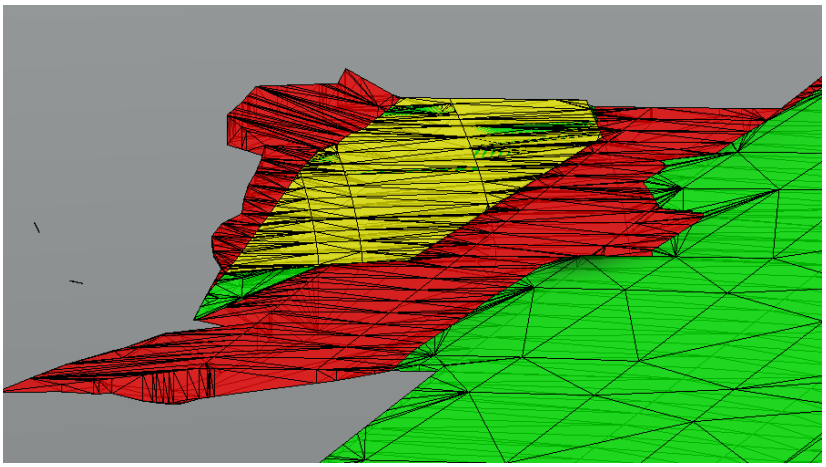
G. Left Click to accept the Calculation Settings.



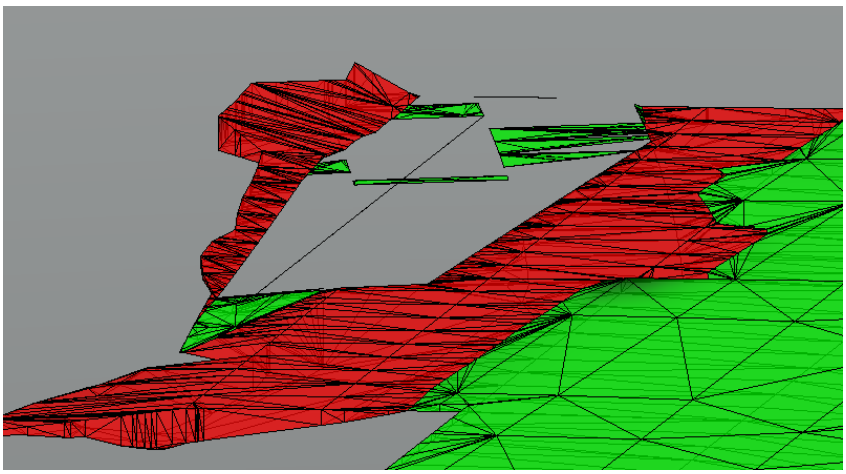
F. At the next prompt select Yes to delete previous results.



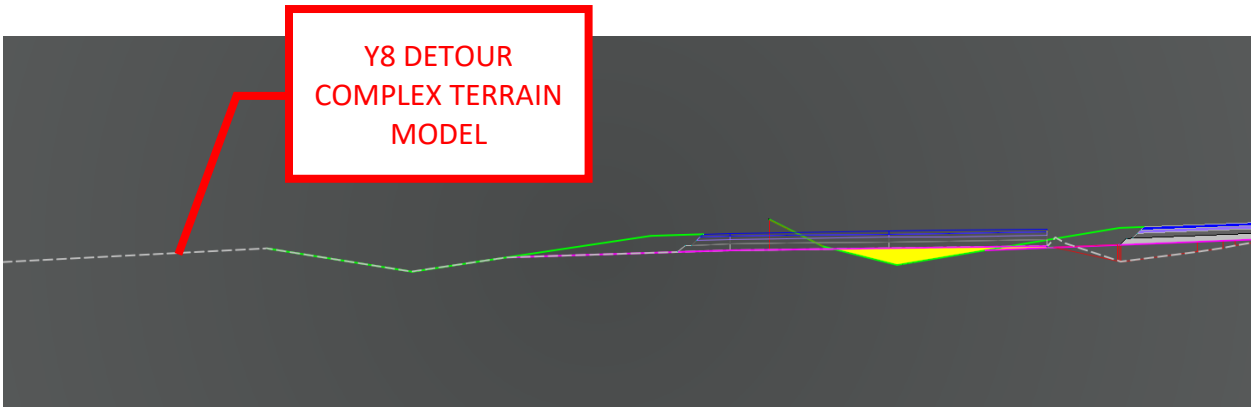
F. After the new Cut and Fill Volume Meshes are created it is clearly visible that the volumes for the detour removal and the detour to remain have been included and correctly calculated by the program.
   - We see all the volumes in the 3D view.



   - By turning of the Detour Mesh Reference file we can see that Cut and Fill have not been included where the Detour Meshes were located. This is because those Closed Mesh Volumes use a feature definition that has the Volume Option set to Custom and the Compute Custom Option was selected when computing the Cut and Fill Volumes.



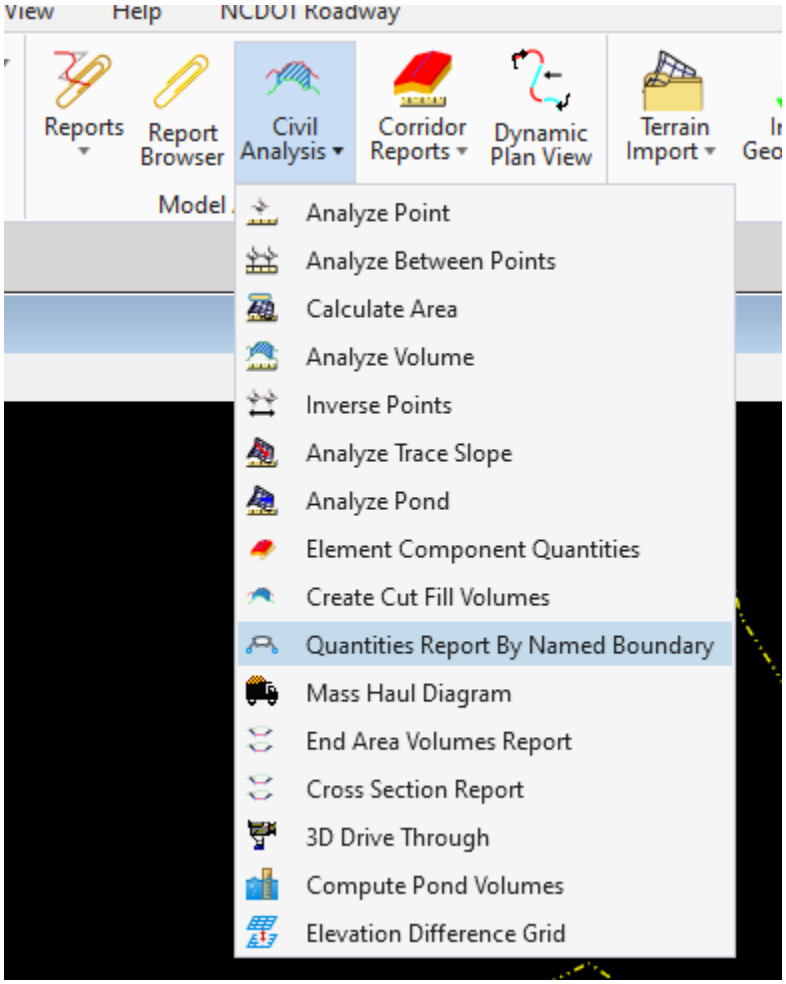
- At station 24+95 we can see the yellow volume that indicates the detour removal that will need to be accounted for to create the roadway ditch section.



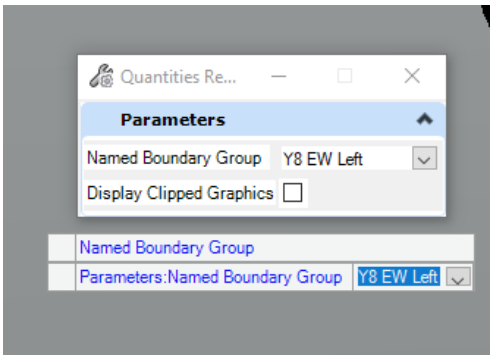
- Note that the provided corridor models are preliminary stage and may not include all the detail required for the finished models and that some volumes may not account for the final design earthwork completely accurately. The workflow is the same at all design stages.

6. Report Quantities

A. Go back to the Home Tab and the Model Analysis and Reporting Tool Group. Under the Civil Analysis dropdown select the Quantities Report by Named Boundary.



- Select the named boundary group. Display Clipped Graphics should not be checked.



B. Just like the previous exercise, this generates a report for the Left Side for Each of the Two Boundaries.
   - There is a Volume for Cut, Fill and Detour Removal that will be included in the Earthwork Balance Card.

TC_Grass Side Slope-Cut:		15579.478	
TC_Bridge Rail Concrete:		2558.821	38.787
Detour Removal:		5410.378	152.038
TC_Grass Shoulder Outside:		1730.706	
TC_Grass Shoulder Inside:		10472.876	
TC_Subgrade Daylight:		7710.201	
Volumes_Fill:		44607.079	2688.344
Volumes_Cut:		89123.682	2365.413
ALG_Centerline Minor Roadway:	1000.000		
TL_Limits of Construction:	875.368		

D. By Comparing these numbers to the previous computation, we can see that the inclusion of the new Closed 3D Meshes has been incorporated into the new Earthwork Calculation.

- Scenario 1 - Performing the calculation without the Custom Option selected the Detour Removal is Ignored and from Station 10+00 to 30+00. Using the Existing Terrain as the Existing Ground for the earthwork Calculations.

  The earthwork volumes are:
  1. Fill = 2528.52 CY
  2. Cut = 2770.18 CY
  3. Detour Removal = 0 CY

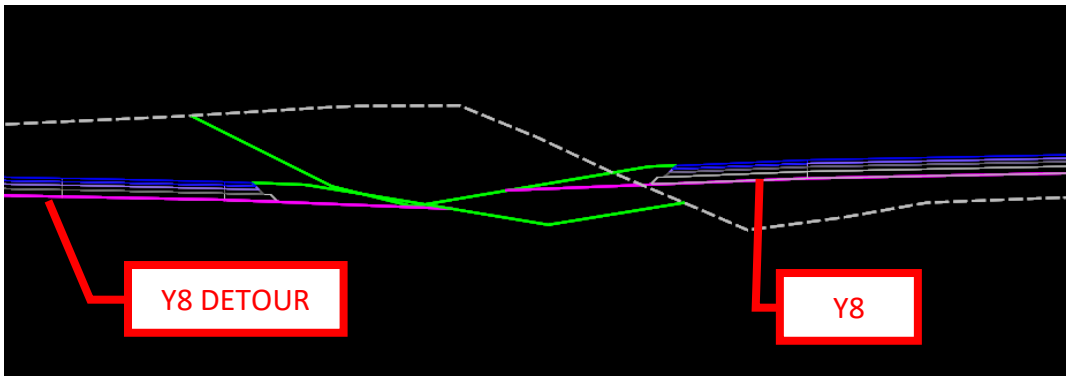
- Scenario 2 - In the next Calculation from Station 10+00 to 30+00 the Custom Option is checked on and the Detour Removal included. The Complex Terrain that includes the completed Detour surface is also used as the Existing Ground for the earthwork Calculations.

  The Earthwork Volumes are:
  1. Fill = 2688.34 CY
  2. Cut = 2365.41 CY
  3. Detour Removal = 152.04 CY

- We can see that the Cut number has been reduced, the Fill Number has been Increased and that the Detour Removal number is now included.

E. `If we refer to a representative section from the project we can see that these results match our expectations. This is the section at Station 29+00 showing Detour Construction on the left and Proposed Roadway Construction on the right.

A closer image where the Detour and Proposed overlap



A key point to remember is that for Scenario 1 we used the Existing Terrain as the Existing Ground and in Scenario 2 we used the Complex Terrain with the Proposed Detour as the Existing Ground.

We can see that the Detour is lower than the Proposed Roadway.

The proposed Roadway Construction will require Fill to backfill the detour ditch. The requires the Fill Volume in scenario 2 to be larger than the Fill Volume in Scenario 1.

A portion of the Excavation for the Final Roadway has already been completed during the Detour Construction. The Cut Volume should be lower in Scenario 2 than in Scenario 1.

These changes in Volumes will be different for each project based on the specific relationship of the Detour to the Proposed construction, but it should not be difficult to review the model and determine that the final volumes including the Detour Removal have been reported correctly.

Exercise 6 – Earthwork Checks and Documentation

Another critical factor in project development is the QA / QC process. The calculated earthwork volumes must be verified. With the Prismoidal Volume Calculation method the earthwork volumes are a true 3D volume based on the triangulated networks of the existing and proposed surfaces. While this is more accurate than the Average End Area method it does present some challenges when the volumes need to be checked and verified.

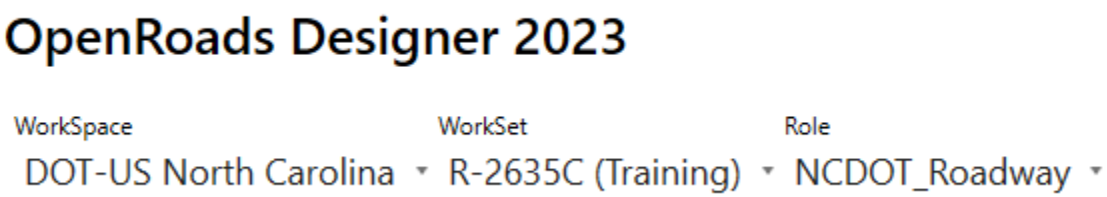
With the Average End Area method users could physically measure the area at each cross section and check them against the calculation looking for errors. This was simple and straightforward and ensured that the earthwork volumes matched the cross sections. The problem was the earthwork volumes did not actually match the project because many areas were not included in the average end areas. Designers accepted the known difference in calculated vs. actual earthwork as a product of the process and available methods. This concept was explained in detail in the beginning of this training.

Now that Prismoidal Volume Calculations are available the designer can compute much more accurate earthwork volumes because each triangle in the existing surface is used to calculate a true 3D volume. This concept is also documented in detail at the beginning of this training. The tradeoff for using this method is there is no way to exactly backcheck the volume calculation with an independent method and verify the total quantity.

But there are several methods the designer can use to have a high level of confidence that the number is correct. Remember that with the Average End Area method it was never possible to verify the earthwork calculation was going to match the actual project earthwork, the designer was also certain that it wouldn't match because there is no way the Average End Area could account for all the irregular areas throughout a project. With the Prismoidal method the actual number cannot be back calculated, but the designer can have a higher level of confidence that the number more accurately reflects the actual earthwork volumes that will be required to construct the project.

Start by selecting the OpenRoads Designer 2023 Desktop Icon

The WorkSpace is DOT_US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



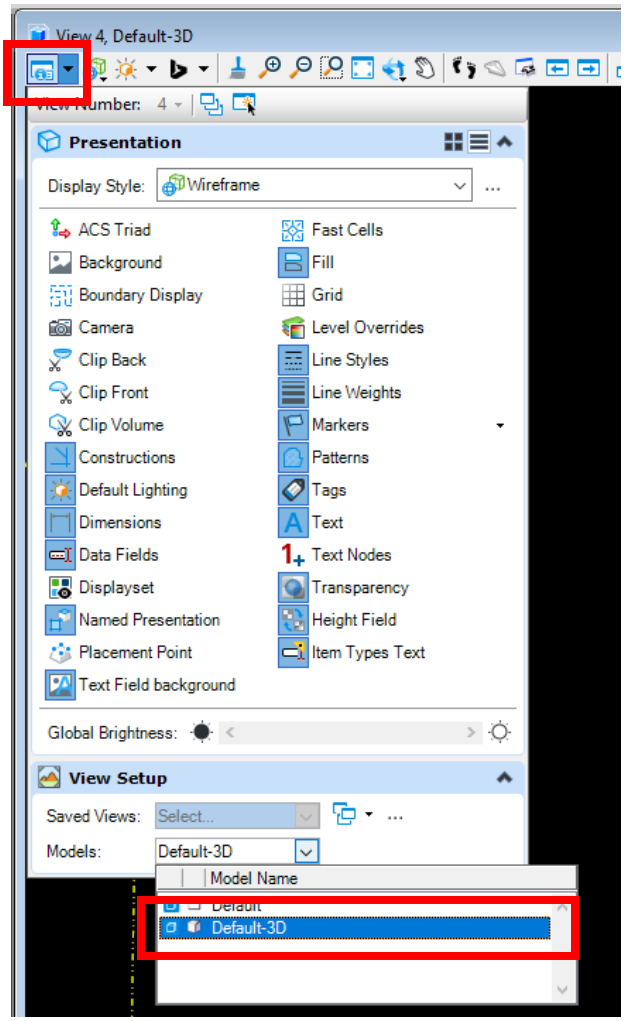
1. Earthwork Check – Visual Inspection.

A. The simplest method to verify the accuracy of the 3D volumes is visual inspection of the earthwork DGN files.

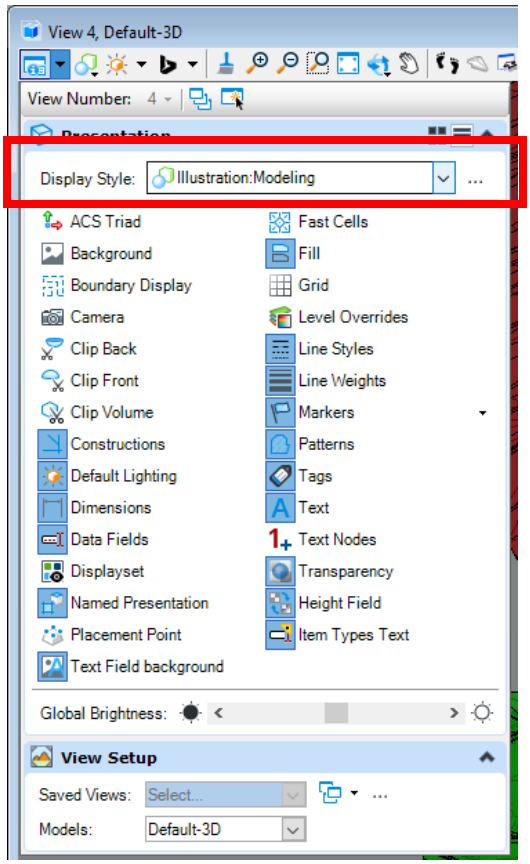
- Open the R-2635C_RDY_EAR_RPY18A.dgn CADD file
  1. This file has previously created earthwork volumes

B. Open the Default 3D model in a View.

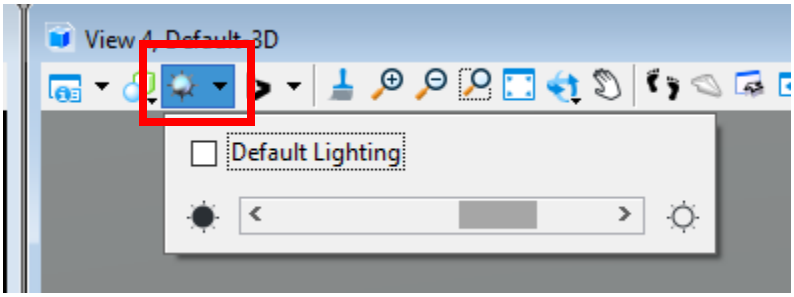
- This is done by selecting the View Attributes dropdown from the top left corner of the view window and selecting Default 3D from the Models Drop down list at the bottom of the dialog.



C. Change the presentation to Illustration Modeling
   - This is done by selecting the View Attributes dropdown from the top left corner of the view window and selecting Illustration Modeling from the Display Style Drop Down

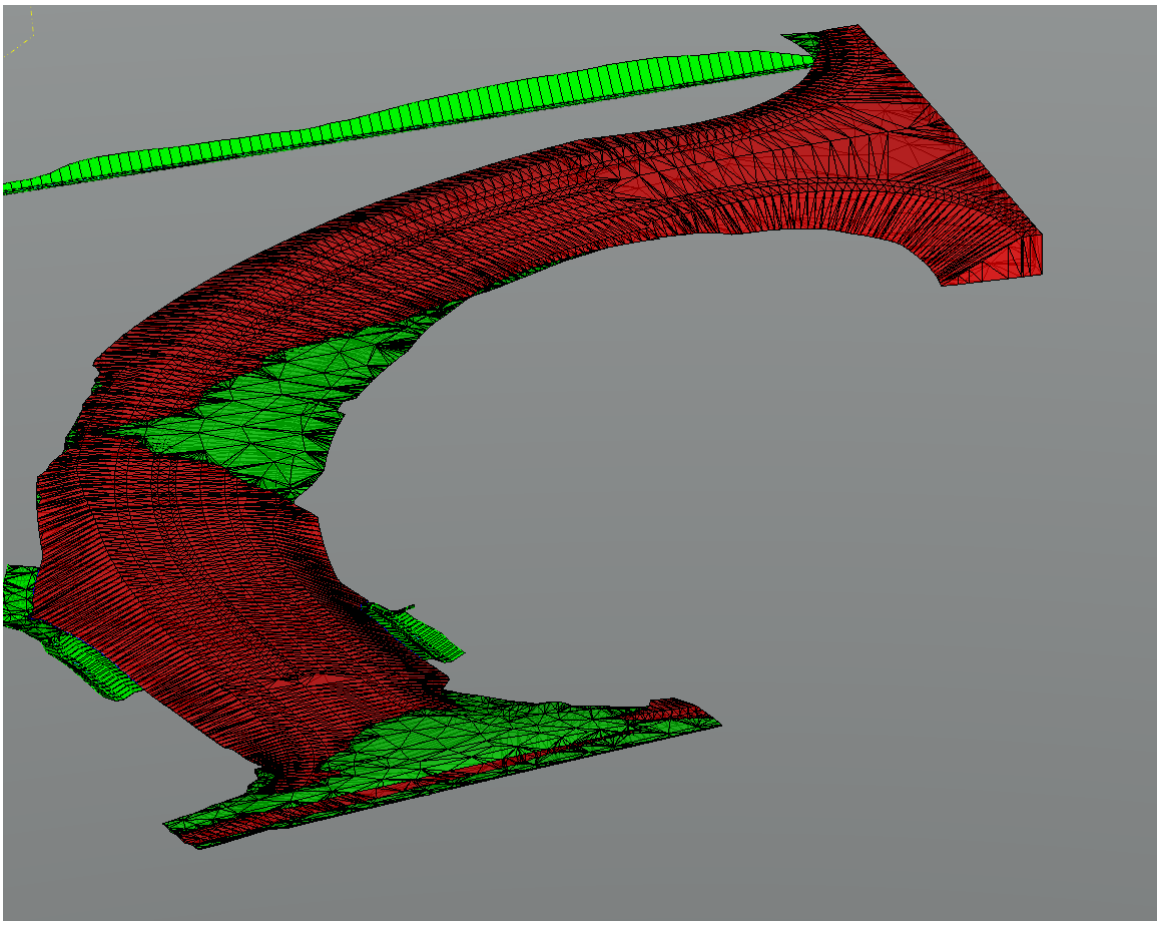


D. Adjust the brightness of the display to the desired level by changing the lighting settings.
   - This is done by Unchecking the Default Lighting Box and Adjusting the slider to change the level of the lighting intensity. This is a personal preference.

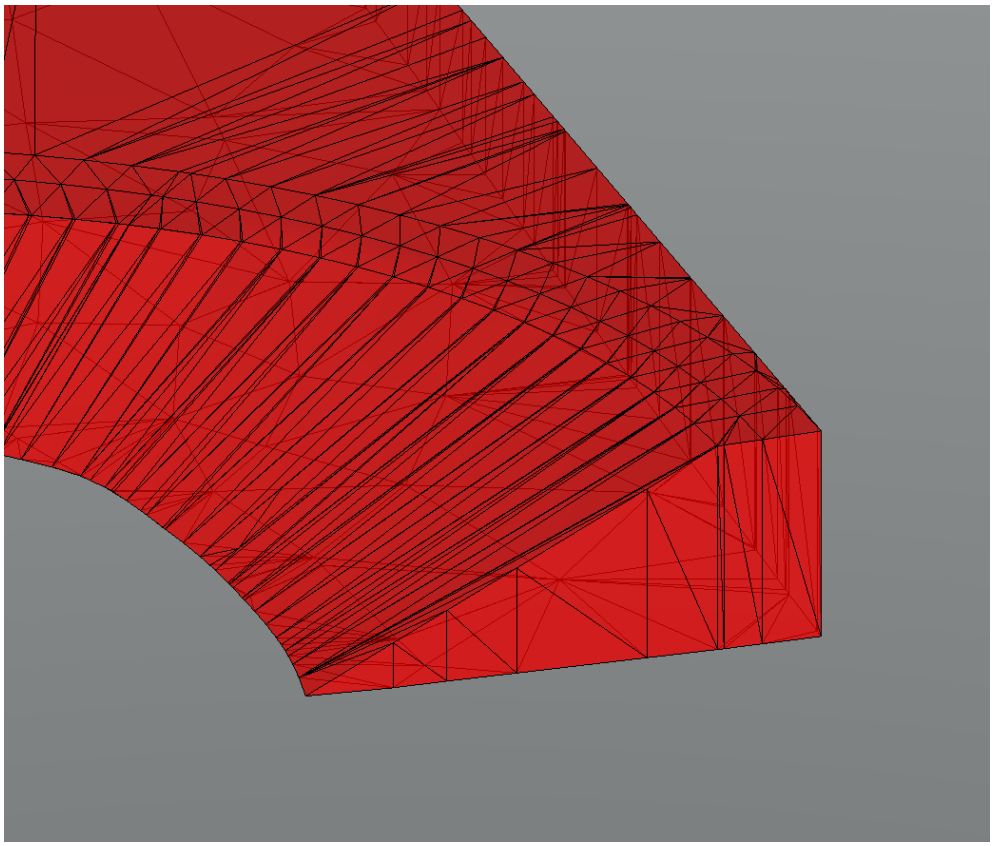


E. Thes setting have the effect of shading in the 3D volumes and making them easier to visually inspect. The first thing to notice is that there are no earthwork volumes shown in the ditches that are computed as DDE.

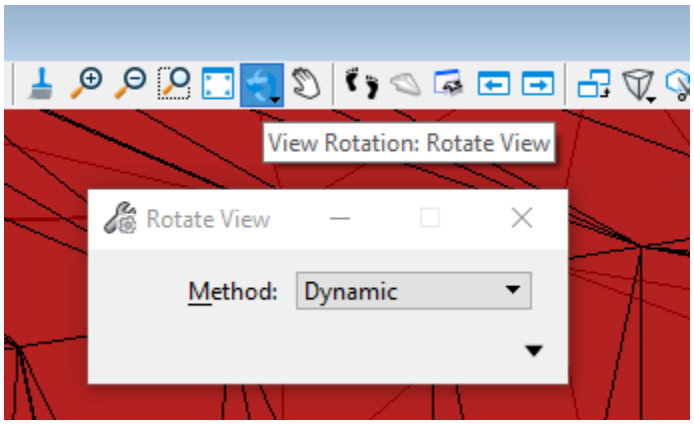
F. The first thing to notice is that we do not see and RED Shapes representing fill or GREEN Shapes representing cut that look out of place. It generally looks like the project corridor.



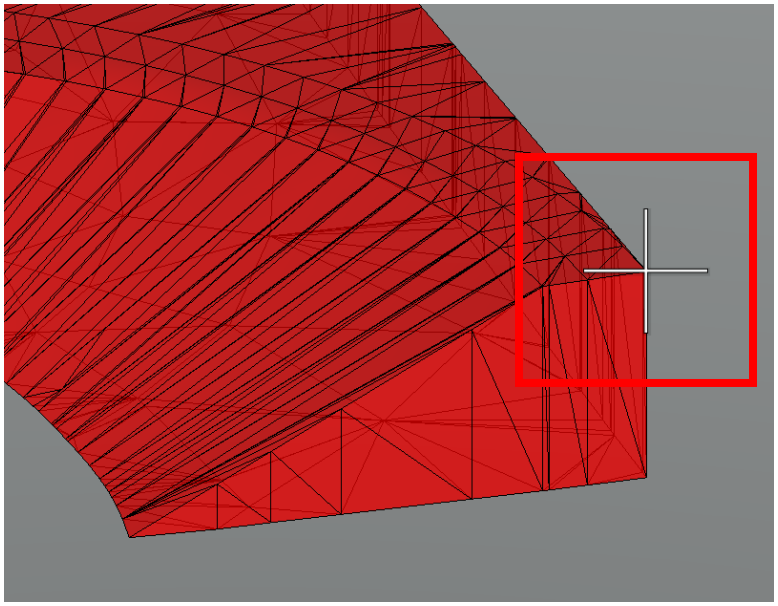
G. The designer can also zoom in and rotate the view in 3D too look at areas in more detail.
   - Zoom into the area in the top right corner near the intersection and we see that it looks like the volume has been sheared correctly with the intersecting roadway.



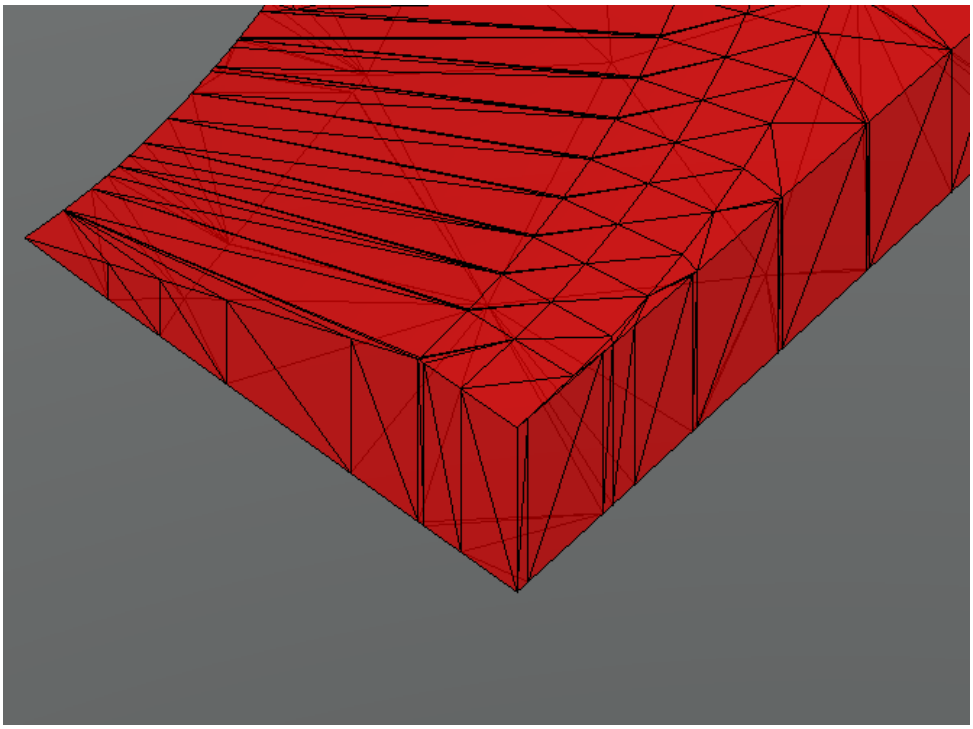
- It may be desirable to rotate the view and review this area from different angles. Rotating a view in 3D can be a challenge.
- Select View Rotation from the View window tool group and set the method to Dynamic.



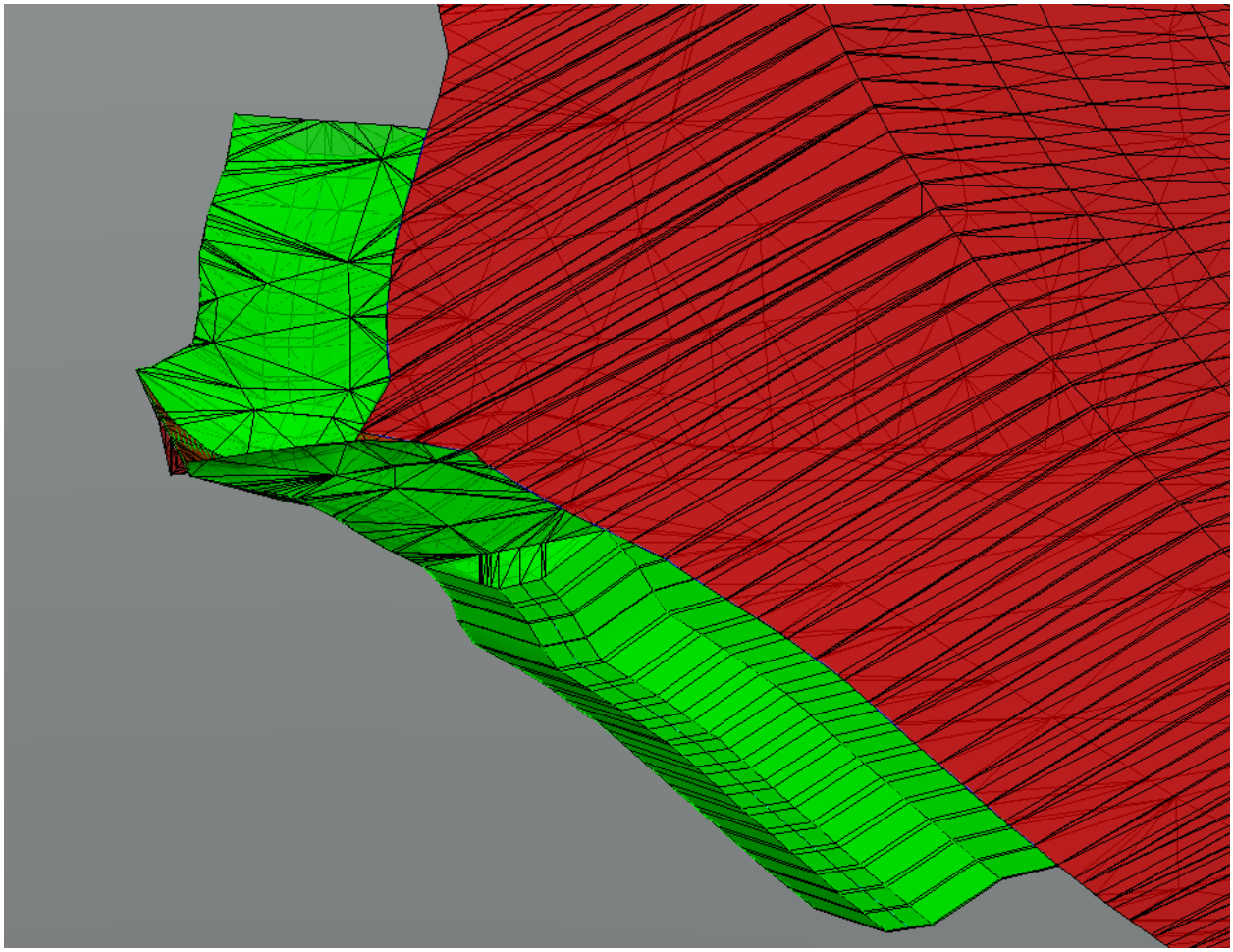
- In the view Window Snap to a corner on the 3D volume shape. A large cross shape should appear, this is an anchor point for the view rotation.



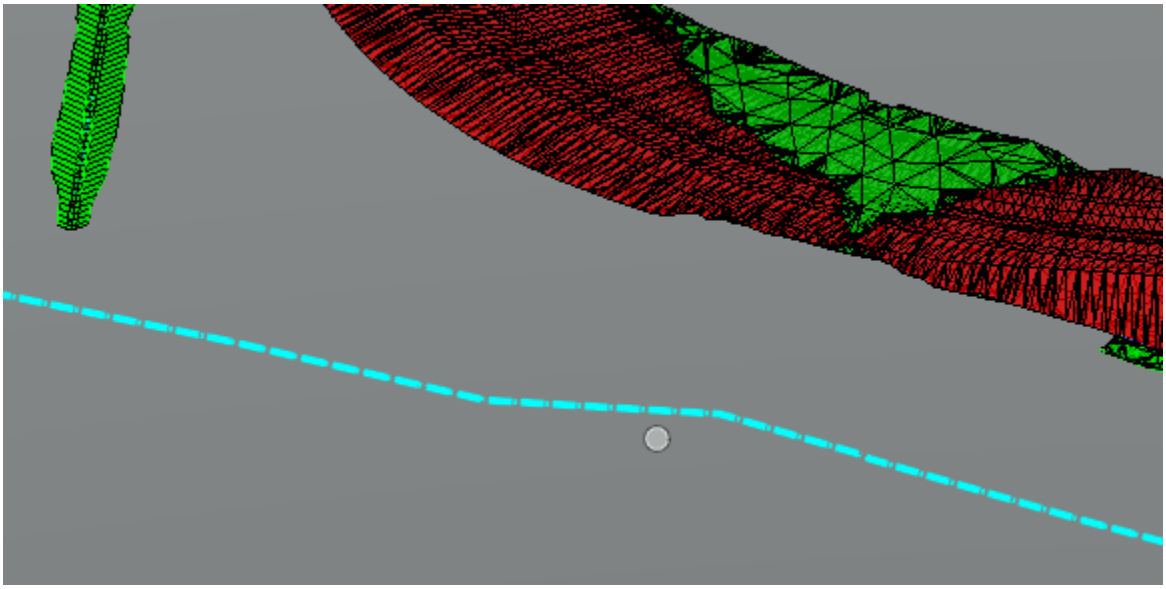
- By manipulating the mouse, the view will rotate around this point. From this angle we can see that the earthwork volume is vertical on the edges at the shear location and the designer can have a high level of confidence that the earthwork has been computed correctly.



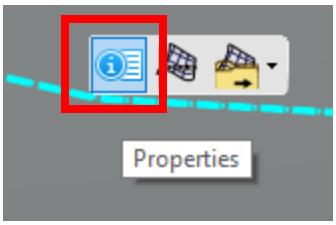
H. By zooming into a new location and rotating the view we can see that the part of the ditch that was computed as UCE is shaded and the part that was computed as DDE was not. The designer can have confidence that the DDE section of the ditch is not included in the earthwork volume calculation.



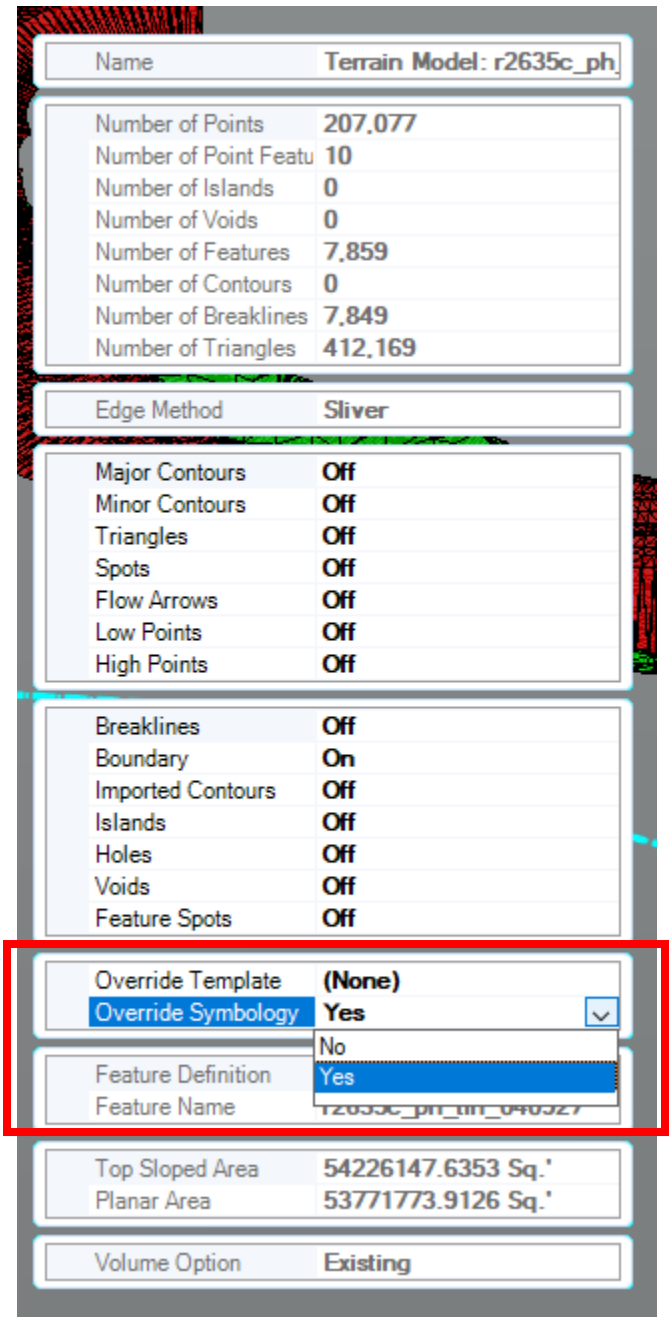
I. For a closer view of how the volumes match to the existing ground, turn on the existing terrain reference. If the triangles are not displayed, they will need to be turned on.
   - In the 3D view use the element selection tool to highlight the terrain boundary, this is a yellow dashed element.



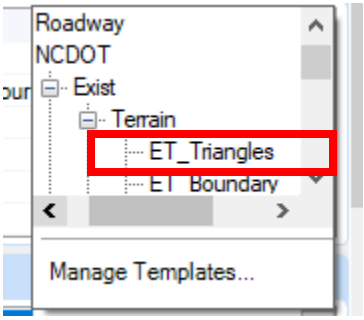
   - By moving the selection away from the terrain element and back to it the pop up menu will be activated. Select the Properties Icon.



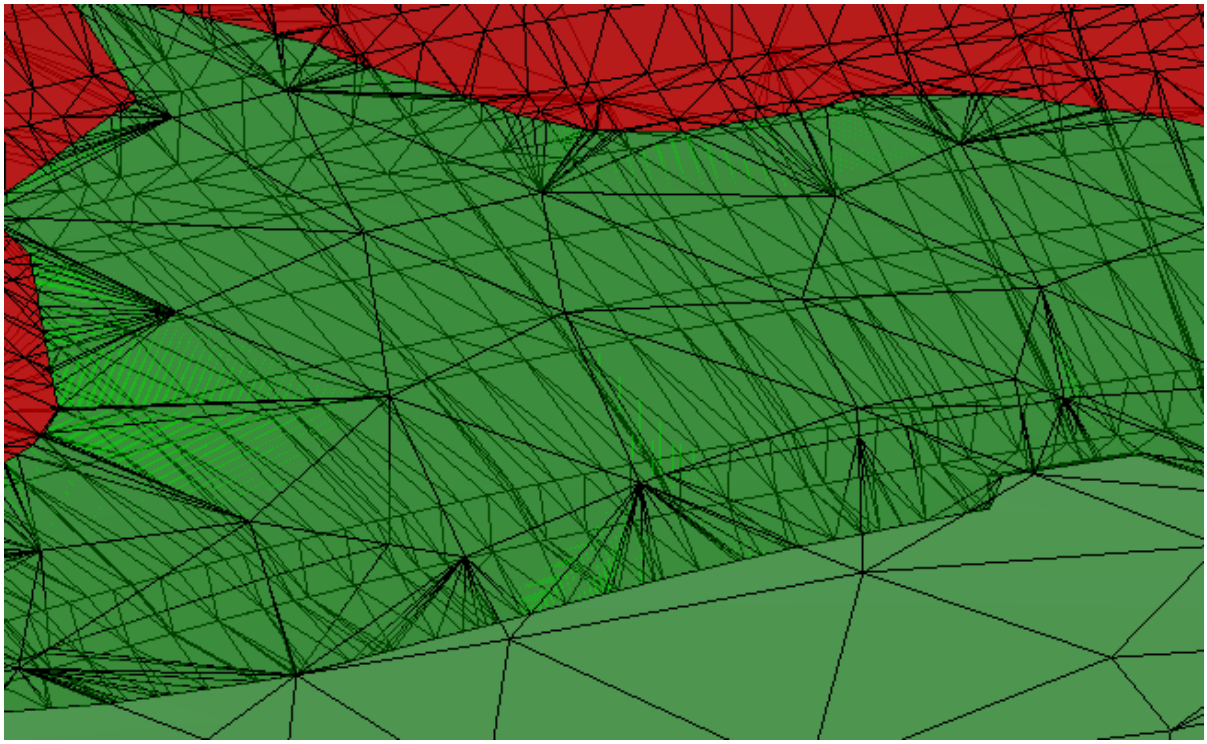
- In the properties dialog set the override symbology to YES



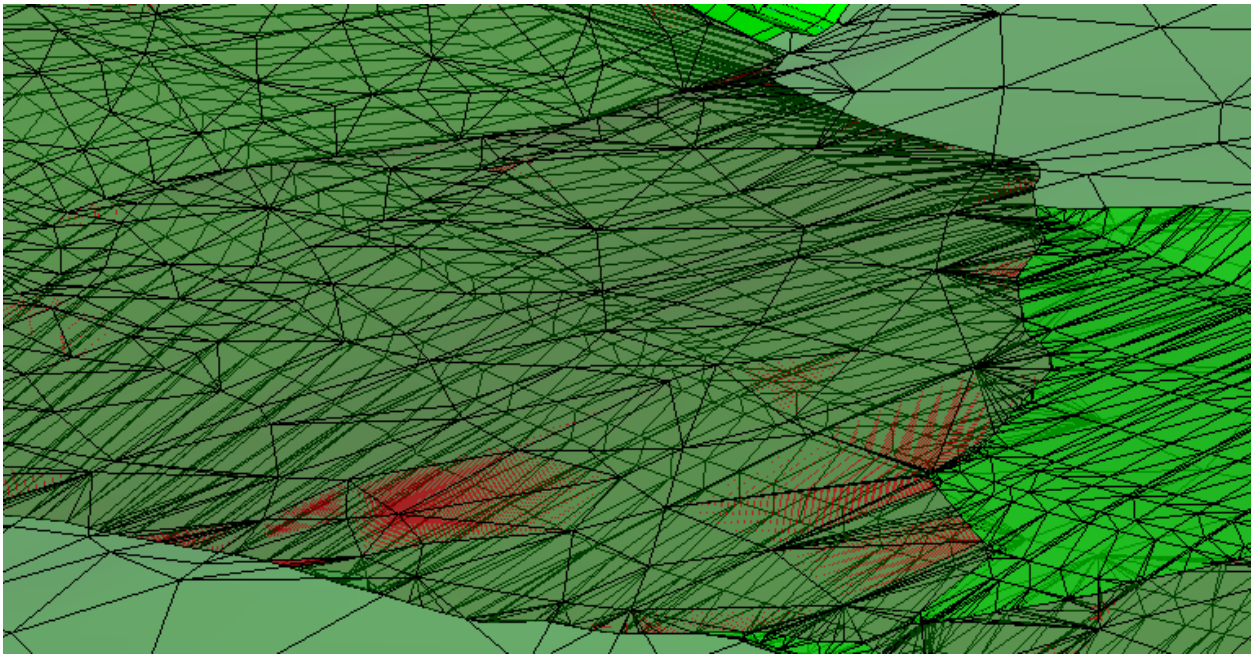
- Set the Override Template to ET_Traingles



J. With the triangles displayed the designer can use the Zoom and Rotate view function to review how the shapes match to the existing terrain.
   - By looking down from the top we can see the dark green matches the top of lighter green cut volume



- By rotating the view to review from underneath the model we can see that the dark green shape matches the bottom red fill volume

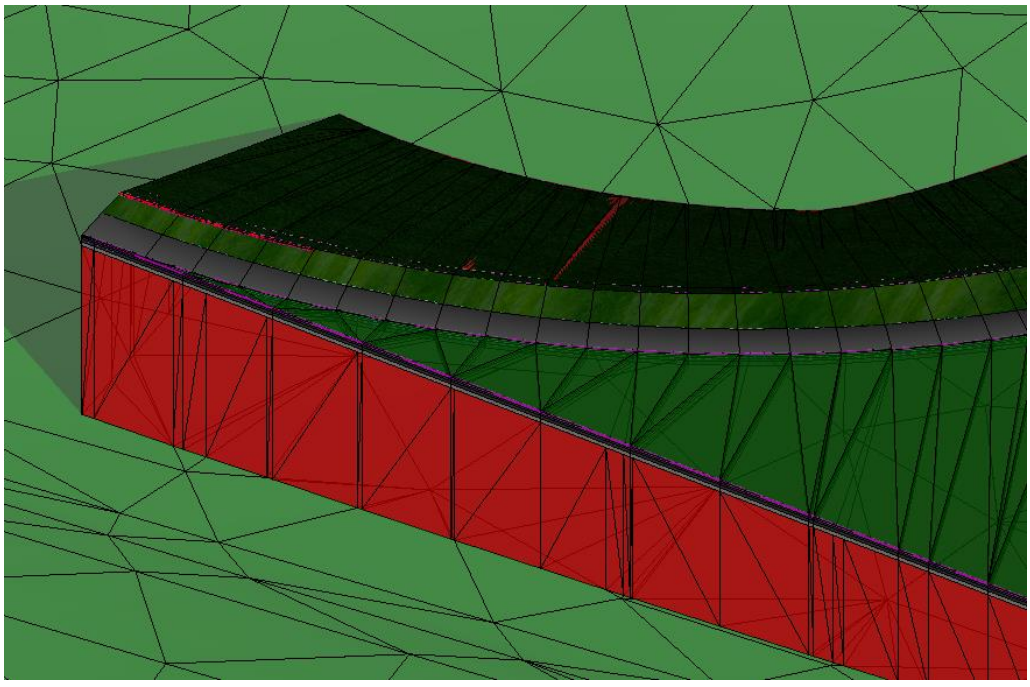


- This is what we would expect from both of these volumes.

K. The final Visual check is to review the 3D earthwork Volumes against the proposed model.
   - Make sure the 3D view is active by selecting the window.
   - In the reference dialog turn on all the references, this should include the proposed model.
     1. R-2635C_RDY_CMD_RPY18A.dgn

Slot		File Name	Model	Description	Logical
1	✓	..\..\Final Survey\R-2635C_NCDOT_FS.dgn	Existing Terrain...	Aligned with Master ...	Ref
2	✓	..\Alignment\R-2635C_RDY_ALG_RPY18A.dgn	Default-3D	Master Model	Ref-1
3	✓	R-2635C_RDY_CMD_RPY18A.dgn	Default-3D	Master Model	Ref-2
4	✓	R-2635C_HYD_CMD_RPY18A_DITCH.dgn	Default-3D	Master Model	Ref-3

   - By reviewing the 3D view using the same Zoom and Rotate tools we can see that the proposed model does match the 3D Earthwork Volumes. It is obvious that any discrepancies would be easily spotted.

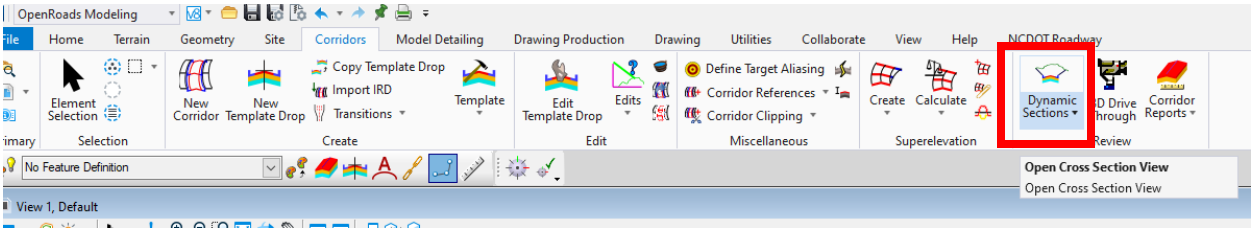


L. Just through a simple visual inspection the designer can have a high level of confidence that the earthwork volumes have been calculated correctly.

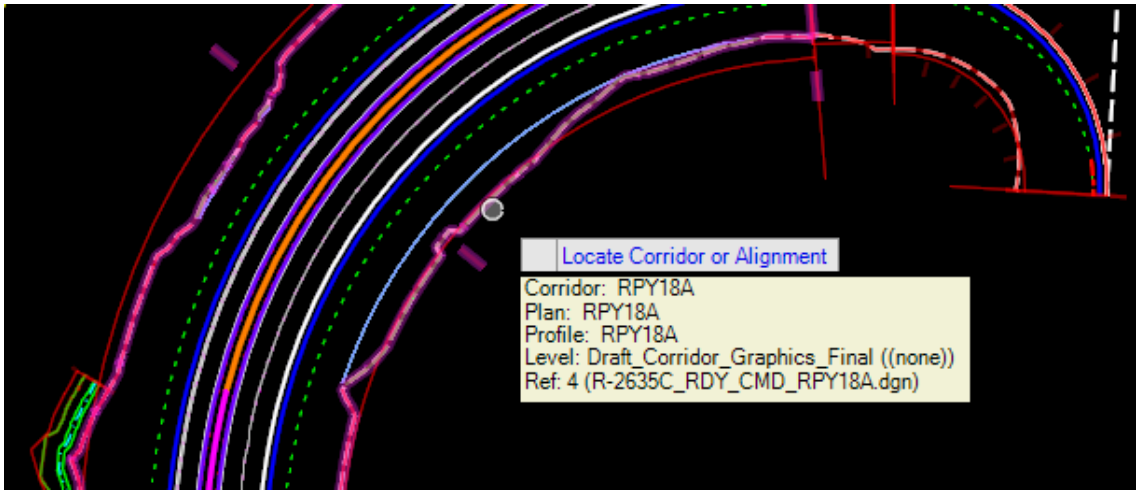
2. Earthwork Check – Review the Dynamic Sections

A. Open the Dynamic Section View

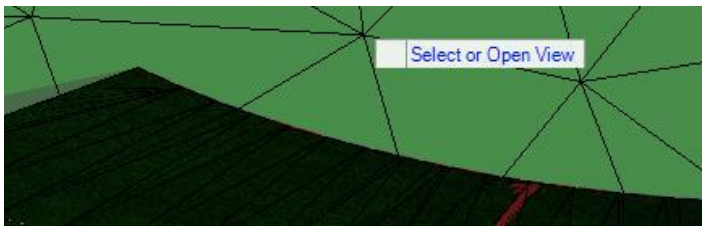
- Use the Dynamic Section tool in the OpenRoads Modeling workflow and the Corridors tab in the Review Section.



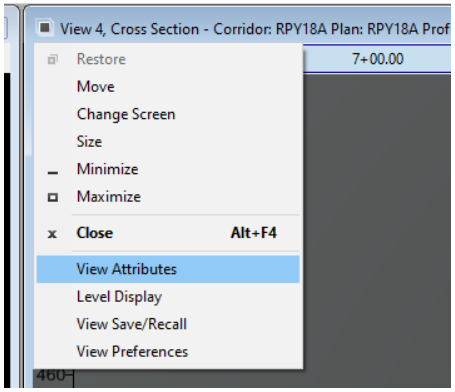
- The tool provides an option to select the Corridor or Alignment. The Cut and Fill areas and volumes are only displayed if the Corridor Option is used at this step.



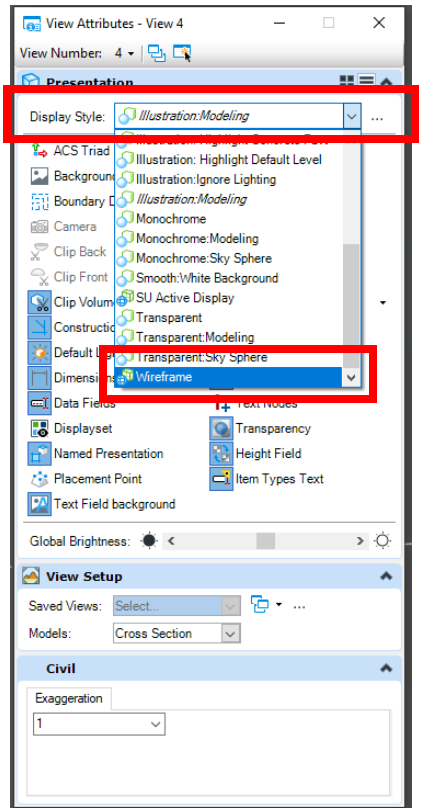
- After the corridor is selected the prompt will be to click in an open window. Left click in the Default 3D view to display the dynamic cross sections.



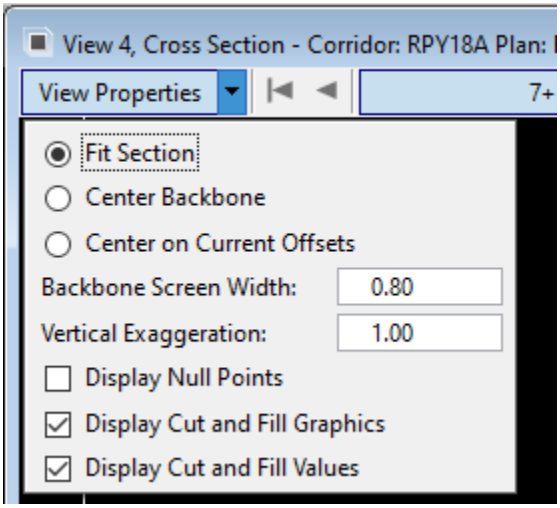
- Note the view style will still be set to Illustration Modeling and it is probably easier to review the sections using the wireframe mode. Select View Attributes from the top left corner, in this view it will be the box to the left of the view name.



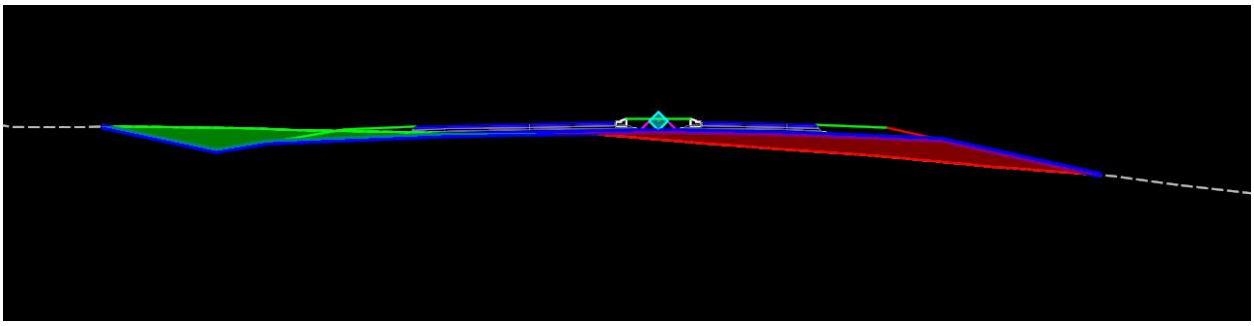
- In the dialog box set the display style back to Wireframe



- Under View Properties Select
  1. Display Cut and Fill Graphics
  2. Display Cut and Fill Values

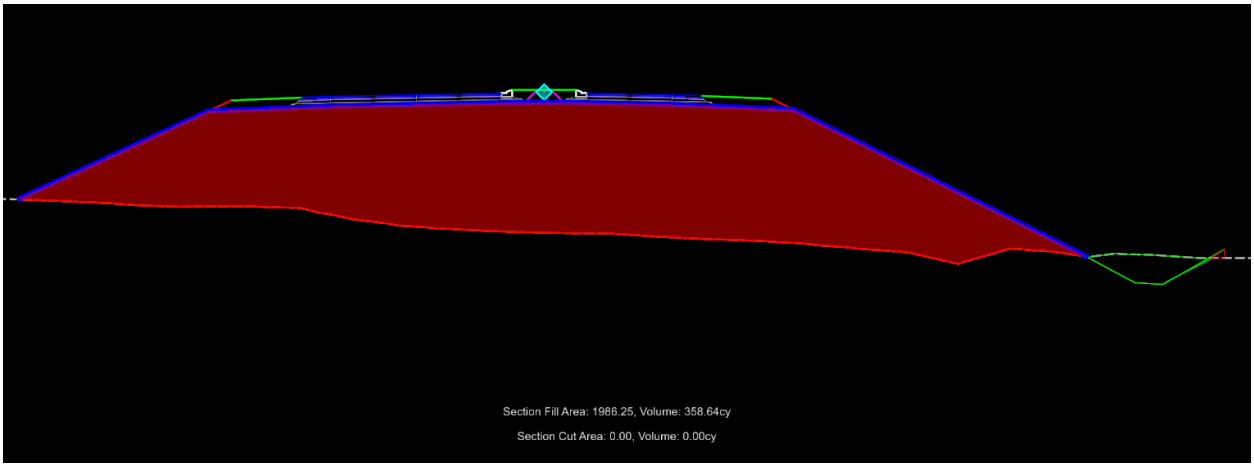


- This will display filled shaped on the cross section view, red for fill and green for cut.

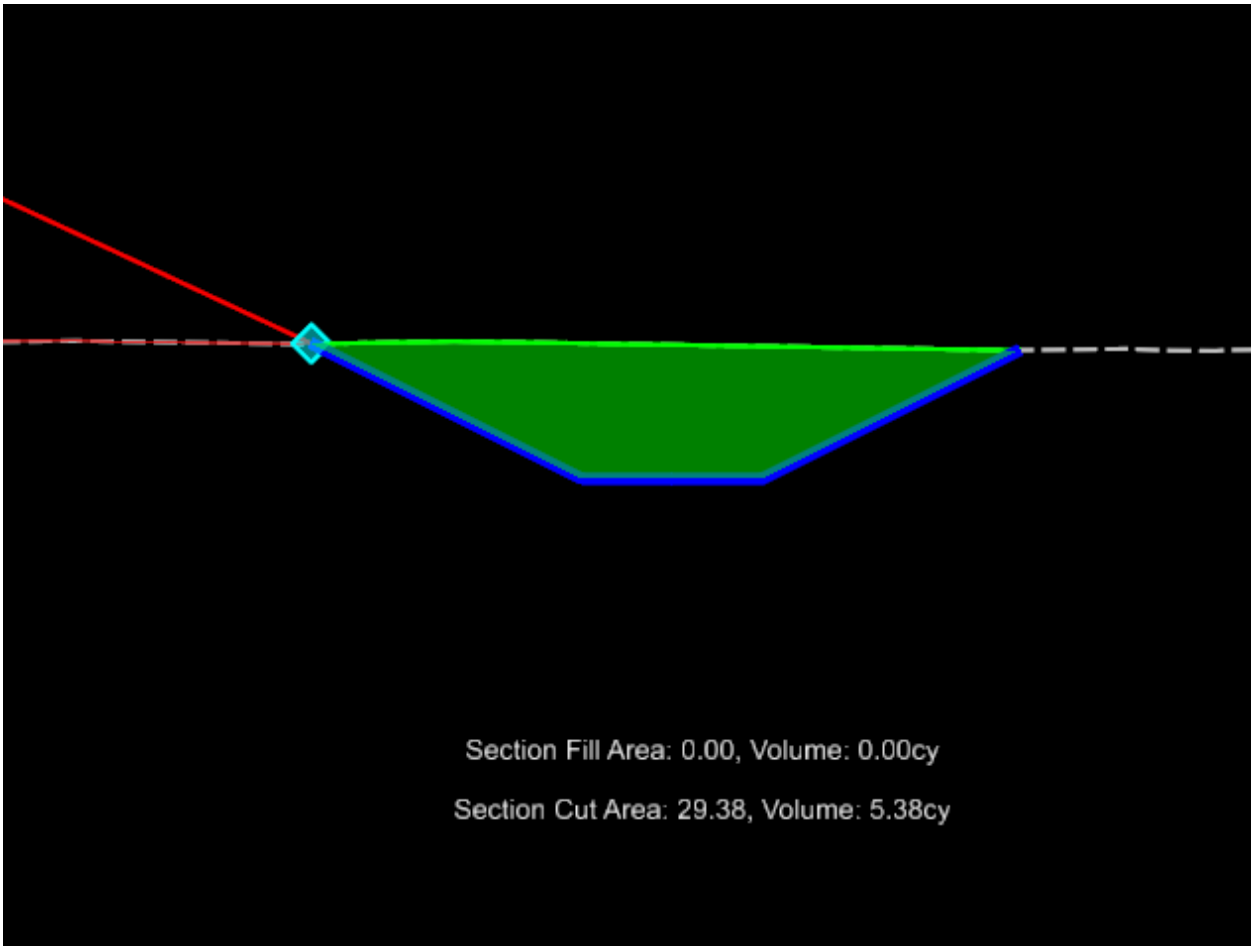


- It will also display the Area for each shape and the Volume. The volume computed is the Average End Area method using the current section and the previous section.

- By using the navigator and reviewing the sections for a corridor the designer can easily see if a shape does not match the proposed or existing surface.
- Note that this method only displays the volumes for the selected corridor. At this section the ditch should be included as UCE but it is not showing, there is no shape and the Cut Area is shown as 0.00.

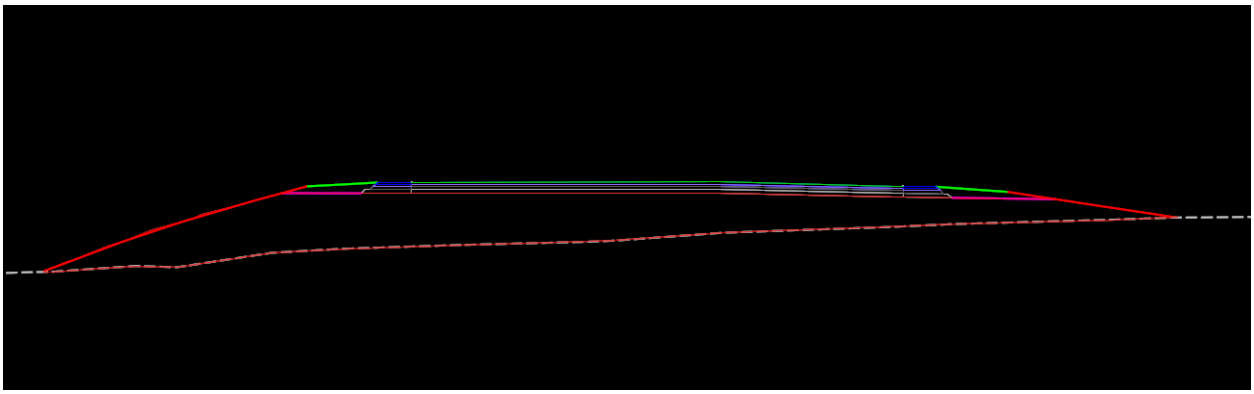


- By restarting the Dynamic Section view and selecting the ditch corridor the designer can see the volumes have been computed correctly.



- Any areas that include detailed modeling and separate corridors will have to be viewed separately.

- Another limitation of this method is that detailed areas that are modeled with surface templates are not corridors and cannot be reviewed. To see dynamic sections of an area that has been modeled with surface templates the Alignment must be selected as the base option. This will display an outline where the 3D volume has been created, it won't be shaded and the Areas and Volumes will not be displayed but it can be reviewed for any possible errors.

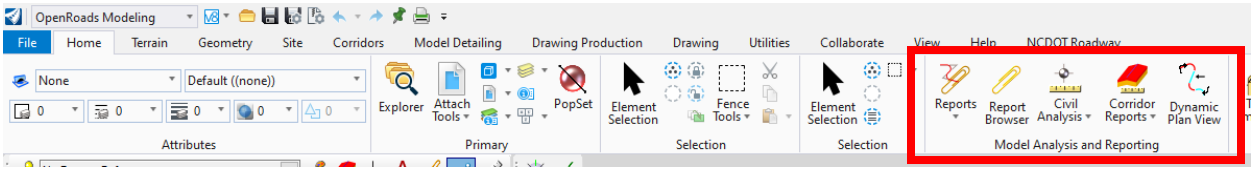


3. Earthwork Check – Component Quantities

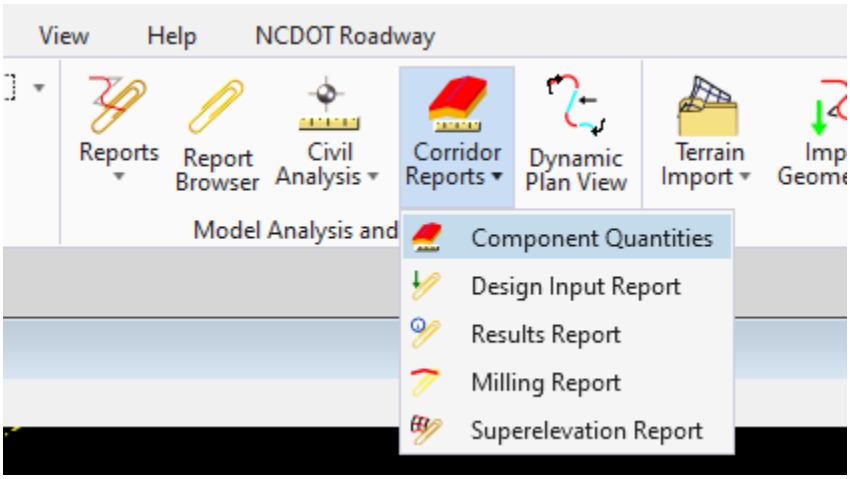
A. Component Quantities can be reported out for any corridor but have some limitations.
- The quantities are only reported for a single corridor at a time, if the project is composed of multiple corridors they will have to be reported individually.
- The quantities are reported for the entire corridor, they cannot be broken at summary stations or for left and right volumes.
- The quantities use the average end are method, this can cause significant issues at grade separation because the section before and after the bridge could be averaged together if the corridor has not been carefully constructed.
- Component quantities cannot be used on areas that have been modeled with surface templates

B. Component quantities also have some benefits
- Not only does this tool report the earthwork but it will also report other quantities and surface areas
- The tool can provide a quick estimate of earthwork volumes during design without the need for additional files or steps

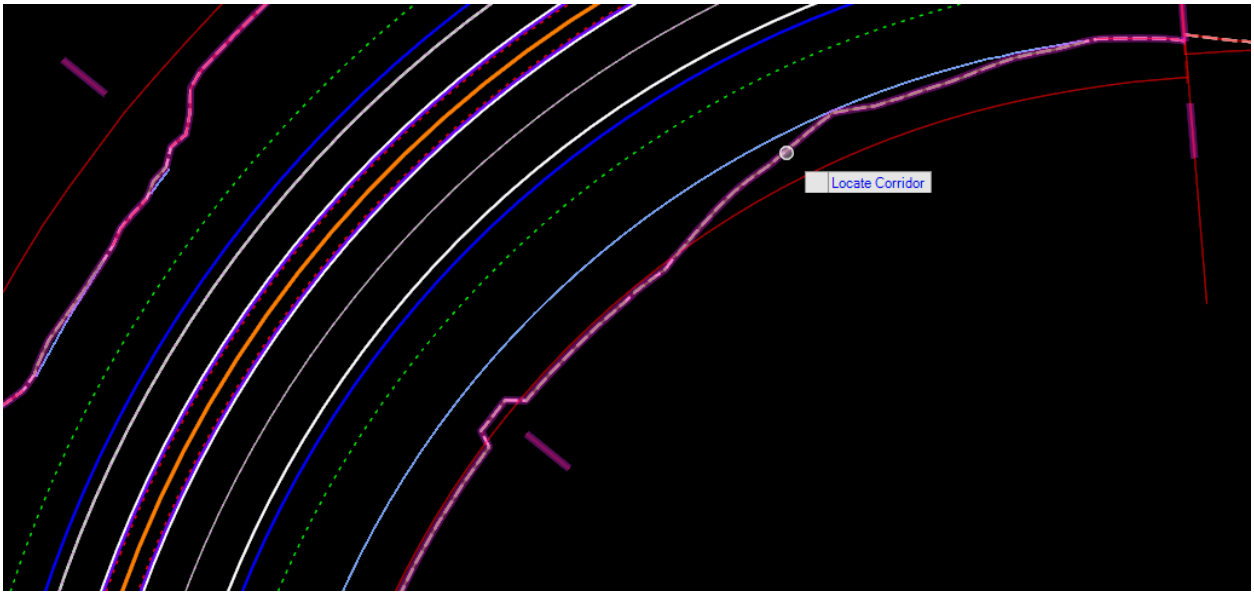
C. Report the Component Quantities for a corridor
   - Under the OpenRoads Modeling workflow find the Home Tab and the Model Analysis and Reporting Section.



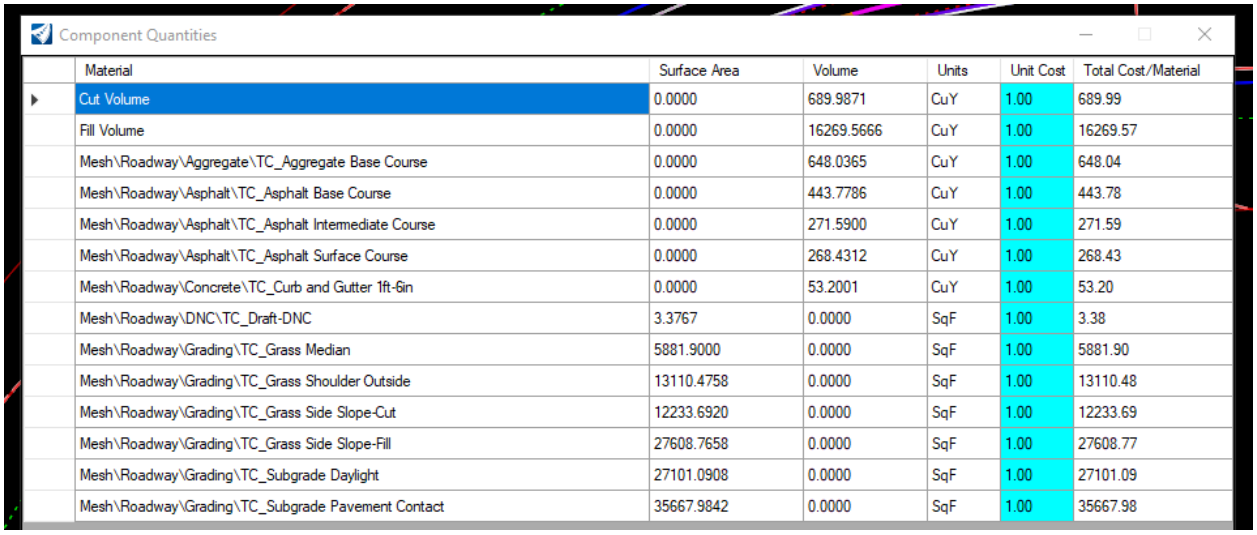
   - Under the Corridor Reports dropdown find the Component Quantities tool



- At the prompt select the corridor, the easiest way to pick the corridor is to left click on the slope stake line.



- This will generate a report of all the components from the corridor. Closed components will report a volume and other components will report a surface area.



Component Quantities

Material	Surface Area	Volume	Units	Unit Cost	Total Cost/Material
Cut Volume	0.0000	689.9871	CuY	1.00	689.99
Fill Volume	0.0000	16269.5666	CuY	1.00	16269.57
Mesh\Roadway\Aggregate\TC_Aggregate Base Course	0.0000	648.0365	CuY	1.00	648.04
Mesh\Roadway\Asphalt\TC_Asphalt Base Course	0.0000	443.7786	CuY	1.00	443.78
Mesh\Roadway\Asphalt\TC_Asphalt Intermediate Course	0.0000	271.5900	CuY	1.00	271.59
Mesh\Roadway\Asphalt\TC_Asphalt Surface Course	0.0000	268.4312	CuY	1.00	268.43
Mesh\Roadway\Concrete\TC_Curb and Gutter 1ft-6in	0.0000	53.2001	CuY	1.00	53.20
Mesh\Roadway\DNC\TC_Draft-DNC	3.3767	0.0000	SqF	1.00	3.38
Mesh\Roadway\Grading\TC_Grass Median	5881.9000	0.0000	SqF	1.00	5881.90
Mesh\Roadway\Grading\TC_Grass Shoulder Outside	13110.4758	0.0000	SqF	1.00	13110.48
Mesh\Roadway\Grading\TC_Grass Side Slope-Cut	12233.6920	0.0000	SqF	1.00	12233.69
Mesh\Roadway\Grading\TC_Grass Side Slope-Fill	27608.7658	0.0000	SqF	1.00	27608.77
Mesh\Roadway\Grading\TC_Subgrade Daylight	27101.0908	0.0000	SqF	1.00	27101.09
Mesh\Roadway\Grading\TC_Subgrade Pavement Contact	35667.9842	0.0000	SqF	1.00	35667.98

- Cut and Fill is always reported as a volume. It is critical to be aware of how component quantities work, Average End Areas, and what they are reporting, quantities from a single corridor.

4. Earthwork Check – End Area Volume Report

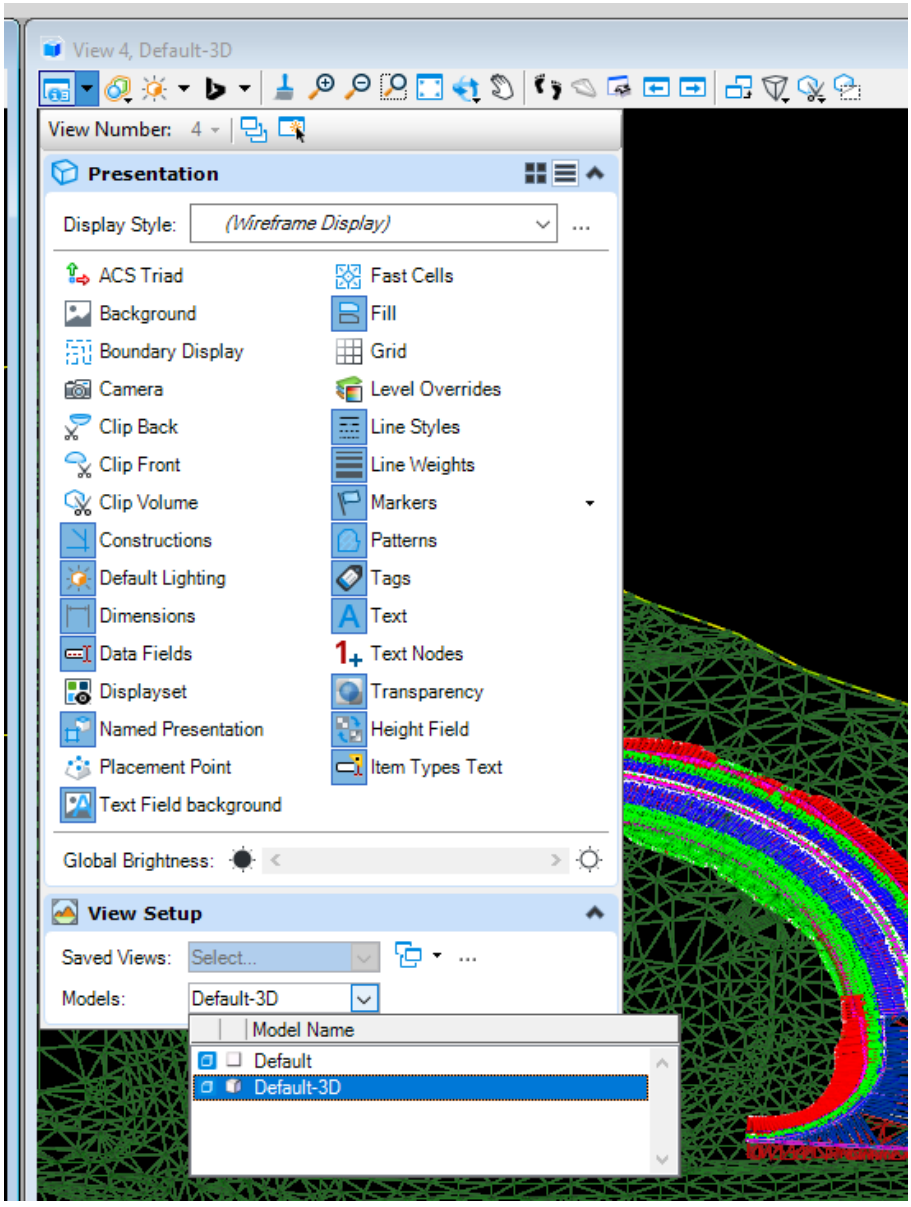
A. This method matches the End Area Volume calculations that have been done in the past.

B. This tool must be used in a file that has the following elements either in the Active File or attached as a reference.
   - Existing Terrain Model
   - Earthwork Volume Shapes
   - Cross Section Named Boundaries

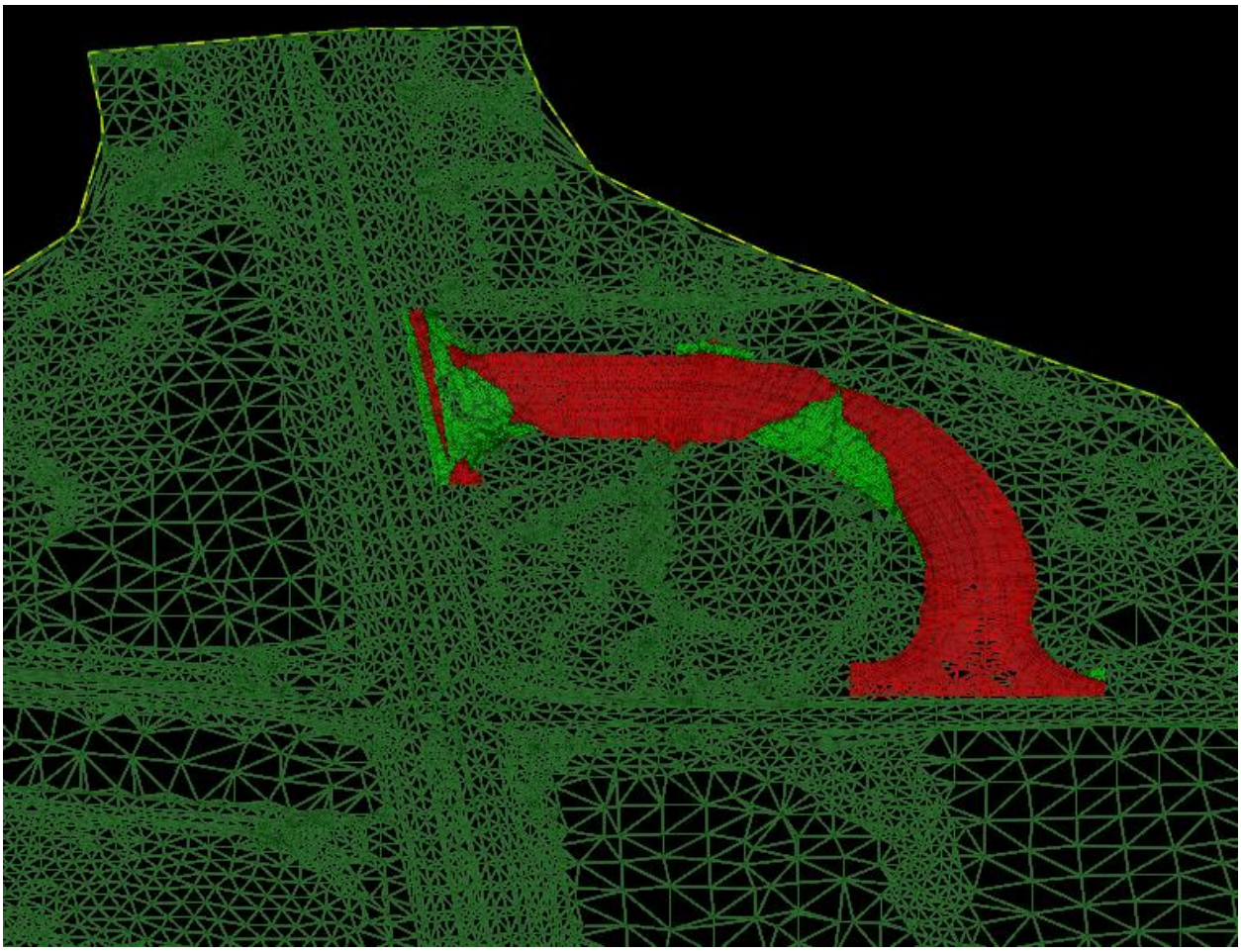
C. The best file to use this tool is likely the file that contains the 3D Earthwork Volume Shapes
   - R-2635C_RDY_EAR_RPY18A.dgn
   - It's not necessary to create a separate file because no elements are created with this tool
   - It could be done in the Cross Section Named boundary file but 3D Earthwork volumes should not be attached to the cross sections so that file would have to be attached and detached for each run.

D. Open the earthwork shape file : R-2635C_RDY_EAR_RPY18A.dgn

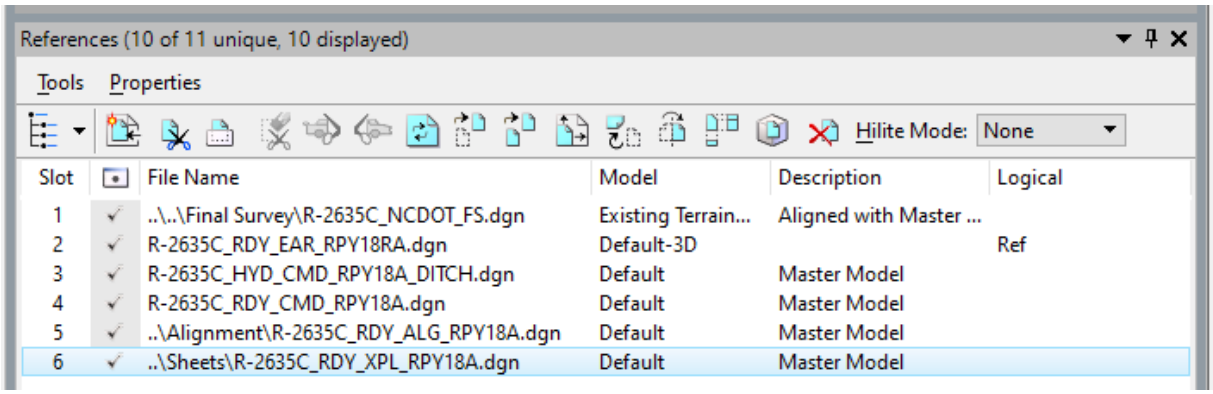
E. At least one view should be the Default 3D view. That selection can be activated under the View Attributes drop down dialog in the top left corner of the view window.



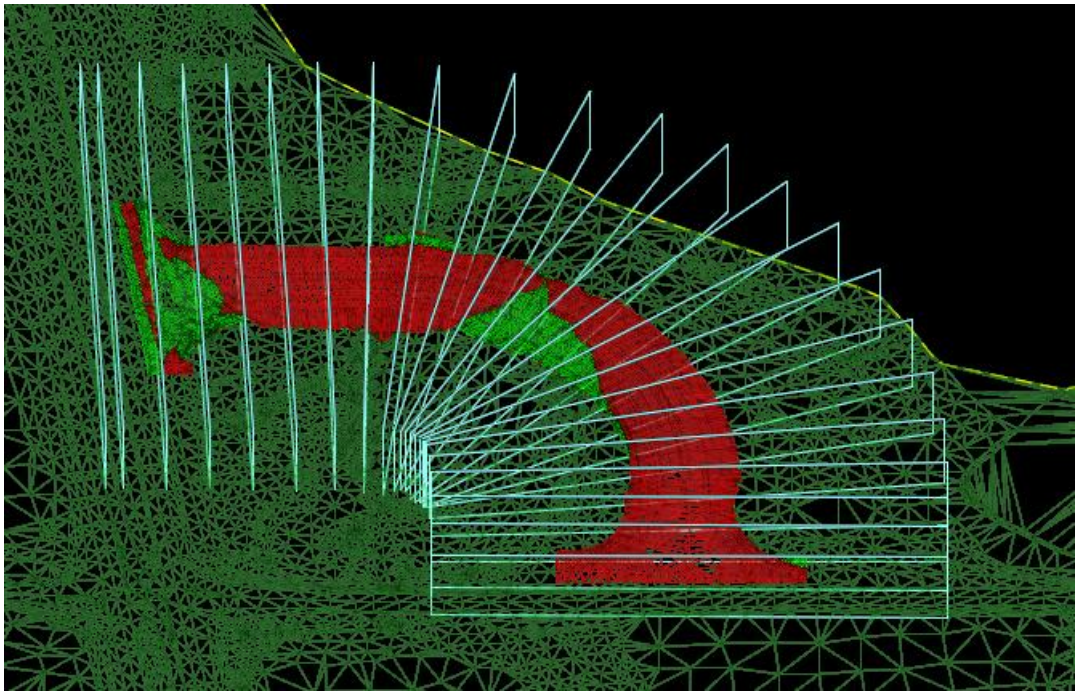
F. The 3D view should have the 3D earthwork volumes in the Active file and the Existing terrain reference should be on. The display setting of the existing terrain do not matter. Any additional references can be off or on it does not matter.



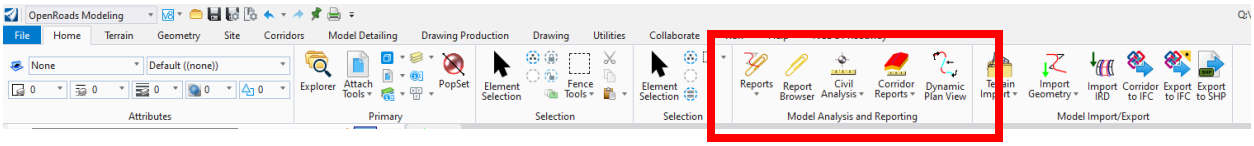
G. Make the default view active by clicking in the window. In the reference dialog attach the Cross Section Named Boundary file
   - ….\R-2635C\Roadway\Sheets\R-2635C_RDY_XPL_RPY18A.dgn
   - It is not necessary to detach any additional reference files



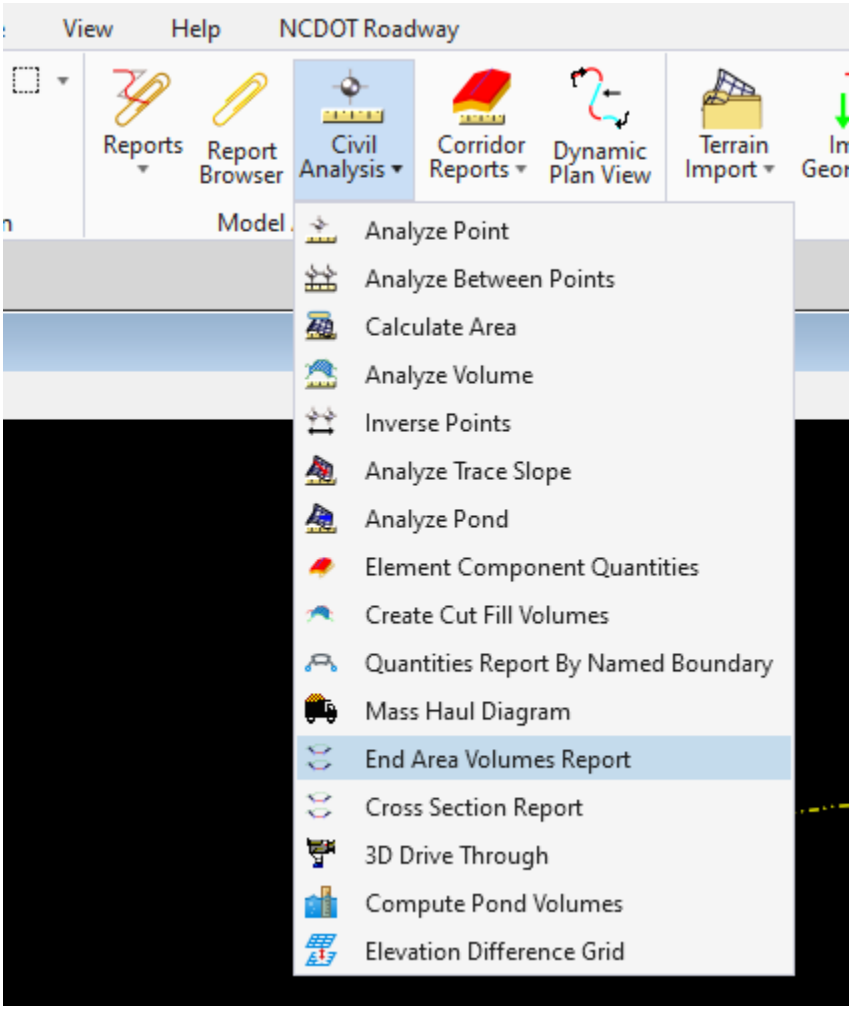
H. The cross section named boundaries now appear in the default 3D view, note that these do not have a default view associated with them and will not show in the default model unless the default 3D reference is on.



I. Switch to the OpenRoads Modeling workflow and the home Tab find the Model Analysis and Reporting Section.



J. Under the Civil Analysis tool group find the End Area Volumes Report tool.

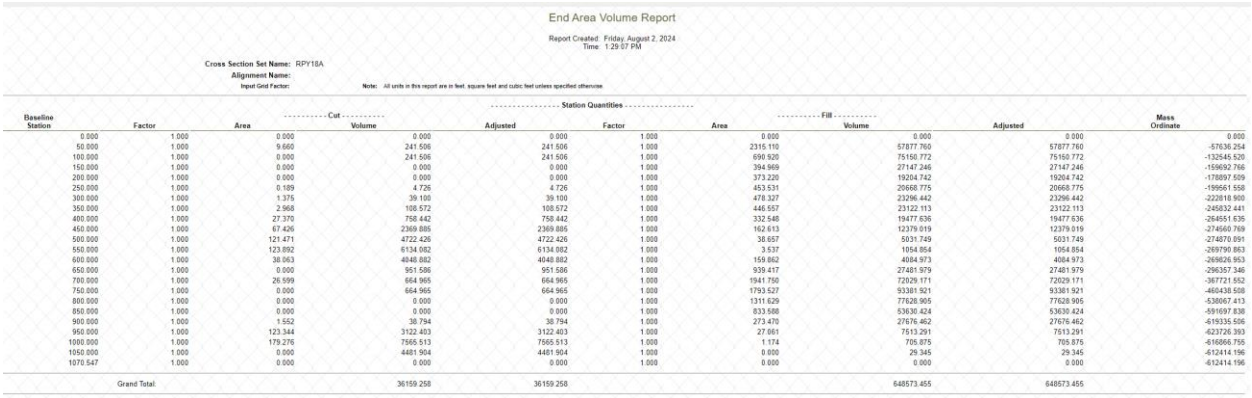


K. The dialog will prompt to select the named boundary group. Select the appropriate group, is only one set of cross section named boundaries is selected it will default to this group. Left click to confirm the selection.

L. The next dialog box asks for a selection for the first named boundary for volume exception. This dialog is slightly misleading if not completely understood. This is asking for the first section to OMIT or Leave Out of the Volume Calculation. For Example, a Begin Bridge cross section. If a cross section is selected here the dialog will ask for the last cross section for the volume exception. This would be where to Start the End Area Volume calculation again, for example an end bridge cross section. If the user mistakenly selected the First and Last cross section then no End Area Volumes would be reported.

Reset to skip this dialog by right clicking in the window.

M. At this point the End Area Volume Report Window will be generated. This is a very familiar format that shows the Station, Cut and Fill Areas, and Cut and Fill Volumes.



End Area Volume Report

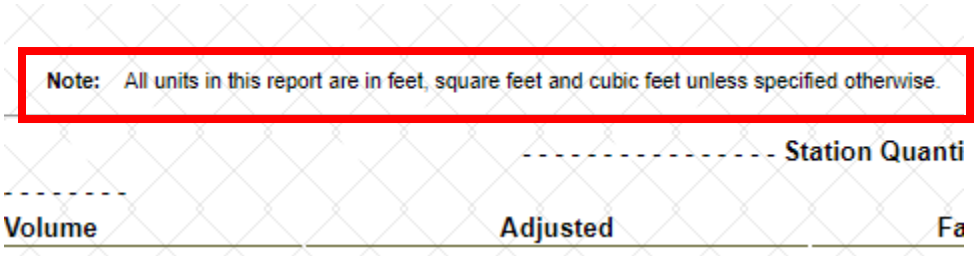
Report Created: Friday, August 2, 2024
Time: 1:29:07 PM

Cross Section Set Name: RPY18A
Alignment Name:
Input Grid Factor:

Note: All units in this report are in feet, square feet and cubic feet unless specified otherwise.

Baseline Station	Station Quantities									Mass Ordinate
	Cut					Fill				
	Factor	Area	Volume	Adjusted	Factor	Area	Volume	Adjusted		
0.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000		0.000
50.000	1.000	9.660	241.506	241.506	1.000	2315.110	57877.760	57877.760		-57636.254
100.000	1.000	0.000	241.506	241.506	1.000	690.920	75150.772	75150.772		-132545.520
150.000	1.000	0.000	0.000	0.000	1.000	394.969	27147.246	27147.246		-159692.766
200.000	1.000	0.000	0.000	0.000	1.000	373.220	19204.742	19204.742		-178897.509
250.000	1.000	0.189	4.726	4.726	1.000	453.531	20668.775	20668.775		-199561.558
300.000	1.000	1.375	39.100	39.100	1.000	478.327	23296.442	23296.442		-222818.900
350.000	1.000	2.968	108.572	108.572	1.000	446.957	23122.113	23122.113		-245832.441
400.000	1.000	27.370	758.442	758.442	1.000	332.548	19477.636	19477.636		-264551.635
450.000	1.000	67.426	2369.886	2369.886	1.000	162.613	12379.019	12379.019		-274560.769
500.000	1.000	121.471	4722.426	4722.426	1.000	38.657	5031.749	5031.749		-274870.691
550.000	1.000	123.892	6134.082	6134.082	1.000	3.537	1054.854	1054.854		-269790.863
600.000	1.000	38.063	4048.882	4048.882	1.000	159.862	4084.973	4084.973		-269826.953
650.000	1.000	0.000	951.586	951.586	1.000	939.417	27481.979	27481.979		-296357.346
700.000	1.000	26.599	664.965	664.965	1.000	1941.760	72029.171	72029.171		-367721.552
750.000	1.000	0.000	664.965	664.965	1.000	1793.527	93381.921	93381.921		-460438.508
800.000	1.000	0.000	0.000	0.000	1.000	1311.629	77628.905	77628.905		-538067.413
850.000	1.000	0.000	0.000	0.000	1.000	833.586	53630.424	53630.424		-591697.838
900.000	1.000	1.552	38.794	38.794	1.000	273.470	27676.462	27676.462		-619335.506
950.000	1.000	123.344	3122.403	3122.403	1.000	27.061	7513.291	7513.291		-623726.393
1000.000	1.000	179.276	7565.513	7565.513	1.000	1.174	705.875	705.875		-616866.755
1050.000	1.000	0.000	4481.904	4481.904	1.000	0.000	29.345	29.345		-612414.196
1070.547	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000		-612414.196
Grand Total:			36159.258	36159.258			648573.455	648573.455		

N. Pay close attention to the units, these are noted on the report in the middle just above the table.

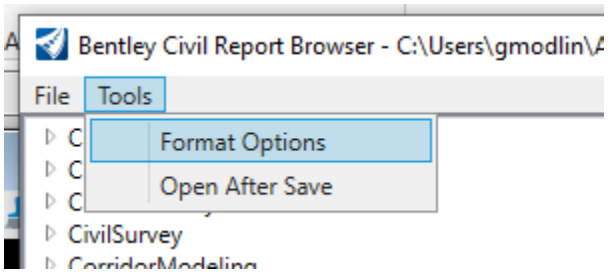


Note: All units in this report are in feet, square feet and cubic feet unless specified otherwise.

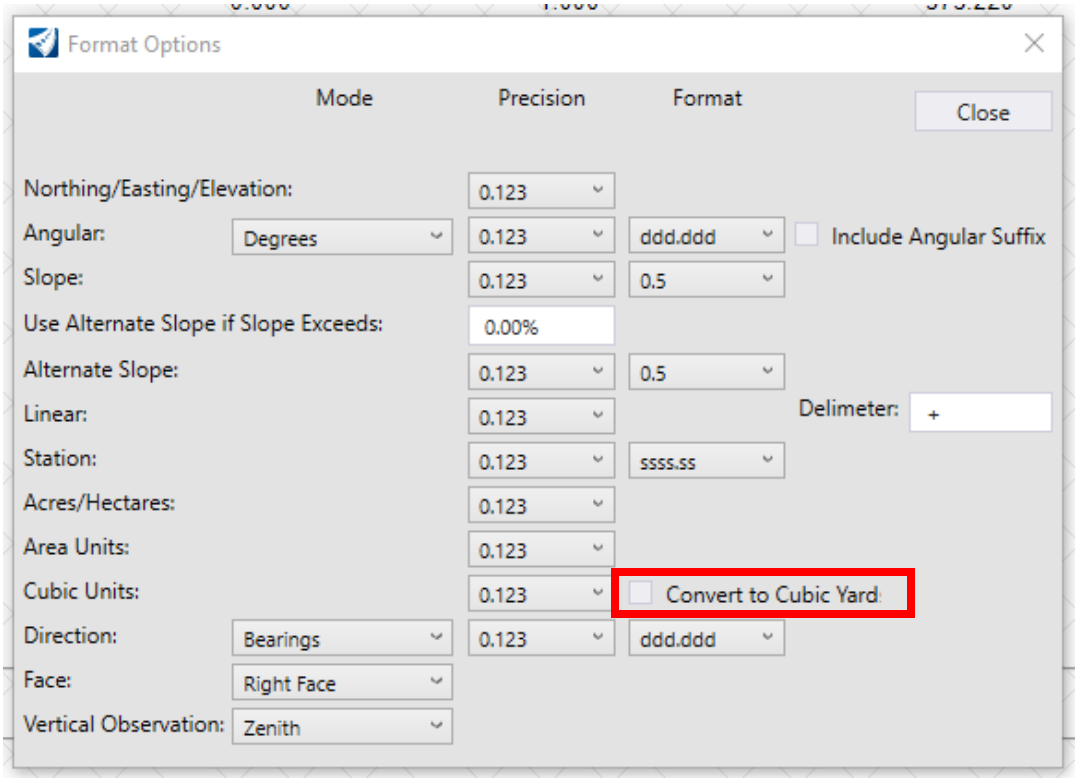
Station Quanti

Volume Adjusted Fa

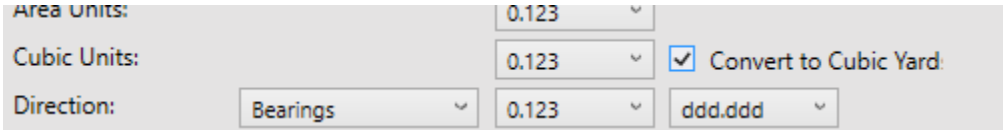
O. Units can be changed without redoing the report. From the top left of the dialog window select Tools – Format Options.



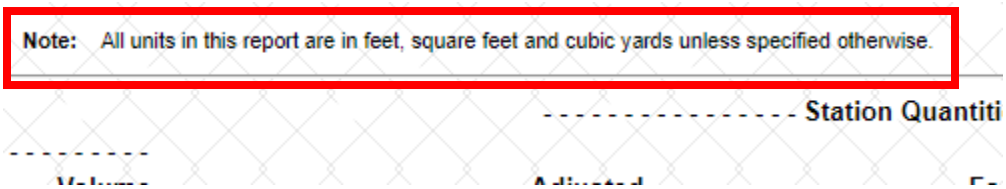
P. This will display all the available formatting options.



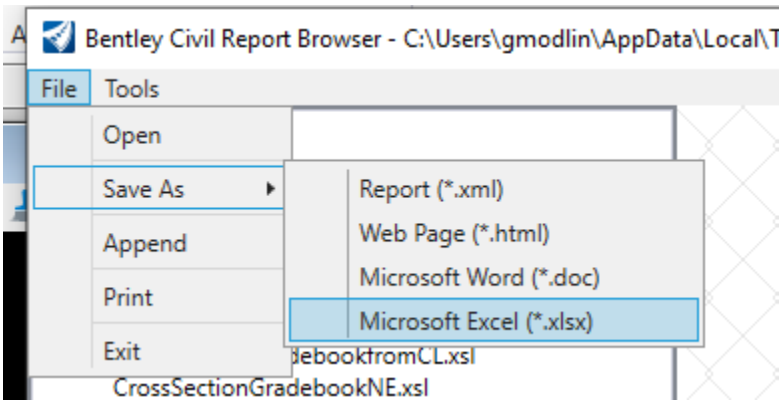
Q. On the Cubic Units line select the check box Convert to Cubic Yards



R. The volume units are now displayed in cubic yards.



S. This report can be saved in various format including Excel for additional review if desired.



5. Accuracy Review

A. A comparison of the various methods reveals the accuracy expected during a review and verification of the Earthwork Volumes. All Volumes below are for RPY18A

B. Cut Volume

- Prismoidal = 1,204.06 CY
- Component Quantities = 1,183.29 CY
  1. (-) 1.7% of Prismoidal
  2. Does not include the intersection areas modeled with surface templates
  3. Includes DDE from the ditch corridors
  4. Would be closer for models that only included corridors and no detailed modeling
- End Area Volume Report = 1,339.23 CY
  1. (+) 11.2% of Prismoidal
  2. Does not account for irregular areas not displayed on cross section
  3. Accuracy could be improved by increasing cross section density

C. Fill Volume

- Prismoidal = 24,477.29 CY
- Component Quantities = 20,470.03 CY
  1. (-) 16.4% of Prismoidal
  2. Does not include the intersection areas modeled with surface templates
  3. Would be closer for models that only included corridors and no detailed modeling
- End Area Volume Report = 24,021.24 CY
  1. (-) 1.9% of Prismoidal
  2. Does not account for irregular areas not displayed on cross section
  3. Accuracy could be improved by increasing cross section density

This shows that while the number cannot be verified directly and exactly that tools are available to determine with a reasonable amount of certainty that the Prismoidal volumes are correct as long as the designer understands the limitations and operation of the alternate methods.

This also shows the learning to navigate the DGN files and review the earthwork shapes visually is a key skill when reviewing earthwork calculations and assuring accuracy.

Exercise 7 – Deliverable to NCDOT

When submitting projects to NCDOT the following files and deliverables will be required for Earthwork Calculations and Documentation.

1. Prismoidal Volumes
   A. This will be a CADD files(s) containing the 3D Prismoidal Volumes representing the Project Earthwork. The Prismoidal Volumes are the Earthwork Volumes that should be included in the plans and the quantities.

2. Named Boundaries
   A. This will be a CADD File(s) containing the named boundaries used to separate the earthwork volumes. These boundaries will be developed in accordance with the Cost Based Estimate Qty Checklist and the NCDOT Roadway Design Manual.

3. Quantity Report by Named Boundaries
   A. This will be a report file that documents the Earthwork quantities based on the Prismoidal Volumes.

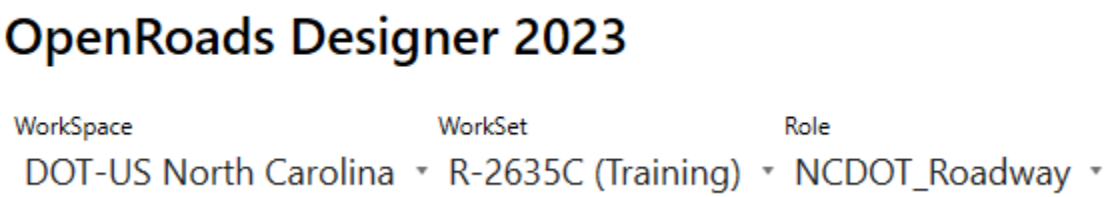
4. Earthwork Balance Card
   A. This is a spreadsheet that totals and documents the Project Earthwork Volumes.

5. End Area Volume Report
   A. This is an OpenRoads Report created from the proposed cross sections. This report will be used by NCDOT to check and verify the Model and the Quantities match the plans and the cross sections. This report is not a replacement for the Prismoidal Volumes.

The following documentation will show an example of each deliverable based on previously completed earthwork files.

Start by selecting the OpenRoads Designer 2023 Desktop Icon

The WorkSpace is DOT_US North Carolina
The WorkSet is R-2635C (Training)
The Role is NCDOT_Roadway



1. Deliverable - Prismoidal Volumes

A. The first deliverable consists of CADD file(s) that contain the 3d Prismoidal Volumes.

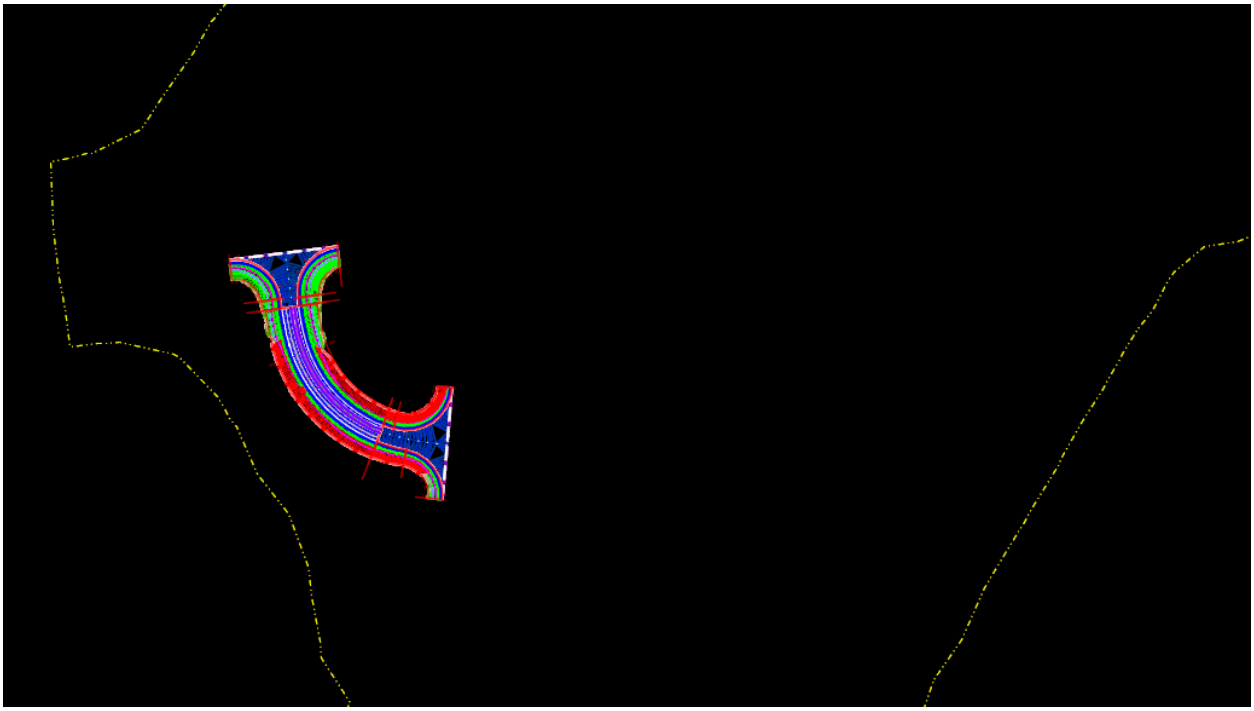
B. For this example we will use 3 corridors

- Y18
- RPY18A
- RPY18B

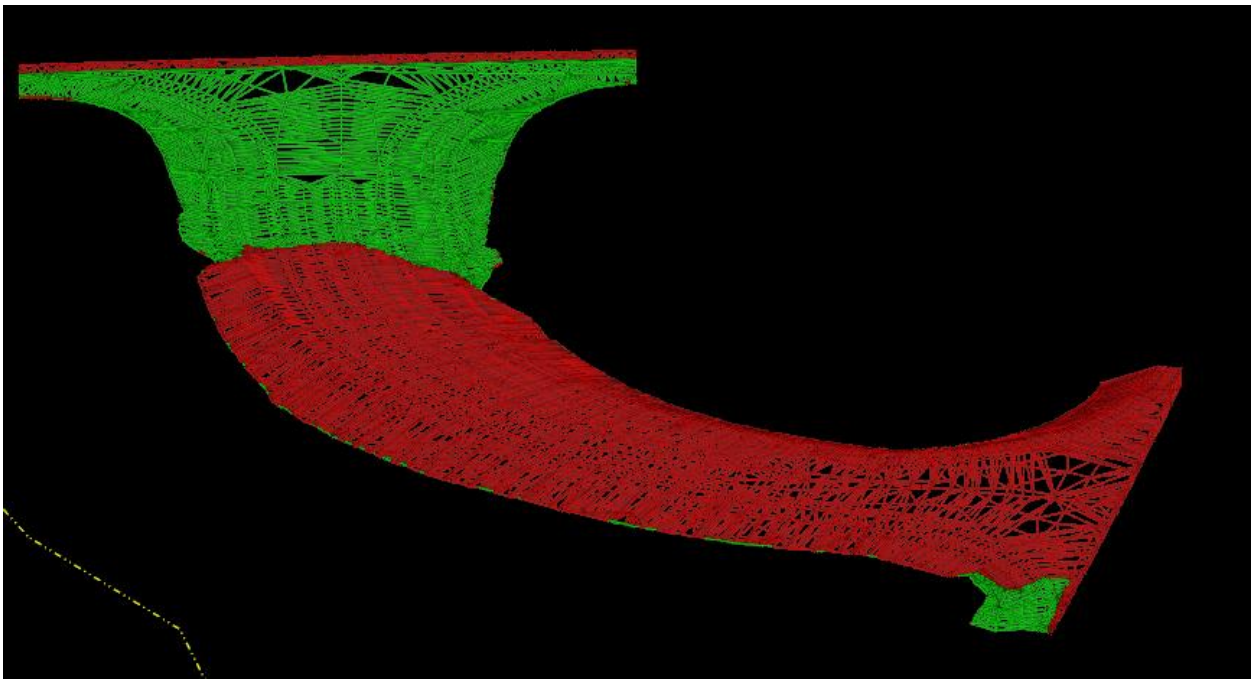
C. The workflow for creating the Prismoidal Earthwork Volumes has been covered extensively in this module. The Volumes for Y18 and RPY18A have already been created. The following abbreviated steps will be used to create the Prismoidal Volumes for RPY18B. For more detailed steps review the previous sections in this training module.

D. Create a new DGN File for the Earthwork Calculation

- R-2635C_RDY_EAR_RPY18B.dgn
- Use the 2D Seed File = Seed2D – English Design.dgn
- Attach the Existing Terrain from the R-2635C_NCDOT_FS.dgn file and Set Active
- Attach the Proposed Corridor R-2635C_RDY_CMD_RPY18B.dgn



E. Create the Prismoidal Volumes
   - On the Home Tab find the Model Analysis and Reporting Section
   - Under Civil Analysis find the Create Cut and Fill Volumes
   - Create the Cut and Fill Volumes and review the shapes for accuracy



F. There are now 3 CADD files containing the Prismoidal Volumes. This is the first part of the required deliverables.
   - R-2635C_RDY_EAR_Y18.dgn
   - R-2635C_RDY_EAR_RPY18A.dgn
   - R-2635C_RDY_EAR_RPY18B.dgn

2. Deliverable – Named Boundaries

A. The next part of the deliverables are the named boundaries. These are required to ensure that the Earthwork Breakdown meets NCDOT requirements.

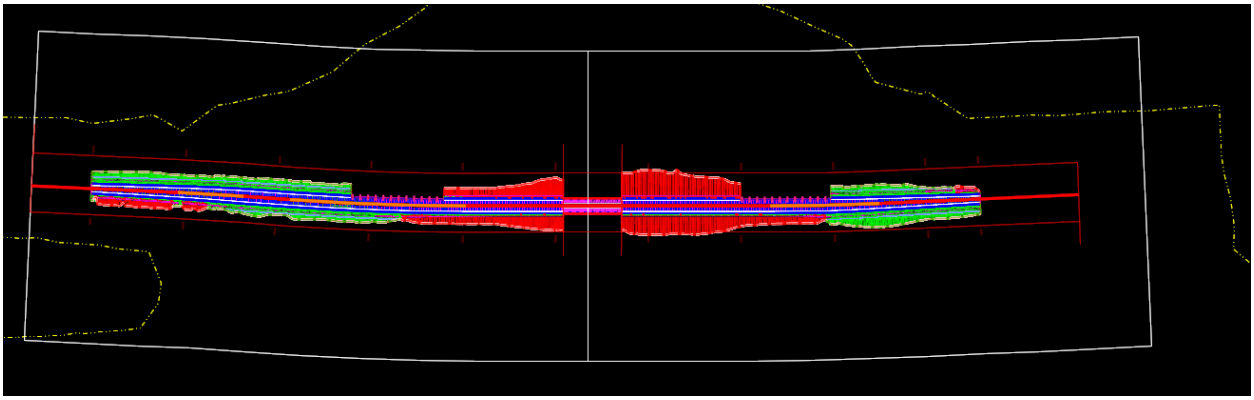
B. There are two sources of information for how to split the project earthwork.

- The Cost Based Estimate Quantity Breakdown
- This form is available on the NCDOT website under Contracts and resources
- Section 1 Earthwork, includes a checklist documenting the required breakdown for the project earthwork volumes.

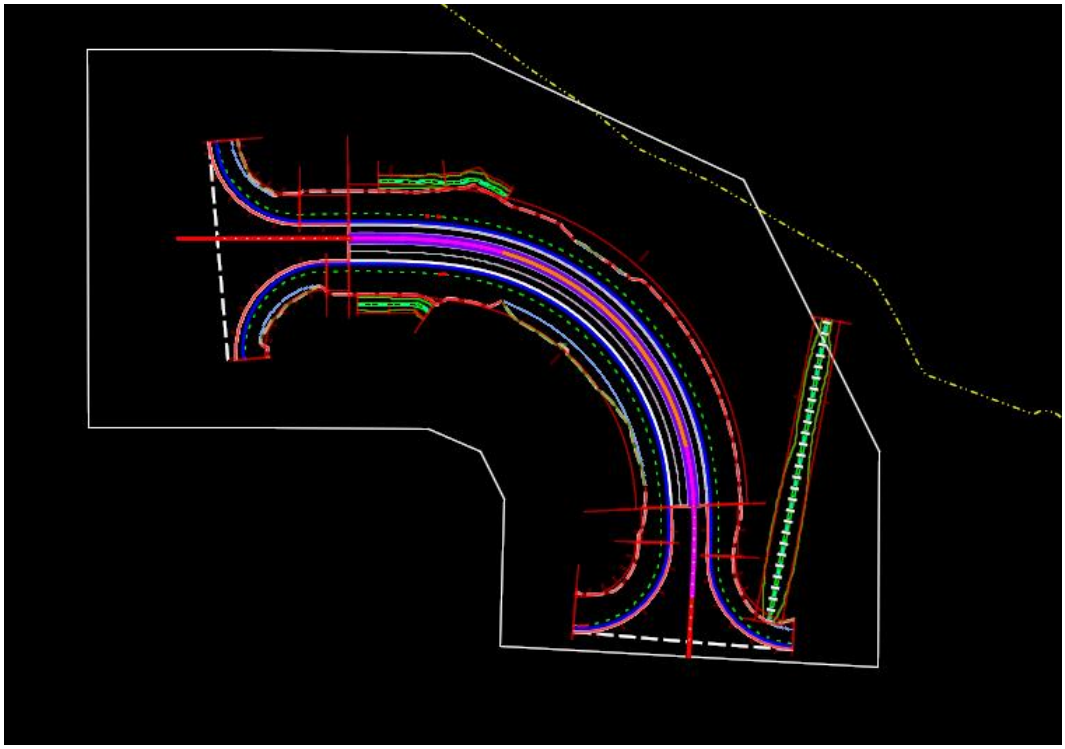
I	Earthwork		
	The earthwork summary in the plans has been prepared in accordance with the following guidelines:		
Yes	No	N/A	
____	____	____	a. Summary points do not exceed 3000'.
____	____	____	b. Summary points end / begin at each bridge (stream or grade separation).
____	____	____	c. Summary points end / begin near each major at-grade multi-lane intersection or
____	____	____	at-grade railroad crossing.
____	____	____	d. -Y- Lines are included in their respective summaries.
____	____	____	e. On widening projects separate summaries are provided for right and left sides.
____	____	____	f. On existing divided facilities to be widened separate summaries are provided for
			right side and median widening.

- The other resource for how to split earthwork volumes is in the NCDOT Roadway Design Manual.
  1. For the May 2024 of the NCDOT RDM this information is in Section 15.4.1.1 Earthwork Balance Sheet.

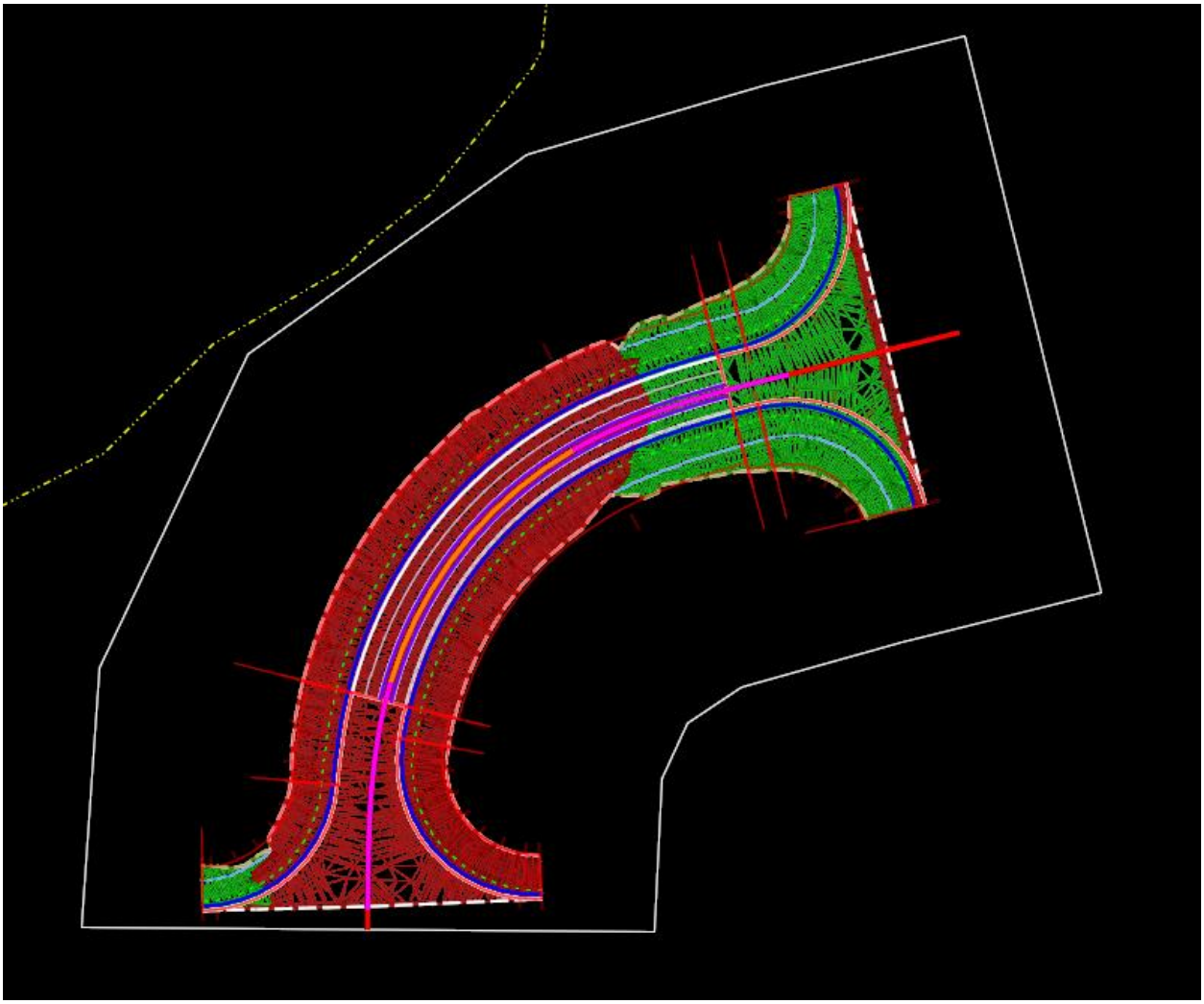
C. Place the named boundaries.
   - The named boundaries can be placed in the earthwork files or in separate files. For this example, we will place the named boundaries in the Earthwork Files.
   - The named boundaries for Y18 have already been placed in the earthwork file
     1. The File name is R-2635C_RDY_EAR_Y18.dgn
     2. The named boundaries were placed to split the earthwork at the grade separation based on NCDOT guidance.
     3. Review Exercise 2 for detailed steps on how to place these named boundaries.



- Add named boundaries for RPY18A
  1. All alignments/corridors will require a named boundary to generate the quantity report even if the earthwork is not broken into smaller sections
  2. Open R-2635C_RDY_EAR_RPY18A.dgn
  3. Select the Named Boundary Tool
     a. Using the Civil Plan option place a named boundary based on the RPY18A centerline.
     b. Adjust the Length and Offset as required to enclose the previously created earthwork volumes.
     c. Based on NCDOT requirements this corridor only requires 1 named boundary.

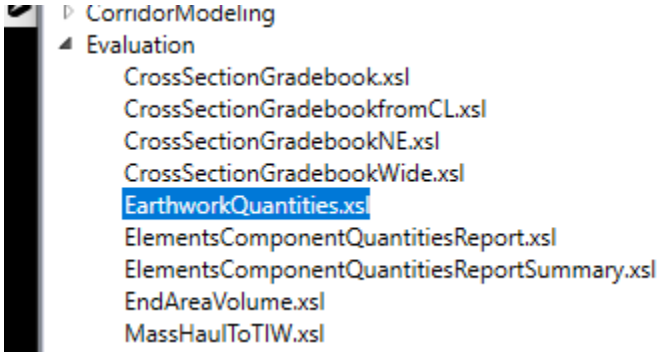


- Repeat this process for Y18RPB
  1. The Named Boundary should be placed in the R-2635C_RDY_EAR_RPY18B.dgn CADD file.
  2. Attach the alignment file R-2635C_RDY_ALG_RPY18B.dgn
  3. Use the Named Boundary Tool to place the Named Boundary
  4. Based on NCDOT requirements and guidelines this Alignment/Corridor only requires 1 Named Boundary.



3. Deliverable – Quantity Reports

A. The quantity reports based on the Plan View named boundaries are a deliverable and are the quantities that should be included in the plans and estimates.
B. The quantities in these reports will match the Prismoidal Volumes and will be broken down into sections based on NCDOT Requirements.
C. These quantities will be used to complete the Earthwork Balance Card.
D. For detailed steps see previous exercises, this workflow was covered in multiple sections throughout the Training Module.
E. Create the quantity reports for Y18
   - Open R-2635C_RDY_EAR_Y18.dgn
   - On the Home Tab in the Model Analysis and Reporting Section select the Quantities report By Named Boundary tool
   - Select the Earthwork Quantities.xsl Style Sheet



- This will display on the Cut and Fill Volumes

Cross Section Set Name: Y18
Alignment Name: Y18
Input Grid Factor: All units in this report are in feet, square feet and cubic yards unless specified otherwise.

Baseline Station	Cut Shrink/ Swell Factor	Station Cut Area	Station Cut Volume	Adjusted Station Cut	Fill Shrink/ Swell Factor	Station Fill Area	Station Fill Volume	Adjusted Station Fill	Mass Ordinate
2800.000	1.000		4931.217	4931.217	1.000		28827.349	28827.349	
			Station Total:	4931.217				28827.349	-23896.132
4600.000	1.000		5158.075	5158.075	1.000		61383.995	61383.995	
			Station Total:	5158.075				61383.995	-80122.052
	Grand Total:		10089.293	10089.293			90211.345	90211.345	

- Save the Report as an HTML Document named EAR_Y18.html. This is the report that will be a deliverable to NCDOT
- Note that the Baseline Station indicates the End Station of the Named Boundary not necessarily the Station where the project end or the earthwork break. In this example the Earthwork will be broken for the Bridge that Begins at 27+18 and Ends at 29+08. Because the earthwork shapes are only created based on the limits Roadway Model we don't necessarily have to break the named boundaries at the Begin or End of the bridge. For more explanation see the Section on Named Boundaries.
- For this example the Prismoidal Earthwork Volumes
  1. Y18 Sta 11+94 to 27+18
     a. Cut = 4,931 CY
     b. Fill = 28,827 CY
  2. Y18 Sta 29+08 to 40+64.91
     a. Cut = 5,158 CY
     b. Fill = 61,384 CY

- Repeat this process for RPY18A and RPY18B
  1. RPY18A Sta 5+20.01 to 15+28.12
     a. Cut = 1,204 CY
     b. Fill = 24,477 CY
  2. RYY18B Sta 5+19.70 to 12+69.09
     a. Cut = 10,925 CY
     b. Fill = 19,377 CY
- This completes the quantity reports and there should be 3 re
- port files saved in HTML format.
  1. EAR_Y18.html
  2. EAR_RPY18A.html
  3. EAR_RPY18B.html

4. Deliverable – Earthwork Balance Card

A. The Earthwork Balance Card is where the Raw Earthwork Volumes created from the Named Boundaries and Prismoidal Shapes are compiled and tabulated to determine the Contract Estimate Quantities.

B. The Final Earthwork Balance Card will include Geotechnical Quantities and recommendations that will also affect the totals.

C. For detailed instructions on how to complete an Earthwork Balance Card see Section 15.4.1 in the NCDOT Roadway Design Manual – Revision May 2024.

D. The completed Earthwork Balance Card for this project:

- Ther are 2 sections separated by the proposed bridge.

STATION	STATION
-Y18- 11+94	27+18
-RPY18B- 5+20	15+28
	SUBTOTAL
-Y18- 29+08	40+65
-RPY18A- 5+20	15+28

- The excavation numbers have been totaled based on the Raw Cut Volumes

EXCAVATION				
TOTAL UNCLASS.	ROCK	UNDERCUT	UNSUIT. UNCLASS.	SUITABLE UNCLASS.
4,931				4,931
10,925				10,925
15,856				15,856
5,158				5,158
1,204				1,204
6,362				6,362

- Embankment and Borrow Numbers have been calculated and totaled based on the Raw Fill volumes.

EMBANKMENT				BORROW
TOTAL	ROCK	EARTH	EMBANK. +20%	
28,827		28,827	34,592	29,661
19,377		19,377	23,252	12,327
48,204		48,204	57,844	41,988
61,384		61,384	73,661	68,503
24,477		24,477	29,372	28,168
85,861		85,861	103,033	96,671

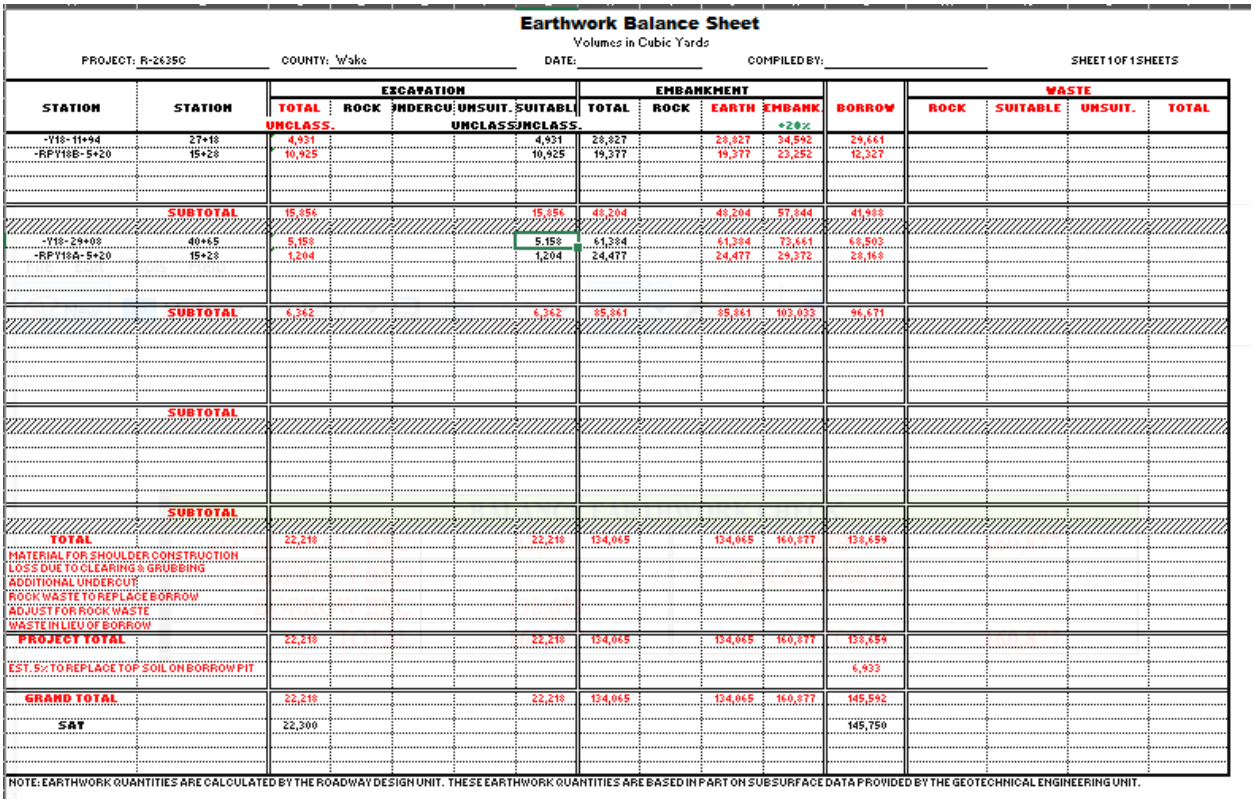
- These columns have been totaled at the bottom of the sheet.

TOTAL		22,218				22,218	134,065		134,065	160,877	138,659
MATERIAL FOR SHOULDER CONSTRUCTION											
LOSS DUE TO CLEARING & GRUBBING											
ADDITIONAL UNDERCUT											
ROCK WASTE TO REPLACE BORROW											
ADJUST FOR ROCK WASTE											
WASTE IN LIEU OF BORROW											
PROJECT TOTAL		22,218				22,218	134,065		134,065	160,877	138,659
EST. 5% TO REPLACE TOP SOIL ON BORROW PIT											6,933
GRAND TOTAL		22,218				22,218	134,065		134,065	160,877	145,592
SAY		22,300									145,750

- There is also a check below the Balance Card that verifies the volumes add together correctly.

BALANCE EARTHWORK CHECK			
TOTAL UNCL. EXC:	22,218	EMB + %:	160,877
UNDERCUT EXC:		TOTAL WASTE:	
BORROW EXC:	138,659		
TOTAL:	**160,877**	TOTAL:	**160,877**

- This completed spreadsheet is a Deliverable to NCDOT.



Earthwork Balance Sheet

Volumes in Cubic Yards

PROJECT: R-2635C COUNTY: Wake DATE: COMPILED BY: SHEET 1 OF 1 SHEETS

STATION	STATION	EXCAVATION					EMBANKMENT				BORROW	WASTE			
		TOTAL UNCLASS.	ROCK	UNDERCUT	UNSUIT. UNCLASS.	SUITABL UNCLASS.	TOTAL	ROCK	EARTH	EMBANK +20%		ROCK	SUITABLE	UNSUIT.	TOTAL
-Y18- 11+94	27+18	4,931				4,931	28,827		28,827	34,592	29,661				
-RPY18B- 5+20	15+28	10,925				10,925	19,377		19,377	23,252	12,327				
	SUBTOTAL	15,856				15,856	48,204		48,204	57,844	41,988				
-Y18- 29+08	40+55	5,158				5,158	61,384		61,384	73,661	68,503				
-RPY18A- 5+20	15+28	1,204				1,204	24,477		24,477	29,372	28,168				
	SUBTOTAL	6,362				6,362	85,861		85,861	103,033	96,671				
	SUBTOTAL														
	SUBTOTAL														
TOTAL		22,218				22,218	134,065		134,065	160,877	138,659				
MATERIAL FOR SHOULDER CONSTRUCTION															
LOSS DUE TO CLEARING & GRUBBING															
ADDITIONAL UNDERCUT															
ROCK WASTE TO REPLACE BORROW															
ADJUST FOR ROCK WASTE															
WASTE IN LIEU OF BORROW															
PROJECT TOTAL		22,218				22,218	134,065		134,065	160,877	138,659				
EST. 5% TO REPLACE TOP SOIL ON BORROW PIT											6,933				
GRAND TOTAL		22,218				22,218	134,065		134,065	160,877	145,592				
SAY		22,300									145,750				

NOTE: EARTHWORK QUANTITIES ARE CALCULATED BY THE ROADWAY DESIGN UNIT. THESE EARTHWORK QUANTITIES ARE BASED IN PART ON SUBSURFACE DATA PROVIDED BY THE GEOTECHNICAL ENGINEERING UNIT.

5. Deliverable – End Area Volume Report

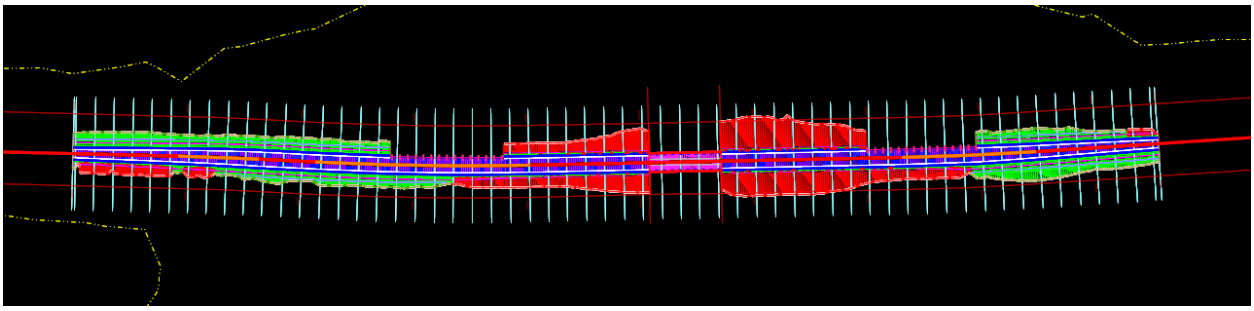
A. The End Area Volume Report was detailed in Exercise 6. This is a tool that reports Earthwork using the Average End Area Volume method and is based on the cross section named boundaries.

B. This report is only used as verification of the Prismoidal Volumes not as a replacement. Generating this report allows for the Cut and Fill Areas from the cross sections to be checked and verified and the volume total generated by Average End Area to be compared to the Prismoidal Volumes. It is only meant to identify large discrepancies.

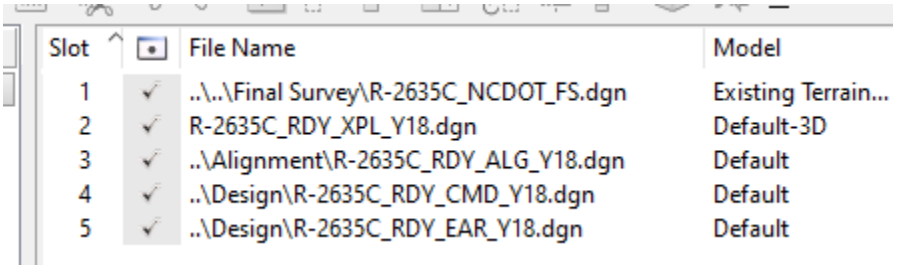
C. See the NCDOT Training Module for Sheeting for information on generating Cross Section Named Boundaries and DGN files.

D. Open the Y18 Cros Section Named Boundary Layout File

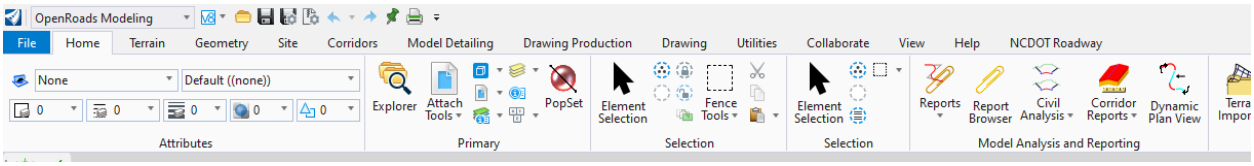
- This file is in the Roadway\Sheets directory
- R-2635C-RDY_XPL_Y18.dgn
- This is the same file used to create the cross section drawing and sheet models. It will already have the following files attached
  1. Existing Surface
  2. Proposed Alignment
  3. Proposed Corridor
  4. Any Detailed Modeling Areas
- The named boundaries will already be created



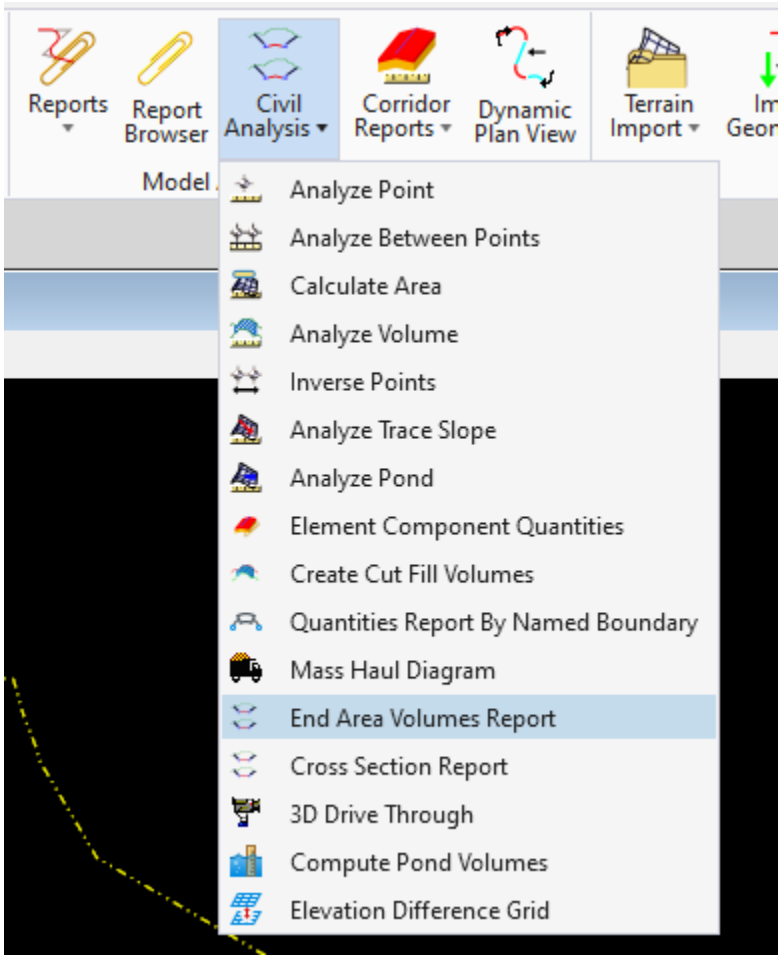
E. Attach the Y18 Cut and Fill Volumes
- R-2635C_RDY_EAR_Y18.dgn
- These are required for the reporting
- The program reads these shapes to determine the aeras at each named boundary.



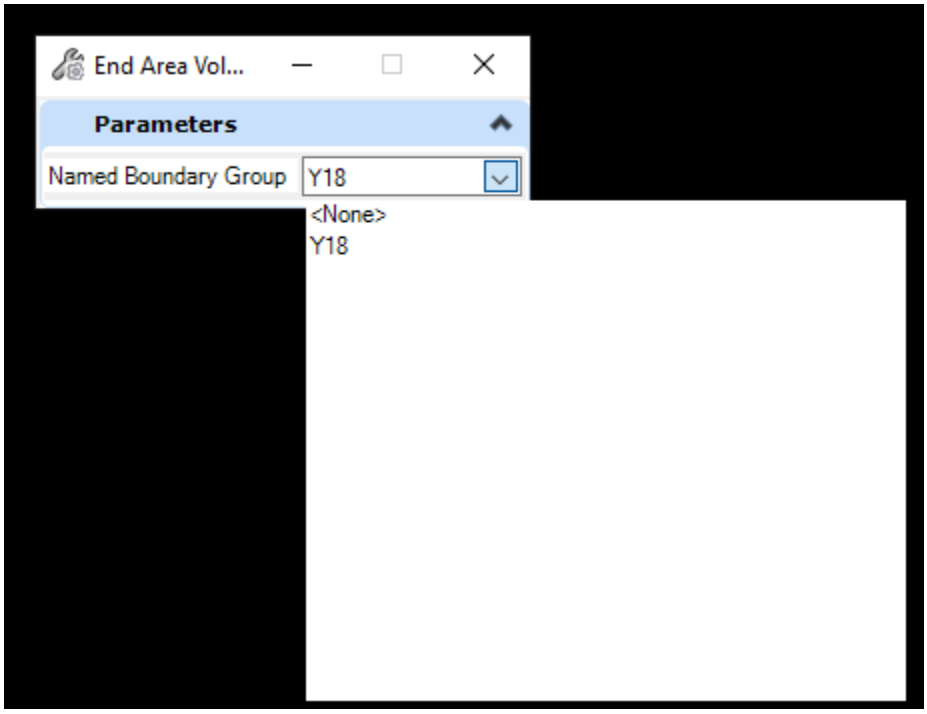
F. Create the End Area Volume report
- The Default 3D view should be open.
- Go to the Civil Analysis section in the Model Analysis and Reporting section on the Home tab



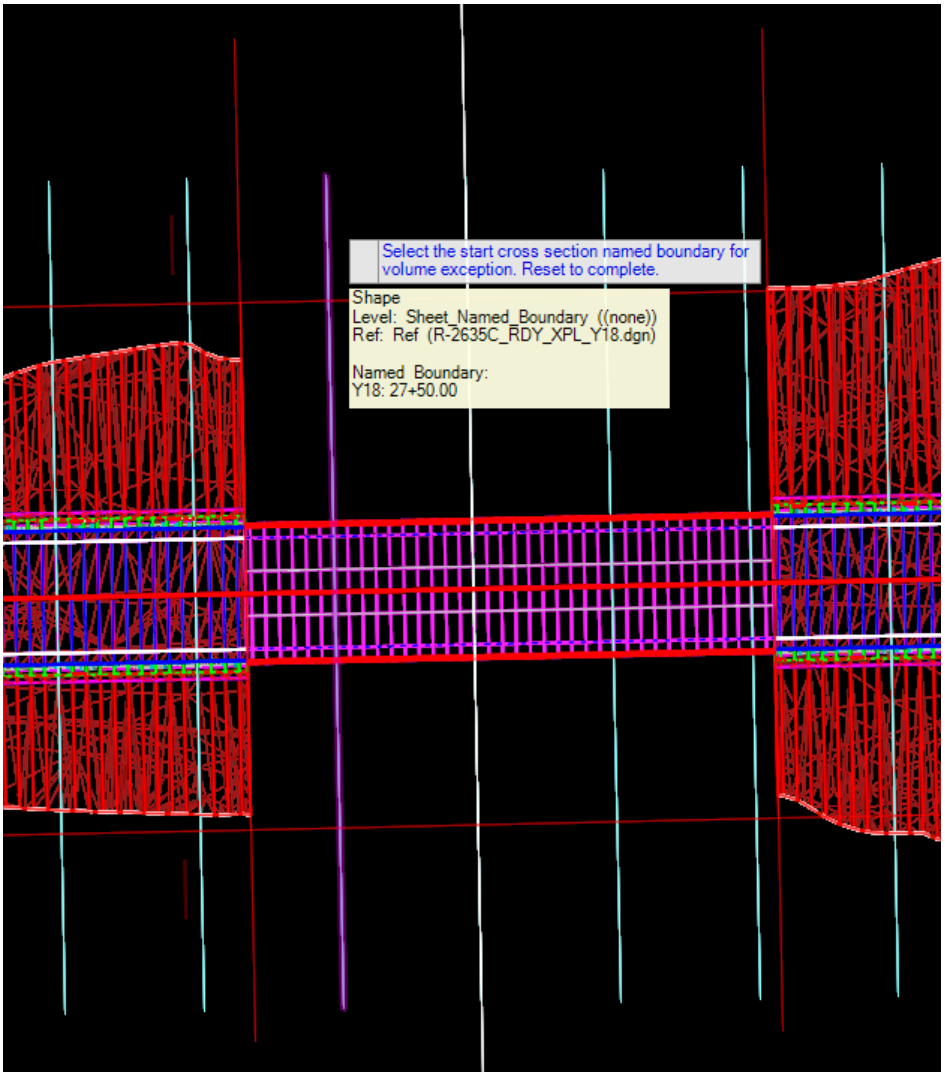
- Select the End Area Volumes Report Tool from the Civil Analysis tool group.



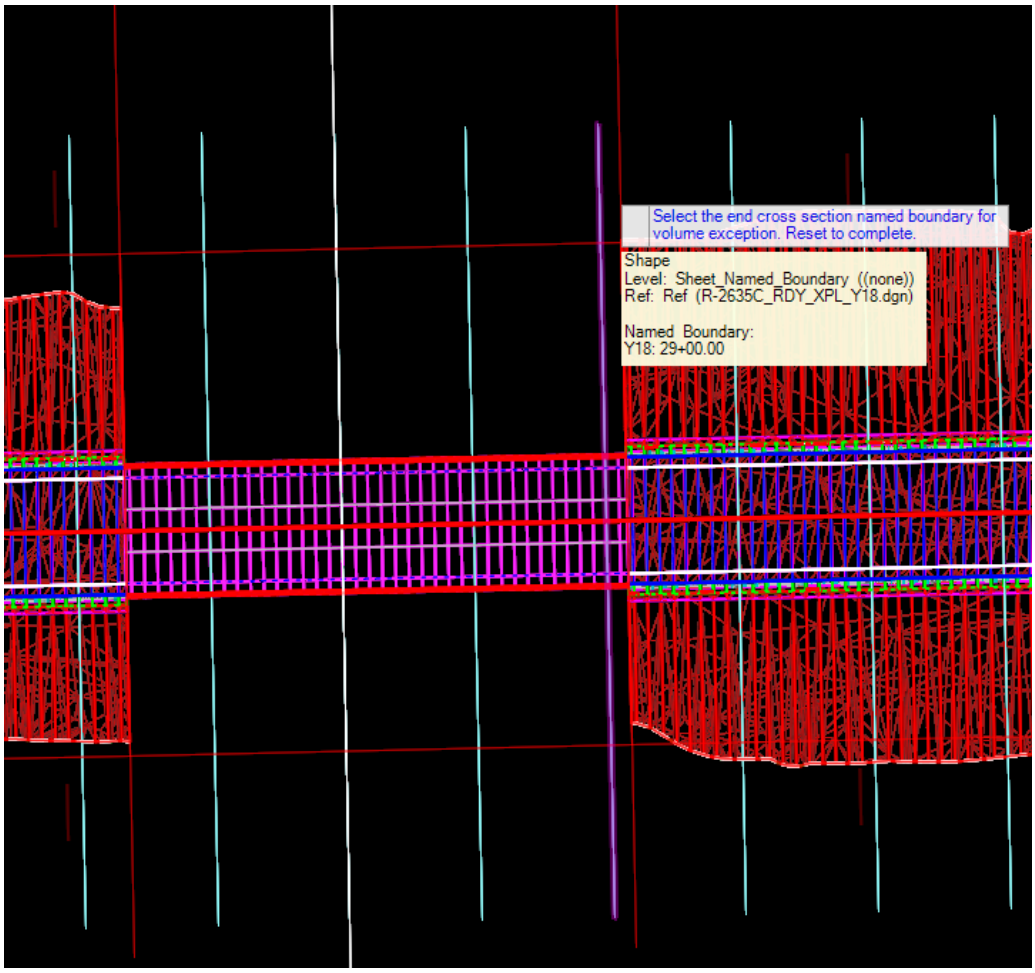
- Select the named boundary group from the drop down, for most projects there will only be a single group available.



- The next prompt asks for the Start Cross Section for Volume Exception. This is not the cross section at the beginning of the project this is the first cross section that will be left out, excluded, from the End Area report. For this example, we want the cross sections that cover the proposed bridge to be left out of the End Area report. Left click the named boundary at station 27+50 to start the exception, this is the first section on the proposed bridge.



- The next prompt is for the end section. This is the section that ends the exception and where the average end area calculations will start again. Select the section at 29+00, this is the last section on the bridge.

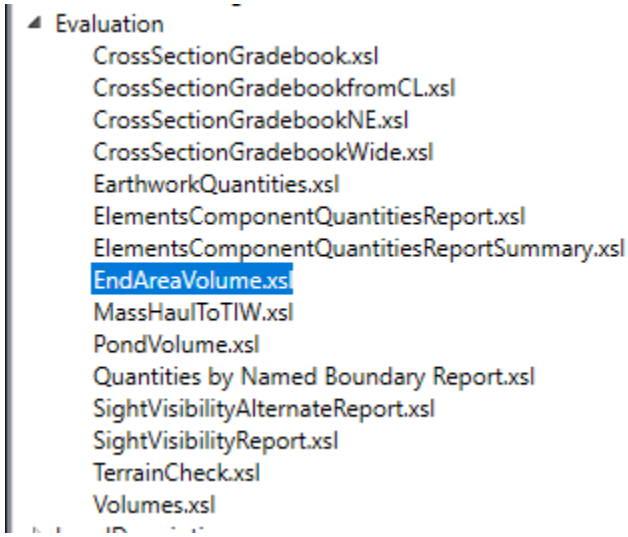


Note that multiple sections can be defined at the same time and included in the same report if required.

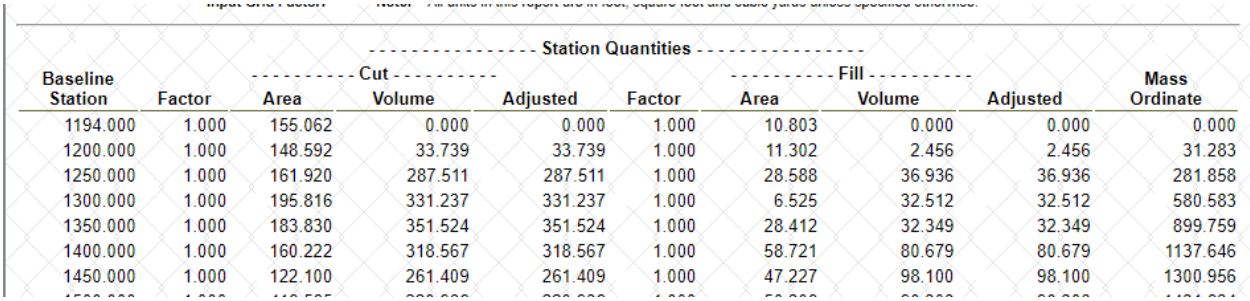
- Right click to reset and complete the Exception Selection process.

Note that the prompt offers the chance to select another starting section.

- This will end the tool and bring up the report. It should automatically default to the EndAreaVolume.xsl style sheet.

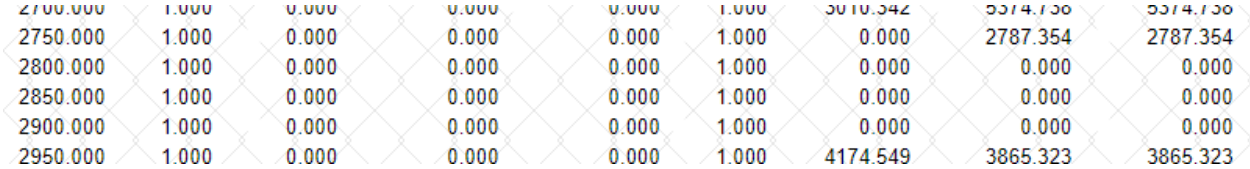


- The report displays Stations, areas and volumes for each cross section named boundary.



Station Quantities									
Baseline Station	Cut Factor	Cut Area	Cut Volume	Cut Adjusted	Fill Factor	Fill Area	Fill Volume	Fill Adjusted	Mass Ordinate
1194.000	1.000	155.062	0.000	0.000	1.000	10.803	0.000	0.000	0.000
1200.000	1.000	148.592	33.739	33.739	1.000	11.302	2.456	2.456	31.283
1250.000	1.000	161.920	287.511	287.511	1.000	28.588	36.936	36.936	281.858
1300.000	1.000	195.816	331.237	331.237	1.000	6.525	32.512	32.512	580.583
1350.000	1.000	183.830	351.524	351.524	1.000	28.412	32.349	32.349	899.759
1400.000	1.000	160.222	318.567	318.567	1.000	58.721	80.679	80.679	1137.646
1450.000	1.000	122.100	261.409	261.409	1.000	47.227	98.100	98.100	1300.956

- Save this report in HTML format
  1. Name this report XS_EAVR_Y18.html
- Notice that the named boundaries from 27+50 to 29+00 are included but the areas are listed as 0.



2700.000	1.000	0.000	0.000	0.000	1.000	3010.342	5374.736	5374.736
2750.000	1.000	0.000	0.000	0.000	1.000	0.000	2787.354	2787.354
2800.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
2850.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
2900.000	1.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
2950.000	1.000	0.000	0.000	0.000	1.000	4174.549	3865.323	3865.323

- Repeat this process for RPy18A and RPY18B. These 3 reports are part of the deliverables to NCDOT.

6. Comparing Prismoidal to Average End Area

A. Now that we have completed the reports for each method we can compare the Prismoidal Volumes to the Average End Area Volumes.

B. Note that the Average End Area method still uses the 3D volumes to determine the area at each named boundary

C. Prismoidal Method

- Y18
  1. Cut = 10,089 CY
  2. Fill = 90,211 CY
- Y18RPA
  1. Cut = 1,204 CY
  2. Fil = 24,477 CY
- Y18RPB
  1. Cut = 10,925 CY
  2. Fill = 19,377 CY
- Total
  1. Cut = 22,218 CY
  2. Fill = 134,065 CY

D. Average End Areal Method

- Y18
  1. Cut = 10,100 CY
  2. Fill = 88,694 CY
- Y18RPA
  1. Cut = 1,164 CY
  2. Fil = 21,877 CY
- Y18RPB
  1. Cut = 9,248 CY
  2. Fill = 18,146 CY
  3.
- Total
  1. Cut = 20,512 CY
  2. Fill = 128,717 CY

E. The difference between the Prismoidal Area and the Average End Area Methods

- Cut = 8%
- Fill = 4%

F. Based on these numbers we can see that the Average End Area method is capable or producing an adequate check of the more accurate Prismoidal Volumes.

7. Final Deliverables

A. The final deliverables to NCDOT from this example that included Earthwork from three alignments, Y18, RPY18A and RPY18B would be as follows.

B. Prismoidal Volume CADD Files
- R-2635C_RDY_EAR_Y18.dgn
- R-2635C_RDY_EAR_RPY18A.dgn
- R-2635C_RDY_EAR_RPY18B.dgn

C. Named Boundary CADD Files
- These could be in separate files for this example they are located in the Prismoidal Volume CADD files

D. Quantity Reports by Named Boundary
- EAR_Y18.html
- EAR_RPY18A.html
- EAR_RPY18B.html

E. Earthwork Balance Card
- R-2635C Balance Sheet – Earthwork.xlsx

F. End Area Volume Reports
- XS-EAVR_Y18.html
- XS-EAVR_RPY18A.html
- XS-EAVR_RPY18B.html