NCDOT Hydraulics Unit Standard Workflows for Ditch Design Using OpenRoads Designer

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Prepared By:

Karl R. Dauber, PE

www.advconsult.net

karldauber@advconsult.net

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I. Introduction

General Workflow

The following general workflow has been developed, as detailed in the remainder of this document.

A. Complete initial layout of channels using OpenRoads tools. All ditches should be developed using corridor modeling methods. Establish initial corridor models for ditches that incorporate civil "rule" dependencies to terrains, geometry, and/or roadway corridors as desired. Some preliminary hydraulic capacity/stability assessment should be performed beforehand to identify approximate ditch dimensions and minimum and maximum ditch slope constraints for the ditch profile.

B. Using the initial ditch layout, including the dimensions and profiles for the ditch reach segments, use FlowMaster, FHWA Toolbox, a spreadsheet, or some other means to perform a hydraulic analysis to check capacity and velocity and determine the required ditch cross-section and lining needed for each reach. If the OpenRoads Drainage and Utility channel layout tools are used for hydraulic analysis of ditches, refer to separate documentation for those tools. However, such channel links in the Drainage and Utility model should never be used for 3D modeling or plan production.

C. Make adjustments of the OpenRoads ditch design based on the hydraulic assessment. Using the proposed cross-section data and lining types for each reach, add parametric constraints and adjust point controls and template drop selections for the ditch corridor model to update the design. If needed, the profile can also be adjusted. Repeat Steps B and C if needed until ditch corridor model is finalized.

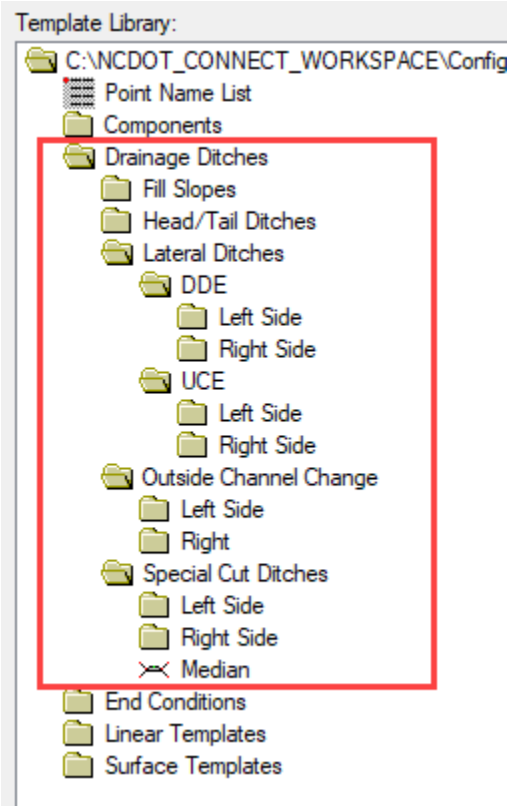
D. After the ditch corridor models are finalized, complete tasks to prepare the Redline Drainage Plans. This includes identifying and preparing the ditch cross section details as well as showing the proposed ditches on the roadway profiles and cross sections, including any needed modifications to the roadway corridor models.

E. After approval of the Redline Drainage Plans, coordinate with the Roadway Design Unit staff to incorporate the needed roadway corridor model modifications as described in detail in this document for various kinds of ditches.

Ditch Terminology

The procedures in this document, and the standard ditch templates in the NCDOT WorkSpace are intended to adhere to the terminology used in the NCDOT document "Ditch Drafting Guidelines".

Below is screen shot of the ditch template library, showing how the ditch templates are organized:



1. Head and Tail Ditches. These are ditches that are not associated with the roadway, and have independent alignments.

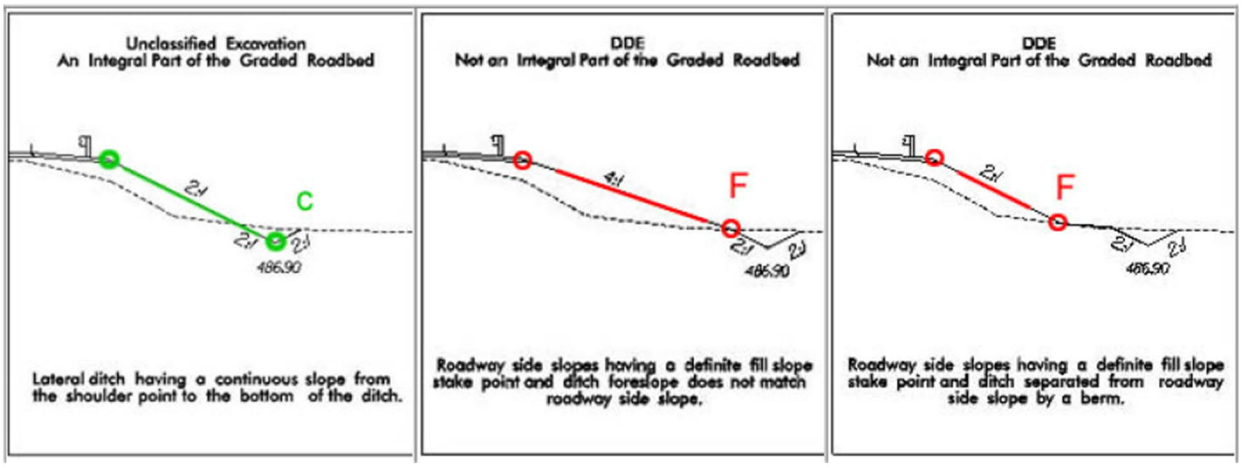
2. Lateral Ditches. These are ditches that are located in true "fill" sections of a roadway. They are located on the outside of the roadway corridor, along the fill slope stake line. As shown in the screen shot on the next page from the Ditch Drafting Guidelines, there are generally two categories of lateral ditches:

    a) Unclassified Excavation (UCE). These ditches have a continuous slope from the roadway shoulder point to the bottom of the ditch. The ditch excavation is considered part of the roadway earthwork quantity, and the roadway is technically considered in a "cut" in such locations. A slope stake line where the fill slope intersects the ground is not shown on the plans.

    b) Drainage Ditch Excavation (DDE). These ditches have berm between the fill slope stake line and the top of the ditch foreslope. Or, there is no berm but the roadway fill slope is different than the ditch foreslope. The ditch excavation is quantified separately from the roadway excavation.

3. Outside Channel Change. These are ditches that relocate or reconstruct existing channels under or adjacent to the roadway.

4. Special Cut Ditches. These are ditches that are located in true "cut" sections of a roadway. They are located in roadway medians and in the shoulder areas. These templates are intended to be used to create Special Cut Ditches that modify the standard cut ditches produced by the roadway corridor models.



Lateral Ditch (UCE)

Lateral Ditch (DDE)

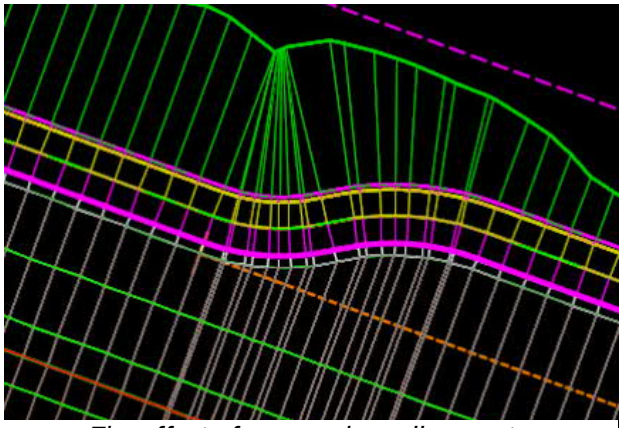
Corridor Modeling Terminology

"Template". This refers to the typical section that is applied to the horizontal and vertical alignment geometry of a roadway or ditch to create the initial corridor model. Default templates are stored in a template library file (ITL) located outside the DGN.

"Point Constraints". This refers to properties of a template specifying how each point in the template is related to, or constrained, to other points. For example, the outside edge of a lane is 12' right of the baseline at a 2% slope.

"Parametric Constraints". This is a type of corridor edit. Parametric constraints override the template point constraints in order to change template dimensions such as lane width, slopes, pavement depth, etc.

"Point Controls". This is a type of corridor edit. Point controls override the location of a point on a template. Points can be controlled by other geometry, other corridor features, specified elevation and grade, etc.



The effect of a secondary alignment

"Secondary alignments". This is a type of corridor edit. By default, templates are applied perpendicular to the horizontal alignment selected for the corridor. However, additional alignments can be added as secondary alignments to force the template drop lines to be placed

perpendicular to these secondary alignments to account for lane tapers, slope stake lines, and other features that are not perpendicular to the roadway baseline.

"End Condition Exceptions" or ECE. This is a type of corridor edit. End conditions are the part of the template beyond the shoulder hinge point – the side slope that seeks existing ground or another feature. An ECE overrides the end conditions specified in the template and replaces them with something else. A specific type of ECE is "backbone only" which turns off the end condition entirely within a specified station range on the left or right side of the road.

"Remove Rule". This is an edit to any ORD civil geometry that is dependent on another feature. For example, a new horizontal alignment may be created from a slope stake line using an Offset tool with the offset set to zero. The alignment would then be dynamically dependent on the slope stake line. This dependence can be removed using the Remove Rule tool. This is often necessary in modeling workflows to avoid circular dependency errors.

Naming Convention

Ditches should be named using the following convention: alignment name, baseline station of ditch starting point (to the nearest foot), and notation of left or right side of road. For example:

L_118+23, LT

Video Links

Throughout this manual, links are provided to videos on the NCDOT YouTube channel that demonstrate the described workflows. The links are indicated by highlighted text shown as (Video) that contain URL links that will direct you to specific locations in videos that correspond to the particular step in the workflow being described in the manual. If viewing the document from a website, you may wish to right-click on the link and choose "open in a new window" to maintain access to this document while simultaneously viewing video segments.

II. Head and Tail Ditches

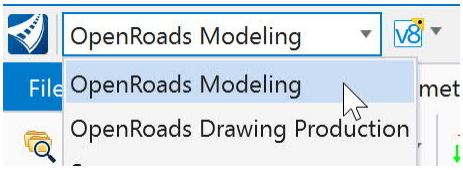
Head and tail ditches have independent alignments – they are not part of, or dependent upon, a roadway corridor model. Head and tail ditches typically flow towards or away from a drainage system element such as an inlet, headwall, end section, or open-ended pipe. However, the following procedures can be used for any ditch with an independent alignment outside the grading limits of a roadway corridor. Ditches should be created in a new DGN file created from a 2D seed.

B. As detailed below, the general workflow includes the following steps:

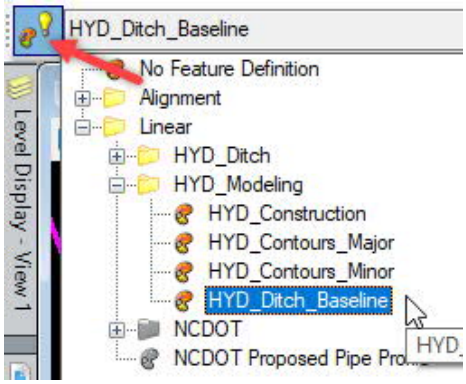
1. Create horizontal alignment.
2. Create vertical alignment and make it the Active Profile for the horizontal alignment.
3. Create a corridor model by applying one of the standard NCDOT ditch templates for head/tail ditches.
4. Make adjustments as needed to the ditch corridor model by adjusting the horizontal and/or vertical alignments. Further adjustments by adding or modifying template drops, or adding parametric constraints are discussed in Chapter IV.

C. Create ditch horizontal alignment. (Video)

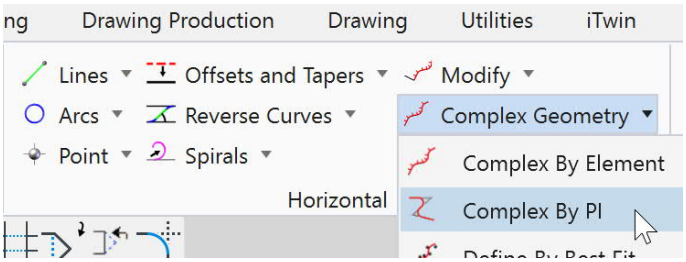
1. Make sure the workflow is set to OpenRoads Modeling.



2. Go to *Geometry* > *Standards* > *Feature Definition Toolbar* and dock it above the view window if not already there. Set the active feature definition to *Linear* > *HYD_Modeling* > *HYD_Ditch_Baseline*, and toggle on Use Active Feature Definition.



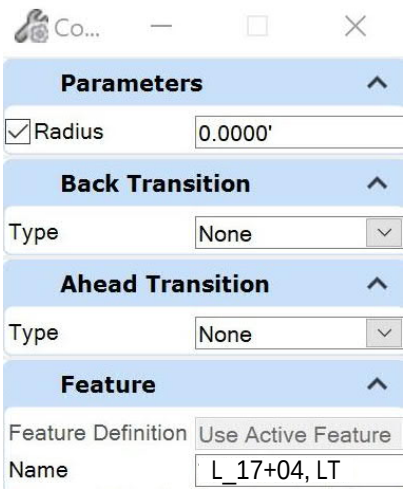
3. Go to *Geometry* > *Horizontal* and select Complex by PI.

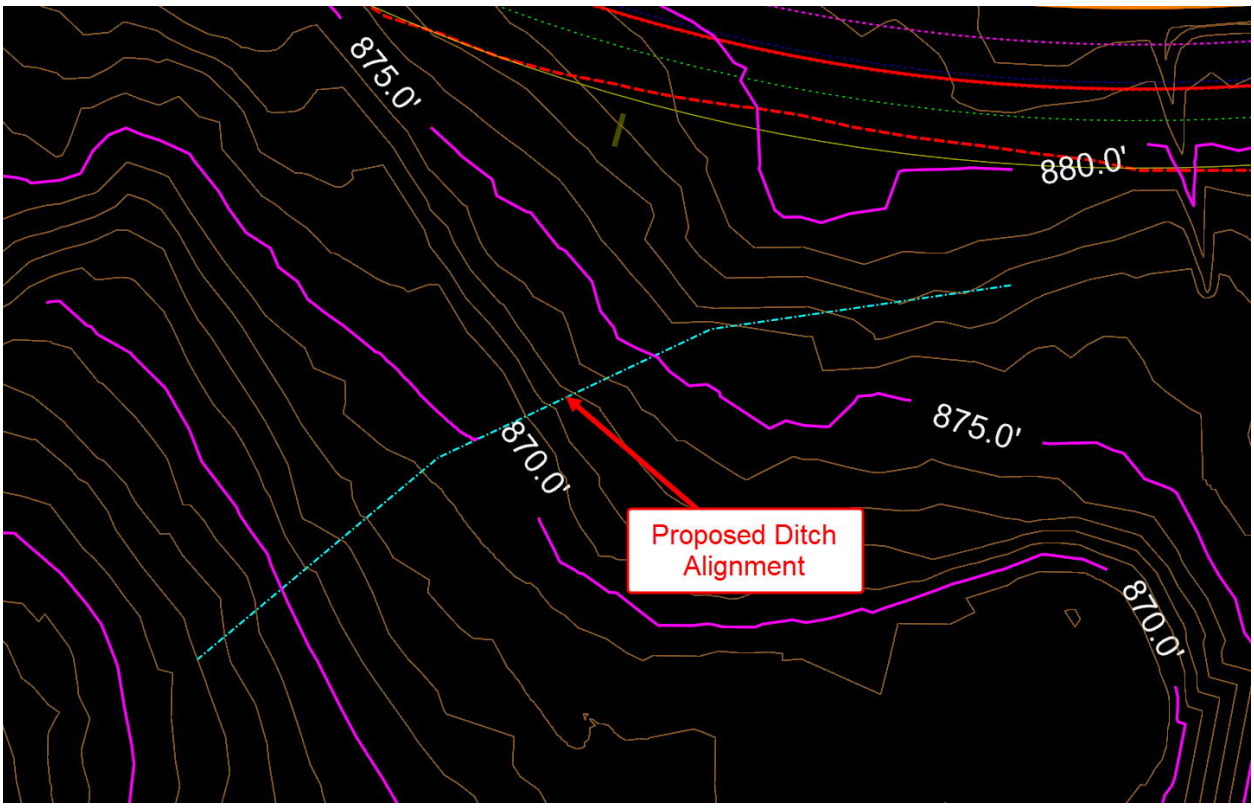


4. In the tool settings dialog or heads up prompt, provide a name for the alignment such as L_17+04, LT.

5. Set the value for radius to 0.0 and set the Ahead and Back Transitions to None.

6. <D> ("accept" or left mouse click for standard right-hand mouse setup) in the design file to place PI points along the proposed ditch centerline to layout an alignment as shown in the example below.

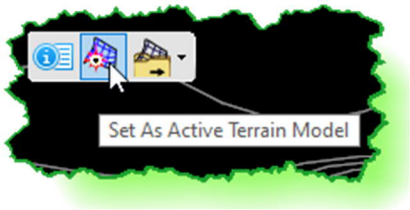




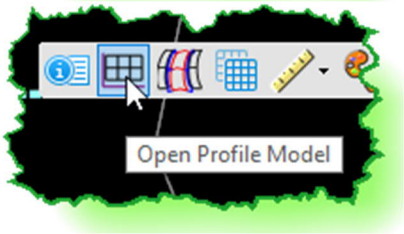
7. After alignment is created, you can revise it by selecting the alignment and clicking and dragging any of the PI points. Go to *Common Tools* > *Table Editor* and use this tool to add a radius to any PI points that create sharp bends in the alignment that may cause crossing templates in the corridor model (if you're not sure, you can hold off and do this later as needed). However, it is usually desirable to avoid curves in order to simplify construction layout.

D. Create ditch invert vertical alignment. (Video)

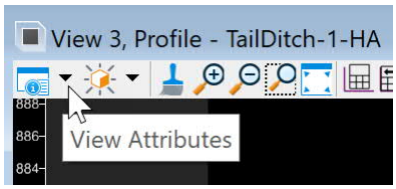
1. Select a feature from the referenced existing terrain and from the fly-out menu select Set As Active Terrain Model.



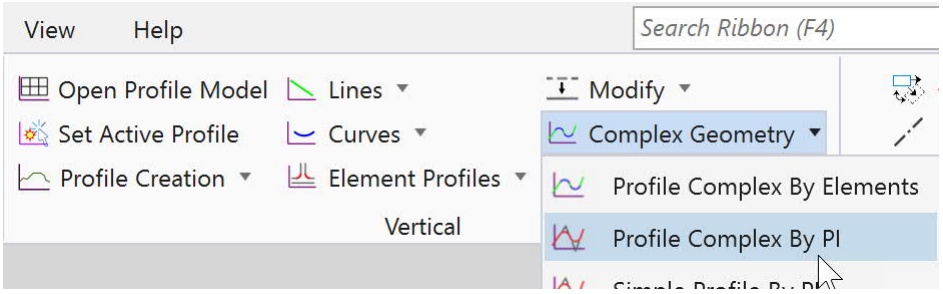
2. Use the Element Selection tool to select the ditch horizontal alignment, and from fly-out menu, select Open Profile Model. Select an unused view window and <D> in the window to create a profile model.



3. Click on the View Attributes in the upper left corner of the profile model view window. Under the Civil tab you can change the profile exaggeration if desired.

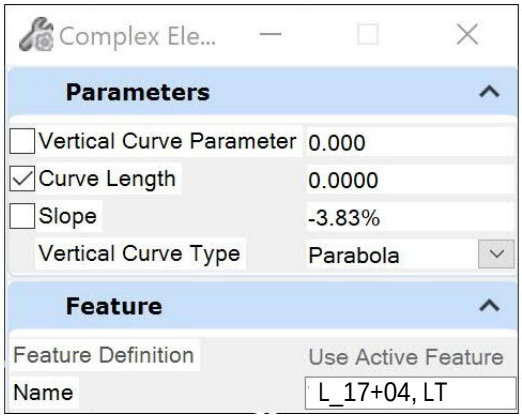


4. Go to *Geometry* > *Vertical* > *Complex Geometry* and select Profile Complex by PI.

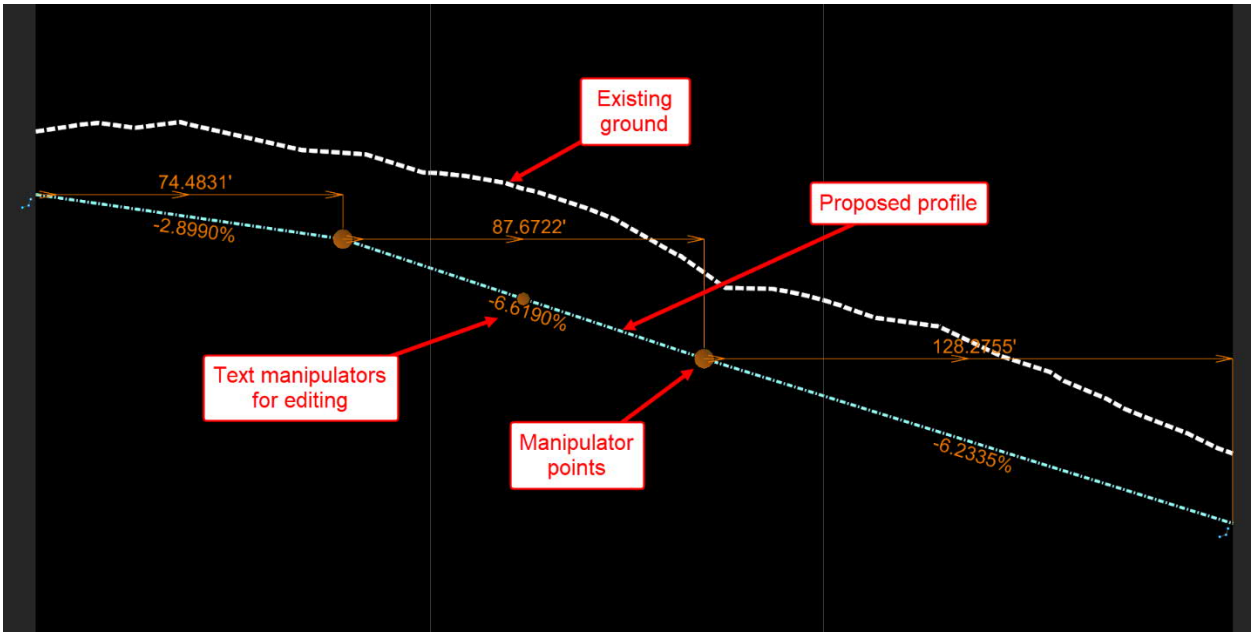


5. Provide a Name such as L_17+04, LT.

6. Check the box for Curve Length, enter a value of 0.0, and leave the other boxes in the dialog unchecked. Profiles for ditches should not use vertical curves.



7. Set invert elevations at upstream and downstream end of the ditch, as well as any intermediate points by placing data points in the profile window to create a series of PI points as shown on the next page. However, read Steps 8 through 11 below before placing your vertical PI points.



8. Remember that when placing the PI points, you can use Civil Accudraw to specify a slope, a particular station and/or elevation, or a vertical offset. If you don't have this toolbar docked, go to *Geometry* > *Civil Toggles* > *Civil Accudraw* and open the toolbar and dock it. Note that stations in a profile view <u>always</u> refer to the station of the element being profiled, not some other baseline reference such as a roadway baseline. The element being profiled is shown in the upper left corner of the profile model window.

Set to Station-Offset Mode

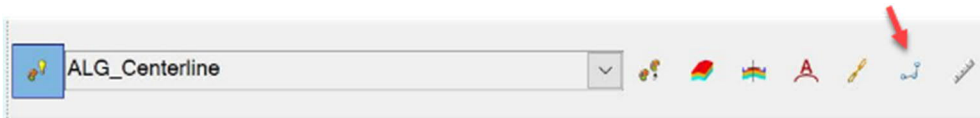
Set to Slope Mode

9. When done, <R> ("reset" or right mouse click for standard right-hand mouse setup) to complete the process.

10. After alignment is created, you can revise it by selecting the alignment and clicking and dragging any of the PI points. Remember you can use the Undo tool at any time. You can also edit the profile using the text manipulators for station and elevation of the PI points, as well as the slope of the lines. You can also use the Microstation Add Vertex and Delete Vertex tools to add PI points.

11. In some situations, you may want to snap to existing ground at the start or end of a profile to tie into the existing surface. Or you may want to snap the vertical PI points to the vertical gray lines in order to make the vertical PI points coincide with the horizontal PI points (which is recommended). However, remember that when you use a snap, you are creating a civil rule.

Do you want to prevent your ditch profile from automatically updating if the terrain model is revised? Do you want to be able to revise the vertical PI points after they have been snapped to the horizontal PI locations? If so, then you do *not* want to create these civil rules. If you ever want to snap to an element without creating a civil rule dependency, toggle off the Persist Snaps and Rule toggle on the Feature Definition Toolbar. It is recommended that you do this when creating ditch profiles.



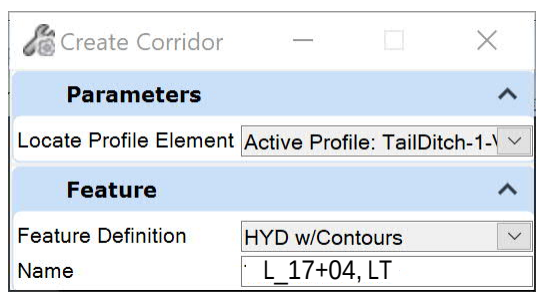
12. When the profile is done, select it and from the flyout menu select Set As Active Profile. The alignment will now appear in the 3D model view if you have it open. Note: any time after the ditch corridor has been created, you can come back to this profile model window and revise the profile and the corridor will automatically reprocess. This is also true of any changes to the horizontal alignment. However, if changes are made to the horizontal alignment, you should check the profile as well to make any needed revisions.

E. Create a corridor model for the ditch. (Video)

1. Go to *Corridors* > *Create* > *Template* and select Create Template. When the dialog opens, go to *File* > *Open* and browse to C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library and select NCDOT-Hydraulics-Ditches.ITL, and then click Open. Then close the Create Template dialog.

2. Go to the *Corridors* tab and select New Corridor.

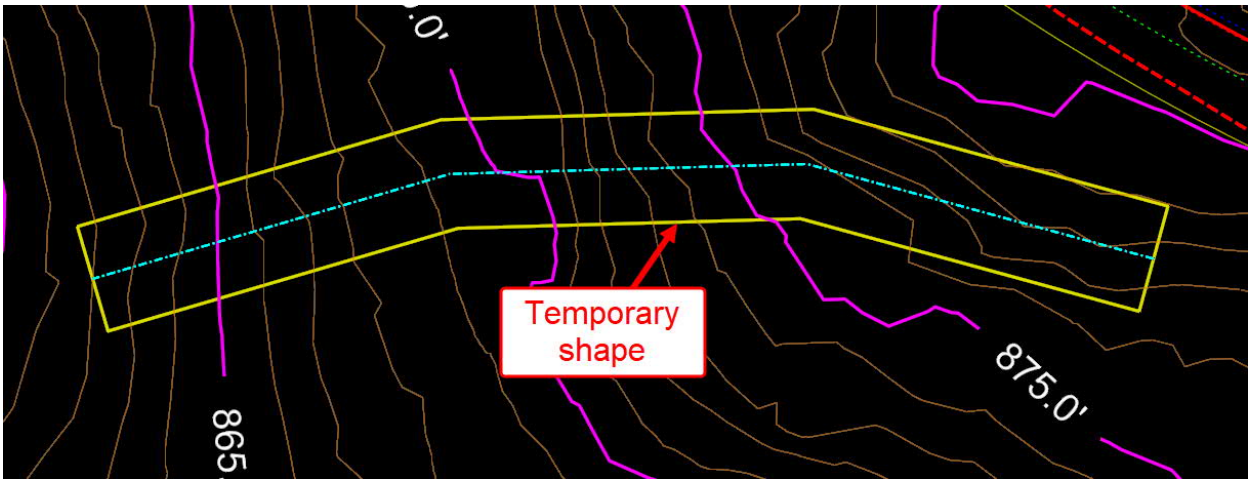
3. In the dialog box, for the Feature Definition go to Corridors and select HYD w/Contours from the drop-down list.



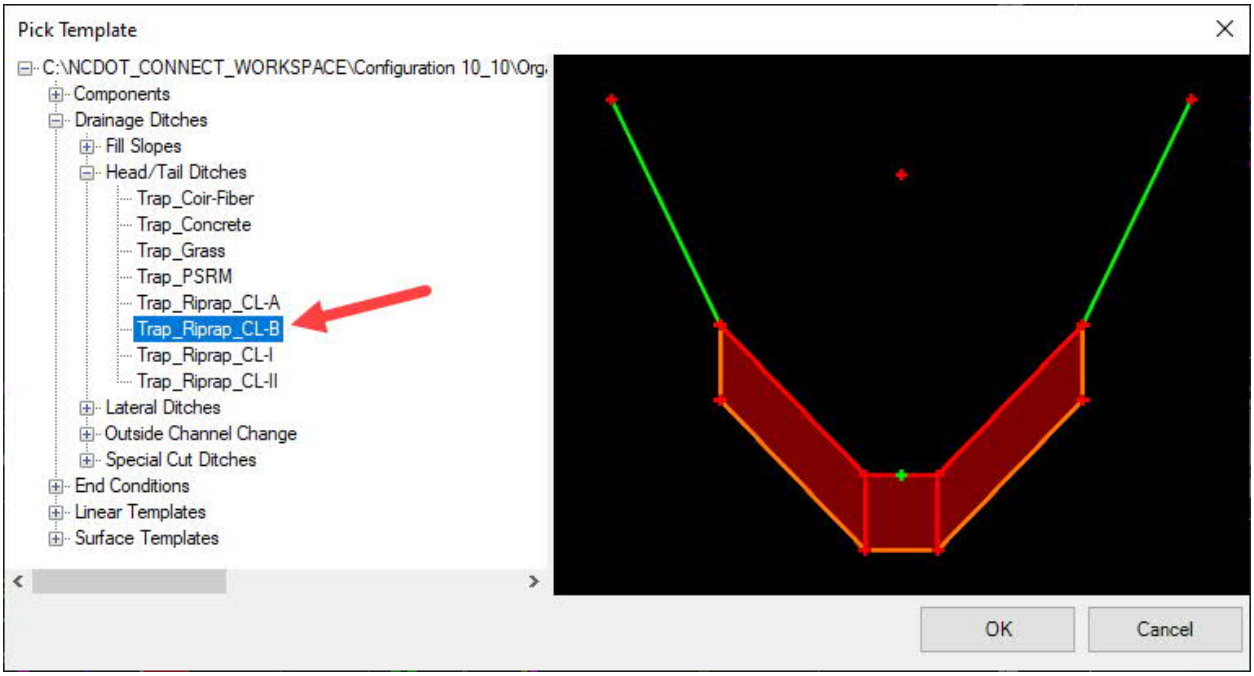
4. At the prompt *Locate Corridor Baseline*, select the previously created horizontal alignment.

5. At the prompt *Locate Profile*, select the profile previously created that represents the ditch centerline profile. Or, you can <R> to select the active profile.

6. At the prompt *Corridor Name*, provide unique name such as L_17+04, LT and <D> to accept. A temporary shape will appear representing the newly-created corridor model (see example on the next page). Move your mouse a little to get the next prompt to select a template drop.



7. If you accidentally exit from the process at this point, simply select that shape and from the flyout menu select Corridor Creation Tools > Create Template Drop.



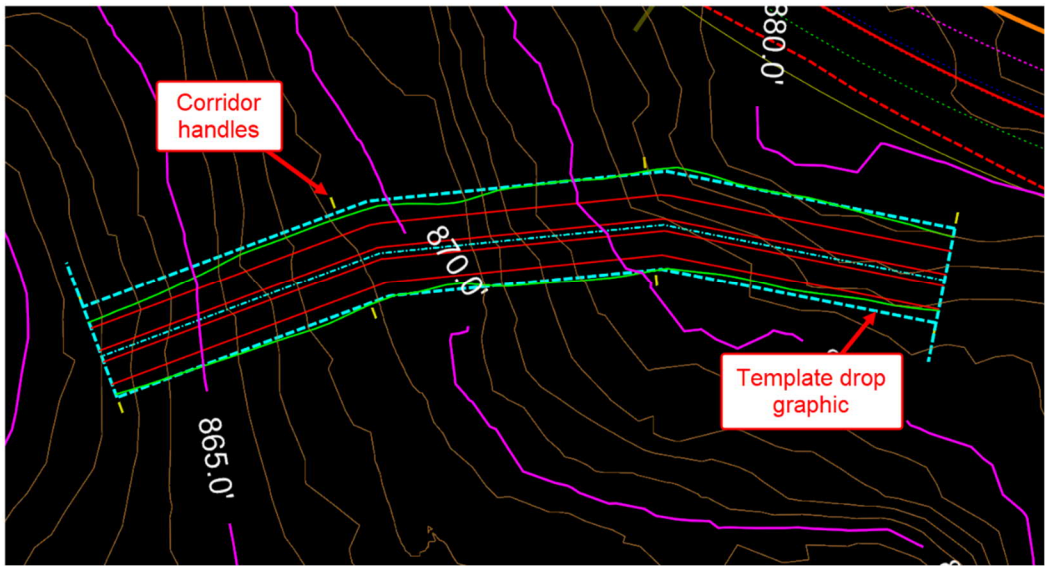
8. In the dialog box, in the Template field, go to *Typical Sections* > *Drainage Ditches* > *Head/Tail Ditches* and select the template Trap_Riprap_CL-B. Or, if using the heads up prompt, press ALT + Down Arrow to select the template. Click OK.

9. Check the boxes for Lock to Start and Lock to End in the tool settings dialog (or press the ALT key if using the heads up prompts) to apply the template to the entire ditch alignment. Alternatively, you can specify specific start and end locations for the template by keying in station values, or by selecting graphically in the file with your mouse.

10. Check the box for Drop Interval and enter a reasonable value. Generally, for ditches this value should be in the range of 1 to 5 feet, depending on the level of precision desired. Since ditches tend to use small and simple corridor models, it is recommended to use 1' most of the time. In this example, 5' is used to make the template drops easier to see. Enter 5.0 in the dialog (or enter directly by using the heads up prompt). You can change this value later.

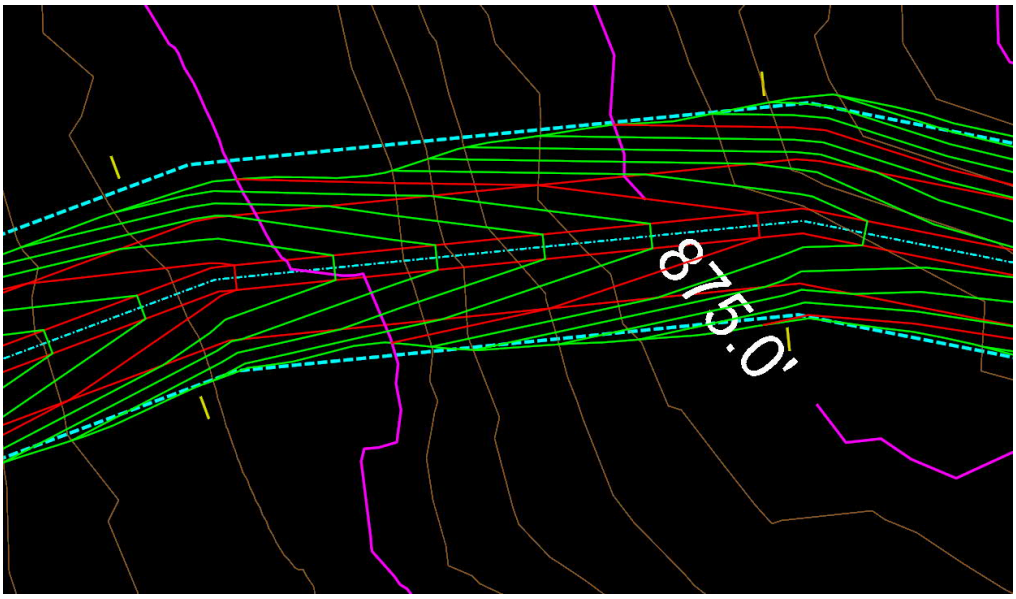
11. <D> in the design file to accept all dialog settings. After confirming the Drop Interval, the corridor model will be created and displayed in the view window.

12. Go to *Home* > *Primary* > *Attach Tools* > *References* and turn off display of the referenced 3D model.



13. Note the graphics that are displayed:
    - Lines for Top of cut slope/limit of grading (green).
    - Line for ditch center (light blue dashed line) and bottom width of ditch (red).
    - Lines for limits of the riprap lining (red).
    - Graphics for the corridor handles (yellow) and template drops (dashed light blue). To edit a ditch corridor, you select these graphics and choose reviewing and editing tools from the flyout menu. If desired, you can turn off display of these graphics which are on the level Draft_Corridor_Graphics_Final.
    - Note: the corridor graphics have an Element Class set to Construction, so they will not plot.

14. Turn on display of the referenced 3D model and go to *Home* > *Primary* > *Level Display*, select the 3D model reference, and turn off display for all levels except P_HYD_Contour_Major and P_HYD_Contour_Major.

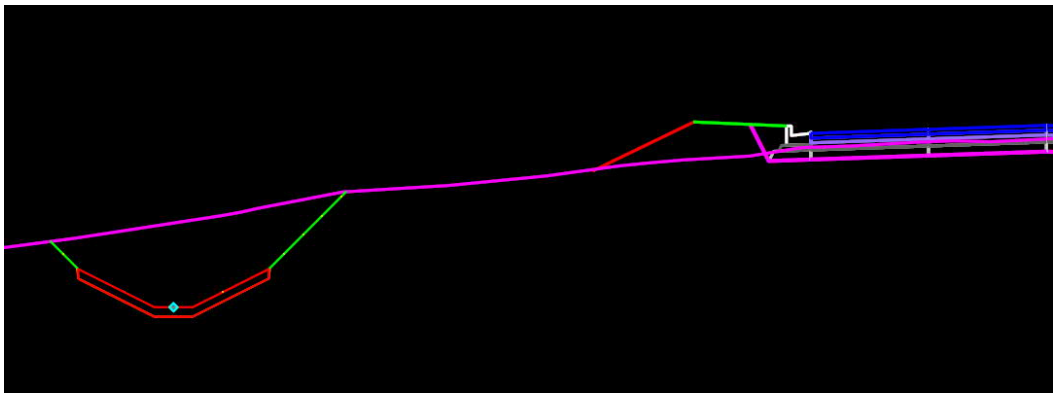


Notice that the displayed contours reflect the 4:1 slope of the riprap lining and the 2:1 slope of the ditch slopes beyond the riprap. As discussed in Section IV of this document, these slopes (as well as other ditch dimensions and channel lining) can be revised as desired after the corridor model has been created.

F. Using Dynamic Sections to Review the Corridor Model (Video)

1. Go to *Corridors* > *Review* > *Dynamic Sections* > *Open Cross Section View*. At the prompt *Locate Corridor or Alignment*, select the manipulator handle for the corridor in the plan view window. Or you can select one of the corridor handles and select this tool from the flyout menu.

2. Select an unused view window and <D> in the window to display a cross-section view of the corridor. Note that the riprap lining and fabric layers are displayed, as well as the existing ground and nearby roadway corridor model. Anything that is referenced to the 3D model will be visible here such as proposed drainage and existing or proposed utilities.

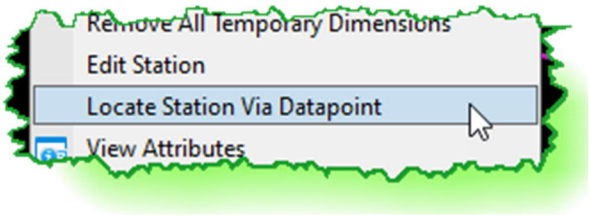


If the road corridor or existing terrain is not shown, make sure the cross section window is active and then go to Level Display and check that the level display for these reference files is turned on.

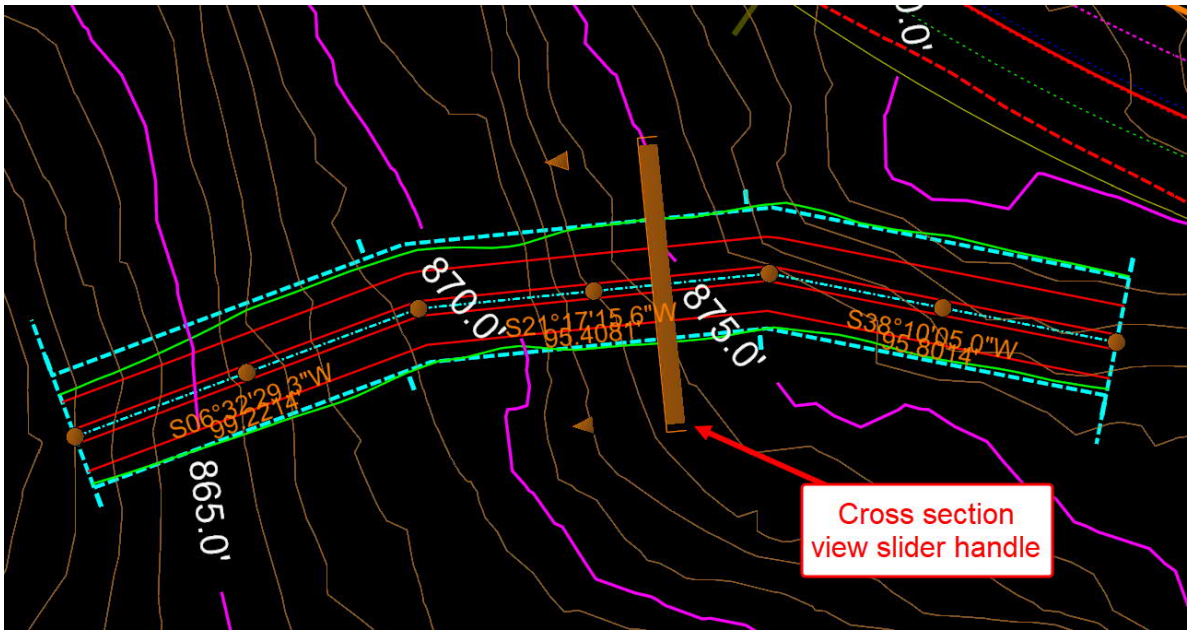
You can use the left and right arrow navigation buttons to step through the corridor cross-sections. However, this can be very tedious. There are better ways to navigate the cross section viewer:

1. Click on the station drop-down list and directly enter a station value. However, be sure your mouse cursor stays in the key-in field when you press ENTER or it will often not work.

2. <R> and press in the cross section view window to display the tool menu. About 2/3 the way down the list select Locate Station Via Datapoint. You will then be prompted to pick a plan or profile view window (note that you can use either) and then <D> to identify the station visually, snap to identify the station from a graphic element, or key-in a specific station.

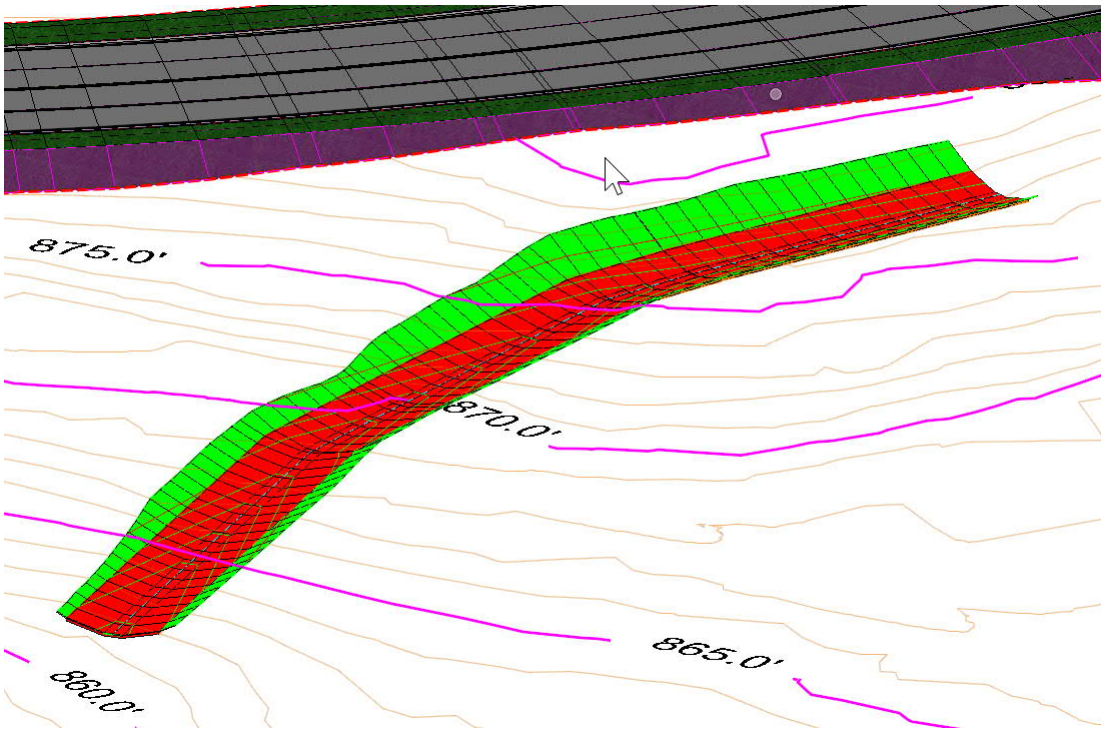


3. Once a cross section view has been established for a corridor, select one of the corridor handles, and a "slider" handle will appear. Drag this slider up and down the corridor to quickly review cross sections. See image below.



G. Using the 3D Model to Review the Corridor Model (Video)

1. Select and open the view window for the 3D model. If one has not been set up yet, then <R> and press in a view window and go to *View Control* > *2 Views Plan/3D* to have OpenRoads create a 3D model view.



2. Select Fit View and zoom to the area of interest. Use Rotate View with Method set to Dynamic to provide a 3D perspective view. Be sure to move the cross-hair so that it snaps to an element near your area of interest before rotating.

3. Go to *Home* > *Primary* > *Level Display* and verify that the levels P_HYD_Contour_Major and P_HYD_Contour_Major for contour display are turned on.

III. Lateral Ditches

Lateral ditches are located next to the toe of a fill slope (slope stake line) for a roadway. Using OpenRoads, such ditches can be dynamically tied to the fill slope stake (SS) line such that shifts of the slope stake line automatically result in a corresponding shift in the ditch location. To accomplish this, a template with an origin point on the left or right side will be needed. Such templates are available in the NCDOT WorkSpace. Ditches should be created in a new DGN file created from a 2D seed, and DGN files containing the existing terrain model, proposed geometry, and roadway corridor model should be referenced.

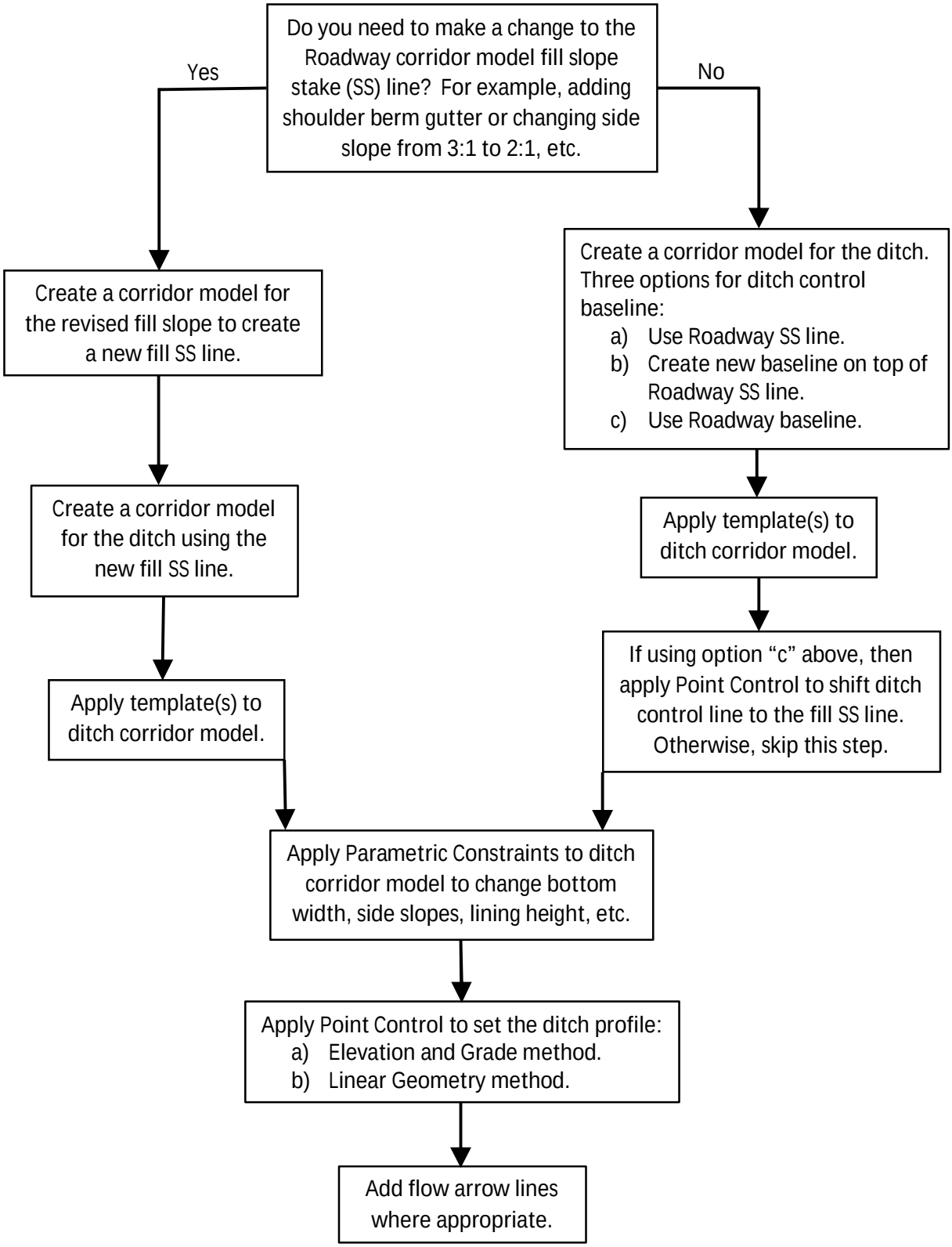
Although the overall concept is straightforward, in practice the processes for modeling lateral ditches are complicated by numerous factors:

- Can the SS line from the Roadway corridor model be used, or will changes to the roadway corridor model be needed to address needs identified by the Hydraulics Unit? For example, changing the fill slope from 3:1 to 2:1 will shift the SS line. If Shoulder Berm Gutter is requested, that will typically change the location of the SS line as well. This will require steps to create a new SS line for ditch modeling.
- Is the SS line fairly straight, or does it contain angular deflections? Due to the nature of corridor modeling using template drops perpendicular to the corridor baseline, such deflections can cause crossing template problems which may need to be addressed by adding small horizontal curves.
- If it is desired to use the roadway baseline as the reference baseline for a lateral ditch instead of the SS line, then additional steps are required in the modeling process to shift the ditch from its initial position at the roadway baseline to its actual position at the SS line. In addition, the SS line needs to be added to the ditch model as a "Secondary Alignment" in order for the template drops to be perpendicular to the ditch (not the roadway baseline) in order to ensure correct ditch dimensions and quantities.
- How will the ditch profile be established? Using the "Elevation and Grade" method, or by creating horizontal and vertical geometry for the ditch profile?

The next page provides a Flow Chart to help visualize these decision points. In the following pages, the steps for modeling lateral ditches under four different ditch control scenarios will be outlined:

1. Use the existing SS line from the Roadway corridor model as the control.
2. Use a new SS line created on top of the existing SS line from Roadway, but with curves added to address crossing templates.
3. Use the Roadway baseline as the ditch control line.
4. Use a new SS line that takes into account needed changes to the Roadway fill slope.

FLOW CHART FOR LATERAL DITCHES



A. Create ditch corridor model using the existing Roadway SS line. (Video)

1. Select a feature from the referenced existing terrain model and set it as the Active Terrain as discussed in the previous section.

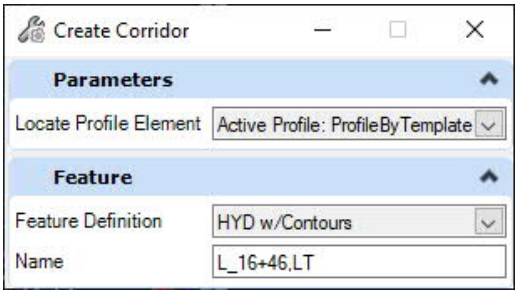
2. Turn on display of the referenced CMD corridor model and ALG geometry files.

3. As discussed in the previous section, in the OpenRoads Modeling workflow, go to *Corridors* > *Create* > *Template* and select Create Template. When the dialog opens, go to *File* > *Open* and browse to C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library and select NCDOT-Hydraulics-Ditches.ITL, and then click Open. Then close the Create Template dialog.

4. Go to *Corridors* > *Create* and select New Corridor.

5. In the dialog box, go to Feature Definition and select HYD w/Contours from the drop-down list.

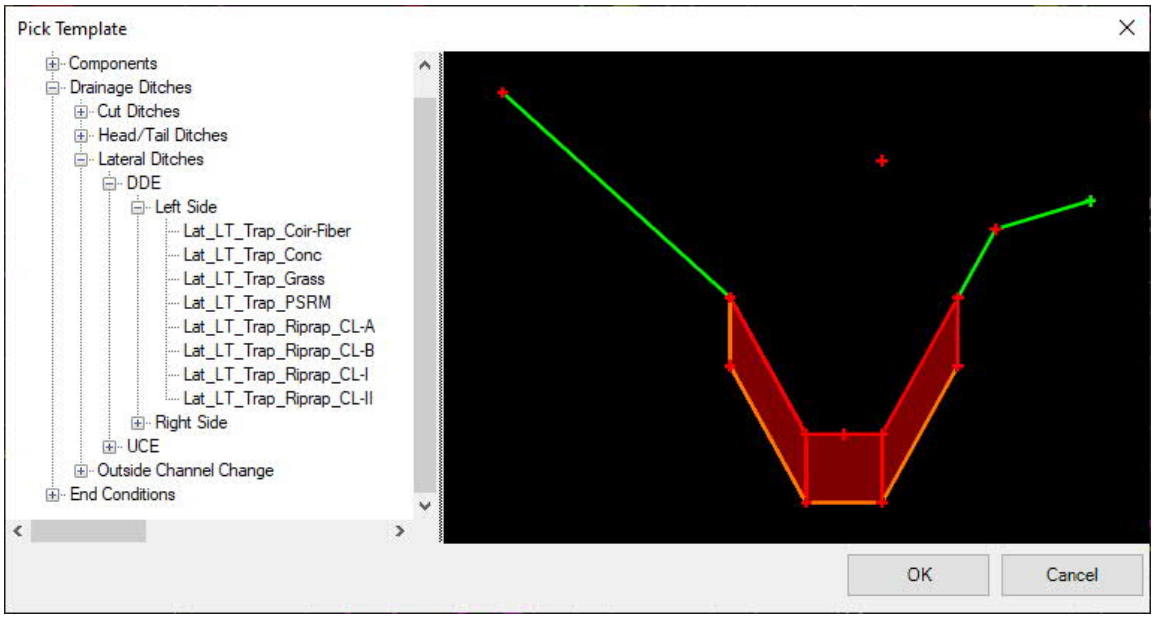
6. At the prompt *Locate Corridor Baseline*, select the toe of slope line feature from the roadway corridor model. Be sure to hover over the feature first and use the ORD attribute feedback to verify you are selecting the correct feature. <R> if needed to cycle through other features that may be located in the same place.



7. At the prompt *Locate Profile*, <R> to select the active profile for the toe of slope line feature.

8. At the prompt *Corridor Name*, provide the name such as L_16+46, LT in the dialog and <D> to accept and then move your mouse a little to bring up the Create Template Drop dialog shown below.

To select a template, you can either click on the ellipsis button in the dialog or use the ALT + Down Arrow key combination on your keyboard to open the Pick Template window.



Note that the Lateral Ditches folder contains two subfolders:

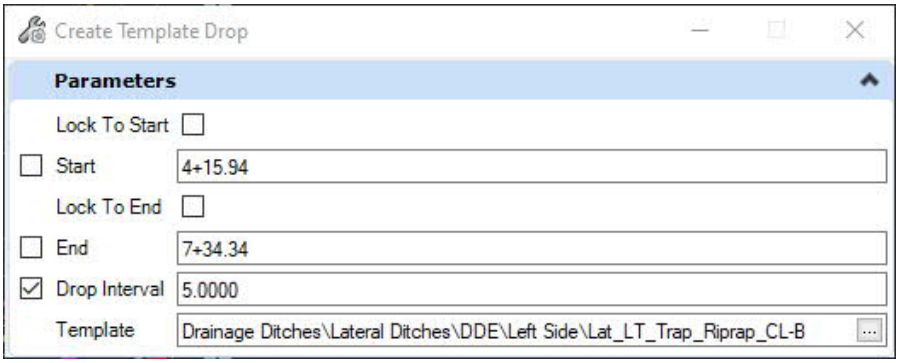
- DDE. Use these templates to model ditches where the ditch foreslope is different than the fill slope (Drainage Ditch Excavation quantity). Typically, such ditches will also have a berm between the slope stake line and the top of the ditch foreslope, but you can choose to change the berm width value to zero if desired by using a Parametric Constraint, as explained in Chapter IV.
- UCE. Use these templates to model ditches where the ditch foreslope is a continuation of the roadway fill slope, with no berm (Unclassified Excavation quantity).

Note also that the above two folders are further divided for ditches that are located on the Left and Right side of the roadway. In accordance with the standard convention, "left" and "right" are defined as looking up-station in reference to the roadway baseline. It is important that you select a template for the correct side.

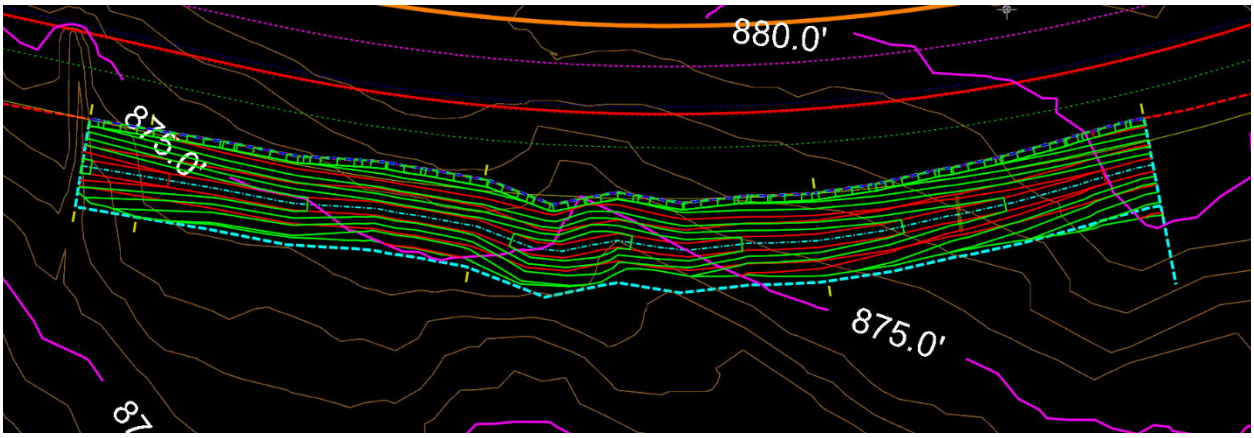
9. In the current example, browse to *Drainage Ditches* > *Lateral Ditches* > *DDE* > *Left Side* and select Lat_LT_Trap_Riprap_CL-B for a base ditch with Class B riprap.

10. Specify the Start and Stop station by using your mouse or entering values. Remember that for lateral ditches the corridor model needs to be stationed <u>in the same direction as the roadway baseline</u>, which may be the opposite direction of the ditch flow.

11. Enter a value for Drop Interval such as 5.0.



12. <D> in the design file to accept all dialog settings. The corridor model will be created and displayed in the plan view window.



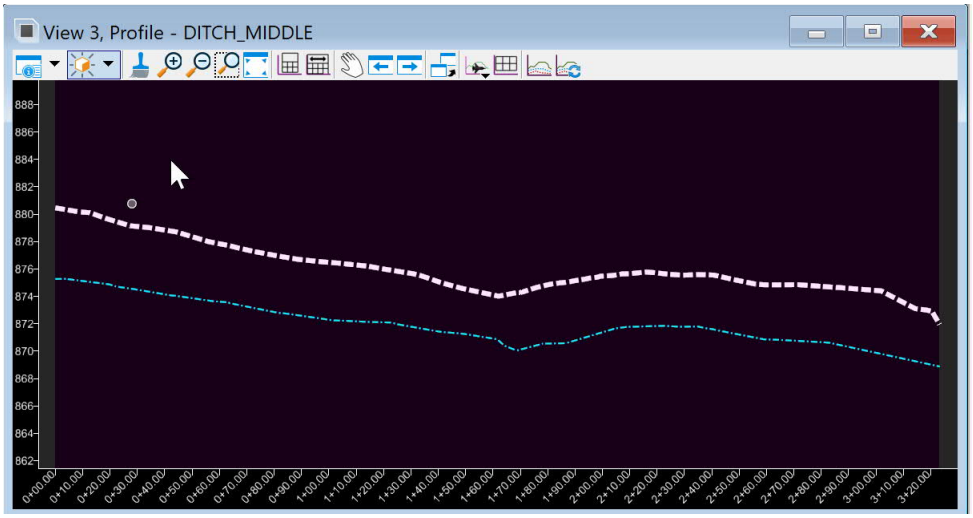
Note that in this example the ditch has a low point in it because it is following the profile of the slope stake line. This will be addressed in the following steps.

13. As discussed in the previous chapter, go to *Primary* > *References* and turn on display for the 3D model to see the contour lines for the new ditch corridor.

14. As discussed in the previous chapter, create a dynamic cross section view window to review the corridor.

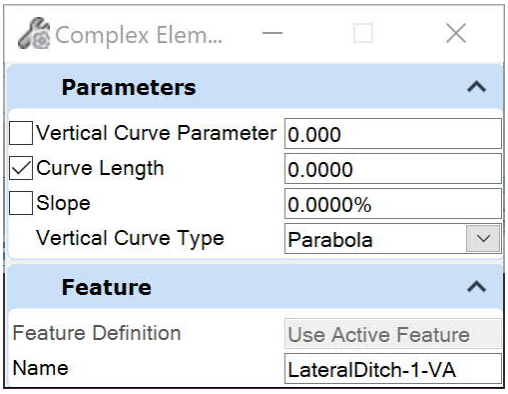
At this point the ditch has a uniform depth such that the ditch bottom is a fixed distance below the toe of the fill slope. We now need to add Point Controls to establish an independent profile for the ditch. (Video)

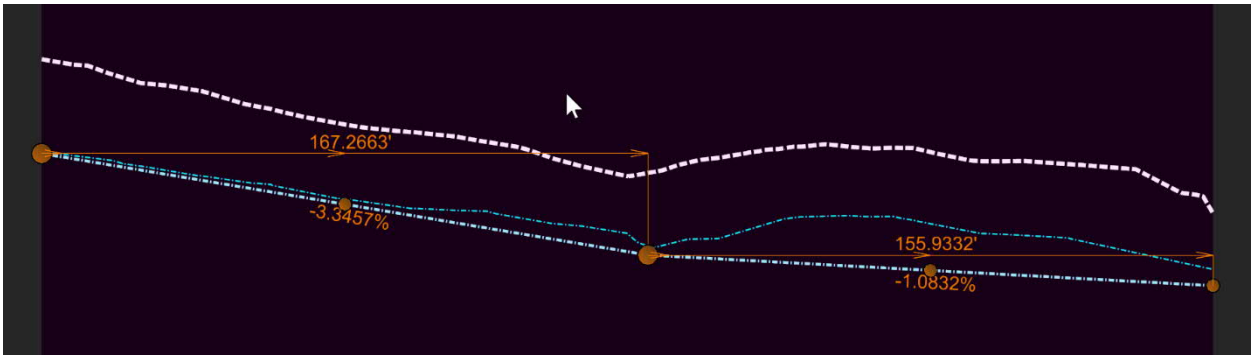
15. As explained in the previous chapter, select the ditch centerline feature in the new ditch corridor and from the fly-out menu select Open Profile Model, select an unused view window and <D> in the window to view the profile. The existing ground profile and the initial ditch invert profile will be displayed.



16. To create the Point Controls for the ditch profile adjustments, you will need a table of start and stop stations, start elevations, and slopes. To develop this data, it is helpful at this point to create a temporary profile in the profile model window to layout your proposed profile points. As explained in the previous section, use the Feature Definition Toolbar to set the default Feature Definition to HYD_Ditch_Baseline.

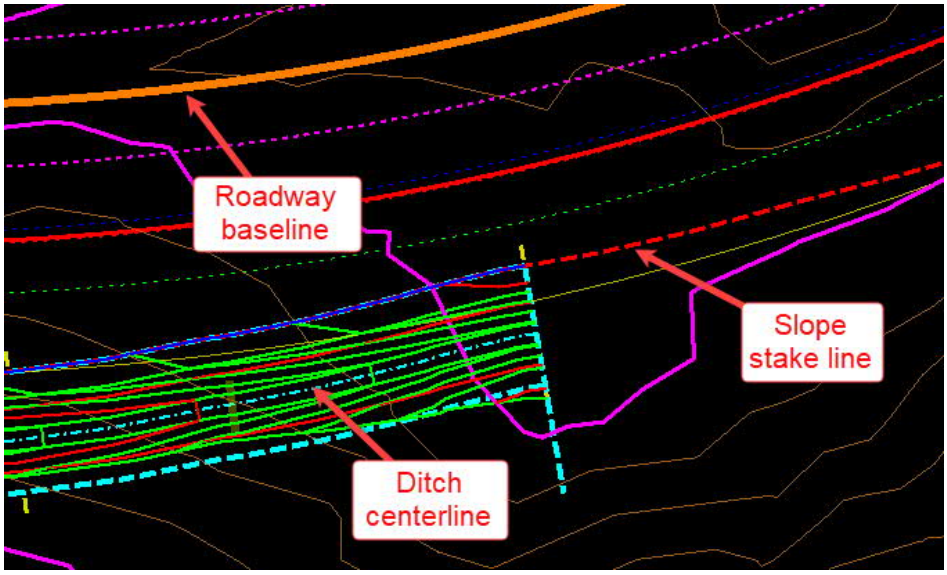
17. Go to *Geometry* > *Vertical* > *Complex Geometry* > *Profile Complex by PI* and use the procedure detailed in the previous chapter to create a profile from PI points. Do not worry about being precise for the first try. You can always make adjustments later. Ensure that the box for Curve Length





is checked and the value is set to zero. Enter the name Working Profile. Don't forget about Civil Accudraw.

We used the slope stake line from the roadway corridor model as the horizontal control for our ditch corridor. Therefore, the stationing for the ditch corridor is taken from the slope stake line, which is different than the roadway baseline stationing. Unless you started your ditch corridor at the very beginning of the slope stake line, the stationing for the ditch centerline (from which you created the profile) is not the same as the ditch corridor stationing or the roadway baseline stationing. The station data for the Point Controls must match the corridor stationing, not the ditch centerline stationing.

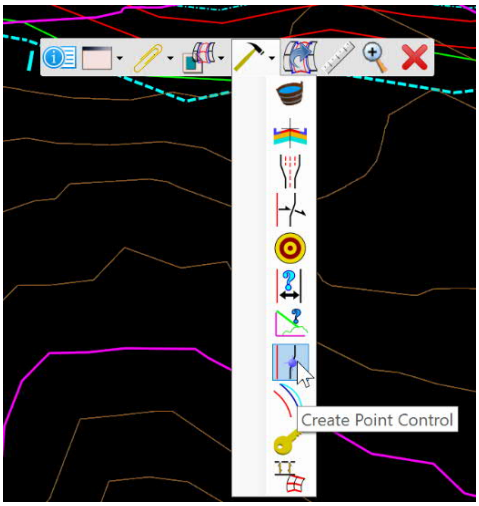


18. Go to *Home* > *Model Analysis and Reporting* > *Civil Analysis* > *Analyze Point*, select the slope stake line in the plan view, and then in the profile view you can obtain the corridor stationing for each of the profile PI points you created.

19. The data shown below is an example; your data will be different.

	Ditch Station	Start Elevation	Slope
Start	415.94	875.27	-3.3457%
PI	582.95	869.67	-1.0832%
End	734.34		

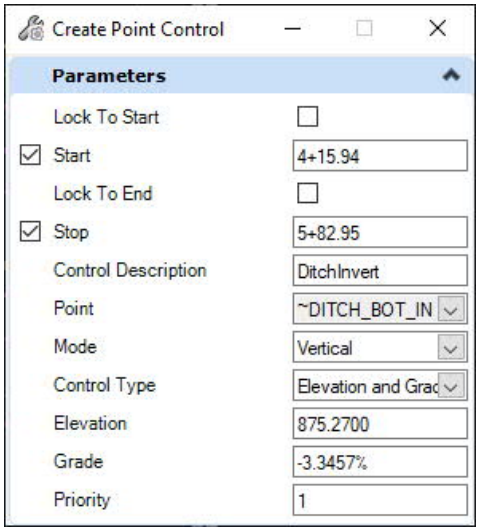
20. Select one of the ditch corridor handles and from the flyout menu go to Corridor Creation Tools and select Create Point Control.



21. In the dialog for Create Point Control (see image below), check the boxes for Start and Stop and enter the first set of stations from the data table: 415.94 and 582.95.

22. For Control Description, enter DitchInvert.

23. From the drop down list for Point, select ~DITCH_BOT_IN. This is the bottom of the ditch foreslope – and the point in the template that is to be controlled by the Point Control.



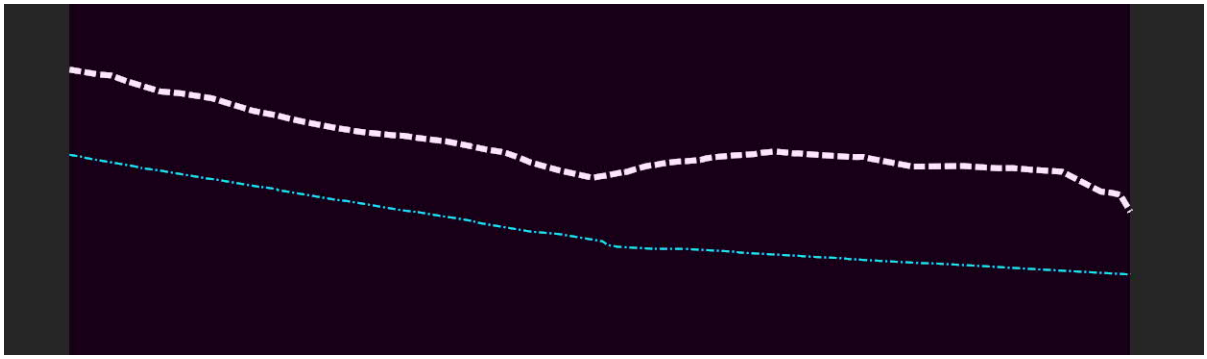
24. Select Vertical for the Mode, and Elevation and Grade for the Control Type.

25. Enter 875.27 for the elevation and -3.3457% from the data table.

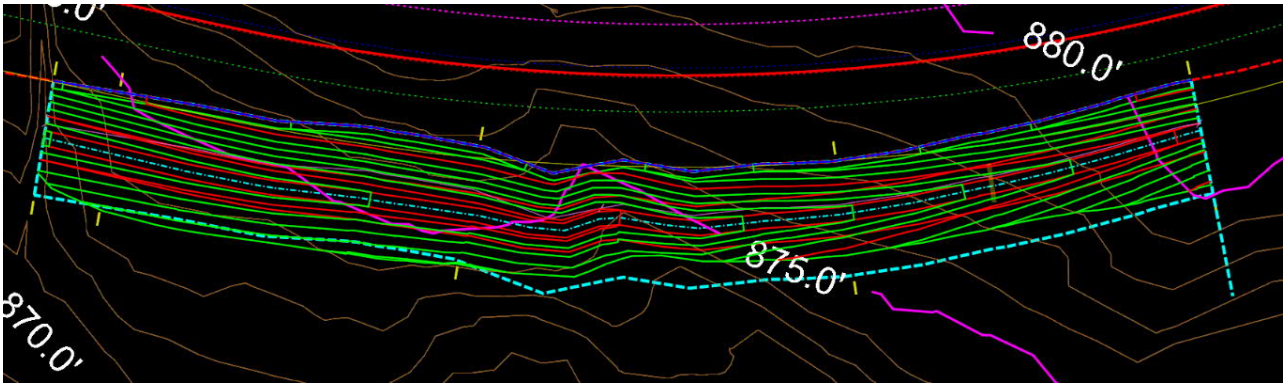
26. <D> in the design file to accept all prompts. The corridor will reprocess, and you will see the ditch profile update. Note that the new profile will not exactly match your temporary profile, and there may also be some "bumpiness". This can happen because the stationing of the corridor is based on the alignment of the toe of the roadway fill slope, not the alignment of the ditch centerline, and it's the ditch centerline that was used for the profile. As the depth of the ditch becomes variable, the ditch centerline feature will no longer be exactly parallel to the the toe of fill slope and the stationing and length of the ditch centerline will be different than the toe of fill line. Changes in ditch alignment can also cause this to happen. For this reason, you will find that this process is often iterative: your initial values for elevation and grade may need to be repeatedly adjusted as you refine the profile to match your intended profile.

27. Redo this process to add a second point control using Start = 582.95, Stop = 734.34, Elevation = 869.67, and Slope = -1.0832%. Continue adding point controls to the corridor until all data has been entered.

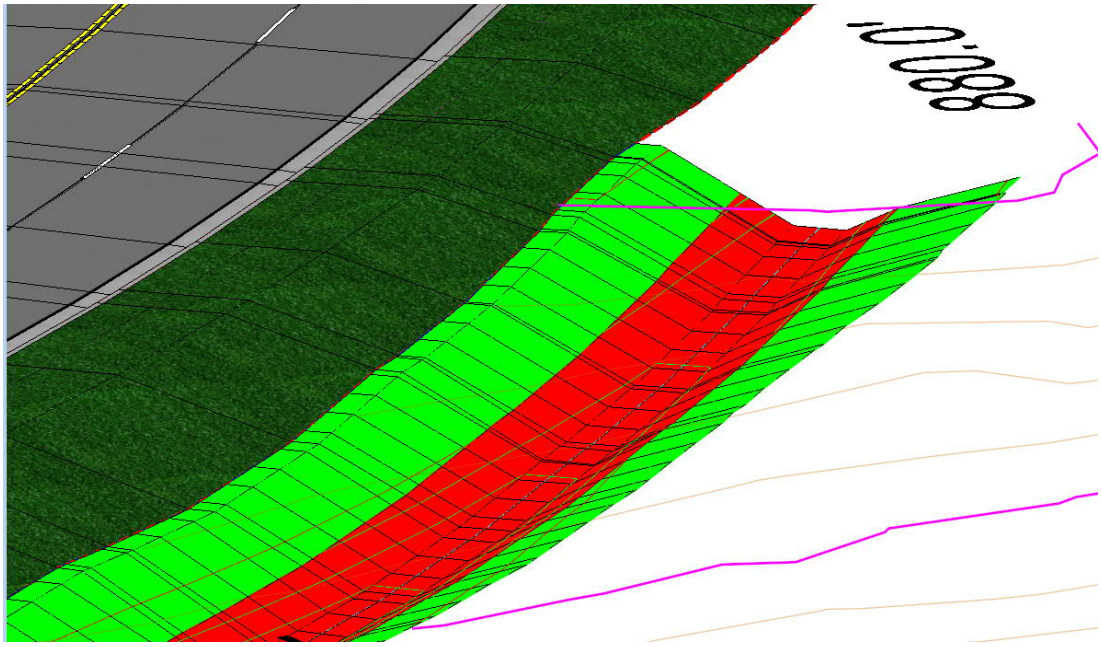
28. In the profile window, delete the temporary profile.



29. Turn on the display of the referenced 3D model and review the contour grading for the ditch. Notice that the low point in the ditch has been eliminated.



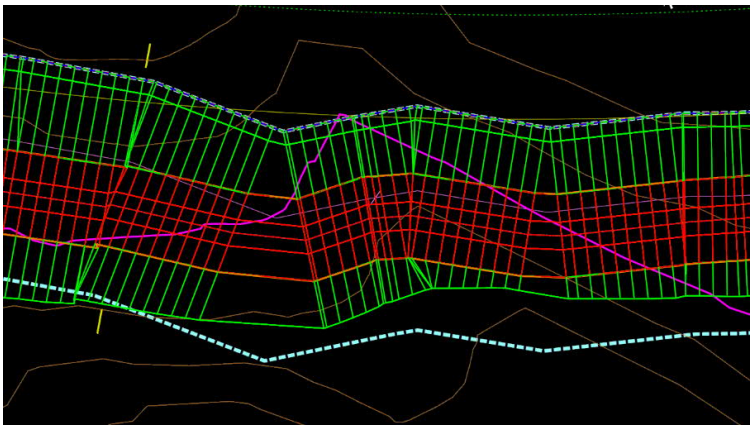
30. Go to the 3D model view window and review the ditch, using the Rotate View tool.



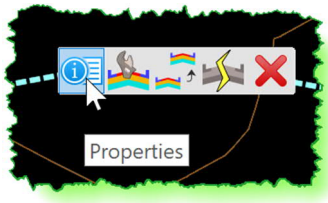
B. Create ditch corridor model using new SS line on top of the existing Roadway SS line with added curves.

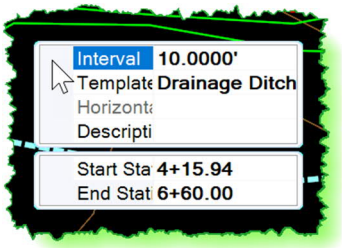
The previous approach works best when the fill slope toe is linear and does not have abrupt angular changes in horizontal alignment. Deflection angles in horizontal alignment may create template drops that cross each other and cause model glitches. Usually, moderate changes in alignment are tolerated fairly well when contours are displayed. As you can see in the example below, there is an area where templates are crossing. Yet, the contour display was acceptable.

If crossing templates become a problem, there are two approaches you can take to address the issue: (Video)



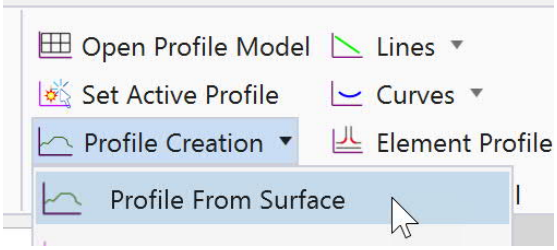
1. The easiest approach is to simply reduce the frequency of template drops by increasing the template drop interval. Select the graphic for the template drop (light blue dashed line) and from the flyout menu select Properties. In the Quick Properties dialog that pops up, type in a new (larger) value for the Interval. This is typically an iterative process – try various values until you obtain the desired results. Usually, continuing to increase the Interval beyond a certain value will not be helpful, so increase the Interval in small steps. If you cannot obtain acceptable results using this approach, then try the second approach below.

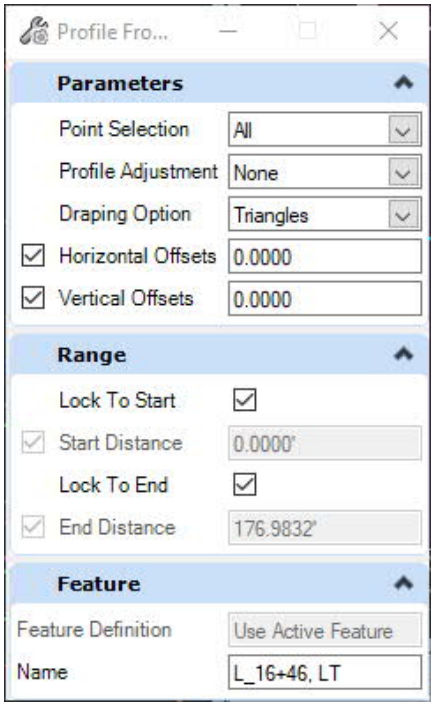




2. Instead of using the roadway corridor slope stake line as the ditch corridor horizontal control, place a separate alignment along the path of the slope stake line. This can be done by using the Complex by PI tool and placing a series of points, snapping to the roadway corridor slope stake line. Be sure that the Persist Snaps toggle in the Feature Definition Toolbar is ON so that your new slope stake line will be ruled to the roadway corridor slope stake line. It is not necessary to snap to every vertex in the slope stake line feature – just add enough points to follow the line.

3. Once this line has been created, you can now use the Table Editor at *Geometry* > *Common Tools* to add small horizontal curves at any interior angles to eliminate the crossing templates. Remember, you can come back later and easily use Table Editor to edit the curve radii. See Chapter IV for further discussion of adding horizontal curves. Some things to remember when using this approach:
   - Once the horizontal alignment has been set, you will need to establish a profile for the control line which is based on draping the alignment on the existing terrain. To do this, go to *Geometry* > *Vertical* > *Profile Creation* > *Profile From Surface*. Follow the prompts or complete the dialog to create a profile and don't forget to set it as the "active" profile when finished.





   - Try using smaller radius values. You can usually eliminate the crossing template drops with small curves in the alignment.
   - Remember that when creating the horizontal alignment, you can snap to the slope stake line wherever you wish to create a "ruled" alignment that will update if the roadway slope stake line shifts.

C. Create ditch corridor model using the Roadway baseline as the ditch control line.

One may use the roadway baseline as the reference baseline for a lateral ditch instead of the SS line. The principal benefit of this is that for corridor edits the stationing is the same as the roadway baseline. However, the disadvantage is that several additional modeling edits must be made. First, a point control must be added to shift the ditch from its initial position at the roadway baseline to its actual position at the SS line. Second, the SS line needs to be added to the ditch model as a "Secondary Alignment" in order for the template drops to be perpendicular to the ditch (not the roadway baseline) in order to ensure correct ditch dimensions and quantities.

1. Go to Corridors > New Corridor. Set Feature Definition to HYD w/Contours as before. (Video)

2. At the prompt *Locate Corridor Baseline*, select the roadway baseline.

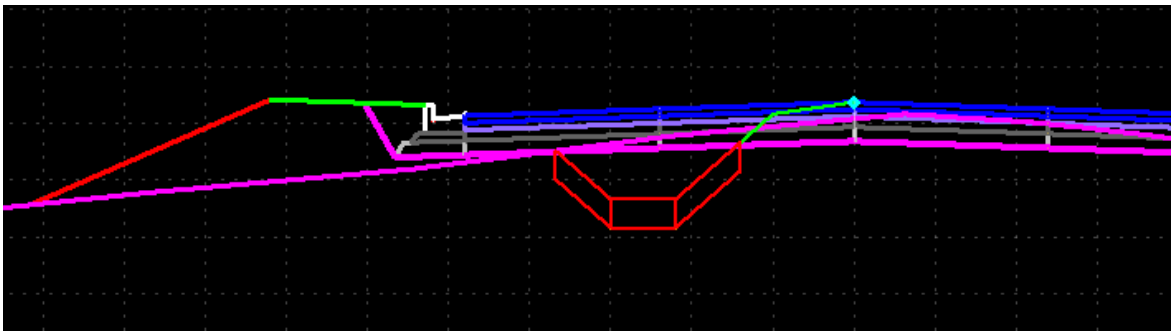
3. At the prompt *Locate Profile*, select profile "Y2" from the list.

4. Enter a ditch name such as Y2_16+46, LT.

5. In the dialog, click on the ellipsis button to launch the Pick Template dialog, and select a template such as Lat_LT_Trap_Riprap_CL-B as in the previous example. <D> to accept the selection.

6. Enter the Start and End stations, based on the roadway baseline stationing. In this example, the start station is 16+46 and the end station is 19+40.

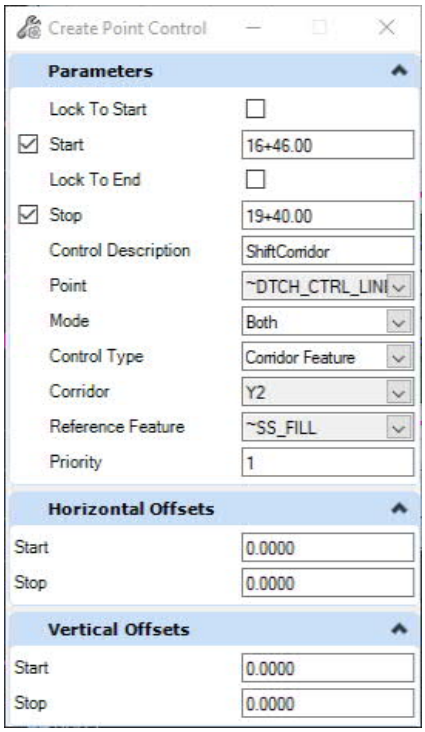
7. Enter a drop interval and <D> to confirm. The initial ditch is then placed at the roadway baseline.



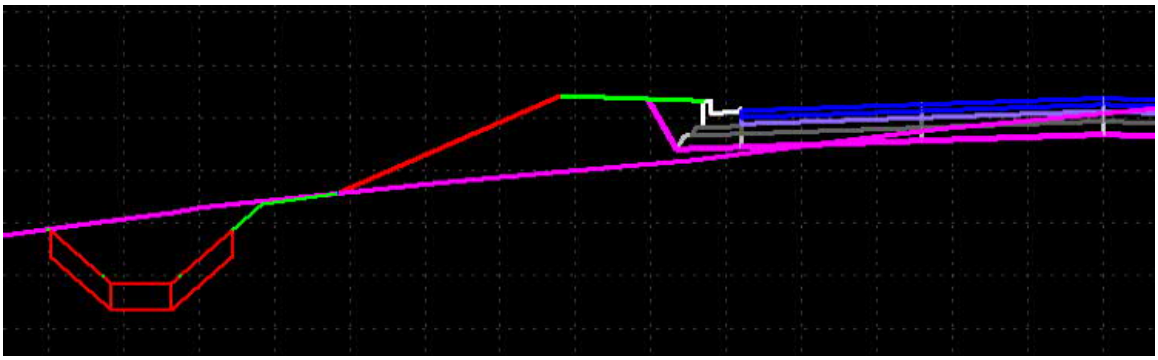
The ditch now needs to be shifted to the slope stake line. This is done using a Point Control.

8. Go to *Corridors > Edit > Edits > Create Point Control*. Or, you can just select one of the ditch corridor handles and select this tool from the flyout menu.

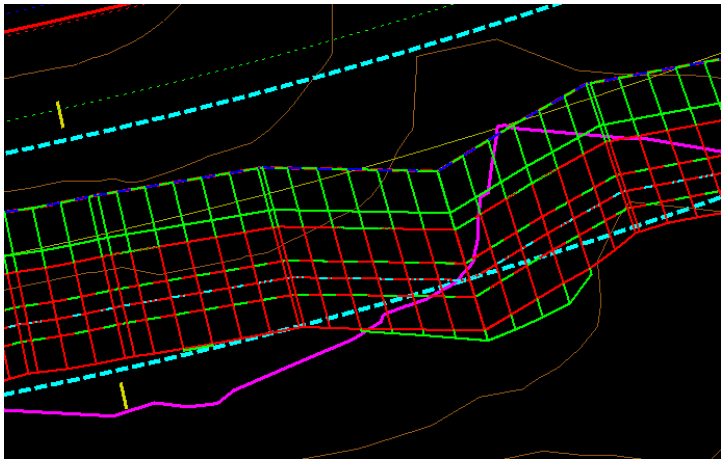
9. Complete the dialog box as shown on the right. It's important that you complete the dialog from the top down. However, you must also pay attention to the head's up prompt and <D> to accept the selected Corridor. If you do not do this, the drop down list for Reference Feature will not show any features to select.



The ditch will then move to the fill slope stake line as shown below.



As a consequence of using the roadway baseline as the baseline for the ditch, the template drops for the ditch are perpendicular to the roadway baseline rather than to the slope stake line. This results in a 3D model which is not consistent with the hydraulic calculations. The inaccurate ditch dimensions will also result in inaccurate ditch quantities for earthwork, riprap, and geotextile. To correct this, a Secondary Alignment needs to be added to the ditch corridor model.



10. Go to *Corridors* > *Edit* > *Edits* > *Create Secondary Alignment*. Or, you can just select one of the ditch corridor handles and select this tool from the flyout menu.

11. At the prompt *Select Corridor*, select one of the corridor handles, and at the prompt *Locate Secondary Alignment*, select the fill slope stake line from the roadway corridor model.

12. Enter and accept the Start and Stop stations, and enter zero for the Start and Stop Offsets. <D> to accept inputs, and the corridor will update.

As shown above, the ditch template drops are now perpendicular to the ditch flow line, as they should be. If crossing template drops become an issue, then you will need to address this as discussed earlier in this chapter by creating a new slope stake line along the original so that you can add vertices or small horizontal curves to eliminate the crossing template drops if needed. After this is done, use the new slope stake line as the source for the Point Control to shift the ditch corridor from the roadway baseline to the slope stake line. You do not need to delete and redo the Point Control done previously, just edit the one you already created by using the Corridor Objects tool.

- In the Point Control settings, change the settings so that the Control Type is Linear Geometry, and you can then select the new slope stake line you created. Also, check the box for Secondary Alignment.

- In the Corridor Objects tool, delete the first Secondary Alignment that was added since you no longer need it.

As explained earlier in this chapter, you can then add a point control to set the ditch profile.

D. Creating a ditch corridor model when changes are required to the Roadway corridor model.

It will often be the case that changes are needed to the roadway corridor model to address Hydro requirements. For example, shoulder berm gutter is to be added, or the fill slope changed from 3:1 to 2:1, etc. These changes are to be shown on the Redline Drainage Plans for approval prior to submitting to Roadway Design Unit. The following workflow in this chapter is intended to provide a coordinated approach that:

- allows Roadway and Hydro staff to work in their own separate files, and
- avoids duplication of effort between the two Units.

The following is an overview of the recommended workflow:

✓ Hydro creates a corridor model of the revised roadway fill slope, which establishes a new fill slope stake line. Both the fill slope component and the new slope stake line will be placed on levels that can be turned off for plan production. They are only to be used for Redline Drainage Plans.

✓ Hydro creates a corridor model for the ditch that uses the new slope stake line as the ditch control point. This corridor model will be used for both Redline Drainage Plans as well as the final construction plans.

✓ After Redline Drainage Plan are approved, Roadway will edit the roadway corridor end conditions so that they match the changes requested by Hydro. Roadway's corridor model will stop at the slope stake line and will not include the ditch, avoiding duplication of modeling effort.

✓ In cases where the roadway has gone from a "fill" section to a "cut" section (as with UCE ditches that have a foreslope which is a continuation of the roadway fill slope), then Roadway will use End Condition Overrides so that the slope stake line is a construction class element that will not appear on the plans, and that change the slope component from a "fill" component to a "cut" component.

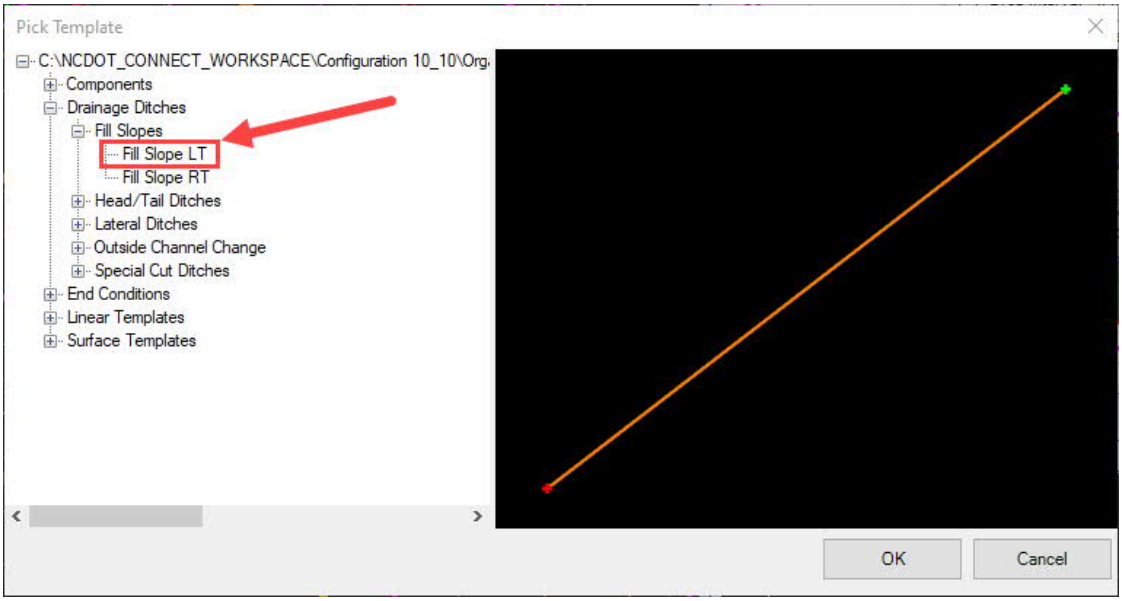
1. Go to *Corridors* > *Create* > *New Corridor*. (Video)

2. At the prompt *Locate Corridor Baseline*, select the roadway baseline geometry.

3. At the prompt *Locate Profile*, select the desired profile from the dropdown list in the dialog.

4. Give the new corridor a name, such as NewFillSlope.

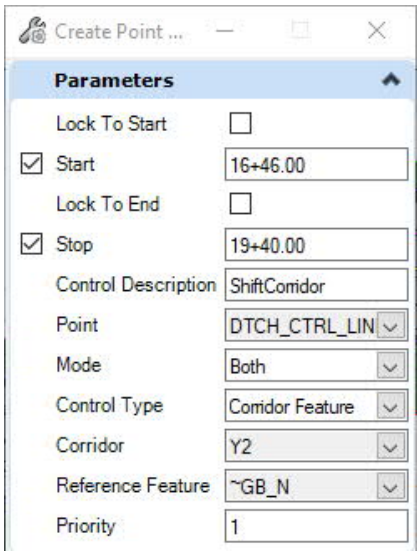
5. At the prompt *Select Template*, select the template Fill Slope LT since the ditch is on the left side of the road.



6. Enter the Start and End stations for the new corridor.

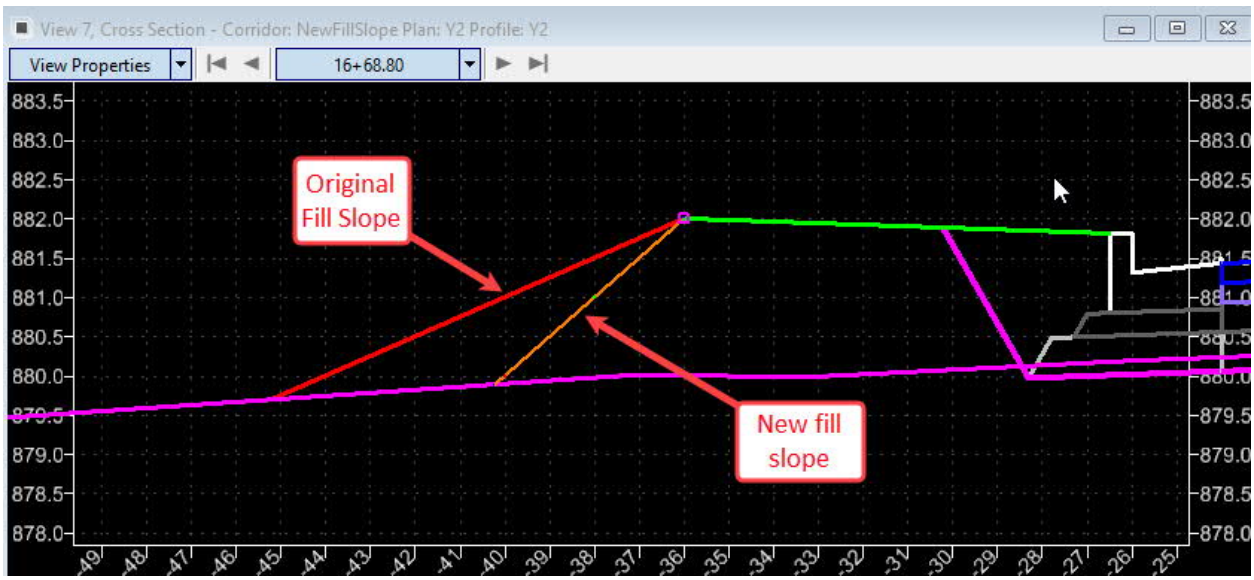
7. Enter the template drop interval. The new corridor will then be created. At this point, it will be located at the roadway baseline.

The next step is to apply a Point Control to shift the corridor to the shoulder break point, using the same procedure as described earlier in this chapter.

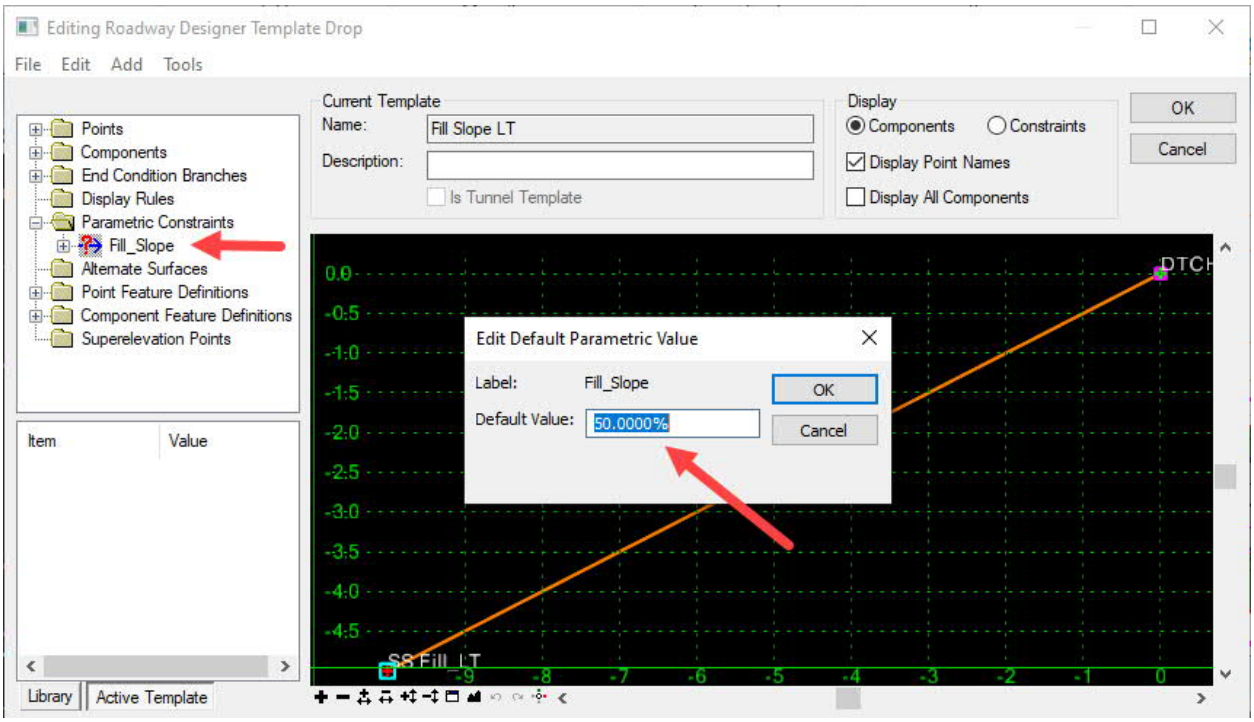


8. Go to *Corridors > Edit > Edits > Create Point Control*. Complete the dialog as discussed earlier in this chapter. The target point name for the shoulder point is "~GB_N". This then shifts the fill slope corridor to the correct location. In this example, the original 4:1 fill slope is being replaced with a 2:1 fill slope.

   The selected template has a default fill slope of 2:1. What if you want a different fill slope? You can apply a Parametric Constraint to change the fill slope. However, an easier approach is to simply edit the template drop so that it uses your desired fill slope.



9. Go to *Corridors > Edit > Edit Template Drop* and select the corridor for the new fill slope in the plan view window. This will launch the template editor. In the editor, select the Active Template tab, and then open the folder for Parametric Constraints. Double click on the entry for Fill_Slope, and you can then enter the desired value for fill slope. See the screenshot on the next page.

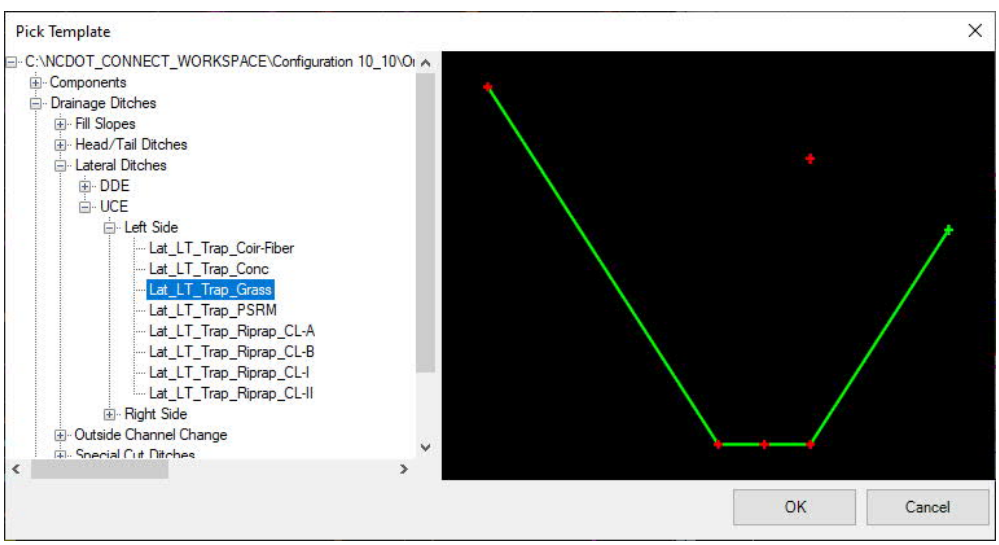


Now that the new fill slope has been established, the corridor model for the proposed ditch can be created. In this example, a grass trapezoid ditch will be provided that has a foreslope that is a continuation of the roadway fill slope.

10. Go to *Corridors* > *Create* > *New Corridor*. (Video)

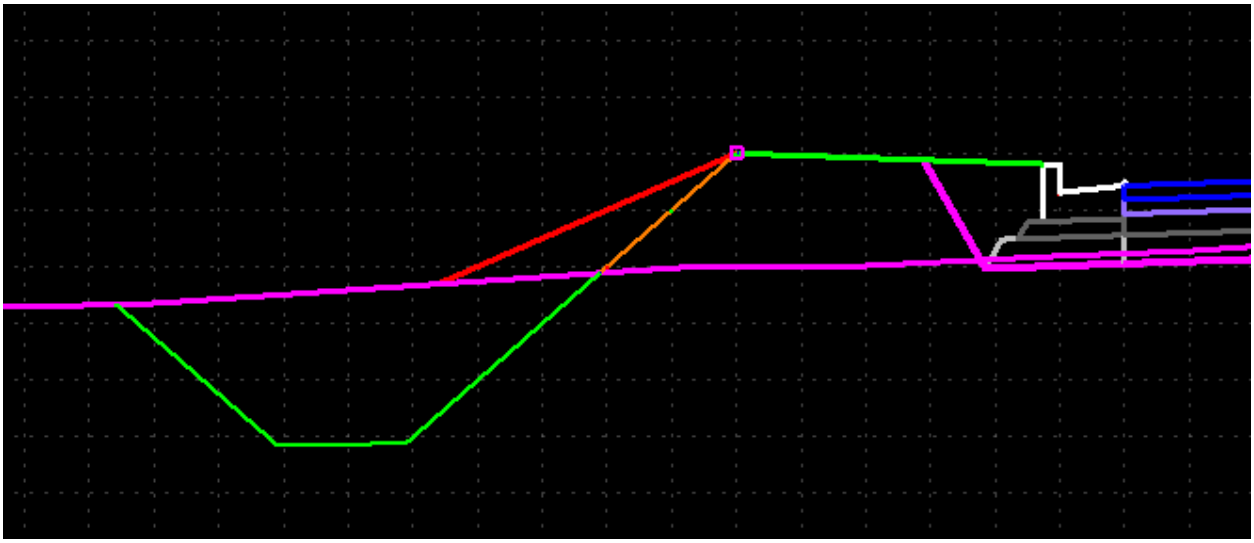
11. At the prompt *Locate Corridor Baseline*, select the new fill slope stake line in the plan view window, and at the prompt *Locate Profile*, <R> to accept the active profile.

12. Give the ditch corridor a name such as Y2_16+46, LT, and at the prompt *Select Template*, select the grass lateral ditch template under the UCE folder.



13. At the prompts for Start and End stations, you can press the ALT key to lock to the beginning and end of the corridor baseline since you are now using the new fill slope stake line, not the roadway baseline, as the corridor baseline.

14. Enter and accept the template drop interval, and the ditch corridor model will be created.



What is shown above can now be used to prepare the Redline Drainage Plans.

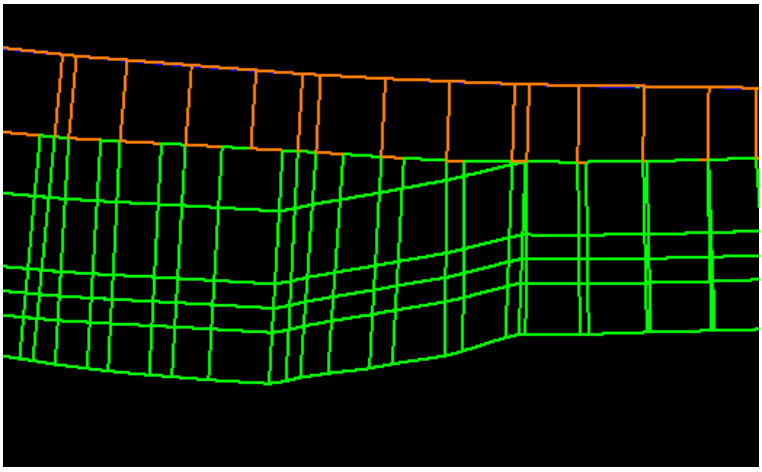
The red line above is the original roadway corridor model fill slope. Once the Hydro design has been approved, Roadway will revise the roadway corridor to match the new fill slope shown above in orange. Roadway must use an End Condition Exception Override that will change their fill slope from a “fill” component to a “cut” component. They must also change the Feature Definition of the fill slope stake line feature so that it creates a 3D linear feature as a construction class element. When changing side slope, remember that it is NCDOT practice to provide at least 50 feet between each 1’ shift of side slope (i.e., 3:1 to 4:1). This can be accomplished using parametric constraints as discussed in the next chapter.

Roadway can then turn off the level P_HYD_TC_Fill_Slope containing the orange fill slope line. The 3D linear features for the ditch control line at the shoulder break point as well as the new fill slope stake line are construction class elements that will not appear on the final plans.

The next steps in the process are to make corridor model edits to change ditch dimensions, add transitions, and add or modify channel linings. This is explained in the next chapter.

E. Special Cases

1. Sometimes a lateral ditch may start out as a UCE ditch (no berm, with ditch foreslope the same as the roadway fill slope) and then transition to a DDE ditch with a slope break and/or a berm between the fill slope stake line and the ditch foreslope. When this occurs, there is no need to create two separate ditch corridor models. You simply change the template being used where the change occurs. This is done by going to *Corridors* > *Create* > *New Template Drop* and provide the Start and End station range, the new template, and the template drop interval. That new template will then replace the existing template in that specified range. You will then likely need to add a parametric constraint (discussed in the next Chapter) to transition from one template to another. In this case, the berm width at the start of the DDE ditch was transitioned from 0' to 5' wide.



2. Earlier in this chapter it was shown how you can create a new fill slope stake line on top of the original line created by the roadway corridor model so that you can add horizontal curves to address crossing templates. Keep in mind that just as you can add a Point Control to shift your ditch model from the roadway baseline down to the slope stake line as shown earlier in this chapter, you can also use a Point Control to shift <u>a portion</u> of your ditch corridor from the original slope stake line to a new slope stake line. That means that you can create a new slope stake line for just that location where the crossing templates occur, and not necessarily for the entire ditch length.

3. If you ever need to change the baseline of a ditch corridor model from one alignment to another, or if the name of the baseline has changed, use the Reattach Corridor tool to do this. You do not need to recreate the corridor. Follow the prompts to select the ditch corridor and then select the new alignment.

IV. Adjusting the Ditch Design

A. Adding Parametric Constraints (Video)

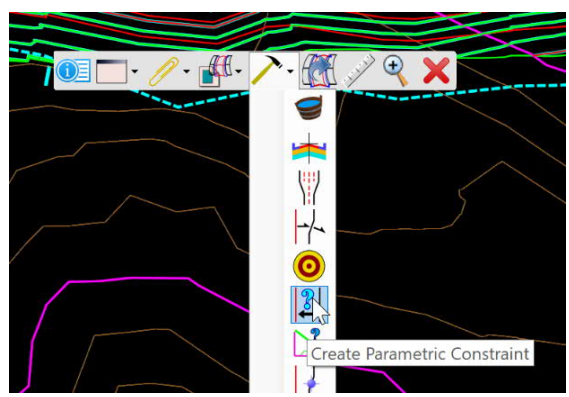
Initially, the ditch corridor model has been created utilizing default values for the bench offset from the slope toe, ditch bottom width, left and right-side slope, height of channel lining, and thickness of channel lining and bedding layers, etc. These default values were taken from the specific template that was selected during the corridor creation process. The next step in the process is to adjust the corridor model based on the hydraulic assessment that was completed.

The NCDOT standard templates for ditches contain "parametric constraints". Parametric constraints allow for template variables, such as bottom width or side slope, to be defined in reference to a parameter that can be varied in the corridor model. In this way, the ditch dimensions can be adjusted at various locations along the corridor without having to re-create the corridor or create new templates. Refer to the Appendix for a list of the available parametric constraints.

Before revising the ditch dimensions, you should first finalize the previously created ditch invert vertical alignment if needed by revising the Point Controls. The corridor will automatically re-process. If the vertical alignment is revised, then review the previous hydraulic analysis and determine if ditch dimensions or linings need to be revised as a result.

In this example, parametric constraints will be used to widen the ditch below station 6+40. A transition section will be added between 6+20 and 6+40. Therefore, two parametric constraints will be needed: one for the widened ditch and one for the widening transition. Remember, however, that the stationing used for the parametric constraints will use the ditch corridor stationing, not the ditch centerline stationing, nor the roadway baseline stationing.

1. Select one of the corridor handles and from the flyout menu go to Corridor Creation Tools and from the drop-down menu select Create Parametric Constraint.



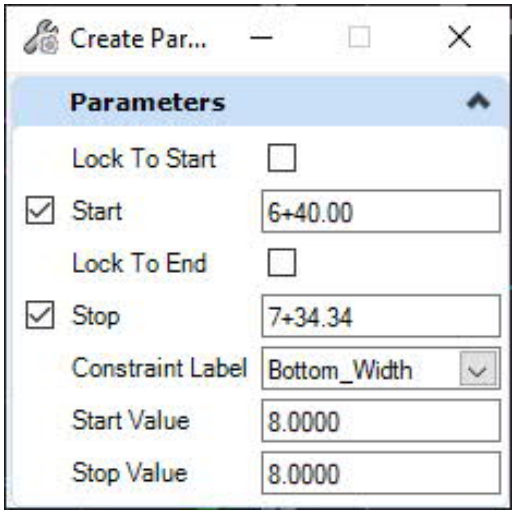
2. In the Create Parametric Constraint dialog (see next page), enter 640.00 for the Start location and 734.34 for the Stop location (the station of the end of the ditch corridor).

3. For the Constraint Label, select Bottom_Width.

4. Change the Start Value and Stop Value for the parametric constraint to 8.

5. <D> in the view window to accept all dialog inputs. The ditch corridor will reprocess, and all views will update.

6. The next step is to add a section to transition the 4' wide bottom width to an 8' wide bottom width. Repeat the above process to add a new parametric constraint.

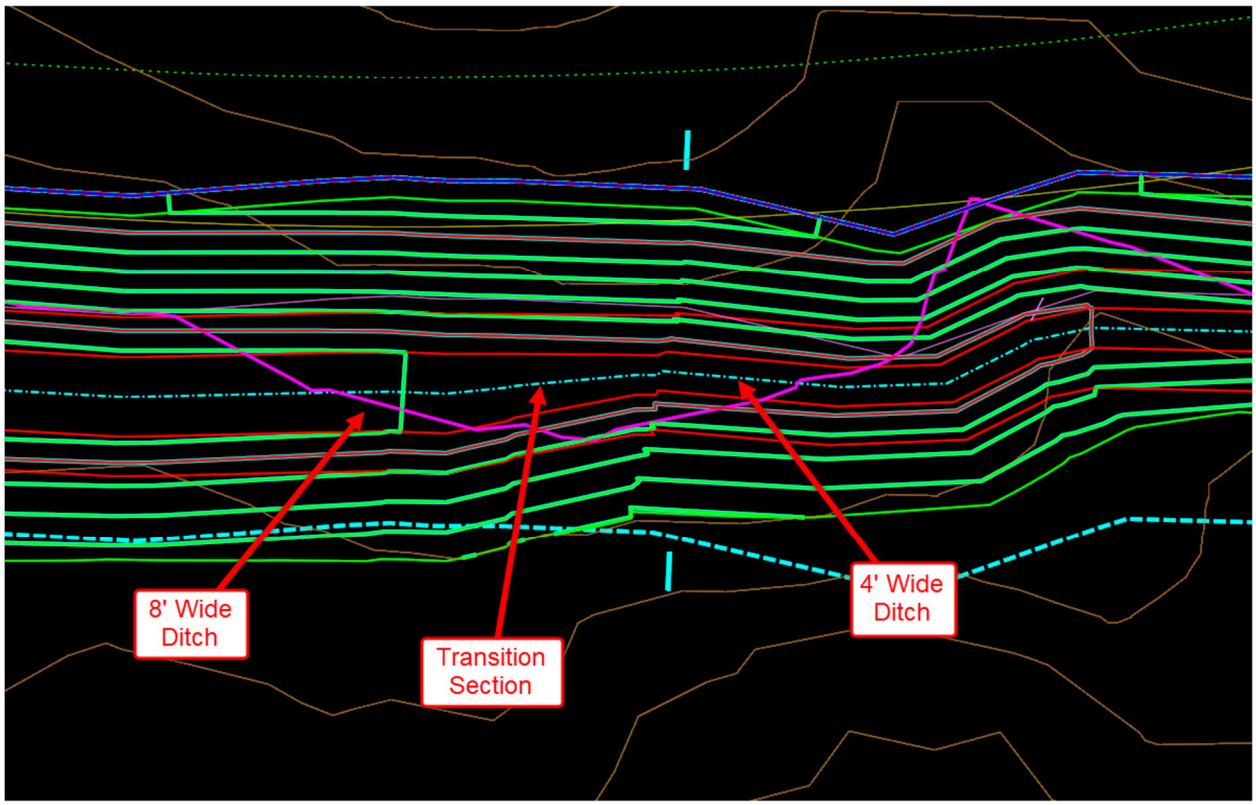


7. Enter 620.0 for the Start location and 640.0 for the Stop location.

8. Enter 4 for the Start Value and 8 for the Stop Value.

9. <D> in the view window to accept all dialog inputs to update the corridor.

10. This same process can be used to change any other dimension of the ditch.



Determining Length of Transitions:

For creating parametric constraints for channel transitions, the NCDOT recommended practice is to apply a 25:1 transition ratio. In the above example, the bottom width was increased from 4 to 8 feet. Since the expansion occurs on one side of the channel, the 4' expansion is multiplied by 25 to obtain a transition length of 100 feet.

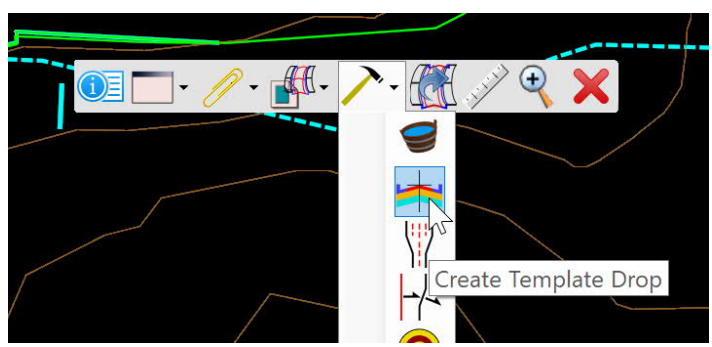
Note that parametric constraints allow you to model linear transitions only. If you want a corridor feature to follow a curved path, then you must use a Point Control as discussed earlier, except that instead of adjusting the profile, you would set the Model to Horizontal and provide a horizontal control element. Also, note that the default templates all assume base (trapezoidal) ditches. Therefore, if you are modeling a V-ditch, then apply a parametric constraint to change the bottom width to zero. You can also use a parametric constraint to transition a ditch from a V-ditch to a base ditch.

Another place where parametric constraints are needed is where a ditch daylights to existing ground. In these cases, the lining on the backslope will automatically transition as the ditch depth reduces to zero. However, the lining on the foreslope will not. Therefore, you will need to add a parametric constraint to gradually reduce the value of "Lining_Height_IN" from its design height to zero over a specified station range.

B. Adding Template Drops (Video)

In order to add, remove, or change the ditch lining it is necessary to revise the template being used for the corridor model for the station range where the change is needed. In the current example, Class B riprap has been used for the entire length of the ditch. It will be revised so that Class II riprap is used for the 8' wide portion of the ditch beginning at 6+40.

1. Select one of the corridor handles and from the flyout menu go to Corridor Creation Tools and from the drop-down menu select Create Template Drop.

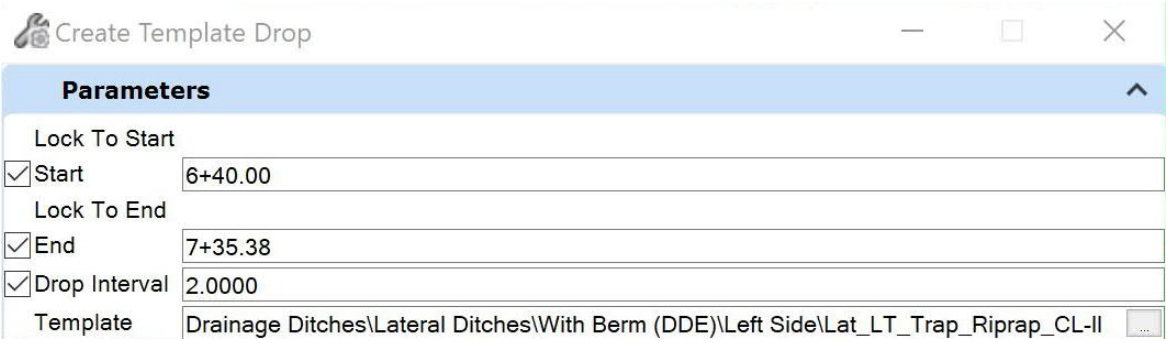


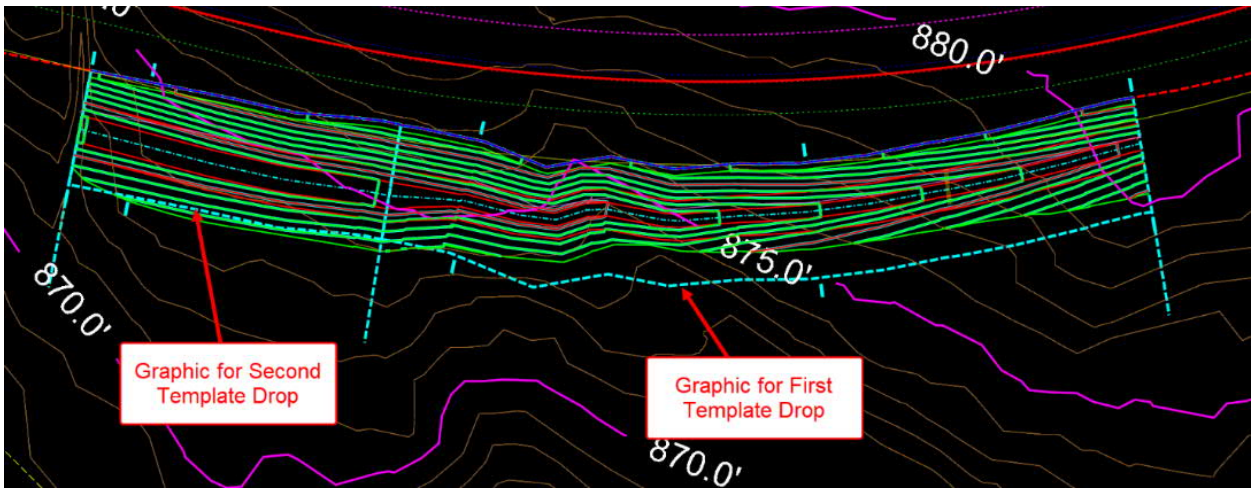
2. In the dialog, check the boxes for Start and End and enter 640.0 and 734.34 for the End.

3. Enter 5.0 for the Drop Interval.

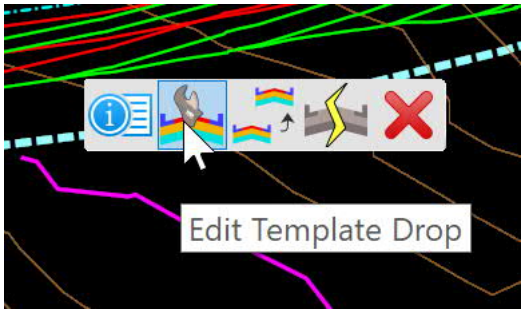
4. From the drop-down list, select Lat_LT_Trap_Riprap_CL-II.

5. <D> in the view window to accept all dialog inputs to update the corridor.

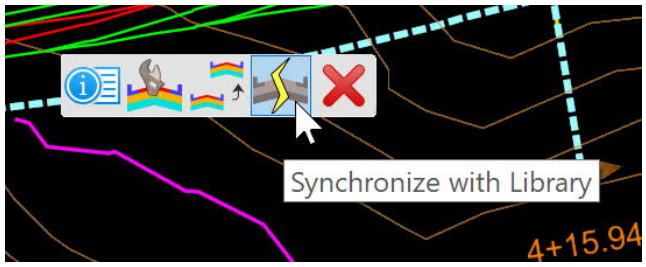




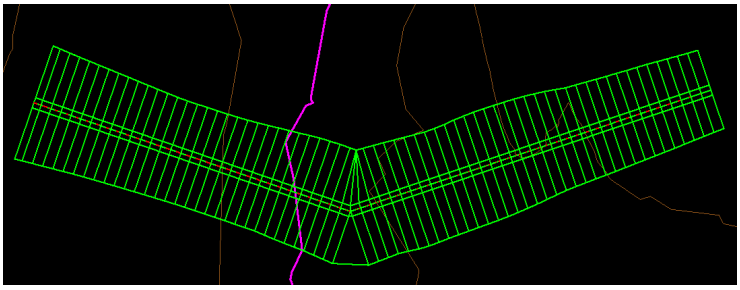
OpenRoads creates graphics in the plan view for the template drops. If edits to a template drop are needed, then select the template drop graphic and from the flyout menu select Edit Template Drop. It is important to remember that once a template has been dropped into a corridor, it is completely separate from the template library from which it came. Edits to the template drop do not change the templates in the library.



If you want the changes to be included in the library, then first make the changes to the library, then select the template drop graphic and from the flyout menu select Synchronize with Library. The changes in the library will then be applied to the template in the corridor.



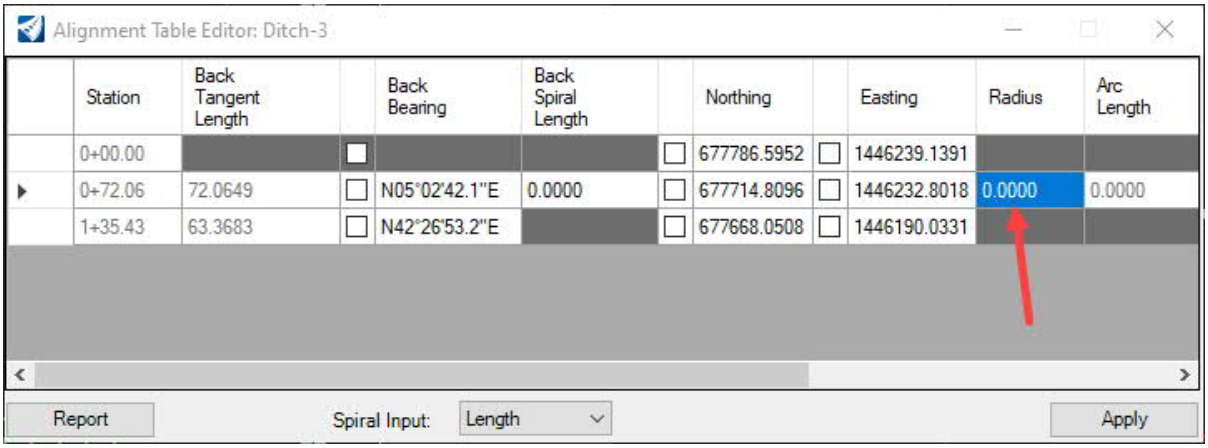
C. Adding Horizontal Curves to Ditches (Video)



It is often necessary to add small horizontal curves to ditch alignments to avoid modeling problems caused by corridor templates crossing each other where there is a deflection in the alignment, as discussed earlier in Chapter III. This is more likely to occur for ditches with relatively large deflection angles and top widths. Fortunately, it is easy to add such curves.

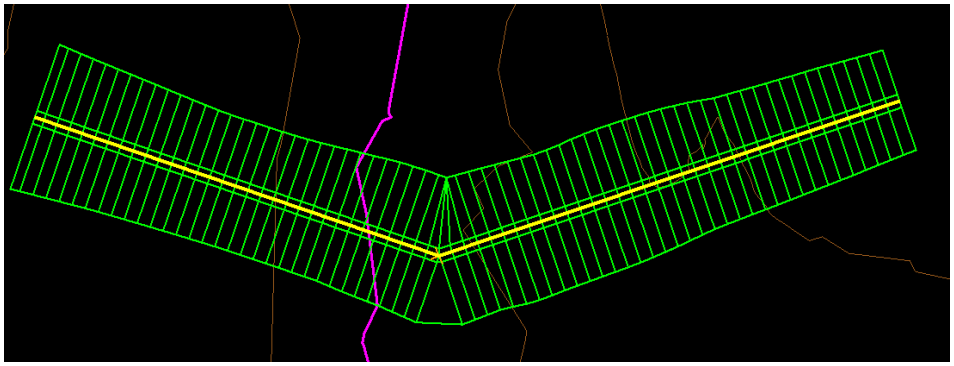
1. Go to *Geometry* > *Common Tools* and select Table Editor.

2. At the prompt *Locate Alignment*, select the baseline of the ditch. This brings up the dialog for Alignment Table Editor.

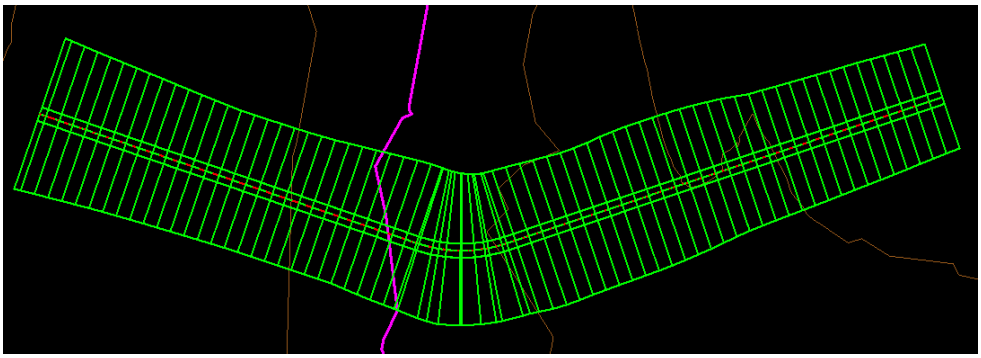


Station	Back Tangent Length	Back Bearing	Back Spiral Length	Northing	Easting	Radius	Arc Length
0+00.00				677786.5952	1446239.1391		
0+72.06	72.0649	N05°02'42.1"E	0.0000	677714.8096	1446232.8018	0.0000	0.0000
1+35.43	63.3683	N42°26'53.2"E		677668.0508	1446190.0331		

3. Select the middle row and in the plan view the tangents on either side of the selected PI point will highlight in yellow.



4. In the Alignment Table Editor, change the value of Radius to 20, and then click Apply to reprocess the corridor to see the change. Experiment with different values for radius. Use the smallest value that provides good results. When finished, close the dialog.

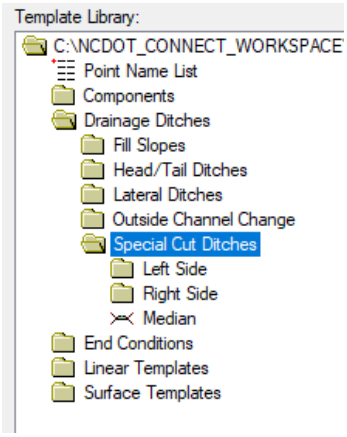


V. Special Cut Ditches

Special cut ditches are located within the limits of the roadway corridor. They modify the "standard" cut ditches that result from the templates used in the roadway corridor model. Some examples include:

- Increasing the ditch grade at crest vertical curves to eliminate flat spots.
- Creating a ditch that slopes in the opposite direction of the roadway grade (i.e., "bucking grade").
- Lowering the ditch grade to match the invert of a cross pipe, or increase conveyance capacity.

Since special cut ditches are incorporated into the project design through modification of the roadway corridor model, it may not be necessary to create separate corridor models for them. It is only necessary to create the horizontal and vertical alignments for the special cut ditches. With this information, the Roadway staff can then use those alignments as point controls for the roadway corridor model to make the needed modifications. However, Hydraulics Unit staff may wish to develop corridor models for the cut ditches as part of the design process to evaluate the impacts of special cut ditch alternatives. This could be a more efficient alternative to the traditional approach of marking up roadway cross sections, especially if the changes affect many cross sections. This chapter provides workflows for developing the horizontal and vertical alignments that are needed by the Roadway staff, as well as workflows for creating corridor models for evaluation purposes.

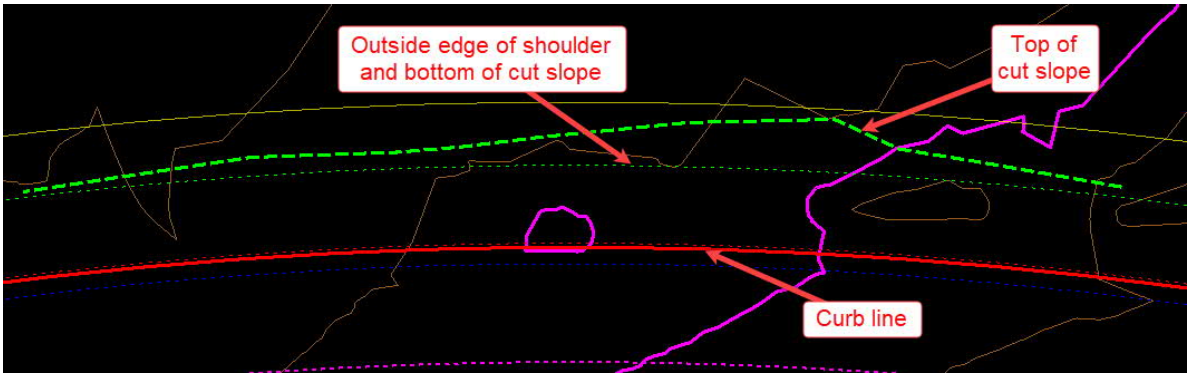


Special cut ditches can be needed in grassed medians as well as the shoulder areas. The NCDOT ditch template library contains different templates for cut ditches to support corridor modeling. One for medians, which has an origin at the center of the template, and others for the shoulders, for left or right side with origin points at the inside edge.

In the example discussed below, the shoulder on the right side of the roadway in a cut section will be modified to create a cut ditch where none currently exists. First, the horizontal and vertical alignments are created. Then, a corridor model is developed so that the impacts can be evaluated.

A. Create a horizontal alignment for the special cut ditch. (Video)

The cut ditch will be created by lowering the point at the outside of the shoulder where the bottom of the backslope begins. This point is represented in plan view by a feature created by the roadway corridor model.



1. As shown in Chapter II, set the default Feature Definition to HYD_Ditch_Baseline and make sure the Use Active Feature Definition toggle is ON.

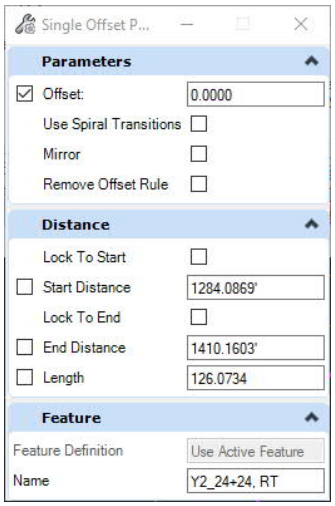
2. Go to *Geometry* > *Horizontal* > *Offsets and Tapers* and select Single Offset Partial.

3. In the dialog check the box for Offset and enter 0.0. Leave all the other boxes unchecked.

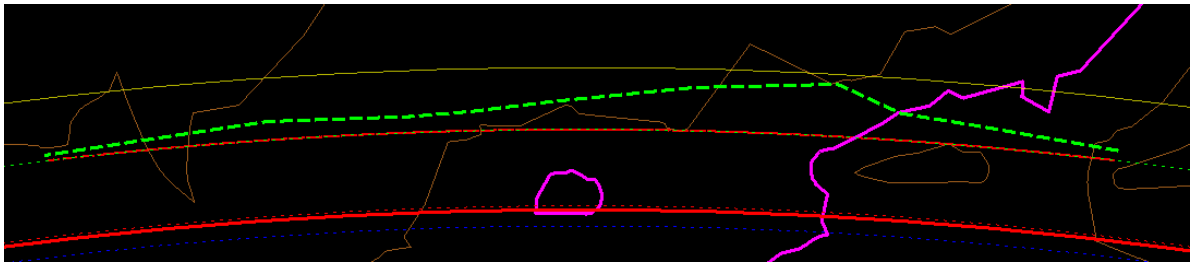
4. Enter the ditch name. In this example, the special cut ditch will start approximately at 24+24 on the right side.

5. At the prompt *Locate Element*, select the feature for the outside edge of shoulder.

6. At the prompt *Start Distance and Offset*, identify the start point of the alignment by clicking with your mouse near the beginning of the cut section.



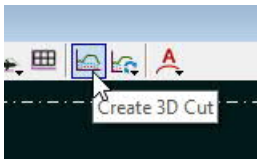
7. At the prompt *End Distance and End Offset*, identify the end point of the alignment by clicking with your mouse near the end of the cut section. The new alignment will then appear over top of the outside edge of shoulder line.



B. Create a profile for the special cut ditch. (Video)

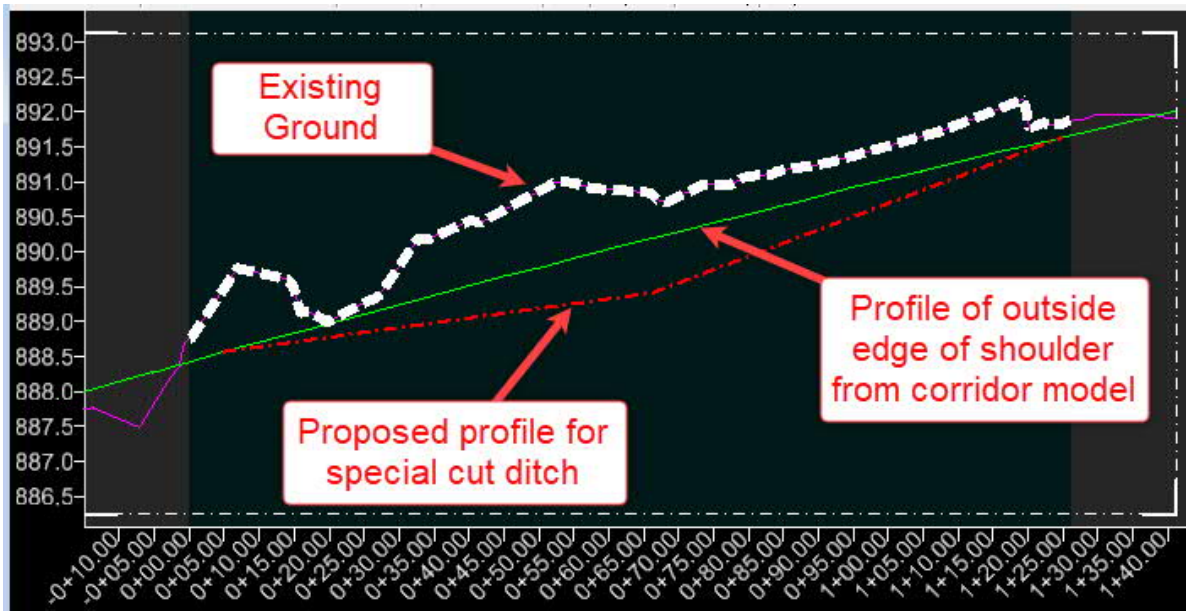
1. As shown in Chapter II, select the horizontal alignment and from the flyout menu select Open Profile Model, and place it into an available view window.

2. In the profile window, go to Create 3D Cut and create a 3D cut window which will display the profile of the outside edge of shoulder line from the corridor model. Go to the References dialog and make sure that Snaps are enabled for the nested corridor model in the referenced 3D model.



3. As shown in Chapter II, go to *Geometry* > *Vertical* > *Profile Complex by PI*, and create a lowered profile as shown below, snapping to the existing profile of the outside edge of shoulder line. Remember that you can use Civil Accudraw to set station and/or elevation of the PI points in reference to the roadway baseline, and/or set the slope of the ditch.

4. Remember to select the profile and make it the active profile.

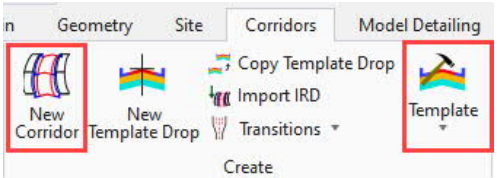


At this point, you now have a horizontal and vertical alignment for the special cut ditch. This information can now be used by Roadway as a Point Control to modify the roadway corridor to lower the outside edge of shoulder to match your proposed profile.

The following workflow will demonstrate how to create a working corridor model for the special cut ditch so that you can evaluate the modifications to the roadway corridor that will result from the proposed ditch profile.

C. Create a corridor model for the special cut ditch. (Video)

1. Go to *Corridors* > *Create* > *Template* and select Create Template. When the dialog opens, go to *File* > *Open* and browse to C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library and select NCDOT-Hydraulics-Ditches.ITL, and then click Open. Then close the Create Template dialog.



2. Select New Corridor.

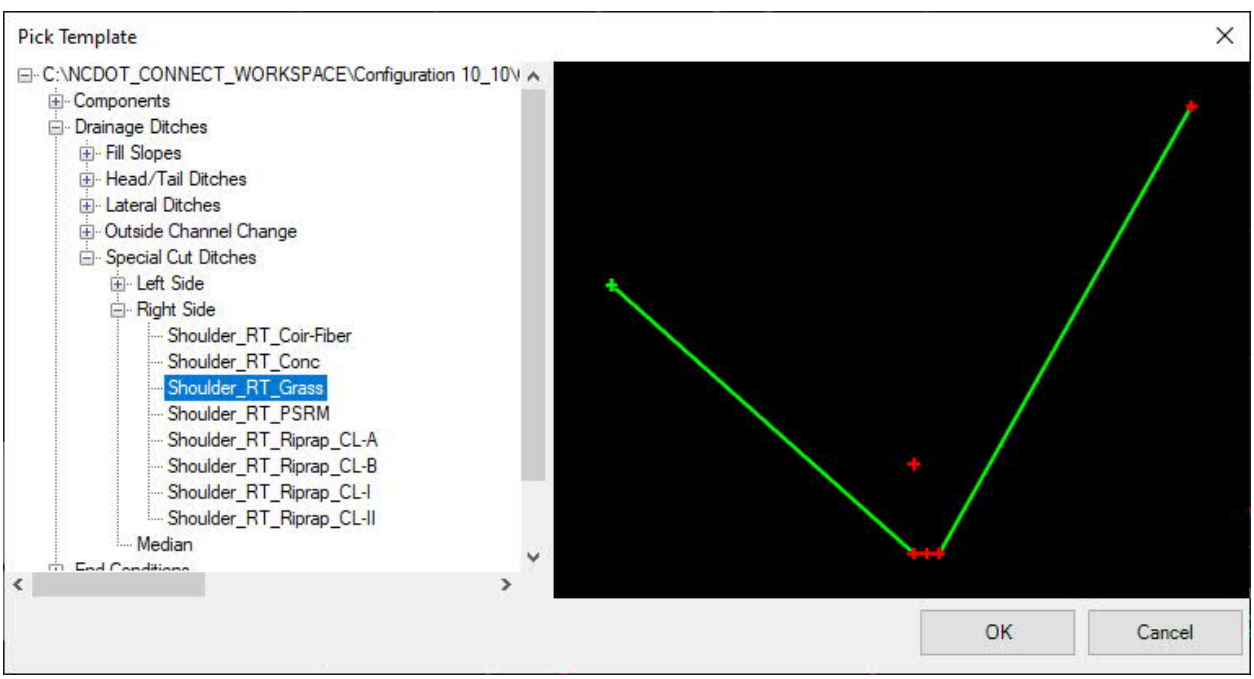
3. In the dialog, set the Feature Definition to HYD w/Contours.

4. At the prompt *Locate Corridor Baseline*, select the corridor model feature representing the back of the curb line.

5. At the prompt *Locate Profile*, <R> to select the active profile.

6. Enter the name Y2_24+24, RT. This will create a yellow temporary box around the roadway alignment. Move your mouse to bring up the next prompt.

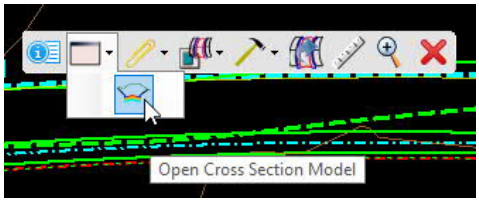
7. In either the heads up prompt or the dialog, select a template to use for the special cut ditch. If using the heads up prompt, press ALT and the down arrow key to bring up the Pick Template dialog. For this example, go to *Drainage Ditches* > *Special Cut Ditches* and select Shoulder_RT_Grass since the special cut ditch is located on the right side of the road. Click OK to close the dialog, then <D> to accept the selection.

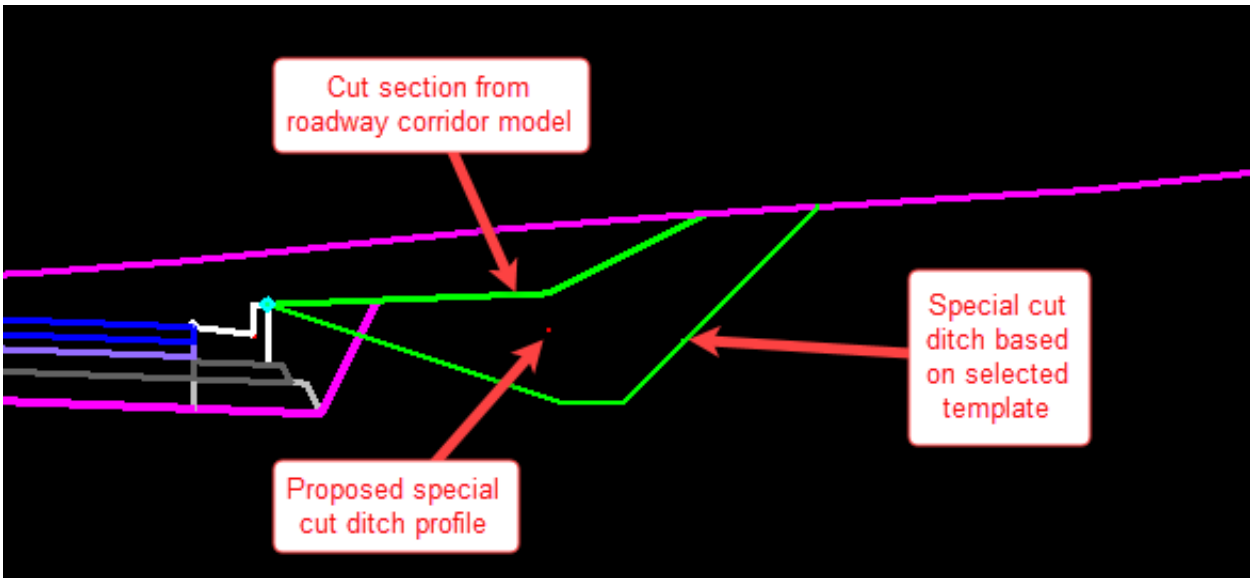


8. Go to the profile model window and using your mouse, snap to the beginning of the special cut ditch profile to establish the start of the ditch corridor model and repeat for the end.

9. At the prompt *Interval*, enter a value of 1.0'. <D> to accept, and the corridor model will be created.

10. Select one of the yellow corridor handles and from the flyout menu select Open Cross Section Model, and select an available view window.

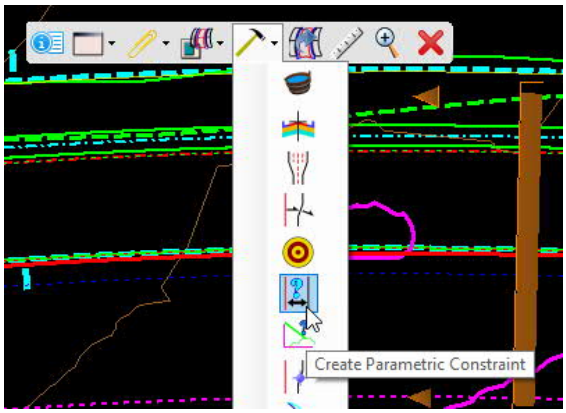


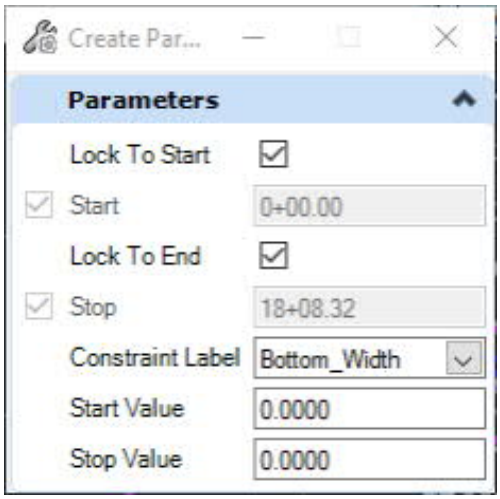


At this point, the selected template has simply been placed along the back of the curb line. We now need to use parametric constraints to adjust the ditch dimensions, and point controls to make the ditch invert follow the proposed special ditch profile.

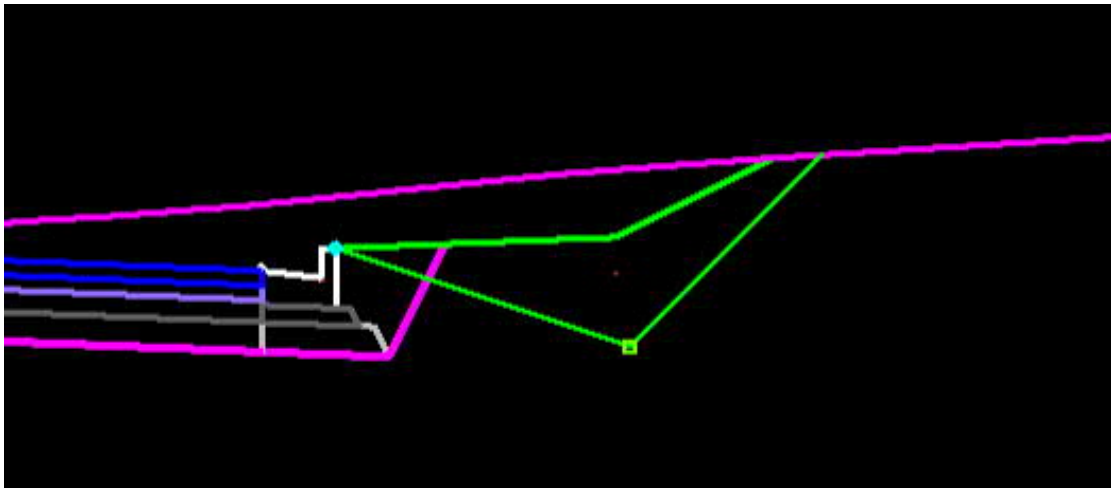
D. Use parametric constraints to change ditch dimensions. (Video)

1. Select one of the yellow corridor handles and from the flyout menu select Create Parametric Constraint.



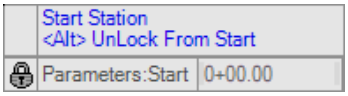


2. The first corridor edit will change the bottom width to zero to create a V-shaped section. Complete the dialog as shown. The <D> to accept all inputs. The changes will be reflected in the cross section view.



3. The next edit will change the backslope to 4:1 to match the roadway corridor. This time, we'll use the heads up prompts instead of the dialog. As before, select a corridor handle and go to Create Parametric Constraint.

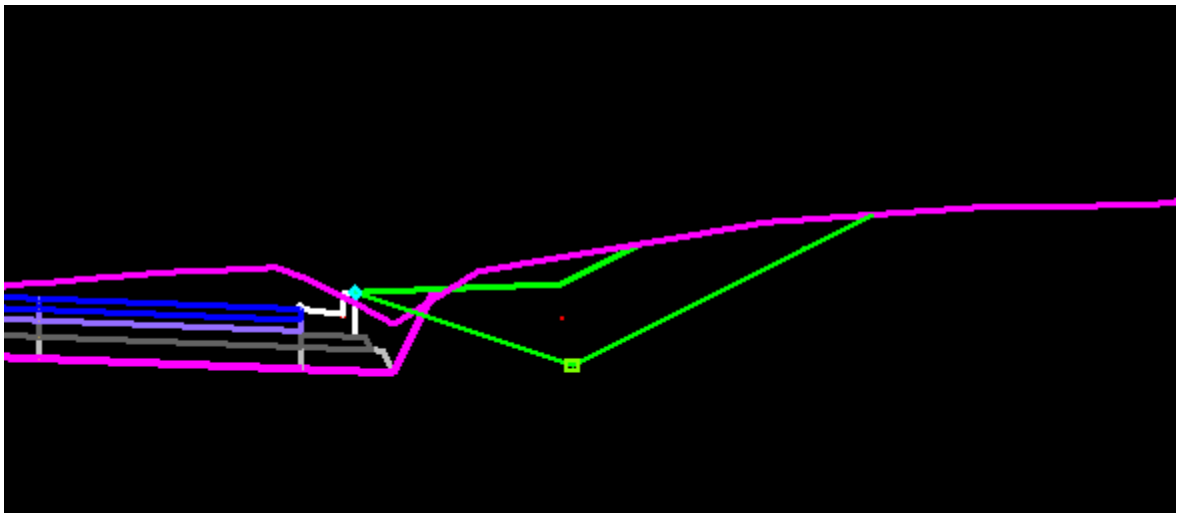
4. At the prompt *Start Station*, press ALT to lock to the beginning and press <D> to accept.



5. At the prompt *End Station*, press ALT to lock to the end and press <D> to accept.

6. At the prompt *Constraint Label*, press the down arrow on your keyboard until BackSlope appears, then press <D> to accept.

7. At the prompts for *Start Value* and *Stop Value*, enter 25% and <D> to accept.

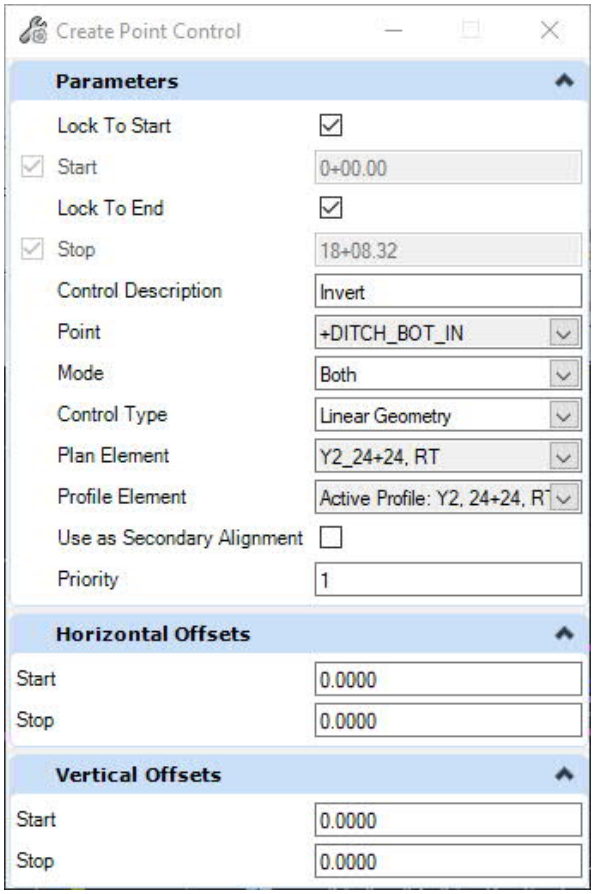


E. Add Point Controls to establish ditch profile. (Video)

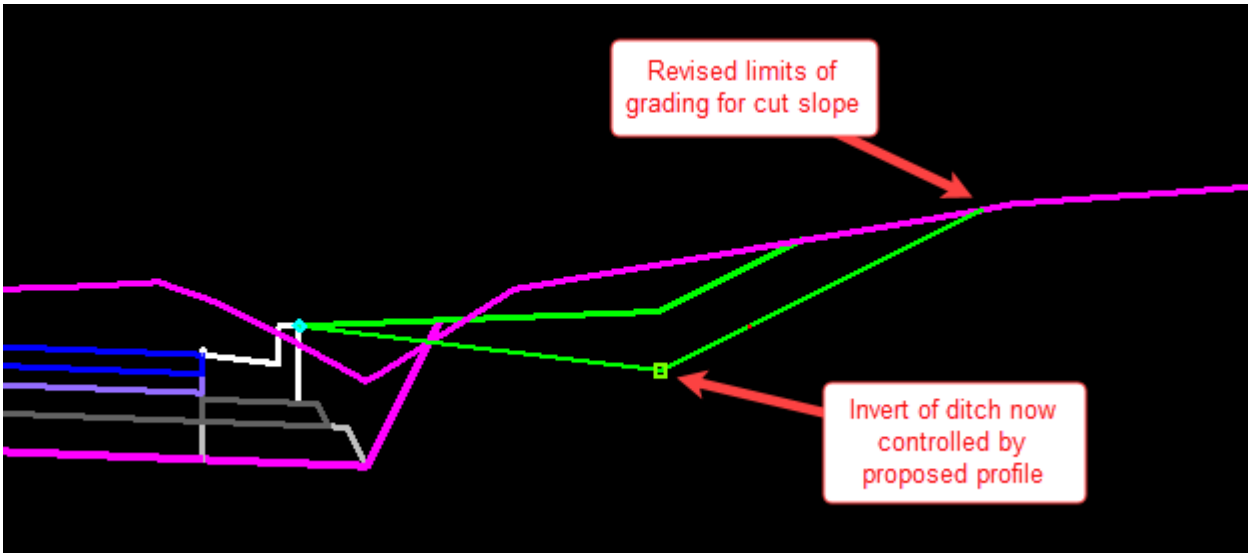
1. Select one of the corridor handles and from the flyout menu select Create Point Control.

2. Complete the dialog as shown:

   - Check the boxes for Lock to Start and Lock to End.
   - Enter Invert as the description.
   - <u>Always</u> select the point +DITCH_BOT_IN as the point to be controlled.
   - Set the Mode to Both and Control Type to Linear Geometry.
   - Select the special ditch geometry for plan and profile control.



3. <D> to accept all inputs. The cross section view will then be updated.



At this point, you now have a working corridor model which you can use to evaluate various ditch design scenarios:

- ✓ Revising the ditch foreslope or backslope.
- ✓ Revising the width of the shoulder.
- ✓ Revising the ditch profile in the previously-created profile model window.

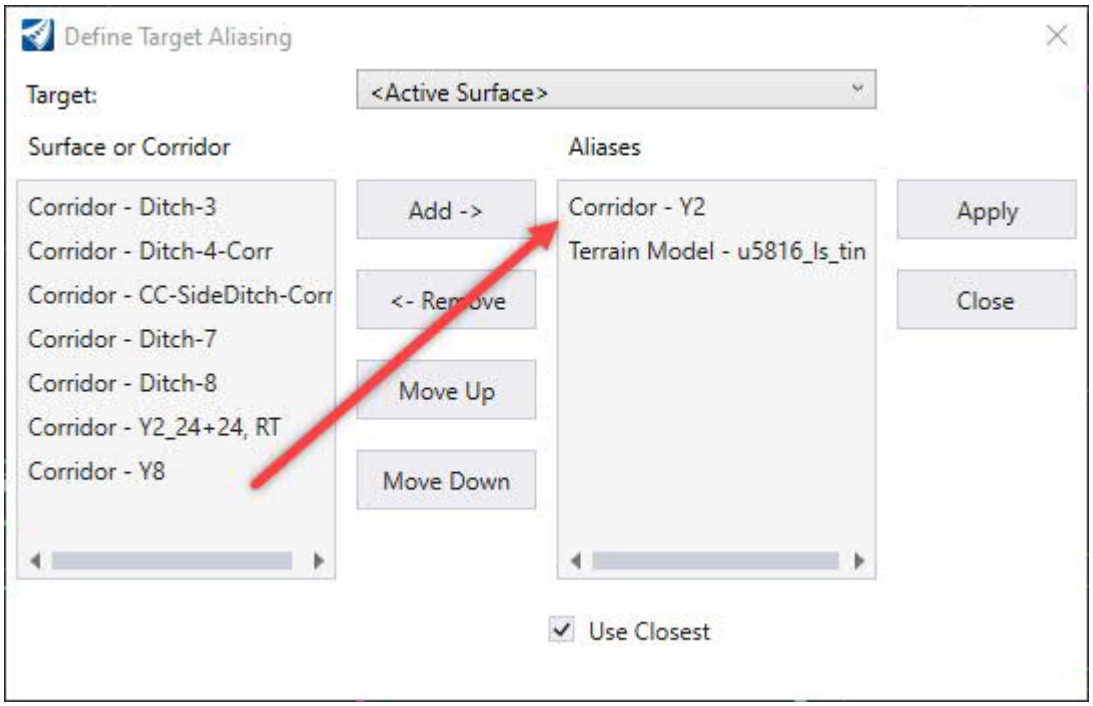
When you make any of these changes, the plan view, 3D model view, and cross section view are all automatically updated, allowing you to view the changes along the entirety of the special cut ditch corridor.

Note: in the above workflow, the template point which was controlled was the point named +DITCH_BOT_IN, <u>not</u> the point named +DITCH_MID. The reason for this is that the default template is for a trapezoidal channel, and the points +DITCH_MID and +DITCH_BOT_OUT are constrained to the vertical location of +DITCH_BOT_IN. The purpose of Point Controls is to override the "point constraints" defined in the ditch template – in this case the location of the point +DITCH_BOT_IN. Therefore, when using Point Controls it is very important that you first review the template so that you understand which points need to be controlled.

In addition, be aware that you can apply more than one point control to the ditch corridor. For example, for a median ditch you may want to use the left side inner EOP to control the left top of ditch line, a special cut ditch profile to control the centerline invert elevation, and the right side inner EOP to control the right top of ditch line.

F. Using Target Alias (Video)

In the previous example, the template which was utilized to model the special cut ditch in the right shoulder area had a backslope that intersected with the existing terrain to establish the location of the top of the cut slope. In some circumstances the special cut ditch will intersect with the roadway corridor surface rather than the existing terrain. For example, a special cut ditch in the median may be designed intersect with the surface of the median modeled by the Roadway staff. To do this, you can use a tool called Target Alias.



1. Go to *Corridors* > *Miscellaneous* > *Define Target Aliasing*.

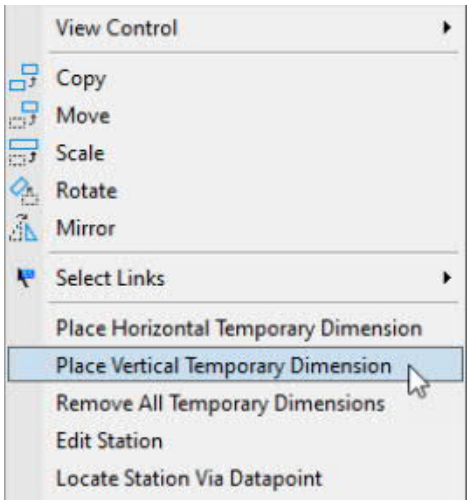
2. At the prompt *Locate Corridor*, select any feature of the special cut ditch corridor model in the plan view. The dialog will then display.

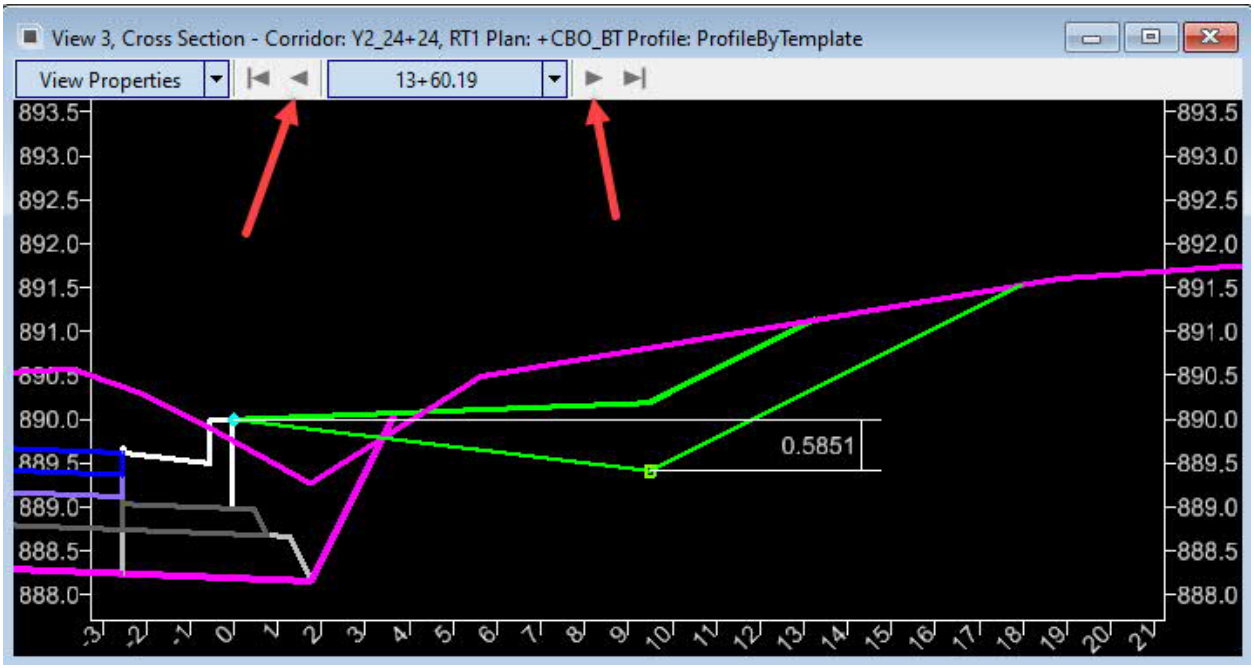
3. All available "surfaces" will be shown on the left. Select the corridor model to be modified by the special cut ditch and then click on Apply.

4. Make sure the box for Use Closest is <u>not</u> checked if you want to be sure that the ditch cut slopes will not seek the existing terrain if it is closer than the corridor model surface. In this case, OpenRoads will check for intersection based on the order in the dialog. In the above example, the corridor model for Y2 will be checked first. Otherwise, check the box if you want the slope to intersect the closest surface.

G. Reviewing Cross Sections with Temporary Dimensions (Video)

1. In the cross section view window, right-press to bring up a pop-up menu.
2. Select Place Vertical Temporary Dimesion.
3. At the prompt *Start Point*, snap to the point at the back of curb.
4. At the prompt *End Point*, snap to the invert of the adjusted cut ditch.
5. At the prompt *Dimension Location*, <D> where you would like the dimension to be shown.



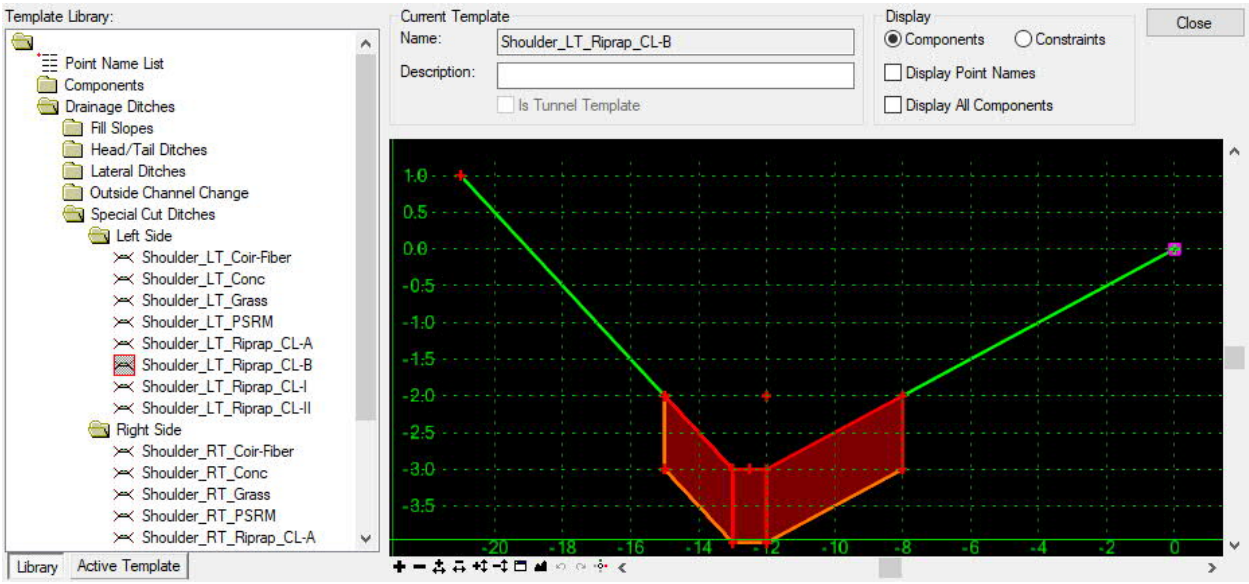


You can now use the left and right arrow buttons in the cross section view window to review the selected dimension along the ditch.

In order to use temporary dimensions, you must create the cross section view from the corridor, not the alignment. Also, you can only use temporary dimensions for features in a corridor that is located within the active DGN, not corridor features from a referenced corridor.

H. Special Cut Ditches with Linings

As with lateral ditches, the templates for special cut ditches in the shoulder areas include options for channel lining including Coir-Fiber, PSRM, concrete, and the four different classes of riprap, as well as options for each side.



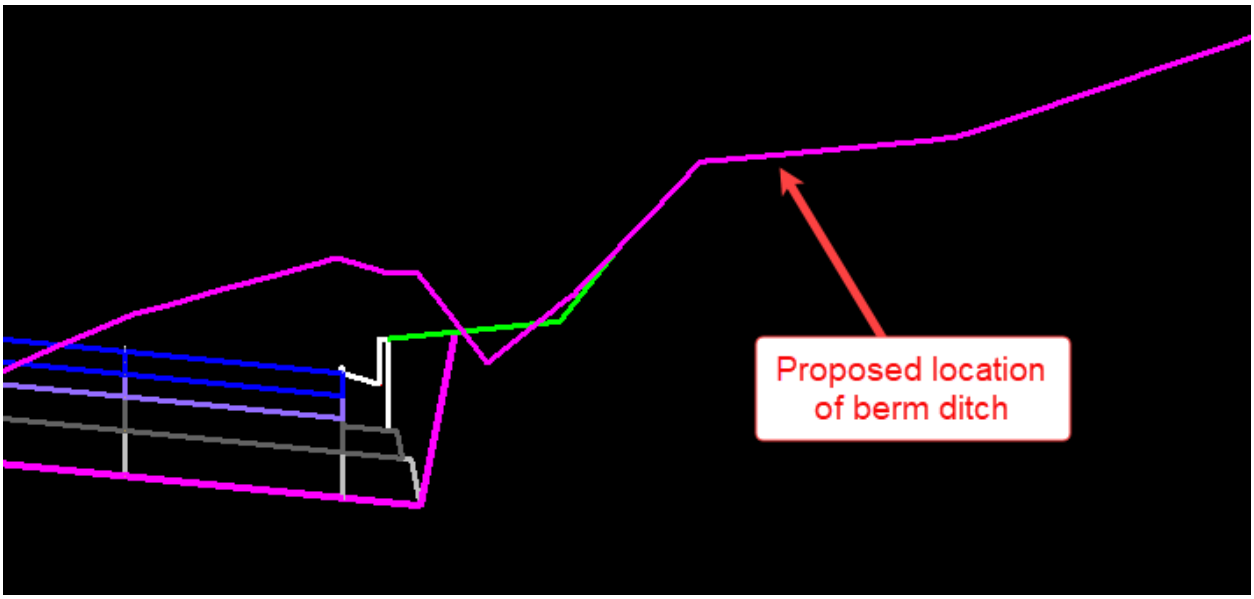
As with lateral ditches, if a special cut ditch with a lining daylights to existing ground, then parametric constraints must be added to gradually reduce the foreslope lining height to zero.

Remember that corridor models for special cut ditches will generally <u>not</u> be used for plan production, but are only intended to be used to provide design parameters to Roadway so that they can edit the Roadway corridor models for the special cut ditches. Specifically, they will use the ditch centerline feature as a point control. However, if special cut ditches have linings, then the ditch corridor models will be used by Roadway to show the linings on the Roadway cross sections. Roadway will only use the levels for the linings, and all other levels will be turned off. For this reason, <u>special cut ditches must be put into a separate DGN file from the other Hydro ditches</u>.

Another purpose of the Hydro special cut ditches is to provide profiles that can be projected onto the Roadway profiles. Refer to Chapter X for detailed discussion of projecting ditch profiles.

VI. Berm Ditches

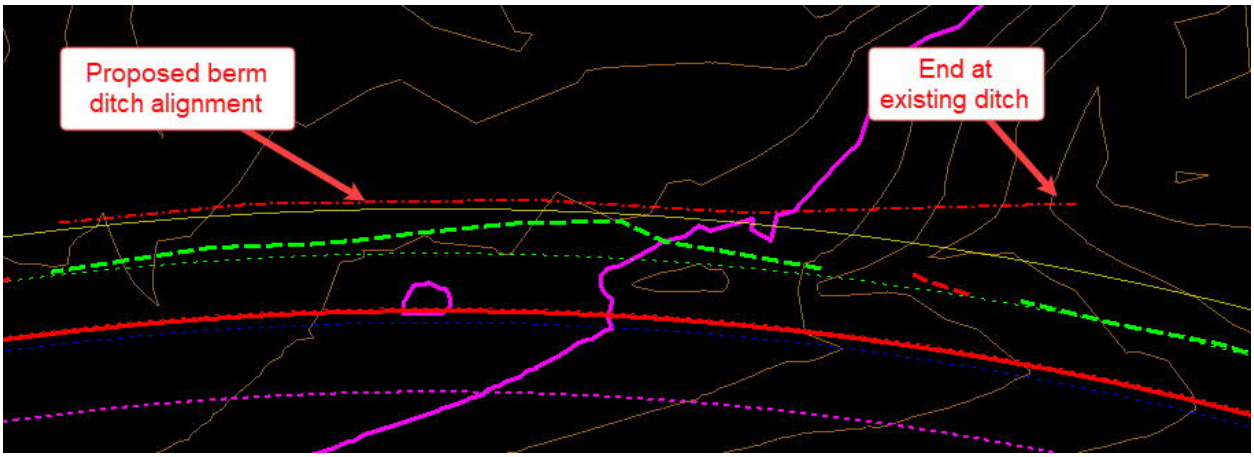
Berm ditches are placed just above the top of cut slopes to intercept overland runoff flowing toward the roadway in order to prevent erosion down the relatively steep face of the cut slope. For modeling purposes, a berm ditch can be treated as either a lateral ditch or a tail ditch, and you can use the same templates in the ditch template library for this purpose. For the lateral ditches along a roadway fill slope that were discussed in Chapter III, we used the roadway fill slope stake line as the control for the ditch. For berm ditches, you can use the top of cut slope feature as the control. Alternatively, you can create a separate control line, drape that line onto the existing terrain, and then use that feature to control the berm ditch. For the following example, we will use the tail ditch approach.



A. Create Berm Ditch Baseline (Video)

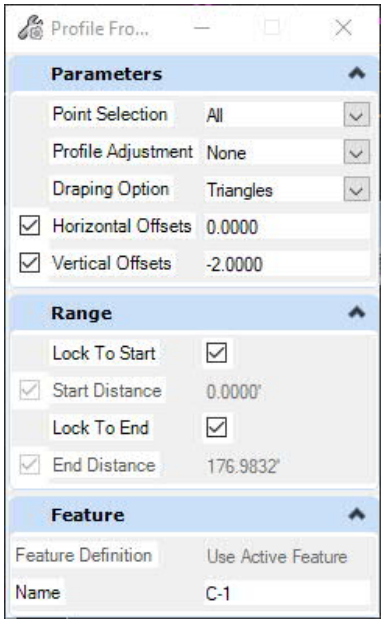
1. In the Feature Definition Toolbar, set the active feature definition to *Linear* > *HYD_Modeling* > *HYD_Ditch_Baseline* and turn on the Use Active Feature Definition toggle.

2. In the OpenRoads Modeling workflow, go to *Geometry* > *Complex Geometry* > *Complex by PI* and layout the proposed horizontal alignment representing the centerline of the berm ditch. Give the ditch a name (for example, Y2_25+48, RT) based on the location of the start of the ditch. Don't worry about being exact – you will tweak the location later. See example below. The end point for the berm ditch has been extended to discharge to an existing ditch.



3. Change the active Feature Definition to HYD_Construction.

4. Select one of the contours and verify that the existing terrain has been set as the Active Terrain Model. Then go to *Vertical > Profile Creation > Profile From Surface*. This will create an initial profile for the ditch based on draping the horizontal alignment on the active terrain.

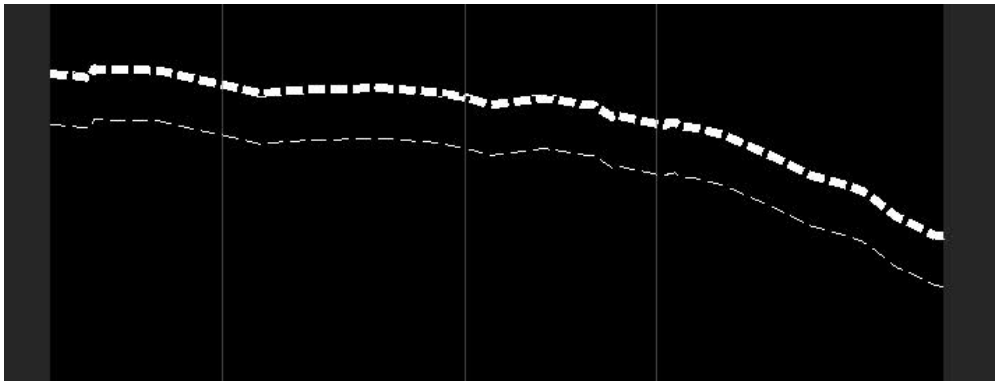


5. Complete the dialog as shown using an offset of -2.0 to set the initial profile 2' below existing ground.

6. At the prompt *Locate Plan Element*, select the horizontal alignment created for the ditch, then <R> to complete.

7. <R> to accept the active terrain model as the reference surface. <D> to accept all remaining inputs.

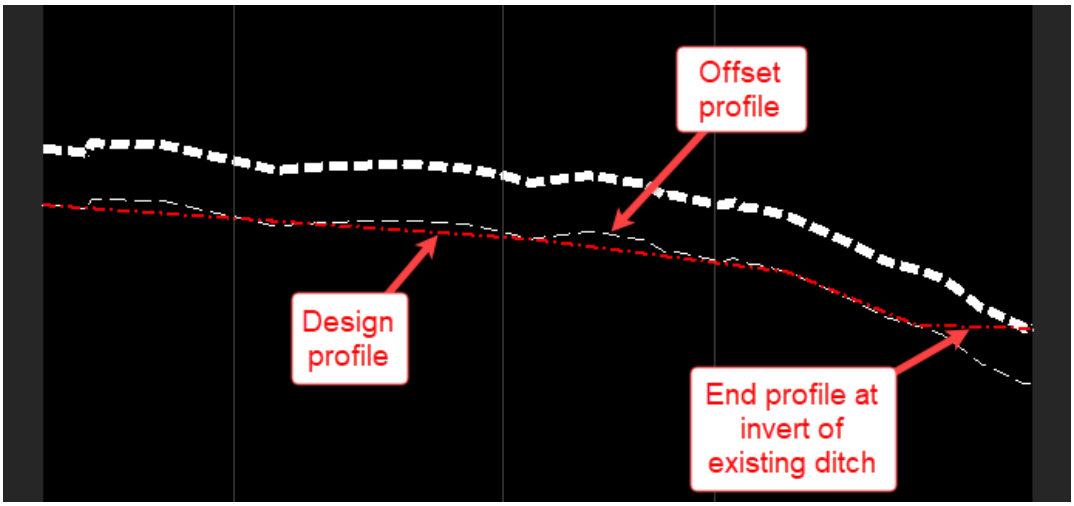
8. Create a profile model to review the profile:



The next step is to create the design profile for the ditch using the offset profile as a guide.

9. Change the active Feature Definition back to HYD_Ditch_Baseline.

10. Go to *Geometry* > *Vertical* > *Complex Geometry* > *Complex by PI* and create a design profile by placing PI points in the profile model window. End the profile by snapping to the invert of the existing ditch.



B. Create Berm Ditch Corridor Model (Video)

1. Go to *Corridors* > *Create* > *Template* and select Create Template. When the dialog opens, go to *File* > *Open* and browse to C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library and select NCDOT-Hydraulics-Ditches.ITL, and then click Open. Then close the Create Template dialog.

2. Go to New Corridor.

3. At the prompt *Locate Corridor Baseline*, select the horizontal alignment for the ditch.

4. <R> to accept the active profile.

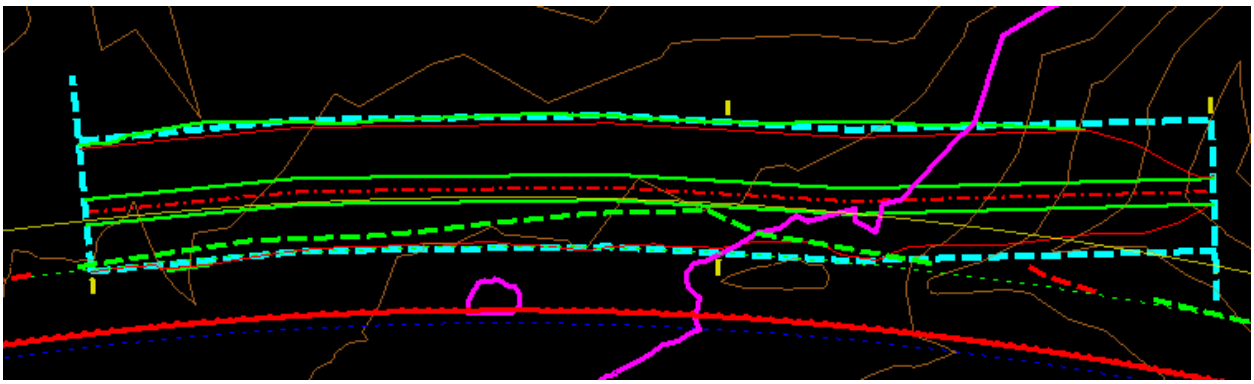
5. <D> to accept the name, which is based on the name of the selected alignment.

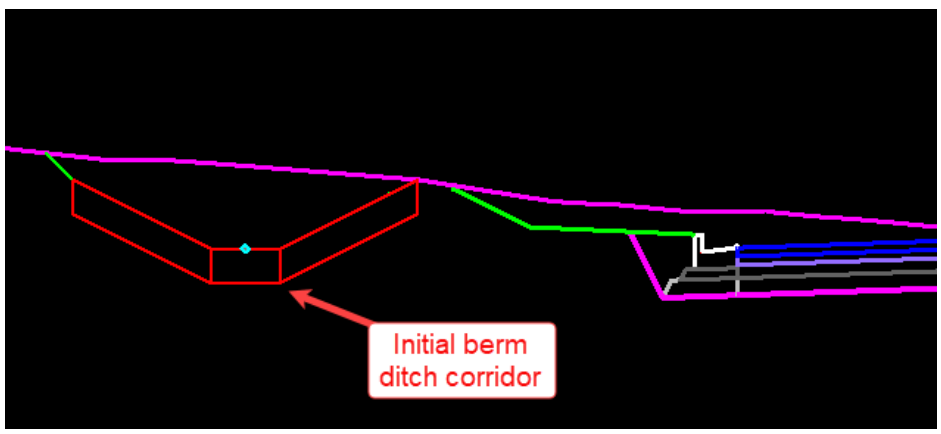
6. Move your mouse to bring up the next prompt: *Select Template*. Press ALT and down arrow key to bring up the Pick Template dialog.

7. In the dialog, select the template at Head/Tail Ditches called Trap_Riprap_CL-B. Click OK to close the dialog, and then <D> to accept the selection.

8. At the prompt *Start Station*, press ALT and then <D> to lock to start and repeat for the *End Station*.

9. Enter 1.0 for the interval, and <D> to accept. The corridor will then be created. See below.

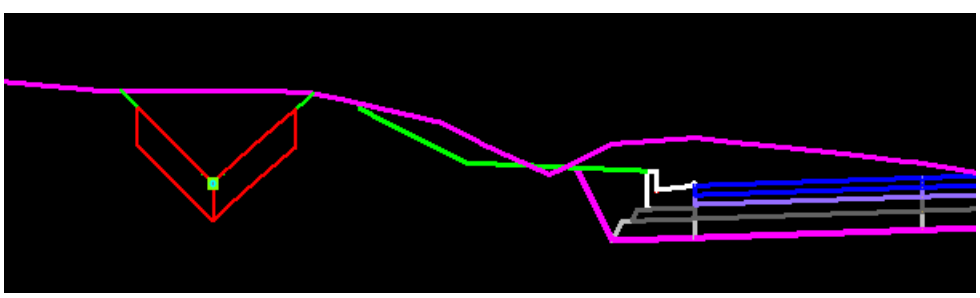




C. Apply Parametric Constraints (Video)

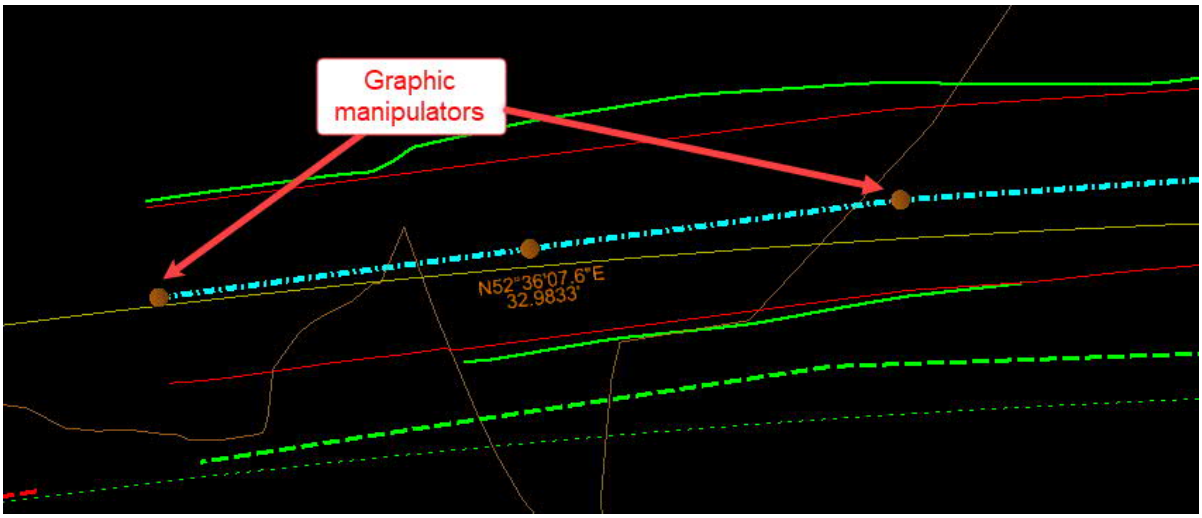
The corridor as initially created uses the default dimensions in the selected template. The next task is to apply parametric constraints to revise the ditch dimensions. Review the procedures detailed in Chapter V to apply parametric constraints and then make the following changes:

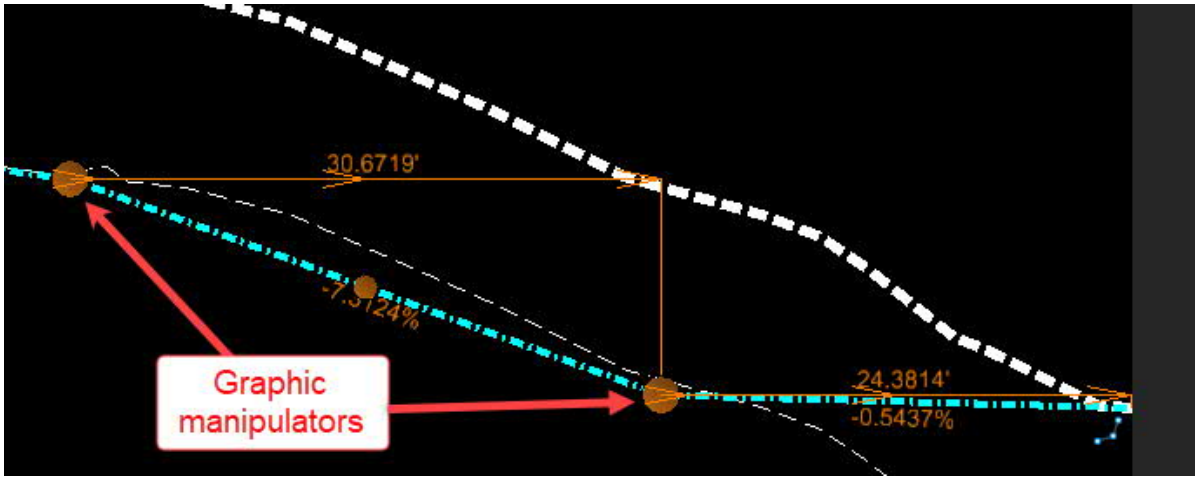
- ✓ Change value for Bottom_Width to 0 to change ditch to V-shape.
- ✓ Change value for Lining_Slope to 50% (enter 50 or 100/2) for 2:1 slope.



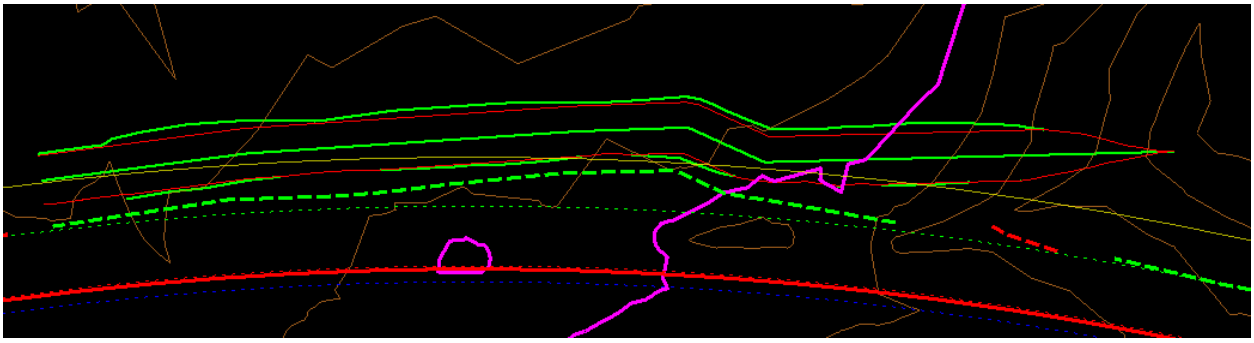
D. Finalize the horizontal and vertical alignment. (Video)

As a result of the changes in ditch dimensions, the limits for grading for the ditch may be very different than when the initial corridor was created. Use the graphic manipulators in both the plan and profile view windows to adjust the ditch horizontal alignment and profile so that the inside top of berm ditch is approximately 5' away from the top of the roadway cut slope in accordance with NCDOT design guidelines.

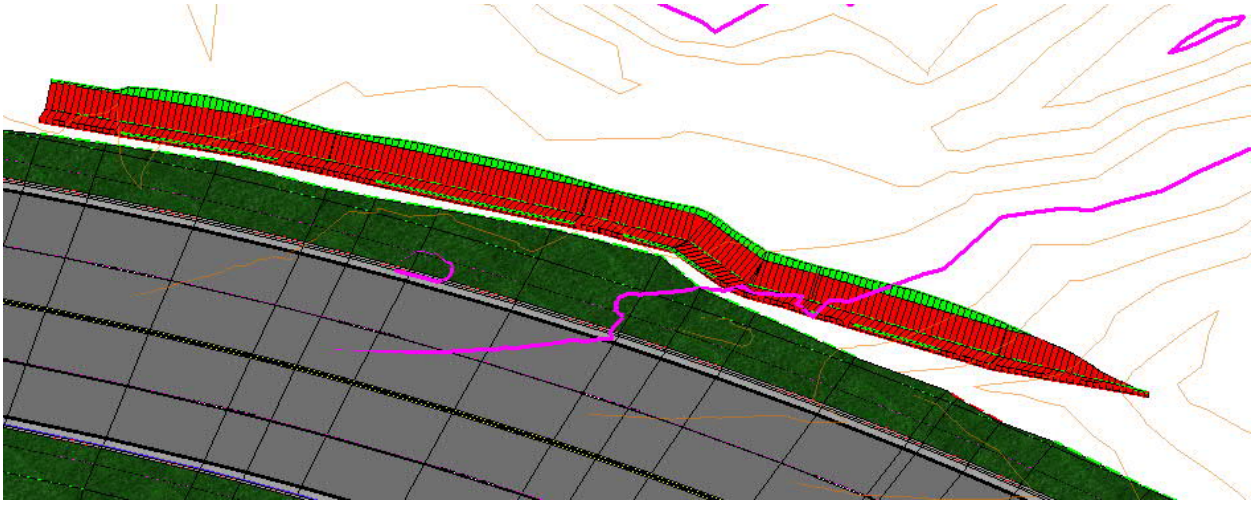




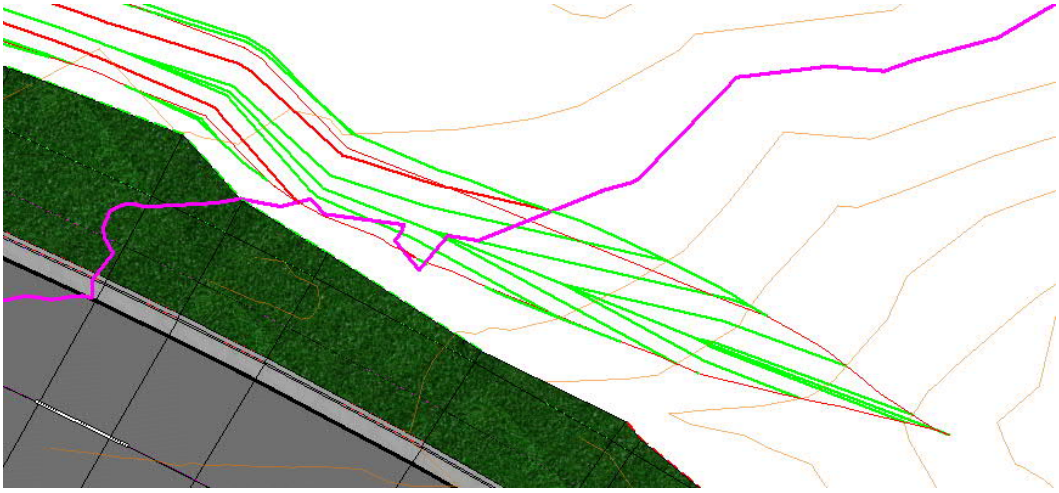
In the plan view, turn off the level Draft_Corridor_Graphics_Final and review the ditch grading after adjustment:



Also review the 3D model view of the berm ditch. Note that the ditch transitions to zero height and depth as the profile approaches existing grade at the end of the ditch:



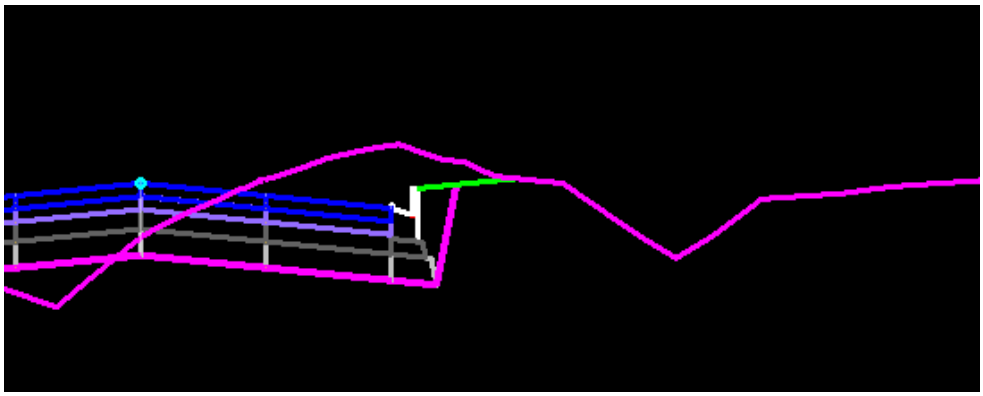
This is the 3D model view with some levels turned off and the contours turned on:



VII. Channel Changes (Video)

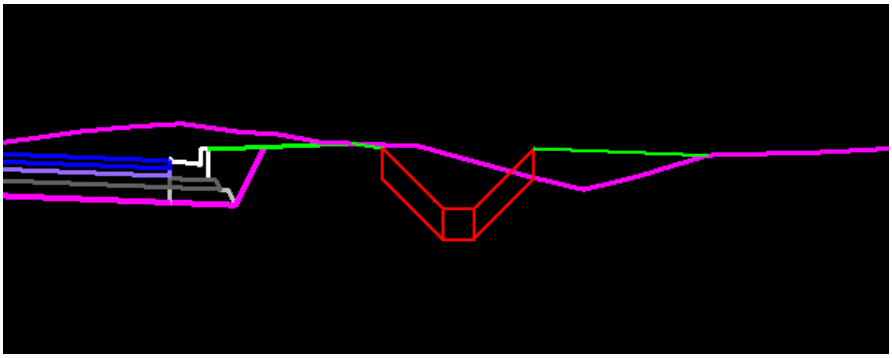
Channel changes occur when an existing channel, either under or outside the limits of the roadway, needs to be relocated. When the channel is located on the outside of the roadway limits, this sometimes results in cross sections where an existing channel needs to be filled adjacent to the location of the new channel location. The NCDOT standard ditch templates are provided to assist in modeling this situation. The template consists of a ditch with fixed dimensions (which are editable through parametric constraints) that also provides an end condition component that will seek the existing terrain to complete the fill of the existing channel to be abandoned. The slope of the end condition component can also be adjusted using a parametric constraint.

Below is an example of a cross section where a channel change might be needed:



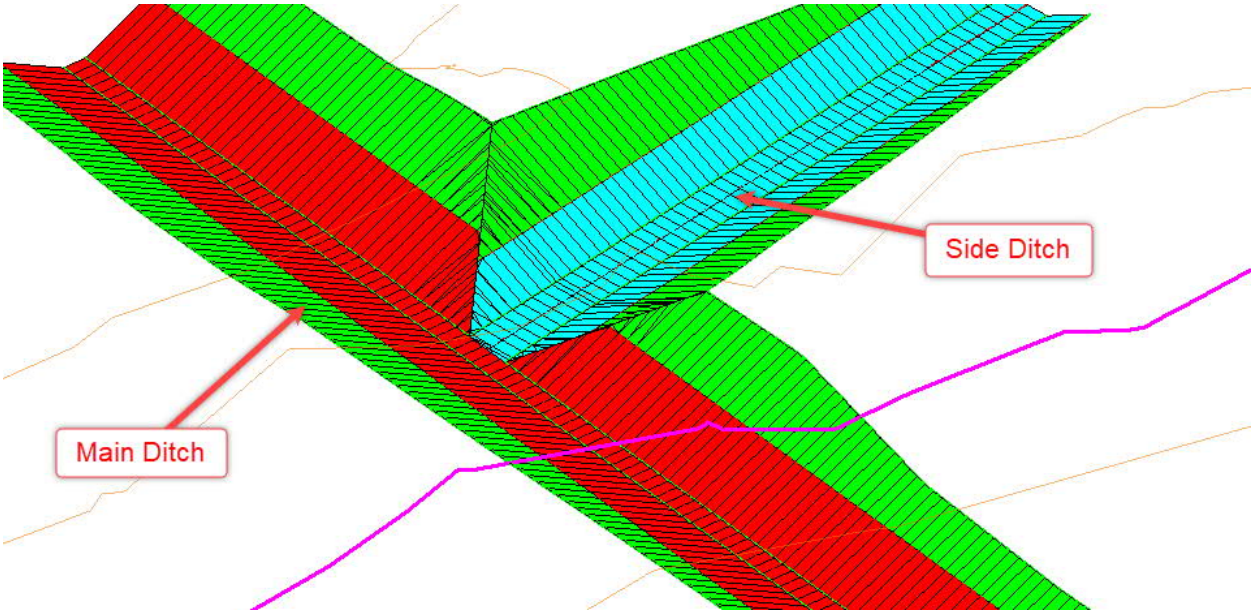
A channel change corridor model is created in the same way as a lateral ditch (see Chapter III). In the above example, the outside edge of the shoulder will be used as the control line along which the template will run.

After creating the corridor model, parametric constraints are then used to revise ditch dimensions. In the example below, the bottom width was reduced from 4' to 2', the channel depth was reduced from 3' to 2', and the slope of the fill was changed from positive 2% to negative 2% as required by the site conditions. Review the procedures in Chapter V for how to apply parametric constraints to a corridor model.



VIII. Ditch Intersections

Modeling the intersections of ditches presents some unique challenges, particularly if we want models that can dynamically update in response to design changes. The intersection shown below illustrates a "side" ditch with PSRM lining entering a "main" ditch with riprap lining.



The workflows detailed in this chapter are divided into two separate sections: a workflow for V-shaped side ditches and a workflow for trapezoidal shaped side ditches. Both workflows can accommodate a main ditch which is either V-shaped or trapezoidal shaped. In this manual it is assumed that the main ditch has a trapezoidal shape. If the main ditch is V-shaped, then substitute the phrase "centerline" for "bottom of bank" in reference to the main ditch in the instructions below.

<u>Procedure for V-shaped side ditches</u>

A. Create horizontal and vertical alignments for the side ditch. (Video)

1. Set the ribbon workflow to OpenRoads Modeling and set the default Feature Definition to Drainage Baseline in the Feature Definition Toolbar.

2. Using Line Between Points or Complex by PI, create a horizontal alignment for the ditch. The side ditch alignment must extend past the bottom of bank feature of the main ditch. For trapezoidal main ditch, you can end the side ditch alignment by snapping to the main ditch centerline. If main ditch is V-shaped, then end the side ditch alignment beyond the main ditch centerline feature by a distance at least equal to the side ditch bottom width. Provide a ditch name that meets NCDOT naming convention such as L_32+89, LT.

3. Select the side ditch alignment and from the flyout menu select Open Profile Model.

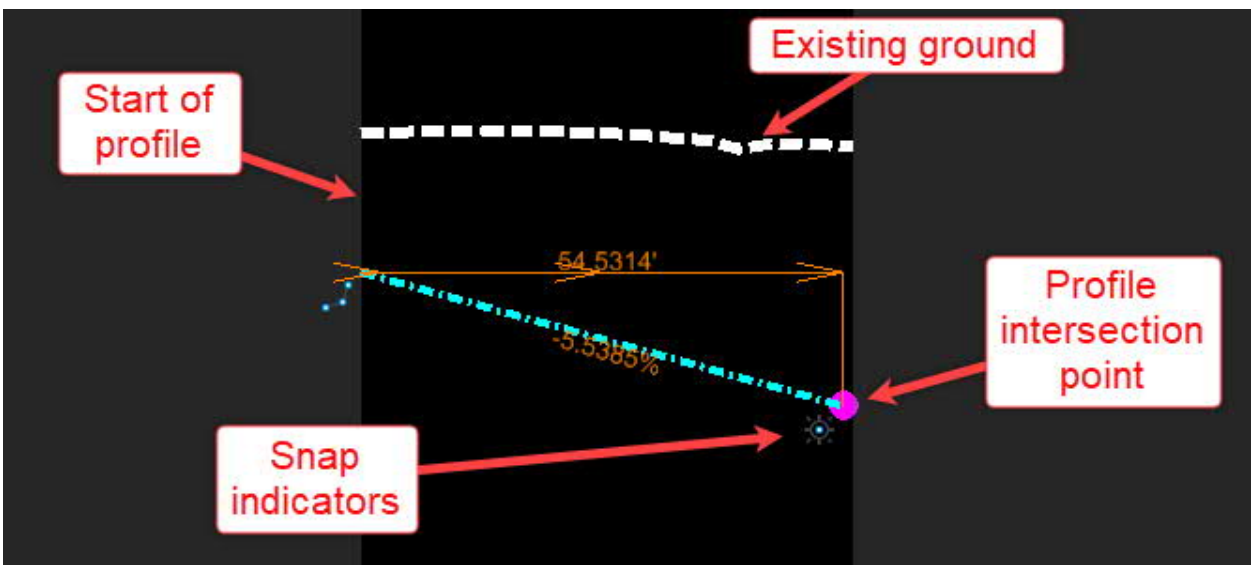
4. Go to *Geometry* > *Vertical* > *Profile Creation* and select Profile Intersection Point.

5. At the prompt *Locate Element to Show Intersection*, select the side ditch alignment.

6. At the prompt *Locate Element Which Intersects*, select the main ditch bottom of bank feature. A dot representing the profile intersection point will appear in the profile model window for the side ditch. This intersection point is ruled to the bottom of bank feature of the main ditch so that if the main ditch is revised, this point will move with it. By snapping to this point, you create a dynamic relationship between the profile of the side ditch and the profile of the main ditch.

7. Go to *Geometry* > *Vertical* > *Lines* and select Profile Line Between Points.

8. In the profile model window, identify the start of the first vertical tangent line by snapping to the start of the profile (not necessarily the existing ground line, but the vertical line representing the beginning of the horizontal alignment). End the line by snapping to the profile intersection point.

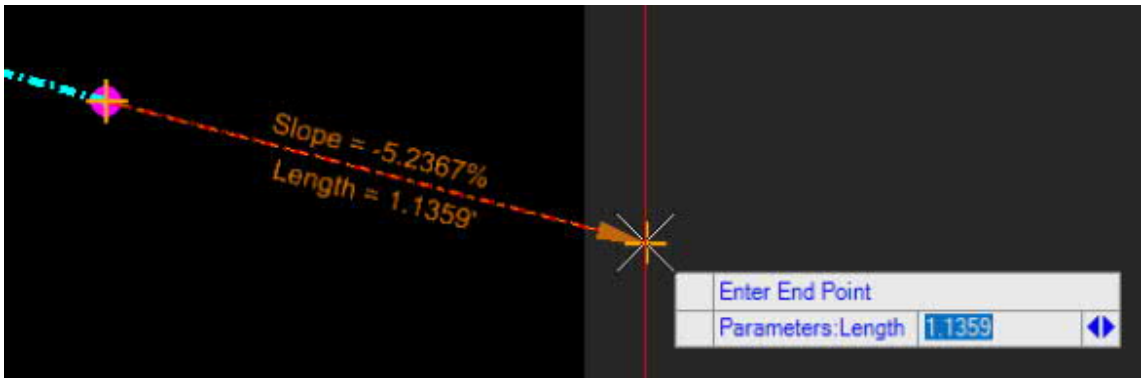


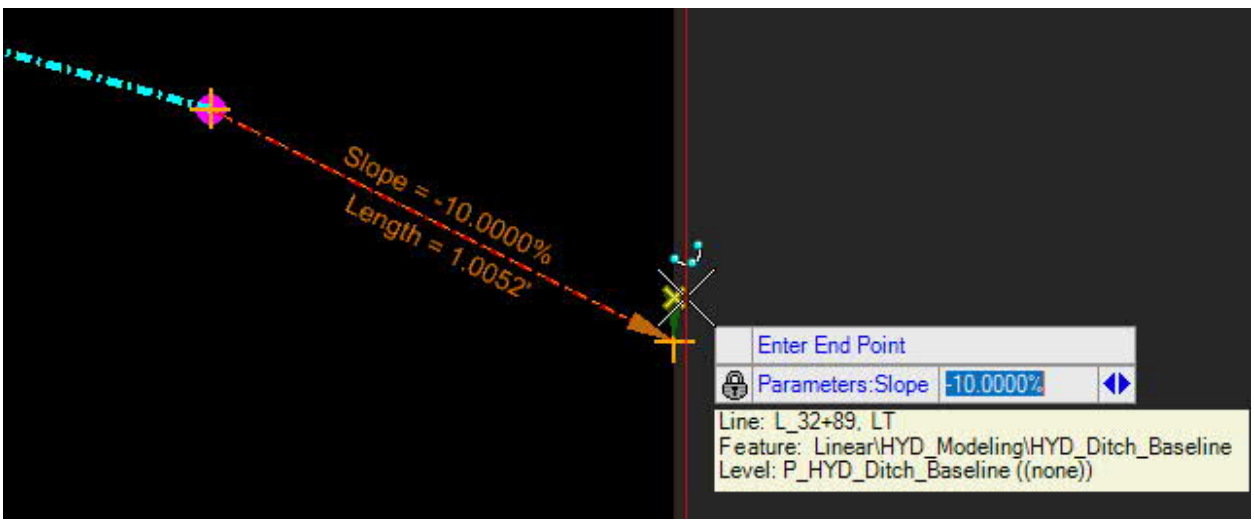
As shown above, if you have successfully snapped to the beginning of the profile and the profile intersection point, when you select the line you should see snap indicators at both ends. It is very important this is done correctly so that the ditch intersection model will dynamically update when design revisions are made.

9. In the profile model window, zoom in toward the profile intersection point, select Profile Line Between Points again, and identify the start of the second vertical tangent line by snapping to the point.

10. In the heads up prompt *Enter End Point*, you will initially be asked to specify the Length. Press the right-arrow key on your keyboard to change the prompt to Slope.

11. Key in a value of -10%, press Enter to lock in the value, and be sure to snap to the end of the profile (the vertical line between back and gray). Make sure you see the yellow "x" and the snap indicator before snapping to end the line.

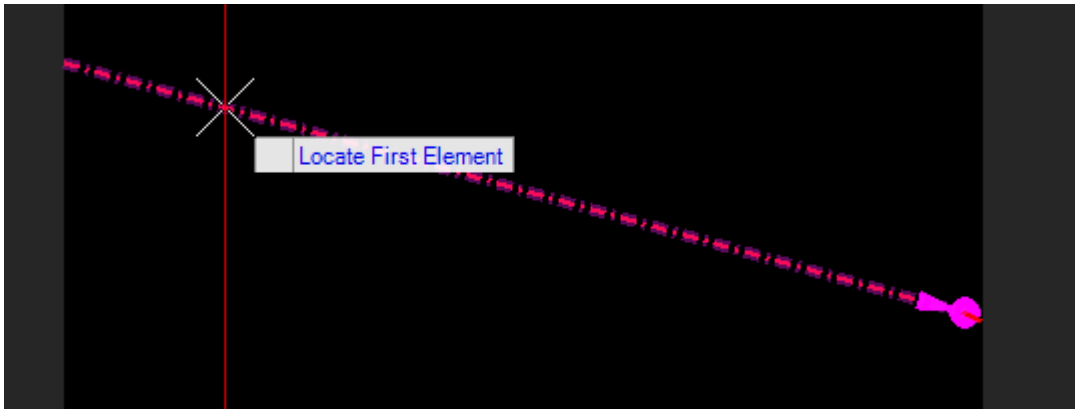




The portion of the profile past the intersection point with the main ditch bottom of bank line is to force the side ditch corridor model below the main ditch corridor model. Eventually, that portion of the side ditch corridor will be trimmed out.

12. The next step is to "complex" both vertical tangents together into a single profile for the side ditch. Go to *Vertical* > *Complex Geometry* and select Profile Complex By Elements. Name the profile L_32+89, LT.

13. At the prompt *Locate First Element*, hover your mouse over the first tangent line in the profile model window, near its left end. Note that an arrow will appear indicating the direction the complexing will run. The arrow should be pointed to the right, in the direction of the second tangent line to be added. See image below.



14. <D> to confirm the direction, and then <D> again to accept the complexed profile. Select the profile and confirm that both tangents highlight, indicating that they are now part of a single complex geometry.

15. While the profile is highlighted, hover your mouse over the profile to bring up the flyout menu and select Set As Active Profile. This is an easy step to forget, but you must always do this so that the profile is associated with the horizontal alignment.

B. Create corridor model for the side ditch. (Video)

1. Go to *Corridors* > *Create* > *Template* and select Create Template. When the dialog opens, go to *File* > *Open* and browse to C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library and select NCDOT-Hydraulics-Ditches.ITL, and then click Open. Then close the Create Template dialog.

2. Select New Corridor and set the FD to HYD w/Contours.

3. At the prompt *Locate Corridor Baseline*, select the side ditch alignment.

4. At the prompt *Locate Profile*, <R> to accept the active profile.

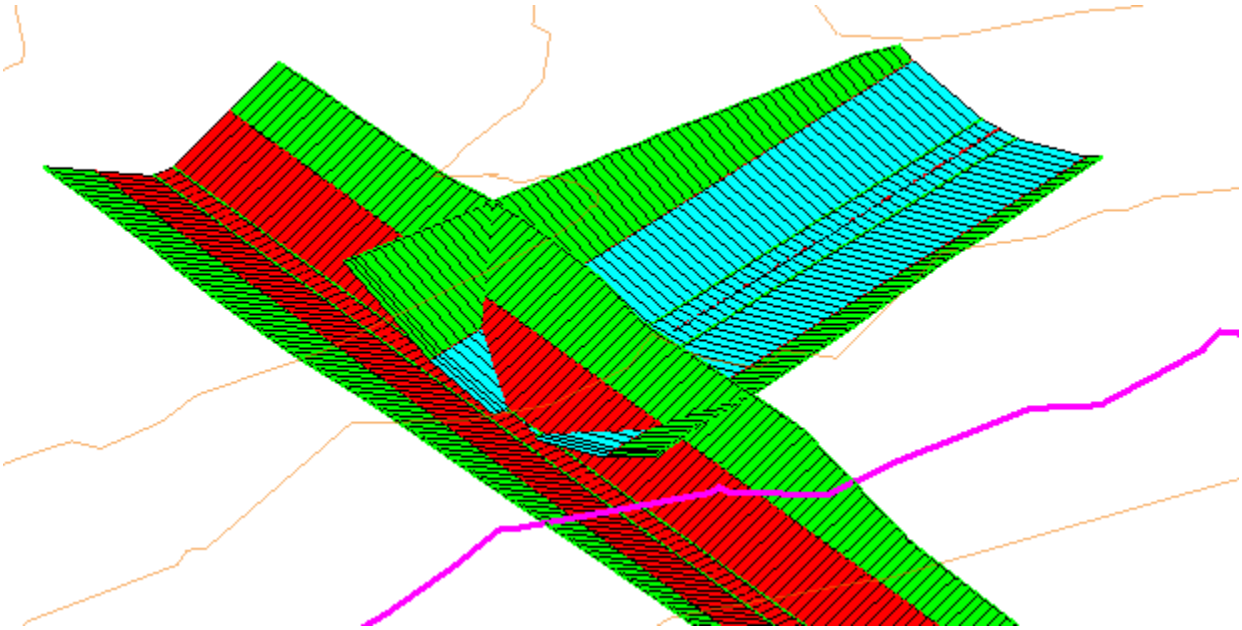
5. <D> to confirm the corridor name and move your mouse to bring up the next prompt to *Select Template*.

6. Press the ALT and down arrow keys to bring up the Pick Template dialog.

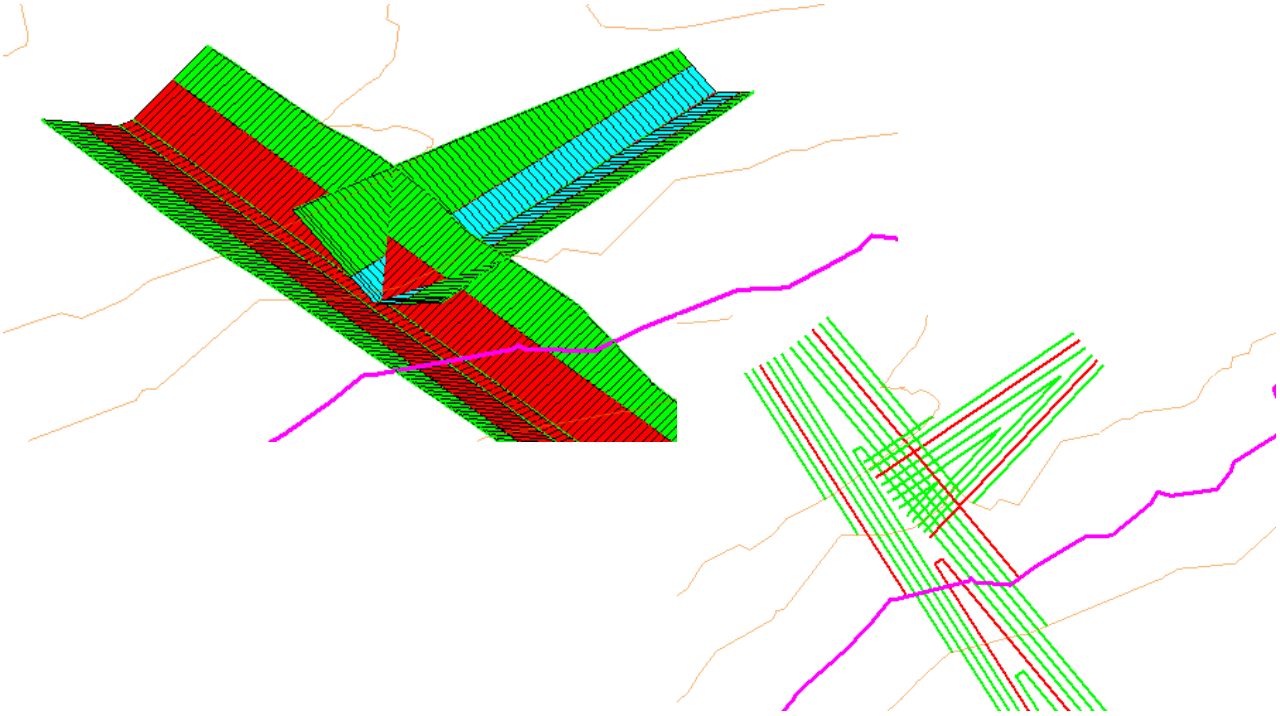
7. Go to *Drainage Ditches* > *Head/Tail Ditches* and select Trap_PSRM. Click OK to close the dialog and then <D> to accept.

8. Press the ALT key to lock the start of the corridor to the beginning of the alignment and then <D> to confirm. Repeat for the end station.

9. Enter 1.0' for the template drop interval, and <D> to accept. The corridor will then be created. It should look something like the image below.



10. Review the procedures detailed in Chapter V to apply parametric constraints and then make the following changes:
    - ✓ Change value for Bottom_Width to 0 to change ditch to V-shape.
    - ✓ Change value for Lining_Slope to 50% for 2:1 slope



C. Use Corridor Clipping to Clean up the Intersection Model (Side Ditch with Constant Slope) (Video)

At this stage, the intersection model may be good enough for conceptual plan development. The horizontal alignments and profiles for both ditches have been established, as well as the grading limits. Once the layout of ditches has been finalized, you can then proceed to the next step of cleaning up the model to trim off the overlapping portions of the corridor models.

1. In the plan view window, turn off the level Draft_Corridor_Graphics_Final.

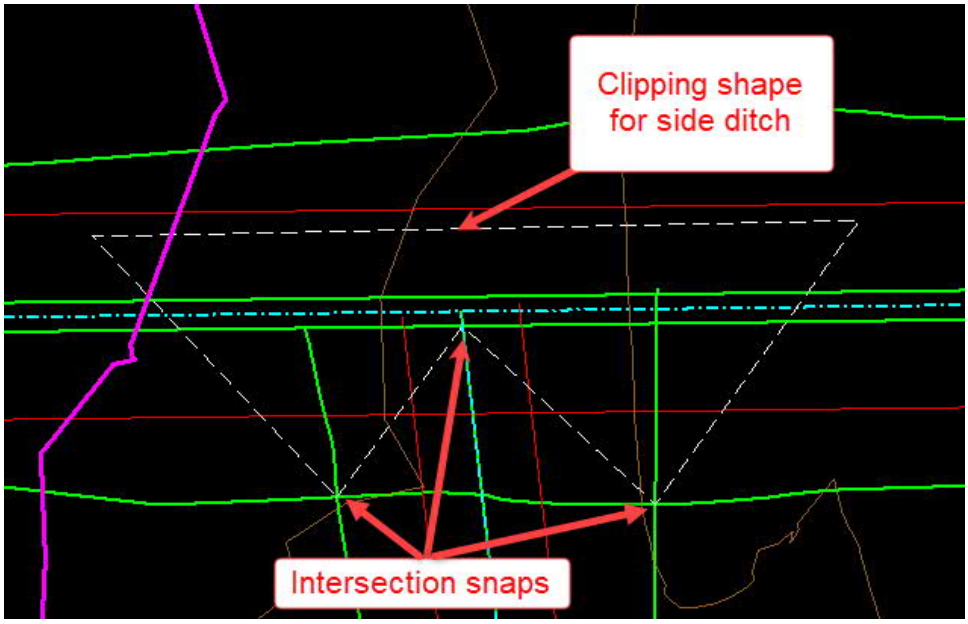
2. Change the default feature definition in the Feature Definition Toolbar to HYD_Construction.

First, we will create a corridor clipping shape for the side ditch:

3. Go to *Geometry* > *Complex Geometry* and select Complex By PI.

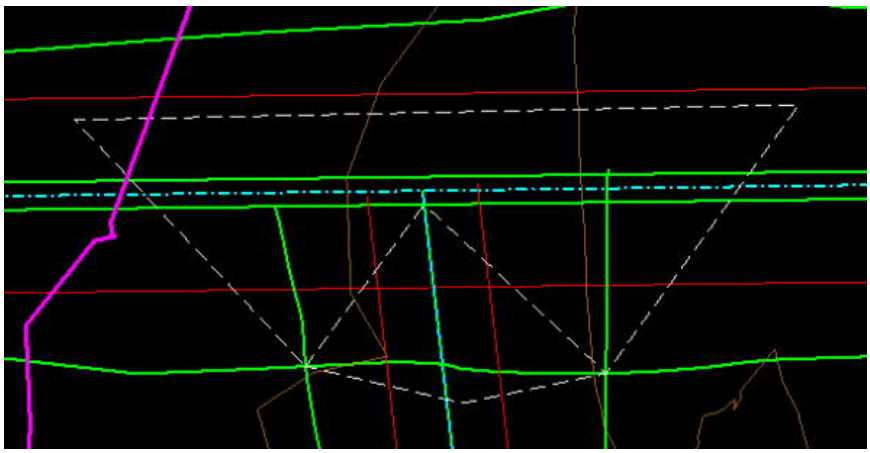
4. Snap to the intersection of where the centerline of the side ditch intersects with the main ditch bottom of bank line, and the intersections of the top of bank lines for both ditches, using "intersection" snap mode.

5. Extend shape around remainder of side ditch, capturing top of bank lines all the way to the end, extending at 45 degree angles to allow for possible future revisions in the skew angle. See below for how the final clipping shape should appear. It's very important that snap rules are established for the three locations indicated, so select the shape and verify that you see the snap indicators.



Next, we will create a corridor clipping shape for the main ditch:

6. Using Complex By PI, snap to the same three intersection points as before, using "intersection" snap mode. Then, add a point offset from the main ditch top of bank line to be sure that the entire line within the overlap area is clipped. See example below for how it should appear with both clipping shapes created.

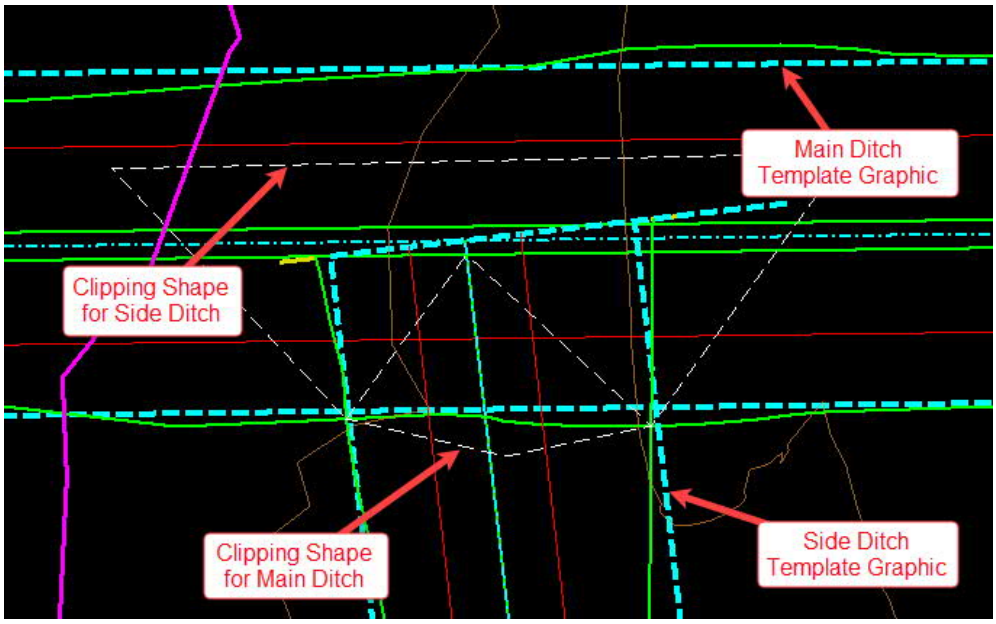


Now that the clipping shapes have been created, we can use them to clip the corridor models.

7. In the plan view window, turn the level Draft_Corridor_Graphics_Final back on.

8. Go to *Corridors* > *Corridor Clipping* and select Add Clipping Reference.

9. At the prompt *Select Corridor To Be Clipped*, select the template graphic for the main ditch. See image below.

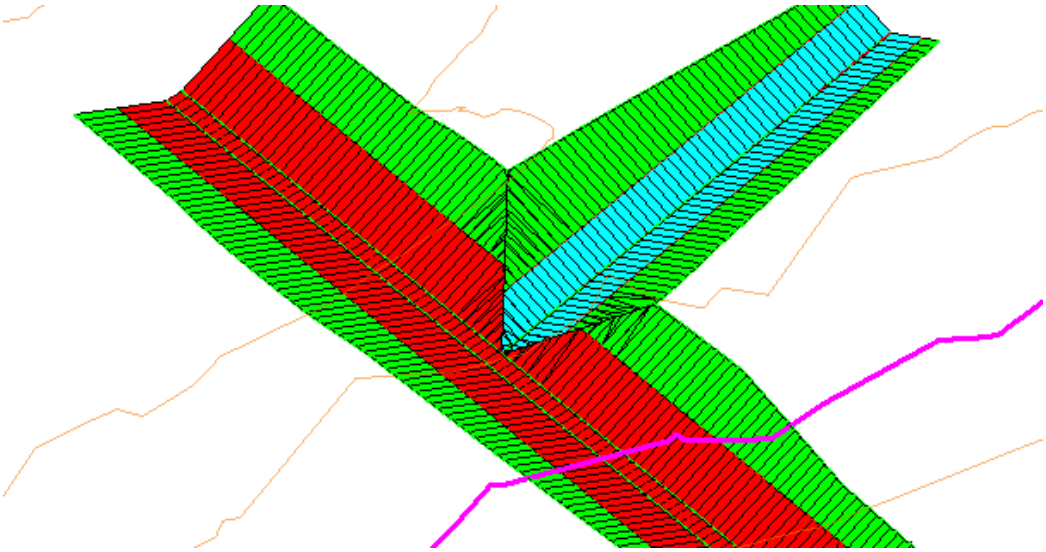


10. At the prompt *Locate First Clipping Reference*, select the clipping shape for the main ditch. Then <R> to complete.

11. Once again, go to *Corridors* > *Corridor Clipping* and select Add Clipping Reference.

12. At the prompt *Select Corridor To Be Clipped*, select the template graphic for the side ditch.

13. At the prompt *Locate First Clipping Reference*, select the clipping shape for the side ditch. Then <R> to complete. The intersection model should now be complete.



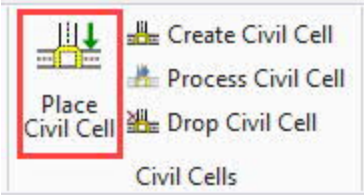
<u>Procedure for Trapezoidal-shaped side ditches</u>

A. Create horizontal and vertical alignments for the side ditch. Use exactly the same procedure as described above for V-shaped side ditch.

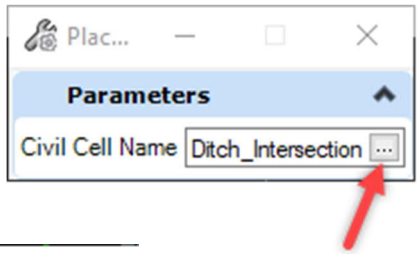
B. Since the geometry and corridor models for trapezoidal ditches are much more complicated than for v-shaped ditches, civil cells are used to simplify the process.

1. If you have not done so already, go to *Corridors* > *Create* > *Template* and select Create Template. When the dialog opens, go to *File* > *Open* and browse to C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library and select NCDOT-Hydraulics-Ditches.ITL, and then click Open. Then close the Create Template dialog.

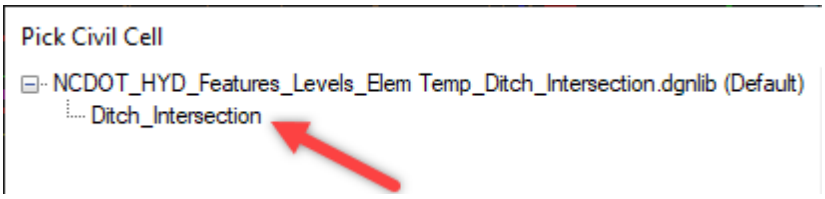
2. Go to *Model Detailing* > *Civil Cells* and select Place Civil Cell. (Video)



3. In the dialog that pops up, click on the ellipsis button to bring up the Pick Civil Cell dialog shown below.



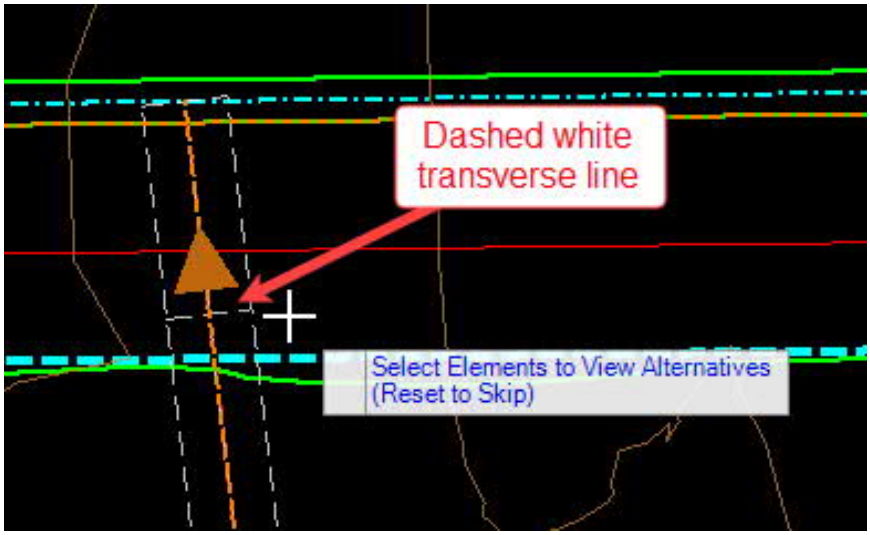
4. In the dialog, select the civil cell named Ditch Intersection.



5. At the prompt *Locate Reference Element: Side Ditch CL*, select the alignment for the side ditch.

6. At the prompt *Locate Reference Element: Main Ditch Bottom of Bank*, select the main ditch corridor feature for the bottom of bank. If the main ditch is V-shaped, then select the ditch centerline feature.

7. At the prompt *Select Elements to View Alternatives*, review the preview of the side ditch corridor that is presented in the plan view window. It should appear as shown below, with the orange arrow pointing in the correct direction for the side ditch. Move your mouse around if needed to get the arrow to show on the side ditch rather than the main ditch. You should also see a dashed white transverse line near the intersection. If arrow is pointing in wrong direction and you don't see the line, then try using a <D> to switch the direction. If the preview looks correct, then <R> to skip to the next prompt.

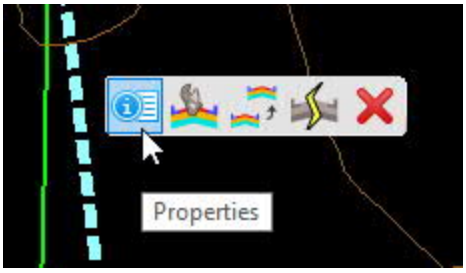


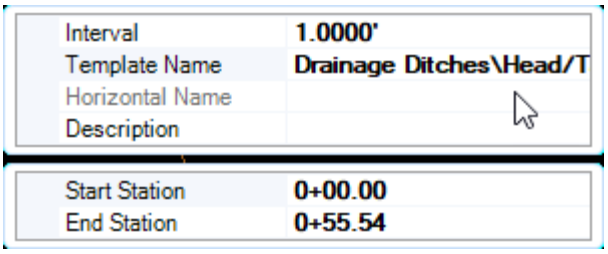
8. At the prompt *Accept Civil Cell Placement*, <D> to accept. The corridor model will then be created and displayed.

9. Go to *Model Detailing* > *Civil Cells* and select Drop Civil Cell.

10. At the prompt *Locate Civil Cell*, select the corridor model for the side ditch.

11. In the plan view window, select the template drop graphic for the side ditch corridor and from the flyout menu select Properties.





12. In the Properties dialog, select the field for Template Name. This brings up the Pick Template dialog.

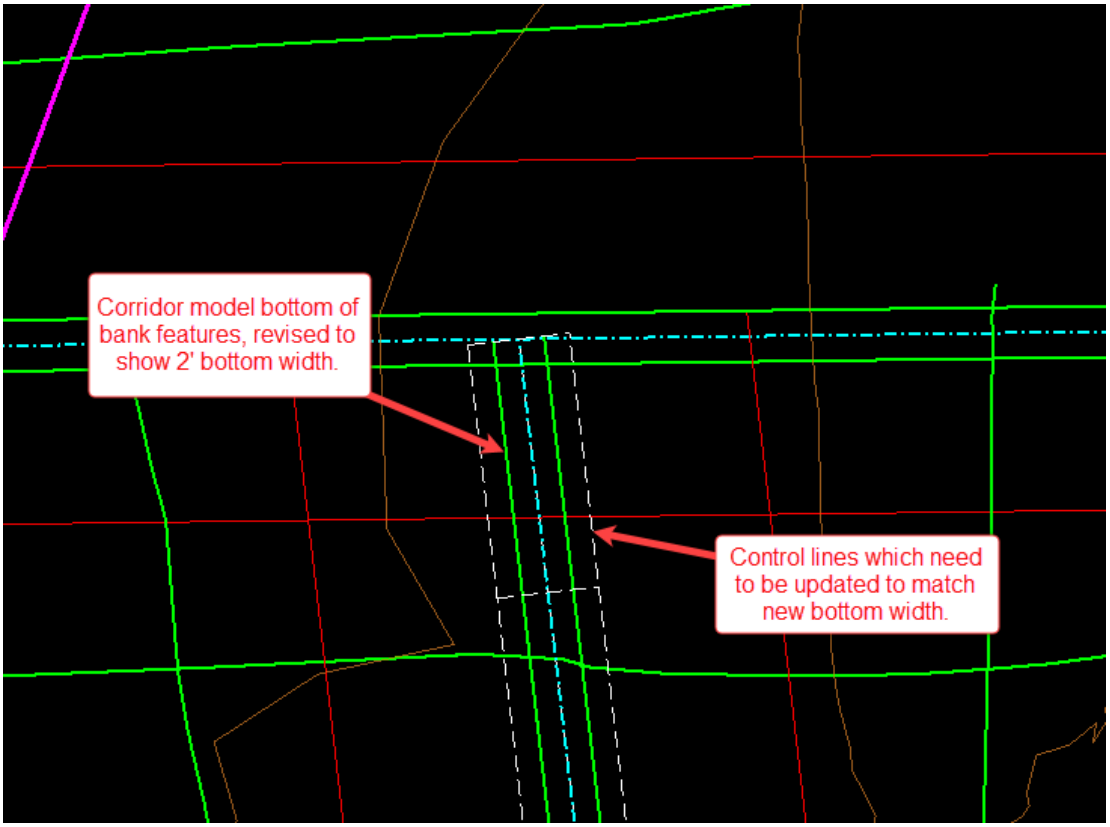
13. Go to *Drainage Ditches* > *Head/Tail Ditches*, select Trap_PSRM, and click OK.

14. Review the procedures detailed in Chapter V to apply parametric constraints and then change value for Bottom_Width to 2'.

<u>Important Note:</u>

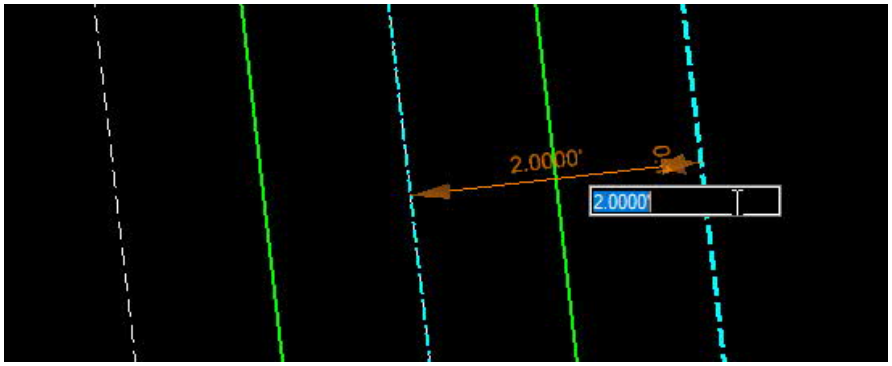
For trapezoidal side ditches, horizontal and vertical geometry and Point Controls for the bottom of bank lines are included in the corridor model that was created through the civil cell. This is needed to "warp" the cross slope of the side ditch bottom so that it matches the longitudinal slope of the main ditch where they meet. This complication is why civil cells are used for trapezoidal side ditches – to save the user the effort of creating the geometry and Point Controls. When the bottom width is changed through a parametric constraint or template drop edit, you must update the side ditch geometry so that the bottom width of these control lines match the new bottom width, as detailed below.

15. Turn off the levels Draft_Corridor_Graphics_Final and Draft_Corridor_Point_Control. The intersection should then appear as shown in the image below.



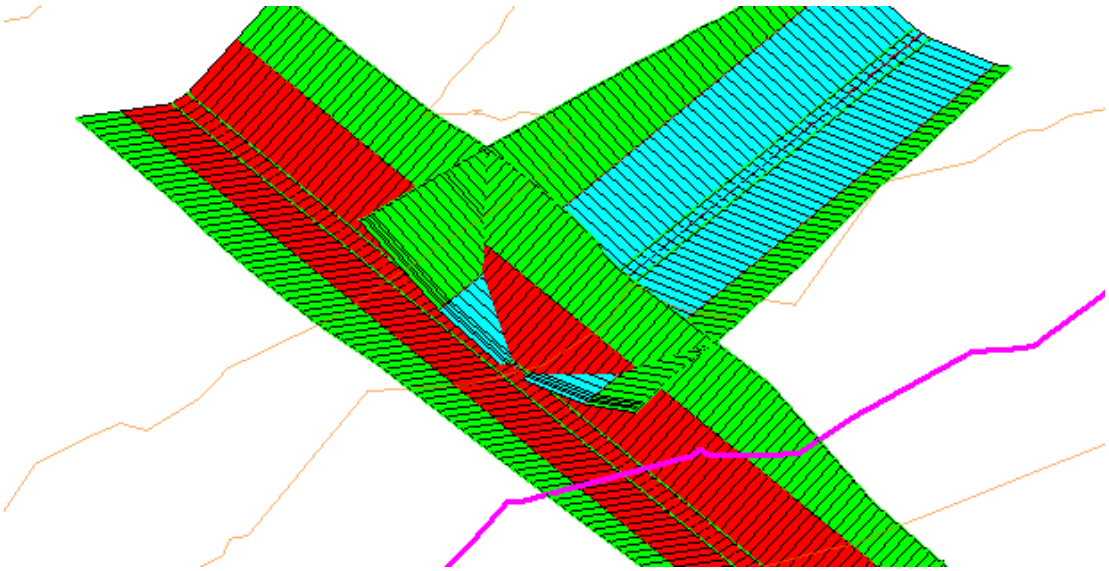
16. Select the white dashed line on the right side of the side ditch. Orange graphic and text manipulators will then appear. Zoom to the text manipulators shown near the <u>middle</u> of the ditch, not either end.

17. Move your mouse over the orange text for the offset until you see it highlight slightly. Then click on the text and this will cause an editing box to pop up. Change the value from 2' offset to 1' offset. Do this for both sides of the ditch. The green corridor model bottom of bank lines and the dashed white lines should now coincide. Be sure to use -1 for the left side.



18. Turn the levels Draft_Corridor_Graphics_Final and Draft_Corridor_Point_Control back on.

    The ditch intersection should now look like this:



C. Use Corridor Clipping and Target Alias to Clean up the Intersection Model (Side Ditch with Variable Slope). (Video)

In the previous example, the side slopes in the side ditch were constant: the slope of the grass and the PSRM lining were the same. In this example, they are different. When variable slopes occur in either the main ditch or the side ditch, a more complex approach is needed.

A greater density of template drops is needed in the vicinity of the intersection. Therefore, a new template drop range will be created for that purpose.

5. Select a corridor handle for the side ditch and from the flyout menu select Create Template Drop.

6. In the dialog, select the same template as before: Trap_PSRM. <D> to accept the selection.

7. At the prompt *Start Station*, with your mouse, graphically identify the start of the new template drop, which should be just before the intersection of the top of bank lines for the two ditches.

8. At the prompt *End Station*, press ALT to lock to the end of the corridor and <D> to accept.

9. At the prompt for *Interval*, enter a value of 0.1 feet and <D> to accept. The corridor will update.

10. In the plan view window, turn off the level Draft_Corridor_Graphics_Final.

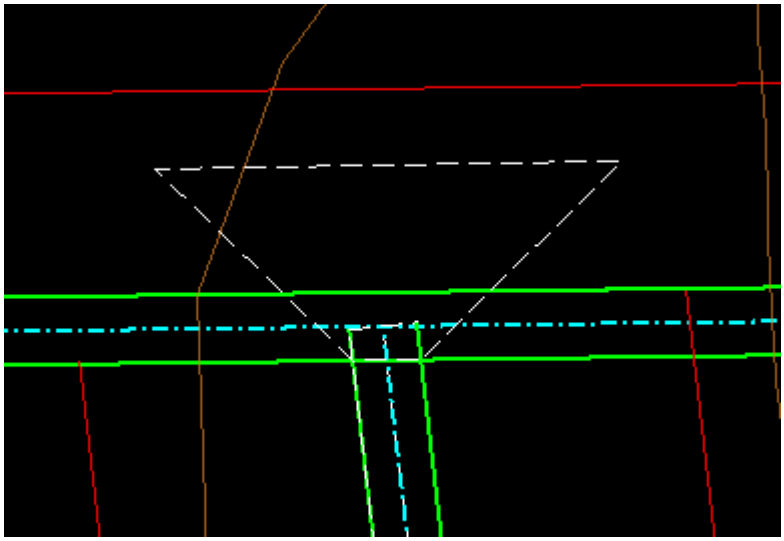
11. Change the default feature definition in the Feature Definition Toolbar to HYD_Construction.

Next, we will create a corridor clipping shape for <u>the portion of the side ditch bottom</u> which projects past the main ditch bottom of bank line:

12. Go to *Geometry* > *Complex Geometry* and select Complex By PI.

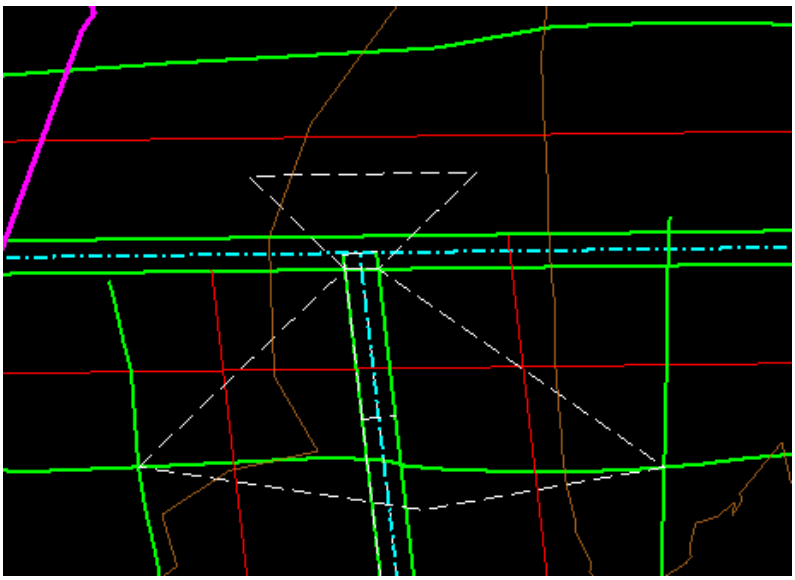
13. Snap to the intersections of where the bottom of bank lines for the side ditch intersect either the main ditch bottom of bank line (if main ditch is trapezoidal) or the main ditch centerline (if main ditch is V-shaped). Be sure to use "intersection" snap mode.

14. Extend shape around remainder of side ditch, capturing top of bank lines all the way to the end, extending at 45 degree angles to allow for possible future revisions in the skew angle. See below for how the final clipping shape should appear. As in the previous example, select the shape and verify that you see the snap indicators.



Next, we will create a corridor clipping shape for the main ditch:

15. Using Complex By PI, with snap mode set to "intersection", snap to the intersections of where the bottom of bank lines for the side ditch intersect either the main ditch bottom of bank line (if main ditch is trapezoidal) or the main ditch centerline (if main ditch is V-shaped). Also snap to the intersection of the top of bank lines for both ditches. Then, add a point offset from the main ditch top of bank line to be sure that the entire line within the overlap area is clipped. See example below for how it should appear with both clipping shapes created.



The next step is to use Target Aliasing to identify the break point where the slope changes in the side ditch.

16. In the plan view window, turn the level Draft_Corridor_Graphics_Final back on.

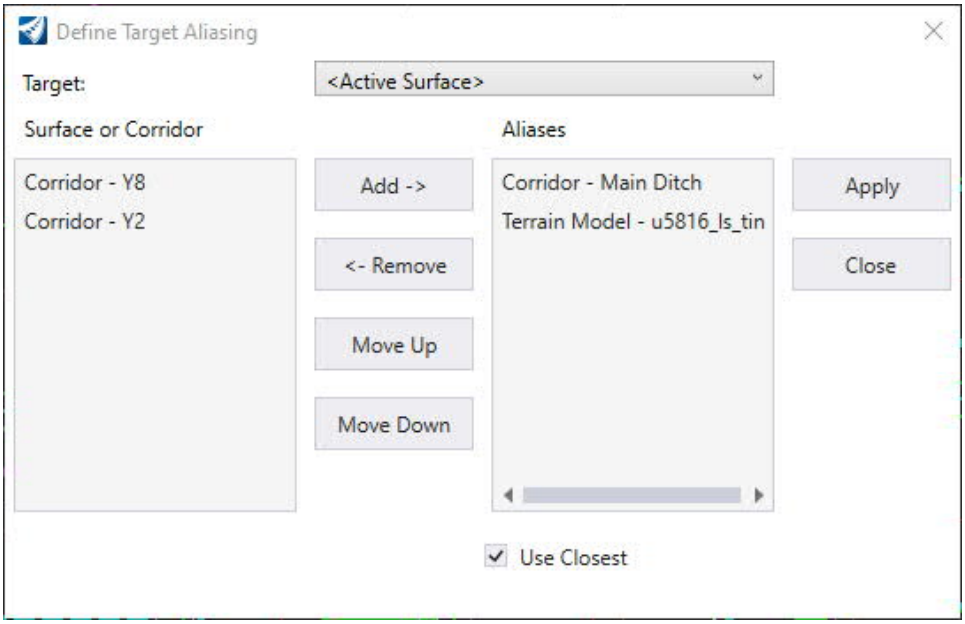
17. Go to *Corridors* > *Miscellaneous* and select Define Target Aliasing.

18. At the prompt *Locate Corridor*, select the side ditch corridor model. This brings up the Define Target Aliasing dialog (shown on the next page).

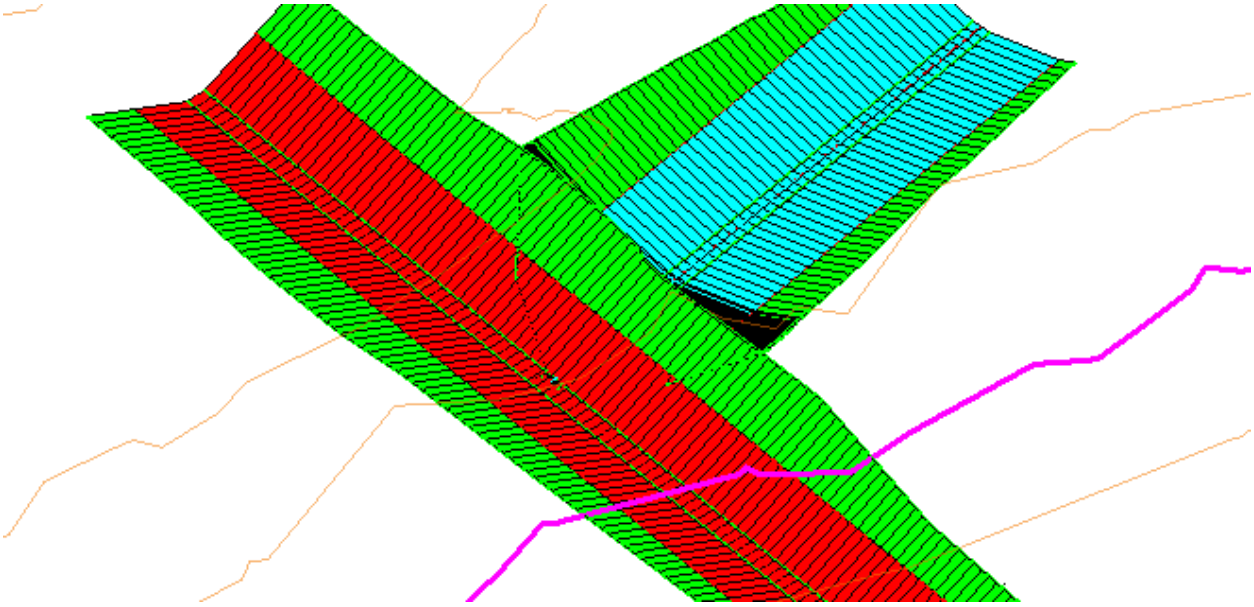
19. Initially, nothing will be listed under the heading "Aliases". Find the existing terrain and the main ditch corridor model in the list under the heading "Surface or Corridor". For each one, select it and then click on Add to move it to the list of Aliases as shown above.

20. Check the box for Use Closest, then click Apply. In the 3D model view window, you will see that the side ditch corridor model has now been trimmed by the main ditch corridor model. Click Close to close the dialog.

Completed Target Aliasing dialog:



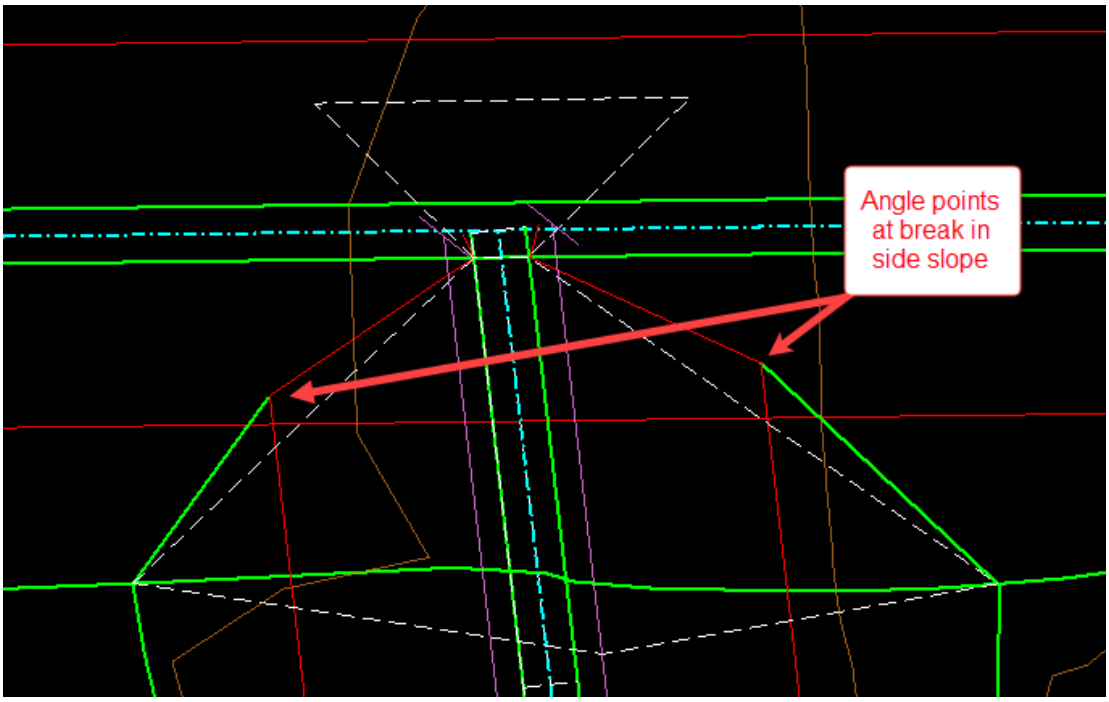
Below shows the side ditch trimmed by the main ditch corridor model:



The clipping shape for the main ditch can now be finalized to clean up the intersection. (Video)

21. In the Feature Definition Toolbar, turn off the toggle for Persist Snaps.

22. Use Insert Vertex to modify clipping shape for main ditch by adding vertices by snapping to angle point where the top of side ditch lining intersects with the main ditch. Do this on both sides of the side ditch.



23. Turn Persist Snaps back on.

24. Go to *Corridors* > *Miscellaneous* > *Corridor Clipping* and select Add Clipping Reference.

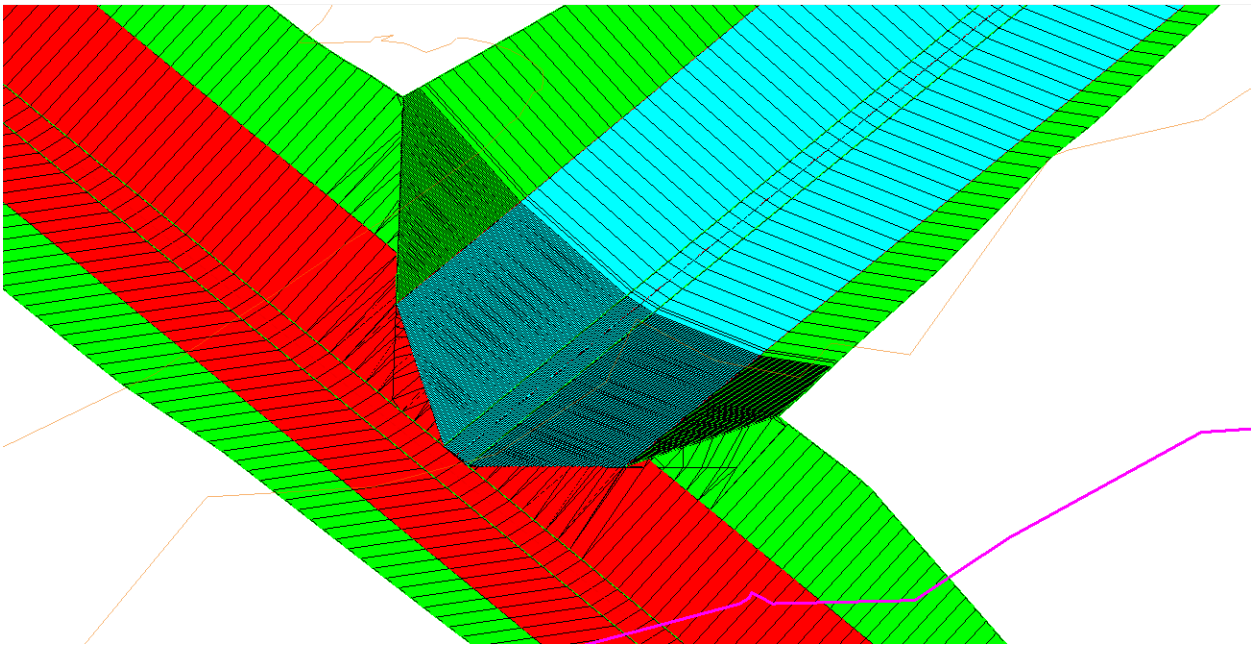
25. At the prompt *Select Corridor To Be Clipped*, select the template graphic for the main ditch.

26. At the prompt *Locate First Clipping Reference*, select the clipping shape for the main ditch. Then <R> to complete.

27. Once again, go to *Corridors* > *Corridor Clipping* and select Add Clipping Reference.

28. At the prompt *Select Corridor To Be Clipped*, select the template graphic for the side ditch.

29. At the prompt *Locate First Clipping Reference*, select the clipping shape for the side ditch. Then <R> to complete. The intersection model should now be complete.



Procedure for revising ditch intersections

The ditch intersection model is dynamic – it will update automatically to changes in ditch dimensions, alignment, and profile of either ditch. It will also update if the connection point of the side ditch to the main ditch is relocated. However, you should follow a particular sequence when making revisions, and note the following for some particular circumstances:

1. If Target Aliasing is being used for a variable slope side ditch (V-shaped or trapezoidal), turn it off before making revisions. Simply open the Target Aliasing dialog as before and remove the main ditch from the list of Aliases.

2. Make ditch revisions.

    a. It is often helpful to turn off certain levels since many lines may be on top of each other. For example, if editing the horizontal alignment then turn off the levels Draft_Corridor_Graphics_Final and P_HYD_Construction so that the baseline is easily accessible.

    b. If changing the bottom width of a trapezoidal side ditch, remember to adjust the ditch bottom control lines as previously explained.

    c. Depending on the scale of the revisions, you may need to adjust some of the points in the clipping shapes that were placed free hand (not snapped). This is especially the case if the connection point between the two ditches has been relocated. Therefore, after making revisions always check the clipping shapes.

3. If Target Aliasing is being used, turn it back on after making revisions and re-adjust the main ditch clipping shape.

4. If a civil cell has been used to create the side ditch corridor for a trapezoidal side ditch, there is one type of revision that cannot be made: revision of the main ditch profile. The main ditch horizontal alignment can be revised, but not its profile. If this change is needed, then the intersection model will need to be deleted and re-created.

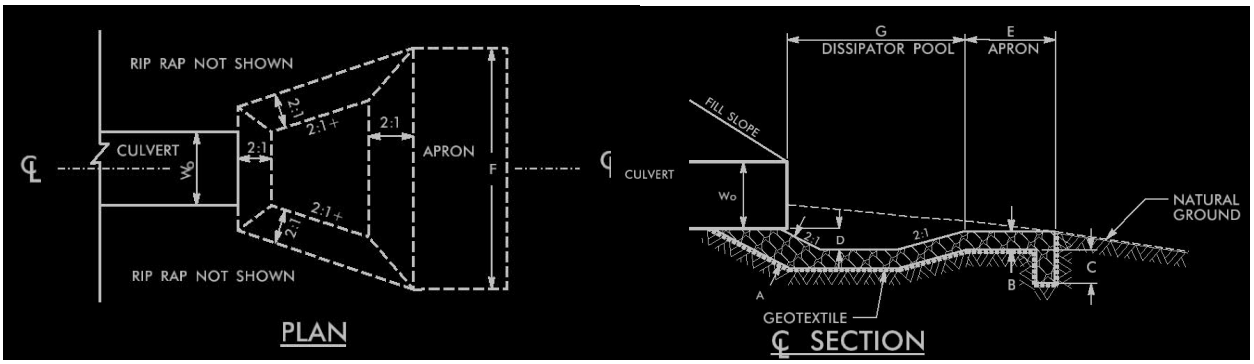
IX. Energy Dissipators.

This section outlines the procedure for creating a dynamic model for a standard NCDOT energy dissipator, as well as the downstream grading transition.

Develop Design Parameters for Energy Dissipator

Complete the design the energy dissipator before attempting to model it. The following parameters must be identified:

1. "Wo" = span of conduit discharging to energy dissipator.
2. "A" and "B" = thickness of riprap lining. For modeling purposes, it is assumed that A equals B, but they can be shown differently on the plan details.
3. "C" = depth of the riprap toe wall at the downstream edge of the apron. This is not used in the 3D model, but will be shown on the plan details.
4. "D" = depth of energy dissipator.
5. "E" = width of the riprap apron at the downstream edge of the energy dissipator.
6. "F" = transverse length of the riprap apron.
7. "G" = length of the dissipator pool.

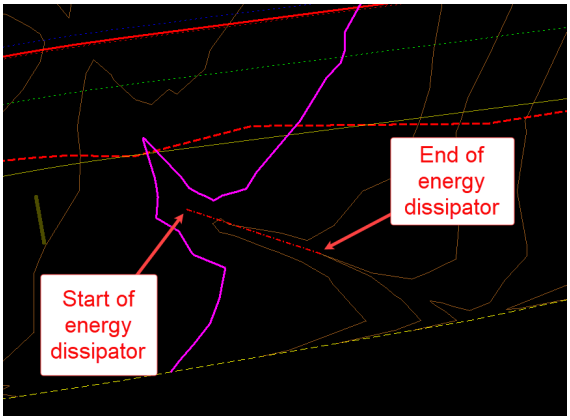


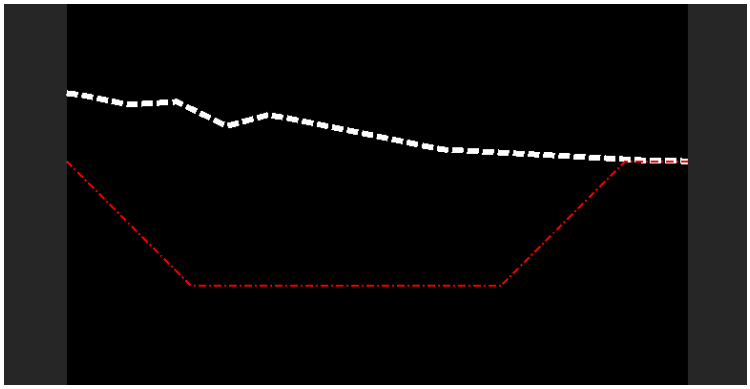
Create Horizontal and Vertical Alignment

1. Create a horizontal alignment that runs through the energy dissipator. It must be a straight line (no angle points or curves) until reaching downstream edge of berm, and then end at that point. The total length of the alignment must be equal to the total length of the designed energy dissipator, which is "G" + "E".

2. Create a vertical alignment, or profile, for the horizontal alignment and make it active. As shown in the NCDOT standard detail, the elevation should be the same for the pipe invert, top of dissipator pool, and downstream apron. Also, this elevation should set to match the stream invert elevation at the downstream edge

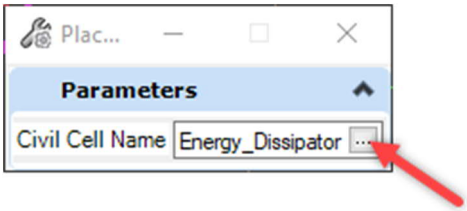
of the apron so that there is no drop off of flow to the existing stream bed. See example below. Profile must include all the break points: 2:1 slope down to bottom, flat bottom, 2:1 slope back up, and flat apron to the end. Refer to the pictures below.



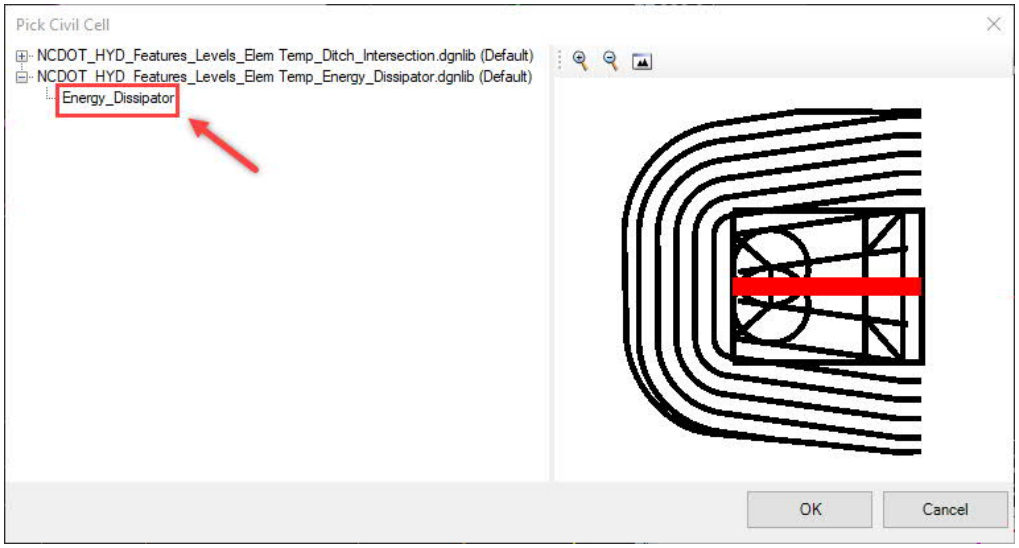


3. Go to *Corridors* > *Create* > *Template* and select Create Template. If not already open, go to *File* > *Open* and browse to *C:\NCDOT_CONNECT_WORKSPACE\Configuration 10_10\Organization-Civil\Disciplines\NCDOT_Hydraulics\Standards\Template Library* and open the file NCDOT_Hydraulics_Ditches.itl to access the template library for the next step.

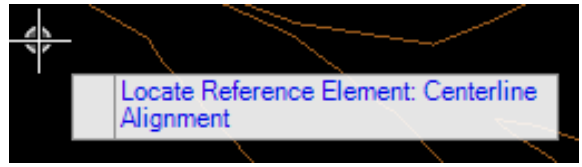
<u>Create Energy Dissipator by Placing a Civil Cell</u> (video)



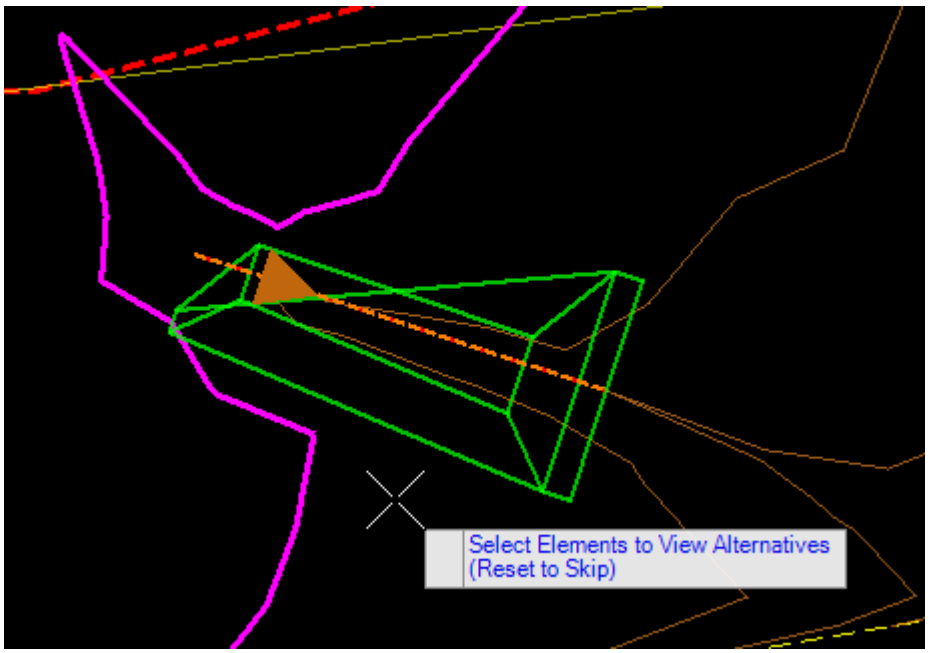
1. In the OpenRoads Modeling workflow, go to *Model Detailing* > *Civil Cells* and select Place Civil Cell.
2. Click on the button with the three dots.
3. In the Pick Civil Cell dialog, select Energy Dissipator and then click OK.



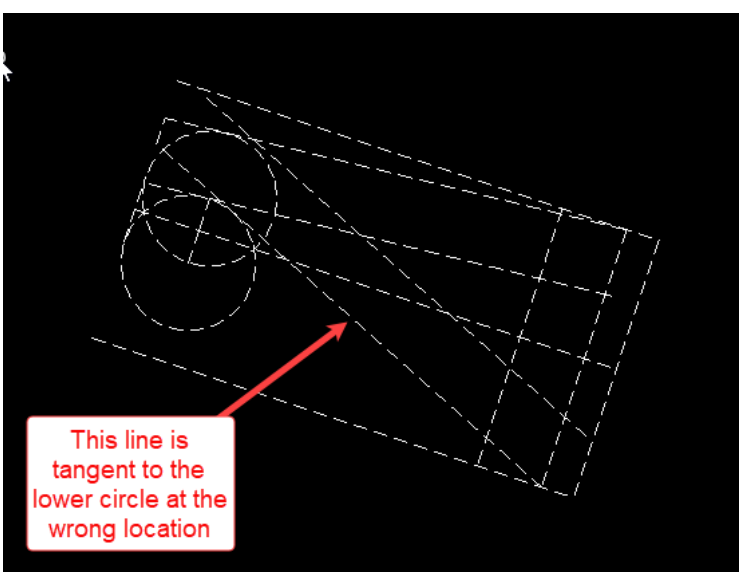
4. At the prompt *Locate Reference Element: Centerline Alignment*, select the horizontal alignment created earlier.



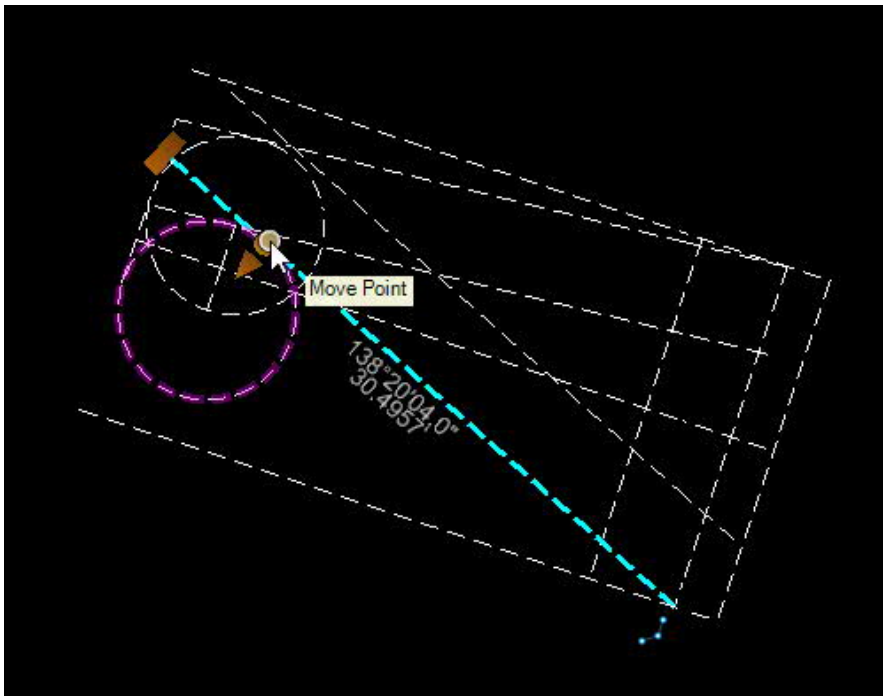
5. At this point, you will likely see a jumbled mess of lines, and the prompt *Select Elements to View Alternatives*. <R> to skip this step.



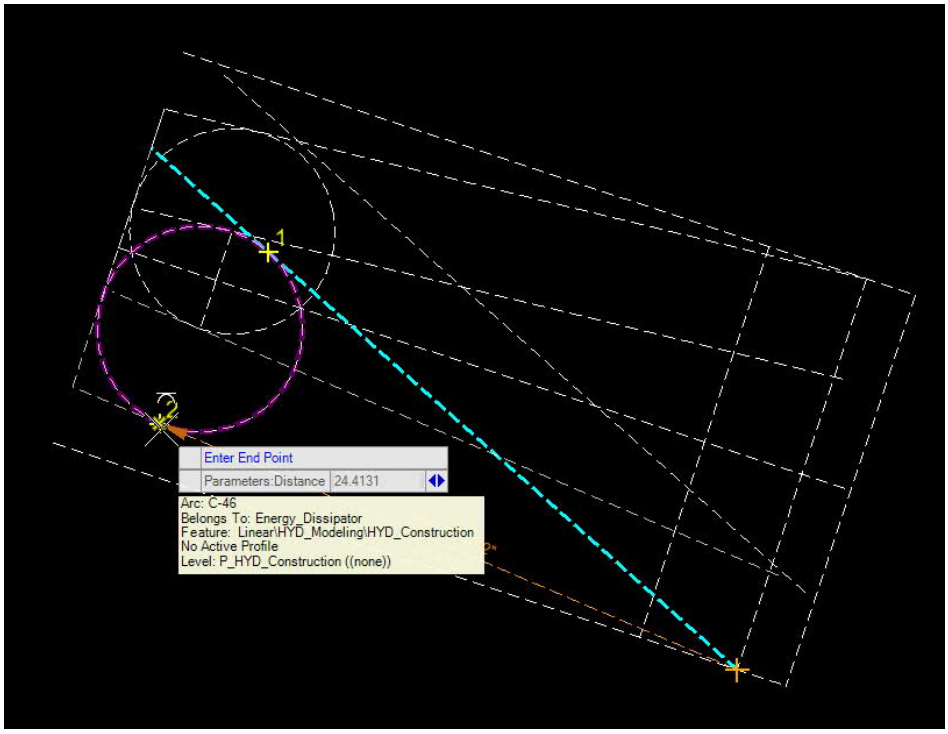
6. At the prompt *Accept Civil Cell* Placement, <D> to accept.
7. With the plan view window activated, go to Level Display and turn off all levels except P_HYD_Construction. It should look similar to the picture below.



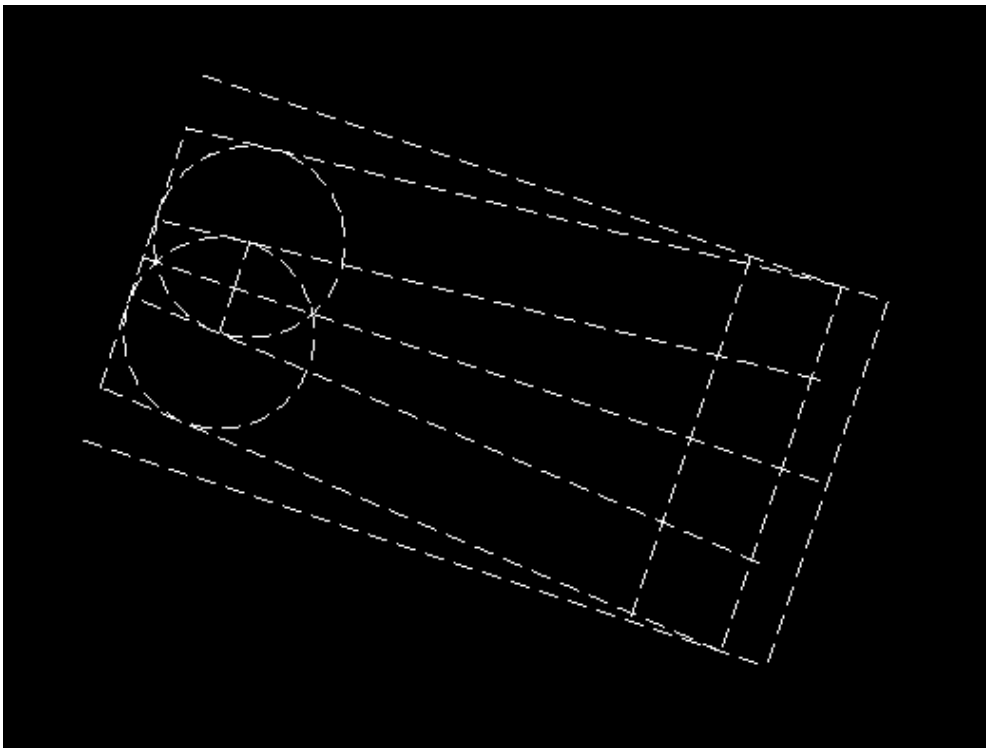
The geometry of the civil cell uses a tangent snap. It is the nature of tangent snaps that there are two possible alternative solutions. One will be correct, and the other incorrect. Any incorrect tangent snaps will have to be manually fixed. In the above example, one line is incorrect. Sometimes both lines may need to be fixed.



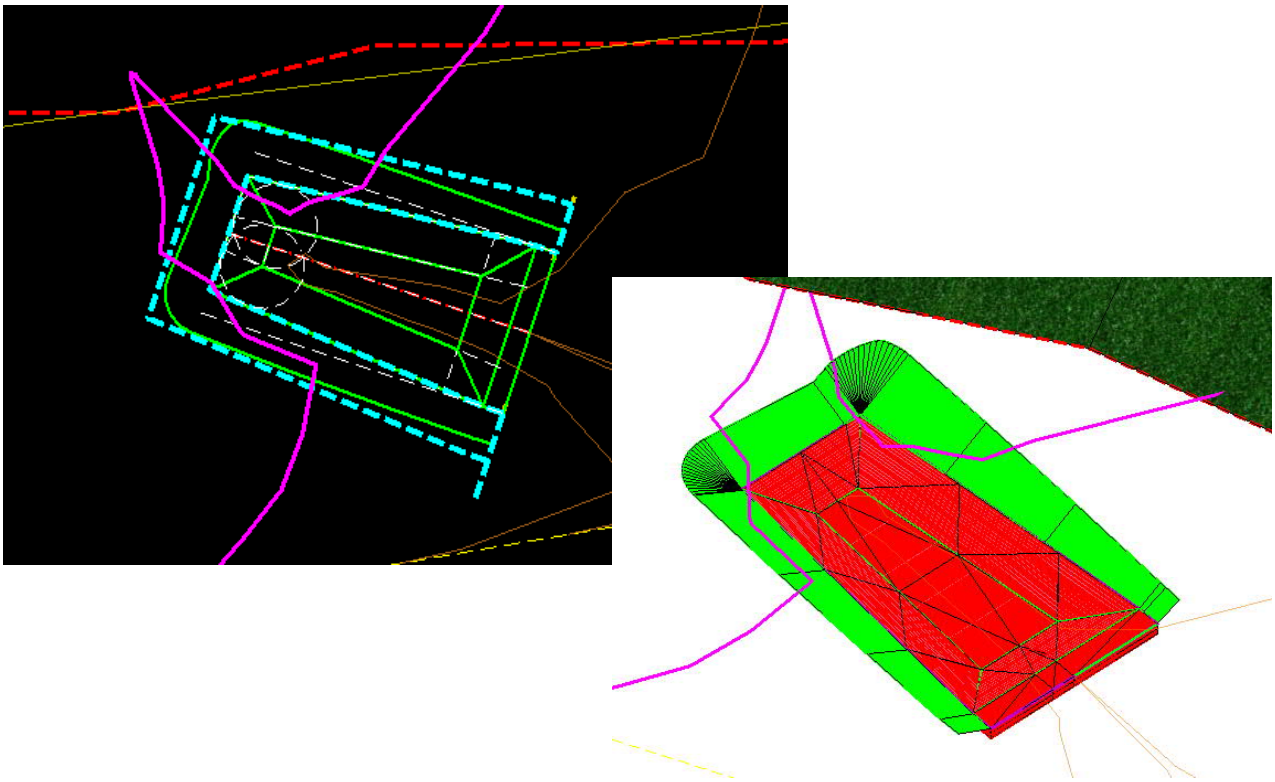
8. Select the line representing the top of the dissipator pool side slope. Move your mouse pointer to the point where the line is tangent to the wrong side of the circle and click on the Move Point graphic manipulator.
9. Set snap mode to Tangent Snap, and move the line and snap to the correct point of tangency (see below). Confirm the tangent snap indicator before you <D> to accept.



10. The geometric layout should now look as shown below.



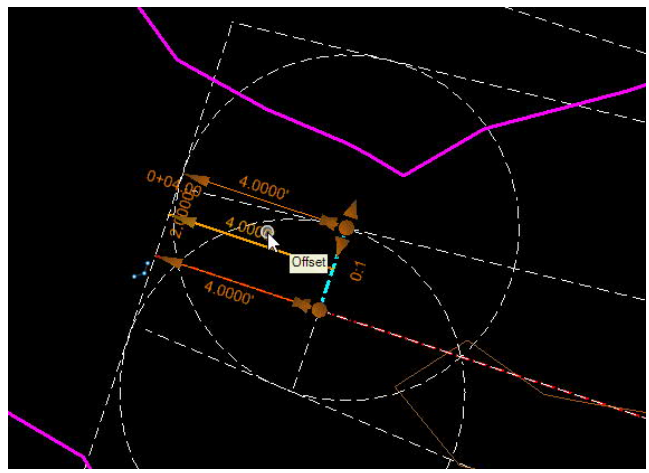
11. Go to Level Display for the plan view and turn on all levels. See below for how the plan and 3D model views should appear.



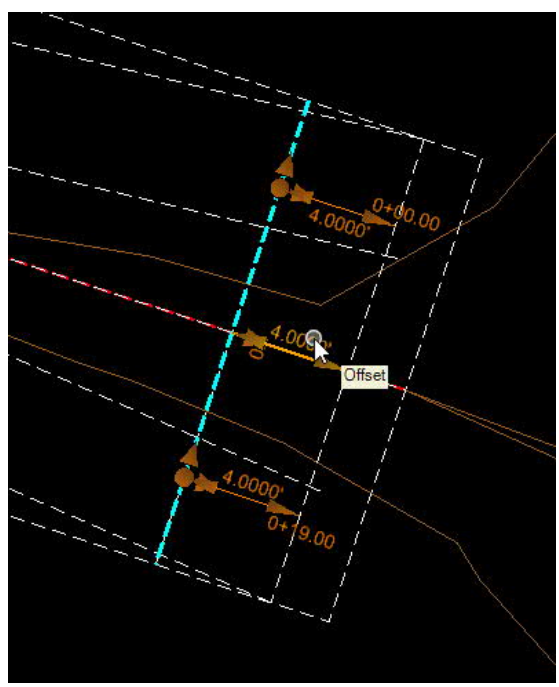
Make adjustments to the Energy Dissipator (video)

When the civil cell was placed, it was longitudinally "stretched" to fit the total length of the horizontal alignment. In addition, the elevations of the top and bottom of the dissipator pool and apron were adjusted to fit the active profile of the alignment. However, the civil cell contains default values for many dimensions and these values may need to be edited to match your specific design.

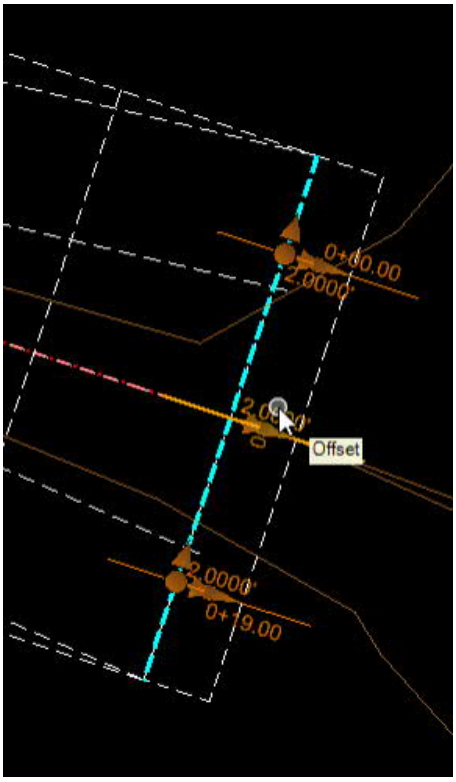
1. Select the Drop Civil Cell tool from the ribbon menu, and select the energy dissipator in the plan view to drop the civil cell and leave behind the geometry, proposed terrain model, surface template, and linear templates so they can be edited more easily.
2. For the plan view window, turn off levels for Draft_Corridor_Graphics_Final, P_HYD_TL_Ditch_Base, and P_HYD_TL_Ditch_Boundary.
3. For each of the two offset lines to which the circles are attached, select the line and adjust the offset value (be sure to select the text manipulator in the middle!).



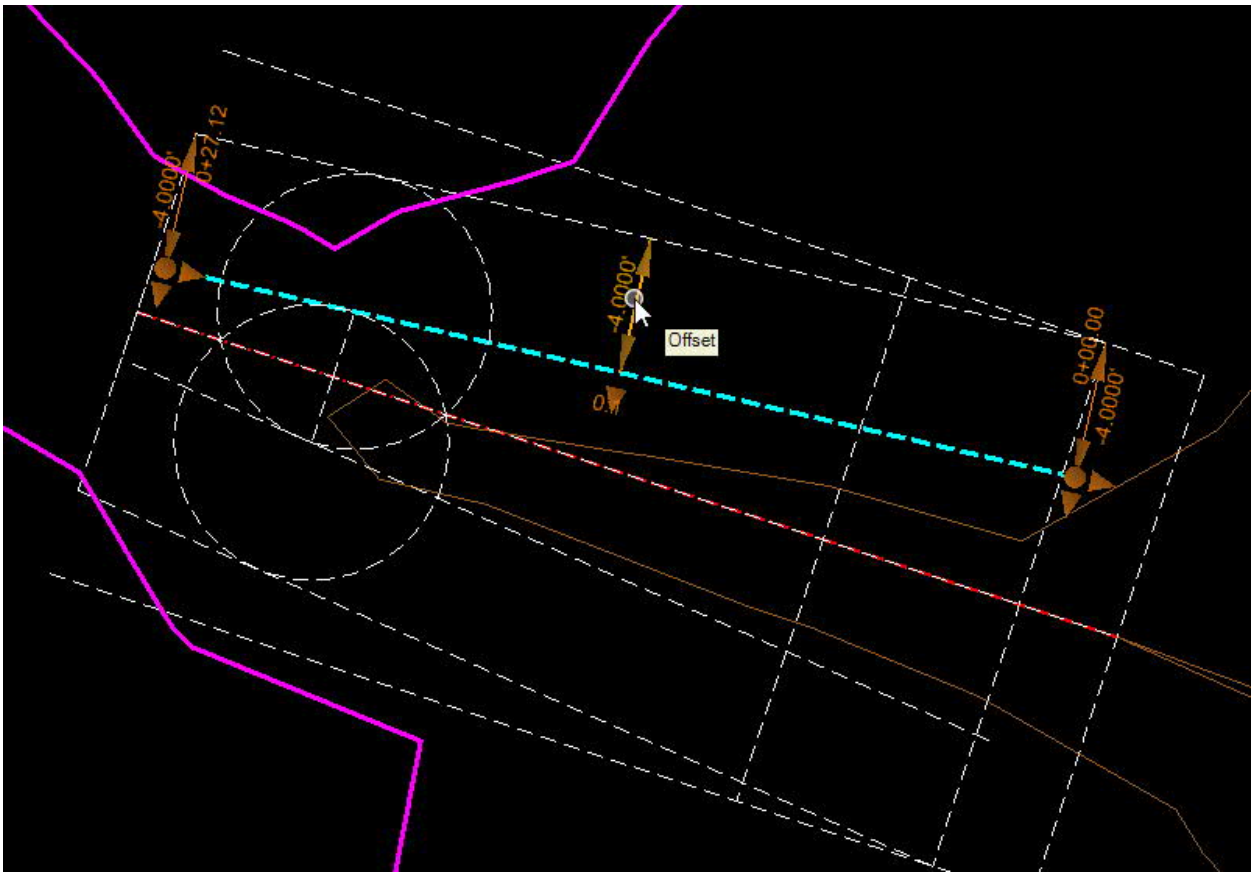
4. Select the line for the bottom of the slope at the end of the dissipator pool. The offset values will at first appear gray and cannot be edited. <R> on the text manipulators and they will turn orange and become editable. Again, be sure to edit the middle value.



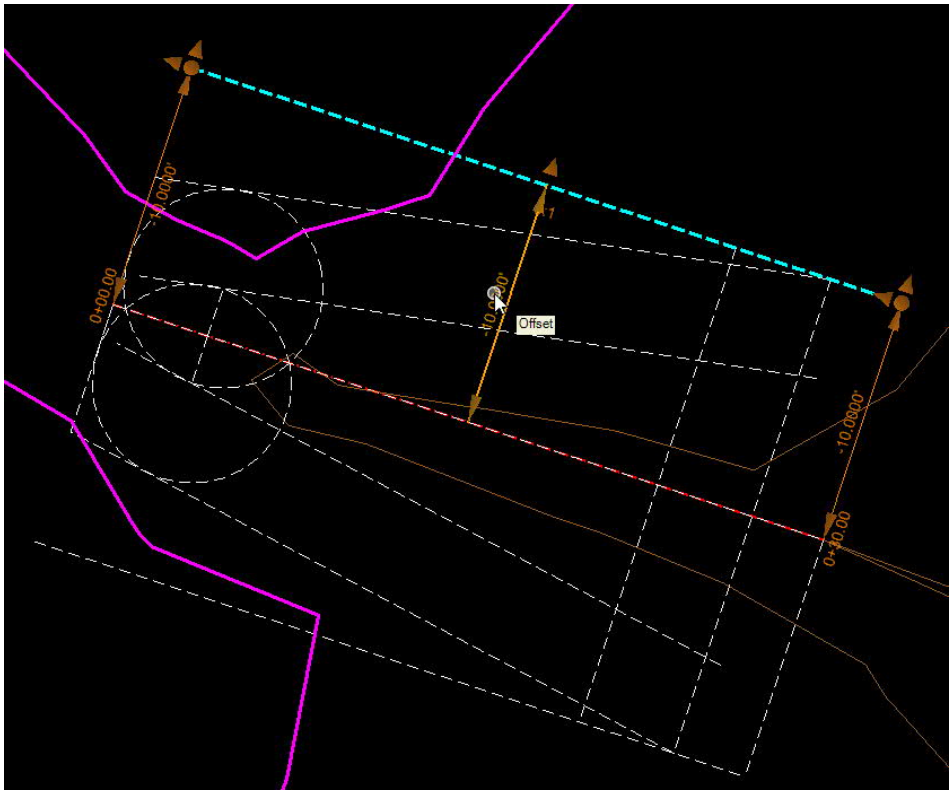
5. Select the line for the top of the slope at the end of the dissipator pool. The offset values will at first appear gray and cannot be edited. <R> on the text manipulators and they will turn orange and become editable. Again, be sure to edit the middle value.



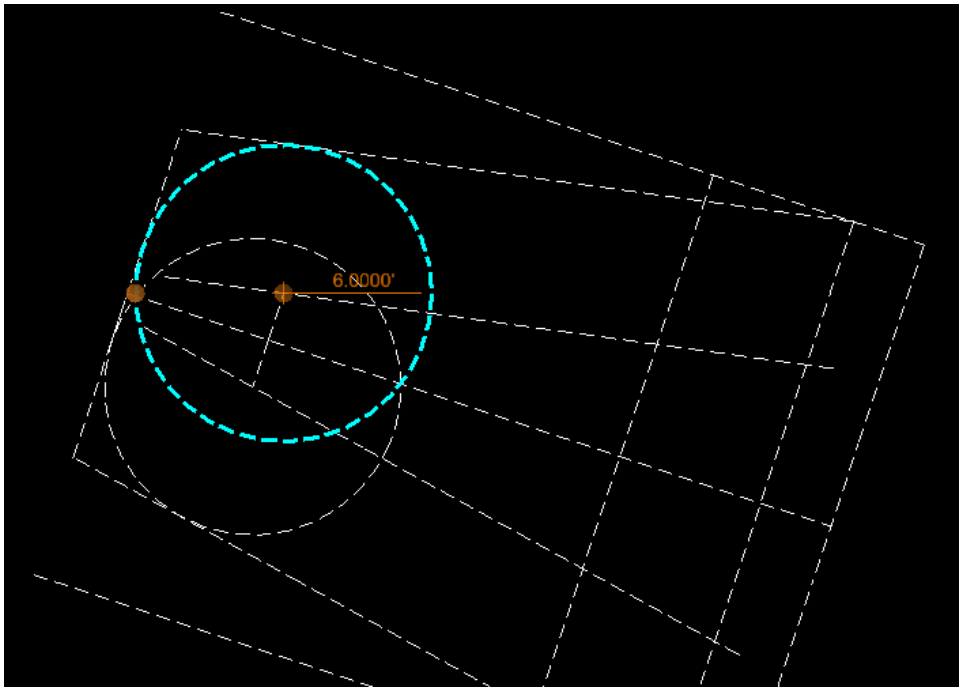
6. Select the line for the bottom of the slope at one of the sides of the dissipator pool. Edit the offset value as needed. Repeat for the other side. Pay attention to positive and negative signs.



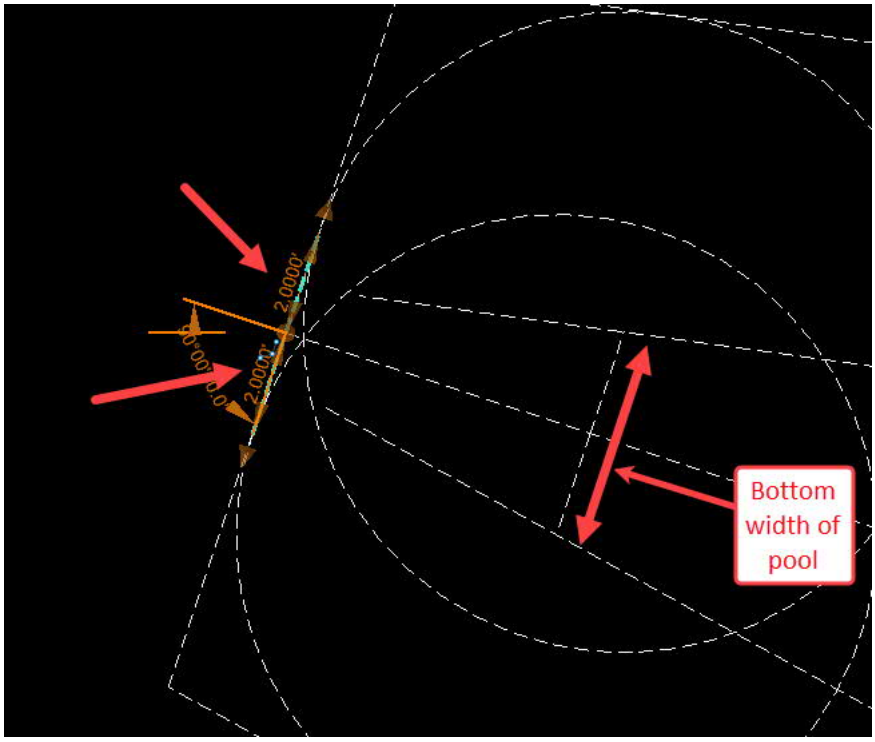
7. Adjust the width of the dissipator pool by selecting the outside line on each side and adjusting the offset values for each.



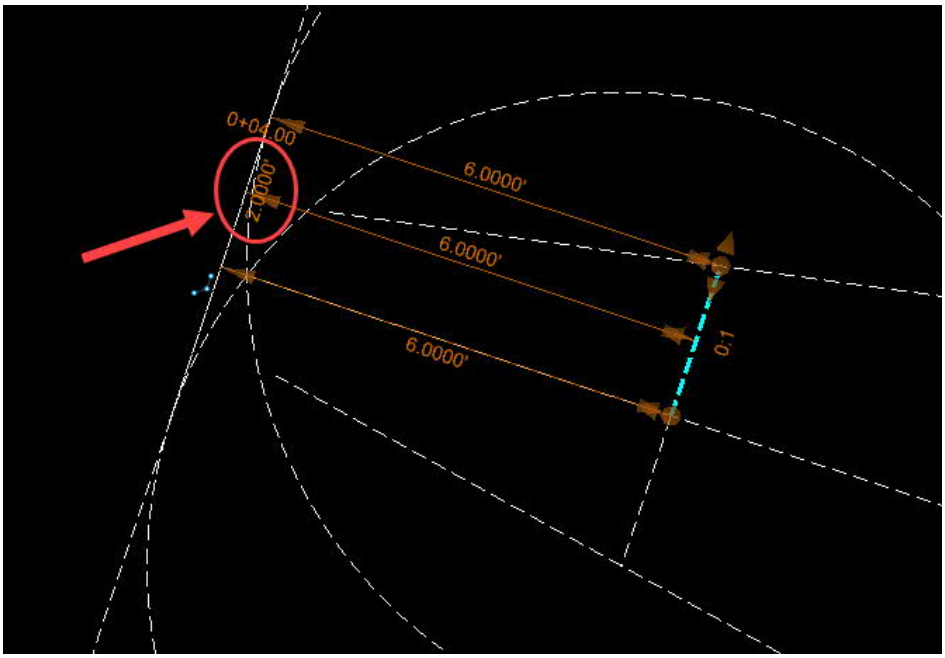
8. Adjust the location of the top of side slope by revising the value of the radius on each side.



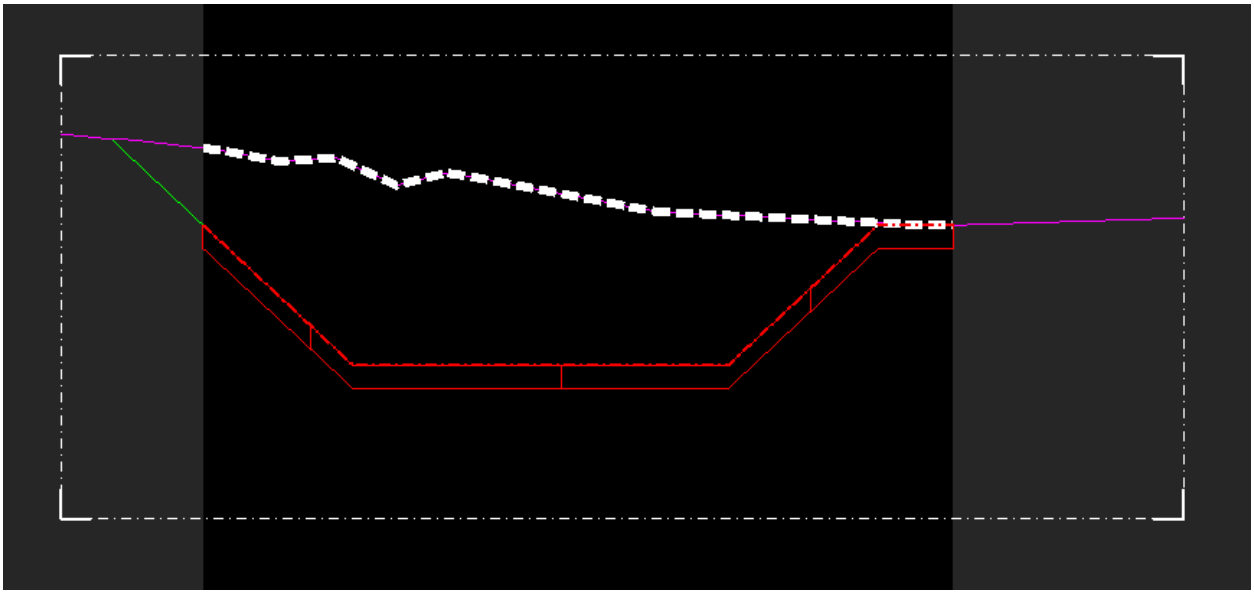
9. To adjust the bottom width of the pool to match the span of the conduit, select the back construction line, and then <R> on it to expose the text manipulators and then change both the offset values as needed. This is the first step.



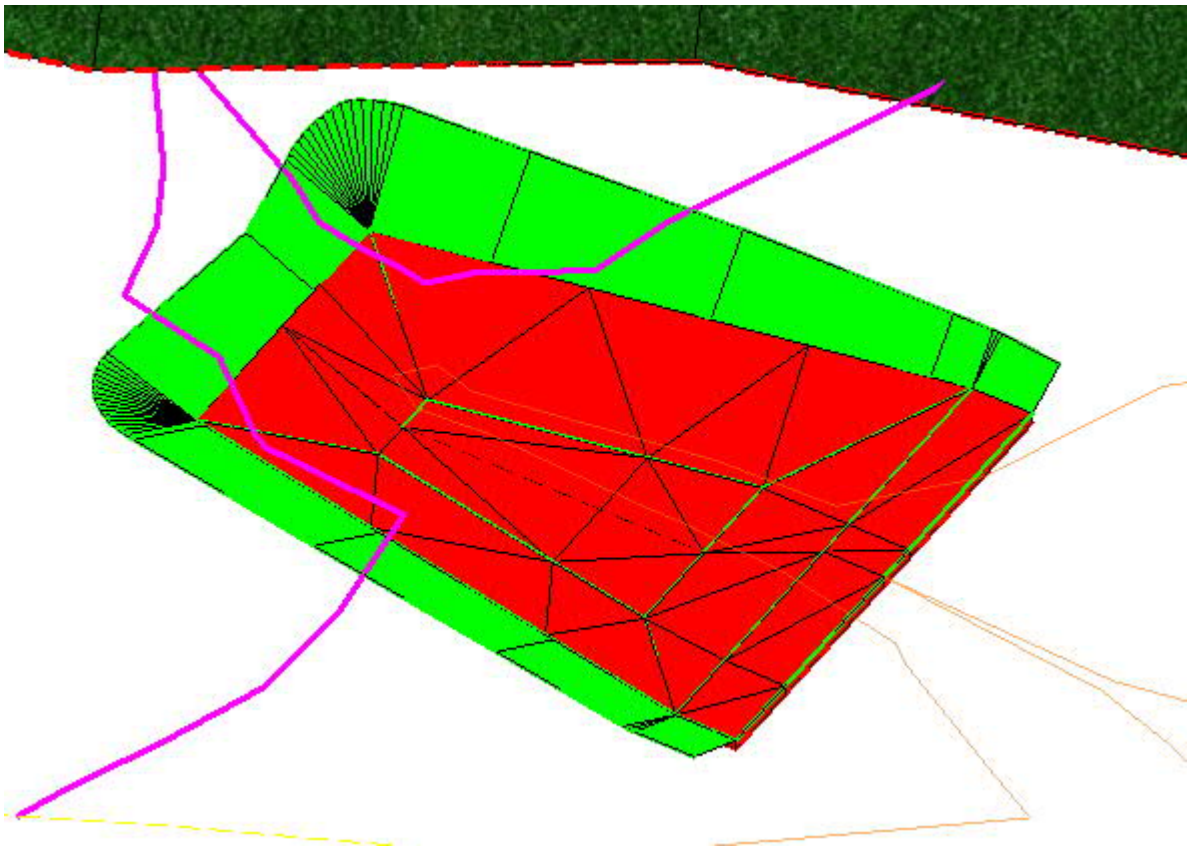
10. Next, select one of the lines to the radius point, and change offset value. Repeat for other side.



11. In the plan view, turn on all levels and turn off the level P_HYD_Construction. Using the baseline feature for the dissipator, create a profile model and then add a 3D Cut to verify that the riprap matches the proposed profile.



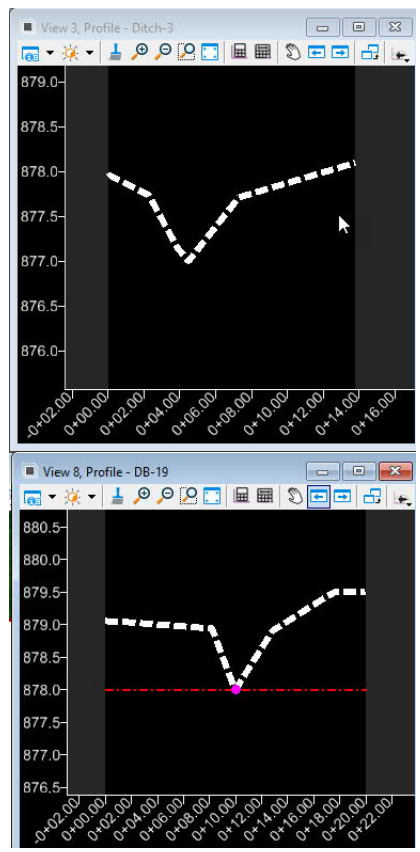
12. Review the 3D model view.

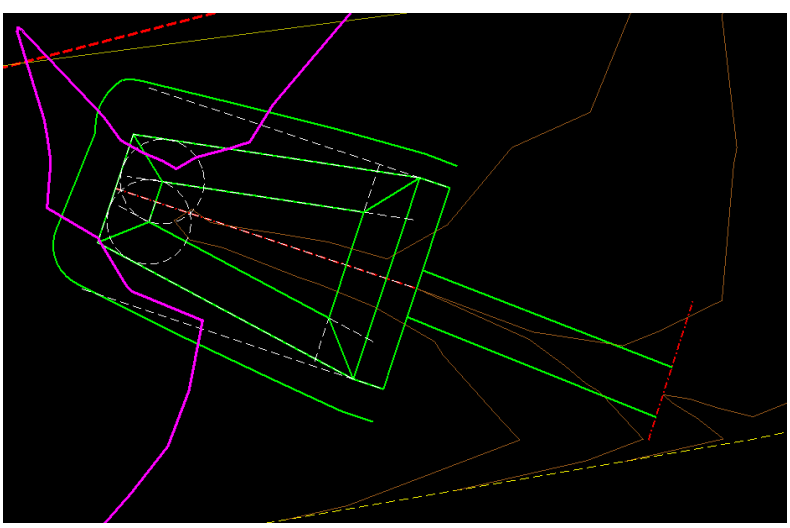


Create Downstream Grading Transition (video)

The final step in the process is to model the grading downstream of the energy dissipator to transition from the riprap apron (which was set at the elevation of the stream invert) to the existing channel.

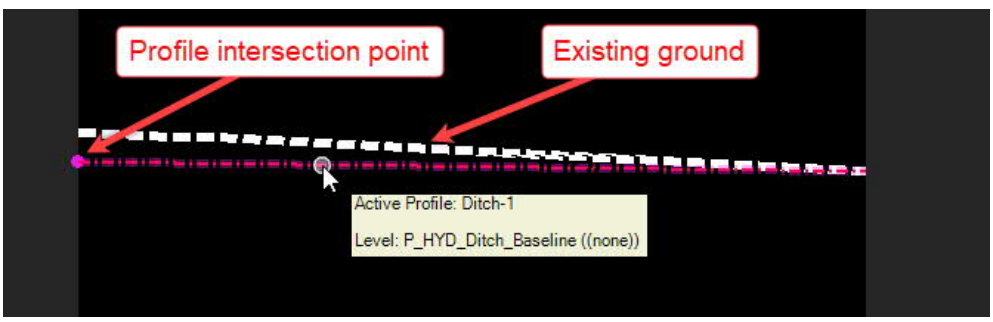
1. For the plan view window, turn on levels for P_HYD_TL_Ditch_Base, and P_HYD_TL_Ditch_Boundary
2. Determine downstream point where transition will end. The transition should be approximately at a 3:1 ratio.
3. If the top and bottom of bank lines are available for the existing stream in the plan view, then create lines connecting the top of banks at the downstream edge of the riprap apron with the top of banks at the downstream transition tie-in point. You can skip the next step.
4. If existing top and bottom of bank lines are not available in the plan view:
   a. Place a temporary transverse line across the stream at the transition end point and create a profile model for it.
   b. Select the linear feature for the downstream edge of the apron and create a profile model for it in a separate view window.
   c. Set the default feature definition to HYD_TL_Ditch_Top.
   d. Place lines for each proposed top of bank line through the transition. Click on the top of bank points in each profile model to set the start and end locations for each line correctly.



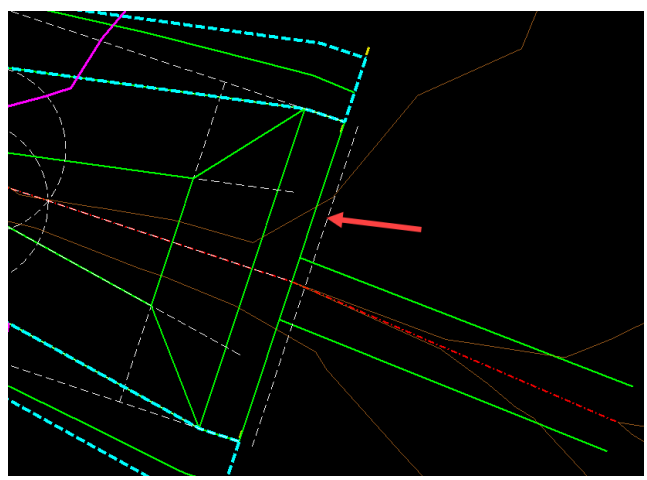


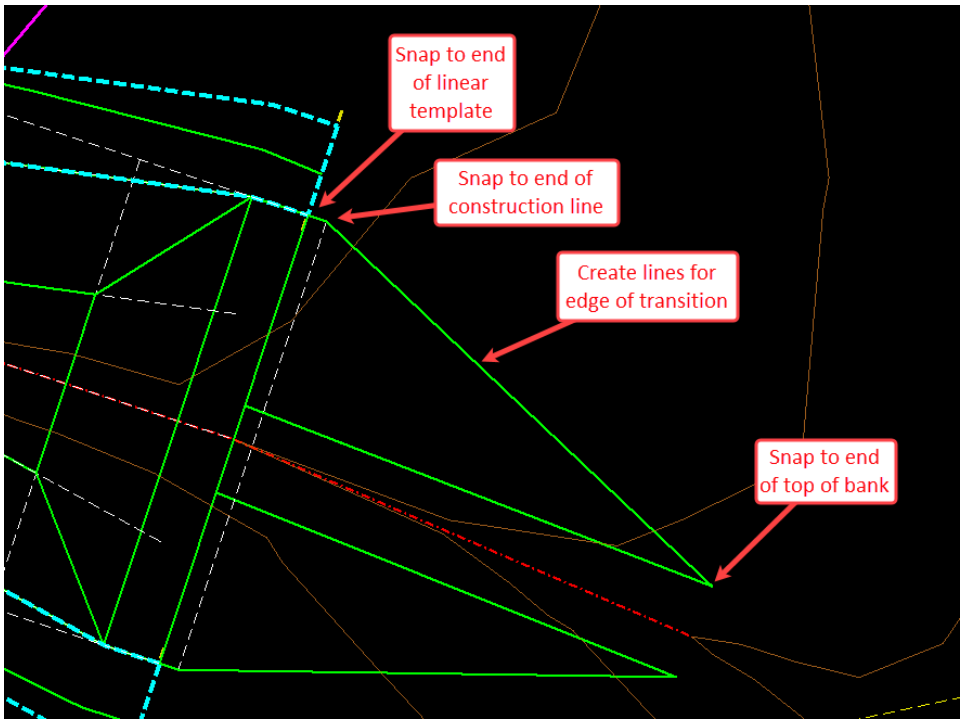
e. Delete the temporary transverse line at the end of the transition.

5. Select one of the top of bank lines and from the flyout menu open a profile model.
6. Go to *Geometry* > *Vertical* > *Profile Creation* and select Profile Intersection Point.
7. At the prompt *Locate Element to Show Intersection* select the top of bank line being profiled.
8. At the prompt *Locate Element Which Intersects*, select the downstream edge of the apron. A pink dot will appear in the profile model window, which will be dynamically tied to the elevation of the apron.
9. Set the default feature definition to HYD_Ditch_Baseline and go to Profile Line Between Points and draw a profile line in the profile model by snapping to the profile intersection point, and then snapping to the existing ground at the end of the profile. Select the profile and from the flyout menu make the profile active. See below.

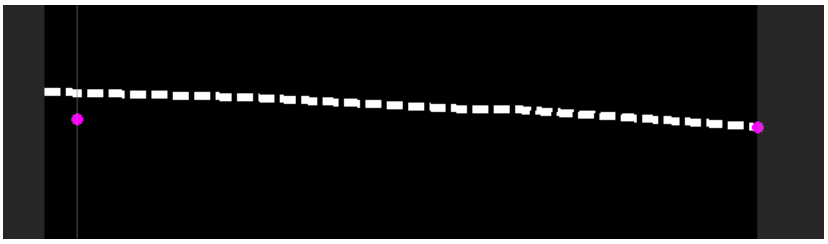


10. Repeat the process to create an active profile for the other top of bank line.
11. Set the default feature definition to P_HYD_Construction.
12. Using the tool Single Offset Entire Element, create a construction line 1' offset from the downstream toe of the apron.
13. Set the default feature definition to HYD_TL_Ditch_Bottom and draw new complex horizontal elements (using Complex by PI) by placing three PI points: snap to the end of the linear template; snap to the end of the construction line; and snap to the end of the top of bank line created previously. Repeat this process for the other side of the grading transition. See image on next page.

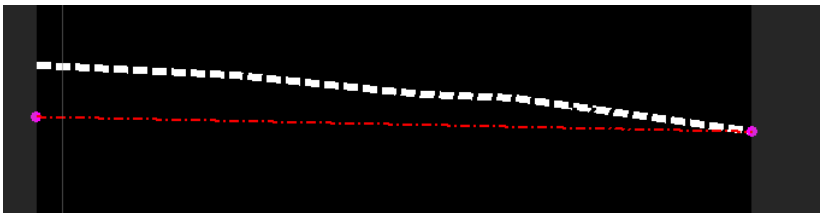




14. Turn off display of the levels Draft_Corridor_Graphics_Final and P_HYD_Construction.
15. Select one of the edge of transition complex elements just created, and from the flyout menu open a profile model. Set the default feature definition to HYD_Ditch_Baseline.
16. Create profile intersection points using the downstream edge of the apron and the downstream end of the top of bank line. See below.

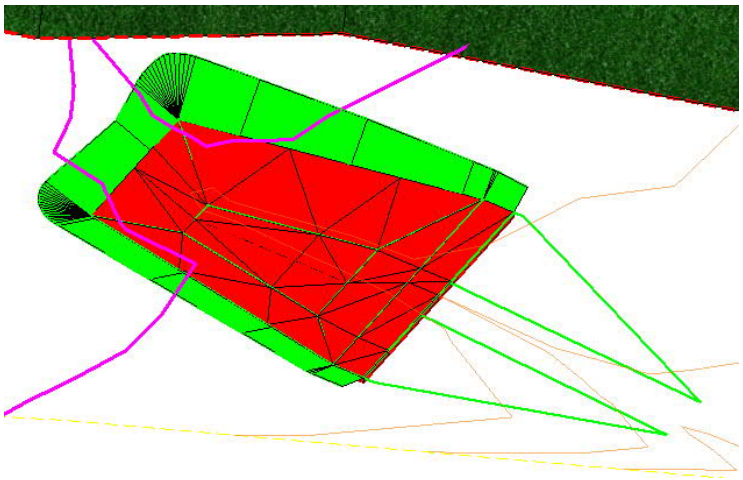


17. Use Profile Line Between Points to place a vertical alignment between the two profile intersection points. Select the profile and from the flyout menu make the profile active. See below.



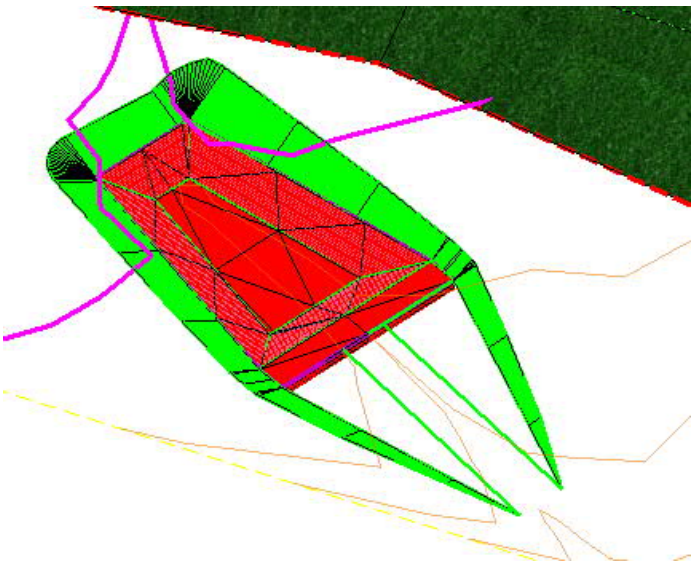
18. Repeat this process for the other top of bank line.

    The 3D model view should now show 3D features for the two triangular grading areas as shown.



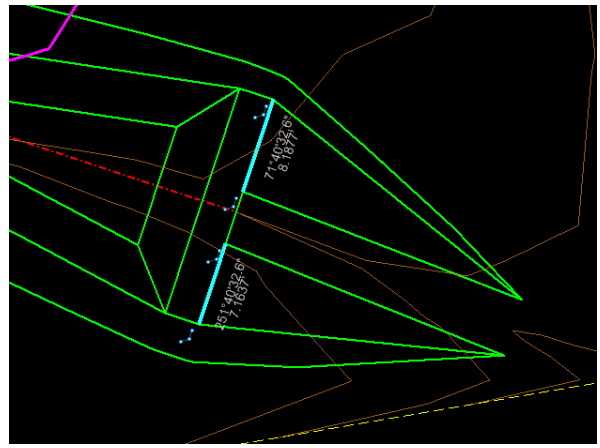
19. Go to *Modeling Detailing > Apply Linear Template*.
20. At the prompt *Locate Element to Apply Template*, select the edge of transition complex element on the right side. (video)
21. Press ALT and the right-arrow key to bring up the Pick Template dialog. Expand the Linear Templates folder and select the template named "Grass". Then click OK. Then <D> to accept the template.
22. In the Apply Linear Template dialog, make sure that the boxes for Mirror and Reflect are unchecked, and that the Feature Definition is set to HYD w/Contours.
23. At the prompt *Start Station*, snap to the beginning of the grading transition complex element. At the prompt *Stop Station*, snap to the end of the grading transition.
24. <D> to confirm the correct side for the linear template, and then <D> again to confirm the exterior corner sweep angle. <D> once more to skip entering a description. The exterior grading slope to existing ground should then appear in the 3D model view.

25. Repeat steps 21 to 26 for the other side of the transition. However, for Step 21 for the left make sure to check the box for Reflect, since the grading slope goes the opposite direction.

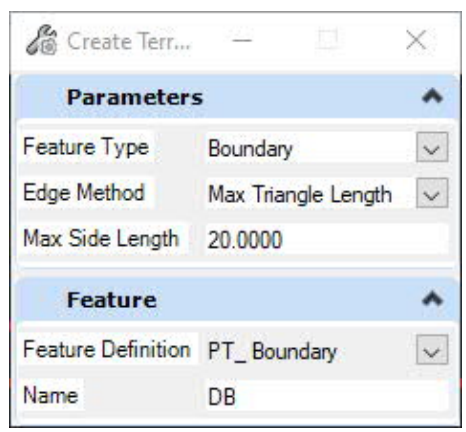


The final task to complete the grading transition is to create a terrain model for each triangular grading area, and then apply a riprap surface template to each one. (video)

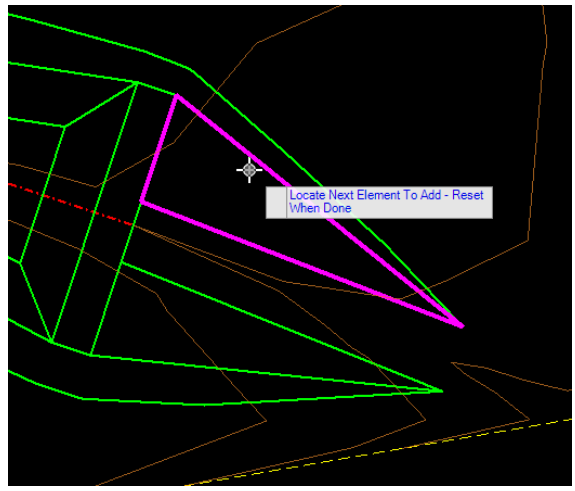
26. Set the default feature definition to HYD_TL_Ditch_Bottom.
27. Go to the Geometry tab and create a line for each of the two grading areas along the downstream edge of the apron as shown.



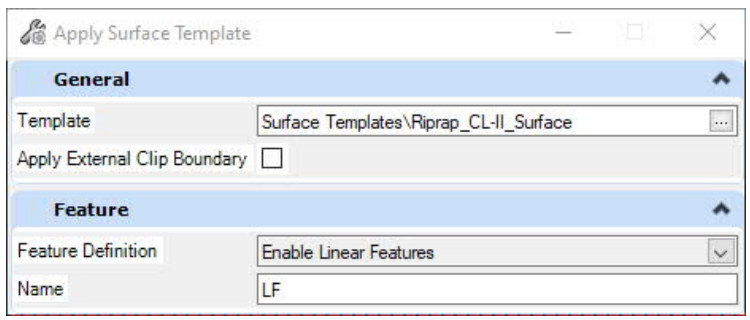
28. Go to Element Profiles and select Profile By Slope From Element. At the prompt *Locate First Element to Profile*, select one of the two lines just created in Step 29.
29. At the prompt Locate *Next Element to Profile*, select the other line. Then <R>.
30. At the prompt *Locate Reference Element*, select the line for the downstream edge of the apron (select it at a location between the two lines). <D> to accept the remaining inputs.
31. Repeat the process for the other side.
32. Go to *Terrain* > *Create* and select From Elements. Set the Feature Type to Boundary and the feature definition in the dialog to PT_Boundary.



33. At the prompt *Locate Element to Add*, in the plan view, select the three sides for one of the triangular grading areas. <R> to accept selections, then <D> to confirm remaining inputs. The terrain model will then be created. Repeat for the other side.

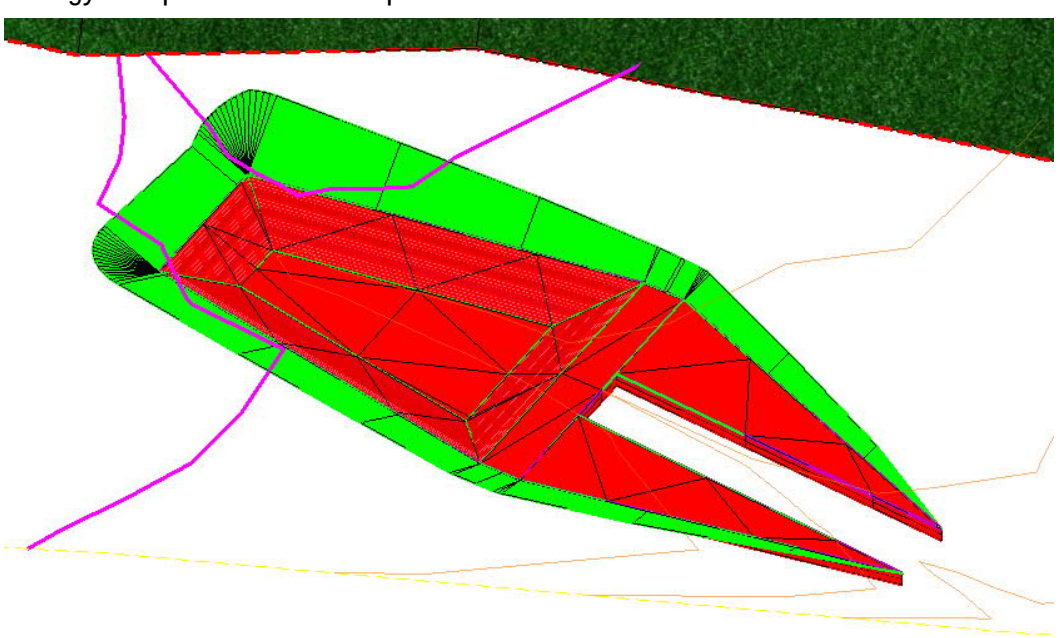


34. Go to *Model Detailing* > *3D Tools Surface Templates* and select Apply Surface Templates.
35. In the dialog, select the template Riprap_Class - II_Surface.



36. At the prompt *Locate a Terrain Model*, select one of the terrain models just created in the 3D model view window. <D> to confirm dialog inputs.
37. Repeat for the other terrain model.

The energy dissipator is now complete.



X. Showing Ditches on the Plans.

As mentioned in Chapter I, this manual is intended to work together with the NCDOT document "Ditch Drafting Guidelines". Display of ditches on the plans should conform to that document. This chapter provides procedures for how to support those guidelines using the tools in OpenRoads.

The Hydraulics Unit staff will also need to provide the necessary information to the Roadway Unit in order to support display of ditches on the roadway plans, profiles, and cross sections. The detailed procedures for this coordination are still under development and will be included in this Manual at a later date.

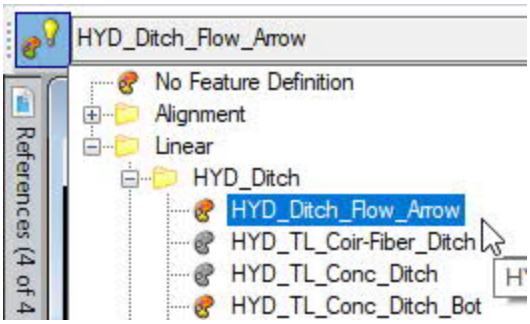
A. Creating flow arrow lines (Video)

As detailed in the Ditch Drafting Guidelines, flow arrows are to be shown for some types of ditches. For lateral ditches that use roadway slope stake lines as the corridor baseline, the ditch corridor stationing must match the direction of the roadway corridor. This means that sometimes the stationing for the ditch corridor will run upstream rather than downstream. Another issue is that for ditch intersections the alignment of the side ditch must extend past the true end of the ditch to accommodate modeling requirements. For these reasons, the centerline feature generated by the ditch corridor cannot itself be used to create the flow arrows by simply using a flow arrow linestyle. However, the procedure below can be used to create the flow arrows from the ditch centerline feature.

The Single Offset Partial tool is useful for many purposes. If you set the offset value to zero, then you can use the tool to "trace" an element to make a copy of it. That copy is then ruled to the original element so that if the original is changed, the copy will automatically update. The copy can have a different feature definition, level, etc. As the name suggests, you can copy only a portion of the original element if desired. In addition, the tool gives you the opportunity to make the direction of the copy the opposite of the original, and we will make use of that feature here.

1. Go to the Feature Definition Toolbar and set the active feature definition to HYD_Ditch_Flow_Arrow.

2. Go to *Geometry > Horizontal > Offsets and Tapers* and select Single Offset Partial.

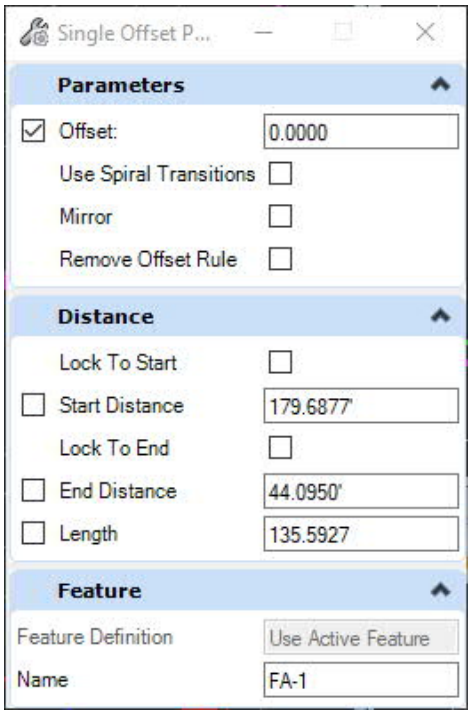


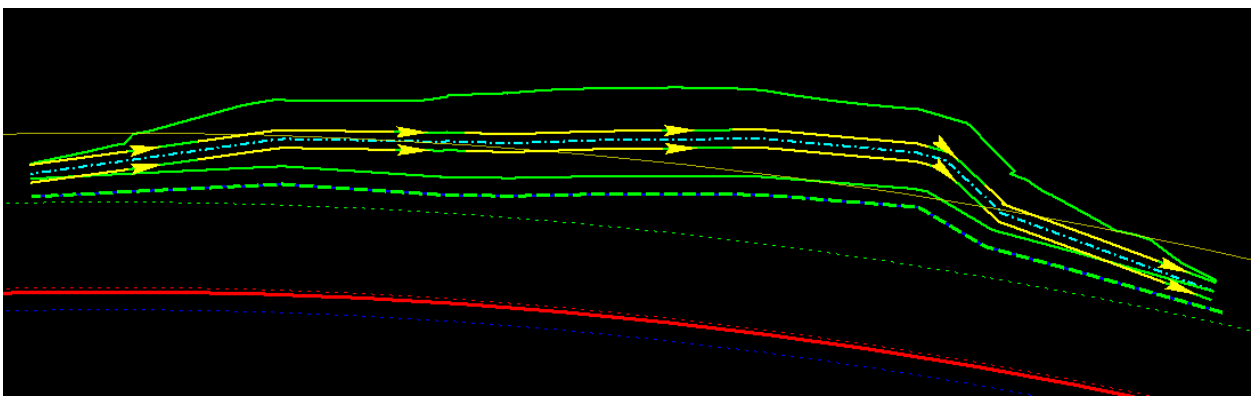
3. In the dialog, set the Offset to zero.

4. At the prompt *Locate Element*, select the ditch center line feature (if a V-ditch) or one of the ditch bottom lines (if a base ditch). Note: for base ditches you will need to complete this process twice since a flow arrow is needed for each ditch bottom line.

5. At the prompt *Start Distance and Offset*, snap to the upstream end of the ditch centerline or bottom of bank line.

6. At the prompt *End Distance and End Offset*, snap to the downstream end of the ditch centerline or bottom of bank line.

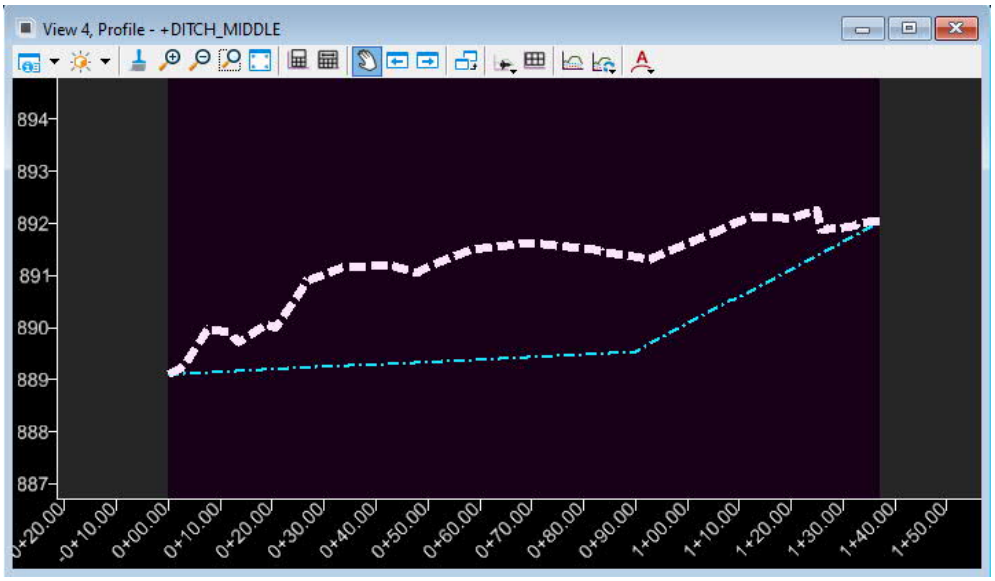




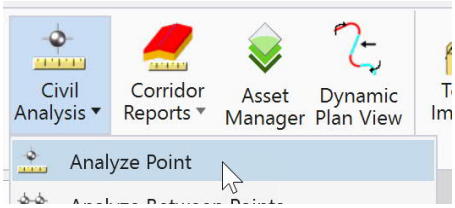
B. Obtaining Station, Offset, and Elevation Data (Video)

Station, offset, and elevation of ditch control points are often needed for construction layout, and the stationing is typically referenced to the roadway baseline. The ditch corridor model provides a ditch centerline in the plan view and a profile of this centerline can be shown in a separate profile window. Use the following workflow to obtain roadway baseline station and offset, as well as ditch invert elevation. For this workflow, you will need to have two view windows open: one for the plan view, and one for the profile model for the ditch centerline.

1. Select the ditch center feature and from the flyout menu select Open Profile Model and select a view window if you don't already have the profile model for "+DITCH_MIDDLE" set up. See image on the next page.

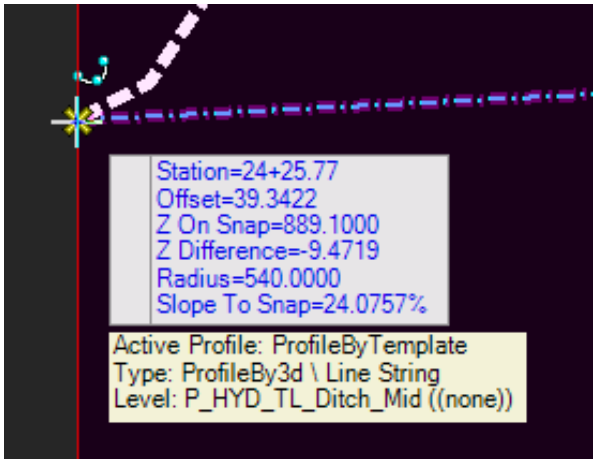


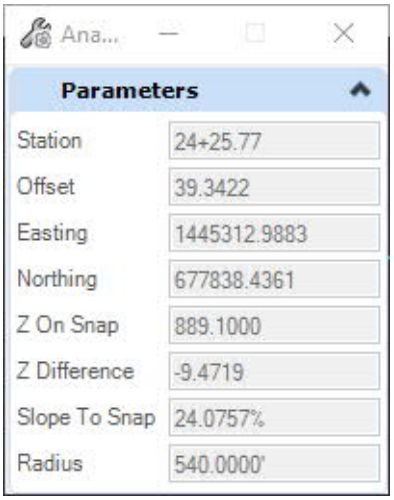
2. *Go to Home > Model Analysis and Reporting > Civil Analysis* and select Analyze Point. This is a very useful tool, and it is recommended that you include it on your Quick Access Toolbar.



3. Select the roadway baseline feature. The Analyze Point tool will now provide feedback relative to the roadway baseline in both the plan and profile windows.

4. In the ditch profile window, snap to the start of the ditch centerline profile. Zoom in closely and be careful to snap to the very beginning of the profile.





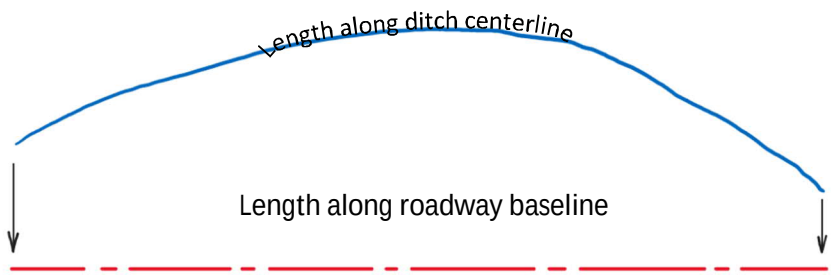
5. In the dialog for the tool, the station, offset, and elevation ("Z on Snap") is shown for the selected point. The elevation reported by Analyze Point should match the

elevation specified for the point control that was applied to the ditch corridor to set the ditch profile.

Continue this process for each vertical PI point to the end of the ditch to obtain all the station, offset, and invert elevation controls for the ditch. This information can now be used for plan and profile sheet annotation.

C. Showing Ditches on Roadway Profiles. (video)

In accordance with longstanding practice, lateral drainage ditches (those along the toe of fill slopes) as well as special cut ditches, are to be shown on the roadway profiles. This is done by "projecting" the profile of the ditch centerline onto the profile of the roadway baseline, as shown in the figure below which shows the plan view of a ditch adjacent to a roadway:



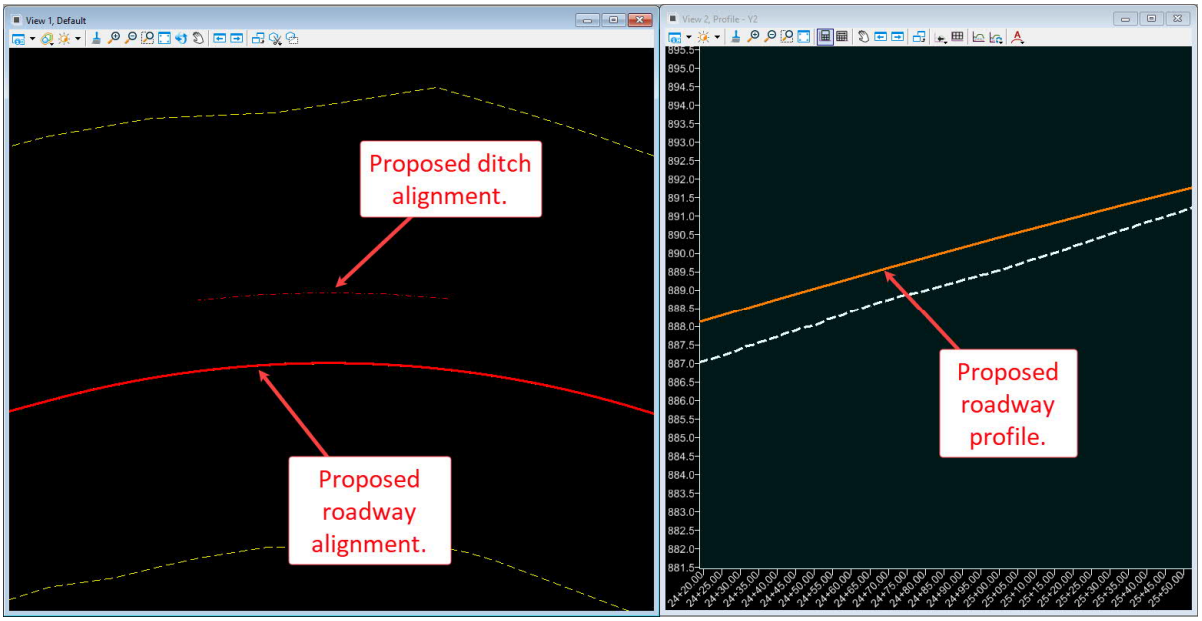
When the ditch profile is projected to the roadway profile, the length of the ditch measured along the roadway baseline will usually be shorter than the actual ditch length. However, it is possible that the actual ditch length will be shorter than the projected length on the roadway profile if the ditch is located on the inside of a curved roadway alignment. For this reason, annotation of ditch lengths and slopes should use data from the ditch itself, not the projected alignment on the roadway profile.

Geometry (horizontal and vertical alignments) for ditch designs should be located in separate files from the Roadway ALG profiles. In order to project the ditch profiles onto roadway profiles, it is necessary to open and edit the Roadway ALG file where the roadway geometry is located. The file containing the ditch geometry is then referenced to the Roadway ALG file, and the ditch profile projected to it using the procedure detailed below. After the ditch profile has been projected, the reference file for the ditch could be detached. However, if this is done the profile will lose its dynamic connection to the source ditch design file. Therefore, it is recommended that the ditch reference file remain attached to the Roadway ALG file to allow for automatic updating of the ditches shown on the roadway profiles and avoidance of unnecessary rework. The following steps detail the process.

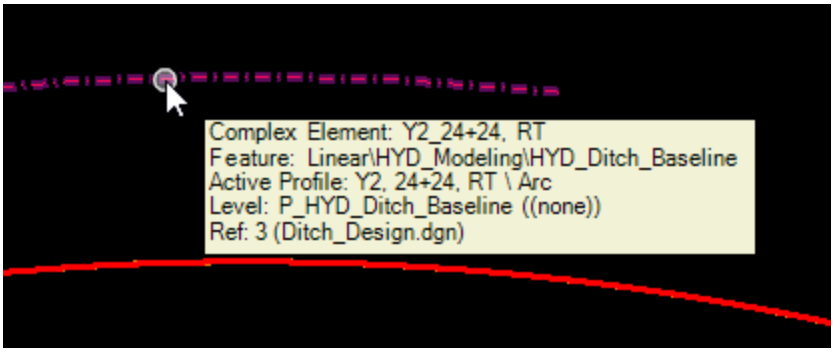
1. Open the Roadway ALG file and zoom to the location where the proposed ditch is located on both the plan and profile views.

2. Go to *Home* > *References* and attach the DGN file containing the ditch geometry. The ditch will then appear in the plan view.

3. Activate the plan view window and go to *Home* > *Level Display* and turn off all levels for the referenced ditch design file except the level named P_HYD_Ditch_Baseline.

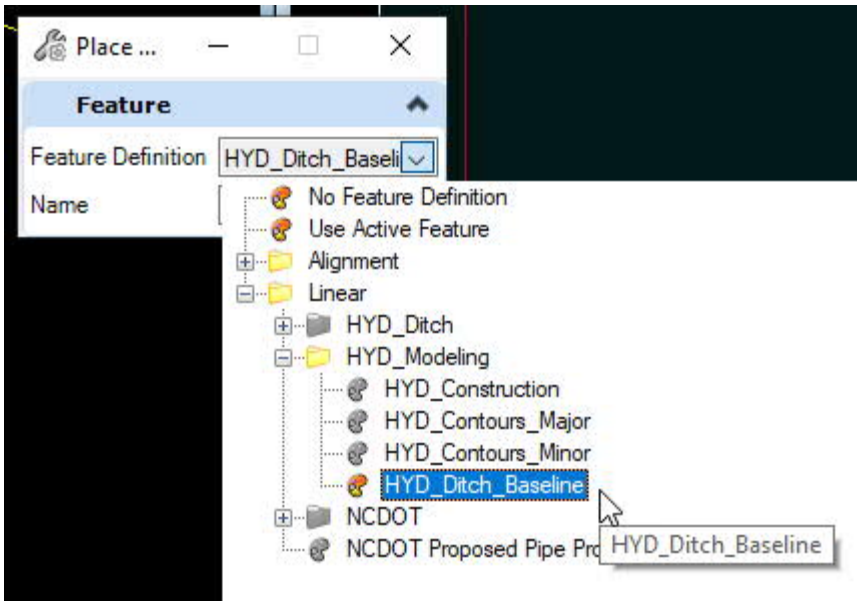


4. Hover your mouse pointer over the ditch alignment in the plan view, and from the attribute feedback obtain the name of the ditch alignment. In this example, the name is "Y2_24+24, RT".



5. Go to *Geometry* > *Vertical* > *Profile Creation* > *Project Profile To Element*.

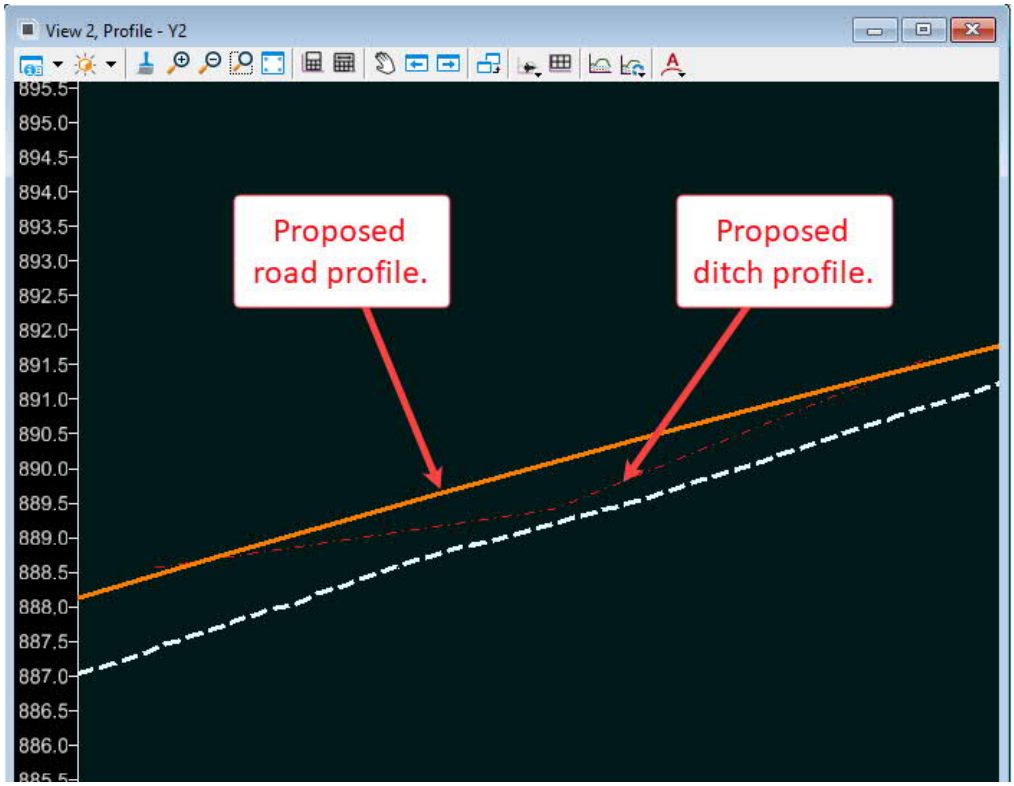
6. In the dialog, set the Feature Definition to *Linear* > *HYD_Modeling* > *HYD_Ditch_Baseline*.



7. Change the Name to the name of the ditch alignment.

8. At the prompt *Select Element to Project*, select the ditch alignment in the plan view.

9. At the prompt *Select Plan Element To Project Onto*, select the road alignment in the plan view. The ditch profile will then appear in the profile view window, as shown on the next page.



The profile can now be incorporated into the drawing and sheet models for the roadway profiles and annotated using the NCDOT annotation standards.

Please note that this same process can be used to project ditch corridor features such as the ditch centerline feature, rather than geometry. It will often be the case that ditch profiles have been developed using point controls with "Elevation and Grade" method rather than using vertical geometry. In these cases, there will be no vertical geometry to project and the corridor centerline feature will be the only feature representing the ditch profile.

XI. Ditch Quantities

Component Quantities (Video)

This tool reports the quantities of components based on a corridor model. Go to *Home > Model Analysis and Reporting > Corridor Reports > Component Quantities*. When prompted, simply select the corridor and a report is provided as shown below. In addition to the cut and fill volume quantities, surface area and volume quantities are provided for each of the template "components" that were used to create the corridor. Note that the surface area values for grass do not include the surface area covered by riprap. Also, surface area values are not provided for components that have thickness such as riprap. Unit costs can be entered into the report to generate an approximate cost estimate if desired.

Volumes are calculated using the Average End Area method, and accuracy is determined by the frequency of the template drop interval. For this reason, the results generated by the Component Quantities report are generally considered approximate, and appropriate for preliminary analysis.

Component Quantities

Material	Surface Area	Volume	Units	Unit Cost	Total Cost/Materi
Cut Volume	0.0000	1142.3283	CuY	1.00	1142.33
Fill Volume	0.0000	2.3156	CuY	1.00	2.32
Mesh\HYD Ditch\HYD TC Geotextile	5098.7281	0.0000	SqF	1.00	5098.73
Mesh\HYD Ditch\HYD TC Grass Berm	636.7914	0.0000	SqF	1.00	636.79
Mesh\HYD Ditch\HYD TC Grass Special Ditch DDE	5267.8918	0.0000	SqF	1.00	5267.89
Mesh\HYD Ditch\HYD TC Riprap CL-B	0.0000	109.9507	CuY	1.00	109.95
Mesh\HYD Ditch\HYD TC Riprap CL-II	0.0000	44.0533	CuY	1.00	44.05

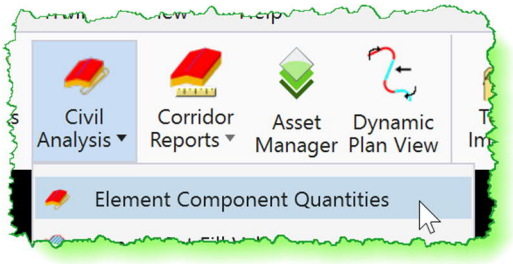
Report

Total Estimated Cost: 12302.06

Clipping is not considered in quantities.

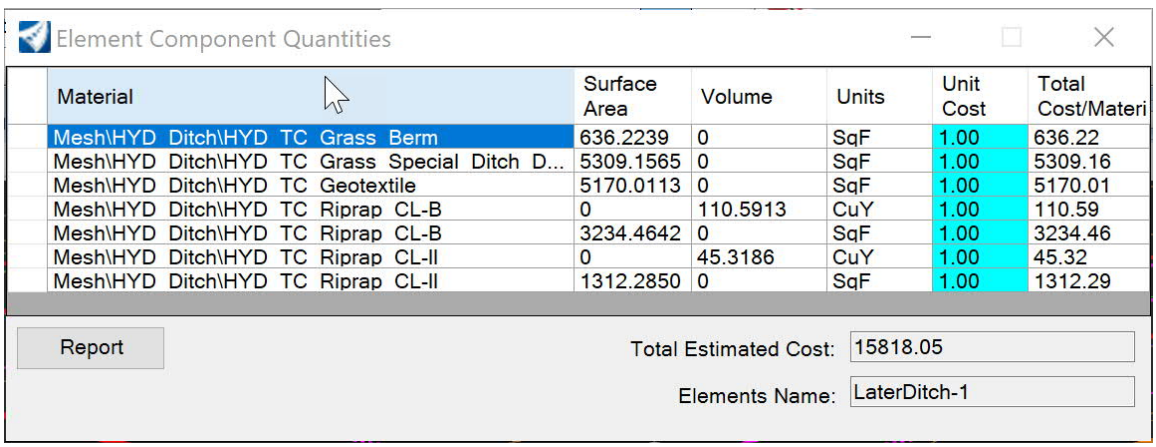
Corridor Name: LaterDitch-1

Element Component Quantities (Video)



This tool reports the quantities of components directly from the 3D elements generated by the corridor model. Go to *Home* > *Model Analysis and Reporting* > *Civil Analysis* > *Element Component Quantities*. When prompted, simply select the corridor and a report is provided.

Element Component Quantities are more accurate than Component Quantities since they are not affected by template drops or the approximations inherent in the Average End Area method. This method also provides surface area quantities for riprap, unlike Component Quantities. However, the Element Component Quantities report only calculates the volumes of closed shapes (components) in the templates used for the corridor. For this reason, earthwork cut and fill volumes are not provided. Also, quantities reported by station are not available, as they are with the Component Quantities tool. Therefore, it is recommended to use Component Quantities to obtain the cut and fill volumes, and Element Component Quantities for the other quantities.



Material	Surface Area	Volume	Units	Unit Cost	Total Cost/Materi
Mesh\HYD_Ditch\HYD_TC_Grass_Berm	636.2239	0	SqF	1.00	636.22
Mesh\HYD_Ditch\HYD_TC_Grass_Special_Ditch_D...	5309.1565	0	SqF	1.00	5309.16
Mesh\HYD_Ditch\HYD_TC_Geotextile	5170.0113	0	SqF	1.00	5170.01
Mesh\HYD_Ditch\HYD_TC_Riprap_CL-B	0	110.5913	CuY	1.00	110.59
Mesh\HYD_Ditch\HYD_TC_Riprap_CL-B	3234.4642	0	SqF	1.00	3234.46
Mesh\HYD_Ditch\HYD_TC_Riprap_CL-II	0	45.3186	CuY	1.00	45.32
Mesh\HYD_Ditch\HYD_TC_Riprap_CL-II	1312.2850	0	SqF	1.00	1312.29

Quantities from 3D Mesh Elements

OpenRoads has a powerful set of tools that can create and utilize 3D mesh elements generated from corridor models using the Create Cut Fill Volumes tool located at *Home* > *Model Analysis and Reporting* > *Civil Analysis*. This tool creates 3D solids, or meshes, in the 3D model of the DGN file. These are then used to compute accurate volume quantities for cut and fill, as well as excavation of unsuitable materials, substrata, and subgrade surfaces. This is a complex topic beyond the scope of this Manual. More information is available through the Bentley Learn Server at https://learn.bentley.com/app/Public/ViewLearningPathWithMasterCourseExpanded?lpId=113539&mcId=103116

APPENDIX

List of Available Parametric Constraints

LIST OF AVAILABLE PARAMETRIC CONSTRAINTS FOR DITCH TYPES

Special Cut Ditches

Bottom_Width	
Side_Slope_LT, Side_Slope_RT	Only for median ditches
Ditch Depth	Only for shoulder ditches
Grass_Slope_IN, Grass_Slope_OUT	Only for shoulder ditches without lining
Lining_Height_IN, Lining_Height_OUT	Only for shoulder ditches with lining
Slope_IN, Lining_Slope_OUT, Grass_Slope_OUT	Only for shoulder ditches with lining
Lining_Thickness	Only for shoulder ditches with lining

Head/Tail Ditches

Bedding_Thickness	Only for ditches with a concrete lining
Bottom_Width	
Grass_Slope	
Lining_Height	Only for ditches with a lining
Lining_Slope	Only for ditches with a lining
Lining_Thickness	Only for ditches with a ripirap or concrete lining

Lateral Ditches

Bedding_Thickness	Only for ditches with a concrete lining
Bench_Slope	Only for ditches with a bench at bottom of roadway fill slope
Bench_Width	Only for ditches with a bench at bottom of roadway fill slope
Bottom_Width	
Ditch_Depth	
Grass_Slope_IN	Only for grass ditches
Grass_Slope_OUT	Only for ditches with a lining
Lining_Height_IN, Lining_Height_OUT	Only for ditches with a lining
Lining_Slope_OUT	Only for ditches with a lining
Lining_Thickness	Only for ditches with a ripirap or concrete lining
Slope_IN	Only for ditches with a lining, applies to both grass and lining

Channel Change

Bedding_Thickness	Only for ditches with a concrete lining
Bench_Slope	
Bench_Width	
Bottom_Width	
Ditch_Depth_IN	
Ditch_Depth_OUT	
Grading_Slope_OUT	For fill area beyond the outside top of bank
Grass_Slope_IN	Only for grass ditches
Grass_Slope_OUT	
Lining_Height_IN, Lining_Height_OUT	Only for ditches with a lining
Lining_Slope_OUT	Only for ditches with a lining
Lining_Thickness	Only for ditches with a ripirap or concrete lining
Slope_IN	Only for ditches with a lining, applies to both grass and lining