

MLK 3D Formation

Road construction

Published: March 2024



Contents

| | |
|--|-----------|
| Introduction | 3 |
| Road project’s geotechnical specifications | 4 |
| Construct and quantitatively compare geo-technically conforming road alignments | 6 |
| Alignment 1 | 6 |
| Alignment 2 | 19 |
| Alignment 3 | 21 |
| Comparing alignments | 24 |
| Surface water management | 24 |
| Watershed tools | 24 |
| Sump design | 26 |
| Ditch design | 34 |
| Stockpile/Dump Design | 36 |
| Plotting | 40 |

Introduction

Formation's earthworks planning tools allows users to quickly and interactively:

- Construct and quantitatively compare geo-technically conforming road alignments.
- Determine cut/fill and stripped volume quantities.
- Plan surface water management through:
 - ⇒ Estimating the amount and the direction of water flow.
 - ⇒ Laying out and designing ditching and storage areas.
- Construct properly sized and located stockpiles.
- Plotting all the information on illustrative and information 3D Maps

This paper will feature these tools while working through a theoretical example with set geo-technical criteria in an area of interest where imagery and survey data have already been acquired.

This tutorial is prepared using v2024 of Muk3D|Formation. While some of the commands may be slightly different to v2023 releases, the tools to complete most of this tutorial currently exist in v2023.

Road project's geotechnical specifications

For the purposes of displaying the earthwork planning tools within *Formation*, this paper will run through the process of planning, the earthworks portion, for a road that conforms to the specifications outlined below in Figures 1 to 3.

We can see in figure 1 below, the cross-section of the road design. On top, we see the cross-section in situations where we would be placing fill above the topography to build the design. Below, we see the cross-section where we would be excavating material to build the design.

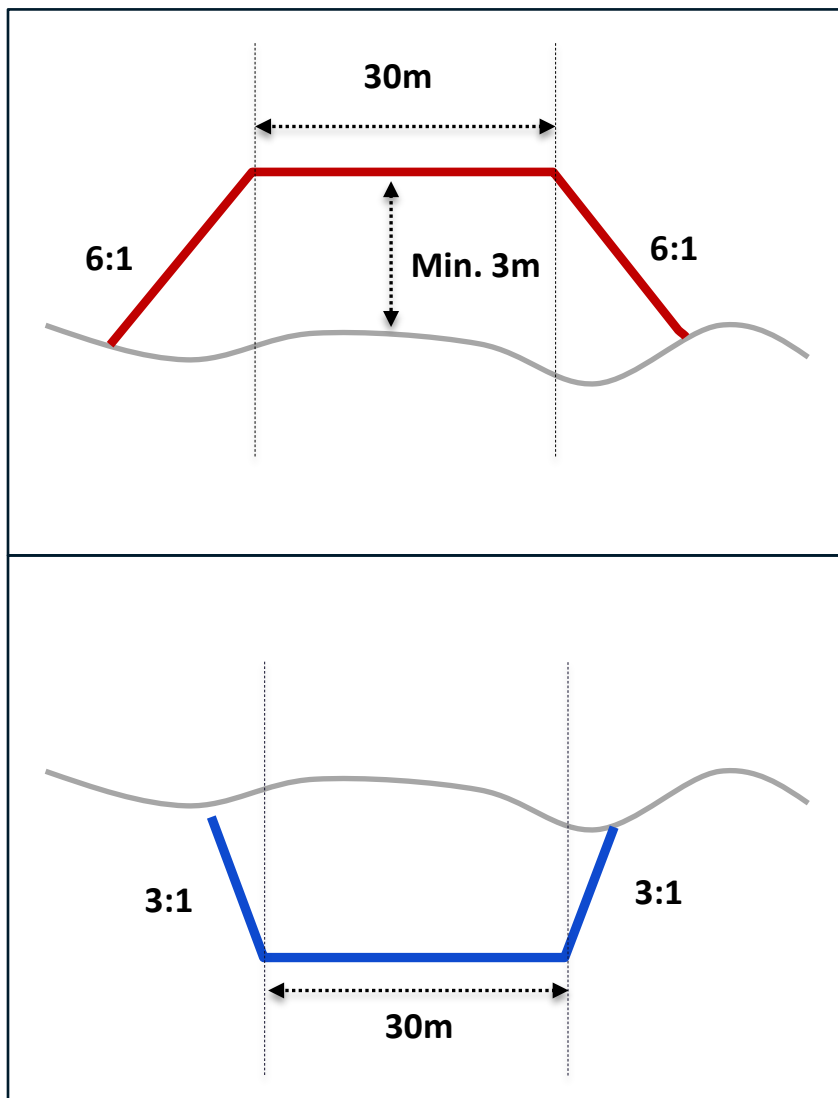


Figure 1: Road design in cross-section when placing above current topography (top) and excavating below current topography (bottom)

From figure 1, we can see that the running surface will be 30 meters wide with no grade. However, when placing material or in a 'fill' situation, the material will need to be placed with 6 to 1 side slopes. Also, a minimum thickness of 3 meters of fill will be required. When material is being excavated, or in a 'cut' situation, the excavation needs to be done at a 3 to 1 side slope. There is no minimum excavation depth however.

In figure 2 below, we see a plan view sketch displaying the right-of-way corridor offset 250m in either direction from the road centerline. This establishes what

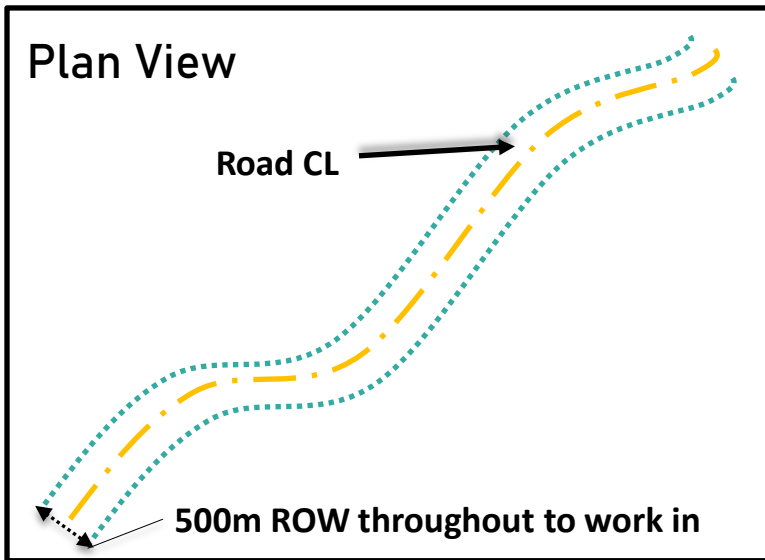


Figure 2: Right-of-way corridor

footprint is available to construct within.

In Figure 3 below, we see a longitudinal section through the centerline of a road. Depending on the location of the alignment, the point-to-point slopes along the centerline, and therefore of the running surface, cannot exceed 8%, 10.5% or 11%.

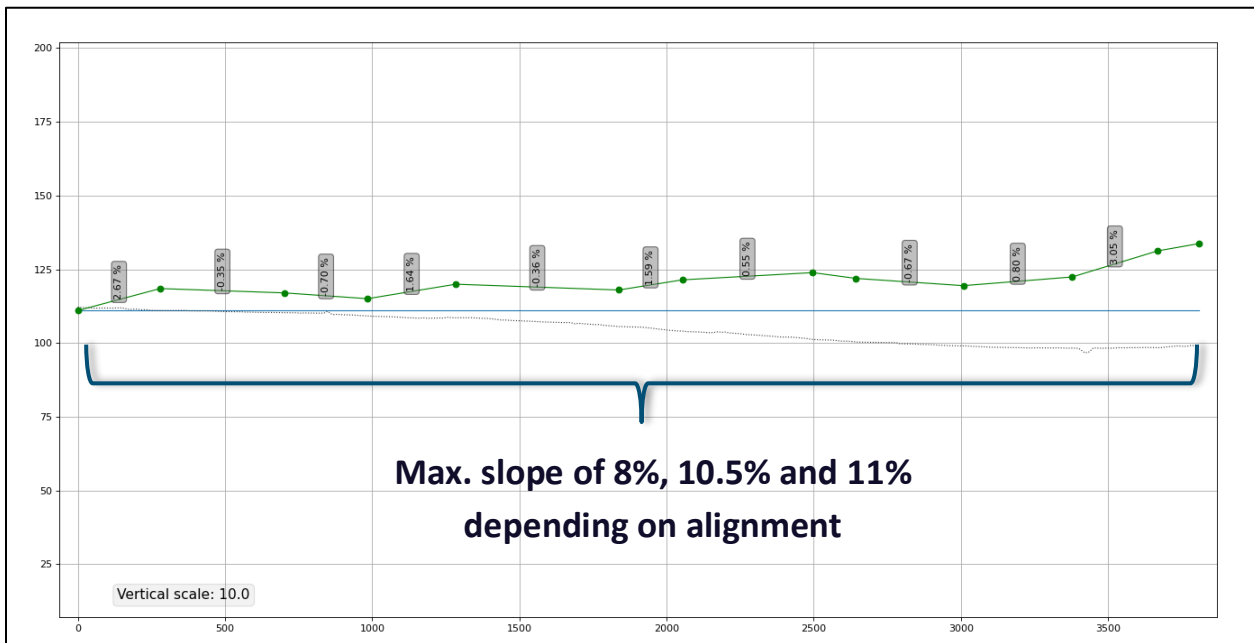


Figure 3: Maximum slope along centerline

Also, the design must result in the cut and fill volume being balanced. Specifically, the volume of material excavated needs to be within 1% of the material placed. This volume does not include topsoil material that cannot be used for embankment purposes.

Construct and quantitatively compare geo-technically conforming road alignments.

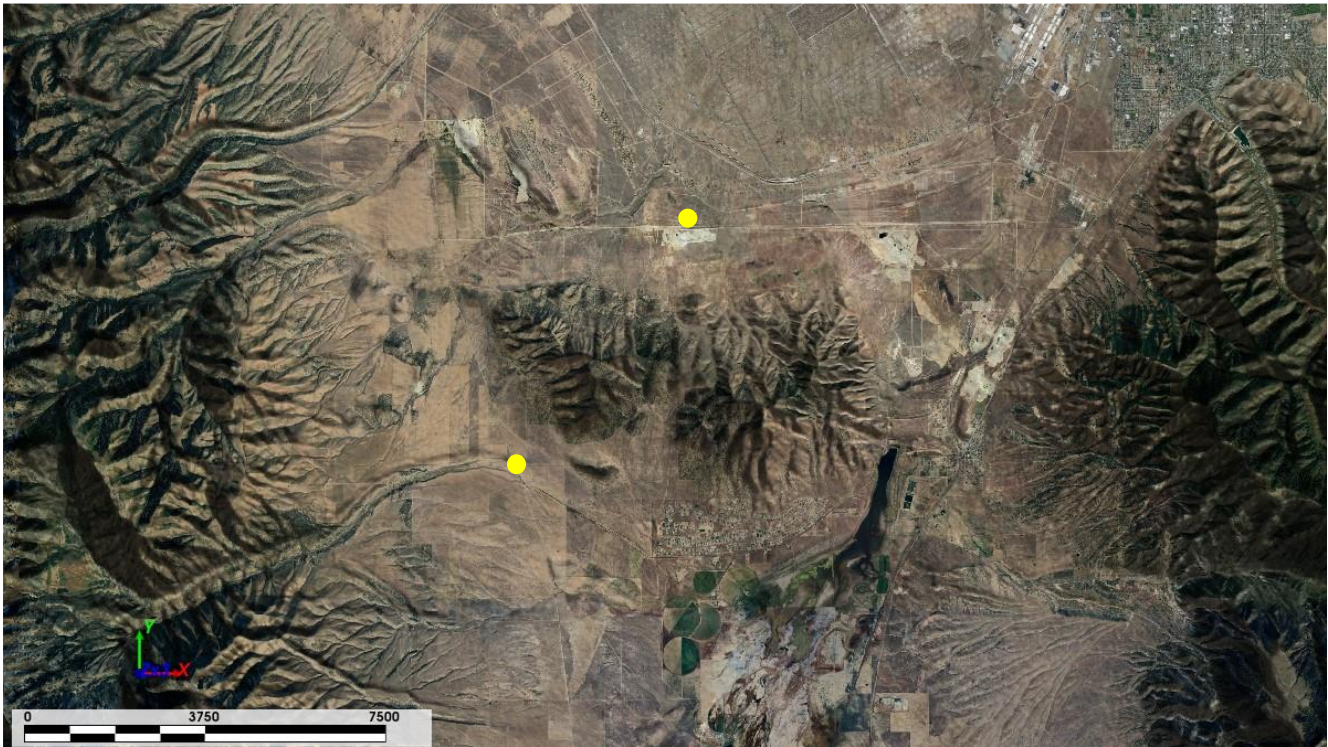


Figure 4: Road start and end points

In Figure 4 above, we can see two yellow points. These represent the two locations the road must connect. In this example, we will layout three different road alignment that must all pass through the mountainous area in between the two points.

Alignment 1

To establish a path through the mountains, we're going to utilize information from the imagery itself. We can see in Figure 5 below, an urban area and, what appear to be, a drainage system that we should avoid.

Next, and as can be seen in Figure 6 below, we apply the preset HSV (hue saturation value) Atlas shading to the surface to highlight changes in elevation. This is done by drag and dropping the style from the DB Viewer menu on the right.



Urban area

Drainage system

Figure 5: Noticeable features on the Satellite imagery

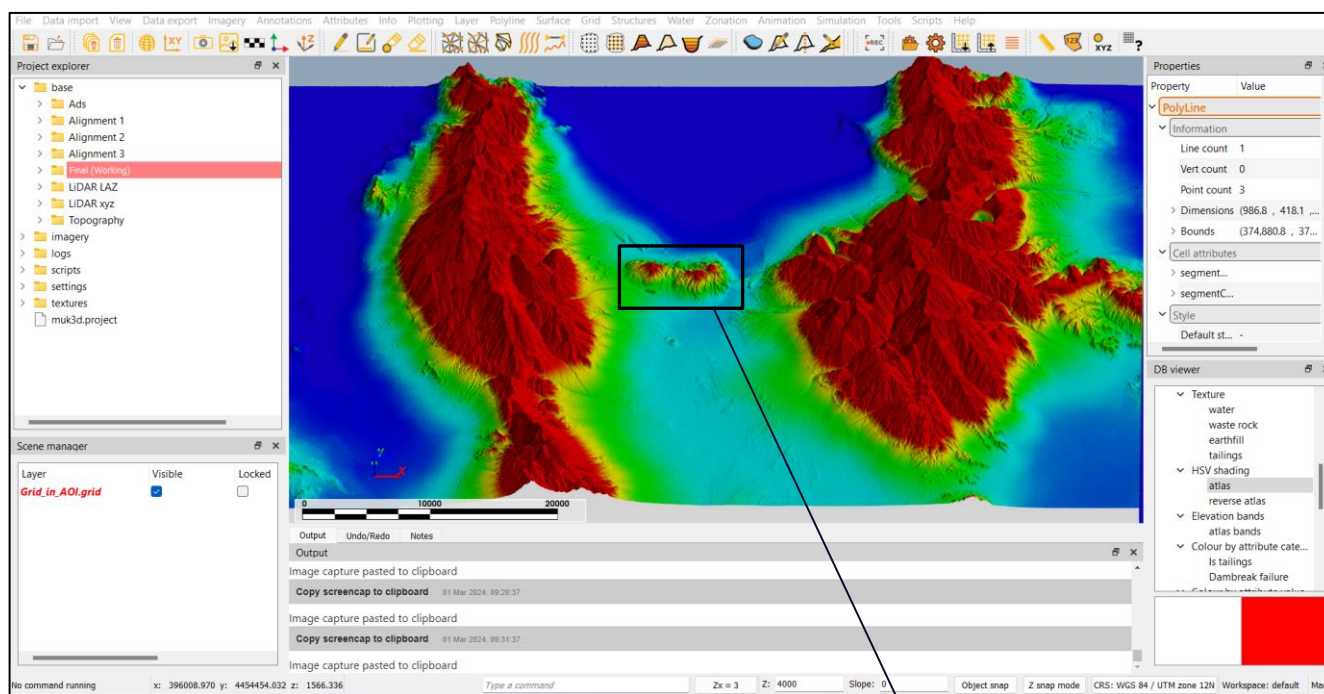


Figure 6: Applying HSV atlas shading

Based on this visual analysis, Alignment 1 (white line) can be seen, on the right, in Figure 7.

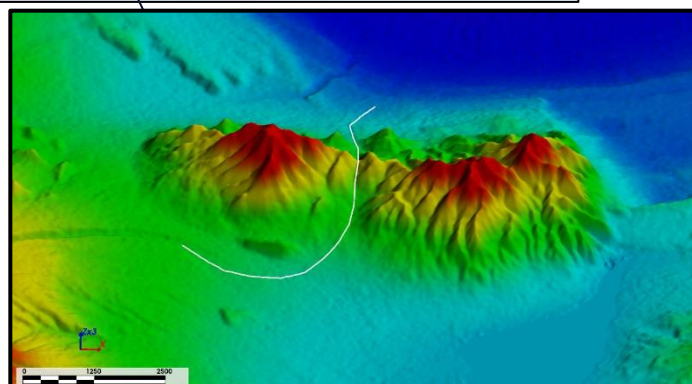


Figure 7: Road alignment 1

Activate all the tools within *Formation* by **Showing all Commands**. Hit the hotkey located on the right-hand side of the top ribbon:



*Please note, this step is only necessary in the 2024 *Formation* release. The 2023 iteration has all commands visible.

Based on this centerline, we can establish the right-of-way corridor by offsetting the alignment 250m in both directions. Go to the **Polyline > Offset**. There you will be presented with several different types of offset options. They all would work. In

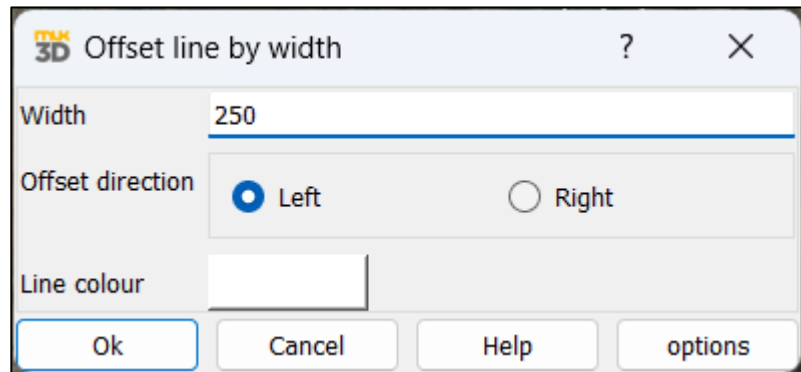


Figure 8: Offset by width

this case, I'm using **Offset by width** (Figure 8) given that I'm establishing a corridor in X and Y where elevation is not relevant. Offset the line in both the 'Left' and 'Right' directions. The corridor and centerline alignment can be seen below in Figure 9.



Figure 9: Alignment 1 centerline and 500m right-of-way corridor

Although this area looks quite arid in the imagery, for the purposes of displaying *Formations* tools, we are going to assume there is a 30 cm deep layer of topsoil that needs to be stripped before competent embankment material can be placed or accessed for excavation purposes.

To account for this while creating the road surface and subsequent design lines, we will drop the topography, within the ROW corridor, by 30cm. After the road has been designed, we can establish exactly what areas will be within the design footprint and would have to have topsoil removed. The process can be summarized as follows:

1. Conservatively lower topography in the construction area to account for construction footprint which would be stripped.
2. Design road surface against 'stripped' topography and establish construction footprint.
3. Re-load original topography. Use established construction footprint from 2. to:
 - a. lower surface within footprint
 - b. Estimate topsoil volume that will need to be managed.

Create a polygon that corresponds to the ROW corridor. This can be done by utilizing the offset polylines in Figure 9. Go to **Polyline > Edit > Join polylines**. Select both polylines and they should join each other on one site. Then, go to **Polyline > Edit > close polyline** and select the joined polyline, which should then close into a polygon.

Save your 500m corridor polygon and go to **Grid > Modify > Modify grid elevation with boundary** (Figure 10). Select your grid, then your boundary and save the modified Grid under a new name.

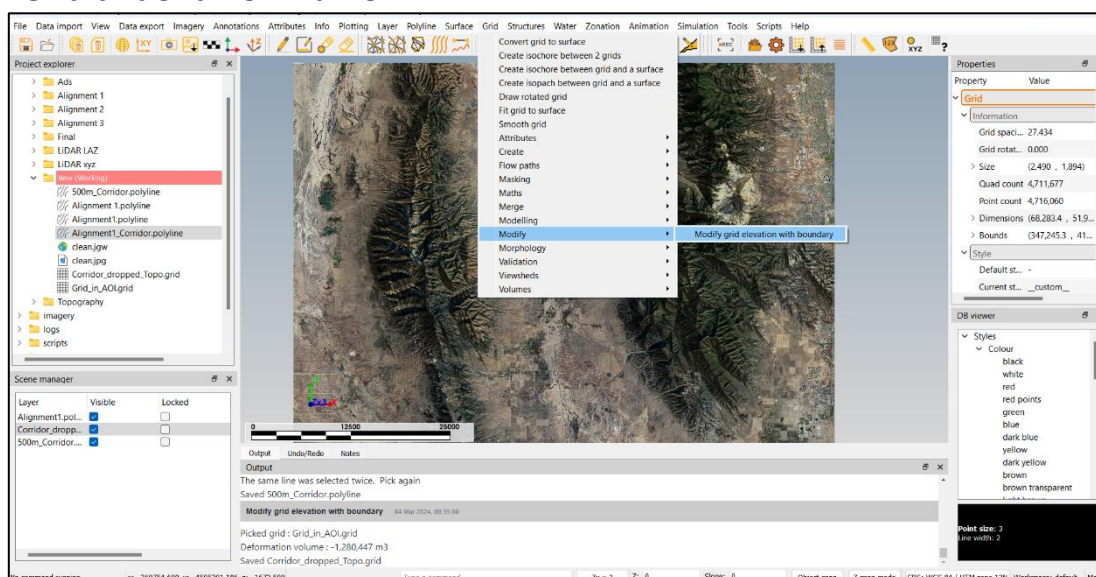


Figure 10: Modify grid elevation function

Load your road alignment or centerline file. At this stage, we want to account for the minimum 3 meters of fill requirement outlined in Figure 1. The process will be as follows:

1. Drape full alignment/centerline onto grid surface. This will densify the polyline with large number of points.
2. Clean polyline and thin down number of points on polyline to make it more manageable to modify.
3. Drape points on polyline onto grid again but this time with 3m positive offset. This will now create a centerline that is above the grid surface by 3m throughout.

Begin by selecting **Polyline > Drape > Drape polyline on surface** (Figure 11). Drape the centerline onto your grid. At this point, we'll choose a 'Vertical offset (m)' of 0m.

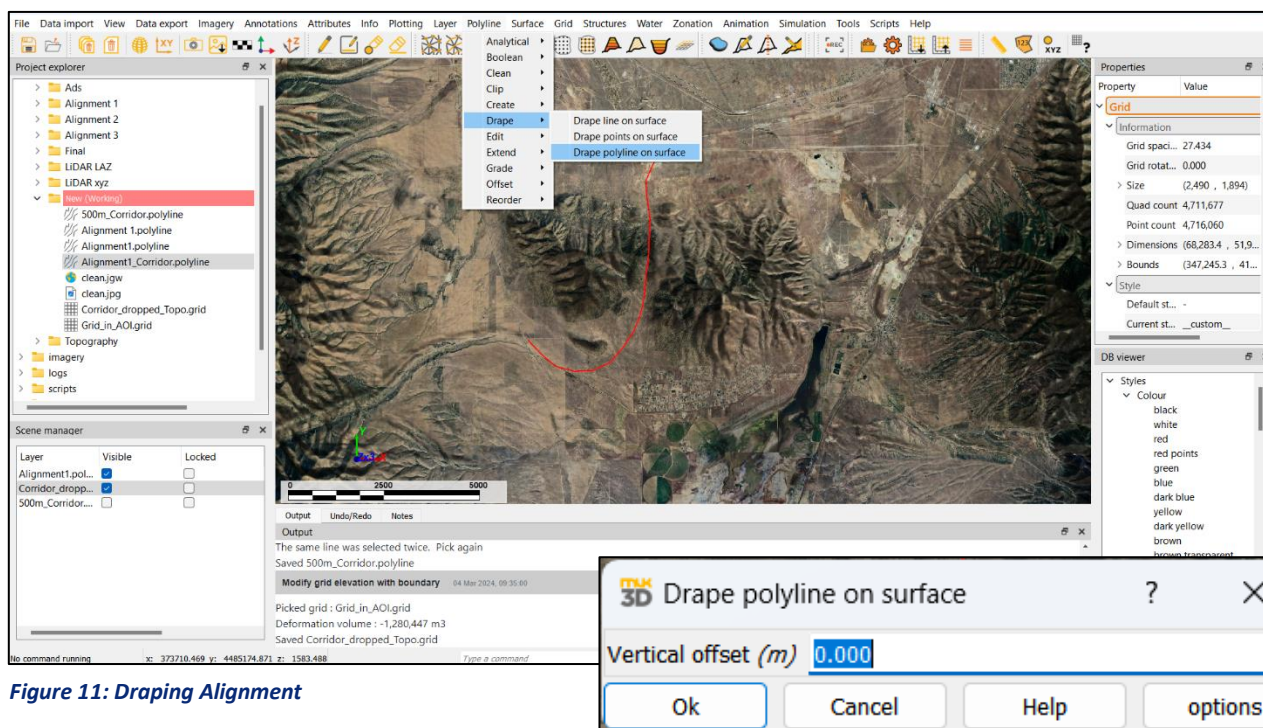


Figure 11: Draping Alignment

Let's then establish how many points now make up our centerline after draping it onto the surface. Go to **Info > Polyline > Polyline details** (Figure 12). Then select your polyline. Alternatively, basic layer information also appears in the Properties window when the layer is selected. As can be seen in Figure 12, the polyline details will display the:

- Number of lines
- Number of points
- Attribute bounds
- Line Distance.

Our centerline at this stage is ~6.87km long with 1083 points. We want to reduce the

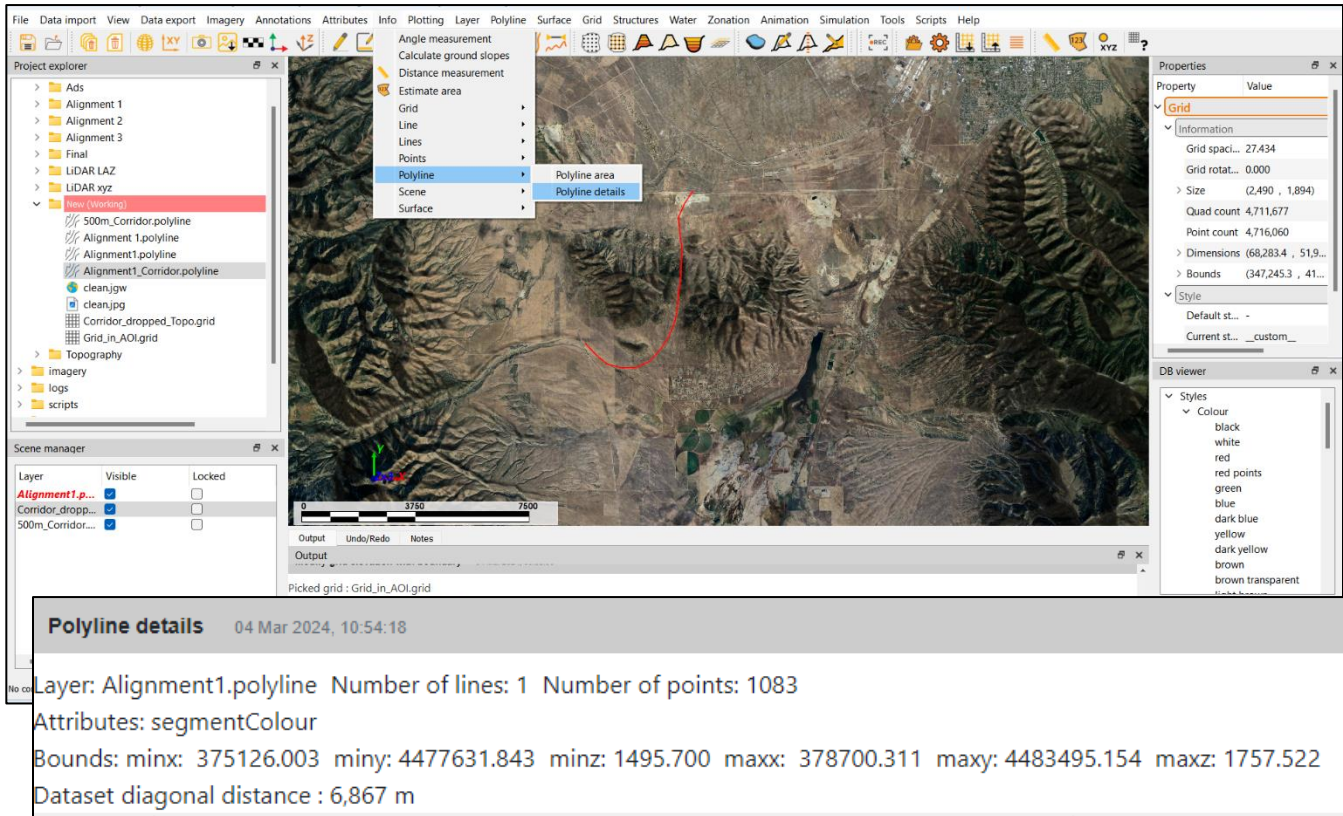


Figure 12: Polyline Details

number of points to a more manageable number. The number of points needed will depend on the level of detail and granularity you would like. To do this go to **Polyline > Clean > Remove duplicate points (Figure 13)**. You will then be asked for your 'Filter

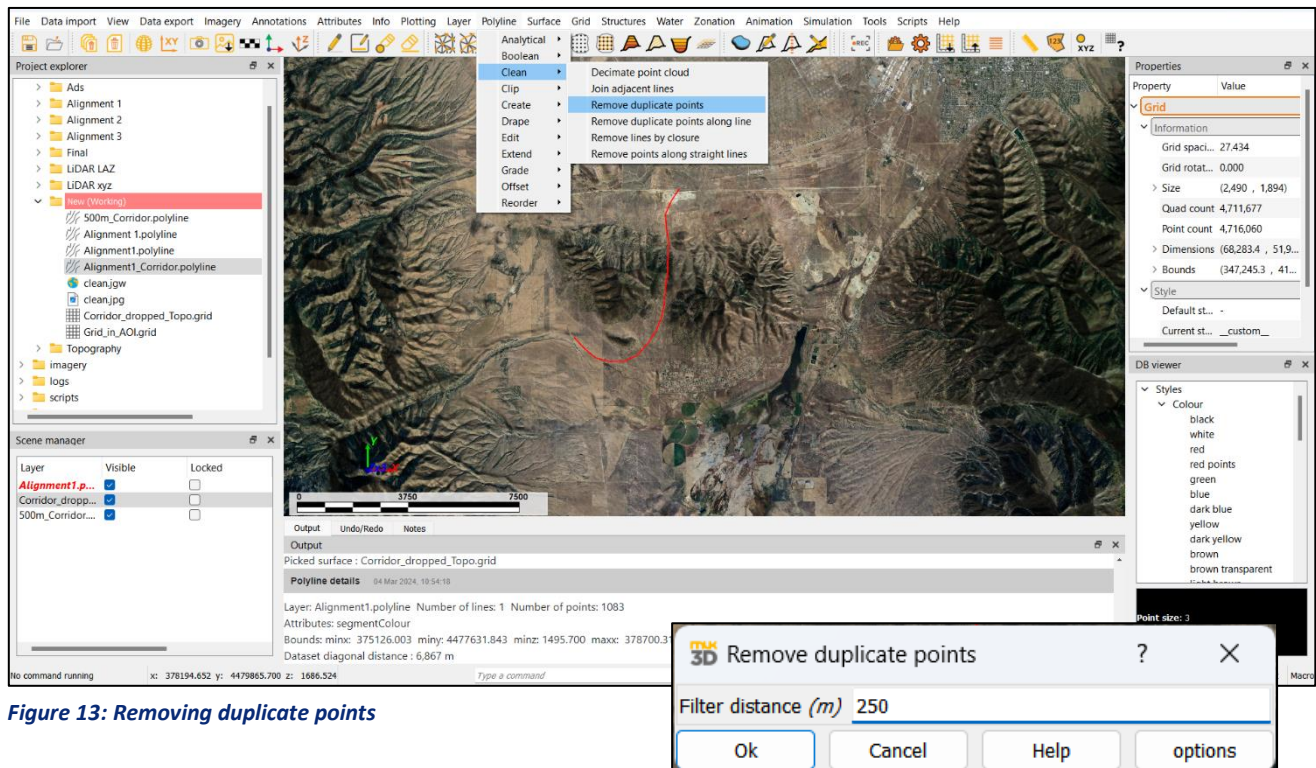


Figure 13: Removing duplicate points

distance’.

In this case, we would like a node or point on the centerline every 250m, which we enter as the ‘*Filter distance (m)*’. The output window will let you know how many points were removed (Figure 15)

When we now check the information on the polyline (**Info > Polyline > Polyline details**), we can now see it contains 33 points (Figure 15).

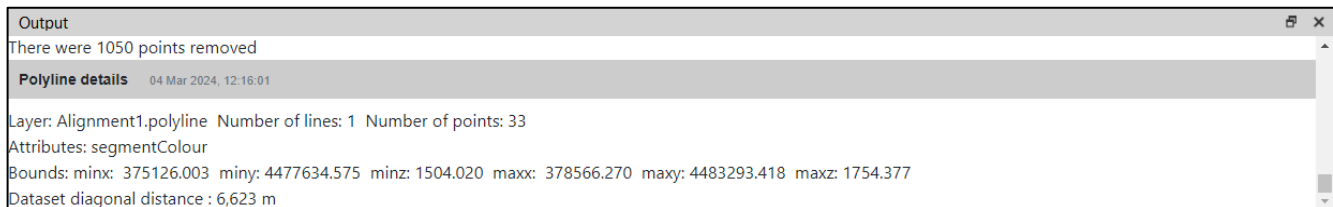
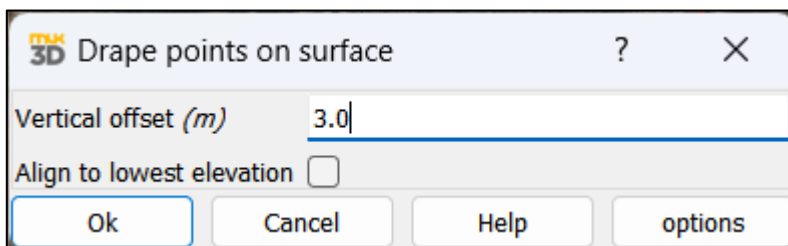


Figure 15: Results of polyline ‘cleaning’

We will now drape the centerline onto the grid but with a **3m positive vertical offset**. This time however, we will use the **Polyline > Drape > Drape points on surface** (Figure 16) vs. **Polyline > Drape > Drape polyline on surface** function. The difference being, ‘Drape points on surface’ will not densify the number of points on the line as a by-product of draping whereas ‘Drape polyline on surface’ will.



You will now have a centerline that is 3m above topography, at the very least, at those 33 locations where there is a point along the centerline.

Figure 16: Draping polyline points on surface with positive offset

Now we will construct and merge the initial road surface into the topographic grid. Go to **Structures > Roads > Create road from centerline** (Figure 17). Given the specification laid out in Figure 1, we set:

- Road width at 30m
- *Cut slope at 3:1*
- *Fill slope at 6:1*

- Cut & Fill shell height to 25m (this is the height of the fill and cut shell surfaces created to build the design. Pick a surface height you know will intersect the topo Grid.
- Select option to ‘Merge into Grid’

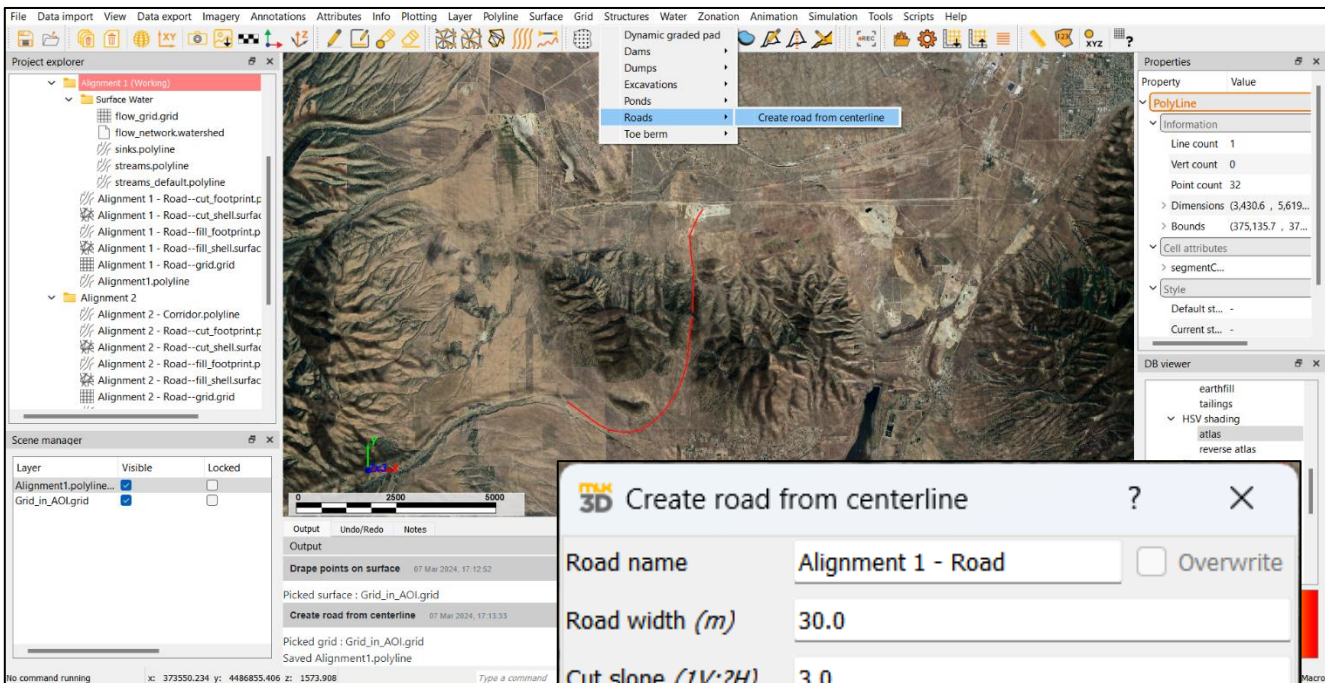


Figure 17: Create Road from centerline function

Then select your grid and centerline.

Formation will then create several new objects (Figure 18) under your chosen road name label.

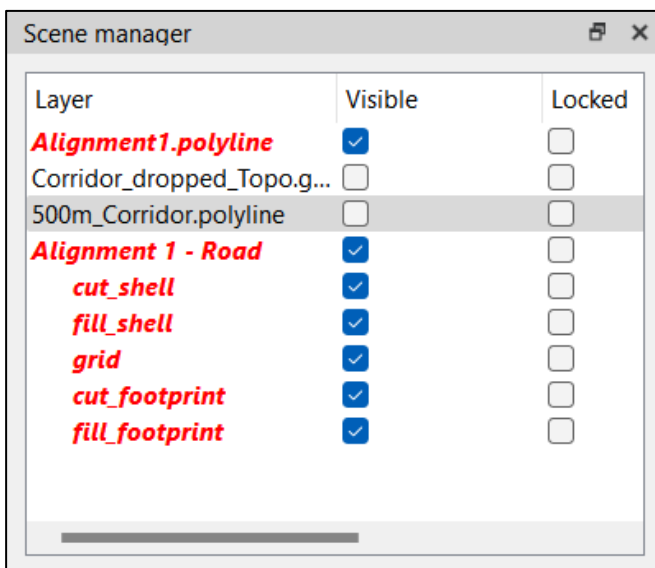


Figure 18: Objects created from creating road

These objects will be:

-cut_shell: full cut surface, along chosen centerline, as per specs entered in ‘Create road from centerline’ input window in Figure 17.

-fill_shell: full fill surface, along chosen centerline, as per specs entered in ‘Create road from centerline’ input window in Figure 17.

-grid: New road surface merged into input grid surface.

- cut footprint: polygons of where the cut shell intersect the input grid surface.
- fill footprint: polygons of where fill shell intersects the input grid surface.

When you select, in this case, 'Alignment 1 – Road' in the *Scene Manager*, the *Properties* window will list the inputs entered into the 'Create road from centerline' function and the output cut/fill volumes (Figure 19). The output objects created in Figure 18 and the resultant cut/fill volumes are all dynamic. In other words, they will update automatically as the input centerline or design inputs are modified.

The design generates cut volume despite draping the alignment with a 3m positive offset. The 30m running surface, 250m point density and variable topography do create cut volume. This can be mitigated by adding points (Figure 24) or incorporating the elevation of the road shoulders into the design.

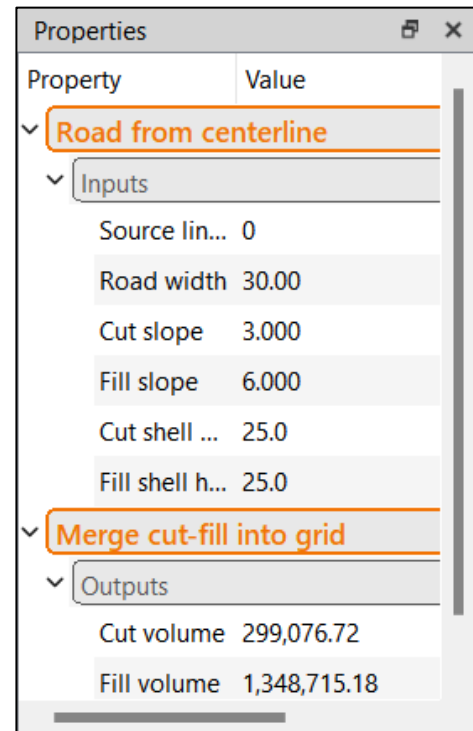


Figure 19: Create road from centerline dynamic design values

In this case, we want to adjust the elevation of the road (road centerline), such that the cut and fill volumes are within 1% while maintaining a low overall volumes. Also, as per Figure 3, we need to be mindful that the point-to-point slopes along the centerline, and therefore of the running surface, cannot exceed **8%**, for this alignment.

Go to **Plotting > Edit line profile**.

Select your centerline and your stripped grid. The *Long section editor* window will appear (Figure 20). This window will display the elevations of the road centerline vs. the topographic base surface, along the centerline. The point-to-point elevations and slopes of the centerline can be

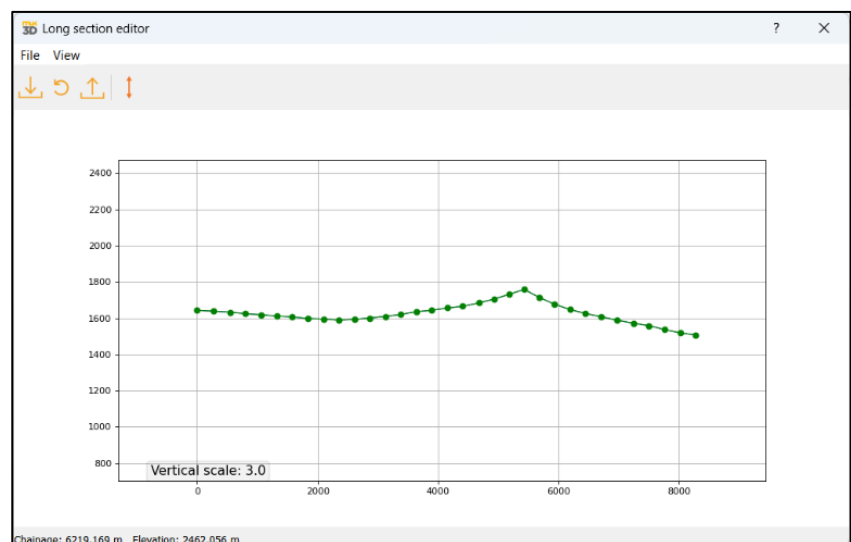


Figure 20: Edit Line profile

interactively adjusted (Figure 21). It can be done manually, by moving them up and

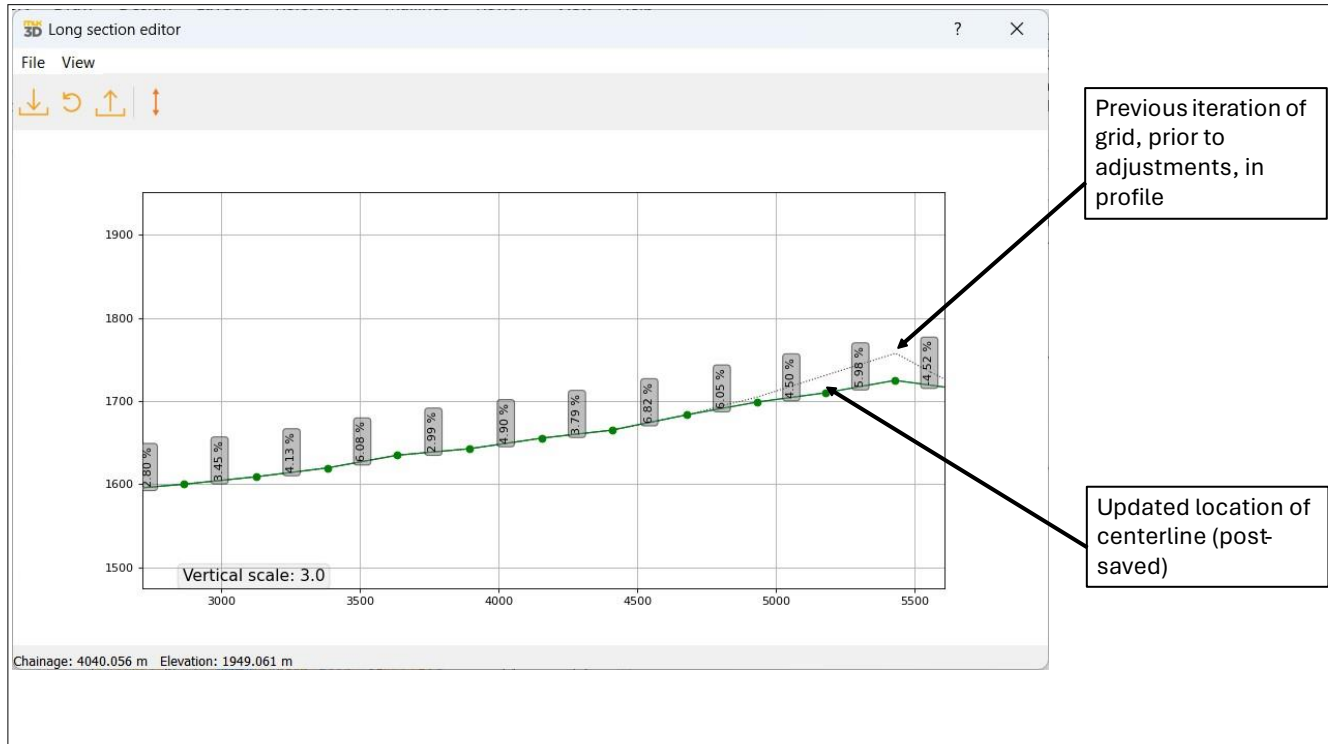


Figure 21: Adjustable point elevations and slopes

down with your cursor. In the view menu, you can set threshold values that'll change the label colour if they are steeper than the entered limit. Additionally, a number of tools exist within the *Long section editor* to streamline the adjustment process. For any point, right-click and the option menu in Figure 22 is available.

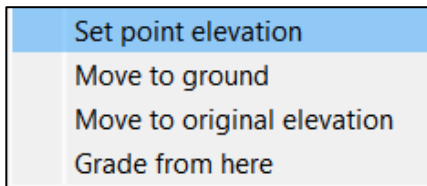


Figure 22: Long section editor – single point options

Select multiple points and the menu in Figure 23 is available. These tools allow you to specifically set elevations or point-to-point slopes for multiple sections along the centerline.

Right-click on the line itself and a new point can be inserted (Figure 24).

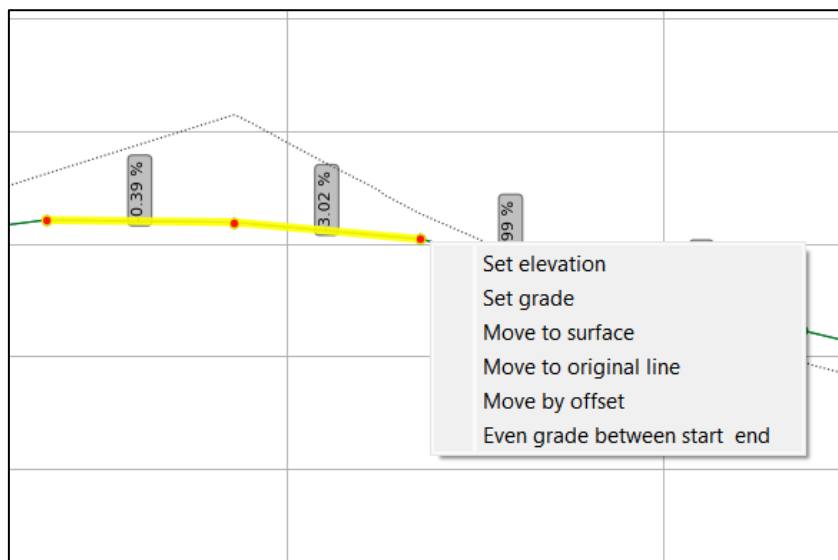


Figure 23: Long section editor – multiple point options

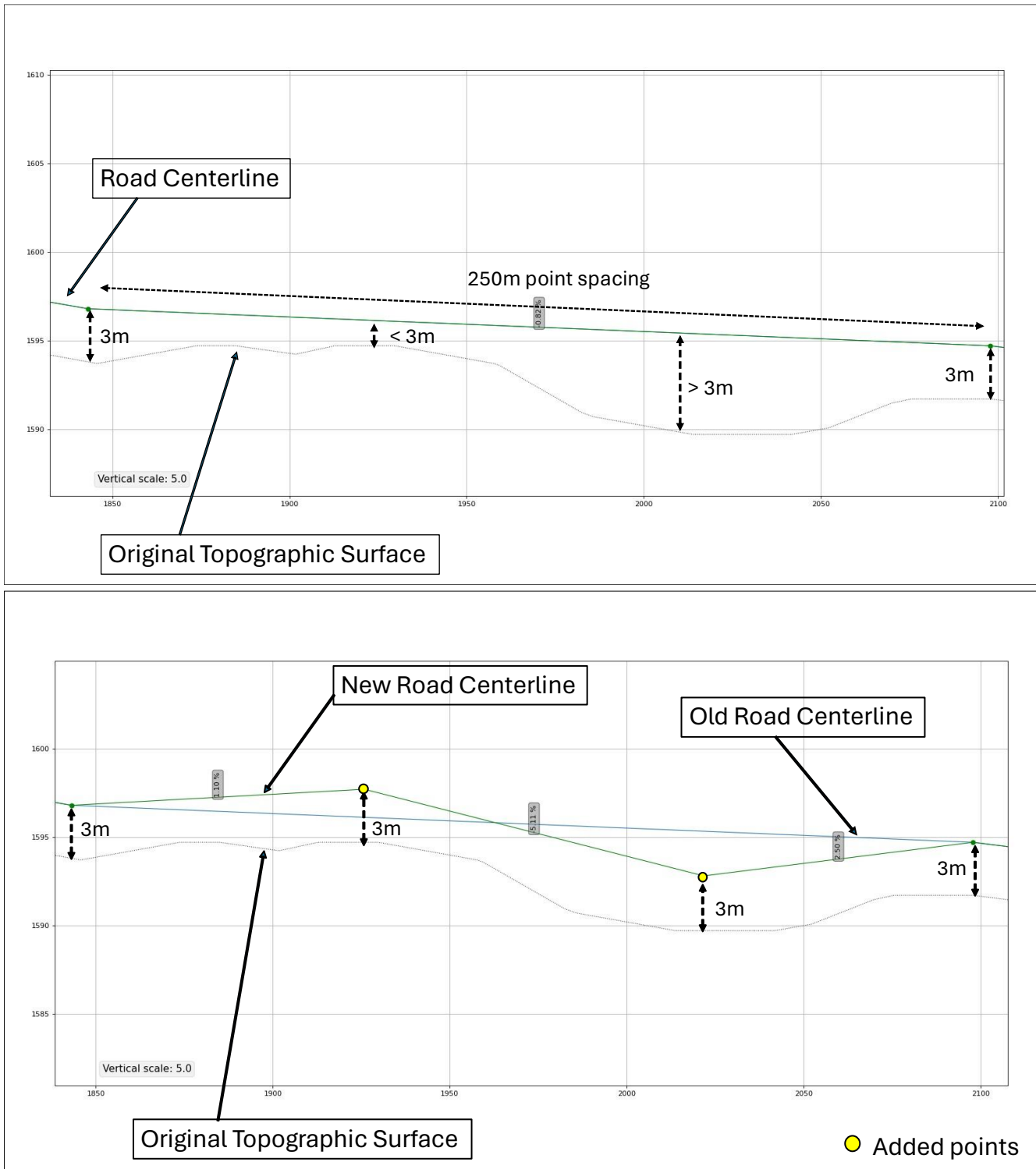




Figure 24: Road centerline & original topo with 250m point spacing (top) vs. adjusted road centerline with additional points & original topo (bottom)

- Save and update the grid surface and road design after adjustments press the  button. Based on your new design, it will update the output volumes in Figure 19.
- Undo any modifications that were made prior to saving, hit the  button.

- Update the editor to only show the post-saved surface, hit the button
- Adjust the vertical exaggeration within the editor, press the button.

In this case, the adjusted centerline configuration is such that the point-to-point sloping doesn't exceed 8%, the cut/fill volumes are balanced, and the overall earthwork volumes have been held to a minimum. In Figure 25 below, the initial road merged grid configuration (centerline draped 3m above topo) is shown as the dashed grey line and the new adjusted configuration is the green line.

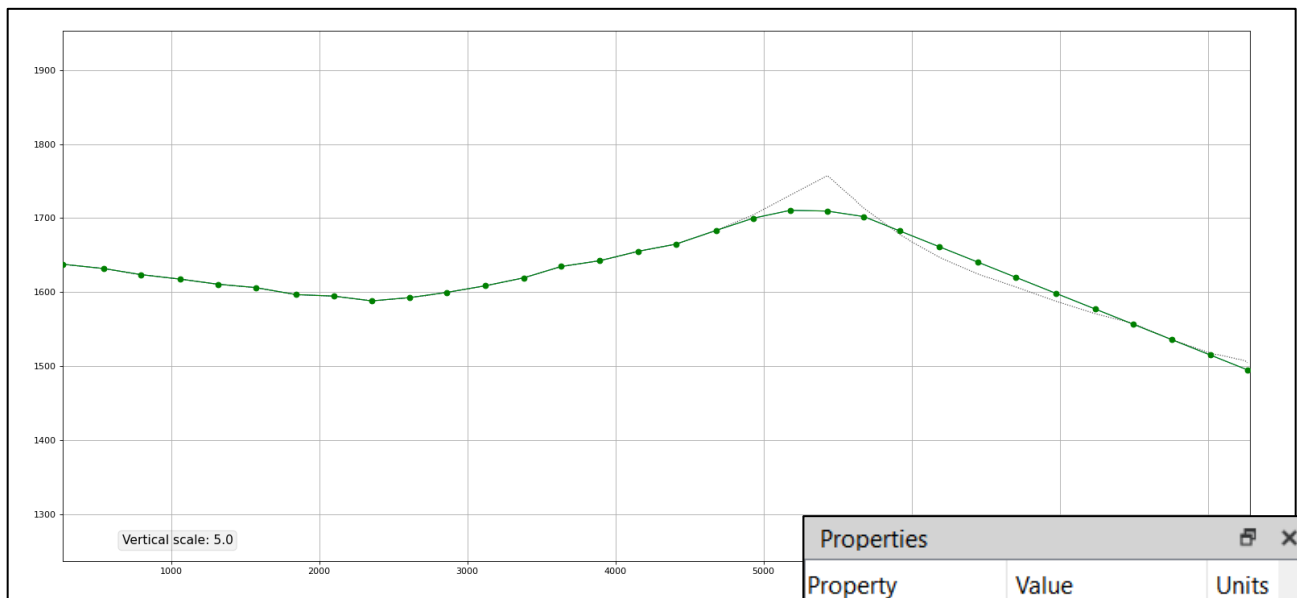


Figure 25: Adjusted centerline alignment and outputs

The modified alignment or centerline results in a road design with the properties shown in Figure 25:

- **cut volume = 2,626,208 m³**
- **fill volume = 2,635,979 m³**
- ⇒ **within 0.37%.**

Initially, the volumetrics were (figure 19):

- cut volume = 299,076 m³
- fill volume = 1,318,745 m³

| Property | Value | Units |
|---------------------------------|--------------|-------|
| Inputs | | |
| Source lin... | 0 | |
| Road width | 30.00 | m |
| Cut slope | 3.000 | 1V:?H |
| Fill slope | 6.000 | 1V:?H |
| Cut shell ... | 25.0 | m |
| Fill shell h... | 25.0 | m |
| Merge cut-fill into grid | | |
| Outputs | | |
| Cut volume | 2,626,208.38 | |
| Fill volume | 2,635,978.77 | |

In Figure 26 below we see:

- The *Project explorer* with the fill and cut footprint objects highlighted in red and blue respectively.

- The Alignment 1 right of way corridor (white), fill footprint (red) and cut footprint (blue) overlaid over the satellite imagery/grid.

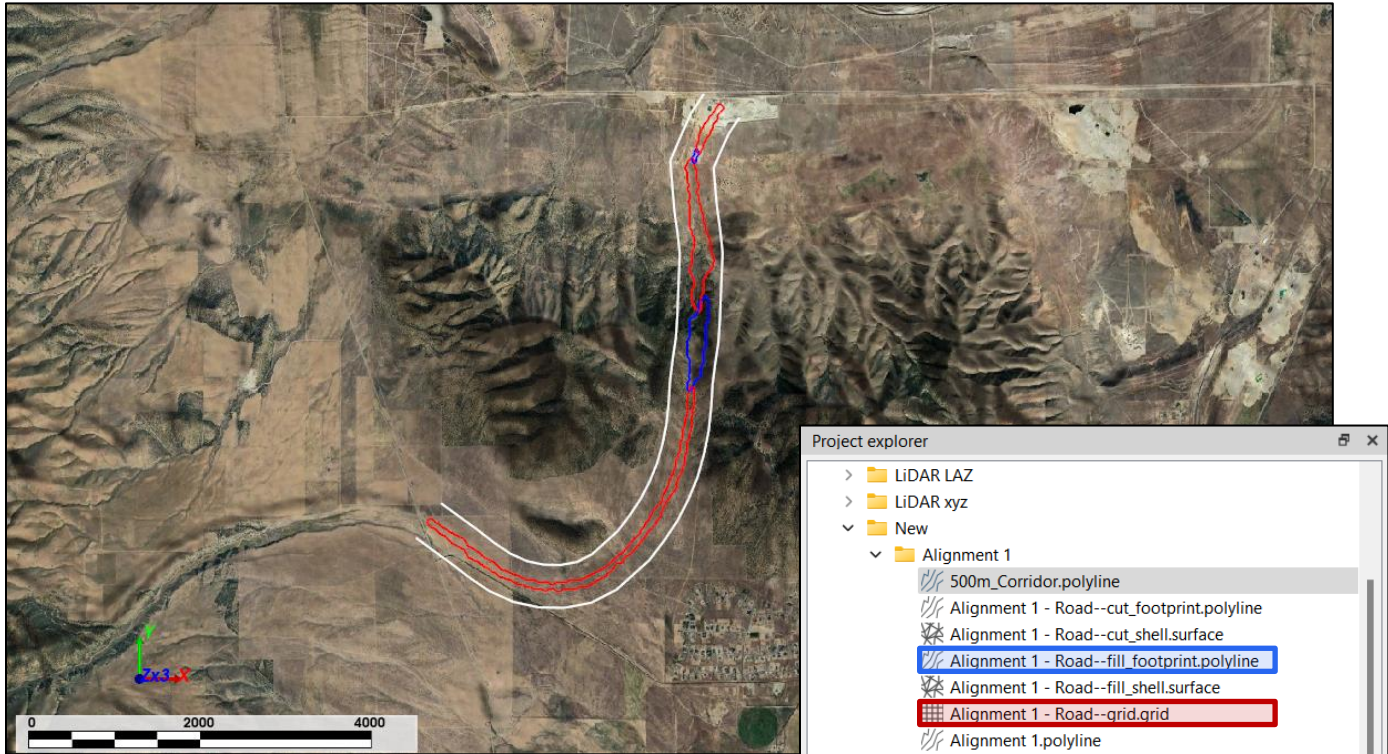


Figure 26: Alignment 1 - Cut and Fil footprints vs. ROW

Comparing the footprints to the ROW, we can establish that the road structure itself can be fully constructed within the 500m corridor. Beyond that, we can estimate the volume of topsoil that will be generated and will need to be managed with this alignment.

Go to **Info > Polyline > Polyline area** and select both polygons separately to establish their area (Figure 27).

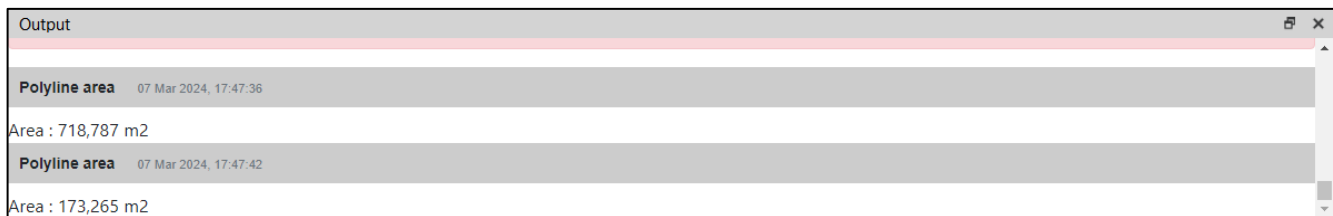


Figure 27: Fill and cut footprint areas

We are working with the assumption that there is 30cm of topsoil that will have to be stripped within the road footprint. As a result, for this alignment:

- **Topsoil volume = (718,787 m² + 173,265 m²) * 0.3 m/m² = 267,615 m³**

Alignment 2

Let's establish and evaluate a second alignment utilizing the same process as above for alignment 1.

1. Utilize features in satellite imagery and topography to establish alignment.
2. Create right-of-way corridor polygon offset 250m on either side from alignment.
3. Drop topographic surface by 0.3m within ROW to account for stripping.
4. Drape entire polyline on topographic surface with ROW stripped.
5. Clean polyline to reduce the number of points to a manageable level.
6. Utilize Polyline > drape > Drape points on surface with 3m positive offset
7. Build road surface from centerline as per specifications.
8. Utilize *Long section editor* to balance cut/fill volumes while adhering to geo-technical criteria.

However, in this case, we will cross the mountains towards the east and relax the point-to-point slope restriction to **10.5%**. Alignment 2 can be seen below in Figure 28.

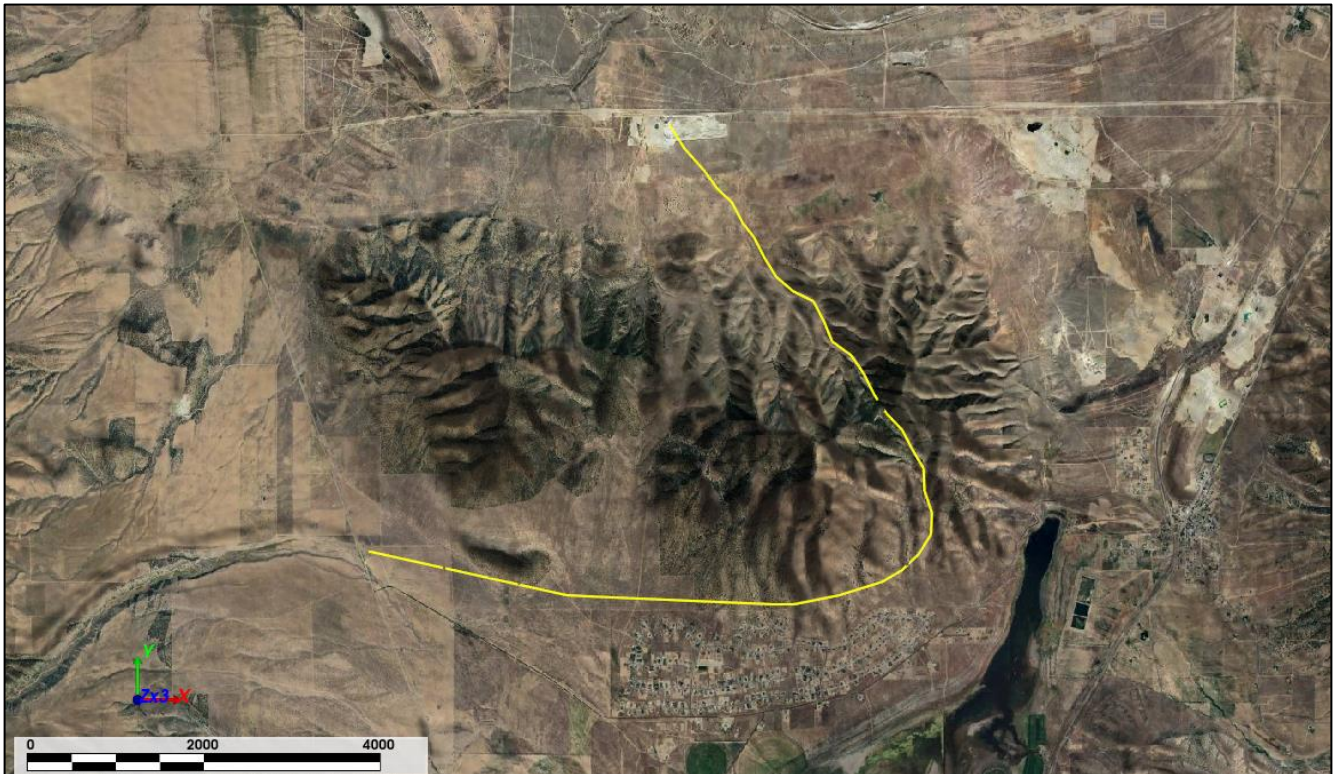


Figure 28: Alignment 2

The alignment 2 outputs, prior to volume balancing and setting the 10.5% point-to-point slope restriction can be seen below in Figure 29. The outputs following

adjustments, as well as the updated alignment can be seen in figures 30 and 31 respectively.

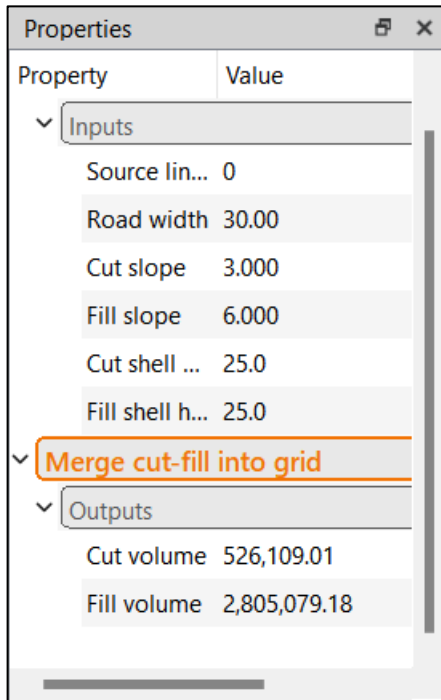


Figure 29: Alignment 2 - preliminary outputs

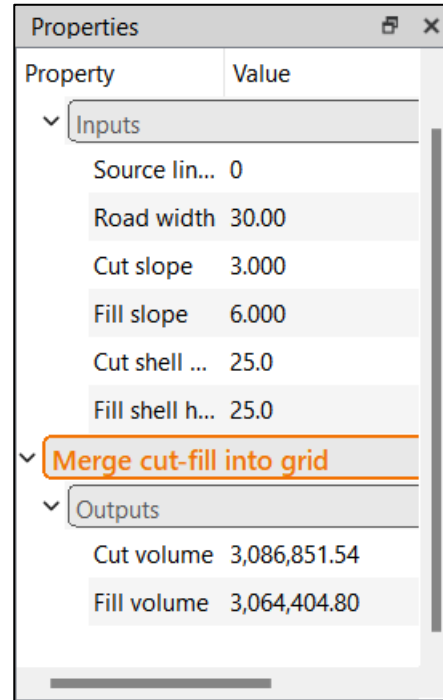


Figure 30: Alignment 2 - adjusted outputs

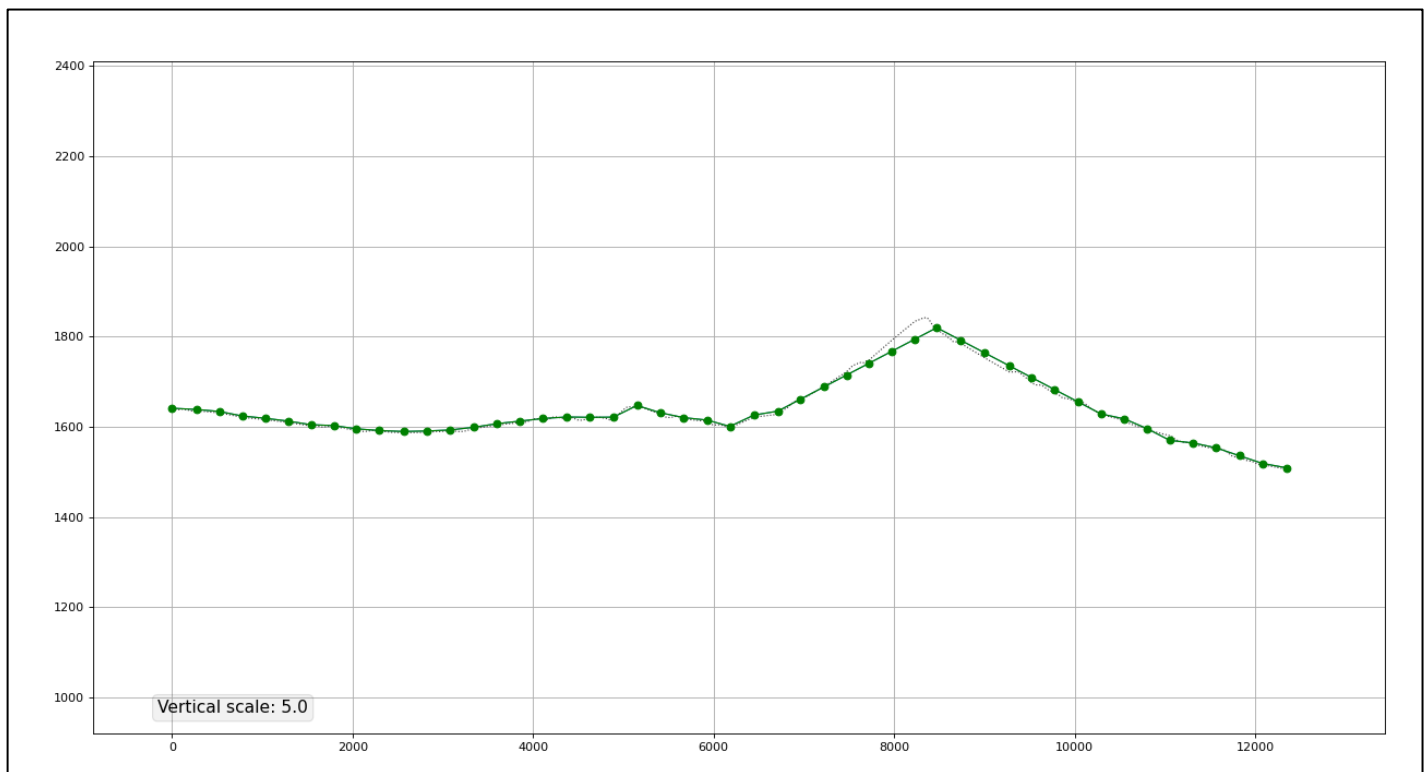


Figure 31: Alignment 2 - adjusted long section profile

- The Alignment 2 right of way corridor (yellow), fill footprint (red) and cut footprint (blue) overlaid over the satellite imagery/grid can be seen in Figure 32 below.

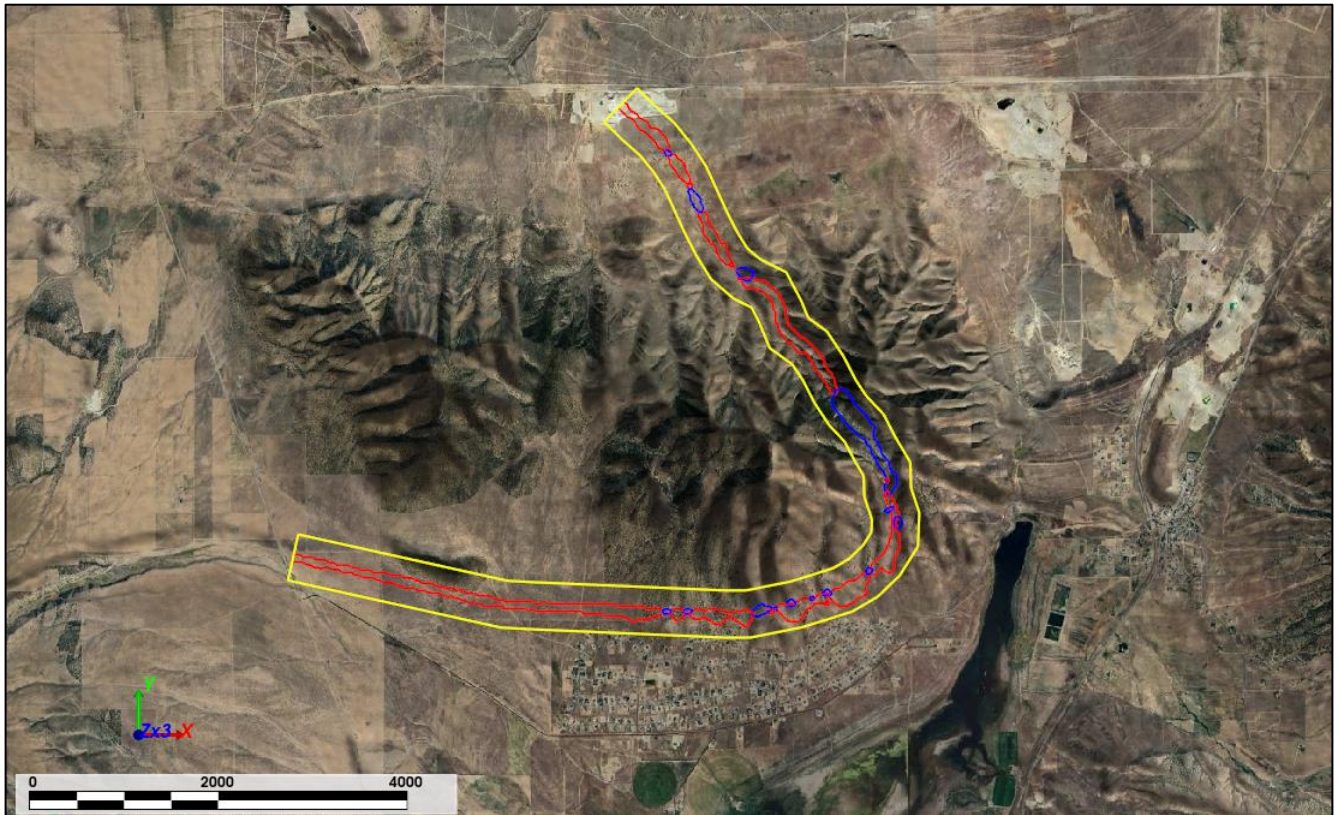


Figure 32: Alignment 2 - Cut and Fil footprints vs. ROW

For this alignment:

- **Topsoil volume = $(1,039,941 \text{ m}^2 + 276,288 \text{ m}^2) * 0.3 \text{ m/m}^2 = 394,869 \text{ m}^3$**

Alignment 3

Let's establish and evaluate a third alignment, that will cross the mountains in the west and has a max. slope spec of **11%**. Alignment 3 can be seen in Figure 33 below. The alignment 3 outputs, prior to volume balancing and setting the 11% point-to-point slope restriction can be seen below in Figure 34. The outputs following adjustments, as well as the updated alignment can be seen in figures 35 and 36 respectively.



Figure 33: Alignment 3

| Property | Value |
|---------------------------------|--------------|
| Road from centerline | |
| Inputs | |
| Source lin... | 0 |
| Road width | 30.00 |
| Cut slope | 3.000 |
| Fill slope | 6.000 |
| Cut shell ... | 25.0 |
| Fill shell h... | 25.0 |
| Merge cut-fill into grid | |
| Outputs | |
| Cut volume | 173,066.43 |
| Fill volume | 1,363,491.96 |

Figure 34: Alignment 3 – Preliminary outputs

| Property | Value |
|---------------------------------|--------------|
| Road from centerline | |
| Inputs | |
| Source lin... | 0 |
| Road width | 30.00 |
| Cut slope | 3.000 |
| Fill slope | 6.000 |
| Cut shell ... | 25.0 |
| Fill shell h... | 25.0 |
| Merge cut-fill into grid | |
| Outputs | |
| Cut volume | 2,199,887.31 |
| Fill volume | 2,221,287.47 |

Figure 35: Alignment 3 – Adjusted outputs

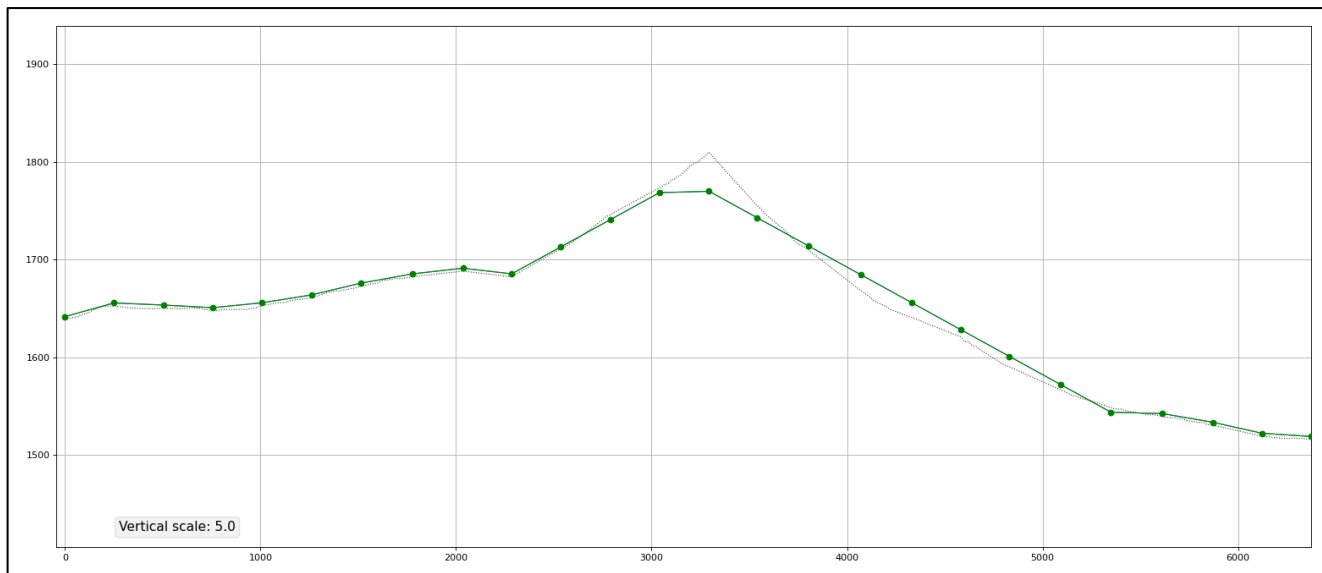


Figure 36: Alignment 3 – Adjusted long section profile

- The Alignment 3 right of way corridor (orange), fill footprint (red) and cut footprint (blue) overlaid over the satellite imagery/grid can be seen in Figure 37 below.

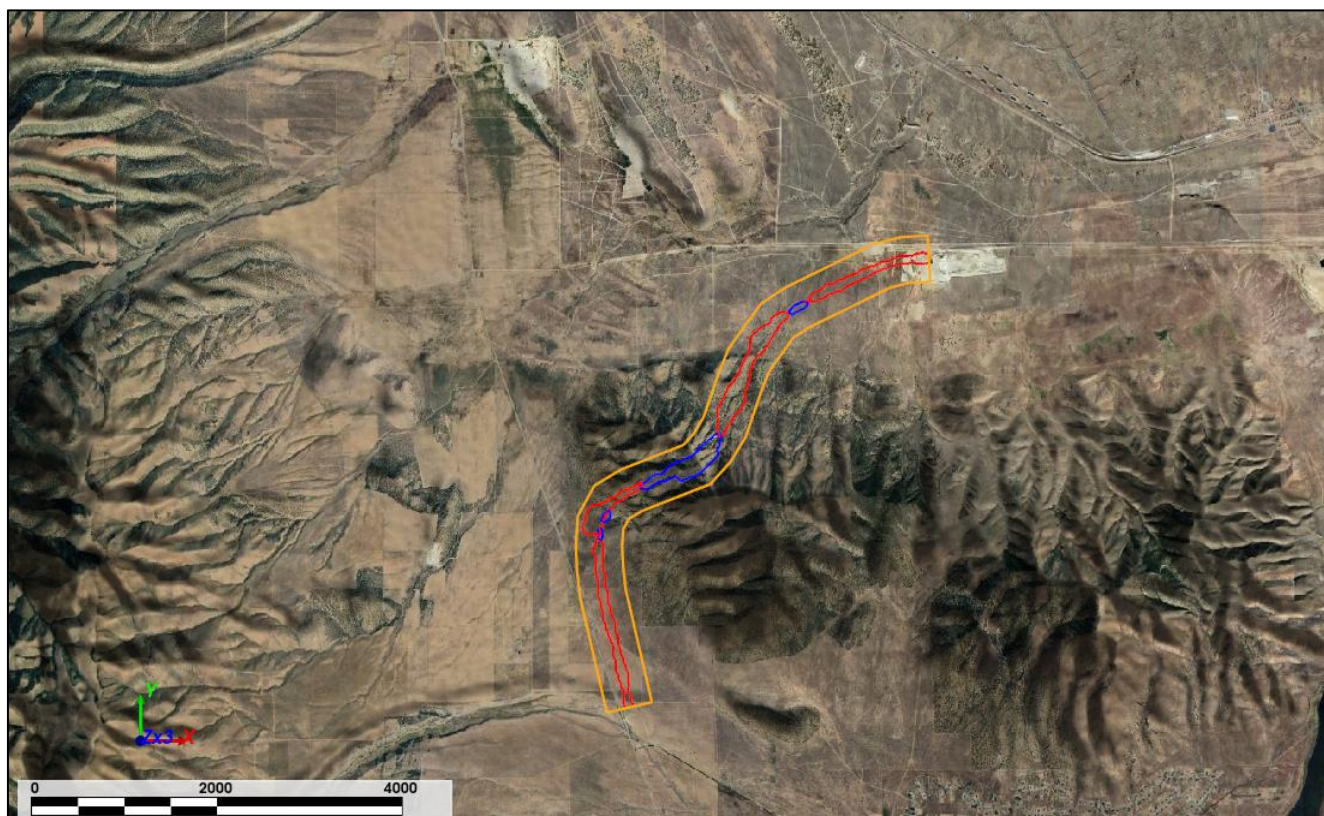


Figure 37: Alignment 3 - Cut and Fil footprints vs. ROW

For this alignment:

- **Topsoil volume = $(604,373 \text{ m}^2 + 178,405 \text{ m}^2) * 0.3 \text{ m/m}^2 = 234,833 \text{ m}^3$**

Comparing alignments

The process above allows us to quantify and compare the alignments against each other. Table 1, below, lists the road lengths, total cut+fill volumes, estimated required stripping volume and slope restriction.

Table 1: Summary table of alignments

| | Length (km) | Cut + Fill volume (m3) | Topsoil volume (m3) | Slope restriction (%) |
|-------------|-------------|------------------------|---------------------|-----------------------|
| Alignment 1 | 6.6 | 5,262,187 | 267,615 | 8.0 |
| Alignment 2 | 8.4 | 6,151,256 | 394,869 | 10.5 |
| Alignment 3 | 6.0 | 4,421,284 | 234,833 | 11.0 |

Surface water management

Let's proceed with Alignment 1 and utilize that road configuration to plan around. We will utilize the merged grid surface, with the Alignment 1 road structure built-in, as our base topography.

Watershed tools

To begin, we need to hydro-reinforce our topographic surface to model the flow of water properly. This is done, within *Formation*, in the following steps:

1. Define the location of any ponds/dams/sinks that allow water to collect.
2. Fill depressions in the grid. If a point can't flow anywhere and its not regarded as a sink, then the point elevation is modified until all points can flow somewhere (except sinks) unless they are on the edge of the grid.
3. Determine flow direction from each point.
4. Count the number of predecessor points that contribute to flow through each point.
5. Create streams for points that have more than a threshold area that contributes to flow.

To generate this surface from the topography you're working with, go to **Water > Watershed > Create a Watershed** (Figure 38). Please note, processing time will depend on the size of input grid. We advise you utilize the **Grid > Create > Extract from existing grid** to delimit the topography to the needed area.

The software will ask you to identify any existing basins or ponds that it should consider in its processing.

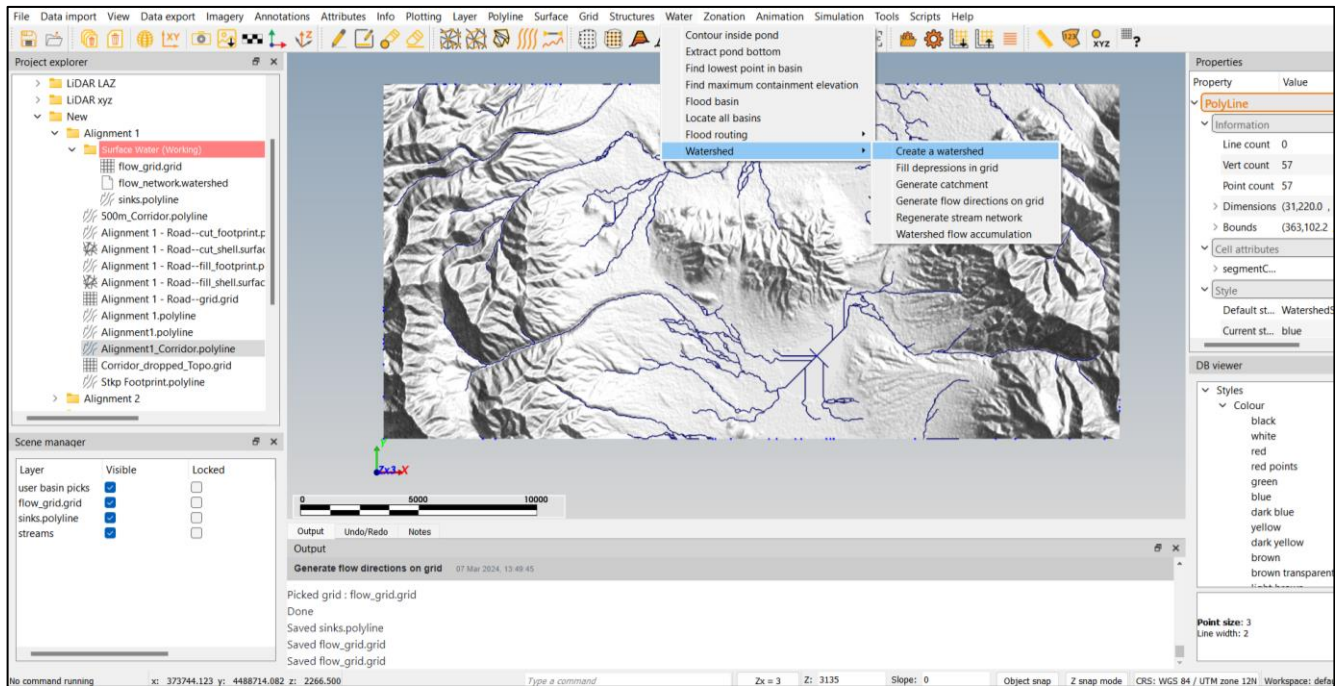


Figure 38: Creating a Watershed

After processing is complete, *Formation* will create the files that can be seen in Figure 39 below. Please note, the *flow_grid* created from the topography is no longer suitable

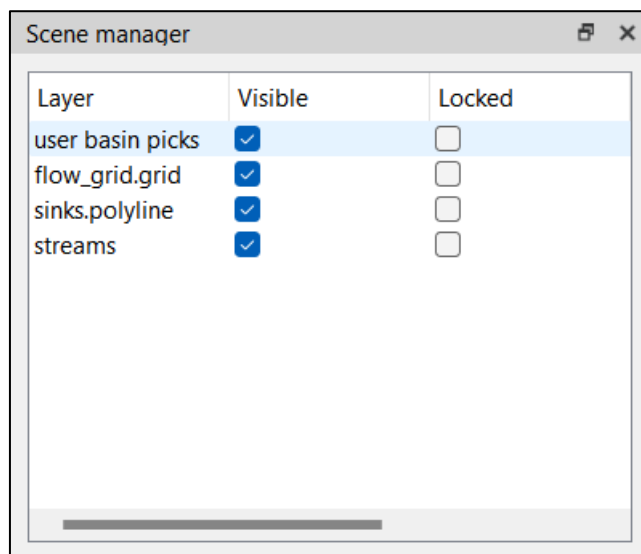


Figure 39: Files generated from creating watershed

for doing geometric modelling. The Fill depressions part of the algorithm may modify surface elevations by an unspecified amount.

After processing is complete, *Formation* will also generate the output seen in Figure 40 below.

The default in this case, generates streams where the minimum catchment area is 47,626,669 m², 10% of the total grid area.

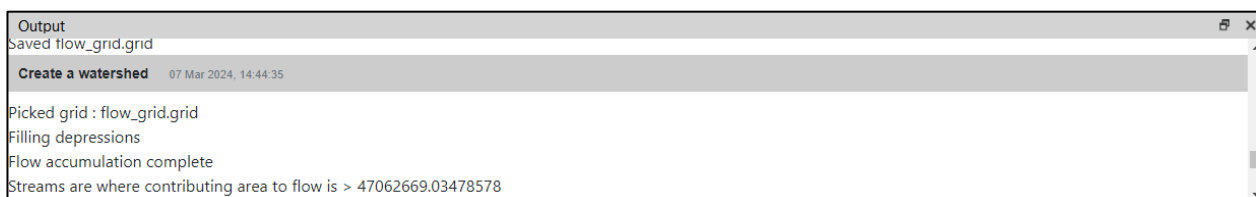


Figure 40: Outputs generated from watershed processing

In order to re-generate streams with more granularity, go to **Water > Watershed > Regenerate stream network** and set a lower minimum catchment area (figure 41).

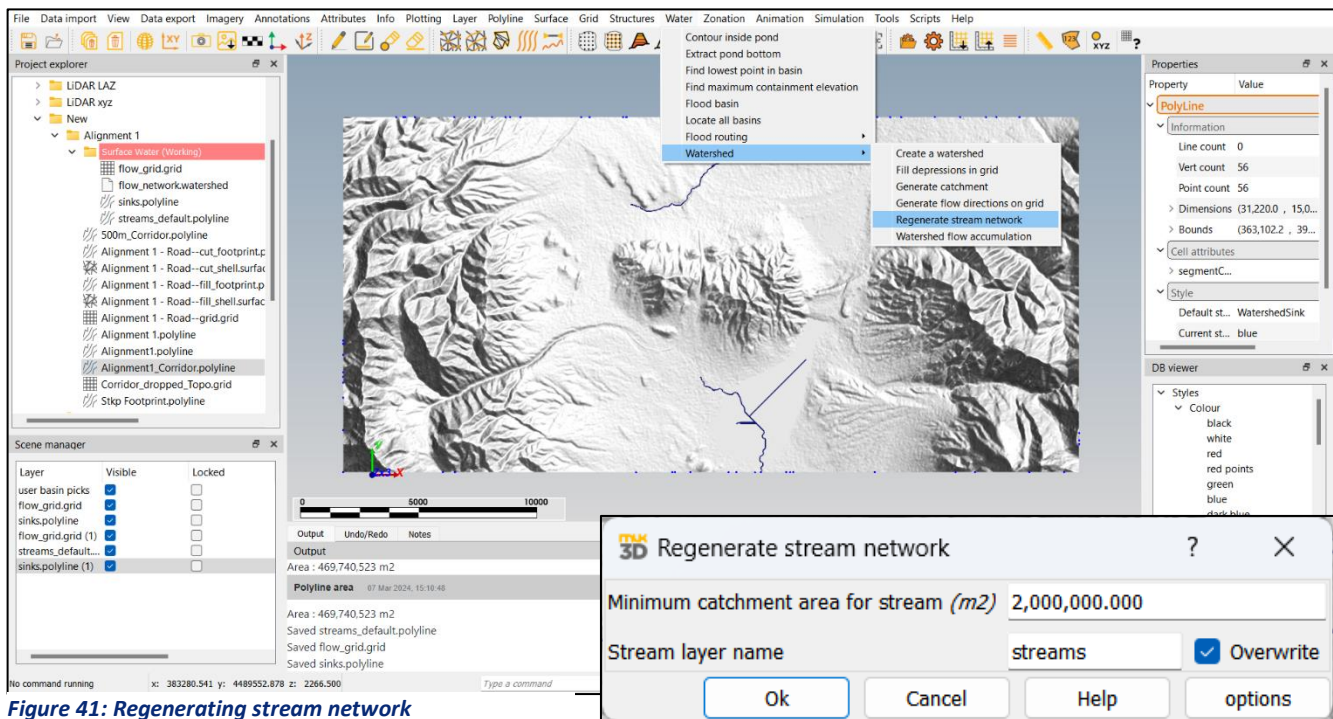


Figure 41: Regenerating stream network

In this case, we're going to set the minimum catchment area to 2,000,000 m² and re-generate the stream network. Figure 42 below displays the difference in streams generated between a minimum catchment area of 470,626,669 m² (left) and 2,000,000m² (right).

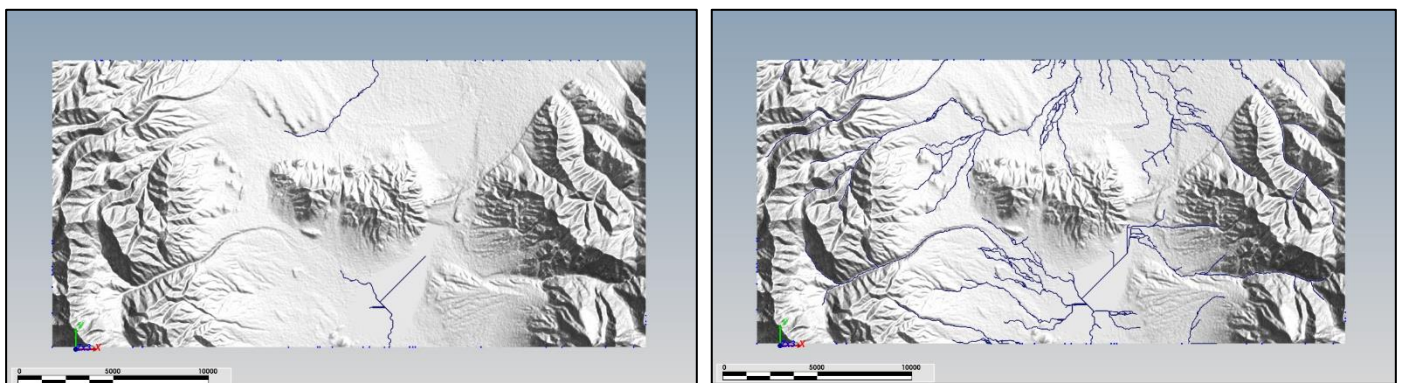


Figure 42: Streams generated with 470,626,669 m² min. catchment area (left) vs. 2,000,000 m² min. catchment area (right)

Sump design

In Figure 43 below, we can see the streams in blue, the 500m ROW corridor in white and the road footprint in black overlaid over the topography with HSV shading, on the

left, and satellite imagery on the right. The yellow squares highlight areas where a stream crosses into the ROW corridor where surface water may become an issue.

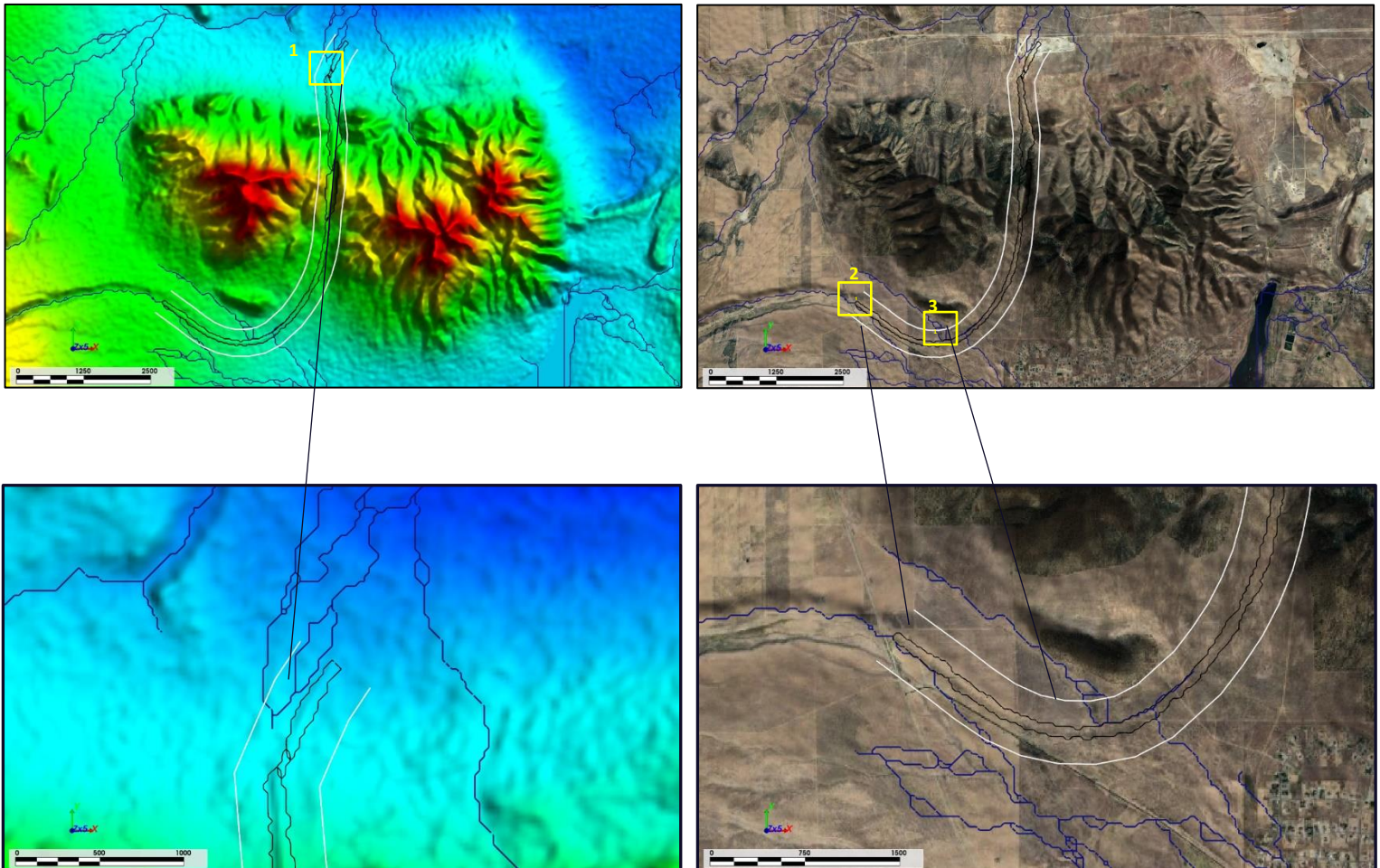


Figure 43: Streams, road footprint, ROW corridor and topography

- Area 1:
 - Although the streams cross into the ROW corridor, it does not contact the road footprint. More importantly, we can see from the HSV shading that the topography is grading down, to the north, and away from the road. In this case, surface water will flow adjacent to the road but away from it.
- Area 2:
 - The water crosses into the corridor and seemingly contacts the road footprint, however, we can see in the satellite imagery that the stream crosses an existing ditch that, we'll assume, should intercept, and divert the surface water in this case.
- Area 3:
 - The water stream crosses into the ROW and through the road. From the HSV shading, we can see the topography grades down into the road from the north-west. Surface water, in this area, needs to be managed. We're

going to place and design a ditch to intercept the stream and carry the water to an excavated sump where the water will collect and be pumped out. The ditch and storage area will be designed inside the ROW and outside the road footprint while utilizing the existing grading of the topography to minimize the excavation. Figure 44 below shows a preliminary layout of the ditch and sump as red polylines.

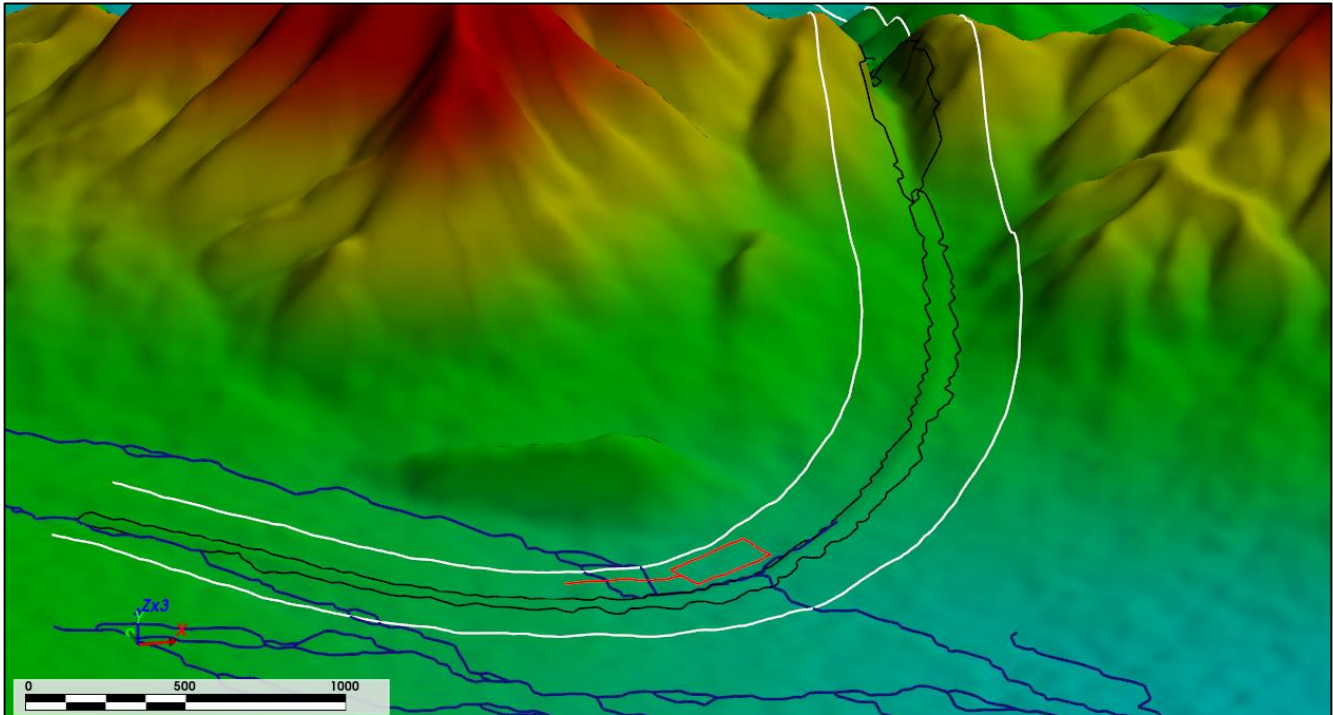


Figure 44: Ditch/sump layout, ROW and road footprint overlaid over HSV topography

To size the capacity of the sump, we need to estimate the amount of surface water that will flow through those streams. In lieu of a detailed hydrological analysis, we're estimating peak storage volumes by determining the catchment area feeding this stream and multiplying it by the appropriate historical precipitation data for this region:

$$\text{Needed storage capacity: } \text{Catchment area (m}^2\text{)} \times \text{Precipitation (m/day)} = \text{Volume (m}^3\text{/day)}$$

In this case, we'll assume a 24h hour rain event producing **30mm** of precipitation. To determine the catchment area go to **Water > Watershed > Generate catchment** (figure 45). Make sure your **flow_grid** and **streams** objects are loaded:

1. *Formation* will ask you to select a grid with flow directions, this must be your **flow_grid**.
2. It will then ask you to select a point. Select a point exactly on the stream of concern (figure 45).

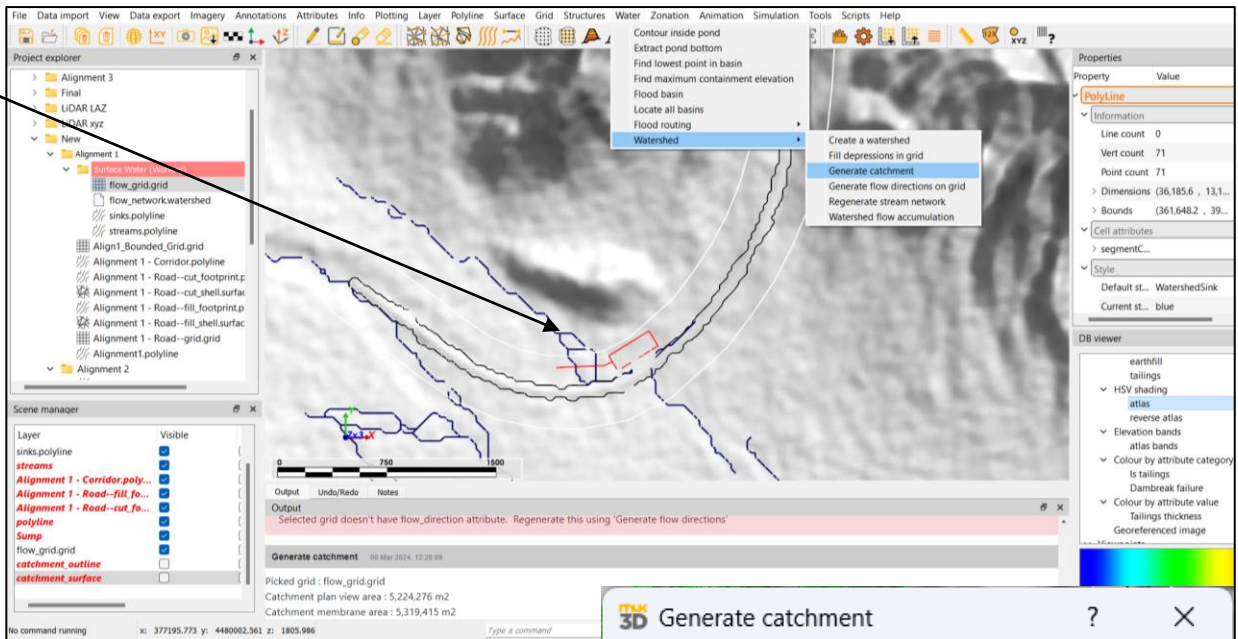


Figure 45: Generate catchment area

Formation will then generate a surface and outline for the catchment area. The

catchment area can be seen, in green, in Figure 46 below. Formation will calculate and display the catchment area value in the output window (Figure 46).

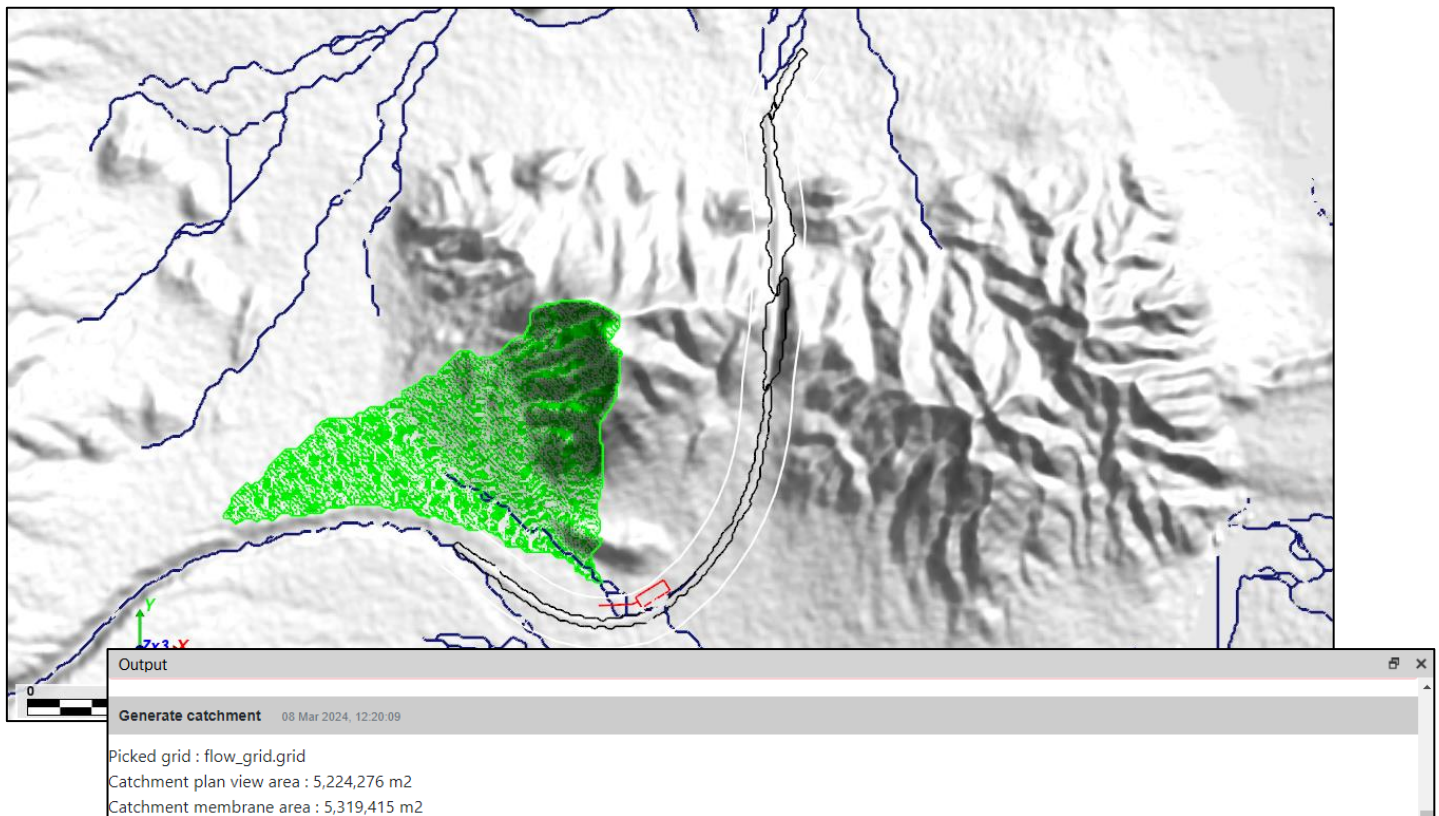


Figure 46: Generated catchment surface, outline, and area

Needed storage capacity: $5,224,276 \text{ (m}^2\text{)} \times 0.03 \text{ (m/day)} = 156,728 \text{ (m}^3\text{)}$

We will now incorporate our water storage structure into the topographic surface with the road structure already merged in. Begin by **loading your merged road grid, not the flow_grid**.

The sump will be designed from its crest in this case. Because this is a purely excavated structure, the crest line also corresponds to the footprint. And given the need to construct this structure within the 500m corridor but outside the road footprint, designing from the crest here is very practical.

The sump crest line can be seen in figures 45 and 46 above. The sump's base elevation will be offset relative to the sump's crest elevation and we want a sump with a consistent base elevation to maximize containment. As a result, we need to set a consistent elevation on the crest line.

Go to **Layer > Change layer elevation** (Figure 47). In this case, we'll set the crest elevation to 1598m, which is close but above the topography throughout the sump's footprint. Select the layer with your sump crest. Set the 'Elevation is...' to **absolute** and enter your desired elevation.

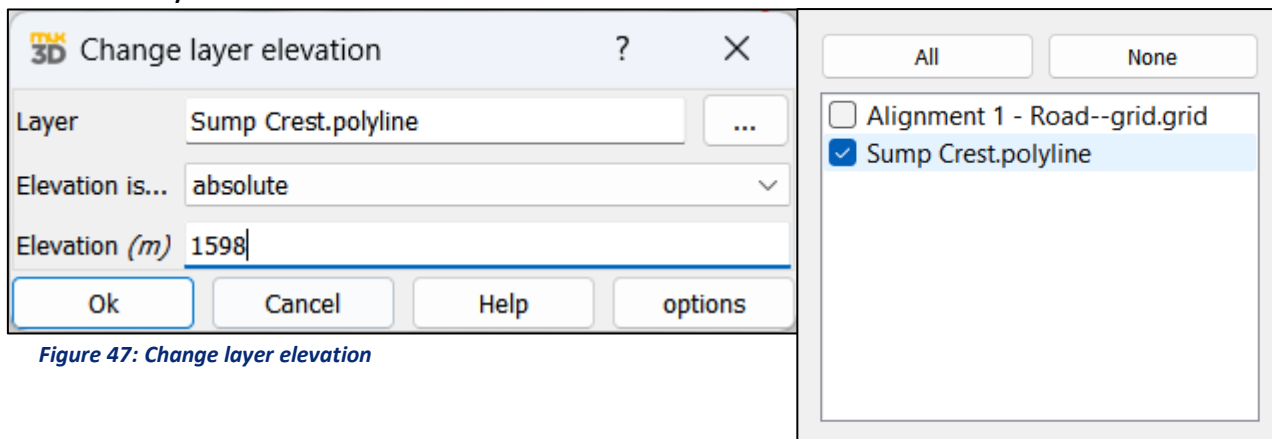


Figure 47: Change layer elevation

Next, go to **Structures > Excavations >**

Excavation from crest (Figure 48). Name your layer, set the excavation slope and the depth, relative to the crest, to excavate down to (*Shell height*). Check '**Merge into grid**' to create a dynamic model. Then select your merged road grid and sump crest polygon.

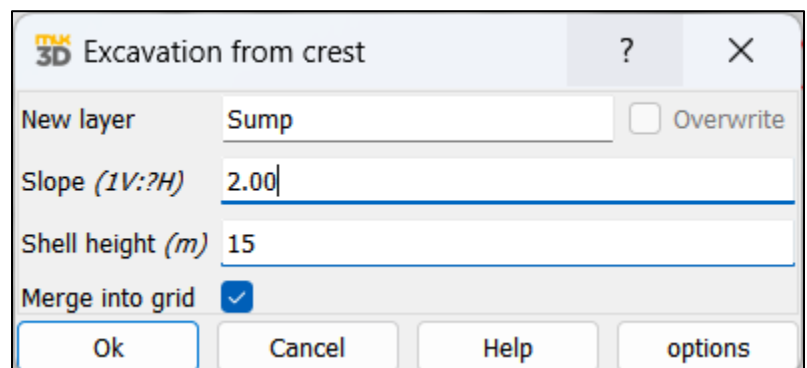


Figure 48: Excavation from crest

Formation will generate the layers, listed with red font in Figure 49 below.

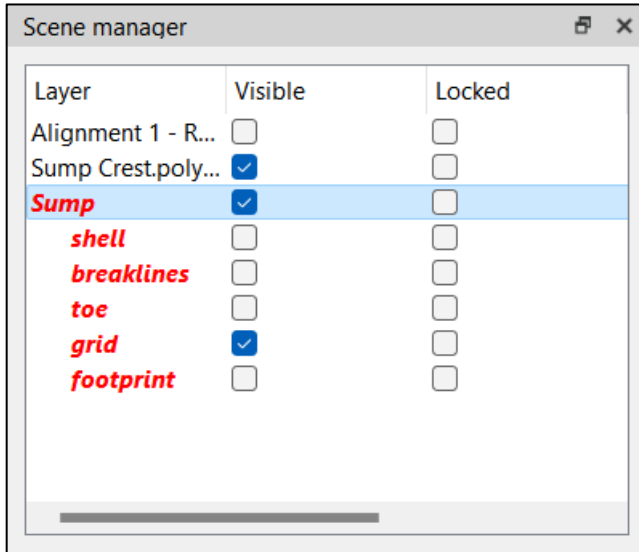
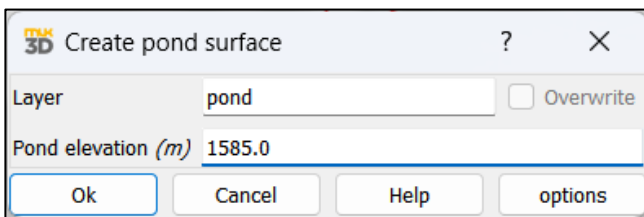


Figure 49: Layers generated from excavating from crest

The 'grid' layer will now have the sump and road structures incorporated. Additionally, the excavation is a dynamic structure. When you select the overall 'Sump' layer in the *Scene manager*, the *Properties window* will list the variable *Inputs* and *Output* (Figure 50). You can change the excavation slope and depth in the inputs which will dynamically update the excavation volume.

Next, we're going to add a dynamic pond surface. Go to **Structures > Pond > Create a pond surface** or hit the button (Figure 51). Name your pond layer and pick an



elevation above sump's base and below the crest. I'm starting with an elevation of 1585m. Then select a point within the new sump. The generated pond surface, within the excavated sump, can be seen in Figure 52 below.

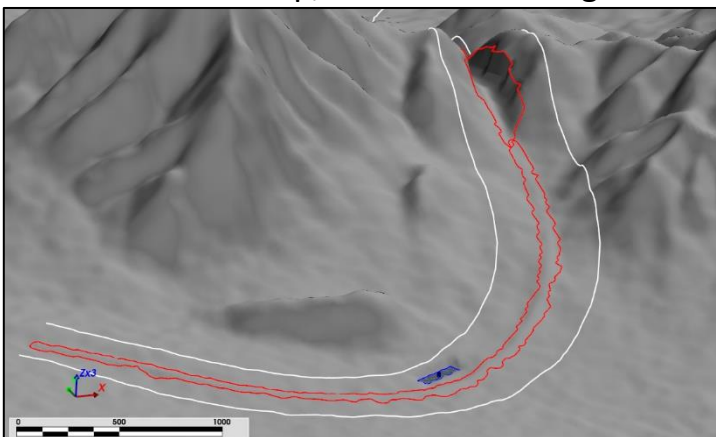


Figure 62: Excavated sump, pond, 500m ROW and road footprint

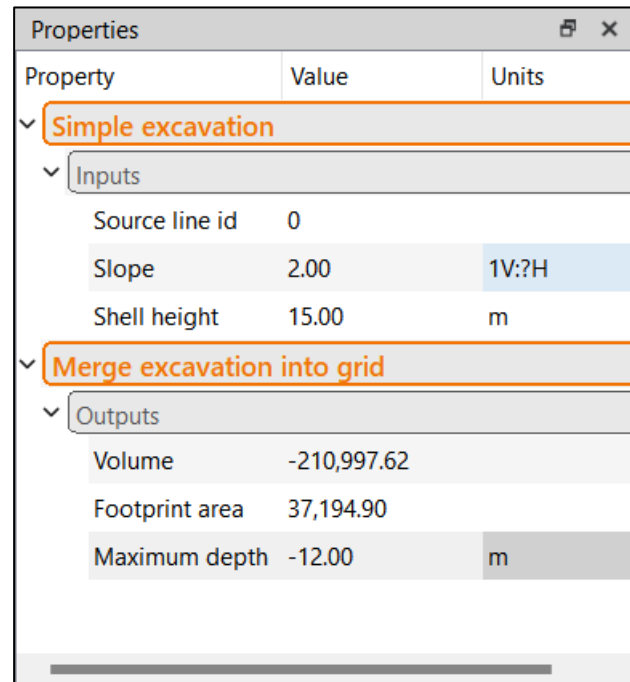


Figure 50: Excavation from crest dynamic properties

New pond layers will be generated in the *Scene manager* and the dynamic inputs and outputs of the pond are visible in the *Properties window* (Figure 53).

We can see in Figure 53, in the properties window, the output volume is 34,583 m³.

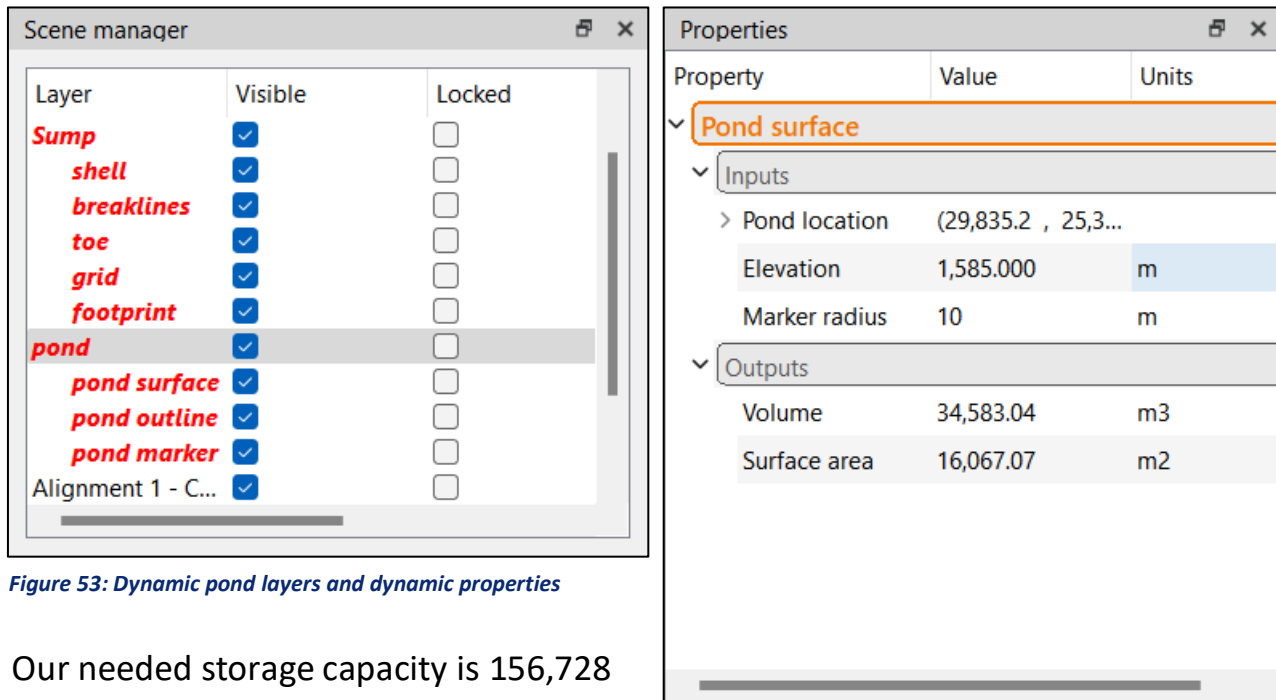


Figure 53: Dynamic pond layers and dynamic properties

Our needed storage capacity is 156,728 m³. Additionally, we would like to have some level of freeboard. Given the sump crest's surface area of 37,195 m² (figure 50), we can estimate that 1m of freeboard in this situation will correspond to ~ 37,000 m³. As a result, to have capacity for 156,728 m³ of water, while maintaining 1m of freeboard, the actual sump capacity should be ~**194,000 m³**.

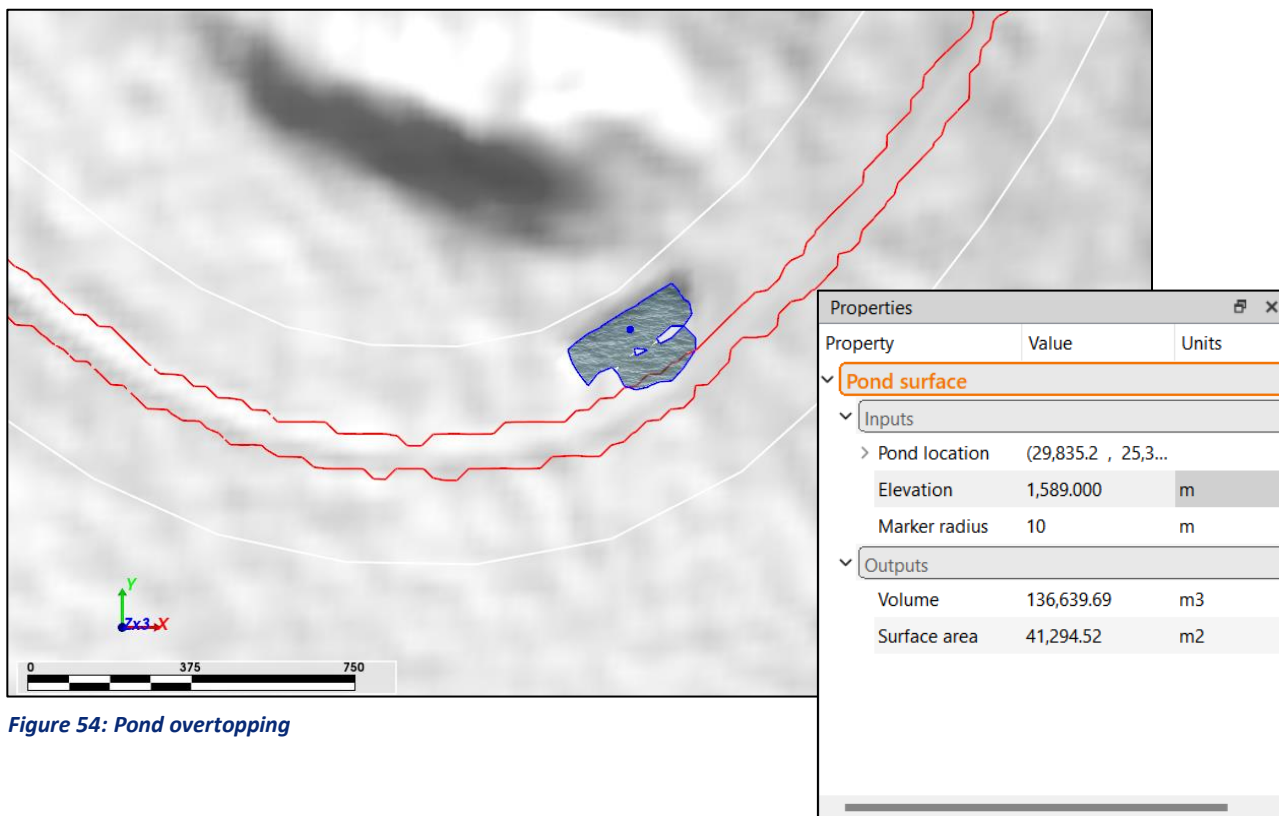


Figure 54: Pond overtopping

As can be seen in Figure 54 above, increasing the pond elevation to 1589m causes the pond to overflow with a water volume of 136,639 m³, well below the needed ~194,000 m³. In this situation, we can either dynamically expand the area of sump through the crest line or increase the excavation depth (shell height) of the sump. In this case, we will increase the excavation depth.

To begin, find the max. or close to the max. elevation before the sump overtops. Set your pond elevation to that value. In this case, the pond stays contained within the sump up to an elevation of 1588m.

Select the *Sump* layer in your *Scene Manager*. Increase the *Shell Height* then select the *Pond* layer in your *Scene Manager* and verify the pond volume. Increase your sump shell height until you've reached a pond volume of ~194,000 m³. In this case, the shell height needed was 23.5m. The final sump (left) and pond (right) properties can be seen in figure 55 below. Make sure to save the sump and pond files.

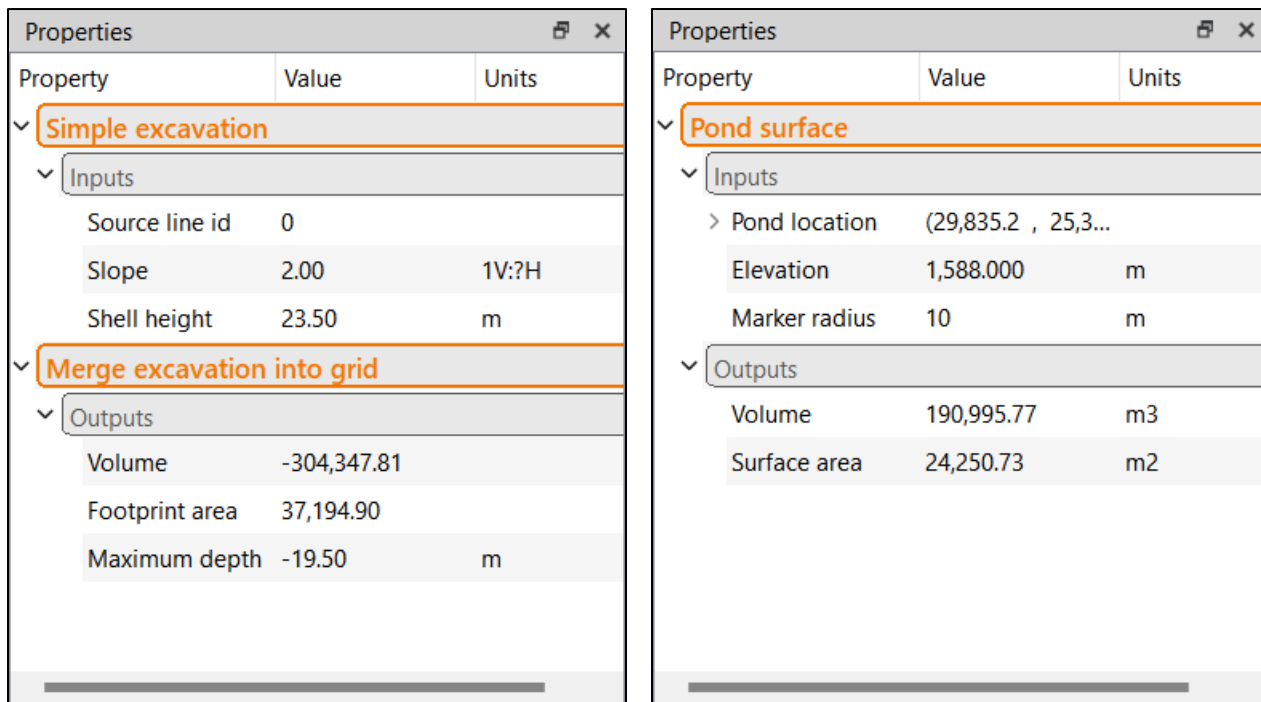



Figure 55: Final sump (left) and pond (right) properties

To visualize items in section quickly, utilize the **Section from 2 points** (Figure 56) function. Begin by hitting the  button. Create your section line. In figure 57 below, we can see the section layout in plan view and the topography with the sump excavation and pond surface in section.

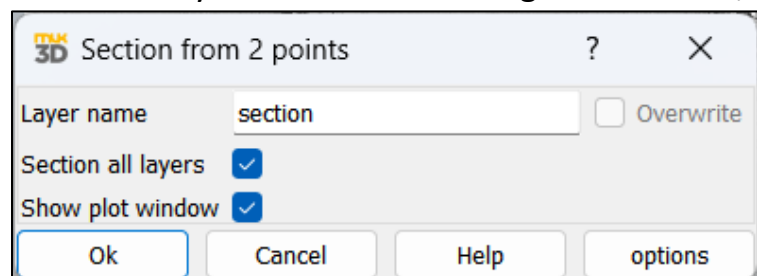


Figure 56: Section between 2 points

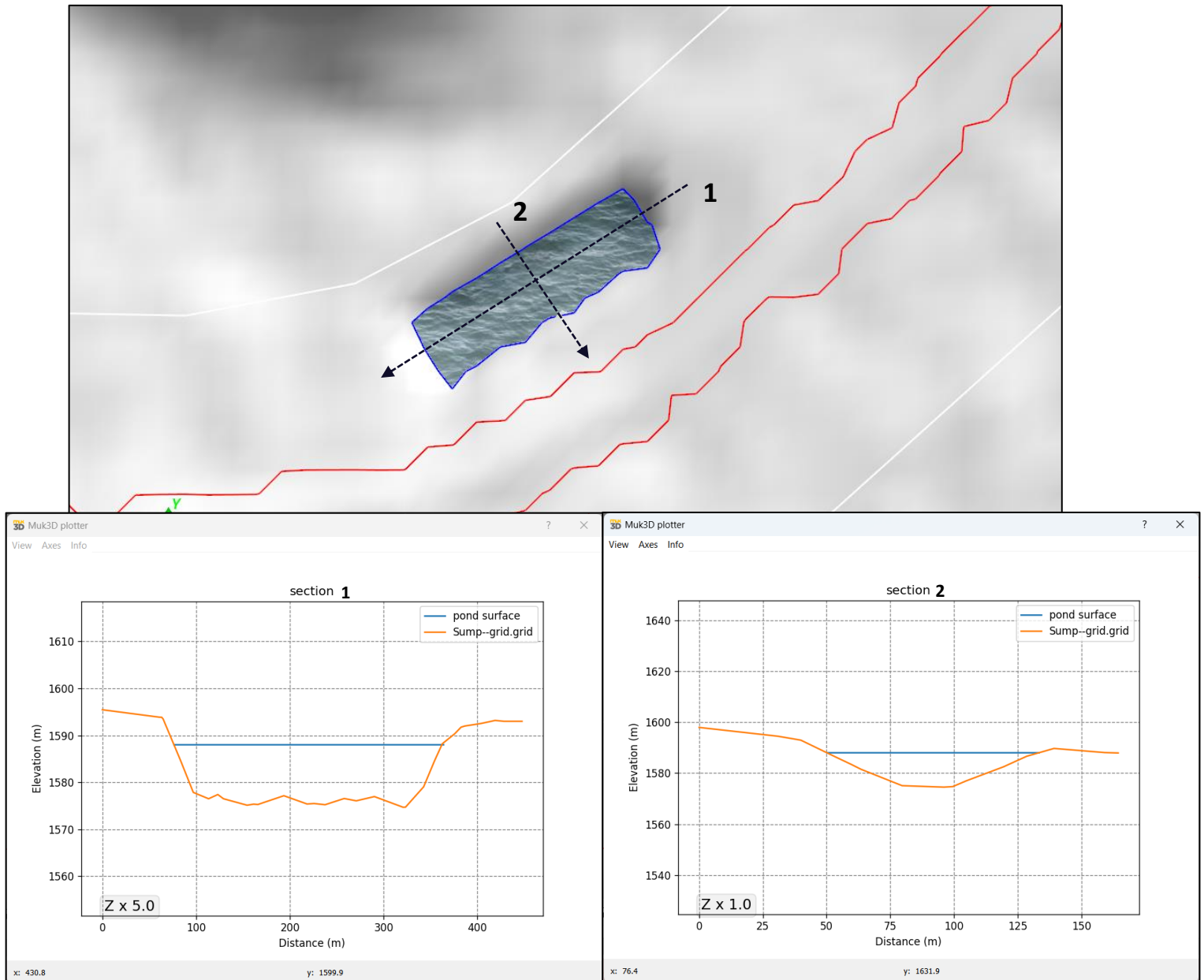


Figure 57: Sump and pond section layout and cross-sections

Ditch design

Next, let's add in our intercept ditch. In Figure 58, on the right, we can see the ditch line (blue), intercepting the incoming streams (navy) and leading to the sump. All the while, inside the ROW (white) but outside the road footprint (red). We're going to create a merged grid surface once again with the ditch incorporated as a dynamic model we can

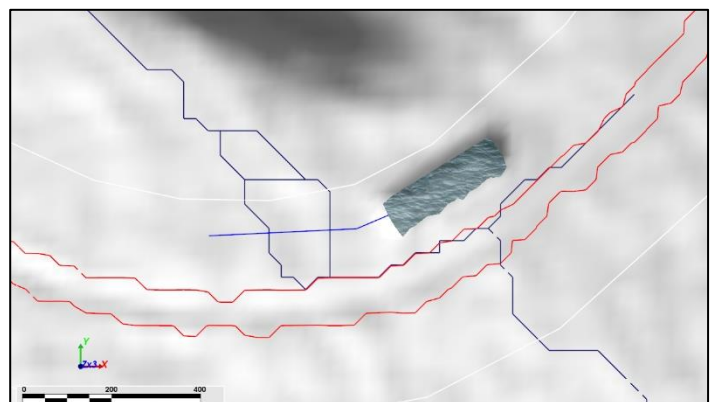



Figure 58: Ditch lay-out relative to streams, ROW, road footprint and sump

manipulate in the long profile editor. The ditch line here is the centerline of the ditch base.

We want the ditch to achieve at least 1m of excavation depth and at least -1% slope along the ditch bottom.

Go to **Polyline > Drape > Drape polyline on surface**. Drape the ditch line with a **'-1m' offset**. This will set your ditch line 1m below the topographic surface.

Go to **Plotting > Edit line profile**. Select your draped/offset ditch line and merged Sump Grid. In Figure 59 below, we see the merged grid (dashed black), -1m offset ditch line (blue) and the final modified ditch line (green). As per the min. 1m depth/1% slope requirement, we adjusted the ditch line such that it is either at or below the blue line in depth with at least a point-to-point slope of -1%. When complete, update your model by pressing the  button.

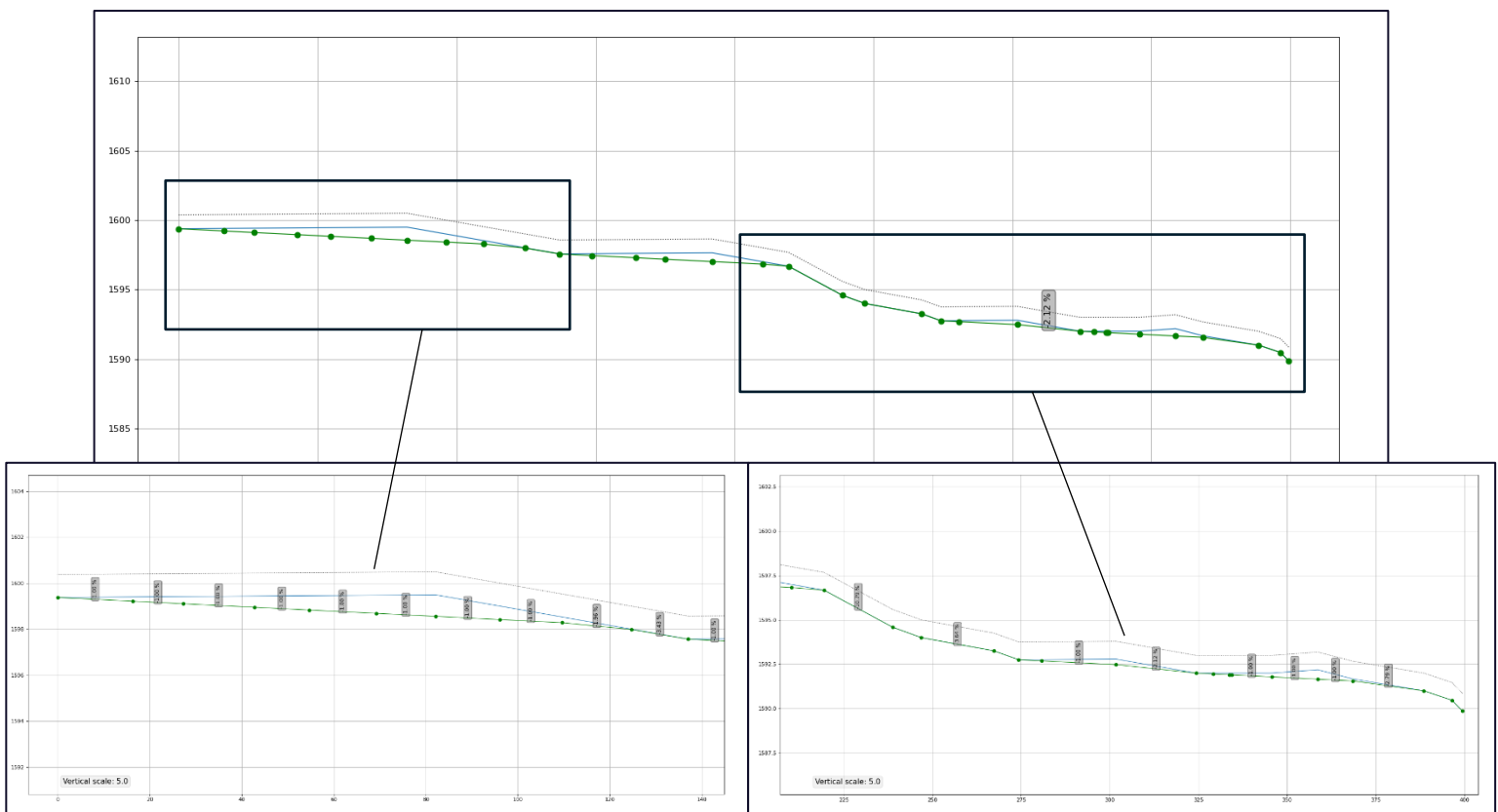


Figure 59: Edit line profile of ditch base centerline. Editing to achieve at least 1m of depth below topo and at least -1% slope.

Go to **Structures > Excavations > Create ditch form centerline** (figure 60). Select the specification of the ditch excavation and make sure to **'Merge into grid'**.

Select the intercept ditch layer in the Scene Manager to view the excavation volume and maximum depth achieved for the excavation (Figure 61).

Figure 60: Create ditch from centerline

| Property | Value | Unit |
|---|--------------------------|------|
| Vertical of... | 0.0 | m |
| Reverse | <input type="checkbox"/> | |
| Merge excavation into grid <input checked="" type="checkbox"/> | | |
| Outputs | | |
| Volume | -6,088.06 | |
| Footprint ... | 10,742.00 | |
| Maximum... | -2.26 | m |

Figure 61: Intercept ditch properties

Stockpile/Dump Design

Let's continue with the Alignment 1 configuration and plan our stockpiles:

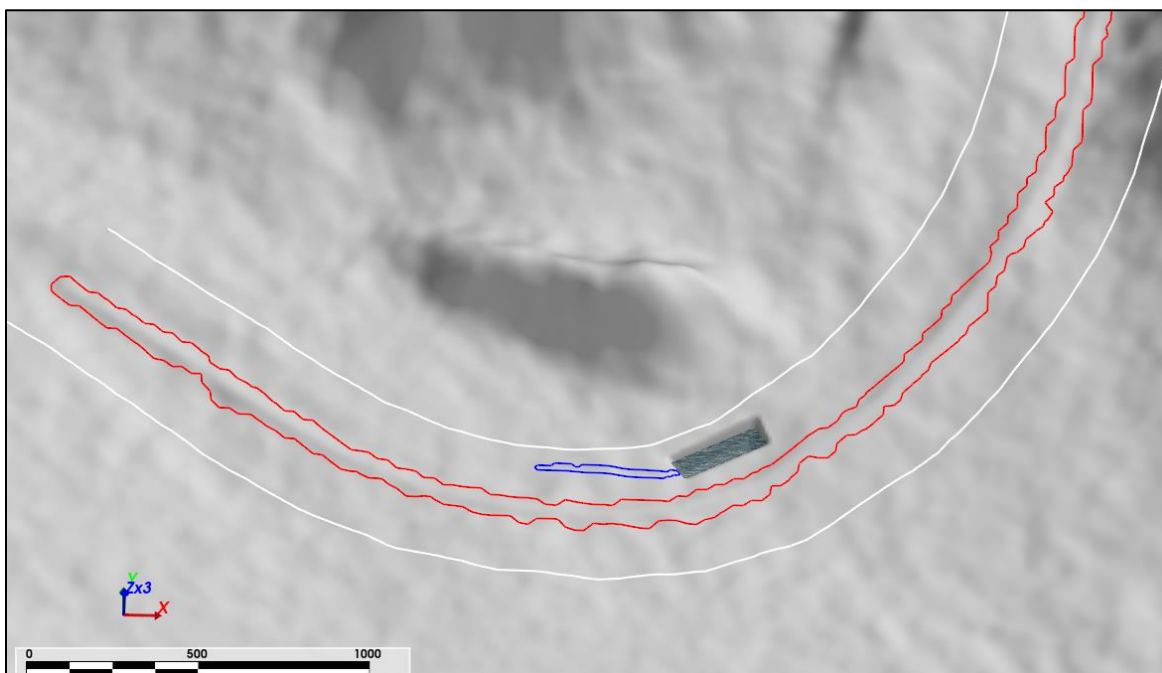
- All stockpiles need to be placed outside the construction (cut/fill) footprints but within the 500m ROW.
- When the earthworks portion of the road is constructed, topsoil will be placed on side-slopes and other areas of the design to protect against erosion.
- A substantial amount of topsoil may need to be stockpiled depending on how much completed design surface is available to be finished with topsoil as it's getting stripped.
- Additional planning should be done to maximize direct placement of the topsoil to avoid rehandle. However, let's assume we will need to stockpile all the topsoil stripped.
 - ⇒ The alignment 1 road itself will generate an estimated **271,319 m³** of stripped topsoil overall (table1).
 - ⇒ Additionally, the topsoil will need to be stripped from the sump and ditch footprints outlined in the section above. From figure 55 and 61 respectively, that a total of:
 - $(37,194 \text{ m}^2 + 10,742 \text{ m}^2) * 0.3\text{m}^3/\text{m}^2 = \mathbf{14,380 \text{ m}^3}$ of topsoil

- ⇒ The total volume of topsoil to be stockpiled is **285,699 m³**
- In order to minimize haul distances, we will assume that there will be two topsoil stockpiles that will be located on either end (north and south) of the alignment. Each stockpile will contain half of the volume or **~143,000 m³**
- Beyond that, the non-topsoil material excavated for the ditch and sump, will be stockpiled, and used to backfill the ditch and sump after the road has been completed.
 - ⇒ From figures 55 and 61, we can see the total excavation volume for the sump and ditch are 304,348 m³ and 6,088 m³ respectively.
 - ⇒ As per above, we've established 14,380 m³ of that is topsoil.
 - ⇒ There will be 304,348 m³ + 6,088 m³ - 14,380 m³ = **296,056 m³** of embankment material to be stockpiled adjacent to the ditch and sump.

Overall, we will have:

- Topsoil stockpile 1 in the 'South' of ~143,000 m³
- Topsoil stockpile 2 in the 'North' of ~143,000 m³
- Embankment material stockpile in the 'South' of ~296,000 m³

Let's begin in the 'south'. In figure 62 below, we see the 500m corridor (white), the road footprint (red), the ditch footprint (blue) and the sump in the 'south'



We'll begin by placing the *Embankment material stockpile* of $\sim 296,000 \text{ m}^3$ adjacent to the sump. Given our need to construct the stockpile, to a defined capacity, within an area between the ROW and road footprint, we will construct the stockpile from the footprint.

Begin by creating a reasonably sized footprint in plan view. The elevation of the footprint is not a concern. The footprint simply needs to be appropriate in X and Y. Go to **Polyline > Create > Draw a line** (figure 63) and create a closed polygon. Once again, the elevation does not matter here but we recommend an elevation above the topography so that the polygon is visible over the topography.

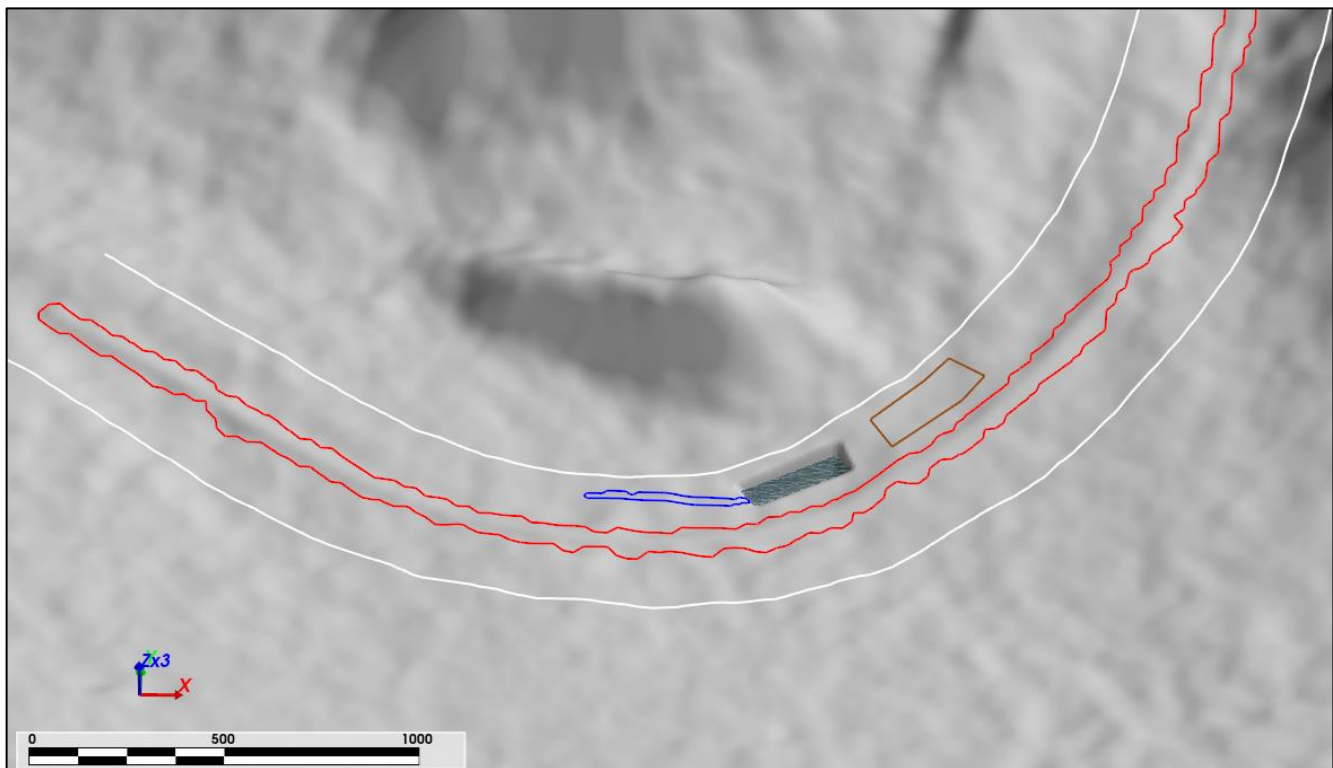


Figure 63: Initial footprint of Embankment material Stockpile (brown)

Then, go to **Structures > Dump > Dump from footprint** (Figure 63). This will create a dynamic dump structure within the footprint of your polygon. Select an initial crest elevation that is reasonable. In this case, the topography's elevation, within the footprint, maxes out around 1605m. As a result, our initial *Crest Elevation (m)* is set at 1615m. You can also set the sideslopes. *Formation* will then generate the layers that can be seen, in red font, in Figure 65

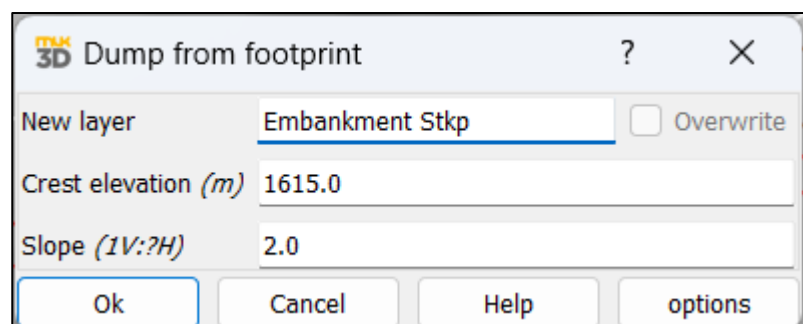


Figure 64: Dump from footprint tool

below. Select the *Embankment Stkp* layer in the *Scene manager* and it will display the items in *Properties* window that can be seen in Figure 66 below.

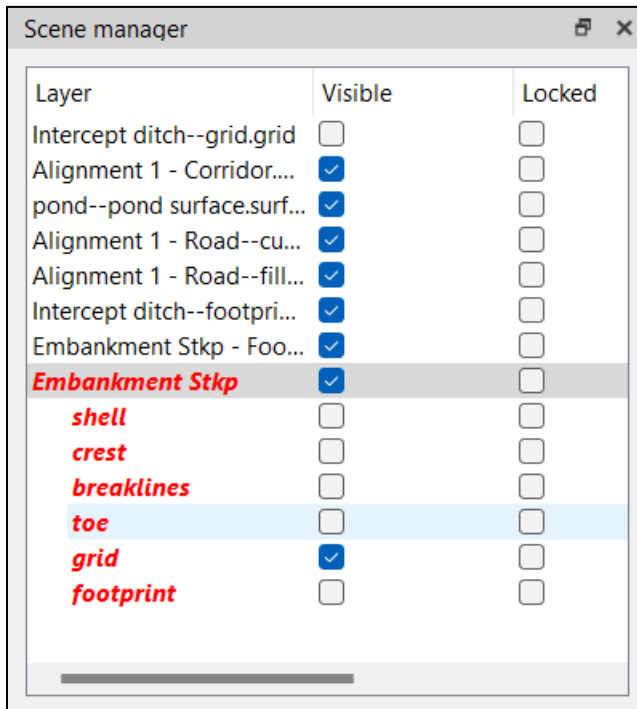


Figure 65: Dump from footprint generated files

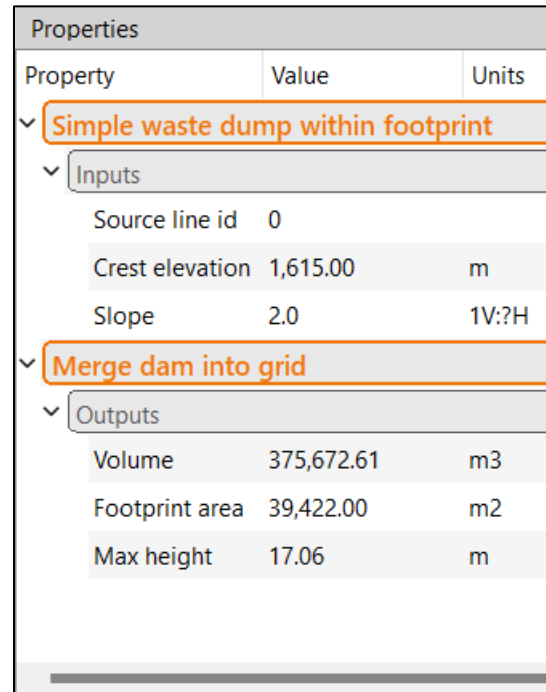


Figure 66: Embankment Stockpile properties

In the outputs section of Figure 66, we can see that the initial stockpile configuration is 375,673 m³. Our target volume is 296,000 m³. To reduce the size of the stockpile by ~ 80,000 m³, there exists two options:

1. Reduce the crest elevation of 1,615m.
2. Modify the input polygon seen in figure 63.

For option 1, simply type a new value into the *Crest elevation* value in the *Inputs* section of the properties window and the volume will update dynamically. In this case, 1,610.75m gets us to 295,807 m³.

For option 2, go to **Polyline > Edit > Move point on line** and modify the configuration of the input footprint polygon.

Please note that the newly created merged grid, with the stockpile incorporated, must be visible or the stockpile outputs won't update.

Next, we repeat the process and place the two 143,000 m³ stockpiles on either side of the alignment. As always, continue to build off the previously created merged grids towards a final grid with all components.

Plotting

Let's combine all the imagery, designs, and topographic data into plotted imagery.

We are going to modify the satellite image to display the different design features. Then overlay that modified imagery over the topographic surface.

The outlines that we're going to utilize are the structure footprint layers automatically generated by *Formation* throughout the design process. This will include:

- The Alignment 1- Road cut footprint.
- The Alignment 1- Road fill footprint.
- The Intercept ditch footprint.
- The Embankment stockpile footprint
- The Topsoil north stockpile footprint
- The Topsoil south stockpile footprint

Go to **Imagery > Add filled outlines to image** (Figure 67).

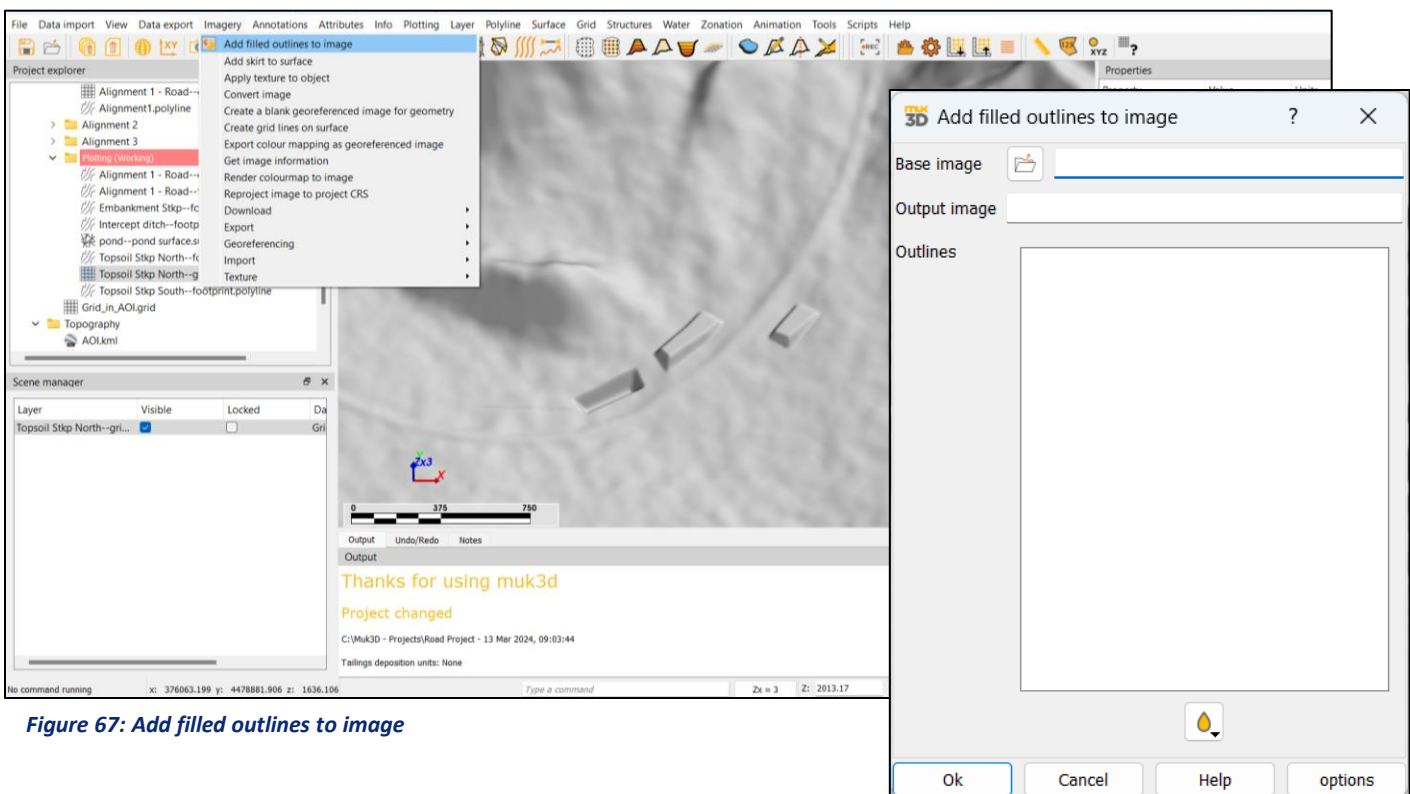


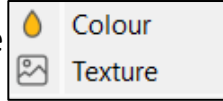


Figure 67: Add filled outlines to image

Hit the  button in the *Base image* row and load the clean.jgw file in the imagery folder. Then name the *Output image*.

Hit the  dropdown button and choose whether you would like to fill that particular footprint with a color or a texture




The 'colour' option fills the outline with a standard colour of your choosing. The 'texture' option allows you to fill the outline with an image. The 2024 version of *Formation* comes with four textures you can use. They can be seen in Figure 68 below.



Figure 68: Formation textures

These textures are also present in the DB Viewer and can be added to any layer, within *Formation*, by dragging and dropping them into the main viewer and selecting the layer you would like to apply it to.

Let's begin by selecting the 'Colour' option initially (Figure 69). Hit the  button and select the Alignment 1 Road's cut footprint and make it blue. Then hit okay. Repeat this

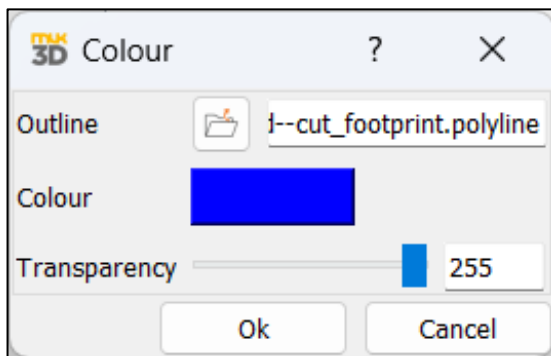


Figure 69: Colour outlines

process with all the outlines you'd like to highlight with a solid color. In this case, we're coloring the Alignment 1 Road fill footprint in red and the Intercept ditch footprint in cyan. We'll utilize the textures to fill in the stockpile footprints. Hit the

'Click to select image' button in the *Texture* row.

The texture files from figure 68 can be found in your root project directory folder. In this case, the Embankment material stockpile footprint will be 'tailings' texture and

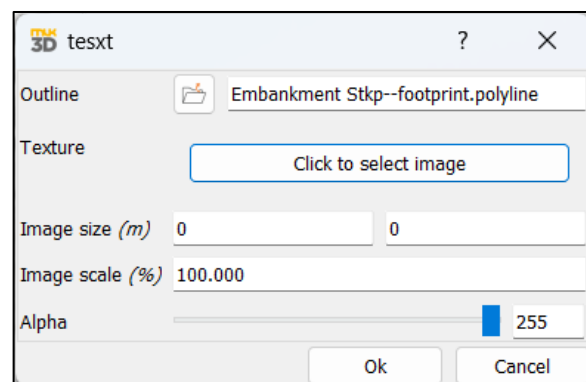


Figure 70: Texture outlines

the topsoil stockpile footprints will be 'dirt' texture. The selection can be seen in Figure 71 below.

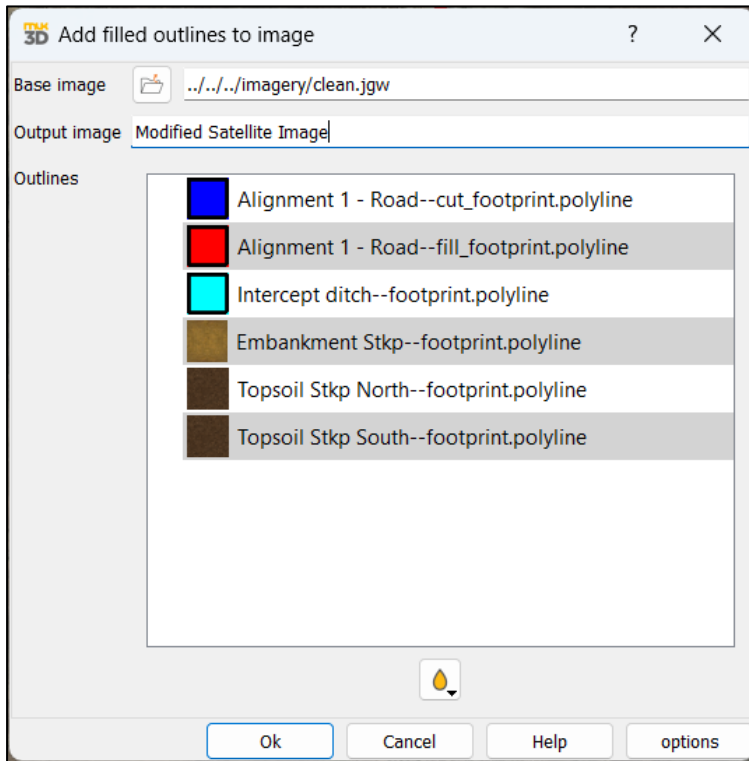


Figure 71: Add filled outlines to image selections

Hit Ok and two new files of your *Output image* will be created in your active work folder. One will be jpg and the other a .jgw. Drag and drop the .jpw file you're your final merged grid surface.

Additionally, we'll make the pond surface visible to highlight the presence of the sump. And finally, make the 500m alignment ROW polylines visible for visual reference. Go to **Imagery > Export**. There you can either copy or save the imagery you see in the main viewer. The imagery can be seen in Figure 72 below.

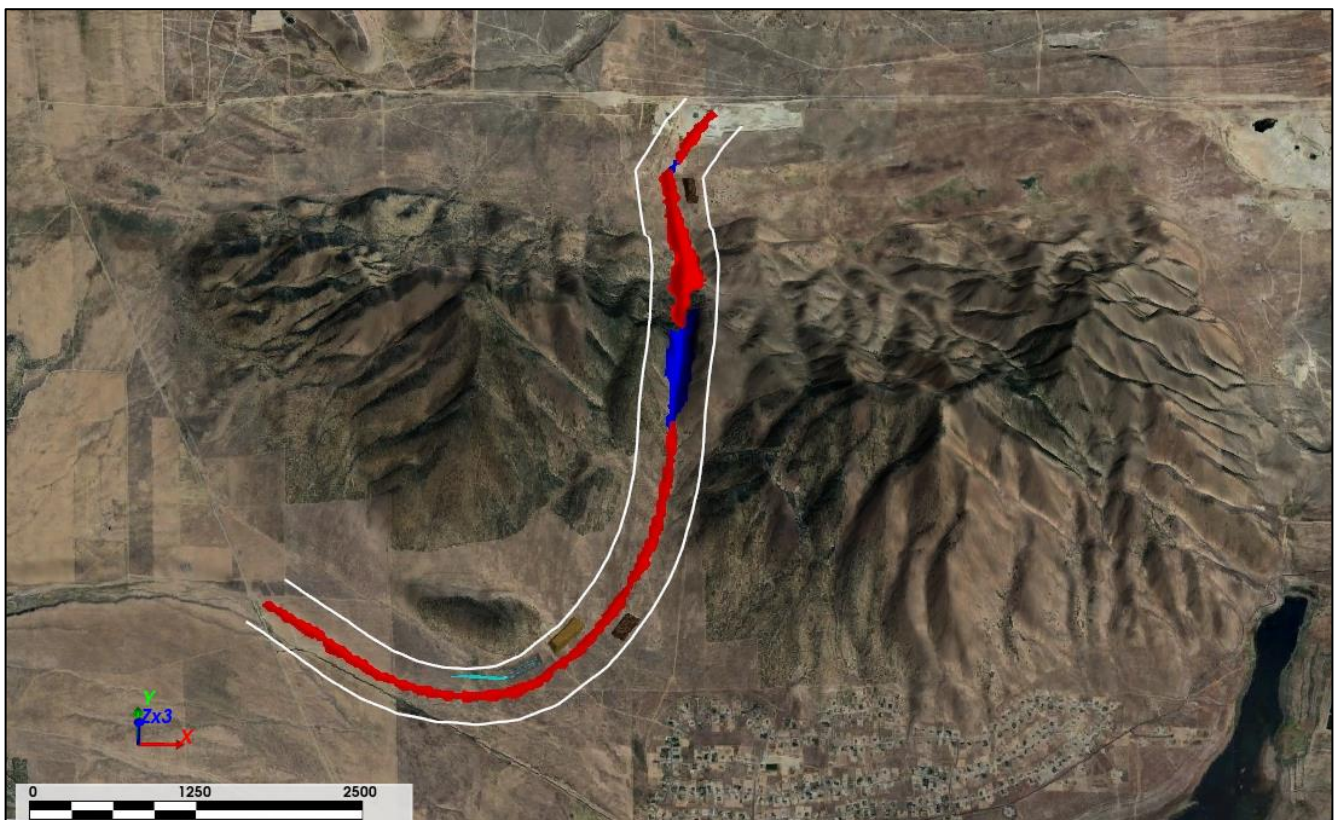


Figure 72: Modified satellite imagery overlaid over topography