AUTODESK

The benefits of using Grading Optimization for Civil 3D

Executive summary

This study explores 5 typical areas of site grading common to the civil and site design industry. Designed by Autodesk and commissioned to an outside consultant, this study looks at direct comparisons of the time, effort, and perceived benefit of completing each specific task using the standard grading tools in Autodesk® Civil 3D® software versus the same tasks using the capabilities in the Grading Optimization for Civil 3D* (Grading Optimization) toolset.

*Grading Optimization for Civil 3D is available to customers with a subscription to the Autodesk® AEC Collection or an Autodesk Enterprise Business Agreement.
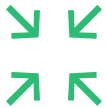
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Key findings

Gained

74% overall productivity gains.

This study shows that grading tasks completed with the Grading Optimization toolset saved more than 2 hours of grading time when compared to the nearly 3 hours needed to conduct the same tasks using the standard grading tools in Civil 3D.

Reduced

In addition to the concrete performance gains measured, this study observed that, because using Grading Optimization does not require constant input from the user while it iteratively grades the site, this allows for many more grading options to be explored with significantly reduced user effort.

One example of this efficiency gain due to the reduction in user action was in pond storage volume requirements. When the storage volume needed to be met, Grading Optimization automatically iterated on grading alternatives and achieved an optimal grading plan that met those requirements in a single cycle. To achieve this grading plan using the standard Civil 3D grading tools would have required several user adjustments and several passes of analyzing the stage storage volume.

Because Grading Optimization iteratively solved for an optimal grading option based on target parameters and with much less user interaction – as in the case of the pond volume example – achieving an optimal grading plan is more time and effort efficient.

The study

This study looked at 5 areas of civil site design that Grading Optimization can help users complete more efficiently. It compared these areas to how they would be approached with the standard grading tools in Civil 3D.

The tests conducted used small building sites that included similar building pads, parking areas, retention ponds, and an area that may require a retaining wall. For the testing of individual workflows, the chosen site areas were roughly 10 acres of development. To test the workflows combined for overall comparison, the chosen sites were roughly 16 acres of development. Each test was run on a unique site so as not to bias choices made during the individual grading operations.

The existing ground conditions for each project were gathered from Autodesk® InfraWorks® models of the project areas. This creates an early project model, prior to survey gathered data, at a phase where Grading Optimization or early surface grading efforts would be used.

The Grading Optimization tools were set to run 25,000 iterations at low-poly mesh quality. The results using Grading Optimization were determined to be successful when the feasibility convergence graph flattened to a minimal proximity measurement change and was not run to the full 25,000 iterations.

Time measurements compared the total time required using the standard grading tools in Civil 3D versus the total time required for Grading Optimization.

All tasks and functions had multiple workflow options. In all cases, the user-task workflow chosen was meant to be the most direct and familiar for the test user to complete in a time-efficient manner. Some users may choose a slightly different process and may or may not experience a different efficiency result, perceived level of effort, or perceived benefits.

This study was conducted against these 5 areas of civil design workflow:

1. Mass site grading
2. Building pad and parking lot
3. Retaining walls
4. Pond creation and storage volume adjustments
5. Overall project grading comparison

A detailed description of the study follows.

Design task 1

Mass site grading

Prior to detailed grading of the site, areas of the site need to be graded to even out the site pad and create appropriate general drainage. The site was graded at not more than 4:1 slope, with tie-in grading to the pad at not steeper than 2:1 slope. Grading near where the building and parking would later be designed was limited to 2% grading.

Steps

Standard Grading Tools in Civil 3D

- Assign Elevations from Surface to each corner of the grading extents feature line.
- Create rough pad area feature lines and fix elevation points where feature lines cross.
- Adjust the slopes of the feature lines.
- Add elevation points to force drainage in appropriate locations.
- Build a surface and add feature lines as Breaklines.
- Edit and adjust feature line points and elevations to refine grading.
- Add incremental elevation points to facilitate triangulation.

Grading Optimization for Civil 3D

- Offset the grading extents line to create a rough pad area.
- Create a polyline area for grading slopes closer to the building and parking areas.
- Draw a polyline that will influence drainage for the site.
- Assign the zones for the grading extents, the rough pad, the closer pad, and the drainage line.
- Run the Optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.

Standard Grading Tools in Civil 3D	Grading Optimization for Civil 3D	Productivity gain using Grading Optimization for Civil 3D
20:51 min	4.25 min	**16:26 min (78%)**

(Figures shown in minutes and seconds)

Special notes:

Using the standard Civil 3D grading tools not only took longer to complete, but the resulting plan was left in a slightly rougher form. We could add more grading details to smooth out the contours, but it was decided to move on and adjust these areas in the finer detailed grading.

Feature line slopes can be adjusted to create proper drainage.
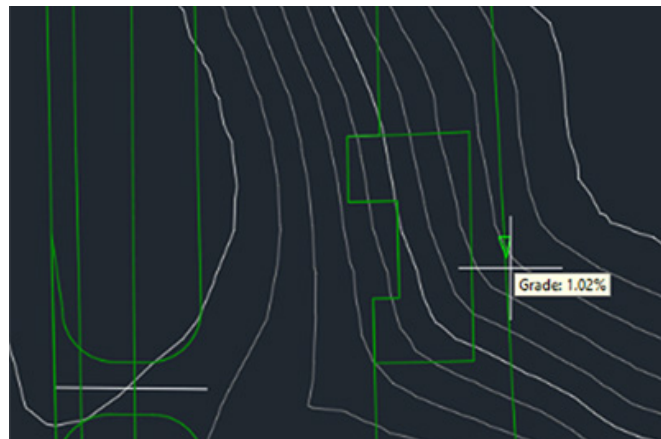
The convergence plot flattens when the optimal grading has been achieved and the Optimizer can be ended.
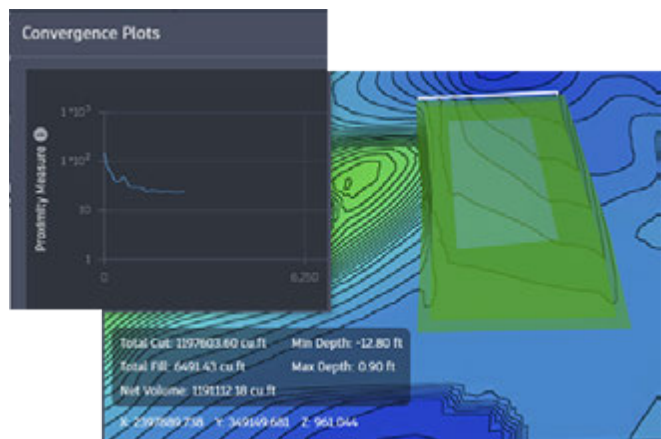
Design task 2
Building pad and parking lot

In this section we tested the grading of the building pad and the parking lot. This represents a finer grading and is concerned with drainage, as well as vehicle and pedestrian use. The building pad is graded flat at an elevation to prevent drainage towards the building. The parking area was graded away from the building at no greater than 2% grade.

Steps

Standard Grading Tools in Civil 3D

- Set the parking area elevations at the tie-in to the street and grade back toward the pad grading.
- Set the parking area feature line slopes and elevations.
- Set the building pad elevation to match the parking area edge.
- Further refine the feature line elevations from the building pad.
- Create a surface and add the feature lines and boundaries.
- Analyze the surface for drainage and make adjustments.
- Add a COGO point for low point drainage inside the parking area.
- Add Breaklines to further refine and adjust the surface.

Grading Optimization for Civil 3D

- Assign a grading extent for the parking area and building. Include max slope parameter.
- Assign the parking area with a max slope and drain slope minimum parameter.
- Assign the building pad as level grading with no set elevation, and no depth of material.
- Create a drain line to encourage flow away from the building.
- Turn off the mass grading extents so the parking extents will be used.
- Run the Optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.
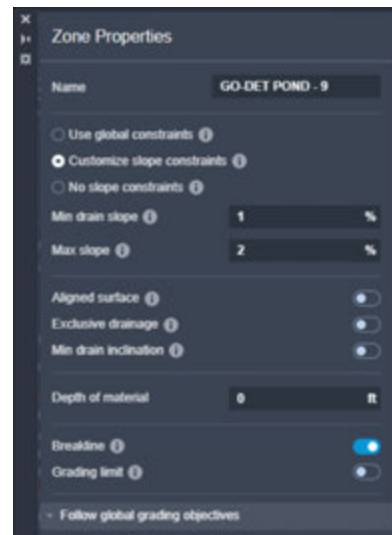
Standard Grading Tools in Civil 3D	Grading Optimization for Civil 3D	Productivity gain using Grading Optimization for Civil 3D
33:00 min	4:10 min	**28:50 min (87%)**

(Figures shown in minutes and seconds)

Special notes

An important aspect of this grading was encouraging drainage away from the building while draining off the surface. Grading using standard Civil 3D grading tools required much more manual iterative adjustments, while Grading Optimization only required drain lines to encourage the automated iterations to create better drainage.

Zone properties identify the parameters in which the Optimizer is allowed to iterate to find a solution.

The building footprint is placed, and elevation adjusted with the Elevation Editor.

Design task 3
Retaining walls

A retaining wall was graded into the project at a location of higher elevation difference and drainage slope. This was designed to better transition the graded elevations while providing safe drainage.

Steps

Standard Grading Tools in Civil 3D

- Create a feature line at the location of the retaining wall, planning for surface tie-in locations.
- Step offset the feature line to the distance and elevation of the bottom of the retaining wall.
- Add the feature lines to the surface.
- Clean and adjust other feature line breaklines to refine the surface.

Grading Optimization for Civil 3D

- Draw polyline at the location of the low end of the wall.
- Draw a closed polyline grading extent.
- Assign the polyline as a retaining wall providing the minimum and maximum elevations. Assign the grading extents area.
- Run the Optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.
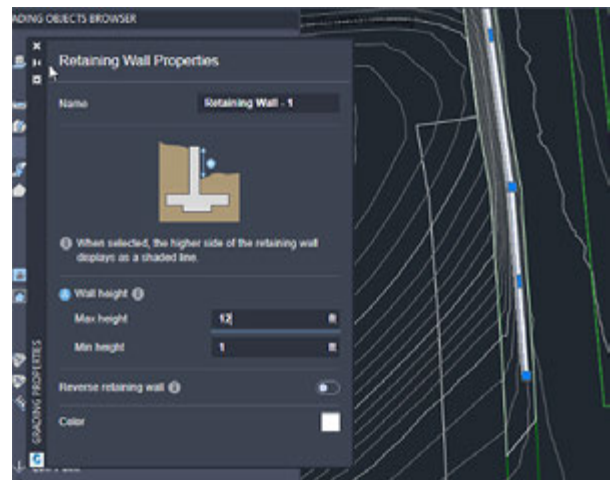
Standard Grading Tools in Civil 3D	Grading Optimization for Civil 3D	Productivity gain using Grading Optimization for Civil 3D
5:53 min	4:26 min	**1:27 min (24%)**

(Figures shown in minutes and seconds)

Special notes:

The Grading Optimization retaining wall works better when a grading limit is placed on the area around the retaining wall. This prevents the grading from branching out and changing other grading areas.

The retaining wall properties provide maximum and minimum elevation of the wall where the polyline object is located.

The Feature Line Edit tools are a key to proper creation of a retaining wall in the standard grading tools in Civil 3D.

The benefits of using Grading Optimization for Civil 3D
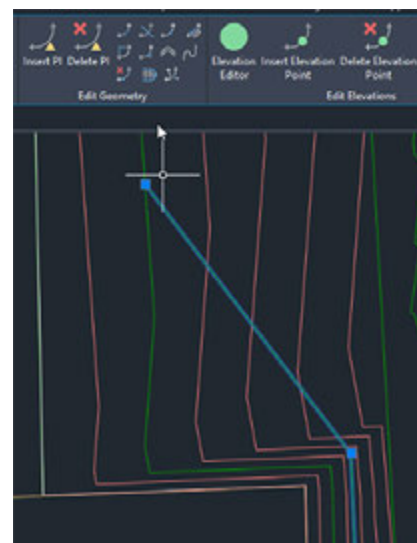
Design task 4

Pond creation and storage volume adjustments

Successful pond grading requires a result that will store a certain amount of volume. This test not only looked at the time to complete a pond grading, but also that of a certain storage capacity. Storage capacity was confirmed using the Stage Storage analysis tools native to Civil 3D. During both processes a new capacity requirement was requested for the project requiring new parameter entries and new gradings. This also required the running of the Stage Storage tools to confirm new storage volumes had been achieved.

Steps

Standard Grading Tools in Civil 3D

- Analyze the surface to locate the pond location and size.
- Create the pond top polyline and translate it into a feature line and set the elevation.
- Add radius curves to smooth the pond edge.
- Use the grading tools to grade to surface outside the pond.
- Use the grading tools to grade the berm top, down to the pond bottom, and infill the bottom.
- Use the Stage Storage analysis to identify the storage volume.
- Make changes to the pond top feature line or to the grading slopes to expand the storage volume.
- Repeat further pond grading adjustments and analyzing the storage volumes until the required volume is achieved.
- Paste the pond grading surface into the site surface.

Grading Optimization for Civil 3D

- Draw the outline of the pond and the space the grading around the pond can take.
- Assign pond and pond limit zones with properties.
- Run the Optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.
- Create a surface and run the Stage Storage analysis to confirm the required storage volume was achieved.
- To adjust to a new higher storage volume, open the Optimizer.
- In the Optimizer select the pond zone and adjust the target storage volume.
- Run the optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.
- Create a surface and run the Stage Storage analysis to check the required storage volume was achieved.

| Standard Grading Tools in Civil 3D	Grading Optimization for Civil 3D	Productivity gain using Grading Optimization for Civil 3D
9:50 min	7:53 min	**1:57 min (19%)**

(Figures shown in minutes and seconds)

Special notes:

- The difference between Grading Optimization and the standard grading tools in Civil 3D was less for this workflow because more options were being explored iteratively. The user effort for Grading Optimization was much less of the amount of time this test took to run.

- In Grading Optimization, the pond zone properties allow for "Allow Boundary Change." This allowed the pond to adjust automatically to create the required storage volume.

The pond zone properties can be graded with a specific storage volume as its goal.
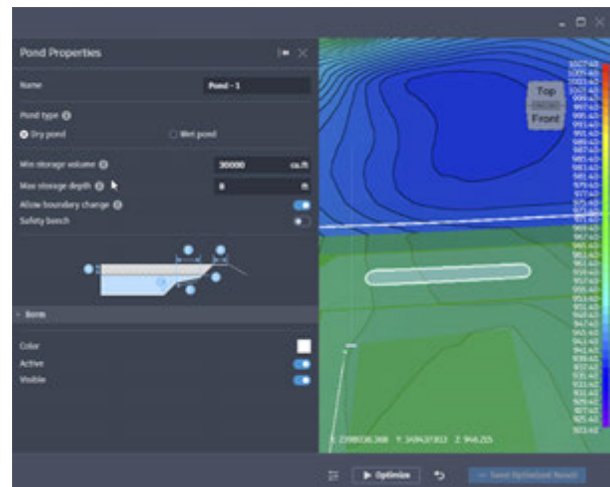
The Grading Editor panorama gives quick access to changing grading criteria.
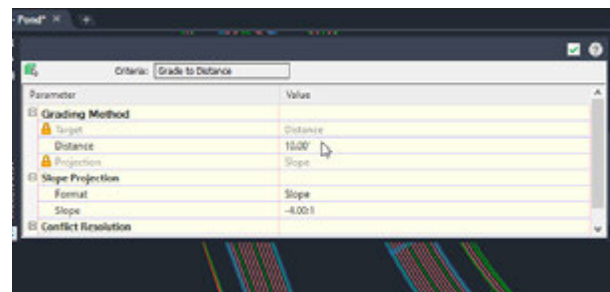
Design task 5

Overall project grading comparison

Completing the overall project grading is meant to test whole project grading rather than the individual tools. Choices and results for an overall grading of a project may differ significantly than those of a focused single function. The same functions were completed in an order appropriate to the overall grading workflow. In both cases the overall process was slightly longer than the individual workflows, which was expected.

Steps

Standard Grading Tools in Civil 3D

- Assign Elevations from Surface to each corner of the grading extents feature line.
- Offset to create the rough pad area feature lines and adjust slopes and elevations.
- Add elevation points to force drainage in appropriate locations.
- Build a surface and adjust feature lines to refine surface by contours.
- Create parking area and building feature lines and adjust elevations and slopes.
- Create a boundary for the parking area and building and create surface.
- Further edit and refine the feature lines.
- Paste the parking and building surface into the Site surface.
- Create a feature line for the retaining wall, tied into the surface at either end.
- Offset the feature line to the high outside edge. Set the elevation to near the contour elevations near the wall.
- Add the feature lines to the site surface and adjust the feature lines as needed.
- Create the pond top polyline and translate it into a feature line and set the elevation.

- Add radius curves to smooth the pond edge.

- Use the grading tools to grade to surface outside the pond.

- Use the grading tools to grade the berm top, down to the pond bottom, and infill the bottom.

- Use the Stage Storage analysis to identify the storage volume.

- Make changes to the pond top feature line or to the grading slopes to expand the storage volume.

- Repeat further pond grading adjustments and analyzing the storage volumes until the required volume is achieved.

- Paste the pond grading surface into the Site surface.

Standard Grading Tools in Civil 3D

- Create a grading extents inside the site.

- Assign parking area and building area zones.

- Draw in drain lines to encourage proper drainage.

- Run the Optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.

- Create a retaining wall polyline and a zone for the retaining wall grading extents.

- Run the optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.

- Create the pond and pond limit zones.

- Run the optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.

- Create a surface and run the Stage Storage analysis to check that the required storage volume was achieved.

- To adjust to a new higher storage volume open the Optimizer.

- In the Optimizer select the pond zone and adjust the target storage volume.

- Run the optimization tool until the feasibility convergence plot flattens out to indicate no more sizeable adjustments can be made.

- Create a surface and run the Stage Storage analysis to check that the required storage volume was achieved.

Standard Grading Tools in Civil 3D	Grading Optimization for Civil 3D	Productivity gain using Grading Optimization for Civil 3D
1:39:06 min	23:22 min	**1:15:44 min (76%)**

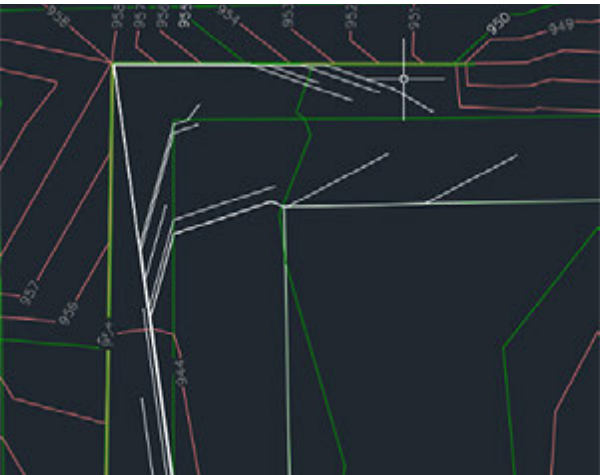(Figures shown in minutes and seconds)

Special notes:

The site dataset for both workflows were slightly larger than the sites used for the individual workflow tests. This may account for a slightly longer test times for both workflows. It is likely that some time differential is from the broader focus on all the workflows tied together rather than the singular focus of the individual workflow tests.

A mixture of Grading Optimization grading zones are combined to optimize the site development.
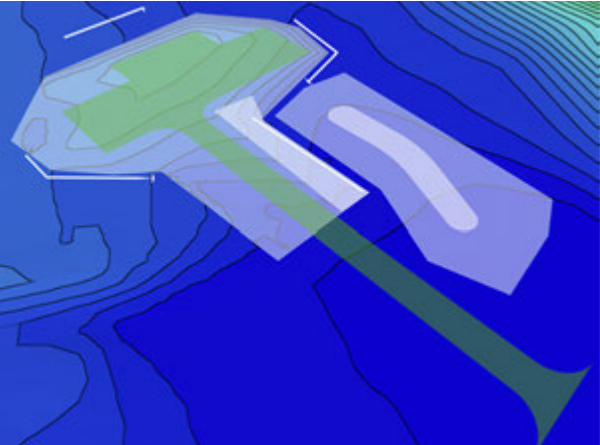
Surface drainage analysis will help identify where more adjustments need to be made.

Final results

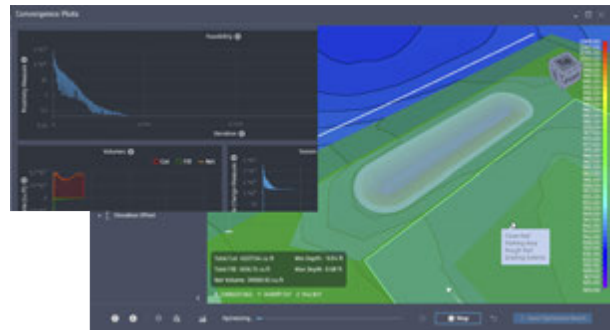| Standard Grading Tools in Civil 3D	Grading Optimization for Civil 3D	Productivity gain using Grading Optimization for Civil 3D
2:48:40 min	44:16 min	**2:04:24 min (73%)**

(Figures shown in minutes and seconds)

These conclusion times are the individual gradings added to the overall gradings in the earthwork workflow.

Notes

- The time used by the Optimizer to conduct the iterations of grading options. Manual grading would require a user to plan a more efficient grading pattern or restart the grading process to find an equivalent or better result. Using the Optimizer provided a better result after the processing time needed with reduced user workload.

- The Grading Optimization visualization tools enabled users to assess the progress of the iterations in real-time. A grading process could be stopped quickly, adjustments made, then restarted to help make sure the optimization logic is correctly laid out. This was NOT needed during these tests but is an option that should be considered in the understanding of the final results.

- A volume calculation was run on the results of both overall workflows. While the sites were of the same size, there were differences in layouts and existing conditions which may account for some differences in calculations. It was observed that the Grading Optimization net volume was less than the standard Civil 3D grading tools earthwork volume by a significant amount – minimizing the cut or fill requirements could represent substantial reductions in project expense. This difference may have been even stronger if the settings had been set to specifically target cut/fill balance, which was not the case.

	Finished earthwork cut volume	Finished earthwork fill volume	Finished earthwork net volume
Standard Grading Tools in Civil 3D	40740.88 cu yd	239.09 cu yd	40501.79 cu yd (cut)
Grading Optimization for Civil 3D	3319.87 cu yd	13846.6 cu yd	10526.73 cu yd (cut)
Difference	**37421.01 cu yd**	**-13607.51 cu yd**	**29975.06 cu yd (cut)**

The convergence plot tracks the iterations of the grading to report the refinement of the site.

Standard Civil 3D grading tools grading is a mix of feature lines and grading objects to complete a site development.
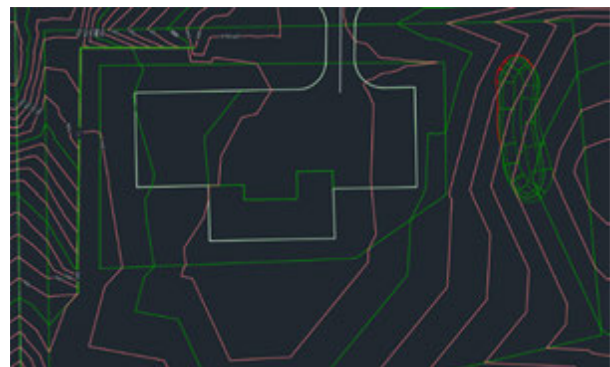
A visual analysis like Hydrology (left) or Result Errors (right) among others can help real-time analysis of the optimization process.
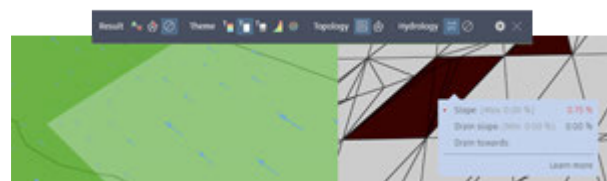
The productivity gains documented in this study were recorded through the course of performing tasks using a specific data set and using Grading Optimization for Autodesk Civil 3D 2022. Using different versions of the software, performing the drafting in different ways, and varying levels of expertise with the software may produce slightly different results. All tests were performed using 'out-of-the box' software.

As with all performance studies, results may vary based on machine, operating system, filters, and even source material. While every effort has been made to make the tests as fair and objective as possible, your results may differ. Product information and specifications are subject to change without notice. Autodesk provides this information "as is," without warranty of any kind, either express or implied.

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