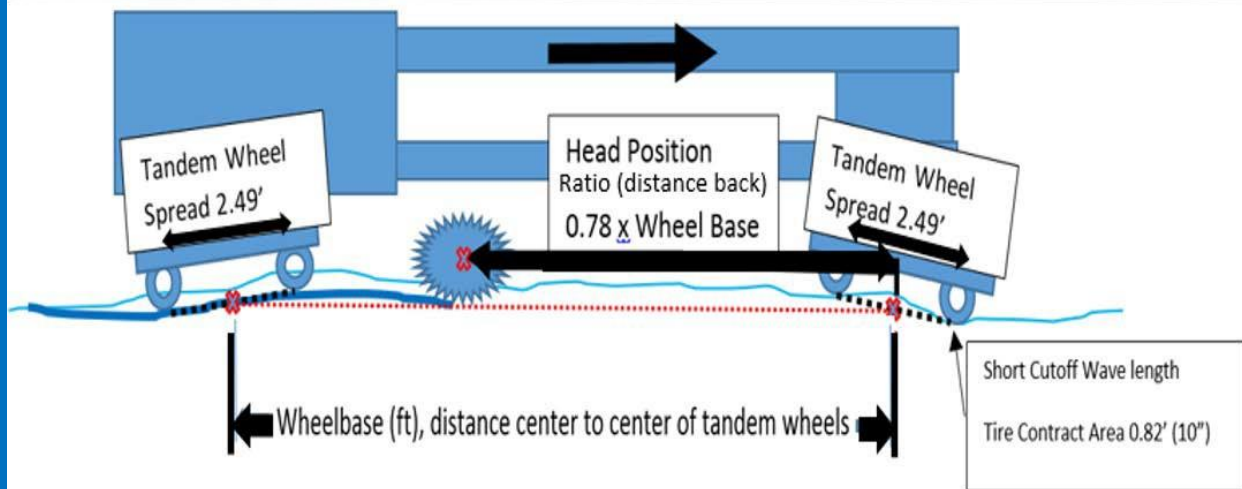
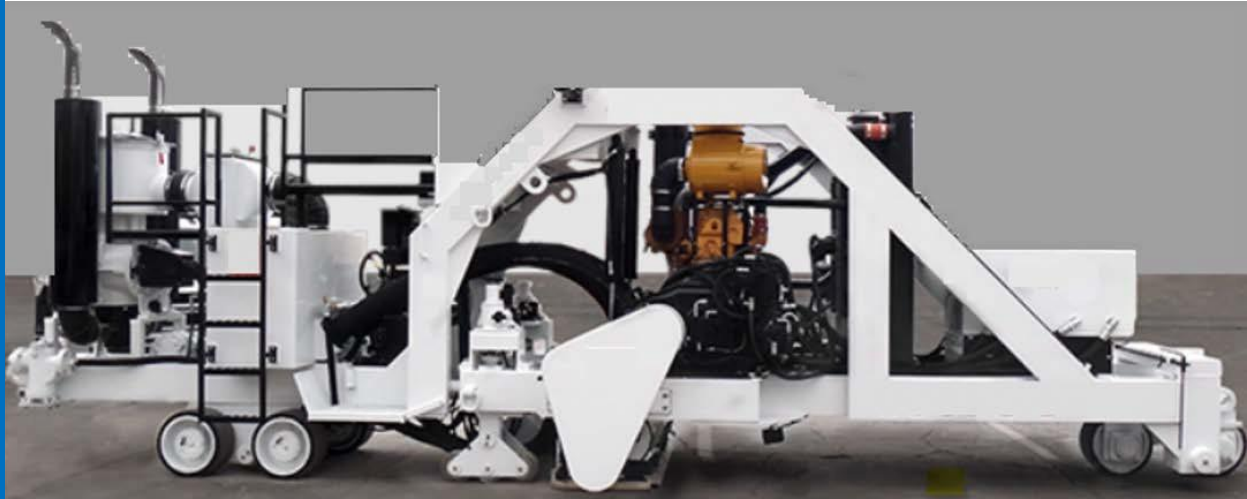


GUIDE TO USING THE ProVAL SMOOTHNESS ASSURANCE MODULE



State of California Department of Transportation
Division of Construction
March 2018



GUIDE TO USING THE ProVAL SMOOTHNESS ASSURANCE MODULE

**State of California Department of Transportation
Division of Construction**

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HOLD HARMLESS AGREEMENT

This document has been developed with review and input from industry and is understood and intended to be used only as guidance in developing grinding plans. In no event is this document intended to be relied on as providing anything other than guidance. In no event will the California Department of Transportation (Caltrans) be liable for any damages, expenses, lost profits, lost savings, or other damages arising out of the use of guidance provided in this document.

SECTION 1 - OVERVIEW

This guide and accompanying online videos were developed pursuant to an approved Rock Products Committee scoping document that identified a need for enhanced ProVAL guidance in developing effective grinding plans.

This guide is intended to:

1. Serve as an “on the job training” tool and reference guide for both Caltrans and contractors.
2. Supplement existing:
 - a. ProVAL training.
 - b. ProVAL User’s Guide.
3. Provide enhanced guidance on use of ProVAL’s Smoothness Assurance Module (SAM) to develop efficient grind plans.
4. Provide Caltrans staff a guide for developing an engineer’s estimate of cost and time for prepaving grinding.

Methods explained in this document are based on Caltrans and industry employee experiences working with the ProVAL SAM software. Users should not interpret the guidance provided herein as the only viable methods for developing grinding plans.

Guidance provided in this document is based on the most recent versions of the free Federal Highway Administration (FHWA) ProVAL software, available as of November 2017.

The sections are summarized in the Table of Contents. If you have minimal experience using ProVAL, review each section; otherwise, use this document and online videos discussed in Section 3 as a supplement to your experience and the ProVAL User’s Guide. All sections referred to appear in this manual unless specified.

SECTION 2 - GRIND SIMULATIONS

The ProVAL software can perform many types of analyses. This document addresses the Smoothness Assurance Module (SAM) used to forecast ride quality after implementation of corrective grinds.

The SAM forecasts ride quality by calculating diamond grinder cutting head elevations over a measured profile. The cutting head elevations are used to forecast new pavement elevations. Existing and predicted ride qualities can then be compared on a single screen. The predicted pavement elevations are calculated using the assumption that the grinder is a fixed frame. The fixed frame assumption estimates the grinder head does not deflect upward as the

grinder moves forward through a cut. The amount of this deflection would vary based on the grinding operator by adjusting the forward speed, or on some grinders the hydraulic pressure controlling the downward force on the grinder head, so a fixed frame assumption removes potential variability.

With incremental user input, the SAM can forecast when the surface would meet a specified smoothness tolerance at grinding locations.

Developing an effective and efficient grind plan using the SAM may require a considerable amount of user input. The process will be covered in detail in Section 10, “Grind Plan Development Methods Using SAM,” of this document.

The grind planning process can be simple or complex, from addressing only areas of localized roughness (ALR), covered in Section 10.1, “Method 1 - Correcting Surfaces for ALR Issues Only” of this manual, to the more complicated process that requires the user to address a high amount of mean roughness index (MRI) problems as well as localized roughness, covered in Section 10.3, “Method 3 - Surfaces with ALR and Significant MRI Issues (Most Difficult).”

The guidance provided in Section 10.1 is intended to guide a novice user through developing a basic grinding plan. The guidance in Section 10.3 is intended for a more experienced user. It's not essential to understand Section 10.3 if you need to only develop grinding plans addressing ALR (for example, prepaving grinding planning).

SECTION 3 - ProVAL ONLINE TRAINING

Videos are available to supplement the information covered in this guide. There is one video for each of the 12 sections covered in this guide. The videos can be accessed on the Caltrans Division of Construction Training website. Access to these videos is granted only after the user accepts conditions in the “Terms of Use” at:

<http://www.dot.ca.gov/hq/construc/training.htm>

SECTION 4 - ProVAL SOFTWARE VERSIONS

The two most recent versions are ProVAL versions 3.5 and 3.6. There are significant differences in the two versions. Users should be aware of the primary differences.

Section 4.1 - Recommended Version for Caltrans Employees

For Caltrans employees, it is recommended that only version 3.5 be used to develop the engineer's estimate for prepaving grinding. Refer to Section 4.3 for reasoning.

To have this software installed, create a service desk ticket at the following internal webpage:

<https://it.onramp.dot.ca.gov/>

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If version 3.6 (3.61.17 released Aug. 26, 2016) has been installed, it is recommended you request that version 3.5 be installed for developing grinding plan estimates.

Section 4.2 - Recommendation for Non-Caltrans Employees

For non-Caltrans employees, an official recommendation will not be made.

Section 4.3 - ProVAL Version 3.5 Versus Version 3.6

ProVAL's Smoothness Assurance Module (SAM) provides a suggested list of grinding locations for each wheel track. There are differences in how versions 3.5 and 3.6 present the information (see Figure 4-1).

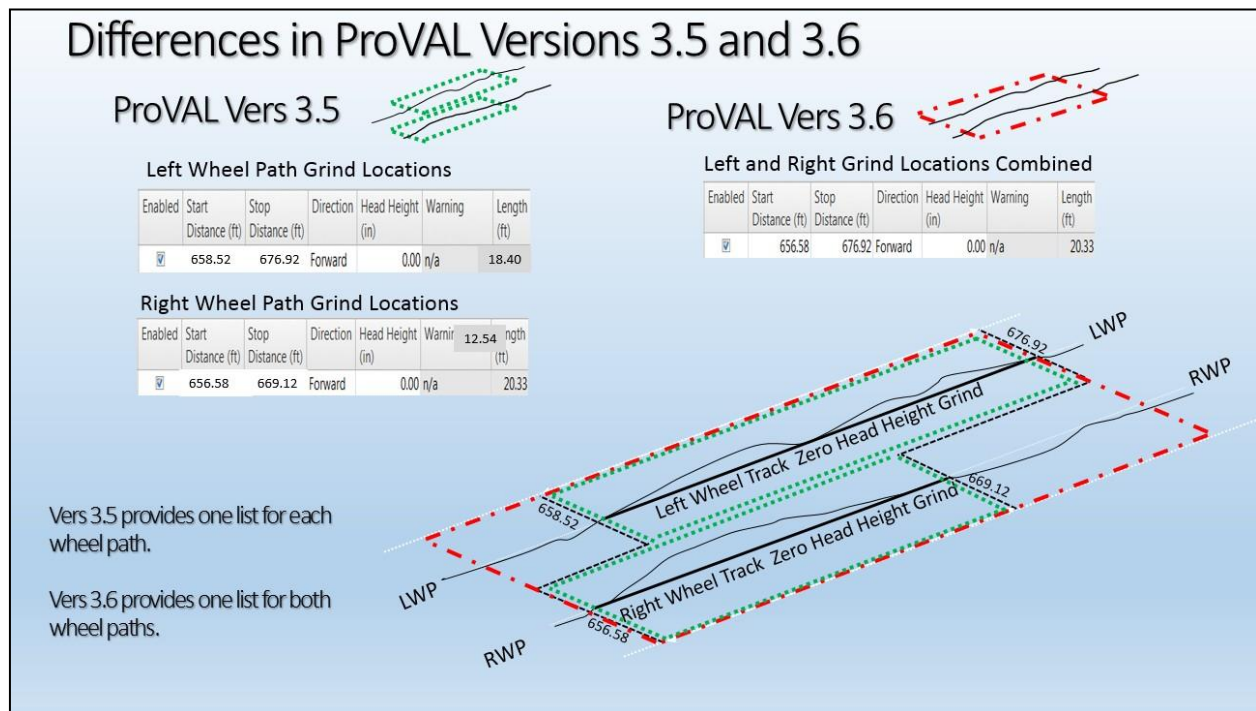


Figure 4-1: Differences in Grind Simulations

Version 3.5 develops the auto-grind list of locations by wheel path. Version 3.6 develops a single list covering both wheel paths. The list developed by version 3.6 does not provide information indicating if the grind is required on one or both wheel paths.

When corrective grinding may only be required in a single wheel path, (for example, HMA surfaces), using version 3.6 can lead to overestimating the amount of required grinding.

Version 3.6 did correct the plotting of short continuous roughness, stopping the plotting within 12.5 feet of defined "leave-outs."

Section 4.4 - Downloading ProVAL

Both versions of ProVAL may be downloaded at no cost from <http://www.roadprofile.com/>. The older version 3.5 can be found by navigating to "Software>Previous Version."

Note that both versions 3.5 and 3.6 can be installed on your computer at the same time. If you have both installed, verify that your computer's "Default Programs" is set to make sure that double-clicking a *.ppf or *.ppv file opens the version you intend to use.

SECTION 5 - USING TEMPLATES

Section 5.1 - Setting Thresholds, Grinder Dimensions, and Comparison Screens

Understanding how to use templates can save you from having to repeatedly enter project criteria. In the Smoothness Assurance Module (SAM) in a single named template, you can save settings for:

1. Ride Quality Index (for example, International Roughness Index [IRI] for analyzing a single wheel path). Using version 3.5, we only use SAM to model grinding plans for a single wheel track.
2. Short Continuous Segment Length and Threshold (for example, 25 feet, and 120, 160, or 180 inches per mile or other value).
3. Long Continuous Segment Length and Threshold (for example, 528 feet and 60 or 75 inches per mile).
4. Fixed Interval Length and Threshold (for example, 528 feet and 60 or 75 inches per mile).
5. Comparison Screen (typically set to "Profile," 300-foot Butterworth High Pass Filter).
6. *Grinder Dimensions.
7. Histograms (typically no need to adjust these).

When a template is saved, the information is saved with your version of the ProVAL software, not the individual inertial profile data file.

You can later apply these template settings during the analysis of any inertial profile data file.

The best practice before saving a template is to visit each screen to confirm the settings are how you want them.

*** Note:** Refrain from saving template settings until you get to the point where you are entering grinder settings to avoid mistakenly applying an old set of grinder dimensions from a template to a profile.

Section 5.2 - Smoothness Assurance: Input Screen

Navigate to the Smoothness Assurance Analysis screen, by clicking the Analysis button in the top tool bar, as shown in Figure 5-1. In the drop-down select, "Smoothness Assurance."



Figure 5-1: ProVAL Tool Bar with Smoothness Assurance Analysis Module Selected

Figure 5-2 shows Ride Quality Index information. To the right of "Ride Quality Index" select "IRI" to evaluate the roughness of one wheel path at a time. Verify it is not set to "MRI" or any of the other values, such as RN or HRI, which are made available for the other states that use this program.

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Smoothness Assurance: Inputs			
Ride Quality			File
Ride Quality Index			20160401
Analysis	Segment Length (ft)	Threshold (in/mi)	Histogram
Short Continuous	25	160	Histogram
Long Continuous	528	75	Histogram
Fixed Interval	528	75	

Figure 5-2: Smoothness Assurance: Inputs

Section 5.2.1 - Smoothness Assurance - Set the Area of Localized Roughness Criteria

On the “Smoothness Assurance: Inputs” screen shown in Figure 5-2, enter the area of localized roughness (ALR) criteria on the row titled “Short Continuous.”

Note that ProVAL’s definition for “Continuous” is synonymous with moving average, and “Short Continuous” is synonymous with the Caltrans definition for ALR, where “Short” is the 25-foot moving average segment length used to determine localized roughness values.

In the threshold column, enter the value for ALR covered by your specifications. Examples of the *Standard Specifications* for ALR are shown in the following table.

Table 1: Common ALR Values

Surface being measured	ALR (max) in/mi
Cold in place recycled surface	240 in/mi
Existing asphalt concrete surfaces to be overlaid with more than 0.25 feet of HMA	180 in/mi
New HMA pavement	160 in/mi
Concrete pavement	120 in/mi

For example, if your project has an ALR criteria of 160 inches per mile, you would enter the values shown in the red boxes in Figure 5-3.

Smoothness Assurance: Inputs			
Ride Quality			File
Ride Quality Index			20160401
Analysis	Segment Length (ft)	Threshold (in/mi)	Histogram
Short Continuous	25	160	Histogram
Long Continuous	528	75	Histogram
Fixed Interval	528	75	

Figure 5-3: Entering ALR Criteria

Section 5.2.2 - Smoothness Assurance - Set the Mean Roughness Index Criteria

If your project has a Mean Roughness Index (MRI) criteria of 75 inches per mile, enter the values shown in the red box in Figure 5-4 on both lines. If it’s 60 inches per mile, enter 60 rather than 75.

Smoothness Assurance: Inputs

Ride Quality

Ride Quality Index IRI

Analysis	Segment Length (ft)	Threshold (in/mi)	Histogram
Short Continuous	25	160	Histogram
Long Continuous	528	75	Histogram
Fixed Interval	528	75	

Note: Values entered on the long continuous row are not needed by Caltrans. It's simply convenient to set the two values the same. ProVAL includes the long continuous criteria row because some states evaluate it.

Figure 5-4: Entering MRI Criteria

Section 5.2.3 - Smoothness Assurance - Set up the Profile Comparison View

Now set up the comparison screen. The comparison screen allows viewing the corresponding road profile elevations in charts below the roughness plots. This allows you to compare the roughness values for deciding which grinds to keep, eliminate, or modify.

To set the “Profile Comparison” view, see Figure 5-5:

1. In the lower left corner of the “Smoothness Assurance: Inputs” screen, in the “Type” drop-down selector, select “Profile.”
2. Find the blue text to the right of Filter, it may say “none.” Click it.
3. In the resulting Wavelength Filter window. Select “Butterworth High-pass.”
4. Then enter 300 in the “Long Cutoff Wavelength (ft)” field.

Figure 5-5: Setting Up the Profile Comparison View

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Setting the Long Cutoff Wavelength filter does not affect IRI values; it only affects the view of the road profiles as displayed in the comparison screen. Figure 5-6 shows the effects. The higher the value in the Long Cutoff Wavelength filter, the flatter the profiles will appear. Experimentation and input from other state departments of transportation indicate that 300 feet is a good value for viewing most road profiles at the 0.1-mile scale setting. A higher value, for example 1,000 feet, will make the bumps indistinguishable. Using too low of a value, for example, 100 feet, will make everything look like a bump.

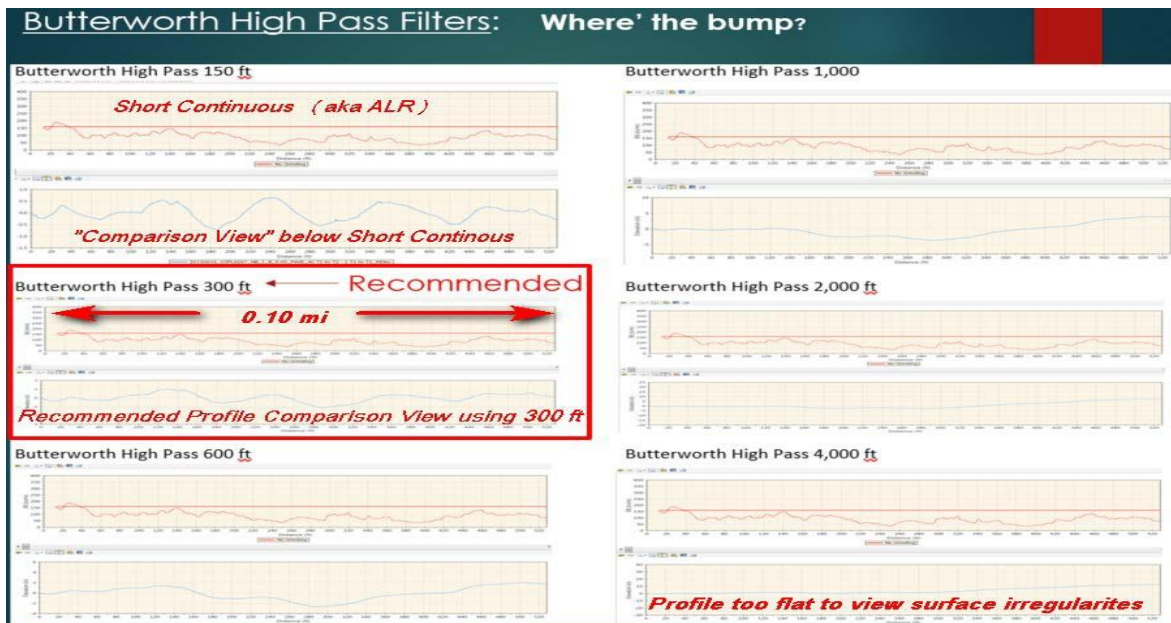


Figure 5-6: Comparison of Profiles Using Various Butterworth High Pass Filter Settings

Section 5.2.4 - Smoothness Assurance- Set the Planned Grinder Dimensions

The second variable that affects the list of locations generated by the auto-grind function is the grinder dimensions.

The grinder dimensions are entered into ProVAL on the “Smoothness Assurance: Grinding” screen. Navigate to this screen from “Smoothness Assurance: Inputs” by clicking the “Navigate” button.

Activating this “Navigate” button requires you first select a single wheel path then analyze a single wheel path. To analyze a single wheel path, you must only check one wheel path. Figure 5-7 shows the selection of the left wheel track on the Smoothness Assurance:

Inputs screen to the right of Ride Quality.

File	Profile	Section	Apply 250mm Filter
20160126_ SB_1_B_40.3_33.9_PAVE_RHMAG	<input checked="" type="checkbox"/> Left	Full	<input checked="" type="checkbox"/>
	<input type="checkbox"/> Center		<input type="checkbox"/>
	<input type="checkbox"/> Right	Full	<input checked="" type="checkbox"/>

Figure 5-7: Select a Wheel Path to Analyze

Smoothness Assurance: Inputs

Ride Quality

Ride Quality Index: IRI

Analysis	Segment Length (ft)	Threshold (in/mi)	Histogram
Short Continuous	25	180	Histogram
Long Continuous	528	75	Histogram
Fixed Interval	528	75	

Comparison


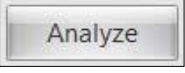
Type: Profile

Straightedge Length (ft): 10.00

Filter: [Butterworth High-pass \(300.00 ft\)](#)

Figure 5-8: Double-Check Your Inputs

But first, double-check to make sure you still have IRI selected in the Ride Quality Index field and that your thresholds are set to your specifications, as in Figure 5- 8.

After selecting the single wheel path (Figure 5-7), the “Analyze” button  will activate  and allow you to click it.

Once the wheel path has been analyzed, the “Navigate” button will then activate.



Click “Navigate,” and in the drop-down, select “Grinding.”

Note: Selecting values from this drop-down list changes the name of the resulting screen to “Smoothness Assurance: xxxxxx,” where “xxxxxx” is what you selected from the “Navigate” drop-down list. In Figure 5- 9, we selected “Grinding.”

The grinder dimensions are entered into the left portion of the Smoothness Assurance: Grinding” screen.

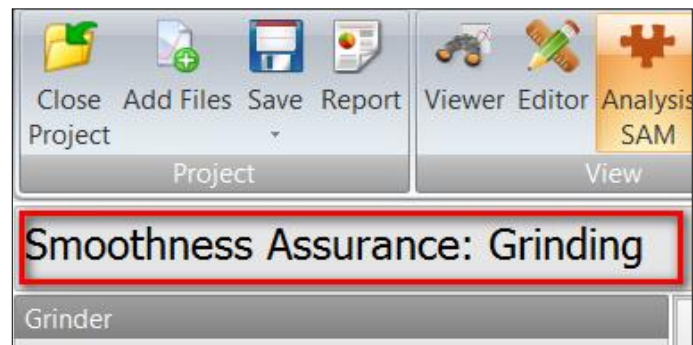


Figure 5-9: Grinding Screen

If you plan to use grinders with different dimensions, you may find it beneficial to use the “Export” function (described in Section 6), to evaluate portions of the lane as a separate file. Separate files are required because ProVAL limits the grinding analysis to one set of grinder dimensions per file.

Tip: If you are a contractor planning to develop grinding plans for pavement to meet a specified tolerance, for the most accurate model, use the dimensions from the grinder you plan to grind with. Pay attention to these settings. Any future grind plan you develop will be based on a “model” that uses these dimensions. Changing the grinder dimensions after developing the list of grinds will not automatically change the grind list for the job. Recognize that the auto-generated grind list and the defined grinder work together in the modeling. Changing grinder dimensions will change the start and stop locations in the auto-grind list.

Section 5.3 - Recommended Grinder Settings for Estimating Prepaving Grinding

If you are a project engineer estimating the amount of prepaving grinding during the design phase, you will need to assume your grinder dimensions. As your grinding plan will be used for estimating purposes only, it's recommended to use the dimensions shown in Figure 5-10.

Smoothness Assurance: Grinding

Grinder

Grinder Type: Custom

Maximum Grinding Depth (in): 0.30

Head Position: 0.78

Wheelbase (ft): 14.5

Tandem Spread (ft): 2.49

Short Cutoff Wavelength (ft): 0.820

Figure 5-10: Recommended Grinder Dimensions for Estimating Prepaving Grinding

Section 5.4 - Saving SAM Template(s)

After you have correctly entered all the information required in the previous steps, click through the previous screens to double-check your settings, as in Figure 5-11.

Smoothness Assurance: Inputs

Ride Quality

Ride Quality Index: IRI

Analysis

	Segment Length (ft)	Threshold (in/mi)	Histogram
Short Continuous	25	2.8	100 Histogram
Long Continuous	25	2.8	75 Histogram
Fixed Interval	25	2.8	75

Comparison

Type: Profile

Straightedge Length (ft): 10.00

Filter: Butterworth Highpass (60000 ft)

Smoothness Assurance: Grinding

Grinder

Grinder Type: Custom

Maximum Grinding Depth (in): 0.30

Head Position: 0.78

Wheelbase (ft): 14.50

Tandem Spread (ft): 2.49

Short Cutoff Wavelength (ft): 0.820

Figure 5-11: Double-Check Your SAM Inputs Before Saving as a Template



Figure 5-12: Using the “Template” Button to Name

Click the “Template” button, as in Figure 5-12, then “New.”

Enter a name that corresponds to the template being saved, then “OK.”

For example, the template that corresponds the settings in Figure 5-11 could be named using the following convention in Figure 5-13.

180-75-14.5

180 indicates the Short Continuous Threshold

75 indicates the Fixed Interval Threshold

14.5 indicates the grinder wheelbase

Note: Use care in naming the template as ProVAL does not prevent you from using the same name twice.

Figure 5-13: SAM Template Naming Convention

Optionally, save the template as a default value, then click “OK.”

Now that you have saved the template, the corresponding settings can quickly be applied to all the fields by selecting the “named template” and “Apply.”

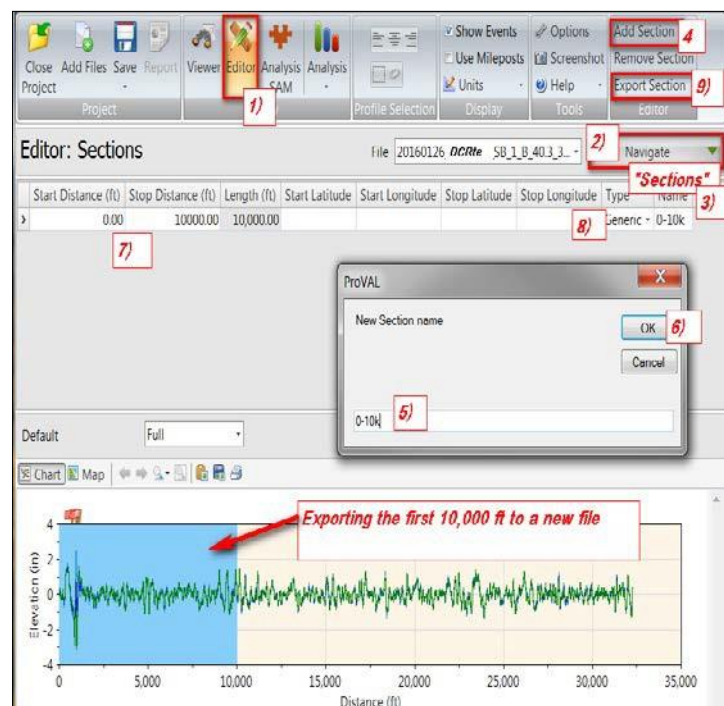
Section 5.5 - Saving the Ride Quality Module Templates

The ProVAL Ride Quality module is used for developing reports on measured conditions, not forecasting smoothness based on a list of grinds. Like the template function in the SAM, the user can also set up templates for this module.

Recognize that SAM templates don’t carry over to the Ride Quality module.

1. You need to get a crew working on the first portion of a grinding plan, while you finish developing the remainder.
2. You need to shorten the processing time to check the results of a series of modifications during the iterative process of developing a grinding plan.
3. Your computer crashes while attempting to process a grinding analysis on a longer section of road.
4. A portion of project is much rougher than another portion. Using two different methods (described in Section 10) to develop a grind plan can be more efficient.

1. Click the “Editor” button
2. “Navigate” to “Sections”
3. Select “Sections”
4. Click “Add Section”
5. Enter a section name
6. Click “OK”
7. Enter the limits you want to export
8. In the Type field, select “Generic”
9. Click “Export Section”
10. “Save As”; save the file with the name and location you choose



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SECTION 7 – OVERVIEW OF ProVAL’s AUTO-GRIND FUNCTION

Grinding plans are developed by ProVAL’s Smoothness Assurance Module (SAM) in a sub-function titled “Grinding.” A portion of this sub-function automatically generates a suggested list of grind locations. The steps to obtain the auto-grind list vary by version:

- In version 3.5, click the “Auto-Grind” button.
- In version 3.6, the auto-grind list automatically populates when the user enters the “Grinding” sub-function.
- Both versions include an option to run a “one grind-what if” scenario in which the grinder runs through the entire profile. The steps to run a “one grind” scenario vary by version:
 - In version 3.5, the scenario automatically populates when the user enters the “Grinding” sub-function.
 - In version 3.6, click the “Strategy” button, then select “One-Grind.”

Section 7.1 - Running the “One Grind – What if” Scenario

Running the “one grind-what if” scenario is a good initial step for seeing how a single pass with a zero head height can affect the smoothness of an entire wheel path. Though represented in the table as a single grind, the “one grind-what if” is a model of a single pass with a defined head height (defaults to 0.0 inches) in which the grinder head daylights into and out of a number of grinds. The one grind won’t tell you where the grinder daylights in and out of a cut (a bump in which the grinder is smoothing), but those points can be seen in the “Profile Comparison.”

Additional variations of this “what if” scenario can be evaluated with different head heights. Figure 7- 1 illustrates a “one grind-what if” scenario.

In Figure 7-1, an existing concrete pavement was evaluated for a design strategy. A few of the 0.1- mile sections showed isolated spikes in the profile elevation comparison. A field review of the project indicated that the spikes were likely because of 1 foot long concrete patches at some of the transverse joints. It appeared that these patches may have caused high IRI values, as shown in the short continuous roughness plots. To forecast the effects of simply grinding off the high points of the patches, a “one grind” scenario was run with the head height of 0.1-inch above the zero head height plane. With the head height raised, grinding would only occur at obviously high patch spot locations. This is also a good example of how grinding a short isolated bump can reduce localized roughness over longer stretches of wheel path.

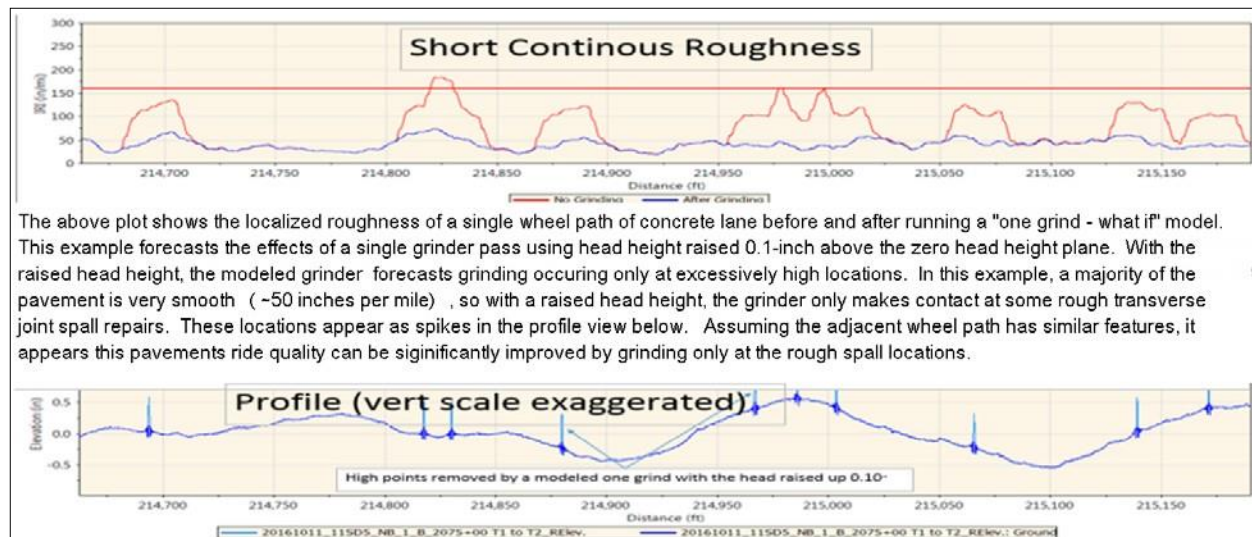


Figure 7-1: Generating a “One Grind-What If” Scenario

Grinding the high points off should lower the mean roughness index (MRI) for that 0.1 mile section and eliminate the three ALR issues in the single 0.1 mile section of wheel path.

Section 7.2 - How ProVAL Develops an Initial Auto-Grind List

The key to successfully using the “Auto-Grind” function is to understand how ProVAL generates the initial list of grind locations.

The algorithm used by ProVAL to develop the initial auto-grind list is a function of:

- the selected wheel path
- the defined grinder dimensions
- the specified short continuous threshold

Modifying the long continuous or fixed interval thresholds has no effect on the initial grind listing. Adjusting the short continuous threshold affects the number of grind locations in the auto-grind generated grind list. See Figure 7-2.

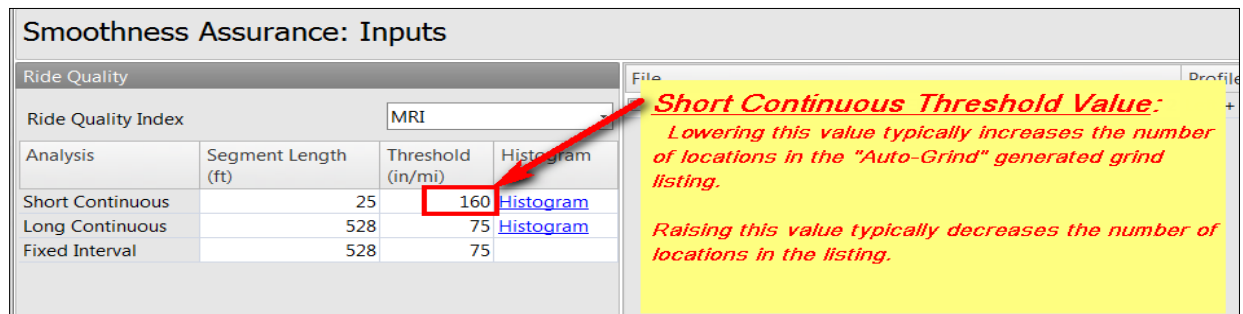


Figure 7-2: Effects of Modifying the “Short Continuous Threshold”

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The algorithm used by the “auto-grind” function is not publicly documented, but appears to list grinds located in a 200- to 250-foot zone in front of each location where localized roughness exceeds the defined “Short Continuous” threshold. See Figure 7-3.

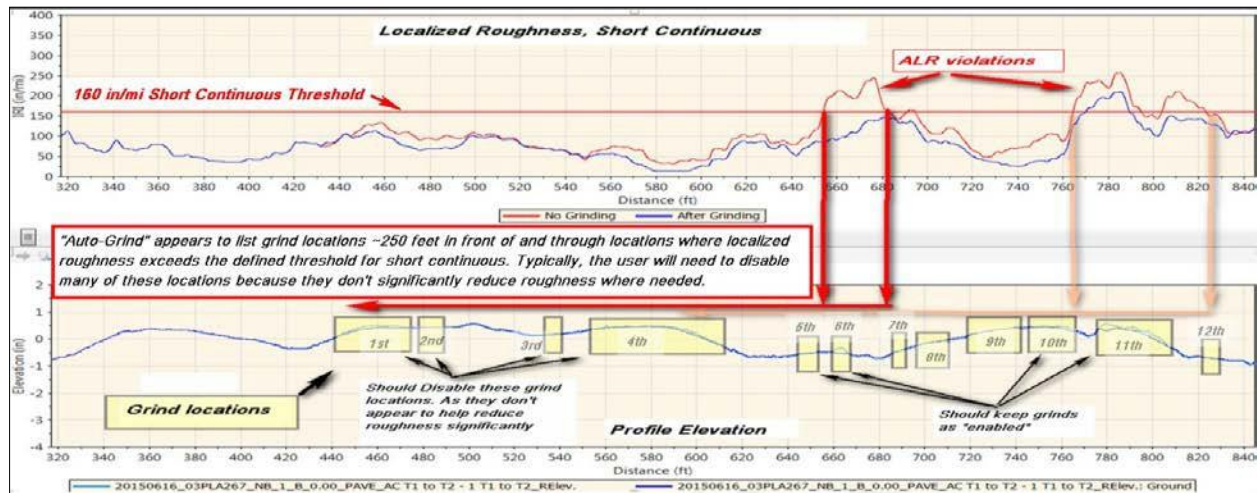


Figure 7-3: Initial Auto-Grind Listings

In Figure 7-3, the grind locations in yellow boxes are from an initial auto-grind list. The start and stop locations are mathematically calculated and presented as the location where a diamond grinder using the defined grinder dimensions would daylight into and out of a cutting condition with a zero head height. This is explained further in Section 7.4. Head height refers to how far the cutting head is from being in a defined plane that passes through the average front and rear supporting elevations. This is explained further in Section 7.3.

By inspection of Figure 7-3, we can make a quick assumption that the first four grind locations aren't needed to eliminate the ALR violation. This and any assumptions are checked by clicking the “Grind” button to run a grind simulation.

Figure 7-4 shows the results of a grind simulation at the same location after disabling the first four locations and a few other locations. In this example, we were able to delete 9 of the 12 grind locations. One of the locations required a second pass. Another required the head height to be lowered 0.06-inch.

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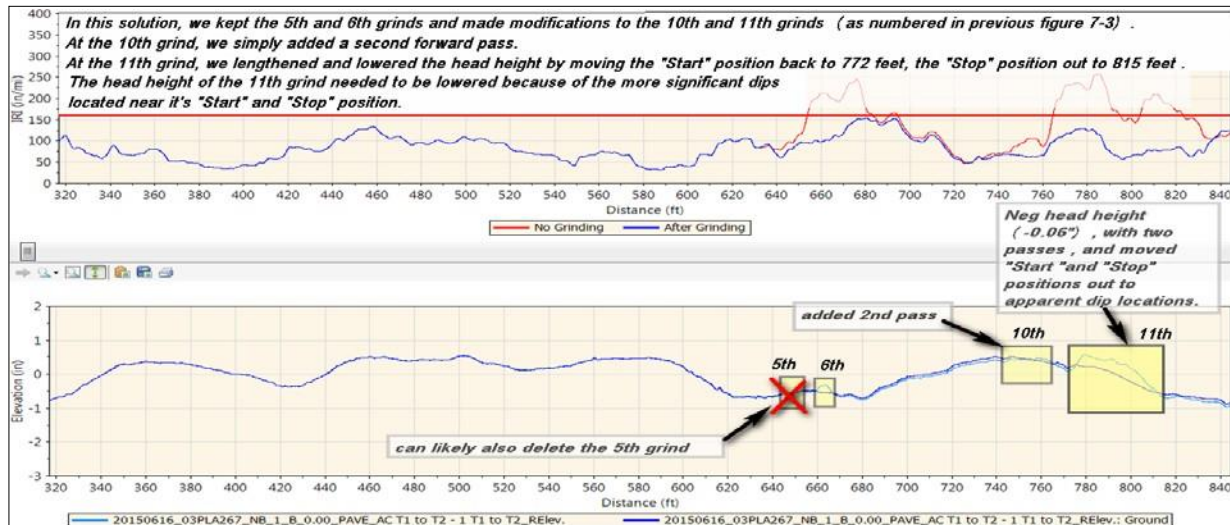


Figure 7-4: Grind Locations After Disabling to Address Localized Roughness

As shown in Figure 7-4, when developing a grind strategy to address ALR, in most cases you will only need to keep grinds that are at or just before locations where the localized roughness exceeds the defined threshold. You will occasionally need to modify some of the listed grind locations by adding a second pass (Forward, Forward), or using a negative head height with modification to the start and stop locations. Modifications will be discussed in detail in Section 10.

In summary, if we simply grind all the locations listed in auto-grind, we may be grinding more pavement than necessary. Auto-grind generates an initial list of grind locations to consider.

Section 7.3 - The Grinder Dimension Variable

Figure 7-5 provides an explanation for what each dimension in the grinder table represents.

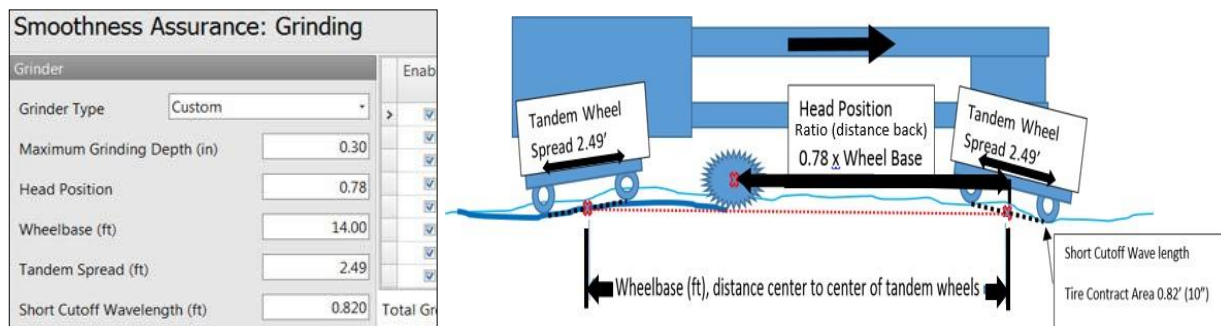


Figure 7-5: Diamond Grinder Dimension Modeling

Section 7.4 - Auto-Grind “Start” and “Stop” Stationing

“Start” and “Stop” grind locations are calculated using the defined grinder dimensions, the road profile elevations, and some basic geometric calculations.

	Enabled	Start Distance (ft)	Stop Distance (ft)	Direction	Head Height (in)	Warning	Length (ft)
>	<input type="checkbox"/>	1207.25	1233.25	Forward	0.00	n/a	26.00
	<input type="checkbox"/>	1235.42	1274.00	Forward	0.00	n/a	38.58

Figure 7-6: Double-Check Your Inputs

When auto-grind is run, the SAM assesses the wheel path 1 inch at a time. At every location, it calculates the stationing and elevation of the supporting wheels and the bottom cutting elevation of the grinder head. The grinder head elevation is assumed to be on a plane that passes through the average supporting points of the front and back tandem wheels (referred to as a zero head height). The supporting wheel elevations are determined as the average elevation of the tire contact areas, the length of the contact area defined as the “Short Cutoff Wavelength.” The wheels are modeled on the previous ground surface elevations when they exist.

As the model assesses the measured profile, every theoretical location where the cutting head begins and ends cutting is maintained in a file as a grind location, but not presented to the user. When an “auto-grind” list is generated, the SAM selectively grabs those that overlap any ALR violation and those that are within a 200- to 250-foot zone in front each ALR violation.

The SAM allows us to model IRI values based on running a grind simulation, as well as making various manual adjustments to: head heights, start and stop values, and a maximum of two passes over each location in the initial auto-grind list.

The predicted grinder head elevations can be viewed in the “Profile” comparison plots immediately below the ride quality plots. If your SAM is not displaying the elevations below the ride quality plots, you need to take steps to set up the comparison screen. See Section 5.2.1 for the steps.

Section 7.5 - Understanding Elevation Plots of Forecast Grinds

When the forecast elevations are in a “cut” condition, they are plotted on the elevation view below existing surface. What’s not obvious is that when the user displays the profiles using the Butterworth High Pass Filter, the elevations are often plotted just above and parallel to the existing grade when there is no cutting and the grinder head is above the existing grade. When the profile comparison filter is set to “none,” this does not occur. See Figure 7-7 for an illustration.

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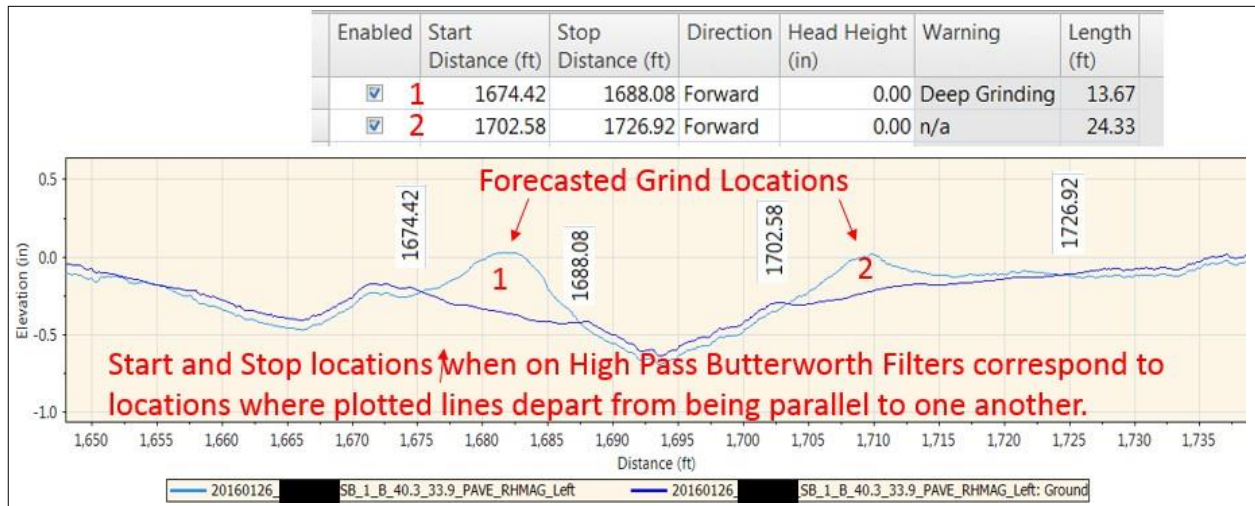


Figure 7-7: Predicted Ground Surface Elevation Plotting Using Butterworth High Pass Filters

The begin and end points of a grind are those locations in Figure 7-7 where the plotted lines of the existing and predicted elevations depart from being parallel with each other.

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The charts in Figure 7-8 show what a comparison profile looks like with and without a filter. Use of the Butterworth High Pass Filter makes the profile differences easy to see.

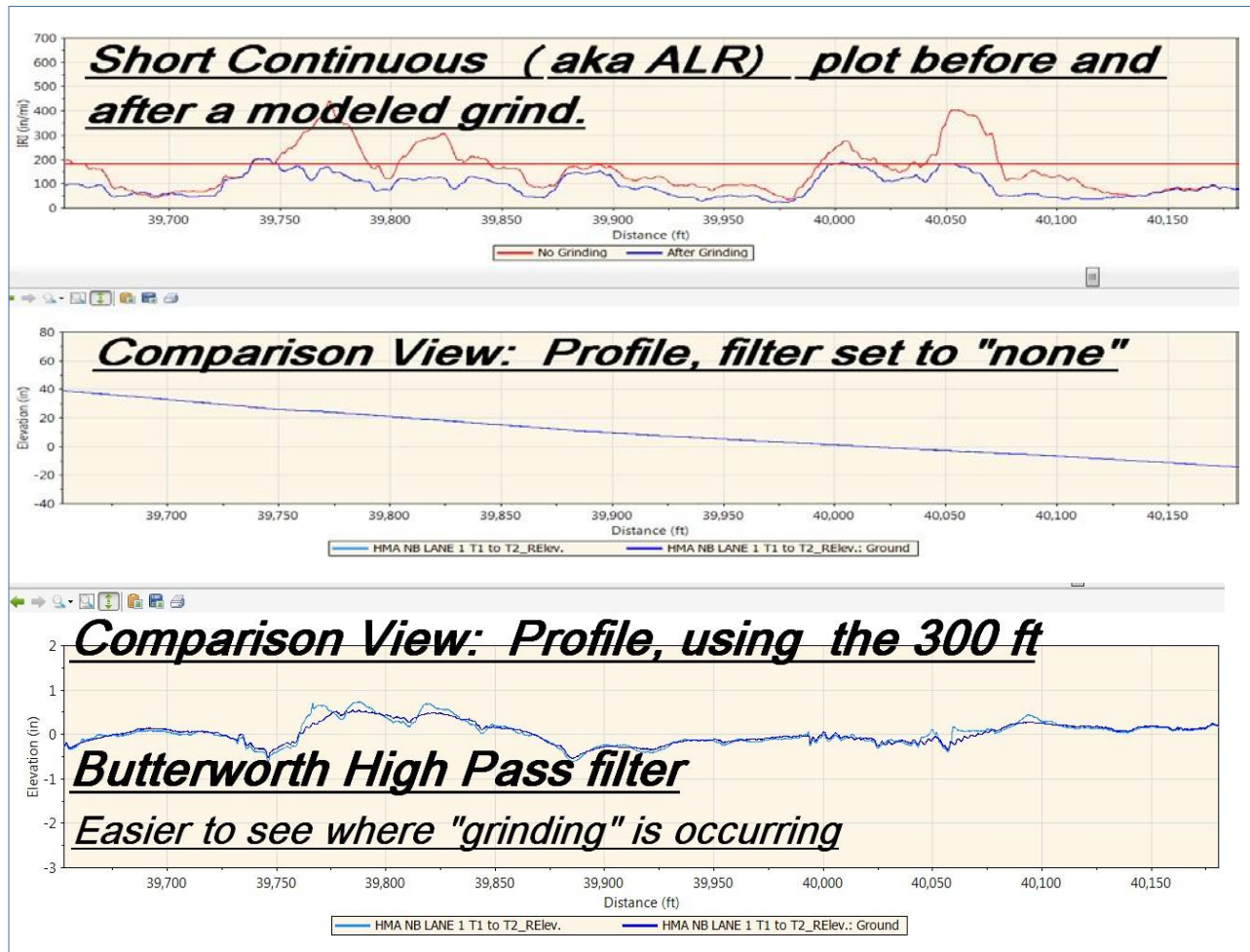


Figure 7-8: Profile Views With and Without a Butterworth High Pass Filter

The use of the filter has no effect on the calculated IRI values, only how the profiles are displayed.

SECTION 8 - REFINING AUTO-GRIND GENERATED LISTS

For an efficient list of grind locations, refinement of the initial auto-grind list is always required. A common error many novice ProVAL users make is to assume the initial list is a final list.

Refinement of any grind list requires running a grind simulation, reviewing the results, making changes to the model, then repeating the process. The number of repetitions can vary based on the profile and the user experience. It is common for this grind planning to require numerous iterations.

Section 8.1 - A Logical Order of Grind Refinements

Running a grind simulation simply requires pressing a “Grind” button, waiting for the calculations, then reviewing the results. The “Grind” button is activated whenever a change to the list of grinds is made.

Making changes to a grind list is typically more effective if made in the following order:

1. Disable grinds with little obvious payback. A questionable grind may be disabled before re- running the simulation. If the simulation indicates the grind was needed, re-enable as necessary.
2. Add a second pass. If an auto-grind doesn't decrease roughness enough, it's very simple to simulate an additional pass. Try changing Forward to Forward, Forward.
3. Change the grinder head height. It's recommended to adjust head heights in no less than 0.06- inch increments at a time. If a lowered head height results in a simulated ground-in step, recognize it can't be replicated in the field because grinders lower their heads until flush with the surface, then drive forward into the bump. If a ground-in step occurs in a simulation, change the start or stop location as necessary to eliminate the step.
4. Change the start and stop locations. Avoid when possible; try adding a second pass. Changing a start and stop typically needs to be performed when a head height is adjusted.
5. Add a grind location. Avoid when possible. The only way to add a grind location is to find a grind that has been disabled and change the start and stop locations. ProVAL SAM does not allow inserting a row between existing grind locations.

Adjusting auto-grind generated start and stop locations, and adding grind locations to a simulated grind listing should be avoided unless steps are taken to review the simulated ground surface to be sure the actual start and stop locations feather into and out of a grinding condition.

The user should always remember that the auto-grind function already identified the start and stop locations using an assumed zero head height for you (see Section 7.4). Changing these locations or head heights can cause increased roughness in the grind simulation and cause more grinding in the field than may be necessary. If the auto-generated start or stop locations or head heights are modified, the user must view the resulting modeled profiles to verify that the modified grinds properly feather into and out of a cutting condition. If they don't, adjustments need to be made until they do. Users who skip this step should anticipate a difference between their modeled smoothness and post grinding smoothness solely

because of the inaccuracy of their model.

Section 8.2 - Using the “Locations” Button

The user can save time correctly using the “enable all, disable all” function under the “Locations” button.

The “enable all” and “disable all” function is accessed by clicking the “Locations” button. If your grind plan requires you only meet a short continuous area of local roughness (ALR) threshold, it’s typically convenient to disable all locations, then re-enable only those locations that are at, or just before, the locations where ALR exceeds the threshold. This and other methods, will be discussed in more detail in the following section.

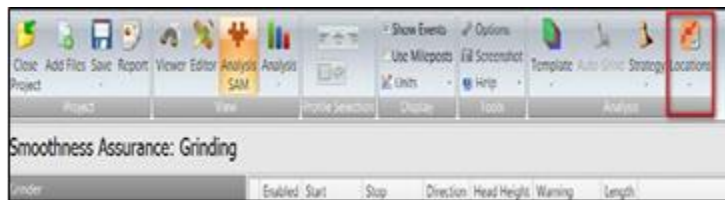


Figure 8-1: Use “Enable All” and “Disable All” to Save Time

SECTION 9 – SAVE AND NAME GRIND LIST STRATEGIES

Section 9.1 - Save Grind List Strategies

The Smoothness Assurance Module (SAM) allows users to save their grind lists as a named strategy. The system allows an unlimited number of strategies to be saved. Developing a strategy can take hours and even days, so it's important to save your progress at regular intervals.

Section 9.2 - Naming Grind List Strategies

Using names that make sense for these strategies is as important as saving them. As an example, a user may have developed an initial auto-grind list using a 14-foot grinder with an ALR (short continuous) threshold set to 180 inches per mile on the left wheel track. A suggested name for the initial strategy may be "Auto14Lt180." The "14" is included as a reminder the list was initially developed using a 14-foot grinder (not the 18-foot or 25-foot default grinders in ProVAL). The "Lt" to indicate the left wheel path, and the "180" to indicate the list was developed using a 180 inches per mile threshold for short continuous.

After making modifications to this list, the user saves it with a new name that makes sense. For example, add "m1" to the end "Auto14Lt180m1" to indicate it was the first modification of the initial list. This saving process is repeated with "m2, m3," for example, at regular intervals. Modifications to files are temporary, and can be deleted. If a significant error occurs, the user can simply revert to the most recently saved modification. Repeat the process for the right wheel path.

Do not use a grind list developed for a left wheel path for the right wheel path, or vice versa. Once you are satisfied you have a final list, it is suggested to use the word "final" and "Lt" or "Rt," and delete all the temporary working files.

Section 9.3 - Saving the File

Now that you have saved your work on the developing grind-list strategies, remember, the strategies are saved with a file, but the file is not yet saved. Save the file using the naming convention defined in Section 36, "General," of the *Standard Specifications* division on subsurfacing and pavements. ProVAL will save the file as a *.pvp to indicate it is a ProVAL Project.

SECTION 10 – GRIND PLAN DEVELOPMENT METHODS USING SAM

This section provides three methods to develop a grind plan using the Smoothness Assurance Model (SAM).

Method 1 provides a process to address areas of localized roughness (ALR) in a single wheel track, and if necessary, some additional steps to address very minor mean roughness index (MRI) issues. This process can be used to estimate the amount of grinding required to address a prepaving grinding threshold.

Method 2 provides a process to address surfaces with ALR and minor MRI issues. This process is similar to Method 1, except that it may require temporarily lowering the localized roughness thresholds to obtain a longer list of auto-grind locations.

Method 3 provides a process to address ALR and significant MRI issues. This method is complicated. This process is similar to Method 2, except that it includes a process that uses histograms to determine an appropriate temporary short continuous threshold setting. Using too low of a temporary short continuous threshold creates extra work disabling grind locations. Using too high of a temporary short continuous threshold can result in too few locations to enable.

The three methods should not be interpreted as the only viable methods to develop a grind plan. Each of the methods requires repeated modifications to an initial auto-grind list of locations. **Figure**

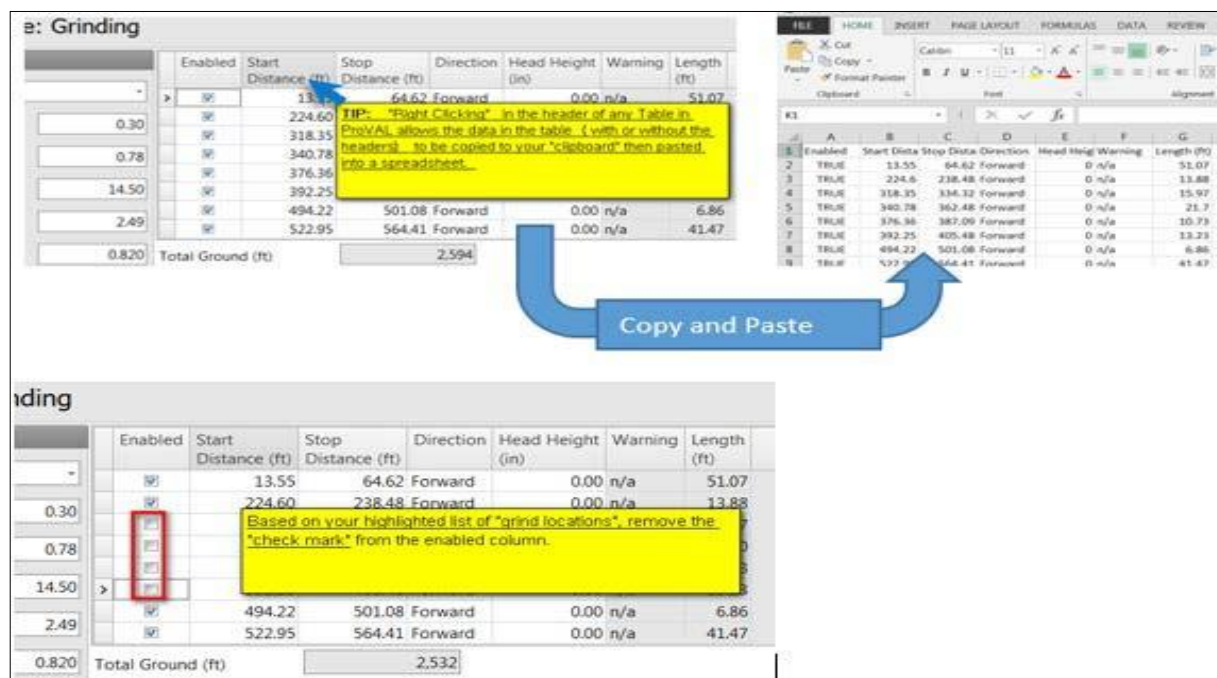


Figure 10-1: Copy Grind List Data to a Spreadsheet for Print Purposes

This requires viewing both the list of grind locations and the ALR plots on the short continuous roughness screen. It is inefficient to toggle back and forth between these two screens. Having a printed copy of the auto-grind list allows the user to view the short continuous roughness plots one 0.1-mile at a time, then note on the printed copy which locations to enable or disable. The grind list can be printed by cutting and pasting it to a spreadsheet. To do this, right click in the header row of the table, then copy and paste to your spreadsheet program, as in Figure 10-1.

Section 10.1 - Method 1-Correcting Surfaces for ALR Issues Only

The initial auto-generated list of grind locations is typically too long and can be shortened by unchecking enabled locations, then re-enabling one or more grinds just before and at the ALR issue, and when making adjustments to head heights or start and stop locations. Follow the steps in Sections 10.1.1 through 10.1.5.

Section 10.1.1 - Generating the Initial “Auto-Grind” List

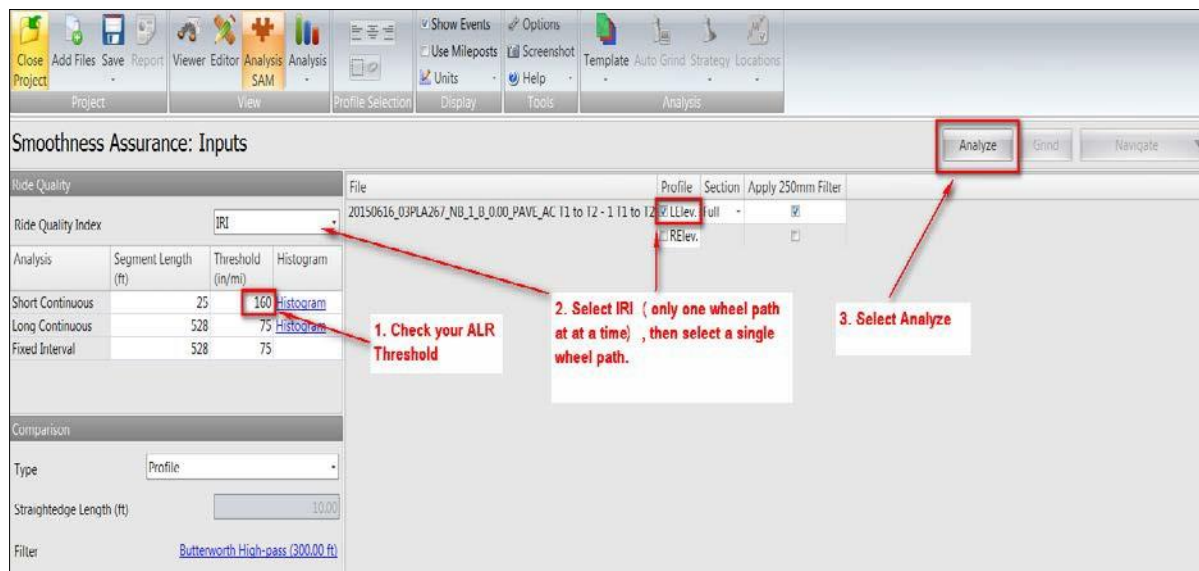


Figure 10-2: Start by Analyzing the Wheel Path

First analyze the wheel path, as in Figure 10-2. Then generate the auto-grind list, and perform the grind simulation, as in Figure 10-3. This allows the simulation to plot the existing and predicted wheel path grades and roughness assuming all auto-grind locations were selected.

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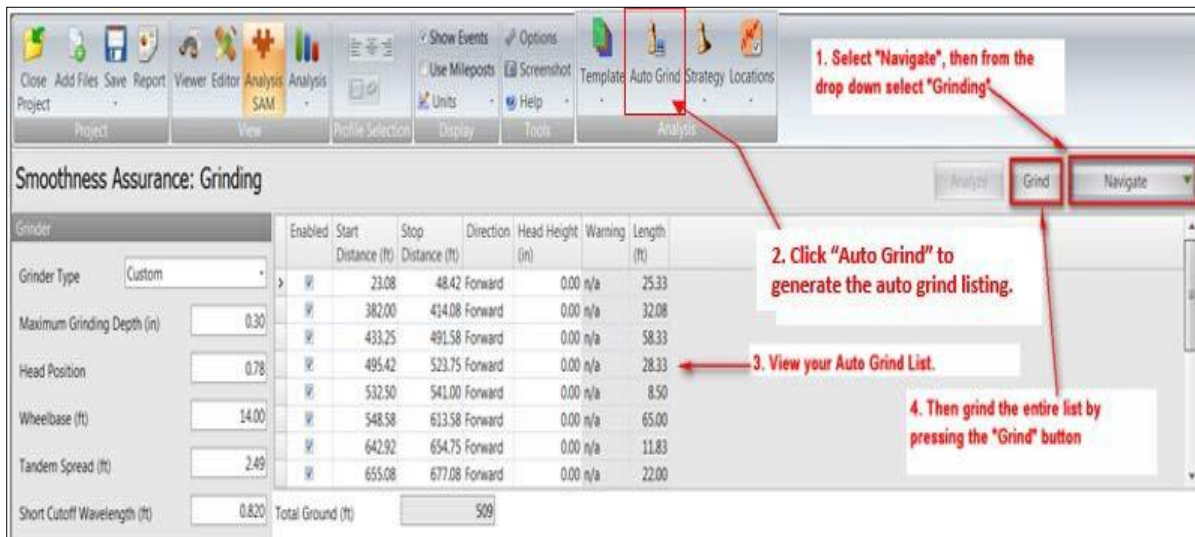


Figure 10-3: Generate the "Auto-Grind" List

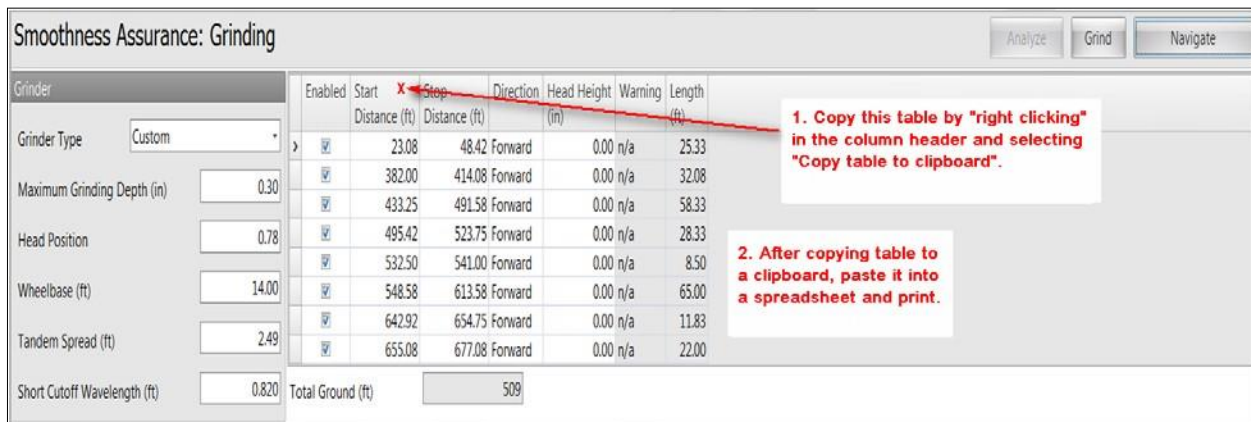


Figure 10-4: Copy Grind List Data to a Spreadsheet for Printing

Copy the auto-grind list and paste it into a spreadsheet, as in Figure 10-4, and print.

Section 10.1.2 - Eliminate Apparent Non-essential Grinds

As Method 1 addresses reducing ALR and not MRI, typically there are more locations in the auto-grind list that can be disabled then left as enabled. When this is the case, it's more efficient to first select "disable all locations," then enable only those locations that are needed to reduce ALR. Using the "Locations" button, select "Disable all locations," as in Figure 10-5.



Figure 10-5: Use the "Locations" Button to Disable All Locations

Navigate to the Short Continuous plot to view the short continuous roughness report versus the Butterworth High Pass Profile plot, as in Figure 10-6.

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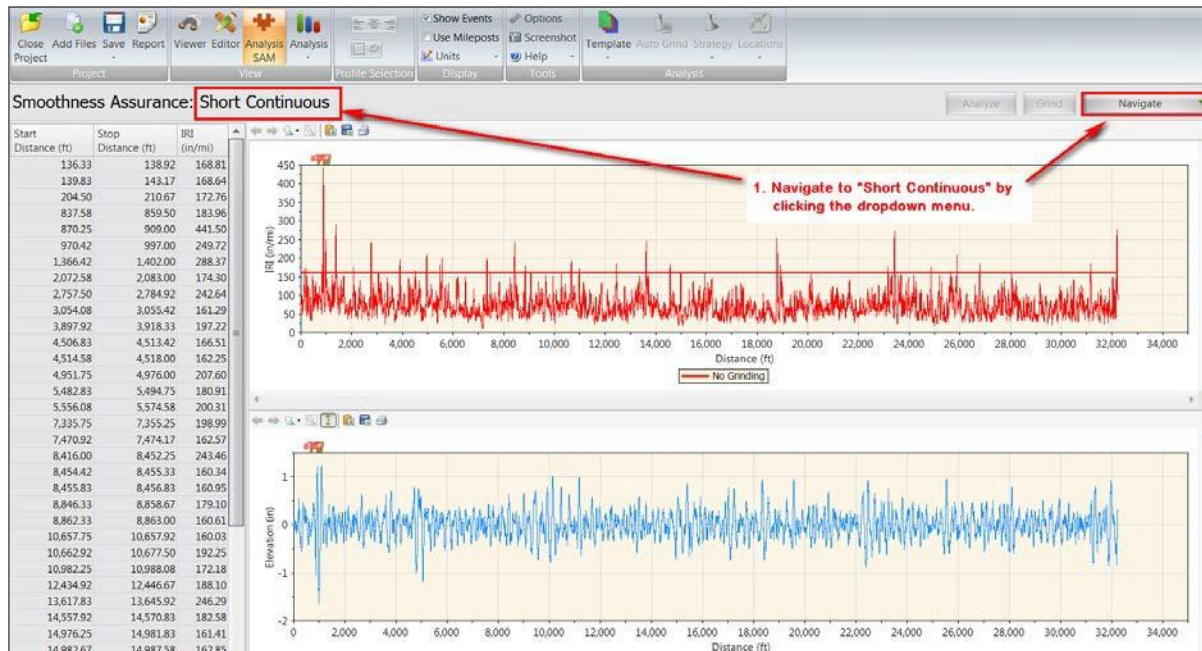


Figure 10-6: Navigate to the Short Continuous Plot

Examine the IRI plot synced to the profile elevation plot using the 0.1-mile scale plotting feature, as in Figure 10-7.

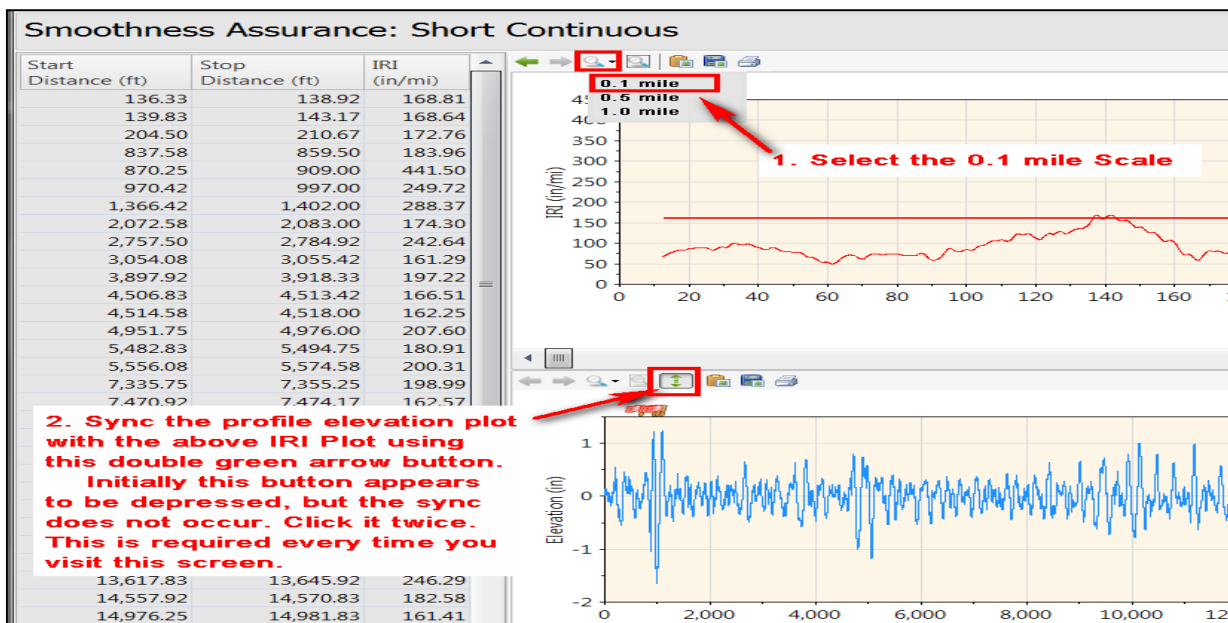
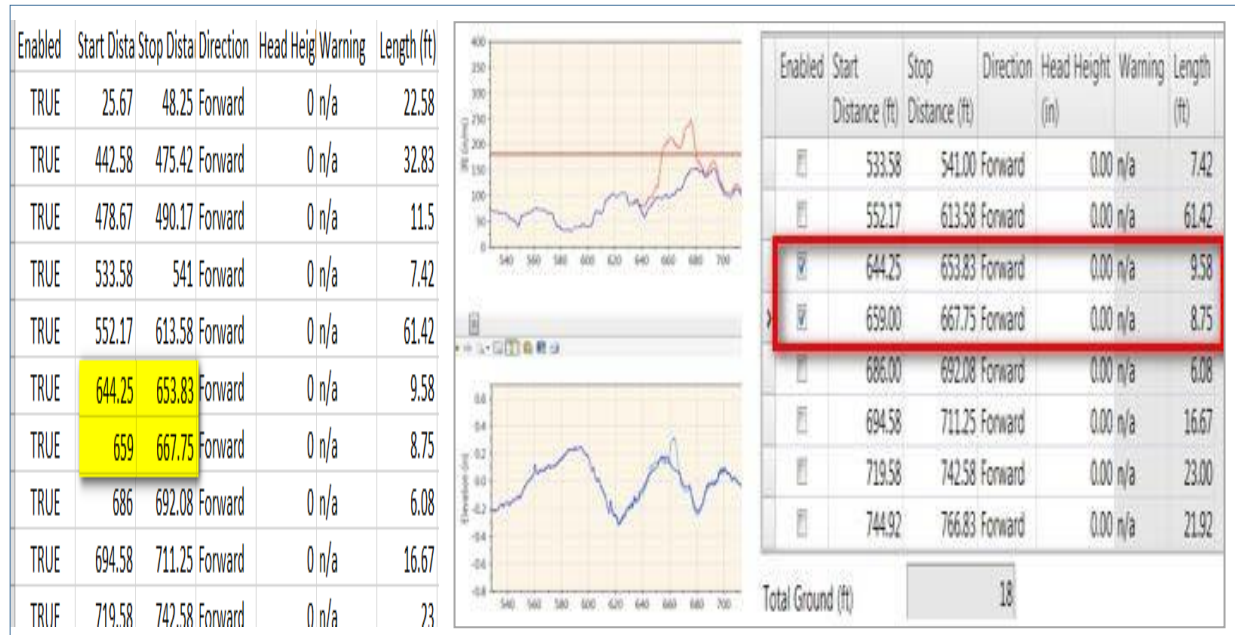


Figure 10-7: View Synced Plots Using the 0.1-mile Scale View

Highlight the grind locations on the printed list that are at or just before where ALR exceeds the threshold. For example, in Figure 10-8, we highlighted two grinds on the printout that were at or just before the location where the ALR exceeded the threshold, enabled those

locations in the SAM, then ran a grind simulation. We can see in this view that the grinds starting at 533.58 feet and 552.17 feet were not needed, and the two enabled grinds were



needed.

Figure 10-8: View the Localized Roughness Plots to Highlight the Auto-Grind Listing

We then continue assessing and highlighting each 0.1-mile scaled view of the short continuous IRI and profile plots for the entire project. When complete, we end up with a highlighted list of grind locations to keep as the first attempt at resolving the short continuous ALR issues.

After disabling all locations, we re-enable only the locations that are highlighted, indicating they are “likely” essential. Then re-run the grind simulation by pressing the “Grind” button. After the initial grind simulation, we review the results and repeat the process, enabling or disabling locations as needed until we are satisfied that we have resolved as many ALR threshold violations as possible using a single pass of a grinder.

Section 10.1.3 - Try a Second Forward Pass to Resolve Remaining ALR Issues

When simply enabling the locations with a single pass doesn't resolve the issue, as in Figure 10-9, we need to try a different method.

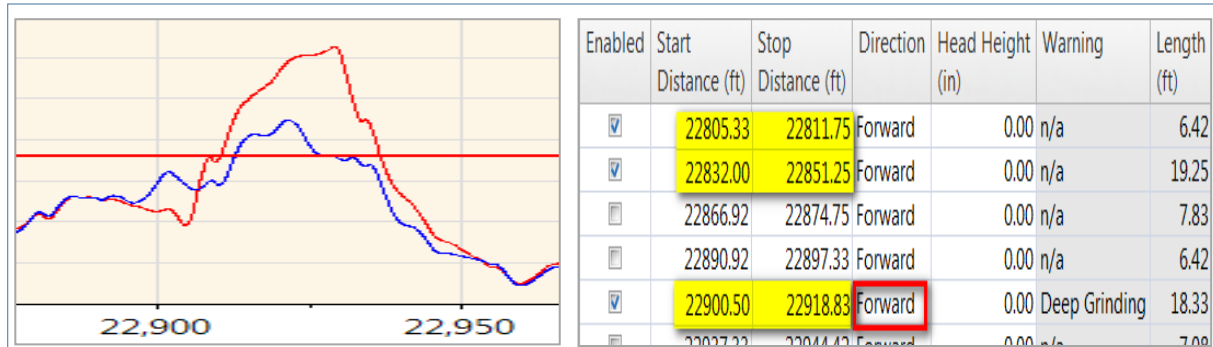


Figure 10-9: Roughness not Eliminated in the First Pass

A second pass with the grinder should be simulated by changing "Forward" to "Forward, Forward," as in Figure 10-10. In this example, adding a second pass resolved the ALR violation.

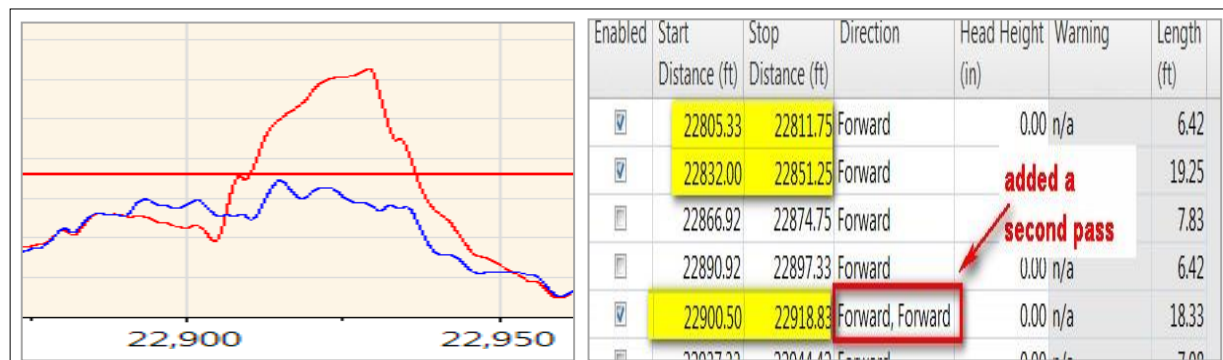


Figure 10-10: Try a Forward, Forward Pass to Resolve Roughness

Section 10.1.4 - Try a Lowered Head Height if a Second Pass Does Not Work

If adding a second pass does not correct the ALR violation, the next option is to simulate the grinder with a lowered head height.

In Figure 10-11, we used the same example as in Section 10.1.3, with a single pass and a head height lowered to 0.12 inches below plane.

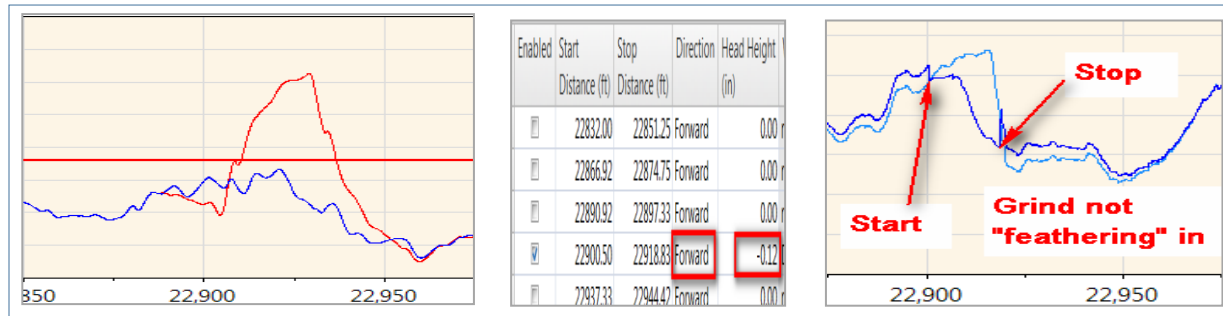


Figure 10-11: Modifying a Grind Location with a Lowered Head Height

Lowering the head height reduced roughness below the threshold, but the model placed a step at the start and stop positions. The steps at the start and stop locations can be seen in the right graphic in Figure 10-11. The step at the stop position is significantly larger than the step at the start position. The step at the stop position appears to require adjustment. To resolve this we can extend the stop position about 5 feet, as in Figure 10-12.

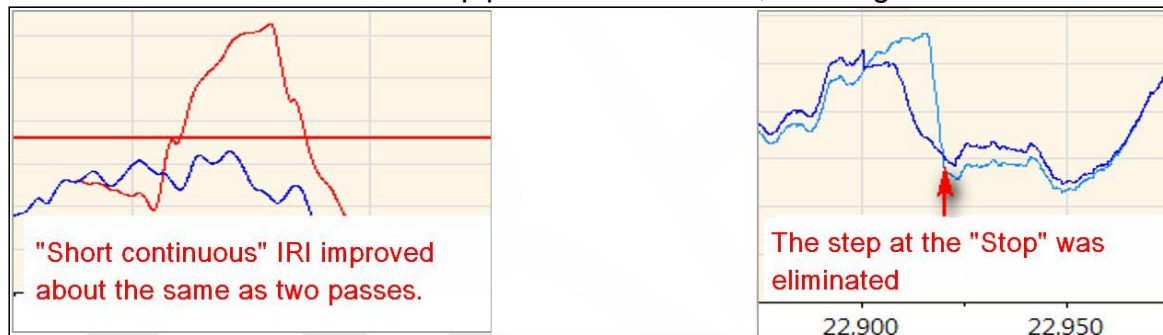


Figure 10-12: A Forward, Forward Pass May Resolve Roughness Related to a Lowered Head Height

Moving the stop position 5 feet eliminated the step and reduced the short continuous roughness.

As shown in Figure 10-12, the step at the start position was not yet revised. This step was later removed by pulling the start position back approximately 5 feet to coincide with the small dip immediately in front of the step.

As shown, simulating grinds using lowered heights can complicate the grind modeling. For this reason, simulating two forward passes as described in Section 10.1.3 is the typically the simplest option.

Section 10.1.5 - Other Pass Direction Combinations

ProVAL can model combinations of grinds and grinding directions including: Forward; Forward, Forward; Forward, Reverse; Reverse; Reverse, Forward; and Reverse, Reverse. The direction is with respect to the direction the inertial profiler recorded the profile data. The Forward, Reverse, and Reverse, Forward combinations are not recommended as they would require turning the diamond grinder around 180 degrees at each grinding location. The combinations with “Reverse” also would typically require the tanker truck to face oncoming traffic, which may create a safety hazard.

Section 10.2 - Method 2-Surfaces With ALR and Minor MRI issues

This method develops grind simulations to address predicted MRI violations that exist after addressing ALR violations.

To address this type of roughness, it may be necessary to:

1. Enable more locations on the auto-grind listing.
2. Lower a head height.
3. Lengthen a grind.
4. Account for the predicted fixed interval roughness of the adjacent wheel path (in other words, the other half of the MRI calculation).

To determine which locations should be enabled, as in the Method 1 example, we will view the short continuous plot using the 0.1-mile scale, then enable grinds where the plot exceeds the MRI value criteria as well as ALR criteria.

In Figure 10-13, the red line at 160 is the short continuous threshold that was plotted in the short continuous ALR graph. In the previous example, we were only reviewing these plots with respect to where the short continuous ALR exceeded the short continuous threshold (160 inches per mile in the following example). In Figure 10-13, a black dotted line was added to represent the overall average roughness of this fixed 0.1-mile section of wheel path. In this example, the average is 92 inches per mile. We need to simulate a grind that will smooth the profile so the average of the blue line when combined with the average of the adjacent lane is below 75 inches per mile, the MRI we are trying to achieve. If the adjacent lane had an average roughness of 65 inches per mile, this wheel path average would only need to be reduced to less than 85 inches per mile, as the average of 85 and 65 equals 75 inches per mile. In this example, we will assume the other wheel path is 75 inches per mile, so this wheel path needs to be reduced to less than 75 inches per mile.

To determine which areas need to be ground, we need to visualize what is driving the average more than 75 inches per mile. The “75 line” was added to the graphic to help visualize where roughness above that value can be more readily reduced to lower the overall average to 75 inches per mile or less. Areas of more extreme roughness are outlined in the red box.

If we can reduce roughness in these localized areas, the overall average roughness will be reduced. If we can lower these areas of localized roughness to close to 75, then its overall average for the 0.1 mile section shown in the plot likely be lowered to less than 75 inches per mile.

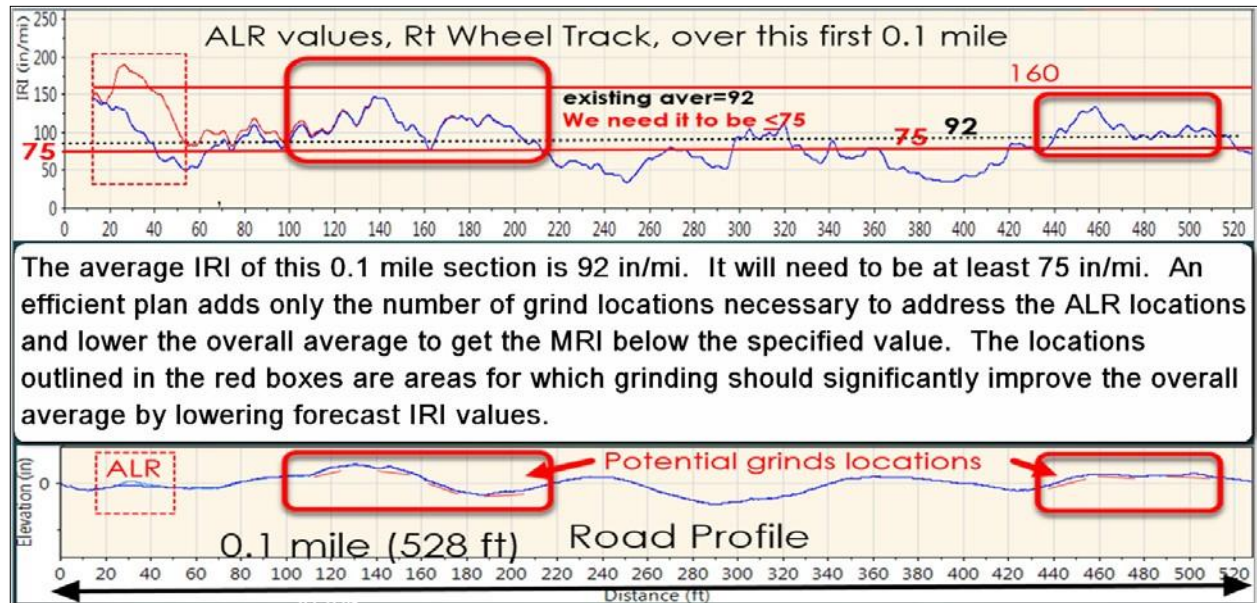


Figure 10-13: Red Boxes in ALR Profiles Show Areas of More Extreme Roughness

If we can generate an auto-grind listing that includes grinds in these areas, then enable those grinds, we can take the steps necessary to reduce the average roughness of this section to less than 75 inches per mile. Recalling what was described in Section 7.2, “How ProVAL Develops an Initial Auto-Grind List,” in this handbook, we may need to temporarily lower the short continuous threshold to approximately 125 inches per mile. Temporarily lowering the threshold for the purpose of generating the auto-grind list will provide more grind locations in the auto-grind listing, including those needed to reduce the average roughness of this 0.1-mile section to 75 inches per mile or less.

Once you have the auto-grind list, the required process described in Section 10.1 can be followed, except that you will be enabling grind locations to reduce the fixed interval roughness, or areas similar to those shown in Figure 10-8.

If there are not enough grind locations in the initial auto-grind list, your MRI issues are significant. Use the following guidance to address those cases. Refer to Section 10.3 for an explanation of significant MRI.

Section 10.3 - Method 3-Surfaces with ALR and Significant MRI Issues (Most Difficult)

When there are significant MRI issues, such as surfaces with a lot of small bumps that do not exceed ALR thresholds, additional steps are needed to develop an initial “auto-grind” list. These additional steps are similar to the “one grind-what if” scenario, except that you will run grind scenarios using various short continuous thresholds, then select the initial list that appears to include enough grinding that when all locations are enabled, most, if not all, the fixed interval or long continuous roughness would be sufficiently reduced. You can use the Long Continuous Histogram tool to assist in determining which auto-grind generated list is the most efficient to start with.

Section 10.3.1 - Use the Long Continuous Histogram Tool

Recognize that ProVAL will plot histograms of roughness and predicted roughness for short continuous and long continuous roughness, but not for fixed interval roughness. The histograms provide an overview of the roughness of the entire wheel path. In Figure 10-14, we can see the Rt Wheel Path long continuous roughness of a single wheel track, on a project that has an MRI requirement of 60 inches per mile. The x-axis on the histograms is percent of long continuous roughness. The horizontal bars indicate how much of the long continuous roughness falls within 10 inches per mile increments. The increments and y-axis limits can be defined by the user.

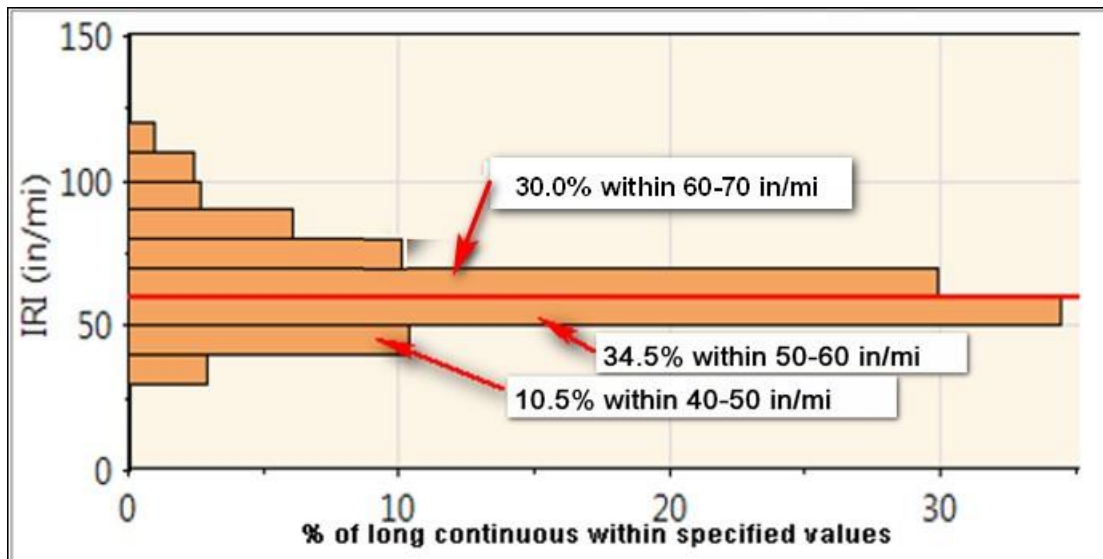


Figure 10-14: Histogram Shows Long Continuous Roughness in an Entire Wheel Path

In Figure 10-14, we see a histogram that provides a graphical representation of how rough a lane is with respect to its long continuous roughness. The histogram tool provides a summary of the roughness of the entire length of the wheel path.

Long continuous roughness is calculated as the moving average roughness of a sliding 0.1-mile segment section of lane. Histograms are not available for fixed interval roughness.

Figure 10-15 is a plot of long continuous roughness. The plot begins and ends one-half of 528 feet inside the beginning and ending points of the lane. This plot gives a general idea of the 0.1-mile average roughness, but not a quantitative idea.

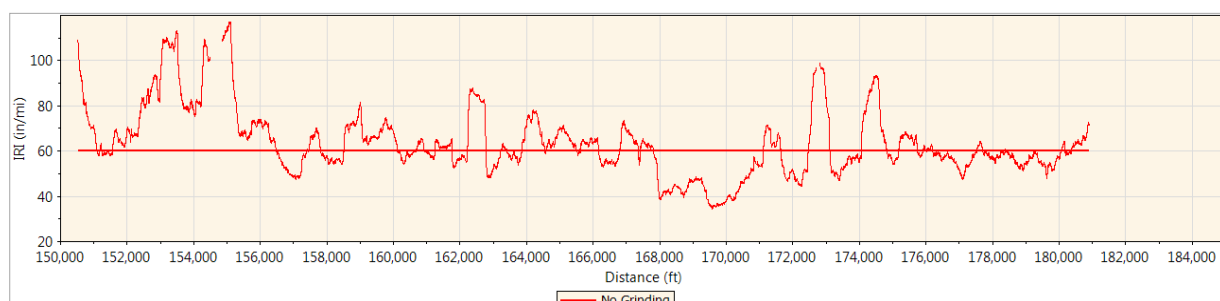


Figure 10-15: Plot of Long Continuous Roughness

Viewing the data in a histogram form rather than an x-y graph form provides a quantitative representation of how much of the area exceeds a specified limit. It is much simpler to compare smoothness effects of various auto-grind scenarios by viewing the corresponding histograms than the corresponding x-y graph of long or short continuous roughness.

In Figure 10-16, the histogram provides an estimate of what percent of long continuous roughness exceeds the specified threshold, and by how much.

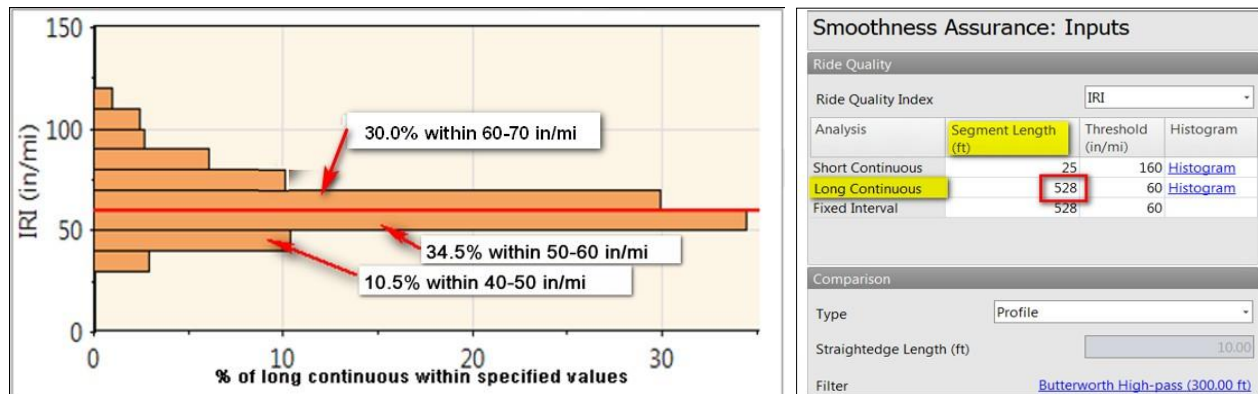


Figure 10-16: Histogram Shows How Rough the Wheel Path Is

In Figure 10-16, about 50 percent of long continuous roughness for this wheel path falls below the 60 inches per mile requirement for long continuous roughness. The histogram represents one wheel track from one 6-mile long lane where a grinding plan was developed to resolve roughness to below specified IRI values.

The following discussion provides a general methodology that can be used to develop an “efficient” grinding simulation that addresses both ALR and significant MRI issues, such as is represented by the Figure 10-16 histogram. This method is not intended for a novice user. The method involves methodical assessment of roughness values after each modification.

There is no known way to correlate the histogram in Figure 10-16 to a defined amount of required corrective grinding. To accurately estimate the amount of grinding, a complete grind plan needs to be developed.

Though approximately 50 percent of the project exceeds the long continuous roughness specification, an adjusted grinding simulation predicted that only 15 percent of the surface required grinding to bring the job into specification.

This Long Continuous Histogram is available by clicking the “Navigate” drop-down selection button in the Smoothness Assurance Module for both “No Grinding” and “After Grinding” scenarios.

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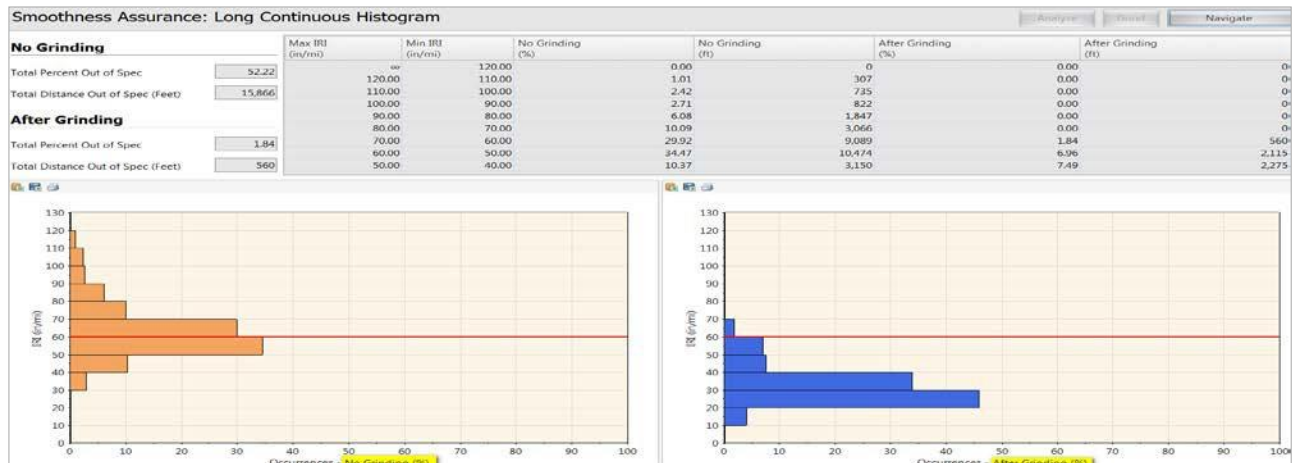


Figure 10-17: Histograms Show No Grinding and After Simulated Grinding

Section 10.3.2 - Use the Long Continuous Histograms to Evaluate Auto-Grind Scenarios

We can repeat the above process using various short continuous ALR thresholds. The labels below each histogram in Figure 10-17 indicate the short continuous threshold setting used by the auto-grind function to develop the initial grind listing.

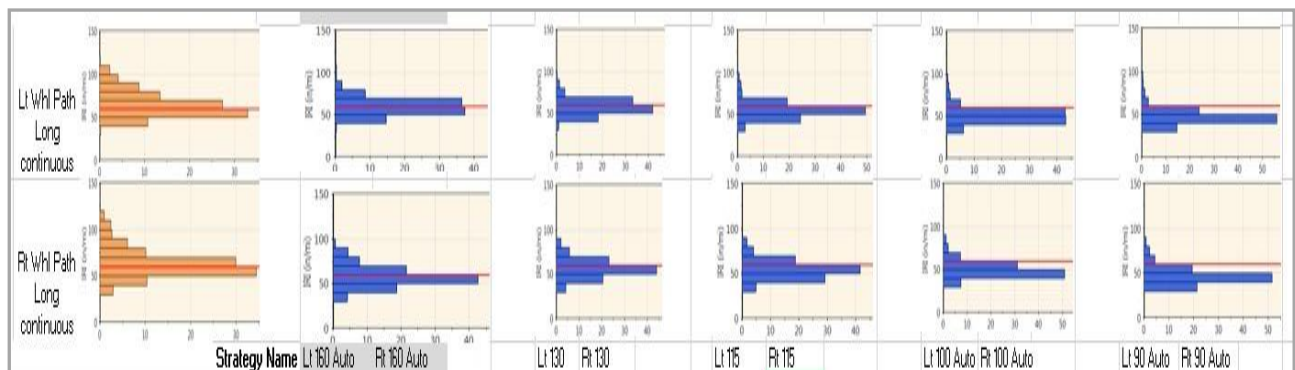


Figure 10-18: Histograms Model Before and After Grinding Non-refined Auto-Grind Generated Lists

In Figure 10-18, we can view the histograms for simulated long continuous roughness after enabling and grinding all auto-grind locations. In this example, we simulated short continuous thresholds of 160, 130, 115, 100, and finally 90.

Section 10.3.3 - Decide Which Auto-Grind List to Start With

As the short continuous ALR threshold is reduced, we can see a change in the percent of long continuous roughness that falls below 60 inches per mile. We can analyze histograms to determine which auto-grind listing would be the most efficient starting point.

If we overestimate how long the initial grind list needs to be, we may spend an excessive amount of time disabling or enabling grind locations.

If we underestimate how long the initial grind list needs to be, we may select a list that does not have enough locations. Recall that ProVAL does not allow a user to add locations, it forces us to start with a longer list than may be necessary.

The user also needs to recognize that when viewing the histograms, there may always be a certain amount of long continuous roughness above 60 inches per mile regardless of where the short continuous threshold is set. This is because the grind simulation used to develop the histogram was not fully refined.

Section 10.3.4 - Analyzing Auto-Grind Scenarios

There is no defined method that can be used to determine which initial auto-grind list should be selected. It may come down to making your best guess and weighing the risks of proceeding with one versus the other. When the initial list is too long, it can take an excessive amount of time disabling locations. If the list is too short, a grind plan can't be developed because there will not be enough locations to enable.

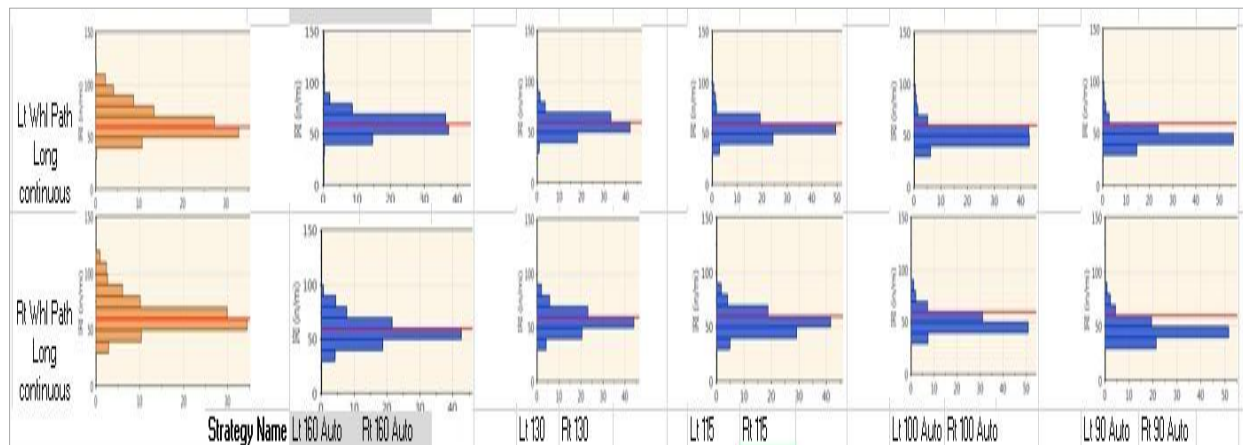


Figure 10-19: Use Histograms to Assist in Defining the Initial Unrefined Auto-Grind List

In Figure 10-19, the “115 inches per mile” histogram was used as the basis for choosing the short continuous threshold to develop the initial auto-grind list. The reasoning follows:

1. Reviewing the 160, 130 and 115 histograms, we can see a significant amount of long continuous roughness being reduced below 60 inches per mile, but there is still a significant amount that is above 60 inches per mile. If we use 160 or 130, there may not be a sufficient number of locations to modify, so we rule these two auto-grind lists out.
2. In the 100 and 90 histograms, the roughness is well below 60 inches per mile, mostly in the 40s and 50s, indicating a potential for too many grind locations on the initial grind listing. If we choose either of these lists, we undoubtedly will have enough locations, but would spend an excessive amount of time disabling grind locations. For this reason, the auto-grind lists associated the 100 and 90 inches per mile thresholds are excessively long.

The 115 inches per mile auto-grind listing was chosen as the initial list for both wheel paths. The lists were eventually fully developed into grind plans that predicted no localized roughness greater than 160, and when combined, no mean roughness index greater than 60 inches per mile. A detailed explanation of this process is provided in Sections 10.3.5 through 10.3.7.

In summary, reviewing histograms provides a logical method to determine which auto-grind list is a good starting point for surfaces with ALR and significant MRI issues.

Section 10.3.5 - Grind for Segment MRI, Not Segment IRI

It's helpful to set up a bookkeeping system, as in Figure 10-20, to track what needs to be addressed on the whole project and avoid unnecessary work. For example, in the ninth fixed interval in Figure 10-20, if we did not know the right wheel path was at 49.4, we may try to lower the 73.4 value to a 60 rather than only to 70.6 or less (the average of 49.4 and 70.6 is 60). ProVAL will not list aggregated grind corrections, and it can only forecast smoothness of a single wheel path.

After making changes to both wheel path grind lists, we can print the predicted fixed interval values from both wheel paths on a spreadsheet to see their net effect on the average value shown in the third column.

The left table in Figure 10-20 shows the 528 foot fixed increment values before making changes. The table on the right is from our spreadsheet which will be updated after periodic changes to the grind list. The table on the right will track the predicted effect on the overall MRI values. The table on the right uses same list as the table on the left, but after making manual modifications to individual grinds needed to get all ALR values of both wheel paths below 160 inches per mile, and average fixed interval of both wheel paths (the MRI) below 60 inches per mile.

Fixed Inc values after grinding all locations using an auto grind listing developed using 115 in/mi for short continuous				FINAL Fixed Inc Values after Grinding, used locations from the 115ALR auto generated, with revisions, to address high ALR, and a elimination of unnecessary locations			
After Grinding IRI (in/mi)	After Grinding IRI (in/mi)	AVERAGE of Lt and Rt MRI		After Grinding IRI (in/mi)	After Grinding IRI (in/mi)	Average	
51.08078	67.35182	59.2163	1st	51.08078	68.67175	59.88	1st
52.27473	53.63515	52.95494	2nd	58.91487	59.04205	58.98	2nd
55.49528	51.96158	53.72843	3rd	55.49525	59.49988	57.50	3rd
46.22535	48.07669	47.15102	4th	57.31548	58.26033	57.79	4th
55.52502	55.28323	55.404125	5th	55.52636	55.26875	55.40	5th
69.4763	67.38094	68.42862	6th	59.09003	58.40736	58.75	6th
54.1495	62.69559	58.422545	7th	54.15165	62.66082	58.41	7th
50.73859	47.90774	49.323165	8th	58.32298	55.80015	57.06	8th
73.40044	49.40587	61.403155	9th	73.12127	39.93624	56.53	9th
76.04572	81.74948	78.8976	10th	50.68753	67.97777	59.33	10th
51.98642	61.98854	56.98748	11th	55.98581	61.98877	58.99	11th
56.61376	64.08983	60.351795	12th	56.59853	60.0098	58.30	12th
55.08664	52.87365	53.980145	13th	55.08664	52.87368	53.98	13th

Figure 10-20: Fixed Increment Roughness Values Before and After Making Changes

In examining the two tables in Figure 10-20, we can see that in the first 0.1-mile increment, a few grinds were eliminated from the right wheel path only.

In the second through fifth 0.1-mile intervals, grinds were disabled until the fixed intervals of each wheel path were predicted to be just below 60 inches per mile.

In the sixth 0.1-mile increment, some existing grinds were modified to create a smoother left and right wheel paths. Those changes included fixing some ALR issues, as well as smoothing some areas with a second passes.

Overall on this project, we were able to eliminate approximately 20 percent of the grinds from the initial auto-grind list.

Section 10.3.6 - Modifying Wheel Track Grind Listings to Address MRI

Once the decision was made to begin refining the auto-grind lists for both the left and the right wheel paths using the 115 inches per mile auto grind lists, the fixed interval values were generated and exported to a spreadsheet to track progress of the changes to the grinding list, as in Figure 10-21.

Fixed Inc values after grinding all locations using an auto grind listing developed using 115 in/mi for short continuous			
After Grinding IRI (in/mi)	After Grinding IRI (in/mi)	AVERAGE of Lt and Rt MRI	
51.08078	67.35182	59.2163	1st
52.27473	53.63515	52.95494	2nd
55.49528	51.96158	53.72843	3rd
46.22535	48.07669	47.15102	4th
55.52502	55.28323	55.404125	5th
69.4763	67.38094	68.42862	6th
54.1495	62.69559	58.422545	7th
50.73859	47.90774	49.323165	8th
73.40044	49.40587	61.403155	9th
76.04572	81.74948	78.8976	10th
51.98642	61.98854	56.98748	11th
56.61376	64.08983	60.351795	12th
55.08664	52.87365	53.980145	13th

The values in the columns from left to right are, Lt Wheel Track Fixed Interval, Rt Wheel Track Fixed Interval, and the average of both representing the MRI for that 0.1-mile fixed interval of lane.

Figure 10-21 Spreadsheet Tracks Progress

In Figure 10-21, the fixed intervals that exceeded the 60 inches per mile threshold were conditionally formatted with red background to indicate additional grinding may be necessary to lower the value to below 60 inches per mile. Data in this spreadsheet indicates no modifications will likely be necessary until the sixth fixed interval, and modifications will be required to both wheel paths. In the ninth fixed interval, the MRI of 61.4 almost meets the 60 requirement, therefore only a few modifications will be necessary to get the left wheel path 73.4 value low enough so that the average of both wheel tracks is 60 inches per mile or less.

Section 10.3.7 - Viewing Predicted Final MRI

After making modifications to the list using independent grind lists for each wheel path, the fixed interval charts were plotted for both wheel paths. Because the predicted MRI of a grind simulation is the average of the forecast fixed interval roughness of both wheel paths, the fixed interval value on one wheel path may be over the threshold if the opposite wheel path's fixed interval is far enough below the threshold. For example, one might look at the left and right fixed interval plots in Figure 10- 22 as separate, but when averaged, the values are below the threshold.

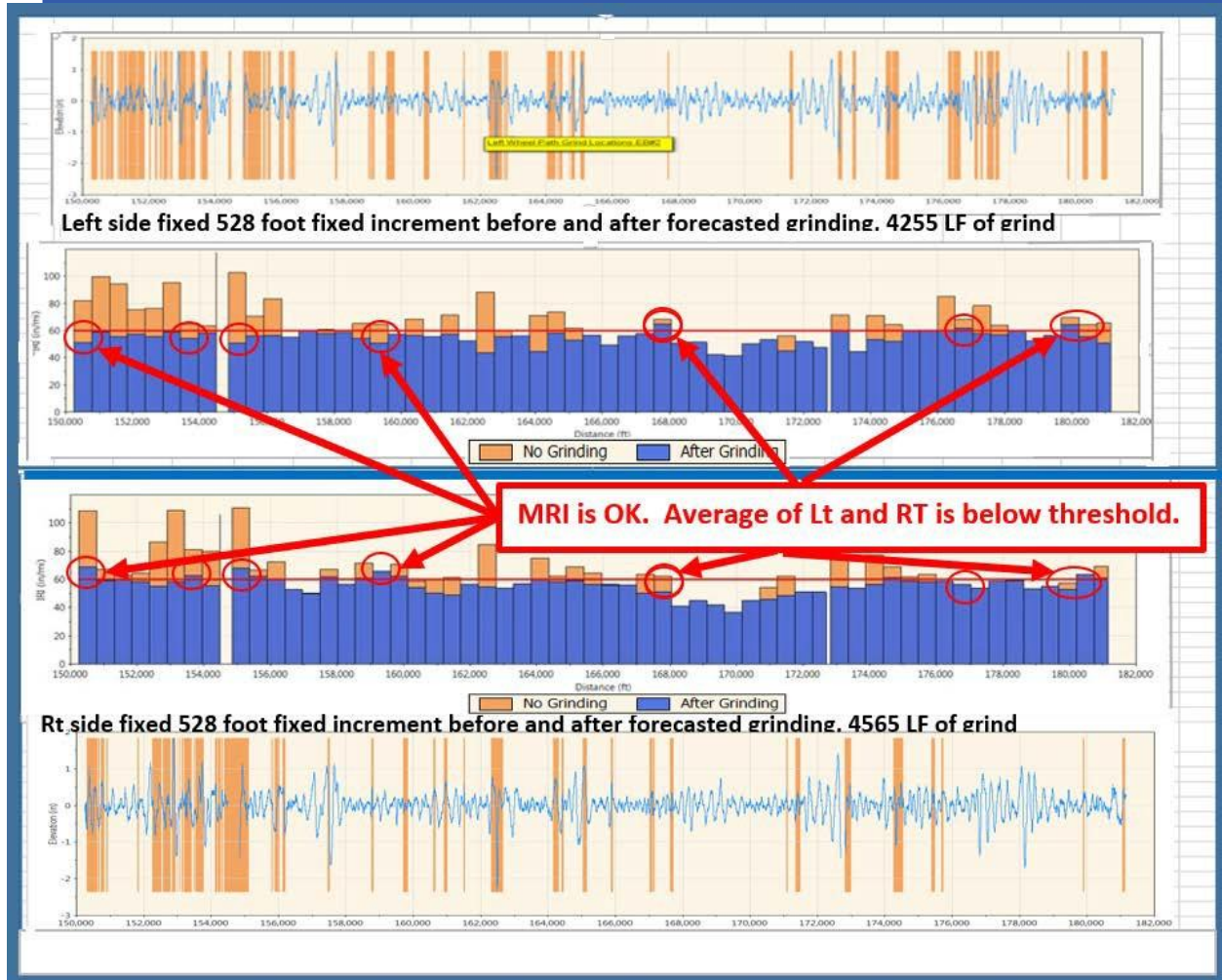


Figure 10-22: ProVAL Fixed Increment Roughness Plots for Both Wheel Paths

Section 10.4 - Using ProVAL SAM for “What If” Scenarios

To address projects with high MRI, a common scenario is to use the “one grind” strategy available under the “Strategy” button. “One grind” forecasts the degree of smoothness that can be achieved if the simulated grinder with a zero head height drove through the entire length of the job. After executing the “one grind” model, viewing the 0.1-mile scale view of the short continuous roughness and the fixed interval plots provides a visual representation of how smoothness can be improved.

Some locations will require a second pass or a lowered head height to resolve roughness. ProVAL SAM is also a good tool to predict how much effort will be required to develop a grinding plan.

A second common scenario involves generating the auto-grind list using short continuous thresholds described in Section 10.3. Variations on the “one grind” strategy can be made by lowering the short continuous threshold to generate longer auto-grind lists, modeling the grind, and viewing the fixed interval reports, until one is found for which a majority of fixed interval issues is being resolved.

Additional scenarios can be simulated using two passes over the project with the one grind simulation.

It's not recommended to use ProVAL to simulate smoothness of a cold planer grinding to a defined depth. This is because the grind simulation is designed to mimic a typical fixed frame diamond grinder that removed high spots. Cold planers typically use an automatic averaging system that cannot be simulated in ProVAL. Also, the ProVAL grinder dimension model is not consistent with a track mounted machine. Running a grind simulation at depths commonly specified for cold planing does not promote the same type of smoothing as removing high spots.

Section 10.5 - Using Multiple Strategies

If a project has a section of high roughness compared to the remainder of the project, the two sections can be exported separately, then analyzed using one of the previously defined strategies. For example, if 2 miles of a 10-mile project have extreme MRI issues, while the remaining 8 miles have only minor ALR issues, break the project into two parts using the "Export" function. The user can use the suggested Method 1 on the 8-mile section and Method 3 on the 2-mile section.

SECTION 11 - SIMULATED GRINDS/EXECUTING GRIND

Section 11.1 - Simulated Grinds in ProVAL

Start and stop stationing of locations determined by auto-grind are based on a fixed frame grinder with zero head height and are mathematically calculated as the point the modeled grinder starts and stops cutting into a surface. The start and stop locations are mathematically determined as the locations the grinder's cutting head is in a skimming condition. At all the points between the start and stop locations, the grinder cutting head is cutting a depth based on the amplitude of the bump the grinder is driving over. Any modification of auto-generated grind locations should be based on an examination of the predicted grind profile to ensure the modeled grind is skimming, or feathering into and out of a cut condition. As shown in Figures 10-11 and 10-12, to efficiently develop a grind plan, users need to make a subjective call regarding this skimming or feathering condition whenever they change a start or stop location, or change the head height from the default 0.0-inch value. Because grinders do not have instrumentation informing the operator of the actual head height, failure to adequately account for such changes will result in a modeled grind that will likely not resemble the actual grind in the field. Because the actual grinder will be in a skimming position when it starts its cut, the model of that grind needs to indicate the same condition in the field.

Section 11.2 - Layout Using Global Positioning Systems (GPS)

Most inertial profilers currently used in California have the ability to record GPS coordinates at 10 hertz (1 per 1/10 of a second). The accuracy of these measurements may be reduced by overhead obstructions such as bridges, buildings, or tree canopy that block satellites.

Section 11.3 - Layout Using Distance Measuring Instruments

If GPS layout is not available, the inertial profiler's distance measuring instruments (DMI) can be used for layout. When taking inertial profiles, the DMI must be calibrated daily to be accurate within 1 foot per 528 feet. The same calibration should occur if it is used for layout. Using DMI may introduce a difference in measurement; however, using a higher number of semi-permanent reference points may help minimize compounding errors.

Accuracy of distance measurements can also be affected by offsets measured between any two runs, for example, the difference between the actual inertial profile run and the layout run. For every 10 degrees in curve angle (regardless of curve radius), and 12 feet of offset, there is a change in curve length of approximately 2.1 feet. If distance measurements between an outside lane and the outside shoulder are taken through a 30 degree curve, the difference in the length of the two curves is 6.3 feet ($= 2.1 \text{ ft} \times 30 \text{ degree}/10 \text{ degree}$). It doesn't matter if the curve radius is 150 feet or 3,000 feet.

Section 11.4 - Layout Using GPS with DMI

Occasionally, GPS and DMI methods are combined to lay out grinds. For example, GPS use may not be practical because of overhead obstacles such as bridges or tree canopy. DMI then may be used as a backup to the nearest useful GPS data.

SECTION 12 – DEVELOPING AN ENGINEER’S ESTIMATE OF GRINDING COST AND TIME

Though this guide is made available to industry, this section is intended for use by California Department of Transportation (Caltrans) personnel only as guidance in preparing an engineer’s estimate. This section is not intended to provide guidance to industry nor is it intended to be relied upon by industry. In no event will Caltrans be liable for any damages, expenses, lost profits, lost savings, or other damages arising out of the use of this guidance on preparing estimates of grinding cost and time.

Developing engineer cost estimates are necessary for:

1. Preparing an engineer’s estimate for Prepaving Grinding Bid Item.
2. Preparing a resident engineer’s estimate of cost for change order work.

Section 12.1 - Developing an Engineer’s Estimate of Cost and Time for Prepaving Grinding

The first step in developing an engineer’s estimate is to use the ProVAL Smoothness Assurance Module (SAM) to determine the quantity of prepaving grinding required to reduce all localized roughness to less than the 180 inches per mile threshold defined in the “Prepaving Grinding” specification. Use Section 10-1 to determine the amount of grinding required in each wheel path.

Note: Never use the total amount of grinding from an initial unmodified “auto-grind” listing, as these quantities are typically excessive.

Input from the diamond grinding industry suggests estimating production rates using 1,000 to 1,500 square feet per hour. This equates to approximately 170 to 250 lineal feet of half-lane width ground per hour. Such estimated rates account for the number of passes required to grind half a lane width using the typical 3- or 4-foot wide diamond grinder. These rates also include a typical amount of non-grinding time moving from one location to the next, and grinding at typical depths. Use these rates to estimate the total number of hours of grinding required and convert to the number of shifts that will be required. Current contract cost data indicates an average cost per shift of \$9,800, for each prepaving grinding day.

It’s recommended to use the lower production rate of about 170 lineal feet of half-lane width grinding per hour when more difficult grinding conditions may exist, such as when complex grinder relocations are spread over longer distances, numerous traffic control setups in a single shift are required, or there is a high number of super-elevated curves.

It’s recommended to use the higher rates of 200 to 250 lineal feet of half-lane width for typical conditions. In most cases, project engineers should use a value in the range of 200 to 250 lineal feet of half-lane width grinding per hour.

Section 12.2 - Example: Engineer's Estimate of Cost and Time for Prepaving Grinding

Project A

Lane closure charts allow closures from weeknights from 9 p.m. to 6 a.m.

Two-lane highway, 6 miles long. The typical cross sections specify placing 0.2 feet of Type A hot mix asphalt (HMA) over three different conditions, including existing asphalt concrete pavement, cold planed pavement, and replaced asphalt concrete pavement, and placing 0.25 feet of Type A over existing asphalt concrete pavement.

The project engineer developed a grinding plan to determine the estimated amount of prepaving grinding required to eliminate localized roughness exceeding 180 inches per mile. The plan was developed using the ProVAL SAM with techniques described in Section 10's Method 1 of this manual. The project engineer verified the ProVAL file included leave-out sections to exclude areas where existing pavement is not subject to the prepaving grinding requirement. On this project, the project engineer added leave-outs to exclude, existing pavement designated to be cold planed, existing pavement to be replaced, existing pavement to be overlaid with more than 0.2 feet of HMA, and existing bridge structures. The project engineer reviewed his grinding plan and quantities shown in Figure 12-1.

Top, left wheel path, 1,114 lineal feet. Bottom, right wheel path, 2,975 lineal feet

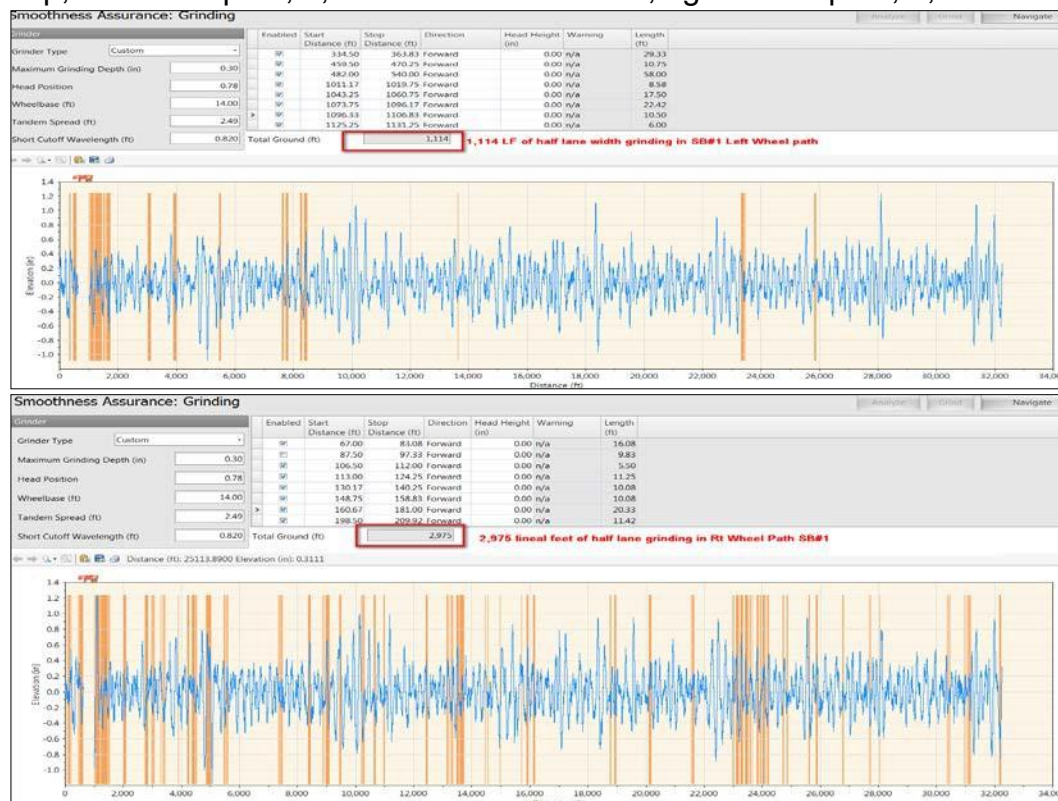


Figure 12-1: ProVAL SAM Grinding Quantities by Wheel Path

Total lineal feet of diamond grinding in **southbound lane** = **4,089** lineal feet of half-lane width grinding.

From a separate analysis of the northbound direction (not shown), the total lineal feet diamond grinding in both wheel tracks **is 3,703** lineal feet (LF) of half-lane width grinding.

Total half-lane width grinding

Southbound 4,089 LF + Northbound 3,703 LF

Total 7,792 LF (half-lane width grinding)

The project engineer reviewed the ProVAL data, and using engineering judgment determined that the grinds are close enough that a higher production rate of 225 LF of half-lane width grinding can be accomplished per hour. The engineer estimated the total amount of grinding shift time to be as follows:

$(7,792 \text{ LF of half-lane width grinding}) / (225 \text{ LF/HR}) = 35 \text{ hours}$

Using lane restrictions from 9 p.m. to 6 a.m., 1 hour of total grinder setup and breakdown time, the engineer determined there was 8 hours available per shift for grinding: 35 hours / 8 hours per shift=

4.4 shifts, round up to 5 prepaving grinding shifts at \$9,800 per shift=\$49,000.00.

Accordingly, the project included 5 working days in the schedule and the following Caltrans bid item to cover this work:

- Item Code 390020 PREPAVING GRINDING DAY, 5 EA at \$9,800.00 = \$49,000.00
- As of spring 2017, Caltrans / Pavement & Materials Partnering Committee has been working on piloting alternate methods to pay for Prepaving Grinding work, including Prepaving Grinding and Localized Roughness Reduction. If a project is advertised using one of these methods, the methods described above for estimating the total cost and time for required prepaving grinding will remain unchanged. The Bid Item Description, Item Code and Unit of Measure will change accordingly