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Intelligent Compaction User Guide

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1.0 Introduction

1.1 What is Intelligent Compaction?

Intelligent Compaction (IC) is the use of rollers equipped with Global Navigation Satellite System (GNSS) positioning equipment, thermal sensing, and accelerometer based measurement systems. These technologies allow for real-time monitoring of location, temperature, and stiffness during the compaction process of soils, aggregates bases, or asphalt pavements. Machine operators utilize a color coded display with the location of the roller, number of roller passes, and material stiffness to ensure proper coverages are made in an efficient manner to achieve the specified density. When utilized for soil or aggregate base compaction, stiffness feedback can identify areas of weak support that need to be addressed before the subsequent layer of material is placed. In asphalt paving, location monitoring is increasingly useful as the majority of paving operations are conducted at night with lower visibility to ensure full and consistent coverage of the mat. The data is stored on a portable storage device or an internet based cloud storage site and can be used for analysis by the contractor or DOT in the Veta software package.

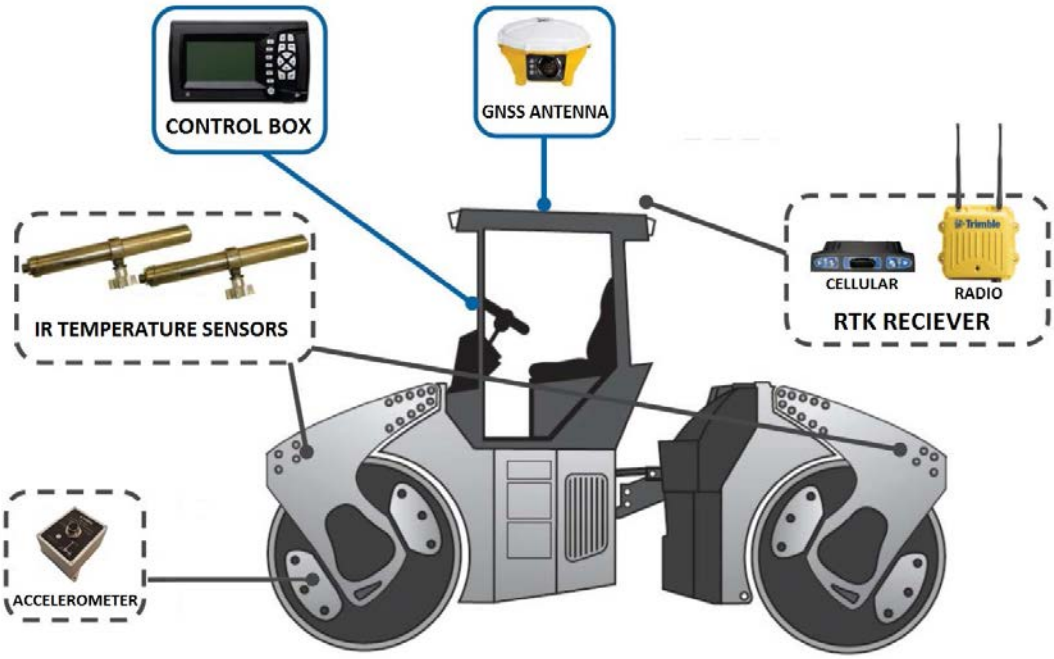


Figure 1-1: Intelligent Compaction Roller (Asphalt)

1.2 Advantages

The advantages of IC are numerous for both the contractors and infrastructure owners. For a contractor, IC is a tool to monitor compaction operations in real time to evaluate efficiency, quality, underlying structural conditions, and material properties. The on screen display on the roller can provide valuable information to help operators track their location which is increasingly helpful during night operations to provide consistency. When the roller is capable

of measuring stiffness, areas of substandard strength can be quickly and definitively identified for stabilization. With the use of an infrared sensor mounted on the paver, asphalt placement temperature can be monitored along with paver speed/stops, which is valuable information in evaluating the consistency of material and trucking efficiency.

From the agency perspective, IC provides a multitude of options for quality analysis. During construction, IC data provides information on differing site conditions or changes in material properties that could have impacts on the service life of the final product. For soil/aggregate operations, soft spots or potential changes in moisture can be identified with stiffness measurements. All types of projects can be evaluated for consistency in rolling using the roller pass analysis. Paving projects can be evaluated for adherence to the established roller pattern for coverages and temperature ranges. Areas at risk for premature failure can be identified using coverages, temperature at the rollers, roller speed and vibratory frequency. When the additional paver mounted system is utilized, temperature at the paver and paver stops can be analyzed as well. The full potential for the data will be realized as more pilot projects are constructed and analyzed.

2.0 Survey

2.1 Survey Needs for Intelligent Compaction

Two types of survey information are needed to construct and evaluate an IC project. The first is a roadway alignment that includes centerline stationing. This data is loaded on the roller so that the operator knows where they are in reference to the project stationing. The other required information is line work that isolates each lane within the project. These lines are used in the Veta software to define the analysis area and filter out the extraneous data. Areas of no work also need to be located so that they can be excluded in the evaluation.

2.2 Survey Data Collection

If there is existing survey data that was used for a previous design that is still valid, this data can be used to create the required files for IC. If there is not sufficient data available from previous projects, a new survey will be required. The most efficient process to collect the necessary data is through a mobile LiDAR scan. This can be requested by completing a Geometronics Project Request form (734-2633). This request should be as detailed as possible to help facilitate the work. The critical pieces for intelligent compaction are specific project limits, width of the roadway to be mapped and desired delivery date. Select the 3-D laser scanning option under Terrestrial products and services. The Geometronics Unit can provide the raw LiDAR data or post-processed mapping depending on your need. Include in the comment box whether you want raw point cloud data or the specific features mapped such as lane lines. Once the request has been received, a more detailed project agreement will be negotiated and a timeline will be established.

2.3 Coordinate Systems

Coordinate systems play a vital role in intelligent compaction. The IC system is based on location, thus a common coordinate system is needed to connect design, construction, and analysis. When survey data is exported for use in the Veta software package, the data can be

projected on to Google Maps or Google Earth. This makes finding actual locations of data points much easier. In cases where historical survey data is used for design, the projection of the data might not match correctly with the Google representation. This makes finding data points more difficult but the data can still be used as long as the same coordinate system is being used during design, construction, and analysis.

The most accurate coordinate systems are the Oregon Coordinate Reference System Zones (OCRS) which are low distortion systems. Projections have been calculated to fit a designed zone for multiple areas around the state. These projection systems are not available in all parts of the state. To find the best fit for your project, use the Geometronics Toolkit online.

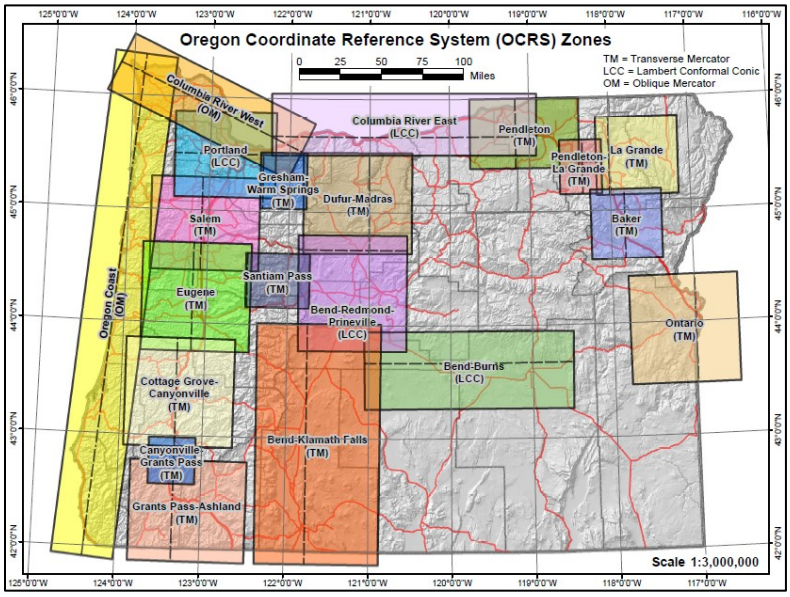


Figure 2-1: Oregon Coordinate Reference System Zones

Most past ODOT projects utilized a local datum plane based on State Plane Coordinates and applied a local combined scale factor. The scale factor is based on the North/South limits of the project and average elevation. These projects will require a coordinate transformation that can be obtained from the Geometronics Unit. The State Plane Coordinate System is a mapping projection that fits the round earth onto a flat surface. The map grid is not at true ground surface and has some distortion. Oregon has two zones, North and South.

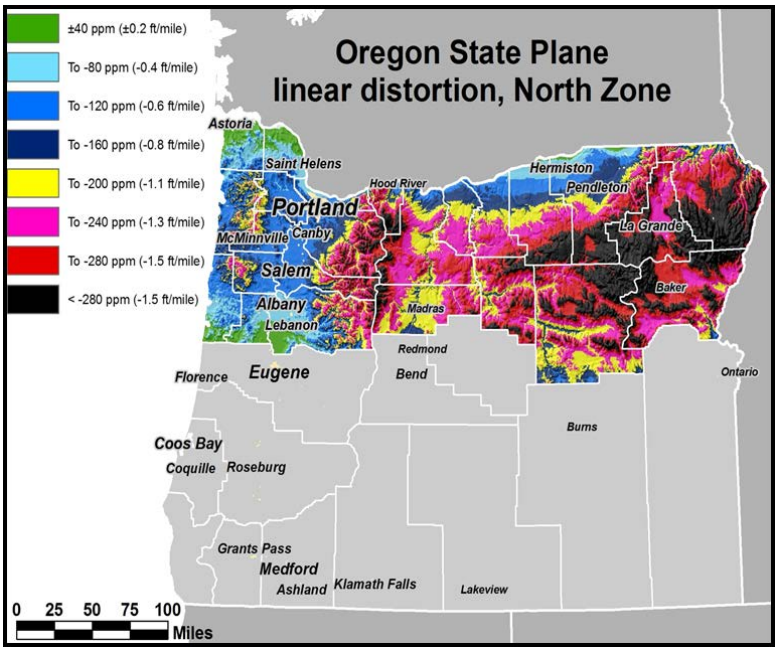


Figure 2-2: Oregon State Plane North Zone

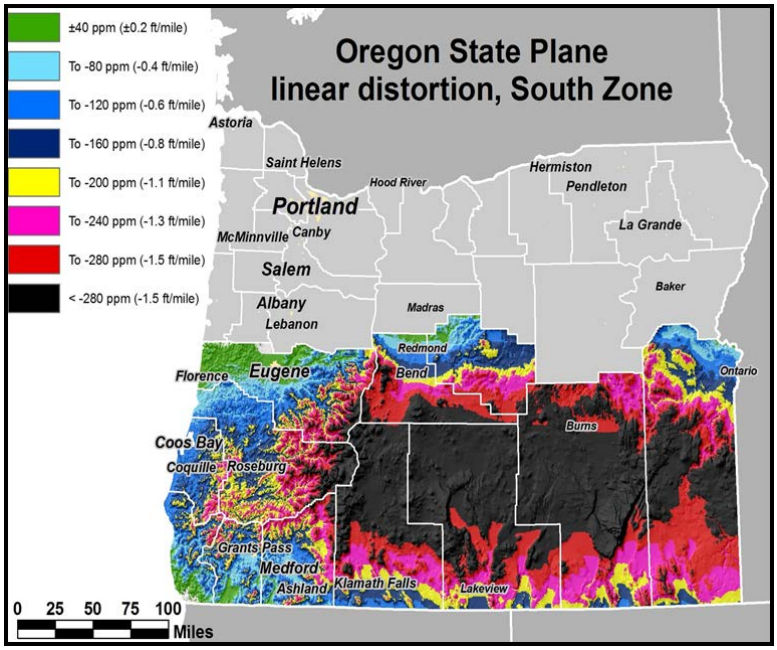


Figure 2-3: Oregon State Plane South Zone

The key point to coordinate systems is that it needs to be defined or known from the beginning of project development and communicated through construction and analysis. The design projection model needs to be known to the contractor to input into his machines for data collection. When the data is then imported into Veta, the correct coordinate system needs to be selected for the data to display properly.

Another piece of information that needs to be input into the Veta software is the Universal Transverse Mercator (UTM) zone. Oregon falls within 2 zones, zone 10 is the western section and zone 11 is the eastern section.

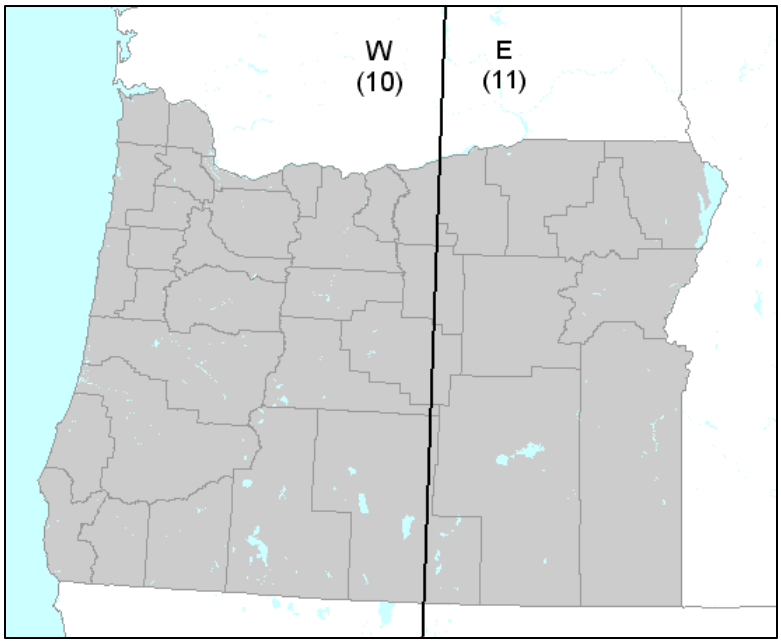


Figure 2-4: Oregon UTM Zones

3.0 Design

3.1 Deliverables

Intelligent Compaction requires the use of background files containing centerline stationing and closed complex shapes, where the edge of each traffic lane and auxiliary lane is closed off at each end. The background files are used to clean the IC data sets for analysis. The contactor and inspectors also need the background files for real-time location of the equipment and data points.

Provide a 2D .dgn and 2D .kmz file for the following

1) Closed complex shape of each travel lane and adjacent auxiliary lanes. Exclude ramps, shoulders, non-continuous turn lanes, and side streets.

2) Alignment with centerline station numbering, stationed project limits, and exclusion areas.

These files are created by the roadway designer and should be provided with the survey handoff package that is delivered to the contractor. Copies of these files should also be provided to the Project Manager that will be administering the project along with Pavement Services and the ETA Unit. If any assistance is needed, contact the ETA Unit.

As 3D design is implemented throughout the agency, it is important to note that the files imported into Veta need to be 2D. When 3D information is attached to the files, the .kmz file automatically creates a triangulated surface, where each side of the triangle is considered a separate line which is available to be chosen for an alignment. Thousands of lines are typically created, making it very difficult to find the appropriate lines for roadway alignment.

3.2 File Creation

Create a closed complex shape for each of the traffic and auxiliary lanes, where the edge of the lane is closed off at each end. Place the complex shapes on a separate and distinguishable Microstation level such as "IC Lanes". For each lane, it is recommended to choose a different color to differentiate the lanes.

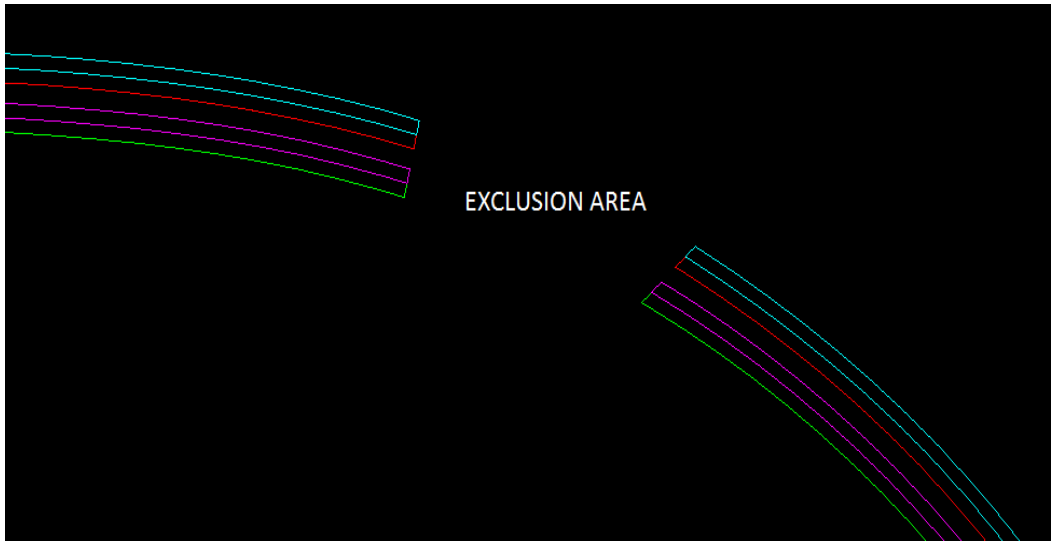


Figure 3-1: Complex Shape w/Exclusion Area

Figure 3-2: Complex Shape in Google Earth

Since these shapes will be used to clean the IC data collected from the rollers, any expected or actual offsets in paving from the lane lines need to be taken into consideration. Contact the Project Managers office to discuss how to handle any paving offsets.

The other information that is needed is the centerline alignment and stationing. The text should be placed outside of the edge of pavement so that it does not overlap any IC data when displayed. Place the tic marks and stationing text on a separate and distinguishable Microstation level from the lane shapes. This data is imported into the construction equipment and computers so that the contractor can locate where the work is being done. The stationing also can be displayed in the analysis software to easily locate specific areas of interest.

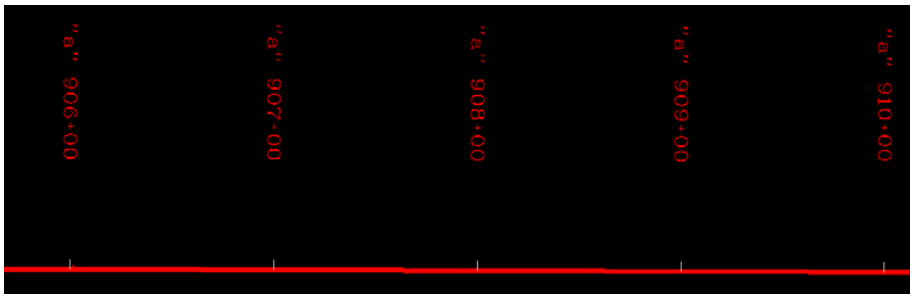


Figure 3-3: Roadway Alignment w/Stationing

Export only the lane shapes and stationing layers to a single Google Earth file (.kmz) for use in Veta. Provide this data to Pavement Services and the ETA Unit in both .dgn and .kmz formats, as the original MicroStation file will be required for modifications if construction joint offsets change throughout the project.

3.3 Quality Control

There are many quality control measures in place for survey and design data. All of those processes will apply to creating these files. A quality control check should be performed by the Project Manager's office to ensure the correct alignments, lanes, exclusions, and offsets are included in the design files. An understanding of how the design files relate to the actual ground surface can be examined by opening the complex shape file (.kmz) in Google Earth to see if there are any location, scaling, or skew issues with the projection.

Figure 3-4: Complex Shape in Google Earth (Matching Projection)

Figure 3-5: Complex Shape in Google Earth (Non-Matching Projection)

If the projection does not match the roadway location as represented in Google Earth, this is not a major issue as long as all the data is projected onto the same coordinate system during construction. For analysis, this will not affect the results but it will make physically locating areas difficult unless stationing is included in the alignment file. If a positioning tool is available you will need to set the coordinate system to the same system that the data was collected in. It may involve some type of site localization or a local coordinate system that is not preloaded into the rover or positioning tablet. Please contact the Engineering Technology Advancement Unit for assistance with this issue.

4.0 Construction

4.1 Site/Equipment Setup

In order to ensure that the data collected is accurate, both the site and equipment must be calibrated to the coordinate system being used on the project. The first step is to confirm the necessary control point information is available and set any temporary control points that are needed. Contact the Geometronics Unit to evaluate and set control points.

The next step is to compare the coordinates from the IC system with an independent measuring device. Verify that the rover(s) or other positioning tools are calibrated to the correct coordinate system, by checking Control Points within the project limits. Complete this verification prior to checking the intelligent compaction system's GNSS.

To calibrate the intelligent compaction system, ensure the machine has been properly measured to locate the position of the GNSS antenna. This information needs to be entered into the onboard system and checked periodically.

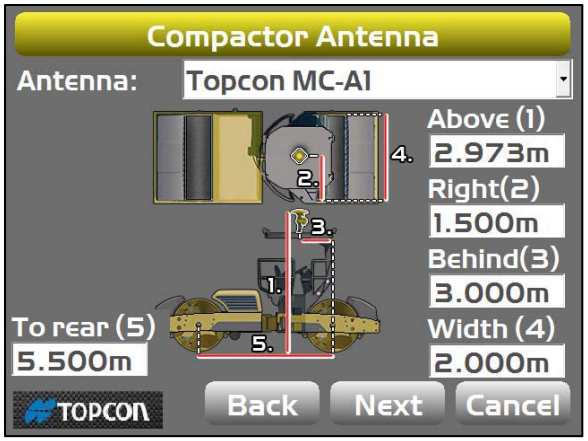


Figure 4-1: Machine Calibration Measurements

To validate the position, mark a spot on the ground next to the drum location being recorded and displayed by the onboard documentation system (e.g., center/left/right of the roller drum or the outside edge of a pneumatic roller tire). Collect and compare the coordinates from the rover and the instrumented roller. The two positions should compare within a horizontal tolerance of 0.5 feet.

To calibrate the temperature sensors on intelligent compaction systems, power on the sensors for a minimum of 10 minutes before verifying measurements. Collect and compare the temperature measurements from a calibrated independent device and the instrumented roller for the front sensor (and optional rear mounted sensor). The temperatures should compare within 3°F or 1.5% of reading, whichever is greater.

4.2 GNSS Corrections

In order to achieve survey grade positioning, a real time corrector is needed to adjust the signal received from the GNSS satellites, this is known as real time kinematic surveying (RTK). These RTK corrections are obtained in two different methods, through a local base or a network corrector.

When using a local base station, a GNSS unit occupying a known point is required. The base station transmits correctors to the other GNSS units in real time through a radio transmitter. Five or more common satellites are needed at any given point in time to get an accurate position. In areas with significant topography, multiple base stations or radio repeaters may be required to transmit the signal throughout the project limits.

When cellular data coverage is available, a network corrector from the Oregon Real-time GNSS Network (ORGN) can be used to achieve an RTK solution instead of a local base station. The GNSS receiver needs to be registered with the Geometrics Unit to obtain a free login and password to receive the corrector signal. The ORGN is a network of base stations located throughout the state, when combined provides a higher quality corrector. There is a risk of ORGN network outages that will not be considered for contract time extensions. In order to continue collecting positioning data, the contractor should have a base station on site to transmit correctors if the ORGN is not functioning.

The ORGN offers three types of solutions to provide correctors. The most accurate and reliable source is the Network MAX solution. This solution is a network RTK corrector with one master reference station and several auxiliary reference stations. It is accurate to a longer range than the other solutions, allowing a working distance of 20 to 25 miles from the master station. The ORGN software uses your location and updates the solution to the closest master station as you move.

The other two solutions provide correctors from a single base station. The range for accurate correctors is reduced to 6 to 8 miles from the base station. The options for this type of solution are Nearest Single Base and Single Base Direct. The Nearest Single Base uses the software to locate and connect to the base that is closest to the equipment. The Single Base Direct allows the user to select the base station that it connects to and does not update with location.

4.3 File Naming Convention

To aid in the identification and organization of project data IC data files have been given a naming convention. The file name will include:

- Direction of work (EB, WB, NB, SB)
- Highway Number (OR213, I5)
- Travel lane (A, B, C, AUX)
- Extents of working area (MP3.5-4.5, STA 100.0-200.0)
- Roller number (R1, R2, R3, AP)
- Date of work (MMDDYY)
- Lift (W, B1, B2)

Roller numbers should be listed as R1 for roller 1, R2 for roller 2, R3 for roller 3, etc. The order of roller numbering should follow the convention set by the Control Strip Method of Compaction form number 734-2084.

Lane of travel shall follow the naming convention demonstrated in the form 1793A Update. For a 2 lane road, A would represent the left lane, B the right lane, S meaning shoulder of the highway. If IC data is collected while paving an on/off ramp, it would be represented with its exit number in this space.

When creating a combined roller file leave out the roller number and put "AP" for all passes at the front of the file.

4.4 Color Convention

To ease in the processing and sharing of intelligent compaction data, a standard color scale has been established to chart roller coverage. Each roller's pass count should follow this color scheme to help ensure proper coverage. The appropriate number of passes per roller to reach optimum compaction must be determined per specification. Contact ODOT Pavement Services (see Chapter 7 for contact info) for current standard.

4.5 Data Types

Two types of data can be exported for analysis:
All Passes Data: Includes all measurements taken during each pass.
Final Coverage Data: Measurements from the last pass at a given area.

It is suggested that both types of data are downloaded from the contractor's cloud storage. In future releases of Veta, it is anticipated that only *all passes* data will be required and the software will generate the final coverage data.

Below are the data types collected during the IC process and represented in the Veta software.

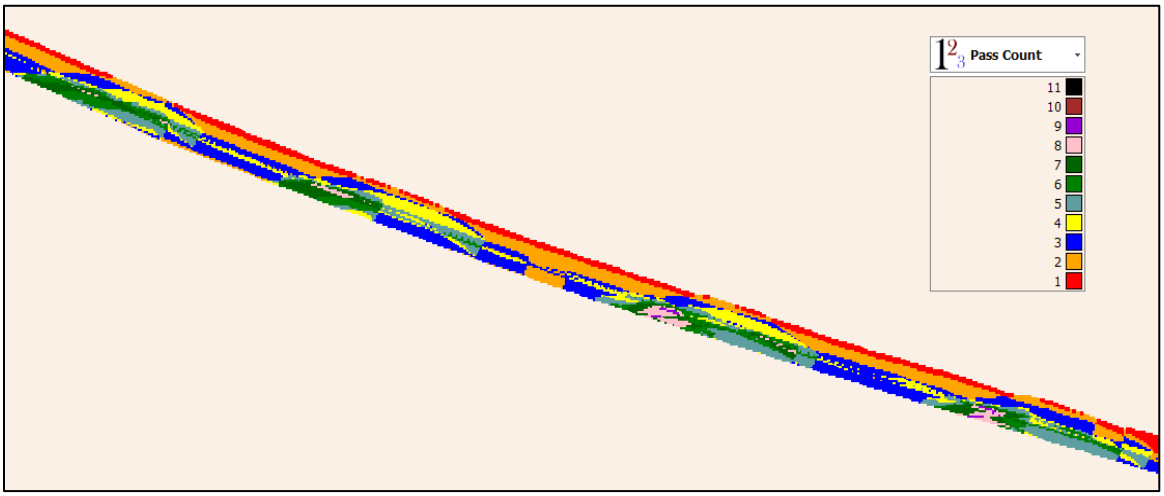


Figure 4-2: Pass Count

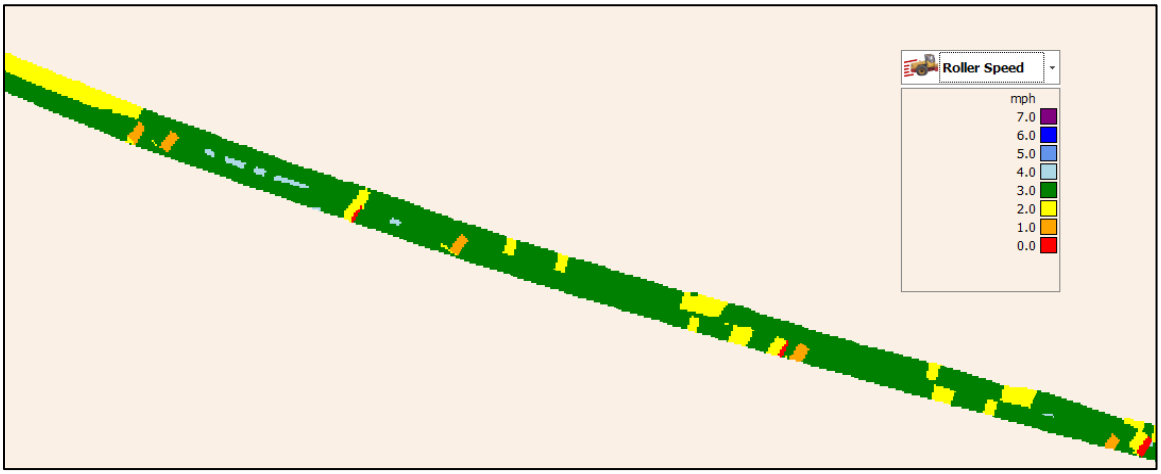


Figure 4-3: Roller Speed

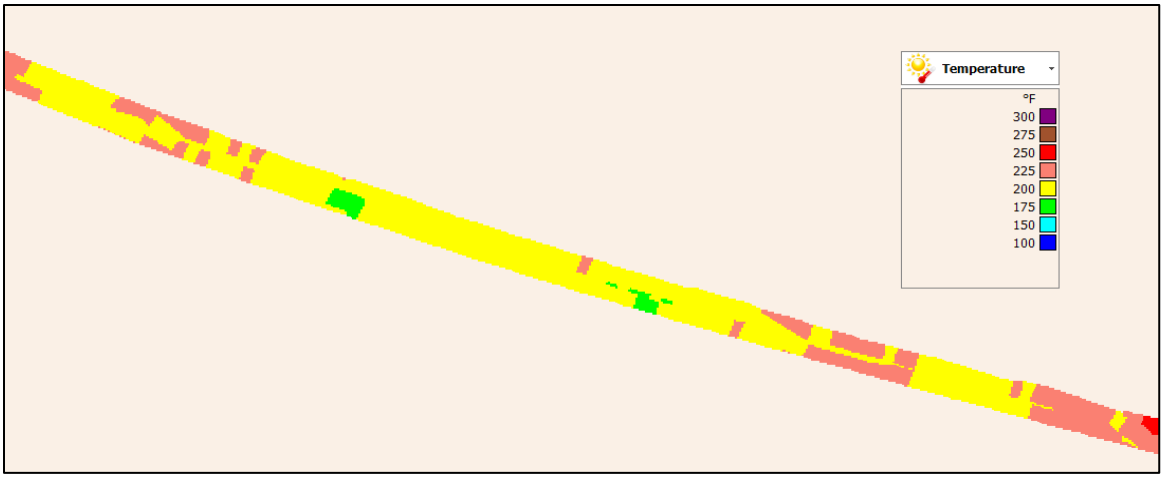


Figure 4-4: Roller Temperature

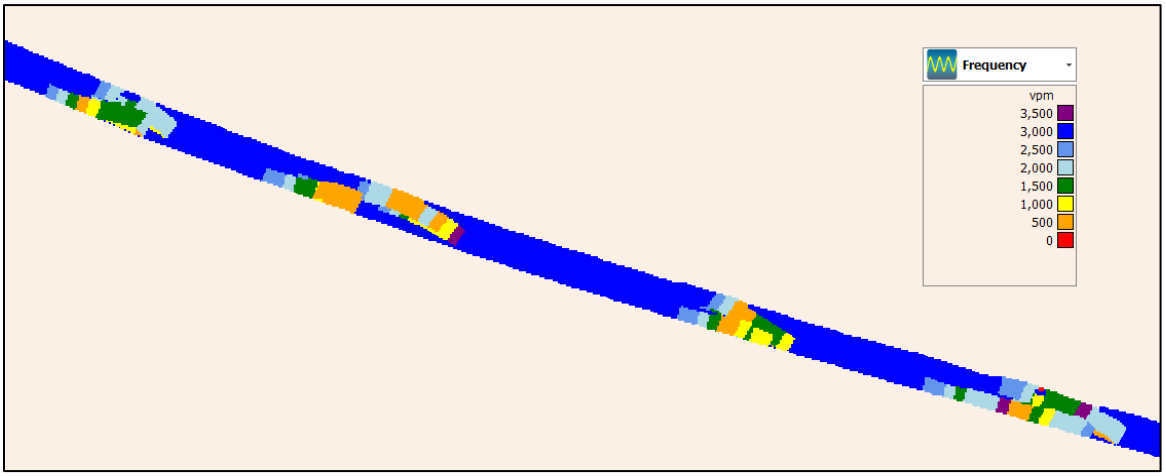


Figure 4-5: Vibration Frequency

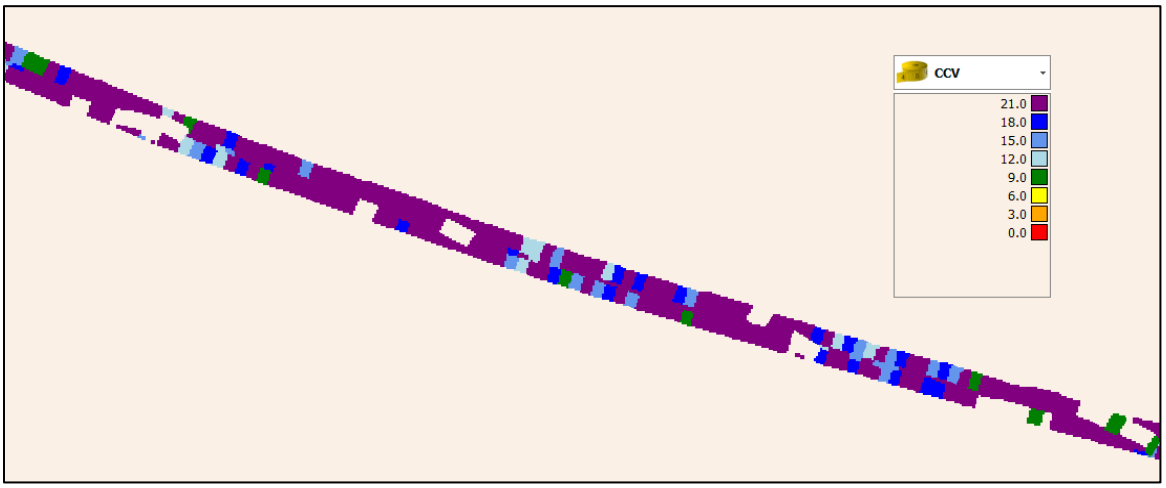


Figure 4-6: Stiffness

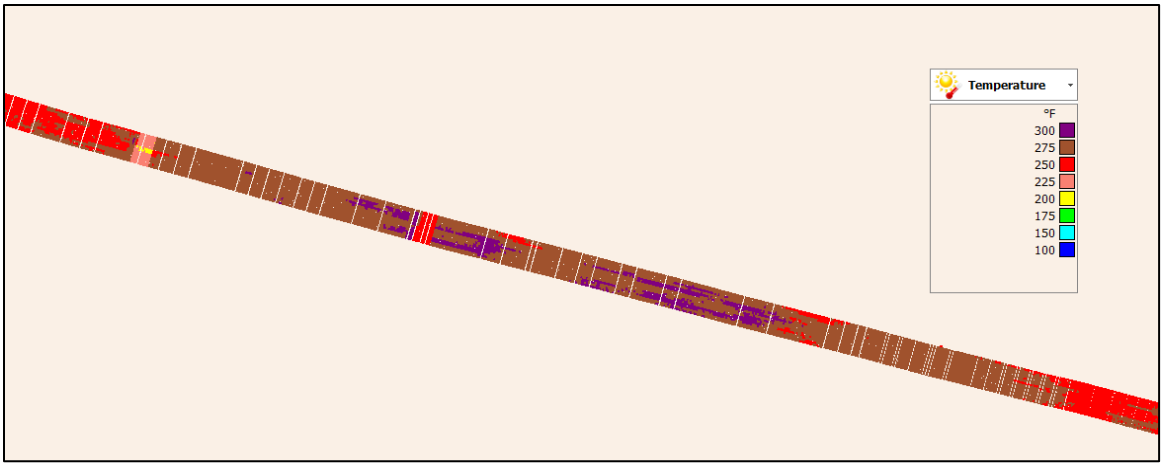


Figure 4-7: Paver Temperature

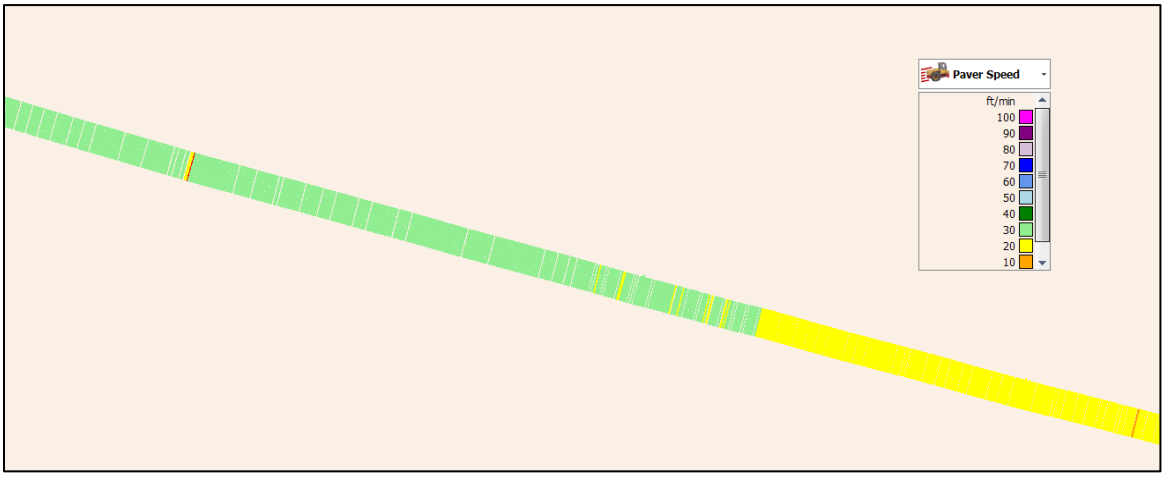


Figure 4-8: Paver Speed

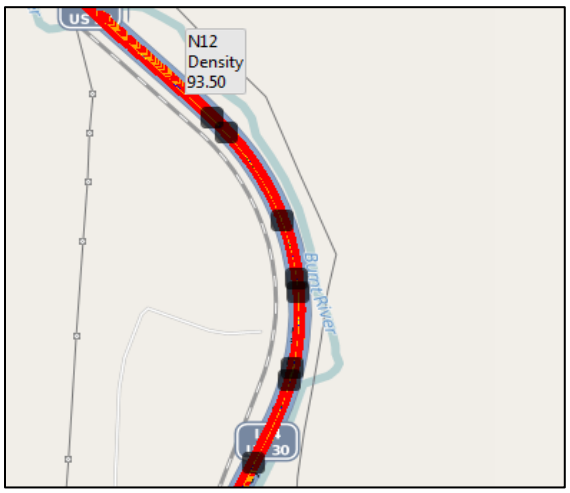


Figure 4-9: Spot Data – Rover or other positioning tool

4.6 Spot Data Collection

Spot data is individual data points that are geospatially located and can be overlaid onto the intelligent compaction data collected by the roller or paver. The data can be collected with any device that has locating and data logging capabilities. The accuracy of the solution should be noted e.g. autonomous, mapping grade, or RTK/survey grade. The types of data that can be imported into Veta are currently constrained to a set of tests shown below.

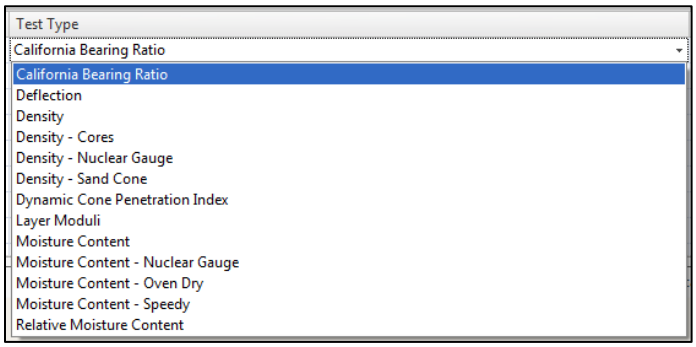


Figure 4-10: Veta Spot Test Data Types

The most common type of spot data is density test information collected for both quality control and quality assurance. For the most efficient importing of the data into Veta, the data should be stored in an excel spreadsheet as shown below.

ID	Northing	Easting	Test Type	Value
1-1-1	4479954.90	499203.81	Density	92.5
1-1-2	4479956.56	499204.26	Density	93.1
1-1-3	4479958.39	499204.39	Density	92.8

Figure 4-11: Spot Data

Other types of spot data that might be collected are start and stop points for paving shifts and exclusion areas. Validation points along the edge of pavement can help ensure the correct location of the alignment files to account for any offset in paving joints. Collecting locations of deficiencies can supplement daily inspection reports.

5.0 Veta

5.1 Software and Support

This document was prepared for Veta version 3.xx. The Veta software package is currently under development with updates being issued on a regular basis. To ensure the latest version of the software is being used, go to http://www.intelligentcompaction.com/veta/current-version/. All updates are explained in the Release Notes document on the website. For a list of contacts for technical support, see Chapter 7.1.

5.2 Project Setup/Importing Data

To create a Veta project, open the Veta software and click on the import data icon.

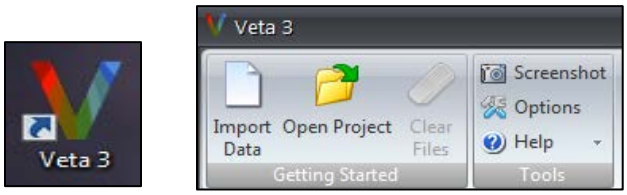
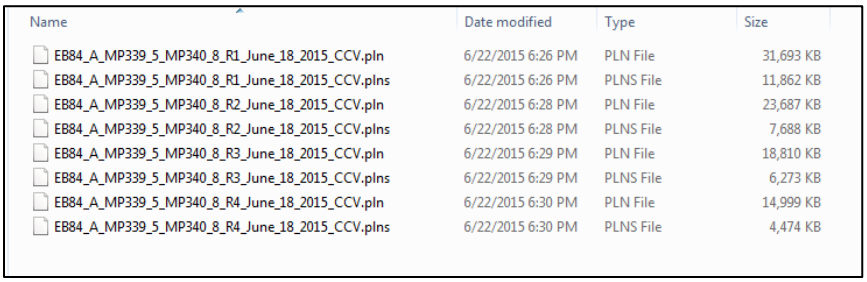


Figure 5-1: Veta Icon/Menu

Locate the files that you want to import to the software. The type of data that can be viewed will be dependent on how the files are exported from the vendor's software package. Examples of data sets are individual rollers vs. all rollers and *all passes* vs. *final coverage*. Select all of the files associated with the data that you want to view. In this example, both the .pln (All Passes Data) and .plns (Final Coverage Data) files would be selected for the roller.



Name	Date modified	Type	Size
EB84_A_MP339_5_MP340_8_R1_June_18_2015_CCV.pln	6/22/2015 6:26 PM	PLN File	31,693 KB
EB84_A_MP339_5_MP340_8_R1_June_18_2015_CCV.plns	6/22/2015 6:26 PM	PLNS File	11,862 KB
EB84_A_MP339_5_MP340_8_R2_June_18_2015_CCV.pln	6/22/2015 6:28 PM	PLN File	23,687 KB
EB84_A_MP339_5_MP340_8_R2_June_18_2015_CCV.plns	6/22/2015 6:28 PM	PLNS File	7,688 KB
EB84_A_MP339_5_MP340_8_R3_June_18_2015_CCV.pln	6/22/2015 6:29 PM	PLN File	18,810 KB
EB84_A_MP339_5_MP340_8_R3_June_18_2015_CCV.plns	6/22/2015 6:29 PM	PLNS File	6,273 KB
EB84_A_MP339_5_MP340_8_R4_June_18_2015_CCV.pln	6/22/2015 6:30 PM	PLN File	14,999 KB
EB84_A_MP339_5_MP340_8_R4_June_18_2015_CCV.plns	6/22/2015 6:30 PM	PLNS File	4,474 KB

Figure 5-2: Construction Files

Next, you will be prompted to enter the coordinate system in which the data was collected. Generally this will be either *GPS* or *State Plane*. Currently the ORCS coordinate system is not supported in Veta but the goal is to have it included in future releases. Choose either the *Oregon North* or *Oregon South* State Plane Zone (see maps in Chapter 2.3 Coordinate Systems) and the *UTM* zone (10 or 11).

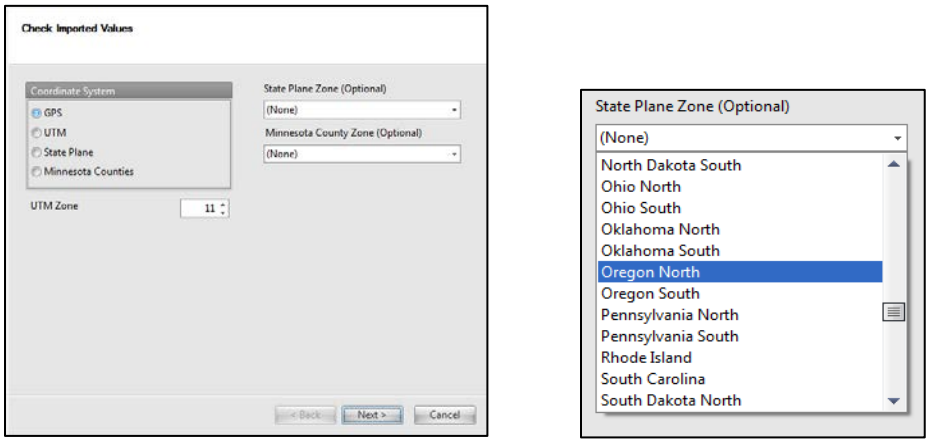


Figure 5-3: Coordinate System Setup

5.3 Pass Count Color Setup

To set the software to display the pass count color convention outlined in Chapter 4.3, make sure *Pass Count* is showing on the drop down menu. Right click in the area that displays the pass count number and associated colors then select *Customize*. The Legend box will appear and allow the user to choose the individual colors for each pass count.

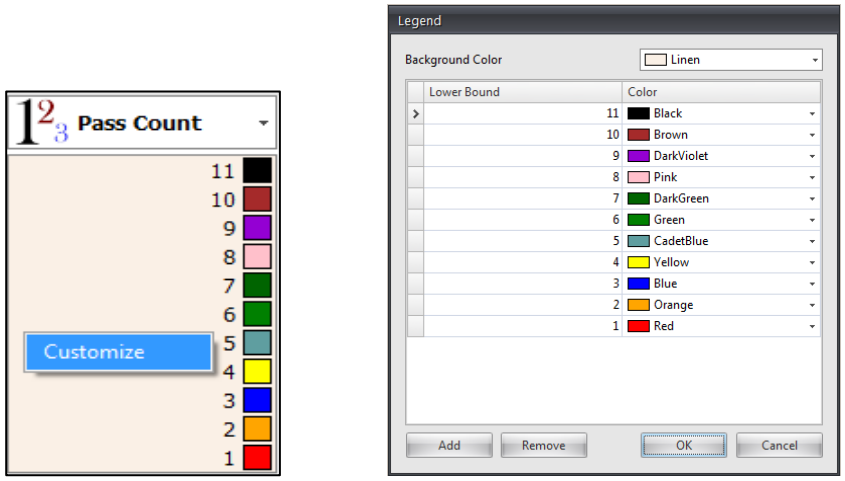


Figure 5-4: Pass Count Color Setup

5.4 Alignments

To load the alignment file, this is the file made up of closed complex shapes for each individual lane (discussed in Chapter 3 and not the centerline alignment), select the *Alignment* tab at the top of the screen then select the *Add* button.

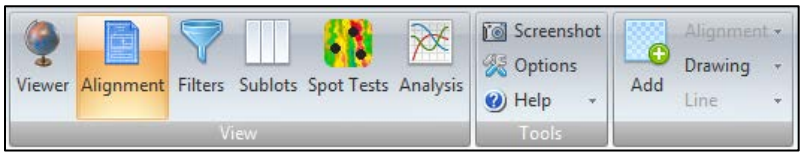


Figure 5-5: Alignment File Setup

Locate your alignment file (.kmz) and open it. The format and naming convention of this data is dependent on how it was produced in MicroStation. If you need further clarification on the available data types in the file, contact the roadway designer. When all the levels are expanded, there will be a list of lines that represent each lane. If there are many lanes and exclusion areas, the list could be long.

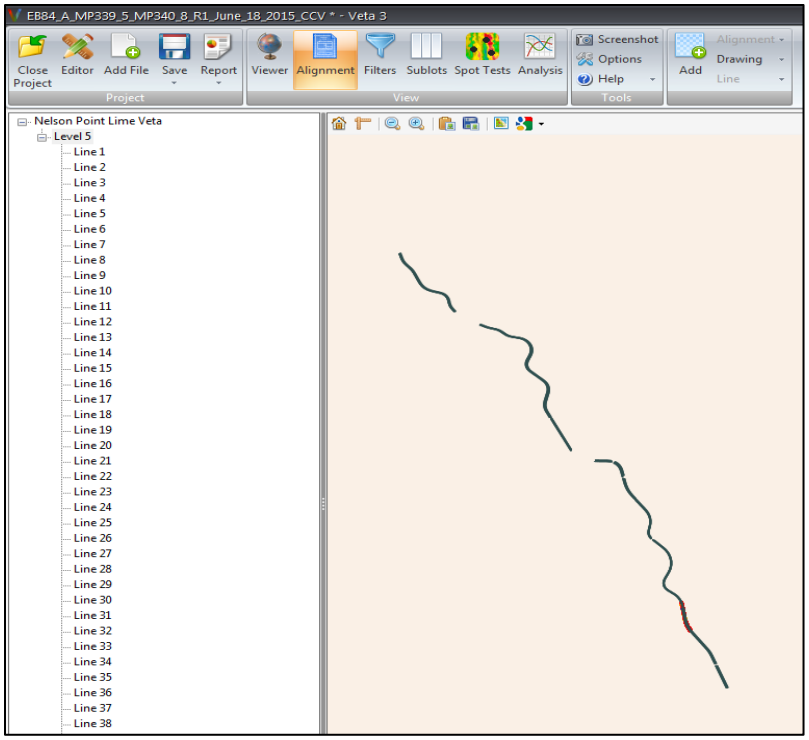


Figure 5-6: Alignment Lane Shapes

In order to determine which line should be used for the loaded data, zoom in on the data and click through the lines until your data is included in the shape. Your data might span more than one line which means multiple analyses will be required to cover all of the data in the file. Note the ID of the line(s) as it will be needed to set up the location filter for analysis.

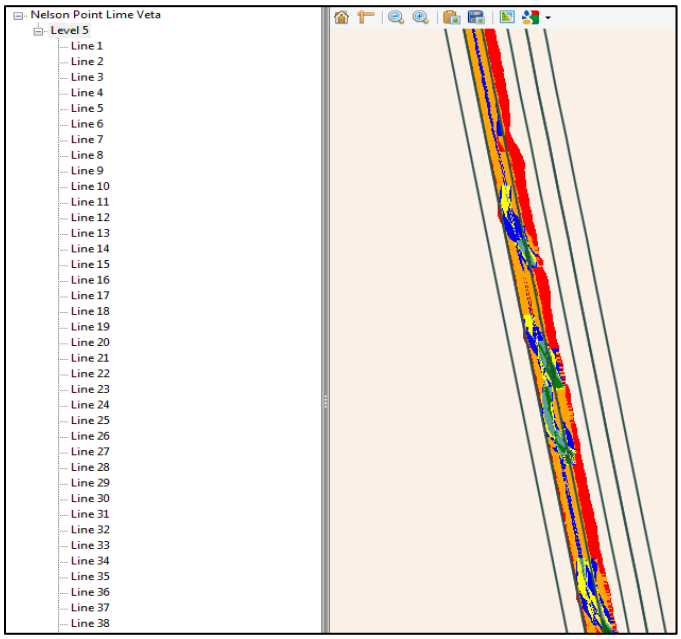


Figure 5-7: Construction Data w/All Lane Lines

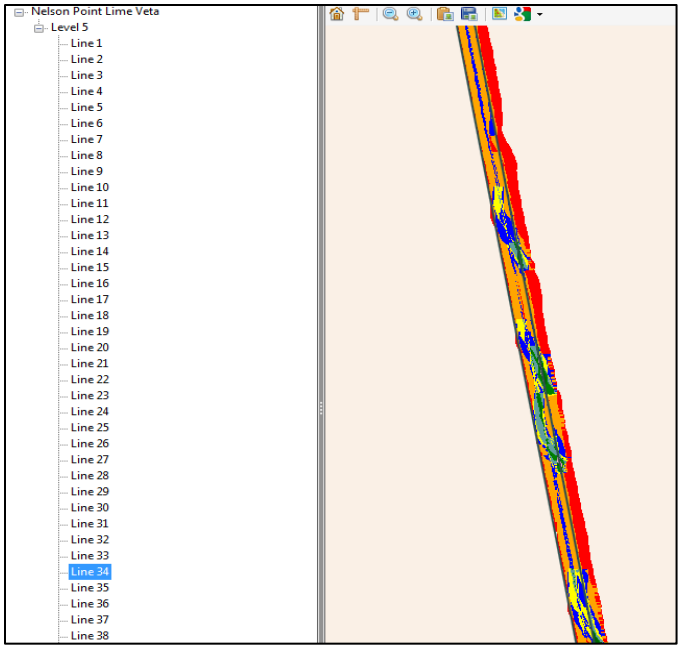


Figure 5-8: Construction Data w/Selected Lane Line

5.5 Filters

To set up a new filter, select the *Filters* button on the top of the screen, right click in the open space below *Groups* and select *Add*. You will be prompted to input a name for the filter. Name this filter so that it has meaning to the data you will be evaluating.

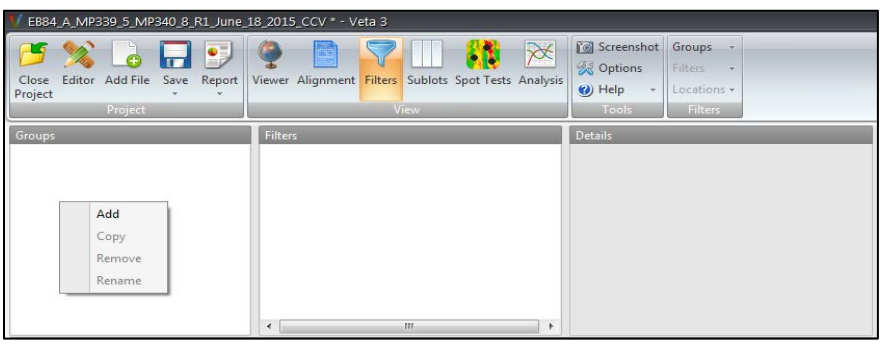


Figure 5-9: Filter Setup

Within the filters, there are multiple attributes that can be used. These filters will apply to the raw data unless the Location Filter is used to clean the data within the selected alignment file. Because the majority of analysis scenarios will pertain to cleaned data, the Location Filter should be set up before looking at data filters.

Select *Location Filter* at the bottom of the *Filters* list then select the *Source…* button. To include all data within the limits of the selected alignment line, select *Copy from an alignment line*. Select the *Alignment* and *Drawing* that contains the shapes of the lanes. If the file was created according to Chapter 3.2, these selections should be automatically selected. Next, choose the line name that contains the shape for the specific lane that is being analyzed and click *OK*.

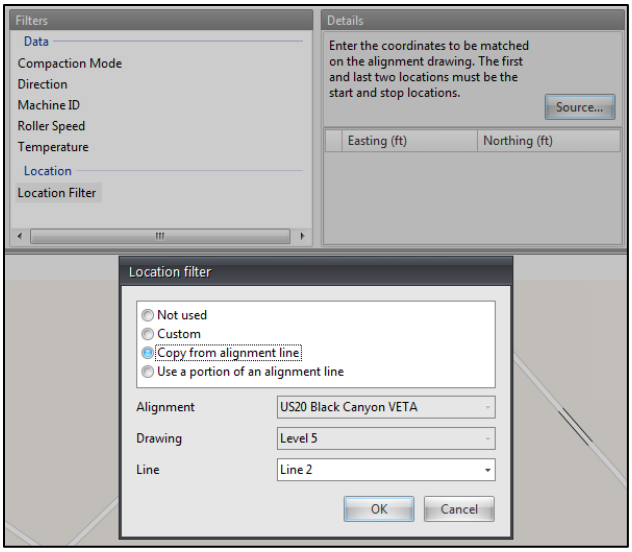


Figure 5-10: Location Filter Setup (Copy)

To filter out portions of the alignment line, right click in the *Filters* box and select *Add exclusion filter*. Only one location filter can be used per filter group, but many exclusion filters can be applied to the location filter.

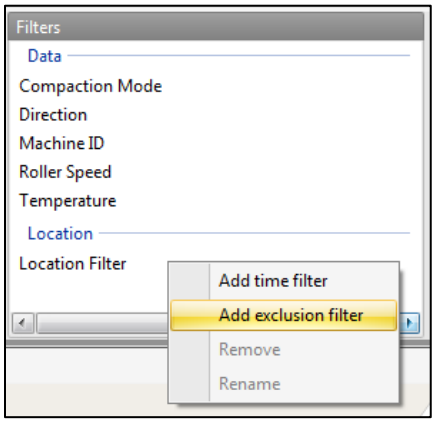


Figure 5-11: Exclusion Filter

To input the exlusion limits, coordinates can be entered manually or chosen visually in the Veta software. To input manually, right click in the *Details* box and select *Add*. Then type the coordinates into the row. If data was collected using a positioning tool, these points can be copied and pasted from Excel by selecting *Paste locations*. To visually input the points, hover the mouse over one of the points, right click and select *Add*. This will record the coordinates in the details table. Do this for all 4 points to complete the area. To edit the point either right click and select *Remove* or drag and drop the point in its new location.

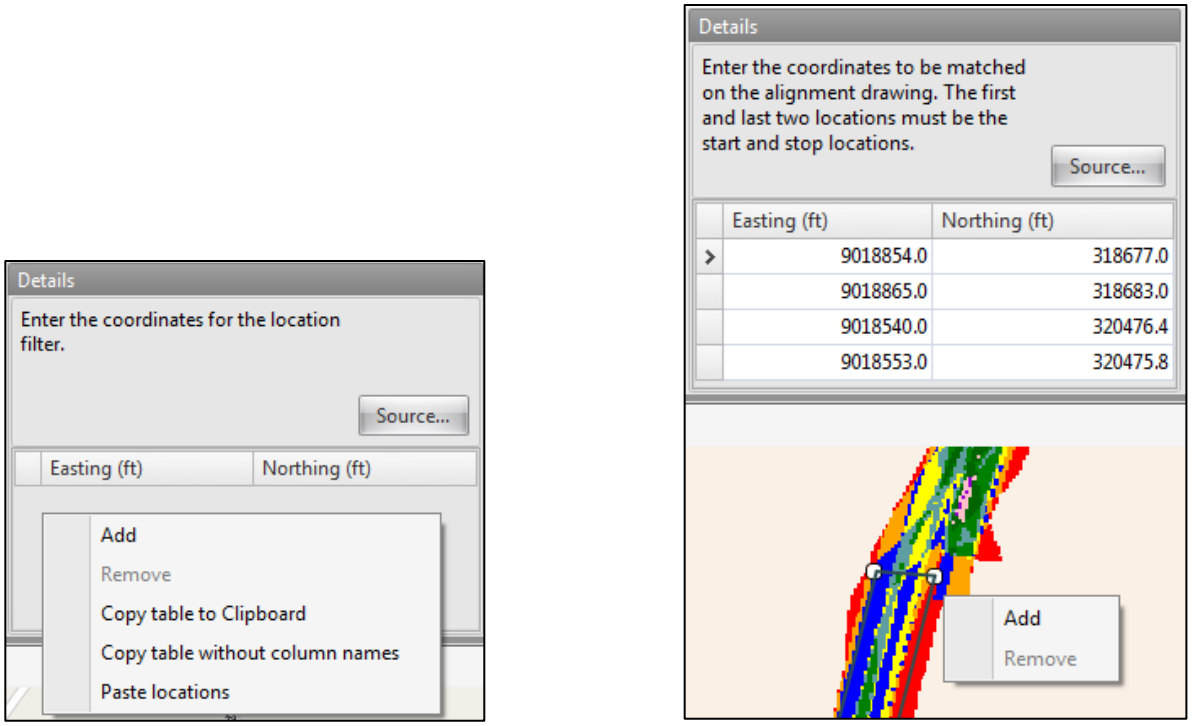


Figure 5-12: Entering Coordinates

Alternatively, to filter data within a given alignment line, Select the radio button labeled *Use a portion of an alignment line*. Select the *Alignment* and *Drawing* that contains the shapes of the lanes. If the file was created according to Chapter 3.2, these selections should be automatically selected. Next, choose the line name that contains the shape for the specific lane that is being analyzed and click *OK*.

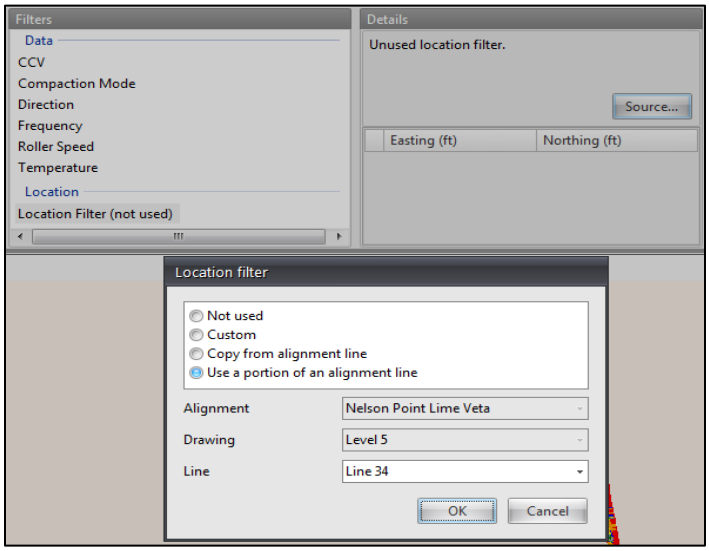


Figure 5-13: Location Filter Setup (Portion)

Once the line is selected, the data will be filtered with the entire shape that was selected. Another level of filtering will be required to exclude any start up/shut down data that occurred

within the limits of the alignment shape. The most accurate way to track the start and end limits for the shift is to use a GNSS rover or other positioning tool to record the 4 corners of the work location. If a positioning tool is not available for the project, the data points can be obtained visually through the Veta software as described in the previous section.

Once the data analysis area has been defined through the *Location Filter*, subsequent data filters can be used to further filter the information. Once the filtered data has been entered, click the *Redraw Map* button to update the data. A list of the available filters is included below:

- Stiffness (This value has different labels for each equipment manufacturer)
  - Minimum
  - Maximum
- Compaction Mode
  - Oscillation
  - Static
  - Tire
  - Vibratory
- Direction
  - Forward
  - Reverse
- Machine ID
  - Specific values
- Frequency
  - Minimum (vpm)
  - Maximum (vpm)
- Roller Speed
  - Minimum (mph)
  - Maximum (mph)
- Temperature
  - Minimum °F
  - Maximum °F

To add a time/date filter, right click in the box labelled *Filters* and select *Add time filter*. Select a specific date or, enter the start and end times to customize the date/time filter. Check the boxes next to the custom start/end times to activate them.

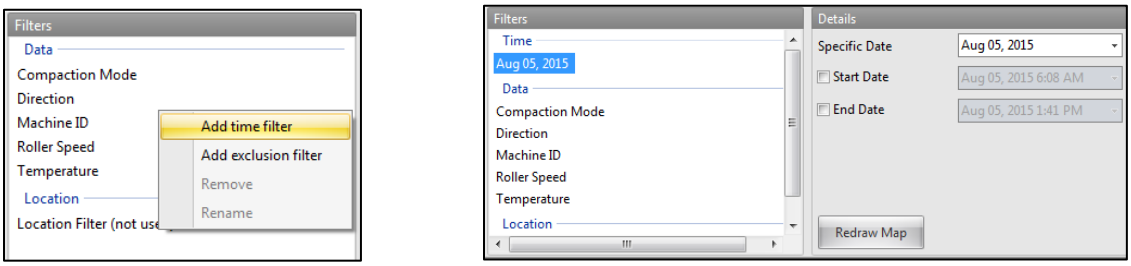


Figure 5-14: Time Filter

The final, filtered result may be viewed in the *Viewer* tab by selecting the applicable filter from the dropdown filter list.

5.6 Sublots

Sublots can be created to divide the data into manageable sections. Select the *Sublots* button at the top of the screen, right click in the open space under *Sublots* and select *Add*. Enter a name to identify the set of sublots that will be created and click *OK*.

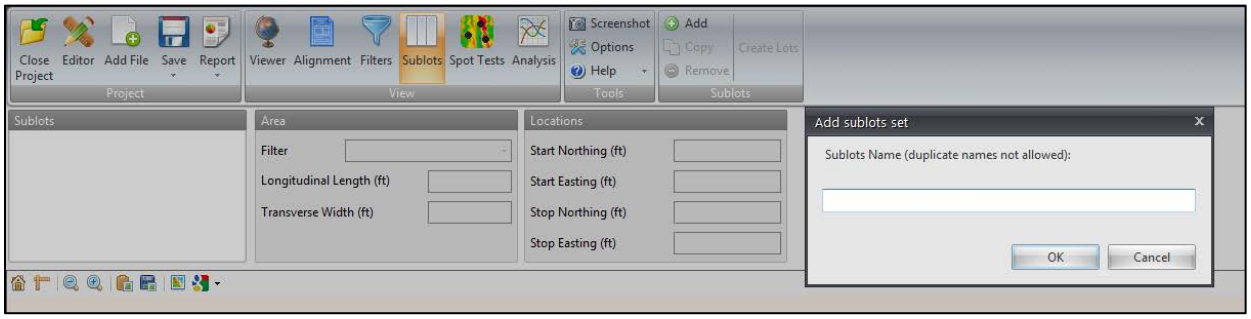


Figure 5-15: Sublot Setup

In the Area box, select the applicable filter (usually the one containing the location filter created in Chapter 5.4). Next, enter the longitudinal length of each sublot and the transverse width. If the location filter is being used, all excess data has already been filtered so there will be no impact to the data analysis as long as the width value is equal to or greater than the width of the alignment shape chosen. Under the locations box, coordinates for the start and stop of sublot creation must be entered. In the data area, right click in the center of the data at the start location and select *Set Start Location*. Repeat this step for the stop location. Finally, select the *Create Lots* button and the sublots will be drawn onto the data.

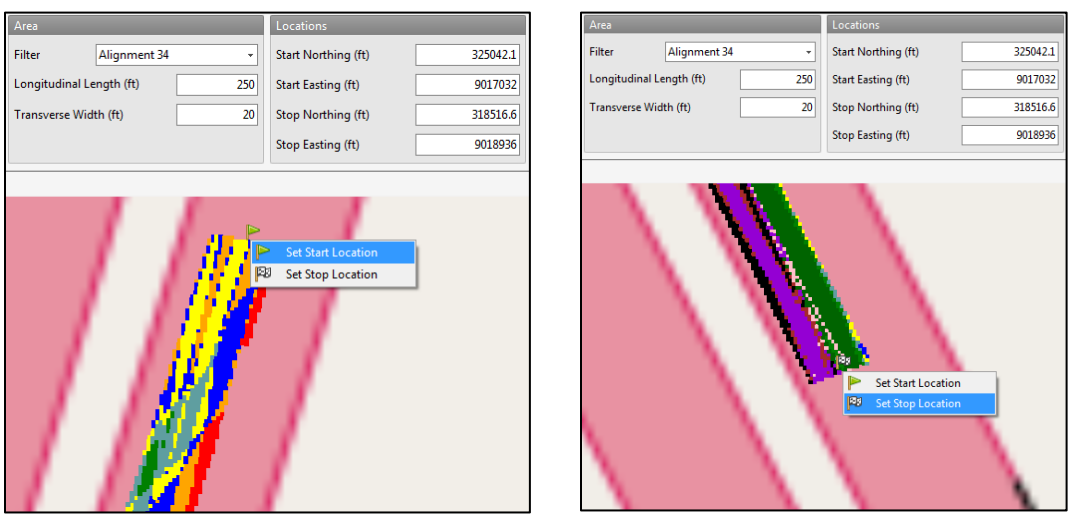


Figure 5-16: Sublot Start/Stop Location

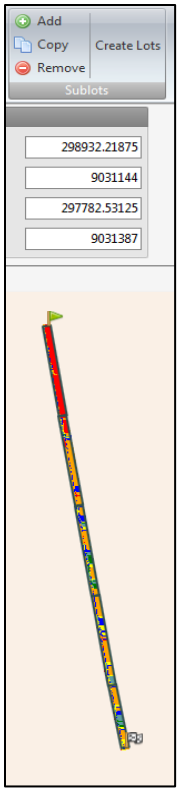


Figure 5-17: Completed Sublots

5.7 Spot Data

Any piece of data that is collected with a positioning tool can be added to the data set with the *Spot Data* button at the top of the screen. This data can be entered manually (+ *Add button*) or copied from a spreadsheet (right click under headers and select *Paste Clipboard* to table). When copying from a spreadsheet, be sure to include the header information in the selection. Each data point is added to either a specific pass or to the final coverage data.

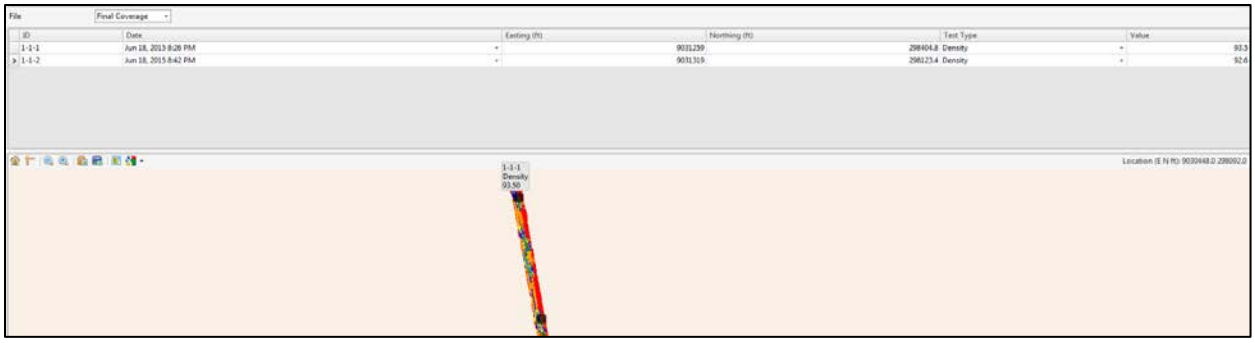


Figure 5-18: Spot Data Input

5.8 Analysis

The Veta software has a very useful analysis function that can evaluate the project data for specification compliance and present findings in an understandable format. To use this function, click on the *Analysis* button on the top of the screen. Then choose the appropriate filter for the data and if sublots were created, choose the corresponding selection from the drop down menu. When a filter group and/or sublots are chosen, the parameters for those selections are shown on the left side of the screen. If spot data is available, a correlation radius can be entered. Depending if roller data or paver data is loaded, the rest of the analysis will be specific to the data type.

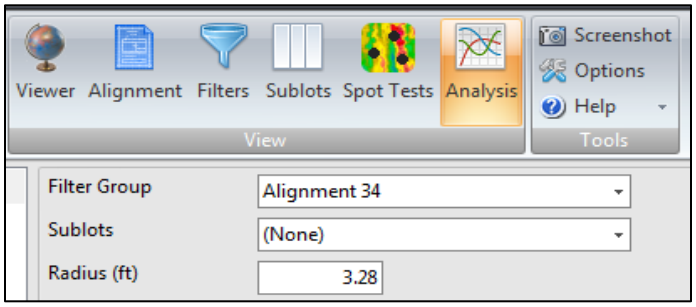


Figure 5-19: Analysis Setup

5.8.1 Roller Data

The roller data analysis gives you multiple parameters to simply report or set acceptance criteria. They include stiffness, pass count, temperature, frequency, and roller speed. The analysis parameters evaluate the percentage of data that is equal to or greater than the user defined target value. To input target values, click on the parameter and check the *Use cumulative target* box. The maximum pass parameter needs to be set to at least 3 passes if all passes data is being analyzed. Once all the appropriate parameters for the analysis have been entered, click *Analyze* to view the results.

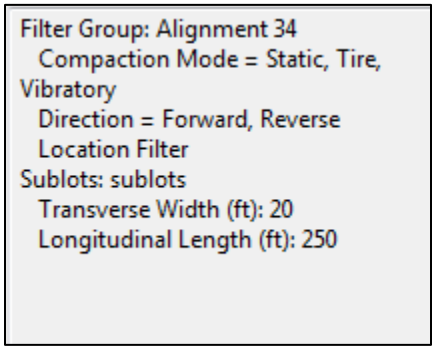


Figure 5-20: Filter Group/Sublot Settings

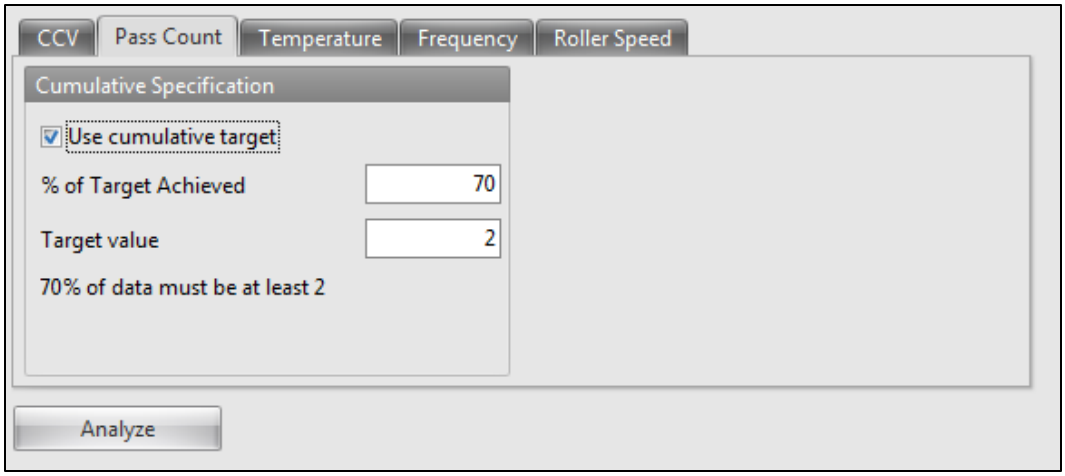


Figure 5-21: Analysis Parameters

The first data set available is a pie chart and statistics for *Coverage*. This view breaks down total coverages and coverage per pass count in both area and percentage of the total filter area. When a high percentage of the area has no passes, it can be an indication of issues with the alignment file lines not matching the actual work area.

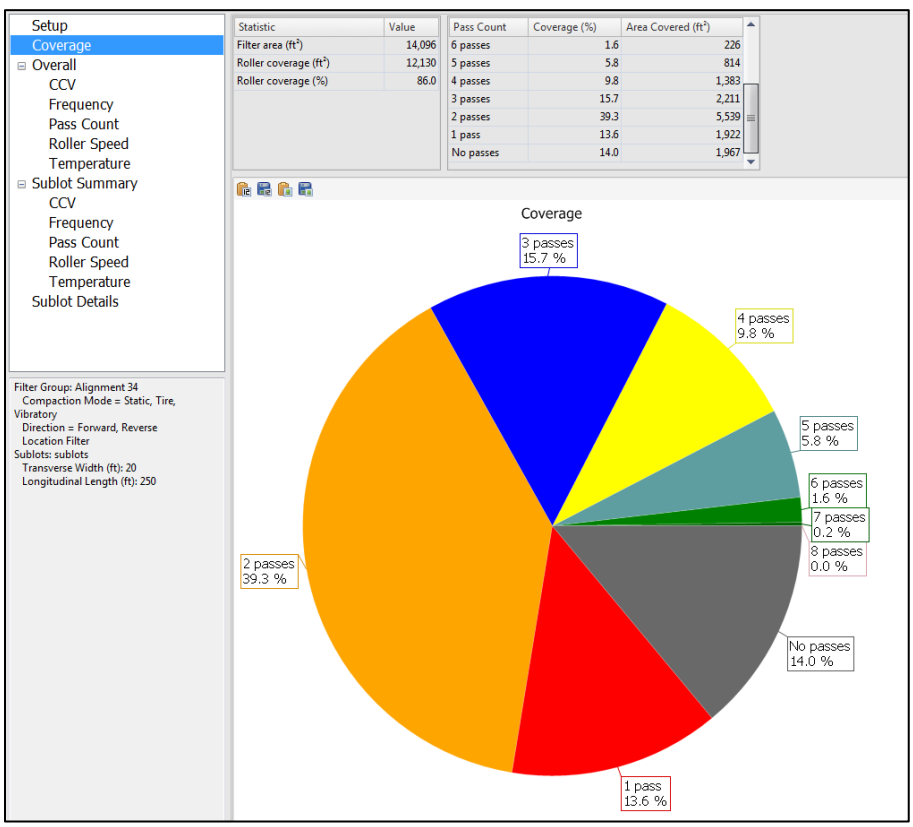


Figure 5-22: Coverage Statistics

The *Overall* section provides data for the total filtered area of the analysis. For each parameter a mean, standard deviation, coefficient of variance, min, max and sample size is reported. If any

targets were set, the target status (Passed/Failed) and the percent of target achieved is reported. A bar chart and cumulative percentage is displayed for the chosen parameter. There is a drop down *Coverage* menu that allows the user to view data associated with final coverage or an individual pass.

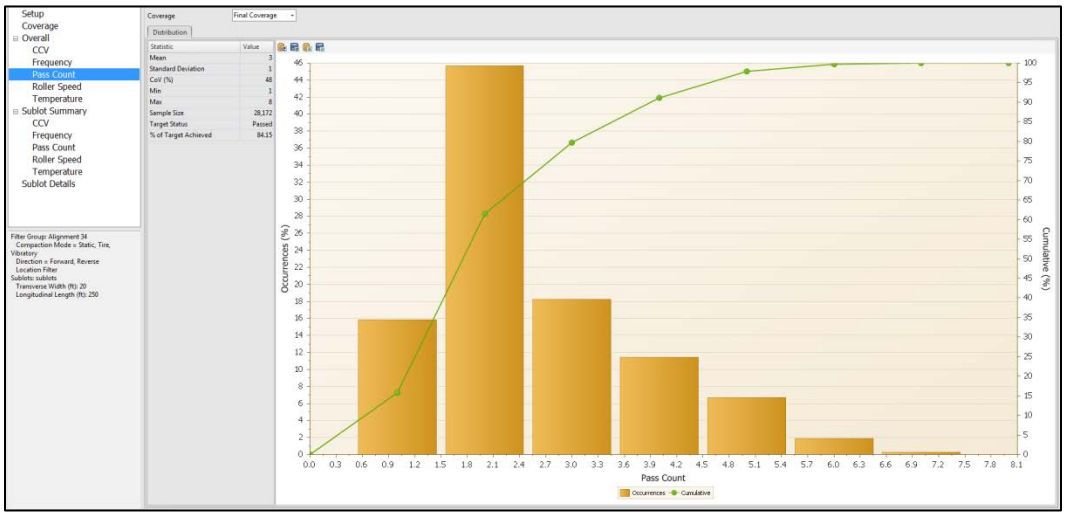


Figure 5-23: Pass Count Overall Analysis

The *Sublot Summary* section provides the same data as the *Overall* section, but breaks the data down into the individual sublot reports.

Figure 5-24: Pass Count Sublot Analysis

5.8.2 Paver Data

Data collected by the paver mounted system will be in a separate file from the roller data. A new project will need to be created with the paver data files. The data collected includes temperature of the asphalt behind the screed and paver speed. The current state of practice in Oregon for paver data (temperature and speed) uses a mapping grade positioning device recording the location of the paver. Due to the lack of accuracy with this system, the data

collected has a low probability of matching the design alignment lines. The unfiltered data includes all data while the system is turned on (e.g. unloading paver, cleanout, etc.). Applying a location filter will exclude some of the relevant data because of deviations from the alignment file.

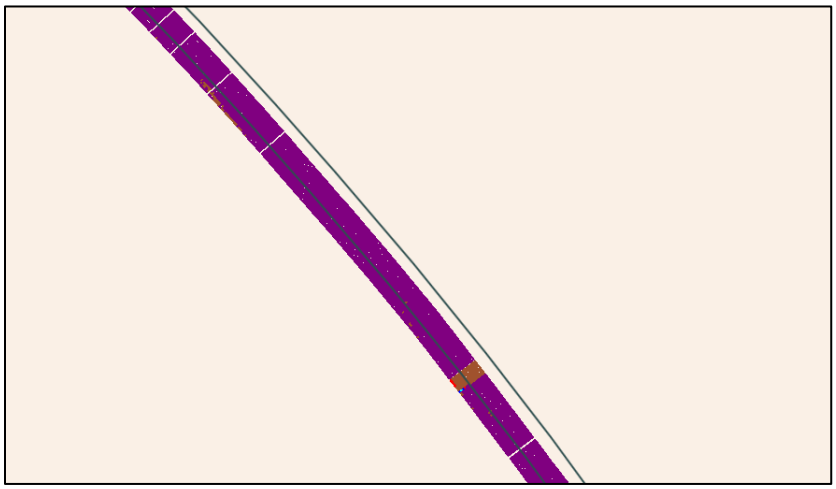


Figure 5-25: Paver Positioning Error

Coverage information is not critical to paver data so a different method can be used to filter the location of the analysis area. To exclude any irrelevant transverse data, the sensor filter can be used to remove any measurements on the existing pavement surface. By creating sublots that cover each continuous work area, the data can be filtered to include only pertinent longitudinal data. Follow the steps outlined in Chapter 5.5 to delineate the analysis area.

In the *Analysis* tab, a paver stop can be defined by the user. Set the minimum stop duration (minutes) and chose whether or not to include the paver stops areas from analysis. Temperature and paver speed targets can be set for analysis or the data can simply be reported.

After the analysis is performed, the *Thermal Profile* and *Paver Stops* will provide data for the entire data set, not just the delineated sublots. The *Thermal Profile* tab shows a graphical depiction of temperature, stop durations, and paver speed. The *Paver Stops* tab visualizes all paver stops longer than the defined paver stop duration on the map view for the entire data set.

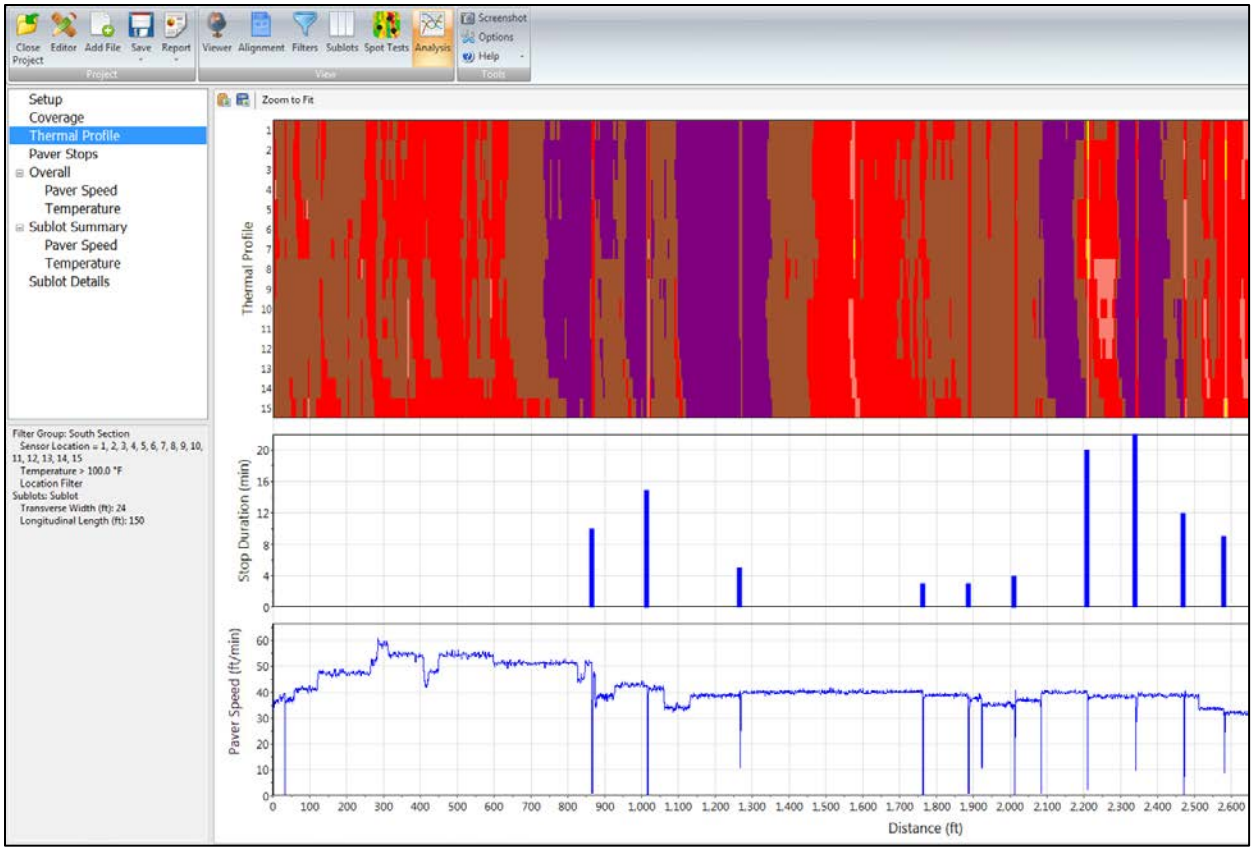


Figure 5-26: Thermal Profile

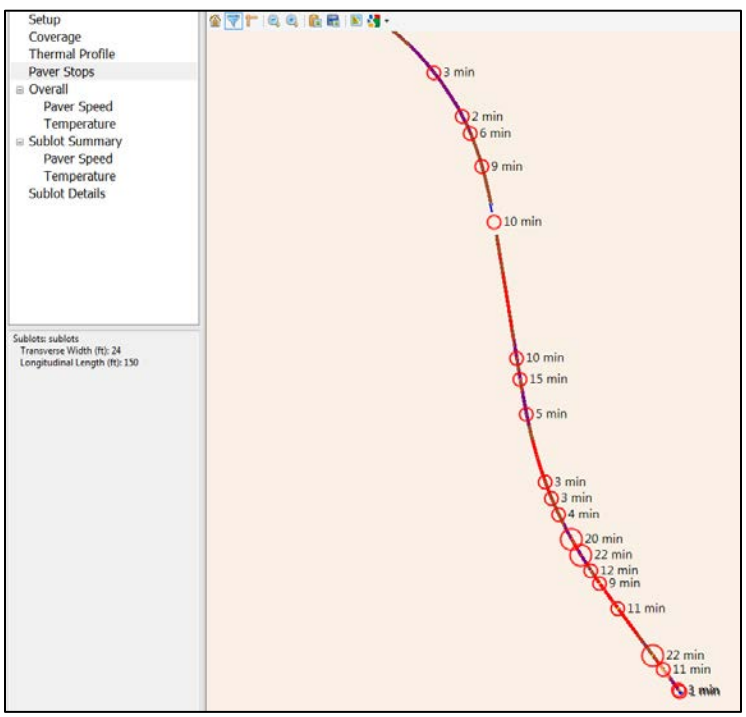


Figure 5-27: Paver Stops

Similar to the roller data, under the sublot section, data for location, min, mean, max, standard deviation, coefficient of variation, and sample size is displayed for both *Paver Speed* and *Temperature*. If targets were set, each sublot will report whether the section passed or failed.

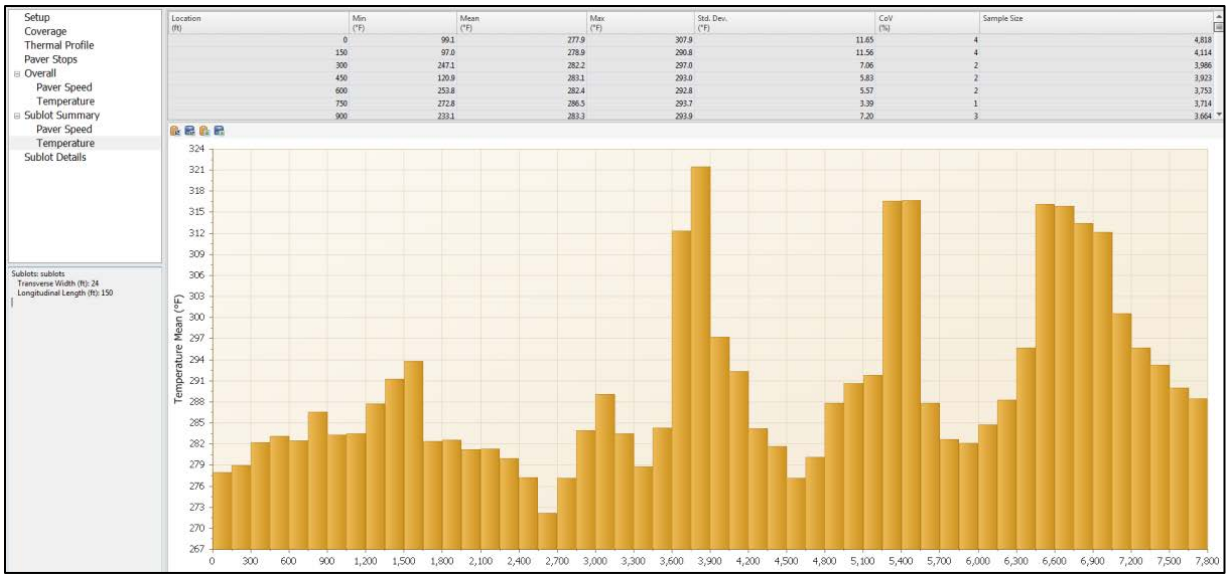


Figure 5-28: Paver Temperature Sublot Analysis

6.0 Critical Items

6.1 Roles and Responsibilities

Designer
- Create centerline alignment with stationing
- Create complex shapes for each lane

Project Management Office
- Inspector daily reports for description/location of work
- Equipment calibration checks
- Control Strip and deviation documentation

Pavement Services
- Project selection
- Specifications
- Data analysis parameters and results
- File naming conventions/color schemes

Pavements/PM Office
- Data download from cloud
- Daily/Weekly analysis
- Additional spot data for location verification

Engineering Technology Advancement (ETA)
- Software updates and troubleshooting
- Training/User Guide
- Alignment file adjustments
- Liaison to specification technical resources
- Liaison to software developers
- Liaison to Geometronics for positioning related issues
- Emerging Technology
- Positioning Tools

Contractor
- Ensure full GNSS corrector signal coverage
- Calibrate equipment for both thermal readings and positioning
- Perform checks on GNSS antennae throughout the project to ensure machine calibration is correct
- Provide Agency access to daily data (USB/cloud storage)
- Provide on-site equipment representative for first 3 days of paving
- Provide an GNSS rover to record density spot data

6.2 Pre-pave Meeting Topics

- Alignment Files (Agency Provided)
  - Provide lane shape and centerline stationing file
- Coordinate System
  - Define and inform
- Naming/Color Conventions
- Data Handoff
  - Cloud access
  - Rover data
- Equipment calibration (initial, daily, etc.)
  - Thermal sensors
  - GNSS antennae
- Documenting changes in rolling pattern/ order of rollers
- PM/Pavements plan for data use
  - Analysis parameters
  - Action plan for identified areas of concern
- Additional rover data
  - Shift start/stop location
  - Exclusion areas
  - Edge of pavement shots

7.0 Resources and Future Development

7.1 Contacts

Engineering Technology Advancement Unit
Chris Harris, P.E.
Office: (503)986-5367
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Christopher.Harris@odot.state.or.us

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Christopher.Pucci@odot.state.or.us

Pavement Services
Larry Ilg, P.E.
Office: (503)986-3072
Cell: (503)559-4994
Larry.D.Ilg@odot.state.or.us

7.2 Websites

ODOT Engineering Technology Advancement Unit
Internal: http://transnet.odot.state.or.us/hwy/eta/SitePages/Home.aspx
External: http://www.oregon.gov/ODOT/HWY/ETA/Pages/default.aspx

Veta software download and support:
http://www.intelligentcompaction.com/veta/

National Intelligent Compaction Support
http://www.intelligentcompaction.com/

7.3 Pooled Fund

ODOT is participating in the pooled fund "Enhancement to the Intelligent Construction Data Management System (Veda) and Implementation" being administered by Minnesota DOT. The pooled fund project focuses on making improvements to the Veta software that is currently in version 3. Enhancements in analysis platforms, filtering, modeling, correlation analysis, and data management are being addressed. Also, incorporation of other data sets such as ProVAL (pavement smoothness), ground penetrating radar, and delimited text data are being explored. As ODOT collects and analyzes more project data, this is an opportunity to have our specific needs heard and addressed. Specifications and contract administration is also being addressed in this study. Having the opportunity to work side by side with other agencies that are actively implementing Intelligent Compaction will provide valuable feedback on the IC experiences around the nation.

7.4 Working Groups

Two working groups are being formed to lead the implementation of Intelligent Compaction on ODOT projects.

The Framework Group will consist of ODOT engineers/managers, APAO leaders, and Contractor owners/management. This group will set overall policy and make decisions on broader IC implementation.

The Technology group will consist of ODOT engineers/project management staff, "on the ground" contractor employees, and equipment vendors. This group will provide recommendations on the IC specification, develop a process to evaluate the pilot projects, and determine how to best utilize IC data in real-time.

Framework Group Co-Chairs:

Larry Ilg, PE - Larry.D.ILG@odot.state.or.us

John Hickey, PE, Esq. - jhickey@apao.org

Technology Group Co-Chairs

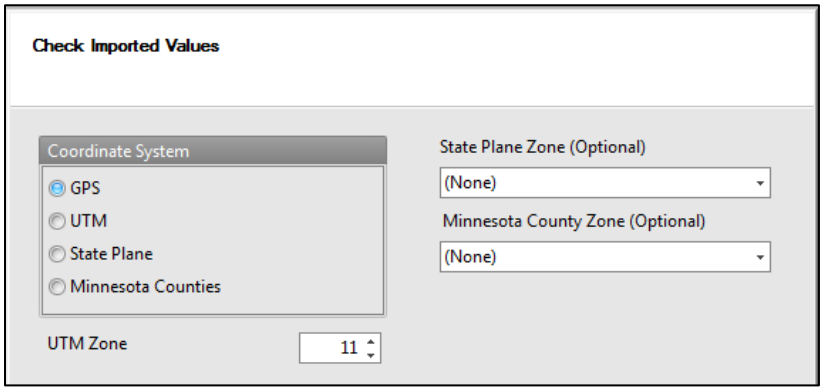
Chris Harris, PE - Christopher.HARRIS@odot.state.or.us

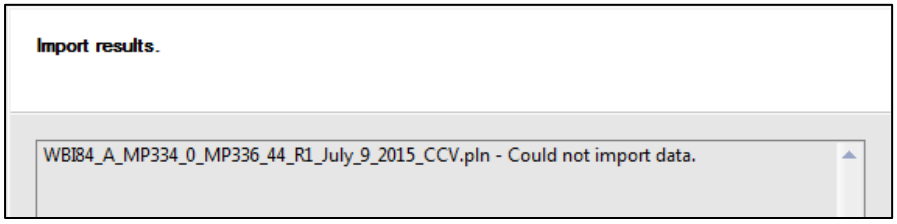
Ashley Monchamp - AshleyM@oregonmainline.com

Appendix – Troubleshooting

Importing Data into Veta

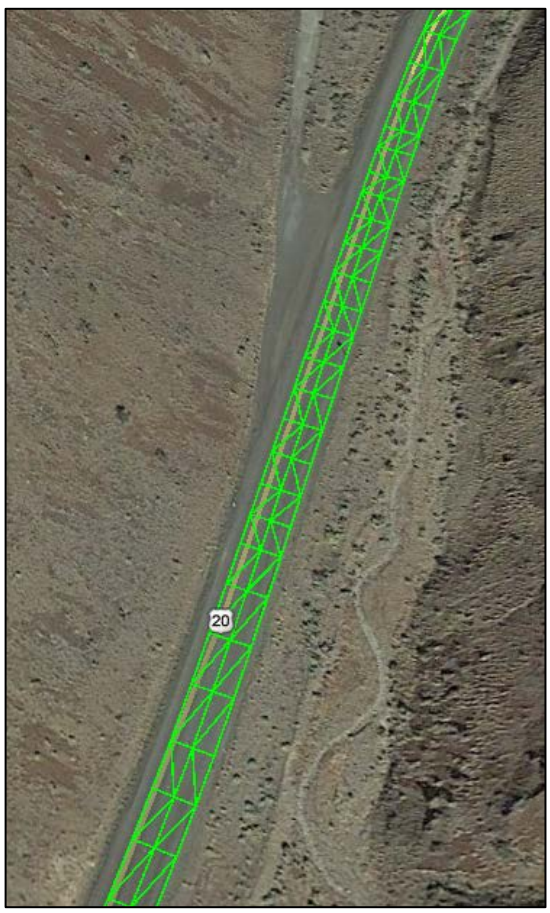
When creating a new project for a dataset, the data must be imported correctly into Veta. Veta can occasionally automatically detect the data settings, at which point it will not allow the user to change certain settings. Two errors can occur when importing data. First, Veta can reject the data completely with the message "Could not import data." Second, the data is imported but it is not in the correct location. These errors occur when the incorrect settings are selected in the Check Imported Values screen. The data will typically be in either GPS (Lat/Long) or State Plane coordinates. The State Plane Zone only needs to be entered if the data is in State Plane Coordinates. The UTM zone is required for all data. If the correct settings are unknown, the user can use trial and error until the data is imported correctly since there are limited choices. For assistance in choosing the correct State Plane Zone and UTM zone, refer to Chapter 5. This information should also be available from the contractor or designer.

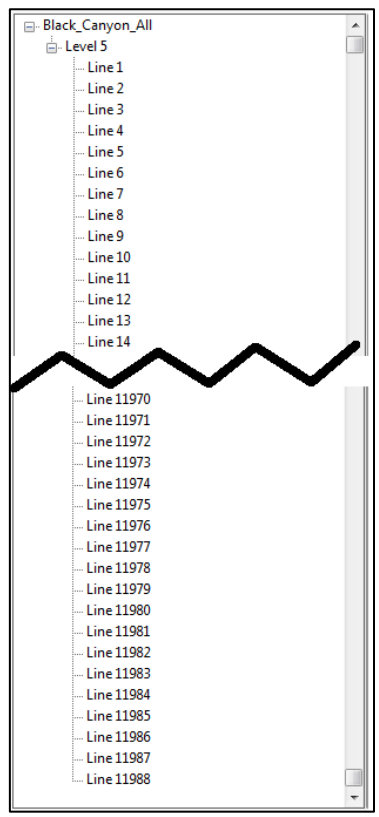




Alignment file creates TIN

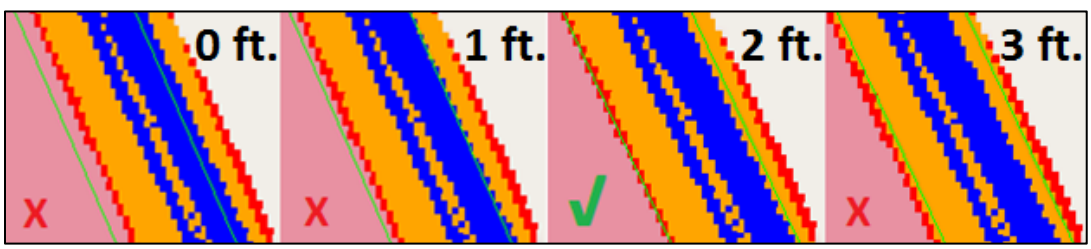
When creating the closed complex shapes for each lane in MicroStation, it is important that only 2D data is used. The user can be working in a 2D workspace but still have 3D data attached unknowingly. To see if the data has 3D information, export the lane shapes to .kmz and view the file in Google Earth. If only the lane line work is displayed then the file is 2D but if a TIN is created then the data is in 3D. Where this will become an issue is in selecting the alignment line in Veta for analysis. Each shape and line will be represented as a choice for alignment. When 3D information is included, each line of the TIN is included in this list, creating thousands of unwanted lines. The original MicroStation file will need to be stripped of the 3D data in order for the .kmz to be properly created. Contact the Engineering Technology Advancement Unit (see Chapter 6) for assistance with this issue.





Alignment File Shift for Paving Joint

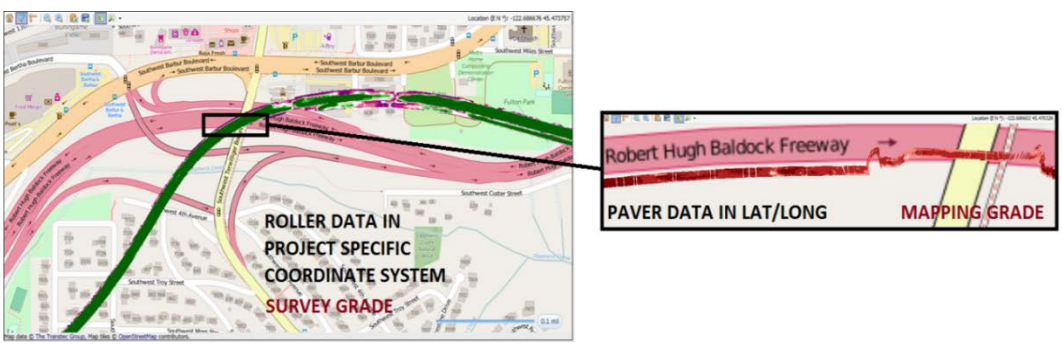
The lane shape files that are imported as alignments in Veta to trim data outside the lanes are originally drawn according to the location of the lane lines. Longitudinal paving joints do not fall directly on the lane line to ensure the striping has a more durable surface to adhere to the pavement. The offset of this joint needs to be accounted for when analyzing data in Veta so that the appropriate areas are within lane shape. A similar issue can arise when the GNSS antenna calibration is input incorrectly into the computer system on the roller. If the calibration measurement shifted, it will shift the data location as it is recorded during construction. To address this issue, first ensure that the equipment is properly calibrated regularly (discuss this interval at the pre-pave meeting). To account for joint offsets, capture points at both edges of pavement during construction with a location device (rover, positioning tablet). These points can be used to properly fit shift the lane shape in Microstation. If this data is not available, make multiple lane shape files with offsets (1 foot offsets shown below) and use engineering judgement as to which file is appropriate. Align the lane shapes with the inside of the lane because shoulder paving is not included in analysis according to the specifications.

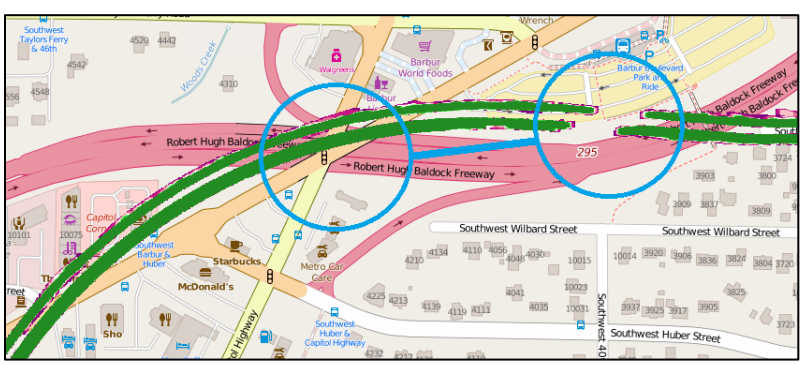


Data Projections and Missing Data

As mentioned in Chapter 3, the data might not match Google Maps when projected in Veta. This is because the project was developed on a different coordinate system than Google Maps. The data is still valid, but it is just represented in a different way. Currently the equipment on the paver collects mapping grade data in Lat/Long which should match Google Maps except the accuracy is only 10 to 15 feet which would explain why the data might not match exactly. The other issue is the roller and paver data won't be projected in the same location when viewing in the software. For analysis, this will not affect the results but it will make physically locating areas difficult. If a positioning tool is available you will need to set the coordinate system to the same system that the data was collected in. It may involve some type of site localization or a local coordinate system that is not preloaded into the rover or positioning tablet. Please contact the Engineering Technology Advancement Unit for assistance with this issue.

In areas where the GNSS signal is interrupted (underpasses, canyons, tall buildings, etc.) there is potential for data loss. This is an inherent limitation of using GNSS technology and it is acceptable to exclude these areas from analysis without penalty to the contractor.

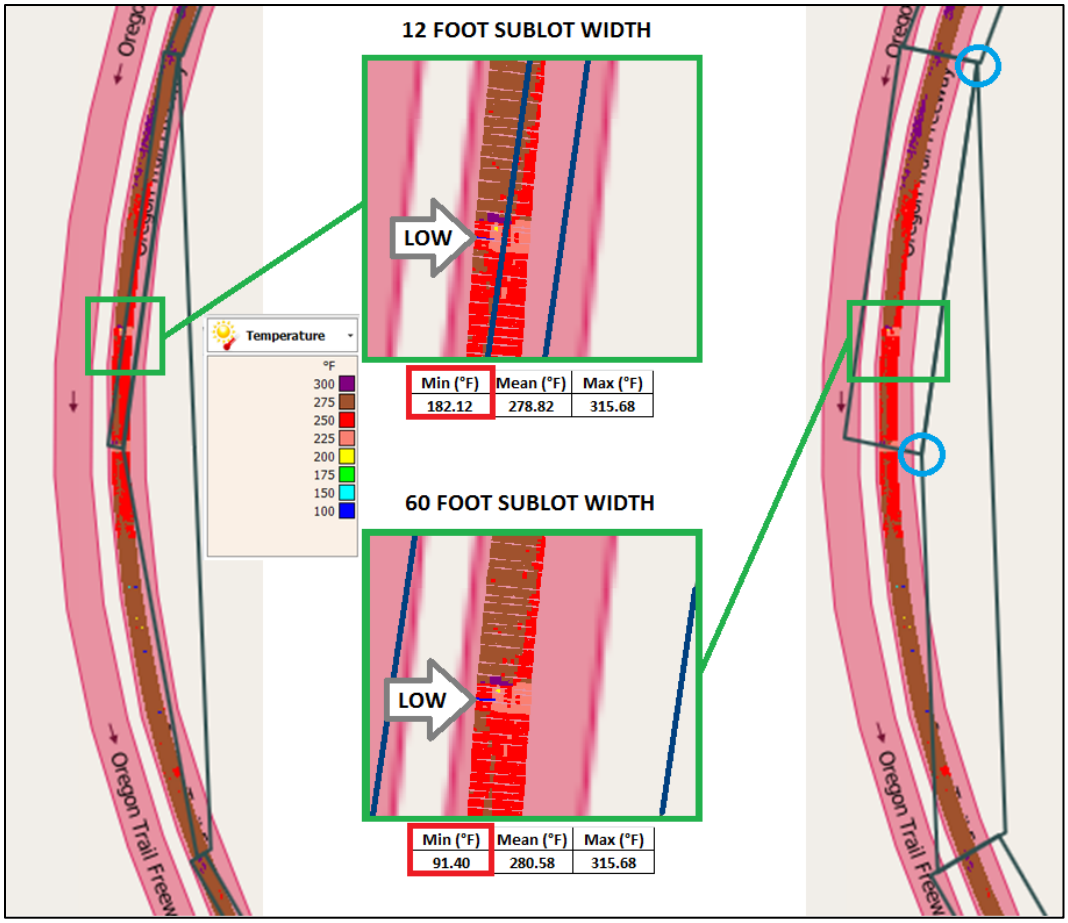




Sublot Creation

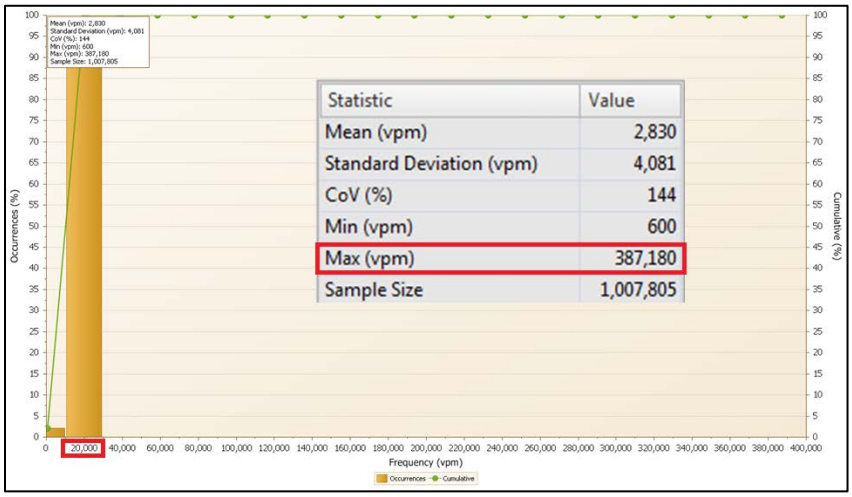
During sublot creation, the corners of the sublot do not always match correctly. This pushes the sublot area outside of the intended location, omitting the relevant data. This issue can occasionally be resolved by switching the start and stop points for sublot creation, but it is not always successful. This sublot may need to be excluded for analysis due to this error.

Sublot width can affect the data that is included in the analysis. When sublots are created, the corners are connected by straight lines which can omit data in curve sections. To avoid this issue, use a sublot width significantly greater than the paving width to capture all of the data in the curve.

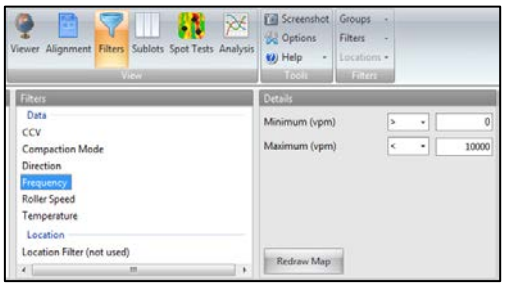


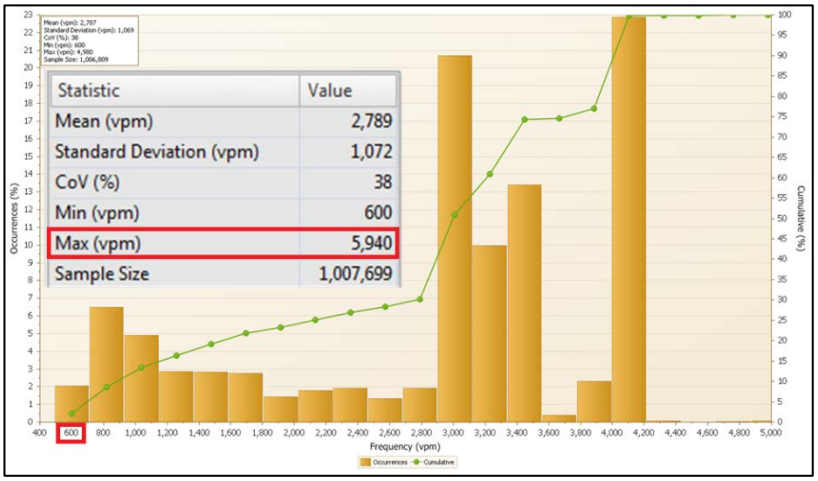
Outliers affecting analysis output

After analyzing the data for a given file, the output statistics and graphs could be skewed because of outlier data. This can cause the graphical output to create data that is not useful because the ranges of values for the histogram bins are too large.



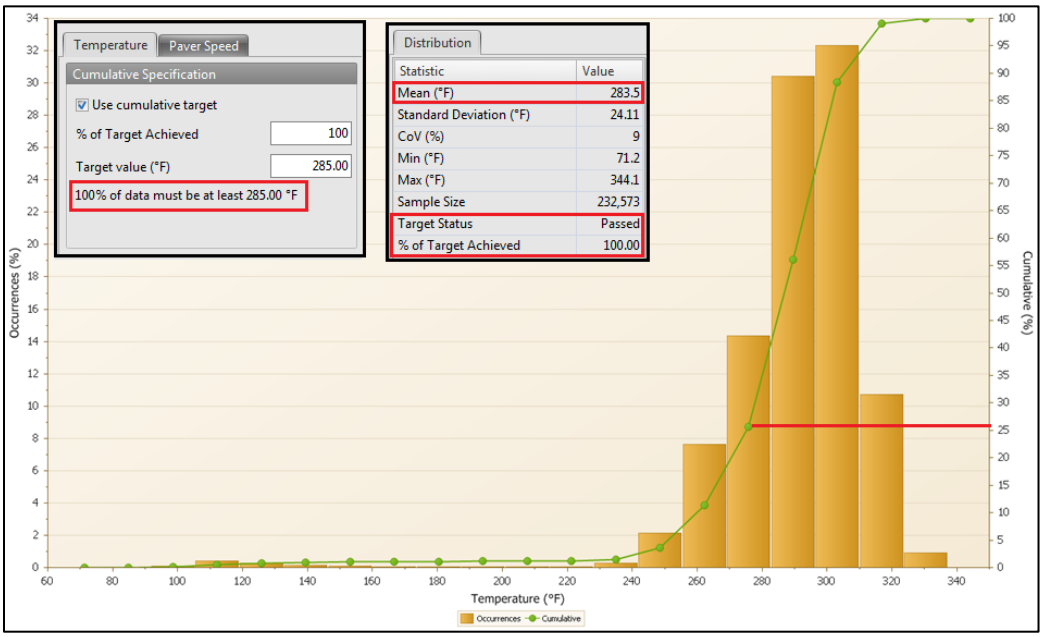
The solution to this issue is to modify the filter that is being applied to the data. Choose the approriate filter for the outlier that is identified and add contraints to only include a reasonable range of data values. The analysis can be performed with the new filter settings and should provide greater detail and more useful data.

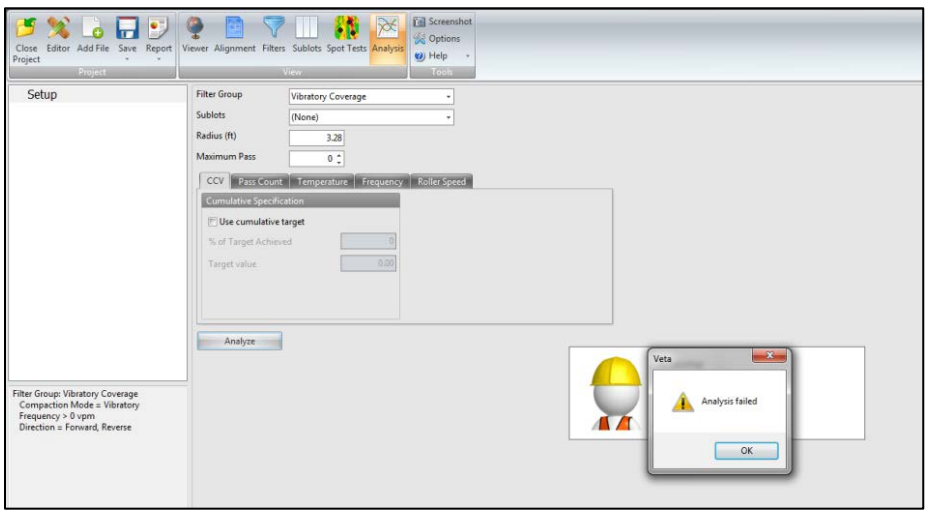
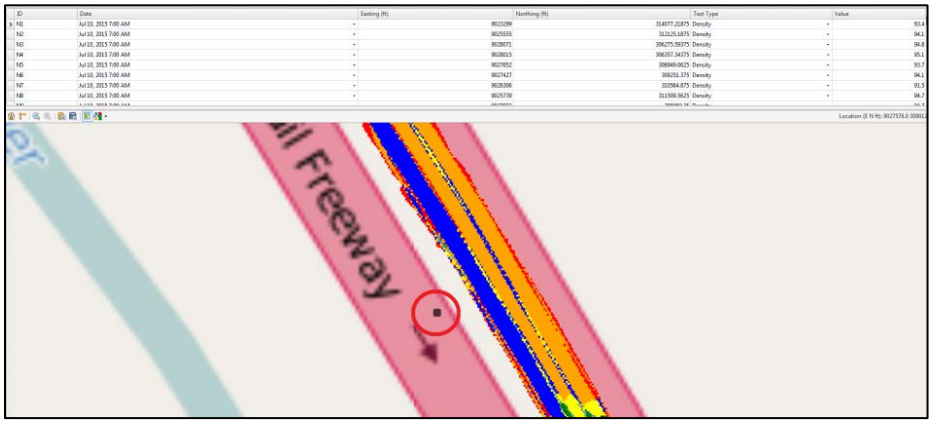




Paver Temperature Analysis

When importing and analyzing paver data (temperature and speed) the Veta software does not analyze the temperature data correctly. The user sets the percent of data that must meet a defined temperature. As shown below, Veta displays that 100% of the data met the defined target yet the mean of the data is below the target. The histogram of temperature data shows that approximately 25% of the data is below the defined value. This needs to be taken into account when analyzing any paver temperature data. The histogram provides accurate information and should be the primary tool for this evaluation until the software issue is resolved.



Spot Data Error Message

When importing spot data into Veta, it is important that all of the spot data is contained within there are that roller or paver data has been collected. When performing data analysis, the software creates correlations between the spot and roller/paver data. When the location of the spot data point does not have any other associated information, an "Analysis failed" dialog box will appear when attempting to perform the analysis. To remove the data points, go to the *Spot Tests* tab and visually identify the ID of the points causing the issue. Select the corresponding row of data and click *Remove*. This must be done individually for each data point as Veta does not allow for the selection of multiple rows. The analysis should successfully run once all the outside points have been removed.