LiDAR

VERMONT SOCIETY of LAND SURVEYORS

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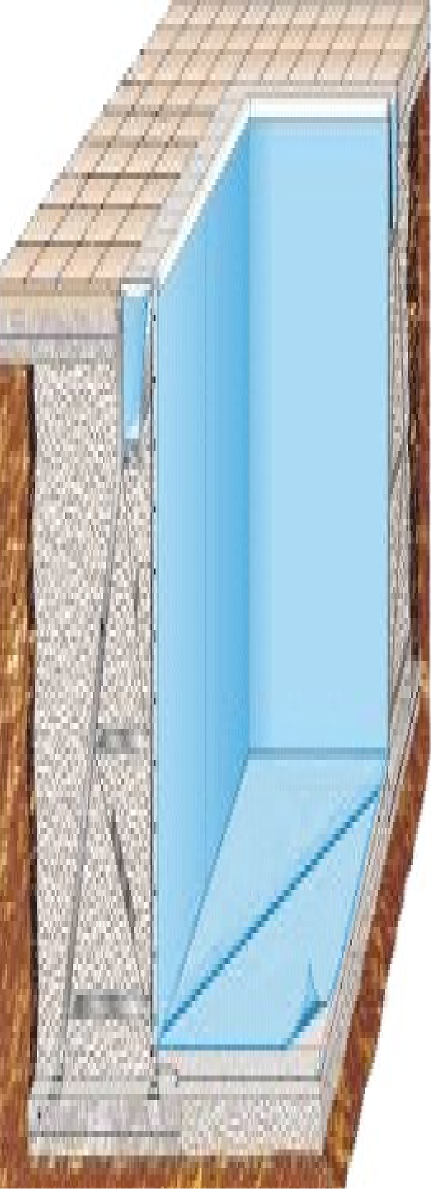
J. Thaddeus "Thadd" Eldredge

- BA in Theoretical Mathematics, Colby College
- PLS Certificate from Wentworth Institute of Technology
- PLS 46471, MA
- Soil Evaluator, MA
- Certified Floodplain Manager, USA
- Has a fancy pants name; goes by Thadd.
- I will try to not put you to sleep.

In 2014 I jumped into the deep end of the LiDAR Pool



The deep end is rather deep

Acquisition – Mobile
Acquisition – Static
Registration – Mobile – Trajectory, Adjustment, Processing
Registration – Static – Combination, QAQC
QAQC – Mobile & Static
Colorizing
Extraction

LiDARUSA Scanlook Suite
FARO Scene
LASTools
Global Mapper
Quick Terrain Reader & Quick Terrain Modeler
Carlson Point Cloud

Fugro Viewer
Arc
Civil3d
Fusion
Cloud Compare
ReCap
MeshLab
PointCloudViz
And more...

Aerial LiDAR data is readily available. While it has limitations, it is an excellent starting point for anybody interested in using LiDAR.

I would have started using this data years ago had I known how well it can be integrated into a Surveying Office.

We got into it because we cannot hire or subcontract enough field crews for the amount of surveying we perform. The use of LiDAR has reduced the amount of field work. It has increased the amount of office work. It has increased the number of services offered.

Sales Pitch

I am a Global Mapper Reseller. If you want a license and work with a reseller, go to them. If you want a license and have no reseller, drop an e-mail. I do provide workflows on my site.

www.ese-llc.com/gmworkflows Password: gm

Sales Pitch

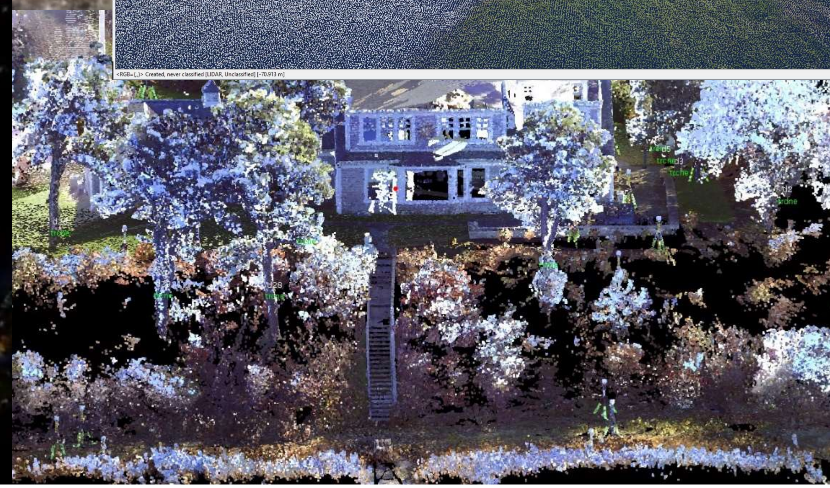
Global Mapper + Lidar – Stuck on one computer $1,000
Global Mapper + Lidar – USB license $1,400
VT LiDAR on a Hard Drive * $300 from VCGI
*There is data available for download from VCGI and USGS Earth Explorer.
Values have been rounded.

Blue Marble Geographics provides a more comprehensive training.

They just added Pixel to Points... It converts drone imagery to point clouds...

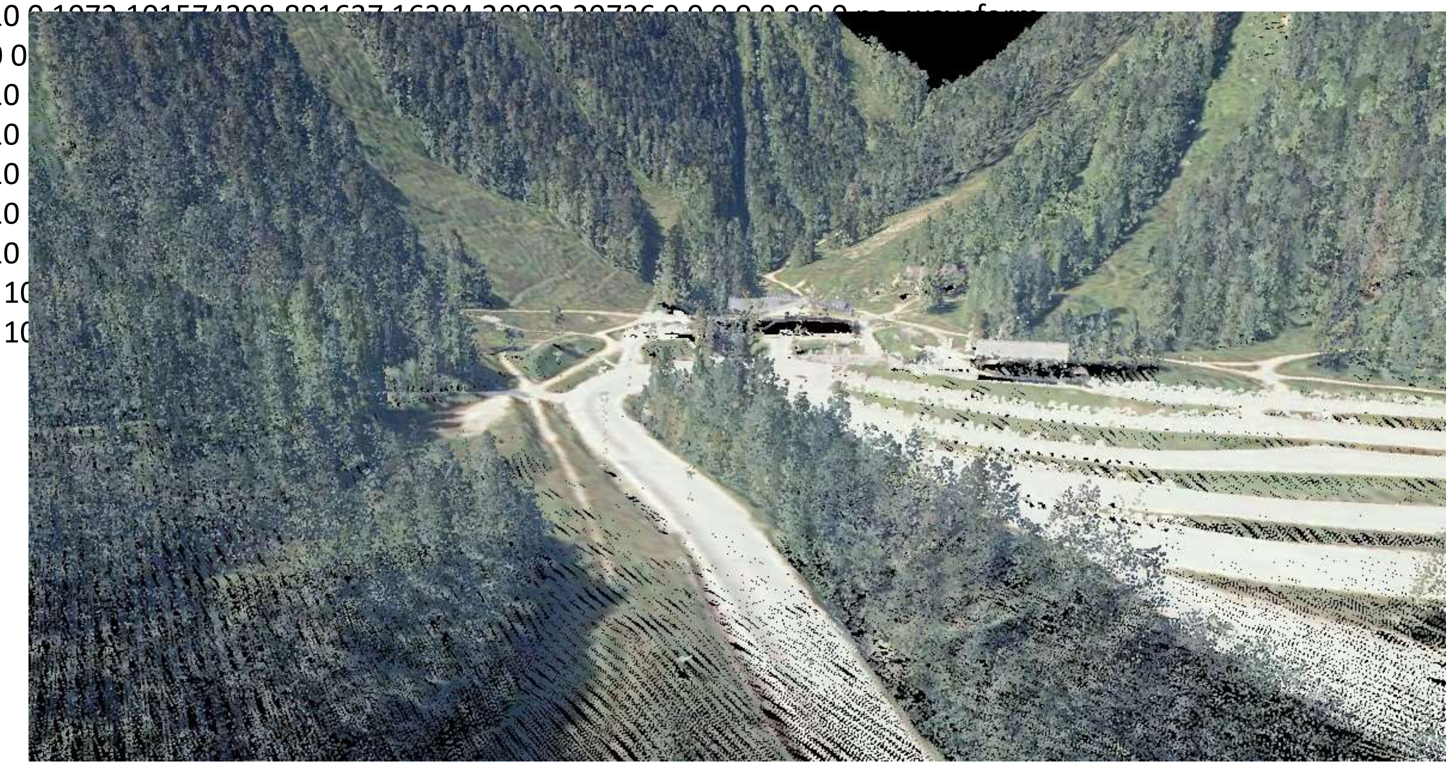
Who Is Using LiDAR?

- Aerial
- Static
- Mobile
- Drone



Point Cloud

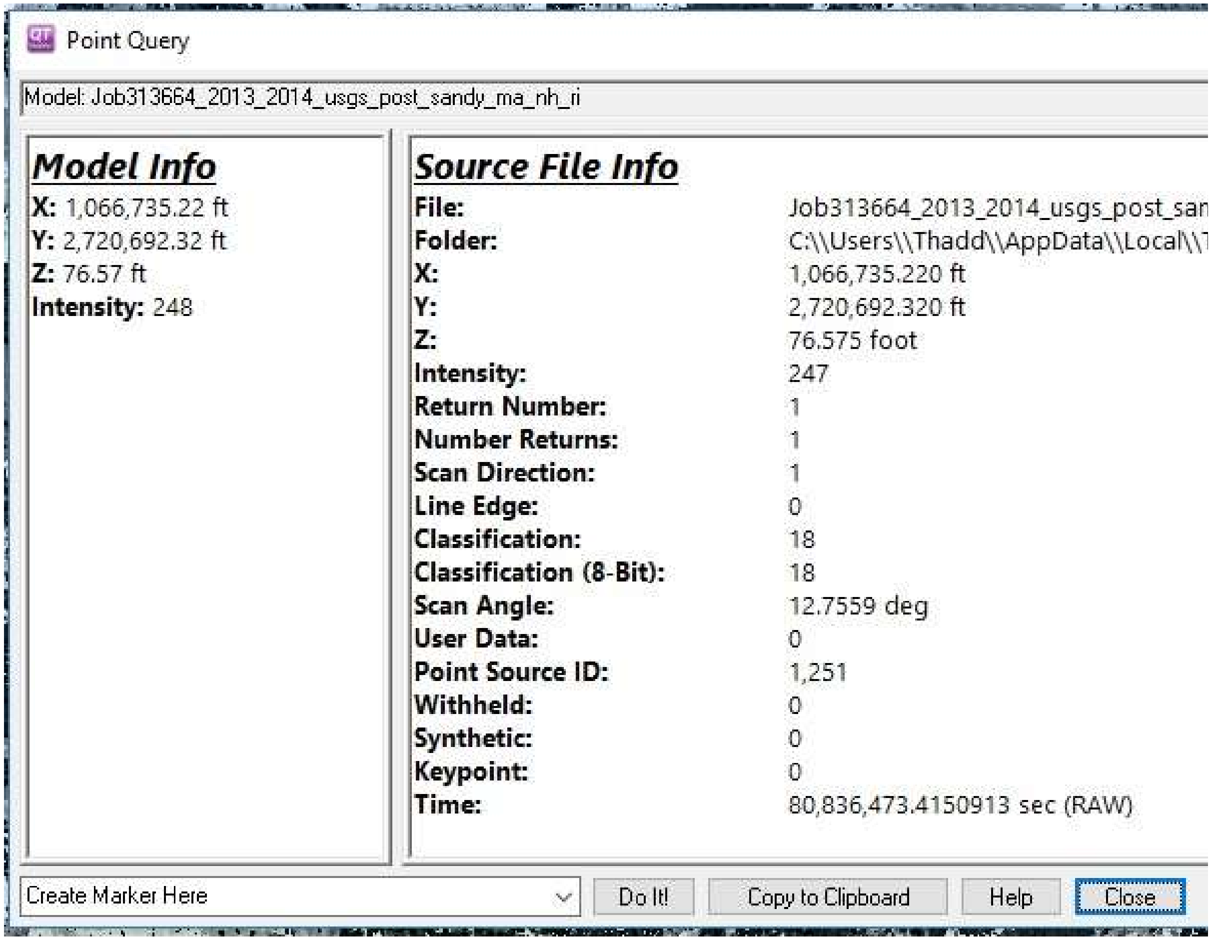
474600.910 124599.670 875.690 20 1 3 1 10 0 1072 101574398.863897 14848 18944 20736 0 0 0 0 0 0 0 no_waveform
474600.910 124599.200 871.840 49 2 3 1 10 0 1072 101574398.863897 19456 23552 25344 0 0 0 0 0 0 0 no_waveform
474601.020 124599.020 857.300 116 2 2 2 10 0 1072 101574398.863911 22272 26368 27648 0 0 0 0 0 0 0 no_waveform
474600.140 124599.330 856.770 238 1 1 2 10 0 1072 101574399.670091 14592 18432 21248 0 0 0 0 0 0 0 no_waveform
474601.000 124599.380 856.920 142 2 2 2 10 0 1072 101574399.681418 18176 22272 23808 0 0 0 0 0 0 0 no_waveform
474602.280 124599.730 859.690 157 1 1 1 10 0 1072 101574398.881623 16640 21248 20736 0 0 0 0 0 0 0 no_waveform
474602.160 124599.800 873.240 15 1 2 1 10
474602.120 124599.630 878.230 2 1 2 1 10 0
474602.060 124598.800 878.010 15 1 3 1 10
474603.080 124599.360 877.820 19 1 3 1 10
474603.130 124599.310 871.030 18 1 2 1 10
474603.180 124599.630 867.110 60 1 2 1 10
474603.240 124599.270 857.780 94 2 2 1 10
474604.600 124599.860 856.200 174 2 2 2 10
474604.540 124599.140 856.860 101 2 2 2 10

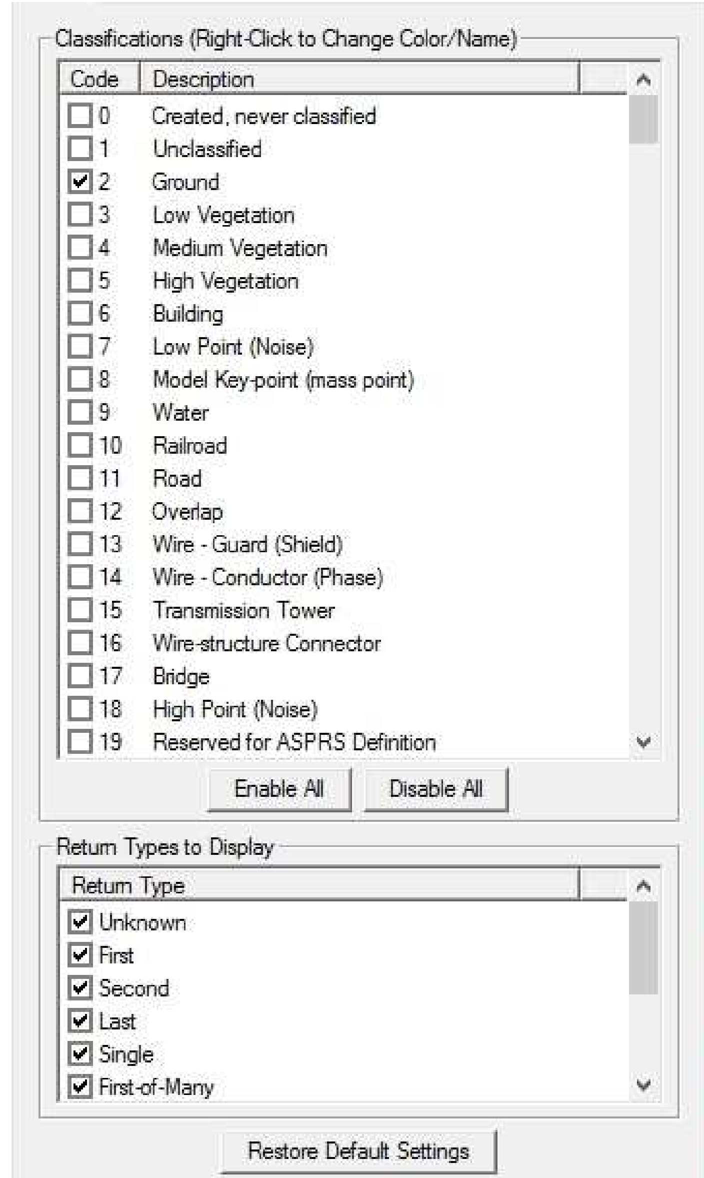


Too many points for numbers.
Never enough points for a perfect model.
'Grainy 3d BMP'
All kinds of other attributes.
Quick 3d models.

Attributes

These are More than Just Points





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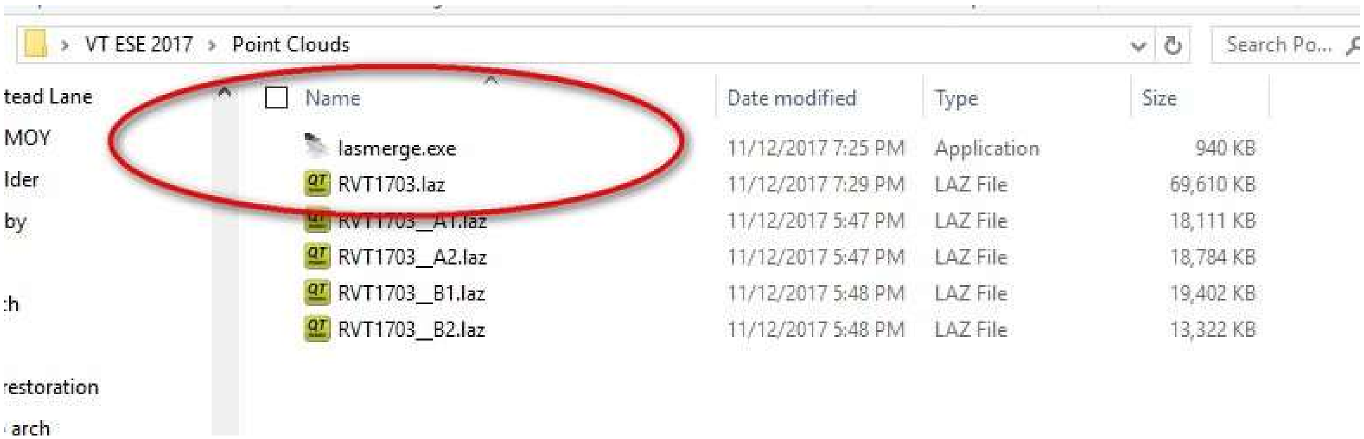
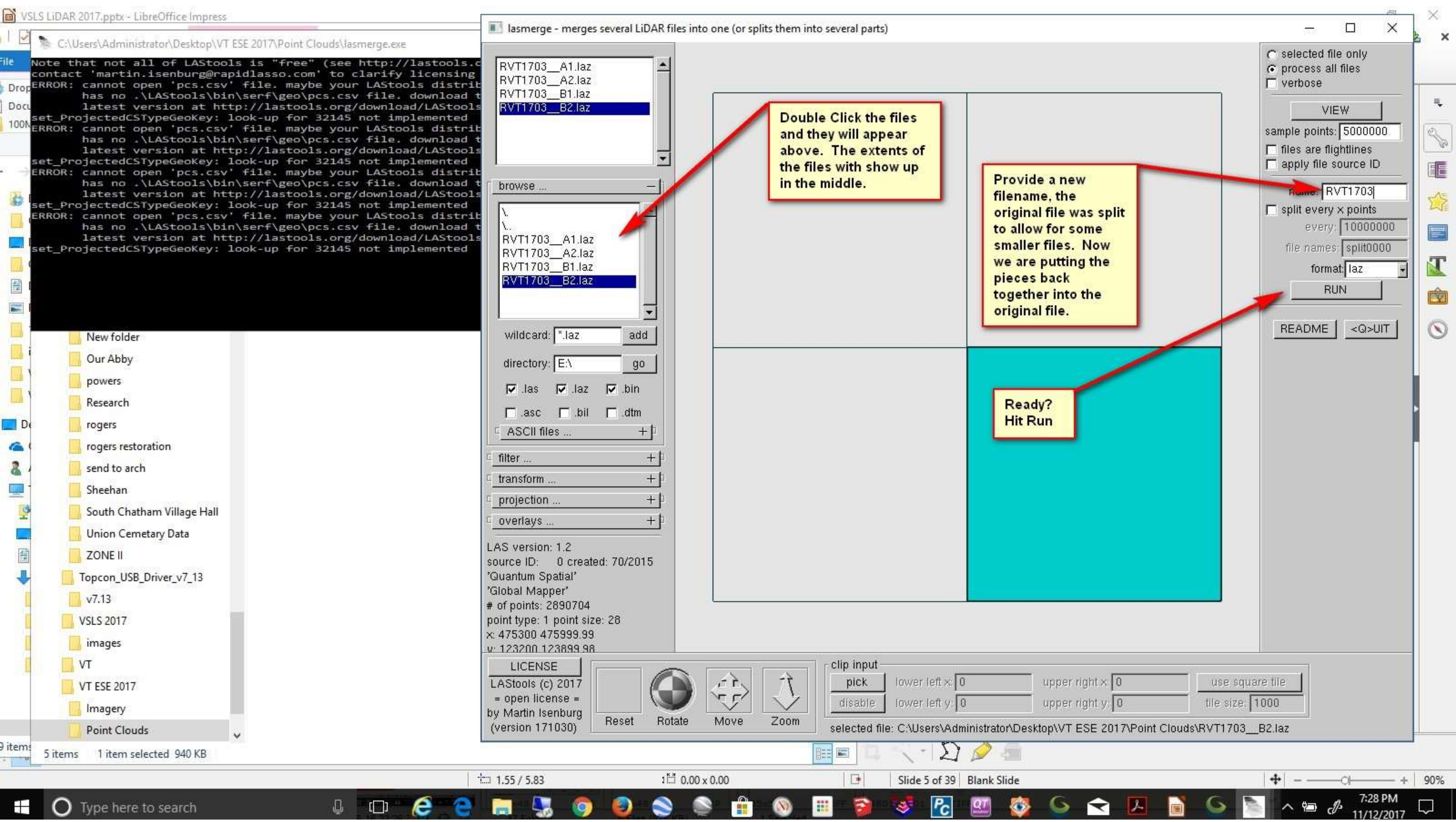
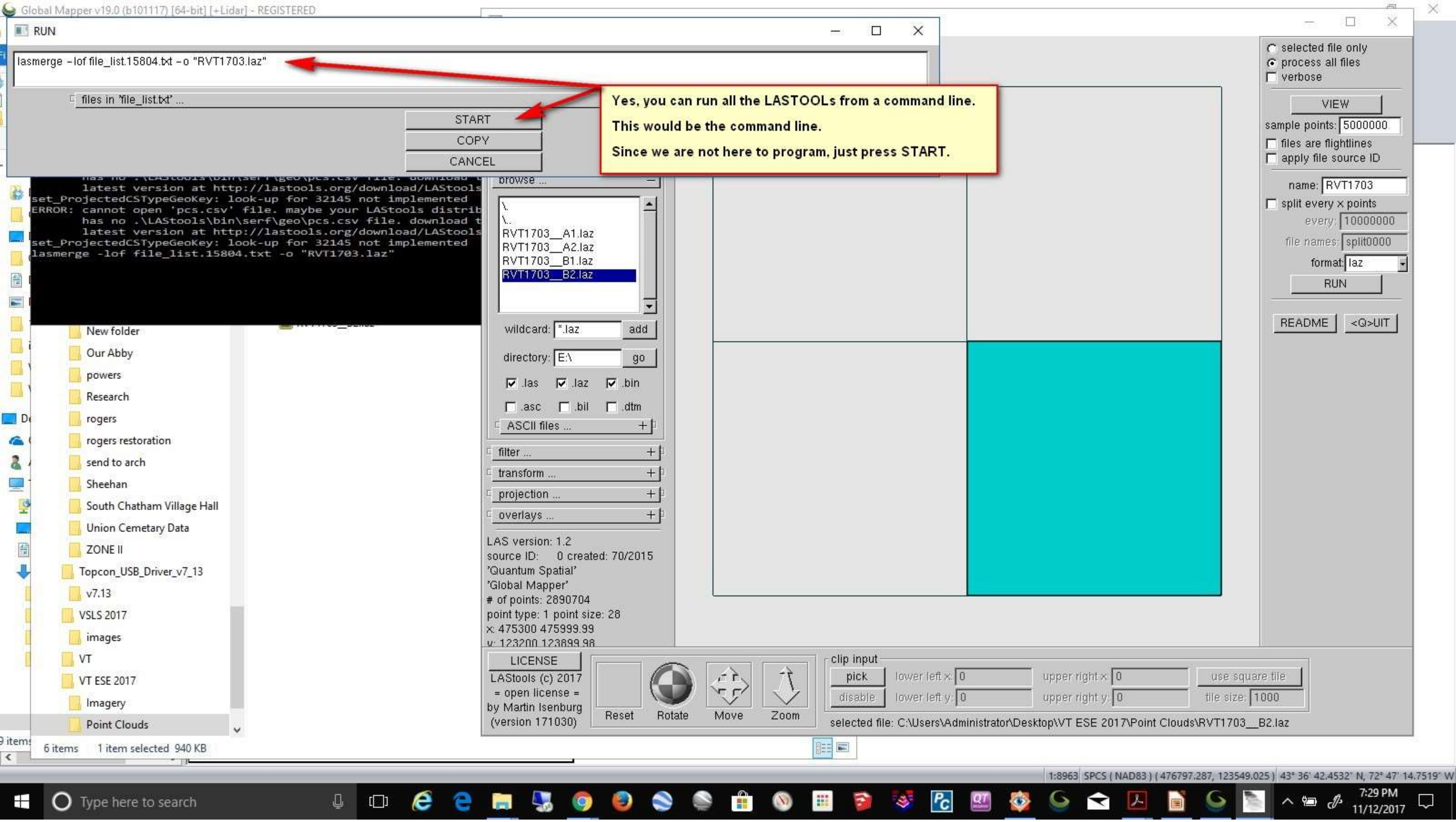
Data Preparation

- LAS Tools are the tools created for LAS and LAZ manipulation.
- The download comes with toolboxes for ARC and QGIS.
- You should have **lasmerge.exe in the Point Cloud folder.**
- **Double click it.**
- It will start in the Point Cloud folder (convenient...)




lasmerge - merges several LiDAR files into one (or splits them into several parts)
Double Click the files and they will appear above. The extents of the files with show up in the middle.
Provide a new filename, the original file was split to allow for some smaller files. Now we are putting the pieces back together into the original file.
Ready? Hit Run
RUN
RVT1703__A1.laz
RVT1703__A2.laz
RVT1703__B1.laz
RVT1703__B2.laz



Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED
RUN
lasmerge -lof file_list.15804.txt -o "RVT1703.laz"
files in 'file_list.txt' ...
START
COPY
CANCEL
Yes, you can run all the LASTOOLs from a command line.
This would be the command line.
Since we are not here to program, just press START.
set_ProjectedCSTypeGeoKey: look-up for 32145 not implemented
ERROR: cannot open 'pcs.csv' file. maybe your LAStools distrib
has no .\LAStools\bin\serf\geo\pcs.csv file. download t
latest version at http://lastools.org/download/LAStools
set_ProjectedCSTypeGeoKey: look-up for 32145 not implemented
lasmerge -lof file_list.15804.txt -o "RVT1703.laz"
browse ...
RVT1703__A1.laz
RVT1703__A2.laz
RVT1703__B1.laz
RVT1703__B2.laz
wildcard: *.laz add
directory: E:\ go
.las .laz .bin
.asc .bil .dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 70/2015
'Quantum Spatial'
'Global Mapper'
# of points: 2890704
point type: 1 point size: 28
x: 475300 475999.99
y: 123200 123899.98
LICENSE
LAStools (c) 2017
= open license =
by Martin Isenburg
(version 171030)
Reset
Rotate
Move
Zoom
clip input
pick
disable
lower left x: 0
lower left y: 0
upper right x: 0
upper right y: 0
use square tile
tile size: 1000
selected file: C:\Users\Administrator\Desktop\VT ESE 2017\Point Clouds\RVT1703__B2.laz
selected file only
process all files
verbose
VIEW
sample points: 5000000
files are flightlines
apply file source ID
name: RVT1703
split every x points
every: 10000000
file names: split0000
format: laz
RUN
README
<Q>UIT
New folder
Our Abby
powers
Research
rogers
rogers restoration
send to arch
Sheehan
South Chatham Village Hall
Union Cemetary Data
ZONE II
Topcon_USB_Driver_v7_13
v7.13
VSLS 2017
images
VT
VT ESE 2017
Imagery
Point Clouds
6 items 1 item selected 940 KB
1:8963 SPCS (NAD83) (476797.287, 123549.025) 43° 36' 42.4532" N, 72° 47' 14.7519" W
Type here to search
7:29 PM
11/12/2017

LAS TOOLS

- What Else? (The really good tools are subject to a license.)
-
- E572las – **E57** is another format. Convert it to LAS/LAZ.
- Las2las – Need to convert **LAZ to LAS**? (Recap)
- Las2txt – You can go to an **ASCII** format (if you really need to)
- LasZip – Have LAS and want **LAZ**? (great compression)
- Txt2las – **Got ASCII?** It can't handle the clouds, so make it LAS/LAZ.
- **Classification tools** (subject to license) We'll go through similar tools in Global Mapper.
- PointZip – This will convert **PTS to LAS/LAZ**. (Separate download)

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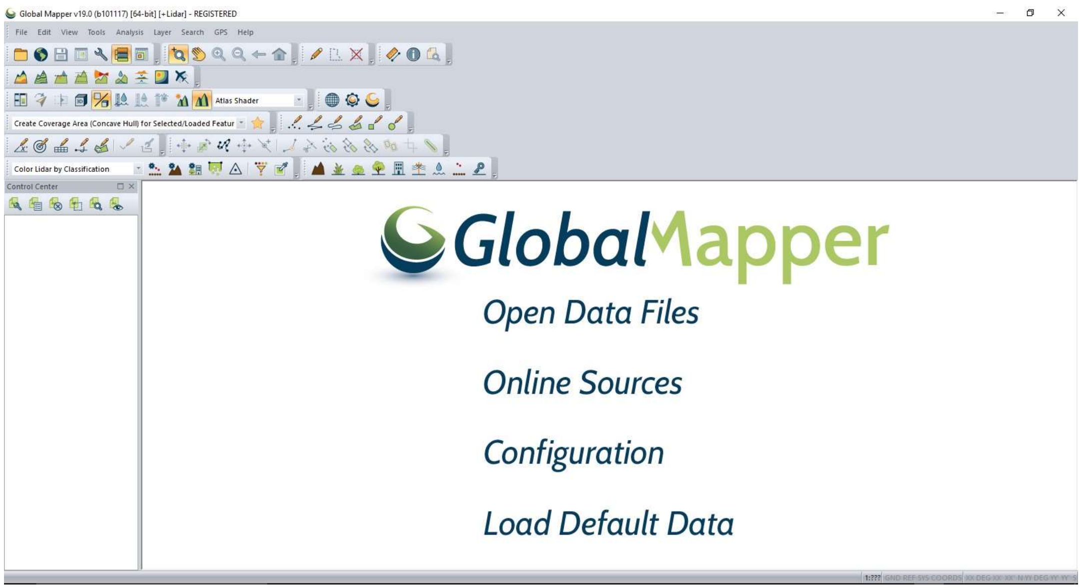
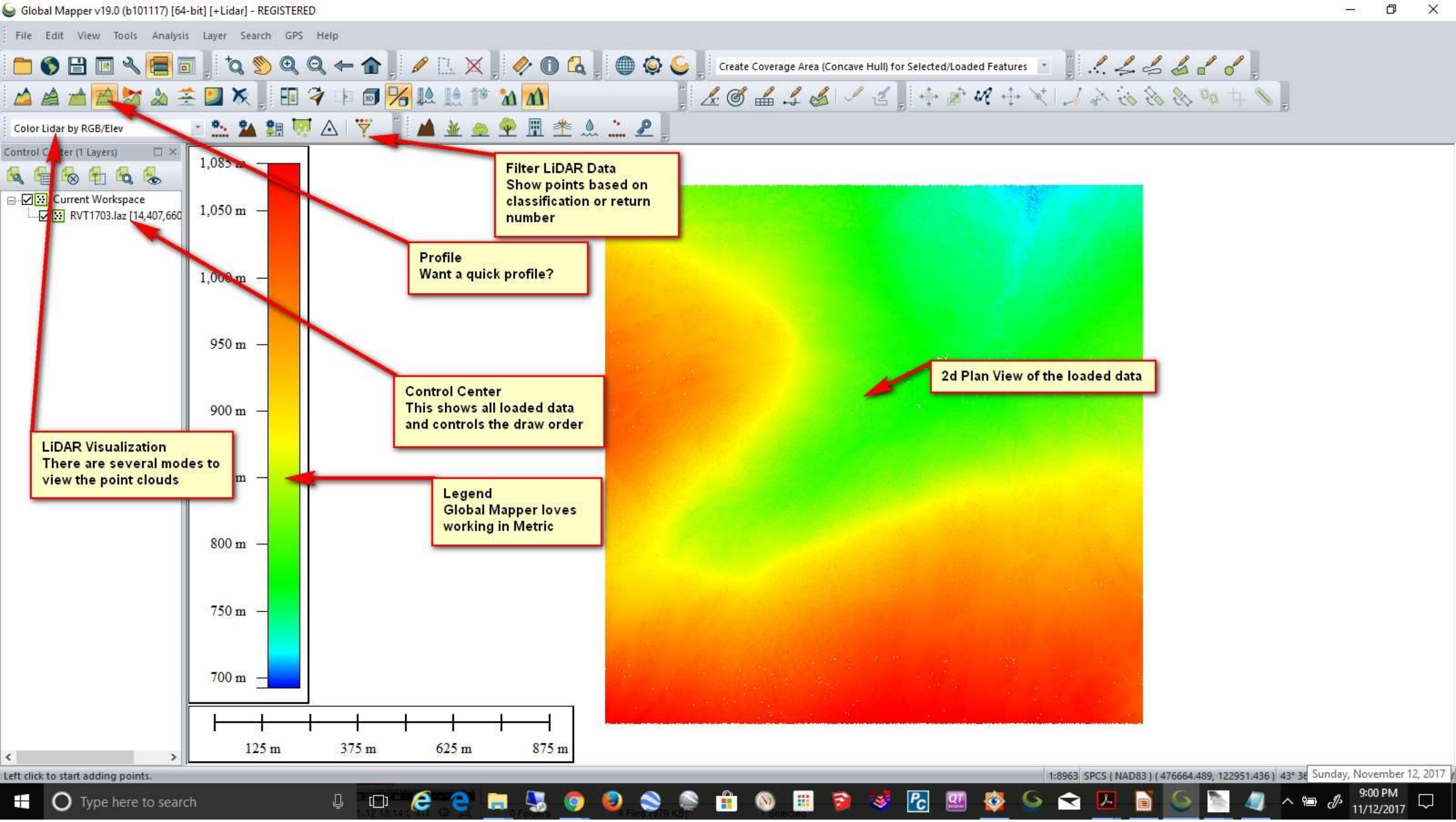


- **Open** Global Mapper
  There's a few ways to load the data, I like the drag & drop
- Open the **Project Folder VT ESE 2017**
- Open the **Point Cloud folder**
- Highlight the RVT1703.laz
- **Drag & Drop** into Global Mapper
- LiDAR Load Options – Just say **OK!**

  If a splash pops up, just click **OK.**


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED
File Edit View Tools Analysis Layer Search GPS Help
Create Coverage Area (Concave Hull) for Selected/Loaded Features
Color Lidar by RGB/Elev
Control Center (1 Layers)
Current Workspace
RVT1703.laz [14,407,660
Filter LiDAR Data
Show points based on classification or return number
Profile
Want a quick profile?
Control Center
This shows all loaded data and controls the draw order
LiDAR Visualization
There are several modes to view the point clouds
Legend
Global Mapper loves working in Metric
2d Plan View of the loaded data
1,085 m
1,050 m
1,000 m
950 m
900 m
800 m
750 m
700 m
125 m
375 m
625 m
875 m
Left click to start adding points.
1:8963 SPCS (NAD83) (476664.489, 122951.436)
Sunday, November 12, 2017
Type here to search
9:00 PM
11/12/2017

Point Cloud: Masses of Points

- Obtained from a **Robotic Total Station with Reflectorless EDM set to hyperactive.**

  Limitations:

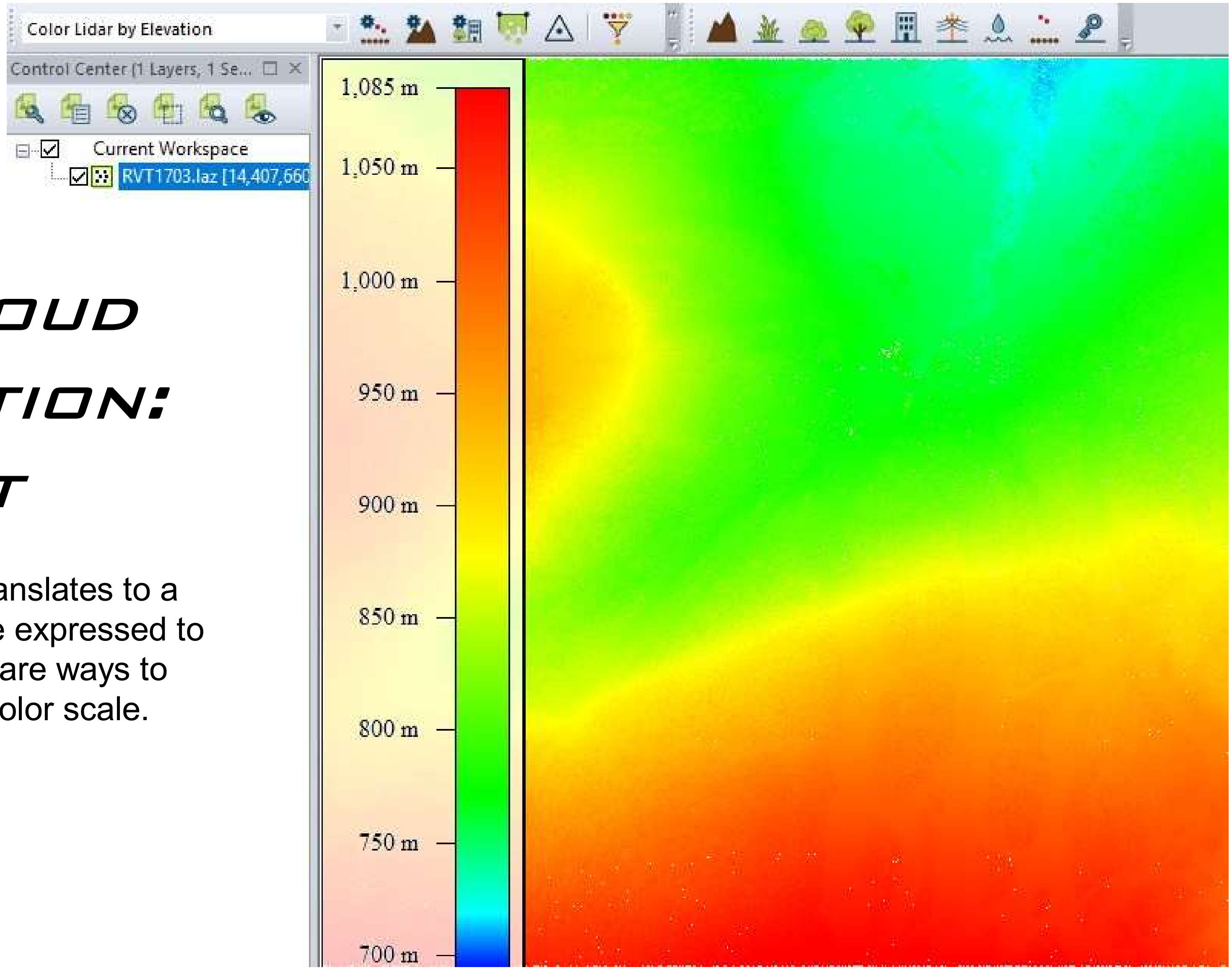
  Line of sight – There are shadows or missing sections of data.

  Angular Spread – The density of points decreases further from the scanner.

  Reflectivity – Water? Mirrors? Glass? Ice? Snow? Well, your cloud will have some noise. You can remove it or just work around it.

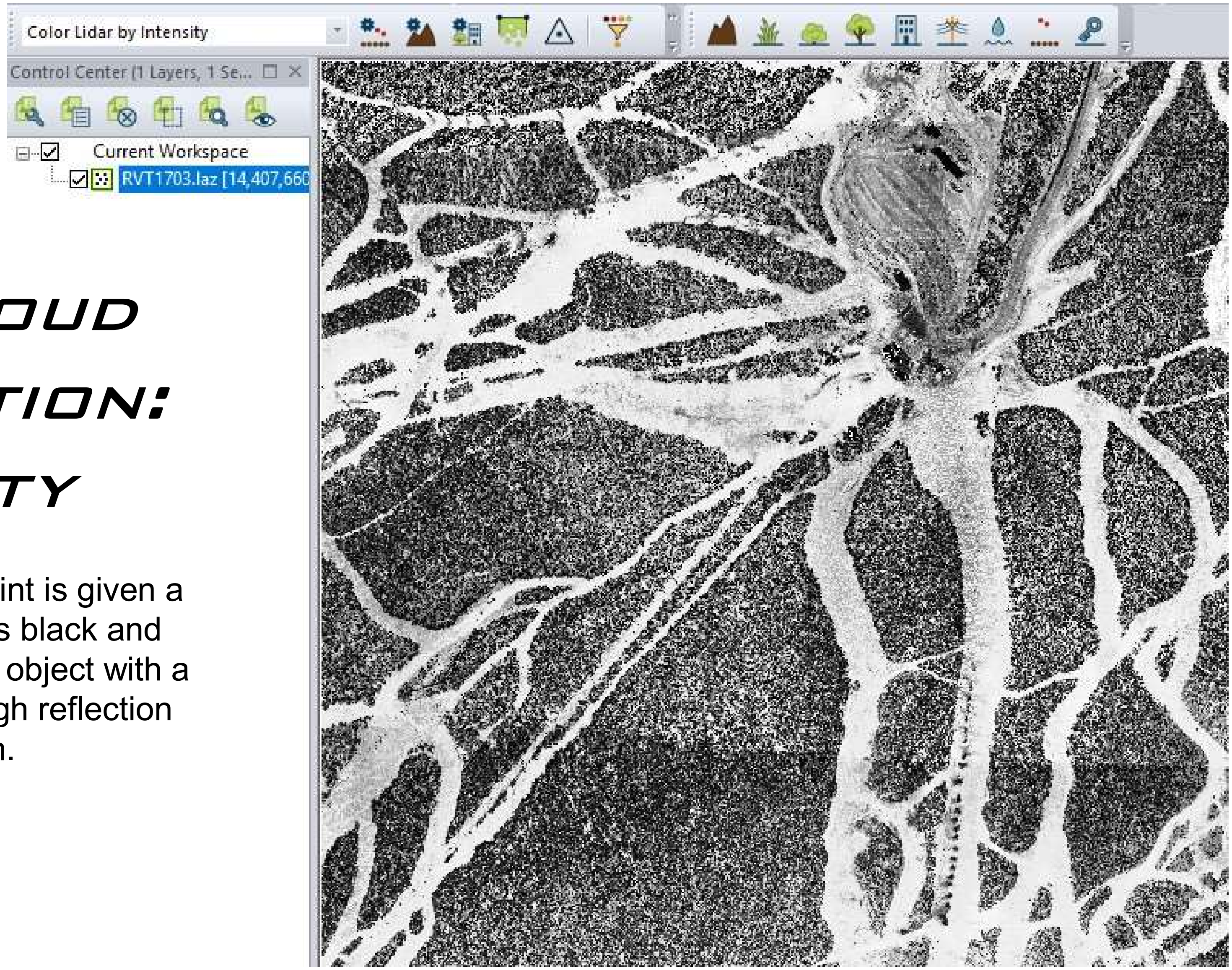
  Stuff – It will scan everything. Don't want the car scanned? Get it out of the way? How about the leaves on the ground? Sand on the roads?
- Most software packages offer 3d and 2d views.

Point Cloud Visualization: Height



The **height** of each point translates to a **color** along a rainbow scale expressed to the left of the cloud. There are ways to change the range and the color scale.

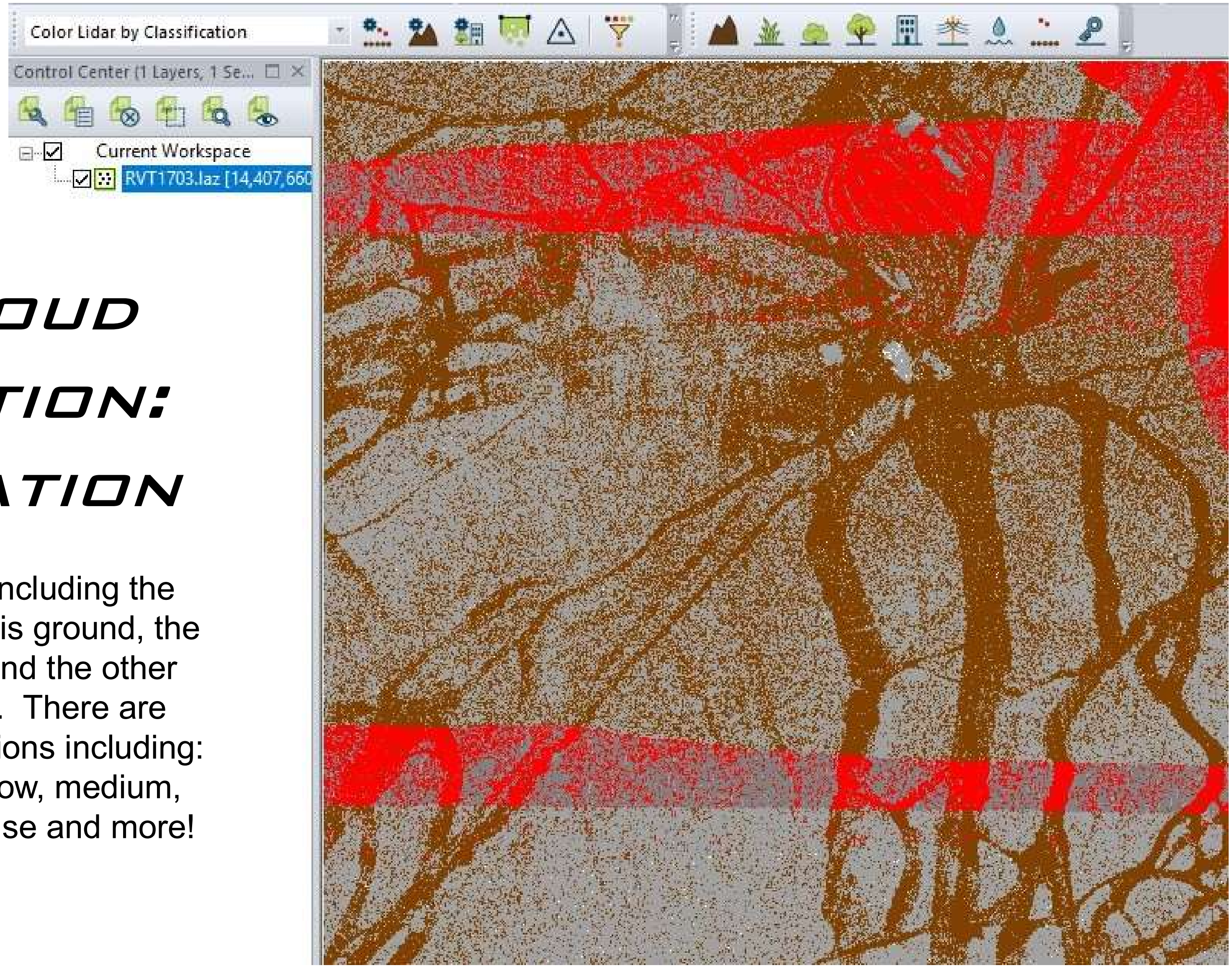
Point Cloud Visualization: Intensity



The **reflectivity** of every point is given a gray scale value. This looks black and white and almost is. A dark object with a high sheen will provide a high reflection and will be white in the scan.

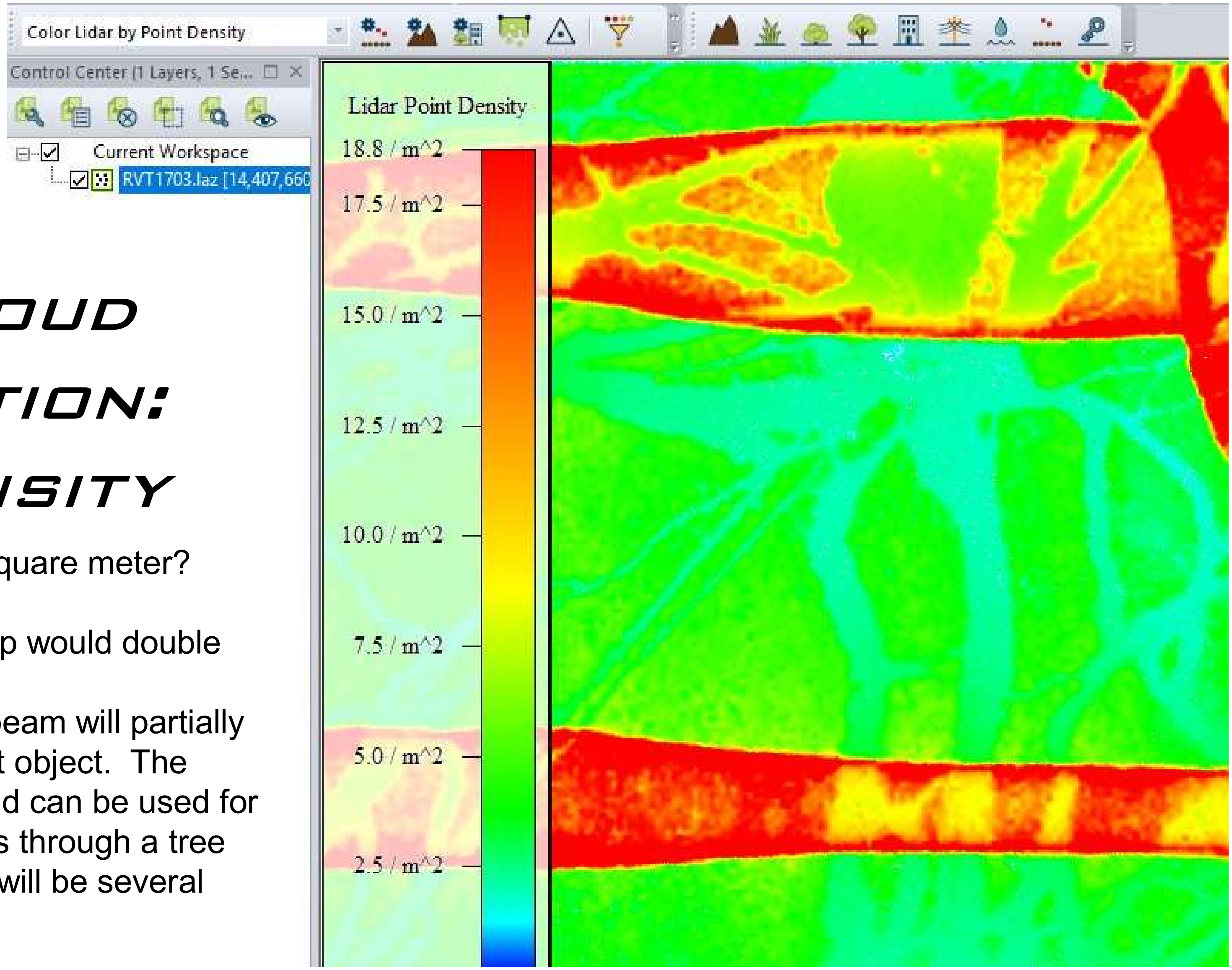
Point Cloud Visualization: Classification

Points are given attributes including the **classification**. The brown is ground, the red are the overlap points and the other points are unclassified gray. There are several standard classifications including: ground, water, vegetation (low, medium, high), utilities, buildings, noise and more!



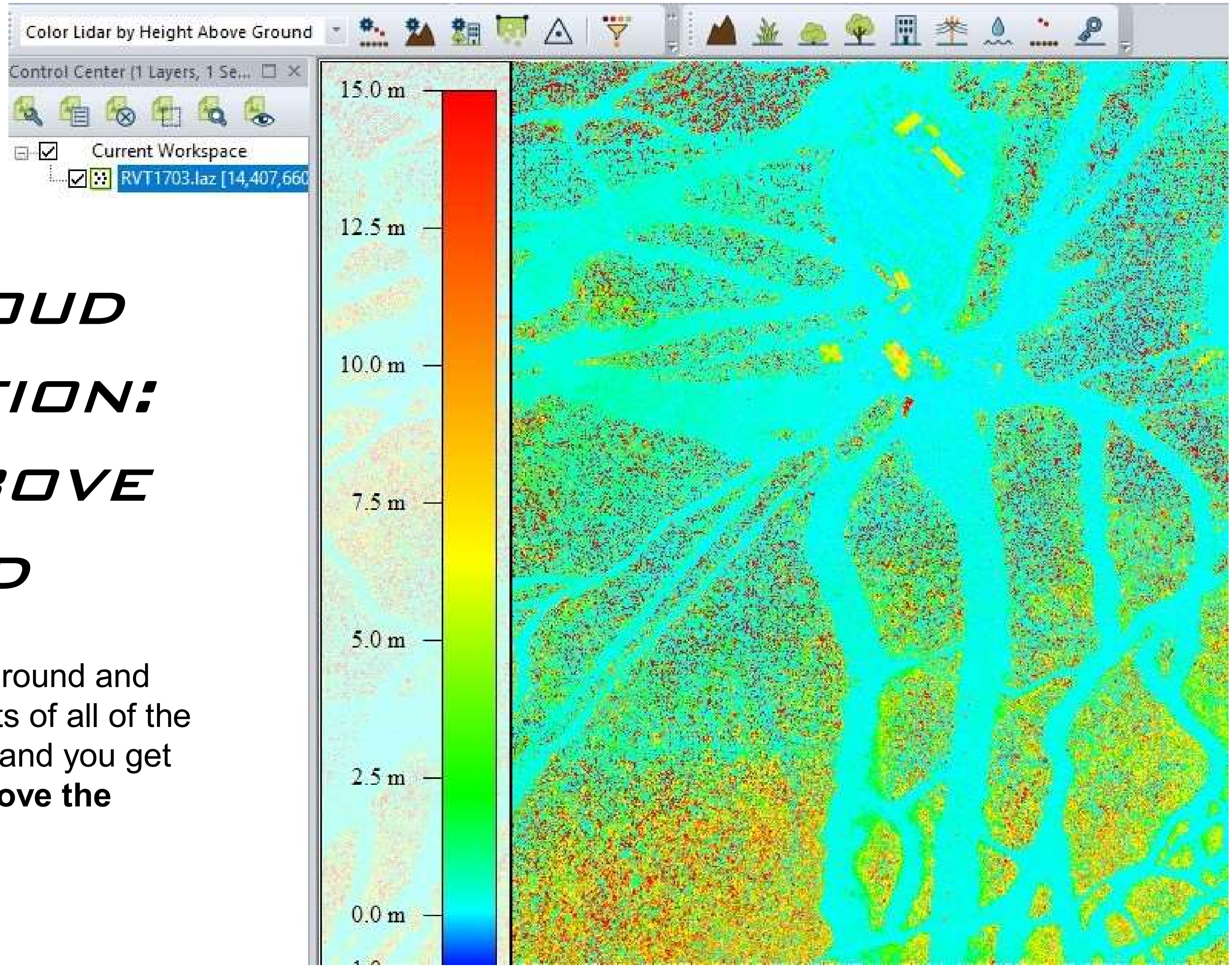
Point Cloud Visualization: Point Density

How many points are there per square meter? 2-18.
18? How do you get 18? Overlap would double the number of points and:
Lasers are not infinitesimal; the beam will partially hit objects on their way to the last object. The multiple hits are called returns and can be used for some modeling. If a laser passes through a tree and hits several branches, there will be several points.

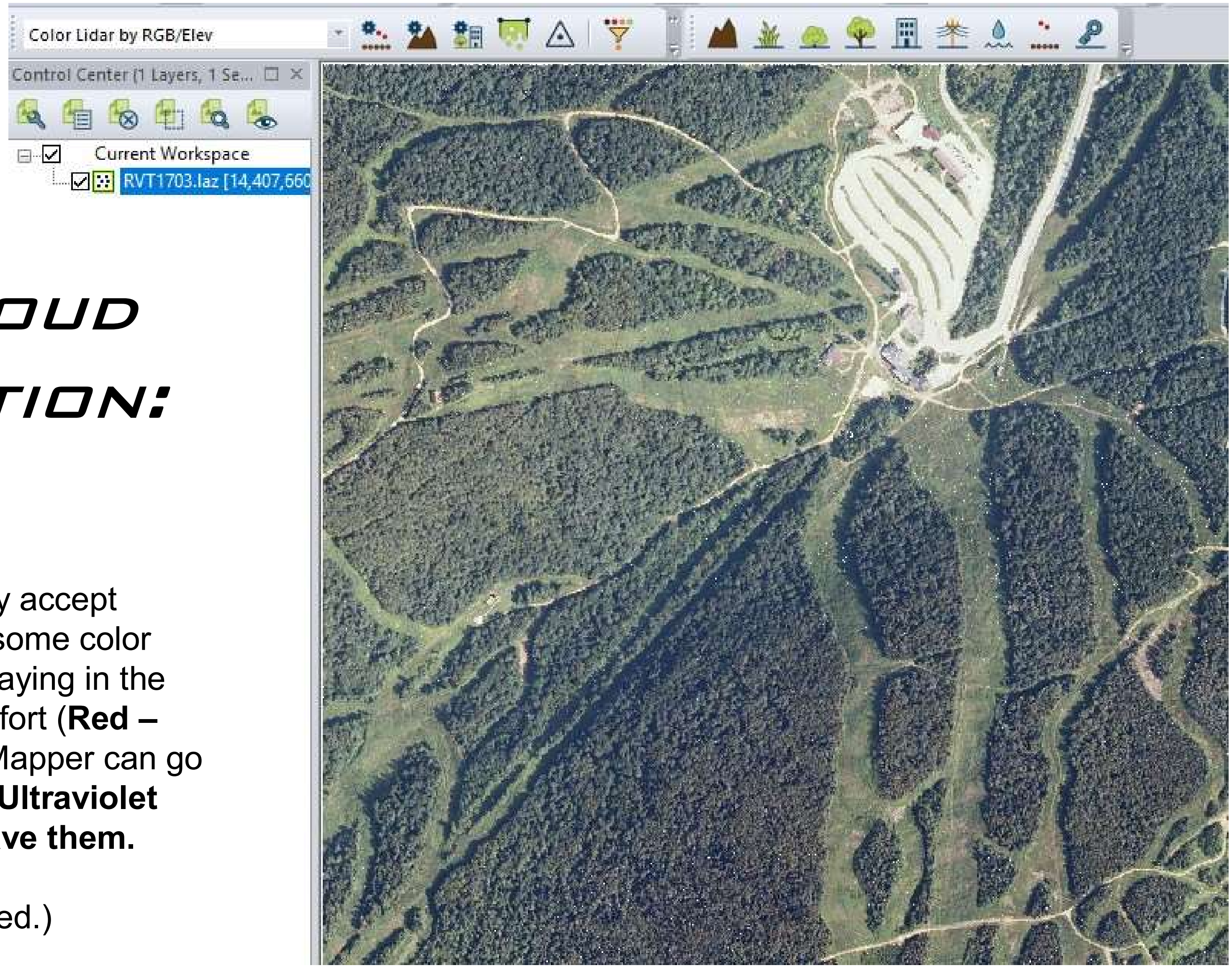


Point Cloud Visualization: Height Above Ground

There was some classified ground and the cloud includes the heights of all of the points... Put those together and you get the **height of the points above the ground.**



Point Cloud Visualization: RGB



The LiDAR Points will gladly accept imagery information to tag some color information. I have been playing in the visible spectrum out of comfort (**Red – Green – Blue**) but Global Mapper can go beyond and add **InfraRed, Ultraviolet and other bands if you have them.**

(Your data is not yet colorized.)

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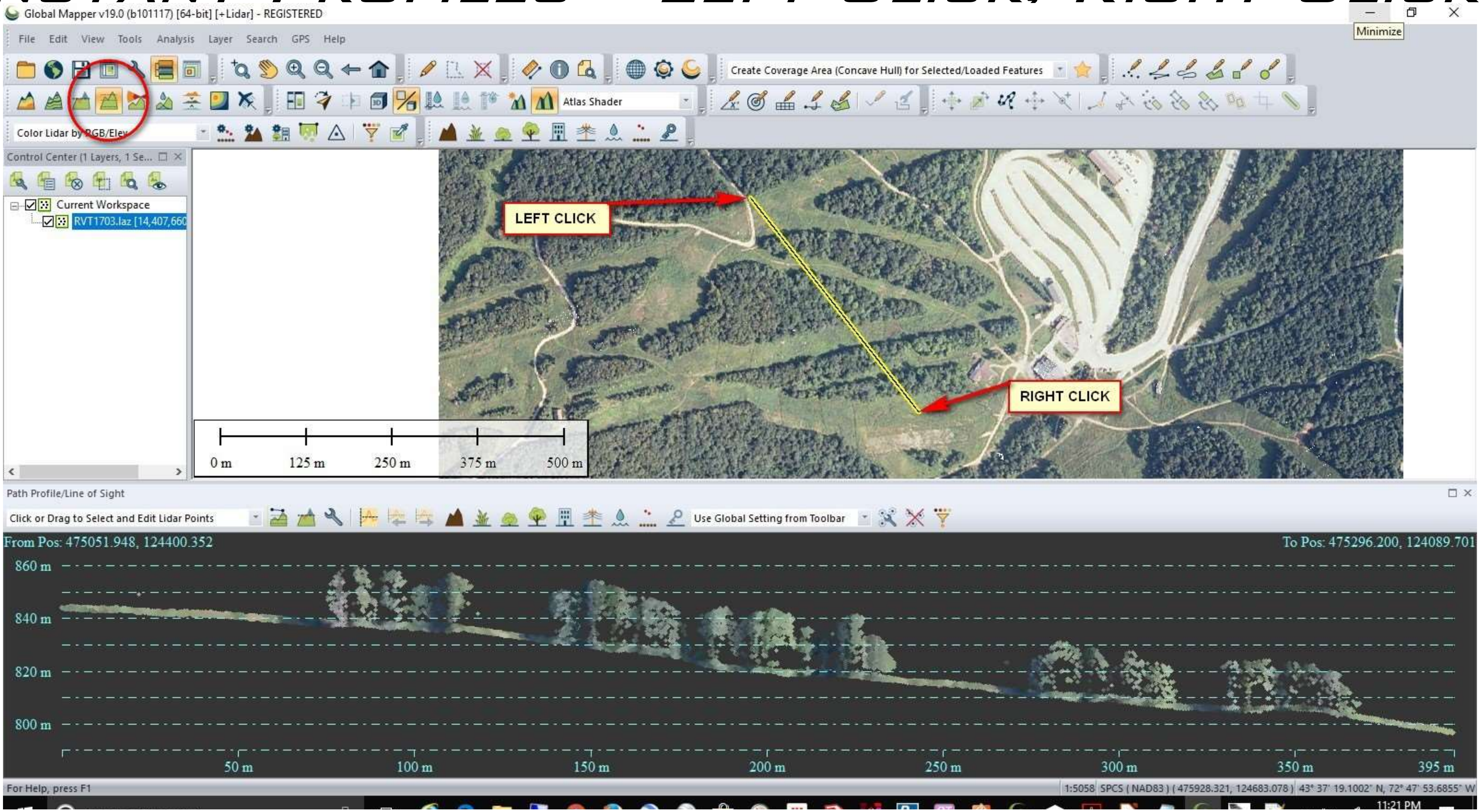
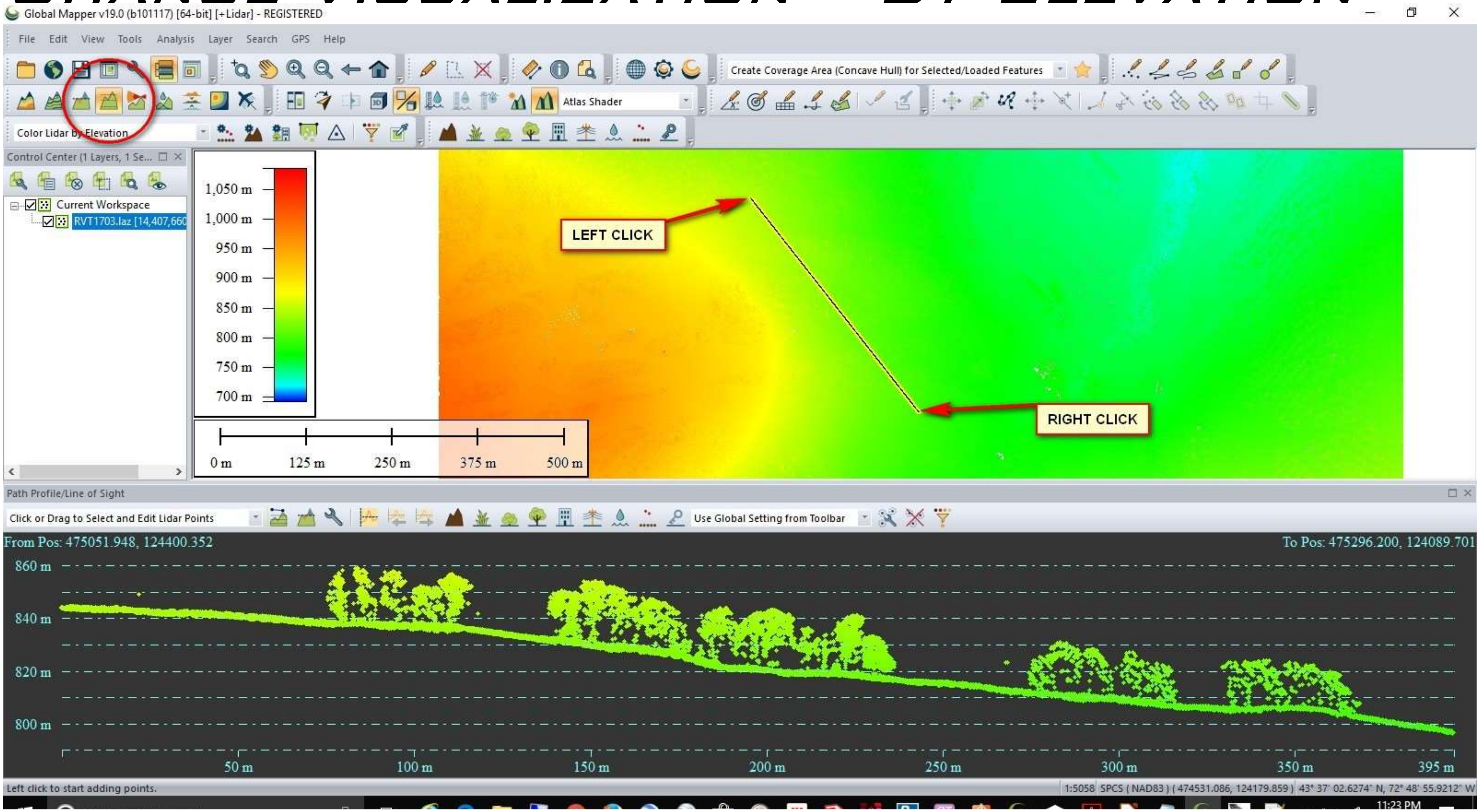
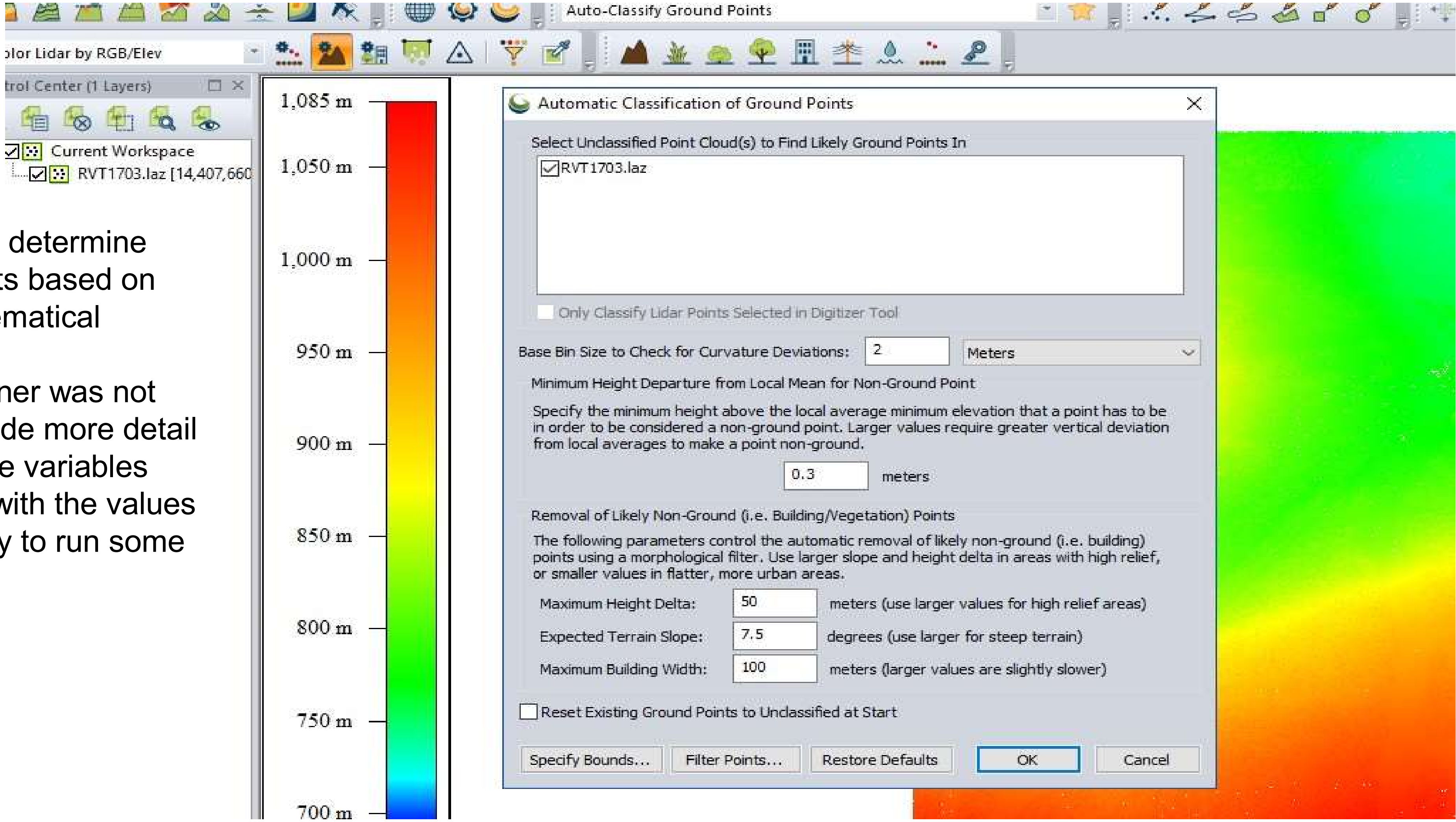
Instant Profiles – Left Click, Right Click



Change Visualization – By Elevation



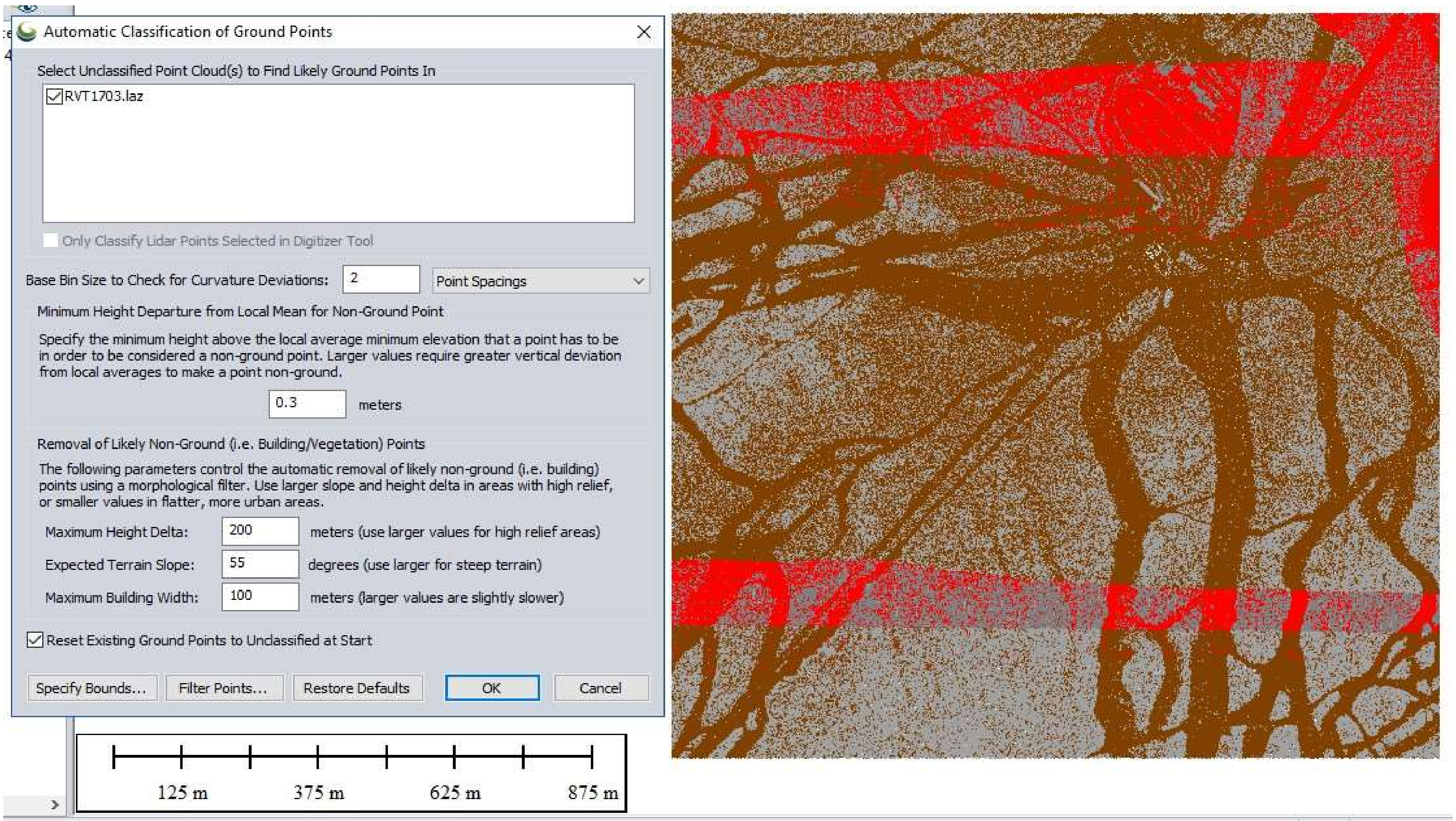
Classification - Ground



This tool will determine ground points based on some mathematical modeling.

The GM trainer was not able to provide more detail on how these variables work. Play with the values and be ready to run some edits.

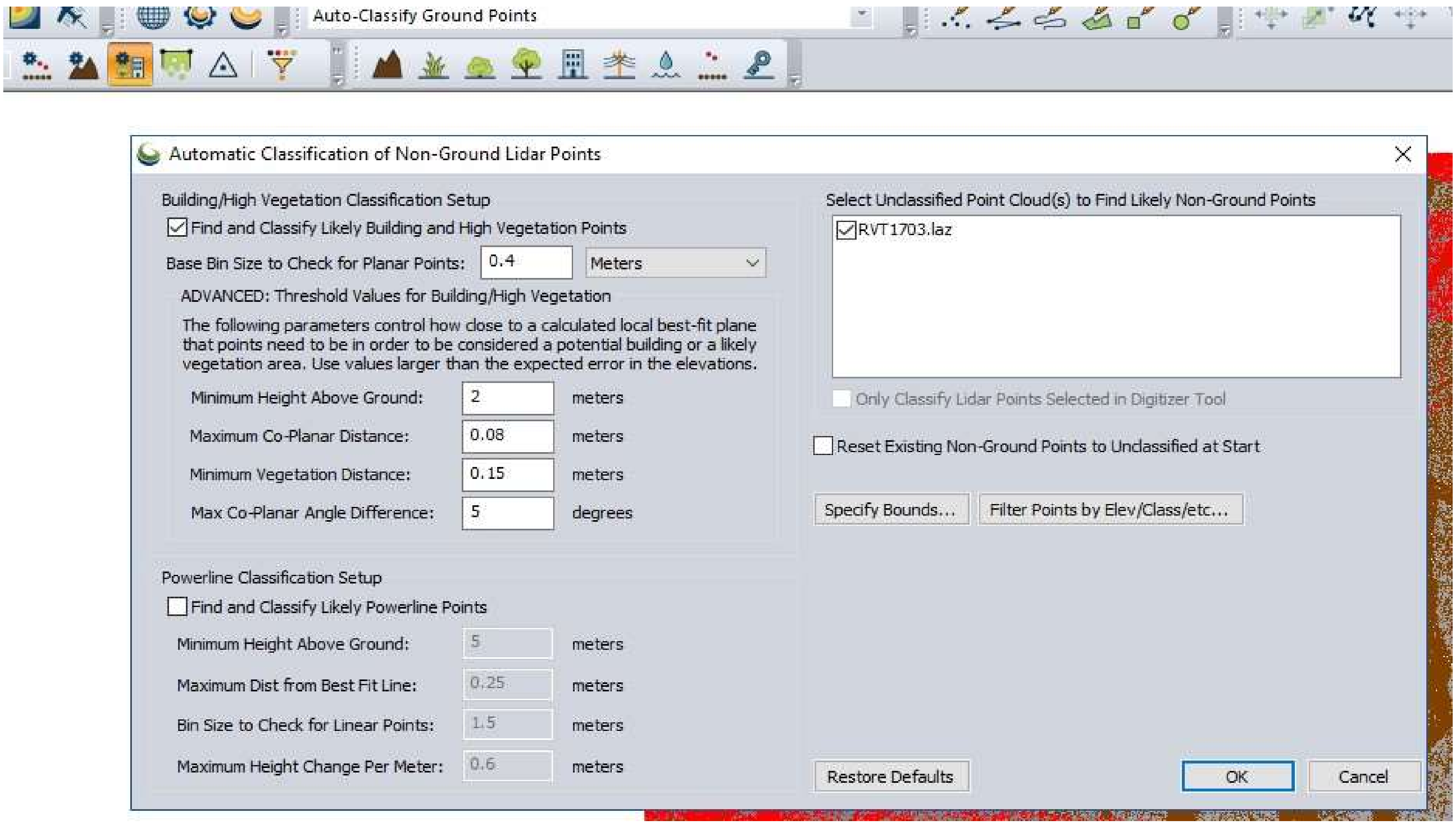
Classification - Ground



"...keep in mind automatic classification will always have some mis-classifications, no automatic algorithms get better than 85-90% accuracy."

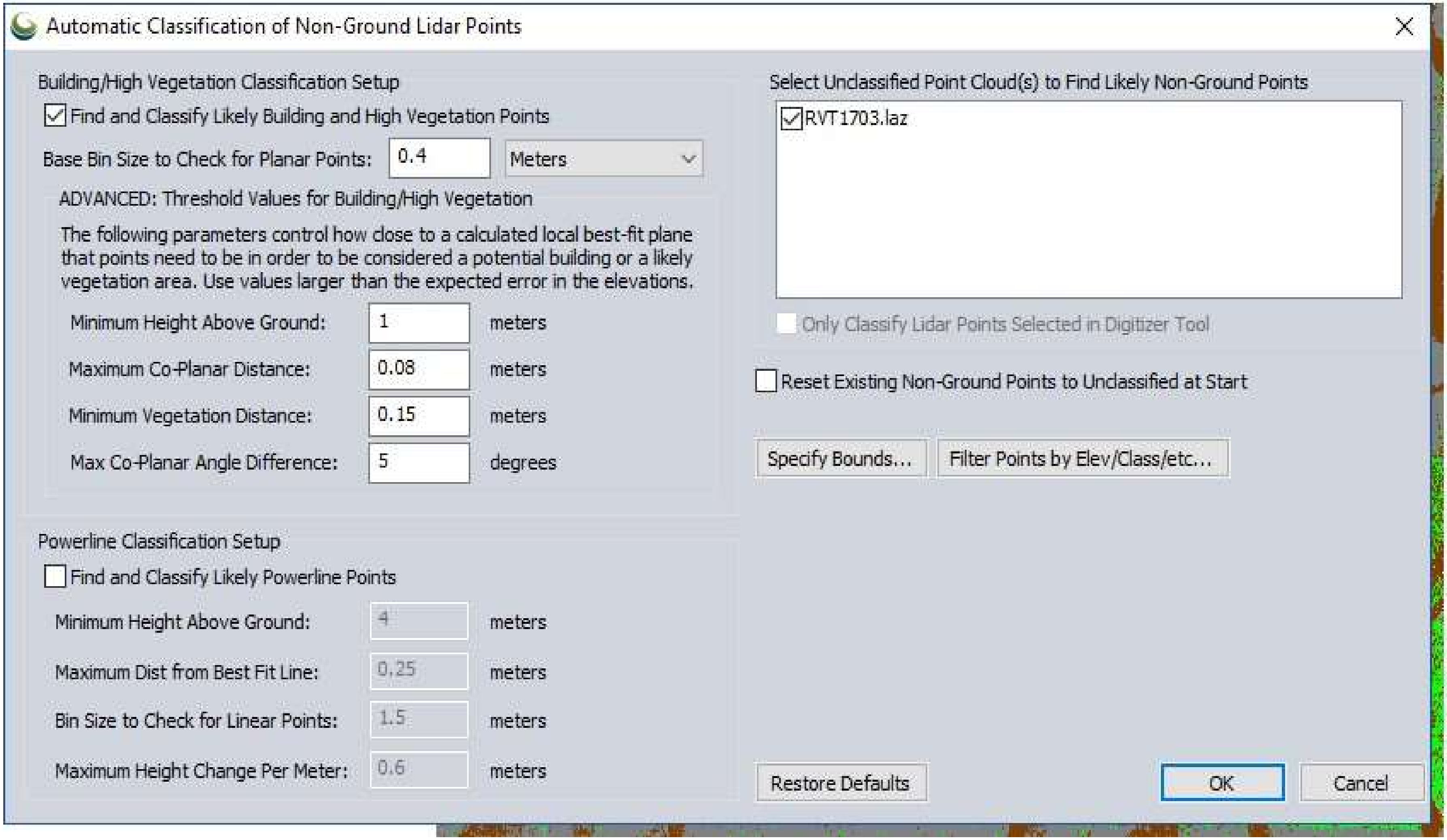
- Mike, a Global Mapper Guru on their forum.

Classification – Non-Ground



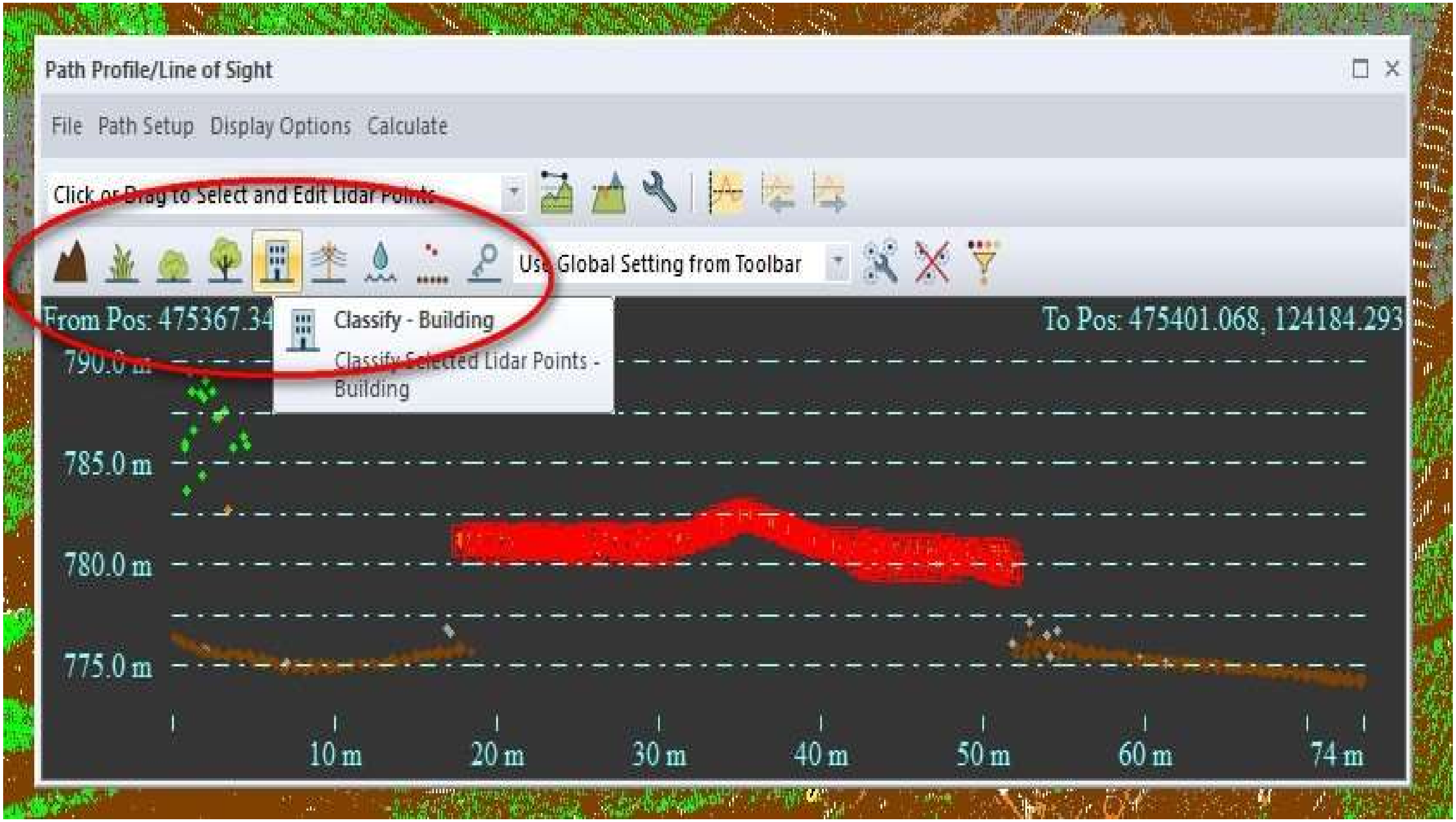
This tool comes with the same hands on experience as the classify ground tool. Play with the settings, use the profile tool to see how it checks out.

Classification – Non-Ground



The settings need to change based on the cloud. Make little changes until you see the desired results.

Classification – by Profile (Manual)



Ground

Low Vegetation

Medium Vegetation

High Vegetation

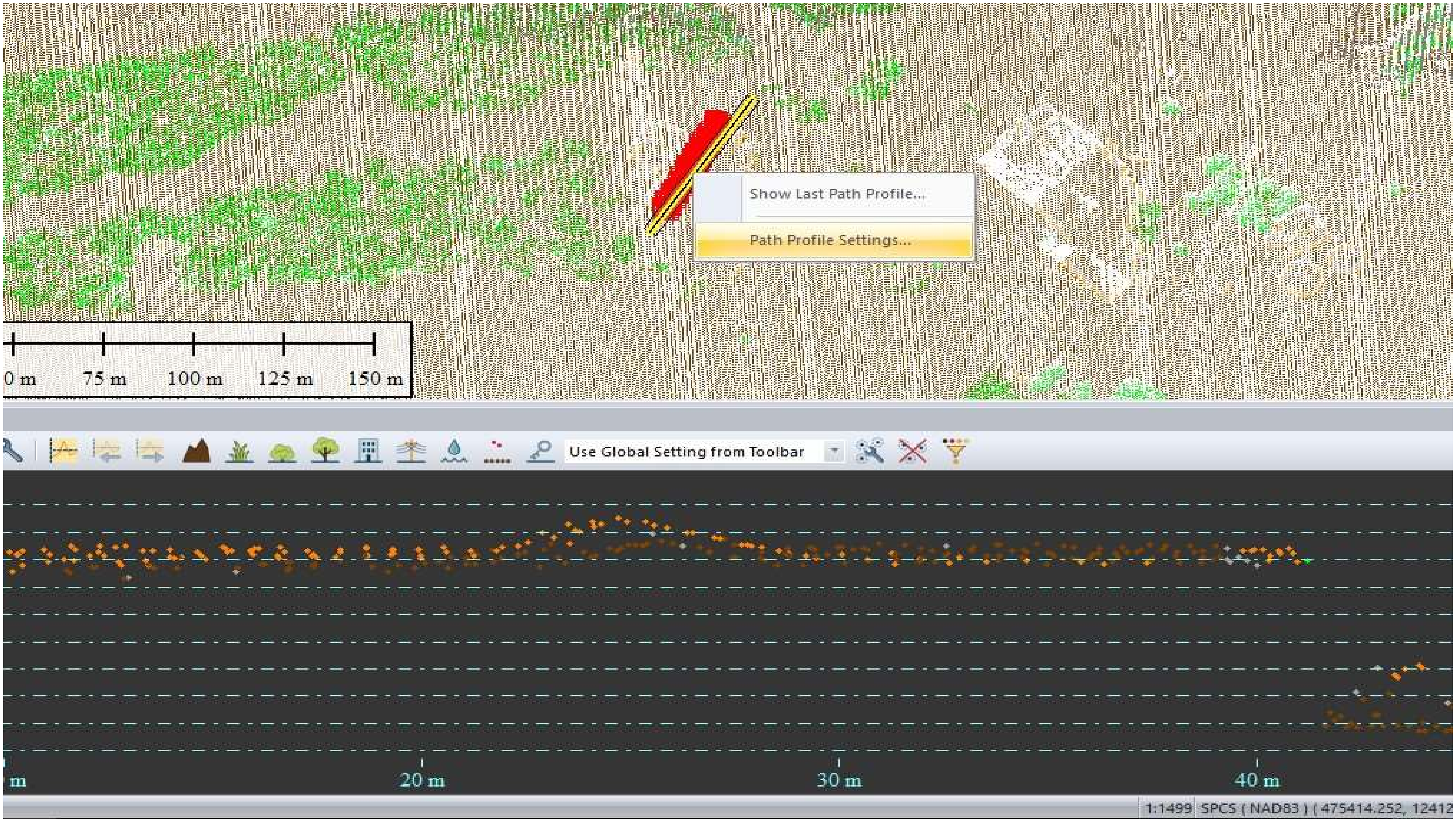
Building

Powerline

Water

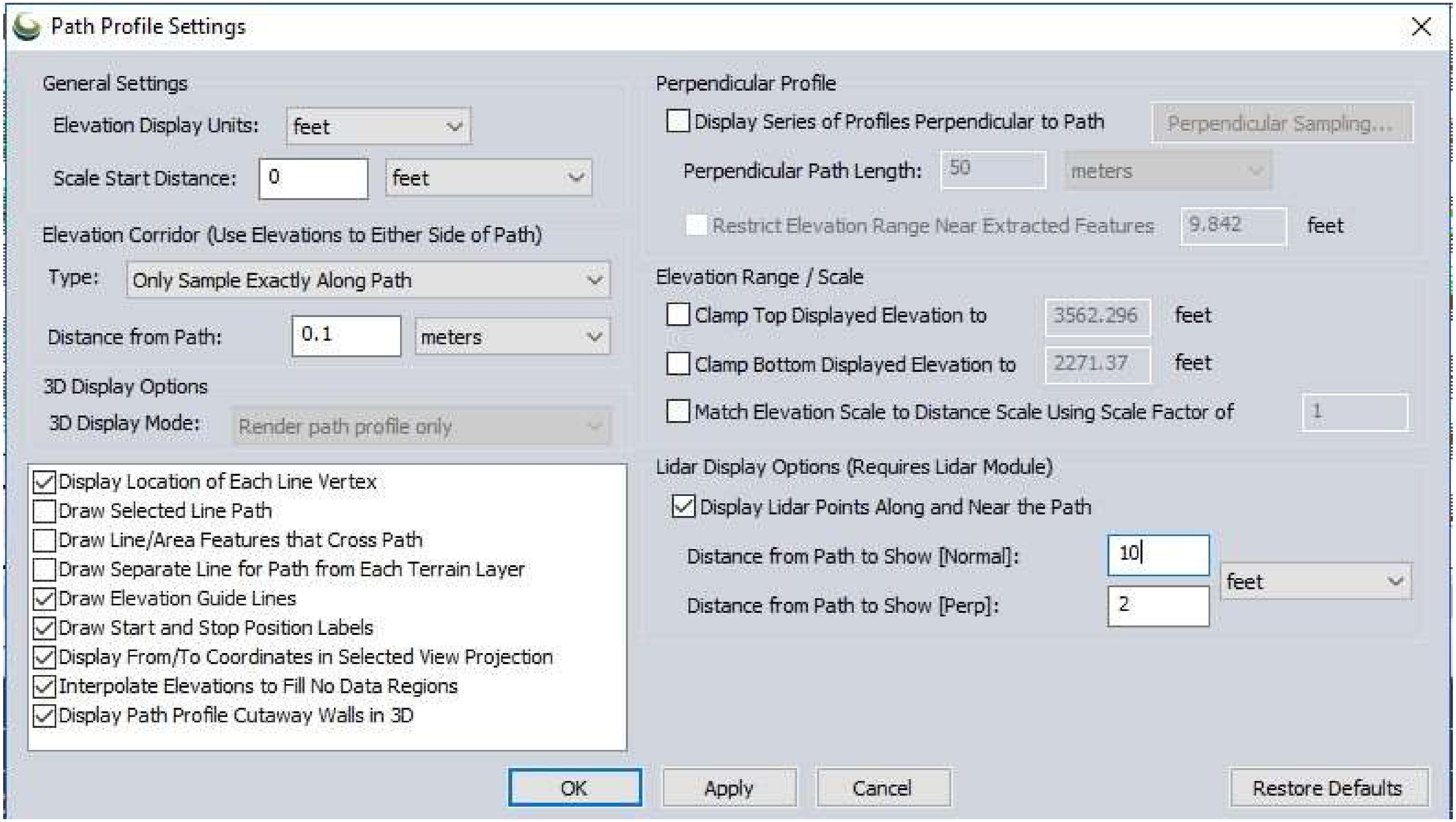
Noise

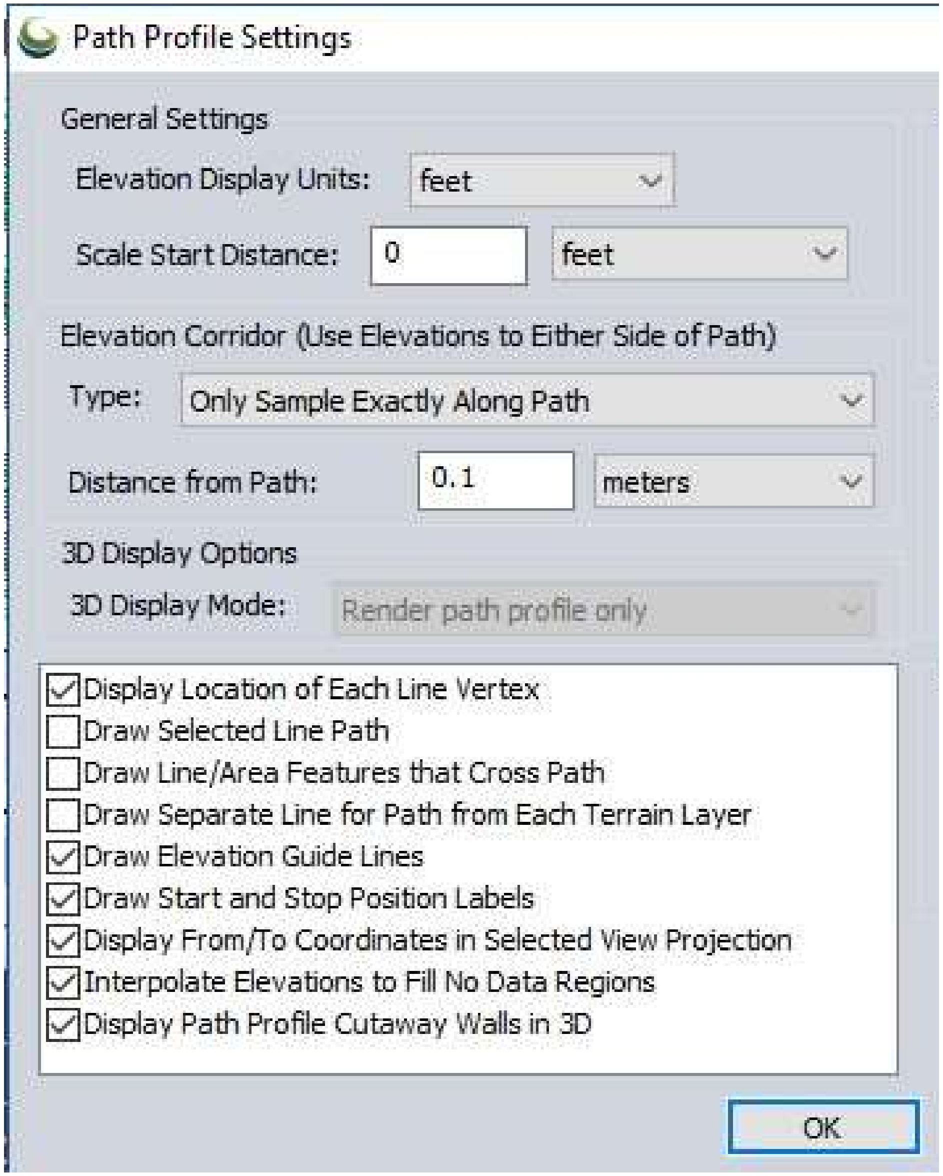
Path Profile Settings



Right Click

An overwhelming menu!





Units can be changed from metric. (please hold applause)

Scale start distance is to modify the 0+00

Samples a surface model to return highs, averages, lows within a distance from the path.

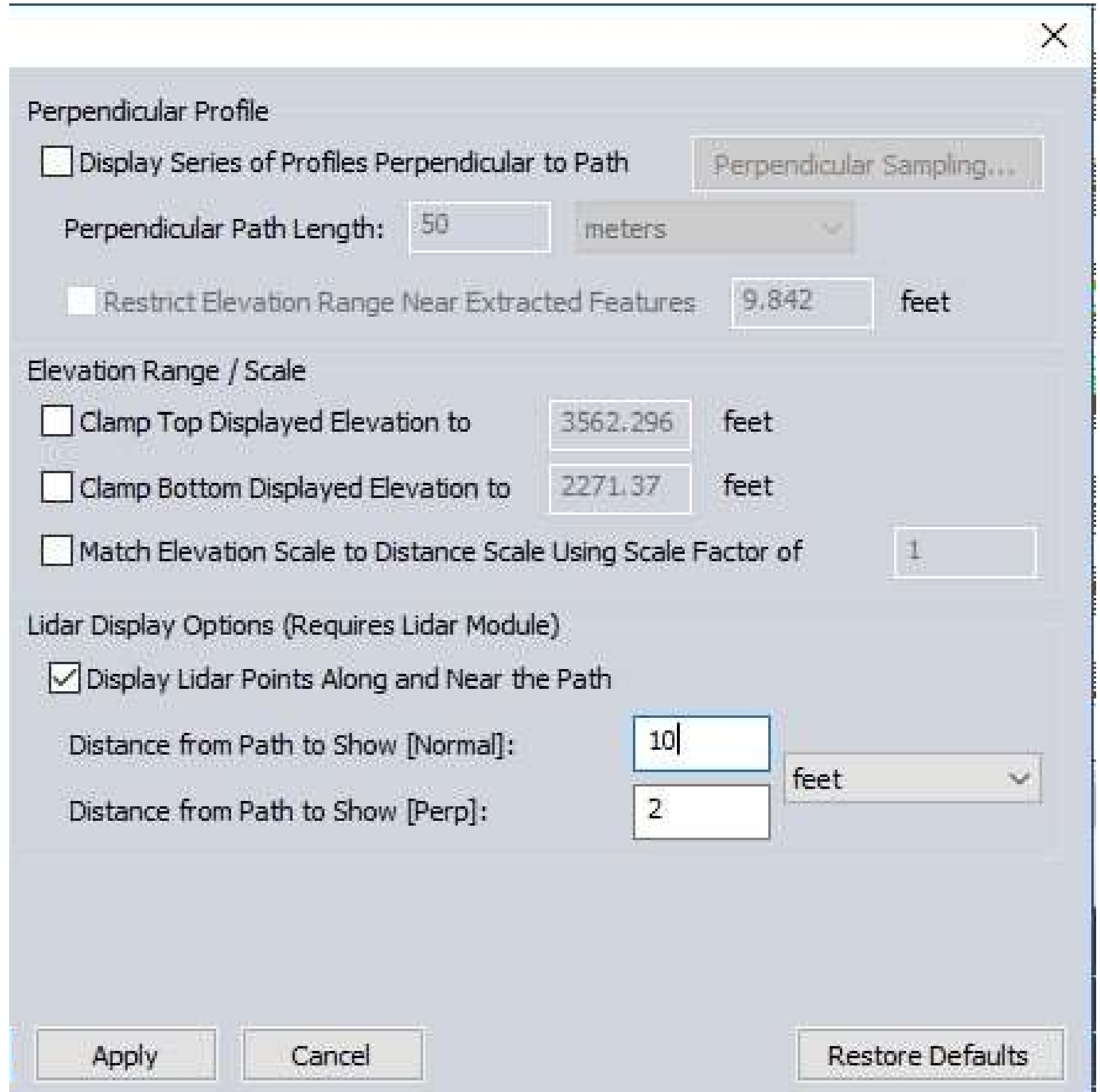
This enables terrain cutaways in the 3d viewer

If your profile has bends the vertices will show
??? (The help file does not know either)
Draw lines and they will show up
If you have two surfaces they will show extra lines
Elevation Guides
Coordinates of the from and to points
Projection or Lat/Long
Interpolation to fill in the gaps
Back to the 3d viewer

This will show you cross sections along the profile and it allows you to extract data along the sections. It is better for dense scan data.

These settings change the height and position of the profile or sections. The elevation scale will be best fit if you don't choose something.

Toggle the display of the LiDAR points.
How wide is your swath?
How wide are your sections?



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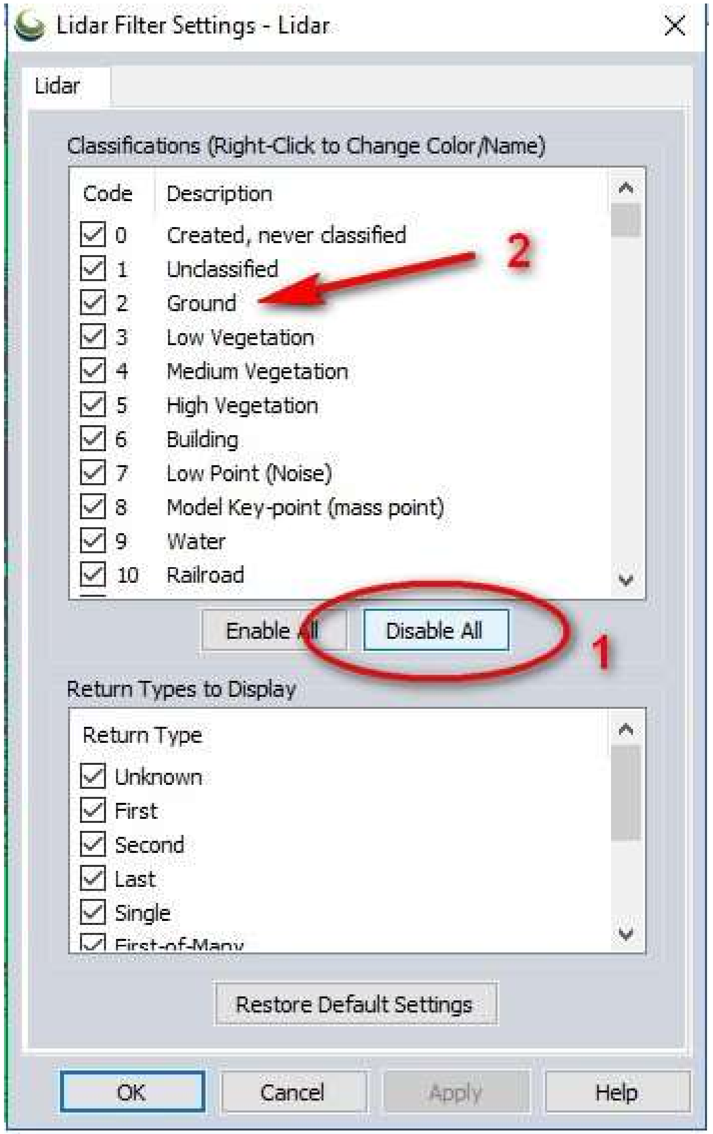
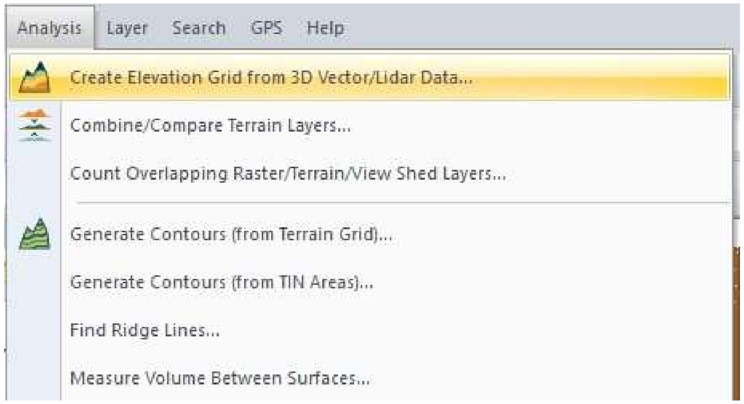
Use the LiDAR Filter Settings to isolate the Ground points in preparation of creating a surface model.



GROUND SURFACE MODEL

Ground Surface Model

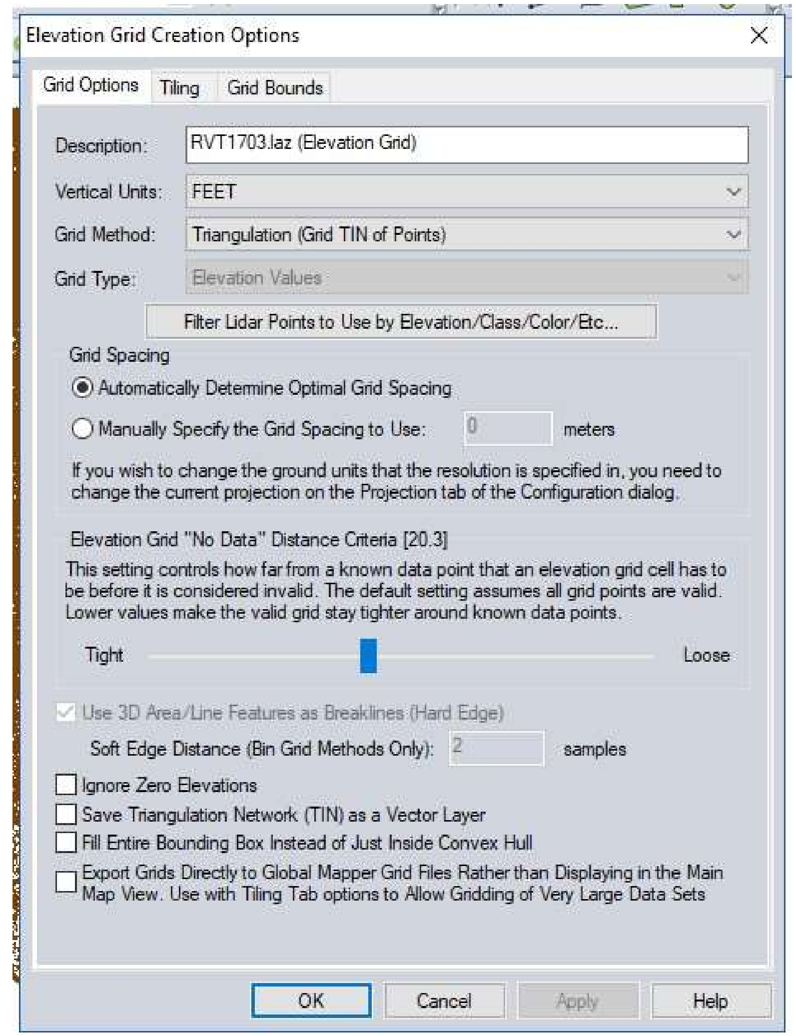


Layer Name
Vertical Units
Grid Method (TIN for now)

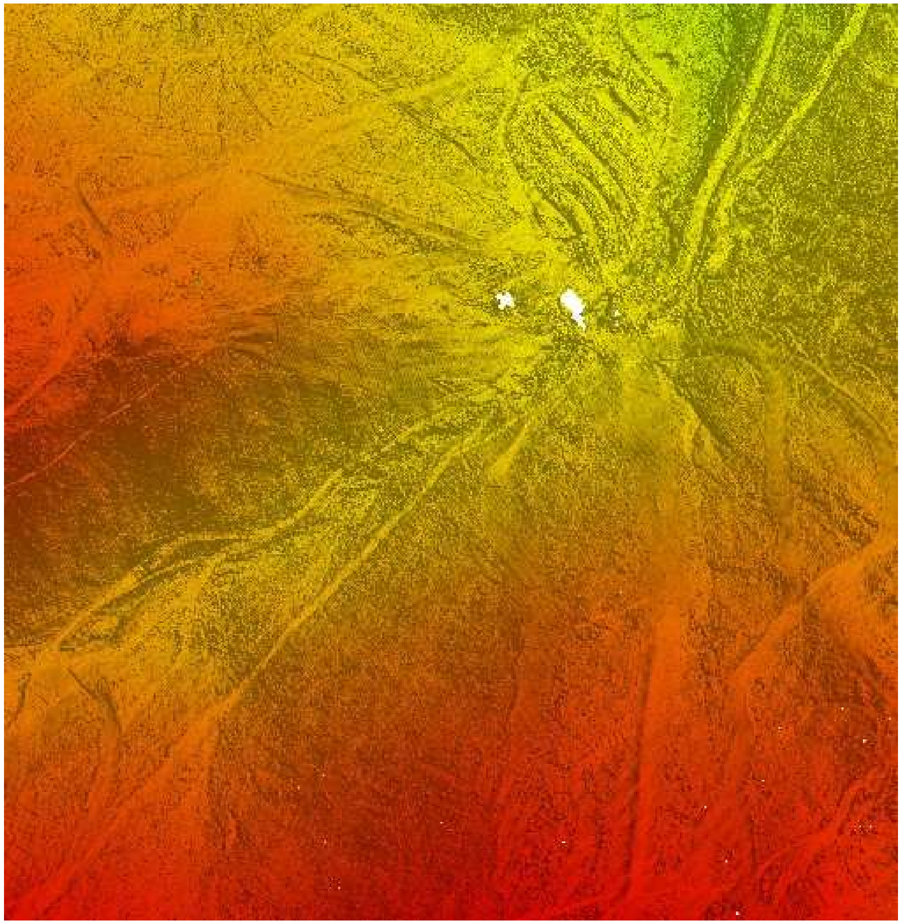
Start with Auto

Choose something between tight and loose for gap filling

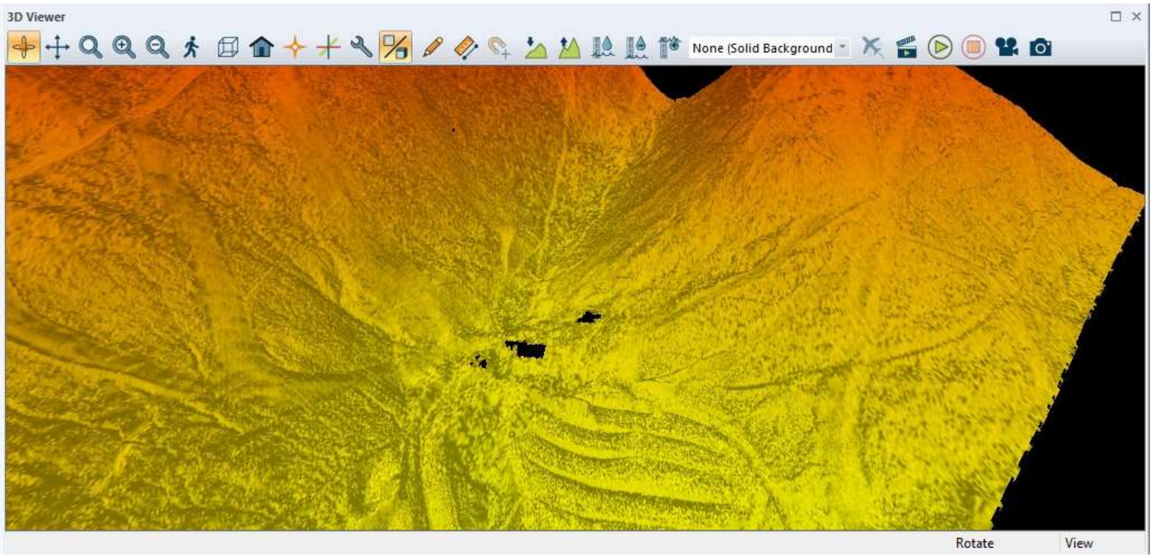
We can add more data to model including digitizing breaklines.
Ignore zero is typical.
Don't save the TIN at first. It will be large.
This is for large files.

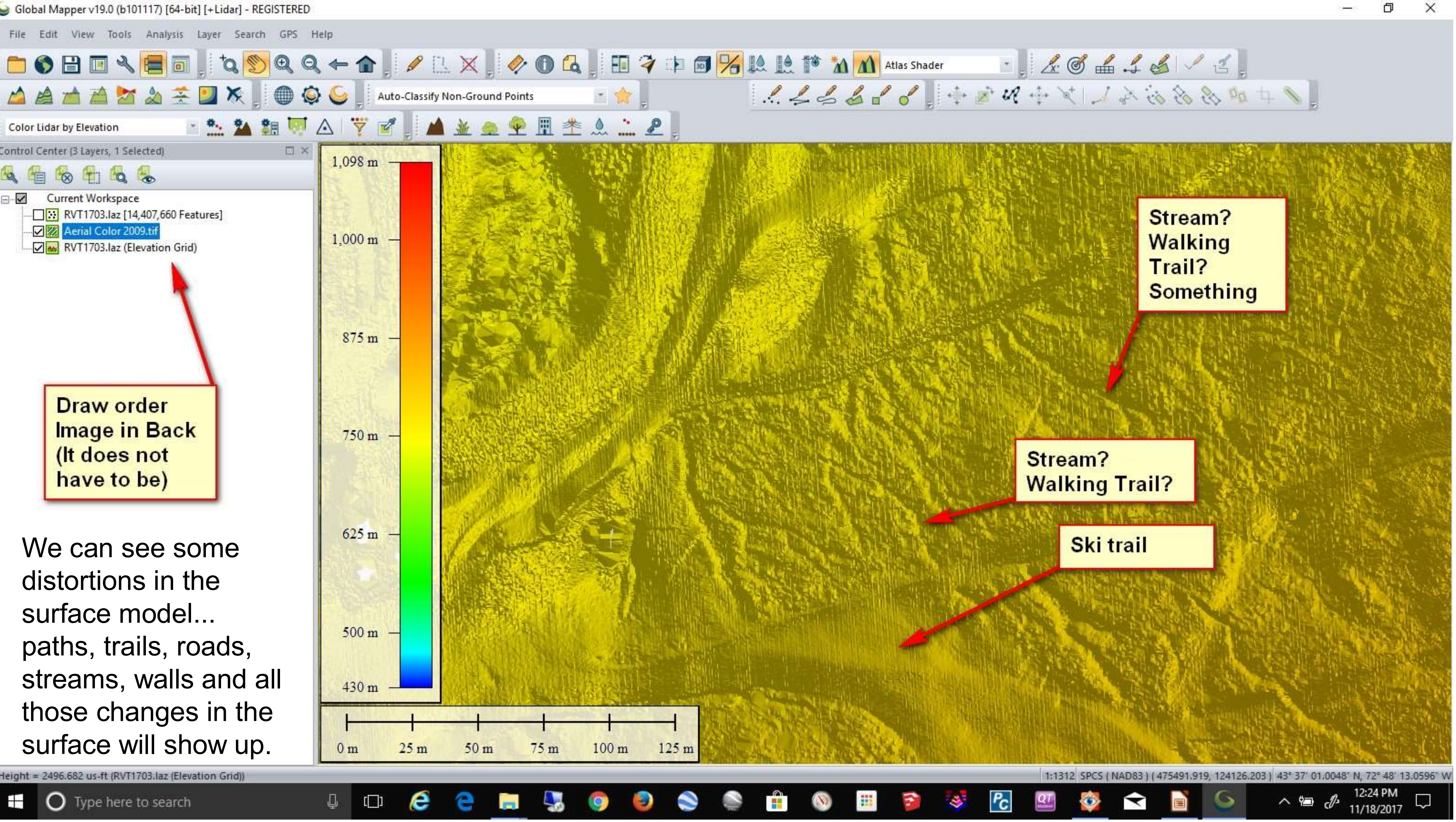


Ground Surface Model



What good is a surface model without looking at it in 3-d?
Turn off the points layer (LAZ) if they are getting in the way.

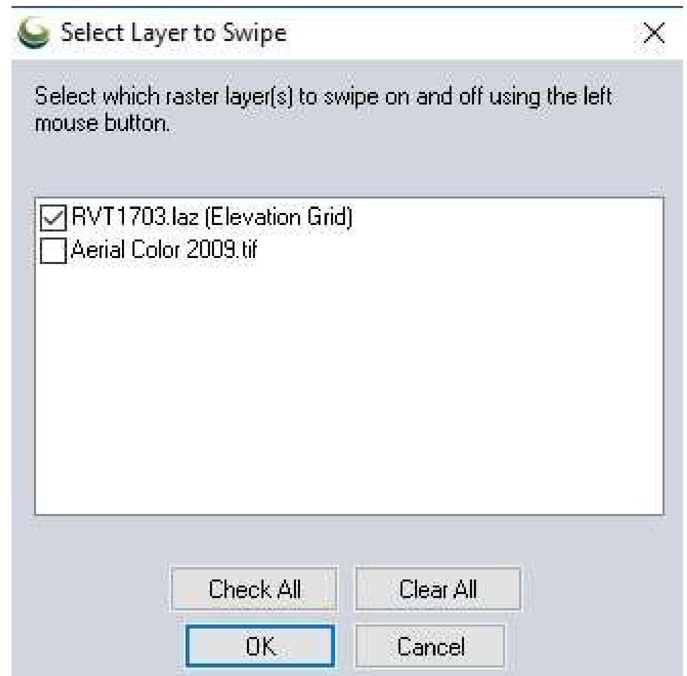


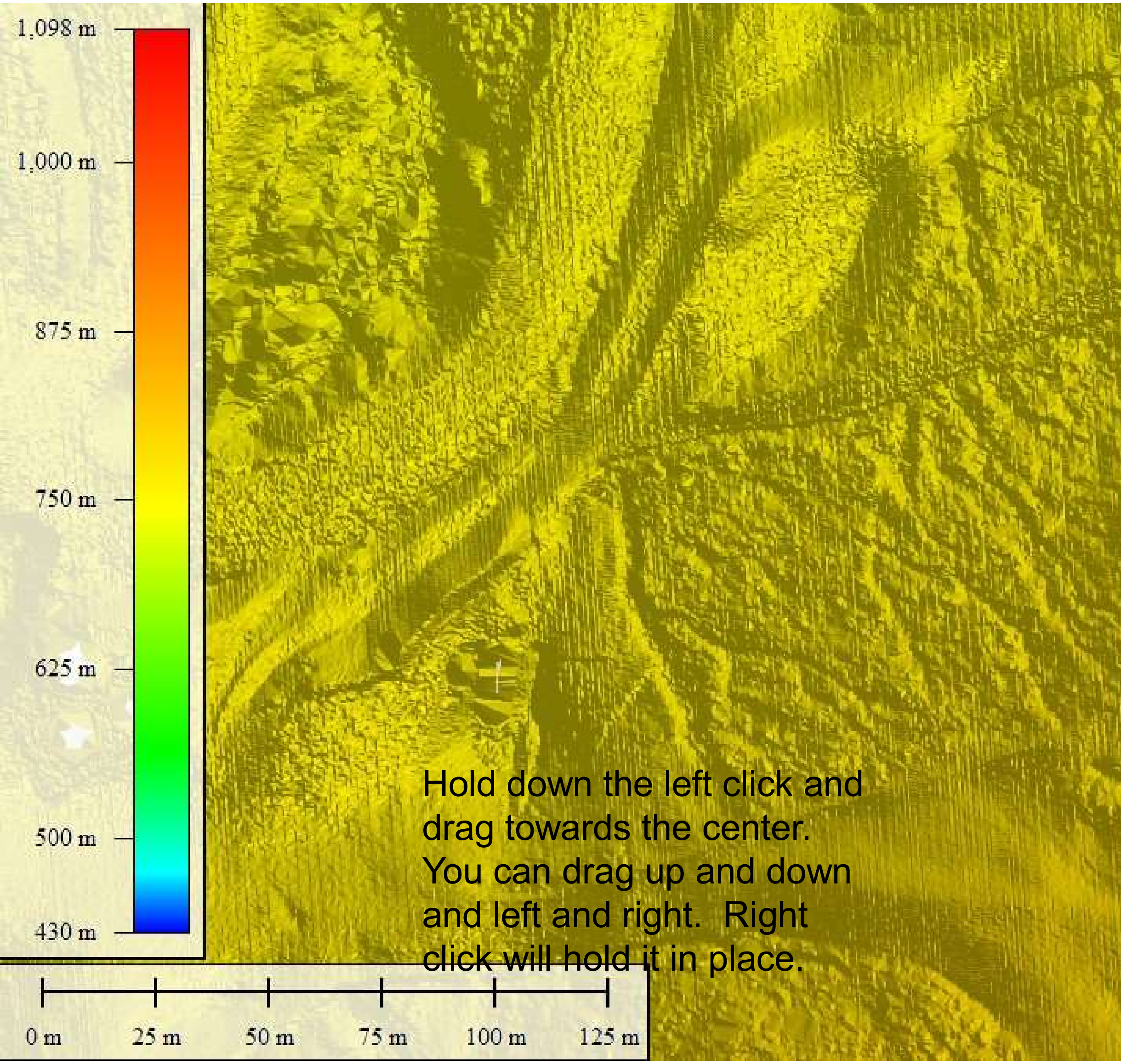


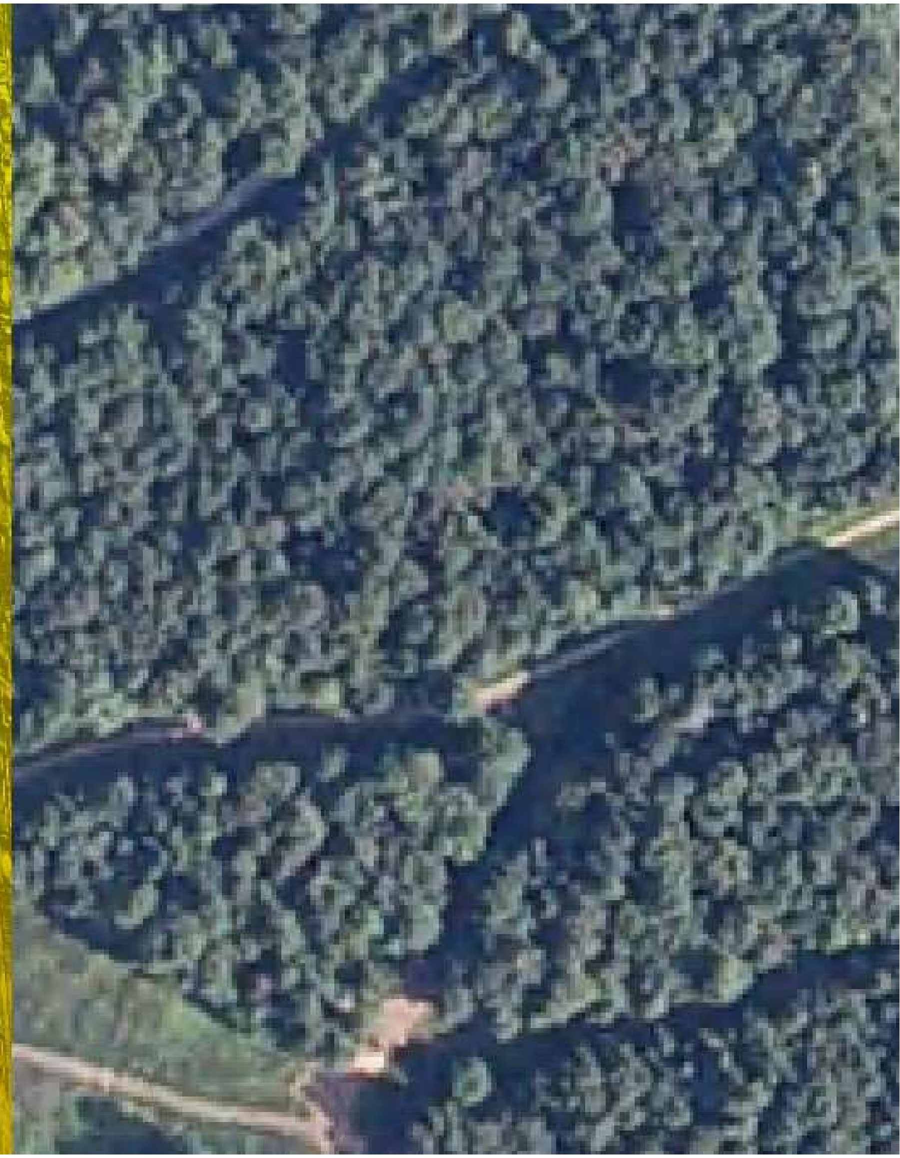
We can see some distortions in the surface model... paths, trails, roads, streams, walls and all those changes in the surface will show up.

Select the Image Swipe tool from the Tools Menu.

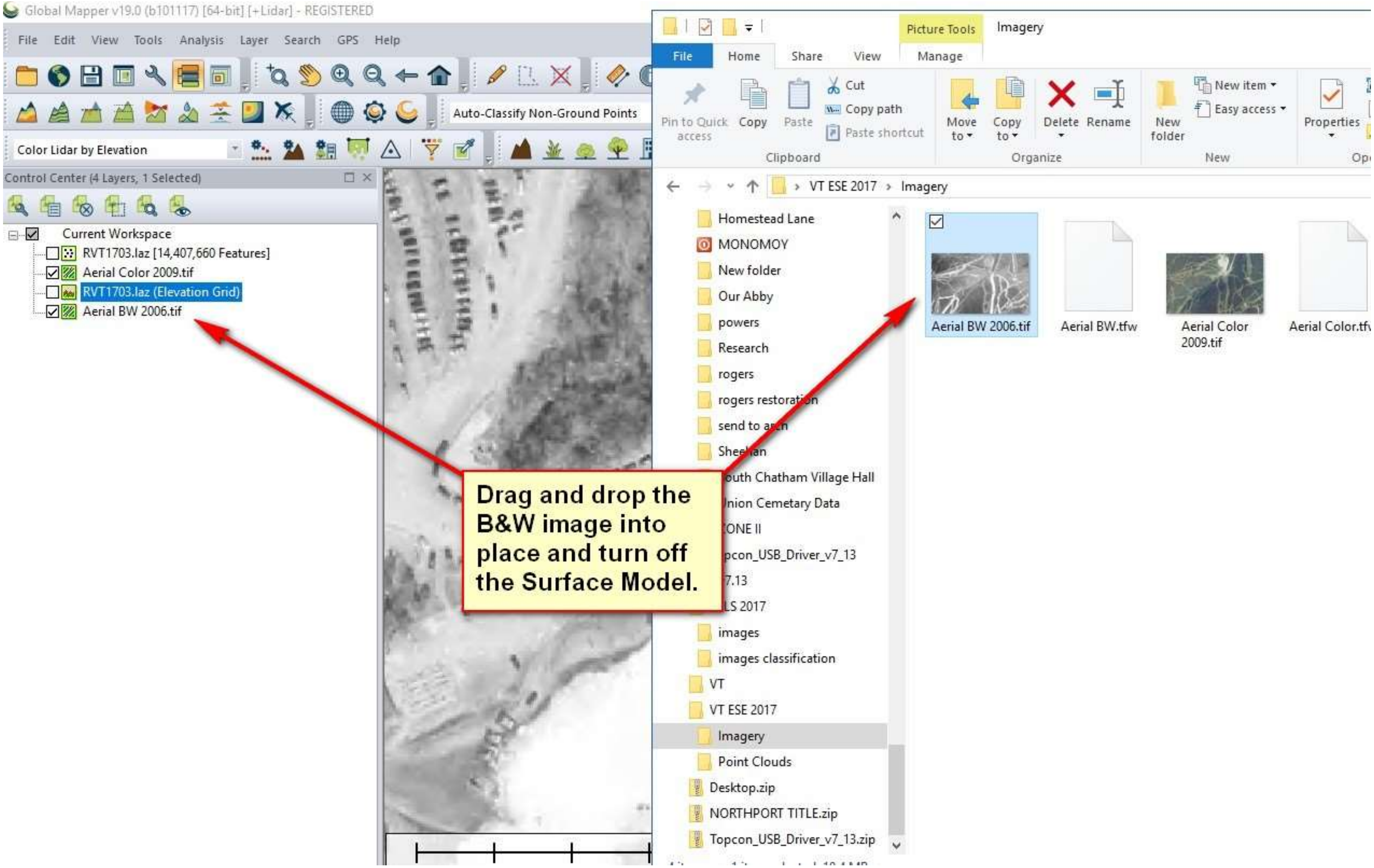
Then select the layer that is on top of the other layer.



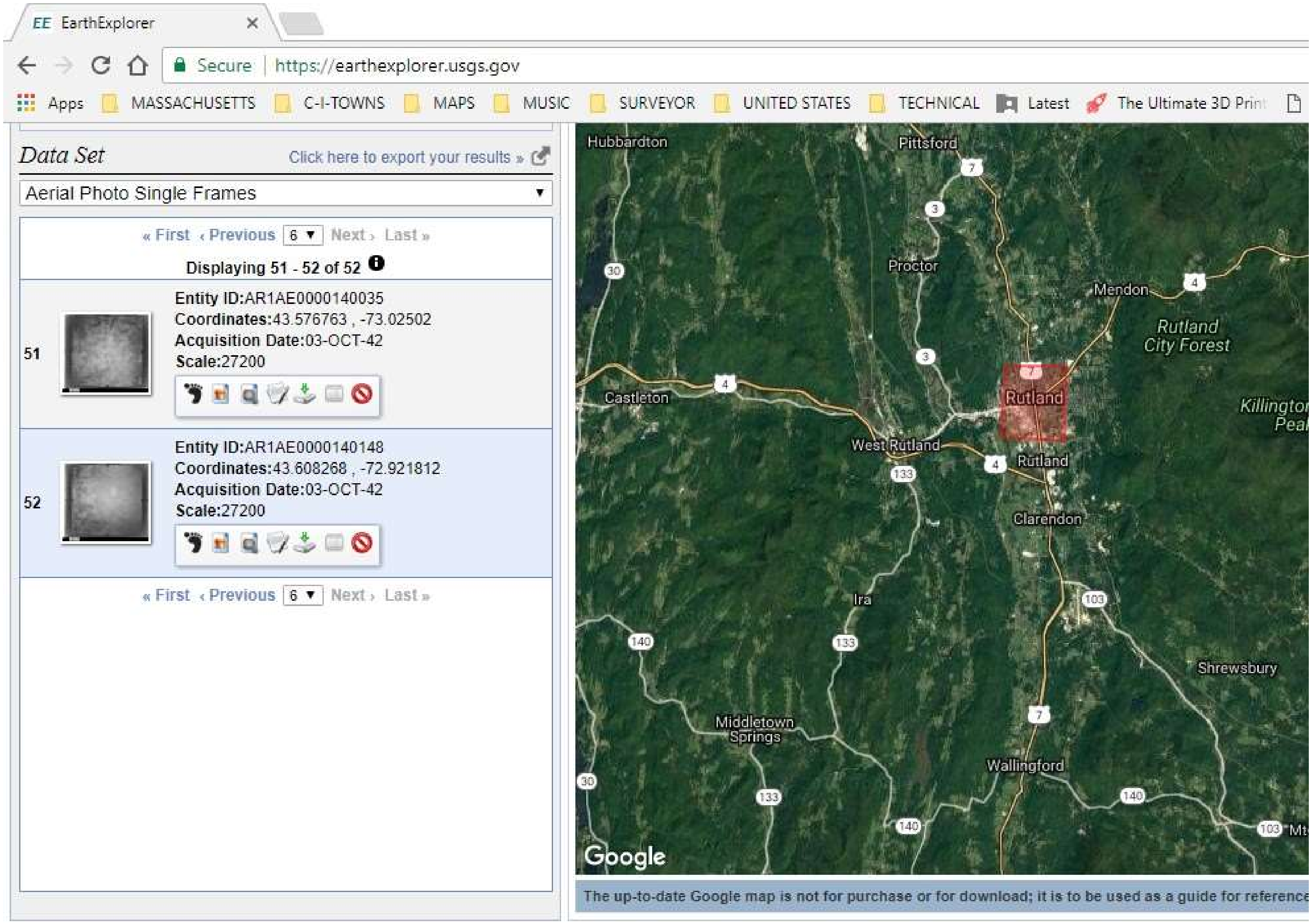




Hold down the left click and drag towards the center. You can drag up and down and left and right. Right click will hold it in place.


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED
File Edit View Tools Analysis Layer Search GPS Help
Auto-Classify Non-Ground Points
Color Lidar by Elevation
Control Center (4 Layers, 1 Selected)
Current Workspace
RVT1703.laz [14,407,660 Features]
Aerial Color 2009.tif
RVT1703.laz (Elevation Grid)
Aerial BW 2006.tif
Picture Tools
Imagery
File Home Share View Manage
Pin to Quick access
Copy
Paste
Cut
Copy path
Paste shortcut
Clipboard
Move to
Copy to
Delete
Rename
Organize
New folder
New item
Easy access
New
Properties
VT ESE 2017 › Imagery
Homestead Lane
MONOMOY
New folder
Our Abby
powers
Research
rogers
images
images classification
VT
VT ESE 2017
Imagery
Point Clouds
Desktop.zip
NORTHPORT TITLE.zip
Topcon_USB_Driver_v7_13.zip
Aerial BW 2006.tif
Aerial BW.tfw
Aerial Color 2009.tif
Drag and drop the B&W image into place and turn off the Surface Model.

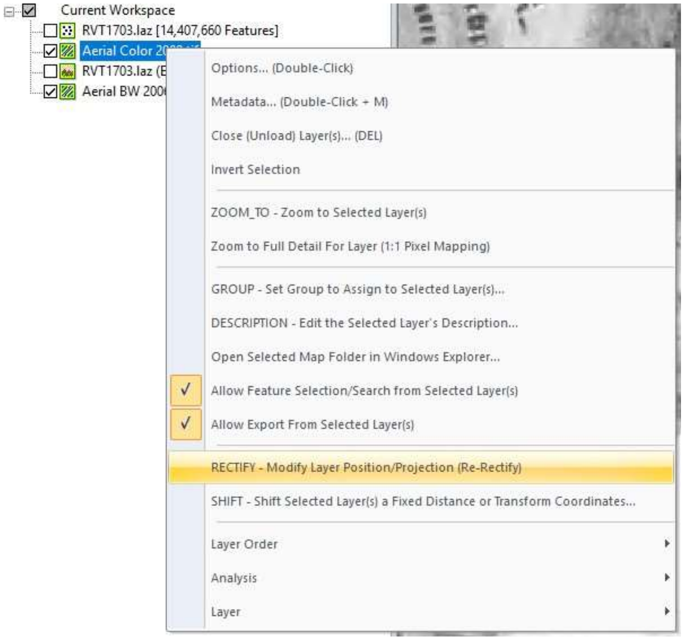

0 m
25 m
50 m
75 m
100 m
125 m
Want to see the history? You
will need the imagery.
Historical Buffs love this stuff.



You might need some older imagery.

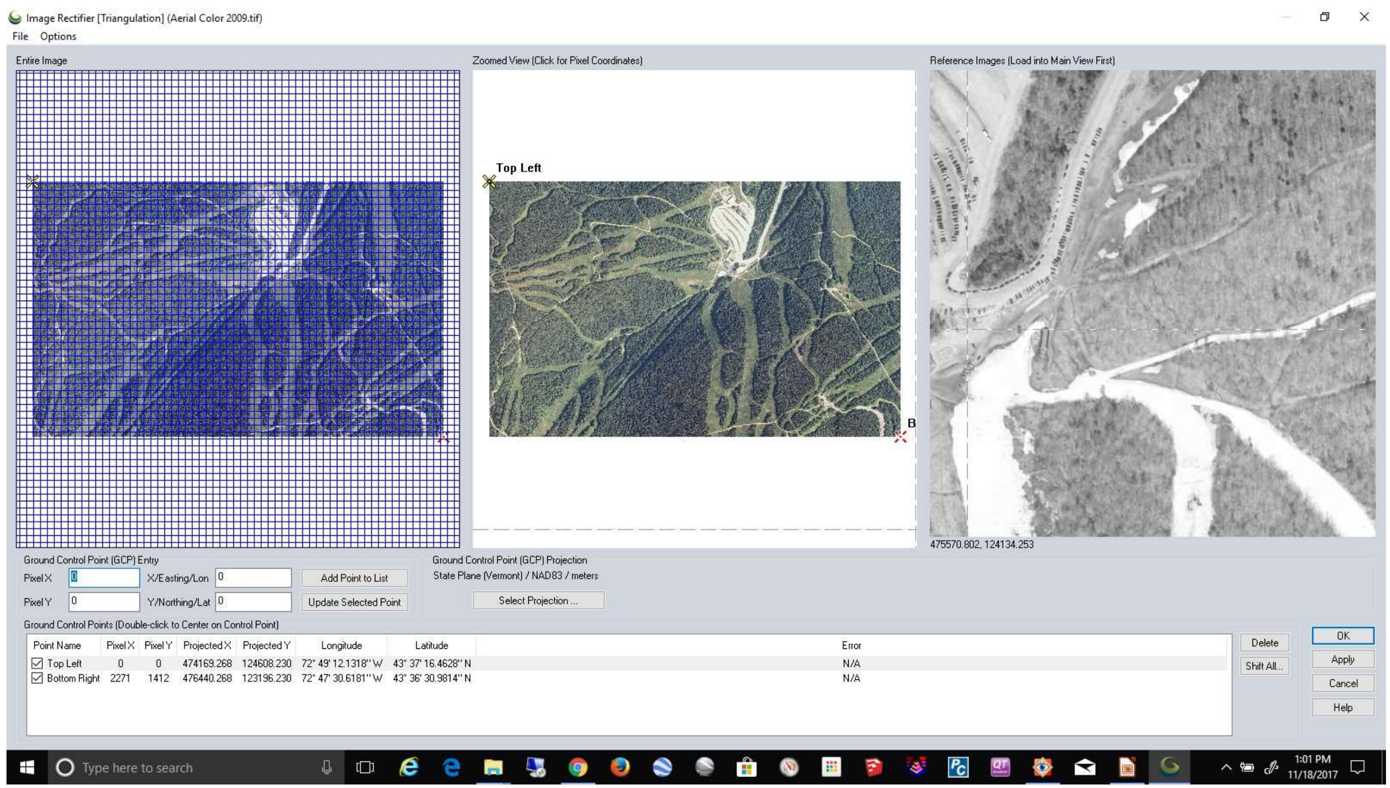
The USGS Earth Explorer can provide some pretty old images.

Unfortunately, these usually are not georeferenced. Global Mapper has a georeferencing tool. You can also fix an image you have in the project because you will soon learn that not all aerial images are correctly rectified.



Future Exercise. (This is how you get to it, you can play with this later.)

Right click on the Layer, select RECTIFY and you get a window that allows you to pick pairs of points. BE SURE TO ADD POINTS TO LIST. (It is easy to forget). There are several mathematical methods to select from and you can either rectify an image or distort it beyond recognition. I have done both.



You can pull in the older images and rectify those to the current images or to vector layers. Exporting the Layers will be covered in a little bit and once you have mastered this, you can export to a format that works in other programs.

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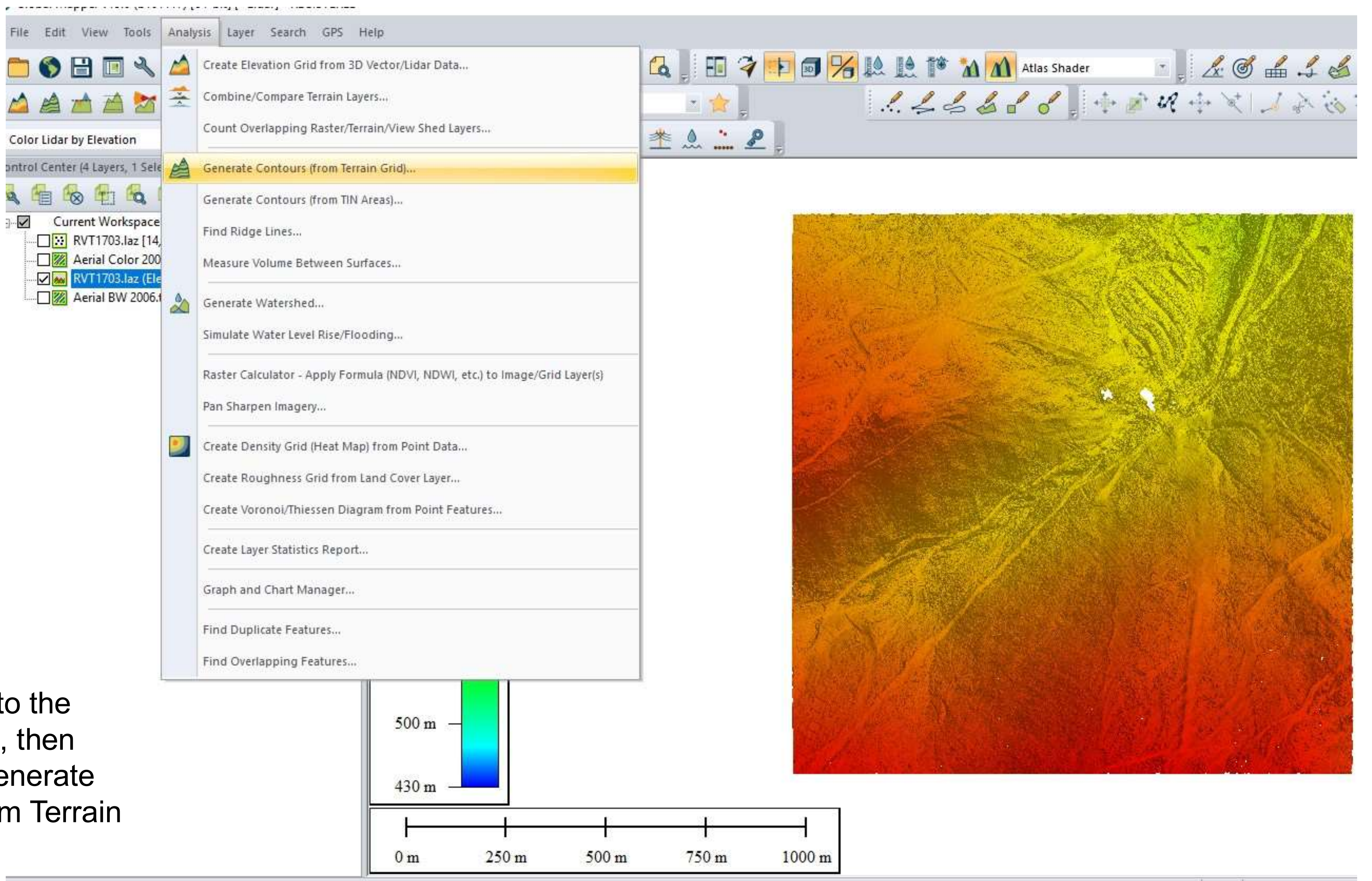


Let's go back to the surface model, then Analysis → Generate Contours (From Terrain Grid).

Another Menu with TMI

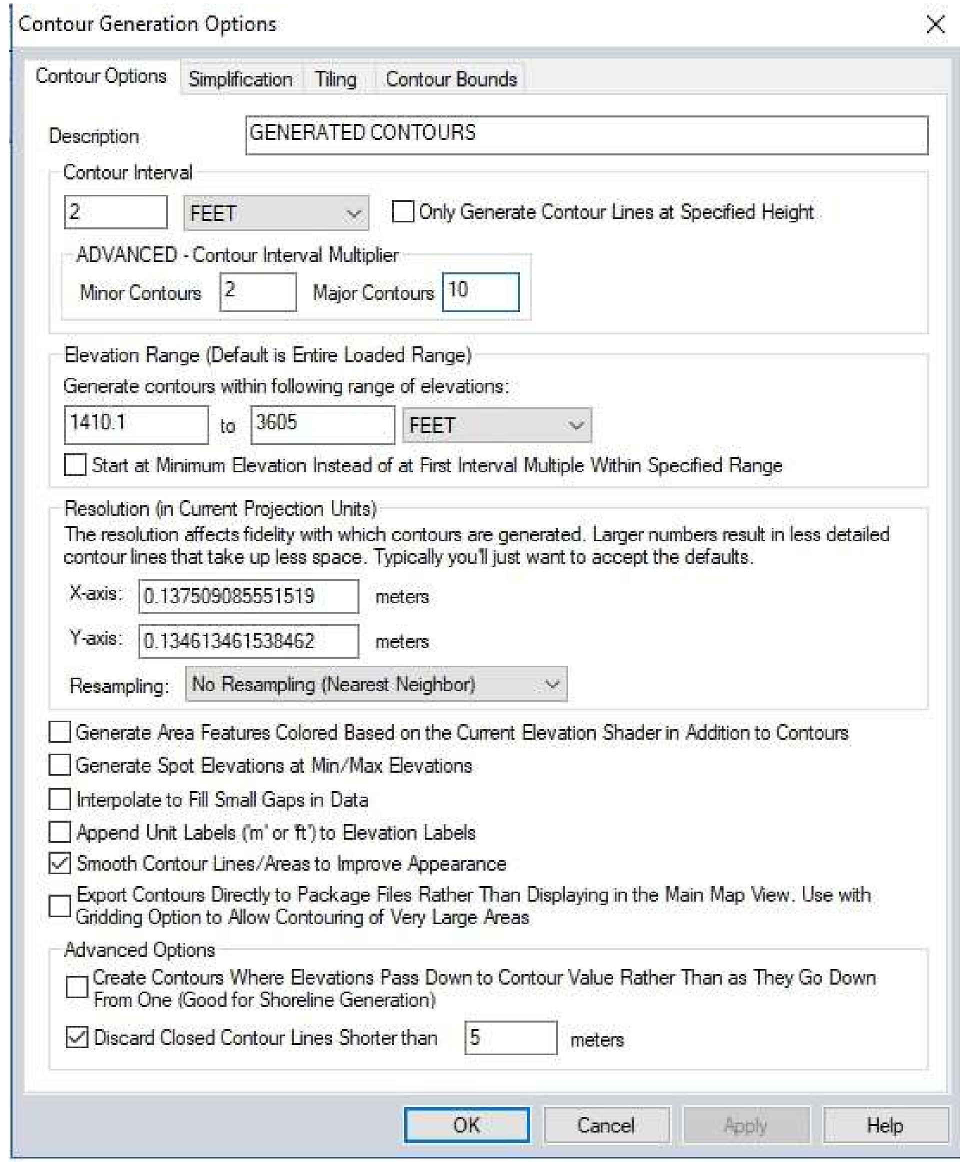
Description is the layer name
Contour interval

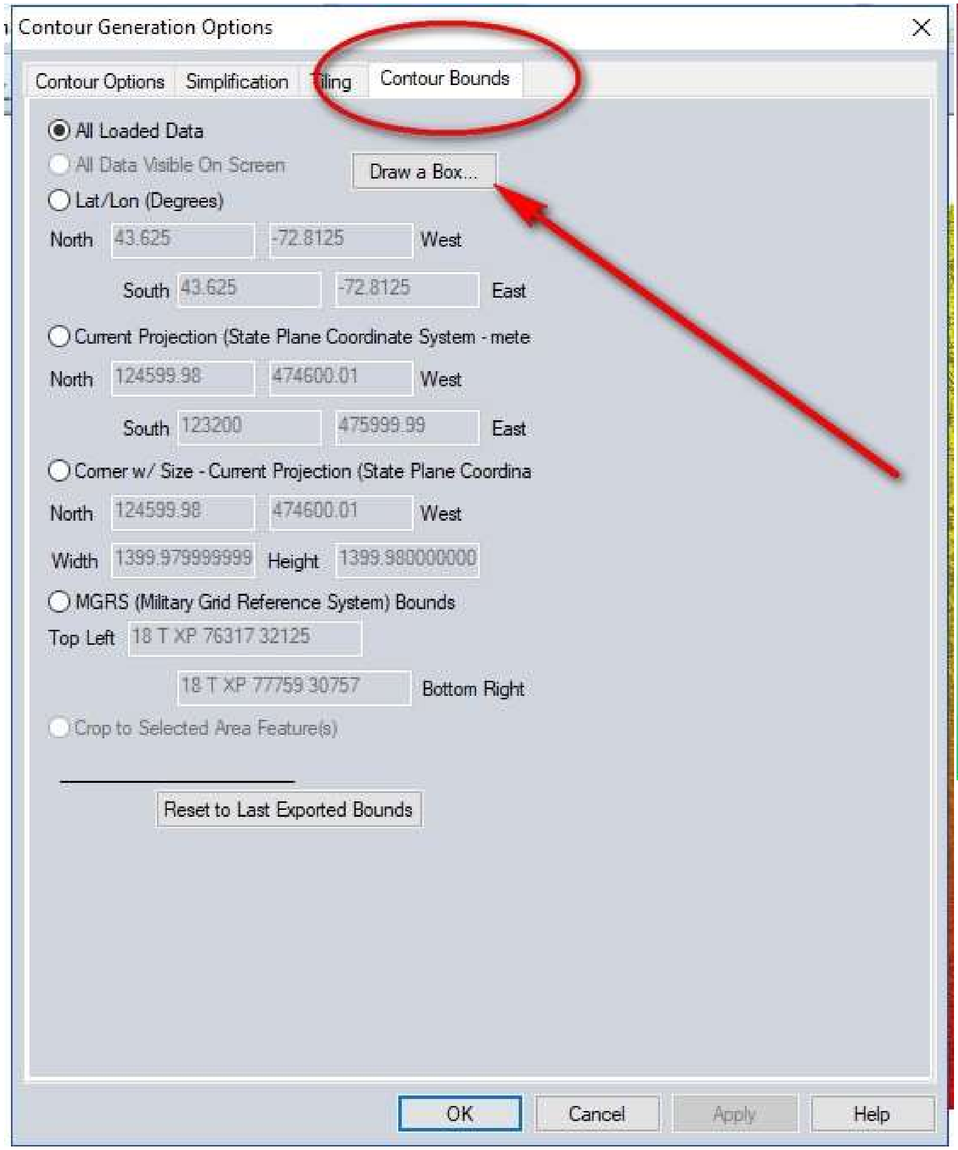
Minor and Major Intervals

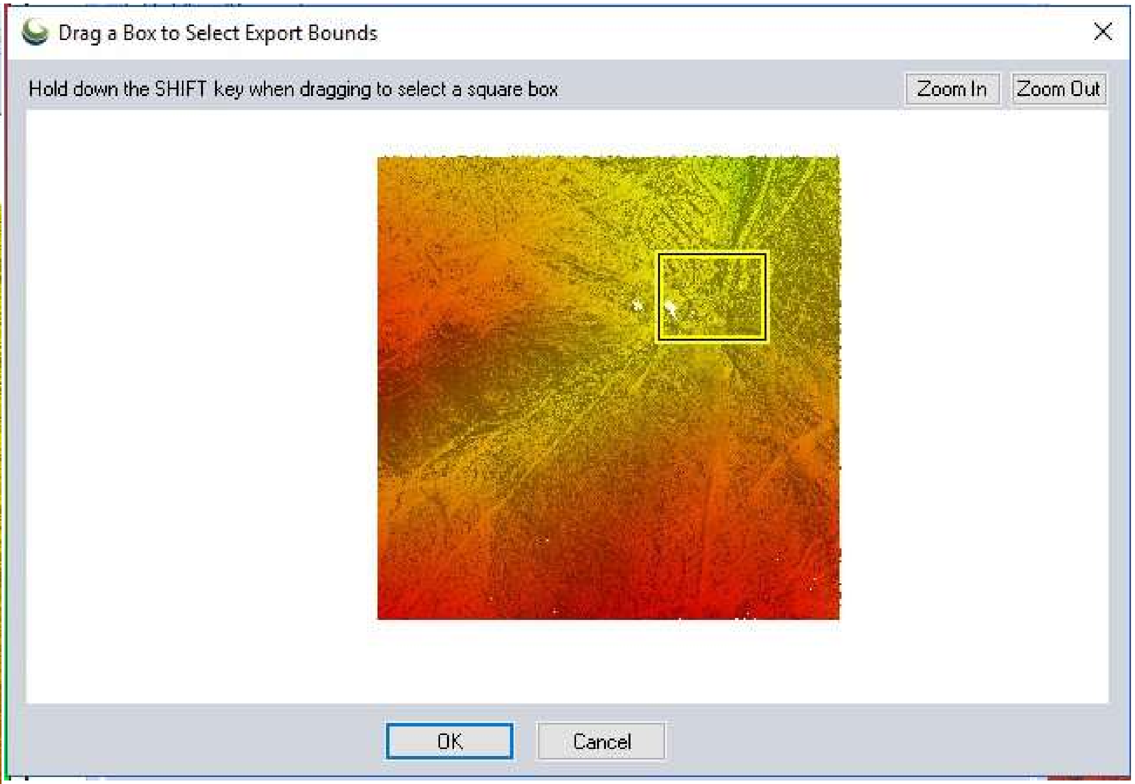
Range to contour

Resolution & Resampling
See further into the presentation

Colorful contours
Spot elevation for Max and Min (only 2 per set)
Fill in the gaps
Labels with units
Smooth
Direct export (a step closer to automation)
Shoreline generation
Discard shorties (you get many where it is Flat)



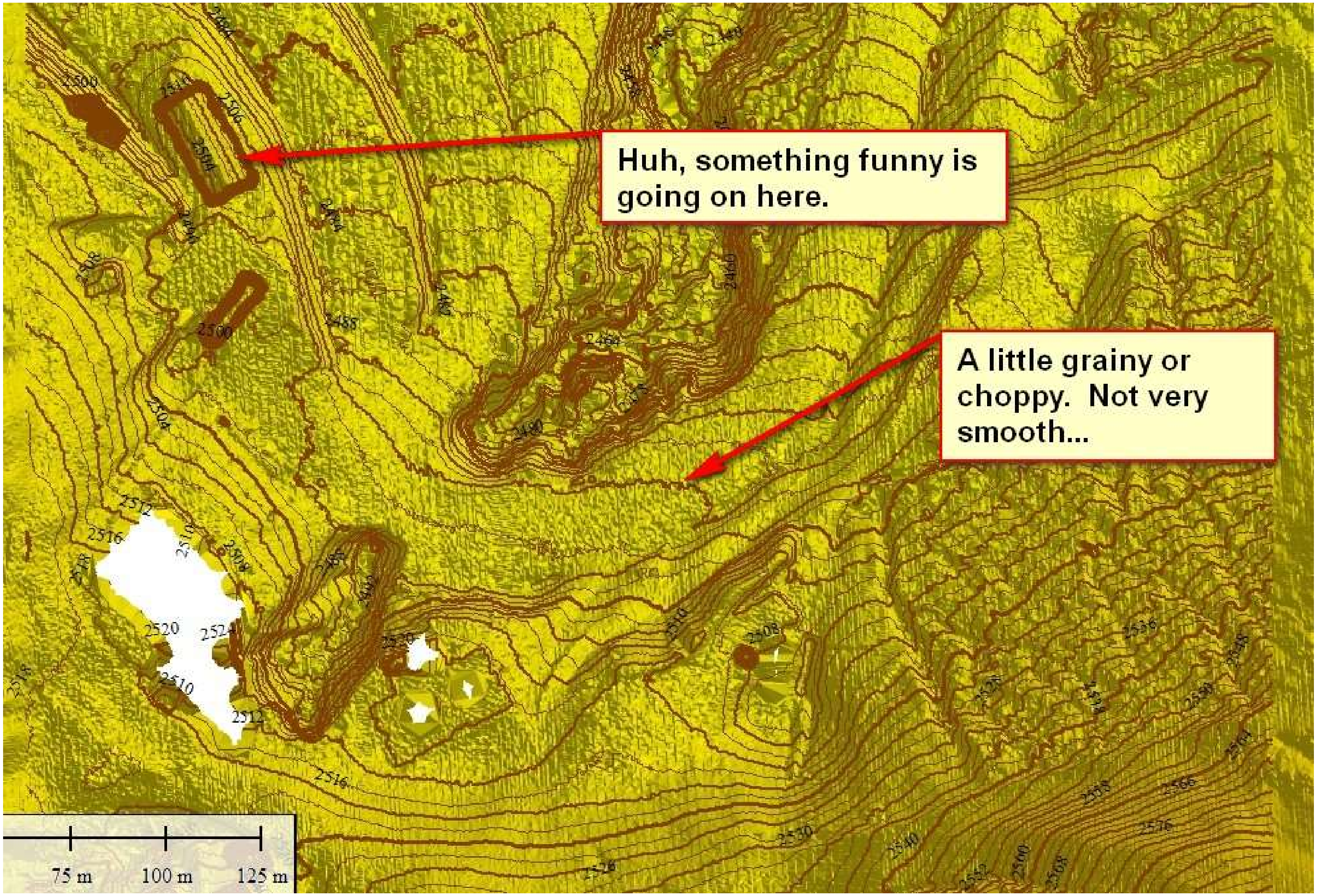




The simplification tab helps to simplify the contours (not recommended). The Tiling will cut up the contour layers. The Contour Bounds allows you to select a small area. Since large areas take longer, let's select a small box to contour.

Review the documentation for the LiDAR quality for the contour interval. You can safely drop the interval to 1' for much of the LiDAR available.

Wonderful for planning, drainage / watershed analysis, preliminary design, augmenting surveys.



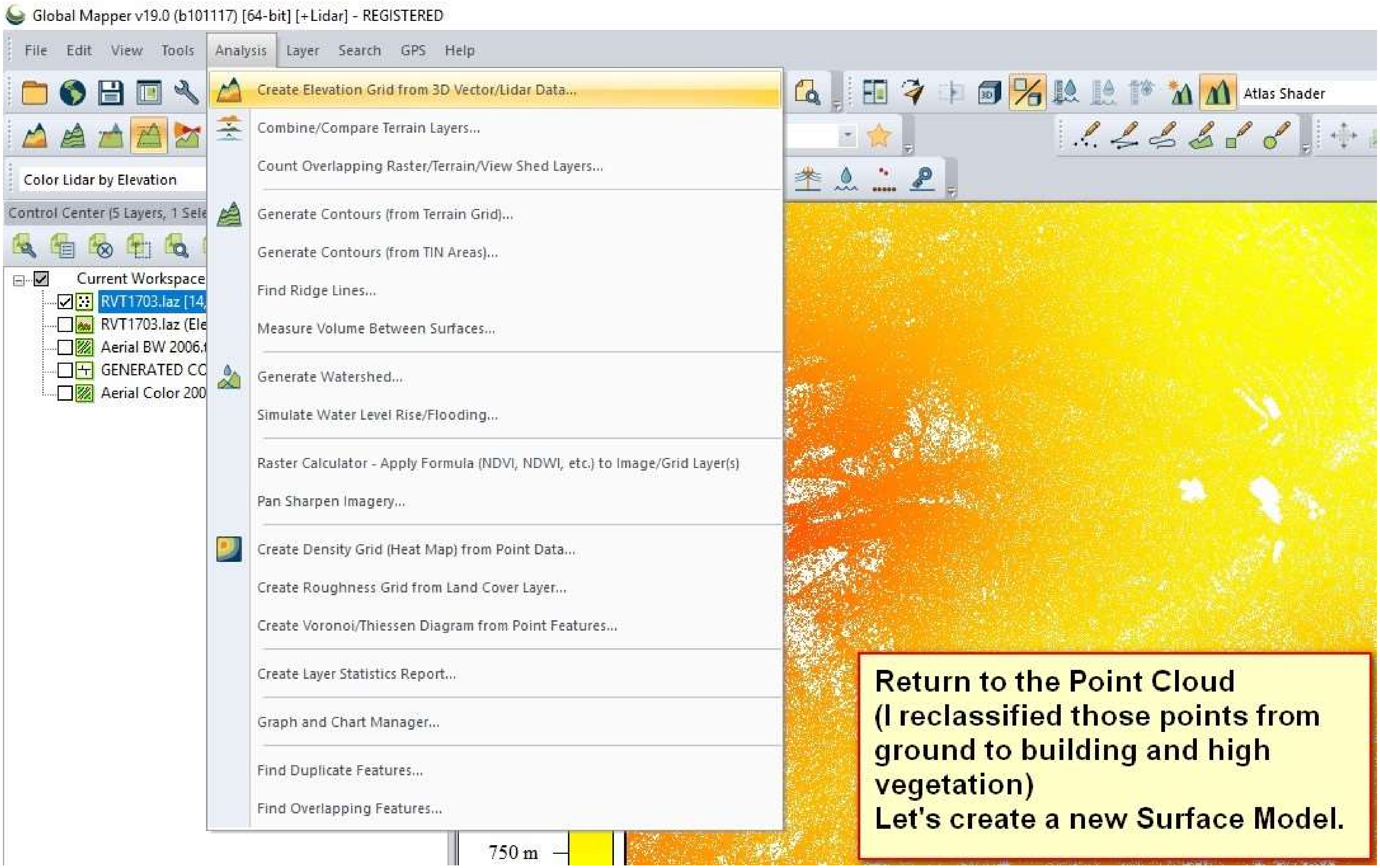
EWWW! That contour looks insane. Who would ever want to work from some nasty looking contour like that? Is this data that worthless?
No. We passed by the Resolution and Resampling options in the contouring options. We can make the contours look better using other methods.
(Well, why did you waste our time with this TIN?) (So you could learn.)

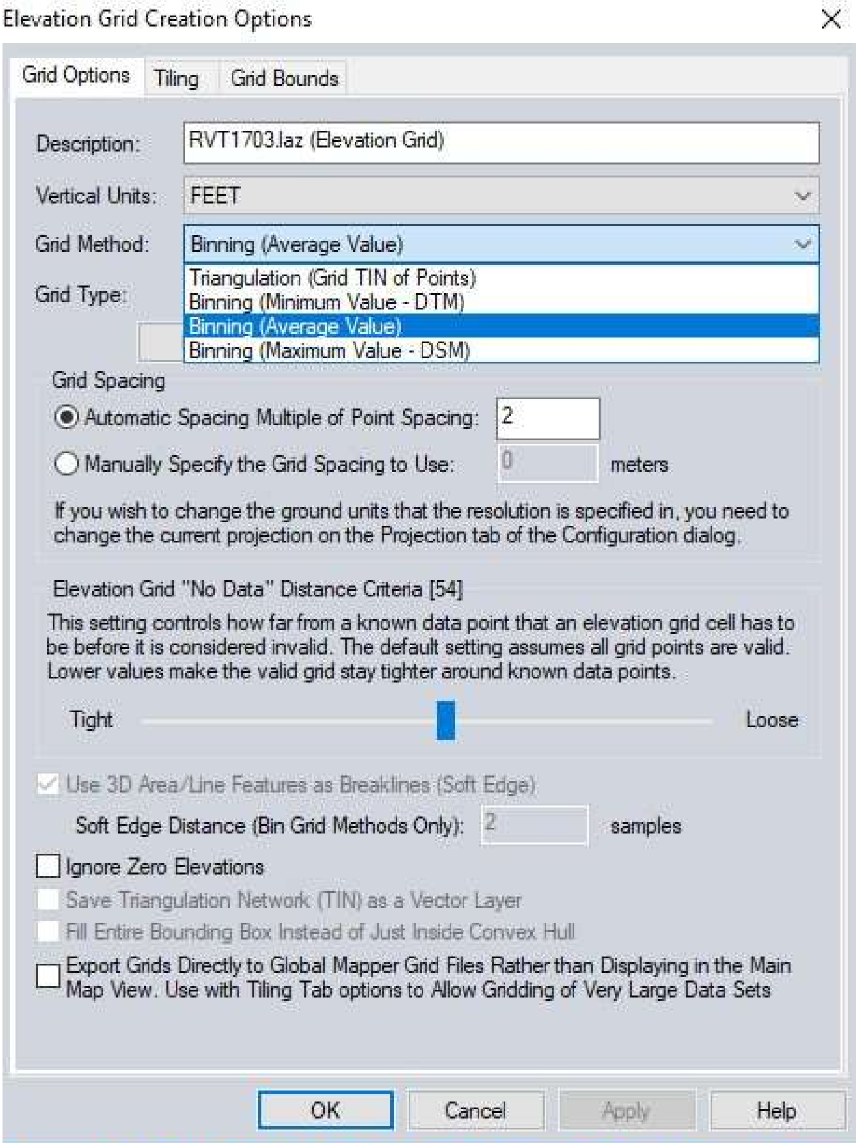
So, our classification called a building and some trees ground...

I turned off the surface, turned on the imagery, changed the draw order and used the image swipe tool to see what was going on with these odd / dense contours.

The Point Clouds provided by the State have the Ground already classified and it is best to just use theirs. You still may run into a false positive that you have to remedy.

Why learn it? If you obtain a raw cloud, you may want to classify the ground points. Where do you get a raw cloud? Scanner, Drone or from others.


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED
File Edit View Tools Analysis Layer Search GPS Help
Create Elevation Grid from 3D Vector/Lidar Data...
Combine/Compare Terrain Layers...
Count Overlapping Raster/Terrain/View Shed Layers...
Generate Contours (from Terrain Grid)...
Generate Contours (from TIN Areas)...
Find Ridge Lines...
Measure Volume Between Surfaces...
Generate Watershed...
Simulate Water Level Rise/Flooding...
Raster Calculator - Apply Formula (NDVI, NDWI, etc.) to Image/Grid Layer(s)
Pan Sharpen Imagery...
Create Density Grid (Heat Map) from Point Data...
Create Roughness Grid from Land Cover Layer...
Create Voronoi/Thiessen Diagram from Point Features...
Create Layer Statistics Report...
Graph and Chart Manager...
Find Duplicate Features...
Find Overlapping Features...
Atlas Shader
Color Lidar by Elevation
Control Center (5 Layers, 1 Sele
Current Workspace
RVT1703.laz [14
RVT1703.laz (Ele
Aerial BW 2006.t
GENERATED CC
Aerial Color 200
750 m
Return to the Point Cloud
(I reclassified those points from
ground to building and high
vegetation)
Let's create a new Surface Model.



Back in the Surface Model (Elevation Grid) we are going to jump into the BIN rather than the TIN.

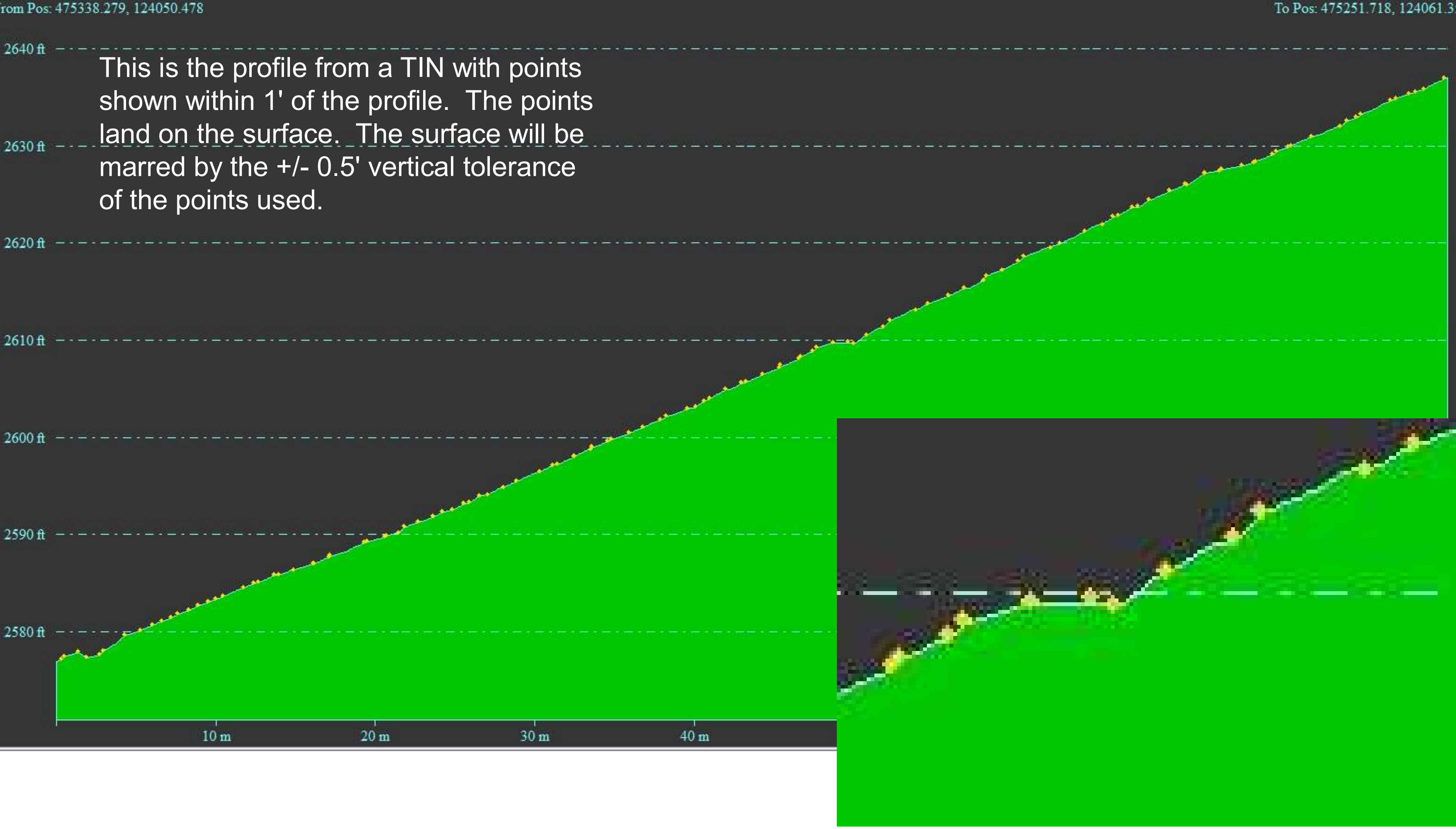
The TIN will create a surface from point to point. The positional tolerance of our points is a half foot.
Surveyors usually deal with a workable number of points: tens, hundreds, thousands. These points are obtained and have a positional tolerance of 0.01' to 0.10' (usually). TINs work.

LiDAR provides too many points to edit. And their position is not as tight as surveyed points (unless you use your own scanner or a drone, then they can be about equal to or better than surveyed points and even more numerous.)

So the BIN will average out the elevation at the point based on the nearby points. If the positional tolerance follows normal distribution, then the average of a few points should result in a better position.

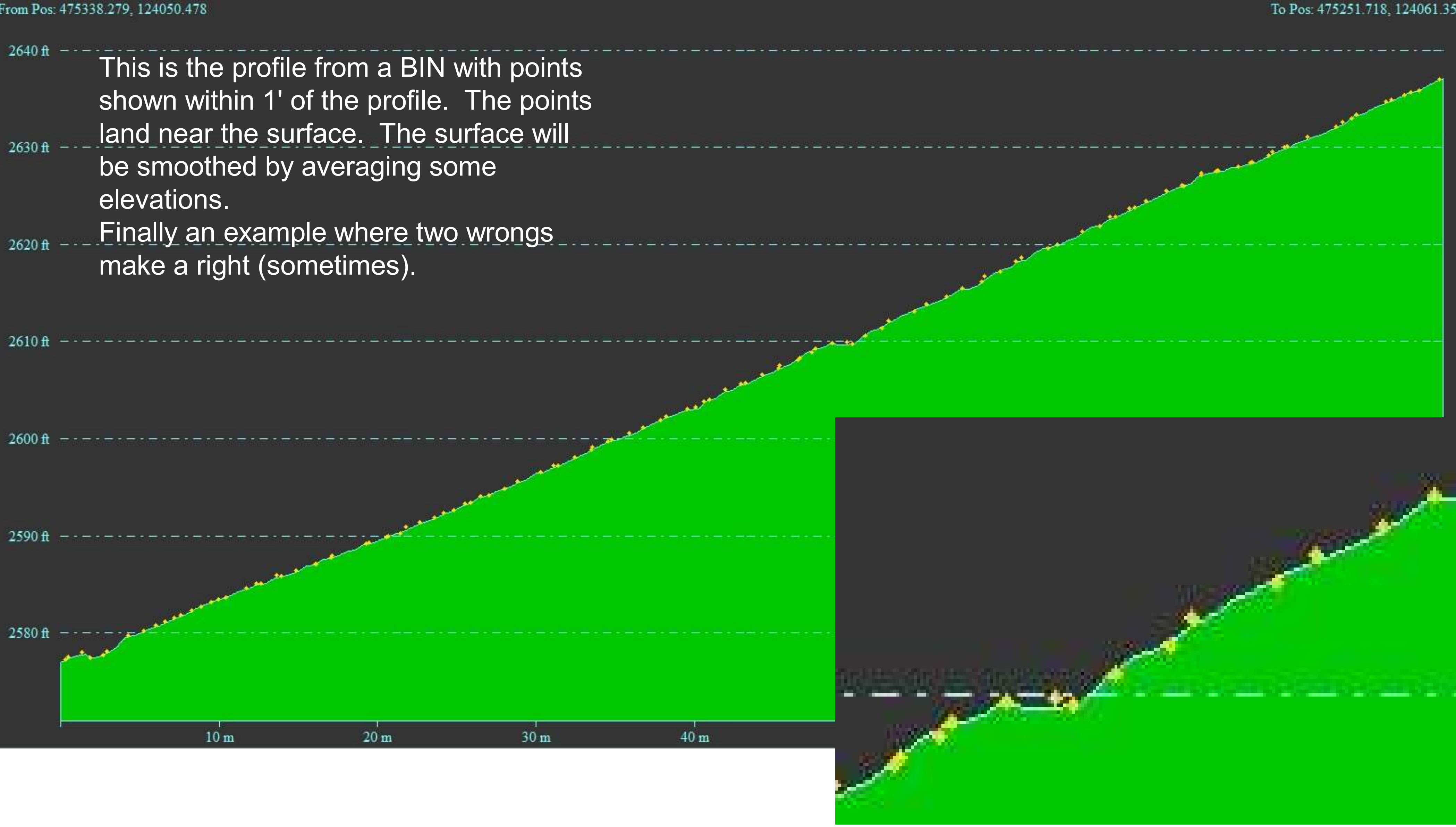
Should is not always.

Do not get on high horses. I have found some LiDAR surfaces from aerials that are better than the surveyed surfaces especially in the thick areas where breaklines cannot be seen or located. Even worse, I have seen better LiDAR surfaces in the wide open where surveyors have not obtained sufficient points to make an accurate surface model.



This is the profile from a TIN with points shown within 1' of the profile. The points land on the surface. The surface will be marred by the +/- 0.5' vertical tolerance of the points used.

This is the profile from a BIN with points shown within 1' of the profile. The points land near the surface. The surface will be smoothed by averaging some elevations.
Finally an example where two wrongs make a right (sometimes).



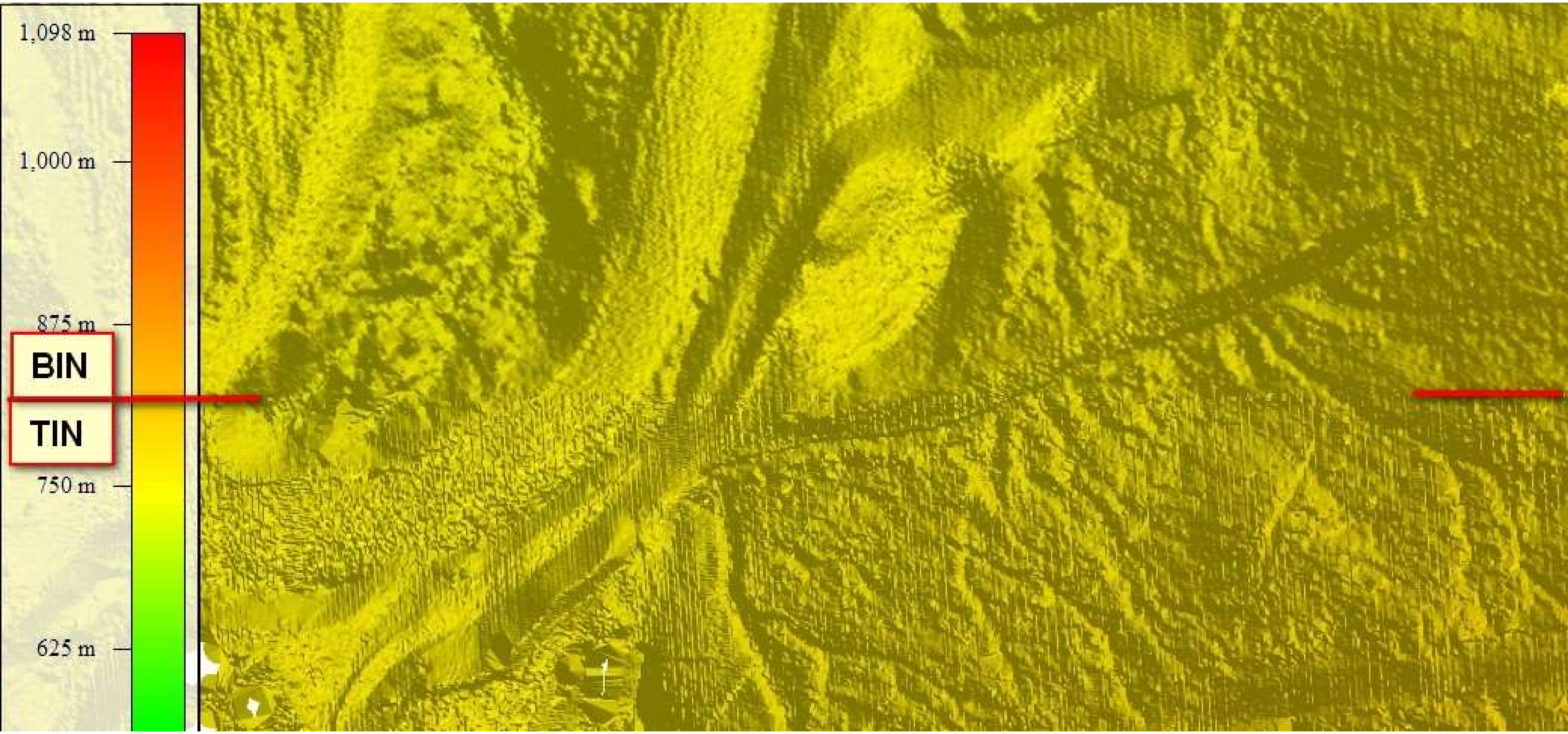
90% of all well-defined features, with the exception of those exaggerated by symbolism, will be depicted within 1/50”.

90% of all well-defined features, with the exception of those exaggerated by symbolism, will be depicted within ½ of the base contour interval.

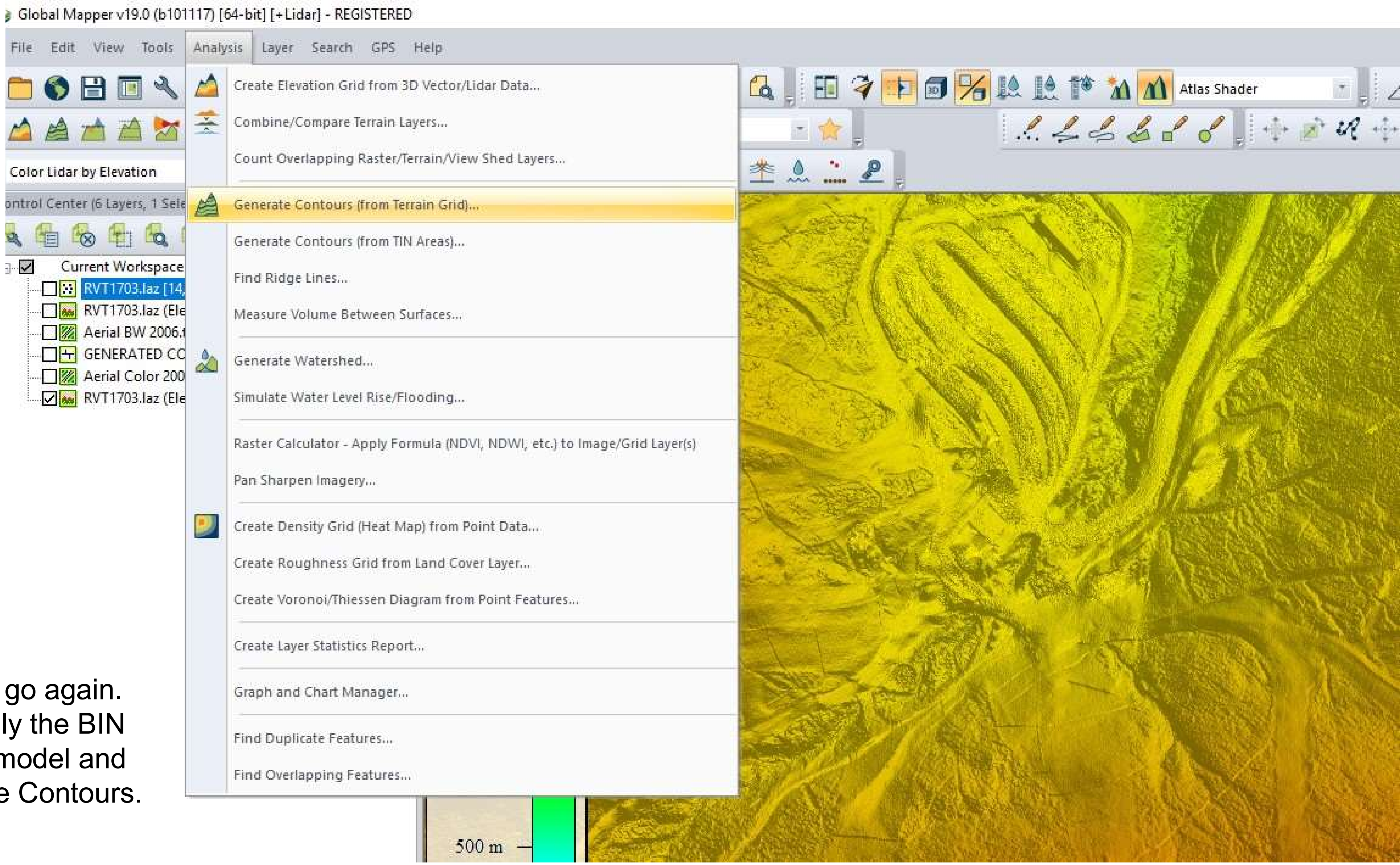
Combining the LiDAR with aerial imagery should allow one to digitize well-defined features within a foot or two or better. Vertically, we generally have half a foot in the wide open.

Running the math, we can produce maps / plans from this information that meet the National Map Accuracy Standards for a **50 to 100 scale map with 1' contours.** You can always zoom into the data, you just need to make the recipient of the data aware that the positional tolerance of the map will become noticeable.

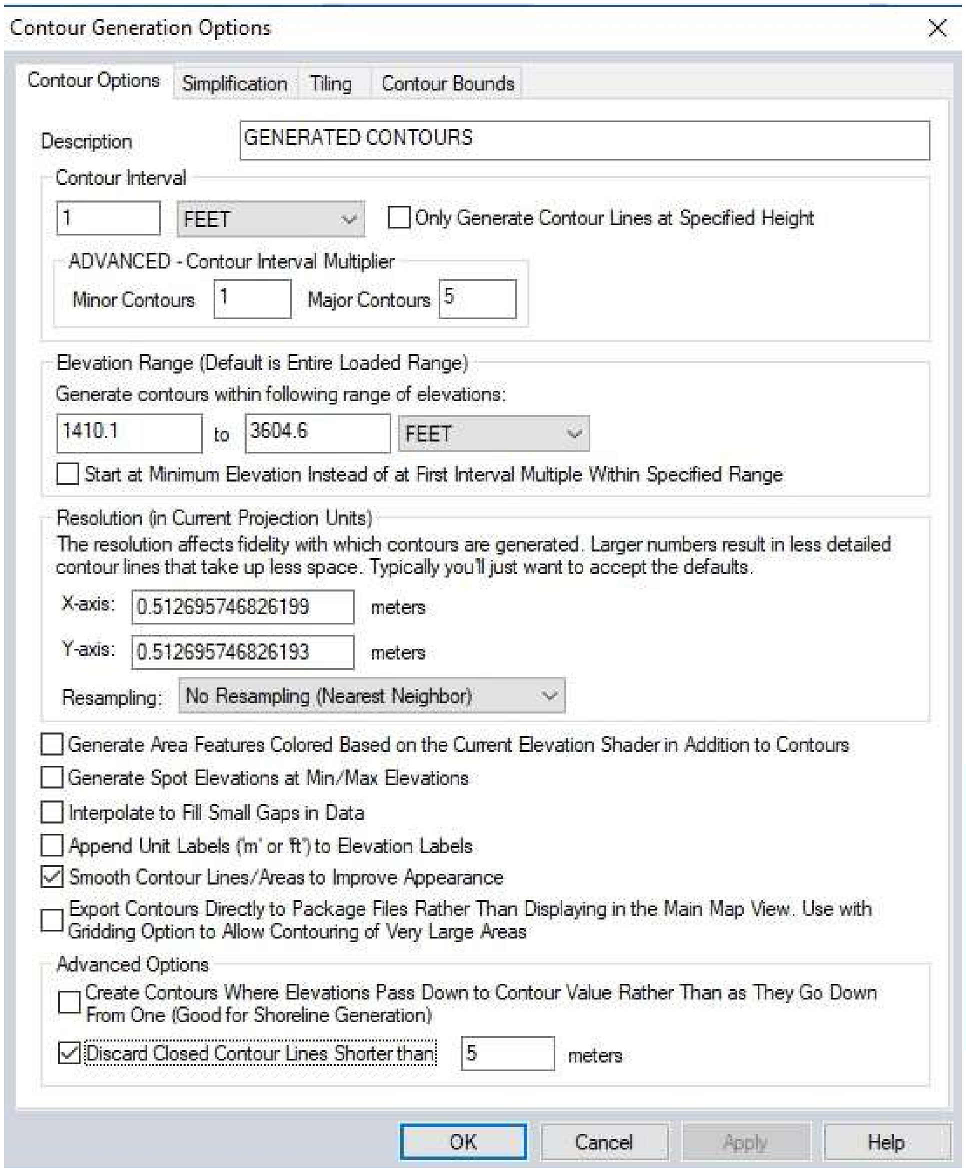
The BIN is noticeably smoother. You can use the Image Swipe Tool to compare between the two surfaces.



The TIN will better show some of the deflections – walls, paths, ditches, streams. Both surfaces have uses.

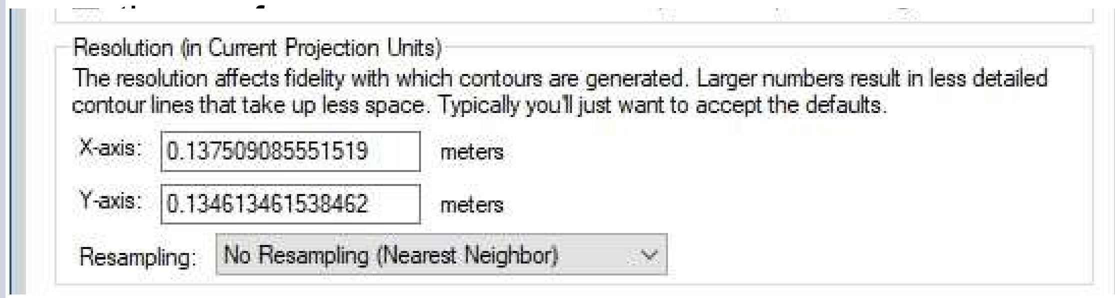


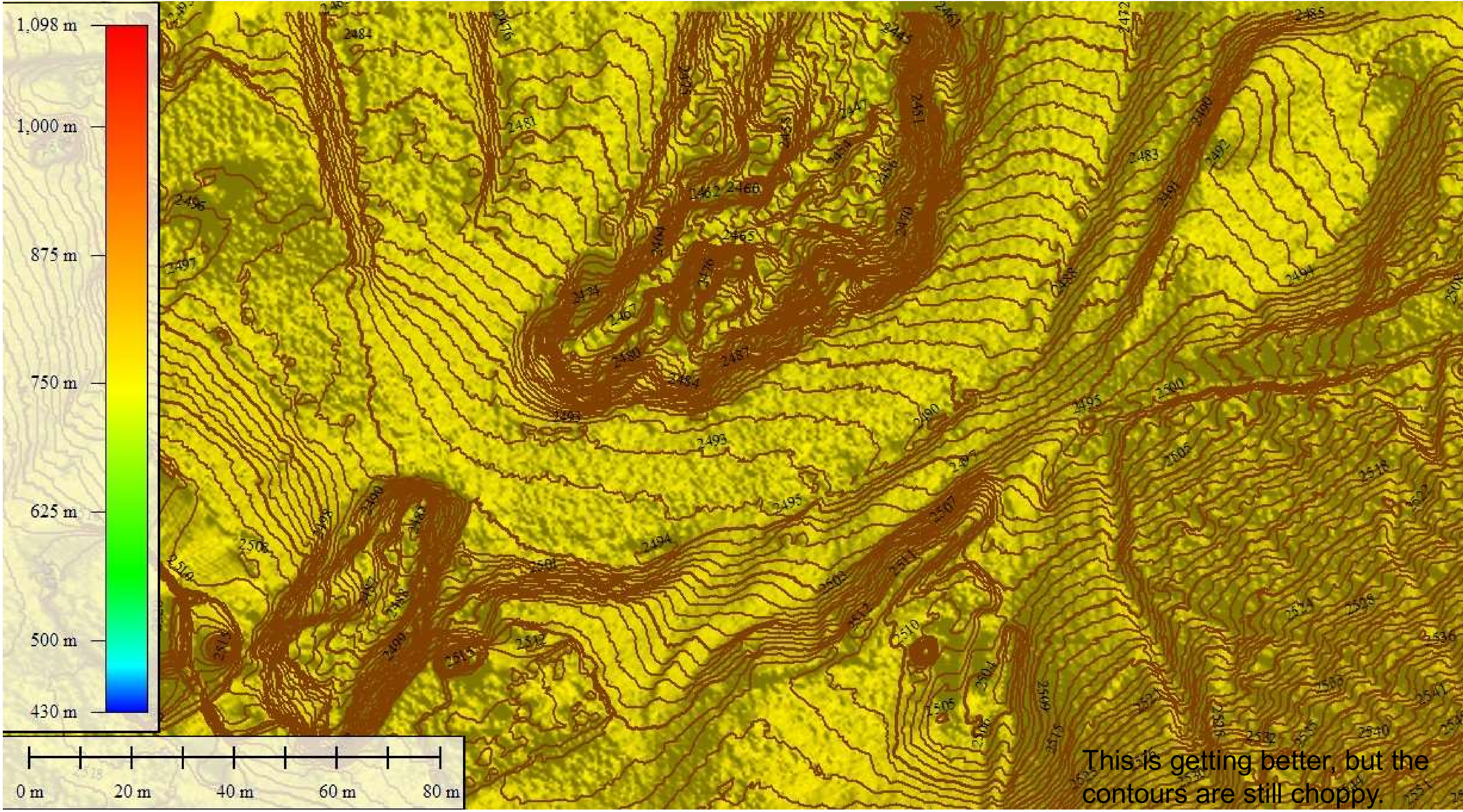
Here we go again. Show only the BIN surface model and Generate Contours.



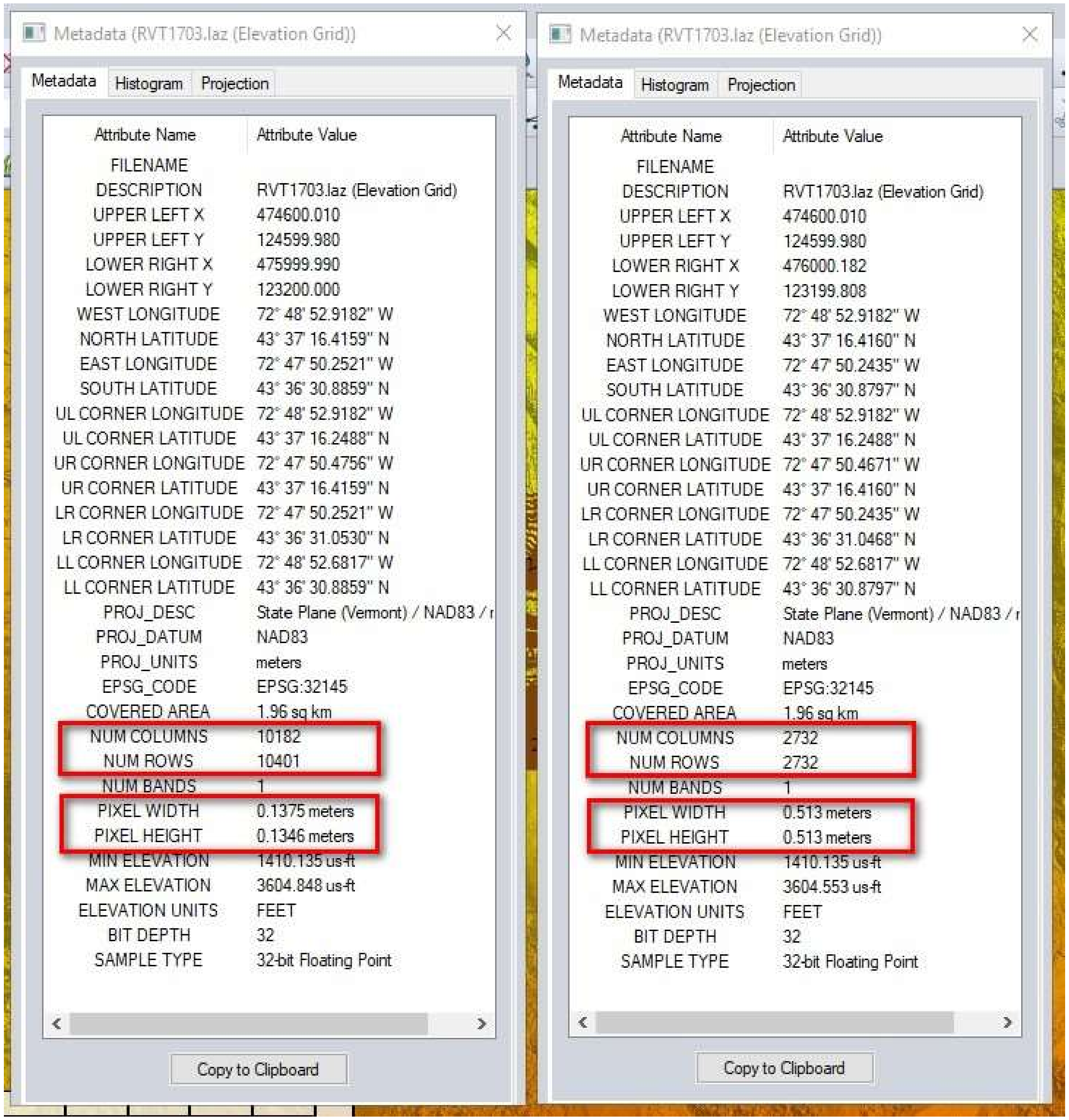
Let's try for some 1' contours with Min / Maj intervals at 1 and 5 feet.
Don't forget to select Contour Bounds for a little area.

Did you notice that the resolution is different?
Below is the resolution from the previous TIN contouring... The surface is not as dense, we averaged things out to make a





This is getting better, but the contours are still choppy.



Metadata (RVT1703.laz (Elevation Grid))

Metadata | Histogram | Projection

Attribute Name	Attribute Value
FILENAME	
DESCRIPTION	RVT1703.laz (Elevation Grid)
UPPER LEFT X	474600.010
UPPER LEFT Y	124599.980
LOWER RIGHT X	475999.990
LOWER RIGHT Y	123200.000
WEST LONGITUDE	72° 48' 52.9182" W
NORTH LATITUDE	43° 37' 16.4159" N
EAST LONGITUDE	72° 47' 50.2521" W
SOUTH LATITUDE	43° 36' 30.8859" N
UL CORNER LONGITUDE	72° 48' 52.9182" W
UL CORNER LATITUDE	43° 37' 16.2488" N
UR CORNER LONGITUDE	72° 47' 50.4756" W
UR CORNER LATITUDE	43° 37' 16.4159" N
LR CORNER LONGITUDE	72° 47' 50.2521" W
LR CORNER LATITUDE	43° 36' 31.0530" N
LL CORNER LONGITUDE	72° 48' 52.6817" W
LL CORNER LATITUDE	43° 36' 30.8859" N
PROJ_DESC	State Plane (Vermont) / NAD83 / r
PROJ_DATUM	NAD83
PROJ_UNITS	meters
EPSG_CODE	EPSG:32145
COVERED AREA	1.96 sq km
NUM COLUMNS	10182
NUM ROWS	10401
NUM BANDS	1
PIXEL WIDTH	0.1375 meters
PIXEL HEIGHT	0.1346 meters
MIN ELEVATION	1410.135 us-ft
MAX ELEVATION	3604.848 us-ft
ELEVATION UNITS	FEET
BIT DEPTH	32
SAMPLE TYPE	32-bit Floating Point

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Metadata (RVT1703.laz (Elevation Grid))

Metadata | Histogram | Projection

Attribute Name	Attribute Value
FILENAME	
DESCRIPTION	RVT1703.laz (Elevation Grid)
UPPER LEFT X	474600.010
UPPER LEFT Y	124599.980
LOWER RIGHT X	476000.182
LOWER RIGHT Y	123199.808
WEST LONGITUDE	72° 48' 52.9182" W
NORTH LATITUDE	43° 37' 16.4160" N
EAST LONGITUDE	72° 47' 50.2435" W
SOUTH LATITUDE	43° 36' 30.8797" N
UL CORNER LONGITUDE	72° 48' 52.9182" W
UL CORNER LATITUDE	43° 37' 16.2488" N
UR CORNER LONGITUDE	72° 47' 50.4671" W
UR CORNER LATITUDE	43° 37' 16.4160" N
LR CORNER LONGITUDE	72° 47' 50.2435" W
LR CORNER LATITUDE	43° 36' 31.0468" N
LL CORNER LONGITUDE	72° 48' 52.6817" W
LL CORNER LATITUDE	43° 36' 30.8797" N
PROJ_DESC	State Plane (Vermont) / NAD83 / r
PROJ_DATUM	NAD83
PROJ_UNITS	meters
EPSG_CODE	EPSG:32145
COVERED AREA	1.96 sq km
NUM COLUMNS	2732
NUM ROWS	2732
NUM BANDS	1
PIXEL WIDTH	0.513 meters
PIXEL HEIGHT	0.513 meters
MIN ELEVATION	1410.135 us-ft
MAX ELEVATION	3604.553 us-ft
ELEVATION UNITS	FEET
BIT DEPTH	32
SAMPLE TYPE	32-bit Floating Point

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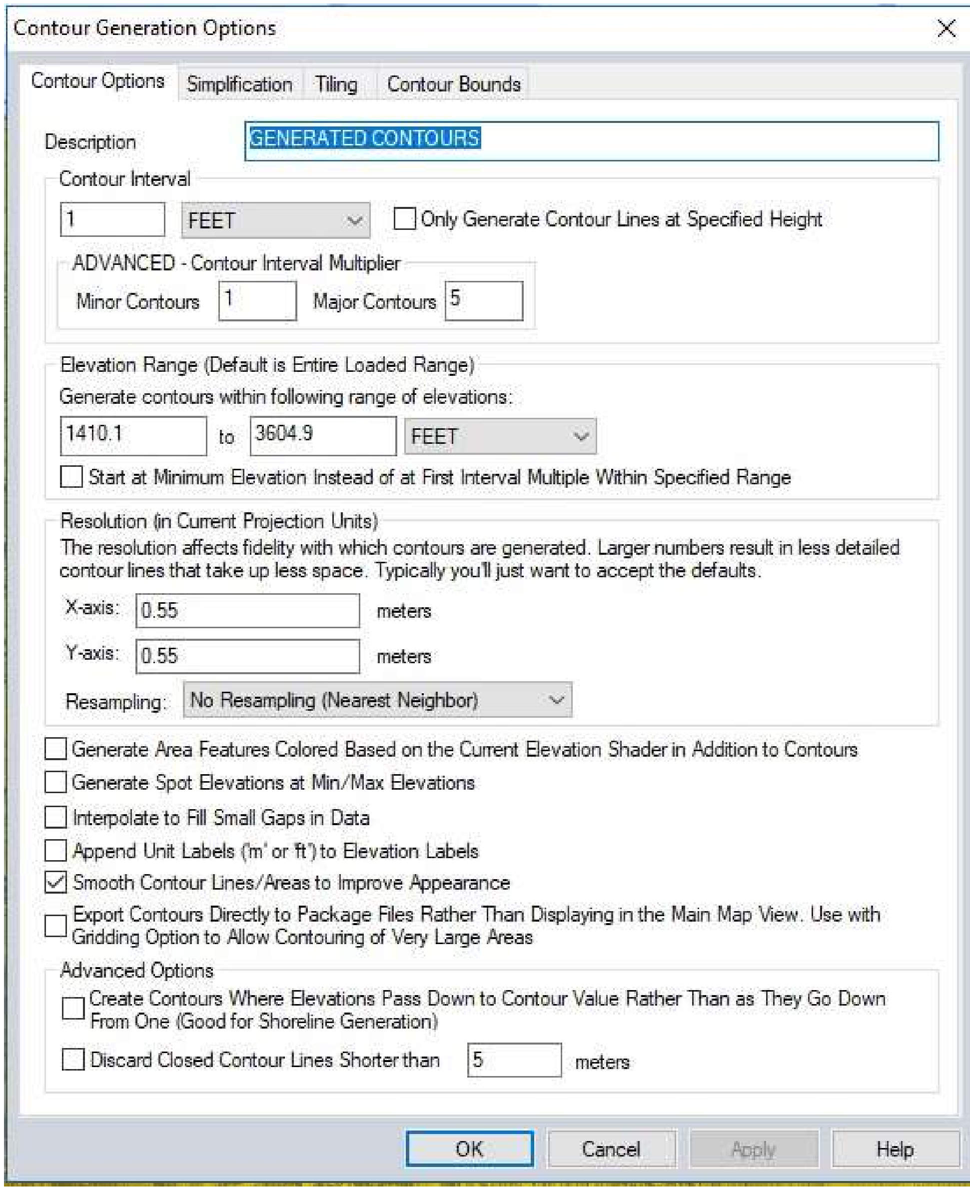
Right clicking on the Layer (surface model in this case) allows one to view the MetaData for that layer.
To the left is the TIN and to the right is the BIN. Both surface models are Grids with different resolutions.

You cannot contour from a better resolution than the Surface Model starts with.

You can contour with a lesser resolution.

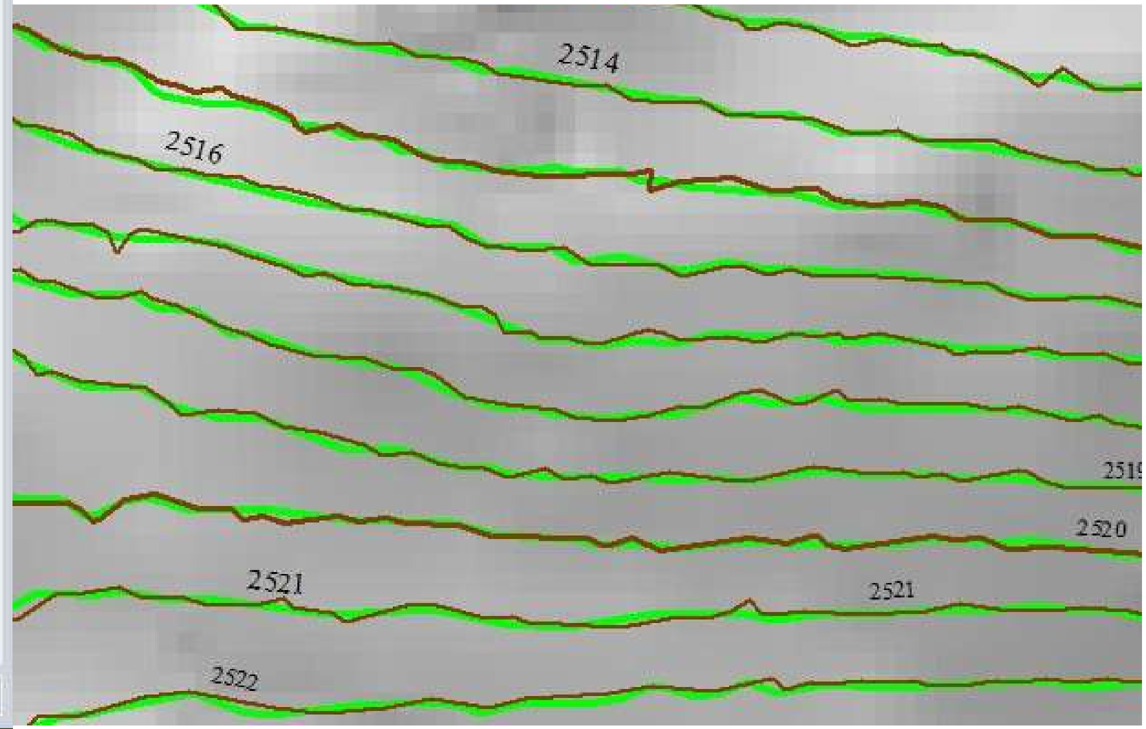


So the BIN is producing better contours than the TIN... But if we resample the resolution of the TIN to be about the resolution of the BIN, what do we get? The brown contours are from the BIN and the green contours are from the resampled BIN.

Those are pretty good.

So, which is better TIN or BIN or TIN resampled? It all depends on what the client desires.

NOTE: Different data sets will need different settings.



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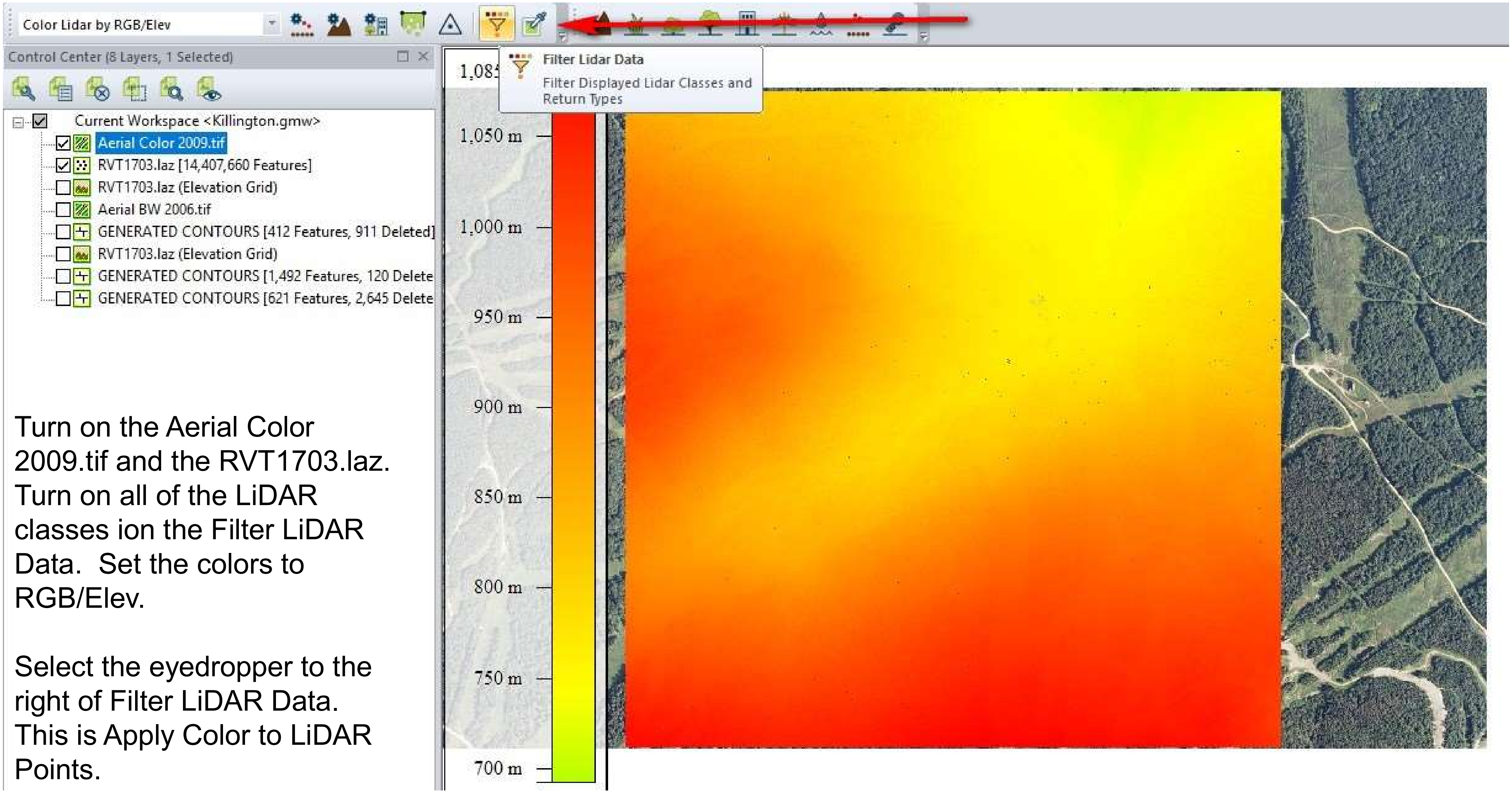
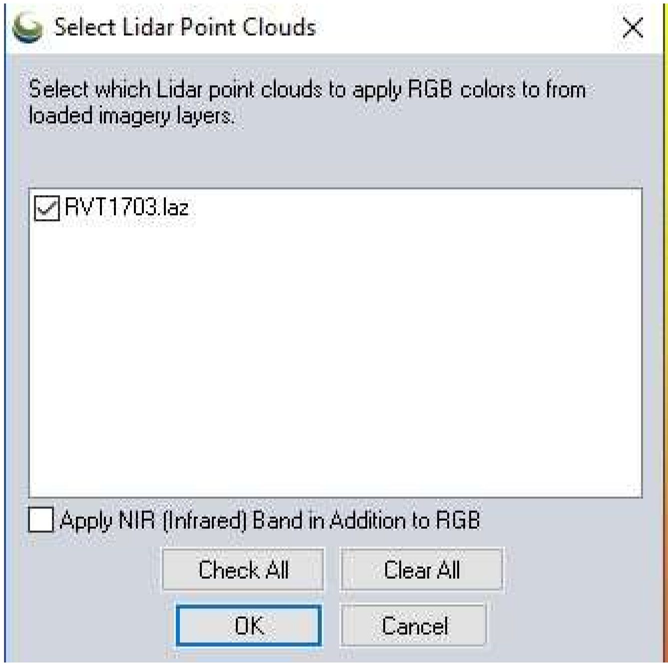
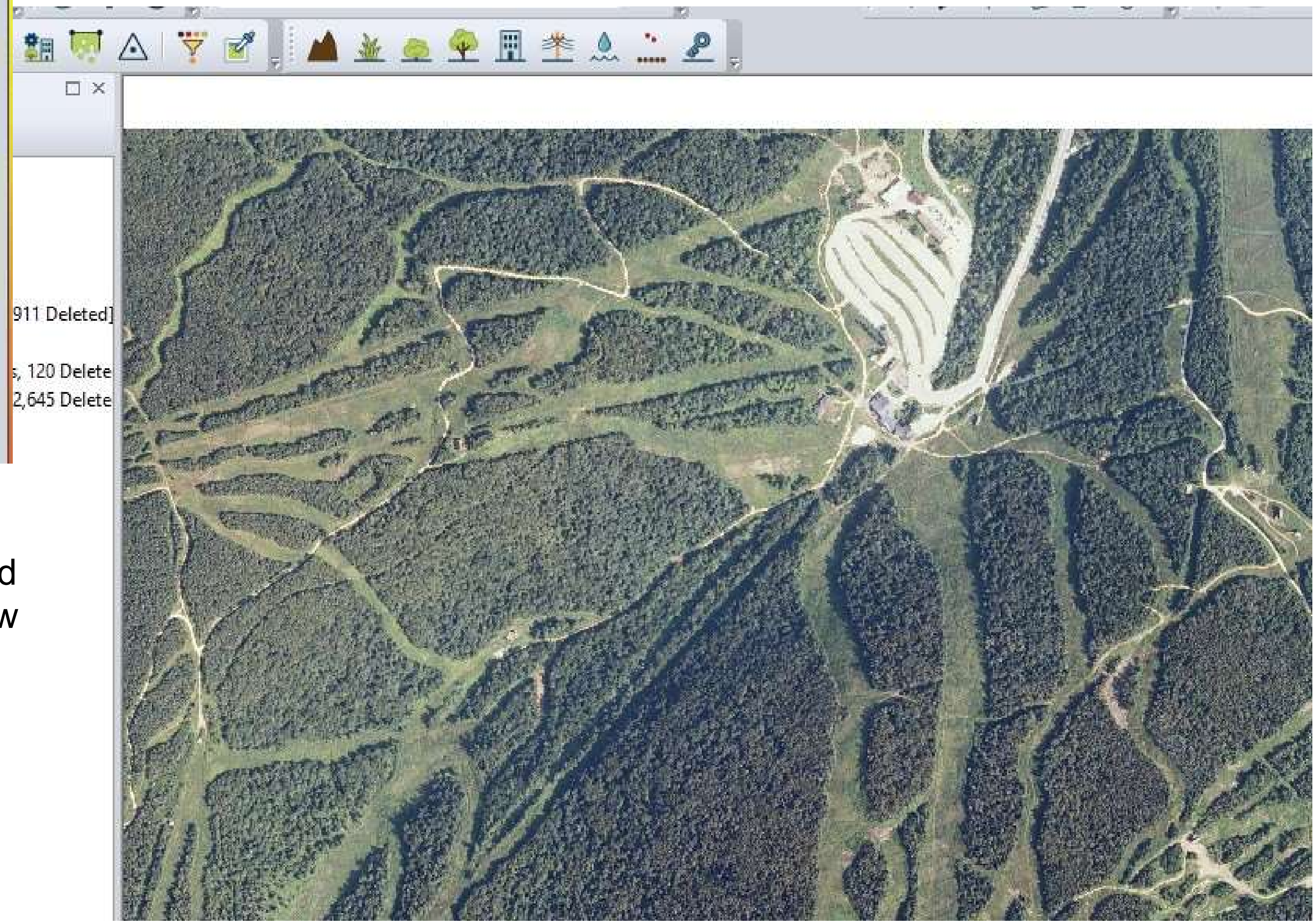


Turn on the Aerial Color 2009.tif and the RVT1703.laz. Turn on all of the LiDAR classes ion the Filter LiDAR Data. Set the colors to RGB/Elev.

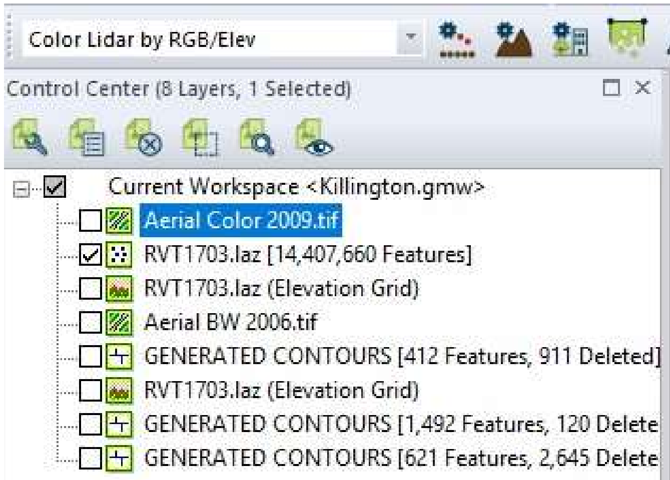
Select the eyedropper to the right of Filter LiDAR Data. This is Apply Color to LiDAR Points.

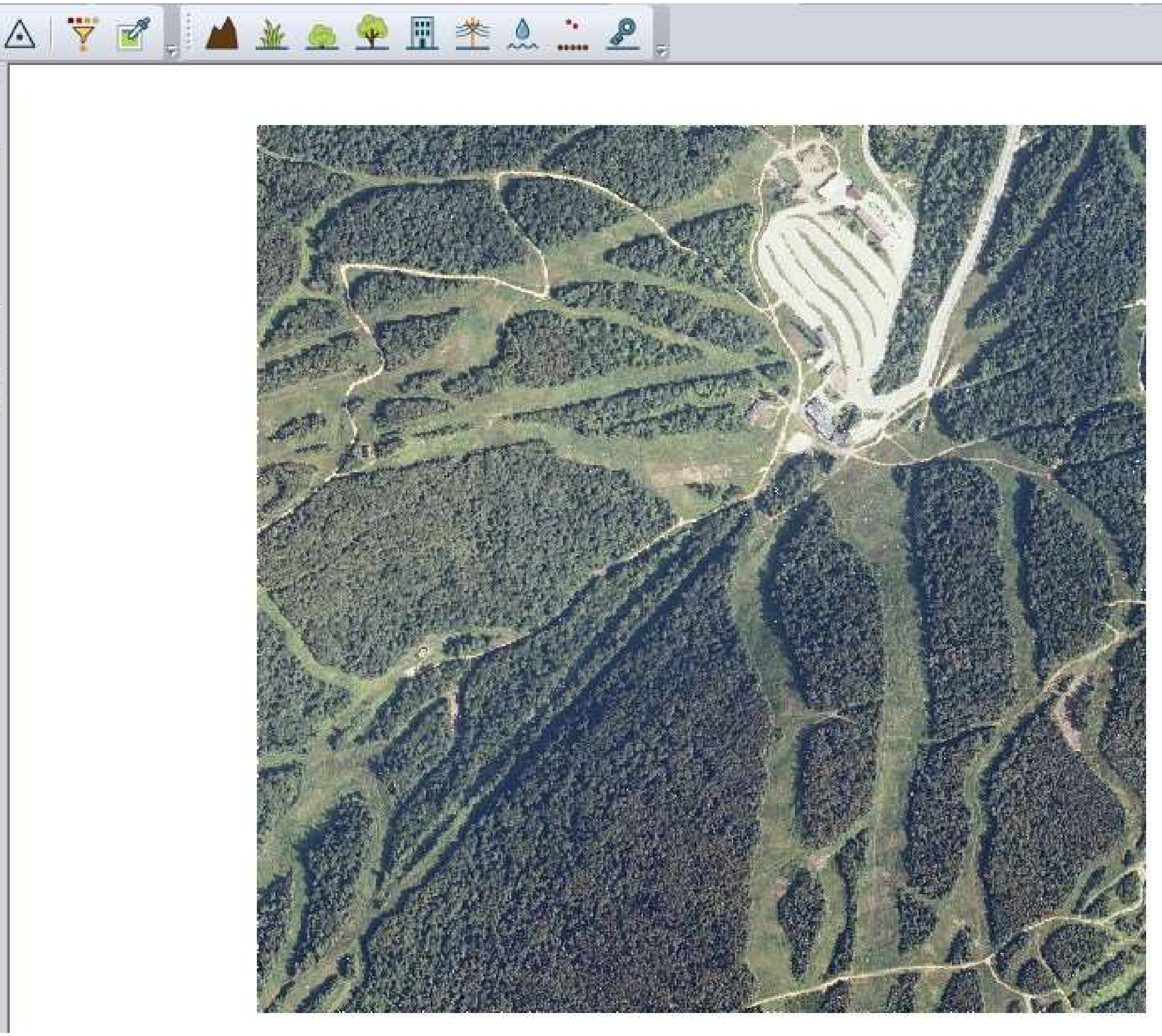




Of course you get to choose options. I like to keep things turned on and off to make it easier to know which data I am working with...

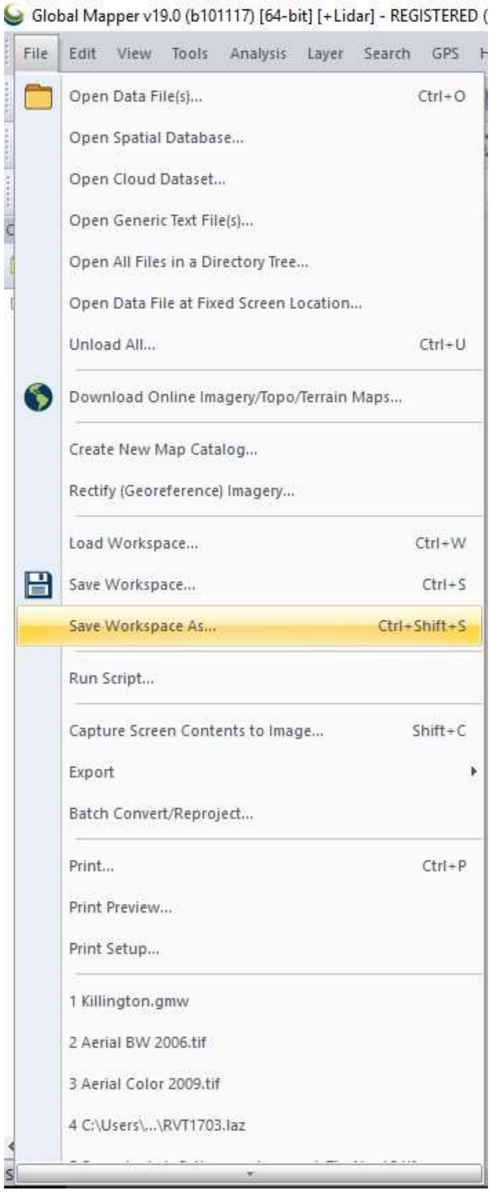
Wait, where did the cloud go?

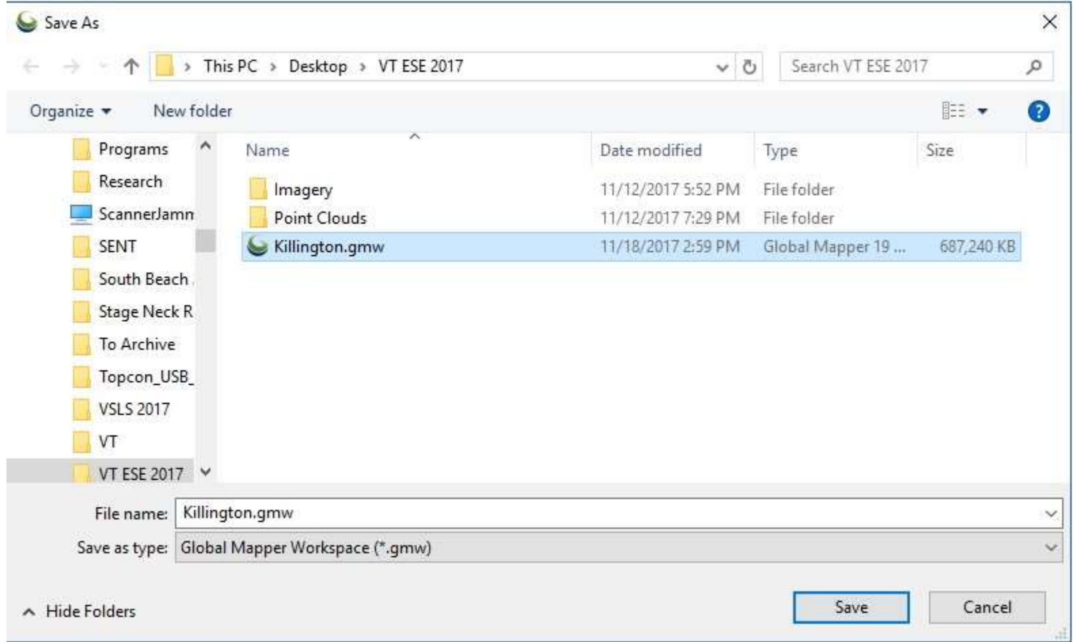




Turn off the Aerial Color 2009.tif layer and what you are left with is a colorized cloud. Colorizing LiDAR is never perfect as the LiDAR is acquired from one sensor and the imagery is acquired from another.

Static scanners have internal cameras but they take images before or after the cloud is acquired so wind will often change things to make the images just a little different than the scans...



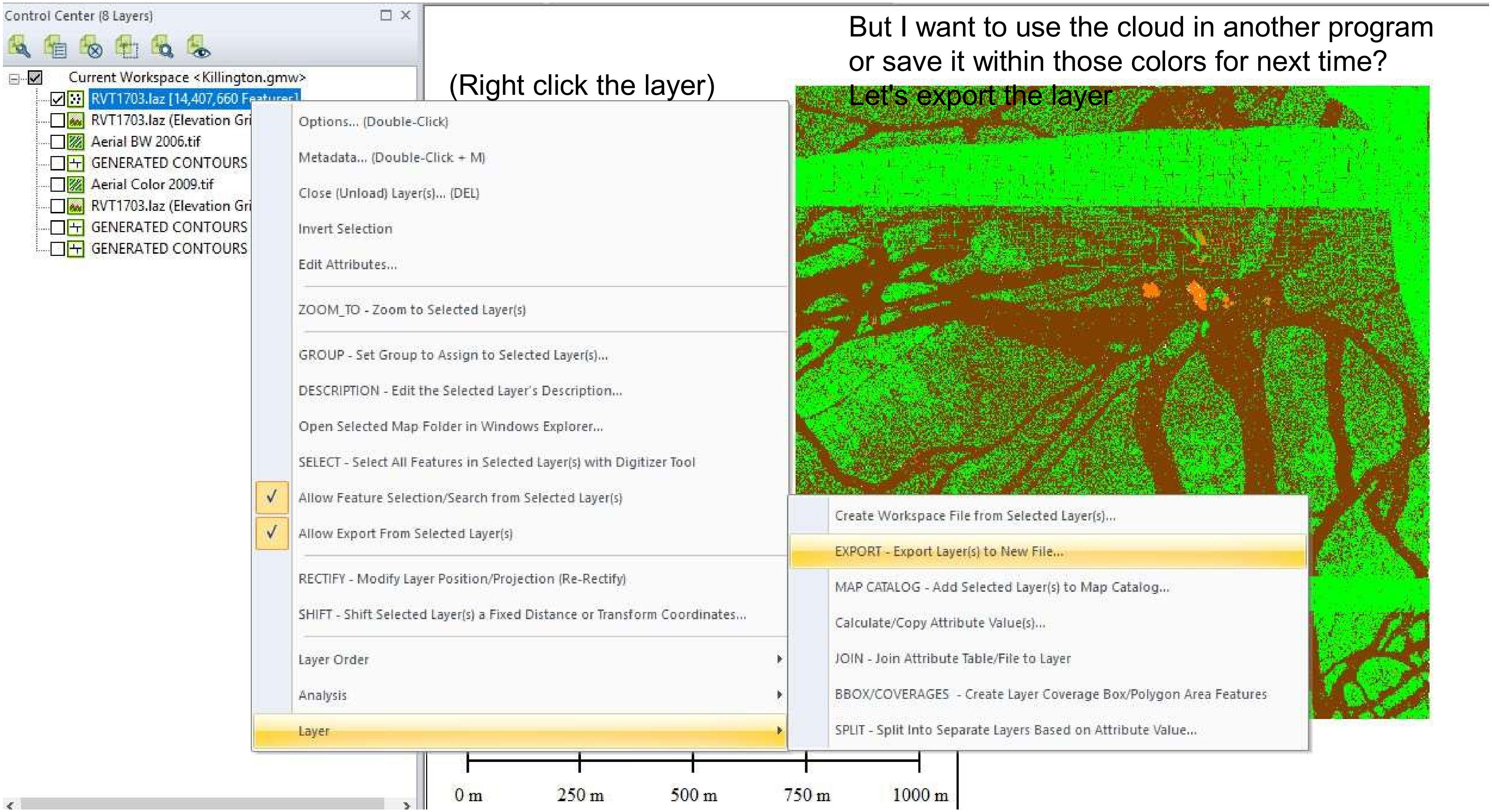


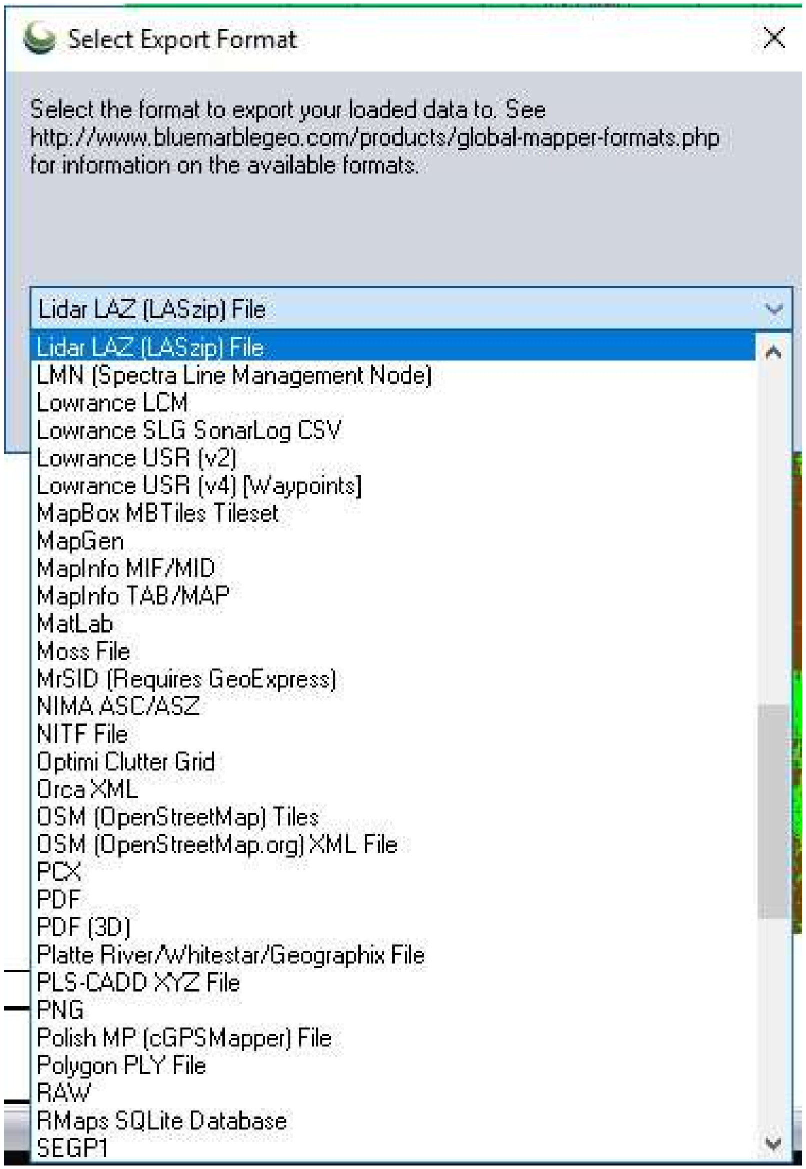
We can save the workspace.

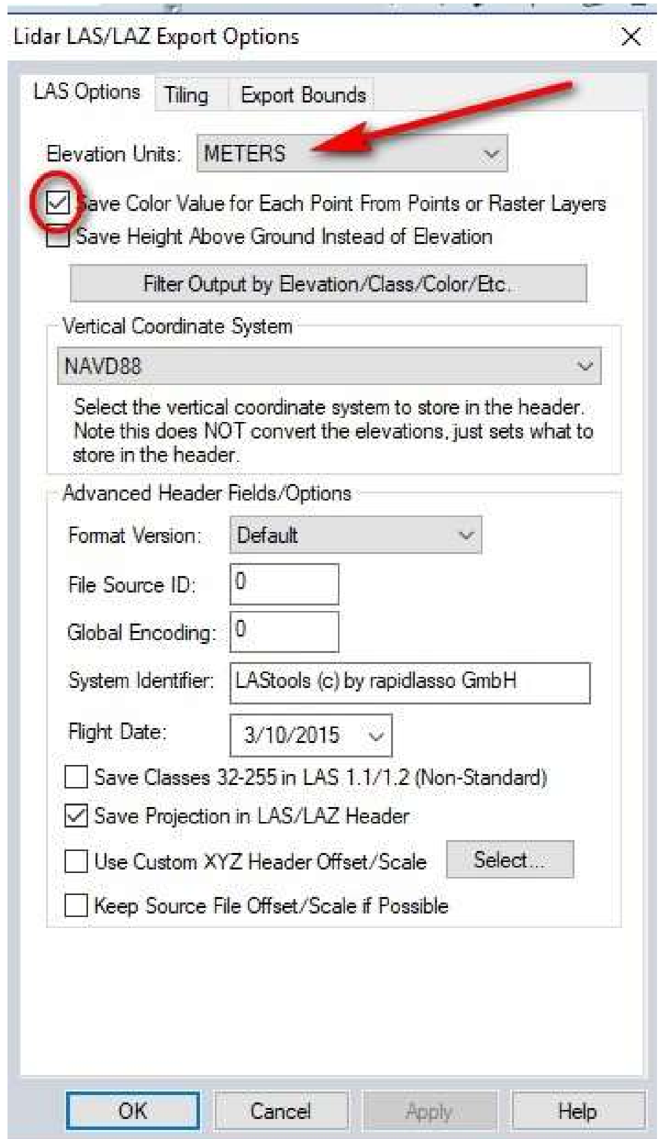
It is important to note that the data files / layers are not saved. Their paths are mapped and the changes to those layers are saved.

But I want to use the cloud in another program or save it within those colors for next time?
Let's export the layer

(Right click the layer)







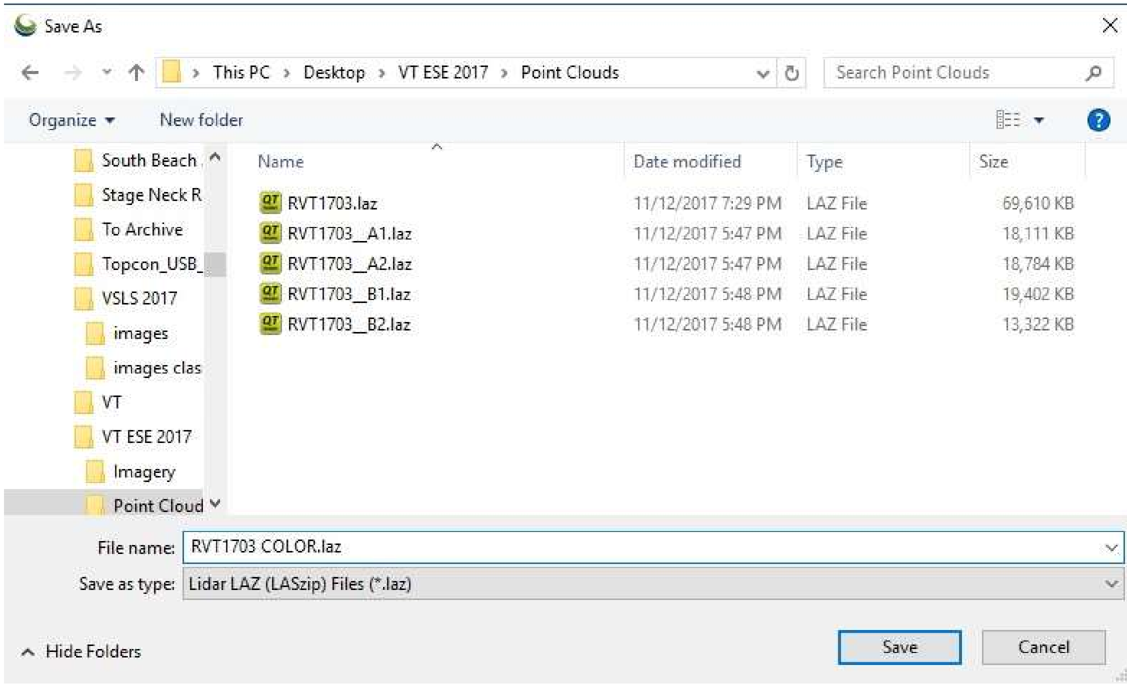
The export options are numerous. Global Mapper has accepted every format I have thrown at it. It will export oodles of formats as well.

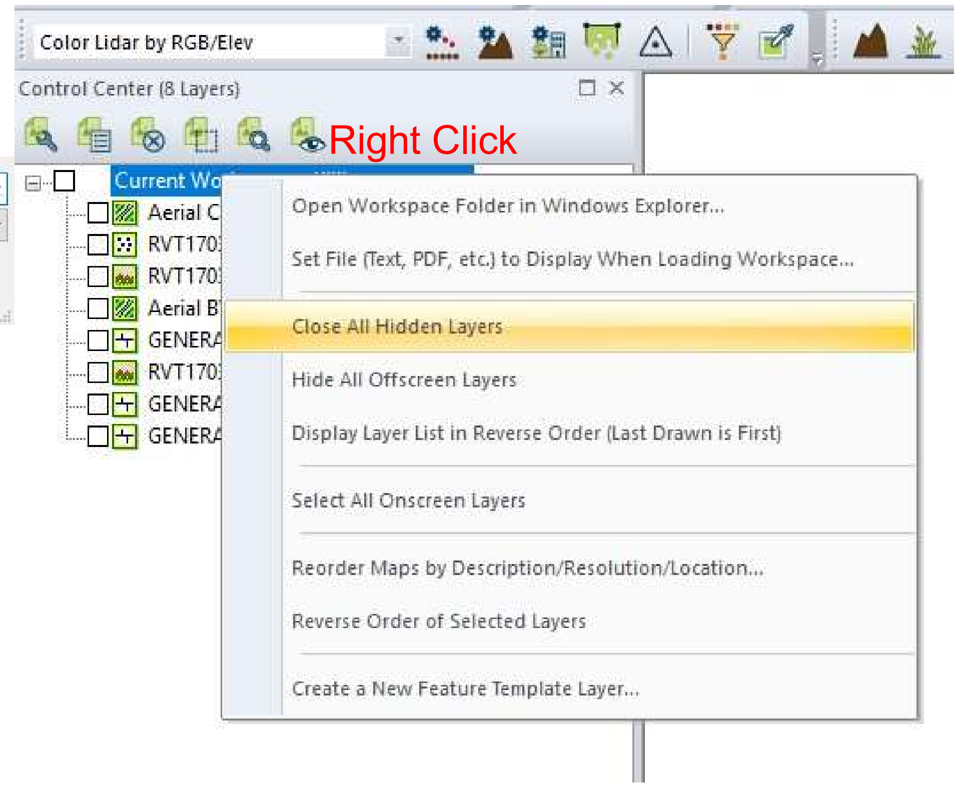
We want to export a LAS/LAZ.

The Elevation units remain in Meters (weird but you get used to it.)

Save the Color Value for Each Point.

We can put it back into the folder and add COLOR to the name.
Then turn off all the Layers and Close All Hidden Layers.
Save the workspace if you want.





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The single most important function of the Land Surveyor is to determine the boundaries of Real Property.

The second most difficult properties to survey are those that time has forgotten. The most difficult are those that include considerable errors by the original surveyor. These are caveats to keep in mind with using this data for boundary:

1. The data is aerial. It was acquired from a couple thousand feet in the sky. The actual altitude is somewhere in the metadata and ultimately makes no difference. It is important to note that it was acquired from a distance away.

2. The laser accuracy is about half a foot, so any point is that plus or minus half a foot. While it does not sound great, for aerial data this is awesome.

3. The surface model is based on a strict TIN - point to point. It's a nasty surface compares to a BIN which will create an average elevation around every desired point. The BIN does not provide the clarity in ridges, ditches and roads but produces a smoother surface model. There is reason for this selection and just know that there are other methods used for other purposes.

4. The surface model helps to visualize. These should be used to help determine where to look for the differences in the surface model. They should never be used in place of boots on the ground surveys. I use these models for approximation, deed compilation and survey planning.

5. I would not hesitate to use these in a court. I would provide all the pertinent caveats and I would overlay my own survey data to show how well the model worked and I would not hesitate to show where the surface model failed. Judges generally respond well to complete honesty. "We know the data is an excellent resource. We know the data is not as accurate as 'boots on the ground' survey data. These are the instances where the model worked within tolerance. These are the instances where it failed or provided false positives."

Story:
Otis Dyer, Jr., PLS of Rehoboth, MA performed a survey in Berkeley, MA. It was being contested and the neighbor hired a Big surveying firm.

Otis, Jr. passed away unexpectedly and his father, Otis Dyer, Sr., PLS came out of retirement at 93 to complete Otis Dyer, Jr.'s projects.

Moe Joyce, the Title Examiner, told me about the project. I told him that the aerial LiDAR could help. I offered to travel to Rehoboth to show them what it could do. They did not take me up on my offer.

I eventually prepared a surface model, exported it to a KMZ file, uploaded it to an FTP server and provided instructions to Moe Joyce.

With some help, Moe was able to download the file and load it into his laptop. He was giddy with excitement at what he saw. He took it to Otis, Sr. who was giddy with excitement by what he saw.

With the surface model, Otis Dyer, Sr., PLS, and a younger field crew were able to recover the original stone walls and roadway that had been covered with vegetation.

After they returned from Depositions, Moe was kind enough to share with me those details he could sahre with me: They took the Big surveyors by surprise, they took the attorneys for the other side by surprise and they may have forced a resolution before this goes to court by using superior evidence.

None of the surveyors involved had been successful in recovering these monuments before knowing where to look.

They could have been more diligent.

They could have cleared out or burned all of the vegetation to recover these monuments.

They could have moved forward with the evidence they had.

They used some technology to help resolve the problem. More importantly: **a 93 year old out of retirement surveyor used LiDAR to recover the original and controlling monuments.**

Maurice F. Joyce
"Land Court Trial Qualified Title Expert"
399 Brook Street
Dighton, MA 02715
MoeJoycell@hotmail.com
1-508-287-4768

November 16, 2017

J. Thaddeus Eldredge, PLS, CFM
Eldredge Surveying & Engineering, LLC
1038 Main Street
Chatham, MA 02633

Re: **LiDAR assistance for surveying**

Dear Mr. Eldredge:

As you are aware I have been working on a boundary line dispute case in South Eastern Massachusetts. The most critical issue in the case was the location of stone walls.

Our engineers had spent a great deal of time in the field prior to my entry into the case. Upon my entry, one of the first steps I took was to contact you for a LiDAR picture of the area in question. Because of this picture, our engineer and his field crew went back out and confirmed the wall positions revealed by LiDAR. Based on this new data, a supplemental plan was created giving our client more land than originally determined.

Recently I was Deposed in the case for six hours; based upon what the LiDAR picture revealed, I had a very good day making two points.

1. The location of the walls based on physical inspection by the survey field crew using LiDAR Data as a starting point; and

2. The lack of any other discernible walls in the area claimed by the opposition.

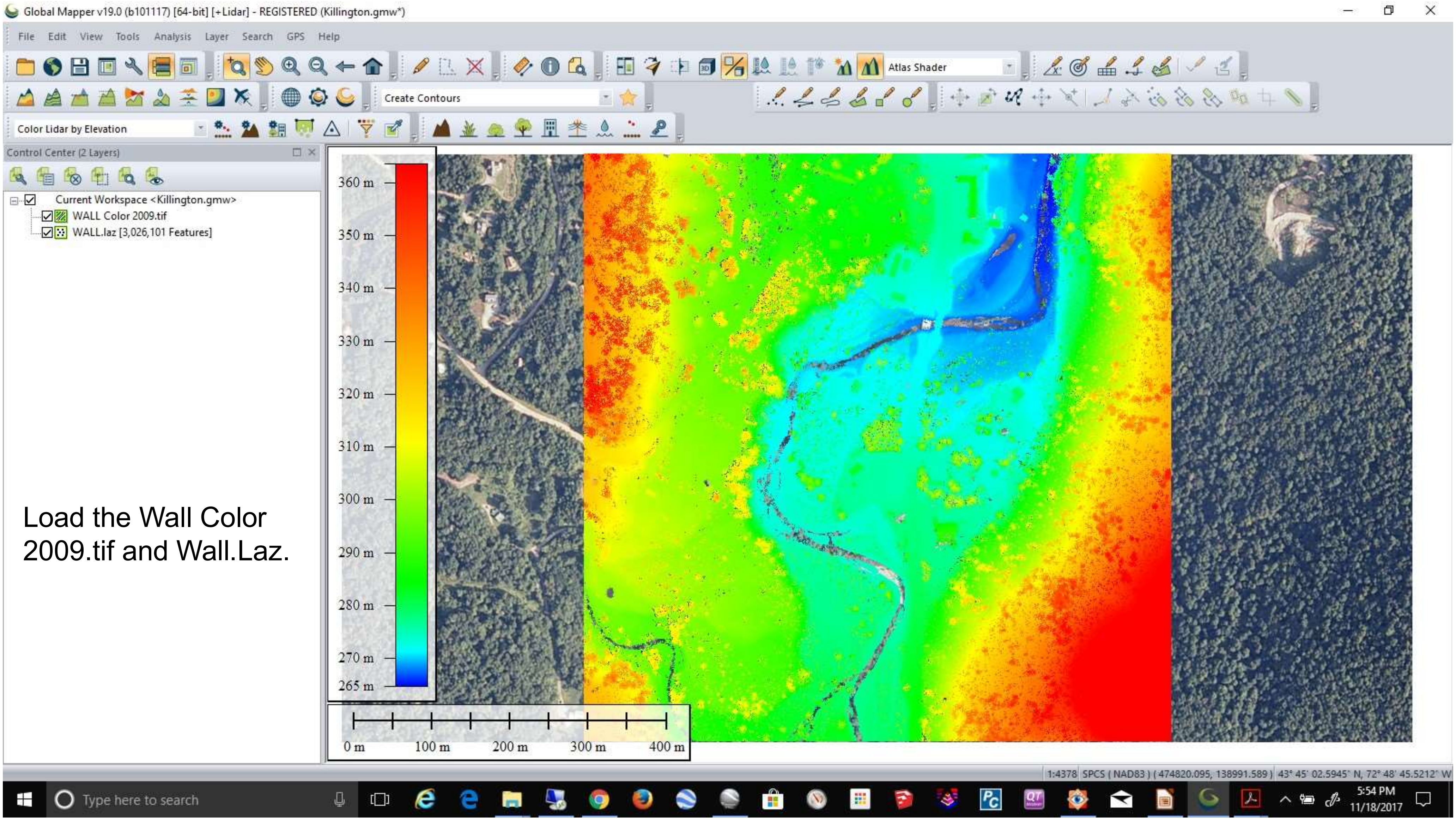
LiDAR is a great addition to the quiver of arrows that are available for use in cases of this nature.

Thank you,

Maurice F. Joyce

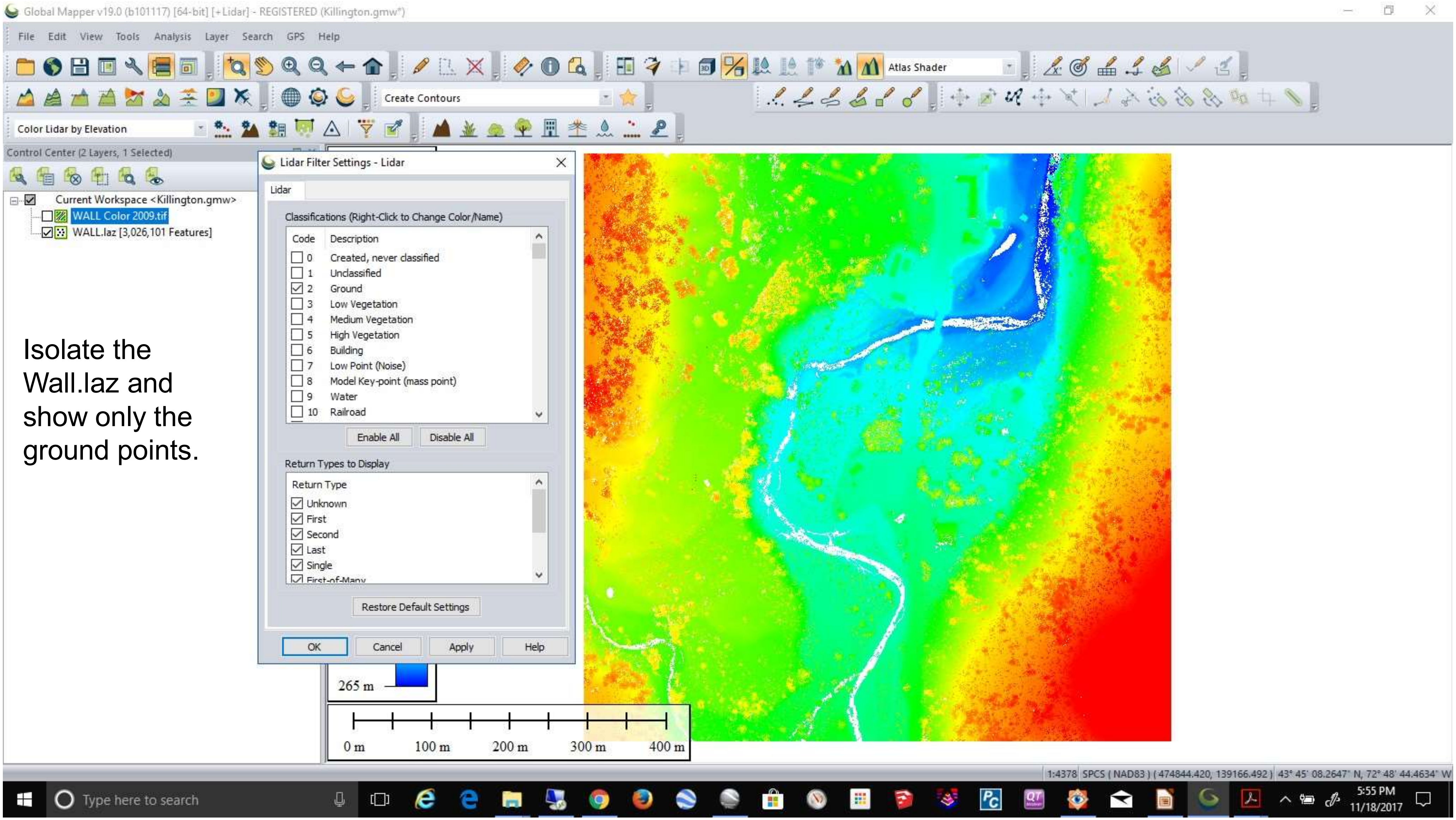
Moe Joyce was kind enough to send a brief letter. Please excuse his inability to write Surveyor. After all, he is a Land Court Trial Qualified Title Expert. For those not familiar, the Land Court System has an Engineering Department whose staff completes all of the Surveying tasks.

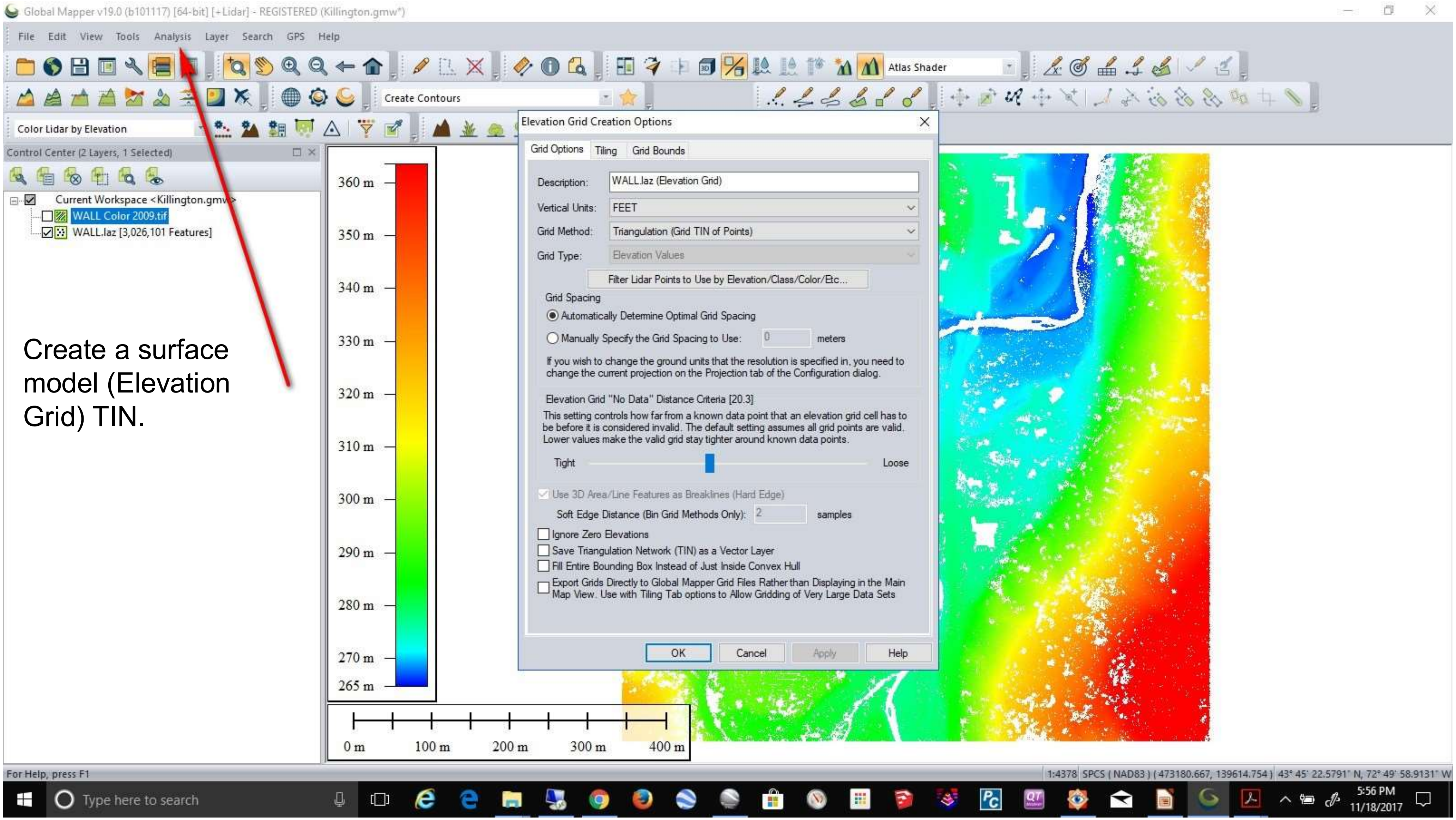
Excited?



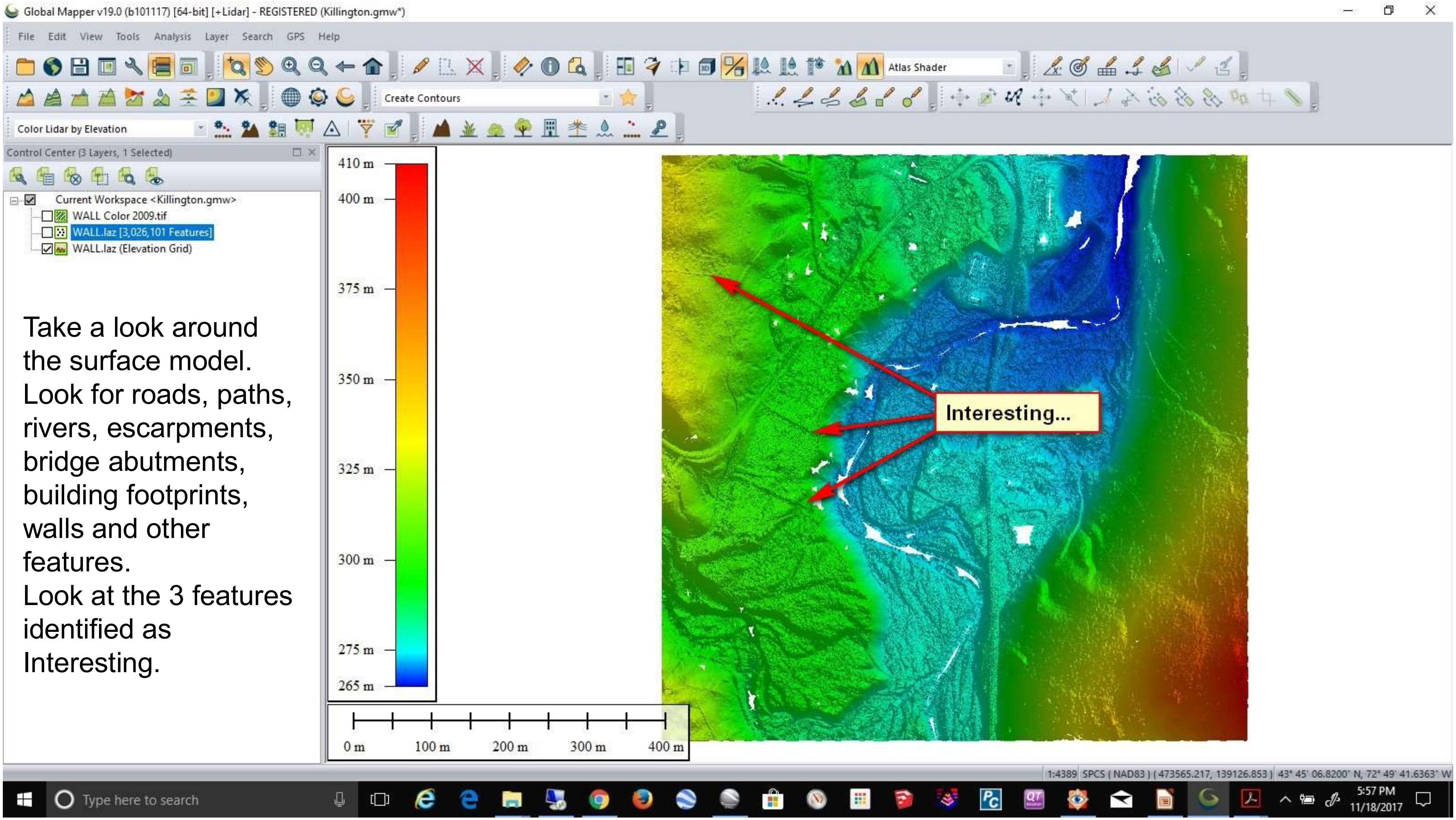
Load the Wall Color 2009.tif and Wall.Laz.

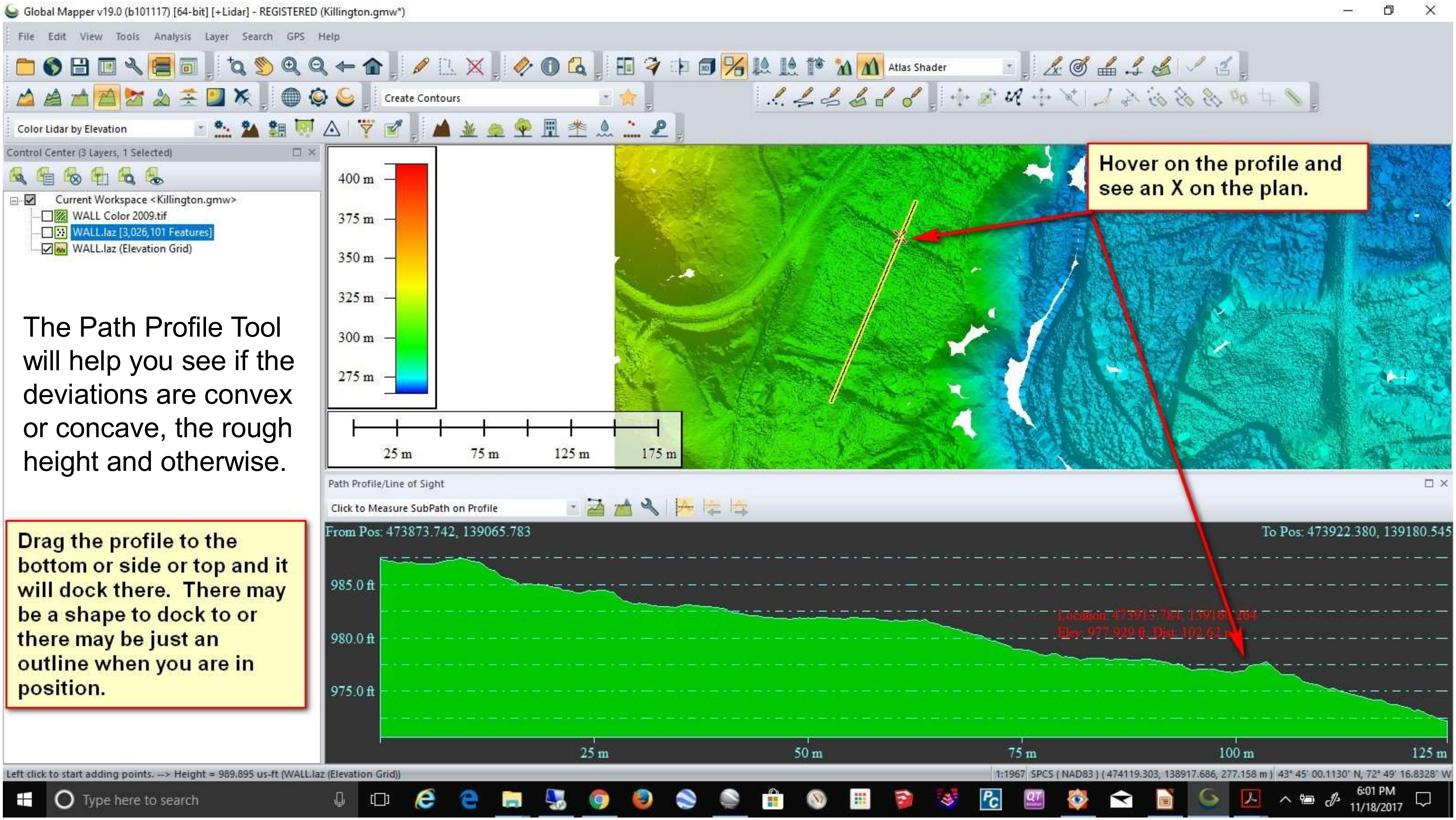
Isolate the Wall.laz and show only the ground points.

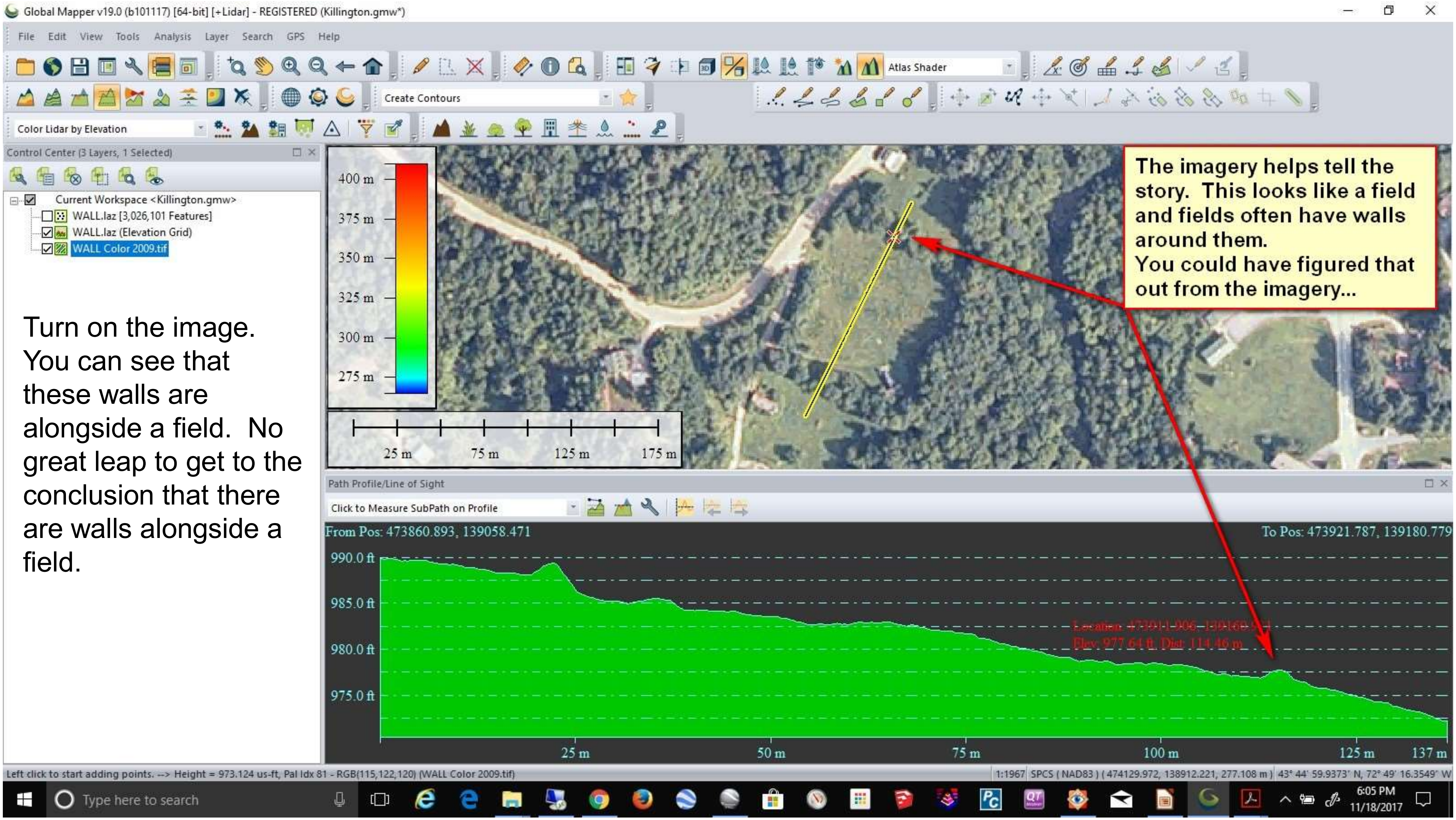


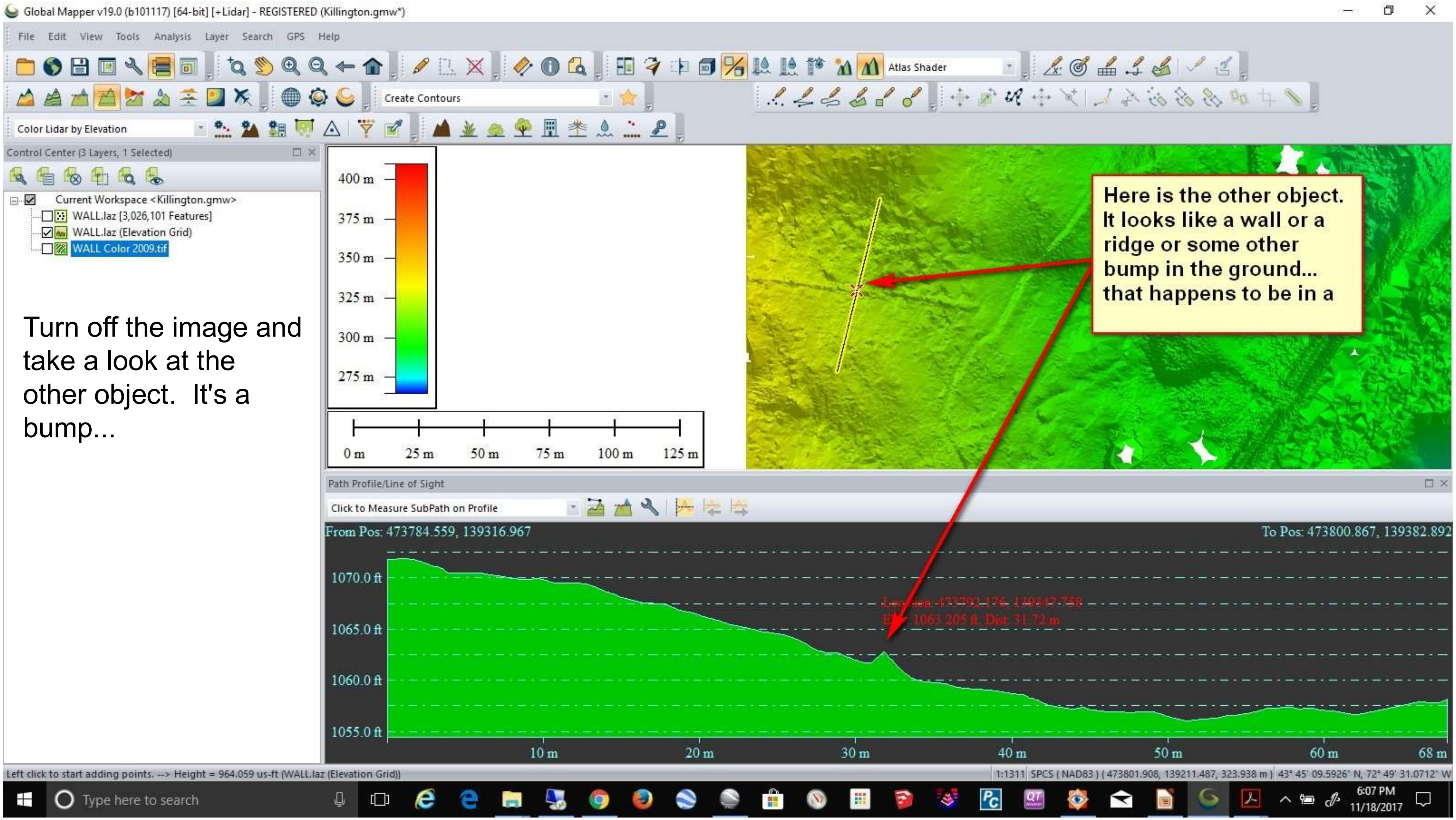


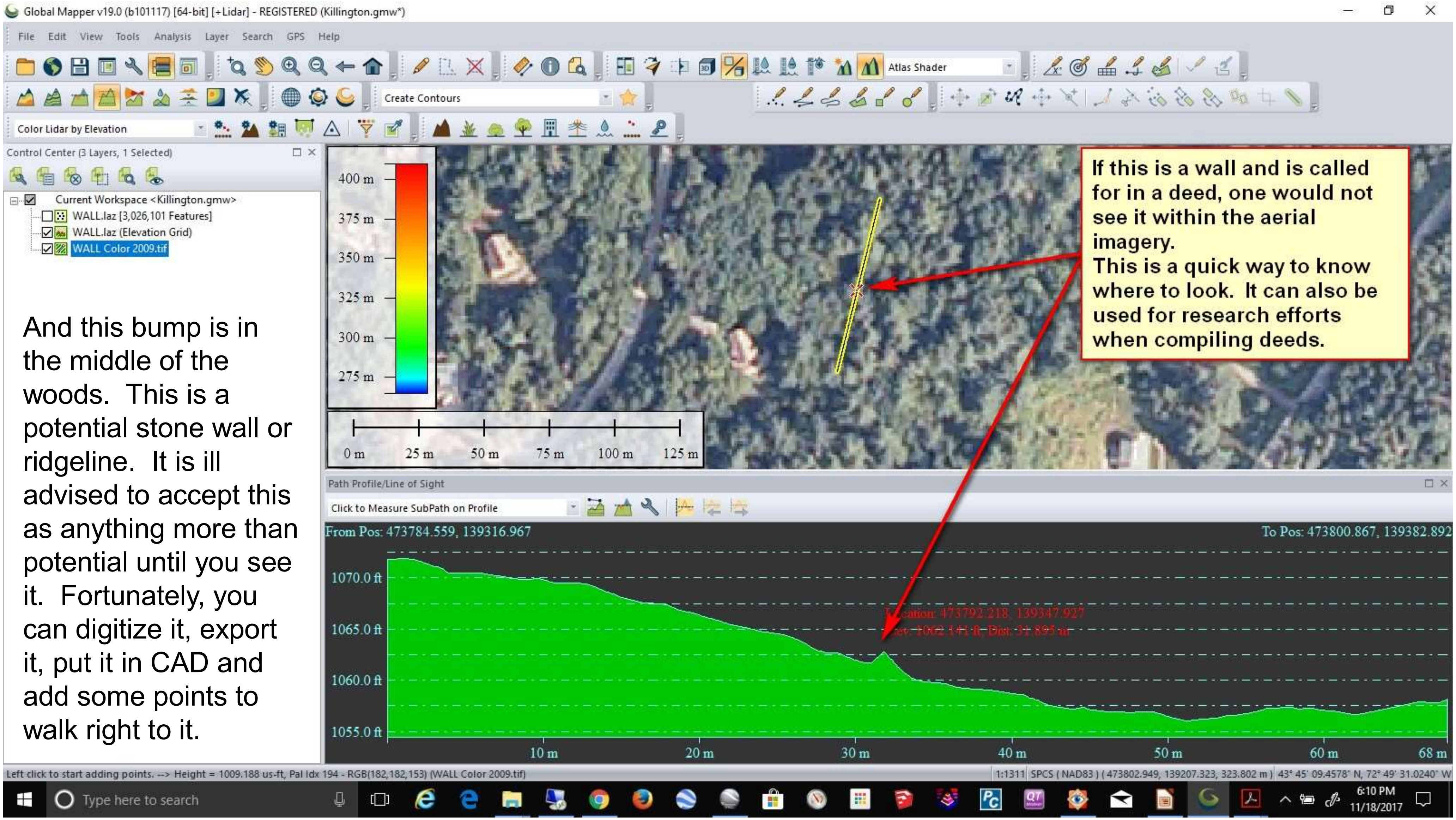
Create a surface model (Elevation Grid) TIN.


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED (Killington.gmw*)
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Contours
Color Lidar by Elevation
Control Center (3 Layers, 1 Selected)
Current Workspace <Killington.gmw>
WALL Color 2009.tif
WALL.laz [3,026,101 Features]
WALL.laz (Elevation Grid)
Take a look around the surface model.
Look for roads, paths, rivers, escarpments, bridge abutments, building footprints, walls and other features.
Look at the 3 features identified as Interesting.
410 m
400 m
375 m
350 m
325 m
300 m
275 m
265 m
0 m
100 m
200 m
300 m
400 m
Interesting...
1:4389 SPCS (NAD83) (473565.217, 139126.853) 43° 45' 06.8200" N, 72° 49' 41.6363" W
Type here to search
5:57 PM
11/18/2017


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED (Killington.gmw*)
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Contours
Color Lidar by Elevation
Control Center (3 Layers, 1 Selected)
Current Workspace <Killington.gmw>
WALL Color 2009.tif
WALL.laz [3,026,101 Features]
WALL.laz (Elevation Grid)
The Path Profile Tool will help you see if the deviations are convex or concave, the rough height and otherwise.
Drag the profile to the bottom or side or top and it will dock there. There may be a shape to dock to or there may be just an outline when you are in position.
Hover on the profile and see an X on the plan.
400 m
375 m
350 m
325 m
300 m
275 m
25 m
75 m
125 m
175 m
Path Profile/Line of Sight
Click to Measure SubPath on Profile
From Pos: 473873.742, 139065.783
To Pos: 473922.380, 139180.545
985.0 ft
980.0 ft
975.0 ft
25 m
50 m
75 m
100 m
125 m
Left click to start adding points. --> Height = 989.895 us-ft (WALL.laz (Elevation Grid))
1:1967 SPCS (NAD83) (474119.303, 138917.686, 277.158 m) 43° 45' 00.1130" N, 72° 49' 16.8328" W
Type here to search
6:01 PM
11/18/2017


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED (Killington.gmw*)
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Contours
Color Lidar by Elevation
Control Center (3 Layers, 1 Selected)
Current Workspace <Killington.gmw>
WALL.laz [3,026,101 Features]
WALL.laz (Elevation Grid)
WALL Color 2009.tif
Turn on the image. You can see that these walls are alongside a field. No great leap to get to the conclusion that there are walls alongside a field.
400 m
375 m
350 m
325 m
300 m
275 m
25 m
75 m
125 m
175 m
The imagery helps tell the story. This looks like a field and fields often have walls around them.
You could have figured that out from the imagery...
Path Profile/Line of Sight
Click to Measure SubPath on Profile
From Pos: 473860.893, 139058.471
To Pos: 473921.787, 139180.779
990.0 ft
985.0 ft
980.0 ft
975.0 ft
25 m
50 m
75 m
100 m
125 m
137 m
Left click to start adding points. --> Height = 973.124 us-ft, Pal Idx 81 - RGB(115,122,120) (WALL Color 2009.tif)
Type here to search
6:05 PM
11/18/2017


Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED (Killington.gmw*)
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Contours
Color Lidar by Elevation
Control Center (3 Layers, 1 Selected)
Current Workspace <Killington.gmw>
WALL.laz [3,026,101 Features]
WALL.laz (Elevation Grid)
WALL Color 2009.tif
Turn off the image and take a look at the other object. It's a bump...
400 m
375 m
350 m
325 m
300 m
275 m
0 m
25 m
50 m
75 m
100 m
125 m
Here is the other object. It looks like a wall or a ridge or some other bump in the ground... that happens to be in a
Path Profile/Line of Sight
Click to Measure SubPath on Profile
From Pos: 473784.559, 139316.967
To Pos: 473800.867, 139382.892
1070.0 ft
1065.0 ft
1060.0 ft
1055.0 ft
10 m
20 m
30 m
40 m
50 m
60 m
68 m
Left click to start adding points. --> Height = 964.059 us-ft (WALL.laz (Elevation Grid))
1:1311 SPCS (NAD83) (473801.908, 139211.487, 323.938 m) 43° 45' 09.5926" N, 72° 49' 31.0712" W
Type here to search
6:07 PM
11/18/2017



And this bump is in the middle of the woods. This is a potential stone wall or ridgeline. It is ill advised to accept this as anything more than potential until you see it. Fortunately, you can digitize it, export it, put it in CAD and add some points to walk right to it.

If this is a wall and is called for in a deed, one would not see it within the aerial imagery.
This is a quick way to know where to look. It can also be used for research efforts when compiling deeds.

This is a rough staking sheet for a property in Harwich, MA. It was forgotten about over a century ago. The monuments sought include:

- Rings of stones
- Old Roads (now paths at best)
- Ridges (Remnants of roads or plow lines often the only demarcation of occupation or boundary)

The crew was able to recover much of the evidence needed to fix the poor deed descriptions.

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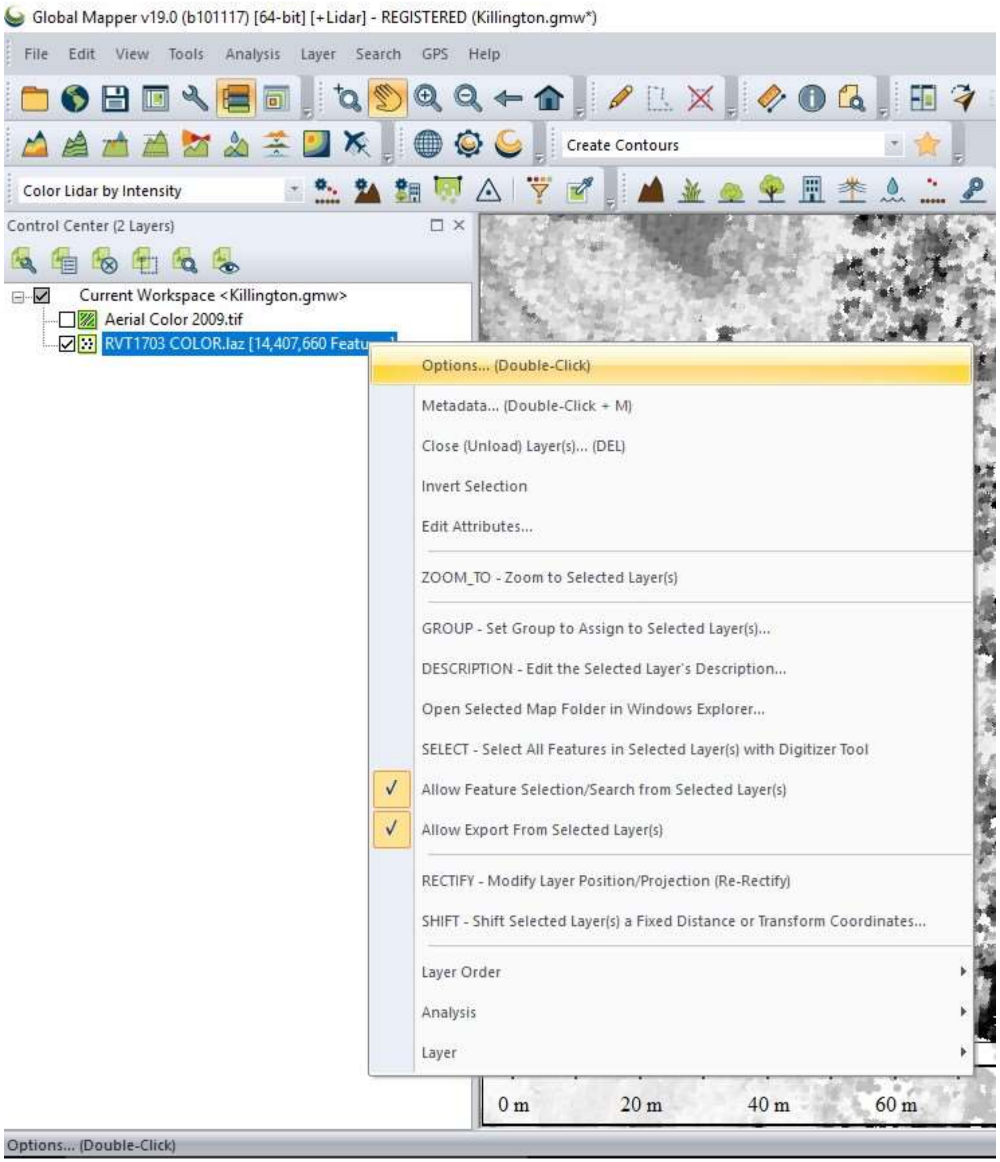
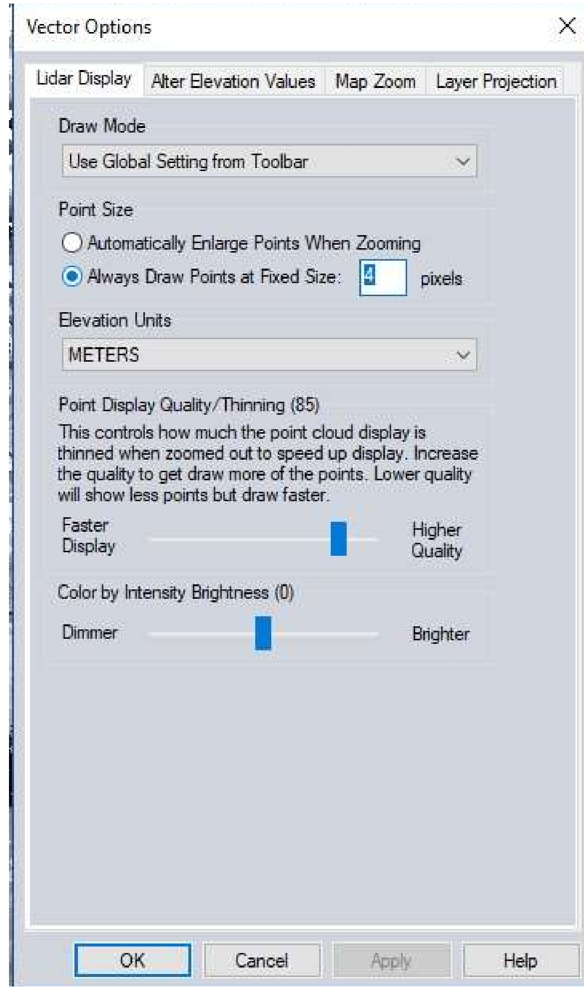
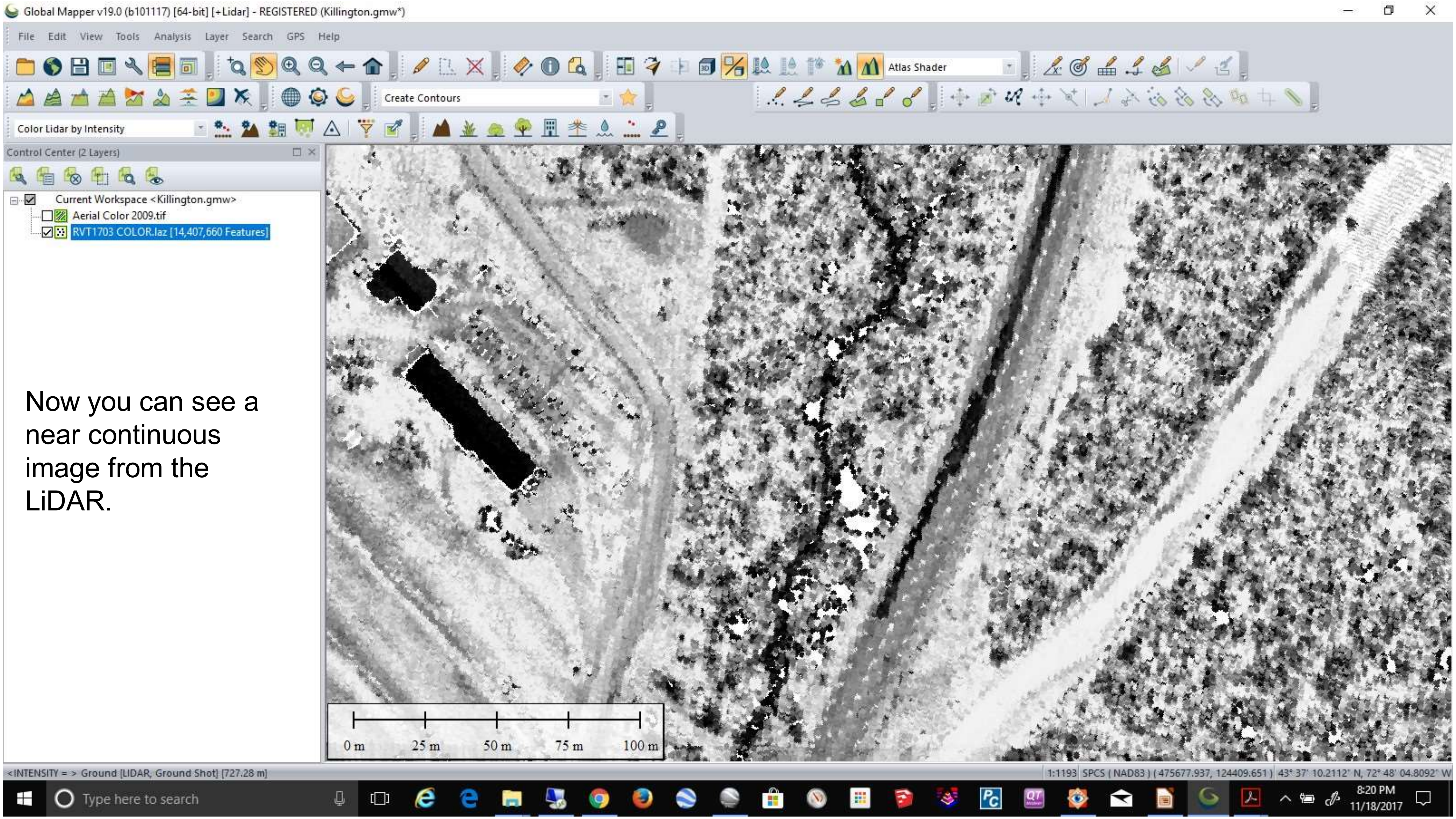




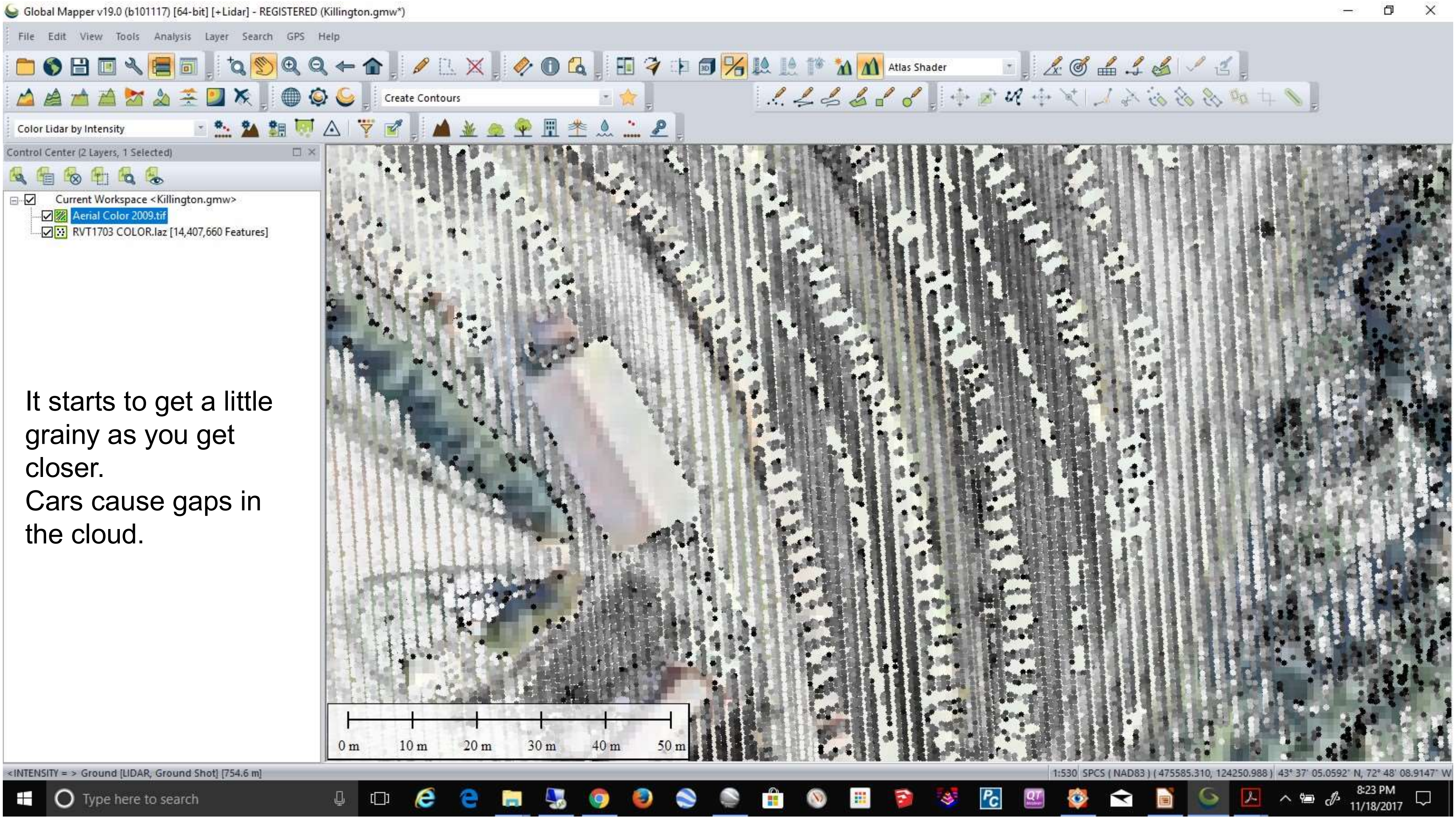
The little points are hard to see, so change the size.

Zoom in to an area of interest or a scale you want to digitize at.

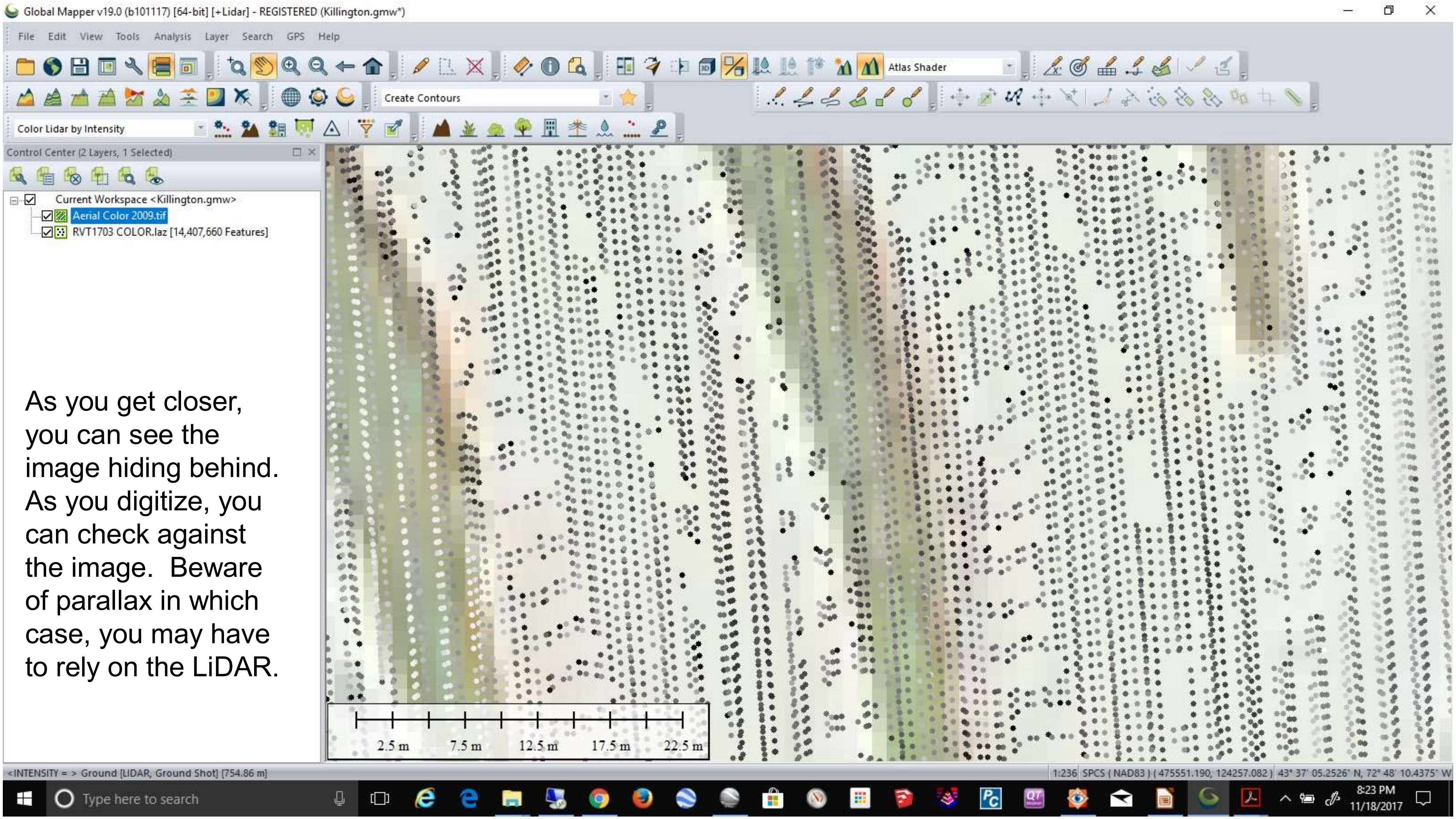
Right click on the Layer, Options, Draw points at a Fixed Size. Press Apply as you change the size and watch it change behind.



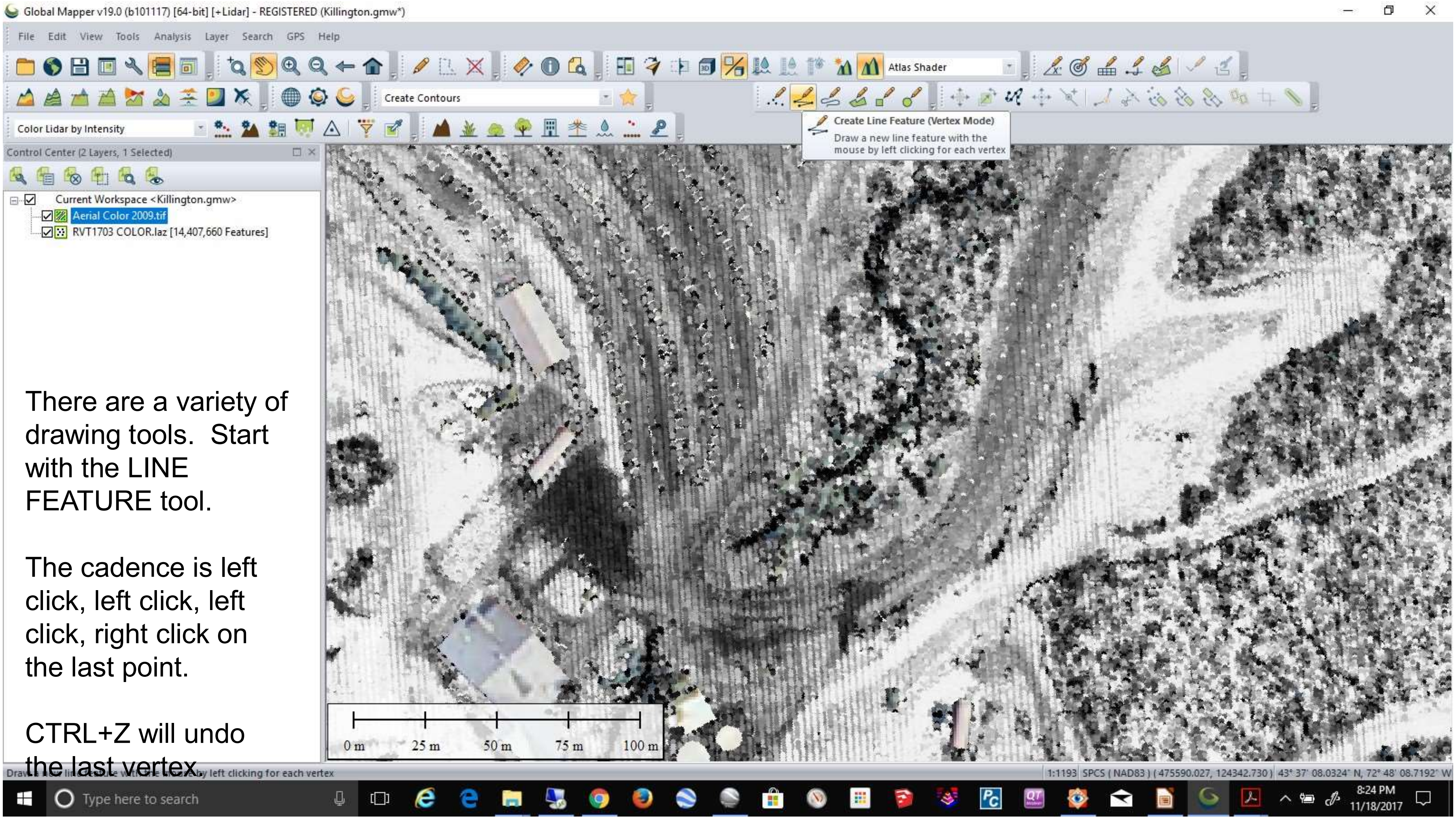
Now you can see a near continuous image from the LiDAR.



It starts to get a little grainy as you get closer.
Cars cause gaps in the cloud.



As you get closer, you can see the image hiding behind. As you digitize, you can check against the image. Beware of parallax in which case, you may have to rely on the LiDAR.

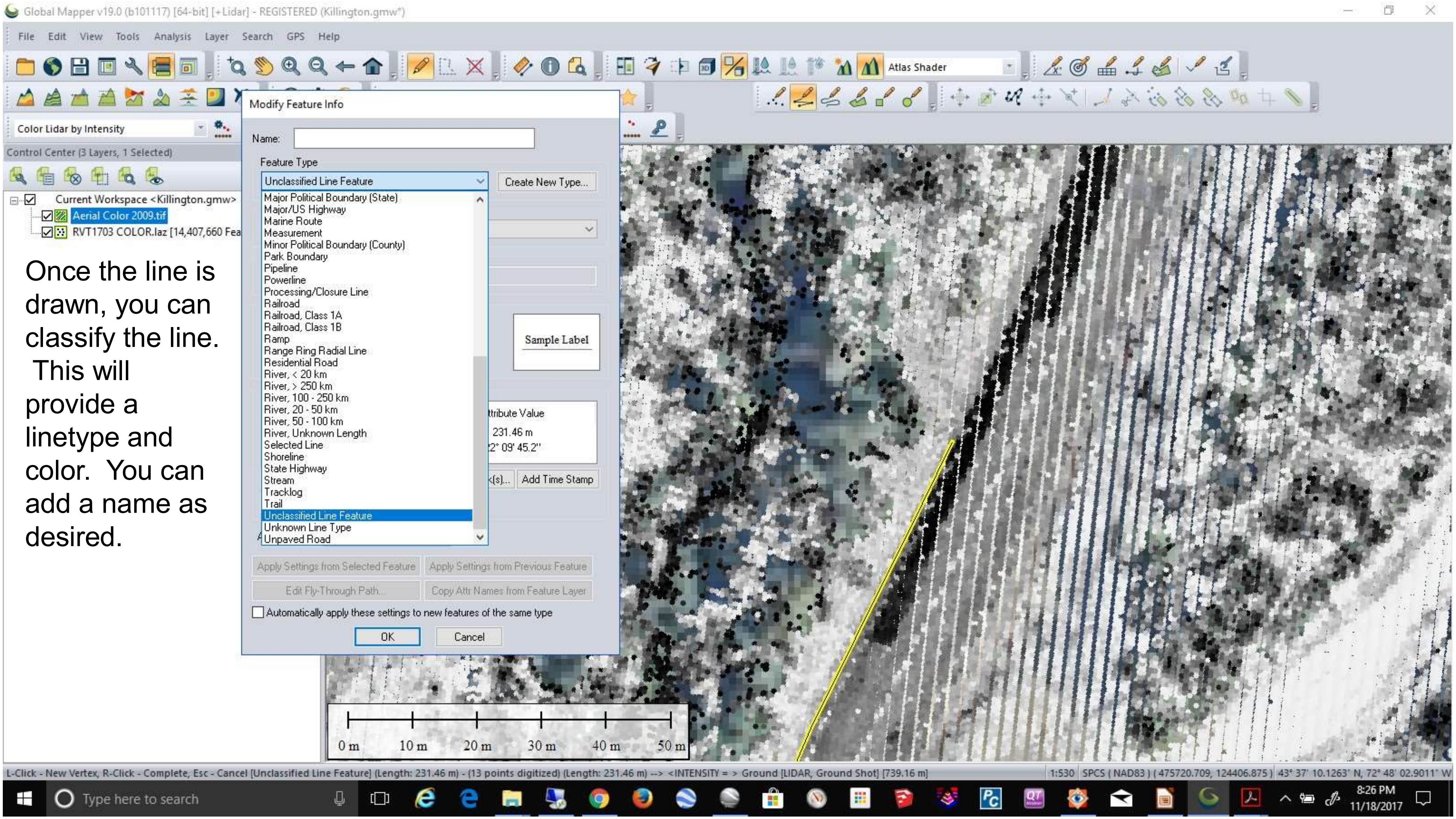


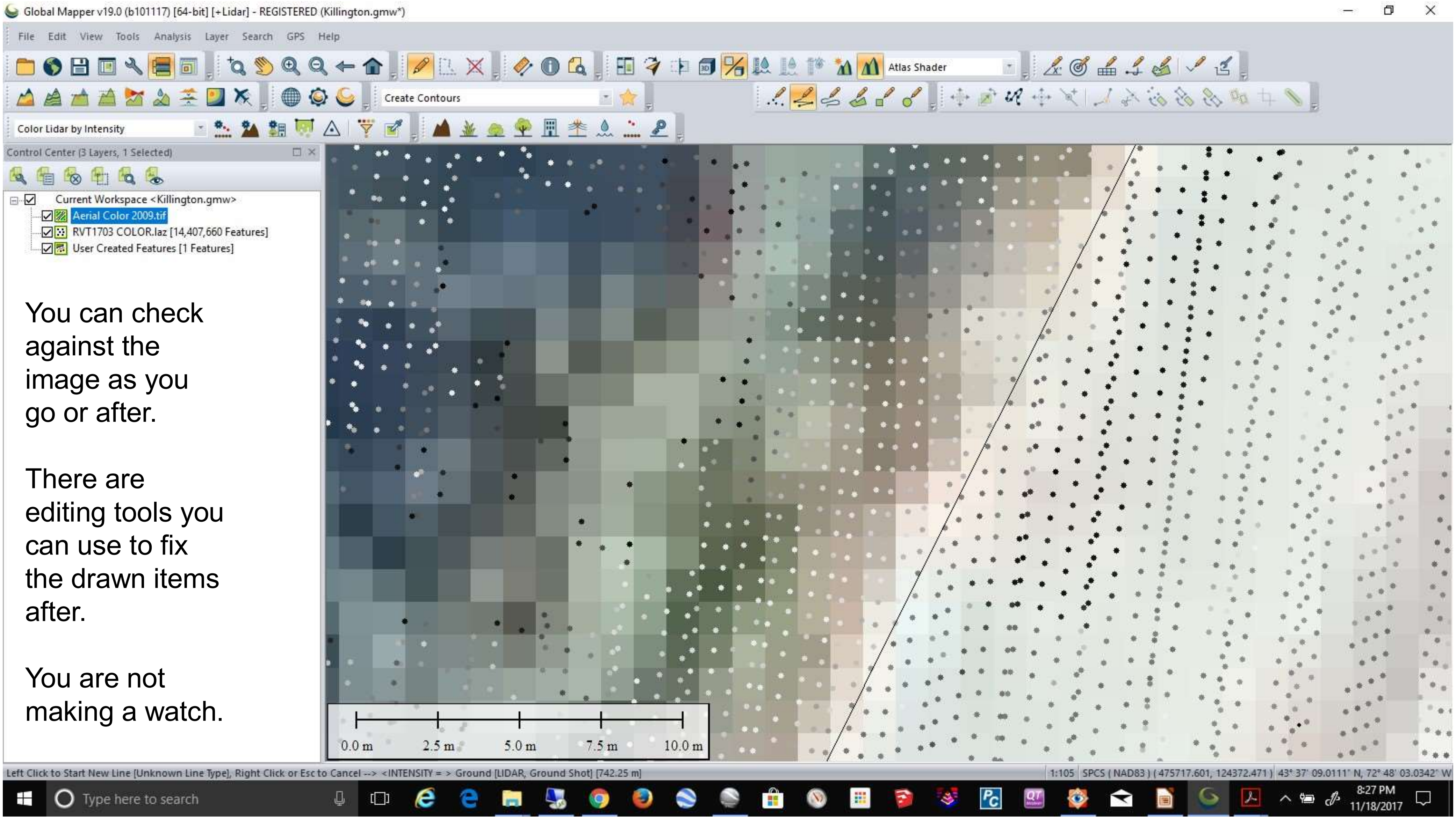
There are a variety of drawing tools. Start with the LINE FEATURE tool.

The cadence is left click, left click, left click, right click on the last point.

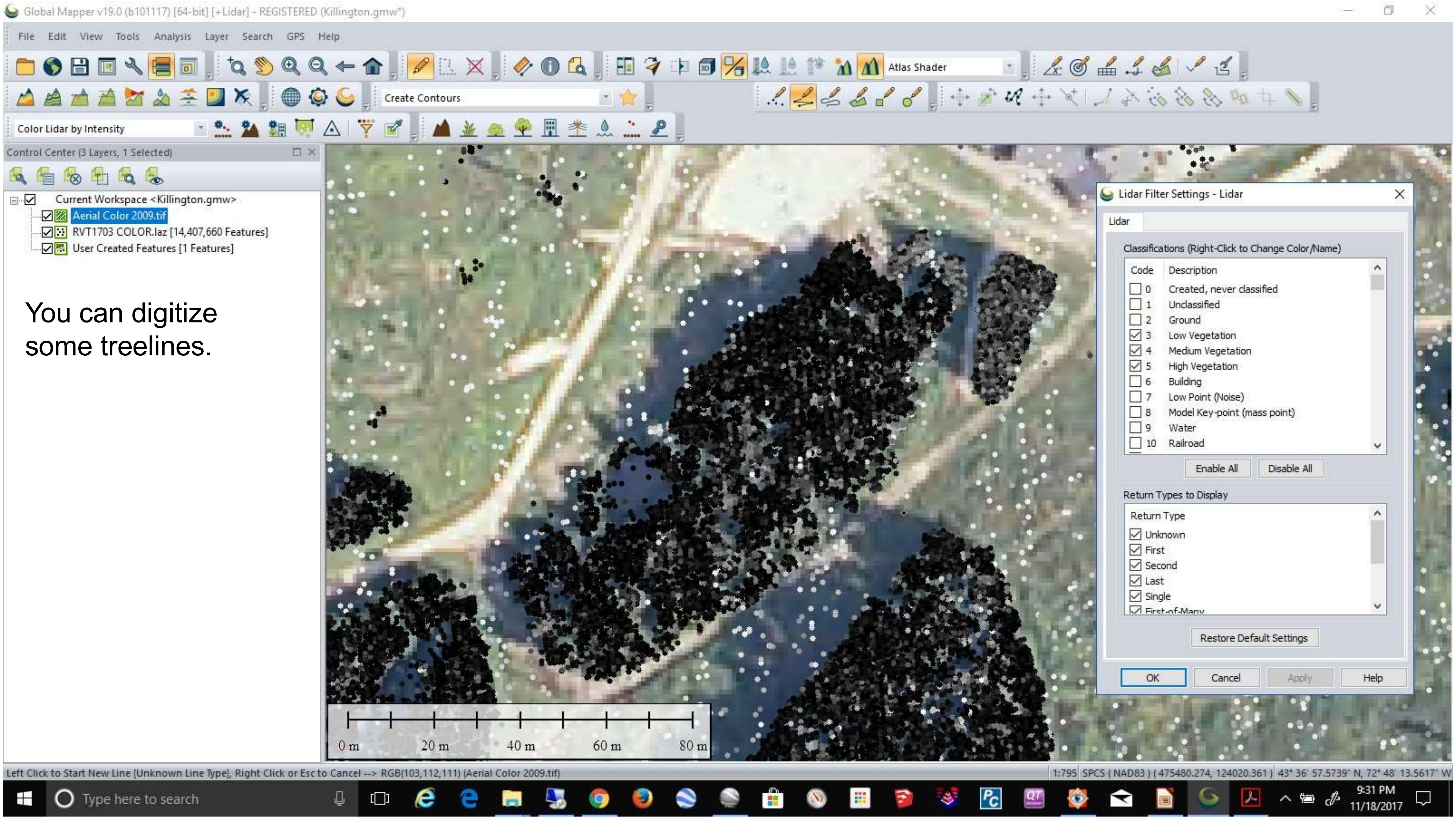
CTRL+Z will undo the last vertex.

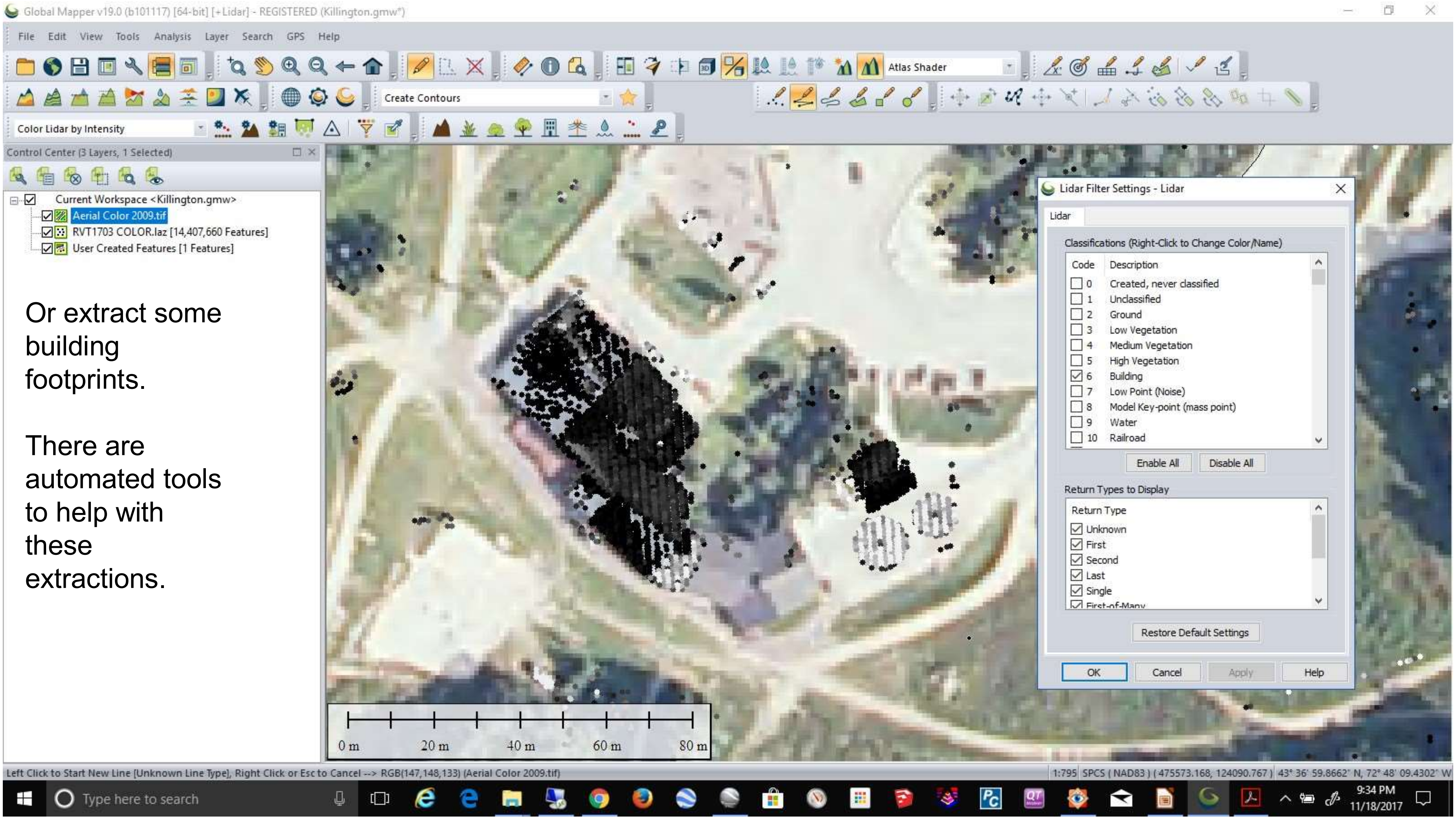
Once the line is drawn, you can classify the line. This will provide a linetype and color. You can add a name as desired.




Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED (Killington.gmw*)
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Contours
Color Lidar by Intensity
Control Center (3 Layers, 1 Selected)
Current Workspace <Killington.gmw>
Aerial Color 2009.tif
RVT1703 COLOR.laz [14,407,660 Features]
User Created Features [1 Features]
You can check against the image as you go or after.
There are editing tools you can use to fix the drawn items after.
You are not making a watch.
0.0 m
2.5 m
5.0 m
7.5 m
10.0 m
Left Click to Start New Line [Unknown Line Type], Right Click or Esc to Cancel --> <INTENSITY = > Ground [LIDAR, Ground Shot] [742.25 m]
1:105 SPCS (NAD83) (475717.601, 124372.471) 43° 37' 09.0111" N, 72° 48' 03.0342" W
Type here to search
8:27 PM
11/18/2017

You can digitize some treelines.





Or extract some building footprints.

There are automated tools to help with these extractions.

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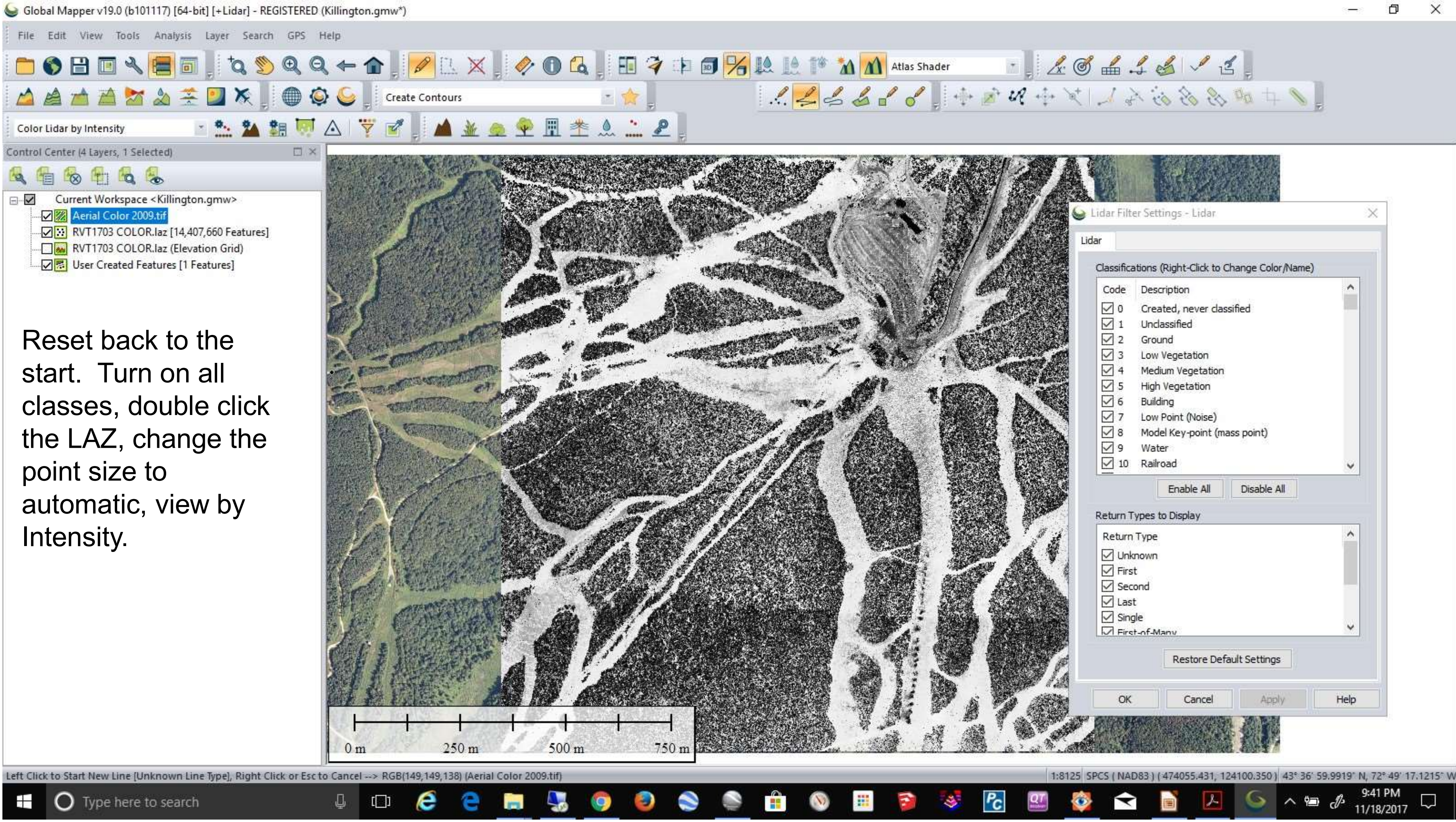
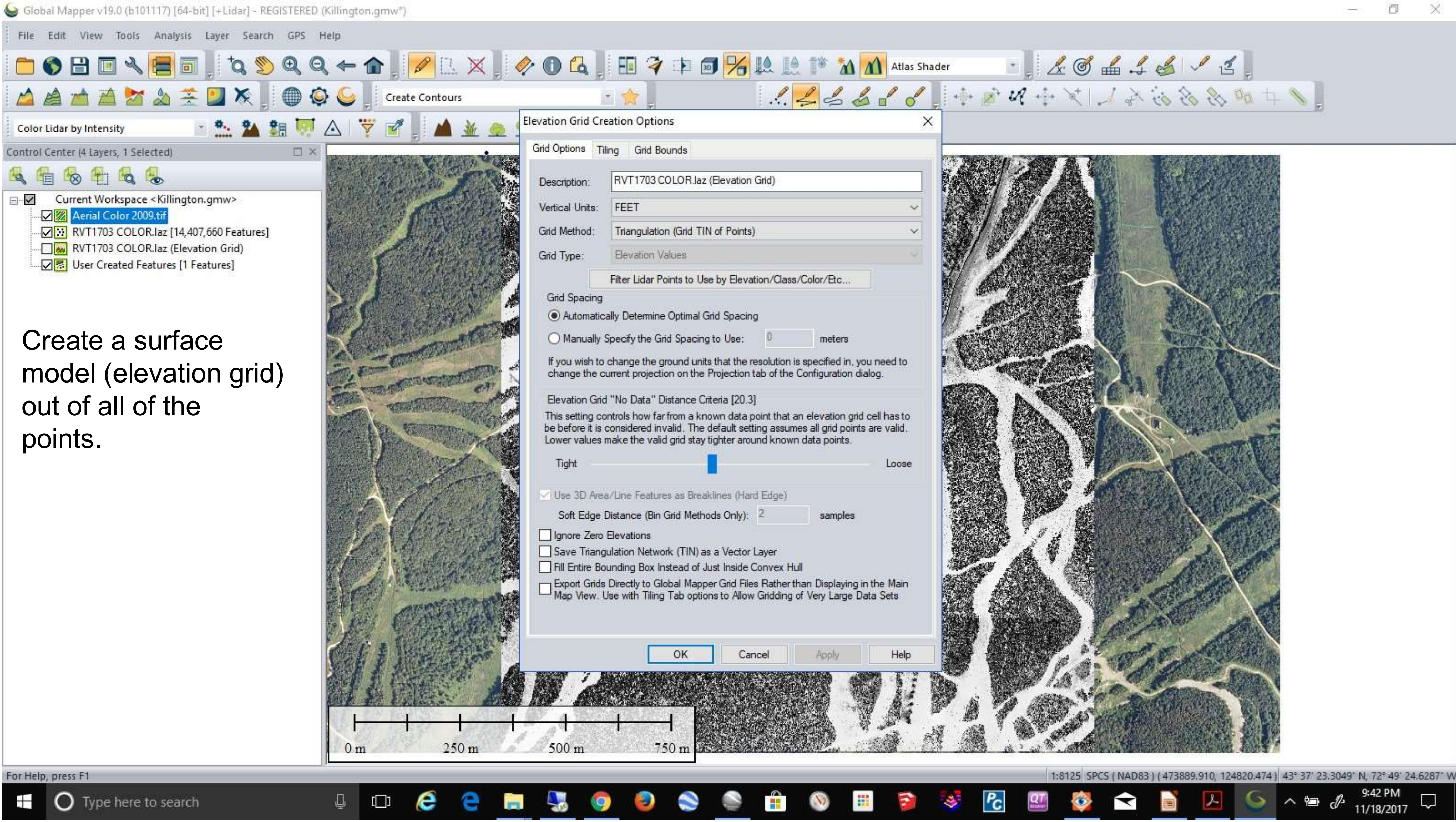
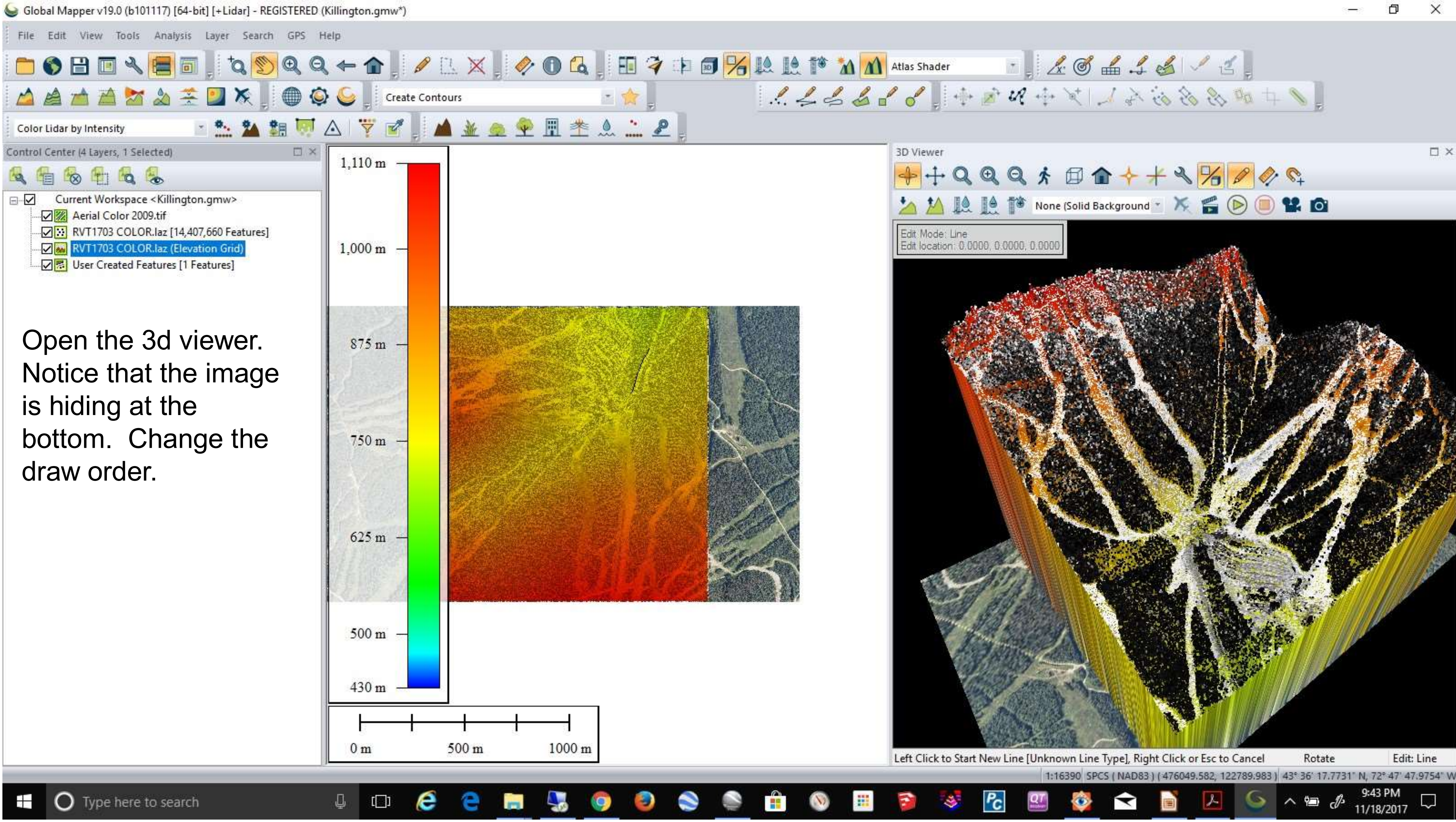


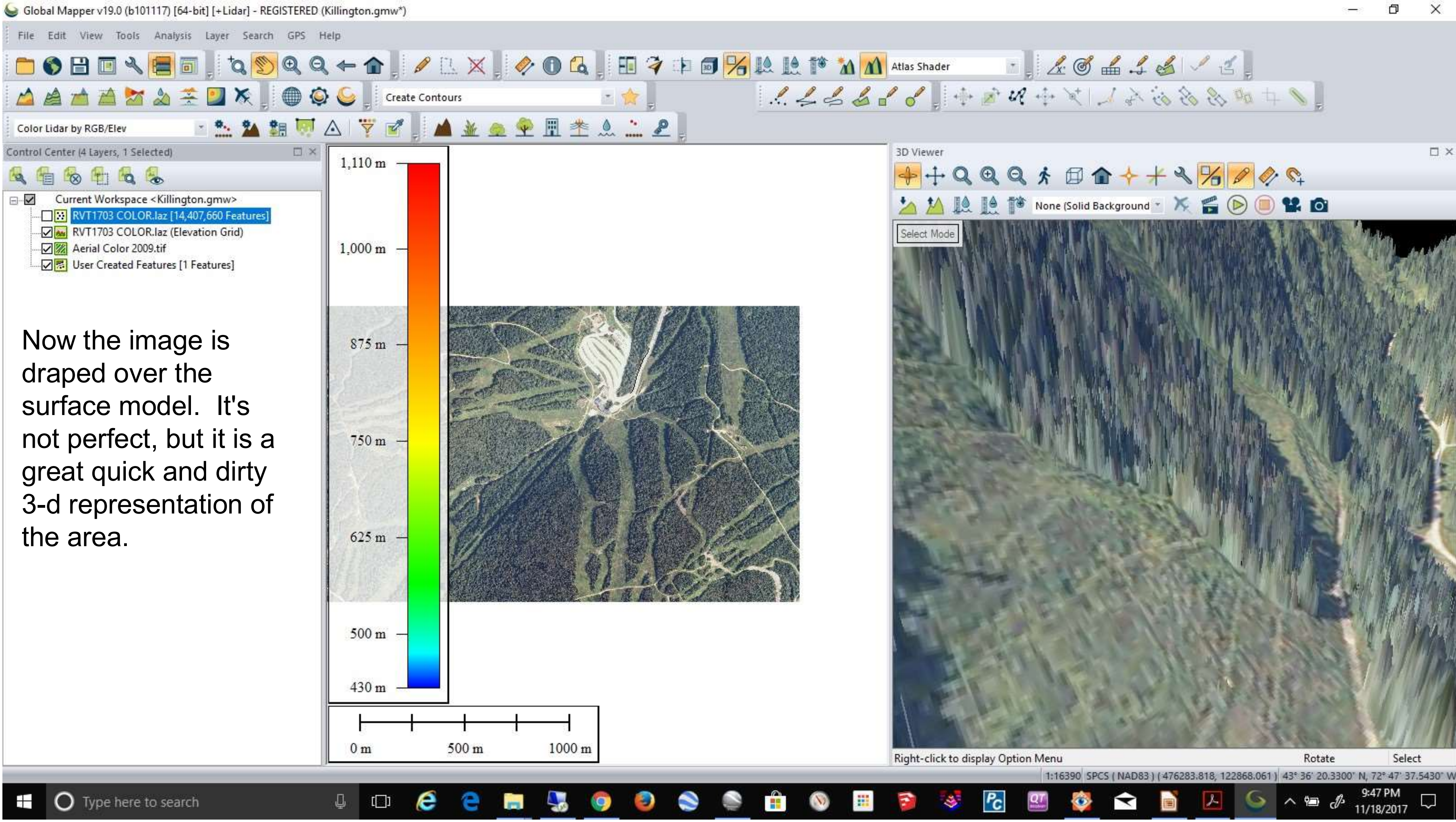
Reset back to the start. Turn on all classes, double click the LAZ, change the point size to automatic, view by Intensity.

Create a surface model (elevation grid) out of all of the points.

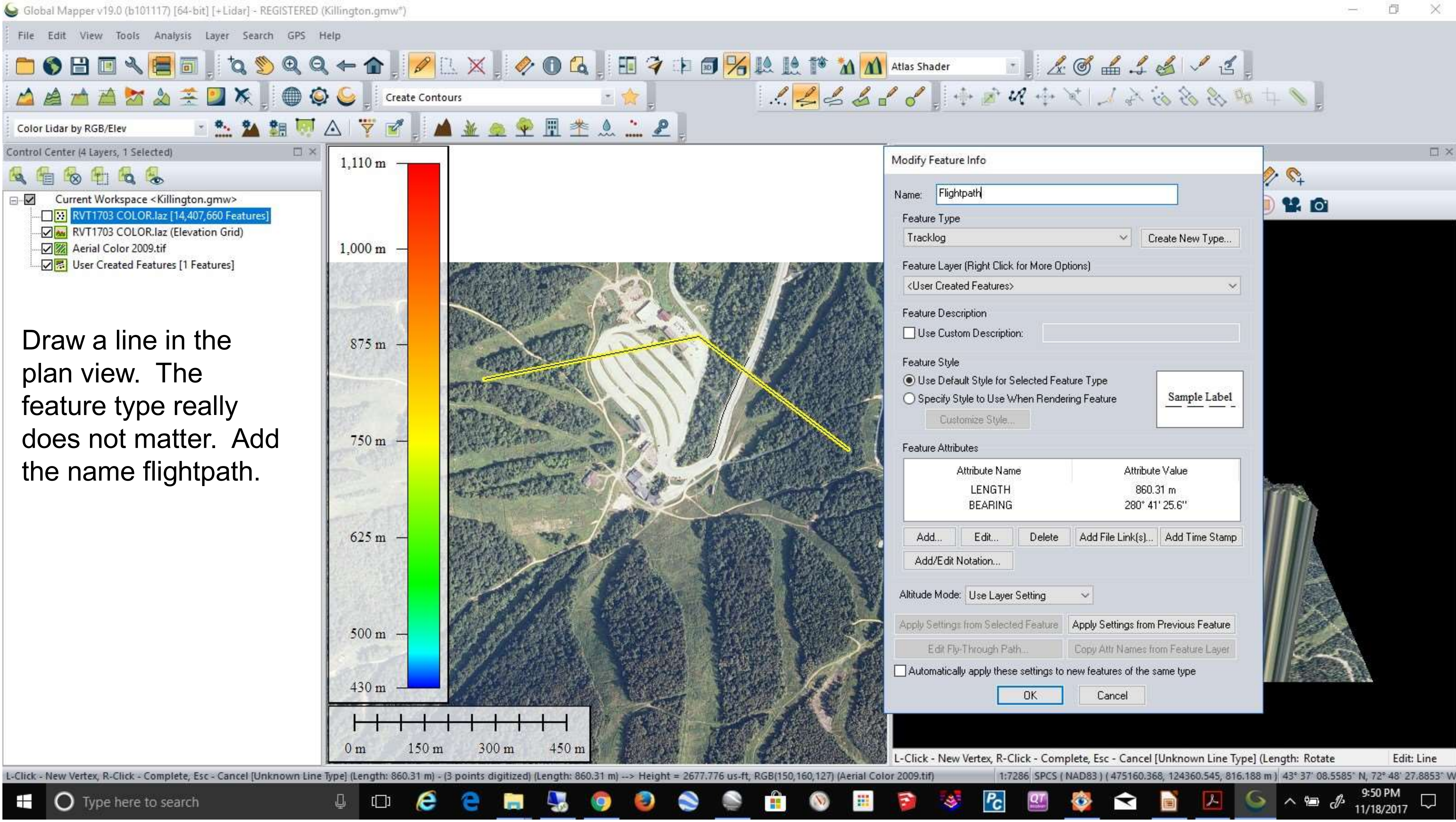




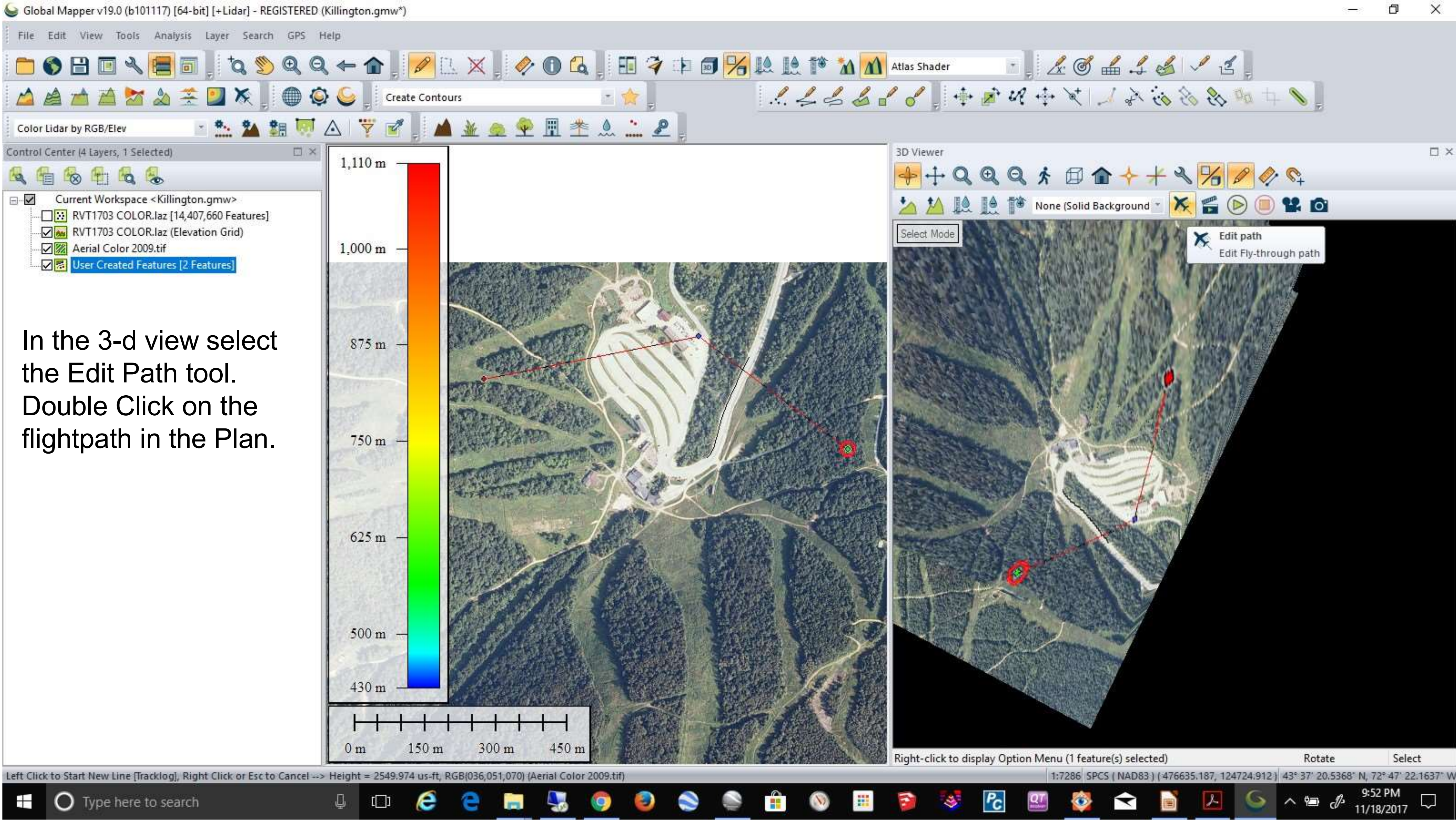
Open the 3d viewer. Notice that the image is hiding at the bottom. Change the draw order.

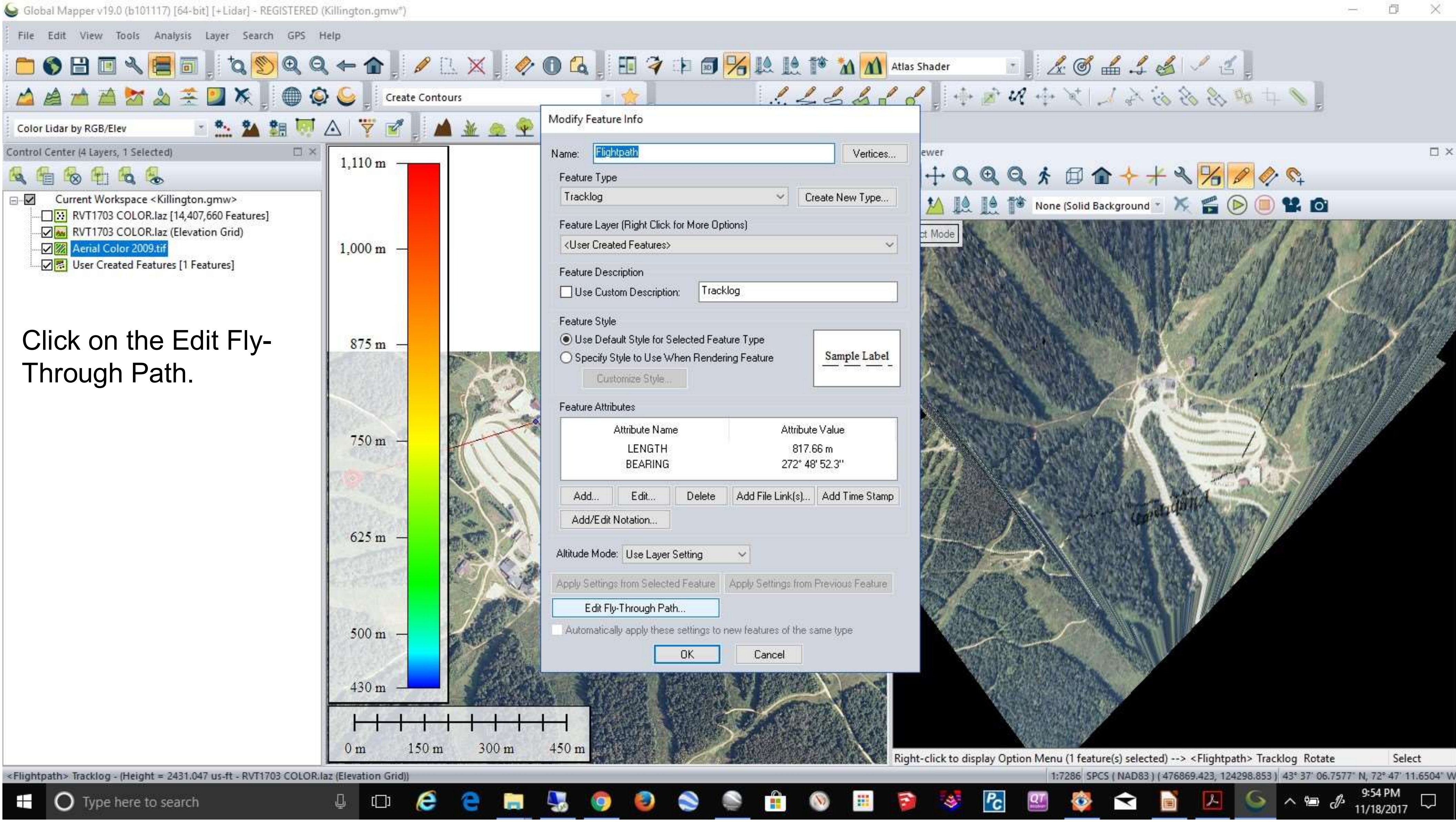


Now the image is draped over the surface model. It's not perfect, but it is a great quick and dirty 3-d representation of the area.

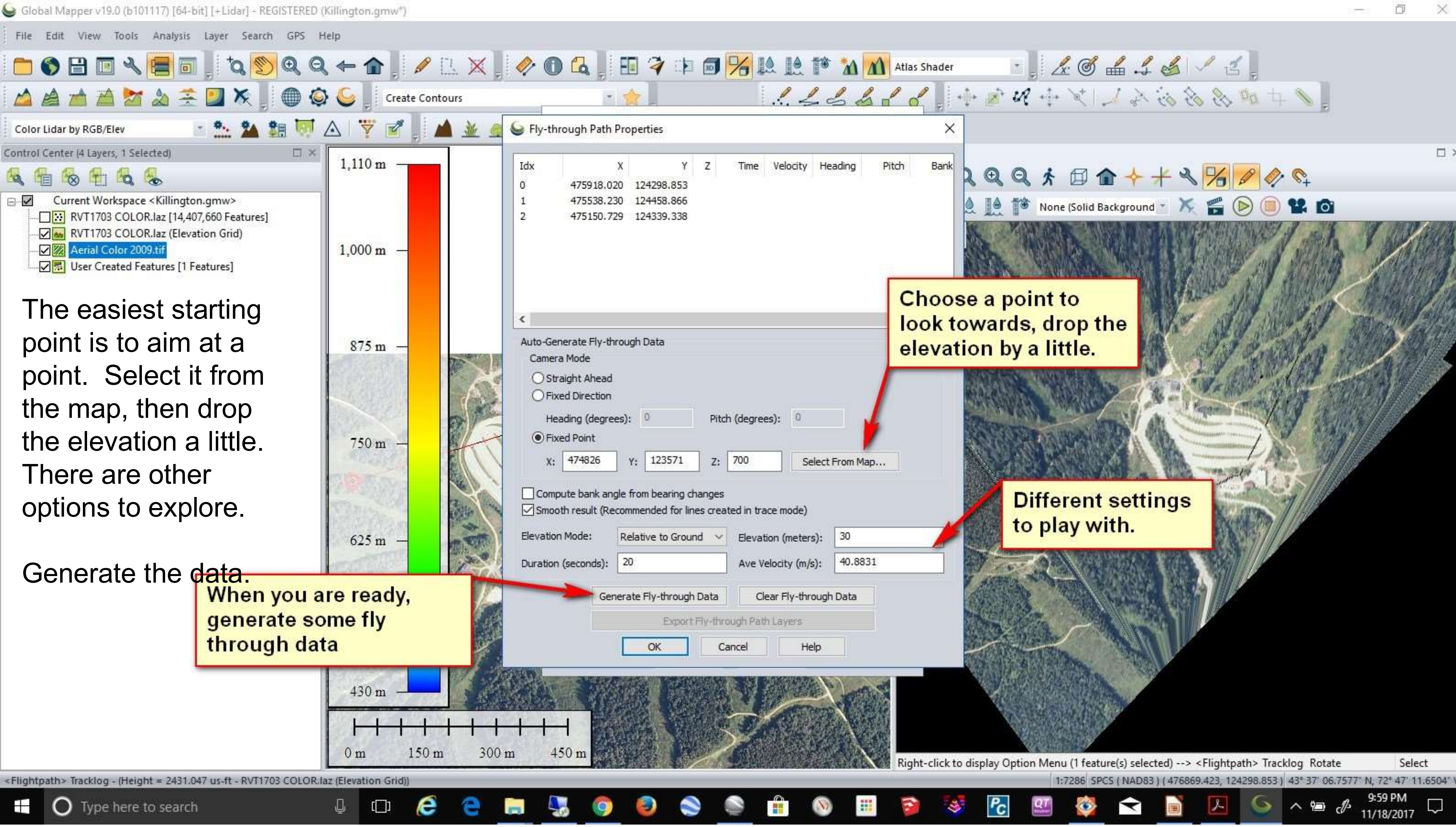


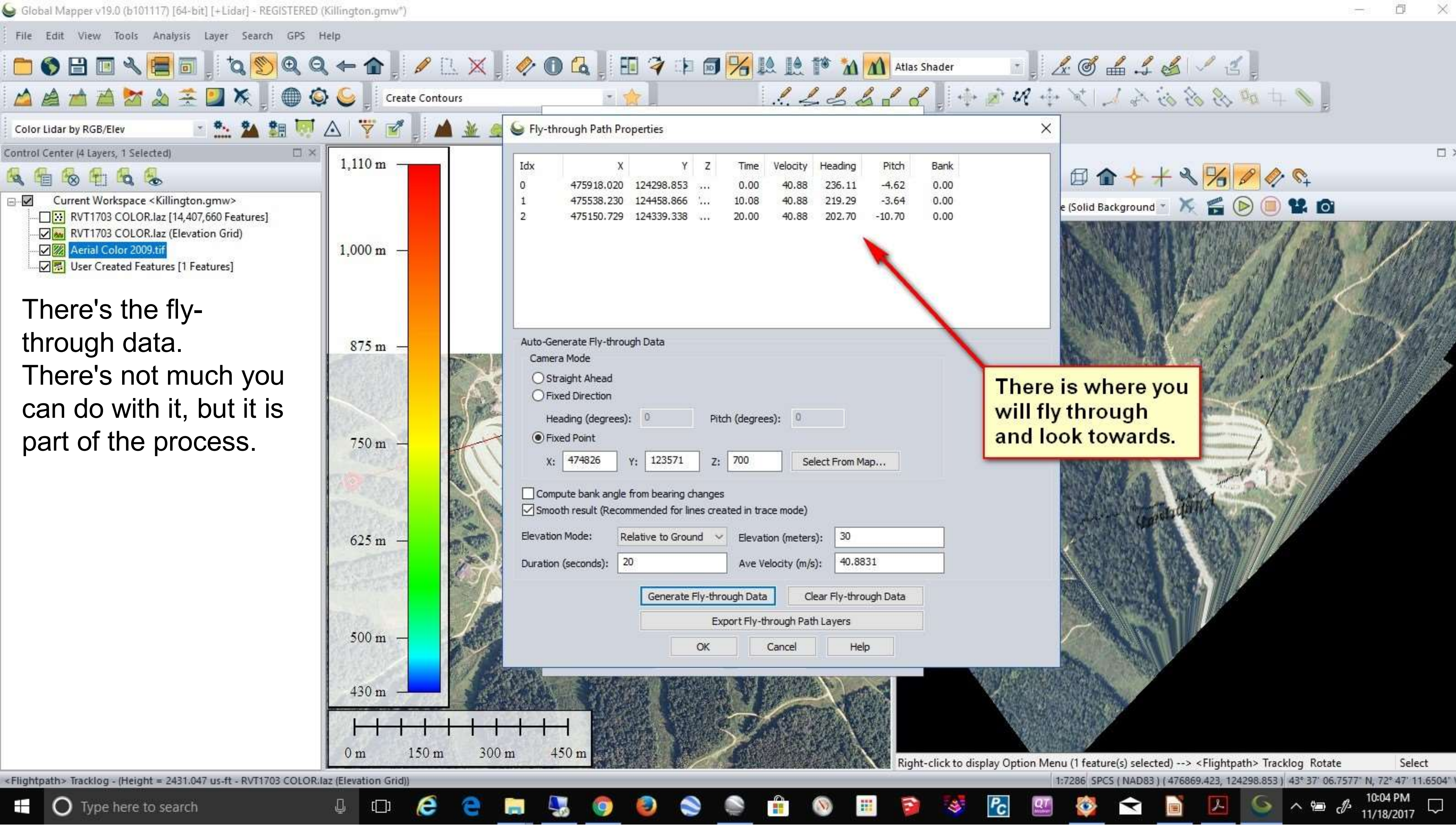
Draw a line in the plan view. The feature type really does not matter. Add the name flightpath.

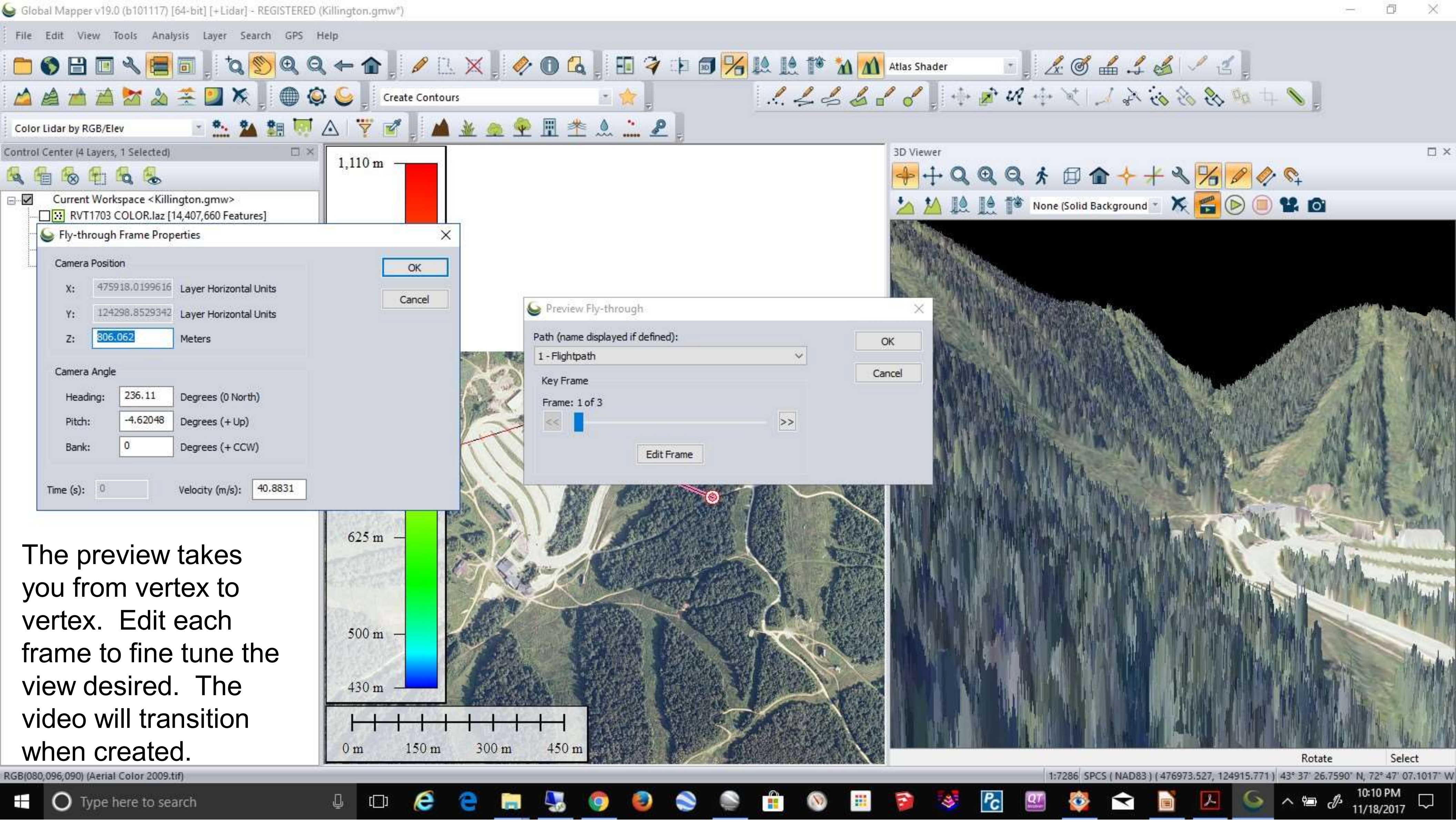

Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED (Killington.gmw*)
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Contours
Color Lidar by RGB/Elev
Control Center (4 Layers, 1 Selected)
Current Workspace <Killington.gmw>
RVT1703 COLOR.laz [14,407,660 Features]
RVT1703 COLOR.laz (Elevation Grid)
Aerial Color 2009.tif
User Created Features [2 Features]
In the 3-d view select the Edit Path tool. Double Click on the flightpath in the Plan.
1,110 m
1,000 m
875 m
750 m
625 m
500 m
430 m
0 m
150 m
300 m
450 m
3D Viewer
None (Solid Background
Select Mode
Edit path
Edit Fly-through path
Right-click to display Option Menu (1 feature(s) selected)
Rotate
Select
Left Click to Start New Line [Tracklog], Right Click or Esc to Cancel --> Height = 2549.974 us-ft, RGB(036,051,070) (Aerial Color 2009.tif)
1:7286 SPCS (NAD83) (476635.187, 124724.912) 43° 37' 20.5368" N, 72° 47' 22.1637" W
Type here to search
9:52 PM
11/18/2017



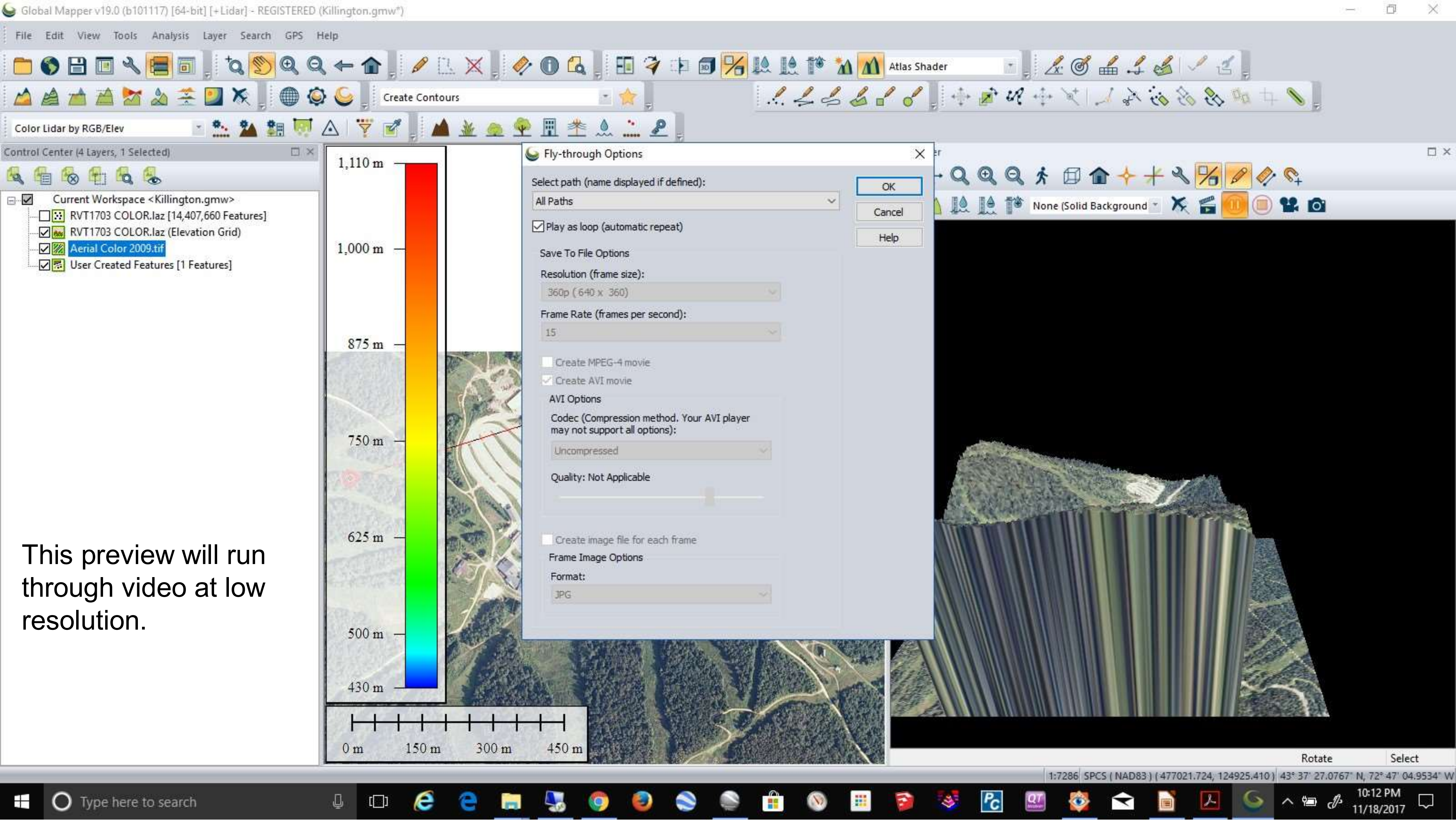
Click on the Edit Fly-Through Path.


The easiest starting point is to aim at a point. Select it from the map, then drop the elevation a little. There are other options to explore.
Generate the data.
When you are ready, generate some fly through data
Choose a point to look towards, drop the elevation by a little.
Different settings to play with.
Fly-through Path Properties
Idx X Y Z Time Velocity Heading Pitch Bank
0 475918.020 124298.853
1 475538.230 124458.866
2 475150.729 124339.338
Auto-Generate Fly-through Data
Camera Mode
Straight Ahead
Fixed Direction
Heading (degrees): 0
Pitch (degrees): 0
Fixed Point
X: 474826
Y: 123571
Z: 700
Select From Map...
Compute bank angle from bearing changes
Smooth result (Recommended for lines created in trace mode)
Elevation Mode: Relative to Ground
Elevation (meters): 30
Duration (seconds): 20
Ave Velocity (m/s): 40.8831
Generate Fly-through Data
Clear Fly-through Data
Export Fly-through Path Layers
OK
Cancel
Help

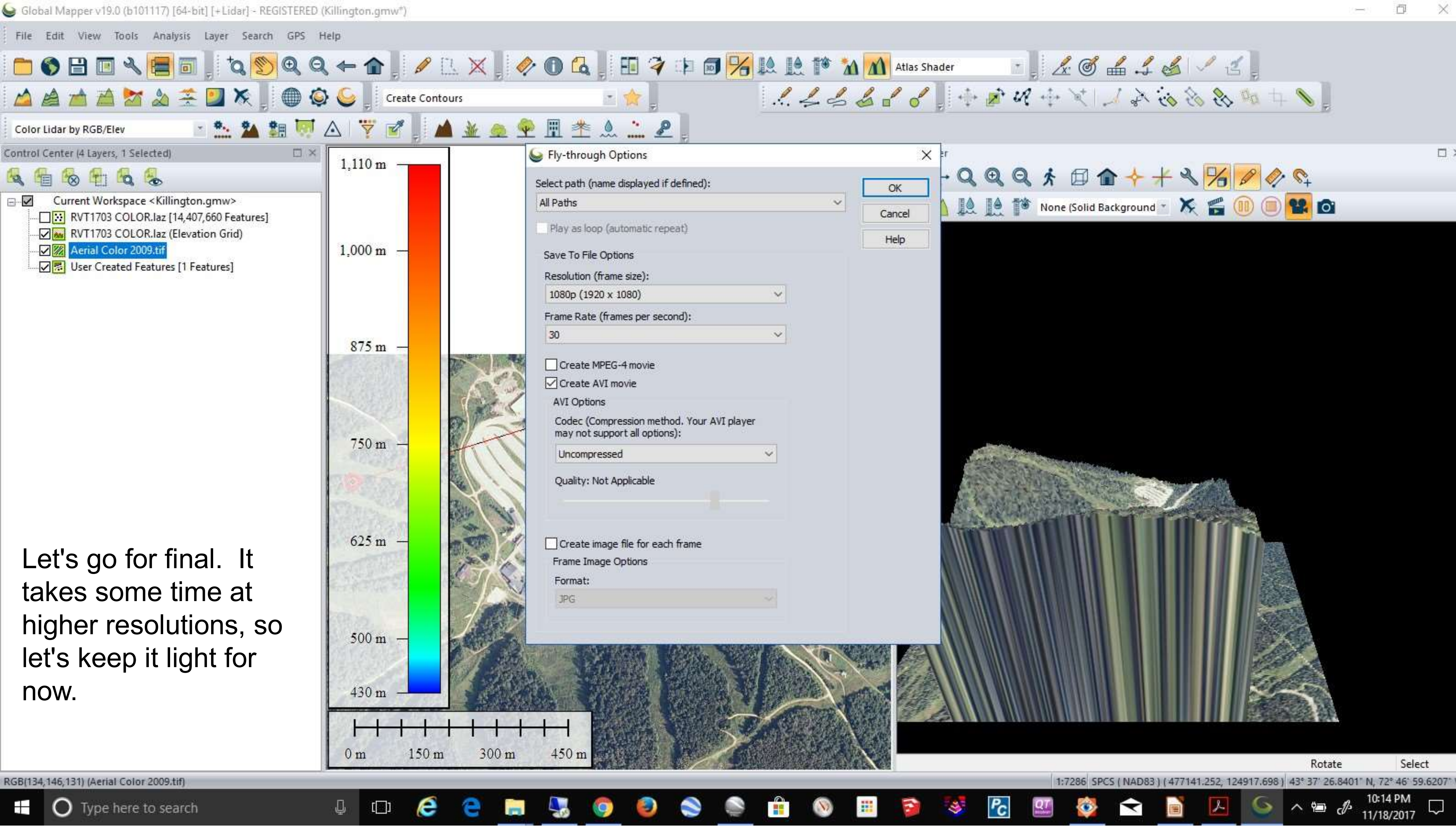

There's the fly-through data. There's not much you can do with it, but it is part of the process.
There is where you will fly through and look towards.
Fly-through Path Properties
Idx X Y Z Time Velocity Heading Pitch Bank
0 475918.020 124298.853 ... 0.00 40.88 236.11 -4.62 0.00
1 475538.230 124458.866 ... 10.08 40.88 219.29 -3.64 0.00
2 475150.729 124339.338 ... 20.00 40.88 202.70 -10.70 0.00
Auto-Generate Fly-through Data
Camera Mode
Straight Ahead
Fixed Direction
Heading (degrees):
Pitch (degrees):
Fixed Point
X: 474826 Y: 123571 Z: 700
Select From Map...
Compute bank angle from bearing changes
Smooth result (Recommended for lines created in trace mode)
Elevation Mode: Relative to Ground
Elevation (meters): 30
Duration (seconds): 20
Ave Velocity (m/s): 40.8831
Generate Fly-through Data
Clear Fly-through Data
Export Fly-through Path Layers
OK
Cancel
Help



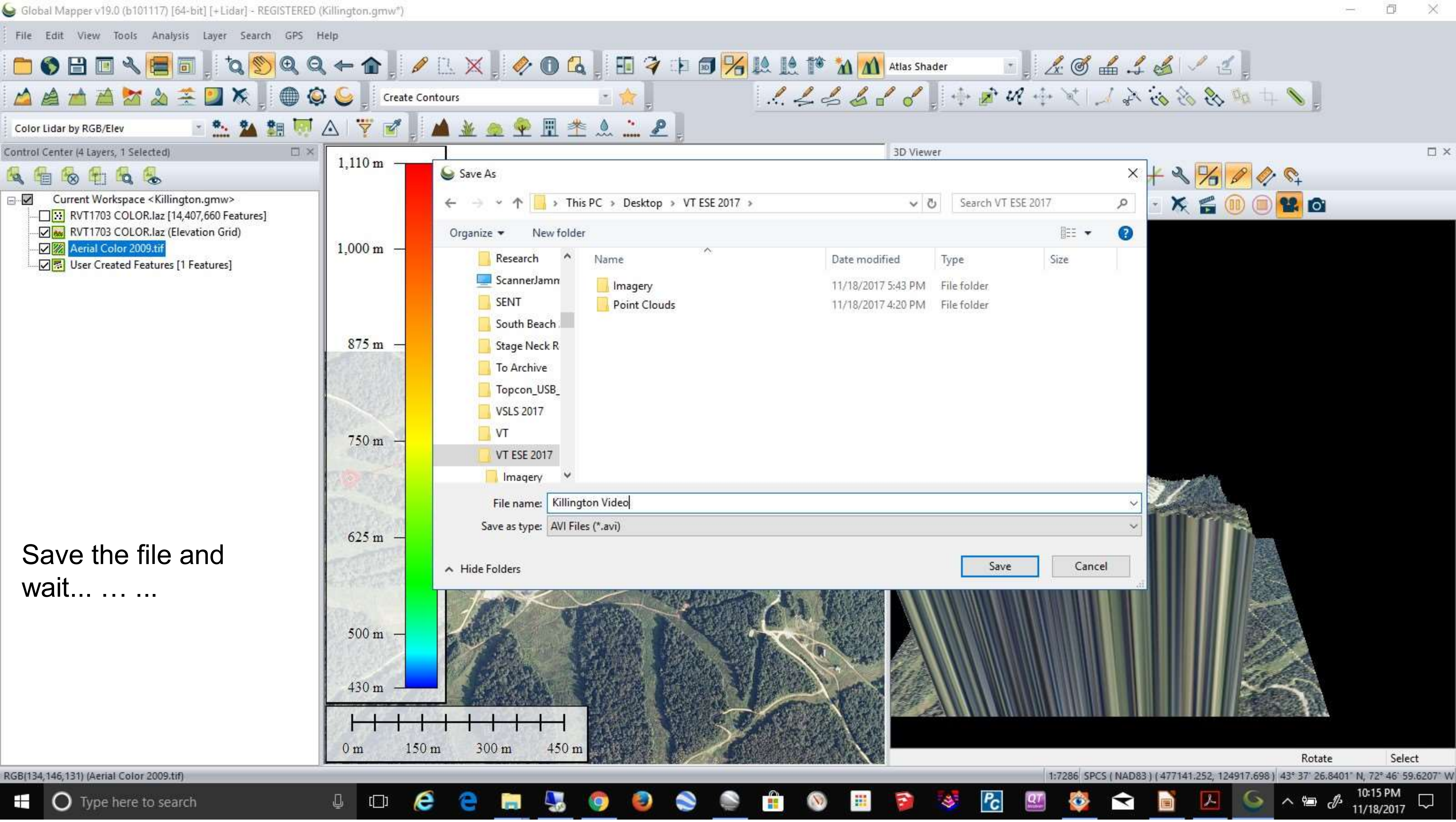
The preview takes you from vertex to vertex. Edit each frame to fine tune the view desired. The video will transition when created.



This preview will run through video at low resolution.



Let's go for final. It takes some time at higher resolutions, so let's keep it light for now.



Save the file and wait... … ...

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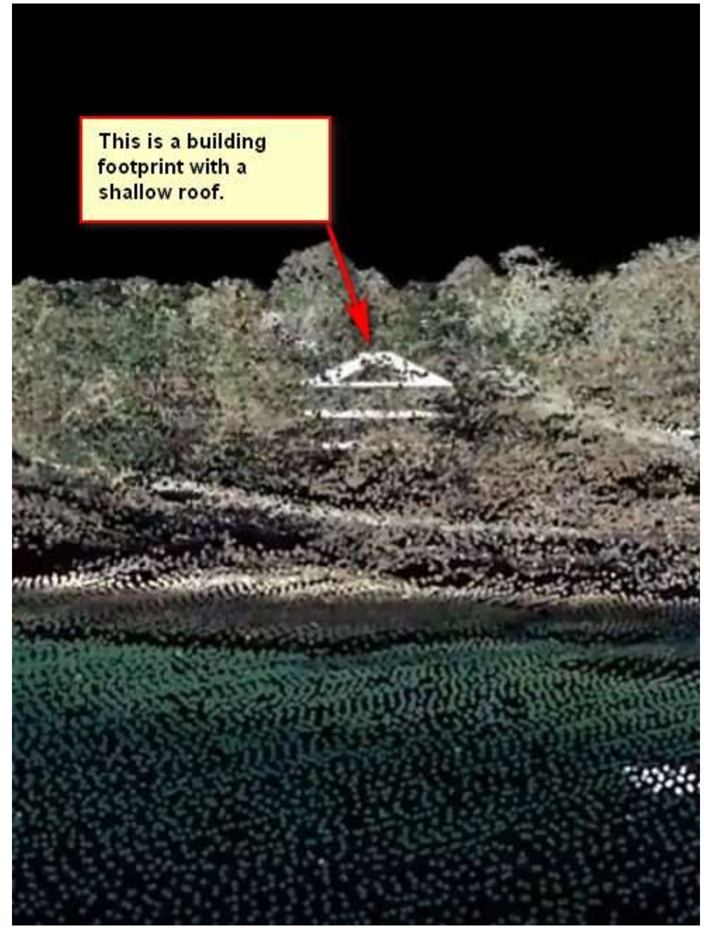
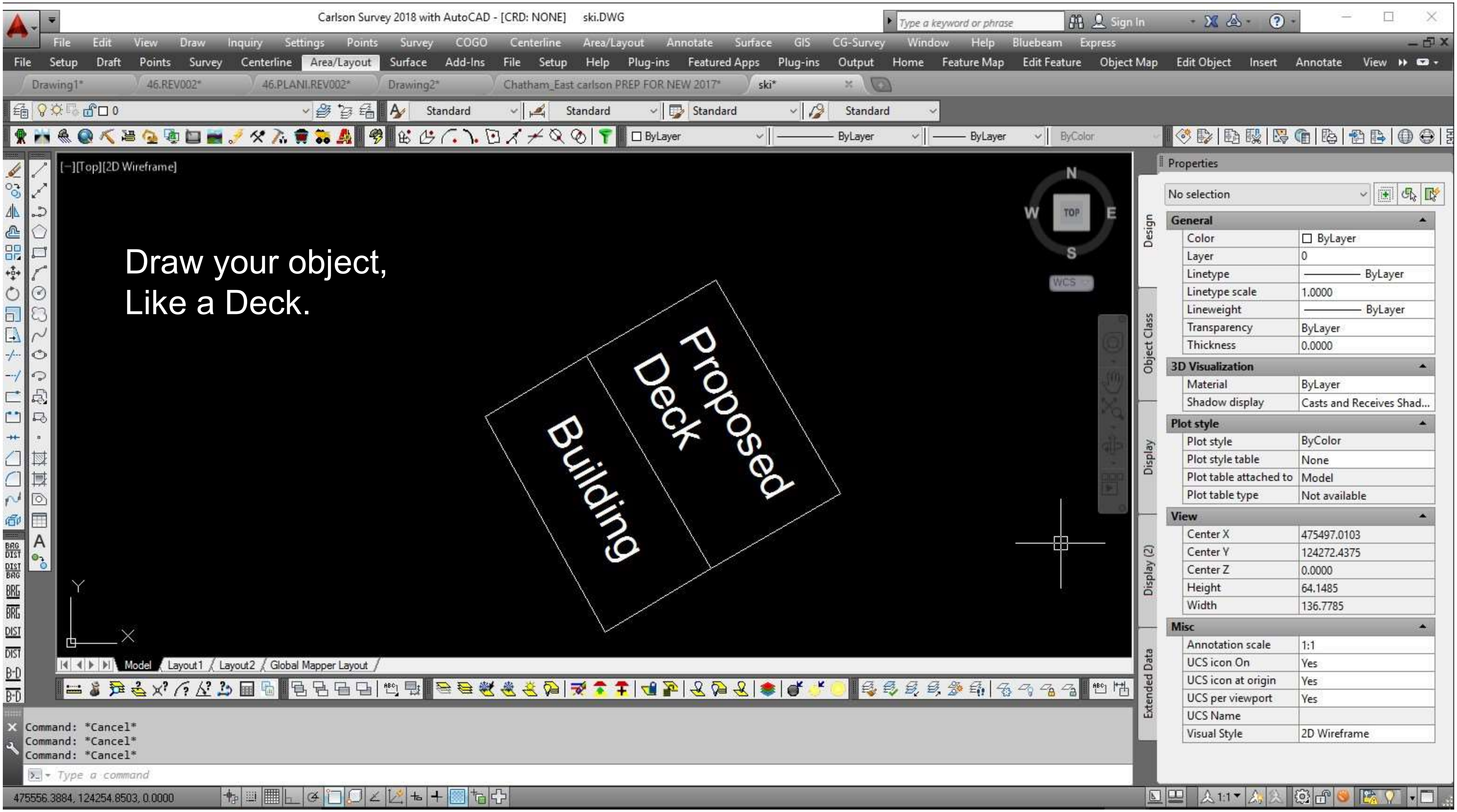
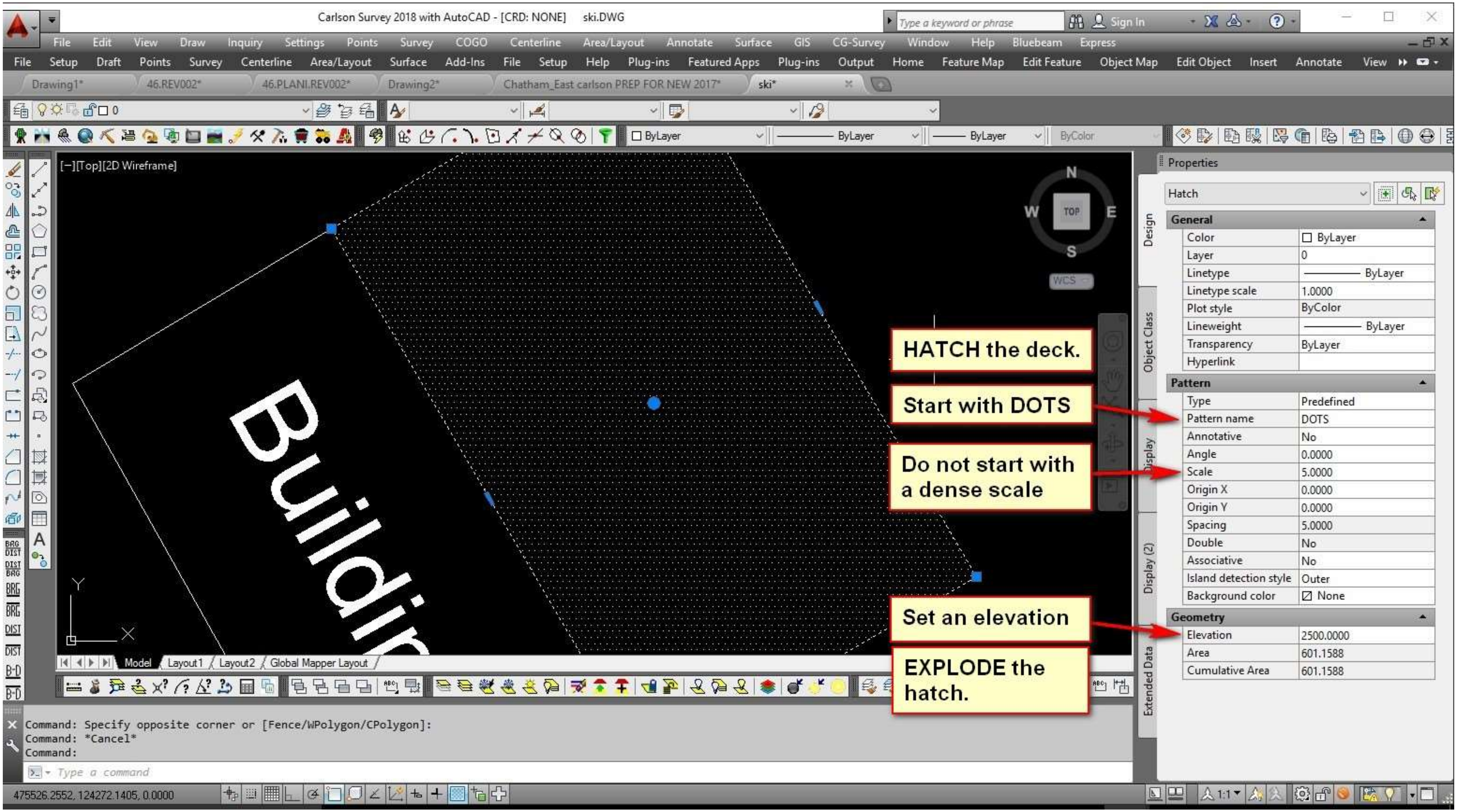
Data Extraction

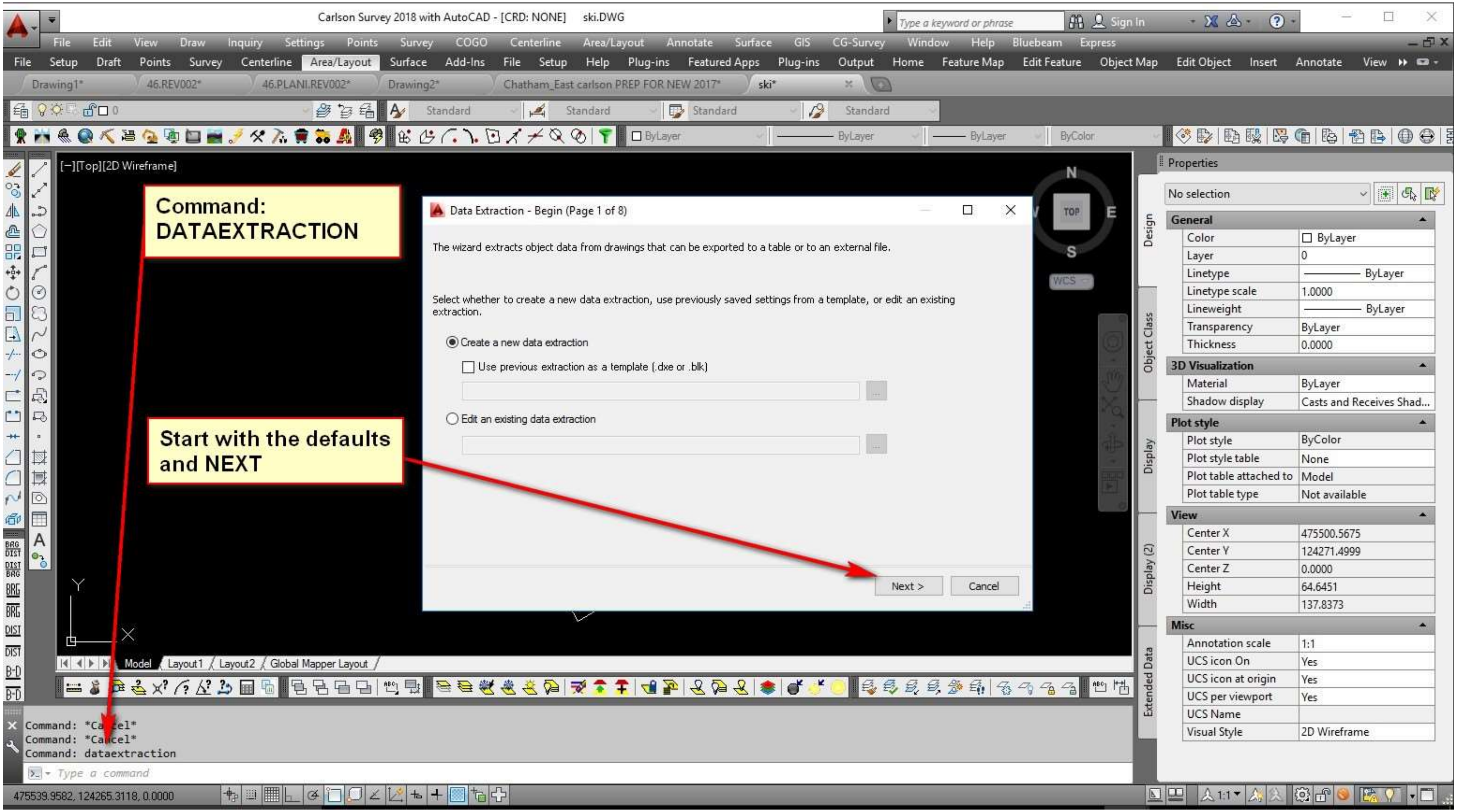
I often would like to get something from CAD into the cloud. How about a conceptual building footprint in 3-d?
Create some dense dot hatches in CAD at specific elevations. You can also offset polylines with elevation (Offset 3d Polyline in Carlson). Explode the hatches and run DENSEPL in Carlson, then explode the polylines.
Now you need AutoDesk and the DATAEXTRACTION function. After about 8 screens of questions it will export a CSV with NEZ values for the endpoints of every line. (The exploded dots are just lines).

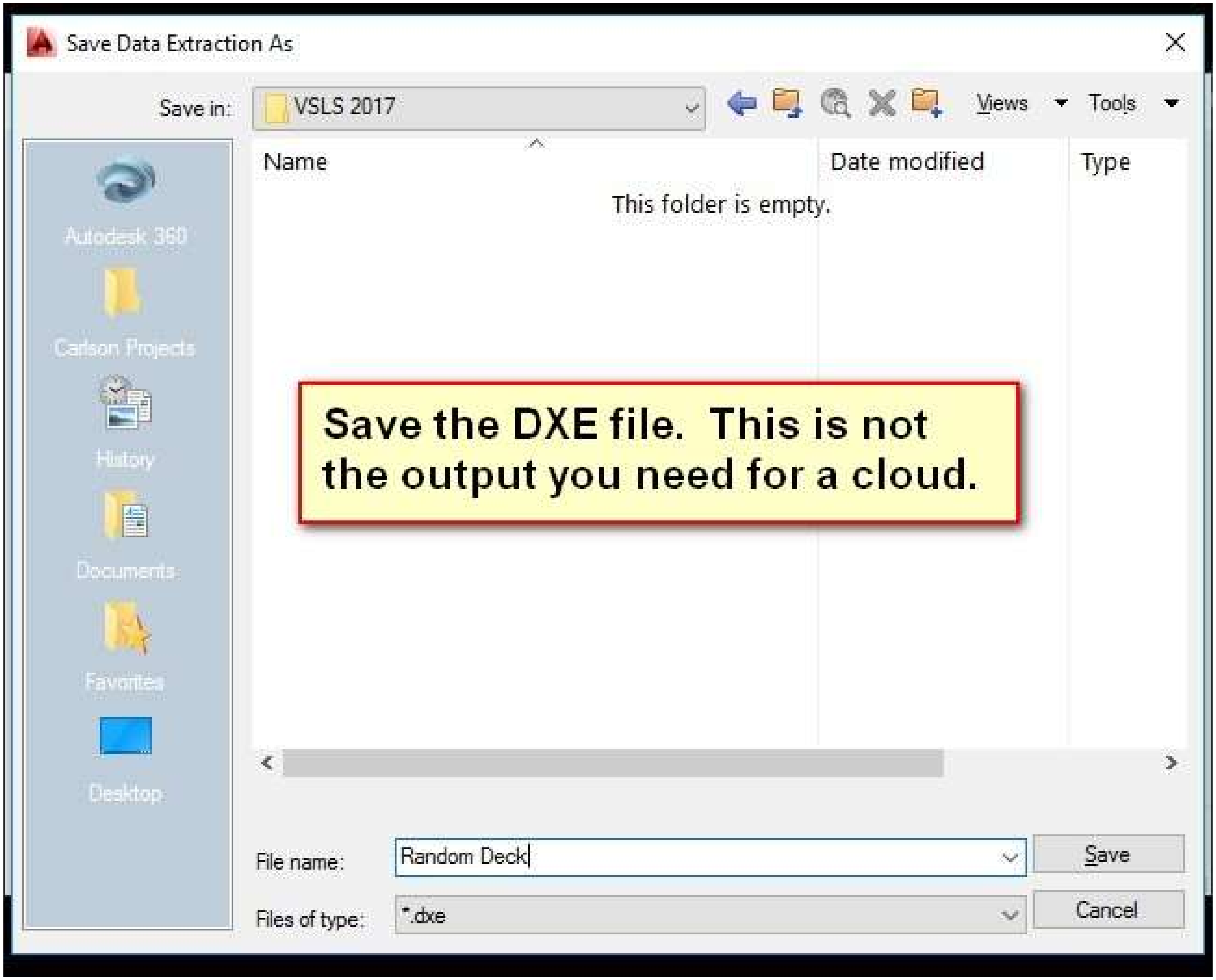
	A	B	C	D
1	End X	End Y	End Z	
2	1076370.500	2703677.700	63.00	
3	1076369.800	2703677.000	63.00	
4	1076369.100	2703676.300	63.00	
5	1076371.300	2703678.400	63.00	
6	1076373.400	2703680.500	63.00	

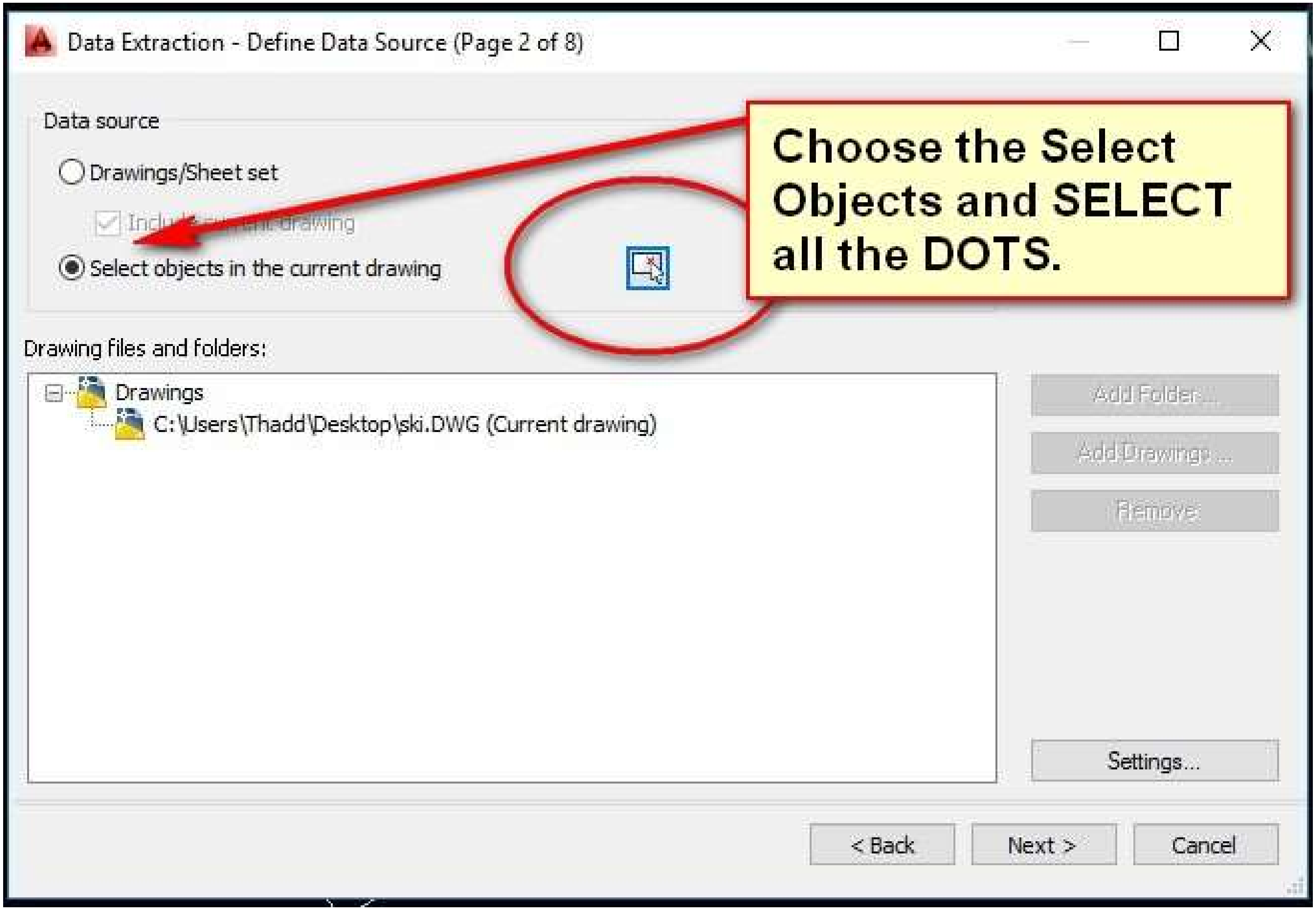


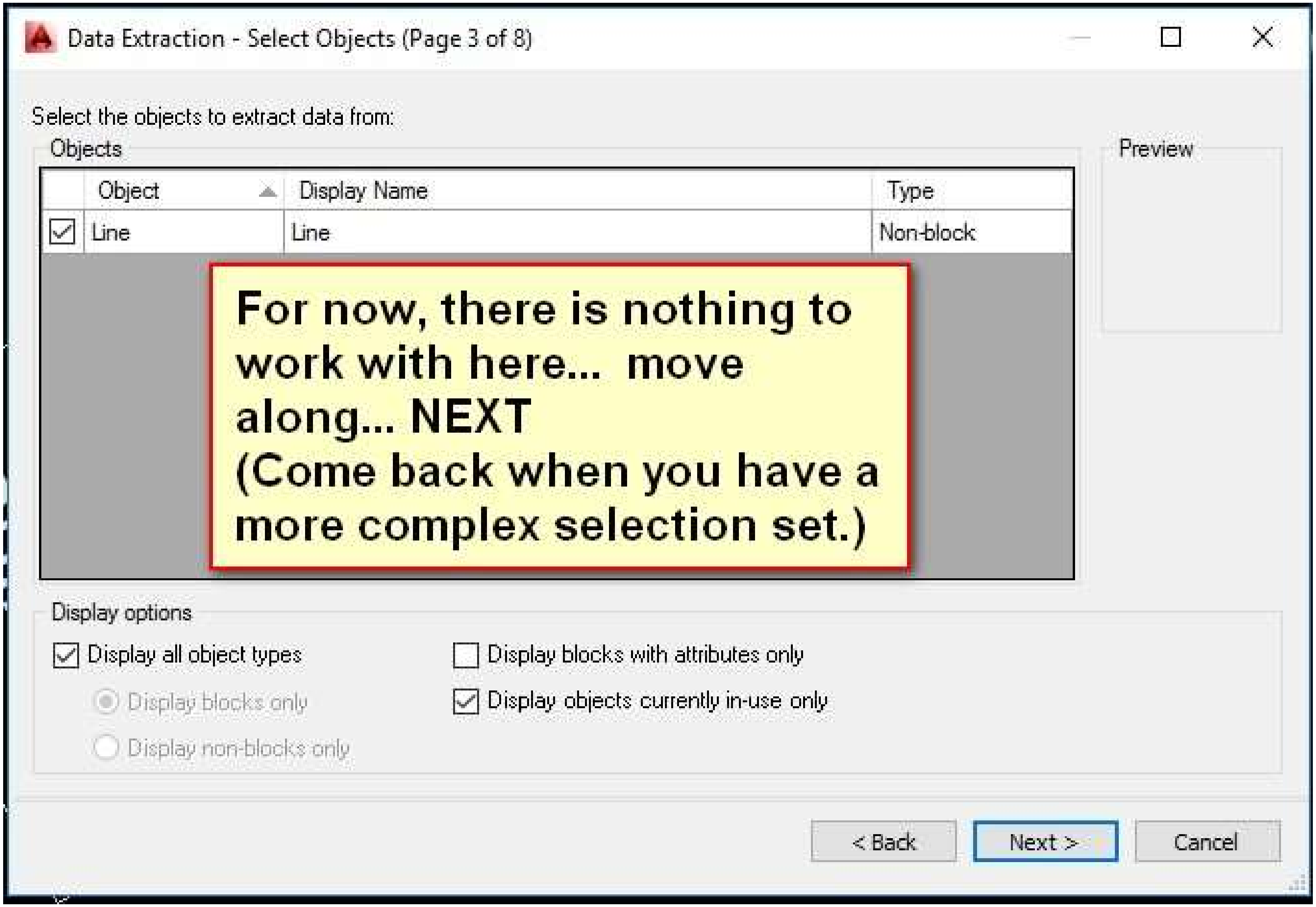

Carlson Survey 2018 with AutoCAD - [CRD: NONE] ski.DWG
Draw your object,
Like a Deck.
Proposed
Deck
Building
Properties
No selection
Command: *Cancel*
Command: *Cancel*
Command: *Cancel*


Carlson Survey 2018 with AutoCAD - [CRD: NONE] ski.DWG
HATCH the deck.
Start with DOTS
Do not start with a dense scale
Set an elevation
EXPLODE the hatch.
Pattern name DOTS
Scale 5.0000
Elevation 2500.0000
Command: Specify opposite corner or [Fence/WPolygon/CPolygon]:
Command: *Cancel*
Command:

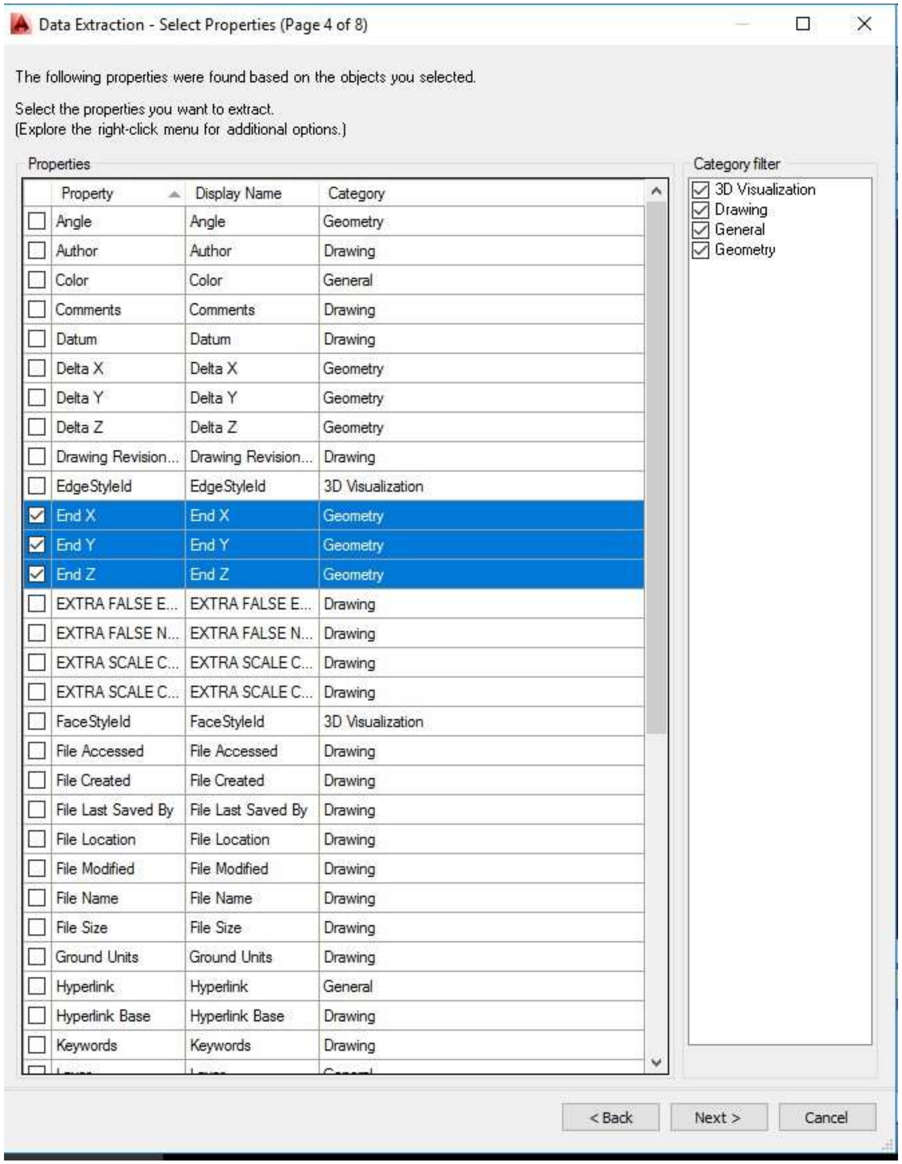

Command:
DATAEXTRACTION
Start with the defaults and NEXT
Data Extraction - Begin (Page 1 of 8)
The wizard extracts object data from drawings that can be exported to a table or to an external file.
Select whether to create a new data extraction, use previously saved settings from a template, or edit an existing extraction.
Create a new data extraction
Use previous extraction as a template (.dxe or .blk)
Edit an existing data extraction
Next >
Cancel
Command: *Cancel*
Command: *Cancel*
Command: dataextraction

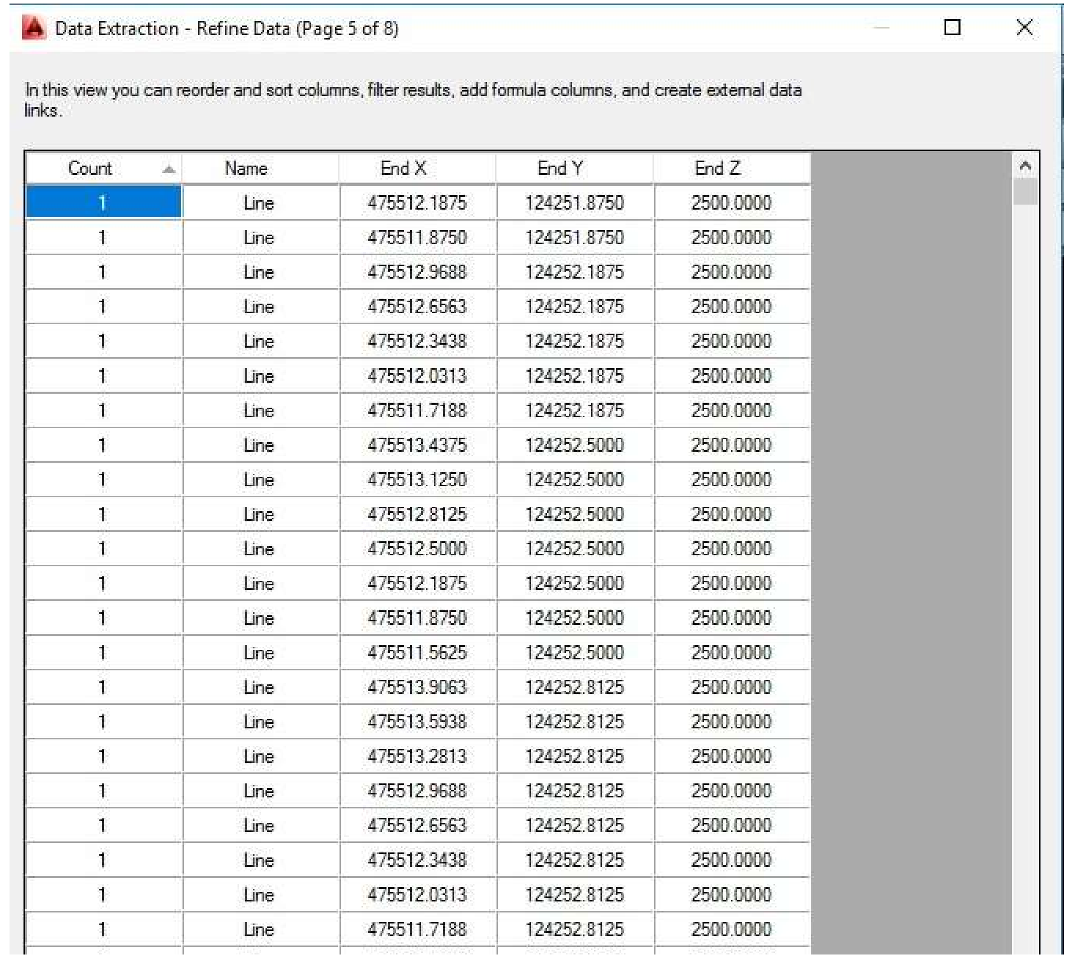

Save Data Extraction As
Save in:
VSLS 2017
Views
Tools
Autodesk 360
Carlson Projects
History
Documents
Favorites
Desktop
Name
Date modified
Type
This folder is empty.
Save the DXE file. This is not the output you need for a cloud.
File name:
Random Deck
Files of type:
*.dxe
Save
Cancel


Data Extraction - Define Data Source (Page 2 of 8)
Data source
Drawings/Sheet set
Include current drawing
Select objects in the current drawing
Choose the Select Objects and SELECT all the DOTS.
Drawing files and folders:
Drawings
C:\Users\Thadd\Desktop\ski.DWG (Current drawing)
Add Folder...
Add Drawings...
Remove
Settings...
< Back
Next >
Cancel

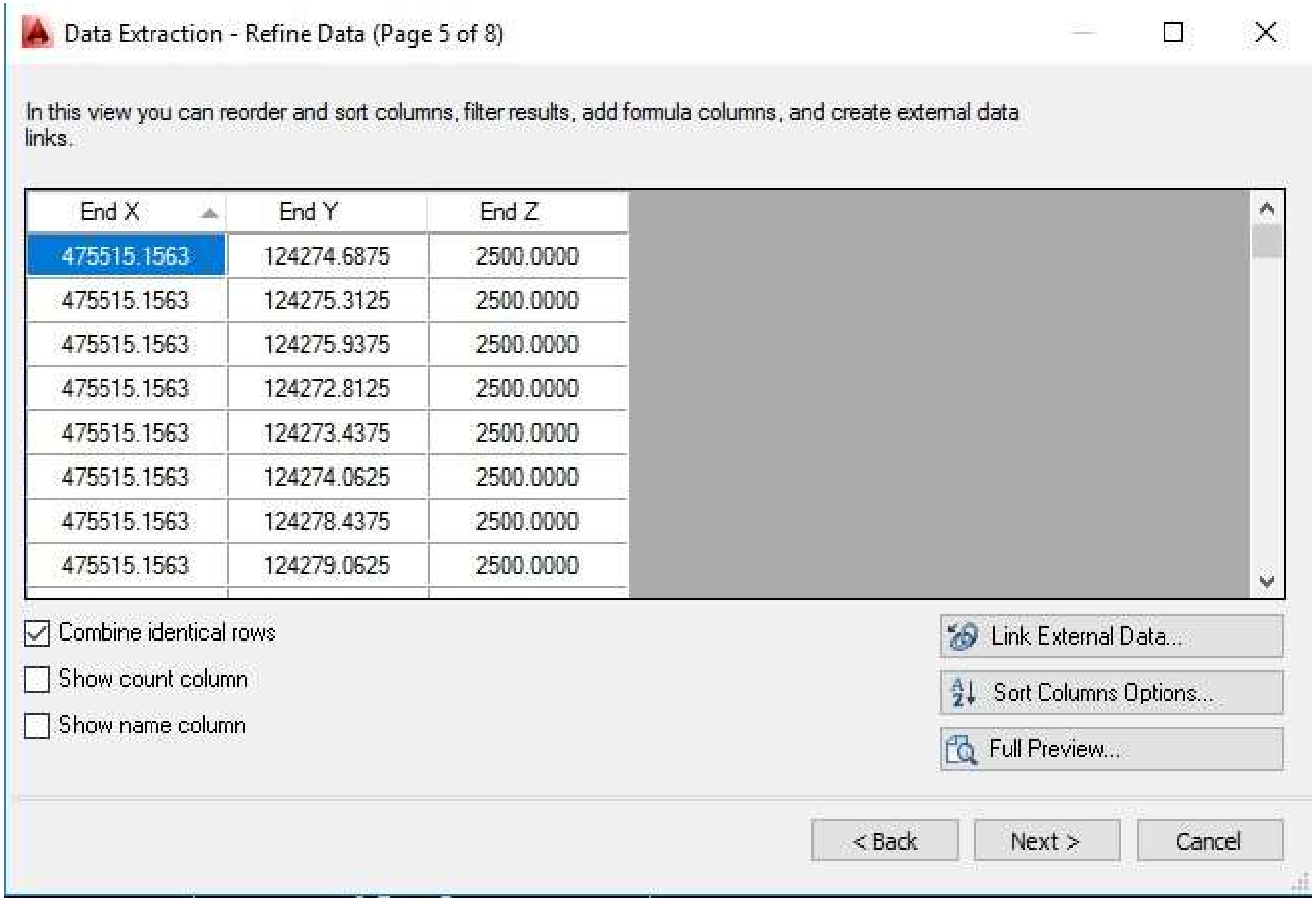

Data Extraction - Select Objects (Page 3 of 8)
Select the objects to extract data from:
Objects
Preview
Object
Display Name
Type
Line
Line
Non-block
For now, there is nothing to work with here... move along... NEXT
(Come back when you have a more complex selection set.)
Display options
Display all object types
Display blocks only
Display non-blocks only
Display blocks with attributes only
Display objects currently in-use only
< Back
Next >
Cancel

So many options. The exploded points are 0 length lines. Choose the start point or the end point. It will provide some data and an XYZ for every point.

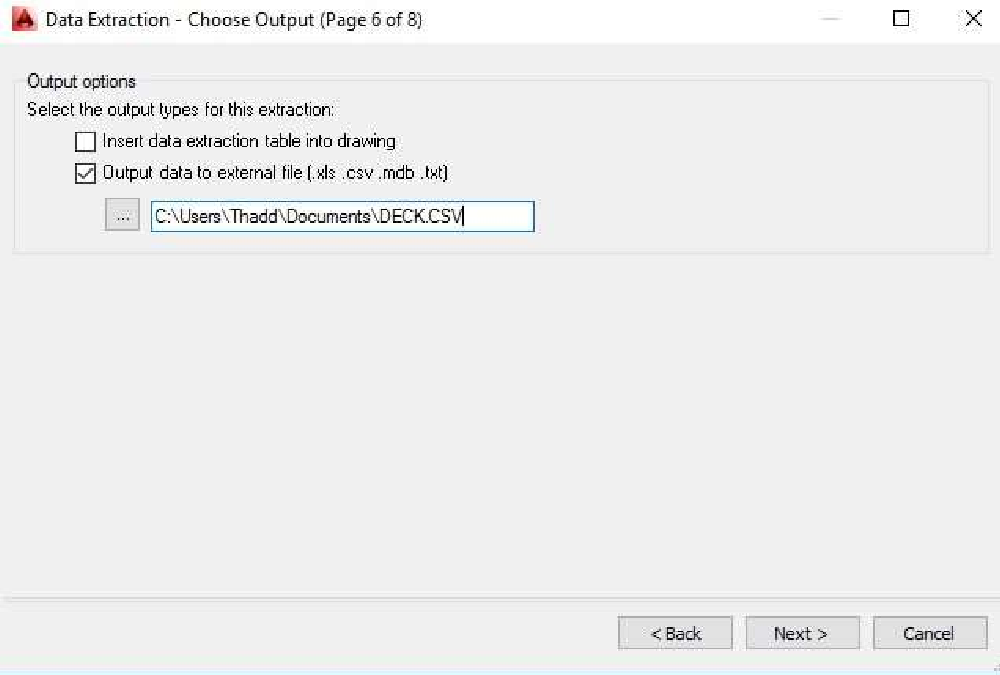




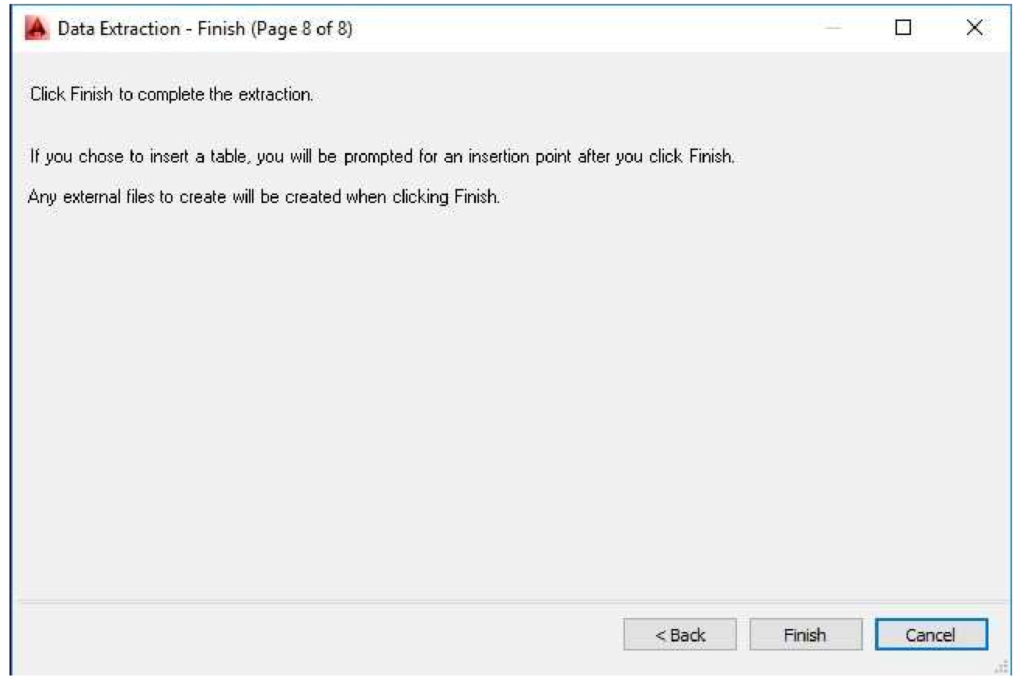
Count	Name	End X	End Y	End Z
1	Line	475512.1875	124251.8750	2500.0000
1	Line	475511.8750	124251.8750	2500.0000
1	Line	475512.9688	124252.1875	2500.0000
1	Line	475512.6563	124252.1875	2500.0000
1	Line	475512.3438	124252.1875	2500.0000
1	Line	475512.0313	124252.1875	2500.0000
1	Line	475511.7188	124252.1875	2500.0000
1	Line	475513.4375	124252.5000	2500.0000
1	Line	475513.1250	124252.5000	2500.0000
1	Line	475512.8125	124252.5000	2500.0000
1	Line	475512.5000	124252.5000	2500.0000
1	Line	475512.1875	124252.5000	2500.0000
1	Line	475511.8750	124252.5000	2500.0000
1	Line	475511.5625	124252.5000	2500.0000
1	Line	475513.9063	124252.8125	2500.0000
1	Line	475513.5938	124252.8125	2500.0000
1	Line	475513.2813	124252.8125	2500.0000
1	Line	475512.9688	124252.8125	2500.0000
1	Line	475512.6563	124252.8125	2500.0000
1	Line	475512.3438	124252.8125	2500.0000
1	Line	475512.0313	124252.8125	2500.0000
1	Line	475511.7188	124252.8125	2500.0000



The lower options allow for the removal of the COUNT and the NAME. This leaves you with the points.

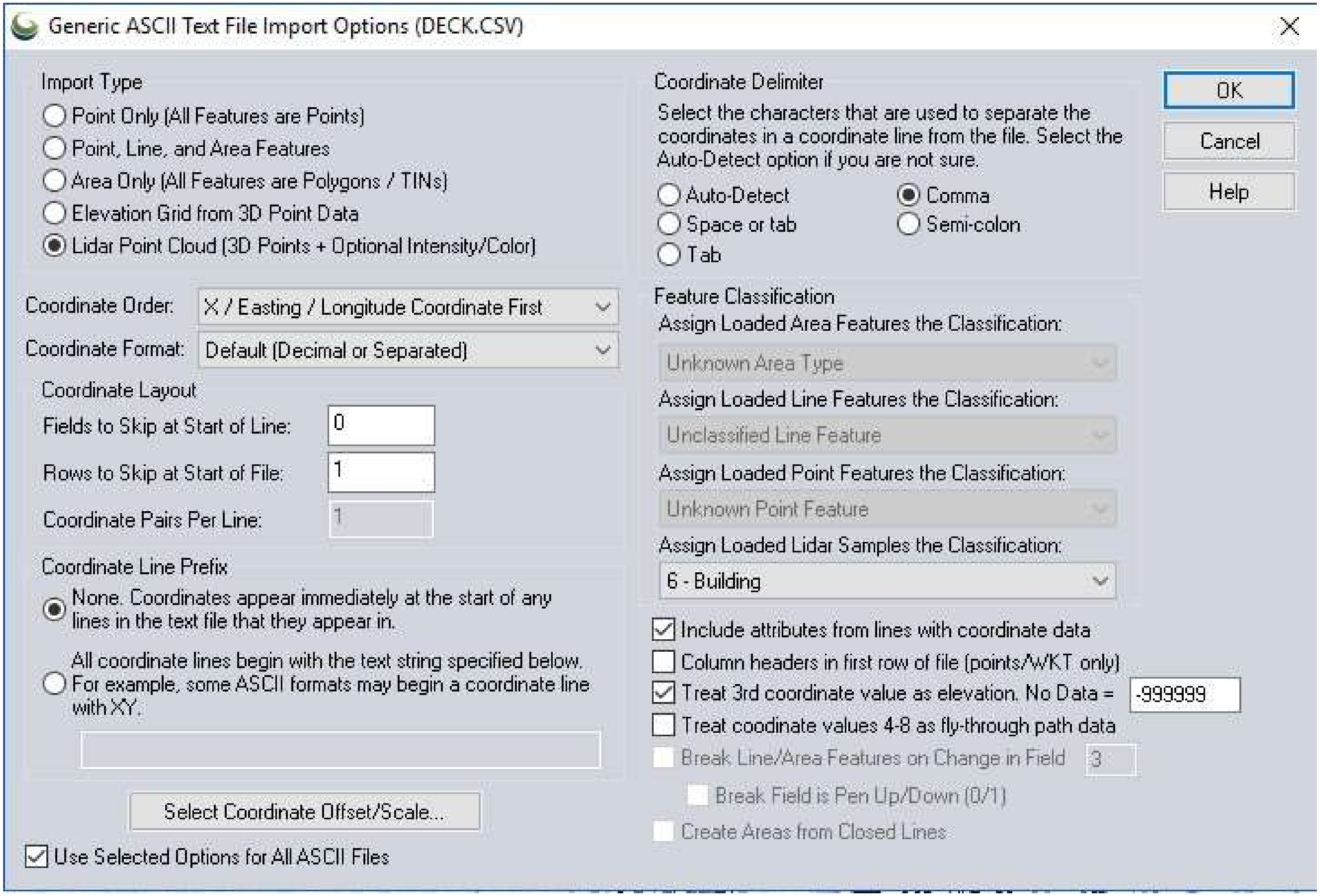


Extract the data to a CSV and blast through the finish screen.



```
End X,End Y,End ZCRLF
475496.0394,124278.7208,0.0000CRLF
475496.2500,124278.7500,2500.0000CRLF
475496.4063,124278.4375,2500.0000CRLF
475496.5625,124278.7500,2500.0000CRLF
475496.5625,124278.1250,2500.0000CRLF
475496.7188,124279.0625,2500.0000CRLF
475496.7188,124278.4375,2500.0000CRLF
475496.7188,124277.8125,2500.0000CRLF
475496.8750,124278.7500,2500.0000CRLF
475496.8750,124278.1250,2500.0000CRLF
475496.8750,124277.5000,2500.0000CRLF
475497.0313,124278.4375,2500.0000CRLF
475497.0313,124279.0625,2500.0000CRLF
475497.0313,124277.1875,2500.0000CRLF
475497.0313,124277.8125,2500.0000CRLF
475497.1875,124278.7500,2500.0000CRLF
475497.1875,124279.3750,2500.0000CRLF
475497.1875,124278.1250,2500.0000CRLF
475497.1875,124276.8750,2500.0000CRLF
475497.1875,124277.5000,2500.0000CRLF
```

It's a bunch of points.



Drag and drop into Global Mapper. Take a look at the settings.

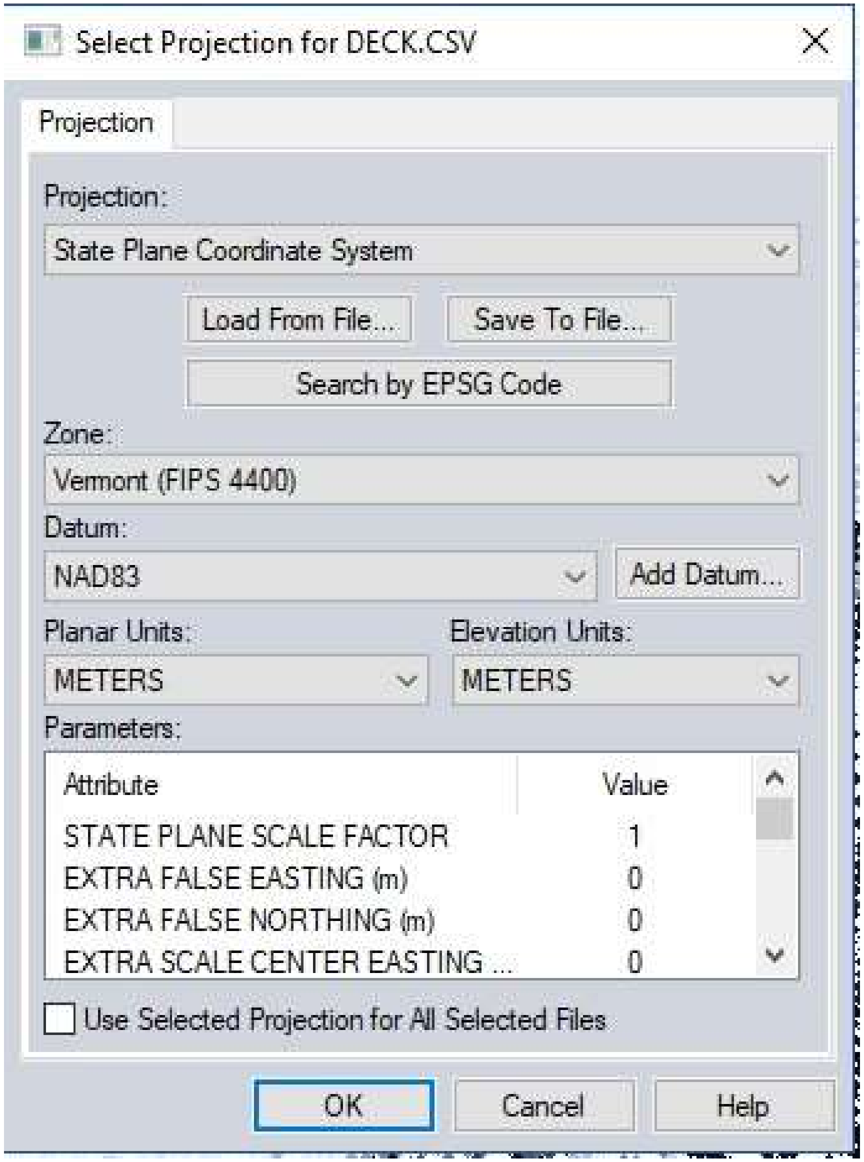
Import LiDAR points.

Coordinate order was exported X first...

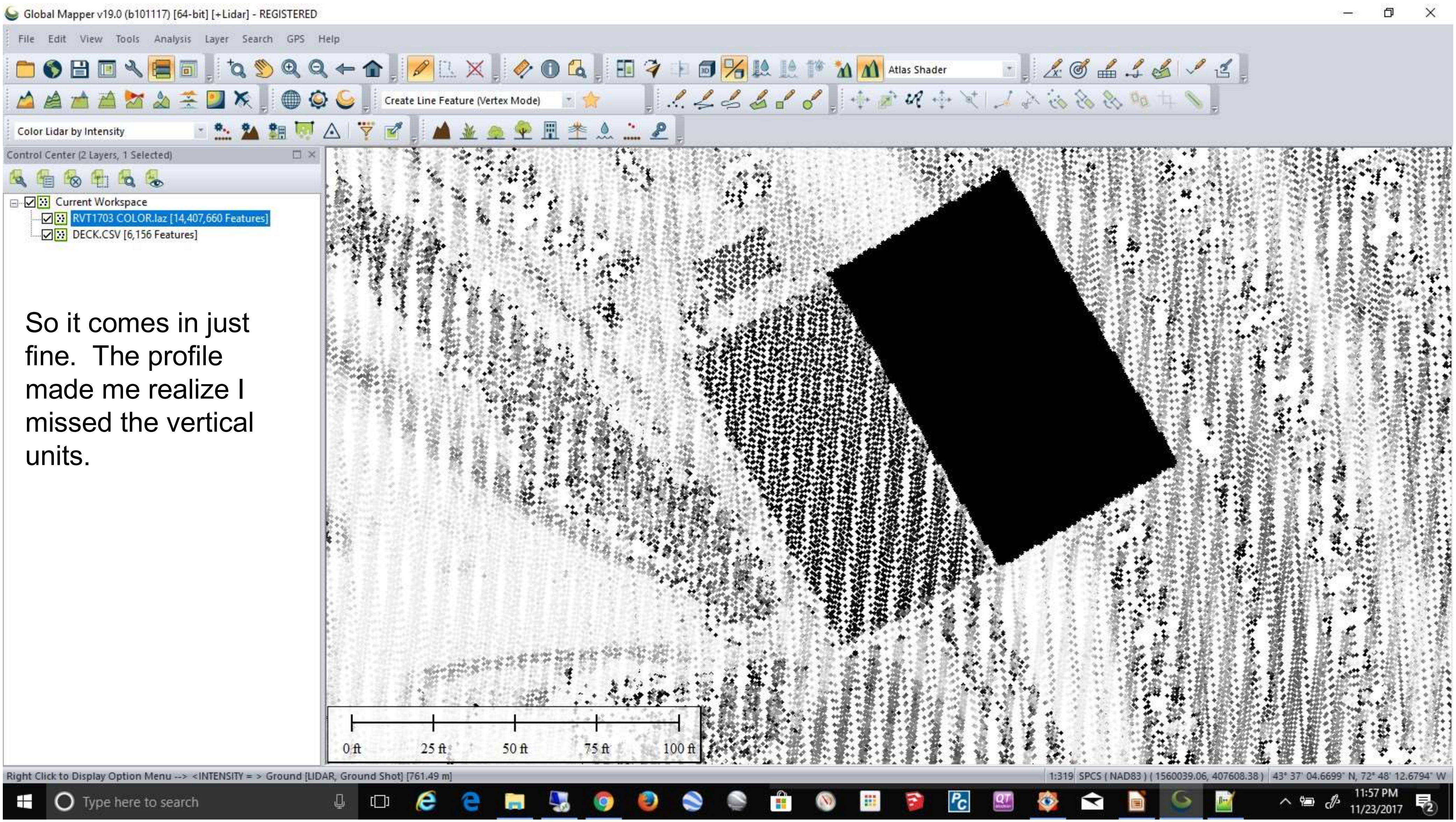
Skip the first row.

Comma delimiter.

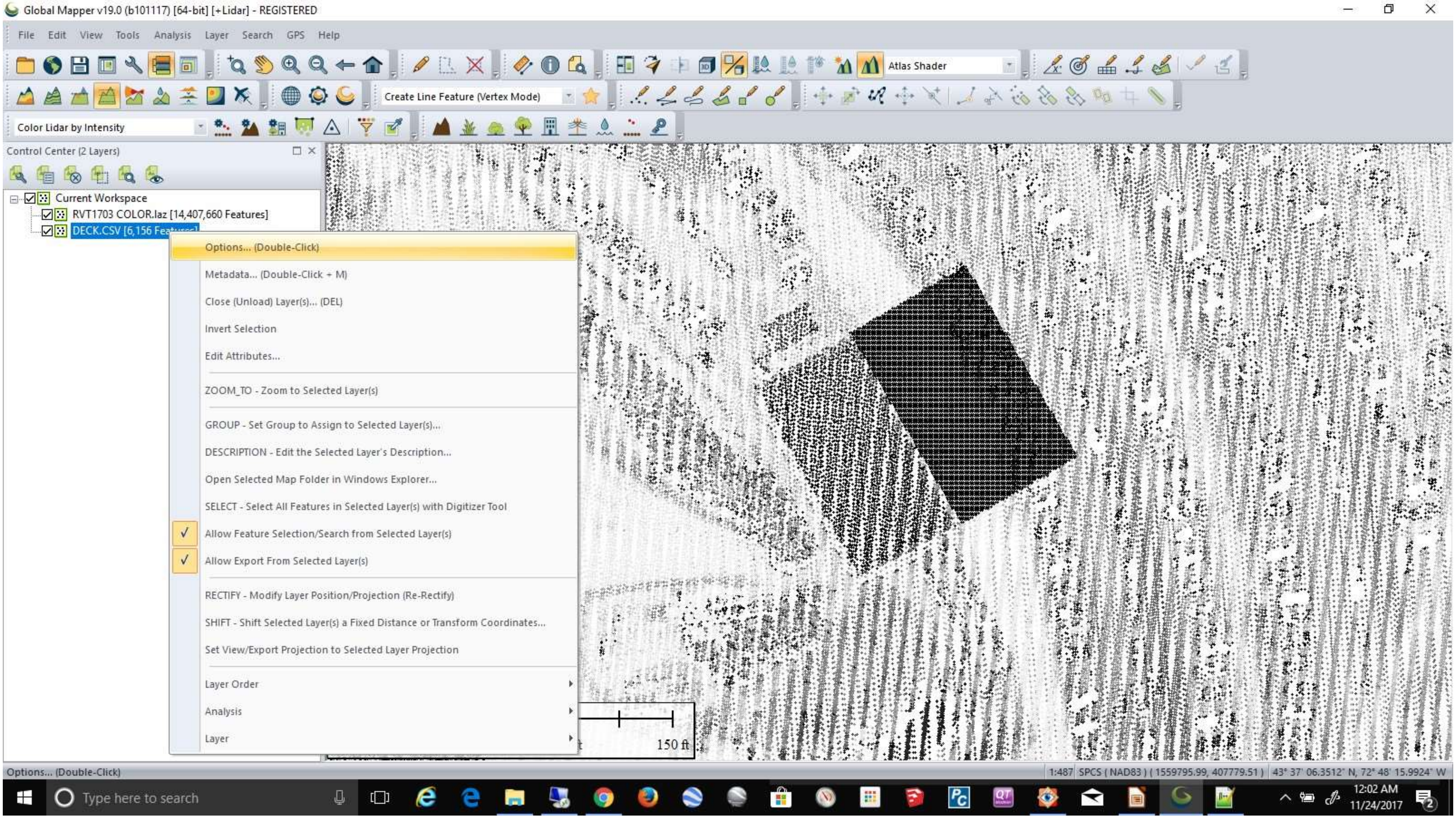
Classify to 6-Building.



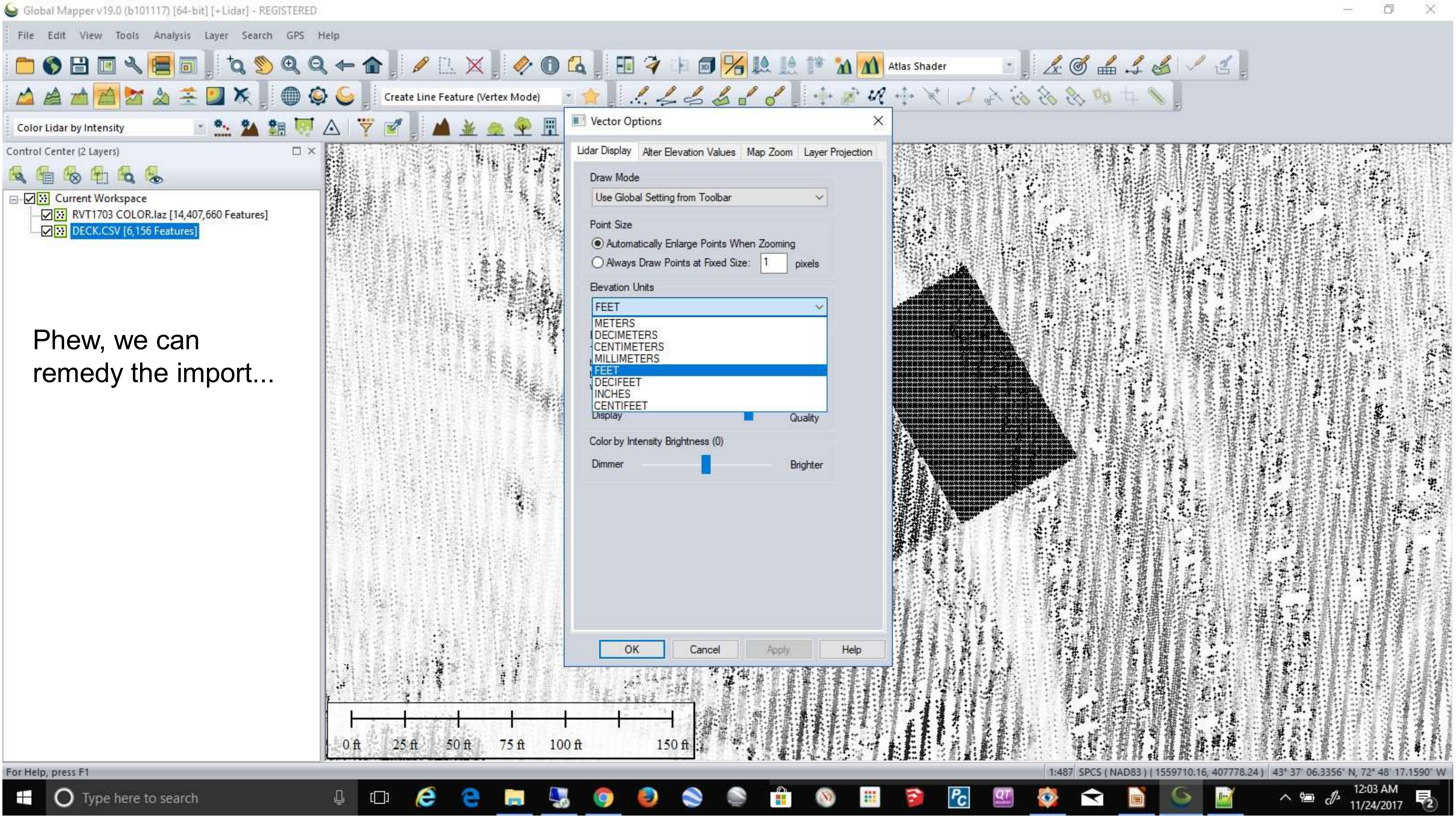
I went too fast... The vertical is in Feet and the Horizontal is in Meters. You can change it here, but I forgot...



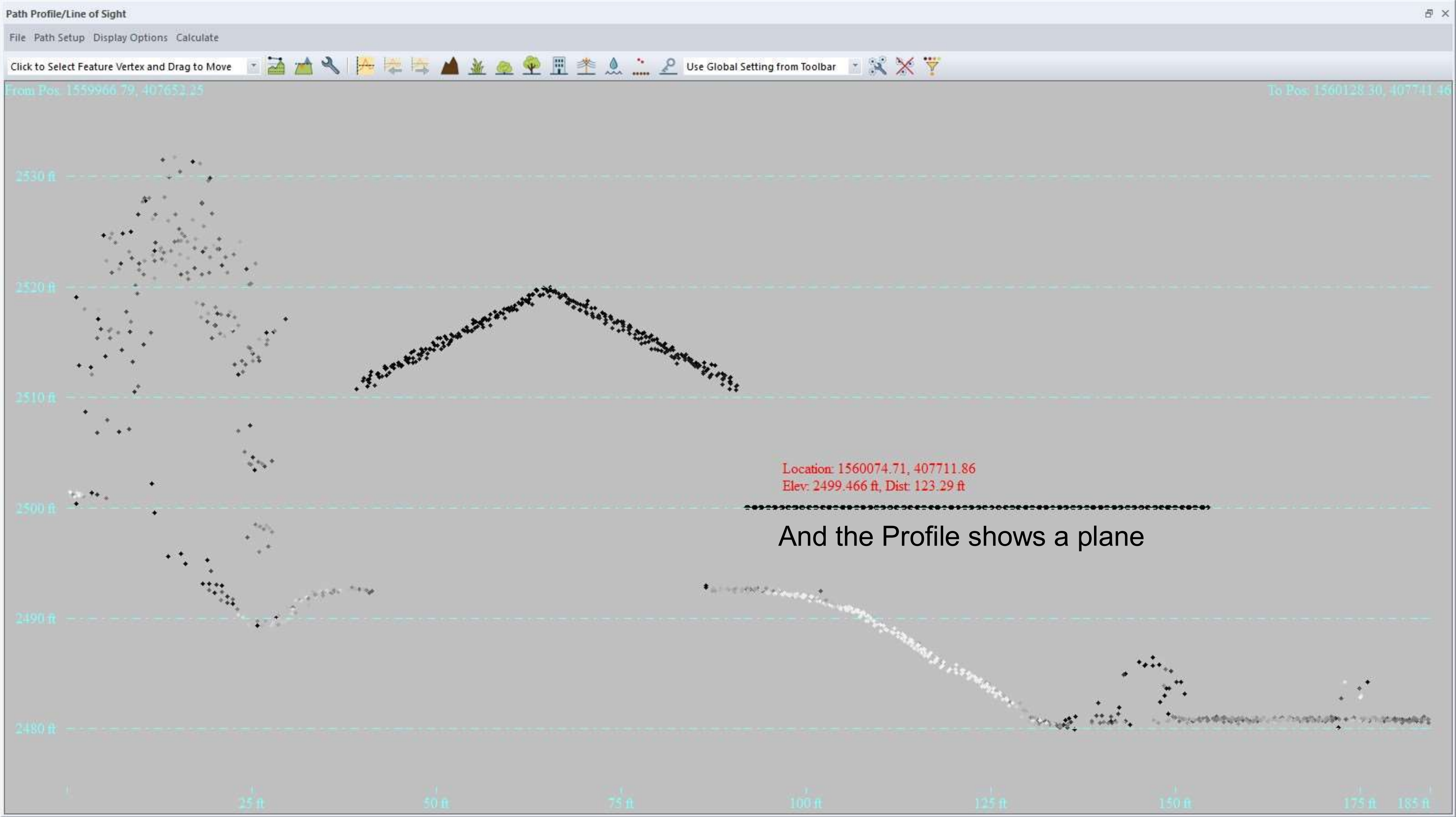
So it comes in just fine. The profile made me realize I missed the vertical units.



Global Mapper v19.0 (b101117) [64-bit] [+Lidar] - REGISTERED
File Edit View Tools Analysis Layer Search GPS Help
Atlas Shader
Create Line Feature (Vertex Mode)
Color Lidar by Intensity
Control Center (2 Layers)
Current Workspace
RVT1703 COLOR.laz [14,407,660 Features]
DECK.CSV [6,156 Features]
Options... (Double-Click)
Metadata... (Double-Click + M)
Close (Unload) Layer(s)... (DEL)
Invert Selection
Edit Attributes...
ZOOM_TO - Zoom to Selected Layer(s)
GROUP - Set Group to Assign to Selected Layer(s)...
DESCRIPTION - Edit the Selected Layer's Description...
Open Selected Map Folder in Windows Explorer...
SELECT - Select All Features in Selected Layer(s) with Digitizer Tool
Allow Feature Selection/Search from Selected Layer(s)
Allow Export From Selected Layer(s)
RECTIFY - Modify Layer Position/Projection (Re-Rectify)
SHIFT - Shift Selected Layer(s) a Fixed Distance or Transform Coordinates...
Set View/Export Projection to Selected Layer Projection
Layer Order
Analysis
Layer
150 ft
Options... (Double-Click)
1:487 SPCS (NAD83) (1559795.99, 407779.51) 43° 37' 06.3512" N, 72° 48' 15.9924" W
Type here to search
12:02 AM
11/24/2017



Phew, we can remedy the import...


Path Profile/Line of Sight
File Path Setup Display Options Calculate
Click to Select Feature Vertex and Drag to Move
Use Global Setting from Toolbar
From Pos: 1559966.79, 407652.25
To Pos: 1560128.30, 407741.46
2530 ft
2520 ft
2510 ft
2500 ft
2490 ft
2480 ft
Location: 1560074.71, 407711.86
Elev: 2499.466 ft, Dist: 123.29 ft
And the Profile shows a plane
25 ft
50 ft
75 ft
100 ft
125 ft
150 ft
175 ft
185 ft

Some thoughts:

The planes of points are fairly rudimentary shapes. You can add more or Extract an exploded hatch, then move it vertically, Extract it, movie it vertically and so on to obtain multiple layers of points.

You can draw some polylines and use the DENSEPL (Carlson) function or an equivalent to break the polylines into segments. Explode those and grab the END POINTS.

2d Polylines with Elevation are easier to manipulate into more complex shapes. Contours, ridges and other shapes can be made.

3d drafting in CAD is OK, but who really does it? If you get the knack, you could do some great things.

The points can be converted to surface models to make things look better.

www.ese-llc.com/vsls

Convinced? Doubtful?
Optimistic? Overwhelmed?

It's all good. Have a Gold Star.

LiDAR

VERMONT SOCIETY of LAND SURVEYORS

www.ese-llc.com/vsls

J. Thaddeus "Thadd" Eldredge

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