

A GIS Analysis of City Park Emma Long Mountain Bike Single Track Trail



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Problem Formulation and Background

I went into this project really wanting to produce something that had not been thought of or created before. I therefore began looking at examples hoping to spark my imagination and thought process. Unfortunately, it took unclipping from my binding like pedals on my mountain bike and tumbling down a set of natural limestone stairs on the main loop at City Park mountain bike trail for an idea to be conceived. I am an avid cross country and aggressive downhill mountain bike rider when not working or studying and it seemed only logical to do something on the sport I sweat, breath, bleed and love. So, lying dazed on my back, I closed my eyes and cursed, “I got it”. In the time it took for me to get up and remove my full face helmet I had a plan.

I want to have a trail map of City Park, showing elevation, technical difficulty and slope gradient, not to mention the general route and distance of the trail. My goal is to create a ski resort like map with a few additions and omissions. To accomplish this I will utilize handheld GPS receivers as well as ESRI’s ArcGIS platform.

Another goal of this project is to identify the demographics of the riders. Since this is one of, if not the most technical and fast paced single track mountain bike trails in Texas, I am intrigued by the notion I may be one of the few young riders of this trail. To attain this human data I will observe and talk to other riders

I met on the trail or in passing in the parking lot. I also ride with a group of friends, all of whom are in their thirties. I have asked them to do the same thing when they ride on their own. The data I will gather includes rider age and gender, as well as the riders' suspension set up (full or front suspension) and wheel base (26 or 29 inch wheel size).

Data Collection

GIS data

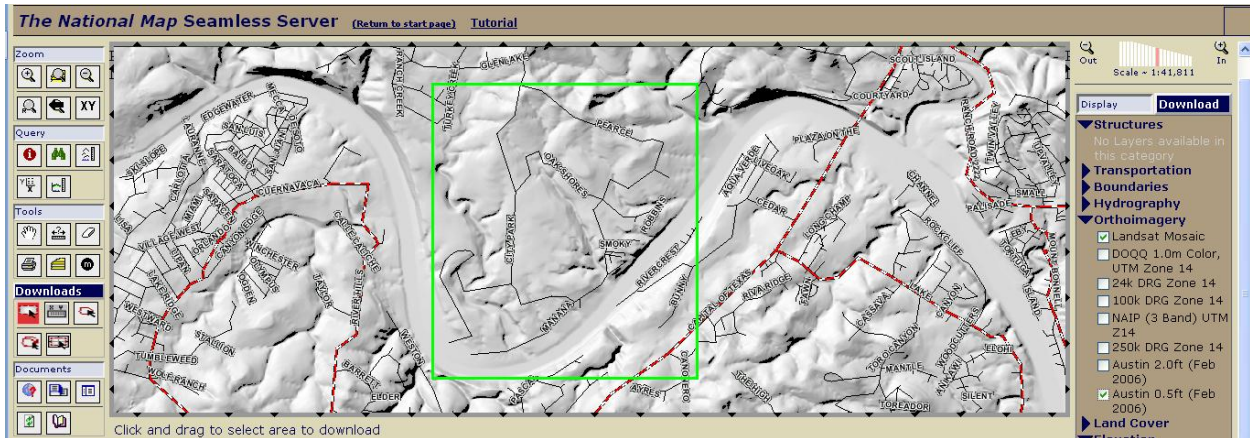
The data I have collected for this project includes: GPS data points of the mountain bike trail with a total of 589 points, six emergency entrance trails totaling to 91 GPS points, and 29 GPS points defining a section of trail closed to riders due to illegal clearing. At first I was using a Trimble handheld receiver with ArcPad, hoping that by utilizing this advanced piece of technology I would be able to jump-start my ArcMap project. However, using the unit in dense growing cedar trees proved to be quite a challenge for the unit. The next GPS unit used was a Garmin 60CSx and produced fantastic results. The Garmin is much lighter and compact when compared to the expensive and cumbersome Trimble. It also has an exposed antenna, which enabled me to traverse my ride with the unit securely inside of my hydration pack. Using the 60CSx isn't as complicated as the Trimble receiver either. As capturing GPS data is only a few manipulations of the menu away. To start collecting a continuous track of data, the Track Log must be cleared in the Tracks tab of the menu. Next, one must turn the Track Log on in order for the unit

to begin taking data. The record method (Auto, Time or Distance) and the interval type (most often, more often, normal, less often or least often) can be altered in the setup subset of the Tracks tab. The Garmin enables user freedom in specifying amount and how the unit calculates a route, while retaining the precision and accuracy that the Trimble would produce.

To add a comparison to my GPS results, I found a GPS trail map done by a rider in 2005. The image (<http://www.austinbike.com/mtb/citypark/index.asp>), a Google Earth snapshot shows a faint red line representing the mountain bike trail. By georeferencing this image I will be able to display my track on top of it to see how the accuracies compare.

From the USGS's seamless server, (<http://seamless.usgs.gov/website/seamless/viewer.htm>) I downloaded a 1/3 arc second NED Shaded Relief DEM, a shapefile of Bureau of Transportation Statistics Roads, Color Orthoimagery of the study area (Austin .5ft) and a water features shapefile. Unfortunately for my study, the USGS does not have a 1/9th arc second map of the area around the City Park Mountain Bike Trail. The 1/9th arc second map has a higher resolution of 3 meters instead of the 1/3rd's 10 meter resolution. In order to download data, follow the above URL to the USGS's website and use the zoom tool to enlarge an area of interest. Browse the available data by expanding the categories to the right of the page; check the boxes which apply to your study. In the Downloads toolset choose "define rectangular

download area” and simply drag the tool across the area of interest. Make sure you have any pop up blockers disabled to insure that a download window appears. Click download on each specific file and choose the appropriate file location. Be aware that this process may take quite some time, especially with large study areas.

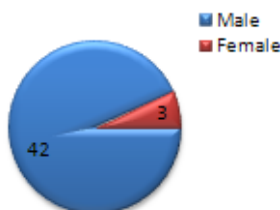


Statistical Human Data

As stated earlier, I had a goal of attaining rider data for City Park Mountain Bike Trail to see where I fall in the distribution. I am 22 years of age and ride a 26 inch full suspension mountain bike. From October 2nd, 2010 up until November 27th, 2010 I rode City Park a total of 26 times. On some days, the parking lot at the start of the trail would be empty and on other days there could be five or six cars. On 16 of these rides, I collected information on rider gender, age and rig setup.

Human Data Results

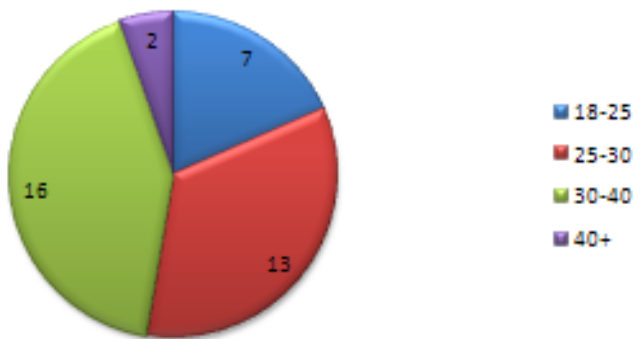
GENDER: Total Riders Sampled



My population size for the study was 45 riders. Of these riders, only 3 were female. The three women were all in the age range of 25 to 30

years old. These women all rode on the same general type of bike set up, 26 inch wheel size with full suspensions. For the male riders of this trail there is much more variance in the results. 30 of the of the 42 male riders ride a 26 inch mountain bike and of these 30, 24 of them have full suspensions. As I suspected, the majority of the riders of this trail are in fact older than I am. This could be due

Male Riders: Age



to the fact that the mountain bike trail at City Park is one of the most challenging in the region. One can infer that to tackle such a demanding and strenuous trail requires experience and repetition, which are directly

correlated to age. Another correlation linked to age is wealth. The bikes ridden at City Park can range in price from (my first true mountain bike) 1,500 dollar entry level full suspension bikes to the other end of the spectrum, 6,500 - 9,000 dollar carbon fiber and technology heavy wonders. Also, limestone isn't friendly to bikes or the rider, so when you fall you could be looking at a cracked frame, shattered handle bars, leaking suspensions, warped oval wheels. The same risk also applies to the rider; hospital bills can be immense. A ride at City Park can essentially cost hundreds of dollars at a time, as well as blood, stitches and casts.

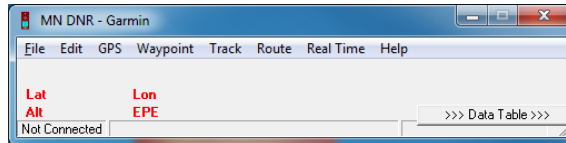
Excel spreadsheet of sample data collected from October 2nd – November 27th.

Date	Rider Number	Female	Male	Age 18-25	Age 25-30	Age 30-40	Age 40+	Full Suspension	Front Suspension	26 inch wheel	29 inch wheel
100210	1	0	1	0	0	1	0	1	0	0	1
100210	2	0	1	0	0	1	0	1	0	1	0
100210	3	0	1	0	1	0	0	1	0	1	0
100510	4	0	1	0	0	1	0	1	0	1	0
100710	5	0	1	1	0	0	0	0	1	0	1
100710	6	1	0	0	1	0	0	1	0	1	0
100910	7	0	1	0	0	0	0	1	0	1	0
100910	8	0	1	0	0	0	0	1	0	1	0
100910	9	0	1	0	0	0	0	1	0	1	0
100910	10	0	1	0	0	0	0	1	0	1	0
100910	11	0	1	1	0	0	0	1	0	0	1
101010	12	0	1	0	0	1	0	1	0	1	0
101610	13	0	1	0	0	1	0	0	1	1	0
101610	14	0	1	0	0	1	0	1	0	1	0
101610	15	0	1	1	0	0	0	1	0	1	0
101610	16	0	1	0	1	0	0	1	0	1	0
101610	17	0	1	0	0	0	1	1	0	0	1
101610	18	1	0	0	1	0	0	1	0	1	0
101910	19	0	1	0	1	0	0	1	0	1	0
101910	20	0	1	0	0	1	0	1	0	1	0
101910	21	0	1	0	0	1	0	1	0	1	0
102210	22	0	1	0	0	1	0	1	0	1	0
102410	23	0	1	1	0	0	0	0	1	0	1
102410	24	0	1	0	0	1	0	1	0	0	1
102810	25	0	1	1	0	0	0	1	0	0	1
102810	26	0	1	0	0	1	0	0	1	1	0
102810	27	0	1	0	0	1	0	1	0	0	1
102810	28	0	1	0	1	0	0	1	0	0	1
102810	29	0	1	0	1	0	0	1	0	1	0
102810	30	1	0	0	1	0	0	1	0	1	0
110110	31	0	1	0	1	0	0	0	1	1	0
110110	32	0	1	0	0	1	0	1	0	0	1
110110	33	0	1	0	1	0	0	1	0	1	0
110410	34	0	1	0	1	0	0	1	0	0	1
110410	35	0	1	0	1	0	0	1	0	1	0
110410	36	0	1	0	0	1	0	1	0	0	1
110710	37	0	1	0	0	1	0	1	0	1	0
110710	38	0	1	0	0	0	1	1	0	1	0
111010	39	0	1	1	0	0	0	1	0	1	0
111310	40	0	1	1	0	0	0	1	0	1	0
111310	41	0	1	0	1	0	0	1	0	1	0
111310	42	0	1	0	0	1	0	0	1	1	0
112010	43	0	1	0	1	0	0	1	0	1	0
112010	44	0	1	0	1	0	0	0	1	1	0
112710	45	0	1	0	1	0	0	1	0	1	0
		3	42	7	16	16	2	38	7	33	12

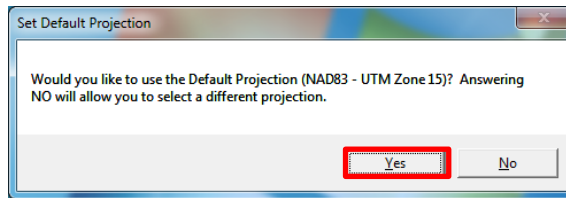
Data Processing With ArcGIS

1. Extracting GPS data

- a. Connect the Garmin 60CSx to computer via universal serial bus
- b. Run DNRGarmin



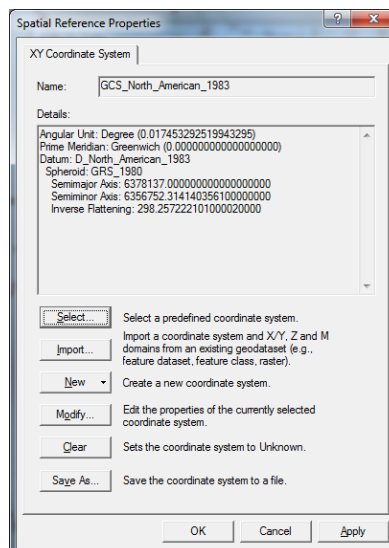
- c. Select a projection



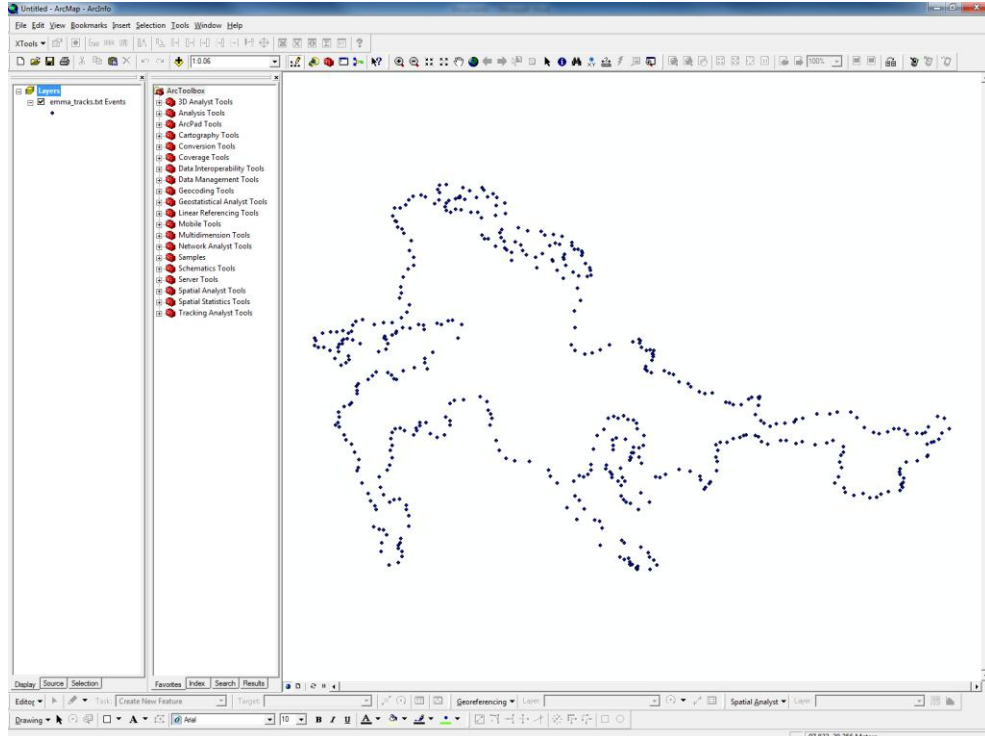
- d. For the Study area of Austin, use NAD83 UTM Zone 14
- e. Since the data was collected as tracks click Track>Download Track

2. Bringing the Track Data into ArcMap

- a. Open ESRI ArcMap and create open a blank map.
- b. To display our GPS track points click Tools>Add XY Data
- c. Browse to the .txt and select X_PROJ for the X Field and Y_PROJ for the Y Field. Also choose a coordinate system by clicking Edit>Select>Projected Coordinate System>UTM>NAD 1983 UTM Zone 14N

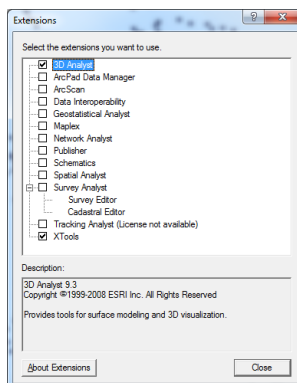


- d. **Click Ok. You should receive a warning message stating that you will be unable to perform queries on the data. Say yes and you should get something like the following.**

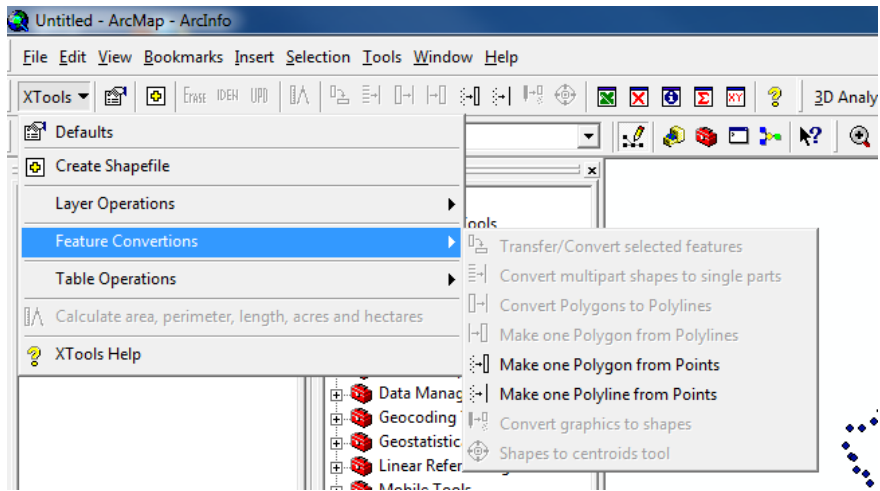


3. Creating a continuous polyline using XTools

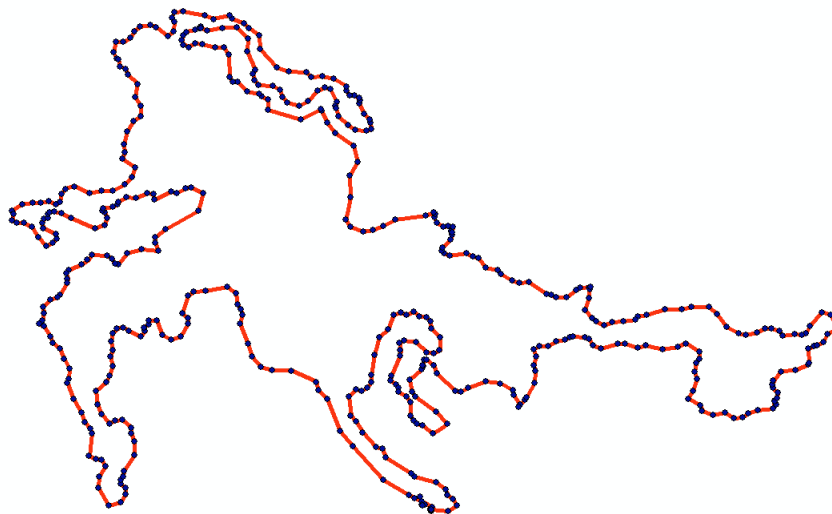
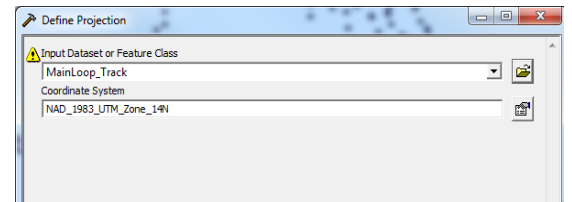
- a.
- b. **Make sure you have the extensions for XTools and 3D Analyst enabled. Tools>Extensions**



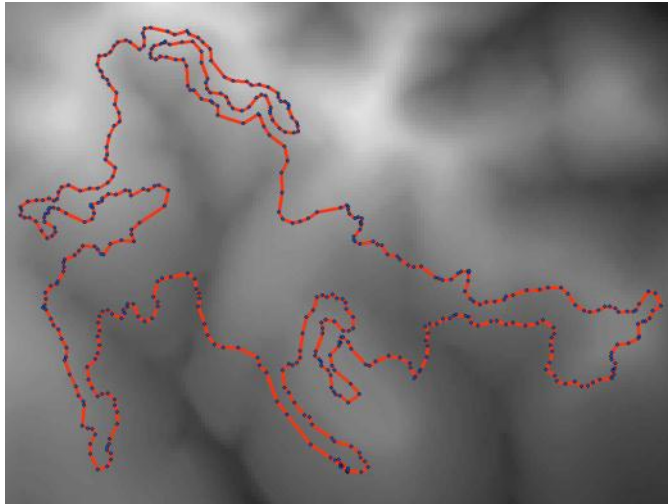
- c. **Open the XTools dropdown menu and select Feature Conversions>Make One Polyline From Points**



- d. **Make sure the correct event is selected and specify a name for the resultant polyline**
- e. **Next we must Define a Projection for the polyline, as it will not display, unprojected. In Arc Tool box, expand Data Management Tools>expand Projections and Transformations and double click Define Projection.**
- f. **Set input Dataset to the Polyline and Select NAD_1983_UTM_Zone_14N as the Coordinate System.**
- g. **Your resulting display should appear as follows.**

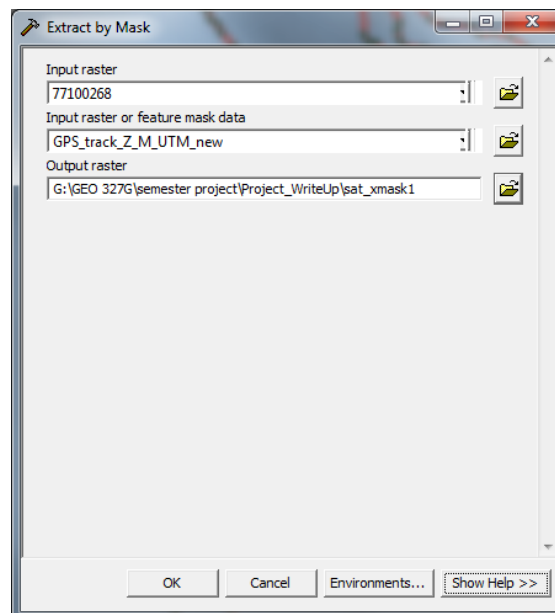


4. **Extracting elevation from the DEM to the mountain bike trail track.**
 - a. **Add the DEM by clicking the add data button.**
 - b. **Notice the default color bar, with bright white as the high and dark black as the low. We will manipulate the symbology later**



to better depict the terrain.

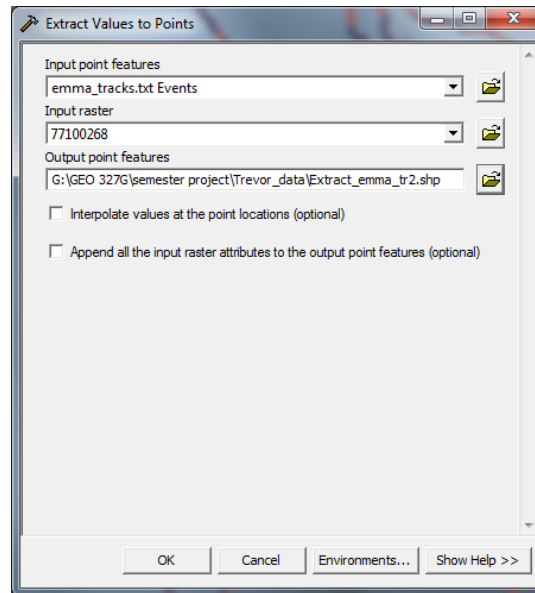
- c. **Next, we wish to create a route showing only the elevation from the DEM.**
- d. **Open the Spatial Analyst Toolset and expand extraction. Select Extract by Mask.**



- e. **Click Ok.**
- f. **Now we have a raster track showing the high and low points of the trail.**



- g. To take this idea further, we need to add correct elevations in meters to our emma_tracks.txt event. This will allow us to create a profile of the trail later. In the same toolset under Extraction double click Extract Values to Points. This overlay method will add a new column to the attribute table.

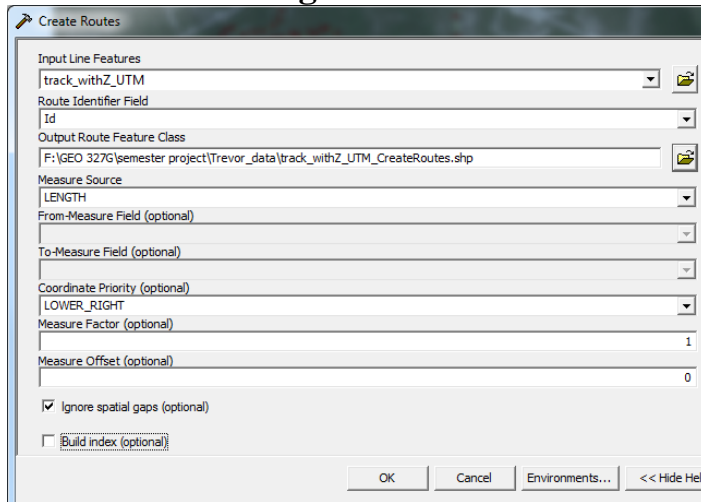


- h. Click Ok and view the modified attribute table, the new column is named RASTERVALU

FID	Shape *	TYPE	IDENT	LAT	LONG	Y_PROJ	X_PROJ	NEW_SEG	DISPLAY	COLOR	ALTITUDE	DEPTH	TEMP	TIME	MODEL	FILENAME	LTIME	RASTERVALU
0	Point	TRACK	11/21/2010	30.344148	-97.826927	3378822.40964	1190314.99351	False	False	1	2667.795898	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	215.28981
1	Point	TRACK	11/21/2010	30.344107	-97.826924	3378817.84946	1190315.57602	False	False	1	2667.795898	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	215.28981
2	Point	TRACK	11/21/2010	30.344132	-97.826938	3378820.54595	1190314.10452	False	False	1	2667.795898	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	215.28981
3	Point	TRACK	11/21/2010	30.344108	-97.826597	3378819.96984	1190347.14911	False	False	1	2669.237793	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	216.021332
4	Point	TRACK	11/21/2010	30.344208	-97.826429	3378832.12494	1190362.67239	False	False	1	2668.756836	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	217.494781
5	Point	TRACK	11/21/2010	30.344329	-97.826507	3378845.07253	1190354.28127	False	False	1	2669.718262	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	218.04837
6	Point	TRACK	11/21/2010	30.344406	-97.826611	3378859.01128	1190343.66767	False	False	1	2671.641113	0	0	1989/12/30-23:59:59	GPSMap60CS		12/30/1989	218.504324

5. Add M value (measurement from start of track in meters) to the GPS track with the elevation values.

a. Linear Referencing Tools>Create Routes



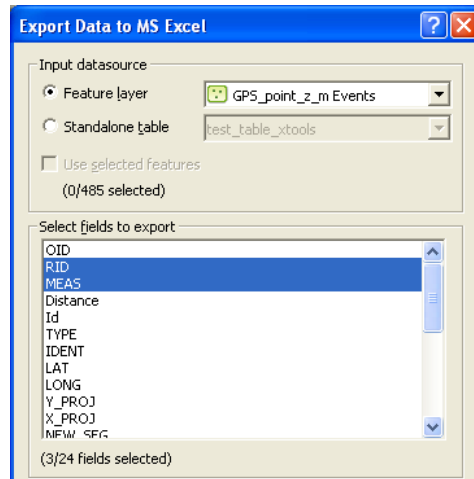
b. As in step 4g, extract the values of the new track to points. View the newly created attribute table.

ID	RID	MEAS	Distance	Id	
0	0	75.5154370954	-0.368059604893	0	TRACK
1	0	18.1200914124	0.0753309267358	0	TRACK
2	0	14.9675792824	0.0585349538697	0	TRACK
3	0	47.402433965	0.0341639742361	0	TRACK
4	0	66.9541059422	0.0648220328402	0	TRACK
5	0	82.2949599193	-0.00211171006099	0	TRACK
6	0	95.4376599285	-0.0781440289128	0	TRACK
7	0	108.207955115	0.0370793251352	0	TRACK
8	0	130.923569524	-0.0171572175543	0	TRACK
9	0	171.776499724	-0.0383431468896	0	TRACK
10	0	180.606378312	0.120854925319	0	TRACK
11	0	237.496986983	0.0704064736311	0	TRACK
12	0	256.093104783	0.081199155711	0	TRACK
13	0	269.189150274	0.0134861131584	0	TRACK
14	0	306.896647262	0.0810193281412	0	TRACK
15	0	306.912836137	0.0810193281412	0	TRACK
16	0	332.433927763	-0.0898516600512	0	TRACK
17	0	348.345492472	0.0728341995818	0	TRACK
18	0	388.835779405	0.0625575961102	0	TRACK
19	0	409.40386717	0.0676180312409	0	TRACK
20	0	419.020879609	-0.0792300119172	0	TRACK
21	0	430.928047969	0.0628549631312	0	TRACK
22	0	444.714388765	0.038779741092	0	TRACK
23	0	460.869587088	-0.0143732301857	0	TRACK
24	0	501.825794621	0.0745672181476	0	TRACK
25	0	540.54988773	-0.00150682498476	0	TRACK
26	0	563.564366035	0.00362424632575	0	TRACK
27	0	594.792403523	-0.0886157430738	0	TRACK
28	0	607.853916801	-0.117982169528	0	TRACK
29	0	619.631282667	-0.0526537829625	0	TRACK
30	0	634.281745076	0.0435297265702	0	TRACK
31	0	647.687188799	-0.0716605131735	0	TRACK

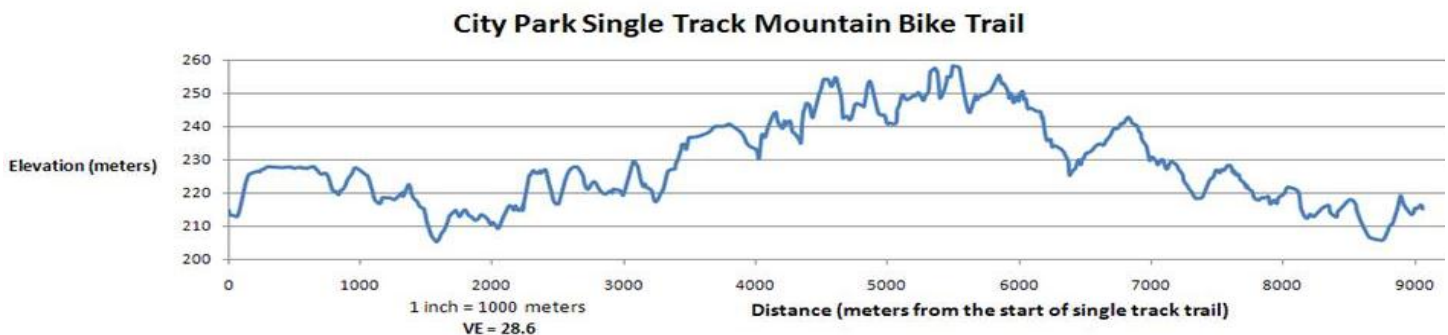
i. Now there is a measurement column in the attribute table showing a distance in meters from the specified start of the track.

6. Export GPS points to Excel to create track profile

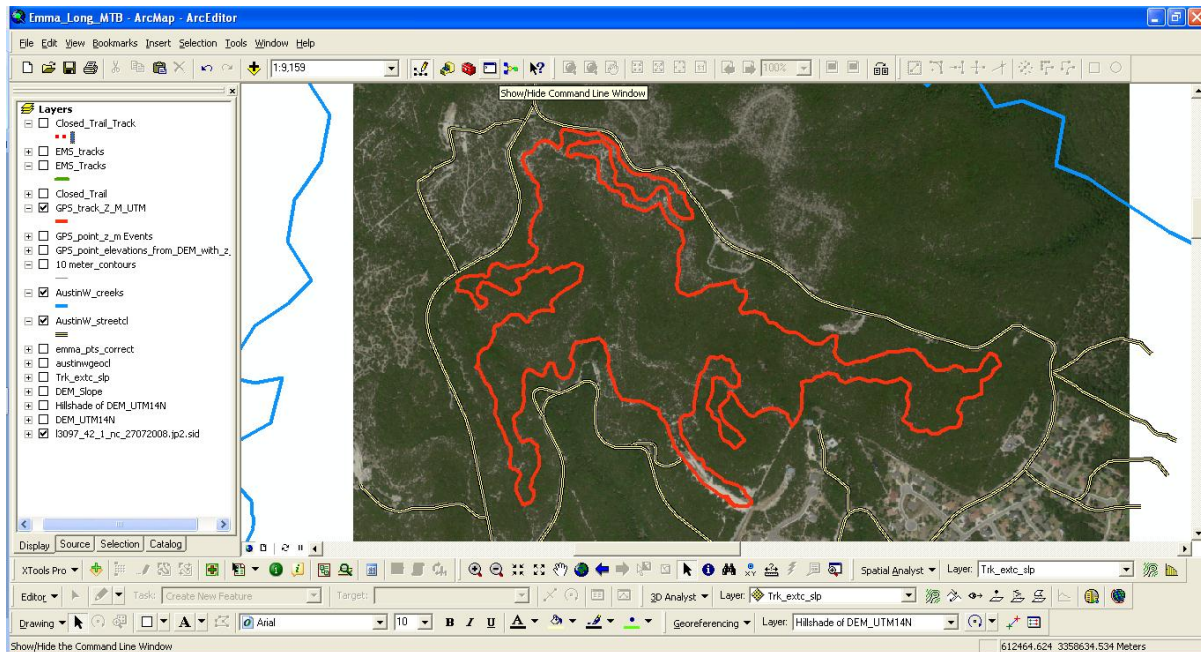
- a. In XTools drop down menu select Table Operation> Export Data to MS Excel.
- b. Select only the RID, MEAS and RASTERVAIU fields.



- c. Click OK, XTools will automatically open Excel.
- d. In Excel we will make a X Y Chart from the Charts menu on the Insert Ribbon. Our raster values are elevation and the measurement values are meters from the start of the mountain bike trail.
- e. Unfortunately, the Linear Referencing tool used to add measured values did not give much adjustment in defining the start and end of the track. Manipulate the table by looking at the unique number in the ArcMap Attribute table to correlate a true starting point in Excel for the track. Once the start is defined, it requires a tedious process of adding and subtracting meter values from the exported distance from ArcMap.
- f. Once completed, create a chart plotting distance verses elevation.
- g. This chart shows the elevation change across the entire length of the trail. Vertical exaggeration equals 28.6.

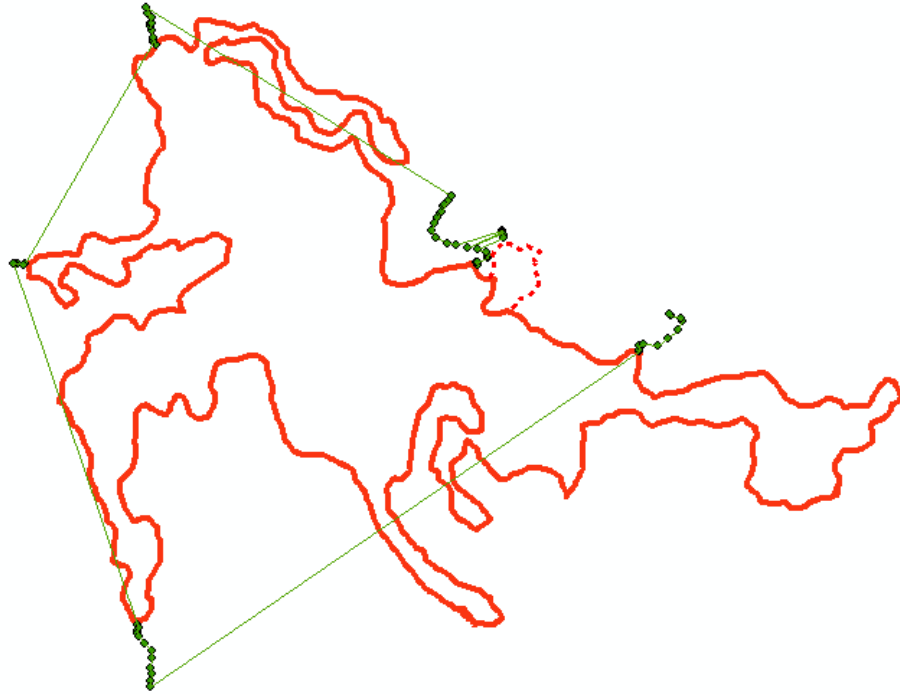


- 7. Add aerial photo, streams and roads to the ArcMap project.**
 - a. File>Add Data**
 - b. Navigate to the file locations of the Orthoimagery, streams and roads shape files downloaded from the USGS's website.**

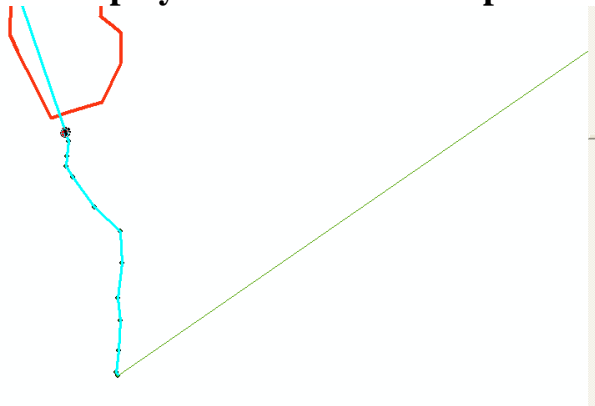


- 8. Adding tracks of 6 EMS entry points as well as one closed trail track**
 - a. Again, using DNRGarmin, download the closed track from your handheld GPS unit.**
 - b. Save as text file and add to your ArcMap project by selecting add x/y data in the tools drop down menu. Make sure you choose the appropriate fields.**
 - c. In the table of contents right click the added "event" and choose Data>export data.**
 - d. Remove the event and make sure you have the XTools extension turned on, because we need to make these GPS points into a polyline. Refer to step 3. Remove the point data file. Symbolize the closed track appropriately.**
 - e. For the EMS tracks, repeat steps a-d but do not remove the GPS point file as this will come in handy in editing the line.**

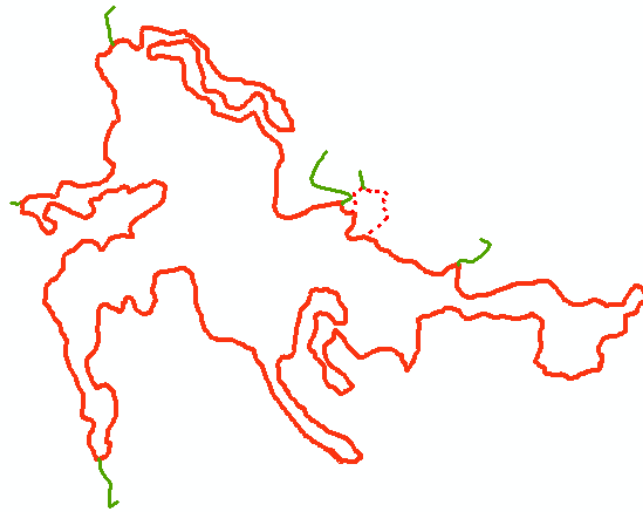
- f. You should get a polyline similar to this (green line is the imported EMS trails, dotted red line is the closed trail track).



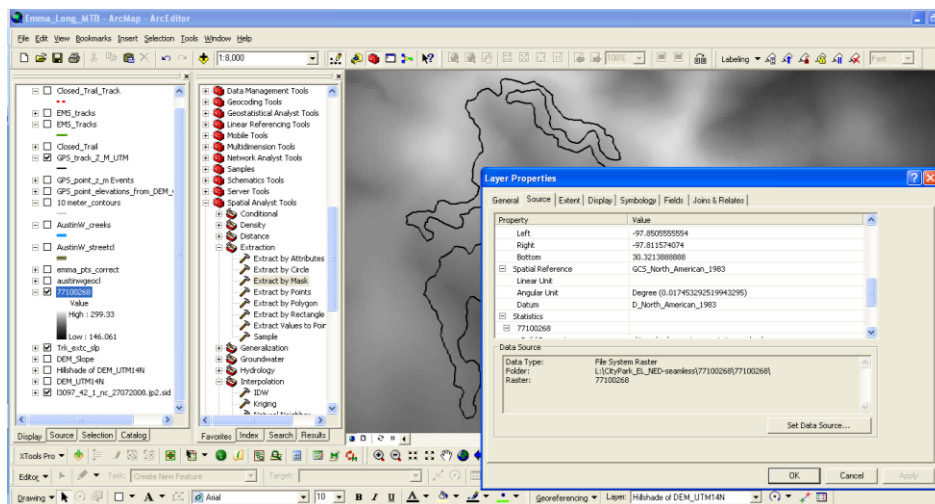
- g. We need to edit this polyline so it becomes six unrelated segments. Turn on the editor tool bar and select start editing, choose the appropriate database to manipulate.
- h. Next, set Task to “Extend/Trim Features” and set your EMS track as your Target to modify. Click the track and then activate the “split tool” located next to the Target drop down menu in the Editor Tool Bar.
- i. Split the polyline around the six point maximums.



- j. Save edits and stop editing.



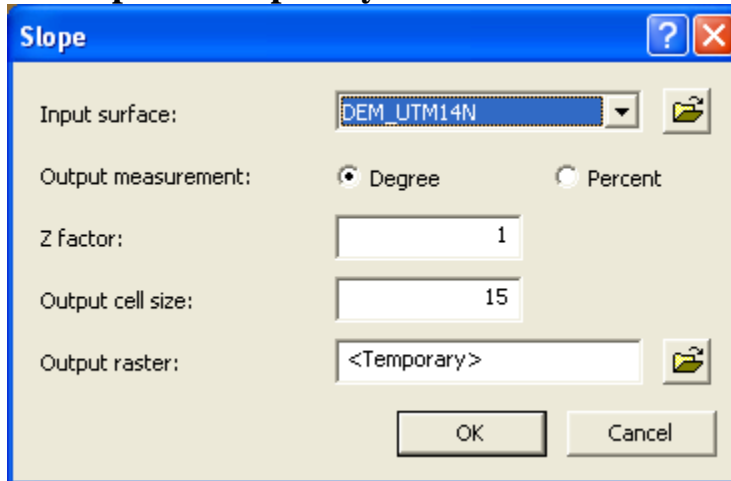
9. **Creating a slope map and a hill shade map from our DEM.**
- a. **Activate the DEM and right click it in the table of contents and choose properties. Navigate to the Source tab. Notice that the Spatial Reference is not projected. We need to project it into**



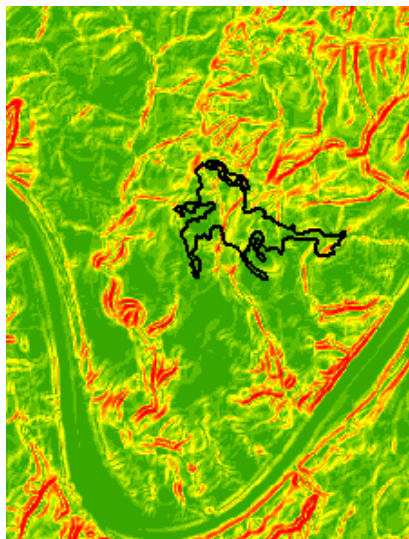
UTM Meters.

- i. **To convert the raster to UTM projected coordinates open the Data Management Toolset and expand Projections and Transformations, expand Raster and double click “Project Raster”.**
 - ii. **Select the DEM as the Input Raster and set the Output Coordinate System to “NAD 1983 UTM Zone 14N”**
- b. **Now we are ready to make a slope map of our study area. On the 3D Analyst Toolbar select Surface Analysis> Slope. For Input surface select the DEM and keep the default settings.**

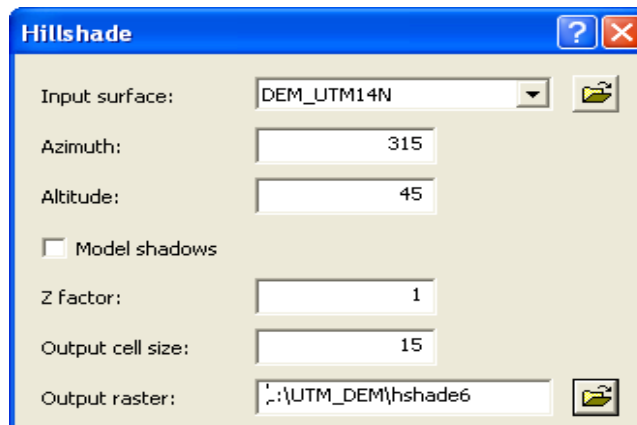
Make sure to specify a file location or ArcMap will simply put the map in a temporary folder.



i. Now we have a slope map of the area around the City Park Mountain Bike Trail.



c. Again use the Surface Analysis tool in the 3D Analyst Toolset. Select Hill shade.

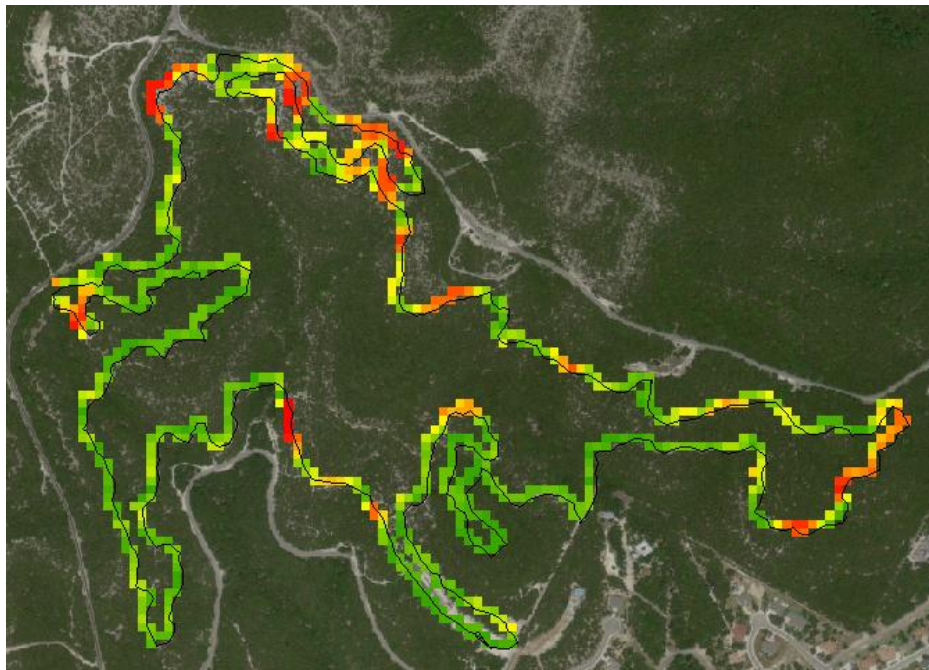


d. The resulting map should look something like this.



11. Using the slope map to create a raster track of the mountain bike trail.

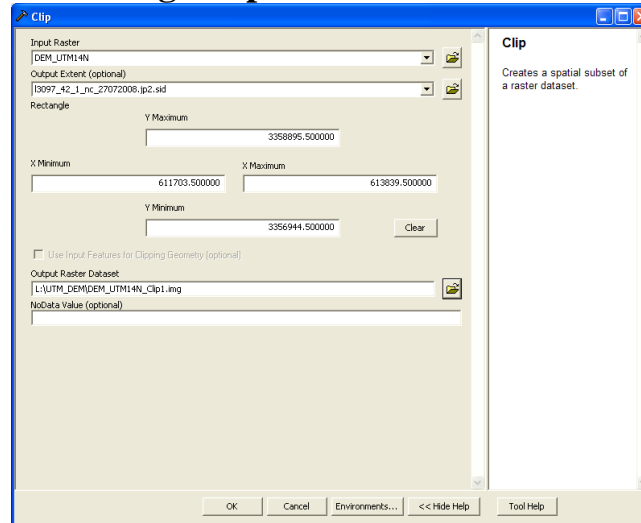
- e. Open the Spatial Analyst Toolset and expand extraction. Select Extract by Mask.**
 - i. For the Input raster choose the slope map. Select the GPS track of the mountain bike trail as the feature mask data. This will define the area to be extracted from the DEM.**
 - ii. The resulting raster will show the slope change across the mountain bike trail.**



10. Creating a Contour Map from the DEM.

a. First, clip the DEM to the aerial photo.

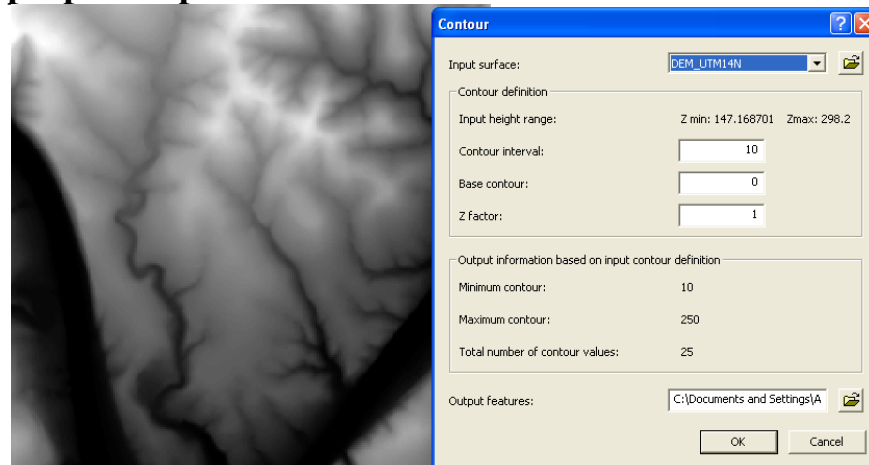
i. Data Management Toolset>Raster>Raster Processing>Clip



ii. Remove the un-clipped DEM from the Table of Contents.

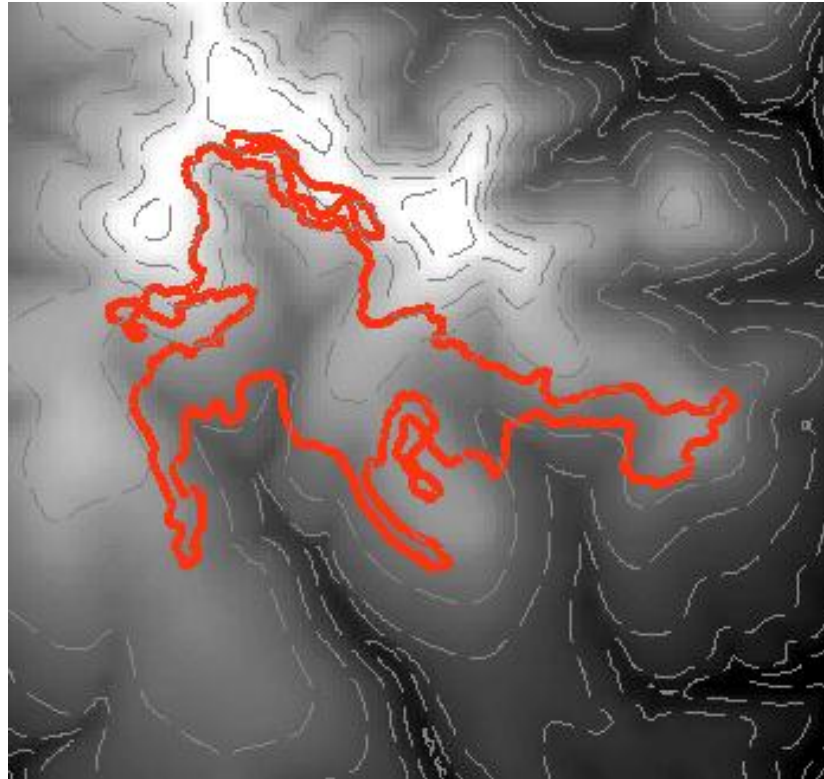
b. Turn on the 3D Analyst Toolset and on the menu bar click the down arrow next to 3D Analyst. Choose Surface Analysis>Contour. Also make sure that you have the Target Layer set to your clipped DEM.

i. Make you interval 10 and z factor 1 and designate a proper output destination

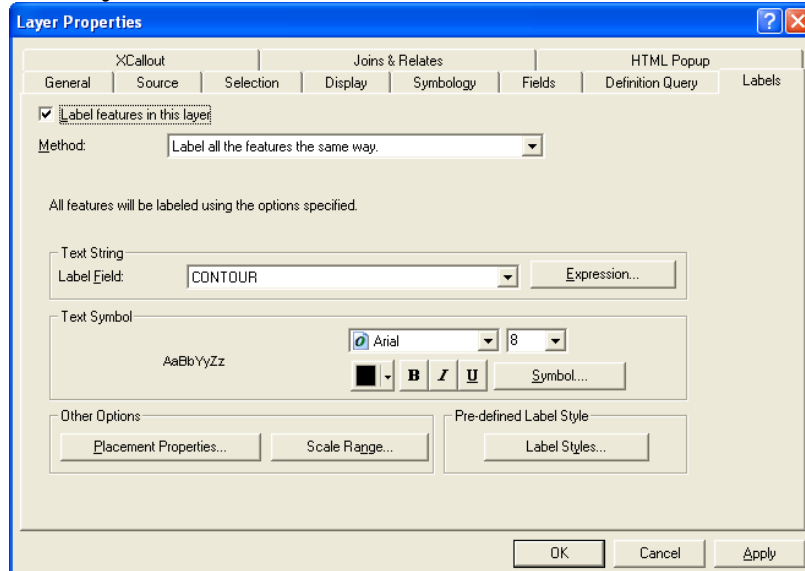


ii. Click Ok

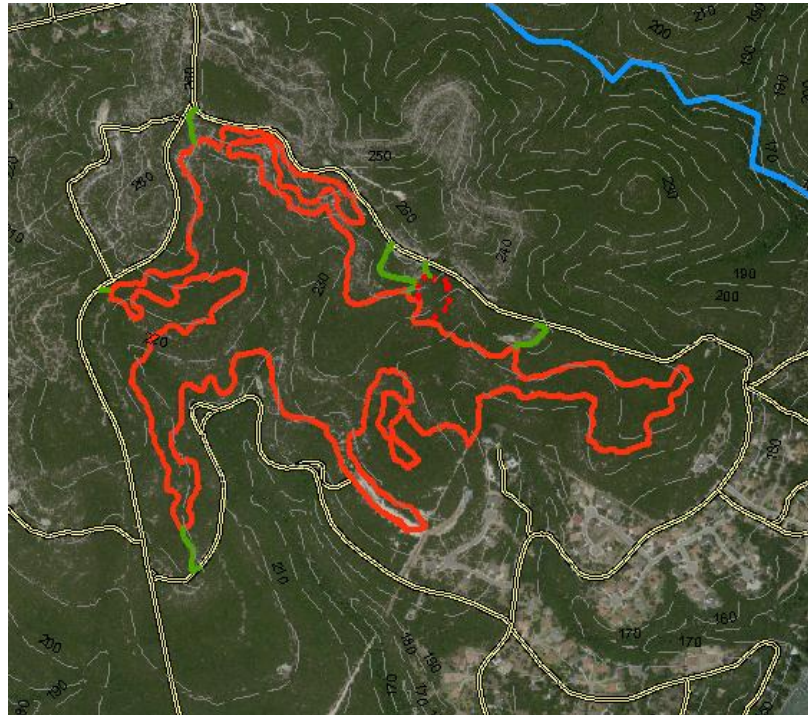
- iii. Your resulting Contour shapefile should look something like this. Contour intervals are in meters.



- iv. Next we should apply contour labels. Right click the layer in the table of contents and choose properties. Select the Labels tab. For text string drop down menu, choose CONTOUR and symbolize the labels appropriately. Check the box next to Label features in this layer.

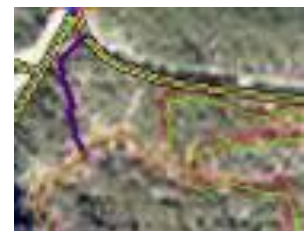


v. Click Ok.



11. Georeferencing the Google Earth image with the GPS data collected in the field.

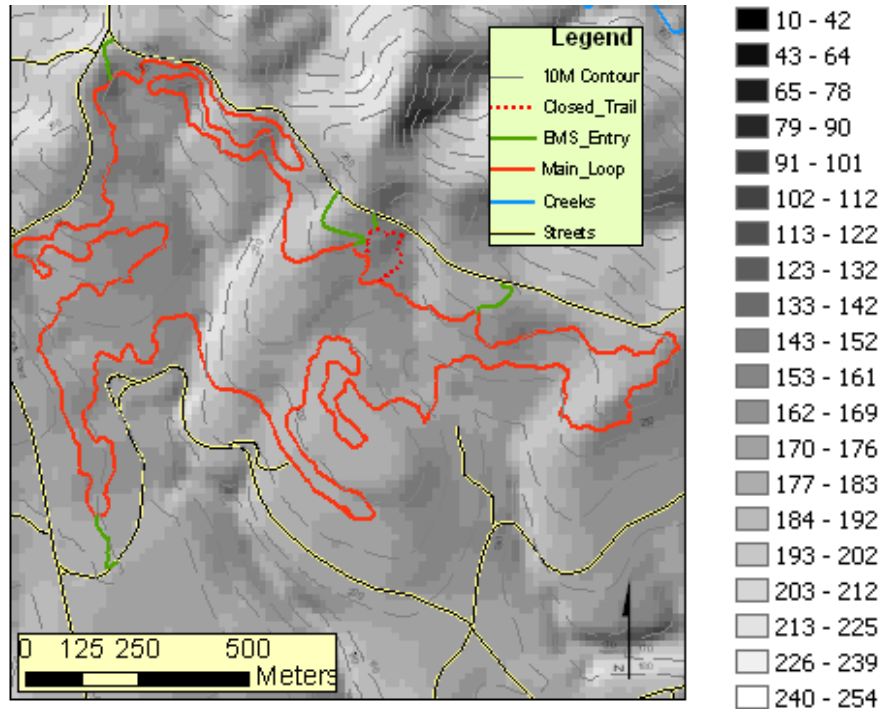
- a. This task will allow comparisons to be made between the collected GPS data points and the trail map found online.
- b. To capture the image from the web, press print screen and paste the screen capture into MS PowerPoint.
 - i. Crop the image
 - ii. Save image as .jpeg
- c. Add the .jpeg to project
 - i. Data management tools>define projection
 1. GCS NAD1983
 - ii. Data management tools>Raster>project raster
 1. PCS UTM NAD1983 zone 14N
 - iii. On the Georeferencing Toolbar select the .jpeg as the target layer.
 1. Zoom to layer
- d. Now, set four to five control points at locations that are obvious in both the .jpeg and the aerial photo.
 - i. GPS field data in green, georeferenced photo with red trail.



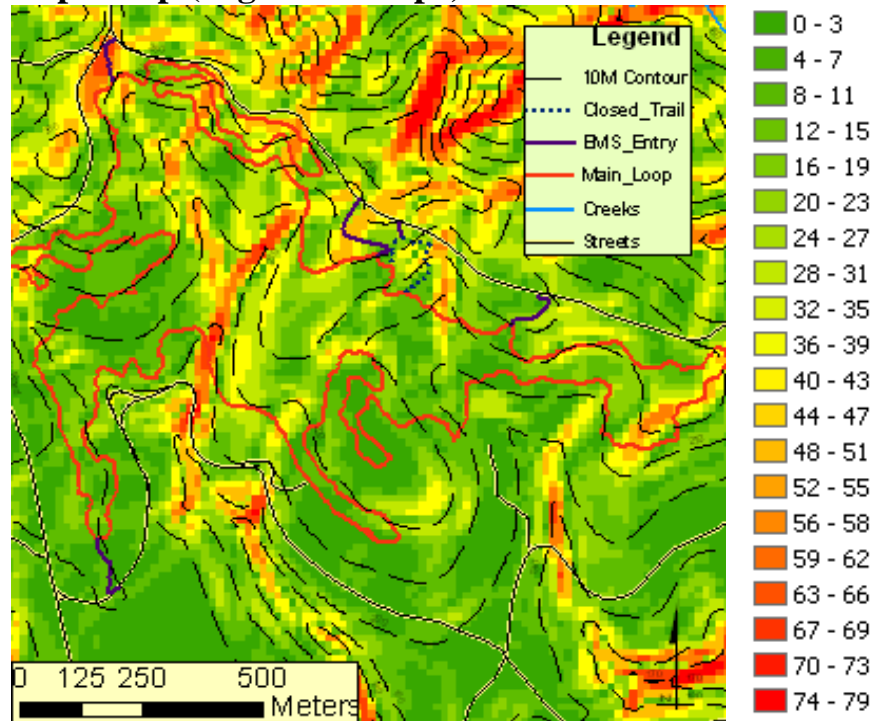
Resulting images and maps created

1. The following maps show the main loop, emergency trail entrances, closed route, streams, roads and contours.

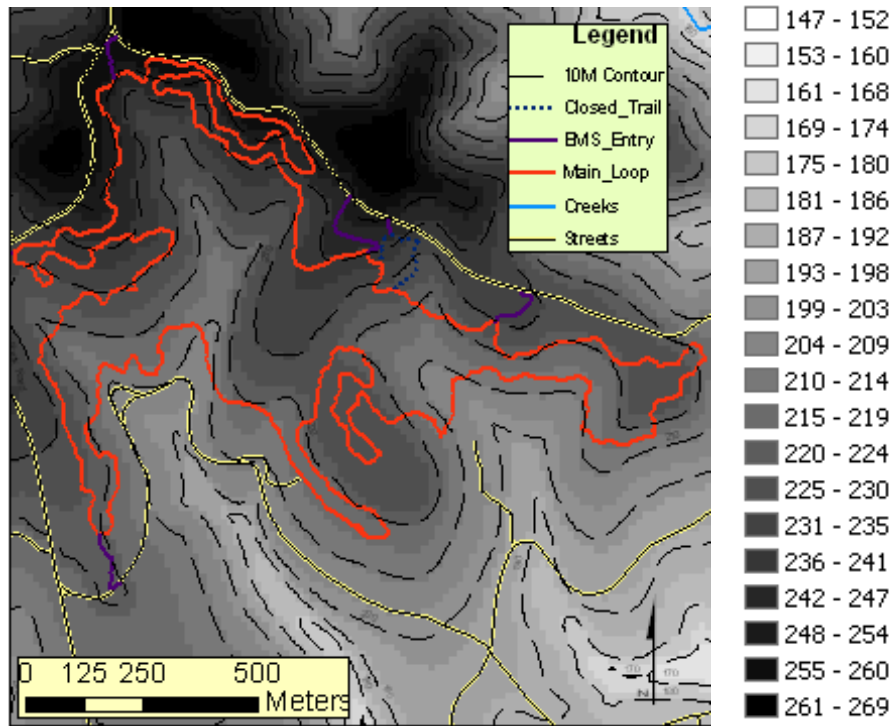
a. Hill Shade Map (calculated using default hillshade settings of 315 degree azimuth and a 45 degree altitude of slope from the sun).



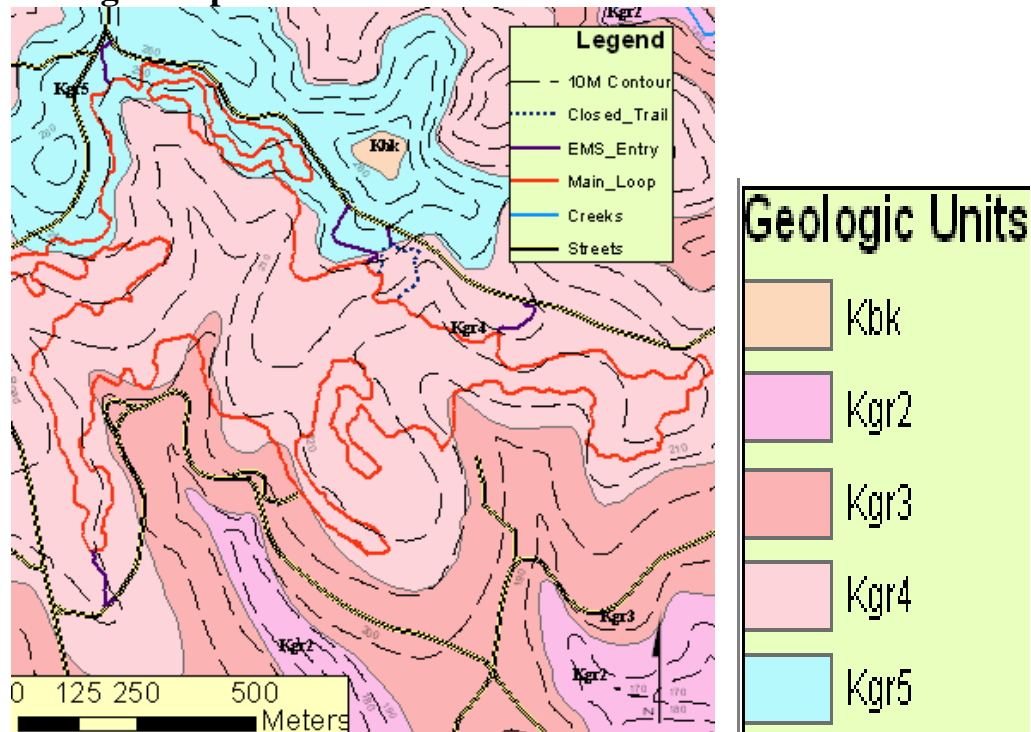
b. Slope Map (degrees of slope).



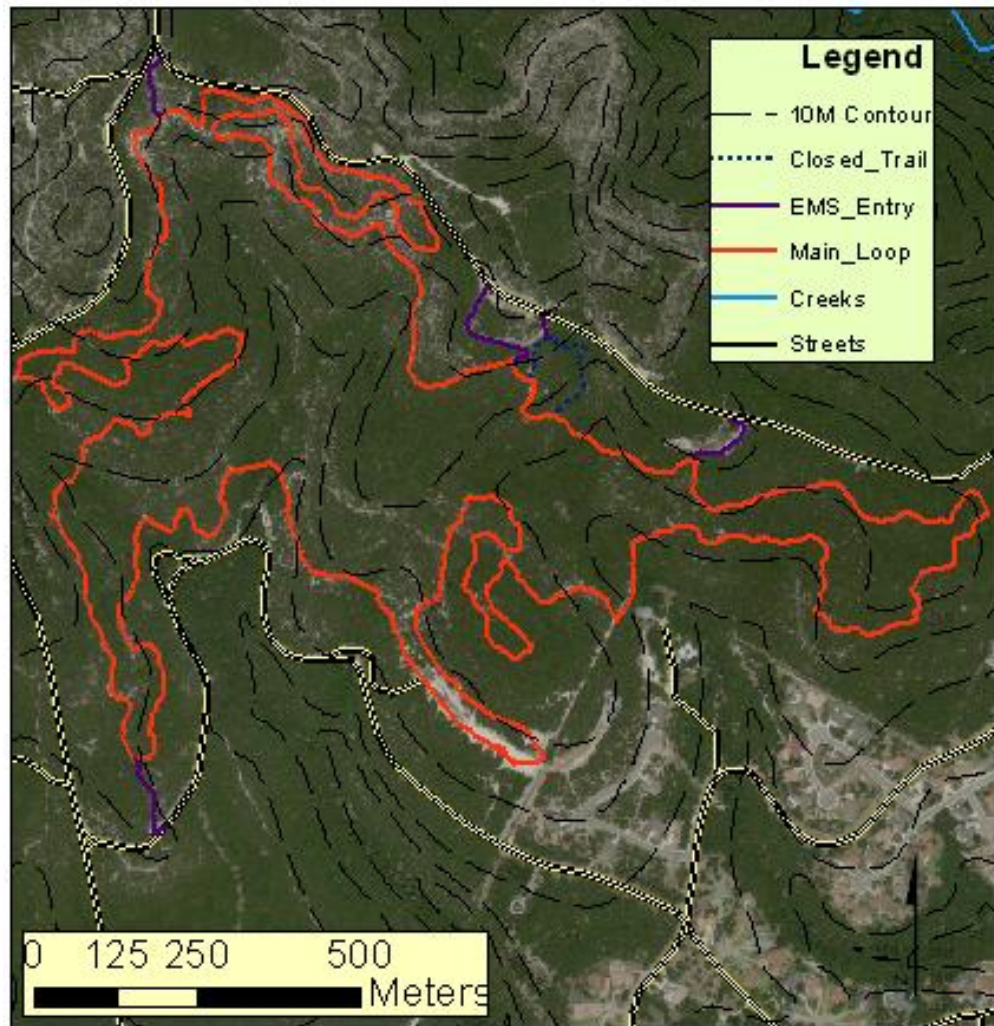
c. Digital Elevation Map (meters).



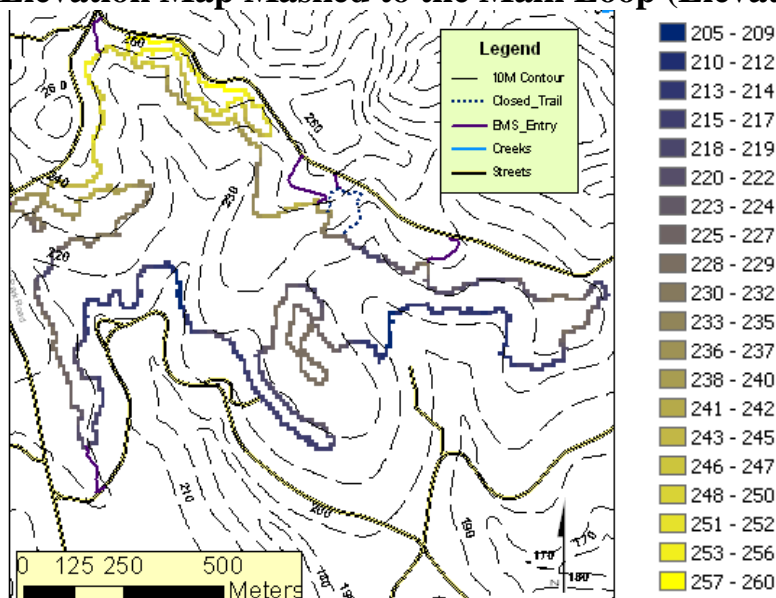
d. Geologic Map Units of The Glen Rose Formation.



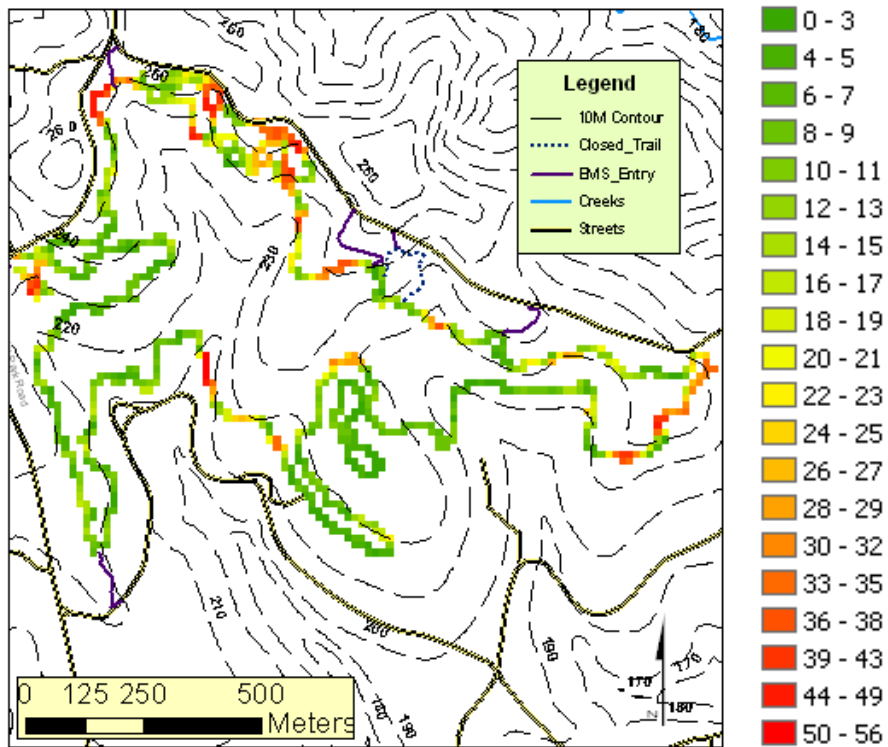
e. Aerial Photo of City Park Mountain Bike Trail.



2. Elevation Map Masked to the Main Loop (Elevation in Meters)

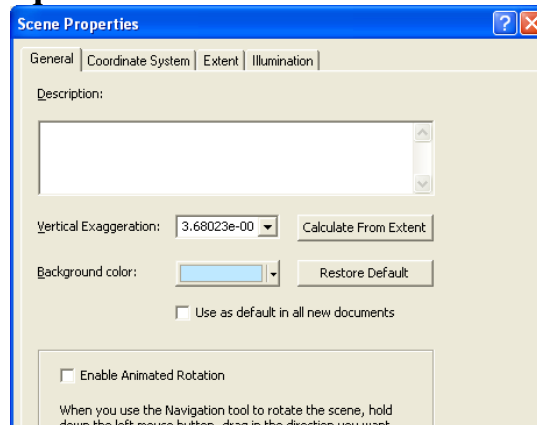


3. Slope Map Masked to the Main Loop (Slope in Degrees)



4. ArcScene Screenshots

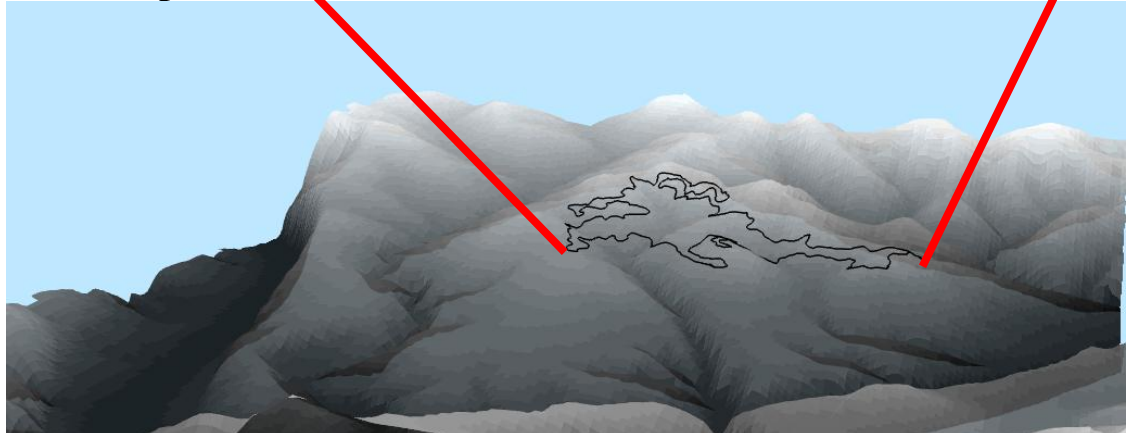
- a. ArcScene allows the user to display ArcMap projects in three dimensions.
 - i. To do so, add your data to a new project in ArcScene.
 - ii. Next you must set your base heights and vertical exaggeration for the Data Frame.
 - iii. Right click Scene Layers and select Scene Properties. From the General Tab click calculate from extent (Vertical Exaggeration). The calculated exaggeration for my ArcScene project based on my data is 3.68023e-00 which equals 3.68023.



- iv. Next set the base heights for each layer in the table of contents. Right click>Properties>Base Heights Tab. We want to obtain our heights from our DEM so select “Obtain heights for layer from surface:” in the drop down, select the DEM. Repeat this for each of the layers.
 - v. To make things display clearer, adjust the transparency of the Surfaces.
- b. Slope Map Masked to the Main Loop.

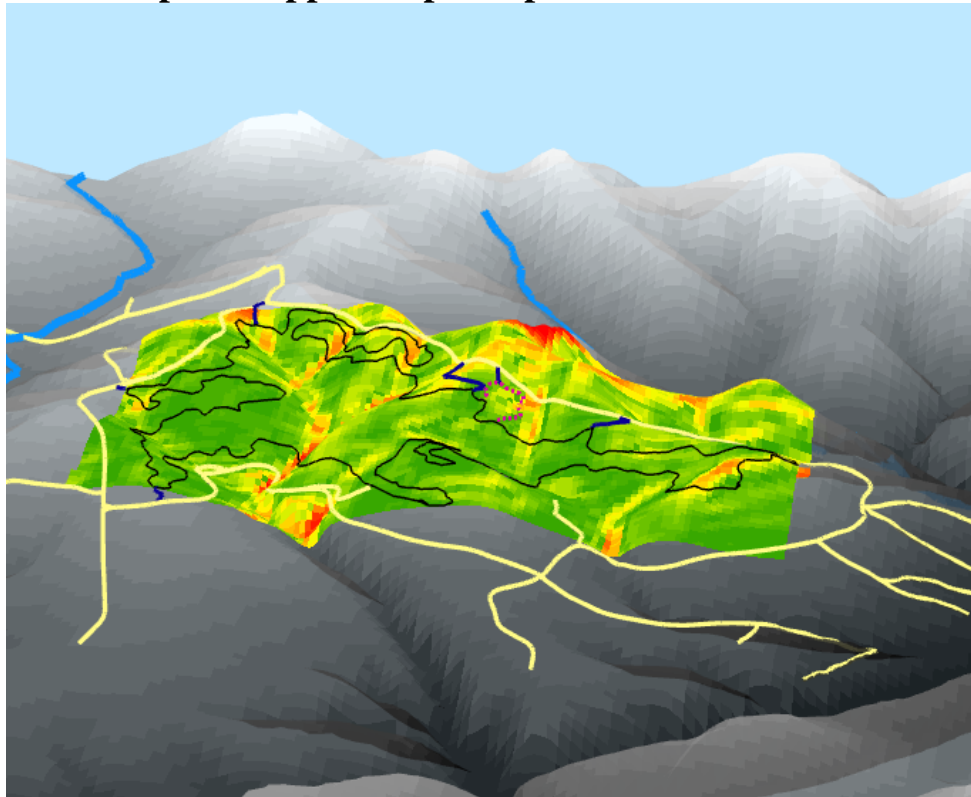


- c. Main Loop on the DEM.

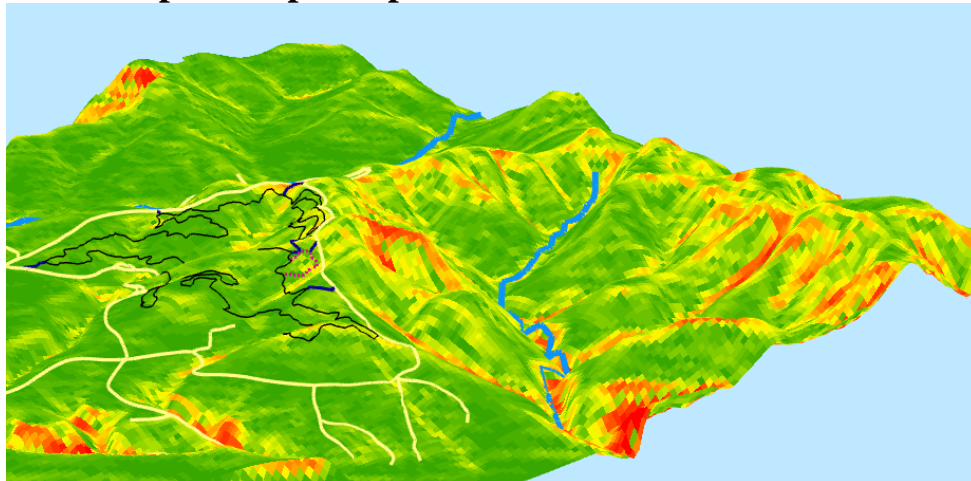


- i. Low elevation of the region is Lake Austin with an elevation of 147 meters and the high elevation of the area is 298 meters. Vertical Exaggeration equals 3.68023.

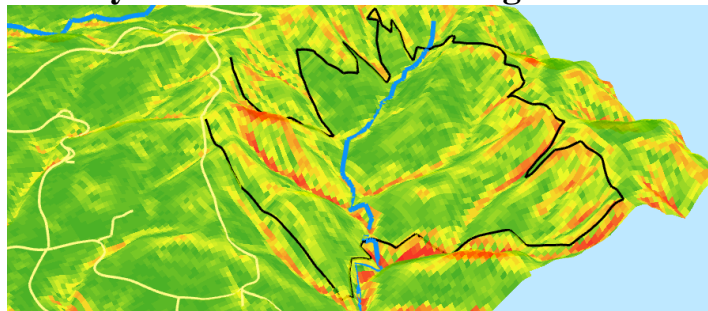
d. Main Loop on Clipped Slope Map and DEM.



e. Main Loop on Slope Map.

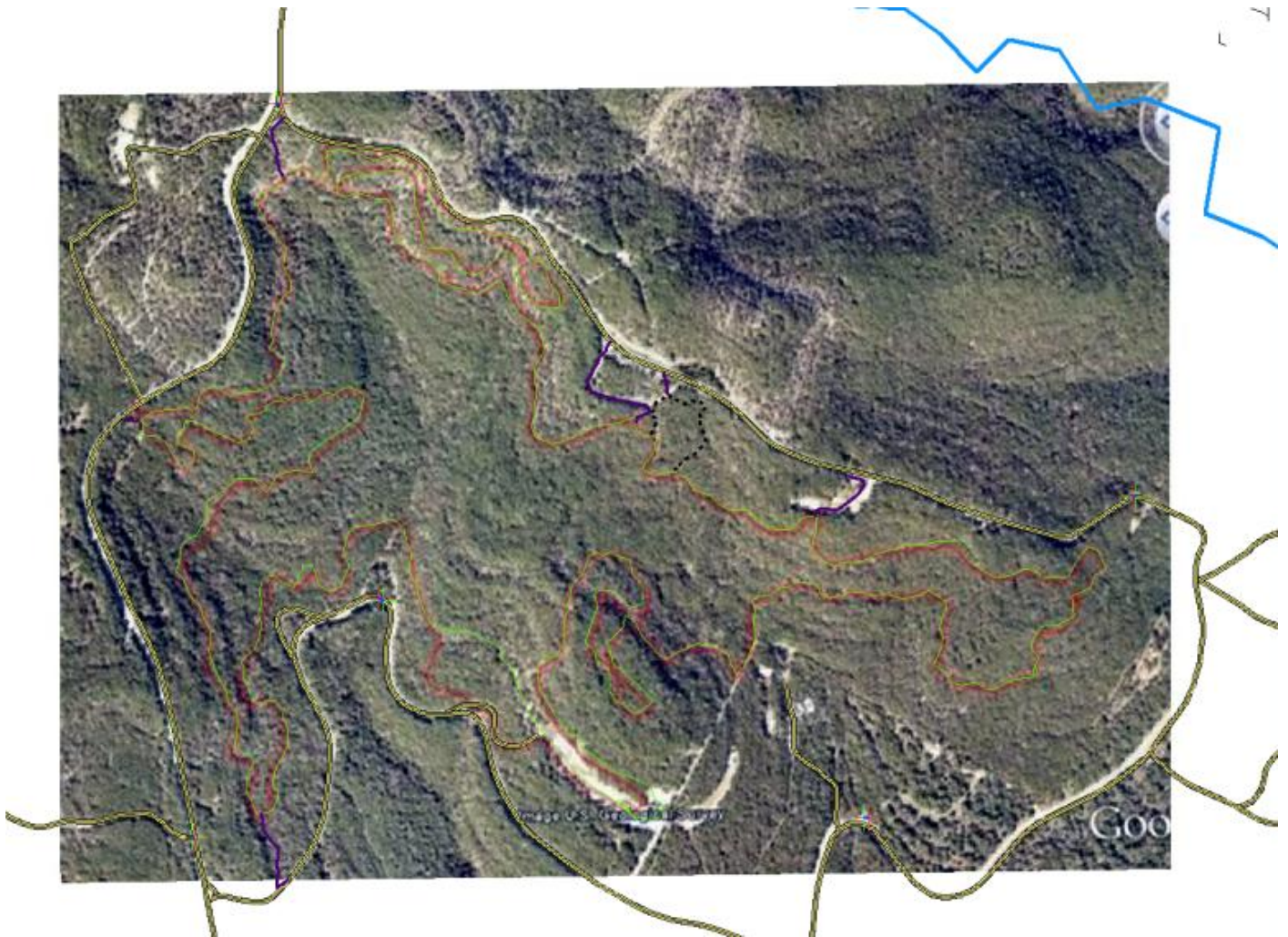


i. Fantasy Downhill trail with tough vertical climbs?



1. Line feature digitized in ArcMap and added to ArcScene. Using the “create steepest path tool” in the 3D Analyst Toolset, I created line segments showing the steepest path down from a point. These lines were then merged into a polyline using XTools. I used this method for about 25 percent of the above black trail. The other three quarters I inferred using my own understanding of how the mountain bike trails follow topology best and the contours created from the DEM. These two sets of polylines were merged using features in the editor toolbar.

5. Georeferenced .jpeg to main loop GPS data.



Conclusion

The City Park Mountain Biking Trail is a very technical ride, as is evidenced by the elevation change and slope gradient. There is a section of low elevation of roughly 210 meters near the start and towards the end of the loop. A maximum elevation is reached in peaks, 4.5 to 6 kilometers from the start of the trail. This maximum elevation ranges from 255 to 260 meters. The average climb and downhill section covers no more than 20 meters of elevation change. These sections also have the greatest slope gradient, which varies from 20 to 50 degrees. The total length of the Trail from start to finish is 9,247 meters, but seems like a lot longer because of the total elevation gain of 266 meters over the course of the trail. Statistically speaking, mainly men in their late twenties to late thirties ride this trail. This is most likely due to the fact that mountain as a hobby or sport is expensive, and can be costly in upkeep and maintenance. Limitations to my survey are the fact that I choose the most aggressive and least ridden trail in Texas, causing my population sample size to be only 45 people. Also, I only rode after class or on the weekends, and would only be on the trail for about an hour and a half. There were clearly more riders on the trail that I wasn't able to observe or survey due to my restricted schedule. Errors in my GPS data are minimal and should be no more than three to five meters off of the actual trail. The elevation data from the GPS can be off by upwards of 20 meters. So, instead the elevation from the digital elevation map (DEM) was used in all elevation calculations in this

study. Despite the limitations and sources of error, I was able to use GIS and GIS applications to produce a useful trail map of City Park Mountain Bike Trail. The data and map synthesized many physical aspects of the trail and will be useful to any rider attempting to conquer this difficult ride.