Drone Delivery: Base Origin Whereabouts?

Drones are the future for accomplishing the last mile delivery so many of us seek. How can we get the things we ordered as fast, as easy and as a safe as possible? This site suitability analysis for our fictional company *Rolling Drones* will create criteria needs for placing a drone base in Greenfield, Massachusetts.

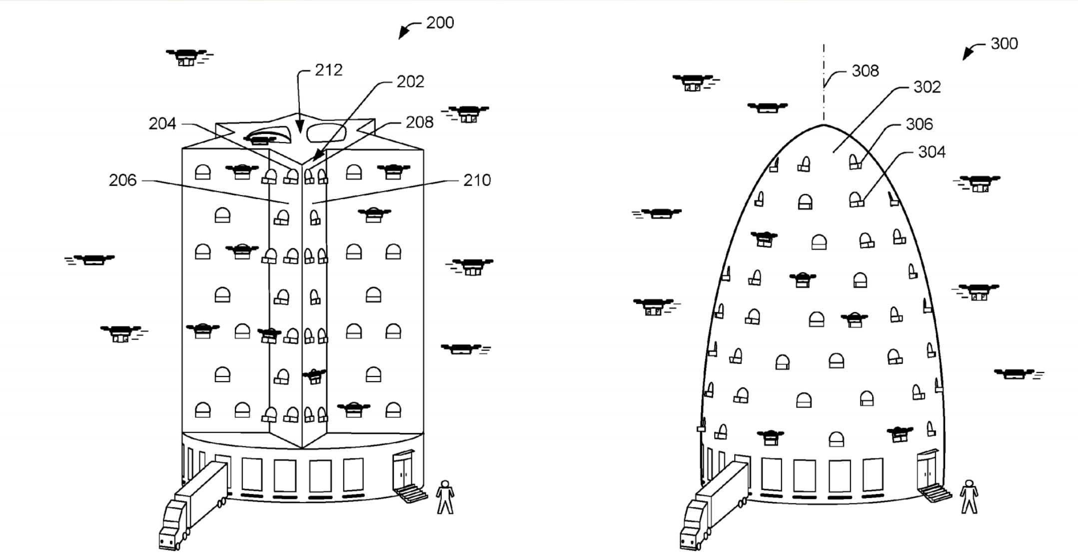

FIG. 2 FIG. 3

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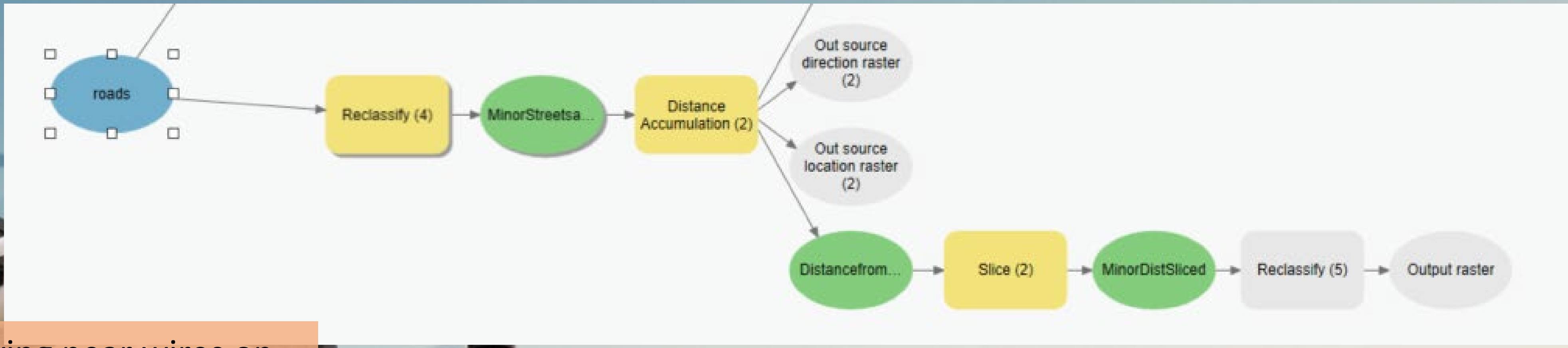
Criteria (1 is best, 10 is worst)	Factors	Details	Data Set
Safety Concerns	Minor streets	Not colliding with wires or other suspended objects on streets	Roads
	Will not interfere in populated areas	The drone should not collide with or hurt people	Buildings
Environmental Concerns	Energy usage	Placing base at a high elevation so it doesn't have to spend more energy gaining height on take off and instead can focus exclusively on landing	Elevation
	Low Steepness	The base should be located on a flat surface so that it does not take a long time to build	Elevation
Efficiency Concerns	Proximity to truck routes	The base should be located near major highways and roads where trucks will come with items, to help minimize distance and cost of "last mile problem"	Roads
	Near to populated areas	Base should be located close to places where many people will be ordering deliveries in order to minimize the wait time for the order	Buildings

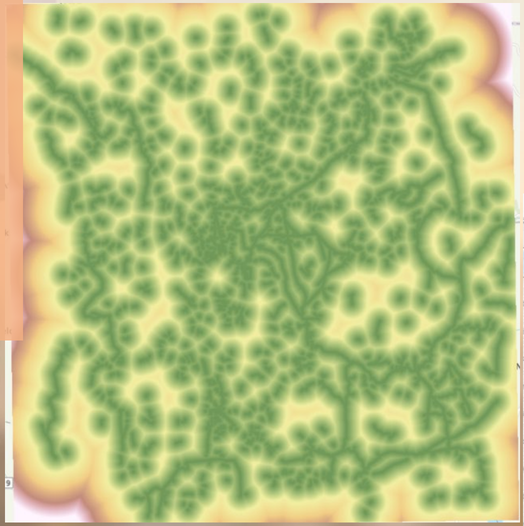
1. Safety Concerns

1. Minor Streets

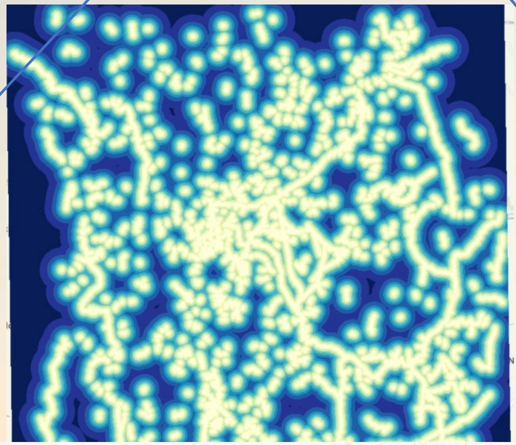


We don't want our drones flying near wires on streets or street lamps as that creates dangerous incidents and potentials for crashes. Therefore, we decided to try to avoid placing the base close to minor roads and streets which are likely to have more of those amenities. We reclassified the roads layer to get only minor streets and roads. Then we used distance accumulation to see the distance from those features. We sliced using equal area with 50 classes and then gave the roads the value of 10 to indicate they were the least suitable and counted down from there.

Distance Accumulation



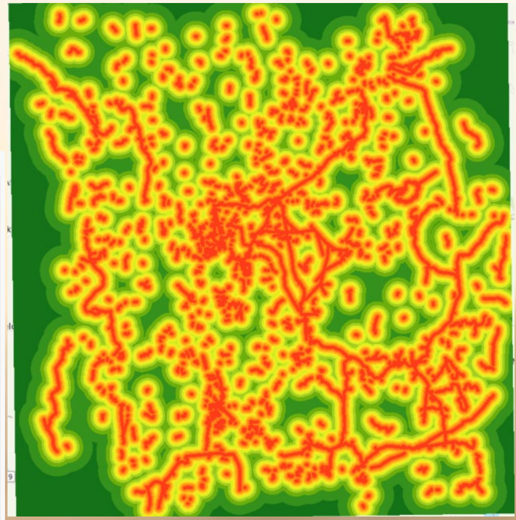
Sliced Layer



Reverse New Values

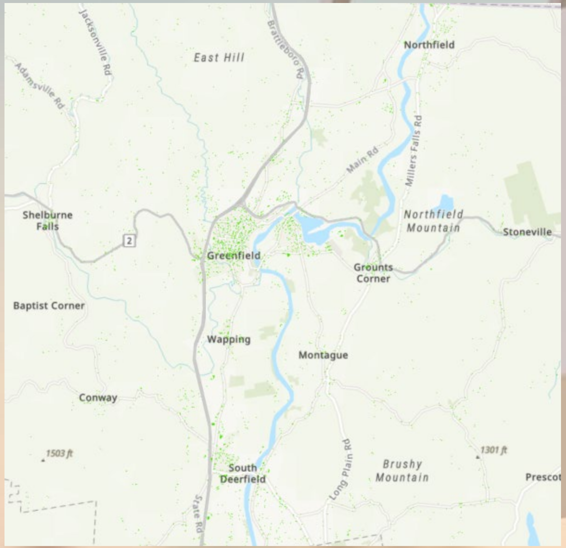
Start	End	New
1	5.9	10
5.9	10.8	9
10.8	15.7	8
15.7	20.6	7
20.6	25.5	6
25.5	30.4	5
30.4	35.3	4
35.3	40.2	3
40.2	45.1	2
45.1	50	1
NODATA	NODATA	NODATA

Final Output Suitability Layer

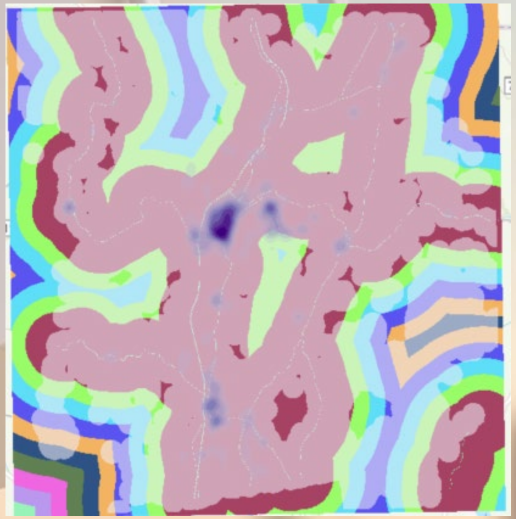


1. Safety Concerns
    2. Avoids populated areas

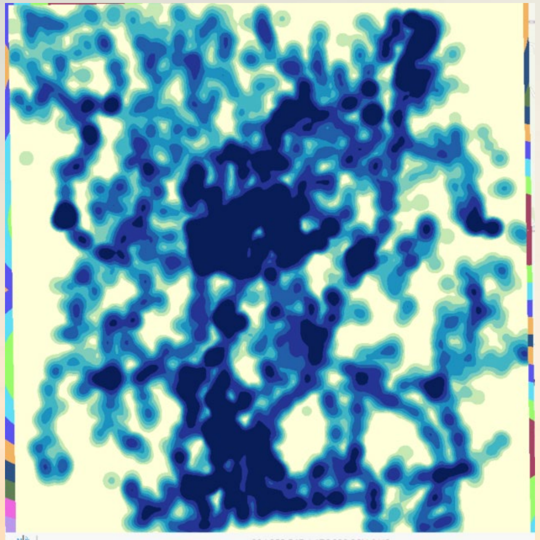
Our base should be located in a placed that avoids populated areas as we do not our drones constantly flying through communities and risking crashes with humans.
We use buildings as a proxy for population. Then we used Kernel Density on the reclassified OnlyBuildings layer. We follow by slicing using Equal Area and 50 output classes. We reclassify the layer giving the closeness to buildings a 10 (indicating its unsuitability) and distance from buildings a 1 (it is suitable).



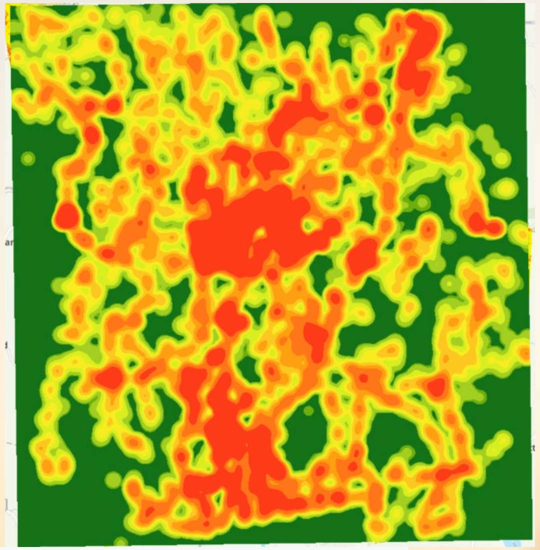
Kernel Density Layer

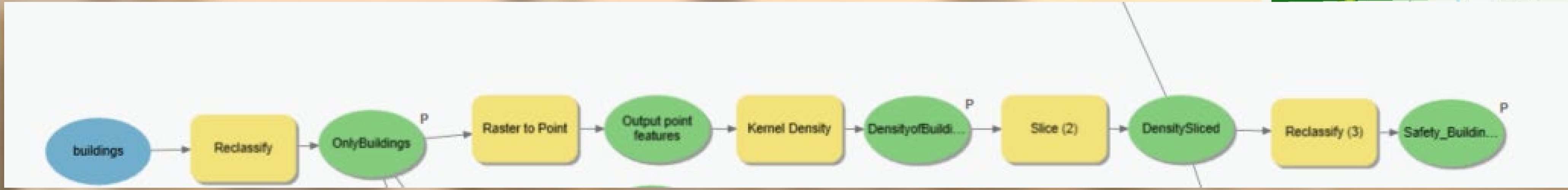


Sliced Layer



Final Output Suitability Layer

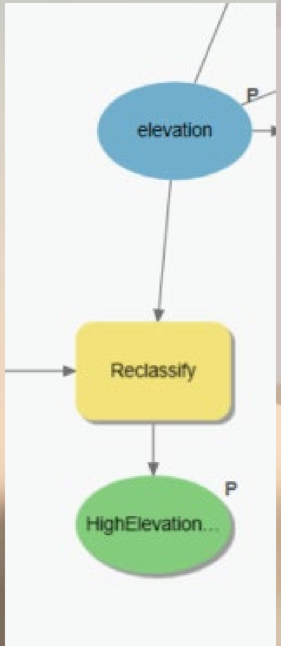


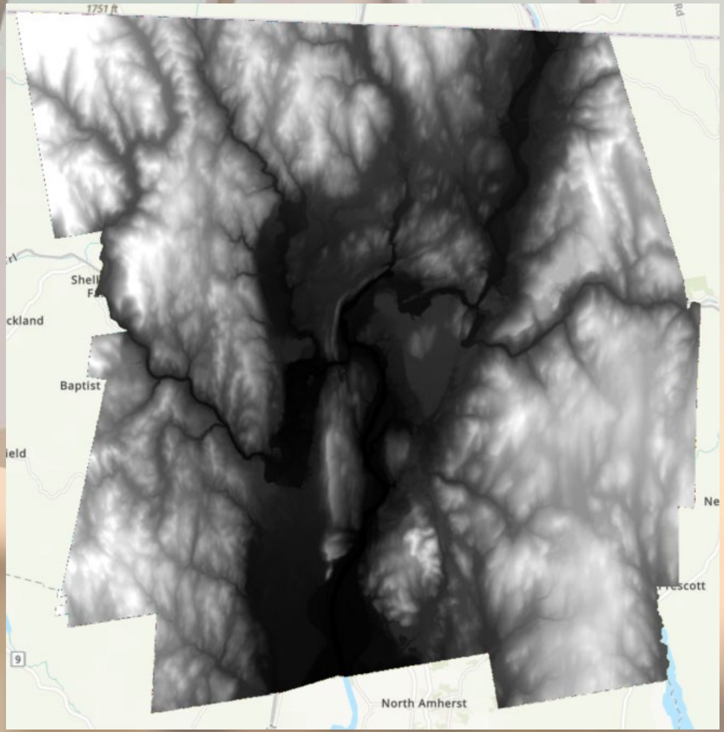


2. Environmental Concerns

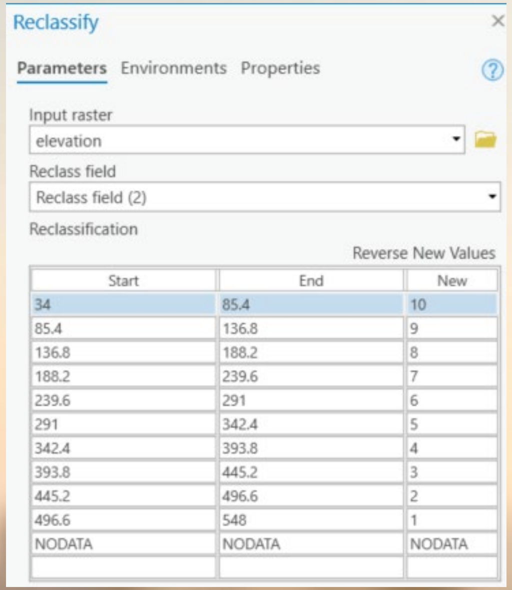
1. Energy Usage

We want the drone base to be located on a higher elevation so that when the drone takes off from the base, it does not waste energy trying to gain height as it is flying to its destination. We use the reclassify tool on the elevation layer and assign low elevation to a 10 (high cost) and high elevation to 1 which means it is the most suitable.





Elevation Layer



Reclassify

Parameters Environments Properties

Input raster: elevation

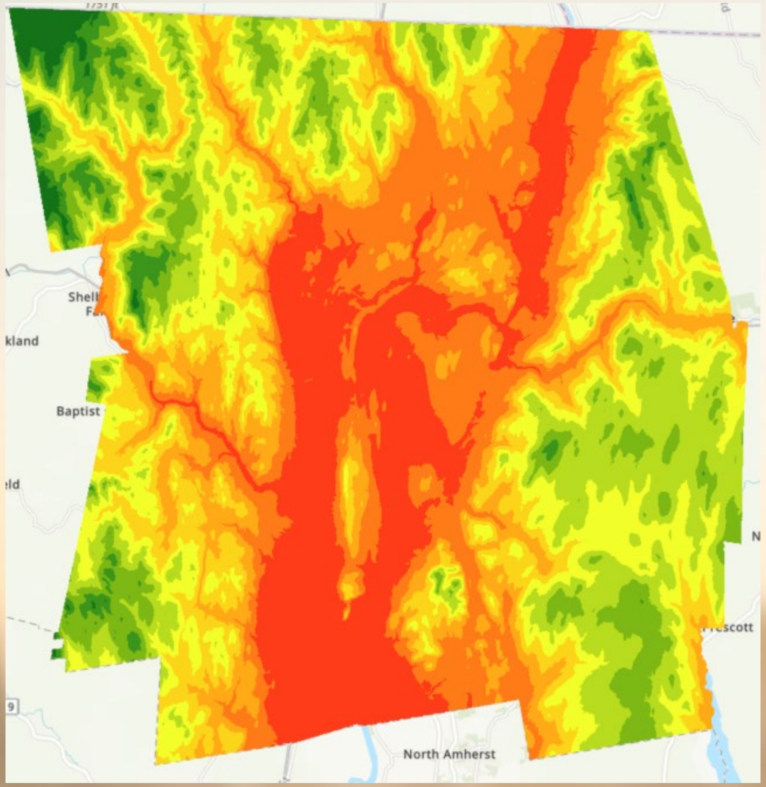
Reclass field: Reclass field (2)

Reclassification

Reverse New Values

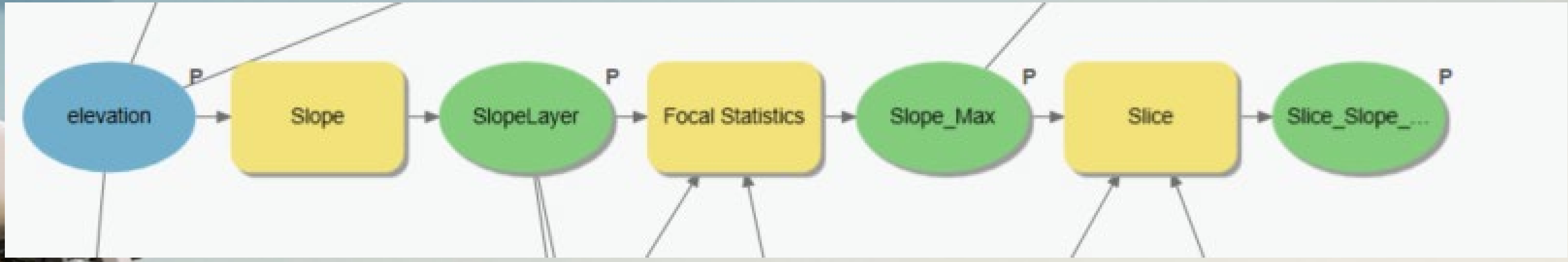
Start	End	New
34	85.4	10
85.4	136.8	9
136.8	188.2	8
188.2	239.6	7
239.6	291	6
291	342.4	5
342.4	393.8	4
393.8	445.2	3
445.2	496.6	2
496.6	548	1
NODATA	NODATA	NODATA

Final Output Suitability Layer

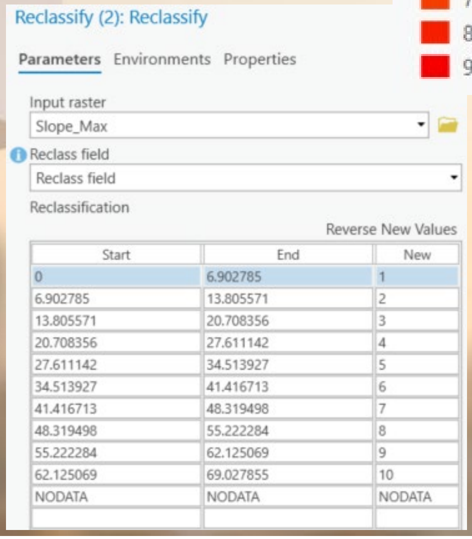


2. Environmental Concerns

2. Flat Surface



We also want the base to be located on a flat area. We therefore use elevation to take slope, then use Focal Stats (Max) to take the maximum of slope in the area and slice into Equal Area with 50 classes, then reclassify to give areas with low steepness values of 1, and other intervals going from flat to steep, values of 2-10. We change the symbology to classify to show the range of steepness



Reclassify (2): Reclassify

Parameters Environments Properties

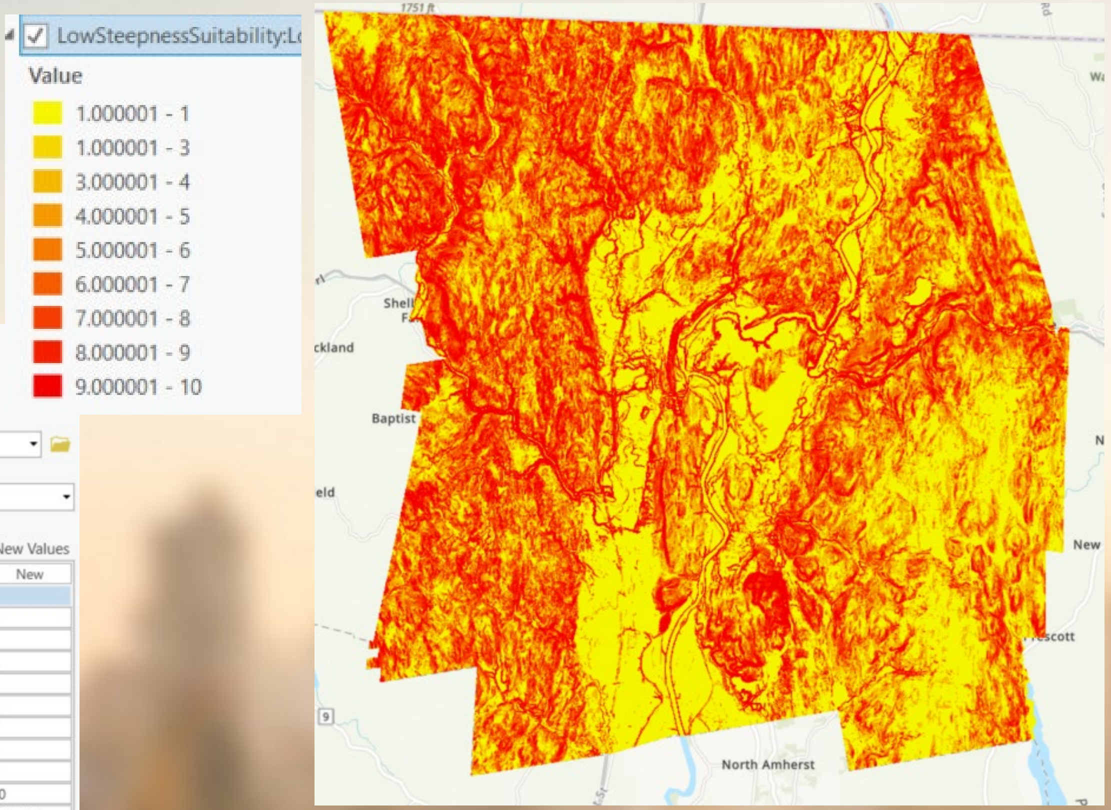
Input raster: Slope_Max

Reclass field: Reclass field

Reclassification

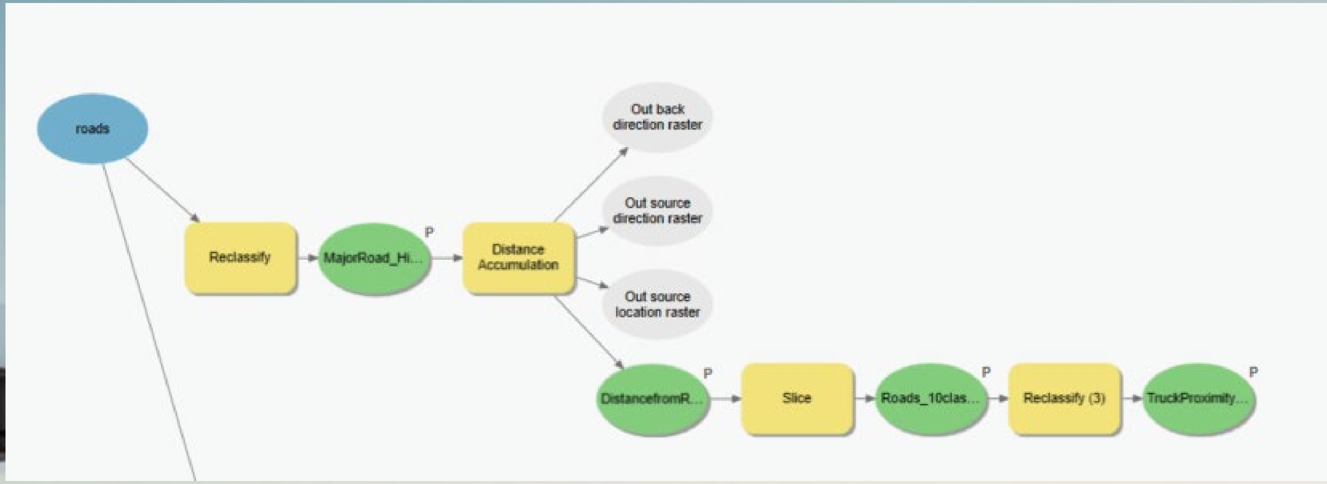
Reverse New Values

Start	End	New
0	6.902785	1
6.902785	13.805571	2
13.805571	20.708356	3
20.708356	27.611142	4
27.611142	34.513927	5
34.513927	41.416713	6
41.416713	48.319498	7
48.319498	55.222284	8
55.222284	62.125069	9
62.125069	69.027855	10
NODATA	NODATA	NODATA



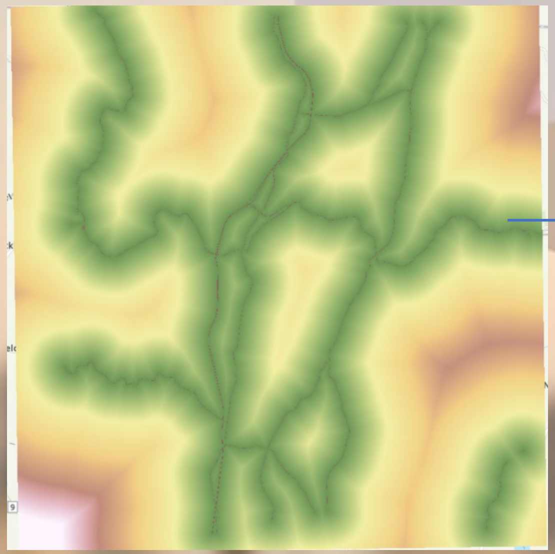
3. Efficiency Concerns

1. Proximity to Truck Routes

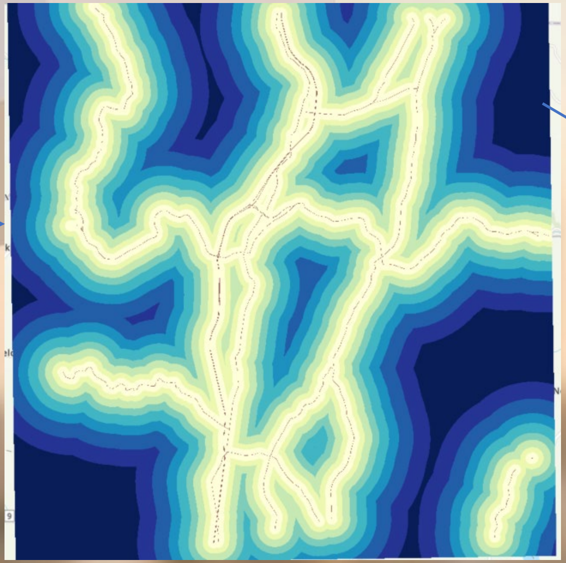


Drone delivery solves the "last mile" problem. What about all the miles before this? We need to site the base very close to a major travel/delivery route so that the trucks can bring the deliveries to the warehouse. First we reclassify our roads layer to get just major roads and highways. Then we run distance accumulation on this layer. Then we slice this layer into 50 classes using equal area. Then we reclassify to 10 classes, giving the closest distance class a value of 10 (because the base can't be on the road itself) and then the next class has a value of 1.

Distance Accumulation



Sliced Layer

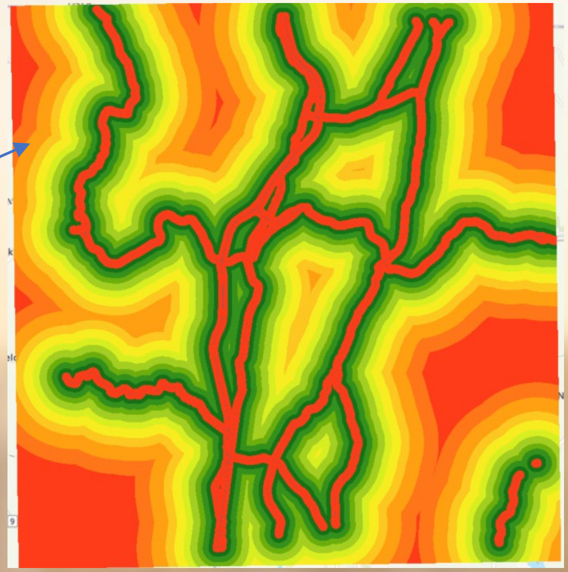


Reclassification

Reverse New Values

Start	End	New
1	5.454545	10
5.454545	9.909091	1
9.909091	14.363636	2
14.363636	18.818182	3
18.818182	23.272727	4
23.272727	27.727273	5
27.727273	32.181818	6
32.181818	36.636364	7
36.636364	41.090909	8
41.090909	45.545455	9
45.545455	50	10
NODATA	NODATA	NODATA

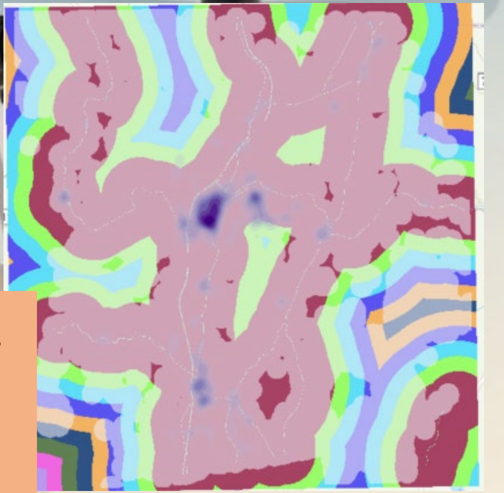
Final Output Suitability Layer



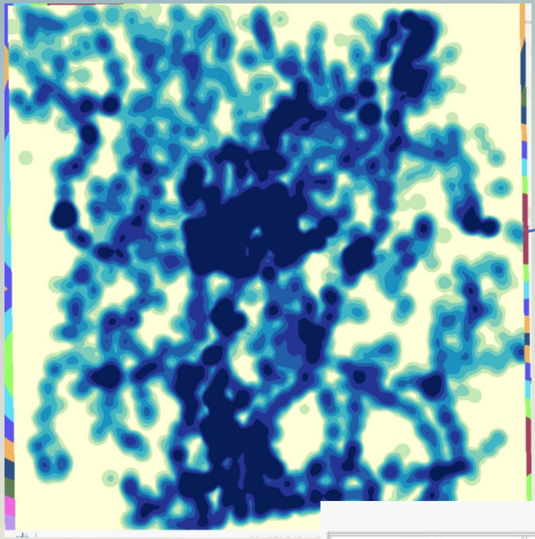
3. Efficiency Concerns

2. Proximity to population dense areas

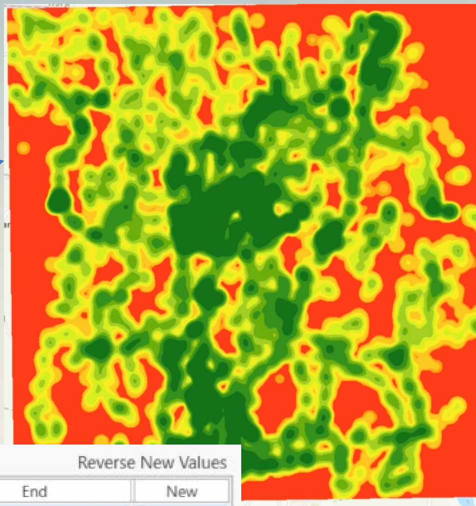
Kernel Density Layer



Sliced Layer



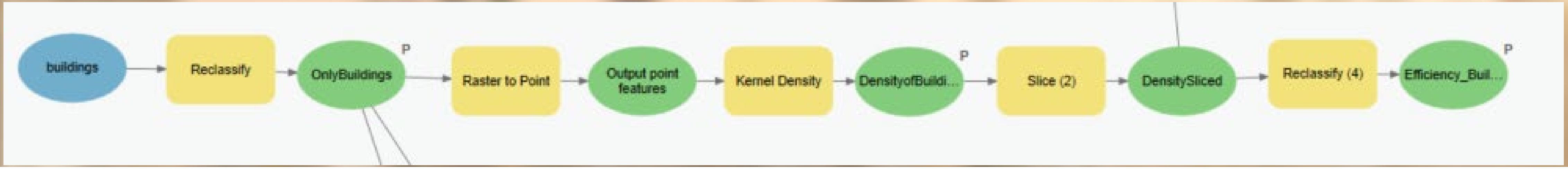
Final Output Suitability Layer



Reverse New Values

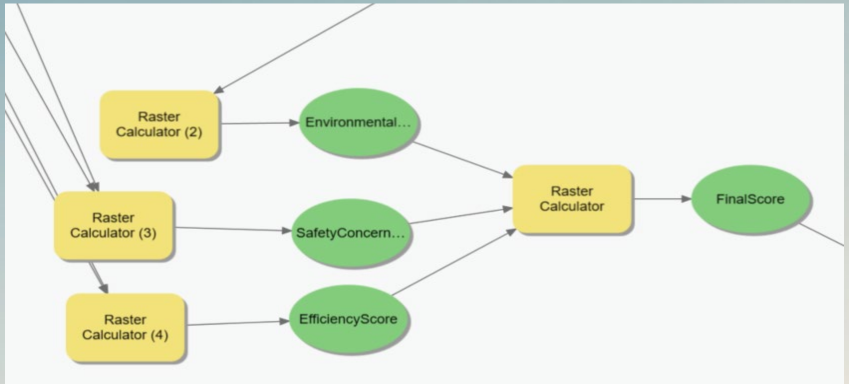
Start	End	New
1	5.9	1
5.9	10.8	2
10.8	15.7	3
15.7	20.6	4
20.6	25.5	5
25.5	30.4	6
30.4	35.3	7
35.3	40.2	8
40.2	45.1	9
45.1	50	10
NODATA	NODATA	NODATA

We use the same exact steps we used in Step 1.2 to find the density of buildings. However, in that example we were avoiding population dense areas. In this example, we desire population dense areas. Thus, we instead reclassify the layer to set the most dense layers to 1 and the least dense to 10.

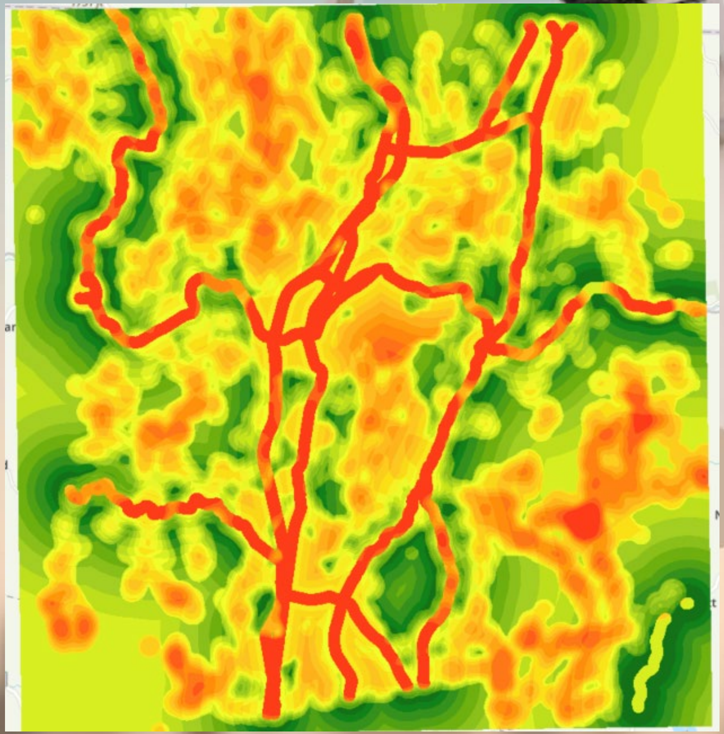


4. Add up Suitability scores for each individual category and weight criteria appropriately.

Use Raster Calculator to add up each suitability layer and assign weights to criteria we perceive as more or less important. For example, we perceive the proximity to people as more important than truck proximity so we assign that layer a higher weight.

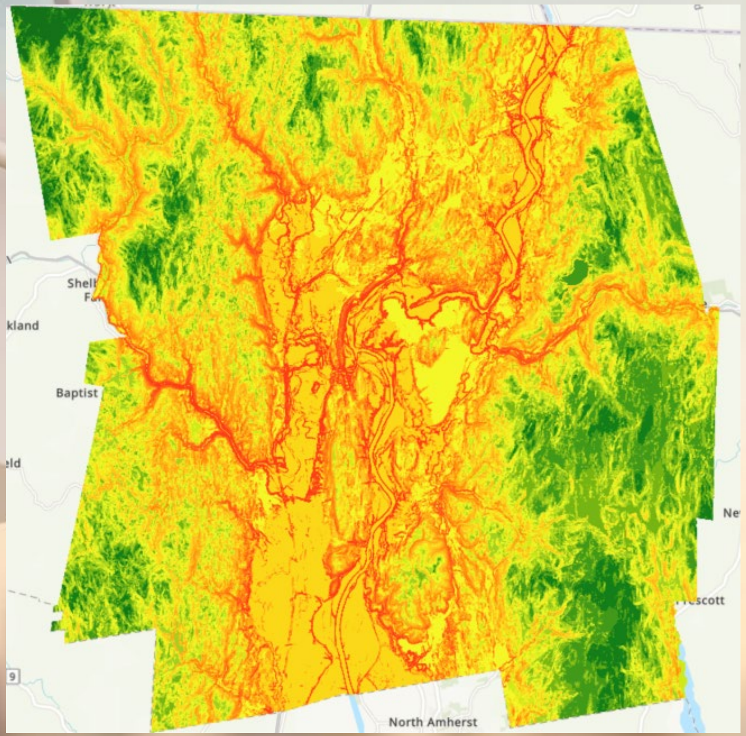


Efficiency Concerns



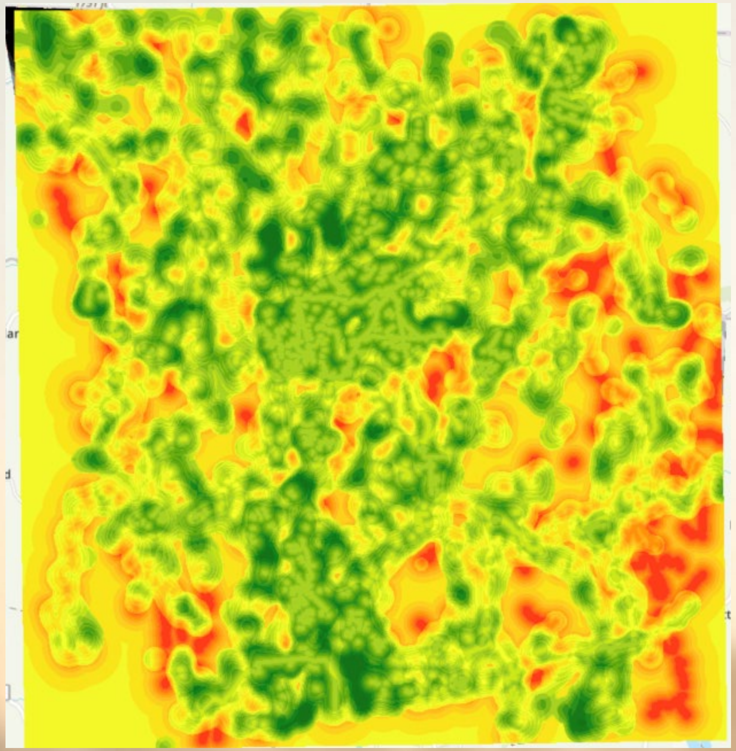
```
("%Efficiency_Building_Suitability%" *.05) + ("%TruckProximitySuitability%" *.04)
```

Environmental Concerns



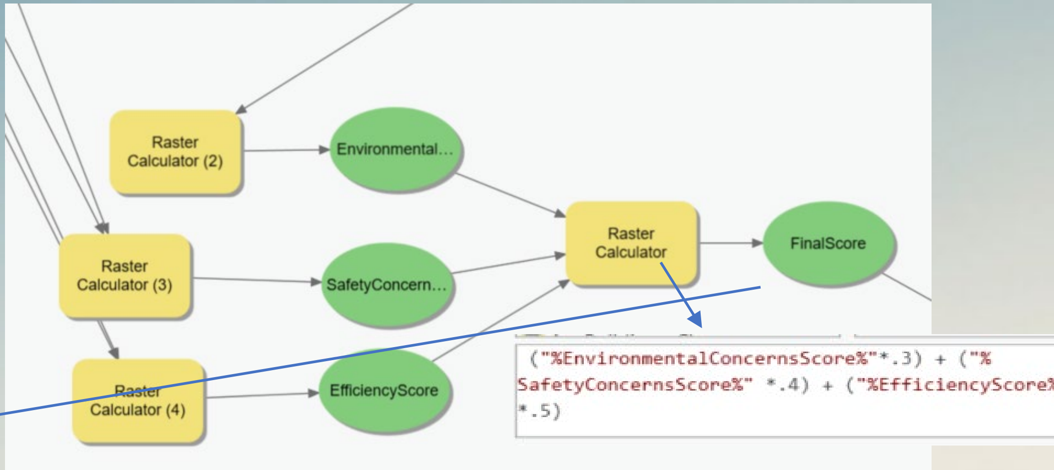

```
("%HighElevationSuitability%" *.04 ) + ( "%LowSteepnessSuitability%"*.02 )
```

Safety Concerns



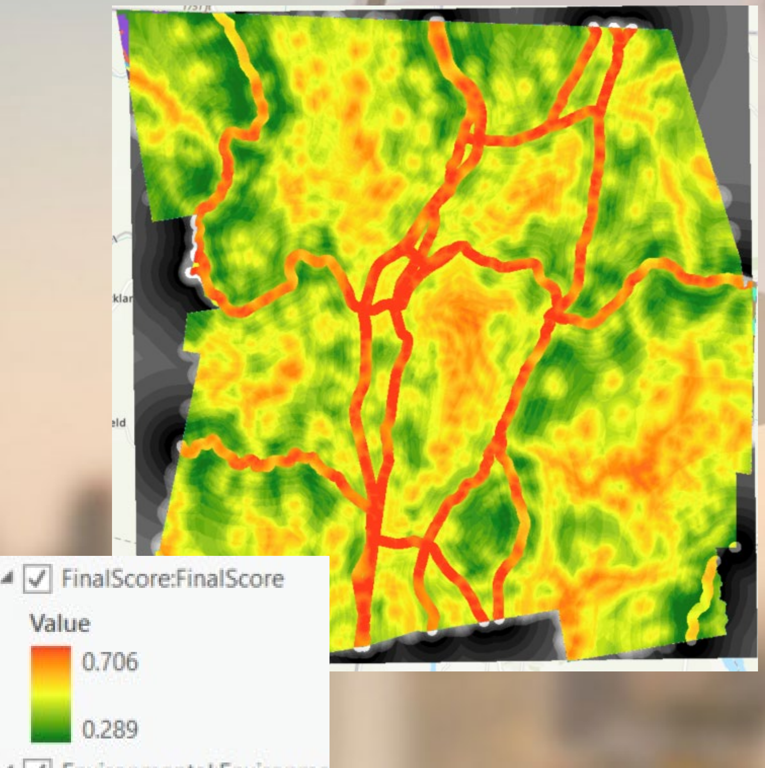
```
( "%MinorRoadsSuitability%"*.03) + ("%Safety_Building_Suitability%"*.04)
```

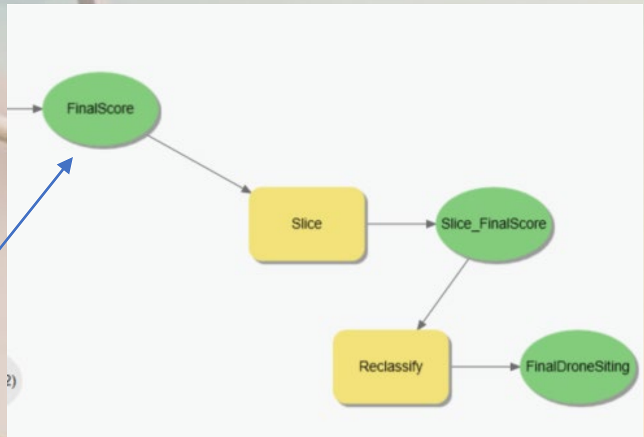
4.2: Combine each layer score into one Final Score:
Use Raster Calculator again to combine each layer into one final score. Within Raster Calculator, we assign different weights to these to emphasize that we think Efficiency is the most important consideration followed by Safety and Environmental considerations. We then slice into 50 classes with equal area and reclassify from 1 to 10.



Final Output Suitability Layer

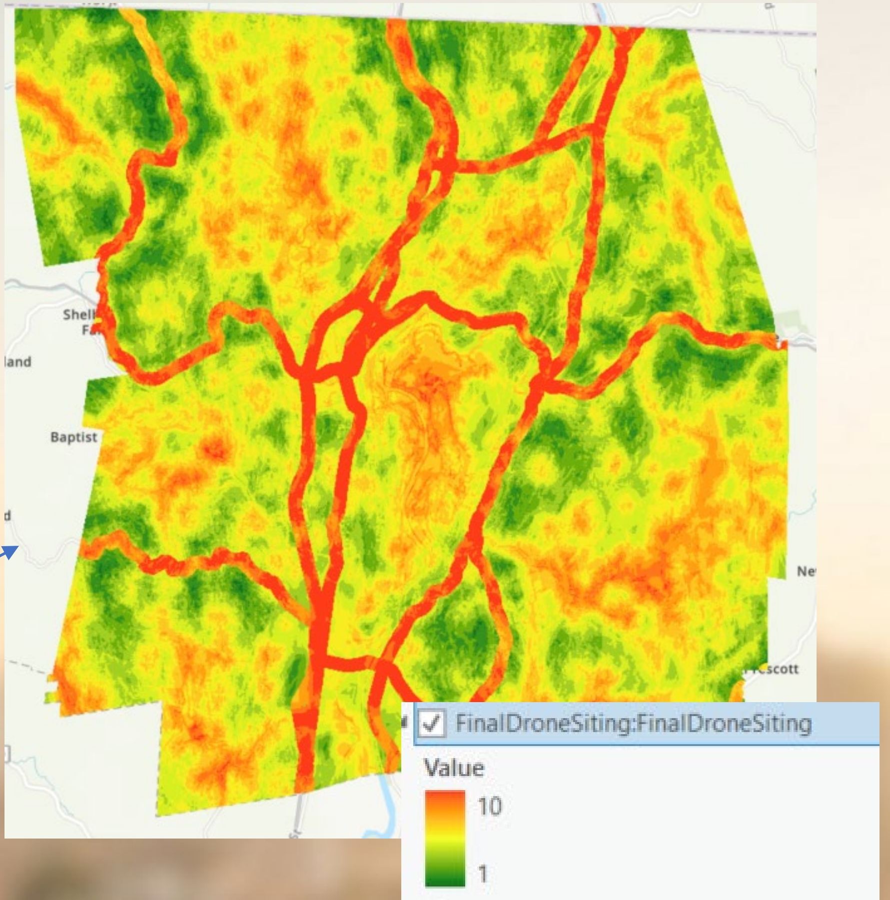
Final Score Layer





Reverse New Values

Start	End	New
1	5.9	1
5.9	10.8	2
10.8	15.7	3
15.7	20.6	4
20.6	25.5	5
25.5	30.4	6
30.4	35.3	7
35.3	40.2	8
40.2	45.1	9
45.1	50	10
NODATA	NODATA	NODATA



Final Drone Delivery Site Suitability Map

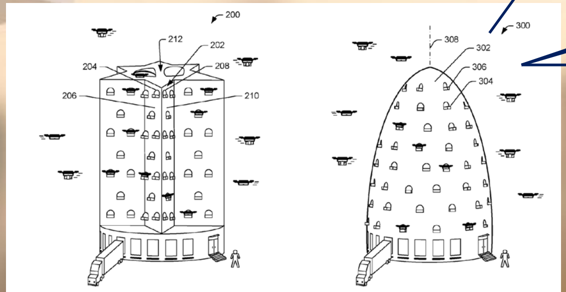


FIG. 2 FIG. 3