# 11.205 – Intro to Spatial Analysis – Fall 2019
**QGIS Exercise**

## Week 6 – Raster Data and Decision Support Analysis: Objectives

**OBJECTIVES**

1. Load Raster Toolbar and Raster Processing Menu
2. Conceptual Workflow Mapping
3. Introduce Decision Support Layers
4. Perform Decision Support Analysis

In lecture this week, we discussed raster data, including some of the methods to work with it, and suitability analysis. In lab this week, we are going to get some hands-on experience working with raster data and perform a site selection suitability analysis.

The Bronx River Alliance is interested in creating an environmental education center near both a school and the Bronx River Greenway. They reason that such a location is appropriate because visitors would have easy access to the Greenway as a learning environment and would be able to work closely with the school. The Alliance wants to identify existing vacant lots on which to site the proposed center. The organization will then research each one to determine the possibility of purchase, acquisition, and site suitability. We will start by helping them narrow down the possible sites.

*Note: Some of the QGIS features in this exercise are unstable, make sure you save your file frequently.*

**OBJECTIVE 1. LOAD RASTER TOOLBAR AND RASTER PROCESSING MENU**

In this lab, we will be using a combination of raster processing tools to complete our suitability analysis. Recall that 'raster' data are spatial data that store attributes in a regular grid of pixels, or cells.

1. Open a blank QGIS project.

2. You can open the Raster toolbar on your computer by going to View > Toolbars > Raster Toolbar. It has the following buttons. You can also explore these tools under the Raster dropdown menu.

## OBJECTIVE 2: CARTOGRAPHIC MODELING

When running multistep GIS analysis, it is helpful to conceptually map out your workflow; in GIS, we call this 'cartographic modeling'. Mapping the workflow step-by-step helps to determine which geoprocessing tools to use, to critically evaluate the steps involved, and to create robust documentation of our analysis. One method is to create a detailed workflow chart. We have already created the conceptual model that details the workflow for today's lab (see image below). **Our goal today is to follow this cartographic model of a site selection analysis.**
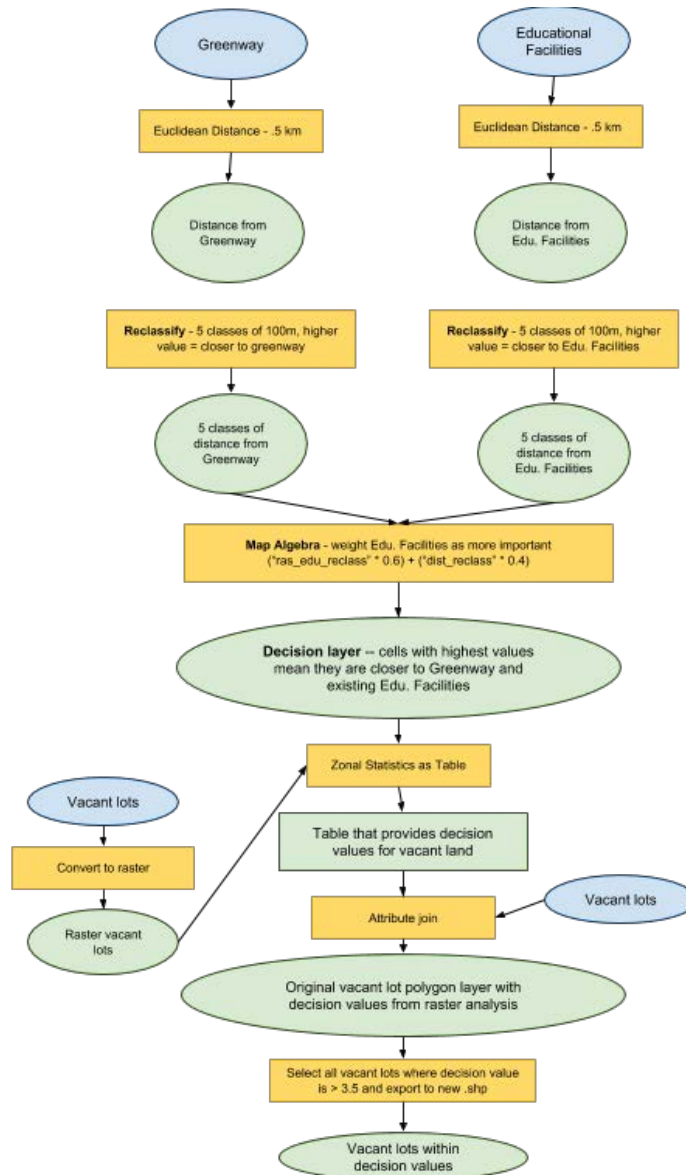


This cartographic model shows the following:
- **Blue ovals are the input layers**. These are layers we start with that are the base components of our analysis. Input layers for this process will be vacant lots, the location of the greenway, and locations of educational facilities (schools).

- **Yellow boxes are the tools and processes.** As shown above, we will be calculating distances, converting files, reclassifying our data, and performing a range of geoprocessing tasks. These tasks are specifically detailed in the yellow boxes.
- **Green ovals represent our output files from each step**. These output files contain temporary files that are intermediary to the process, and decision support files that contain the criteria on which we are basing our site selection analysis. Note, for example, the decision map created by overlaying the educational facilities buffers and the greenway buffers. This is an important file that contains raster cells with the values indicating suitability.

Cartographic modeling is a form of concept mapping that is important when scoping out GIS work. You can reference this workflow map throughout the rest of the lab.

## OBJECTIVE 3: CREATE DECISION SUPPORT LAYERS

To begin our analysis, we need to create layers that allow us to make decisions based on spatial criteria. These layers are referred to as **decision support layers** because they represent the criteria that will be used to make our decisions.

## 1. Create the 'Distance from Greenway' Decision Support Layer

An expert informed us that 0.5 kilometers is the maximum distance greenway visitors are likely to walk to visit an environmental education center. Given this information, we will only consider locations within 0.5 kilometers of the greenway for our site. The expert also told us that the closer to the site the better. With this knowledge, we can create the decision support layer that represents this.
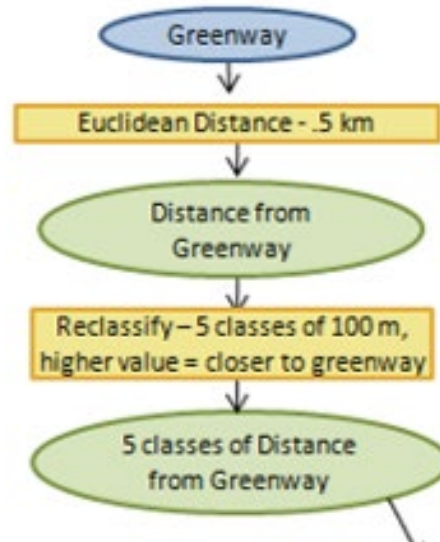


**a. Preliminary Work**

To begin, we are going to define the geography for our analysis, set up some processing options, and create a bookmark.

1. Add data. Add the **bx_river_greenway.shp** and the **edu_facilities.shp** layer to your map. Click the 'Zoom Full' button in the top toolbar (a magnifying glass with three arrows), or use the Shift – Cmd – F hotkey (or Shift-Ctl-F on Windows). Like the image below, you should be able to see the full extent of both layers in your screen.
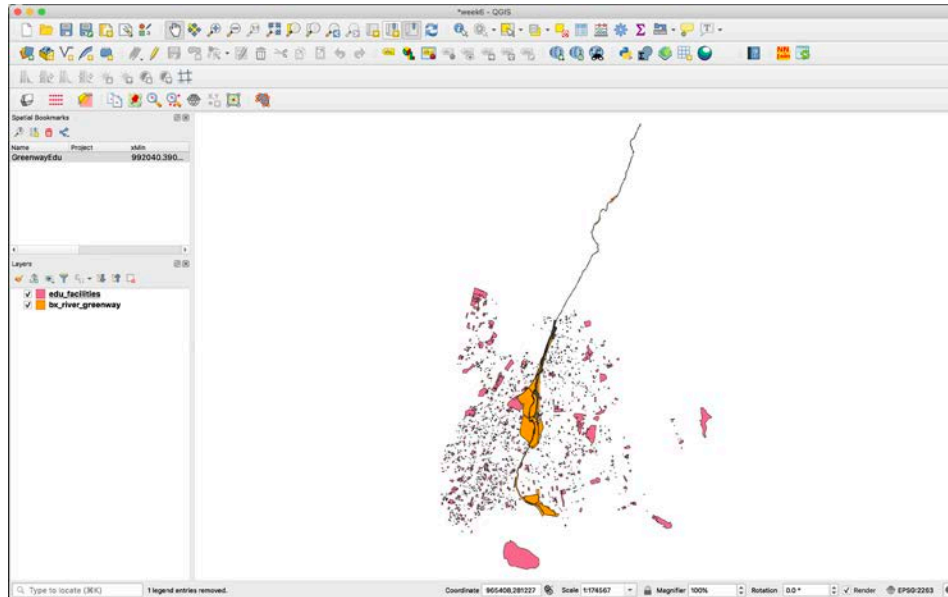


2. Now, let's create a bookmark that we can use as a placeholder to return to this map extent. Click on View > New Bookmark. The Spatial Bookmarks Panel will appear on the side of your screen. Name the bookmark 'GreenwayEdu'.

3. We will make sure we do all of our processing from this bookmark. In the bookmark panel, note the values of xMin, yMin, xMax, and yMax. Mine were  992040,  223542,  1060508, and  302340, respectively. Note that these values may vary slightly depending on your zoom extent. We'll use these when we rasterize our vector layers.

**b. Processing**

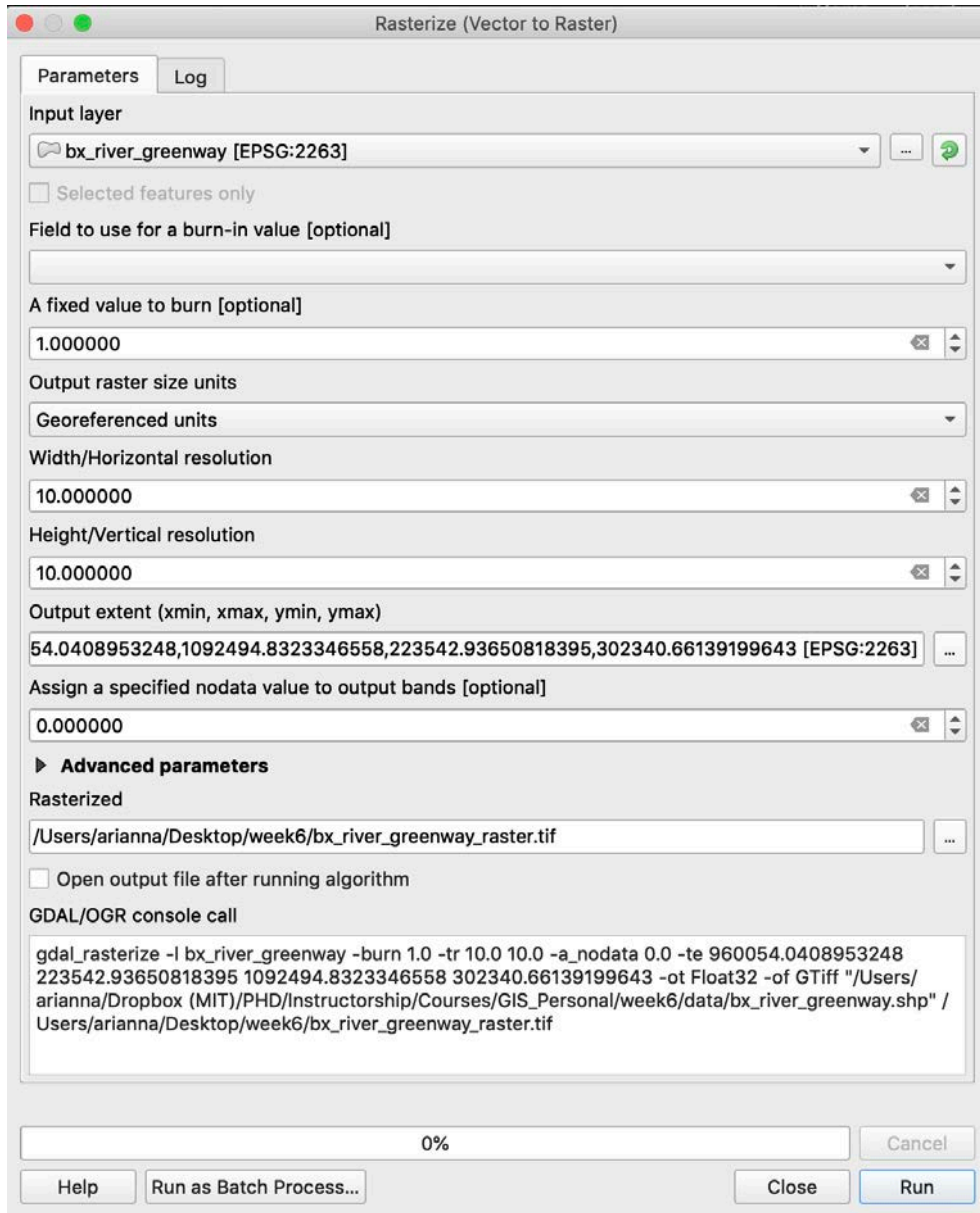Now we are ready to begin the processing of data that we want to perform in QGIS.

1. We will use the Proximity (Raster Distance) tool in order to create gridded representations of distance from features of interest. Then, we will use the Raster Calculator to calculate the average distance from each criterion. However, we first need to convert our vector representations into gridded raster representations.

Navigate to Raster > Conversion > Rasterize (Vector to Raster).
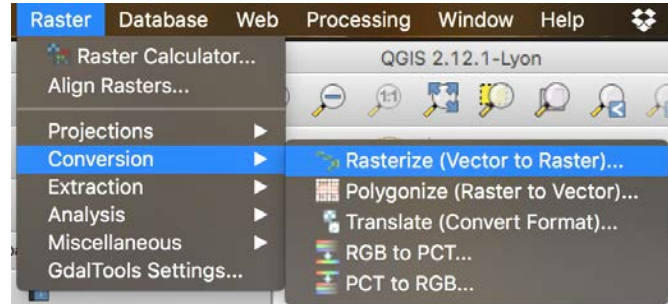
In the dialog, select the following:

a) **Input Layer:** bx_river_greenway
b) **A fixed value to burn:** 1
    a. This says, 'where there is a feature, the value should be 1'.
c) **Output raster size units:** Georeferenced units.
    a. This says that the raster layer's grid resolution should be measured in the units of the map (in our case, feet).
d) **Width/horizontal resolution:** 10
e) **Height/vertical resolution:** 10
    a. Both the above say 'make a grid in which each cell is 10 feet wide'.
f) **Output extent:** Click the '…' button and select 'Use Canvas Extent'
    a. Make sure you've zoomed to your bookmark! You can also manually input the xMin, yMin, etc values of your bookmark… but that sounds tedious.
g) **Rasterized:** save the file as **bx_river_greenway_raster.tif** in your project folder.
h) **Uncheck** the 'Open output file after running algorithm'
i) Click 'Run' and then Close.

## Rasterize (Vector to Raster)

**Parameters** | Log

**Input layer**

bx_river_greenway [EPSG:2263]

☐ Selected features only

**Field to use for a burn-in value [optional]**

**A fixed value to burn [optional]**

1.000000

**Output raster size units**

Georeferenced units

**Width/Horizontal resolution**

10.000000

**Height/Vertical resolution**

10.000000

**Output extent (xmin, xmax, ymin, ymax)**

54.0408953248,1092494.8323346558,223542.93650818395,302340.66139199643 [EPSG:2263]

**Assign a specified nodata value to output bands [optional]**

0.000000

▶ **Advanced parameters**

**Rasterized**

/Users/arianna/Desktop/week6/bx_river_greenway_raster.tif

☐ Open output file after running algorithm

**GDAL/OGR console call**

gdal_rasterize -l bx_river_greenway -burn 1.0 -tr 10.0 10.0 -a_nodata 0.0 -te 960054.0408953248 223542.93650818395 1092494.8323346558 302340.66139199643 -ot Float32 -of GTiff "/Users/arianna/Dropbox (MIT)/PHD/Instructorship/Courses/GIS_Personal/week6/data/bx_river_greenway.shp" /Users/arianna/Desktop/week6/bx_river_greenway_raster.tif

0%

Help | Run as Batch Process... | Close | Run

2. Add your newly created raster layer to the project. You should now have a raster file of the Bronx River in your layers that looks like the image below.
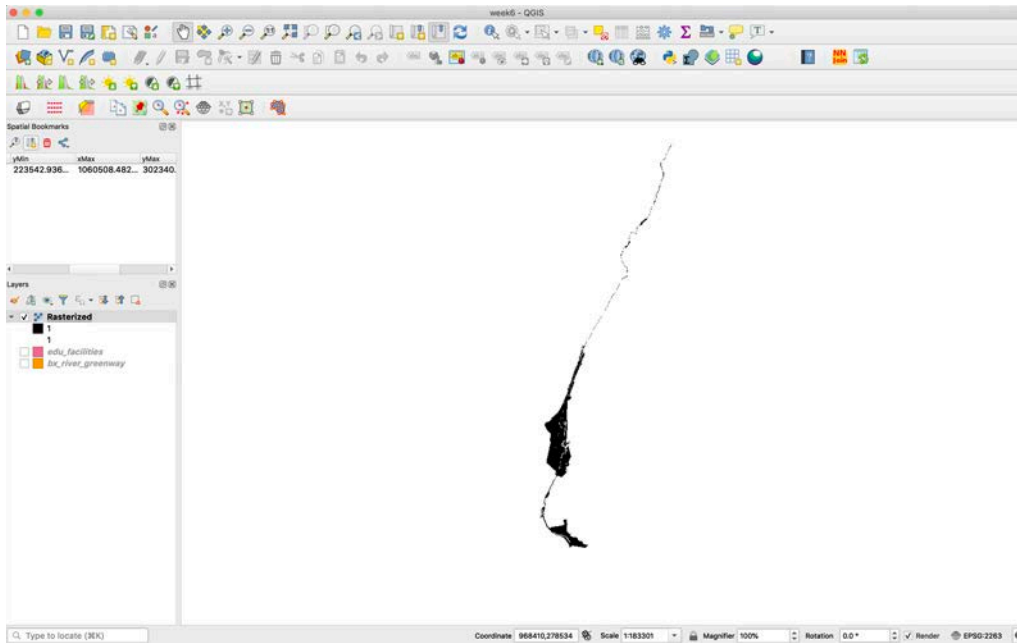
3. Now we will create a thematic map based on proximity between each pixel. Navigate to Raster > Analysis > Proximity (Raster Distance).

This is a raster output tool that gives each raster cell a unique distance value based on the distance from a source feature.

In the Proximity dialog, use the following parameters:
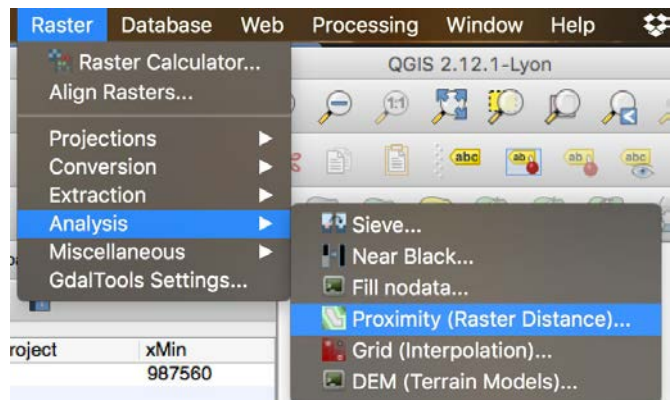
a) **Input layer:** The **'bx_river_greenway_raster'** layer. (Note: it may be called 'Rasterized' if you automatically added it to your project file.)
b) **Band number:** Band 1 (Gray)
c) **A list of pixel values…:** **1** is the pixel value in the source image to be considered target pixels.
d) **Distance Units:** Georeferenced Units
e) **The maximum distance…:** **1640** in georeferenced coordinates (approximately 0.5 kilometers in feet). The unit of measurement is feet because our layer is in a State Plane projection that uses feet.
f) **Nodata value…:** Use -1 as the nodata value. We do this to replace values beyond 1640 with a recognizable value (-1) to excluded from layer symbolization in the following steps.
g) Name the proximity map (output file) **'greenway_raster_dist.tif'** and save it in your project folder.
h) **Uncheck** the 'Open output file after running algorithm'
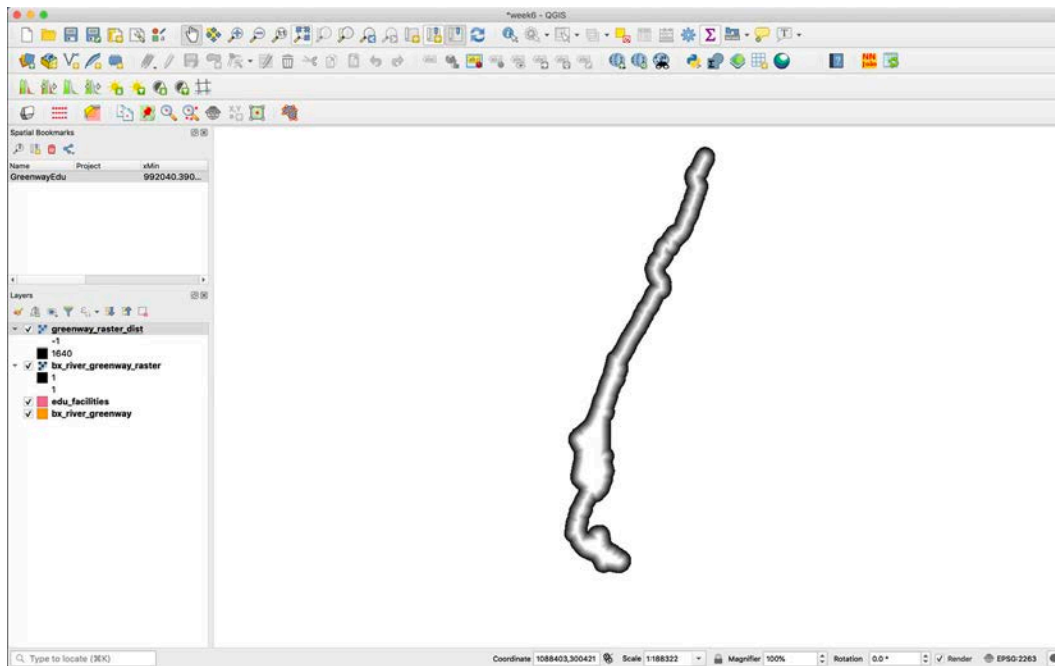i) Click 'Run' and then Close.

Your dialog box, when ready, should look like the following.
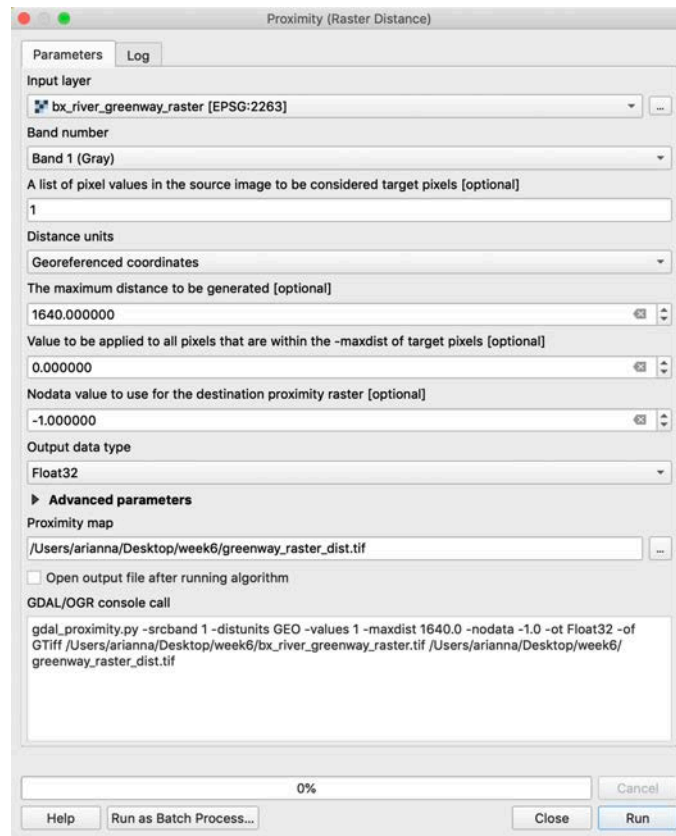


4. Add the raster file **greenway_raster_dist.tif** to your map. Change the symbology color gradient from 'White to Black' by right-clicking on your new distance layer and going to Properties > Symbology (see image below).
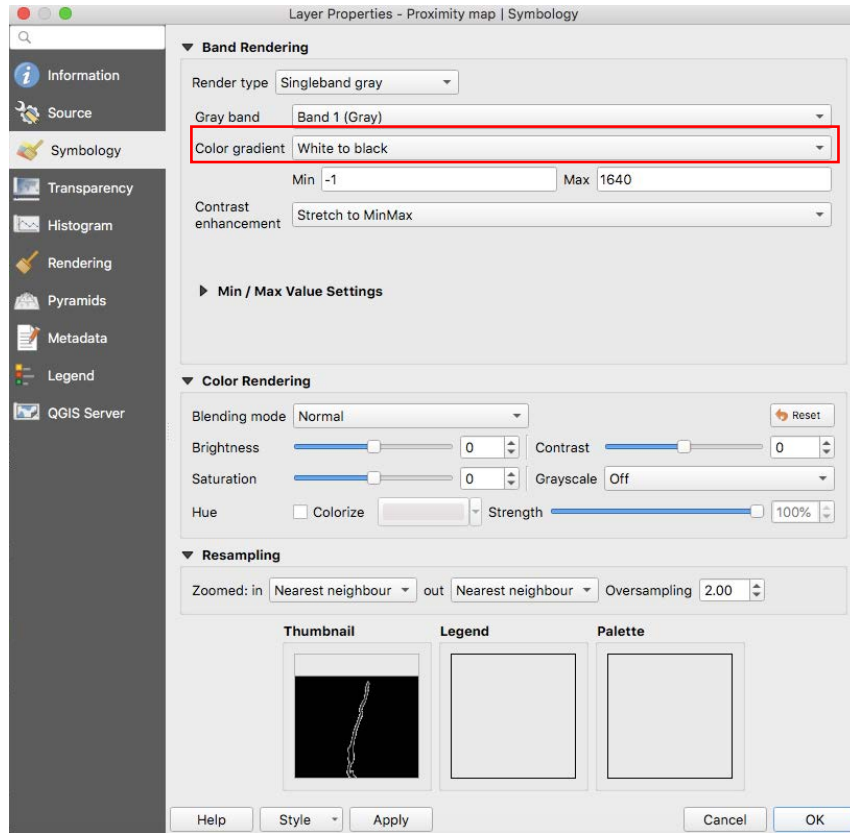
You should see something like the image below.

This tool creates a raster file with each cell is given a value according to its distance from the greenway. Because we set a maximum distance, areas that are more than 1640 feet away from the greenway are not considered.

5. We ultimately want to reclassify the data so that each 100 meters (or roughly 328 feet) is coded with a different suitability level. Areas that are closest to the greenway will have the highest suitability values, areas that are farthest away from the greenway will have the lowest suitability values.

Let's begin by visualizing this. Open the layer properties dialog for the **'greenway_raster_dist'** layer (note that this layer might be called 'Proximity map' if you automatically added the result of the geoprocessing operation). Go to the Symbology tab and change the Render Type to 'Singleband pseudocolor.' Make sure the min and max values are 0 and 1640, respectively. Change the color interpolation to 'Discrete' in order to only show up to the max value of 1640. Choose the Spectral color ramp.

Change the max value in the color range to 1640 and have 5 *equal interval* classes. This will give us intervals every 328 feet. (1640 feet/5 classes).
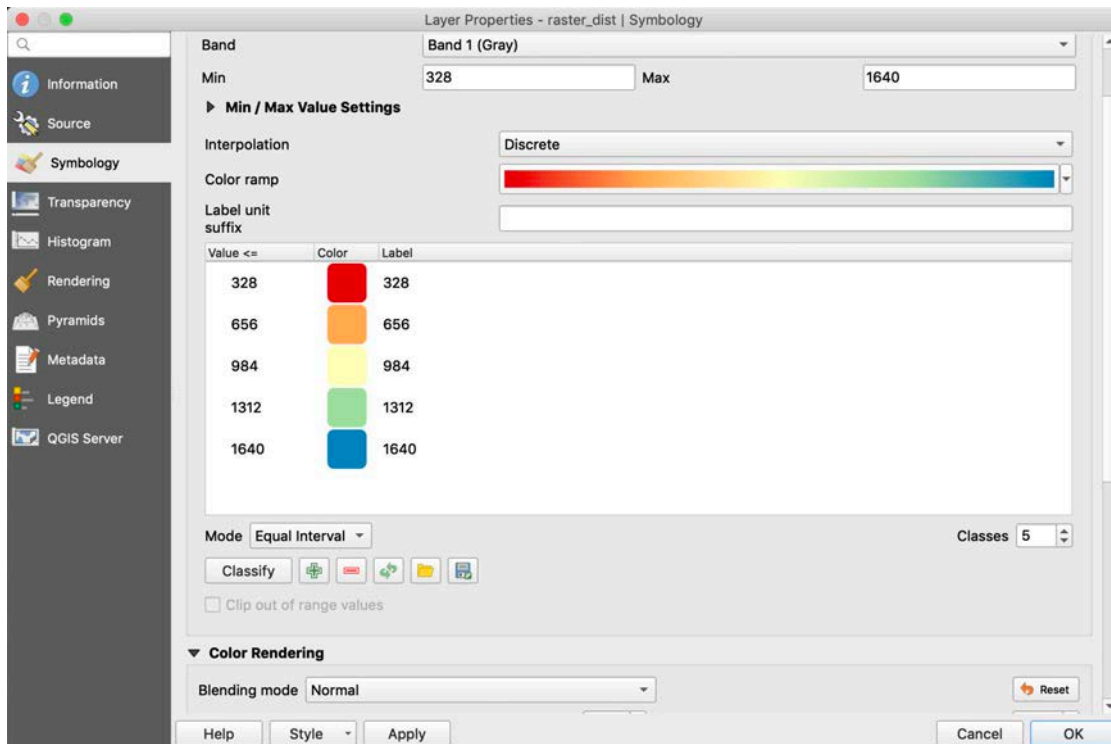


When you click 'OK', your map should look like the following:
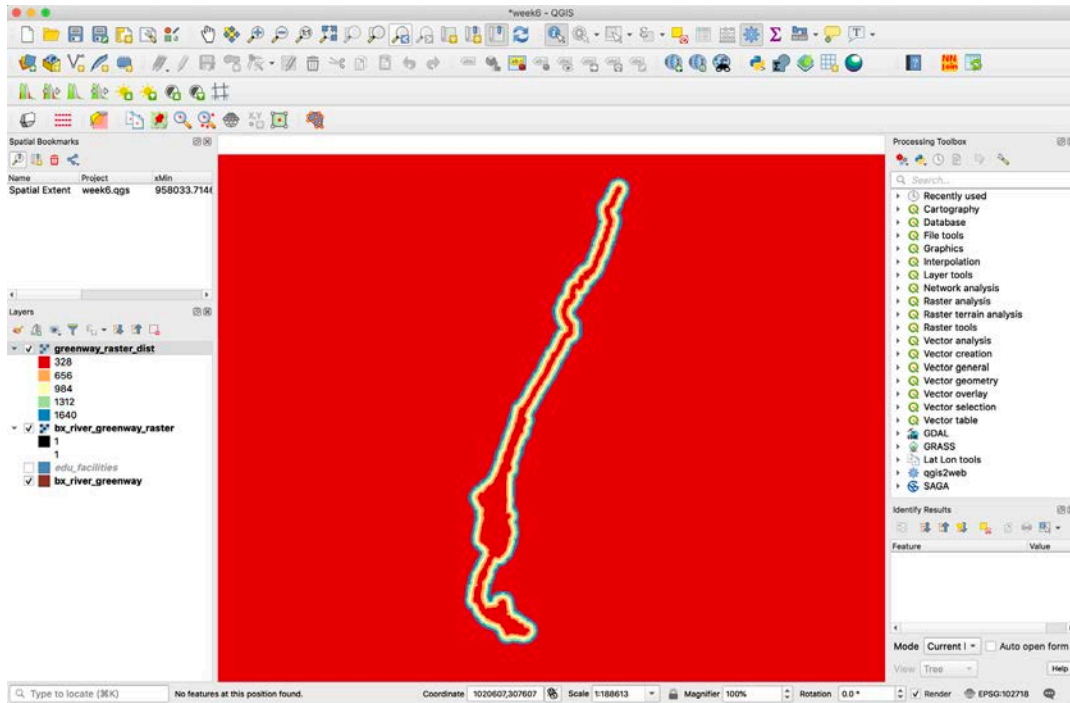
To see the value of each pixel, click on locations covered by the raster using the information tool . In the 'Identify Results' panel, change the 'View' to 'Table'. The 'Value' field represents a unique distance value. If you zoom in closely you will notice the pixelated nature of the output.

Note that both the center of the buffer and the area outside it have the same color (in my case, they are both red). **Click on these two areas using the information tool.** You will notice that the outside has a value of -1 (which is the value we assigned to areas located beyond our 1640 cut-off) and the center has a value of 0.

Let's visualize these differences in values further! Open the Symbology tab again, and manually add a color category using the '+' button. Make the color transparent by adjusting the color opacity and replace the value with -1. Click Ok.
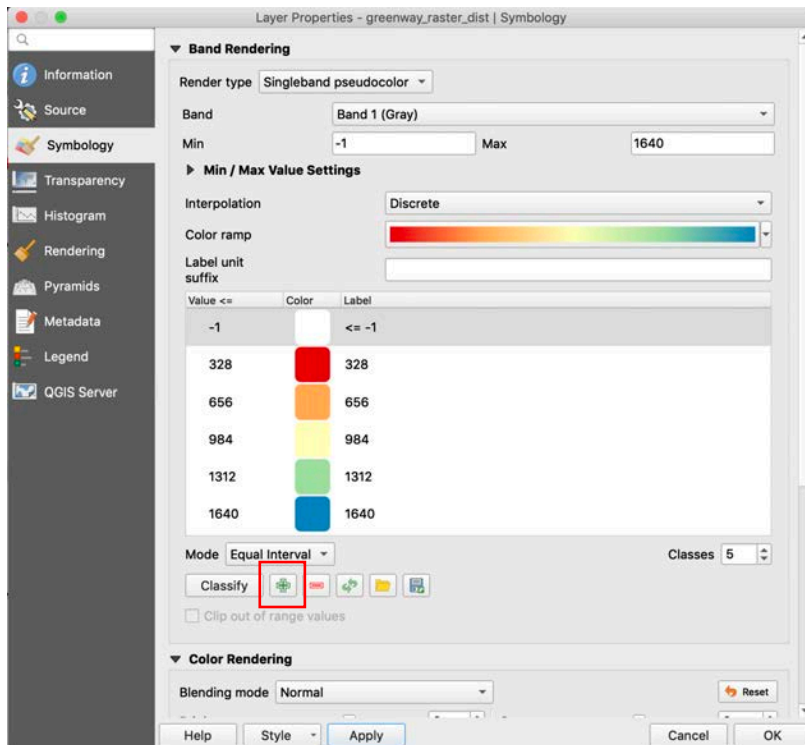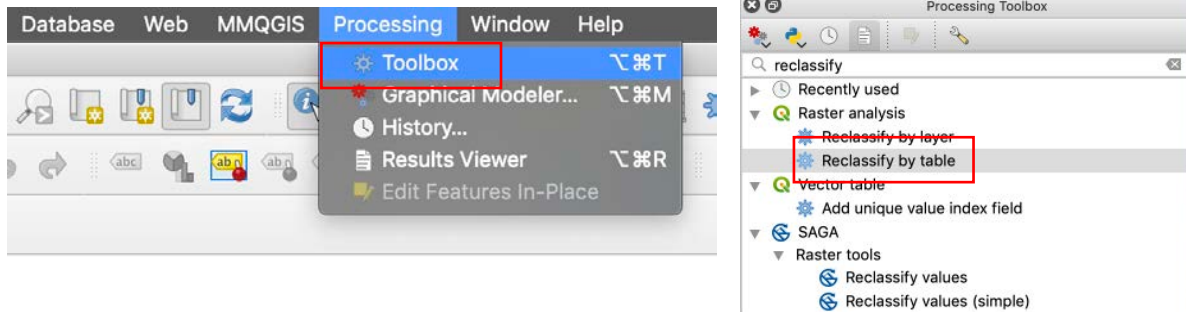
Your map should now look like the image below.
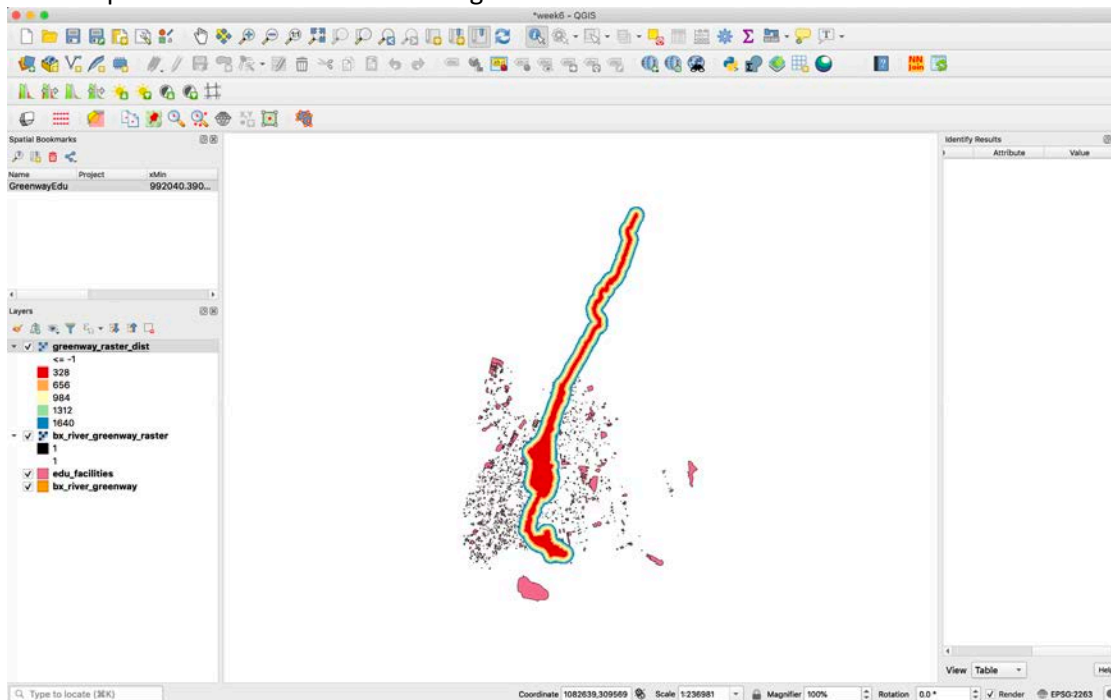


6. Reclassify your data.  We want to reclassify our raster data to assign high values for the areas closer to the greenway, and low values for areas farther away from the greenway.

Go to View > Panels > Processing Toolbox. Then, search "**Reclassify**" and select the QGIS Reclassify by Table tool from the Raster Analysis toolset.



Select the **greenway_raster_dist** as the Raster Layer. Create a new reclassification table. Add 5 rows, then enter these values:

| Minimum | Maximum | Value |
|---------|---------|-------|
| 0 | 328 | 5 |
| 328 | 656 | 4 |
| 656 | 984 | 3 |
| 984 | 1312 | 2 |
| 1312 | 1641 | 1 |

We use 1641, rather than 1640 to ensure that the top end of our distance range is included.

Under "Advanced Parameters" …

- Your Output no data value should be 0.
- Your Range boundaries should be min <= value < max.
  Make sure that 'Use no data when no range matches value' is checked – this ensures that the -1 values outside of our proximity analysis result are classified as 0.

Save the file as **greenway_raster_reclass.tif** and uncheck the 'open output file after running algorithm'. The window should look like the following:
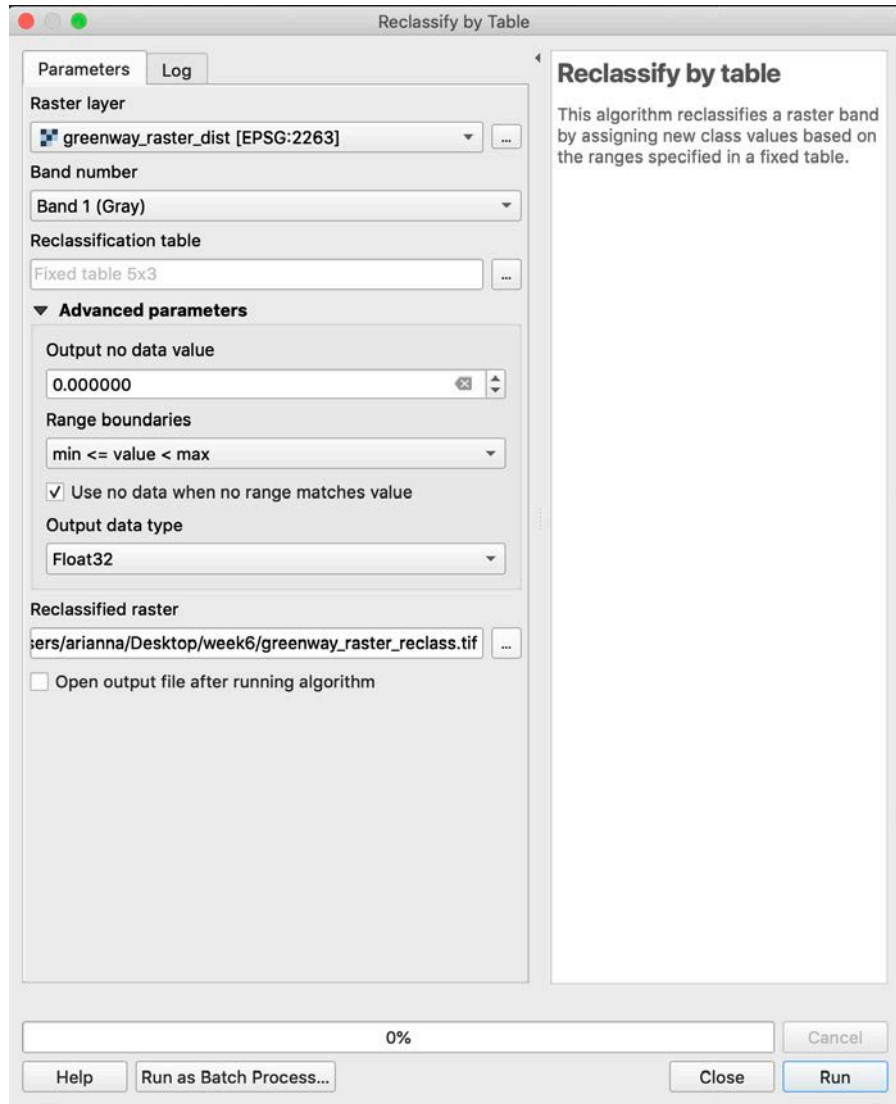
7. Add the raster layer to your map. You will need to redo the symbology. To visualize the raster with a single color for each raster value, open layer properties and set your style as follows. Remember to symbolize 0 using a transparent symbol.
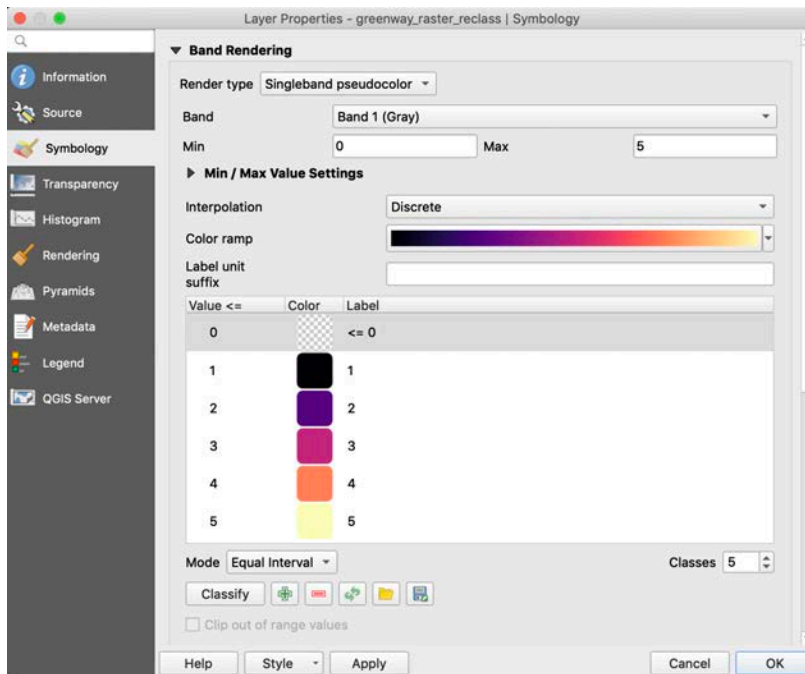
Your output should look similar to the following:
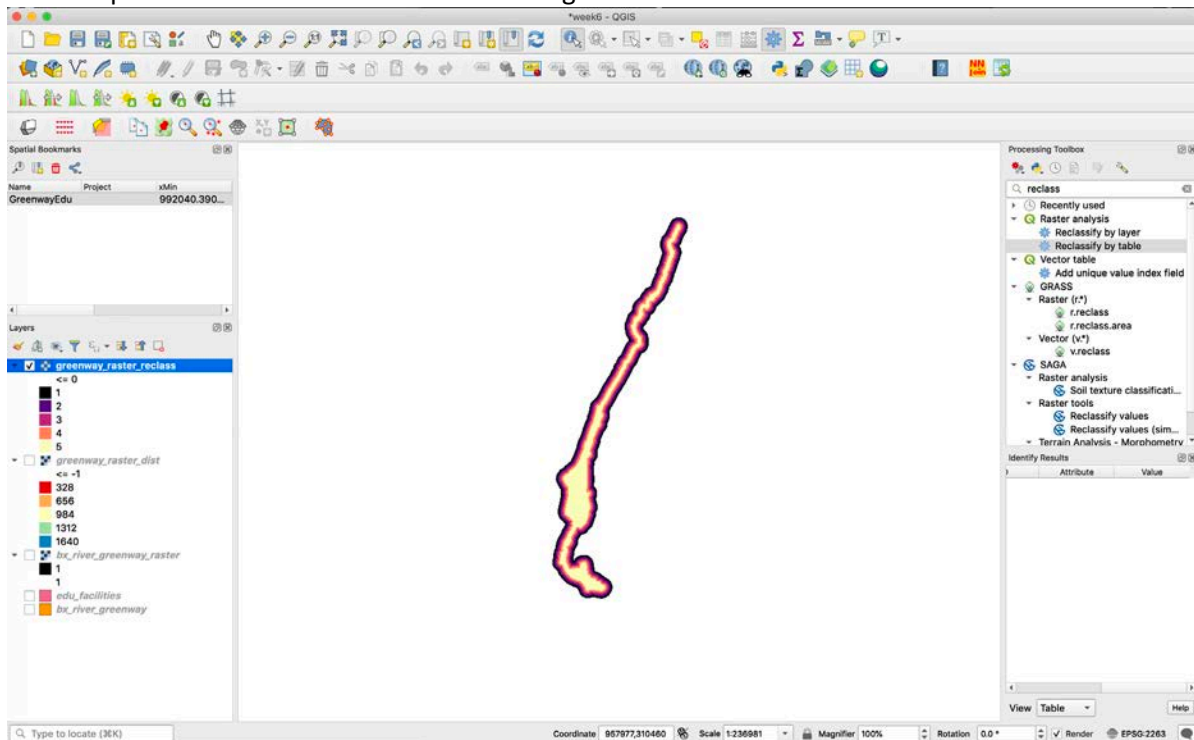


To recap, we used the **Proximity tool** and the **Reclassify by table tool** to create a suitability layer for the proximity to the greenway. According to solely to the criteria of distance, high values, those with value '5', have high suitability, while low values, those with value '1', have low suitability. This is our Decision Support Layer for the greenway.

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## 2. Create the 'Distance from Educational Facilities' Decision Support Layer

We now need to create the Decision Support Layer for proximity to Education Facilities. One of the criteria laid out by the Bronx River Alliance is proximity to schools, and we need to create another decision support layer containing this suitability information. We will follow a very similar workflow as we did for the greenway proximity layer.
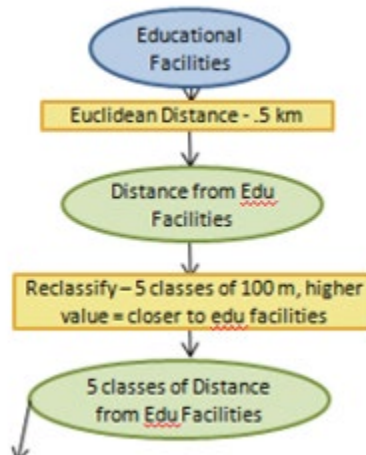


1. Navigate to Raster > Conversion > Rasterize. Remember that you need to make sure you've zoomed to the bookmark that you've created. This is exactly the same process we followed earlier!  In the rasterize dialog, select the following**:**

- a) **Input Layer:** edu_facilities
- b) **A fixed value to burn:** 1
    - a. This says 'where there is a feature, the value should be 1'.
- c) **Output raster size units:** Georeferenced units.
    - a. This says that the raster layer's grid resolution should be measured in the units of the map (in our case, feet).
- d) **Width/horizontal resolution:** 10
- e) **Height/vertical resolution:** 10
    - a. Both the above say 'make a grid in which each cell is 10 feet wide'.
- f) **Output extent:** Click the '…' button and select 'Use Canvas Extent'
    - a. Make sure you've zoomed to your bookmark!
- j) **Rasterized:** save the file as **edu_facilities_raster.tif** in your project folder.
- k) **Uncheck** the 'Open output file after running algorithm'
- l) Click 'Run' and then Close.
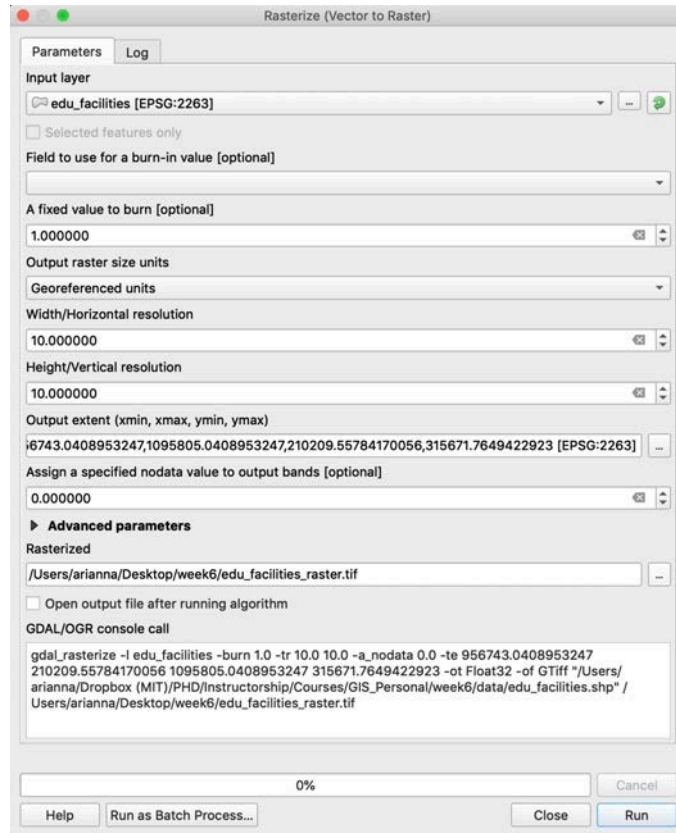
2. Add the **edu_facilities_raster** layer to your project and move it on top of your Bronx Greenway layers – if you have not set your transparent colors in your layer symbology, you may not be able to see the educational facilities! You should see something like the image below:
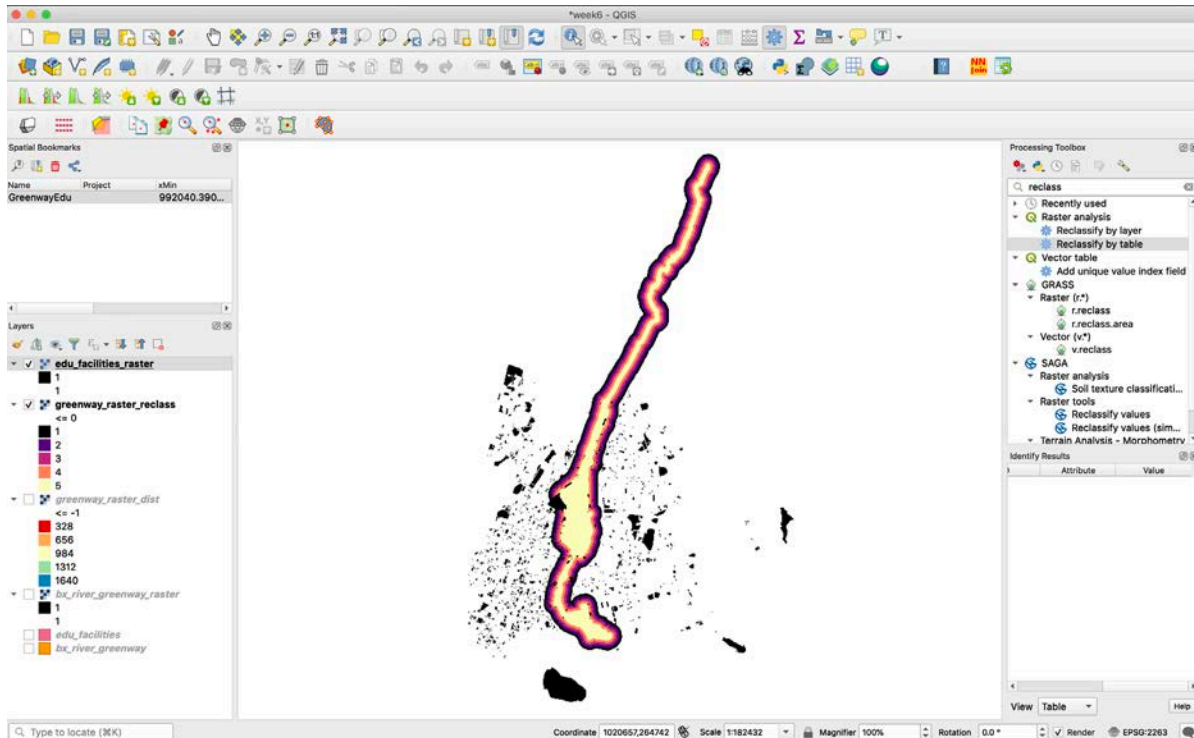
3. Now we will create a thematic map based on proximity between each pixel. Navigate to Raster > Analysis > Proximity (Raster Distance).

   a) **Input layer:** The **'edu_facilities_raster'** layer.
   b) **Band number:** Band 1 (Gray)
   c) **A list of pixel values…:** **1** is the pixel value in the source image to be considered target pixels.
   d) **Distance Units:** Georeferenced Units
   e) **The maximum distance…:** **1640** in georeferenced coordinates (approximately 0.5 kilometers in feet). The unit of measurement is feet because our layer is in a State Plane projection that uses feet.
   f) **Nodata value…:** Use -1 as the nodata value. We do this to replace values beyond 1640 with a recognizable value to excluded from layer symbolization in the following steps.
   g) Name the proximity map (output file) **'education_raster_dist.tif''** and save it in your project folder.
   h) **Uncheck** the 'Open output file after running algorithm'
   i) Click 'Run' and then Close.

4. Add the newly created raster layer to your project. Go into the layer properties and Style the layer to classify the output into 5 categories, plus a transparent category for -1 (as shown below).
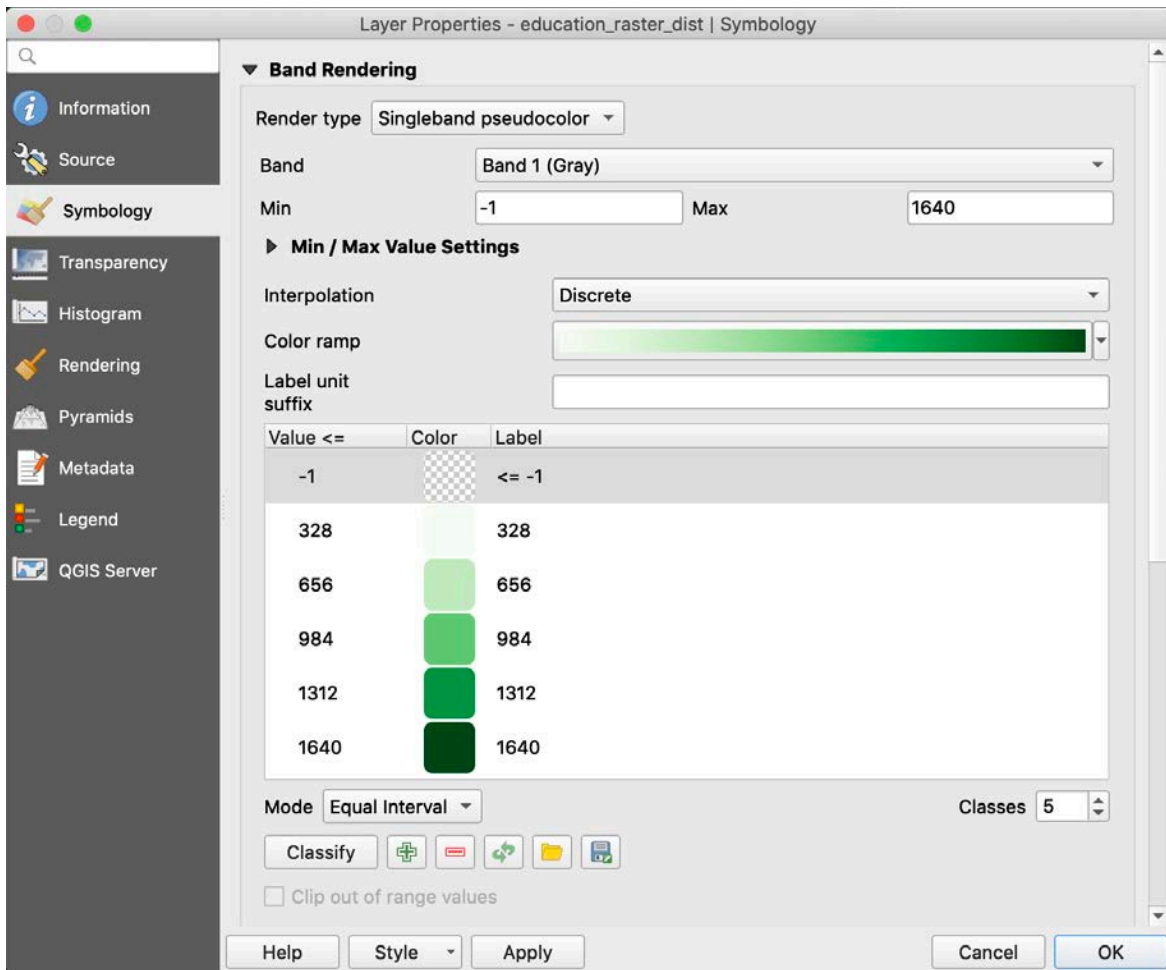
Once you style the layer, the output for the Proximity tool should look like the following.
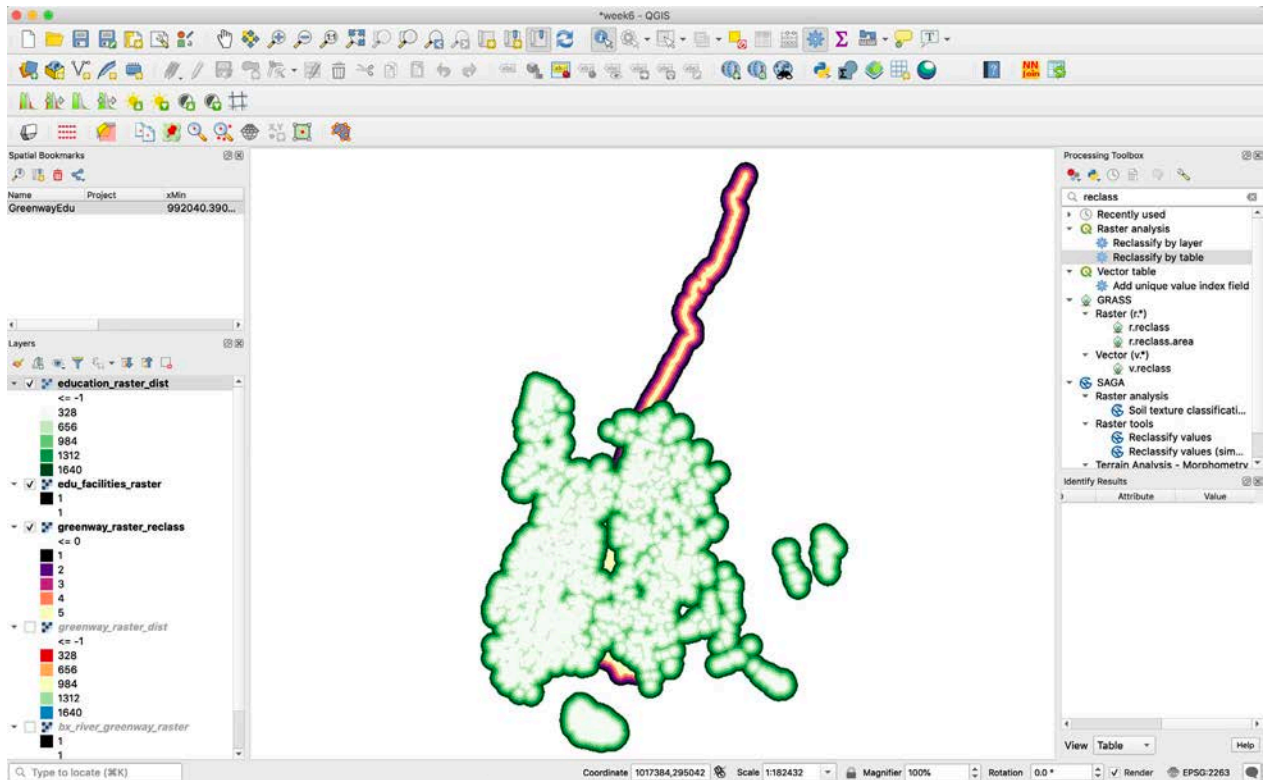
5. Again, we want to reclassify the data so that each 100 meters (or roughly 328 feet) has a different suitability value. Areas closer to educational facilities will have higher suitability values, and areas farther will have lower suitability values. **We will use the Reclassify by table tool again.**

Select **the education_raster_dist** as the Raster Layer.

Create a new reclassification table. Add 5 rows, then enter these values:

| Minimum | Maximum | Value |
|---------|---------|-------|
| 0 | 328 | 5 |
| 328 | 656 | 4 |
| 656 | 984 | 3 |
| 984 | 1312 | 2 |
| 1312 | 1641 | 1 |

We use 1641, rather than 1640 to ensure that the top end of our distance range is included.

Under "Advanced Parameters" …

- Your Output no data value should be 0.
- Your Range boundaries should be min <= value < max.
  Make sure that 'Use no data when no range matches value' is checked – this ensures that the -1 values outside of our proximity analysis result are classified as 0.

Save the file as **education_raster_reclass.tif** and uncheck the 'open output file after running algorithm'. Add the newly created raster to your project. Your window should look like the following:
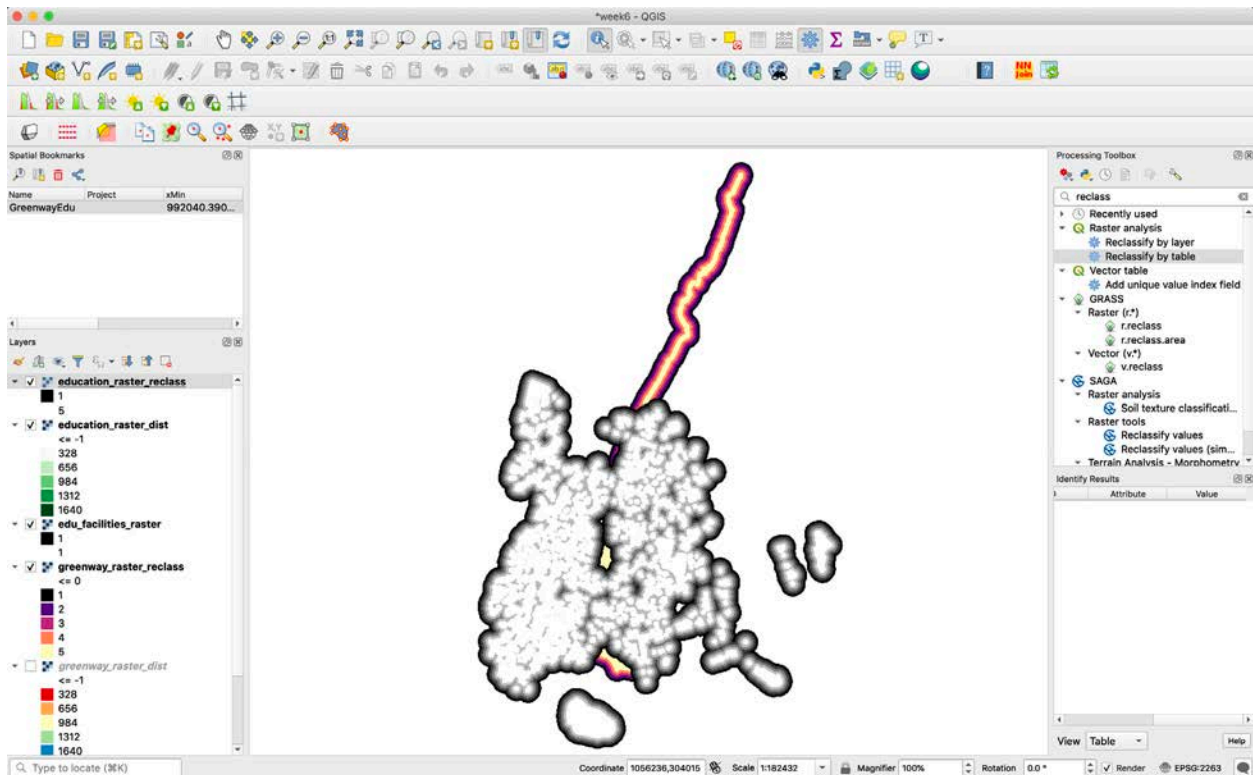


<span style="color:red">This is our second decision layer, the one outlining suitability according to proximity to educational facilities.</span>

## 3. Use 'Map Algebra' to Combine our Decision Layers

We have created two decision layers that hold the proximity criteria. We can now add these two layers together to locate the areas that best meet both of the proximity criteria. We do this by using 'Map Algebra.' The cells in the resulting output that have the highest values will represent the cells that had the highest combined values in each decision layer. **These high value cells represent the areas that are close to both the greenway and to an educational facility, and therefore, by our criteria, the 'most suitable'.**
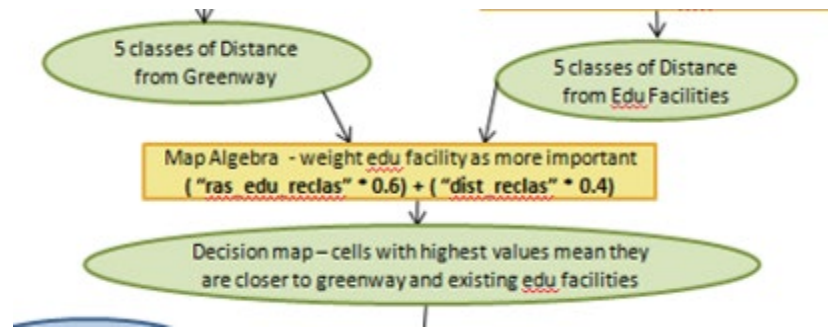
1. Use Map Algebra and provide weights for the decision layers

We are going to use the **Raster Calculator tool** found in the Raster dropdown menu. One of the features of this tool is to give weights to each input layer. The Bronx River Alliance believes it is more important for the new environmental education center to be close to a school than it is for it to be close to the greenway. This position is supported by their belief that schools would be more likely to take ownership of an environmental education facility that is closer to its property. If the education center is too far away from any school, they are worried that no single school will take ownership and, therefore, that the education center will not be used regularly. Given this assumption, they would like you to give extra consideration to those areas that are proximate to schools. In the Raster -> Raster Calculator tool, we will grant a higher weight to proximity to schools.
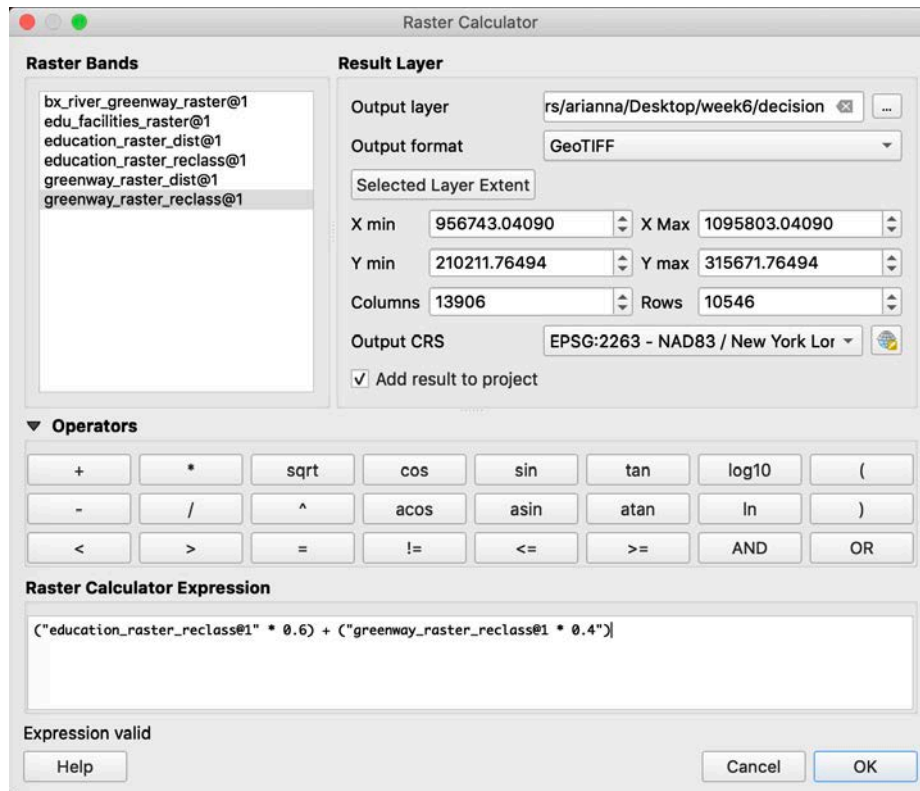
Navigate to **Raster -> Raster Calculator**. The Raster Calculator dialog will appear. In the dialog, specify that we want to perform the calculation below by double clicking the layers and typing in the expression.

("education_raster_reclass@1" * 0.6) + ("greenway_raster_reclass@1" * 0.4)

Note that the 0.6 represents that we want the educational facilities to be weighted more heavily than the greenway, which we gave a value of 0.4. The values add up to 100%.

Name the output file **'decision'** and ensure that your Output CRS is EPSG: 2263.
The dialog should look like below. Click OK. This may take a while, so lean back and take a stretch break!

**Raster Calculator**

Raster Bands
- bx_river_greenway_raster@1
- edu_facilities_raster@1
- education_raster_dist@1
- education_raster_reclass@1
- greenway_raster_dist@1
- greenway_raster_reclass@1

Result Layer

Output layer: rs/arianna/Desktop/week6/decision

Output format: GeoTIFF

Selected Layer Extent

X min: 956743.04090    X Max: 1095803.04090
Y min: 210211.76494    Y max: 315671.76494
Columns: 13906    Rows: 10546

Output CRS: EPSG:2263 - NAD83 / New York Lor

☑ Add result to project

Operators: + * sqrt cos sin tan log10 ( - / ^ acos asin atan ln ) < > = != <= >= AND OR

Raster Calculator Expression

("education_raster_reclass@1" * 0.6) + ("greenway_raster_reclass@1 * 0.4")

Expression valid

Help    Cancel    OK

2. The 'decision' layer now in your map contains areas that are most desirable according to our proximity criteria. Use the information tool to click on the map to see the values of each pixel. High values have higher suitability.

3. Go to the style tab to visualize the data. Your Decision layer should look like below:
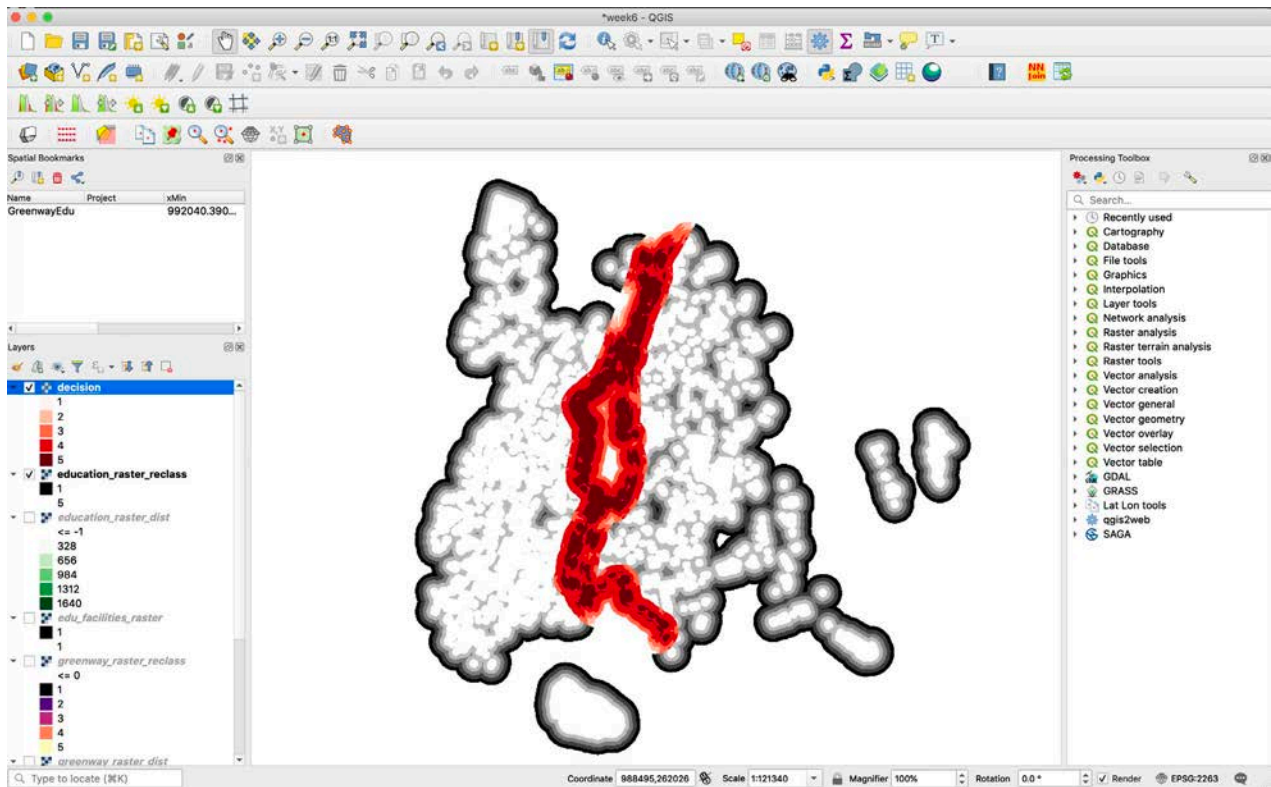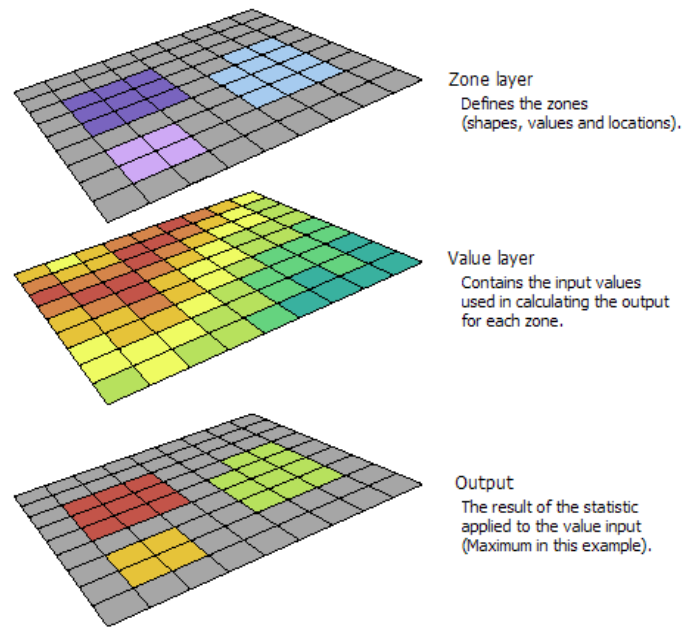
4. Add the **'vacant_land.shp'** to the map document. Place it on top of the 'decision' layer. Notice there are a number of areas where vacant land overlaps areas that have been given high decision criteria according to our 'decision' layer.
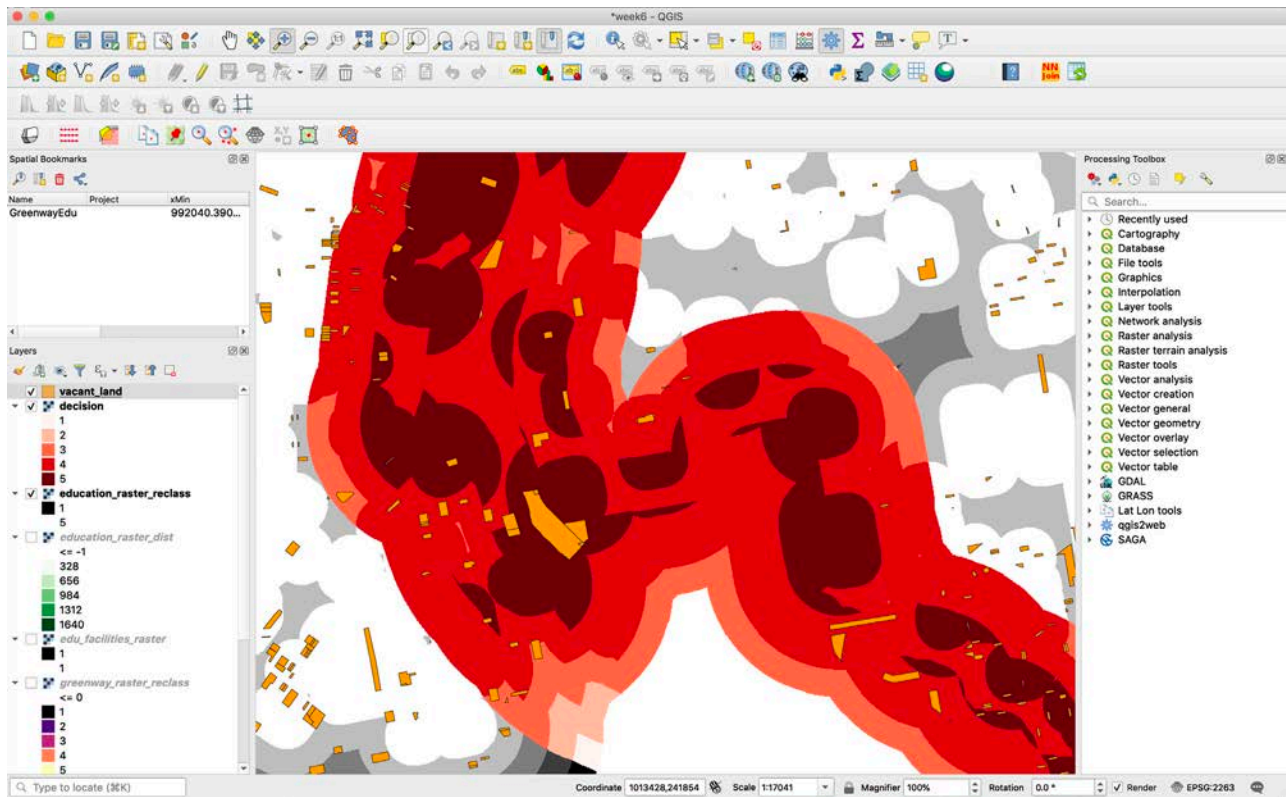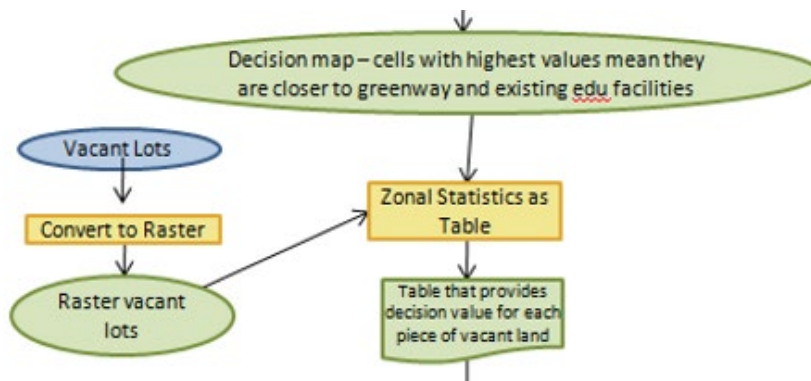
## 4. Use Zonal Statistics to Associate Decision Values with Each Vacant Land Parcel

In our map document, we need to combine our 'decision' layer with the vacant land layer in order to determine which vacant land parcels should be pursued for the location of the new environmental education center. To do this, we will use a tool called Zonal Statistics. Zonal Statistics will calculate an average suitability score for each vacant parcel based on the cells that lie underneath each vacant parcel.

Zone layer
Defines the zones
(shapes, values and locations).

Value layer
Contains the input values
used in calculating the output
for each zone.

Output
The result of the statistic
applied to the value input
(Maximum in this example).

Let's use Zonal Statistics to figure out which vacant parcels have the highest decision values.



1. Zoom to the Spatial Extent bookmark. Open the Zonal Statistics tool: Processing > ToolBox > Search for Zonal Statistics > **Zonal Statistics**. If this doesn't appear you may have to load or install the Zonal statistics plugin using the 'Manage and Install Plugins…' feature. In the dialog, select the following:

a) **Decision** is your raster layer**.**
b) **vacant_land.shp** Is your vector layer containing zones.
c) In Statistics to calculate, select 'mean' and click OK.
d) Click Run
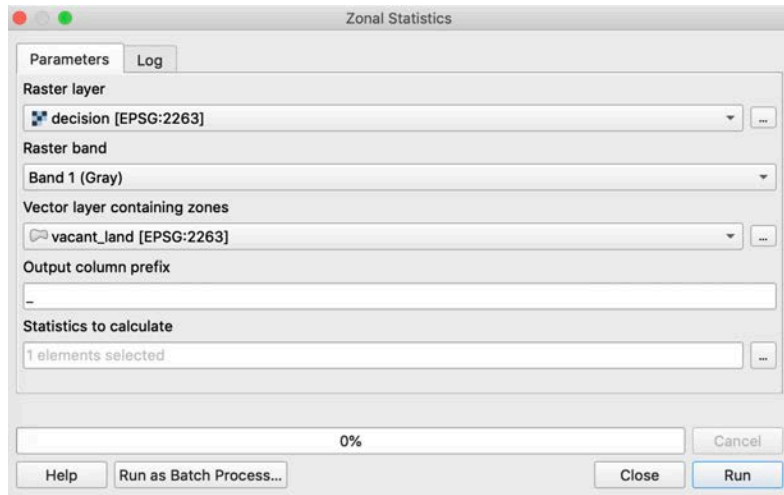
The resulting output will be a column called **'_mean'** in the attribute table for **vacant_land**. This column contains the mean value of the decision layer cells.

2. Let's explore this column further. Open up the attribute table for '**vacant_land**' and scroll to the right to see the appended fields. **_mean** contains our suitability value. Note: Many parcels will have null values. This is because they do not intersect with the decision layer.



**5. Select all Vacant Parcels with a Mean Greater Than or Equal To 4.5 and Export a New Shapefile**

The next step of our process is to select only the most suitable vacant parcels and export a shapefile. This is performed by running a simple query and then exporting the selected parcels.

1. Using 'Select by Expression' in the 'vacant_land' attribute table, **select all parcels that have a mean value greater than or equal to 4.5 (see image below).** Click the 'Select Features' button, and then close. The dialog will look like the following.
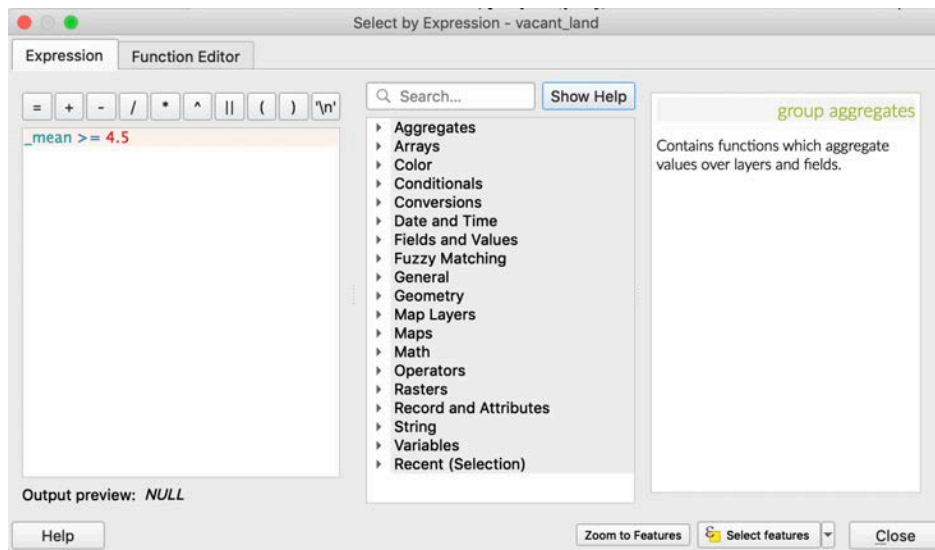
2. Right-click on the **'vacant_land'** layer in the Layers Panel. In this layer, all the parcels with greater than 4.5 suitability are currently selected. Go to Export and Click 'Save Selected Features As.'  Save the layer in your weekly workspace with the name 'decision_above_45'. Add it to your map document. This layer contains the sites that best met the criteria according to this analysis. It will look something like the following.
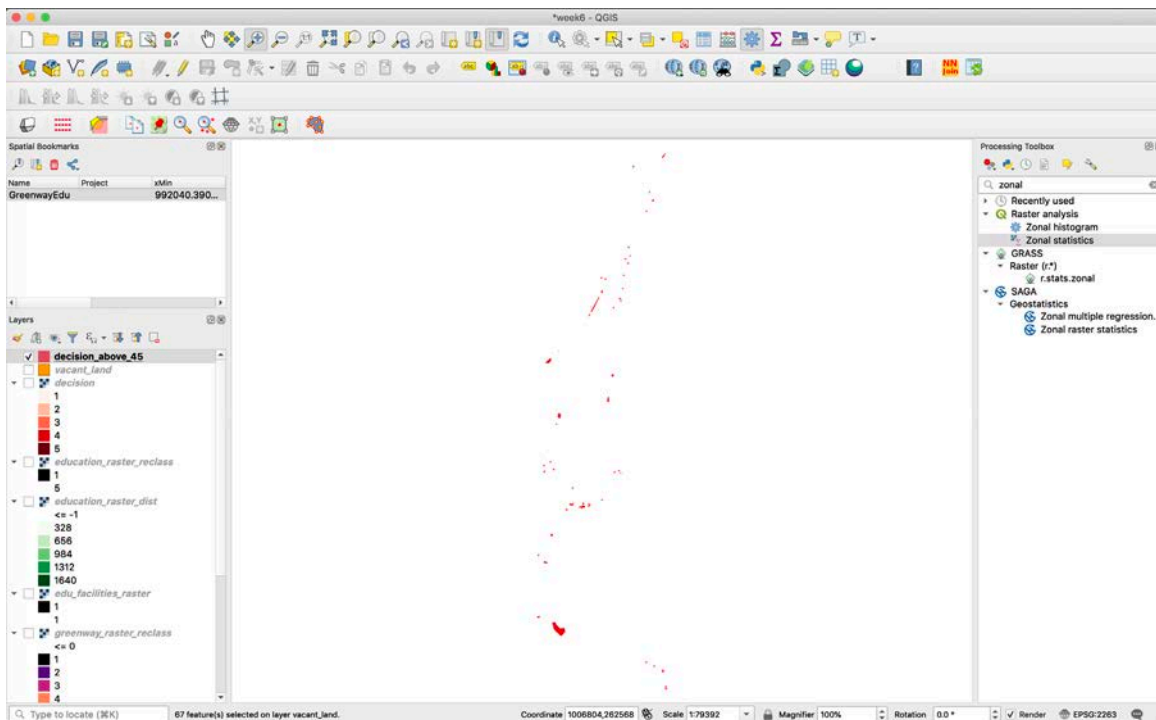


## 6. Add Aerial Imagery and Investigate Each Location

The final step in our process is to add aerial imagery and investigate each location.

1. Add aerial imagery. To do this, go to "View" > "Panels" > "Browser".  A panel will open in the left-hand column. Right click on "XYZ Tiles" and then select "New Connection". Name the connection "Google Satellite" and then http://www.google.com/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z} for the URL. Click OK. Right click the new connection in the browser panel and select "Add layer to project"

2. Zoom in and investigate each site. You may want to add the educational facilities layer to investigate what is near the vacant sites.
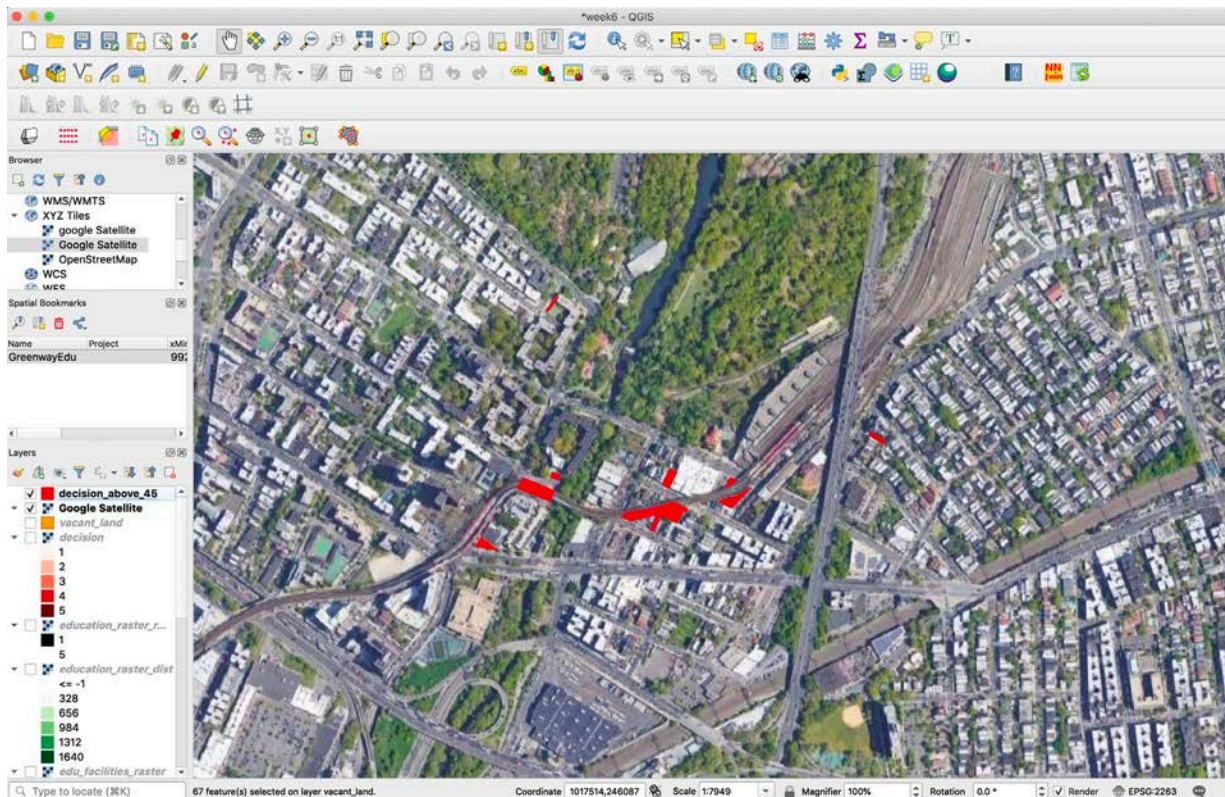


Take Home Exercise 3 asks you to continue this site investigation process. You will need the products created in lab today to complete Exercise 3.

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