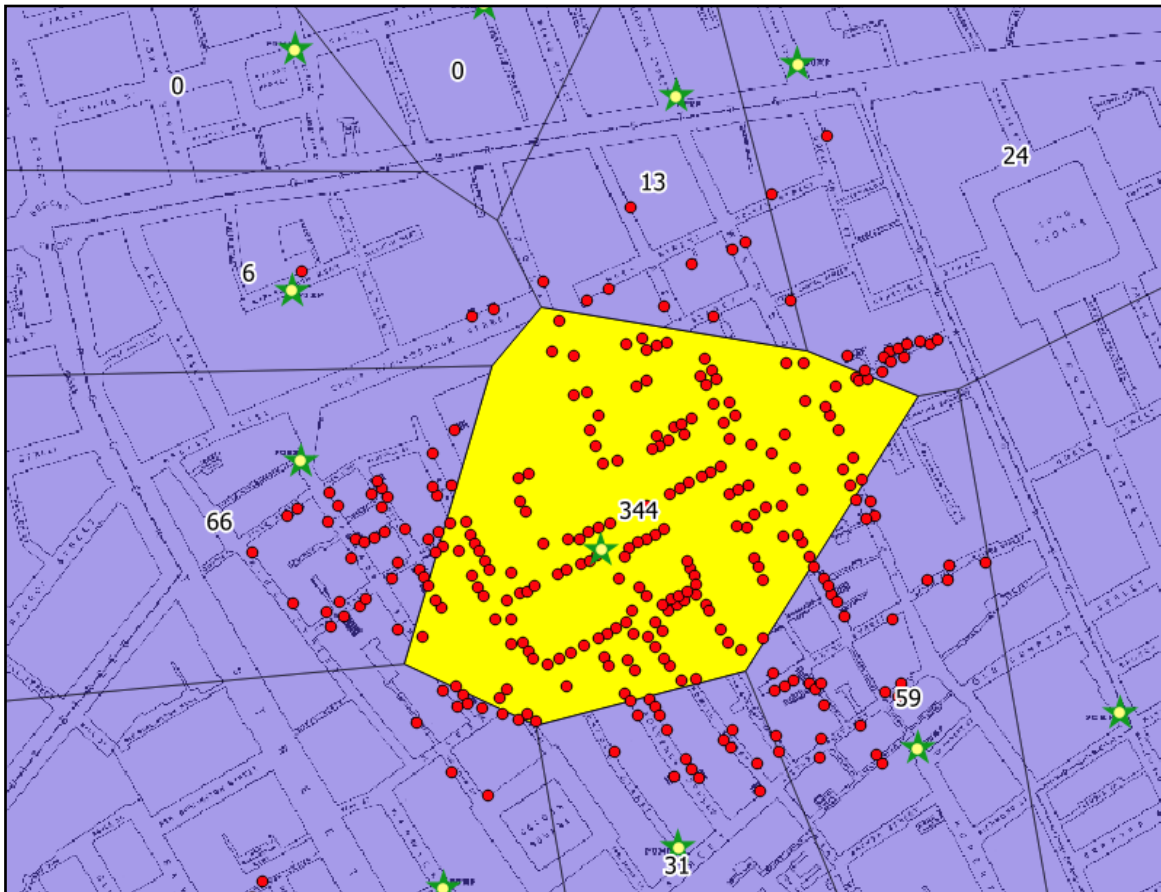


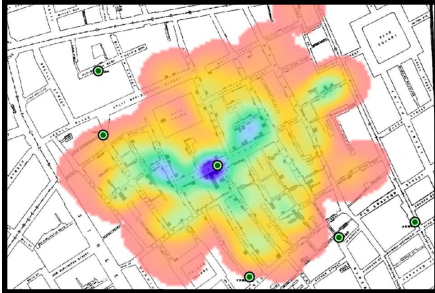
# Spatial Analysis: Heat Maps & Voronoi Polygons

## A Cholera Case Study

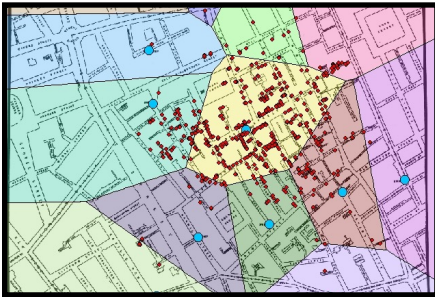


**What is the purpose of spatial analysis?** Mapped data can visualize what *is* (it can be descriptive), but for a map to make an effective argument, it must also explain *why*. Spatial analysis helps because it wrangles data into patterns. Point datasets, for instance, can be dauntingly large, complex, and seemingly without pattern or meaning. To the naked eye, it is often difficult to detect the densest clusters of points. It is arguably more difficult to find areas with the fewest occurrences of an observed theme. What would we do if we wanted to examine the spatial relationships between multiple themes represented by points on your map? Today we will explore two spatial analysis tools: heat maps and Voronoi (or Thiessen) polygons. These tools will help us harness point data to make an argument about disease and space.

**Introduction:** Today we will explore John Snow's map of the 1854 London cholera outbreak. Snow's thematic map of cholera victims in the Soho neighborhood was not without precedent in medical cartography, but it was nevertheless an effective method of arguing that a **spatial relationship** existed between cholera victims and the Broad Street pump. Using GIS, we can explore alternate methods of visualizing these relationships using modern spatial analysis tools.

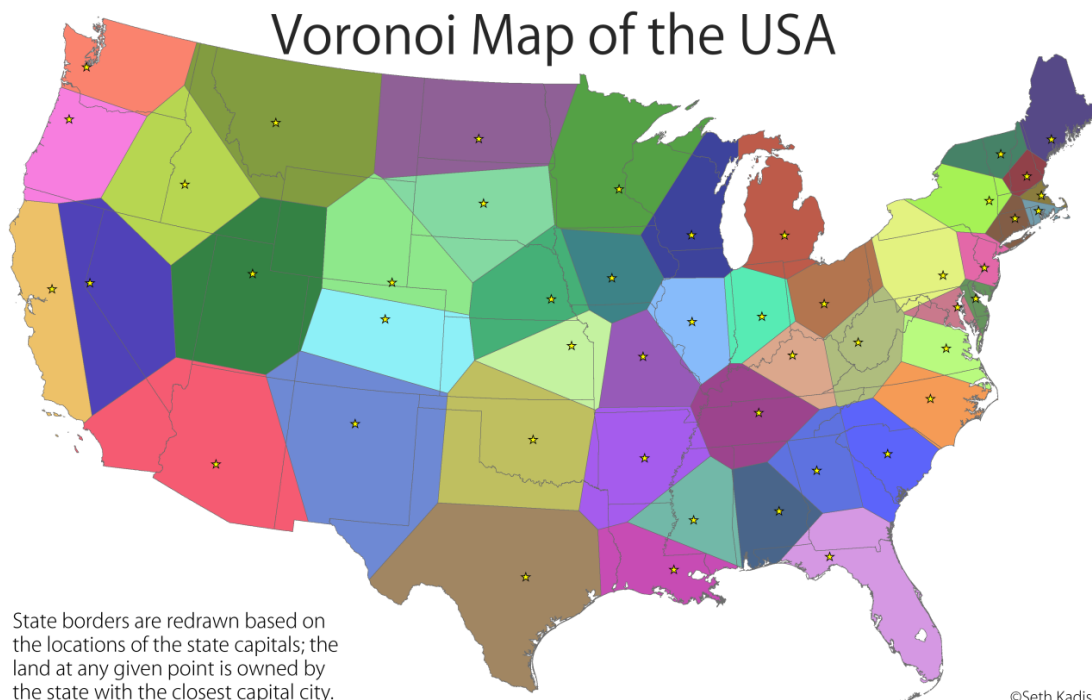


**Heat Maps** - heat maps are a very common method of identify dense concentrations of a theme represented by your point data. Oftentimes, a color gradient is employed to visualize high or low values. Using a form of density analysis, QGIS will produce an **interpolated** (estimation of unknown values based on existing data) raster file.



**Voronoi (Theissen) polygons** - Vector files that denote a point value's area of influence. In any part of the polygon surrounding a given point, the influence of that point will be greater than any other surrounding point.

**BONUS:** Fun with Voronoi diagrams - what would the United States look like if states were reorganized according to distance between state capitals??



## Instructions:

1. Create a new folder, "Week 8" and save it to your computer. **NOT YOUR DOWNLOADS OR TEMP FOLDER.** Download and transfer files from the google drive. [https://drive.google.com/drive/folders/1XJ-dqYDq\\_o7IfZgSBt52bsmRONYrFxFxLM?usp=sharing](https://drive.google.com/drive/folders/1XJ-dqYDq_o7IfZgSBt52bsmRONYrFxFxLM?usp=sharing)
2. Open QGIS. Add a basemap layer. Now, add the *raster* file "SnowMap.tif". The file has already been georeferenced to the Soho neighborhood of London. Take a moment to observe some of the notable changes to the city that have occurred since 1854. For instance, you can open the "properties" of the map and change the transparency. If you would like to see an ungeoreferenced, high resolution image of Snows Map for comparison in your image browser, it is in your folder marked "snow\_map.png."
3. Next, add the *vector* layer "Cholera\_Death." If the point symbols are not visually striking enough, change the symbology to make the contrast more apparent.

4. *What kind of data does this layer contain? Does each point represents a person who died? Does it represent a location where multiple people died? Use the*



"identify features" tool to see what each point represents. The identify features tool give you quick, targeted access to the data associated with that feature from the attribute table.

5. The points contain the information that Snow visualized as bars. Some points represent one death, other points represent several. For that reason, we can't equate the number of



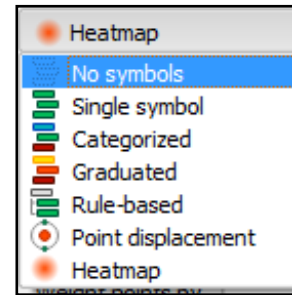
points with the number of victims. You could go through the attribute table and add up all of the values to determine that information, but that would take too long. Instead, we will use QGIS's "Basic Statistics" function. In your main window, select "vector," "analysis tools," "Basic statistics for fields." In the basic statistics window, select "Cholera\_Death" for your input vector and make sure your target field is "count." Click Run. A new window

appears at right with a URL. Click the URL to see your results. “Sum” calculates the values of your count field. *How many individuals died in this part of London during the 1854 epidemic?*

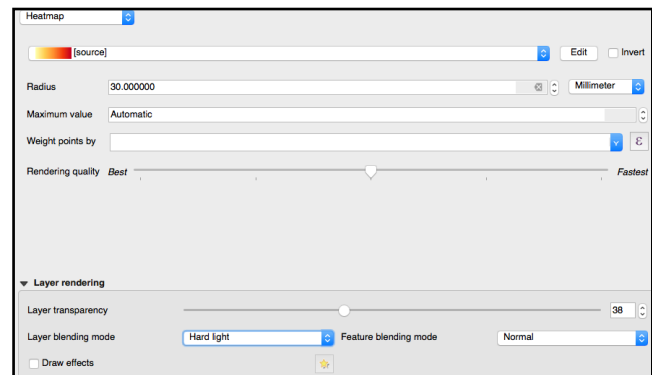
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Algorithm: Statistics
File path: C:\Users\lads11374\AppData\Local\Temp\processing_2b5ba2abba864bb88d38c85f38b8cd8e1c6af5c58e7324a0d8aab728e3bf4c5ae\OUTPUT_HTML_FILE.html
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6. We have a good sense now that this was a pretty severe epidemic and that it was certainly clustered in a specific part of the Soho neighborhood. Where precisely were the hardest hit areas? To answer this, we can use a heat map to identify the densest clusters of cholera deaths.

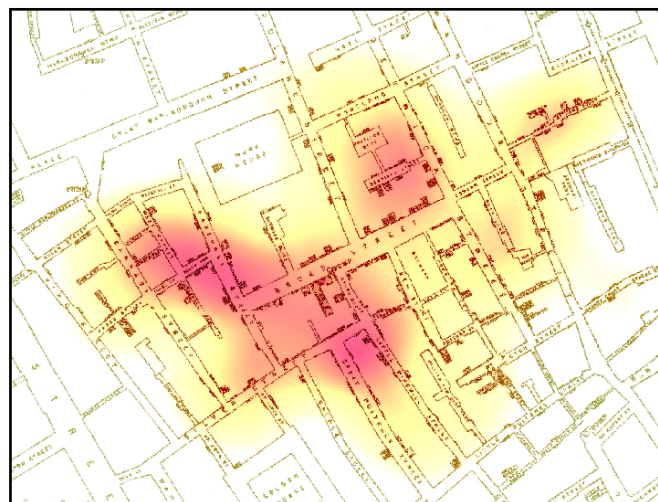
7. There are two ways to visualize heat maps. If you are interested in simply displaying your point data as a heat (rather than creating a heat map layer), you can change the symbology of the layer. We did this last week. Right click your Cholera\_death layer, select properties. Look to the upper left visualization dialogue box and click the drop down menu. Select heatmap.



8. In the “layer properties” window, change the color ramp from grayscale to a color scheme of your choice, make the radius 30 (this changes the size of the circles being visualized around your points). Experiment with the layer rendering. Chose a layer transparency, layer blending and feature blending mode that seems best to you. Click ok.

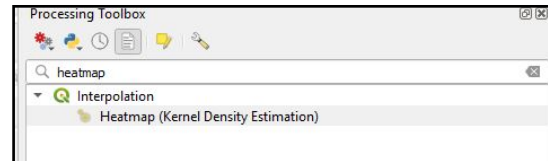


9. This heat map visualization helps us identify “hot” spots of disease. Where is the Broad Street Pump here? Export this first heat map image as a file so you can upload it to your blog. Go to "Project" at the top, "import/export," "export map to image." Save the file to your Week 8 folder.

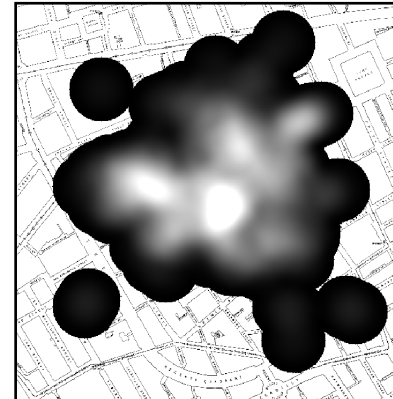


10. This gives us a decent, impressionistic sense of the spatial relationship between the Pump and Cholera, but it would be difficult to do any quantitative spatial analysis with this

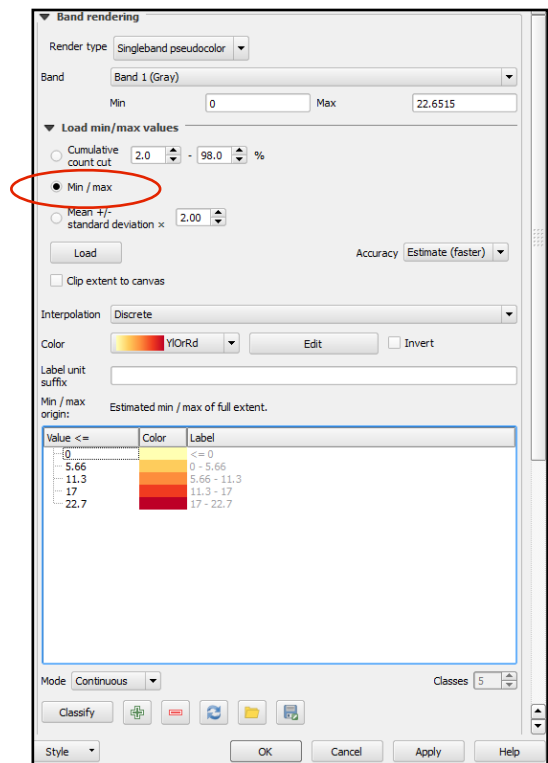
type of heat map since its shades of color do not have associated data values. For that, we will have to create a heat map raster layer.



- Heatmaps are simple to create and the newer QGIS releases include them in your basic setup. First, return your point layer to “single symbol” rather than its current heat map style. Next, click “processing” in the main window. In the processing toolbox, search for “heatmap” (under interpolation) and open the heatmap (Kernel Density Estimation) application.



- In the heatmap plugin window, make sure your point layer is “cholera\_death” set a new location for your output raster. (Make sure you are saving this and all data to your new Week 8 folder on your hard drive). Call the image Cholera\_hotspot. Set the radius to 100 (this is in layer units - meters - rather than the mm of the previous heatmap visualization). Click Run. This may take some time. You’ve now created a grayscale heatmap.

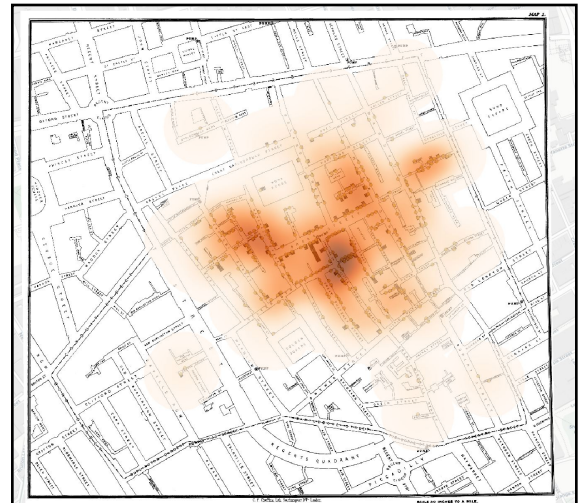


- Just like before, you will want to change the visualization of your heatmap. Double click the heatmap layer in the layers panel and go to symbology. You will already notice that there are now values associated with this raster (unlike our "on-the-fly-heatmap" before). Having values gives you the option of performing spatial analysis. Let's take a look at this data. Under “render type,” select “single band pseudo color.” Change the color ramp to a style of your choice. Under “min/max value settings” you will note that the default is “min/max.” If not, click it. Next, click “classify” and OK.

- Your hotspot now has interpolated values associated with them. Because these colors represent newly created data, you can use the “identify features” tool to get values for every pixel within your heatmap raster. You can also reclassify your data according to every statistical classification mode (pretty breaks, quantile, etc) you choose.

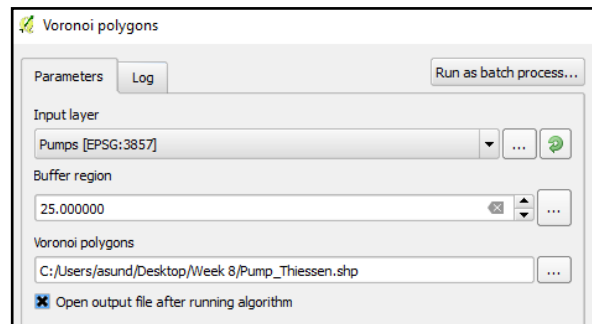
- Heatmaps are helpful to identify the densest clusters of victims, but what if you want to make an argument about *why* those areas experience the most cholera deaths. Likely, the

answer lies in the “hottest” spots of the map. Snow observed a connection between cholera deaths and people who drank from the Broad street water pump. To prove a connection, he mapped the pumps on his map as well.

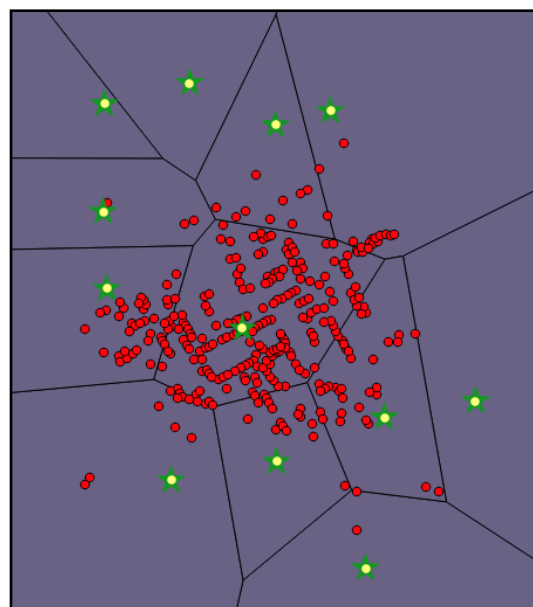


16. I have not included the pump data in this exercise. However, there are only thirteen. Use the georeferenced map (in combination with the .png image if you have trouble reading the mapped data) to create a new shapefile point layer called “pumps.” Include a point for every pump you can find (no other attribute data is needed). DON'T FORGET TO SAVE IT TO THE CORRECT FOLDER. Also, make sure it has the same CRS (projection). There should be 13.

17. Already we can tell that the likely guilty pump is the only one within the “hottest” area of the heatmap, but remember what Snow was facing? Miasma theory posited that disease originated from toxic/polluted air, which could have also emanated from this area. He needed to figure out a way to show that pumps, not just a general region, produced the disease.



18. To double check our findings, we will do one further analysis. We will create Voronoi polygons (also called Thiessen polygons) around our pump point data. This analysis will display the space (defined by distance) which is most influenced by that pump.



19. Under “vector” select “geometry tools,” then “Voronoi polygons.” In the next window, make sure you select “pumps” as your input vector layer. Expand the buffer region to 25 to capture all of your data. Make a new polygon shapefile called "pumps\_voronoi" and save it to the same location as your other data. Click OK.
20. Now that you have voronoi polygons, move your cholera deaths and pumps layer above the

voronoi layer in your layer panel so you can see them. You can already tell that the largest number of deaths are within the influence of the broad street pump.

21. If we want to count mortality within these voronoi polygons, we can create a new shapefile layer that counts the points.

22. Under Vector in the main window, select "analysis tools" then "count points in polygon." **If you don't**

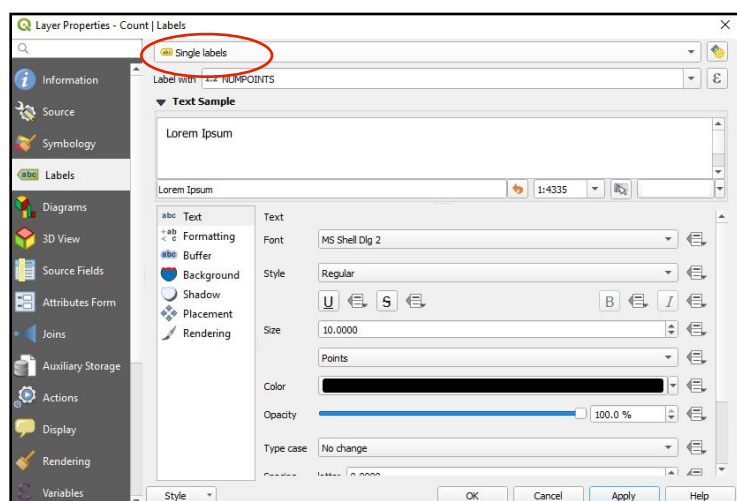
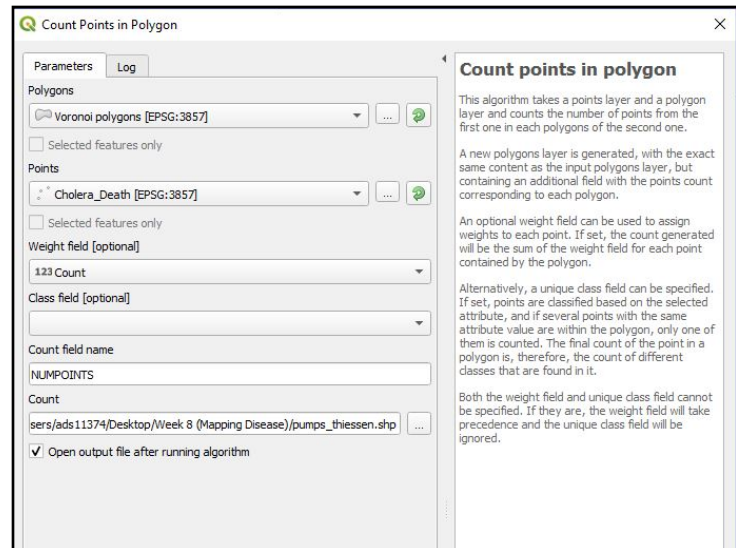
**see this tool**, click on the "processing" tab at the top of the window, then "toolbox." In the processing toolbox window, search for "count points in polygon (weighted)" and open the resulting tab.

23. In the "count points in polygon" window, your input polygon layer should be your Voronoi layer, your input point layer should be "Cholera\_death" and make sure your "weight field" is "count" (NOT ID). We want to count the number of dead, not the number of points. Save it to your folder with a new name (I called mine "deathcount" but you can choose something less morbid). Click run.

24. Your resulting polygon layer won't look much different, but it will now have totaled the sum of the dead per voronoi polygon in the attribute table. You can examine this in the attribute table (the number is called "NUMPOINTS"), but if you want to make this data more apparent on your map we will need to label this feature.

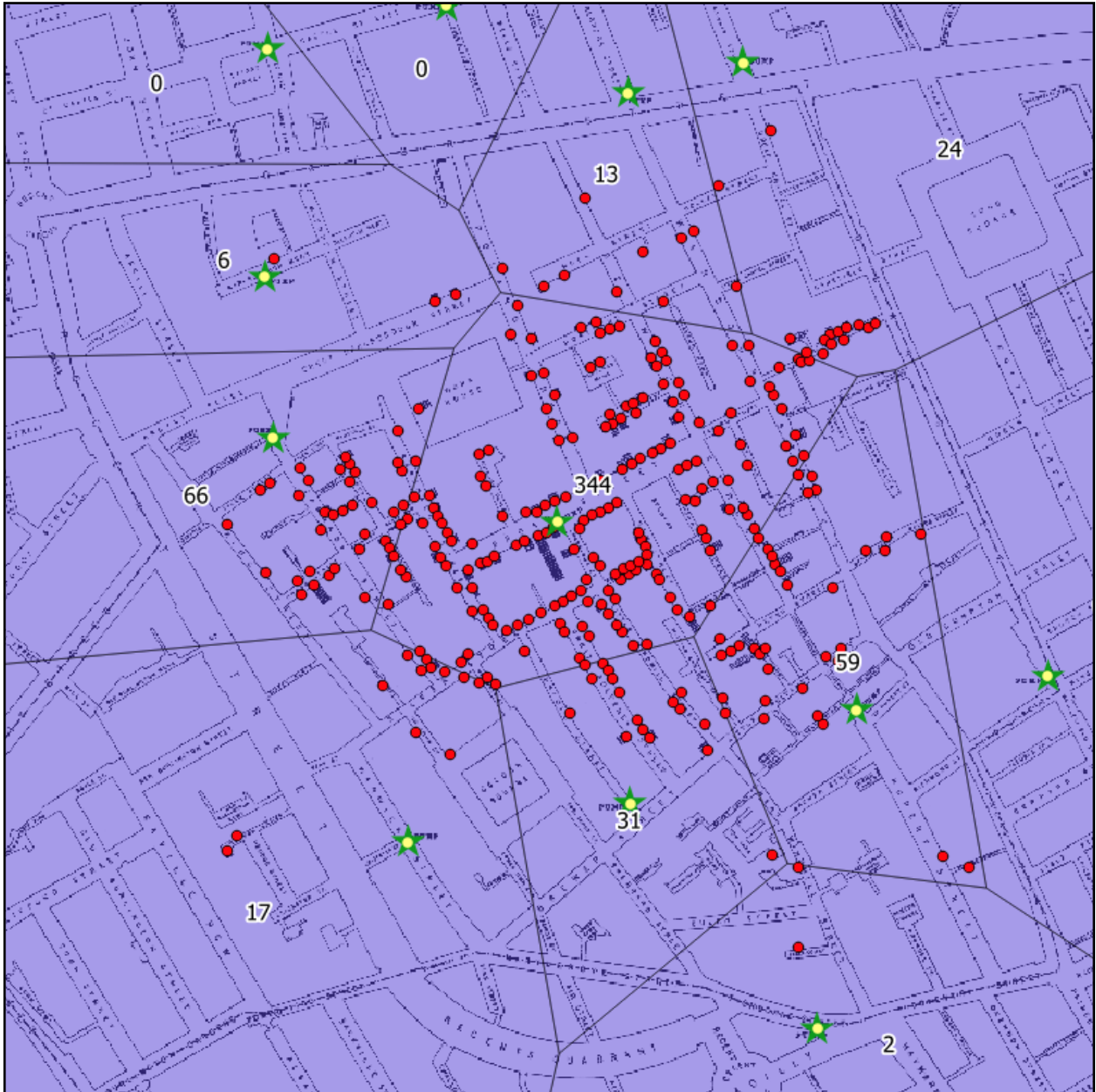
25. Labelling is relatively simple. Right click your "deathcount" or "Weighted Count" layer and choose "labels" from the left-hand part of the properties window.

26. In the next window, at the top, click "single labels" from the dropdown menu. Label with "NUMPOINTS" and click "okay." **You can label any shapefile**



with data drawn from its attribute table in this way.

27. The last thing to do to this map is to change the styling. Move the cholera death data and pump data to the top so that they are all visible. Change the transparency of the Voronoi/



deathcount polygons so that the original map is visible. Change the colors to something more appealing. (Hint - you may want to place a buffer around your labels to make them more visible).

28. Post your heatmap and your Voronoi polygon layers to the blog. Although Voronoi polygons and heat maps are powerful methods of wrangling data to show spatial



relationships, John Snow used neither, yet came to a similar conclusion about the culpability of the Broad St pump.

Blog Question:

*Aside from mortality data during an epidemic, can you think of any other situations where a heat map or Voronoi polygons would be useful ways to analyze spatial data? How might they be useful in this context of your final project (if at all)?*

Sources: Georeferenced .tiff of Snow's map courtesy of Robin Wilson (robin@rtwilson.com, [www.rtwilson.com/academic](http://www.rtwilson.com/academic)) - Jan 2011.