

Stream Acidification Due to Mining in the Colorado Mineral Belt, Colorado

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Geo 327G

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Problem

The Colorado Mineral belt is a highly mineralized stretch of Colorado across the Rocky Mountains. Rocks were enriched in metal ions, predominantly Gold, Silver, and Lead, during the Laramide Orogeny about 70-80 Ma. Chemical leaching processes used in the refining process by using reducing agents to drive off the extraneous material. This produces many toxic compounds, including sulfuric acid, and is used in the refinement of many of the metals found in the mineral belt. Can a map be used to provide insight on the types of mines affecting the pH in the region?

Goal

The goal was to use GIS techniques and spatial analysis to determine acidity levels in the rivers and streams in the Colorado Mineral Belt. By using spatial analysis and interpolation techniques, the streams can be assigned with pH data from the NURE- HSSR database. This data, coupled with the locations of metal mines within the mineralized area can help determine the effects of mining on the pH levels of the local streams.

Data

Finding data for the Colorado area was not a problem, as Colorado has several organizations that provide data at no cost. Combined with the USGS database and the National Uranium Resource Evaluation (NURE) databases, data was readily available.

The following sources were used for shapefile and data acquisition:

- <http://www.usgs.gov/> provided the shapefile for the NURE- hydrogeochemical and stream sediment reconnaissance (HSSR).
- <http://dtdapps.coloradodot.info/otis> is the location for Colorado Department of Transportation 's downloadable GIS data. I used this site for shapefiles of city locations and county boundaries, as well as the major highways in Colorado.
- www.Coloradoview.org is a collection of surveying and geospatial data in Colorado. This website provided : the aerial imagery and false color relief shapefile as well as the permitted mine location data
- <http://water.state.co.us> is the location for Colorado's Department of Water Services provided the Stream shapefile for all rivers in Colorado.

Many of the files did not include metadata. This was important, and a slight obstacle in the project. Because the data was taken from several sources, I was required to change the coordinate system in many of the feature classes to NAD83_UTM_Zone_13N. This was done by on-the-fly projection, though in some cases, I changed the projection in Arc Catalog.

I created a new shapefile outlining the Colorado Mineral Belt by Georeferencing a .jpeg file and tracing the polygon using the Editor feature. This allowed me to copy a spatially accurate, shaded region of interest onto my map.

Method

As we have learned over the course of the semester, I began my project with a blank map document in ArcMap. I made a folder connection to H:/Colorado Project where I kept my data for this project on my flash drive. At this point I loaded:

- TI_2009_08_cousub.shp (County Boundaries)
- Co_ned90_rgb5x_whitebk.TIF (Shaded relief map)
- Nurewtr-fUS08.shp (NURE water data)
- Streams.shp
- Permittedmines.shp
- Cities.shp
- HIGHWAYS.shp

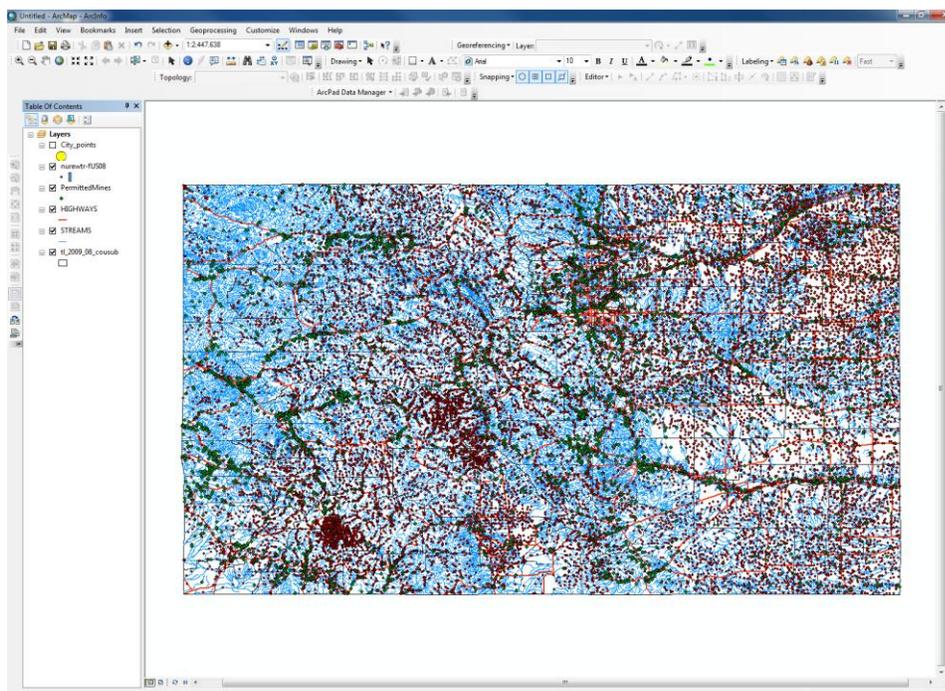


Figure 1 (Very messy map, so I hid some layers while working)

Feature To Point

The first thing to do in order to get the average pH value assigned to river segments was to turn the lines of the streams into individual points

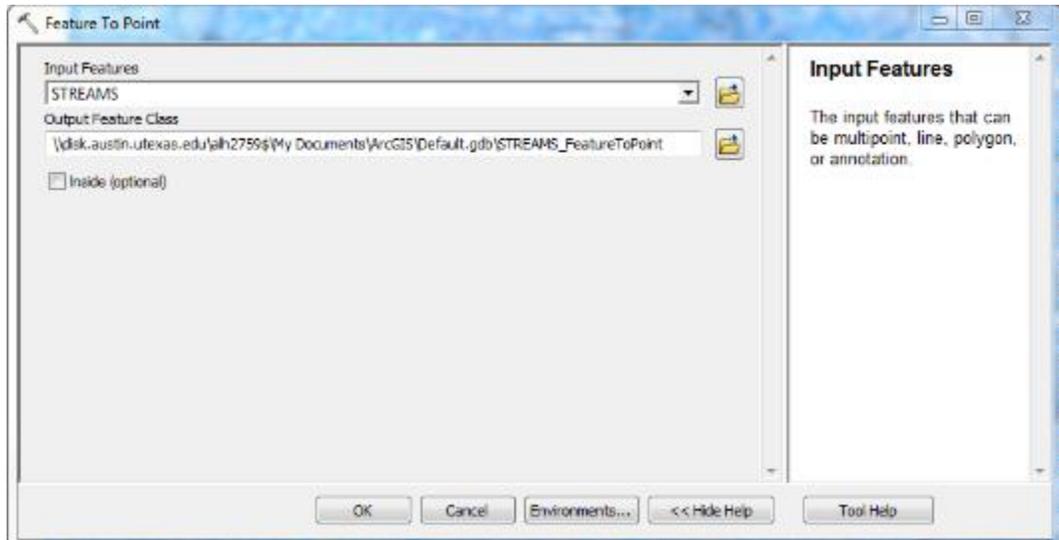


Figure 2 (ArcToolbox>Data Management> Feature>Feature to Point)

I put the shapefile created by this process to the side while I modified the NURE-HSSR data in the next two steps.

Interpolation of Data

I used the Inverse Distance Weighing technique to rasterize the data points provided in the NURE shapefile. This method made sense for this project because the pH values in the streams were unlikely to be higher or lower than the recorded measurements.

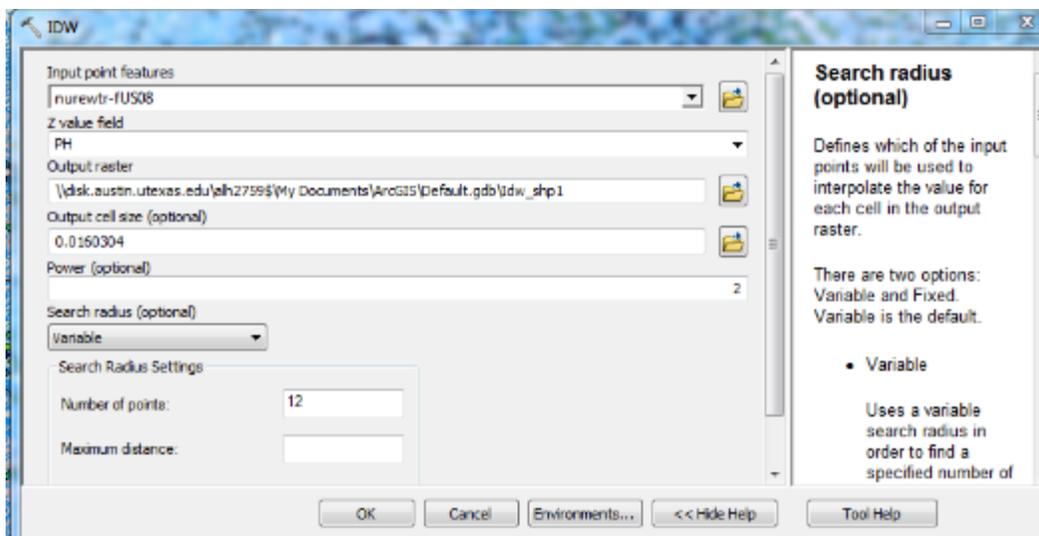


Figure 3. (ArcToolbox>Spatial Analyst> Interpolation>IDW)

I set the field of interpolation to pH and made the output cell size very small. The fine resolution of my raster meant I would have the most accurate values of pH interpolated at distances from the streams.

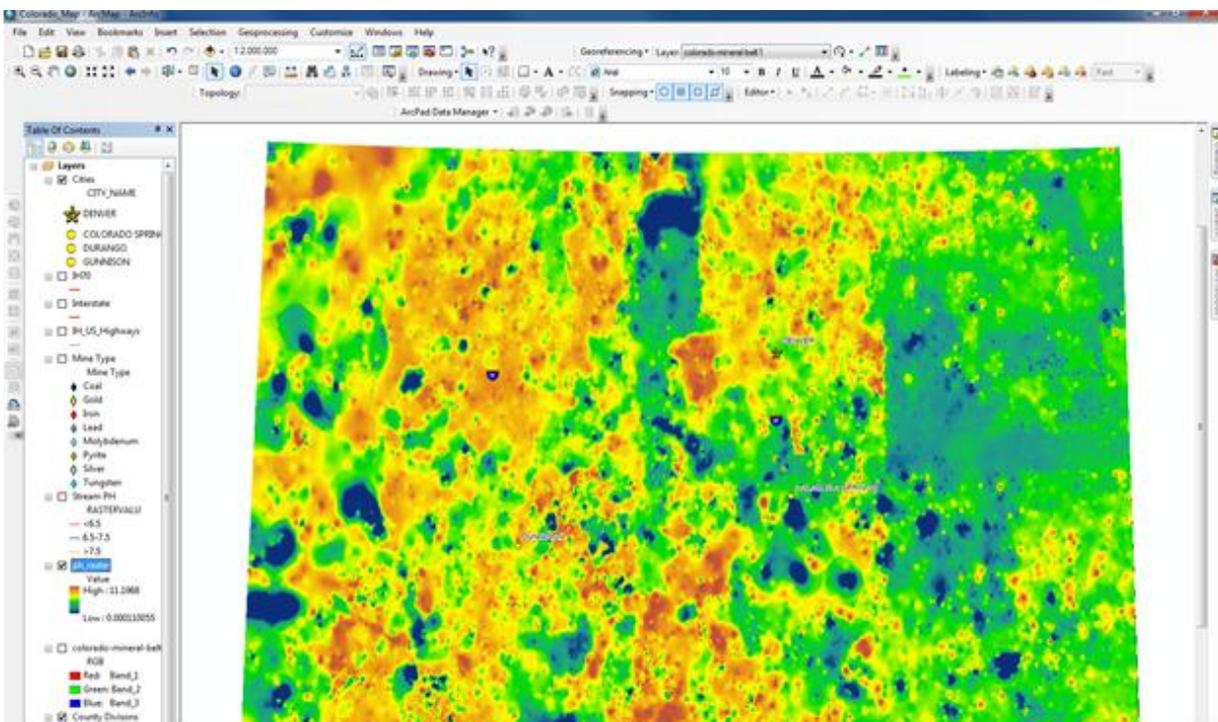


Figure 4 (Ooh! Pretty colors, but they are not good for the water!)

Extract Value to Point

Next, the pH values needed to be extracted from the raster as points. This is where I used the stream points. This step was necessary in order to provide a fair average value for the discrete stream segments.

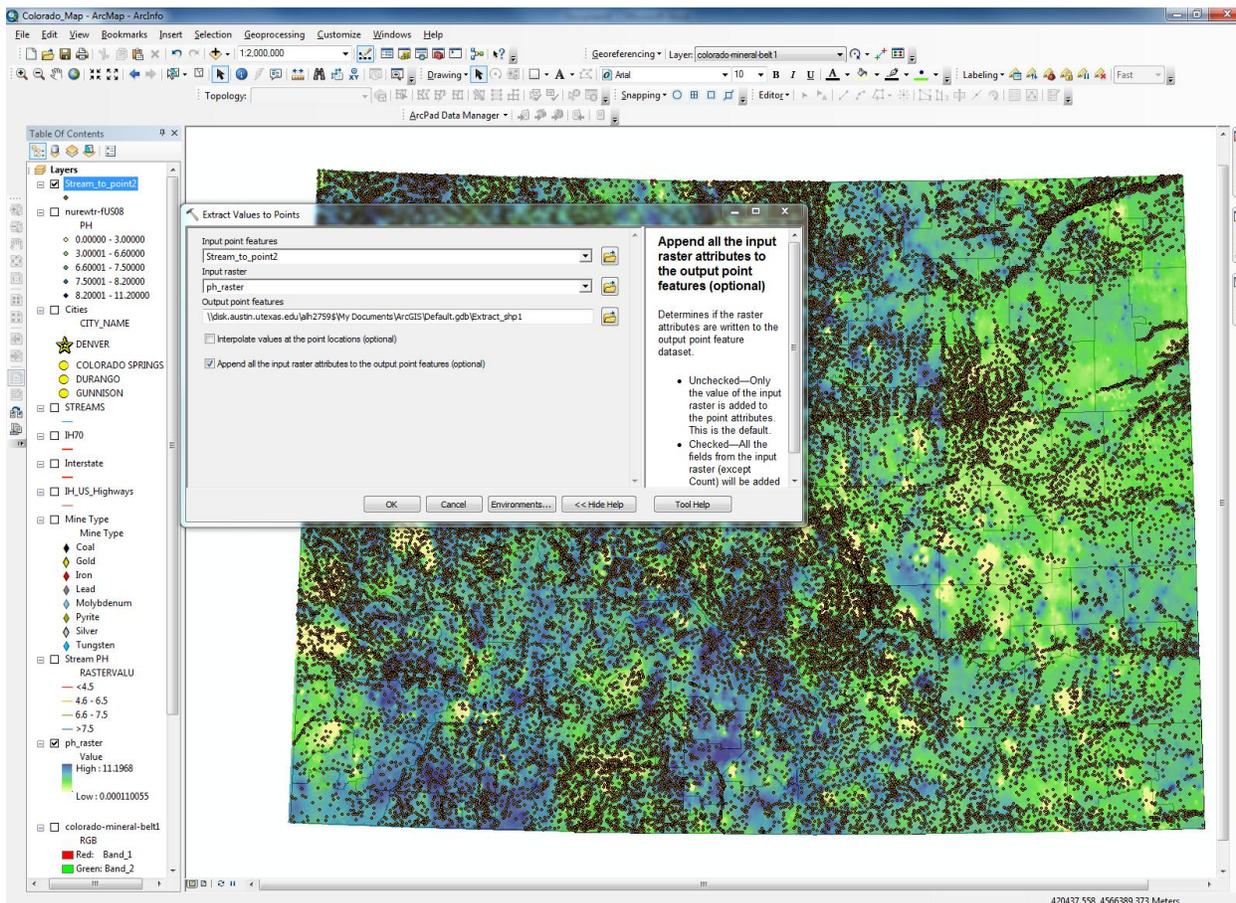


Figure 5 (ArcToolbox>Analysis Tools>Extract>Extract Value to Point)

I set the point feature as our stream points, and our input raster as the pH raster from the interpolation.

Extracting from the raster yields the interpolated pH for the area, which I joined with the Stream shapefile in the next step. The new shapefile contained the average values with the Stream point locations.

Joining the Data

Now the raster value for the pH was contained in the stream points, I simply joined the two features by right clicking the Streams feature class and clicking Join.

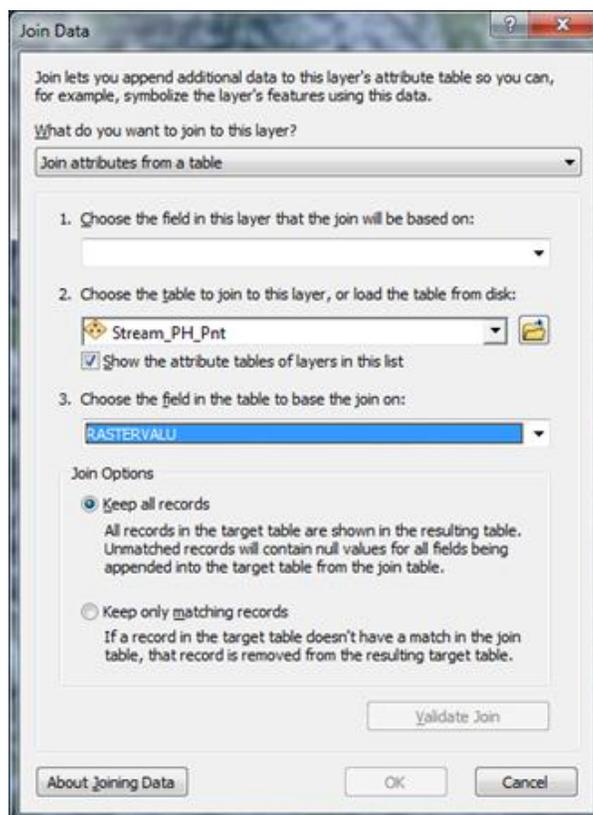


Figure 6 (Right Click Streams > Join)

I chose to join the Stream_PH_Pnt shapefile based on the extracted RASTERVALU value. This recombined the stream points with the stream lines, but created a new attribute for the lines called RASTERVALU which was later renamed pH.

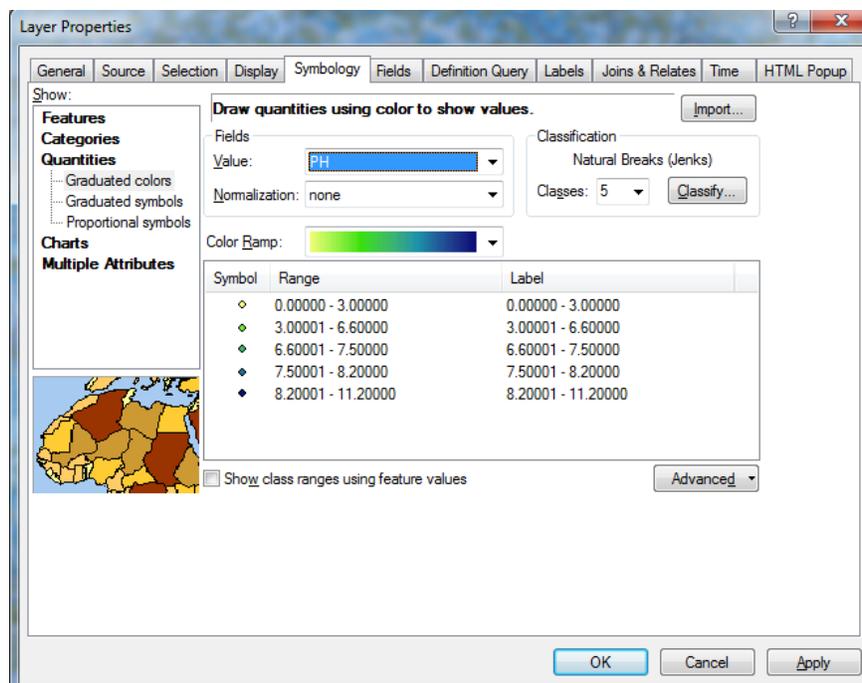


Figure 7 (Symbology)

Once the new Join output was created, I changed the Symbology of the Streams to show a gradient by pH. I broke the colors into 4 classes to represent acidic, basic, and neutral waters.

Georeferencing and Creating a Shapefile

In order to only work with the Colorado Mineral Belt, I had to create a shapefile of the area. I downloaded a .jpeg and used the Georeferencing tool to match the image to my map's coordinate system.

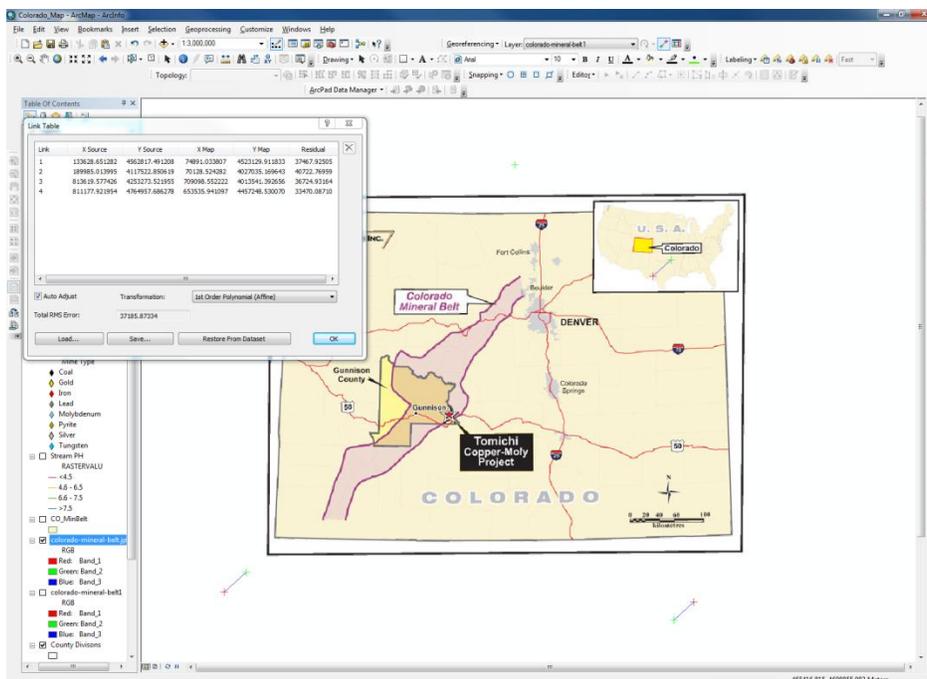


Figure 8 (This was the only good image of the mineral belt I could find)

Once it was properly referenced, I changed the display to 50% Transparent so I could see my map under the .jpeg. I created a shapefile in ArcCatalog and used the Editor feature to make its dimensions the same as the purple shaded zone in the .jpeg.

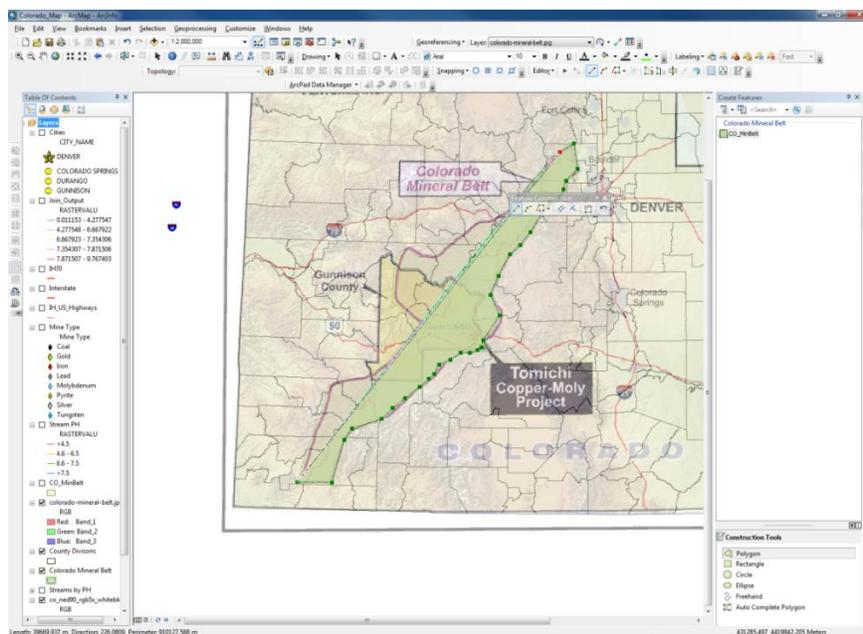


Figure 9 (So I copied it for my shapefile!)

When the polygon was finished, I deleted the .jpeg and was left with the mineral belt boundary.

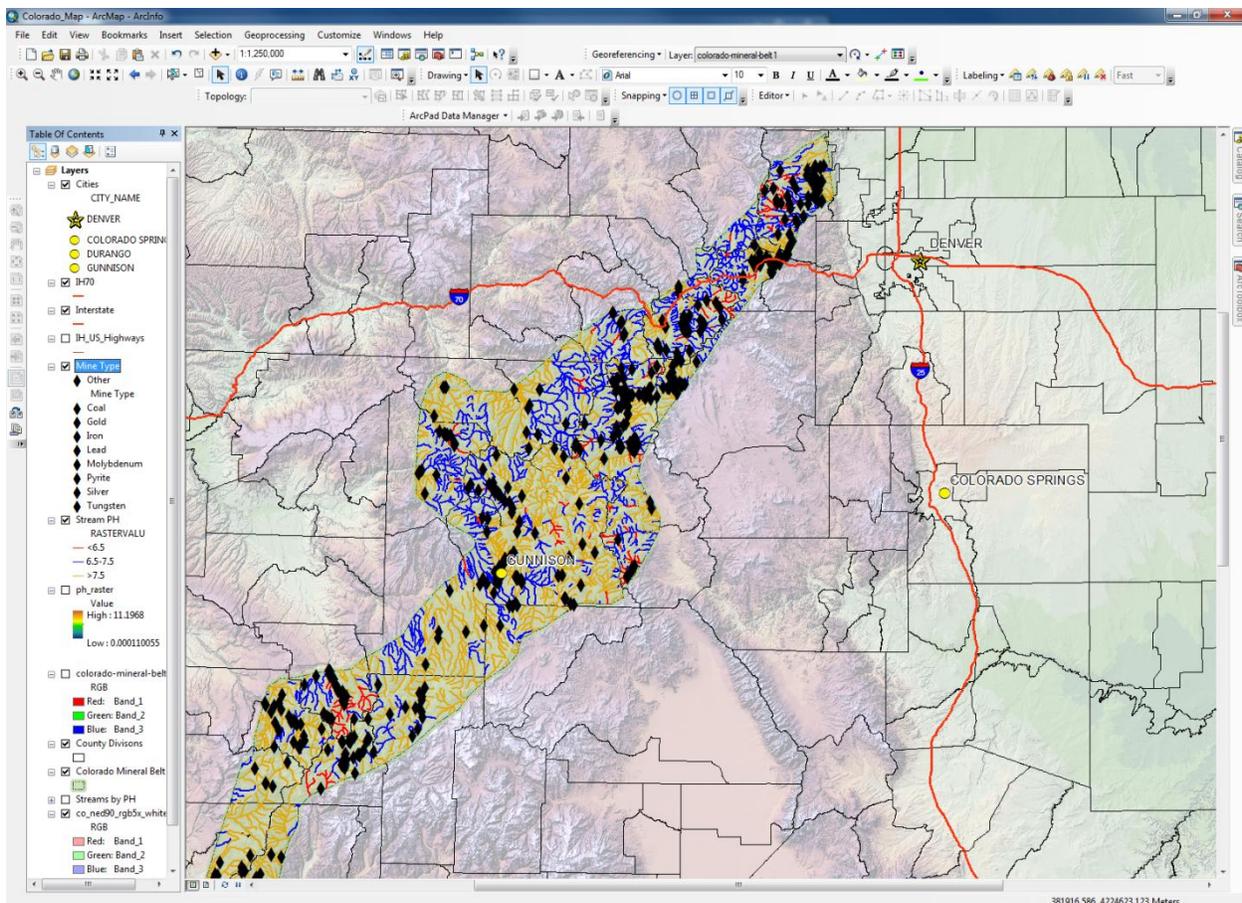


Figure 11 (Getting there...)

Next, I went into the attribute table and selected only the mines producing metals, Gold, Iron, Lead, Molybdenum, Pyrite, Silver, and Tungsten, as well as Coal. I changed the symbology of each in order to identify them, and removed other mines from the map.

Graph

To clearly show the number of river segments with adverse pH values, I decided to create a graph from the attribute table of the streams. I created a histogram for this from the Attribute Table menu.

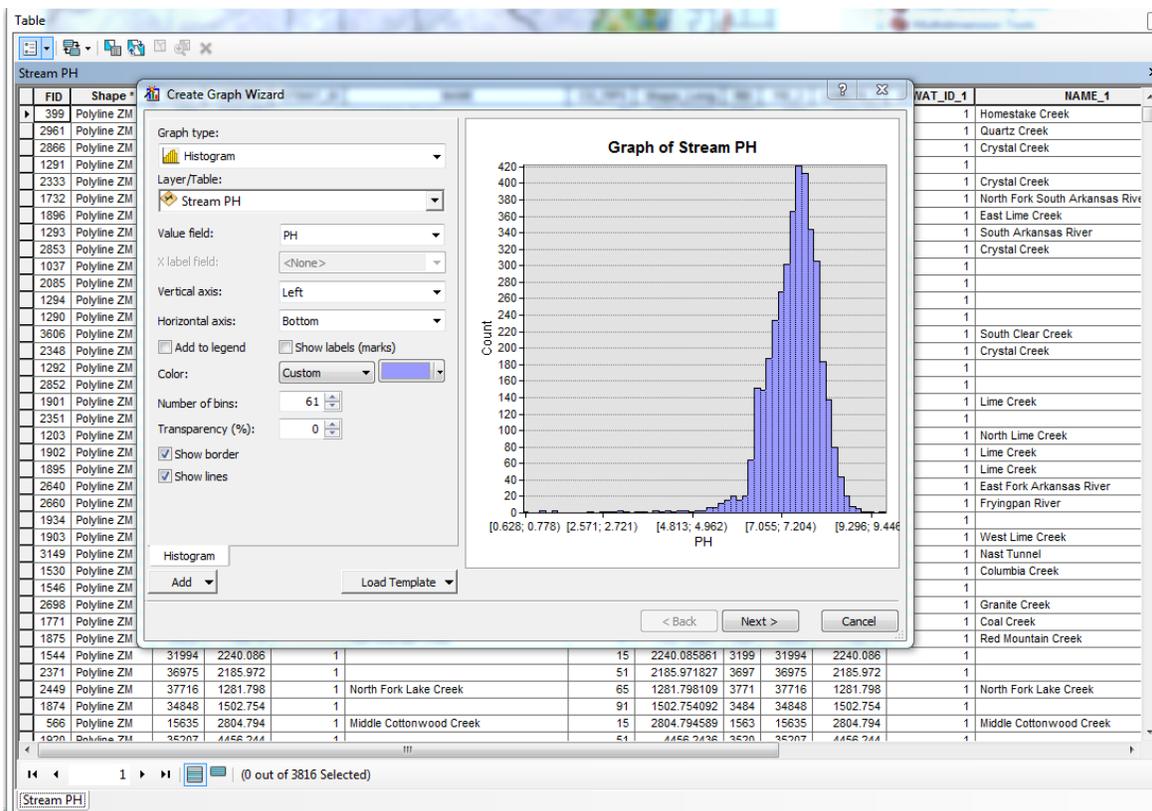


Figure 12 (The graph helps give readers an idea of just how many streams are not suitable)

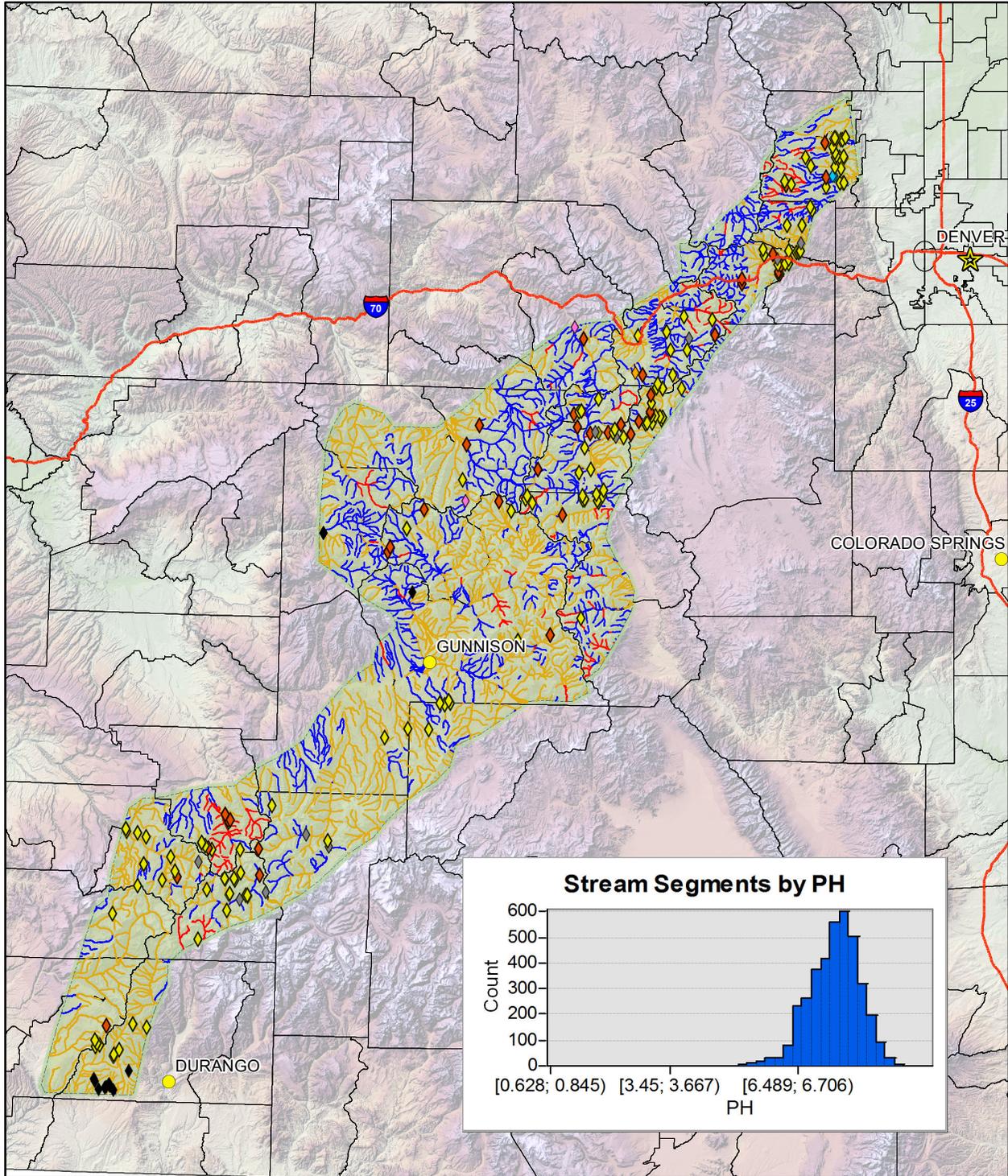
In Layout view, I added the graph to the map, adjusted the labeling, and added the Explanation and scale.

Conclusion

The flexibility of ArcMap allowed me to easily analyze tons of spatial data over the region. I was able to combine data and relate files and objects in new ways. By joining the pH data to the streams and overlaying the mines in the region, I created a map that clearly presents the information necessary to address the problem of water quality due to mining in the Colorado Mineral Belt.

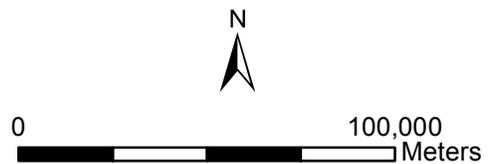
The final map shows that the mining of the rare metal minerals in the Colorado Mineral Belt has affected the pH of the streams in the area. The majority of streams in the area are basic, rather than acidic. It is unclear whether this issue stems from mining, or unrelated environmental issues. High concentrations of Gold mines in the southwest and northeast regions show acidification of the streams. In the central area, large numbers of Silver mines are also showing acidic stream water. The refinement process and waste from mining pollution clearly leads to acidic waters and should be examined further to prevent more environmental damage.

Mining and Stream Acidity in the Colorado Mineral Belt



Explanation

- | | | |
|-----------------------|------------------|----------------------|
| DENVER | Mine Type | Stream PH |
| COLORADO SPRINGS | Coal | <math>< 6.5</math> |
| DURANGO | Gold | $6.5-7.5$ |
| GUNNISON | Iron | > 7.5 |
| Interstate | Lead | |
| County Divisions | Molybdenum | |
| Colorado Mineral Belt | Pyrite | |
| | Silver | |
| | Tungsten | |



1:2,000,000
NAD83 UTM Zone 13N