Sarah Doyle

May 6th, 2010

GEO 326G/387G

GIS Final Project: Glacial Meltwater Flow Paths around Katla Volcano, Iceland

Introduction

Iceland is an island nation on top of the Mid-Atlantic Ridge just below the Arctic Circle. Formed by volcanic activity, it contains many active volcanoes, many of which have caused regional and global havoc. The 1785 eruption of the Laki volcano produced enough volcanic ash to cause worldwide famine, and the April, 2010 eruption of the Eyjafjallajokull volcano created an ash cloud that upset air travel across Europe. In addition to volcanic activity, Iceland is known for its vast glaciers. The largest glacier in Europe is located here and it covers an area of 8,160 km^2 and in some places is more than 1000 m thick (http://notendur.hi.is/oi/icelandic_glaciers.htm). The combination of glaciers overlying active volcanoes makes “jokulhlaups”, or bursts of glacial meltwater that create fast moving floods of high volumes of water, a major natural hazard.

The Katla volcano underlies the Myrdalsjokull glacier (Area in 2000 of 590 m^2) in southern Iceland. On the occurrence of a volcanic eruption (roughly every 40-80 yrs since 930 AD) this glacier has produced jokulhlaups of large volumes. A 1755 eruption was estimated to have a peak discharge of 200,000-400,000 m^3/s (en.wikipedia.org/wiki/Myrdalsjokull). Iceland is a relatively low-lying, flat island, besides the high topography created by volcanoes. Therefore, floods can travel long distances, and around the bases of calderas, can have great velocities. The Katla volcano is due to erupt again soon, and was feared to do so around the same time as the nearby Eyjafjallajokull volcano which erupted this April. Because of this and its history of creating glacial floods, it is the area of Iceland studied for this project. Images of Katla volcano and the other Icelandic features are in Figures 1 and 2.

Purpose

In order to answer, “Where would glacial meltwaters flow down the Katla volcano during a volcanic eruption?,” I used the elevation data for Iceland and from this found likely flow paths for melt waters by creating a drainage network. Ways this information can be used include, estimating likely locations of fast moving floods down the sides of Katla volcano and areas of flooding around the base of the volcano, and assessing the hazards for tourists, who come to the area on the “ring-road”, which circles Iceland, for scenic views of the southern coastline and to witness fissure eruptions of smaller volcanoes around Katla.

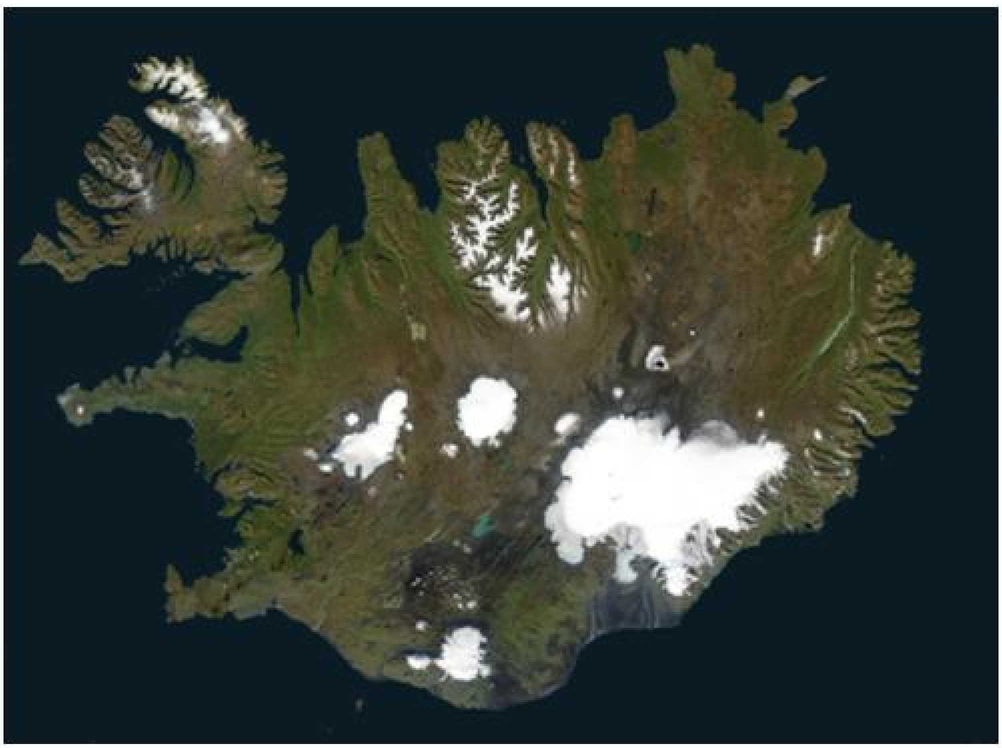


Figure 1: Satellite image of Iceland showing locations and areas covered by glaciers. (cleaned image created from a ASTER NASA image found in Wikimedia commons).

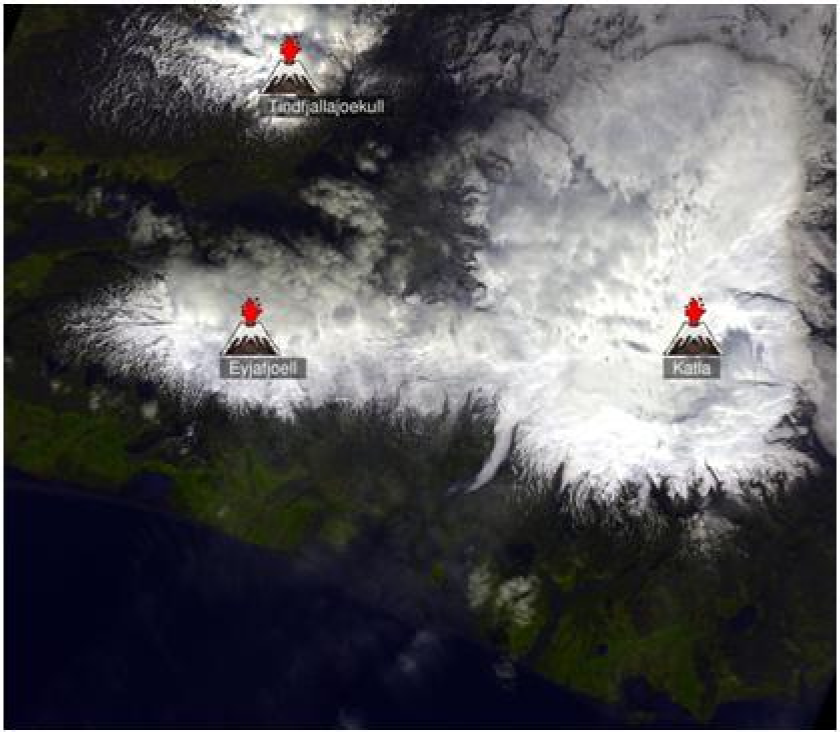


Figure 2: Image of Katla and Eyjafjallajokull volcanoes in southern Iceland (ASTER NASA image)

Data Accumulation

I expected to be able to find data easily for Iceland, considering its recent spotlight in the news with the eruption of the Eyjafjallajokull volcano. It was difficult, however, in that most data was not available for public use. Other volcanic hazards, such as ash production, could be analyzed using ArcGIS, if data had been available.

Shapefiles were found from different sources. Hypsography and the political boundary polygon shapefiles were downloaded from http://data.geocomm.com/. After expanding these files they were in the form of .e00. They were converted to shapefiles using the "Import from Interchange File" tool under Coverage Tools in ArcToolbox.

The political boundary shapefile was dissolved into a single polygon using the "Dissolve" tool and using the country code as the attribute to dissolve by. The result is an outline of Iceland (Iceland.shp) that can be used as the analysis mask for raster calculations.

The volcano, road and waterway shapefiles were found at www.mapcruzin.com. They also had to be expanded. The volcano shapefile has locations for every major volcano in the northern hemisphere. By using "selection by location" under the selection tab and selecting all volcanoes within

Iceland.shp, I was able to export the selected volcanoes into a shapefile for Icelandic volcanoes (vol_clip.shp).

Elevation data for Iceland was found at http://www.viewfinderpanoramas.org/dem3.html. It was downloaded as a .hgt file. By also downloading a viewing program called 3DEM, I was able to convert the file to a .dem file. Once loaded into ArcGIS (Figure 3), the file was then converted to a raster. Interestingly, the spatial reference for this file is GCS_WGS 1984 with units of decimal seconds (cell size of 3x3 decimal seconds). This is important to keep note of for raster processing (eg. creating hillshades).

A Satellite image of Iceland taken by ASTER NASA (Figure 1) was found at Wikimedia commons in a .bmp format. A closer image of Katla volcano was taken from Google Earth.

The stretched out view of Iceland was similar for all projections, because of its high latitude. Therefore WGS 1984 was kept as the projection (Figure 4). The shapefiles could not be converted to the same spatial reference due to their units being in decimal degree. How to clip rasters to the Iceland.shp is discussed later.

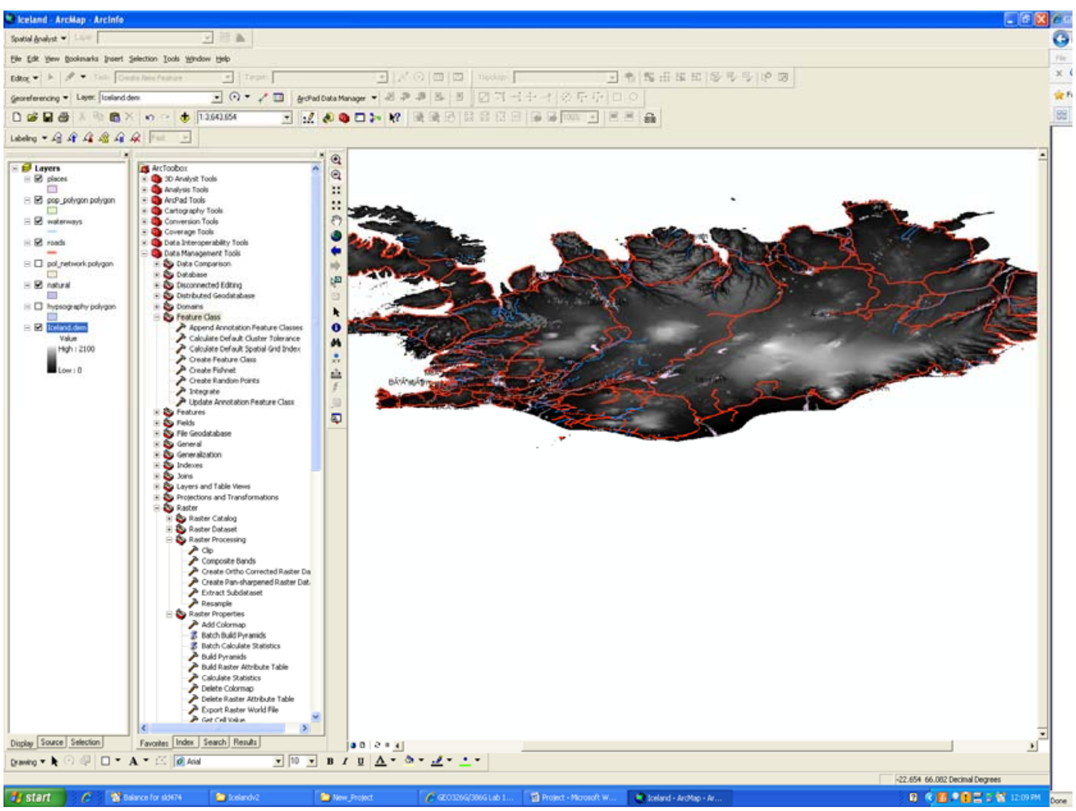


Figure 3: The original DEM of Iceland.

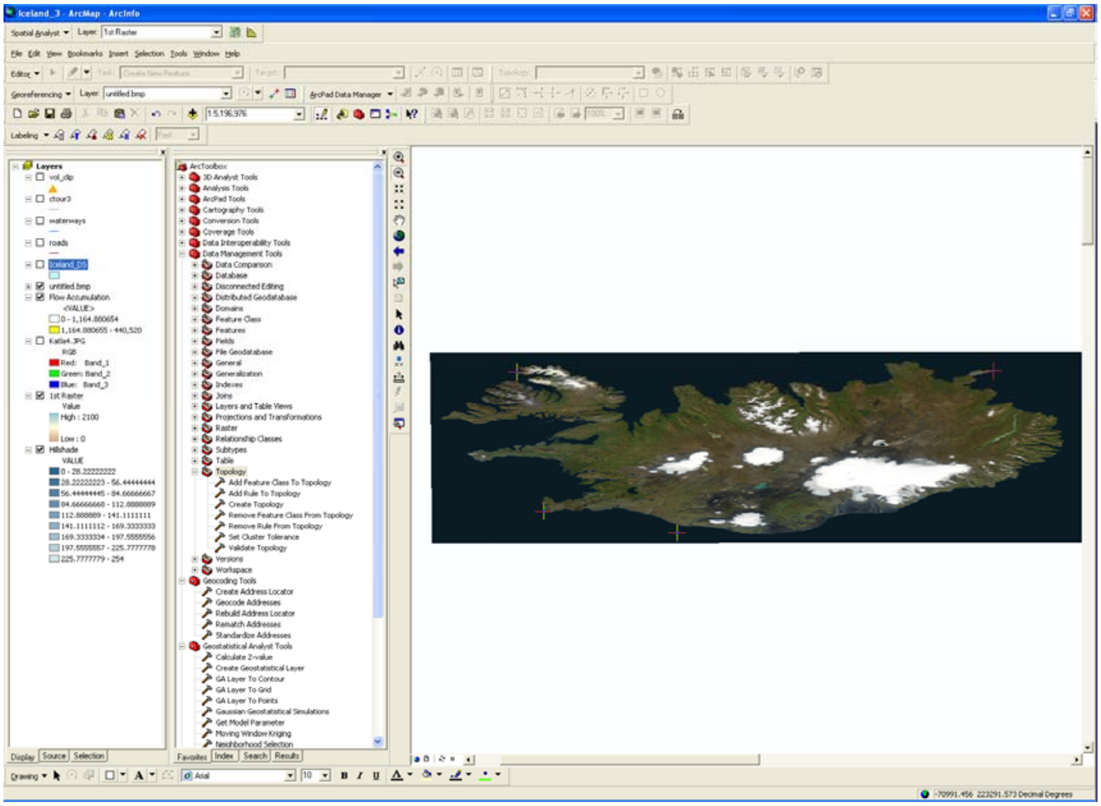


Figure 4: BMP image of Iceland projected into a customized projection.

Raster Analysis

Hillshade

Since the cell size for the raster is 3 by 3 decimal seconds, the z factor for creating a hillshade is around 0.0325. A screen shot of the hillshade can be seen in Figure 5.

Flow Direction and Accumulation

In order to determine where flow is likely to begin at high topographies, knowing the slope and channel pathways to lower elevations is necessary. The Flow Direction and Flow Accumulation tools found in the Hydrology section of the Spatial Analyst Tools in the ArcToolbox were used to do this.

First the Flow Direction tool shows the direction of steepest slope to the nearest cells. This is necessary to have in order to use the Flow Accumulation tool. This tool determines how much flow can accumulate in nearby cells due to the flow directions around them.

The flow accumulation raster is shown in Figure 6. As expected, many of the flow paths overlap the river shapefile, but many new channels are shown. This shows that new “temporary” rivers could form if glacial melts are large enough.

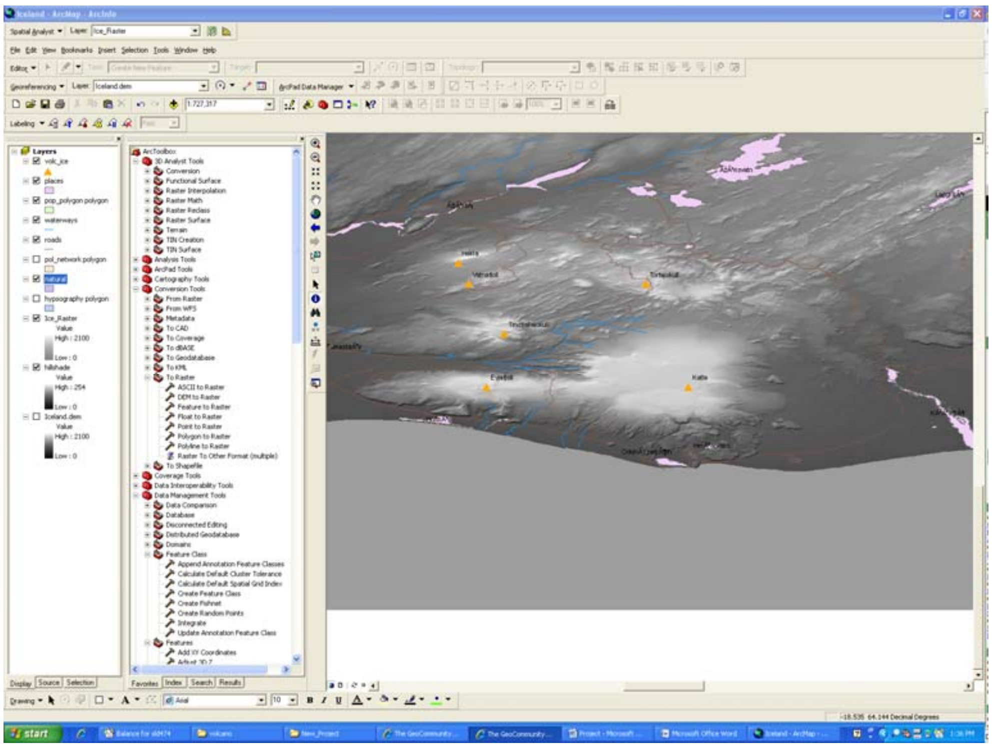


Figure 5: Close up of hillshade layer around Katla volcano.

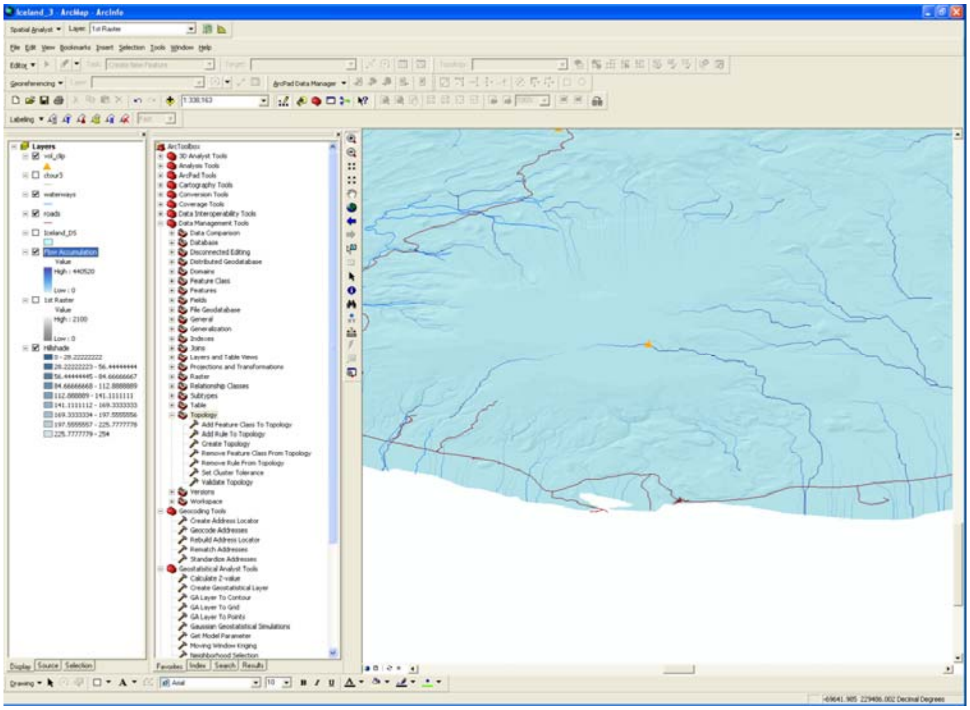


Figure 6: Close-up on Katla volcano of flow accumulation raster. The dark blue lines are the “flow paths”.

Clipping rasters to Iceland’s coastline

In order to clip the rasters to the outline of Iceland, the Iceland.shp file needed to have the same units as the rasters which are in decimal seconds. In order to do this, a custom coordinate system needed to be created for the data frame.

In the coordinate system tab of the data frame properties, “New…” > Geographic Coordinate System was selected. Figure 7 shows what was inputted in order to have a custom system based on the datum of the shapefiles, Clark 1866, and converting the axes to seconds from meters. The conversion is 30.72 m/sec. The units were also changed to seconds.

Once this was done, adding the Iceland.shp file to the data frame and then exporting it as Iceland_DS.shp gave it the new coordinate system with units of decimal seconds. It could then be used as the analysis mask to clip rasters to. The hillshade, flow accumulation, and initial Iceland elevation rasters were all clipped, so that no data was present outside of Iceland's borders. Now the locations of where Myrdalsjokull's glacial meltwater flow paths enter the ocean can be seen.

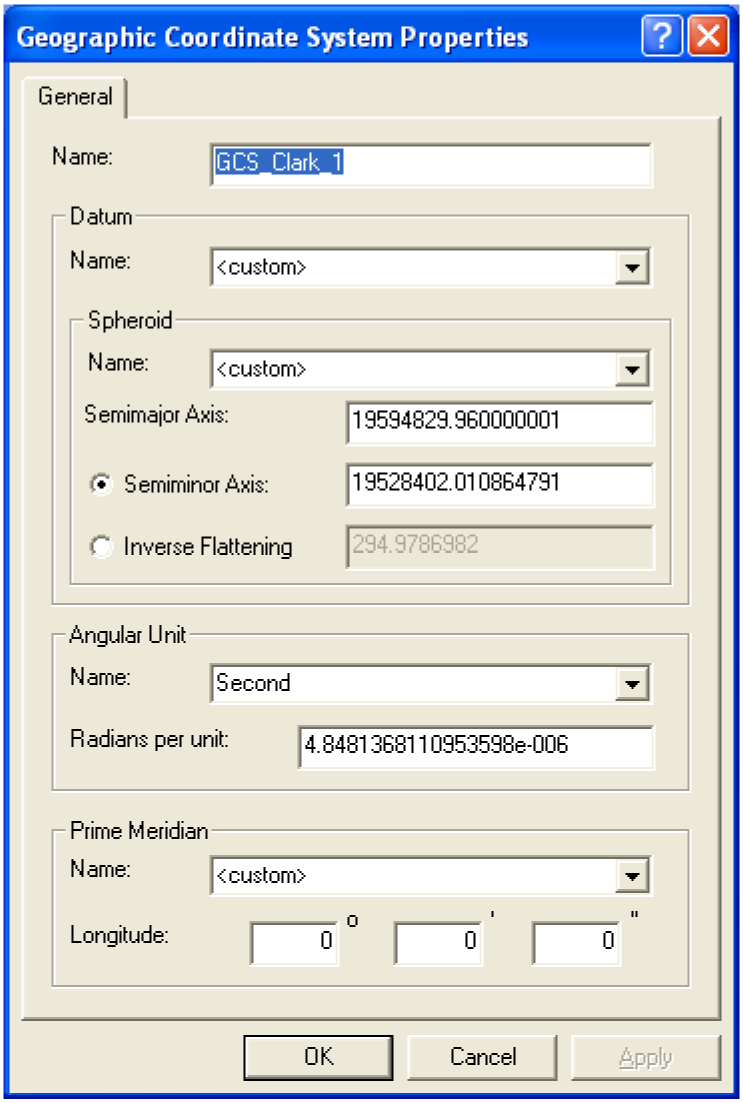


Figure 7: Creating a custom coordinate system. It was based on the datum of Clark 1866 and the values of meters for the axes were converted to seconds.

View of the Flow Accumulation Raster

To make values of low or no accumulation not visible, the symbology of the raster was changed from stretched values to classified. By creating categories that separated the values for non-flowpaths from apparent flow paths, the defined flow paths could be overlain on the hillshade and raster (Figure 8). The non-flowpath values were displayed as null color, and the flow paths are dark blue lines.

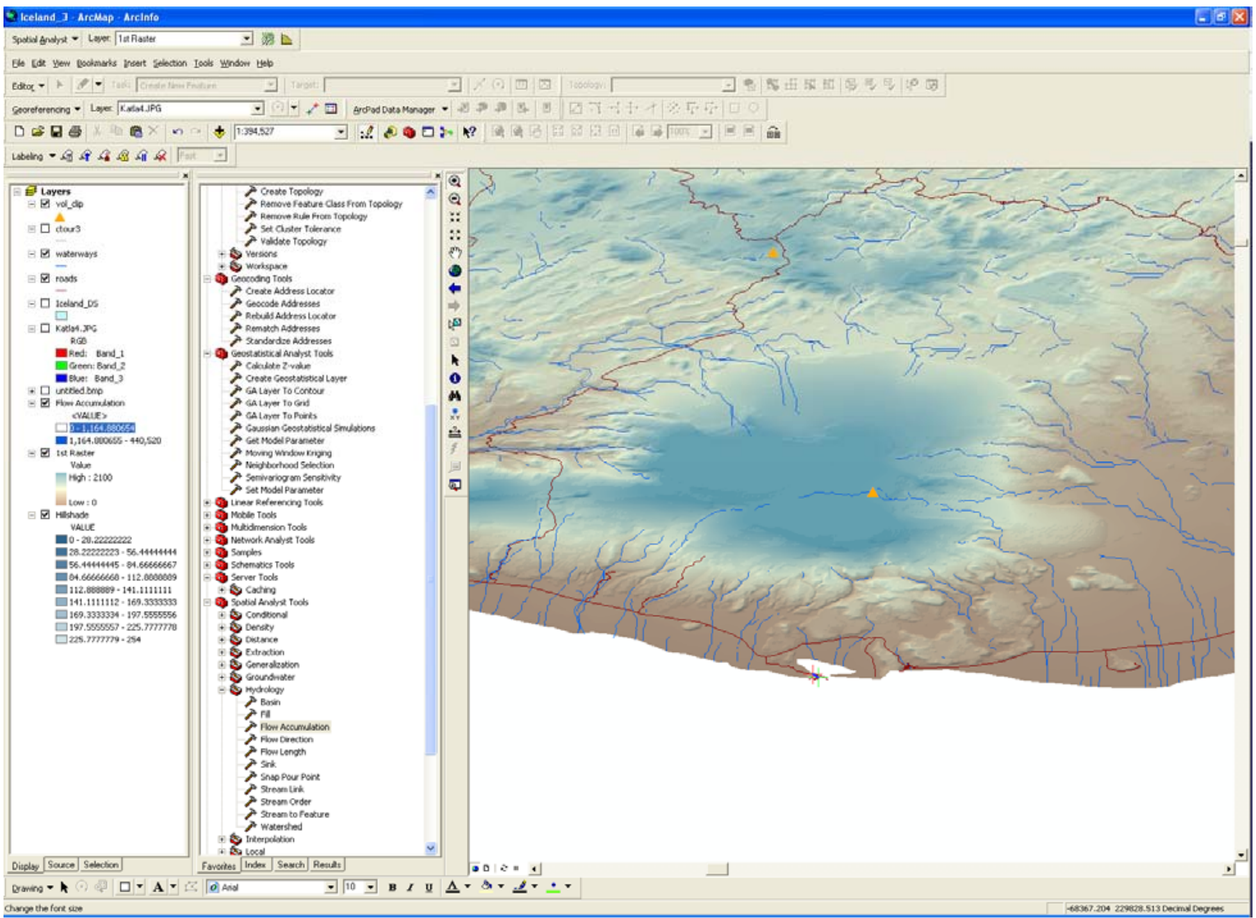


Figure 8: Flow paths of glacial meltwater around the Katla volcano (lower orange triangle). The flow lines are blue.

Georeferencing Satellite Images

The satellite image found from Google Earth of Katla volcano was added to the map and georeferenced and rectified. This image has a mosaic of slightly different quality on the bottom left corner of the volcano. It appears to be an image taken in a different season, winter, and is slightly higher resolution. The image of Iceland found, a cleaned version of a NASA ASTER image from Wikimedia commons, was also georefenced and rectified as a new file and both were added to the map.

The Google Earth image is layered under the flow accumulation raster to view where rivers are on the land surface (Figure 9), and then also to see where flows created by glacial melt would occur (Figure 10). Flow paths on the lower left side of the volcano match up with rivers and valleys that can be seen in that area. This is a good sign that this calculation is accurate.

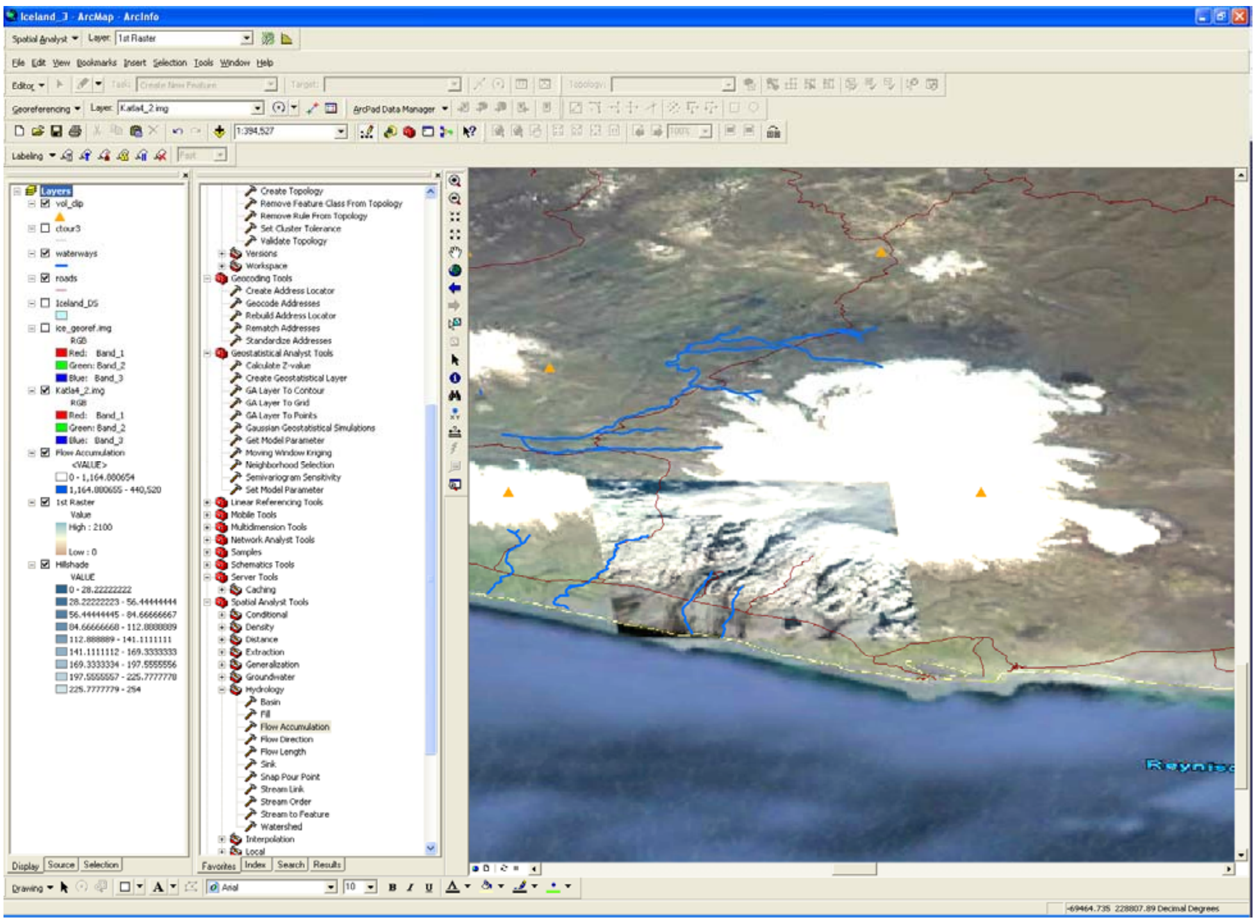


Figure 9: Georeferenced Google Earth image of Katla showing the locations of rivers.

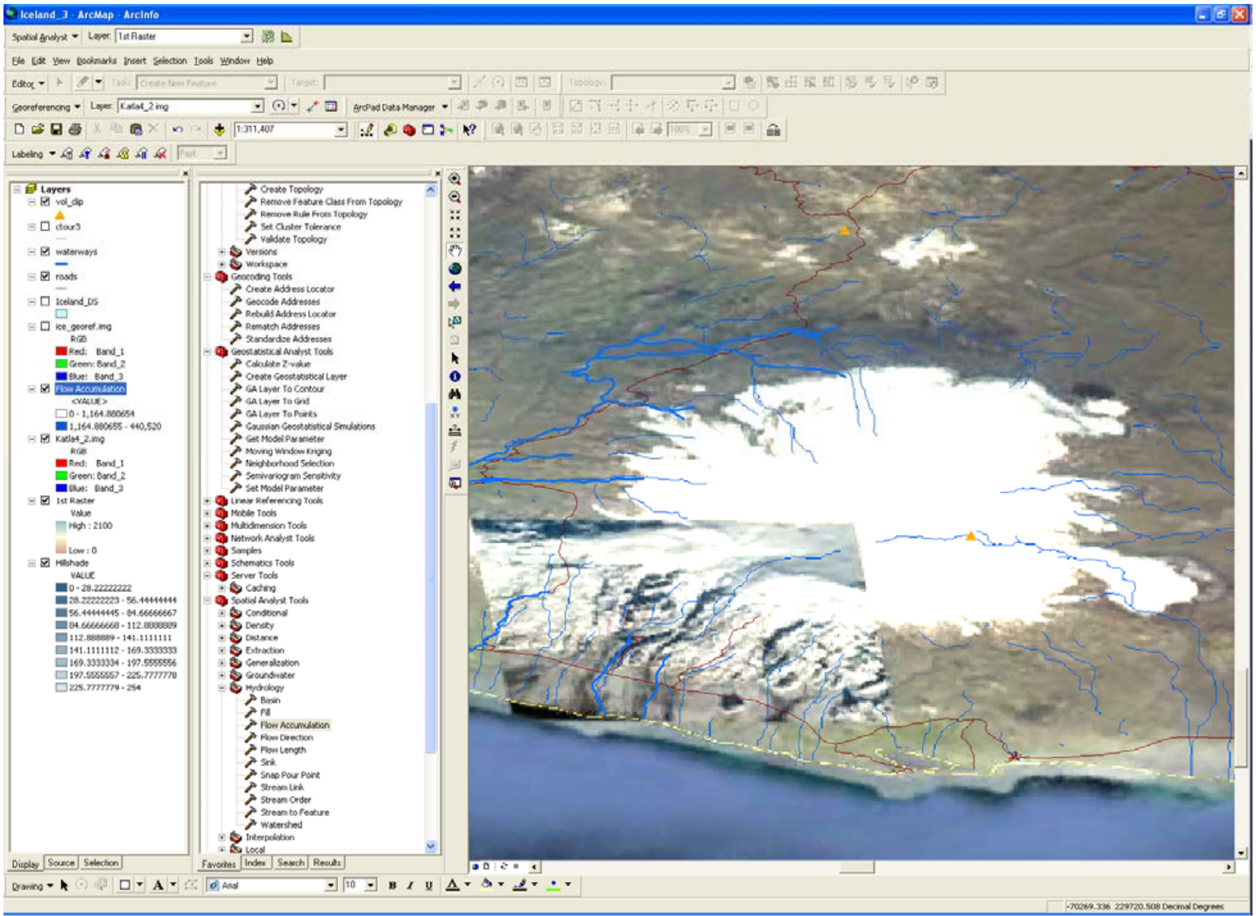


Figure 10: Same as Figure 9 with flow paths.

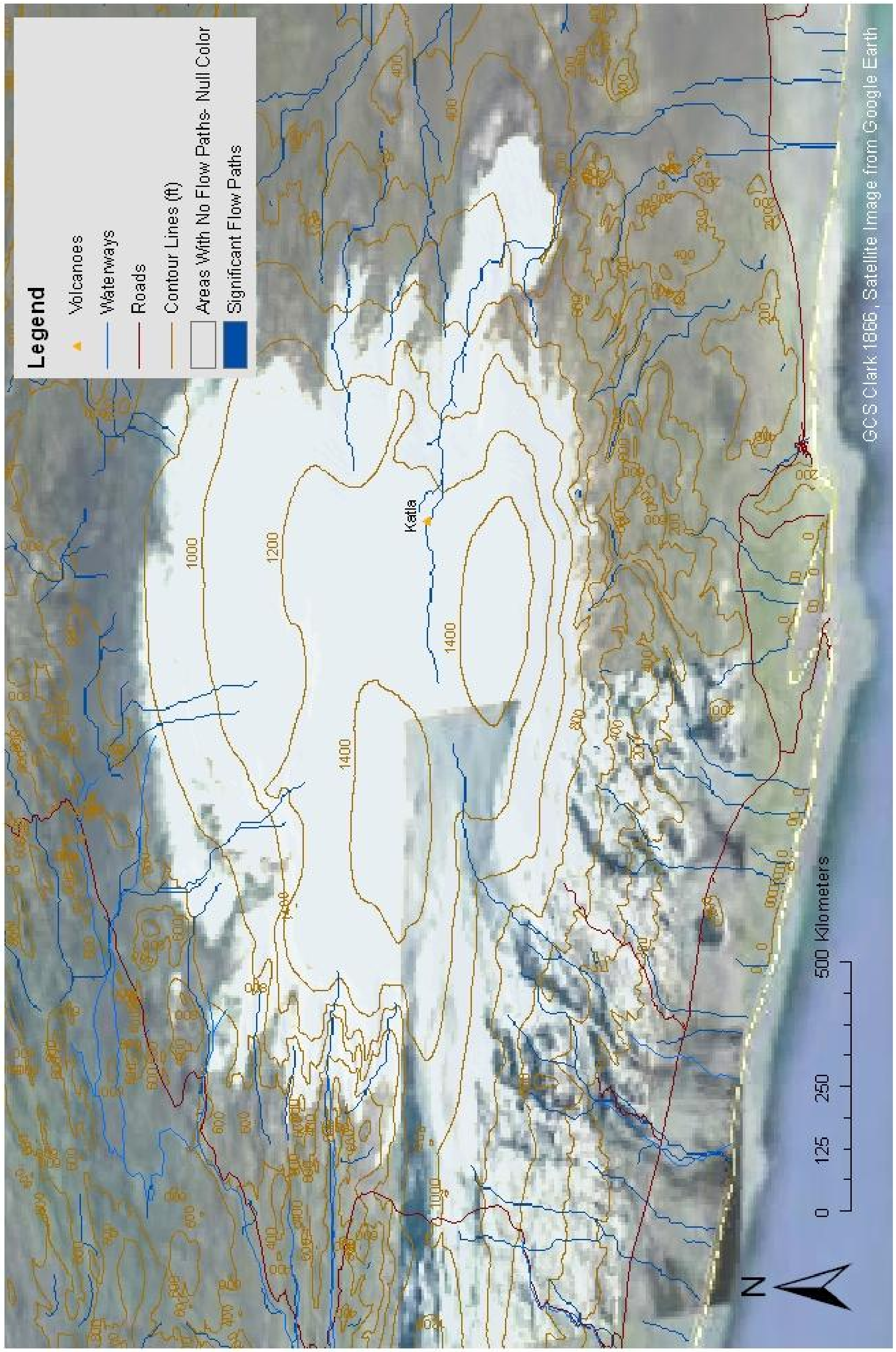
Conclusions

Using ArcGIS tools made identifying a drainage network for glaciers possible. Overlying an active volcano, Katla, the likeliness of glacial meltwater floods from the Myrdalsjokull glacier is great, and so this type of information is useful to know. This method could also be used to determine the flowpaths for meltwater flows from other glaciers in Iceland and worldwide. This project helped to show that large amounts of melt, that could be caused by the increased heat from a volcanic eruption, could created new temporary channels that don't necessarily follow established waterways. By estimating the volume of meltwater, an area of flooding around continental ending points of the flowpaths at the base of the volcano could even be estimated.

Final Maps

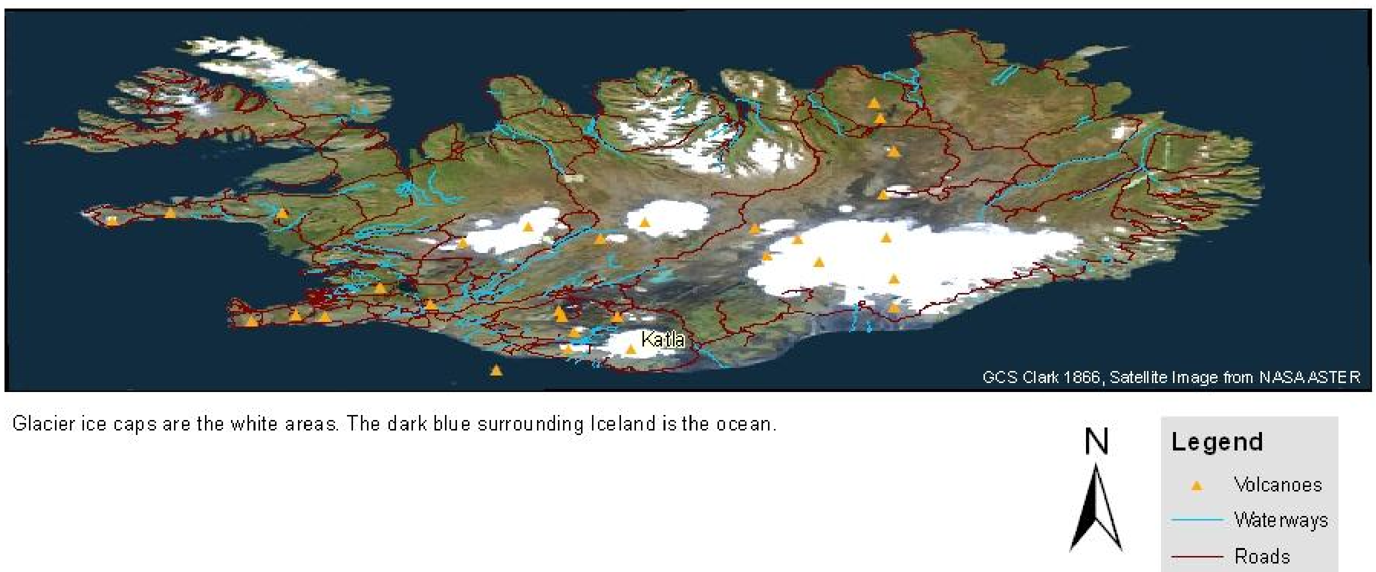
GIS Final Project by Sarah Doyle, Spring 2010

Map 1: Glacial Meltwater Flow Paths Around Katla Volcano, Iceland



GIS Final Project by Sarah Doyle, Spring 2010

Map 2: Locations of Glaciers and Volcanoes in Iceland



Glacier ice caps are the white areas. The dark blue surrounding Iceland is the ocean.