Rebecca Risch

EARS 77 – Environmental Applications of GIS

Professor Jonathan Chipman

15 January 2024

Lab 1: Modeling Isostatic Rebound and Glacial Lake Hitchcock

The main objective of this lab was to use GIS, specifically ArcGIS Pro, to model the extent and volume of the glacial Lake Hitchcock, which was formed in the Upper Valley area and the larger Connecticut River Watershed at the end of the last glacial maximum (LGM) 13,000 years ago from the melting of the Laurentide ice sheet. To do this, we needed a contemporary Digital Elevation Model representative of the area, so we modeled isostatic rebound of the land as the ice sheet melted, to then place Lake Hitchcock before that geological context. To determine the isostatic rebound that has occurred, we assumed the elevations of the deltas deposited by Lake Hitchcock were all once equal, and then mapped the difference (the slope) of the current elevations- indicating increasing amounts of uplift, and therefore increasing masses of paleo ice, as distance from the ice margin increases.

The process for this lab is as follows: first, I derived a stream network from the provided DEM. I filled the holes in the DEM with the Hydrology Fill function, which uses spatial autocorrelation. I then found the flow direction for each cell based on the DEM (how water would flow between cells based on elevation differences) and accumulated those (calculating how many pixels flow into each other pixel), allowing me to narrow down the results to only include streams with an upstream drainage of over 1000 grid cells. After linking and vectorizing the streams, I now had a stream network. Second, I derived the watershed boundaries (Figure 1). I found the pour point- the lowest point on the boundary of the watershed, where all of the water drains- and used that, along with the Flow Direction raster, to define the watershed boundaries as the upslope drainage of the pour point.

Third, I developed the model of postglacial isostatic rebound. I calculated the distance and direction of each pixel to a given ice margin, specifically looking at these values belonging to Lake Hitchcock's ancient deltas, along with the delta's elevations. I used a given python script to visualize the relationship between the deltas' distances from the ice margin and the deltas' elevations, and overlaid a linear regression model on top of this plot (Figure 4). I also found the mean (342.06 degrees) and standard deviation (3.89 degrees) of the direction of increasing uplift from the ice margin. I printed key statistics of this relationship from the regression model: slope, intercept, R^2, p-value, and standard error. I then found Lake Hitchcock's pre-rebound water level (h) at about -88m by subtracting the intercept from the given uplift at the ice margin. Fourth, I removed isostatic rebound from the DEM by subtracting the uplift model (30m + b_1 * distance, where $b_1 = 0.8763$) from the modern DEM. Fifth, I estimated the water level of Lake Hitchcock and mapped its spatial extent (Figures 2 & 3). I mapped the land covered by the lake (the land whose pre-uplift elevation was below Lake Hitchcock's water level) with the raster calculator set to paleo_dem (the DEM pre-isostatic rebound) < h. I converted this shape's area in pixels to km^2 and found the lake's extent to be 1835.6 km^2. Finally, I found the lake's volume by finding the depth of water in each lake pixel using the raster calculator (h - paleo_dem), found the average depth over all lake pixels as 0.02895 km, and multiplied this average depth by lake surface area to find a value for Lake Hitchcock's volume: 53.1417 km^3.

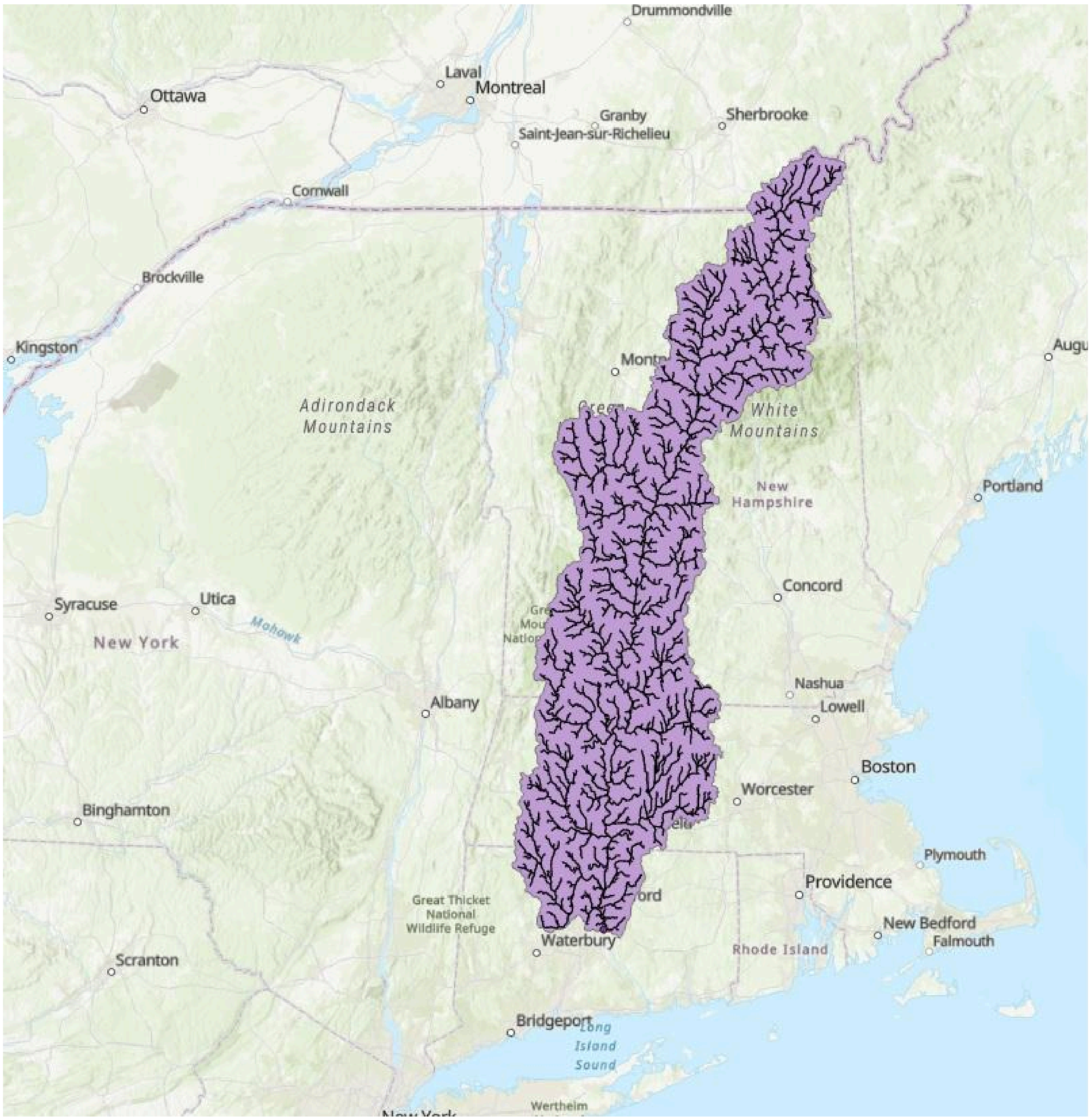

Figure 1: Connecticut River Watershed- stream network with watershed boundaries and pour point.

Figure 2: Lake Hitchcock's extent overlaid onto the Connecticut River watershed.

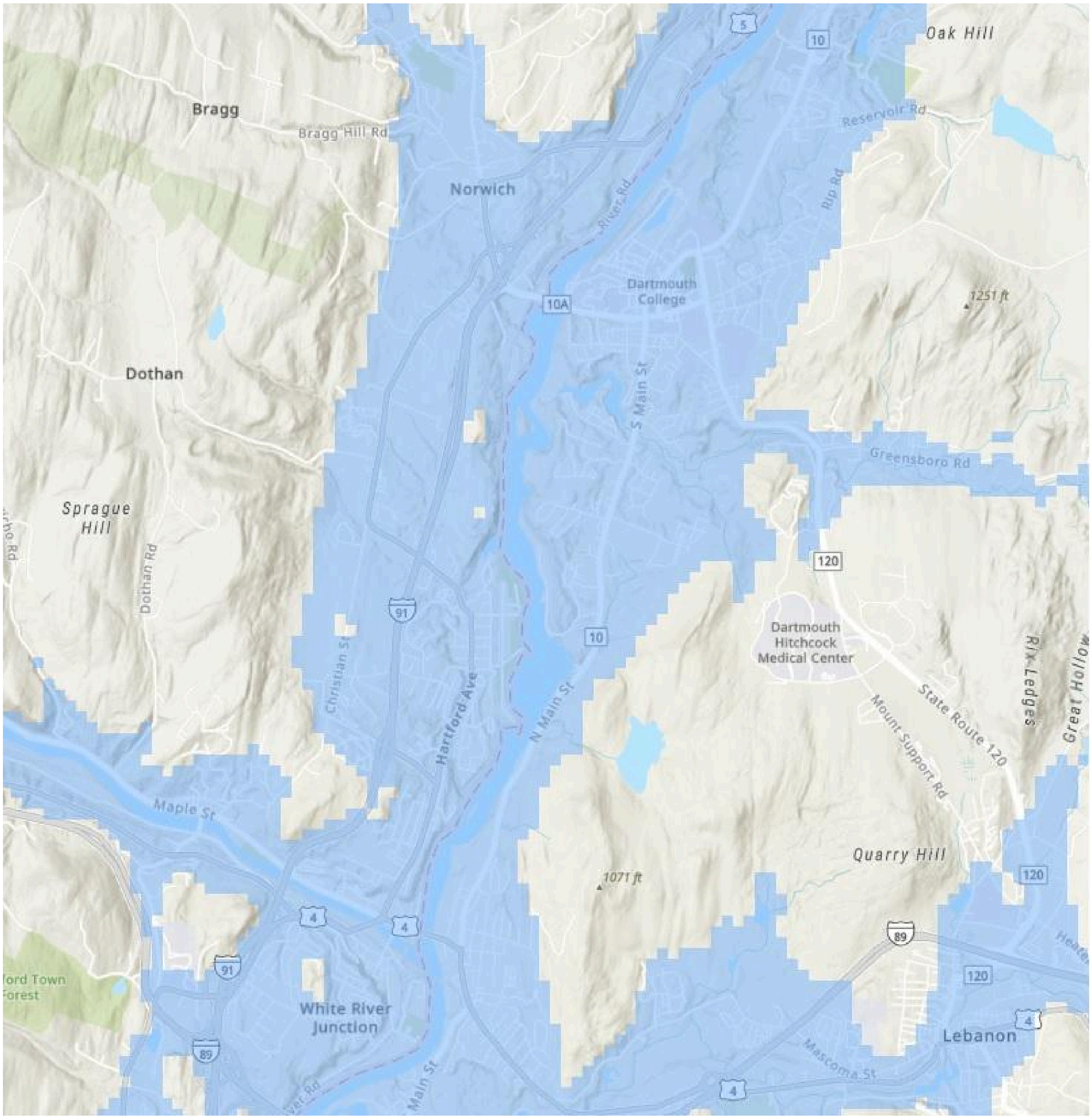

Figure 3: Lake Hitchcock's extent over the Upper Valley area.

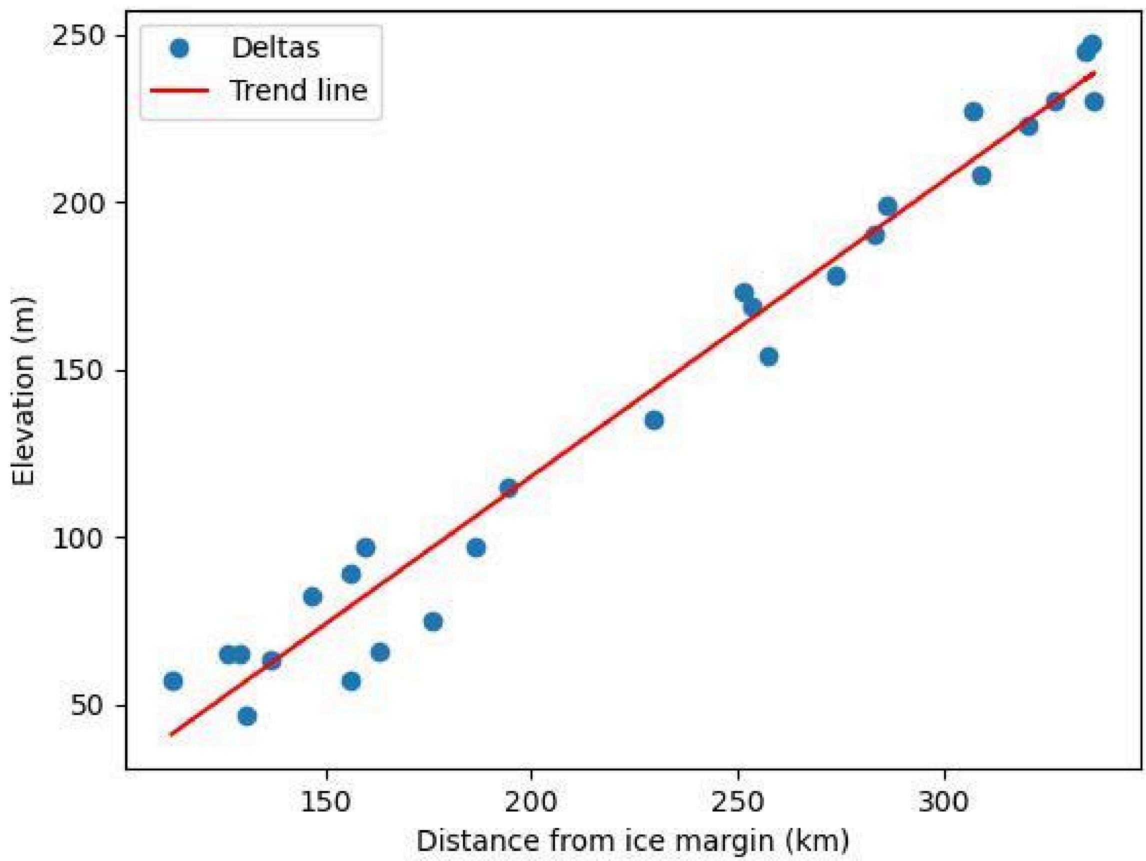

Figure 4: Distance from ice margin (km) vs Elevation of Lake Hitchcock's deltas (m), overlayed by linear regression model.