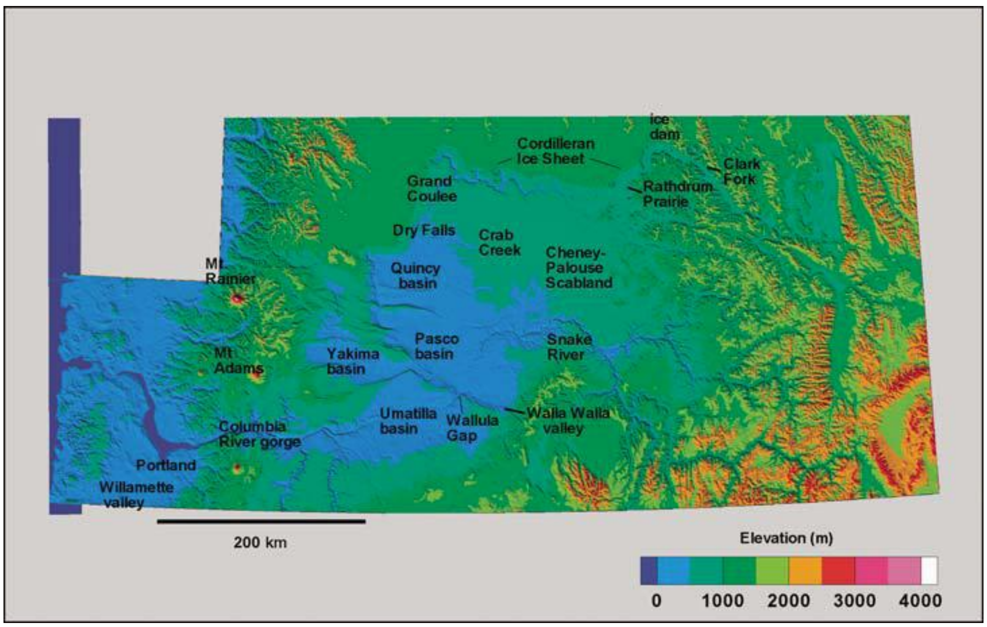
Modeling the Lower Columbia during the Lake Missoula Floods: Corrections to the Denlinger and O'Connell Model



From: Denlinger, R.P. and O'Connell, D.R.H., 2010, Simulations of cataclysmic outburst floods from Pleistocene Glacial Lake Missoula: GSA Bulletin, v.122, p.678-689, doi: 10.1130/B26454.1

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GEO 386G: GIS & GPS Applications in the Earth Sciences

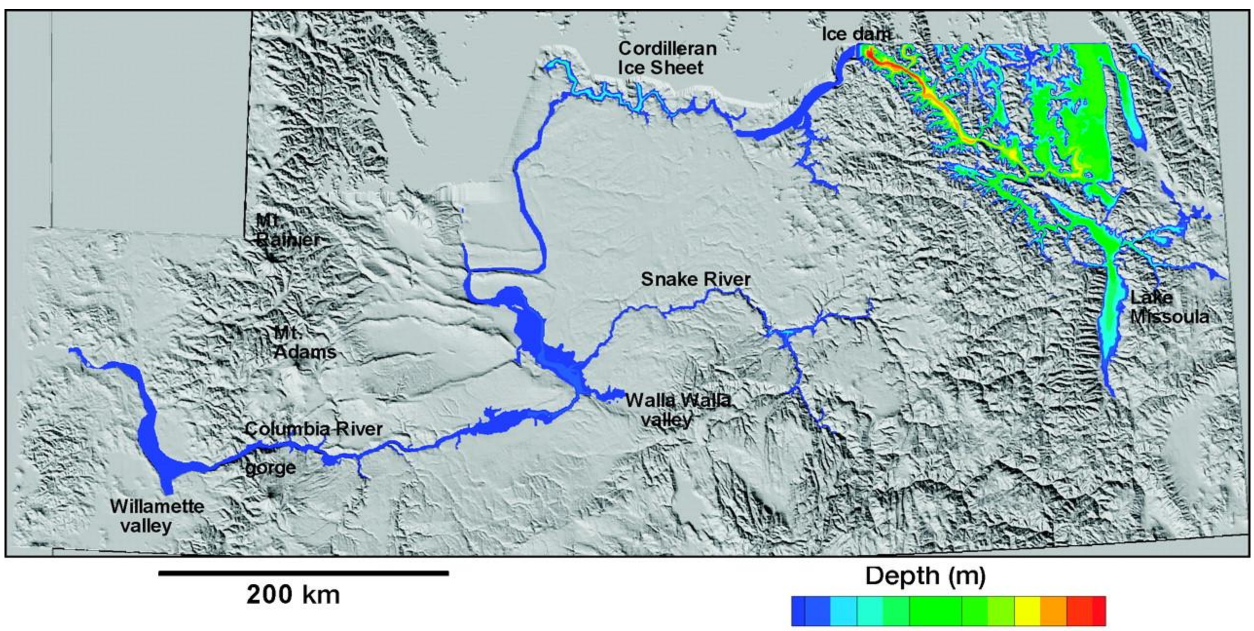
May 2, 2010

Introduction

The late Pleistocene Glacial Lake Missoula (GLM) floods inundated the Columbia River valley with enormous discharge, carving the dramatic topography of the Channeled Scablands. The episodic failure of the ice dam created where the Okanogan Lobe of the Cordilleran Ice Sheet obstructed the Clark Fork river drainage system of GLM scoured the Columbia Plateau, leaving geomorphic and stratigraphic evidence of maximum flood levels throughout the Columbia River Valley.

Denlinger and O'Connell have just published an extensive simulation of the flooding in the upper regions of the Columbia River Valley, above the Wallula Gap. In this analysis, I will bring together maximum flood levels found below the Wallula Gap (from Benito and O'Connor, 2003) with their analyses of flood volume and discharge.

Figure 1:
Initial Conditions for Lake Missoula flood, from Denlinger and O'Connell, 2010.



Inundation to the Wallula Gap took at least 55 h (Denlinger and O'Connell, 2010), as flood waters filled the Cheney-Palouse scablands, the upper Columbia channels, and the Pasco and Yakima Basins. There were two major stages of drainage; first the rapid flooding of the upper basins, and later the slow drainage of the basins through the Columbia Gorge to the sea.

The simulations of Denlinger and O'Connell provide excellent models for the initial (Stage 1) flooding, but they do not account for many of the maximum flood level indicators provided by Benito and O'Connor. In the conclusion of their (Denlinger and O'Connell) paper, they admit that "However, our modeled peak flood stages at Walulla Gap are 10 m to 40 m lower than peak-stage indicators in the field."

Base maps

DEMs

The analysis was based primarily on the Digital Elevation Models for the lower Columbia River Valley. I needed DEMs covering the Columbia River downstream from the Wallula Gap. It was necessary to take DEMs at least to the contour of the maximum flood level on both banks of the River. The most comprehensive source for these data is the US Seamless Server, containing the National Elevation Dataset data. I also briefly (and futilely) searched for DEM's through GIS servers maintained by various Washington and Oregon state departments.

Other Maps

I referred to other maps included in the Denlinger and Benito papers

Data Processing

I created an Excel file from the data in table 5 of the Denlinger paper, which shows the differences between the field measurements of maximum flood level below the Wallula Gap published by Benito and O'Connor, and the maximum flows modeled by Denlinger and O'Connell using the maximum levels at the dam site along with flow model. Coordinate data was provided in Table DR2 of the Benito and O'Connor paper.

To preprocess this data, I first converted DMS coordinates to Decimal Degrees, and created separate sheets for the 2003 (field) data and 2010 (modeled) data to import into ArcMap. To import the data, first I added XY data in ArcMap, and then created a shapefile of the points with X,Y and Z coordinates in a NAD 1983 datum.

At Wallula Gap, Denlinger and O'Connell model the maximum height of the flood waters at 300m.

ArcGIS Processing

After many attempts at downloading the DEM, two NED DEM grids were added to my ArcMap project. The eventual solution was to download NED DEM's from the US Seamless Server to a flash drive for use in the project. It took two 222MB files from the Seamless Server to cover my study area.

As an information sciences student, adding the appropriate metadata to the newly created DEM's is very important to me, and unfortunately the metadata from the Seamless Server did not import to my DEM files. I added most of the metadata by hand through ArcCatalog, copying the metadata from the XML file into the ArcCatalog metadata creator.

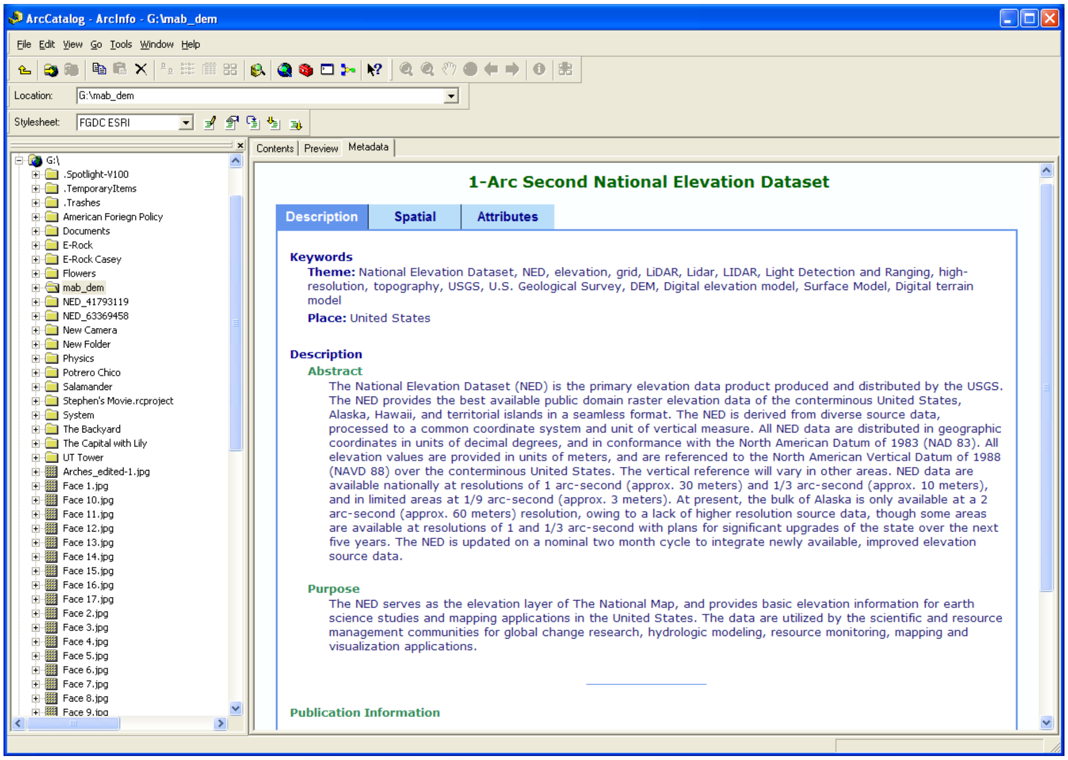


Figure 2:

Descriptive metadata added to the new DEM covering my study area

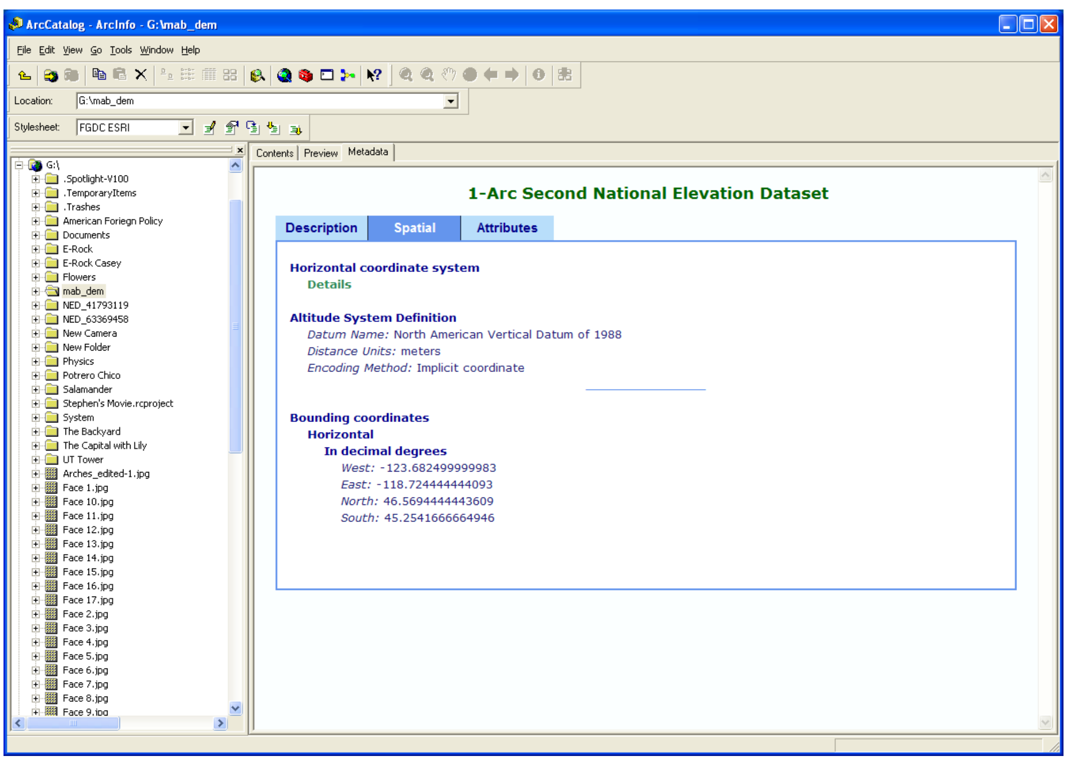


Figure 3:

Spatial metadata added to the DEM created for my study area

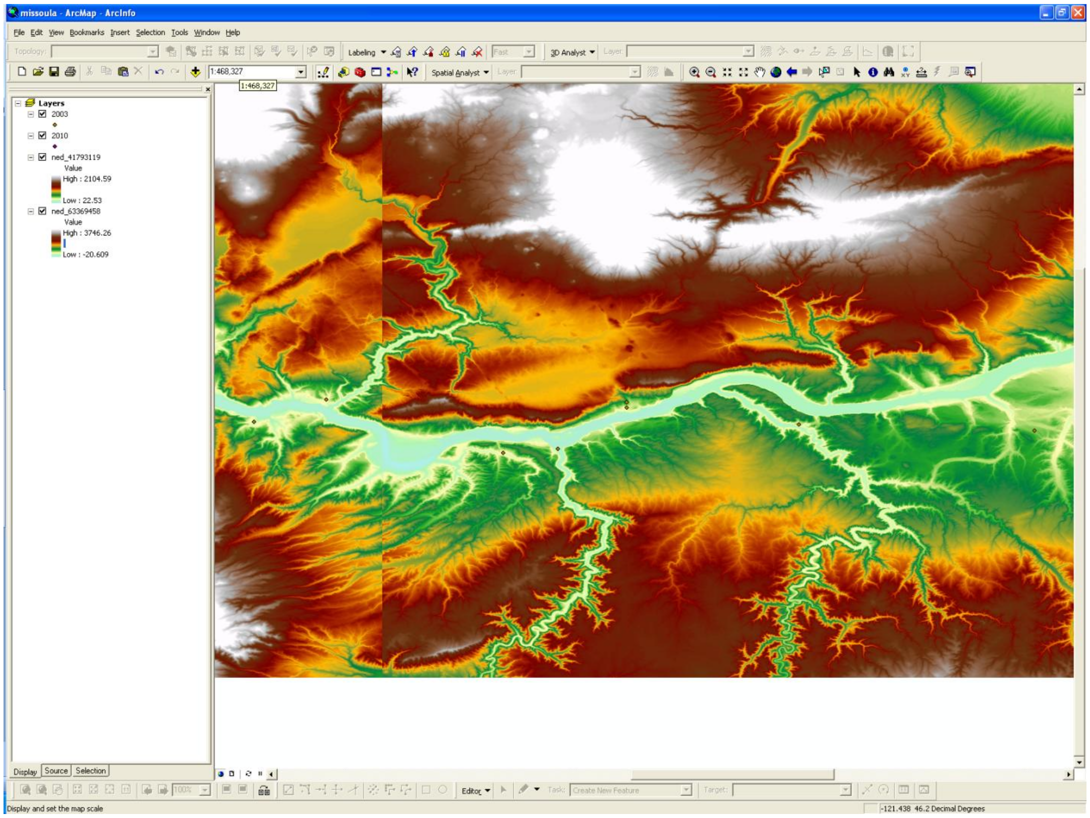


Figure 4:
2003 and 2010 flood level point data with two NED digital elevation models as downloaded from the US Seamless Server. Notice color offset between the two DEM on the western quarter of the map

It was necessary to merge (mosaic) the two DEM's so that they could be symbolized together and manipulated using Spatial Analyst tools.

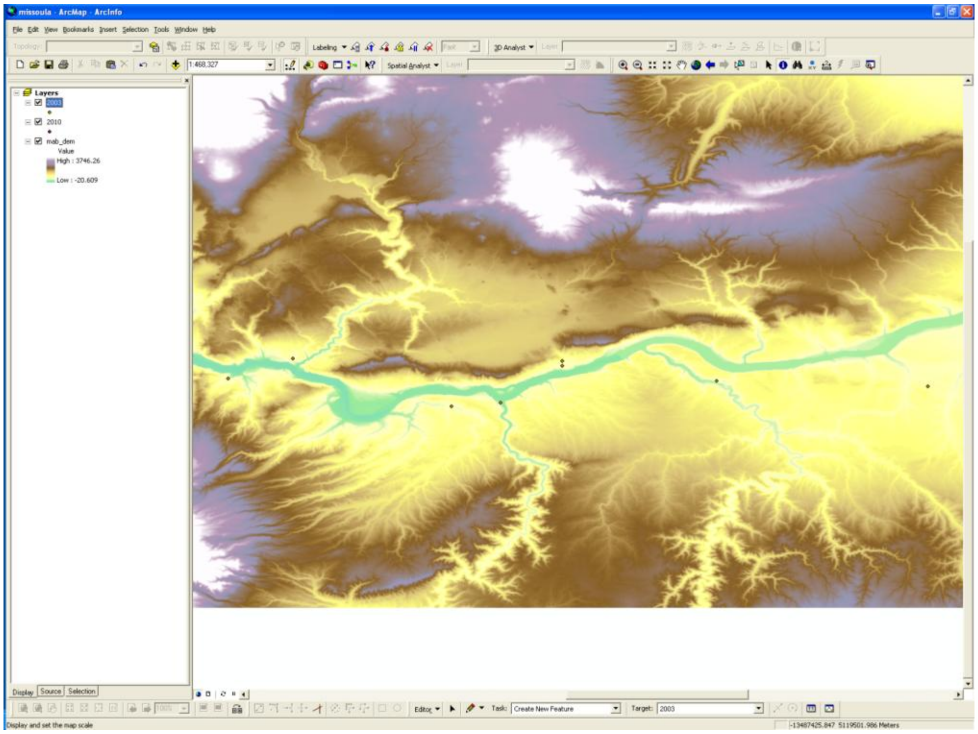


Figure 5:
Map with DEM after the mosaic

In order to eventually create flood level polygons, I used the Spatial Analyst tools to create a Hillshade (which I then symbolized using 50% transparency) and contour lines that would allow me to create vector polygons.

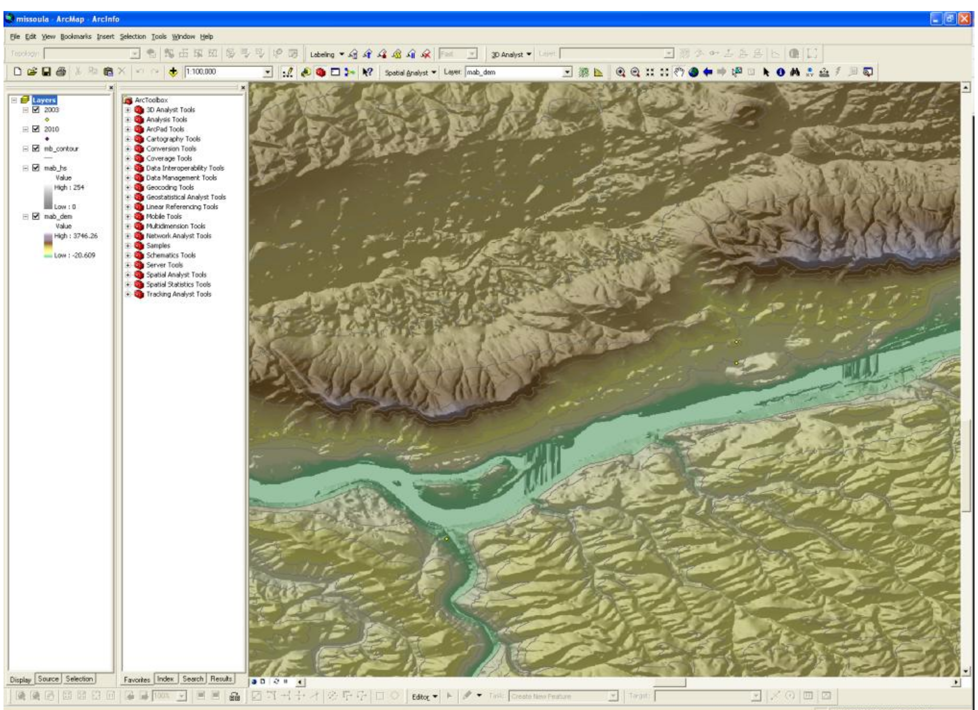


Figure 5:
Map with DEM, Hillshade and Contours, zoomed to 1:100 000

To model the lake levels, my first approach was to resymbolize the DEM with blue as the color as anything below 280 meters, which is the maximum flood level at the upper most site of my analysis. At this point the 2003 field measurement of maximum flood level (280 meters)and the 2010 modeled measurement of maximum flood level are approximately equal.

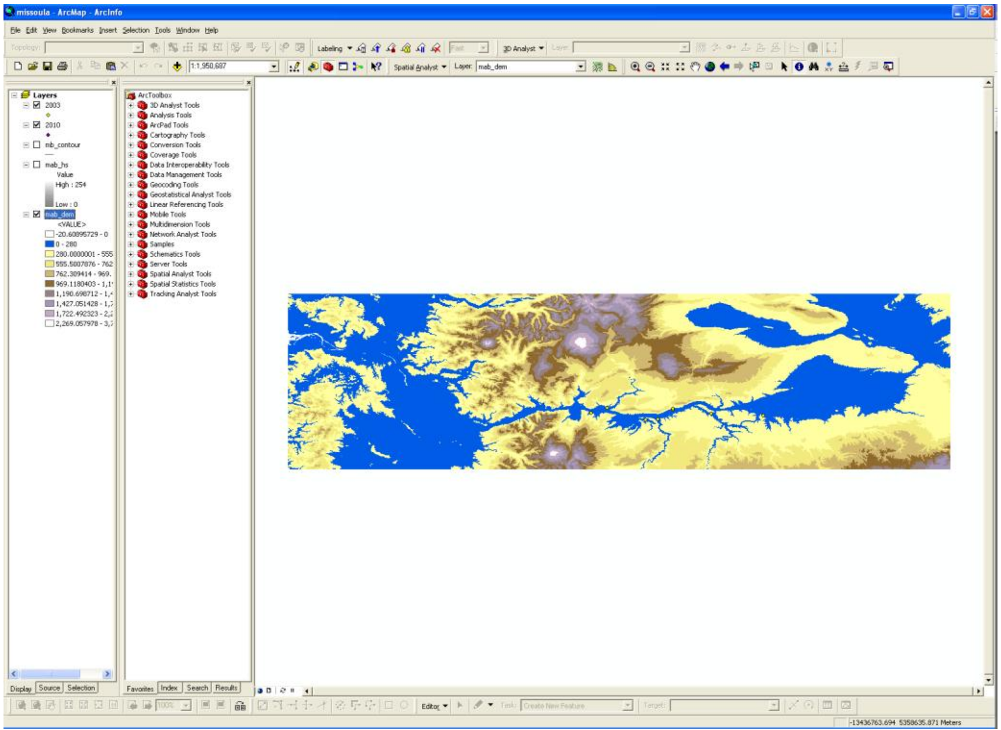


Figure 7:

Flood Stage Map at 280 m, measured at upper most point. Blue symbolizes the flood level, white (on far western side) is the current ocean level

Using the raster calculator, I created polygons at each level of the maximum flood. I simply identified all elevations in the DEM that were less than or equal to the flood elevation at each of the given points and for each study.

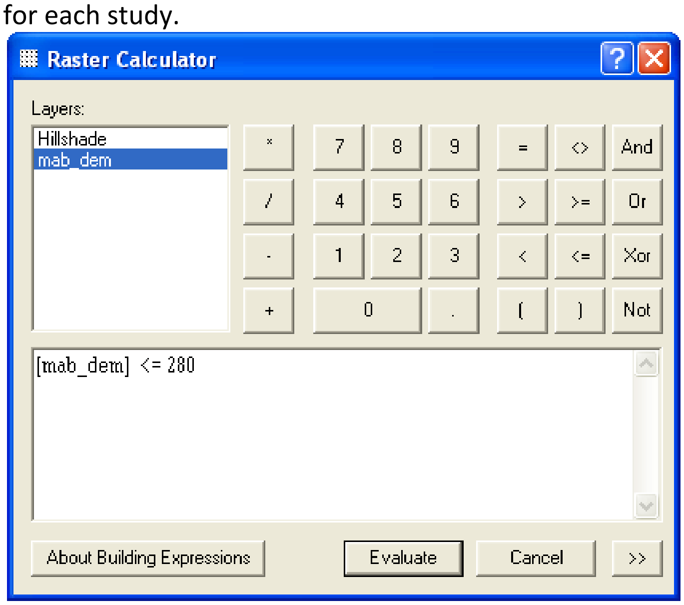


Figure 8: Raster Calculator, with functions used to calculate lake level

Figure 9:
Hillshade map with maximum and minimum flood levels as taken from the 2003 field measurements

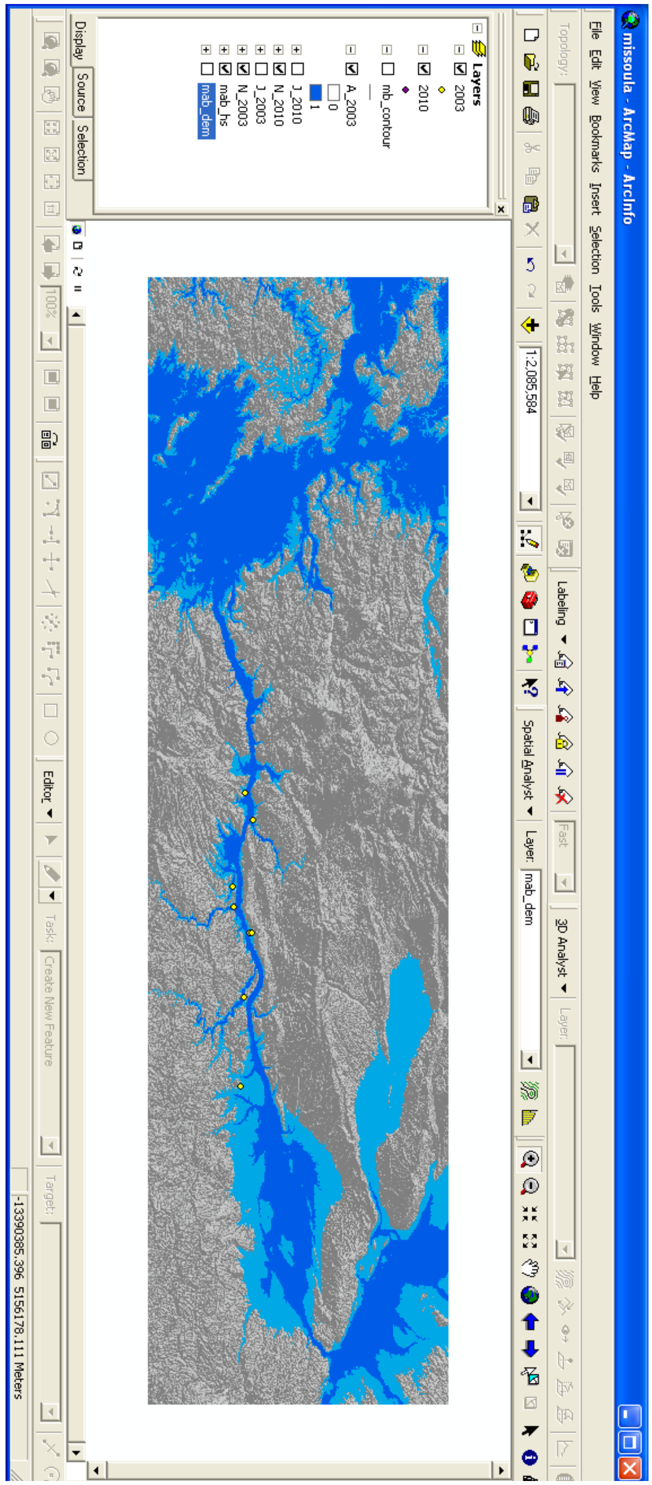
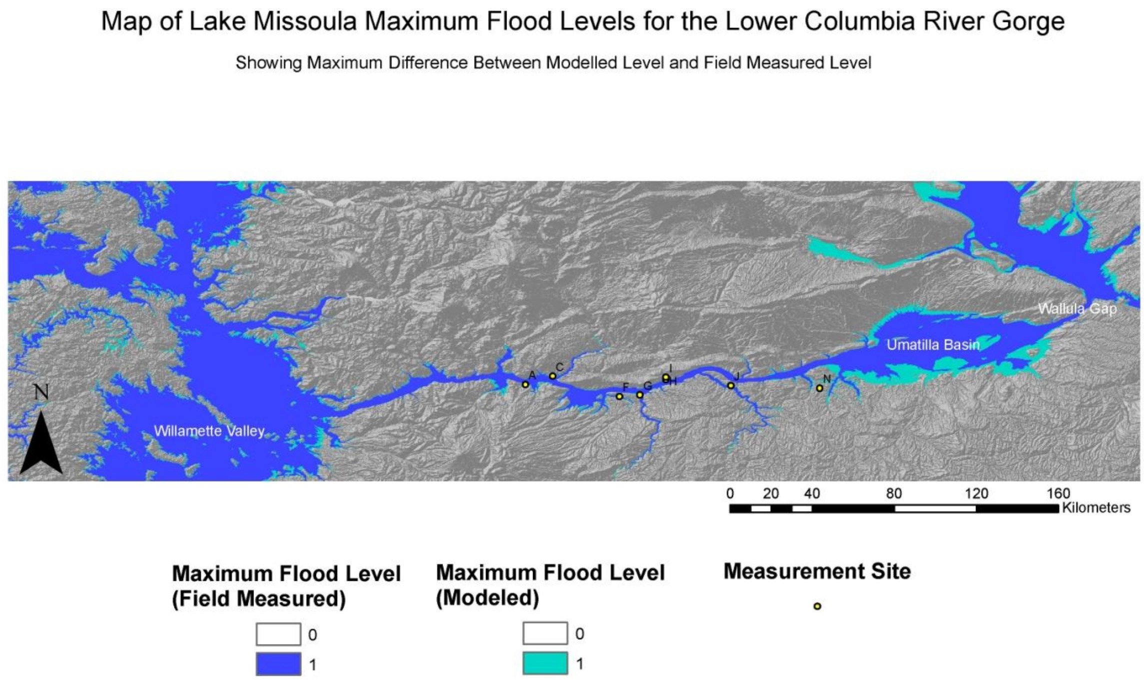


Figure 10:
Final Map of Maximum Flood Levels at Largest Difference Between the 2003 Data and 2010 Data



To compare the lake sizes, I calculated the surface area of the river at each flood level. The modeled lake contained 15980344 raster cells, while the measured/ 2003 flood level calculation came to 19070499 raster cells. The modeled flood level is 1.2 times larger than the measured flood.

Conclusion

Using ArcGIS for this type of an analysis is very useful. The majority of the work was spent acquiring the data and manipulating the DEMs. The results of the analysis were not surprising, but have interesting implication for the newly published model. The most dramatic differences in flood levels in the comparison of the 2003 and 2010 maximum flood levels are located in the basins (the Umatilla Basin and Willamette Valley). These are the areas with the lowest relief, so the changes are expected.

It would be interesting to statistically analyze the differences volume between the various flood stages, and to give the water surface a better (i.e. not perfectly horizontal) modeled surface. Writing more accurate equations into the raster calculation could account for the maximum flood heights recorded at downstream locations.

It is clear that the Denlinger and O'Connell model does not take into account the complex drainage systems that were occurring at and below the Wallula Gap. Their new "shallow-water" model is valuable evidence for the lower volume flood theory, yet the observed flood heights do not yet match even the newly modeled flood levels.

References

Benito, G., and O'Connor, J.E., 2003, Number and size of last-glacial Missoula floods in the Columbia River valley between the Pasco Basin, Washington, and Portland, Oregon: GSA Bulletin, v.115, p.624-638; Data Repository item 2003067

Denlinger, R.P. and O'Connell, D.R.H., 2010, Simulations of cataclysmic outburst floods from Pleistocene Glacial Lake Missoula: GSA Bulletin, v.122, p.678-689, doi: 10.1130/B26454.1