# Runoff and geomorphic properties of North Carolina rivers

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CE 394K.3

## Introduction

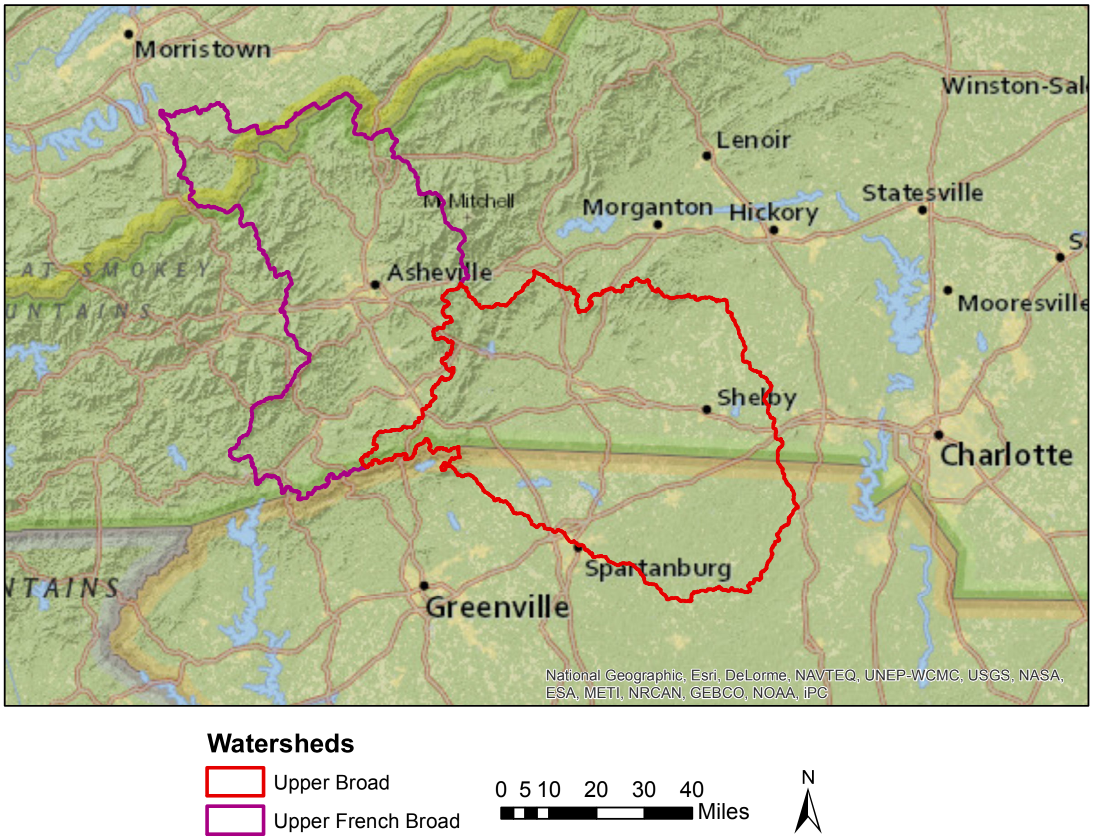
Hypsometric analysis is used in a several geologic fields, including hydrology. A number of studies on the relationship between hypsometry and hydrology have found that hypsometric curve parameters have a strong relationship with basin hydrology, especially flood response. (Perez-Pena et al., 2009) GIS provides powerful tools for the study of these properties, especially through the utilization of digital elevation models.

For the purposes of this study, two watersheds originating in western North Carolina will be studied: the Upper French Broad River watershed (HUC8 06010105) and the Upper Broad River watershed (HUC8 03050105).

The French Broad River flows for 213 miles, starting in the Appalachian Mountains of Transylvania County, N.C., and ending in Knoxville, TN, where it joins with the Holston River to form the start of the Tennessee River. The Upper French Broad River watershed has an area of 4,868 $km^2$.

The Broad River flows for 150 miles, beginning in the Blue Ridge Mountains of Buncombe County, N.C., and eventually joining the Saluda River to form the Congaree River near the city of Columbia, S.C. The Upper Broad river watershed has an area of 6,419 $km^2$.

# Watershed locations



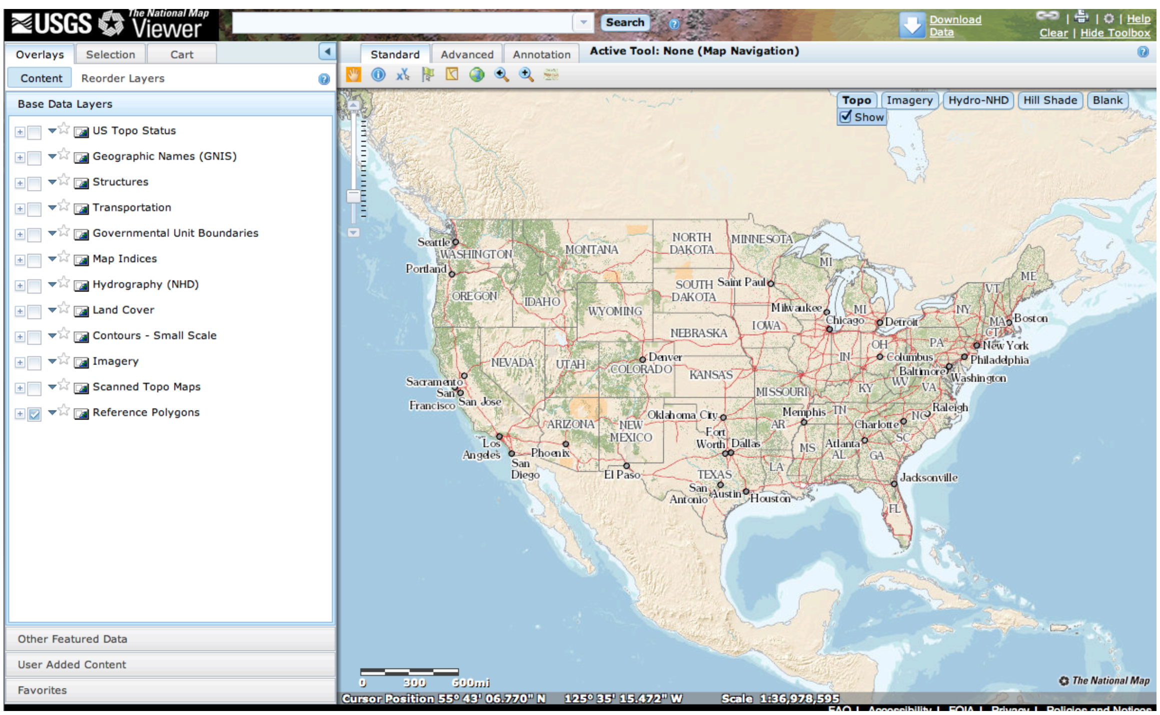
## Data gathering

Data for this project was acquired primarily from the USGS's National Map Viewer. Elevation data was downloaded in the form of nine individual

1/3 arcsecond digital elevation maps.

Hydrography data from the National Hydrography Dataset were also found through the National Map Viewer. This data contained watershed boundaries that allowed for delineation of these watersheds as well as flowline data for all streams within.

Precipitation and stream discharge data were gathered from the National Water Information System (NWIS).



**Data processing**

In order to work with a cohesive DEM, the nine individual tiles, in GeoTIFF format, were stitched together using the Mosaic to New Raster tool in ArcGIS. This allows for a uniform shading scale to be used across the study areas.

Given the high resolution of this DEM, before any further processing of the DEM took place, it was clipped to just the two watersheds being considered to save on processing time. The Extract by Mask tool and the previously delineated watershed boundaries were used in this task. Then, the Fill tool was used to eliminate pits from the DEM, and its symbology was altered to use a color gradient to represent the changes in elevation across the watersheds.

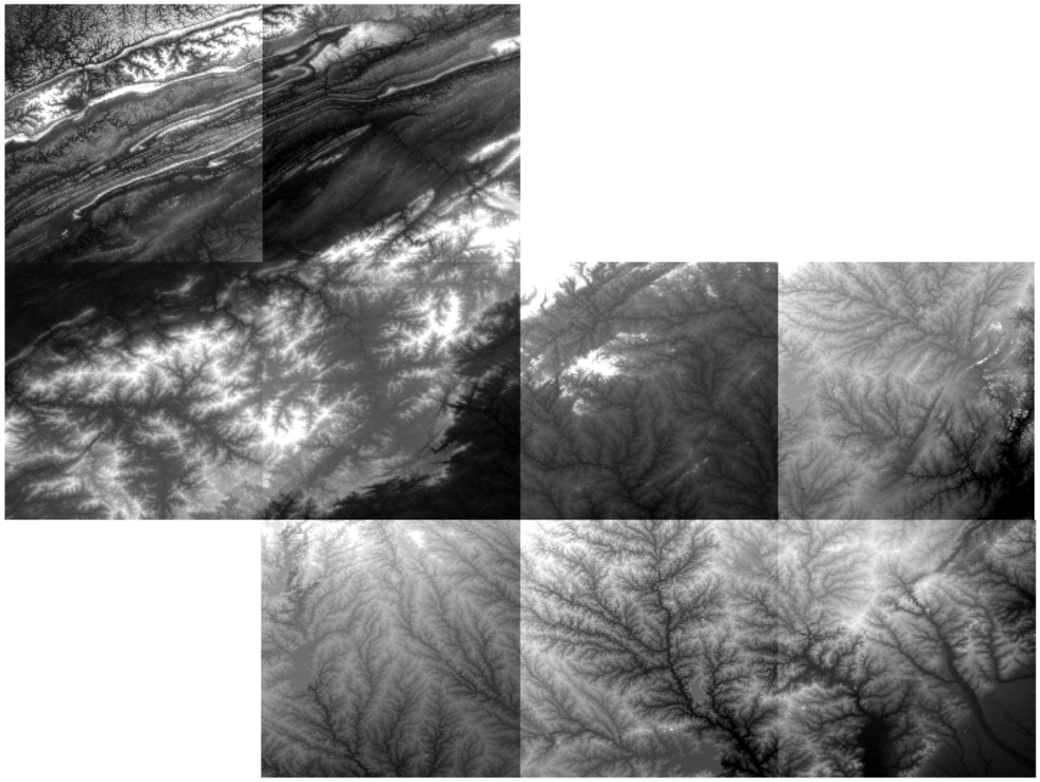
After preparing the DEMs, a hypsometric curve was constructed for each watershed. To accomplish this, a Hypsometric Tools toolbox was downloaded from ESRI (http://arcscripts.esri.com/details.asp?dbid=16830), and graphs were generated from the new rasters that were created.

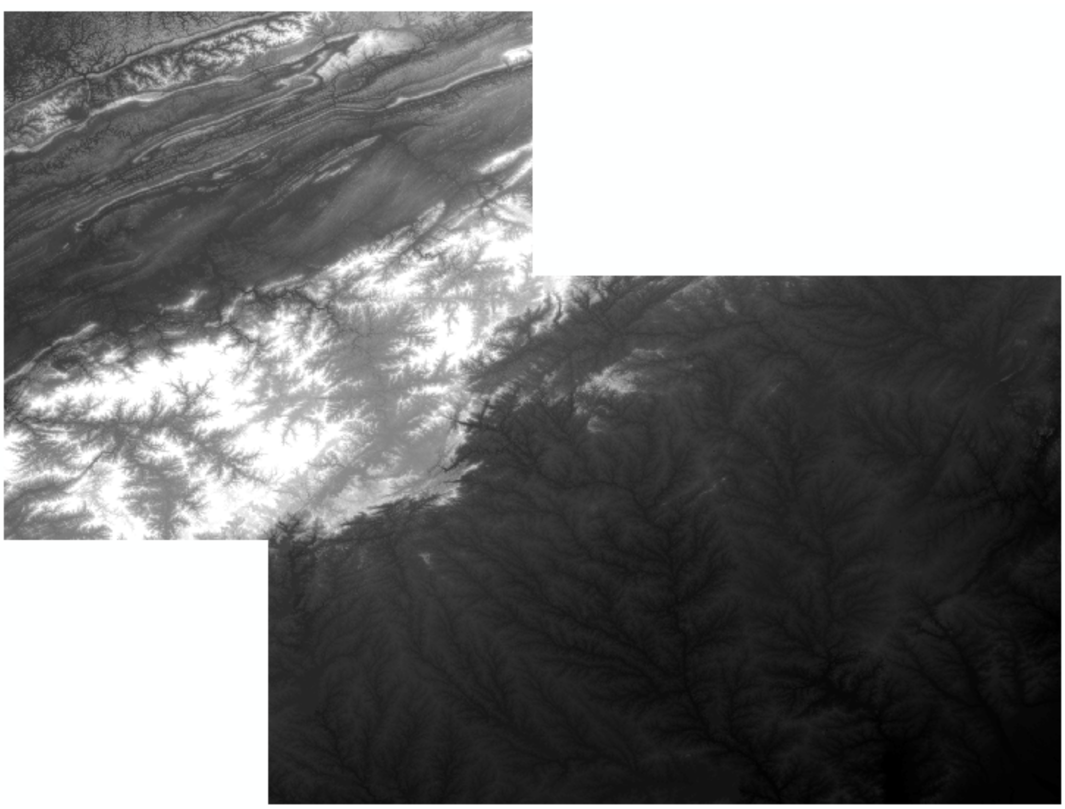
Using the hydrography data from the NHD, flowlines for the watershed were added to the map, with emphasis placed on the French Broad and Broad rivers. A number of rain gages were located in NWIS, and data from 2010 was used as representative for this project. The precipitation data was used to calculate an average precipitation for each watershed. A simple mean was used since technical difficulties forced me to abandon my original plan to use an interpolation scheme to find the average precipitation. Also, given the lack of any official rain gages within the Upper Broad River watershed, three rain gages adjacent to the watershed boundaries were selected in an attempt to approximate precipitation within the watershed.

A representative stream gage was also located in each watershed in order to find the flow rate out of the watershed. The gage for the French Broad watershed is located very close to the outflow point to the next watershed and should provide a good approximation. However, the gage selected for the Upper Broad River watershed is at a less than optimal location given the dearth of gages within this watershed. The locations of these stream gages are marked with red dots on the following maps.

The precipitation and streamflow data will be used to calculate the runoff ratio – the fraction of runoff that becomes streamflow – for each watershed.

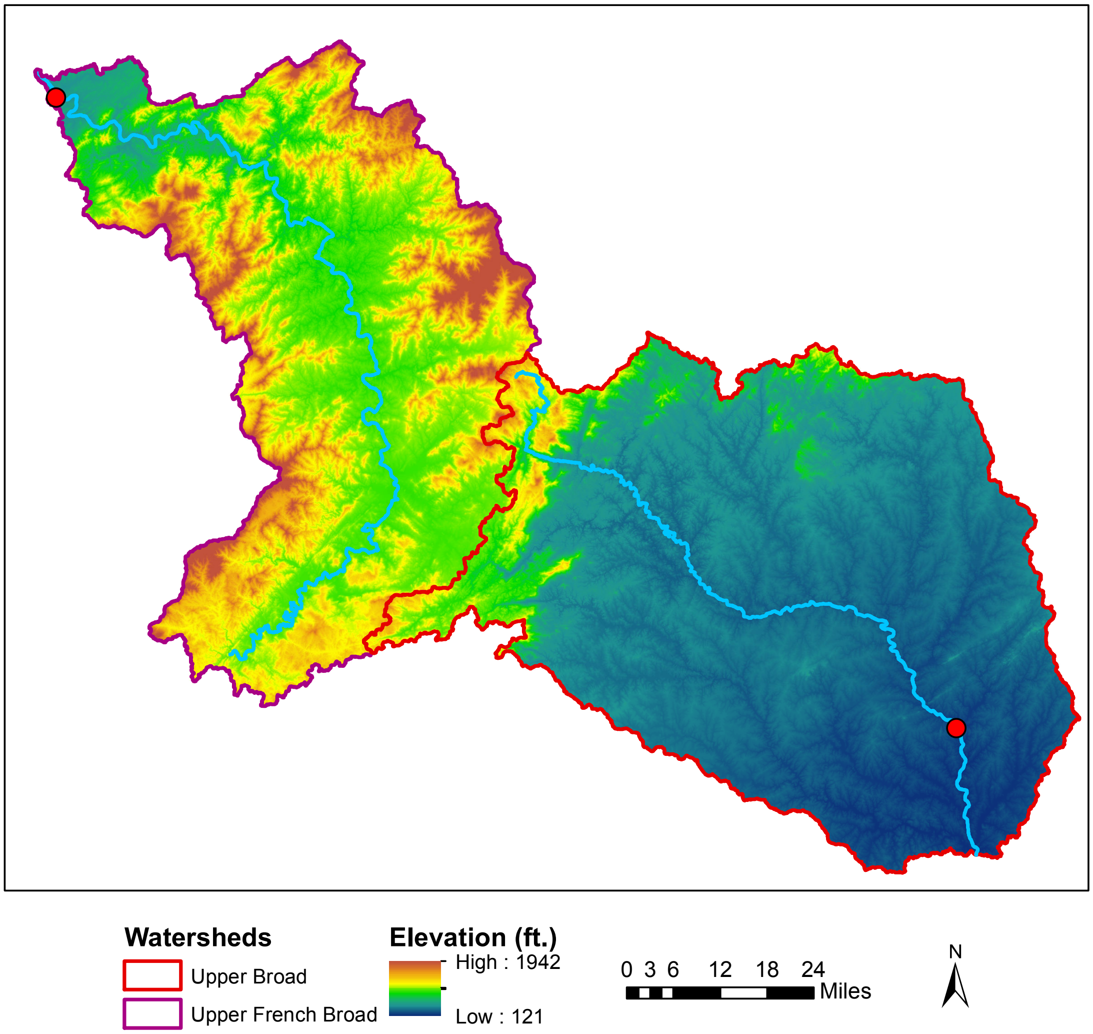
| **Rain gages used in precipitation analysis** | | | | |
|---|---|---|---|---|
| Longitude | Latitude | Station ID | Description | 2010 precip |
| -82.820556 | 35.137222 | 350824082494545 | Raingage at Rosman, NC | 71.99 |
| -82.696667 | 35.249444 | 351458082414845 | Raingage at Brevard, NC | 57.27 |
| -82.397778 | 35.641944 | 353831082235245 | Raingage at Beetree Dam, NC | 34.33 |
| -82.660000 | 35.723333 | 354324082393645 | Raingage at Leicester, NC | 32.56 |
| -82.465556 | 35.352222 | 352059082275545 | Raingage at Hendersonville, NC | 43.77 |
| -81.035000 | 35.033333 | 350200081020345 | Raingage at Tega Cay Town Hall, SC | 31.23 |
| -81.725556 | 35.717222 | 354302081433245 | Raingage at Glen Alpine RS Well, NC | 41.52 |



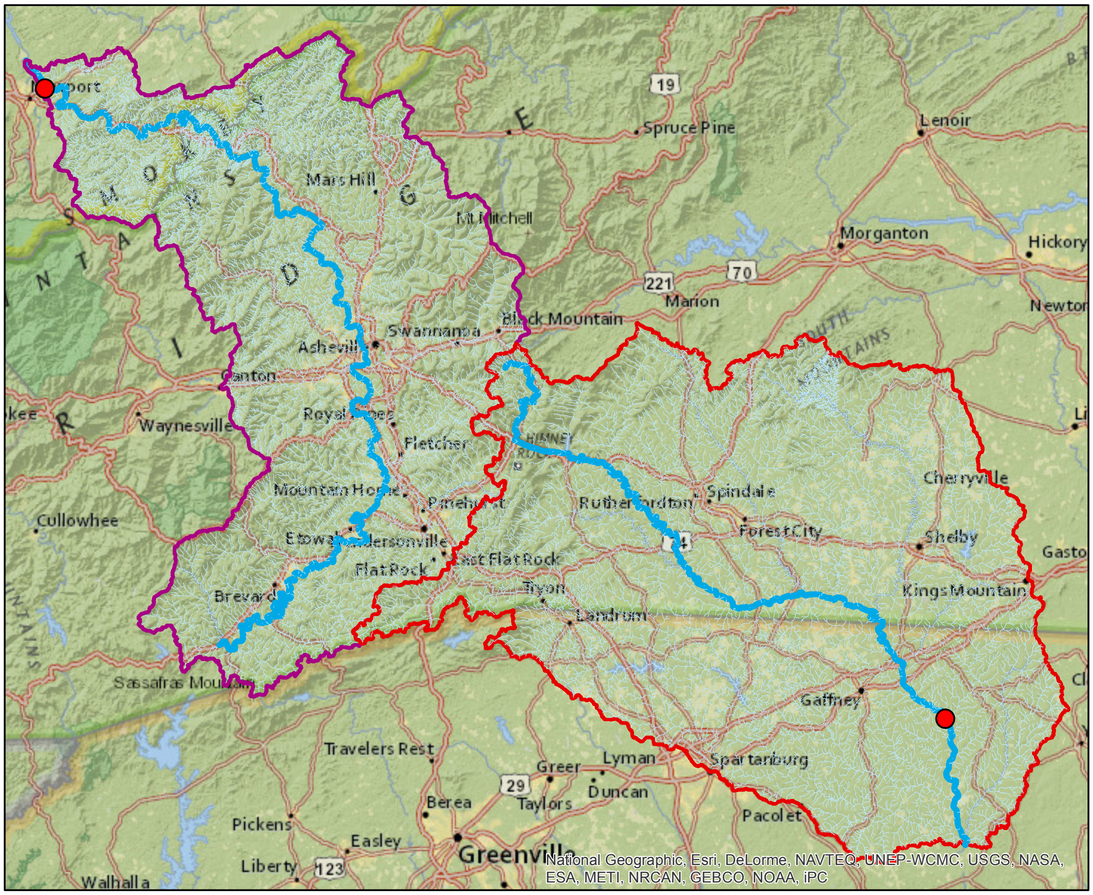


The nine individual 1/9 arcsecond DEMs acquired from the USGS (above) were stitched into one cohesive DEM (below) using the Mosaic to New Raster tool in ArcGIS.

# Watershed elevations



# Watershed streamlines




**Watersheds**

Upper Broad

Upper French Broad

0 3 6 12 18 24 Miles

N

**Data analysis**

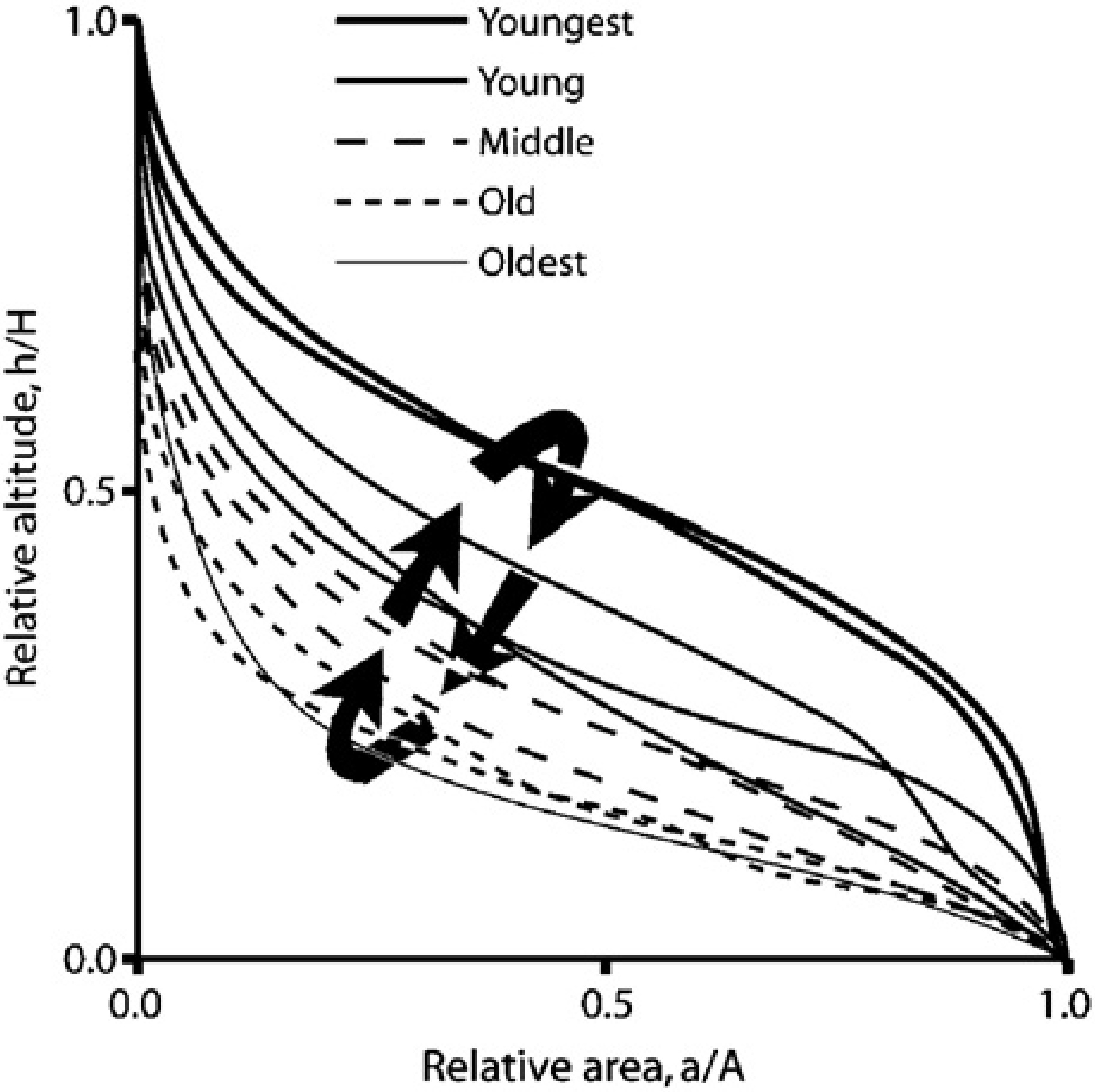
The shape of a hypsometric curve can be indicative of a number of factors, including changes in geomorphology and the relative age of such features (Perez-Pena et al., 2009). While both watersheds exhibit concave hypsometric curves, the curve for the Upper Broad River is extremely concave, since most of the land within the watershed is at the low end of the elevation scale. This is reflective of the much more even terrain of the watershed, which has likely experienced more weathering than the Upper French Broad River watershed.

The calculated runoff ratio for each watershed also reflects the differing topography between the two areas. Using the equation

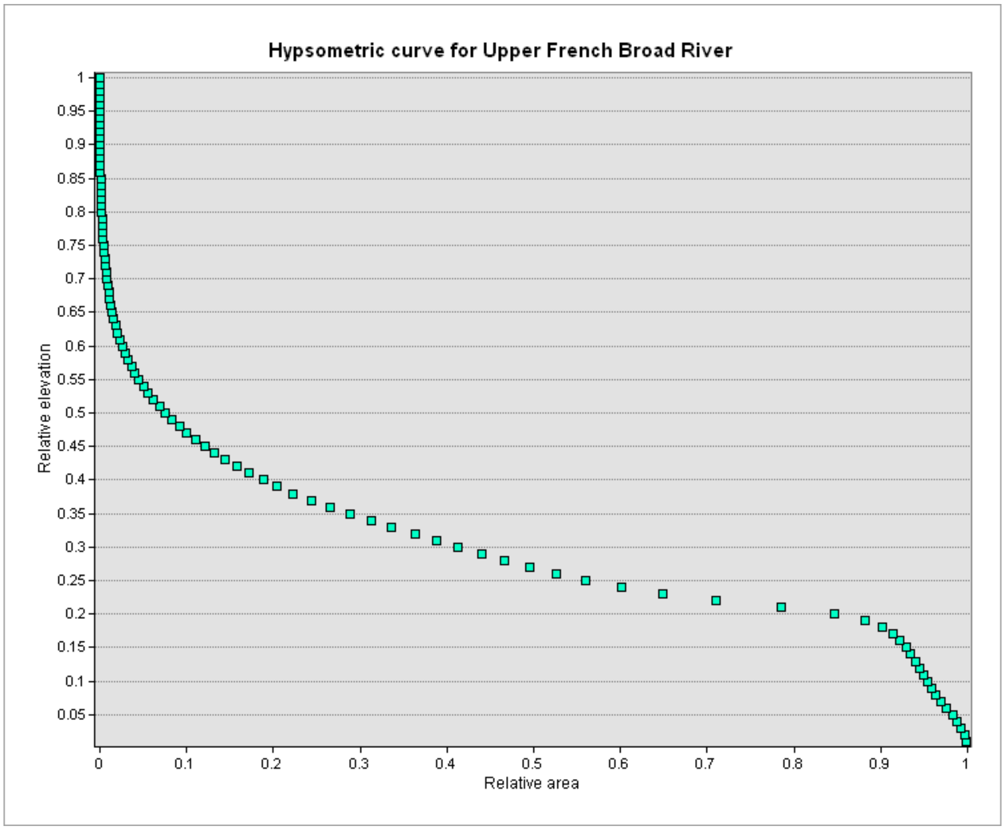
$$w = Q / P$$

where Q is long term streamflow and P is long term precipitation (each found using the aforementioned methods), the runoff ratio for the Upper French Broad River watershed was found to be .449, which the runoff ration for the Upper Broad River watershed was found to be .293. While estimations were made in calculating these ratios, this is the expected result. The Upper French Broad has both greater topography overall and steeper topography, both of which typically generate more runoff. This is because on steeper slopes, it is more difficult for water to infiltrate the ground, and more precipitation finds its way to stream channels.

Given these factors, the Upper French Broad River watershed is likely more prone to flooding than the Upper Broad River watershed.




An explanation of what the different shapes of hypsometric curves reflect. Generally, if a curve has a convex shape, it indicates younger geomorphology, while S-shapes and concave curves indicate greater maturity. (Perez-Pena et al., 2009)


Hypsometric curve for Upper French Broad River
Relative elevation
Relative area
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Hypsometric curve for Upper Broad River
Relative elevation
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0.4
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0.3
0.25
0.2
0.15
0.1
0.05
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

## References

Perez-Pena, J.V.; J.M. Azanon; A. Azor, "CalHypso: An ArcGIS extension to calculate hypsometric curves and their statistical moments. Applications to drainage basin analysis in SE Spain," 2009, Computers & Geosciences, Vol. 35, P. 1214-1223.