Lab 2: Catchment water balance
Course: ESM 235 – Watershed Analysis

Background. The water balance is a crucial concept in water management. Hydrologists tasked with calculating the fate of rainfall often explore water resources through the lens of a *catchment*, defined by the natural drainage area that contributes water to a single point located at a lower elevation. The boundaries of the catchment are known as *divides*, often locates along ridgelines at higher elevations. A key component of any water budget is an estimate of precipitation inputs to the system. Precipitation inputs can be challenging to quantify because measurements are made at points, whereas precipitation rates are sought over the watershed. Precipitation monitoring stations are rarely spaced evenly, and catchments usually have irregular shapes. There are a number of approaches that hydrologists take to extrapolate precipitation measurements to a catchment. Two are:

Theissen Polygons. Theissen polygons are used to subdivide an area based on the proximity of any given point within the area to a precipitation gauge. To construct a set of Theissen polygons: (step a) draw lines connecting the gauges, (step b) draw lines that bisect each of the lines connecting the gauges (drawn in step a). The bisecting lines are to be drawn half way between the gauges. The solid lines will meet to form polygons – known as Theissen polygons. Once Theissen polygons are drawn, the area of each polygon that lies within the catchment can be calculated by counting grid cells (or using the 'Calculate Area' tool in ArcGIS' attribute table). Assuming precipitation rates in each of the Theissen polygons equal that of the precipitation gauge located within the polygon (**this is an oversimplification*), one estimates catchment-averaged precipitation following:

$$[\text{catchment-averaged precipitation}] = [A_1P_1 + A_2P_2 + A_3P_3 \ldots\ldots A_nP_n] / [A_1 + A_2 + A_3 \ldots\ldots A_n] \quad \textit{Eqn. 1.}$$

where P_x is the precipitation rate at gauge x, and A_x is the area of the Theissen polygon within boundaries of the catchment corresponding to gauge x.

Isohyetal Approach. The isohyetal (i.e., "equal" "rainfall") approach subdivides the catchment by contouring precipitation rates. The diagram shows isohyets for a hypothetical drainage basin. The isohyets are constructed by contouring precipitation rates between or overlapping the gauging station data. The catchment-average precipitation rate is determined by weighting the contoured precipitation rates by their areal coverage in the basin.

$$[\text{Average P rate}] = [A_1P_1 + A_2P_2 + A_3P_3 \ldots\ldots A_nP_n] / [A_1 + A_2 + A_3 \ldots\ldots A_n] \quad \text{Eqn. 2.}$$

where P_x is the precipitation rate within the area delineated by contour x, and A_x is the area of the isohyetal polygon x that lies that lies within boundaries of the catchment.

Part 1 – Annual Precipitation [10 marks, total]

Because of the ongoing, longest-ever U.S. government shutdown, most national precipitation data sources remain unavailable (e.g., https://www.ncdc.noaa.gov/cdo-web/datatools/records leads to: https://governmentshutdown.noaa.gov/). So, our 2019 ESM 235 team will explore local precipitation data curated by the County of Santa Barbara's Public Works Department (https://www.countyofsb.org/pwd/dailyrainfall.sbc) for Lab 2.

I've uploaded n=80 precipitation stations for the county (downloaded Jan-2019 from: https://www.countyofsb.org/pwd/dailyrainfall.sbc). Each tab in the Excel sheet labelled 1-80 contains daily precipitation data for the station (note that only "wet days" are in the database; that is, days where the station records zero precipitation are not in the dataset). This lab has been designed to provide an opportunity to enhance GIS and 'large data' analysis skillsets.

Product 1 [4 marks, total]: Analyze the precipitation dataset and create a map of long-term mean annual precipitation. Ensure a legend is included on your map, and that you specify the units of measurement [3 marks for correct results; 1 mark for map presentation quality].

Product 2 [1 mark, total]: Create a plot long-term mean annual precipitation rates (one point for each station) against elevation. Plot only the n=13 points with "Y" listed under the heading "SB/Goleta Region". Ensure your plot axes are appropriately labelled, and that units of measurement are presented [1 mark].

Product 3 [5 marks, total]: Write a short ~300 word paragraph. In this, detail (i) the range of mean annual precipitation rates measured among the n=80 stations [1 mark], (ii) the median annual precipitation rate among the n=80 stations [1 mark], (iii) spatial variations in mean annual precipitation among the study sites [1 mark], (iv) any correlation between station elevation and annual precipitation among points with "Y" listed under the heading "SB/Goleta Region" [1 mark], and (v) what processes may lead to any observed correlation discovered between station elevation and annual precipitation [1 mark].

Part 2 – Catchment Inputs [8 marks]

We will now explore some simple ways one may estimate precipitation inputs to a catchment using point (i.e., meteorology station) data. Download the provided shapefile for the Santa Ynez watershed.

Product 4 [1 mark, total] Calculate the total area of the delineated catchment [1 mark]. Report the units of your estimate.

Product 5 [4 marks, total] Create a map of the Santa Ynez watershed overlaid by Theissen polygons constructed from the n=80 precipitation stations [1 mark]. Create a table detailing the fraction of the Santa Ynez watershed that intersects each precipitation monitoring station's Theissen polygon [2 marks]. At the base of the table, calculate your estimate of mean annual precipitation in the Santa Ynez watershed (Eqn. 1) [2 marks].

Product 6 [3 marks, total] Write a short ~300 word paragraph describing (i) how mean annual precipitation varies spatially within the watershed [2 marks], (ii) a limitation of the mean annual precipitation analysis based on Theissen-polygons [1 mark], (iii) the runoff ratio for the watershed (mean annual flow at outlet is 1.7 m^3/s (USGS site ID: 11134000) [1 mark].

Part 3 – Jalama Watershed [7 marks]

I've uploaded a shapefile for Jalama watershed. Use spatial data and develop an estimate of annual precipitation inputs for the watershed. You may use the Theissen polygon approach, or develop another approach. Justify your answer with written text describing your methodology and results [3 marks]. Present at least two figures (maps, plots) [4 marks: one mark for presenting each of the two figures, another mark for each figure based on the quality of presentation in the figure].