Stanford University
School of Engineering

CEE 166A/266A

WATERSHEDS AND WETLANDS

- Delineating and Characterizing Catchments

Characterizing the Watershed

- Recall our definition:

  All land area from which water flowing by gravity on the land surface would pass through a given cross-section of a stream channel

- Delineating the watershed

  The divide

The Divide Concept

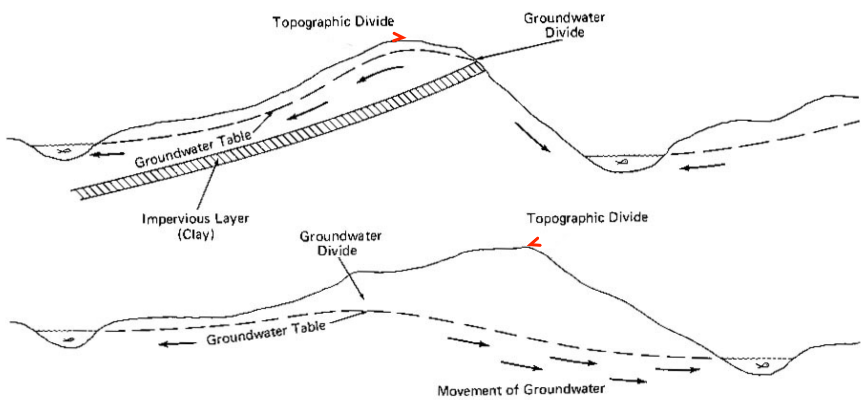
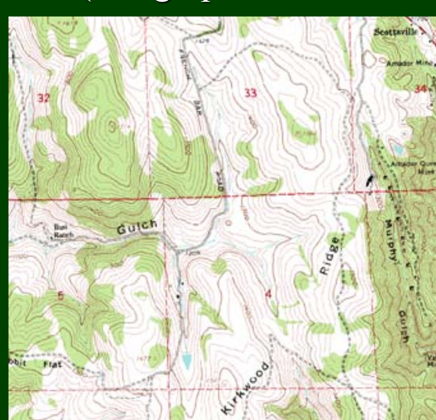
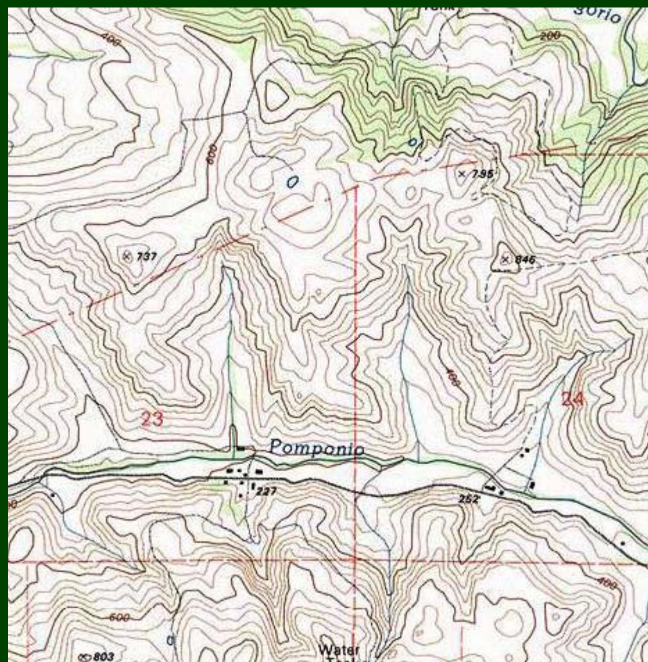


FIGURE 9.2
Idealized diagrams showing that the topographic divide may not necessarily coincide with the groundwater divide. Hence, a portion of the infiltrated waters is diverted from one surface watershed to an entirely different stream basin.

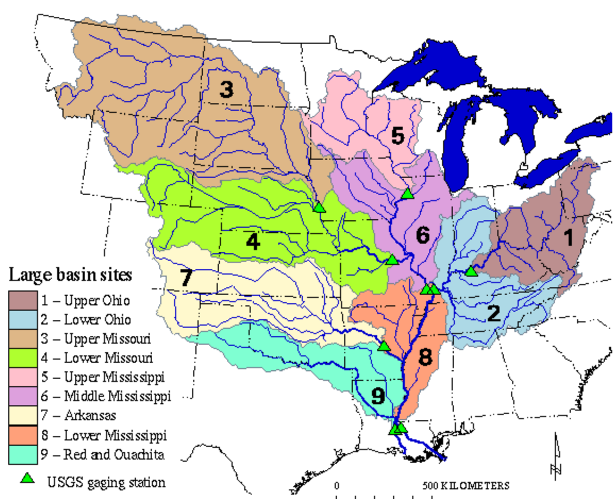
Topographic Mapping

- Manual delineation using topographic maps
- Automated delineation using DEMs (Digital Elevation Models and GIS (Geographic Information Systems)



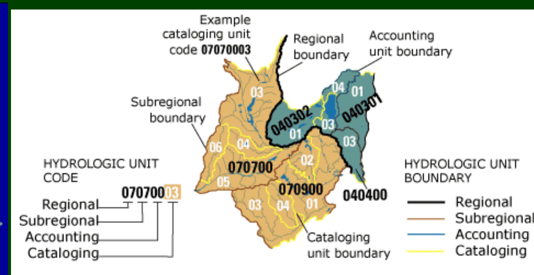


Watersheds and Subwatersheds



Watersheds and Subwatersheds

- In the US: Watershed Boundary Dataset

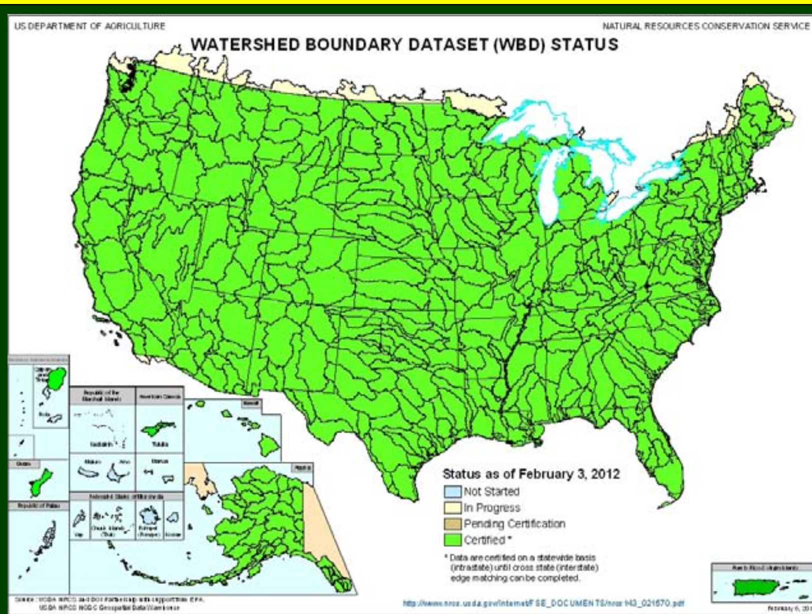


Watershed Definitions (Watershed Boundary Dataset)

Name	Level	Digit	Number of HUCs*
Region	1	2	21
Subregion	2	4	222
Basin	3	6	352
Subbasin	4	8	2,149
Watershed	5	10	22,000
Subwatershed	6	12	160,000

*Hydrologic Unit Codes

Watersheds and Subwatersheds



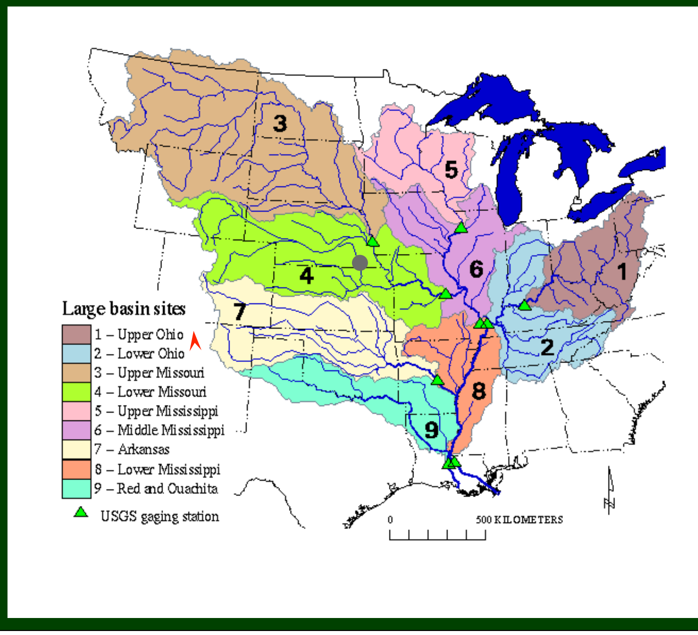
Characterizing the Watershed

- Physiographic characterization
  - Area
    - Drainage area
    - Specific catchment area
  - Elevation
    - Relief: maximum elevation - minimum elevation
    - Hypsometric curve: elevation vs. area below/above that elevation
  - Length
  - Slope
    - Relief ratio: relief/length of basin [approximately parallel to main channel])
    - Main-channel slope

Quantifying Drainage Area

- The polar planimeter
  - http://persweb.wabash.edu/facstaff/footer/Planimeter/ PLANIMETER.HTM
  - http://www.leinweb.com/snackbar/planimtr/wheatley/s0-4.htm
- Tips
  - Read the manual/websites
  - Practice
  - Calibrate
  - Close the loop
  - Subdivide if necessary
  - Use replicates

Quantifying Drainage Area



Specific Catchment Area

- Upstream area per unit elevation contour width

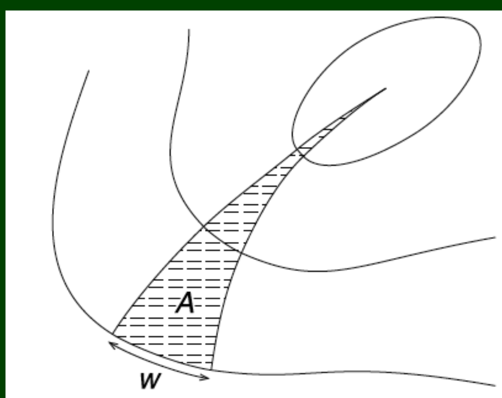


Figure 1. An idealized stream tube originating at a hilltop and terminating at a contour on a hillslope. The average specific catchment area *a* along the contour segment is the ratio of contributing area *A* to flow width *w*.

Gallant, J.C. and M.J. Hutchinson, *Water Resour. Res., 47*, W05535, doi: 10.1029/2009WR008540

Characterizing the Watershed

- Physiographic characterization

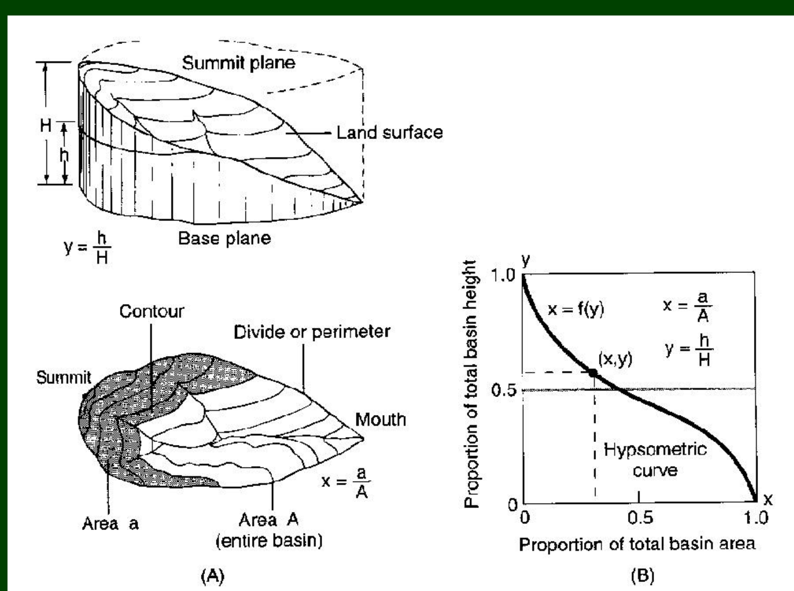
  Area
  - Drainage area
  - Specific catchment area

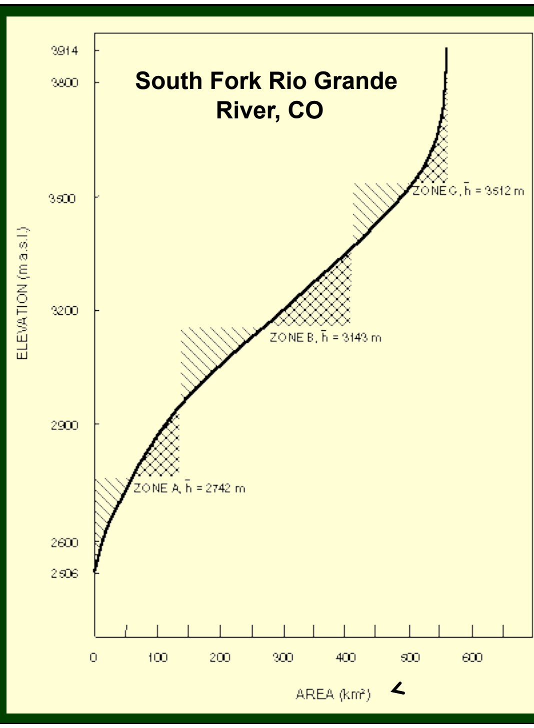
  Elevation
  - Relief/height: maximum elevation - minimum elevation
  - Hypsometric curve: elevation vs. area below/above that elevation

  Length

  Slope
  - Relief ratio: relief/length of basin [approximately parallel to main channel])
  - Main-channel slope

Hypsometric Curve





Hypsometric Curve

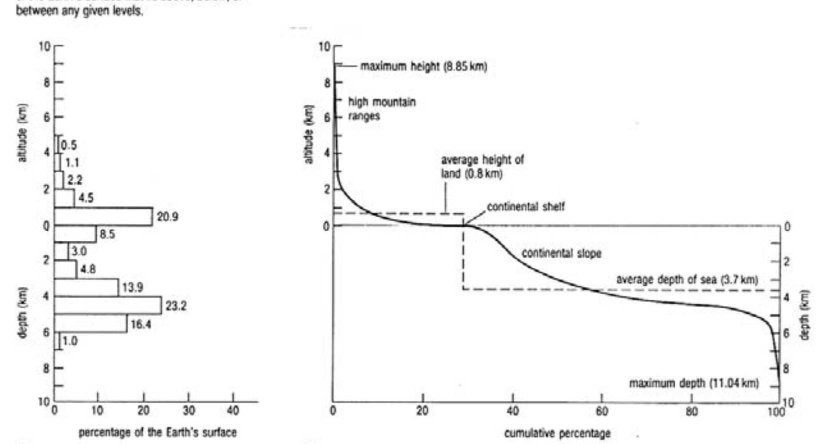
Area below elevation

Hypsometric Curve

Figure 2.4 The distribution of levels on the Earth's surface.

(a) A histogram showing the actual frequency distribution.

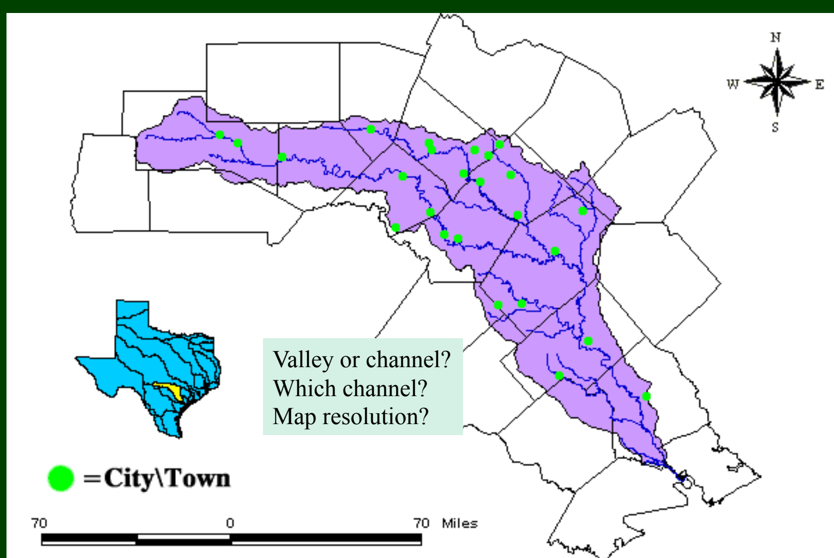
(b) The hypsographic curve: a cumulative frequency curve based on (a). This is *NOT* a profile of the Earth's surface; it is a curve showing the percentages of the Earth's surface that lie above, below, or between any given levels.



Characterizing the Watershed

- Physiographic characterization
  - Drainage area
  - Elevation
    - Relief: maximum elevation - minimum elevation
    - Hypsometric curve: elevation vs. area below/above that elevation
  - Length
  - Slope
    - Relief ratio: relief/length of basin [approximately parallel to main channel])
    - Main-channel slope

Quantifying Length



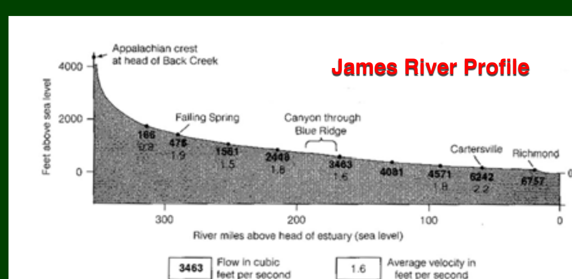
Guadalupe River Basin, TX

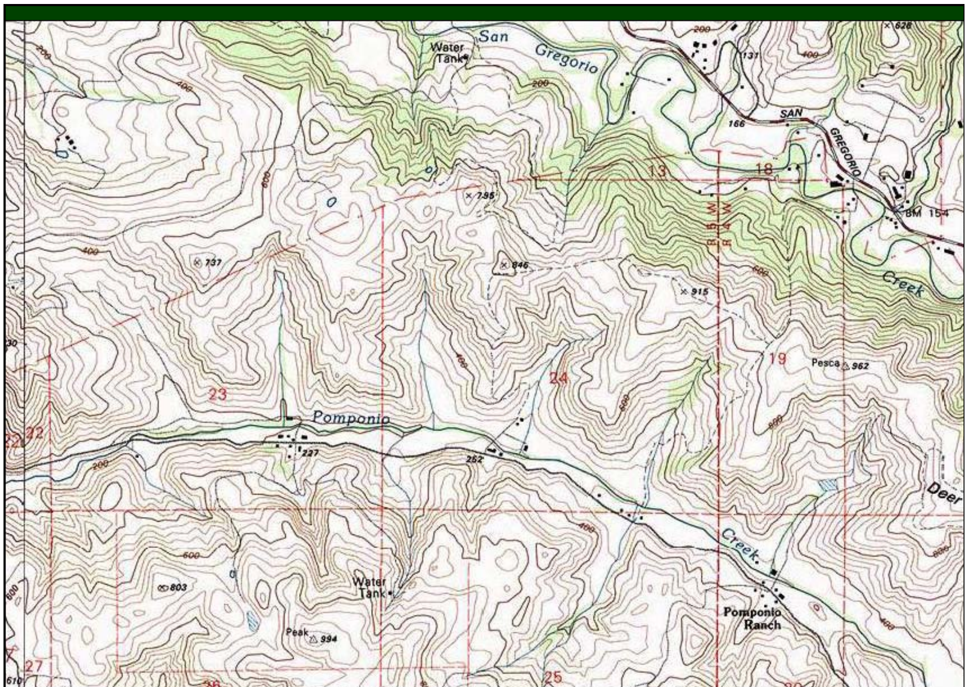
Characterizing the Watershed

- Physiographic characterization
  - Drainage area
  - Elevation
    - Relief: maximum elevation - minimum elevation
    - Hypsometric curve: elevation vs. area below/above that elevation
  - Length
  - Slope
    - Relief ratio: relief/length of basin [approximately parallel to main channel])
    - Main-channel slope

Main-channel Slope

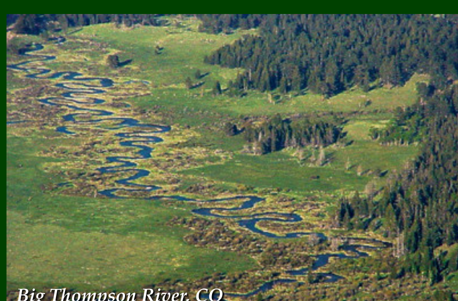
- Main-channel slope is used as a surrogate for catchment average slope
  - Extend channel to divide following “natural” topographic low
  - Measure length of channel + extension
  - Find elevation at points 10% and 85% of the way along the channel + extension
  - Calculate main channel slope as: $S = \dfrac{Elevation_{85\%} - Elevation_{10\%}}{0.75 * Length}$



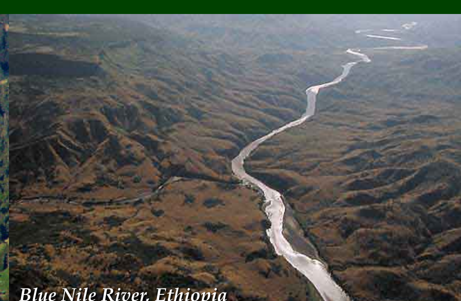


Map created with TOPO!® ©2003 National Geographic (www.nationalgeographic.com/topo)

Stream Channels



Big Thompson River, CO



Blue Nile River, Ethiopia

Colorado River, AZ

Martis Creek, CA

Stream Channels

Stream Channels

Stream Channels

- Patterns (planform)
  - Spatial scale
    - Drainage network (A)
    - Channel reach (B)
    - Individual feature (e.g., meander) (C)
    - Bedforms, sedimentary structures (D, E)
    - Grains (F)
  - Categories
    - Bedrock
    - Semi-controlled
    - Alluvial

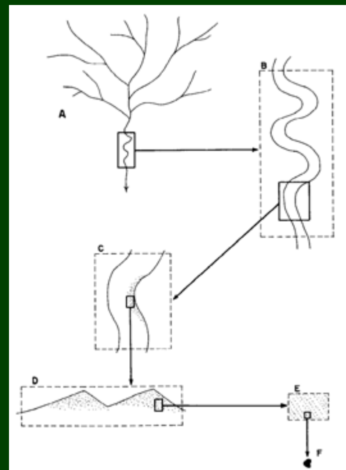
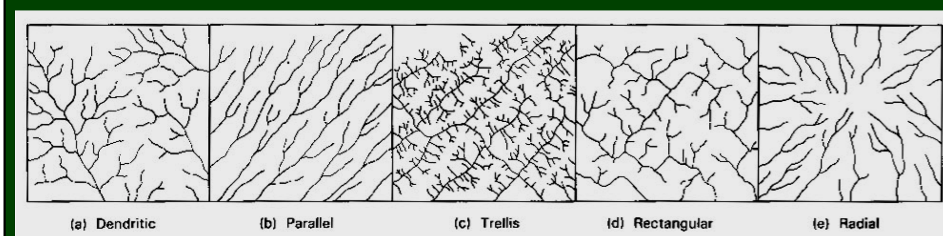
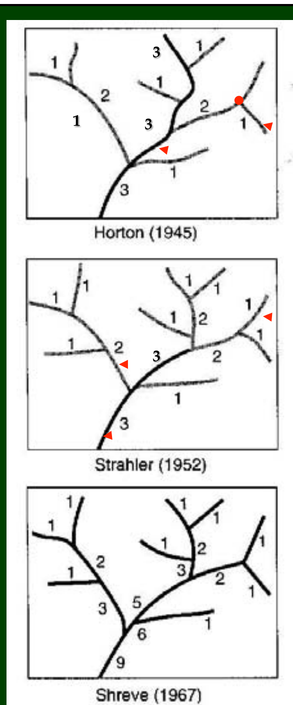


Figure 1 The fluvial system and its components.

Stream Channel Networks



Drainage Patterns



Horton (1945)

Strahler (1952)

Shreve (1967)

The Stream Network

Node
Exterior link
Interior link

Stream Ordering

- First-order stream (9)
- Second-order stream (3)
- Third-order stream (1)

Magnitude = ∑ Exterior links

The Stream Network

- Drainage density

$$D_d = \frac{\sum L}{A}$$

- Horton's laws of drainage network composition

Law	Ratio	Usual Range
Stream numbers	$R_B = N_\omega / N_{\omega+1}$	$3 < R_B < 5$
Stream lengths	$R_L = L_{\omega+1} / L_\omega$	$1.5 < R_L < 3.5$
Drainage areas	$R_A = A_{\omega+1} / A_\omega$	$3 < R_A < 6$

R_B = Bifurcation ratio
R_L = Length ratio
R_A = Area ratio

N_ω = Number of streams of order ω
L_ω = Average length of streams of order ω
A_ω = Average drainage area of streams of order ω

To-do List

- *Precision, Errors, and Significant Figures*
- Review topographic maps, if necessary
  - One recommendation:
    - http://geology.isu.edu/geostac/Field_Exercise/topomaps/index.htm
- Mays
  - § 8.1