Some Terminology

• **Hydrology** (ηδρολογια)
  – Hudor - “water”; Logy - “study of”
  – *Study of Water* and its properties, distribution, and effects on the Earth’s surface, soil, and atmosphere

• **Water Management**
  – Sustainable use of water resources
  – Manipulating the hydrologic cycle
    • Hydraulic structures, water supply, water treatment, wastewater treatment & disposal, irrigation, hydropower generation, flood control, etc.
Some History

- **Water Management**
  - Civilization developed on rivers:
    - Hydraulic engineers build canals, levees, dams, water conduits, and wells
    - Egyptians (Nile)
    - Romans (Tiber)
    - Mesopotamia (Tigris and Euphrates)
    - China (Huang Ho and Yangtze)
    - Pakistan (Indus)
    - India (Ganges)
Some Misperceptions

- **Thales (Greek, 640-546 bc)**
  - wind blew water into rocks along the coast, forcing water up through the rock under high pressure, where it eventually emerged in springs

- **Plato (Greek, 427-347 bc)**
  - water was contained in a single underground cavern, the 'Tartarus', and was pushed up into springs by underground forces to return to the oceans

- **Aristotle (Greek, 384-322 bc)**
  - water vapor from the soil condensed in cool mountain caverns and formed underground lakes that fed springs.

- **Seneca (Roman, 4 bc - 65 ad)**
  - precipitation that fell to the earth and infiltrated was not sufficient to supply water that was observed as streamflow.

- **Kepler (German, 1571-1630)**
  - earth digested salt water and excreted fresh water as waste.
Figuring It Out

• da Vinci and Palissy (16th cent.)
  – linked underground water to rainwater infiltrating into the soil and then to stream flow

• Perrault (French, 17th cent)
  – measured rainfall in the Seine River watershed and showed precipitation to be six times more than the river flow proving that the source of water in rivers is precipitation falling on soil

• Halley (English, 1656-1742)
  – evaporation experiments, investigated the water balance of the Mediterranean

• 19th Century
  – Dalton - Evaporation
  – Darcy - Groundwater flow
  – Manning - Open channel flow
Units

• If $\frac{1}{2}$ in. of rain falls on 1 sq. mi., what is the equivalent volume of water?

$$0.5 \text{ in.} \times \frac{1 \text{ ft}}{12 \text{ in}} \times (1 \text{ mi} \times 5280 \text{ ft/mi})^2 =$$

$$0.0416 \text{ ft} \times 27,878,400 \text{ ft}^2 =$$

$$1,161,600 \text{ ft}^3 \approx$$

$$8.67 \text{ million gal} \div 26.4 \text{ gal/day} =$$

$$328,000 \text{ people for a day} =$$

$$899 \text{ people for a year} =$$

That’s a lot of water!

• If 10 mm of rain falls on 259 hectares (ha = 10,000 m$^2$), what is the equivalent volume of water?

$$100 \text{ L/day} = 26.4 \text{ gal/day}$$
More Units

- $1 \text{ ft} = 0.3048 \text{ m}$
- $1 \text{ m}^3 = 28.3168 \times 10^{-3} \text{ ft}^3$
- $1 \text{ m}^3 = 35.3147 \text{ ft}^3$
- $1 \text{ ha} = 10,000 \text{ m}^2$
- $1 \text{ acre} = 43,560 \text{ ft}^2$
- $1 \text{ gal} = 3.785 \times 10^{-3} \text{ m}^3$
- $1 \text{ m}^3 = 8.11 \times 10^{-4} \text{ af}$
- $10^9 \text{ m}^3 = 8.11 \times 10^5 \text{ af}$
- $1 \text{ km}^3 = 0.811 \text{ maf}$
- $1 \text{ m}^3 = 264 \text{ gal}$
- $10^9 \text{ m}^3 = 264 \times 10^9 \text{ gal}$
- $1 \text{ km}^3 = 264 \text{ bg}$
- $1 \text{ km}^3/\text{yr} = 0.7234 \text{ bgd}$
Global Water Resources

A World of Salt
Total Global Saltwater and Freshwater Estimates

- 0.3% Lakes and river storage
- 30.8% Groundwater, including soil moisture, swamp water and permafrost
- 68.9% Glaciers and permanent snow cover

Freshwater
2.5%
35,000,000 km³

Saltwater
97.5%
1,365,000,000 km³

Only this portion is renewable

Global Water Cycle

Residence time:
Average travel time for water through a subsystem of the hydrologic cycle

\[ T_r = \frac{S}{Q} \]
Storage/flowrate

Principal sources of fresh water for human activities
(44,800 km³/yr)
Global Water Availability

Countries with the least freshwater resources
- Egypt: 26
- United Arab Emirates: 61

Countries with the most freshwater resources
- Suriname: 479,000
- Iceland: 605,000

Data not available

Population and Water Use

- Global freshwater use is ~4000 km³/year.
- This is ~10% of the renewable supply (44,800 km³/year).
Global Water Withdrawal & Consumption
Global Water Use

Withdrawal and Consumption by Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Assessment</th>
<th>Forecast</th>
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</thead>
<tbody>
<tr>
<td>Agricultural</td>
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<tr>
<td>Domestic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Withdrawal
- Consumption
- Waste
Typical Domestic Water Use

- 10 – 40 L/person/day (water scarce)
- 50 – 100 L/person/day (low-income)
- 100 – 600 L/person/day (high-income)

- Differences in domestic freshwater use:
  - Piped or carried
  - Number/type of appliances and sanitation
Water Stress Index

- Based on human consumption and linked to population growth
- Domestic requirement:
  - 3.65 - 14.6 m³/person/year (water scarce)
  - 36.5 - 219 m³/person/year (high-income)
- Associated agricultural, industrial & energy need:
  - 20 x domestic requirement
  - 73 – 292 m³/person/year
  - 730 – 4380 m³/person/year
- Total need:
  - 77 – 307 m³/person/year (water scarce)
  - 767 – 4599 m³/person/year (high-income)

http://www.veoliawater.com
Water Stress (m\(^3\)/person/year)

- **Water scarcity**: <1000 m\(^3\)/person/year
  - chronic and widespread freshwater problems
- **Water stress**: <1700 m\(^3\)/person/year
  - intermittent, localised shortages of freshwater
- **Relative sufficiency**: >1700 m\(^3\)/person/year

www.transboundarywaters.orst.edu
Watershed

- **Watershed**: Area of land draining to a stream at a given location
- **Watershed Divide**: Line dividing land draining to a stream from land draining away from the stream
- **Synonyms**: Watershed, Catchment, Basin, Drainage area
Atmospheric Moisture

Snow

Interception

Throughfall and Stem Flow

Snowpack

Snowmelt

Pervious Surface Impervious

Infiltration

Soil Moisture

Percolation

Groundwater

Groundwater Flow

Streams and Lakes

Channel Flow

Runoff

Rain

Evaporation

Evapotranspiration

Overland Flow

Evaporation

Watershed Boundary

Energy
Digital Elevation Model

Rio Conchos Basin
In Mexico
<table>
<thead>
<tr>
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<th>688</th>
<th>682</th>
<th>688</th>
<th>695</th>
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Cell Definition

Elevation of a cell

Part of a Digital Elevation Model

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<td>12</td>
<td>11</td>
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</table>

50 (cell value)

cell size

cell
Eight Direction Pour Point Model

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<th>128</th>
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</thead>
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Direction of flow
### Flow Direction Grid

**Direction of flow**

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<th>2</th>
<th>4</th>
<th>4</th>
<th>8</th>
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<tbody>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>

Part of a Digital Elevation Model
Flow Accumulation Grid

3 cells flow to this cell
0 cells flow to this cell

Water will flow from low values to high values.
Set a threshold, e.g., Streamflow if Accumulation > 5
Stream Network for Different Thresholds

100 grid cell threshold

1000 grid cell threshold
Waller Creek
Waller Creek
Waller Creek

Thanks to: Esteban Azagra