CE 374 K – Hydrology

Global Water Cycle

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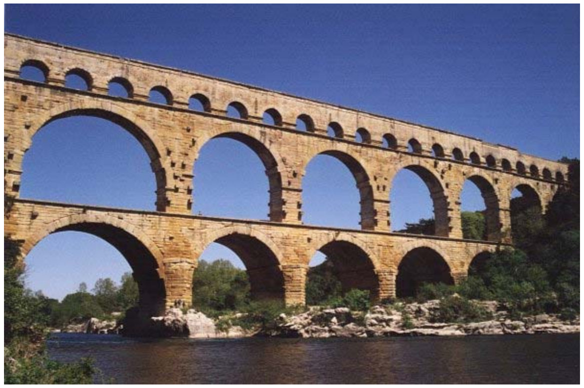
Some Terminology

- **Hydrology** (ηδρολογια**)**
  - Hudor - “water”; Logy - “study of”
  - <u>Study of Water</u> and its properties, distribution, and effects on the Earth’s surface, soil, and atmosphere
- **Water Management**
  - Sustainable use of water resrouces
  - 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)

Minoan culture of Thera

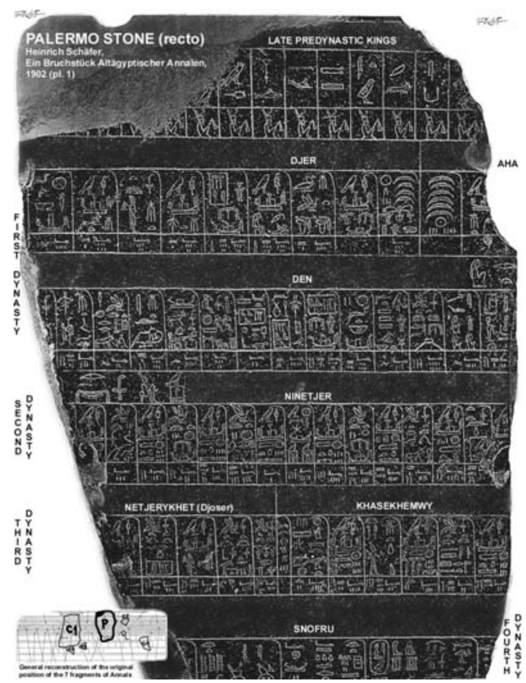


Roman aqueduct in France

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.

height of the flooding of the Nile in various years



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 ½ in. of rain falls on 1 sq. mi., what is the equivalent volume of water?

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

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

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

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

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

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

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 ft = 0.3048 m
- 1 m^3 = 28.3168x10^{-3} ft^3
- 1 m^3 = 35.3147 ft^3
- 1 ha = 10,000 m^2
- 1 acre = 43,560 ft^2
  = 0.4047 ha
  = 4047 m^2
- 1 gal = 3.785x10^{-3} m^3
  = 3.785 L

- 1 m^3 = 8.11x10^{-4} af
  10^9 m^3 = 8.11x10^5 af
  1 km^3 = 0.811 maf

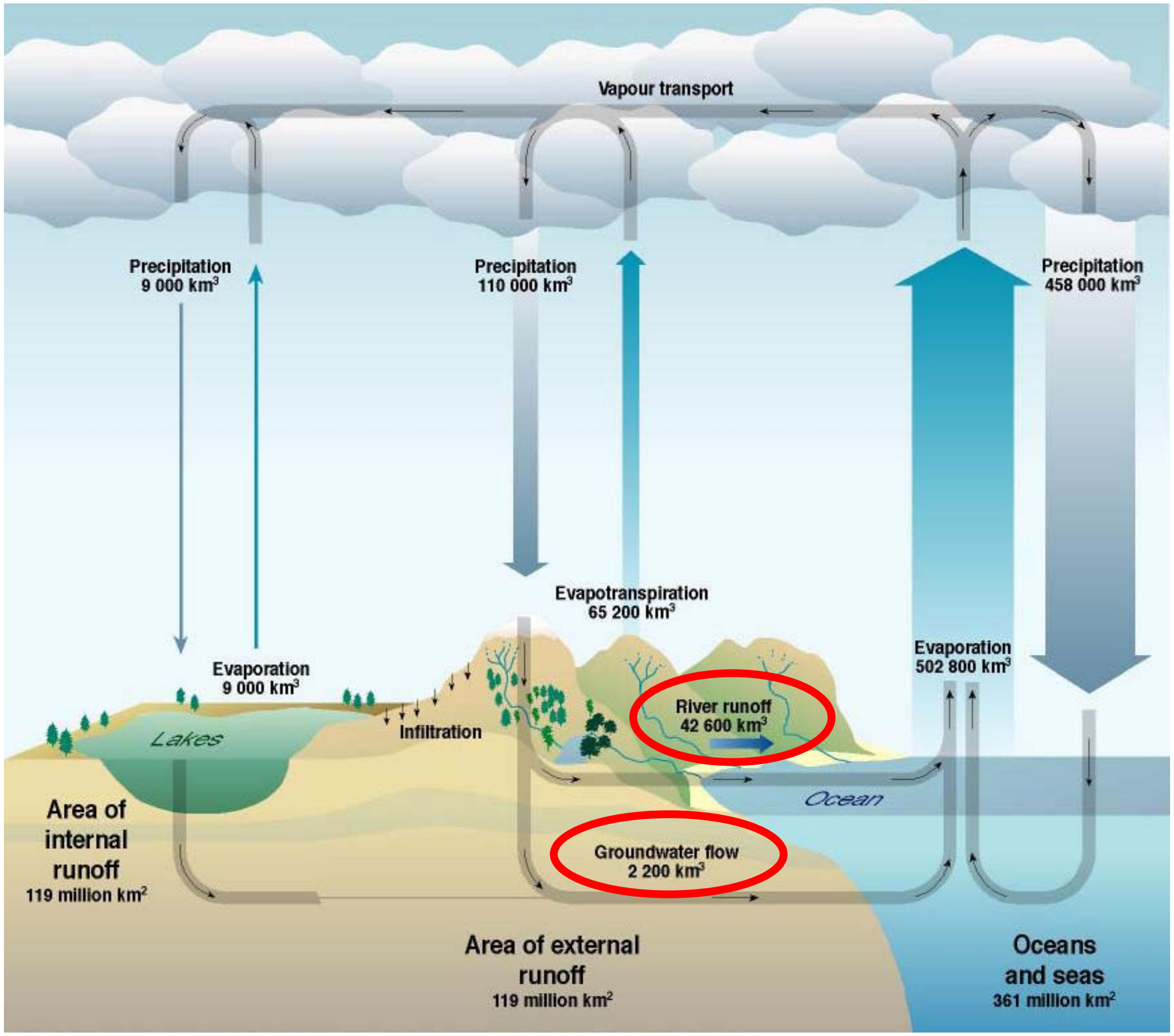
- 1 m^3 = 264 gal
  10^9 m^3 = 264x10^9 gal
  1 km^3 = 264 bg
  1 km^3/yr = 0.7234 bgd

Global Water Resources

Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational, Scientific and Cultural Organisation (UNESCO, Paris), 1999.

Only this portion is renewable

Global Water Cycle

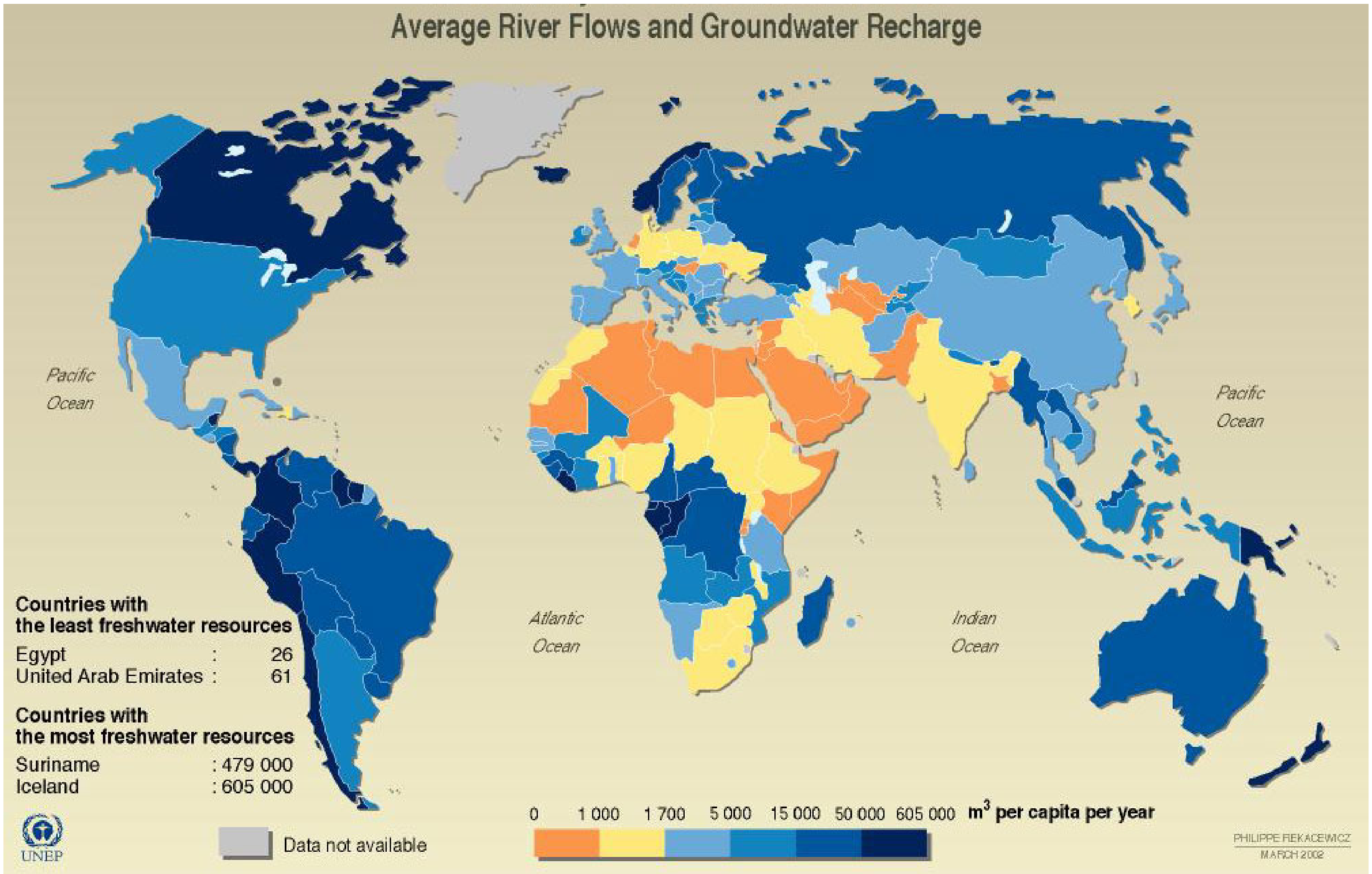


<u>Residence time:</u> Average travel time for water through a subsystem of the hydrologic cycle

$T_r = S/Q$
Storage/flowrate

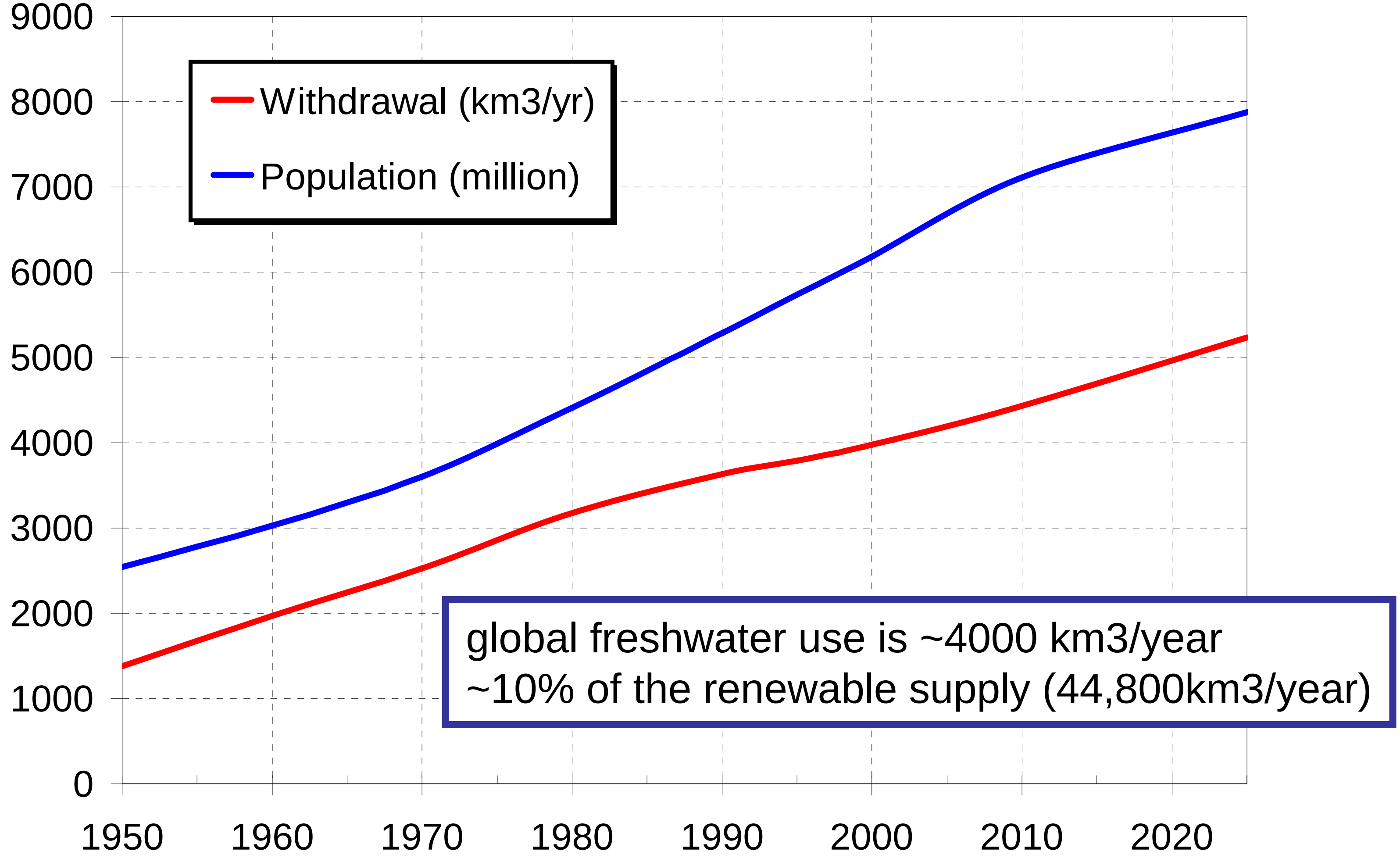
Principal sources of fresh water for human activities (44,800 km3/yr)

Global Water Availability

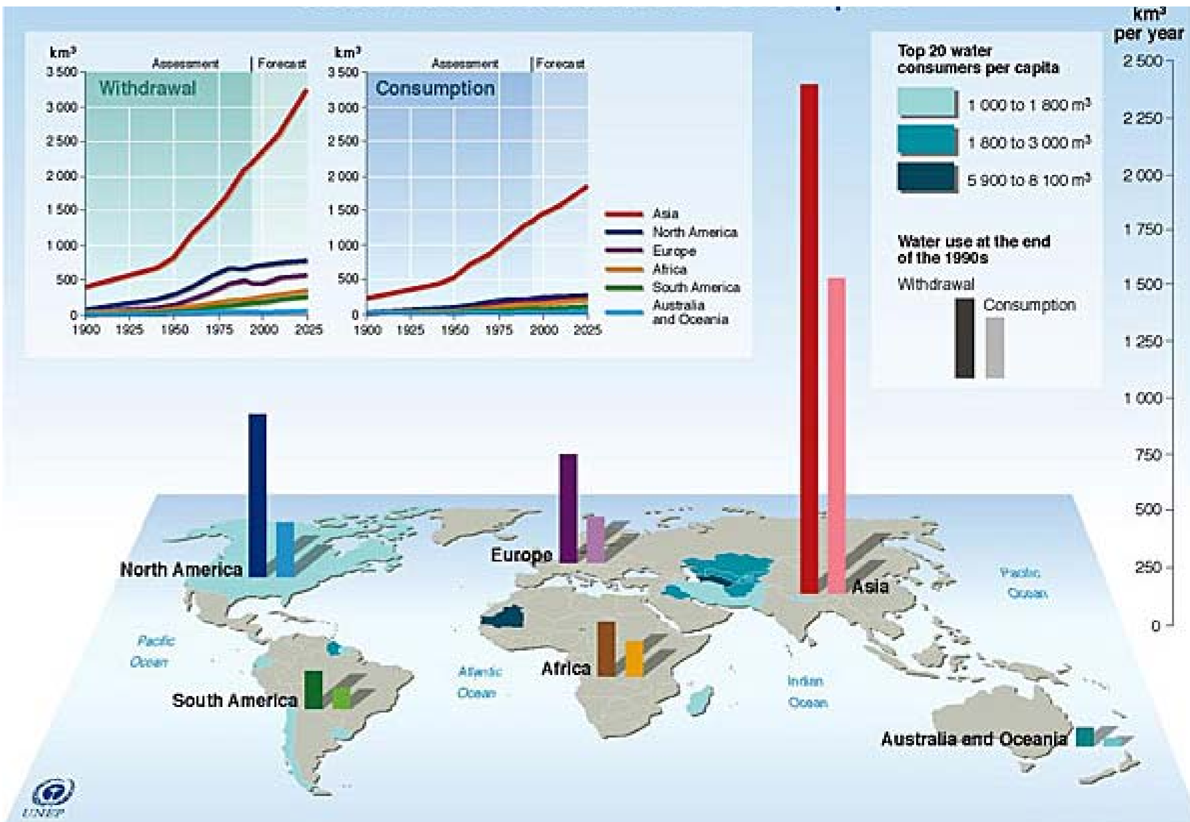


Source: *World Resources 2000-2001, People and Ecosystems: The Fraying Web of Life*, World Resources Institute (WRI), Washington DC, 2000.

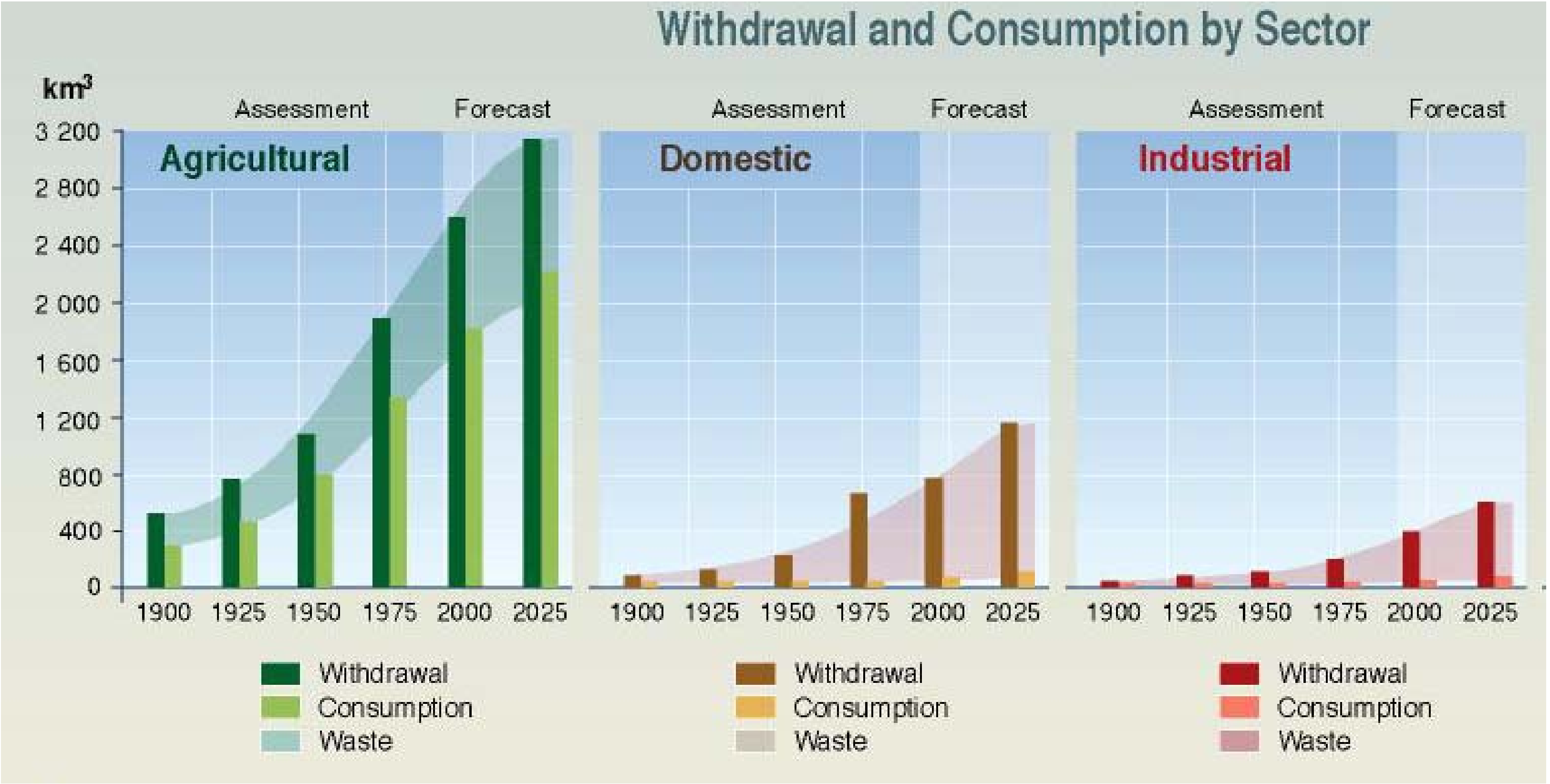
Population and Water Use



Global Water Withdrawal & Consumption



Global Water Use



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 m^3/person/year (water scarce)

  36.5 - 219 m^3/person/year (high-income)
- Associated agricultural, industrial & energy need:

  20 x domestic requirement

  73 – 292 m^3/person/year

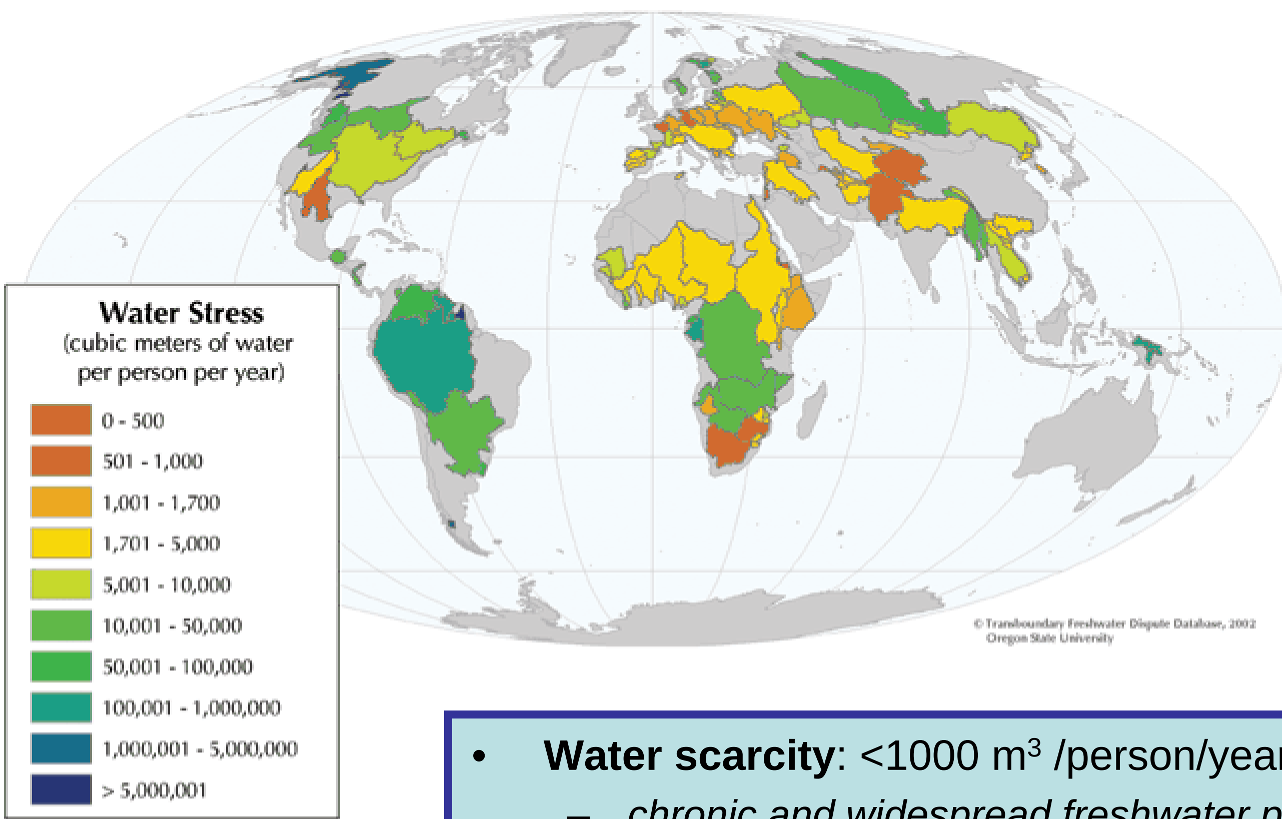
  730 – 4380 m^3/person/year
- Total need:

  77 – 307 m^3/person/year (water scarce)

  767 – 4599 m^3/person/year (high-income)

http://www.veoliawater.com

Water Stress (m3/person/year)

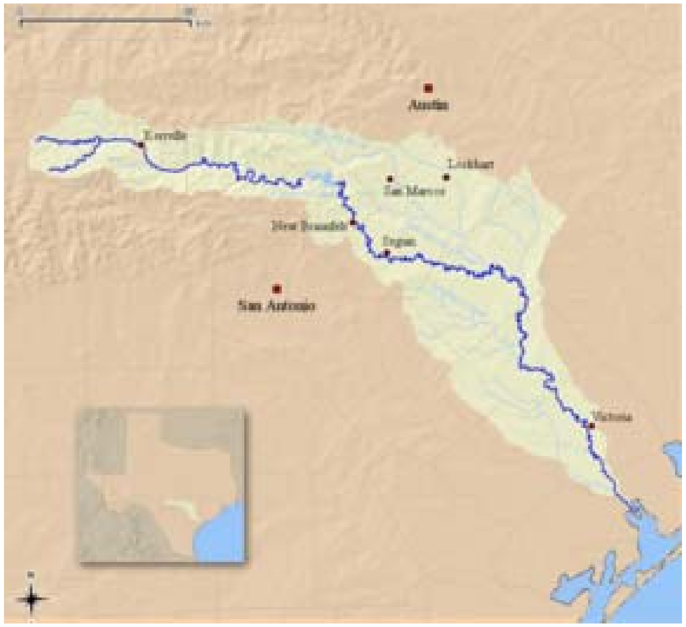


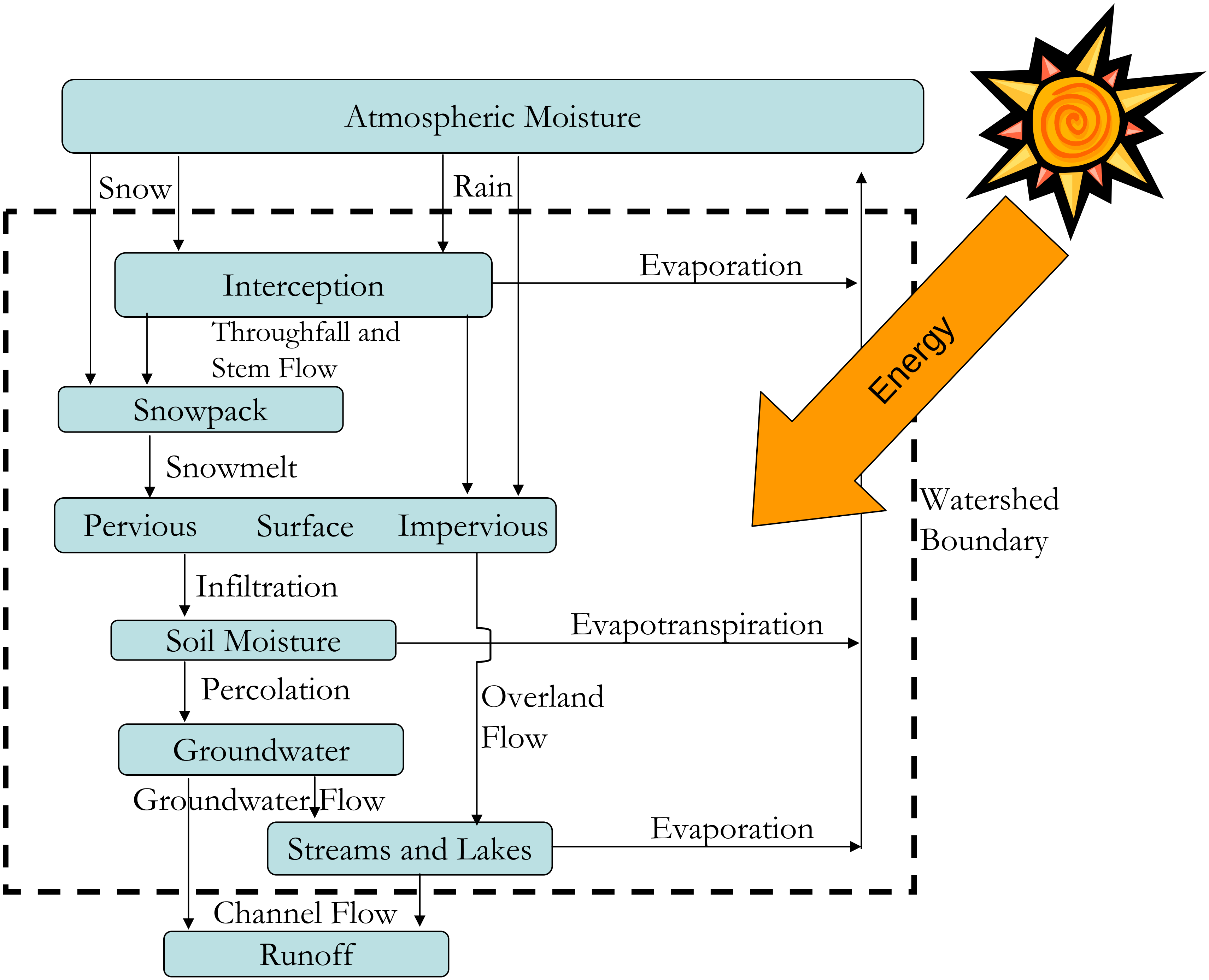
www.transboundarywaters.orst.edu

- **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

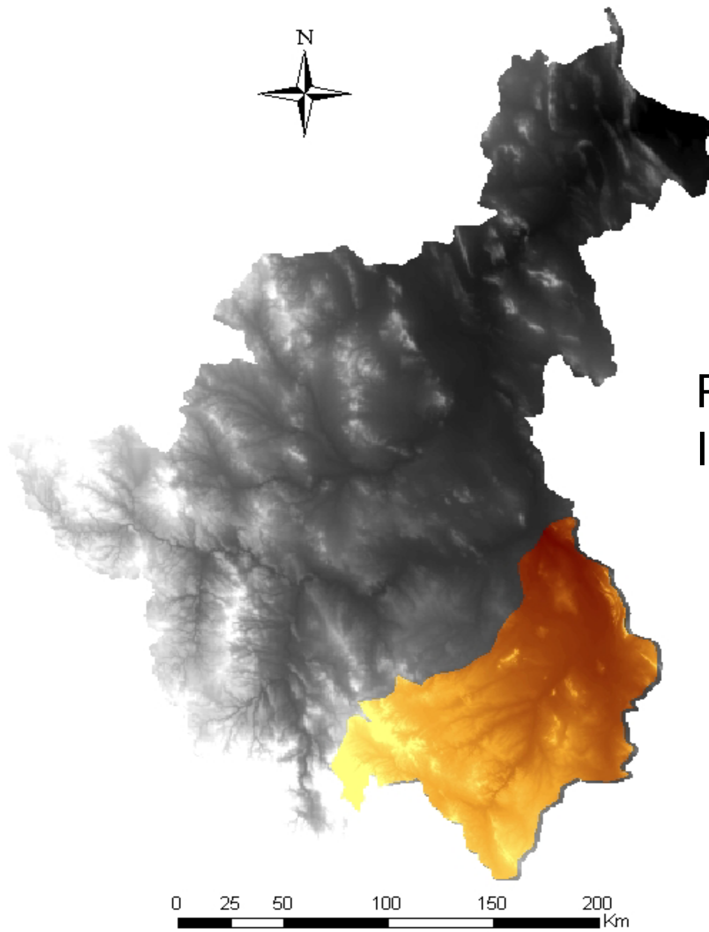
Watershed

- **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



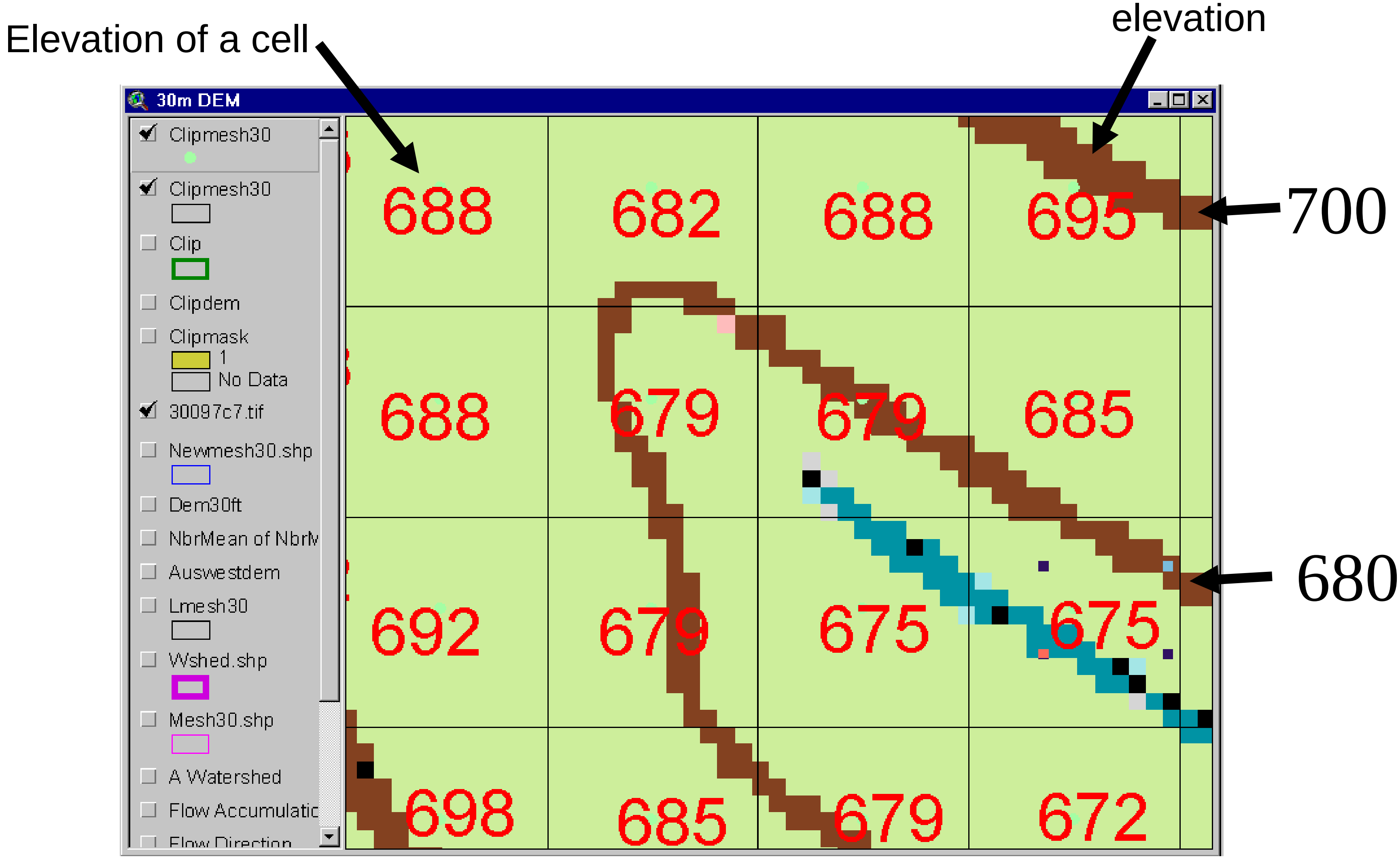

Atmospheric Moisture
Snow
Rain
Interception
Evaporation
Throughfall and
Stem Flow
Snowpack
Snowmelt
Energy
Pervious Surface Impervious
Watershed
Boundary
Infiltration
Soil Moisture
Evapotranspiration
Percolation
Overland
Flow
Groundwater
Groundwater Flow
Streams and Lakes
Evaporation
Channel Flow
Runoff

Digital Elevation Model

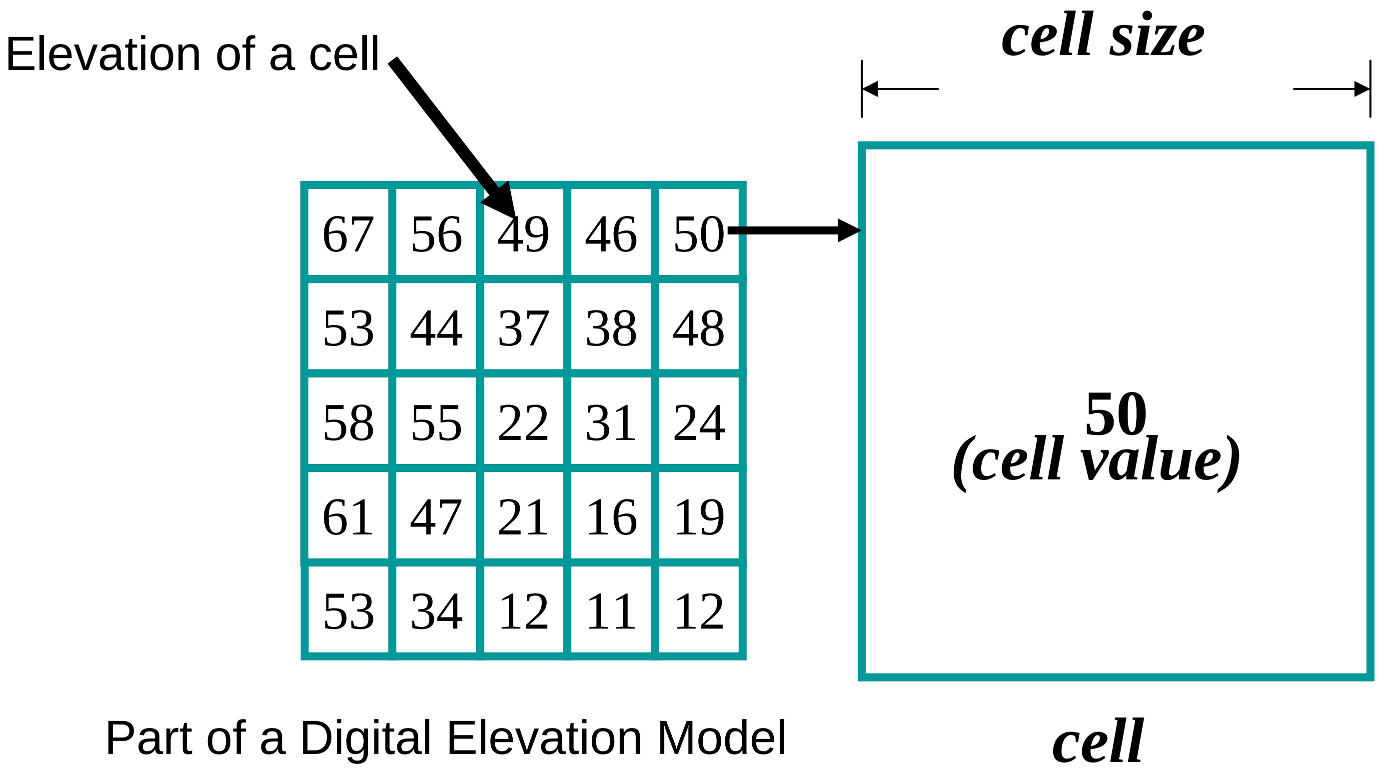


Rio Conchos Basin
In Mexico

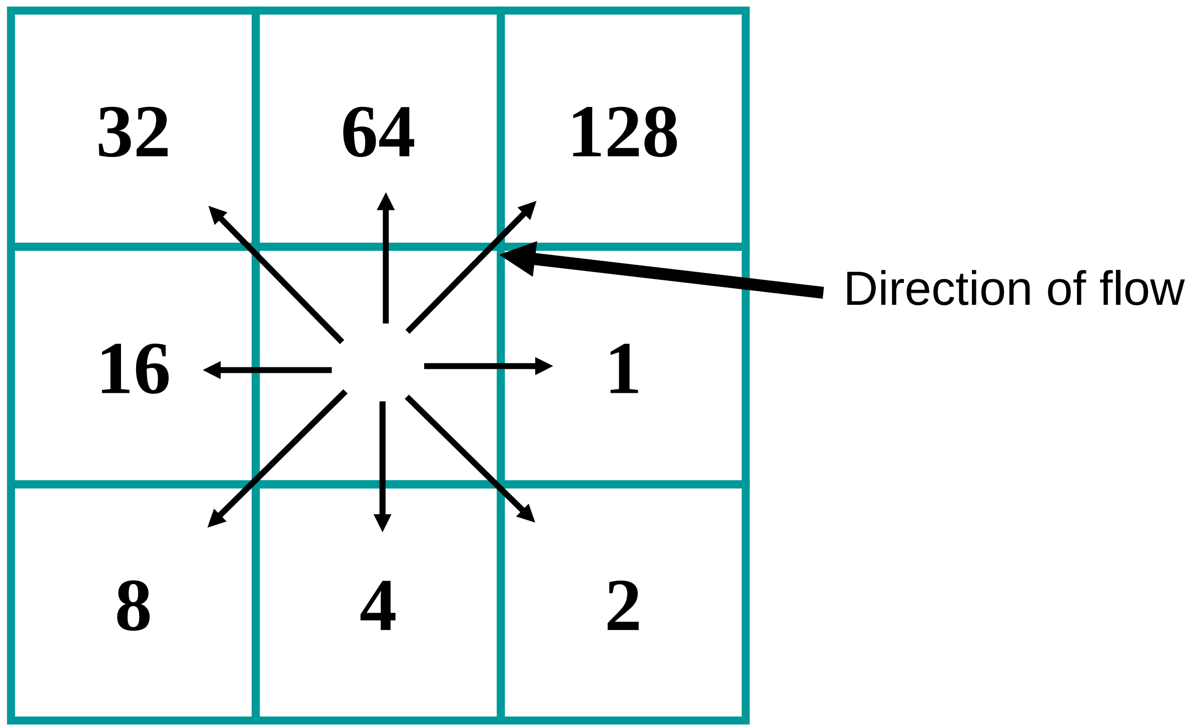
DEM Elevations



Cell Definition



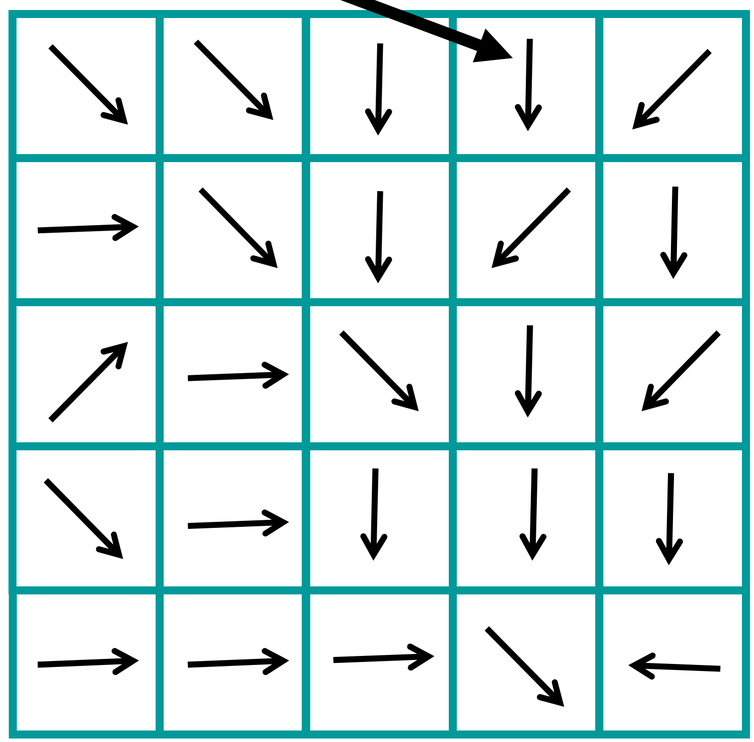
Eight Direction Pour Point Model



Flow Direction Grid

Direction of flow

2	2	4	4	8
1	2	4	8	4
128	1	2	4	8
2	1	4	4	4
1	1	1	2	16



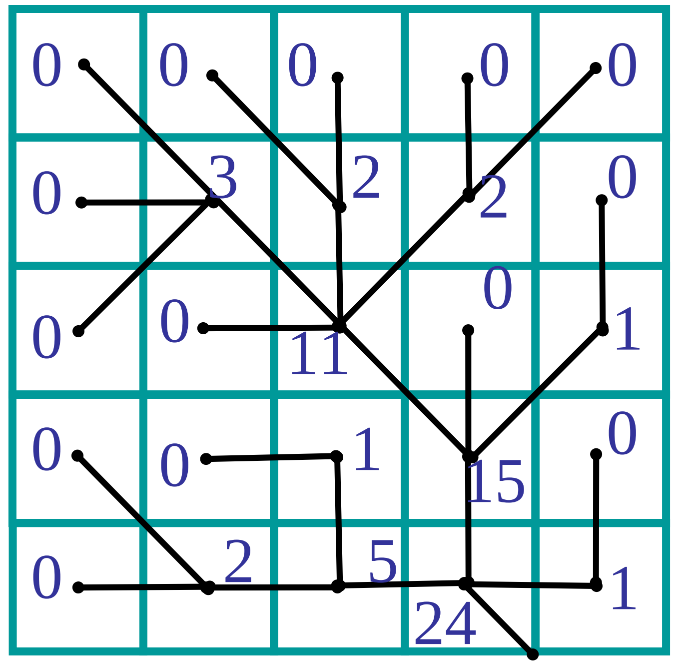
Part of a Digital Elevation Model

Flow Accumulation Grid

3 cells flow to this cell

0 cells flow to this cell

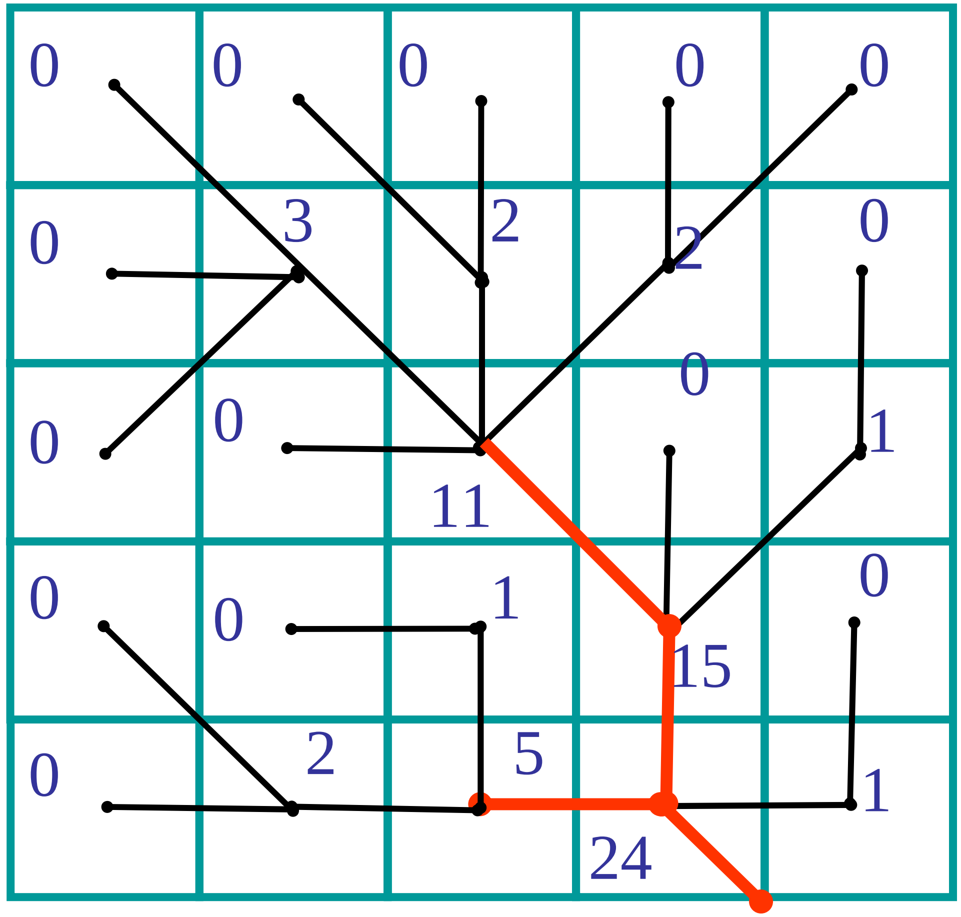
0	**0**	**0**	**0**	**0**
0	**3**	**2**	**2**	**0**
0	**0**	**11**	**0**	**1**
0	**0**	**1**	**15**	**0**
0	**2**	**5**	**24**	**1**



Water will flow from low values to high values

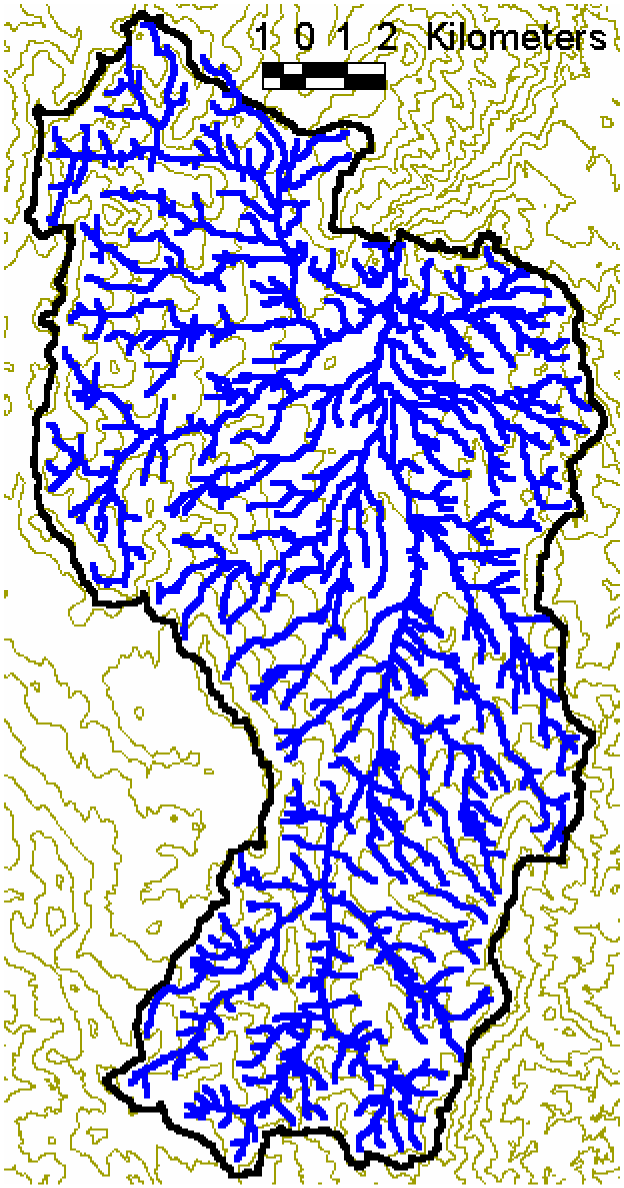
Stream Network

Set a threshold,
e.g, Streamflow if Accumulation > 5

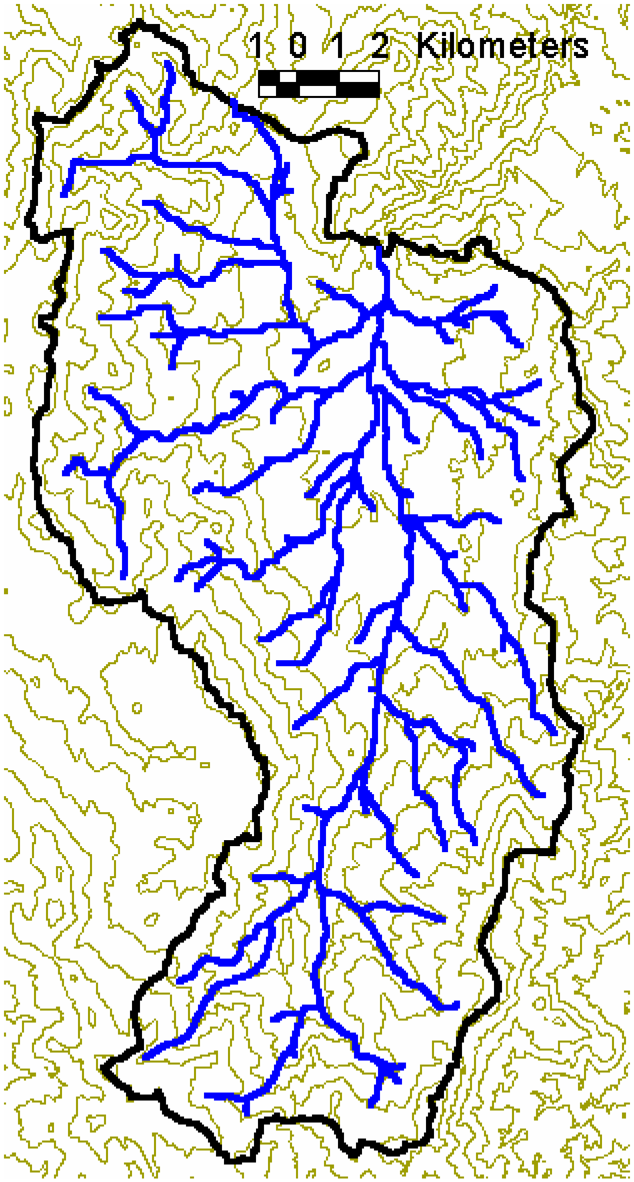


Stream Network for Different Thresholds

100 grid cell threshold

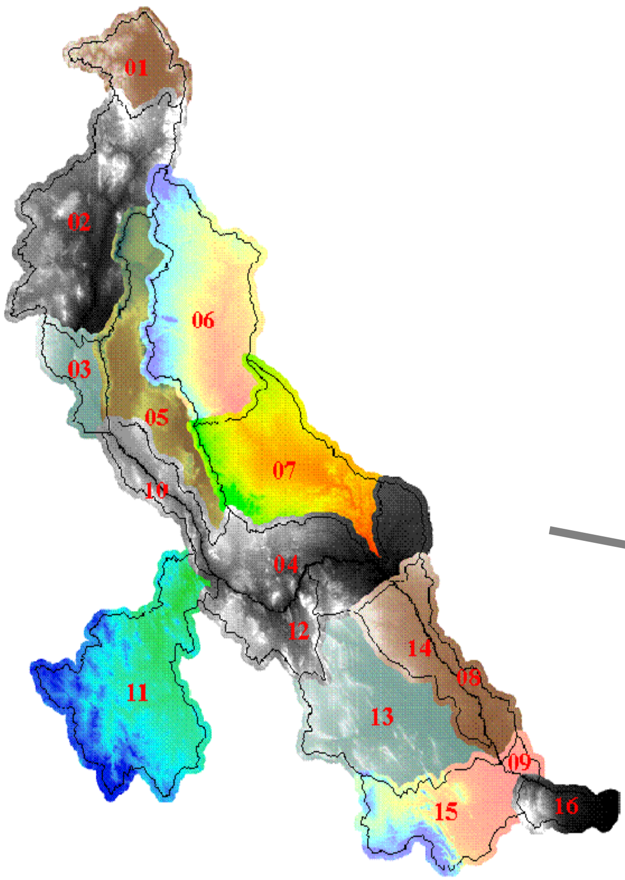


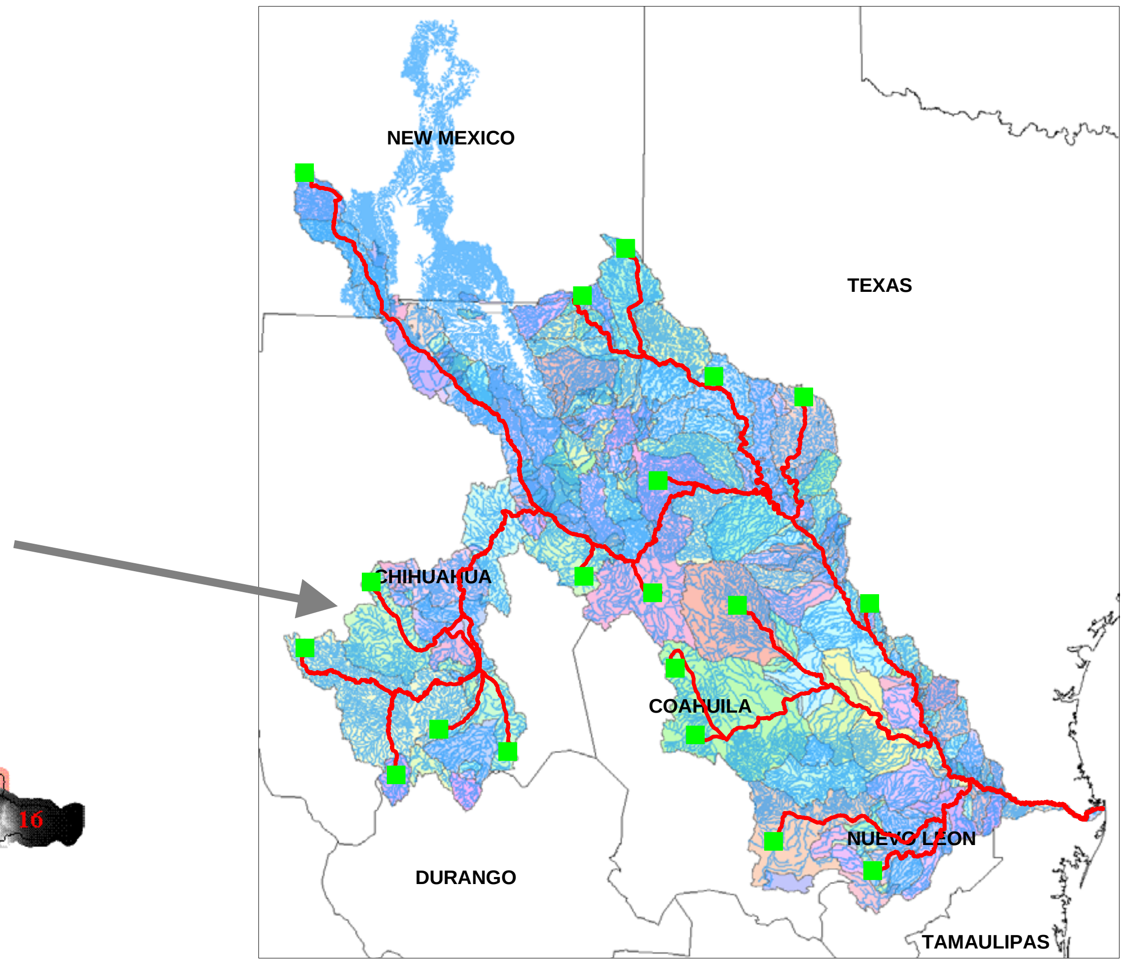
1000 grid cell threshold



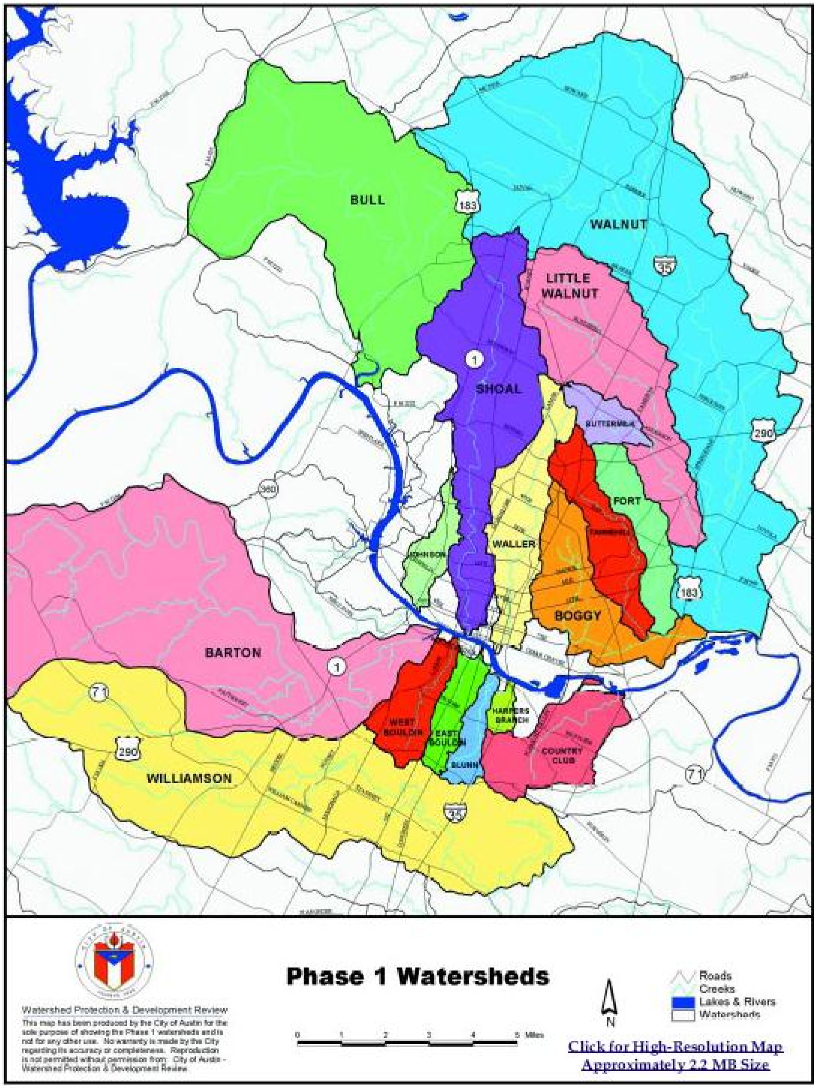
Rio Grande Basin

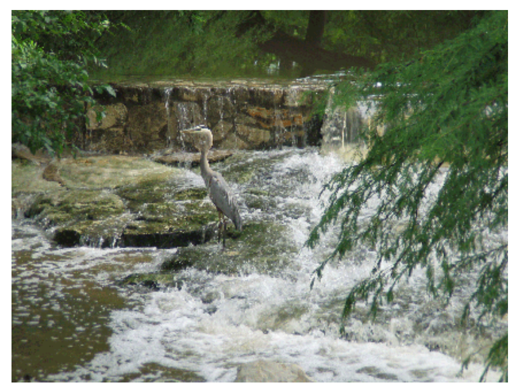
Rio Grande


01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16

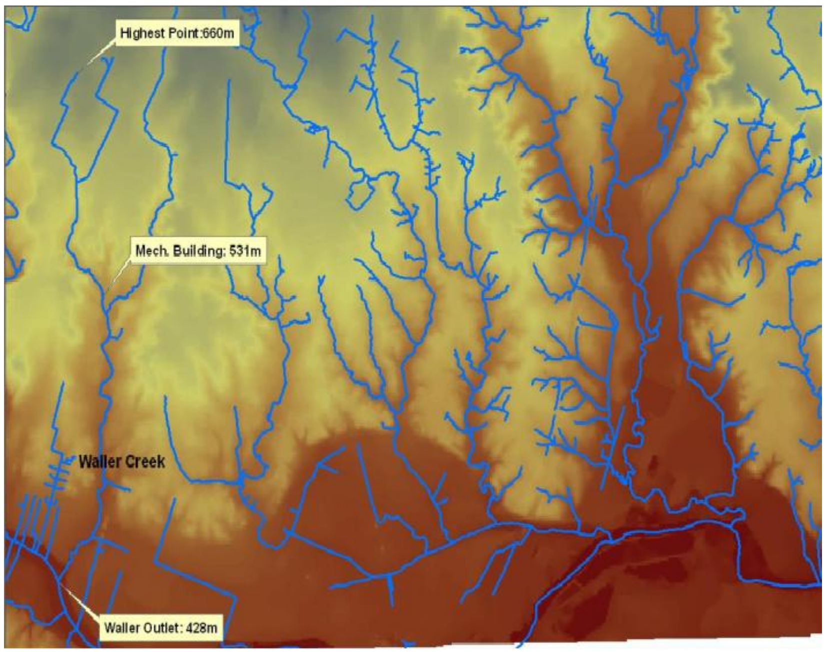

NEW MEXICO
TEXAS
CHIHUAHUA
COAHUILA
NUEVO LEON
DURANGO
TAMAULIPAS

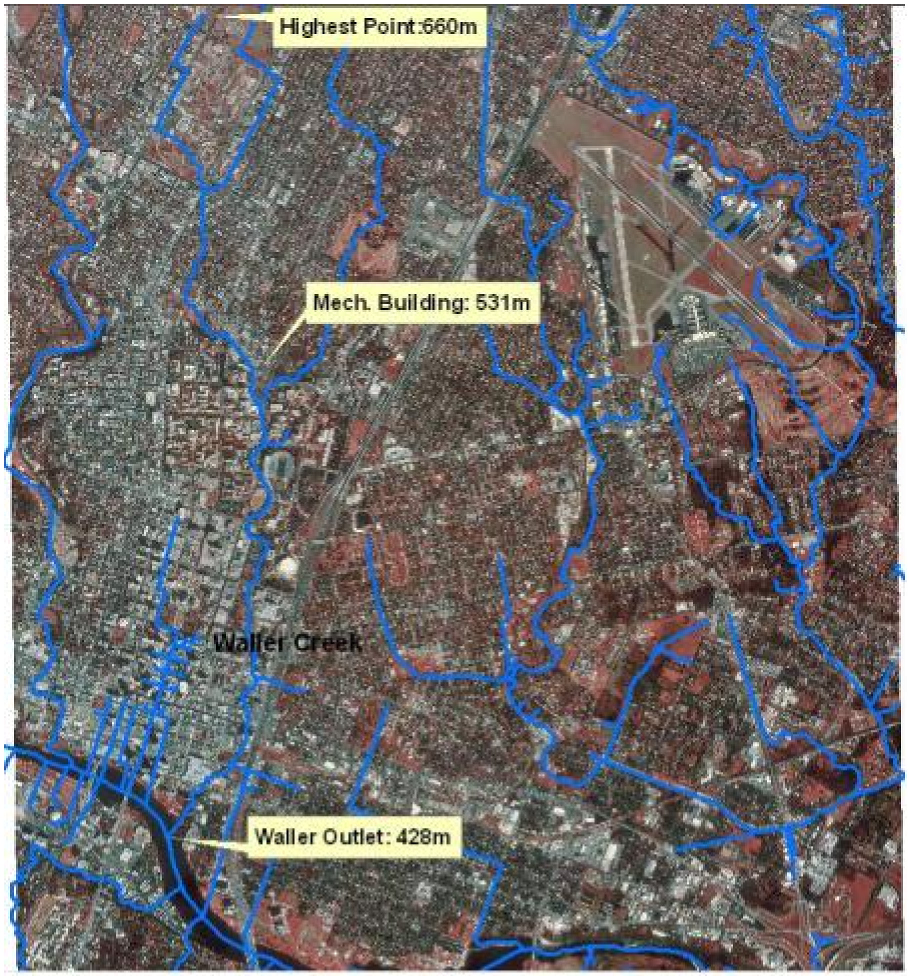
Waller Creek



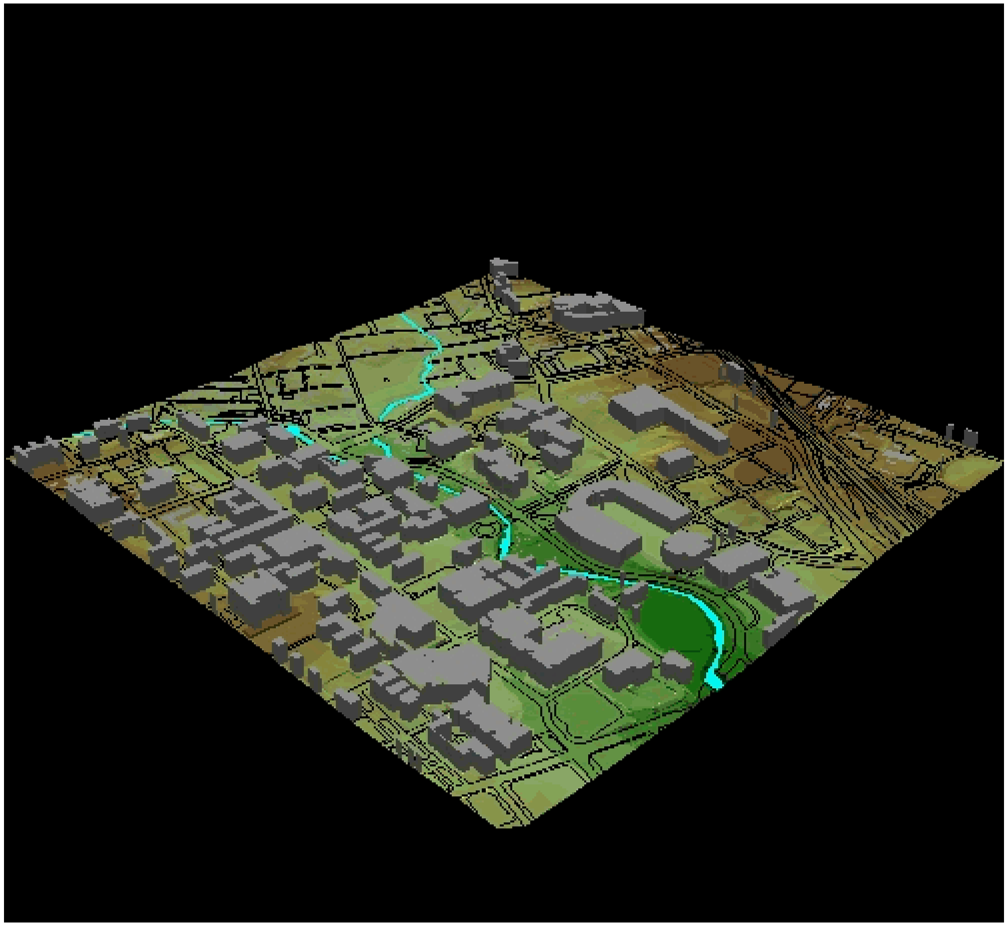


Waller Creek





Waller Creek



Thanks to: Esteban Azagra