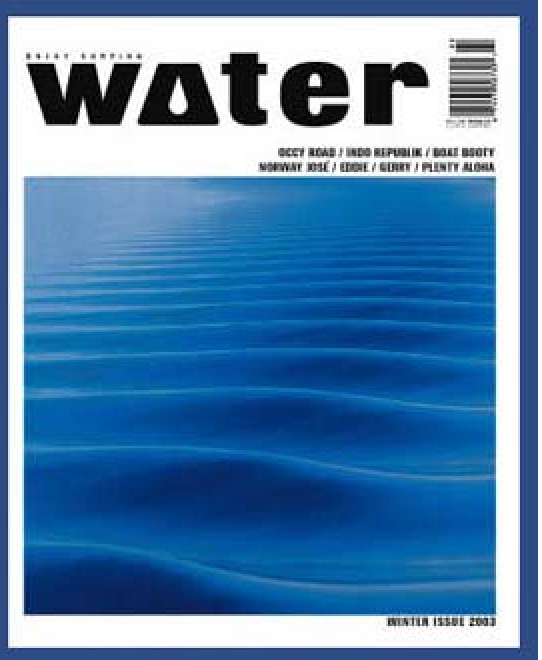
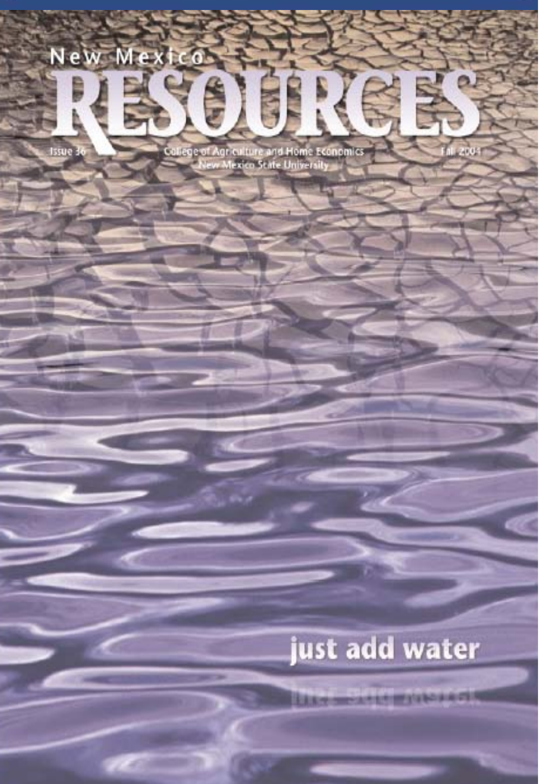
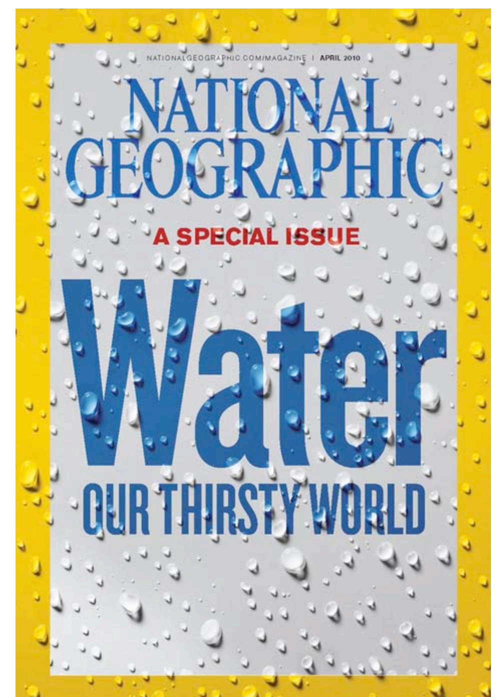
Water

Ronald Turco, College of Agriculture

Professor, Environmental Microbiology &
Director, Purdue Water Community







PURDUE UNIVERSITY Discovery Park

Global Sustainability Initiative at Purdue (GSI)

Center for the Environment

Energy Center

Purdue Climate Change Research Center

Food Security

Water Community

Advanced Computational Center for Engineering and Sciences

- Cyber Center
- Computing Research Institute
- Rosen Center for Advanced Computing

Oncological Sciences Center

Regenstrief Center for Healthcare Engineering

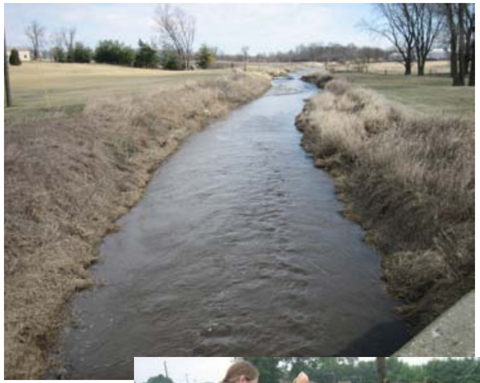
Bindley Bioscience Center

Birck Nanotechnology Center

Burton D. Morgan Center for Entrepreneurship

Discovery Learning Center

The Purdue Water Community



55 faculty members

FOCUS AREAS

- Water in the Landscape
- Agricultural Runoff
- Great Lakes Issues
- Public Health Impacts
- Large River and Watershed Functions
- Water Infrastructure
- **Water Sustainability**

Example Projects

Impacts of Biofuel Production
Water Reuse in Large Watersheds
Fate and Impact of Hormones in the Environment

So how much fluid does the average, healthy adult living in a temperate climate need?

Adequate intake (AI) for men is roughly 3 liters (about 13 cups) of total beverages a day.

The AI for women is 2.2 liters (about 9 cups) of total beverages a day.

Access to water is critical factor in a free and well educated society.

Millions of women spending several hours a day collecting water limits their time in school.

http://www.mayoclinic.com/health/water/NU00283/

You are 55 to 78% water and it is a major part of everything you do!

Water per day per person

Drinking	**2-4 L**
Domestic	**40-400 L**
Food & Products	**1000-5000 L (and more)**

(the hidden water)

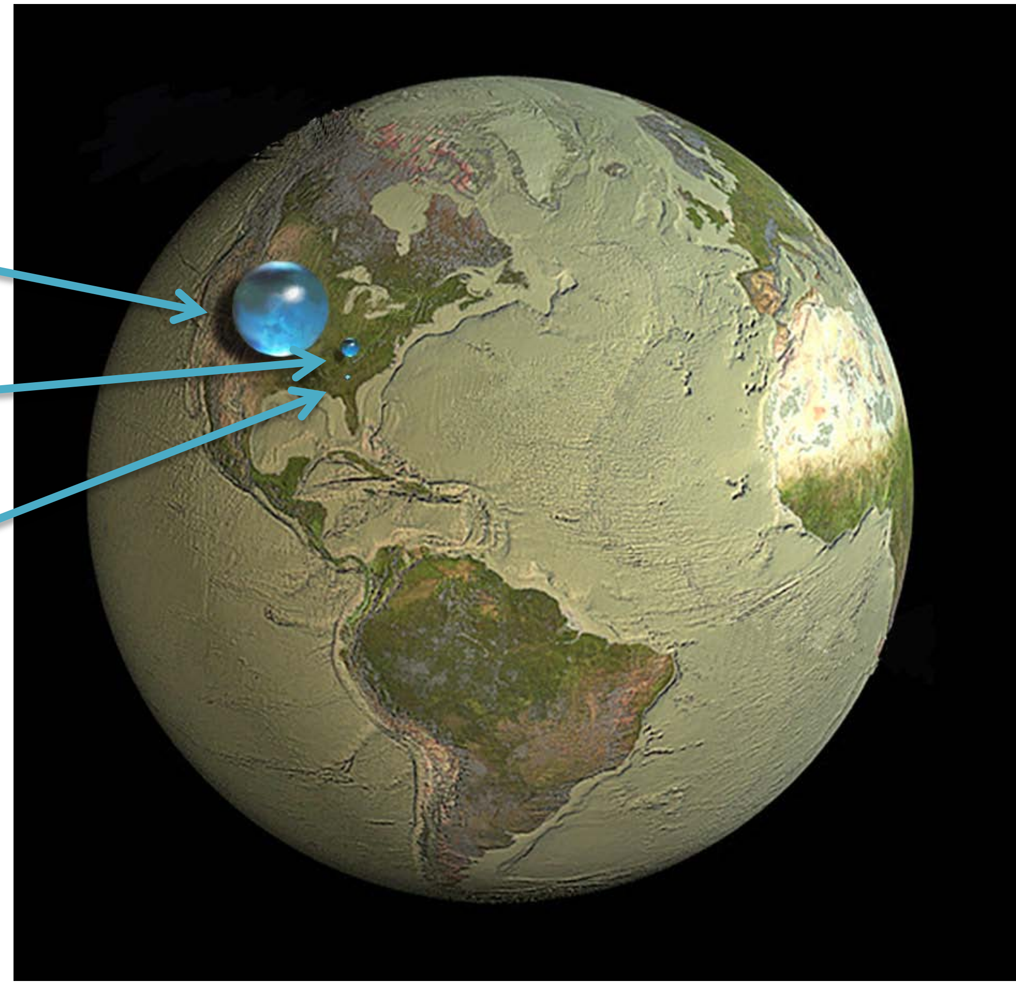
The average American uses about 378 L water per day **not accounting for water embedded in food and other products**.

9.30 x 10^{16} L of available water or 1.33 x 10^{7} L per person on earth, if it was evenly distributed!

All Water
Dia= 860 miles
Volume = 332,500,000 mi^3

All Fresh Water
Dia= 169 miles
Volume = 2,551,100 mi^3

Available Water
Dia= 35 miles
Volume = 22,339 mi^3
Lakes and Rivers



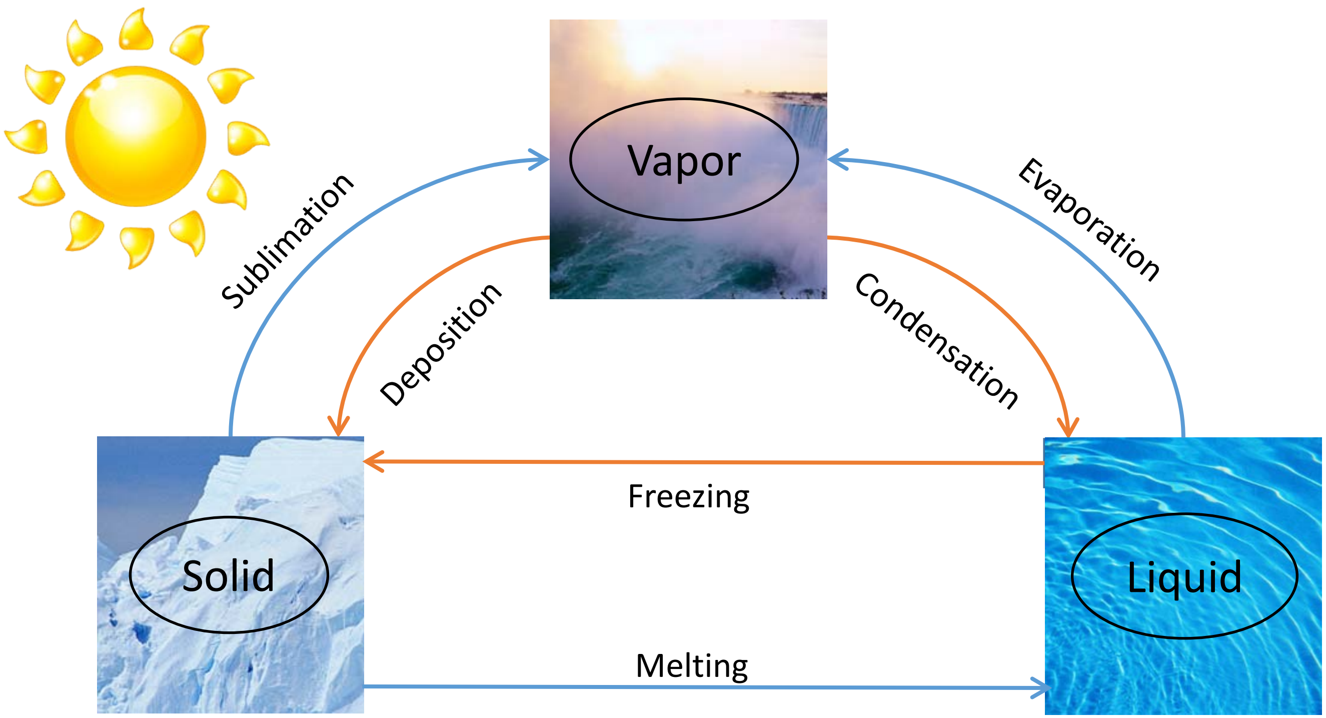
1 $mile^3$ of water = 4.16 Trillion L
7 billion people / earth **(today)**

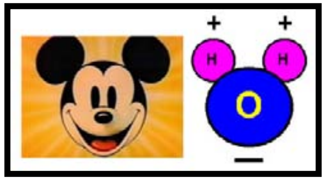
http://ga.water.usgs.gov/edu/2010/gallery/global-water-volume.html

Less than 0.007% of all water on Earth is drinkable !!


The same water
that existed on Earth
billions of years ago
still exists today.

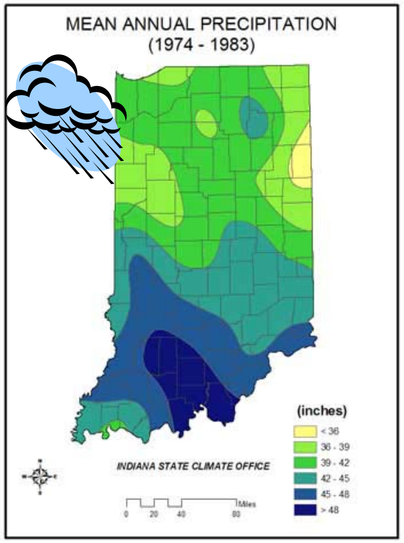
The total amount of water on earth is fixed at about 1.36 x 10^{20} liters (3.6 x 10^{19} gal) – it is constantly moving between three phases.





Dihydrogen monoxide

Evapotranspiration is the dominate loss mechanism from soil

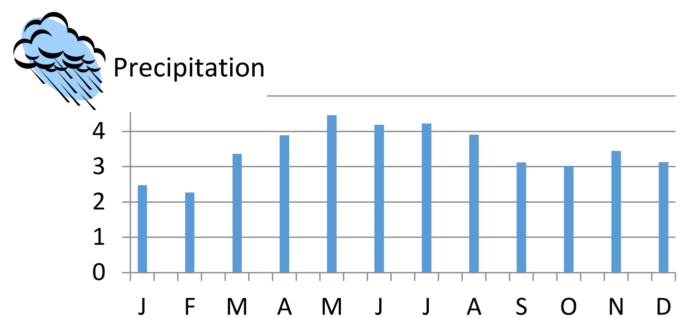


Precipitation
38 to **40** inyr^{-1}

Evapotranspiration
Evaporation
26 inyr^{-1}

Groundwater recharge
3 to 4 inyr^{-1}
< 10% replacement

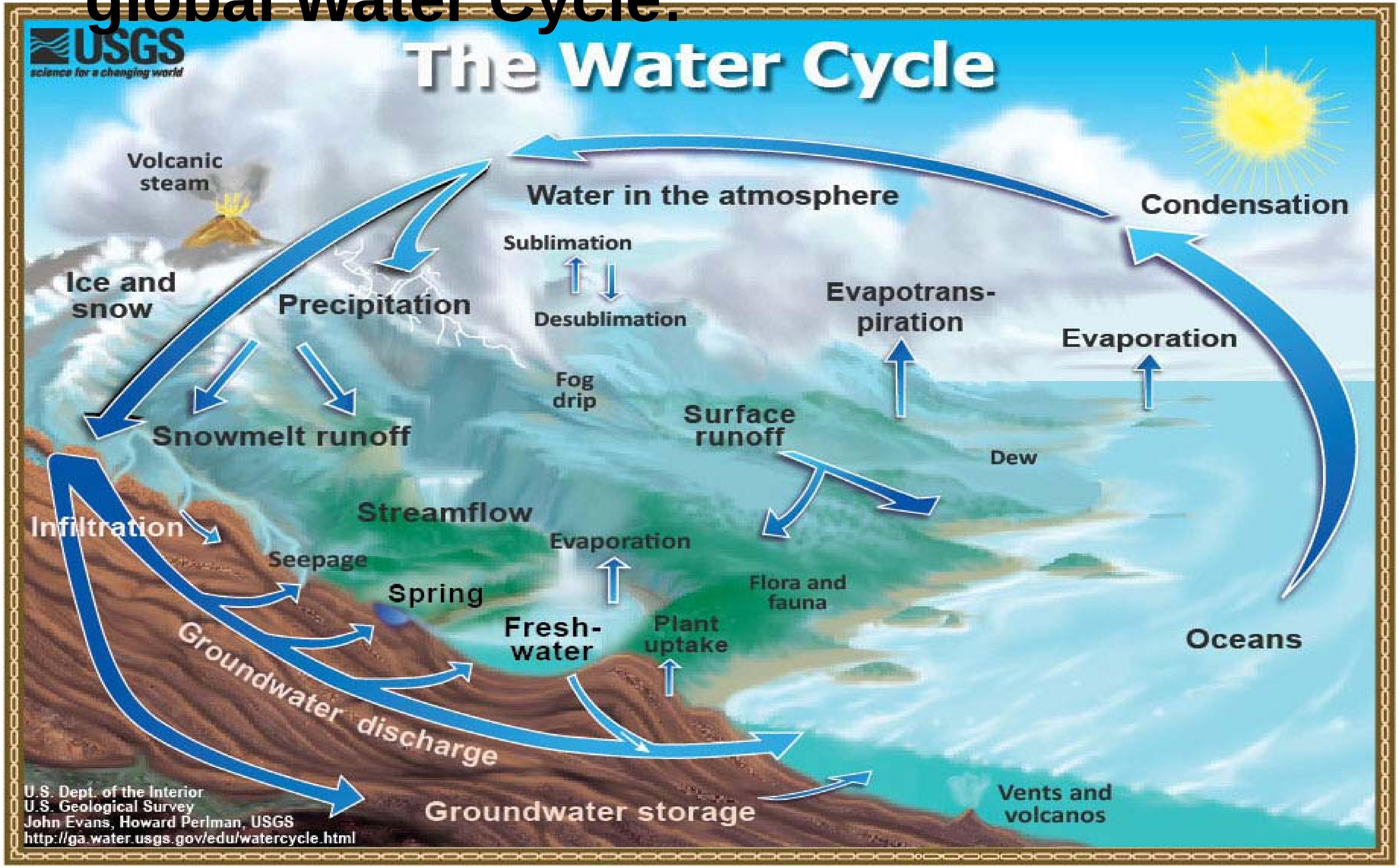
Surface Runoff
8 to 9 inyr^{-1}



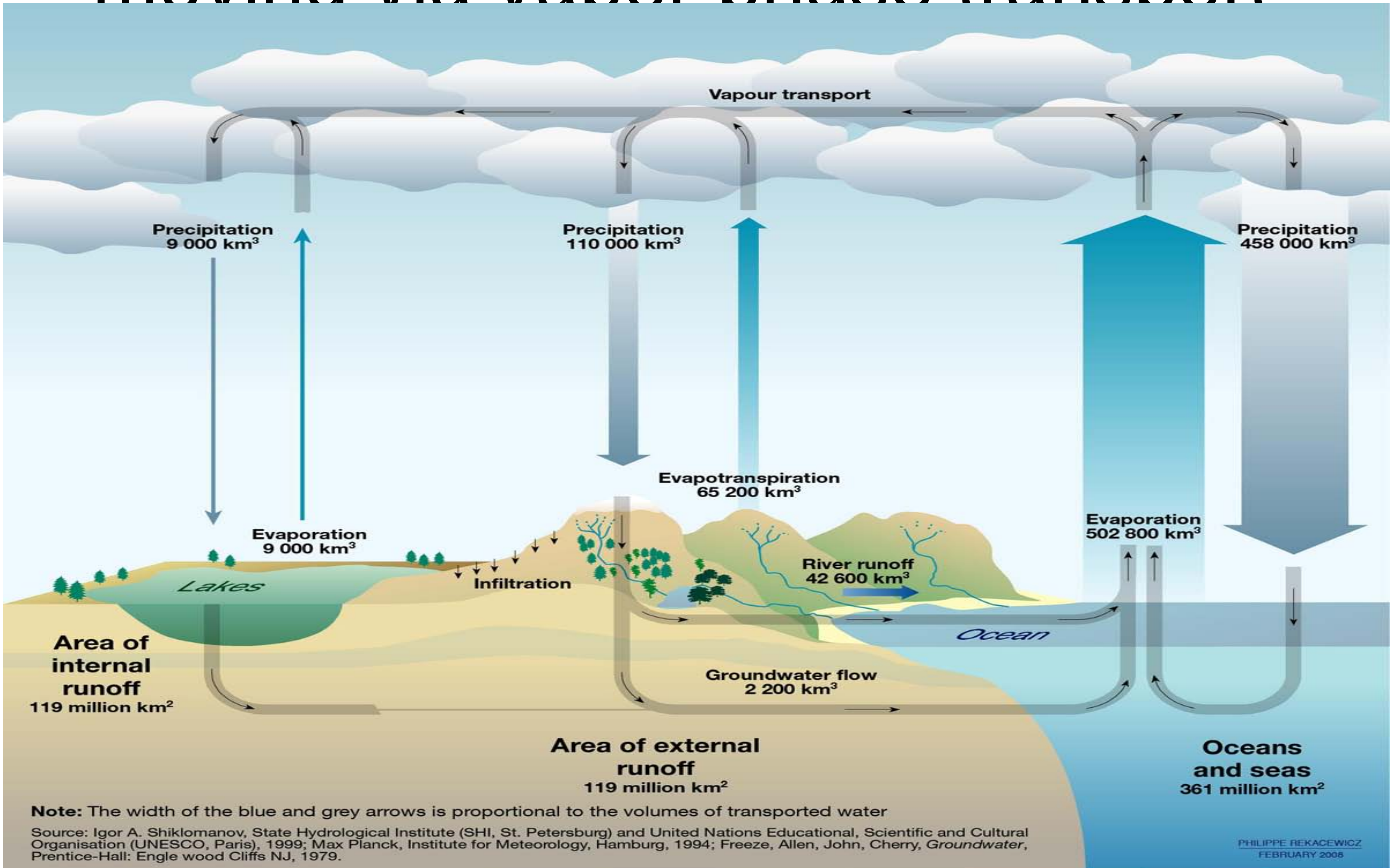
From Clark, 1980

https://climate.agry.purdue.edu/climate/facts.asp

The three phases control the world's available water supply as part of a global Water Cycle.

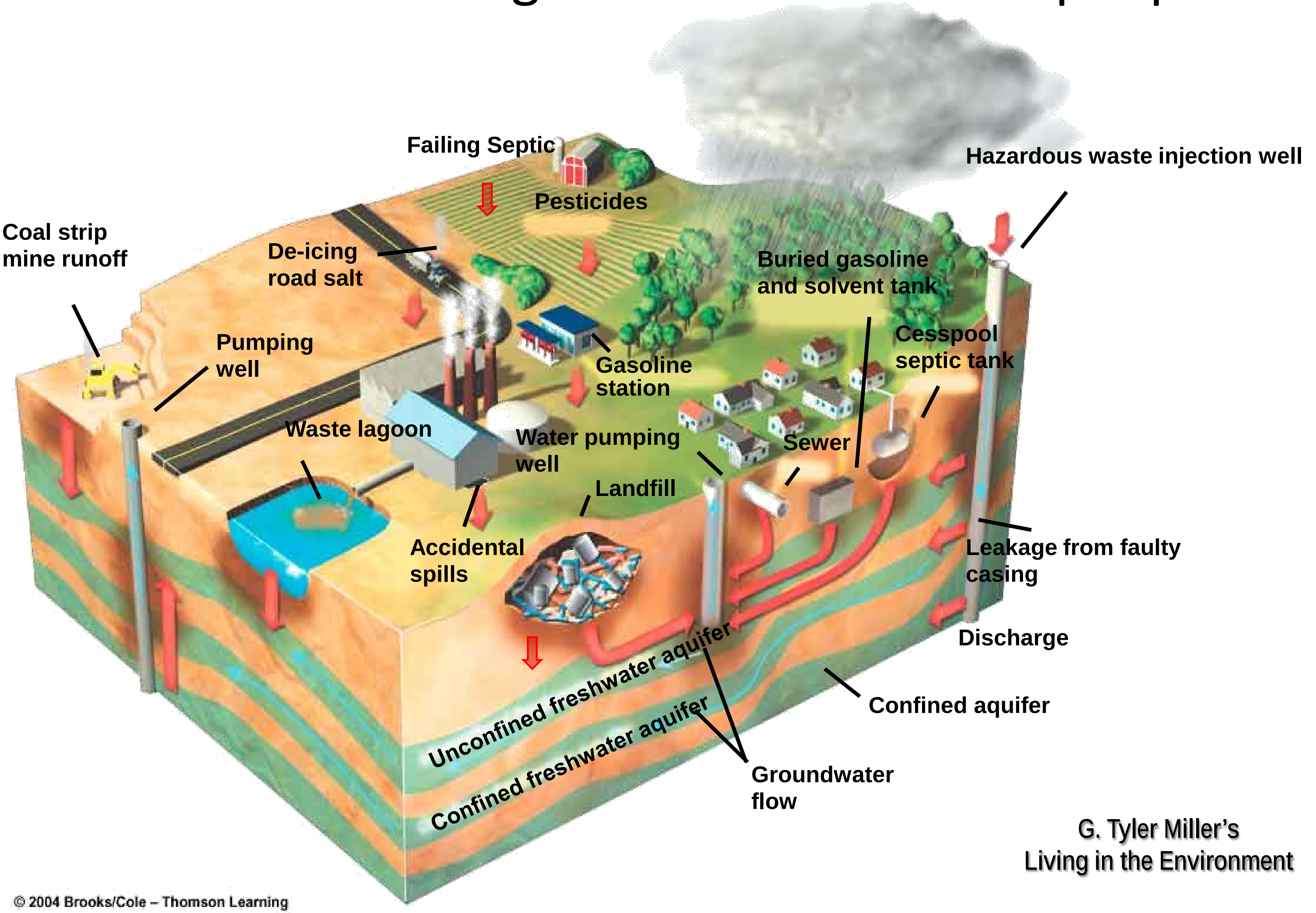


On the global scale most water is moving via vapor phase transport



http://www.grida.no/graphicslib/collection/vital-water-graphics-2

The water left on the ground interacts with people



G. Tyler Miller's
Living in the Environment

Sustainable Water – the measures

Sustainable water is critical in providing the “public”(e.g., users) with clean and safe water and to help ensure the social, environmental, and economic sustainability of those using the resource.

A Sustainable Enterprise considers:

Supply (development and protection)

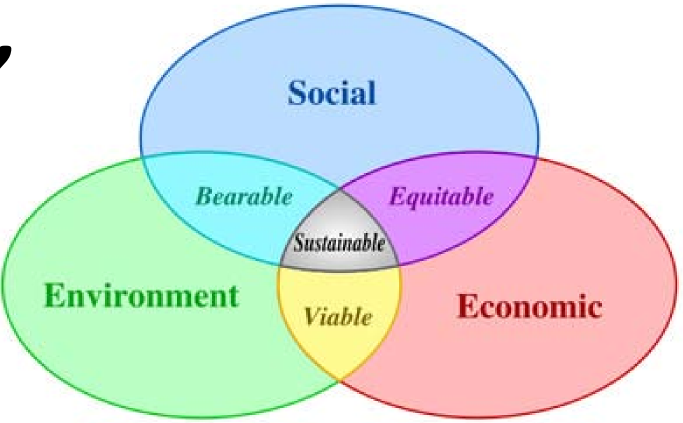
Delivery Systems (infrastructure management)

Waste Water treatment (optimized for resource capture)

Environmental Impacts (the collective effects)

Sustainable Water

A <u>sustainable</u> water use
does not harm ecosystems,
degrade water quality,
or compromise the ability
of future generations
to meet their own needs.



Dr. Deborah L. Swackhamer, University of Minnesota - Water Resources Center - 2009 Minn. Laws. Ch. 172, Art. 2 § 30 at 45-46

The majority of agriculture is rain fed.

Irrigated agriculture provides 40% of the world's food and consumes 75% of world's freshwater resources; up to 95% in some developing countries.

Today

- 14 plants and 8 terrestrial animals provide 90% of the worlds calories from some 30,000 eatable plant species
- Wheat, rice, and corn provide ½ world's calories
- Four primary forms of animals: fish, beef, pork, and chicken

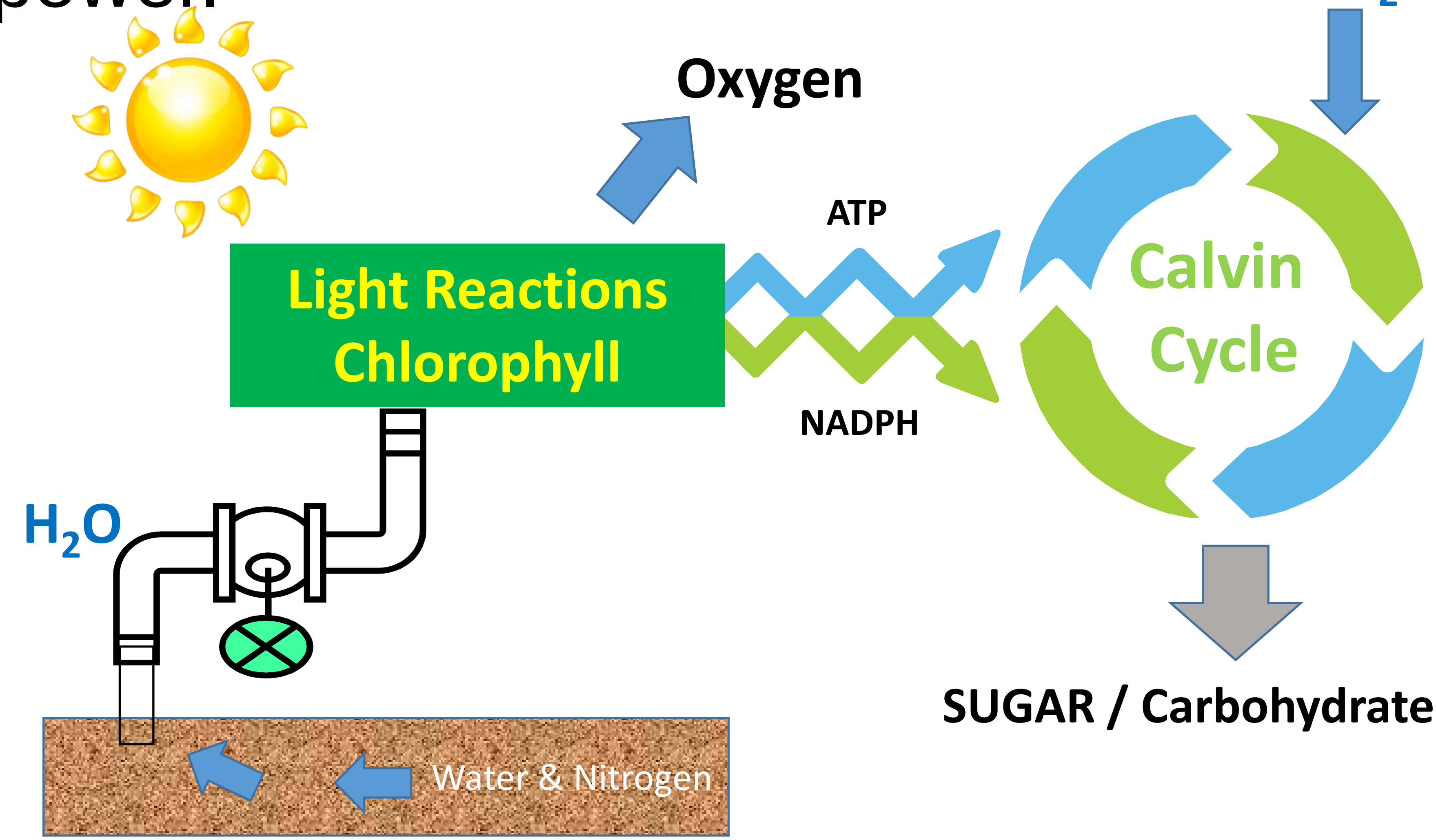
Agriculture uses three types of water: green, blue and gray water – two are free and one is not.

Green water = precipitation

Blue water = irrigation removed from other fresh water sources

Gray water = irrigation from high grade waste water

Water's role in plant growth is critical as it holds up the plant, moves nutrients and waste materials and is a source reducing power.



The ability to supply water to a plant is significant for production.

How much water does it take to produce a 1.5 lb. bag of alfalfa?

- A) 10 lbs. (1.2 gallons)
- B) 50 lbs. (6 gallons)
- C) 100 lbs. (12 gallons)
- D) 1000 lbs. (121 gallons)
- E) 2000 lbs. (241 gallons)

A 1.5 lb. Bag of Alfalfa requires a lot of water – its water use efficiency (WUE) is not great.

E) 2000 lbs. (241 gallons)

WUE is expressed as kg H_2O/kg DM

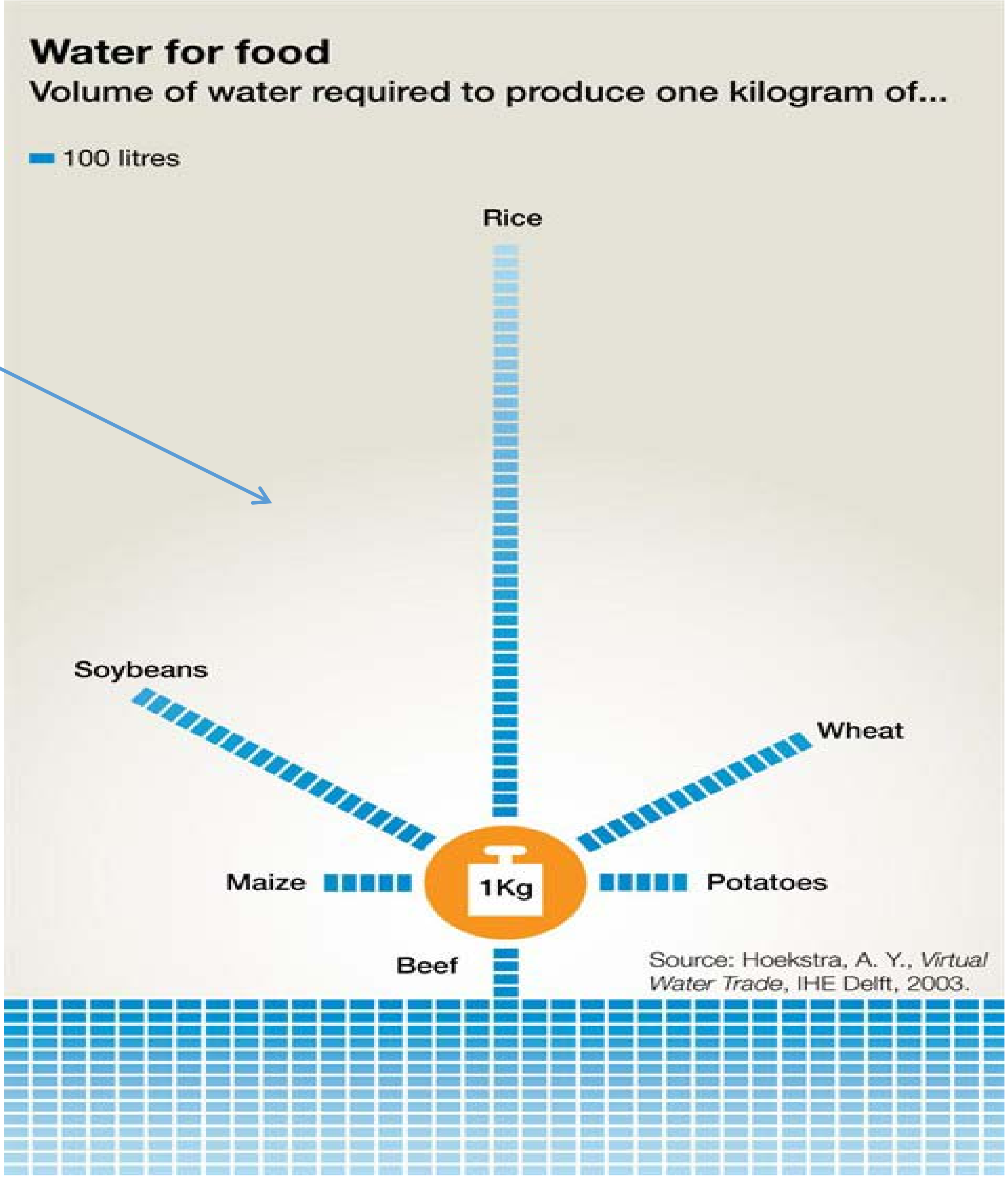
WUE=350 means that 350 kg H_2O is needed to produce 1 kg of plant biomass a low number is preferred

Ranges from 250 >1000

Factors that improve yield also tend to improve WUE

Food is water

Total water used



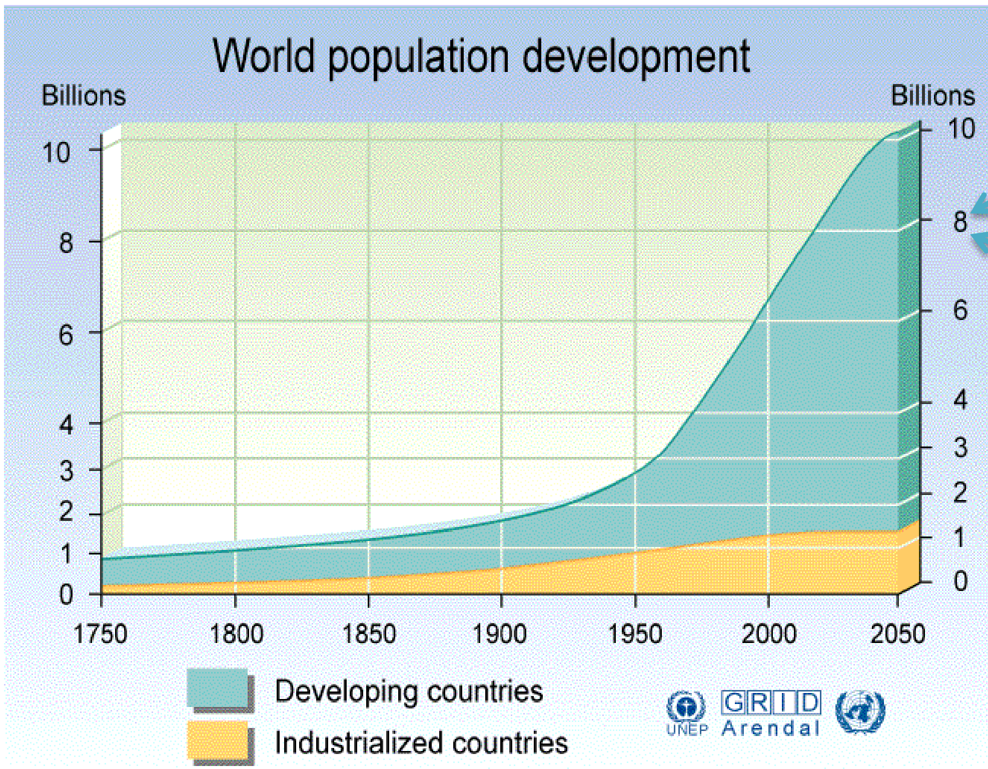
The water foot print of a number of important food products reveal huge amounts of water are needed for the items.

Item	Water
1 kg wheat	1 m^3
1 kg rice	3 m^3
1 kg milk	1 m^3
1 kg cheese	5 m^3
1 kg pork	5 m^3
1 kg beef	15 m^3

Item	Water
1 egg	135 L
1 beer (L)	25 L
1 hamburger	2400 L
1 coffee (8oz)	140 L
1 sheet paper	10 L

Hoekstra & Chapagain, 2008

The increasing population on earth is putting a demand on water resources via both direct consumption and to a far larger degree, indirect consumption in food and other products.



8.76×10^{15} L / year drink demand

2.08×10^{18} L / year food demand

Direct Consumption is less than 1% of the world's total yearly need for fresh water.

3L per day drink
5000L per day food

http://www.grida.no/graphicslib/collection/vital-water-graphics-2

Virtual water is the water ‘embodied’ in a product (i.e., food or cell phone), not in real sense, but in virtual sense. It refers to the water needed , at all steps, for the production of the product.

Virtual water content of a crop

Crop water use (m^3/ha) / Crop yield (ton/ha)

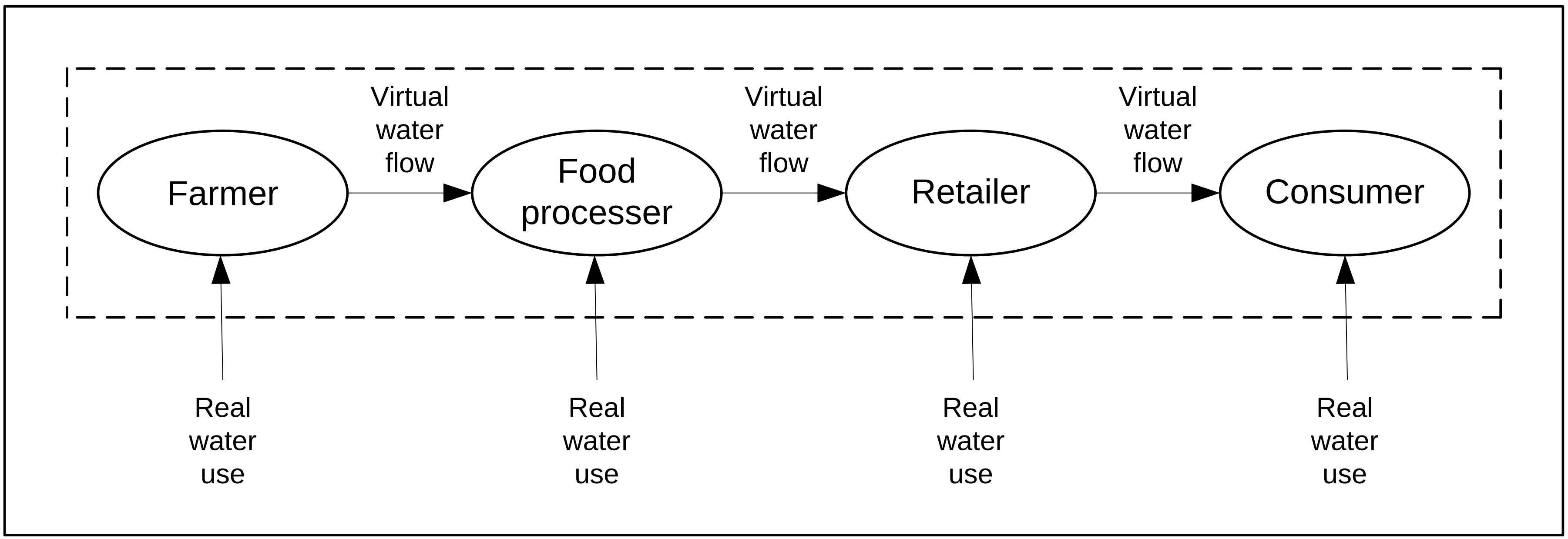
Virtual water content of an animal

Sum of water for feed, drinking and servicing

Virtual water content of product

Sum of water used to make the item or the fuel used to move the item

The Water Footprint of a product is the volume of fresh water used to produce the product, summed over the various steps of the production chain.



The water footprint: allows the linkage between consumption in one place and water systems impact in another place to be considered.

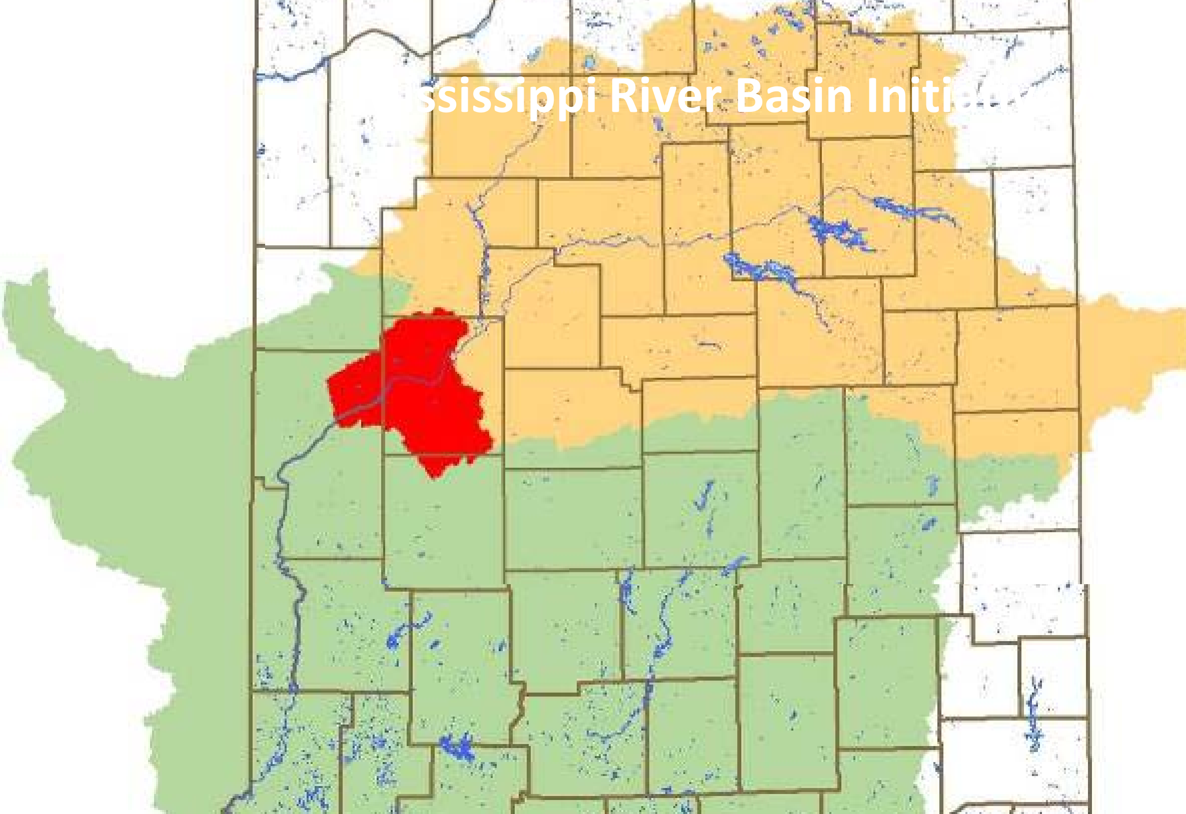
For small & large river systems

Is the water clean ?

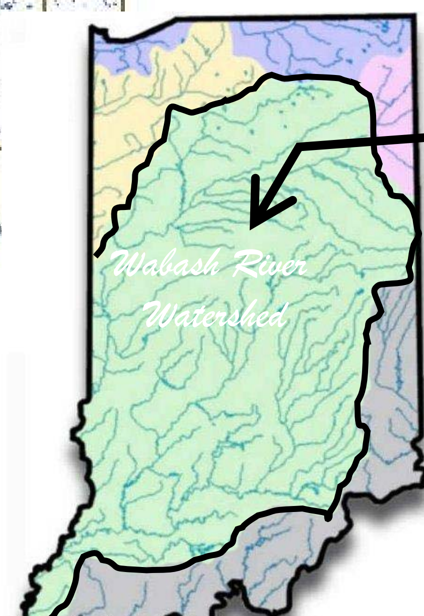
Is land management impacting water quality/quantity ?

Can we alter practices

Can we measure changes?



Wabash River Watershed



~3.6 M People
32,910 mi^2
12 Watersheds
Two Ecoregions..

Characterizing the Wabash River Watershed's Human-water cycle "Virtual water powers Indiana"

Julia Wiener, ESE PhD Student
Faculty Advisors:
Loring Nies, School of Civil Engineering
Chad Jafvert, School of Civil Engineering
Luo Si, Department of Computer Sciences

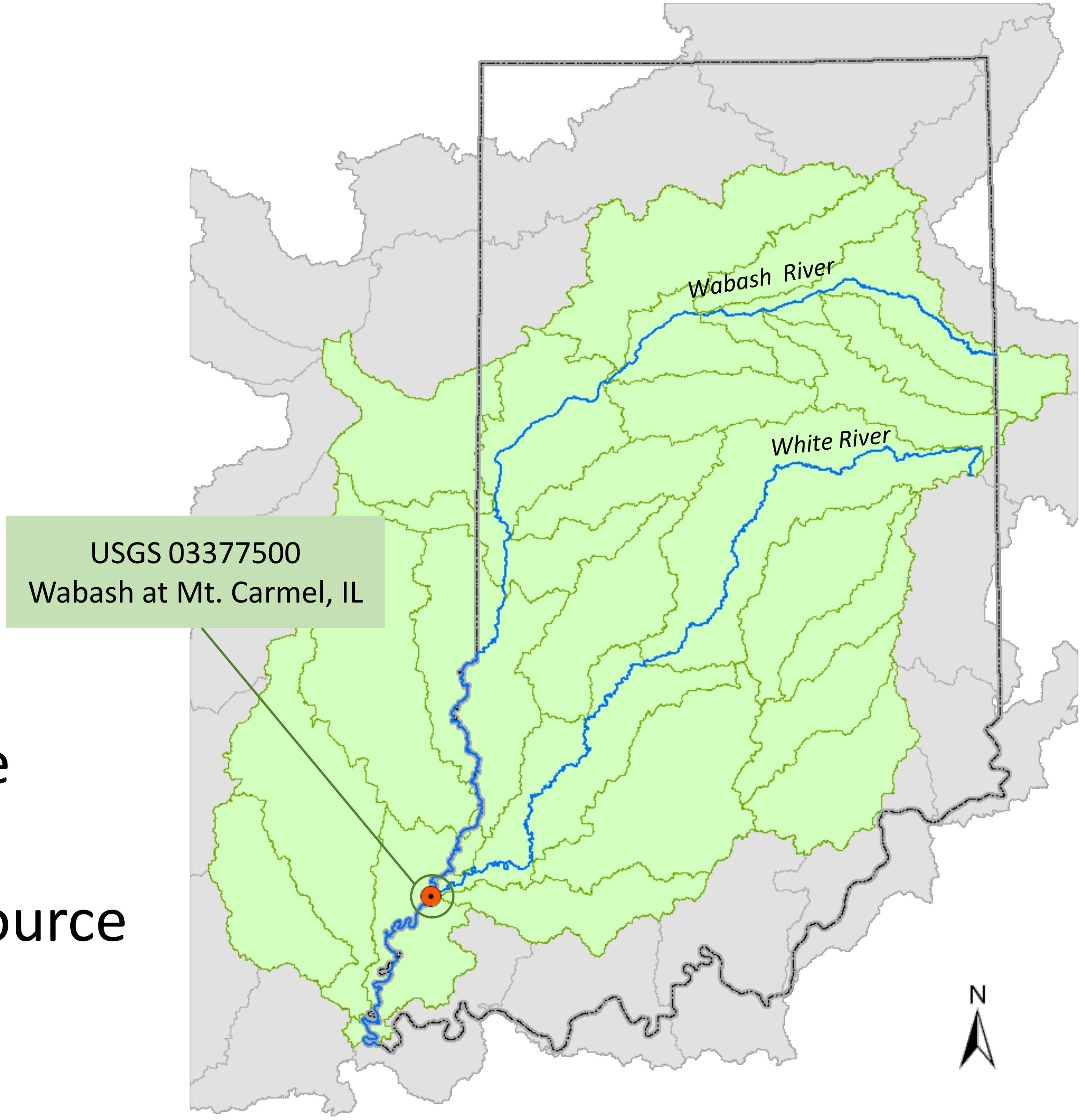
Preliminary case study

- Water Balance on Wabash Basin

- Objectives:

  - Develop a methodology

  - Demonstrate the significance of an holistic water resource analysis

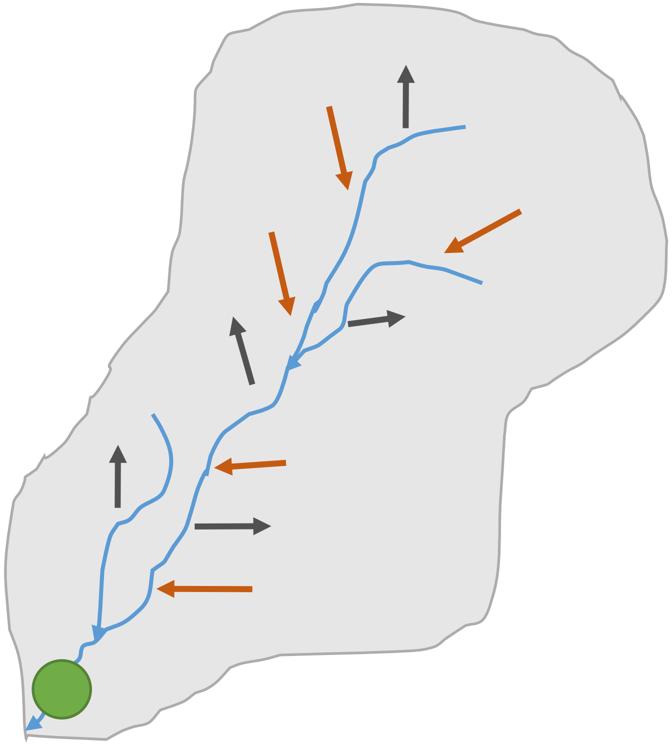


Human Water Cycle...

- Human activity alters the natural water cycle
- When you withdraw water downstream, was it previously used upstream? If so, how much are we reusing the water of the rivers?
- Literature review: EPA's Wastewater in receiving waters at water supply abstraction points, 1980
- Relevance in terms of water resources planning, water quality, public health, inter-jurisdiction regulations/ collaboration/ research.

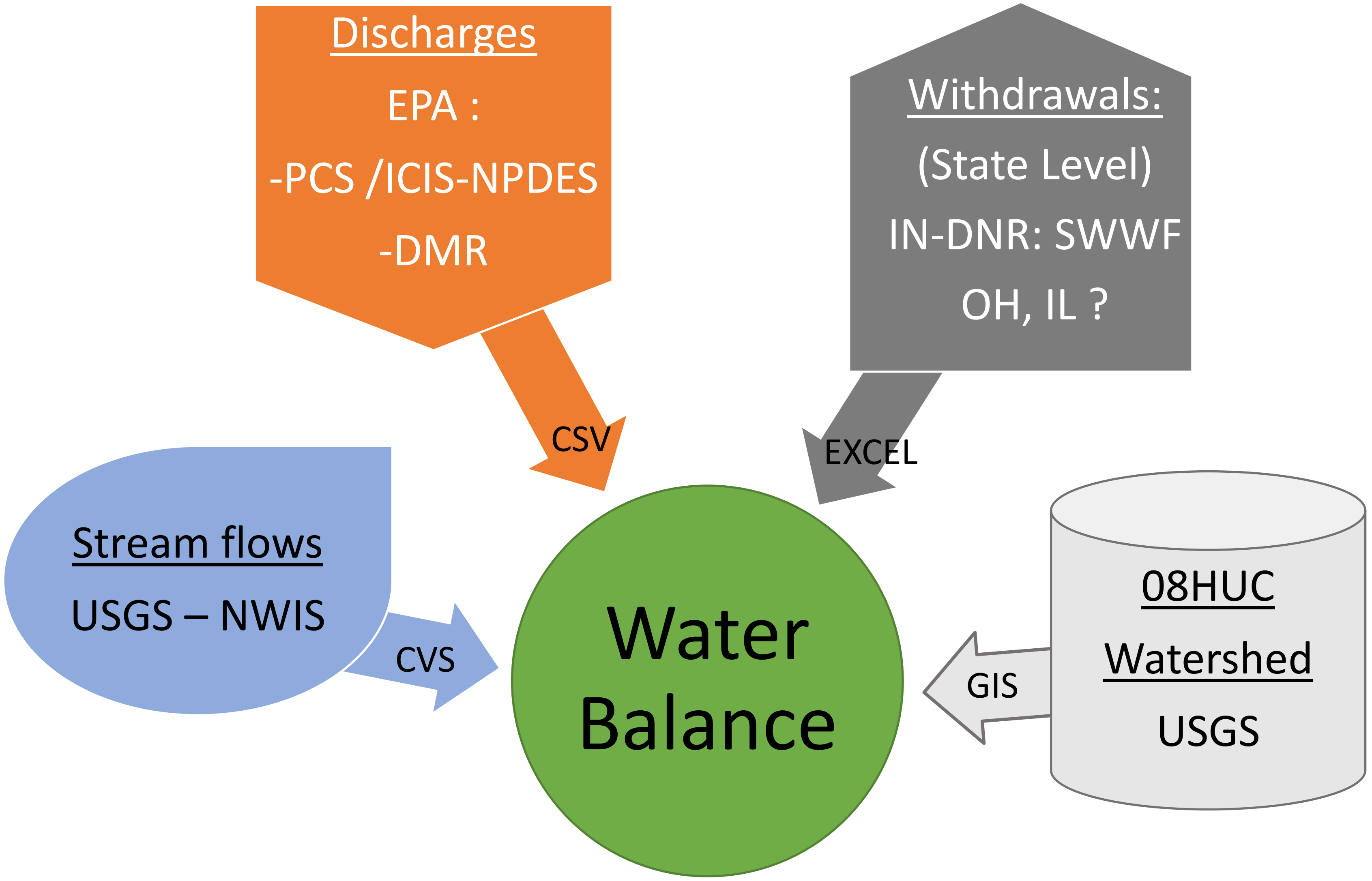
Theoretical Basis

- Assess water reuse by:
  - Determining volume of water DISCHARGED into streams
  - Take US Geological Survey (USGS) gauging station STREAM FLOW measures as reference
  - Evaluate the relationship between discharges and surface waters stream flow



- Compare with volume of surface water WITHDRAWN
- Analysis at different Hydrologic Unit Code (HUC) Levels

Preliminary datasets

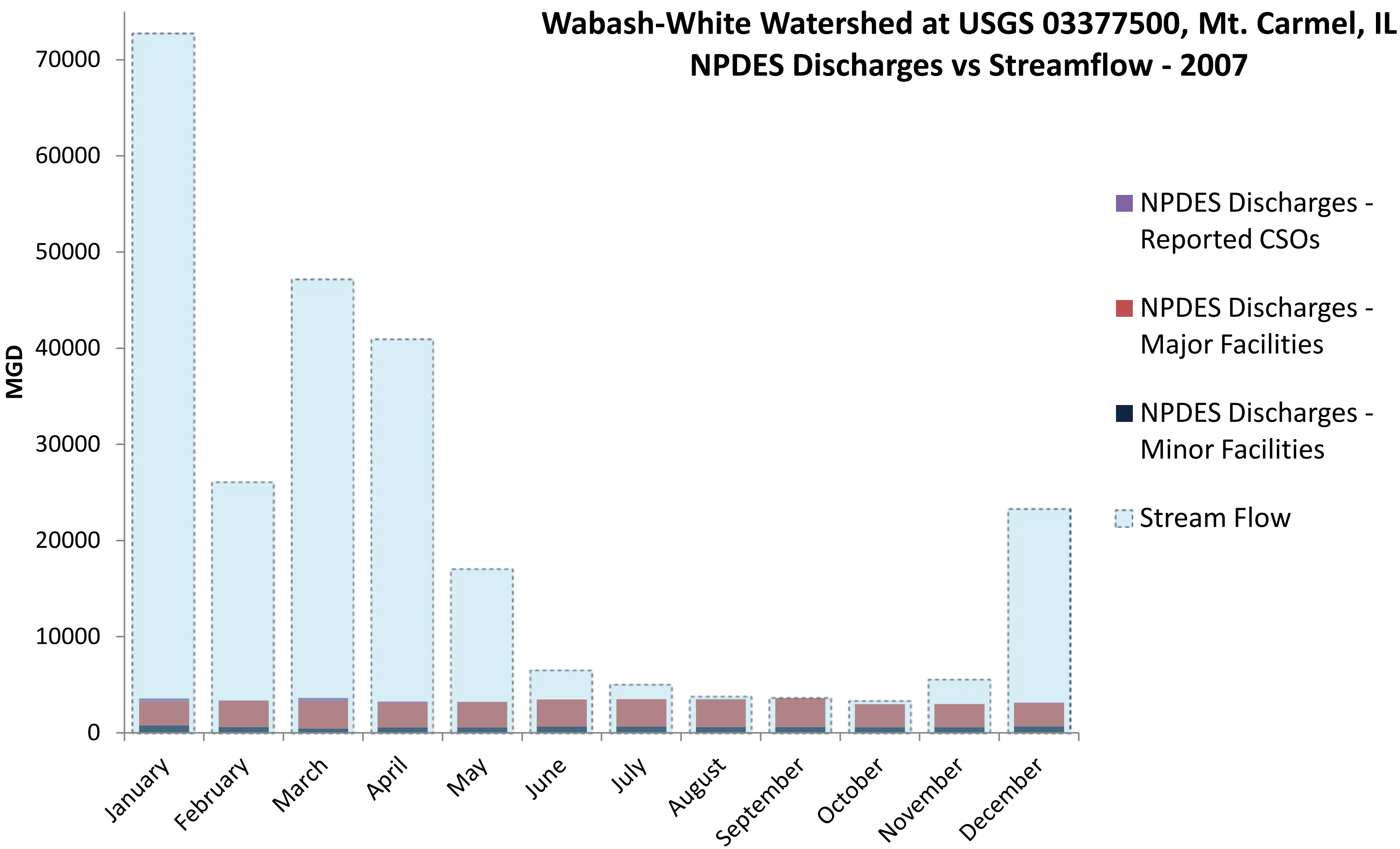


Results

- Integrated geospatial + temporal water use database for Wabash Watershed
  - Quantitative data:
    - Stream flows (time-series)
    - Volume of water withdrawals / discharges
  - Qualitative data:
    - Discharges / withdrawals characterization
    - Watersheds water use and reuse profiles

- Key element: Watershed Hydrologic Unit Code (HUC) – Natural Boundaries vs Political Boundaries

Results



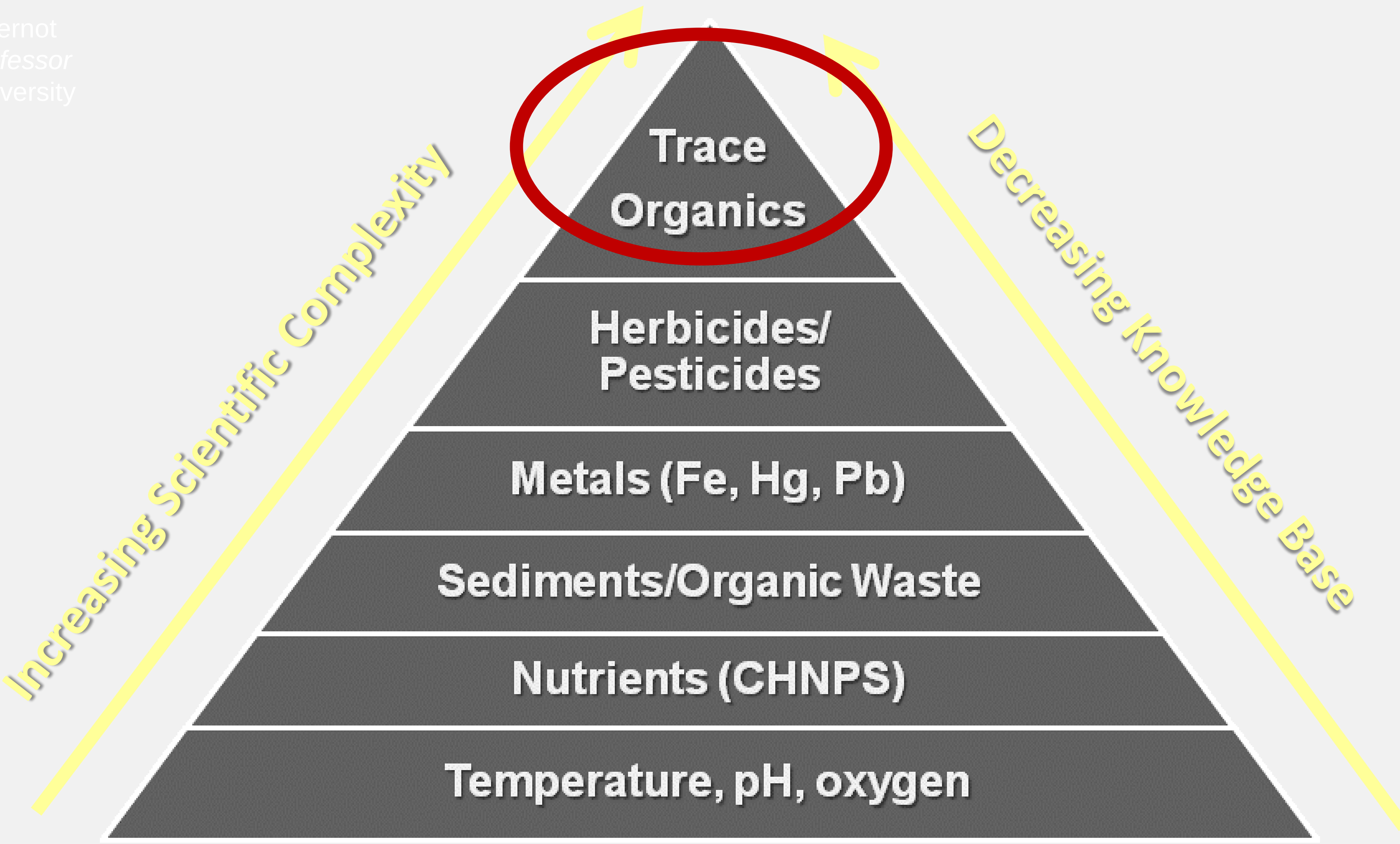
Wabash-White Watershed at USGS 03377500, Mt. Carmel, IL
NPDES Discharges vs Streamflow - 2007
MGD
70000
60000
50000
40000
30000
20000
10000
0
January
February
March
April
May
June
July
August
September
October
November
December
NPDES Discharges - Reported CSOs
NPDES Discharges - Major Facilities
NPDES Discharges - Minor Facilities
Stream Flow

Significance

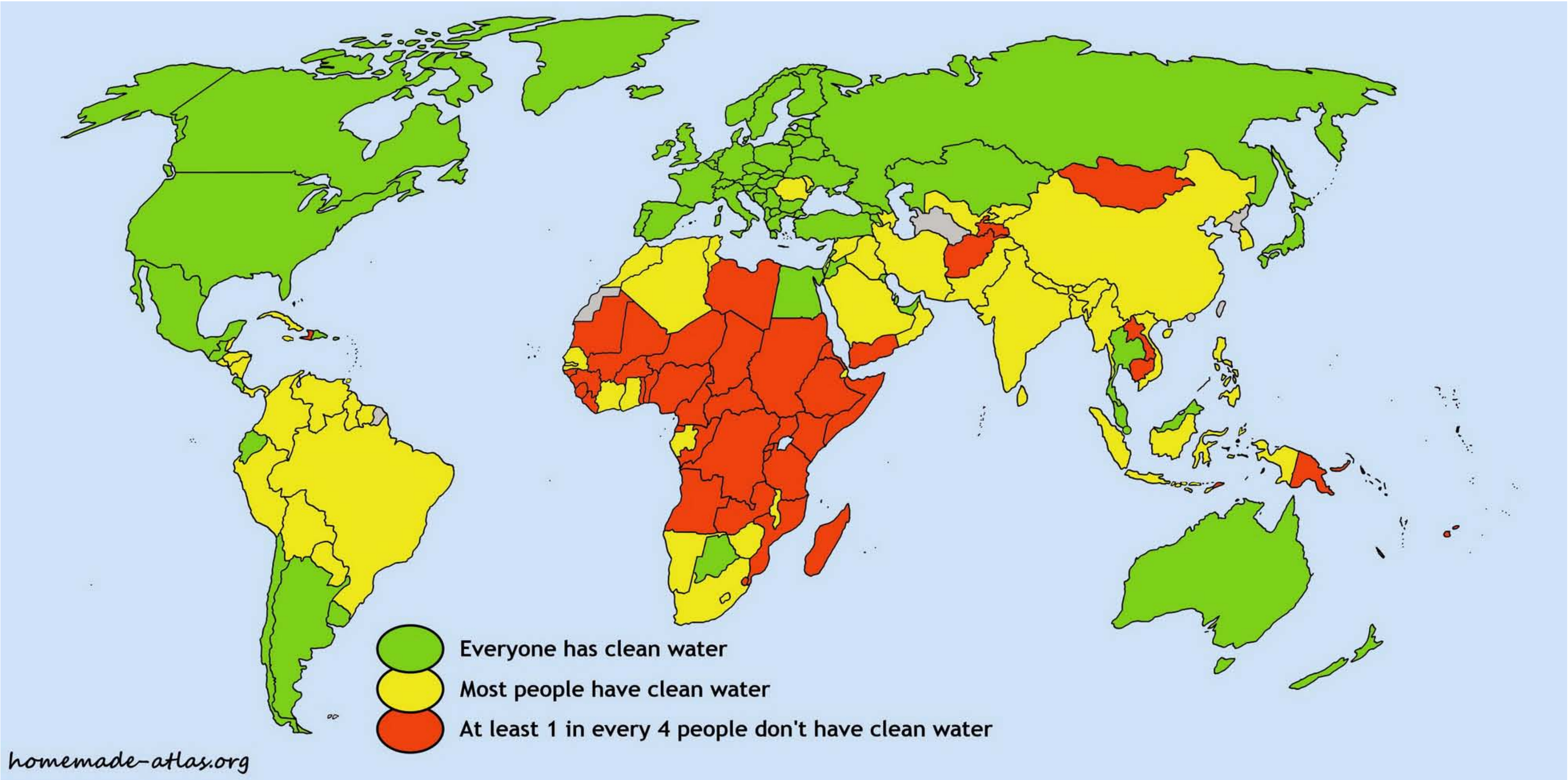
- During low flow months:
  - “Used” water ranges between 5 – 98%
  - We are essentially withdrawing, using, treating and discharging the entire volume of the river
- Relevance of holistic approach – Extent of unplanned water reuse + withdrawals situation => discussion about managing our water resources
- Coordinated data acquisition, data organization and data management would facilitate this type of research

Hierarchical complexity of freshwater pollutants

y J. Bernot
nt Professor
te University



Combination of weak supplies and contamination results in ~ 3 million water related deaths per year.



http://www.indianawaterways.com/rivermaps.htm

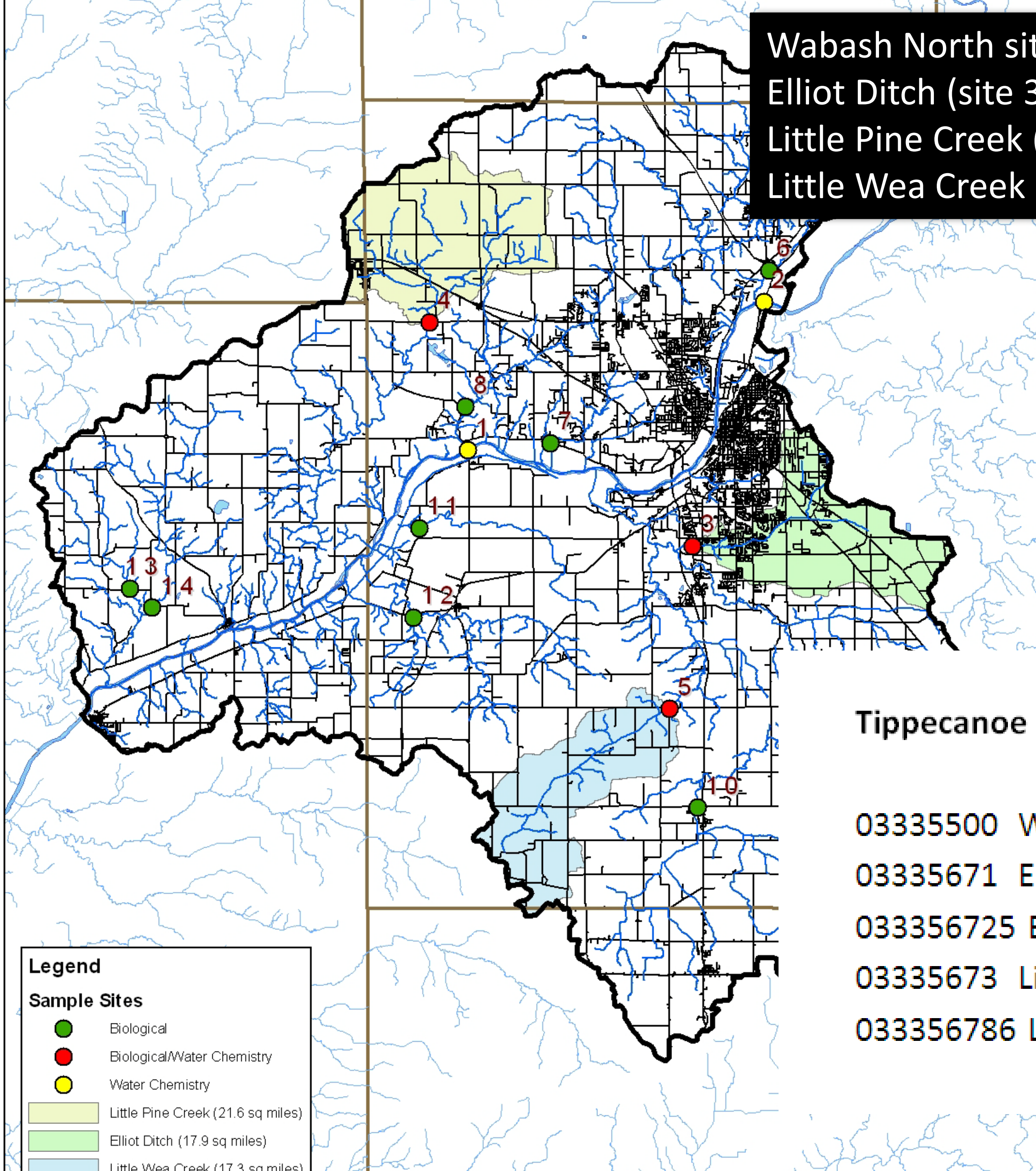
Components of the watershed planning and implementation that benefit from monitoring

- Identify Problems and Causes
- Identify Sources and Calculate Loads (con x vol)
- Identify Critical Areas (where to manage)
  - Choose Best Management Practice to apply
- Show Improvement

Three types of monitoring

Sampling Blitz (public participation)	**200 sites, 2 times per year**
Biological Monitoring	**10 sites, 4 times per year**
Weekly & continuous water sampling for flow, water microbiology and chemistry	**5 sites; 52 times per year or Continuous**

Wabash North site 1 / Wabash South site 2
Elliot Ditch (site 3– 46 km^2 area)
Little Pine Creek (site 4– 56 km^2 area)
Little Wea Creek (site 5– 45 km^2 area)

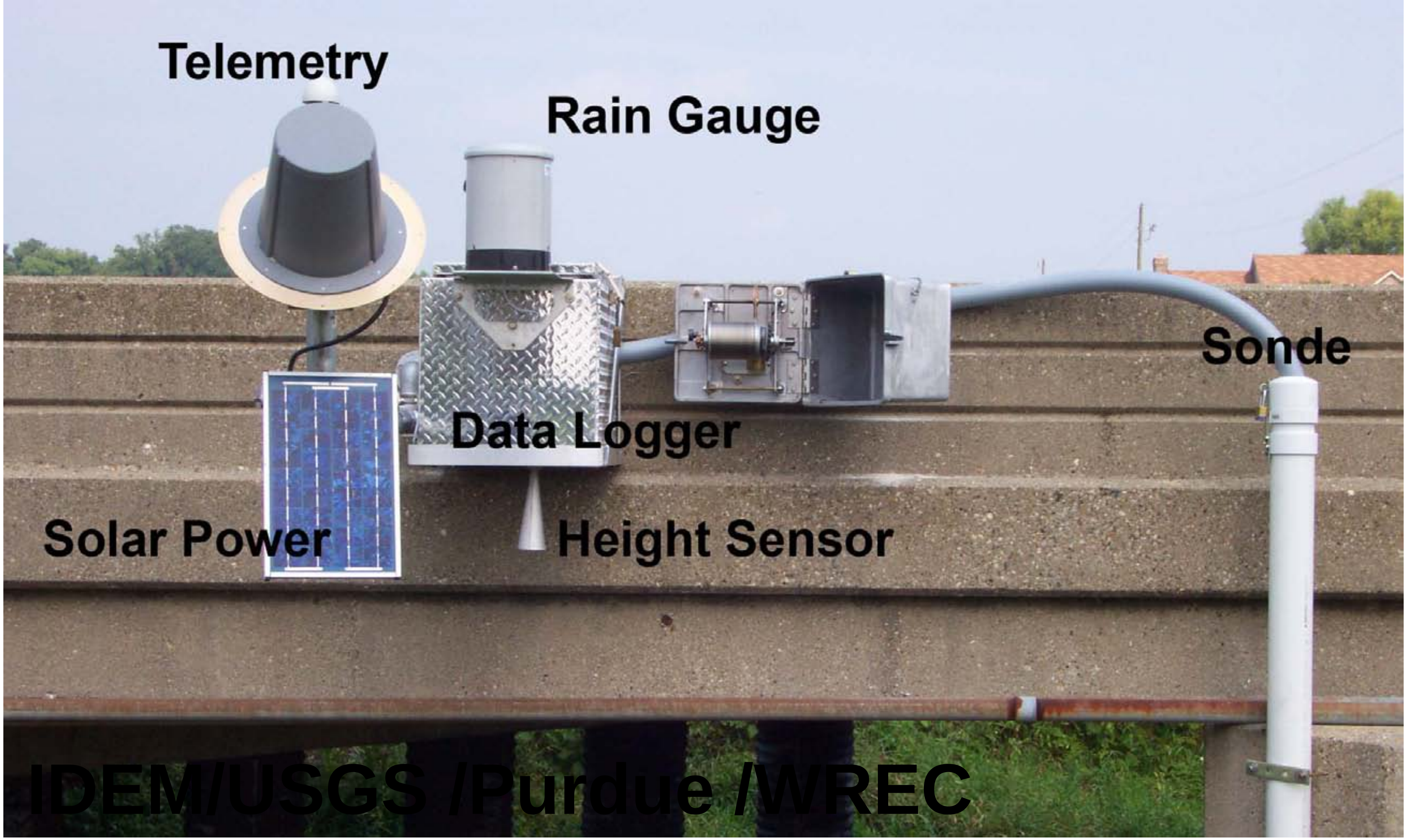


Tippecanoe County, Indiana Gage Sites

03335500 Wabash River – Lafayette IN
03335671 Elliott Ditch (lower section)
033356725 Elliott Ditch (upper section)
03335673 Little Wea Creek
033356786 Little Pine Creek

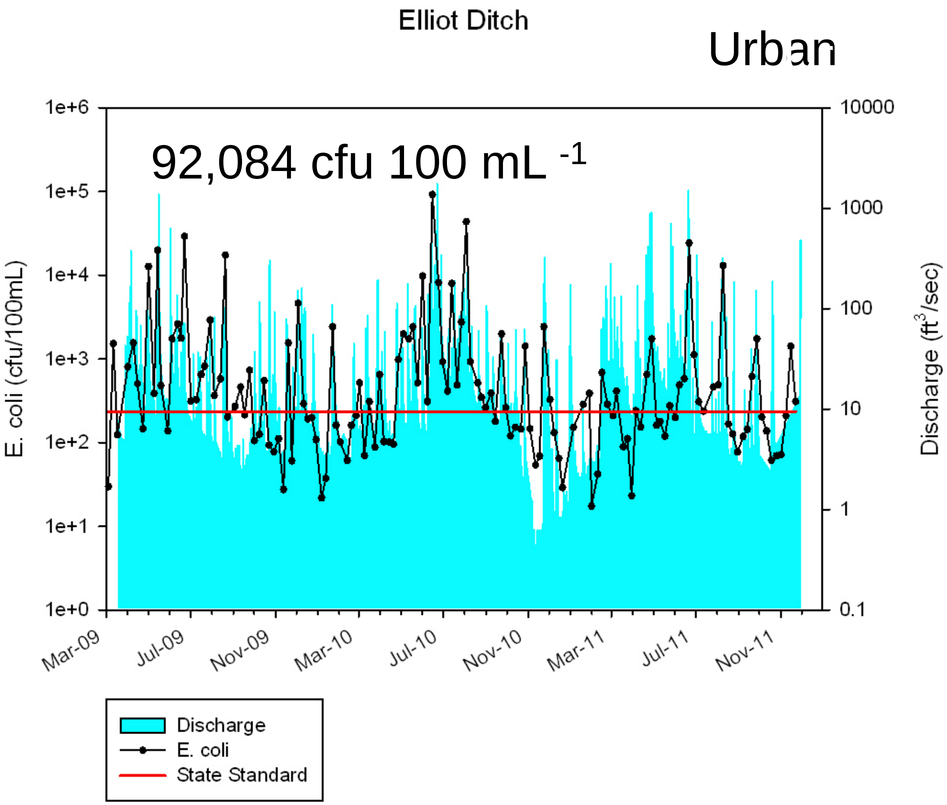
Water Quality Assessment

Gauging Station with Sonde



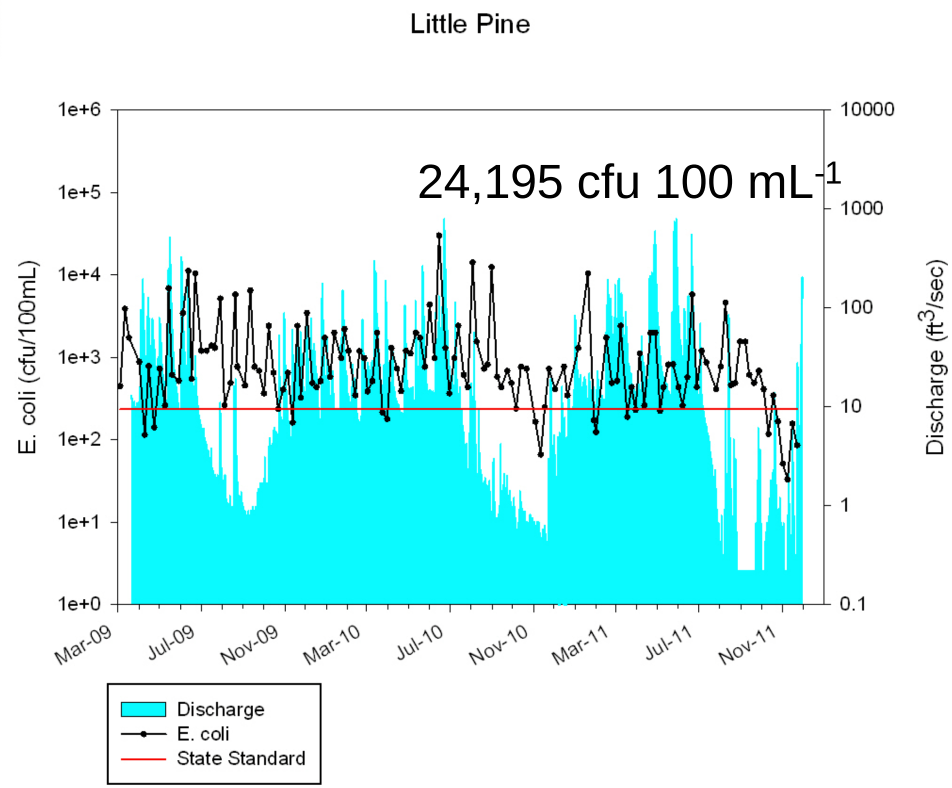
Urban

E. coli & Small Tributaries



X= 2,452 cfu 100 mL^{-1}

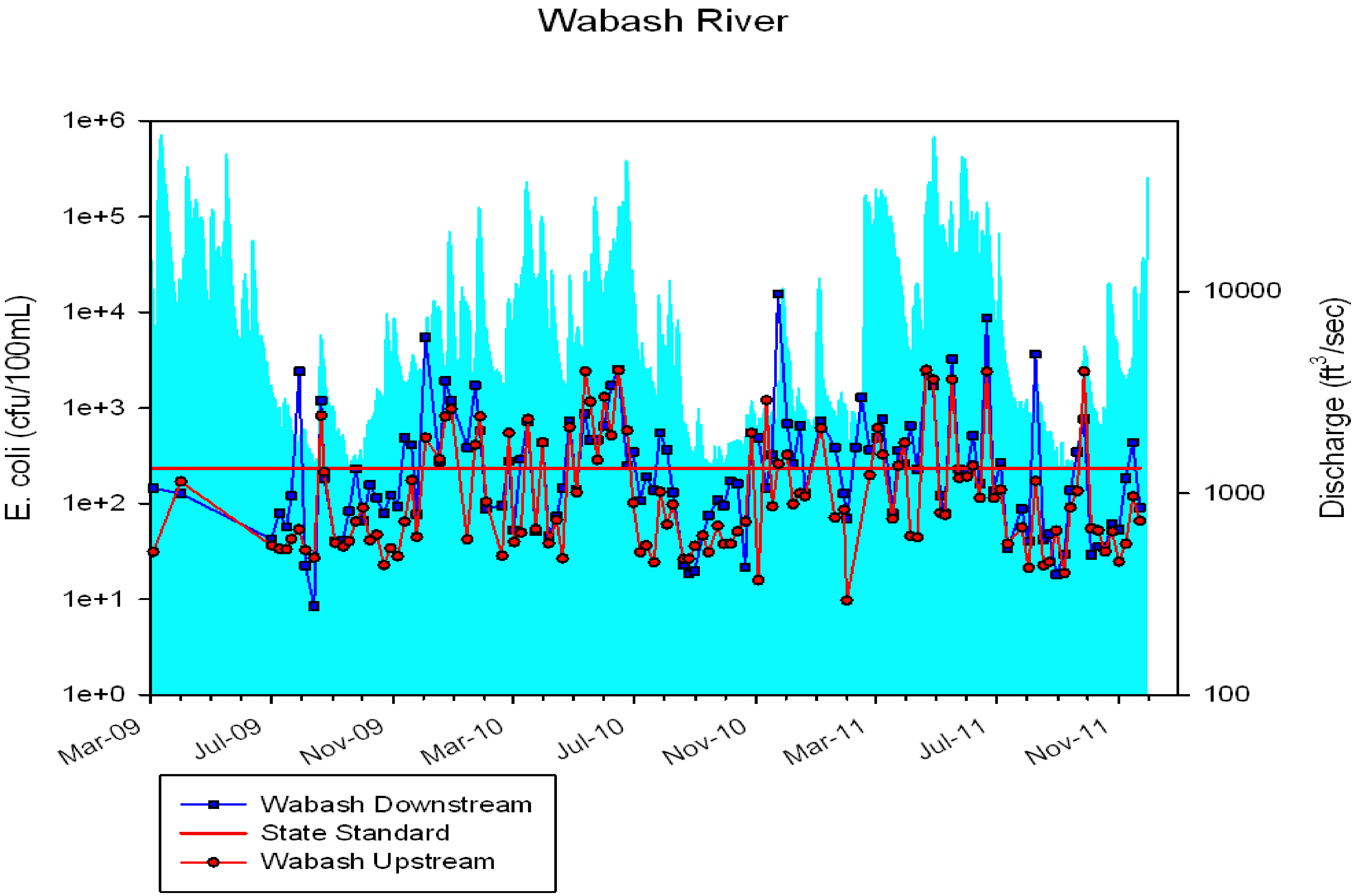
σ =9,444



X= 1,671 cfu 100 mL^{-1}

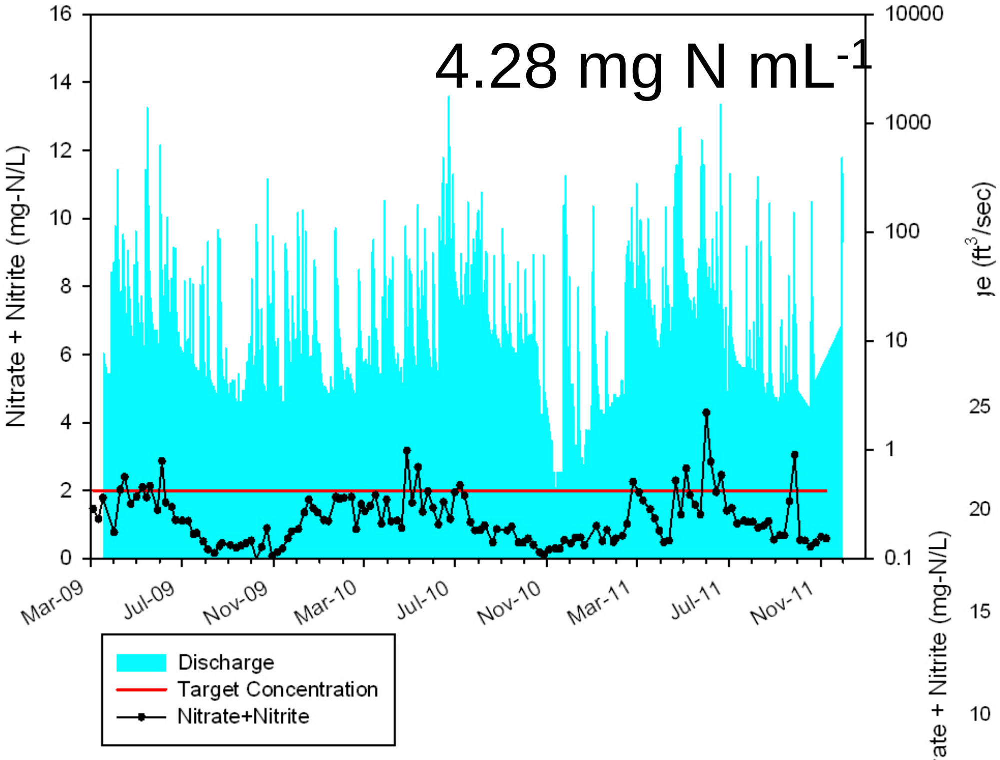
σ =1,237

E. coli in the Wabash



$NO_{3(2)}$ & *Small Tributaries*

Elliot Ditch

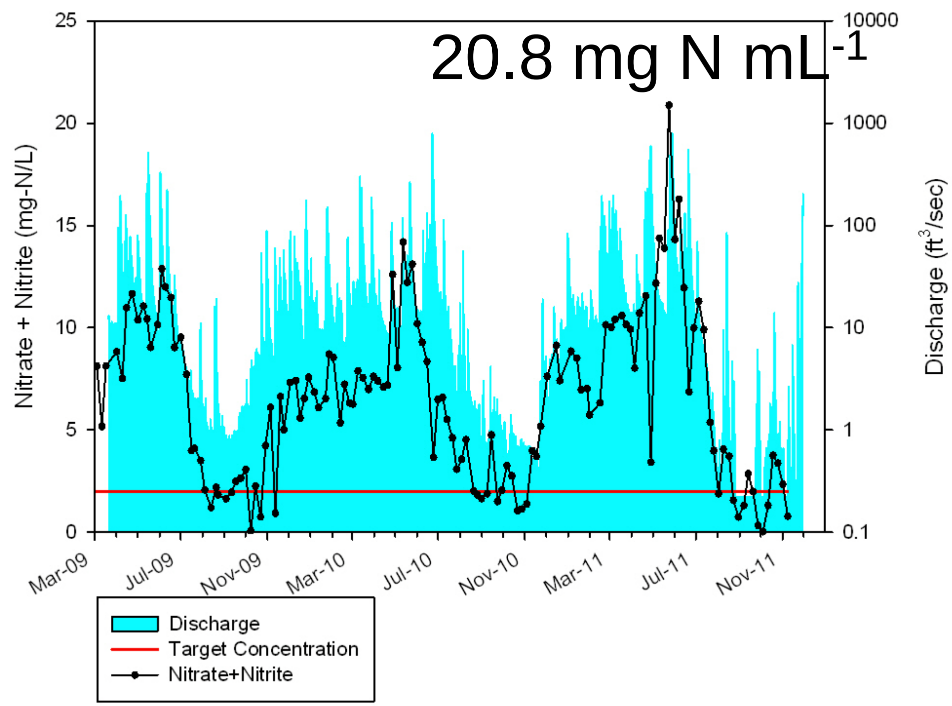


4.28 mg N mL^{-1}

X= 1.14 mg N mL^{-1}

σ =0.74

Little Pine



20.8 mg N mL^{-1}

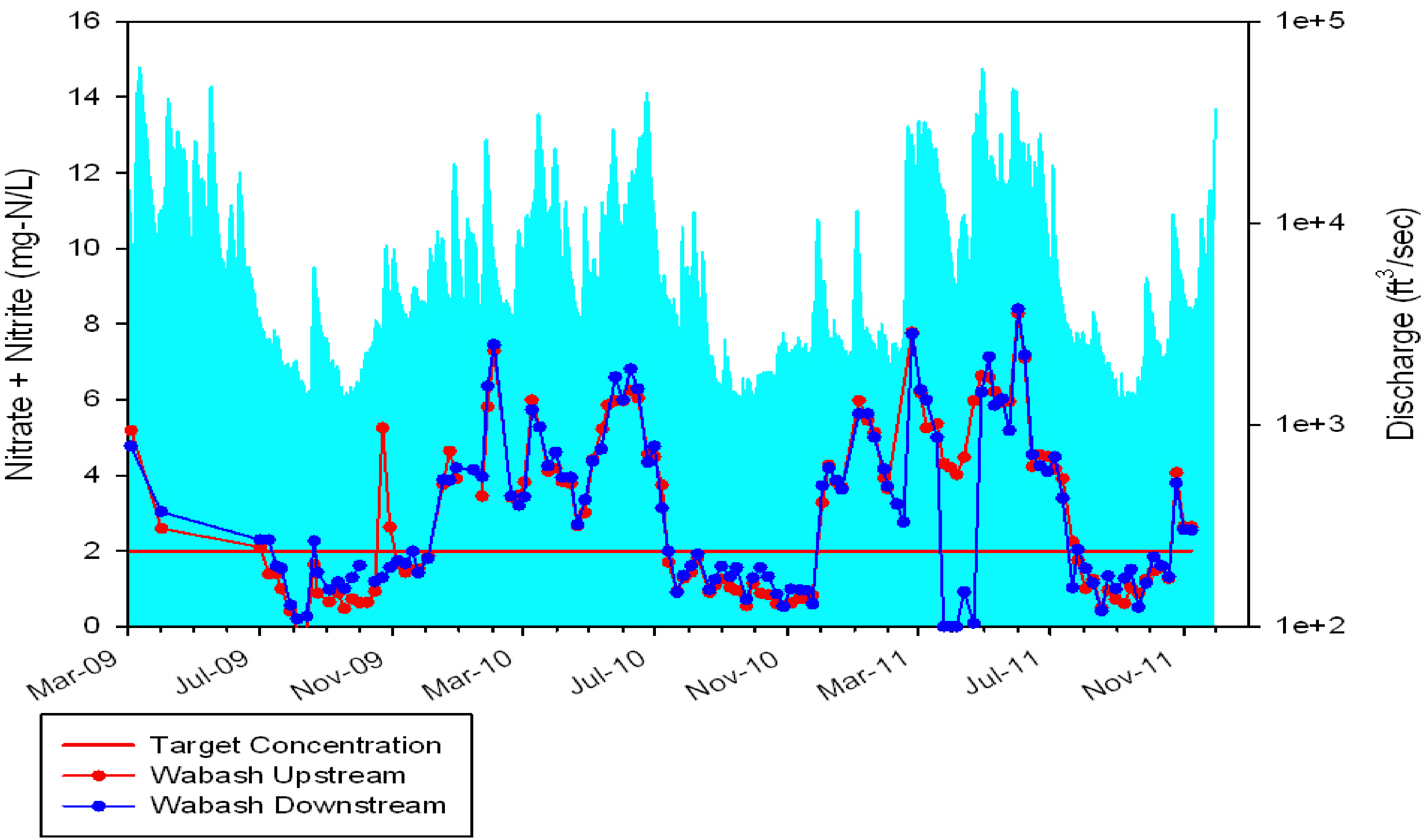
X= 6.42 mg N mL^{-1}

σ =3.99

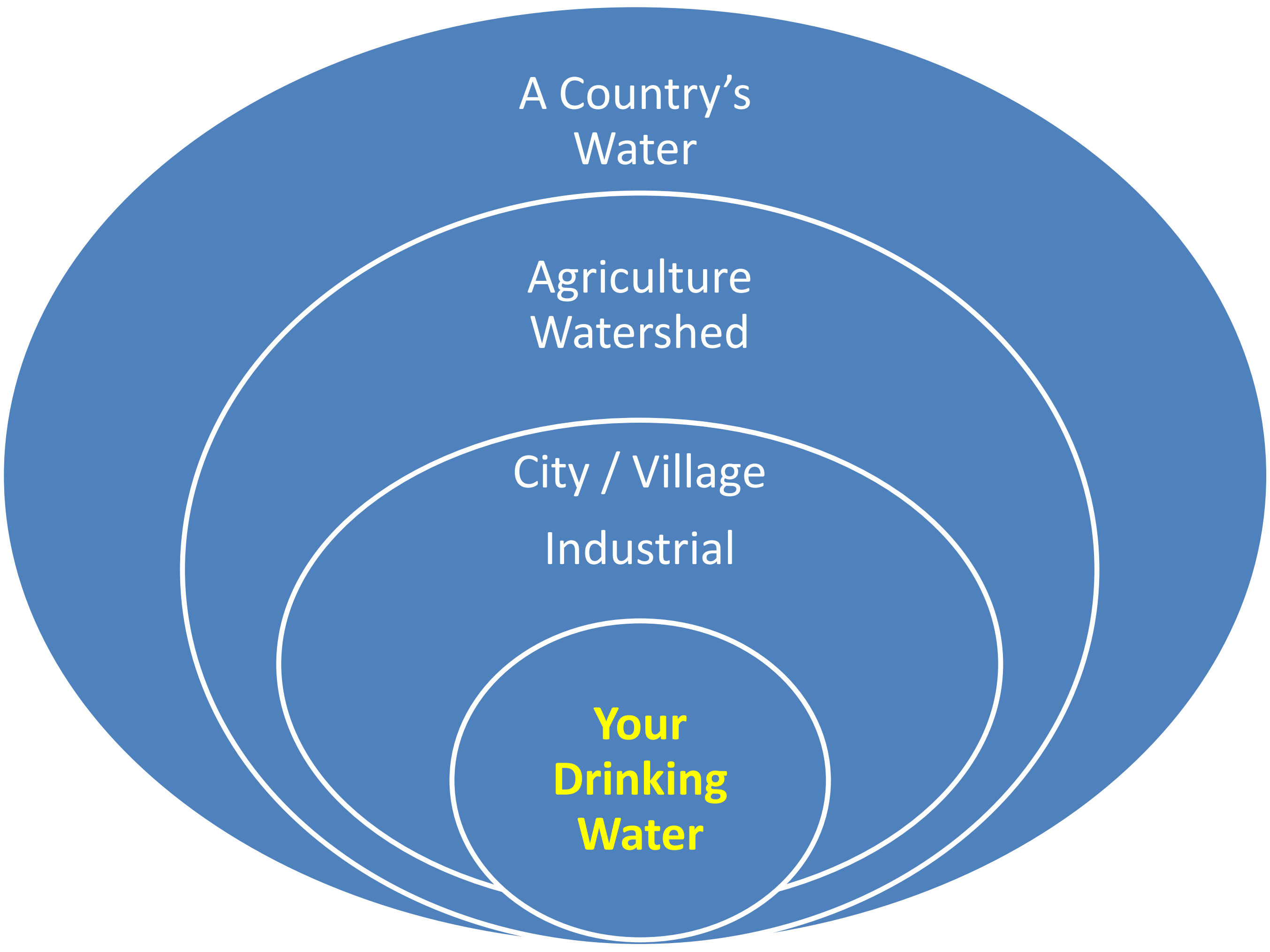
Findings

- Urban system lower number
- Agricultural system shows strong seasonal response

$NO_{3(2)}$-*N* in the Wabash



Your level of concern about water is directly related to where you are standing ..



Sustaining Water

- **Protect and Restore Water Quantity and Quality**
  - Model water balance
  - Require implementation of pollutant reductions and equity in solution
  - Address future contaminants (anticipate the impacts)

- **Address Interconnected Nature of Water**
  - Integrate water and land use planning
  - Align water, energy, land, transportation policies for sustainability