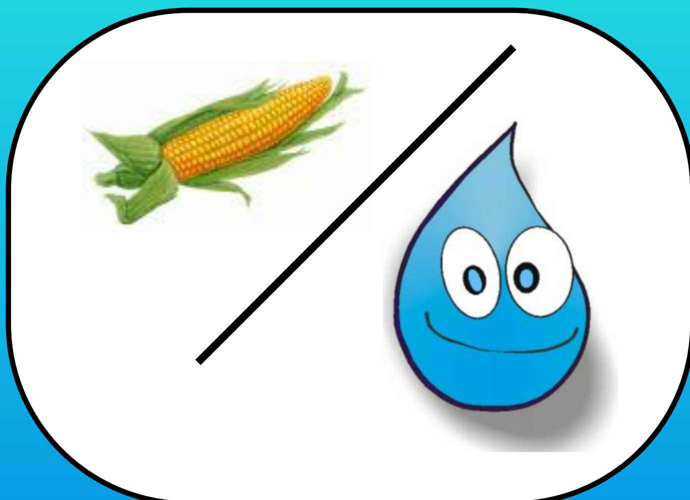
Irrigation Efficiency v.s. Sustainability

Confusing Productivity with Aquifer Life



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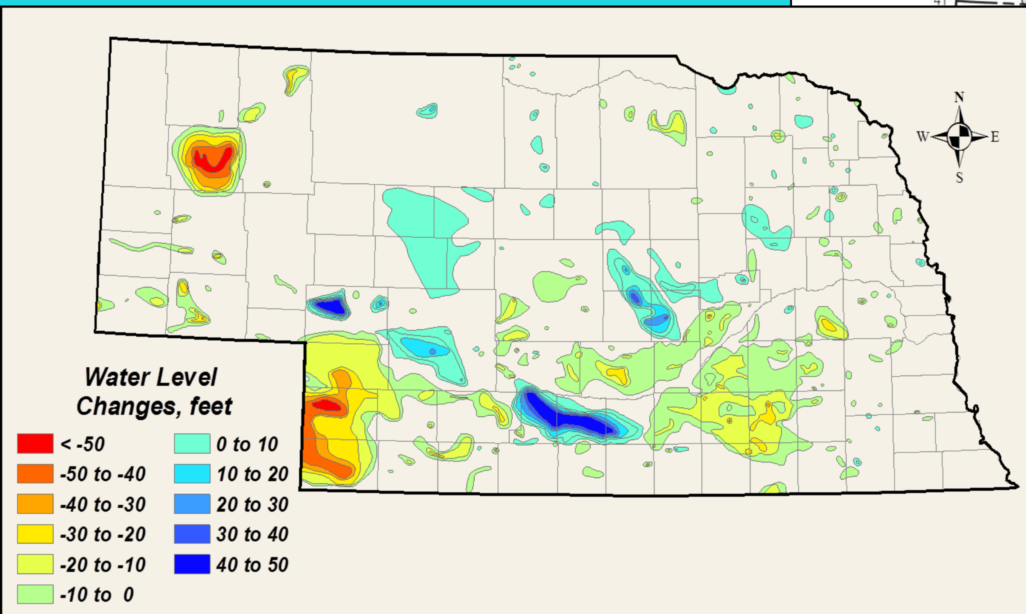
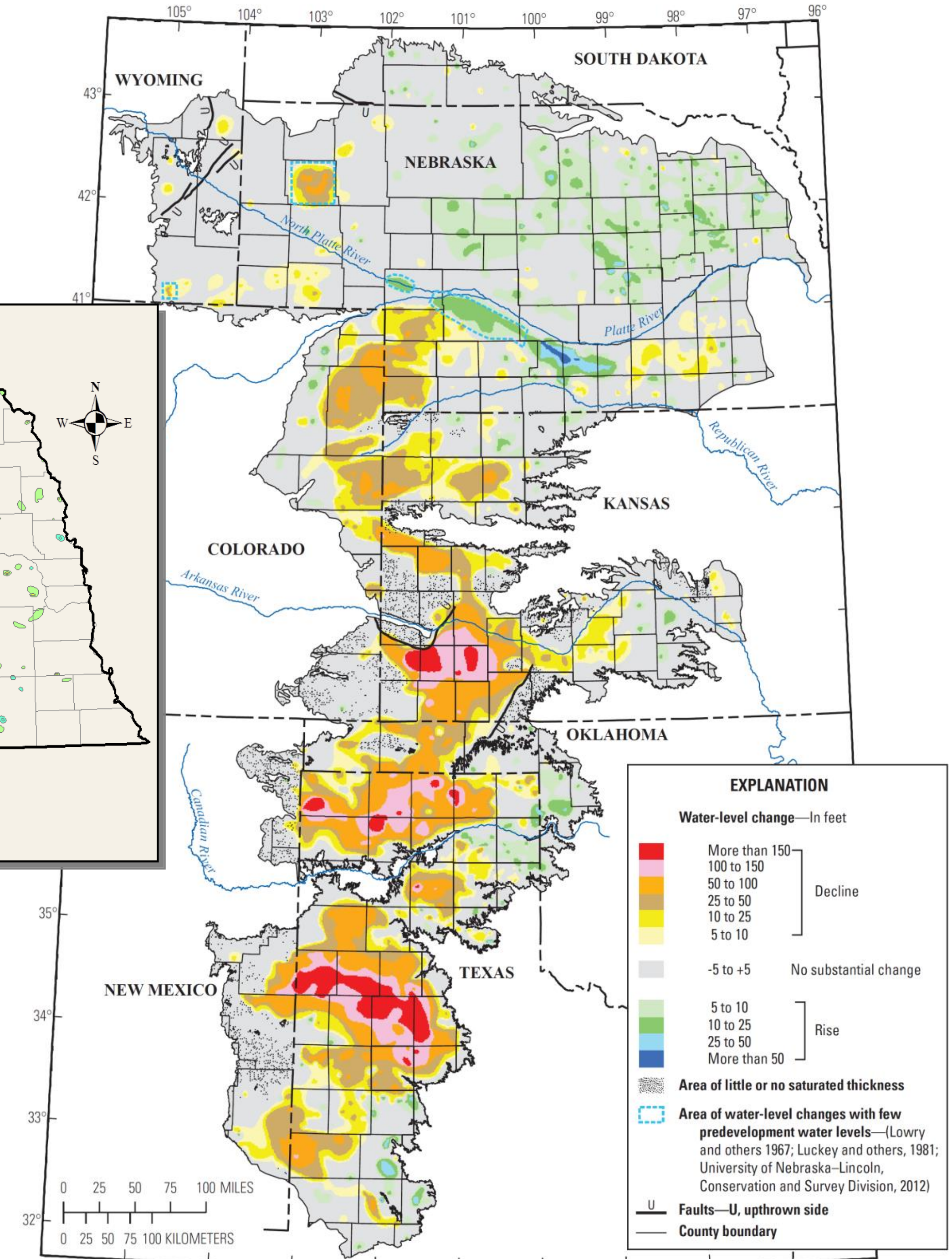
University of Nebraska - Lincoln

What do you see in this picture?

Groundwater Level Changes
Since Predevelopment



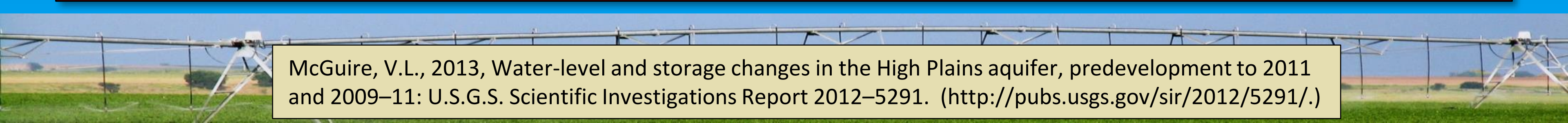


Aquifer Going Dry??

Changes in High Plains Aquifer (1950 - 2011)

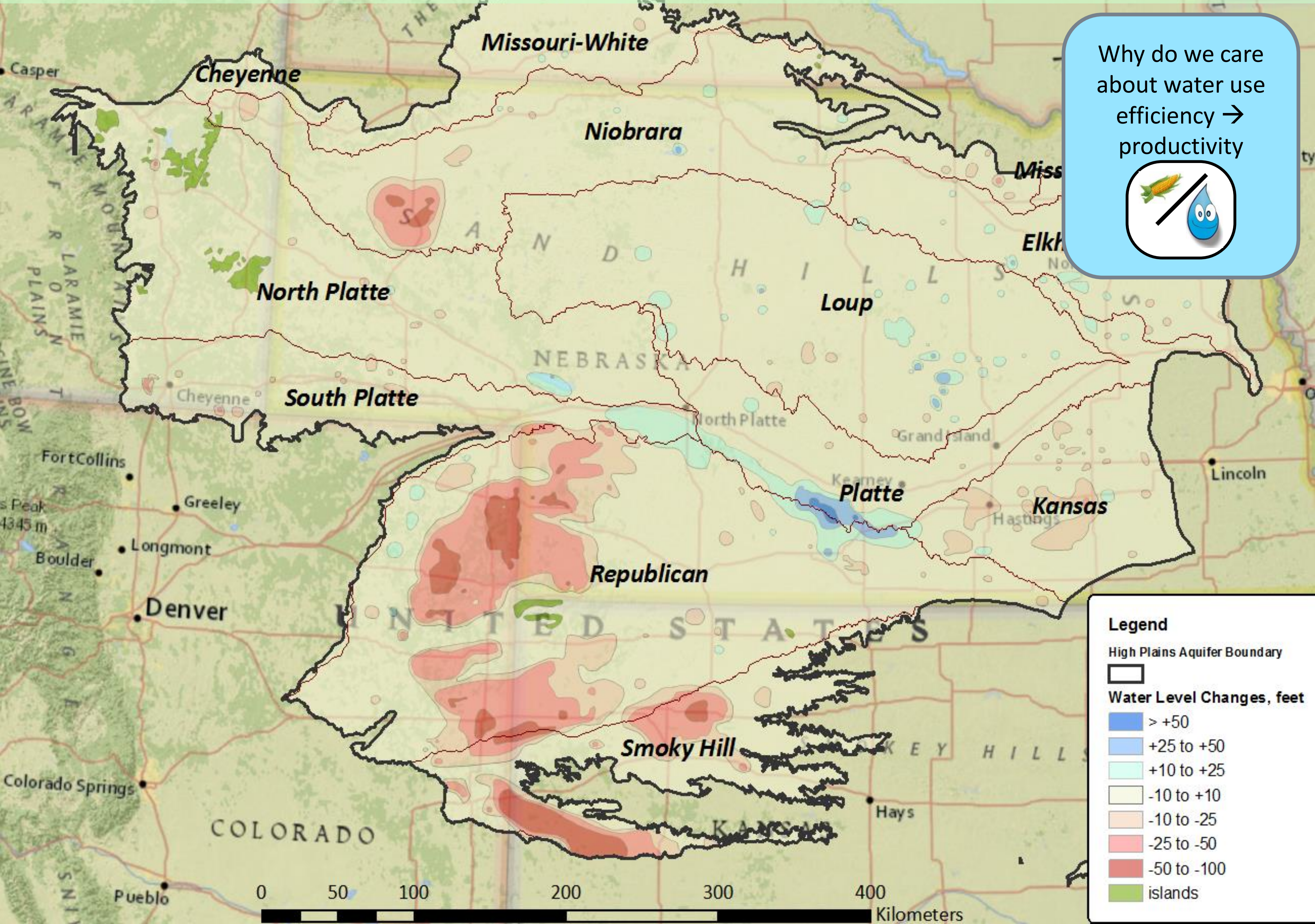
State	Area-Weighted Water-Level Change, feet	Change In Water Storage, millions acre-feet
Colorado	-12.9	-14.8
Kansas	-23.5	-58.2
Nebraska	0.7	1.1
New Mexico	-15.2	-8.2
Oklahoma	-11	-7.5
South Dakota	1.9	0.2
Texas	-38.9	-136.5
Wyoming	-1.1	-0.7
High Plains Aquifer	-13.9	-224.6

60% of Total Volume Depleted in Texas & 26% in Kansas



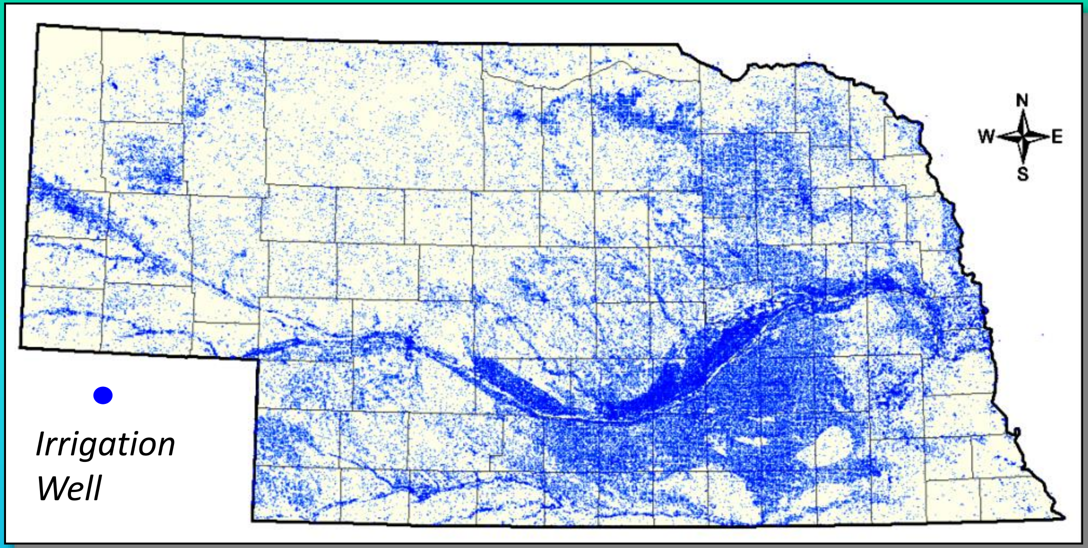
McGuire, V.L., 2013, Water-level and storage changes in the High Plains aquifer, predevelopment to 2011 and 2009–11: U.S.G.S. Scientific Investigations Report 2012–5291. (http://pubs.usgs.gov/sir/2012/5291/.)

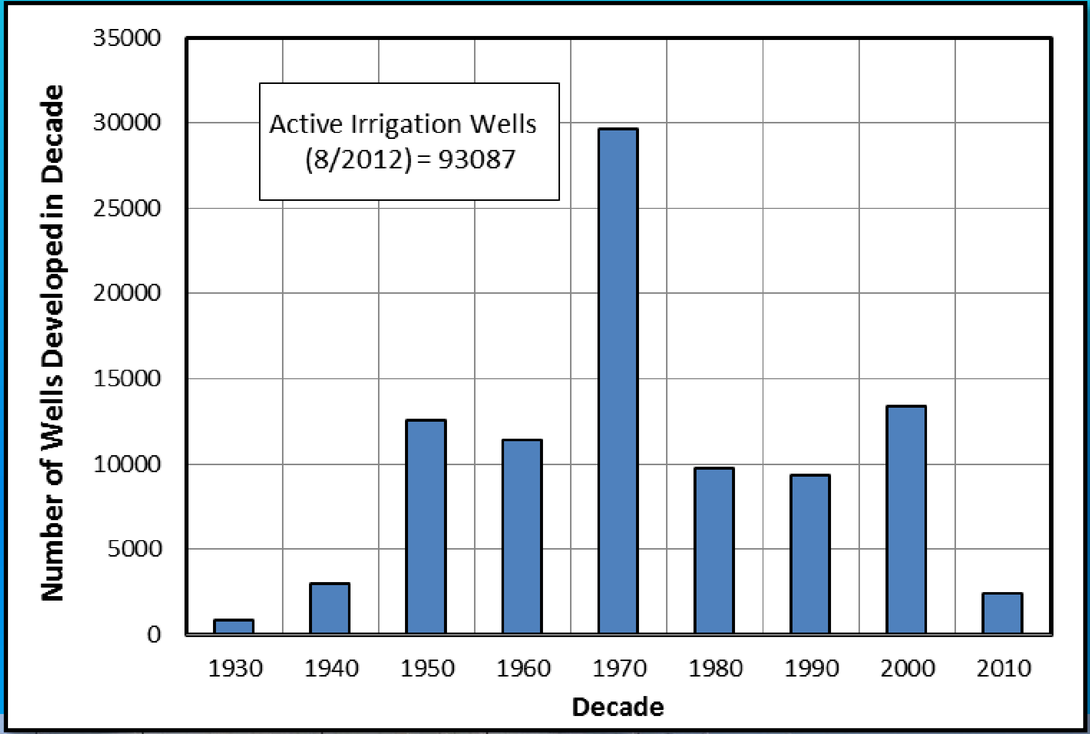
Groundwater Levels in the Northern High Plains



Irrigation Development

Active Irrigation Wells
~ 93,000
$6-8 Billion Investment

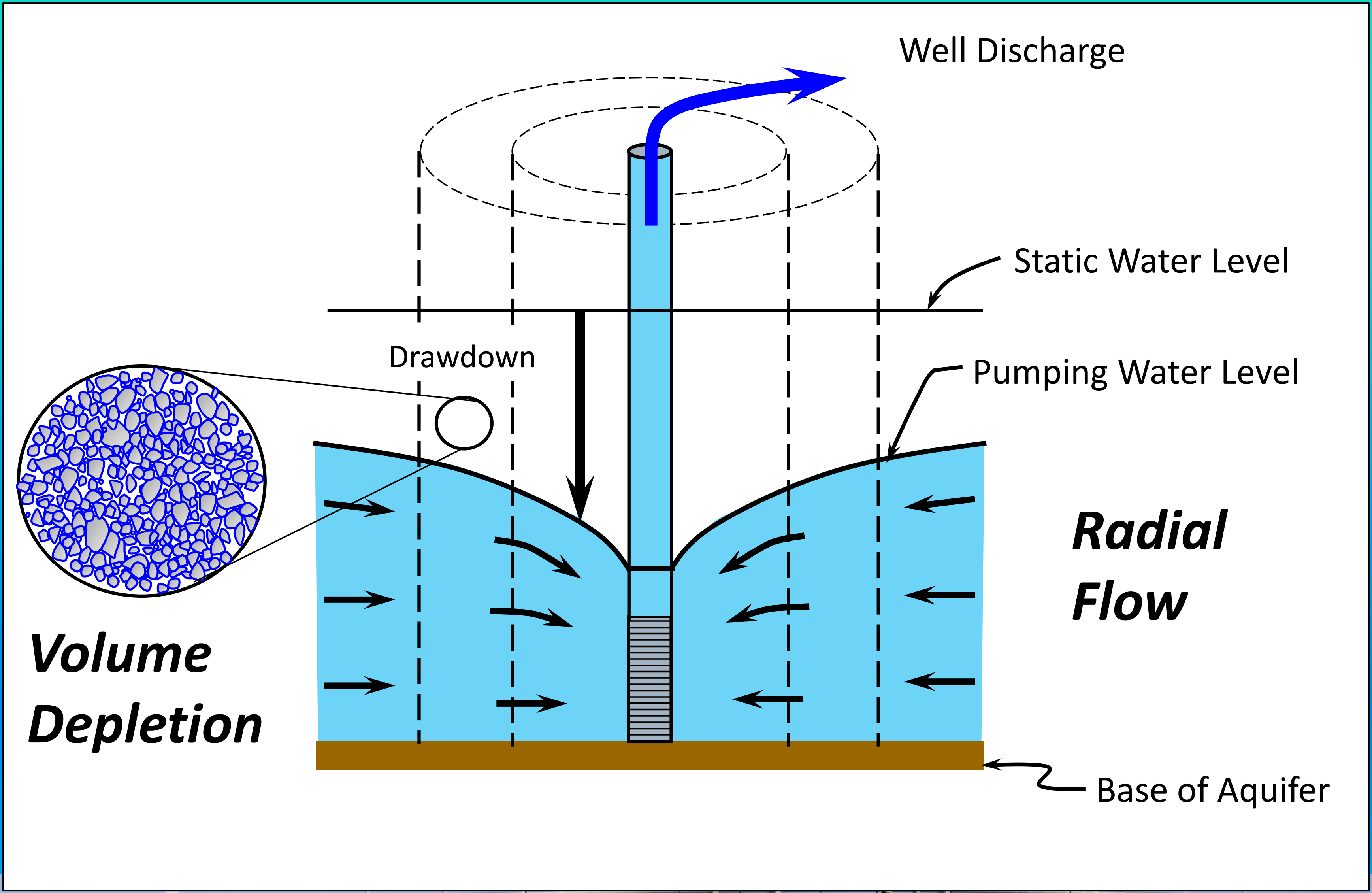




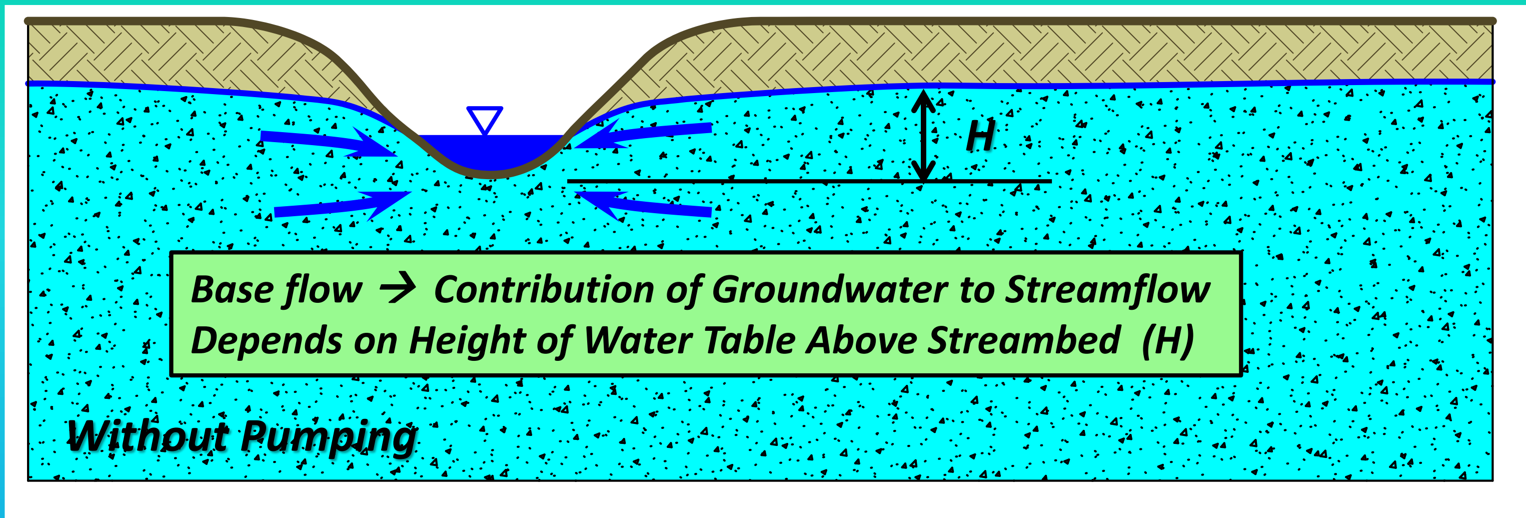
Major development occurred in 70's, but growth continues at about 2000 wells per year

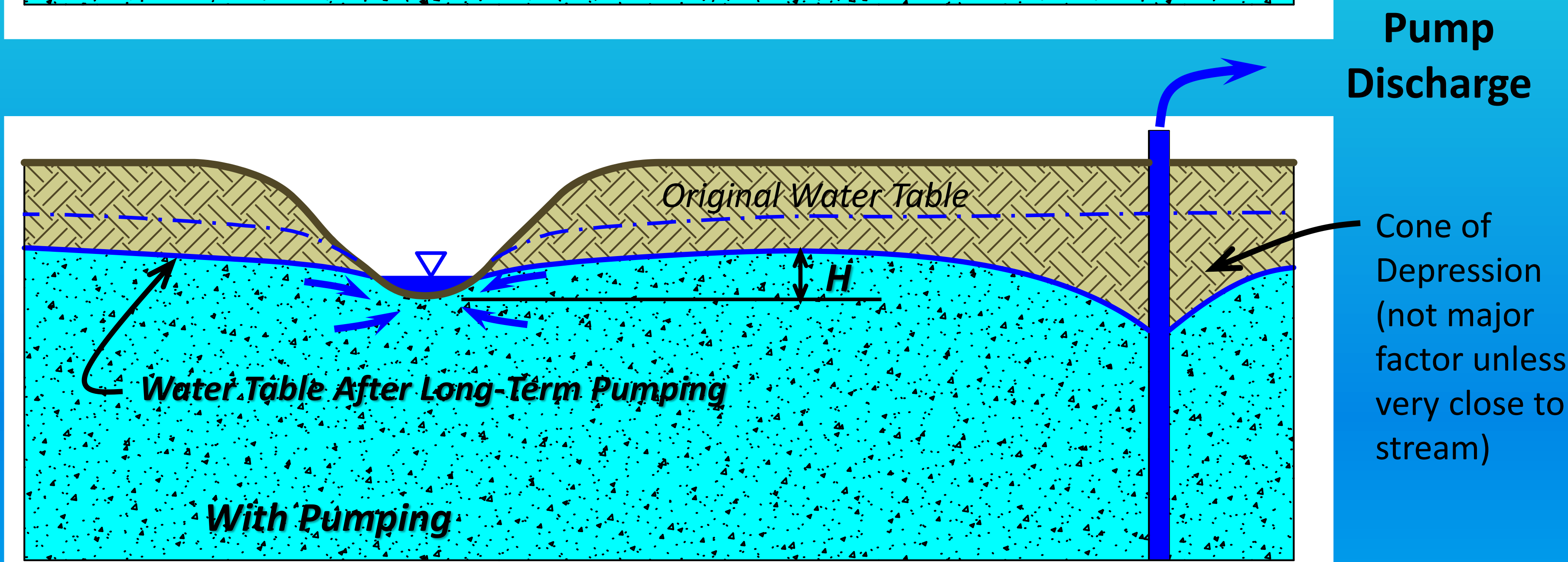
Pumping From An Unconfined Aquifer

Where does the water come from?



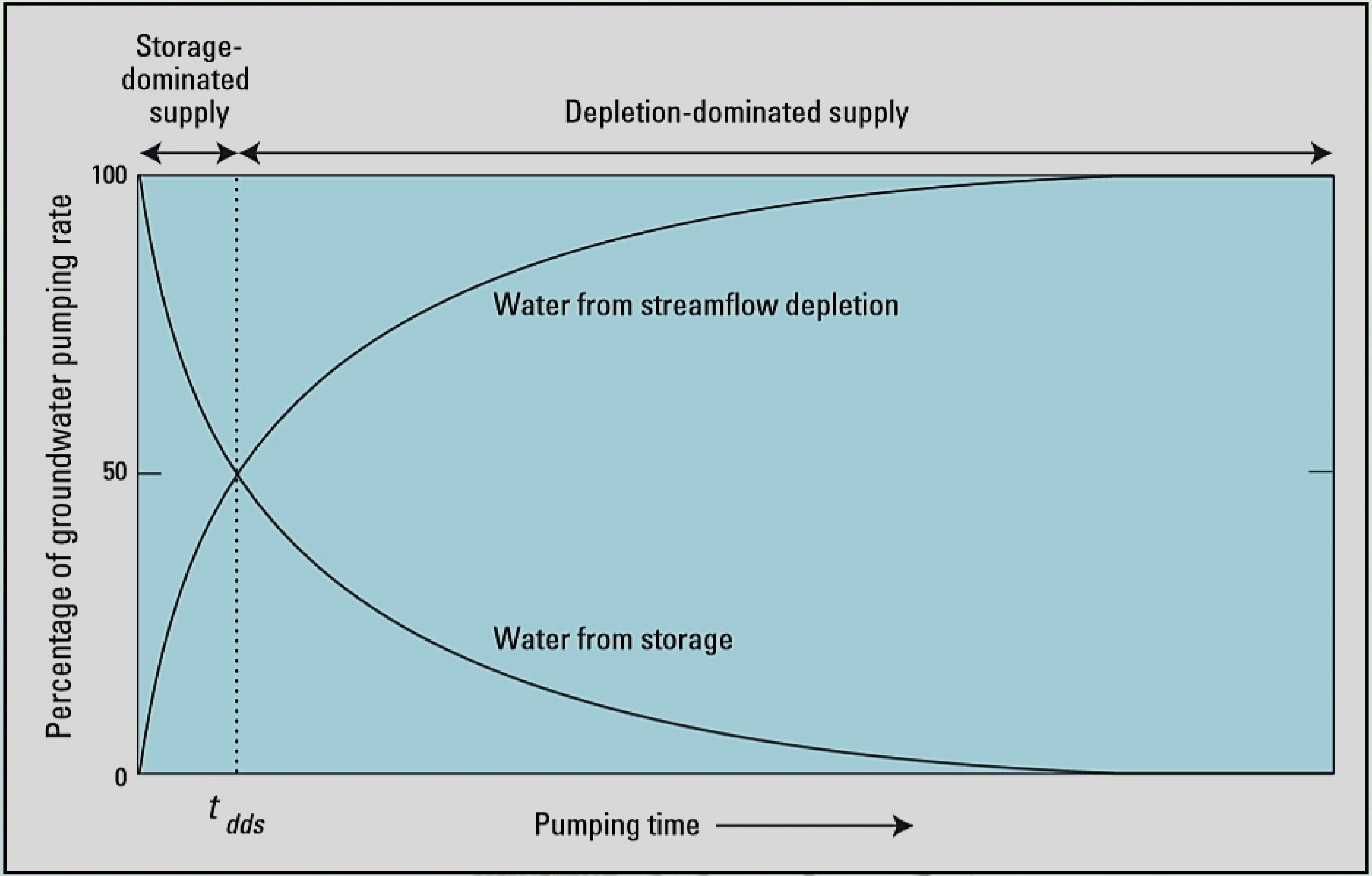
Affect of Pumping on Stream Flow





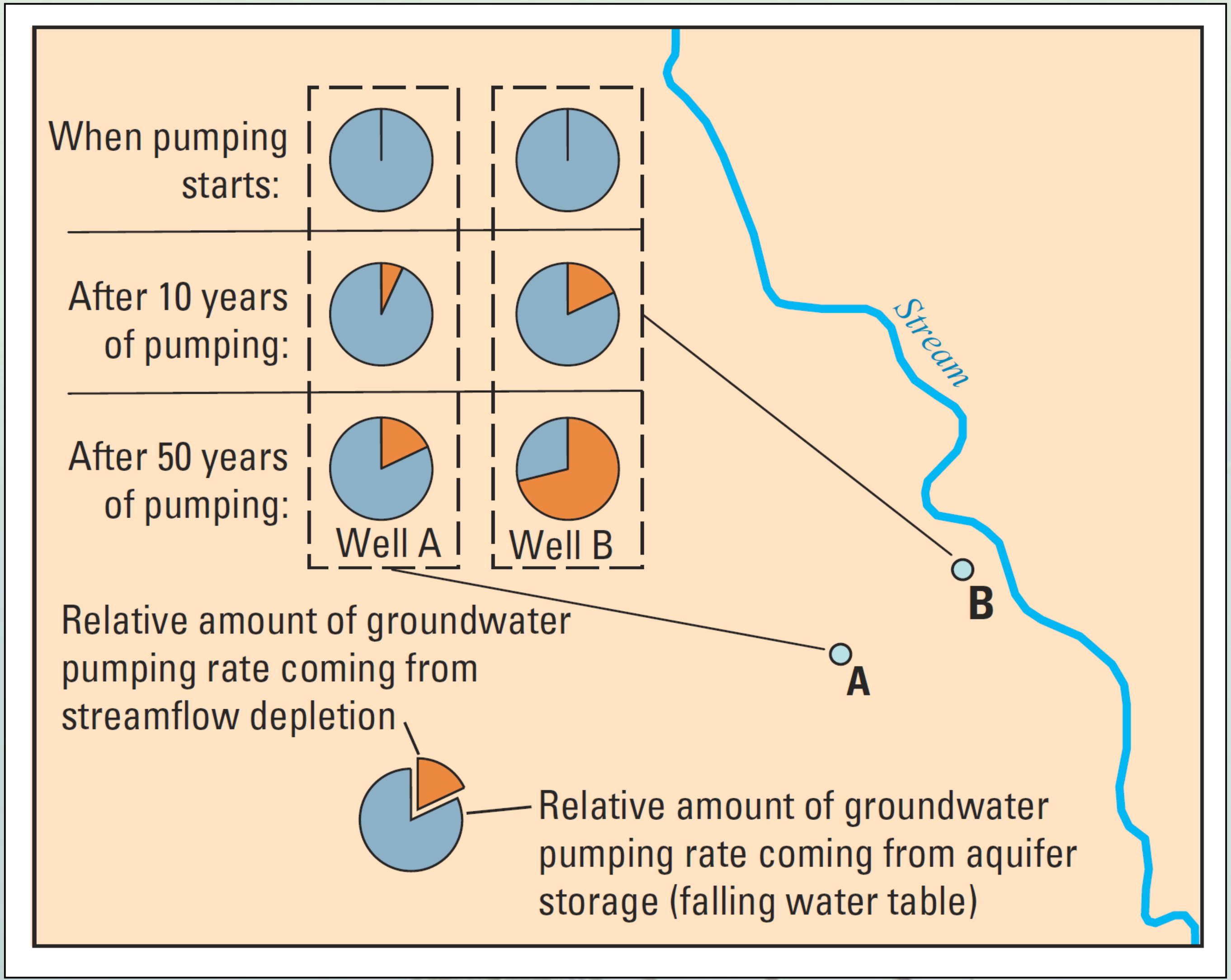
Major affect on baseflow is due to the drop of the static water level.

Source of Pumpage Over Time



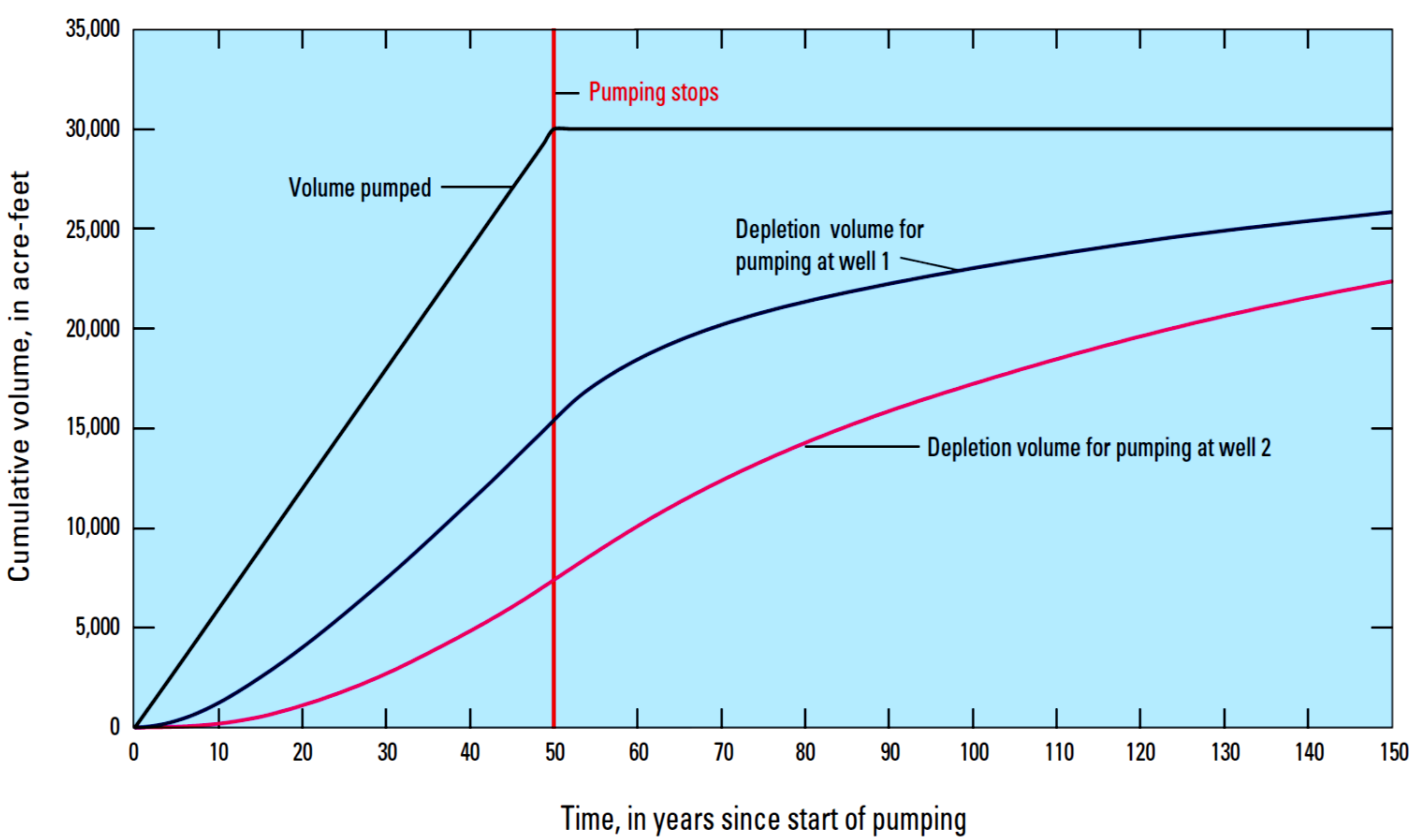
Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion... U.S.G.S. Circular 1376. at http://pubs.usgs.gov/circ/1376/.)

Effects Depend on Distance from Streams



Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion… U.S.G.S. Circular 1376. at http://pubs.usgs.gov/circ/1376/.)

Time Frame for Stream Effects



Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion… U.S.G.S. Circular 1376. at http://pubs.usgs.gov/circ/1376/.)

Water from Energy

- Energy to lift/pressurize water is major input
- Over half of systems powered with electricity
- If all systems were diesel, equivalent use would be about 350 million gallons annually

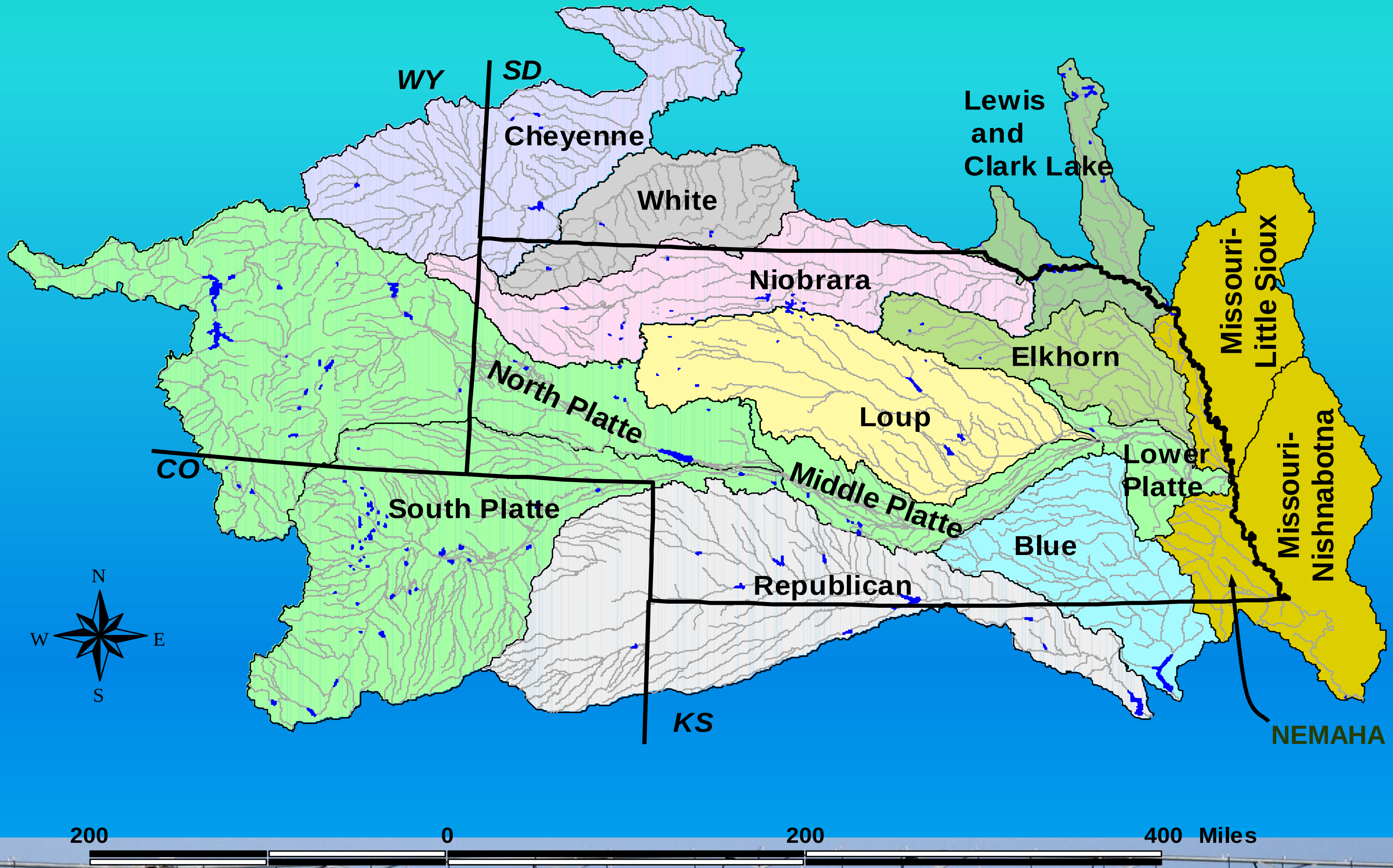
Energy from Water

- Water rights based on irrigation use, energy benefits from storage and controlled release
- Hydropower pays large share of bills for districts
- Biofuels major consumption of production → water
- Often increases federal controls that would not exist without hydropower
- Conservation—Development cycles

- Ethanol a

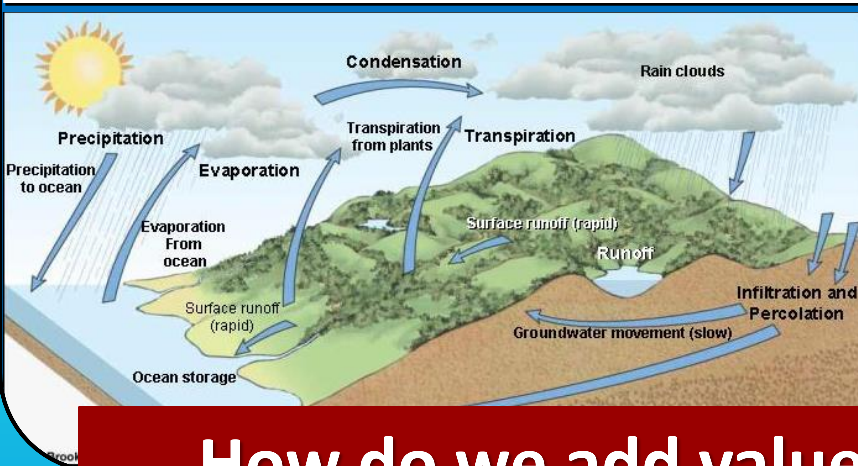
Shared Watersheds Exacerbates Conjunctive Management

Maintenance of Instream Flow is ***THE*** Issue for Downstream State → Big Instream Demand

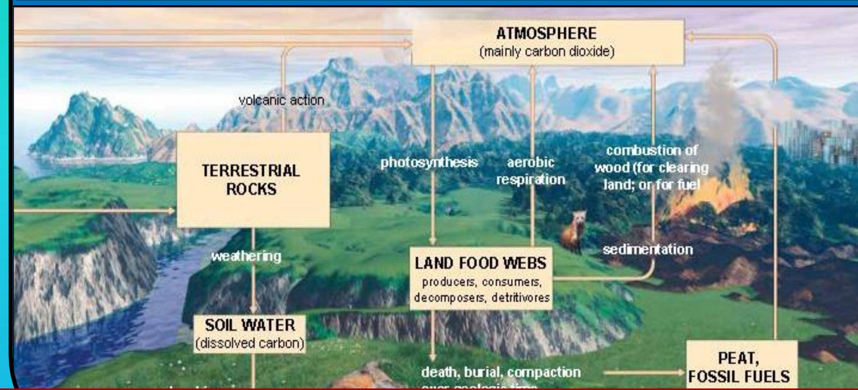


Ecosystem Processes and Functions

Hydrologic (Water) Cycle



The Carbon Cycle

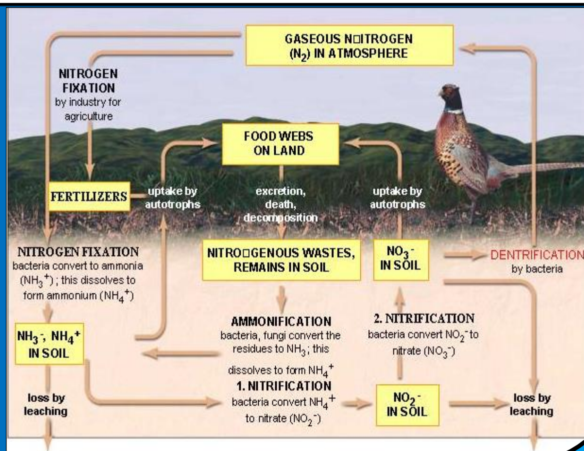


How do we add value/money to the producer?

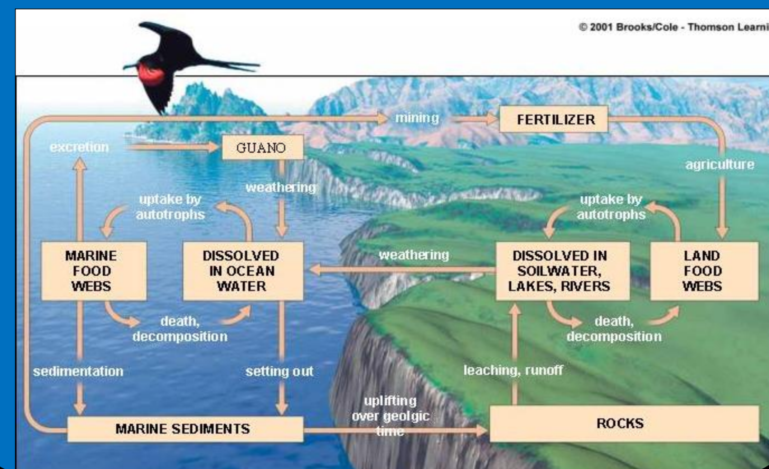
The Nitrogen Cycle

Root nodules on legumes

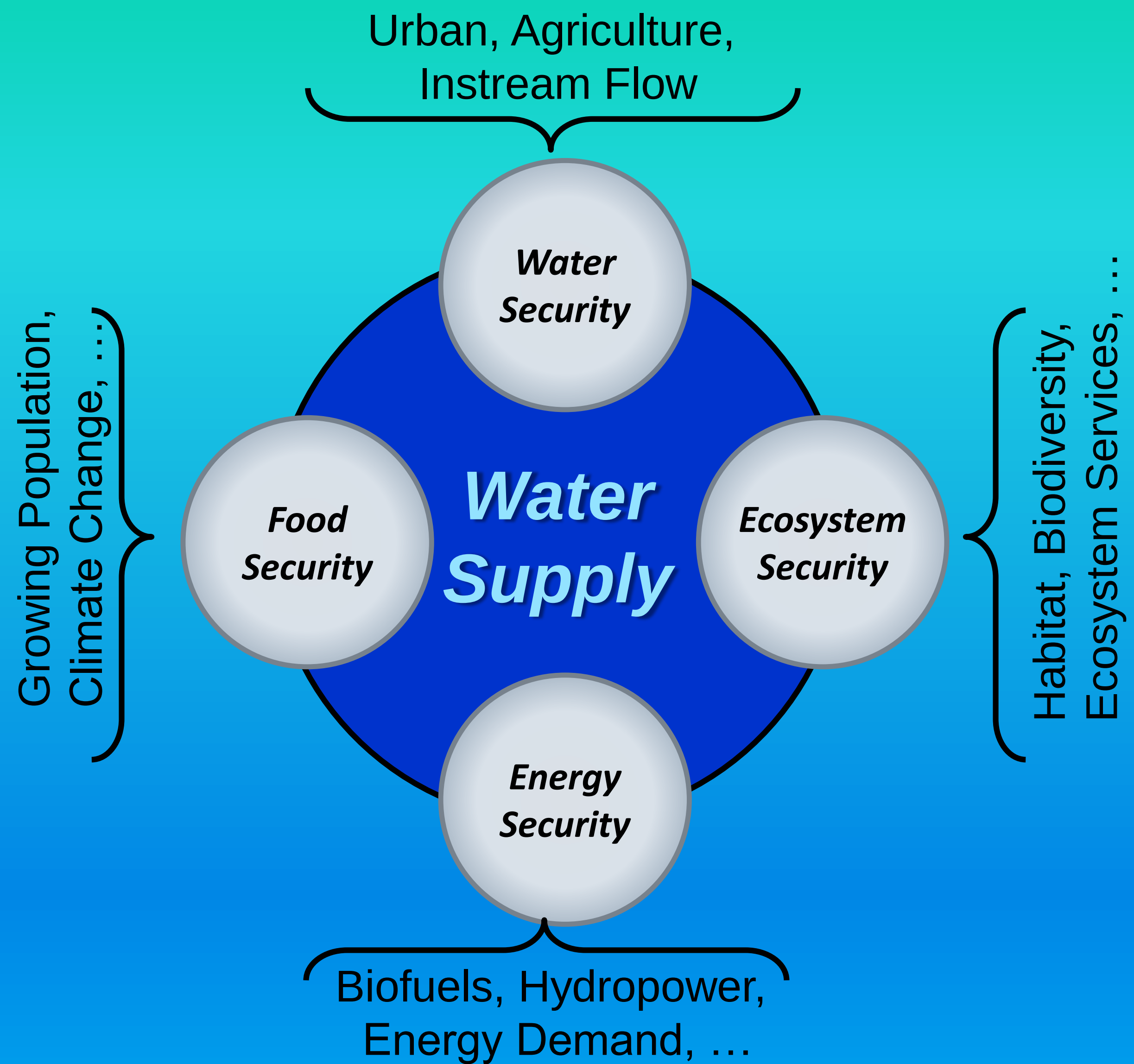
Cyanobacteria



The Phosphorus Cycle



Water-Food-Energy-Environment Nexus



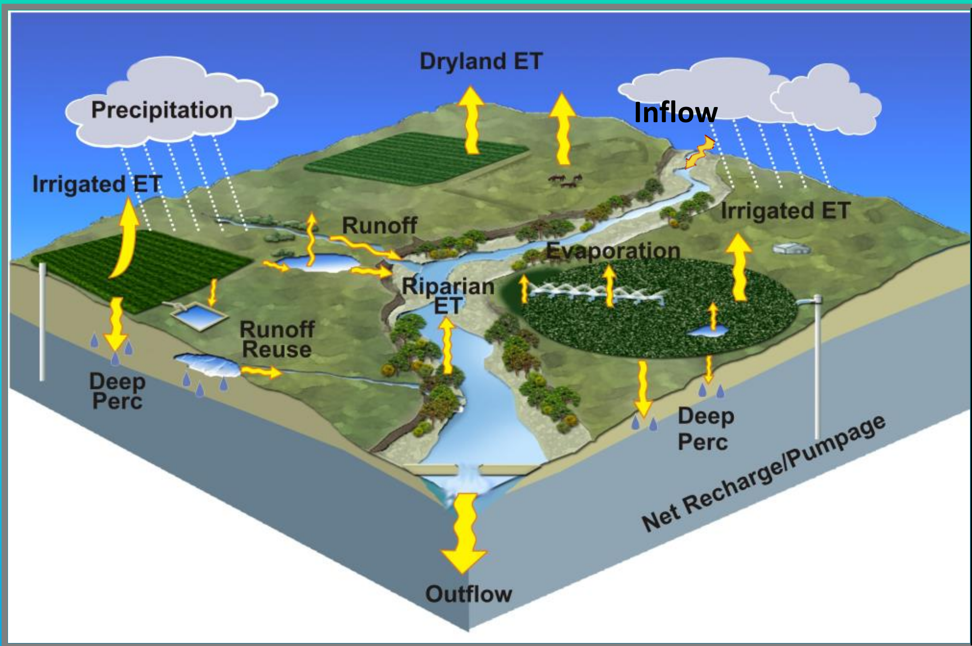
Keeping Everything in Balance

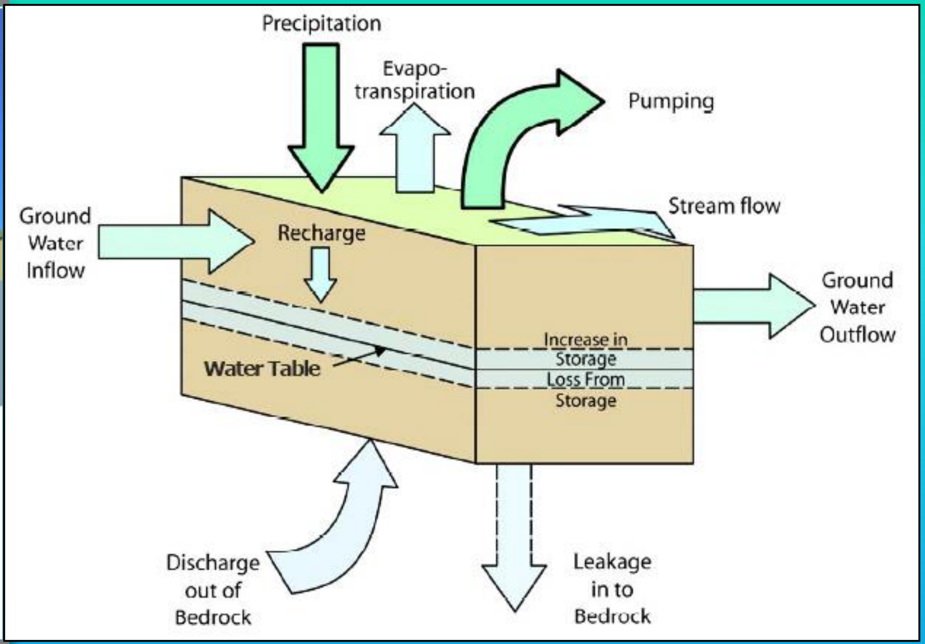
Many have the vision of harmonious balanced systems.

However, things are dynamic and chaotic.

Balancing is much harder than we imagine.

Irrigation Sustainability → Sustainable Development





Surface Water ***Groundwater***

$$\text{Outflow Rate} = \text{Precip} + \text{Inflow Rate} + \text{Net Baseflow Rate} \pm \text{Storage Change} - \text{ET} - \text{Recharge}$$

$$\frac{\text{GW Change}}{\text{Time}} = \text{Recharge} \pm \text{Lateral Inflow} - \text{Pumpage} - \text{Net Baseflow}$$

Water Budget Myth Revisited: Why Hydrogeologists Model

John D. Bredehoeft

1. Some hydrologists believe that a pre-development water budget (a water budget for natural conditions before humans used the water) can be used to calculate amount of water available for consumption (safe yield).
2. Thus, development of ground-water system is considered to be "safe" if rate of ground-water withdrawal does not exceed rate of natural recharge.
3. Concept → "Water-Budget Myth" (Bredehoeft and others, 1982).
4. Oversimplification, as human activities change, components of the water budget (inflows, outflows, and storage) also change
5. Understanding water budgets and how they change in response to human activities is essential

Water Budget Myth Revisited: Why Hydrogeologists Model

John D. Bredehoeft

Idea persists that:

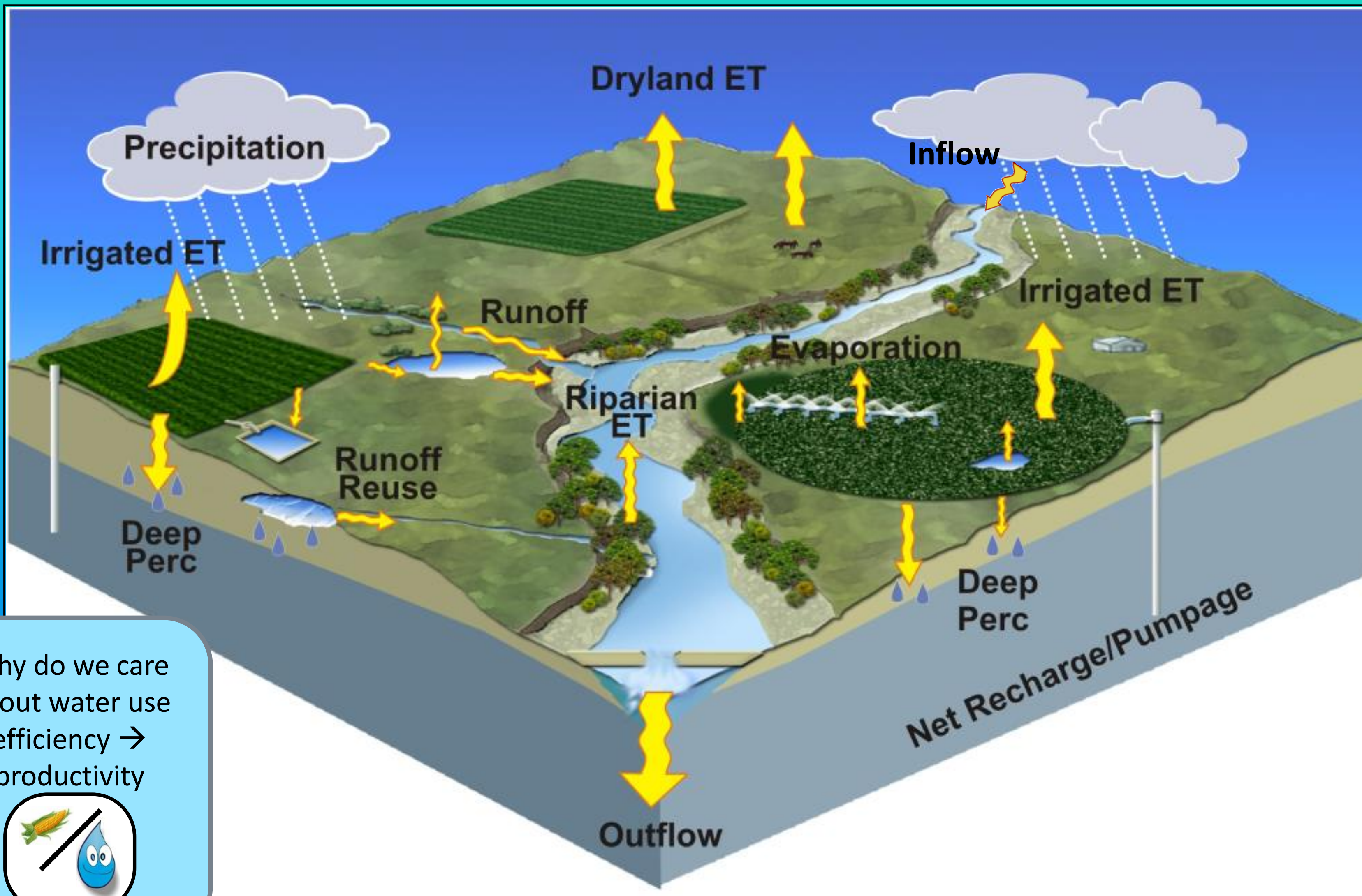
- if one can estimate recharge to a ground water system, one can determine size of a sustainable development.
- Theis addressed this idea in 1940 and showed it to be wrong-yet the myth continues.

Size of sustainable ground water development depends on how much of discharge from the system can be “captured” by development.

- Capture is independent of the recharge;
- it depends on the dynamic response of the system to the development.

Models were created to study the response dynamics of ground water systems; it is one of the principal reasons hydrogeologists model.

Managing the Watershed



Why do we care about water use efficiency → productivity

How to add value to water use → Performance Indices

Water Footprint

(Volume ... ter/Unit Food):

- Wh t alterna ve use of land?
- Ho wou the ternative land use affe the wa hed?
- Useful misleading??

Water Use Efficiency or Water Productivity:

$$WUE = \frac{Yield}{Irrigation\ Water\ Withdrawn}$$

$$WUE = \frac{Irrigated\ Yield\ -\ Rainfed\ Yield}{Irrigation\ Water\ Withdrawn}$$

More useful but:

- Does not show how to improve
- Where to spend efforts?
- Maximizing WUE → Don't irrigate
- How to feed 9 billion people?

Components of Water Use Efficiency

Water Extraction

Agronomics –
Yield per Unit of Water Consumed

Irrigation Efficiency –
Fraction of Applied Water that is Consumed

Conveyance Efficiency –
Fraction of Extracted Water that is Applied to Field

Marketable Yield

Derrel Martin, Biological Systems Engineering

Breaking Down Water Use Efficiency – Enhancing Productivity and Value

$$\frac{Yield_{irr} - Yield_{rainfed}}{Trans_{irr} - Trans_{rainfed}}$$

- Transpiration is energy driven
- Add value by increasing plant productivity.

Genetics

Agronomics

Breaking Down Water Use Efficiency – Enhancing Productivity and Value

$$\frac{Trans_{irr} - Trans_{rainfed}}{ET_{irr} - ET_{rainfed}}$$

- Yield is closely correlated to transpiration
- About 30% of annual water use for irrigated crops is due to evaporation
- Add value by minimizing nonproductive evaporation of water from soil and plant surfaces

Irrigation Field Practices

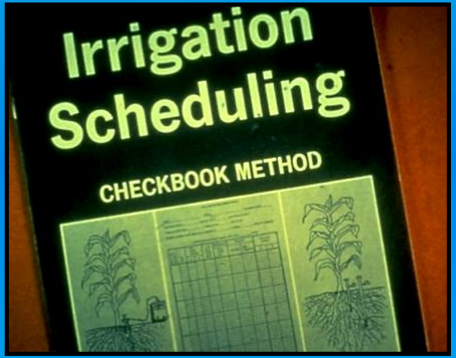
- Reduced Tillage
- Residue Management
- Improved Water Application
- Deficit Irrigation

Breaking Down Water Use Efficiency – Enhancing Productivity and Value

$$\frac{ET_{irr} - ET_{rainfed}}{\text{Root Zone Storage}}$$

- Utilize water for beneficial uses

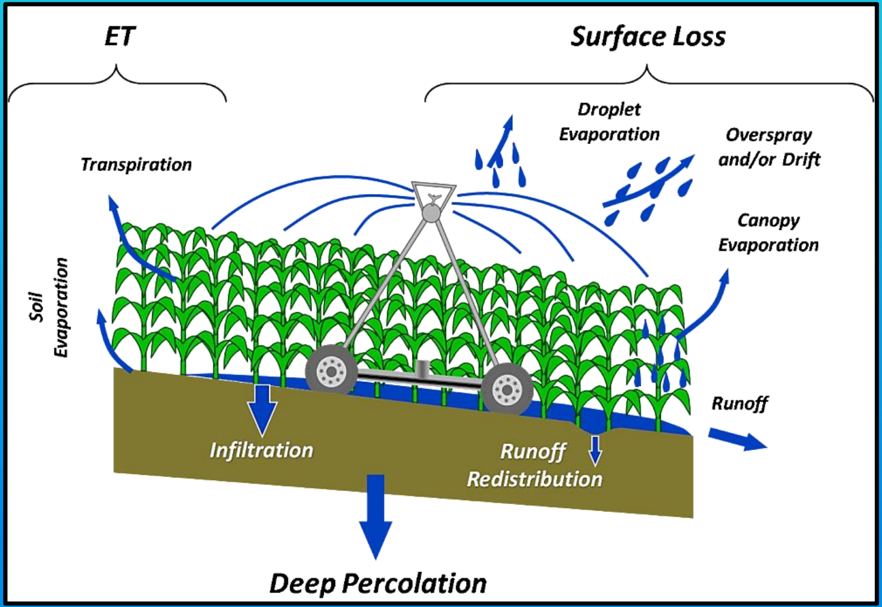
- Measure & Manage Soil Water
- Measure & Predict ET
- Schedule Irrigations
- Minimize Pumping
- Water Quality Gains



Breaking Down Water Use Efficiency – Enhancing Productivity and Value

Root Zone Storage
Irrigation Application

- Ensure that water is available to crops
- Maximize efficiency of application
- Avoid non-beneficial use of water



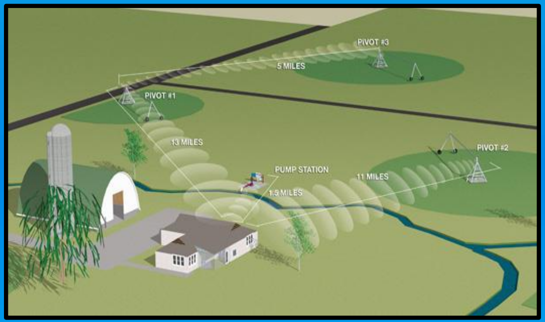
Better Accounting of Where the Water Goes

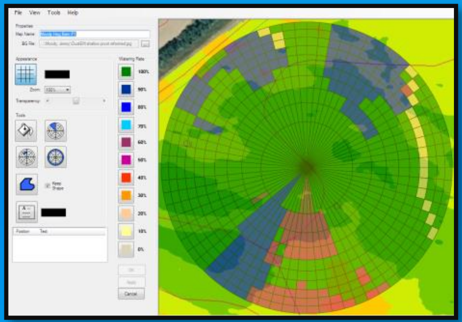
Breaking Down Water Use Efficiency – Enhancing Productivity and Value

Irrigation Application / *Withdrawal*

- Control water delivery to minimize non-beneficial use and protect water quality
- Determine the disposition of the water
  - More delivery → more ET
  - Same delivery → more storage (GW and/or SW)

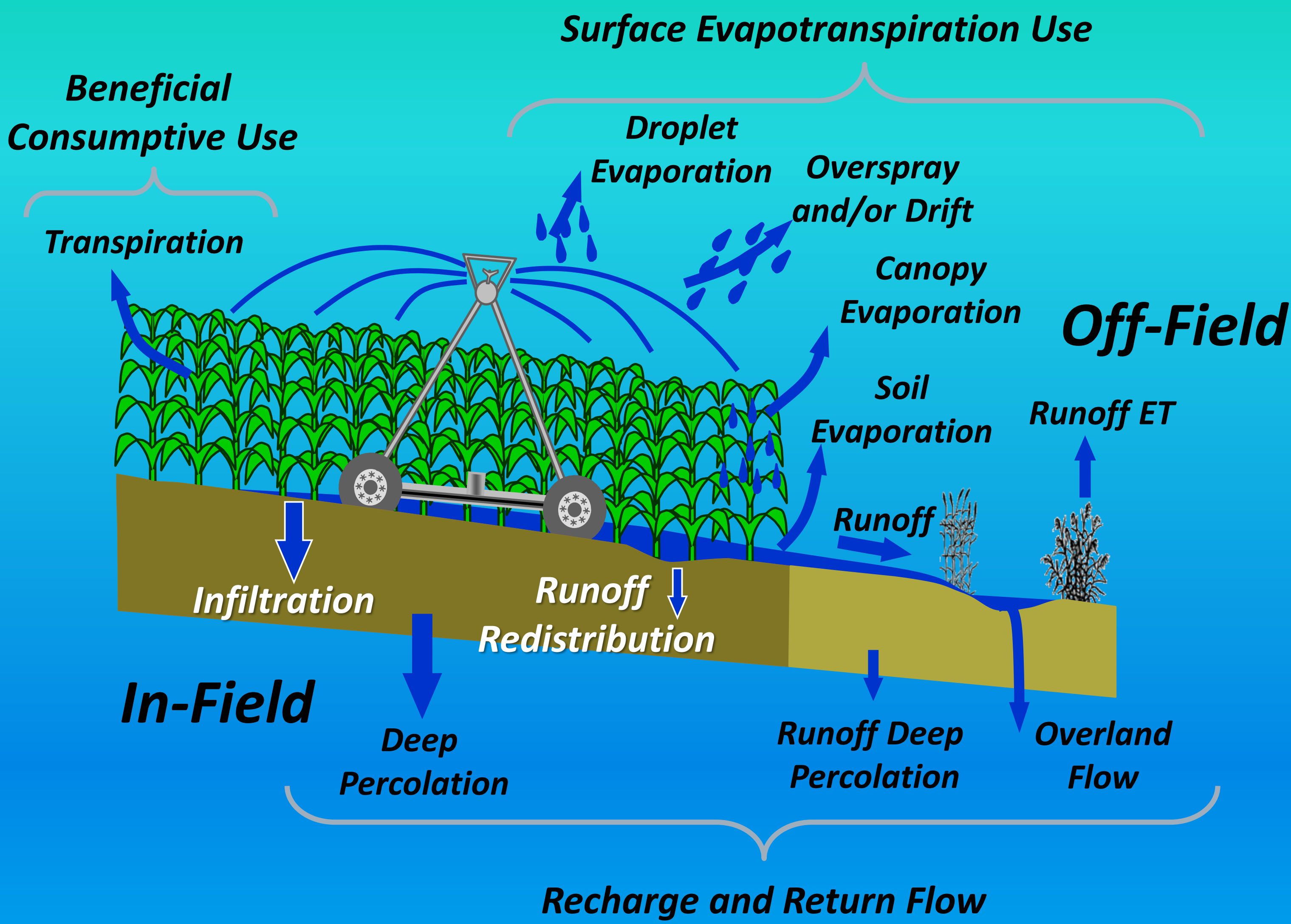
Improved Water Delivery → Retain water at source to provide options





Improved On-Farm Control → Put water where it is most economical

Irrigation Water Balance



Sustainability versus

Water Productivity/Use Efficiency

Crop per Drop

Yield Gap

Water Footprint

<u>Not Directly Related</u>

Sustainability → How much of available supply are you consuming (converting to water vapor)

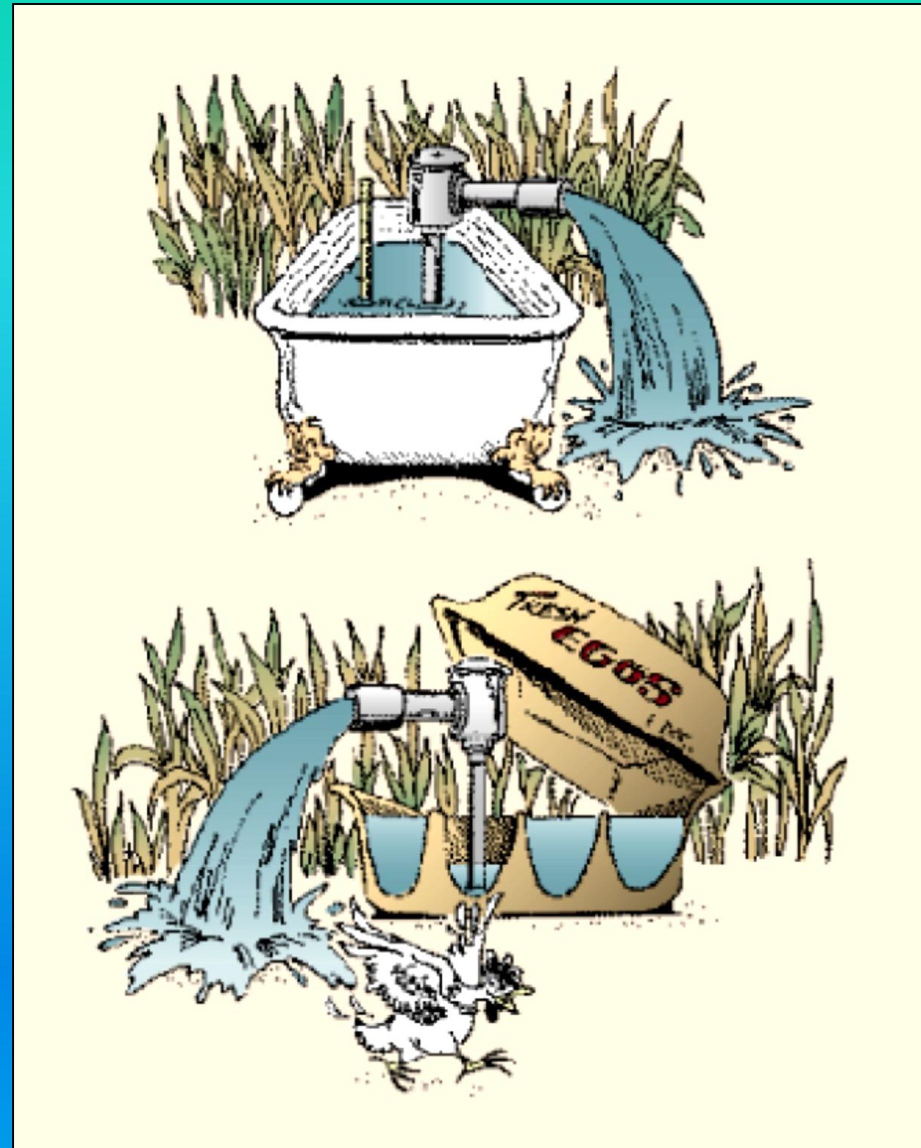
- Area Irrigated
- Consumptive Use per unit area
- Recharge

Productivity/Efficiency → How much to you derive from consumption

How Do You View Groundwater

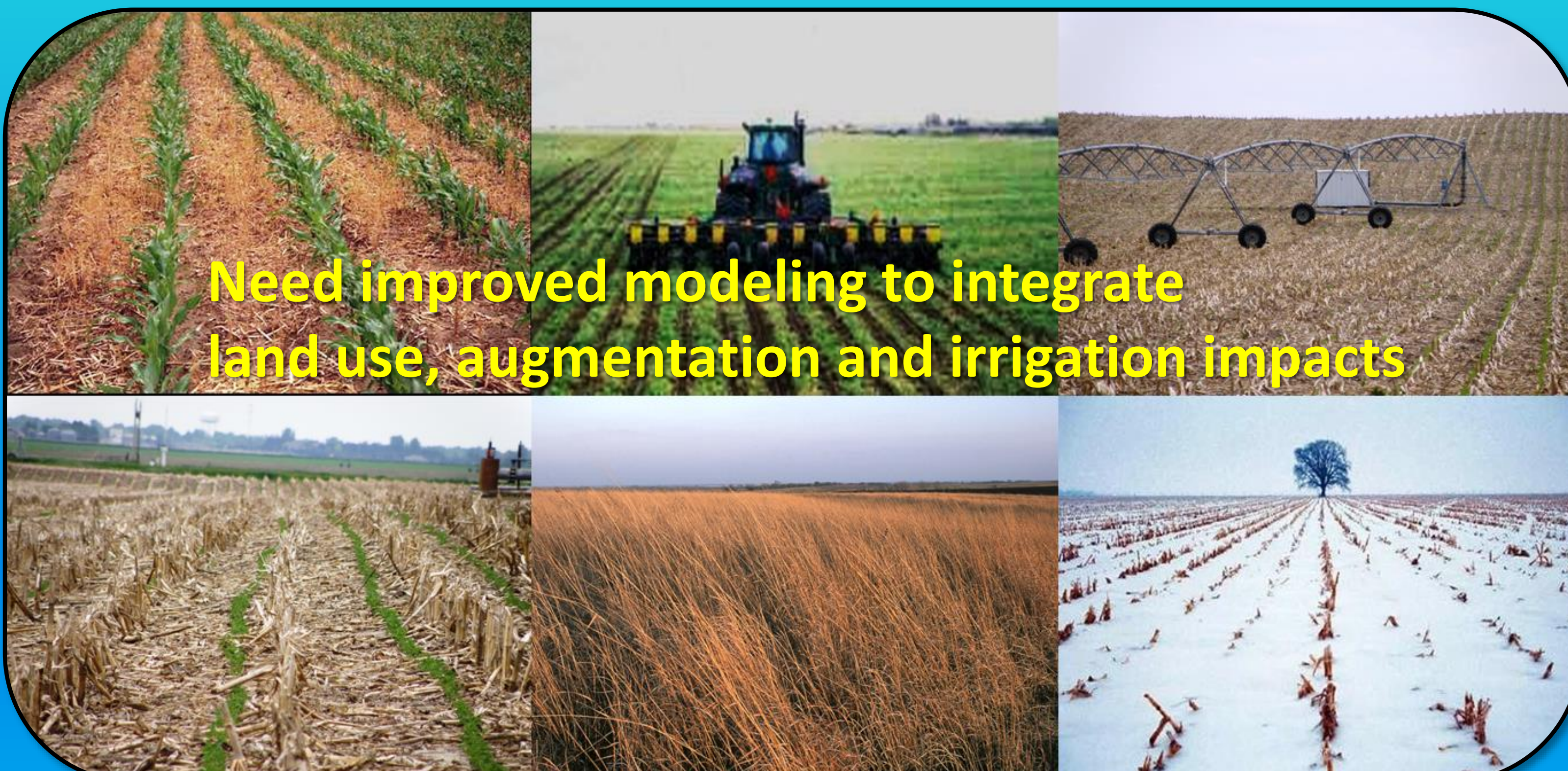
Bathtub → groundwater is shared by all and if you don't use it, someone else will. What you do has little effect on the whole supply.

Egg carton → Your groundwater is local and good stewardship will enhance your long-term benefit.



Management for Soil Protection and Water Conservation

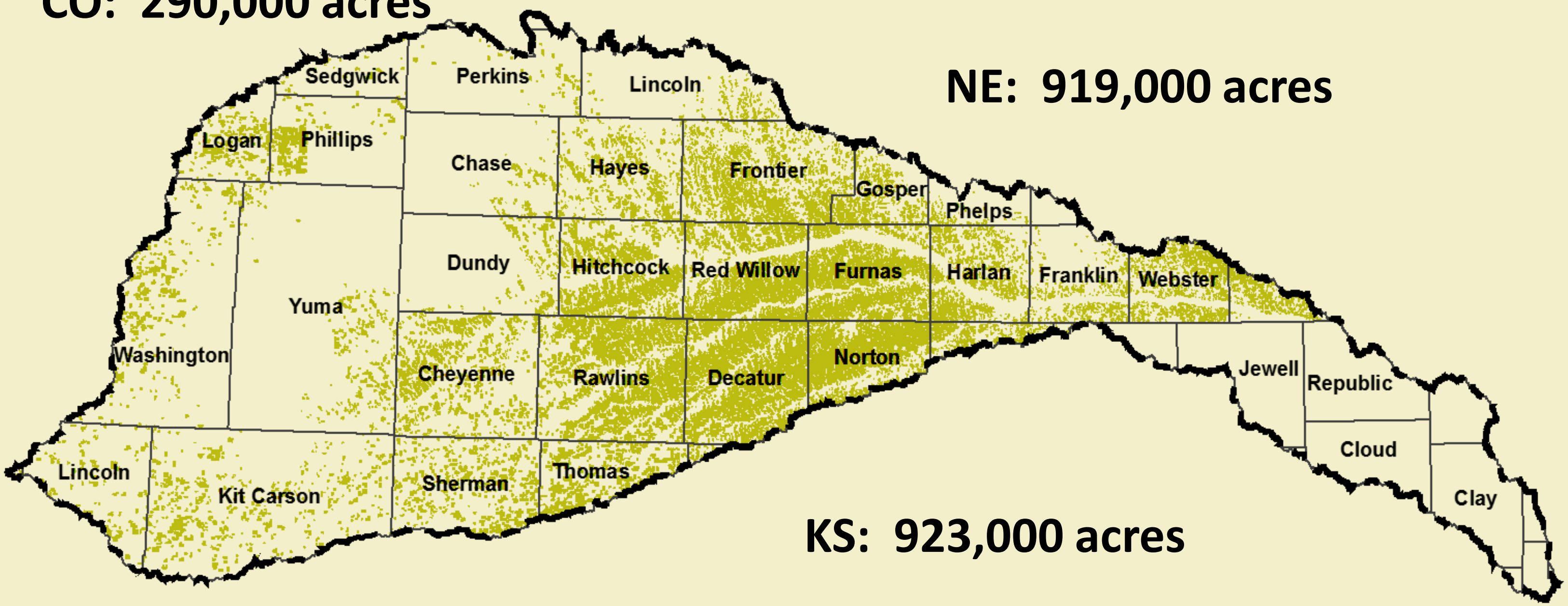
- Not all watershed impacts are due to irrigation
- Continue evolution of tillage for soil, water and energy conservation
- CRP reverting to cropland → what are the impacts?
- How does land use affect streamflow?



Land Terraced in the Republican River Basin

CO: 290,000 acres

NE: 919,000 acres

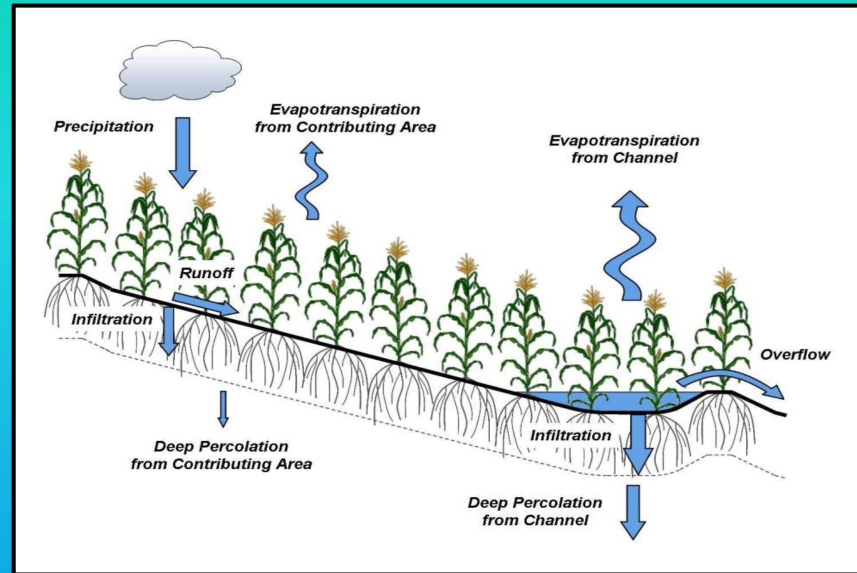


KS: 923,000 acres

Total Terraced Land: 2,130,000 acres

Land Area Above Hardy Gage = 14,340,000 acres
Percent Terraced = 15%
Percent of Contributing Drainage Area = 22%

Impact of Land Use on Streamflow



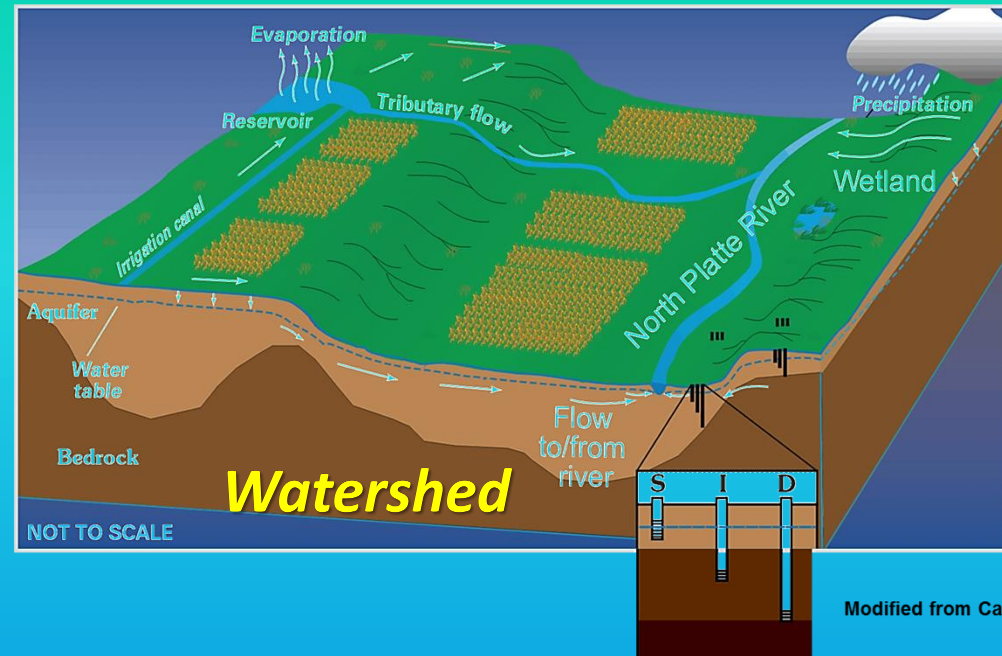
Average ET and Recharge Increase = 125,000 acre-feet per year

ET increase is about 42,000 ac-ft/year and recharge is about 83,000 ac-ft/year

Average Runoff and Transmission Lost Reduction = 125,000 acre-feet per year

Benefits of Improved Management and Technology

vs



Modified from Cannia

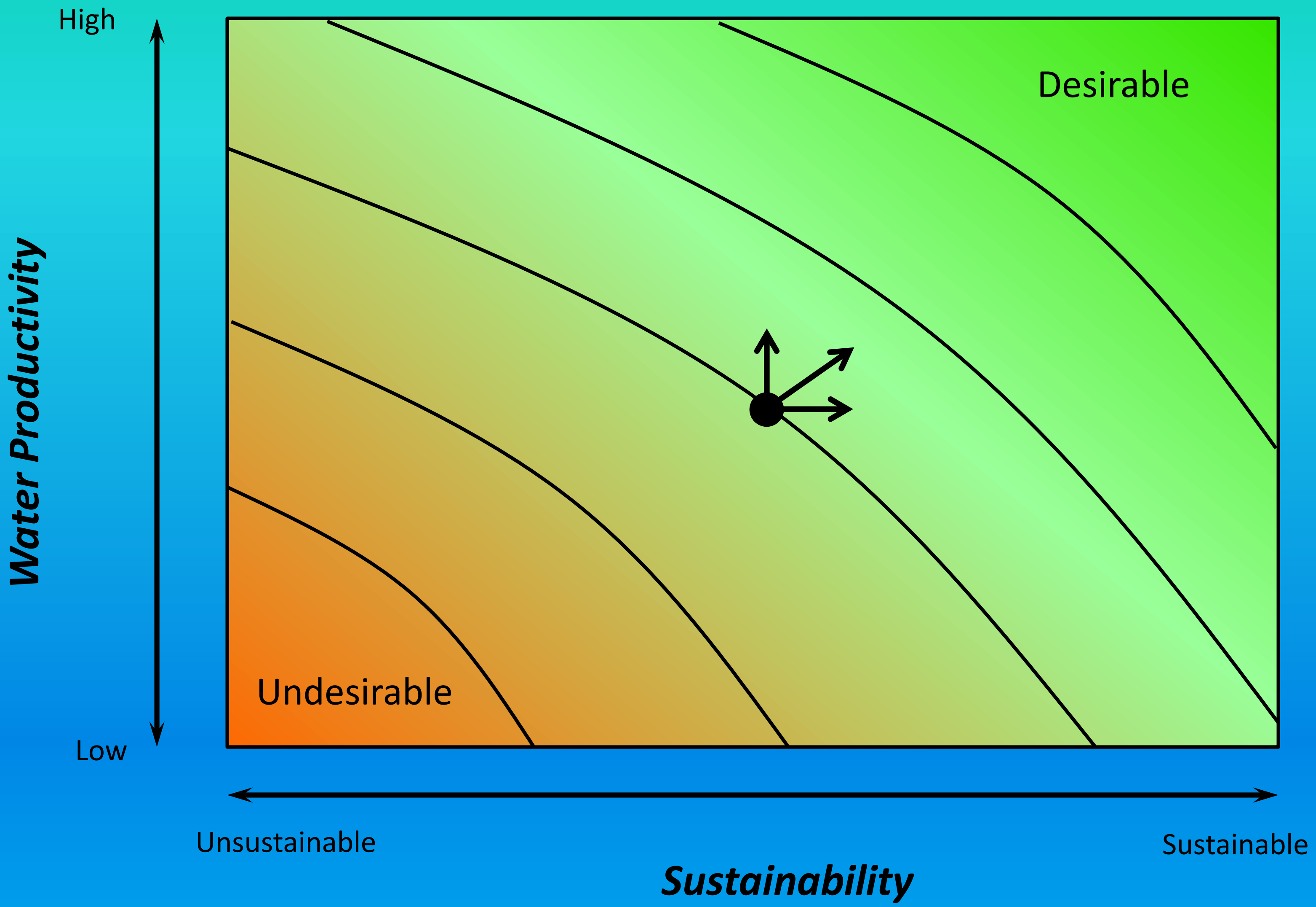
Many past improvements focused on irrigator, not watershed

- *Improvements not always beneficial to watershed*
- *Innovation for watershed enhancement is possible*
- *Hopefully win-win advancements*
- *Who will pay for watershed technology?*

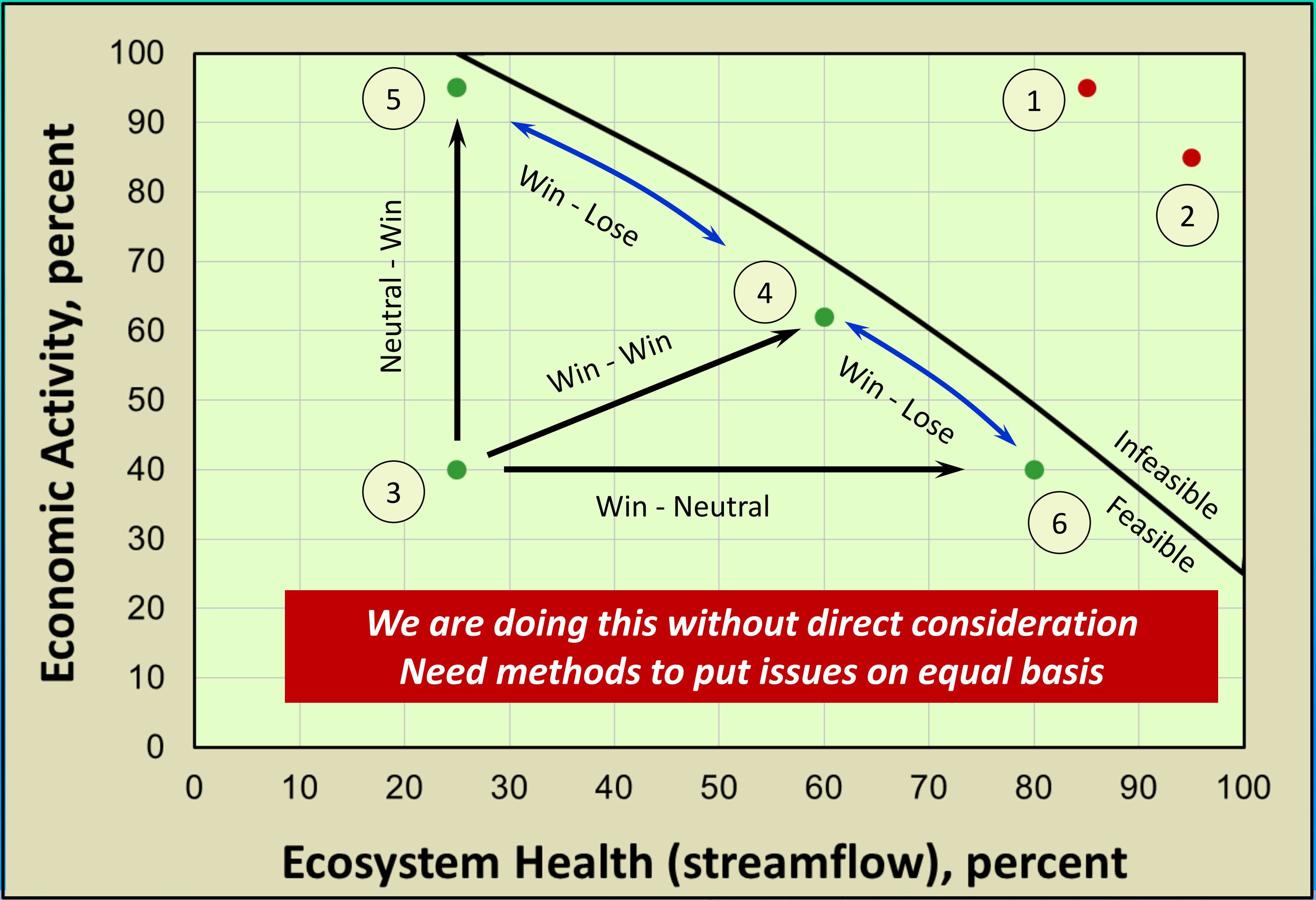
Examples of Contradiction of Practices at Farm and Watershed Levels

Practice / Impact	Crop Production	Streamflow
Improved Irrigation Efficiency		
Convert Runoff to ET	☺	☹
Convert Deep Percolation to ET	☺	☹
Reduce Evaporation from Soil and Plants	☺	☺
Improved Irrigation Scheduling	☺	😐
Conservation Tillage:		
Enhanced Infiltration – Less Runoff	☺	☹
Increased Crop ET and Productivity	☺	☹
Reduced Evaporation from Soil	☺	☺
Canal Lining and Automation		
Seepage and Spill Reduction	☺	😐
More Water Delivered	☺	☹
More Water Retained in Storage	😐	☺

Productivity ←→ Sustainability Frontier

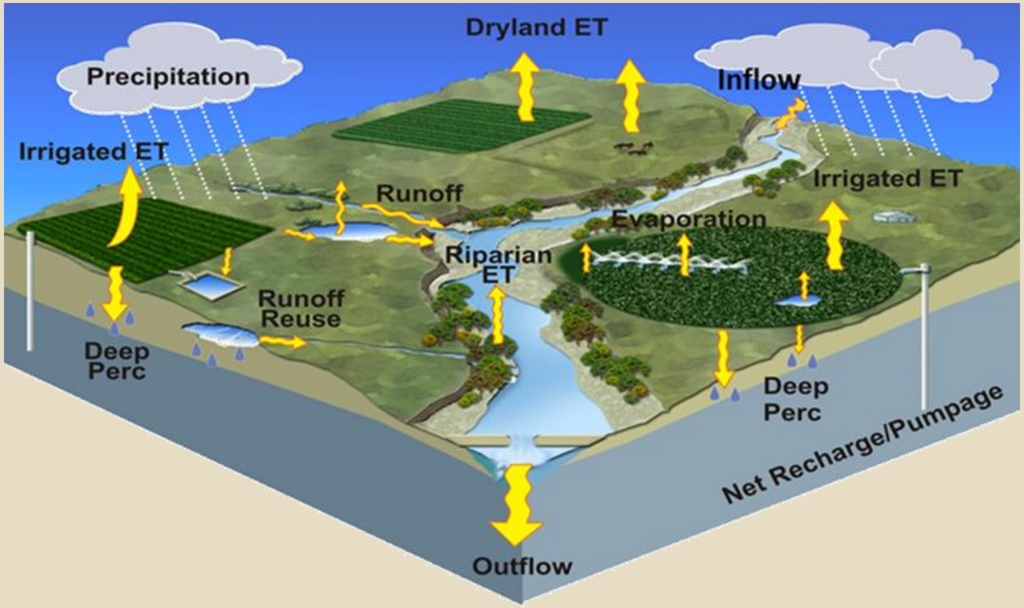


Classic Tradeoff



Advancements Needed for Managing Watersheds

- Advance understanding of processes that govern consumptive use
- Develop water balances in agricultural and grassland ecosystems
- Develop and simulate watershed management alternatives
- Partner with stakeholders and agencies to transfer results



- ***Manage watersheds by accounting for where the water goes.***
- ***Develop tools for water transfer and offsets to meet downstream needs***

Exciting Future – Think of the Possibilities

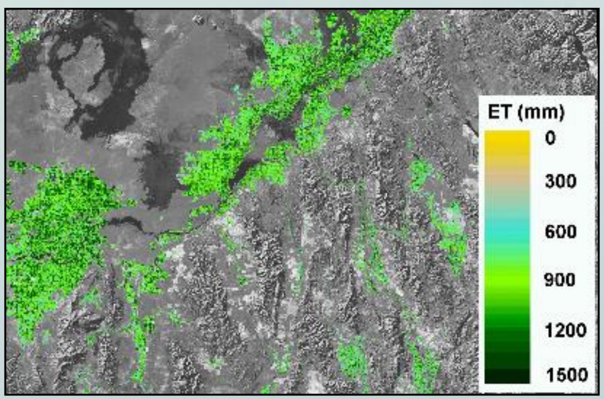
Look at Recent Developments

GMO Crops

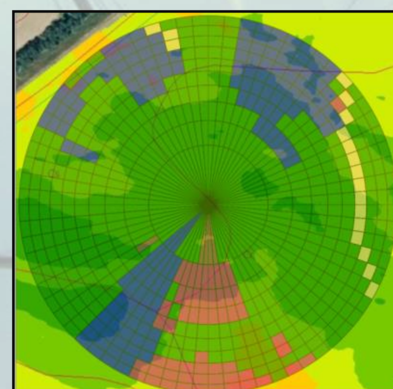
Encapsulated Fertilizer

Soil/Plant Monitoring Satellite Communication

Auto Steer Vehicles



ET from Remote Sensing



Variable Rate Irrigation

Monitoring with Unmanned Vehicle

How do we put it all together

N EXTENSION

Thank You, Questions?