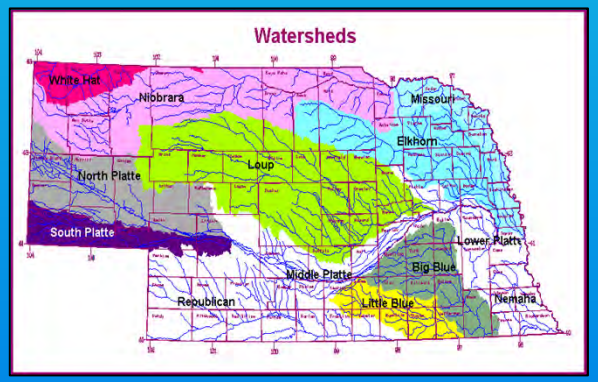
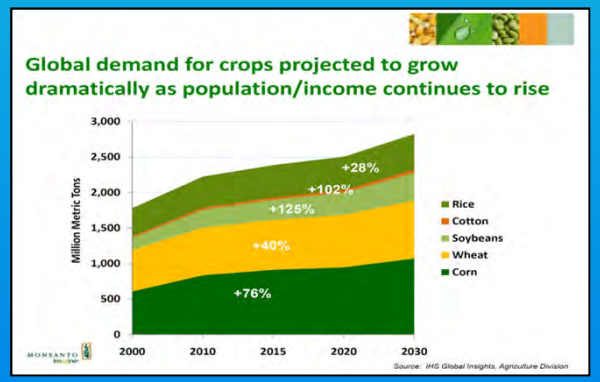
Challenges For Crop Production, Irrigation and Watershed Management

Many Factors Affect Water Management Today





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Summary of Discussion

- ***Overview some resource issues***
- ***Identify some activities that assist watershed management***
- ***Identify some activities that add to value of water***
- ***Consider tradeoff between farm and watershed benefits***

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What do you see in this picture?

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- **Many Perspectives**
- **Some of my thoughts.**

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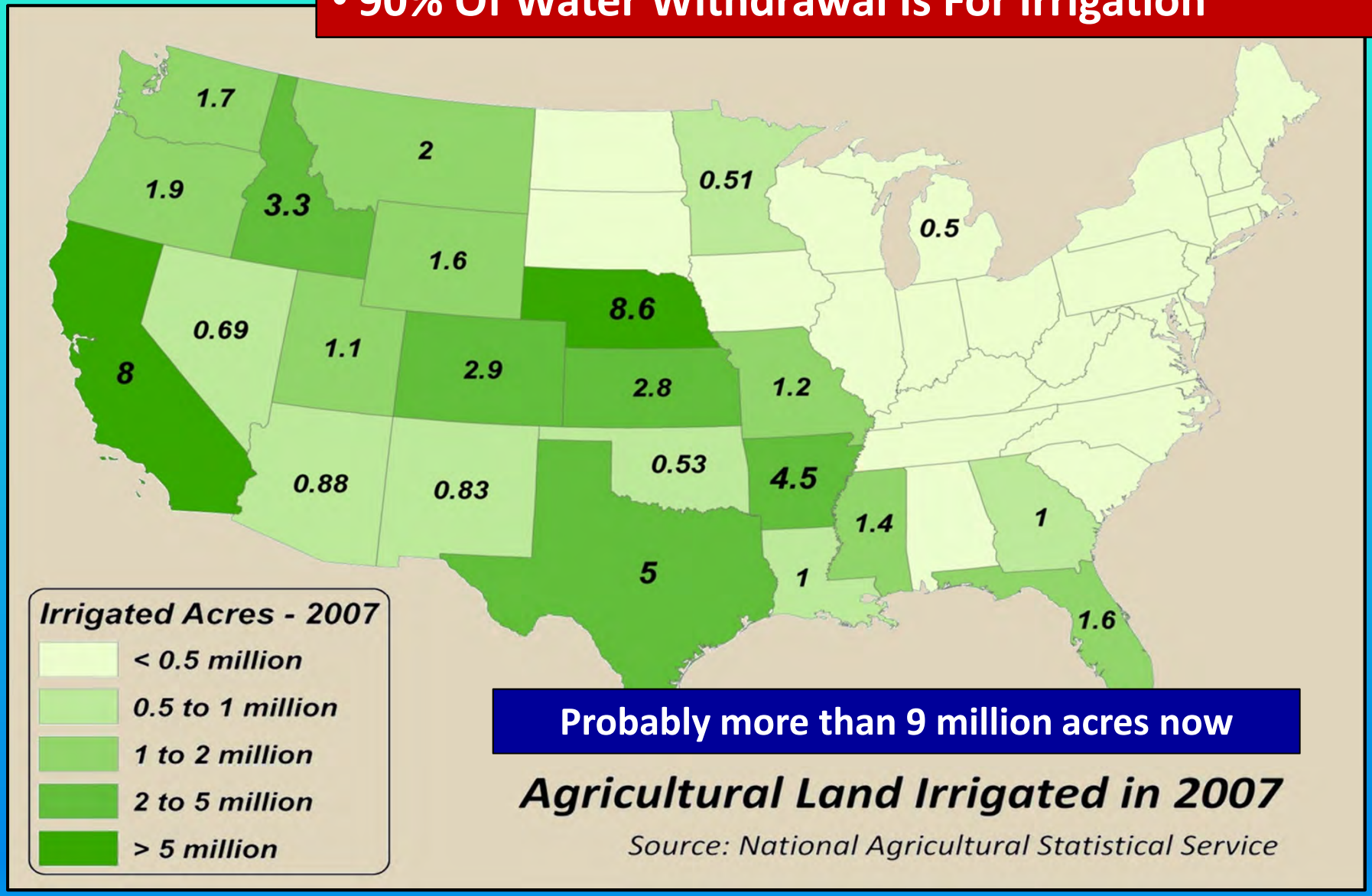
- 16% Of National Irrigated Land Is In Nebraska
- 90% Of Water Withdrawal Is For Irrigation



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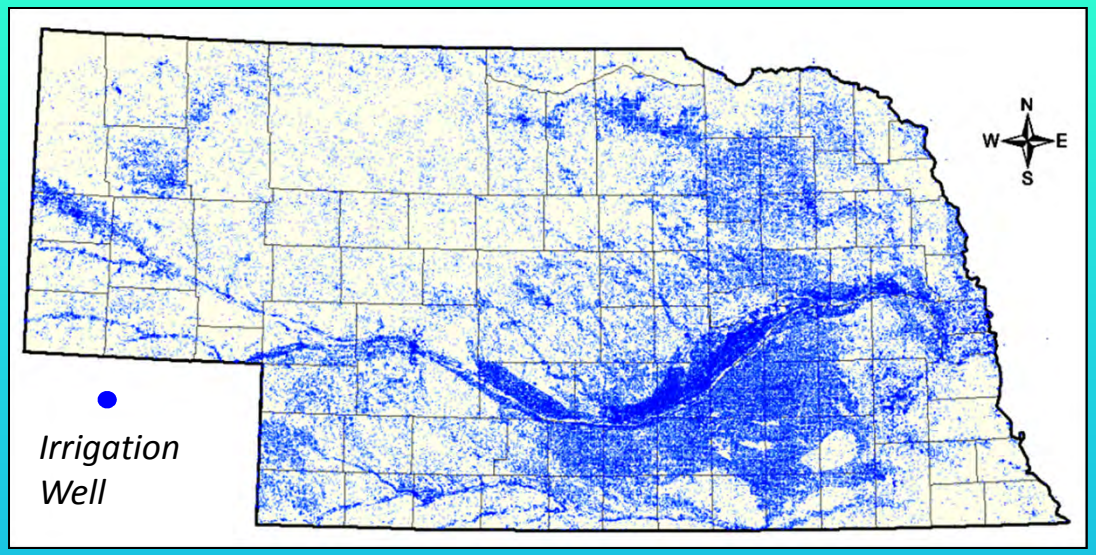
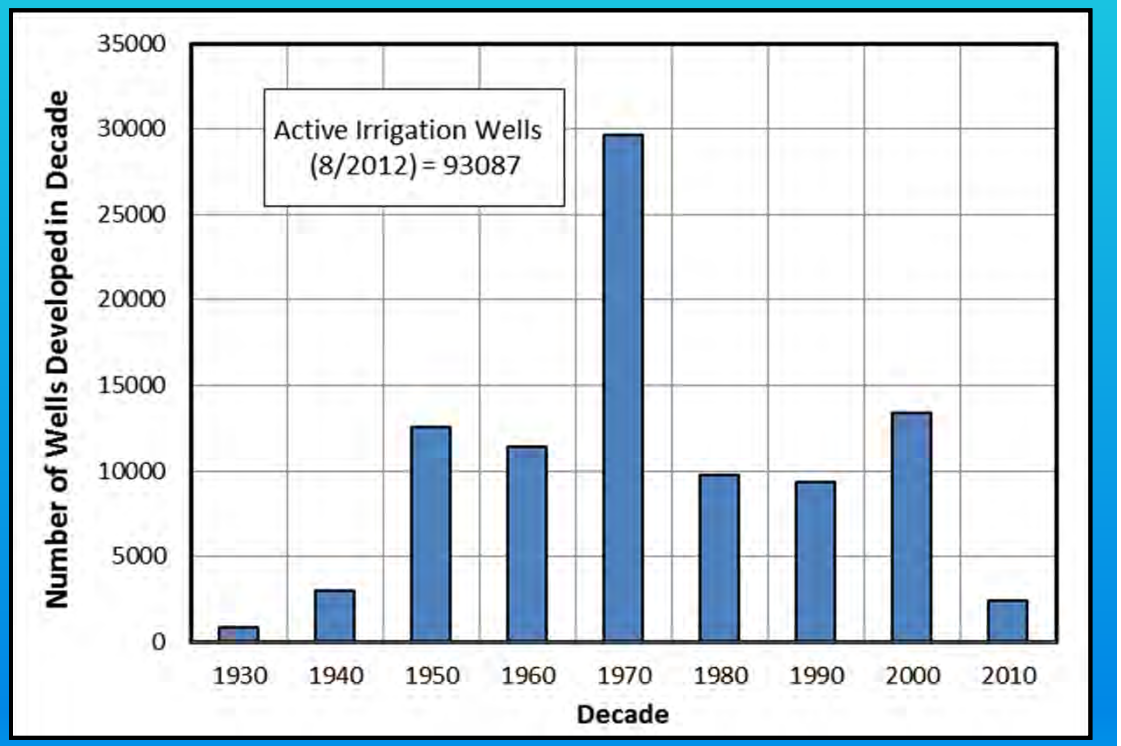
Irrigation Development

Active Irrigation Wells
~ 93,000
$6-9 Billion Investment

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





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Economic Impact of the Ability of Nebraska Agriculture to Irrigate - The Case of 2012

- **31,221** fewer jobs
- **$11.0 billion** in lower Output
- **$5.5 billion** in lower Total Value-Added
- **$3.3 billion** in lower Labor Income

Impact Type	Employment	Labor Income	Total Value-Added	Output
Direct Effect	-	($2,131,837,655)	($3,307,799,895)	($7,083,745,522)
Indirect Effect	(13,550)	($529,417,314)	($1,070,608,174)	($1,938,585,249)
Induced Effect	(17,672)	($643,189,735)	($1,150,415,492)	($1,947,118,568)
Total Effect	(31,221)	($3,304,444,704)	($5,528,823,562)	($10,969,449,338)

Prepared For: Nebraska Farm Bureau

Prepared By: Decision Innovation Solutions. Bridging Your Research Needs.

November 16, 2012

Drought Year
Good Commodity Prices
Probably Higher Impact than Normal
But Major Impact on Nebraska's Economy
Does Not Consider Land Values or Investments

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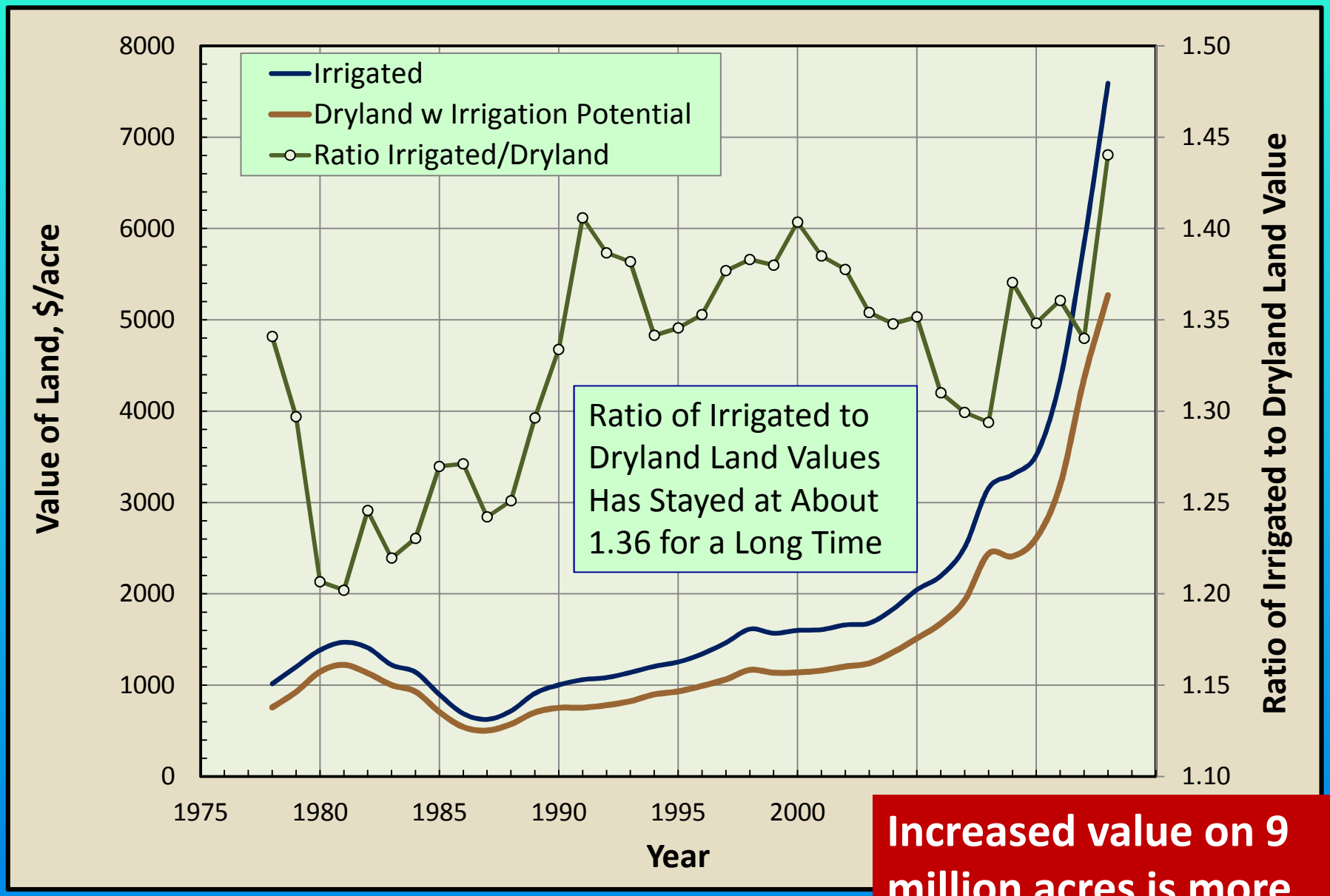
Change in Land Values – State Average



Increased value on 9 million acres is more than $20 billion

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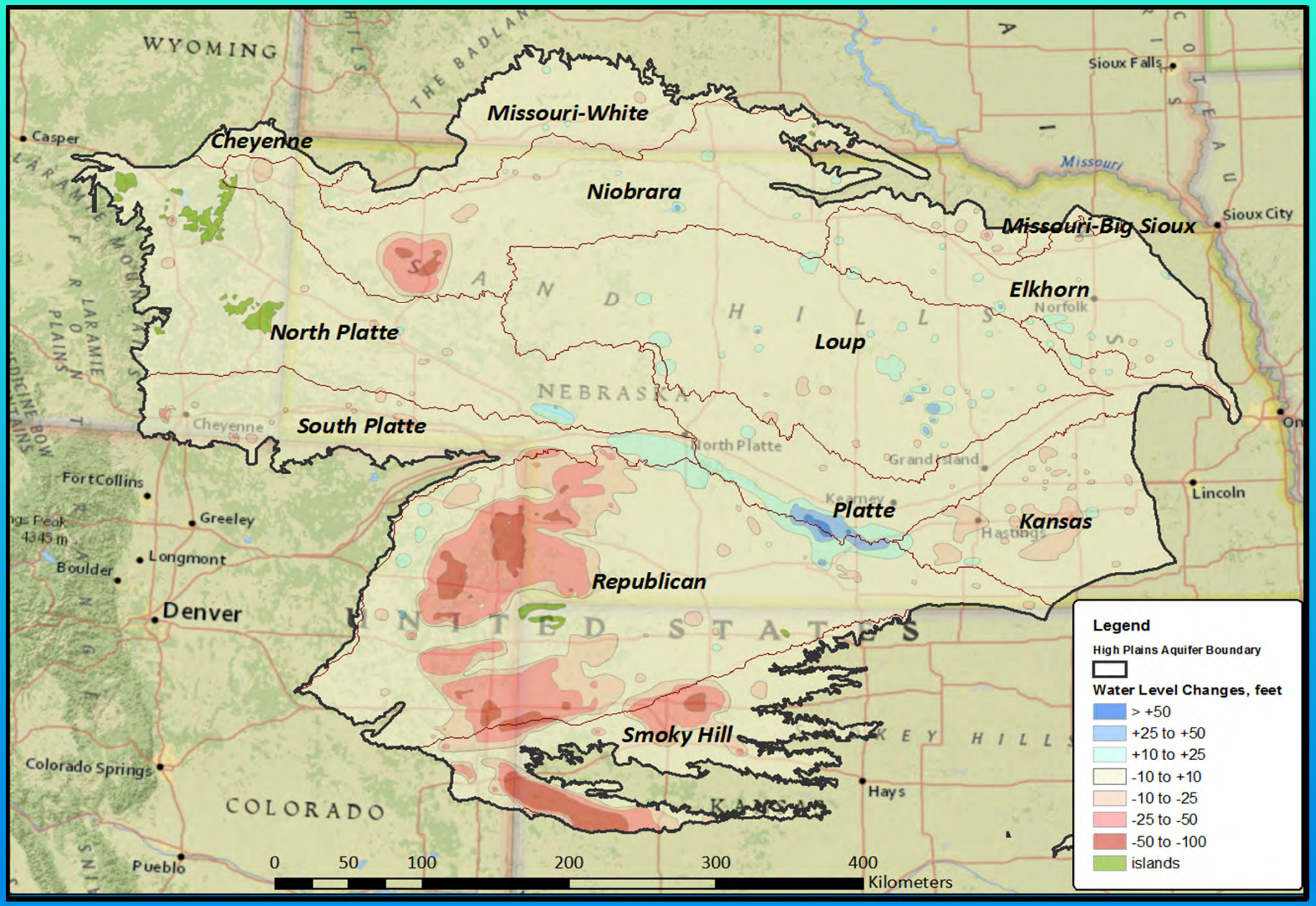
Groundwater Levels in the Northern High Plains



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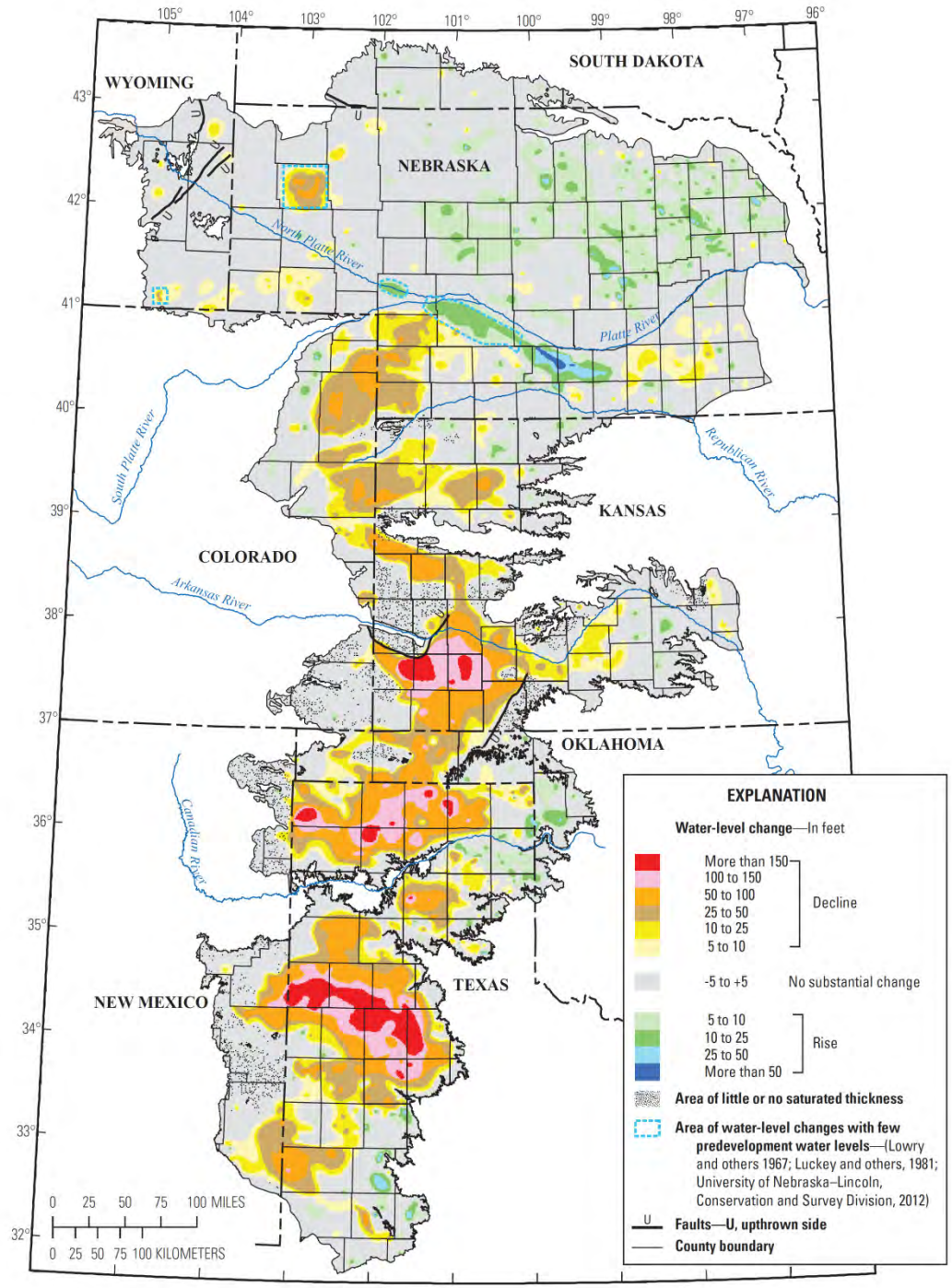
Groundwater Level Changes Since Predevelopment (about 1950)

Aquifer Going Dry??



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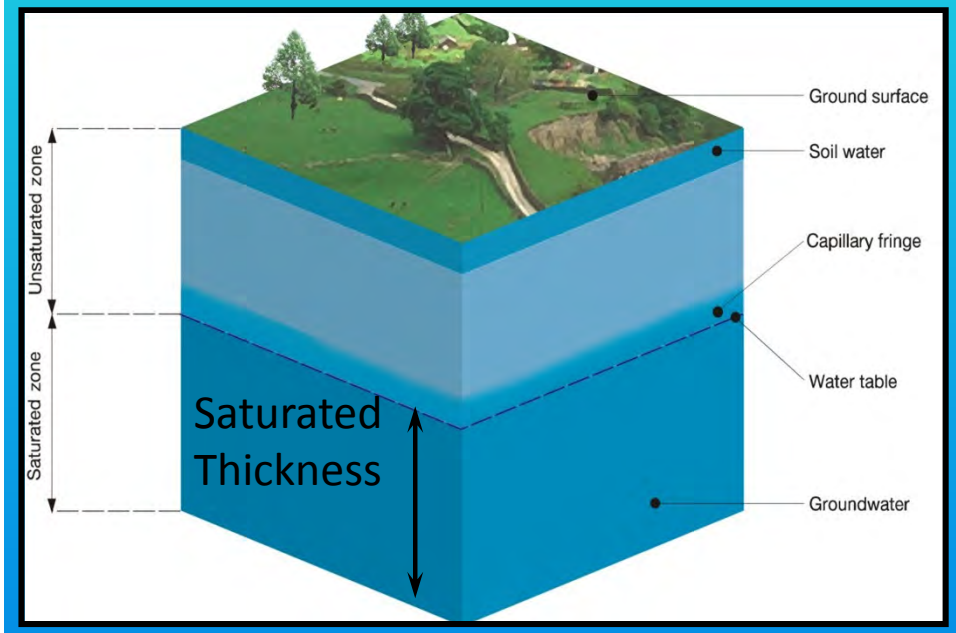
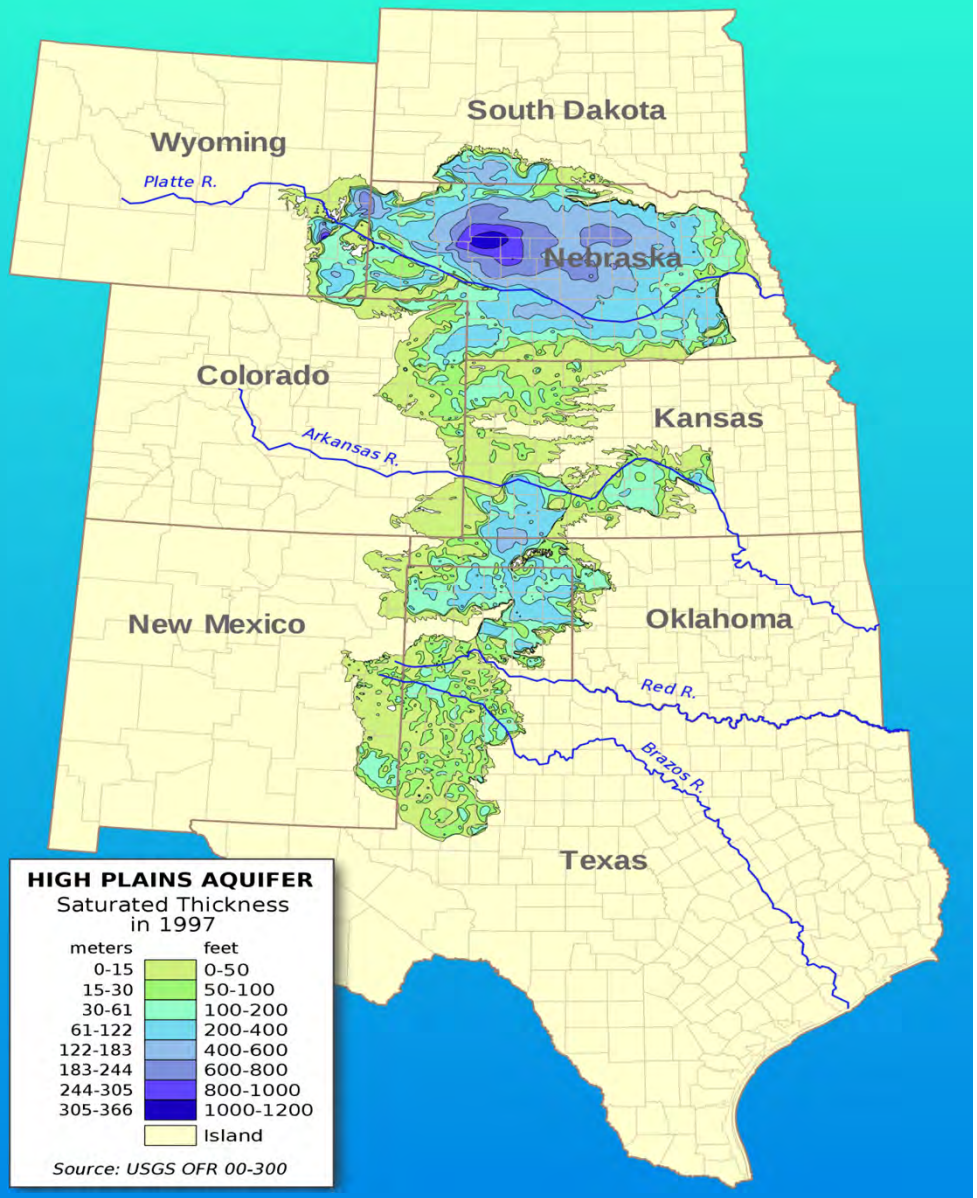
Saturated Thickness of Aquifer Defines Volume of Water Available





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Depletion as Fraction of Saturated Thickness of the Aquifer

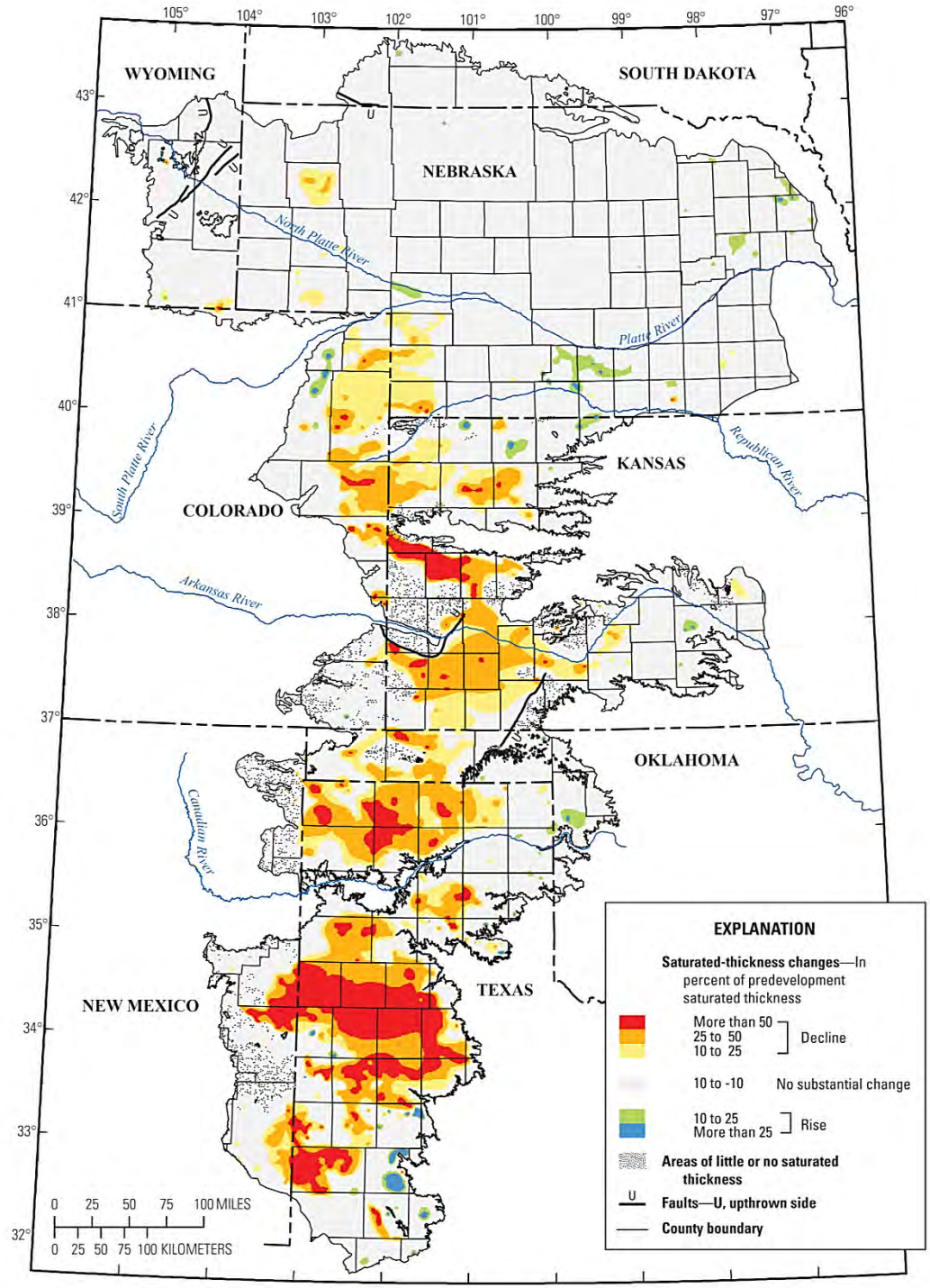
(McGuire , 2011)

Depletions in southern High Plains > 50% of saturated thickness

Small area in Nebraska > 25% of saturated thickness

Aquifer Going Dry??

Not in general
Problems in some areas



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Characteristics of the High Plains Aquifer (McGuire, 2009)

State	Percent of total aquifer area, %	Average area-weighted saturated thickness in 1980, ft	Volume of drainable water in storage in 1980, million ac-ft	Portion of H.P. Aquifer Drainable Water in State (1980), %	Change in Storage from ~ 1950 to 2007, million ac-ft	2007 Aquifer Depletion as Percent of 1980 Storage
CO	8.6	79	120	3.7%	-17.4	14.5%
KS	17.5	101	320	9.8%	-63	19.7%
NE	36.6	342	2,130	65.5%	-21.4	1.0%
NM	5.4	51	50	1.5%	-10.3	20.6%
OK	4.2	130	110	3.4%	-12.2	11.1%
SD	2.7	207	60	1.8%	-0.6	1.0%
TX	20.4	110	390	12.0%	-140.1	35.9%
WY	4.6	182	70	2.2%	-2.3	3.3%
Total	100	190	3,250		-267.5	8.2%

Drainable Water in NE ≈ Half of Volume of Lake Michigan

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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

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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/.)

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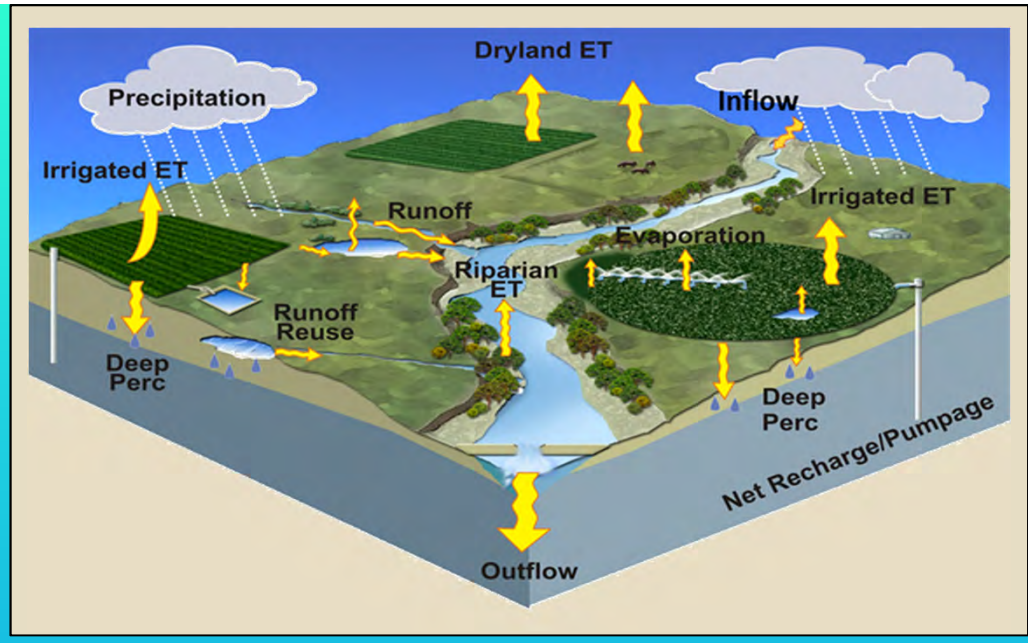
Watershed Sustainability



Sustainability Seems Simple But

- Many Questions
- Unintended Consequences
- Reservations & Misunderstandings

1. **What to sustain, economy, ecosystems, …?**
2. **Balance upstream (rural) opportunity versus downstream thirst?**
3. **What to do with ground water?**
4. **What management timeframe?**
5. **How to balance property rights versus "Community" good?**
6. **How to construct an "Adaptive Management" strategy and benchmarks?**

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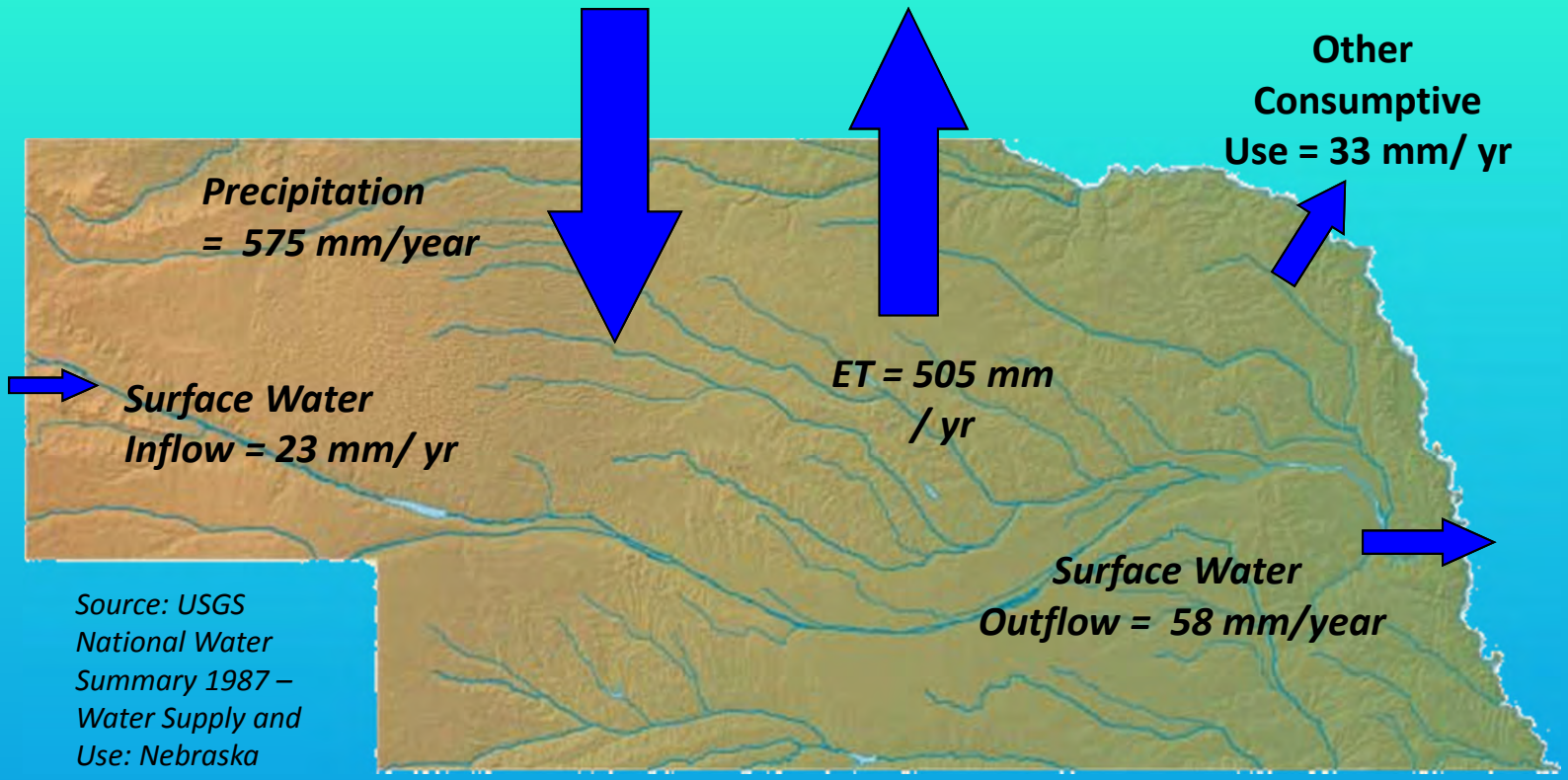
Nebraska's Water Supply (average conditions)



Source: USGS National Water Summary 1987 – Water Supply and Use: Nebraska

~ 88% of Precipitation Goes to Evapotranspiration

~ 6% of Precipitation Goes to Increased Stream Flow

~ 8% of Evapotranspiration due to Irrigation

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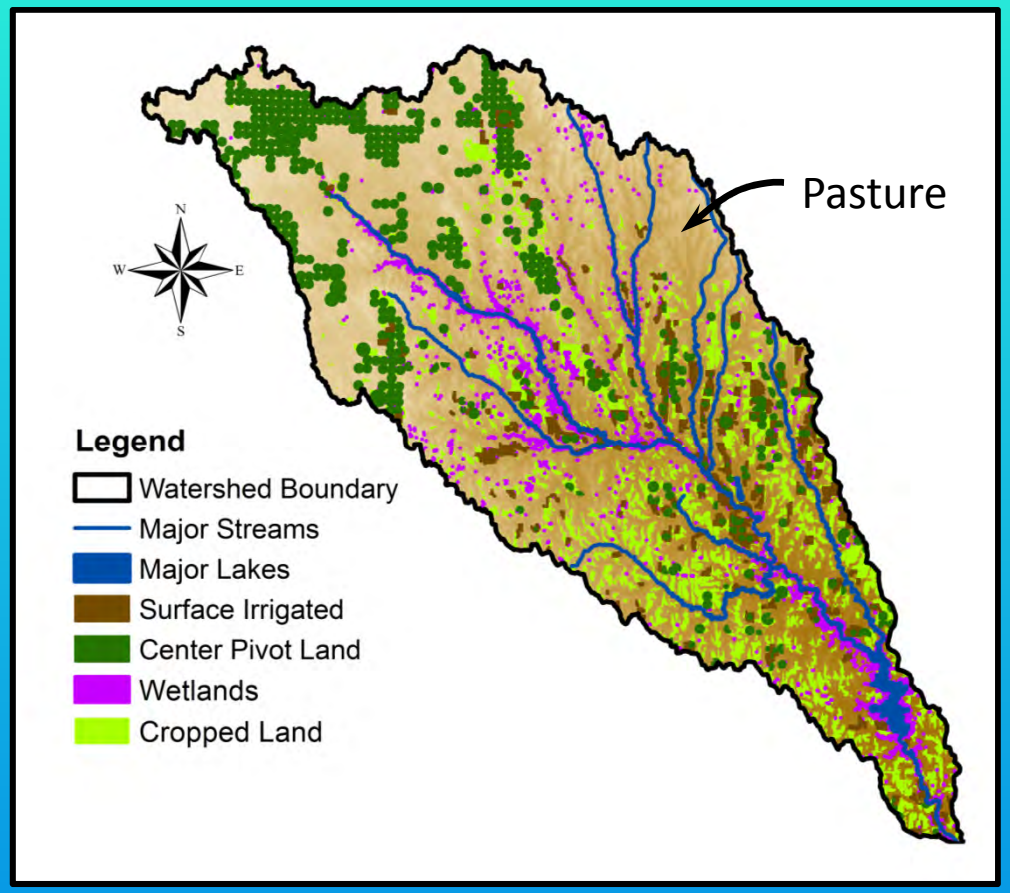
Watershed or Basin Impacts

Focus on streamflow requires long-term analysis of the water balance for the basin.



Water balance for basin depends on:

- **Area of land use**
- **Annual evapotranspiration of land uses**
- **Basin precipitation**
- **Groundwater withdrawals**
- **Runoff**
- **…**

How do land use and management practices affect outflow from basin?
Our emphasis has been on modeling groundwater.
We are not doing enough analysis of land use and management.

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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?

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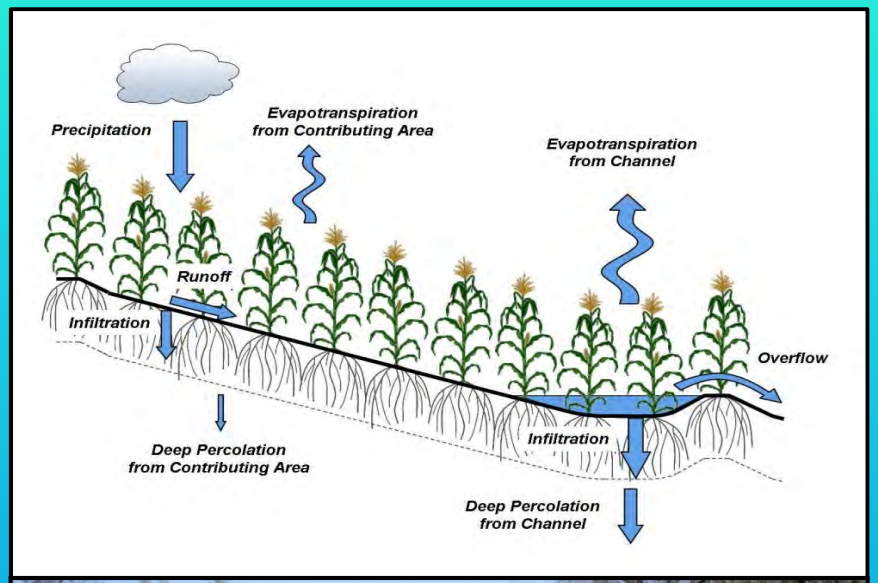
Impact of Land Use on Streamflow



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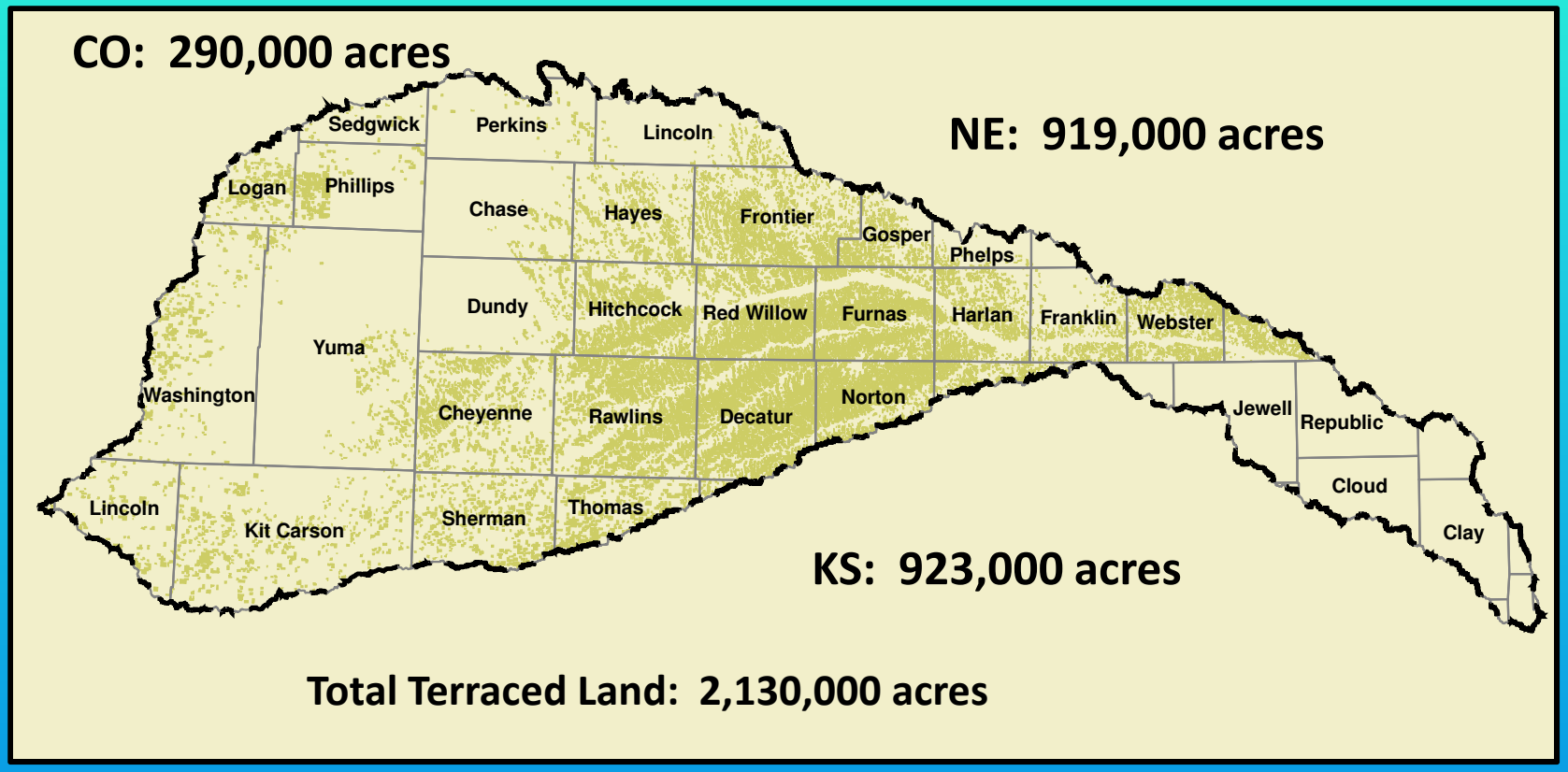
Land Terraced in the Republican River Basin



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%

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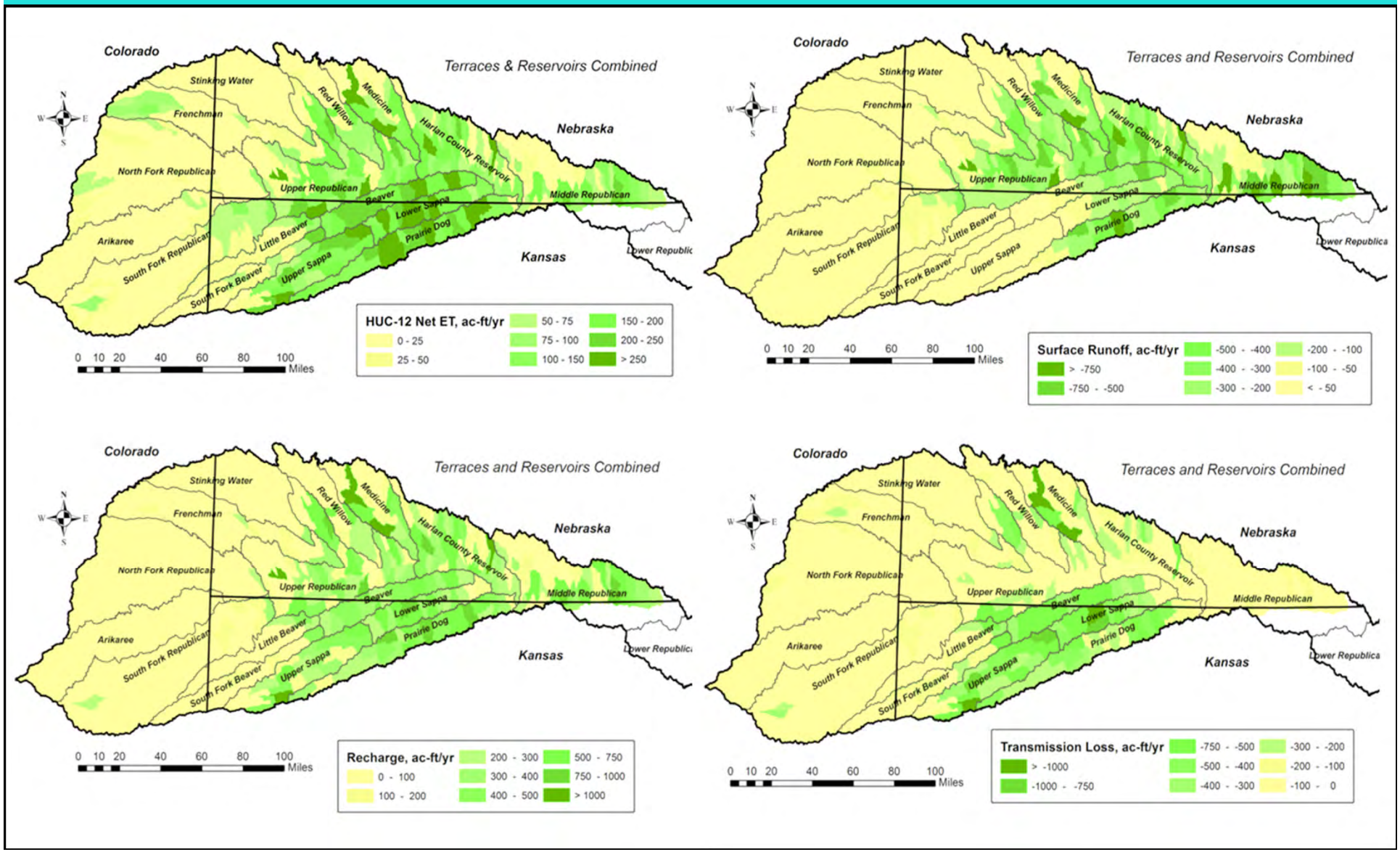
Impact of Terraces and Small Reservoirs

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

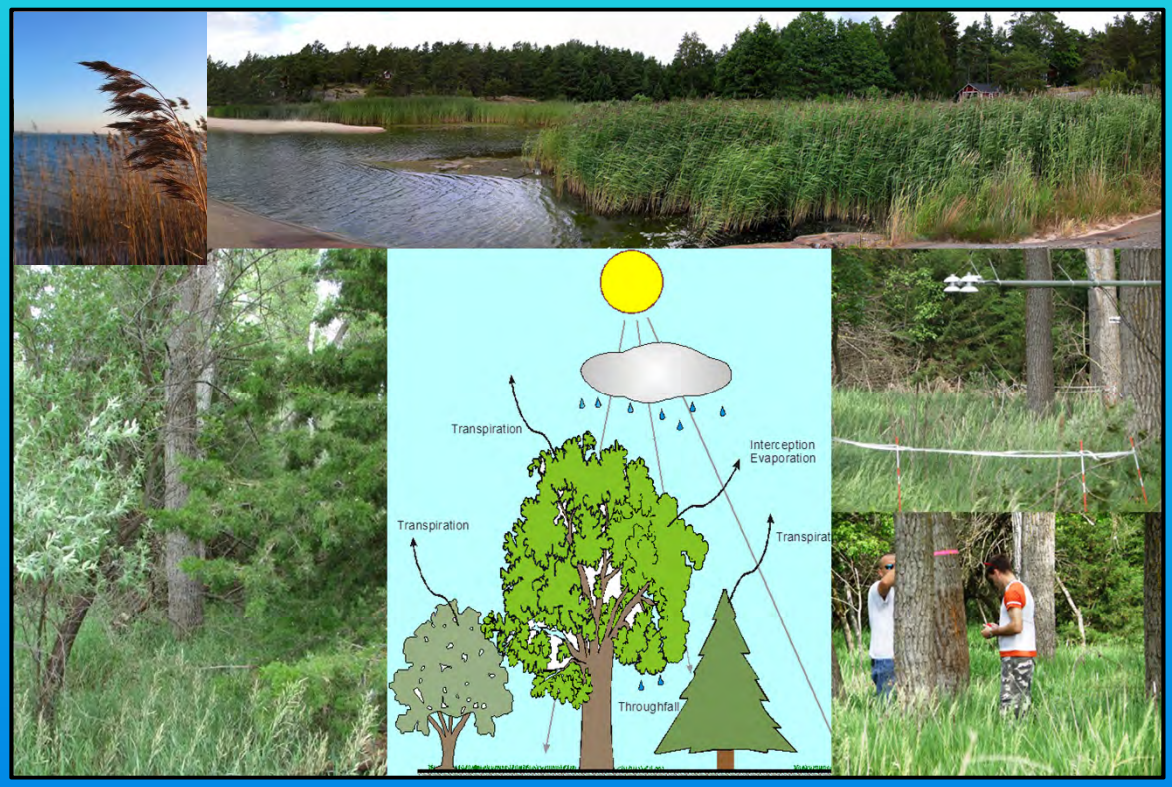
ET increase is about 42,000 ac-ft/year and recharge is about 83,000 ac-ft/year

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



Water Balance in Riparian Zones

- Invasive species have spread in riparian zones
- ET is considered nonbeneficial
- Quantifying how much water is used compared to native species
- Project funded by DNR and NRDs, partnership with other Departments



Invasive species:

- Phragmites,
- Red Cedar,
- Russian Olive

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Activities Affecting Watersheds

- ***Groundwater Pumpage***
- ***Farming Practices – Reduced Tillage, Less Runoff, More ET***
- ***Terraces***
- ***Reservoirs***
- ***Cropping Patterns → Land Use Change***
- ***Irrigation Efficiency***
- ***Deficit Irrigation***
- ***Expansion of Riparian Species that May Use More Water***
- ***Biofuel Expansion***
- ***Future Augmentation Projects to Capture "Flood" Flows***
- ***…..***

Need to assess all of these to manage the watershed

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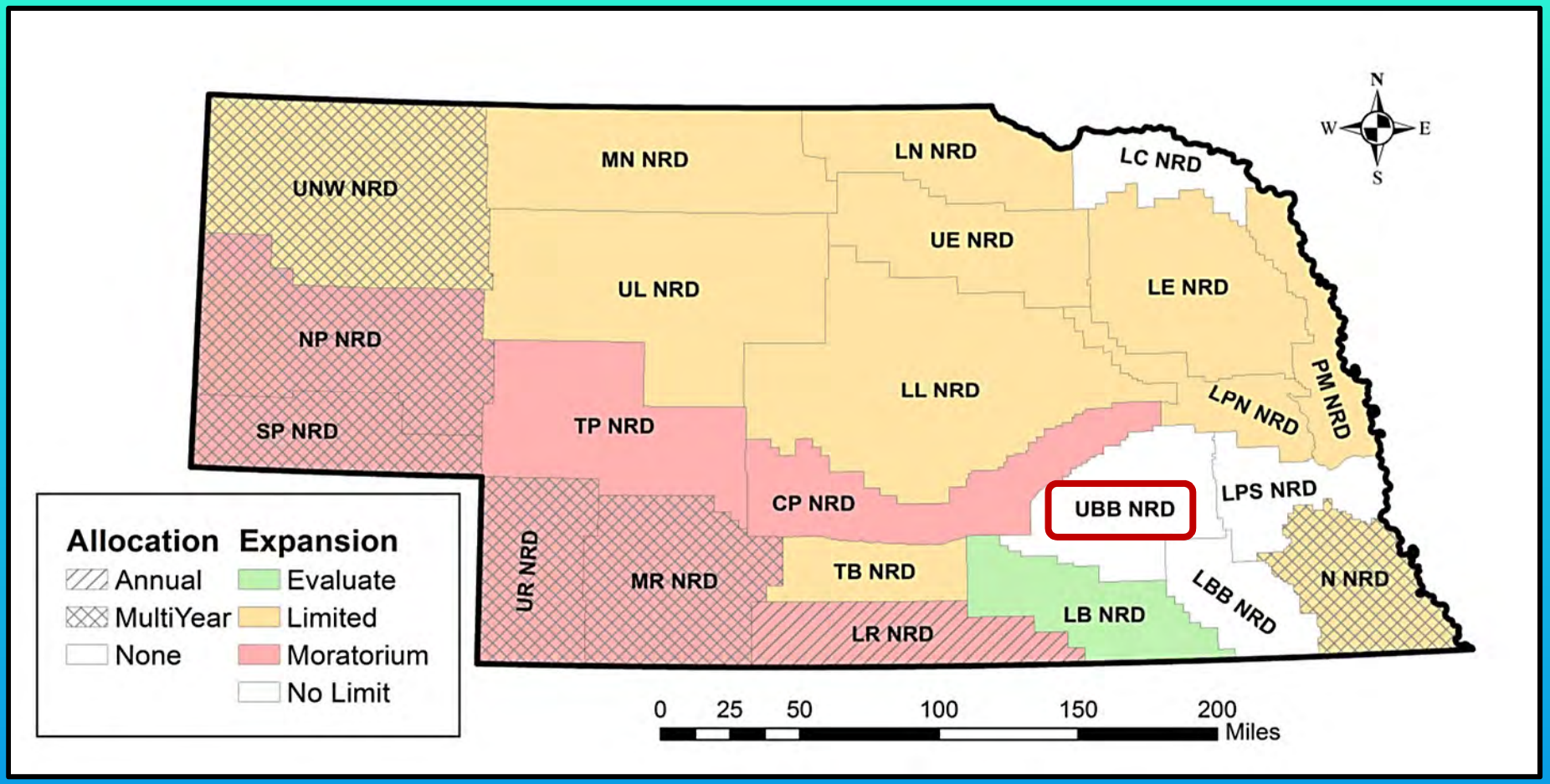
Water Control Programs in Nebraska



- Allocation programs limit volume of pumpage over a period of time
- Expansion limits restrict development of new wells or new irrigated areas
- Upper Big Blue considering allocation program
- Other western states have similar issues/programs

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Nebraska Approach to Watershed Management

1. NRD Sets Withdrawal or Pumpage Limit
2. Farmers Access Opportunities
3. Innovation Allows for Higher Efficiency
4. More Evapotranspiration or Consumptive Use than Planned
5. Streamflow Depletion Larger than Expected

- Some Colleagues Criticize Approach
- Not Direct Solution
- However, Encourages Innovation
- Ultimately this Increases the Value of the Water
- Must Agree to Continued Revisions

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How to add value to water use → Performance Indices

Water Footprint

(Volume of Water/Unit Food):

- What is alternative use of land?
- How would the alternative land use affect the watershed?
- Useful but misleading??

Water Use Efficiency or Water Productivity:

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

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

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

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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.

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Genetics **Agronomics**

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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

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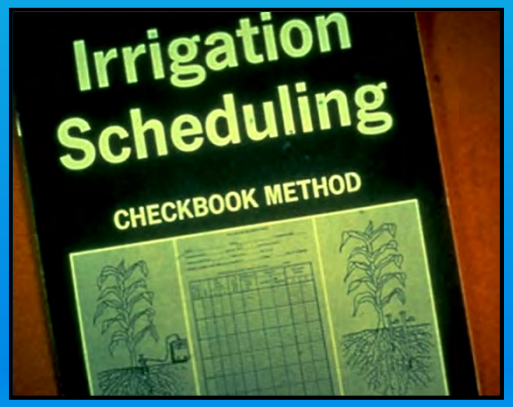
Breaking Down Water Use Efficiency – Enhancing Productivity and Value

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

- Utilize soil water for beneficial uses
- Minimize pumping & water quality impacts

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



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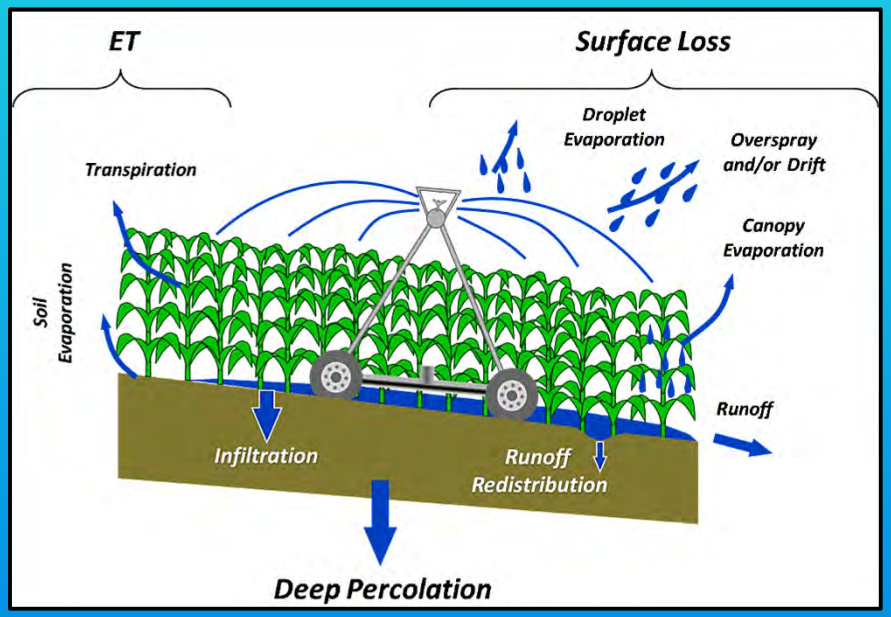
Breaking Down Water Use Efficiency – Enhancing Productivity and Value

$$\frac{\text{Root Zone Storage}}{\text{Irrigation Application}}$$

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



Better Accounting of Where the Water Goes

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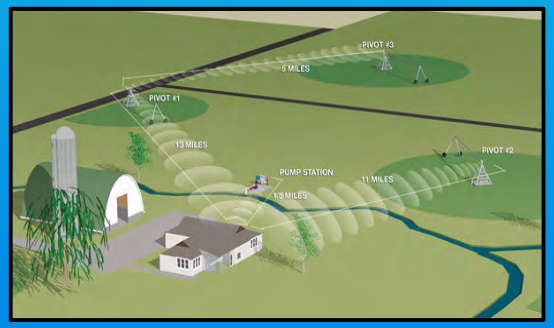
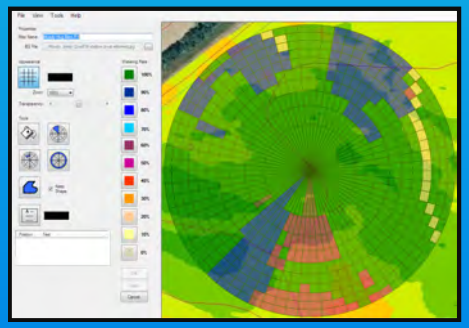
Breaking Down Water Use Efficiency – Enhancing Productivity and Value

$$\frac{\textit{Irrigation Application}}{\textit{Withdrawal}}$$

- 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

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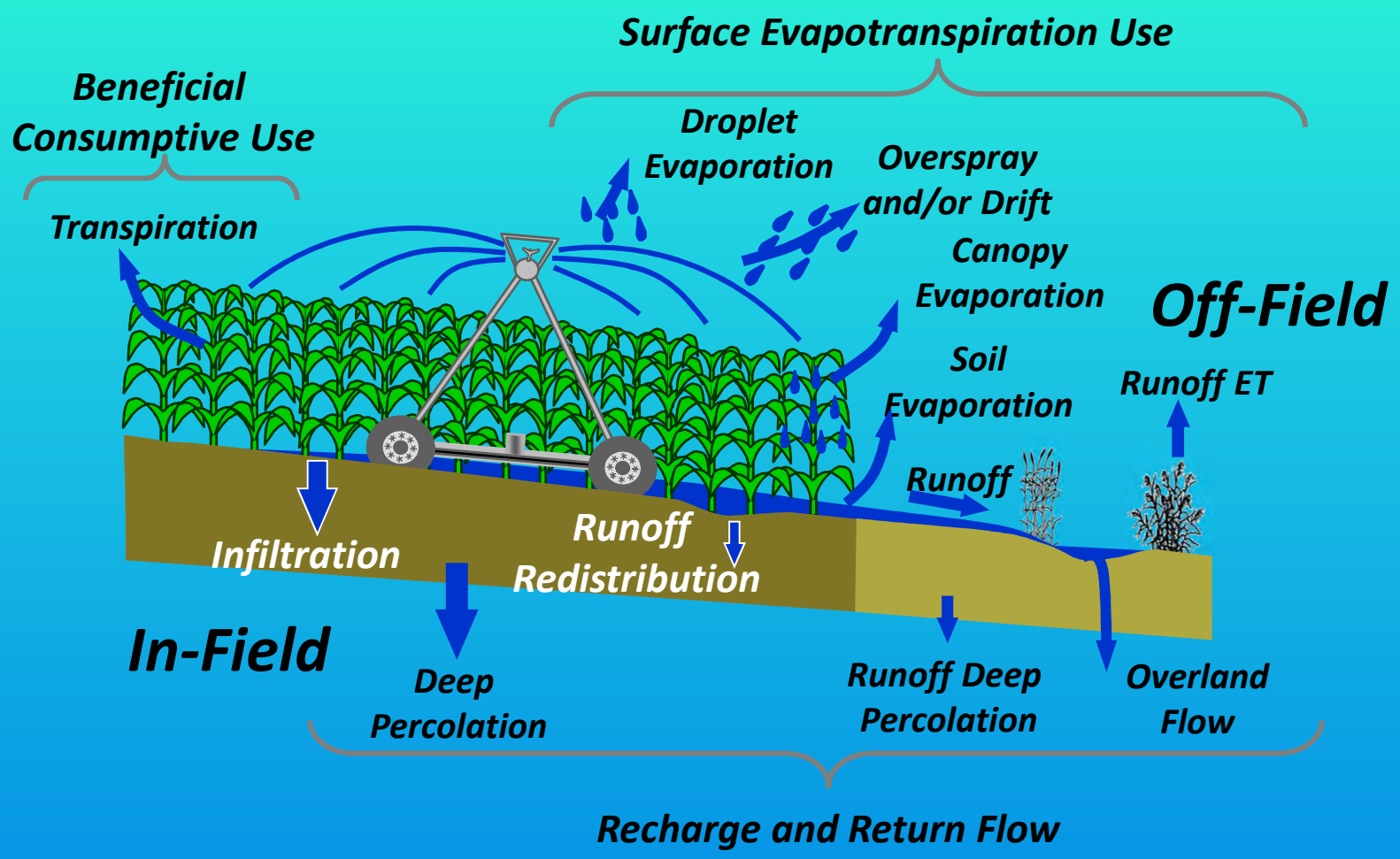
Water Balance - where does irrigation water go



- *Manage watersheds by accounting for where the water goes.*
- *Developing tools for water transfers and offsets to meet instream flow needs*

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Opportunities for Improvement

River and Watershed Systems and Management

On-Farm Systems & Management

Plant Productivity & Water Use

Where does the water go?
Must be interdisciplinary.
Need better accounting tools.

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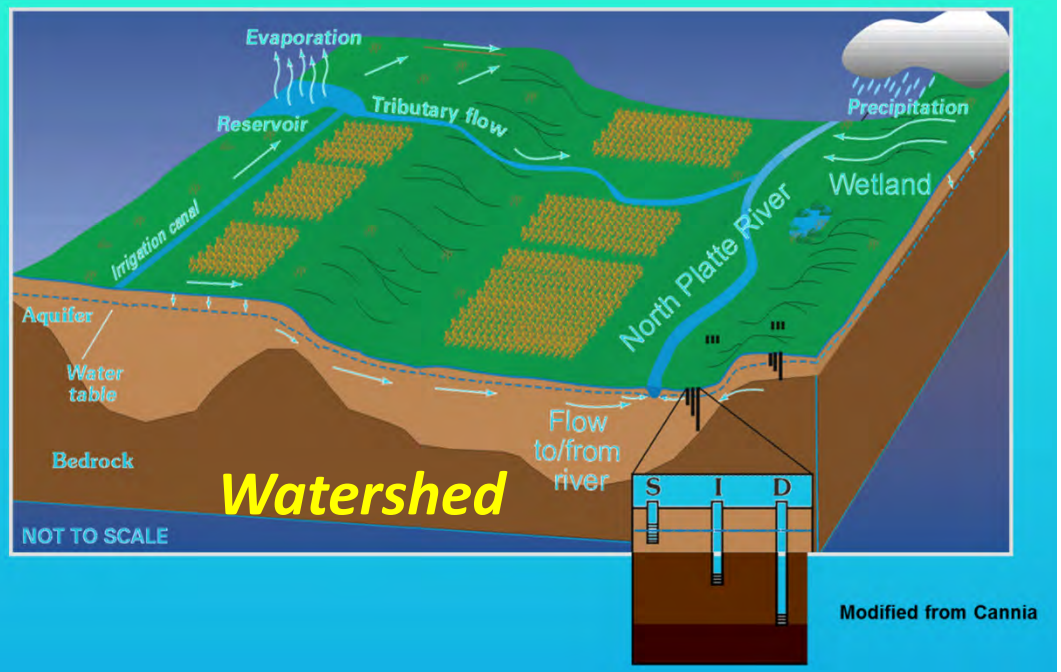
Benefits of Improved Management and Technology

vs



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?*

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Examples of Inconsistency of Land Use 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	😐	☺

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Resource Management Tradeoffs

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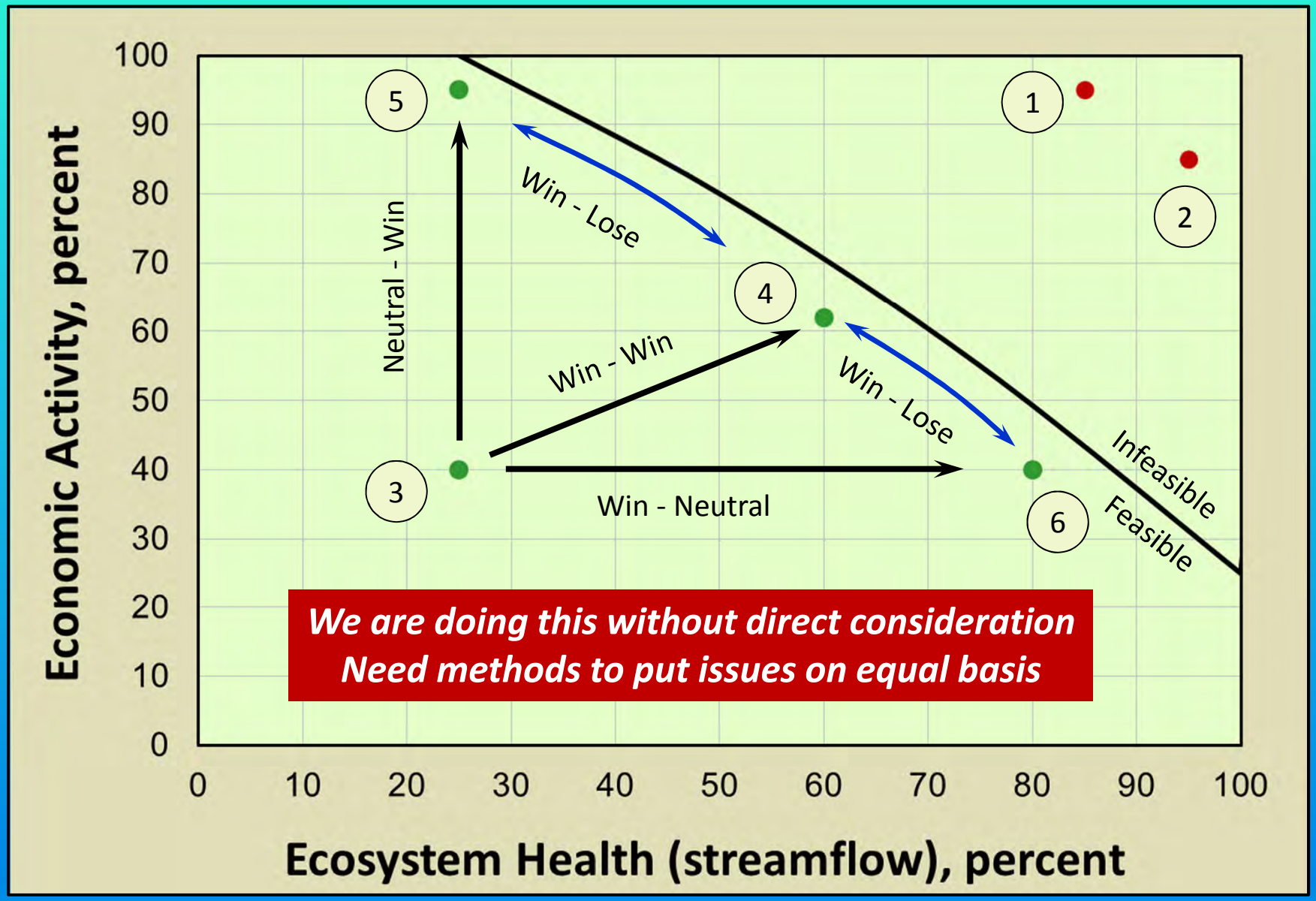
Classic Tradeoff



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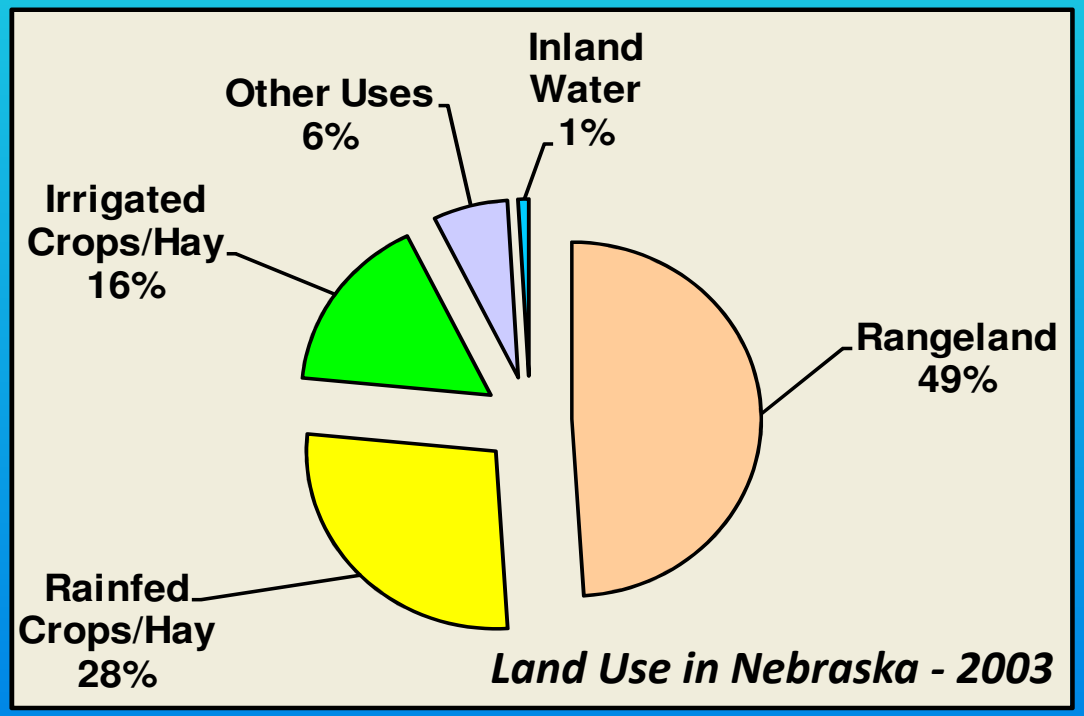
Must Focus on Needs of Clients / Stakeholders

- *Our clients are not all the same*
- *We have to design for variability and acceptance*



Land Use in Nebraska - 2003

- **Private ownership of 93% of land in Great Plains**
- **Must consider how stakeholders are affected**

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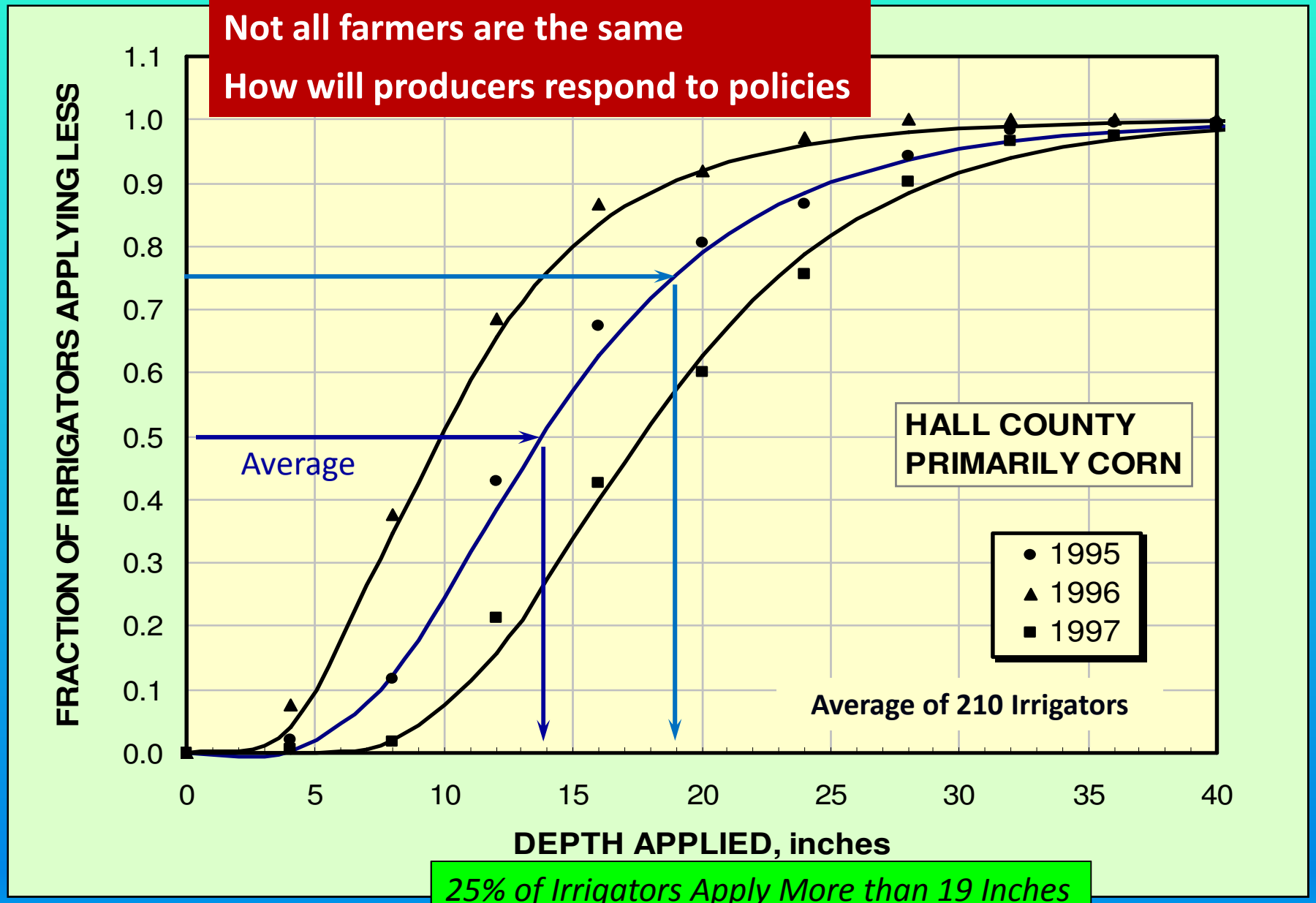
Variation Between Irrigators On Pumping Depth

Not all farmers are the same

How will producers respond to policies



25% of Irrigators Apply More than 19 Inches
5 Inches More than the Average Pumpage

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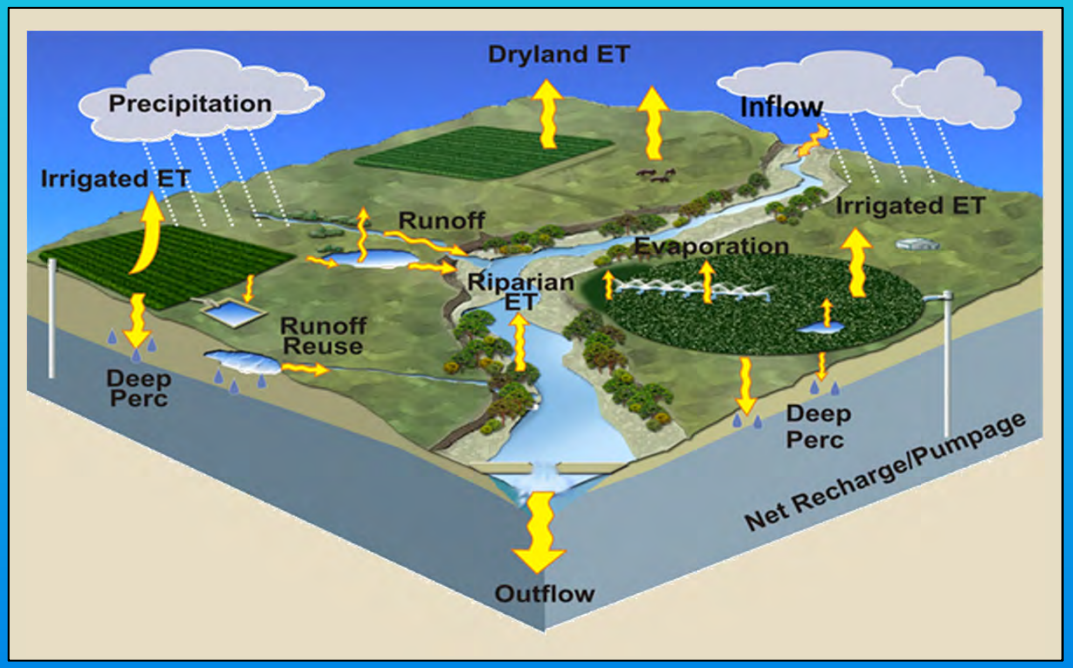
Advancements Needed for Managing Watersheds

- 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***

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Exciting Future – Think of the Possibilities

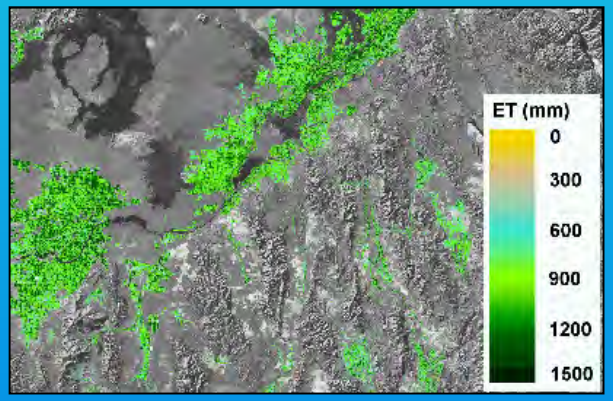
Look at Recent Developments

GMO Crops

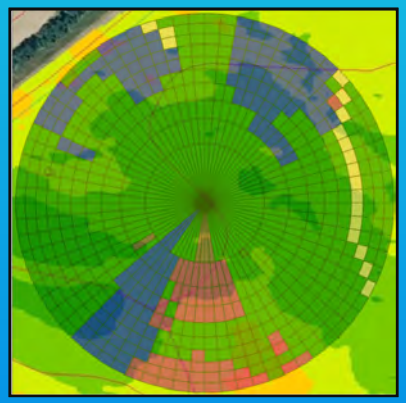
Encapsulated Fertilizer

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

Derrel Martin,
Biological Systems Engineering

University of Nebraska Lincoln

Thank You, Questions?

Derrel Martin,
Biological Systems Engineering

University of Nebraska Lincoln

Opportunities for Improving our Crop Production Efficiency

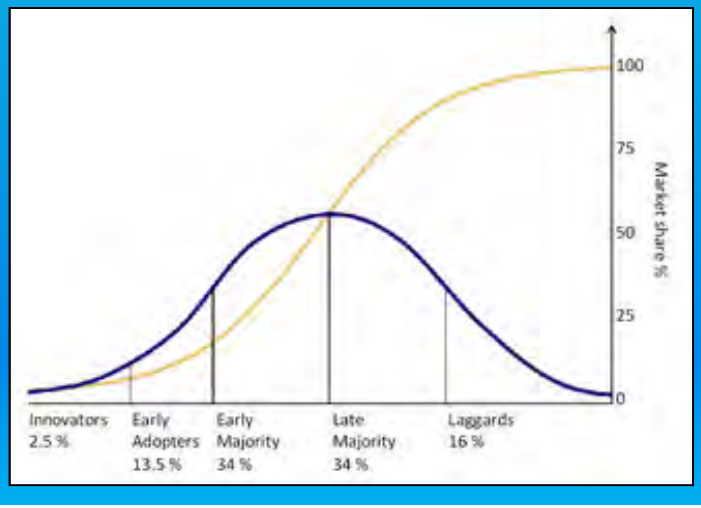
- Agricultural technology development has occurred rapidly over the past few years
- Tools available today have exceeded our agronomic understanding for application in some cases
- Further integration of these tools will allow for more innovation in our crop production system
- This will allow producers to become even more efficient in large-scale production operations

Increasing our Input-Use Efficiency

- One of the primary goals of precision agriculture or site-specific crop management is to improve how we use our crop production inputs
- Many technologies have allowed for advances in this area
- Software provides us with the ability to track and analyze how the production system is operating
- Feedback from these systems allow for better decision making

Technology Adoption by Producers takes time

- Many technologies that are considered “plug and play” are often readily adopted by producers
- These systems require less time investment to manage and can be done in-cab
- Moving to the next level (variable-rate application) requires data management and analysis skills
- Producers must take time to develop these skills or find a trusted advisor to manage their data

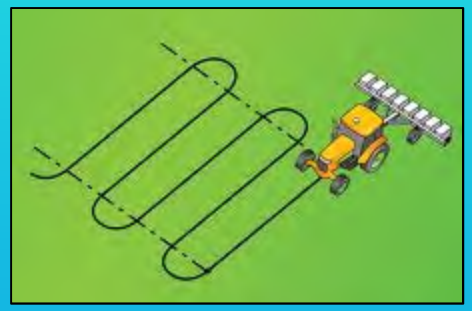


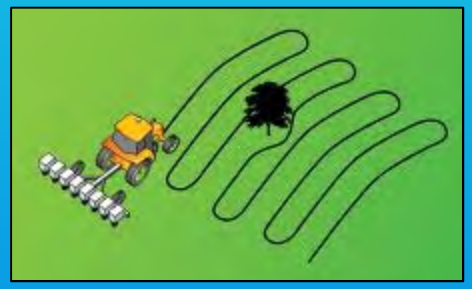
Examples of Cost-Saving Equipment Technologies

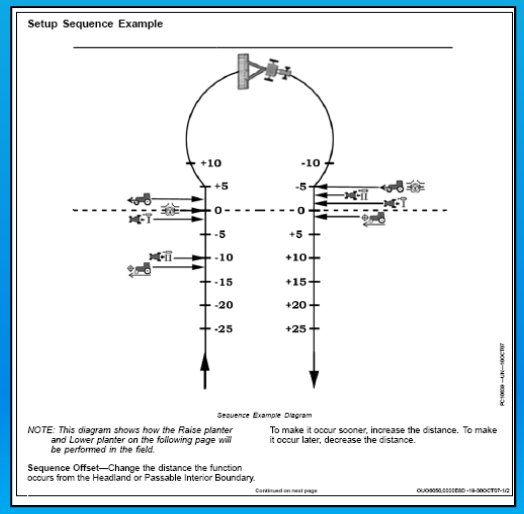
- Global Positioning Systems (GPS) are still at the heart of agricultural technology
- Automated steering systems come in different forms
- Pass-to-pass overlap can be greatly reduced
- Most new equipment comes fully integrated
- Savings range from 2% to 5% in some cases

Examples of Cost-Saving Equipment Technologies

- Steering systems have become more advanced and can adapt to different situations
- Further advancements automate headland turning
- The goal is to increase field efficiency

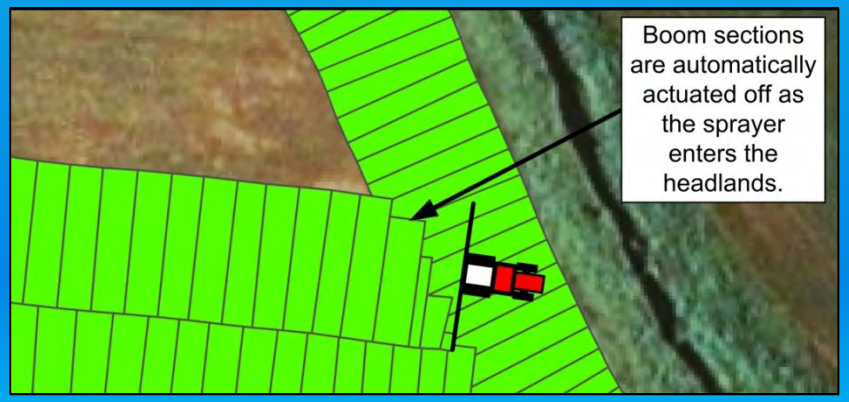


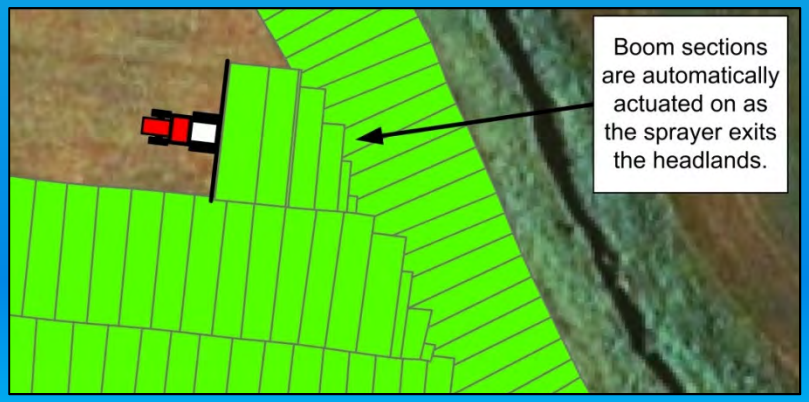




Examples of Cost-Saving Equipment Technologies

- Automatic section control (ASC) systems give the ability to control large equipment more precisely
- GPS is used to track field coverage, control sections are turned on or off depending on field position
- ASC systems may be added to sprayers, planters, and fertilizer applicators



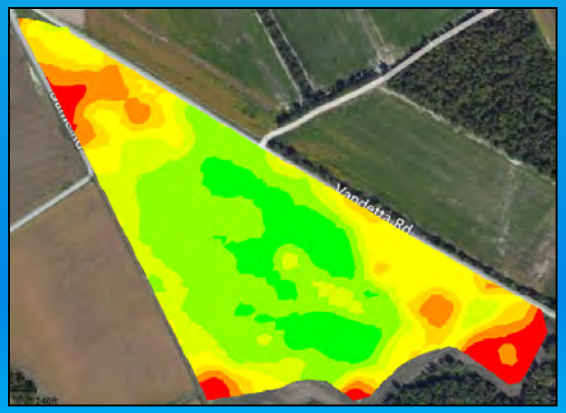


Examples of Cost-Saving Equipment Technologies

- Savings depend on equipment width, number of control sections, and field shape/size
- An 1800 acre case study in KY found application reductions from 4% to 20% for an 80 foot sprayer
- Average reduction in the case study was nearly 9%
- Mapping function can also eliminate application to environmentally-sensitive areas

Map-Based Variable-Rate Application for Crop Inputs

- Acquire spatial data from field equipment (e.g., yield, pH, EC, and soil test data)
- Develop prescription maps for application of crop inputs (seed and nutrients) based on management zones
- Analyze data from previous year's management strategies
- Data analysis and software skills required
- Upload prescriptions to equipment control monitors



Variable-Rate Application Systems

- Variable-Rate Application (VRA) systems have been receiving more attention in the past 5 to 10 years
- Advances in control technologies have been applied to numerous application equipment
  - Nitrogen
  - Nutrients
  - Lime

Variable-Rate Application Systems

- More recently, VRA systems have been developed for controlling plant population across fields
- Electric drives or electro-hydraulic drives are capable of controlling individual rows
- Plant population is varied according the prescription map previously uploaded to control monitor
- Variable hybrid within fields?
- May become an option

Sensor-Based Variable-Rate Nitrogen Application

- Recently developed crop canopy sensors are being adopted for split application of Nitrogen
- Plant stress and growth is sensed at the time of application and Nitrogen is applied accordingly
- Generally used with liquid Nitrogen today
- Operator input is still critical for proper application, maximum and minimum rates must be specified

Tillage Reduction and Nutrient Placement

- Strip-tillage may offer an opportunity to reduce conventional tillage in some areas
- Most systems offer the ability to place nutrients in the strip, planting occurs shortly after
- Some systems incorporate VRA for nutrients
- Direct planting is an option, reducing additional fieldwork

Agricultural Telematics and Wireless Communication

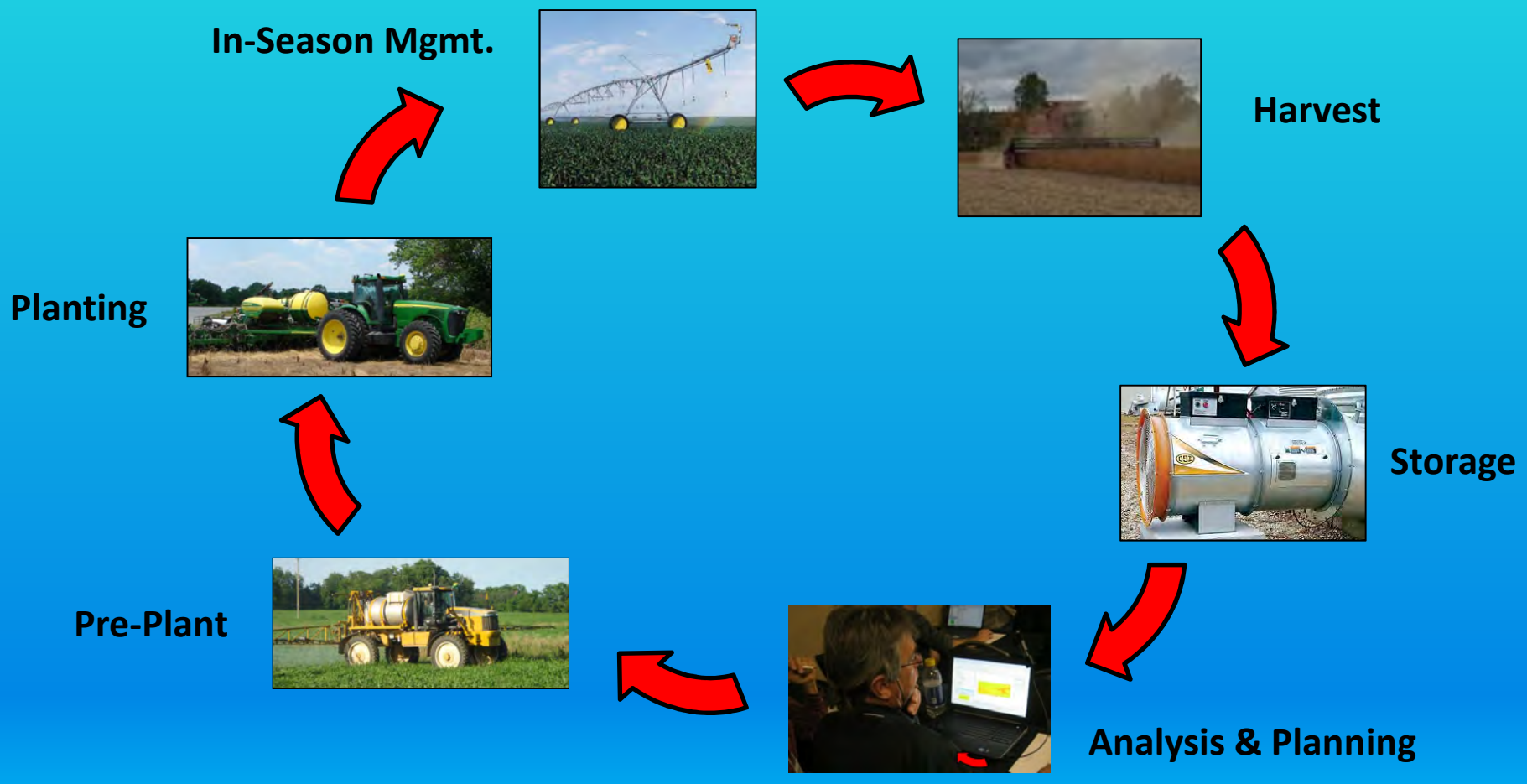
- Wireless communication has allowed for advances in telematics (transfer and analysis of data) to and from the field
- Endless applications range from machinery management (machine health) to crop monitoring pre- and post-harvest
- Machine to machine communication may help improve field efficiency

Remote Sensing and UAV Technologies

- Monitoring crop stress response to the environment (phenotyping) is poised for future growth as we try to diagnose and treat crop health issues during the season
- Crop Nitrogen application is just the beginning
- Sensing systems to monitor water, disease, infestation, and other nutrient deficiencies are on the horizon
- Mobile platforms can improve timeliness of data collection

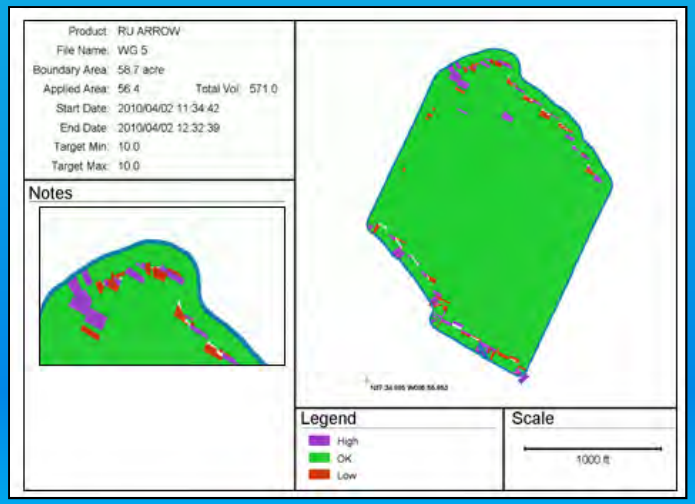
Technology can Gather Information Throughout the Production Cycle

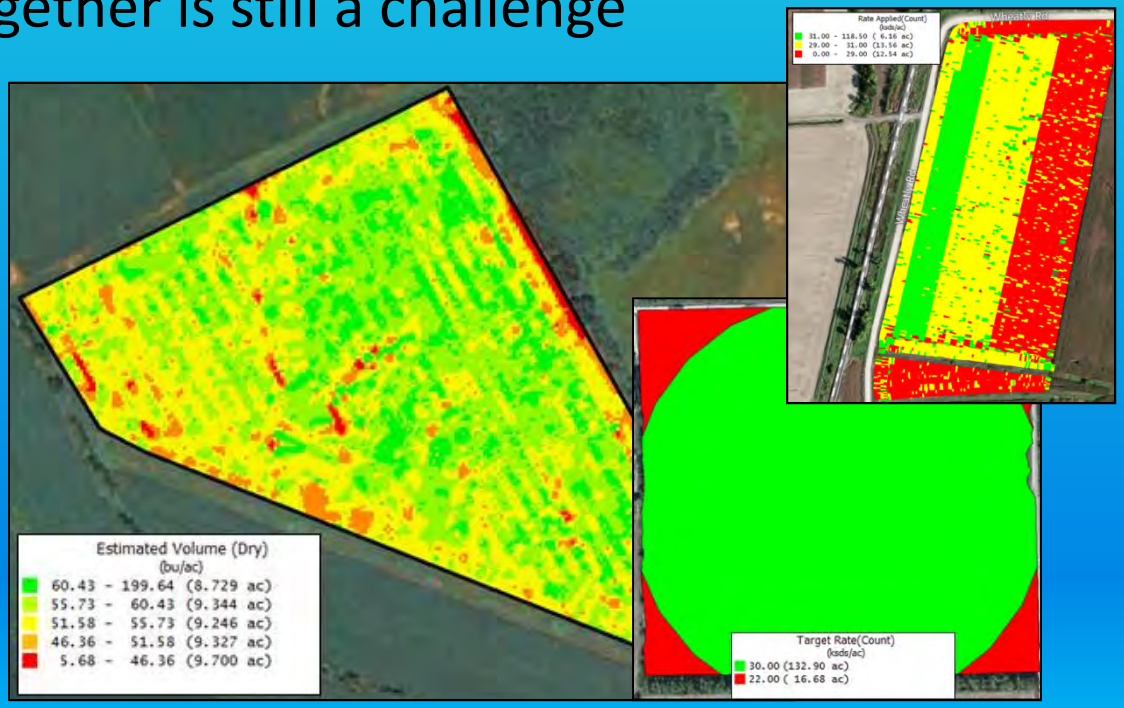
- Making good use of the data for management decisions is key



Harnessing Spatial Data for Improving Management

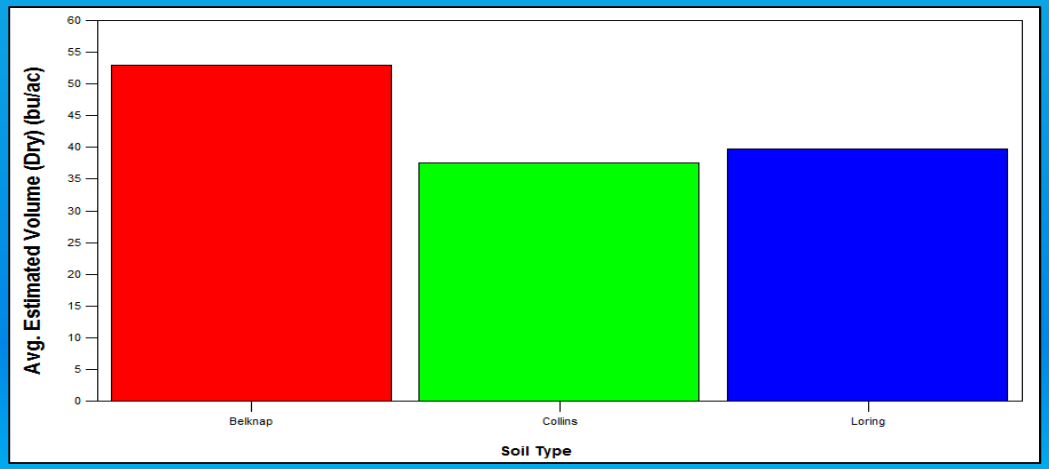
- Making use of all of this information is still a great opportunity
- As-applied maps (seed, nutrients, water) will be necessary to evaluate how efficient the crop production was performed
- Bringing these data together is still a challenge

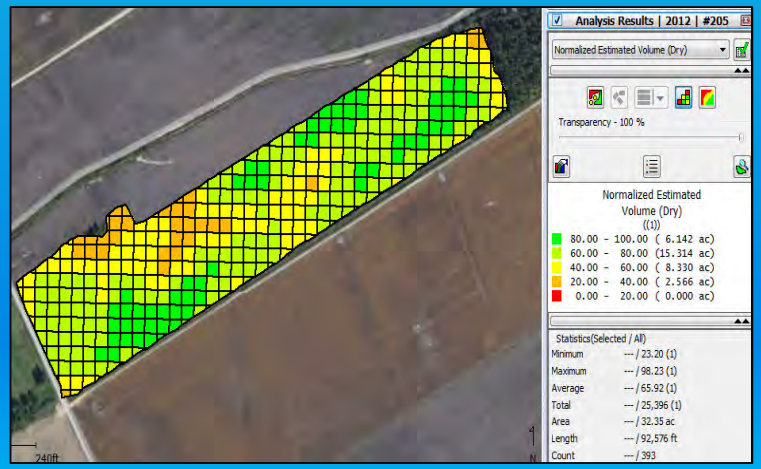




Harnessing Spatial Data for Improving Management

- Evaluation of the production system must happen at the end of the year to plan ahead
- What areas will consistently yield high or low, how do we plan for this instability before the year?
- Risk management analysis may help growers evaluate how their choices may affect productivity (timing/amount of fertilizer or pesticides) during the growing season





Where are we Headed?

- We are at an exciting time in agricultural crop production
- Technologies are allowing producers to grow crops with less inputs providing economic and environmental benefits
- Companies are positioning themselves to improve data transfer and management (John Deere and Pioneer partnership)
- Many other companies are taking part in these efforts

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Thanks for your time!

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