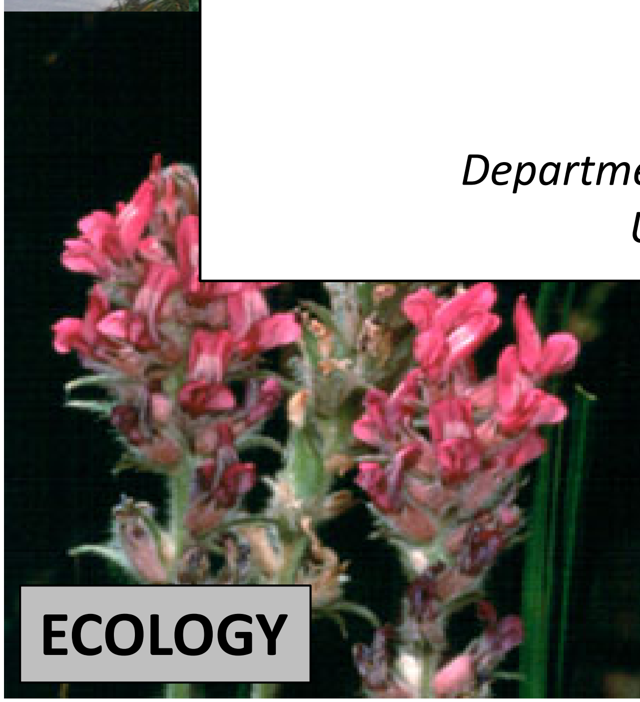
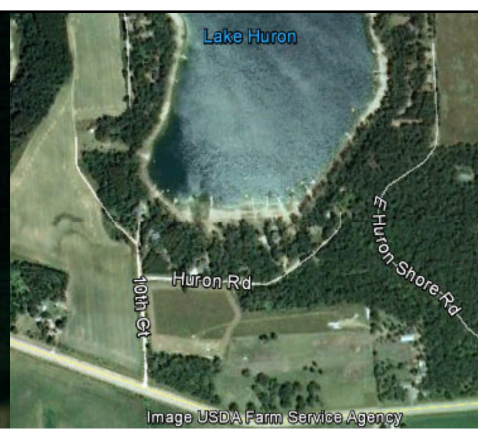
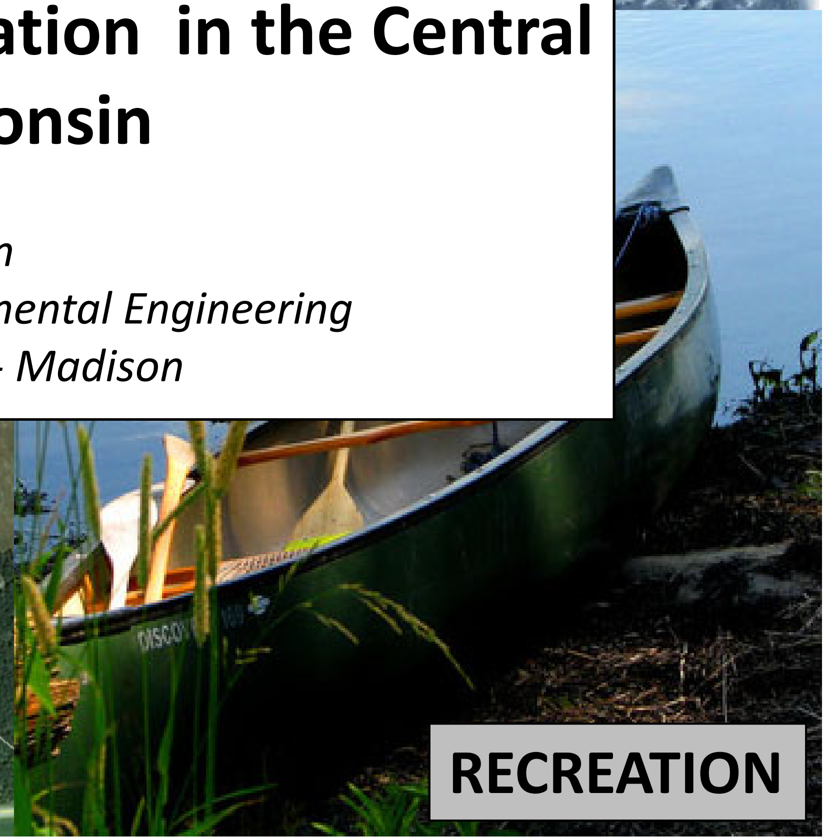
Investigating the Effects of High-Capacity Irrigation Well Pumping on the Groundwater Recharge and Evapotranspiration in the Central Sands of Wisconsin

Maribeth Kniffin
Department of Civil and Environmental Engineering
University of Wisconsin - Madison



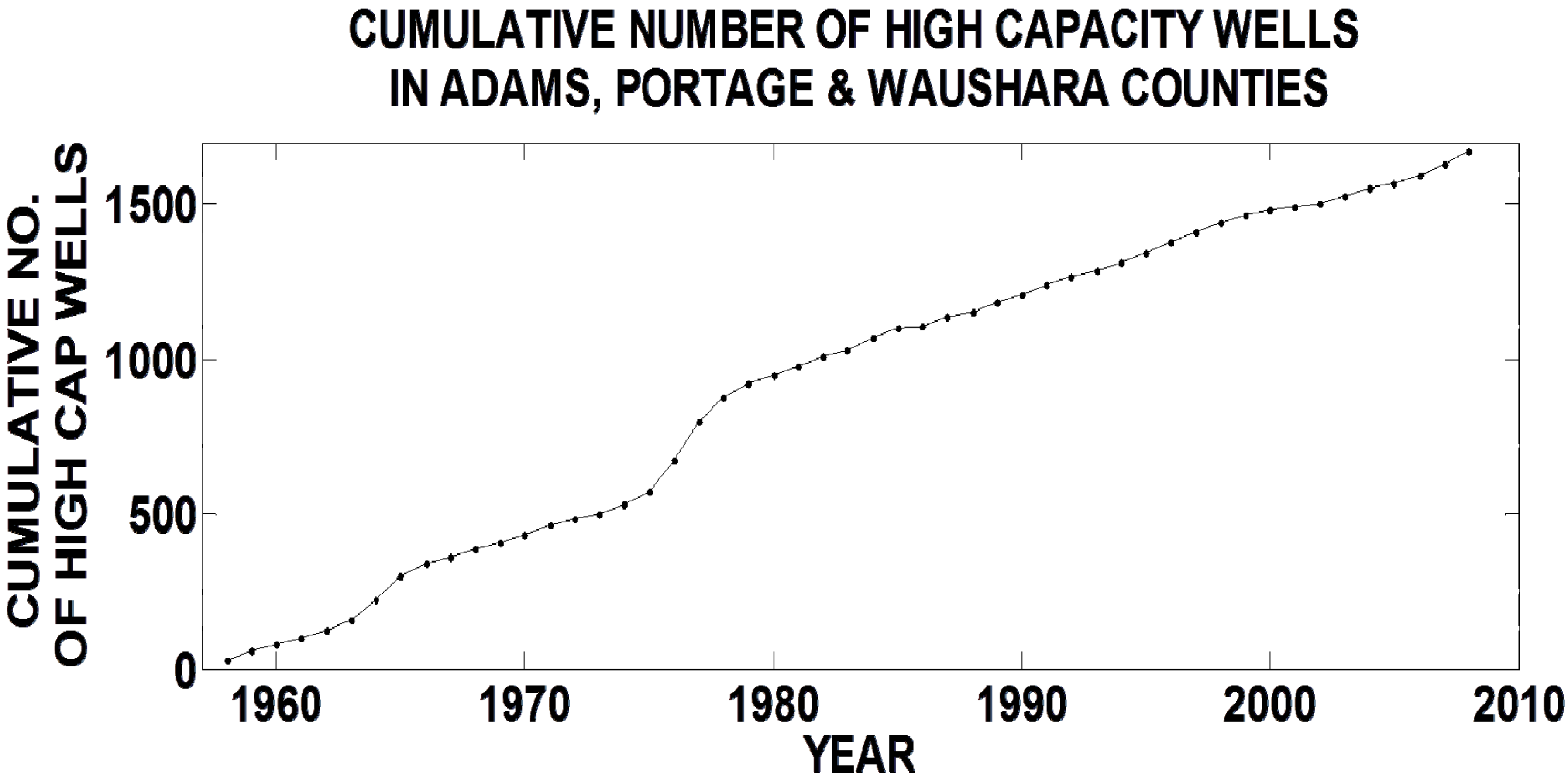




Outline

- Motivation
- Research Question
- Methods & Results
  - ET Model
  - Regression Model
- Future Directions

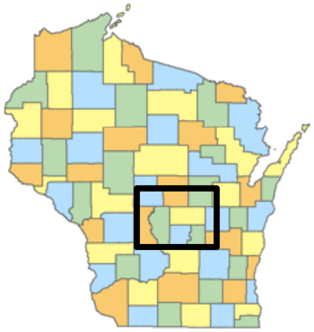
Land-Use Change



WDNR Well Construction Report Data, 2010

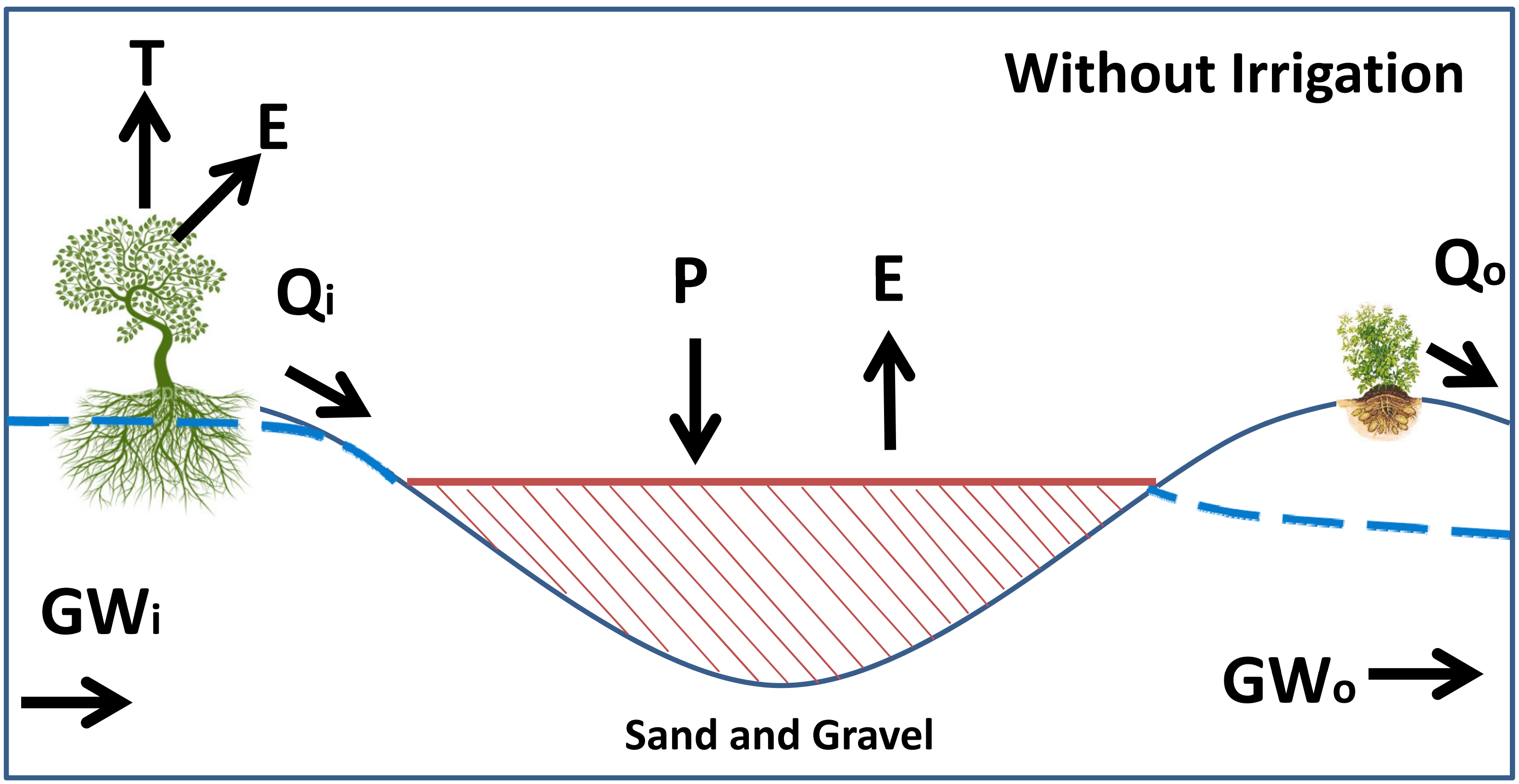
Factors Affecting Lakes & Streams

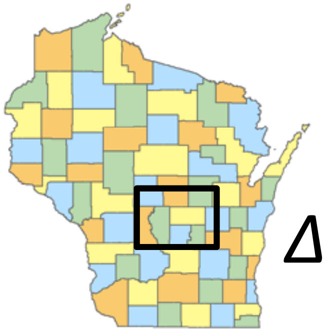
- Lake morphology
- Hydrology
- Natural variability in weather
- Land-use patterns
- Human water use
- Climate change



$$\Delta Storage = Inflow - Outflow$$

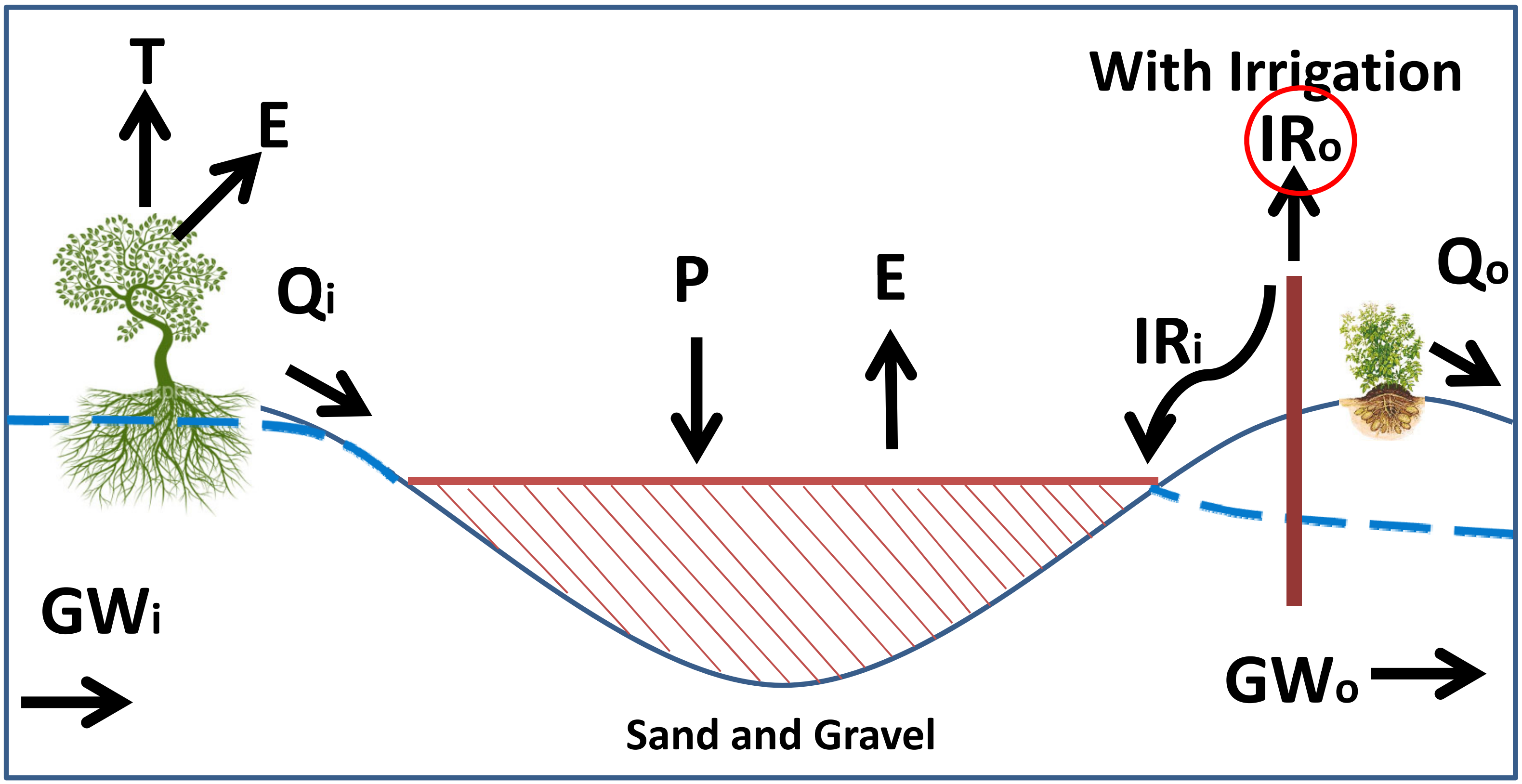
$$\Delta S = P + GW_i - GW_o + Q_i - Q_o - ET$$





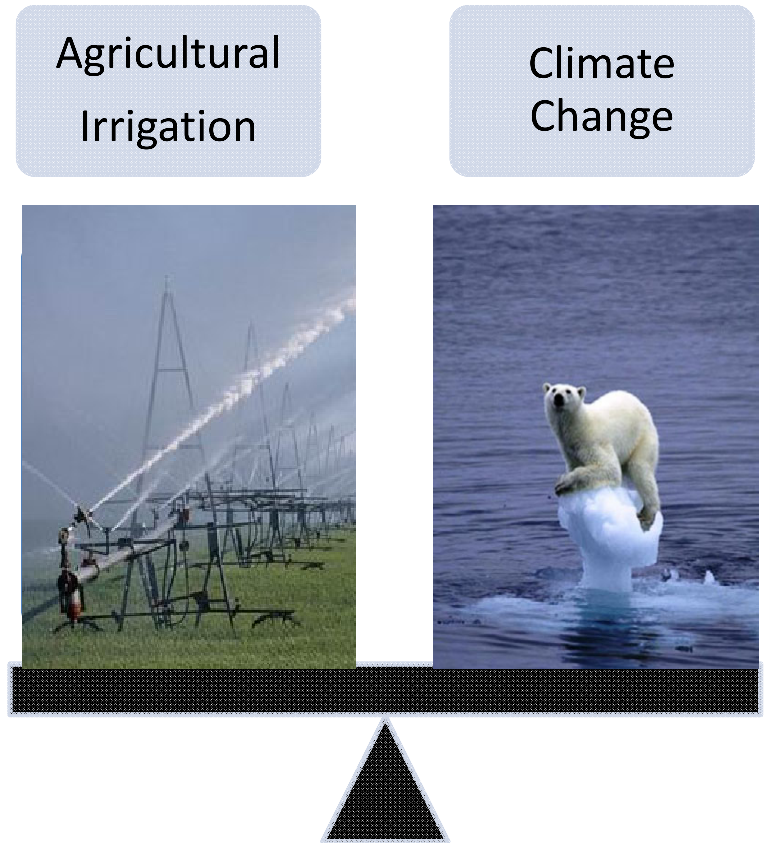
$$\Delta\text{Storage} = \text{Inflow} - \text{Outflow}$$

$$\Delta S = P + GW_i - GW_o + Q_i - Q_o - ET + IR_i - IR_o$$

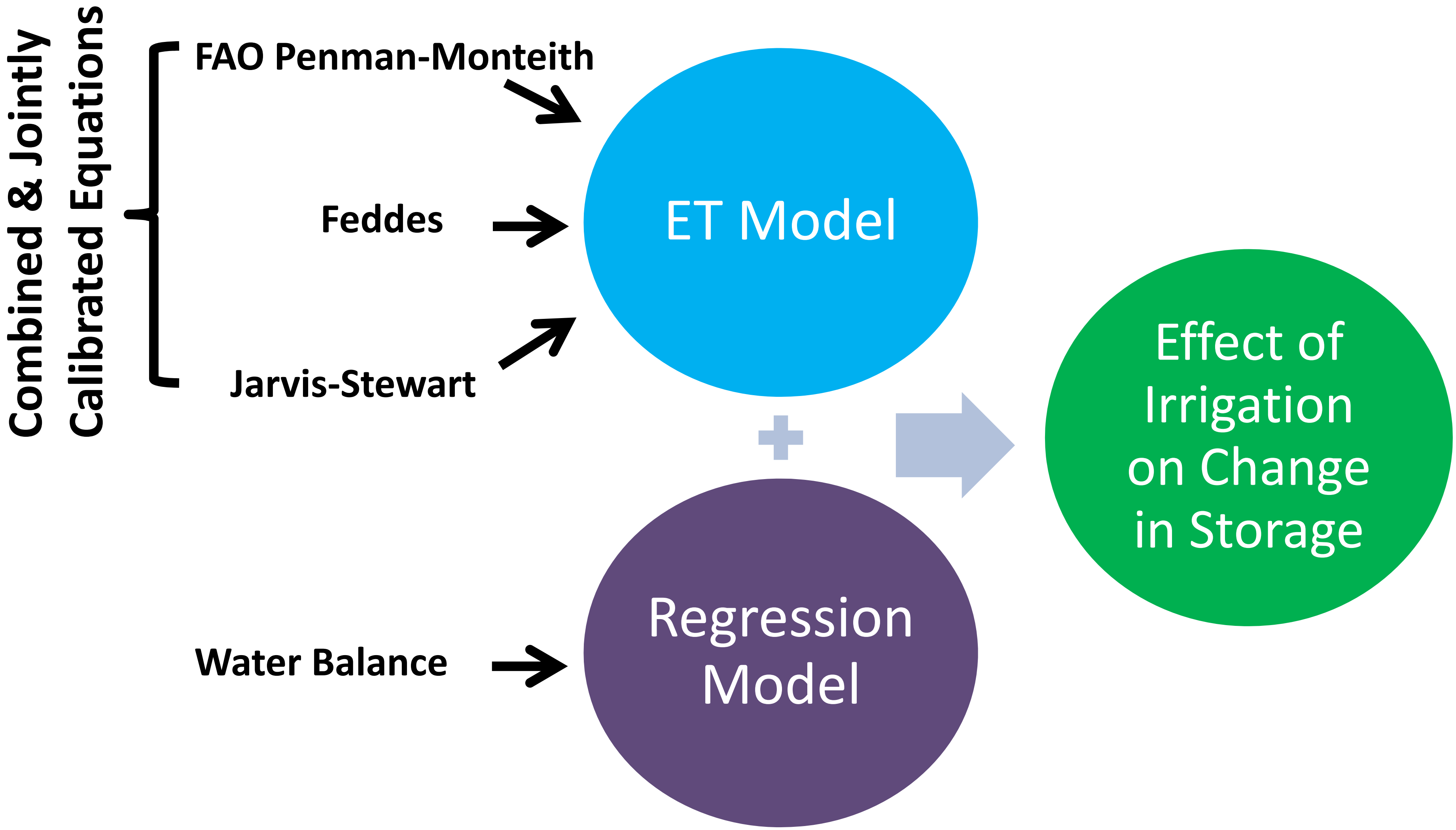


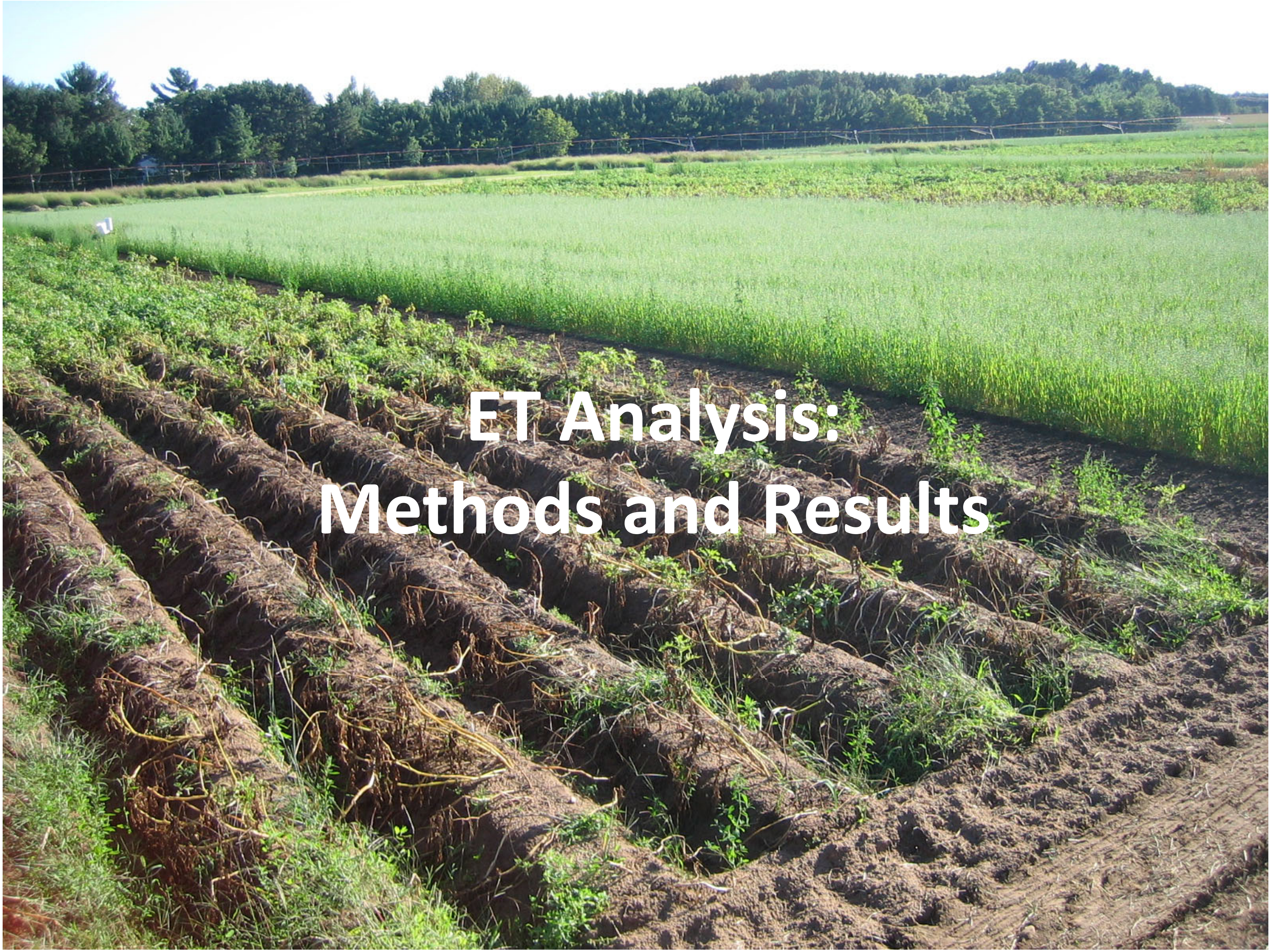
Research Question

Has there been a **change** in **groundwater levels** due to **irrigation** high capacity well pumping in the Central Sands of Wisconsin?



Model Overview

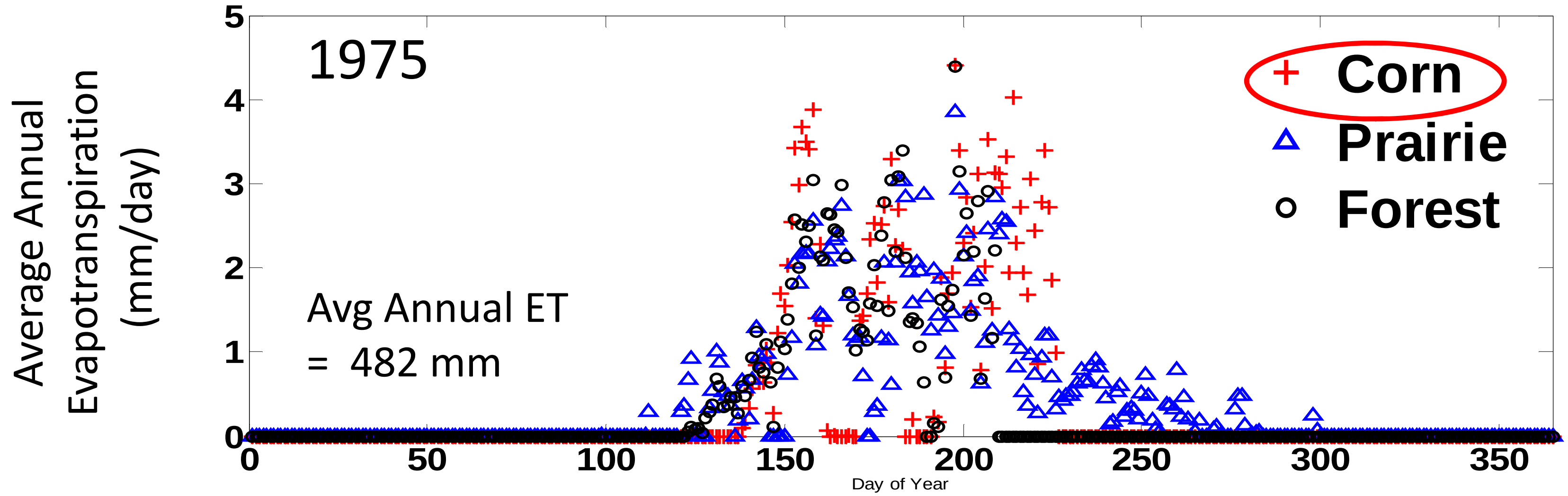


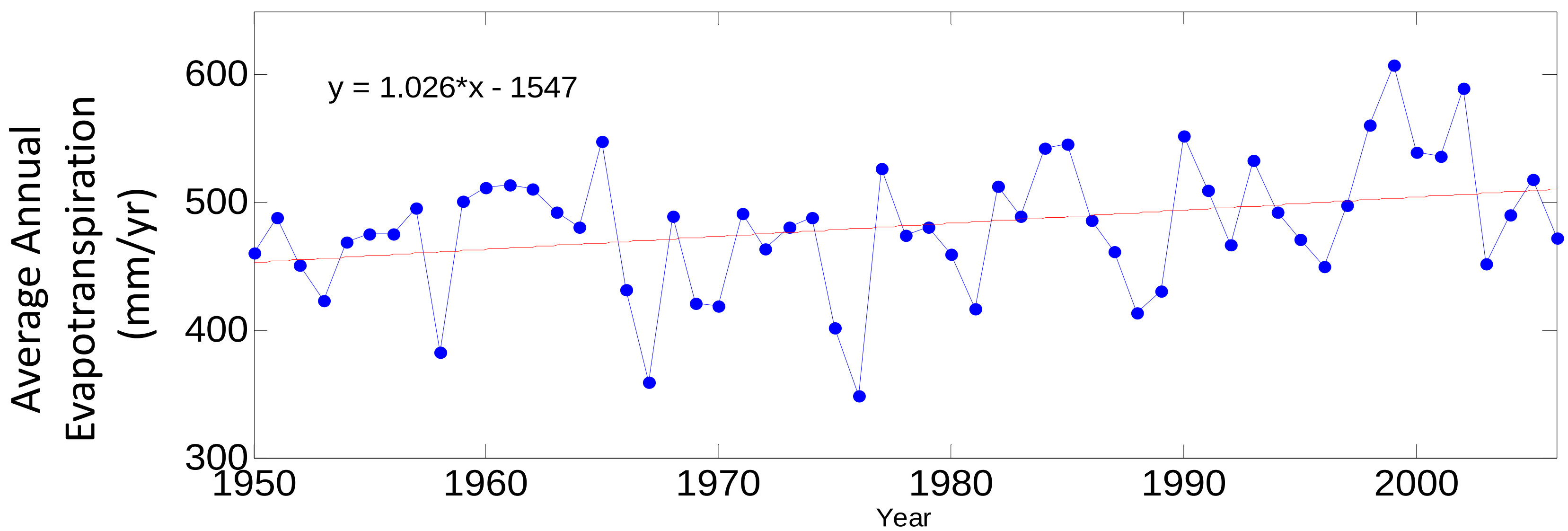

ET Analysis:
Methods and Results

Evapotranspiration Model

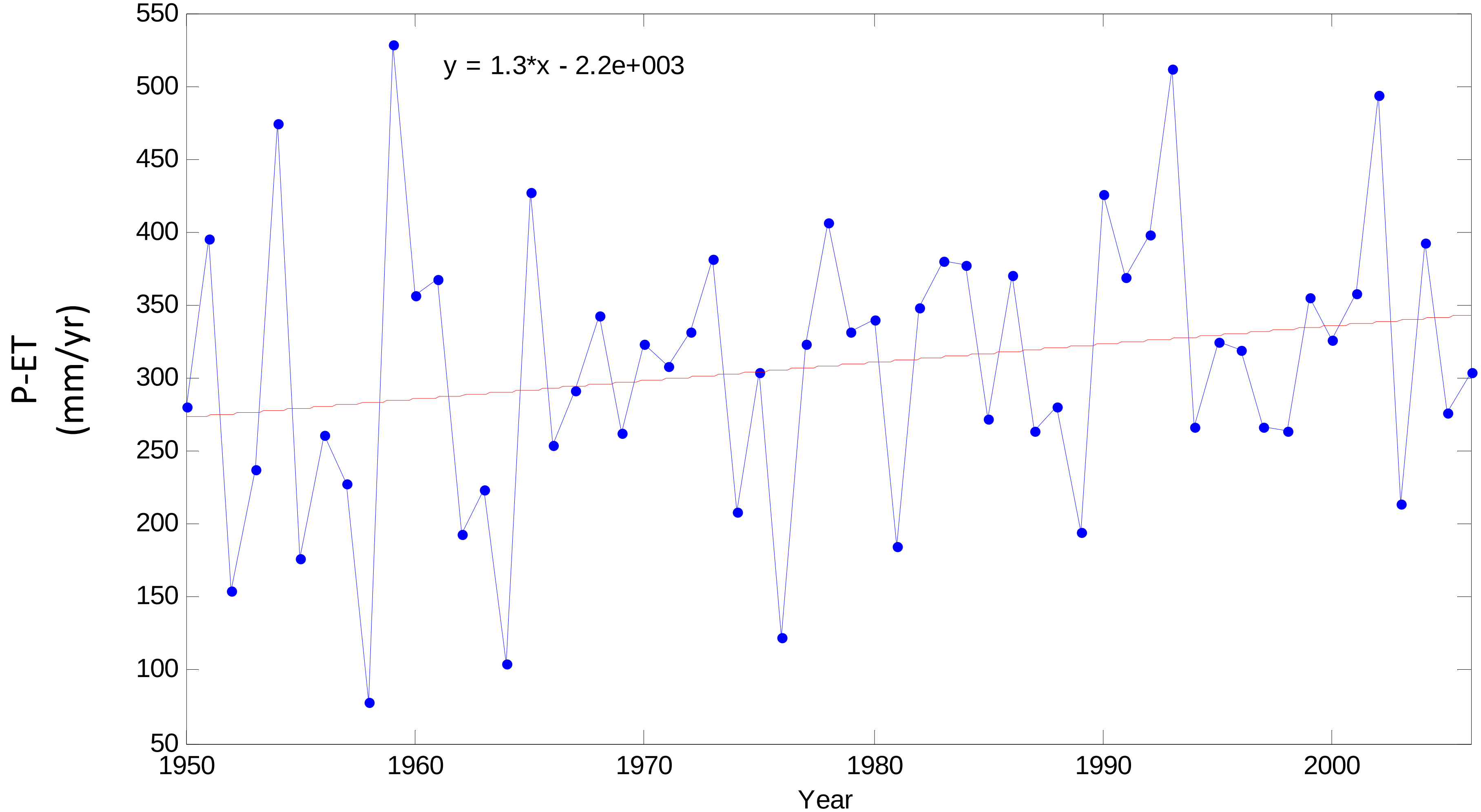
- Data sets: 1950-2007
  - Kucharik
    - Temperature
    - Precipitation
  - National Centers for Environmental Protection
    - Wind speed
    - Relative humidity
    - Radiation (Solar and Net)
- Locations
  - Hancock
- Crop and Soil Type
  - Corn and Sandy Soil

ET Model Results

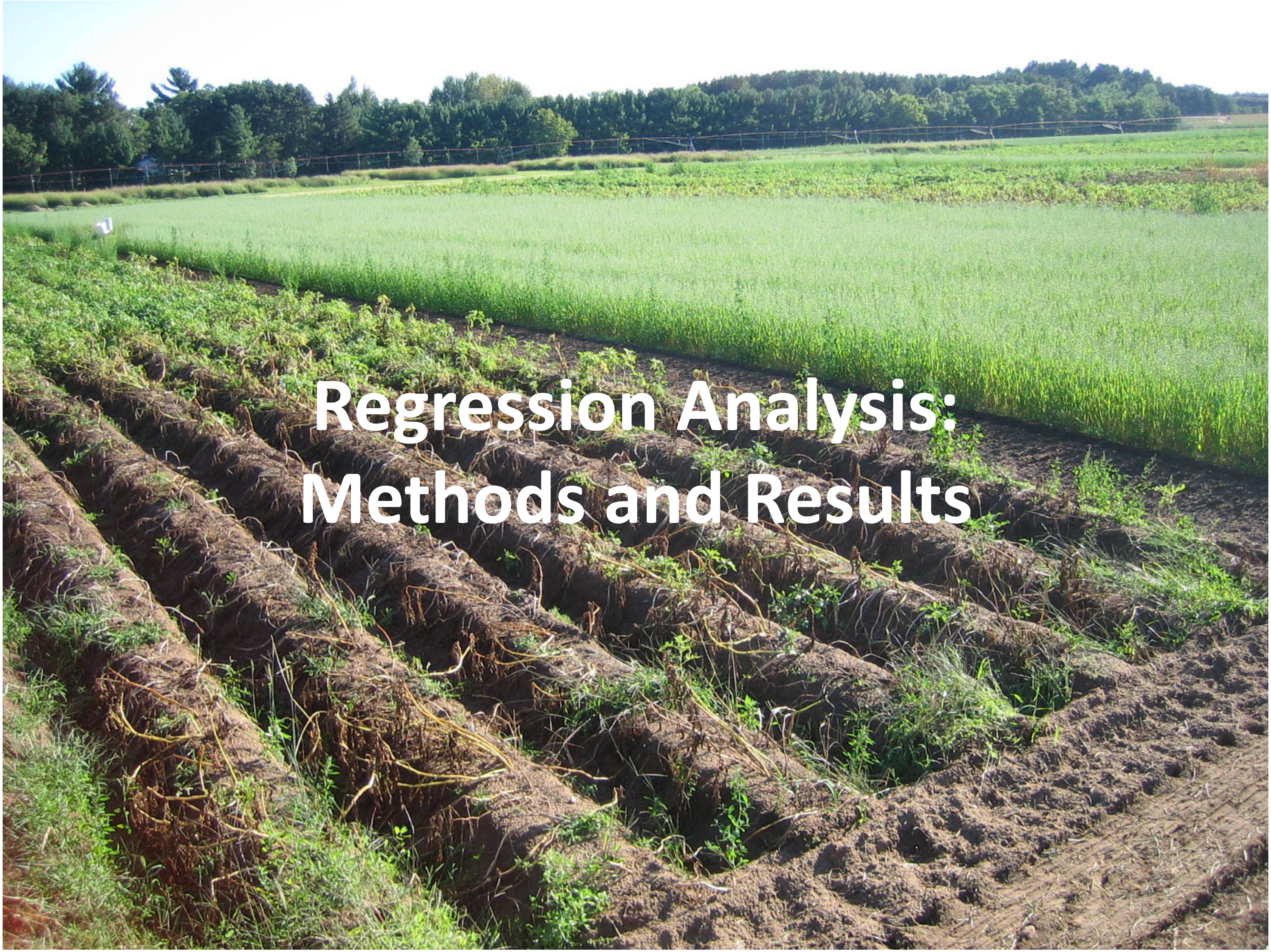




ET Model Results



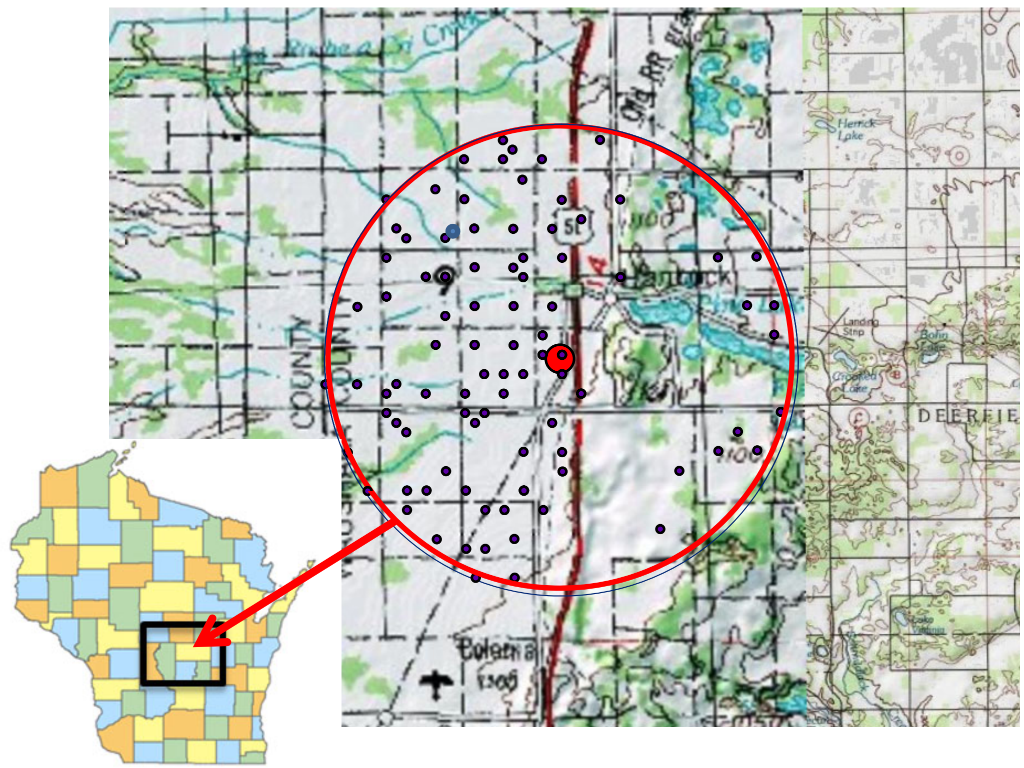
Regression Analysis: Methods and Results



Water Balance -> Regression

$$\Delta S = P + GW_i - GW_o + \cancel{Q_i} - \cancel{Q_o} - ET + \cancel{IR_i} - IR_o$$

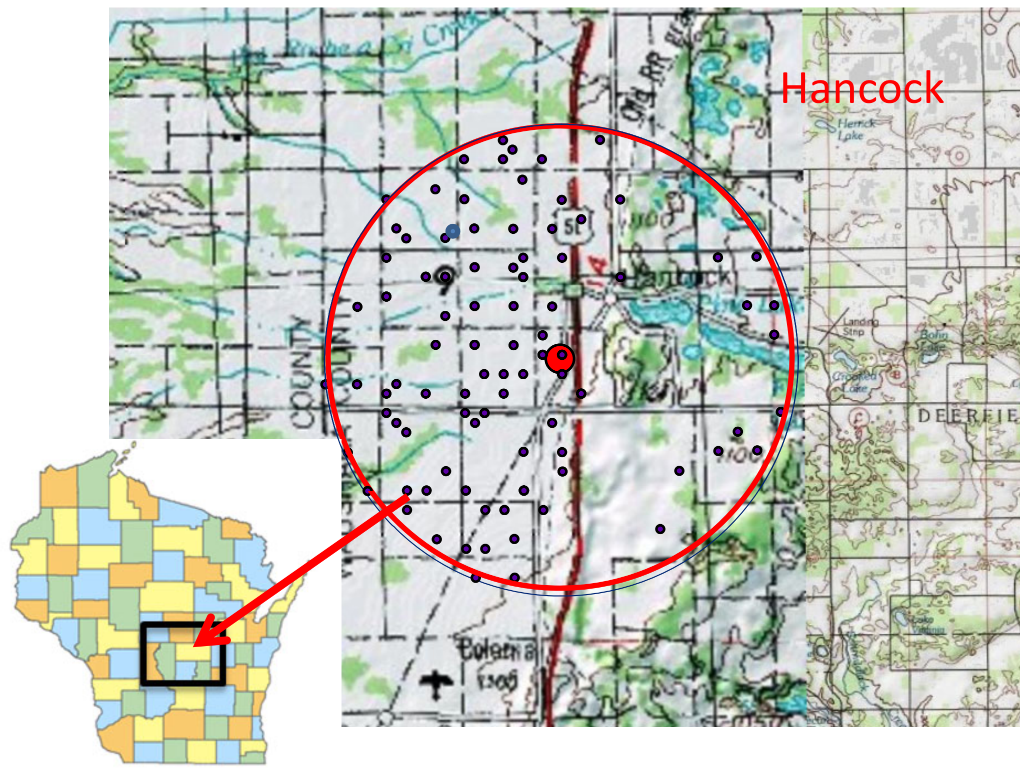
- Assumptions
  - $\Delta S \propto \Delta GW$
  - $GW_i - GW_o \propto$ GW elevation
- Terms:
  - ΔS = Change in storage
  - P = Precipitation
  - GW = Groundwater
  - Q = surface flow
  - ET = Evapotranspiration
  - IR = Irrigation
  - i = inflow
  - o = outflow



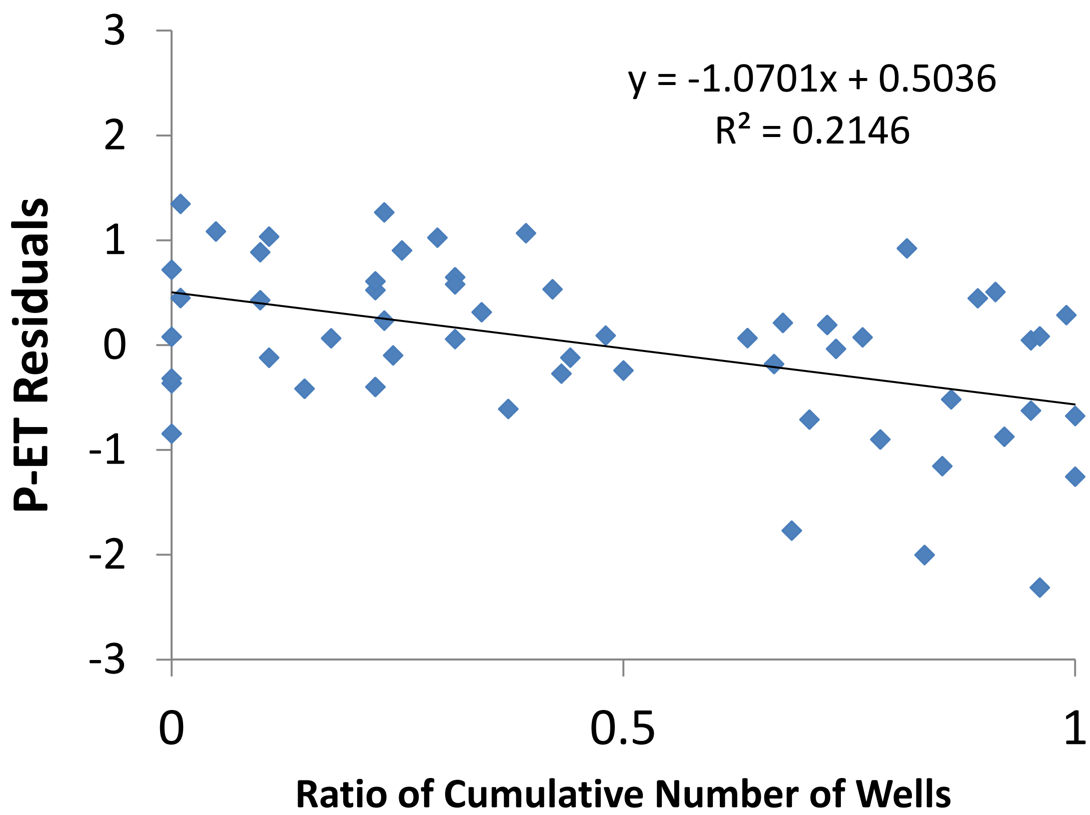
Regression Model

$$G_{N_{365}} - G_{N_0} = \beta_0 + \beta_1 [P_N - E_N] + \beta_2 G_N + \beta_3 I_N + e$$

- Study site: Hancock
- Terms:
  - I = Cumulative number of high capacity wells
  - e = error



Regression Model Results



Regression Statistics	
Multiple R	0.86
R-Squared	**0.74**
Standard Error	0.71
Observations	56
Coefficients	
Intercept	-3.44
Avg Annual GW Elevation	-0.01
Avg Annual P-ET	3.74
Cumulative # Wells	**-1.13432**

p = 1.07E-16

p = 2.66E-4

In the region of Hancock in the **Central Sands** of Wisconsin, **groundwater pumping** used to support irrigated **agriculture** has **decreased** recharge and, thus, **water** available for **lakes** and **streams.**

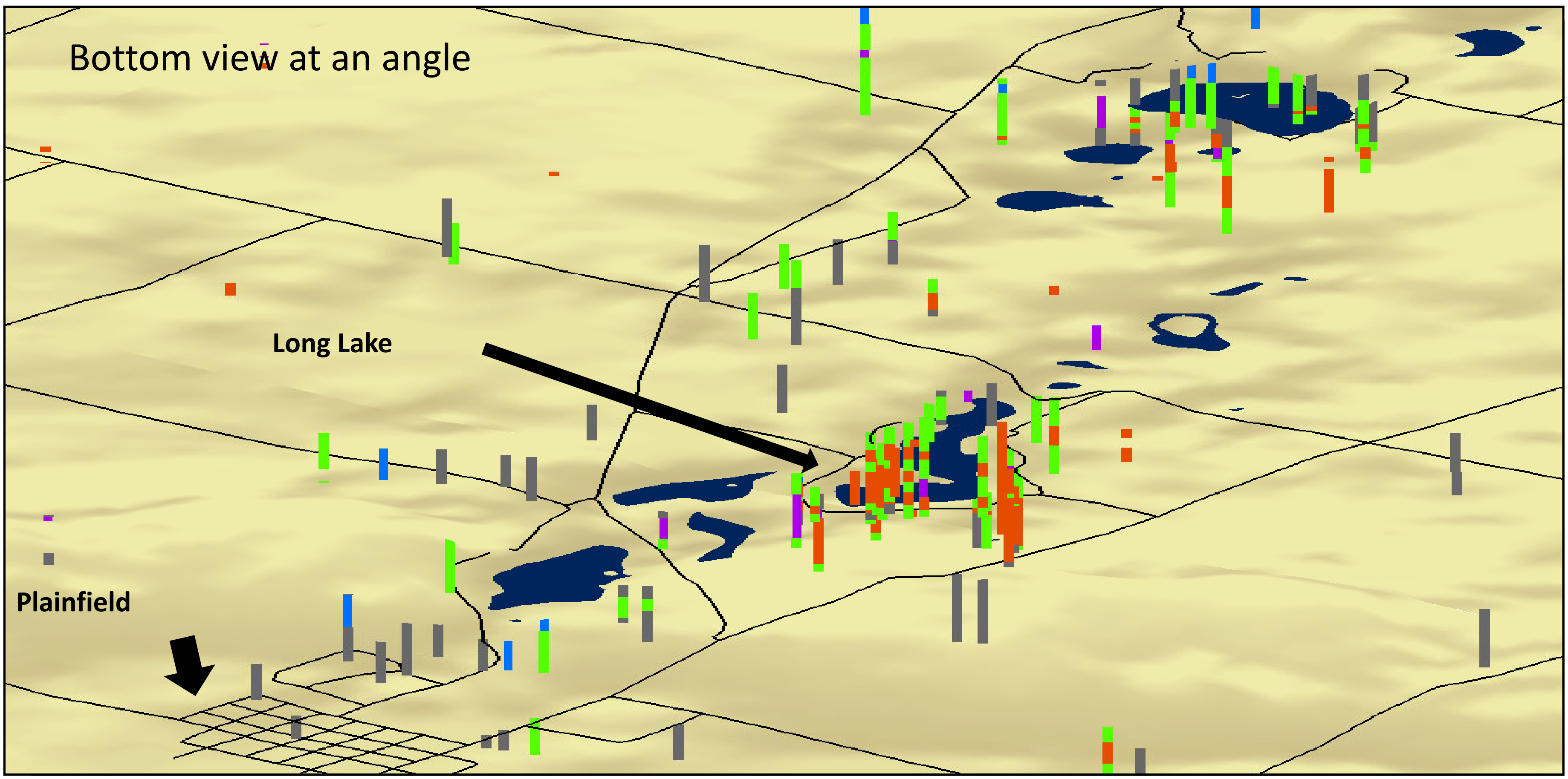
Where are we at?

- **Identify problem**
  - Quantitative characterization of hydrologic cycle with and without irrigation
  - Uncover conflicting community values and priority areas
- **Establish Process**
  - Stakeholder Engagement
  - Groundwater modeling & scenario building
- **Identify potential solutions**
  - Improve water delivery efficiency / precision agriculture
  - Agricultural innovations and land-use change (e.g. crop choice, genetic modification)
  - Ditch management
- **Quantify variables**
  - Quantification of environmental impacts of pumping
  - Quantification of reductions in pumping at specified locations
  - Optimization of temporal and spatial distribution of pumping reductions
  - Multiple criteria decision-making analysis tools

Next Steps

- Small scale, high resolution transient groundwater flow modeling
- Collaboration with graduate students and stakeholders

Water body
Land surface
Clay
Sand and Clay
Sand
Sand and Gravel
Gravel and Cobble
Well
Roads



Acknowledgements

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- Mack Naber, Soil Science Department
- Wisconsin Institute for Sustainable Agriculture

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- Kucharik, C. J., S. P. Serbin, S. Vavrus, E. J. Hopkins, and M. M. Motew. 2010. Patterns of Climate Change Across Wisconsin From 1950 to 2006. Physical Geography 31:1-28.
- Naber. 2011. One-dimensional, soil-plant-atmosphere modeling of the Wisconsin Central Sand Plain to Estimate Evapotranspiration and Groundwater recharge under different vegetation types. Master’s Thesis.

Questions?

Discussion Questions

- What rights do landowners have on "their" property? What rights do non-human living organisms have on land?
- Can/should the federal or state government limit water use? If so, what strategies should they use? If not, how else could the resource be managed?
- How does science and technology play a role in addressing water resources management?
- Is applied science a "true" science?
- How do applied scientists contribute to the scientific community?
- What is the role and purpose of science within our culture and government?
- What constitutes a renewable resource?
- What does adaptive management mean to you? How would you try to implement adaptive management?

Ground Penetrating Radar