Chippewa County Groundwater Study

4th Stakeholders Group Meeting

Chippewa Falls, WI

03/17/2015

USGS science for a changing world

Chippewa County Land Conservation and Forest Management "Stewardship for Sustainability"

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Wisconsin Geological & Natural History Survey

Today's outline

- Brief review of study *(WGNHS / USGS)*
- Progress to date *(WGNHS / USGS / Chippewa Co.)*
  - Subsurface data and hydrostratigraphy
  - Water-use data collection
  - Compilation of site data for modeling
  - Soil water balance (SWB) modeling and infiltration testing
  - MODFLOW model building
- Focused stakeholders discussion
  - SWB, reclamation, future water-use, and future scenario testing
- What's next ?
- Other agenda items to include?

Review of study

Study area

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Review of study

Objectives

- **Modeling** - develop soil water balance (recharge) and groundwater flow models to evaluate current and future water use and landscape changes on the hydrologic system
  - Calibrate MODFLOW model to pre-mine recharge and pumping rates
  - Test future scenarios *(e.g., least developed, most developed)* which incorporate changes in recharge *(e.g., soil types, vegetative cover, hill slope geometry)* and pumping rates
  - Evaluate potential impacts to water levels and base flow to streams
- **Outreach** - disseminate the study results to stakeholders and the general public
- **Transferability**- transfer the study results to similar geologic and hydrologic settings as appropriate

Review of study – workflow and schedule

TABLE 1 - Project Workflow and Activities Schedule

Calendar Year	2012				2013				2014				2015				2016				2017			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Data collection / Interp.																								
- Collect and compile well & geophysical data			X	X	X	X																		
- Analyze & process				X	X	X	X	X																
- Interpretation (i.e., build model layers)							X	X	X	X														
Soil-water-balance model																								
- Collect climate/soils data			X	X	X	X																		
- Collect land use and elevation data			X	X	X	X																		
- Build model						X	X																	
- Review model							X	X																
- Define scenarios							X	X																
- Conduct model runs								X	X															
- Complete/Format results									X	X														
Groundwater model, calibration																								
- Construct model grid and decide on modeling packages					X	X	X	X																
- Build hydrological model								X	X	X	X	X	X	X										
- Calibrate model												X	X	X	X									
- Compile/Format results														X	X	X	X							
Scenario testing																								
- Define test scenarios										X	X	X	X	X	X	X	X	X						
- Conduct model runs																X	X	X	X					
- Compile/Format results																		X	X	X				
Transferability																								
- Conduct analysis																	X	X						
- Compile/Format results																			X	X				
Fact sheet																								
- Identify purpose/content (WGNHS)			X	X																				
- Prepare & finalize drafts (WGNHS)				X	X																			
- Print & distribute (WGNHS)					X																			
Public outreach meetings																								
- Identify purpose/content			X	X																				
- Conduct public outreach meetings					X																			
- Conduct stakeholders meetings - Specific times TBD					X		X			X				X				X						
Reporting																								
- Complete annual report (Chippewa Co LCFM)					X				X				X				X							
- Complete interim project report (WGNHS)												X												
- Complete final project report (WGNHS / USGS)																							X	
				Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Federal Fiscal Year (USGS)					2013				2014				2015				2016				2017			
State Fiscal Year (WGNHS)				2013				2014				2015				2016				2017				

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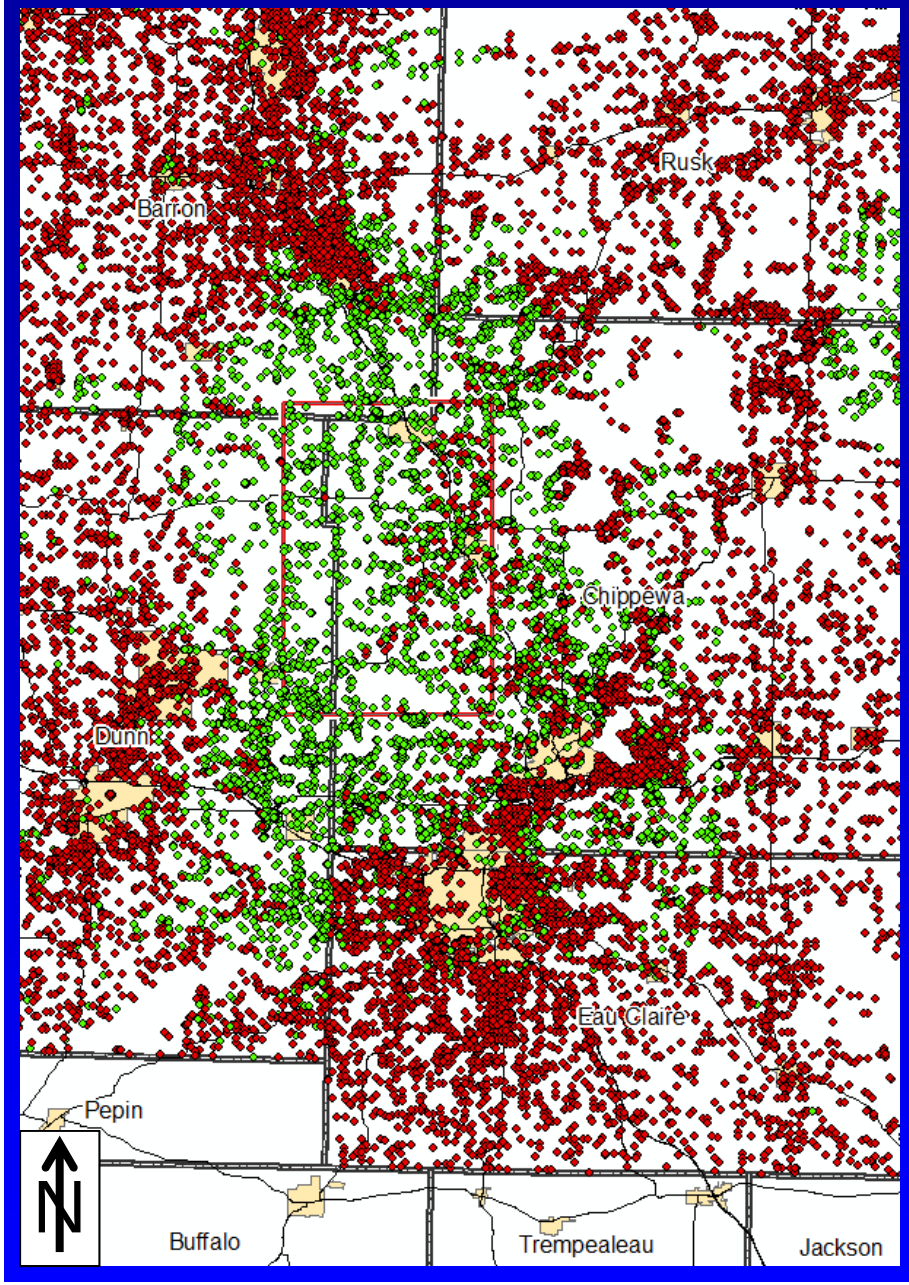
Hydrostratigraphic data



Well construction records (WCRs)

- Obtained data from WDNR
- WGNHS data refinements
  - Green = verified locations
  - Red = non-verified locations

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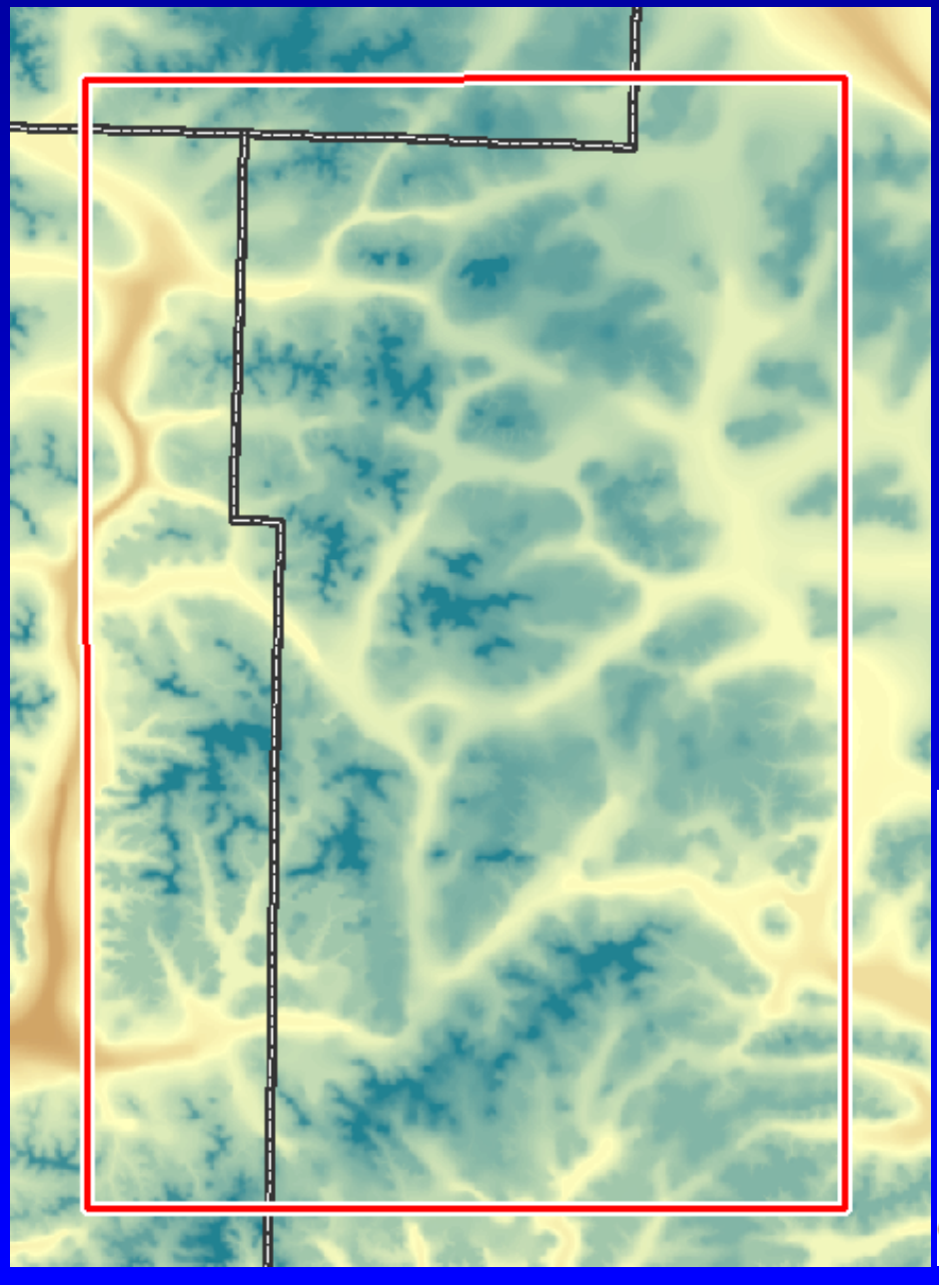
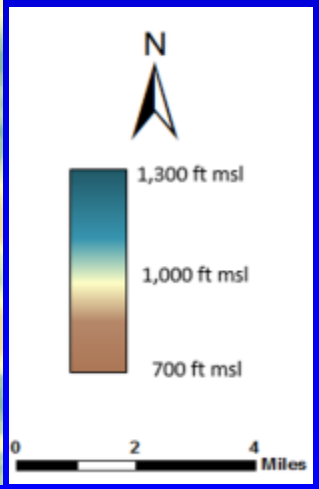
Hydrostratigraphic interpretation



Bedrock elevation surface

This is the bottom of the sand & gravel aquifer (model layer 1)



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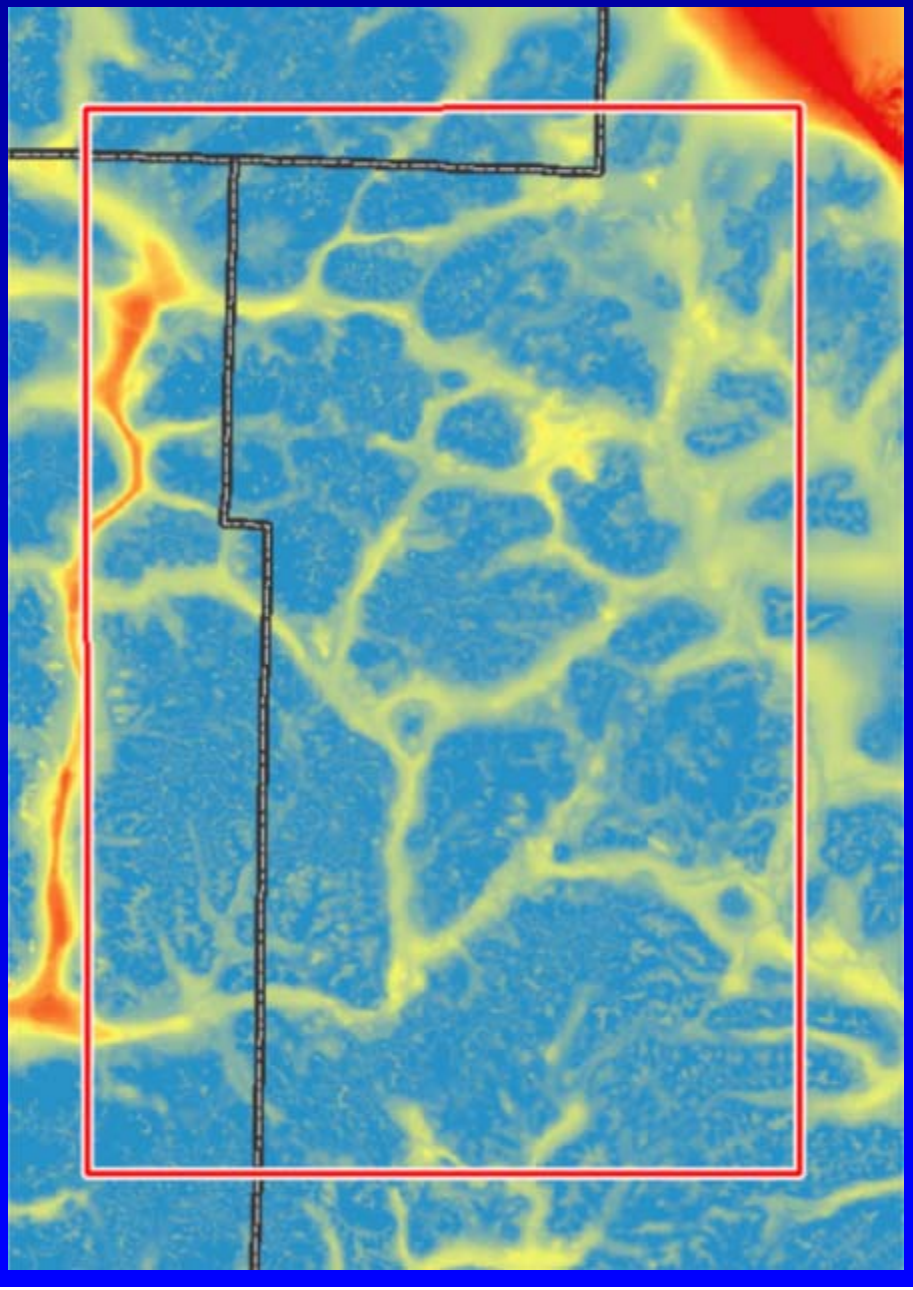
Hydrostratigraphic interpretation

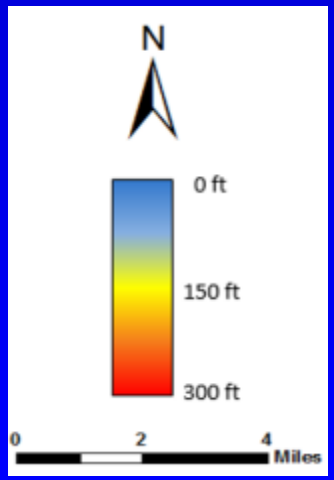


Unconsolidated thickness

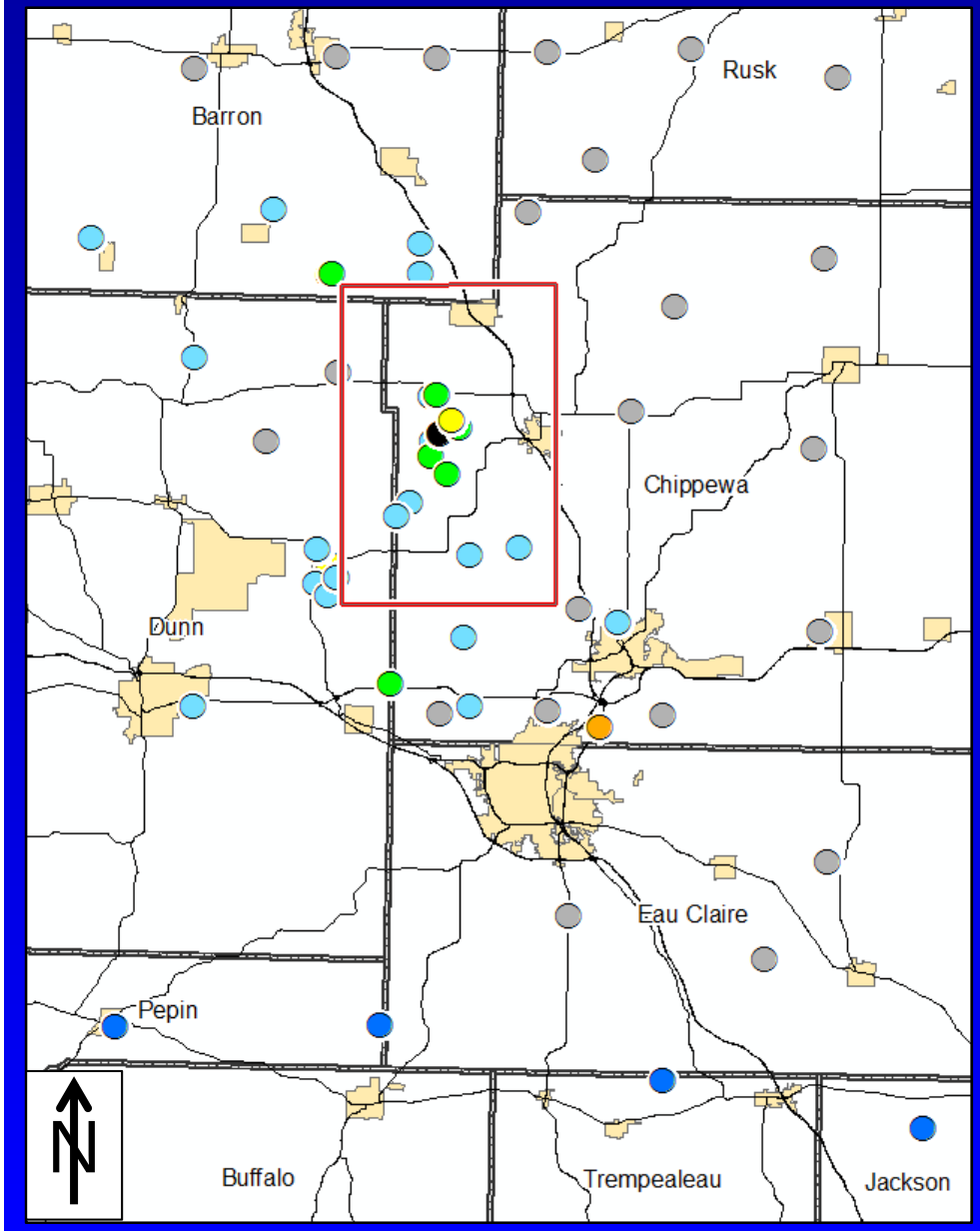
= Land surface elevation –

Top-of-bedrock elevation

This is the thickness of the sand & gravel aquifer (model layer 1)



Hydrostratigraphic data



- Geophysical logs
- Geologic logs from cuttings
- Select WCRs
- Geologic maps
- Sand mine plans & maps
- Outcrops
- “Smoothing” points

Geophysical Log
Geologic Log
WCR
Geologic Map
Mine Plan/Map
Outcrop
Smoothing

& Land surface elevation maps

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Hydrostratigraphic data

Provides detailed information about geology and hydrogeology

Allows for detailed hydrogeological characterization

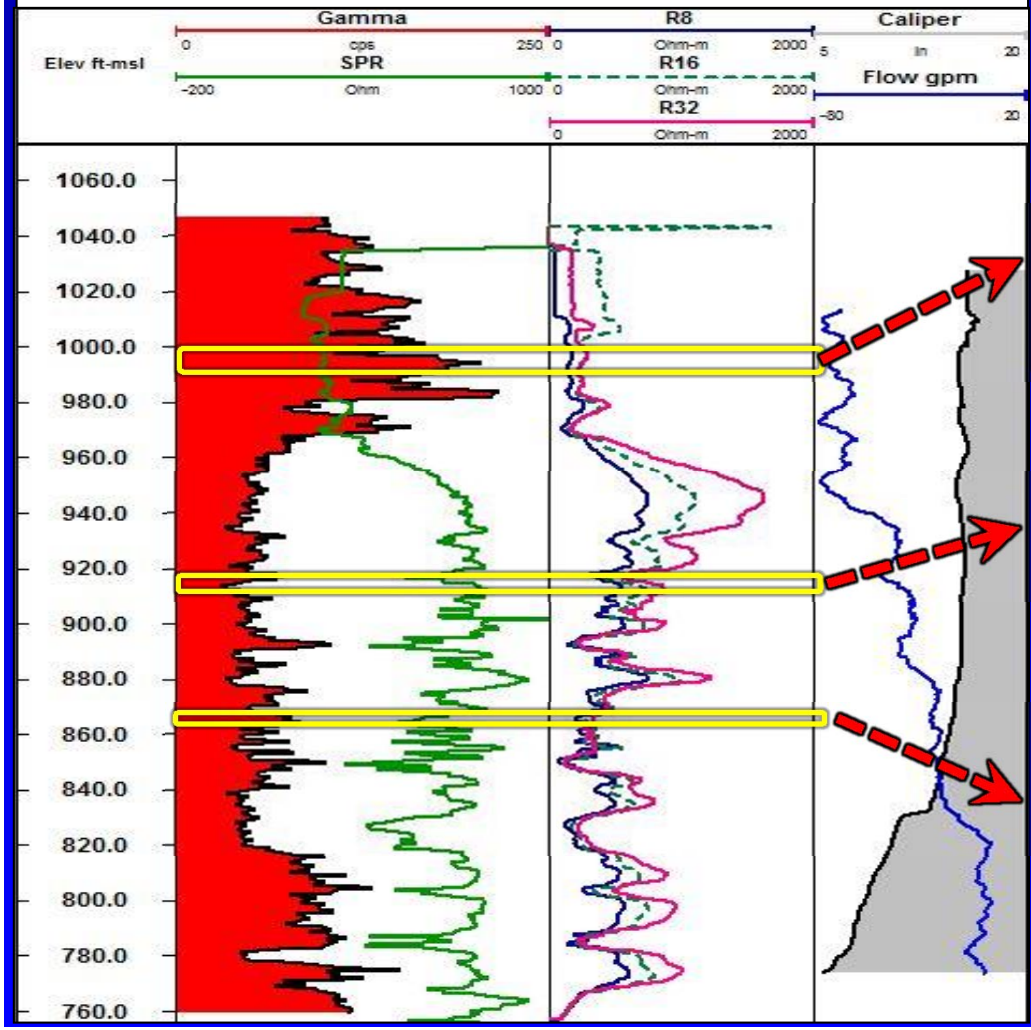
7 Geophysical logs

- Superior Silica Sands-Culver mine (2011)
- Preferred Sands-LaGesse mine (2011)
- Village of Lake Hallie (2012)
- Dan Stiehl farm (2013)
- Tony Pecha farm (2014)
- Tony Christopherson farm (2014)
- Superior Silica Sands-Thompson Mine (2014)

Hydrostratigraphic data

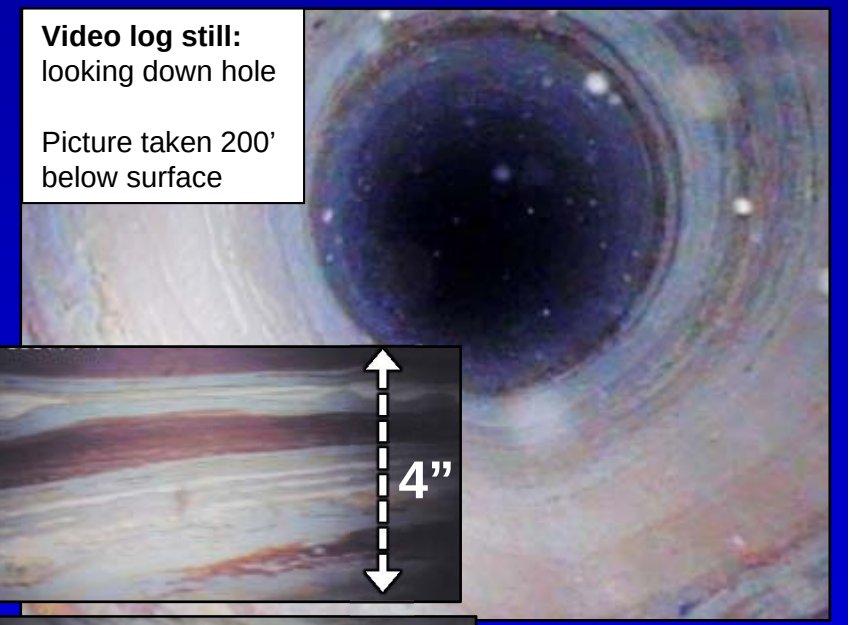
Geophysical log of a 320' irrigation well

High-capacity well - western Chippewa County

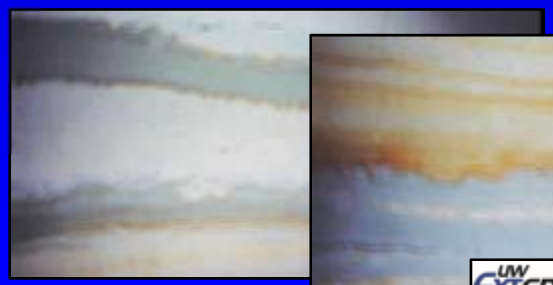


Video log still:
looking down hole

Picture taken 200' below surface



Video log stills:
looking at wall of hole



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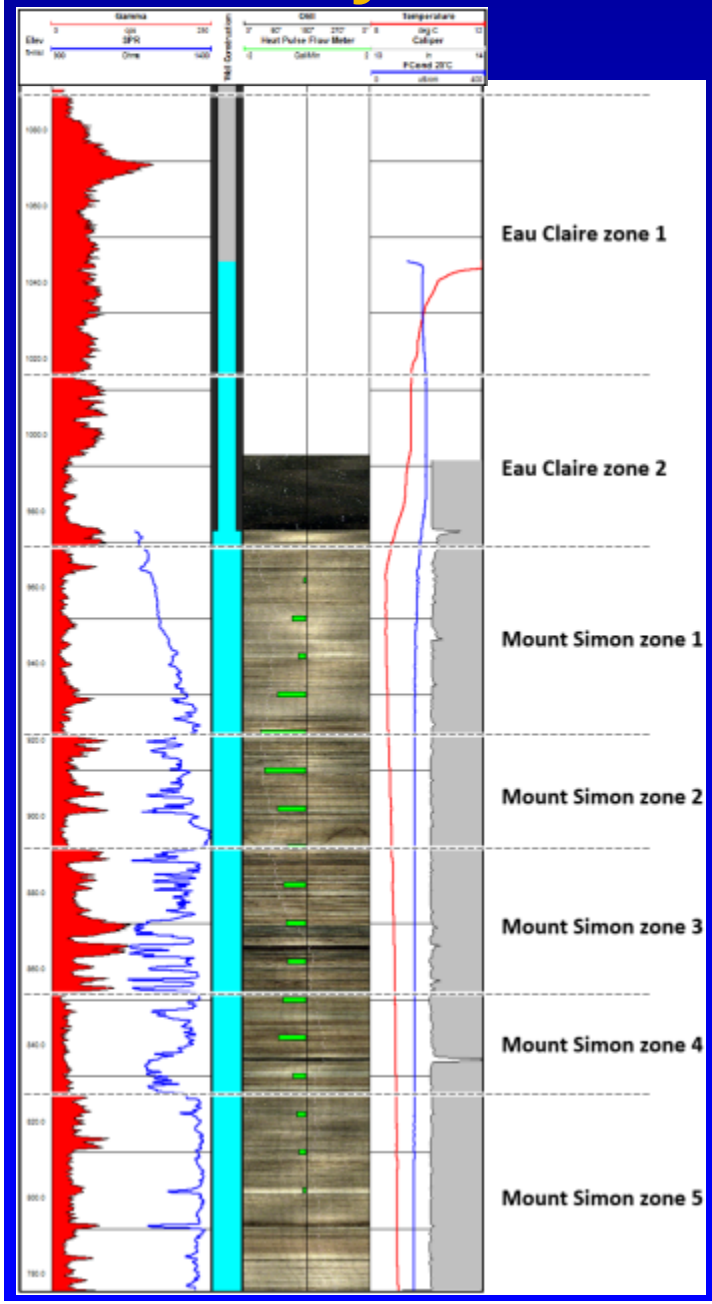
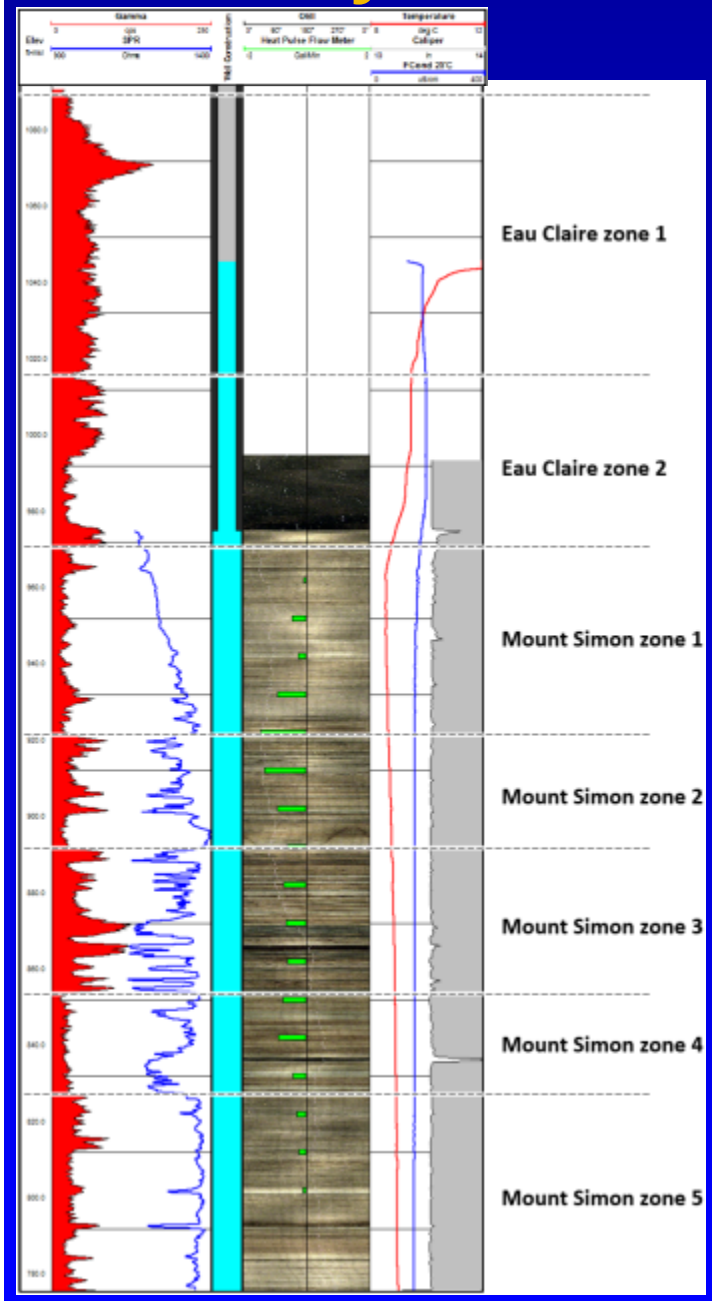
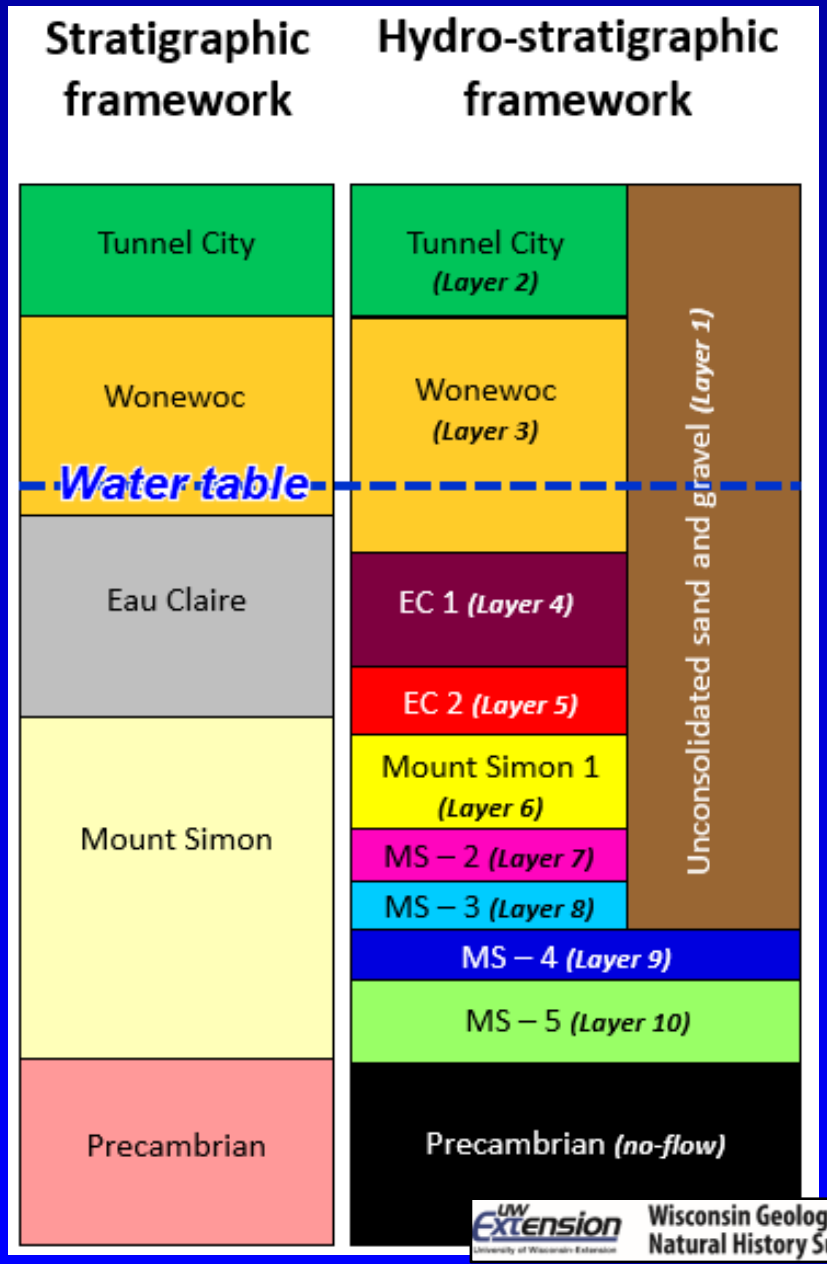
Hydrostratigraphic interpretation



- Geophysical logs were the highest quality dataset available
- GP logs were used to delineate hydrostratigraphic zones (or units)
- These zones were extrapolated across the data collection area
- Other data sets were used to constrain hydrostratigraphic interpretation in areas without GP logs

Hydrostratigraphic interpretation





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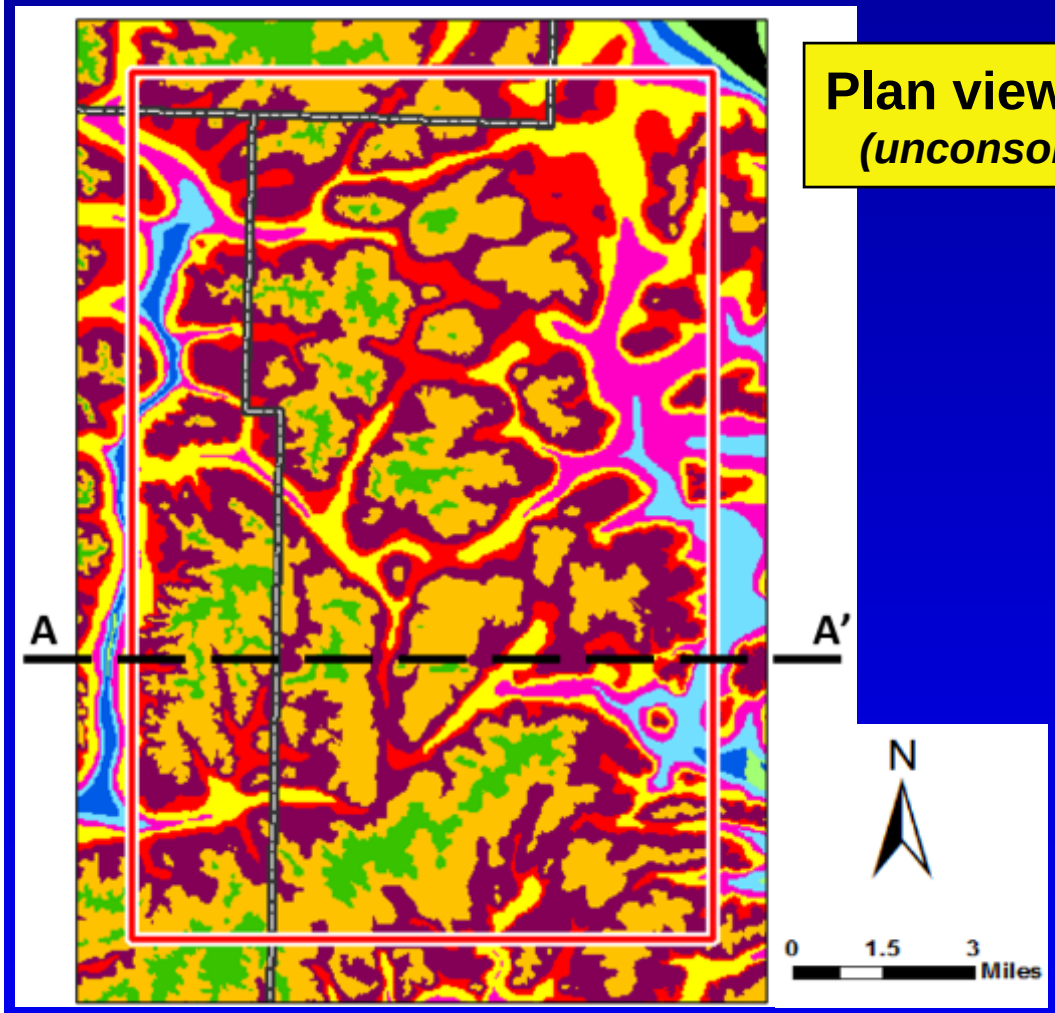
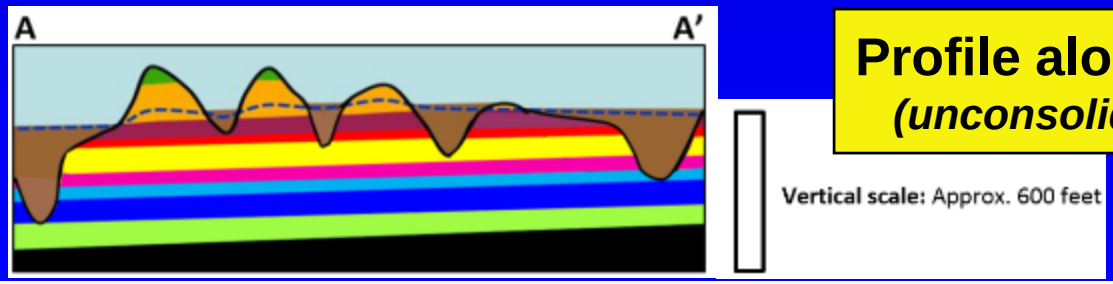
Hydrostratigraphic interpretation



Plan view showing bedrock units
(unconsolidated materials not shown)



Profile along A-A' showing all units
(unconsolidated materials are in brown)

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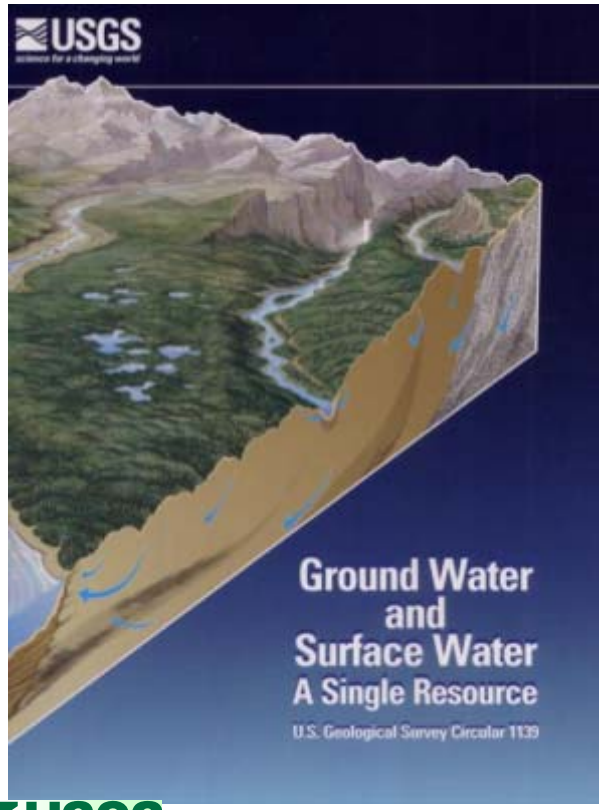
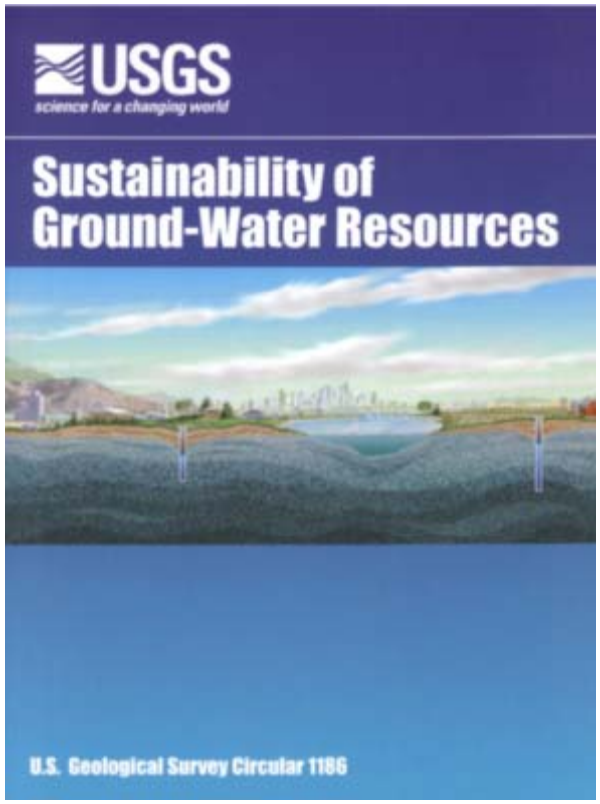
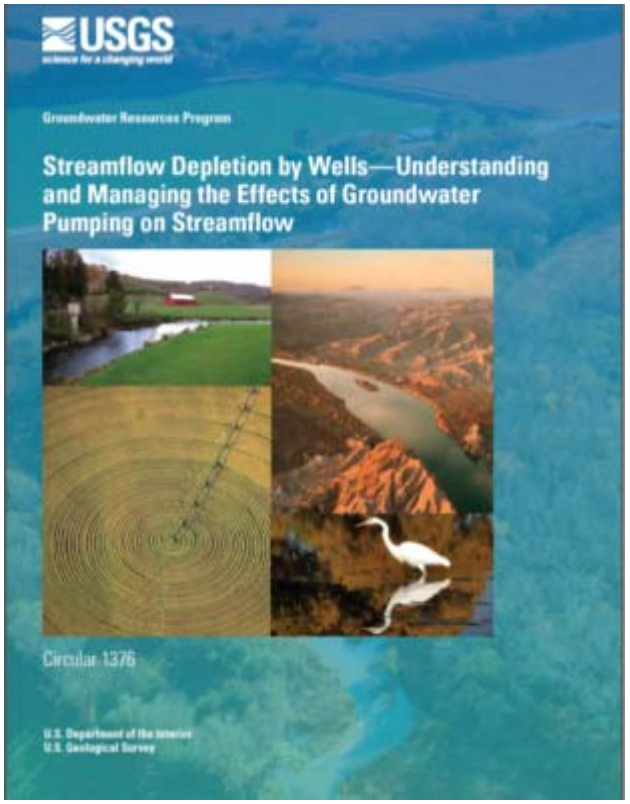
Why Does Water Use Matter?

- Groundwater and surface water are connected







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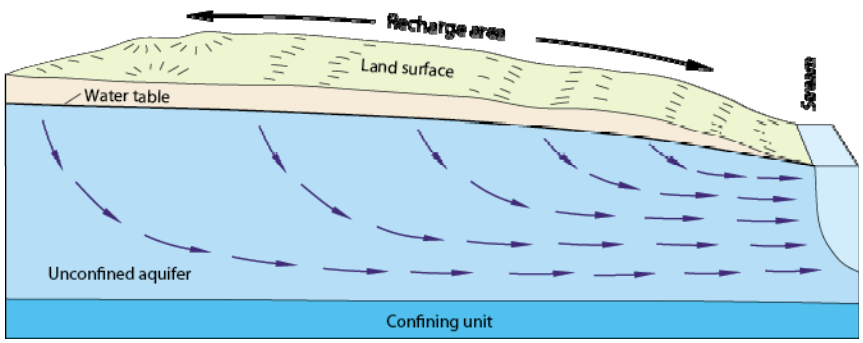
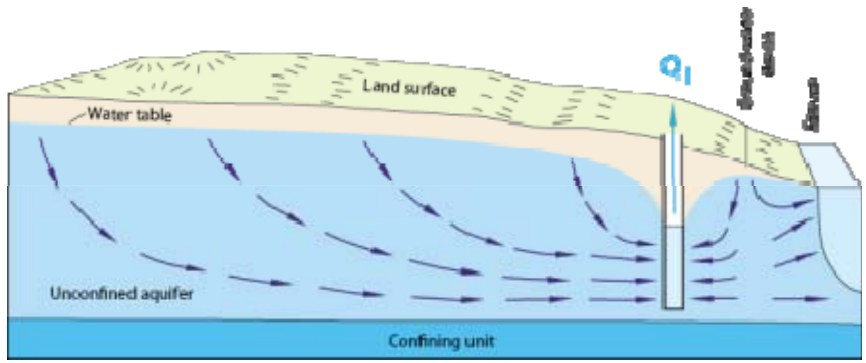
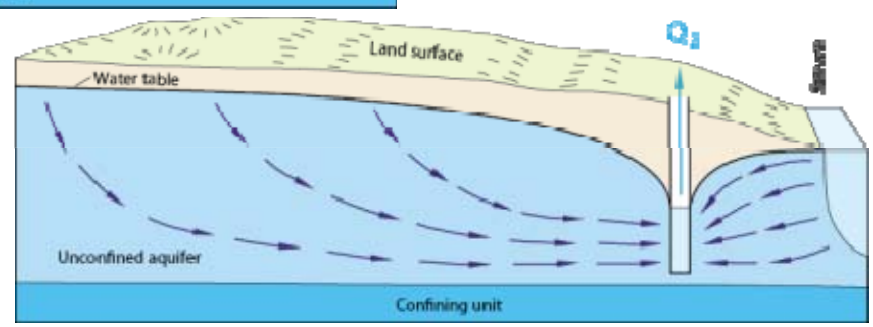
Water Use & 'Capture'



- Capture depends on aquifer geometry and properties, and the well's pumping rate & proximity to streams (including depth)



- Difficult to measure due to natural variability
- Quantify capture using physically based models



from Alley, Reilly, and Franke, USGS Circular 1186, 1999

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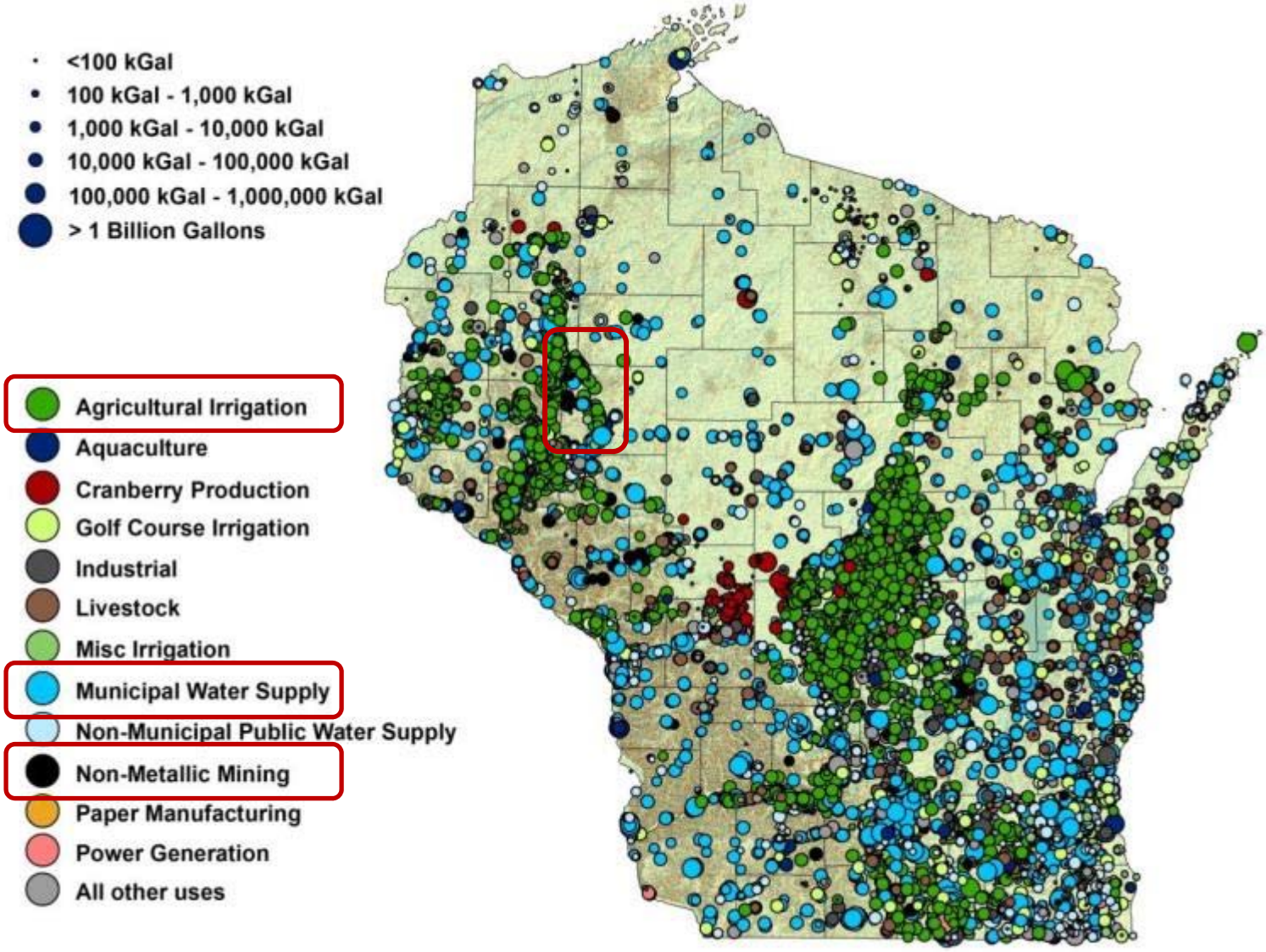
Groundwater Use in Wisconsin:

2013 Withdrawals



Water Use Focus in Chippewa County

Industrial sand mining

- ~250 - 400 feet deep (Mount Simon Sandstone)
- Pump: ~20 - 95 million gallons per year per well
- Number of wells: 0 – 3 wells per mine

Municipal supply

- ~150 - 300 ft deep
- Pump: ~88 million gallons per year
- Number of wells: 4 (plus other villages)

Irrigated agriculture

- ~50 - 300 feet deep
- Pump: <10 - 30 million gallons per year per well (varies by well & year)
- Number of wells: >20 in study area, >100 in modeled area

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Well information supplied by WiDNR

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Progress to date – Data collection

- Compilation of site data by Chippewa Co. LCFM

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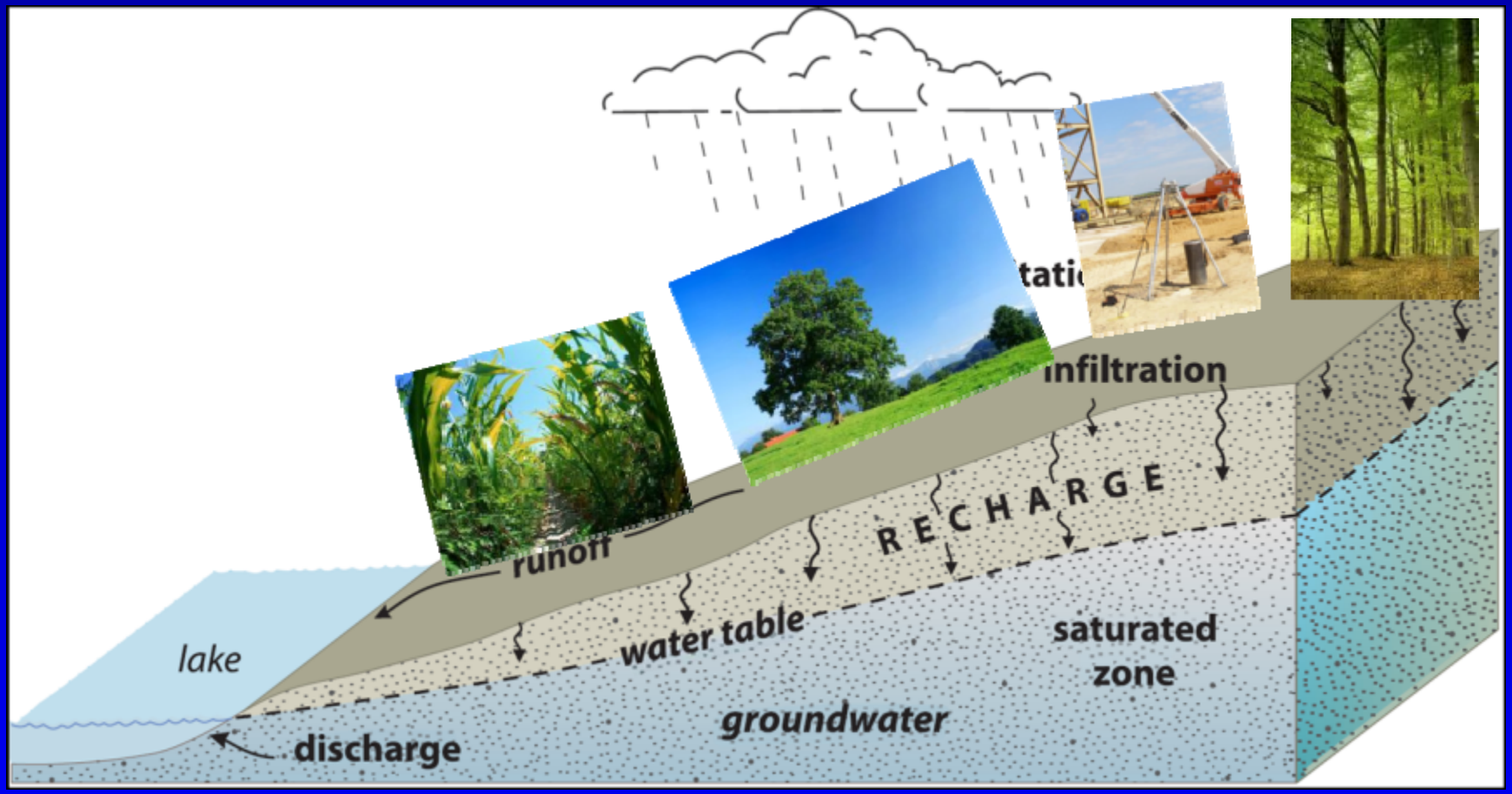
Recharge (R) is water that enters the groundwater system

R = Precipitation – Runoff – Interception – Evapotranspiration



Soil water balance model

Is one of many methods used to estimate recharge

Useful to estimate change in R over time, given a set of changes to the landscape

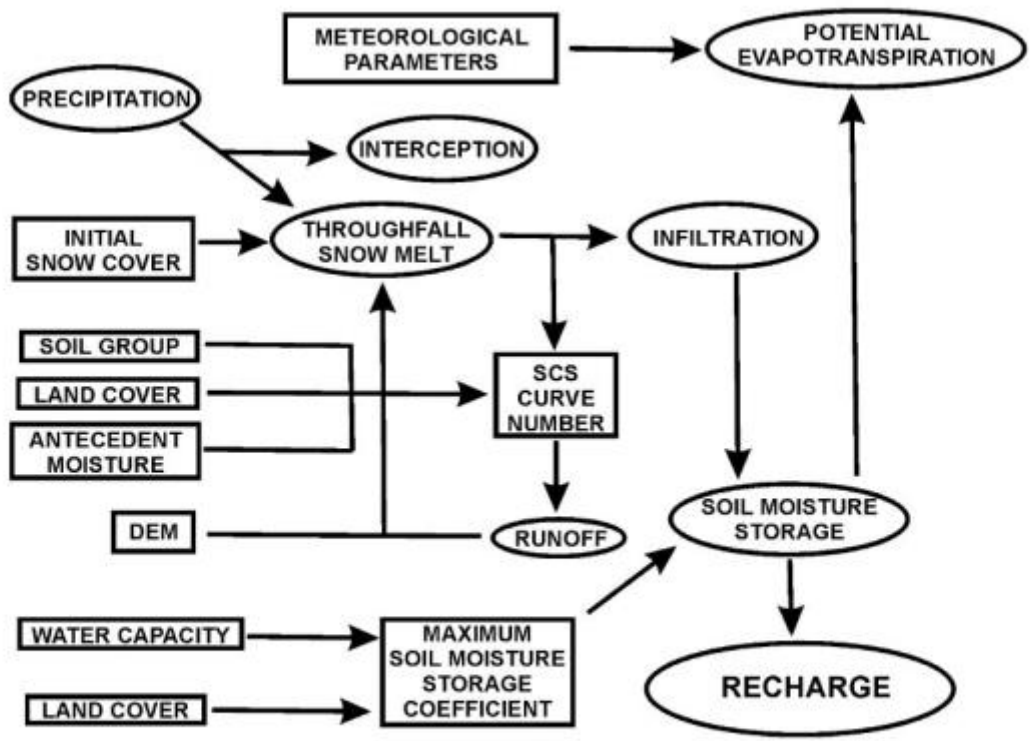


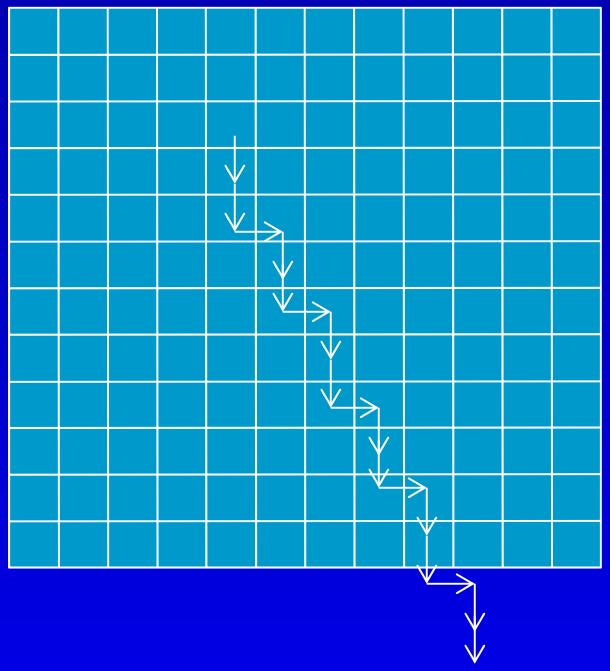
Fig. 1 A simplified flow chart for the soil–water balance (SWB) model. The *ovals* represent the major components of the water budget; the *rectangles* are the physical characteristics of the site. *DEM* digital elevation model, *SCS* Soil Conservation Service

Hydrogeology Journal (2007) 15: 433–444 DOI 10.1007/s10040-007-0160-6

Soil Water Balance Model

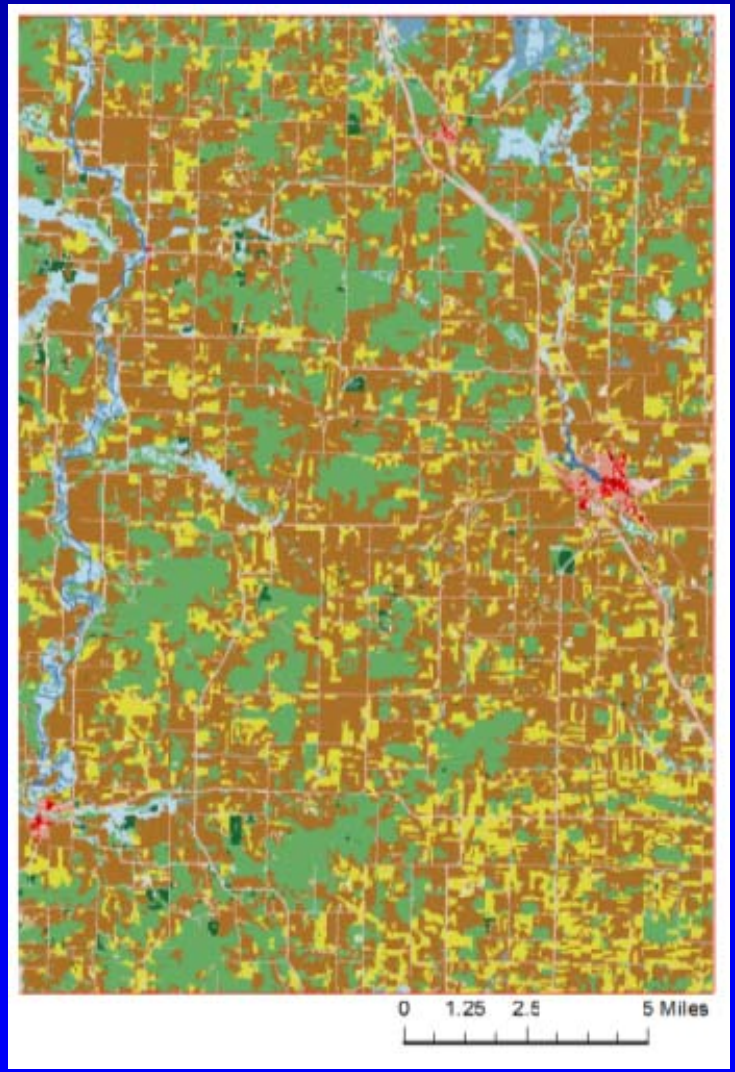
Recharge = Precipitation - Evapotranspiration - Soil Storage – Runoff

- Equation applied to each cell
- Daily precipitation is evaporated, stored, or recharges groundwater
- Recharge is limited by soil permeability and storage; any excess water runs off to next down- gradient cell
- Repeat until all runoff infiltrates or reaches surface water

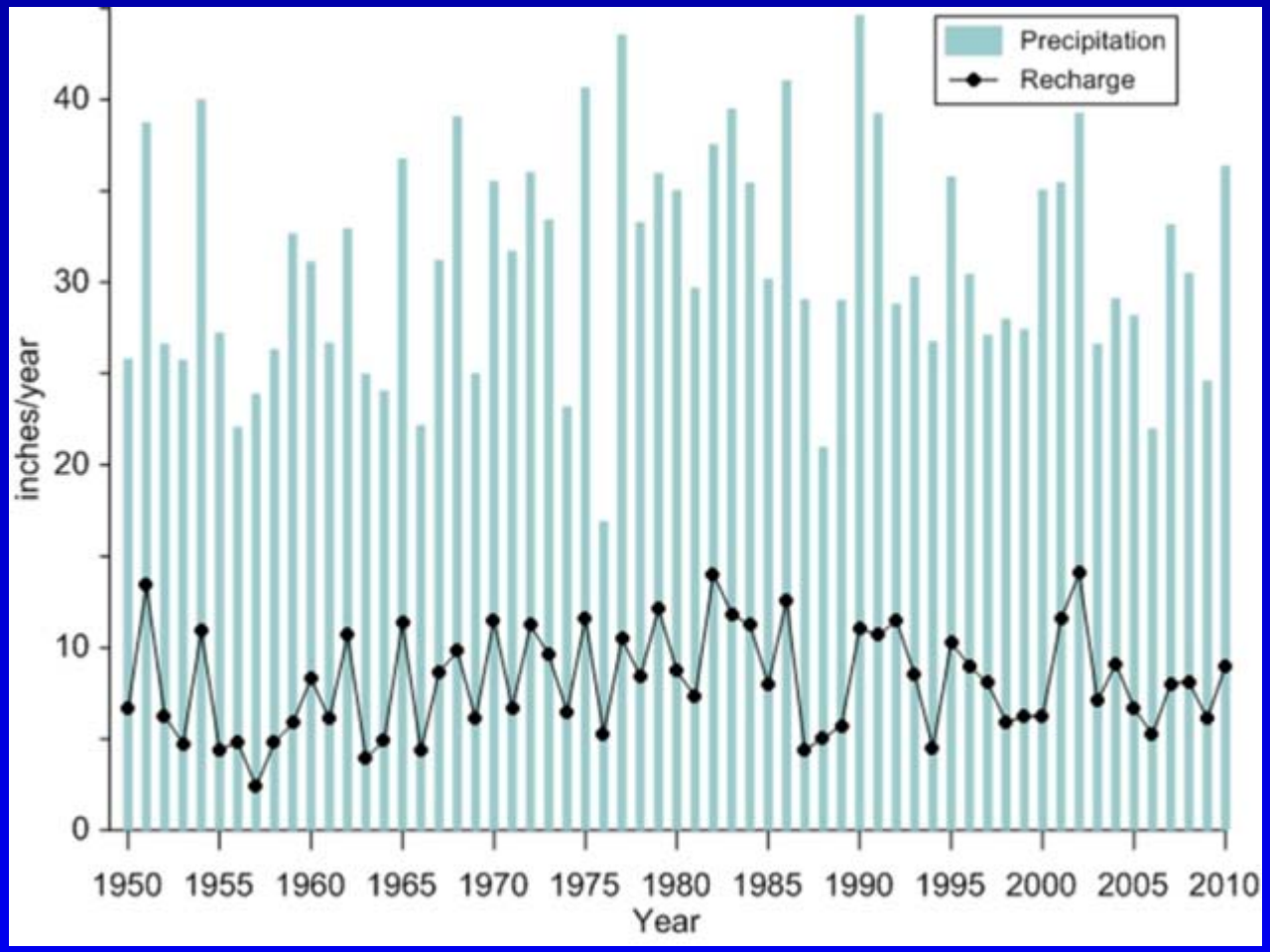


SWB Model uses four maps

Land surface slope: runoff direction
Soil type
    infiltration rate
    available water storage
Land use



Estimated annual average recharge, 1950 - 2010

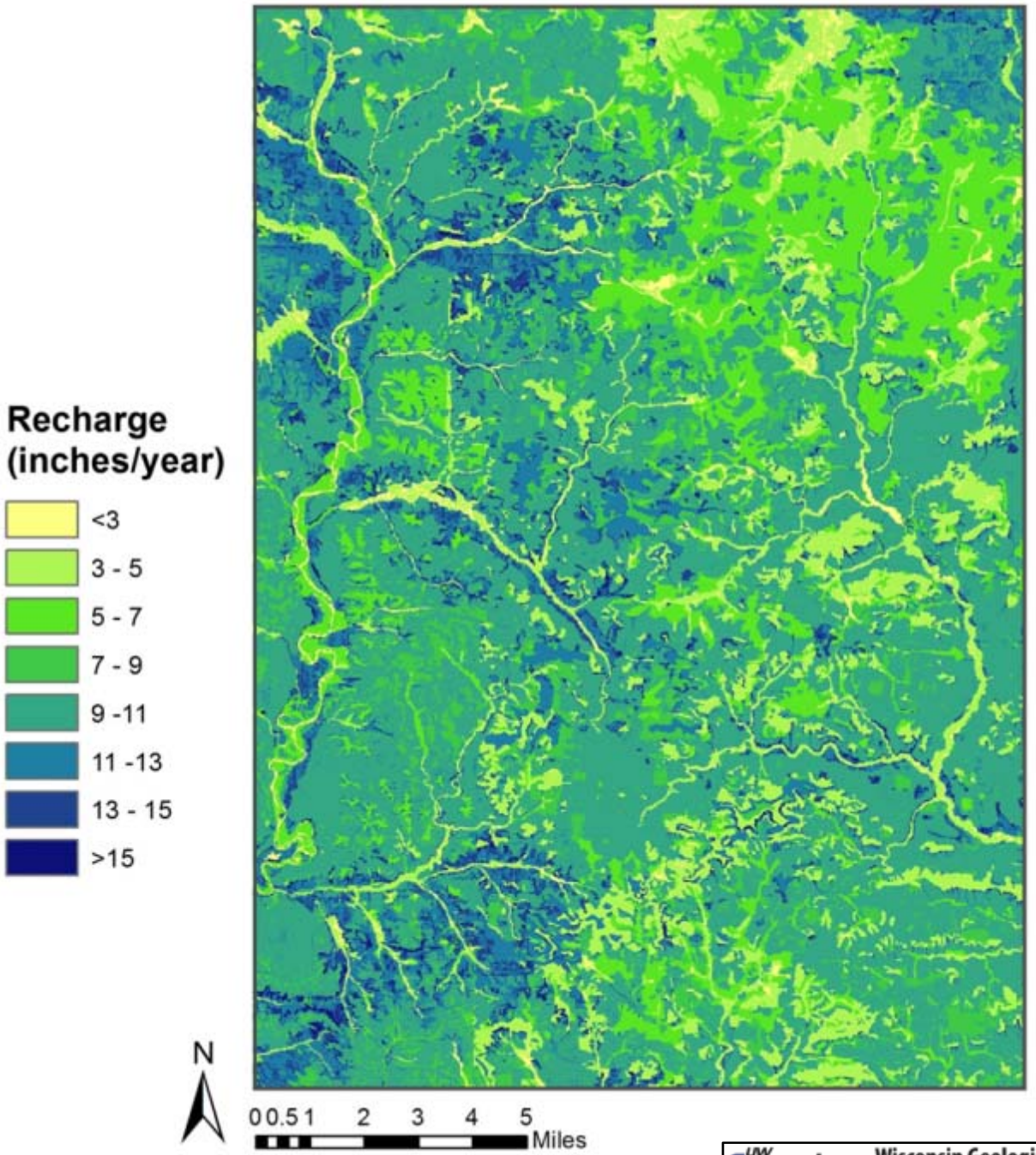


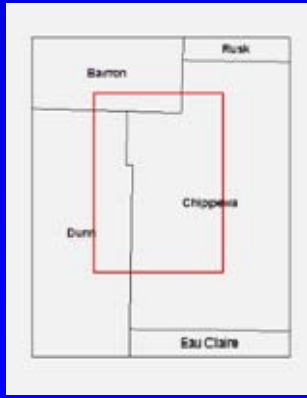
Annual precipitation
Average 31 inches
Min. 17 inches
Max. 45 inches

Annual recharge
Average 8.2 inches
Min. 2.5 inches
Max. 14 inches

About 27% of precipitation recharges groundwater

Estimated recharge, 1993





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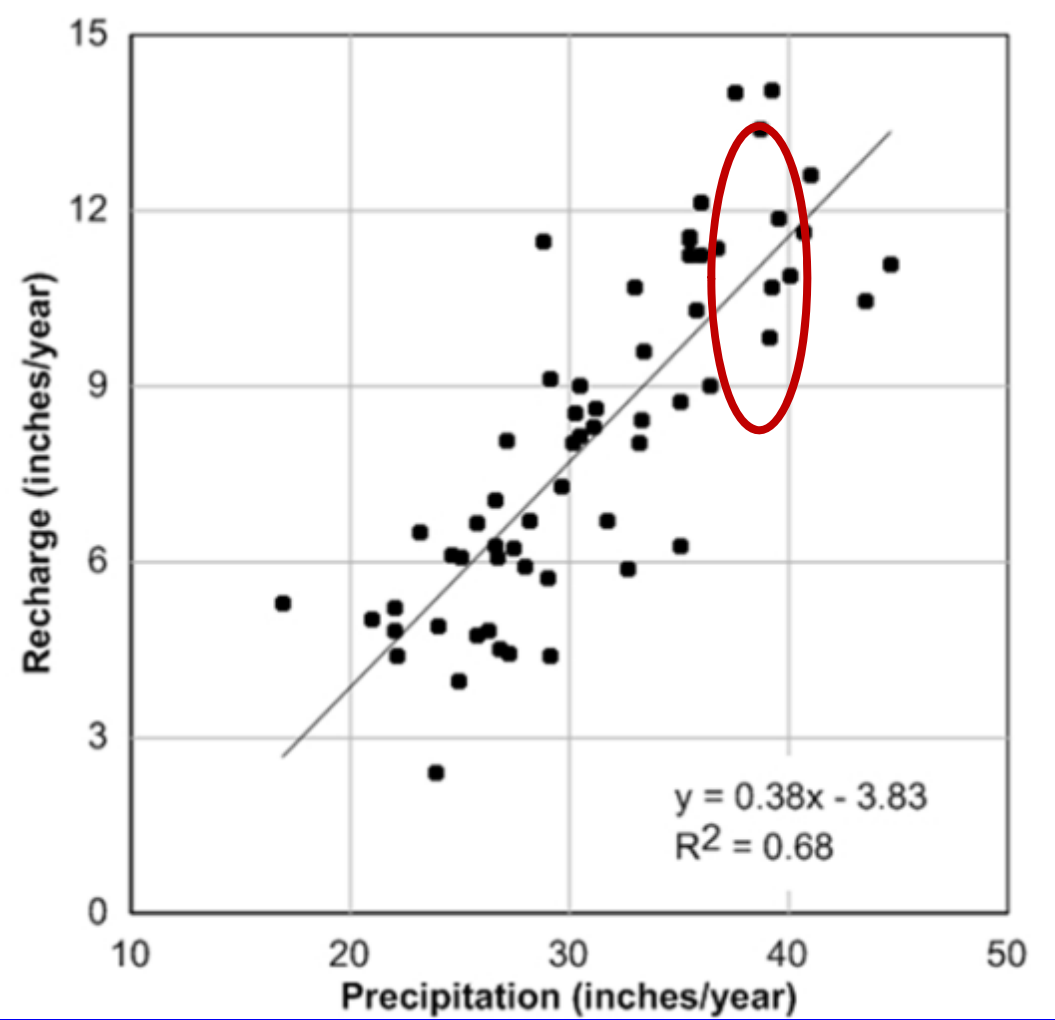
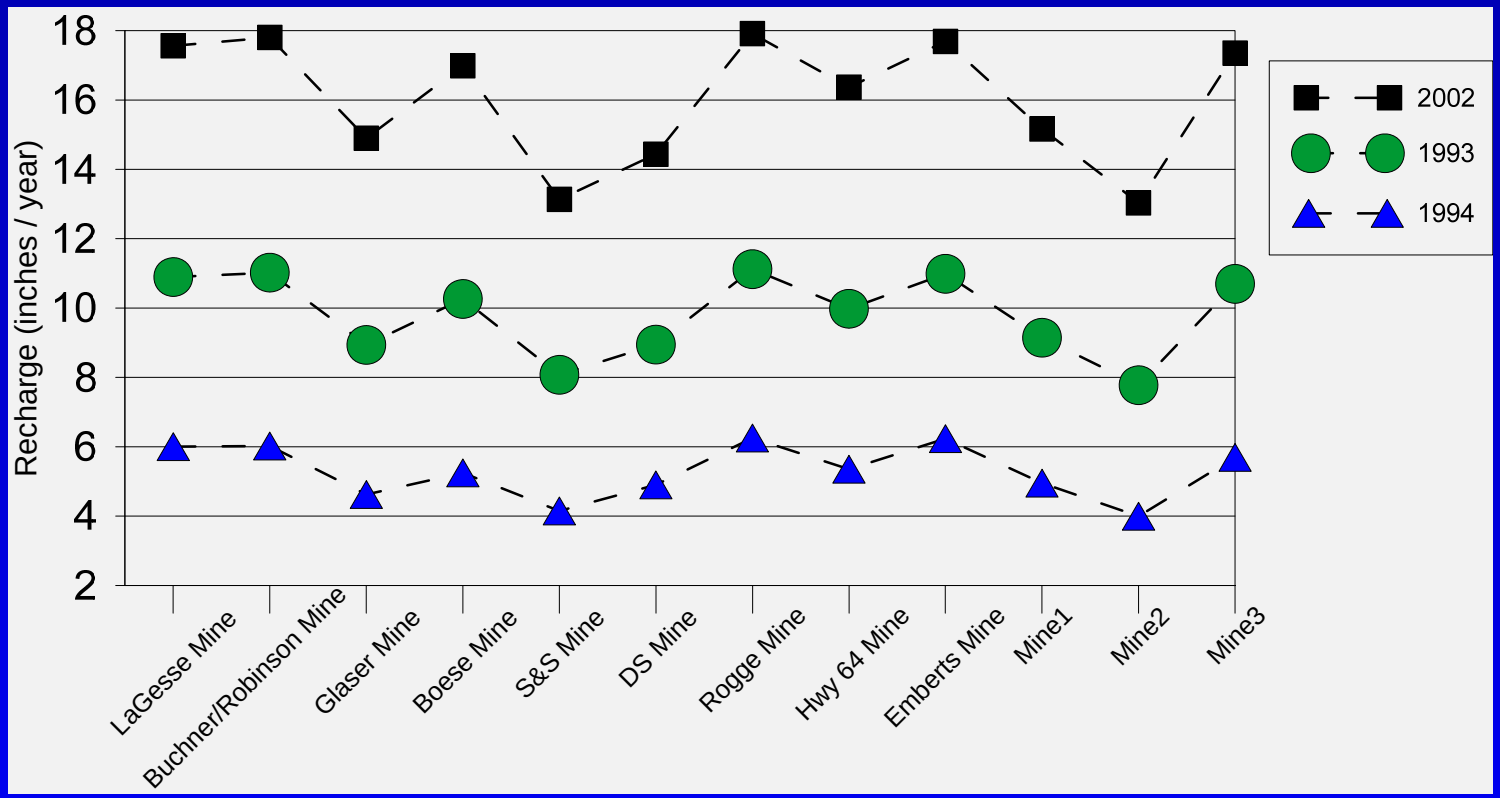
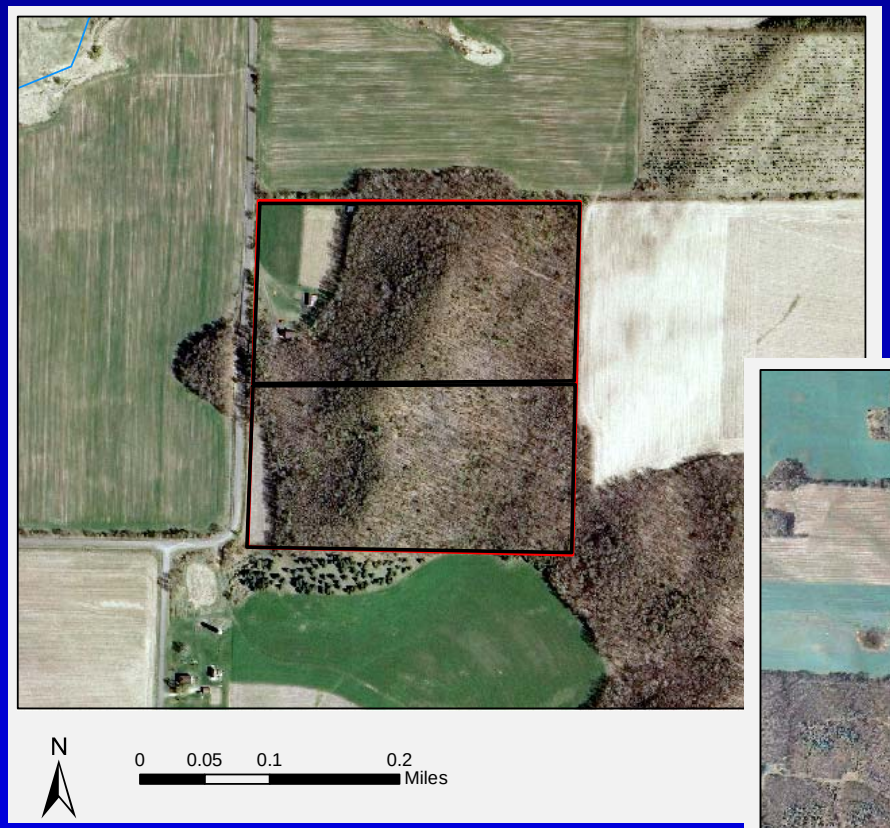
Effect of Weather

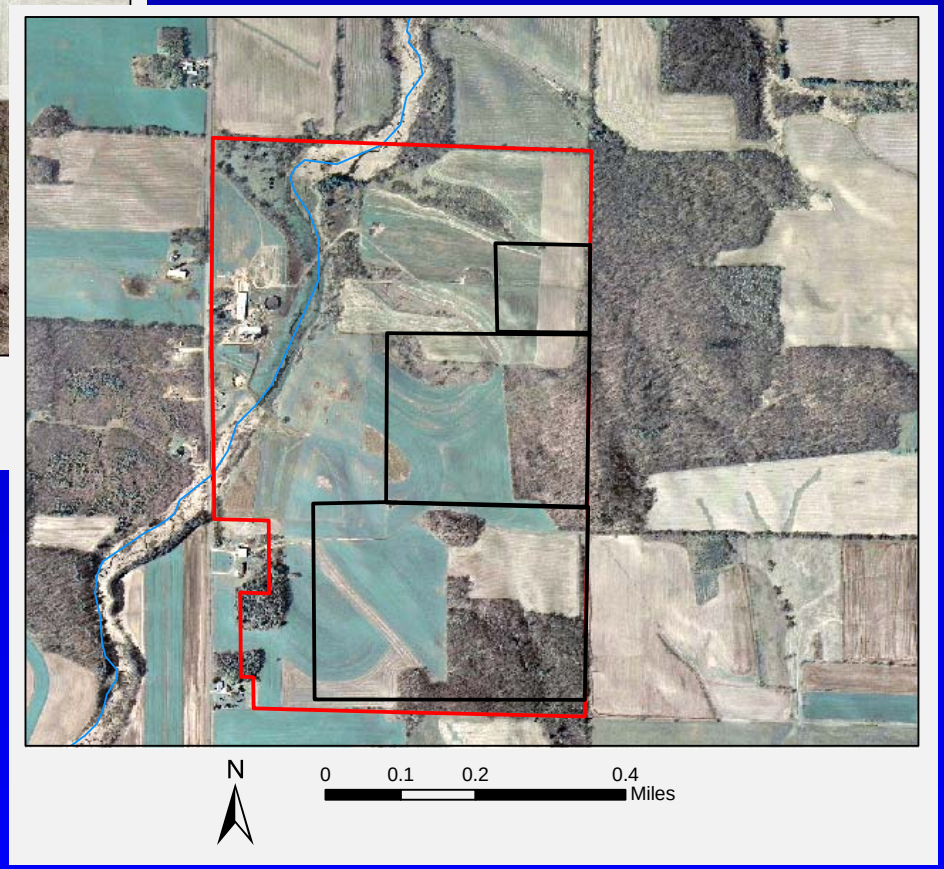


Effect of soil and land use

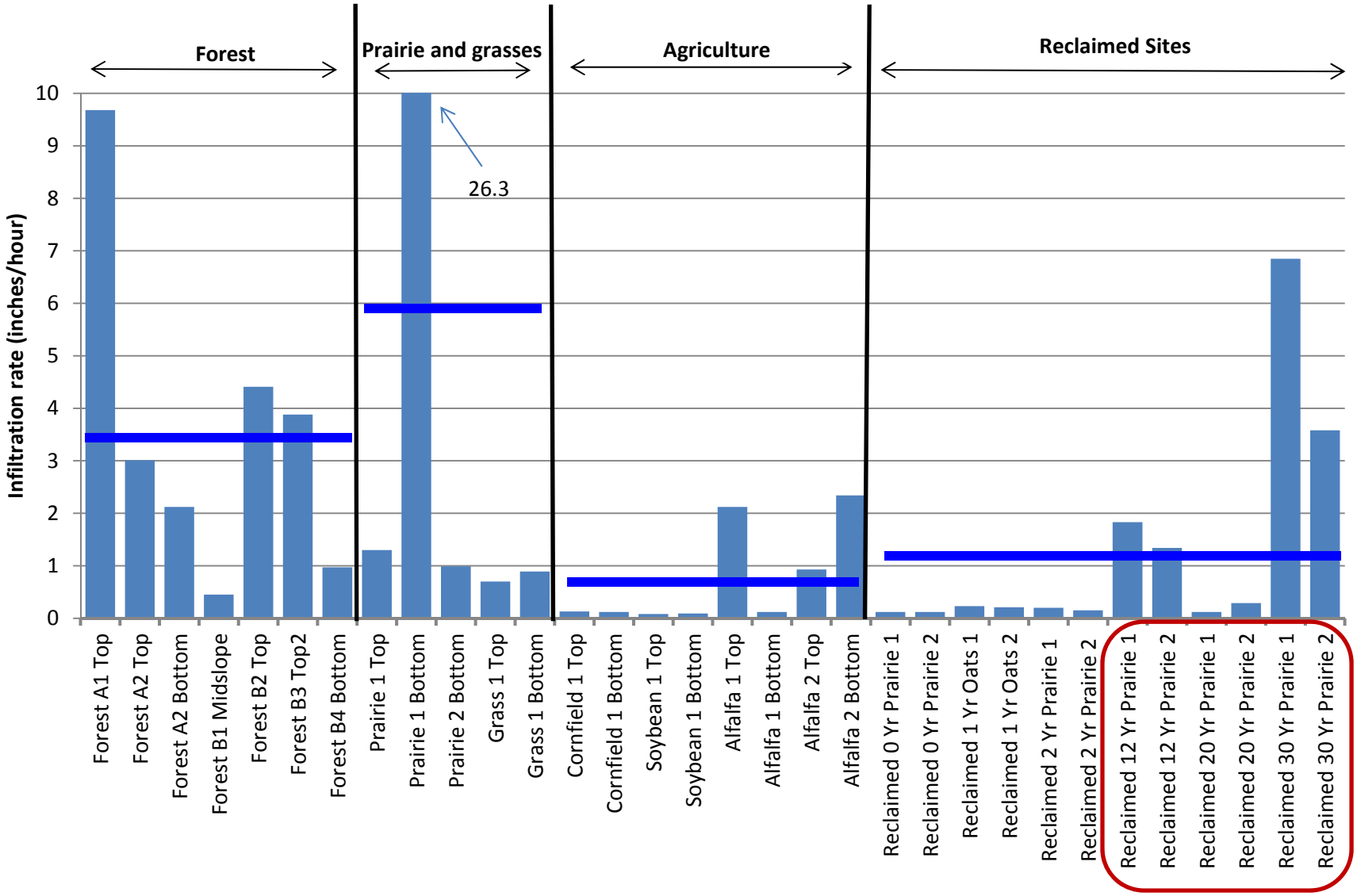


Extent of mineable area
Portion actively mined



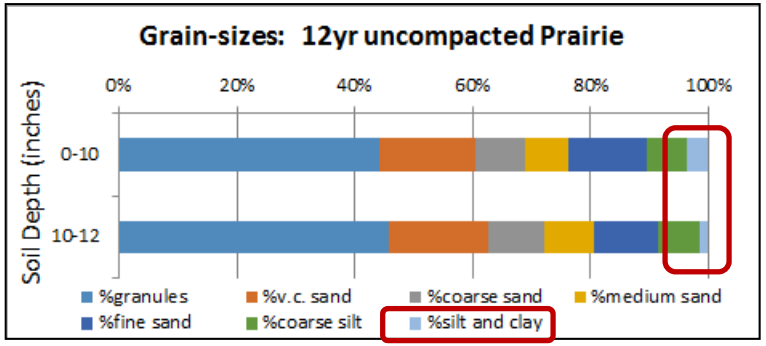


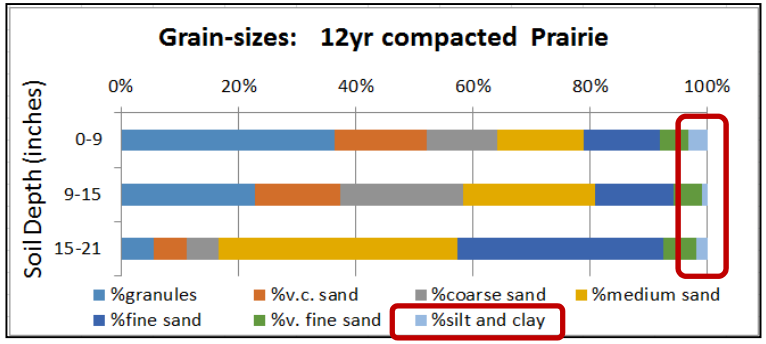
Infiltration[1]

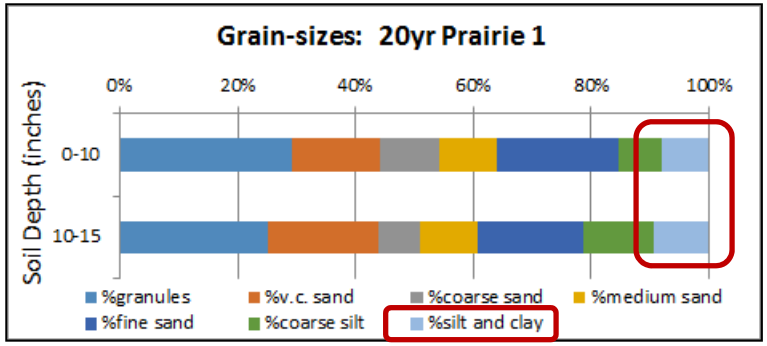


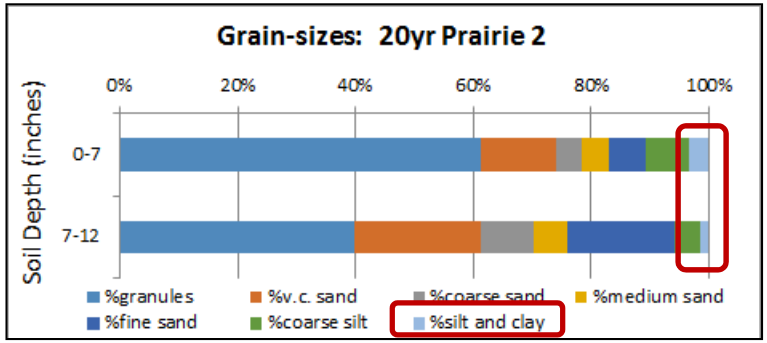
[1] These data are preliminary and are subject to revision. They are being provided to meet the need for timely best science. The data have not received final approval by the U.S. Geological Survey (USGS) and are provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the data.

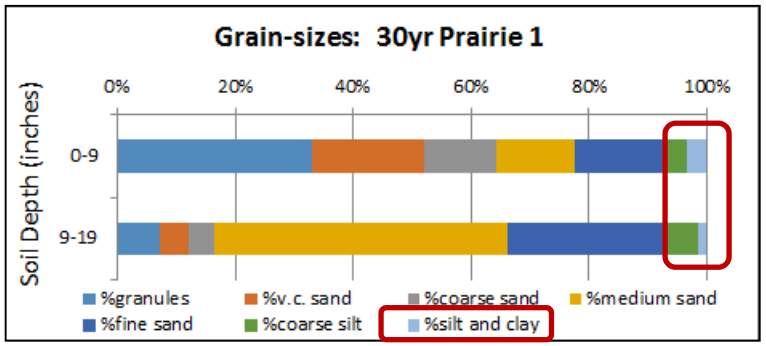
Grain-sizes: Percent by Weight[1]

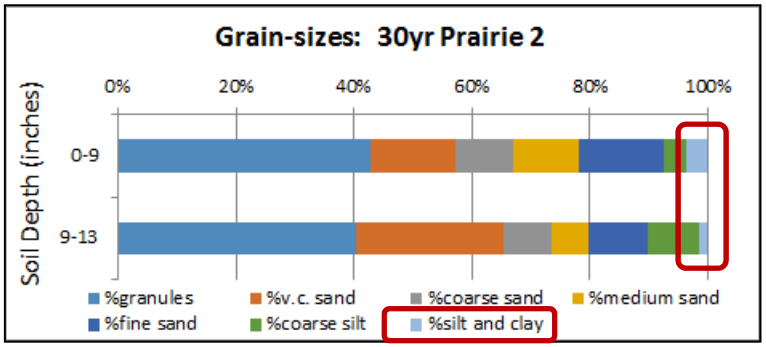






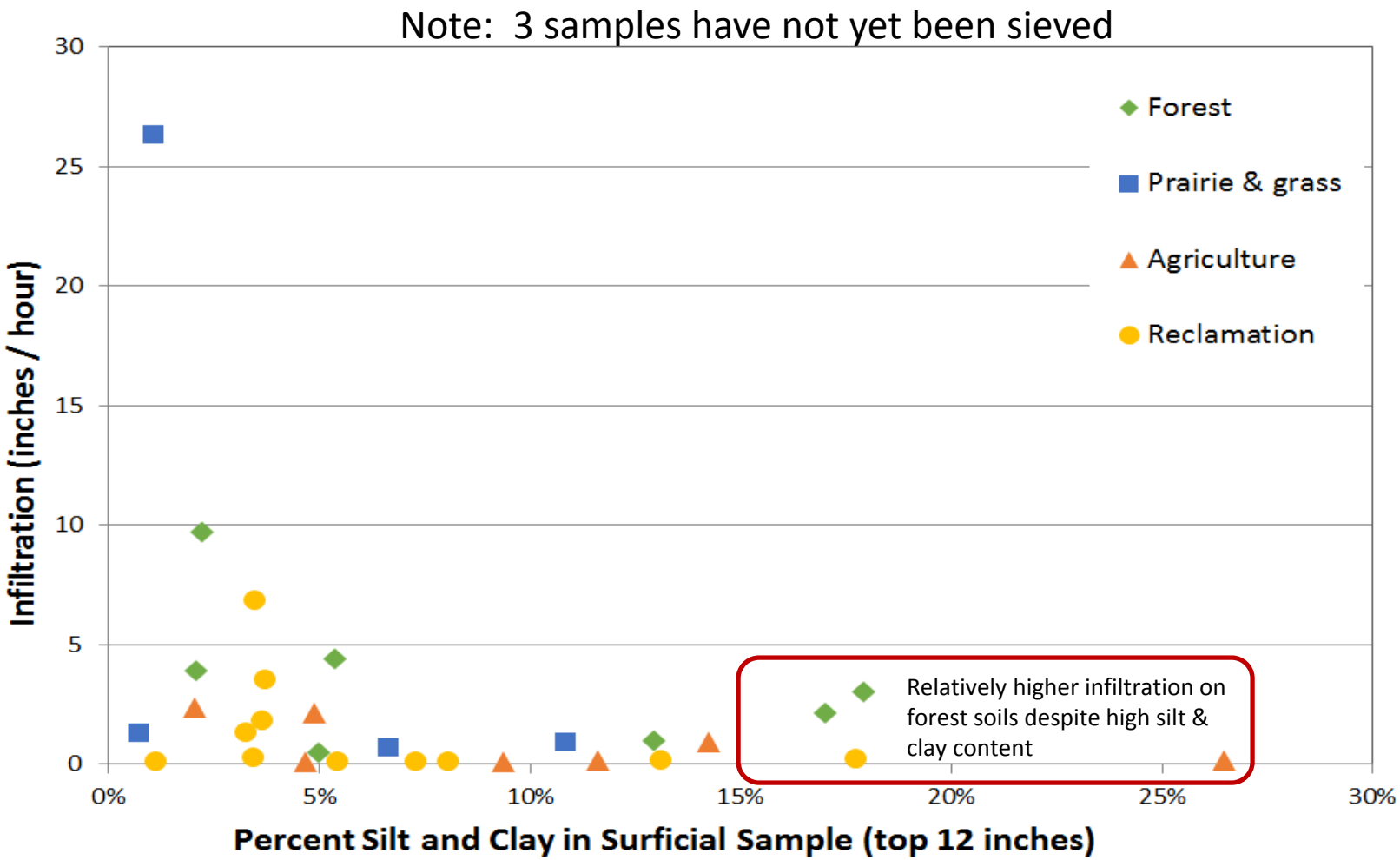






[1] These data are preliminary and are subject to revision. They are being provided to meet the need for timely best science. The data have not received final approval by the U.S. Geological Survey (USGS) and are provided on the condition that neither the USGS nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the data.

Infiltration vs. Percent Silt & Clay[1]



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Infiltration Summary

- High variability among all land covers
  - Soil texture & compaction
  - Vegetation & land use
- “Actively used” land associated with reduced infiltration
- Infiltration may increase after reclamation (years)
  - Length of time
  - Land cover & vegetation
  - Soil characteristics

USGS

Today's outline

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- What's next ?
- Other agenda items to include?

mod•el |ˈmädl|

noun

• a simplified description, esp. a mathematical one, of a system or process, to assist *calculations* and *predictions*.

ORIGIN late 16th cent. (denoting a set of plans of a building): from French ***modelle***, from Italian ***modello***, from an alteration of Latin ***modulus*** (see **modulus**).

USGS

from: New Oxford American Dictionary

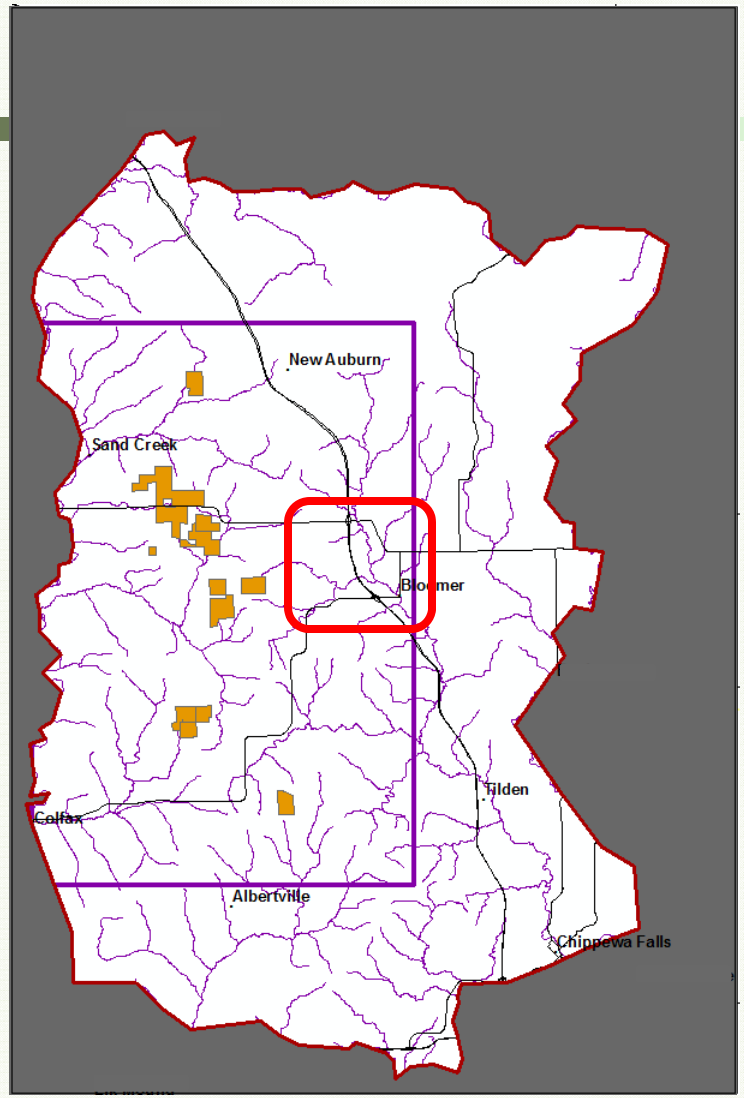
Building a MODFLOW Model: Basics

Start with a basemap

Focus in on area of interest

Extend out to hydrologic boundaries

Add a computational grid



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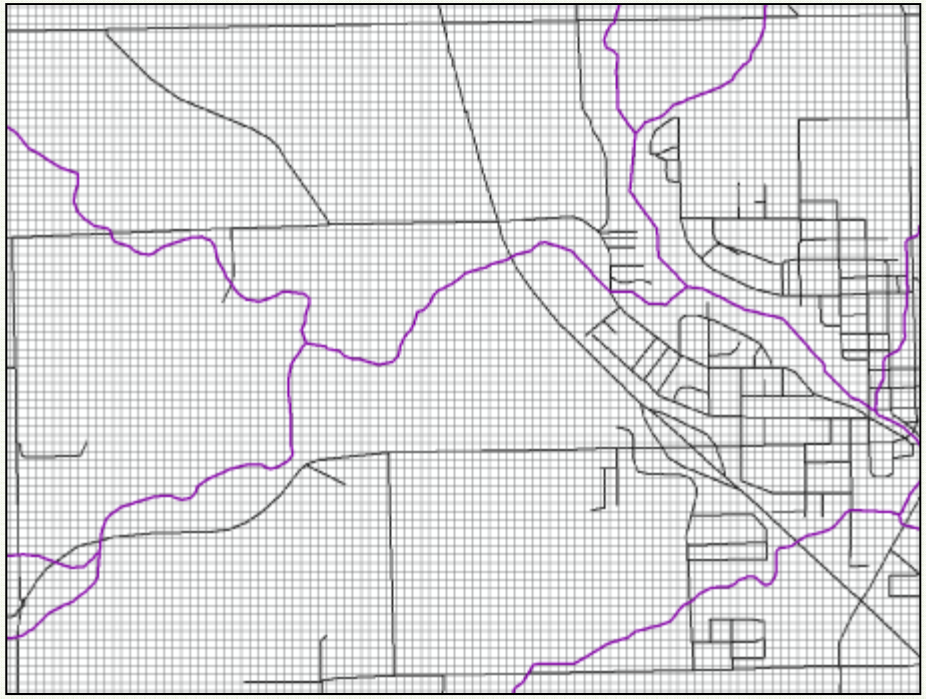
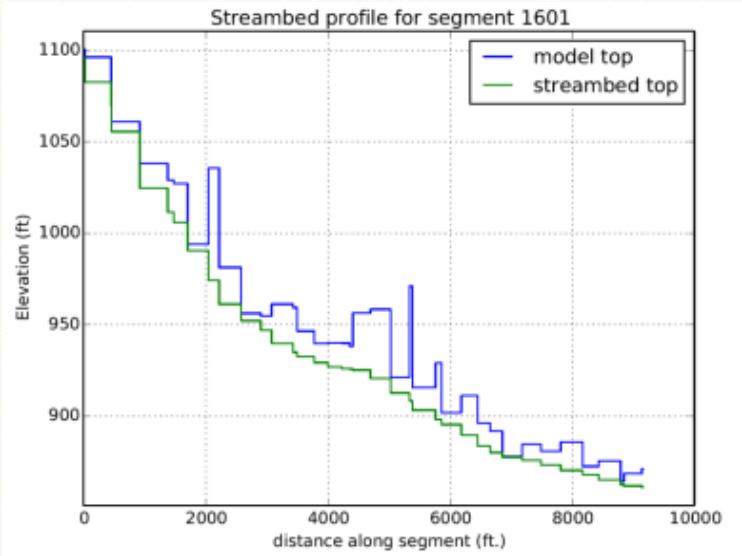


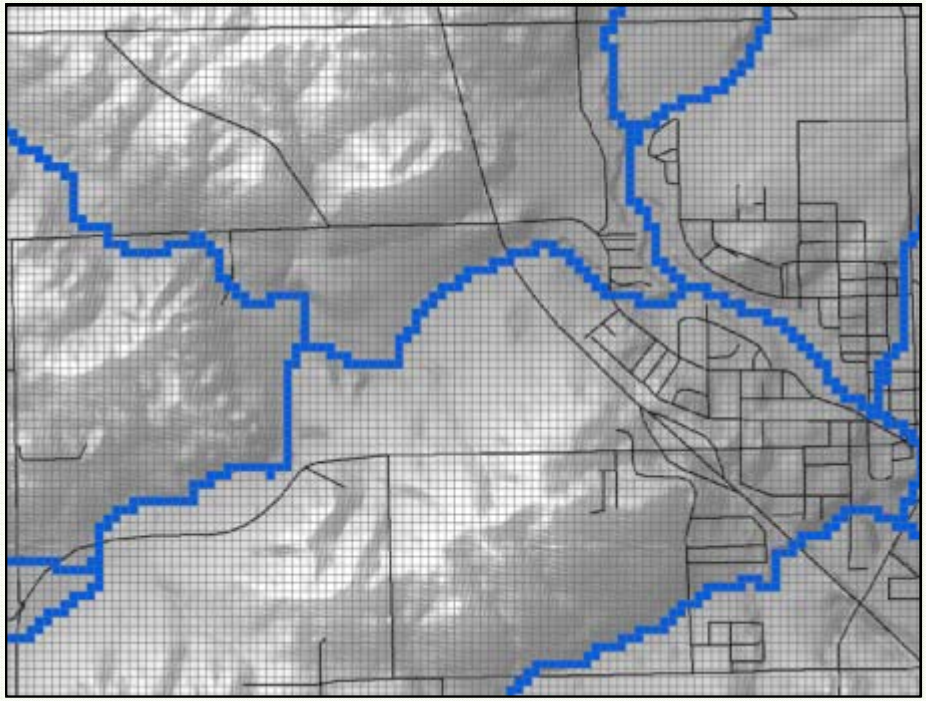
Building a MODFLOW Model: Streams and Elevation

Focus in on the stream network

Assign streams to model cells

Routing water downstream/downhill





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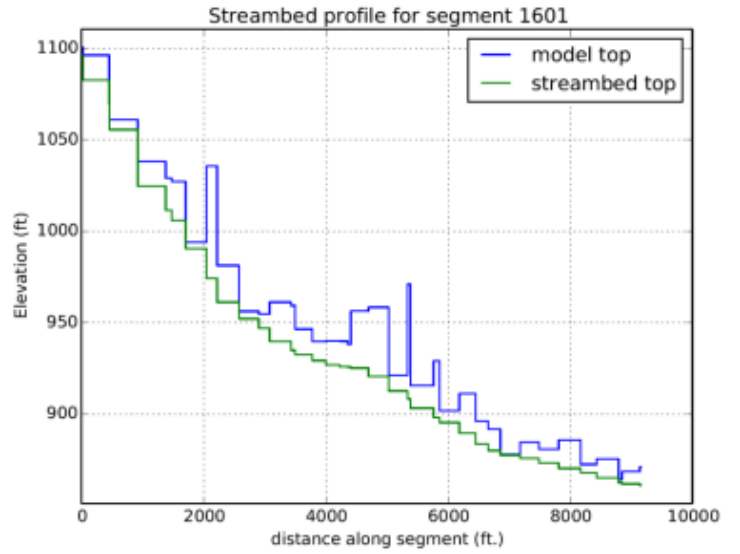
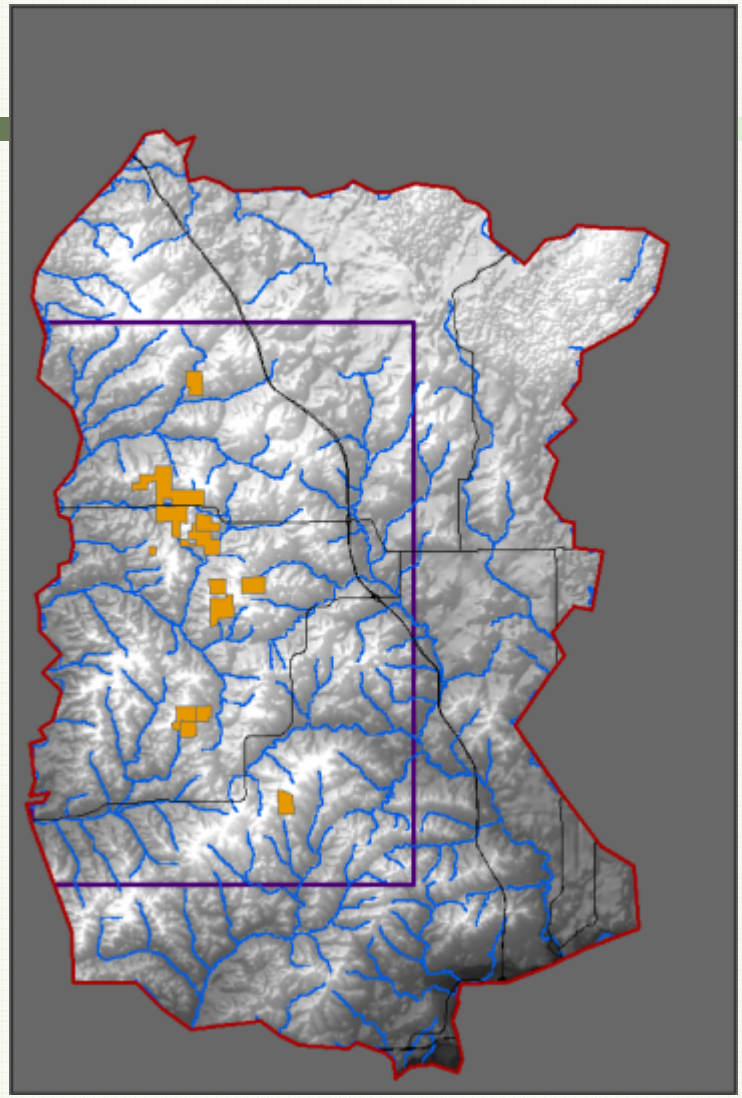




Building a MODFLOW Model: Hydrostratigraphy

Start with a basemap

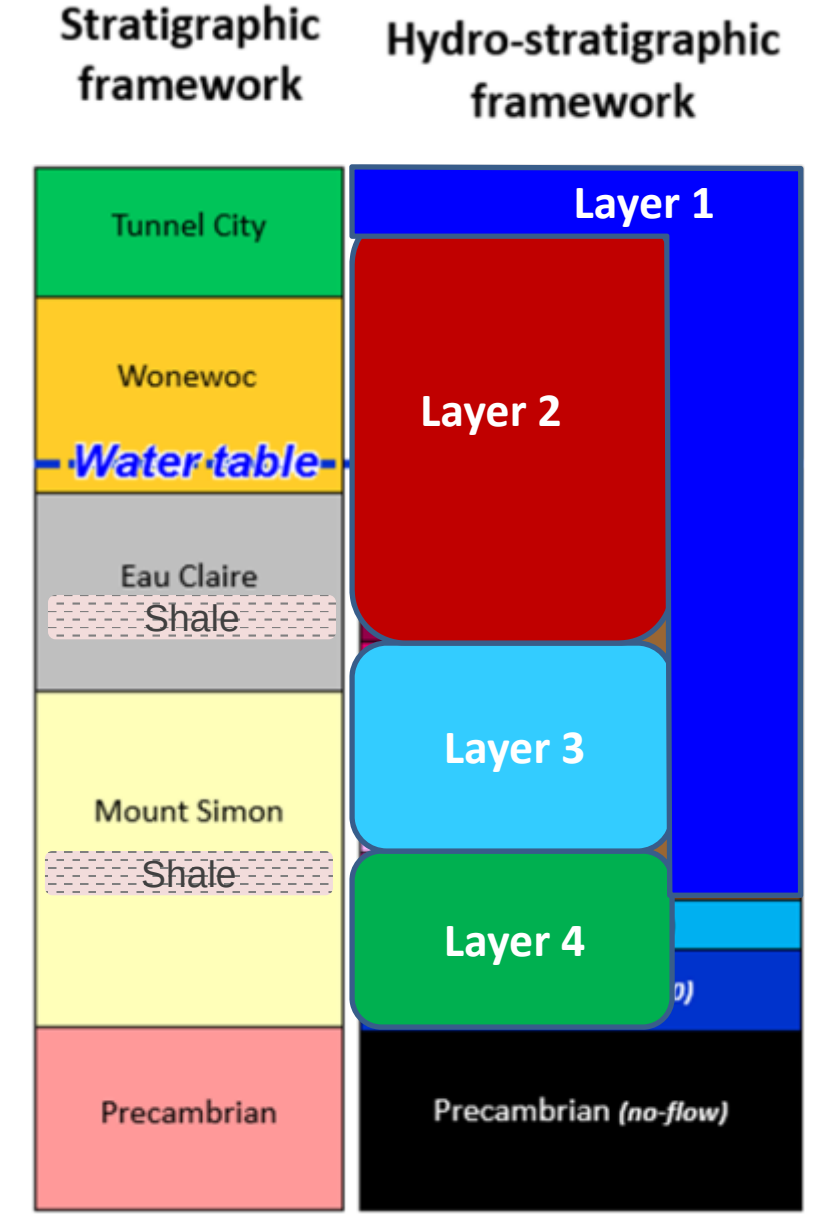
Focus in on area of interest

Extend out to hydrologic boundaries

Add a computational grid

Add streams

Convert hydrostratigraphy to model layers

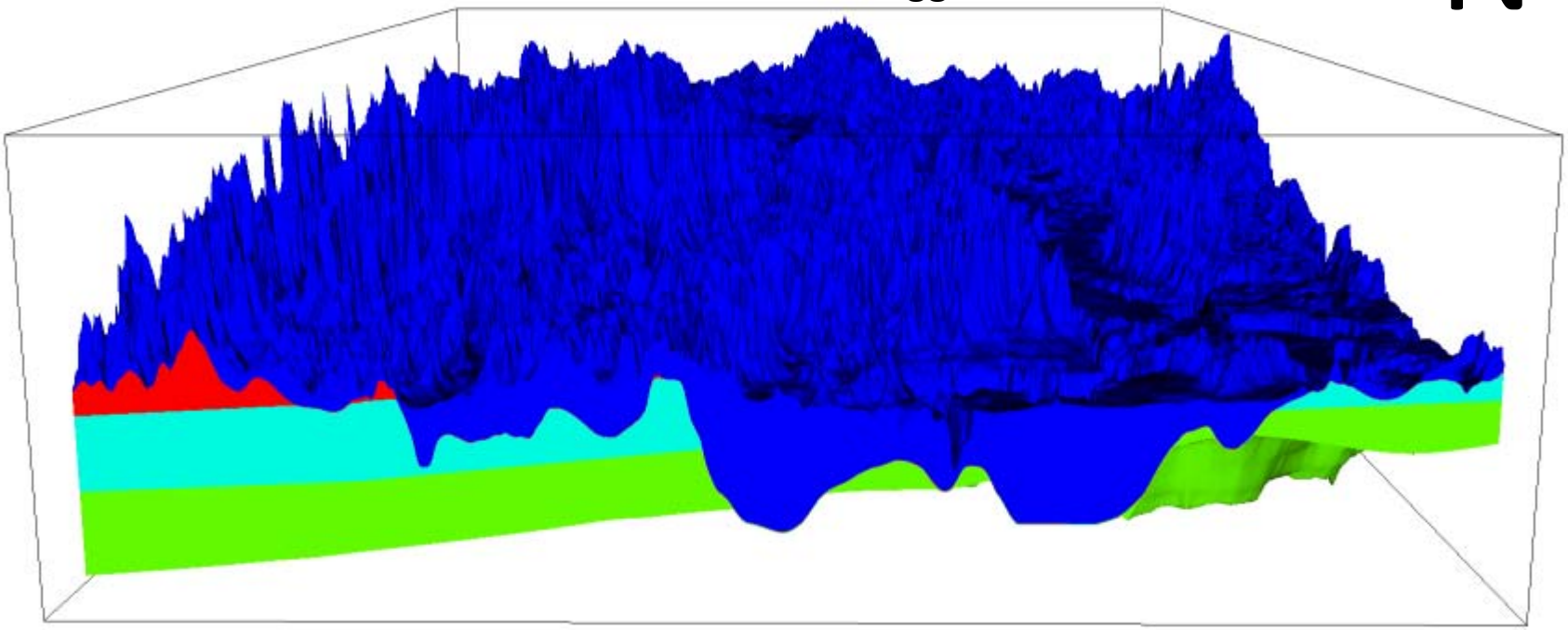


USGS

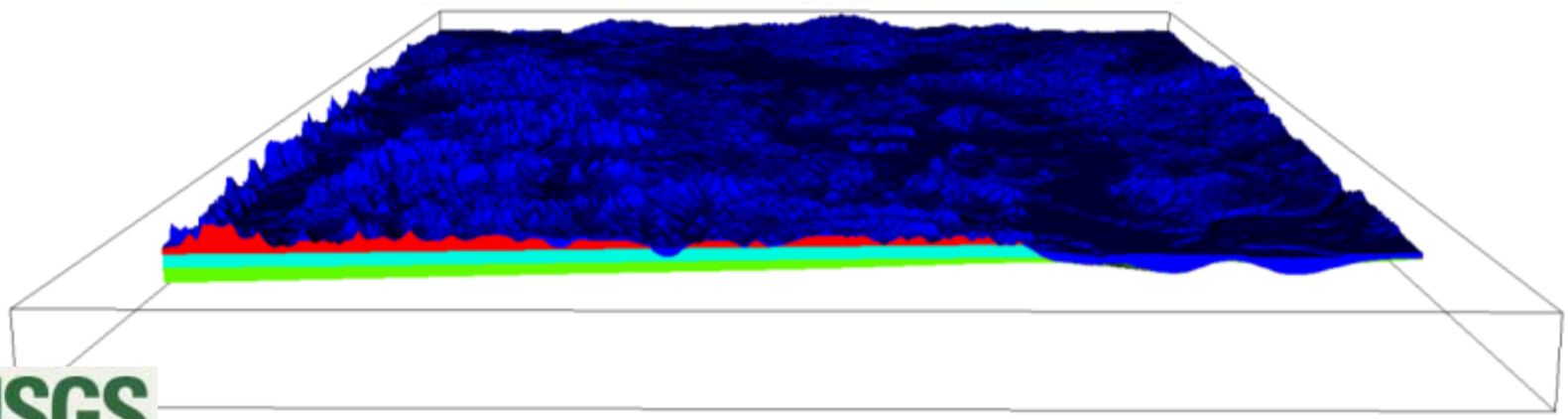
Model Layers

N

50x vertical exaggeration



10x vertical exaggeration

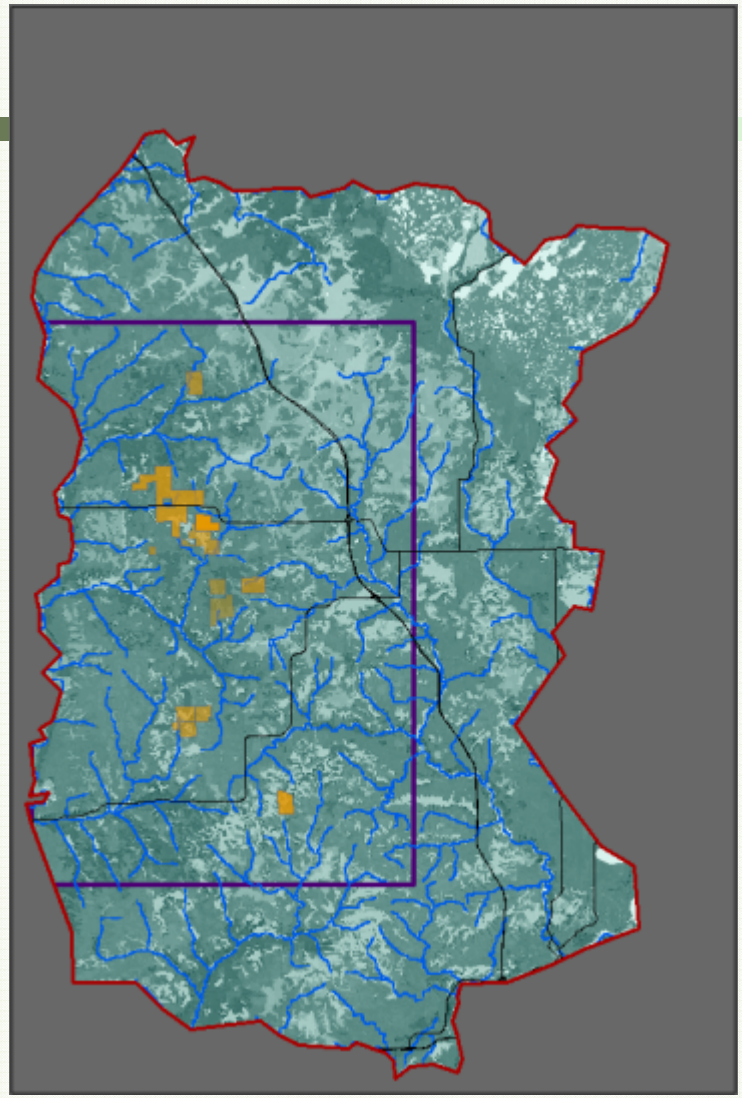


USGS

Building a MODFLOW Model: Recharge

Add groundwater recharge from the Soil-Water-Balance model

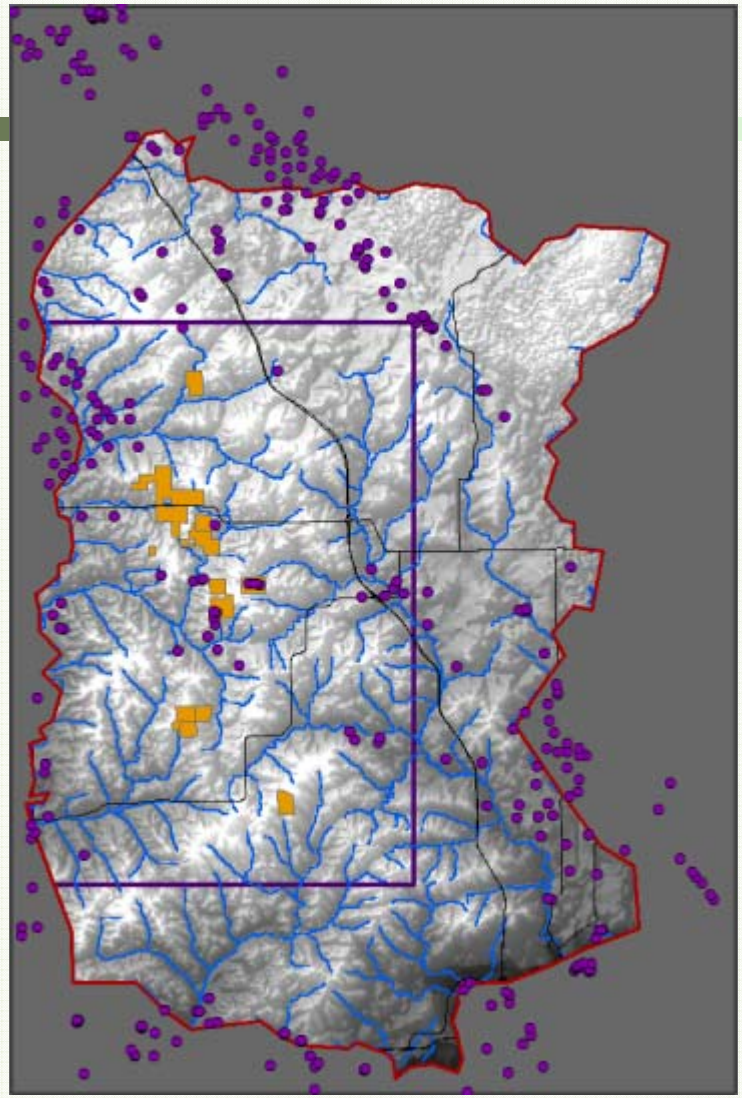
Darker colors = higher recharge



Building a MODFLOW Model: Water Use

Add groundwater wells to simulate pumping for mines, towns, and agriculture

2013 high-capacity well provided by the WI DNR; Locations refined by WGNHS

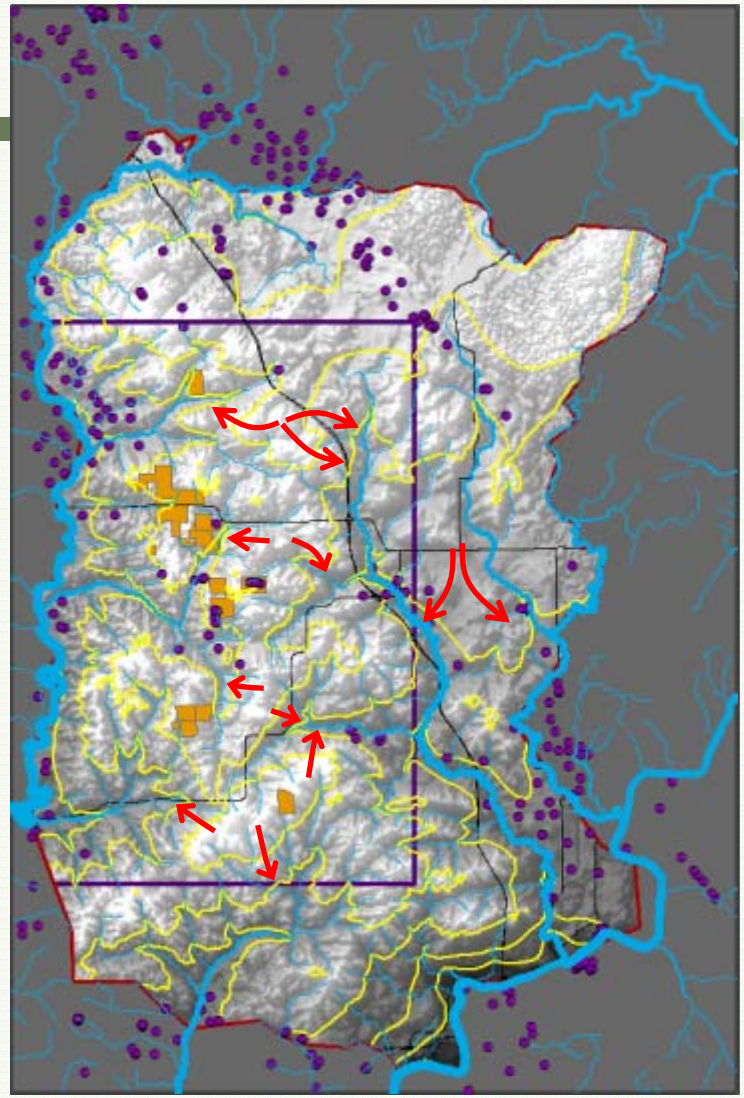


Building a MODFLOW Model: Initial Simulation

Use estimated property values

- permeability
- recharge

Simulate water levels…
and baseflows

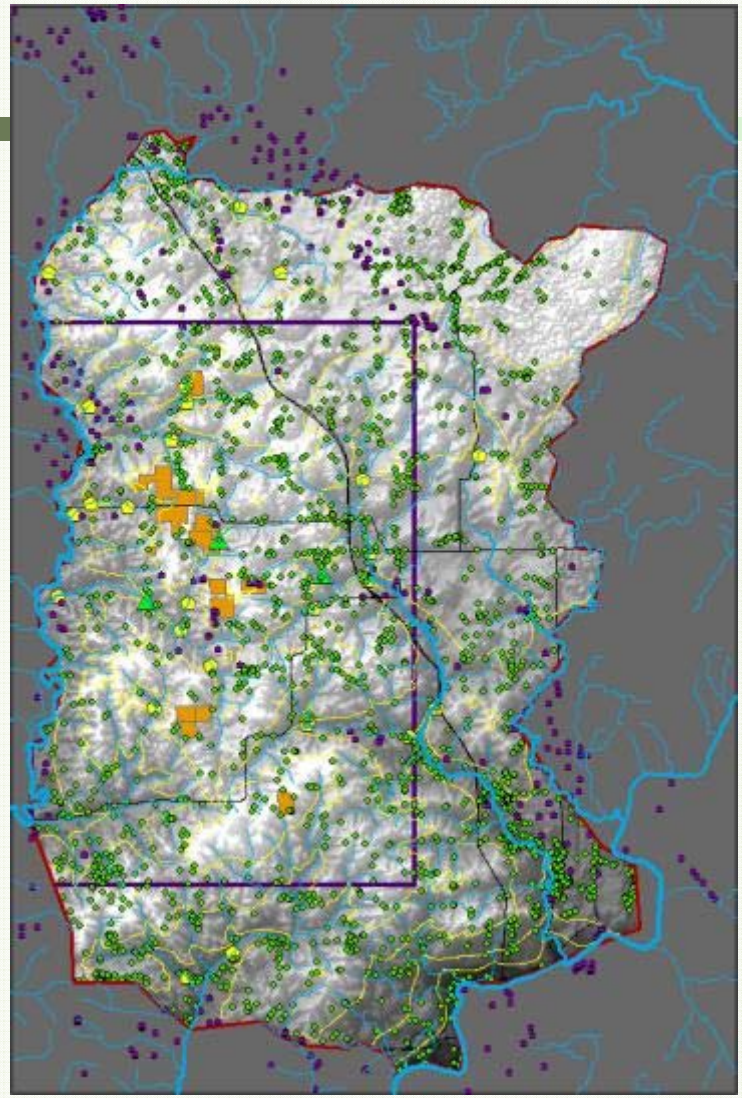


Building a MODFLOW Model: Calibration

Add stream baseflow targets

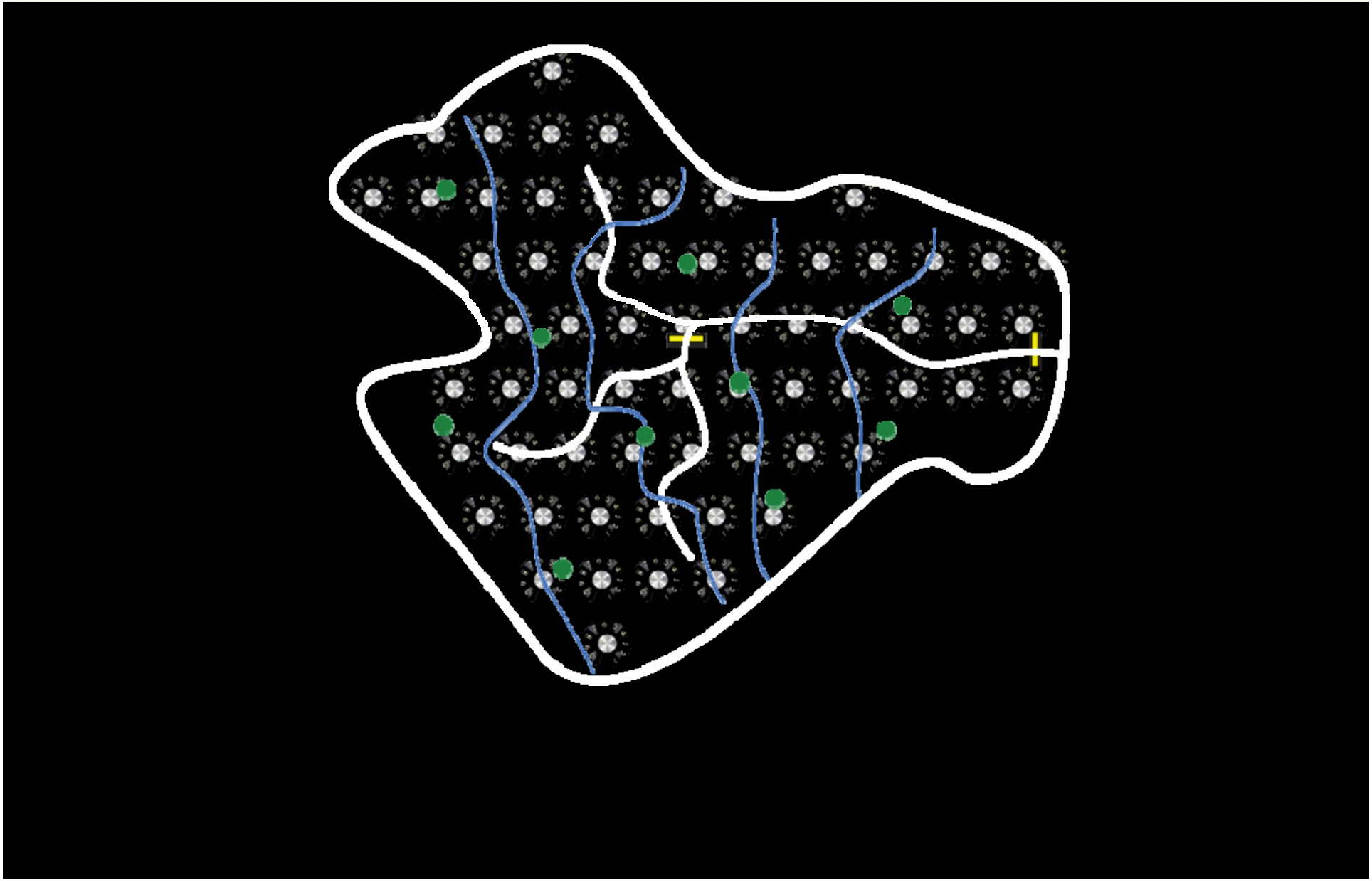
- Gaging stations
- Synoptic measurements

Add water level targets



Calibration

Calibration



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Modeling Flowchart (?)

Calibrate GW & SWB models:

- 2011-2013 weather, land use, pumping
- 2011-2013 water level and stream-flow targets

No overlapping areas

Pre-mining Scenario:

- Consistent weather pattern
- No mining land use (recharge)
- Remove mining wells

Mining Development Scenario:

- Consistent weather pattern
- Mining land use covers reasonably mineable area (recharge)
- Add wells mines at observed per-mine rates?

Irrigated Agriculture Development Scenario:

- Consistent weather pattern
- Mining land use and wells = no change from calibrated model
- Add Irrigated agriculture wells on per-acre basis from DNR-computed rates?

USGS

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What's next...

- Complete construction of MODFLOW model
- Finish compilation of data for model calibration
- Calibrate MODFLOW model to 2011-2013 conditions
- Perform future scenario runs incorporating feedback from Stakeholders

Upcoming meetings and deliverables

- **Public meeting tonight at the Bloomer Middle School**
  - **5:00 – 7:00pm Outreach workstations**
  - **7:00 – 9:00 pm Public meeting**
- Next meetings (2016 annual update)
  - Stakeholders meeting – Q1 2016
  - General public meeting – Q1 2016
- Deliverables
  - Final report – Q3 2017 (final model, scenarios, transferability results)

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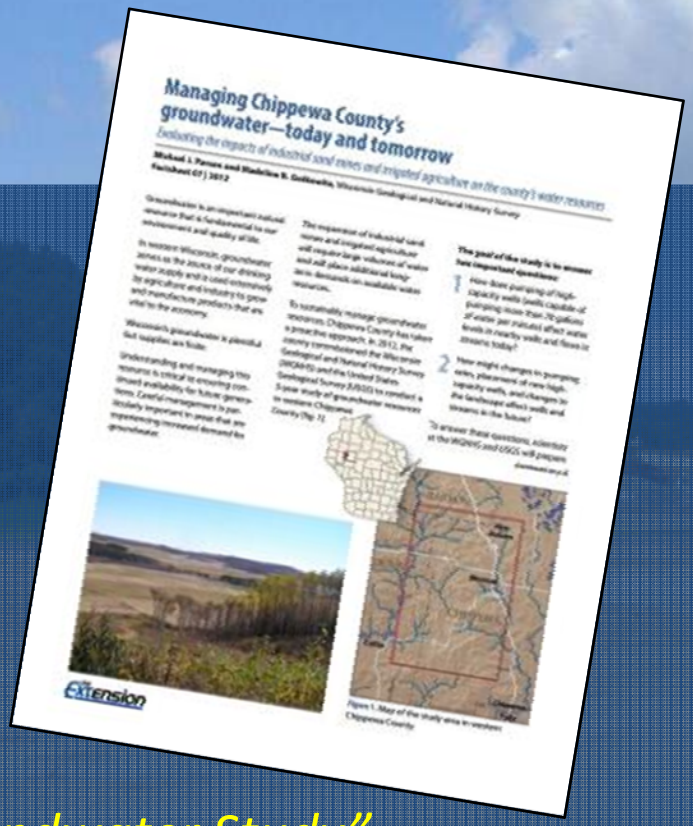
Chippewa County Groundwater Study

4th Stakeholders Group Meeting



To find out more visit the

WGNHS website:

www.wisconsingeologicalsurvey.org

Or,

Chippewa County website:

co.chippewa.wi.us/lcfm and

click on the link *"Chippewa County Groundwater Study"*

USGS science for a changing world

Chippewa County Land Conservation and Forest Management "Stewardship for Sustainability"

UW Extension University of Wisconsin-Extension

Wisconsin Geological & Natural History Survey