

# Groundwater flow model for Western Chippewa County

*Including analysis of water resources related to  
industrial sand mining and irrigated agriculture*

Chippewa County Board Meeting  
Chippewa Falls, WI - May 14<sup>th</sup> 2019

Mike Parsen  
*Mike.Parsen@wisc.edu*  
www.wisconsin Geological Survey.com

Paul Juckem (USGS)  
Mike Fienen (USGS)  
Madeline Gotkowitz (WGNHS)





## Study overview

- **Started fall 2012**
  - Project team
    - WGNHS
    - USGS
    - Chippewa Co. LCFM
  - Stakeholders group
    - All active sand mining companies
    - WI Farmers Union
    - WI DNR
    - Trout Unlimited
    - Local farmers and citizens
- **5-year study effort**
  - Technical investigation and modeling
  - Outreach and reporting





Attachment: Groundwater Presentation Report for CB 05-14-19 (5003 : WGNHS Groundwater Study)

### Study overview



**Frac sand mining**





**Water used to wash sand, transport sand onsite and control dust**



### Study overview



**Municipal supply**

**Irrigated agriculture**







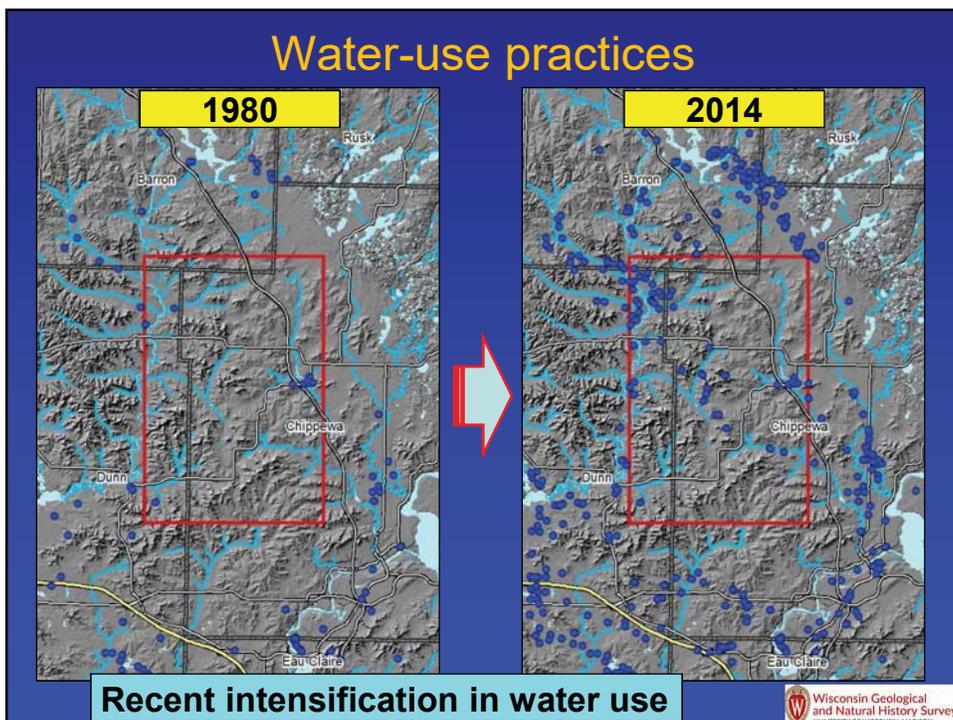
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## Study overview

- Why do we care?
  - Pumping in upland areas near headwaters of streams
  - Intensifying water-use practices
  - Changes to landscape and implications for groundwater recharge
  - Long-term water resource management and sustainability



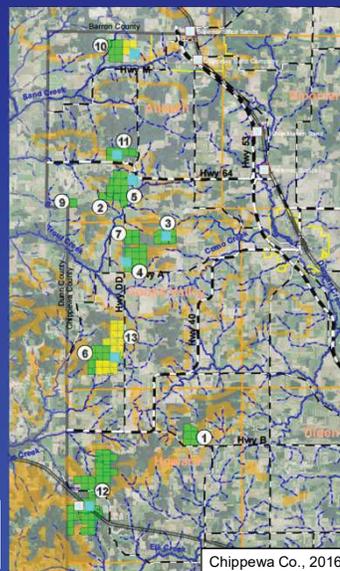
## Water-use practices



# Changes to landscape



Groundwater recharge implications



- Permitted mines
- Application received

Chippewa Co., 2016

## Expansion of industrial sand mining



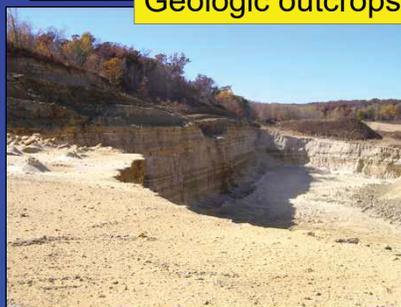
# Data collection



Driller's records



Geologic outcrops



## Data collection



**Borehole geophysics**



**Streamflow surveys** *P. Juckem*

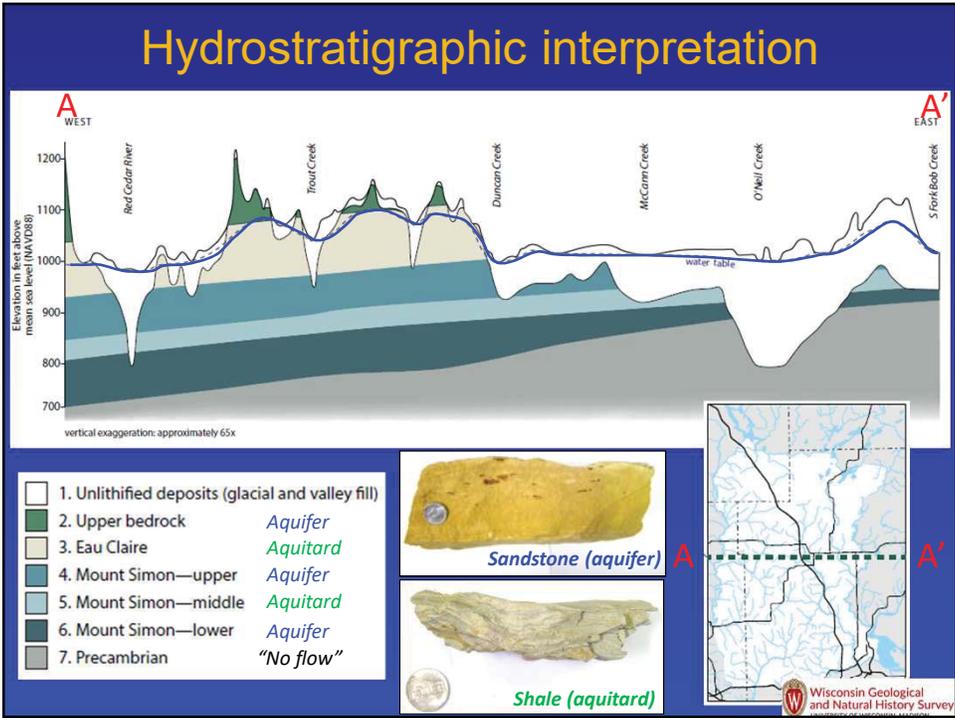


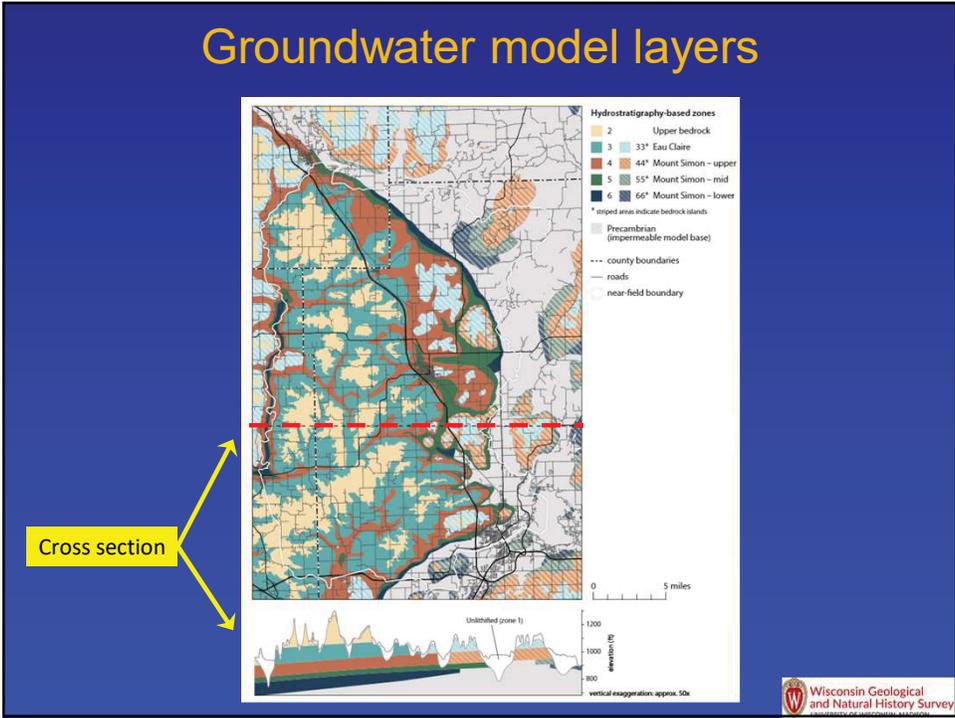
**Infiltration testing** *Z. Vande Sluit*



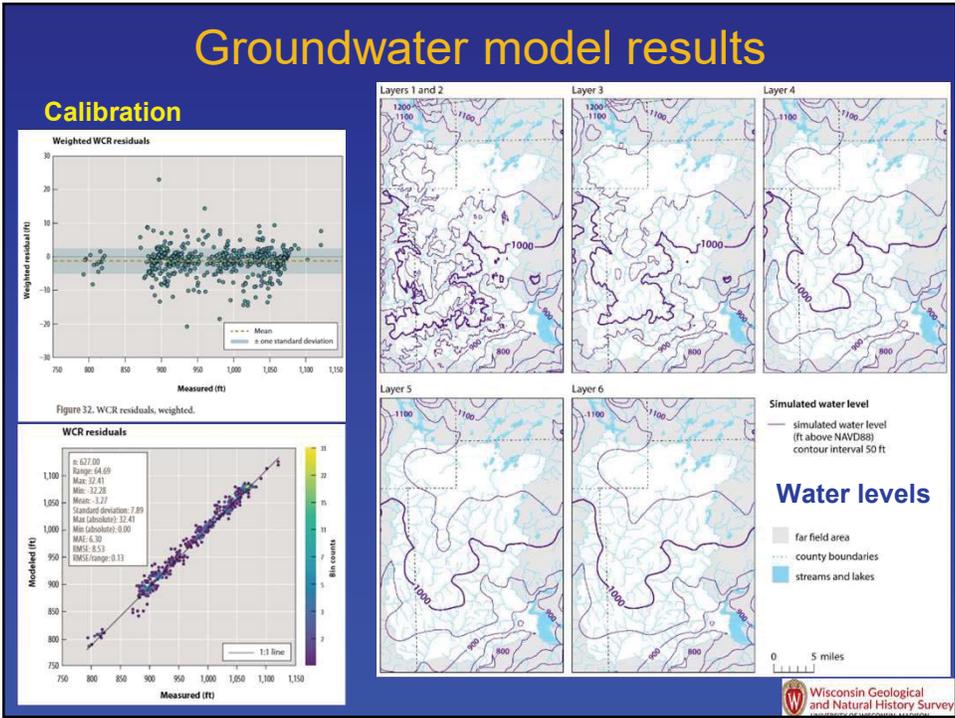
**Water-use records** *J. Clark*



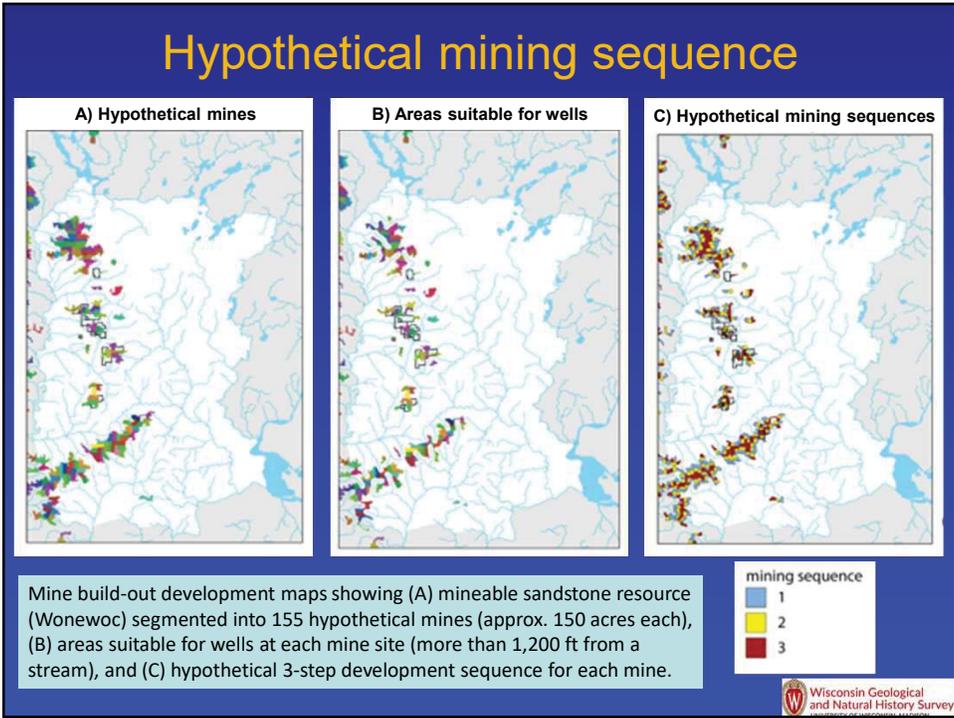
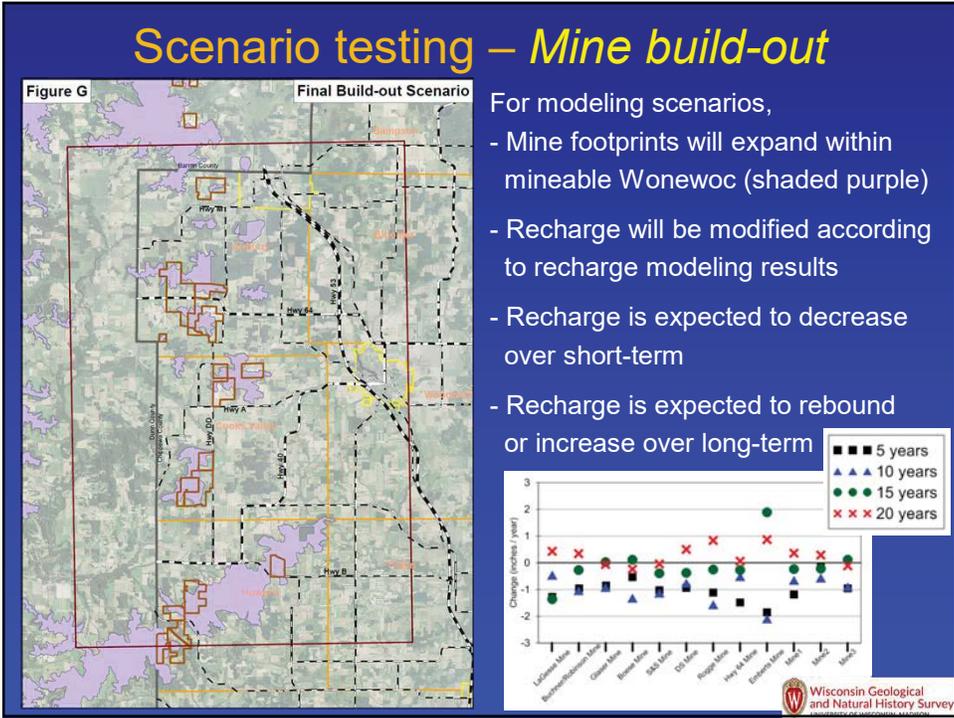




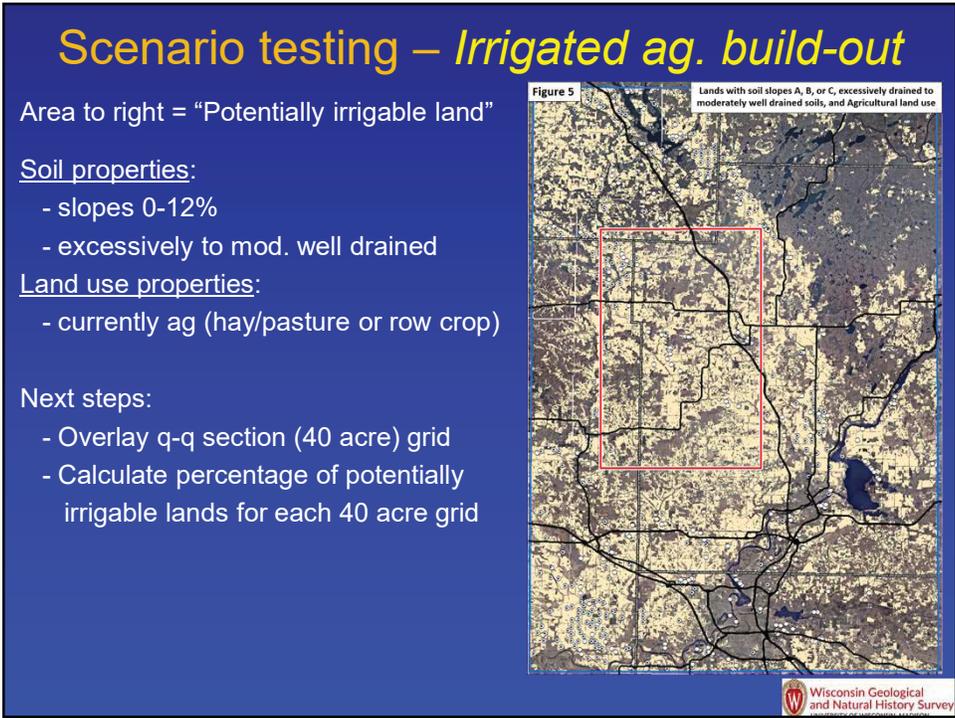
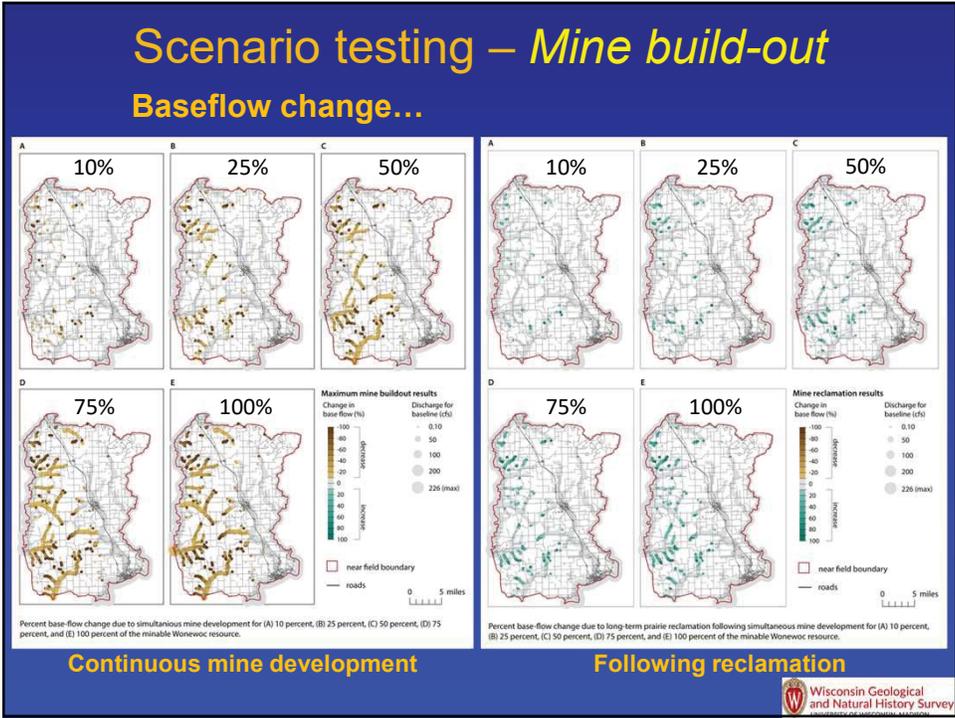
Cross section



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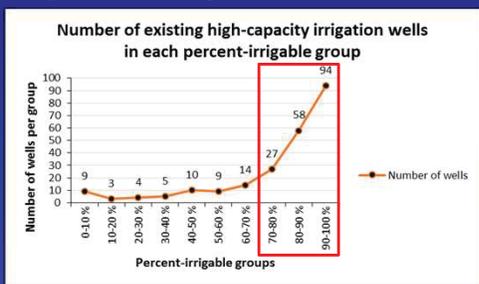
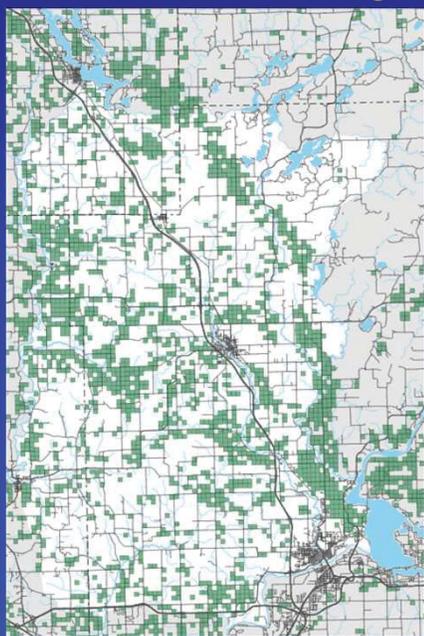


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## Scenario testing – Irrigated ag. build-out



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Cells < 1,200' from a stream were removed from consideration.

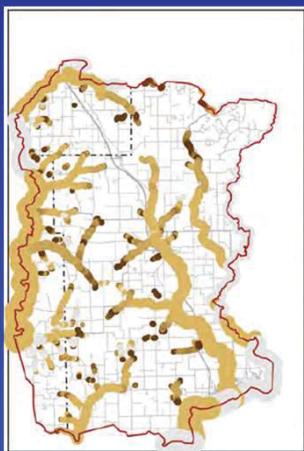
Took into account local farmer knowledge about lands unsuitable for irrigation

--- county boundaries  
 --- roads  
 streams and lakes  
 far-field area



## Scenario testing – Irrigated ag. build-out

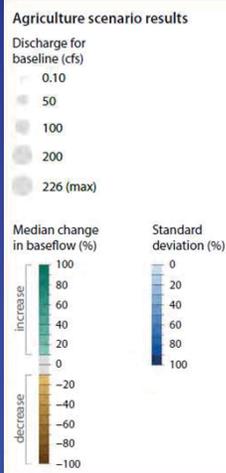
### Baseflow change...



Median change in baseflow



Standard deviation



## Key conclusions

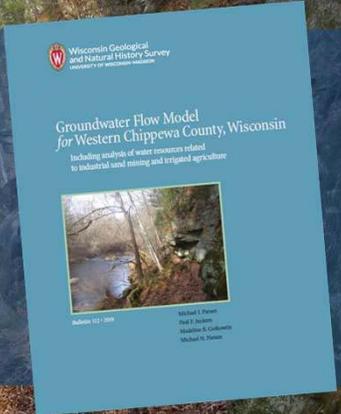
- **Water-resource takeaways**
  - **Headwater streams are most sensitive** to groundwater withdrawals and changes in recharge associated with sand mining and irrigation
  - Baseflow is expected to decrease as groundwater withdrawals increase or recharge rates decline
  - Simulated reductions in baseflow lower the baseline of streamflow from which natural seasonal variability will occur
  - Carefully planned expansion of water withdrawals and mine reclamation could help mitigate some of the simulated effects:
    - Locate pumping as far away as possible from sensitive streams,
    - Stagger mine development over time,
    - Reclaim mined areas to high-infiltration land cover and land uses that enhance macropore development and limit compaction.



## Groundwater flow model for Western Chippewa County

To find out more visit the WGNHS website:  
[www.wisconsingeologicalsurvey.org](http://www.wisconsingeologicalsurvey.org)

Or,  
 Chippewa County website:  
[co.chippewa.wi.us/lcfm](http://co.chippewa.wi.us/lcfm), click on the link  
 "Chippewa County Groundwater Study"



Mike Parsen  
 Mike.Parsen@wisc.edu  
 www.wisconsingeologicalsurvey.com

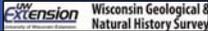






### Today's outline

- Study overview
- Data collection and hydrostratigraphy
- Estimating groundwater recharge
- Groundwater model development
- Future scenario testing



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Wisconsin Geological & Natural History Survey

## Study overview

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Photo: Chippewa Co.

**Water used to wash sand, transport sand onsite and control dust**

Wisconsin Geological & Natural History Survey

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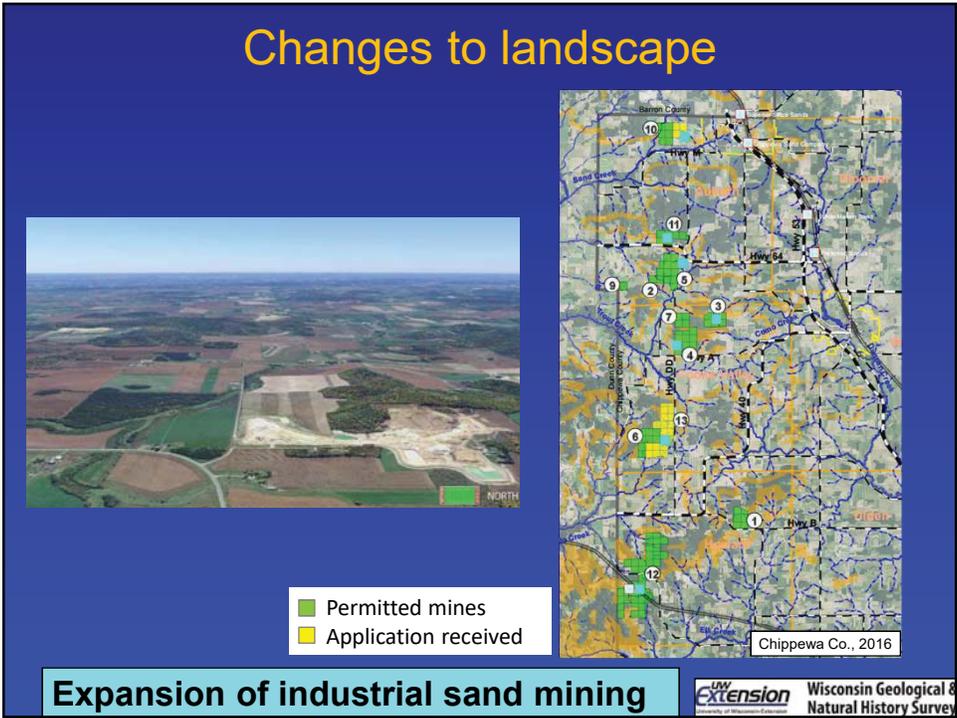
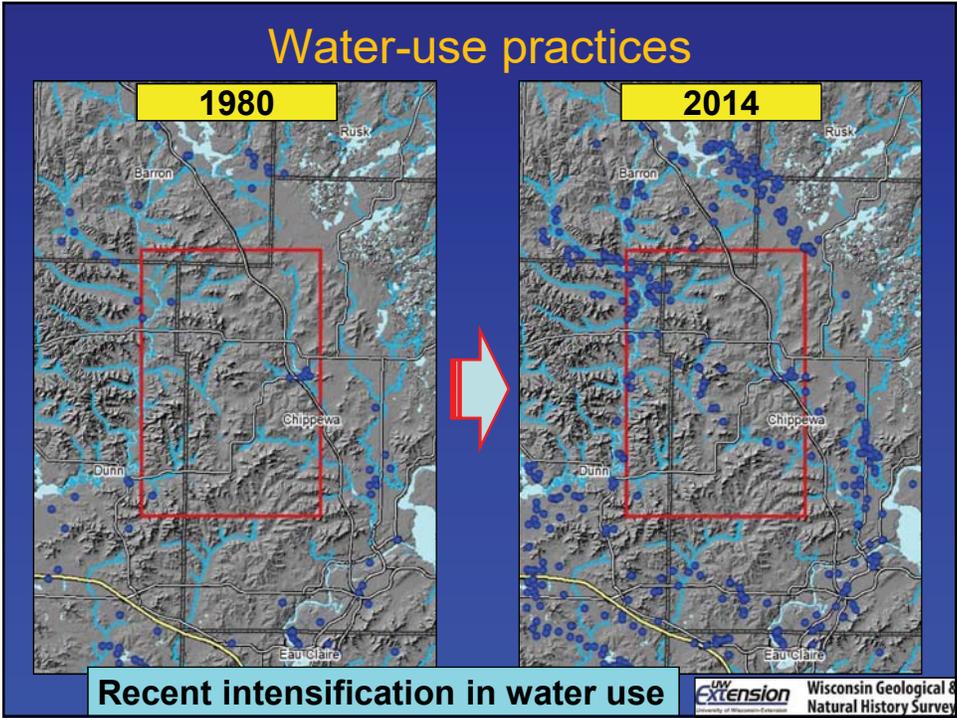
 Wisconsin Geological & Natural History Survey

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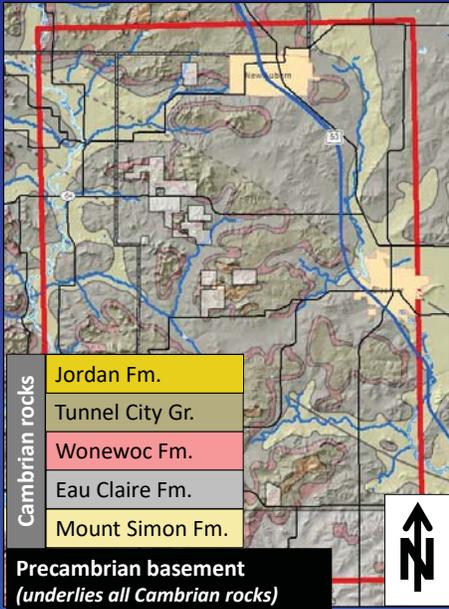
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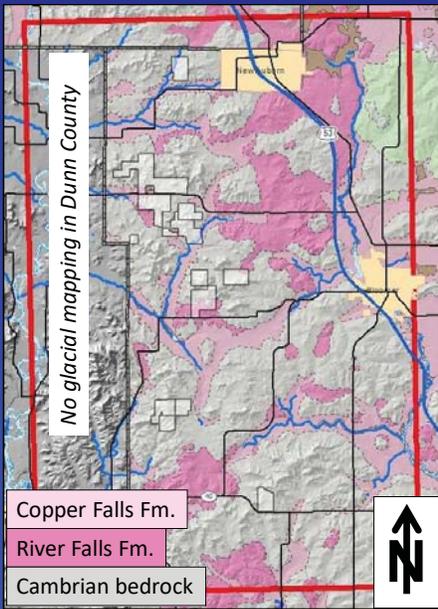


## Data collection



- **Bedrock geology (WGNHS)**
  - Northwest WI (1987)
  - West Central WI (1988)
  - 1:250,000 scale
- Good framework but relatively small-scale mapping

### Data collection



- **Glacial geology** (WGNHS)
  - Chippewa County (2007)
  - Barron County (1986)
  - 1:100,000 scale

### Data collection



- **Well construction reports** (DNR)
- Driller's descriptions of cuttings in the field

### Data collection



- **Well construction reports** (DNR)
- Driller's descriptions of cuttings in the field
- Provides information about
  - Depth to bedrock
  - Depth to Precambrian rock
- Hydrogeologic data
  - Estimates of hydraulic conductivity (well development)
  - Water levels (for calibration)

### Data collection



- **Geologic logs** (WGNHS)
- Cuttings from municipal supply or other high-capacity wells
- Evaluated by WGNHS geologists in the laboratory
- Many recent cutting sets have been obtained directly within the study area
- Higher quality than drillers logs

**Data collection**

**Outcrops**



**Irvine Park in Chippewa Falls**  
Contact: Precambrian Granite and Mount Simon Fm. (Cambrian)

**Data collection**

**Outcrops**



**South of Colfax above Hwy 40**  
Contact: Tunnel City Gr. and Wonewoc Fm.

## Data collection

Outcrops (in active mines)



**Superior Silica Sands Mine, Hwy 64 at DD**  
Contact: Tunnel City Gr. and Wonewoc Fm.

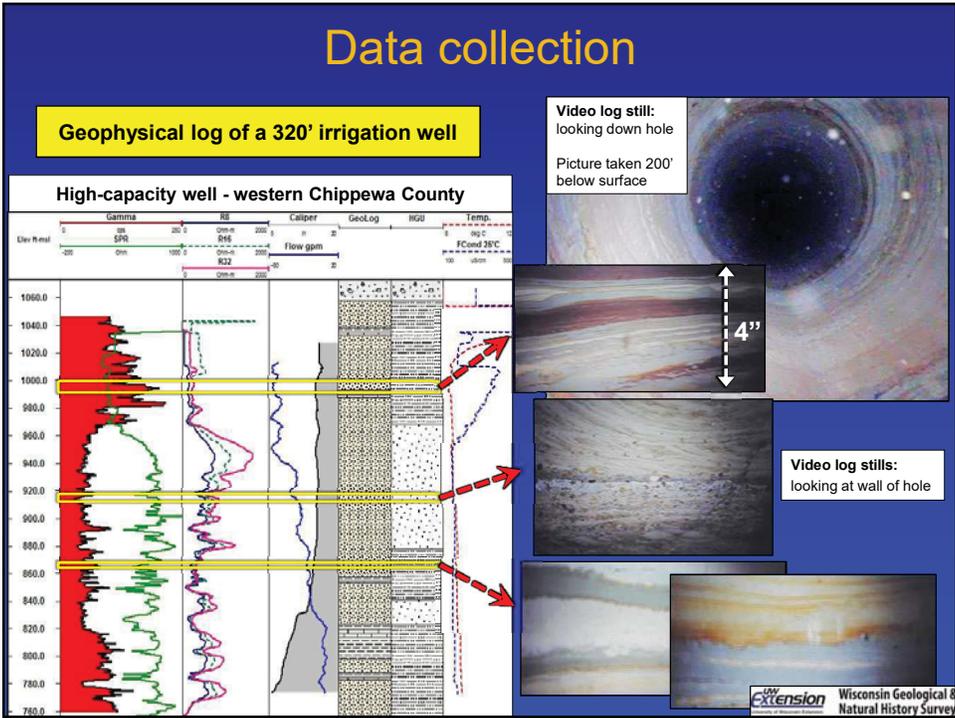
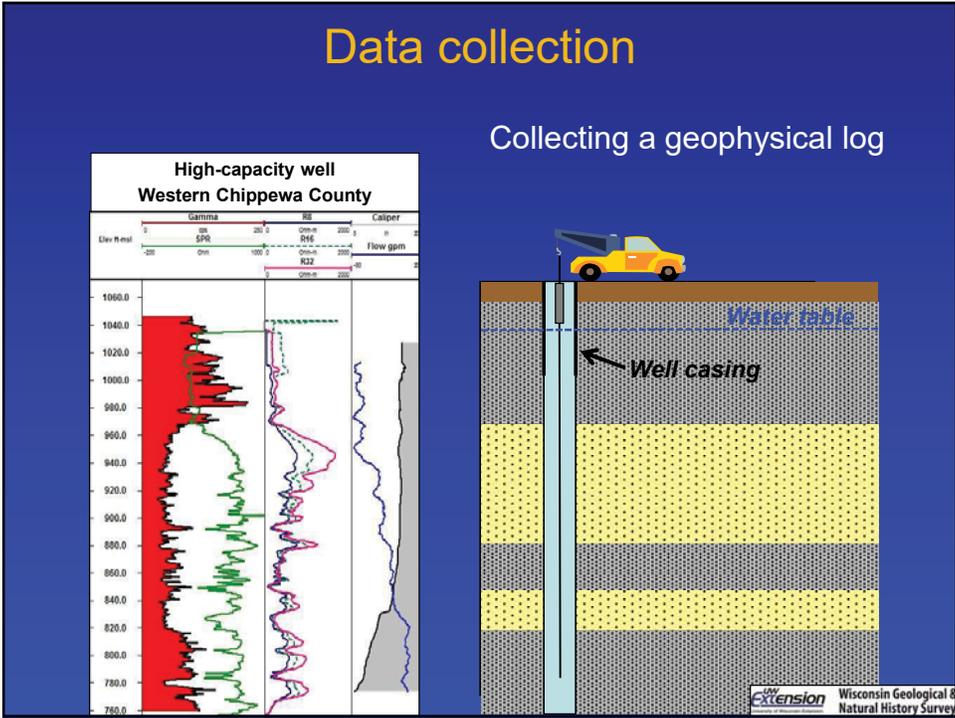
## Data collection



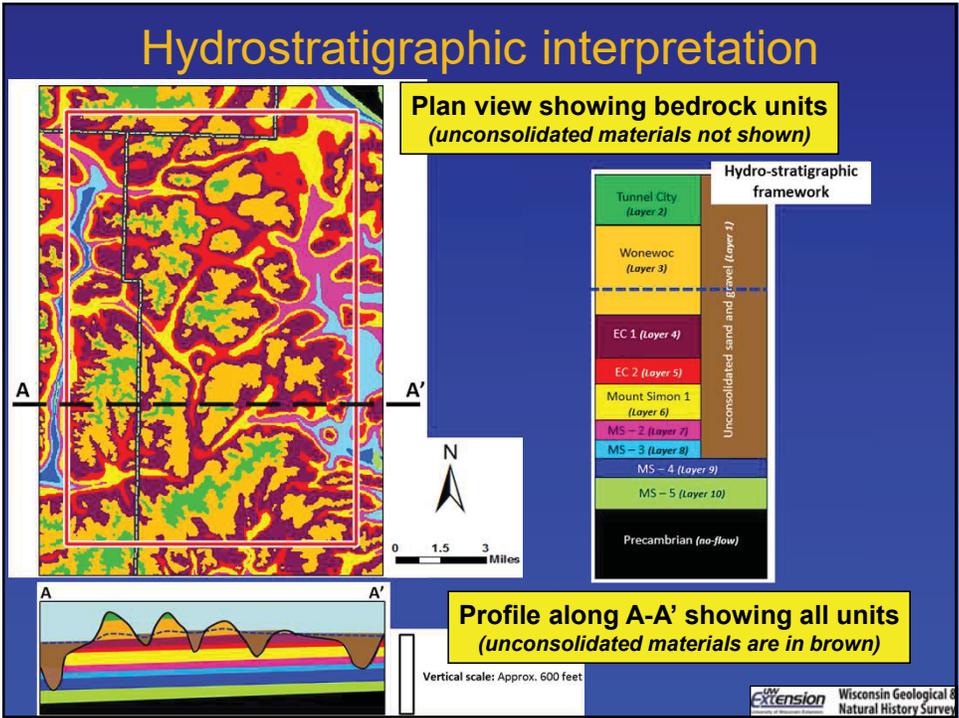
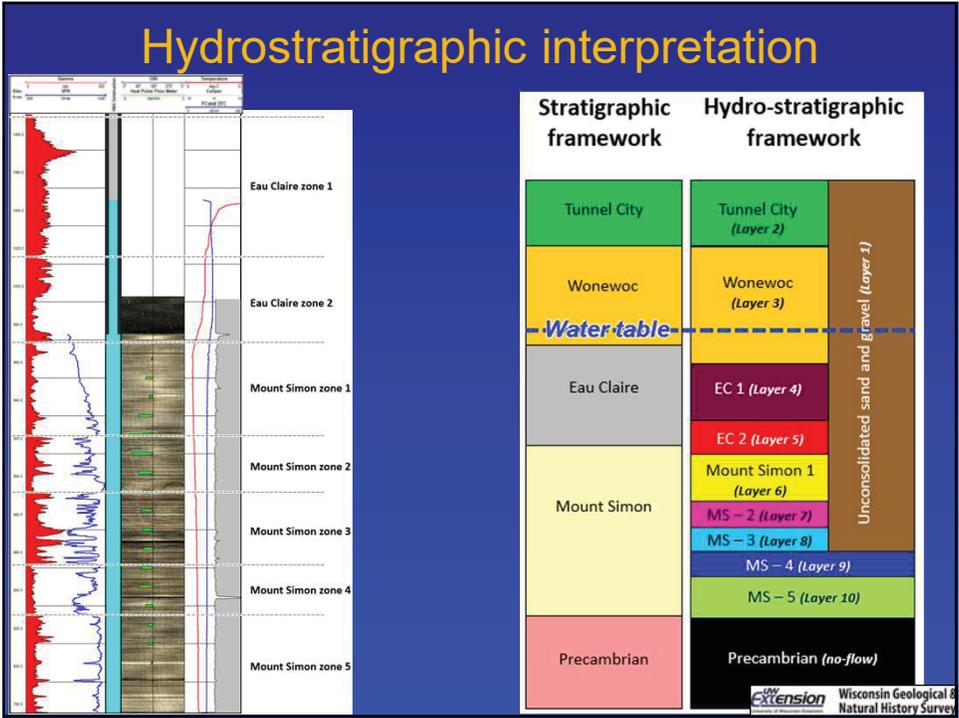
**Geophysical logs**

- Detailed profiles of geology and hydrogeology
- Allows for hydrogeological characterization

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Attachment: Groundwater Presentation Report for CB 05-14-19 (5003 : WGNHS Groundwater Study)



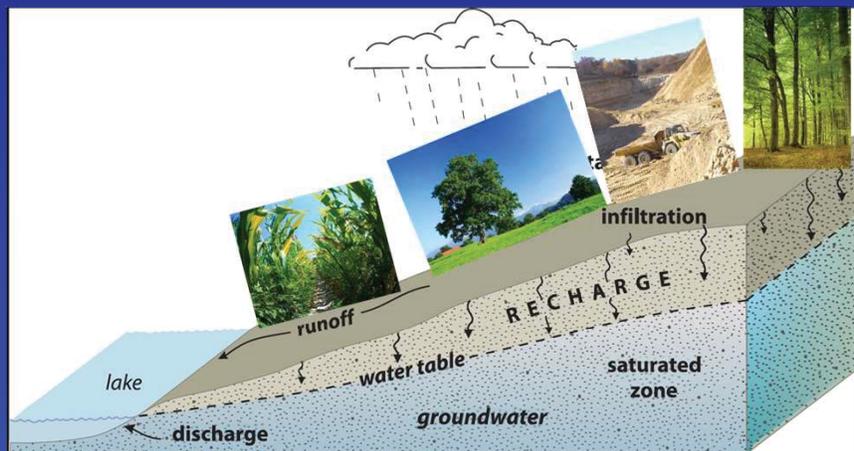
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Recharge (R) is water that enters the groundwater system

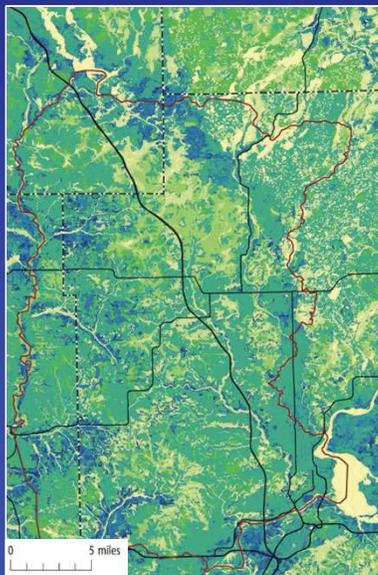
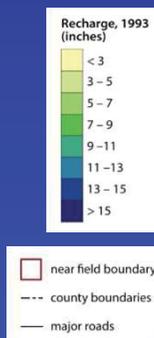
$$R = \text{Precipitation} - \text{Runoff} - \text{Interception} - \text{Evapotranspiration}$$



## Estimating recharge

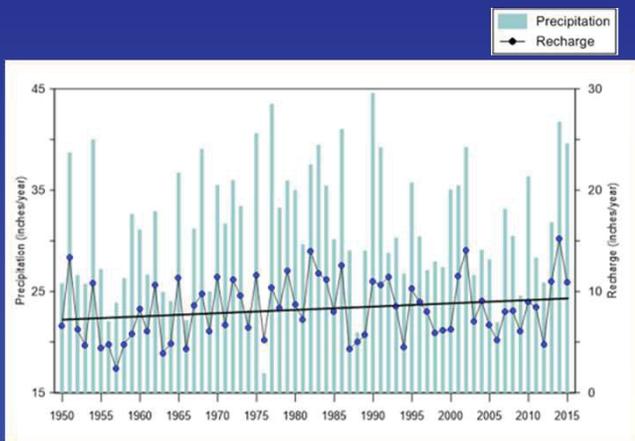
Soil-water-balance (SWB) model based on:

- Soil type
- Surface topography
- Soil-water storage
- Land use
- Climate data



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## Estimated annual average recharge, 1950 - 2010



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

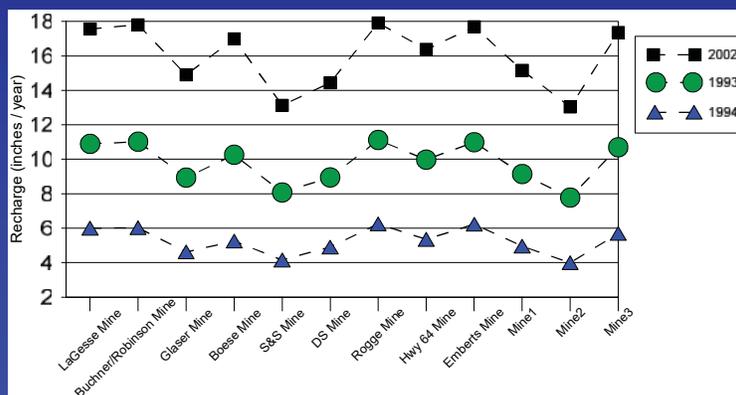
Annual recharge  
Average 8.2 inches  
Min. 2.5 inches  
Max. 14 inches

1993 = average weather year

About 27% of precipitation recharges groundwater

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## Effect of soil and land use

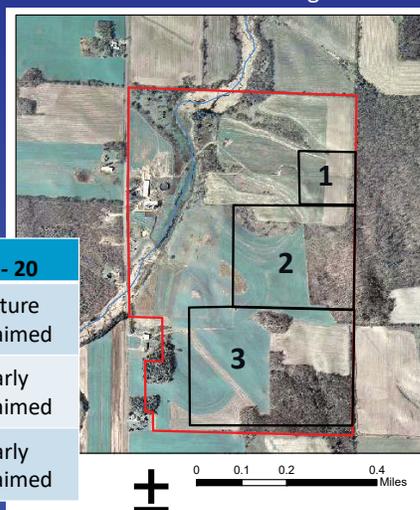


Recharge fluctuates at each mine site due to variations in weather...

## Recharge in mined and reclaimed areas

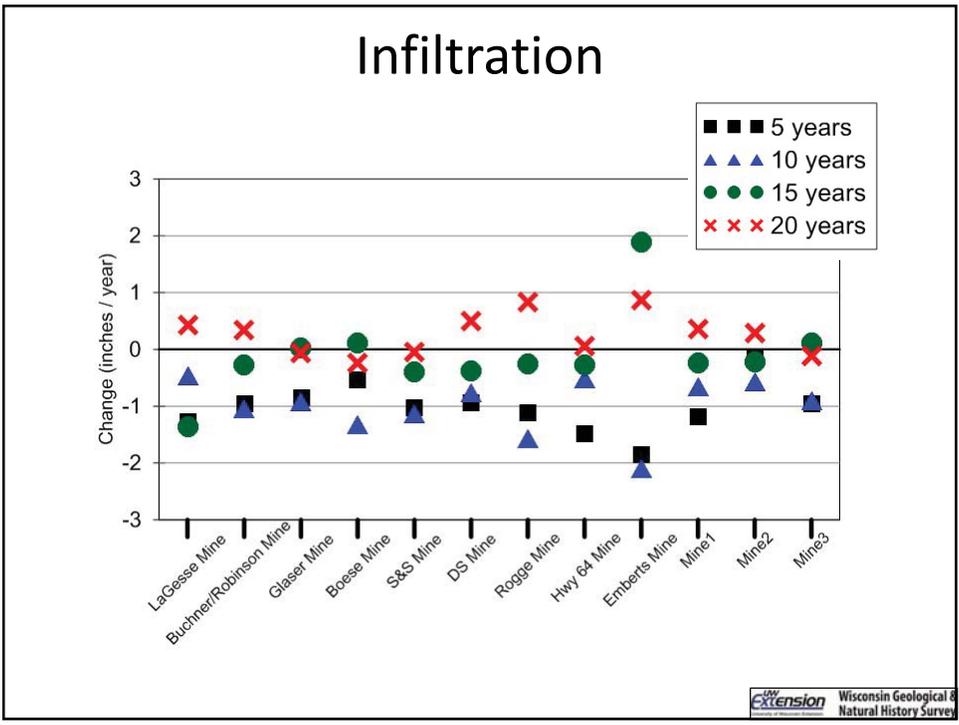
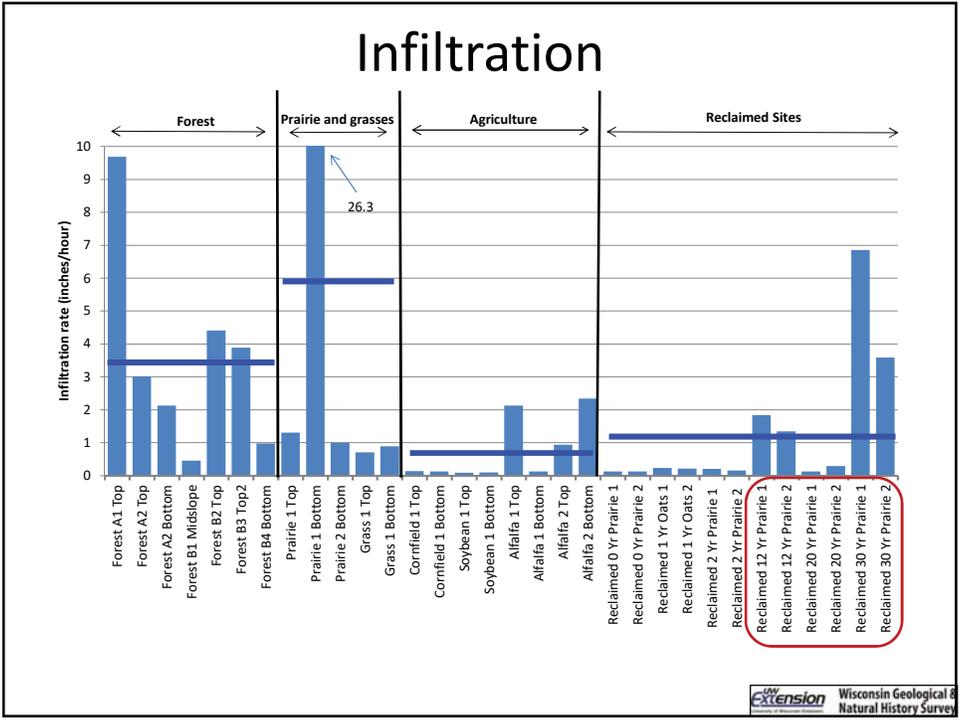
*Conceptual model of mine development and reclamation*

Mine extent and mining areas



Development and reclamation schedule

Years	1 - 5	6 - 10	11 - 15	16 - 20
Area 1	quarry	early reclaimed	early reclaimed	mature reclaimed
Area 2	existing	quarry	early reclaimed	early reclaimed
Area 3	existing	existing	quarry	early reclaimed



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**mod•el** |'mädl|  
noun

---

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

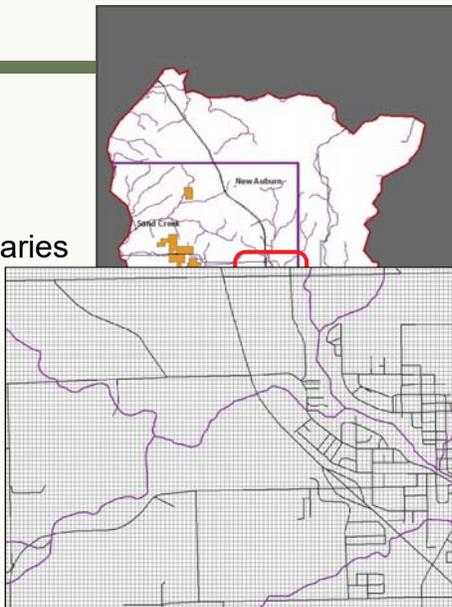
ORIGIN late 16th cent. (denoting a set of plans of a building): from French *modelle*, from Italian *modello*, from an alteration of Latin *modulus* (see **modulus** ).



from: New Oxford American Dictionary

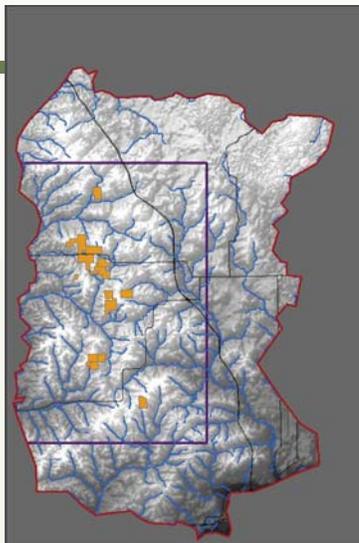
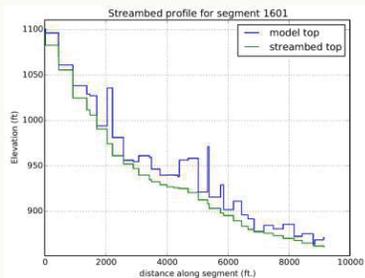
### Building a MODFLOW Model: Basics

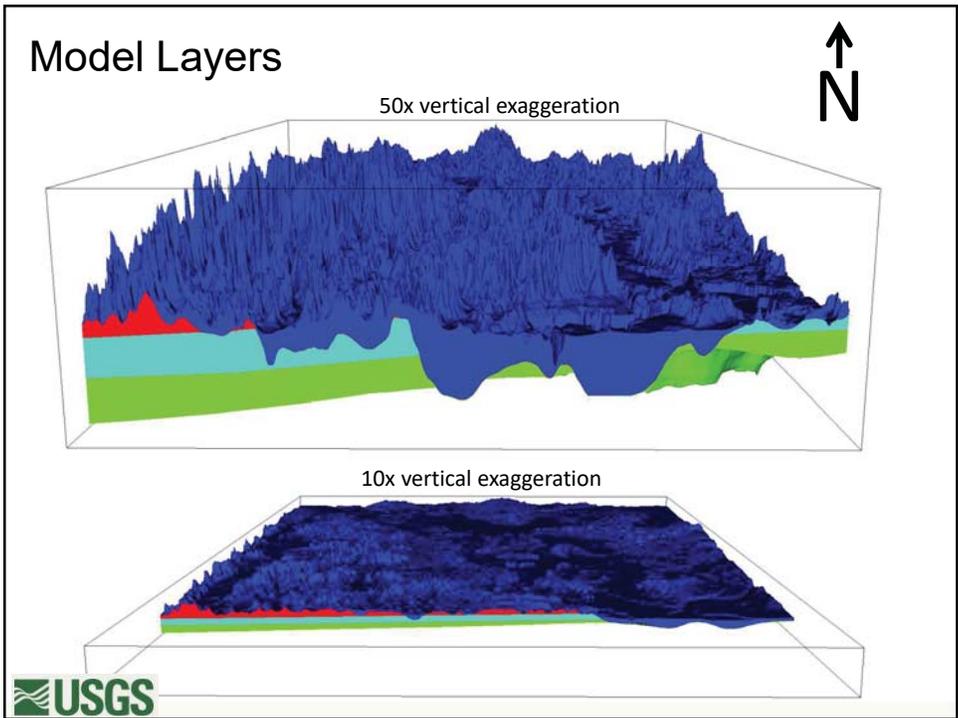
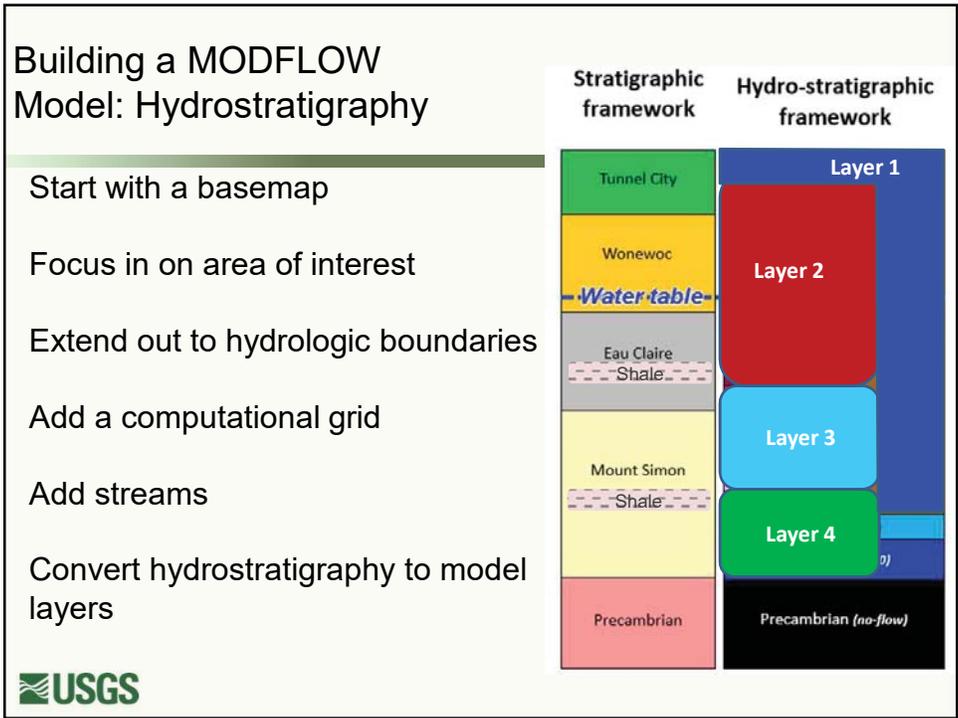
- Start with a basemap
- Focus in on area of interest
- Extend out to hydrologic boundaries
- Add a computational grid



### Building a MODFLOW Model: Streams and Elevation

- Focus in on the stream network
- Assign streams to model cells
- Routing water downstream/downhill



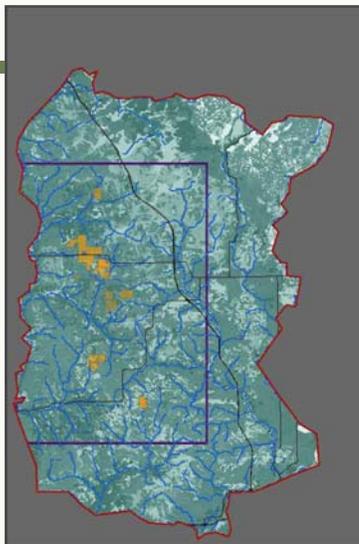


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### Building a MODFLOW Model: Recharge

Add groundwater recharge from the Soil-Water-Balance model

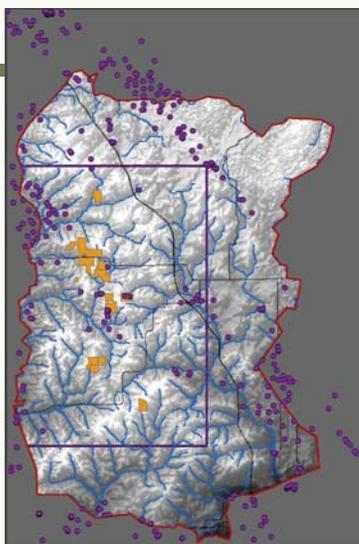
Darker colors = higher recharge



### Building a MODFLOW Model: Water Use

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

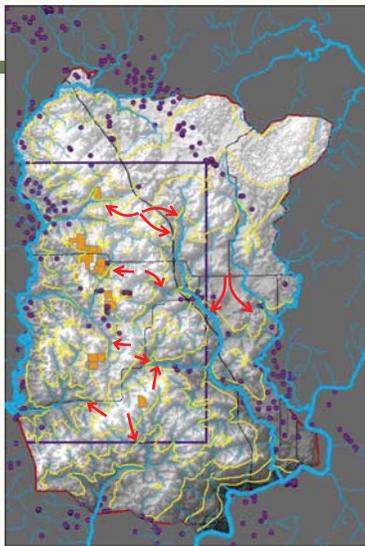
2013 high-capacity well provided by the WI DNR; Locations refined by WGNHS



### Building a MODFLOW Model: Initial Simulation

- Use estimated property values
- permeability
  - recharge

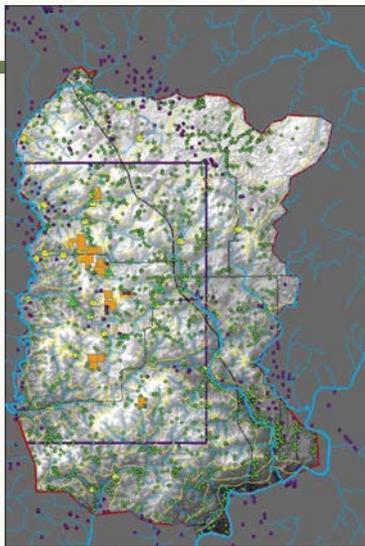
Simulate water levels... and baseflows

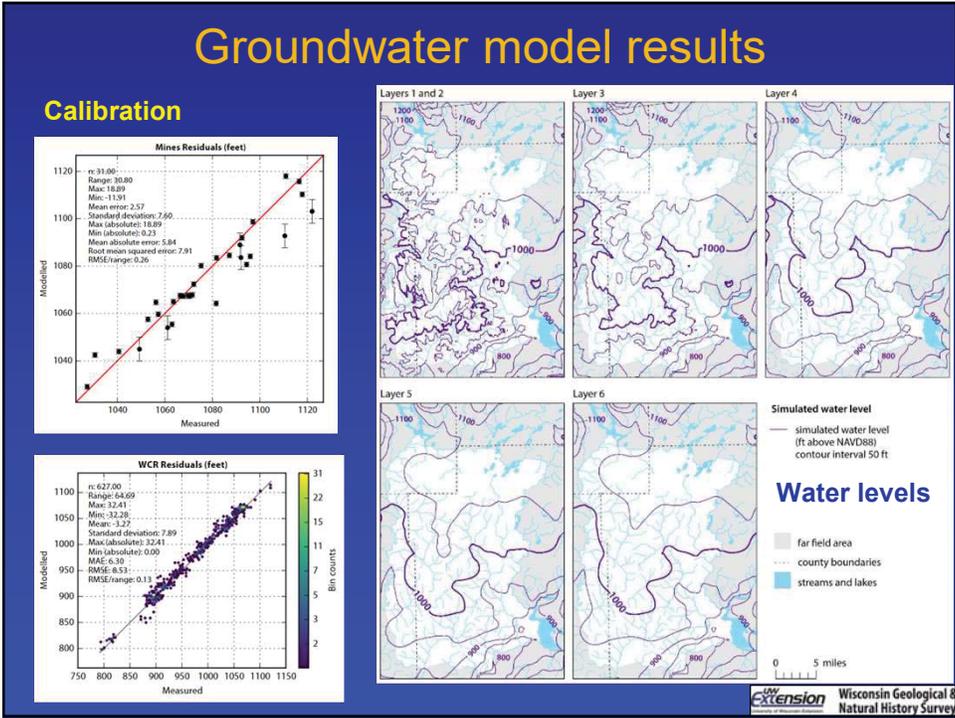


### Building a MODFLOW Model: Calibration

- Add stream baseflow targets
- ▲ Gaging stations
  - ◆ Synoptic measurements

Add water level targets ◆

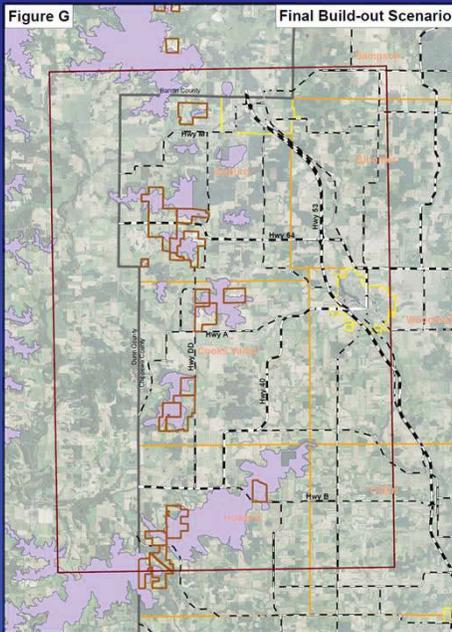




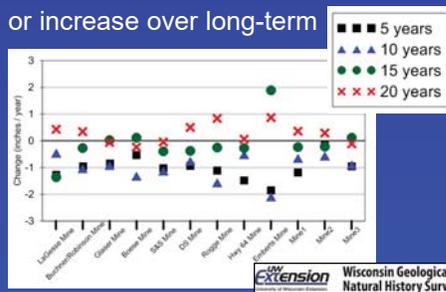
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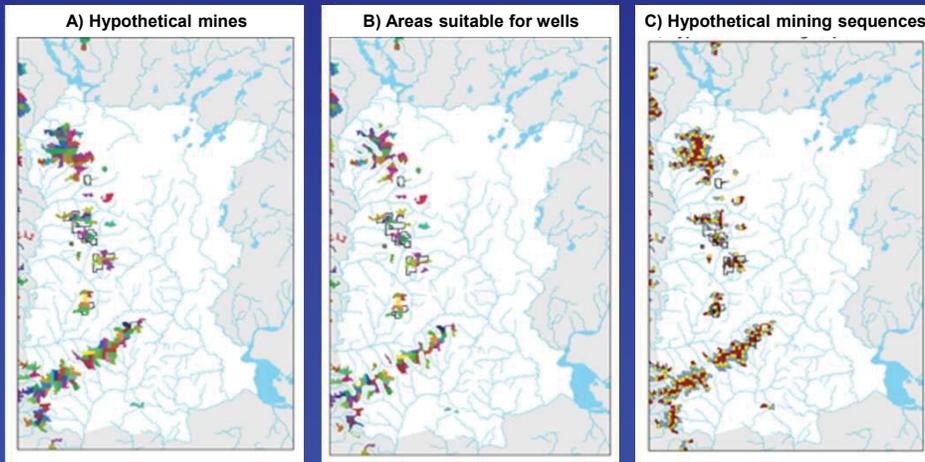
## Scenario testing – Mine build-out



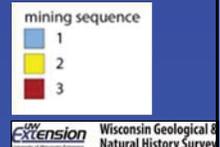
- For modeling scenarios,
- Mine footprints will expand within mineable Wonewoc (shaded purple)
  - Recharge will be modified according to soil-water-balance results
  - Recharge is expected to decrease over short-term
  - Recharge is expected to rebound or increase over long-term



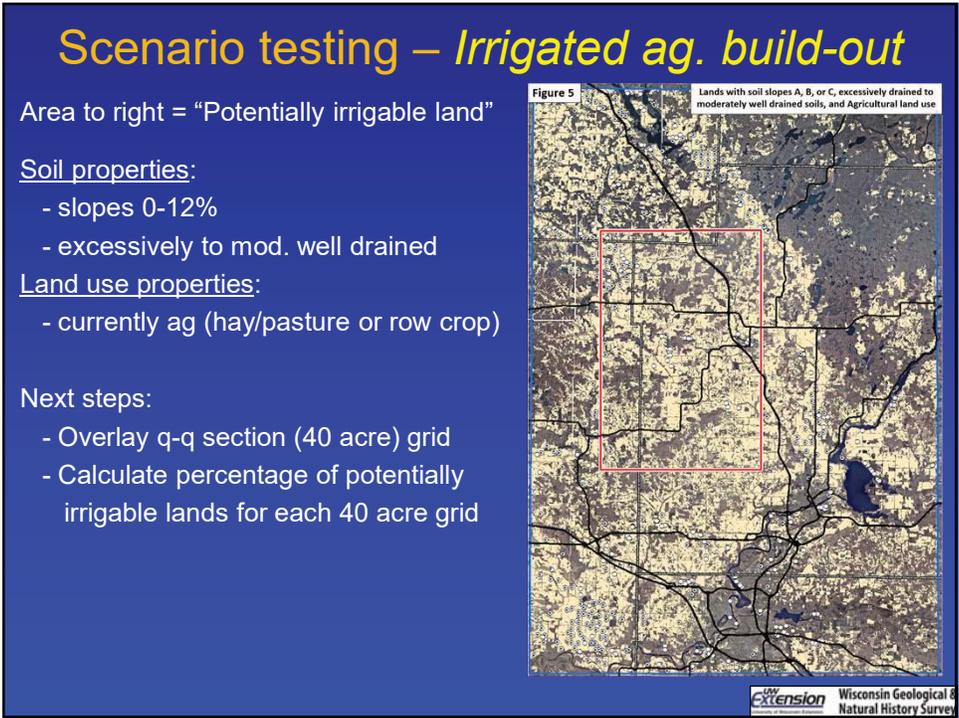
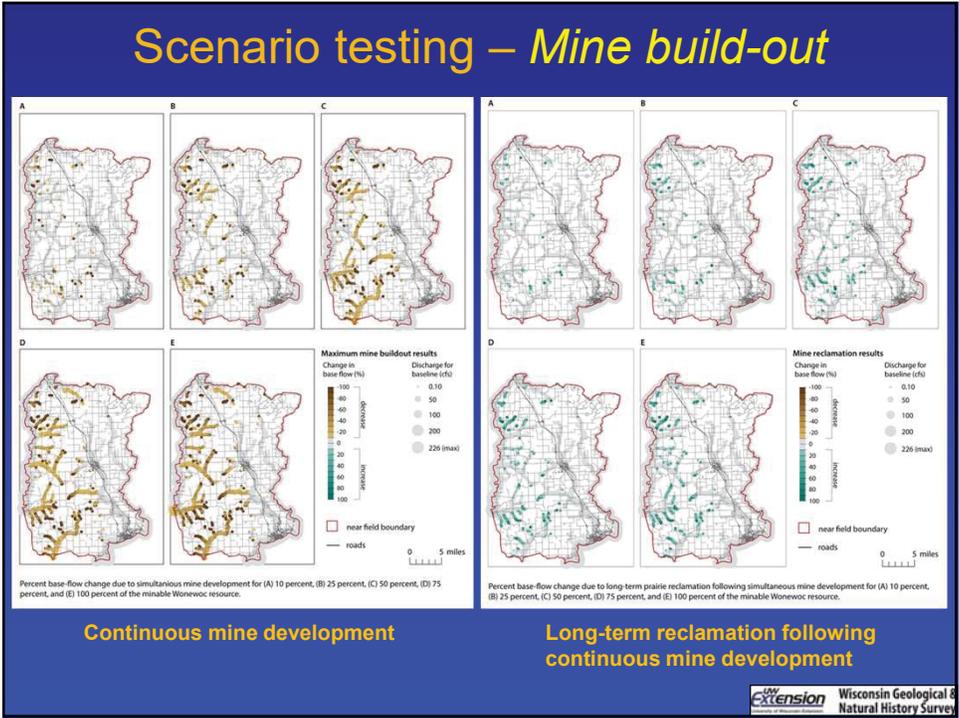
## Hypothetical mining sequence



Mine build-out development maps showing (A) mineable sandstone resource (Wonewoc) segmented into 155 hypothetical mines (approx. 150 acres each), (B) areas suitable for wells at each mine site (more than 1,200 ft from a stream), and (C) hypothetical 3-step development sequence for each mine.

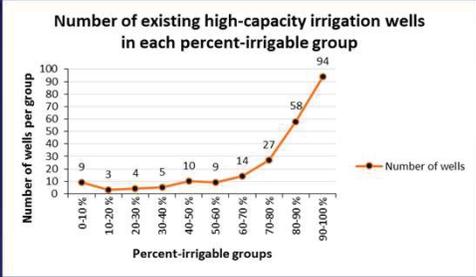
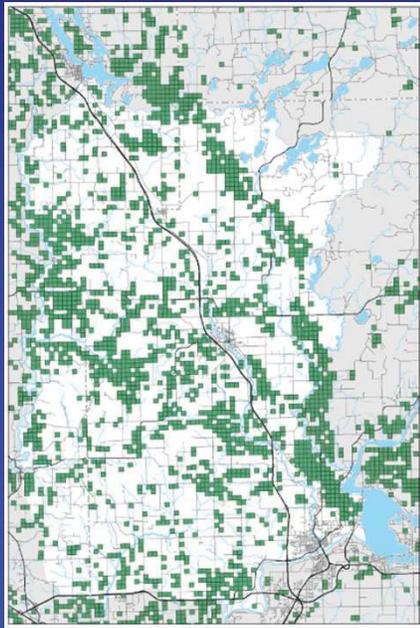


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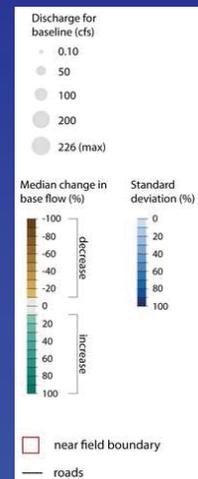
### Baseflow change using Null-Space Monte Carlo



Median change in baseflow



Standard deviation

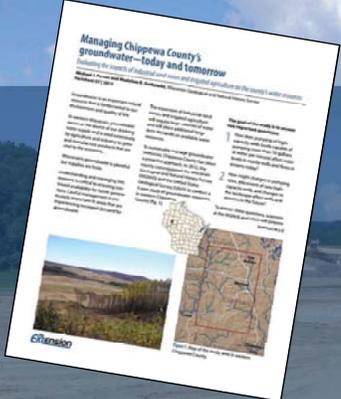


# Chippewa County Groundwater Study

## Thank you! Questions?

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[www.wisconsingeologicalsurvey.org](http://www.wisconsingeologicalsurvey.org)

Or,  
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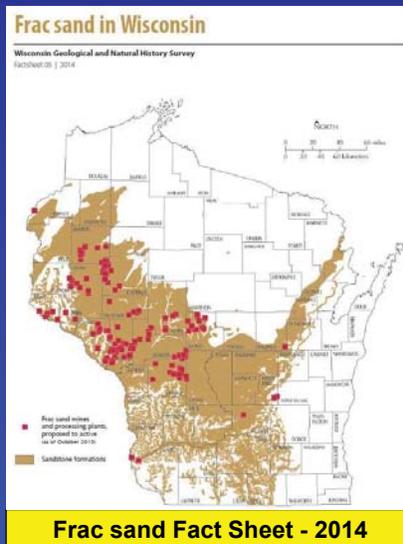






## WGNHS: Publications & resources

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- General interest maps
- Fact sheets

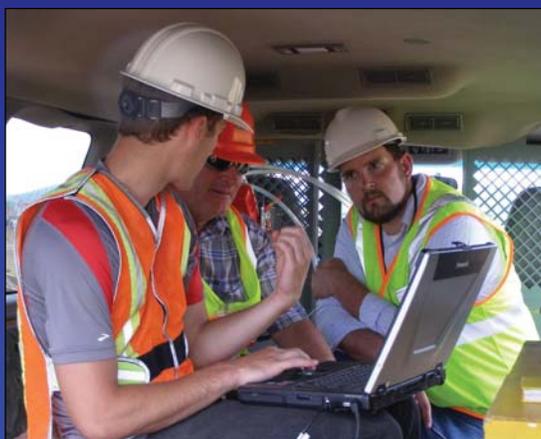


Frac sand Fact Sheet - 2014

UNW Extension Wisconsin Geological & Natural History Survey

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- Outreach activities
- Direct engagement with counties and other stakeholders

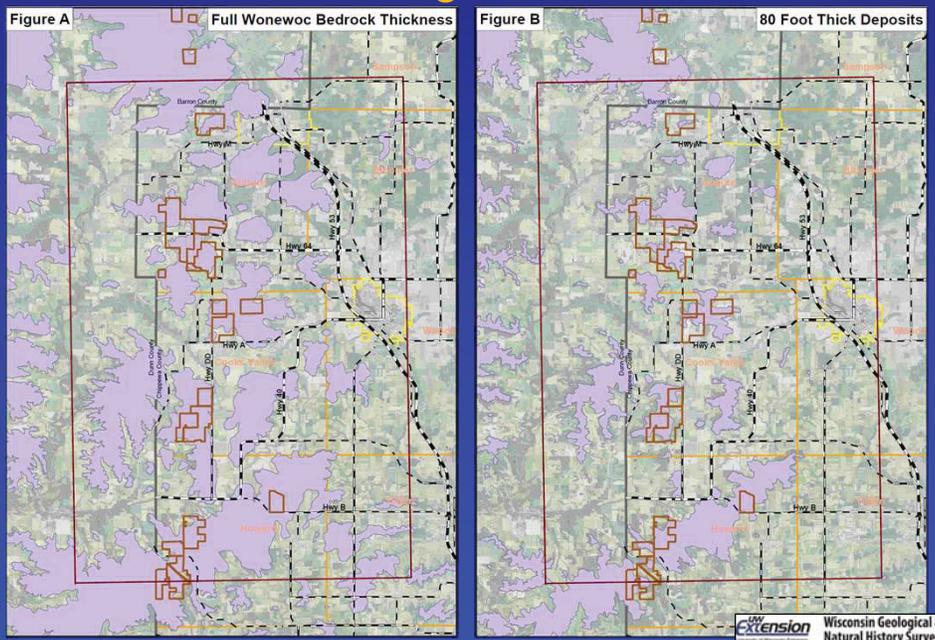


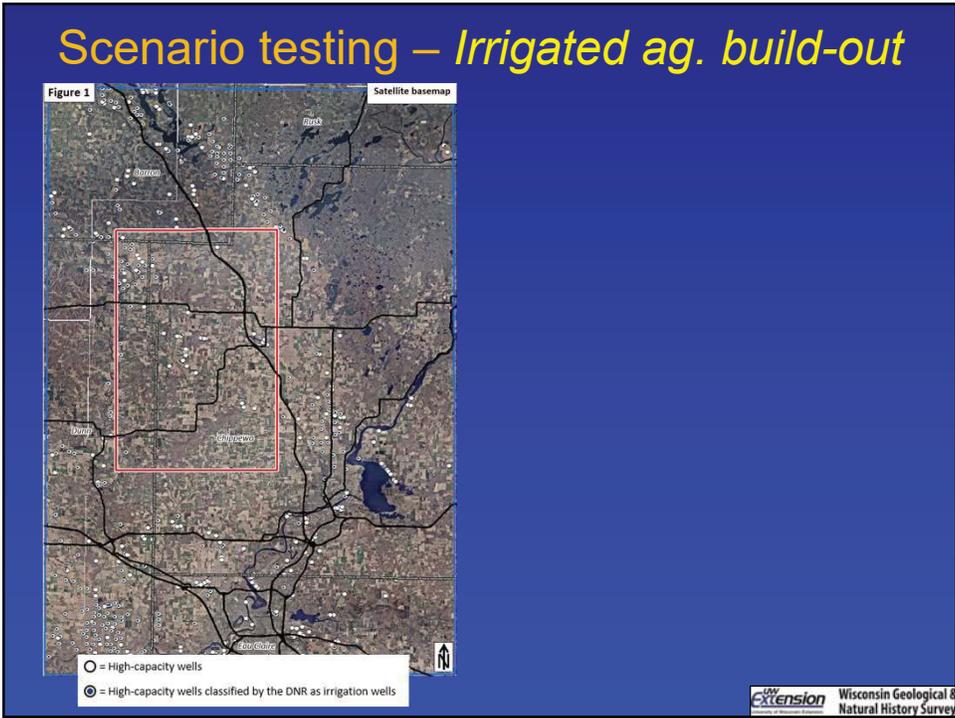
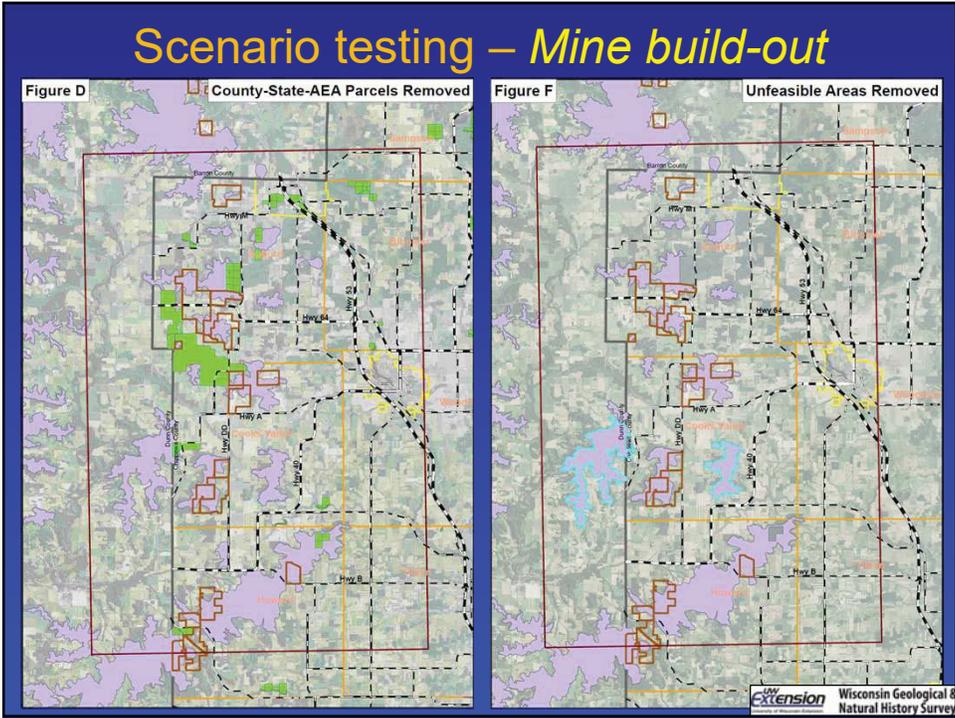
UNW Extension Wisconsin Geological & Natural History Survey

## Today's outline

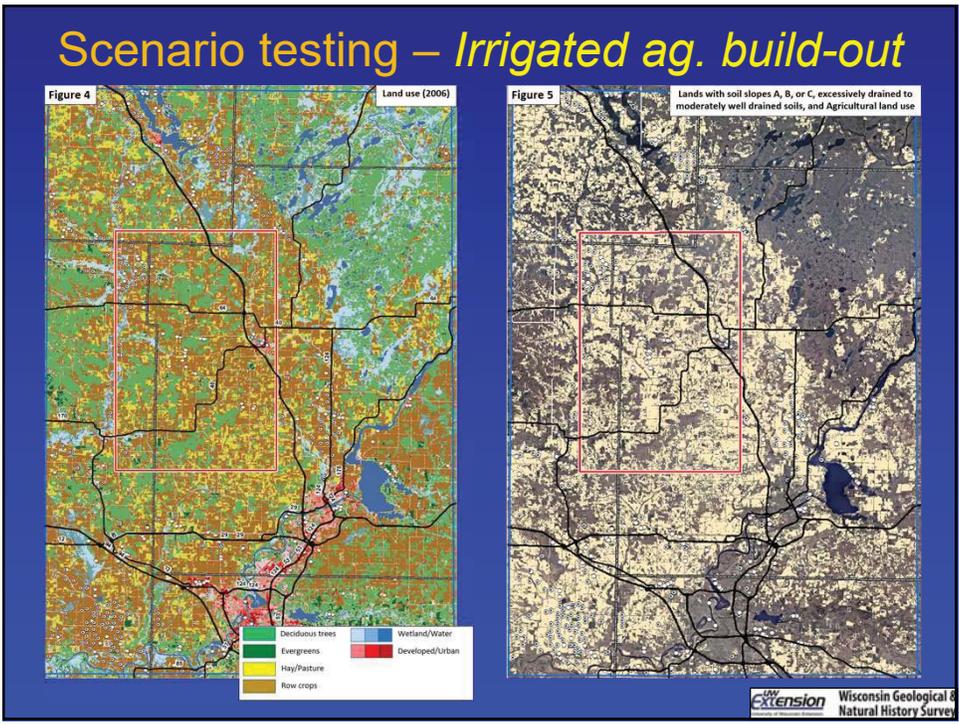
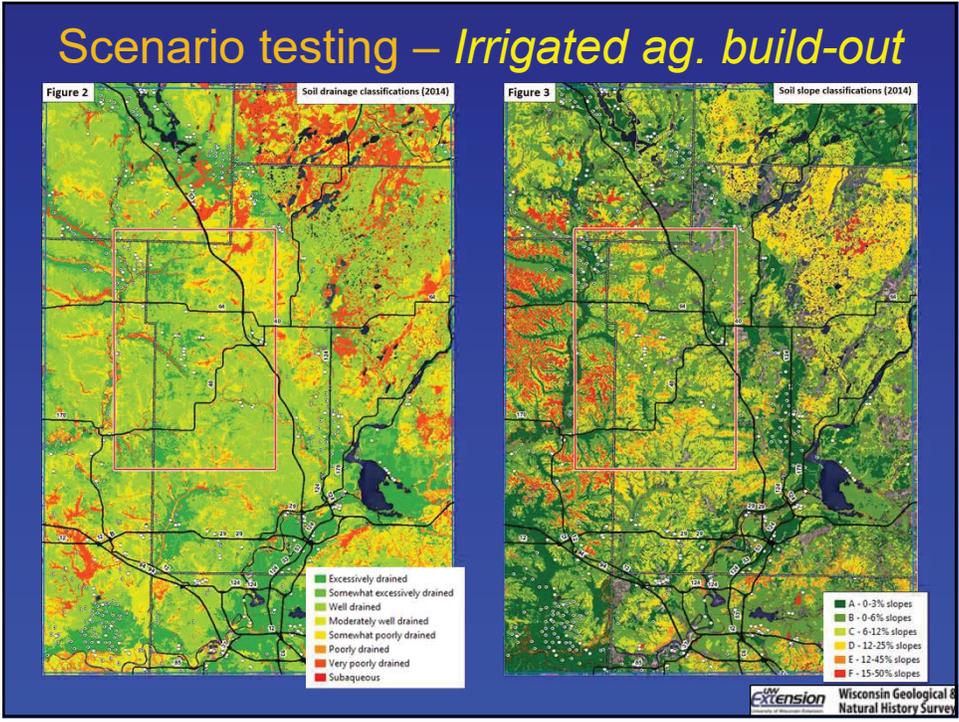
- Brief overview of the groundwater study
- Subsurface data collection and hydrostratigraphy
- **Water-use data and trends**
- Estimating groundwater recharge
- Groundwater model development
- Future scenario testing
- Questions?

## Scenario testing – Mine build-out

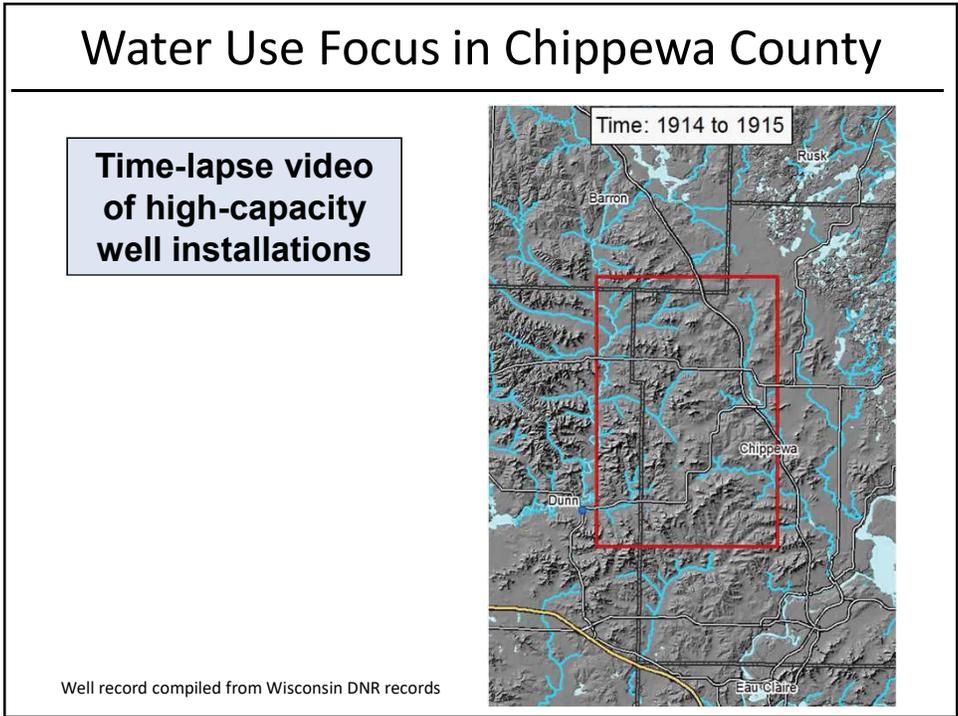
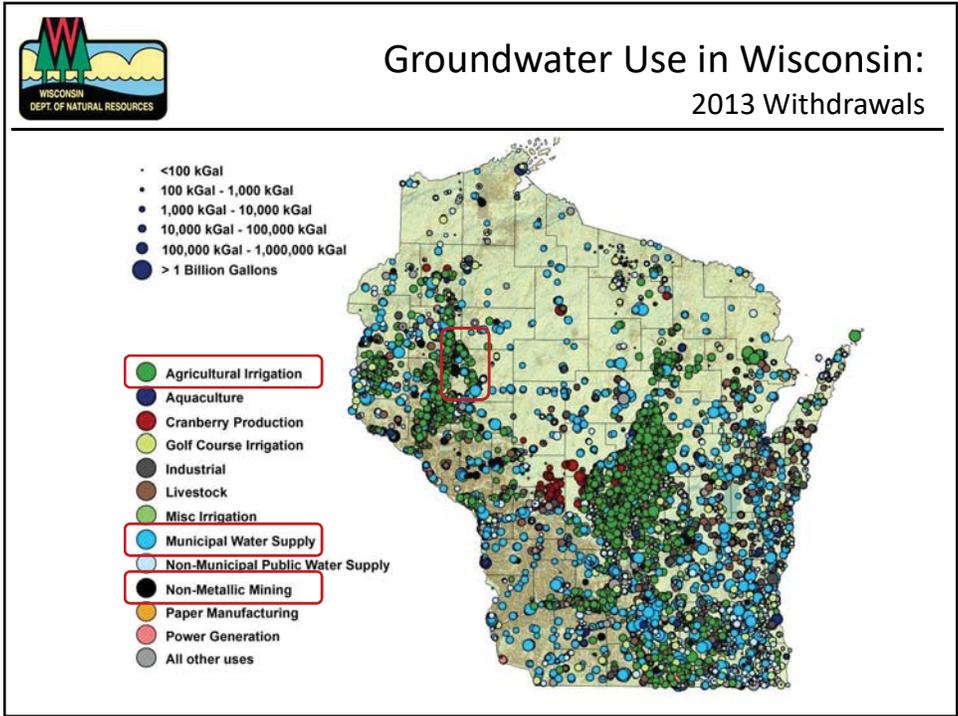




Attachment: Groundwater Presentation Report for CB 05-14-19 (5003 : WGNHS Groundwater Study)



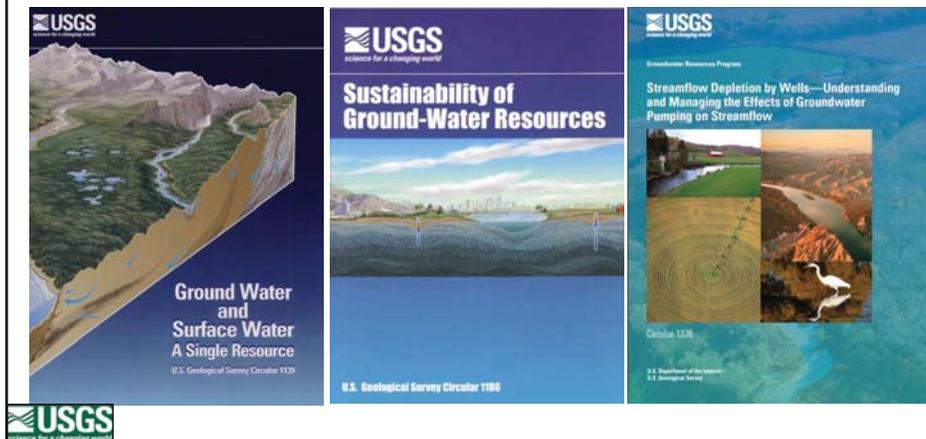
Attachment: Groundwater Presentation Report for CB 05-14-19 (5003 : WGNHS Groundwater Study)



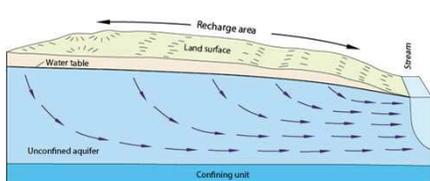
Attachment: Groundwater Presentation Report for CB 05-14-19 (5003 : WGNHS Groundwater Study)

# Why Does Water Use Matter?

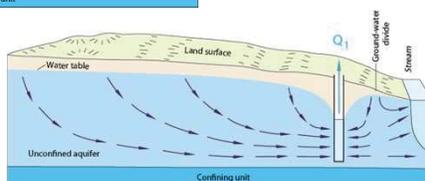
- Groundwater and surface water are connected



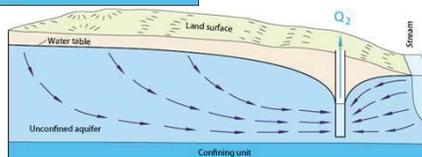
# Water Use & 'Capture'



- 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

### Water-use practices

	Well Depth	Pump rate	# Wells	Season
<b>Industrial sand mining</b> 	250 - 400'	20 - 95 million gal. per year, per well	5	10 months ~ Feb - Nov
<b>Municipal supply</b> 	150 - 300'	80 - 90 million gal. per year, per well	6	Year round
<b>Irrigated agriculture</b> 	100 - 300'	<10 - 30 million gal. per year, per well	31	5 months ~ May - Sept

Well information provided by WDNR

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