Chippewa County Groundwater Study

1st Stakeholders Group Meeting

Stakeholders Group Meeting
Chippewa Falls, WI
10/10/2012

USGS science for a changing world

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

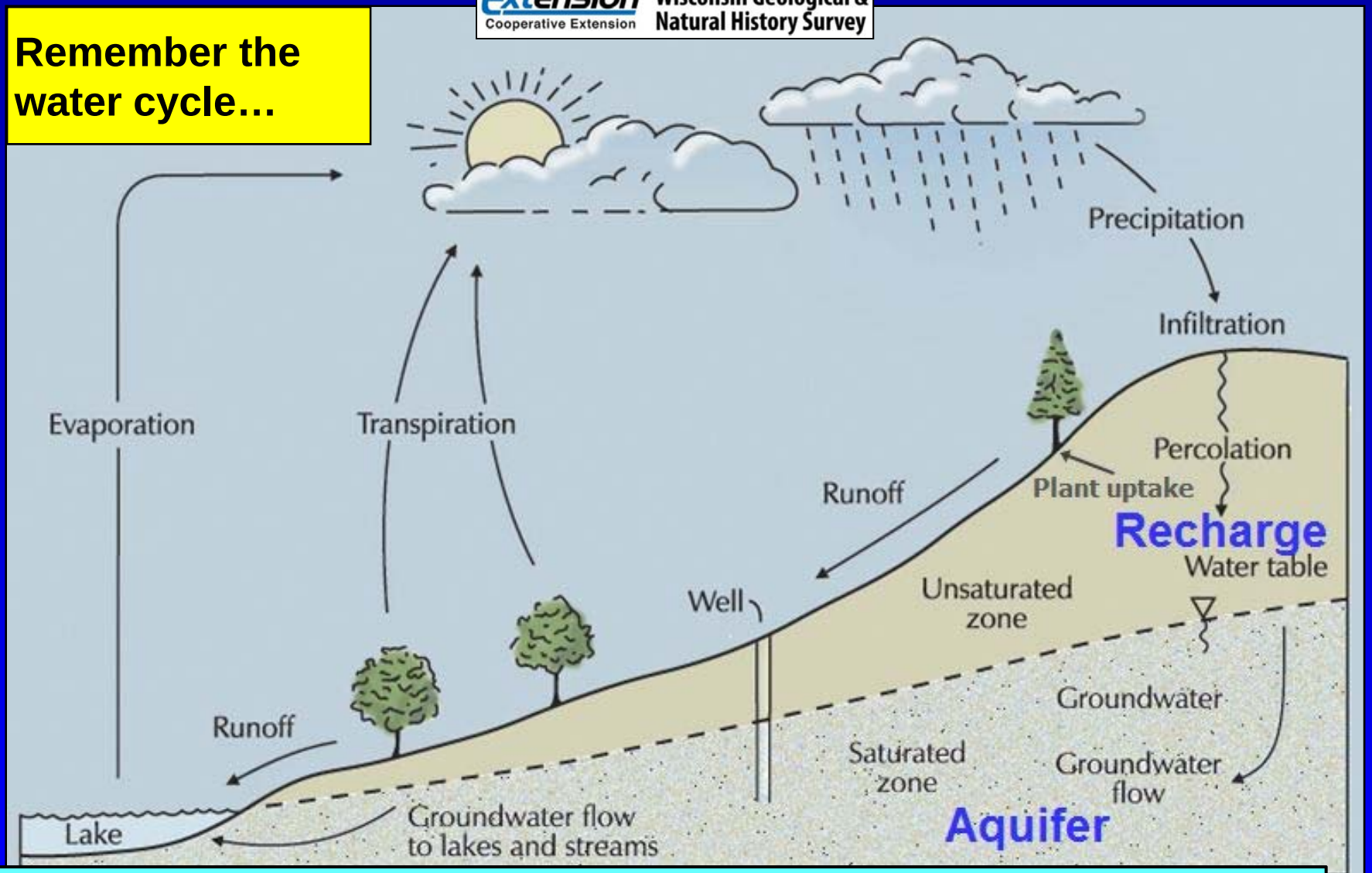
UW Extension Cooperative Extension

Wisconsin Geological & Natural History Survey

Today's outline

- Review of hydrogeology *(WGNHS)*
- Overview of project proposal *(WGNHS)*
- The value of a groundwater flow model *(USGS)*
- Review of data needs *(WGNHS / USGS)*
- Future scenarios discussion *(WGNHS / USGS)*

Hydrogeology – the hydrologic cycle

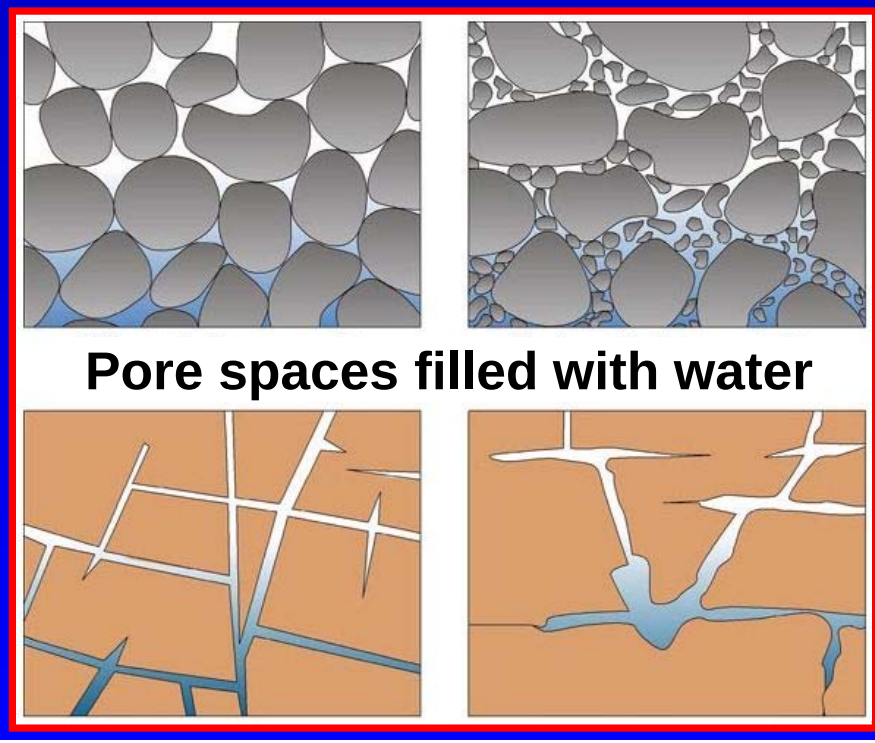


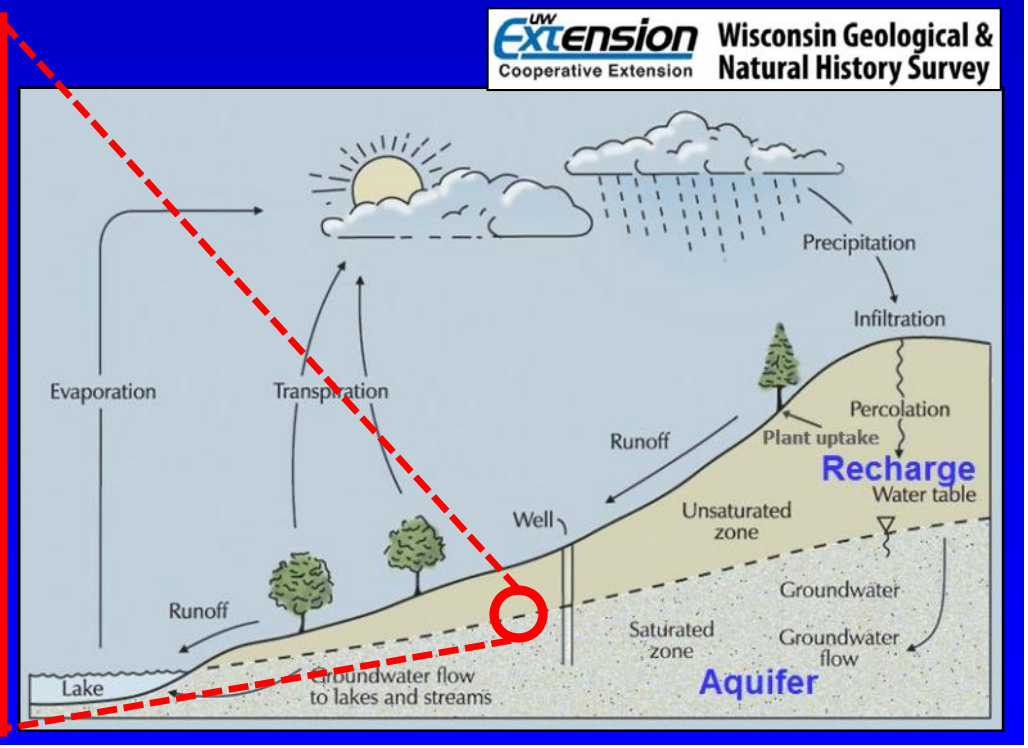
Recharge occurs everywhere on the landscape, not just the uplands…

Hydrogeology – the hydrologic cycle

What is groundwater?

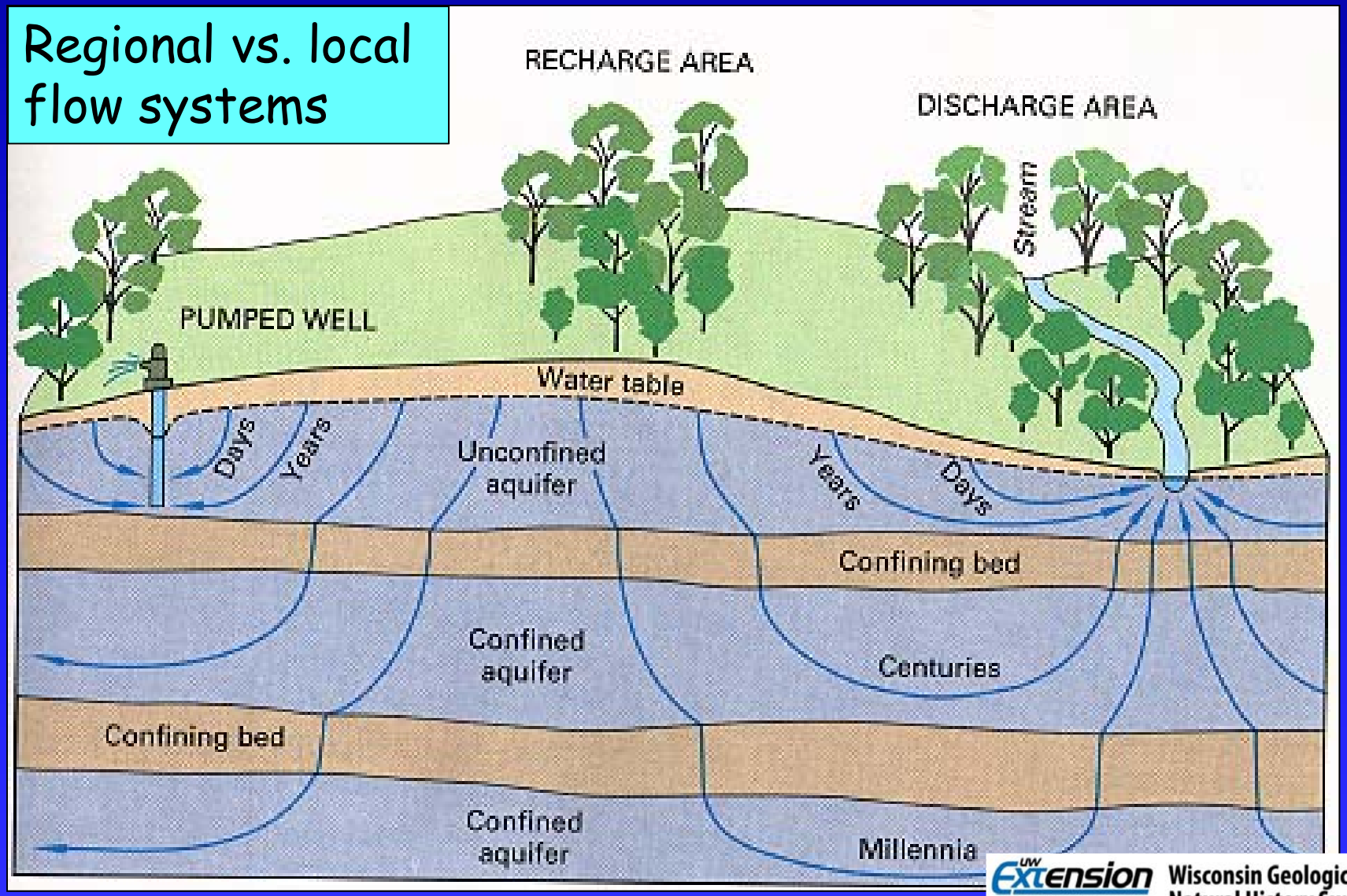
- Groundwater is water filling pores, cracks, fractures, and other voids in geologic materials beneath the earth's surface.
- It's not an underground lake or river system!





Hydrogeology – the hydrologic cycle

Regional vs. local flow systems



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Groundwater moves from recharge areas to discharge areas

Aquifers are geologic materials that are very permeable

Aquitards retard or restrict the flow of groundwater

Core of the Wonewoc sandstone

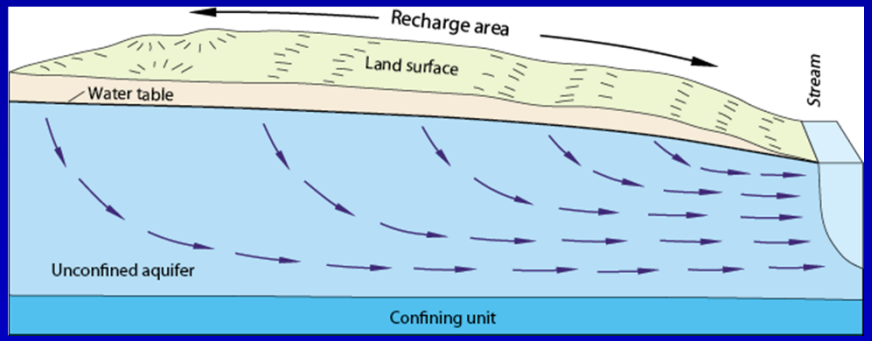
Aquifers composed of sand, gravel and sandstone convey lots of water to wells.

Aquitards are composed of clay and shale.

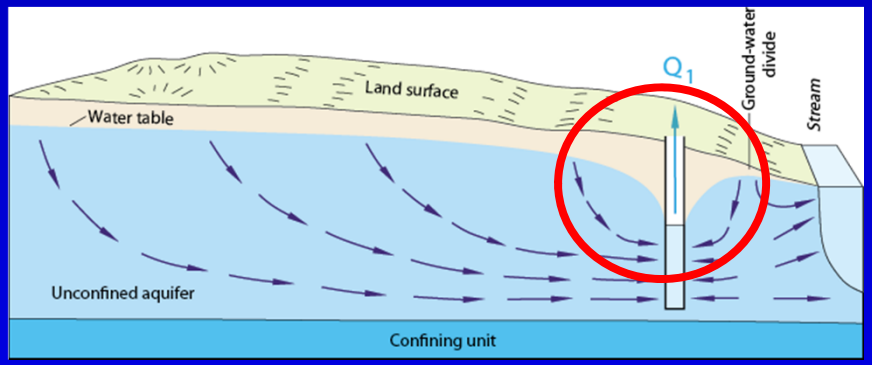
Core of the Eau Claire shale

Hydrogeology – high capacity well impacts

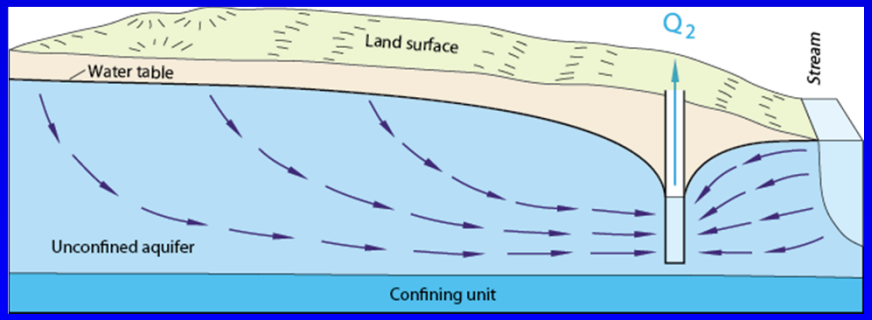
Pumping wells affect groundwater movement



The well causes a cone of depression



Well pumping can reduce flow to surface water



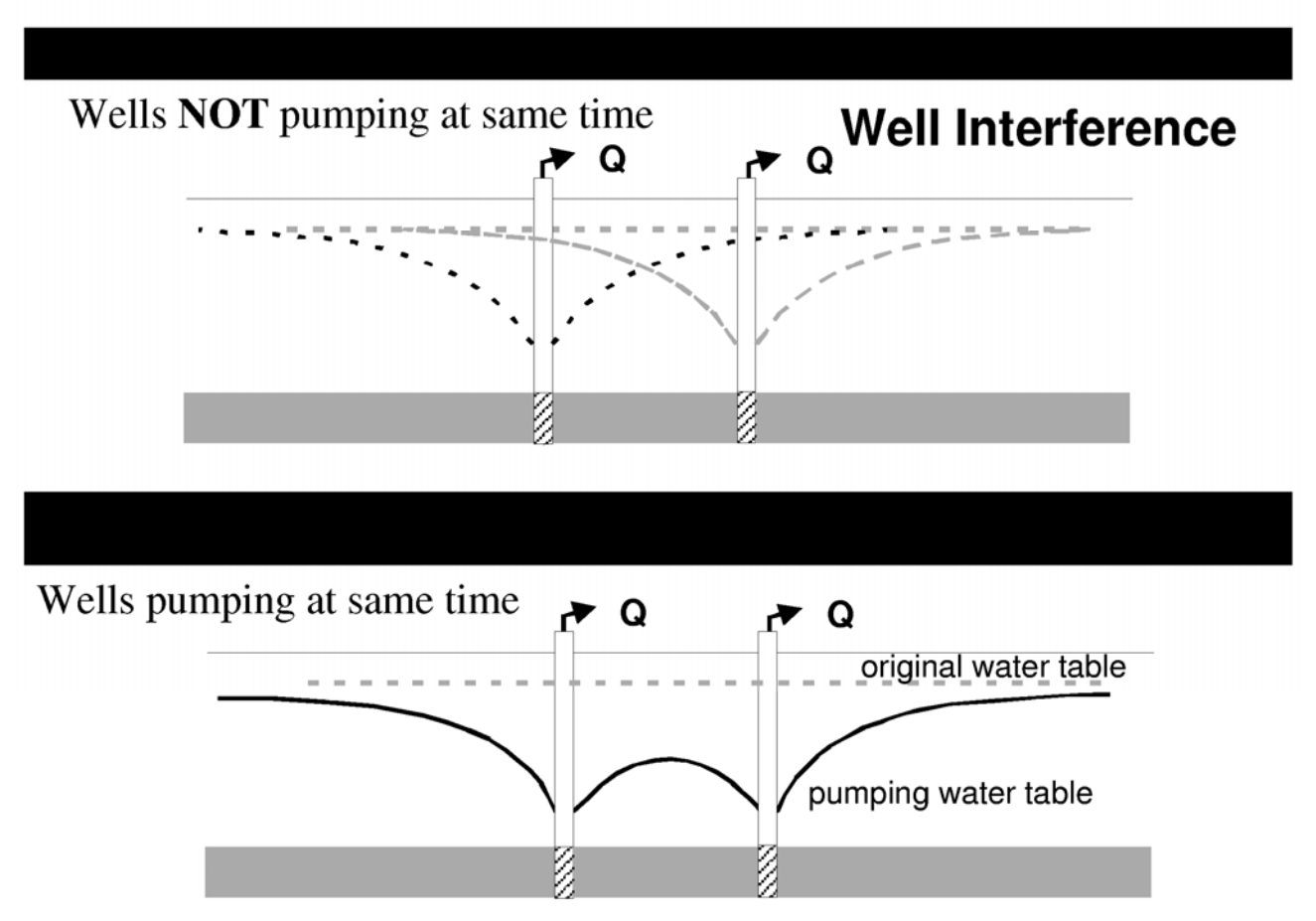
Source: Alley, Reilly, and Franke, USGS Circular 1186 (1999)

Hydrogeology – high capacity well impacts

When wells are close to each other, their cones of depression can overlap, and the wells hydraulically interfere with each other.

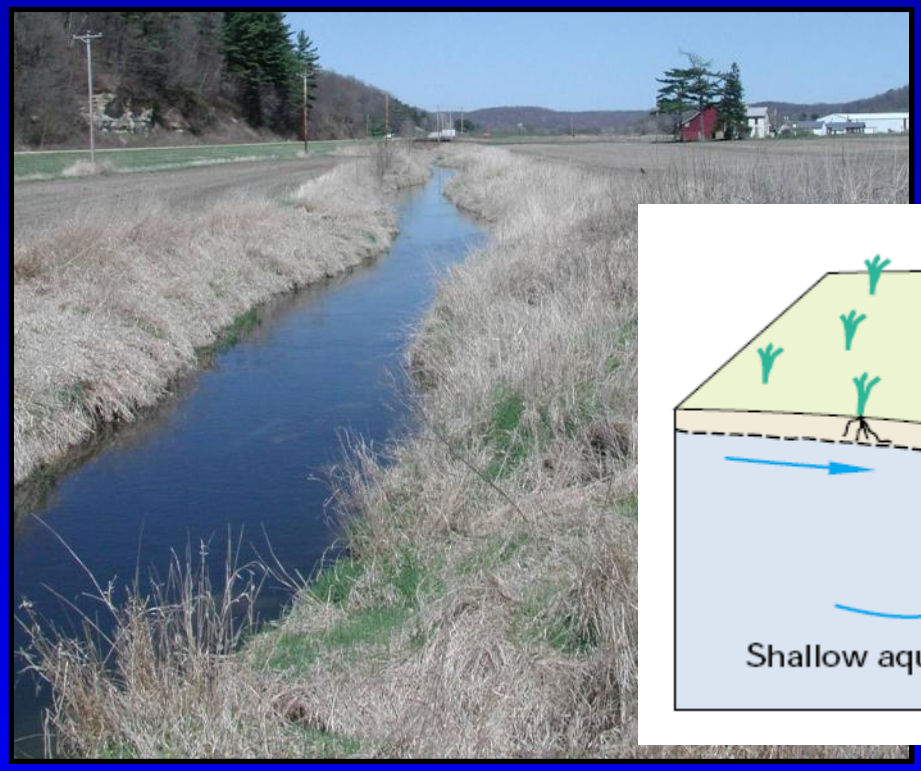
Drawdown reduces well yield

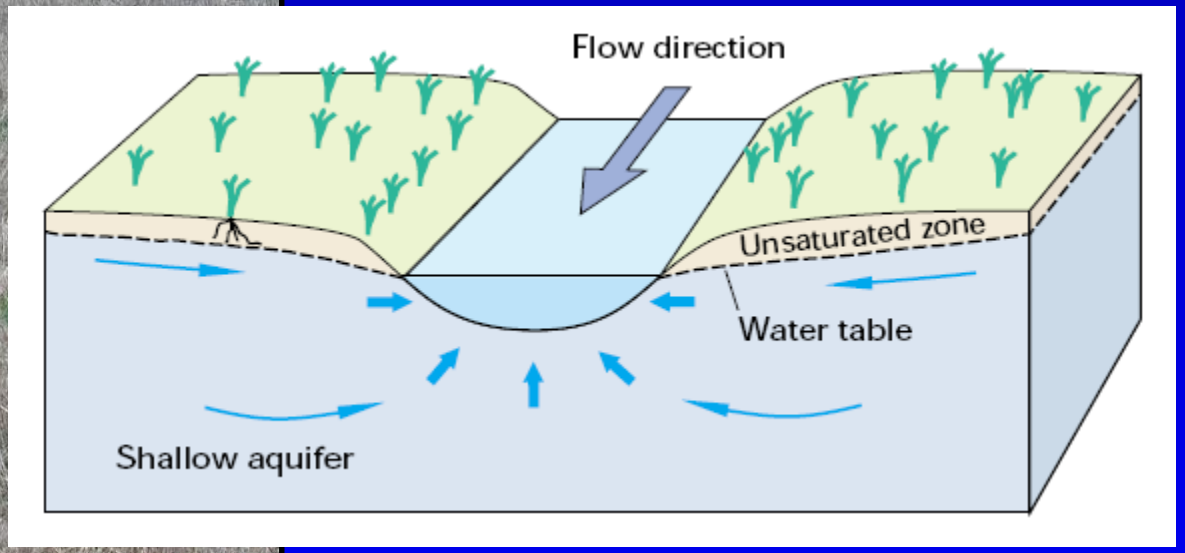
Drawdown may impact neighboring wells or surface water features



Hydrogeology – our water supply in WI

Groundwater provides cold, clear water to streams, rivers and lakes.





USGS Circular 1139 (1998)

Baseflow is usually of excellent quality compared to runoff to streams, which contains sediment and nutrients.

Hydrogeology – our water supply in WI

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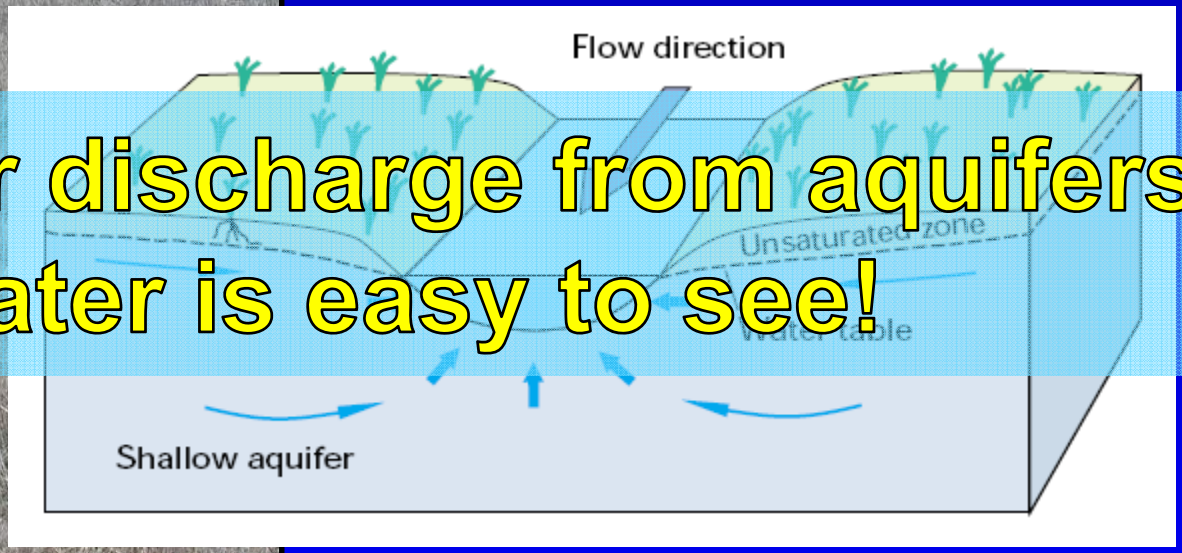

Groundwater discharge from aquifers to surface water is easy to see!

USGS Circular 1139 (1998)

Baseflow is usually of excellent quality compared to runoff to streams, which contains sediment and nutrients.

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Overview of project proposal

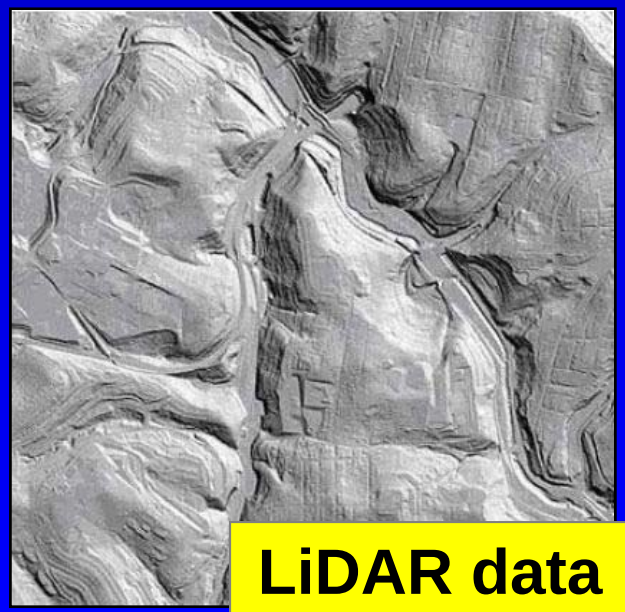
- Objectives
  - Develop soil water balance (recharge) and groundwater flow models to evaluate current and future water use and landscapes on the hydrologic system
  - Disseminate the study results to stakeholders and the general public
  - Transfer the study results to similar geologic/hydrologic settings as appropriate
- Limitations
  - Model solution is valid only within the Area of focus
  - Steady state model (not transient)

Overview of project proposal

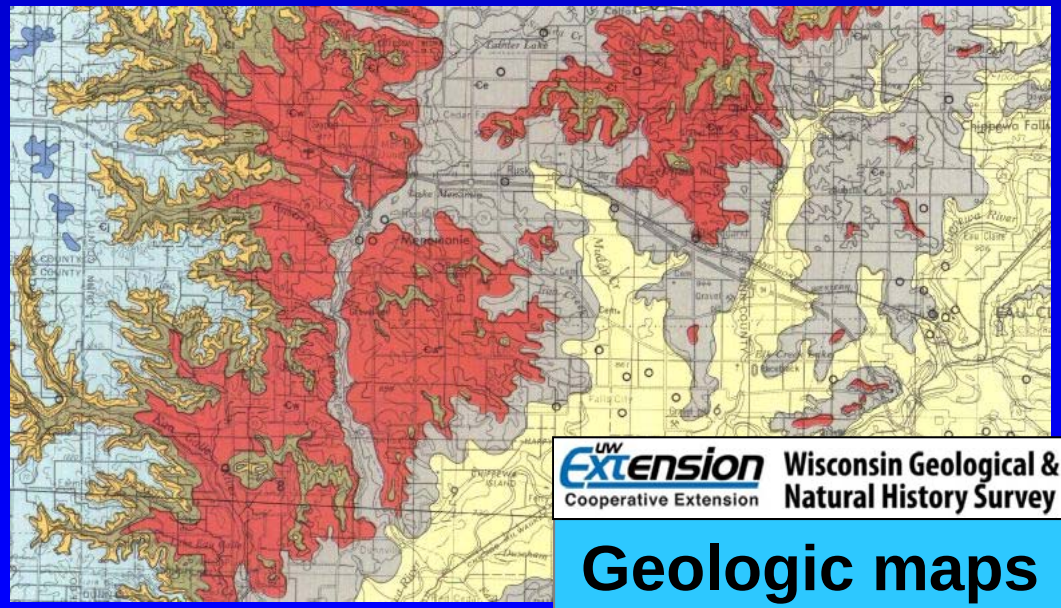
- Technical investigation and modeling *(5 Tasks)*
  - Data collection
  - Recharge modeling (SWB model)
  - Groundwater modeling
  - Scenario testing
  - Transferability

Technical Investigation – *data collection*

- Bedrock Geology of Chippewa County – *WGNHS (1987-88)*
- Pleistocene Geology of Chippewa County – *WGNHS (2007)*
- LiDAR data – *Chippewa County Land Information Office (2011)*
- DEM surface maps – *USGS (2003)*
- Hydric soils – *US Department of Agriculture (2011)*
- Well and borehole data – *WDNR, WGNHS, and Consultants*
- Streamflow measurements – *USGS, WDNR, and others*



LiDAR data



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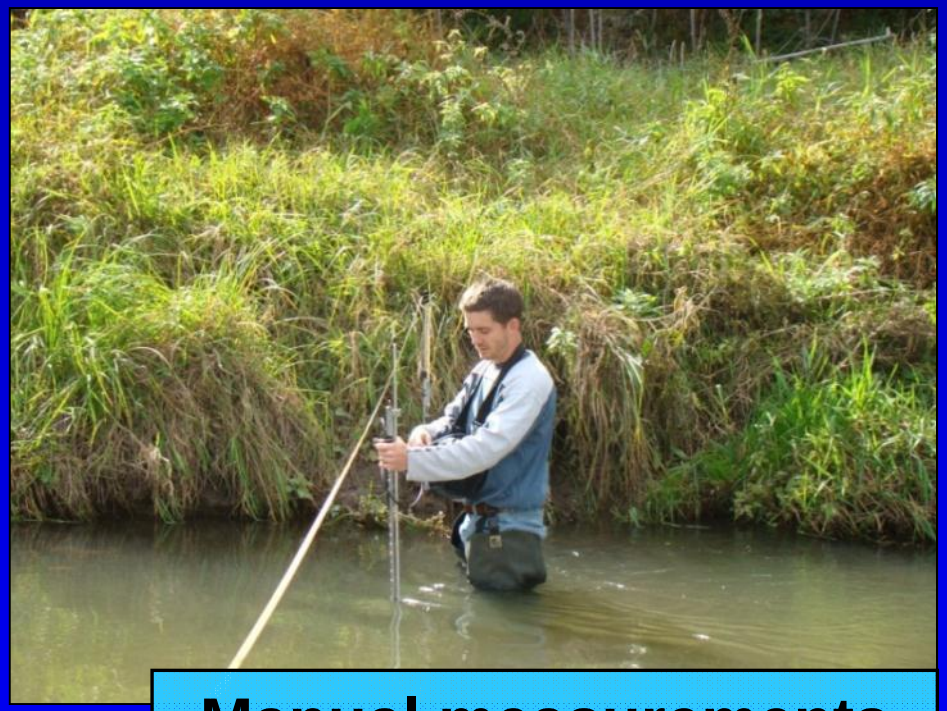
Geologic maps

Technical Investigation – *data collection*

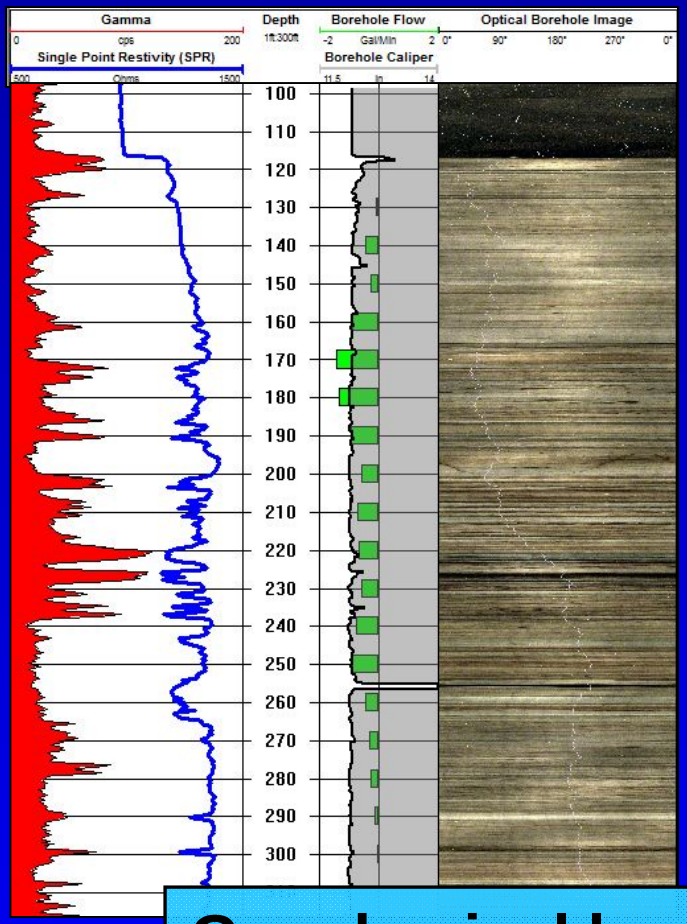
USGS gaging stations



Manual measurements

Technical Investigation – *data collection*

Geophysical logging



Geophysical log

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Geophysical logs are high quality subsurface data which aid in correlating and delineating regional (hydro)geologic features

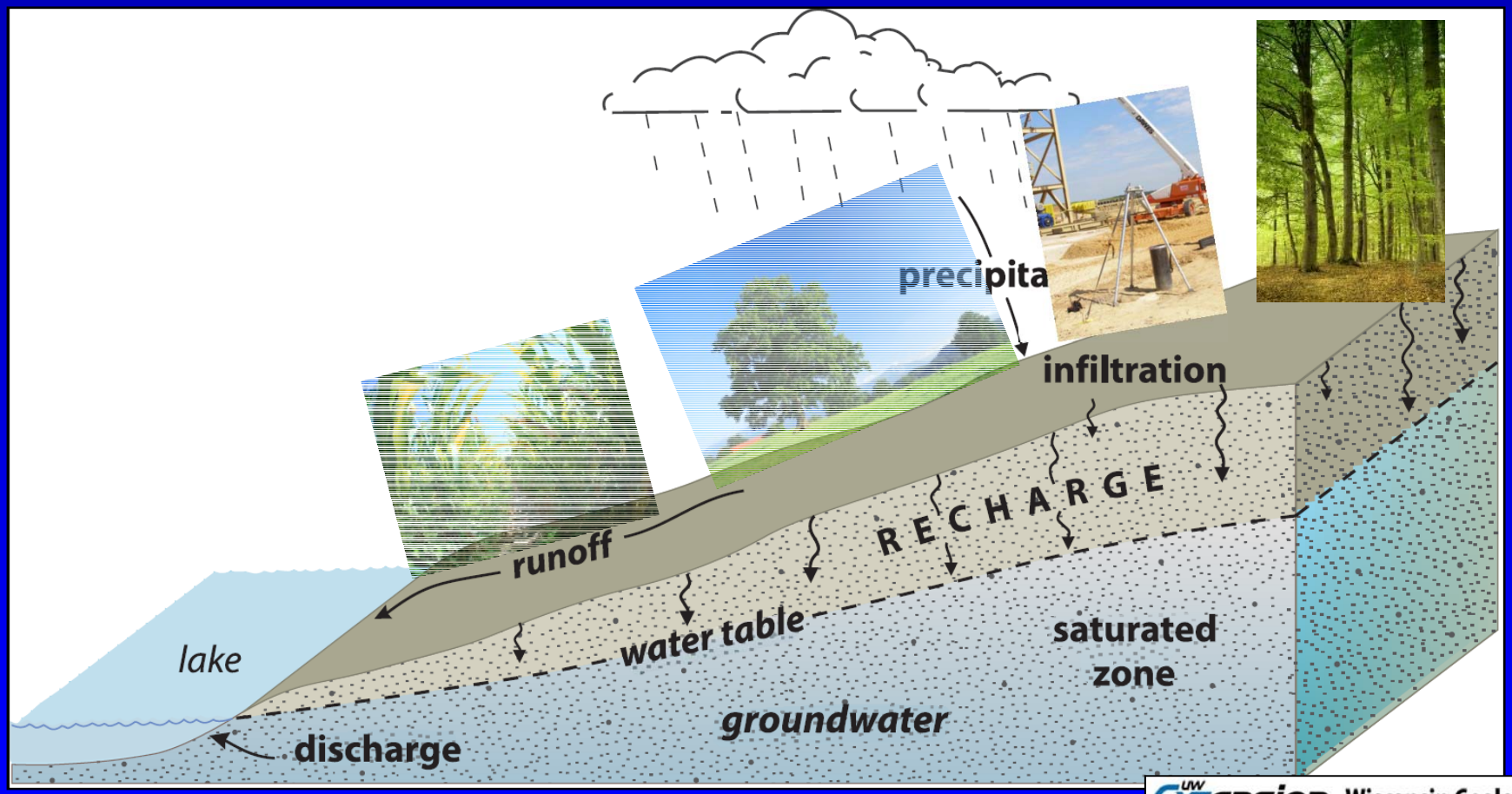
Overview of project proposal

- Technical investigation and modeling *(5 Tasks)*
  - Data collection
  - Recharge modeling (SWB model)
  - Groundwater modeling
  - Scenario testing
  - Transferability

Recharge

- Recharge (R) is water that enters the groundwater system

R = Precipitation – Runoff – Interception – Evapotranspiration



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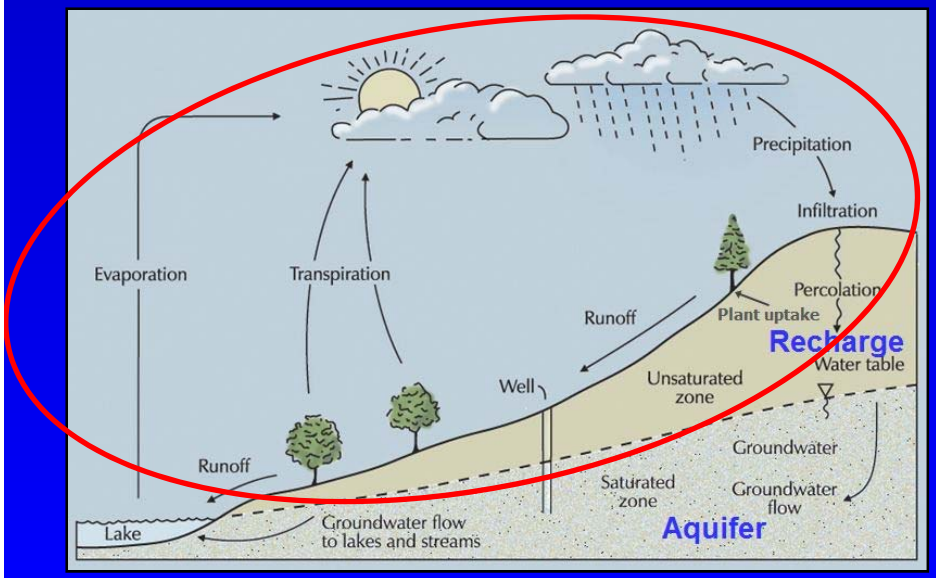
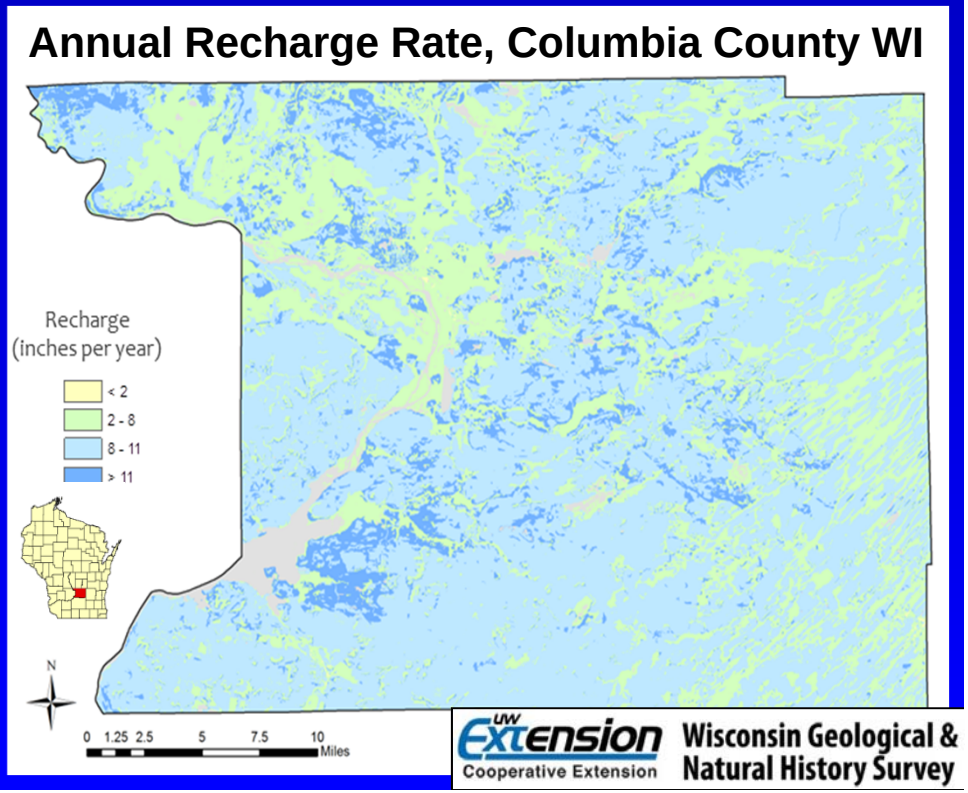
Estimating Recharge

- The soil-water-balance (SWB) model calculates recharge based on:
  - Land Cover: forest, pasture, row crop, pavement (affects ET)
  - Soil type: water-holding capacity (affects ET)
  - Daily precipitation, temperature (frozen ground, saturation)
  - Land surface slope (runoff)





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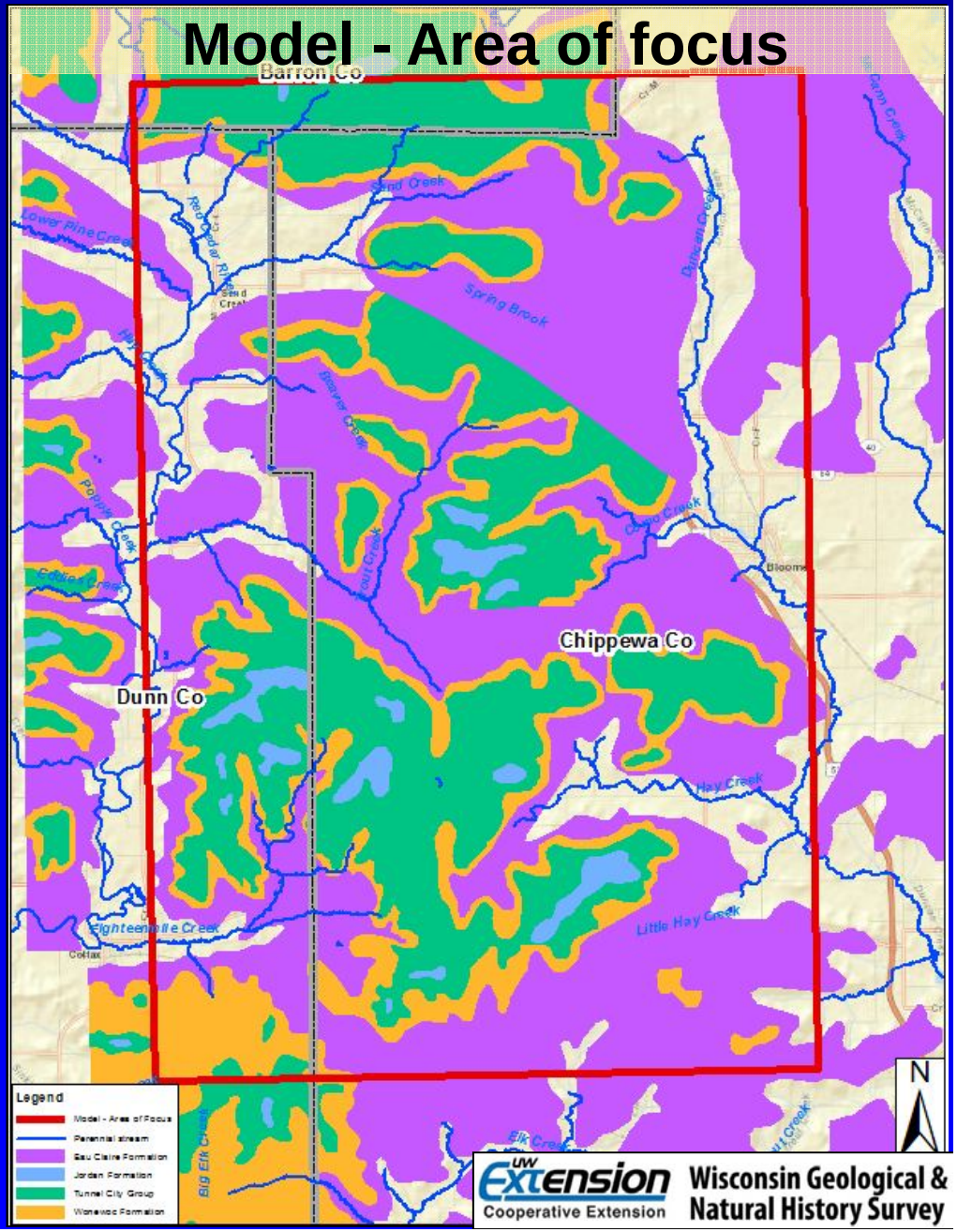
Overview of project proposal

- Technical investigation and modeling *(5 Tasks)*
  - Data collection
  - Recharge modeling (SWB model)
  - Groundwater modeling
    - MODFLOW model
    - Incorporate significant features of hydrologic cycle
    - Calibrate to steady state conditions
    - Represent water use and landscape conditions prior to frac sand mining
  - Scenario testing
  - Transferability

Technical Investigation – *Groundwater modeling*

- Area of focus
- Perennial streams
- Geology



Overview of project proposal

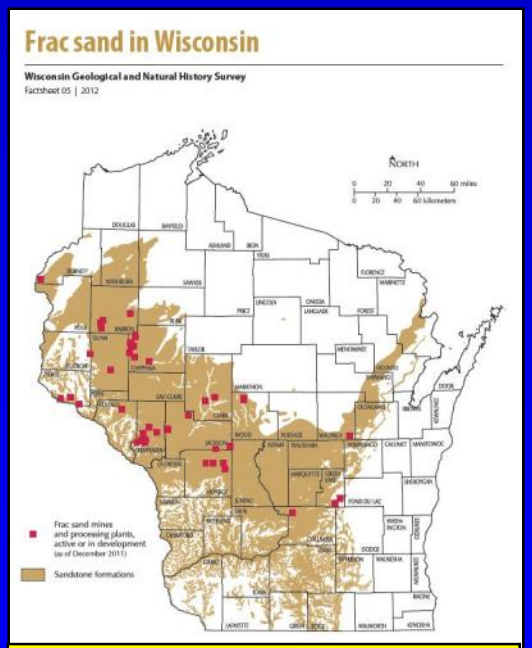
- Technical investigation and modeling *(5 Tasks)*
  - Data collection
  - Recharge modeling (SWB model)
  - Groundwater modeling
  - Scenario testing
    - Use calibrated model to evaluate impacts for two scenarios
    - Scenario 1 – peak sand mine operations (~ 2030)
    - Scenario 2 – post-mine reclamation (~ 2050)
    - **Scenarios are designed to be illustrative of impacts not predictive!**
  - Transferability

Overview of project proposal

- Technical investigation and modeling *(5 Tasks)*
  - Data collection
  - Recharge modeling (SWB)
  - Groundwater modeling
  - Scenario testing
  - Transferability
    - Apply models to evaluate general system responses to expected changes in groundwater pumping and recharge associated with frac sand mining and irrigation operations
    - These operations are common to west-central Wisconsin
    - These changes may become increasingly common within west-central Wisconsin

Overview of project proposal

- Public outreach and reporting *(3 Tasks)*
  - *Fact sheet – Released Q1 2013*
  - *Public outreach and stakeholders meetings – Annual update meetings*
  - *Interim and final reporting – 2014 and 2017 respectively*



Frac sand Fact Sheet

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Overview of project proposal

- Project budget
  - 5-year cooperative project between WGNHS and USGS
  - $433,223 total cost to Chippewa Count
  - WGNHS and USGS report directly to Chippewa County
- Workflow and activities schedule *(major milestones)*
  - Contract signed August 8, 2012
  - Fact sheet – Q1 2013 *(i.e., project objectives, overview)*
  - 1st public outreach meeting – Q1 2013 *(updated annually)*
  - Next stakeholders group meeting – Q1 2013 *(updated annually)*
  - Interim report – Q4 2014 *(data collection and SWB results)*
  - Final report – Q3 2017 *(final model, scenario and transferability results)*

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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

Models are ubiquitous

The value of models

conceptual model

A cohesive framework to consolidate and interpret data

computer simulation

A platform on which to test scenarios, evaluate responses, add margin of safety

decision making

A feedback mechanism to revise interpretation and guide future work

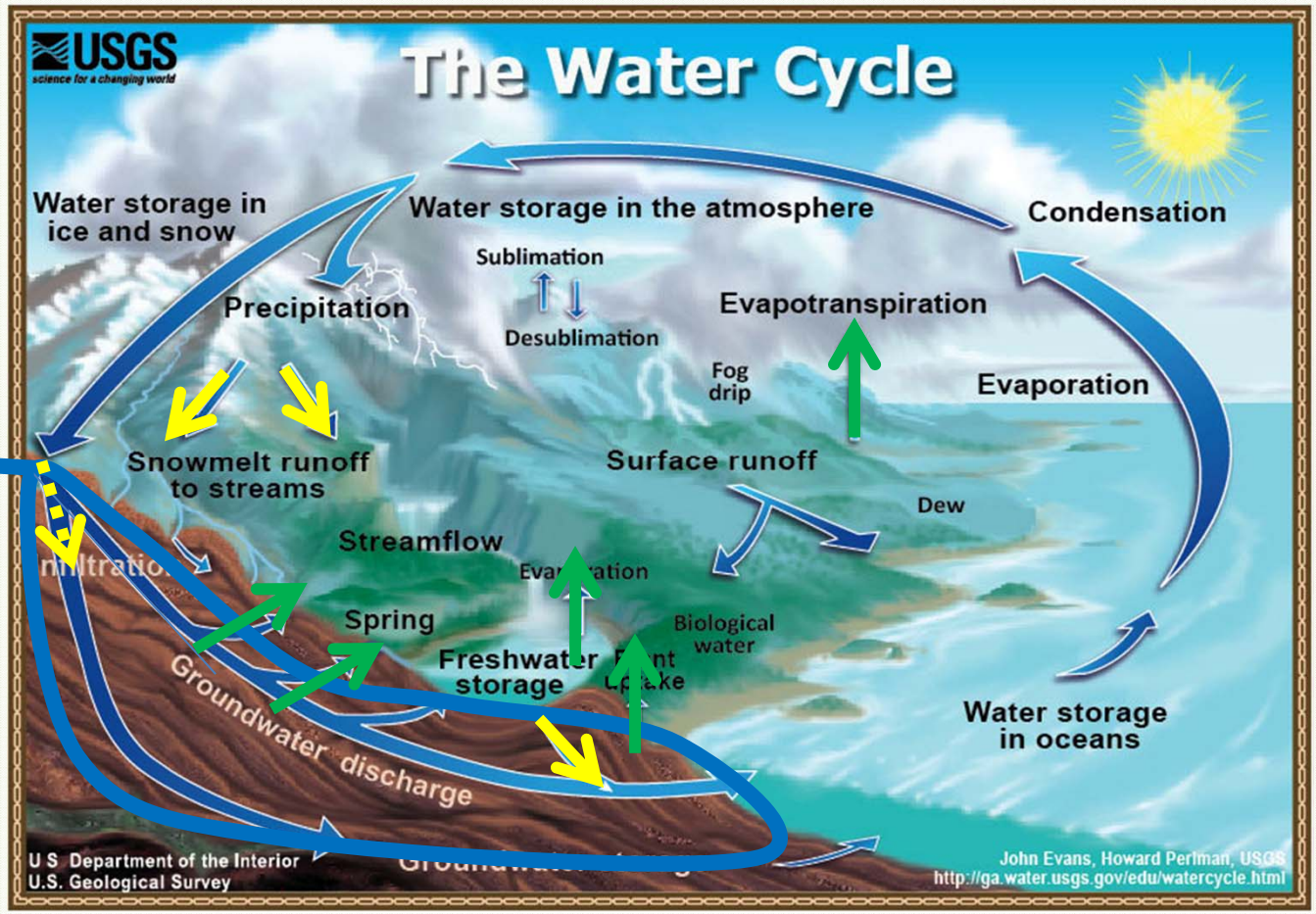
USGS

Groundwater in the Hydrologic Cycle

Groundwater System

Water Entering the System

Water Exiting the System

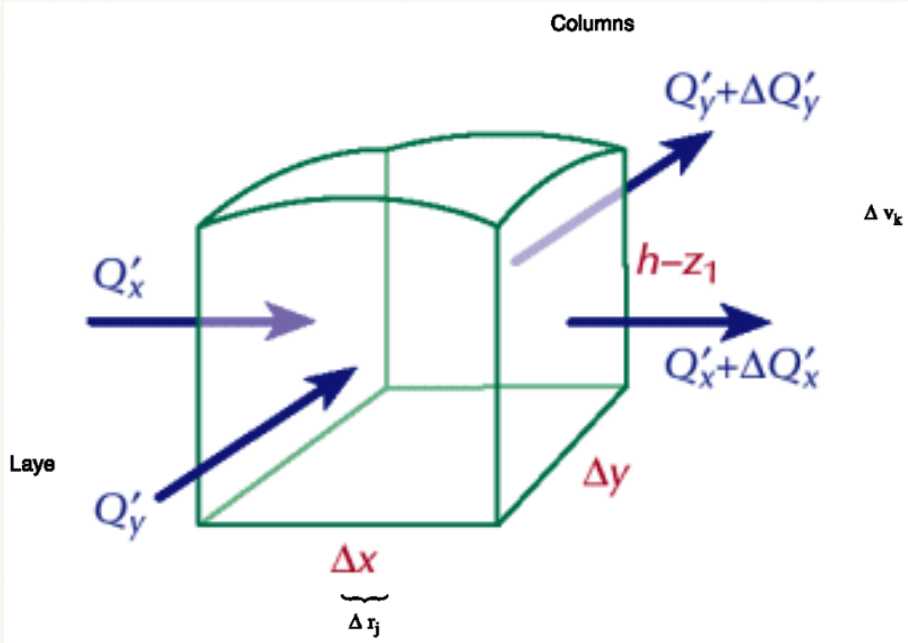


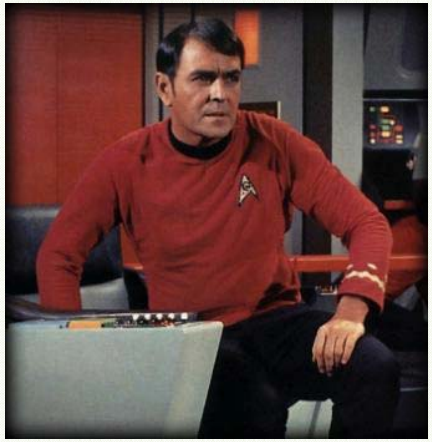
USGS

Conservation of Mass—Scotty's Rule

Matter cannot be collapsed—
water is incompressible

Must balance water inflow and outflow



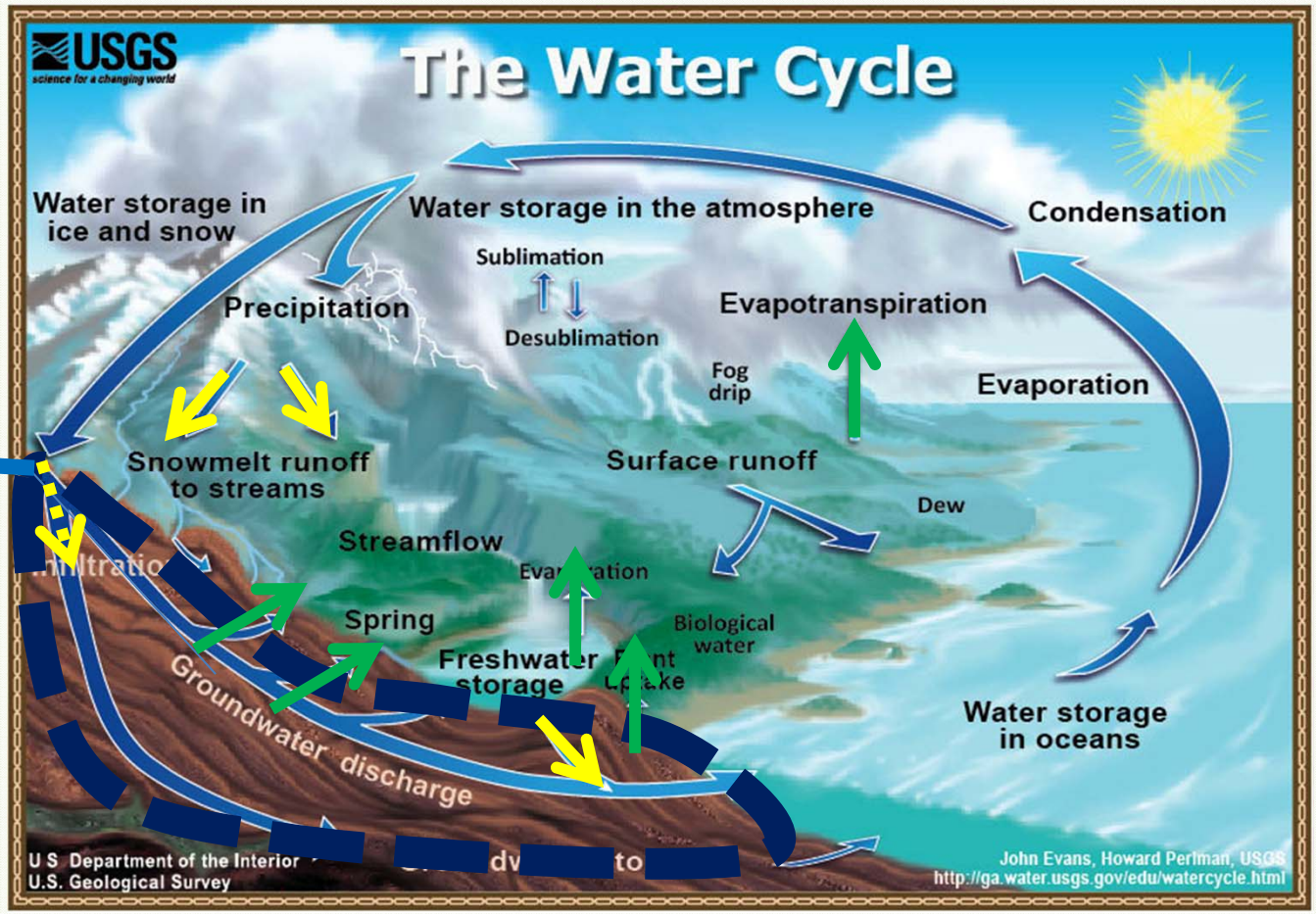


Control volume over which to balance inflows and outflows.

Groundwater System

Water Entering the System

Water Exiting the System



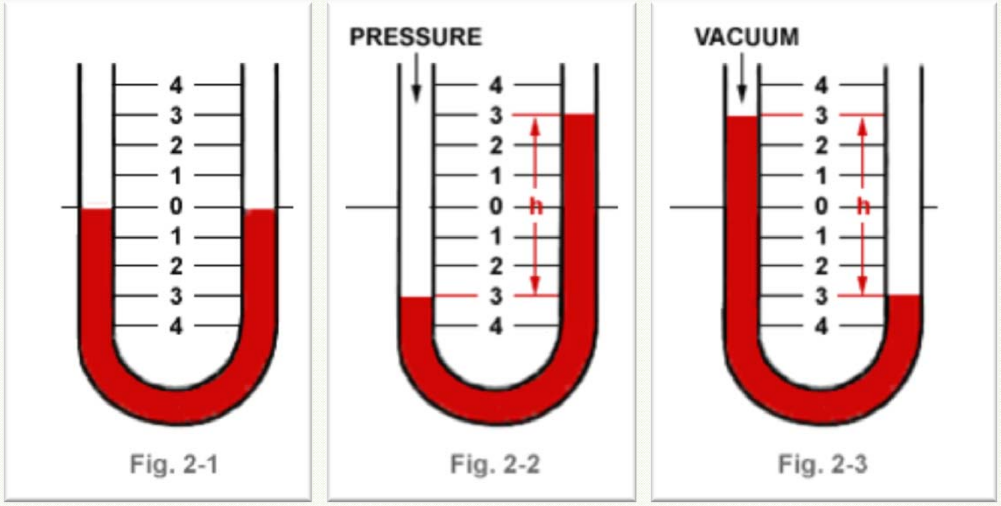
USGS

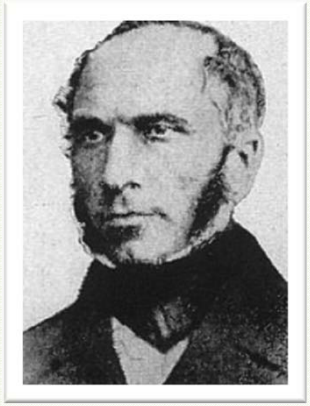
Conservation of Energy—Plumber's Rule

Water flows "downhill"

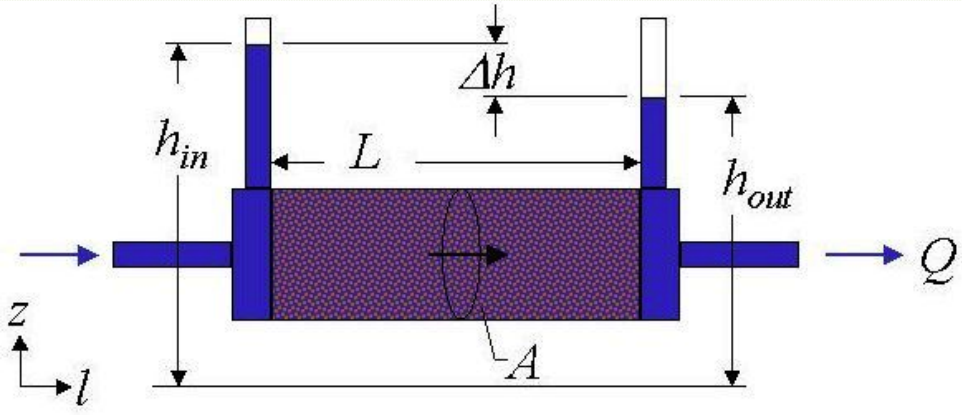
Energy entering the system must
either leave the system or
get converted to heat through friction.

“downhill”, pressure, and Darcy’s Law





Henry Darcy
1803-1858



flow is a function of:

- geometry (area)
- resistance (hydraulic conductivity)
- energy in/out (boundary conditions)

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manometer image from: http://www.dwyer-inst.com/Products/ManometerIntroduction.cfm
Henry Darcy image from: Wikimedia commons
Falling head experiment image from: http://bioen.okstate.edu/Darcy/LaLoi/basics.htm

Conceptual model and choice of techniques

The choice of modeling technique and data acquisition are motivated by the nature of the question being asked.

nearby streamflow impact
groundwater levels
water quality in mine water
water supply to wetlands

The results of all models are contingent on conceptual, technique and data choices made.

A model designed to answer one question with a margin of safety may be at odds with another.

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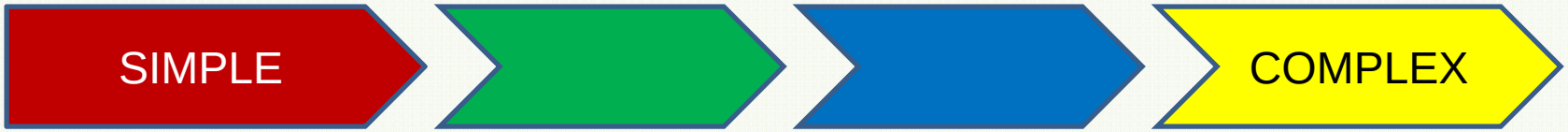
Choosing a model

What kind of model is required?



Tools:

Hand calculations	Analytic Elements	Fully Numerical
spreadsheet/paper	GFLOW	MODFLOW
		FEFLOW
		FEMWATER

Computational/Accuracy Issues:

Patience	Complexity of Geometry	Node/Element Size

Timing:

"Steady State" or "Transient"?

In all cases, an important consideration is track record/legal history

Parameters controlling the model

Groundwater flow models rely on several parameters

Within the groundwater system
hydraulic conductivity
water levels at boundaries
geometry
reaction kinetics
porosity

Hydrologic cycle connections
recharge
precipitation, infiltration, losing streams
discharge
springs, gaining streams, lakes, evaporation, plant uptake,

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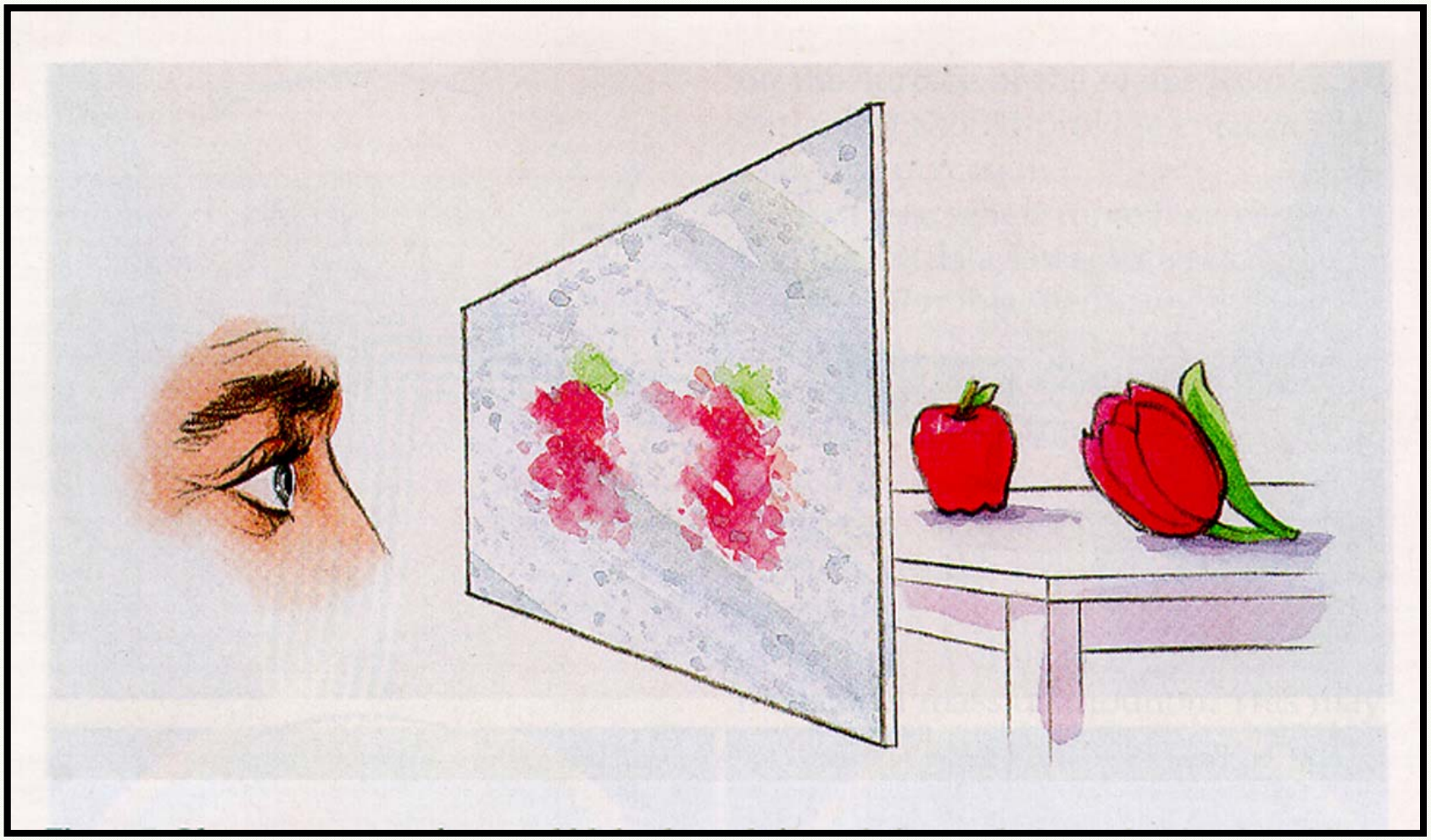
Parameters cannot be measured – they are inferred. But, the solution is not unique



Calibration and Uncertainty

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Calibration and Uncertainty

More complex models → many parameters

Beyond Trial-and-Error → robust statistical techniques can help

Each parameter has some uncertainty associated with it

Predictions made using the model and these parameters will also have uncertainty to consider.

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Models and uncertainty

"Essentially, all models are wrong,
but some are useful."

George E. P. Box

We should not expect to perfectly reproduce the measurements with a model.

We acknowledge that the model is imperfect.

We also acknowledge that our measurements are imperfect.

We thus rely on robust statistical techniques to quantify and explicitly consider these uncertainties.

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Review data needs – *See handout*

- Hydrostratigraphy
  - Well construction reports (WCRs)
  - Geophysical logs (new wells of opportunity)
  - Pumping test data
- Surface water features
  - DNR and LiDAR derived features
  - Streamgaging to measure flow rates
- Water use
  - Pumping rates at sand mines and irrigated farms
  - Municipal wells, other high-capacity wells
  - WWTP discharges

Review data needs – *See handout*

- Soil Water Balance (SWB) modeling
  - Soil type, land use and topography
  - Current conditions (pre-mine) and future scenarios
- Calibration targets
  - Groundwater levels (hydraulic heads)
  - Surface water flows (gaging stations, streamgaging)
  - Surface water levels
- Scenario testing
  - Data dependent on decision of future scenarios
  - Estimates of future pumping rates
  - Future SWB scenarios

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Future scenario discussion

- Two scenarios will be developed to estimate hydrogeological response to changes in pumping and recharge
- Comparisons will be made between the calibrated model representing current conditions and the two scenarios.
- *Example scenarios included in proposal:*
  - Scenario 1 – peak sand mine operations (~ 2030)
  - Scenario 2 – post-mine reclamation (~ 2050)

Chippewa County Groundwater Study

1st Stakeholders Group Meeting

Thank you…

USGS science for a changing world

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