Groundwater/Surface-Water Interaction: Fundamental Concepts

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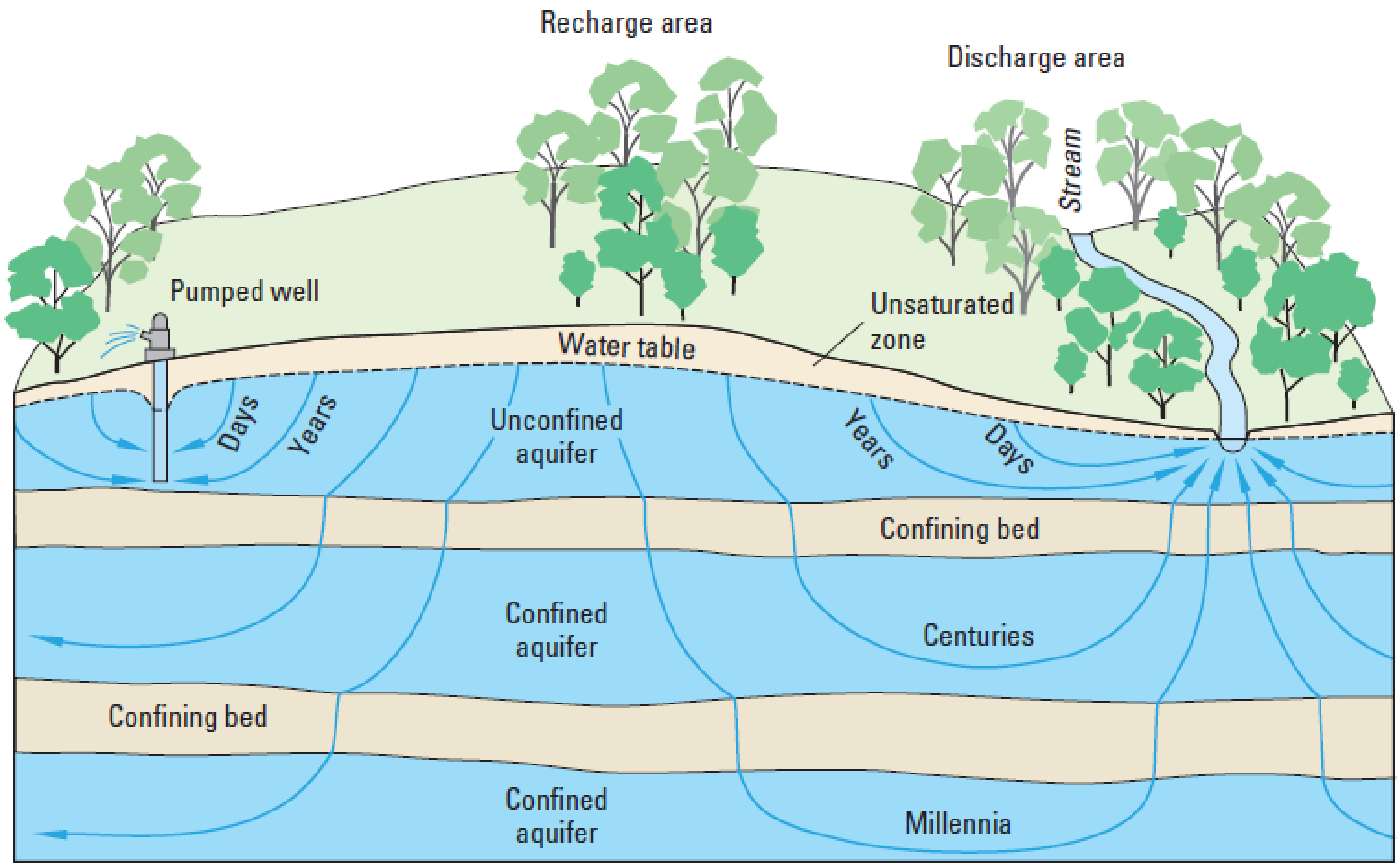
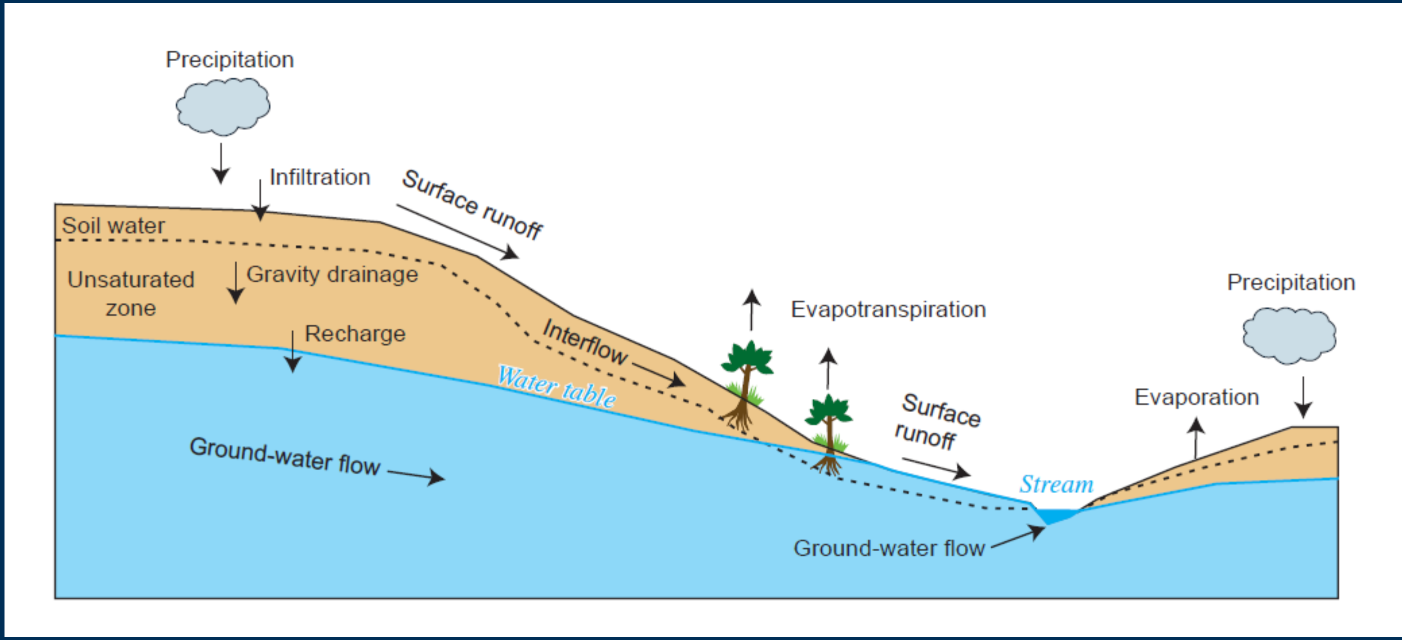
Groundwater Fundamentals

USGS


Recharge area
Discharge area
Stream
Pumped well
Unsaturated zone
Water table
Days
Years
Unconfined aquifer
Years
Days
Confining bed
Confined aquifer
Centuries
Confining bed
Confined aquifer
Millennia

USGS



Groundwater discharge is the main component of streamflow during the summer and fall months after snow has melted and there is little rainfall.

Groundwater discharge to streams is commonly evidenced by:

- A water-table sloping toward streams
- Gaining stream reaches
- Presence of springs
- Robust late-season streamflow
- Upward head gradients (artesian wells)

USGS

The Sources of Water to Wells

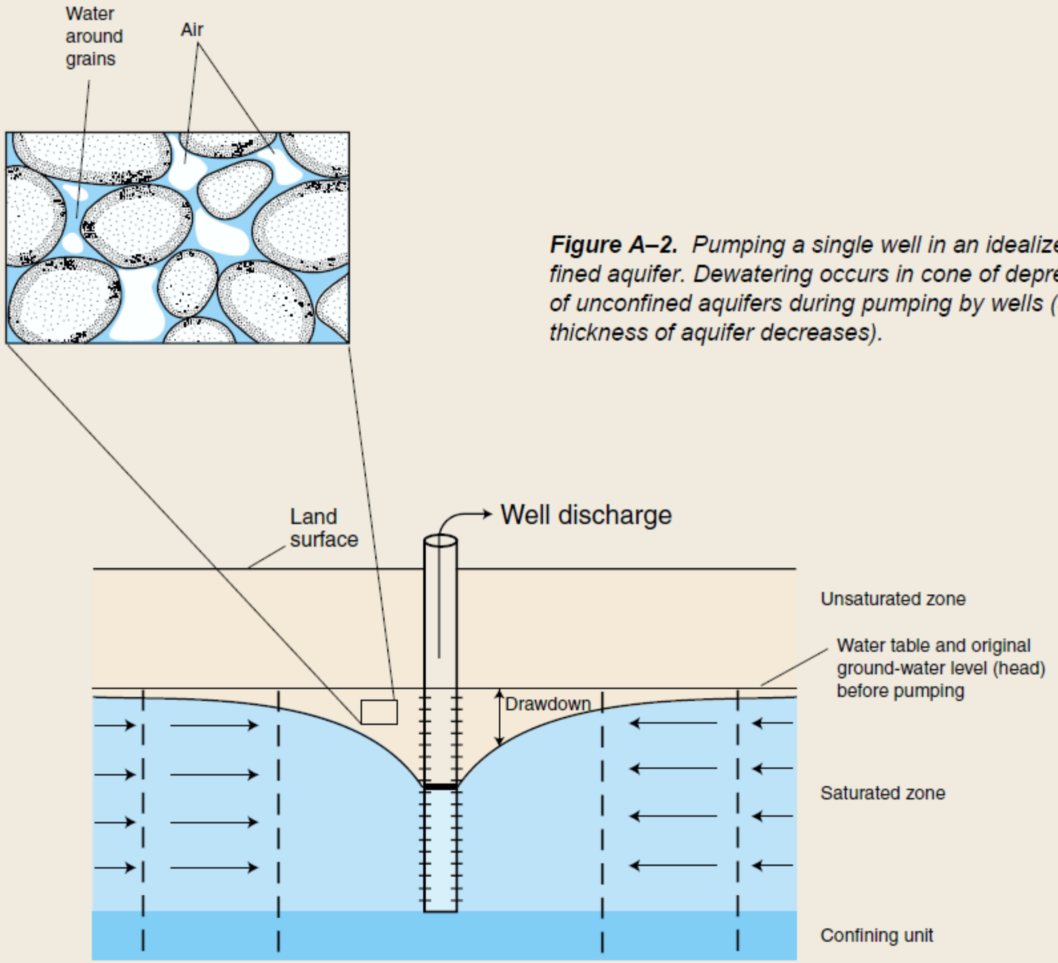
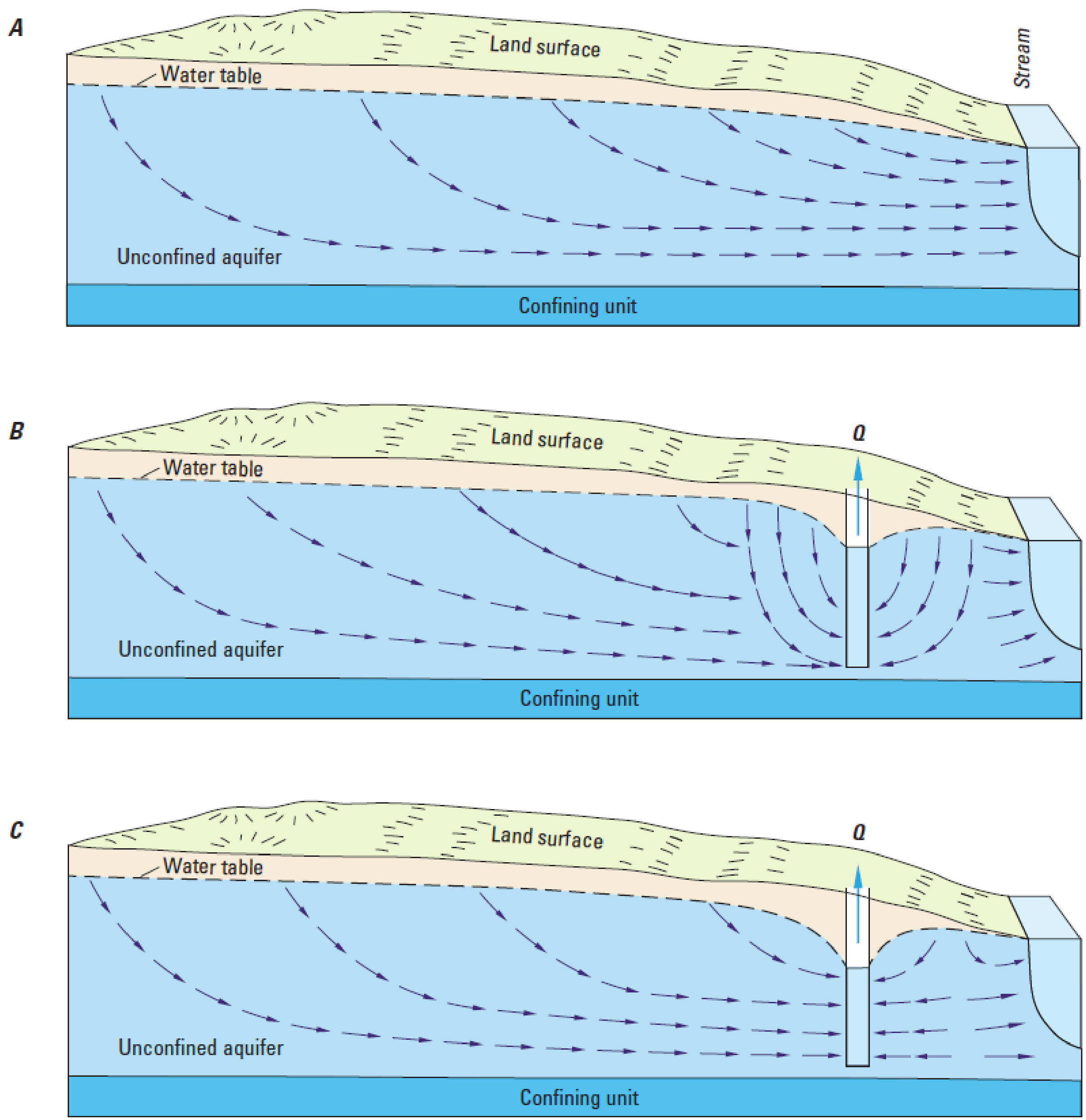


***Figure A–2.** Pumping a single well in an idealized unconfined aquifer. Dewatering occurs in cone of depression of unconfined aquifers during pumping by wells (saturated thickness of aquifer decreases).*

USGS


A
Land surface
Water table
Stream
Unconfined aquifer
Confining unit
B
Land surface
Q
Water table
Unconfined aquifer
Confining unit
C
Land surface
Q
Water table
Unconfined aquifer
Confining unit

Key Points

- Groundwater flows from recharge areas to discharge areas such as streams, springs, and wetlands.
- Identifying areas where groundwater is supplying streamflow is easily done using widely available information.
- Water removed from the groundwater system through wells comes from either 1) a change in aquifer storage, or 2) changes in flow to or from boundaries, most commonly streams or other surface water features.

USGS

Impacts of Wells on Streams

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College of Earth, Ocean, and Atmospheric Sciences

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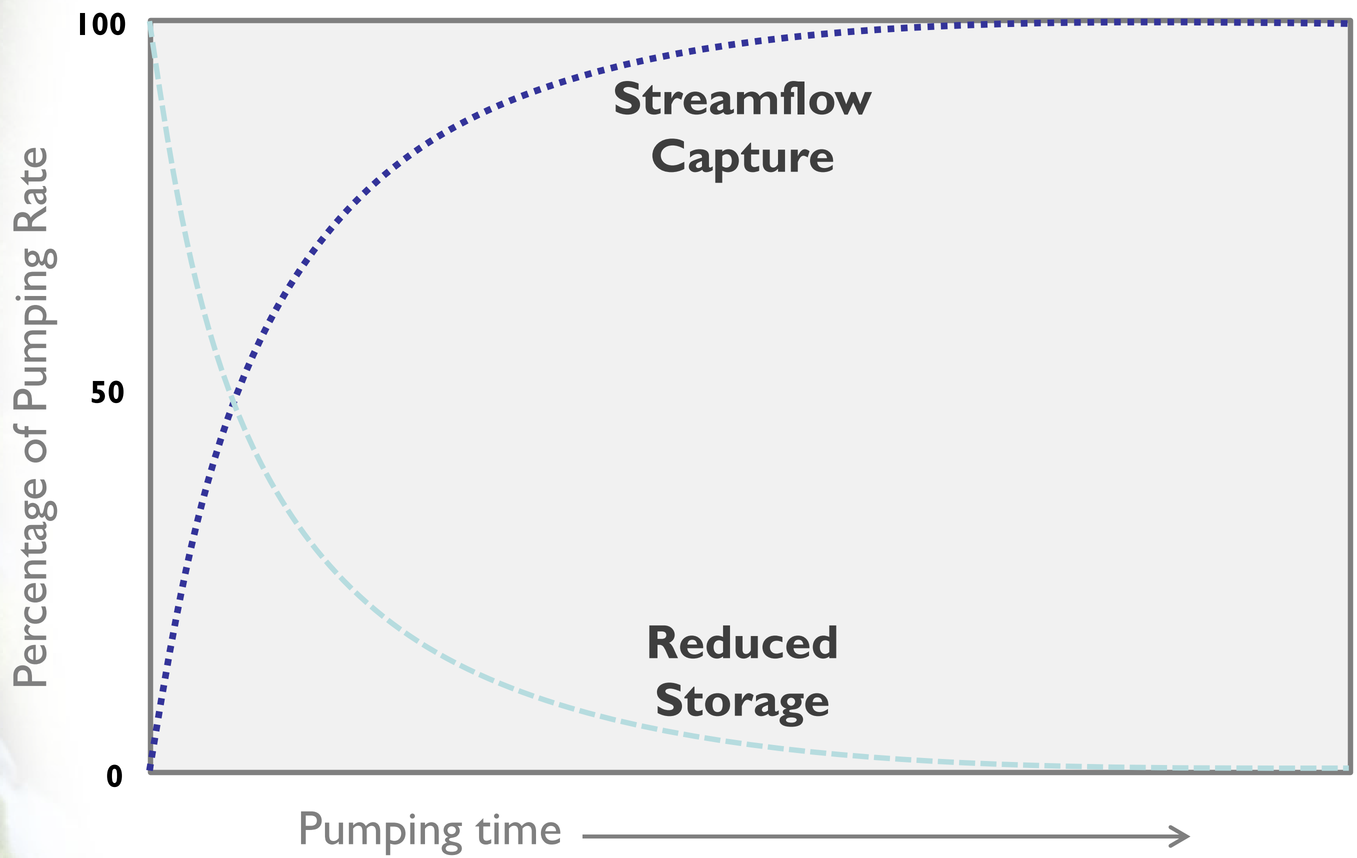
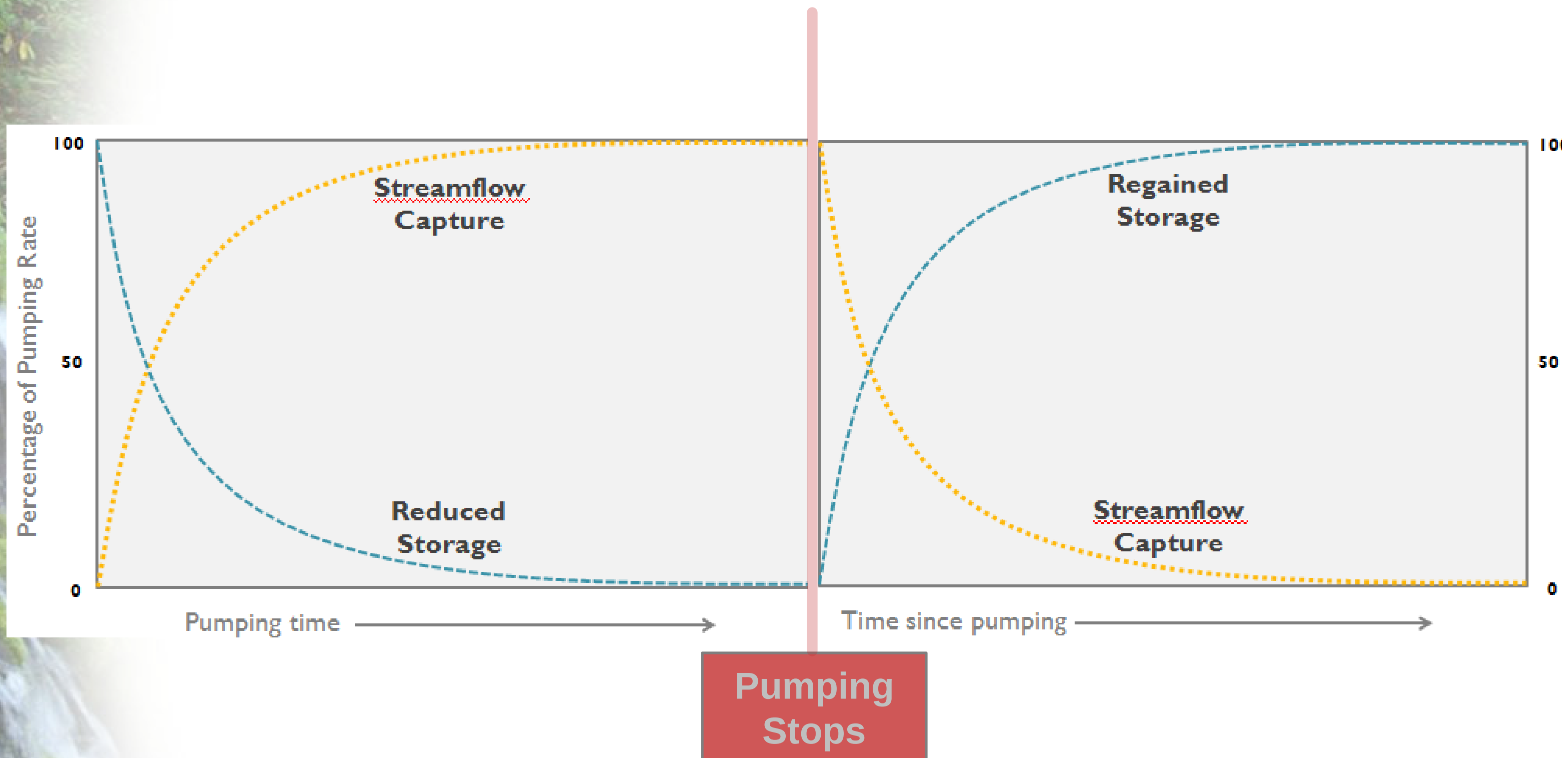
Pumped water comes from a balance of reduced aquifer storage and streamflow capture.



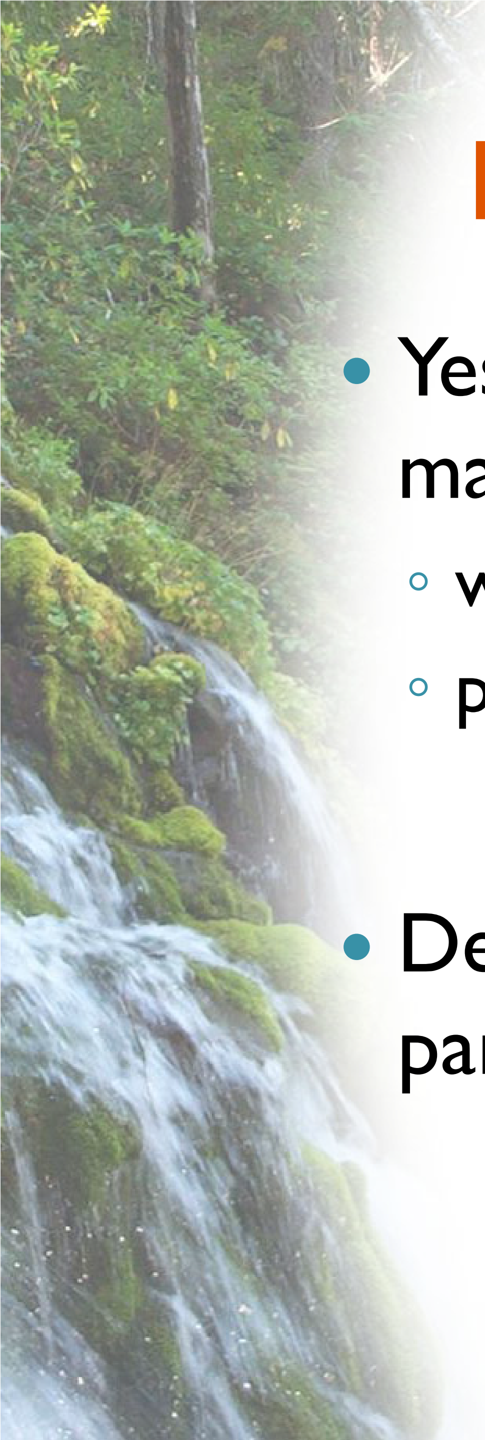
After *Barlow & Leake* (2012) but known since *Theis* (1942)

Their respective contributions change over time

The effects of groundwater pumping are persistent.



Plan on residual effects after pumping stops.



Do we <u>know</u> this?

- Yes. Pumping depletes surface water. It is a matter of mass balance. Little uncertainty.
  - water is not created or destroyed;
  - pumped water comes from somewhere

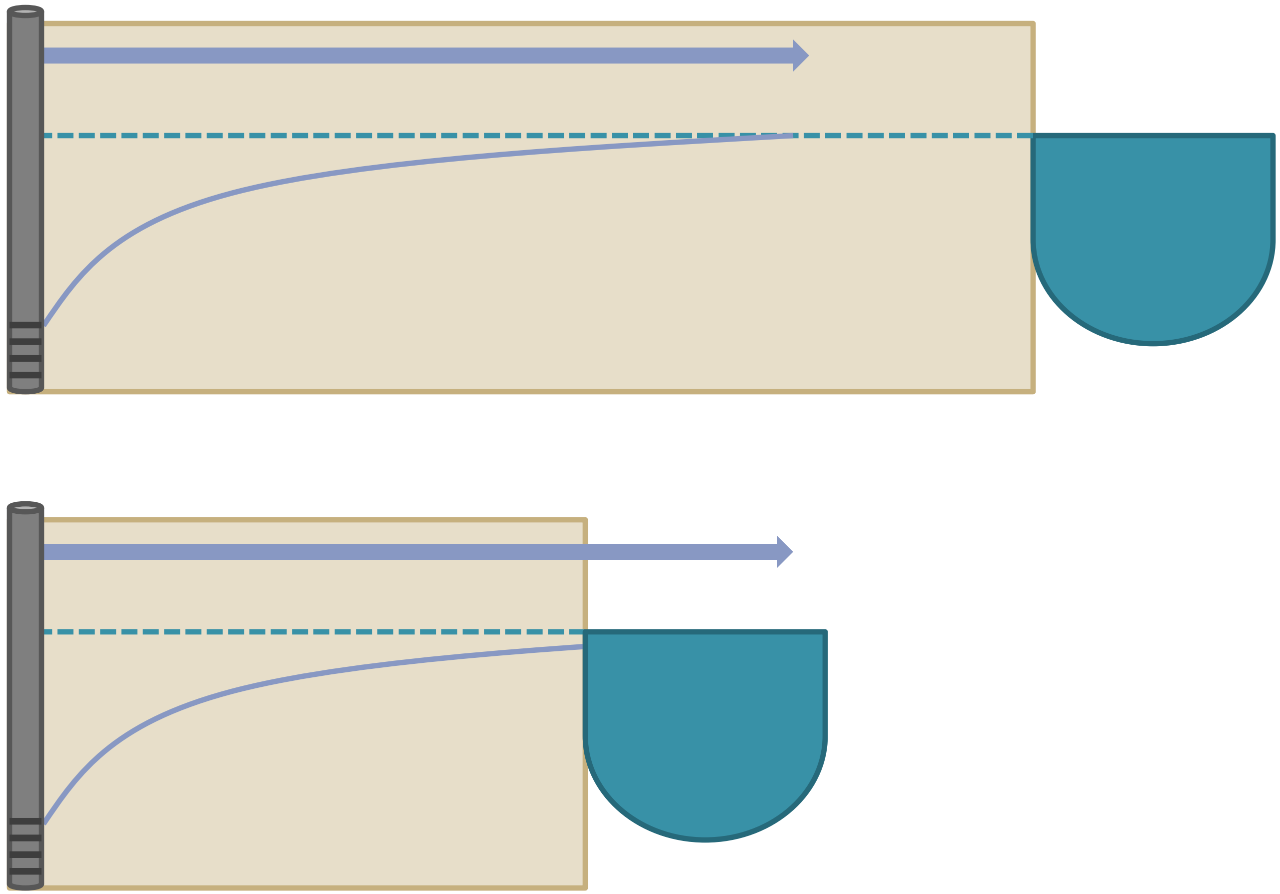
So what is uncertain?

- Details of timing. Timing depends on the particulars of transmissivity & storage.

1942

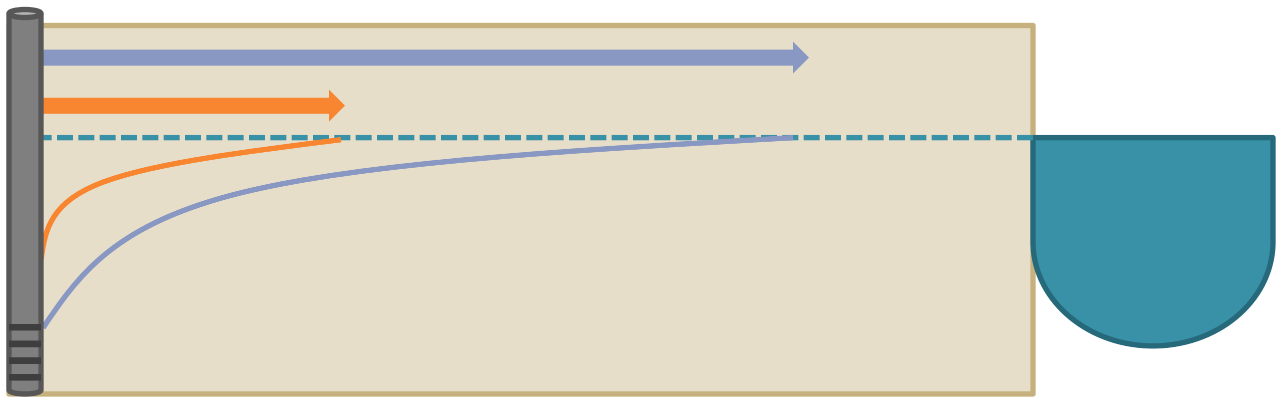
Santa Cruz River near Tucson, AZ. Photo by Robert Webb, USGS

The speed of streamflow response also varies with distance to a stream, squared (a^2)



Changes in head reach the closer streams faster, all other things being equal.

… and with aquifer transmissivity (T) and storativity (S).



Changes in head reach the stream faster in **high** *T*/*S* aquifers and slower in **low** *T*/*S* aquifers.

What are the methods we use?

1. “Analytical” methods. I.e., equations.
A simple one is the <u>streamflow depletion factor</u> (SDF).

Time required for stream depletion rate to reach ~50% of pumping rate.

$$SDF = \frac{a^2 S}{T}$$

a – Distance to well [cheap, accurate]

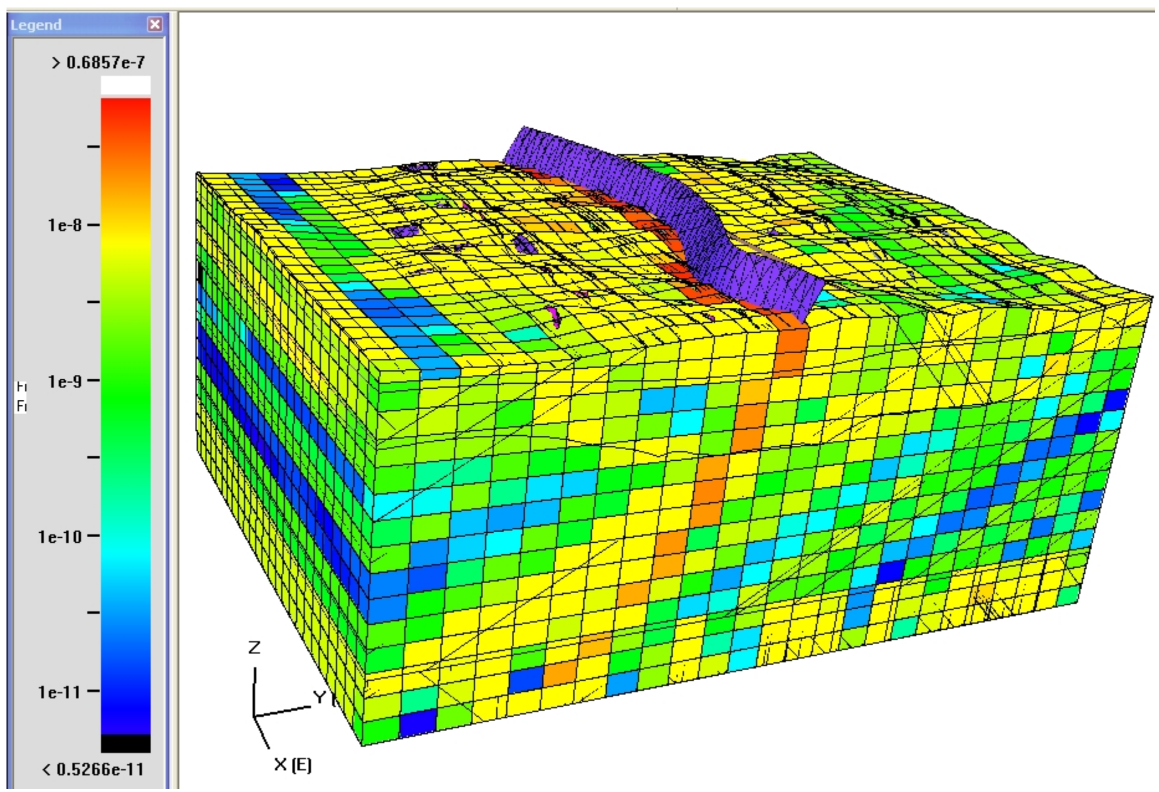
T– Transmissivity [expensive, uncertain]

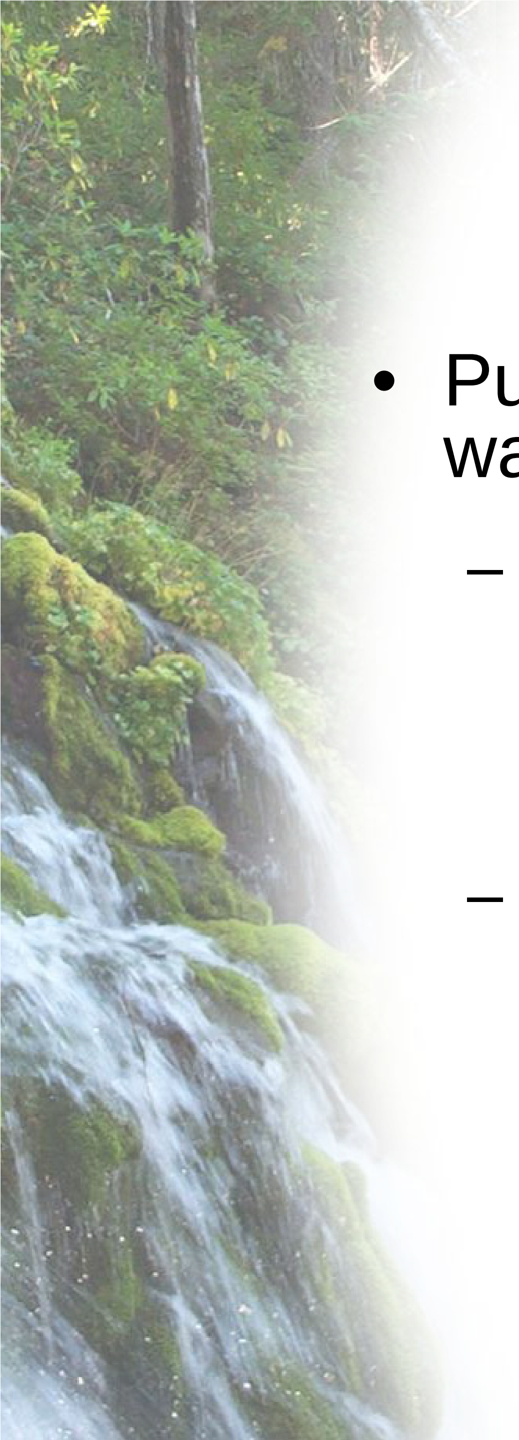
S – Storage [expensive, somewhat uncertain]

What are the methods we use?

2. Modeling.

Solution of the same equations, but able to account for larger set of circumstances and complications.

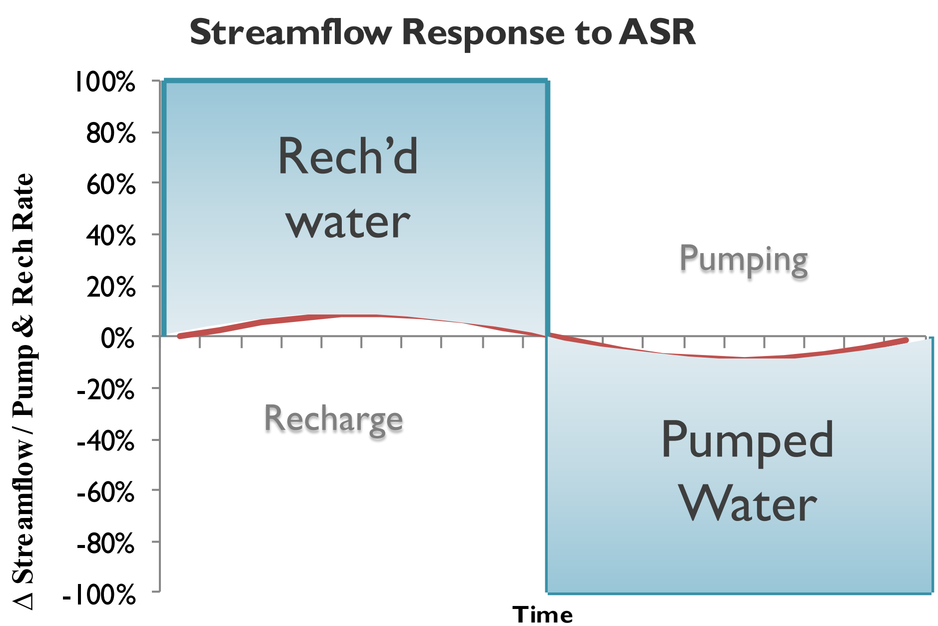




Key points

- Pumping always depletes surface water, somewhere, sometime.
  - Predicting **overall** streamflow effects has low uncertainty and is relatively inexpensive.
    - It is a matter of mass balance
  - Predicting **timing** of streamflow effects has greater uncertainty and is expensive.
    - Depends on uncertain details

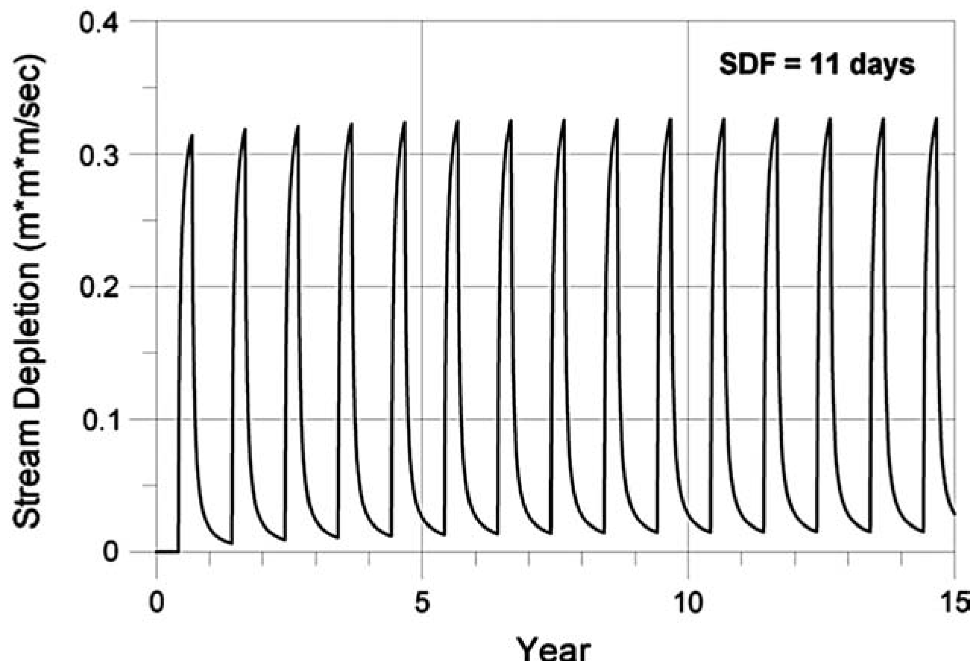
High & Low SDF



High SDF

Zero SDF

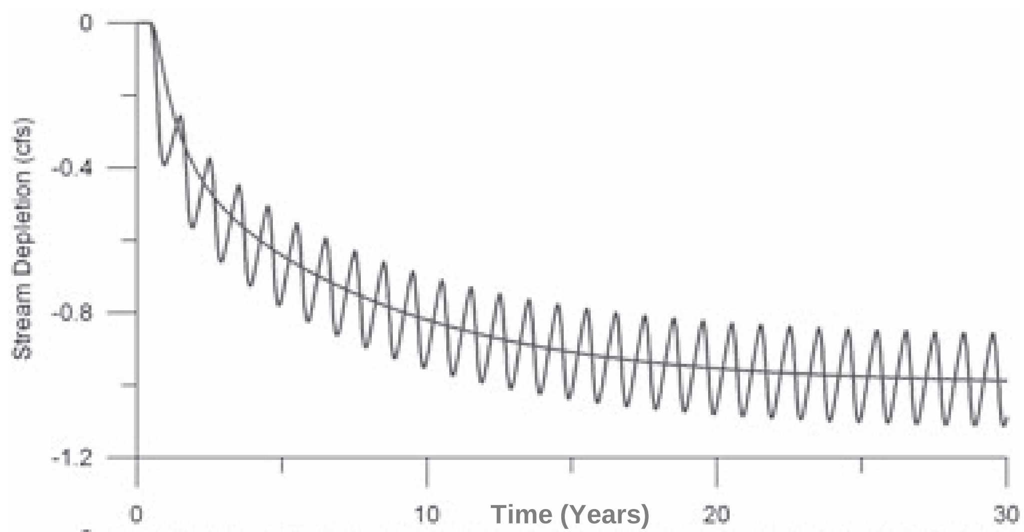
Near-stream (Low SDF) wells



Most streamflow depletion is during pumping season. There is little to no carryover. If summer streamflows are the concern, trade SW right for GW right. Bredehoeft (2010)

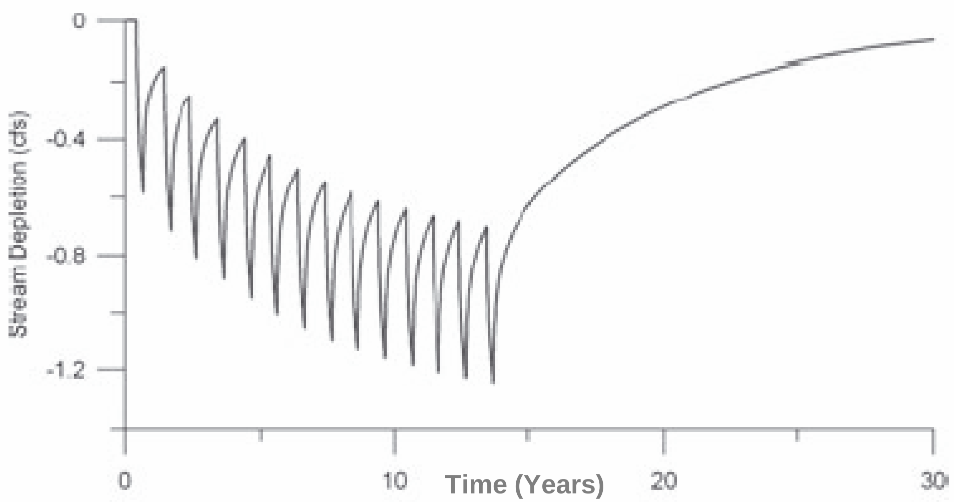
Figure: Bredehoeft (2010)

Wells far from streams (High SDF)



Pumping effects [ultimately] become averaged throughout the year. Pumping for 120 days at any point in the year will reduce streamflow by 1/3 of that rate… all year long. Bredehoeft (2010)

Pumping in High SDF areas also poses long-term consequences, even after pumping stops.



In High SDF areas, pumping will affect streamflow long after we receive its economic benefits (Bredehoeft, 2010).

Figure: Bredehoeft (2010)