Possible Effects of Groundwater Pumping and Artificial Recharge on the Verde River and Tributaries

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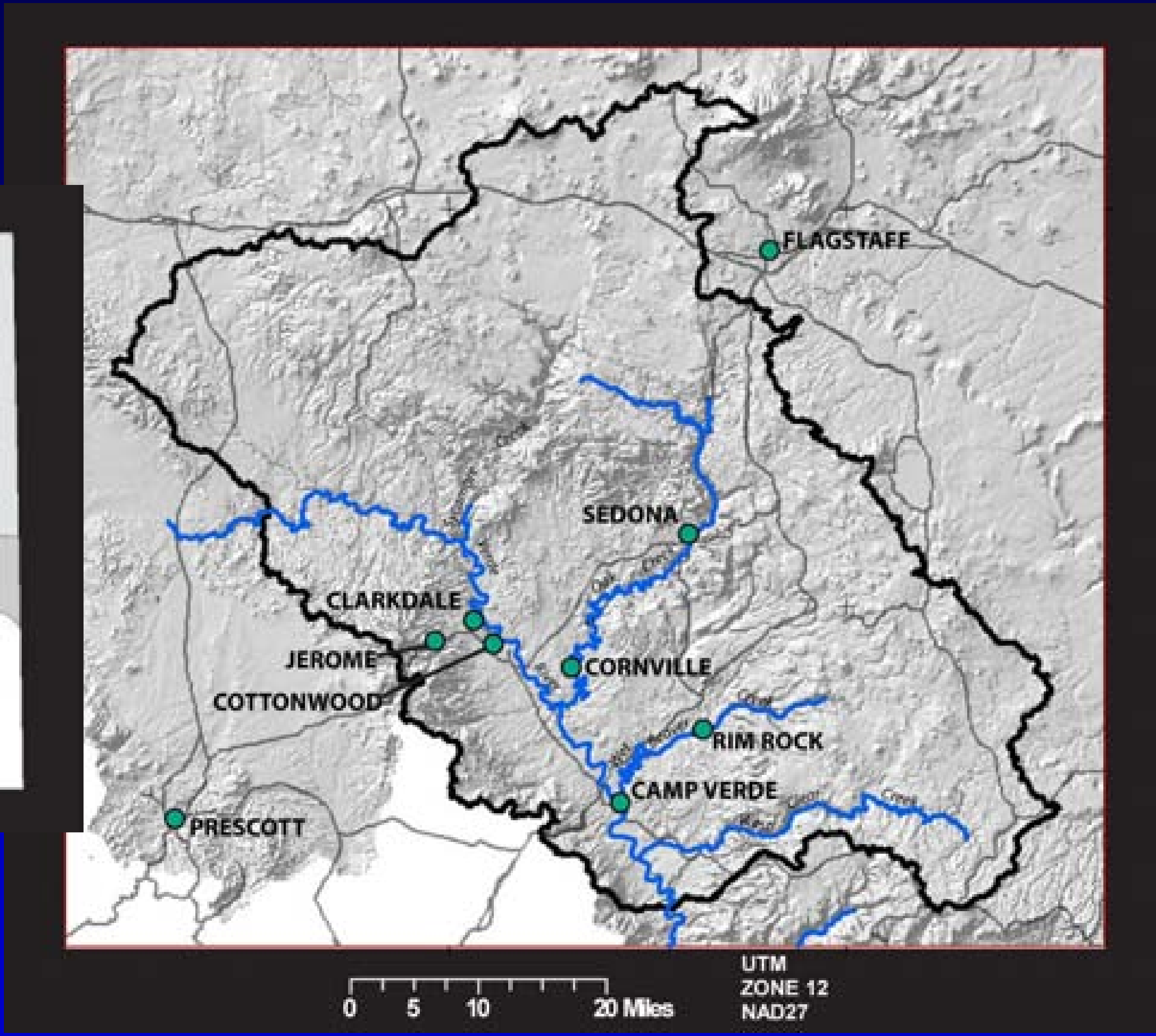
USGS

Study Area

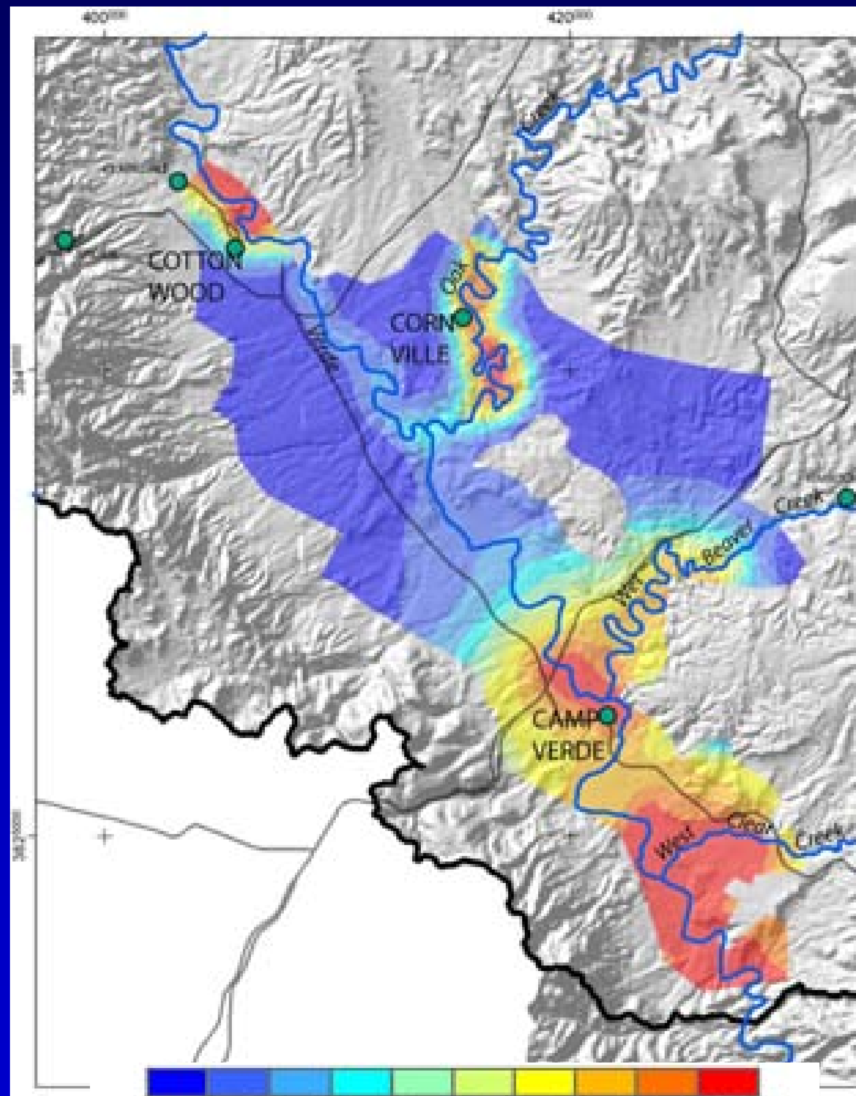

Colorado Plateau
Transition Zone
Basin and Range Lowands


FLAGSTAFF
SEDONA
CLARKDALE
JEROME
COTTONWOOD
CORNVILLE
RIM ROCK
CAMP VERDE
PRESCOTT
0 5 10 20 Miles
UTM
ZONE 12
NAD27

Background

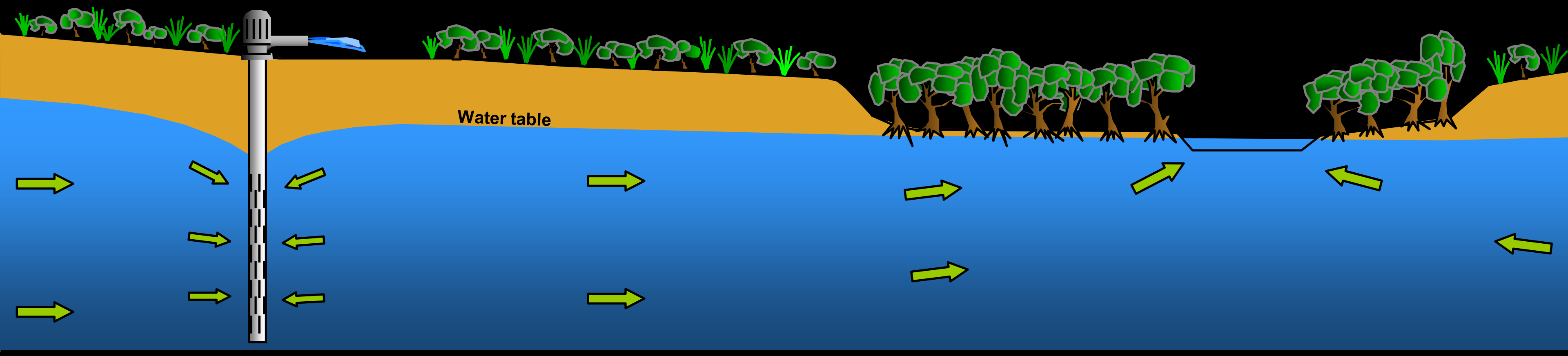
- The Verde Valley in north-central Arizona has experienced rapid population growth and increased groundwater use in recent decades
- Managers need better information on timing of effects of groundwater pumping and artificial recharge on surface water and evapotranspiration
- A new regional model is the best tool available for understanding these effects in the study area
- A big-picture understanding of timing of effects could be done by mapping streamflow decrease or increase as a function of well or recharge location, as was done for the San Pedro Basin

EXAMPLE MAP SHOWING EFFECTS OF PUMPING OR ARTIFICIAL RECHARGE ON SURFACE WATER



Total change (decreased or increased surface-water flow and ET) as a percentage of pumping rate

How Groundwater Pumping Can Affect Surface Water



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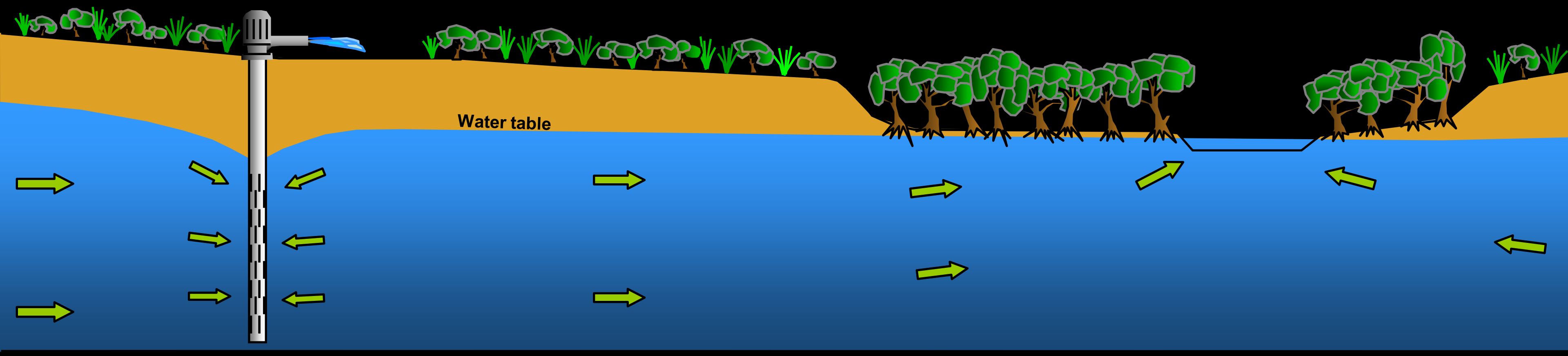

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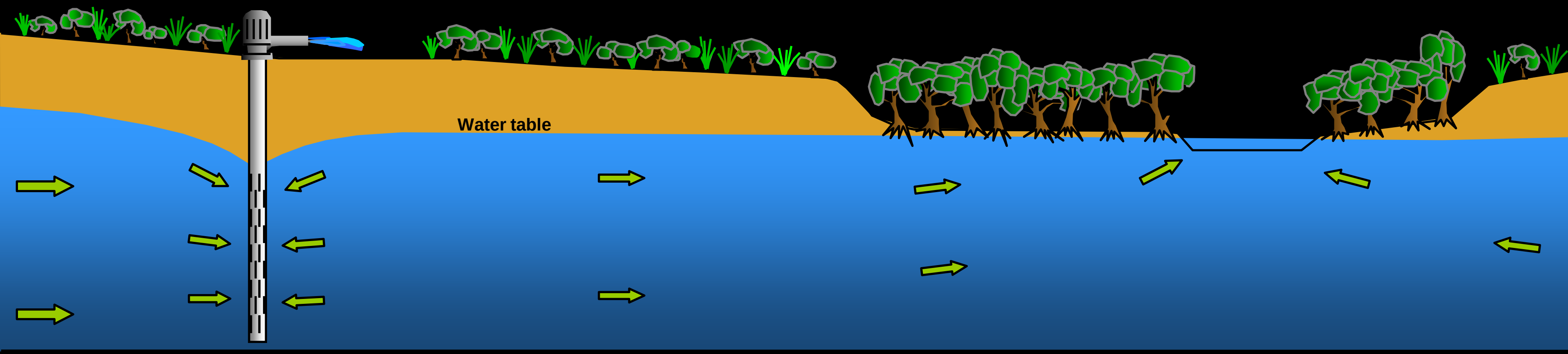

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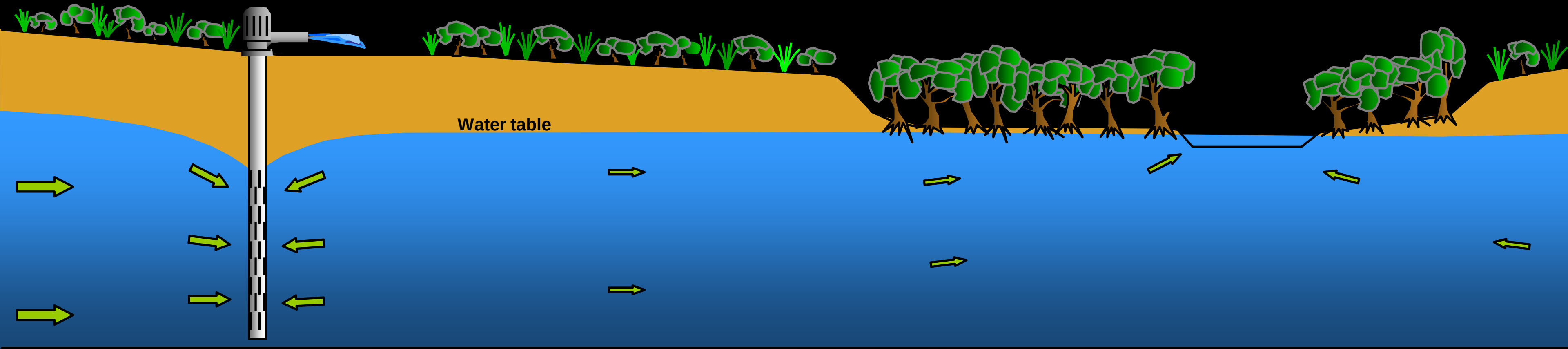

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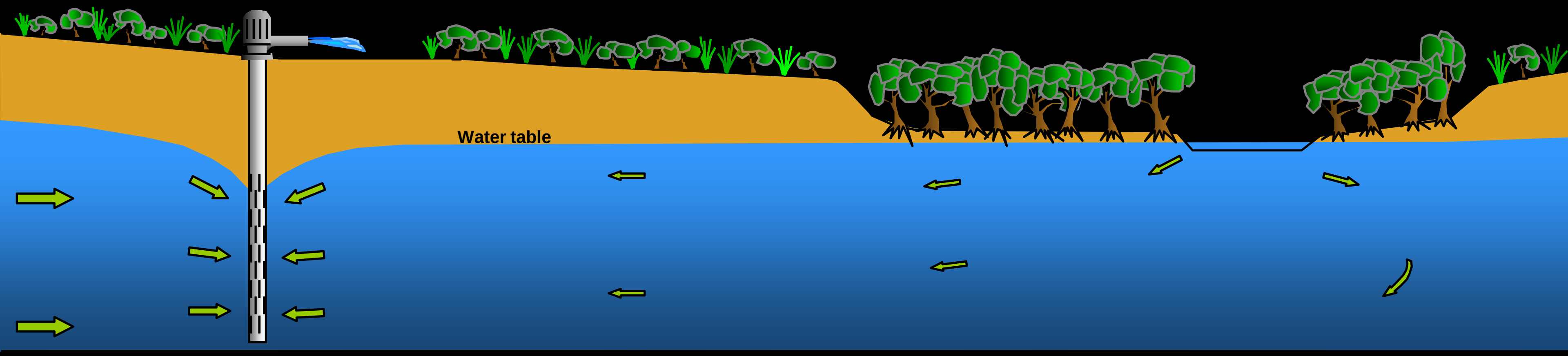

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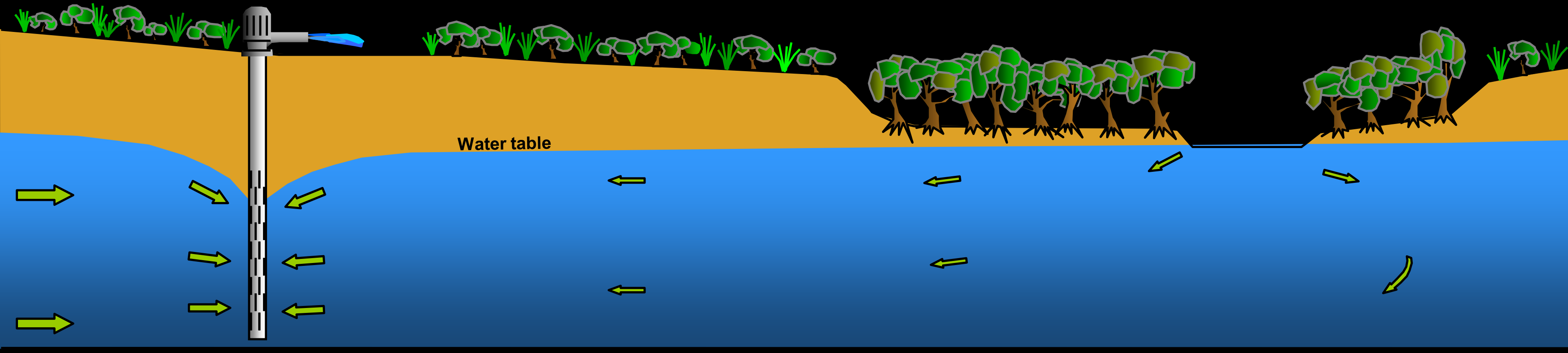

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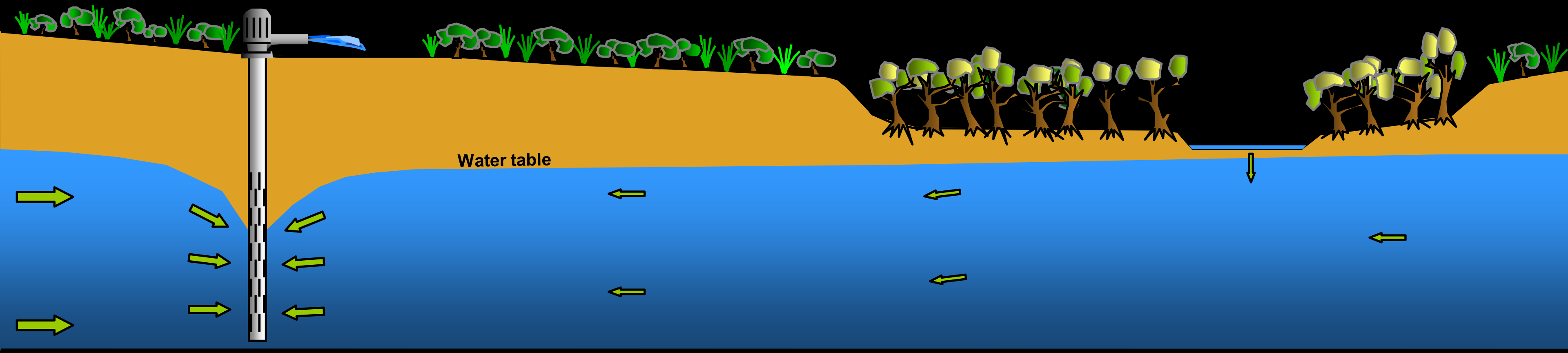
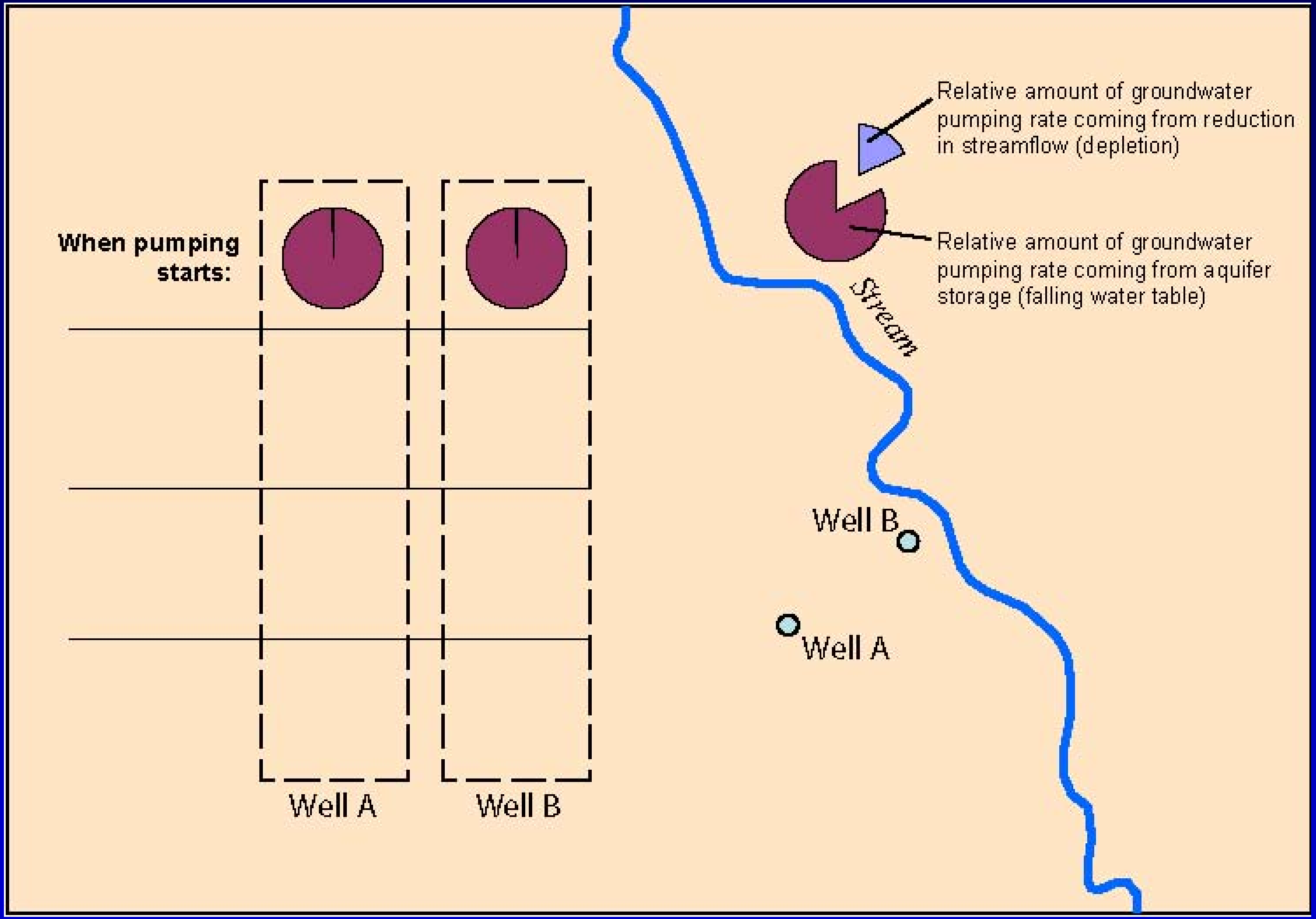


Sources of Water to a Pumped Well



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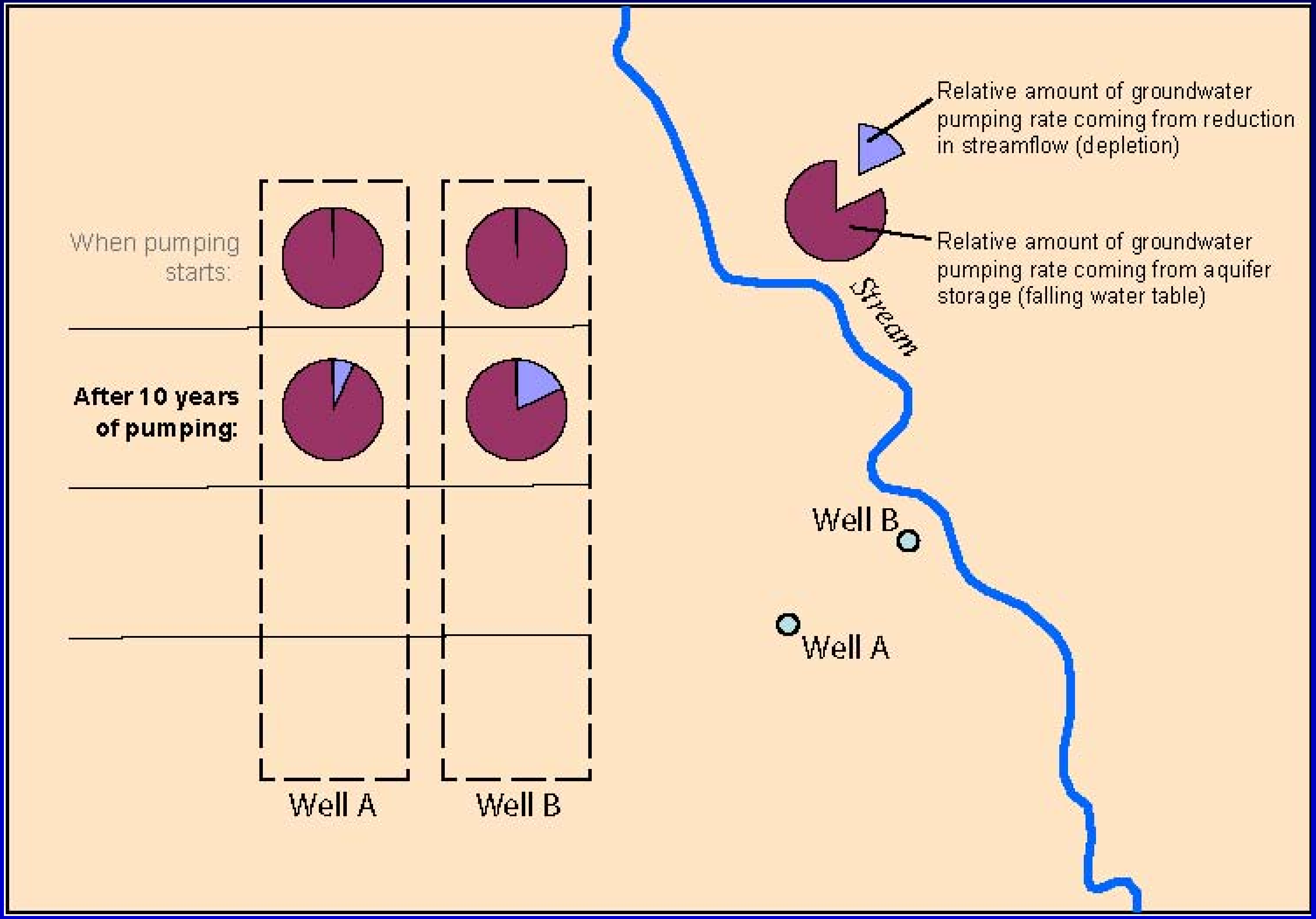

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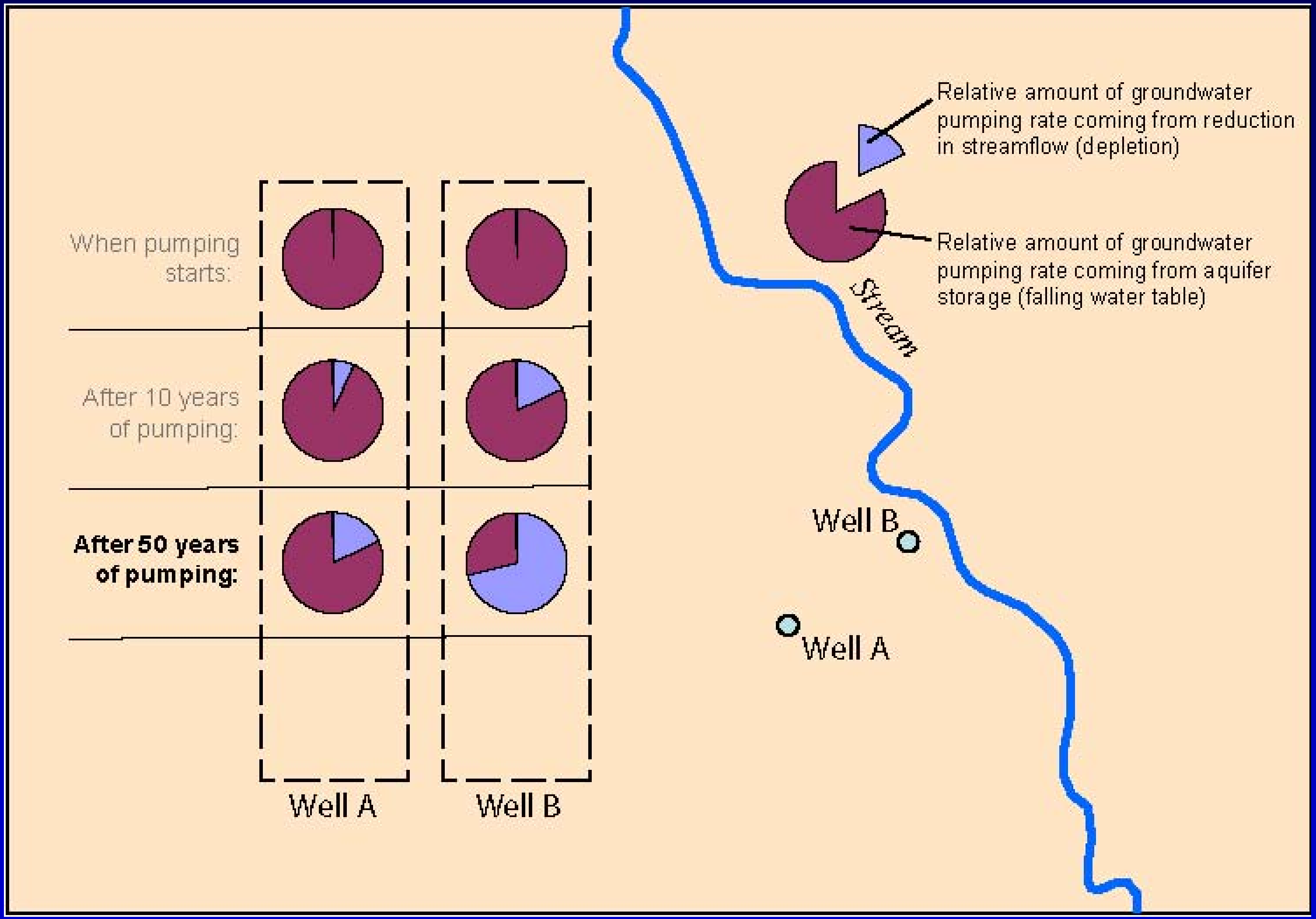

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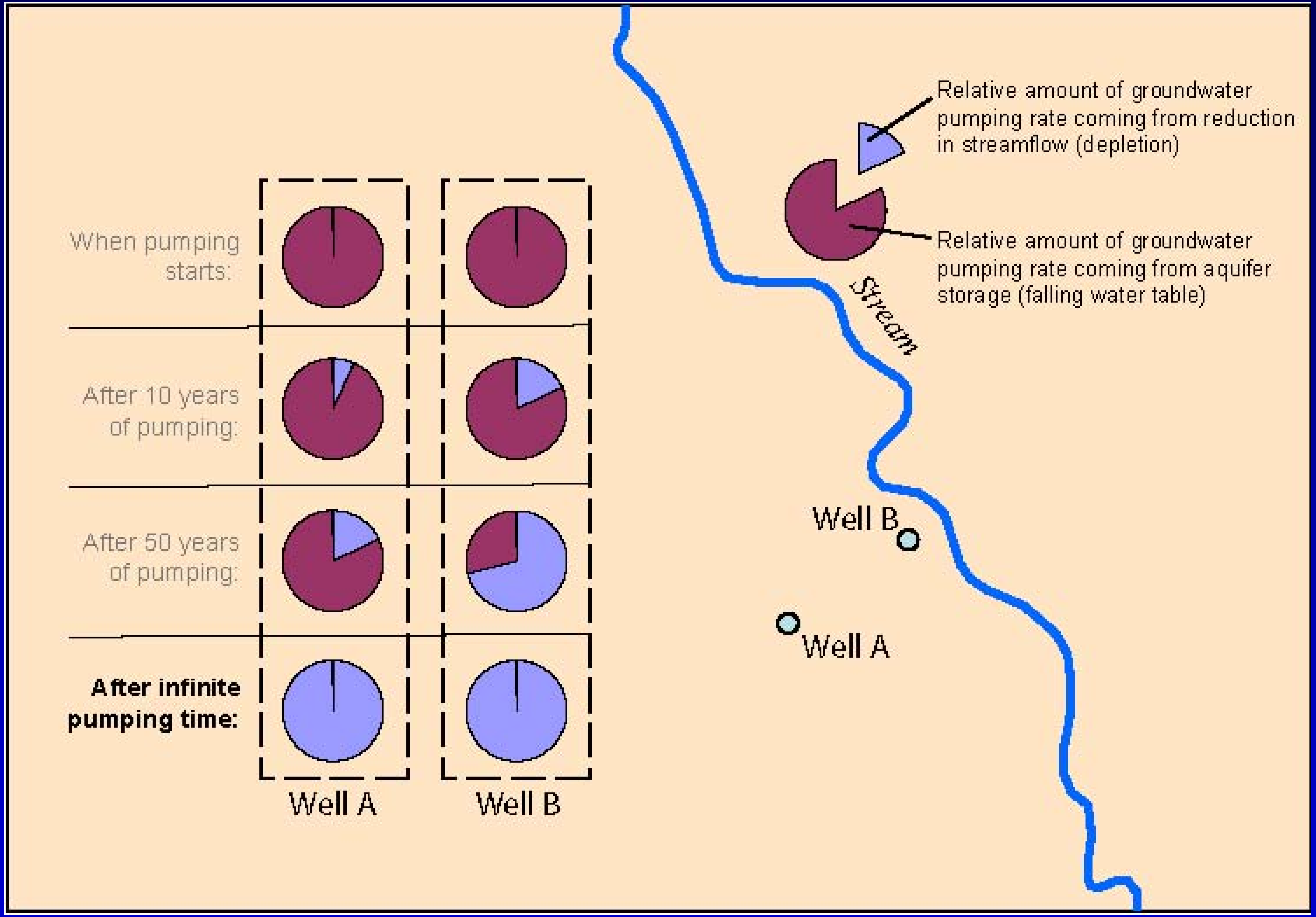
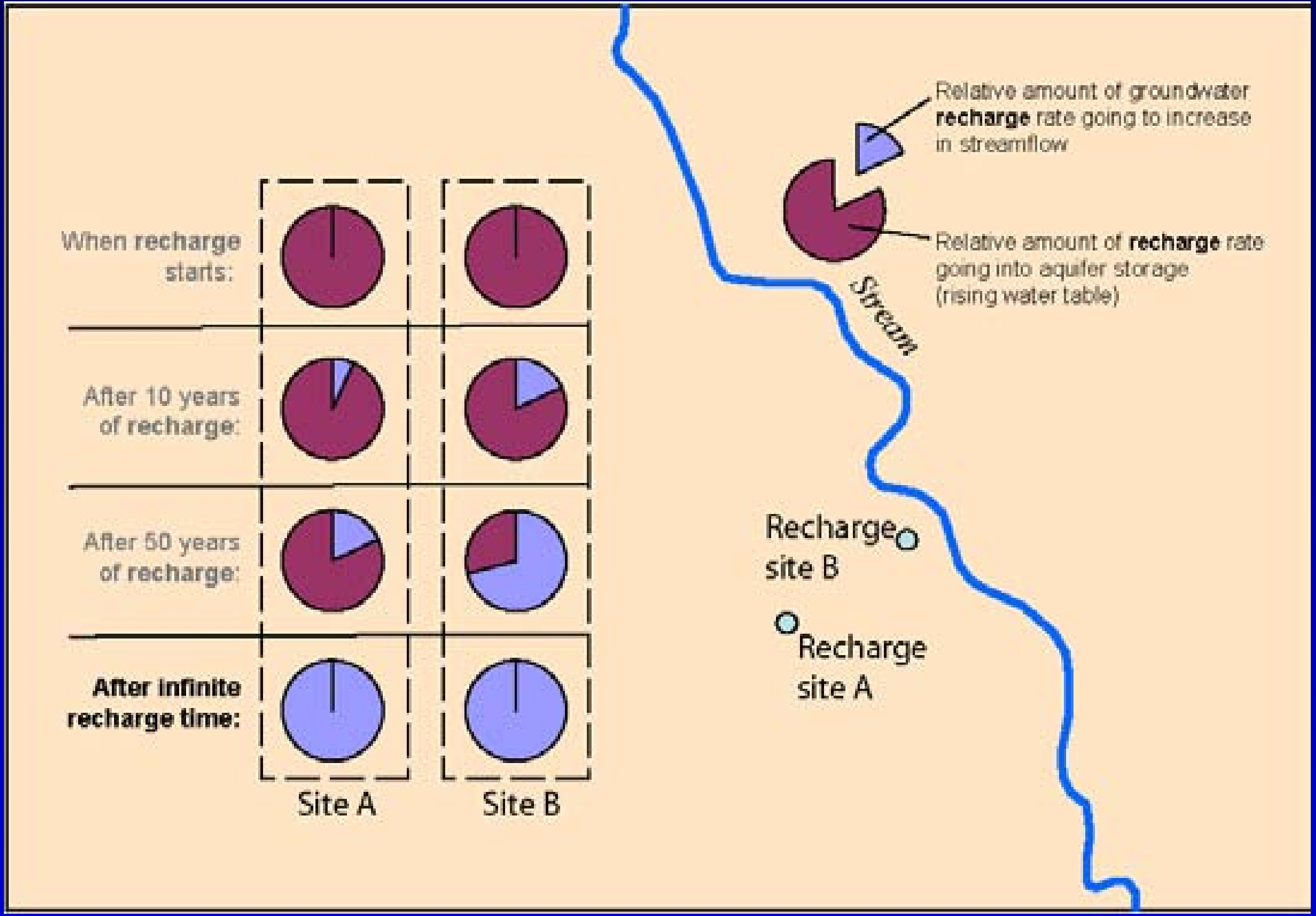


Fate of Artificial Recharge



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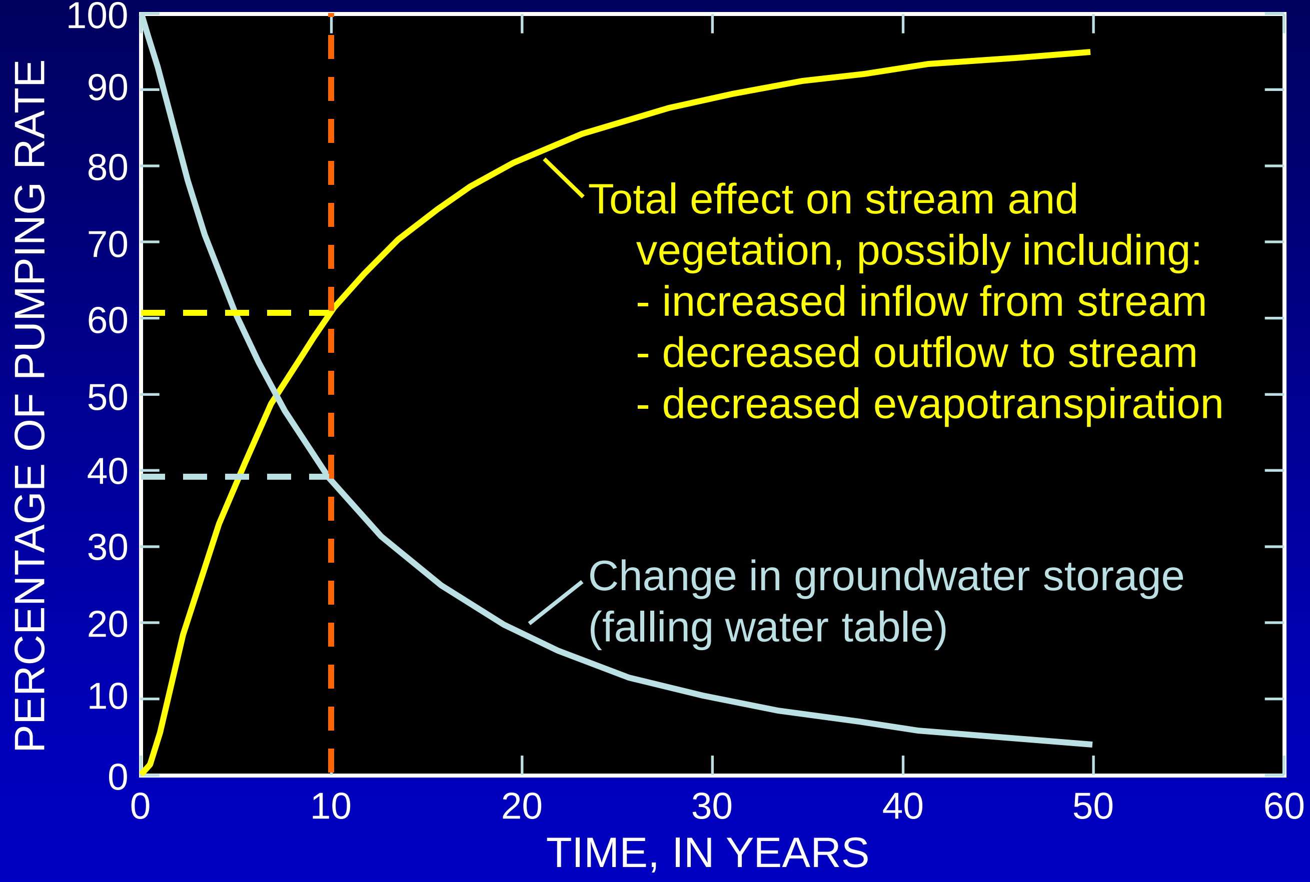
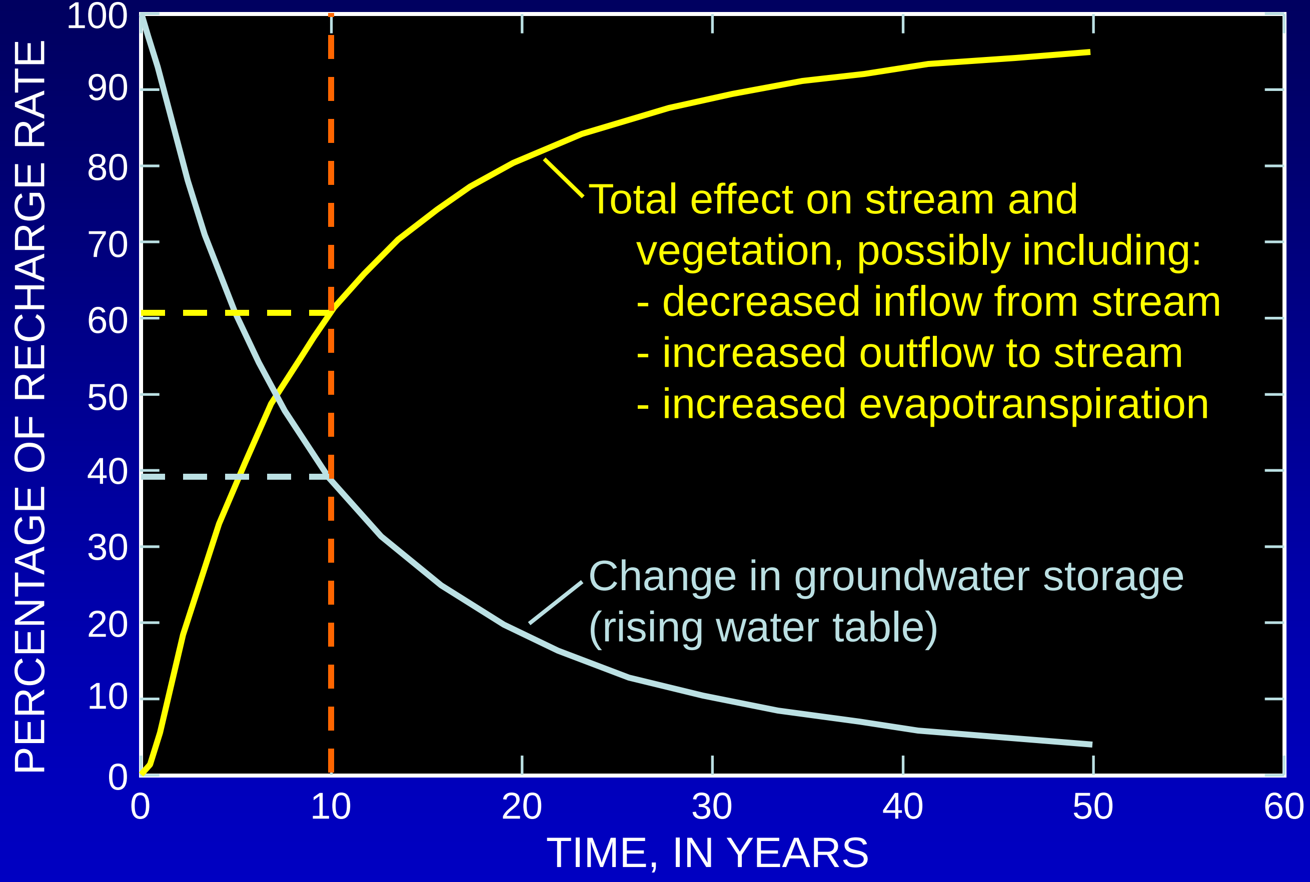


The timing of effects of pumping depends on

- Aquifer properties
- Distance to connected SW features

Fate of Recharged Water



The timing of effects of recharge depends on

- Aquifer properties
- Distance to connected SW features

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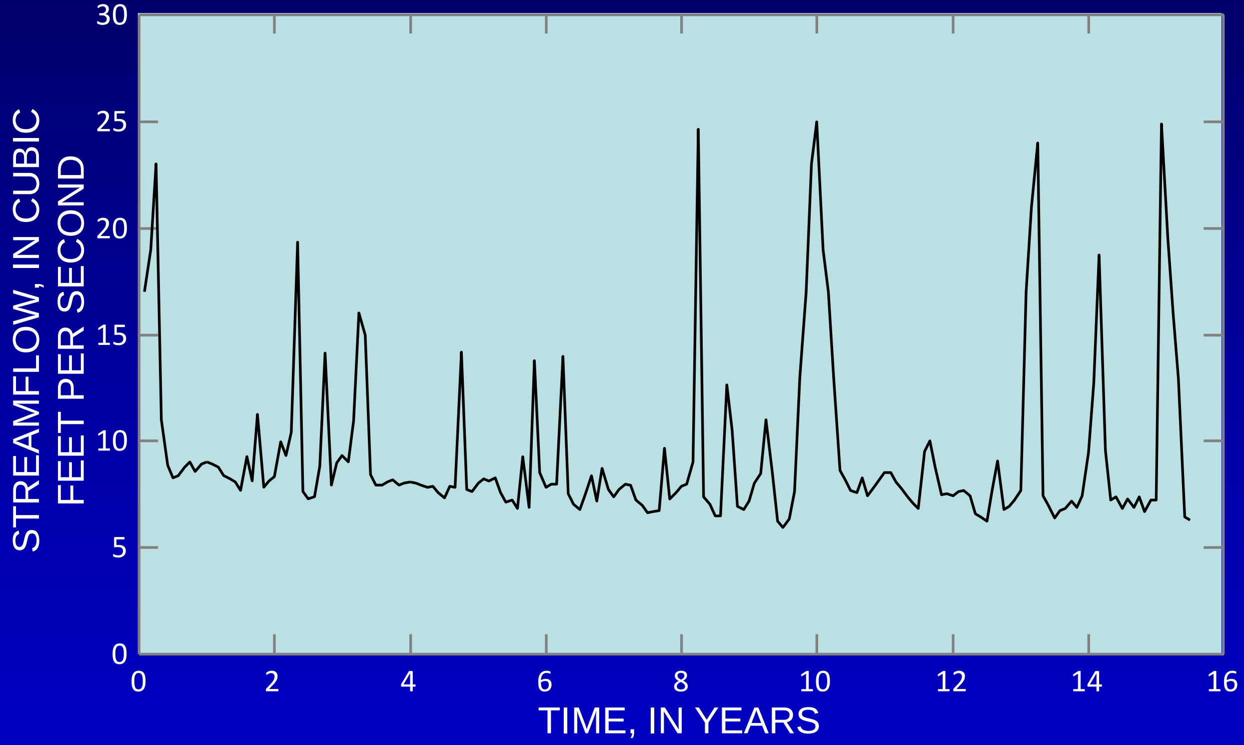
Effects of Artificial Recharge and Groundwater Pumping on a Stream Hydrograph

1. Hypothetical streamflow not affected by artificial recharge or groundwater pumping



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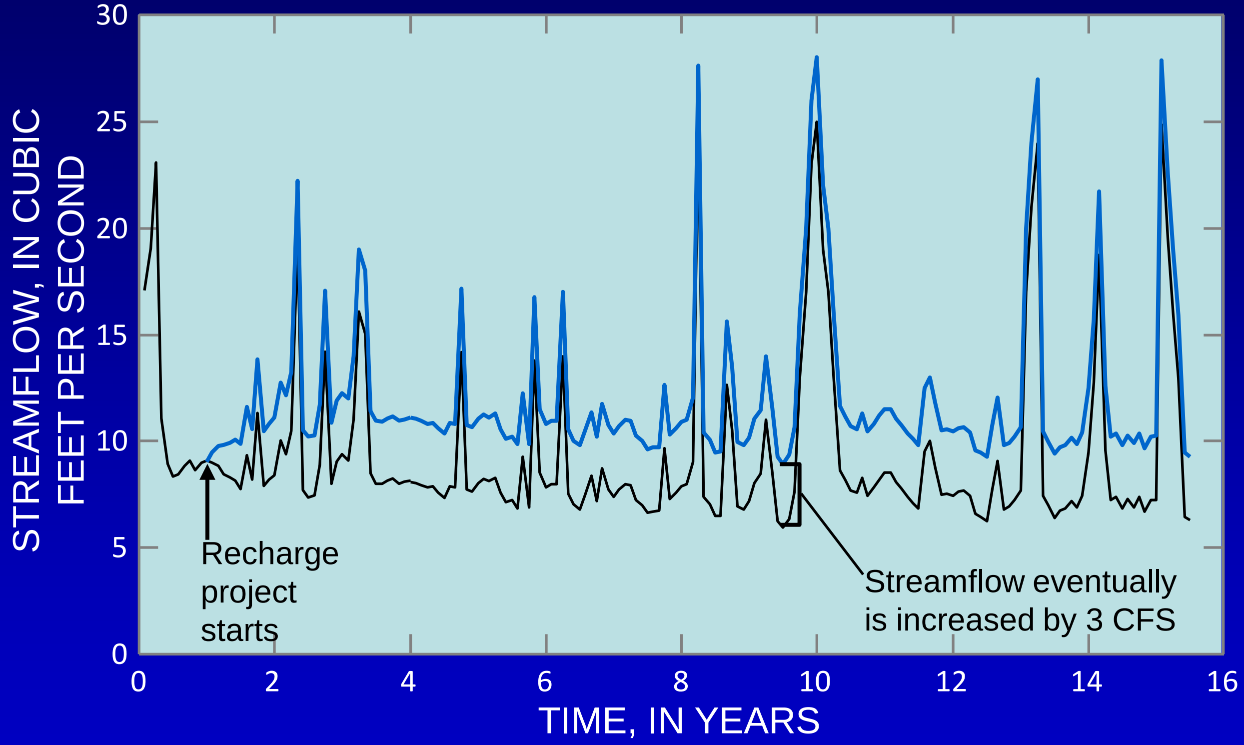
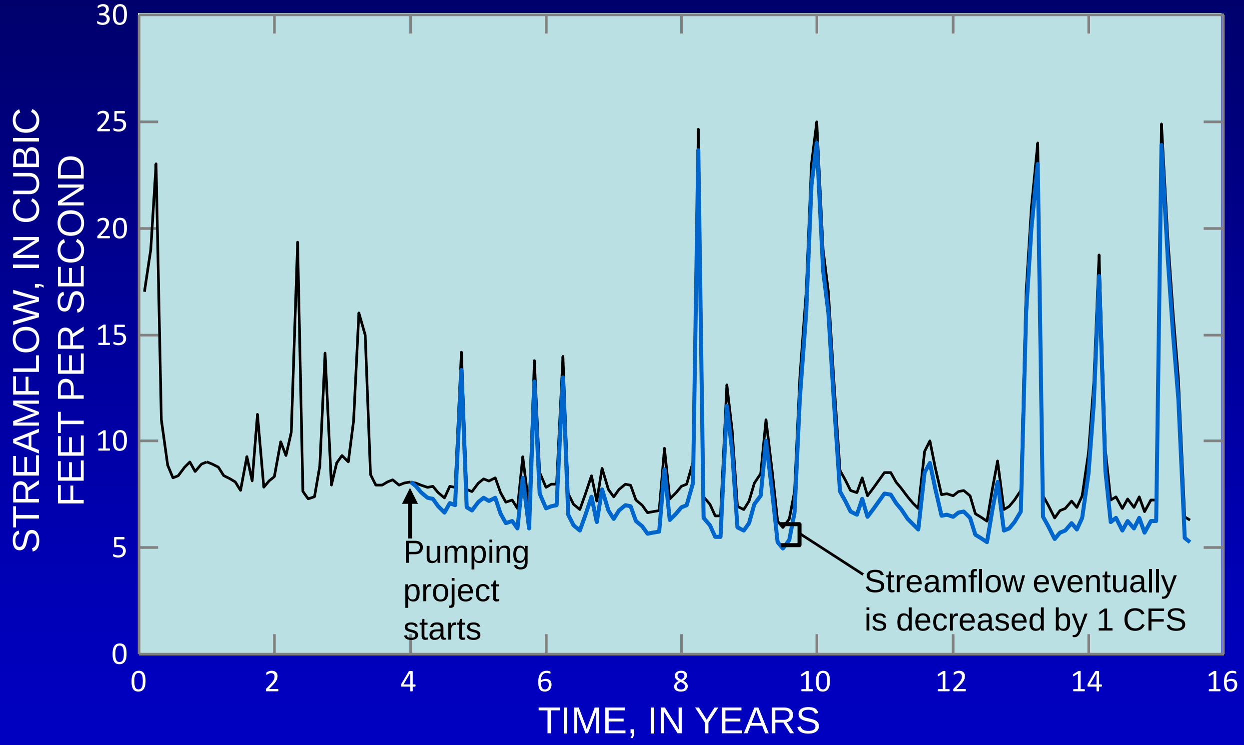
Effects of Artificial Recharge and Groundwater Pumping on a Stream Hydrograph

2. A nearby artificial recharge project of 3 CFS starts at time = 1 year



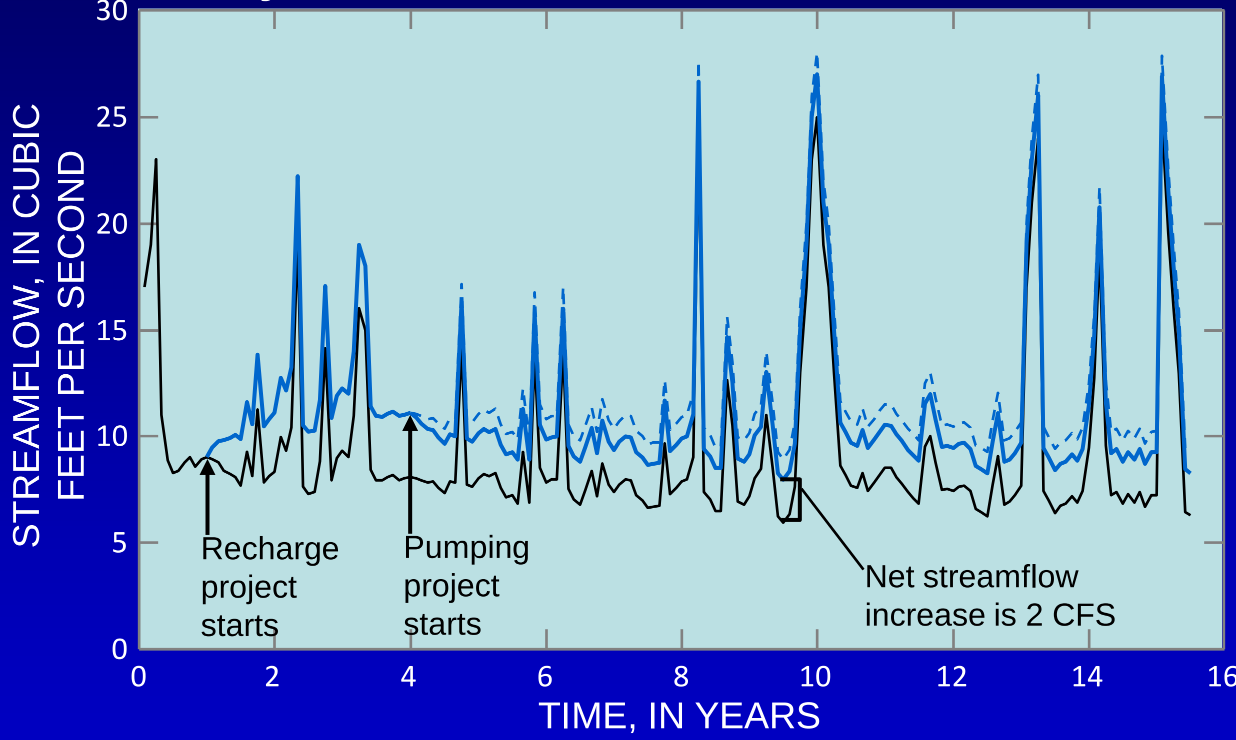
Effects of Artificial Recharge and Groundwater Pumping on a Stream Hydrograph

3. A nearby groundwater pumping project of 1 CFS starts at time = 4 years



Effects of Artificial Recharge and Groundwater Pumping on a Stream Hydrograph

4. Artificial recharge of 3 CFS begins at time = 1 year and groundwater pumping of 1 CFS begins at time = 4 years



Possible Factors for Mitigation of Streamflow Depletion

1. Artificial recharge of external water or water from within basin that would not have otherwise recharged the aquifer.

2. Capture of previously rejected recharge.

3. Return flow of some of the pumped groundwater.

How can we compute the timing of depletion from groundwater pumping?

1. Analytical solution

- used for regulatory purposes in Colorado and elsewhere
- assumes the stream or river is straight
- assumes the stream of river fully penetrates the aquifer
- does not consider properties of different aquifer layers

2. Groundwater-flow model

- used for regulatory purposes in Nebraska and elsewhere
- can consider complex river and aquifer geometry
- We have the newly developed Northern Arizona Regional Groundwater Flow Model that includes the Verde Valley sub-basin

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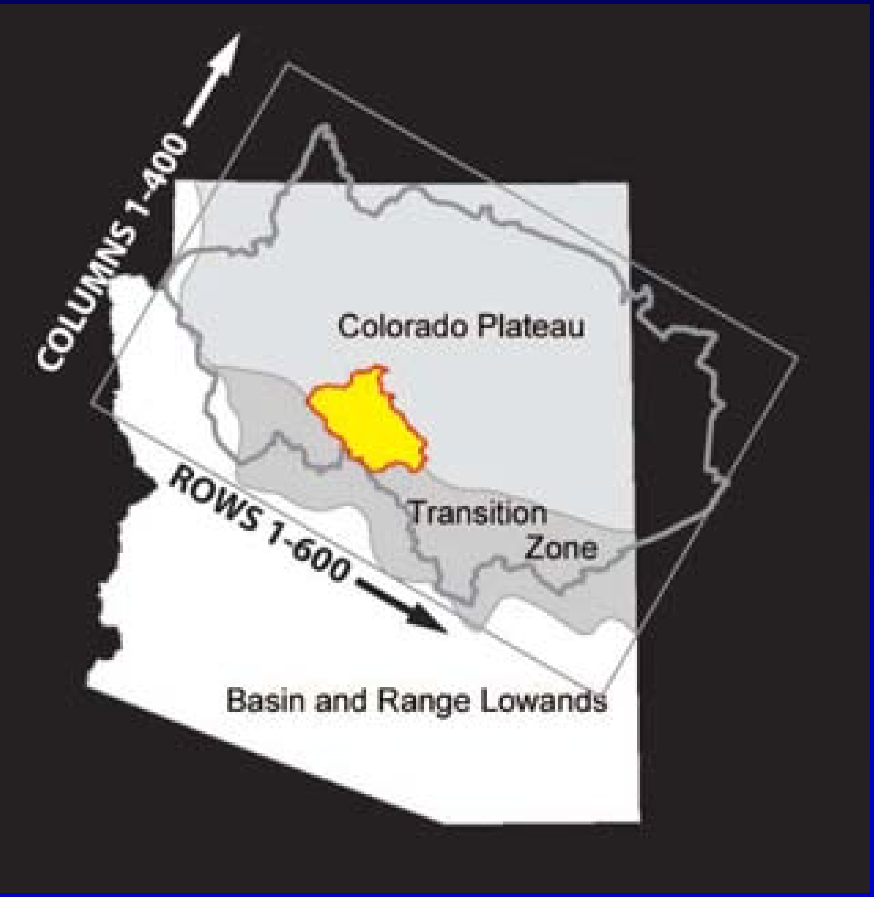
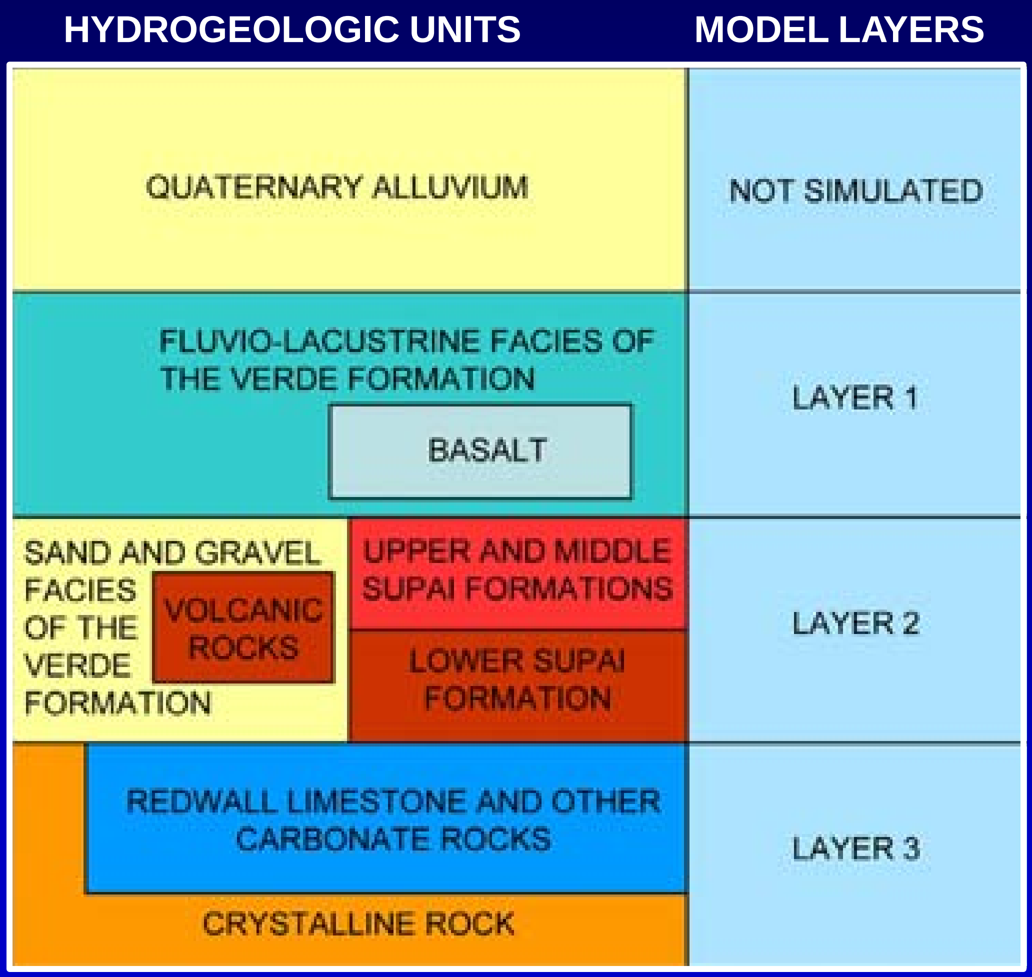
Northern Arizona Regional Groundwater Flow Model

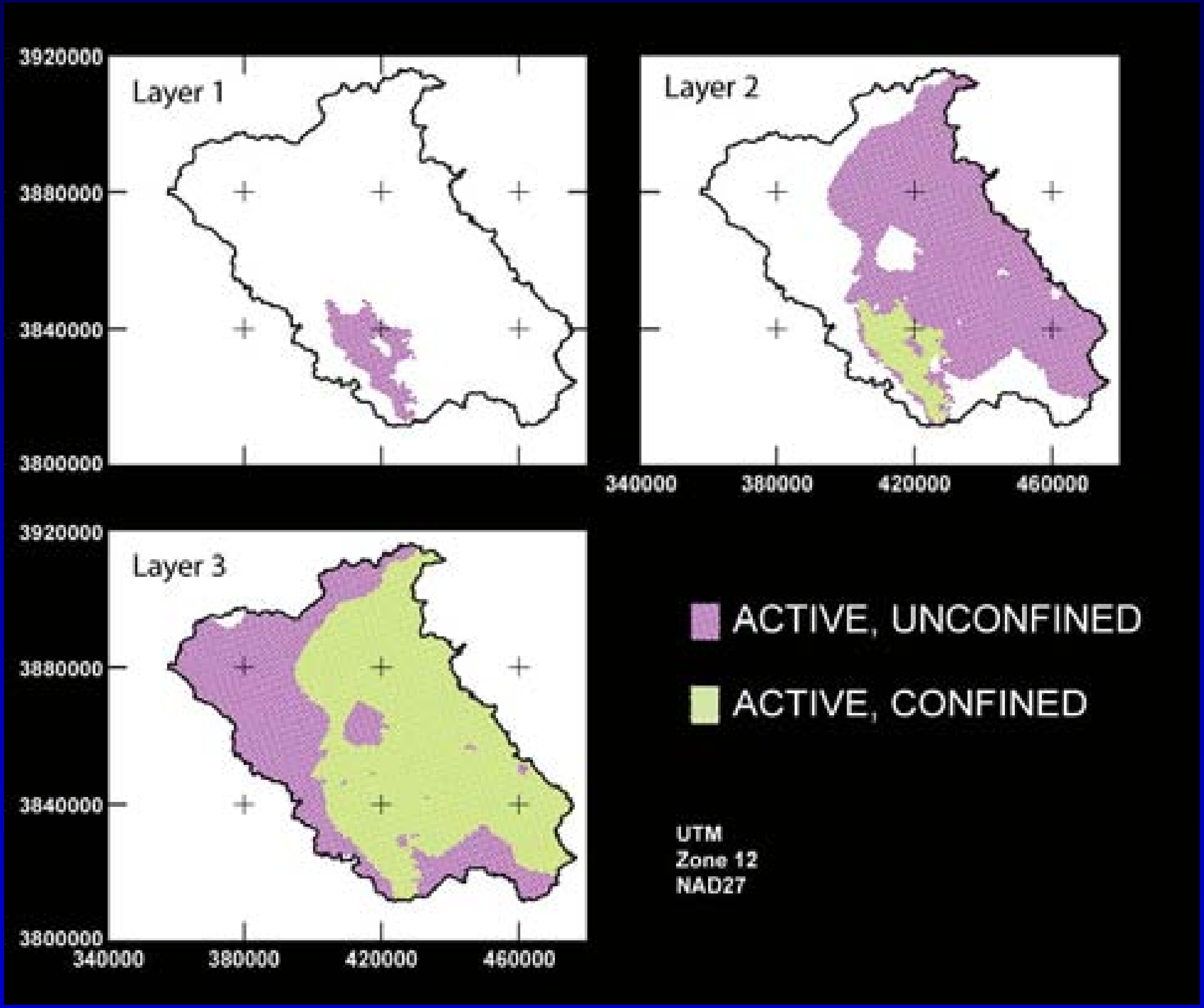


- 600 rows and 400 columns with 1-km grid spacing
- Three model layers representing different aquifer units
- Has no artificial boundaries
- Model report is “in press” and should be released soon

Flow Model in Study Area—hydrogeologic units



Flow Model in Study Area—active areas



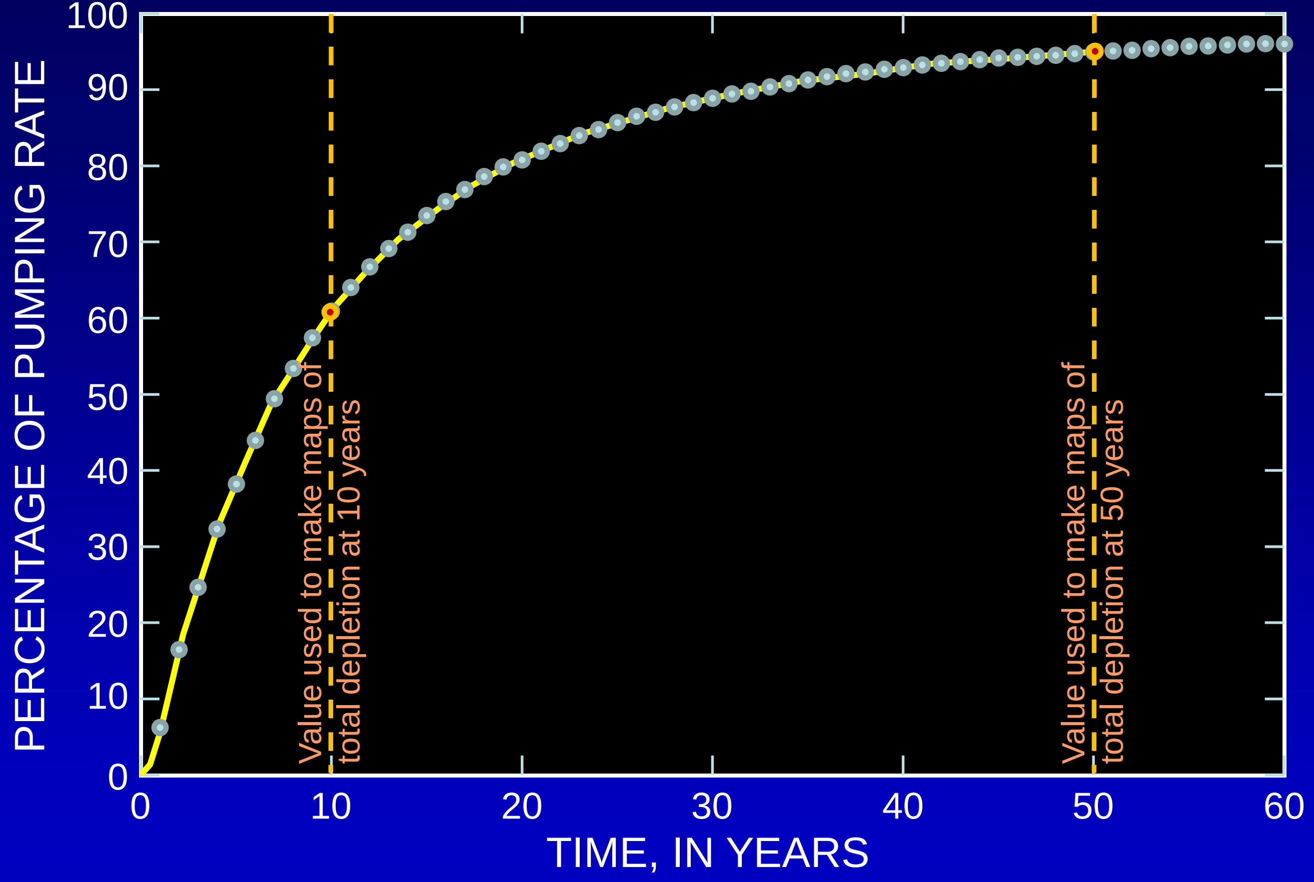
Main Products of Study

- Report with select results including maps of total depletion for pumping locations in layers 1 and 2 for pumping times of 10 and 50 years

- A USGS fact sheet that shows main maps with explanations for less technical readers

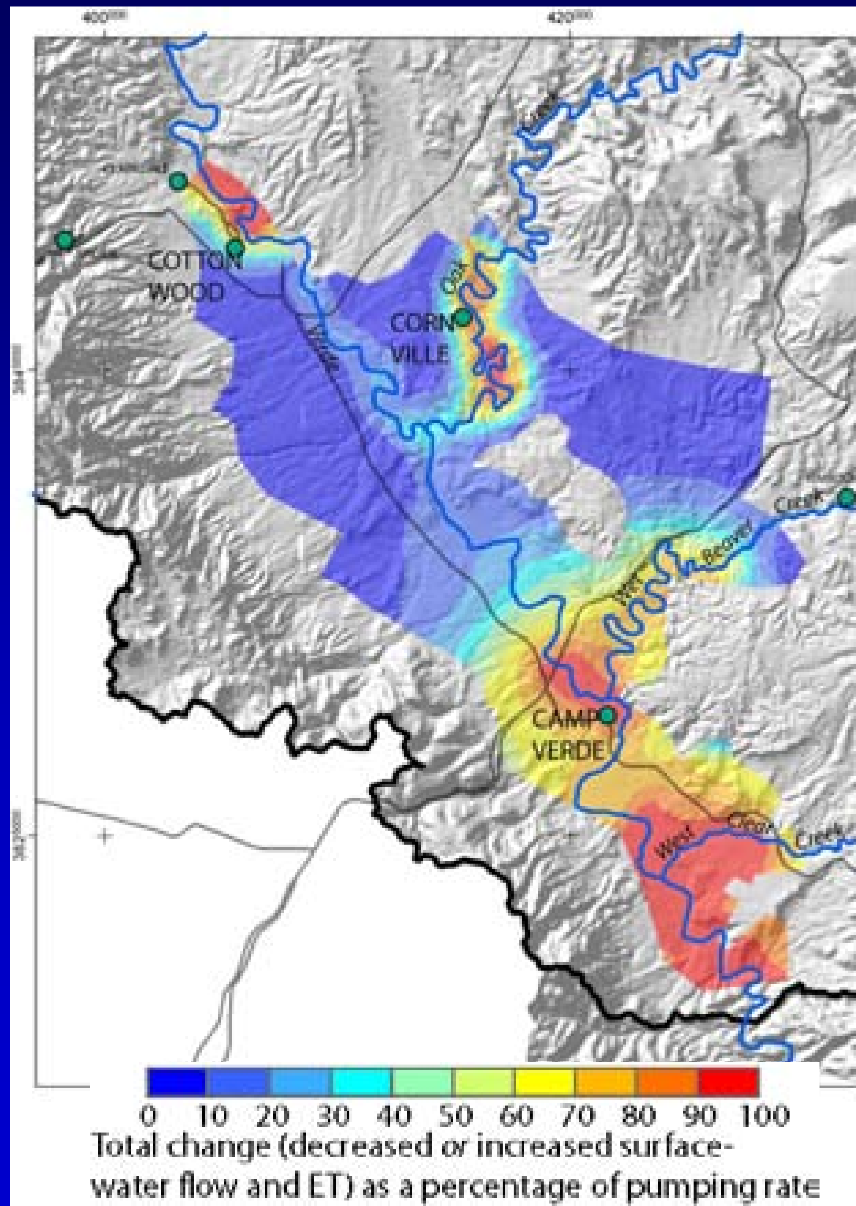
- "Response functions" that can be used to make other maps or to compute effects of more complicated pumping and recharge scenarios

What is a response function?

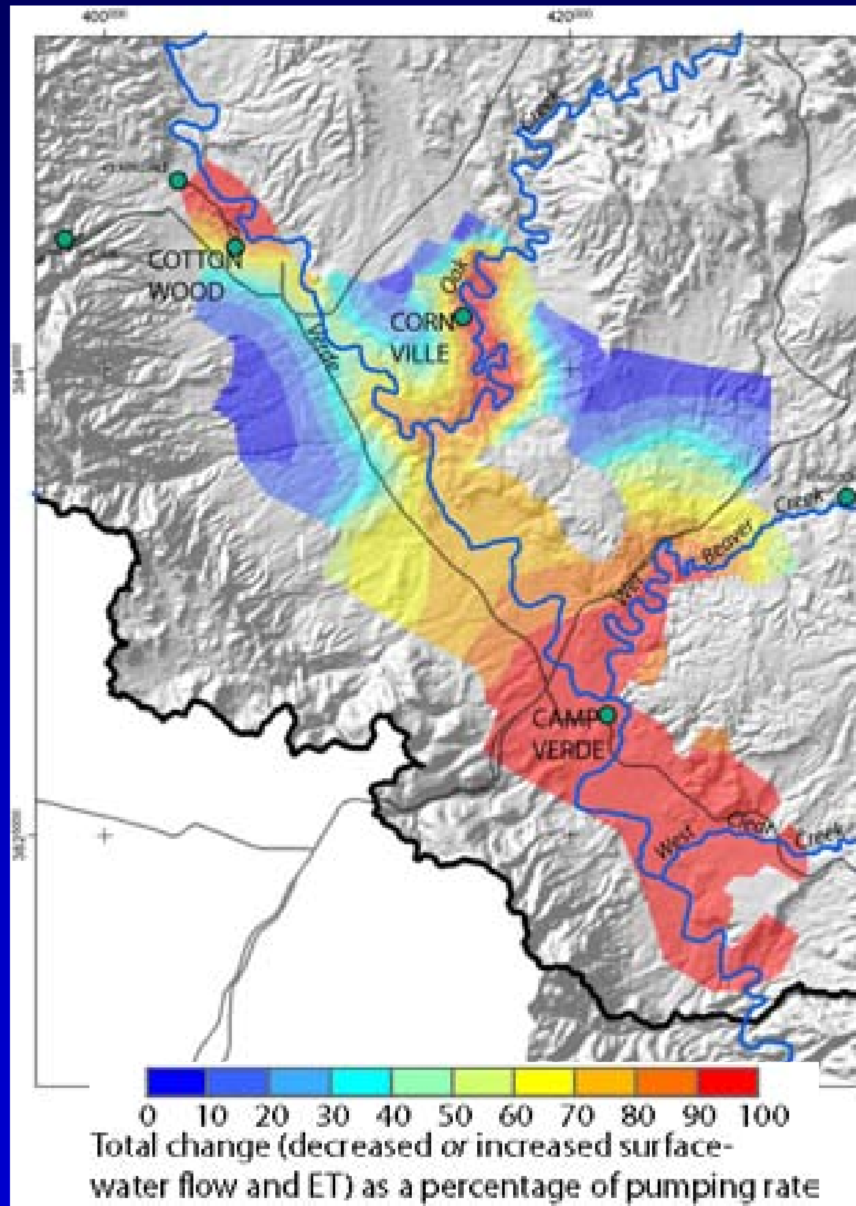


Each transient response function for total depletion consists of depletion percentages for years 1-100. A separate response function exists for each pumping location.

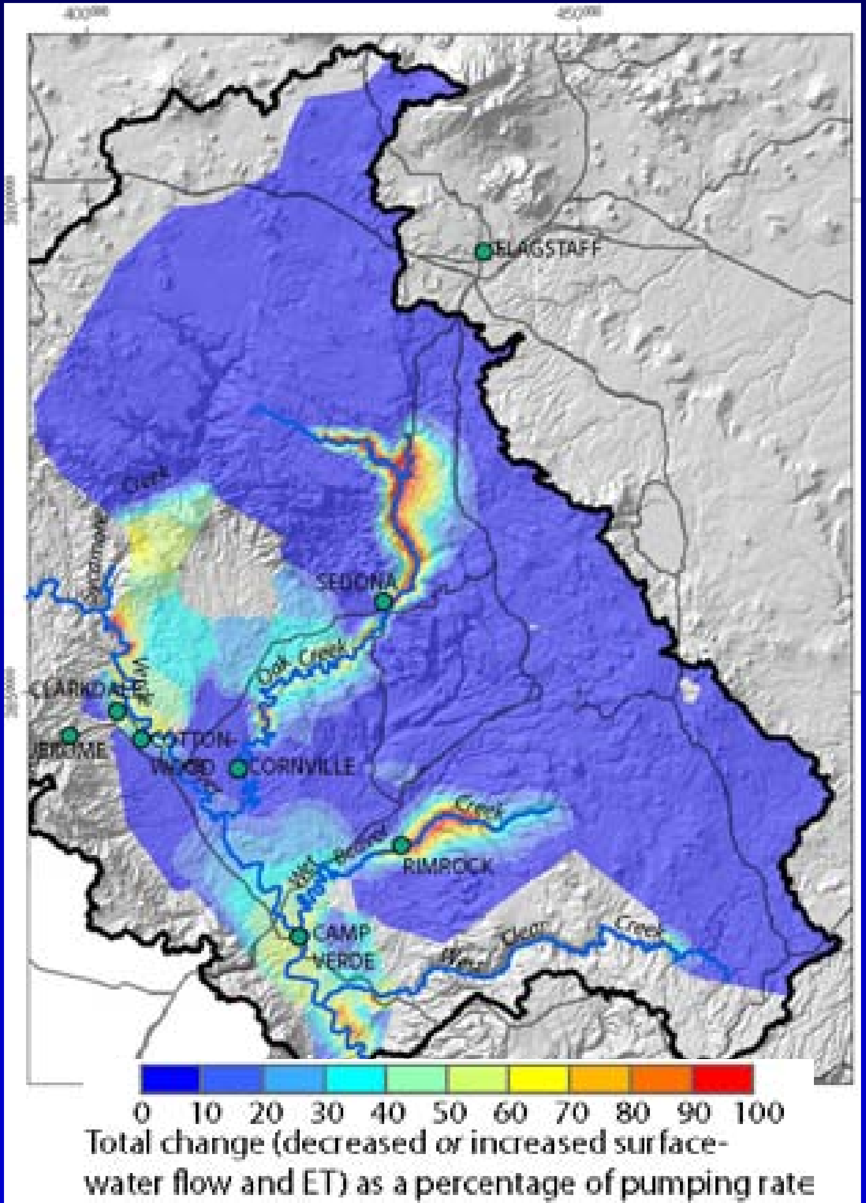
Application for Verde Watershed—response at 10 years, layer 1



Application for Verde Watershed—response at 50 years, layer 1



Application for Verde Watershed—response at 10 years, layer 2



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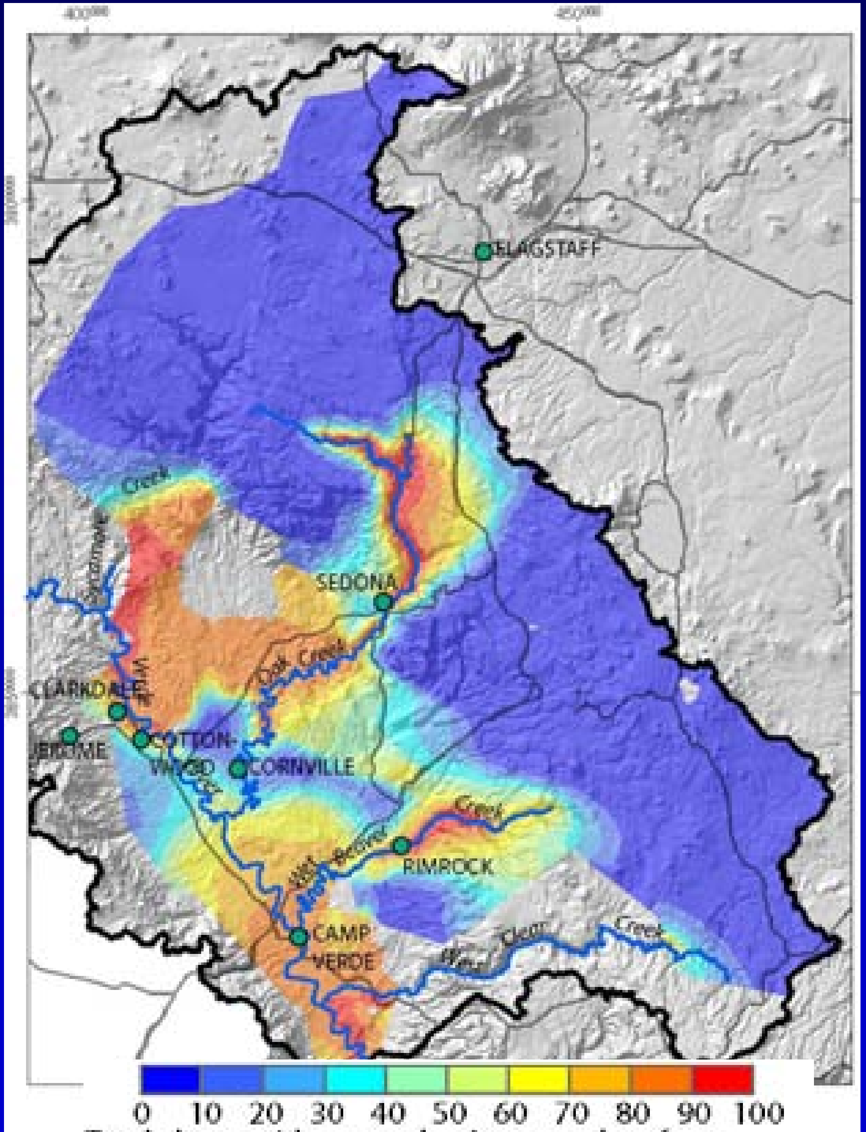
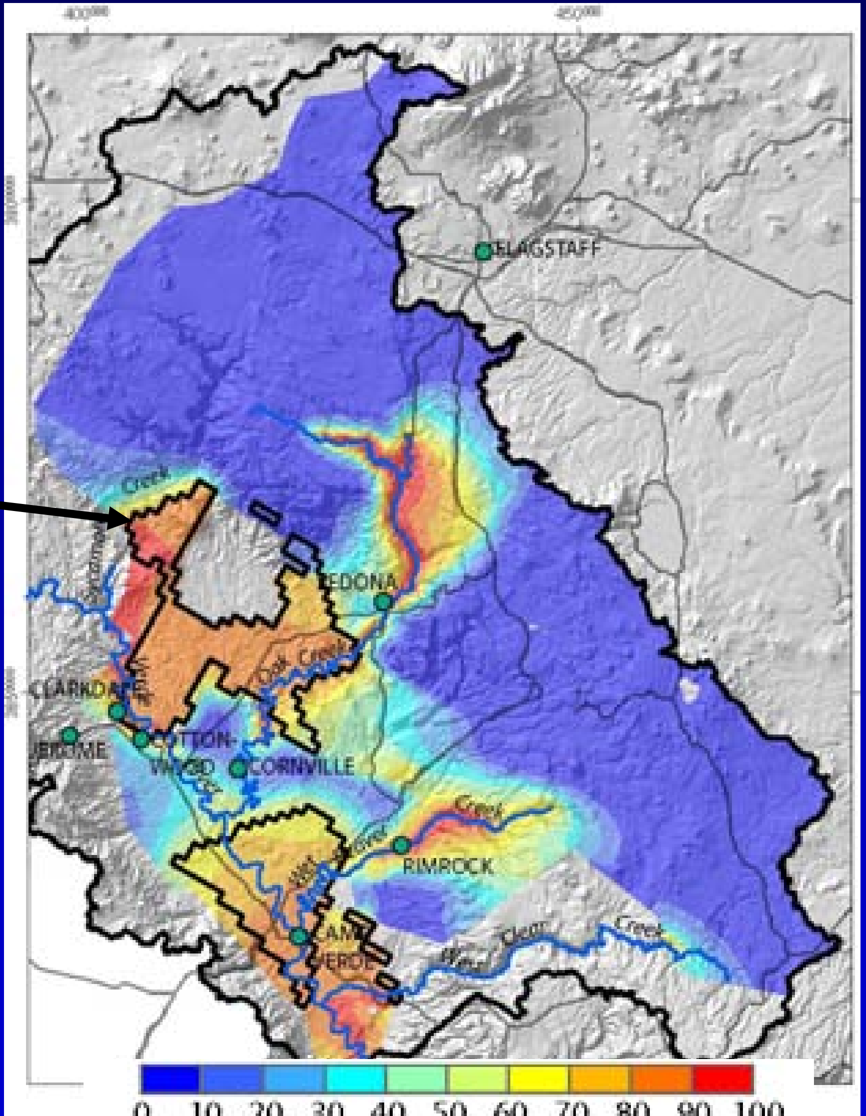


Total change (decreased or increased surface-water flow and ET) as a percentage of pumping rate

Application for Verde Watershed—depletion at 50 years, layer 2

Areas where aquifer hydraulic conductivity in the model is the highest



Total change (decreased or increased surface-water flow and ET) as a percentage of pumping rate

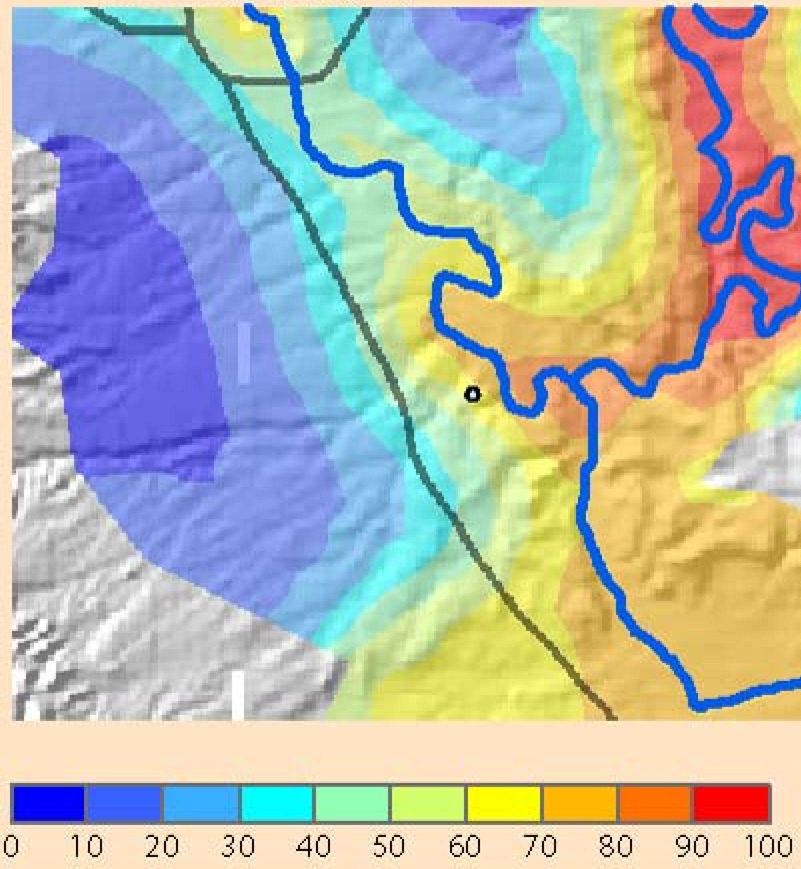
EXAMPLE USE OF MAPS TO CALCULATE DEPLETION FOR A SINGLE WELL

Well pumps an average of 10 acre-feet per year from the upper part of the Verde Formation for 50 years

Step 1-Select the right map

- Use figures 4a and 4b for wells open in the upper part of the Verde Formation.
- Use figures 5a and 5b for wells open in the lower part of the Verde Formation, the Supai Group, and volcanic rocks.

Part of map showing depletion in model layer 1 (the upper part of the Verde Formation) at a pumping time of 50 years (fig. 4b)



Total depletion (reduced flow and evapotranspiration) as a percentage of pumping rate

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Step 2-Find the location of the well on the map

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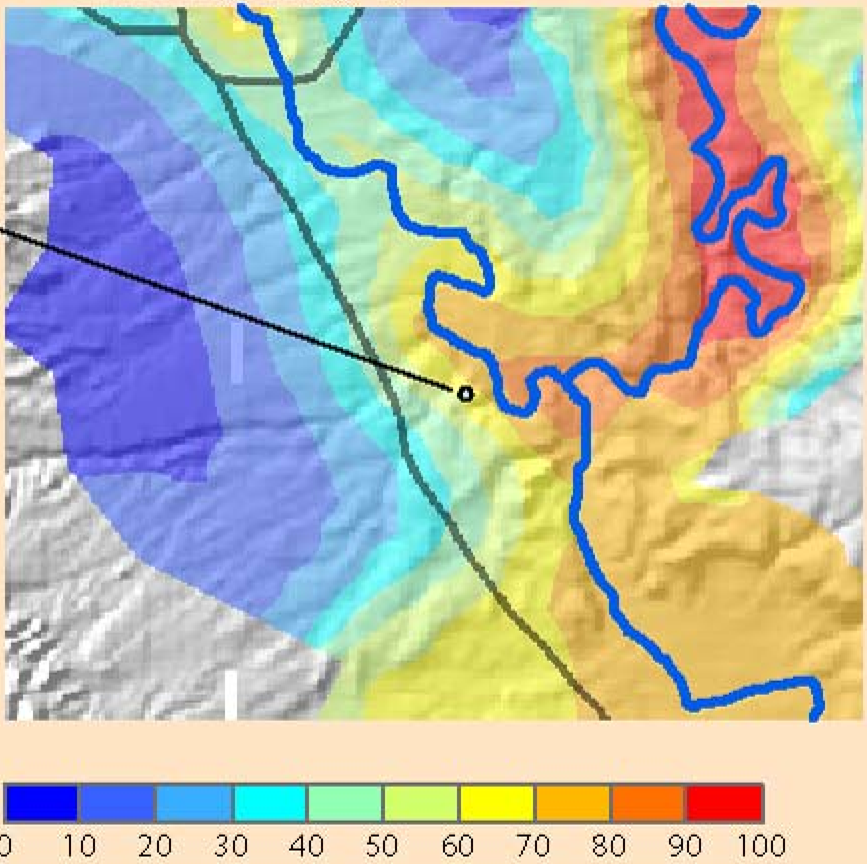

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In this example the range is 60 to 70 percent.

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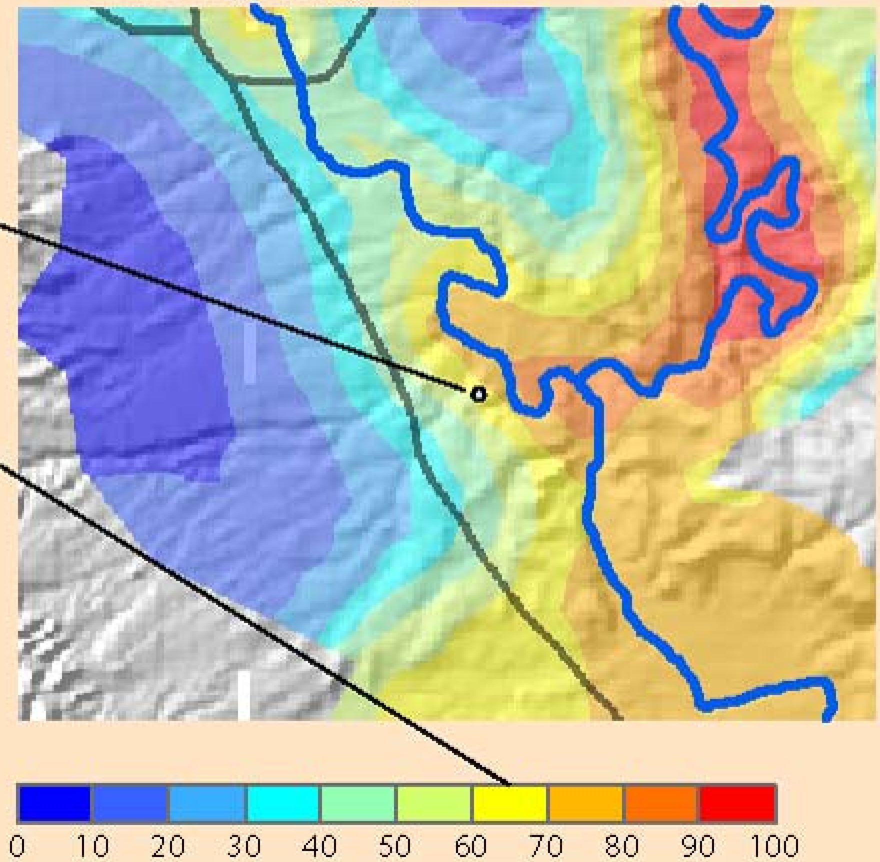

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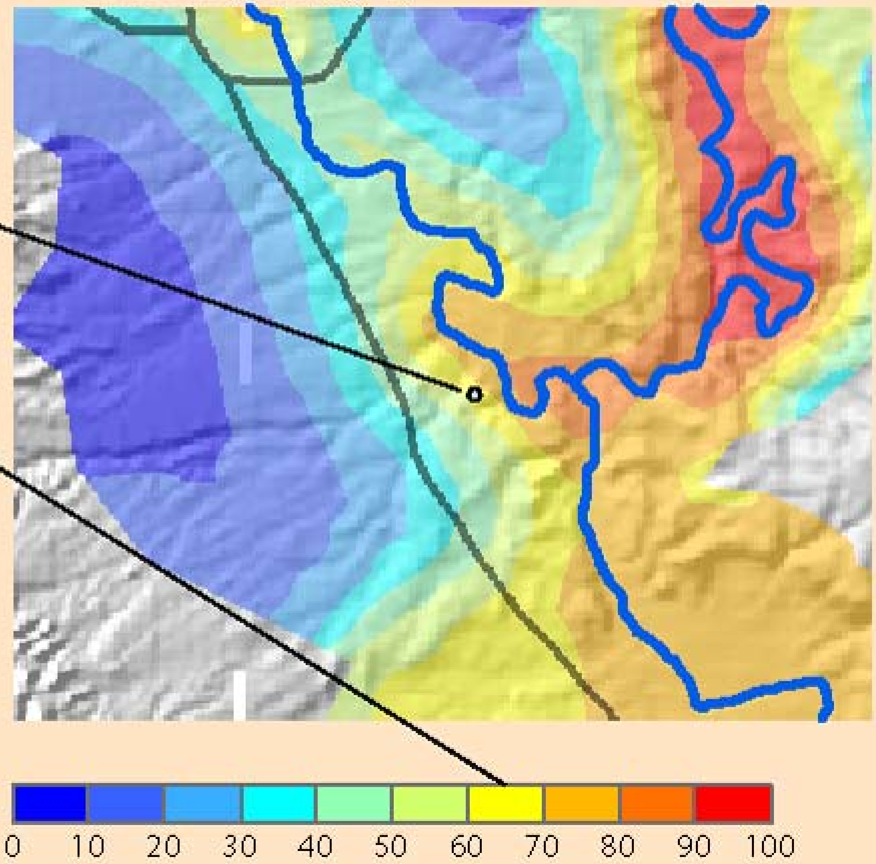
In this example the range is 60 to 70 percent.

Step 4-Multiply corresponding fraction for color range by average well pumping rate to get average depletion rate

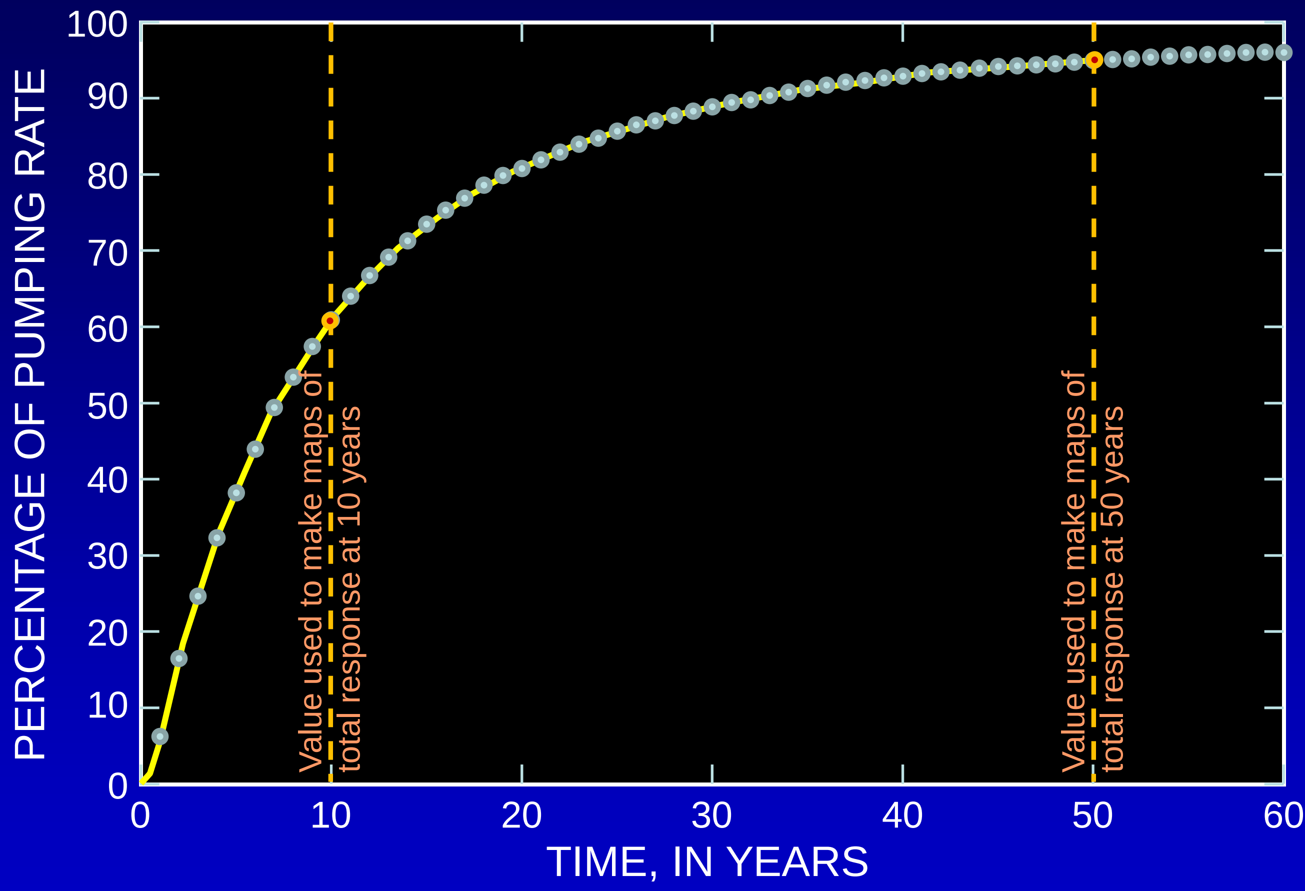
For the depletion range of 60 to 70 percent in this example, use a fraction of 0.65. Calculation is 0.65 x 10 acre-feet per year = 6.5 acre-feet per year of depletion at a pumping time of 50 years.

Part of map showing depletion in model layer 1 (the upper part of the Verde Formation) at a pumping time of 50 years (fig. 4b)



Total depletion (reduced flow and evapotranspiration) as a percentage of pumping rate

What is a response function?



Each transient response function for total decrease or increase in streamflow consists of percentages of pumping or recharge rate for years 1-100. A separate response function exists for each location.

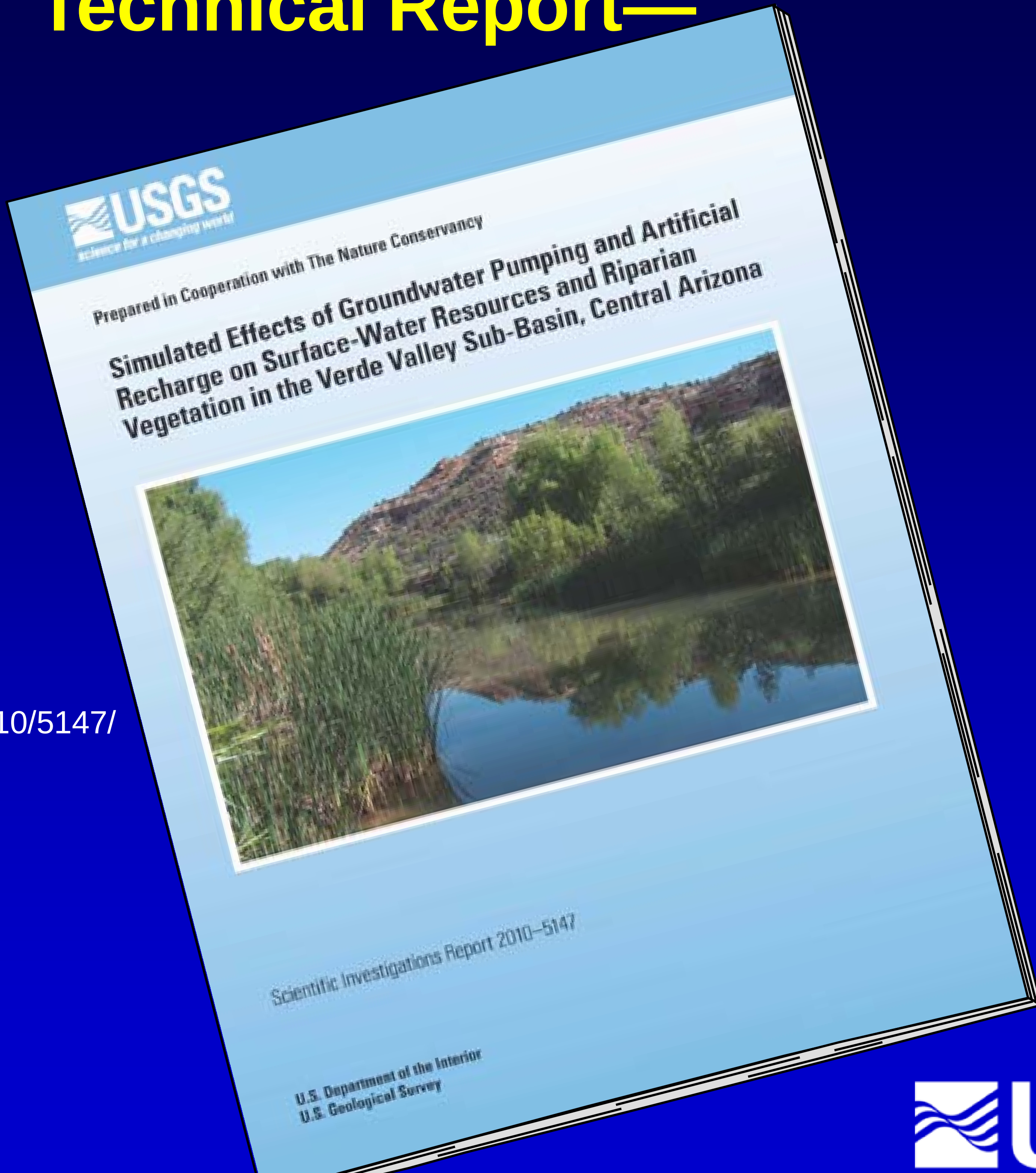
Possible uses of response functions

Calculations of streamflow decrease or increase

- for times and locations (i.e. layer 3) not shown in report
- in select stream segments (transient or steady-state)
- from a well pumping at a variable rate, including intermittent pumping
- from multiple wells pumping at different locations and rates (an alternative to running the model for pumping scenarios)

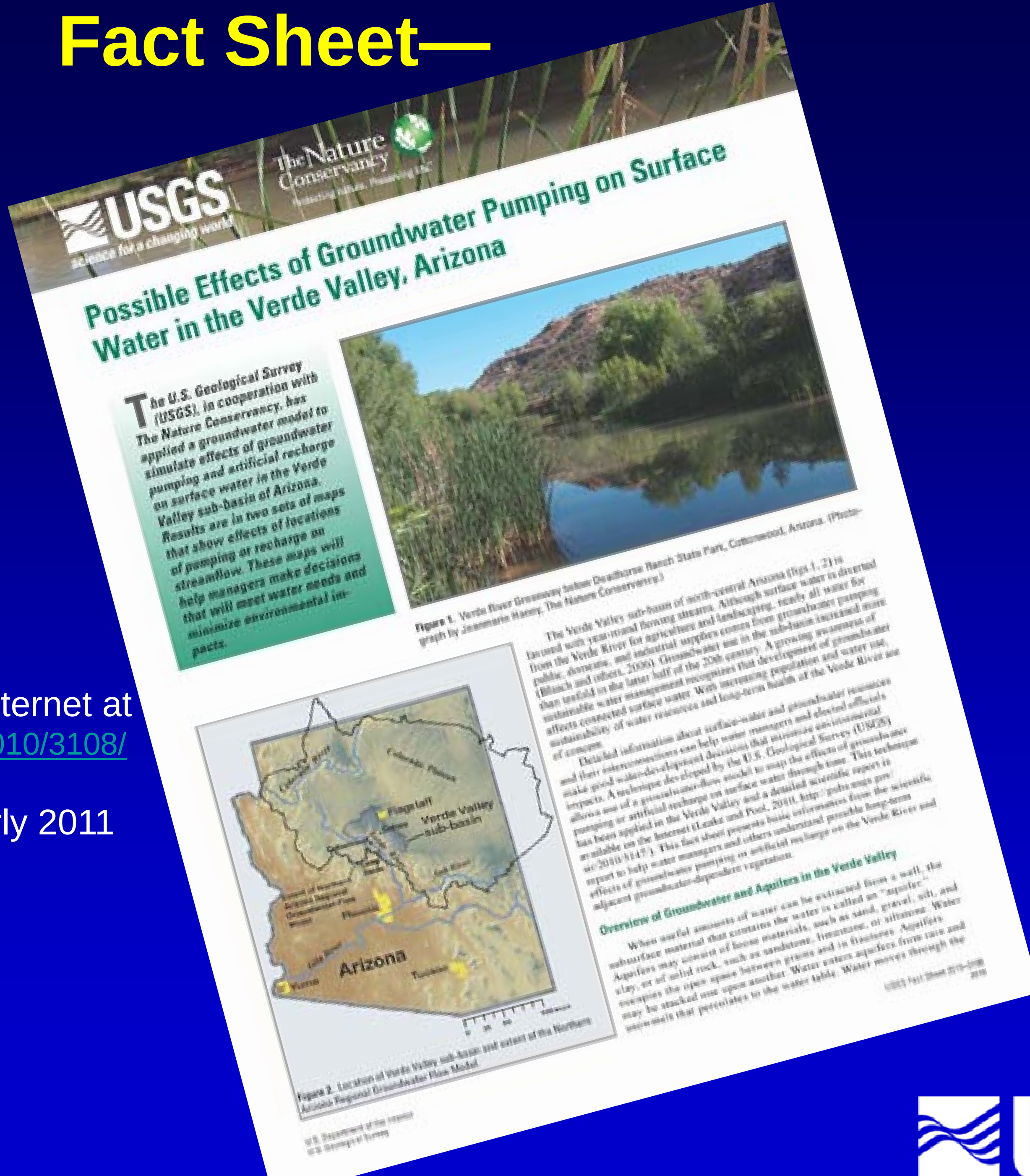
Note: these applications assume reasonably linear behavior

Technical Report—



On the internet <u>only</u> at
http://pubs.usgs.gov/sir/2010/5147/

Fact Sheet—



To be posted on the internet at
http://pubs.usgs.gov/fs/2010/3108/

—will be printed in early 2011