

Verde Integrated Surface and Groundwater Modeling



Stakeholder Workshop #5

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Presented by

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 Lacher Hydrological Consulting

Southwest
Decision
Resources 

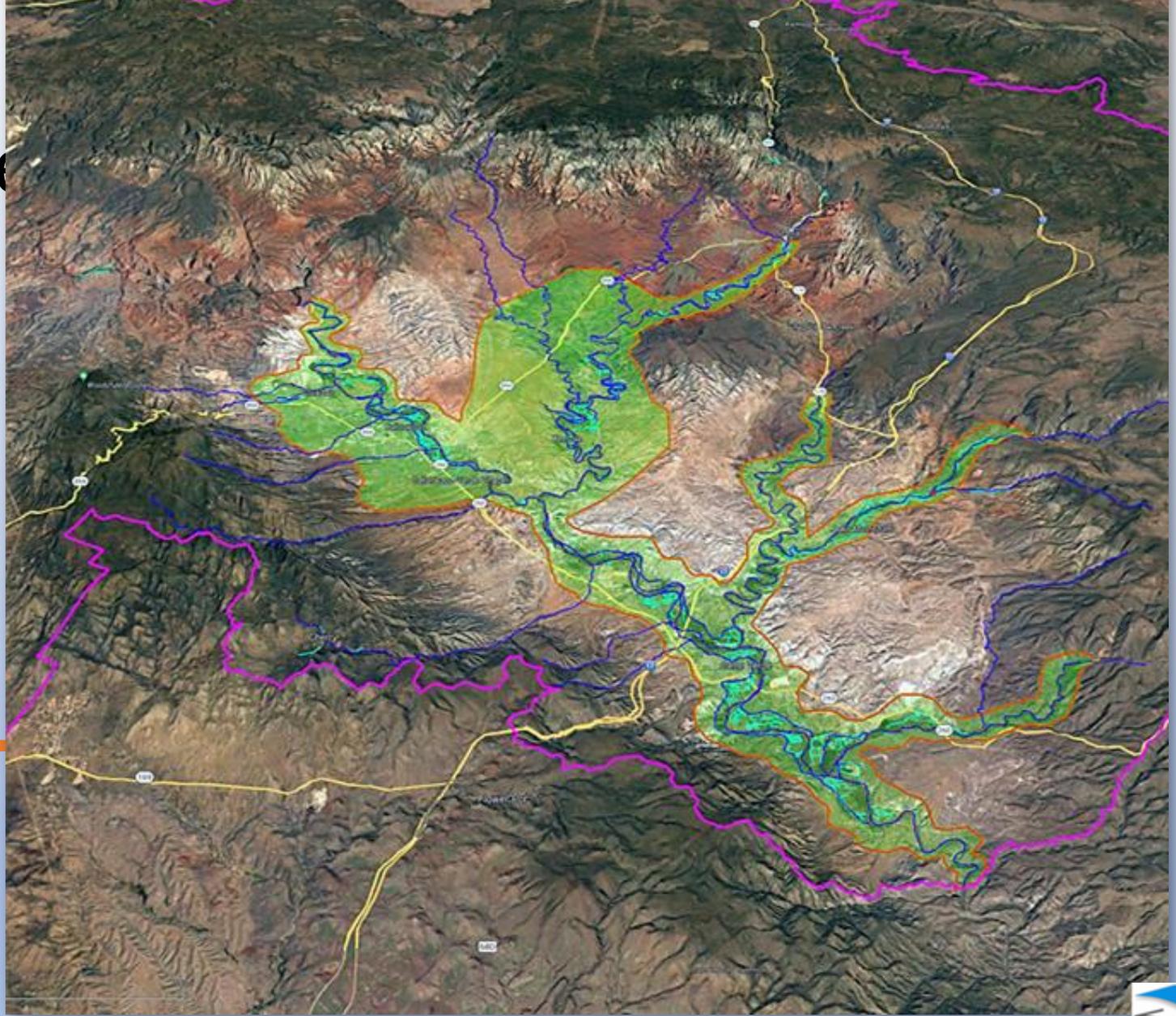

INTEGRATED HYDRO SYSTEMS, LLC

**The results presented today are preliminary
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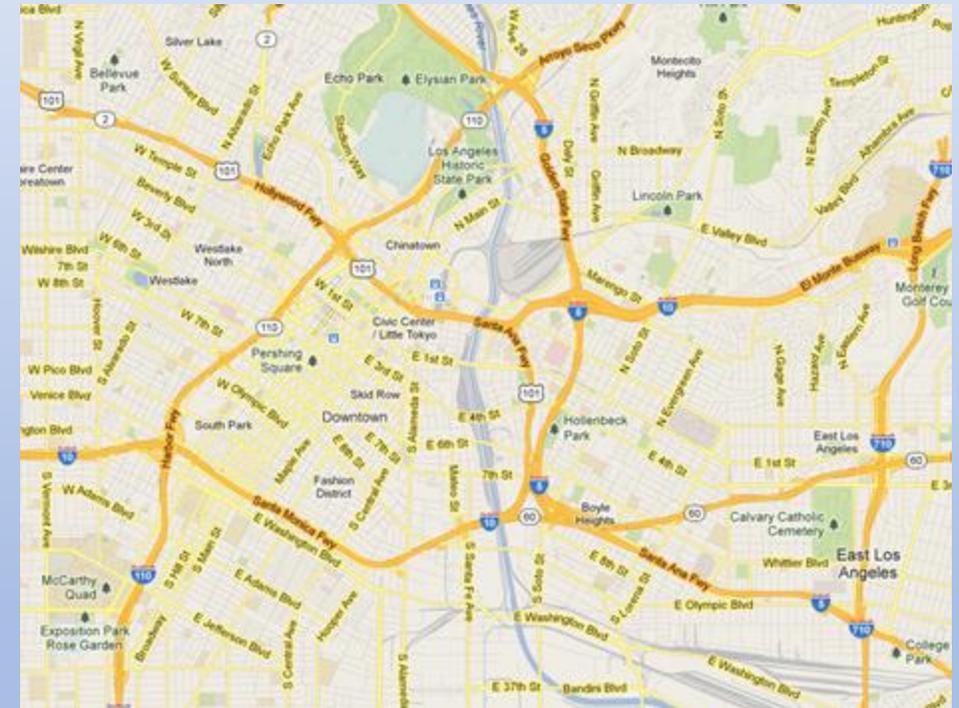
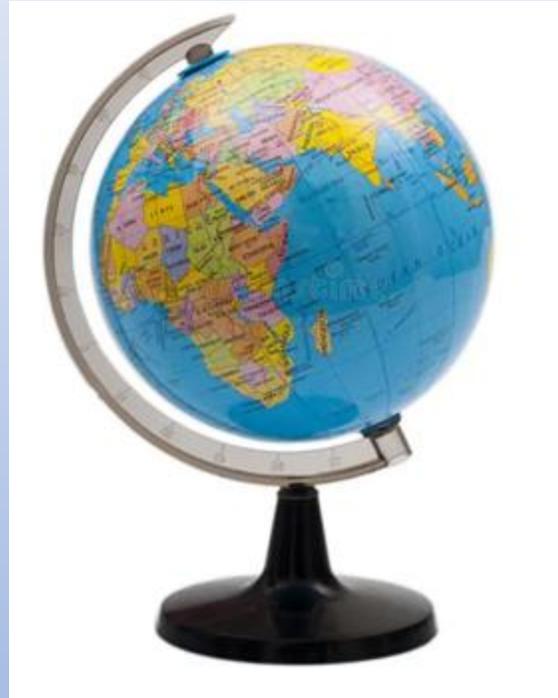
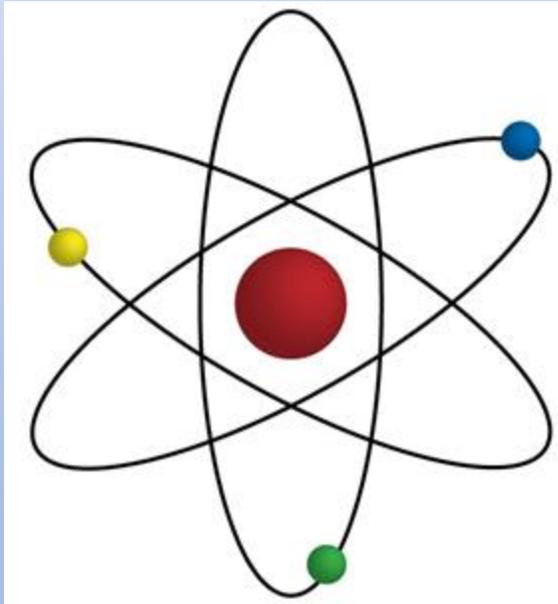
Review of Verde Valley-Oak Creek Integrated Hydrologic Model

MIKESHE

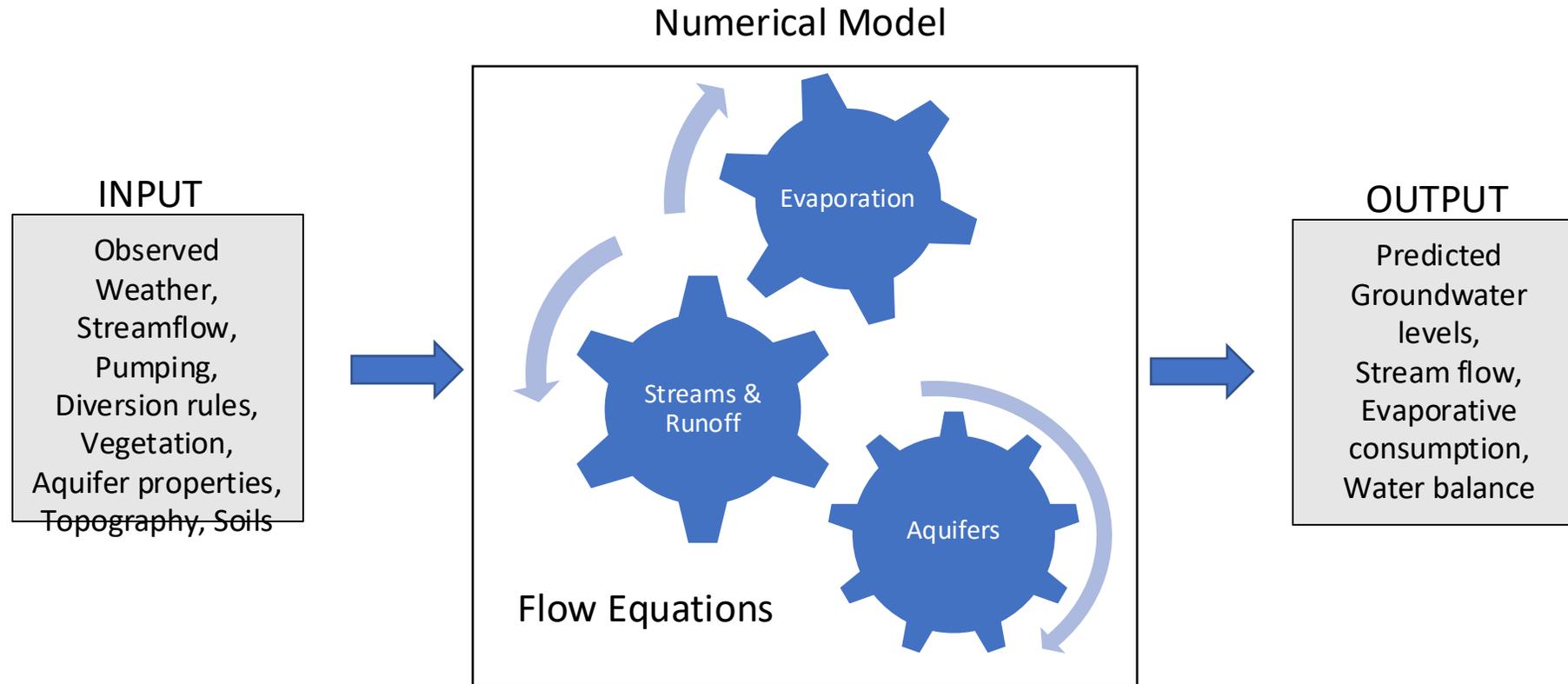


MODEL: A Description or Analogy Used to Help Visualize Something that Cannot be Directly Observed.

-- Merriam-Webster Dictionary definition no. 11

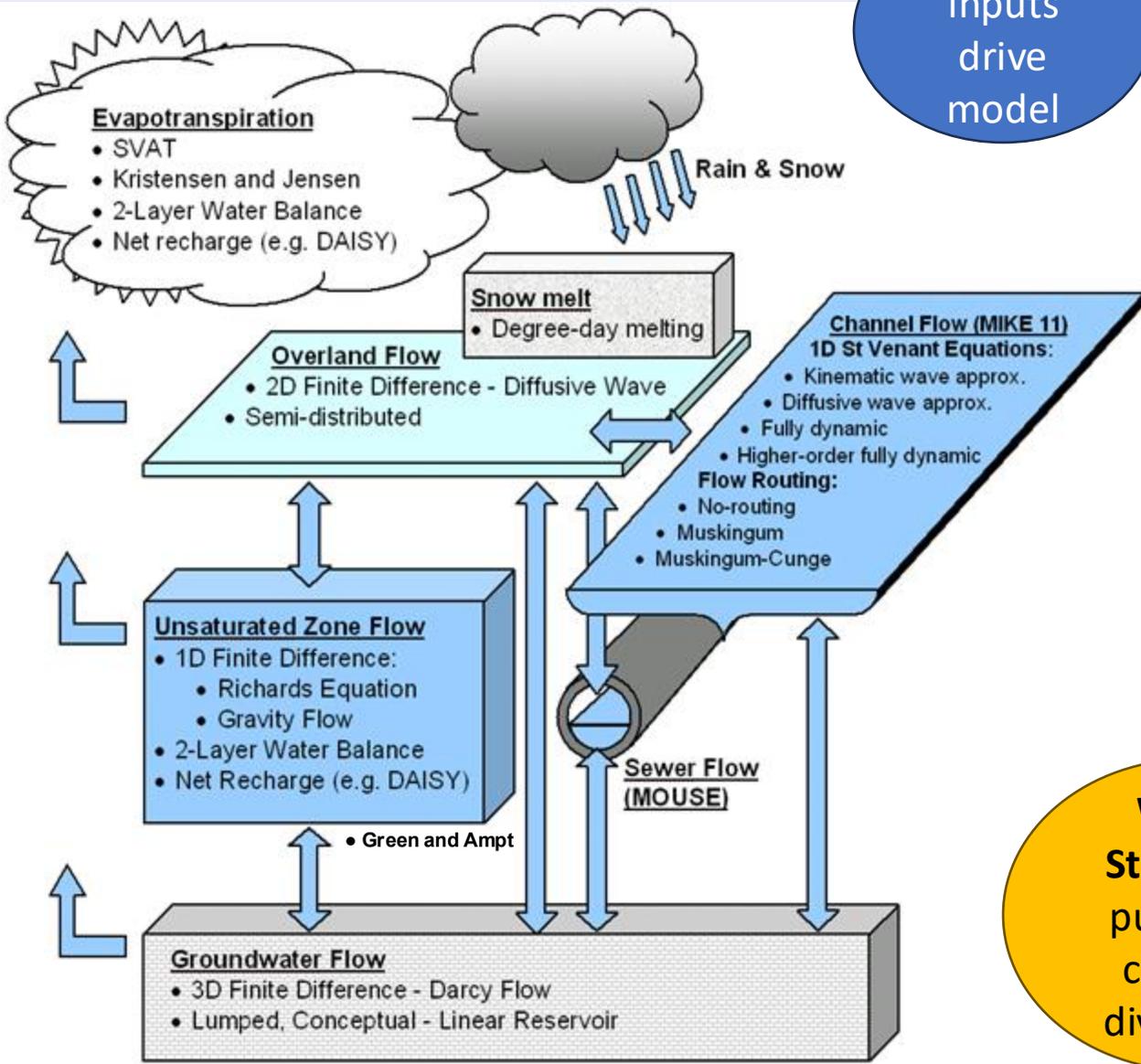


HYDROLOGIC MODEL: A Computer Program that Uses Flow Equations to Make Sense of a Complex Natural System.

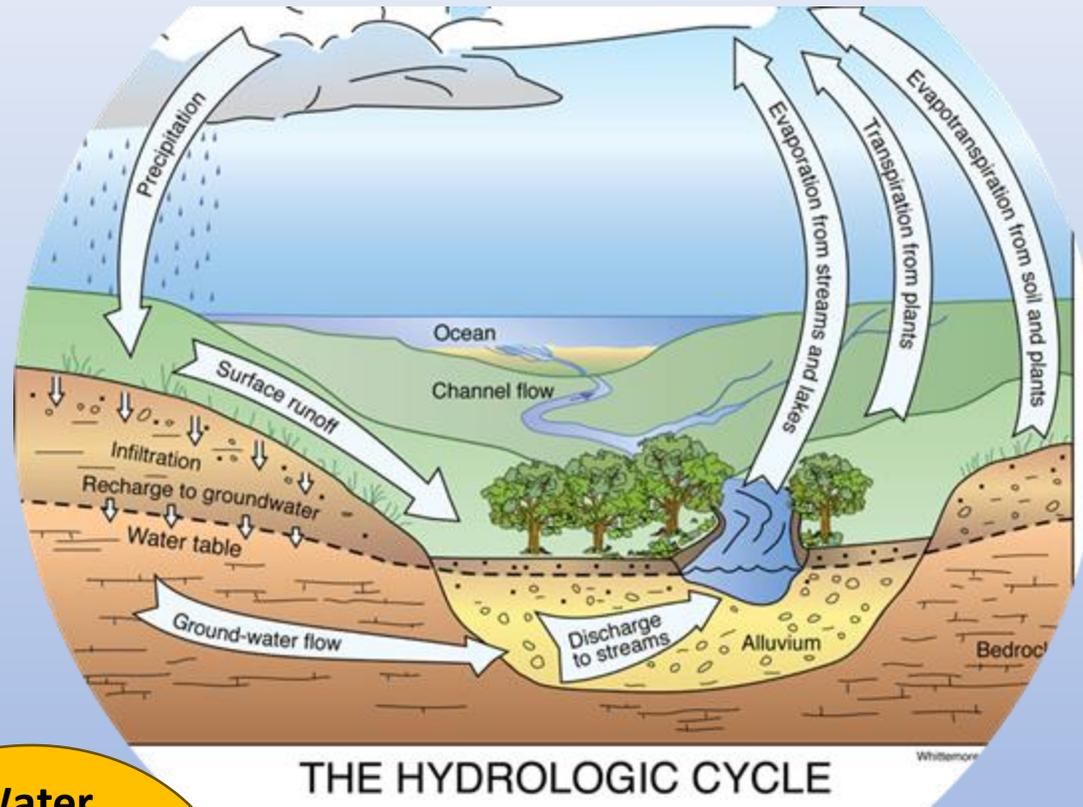


MIKESHE Model

Weather inputs drive model

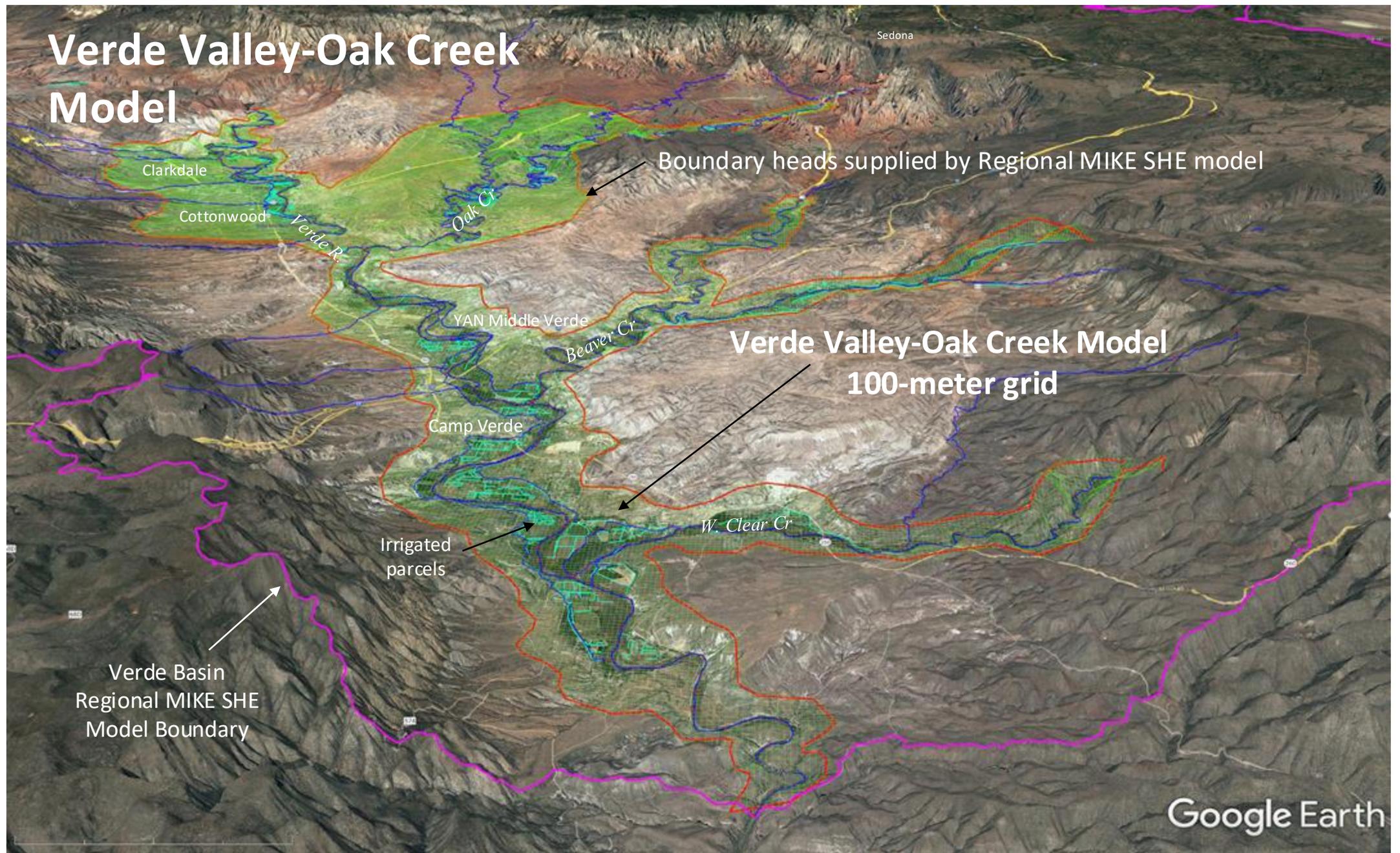


Represents Entire Hydrologic Cycle



Water Stressors:
pumping,
climate,
diversions

Verde Valley-Oak Creek Model



How are Water Conservation and Water Stress Represented in the Model?

Water Stressor:
action that depletes water in natural system

Conservation Measure	Model Representation
Reclaimed water reuse	Less groundwater pumping; less reclaimed water recharge
Low-water plumbing fixtures	Less groundwater pumping
Rainwater harvesting	Less groundwater pumping
Recharge well or basin	Increased groundwater recharge
Xeriscape landscaping	Less groundwater pumping
Stormwater catchments	Increased groundwater recharge; decreased storm runoff

Recharge is infiltrated water that makes it to aquifer

Evapotranspiration = water used by plants + evaporation



Six Model Scenarios in 3 Categories

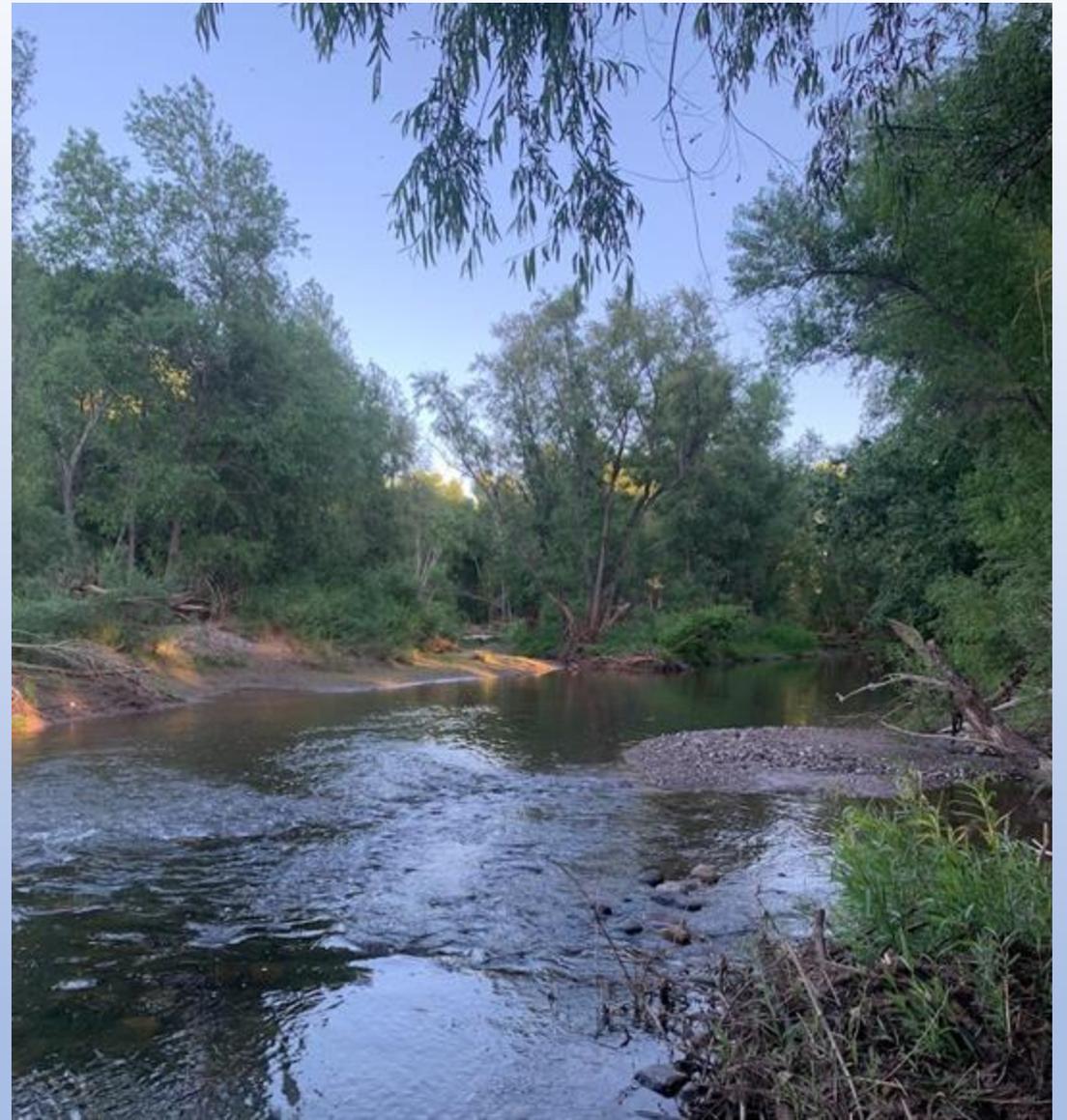
Scenario Category	Scenario Name and Number		
Population/Water-use Growth	Growth (#1)	Growth with Conservation (#2)	Higher Growth (#4)
Reduced Verde Flows	50% Verde Flow at Clarkdale Gage (#5)		
Climate Change	Moderate Climate Change (#3)	Hot and Dry Future Climate (#6)	

System Water Stress





Scenarios



Population Growth Scenarios

Assumptions:

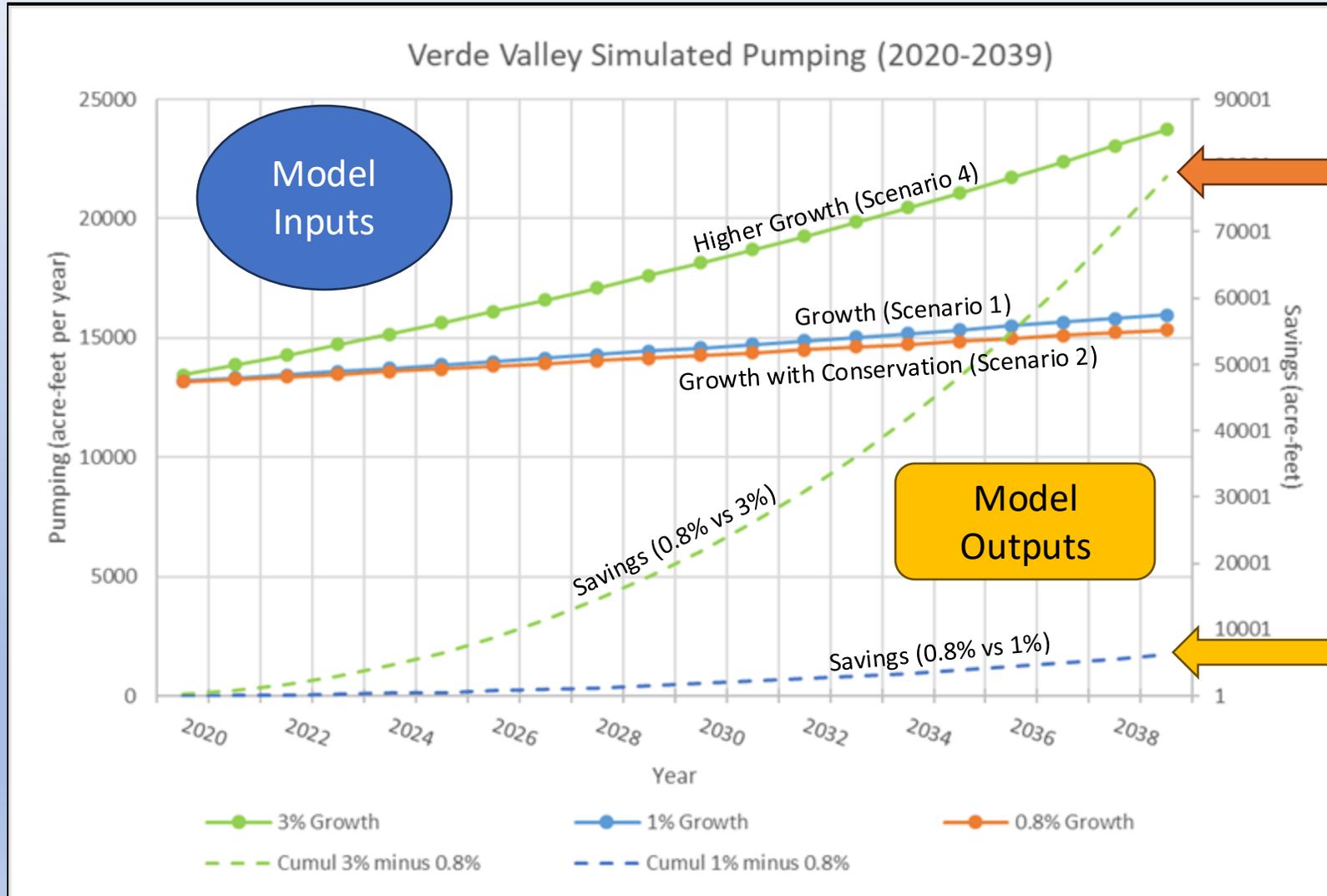
- Water use grows at same rate as population for 20 years
- Water use patterns remain constant over time (no change in farms or golf courses)
- No change in climate or other external stresses
- Future pumping and recharge occur at existing wells and recharge sites

Scenarios:

1. Growth (1% per year)
2. Growth with Conservation (0.8% per year)
4. Higher Growth Rate (3% per year)



Population Growth Scenarios



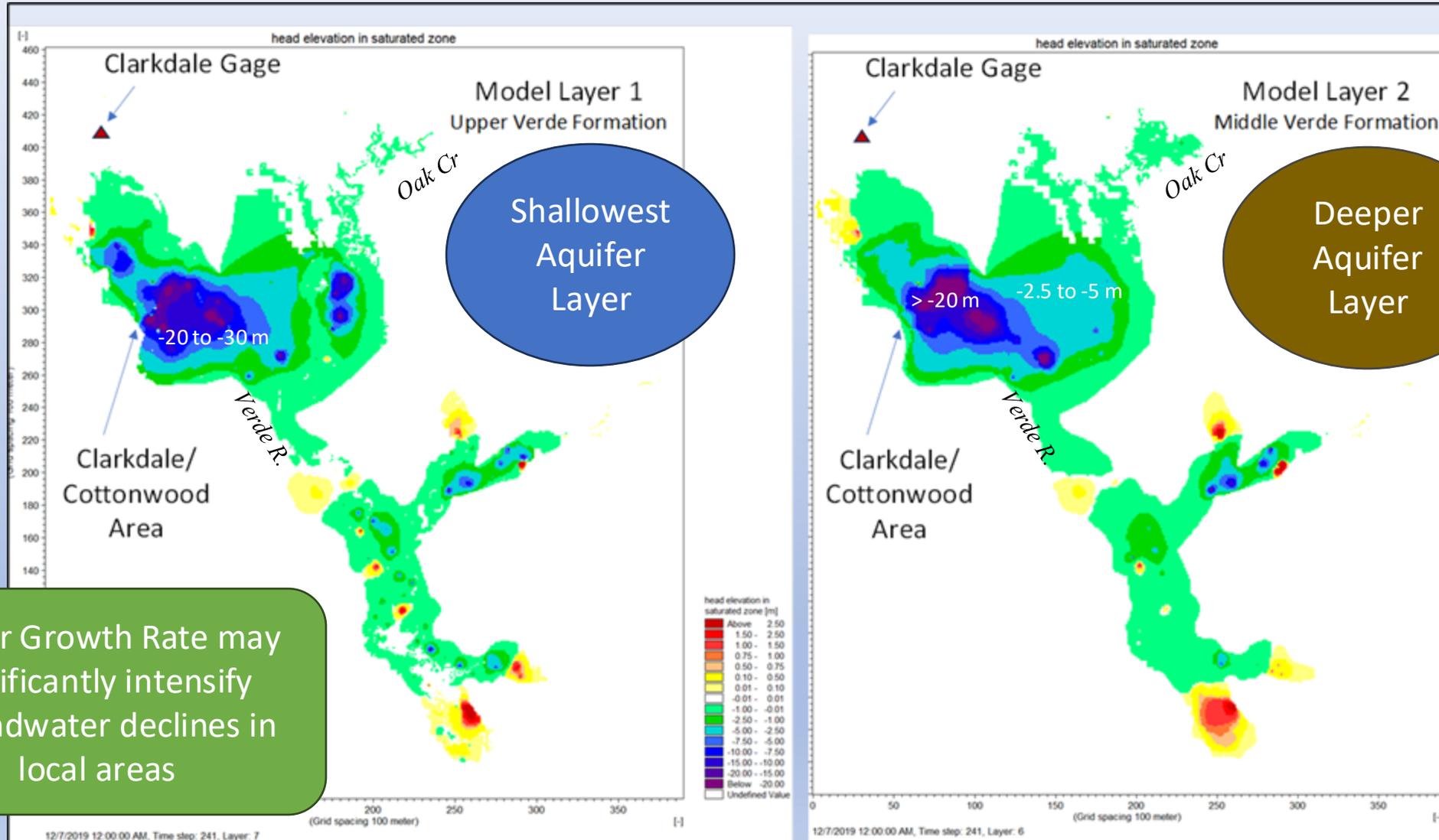
78,000 acre-feet Saved over 20 years

Benefits of Strong Conservation (0.8% growth) Grow Quickly

6,700 acre-feet Saved over 20 years



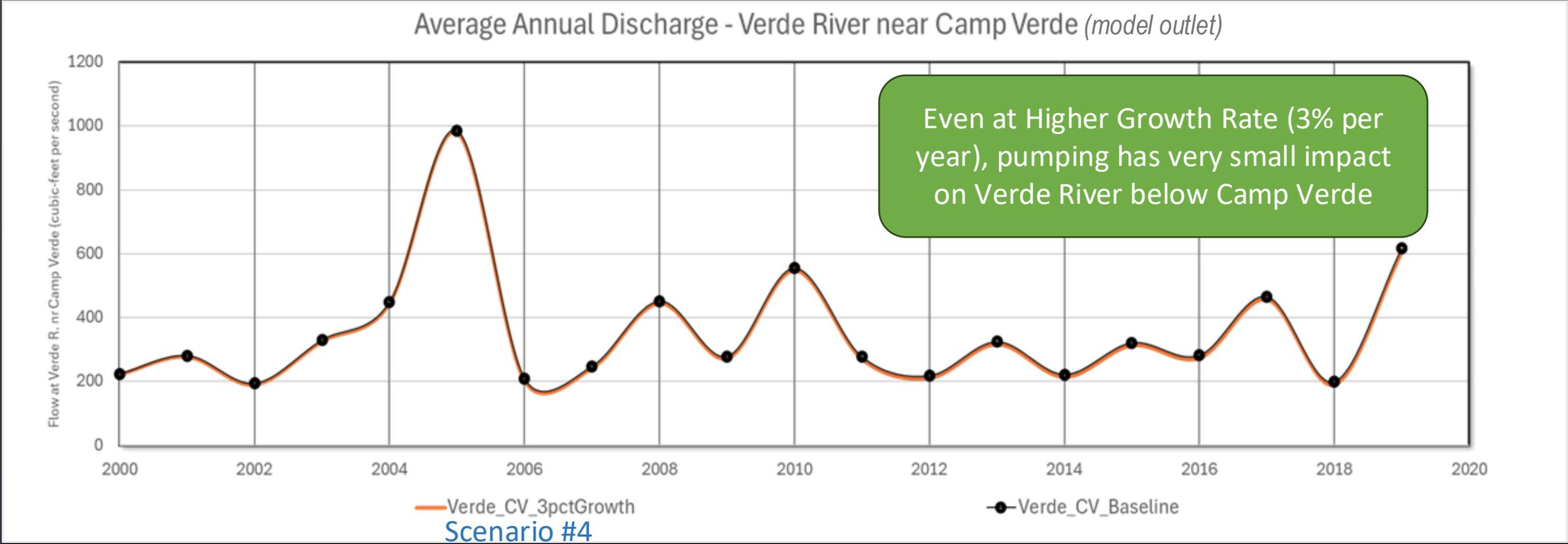
Simulated Groundwater Level Change Over 20 Years with 3% Annual Growth Rate



ical Consulting

Higher Growth Rate may significantly intensify groundwater declines in local areas

Simulated Verde River Flow near Camp Verde – Baseline and Higher Growth Scenario (#4)



Key Conclusions: Population Growth Scenarios (1,2 and 4)

- Over 20 years, Conservation Growth (0.8% per year) would save nearly 80,000 acre-feet of groundwater compared to 3% growth and about 7,000 acre-feet of groundwater compared to 1% growth rate.
- Pumping impacts are near pumping centers and more significant in deeper aquifer layer where larger wells are located.
- Higher growth rate (3% per year) lowers groundwater levels by over 20 meters (66 ft) in areas with concentrated pumping over 20-year period; effects are most pronounced upstream of Oak Creek confluence.
- Faulting may help shield river from some pumping impacts.





Reduced Verde River Flow Scenario

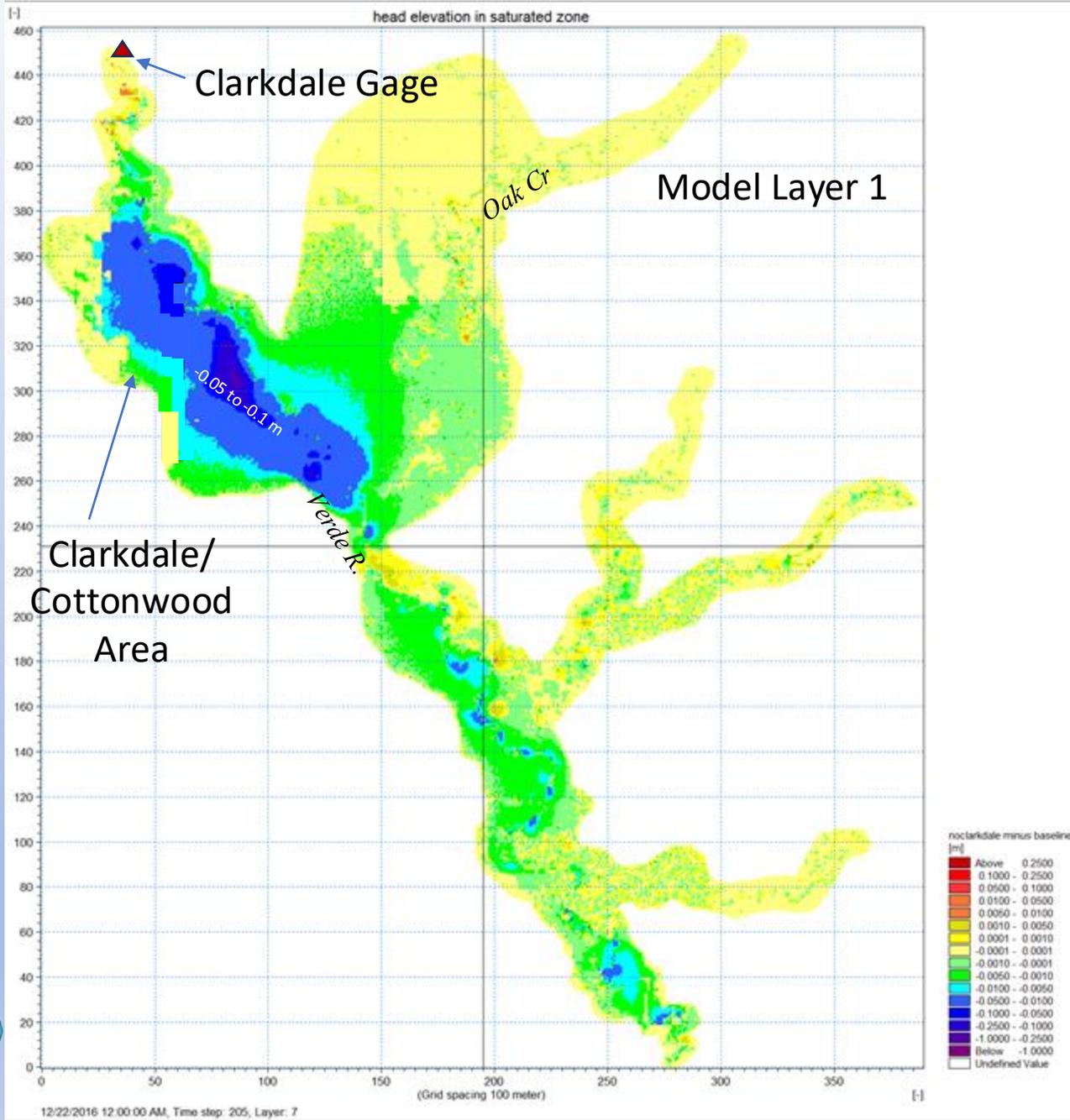
Assumptions:

- Verde River flow measured at Clarkdale Gage is reduced where it enters model area
- No other changes in model from baseline

Scenario 5:

- 50% reduction in Verde River flows at Clarkdale Gage over 20 years





Simulated Groundwater Impacts Shallowest Model Layer Scenario 5

Reduced Verde Flows (50% Reduction in Clarkdale Gage Flow) 2000-2020

Groundwater Results:

Small (< 1 m; 3.3 ft), localized/compartimentalized groundwater declines near Verde River

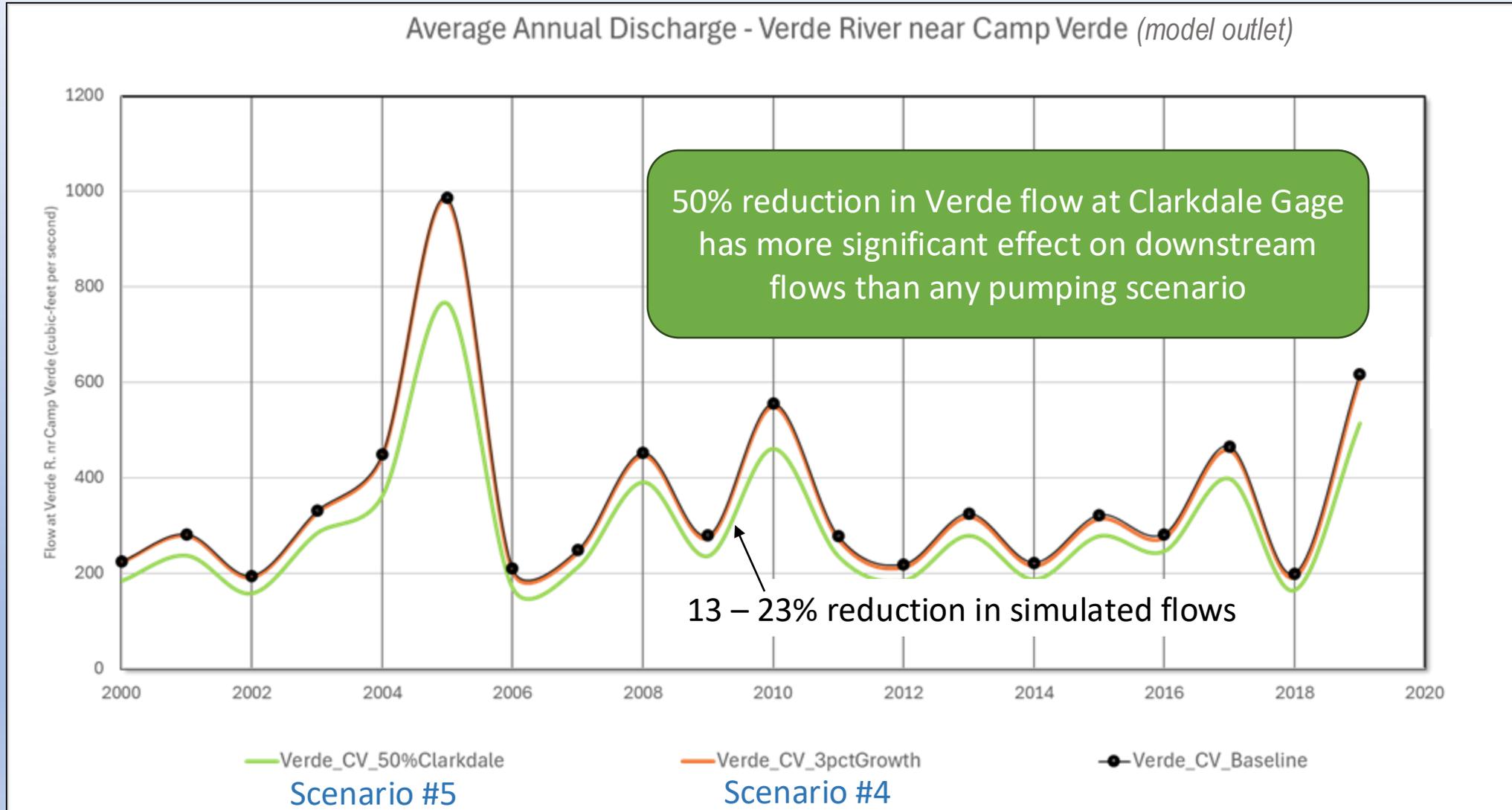
- ❖ Verde Formation has areas of “tight” materials (e.g., clay and unfractured limestone)
- ❖ faulting parallel to river helps restrict groundwater declines from spreading far

Less water in river means:

- More groundwater discharging to river.
- Riparian plants consume more groundwater.
- Riparian zone more vulnerable to pumping.

Simulated Verde River Flow near Camp Verde

Baseline, Higher Growth (#4), and Reduced Verde Flow at Clarkdale Gage (#5)



Key Conclusions: 50% Reduced Verde Flow at Clarkdale Gage (Scenario 5)

- Groundwater impacts are small and localized near river above confluence with Oak Creek
- 13-23% reductions in annual flows on the Verde River below Camp Verde (model outlet); Oak Creek significantly mitigates downstream impacts.
- Effects on streamflow are much more significant than in any of the pumping scenarios.



Climate Change Scenarios



Assumptions:

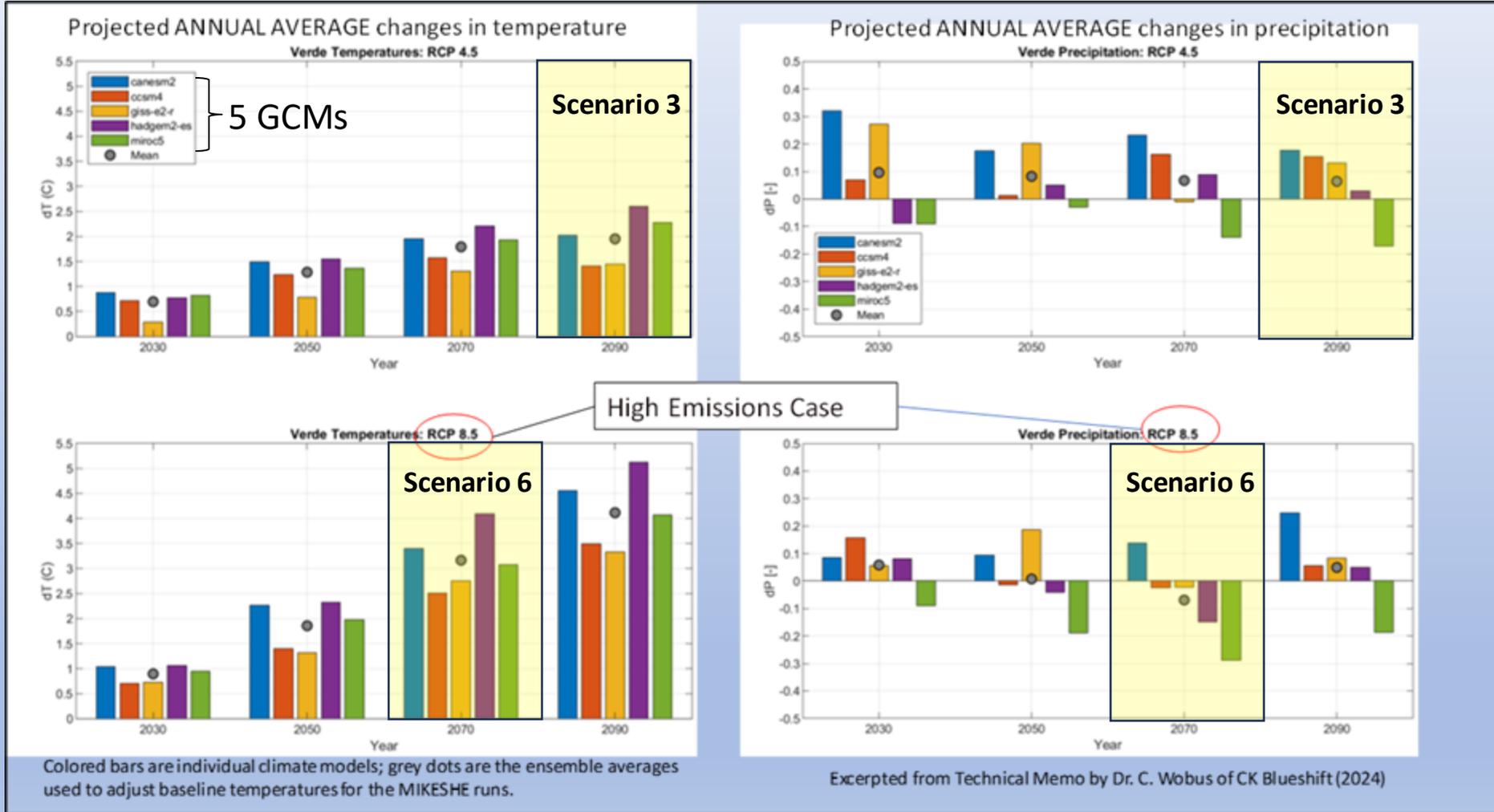
- Model inputs to temperature, precipitation and reference ET are derived from downscaled IPCC Global Climate Change Models (GCMs) for local Verde area in 20-year increments from 2020 to 2099.
- No other changes in model conditions from baseline.

Scenarios:

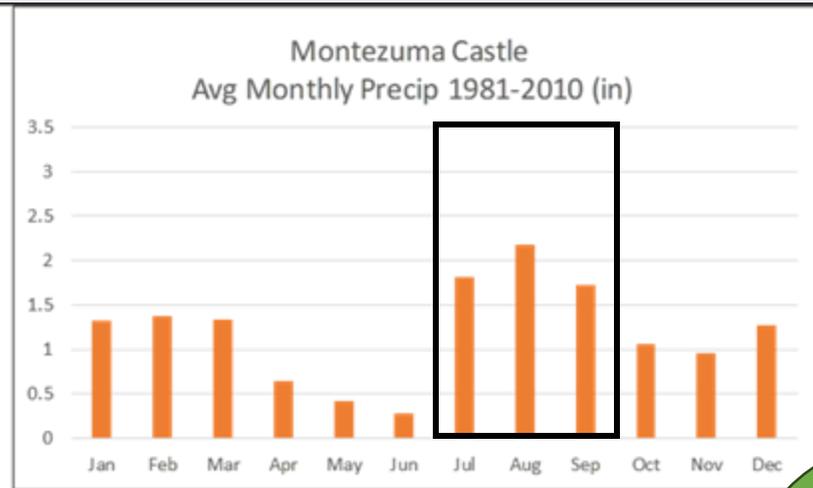
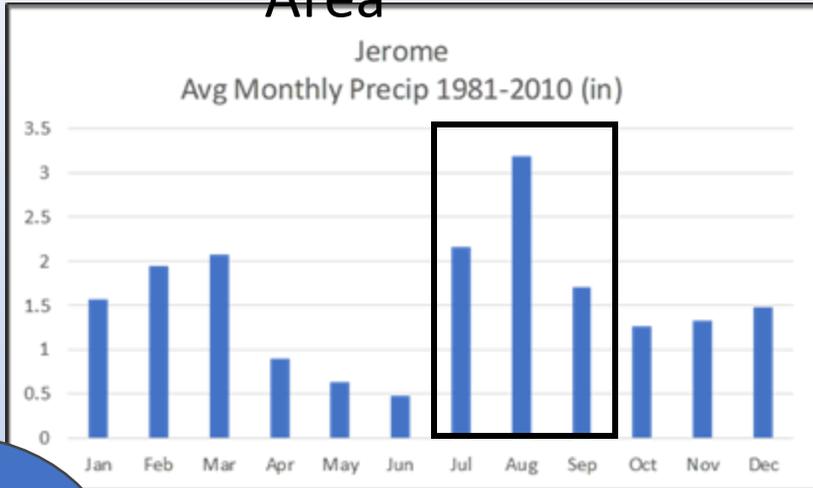
3. Moderate climate change (2090, RCP4.5 emissions scenario)
6. Hotter and drier climate (2070, RCP8.5 emissions scenario)



Average Annual Change in Predicted Precipitation and Temperature from GCMs

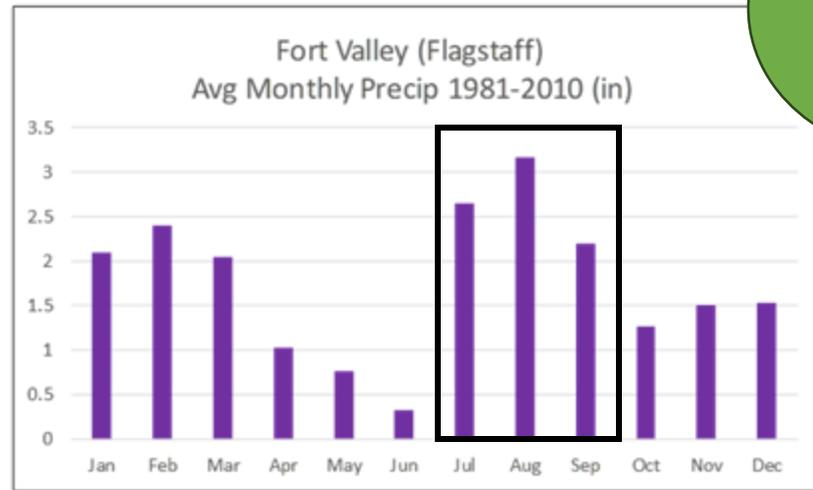
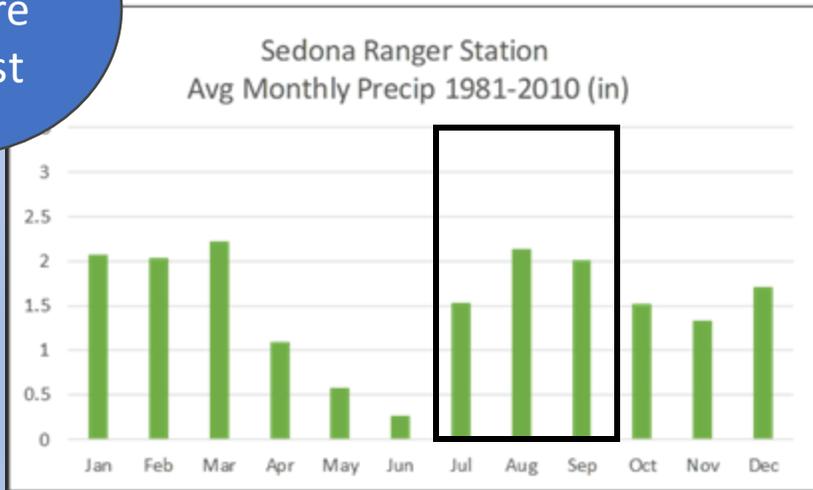


Monthly Precipitation Trends in Verde Valley Area



July, Aug, Sept are wettest

Apr, May, June are driest



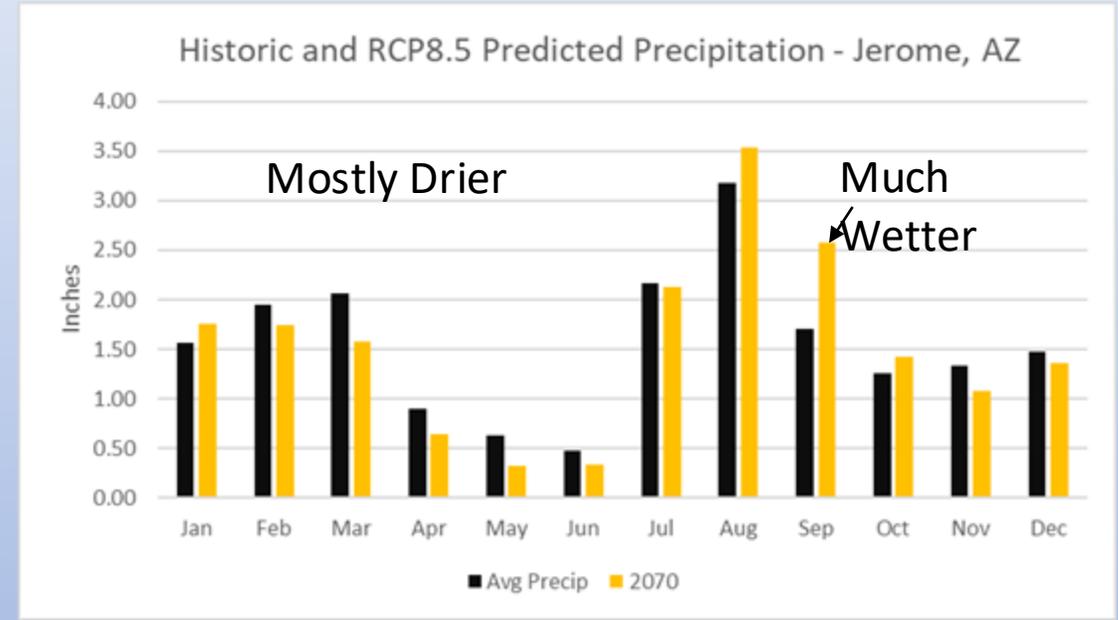
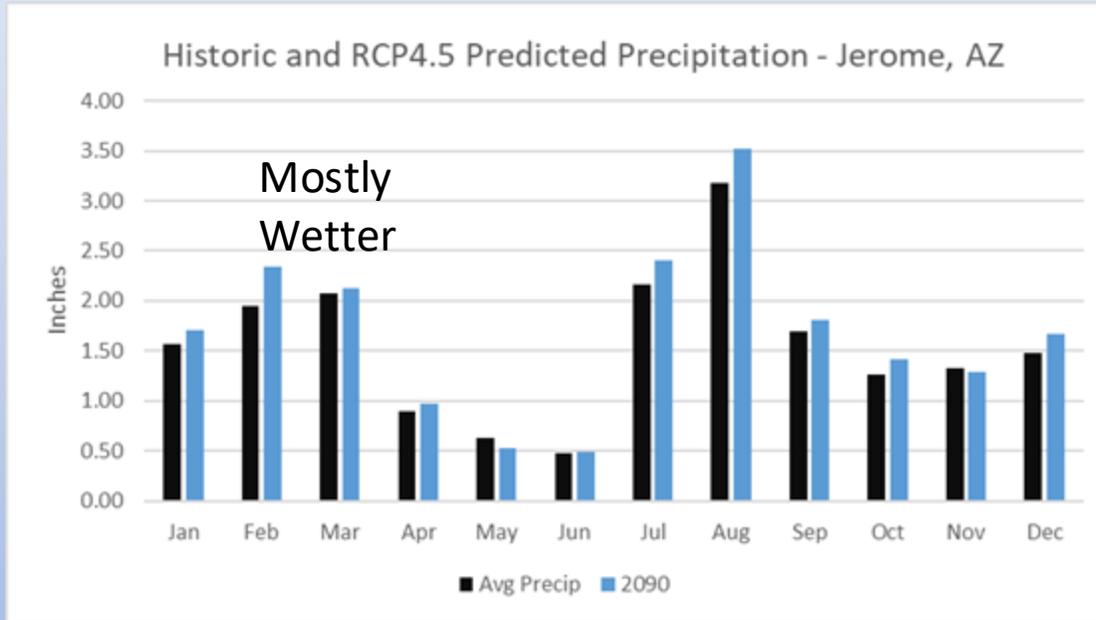
Average MONTHLY Change in Predicted Precipitation from GCMs

Small increases in wet months can be more significant than large decreases in dry months

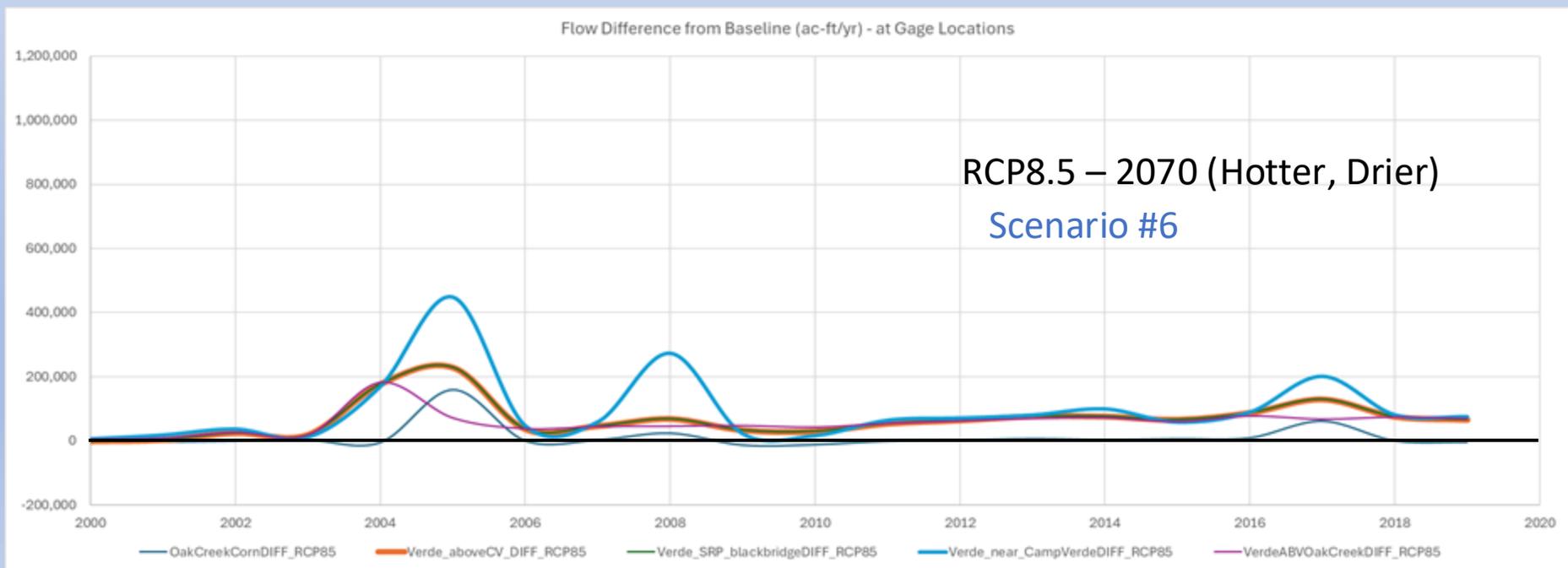
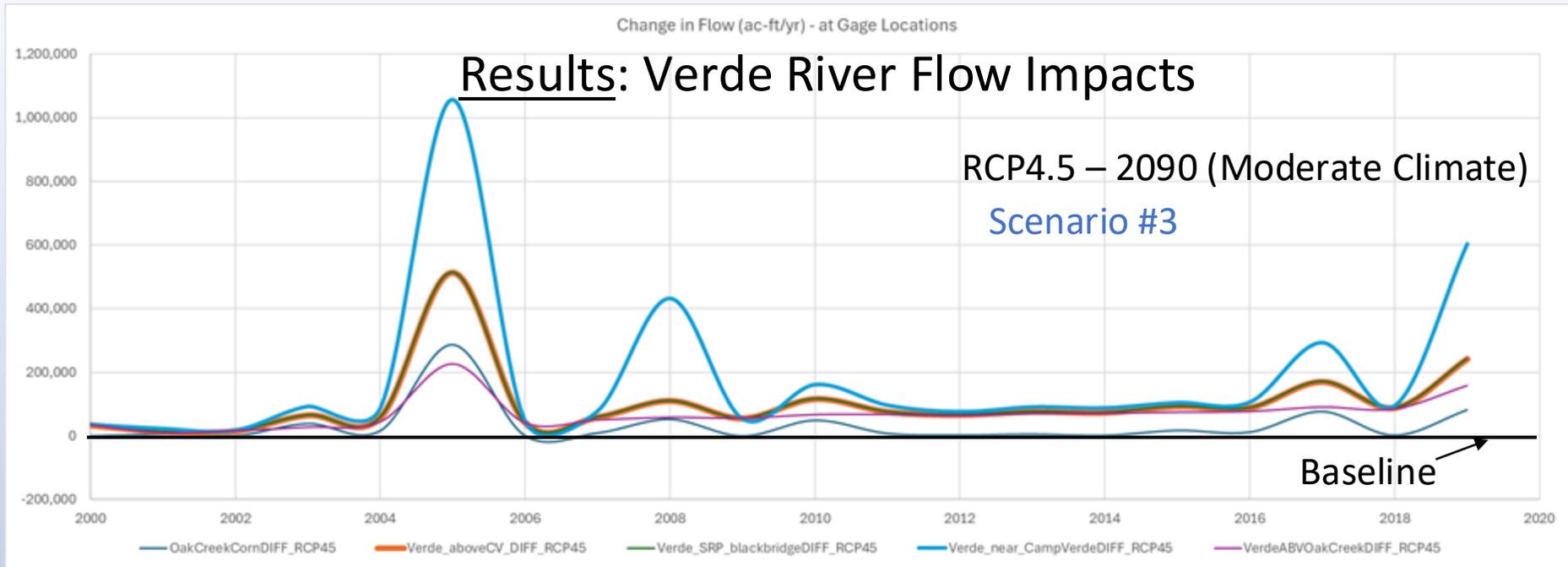


Scenario 3 – 2090, RCP4.5

Scenario 6 – 2070, RCP8.5



In both scenarios, the wettest months get wetter!

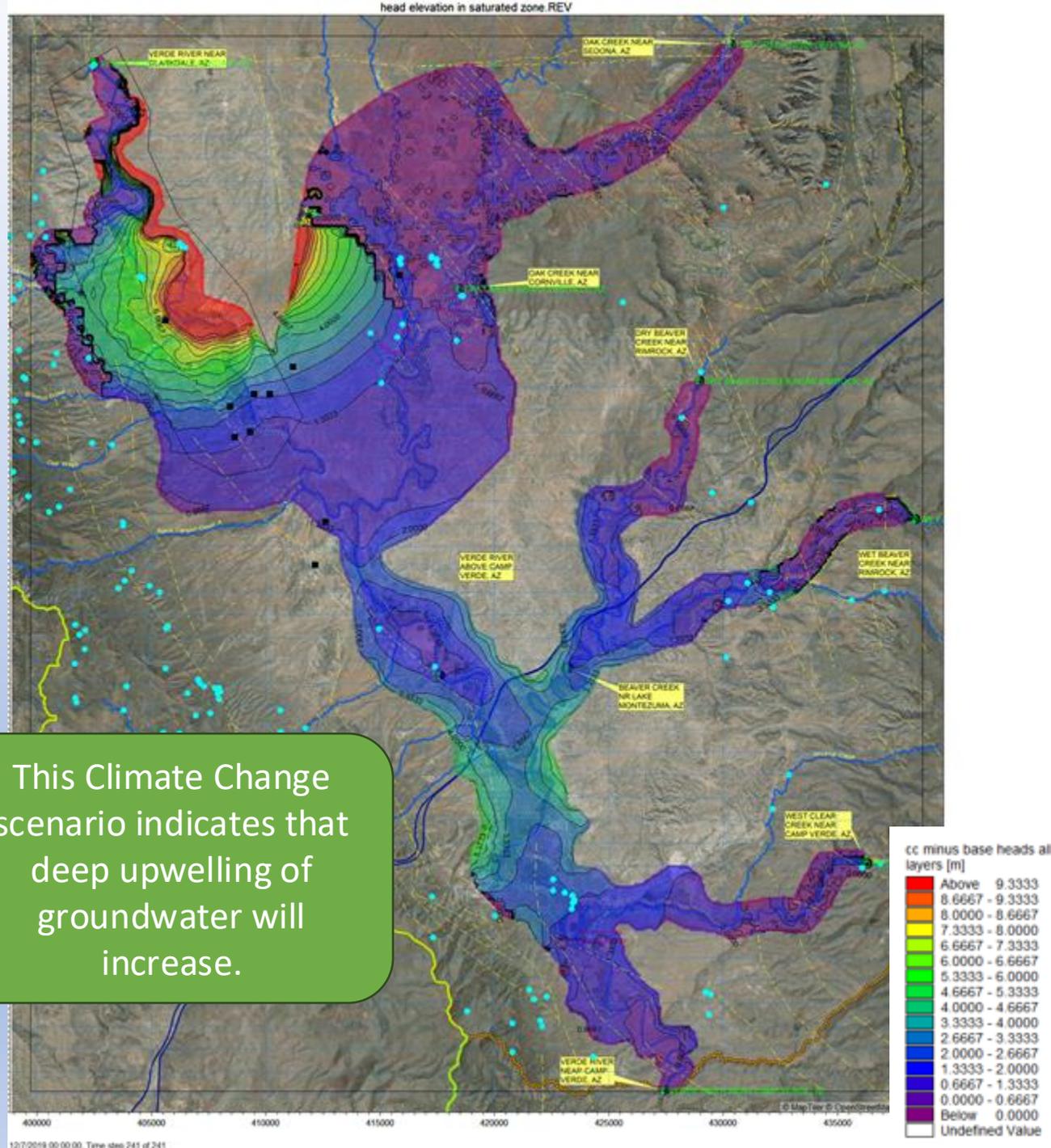


Scenario 3: Climate Change Effects on Groundwater Levels

Layer 2 (Middle Verde Fm.)

- Emissions scenario RCP 4.5
- Bright colors indicate larger INCREASE in groundwater levels due to climate change
- Changes in this deeper layer are not moderated by direct stream-aquifer interaction (as in Layer 1).

This Climate Change scenario indicates that deep upwelling of groundwater will increase.



Key Conclusions: Climate Change (Scenarios 3 and 6)

- Moderate Climate Change (#3) significantly increases groundwater and surface water flows into and within the Verde Valley due to increased rain in wettest months
- Scenario #3 has far greater impact on Verde River flows than changes in pumping in scenarios #1 & #2.
- Hotter and drier climate (#6) may still increase runoff in wettest months.
- Flooding and erosion could be exacerbated by Climate Change.
- Increased deep groundwater inflows from Mogollon Rim may result from faster melting of snowpack.



Summary of Results

Scenario #	Name	Description (20-year simulations)	% Change in Leakage FROM Stream TO Aquifer	Avg Annual Change in Verde River at Camp Verde Gage (ac ft/yr)	Change in Groundwater Levels	Change in Actual ET (AF/yr)
1	Growth	1% annual growth in pop. and groundwater use from 2019	0%	Negligible	Dedines of > 10m (33 ft) in isolated pumping centers at Cottonwood, Cornville, and Rimrock	0%
2	Growth with Conservation	0.8% annual growth in groundwater use from 2019	0%	Negligible	Lesser declines (by ~0.1-0.5m; 0.33-1.6 ft) in pumping centers than Scenario 1	0%
3	Climate Change (moderate)	RCP4.5- moderate emissions climate for 2080-2099 period; 2000-2019 population	-19%	71%	Up to 10-m increase in some areas, especially in the deeper parts of Verde Formation aquifer.	9%
4	High Growth	3% annual growth in groundwater use	9%	-2%	Broad area of groundwater decline above Verde-Oak Cr confluence with maximum > 20 m (66 ft)	-1%
5	Reduced Verde Flow	50% reduction in Verde River at Clarkdale gag	-2%	-16%	Less than 0.5m (1.6 ft) decline mostly limited to areas near Verde River above the Oak Cr confluence	0%
6	Climate Change (hot & dry)	RCP8.5- high emissions climate for 2070-2089 period; 2000-2019 population	-21%	35%	Negligible	5%
			Blue= more water from streams to aquifer	Blue = more streamflow	Blue = rising gw levels	Blue = more ET consumption

More pumping induces more leakage from streams to aquifer.
 → Riparian areas more vulnerable to pumping

Climate change increases runoff in wettest months and deep recharge from less frozen soils in high country.
 → Increased flooding and erosion risk.

Reduced Verde River flows at Clarkdale are mitigated by Oak Creek and other tributaries.
 → Important to protect all streams from pumping impacts.

Things to Remember

- Models can help us understand things we can't see and test effects of different stresses.
- These simulations used dramatic but isolated stresses for demonstration purposes.
- In real life, different types of stresses will overlap and compound.
- We don't know exactly how things will change in the future but starting to plan now will increase resiliency.

