SIMULATION OF GROUNDWATER AND SURFACE-WATER RESOURCES OF THE SANTA ROSA PLAIN WATERSHED

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WHAT THE MODEL IS AND IS NOT

The Model Is

- Simplification of a real hydrologic system
- Supplemental water management tool
- Computer program used to simulate and predict hydrologic and aquifer conditions
- Approximation of water transfer between surface and subsurface
- A tool to estimate water budgets and hydrologic response to changes in stresses

The Model Is Not

- A unique solution
- The only true and absolute answer
- Certain in what is simulated and predicted
- Does not replace field investigations and the need for real data

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Overview

- Background
- Study area and model
- Inputs for watershed and groundwater components
- Calibration of the integrated model
- Model results
- Future-climate scenarios
- Limitations

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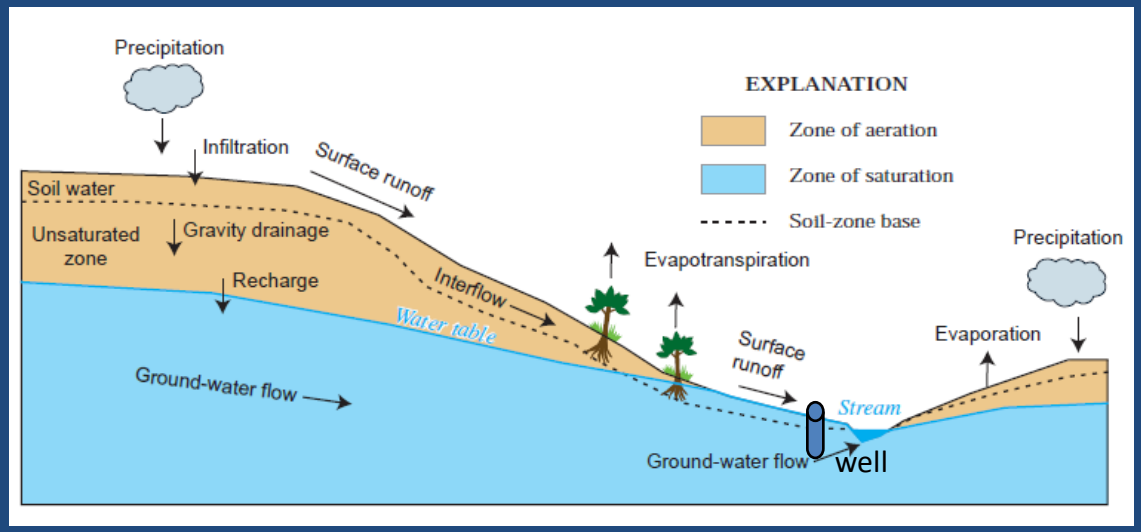
Background

- The Santa Rosa Plain hydrologic model was developed using GSFLOW to better understand and to help manage the hydrologic resources in the Santa Rosa Plain watershed
- GSFLOW is an integrated groundwater and surface-water model that consists of two components: a watershed component (PRMS) and a groundwater component (MODFLOW-NWT)
- The goals of the model are to evaluate the hydrologic impacts of alternative management strategies and future-climate scenarios for the watershed

Modified from Markstrom and others, 2008



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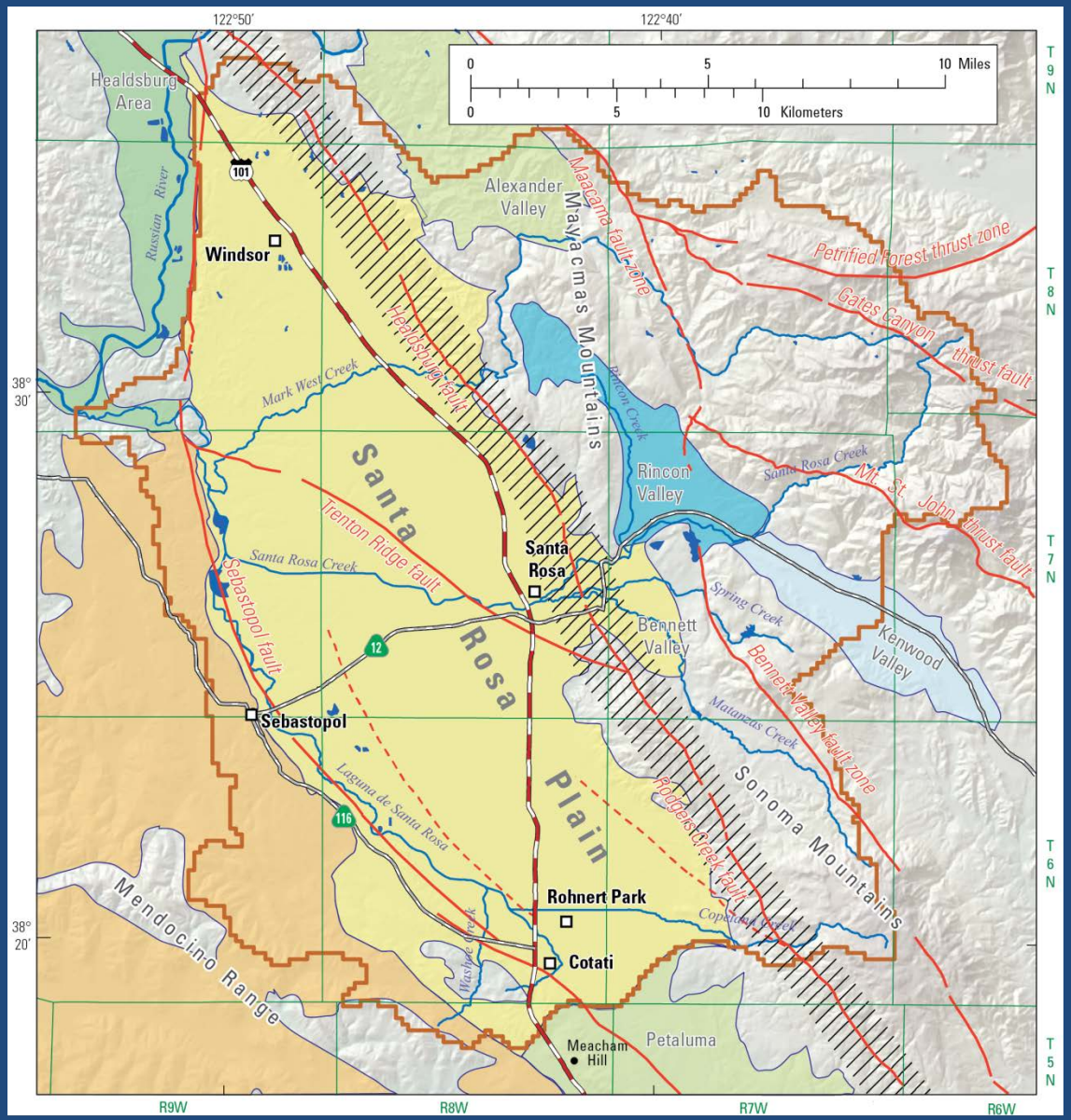
Study Area

Groundwater basin or subbasins

- Wilson Grove Formation highlands
- Santa Rosa Plain
- Rincon Valley
- Healdsburg area
- Kenwood subbasin
- Other subbasins



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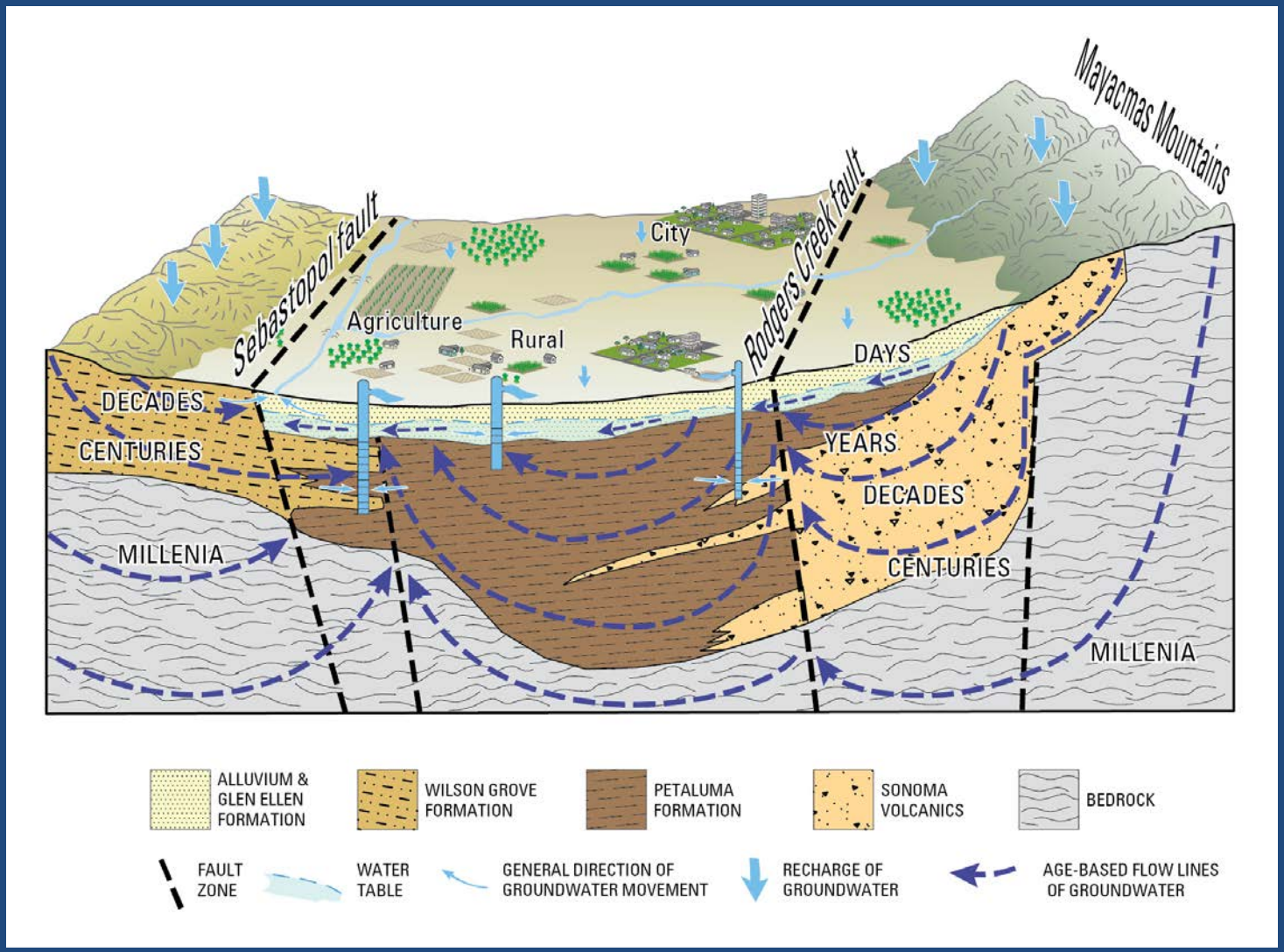
Conceptual Model



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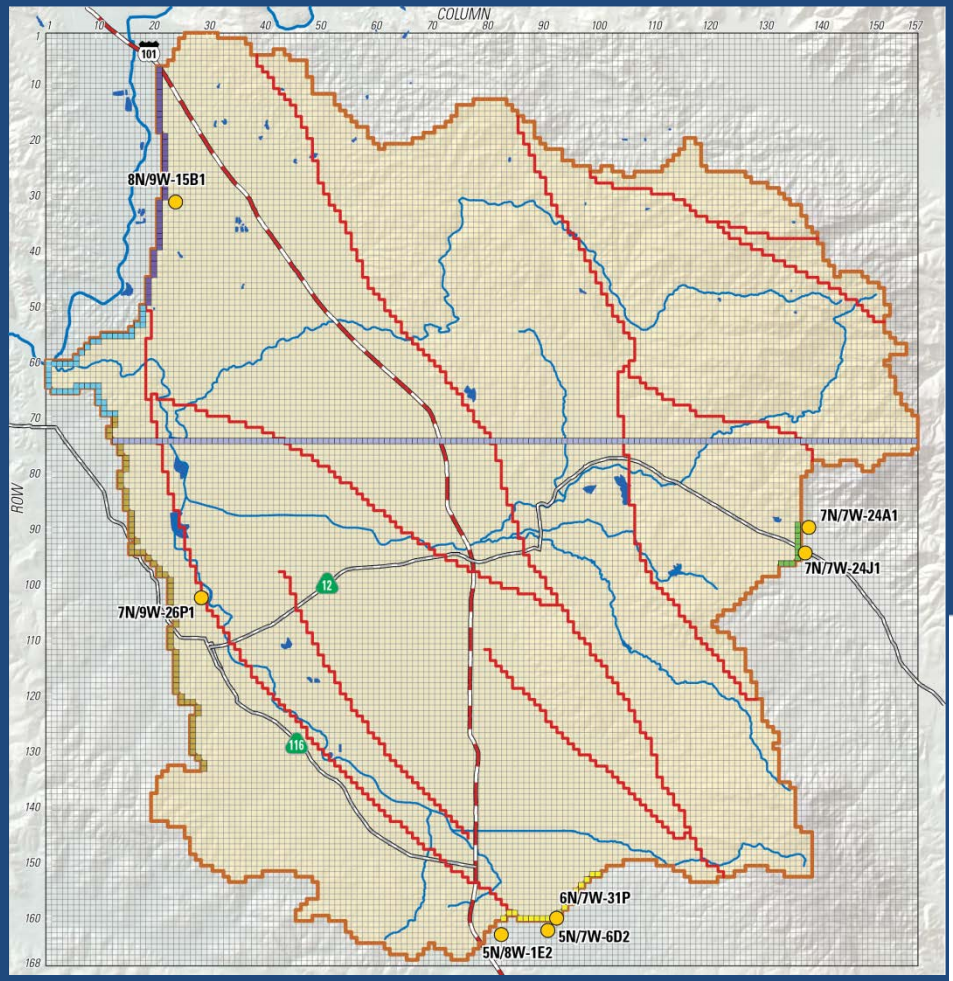
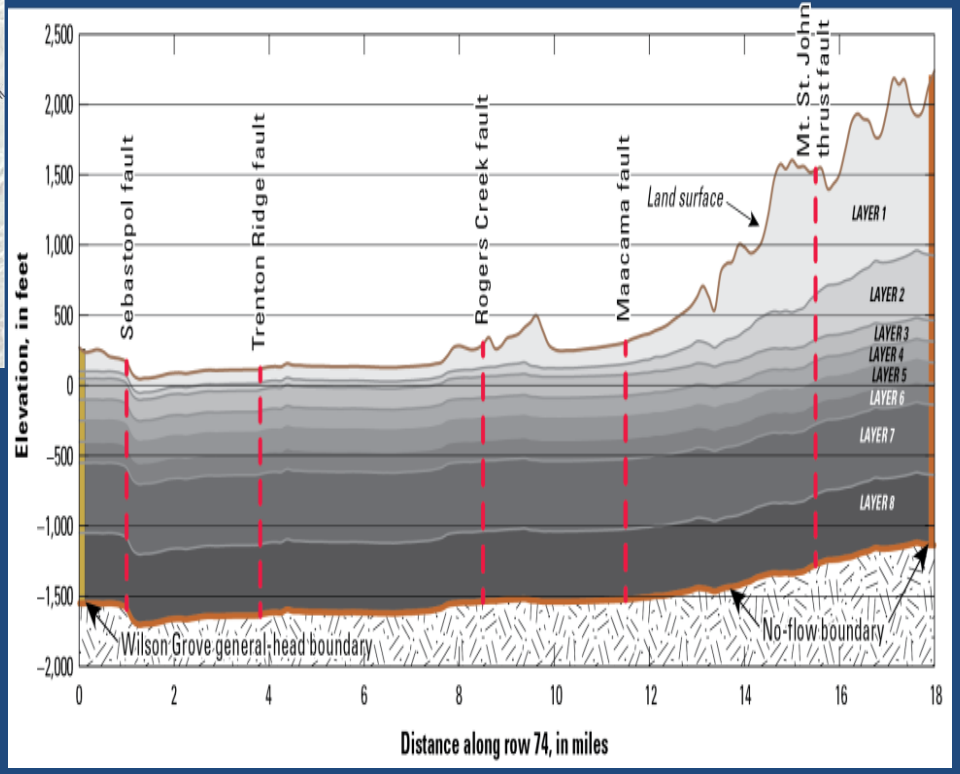
Model Grid and Boundaries



- Cell size is 660 ft X 660 ft
- 8 layers
- Simulation period is water years 1975-2010
- No-flow and head-dependent boundaries



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Model Input – Watershed Component

- Precipitation
- Minimum and maximum air temperature
- Soils data
- Vegetation data
- Land Use – including percent impervious area

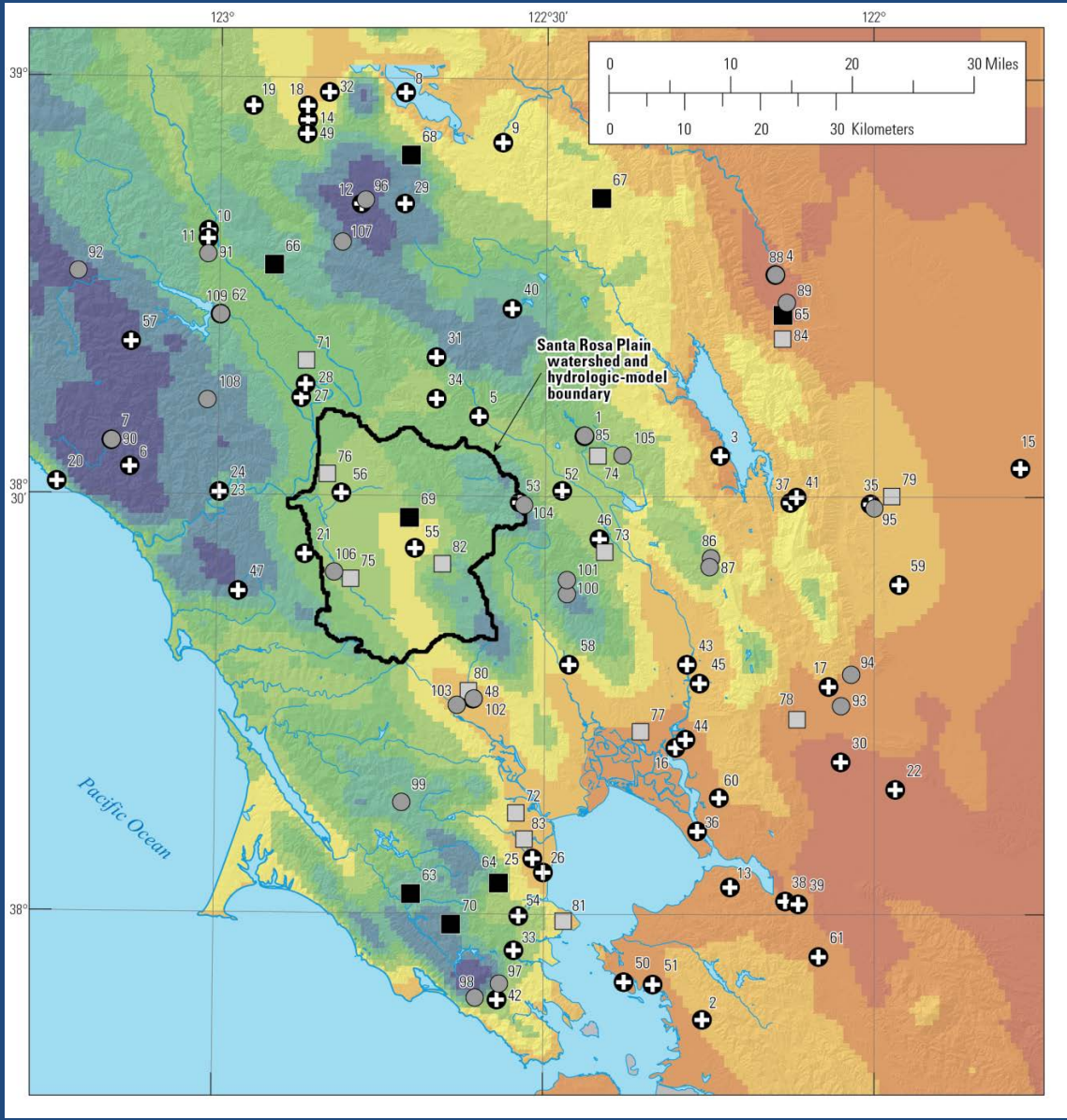
Example Watershed-Component Input - Precipitation

PRISM average January precipitation, in inches

- 2.65 to 4
- 4.01 to 5
- 5.01 to 6
- 6.01 to 7
- 7.01 to 8
- 8.01 to 9
- 9.01 to 10
- 10.1 to 12
- 12.1 to 16.2

Climate stations

- CIMIS Daily Climate
- NCDC Daily Climate
- NCDC Hourly Precip
- RAWS Daily Climate



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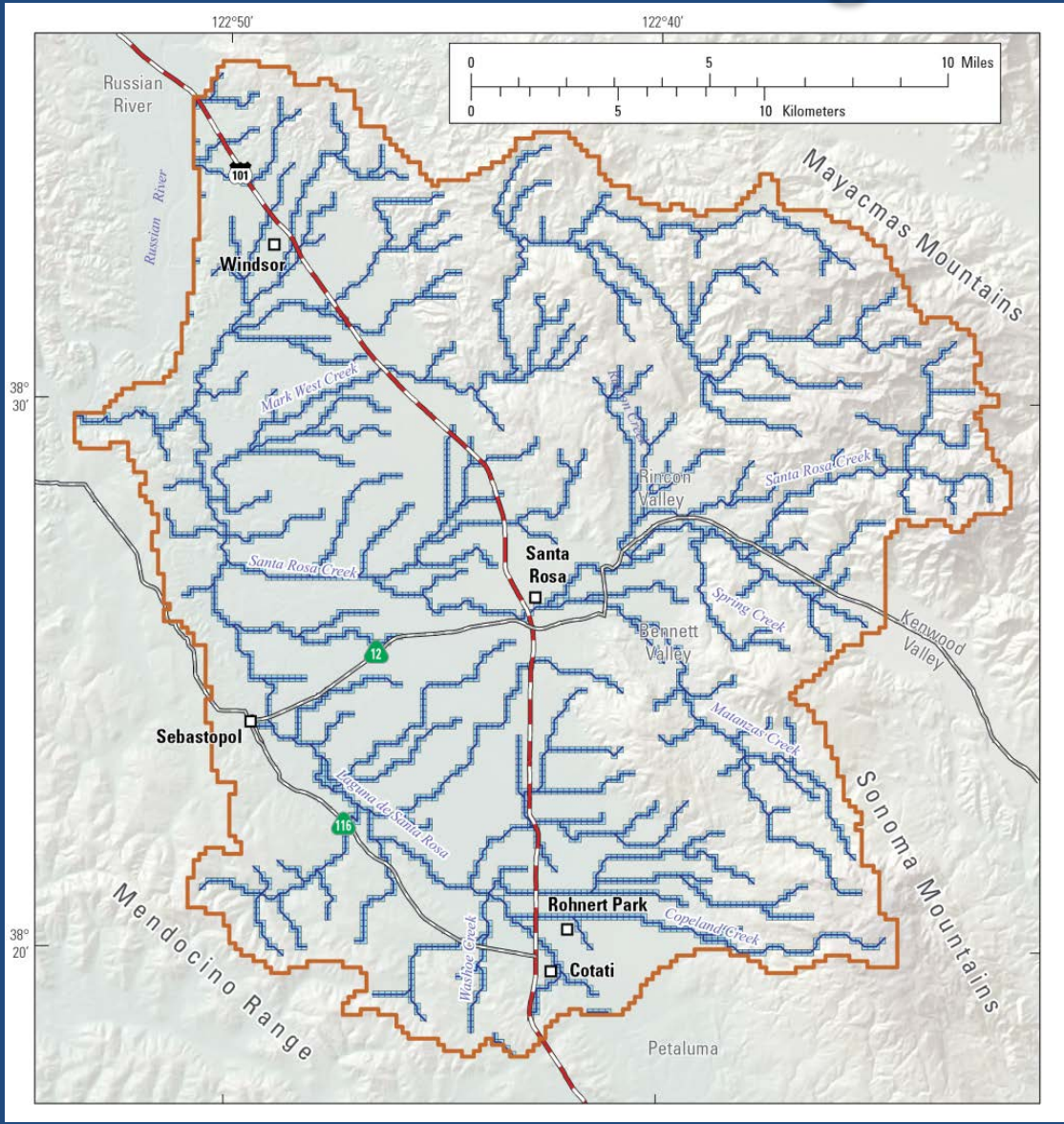
Model Input – Groundwater Component

- Pumpage
- Reclaimed water
- Initial estimates of
  - -aquifer properties
  - -boundary heads and conductances
  - -streambed properties – including conductivity and channel width
  - -unsaturated-zone properties

Example Groundwater-Component Input – Streamflow-Routing Cells



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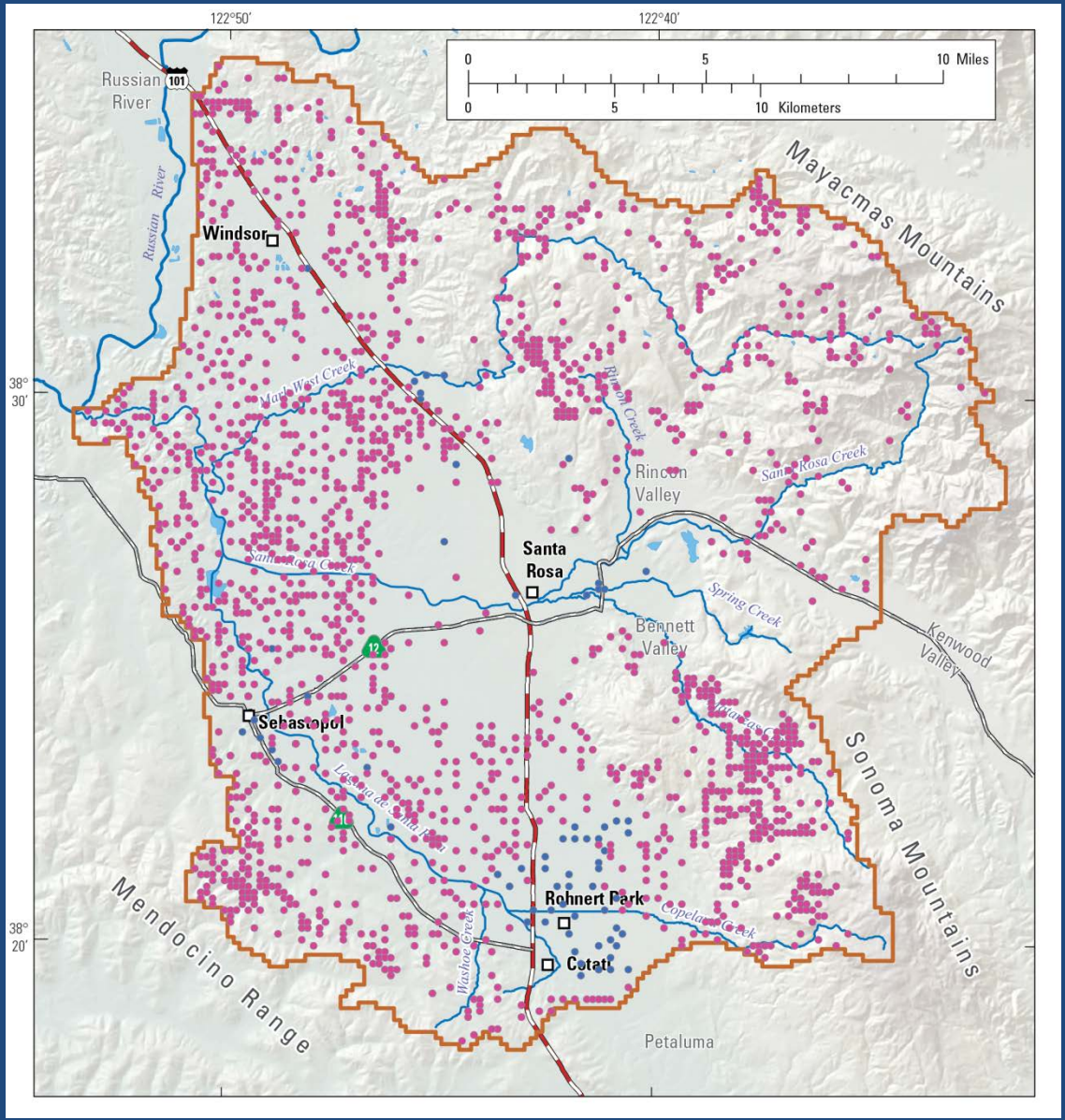
Example MODFLOW Input – Pumping Wells

- Public-supply well
- Rural well



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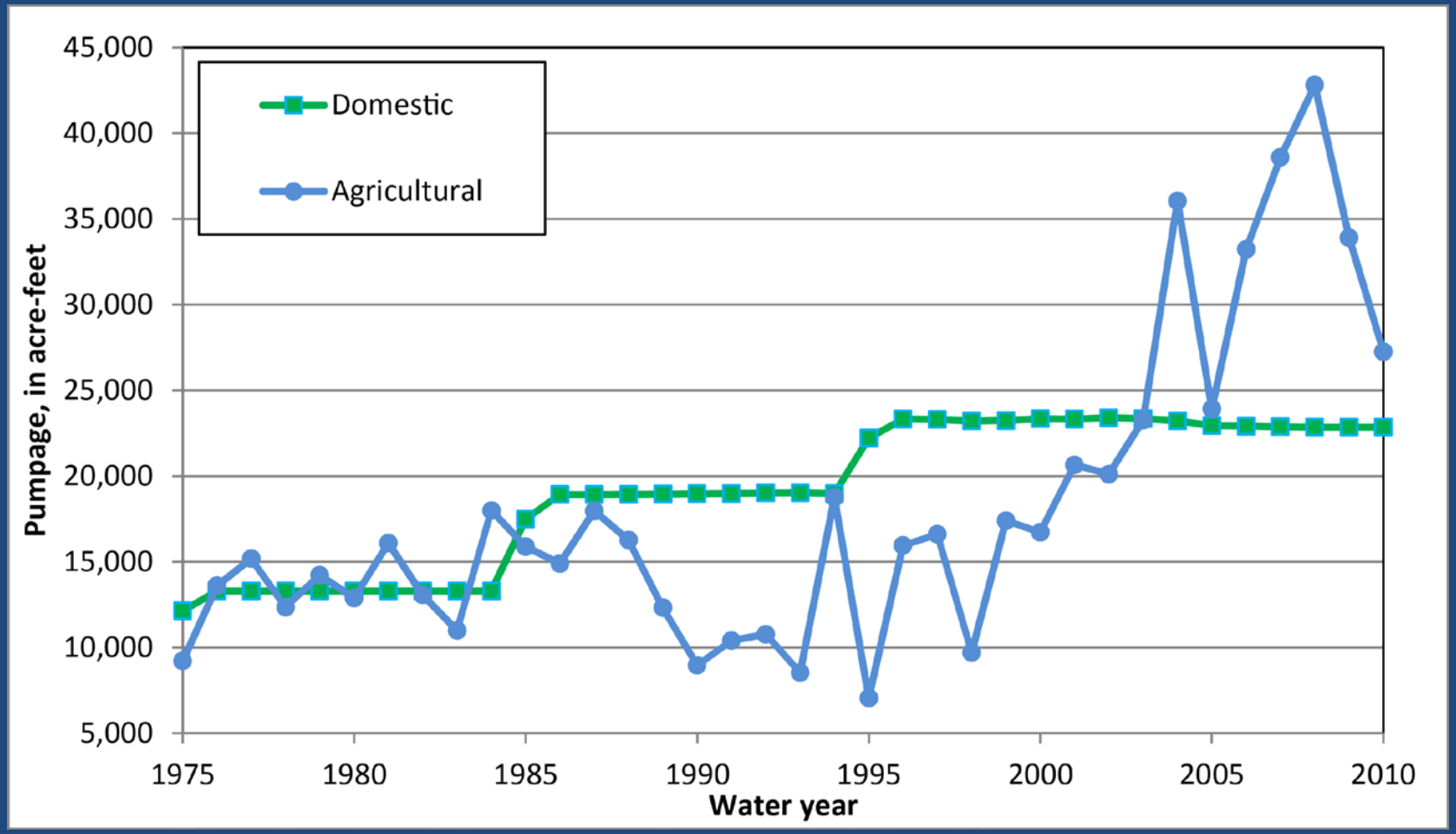
Rural Pumpage

- Rural pumpage is the combination of agricultural pumpage and domestic pumpage and is not reported
- Agricultural pumpage was estimated using a crop water-demand model
- Estimated irrigation values assigned to wells in or near areas of irrigated crop type and distributed vertically on the basis of perforated interval and hydraulic conductivity

Rural Pumpage - *continued*

- Domestic pumpage was estimated on the basis of population density in rural and semi-rural census tracts and using a consumptive-use factor of 0.19 acre-ft per capita per year
- The total annual water demand per tract was divided evenly per month and by the number of wells with defined locations in each tract

Estimated Rural Pumpage



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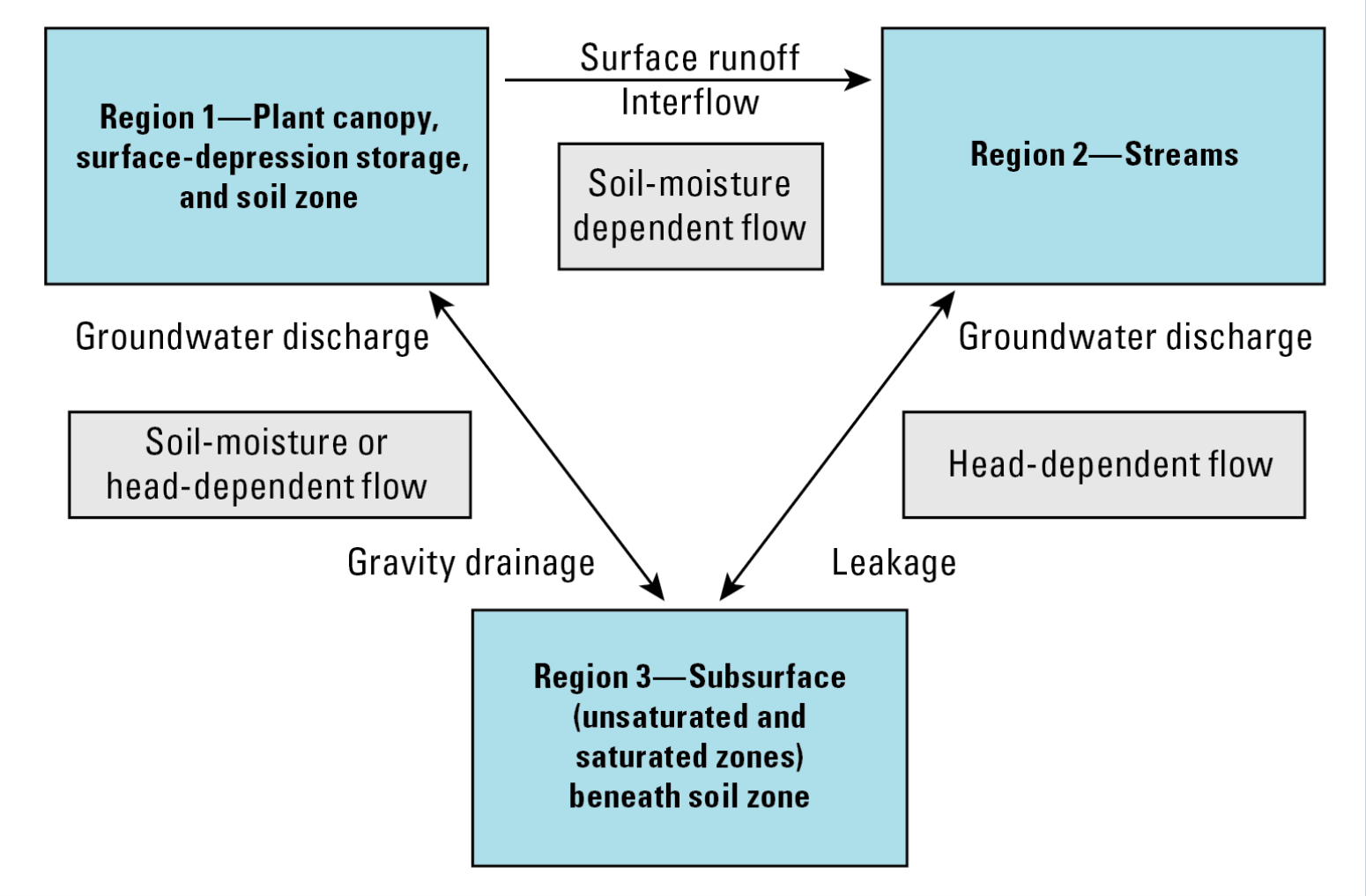
Integrated Model Calibration



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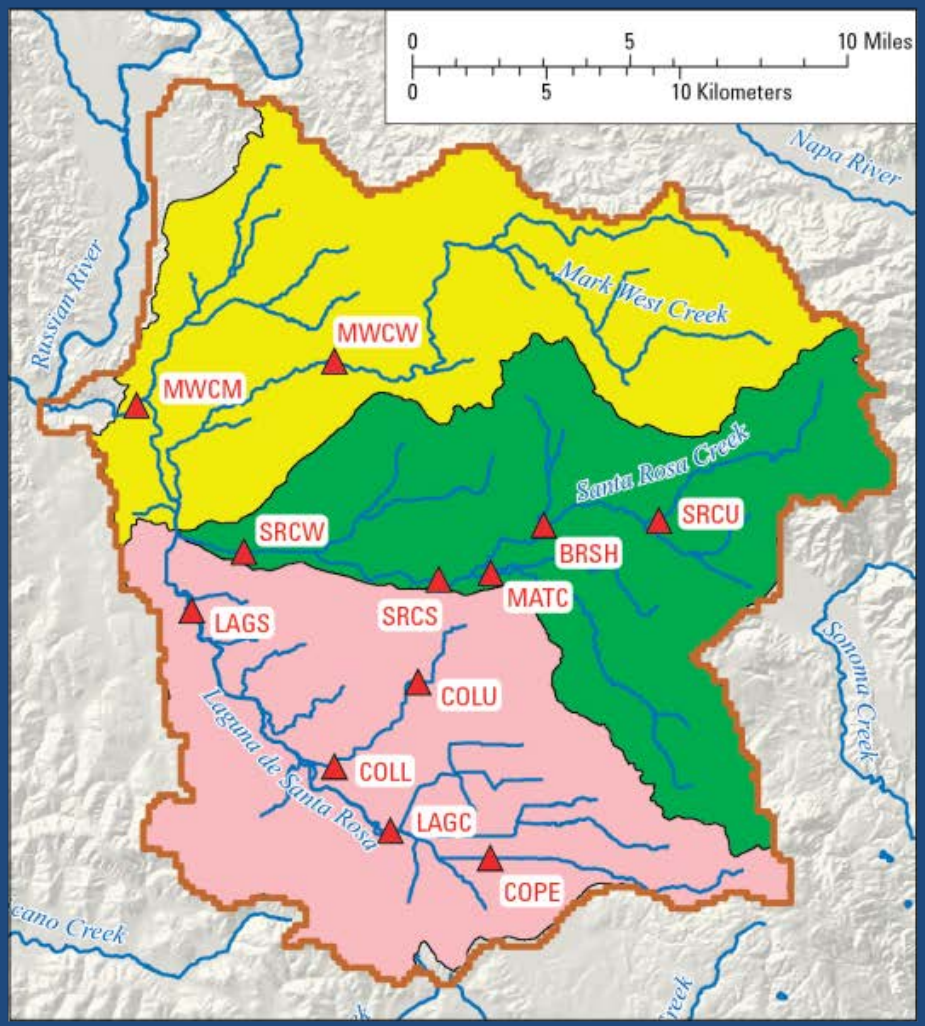
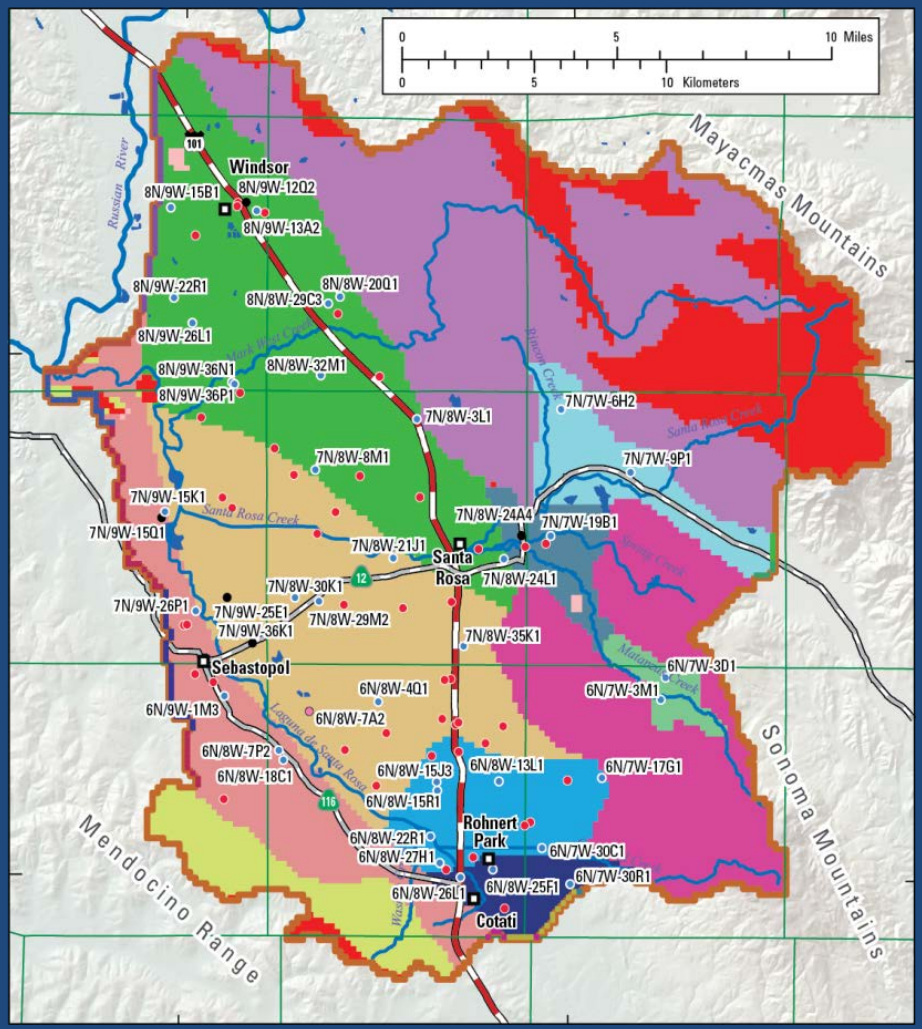
Calibration Approach

- Trial and error approach with streamflow and heads calibrated together
- Simulated and measured streamflow comparison for 12 USGS streamgages
- Simulated heads and measured water-level comparison at 83 wells

Gaging Stations and Wells Used for Calibration





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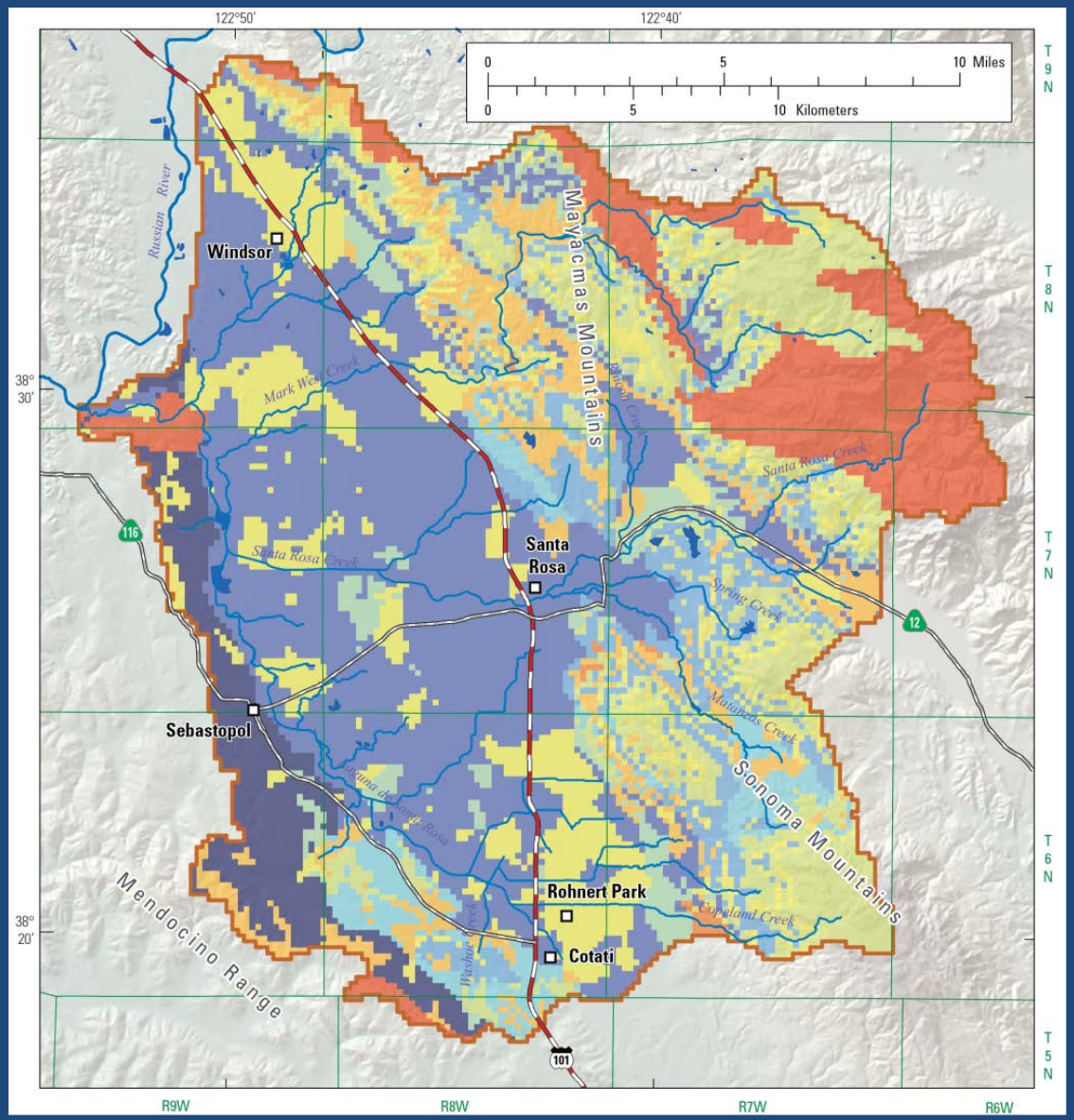
Calibrated Watershed Infiltration Parameter

PRMS input parameter:
ssr2gw_rate (inches/day)

- 0.00015
- 0.000151 to 0.0005
- 0.00051 to 0.001
- 0.0011 to 0.005
- 0.0051 to 0.01
- 0.011 to 0.02
- 0.021 to 0.03
- 0.031 to 0.04
- 0.041 to 0.05
- 0.051 to 0.055



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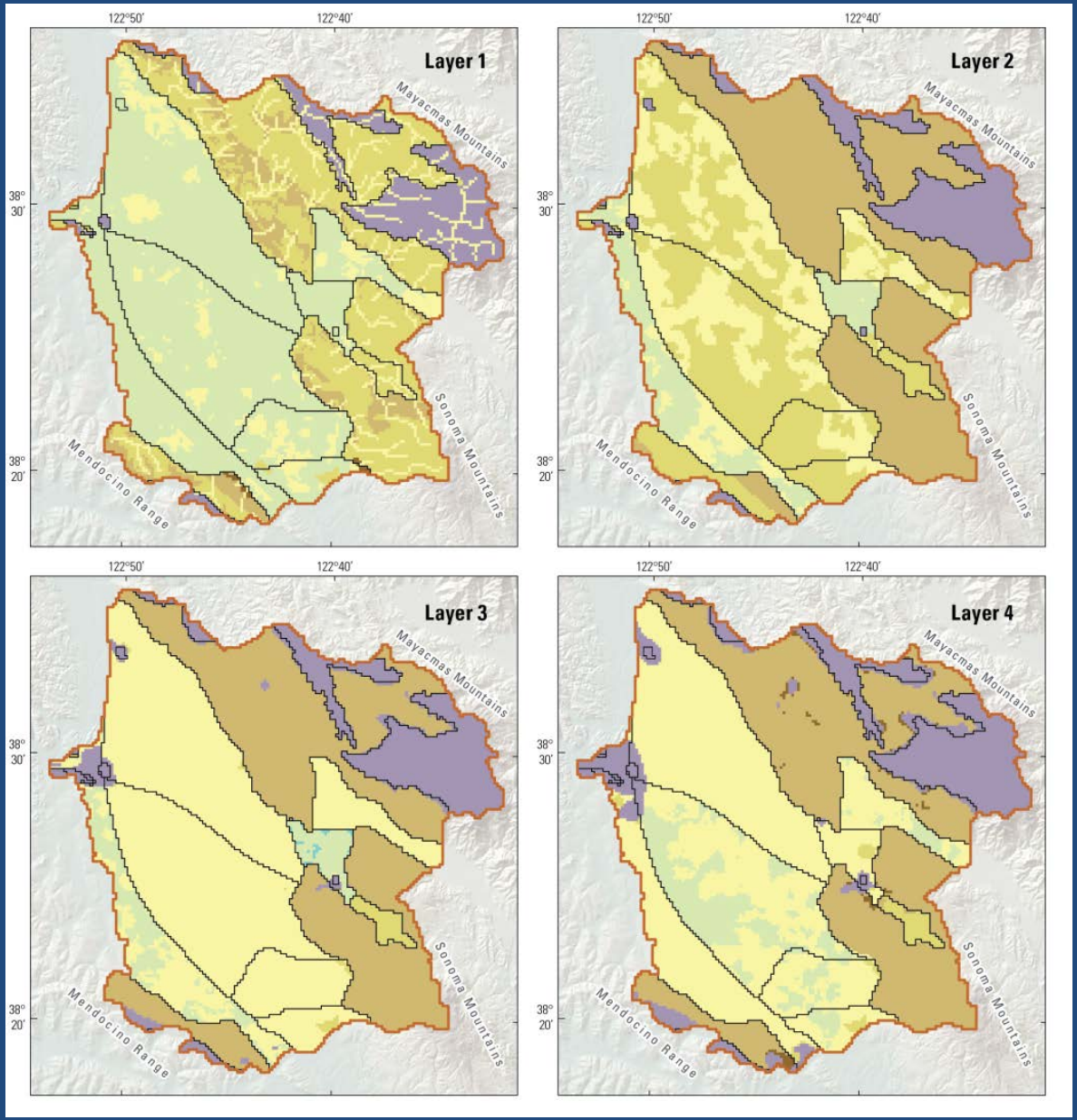
Calibrated Groundwater Parameter

Horizontal conductivity, in feet per day

- 0.0 to 0.0001
- >0.0001 to 0.001
- >0.001 to 0.01
- >0.01 to 0.1
- >0.1 to 1.0
- >1.0 to 10
- >10 to 100
- >100 to 124



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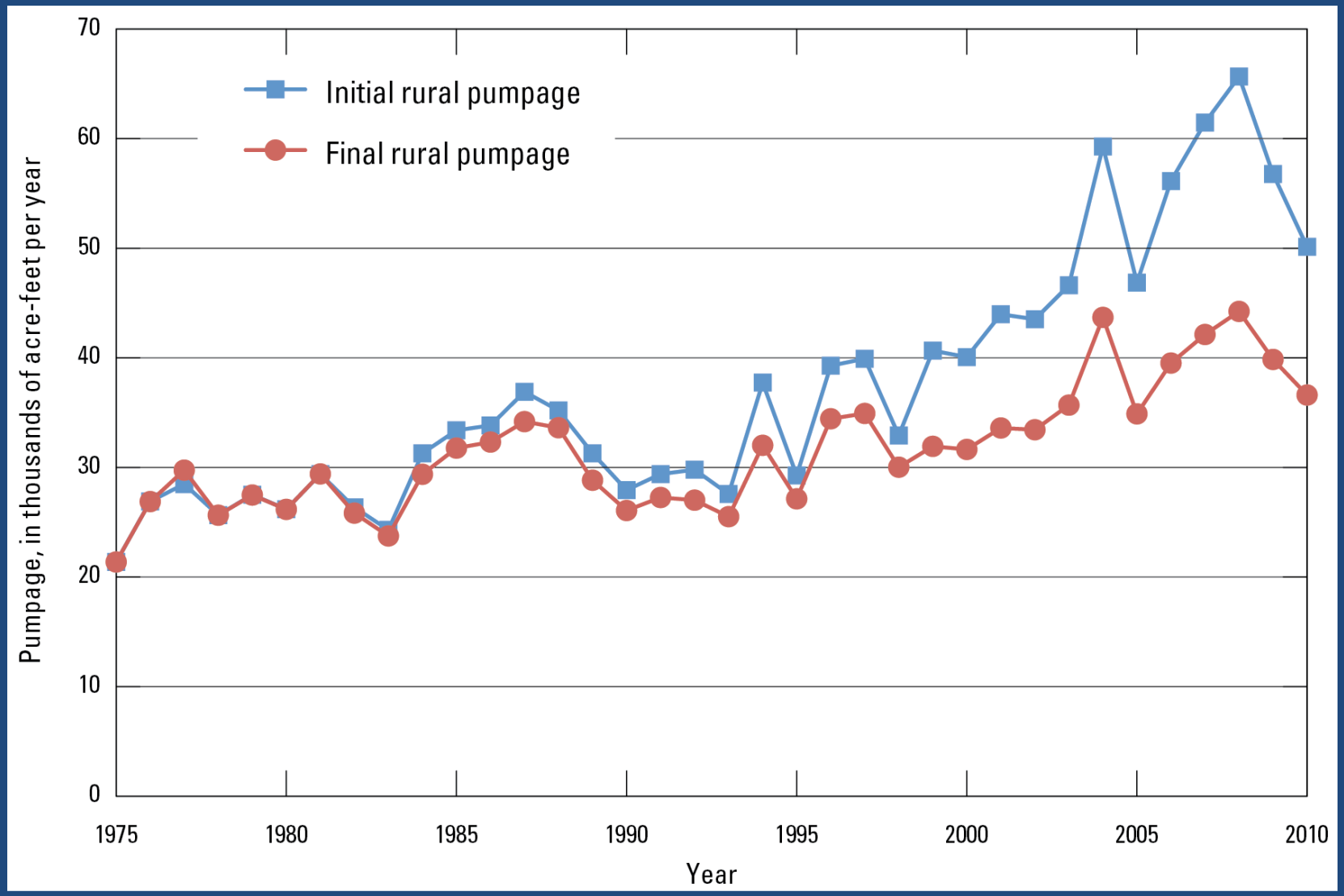
Rural Pumpage



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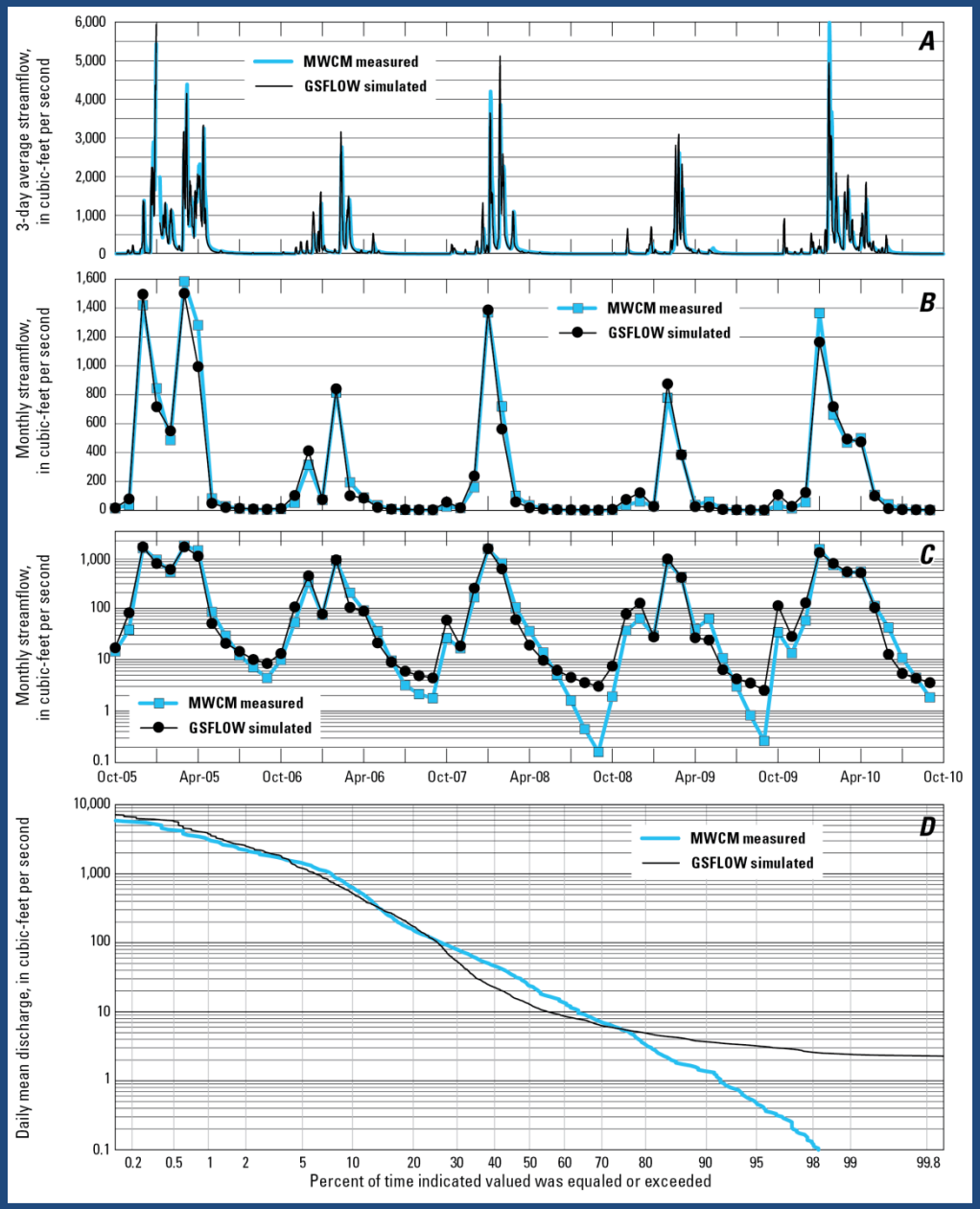
Calibrated Streamflow – MWCM Gage



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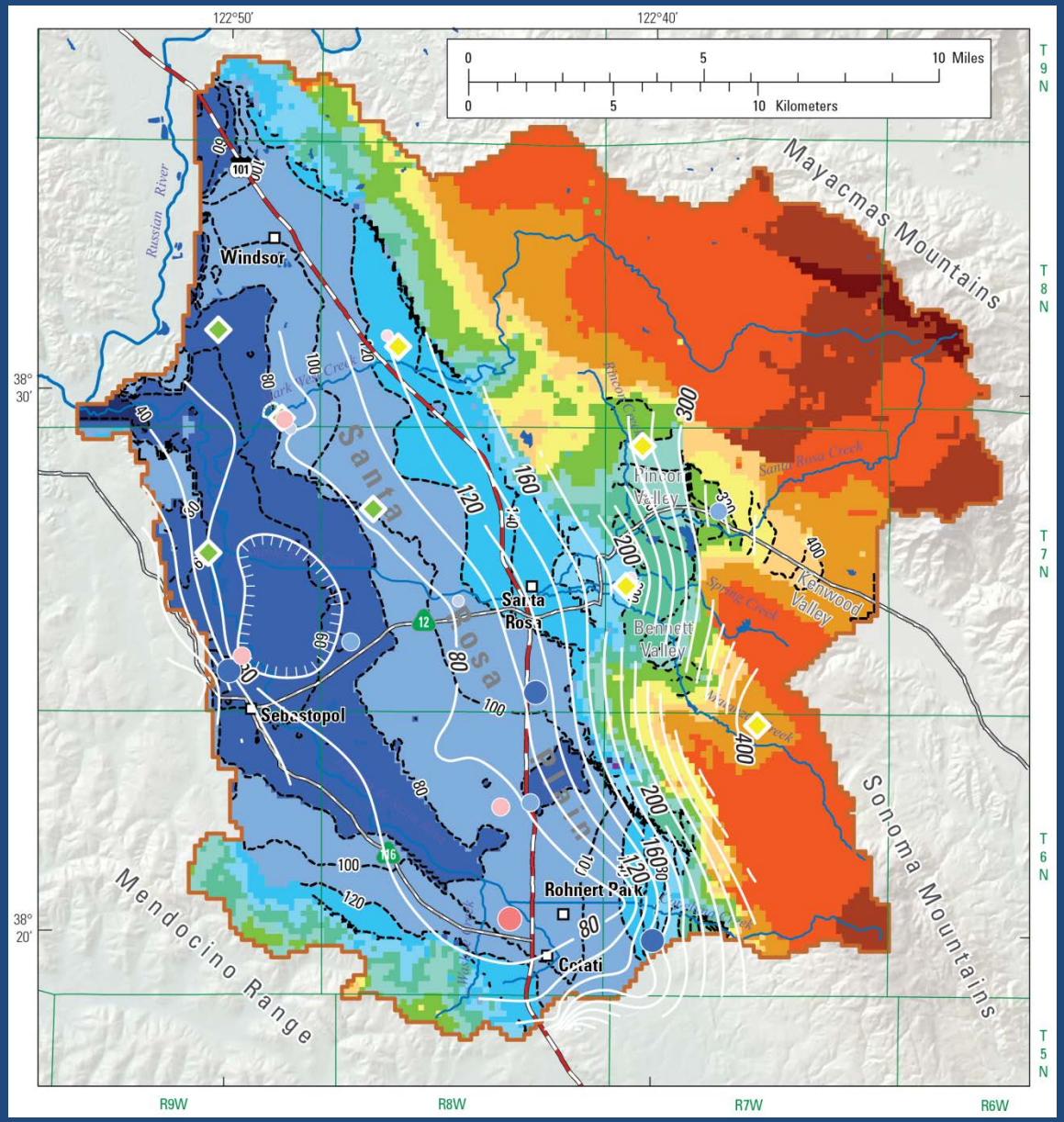
Measured and Simulated Groundwater Levels

Spring 2007

Simulated hydaulic head, in feet

- –40 to <0
- 0 to 40
- >40 to 80
- >80 to 120
- >120 to 160
- >160 to 200
- >200 to 240
- >240 to 280
- >280 to 320
- >320 to 360
- >360 to 400
- >400 to 500
- >500 to 1,000
- >1,000 to 1,500
- >1,500 to 2,000

Line of measured water level, Contour interval is 20 feet.



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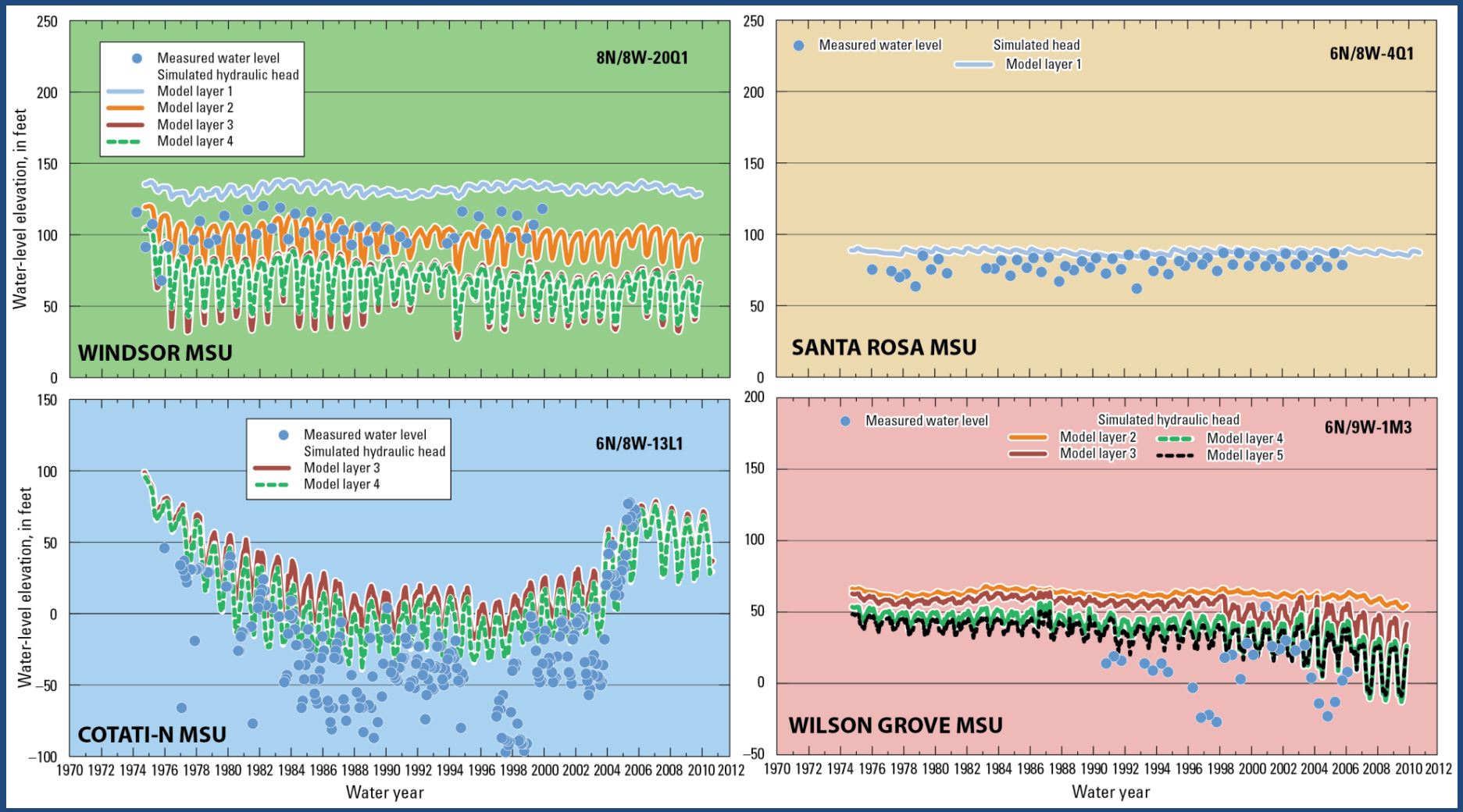
Groundwater-Level Hydrograph Comparison



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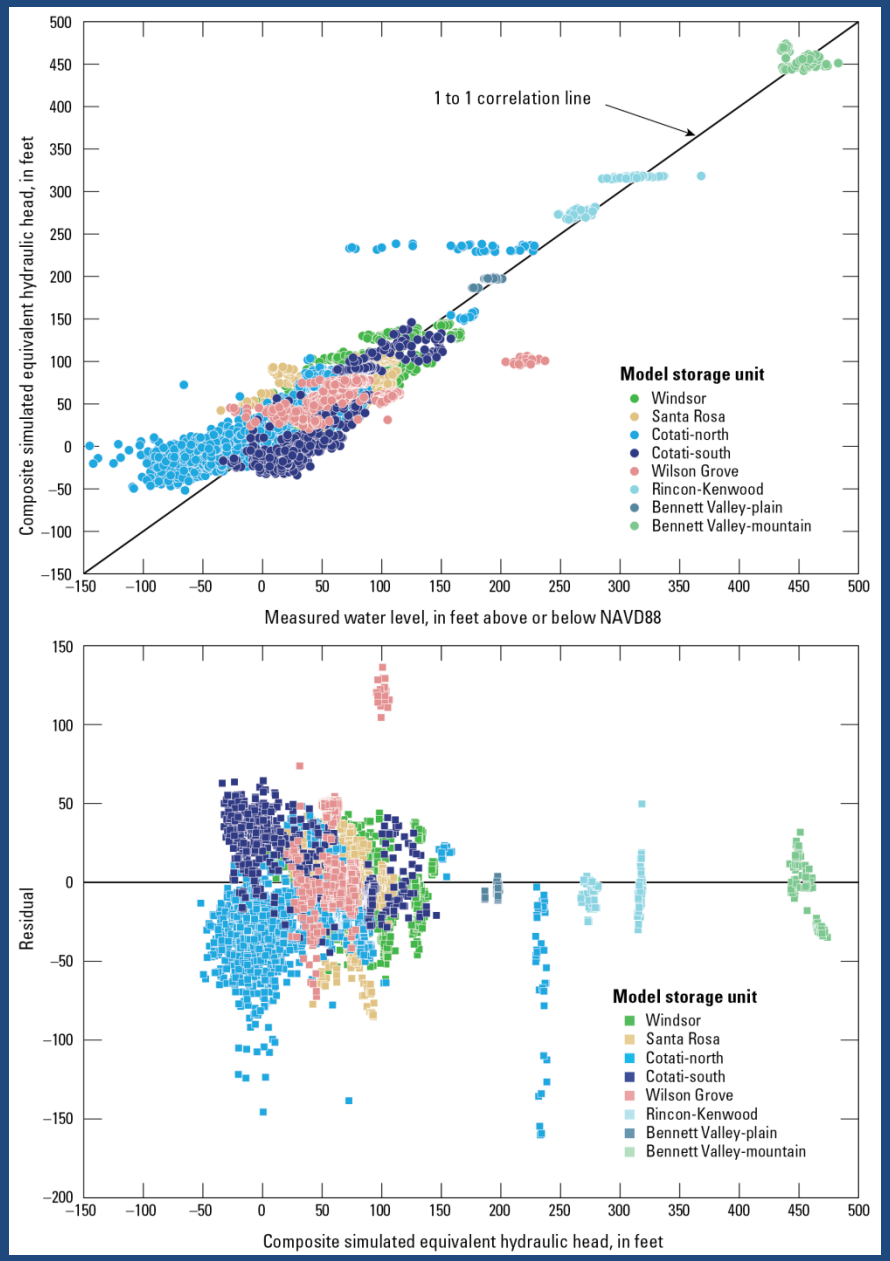
Calibrated Groundwater Levels



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Model Results

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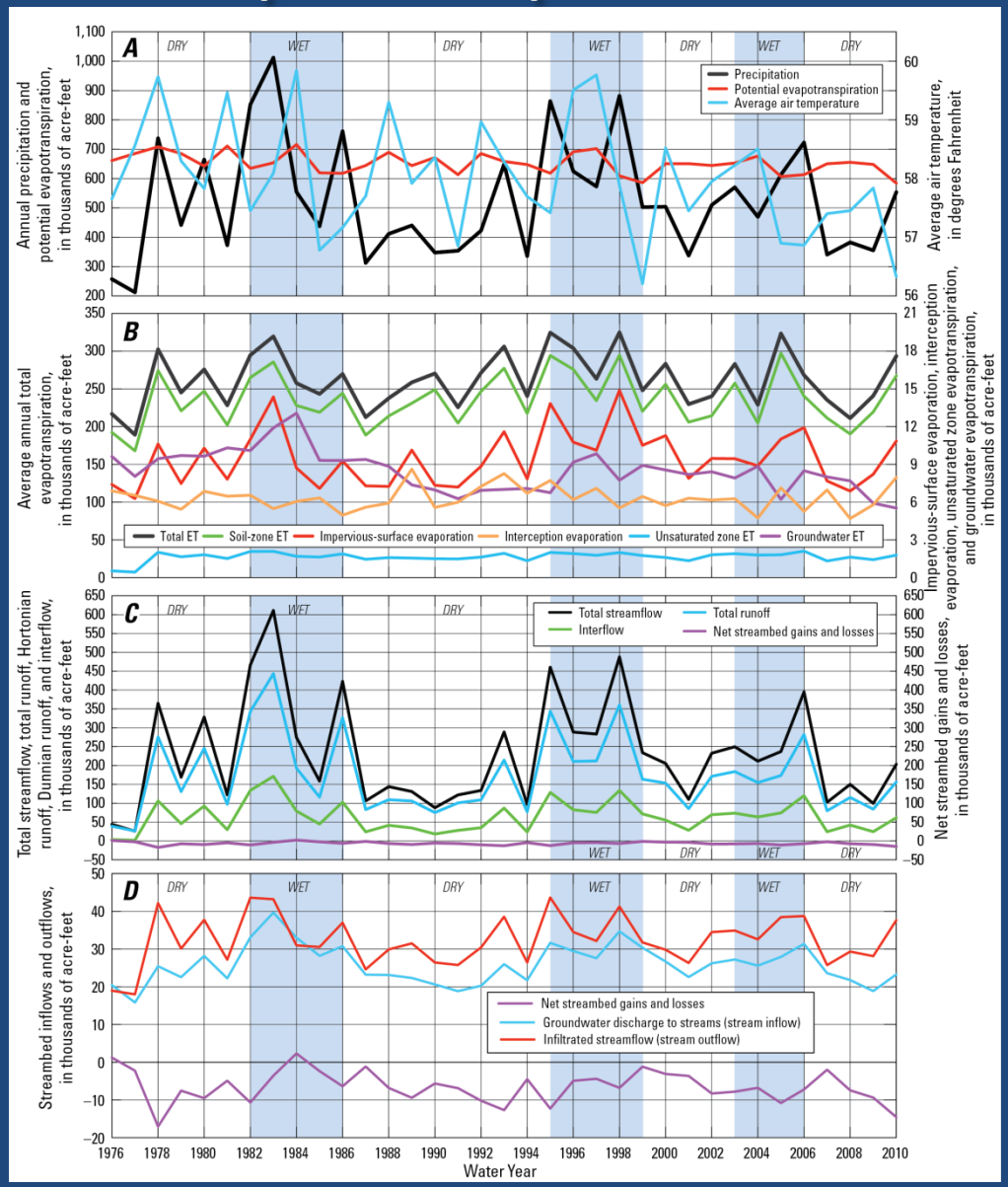
Components of Total Streamflow and Total Evapotranspiration



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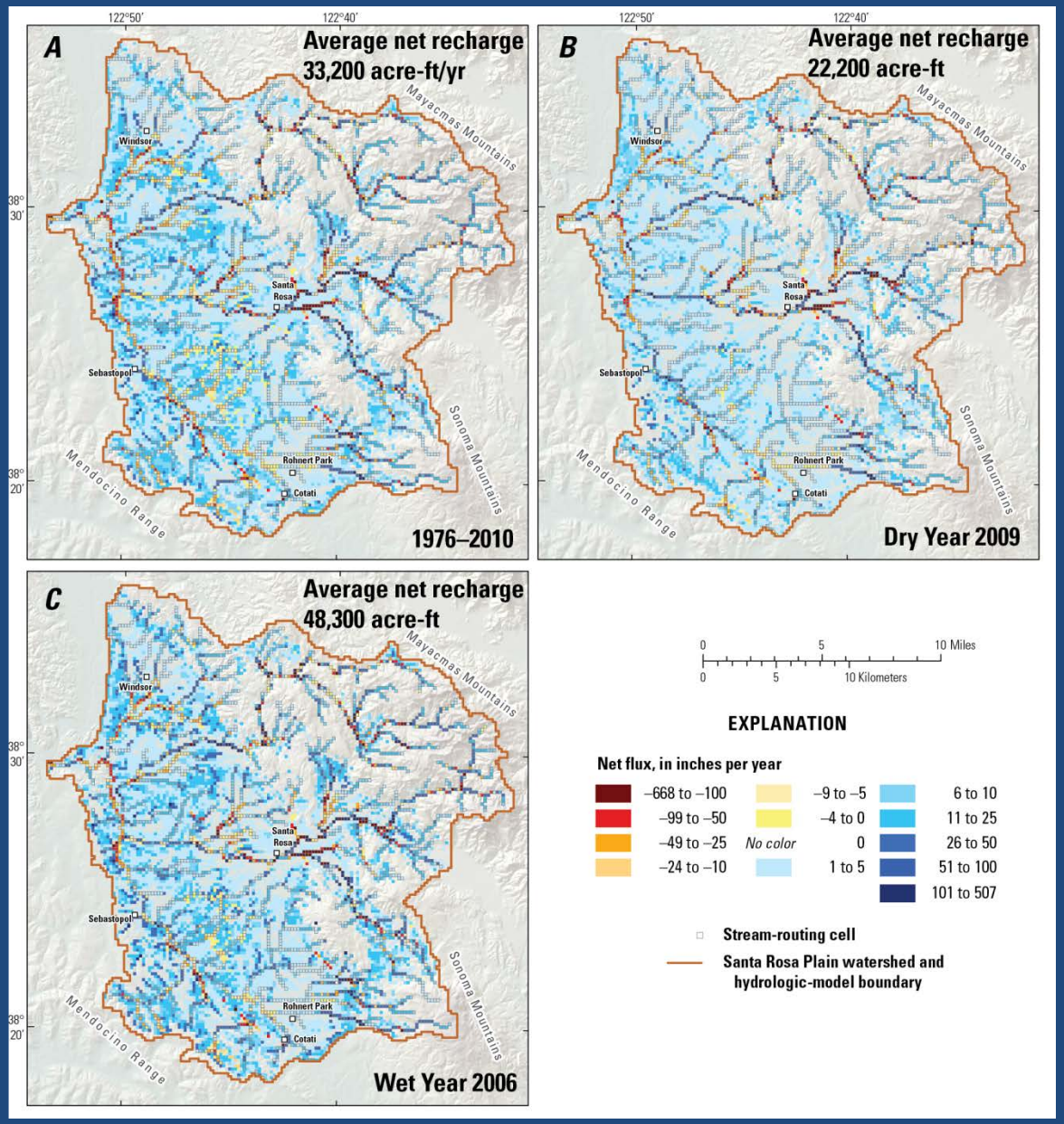
Average Groundwater Budgets

INFLOWS AND OUTFLOWS	Long-term average 1976-2010 water years (acre-feet per year)	Short-term average 2004-2010 water years (acre-feet per year)	Dry water year (2009) (acre-feet)	Wet water year (2006) (acre-feet)
Precipitation	525,000	491,000	355,000	723,000
INFLOWS				
Boundary Flows	7,200	7,200	7,300	7,000
Extra-Channel Recharge	41,000	41,700	21,500	69,700
Stream Recharge	32,400	32,900	28,100	38,700
Total Inflow	80,600	81,800	56,900	115,400
OUTFLOWS				
Pumpage	35,600	42,000	42,700	39,700
Boundary Flows	7,900	7,600	7,100	8,300
Groundwater evapotranspiration	8,500	7,200	5,900	8,500
Surface Leakage	6,100	5,200	3,100	8,100
Groundwater discharge to streams	25,800	24,600	18,900	31,400
Total Outflow	83,900	86,600	77,700	96,000
Groundwater Storage Change	-3,300	-4,800	-20,800	19,400

Net Flux



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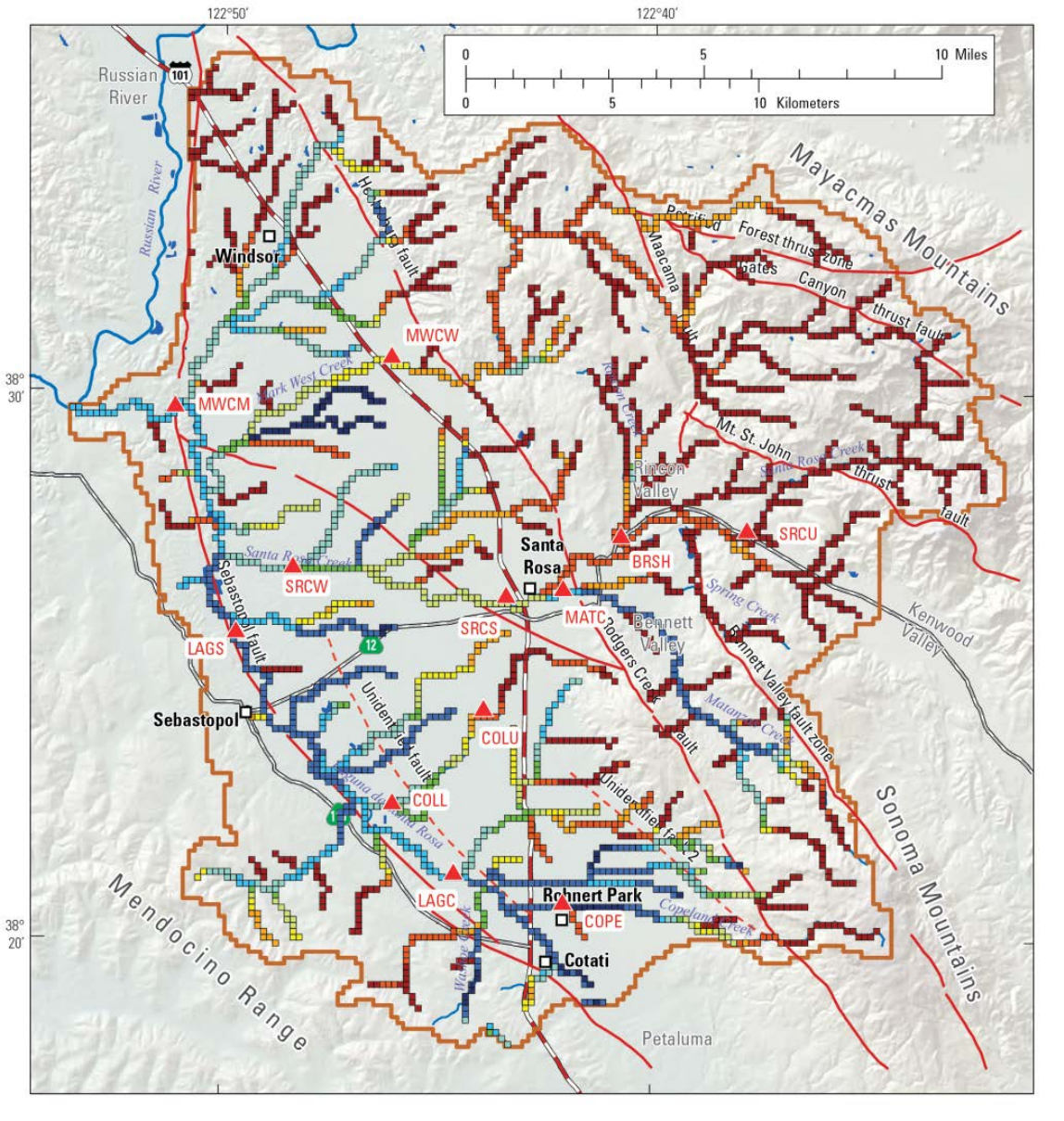
Effect of Pumping on Streamflow

Percentage reduction in average streamflow

- <1.0
- 1.1 to 2.0
- 2.1 to 3.0
- 3.1 to 4.0
- 4.1 to 5.0
- 5.1 to 6.0
- 6.1 to 8.0
- 8.1 to 10
- 11 to 15
- 16 to 56



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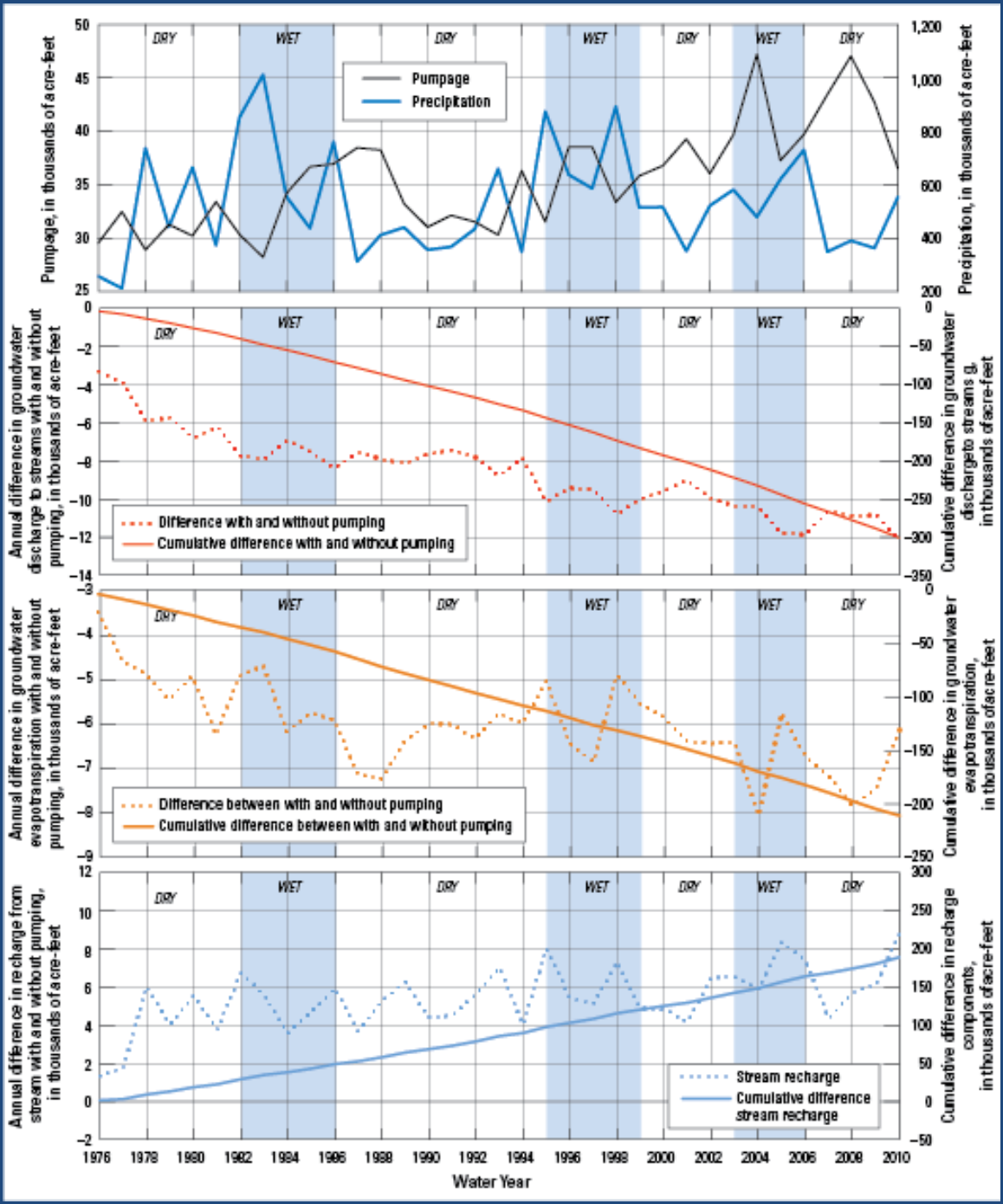
Effect of pumping on selected groundwater components



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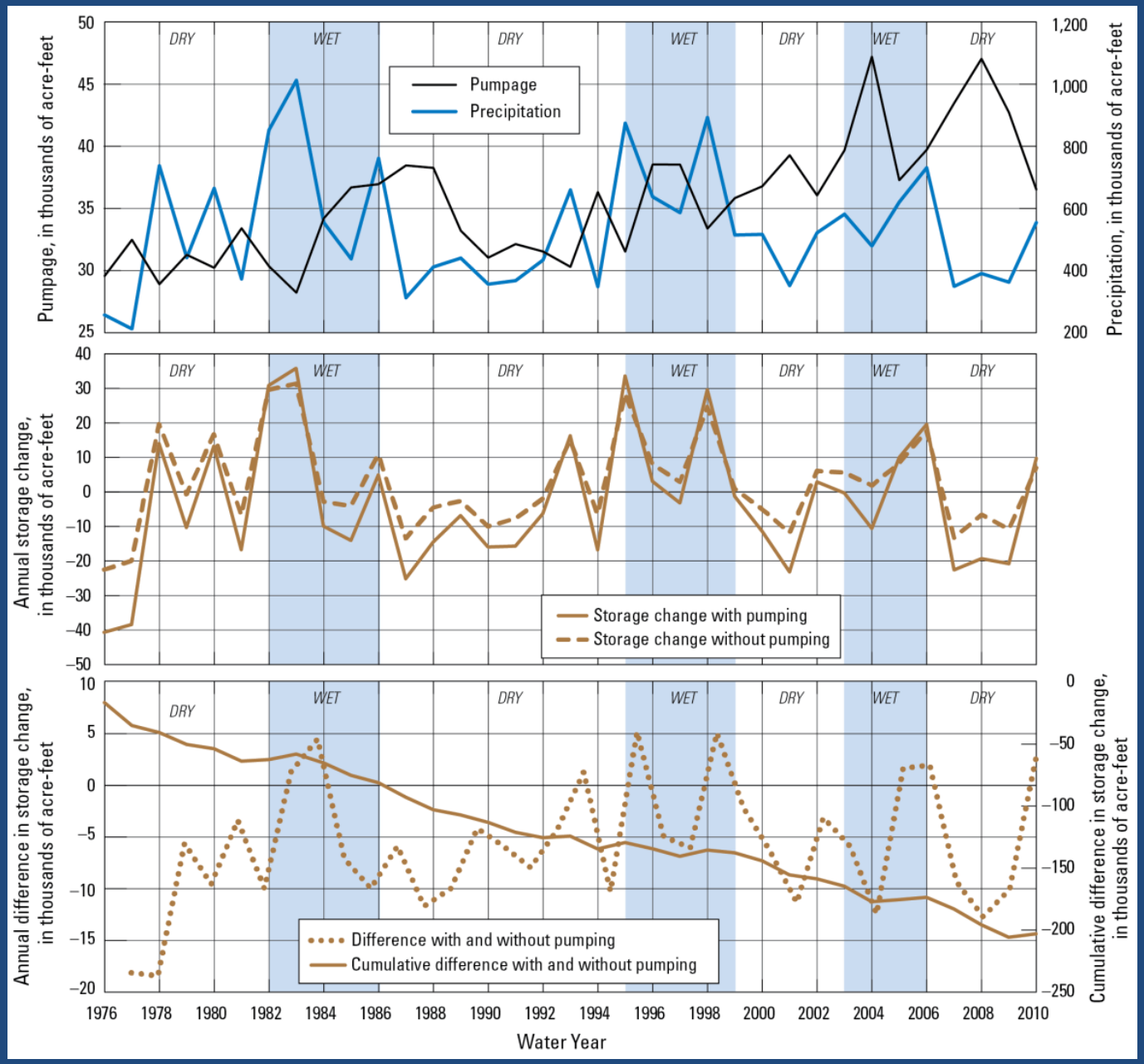
Effect of Pumping on Groundwater Storage Change



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Model Application: Future-Climate Scenarios

- 4 climate scenarios compared to historical-climate baseline period of water years 1981-2010
- Model runs without pumping for water years 2005-99 show effect of only climate on the hydrologic system
- Model runs with projected pumping show the combined of effect of projected pumping and future climate for water years 2005-40
- Agricultural pumpage estimated using future climates; domestic pumpage estimated using assumed growth rate; and reported estimates used for public-supply pumpage

Average Climate for Water Years 1981-2010 and 2005-99

Scenario	Historical	GA2	GB1	PA2	PB1
Precipitation					
Average (in/yr)	38.9	34.6	36.5	38.9	41.8
Maximum (in)	57.1	64.9	87.7	86.2	87.8
Minimum (in)	15.2	8.6	7.5	8.0	13.0
Standard deviation (in)	11.8	12.1	14.4	14.3	15.9
Average daily air temperatures					
Average (deg F)	57.9	61.6	60.5	60.8	59.9
Maximum (deg F)	60.0	67.3	63.9	65.0	62.7
Minimum (deg F)	55.5	57.1	57.3	56.6	56.8
Standard deviation (deg F)	1.1	2.5	1.5	1.8	1.2

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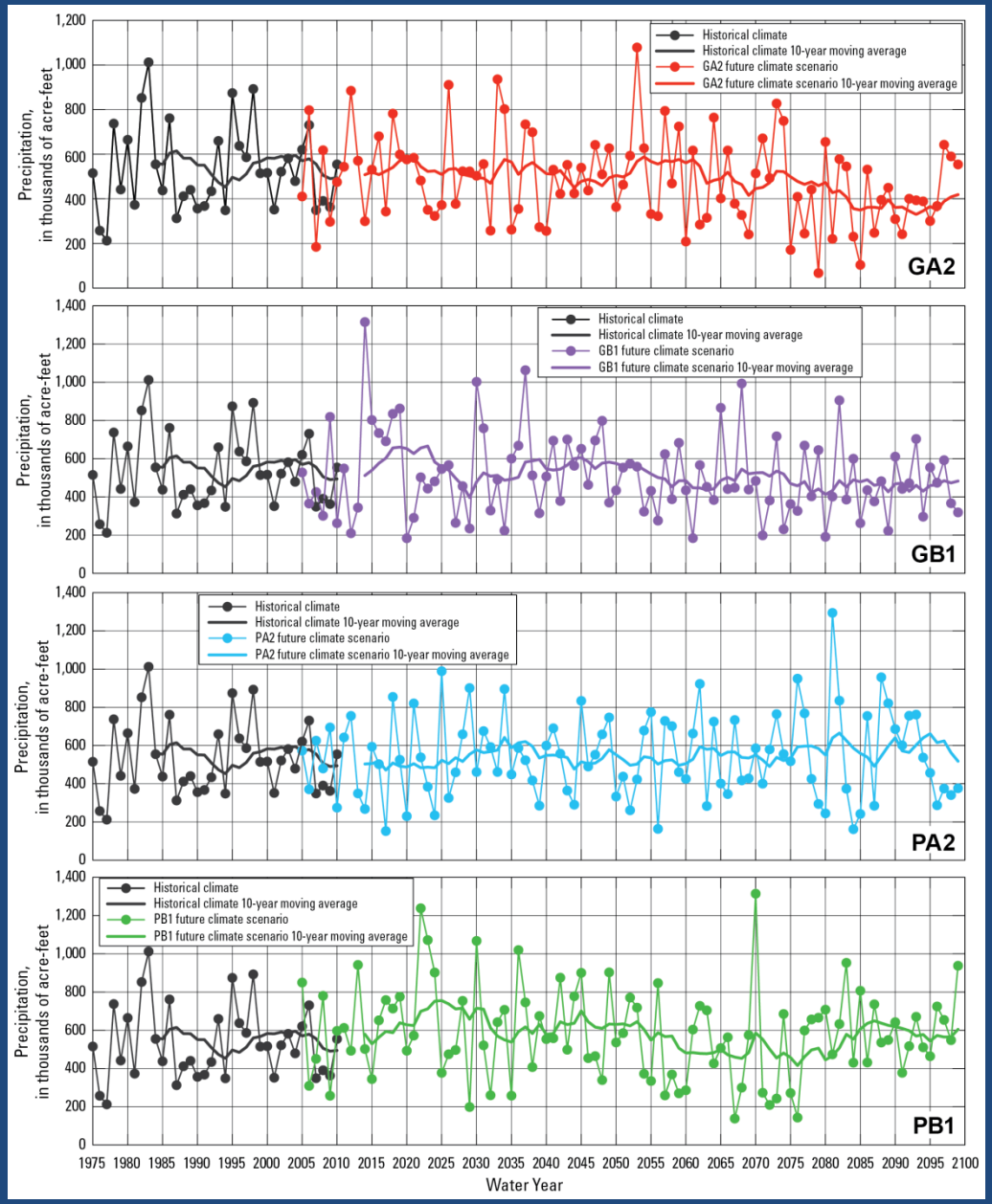
Precipitation

- All more variable
- Decline in later years



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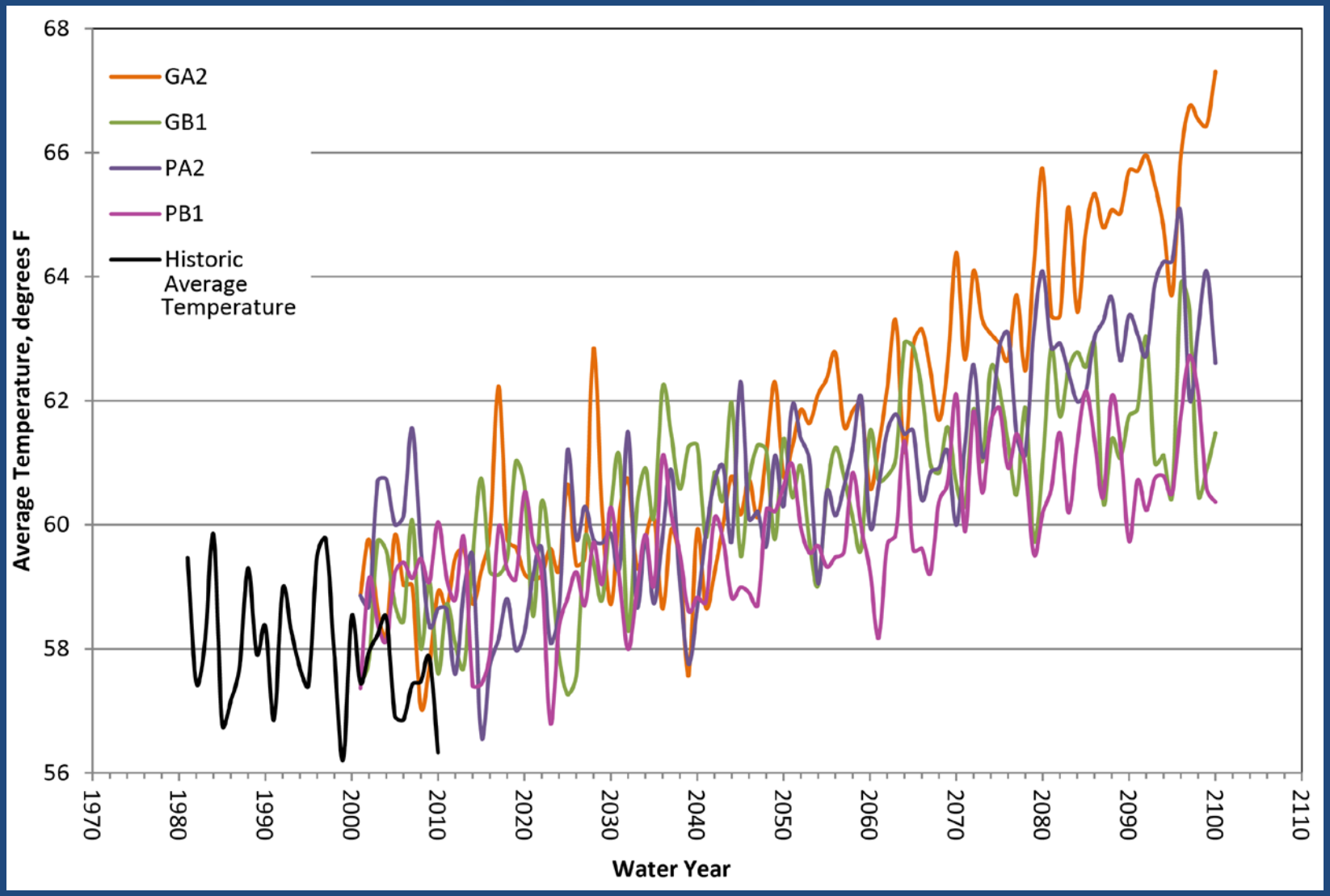
Average Temperature



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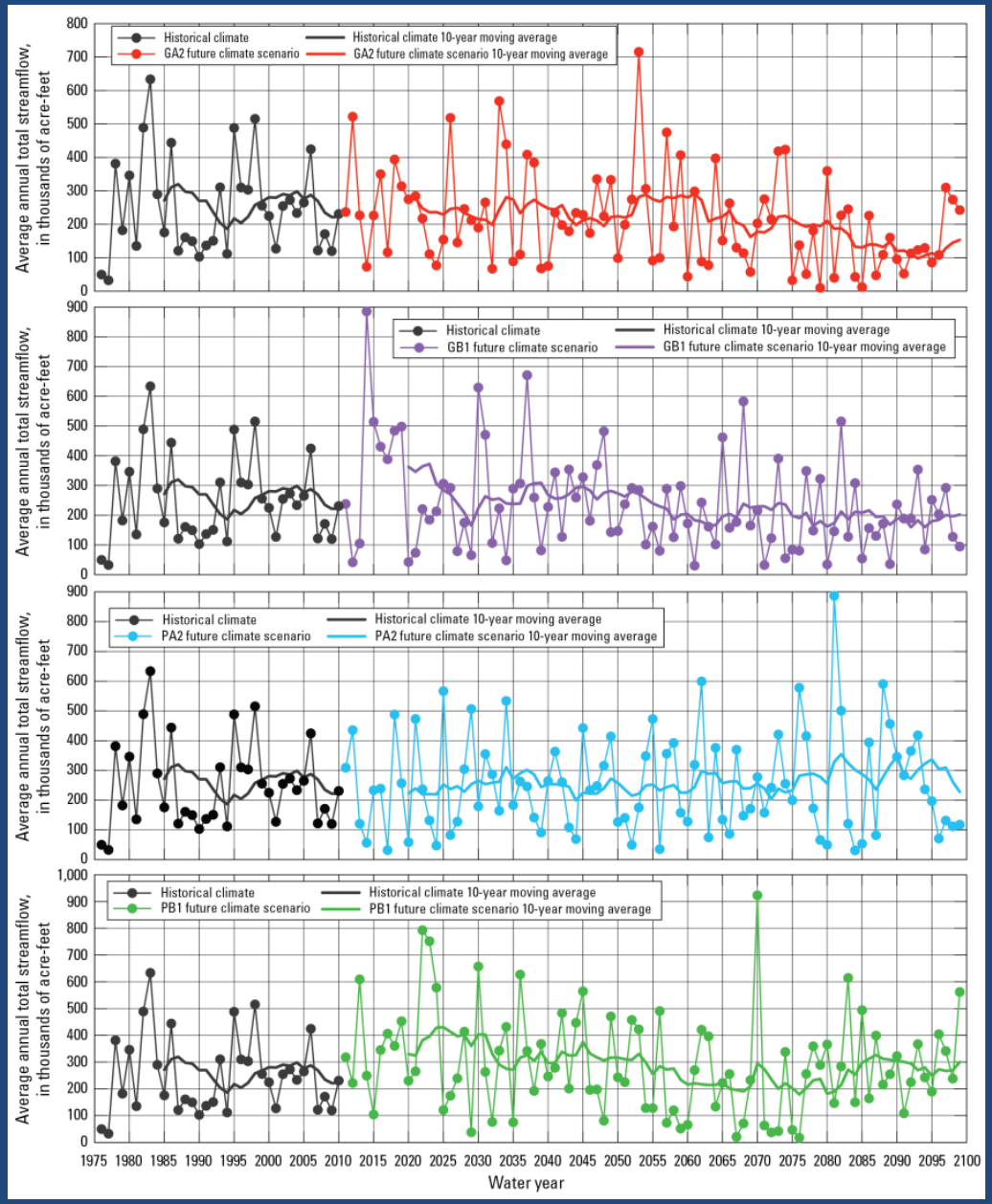
Effect of Future Climate on Total Streamflow



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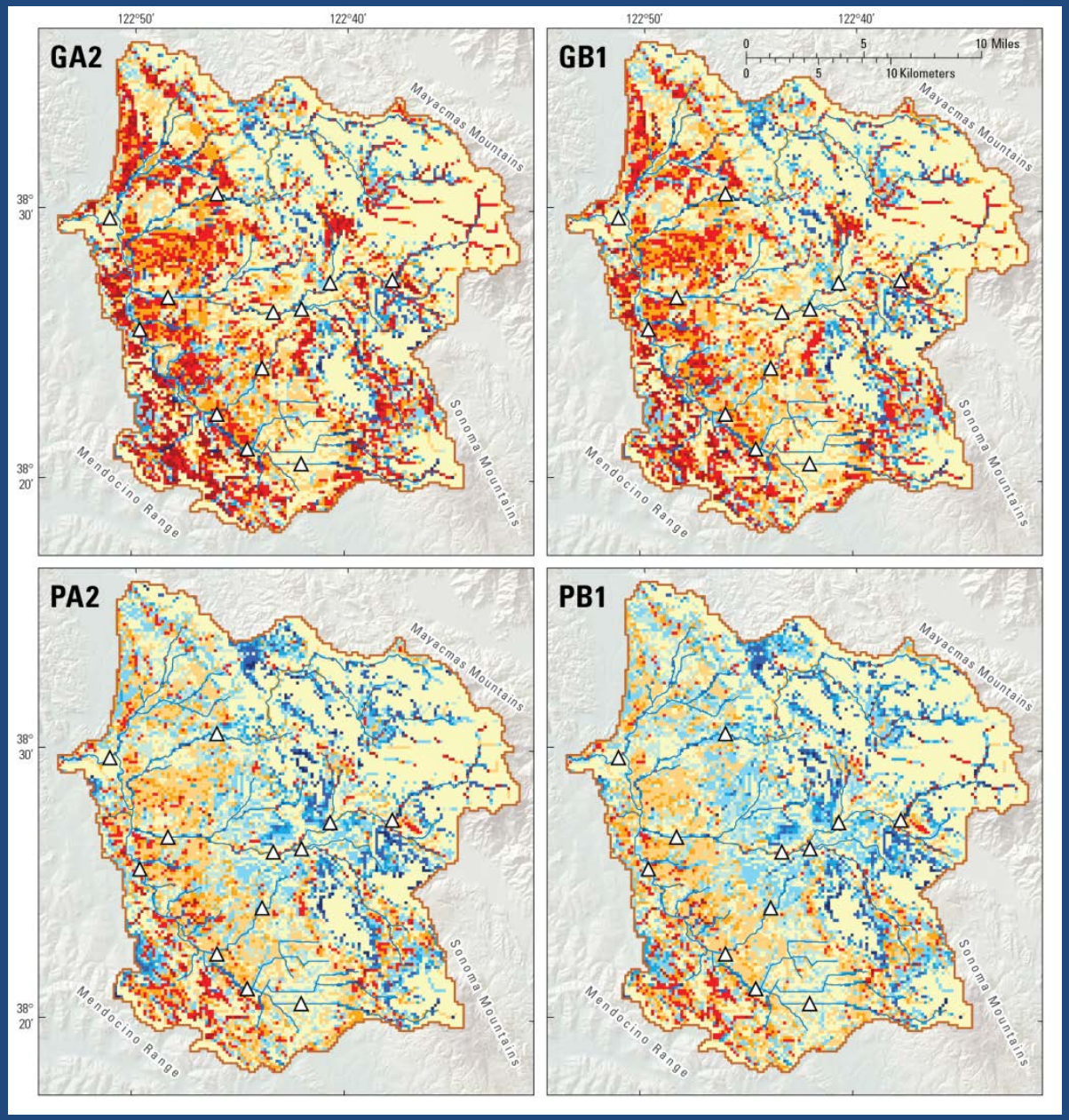
Effect of Future Climate on Recharge

Difference in 30-year average recharge, in inches per year, for future-climate scenarios (2070–2099) minus historical climate (1981–2010)

- –81 to –5
- –4.9 to –2
- –1.9 to –1
- –0.9 to –0.1
- –0.09 to 0
- 0.01 to 0.1
- 0.11 to 1
- 1.1 to 2
- 2.1 to 5
- 5.1 to 91



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Average Climate for Water Years 1981-2010 and 2005-40

Scenario	Historical	GA2	GB1	PA2	PB1
Precipitation					
Average (in/yr)	38.9	38.0	40.4	38.4	46.3
Maximum (in)	57.1	61.4	87.7	60.1	87.8
Minimum (in)	15.2	17.3	18.9	15.0	13.3
Standard deviation (in)	11.8	11.2	18.8	11.9	17.6
Average daily air temperatures					
Average (deg F)	57.9	59.7	59.7	59.1	59.1
Maximum (deg F)	60.0	62.8	62.2	61.5	61.1
Minimum (deg F)	55.5	57.6	57.3	56.6	56.8
Standard deviation (deg F)	1.1	1.0	1.3	1.1	1.0

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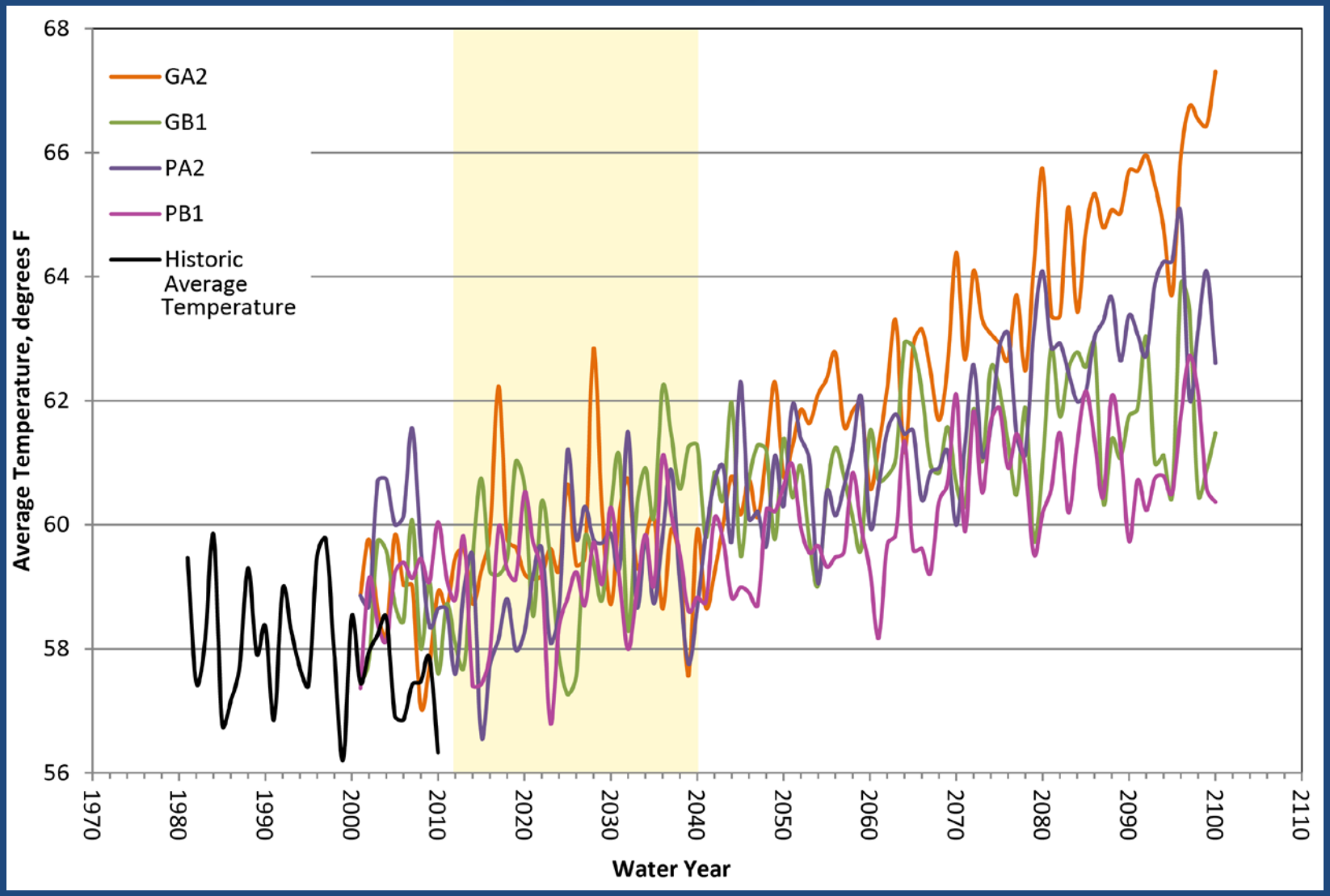
Average Temperature



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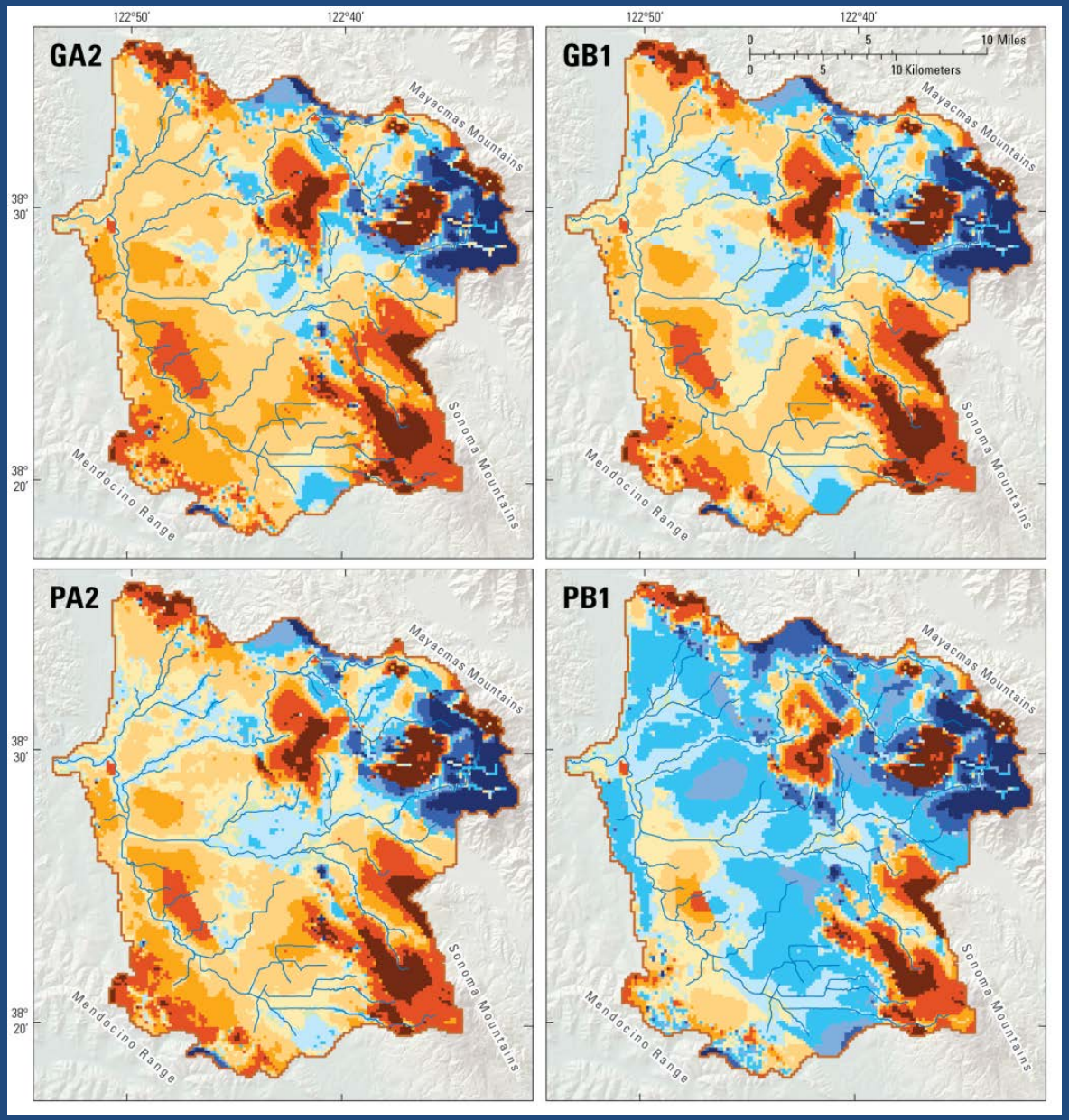
Average Groundwater Budgets

Selected surface-water components	Historical-climate baseline 1981-2010 water years ac-ft/yr	GA2 2011-2040 water years ac-ft/yr	GB1 2011-2040 water years ac-ft/yr	PA2 2011-2040 water years ac-ft/yr	PB1 2011-2040 water years ac-ft/yr
Precipitation	543,000	530,000	559,000	538,000	641,000
Total Streamflow	238,000	217,000	256,000	219,000	314,000
Runoff	178,000	164,000	192,000	165,000	299,000
Interflow	66,200	67,400	78,000	68,900	96,000
Net stream leakage	6,400	14,800	14,600	15,400	11,200
GROUNDWATER INFLOWS					
Boundary Flows	7,200	7,500	7,500	7,500	7,300
Extra-Channel Recharge	43,500	40,900	43,200	39,400	50,900
Stream Leakage	32,800	35,900	36,300	36,300	36,700
Total Inflow	83,500	84,300	87,000	83,200	94,900
GROUNDWATER OUTFLOWS					
Pumpage	36,500	47,300	47,600	45,900	46,300
Boundary Flows	8,000	6,500	6,600	6,500	7,100
Groundwater ET	8,300	7,000	7,200	6,700	8,400
Surface Leakage	6,300	3,400	3,800	3,400	5,400
Groundwater discharge to streams	26,400	21,100	21,700	20,900	25,500
Total Outflow	85,500	85,300	86,900	83,400	92,700
Storage Change (Inflows–Outflows)	-2,000	-1,000	100	-200	2,200

Water-Level Change Spring 2010 to 2040

Difference in hydraulic head, spring 2040 minus spring 2010, in feet

- <–25
- –25 to <–10
- –10 to <–5
- –5 to <–1
- –1 to 0
- 0
- 0 to 1
- >1 to 5
- >5 to10
- >10 to 25
- >25



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Model Limitations

- Pumpage estimates – quantity of pumpage and location of wells
- Limited measured streamflow data
- Few multiple-completion well sites for depth-dependent data
- Uncertainty associated with the spatially distributed daily precipitation input
- Little borehole-geophysical data for the hydrologic framework model

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Model Limitations for Future-Climate Scenarios

- Future-climate scenarios are not forecasts of climate; they are representations of the characteristics of potential future climates
- Estimated agricultural irrigation assumed distribution of crops in 2008 can be applied to water years 2005-2040
- Other changes in the characteristics of land cover were not addressed

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Appropriate Use of the Model

- The model can be used for simulating hydrologic responses to various changes in stresses to the groundwater and surface-water flow systems

- The potential hydrologic response to changes in stresses can be assessed by evaluating simulated results from management scenarios together with the simulated results from the calibrated model

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