Estimating components of the Central Valley hydrologic flow system with the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM)

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Outline

History and development

Tools: IWFM and C2VSIM

Calibration

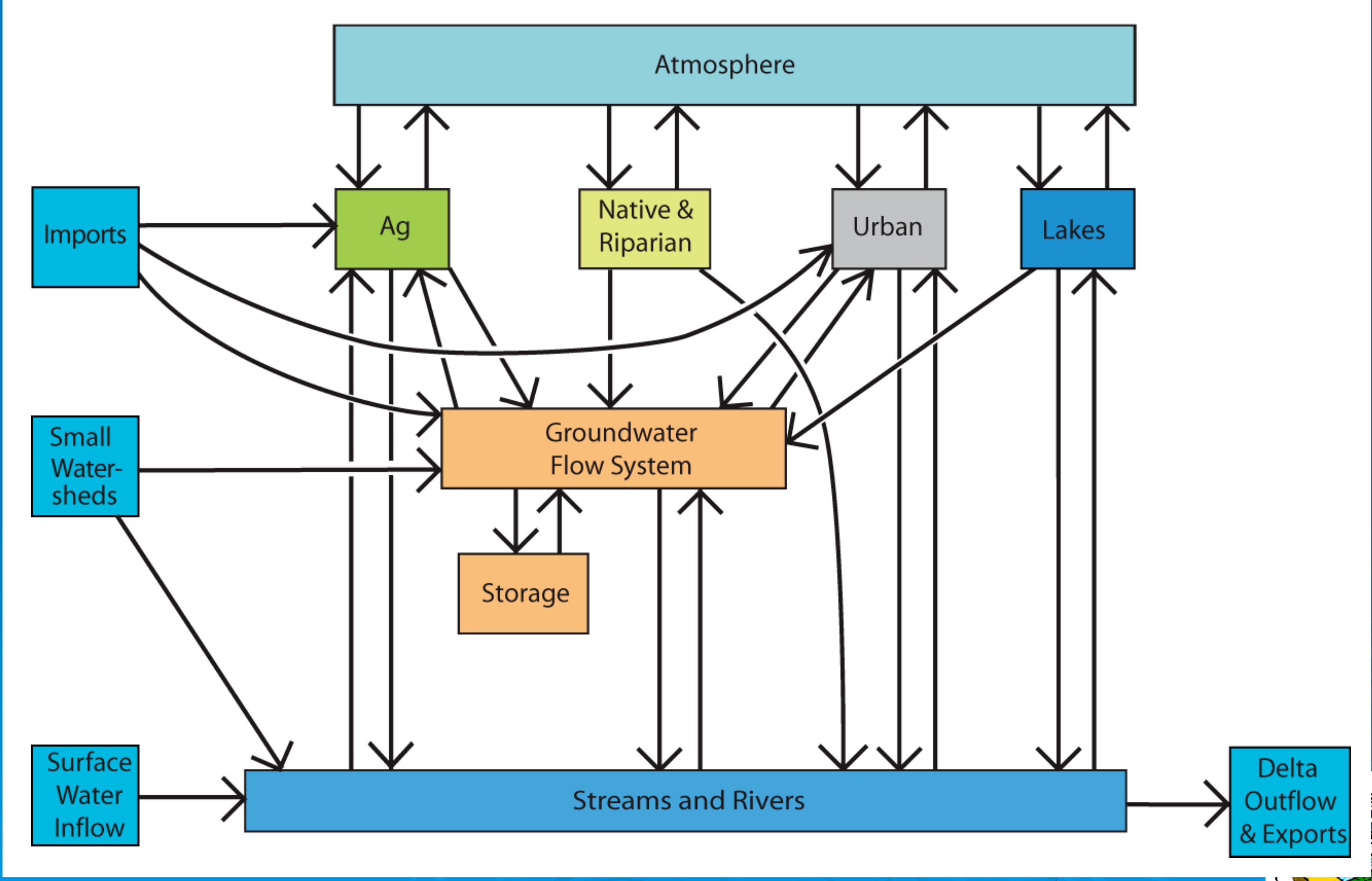
Simulation Results

Summary

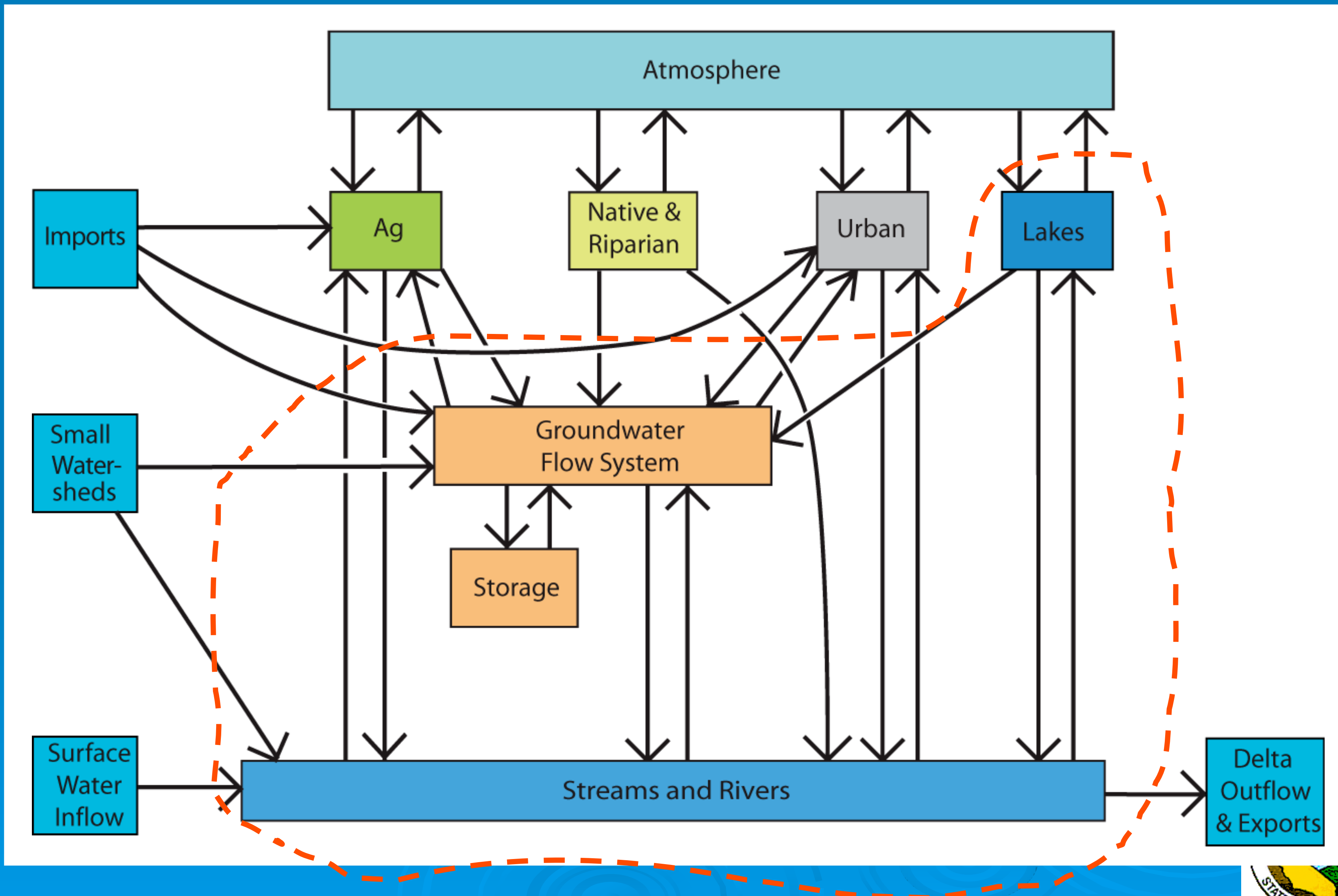
History

- Boyle Engineering (1987)
- J.M. Montgomery (1990):
  - IGSM: Coupled Land, Groundwater, Streams
  - CVGSM: monthly data WY 1922-80
- CH2MHill (1996): CVGSM update to 1993
- DWR (2000,2004): update to 1998, 2003
- DWR (2001-05): IWFM and C2VSIM
  - Modify solver in IGSM -> IWFM
  - Additional modifications (now IWFM 3.0)
- DWR (2007):
  - IWFM groundwater linked to WRIMS
  - C2VSIM groundwater linked to CALSIM-III

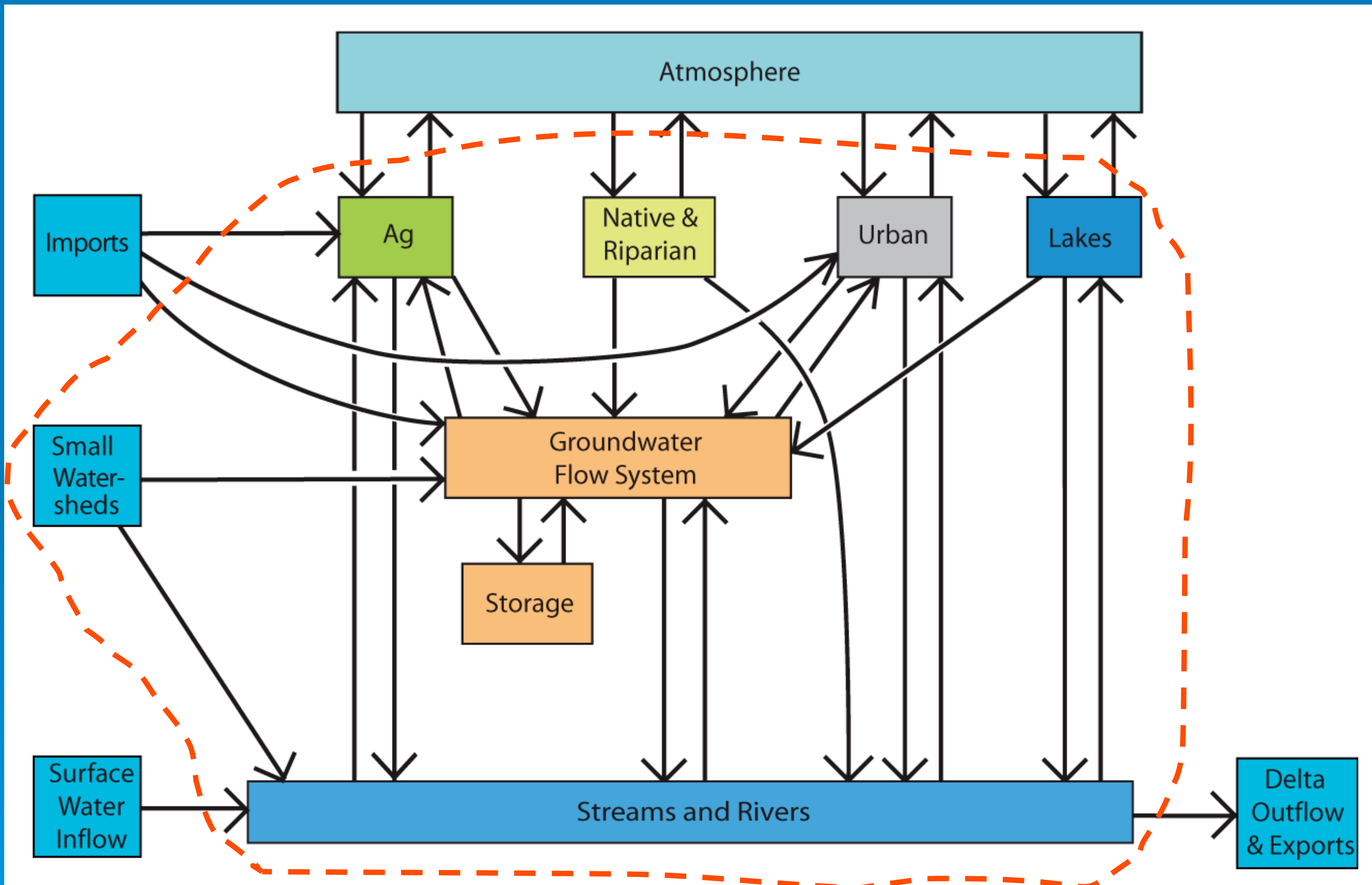
Groundwater Model Components



Groundwater Model Components



Integrated Model Components



IWFM - Integrated Water Flow Model

- Components
  - Groundwater Flow Process
    - Finite Element Grid
    - Saturated and unsaturated flow
  - Land Surface Process
    - Precipitation and Evapotranspiration
    - Land Type and Crop Acreages
    - Irrigation with Surface Water & Groundwater
  - Surface Water Processes
    - Streamflow routing
    - Lakes
    - Surface Water Diversions
  - Small Watersheds
    - Inflows from Ungaged Boundary Watersheds
- Outputs:
  - Water Budget Components
  - Estimated Groundwater Pumping

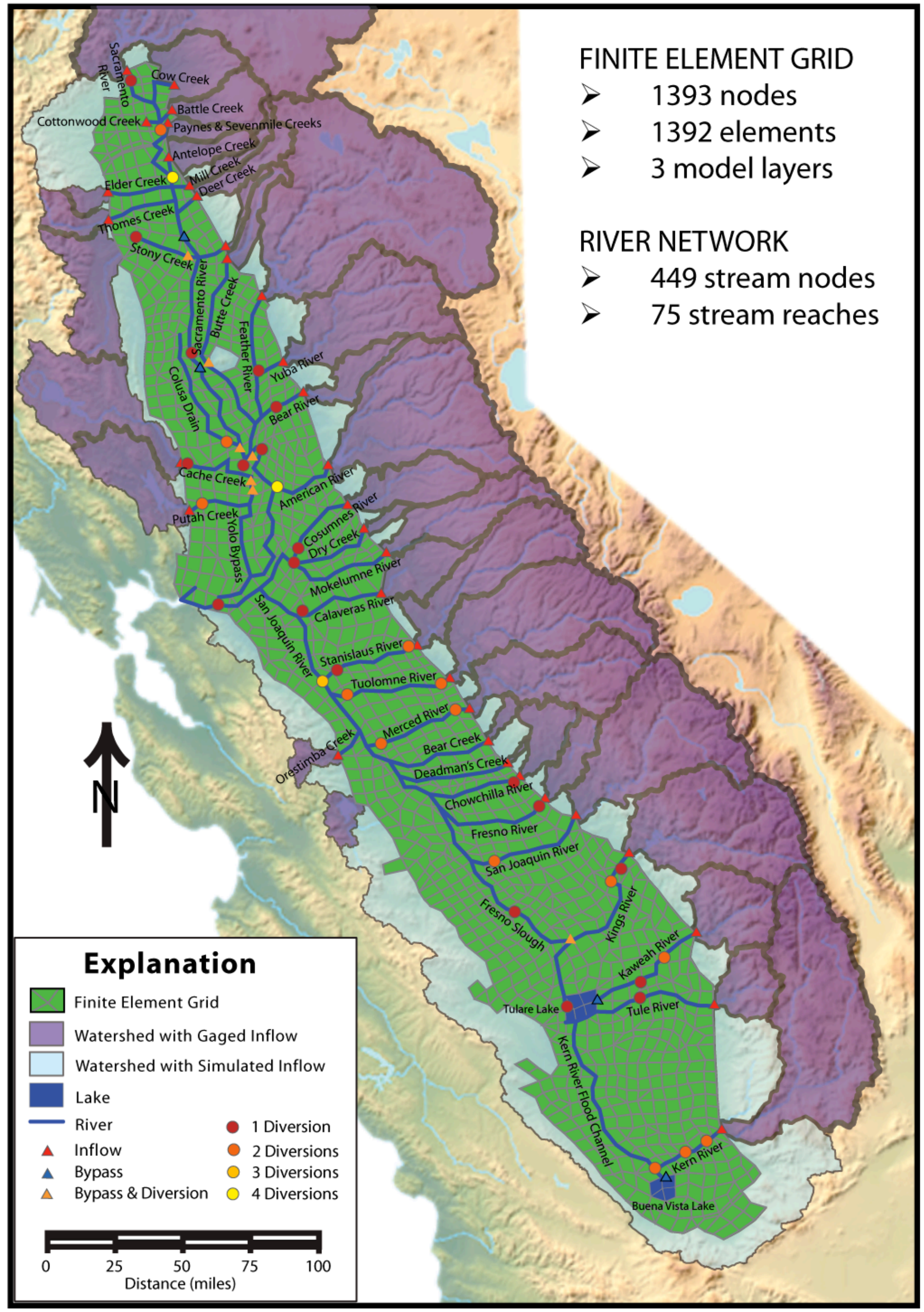
Framework

Finite Element Grid
- 3 layers
- 1393 nodes
- 1392 elements

Surface Water System
- 75 river reaches
- 2 lakes
- 97 surface water diversion points
- 6 bypasses

Land Use Process
- 21 subregions
- 4 Land Use Types
  - Agriculture
  - Urban
  - Native
  - Riparian

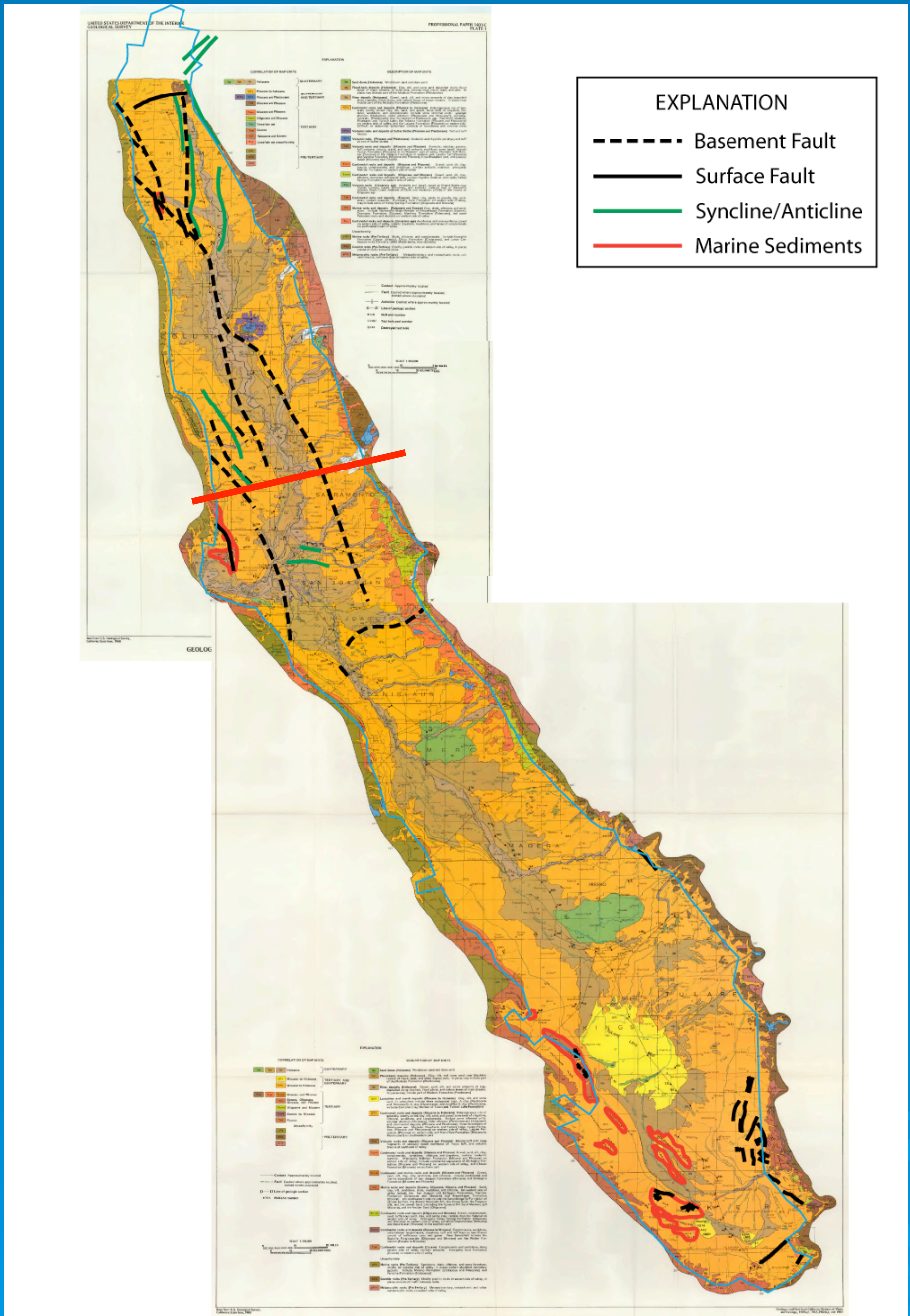
Simulation periods
- 10/1921-9/2003 (<8 min)
- 10/1972-9/2003 (<4 min)



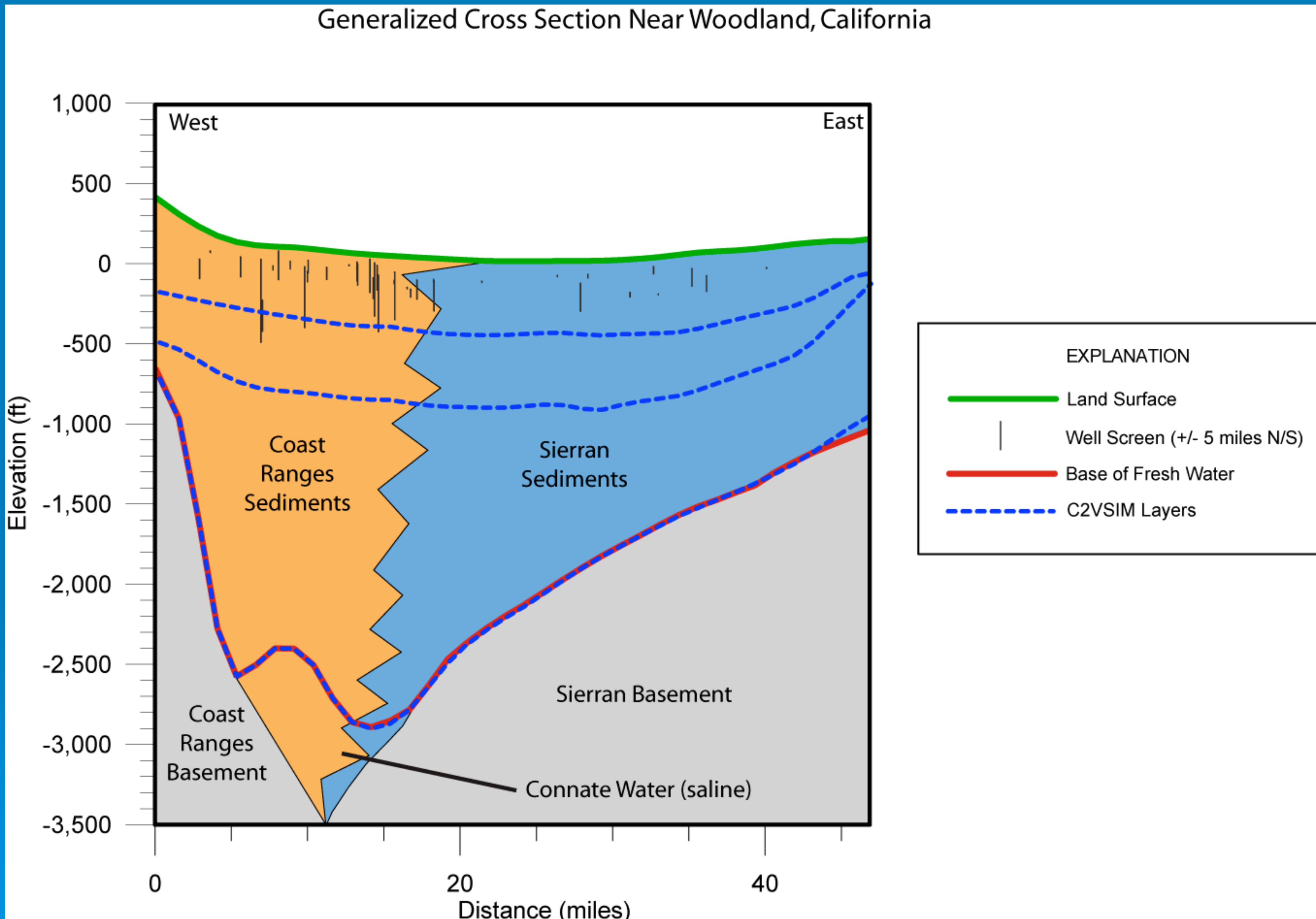
CVGSM to C2VSIM

Update Conceptual Model

- Layering
- Stream-bed elevations
- Uniform Curve Numbers (rainfall runoff)
- Agricultural root-zone process
- Small watershed delineation



Page, Ronald W. 1986. Geology of the fresh ground-water basin of the Central Valley, California. Washington, DC: U.S. Geological Survey Professional Paper 1401C.


Generalized Cross Section Near Woodland, California
West
East
1,000
500
0
-500
-1,000
-1,500
-2,000
-2,500
-3,000
-3,500
Elevation (ft)
Coast Ranges Sediments
Sierran Sediments
Sierran Basement
Coast Ranges Basement
Connate Water (saline)
0
20
40
Distance (miles)
EXPLANATION
Land Surface
Well Screen (+/- 5 miles N/S)
Base of Fresh Water
C2VSIM Layers

C2VSIM Subregions

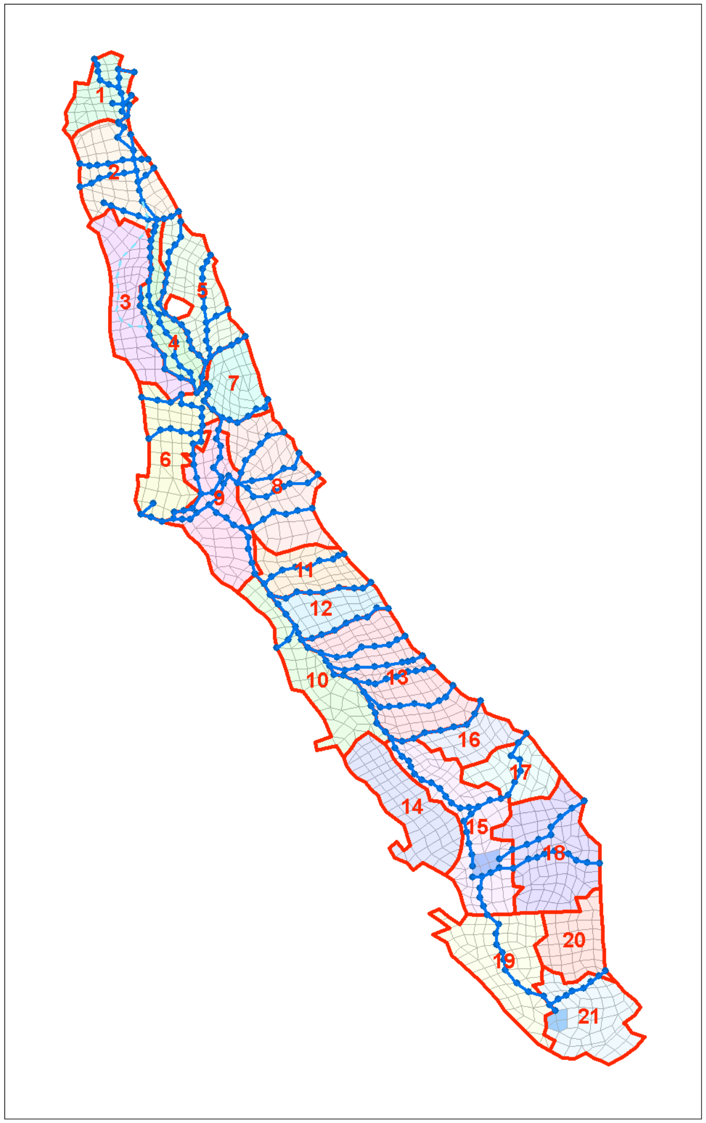
Water Budget Calculations

- Land use by element
- Aggregate to subregion

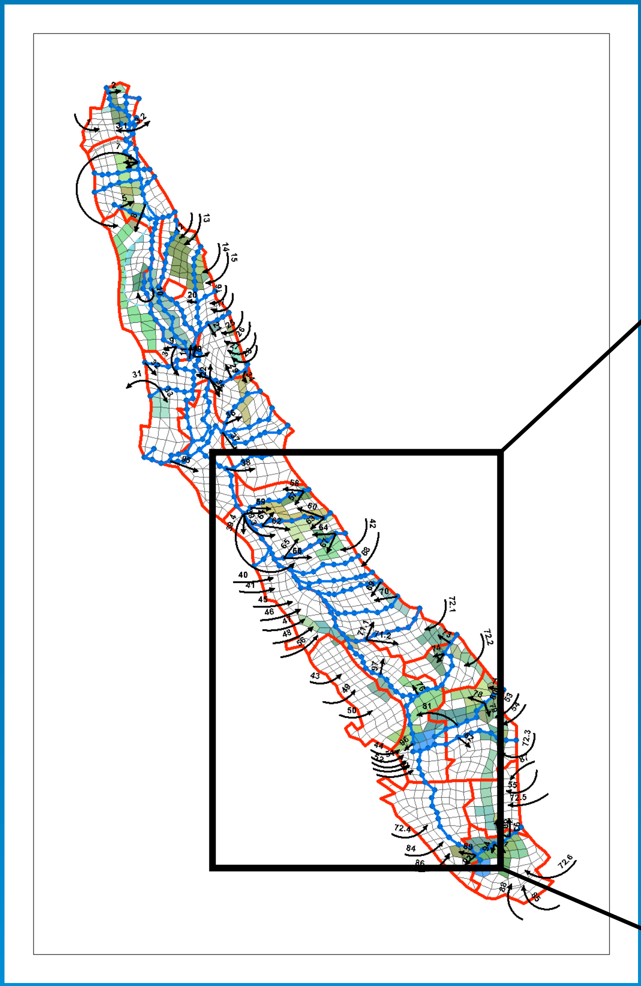
By land use in subregion:

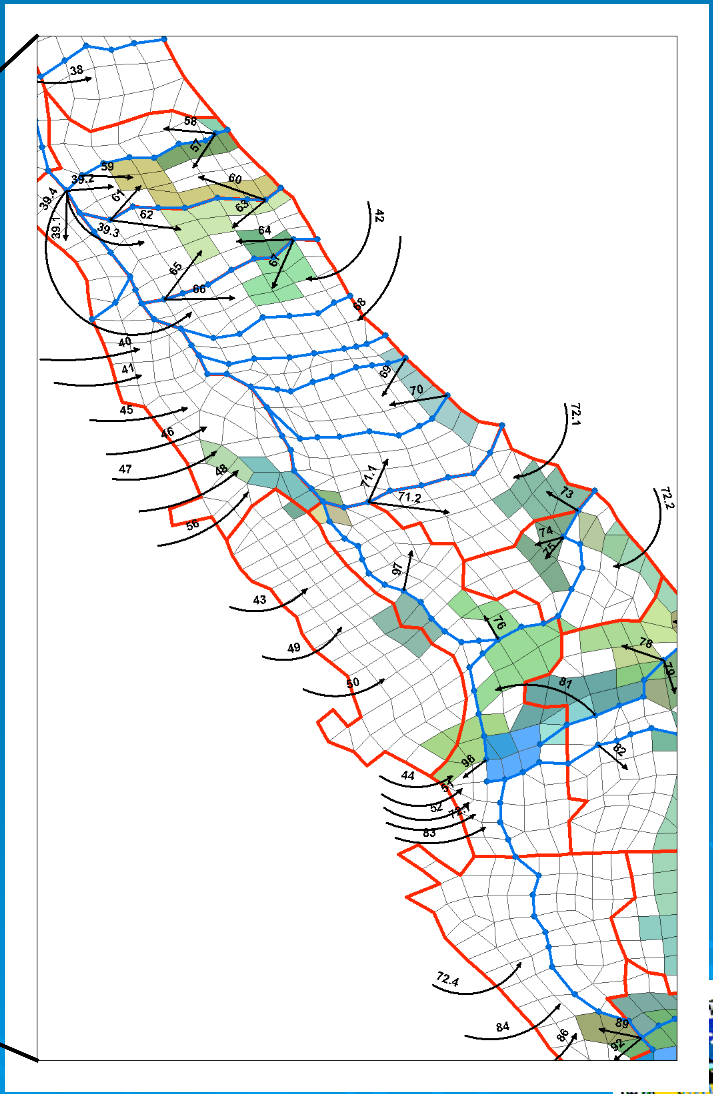
- Calculate water demands
- Apply soil moisture
- Apply surface water diversions
- Apply/estimate groundwater pumping
- Calculate soil moisture, recharge, return flows

Allocate to elements by land use areas



C2VSIM Diversions





C2VSIM Initial Calibration

Pilot Points

- 139 in layers 1 and 2 (K_h, K_v, S_y, S_s)
- 39 in layer 3 (K_h, K_v, S_s)
- 19 for Corcoran Clay (K_v)

Calibration Observations

Sites	per site	total
221 groundwater head	52	10,503
9 vertical head gradient	52	1,976
9 river flow	52*	3,276
34 stream-groundwater flow reaches	1**	34

Calibration Period Water Years 1975-99 (IC 10/1972)

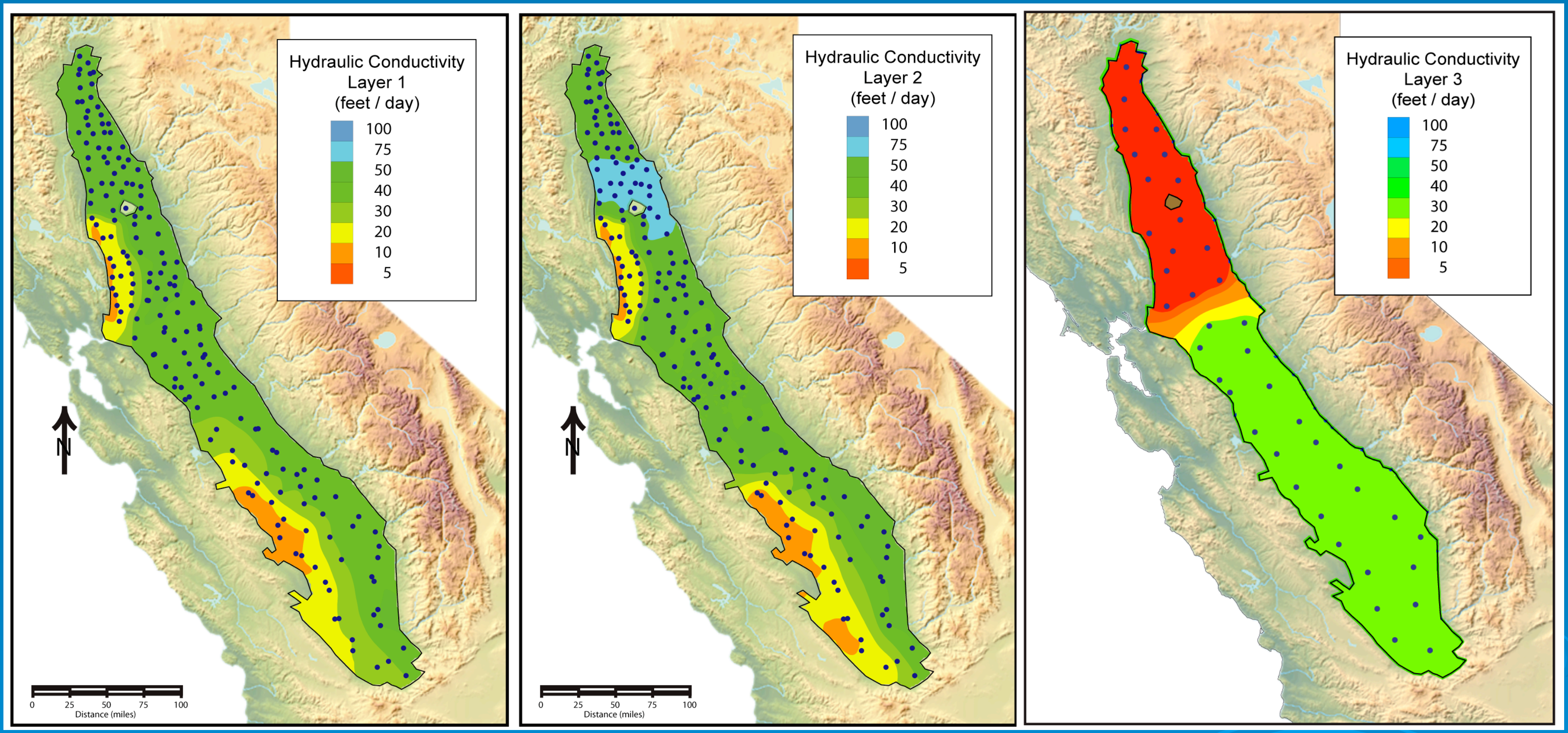
Validation Period Water Years 1975-99 (IC 10/1921)

* For 8 of 9 ** monthly average rate

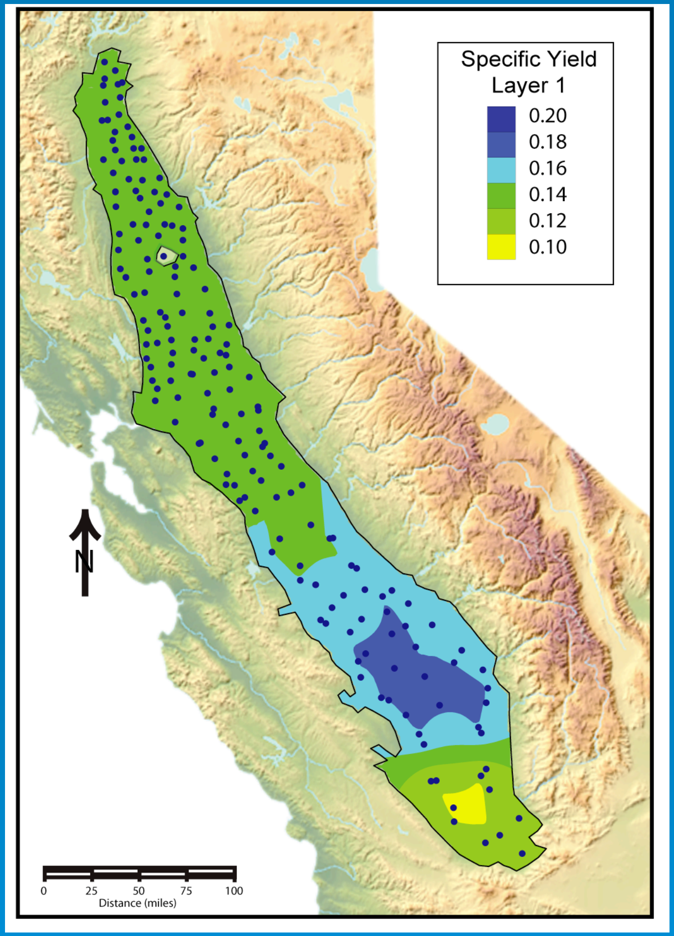
C2VSIM calibration sequence

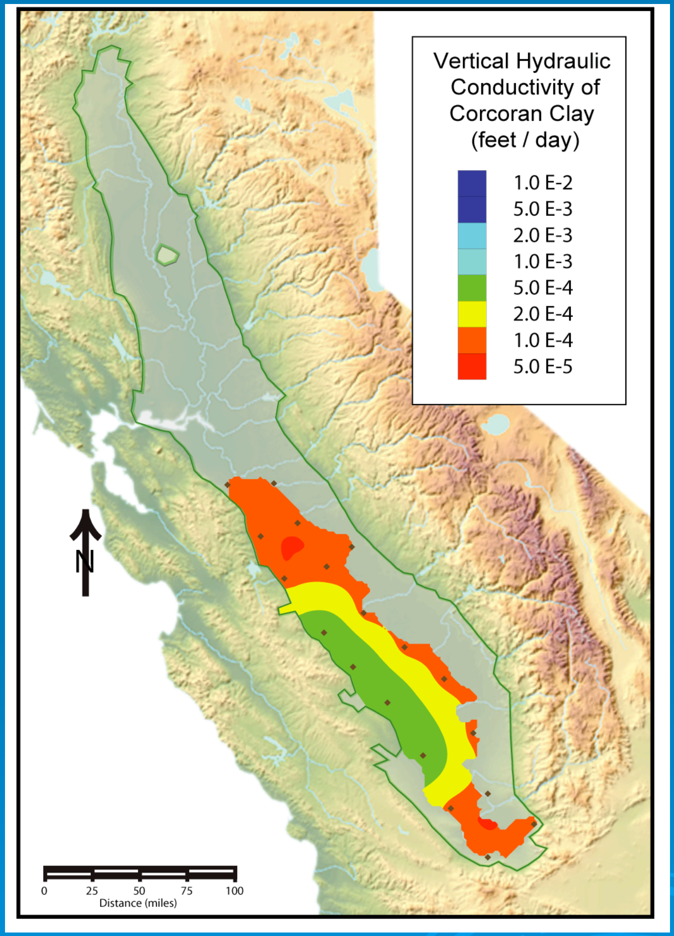
- Land use process
  - Agricultural root-zone process
  - Curve numbers
- Groundwater flow system
  - Hydraulic conductivity of layers 1 & 2
  - Vertical anisotropy 1:1,000
  - Specific yield in layer 1
  - Specific storage held constant
- Surface water flow system
  - Stream-bed conductivity

Hydraulic Conductivity

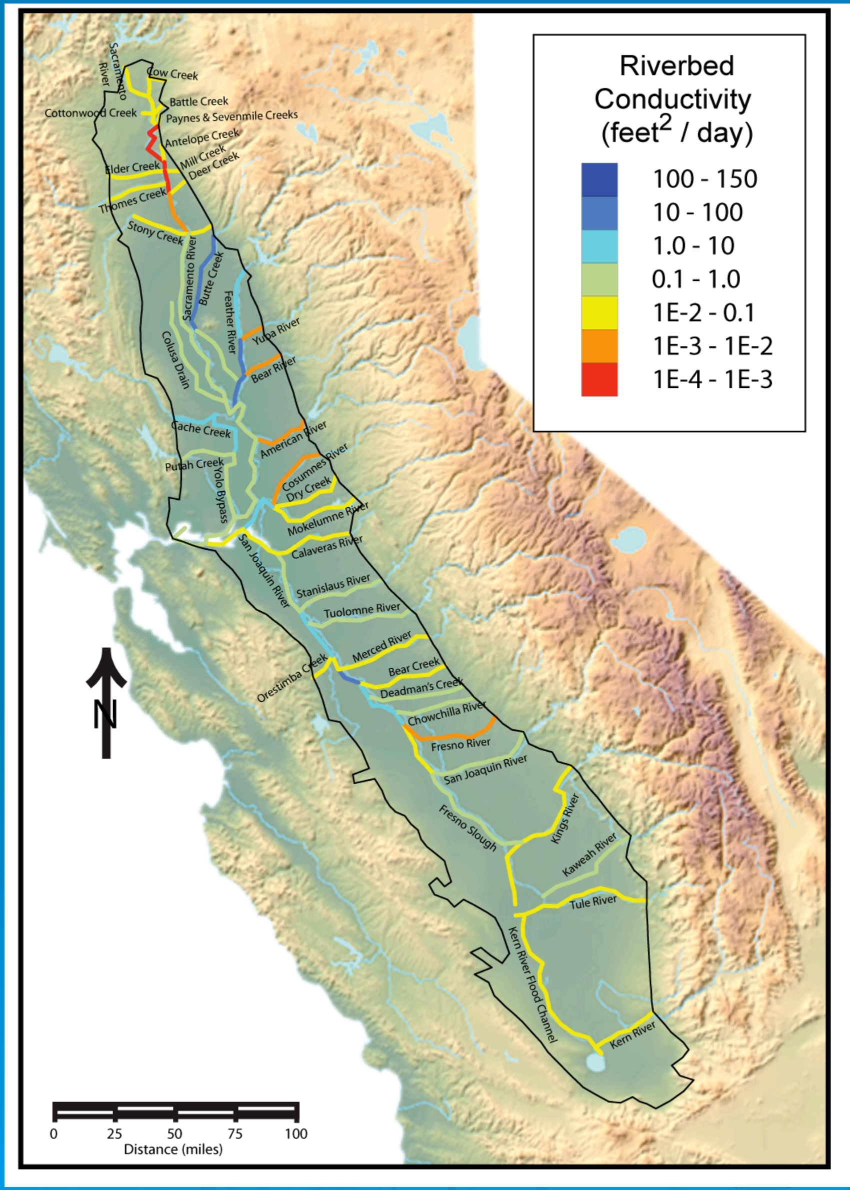


Specific Yield & Kv of Corcoran Clay

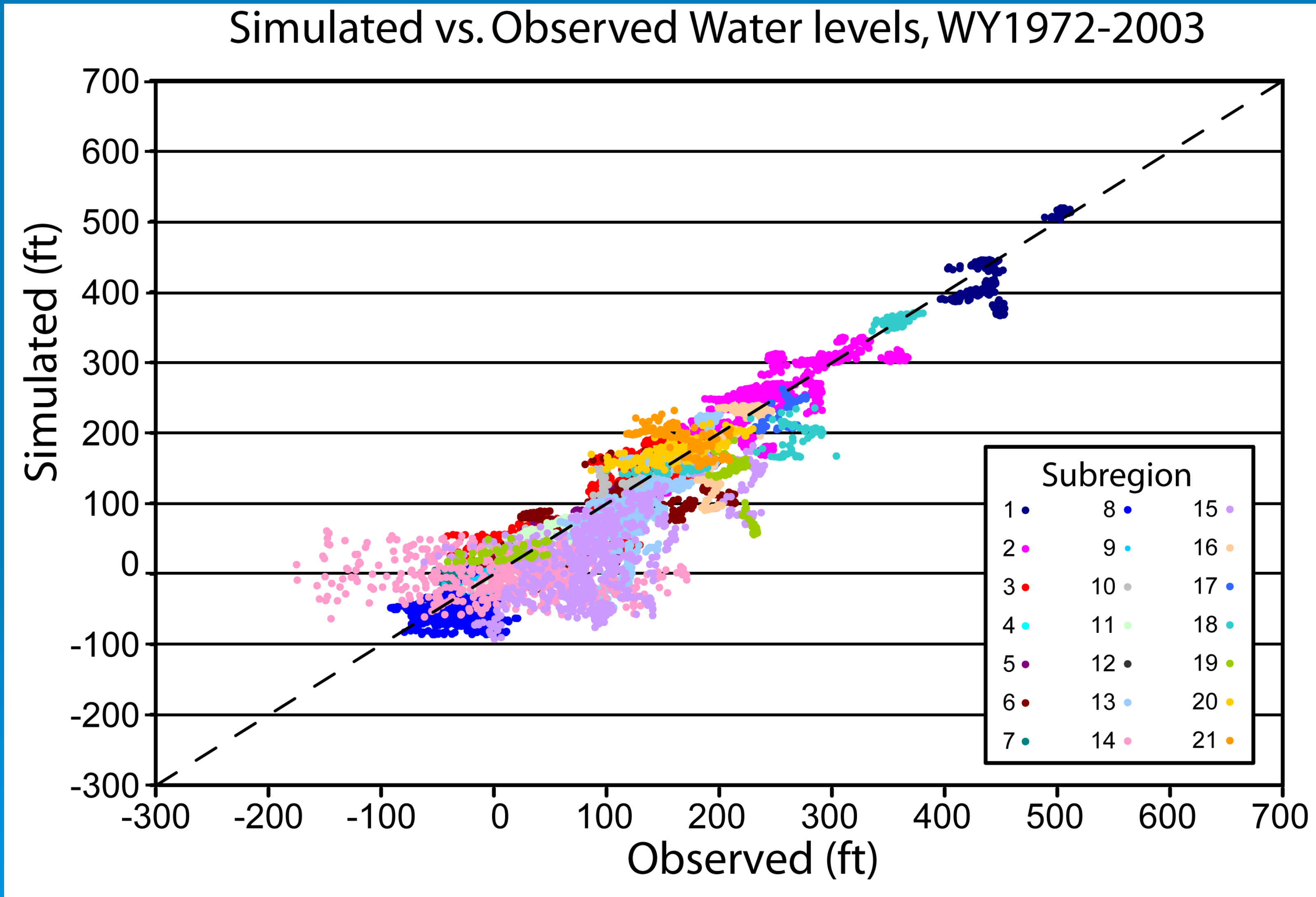




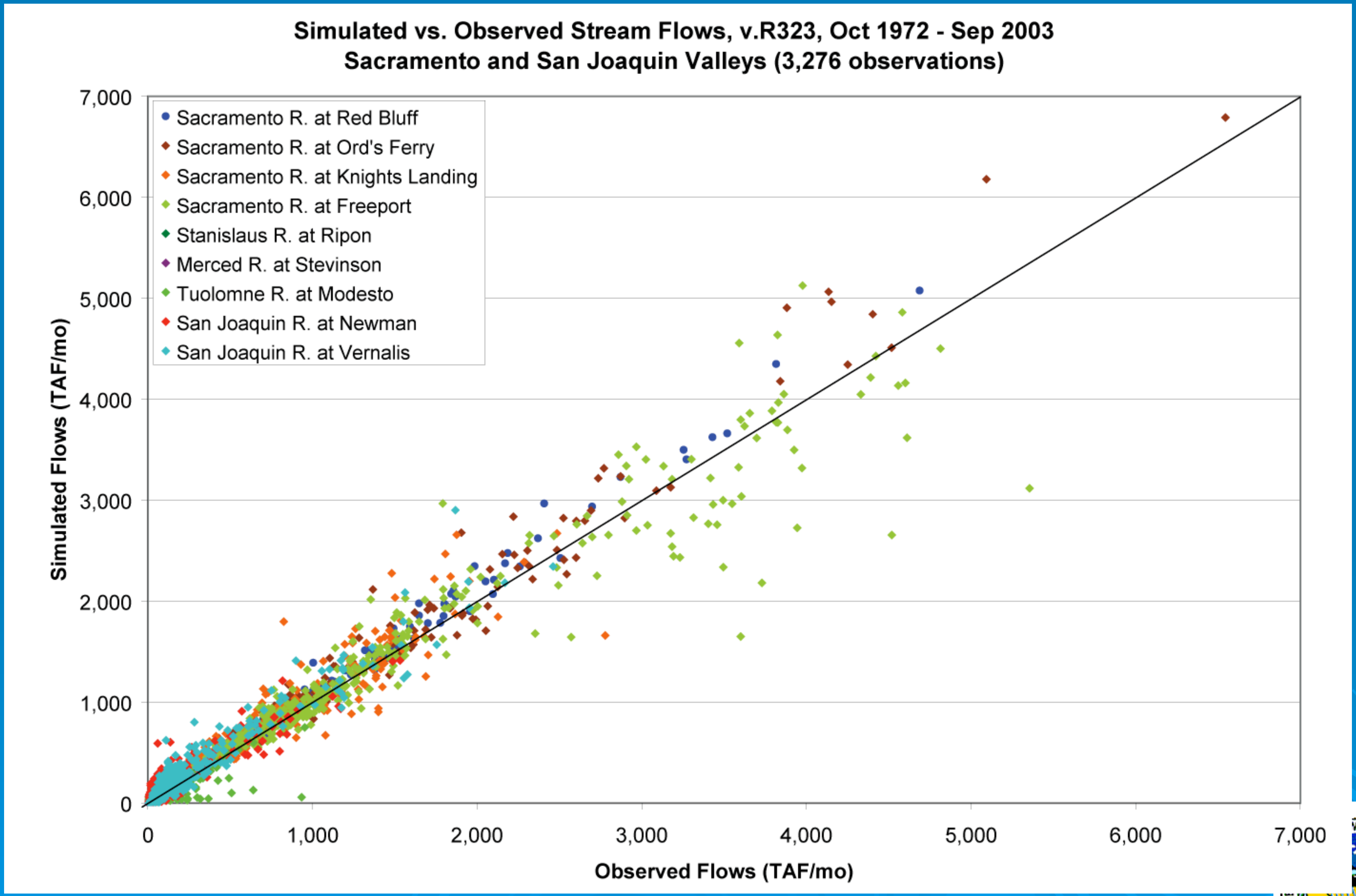
Streambed Conductance



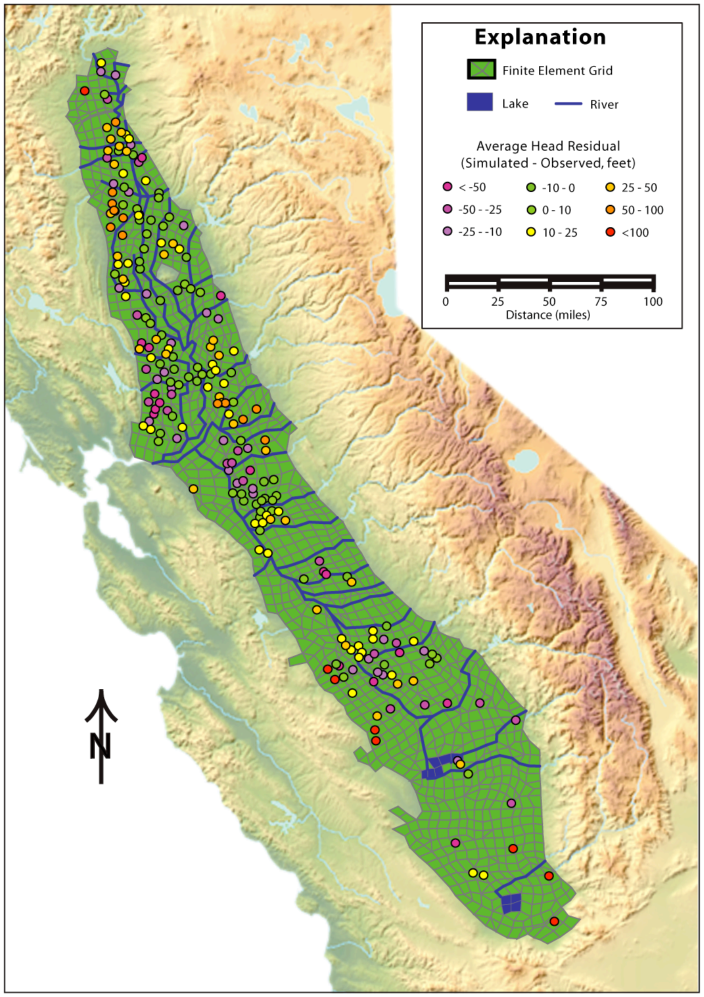
C2VSIM Performance – Heads
R305 – Initial Calibration

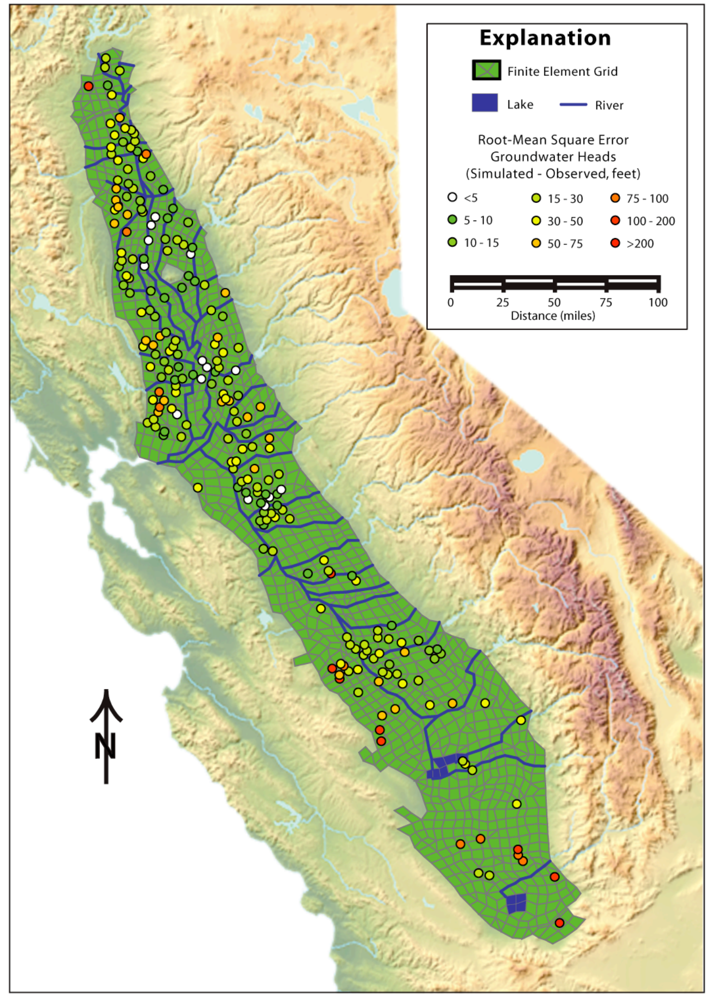


C2VSIM Performance - Flows



C2VSIM Performance – RMSE and BIAS





Model Performance

- Water Levels:
  - Layer 1 generally good
  - Layer 2 high beneath Corcoran Clay
- Spatial correlation of head residuals
  - Reasonable in Sacramento Valley (low on western edge)
  - Low in western San Joaquin Valley
  - High in southern Kern County
  - High beneath Corcoran Clay
- Simulated water level trends match observed water level trends on a regional basis
- Corrected hydrology in the Tulare Basin

Simulated Water Budget Components

Average Annual Rates for Water Years 1975-2003

	Storage	Stream Leakage	Subsidence	Pumpage	Recharge	Interbasin Flows
Sacramento Valley	60,485	-857,062	-90	-1,918,139	2,706,529	8,277
Delta	-118,828	-93,135	-137	-259,201	574,955	-103,654
Eastside Streams	90,280	104,353	25	-782,252	369,294	218,299
San Joaquin Basin	152,289	-487,829	1,077	-1,769,312	2,273,302	-169,533
Tulare Basin	1,644,289	500,091	6,169	-5,604,895	3,405,544	46,611
Central Valley	1,828,516	-833,582	7,044	-10,333,799	9,329,624	0

[Million Acre-Feet per Year]

C2VSIM version R323, 6/19/2008

Simulated Water Budget Components

Average Annual Rates for Water Years 1975-2003

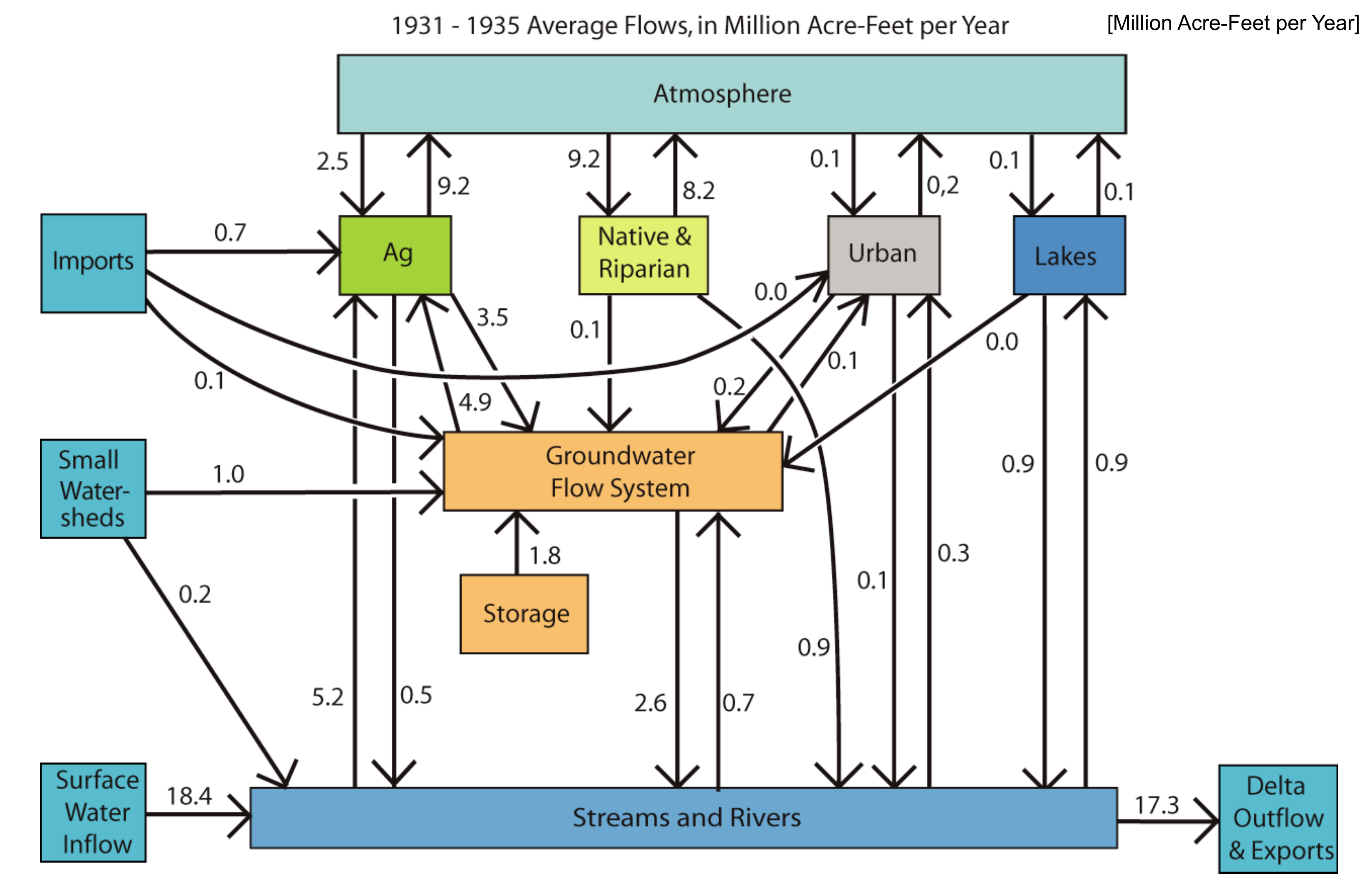
	Surface Water Inflows*	Surface Water Outflows*	Precipitation	Actual Evapo-transpiration
Sacramento Valley	19,899,492	18,295,025	6,849,346	7,718,186
Delta	30,015,881	25,396,129	926,265	1,443,876
Eastside Streams	1,303,644	1,443,081	1,405,900	1,625,708
San Joaquin Basin	5,047,764	3,758,962	2,521,049	5,541,265
Tulare Basin	3,201,665	409,274	3,584,871	11,077,098
Central Valley	30,839,488	25,665,545	15,287,431	27,406,133

* Surface water inflows and outflows do not add up across hydrologic regions

[Million Acre-Feet per Year]

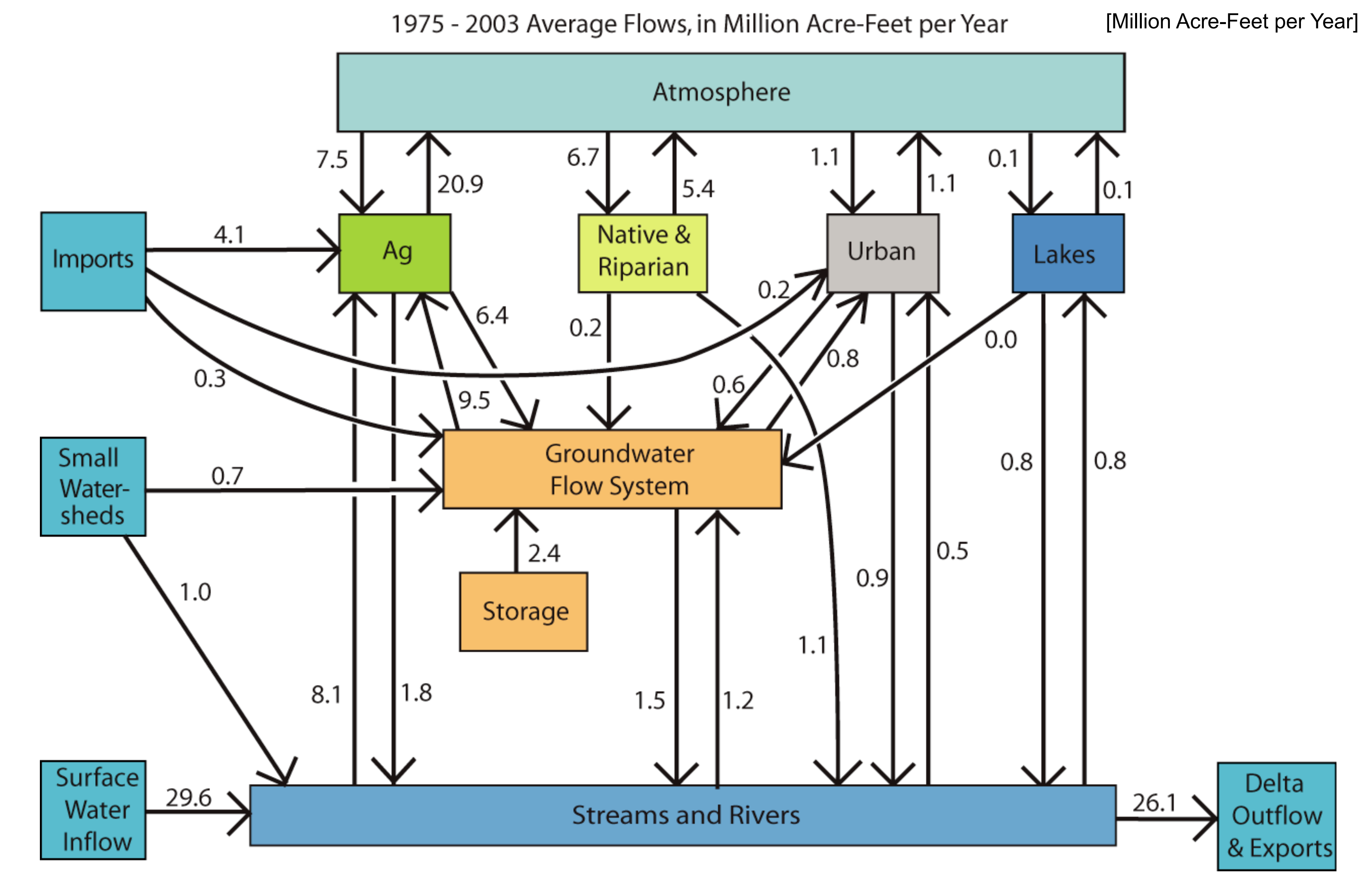
C2VSIM version R323, 6/19/2008

Water Budget



C2VSIM version R323, 6/19/2008

Water Budget



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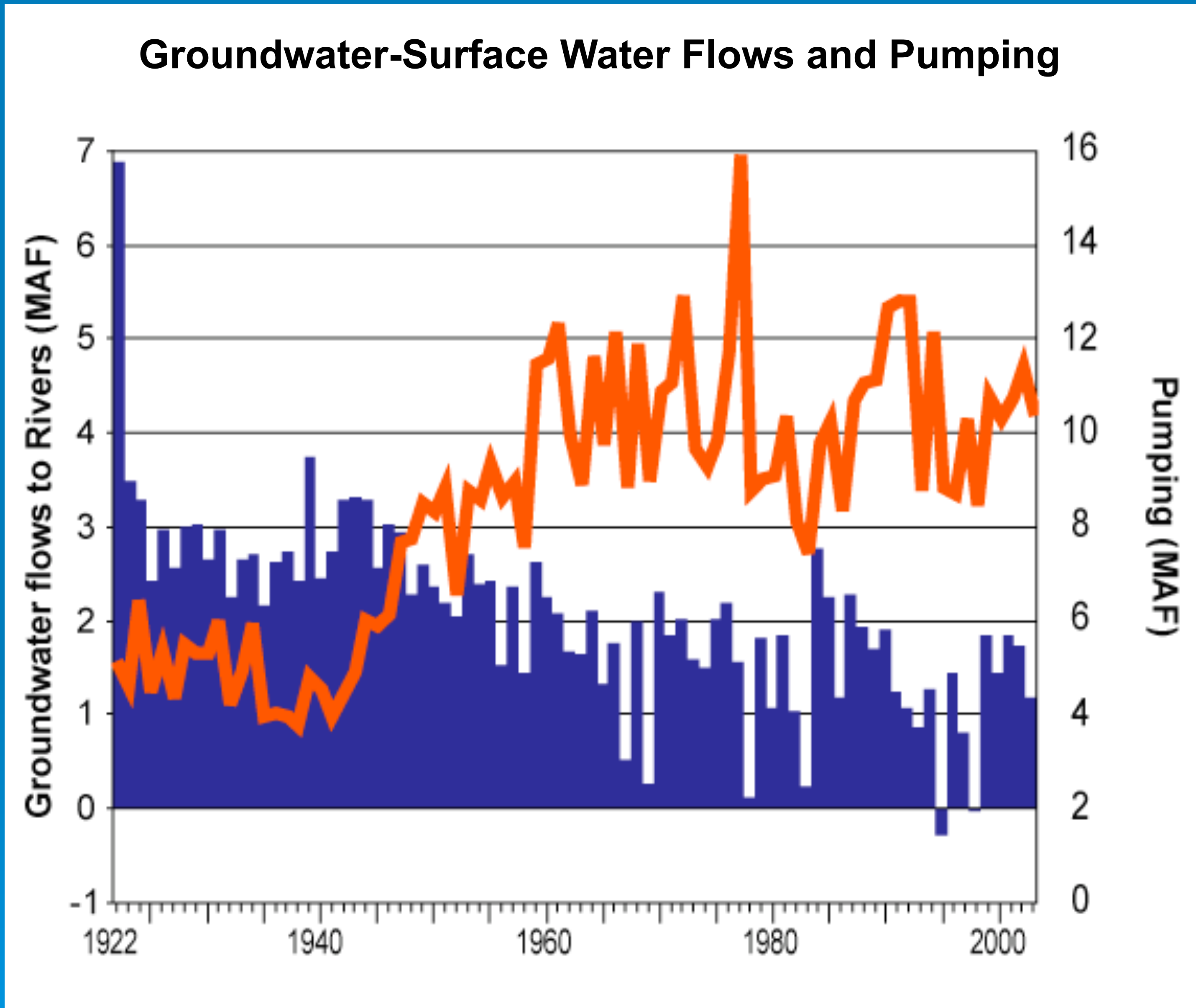
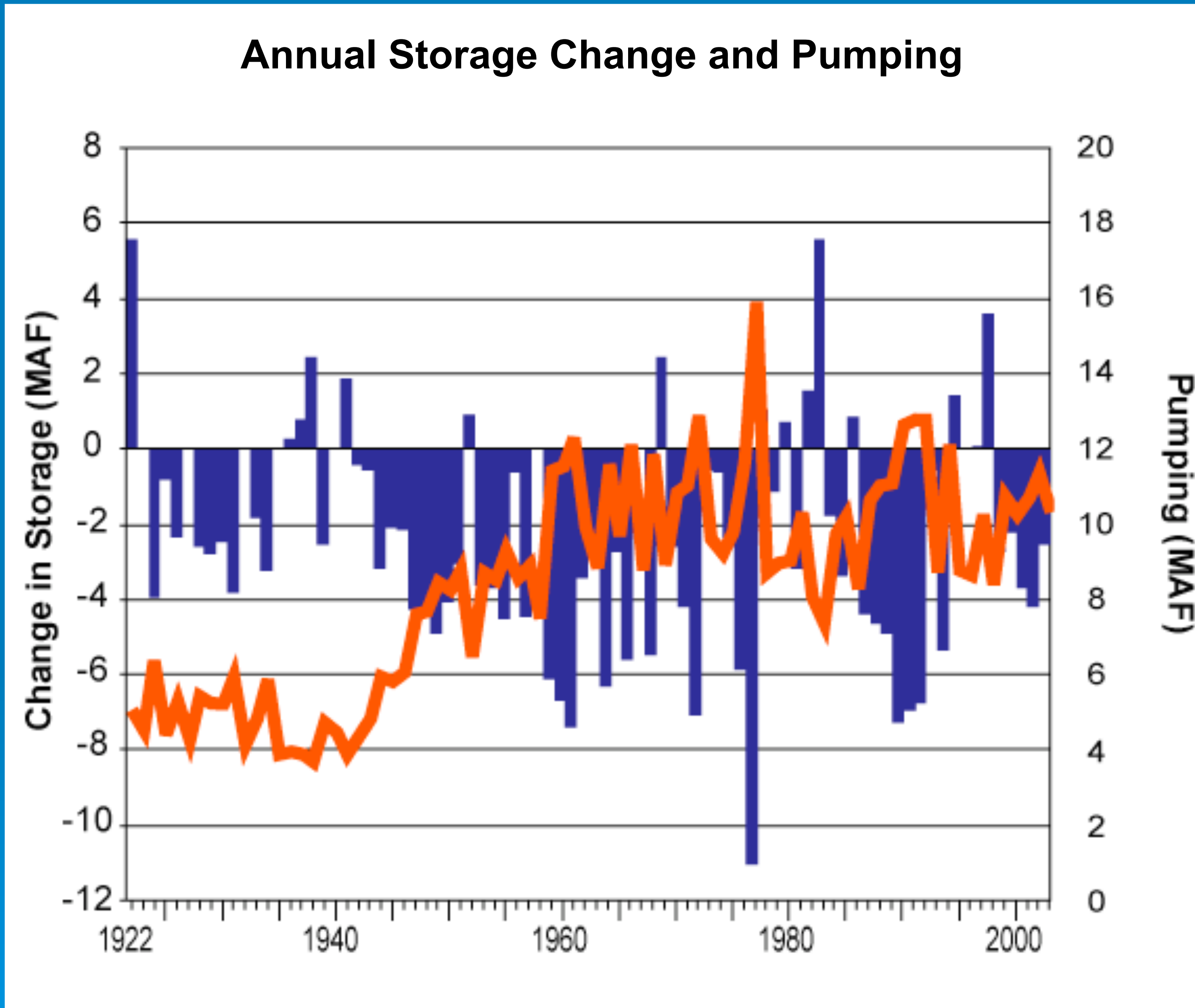
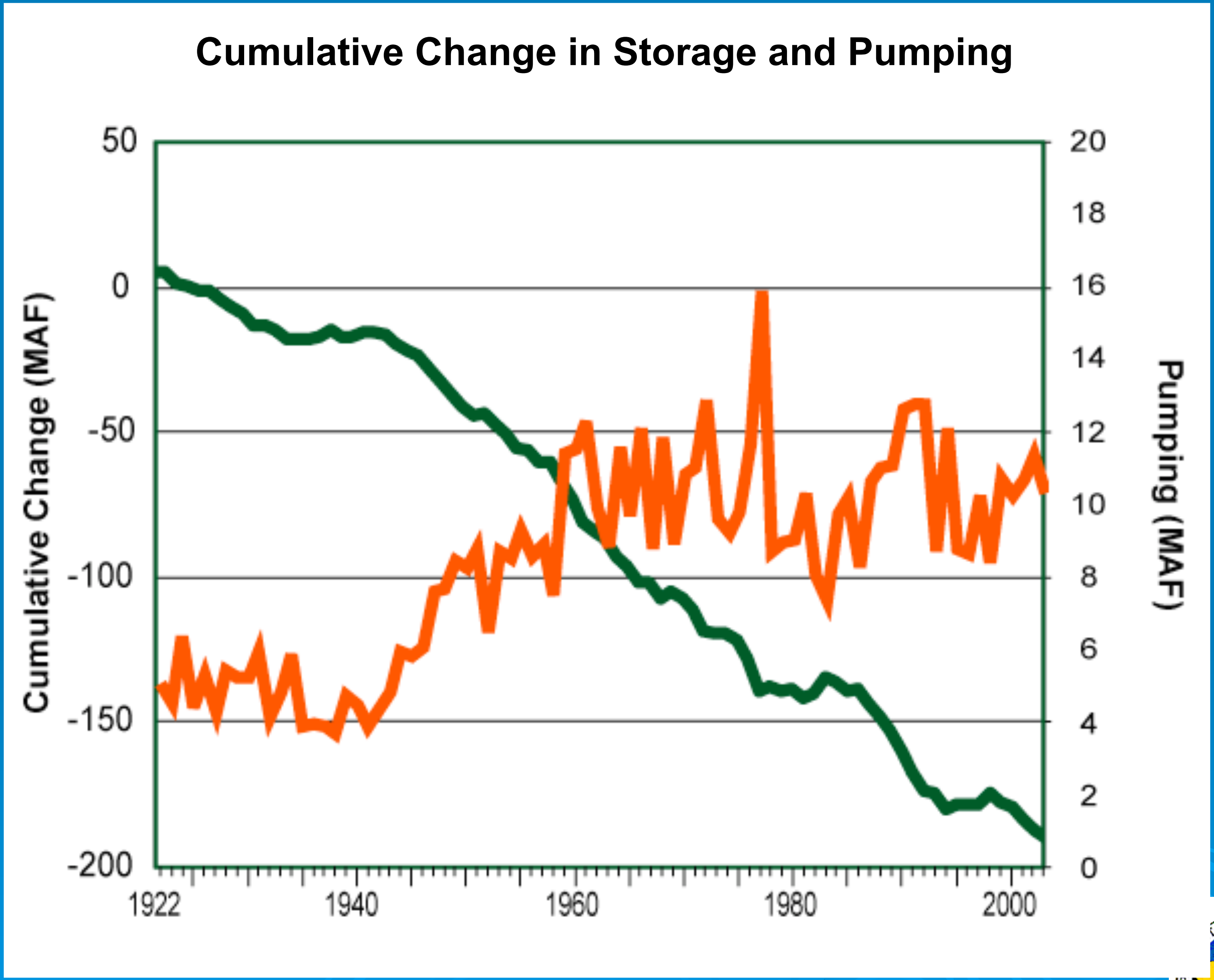

Groundwater-Surface Water Flows and Pumping
Groundwater flows to Rivers (MAF)
Pumping (MAF)
7
6
5
4
3
2
1
0
-1
16
14
12
10
8
6
4
2
0
1922
1940
1960
1980
2000


Annual Storage Change and Pumping
Change in Storage (MAF)
Pumping (MAF)
8
6
4
2
0
-2
-4
-6
-8
-10
-12
20
18
16
14
12
10
8
6
4
2
0
1922
1940
1960
1980
2000


Cumulative Change in Storage and Pumping
Cumulative Change (MAF)
Pumping (MAF)
50
0
-50
-100
-150
-200
20
18
16
14
12
10
8
6
4
2
0
1922
1940
1960
1980
2000

Water Budget Comparison

- C2VSIM pumpage is close to CVGSM and CVRASA pumpage
- C2VSIM shows net groundwater discharge to streams, CVGSM and CVRASA showed net flow from streams to groundwater
- C2VSIM simulated stream accretions and depletions have same sign as observed, and magnitude is close

Summary

C2VSIM model performs well

- Regional parameters provide good results
- Lots of information – areal recharge, storage, GW-SW
- Groundwater pumping estimates look reasonable
- Subregional ‘virtual farms’ limit spatial resolution

Historical Changes in Water Budgets

- Groundwater pumping and Surface Water Diversions have significantly altered the Central Valley’s flow system
- Agricultural use increased from 9 MAF to 21 MAF/yr between 1930s and 1970s
- Agricultural use steady 1970s to 2000s
- Increase in ‘de facto’ conjunctive use

Model Improvements

Further spatial refinement of parameters

Increase calibration data set (observations)

especially vertical head gradients, stream-groundwater flow

Review selected water budget components:

- Aquifer storage & recovery (direct recharge & pumping)
- Groundwater exports
- High wet-season diversions (refuges?)
- Check crop ET values
- Verify simulated runoff

Future thoughts:

- Water budget areas = Water districts