



# **The California Central Valley Groundwater-Surface Water Simulation Model**

## **C2VSim Overview**

CWEMF C2VSim Workshop  
January 23, 2013



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California Department of Water Resources, Sacramento, CA





# Outline

Background and Development History

C2VSim Framework

Coarse-Grid and Fine-Grid Versions

Future Directions

# California's Central Valley



- 20,000 sq. mi. (55,000 sq. km.)
- 30 MAF/yr Surface Water Inflow
- Agricultural Production
  - 6.8 million acres (27,500 sq. km)
  - <1% of US farm land
  - 10% of US crops value in 2002
- Population Growth
  - 1970: 2.9 million
  - 2005: 6.4 million
- Groundwater Pumping
  - ~9 MAF in 2002
  - 10-18% if US pumping
  - Not measured or regulated



# C2VSim Development

## Derived from the CVGSM model

- WY 1922-1980 Boyle & JM Montgomery (1990)
- WY 1981-1998 CH<sub>2</sub>M Hill for CVPIA PEIS

## Steady modification

- DWR IWFM/C2VSim development began in 2000
- IWFM process and solver improvements
- C2VSim data sets reviewed and refined
- C2VSim input data extended through WY 2009

## Calibration

- PEST parameter estimation program
- Three phases: Regional, Local, Nodal
- Calibration Period: WY 1973-2003 in phases 1 & 2, 1922-2004 in phase 3

## Release

- C2VSim 3.02-CG released December 2012
- C2VSim 3.02-FG expected summer 2013



# C2VSim Applications

- CalSim 3 groundwater component
- Integrated Regional Water Management Plans
- Stream-groundwater flows
- Climate change assessments
- Groundwater storage investigations
- Planning studies
- Ecosystem enhancement scenarios
- Infrastructure improvements
- Impacts of operations on Delta flows



# C2VSim Versions

## **C2VSim CG 3.02 (R367): Release Version**

- Current version, released December 2012
- Water Years 1922-2009, monthly time step
- IWFM version 3.02

## **C2VSim FG 3.02 (R356): Draft Version**

- Based on C2VSim 3.02 CG of Jan 2012
- Refine rivers, inflows, land use
- Upgrade to match CG version before release
- Expected release in Summer 2013

## **Planned Improvements**

- C2VSim 3.02 CG/FG: Extend to WY 2011 or 2012
- C2VSim 4.0 FG: Element-level land use, crop and diversion data

# C2VSim Coarse Grid

“C2VSim CG-3.02”

## DWR Web Site

- Model files
- Documetation
- C2VSim ArcGIS GUI
- IWFM Application
- IWFM Tools

## Support

- **Training:** IWFM and C2VSim workshops will be offered through CWEMF
- **Technical support:** Email and telephone

A Google search for “C2VSim” brings up this page

**C2VSim: California Central Valley Groundwater-Surface Water Simulation Model**

DEPARTMENT OF WATER RESOURCES  
BAY-DELTA

**C2VSim: California Central Valley Groundwater-Surface Water Simulation Model**

(Web Site Last Updated: December 20, 2012)

**Description**  
The California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) is an integrated numerical model that simulates water movement through the linked land surface, groundwater and surface water flow systems in California's Central Valley. The C2VSim model contains monthly historical stream inflows, surface water diversions, precipitation, land use and crop acreages from October 1921 through September 2009. C2VSim dynamically calculates crop water demands, allocates contributions from precipitation, soil moisture and surface water diversions, and calculates the groundwater pumpage required to meet the remaining demand. The model simulates the historical response of the Central Valley's groundwater and surface water flow system to historical stresses, and can also be used to simulate the response to projected future stresses.

The C2VSim model can be run with either a coarse finite element grid (C2VSim-CG with 1,392 elements, run-time 6 minutes) or with a fine finite element grid (C2VSim-FG with over 35,000 elements, run-time 6 hours). For both versions, the elements are grouped into 21 water budget subregions. Hydrologic parameters were calibrated to match observed surface water flows, groundwater heads, groundwater head differences between well pairs, and stream-groundwater flows for the period between September 1975 and October 2003.

The C2VSim-CG model is being used as the basis for the groundwater flow component of CalSim 3, and has also been used to investigate how Sacramento Valley water transfers may affect Delta flows and how an extended drought may impact groundwater levels. Both C2VSim versions will also be useful tools for integrated regional water management plans, planning studies, groundwater storage investigations, assessing infrastructure improvements, evaluating ecosystem enhancement scenarios, conducting climate change studies, and assessing the impacts of changes to water operations.

C2VSim was developed using the [Integrated Water Flow Model \(IWFM\) Version 3.02](#).

**Coarse Grid C2VSim Model (C2VSim-CG)**

- **Model Files**
  - [C2VSim 3.02-CG Water Years 1922-2009](#)
  - [C2VSim 3.02-CG Water Years 1973-2009](#)
- **Documentation**
  - [Brush, C.F., and Dogrul, E.C. 2012](#), User Manual for the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG.
  - [Brush, C.F. 2012](#), Historical Rim Inflows, Surface Water Diversions and Bypass Flows for the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG.
- **ArcGIS Tool**
  - [Tool Installer](#)
  - [ArcGIS Files: C2VSim 3.02-CG Water Years 1922-2009](#)
  - [ArcGIS Files: C2VSim 3.02-CG Water Years 1973-2009](#)

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# C2VSim Portal

## Interactive Web Site

- Tutorial Files
- Project Files
- Collaboration
- Message Board
- User/Password for additional access

**Document Library (CVWRSM)**

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### C2VSim Tutorial

[Back to Documents Home](#)

Files for use in the CWFEMF-sponsored Technical Training Workshop on C2VSim: Introduction & Training for the California Central Valley Groundwater-Surface Water Simulation Model. This training is being held on Wednesday and Thursday, January 23-24, 2013 from 9:00 to 4:30, in the Klamath Training Room, 2nd Floor, CalEPA Building, 1001 "I" Street, Sacramento (10th and "I" Streets). The C2VSim model files are available at [http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index\\_C2VSim.cfm](http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/index_C2VSim.cfm). All of the workshop files are in the (702 MB) file "Everything\_for\_the\_Workshop.zip".

Last Updated 1/22/13 6:17 PM | 0 Subfolders | 6 Documents

#### ▼ Documents

Name	Size	Downloads	Locked	
<a href="#">ASR Example_Complete.zip</a>	125,655.1k	6	No	<a href="#">Download (125,655.1k)</a>
<a href="#">C2VSim 201 Software.pdf</a> <a href="#">How to download and install the software and files.</a>	147.7k	6	No	<a href="#">Download (147.7k)</a>
<a href="#">Everything_for_the_Workshop.zip</a> <a href="#">All the files for the C2VSim Workshop</a>	701,819.6k	12	No	<a href="#">Download (701,819.6k)</a>
<a href="#">GWP Example_Complete.zip</a>	115,430.5k	3	No	<a href="#">Download (115,430.5k)</a>
<a href="#">TM_C2VSim_Tutorial_Draft.pdf</a> <a href="#">Draft hands-on tutorial instructions</a>	12,337.7k	4	No	<a href="#">Download (12,337.7k)</a>
<a href="#">Tools.zip</a>	3,109.3k	4	No	<a href="#">Download (3,109.3k)</a>

Showing 6 results.

#### Message Boards (CVWRSM)

[Message Boards Home](#) [Recent Posts](#) [Statistics](#)

[RSS](#) (Opens New Window)

[https://msb.water.ca.gov/c2vsim/-/document\\_library/view/140143](https://msb.water.ca.gov/c2vsim/-/document_library/view/140143)

# C2VSim Coarse-Grid

“C2VSim CG-3.02”

## Finite Element Grid

- 3 Layers or 9 Layers
- 1393 Nodes & 1392 Elements

## Surface Water System

- 75 River Reaches, 2 Lakes
- 243 Surface Water Diversions
- 38 Inflows, 11 Bypasses
- 210 Small-Stream Watersheds

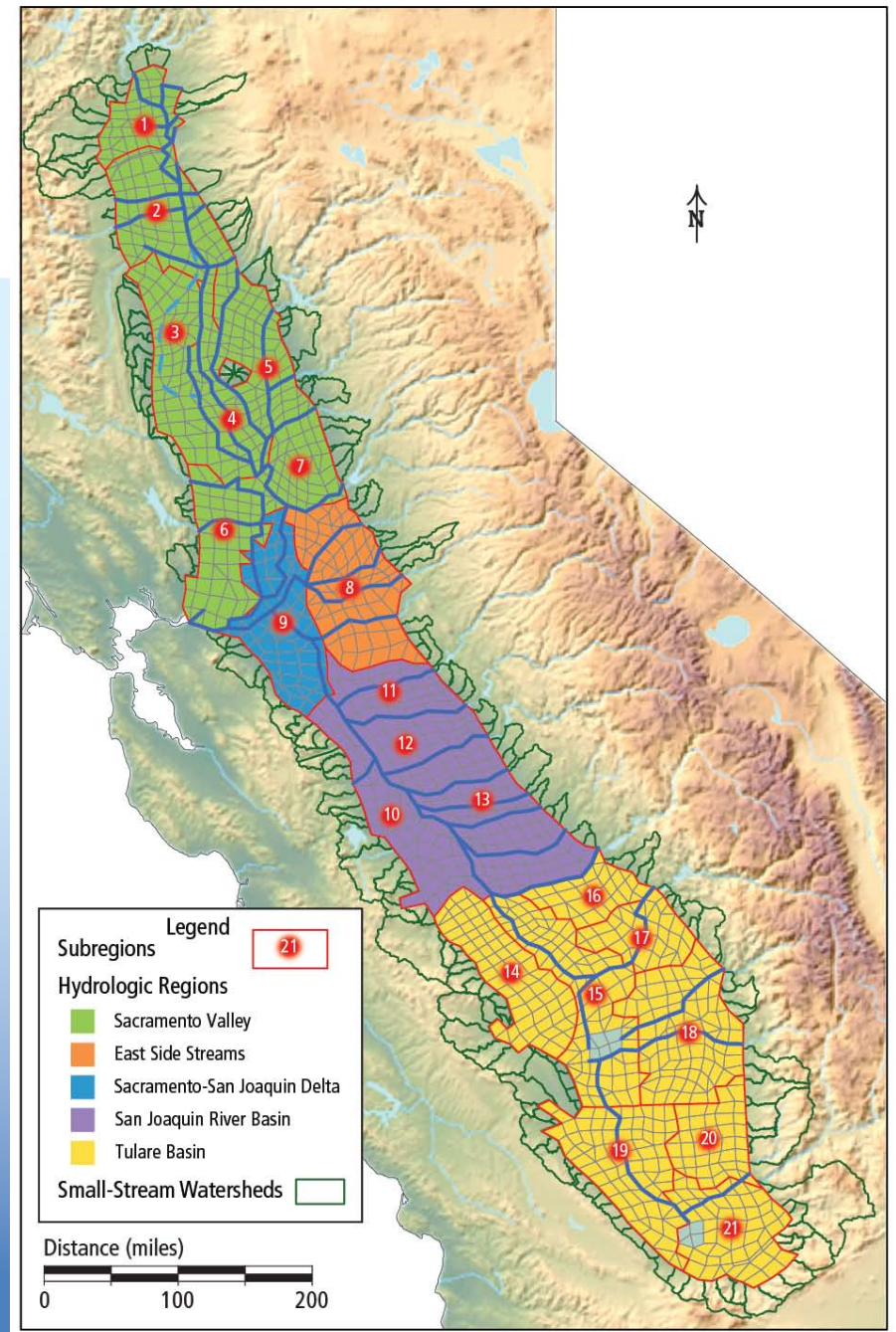
## Land Use Process

- 21 Subregions (DSAs)
- 4 Land Use Types

## Simulation periods

- 10/1921-9/2009 (88 yrs)
- runs in 3-6 min

## IWFM version 3.02

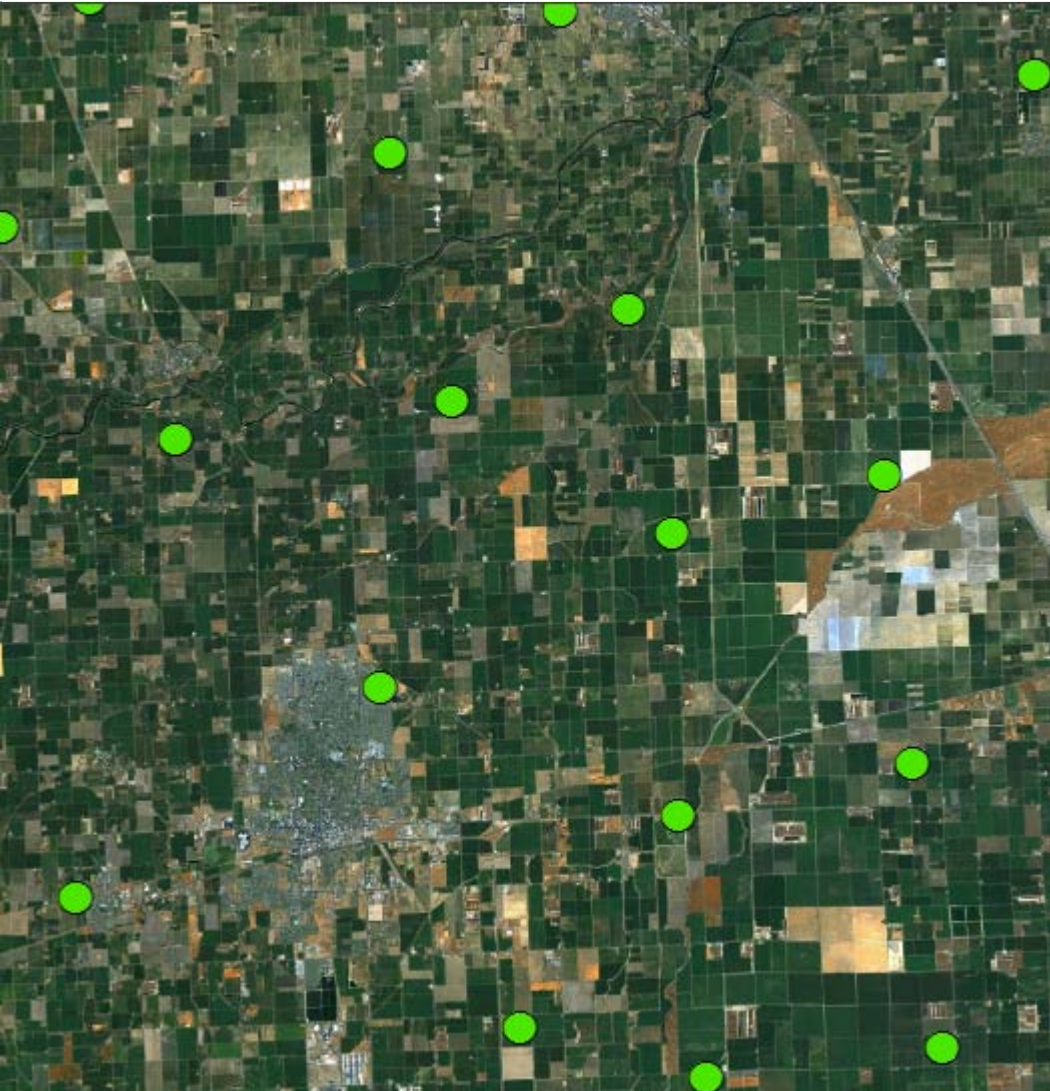
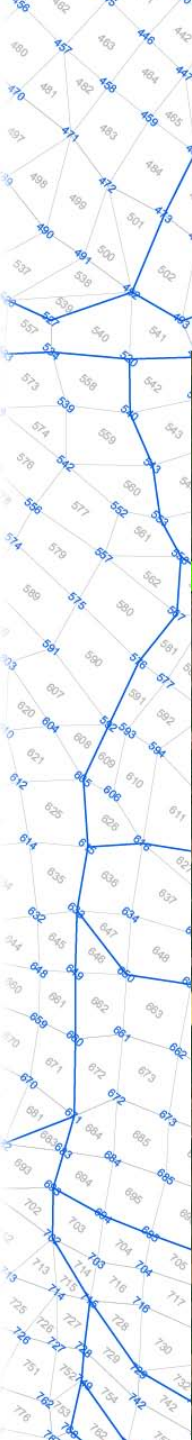


# C2VSim Framework

Pre-processor

- Nodal coordinates
- Nodes form elements
- Vertical aquifer stratigraphy
- Lakes
- River nodes
- River reaches & flow network
- Element properties
- Pumping wells
- Assign elements to subregions

# Nodes



## X-Y Grid

- UTM 10N
- X = Easting
- Y = Northing

## Convert to FT

- FACT = 3.2808

```
C*****
C                                     Groundwater Node Specifications
C
C ND;      Number of groundwater nodes
C FACT;    Conversion factor for nodal coordinates
C-----
C VALUE                                DESCRIPTION
C-----
C 1393                                         /ND
C 3.2808                                       /FACT
C-----
C                                     Groundwater Node Locations
C The following lists the node number and x & y coordinate of
C
C ID;      Groundwater node number
C X,Y;     Coordinates of groundwater node location; [L]
C-----
C Node      -----Coordinates-----
C ID          X              Y
C-----
C 1          551396.4        4496226
C 2          555618.8        4497861
C 3          561555.5        4500441
C 4          568374.3        4498058
C 5          553186.9        4492706
C 6          558611.6        4492797
C 7          566864.0        4493337
C 8          548989.2        4487360
C 9          553710.4        4488293
C 10         559339.9        4488690
C 11         566095.7        4489966
C 12         576267.3        4488069
C 13         539084.8        4481476
```

# Elements

## Finite Element Mesh

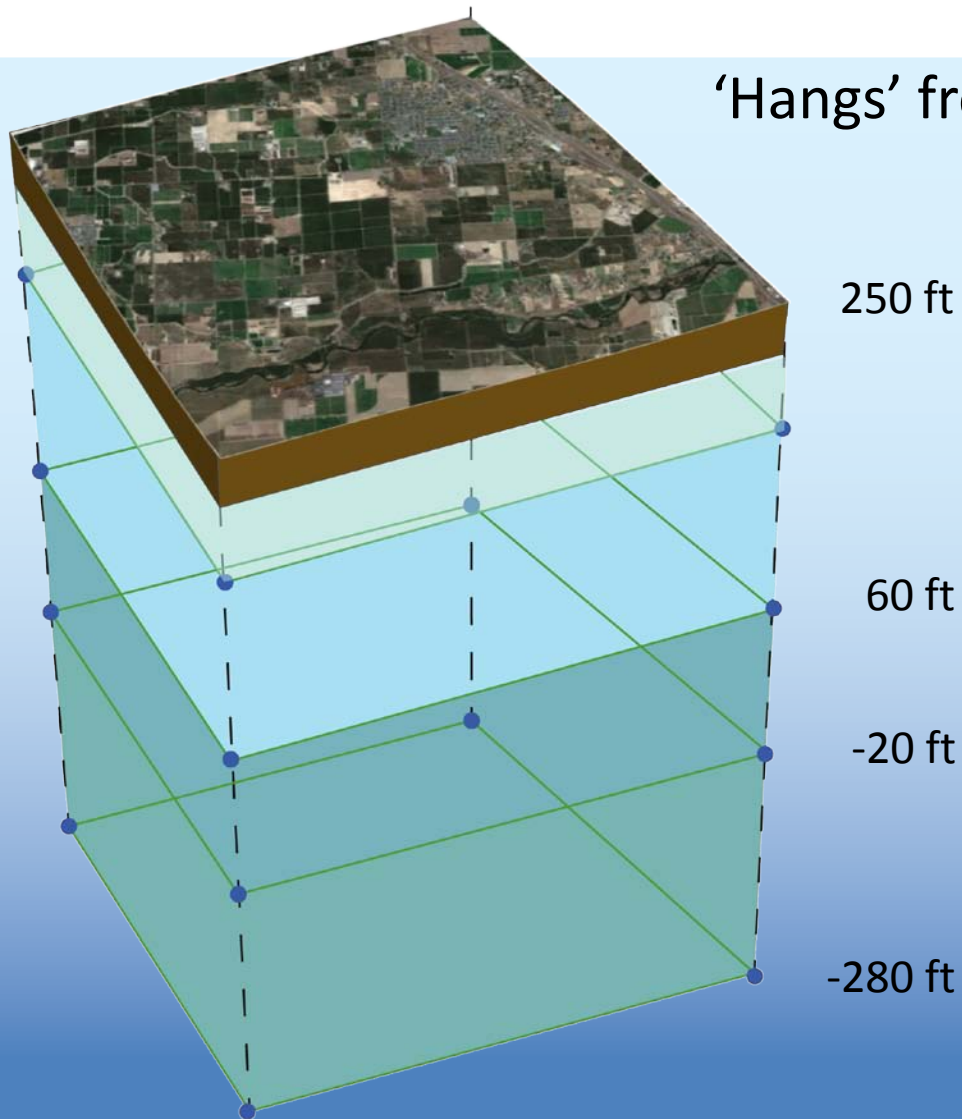
- 4 nodes = quadrilateral
- 3 nodes = triangle

1392 elements

```
C*****
C                                     Element Configuration Data
C
C   NE;   Number of elements within the model domain
C-----
C VALUE                                     DESCRIPTION
C-----
C   1392                                     /NE
C-----
C*****
C
C   The data listed below represents all elements and corresponding
C   nodes within the model domain.
C
C   IE;   Element number
C   IDE;  Nodes corresponding to each element
C          *Note* IDE(4) is zero for all triangular elements
C-----
C   Element      -----Corresponding Nodes-----
C   IE           IDE (1)      IDE (2)      IDE (3)      IDE (4)
C-----
C   1             1             8             9             5
C   2             1             5             6             2
C   3             2             6             7             3
C   4             3             7             4             0
C   5             5             9             10            6
C   6             6             10            11            7
C   7             8             14            15            9
C   8             9             15            16            10
C   9             10            16            17            11
C   10            11            17            18            12
C   11            13            19            20            14
C   12            14            20            21            15
C   13            15            21            22            0
```

# Stratigraphy

'Hangs' from Ground Surface



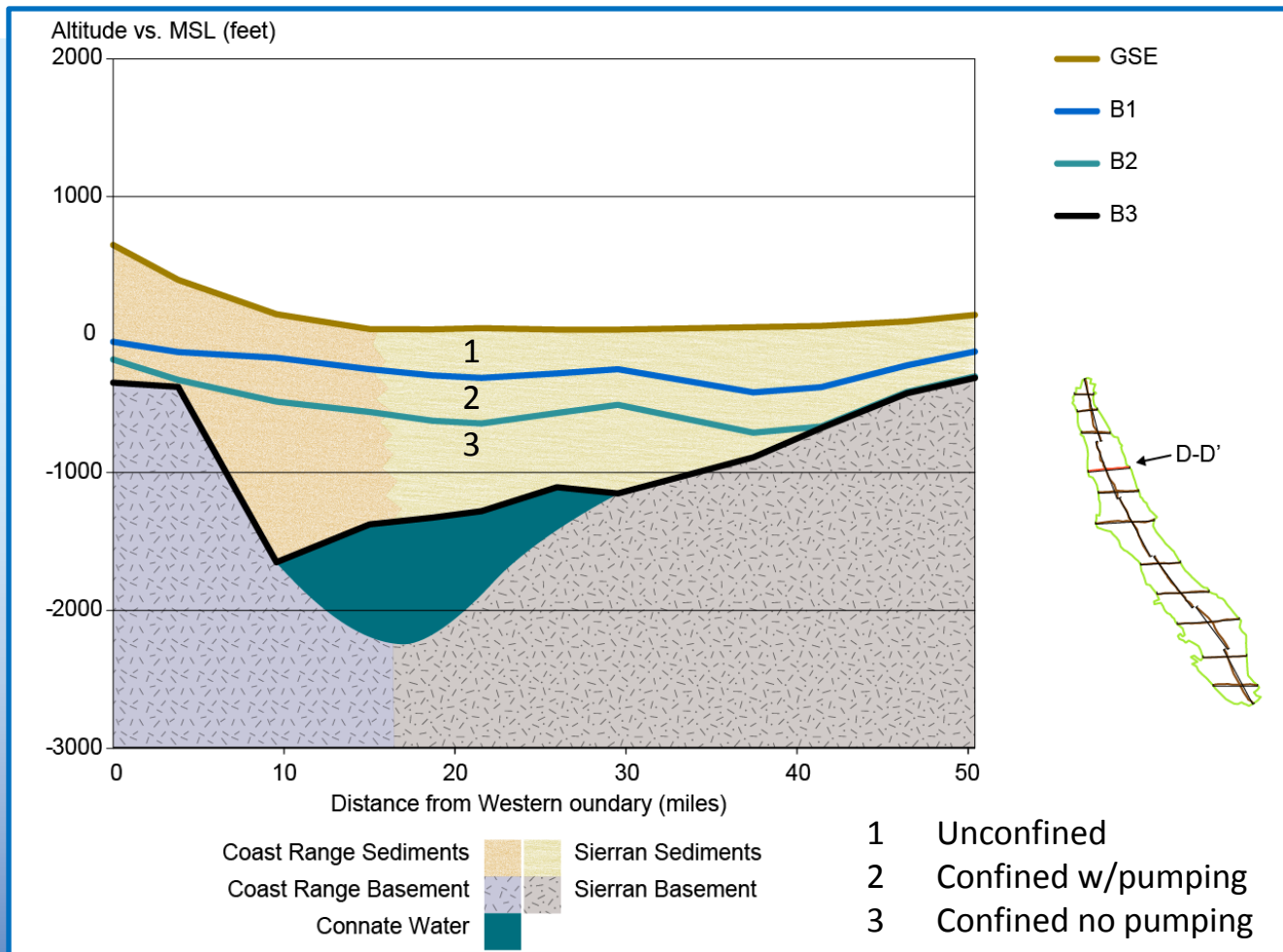
- Aquiclude thickness
- Aquifer thickness

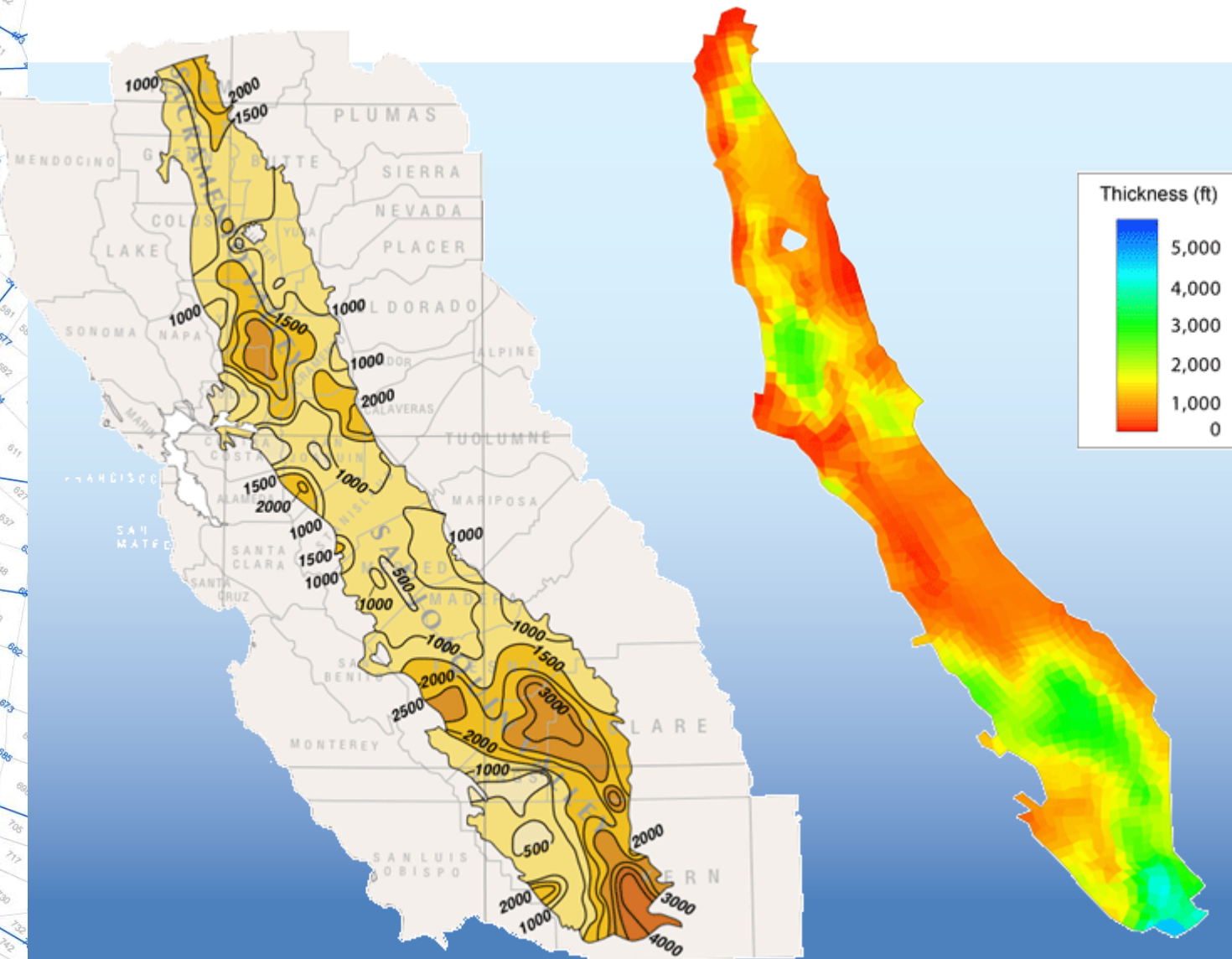
```

C *****
C                               Stratigraphy Specification Data
C
C   NL;      Number of layers to be modeled
C   FACT;    Conversion factor for stratigraphic data
C -----
C   VALUE                                DESCRIPTION
C -----
C       3                                /NL
C       1                                /FACT
C -----
C -----
C   Node      Elevation    --Layer #1--    --Layer #2--    --Layer #3--
C   ID        ELV         W (1)      W (2)      W (3)      W (4)      W (5)      W (6)
C -----
C       1      733         0      243      0      100      0      100
C       2      695         0      245      0      100      0      100
C       3      705         0      235      0      100      0      100
C       4      732         0      282      0      100      0      100
C       5      463         0      89       0      133      0      134
C       6      590         0      186      0      134      0      133
C       7      705         0      334      0      133      0      134
C       8      613         0      213      0      100      0      100
C       9      455         0      133      0      133      0      133
C      10      554         0      296      0      178      0      179
C      11      460         0      168      0      143      0      144
C      12      800         0      326      0      134      0      134
C      13      1056        0      606      0      100      0      100
C      14      795         0      345      0      100      0      100
C      15      418         0      144      0      163      0      164
C      16      496         0      317      0      235      0      236
C      17      499         0      340      0      248      0      249
C      18      777         0      474      0      167      0      166
C      19      885         0      305      0      100      0      130
C      20      818         0      314      0      133      0      134
C      21      599         0      326      0      198      0      198
C      22      403         0      420      0      413      0      413
C      23      457         0      401      0      319      0      318
C      24      635         0      411      0      186      0      185
C      25      631         0      122      0      133      0      133
C      26      622         0      257      0      164      0      165
C      27      669         0      536      0      317      0      318
C      28      580         0      808      0      654      0      653
C      29      372         0      341      0      333      0      334
C      30      594         0      424      0      213      0      213
C      31      613         0      20       0      120      0      133
C      32      735         0      226      0      133      0      133
C      33      726         0      313      0      140      0      139
C      34      521         0      246      0      215      0      216
C      35      436         0      346      0      351      0      351
C      36      408         0      706      0      697      0      698

```

# C2VSim Aquifer Cross Section





# Base of Fresh Groundwater in the Sacramento Valley, California

California Department of Water Resources Report name/#

Steven Springhorn, Nick Hightower, and Tad Bedegrew  
October, 2012



## Abstract

A base of fresh groundwater (BFG) contour map was created to identify the approximate lower limit and the thickness of the fresh water aquifer system in the Sacramento Valley. The BFG map is useful for groundwater resource and storage analysis, groundwater modeling, and delineating subsurface geologic features in the Sacramento Valley.

Two BFG maps covering the Sacramento Valley were previously created by the USGS in 1961 (Cronsted and Davis) and 1973 (Santarelli). The BFG map in this study relies on a substantial amount of new subsurface geophysical and water quality data that has been collected since the earlier BFG maps.

Fresh groundwater is defined in this study as water containing less than 1,000 mg/L total dissolved solids (TDS). The BFG map is based on approximately 1,500 geophysical logs, 1,000 well logs, and 1,000 water quality logs. The BFG map is based on a composite of geophysical logs and lithologic logs from geophysical logs and lithologic logs. The BFG map is based on a composite of geophysical logs and lithologic logs.

The BFG boundary occurs primarily in late Tertiary to Quaternary unconsolidated sediments at depths near and surface to more than 3,500 feet below ground surface. The BFG is an uneven boundary that in some places reflects the major geologic structures underlying the Sacramento Valley and in other areas, topographic features underlying geologic structures. In some areas, the BFG boundary is well below the base of post-glacial marine strata. This is most likely caused by high salinity brines and coastal water masses in deep aquifers in the Sacramento Valley, which have been documented in Department of Water Resources (DWR) monitoring wells. This suggests that migration of poor quality water into continental sediments that previously contained freshwater has occurred over geologic time. The finding has implications for brackish and saline water spacing between areas of protected groundwater purging in the Sacramento Valley.

## Criteria for Approximating Base of Fresh Groundwater

A qualitative approach is used in this study to approximate the BFG surface for the Sacramento Valley. The BFG surface is defined by the depth of the first geophysical log showing a resistivity signature that is consistent with the BFG. The BFG surface is determined by the depth of the first geophysical log showing a resistivity signature that is consistent with the BFG. The BFG surface is determined by the depth of the first geophysical log showing a resistivity signature that is consistent with the BFG.

The BFG was approximated:

1. At the depth where both short and long resistivity signatures decrease below 10 to 15 ohm-meters consistently.
2. If 10 to 15 ohm-meters was determined by conductivity values from water quality analyses, and does not account for wells geologic formation (pore free, permeable, already having the section more conductive than sandstone).
3. This number is consistent by water quality samples from DWR monitoring wells completed at or near the BFG (TDS compared to resistivity).
4. Where short and long resistivity signatures are consistently similar in value (long resistivity is less than 10 to 15 ohm-meters) showing that brackish conditions are still high resistivity.
5. At or just above the depth where the SP signature deviates, displaying significant deflections.
6. At the depth where the conductivity signature increases, above 100-200 ohm-meters consistently and above on figure to the left.
7. Using other well logs and lithologic information in the same geographic area to constrain the BFG section.

Since the BFG is just a line, there may be intervals that have resistivity signatures above it. Usually these features are less than 10 to 20 feet in thickness. These features, however, were not considered in the BFG section because the confidence of these intervals for fresh water resources is not limited.

BFG was not considered to be the lowest TDS found.

## Definition of Fresh Groundwater

Fresh water is defined in this study as water containing less than 1,000 mg/L TDS (approximately 1,500 µmhos/cm conductivity) as defined by Fries and Cherry (1979). This conductivity is based on a composite of geophysical logs and lithologic logs from geophysical logs and lithologic logs. The BFG map is based on a composite of geophysical logs and lithologic logs.

Category	Total Dissolved Solids (mg/L)
Fresh water	< 1,000
Brackish water	1,000 - 10,000
Saline water	10,000 - 100,000
Very saline	> 100,000

Source: Modified from U.S. Geological Survey, 1979.

## Data Sources

The BFG was estimated based on 2,750 geophysical logs and water chemistry data from 110 monitoring wells screened near the BFG or in areas of brackish water near and surface. Brackish geophysical logs were obtained from the following sources:

- 400 groundwater resource geophysical logs
- 1,350 California Division of Oil and Gas well logs

Brackish Geophysics

The primary data used to approximate the BFG are electric logs from DWR monitoring wells or private water wells, and electric and induction logs of wells drilled for natural gas obtained from DWR. Because of the small extent of the study and the variability of the subsurface, the geophysical logs were interpreted by inspection, and no resistivity measurements were made to calculate the bulk formation resistivity or compute the sodium-chloride content.

Lithologic Information

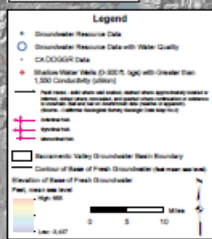
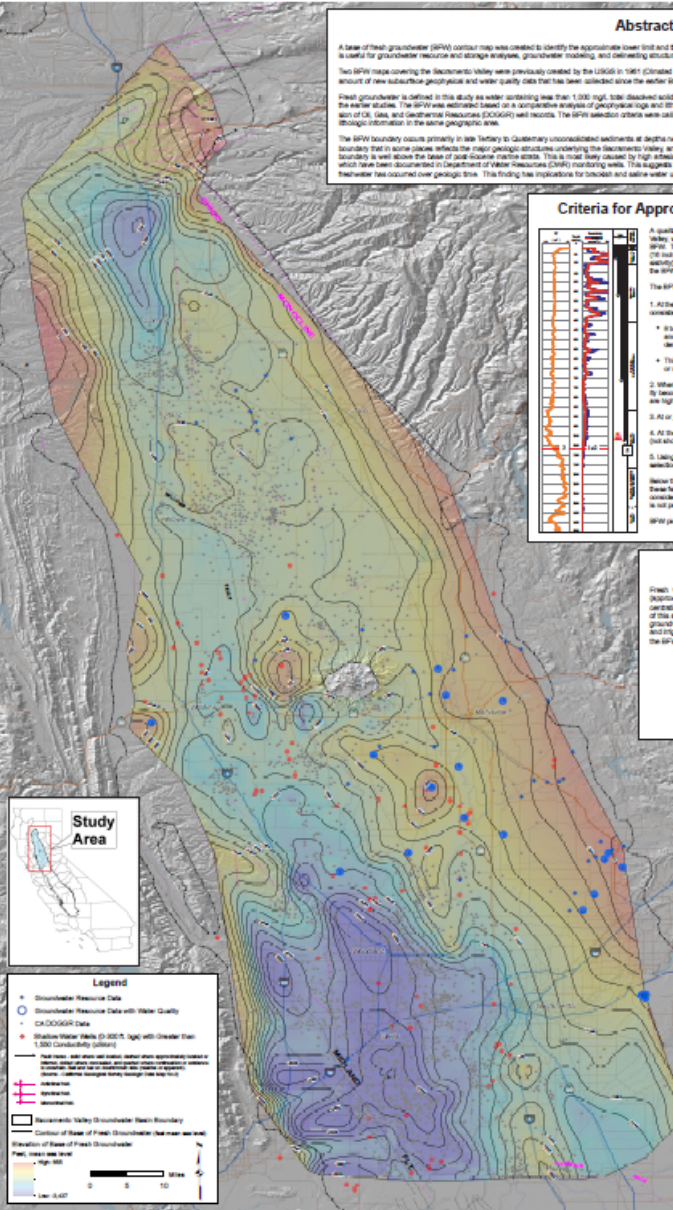
It is important to have lithologic data to compare to the brackish geophysical logs when estimating BFG, because the lithologic logs provide an independent check on the interpretation. In some cases, very low resistivity signatures can be produced by the permeability of sand, silt, and clay, which are not consistent with the resistivity of the water. When high resistivity signatures are found, they are usually associated with very low resistivity signatures and a developed SP signature can be used to determine the resistivity of the water. Lithologic information also provides insights on the depositional environment in which each subsurface formation was deposited, which helps to determine if the salt was formed in a marine (expected to contain saline or brackish water) or continental setting (expected to contain freshwater).

Water Chemistry Data

The BFG boundary was estimated by comparing the brackish geophysical logs with water chemistry results from 110 wells screened near the BFG and 20 wells screened in the brackish water system (BWS) of the BFG. The water chemistry results provide an independent check on the BFG estimate used in this study.

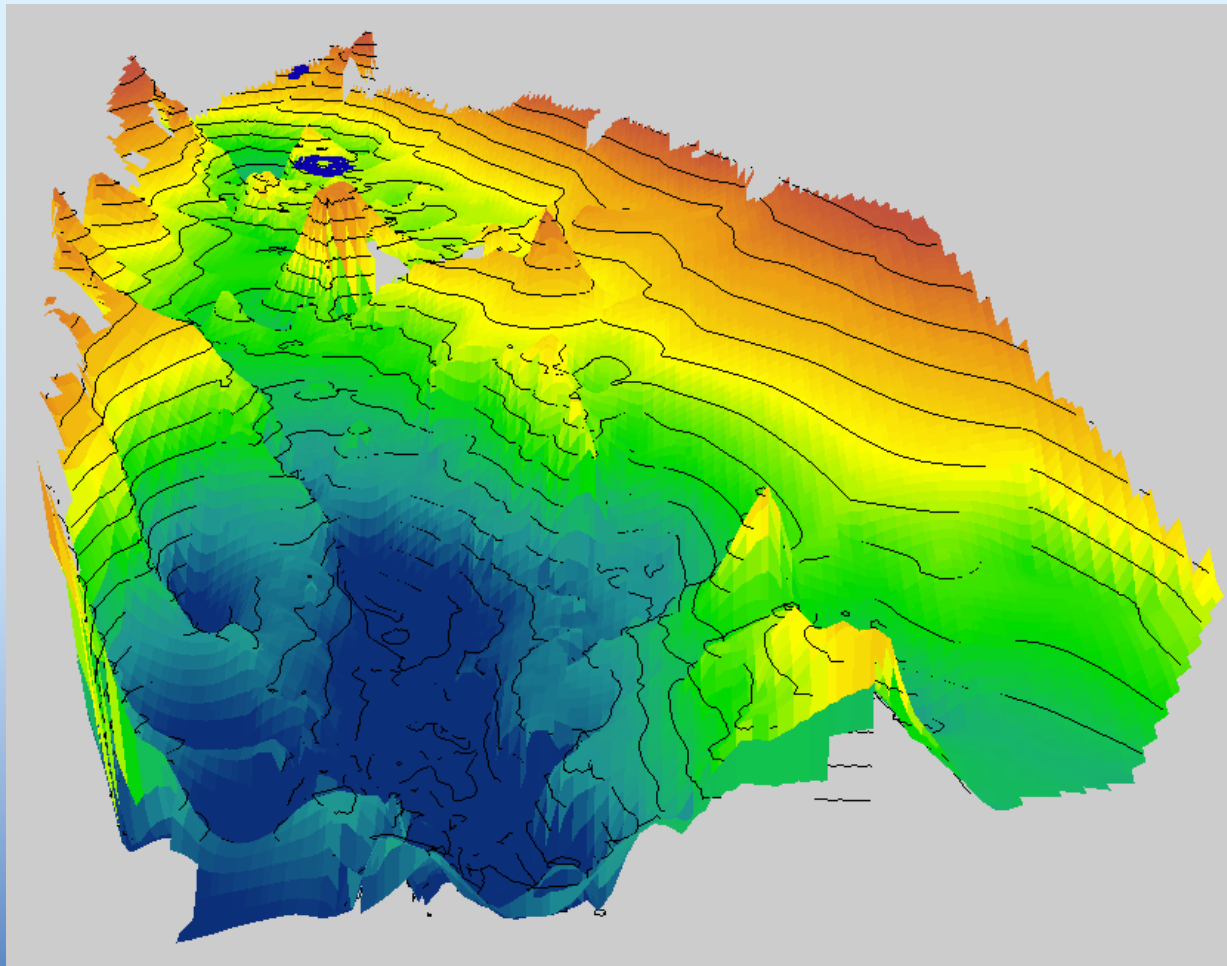
## References

- Santarelli, C.F., Jr., 1973, Base of fresh groundwater, approximately 1,000 ohm-meters, in the Sacramento Valley and San Joaquin Valley, California, U.S. Geological Survey Water Resources Investigations 6-73, 1 p.
- Fries, R. and Cherry, J.A., 1979, Groundwater, Prentice-Hall, Inc., Englewood Cliffs, N.J.
- Cronsted, R. and Davis, G.H., 1961, Design features and ground-water storage capacity of the Sacramento Valley, California, U.S. Geological Survey Water Supply Paper 1457, 201 p.



# Base of Fresh Water

Three dimensional view (looking north) of the base of fresh water surface



# River Nodes and Reaches

Listed by Reach  
Nodes linked to mesh

```
C*****
C                                     Stream Reach Specifications
C
C NRH;   Number of stream reaches modeled
C NR;    Number of stream nodes modeled
C NRTB;  Number of data points in stream rating tables
C
C-----
C VALUE                                DESCRIPTION
C-----
C      75                               / NRH
C     449                               / NR
C       5                               / NRTB
C-----
```

```
C-----
C REACH 1 - KERN RIVER
C Reach Upstream Downstream Outflow
C       Node      Node      Node
C ID     IBUR     IBDR     IDWN
C-----
C      1         1         9     434
C-----
C Stream Groundwater Subregion
C node   node       number
C IRV    IGW       IRGST
C-----
C      1      1304      21
C      2      1315      21
C      3      1317      21
C      4      1326      21
C      5      1325      21
C      6      1333      21
C      7      1332      21
C      8      1331      21
C      9      1342      21
C-----
```

```
C-----
C REACH 2 - KINGS RIVER
C Reach Upstream Downstream Outflow
C       Node      Node      Node
C ID     IBUR     IBDR     IDWN
C-----
C      2      23      32      33
C-----
C Stream Groundwater Subregion
```

# River Nodes and Reaches

Rating table for each node  
at the end of the file

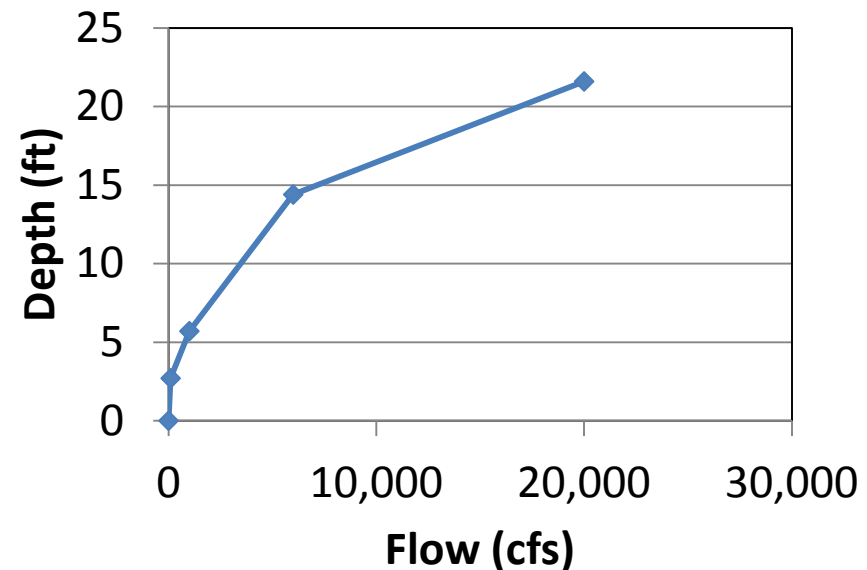
C	-----			
C	VALUE	DESCRIPTION		
C	-----			
	1.0	/	FACTLT	
	60.0	/	FACTQ	(cfs --> cu.ft./min; since "second" is not recognized
	1min	/	TUNIT	
C	-----			
C	The following lists a stream rating table for each of the stream nodes			
C	*Note* In order to define a specified stream depth, enter all HRTB values			
C	as equal to the specified depth value			
C				
C	ID;	Stream node number		
C	BOTR;	Stream bottom elevation relative to a common datum [L]		
C	HRTB;	Stream depth [L]		
C	QRTB;	Flow rate at stream depth HRTB [L^3/T]		
C	-----			
C	Stream	Bottom	Stream	Flow
C	node	elevation	depth	rate
C	ID	BOTR	HRTB	QRTB
C	-----			
	1	420.0	0.0	0.00
			2.7	100.00
			5.7	1000.75
			14.4	6000.00
			21.6	20000.00
	2	400.0	0.0	0.00
			2.7	100.00
			5.7	1000.75
			14.4	6000.00
			21.6	20000.00
	3	378.3	0.0	0.00
			2.7	100.00
			5.7	1000.75
			14.4	6000.00
			21.6	20000.00
	4	354.0	0.0	0.00
			2.7	100.00
			5.7	1000.75
			14.4	6000.00
			21.6	20000.00
	5	328.7	0.0	0.00
			2.7	100.00
			5.7	1000.75
			14.4	6000.00

# River Nodes and Reaches

Rating table for each node  
at the end of the file

```
C-----
C  VALUE                DESCRIPTION
C-----
C      1.0                /  FACILT
C      60.0                /  FACIQ      (cfs --> cu.ft./min; since "second" is not recognized
C      1min                /  TUNIT
C-----
C  The following lists a stream rating table for each of the stream nodes
C  *Note* In order to define a specified stream depth, enter all HRTB values
C          as equal to the specified depth value
C-----
C  ID;      Stream node number
C  BOTR;    Stream bottom elevation relative to a com
C  HRTB;    Stream depth [L]
C  QRTB;    Flow rate at stream depth HRTB [L^3/T]
C-----
```

Stream node ID	Bottom elevation BOTR	Stream depth HRTB	Flow rate QRTB
1	420.0	0.0	0.00
		2.7	100.00
		5.7	1000.75
		14.4	6000.00
		21.6	20000.00
2	400.0	0.0	0.00
		2.7	100.00
		5.7	1000.75
		14.4	6000.00
		21.6	20000.00
3	378.3	0.0	0.00
		2.7	100.00
		5.7	1000.75
		14.4	6000.00
		21.6	20000.00
4	354.0	0.0	0.00
		2.7	100.00
		5.7	1000.75
		14.4	6000.00
		21.6	20000.00
5	328.7	0.0	0.00
		2.7	100.00
		5.7	1000.75
		14.4	6000.00
		21.6	20000.00



# Lakes

Groups of Elements

Outflow = River Node #

```
C*****
C                               Lake Configuration Data
C
C  NLAKE ; Number of lakes that are being modeled
C  NTELAKE; Total number of lake elements
C
C-----
C  VALUE                DESCRIPTION
C-----
C      2                / NLAKE
C     10                / NTELAKE
C-----
C
C
C  ID      ; Sequential number for the lakes
C  INLAKE ; Next downstream lake number
C           0 : if flow from lake leaves the modeled area
C          -nd : if flow from lake goes to stream node nd
C           nd : if flow from lake goes to the downstream lake, nd
C  NELAKE ; Number of lake elements where lake lies
C  IELAKE ; Element in which the lake is located
C-----
C  Lake No.   Next Lake   Elem per Lake   Element
C   ID        INLAKE      NELAKE        IELAKE
C-----
C  Buena Vista Lake
C    1        -434         4             1352
C                                         1353
C                                         1363
C                                         1364
C
C  Tulare Lake
C    2        -42         6             1109
C                                         1110
C                                         1111
C                                         1136
C                                         1137
C                                         1138
```

# Element Characteristics

- Precipitation data column
- River node receiving drainage
- Subregion
- Soil type

A = 1

B = 2

C = 3

D = 4

C  
C The following lists the hydrologic characteristics of each element:  
C  
C IE; Element number  
C IRNE; Rainfall station assigned to the element IE  
C (enter zero for all elements if no land processes other than  
C streams and lakes are modeled)  
C FRNE; Factor to convert rainfall at the assigned rainfall station to  
C rainfall at the element IE  
C ISTE; Stream node to which surface water from element IE drains to  
C (enter zero if the surface flow from element IE leaves the model area)  
C IRGE; Subregion number to which element IE belongs to  
C ISGE; Element sub-group number to which element IE belongs to  
C ISOILE; Hydrologic soil property of the element (ie. A=1, B=2, C=3, D=4)  
C (Reference for A-D soil types: USDA, 1985)  
C

C	Element	Rain	Rain	Drain	Sub-	Sub-	Soil
C	number	station	factor	node	region	group	type
C	IE	IRNE	FRNE	ISTE	IRGE	ISGE	ISOILE
C							
	1	1	1	207	1	1	3.100
	2	2	1	206	1	1	3.000
	3	3	1	206	1	1	3.000
	4	4	1	206	1	1	3.000
	5	5	1	207	1	1	3.850
	6	6	1	207	1	1	3.150
	7	7	1	208	1	1	3.150
	8	8	1	208	1	1	4.000
	9	9	1	208	1	1	4.000
	10	10	1	213	1	1	2.200
	11	11	1	209	1	1	3.000
	12	12	1	209	1	1	3.100
	13	13	1	209	1	1	3.000
	14	14	1	209	1	1	3.900
	15	15	1	210	1	1	3.850
	16	16	1	214	1	1	2.200
	17	17	1	216	1	1	3.000
	18	18	1	216	1	1	3.000
	19	19	1	216	1	1	3.200
	20	20	1	216	1	1	2.900

# Pumping Wells

## X-Y Location

- UTM 10N
- X = Easting
- Y = Northing

## Convert to FT

- FACT = 3.2808

## Well Properties

- RWELL = 1
- Screen Top
- Screen Bottom

### List of modeled wells and their corresponding parameters

NWELL ; Number of wells modeled  
FACTCX; Conversion factor for well coordinates  
FACTRW; Conversion factor for well diameter  
FACTLT; Conversion factor for perforation depths

VALUE	DESCRIPTION
-------	-------------

133	/ NWELL
3.2808	/ FACTCX
1.0	/ FACTRW
1.0	/ FACTLT

ID; Well identification number  
XWELL,YWELL; X-Y coordinates for each well; (L)  
RWELL; Well diameter; (L)  
PERFT,PERFB; Elevations of the top and bottom perforations; (L)

ID	XWELL	YWELL	RWELL	PERFTOP	PERFBOT	
1	559446	4477519	1	200	0	/ Anderson
2	560944	4470571	1	200	0	/ Cottonwood
3	551369	4492833	1	450	400	/ Redding A (Downtown)
4	555410	4490970	1	450	400	/ Redding B (Enterprise)
5	570071	4419834	1	200	0	/ Corning
6	584397	4399421	1	50	-100	/ Hamilton City
7	576717	4430310	1	50	-100	/ Los Molinos
8	568798	4399798	1	150	0	/ Orland
9	564962	4447605	1	200	0	/ Red Bluff
10	574748	4430889	1	50	-100	/ Tehama
11	581466	4318921	1	50	-100	/ Arbuckle
12	573445	4334080	1	0	-200	/ Williams
13	569277	4375051	1	50	-150	/ Willows
14	585470	4340806	1	0	-200	/ Colusa
15	610713	4363090	1	-50	-150	/ Biggs
16	599583	4398071	1	50	-150	/ Chico
17	612513	4357721	1	0	-100	/ Gridley
18	615500	4348007	1	0	-100	/ Live Oak
19	621676	4333692	1	-50	-200	/ Marysville
20	625136	4328130	1	-50	-200	/ Olivehurst
21	607655	4335030	1	-50	-200	/ Sutter
22	636457	4318838	1	-50	-150	/ Wheatland
23	619438	4333059	1	-50	-200	/ Yuba City
24	609719	4266809	1	-100	-300	/ Davis
25	602713	4255729	1	-100	-300	/ Dixon
26	585403	4282871	1	50	-50	/ Esparto



# Calibrated Parameters

## Aquifer nodes

- Conductivity
- Storage
- Subsidence

## River nodes

- Conductance

## Unsaturated Zone

- Porosity
- Conductivity

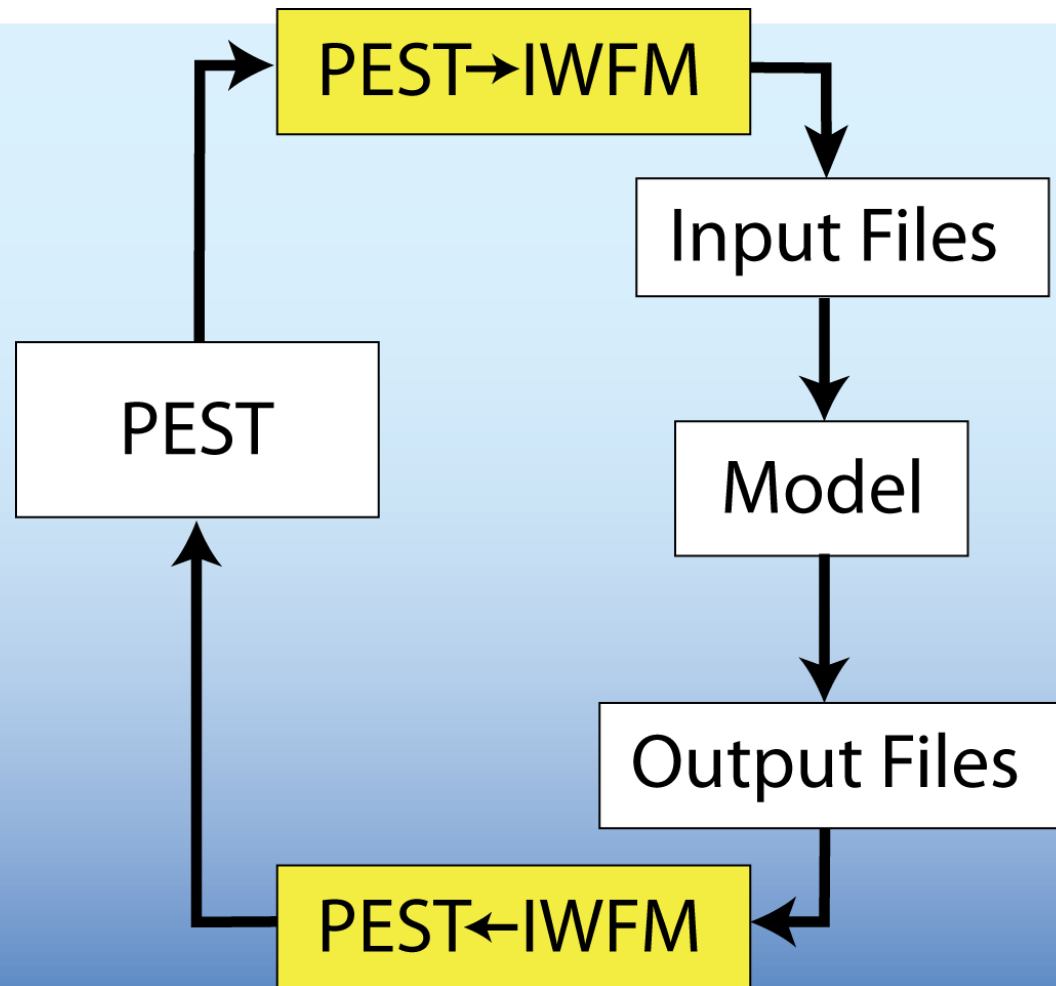
## Soil properties

- Field capacity
- Porosity
- Recharge factor
- Curve Numbers

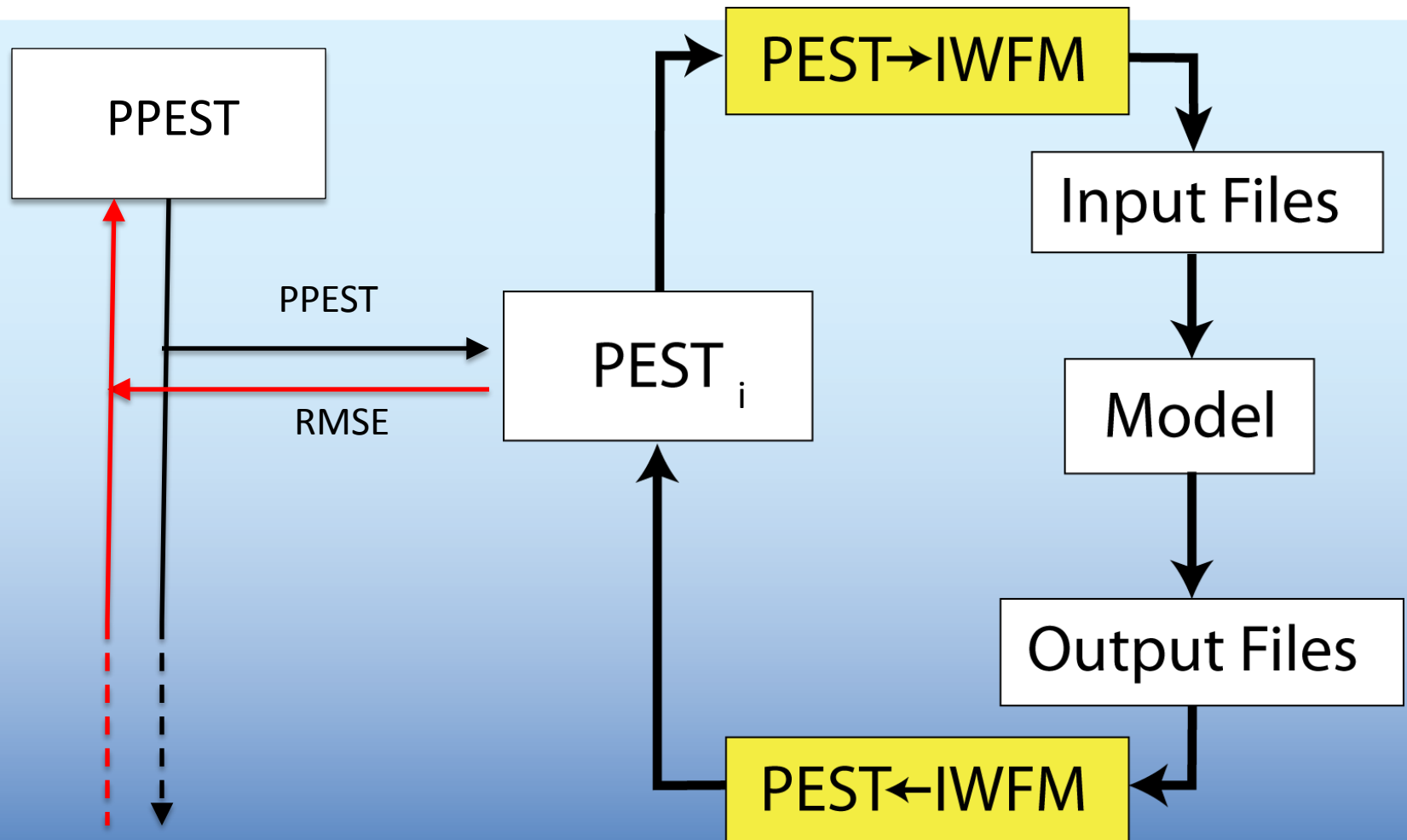
## Small Watersheds

- Field capacity
- Porosity
- Conductivity
- Discharge threshold
- Recession coefficients

# Calibration with PEST



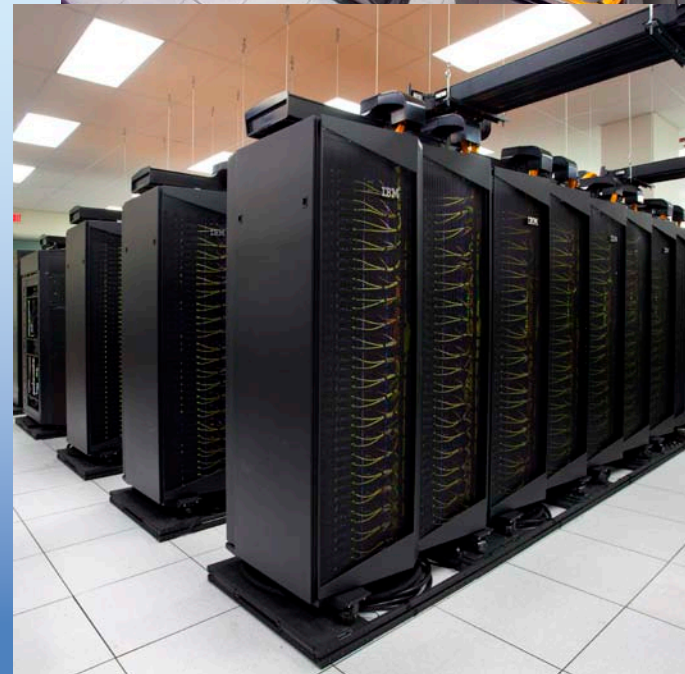
# Calibration with PPEST



# C2VSim Calibration

- Calibrate parameter values at each model node and layer
- Using computers at the USDOE National Energy Research Scientific Computing Center (NERSC)
  - Carver
    - IBM iDataPlex
    - 3,200 CPU cores, 34 Tflop/s
- Comparison:

	PPs	Compter	Run Time
R300	137	15 PCs	1 week
R326	394	15 PCs	3 weeks
R346	1393	15 PCs	16 weeks
R346	1393	NERSC	2 weeks



## Groundwater Heads

- 56,947 observations at 1,145 wells

## Vertical Head Difference

- 3,017 observations at 121 well pairs

## Surface Water Flow

- 5,636 observations at 21 locations

## Stream-Groundwater Flows

- Average annual rates on 24 reaches

# Parameter Sensitivity

Parameters

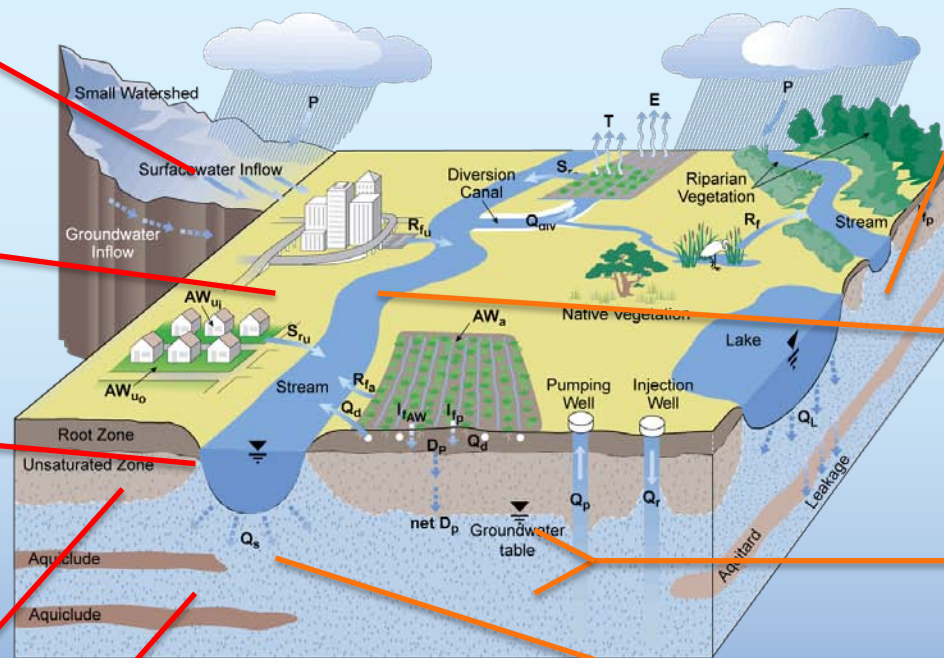
Ungaged Watersheds

Land Surface

Streambed

Unsaturated Zone

Saturated Zone



Observations

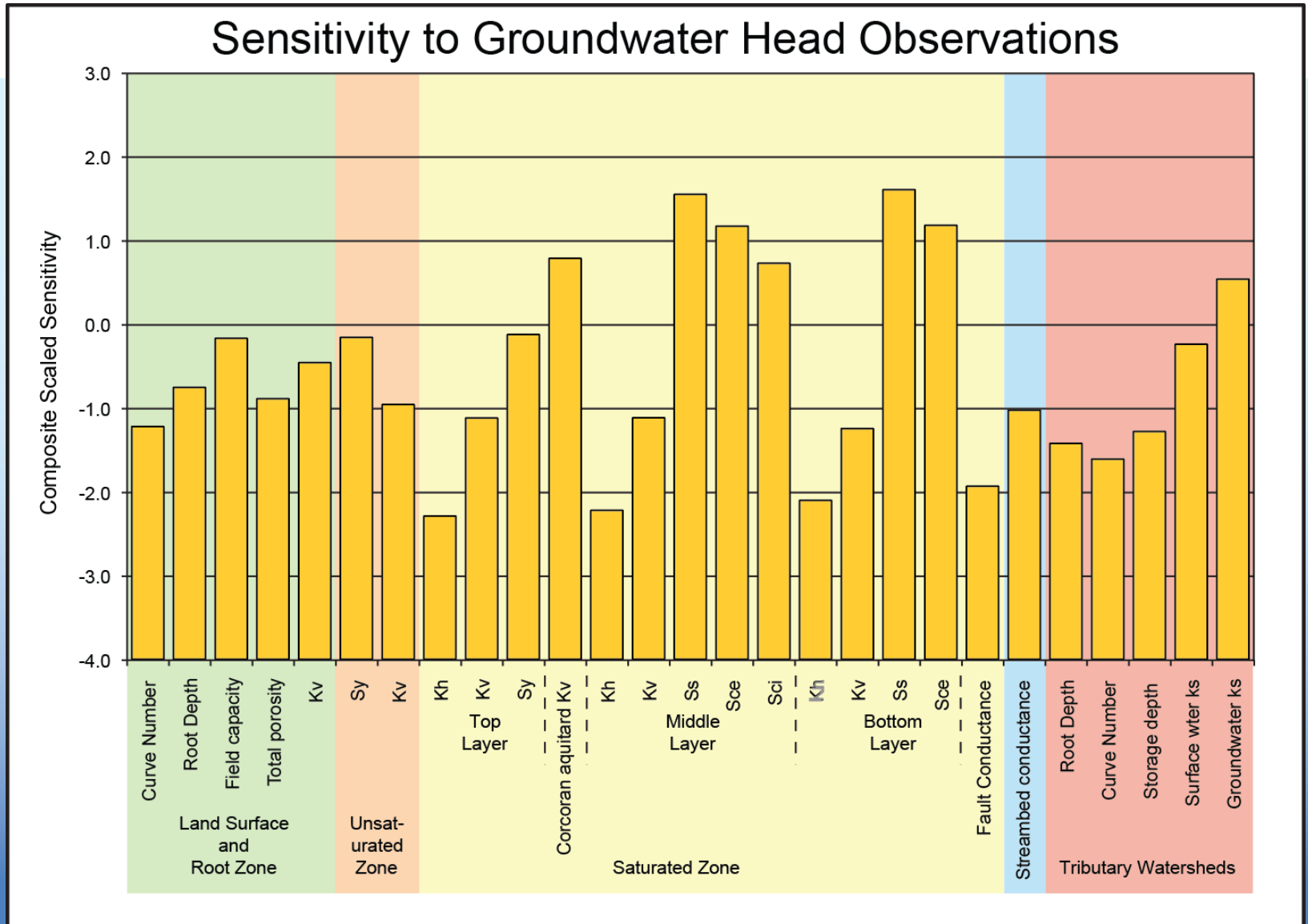
Groundwater Head

River Flow

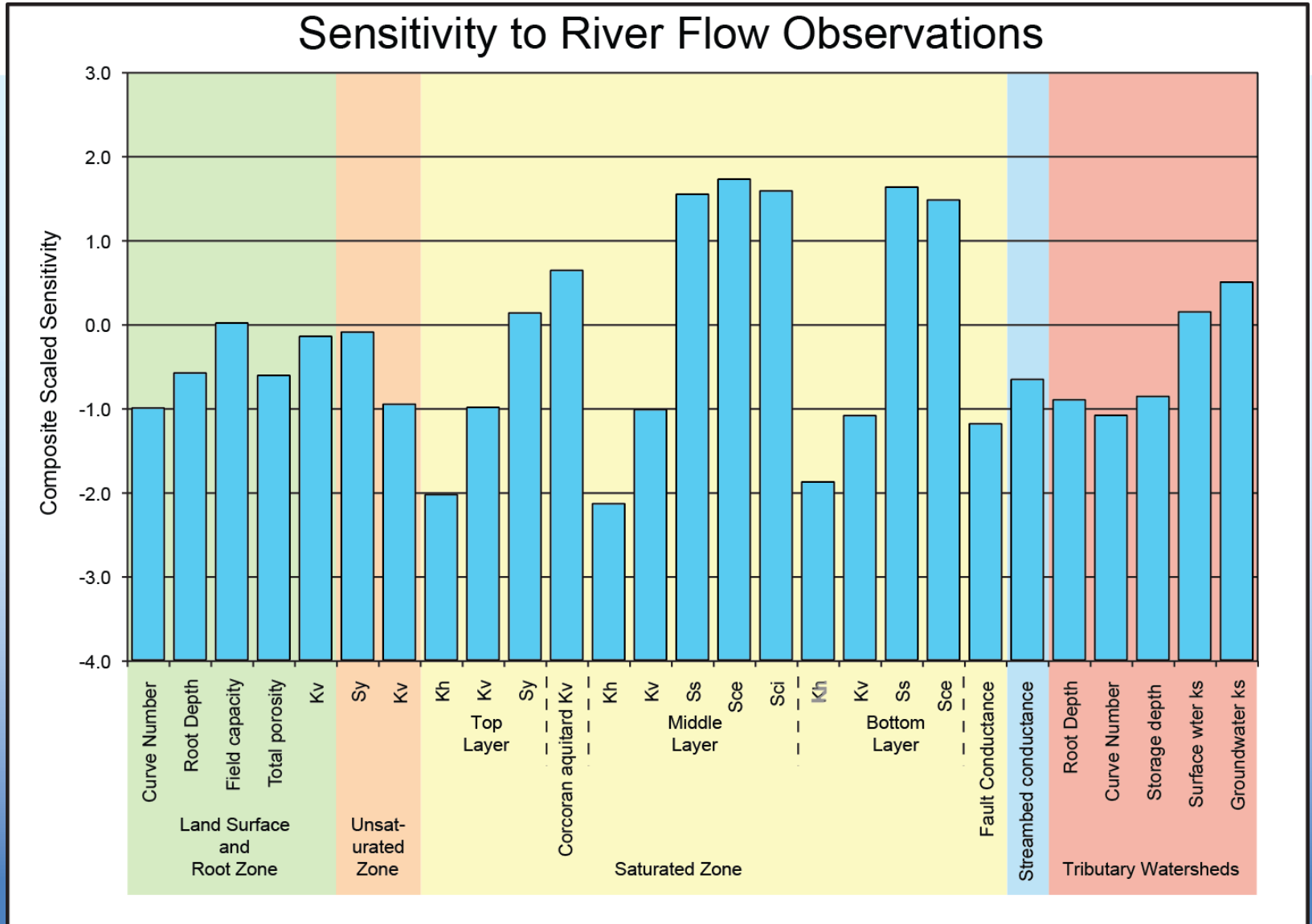
Groundwater Gradient

Stream-Groundwater Flow

# Parameter Sensitivity

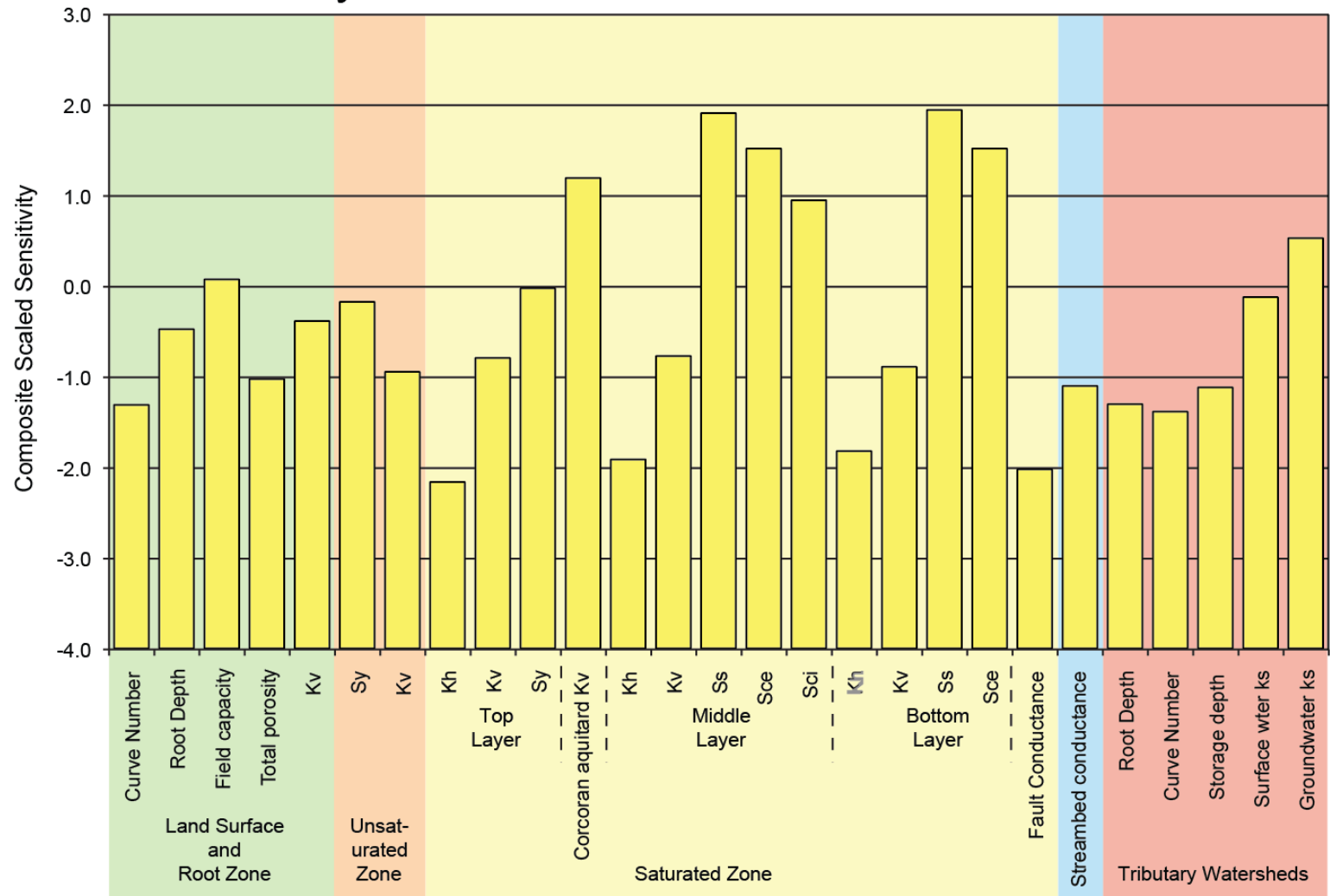


# Parameter Sensitivity

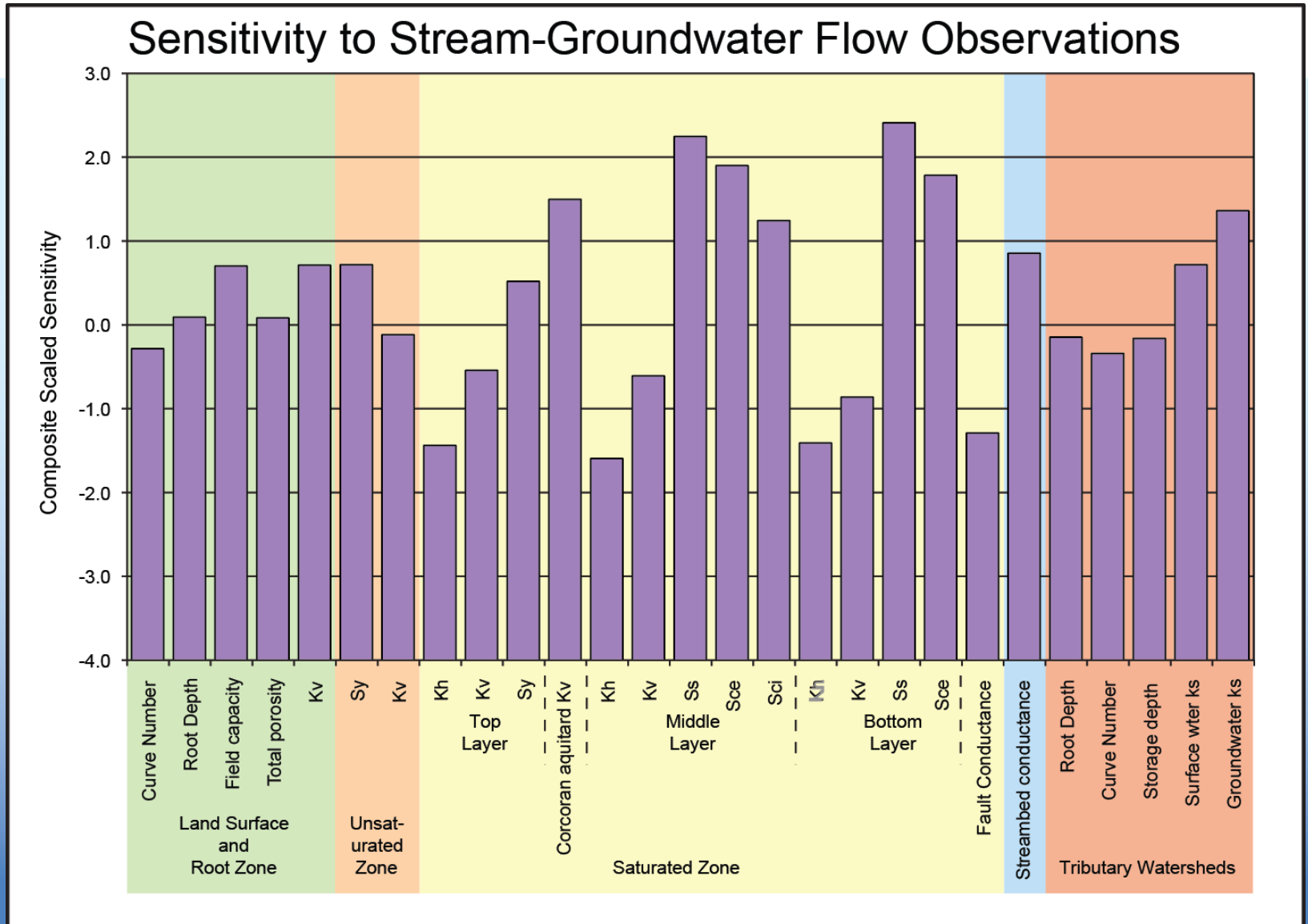


# Parameter Sensitivity

## Sensitivity to Vertical Head Difference Observations

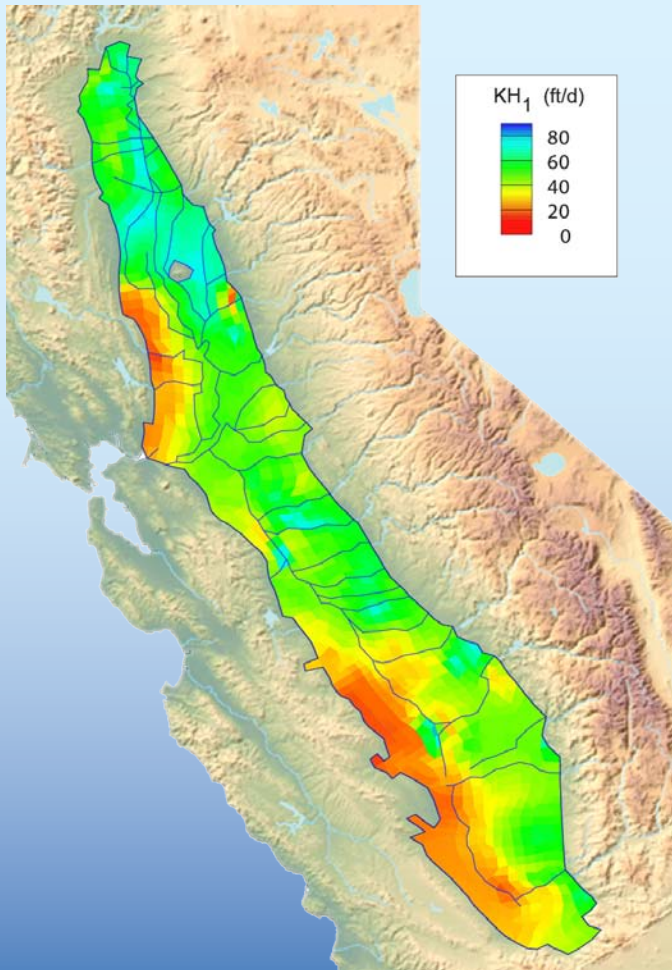


# Parameter Sensitivity

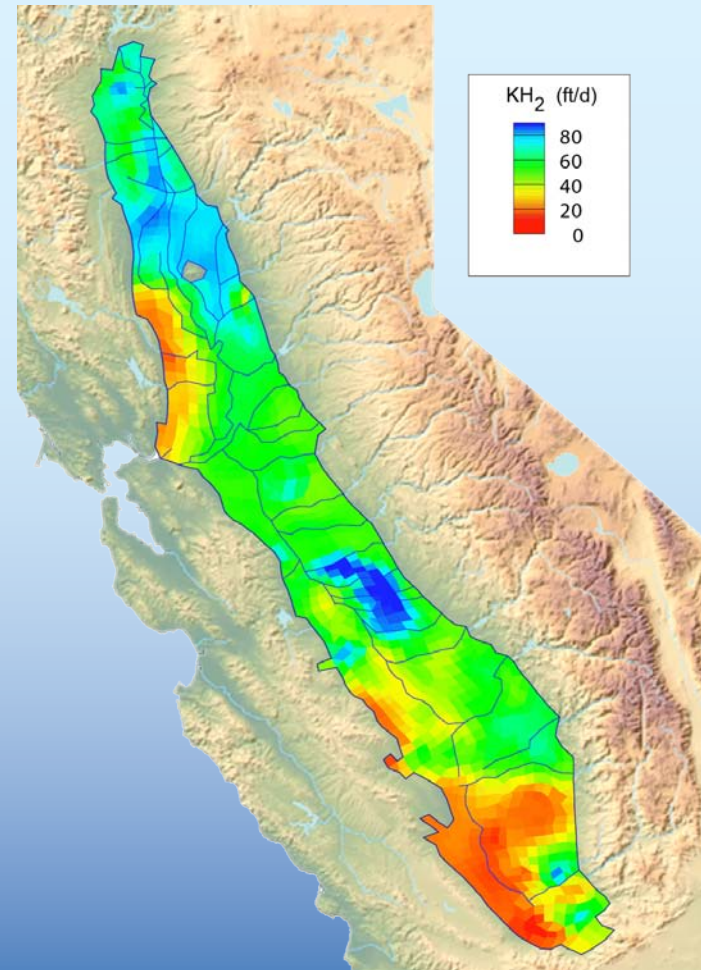


# Hydraulic Conductivity

Layer 1

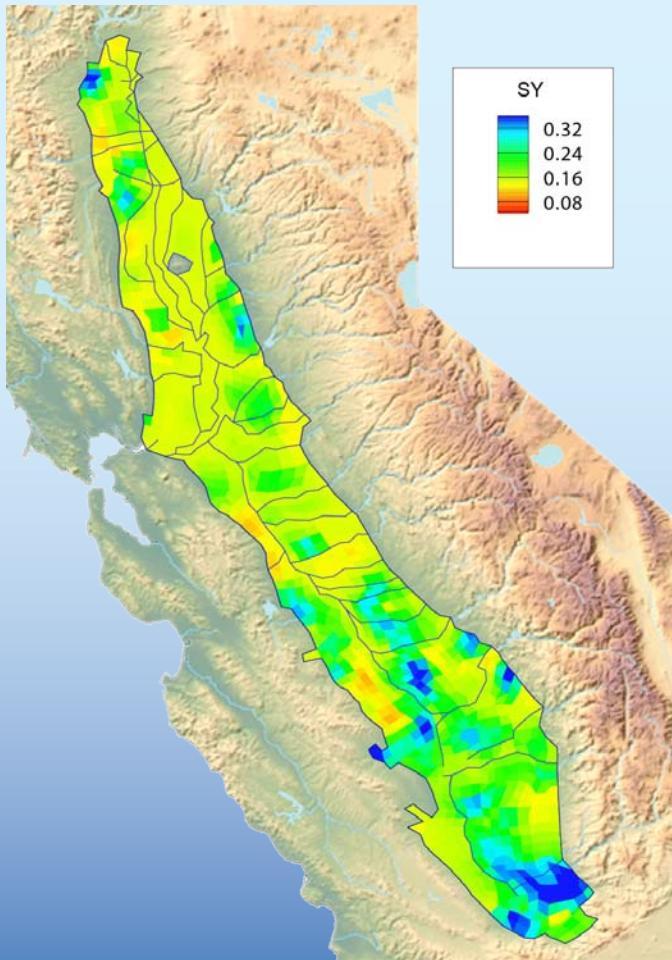


Layer 2

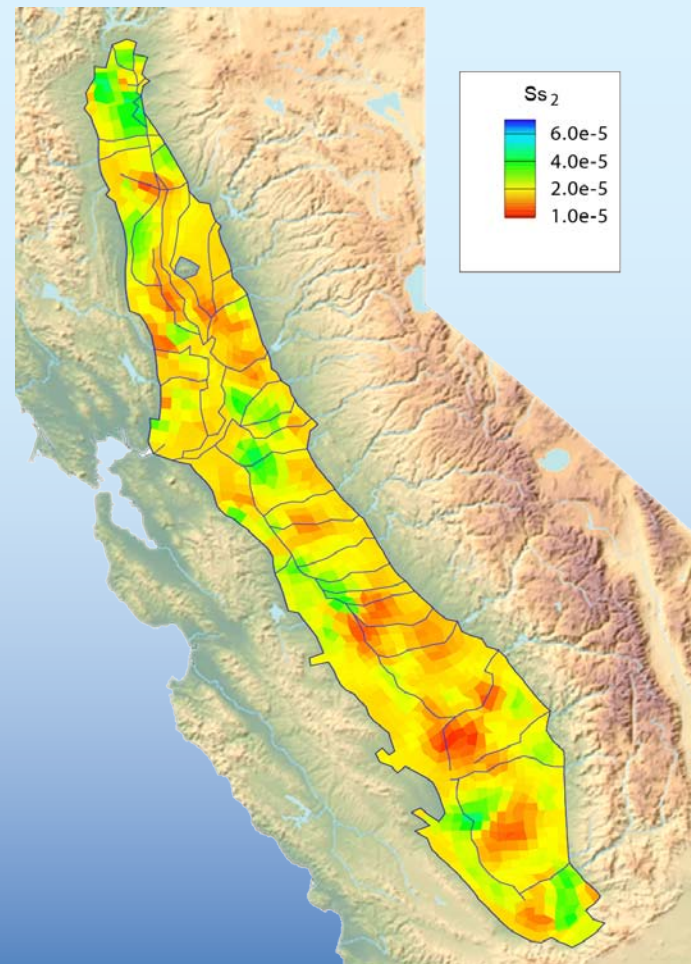


# Storage Parameters

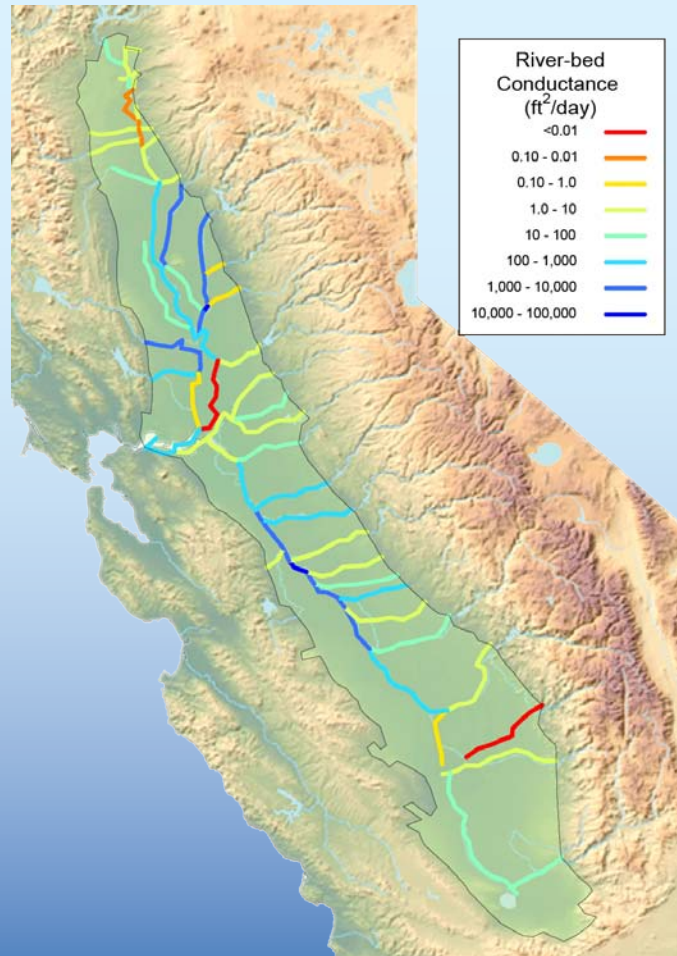
Layer 1



Layer 2



# River-Bed Conductance



# Model Performance

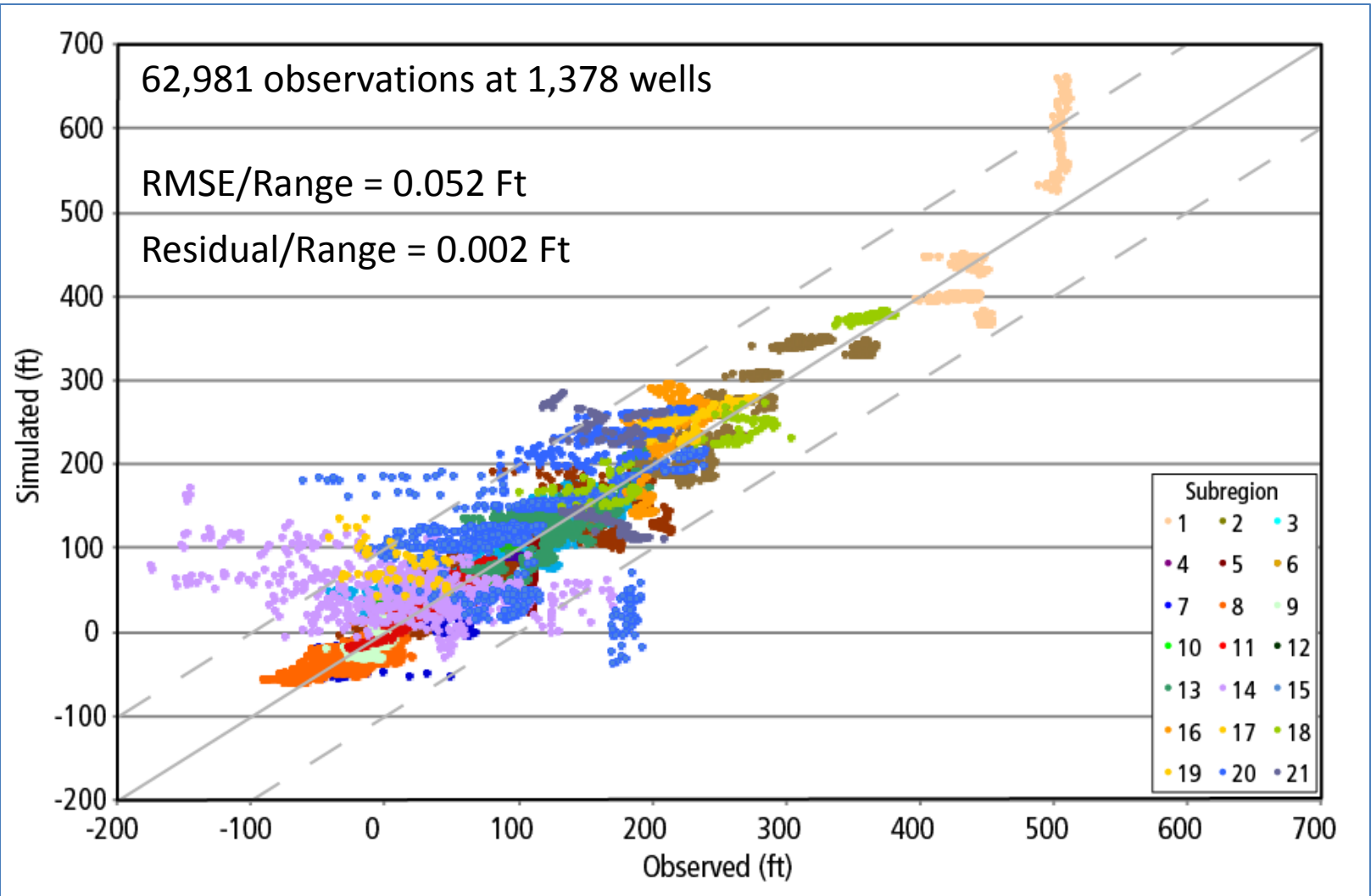
Observation Type	No. Observation Sites	No. Observations	Range
Groundwater heads	1,378	62,981	1,252
Vert. Groundwater Head Difference	163	3,017	698
River Flows	22	5,636	6,561,453
River-Groundwater Flows	33	33	38,117
Subsidence	24	3,700	6.2
<b>TOTAL</b>	<b>1,620</b>	<b>75,367</b>	

Observation Type	Root Mean Squared Error	Residual	<u>RMSE</u> Range	<u>Residual</u> Range
Groundwater heads	65.4	2.14	0.052	0.002
Vert. Groundwater Head Difference	96.2	-13.3	0.138	-0.019
River Flows	145,591	-13,720	0.022	-0.002
River-Groundwater Flows	8,875	3,620	0.233	0.095
Subsidence	17.4	-11.5	2.81	-1.86

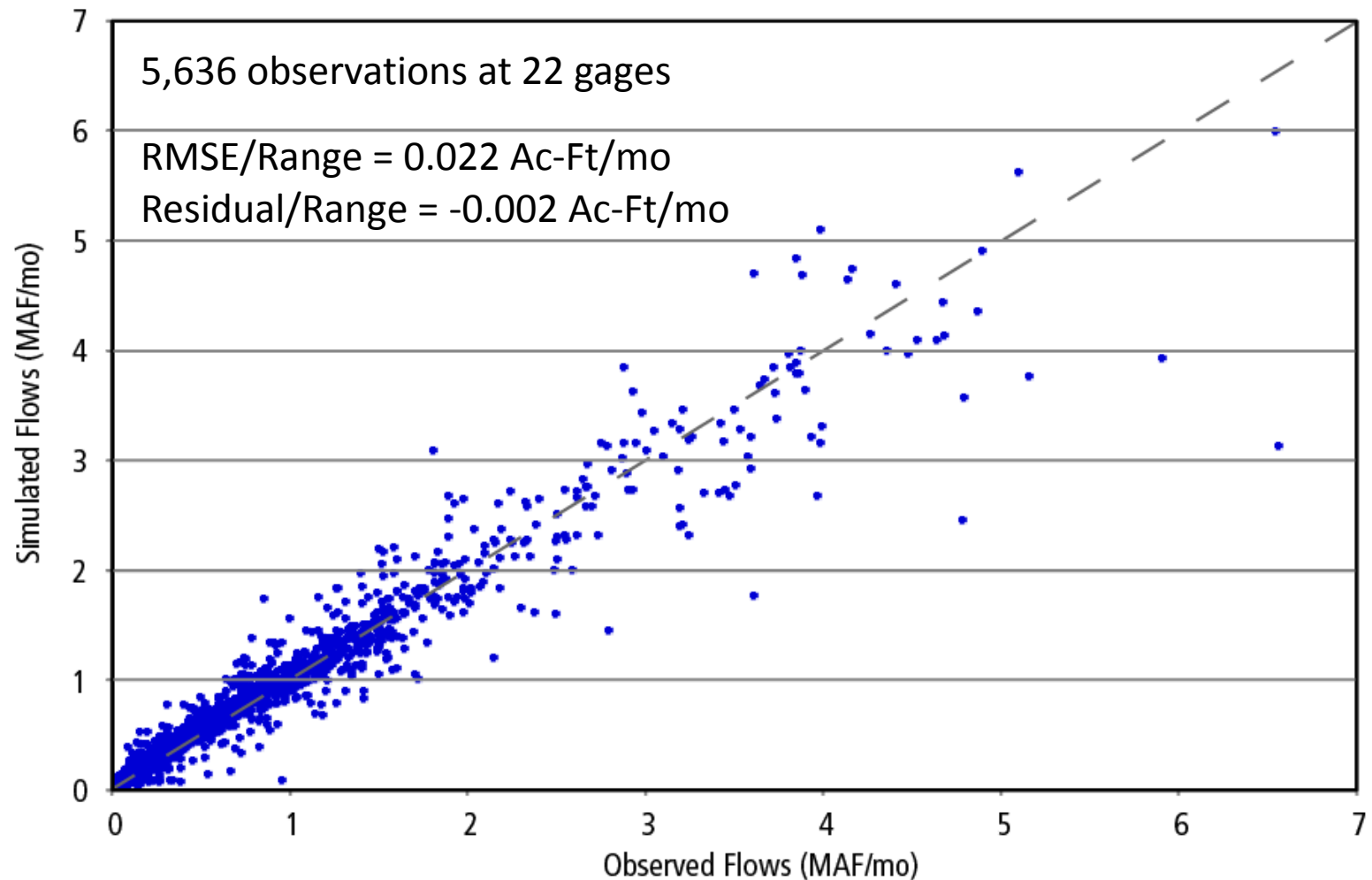
Units: Heads and subsidence in feet, flows in acre-feet

Head and flow observations from October 1975 to September 2003, Subsidence observations from September 1957 to May 2004

# Groundwater Heads

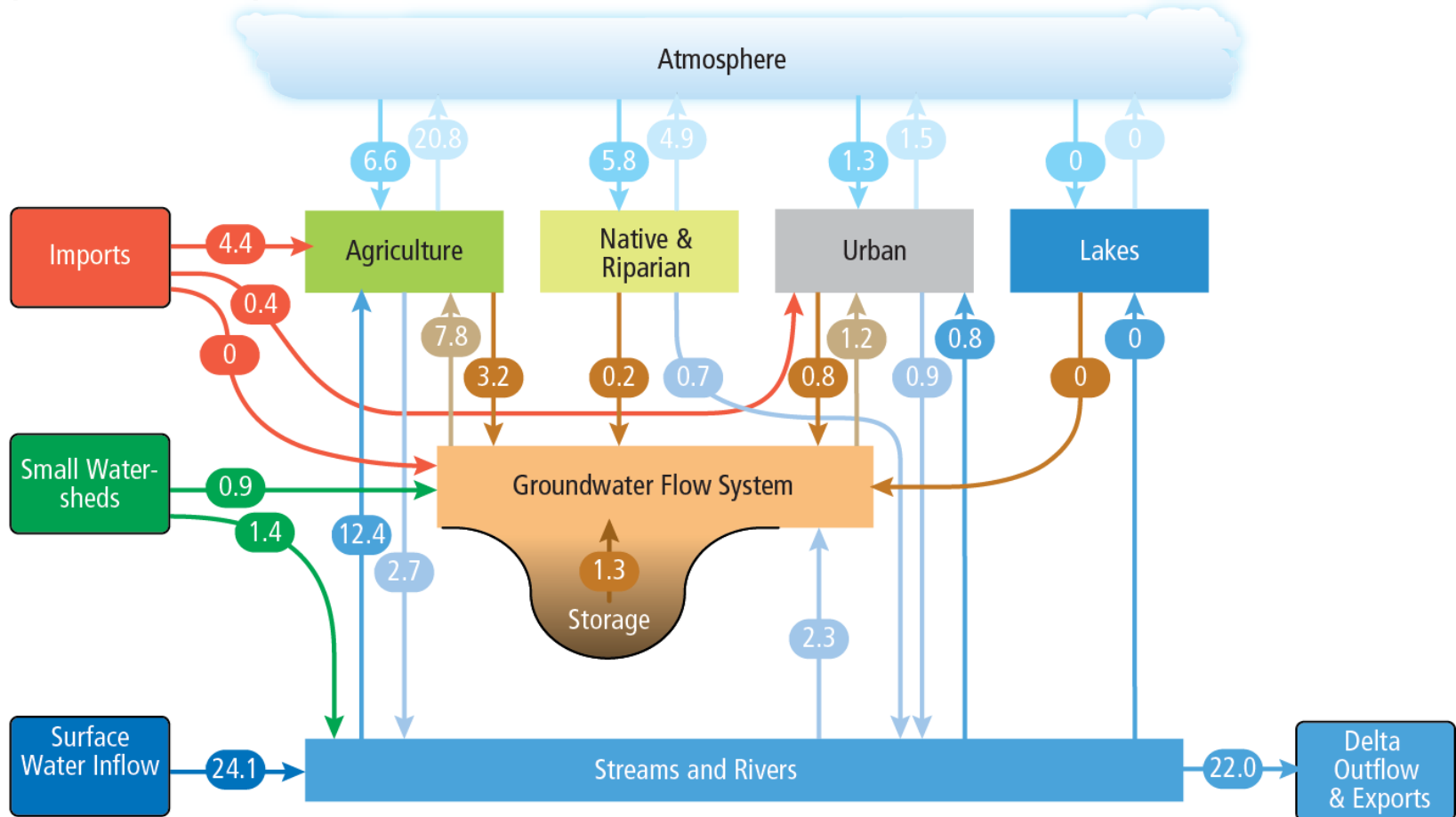


# Surface Water Flows



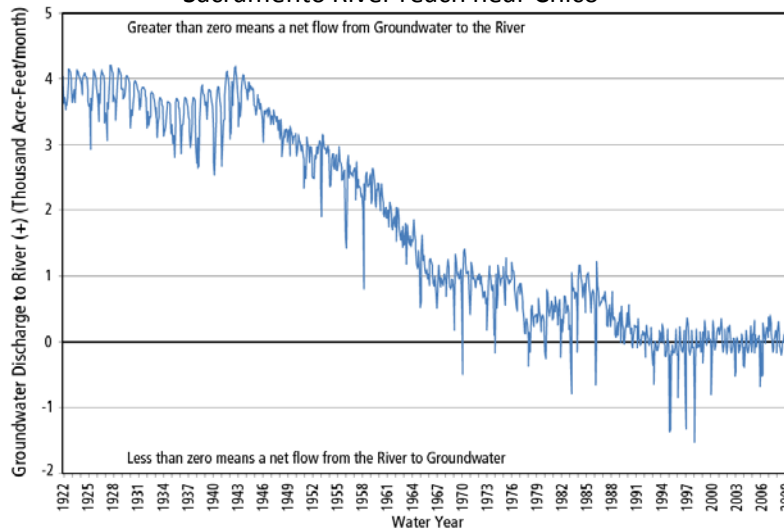
# Simulated Annual Water Budget

Average Flows for water years 2000-2009  
[Million Acre-Feet/Year]

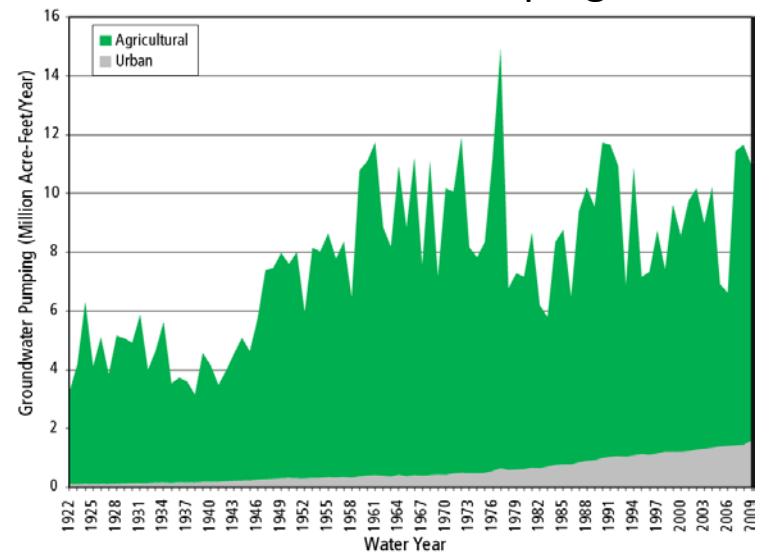


## River-Groundwater Flows

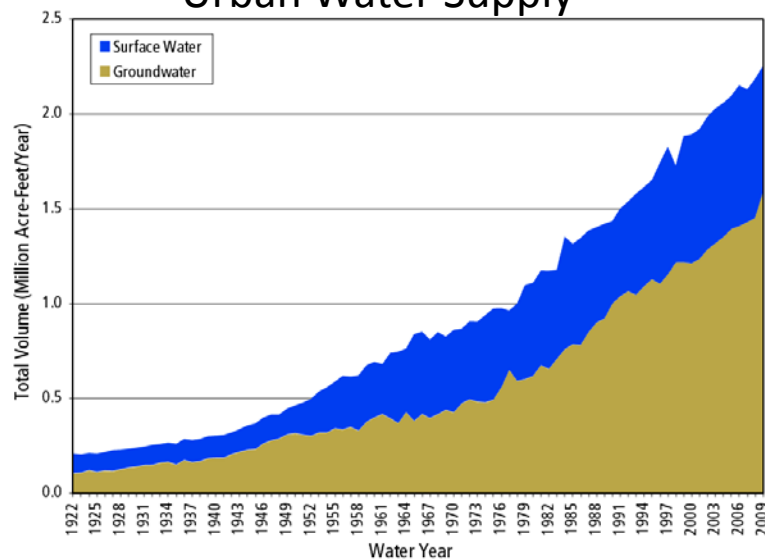
Sacramento River reach near Chico



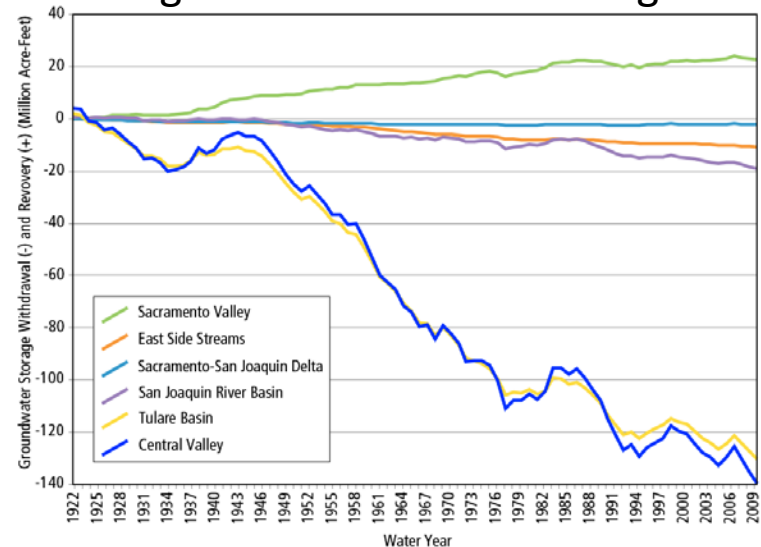
## Groundwater Pumping



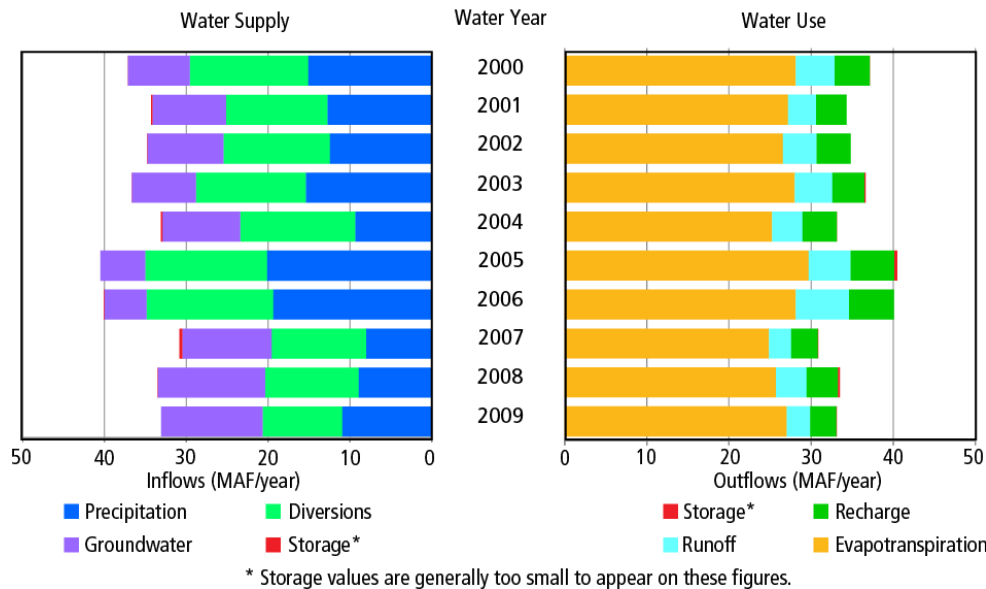
## Urban Water Supply



## Change in Groundwater Storage



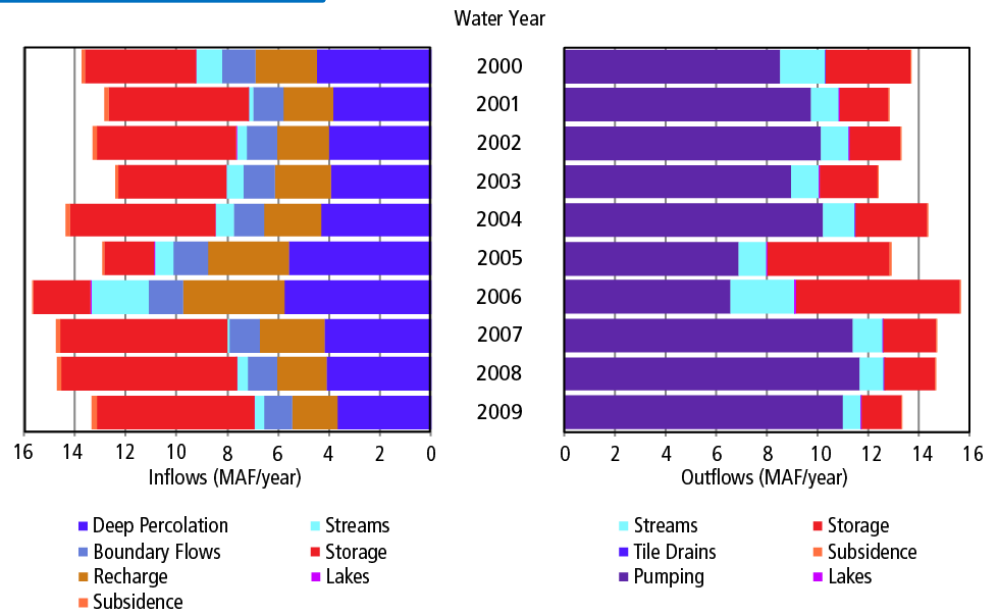
## Land Surface Budget



Process-level output tables have a complete water balance, and can be used to produce budget figures

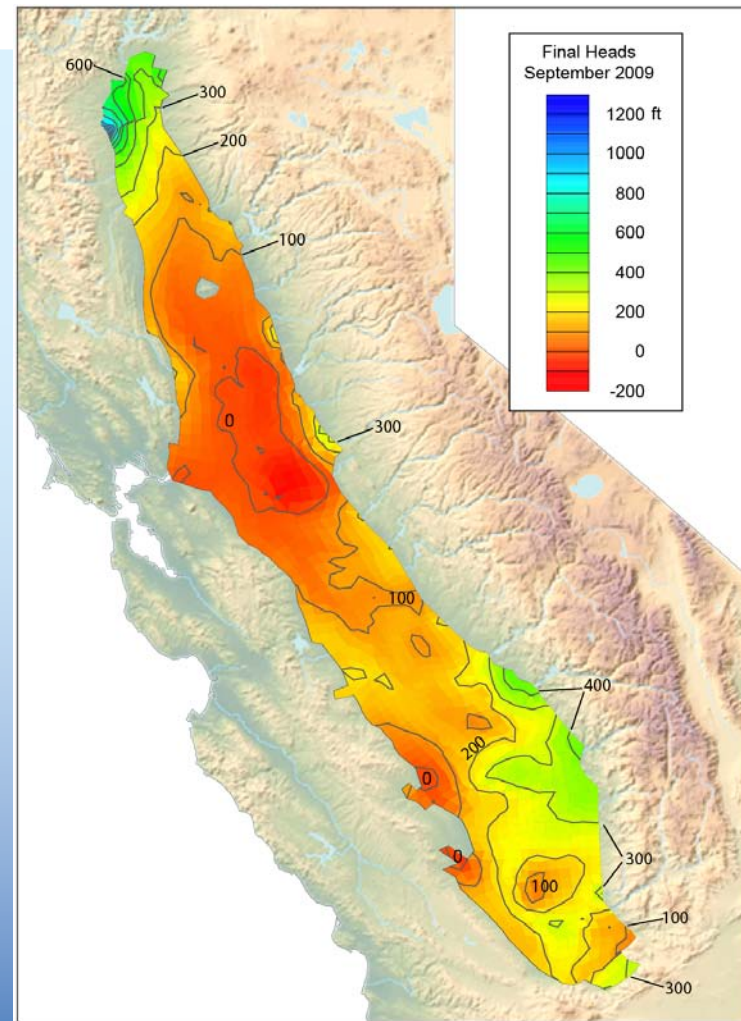
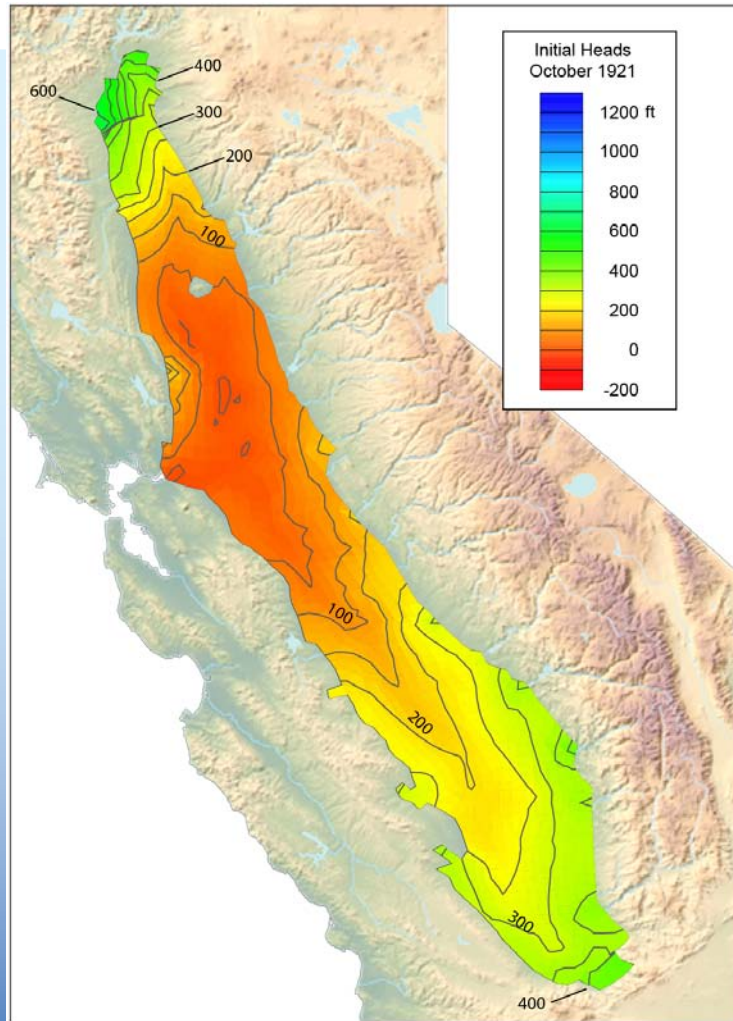
Groundwater budgets can also be produced for 'zones' of one to many elements

## Groundwater Budget

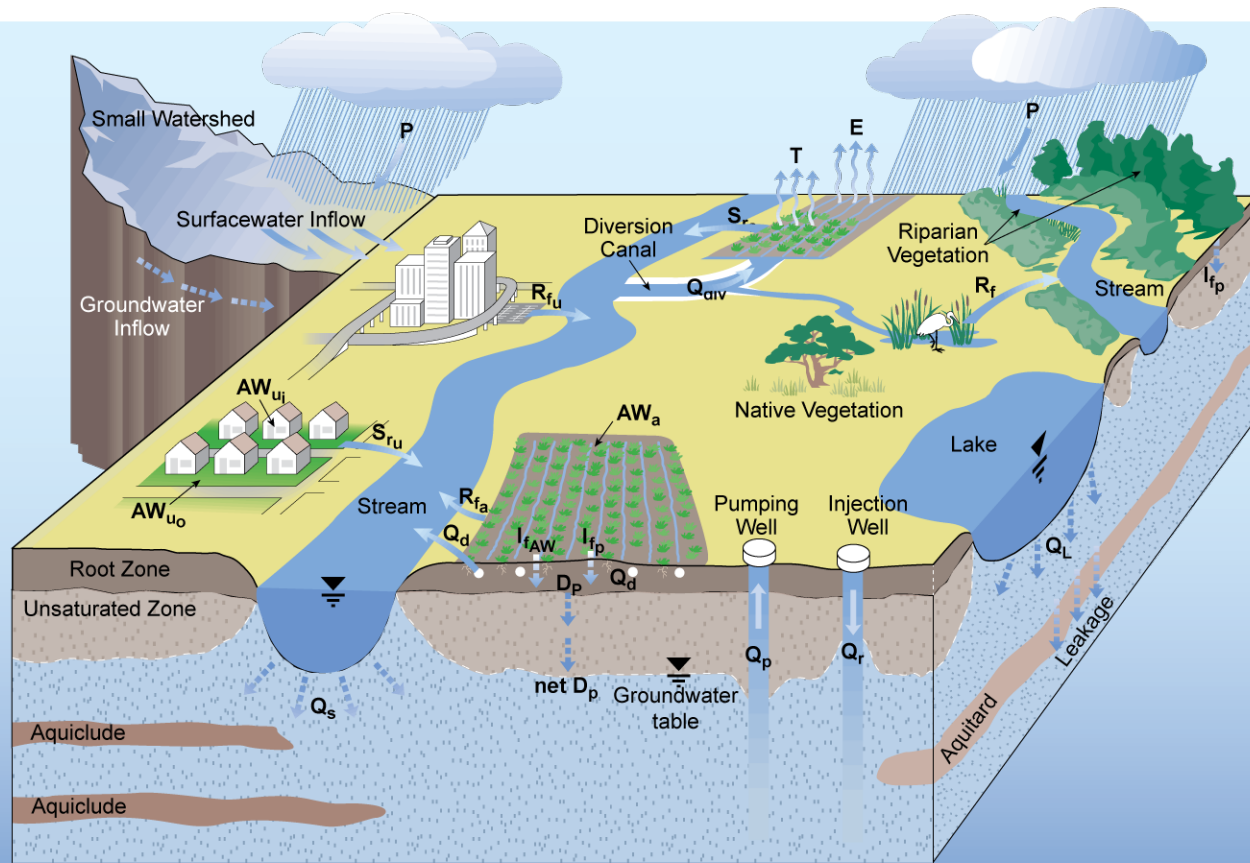


# Water Table Altitude

Produced from IWFM's TecPlot® output files



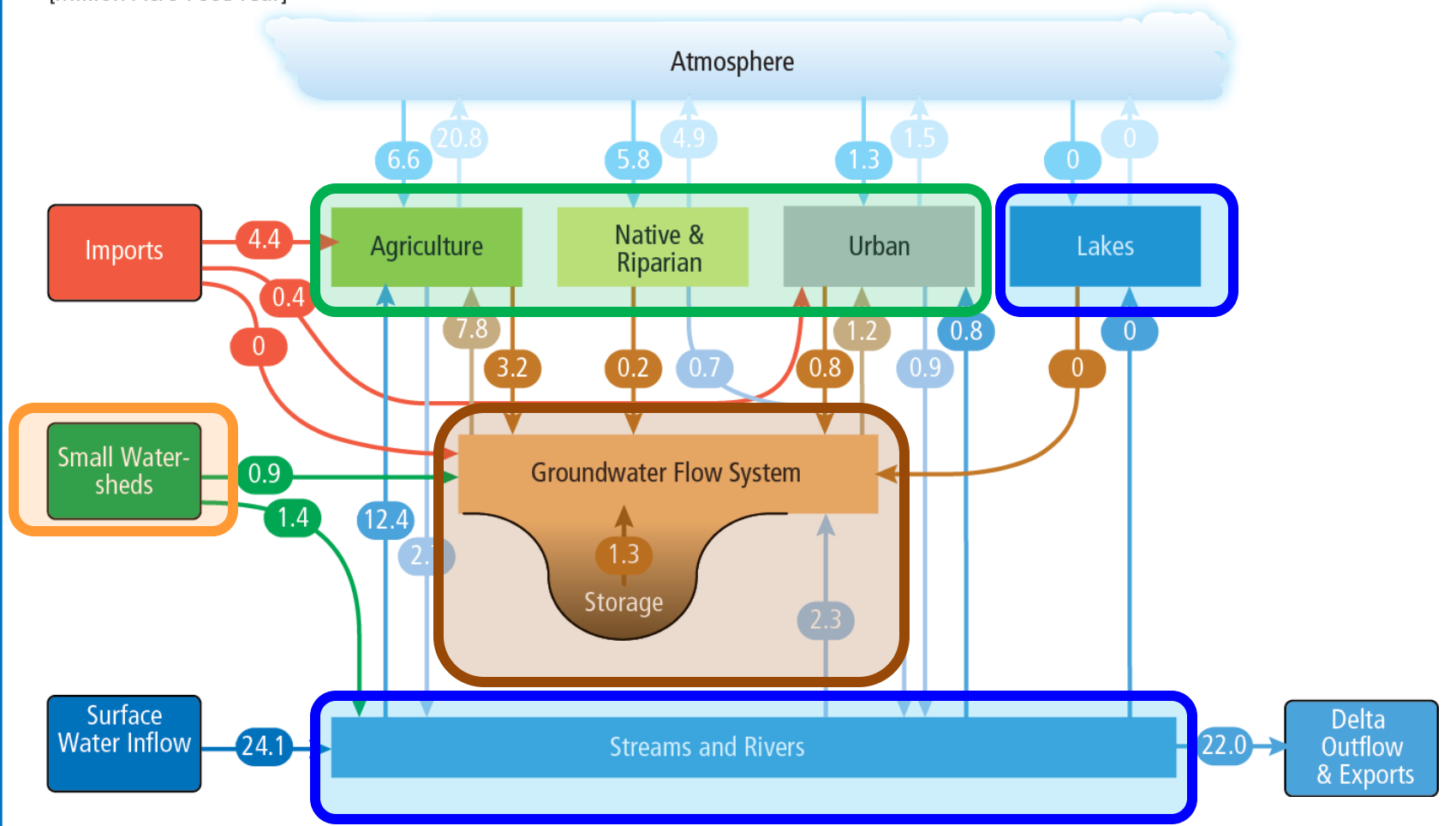
# IWFM



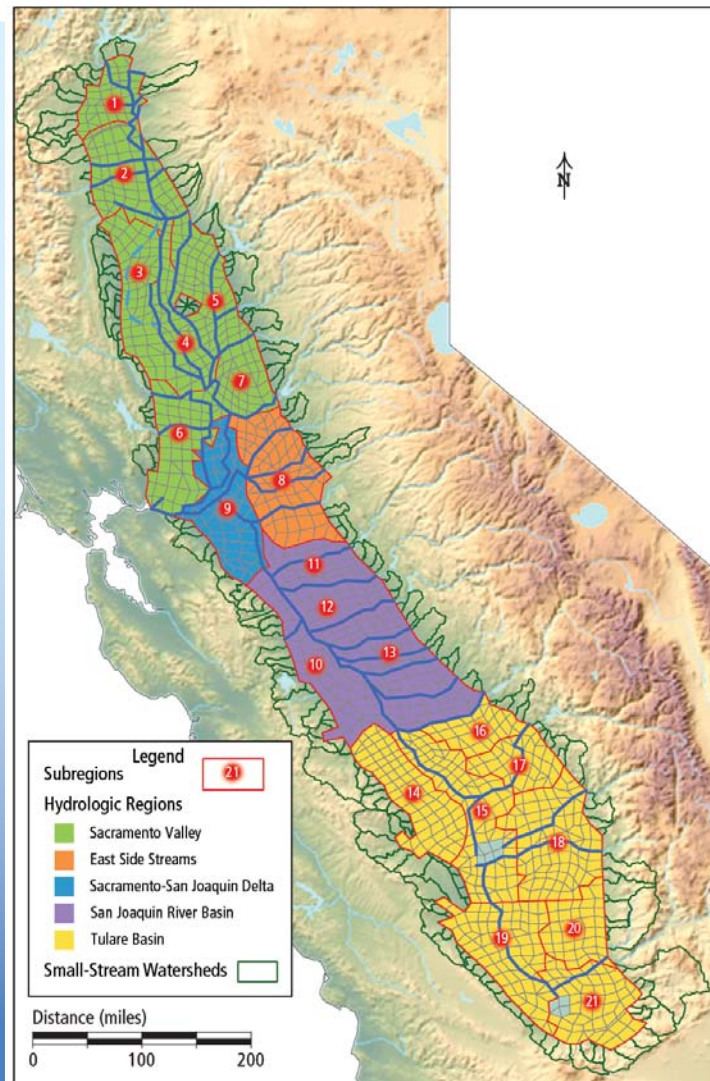
# IWFM Water Balance Diagram

## Simulated Annual Water Budget

Average Flows for water years 2000-2009  
[Million Acre-Feet/Year]



# C2VSim Model



- Land Surface Processes
  - Land and Water Use Budget
  - Root Zone Budget
- Groundwater Process
  - Groundwater Budget
  - Z-Budget Budget
- Surface Water Processes
  - Stream Reach Budget
  - Lake Budget
- Small-Streams Watershed Process
  - Small Watershed Budget



END