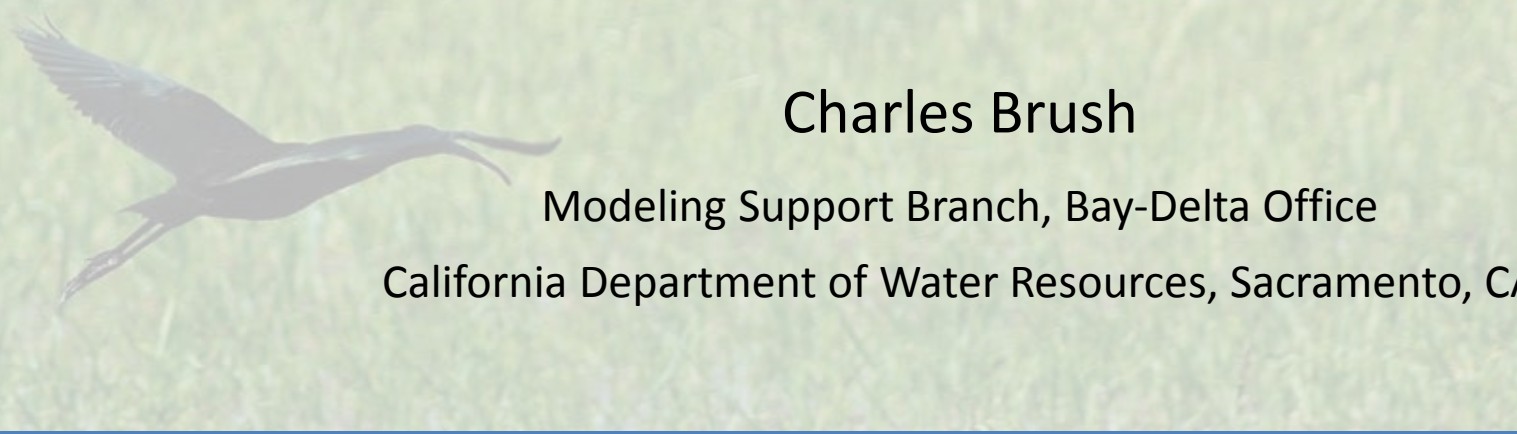


An aerial view of a large-scale agricultural irrigation system, showing a network of canals and numerous sprinkler heads spraying water across a green field.

The California Central Valley Groundwater-Surface Water Simulation Model

C2VSim Overview

CWEMF C2VSim Workshop

A photograph of a large, dark bird, possibly a heron or egret, in mid-flight over a body of water. The bird's long neck is extended forward, and its wings are fully spread.

Charles Brush

Modeling Support Branch, Bay-Delta Office

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% of US pumping
 - Not measured or regulated



C2VSim Development

Derived from the CVGSM model

- WY 1922-1980 Boyle & JM Montgomery (1990)
- WY 1981-1998 CH₂M 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, updated June 2013
- C2VSim 3.02-FG expected in 2014



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 CG 3.02 (R374): Release Version

- Current version, released June 2013
- Water Years 1922-2009, monthly time step
- IWFM version 3.02

C2VSim FG 3.02 (R374): Draft Version

- Based on C2VSim 3.02 CG
- Refine rivers, inflows, land use
- Upgrade to match CG version before release
- Expected release in 2014

Planned Improvements

- C2VSim 3.02 CG/FG: Extend to WY 2011 or 2012
- C2VSim 4 FG: Element-level land use, crop and diversion data



Steady Improvement of C2VSim

R375: September 2013

- Make the supply adjustment flags easier to use

R376: November 2013

- Modify irrigation schedules in subregions 15-17
- Modify curve numbers in small watersheds 103-114
- Add M&I imports from Placer Co Water Agency
- Make irrigation fraction flags easier to use

R377: April 2014

- Remove ASR at end of the Tule & Kaweah Rivers
- Limit ASR on the Kern River Flood Channel to 1,000 cfs

R378: April 2014

- Modify basement altitude between Merced and Los Banos to match base of fresh water

C2VSim Coarse Grid

“C2VSim CG-3.02”

DWR Web Site

- Model files
- Documentation
- 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

(Web Site Last Updated: July 23, 2013)

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 at flow 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 Version R374 (C2VSim-CG_R374)
(Released: June 28, 2013)

- **Model Files**
 - [C2VSim 3.02-CG Water Years 1922-2009](#)
 - [C2VSim 3.02-CG Water Years 1973-2009](#)
- **Documentation**
 - [Brush, C.F., Dogrul, E.C., and Kadir, T.N. June 2013](#), Development and Calibration of the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG.
 - [Brush, C.F., and Dogrul, E.C. June 2013](#), User Manual for the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG. [Addenda](#)
 - [Brush, C.F. June 2013](#), Historical Rim Inflows, Surface Water Diversions and Bypass Flows for the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG.
 - [Brush, C.F. March 2013](#), Hands-On Tutorial for the California Central Valley Groundwater-Surface Water Simulation Model Coarse Grid, version 3.02 (C2VSim v3.02-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](#)
- **Animations**
 - [Water Table \(aquifer layer 1\)](#)
 - [Confined Head \(aquifer layer 2\)](#)

[Additional Resources](#)

Section Pages

- [Central Valley Modeling](#)
- [Delta Modeling](#)
- [Computer Assistance](#)

Quick Hits

- [IWFM](#)
- [IDC](#)
- [WRIMS 1/CalSim 2](#)
- [WRIMS 2](#)
- [CalLite](#)
- [DSM2](#)

Bay-Delta Office
Department of Water Resources

1416 9th Street,
Sacramento, Ca 95814

Mailing Address:
P. O. Box 942836,
Sacramento, Ca 94236-0001

C2VSim Portal

Additional Tools tab on C2VSim page

Interactive Web Site

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

C2VSim Tutorial - CVWRSM - Modeling Support Branch - Windows Internet Explorer

https://msb.water.c...

File Edit View Favorites Tools Help

Modeling Support Branch CVWRSM C2VSim C2VSim Training Materials C2VSim Tutorial

Document Library (CVWRSM)

Documents Home Recent Documents

C2VSim Tutorial

Back to C2VSim Training Materials

Tutorial, tools and completed examples for learning to use the C2VSim model. (The tutorial report was created using C2Vsim-CG version R369 released in March 2013. The examples have been updated to C2VSim-CG version R374 released June 2013)

Last Updated 11/9/13 9:46 PM 0 Subfolders 5 Documents

Documents

Name	Size	Downloads	Locked
ASR Case Study Complete.zip	129,572.1k	0	No
C2VSim Tutorial 201303.pdf Hands-On Tutorial for the California Central Valley Groundwater-Surface Water Simulation Model Coarse Grid, version 3.02 (C2VSim v3.02-CG R369)	25,534.1k	31	No
GST Case Study Complete.zip	141,042.2k	0	No
GWP Case Study Complete.zip	125,071.6k	0	No
Tools.zip	3,111.5k	10	No

Showing 5 results.

Message Boards (CVWRSM)

Message Boards Home Recent Posts Statistics

Threads

There are no threads in this category.

C2VSim Tutorial

Access from Desktop

RSS (Opens New Window)

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

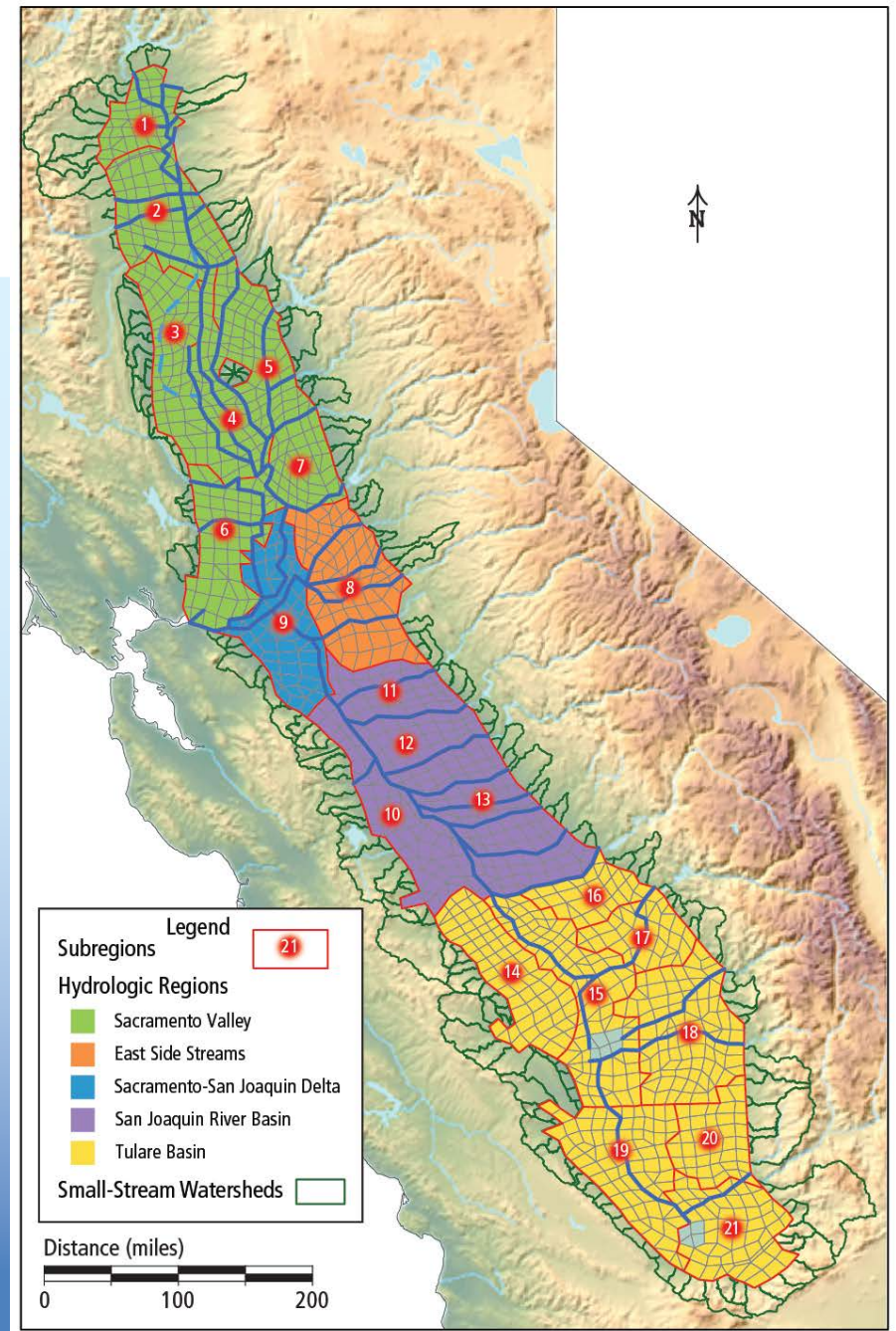
Land Use Process

- 21 Subregions (DSAs)
- 4 Land Use Types

Simulation periods

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

IWFM version 3.02

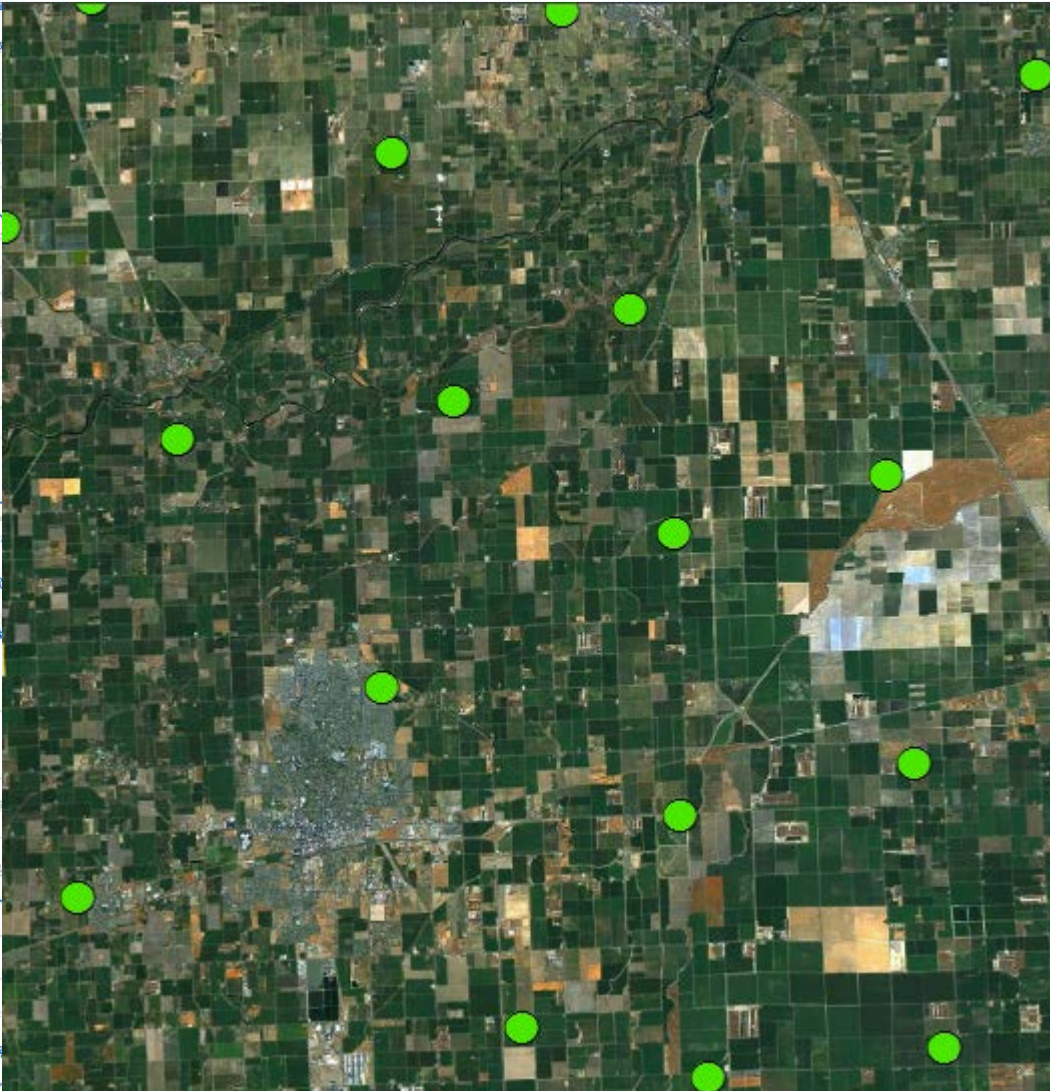
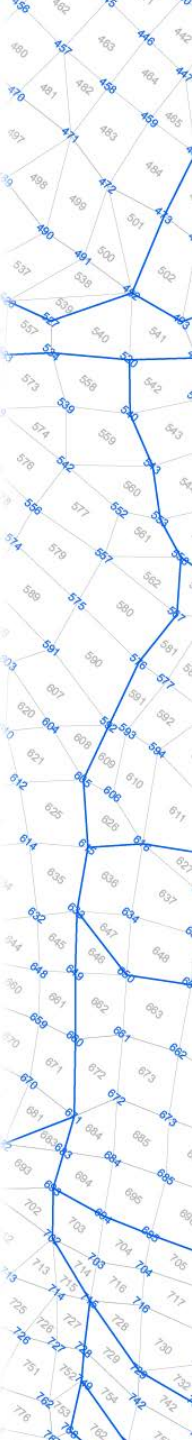


C2VSim Framework

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

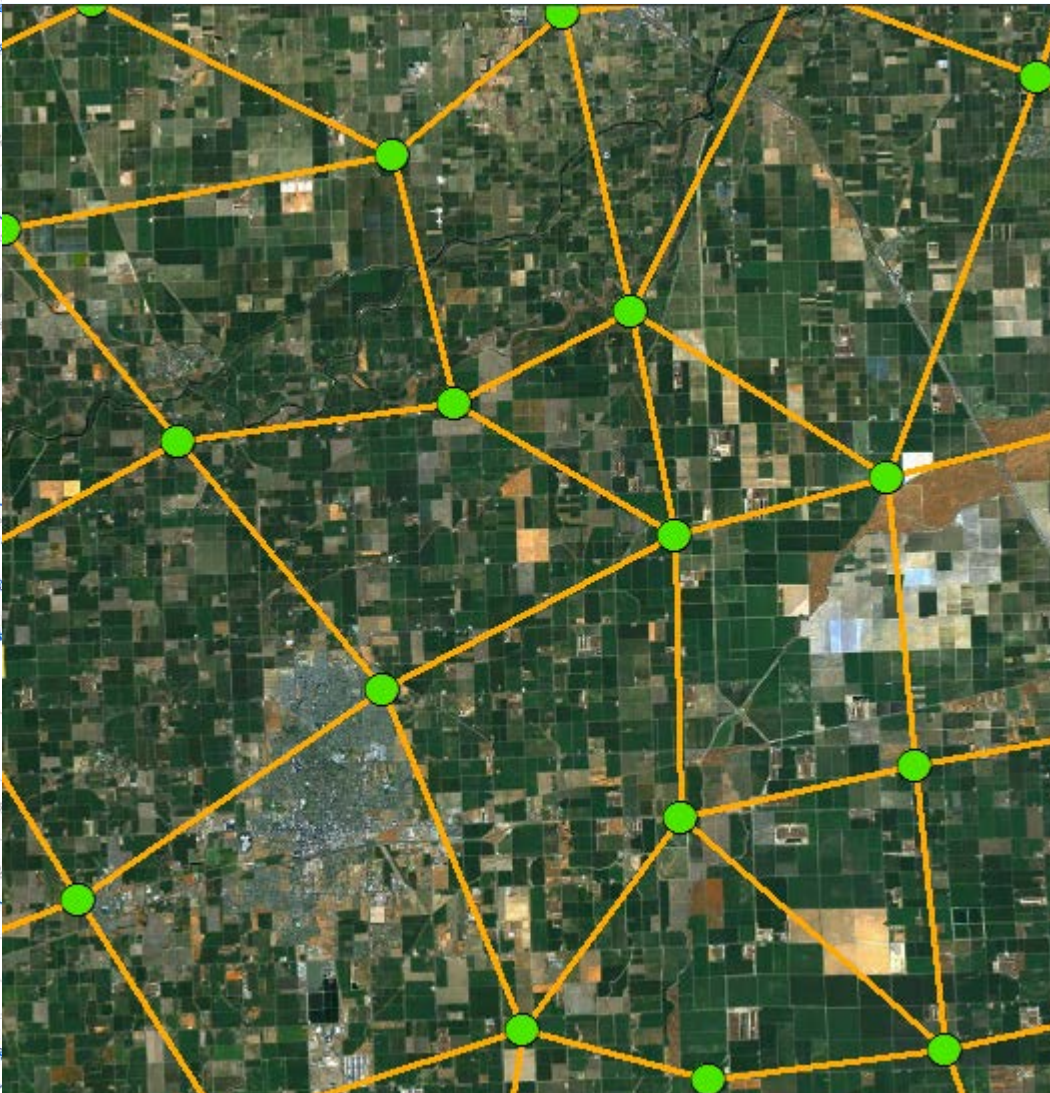
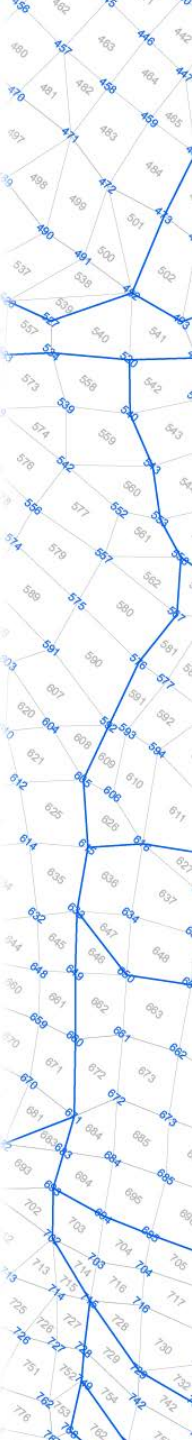
- UTM 10N
- X = Easting
- Y = Northing

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*****
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

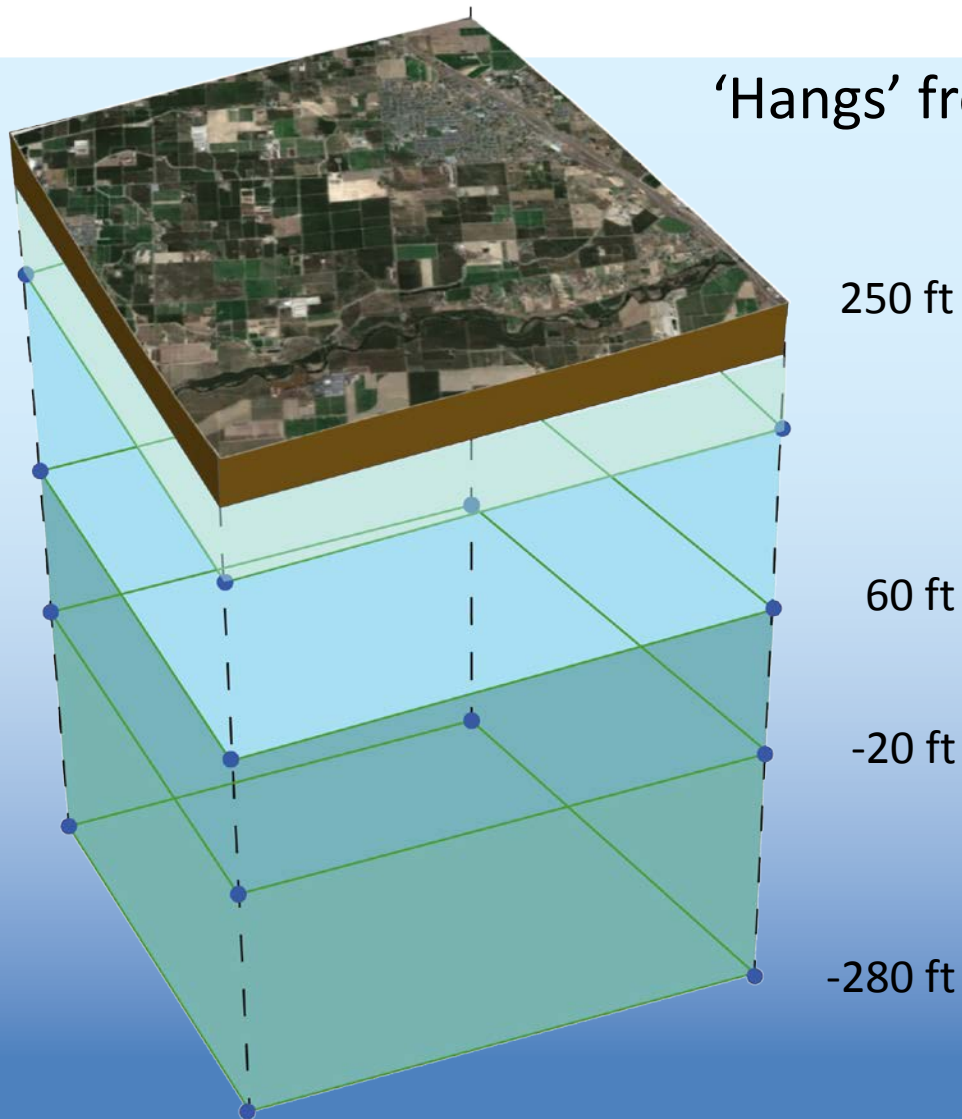
- 4 nodes = quadrilateral
- 3 nodes = triangle

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



Stratigraphy

At each node:

Land Surface Elevation

For each layer

- Aquiclude thickness
- Aquifer thickness

Stratigraphy Specification Data

NL; Number of layers to be modeled

FACT; Conversion factor for stratigraphic data

VALUE

DESCRIPTION

3

/NL

1

/FACT

Node Elevation --Layer #1-- --Layer #2-- --Layer #3--

ID ELV W (1) W (2) W (3) W (4) W (5) W (6)

1 733 0 243 0 100 0 100

2 695 0 245 0 100 0 100

3 705 0 235 0 100 0 100

4 732 0 282 0 100 0 100

5 463 0 89 0 133 0 134

6 590 0 186 0 134 0 133

7 705 0 334 0 133 0 134

8 613 0 213 0 100 0 100

9 455 0 133 0 133 0 133

10 554 0 296 0 178 0 179

11 460 0 168 0 143 0 144

12 800 0 326 0 134 0 134

13 1056 0 606 0 100 0 100

14 795 0 345 0 100 0 100

15 418 0 144 0 163 0 164

16 496 0 317 0 235 0 236

17 499 0 340 0 248 0 249

18 777 0 474 0 167 0 166

19 885 0 305 0 100 0 130

20 818 0 314 0 133 0 134

21 599 0 326 0 198 0 198

22 403 0 420 0 413 0 413

23 457 0 401 0 319 0 318

24 635 0 411 0 186 0 185

25 631 0 122 0 133 0 133

26 622 0 257 0 164 0 165

27 669 0 536 0 317 0 318

28 580 0 808 0 654 0 653

29 372 0 341 0 333 0 334

30 594 0 424 0 213 0 213

31 613 0 20 0 120 0 133

32 735 0 226 0 133 0 133

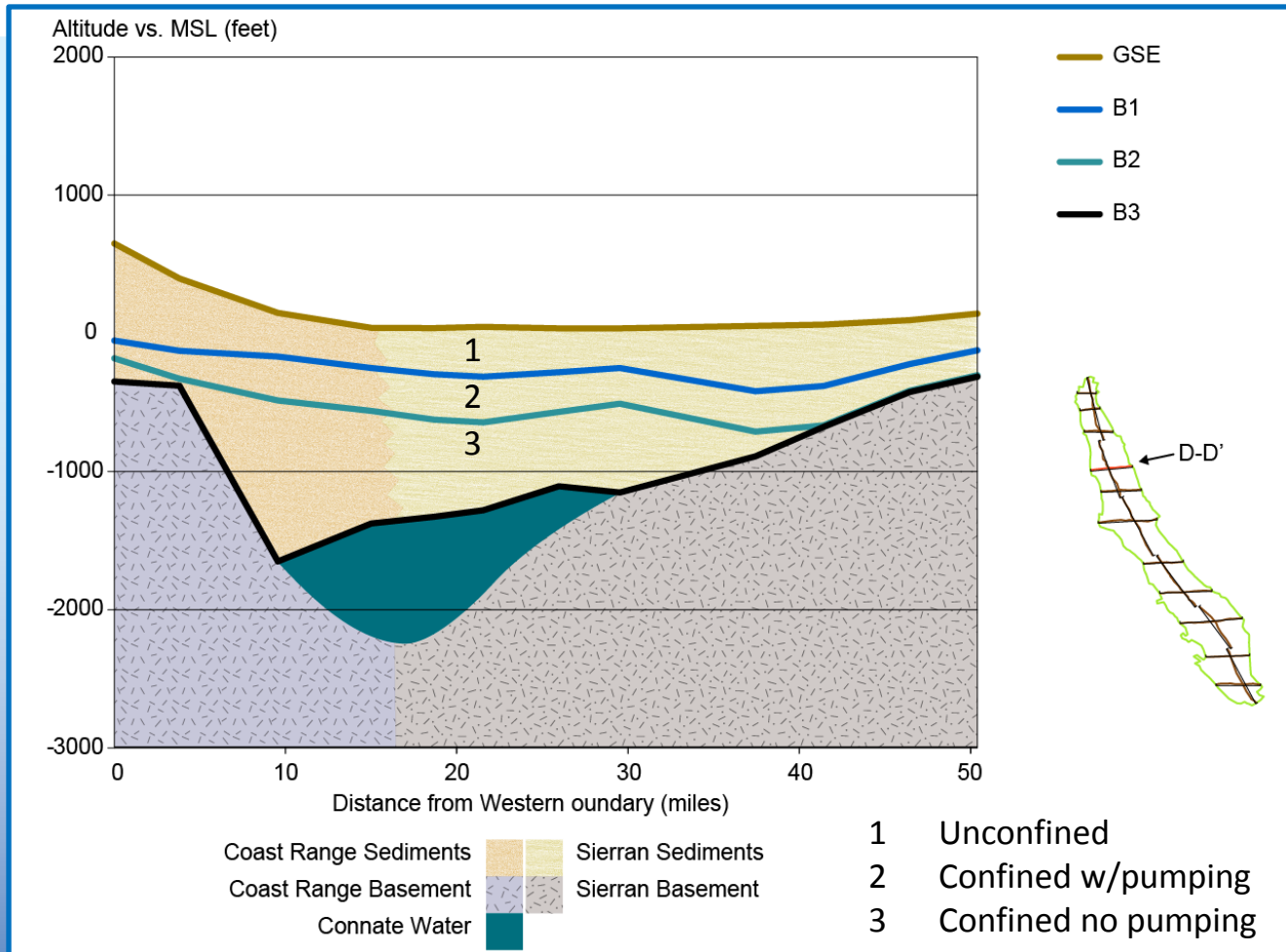
33 726 0 313 0 140 0 139

34 521 0 246 0 215 0 216

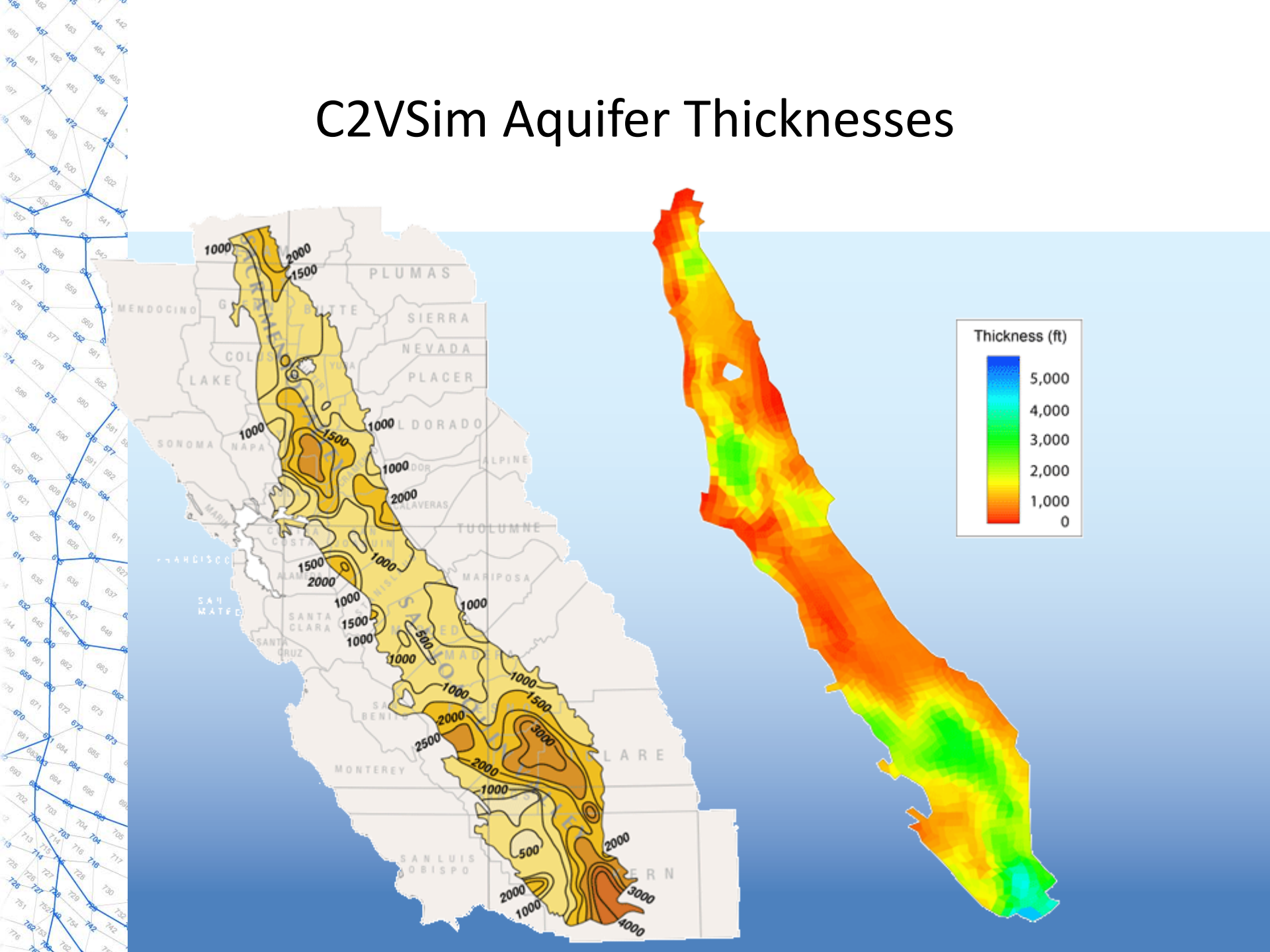
35 436 0 346 0 351 0 351

36 408 0 706 0 697 0 698

C2VSim Aquifer Cross Section



C2VSim Aquifer Thicknesses



Base of Fresh Groundwater in the Sacramento Valley, California

California Department of Water Resources Report name/#

Steven Springhorn, Nick Hightower, and Tad Bedagrew
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 structural geologic features in the Sacramento Valley.

Two BFG maps covering the Sacramento Valley were previously created by the USGS in 1981 (Cronsted and Davis) and 1982 (Bedagrew). 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) (approximately 1,500 µmhos conductivity). TDS is used in the earlier studies. The BFG was estimated based on a combination of geophysical logs and lithologic logs from 2,780 geophysical logs and 1,000 lithologic logs and 1,000 geophysical logs and 1,000 lithologic logs. The BFG was estimated based on a combination of geophysical logs and lithologic logs from 2,780 geophysical logs and 1,000 lithologic logs and 1,000 geophysical logs and 1,000 lithologic logs.

The BFG boundary occurs primarily in late Tertiary to Quaternary unconsolidated sediments at depths near and above 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, it integrates underlying geologic structures. In some areas, the BFG boundary is well below the base of post-closure mafic dikes. This is most likely caused by high salinity conditions and spatial variations 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. This finding has implications for brackish and saline water appearing beneath areas of prolonged groundwater pumping 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 determined using 1D and 2D geophysical logs and 1D and 2D lithologic logs. The BFG surface is determined using 1D and 2D geophysical logs and 1D and 2D lithologic logs. The BFG surface is determined using 1D and 2D geophysical logs and 1D and 2D lithologic logs.

The BFG was approximated:

1. At the depth where both short and long resistivity signatures decrease below 6 to 10 ohm-meters/m resistivity.

• 6 to 10 ohm-meters/m was determined by resistivity values from water quality analyses, and does not account for multi-geologic formation processes (porosity, permeability, etc.) using the resistivity curve correlation that is available.

• This number is consistent with water quality samples from DWR monitoring wells completed at or near the BFG (TDS compared to resistivity).

2. Where short and long resistivity signatures are consistently similar in value (high resistivity), the BFG was approximated at the depth where the resistivity signatures are highly variable.

3. At or just above the depth where the BFG signature develops, displaying significant deflections.

4. At the depth where the resistivity signatures increase above 150-200 ohm-meters/m resistivity (not shown in Figure 1a-b-f).

5. Using other well logs and lithologic information in the same geographic area to constrain the BFG selection.

Below the BFG pick, there may be intervals that have resistivity signatures above 6 ohms. Usually these features are less than 10 to 20 feet in thickness. These thin, more resistive intervals were not considered in the BFG selection because the thickness of these intervals for fresh water resources is not predicted.

BFG picks are rounded to the nearest 10-foot interval.

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 conductivity) as defined by Frazee and Cherry (1979). This concentration is used instead of 2,000 mg/L TDS used in earlier studies (1981), because the focus of this study is on the concentration of the fresh water aquifer in the Sacramento Valley and groundwater exceeding 1,000 mg/L TDS is generally considered unsuitable for drinking water and irrigation water. Other measurements of the TDS or conductivity in water samples at or near the BFG were performed in 110 water wells in the study area.

Category	Total Dissolved Solids (mg/L)
Fresh water	0 - 1,000
Brackish water	1,000 - 10,000
Saline water	10,000 - 100,000
Sea water	>100,000

Source: Frazee and Cherry, 1979, p. 10.

Data Sources

The BFG was estimated based on 2,780 geophysical logs and water chemistry data from 110 monitoring wells collected near the BFG or in areas of brackish water near and surface. Some geophysical logs were obtained from the following sources:

- 458 groundwater resource geophysical logs
- 1,000 California Division of Oil and Gas well logs

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

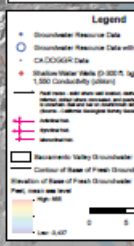
Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

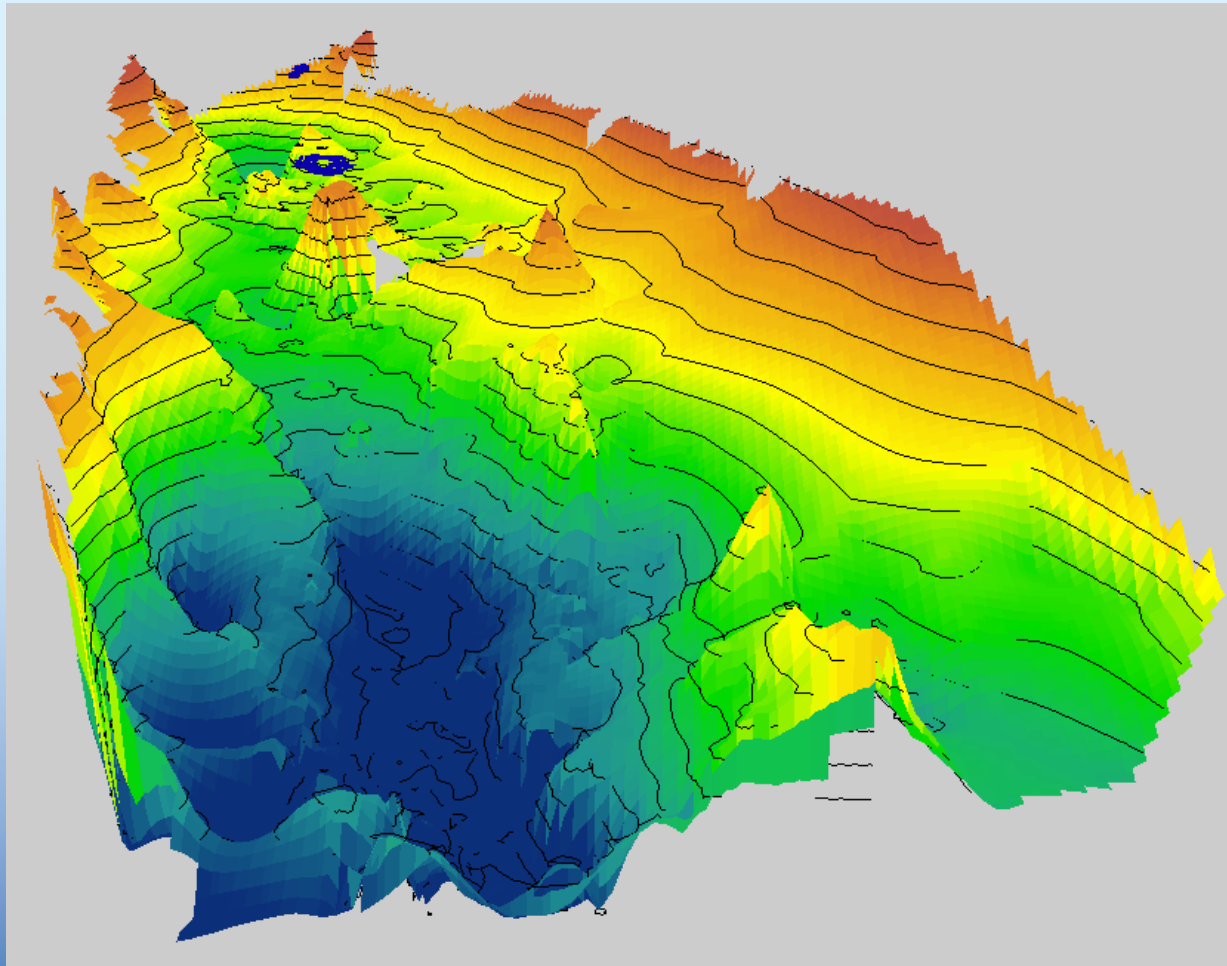
Some geophysical logs were obtained from the following sources:

Some geophysical logs were obtained from the following sources:

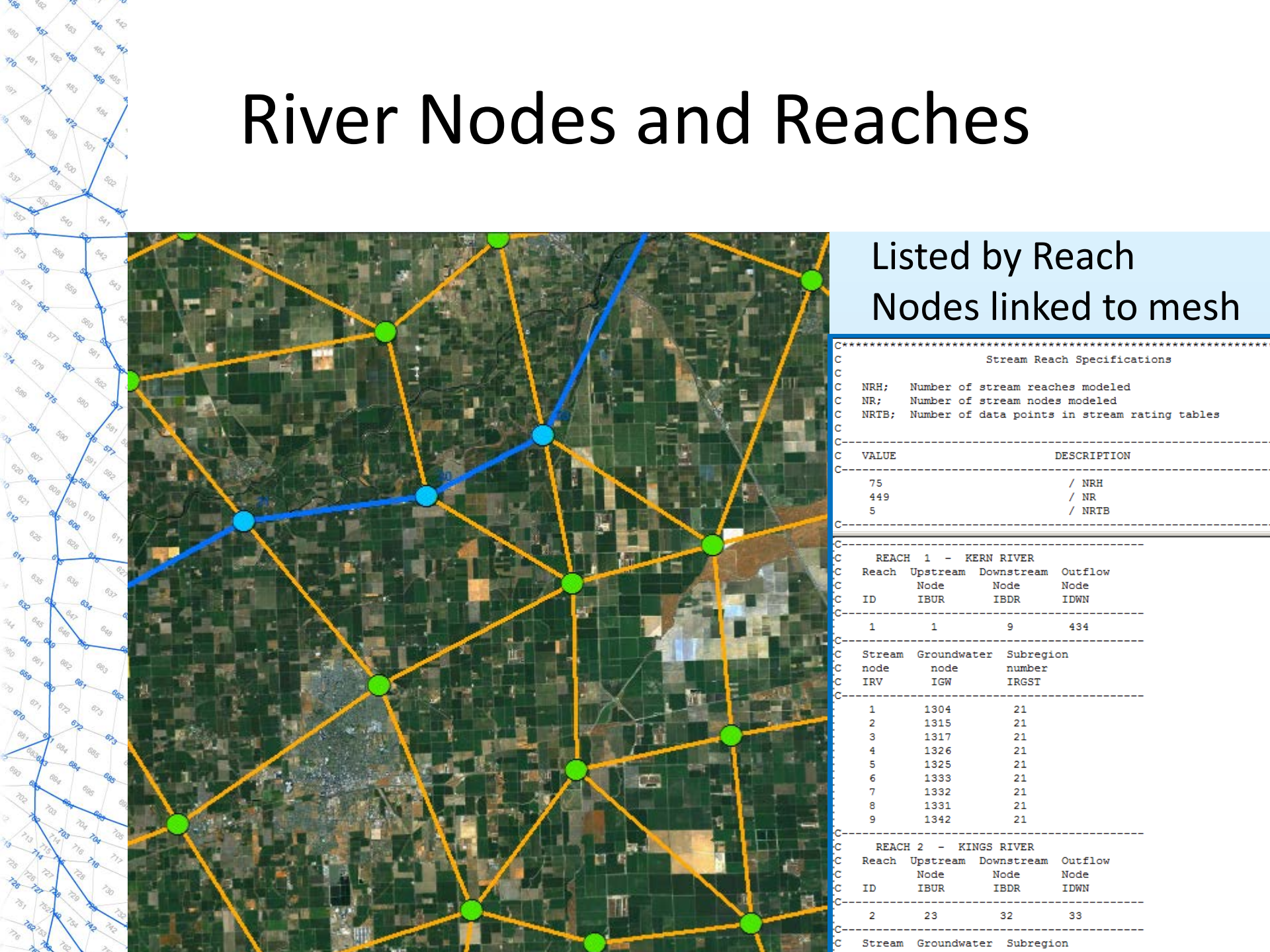


Base of Fresh Water

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

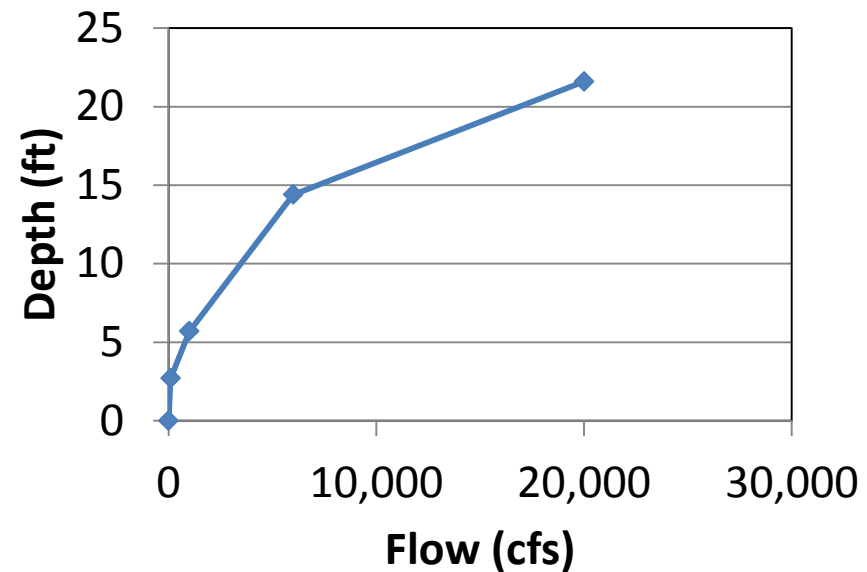
Rating table for each node
at the end of the file

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/I]		
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                /  FACTLT
C     60.0                /  FACTQ      (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/I]
C-----
C  Stream  Bottom  Stream  Flow
C  node   elevation depth  rate
C  ID      BOTR   HRTB    QRTB
C-----
C      1      420.0    0.0      0.00
C                       2.7     100.00
C                       5.7    1000.75
C                       14.4   6000.00
C                       21.6  20000.00
C      2      400.0    0.0      0.00
C                       2.7     100.00
C                       5.7    1000.75
C                       14.4   6000.00
C                       21.6  20000.00
C      3      378.3    0.0      0.00
C                       2.7     100.00
C                       5.7    1000.75
C                       14.4   6000.00
C                       21.6  20000.00
C      4      354.0    0.0      0.00
C                       2.7     100.00
C                       5.7    1000.75
C                       14.4   6000.00
C                       21.6  20000.00
C      5      328.7    0.0      0.00
C                       2.7     100.00
C                       5.7    1000.75
C                       14.4   6000.00
```



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  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  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

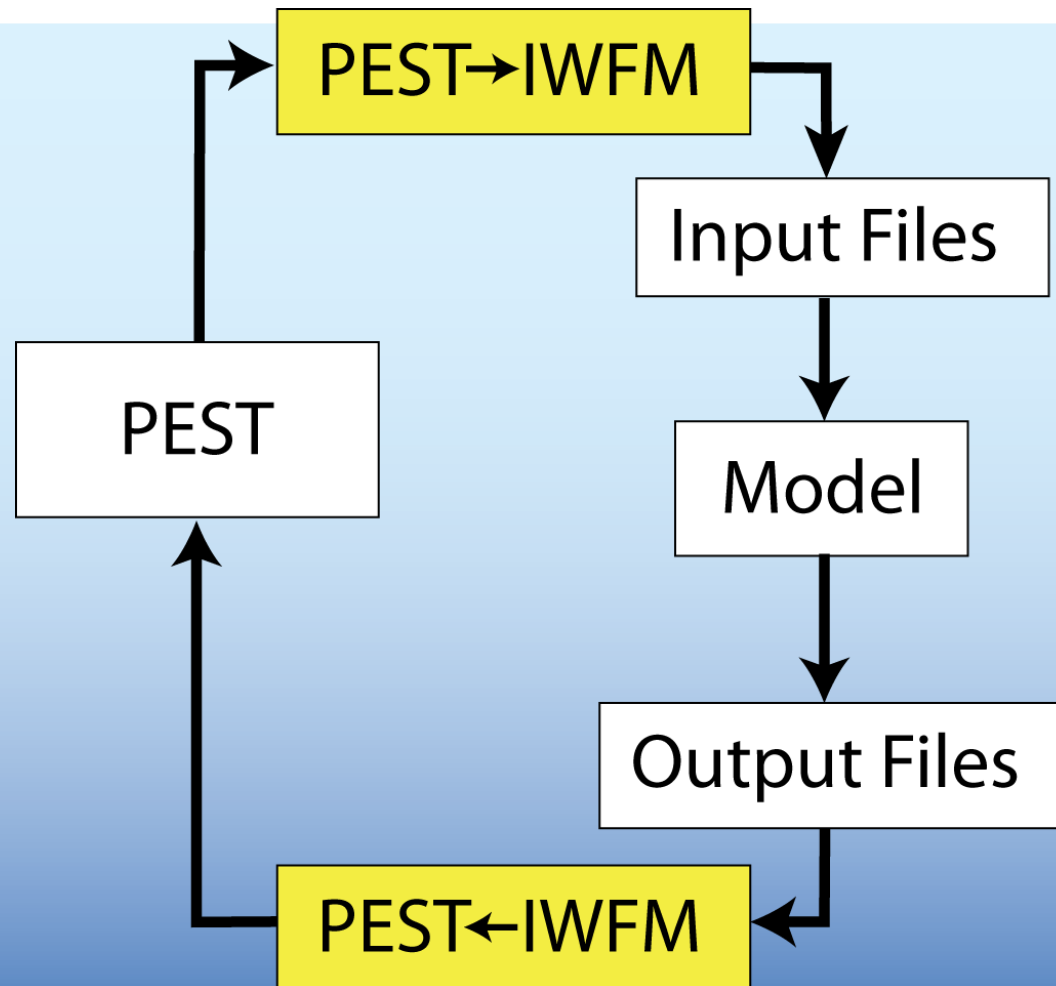
Soil properties

- Field capacity
- Porosity
- Recharge factor
- Curve Numbers

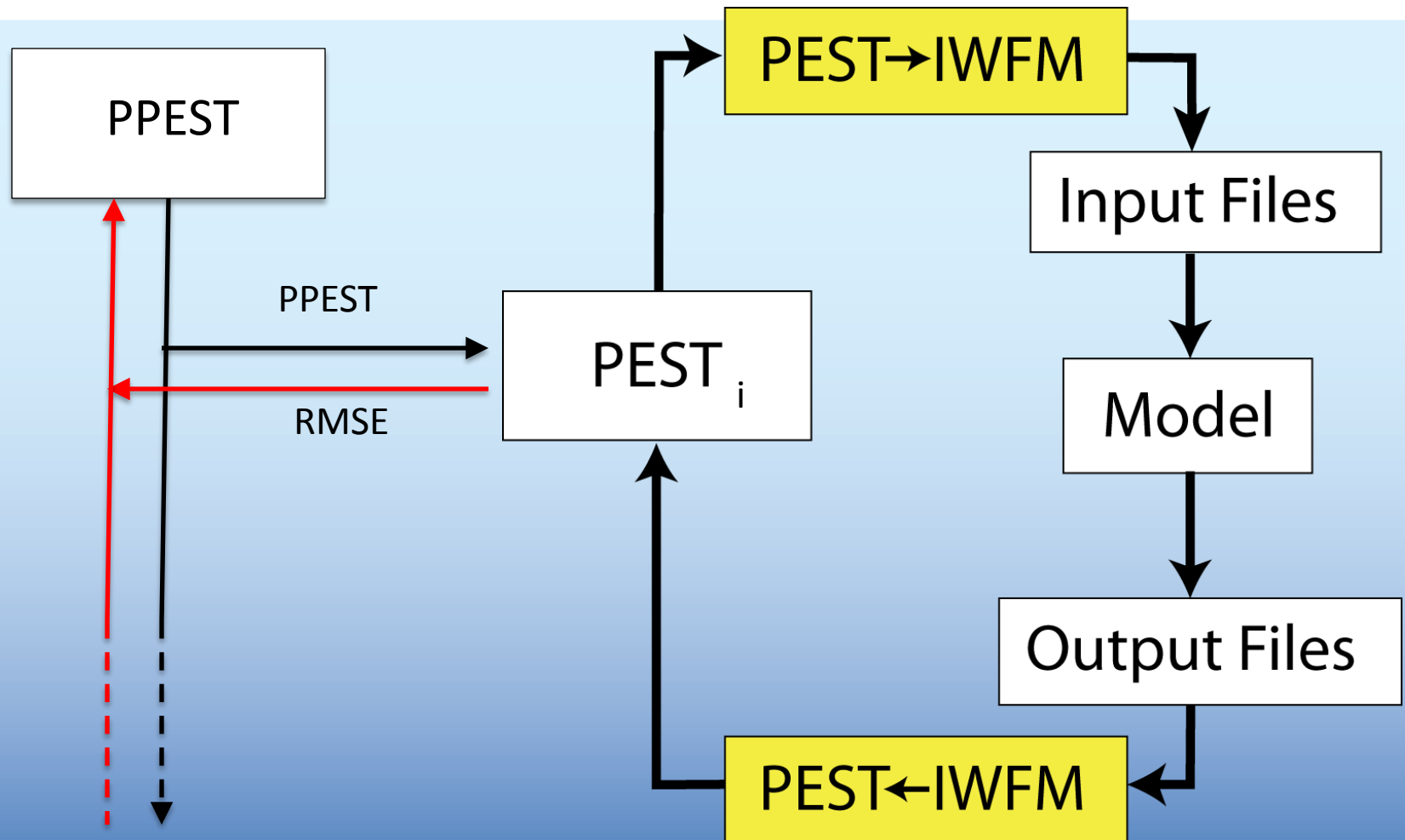
Small Watersheds

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

Calibration with PEST



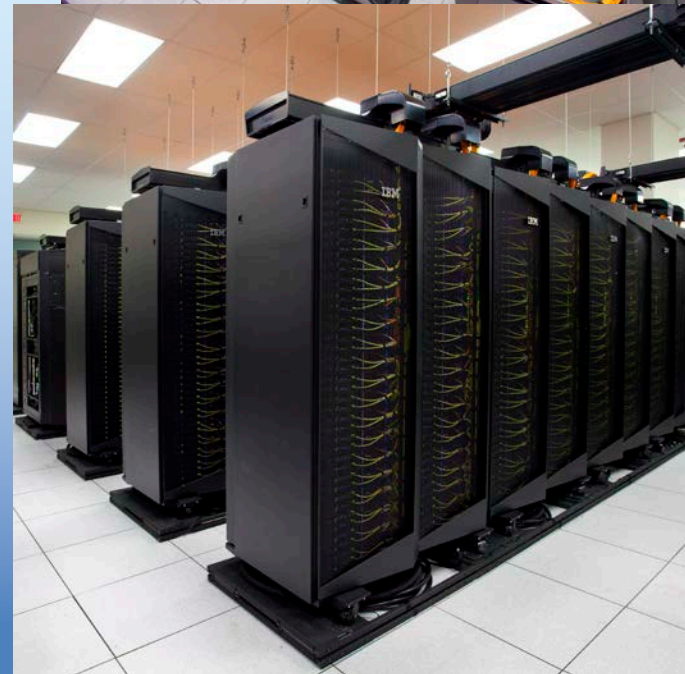
Calibration with PPEST



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





Calibration Observations

Groundwater Heads

- 56,947 observations at 1,145 wells

Vertical Head Difference

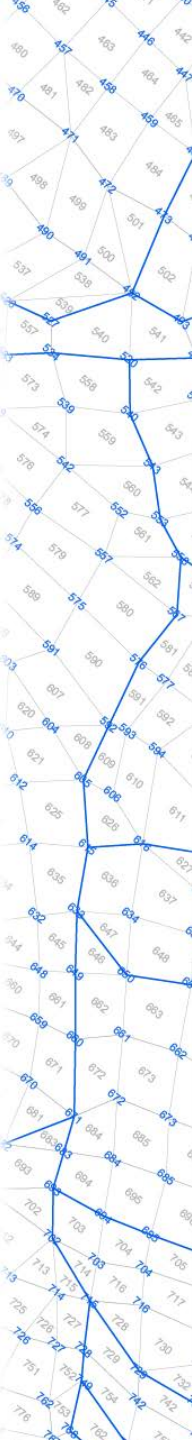
- 3,017 observations at 121 well pairs

Surface Water Flow

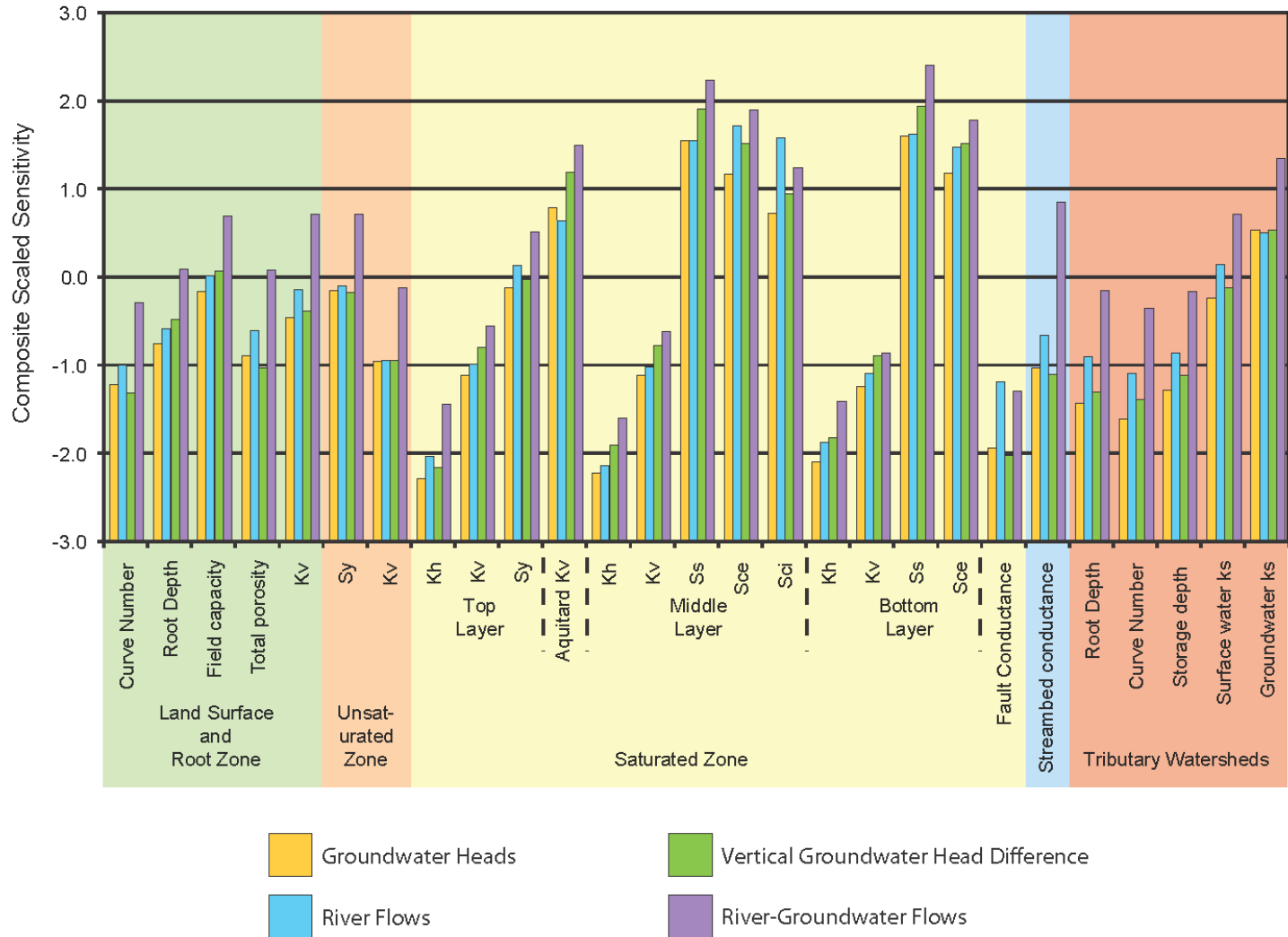
- 5,636 observations at 21 locations

Stream-Groundwater Flows

- Average annual rates on 24 reaches



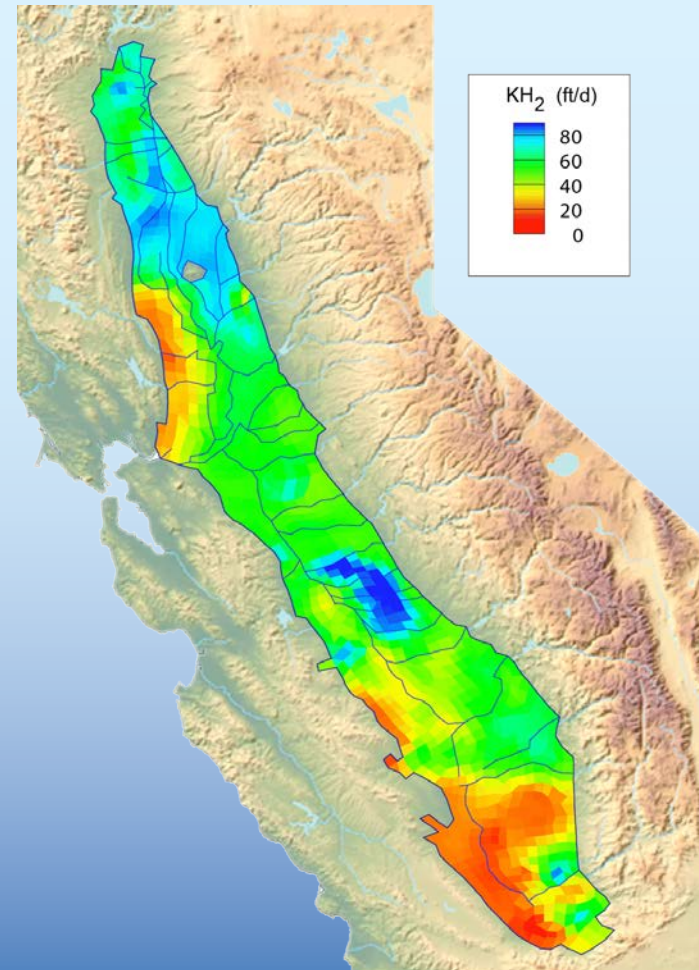
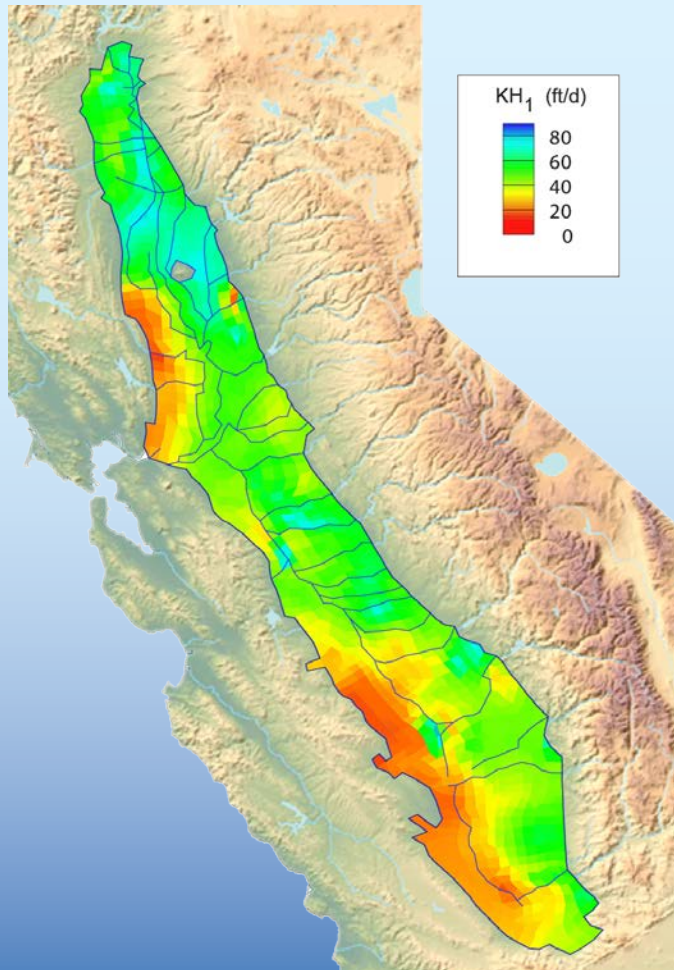
Parameter Sensitivity



Hydraulic Conductivity

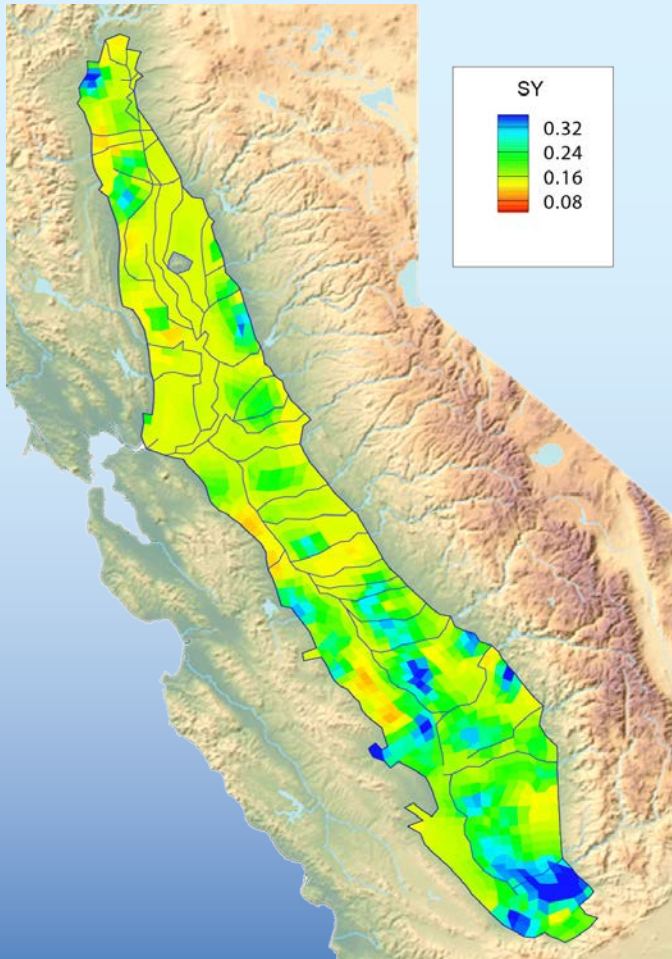
Layer 1

Layer 2

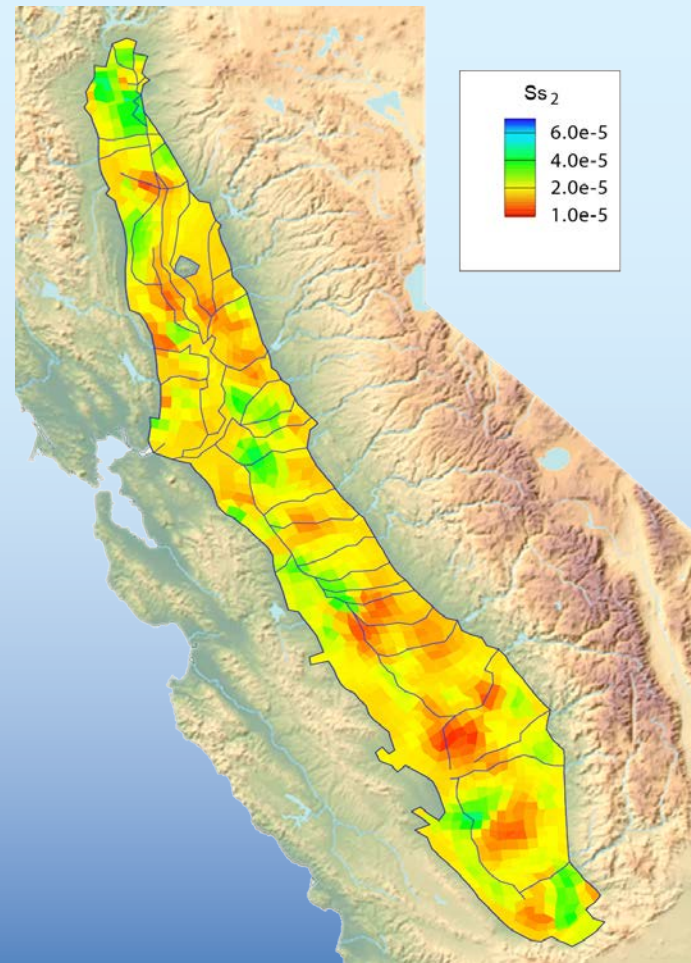


Storage Parameters

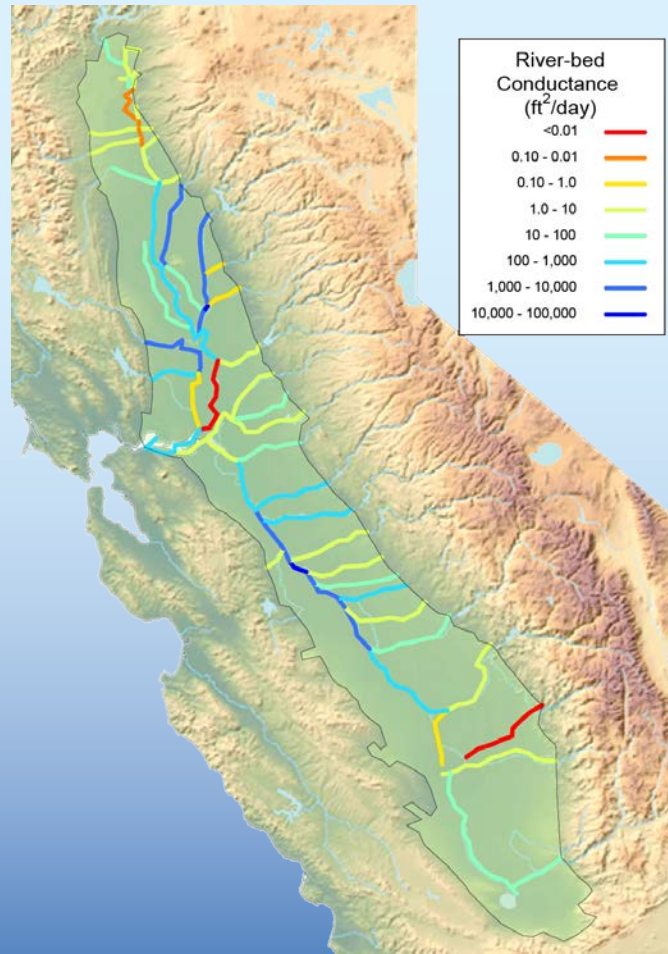
Layer 1



Layer 2



River-Bed Conductance



Model Performance

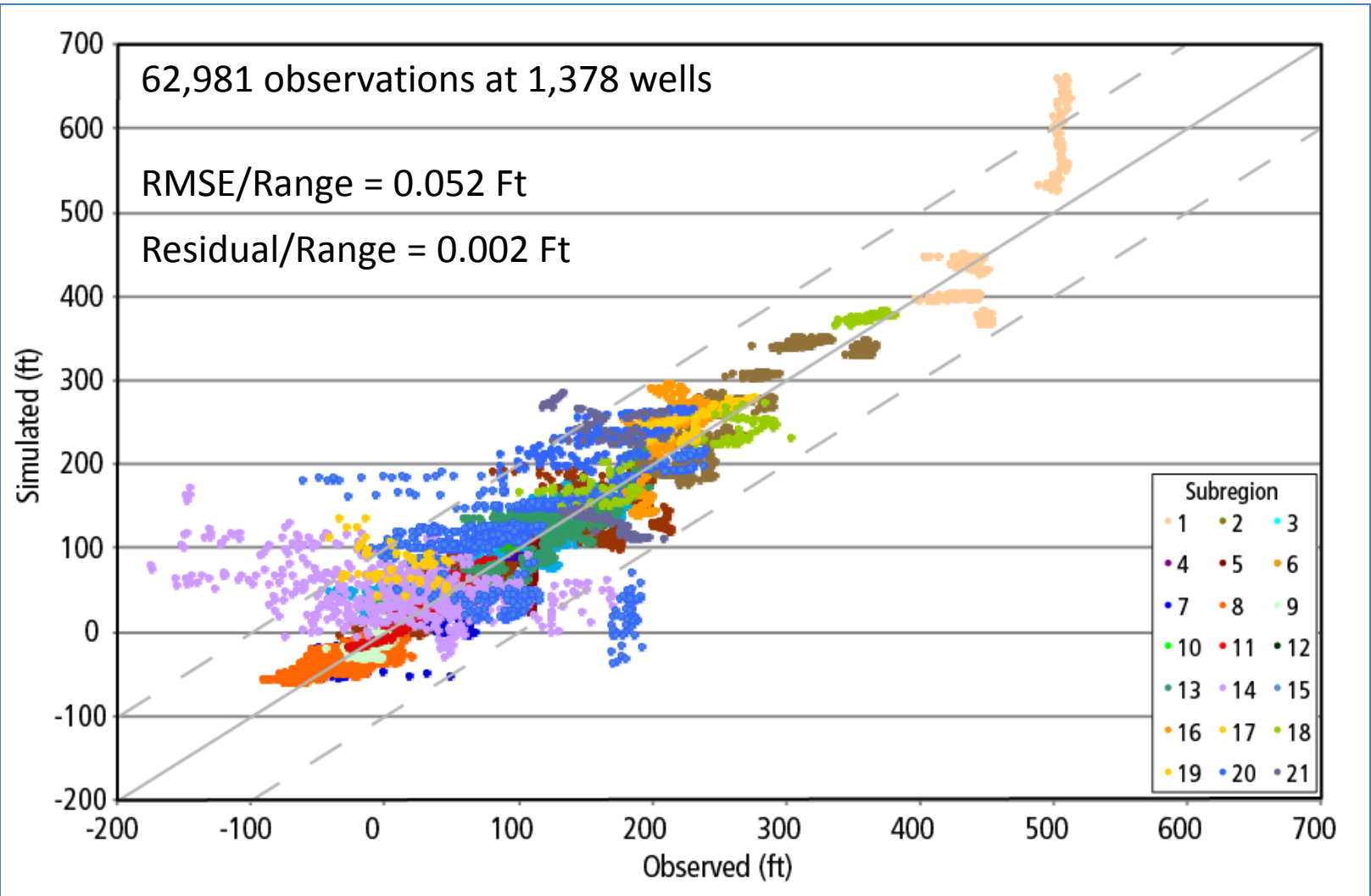
Observation Type	No. Observation Sites	No. Observations	Range
Groundwater heads	1,378	62,981	1,252
Vert. Groundwater Head Difference	163	3,017	698
River Flows	22	5,636	6,561,453
River-Groundwater Flows	33	33	38,117
Subsidence	24	3,700	6.2
TOTAL	1,620	75,367	

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

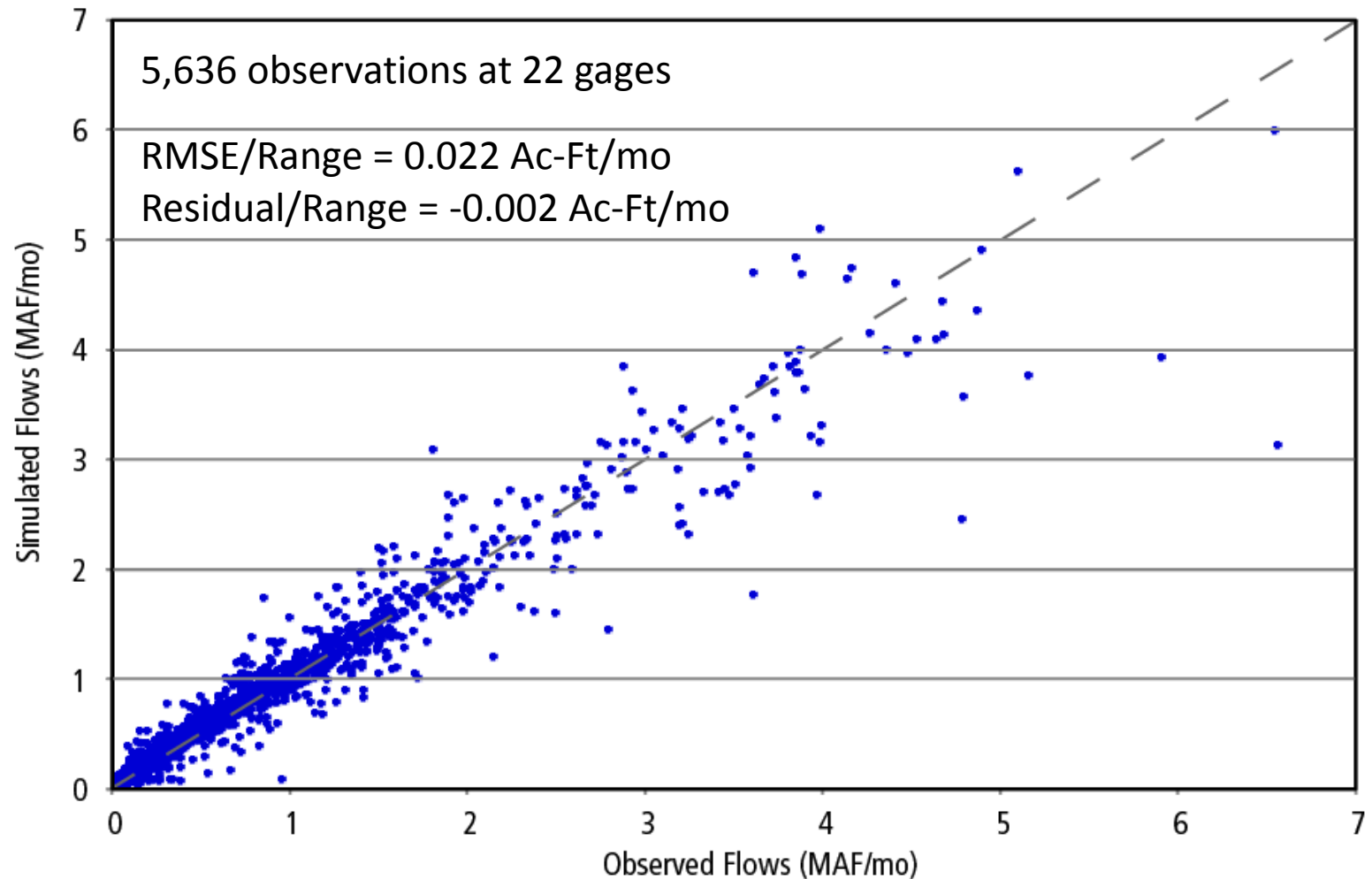
Units: Heads and subsidence in feet, flows in acre-feet

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

Groundwater Heads

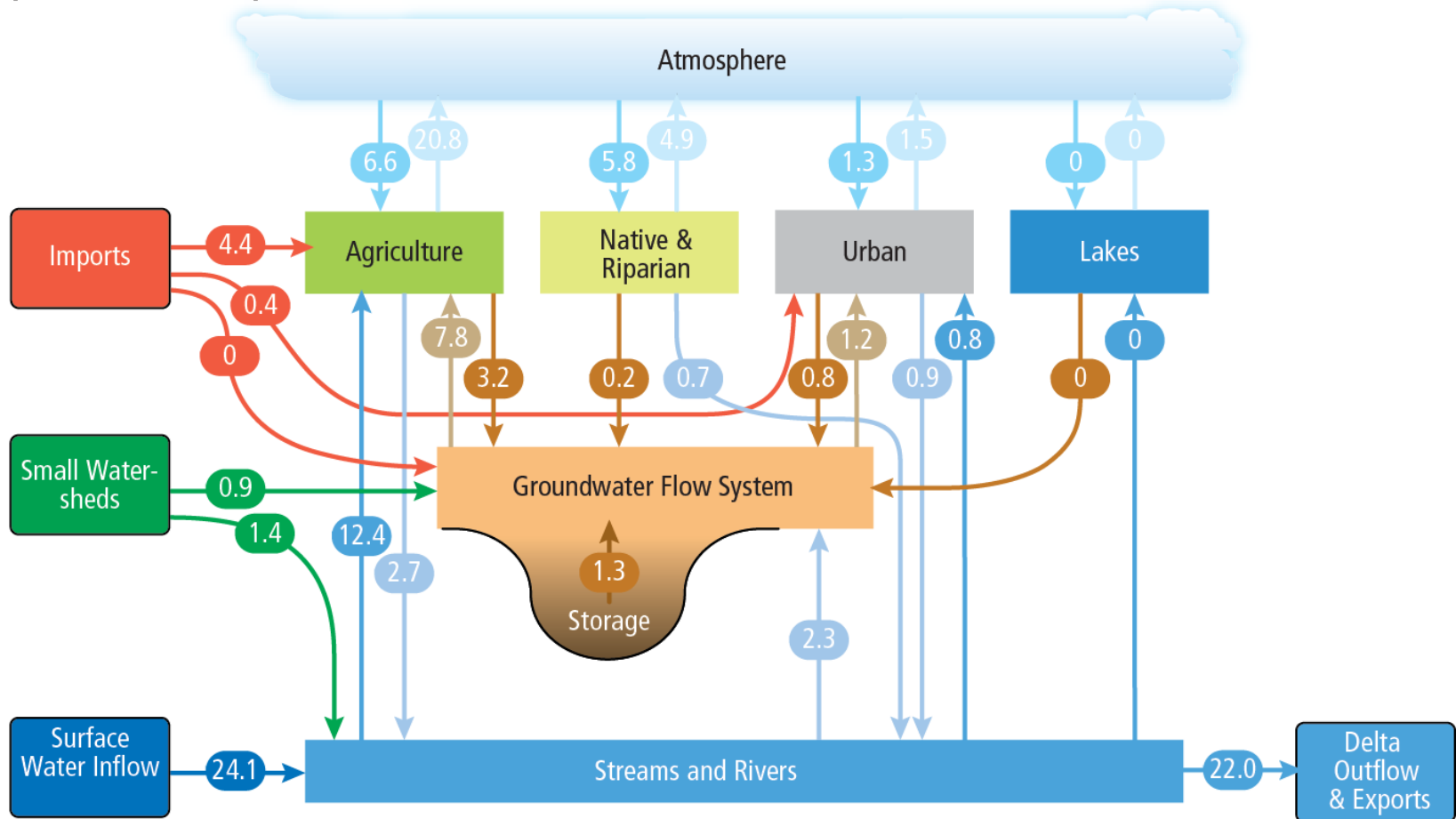


Surface Water Flows



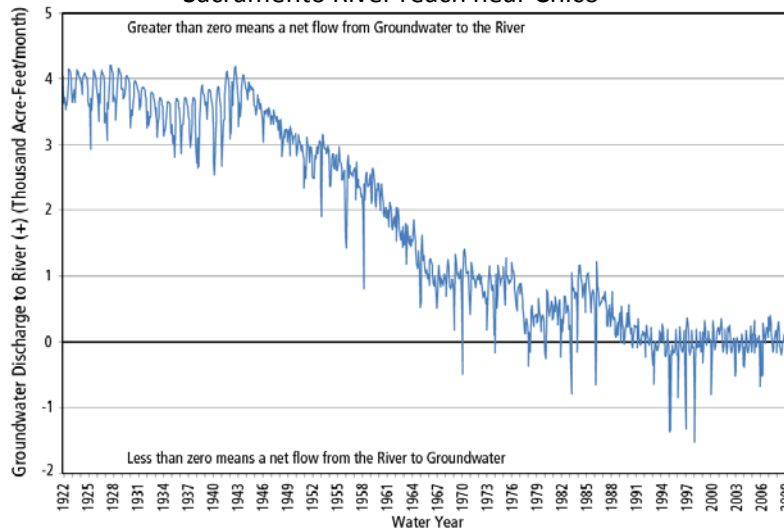
Simulated Annual Water Budget

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

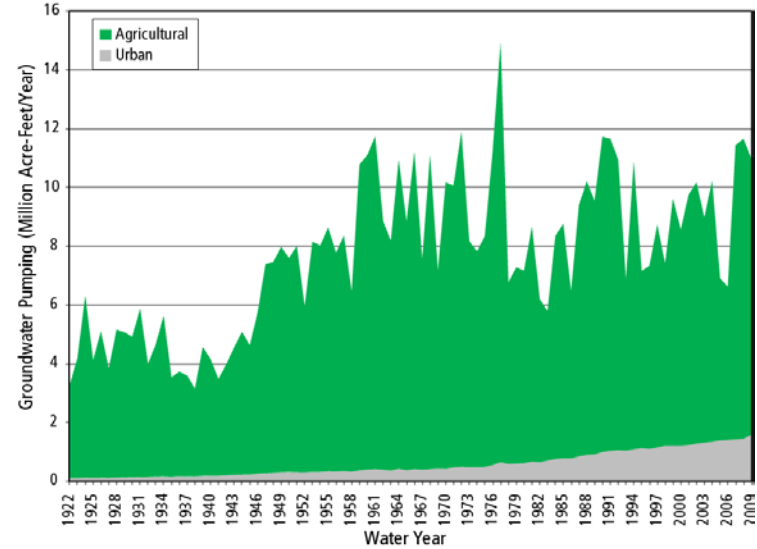


River-Groundwater Flows

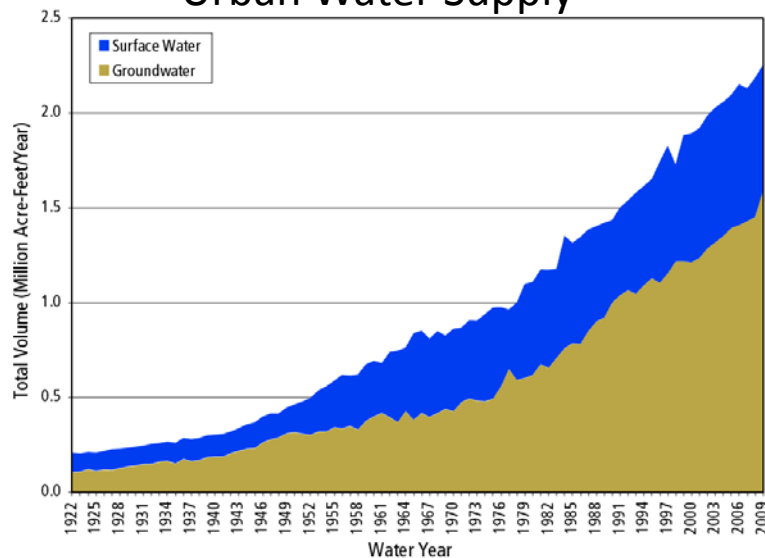
Sacramento River reach near Chico



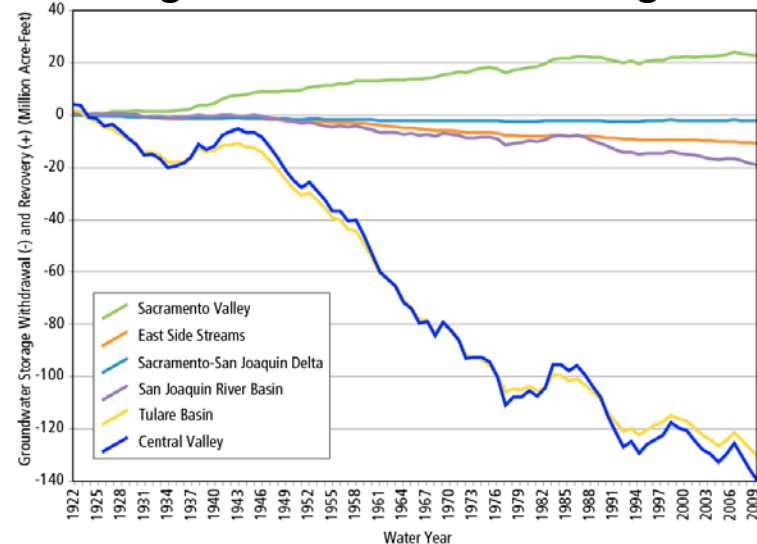
Groundwater Pumping



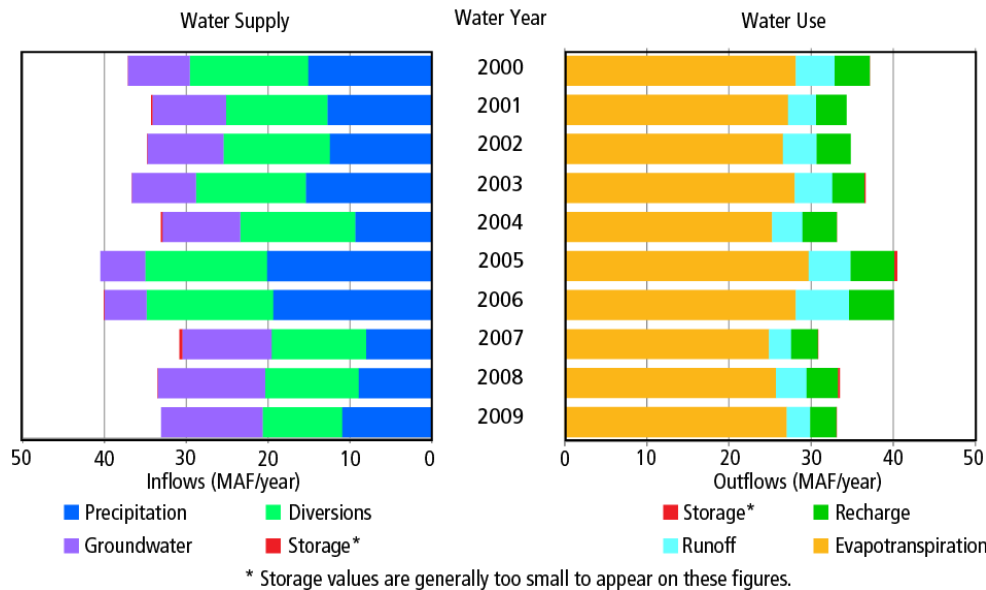
Urban Water Supply



Change in Groundwater Storage



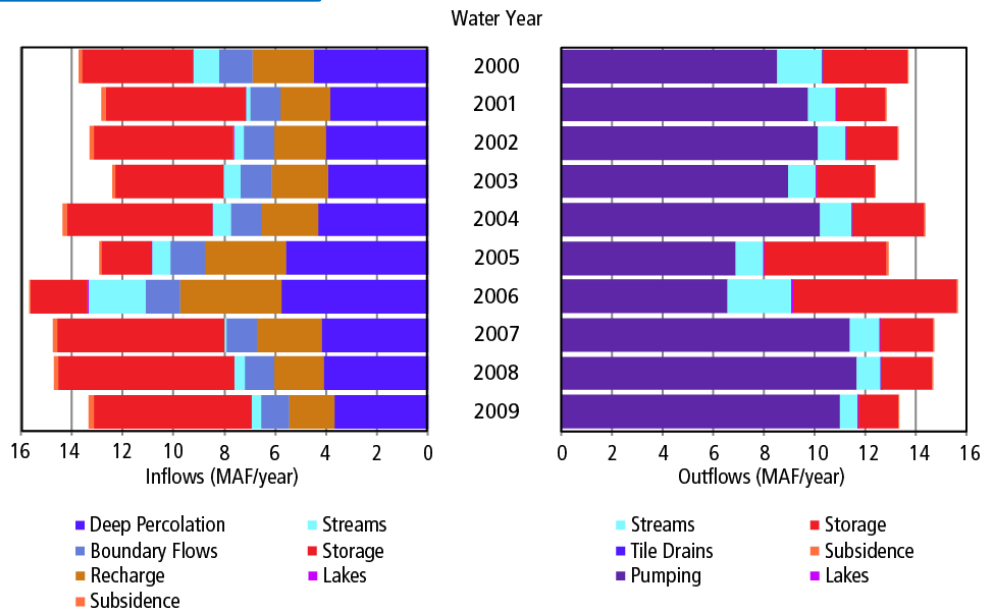
Land Surface Budget



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

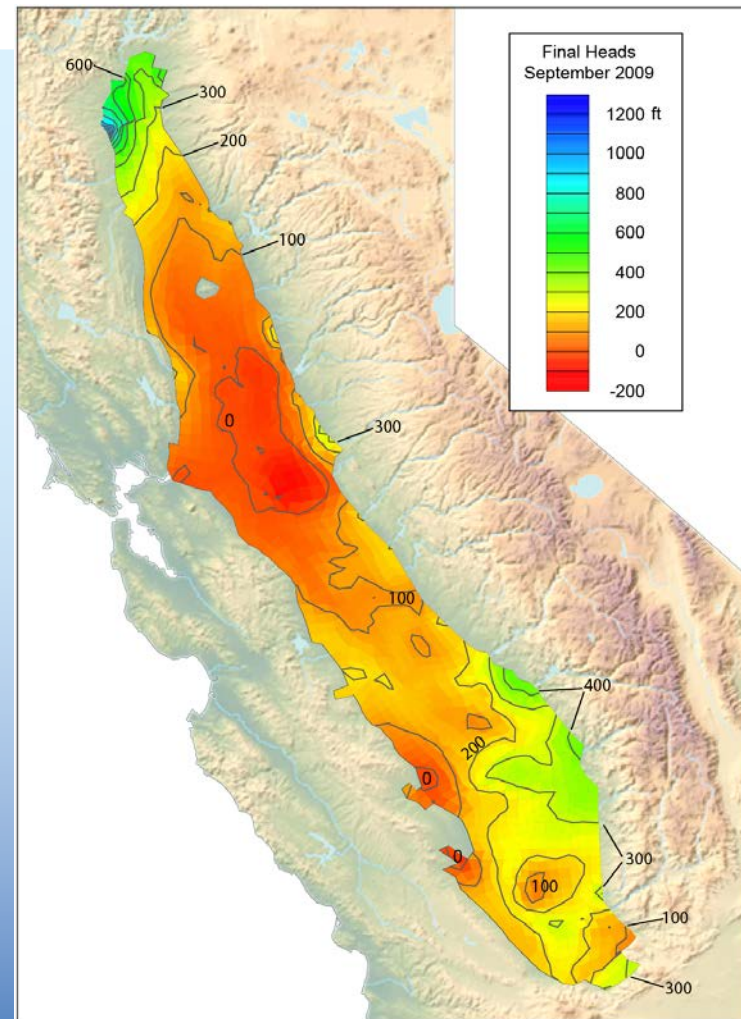
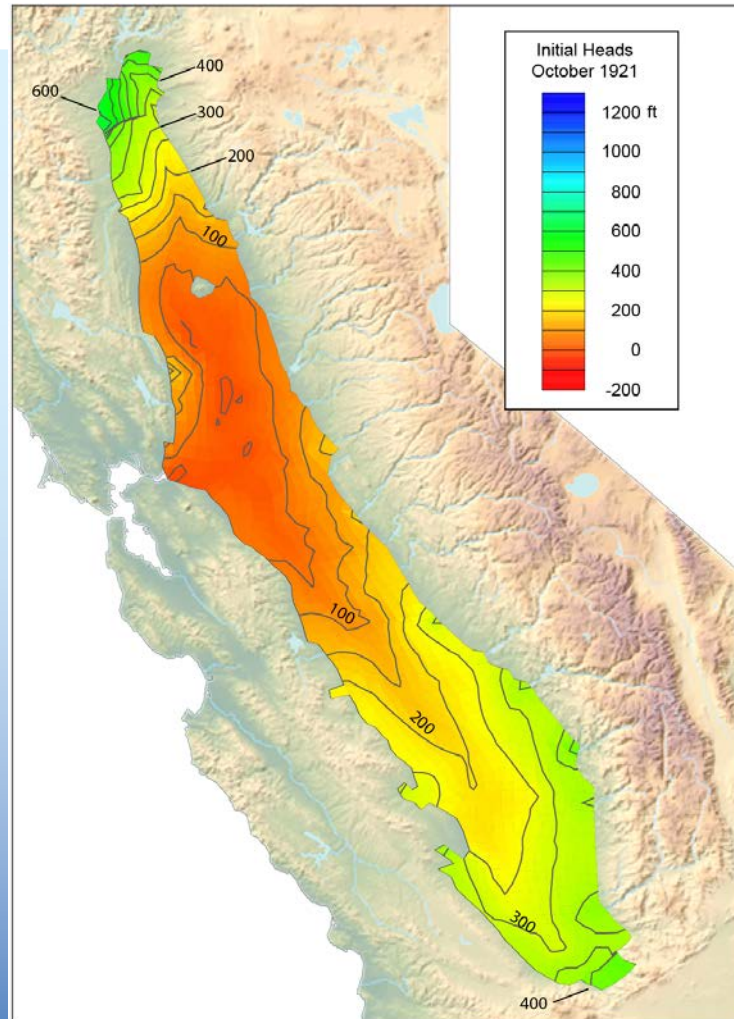
Groundwater budgets can also be produced for 'zones' of one to many elements

Groundwater Budget

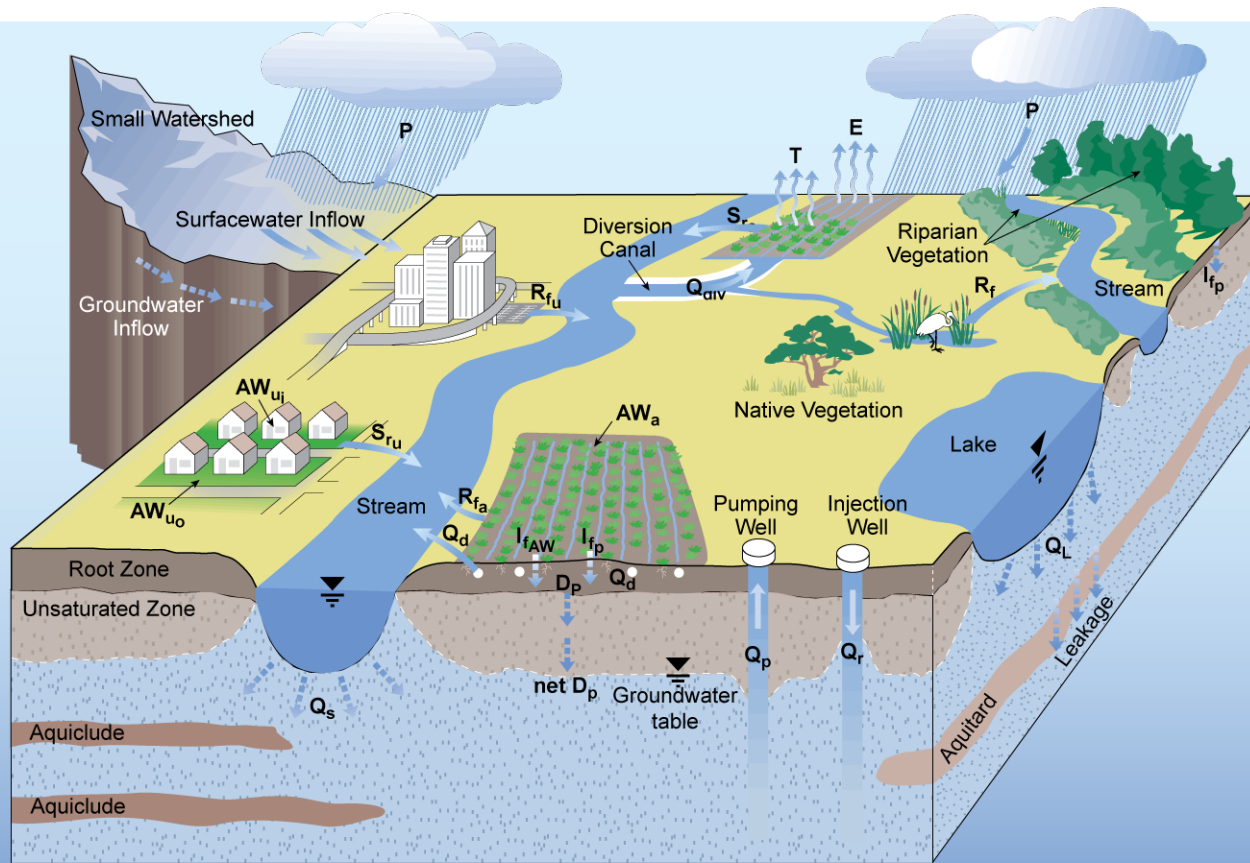


Water Table Altitude

Produced from IWFM's TecPlot® output files



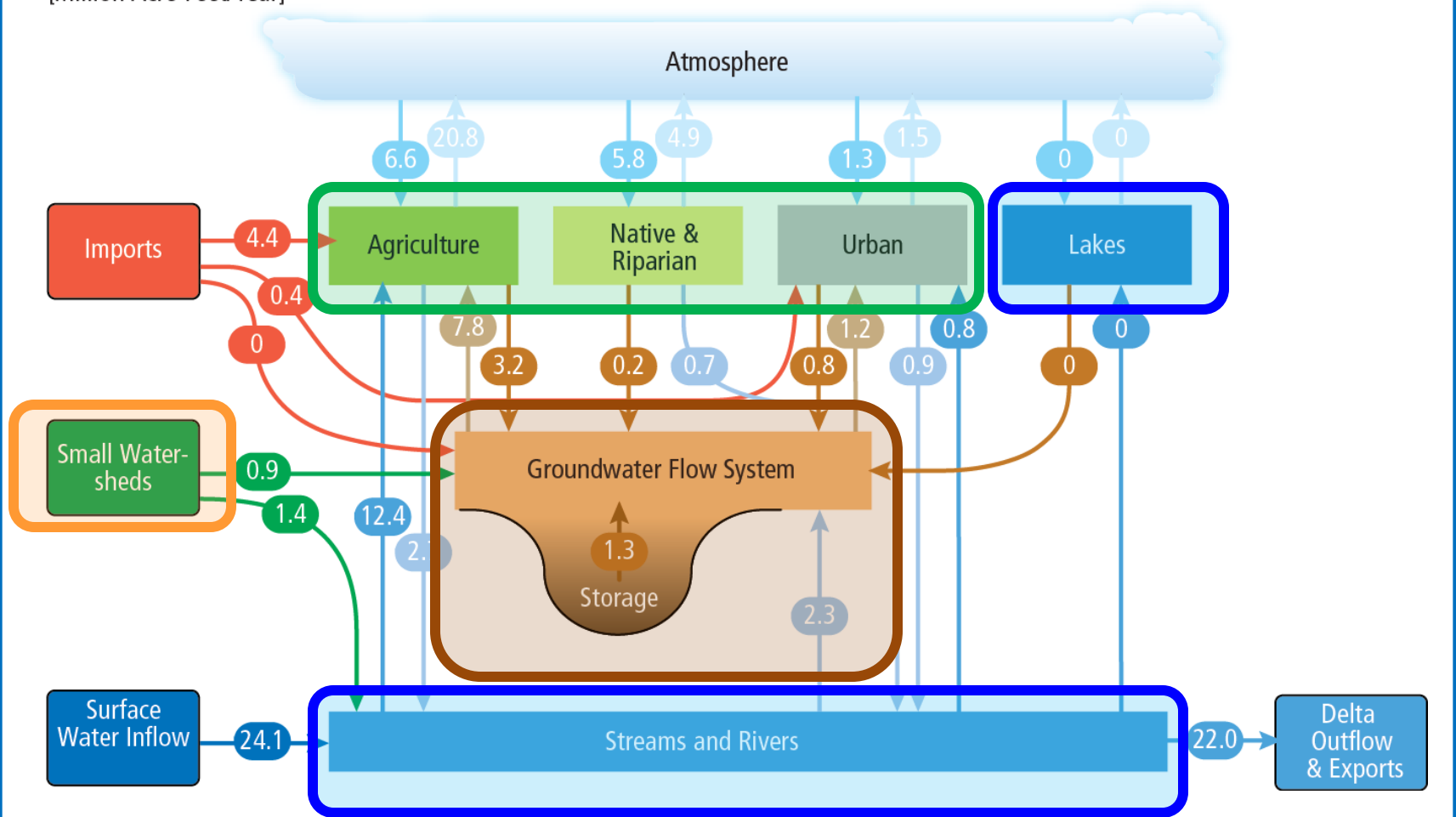
IWFM



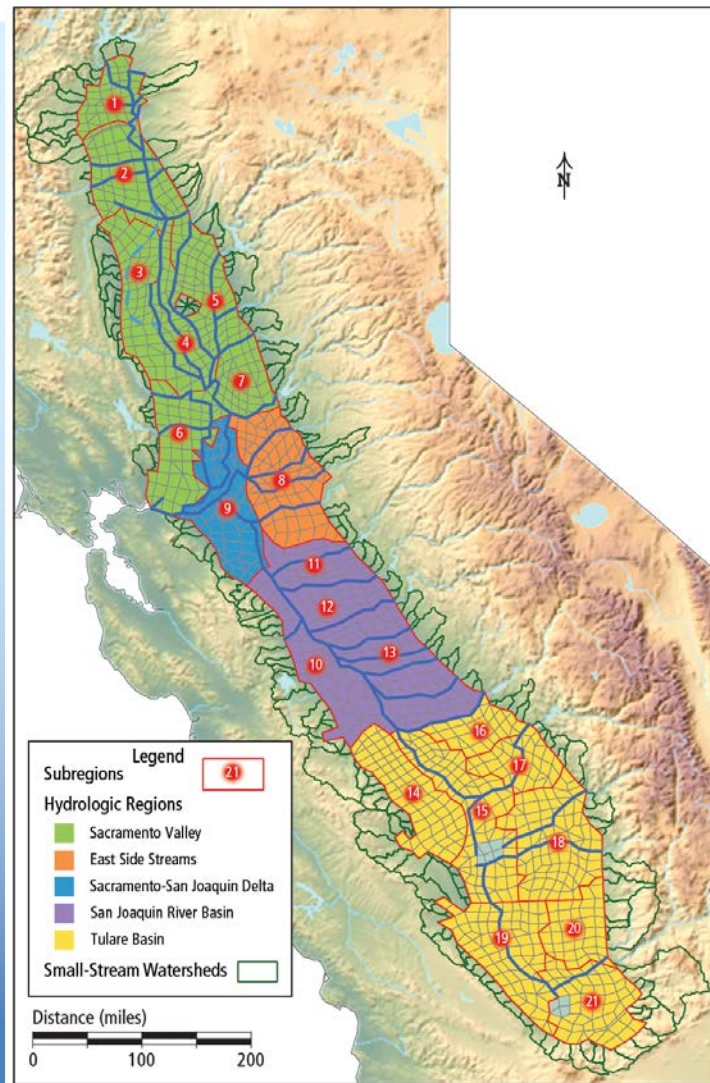
IWFM Water Balance Diagram

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