Central Valley Natural Flow Hydrology

Study funded by: State Water Contractors, San Luis and Delta-Mendota Water Authority, and Metropolitan Water District of Southern California

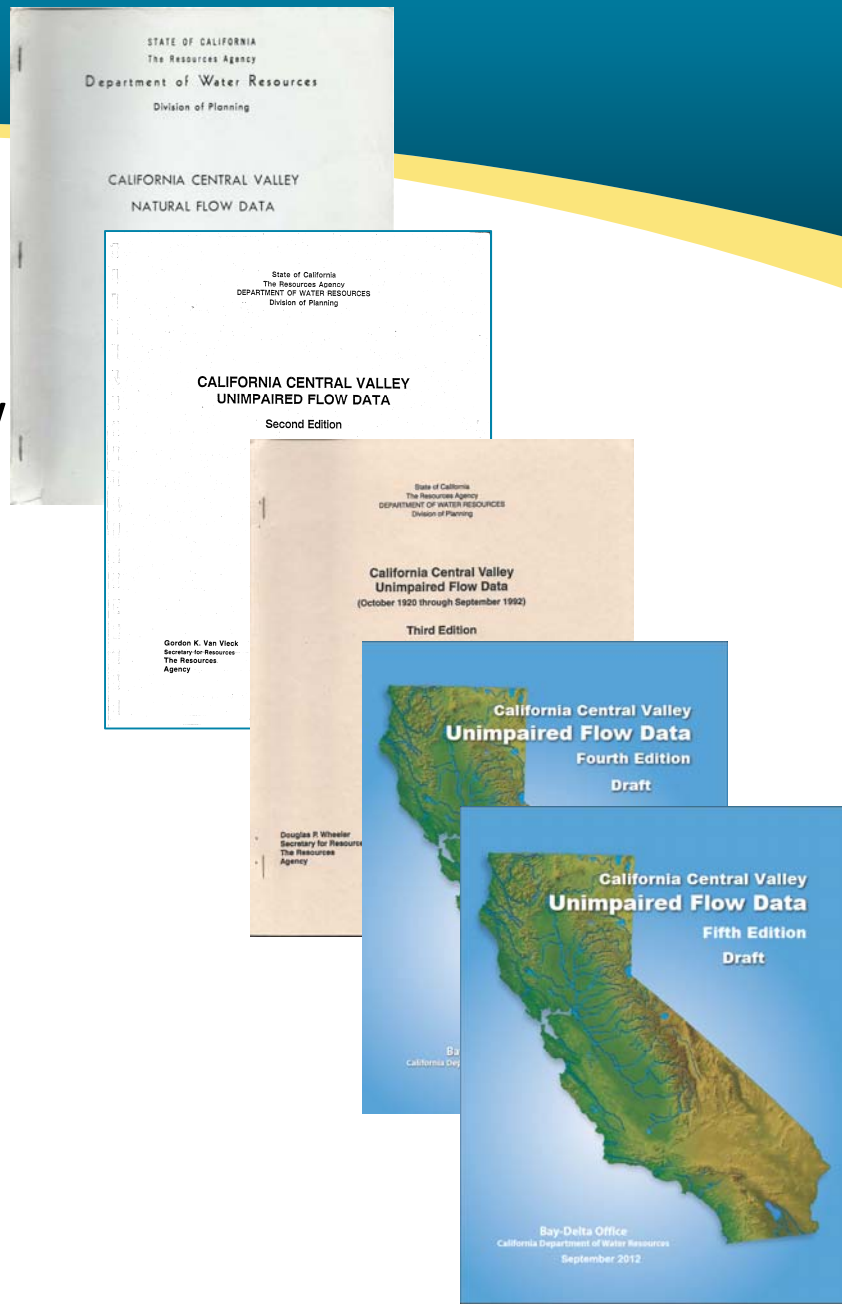
Natural Water Balance

Natural Water Balance 1922-2009

	GRASSLANDS - CONSTANT AREA				GRASSLANDS - VARIABLE AREA		OTHER VEGETATION	
	Case I	Case II	Case III	Case IV	Case V	Case VI	Case VII	Case VIII
	WATER SUPPLY (MAF/year)							
Inflow	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Precipitation	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Total Water Supply	**40.6**	**40.6**	**40.6**	**40.6**	**40.6**	**40.6**	**40.6**	**40.6**
	WATER USE (MAF/year)							
Sacramento Basin	**11.5**	**12.9**	**14.8**	**14.8**	**12.7**	**12.6**	**12.6**	**14.8**
San Joaquin Basin	**7.7**	**9.5**	**11.5**	**5.4**	**9.1**	**8.6**	**7.9**	**4.1**
Delta	**2.8**	**2.9**	**3.0**	**3.0**	**2.8**	**2.8**	**2.8**	**3.0**
Total Water Use	**21.9**	**25.2**	**29.2**	**23.2**	**24.7**	**24.1**	**23.2**	**21.9**
Delta Outflow	**18.7**	**15.4**	**11.4**	**17.4**	**15.9**	**16.5**	**17.4**	**18.7**

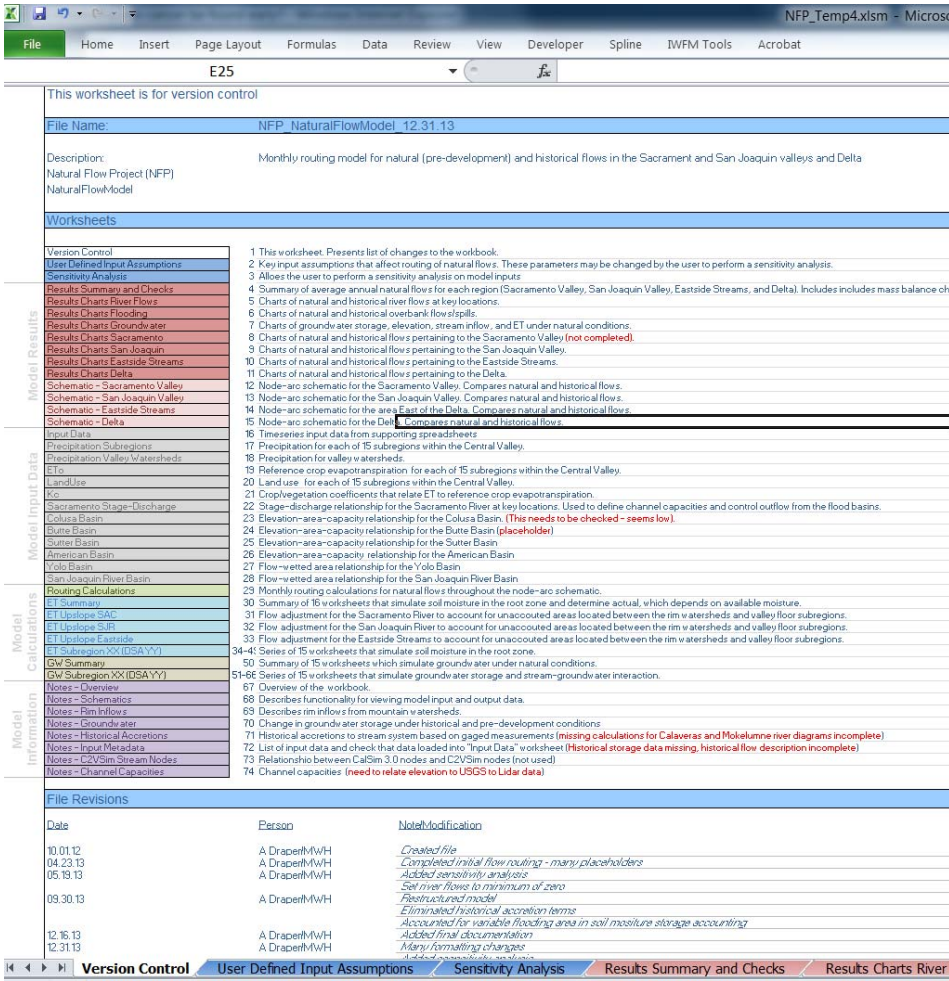
Unimpaired Flows

- DWR has a long tradition of publishing monthly unimpaired flow data
- For the valley floor:
  - Does not account for extensive over-bank flooding and detention storage.
  - Does not account for groundwater inflows or outflows to the stream system that could sustain or deplete river flows.
  - Does not account for depletions from riparian vegetation.



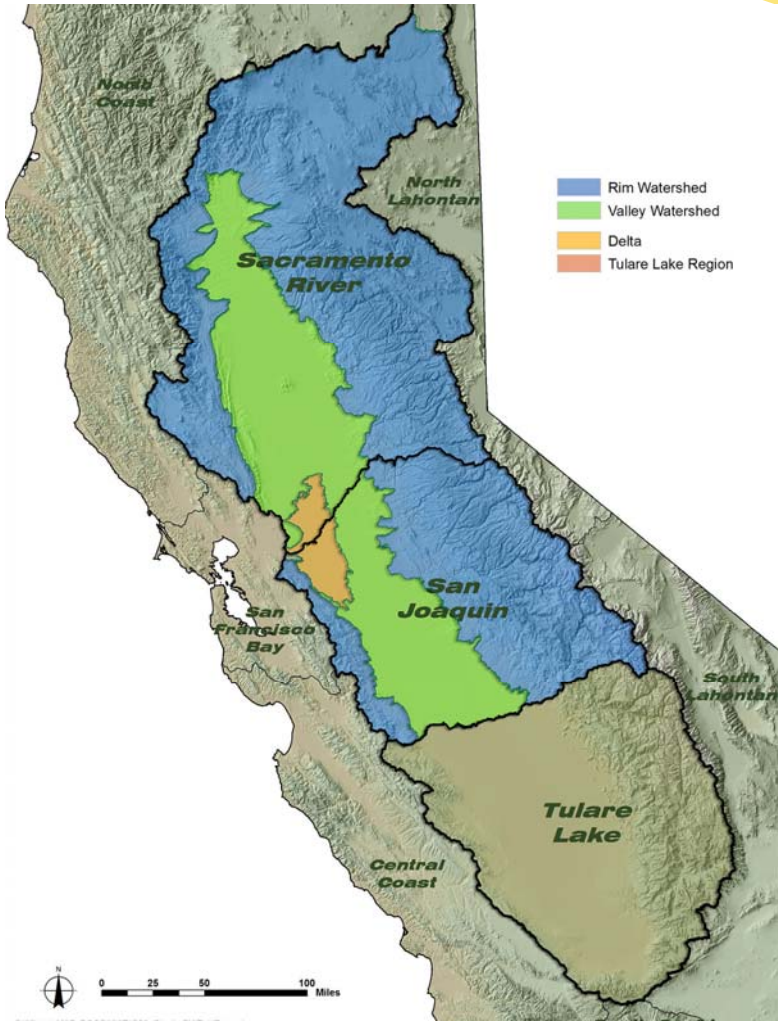
Study Purpose

- Develop a simple spreadsheet-based model to:
  - investigate monthly net Delta outflow under natural conditions.
  - Understand role played by the floodplain and groundwater aquifer.
  - Identify main determinants of river flow.



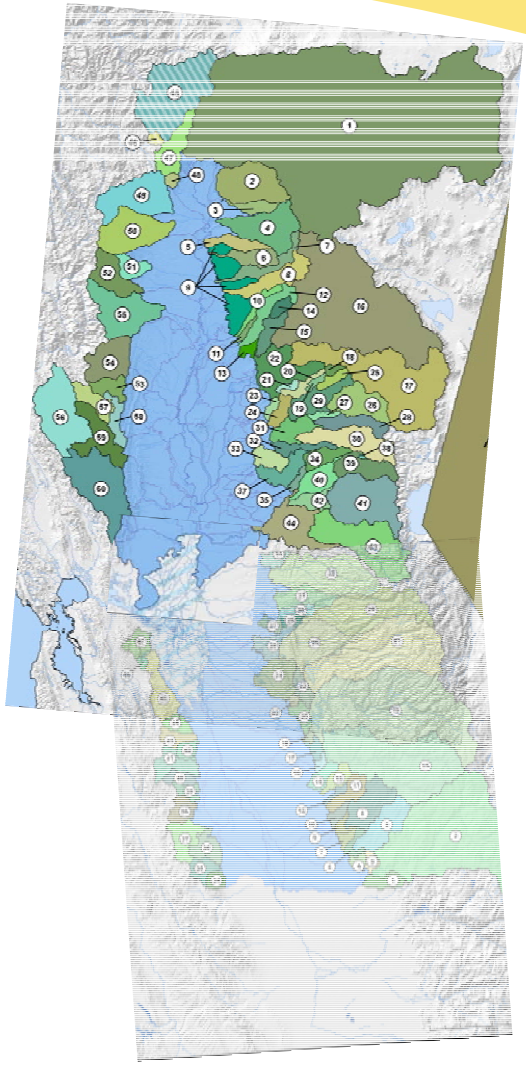
Rim Watersheds, Valley Watersheds, and Delta

- For modeling purposes Sacramento and San Joaquin hydrologic regions divided into:
  - Rim watersheds
  - Valley watersheds
  - Delta
- Partial treatment of the Tulare Lake hydrologic region.

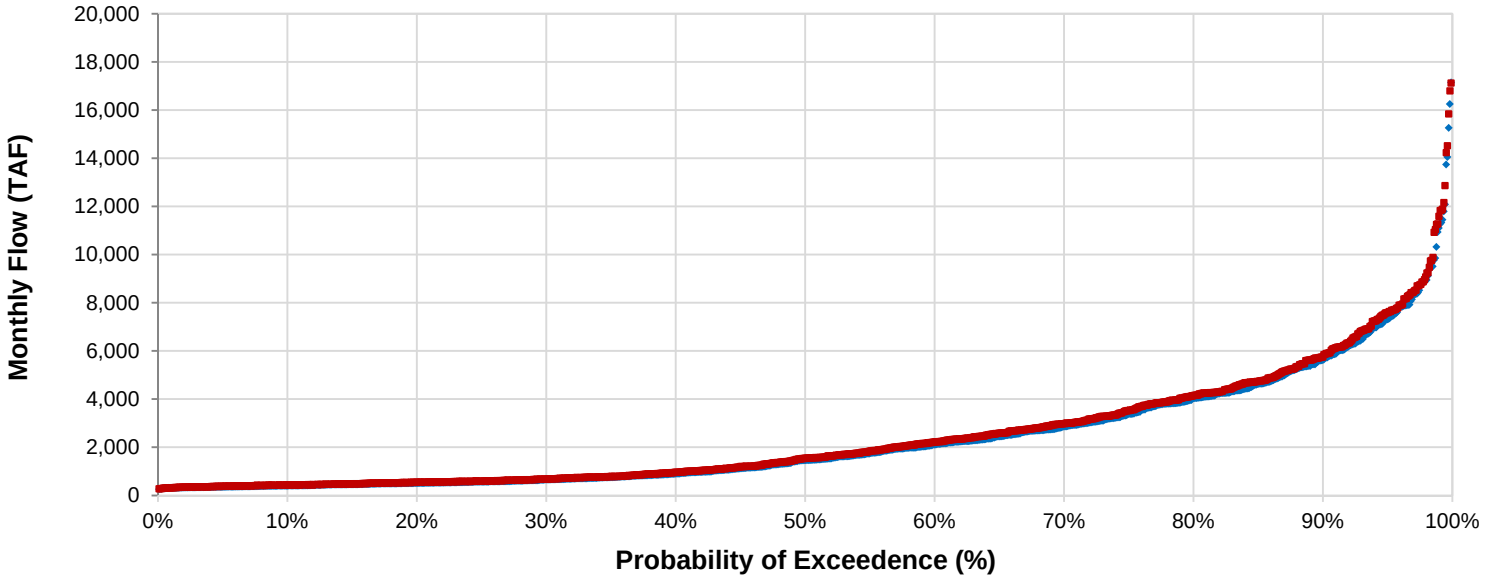


Rim Watersheds

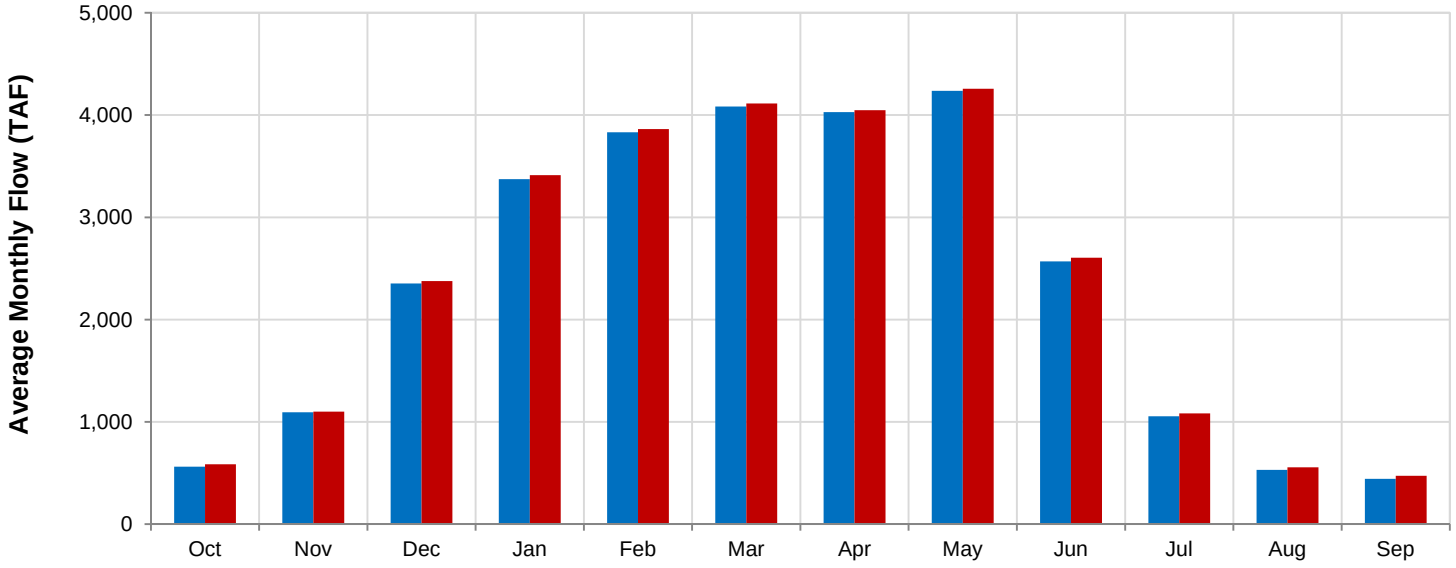
- No precise boundary defining “valley floor”.
- Boundary follows stream gage locations and foothill dams, where historical stream flows are known.
- This flow-based boundary typically lies slightly upslope of the deep alluvial soils of the Central Valley aquifer.



Rim Watersheds

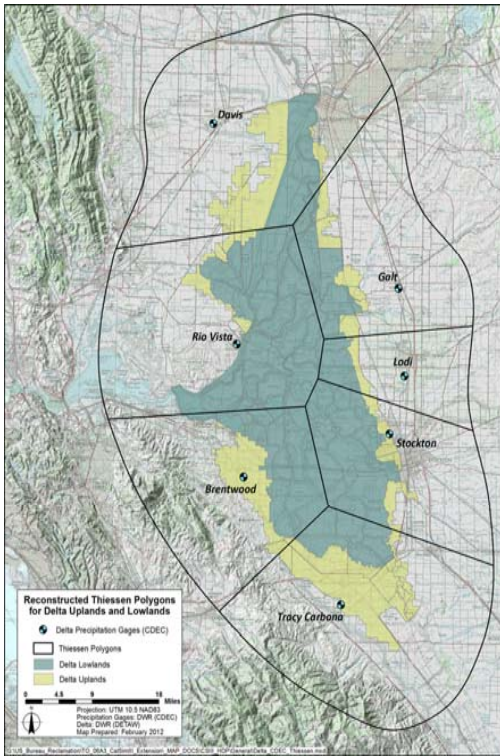


Annual average = 27.6 MAF



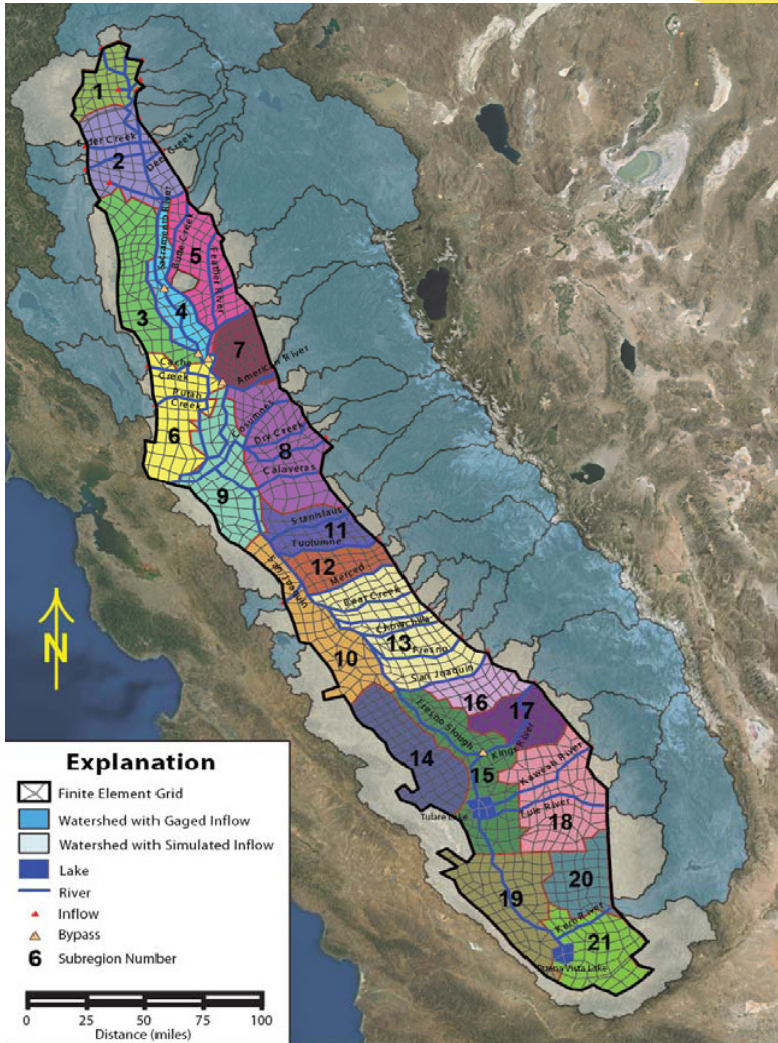
Sacramento-San Joaquin Delta

- Modeled as simple monthly mass balance between precipitation and ET.
  - No changes in storage other than root zone soil moisture.
  - Storage in the lower Yolo Basin (south of I-80) and the Sacramento Basin not represented.
  - Groundwater not represented.
  - ET always met in full.
- Land use from P. Fox et al. 2014
- Precipitation average 0.85 MAF/year
- ET average 2.9 MAF/year.



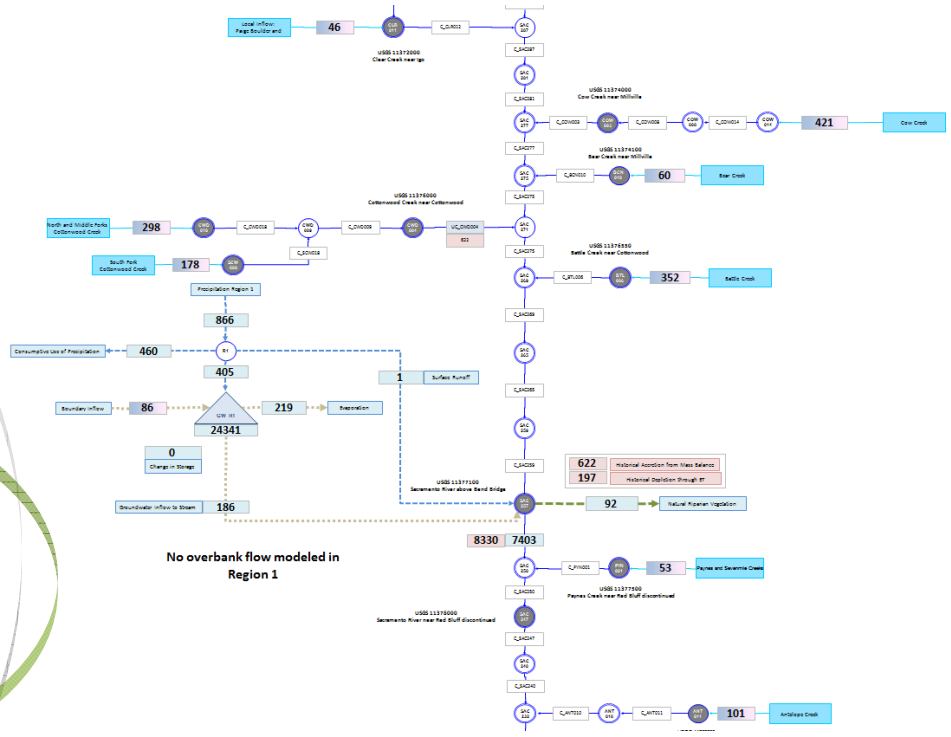
Valley Watershed Subregions

- For surface water and groundwater hydrology. Valley watersheds divided into subregions:
  - Subregion initially based on C2VSim subregions
  - 3 subregions located upslope of alluvial groundwater aquifer
  - 12 subregions overlying aquifer
    - *Sacramento Valley (1-7)*
    - *Eastside Streams (8)*
    - *San Joaquin Valley (10-13)*
  - Subregions 4, 5, and 6 redrawn to better match Colusa, Butte, and Sutter flood basins.



Valley Watersheds - Components

1. Stream system
   - *Rim inflows from mountain watersheds*
   - *Bank overflow, return flow*
   - *Riparian ET*
   - *Surface runoff*
   - *Groundwater inflow*
2. Land surface/root zone
   - *Precipitation*
   - *Surface runoff*
   - *Infiltration, deep percolation*
   - *Soil moisture*
   - *ET*
3. Flood Basins
   - *Storage*
   - *Infiltration*
   - *Return flow*
4. Groundwater
   - Lateral and vertical recharge
   - Storage
   - Capillary rise/ET
   - Discharge to stream system

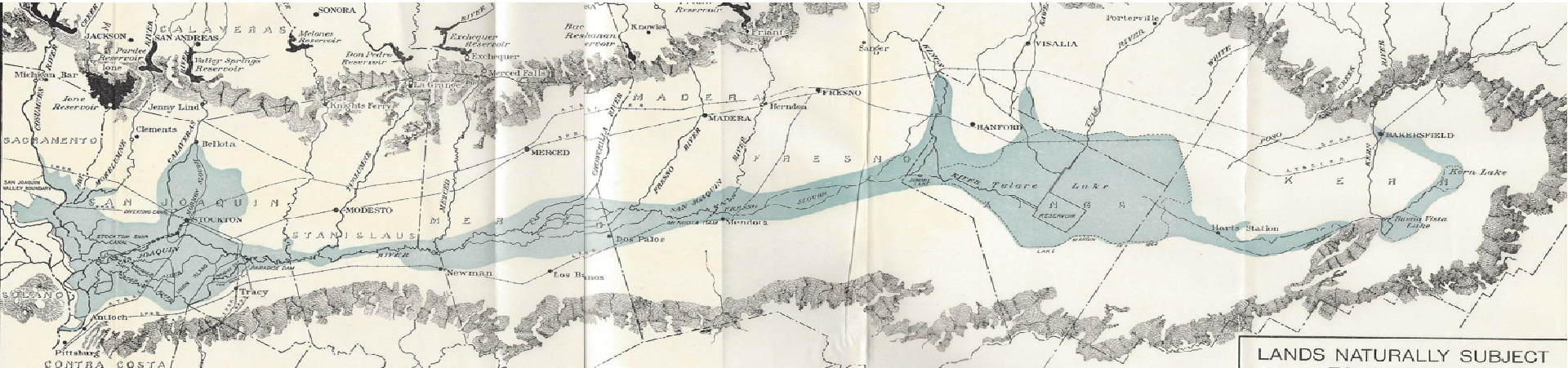


1. Stream System - Channel Capacity

- Sacramento Valley
  - Existing capacity proxy for pre-development capacity
  - Channel capacity and stage from HEC-RAS analysis
  - Assume existing levee toe elevation corresponds to natural bank top

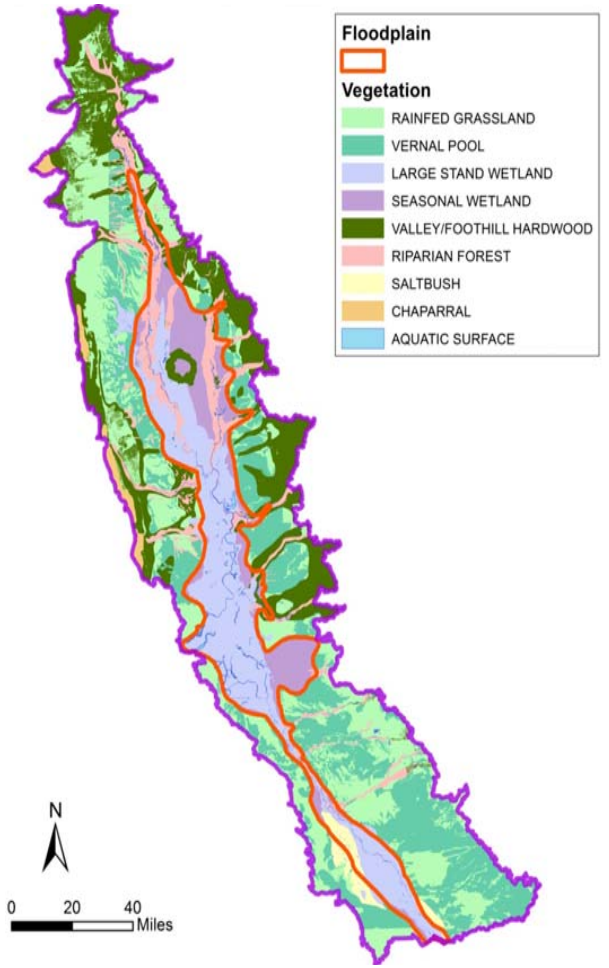
1. Stream System - Channel Capacity

- San Joaquin Valley:
  - Bankfull flows are important for forming and maintaining stream channel cross-sectional area in alluvial streams. Bankfull flow is subject to minimum flow resistance and transports the most sediment over time.
  - Bankfull events have been determined to have a recurrence interval of approximately 1.5 to 3.0 years (Leopold et al. 1964).
  - Assume bankfull capacity equal to 1 in 1.5 year flow event



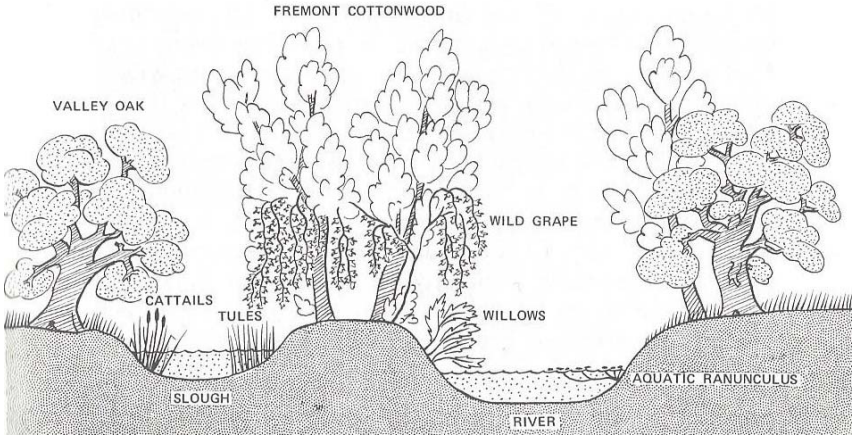
2. Land Surface/Root Zone

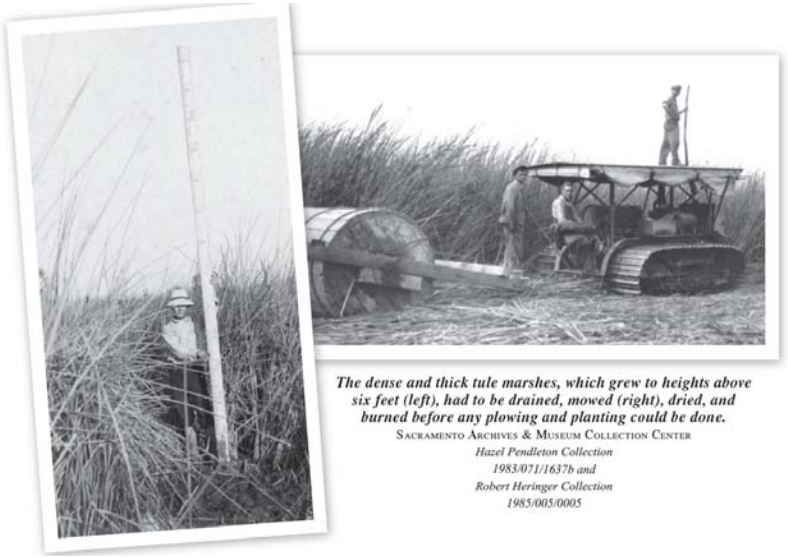
- Küchler (1977), Chico State (2003), Fox et al. (2014)
- Land use types considered:
  - Aquatic (1%)
  - Grassland - annual/perennial (49%)
  - Hardwood (18%)
  - Chaparral (1%)
  - Riparian (9%)
  - Wetland - seasonal/perennial (21%)
  - Saltbush (1%)
- Assumptions for grasslands and wetlands critical



2. Land Surface/Root Zone

- Aquatic:
  - open water evaporation
- Riparian:
  - no water stress, taps groundwater or water percolating through streambed
- Hardwood:
  - effects of moisture stress preprocessed
- Grassland, wetland, chaparral, saltbush:
  - ET dependent on water availability





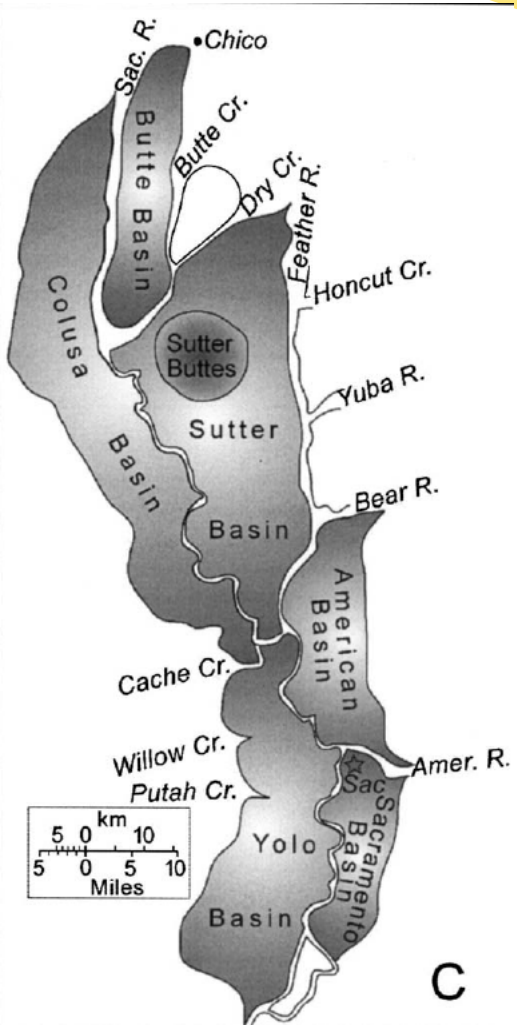
The dense and thick tule marshes, which grew to heights above six feet (left), had to be drained, mowed (right), dried, and burned before any plowing and planting could be done.
Sacramento Archives & Museum Collection Center
Hazel Pendleton Collection
1983/071/1637b and
Robert Heringer Collection
1985/005/0005

2. Land Surface/Root Zone

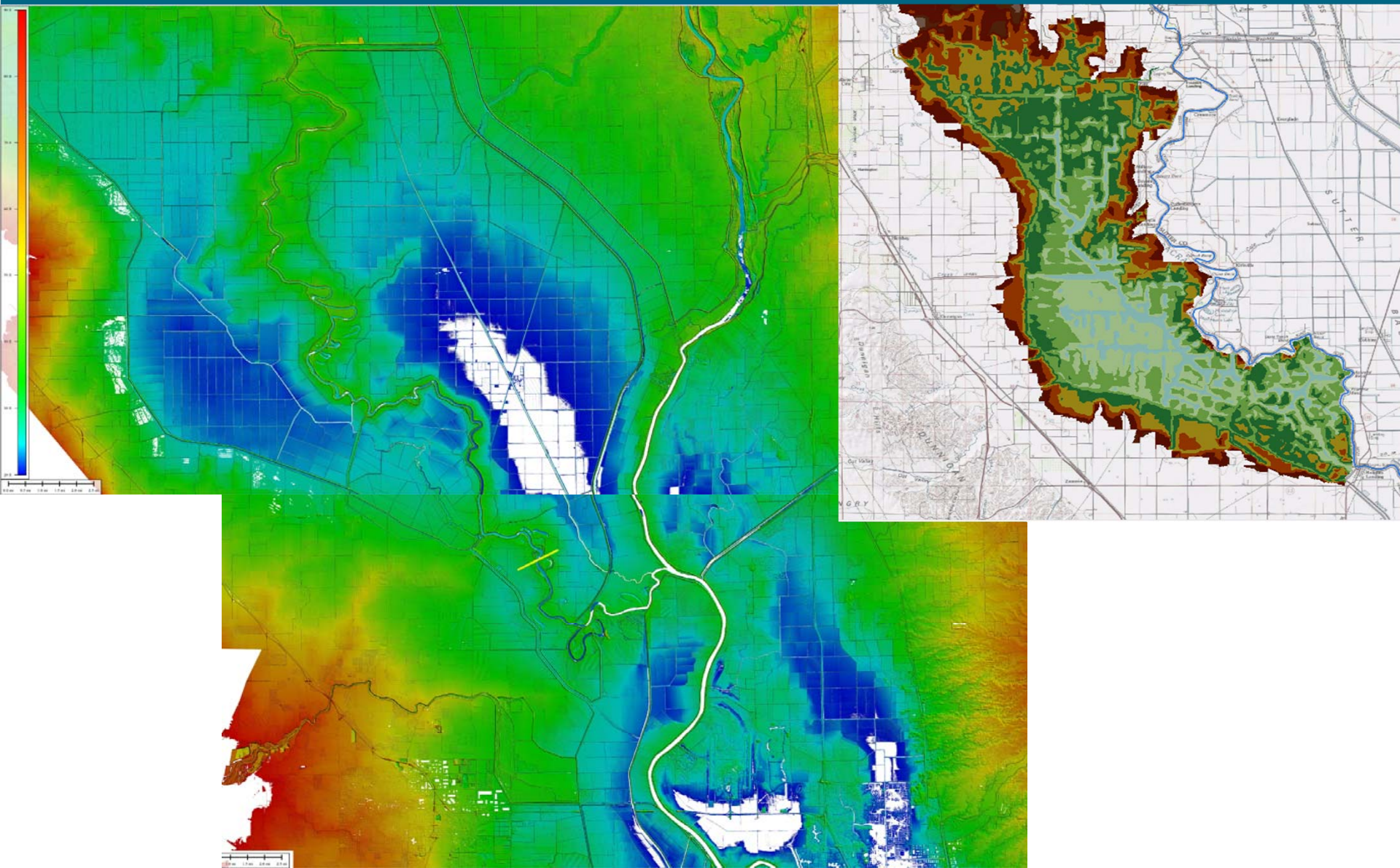
- Series one-dimensional root zone “buckets”:
  - For each subregion
  - For each land-use class
  - Flooded/not flooded
- Assumptions
  - No runoff until saturated
  - Deep percolation limited by infiltration rate
  - Groundwater available to meet ET once soil moisture depleted
- Inputs
  - Land use (Fox)
  - Precipitation (2km grid PRISM)
  - Potential ET_v (Howes)

3. Flood Basins

- Sacramento Valley
  - Approximately 1 million acres or nearly 40 percent of lands within the Sacramento Valley were subject to flooding.
  - Colusa, Sutter, American Basins
    - *Assume outflow controlled by river stage*
  - Butte Basin
    - *Assume outflow controlled by channel constriction*
  - Yolo Basin
    - *No detention storage, flooded area based on steady-state flow analysis*
- San Joaquin Valley
  - *No detention storage, flooded area based on steady-state flow analysis*

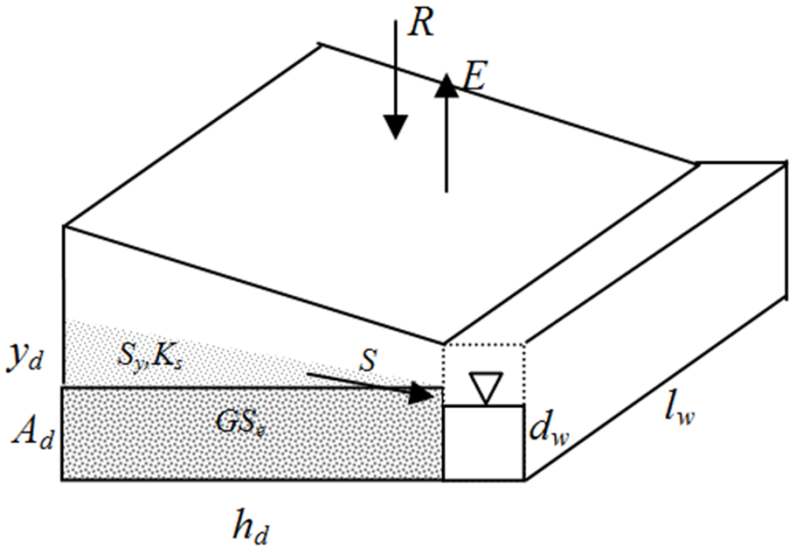


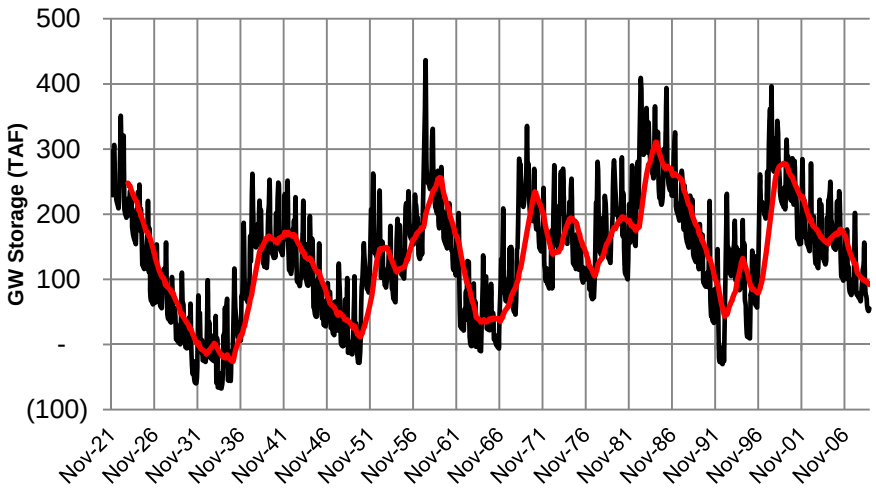
3. Flood Basins



4. Groundwater

- Set of lumped parameter models
  - Groundwater is represented as a wedge that is parallel to the major river system
  - Vertical recharge from precipitation and flood water
  - Lateral outflow depends on the elevation between the groundwater table and river stage
  - High groundwater elevations may support grassland and wetland ET during summer months

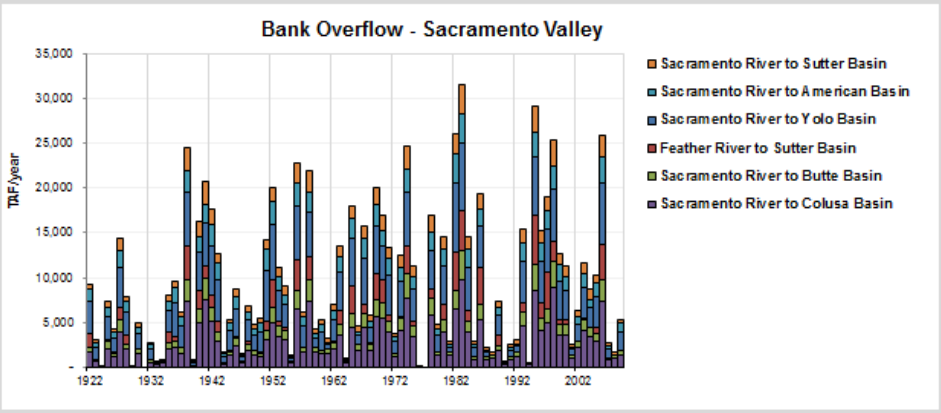


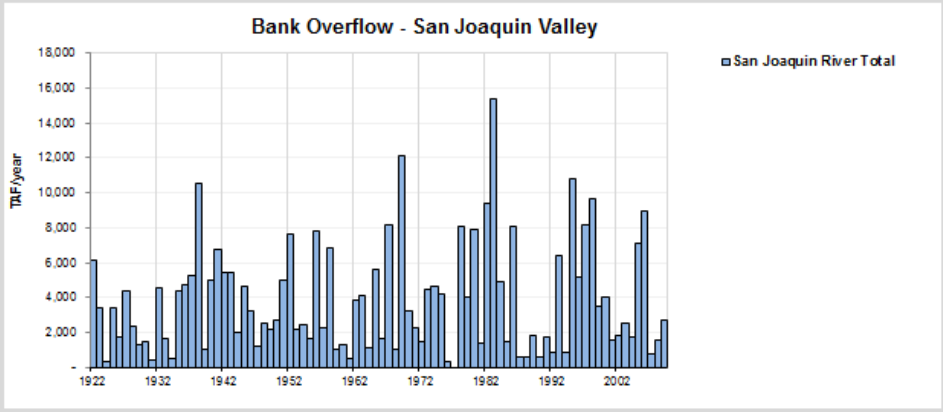


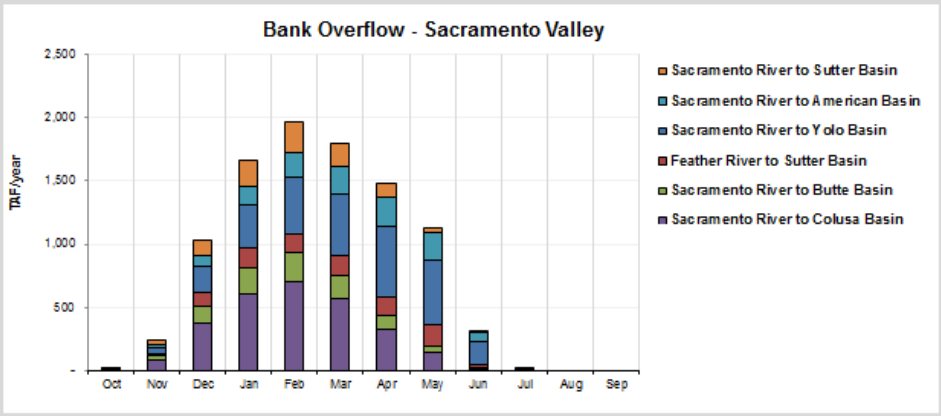
Model Input Parameters

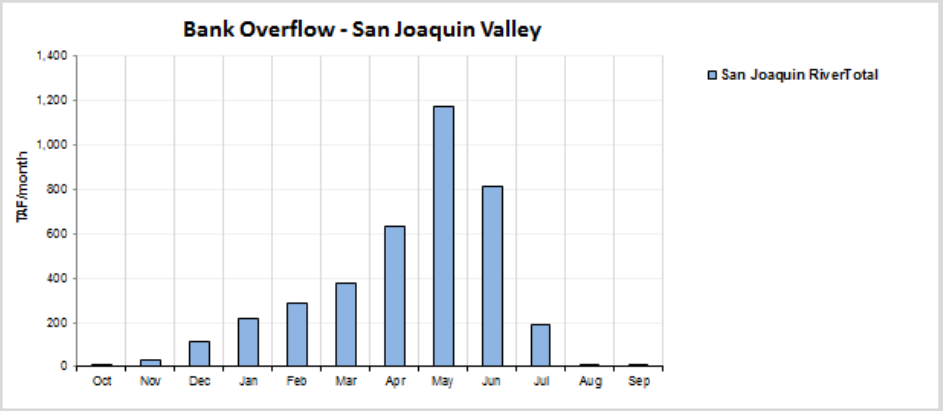
Channel Capacity - Bank Overflow

Channel	Where Referenced in Routing	Description
10,000	column= 20, column = 30, column = 56	Sacramento River channel capacity between Ord Ferry and Knights Landing
25,000	column= 74, column = 76	Sacramento River channel capacity between Knights Landing and Sacramento
20,000	column = 54	Feather River channel capacity at Yuba City
2,500	column= 136, column = 140	San Joaquin River capacity between Mendota and Newman
5,000	column= 147, column = 151	San Joaquin River capacity between Newman and Vernalis
1,000		Yolo Bypass capacity - natural flood channel
0.6	column = 30	Fraction of flow above threshold that spills to Colusa compared to Butte/Sutter Basins
0.2	column = 20	Fraction of flow above threshold that spills to Butte compared to Colusa/Sutter Basins
0.2	column = 56	Fraction of flow above threshold that spills to Sutter compared to Colusa/Butte Basins
0.7	column = 74	Fraction of flow above threshold that spills to Yolo compared to American Basin
0.3	column = 76	Fraction of flow above threshold that spills to American compared to Yolo Basin









Sensitivity Analysis

Sensitivity Analysis

All values correspond to long-term average, water years 1922-2009. Values are in TAF/month.

Set values to 1 in this column to run sensitivity analysis. Rows with values other than 1 will be ignored.

In the sensitivity analysis the input parameter defined in the worksheet **User Defined Input Assumptions** will be multiplied by the values in this column.

Model Input Parameters to be Increased in Sensitivity Analysis by the Multiplier			
Parameter	**Description**	**Analyze**	**Multiplier**
SacCapacityOrdFerry	Bank-full capacity for the Sacramento River between Ord Ferry and Knights Landing	1	0.50
SacCapacitySacramento	Bank-full capacity for the Sacramento River between Knights Landing and Sacramento	1	0.50
feathercapacityyubacity	Bank-full capacity for the Feather River near Yuba City	1	0.50
ChannelCapacity_SanJoaquinRiver_MendotaToNewman	Bank-full capacity for the San Joaquin River between Mendota and Newman	1	0.50
ChannelCapacity_SanJoaquinRiver_NewmanToVernalis	Bank-full capacity for the San Joaquin River between Newman and Vernalis	1	0.50
ColusaBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the Colusa Basin	1	0.00
ButteBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the Butte Basin	1	0.00
SutterBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the Sutter Basin	1	0.00
AmericanBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the American Basin	1	0.00
AquaticET	Monthly potential ET for aquatic land-use class	1	1.20
GrasslandET	Monthly potential ET for grassland land-use class	1	1.20
ChaparralET	Monthly potential ET for chaparral land-use class	1	1.20
RiparianET	Monthly potential ET for riparian land-use class	1	1.20
HardwoodET	Monthly potential ET for hardwood land-use class	1	1.20
WetlandET	Monthly potential ET for wetland land-use class	1	1.20
SaltbushET	Monthly potential ET for saltbush land-use class	1	1.20
Hydraulic Conductivity	Groundwater parameter	1	0.10
Width to Breadth Ratio	Groundwater parameter	1	2.00
Specific Yield	Groundwater parameter	1	2.00
Seepage Rate	Groundwater parameter	1	2.00
Height for Base Flow Only	Groundwater parameter	1	2.00
Height of Root Zone above Datum	Groundwater parameter	1	2.00
Default Settings			
Unimpaired Flows			
Historical Flows			

Sensitivity Analysis

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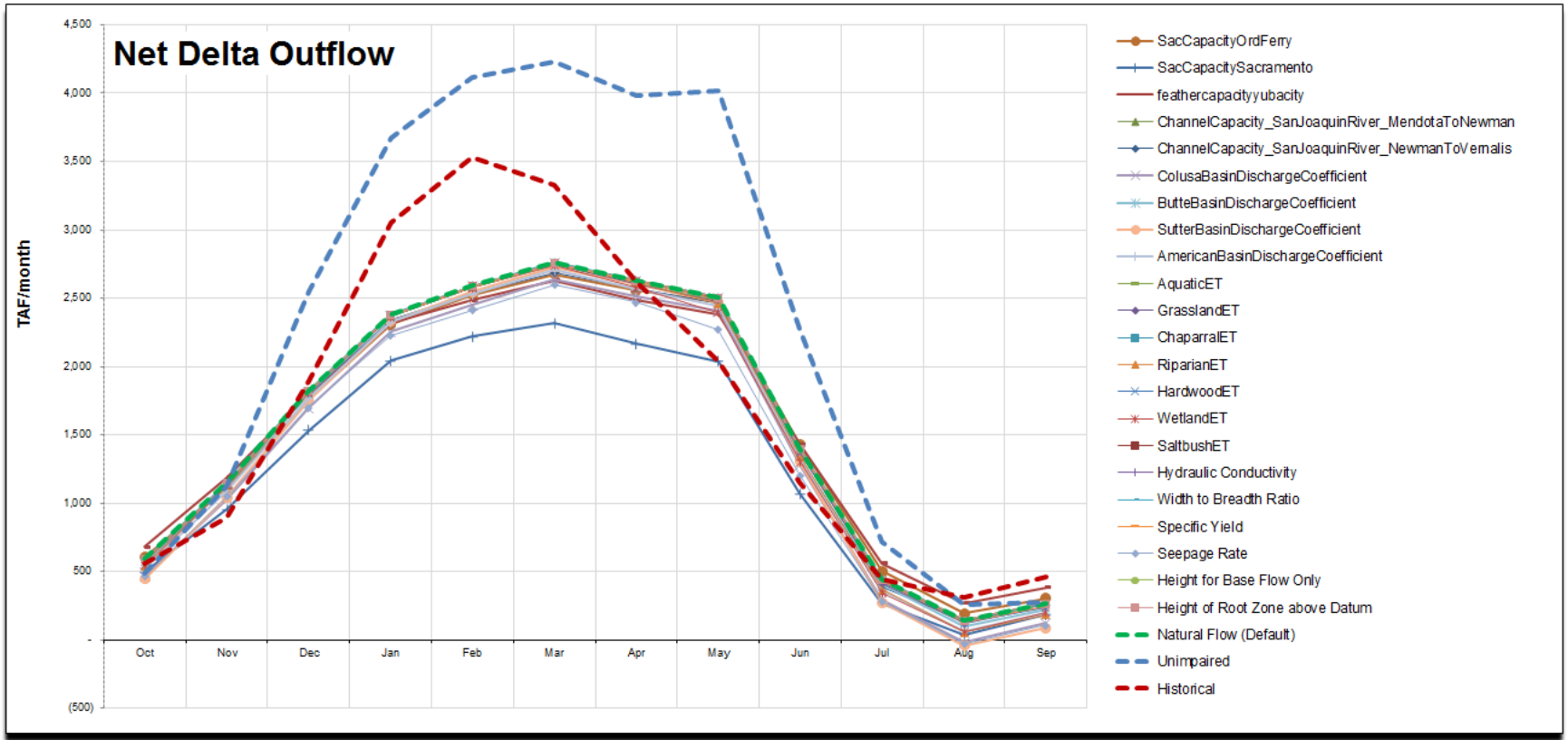
Model Input Parameters to be Increased in Sensitivity Analysis by the Multiplier

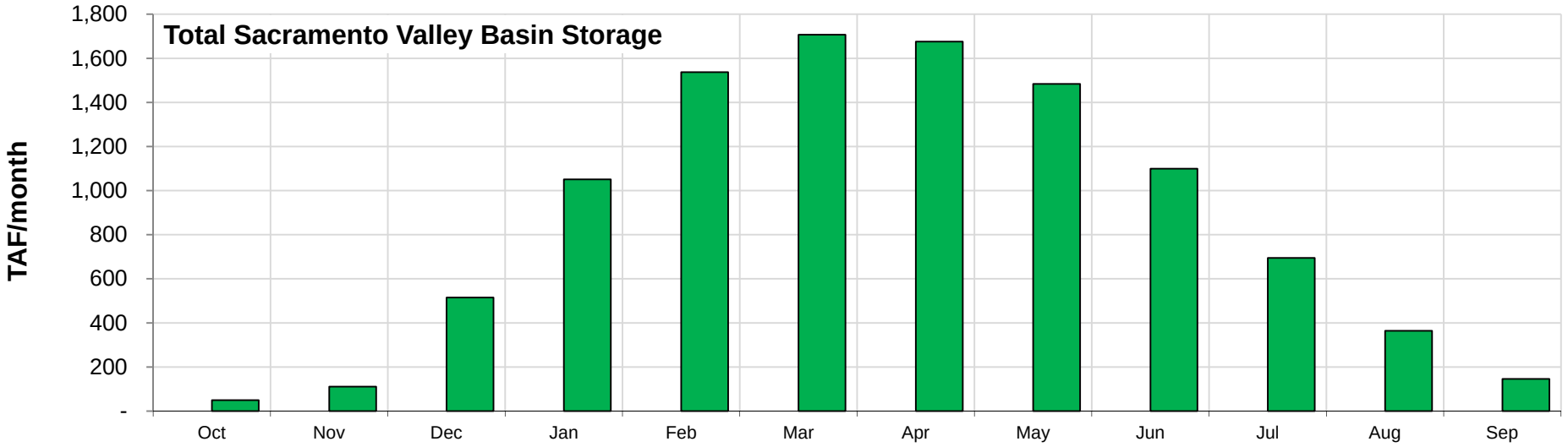
Parameter	Description	Analyze	Multiplier
SacCapacityOrdFerry	Bank-full capacity for the Sacramento River between Ord Ferry and Knights Landing	1	0.50
SacCapacitySacramento	Bank-full capacity for the Sacramento River between Knights Landing and Sacramento	1	0.50
feathercapacityyubacity	Bank-full capacity for the Feather River near Yuba City	1	0.50
ChannelCapacity_SanJoaquinRiver_MendotaToNewman	Bank-full capacity for the San Joaquin River between Mendota and Newman	1	0.50
ChannelCapacity_SanJoaquinRiver_NewmanToVernalis	Bank-full capacity for the San Joaquin River between Newman and Vernalis	1	0.50
ColusaBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the Colusa Basin	1	0.00
ButteBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the Butte Basin	1	0.00
SutterBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the Sutter Basin	1	0.00
AmericanBasinDischargeCoefficient	Discharge coefficient for head-dependent outflow from the American Basin	1	0.00
AquaticET	Monthly potential ET for aquatic land-use class	1	1.20
GrasslandET			
ChaparralET			
RiparianET			
HardwoodET			
WetlandET			
SaltbushET			
Hydraulic Conductivity			
Width to Breadth Ratio			
Specific Yield			
Seepage Rate			
Height for Base Flow Oi			
Height of Root Zone abo			
Default Settings			
Unimpaired Flows			
Historical Flows			

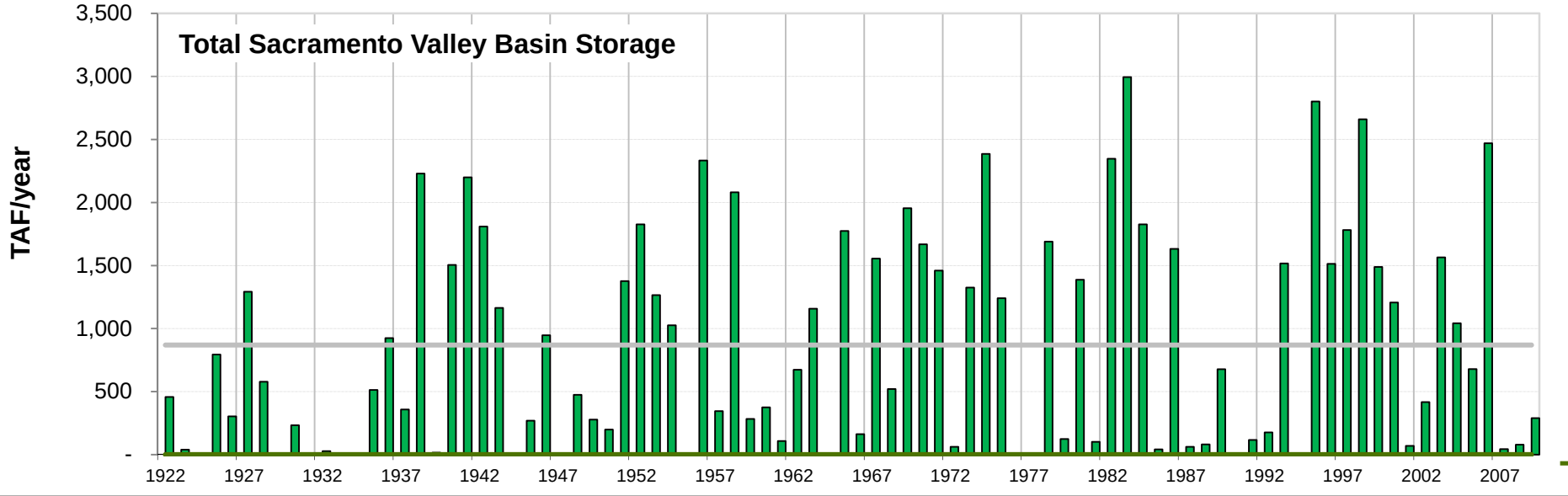


Key Model Drivers

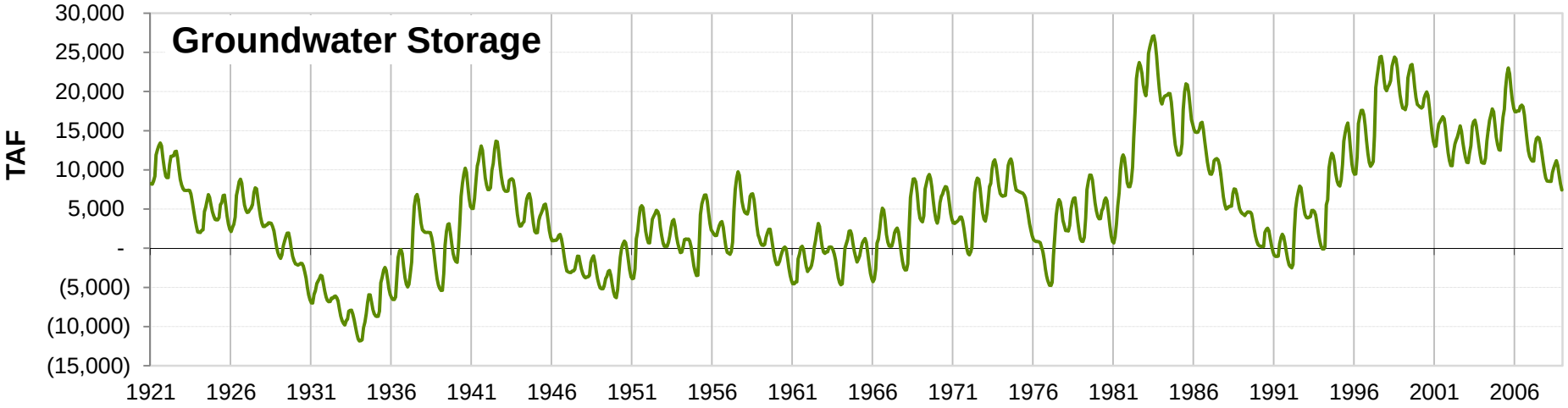
- Channel Capacity
  - Amount of over-bank flow
  - Frequency/timing of over-bank flow
- Detention storage
  - Discharge characteristics
  - Infiltration capacity
- Groundwater hydraulic conductivity
  - Controls balance between ET and outflow to stream
- Evapotranspiration
  - Source of water for riparian vegetation
  - Land classes dependent on groundwater elevation

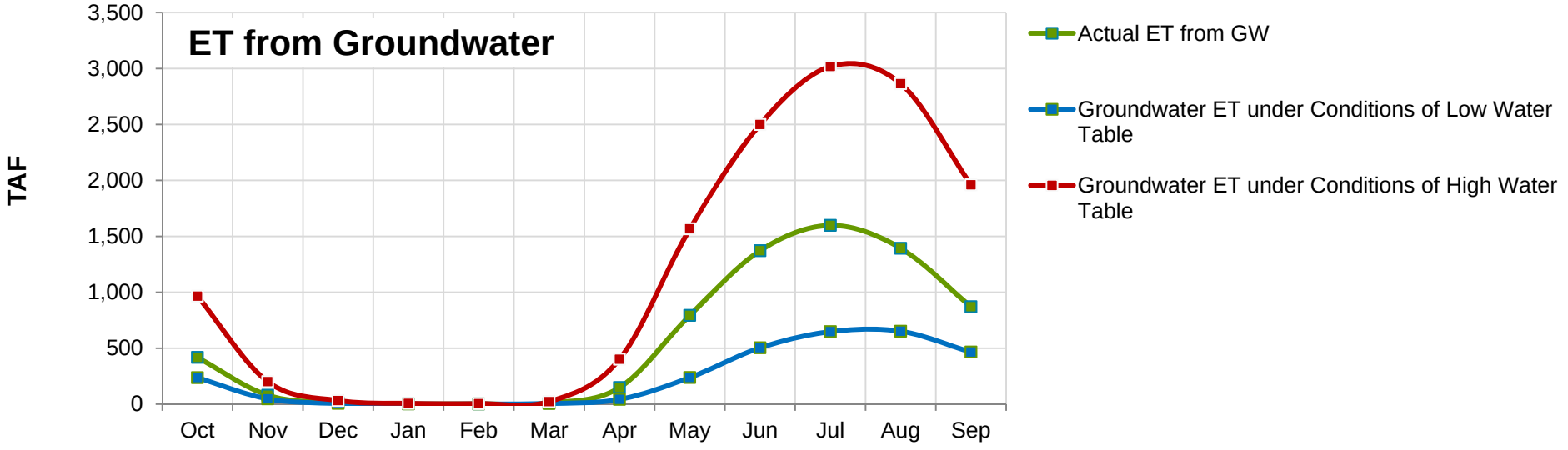
Model Results: Detention Storage



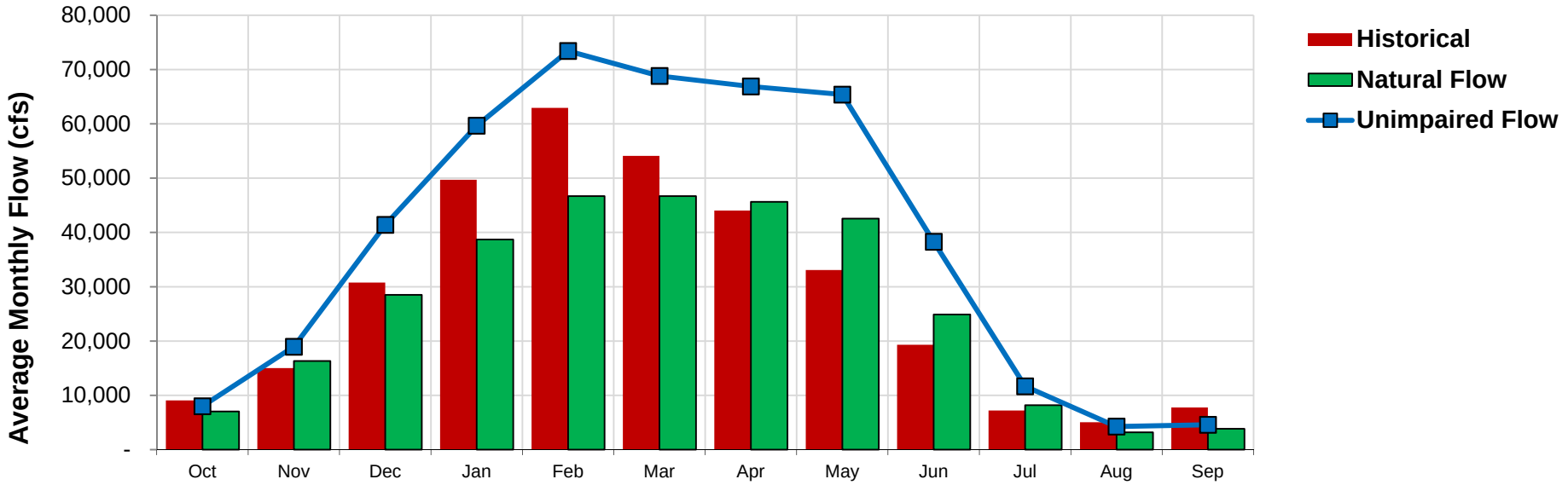


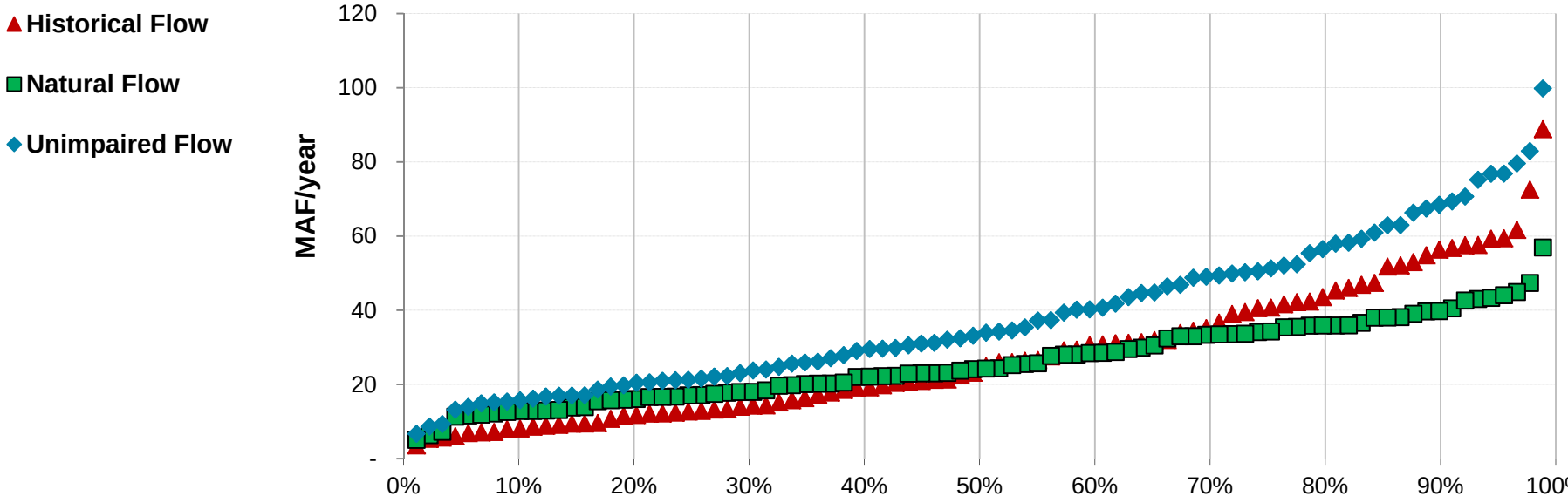
Model Results: Groundwater





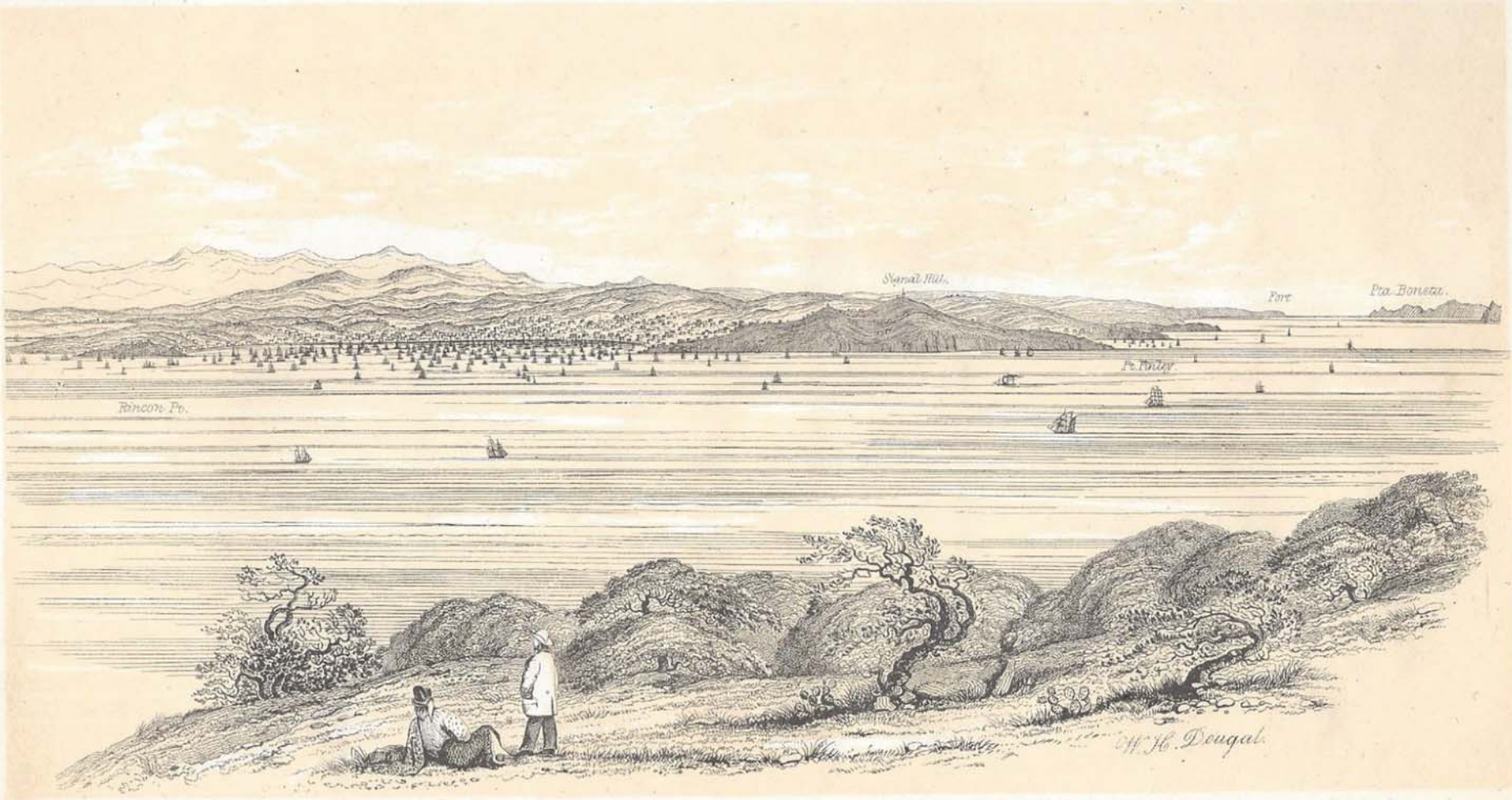
Model Results: Net Delta Outflow





Conclusions

- Model able to match long-term net Delta Outflow predicted by Fox et al. (Case I: 18.7 MAF/year).
- Simulated annual volumes and monthly flow pattern is sensitive to some model input parameters.
- Helps understand role flood basins and groundwatre played under natural conditions.
- Distributed surface water groundwater model needed to better simulate groundwater's role in meeting ET.



View of San Francisco from Yerba Buena Island.

Historical Narrative

- William Hammond Hall served as California's first State Engineer from 1878 to 1889. During those years, Hall surveyed and reported on the state's water resources, both calling attention to problems and recommending solutions. Hall's examinations still serve as the most extensive study of California's water systems to date, the scale of which, considering the fiscal situation of California's state government, is likely never to be matched.