

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



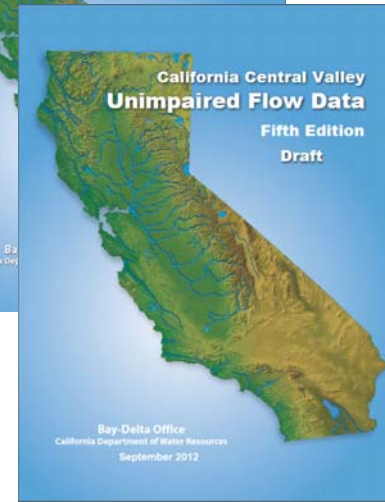
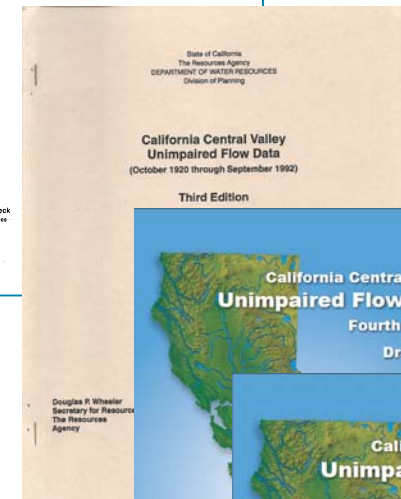
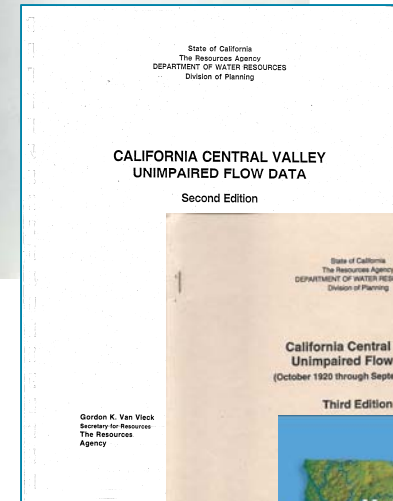
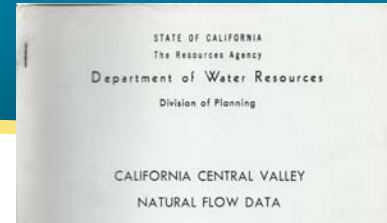
Natural Water Balance

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.

NFP_Temp4.xlsm - Microsoft Excel

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E25

This worksheet is for version control

File Name:	NFP_NaturalFlowModel_12.31.13
Description:	Monthly routing model for natural (pre-development) and historical flows in the Sacramento and San Joaquin valleys and Delta
Worksheets	
Version Control	1 This worksheet. Presents list of changes to the workbook.
User Defined Input Assumptions	2 Key input assumptions that affect routing of natural flows. These parameters may be changed by the user to perform a sensitivity analysis.
Sensitivity Analysis	3 Allows the user to perform a sensitivity analysis on model inputs
Results Summary and Checks	4 Summary of average annual natural flows for each region (Sacramento Valley, San Joaquin Valley, Eastside Streams, and Delta). Includes includes mass balance check
Results Charts River Flows	5 Charts of natural and historical river flows at key locations.
Results Charts Flooding	6 Charts of natural and historical overbank flow stippling.
Results Charts Groundwater	7 Charts of groundwater storage, elevation, stream inflow, and ET under natural conditions.
Results Charts Sacramento	8 Charts of natural and historical flows pertaining to the Sacramento Valley (not completed).
Results Charts San Joaquin	9 Charts of natural and historical flows pertaining to the San Joaquin Valley.
Results Charts Eastside Streams	10 Charts of natural and historical flows pertaining to the Eastside Streams.
Results Charts Delta	11 Charts of natural and historical flows pertaining to the Delta.
Schematic - Sacramento Valley	12 Node-arc schematic for the Sacramento Valley. Compares natural and historical flows.
Schematic - San Joaquin Valley	13 Node-arc schematic for the San Joaquin Valley. Compares natural and historical flows.
Schematic - Eastside Streams	14 Node-arc schematic for the area East of the Delta. Compares natural and historical flows.
Schematic - Delta	15 Node-arc schematic for the Delta. Compares natural and historical flows.
Input Data	16 Timeseries input data from supporting spreadsheets
Precipitation Subregions	17 Precipitation for each of 15 subregions within the Central Valley.
Precipitation Valley Watersheds	18 Precipitation for valley watersheds.
ETs	19 Reference crop evapotranspiration for each of 15 subregions within the Central Valley.
Land Use	20 Land use for each of 15 subregions within the Central Valley.
Kc	21 Crop/vegetation coefficients that relate ET to reference crop evapotranspiration.
Sacramento Stage-Discharge	22 Stage-discharge relationship for the Sacramento River at key locations. Used to define channel capacities and control outflow from the flood basins.
Colusa Basin	23 Elevation-area-capacity relationship for the Colusa Basin. (This needs to be checked - seems low).
Butte Basin	24 Elevation-area-capacity relationship for the Butte Basin (placeholder).
Sutter Basin	25 Elevation-area-capacity relationship for the Sutter Basin.
American Basin	26 Elevation-area-capacity relationship for the American Basin.
Yolo Basin	27 Flow-weighted area relationship for the Yolo Basin.
San Joaquin River Basin	28 Flow-weighted area relationship for the San Joaquin River Basin.
Routing Calculations	29 Monthly routing calculations for natural flows throughout the node-arc schematic.
ET Summary	30 Summary of 16 worksheets that simulate soil moisture in the root zone and determine actual, which depends on available moisture.
ET Upslope SWS	31 Flow adjustment for the Sacramento River to account for unaccounted areas located between the rim watersheds and valley floor subregions.
ET Upslope SWS	32 Flow adjustment for the San Joaquin River to account for unaccounted areas located between the rim watersheds and valley floor subregions.
ET Upslope Eastside	33 Flow adjustment for the Eastside Streams to account for unaccounted areas located between the rim watersheds and valley floor subregions.
ET Subregion XX (DSAYYY)	34-41 Series of 15 worksheets that simulate soil moisture in the root zone.
GW Summary	50 Summary of 15 worksheets which simulate groundwater under natural conditions.
GW Subregion XX (DSAYYY)	51-66 Series of 15 worksheets that simulate groundwater storage and stream-groundwater interaction.
Notes - Overview	67 Overview of the workbook.
Notes - Schematics	68 Describes functionality for viewing model input and output data.
Notes - Rim Inflows	69 Describes rim inflows from mountain watersheds.
Notes - Groundwater	70 Change in groundwater storage under historical and pre-development conditions.
Notes - Historical Accretions	71 Historical accretions to stream system based on gaged measurements (missing calculations for Calaveras and Mokelumne river diagrams incomplete).
Notes - Input Metadata	72 List of input data and check that data loaded into "Input Data" worksheet (Historical storage data missing, historical flow description incomplete).
Notes - C2VSim Stream Nodes	73 Relationship between CalSim 3.0 nodes and C2VSim nodes (not used).
Notes - Channel Capacities	74 Channel capacities (need to relate elevation to USGS to LIDAR data).

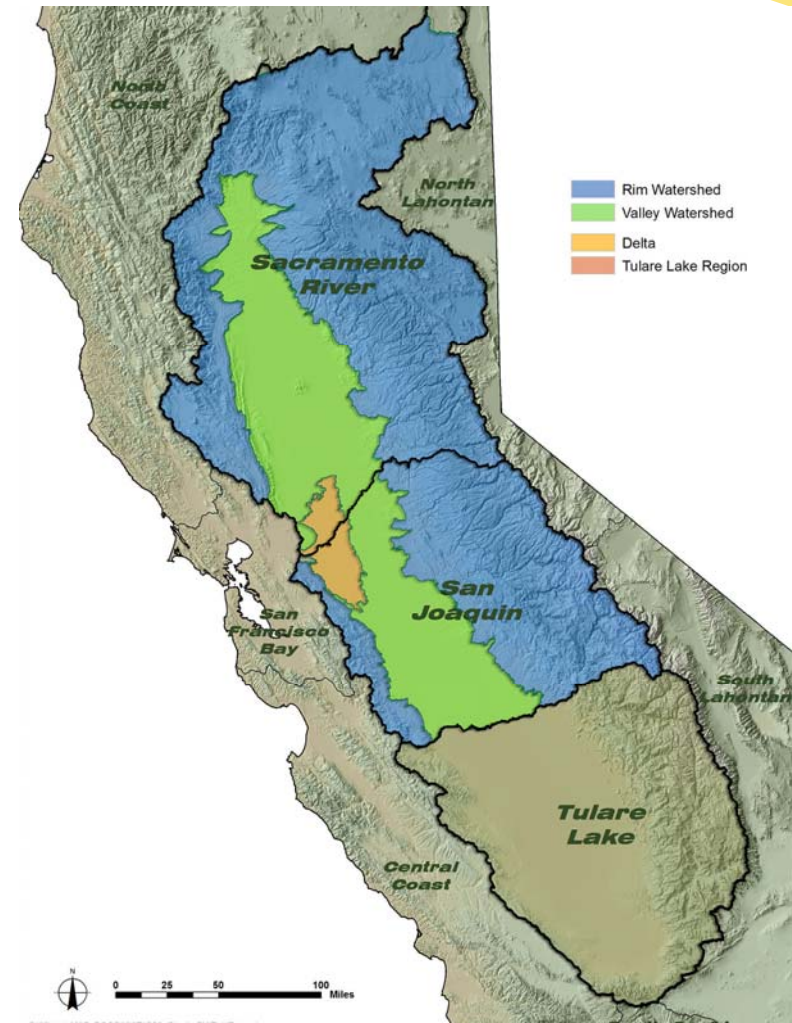
File Revisions

Date	Person	Note/Modification
10.01.12	A. Draper/MvH	Created file
04.23.13	A. Draper/MvH	Completed initial flow routing - many placeholders
05.13.13	A. Draper/MvH	Added sensitivity analysis
08.30.13	A. Draper/MvH	Set river flows to minimum of zero Restructured model Eliminated historical accretion terms Accounted for variable flooding area in soil moisture storage accounting
12.16.13	A. Draper/MvH	Added final documentation
12.31.13	A. Draper/MvH	Minor formatting changes Added accessibility to worksheets

Version Control User Defined Input Assumptions Sensitivity Analysis Results Summary and Checks Results Charts River

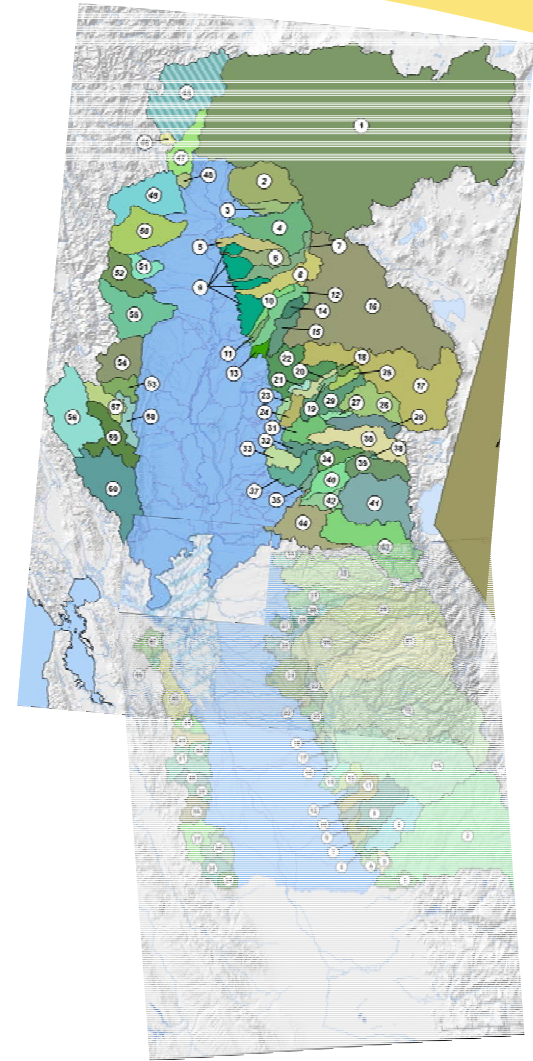
Rim Watersheds, Valley Watersheds, and Delta

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

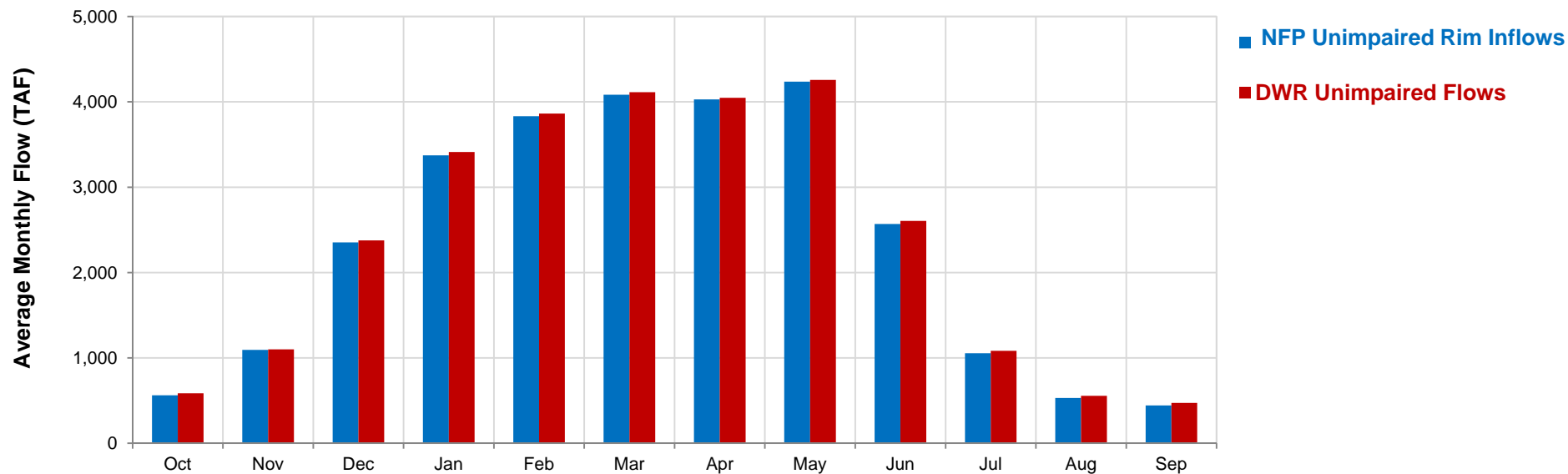
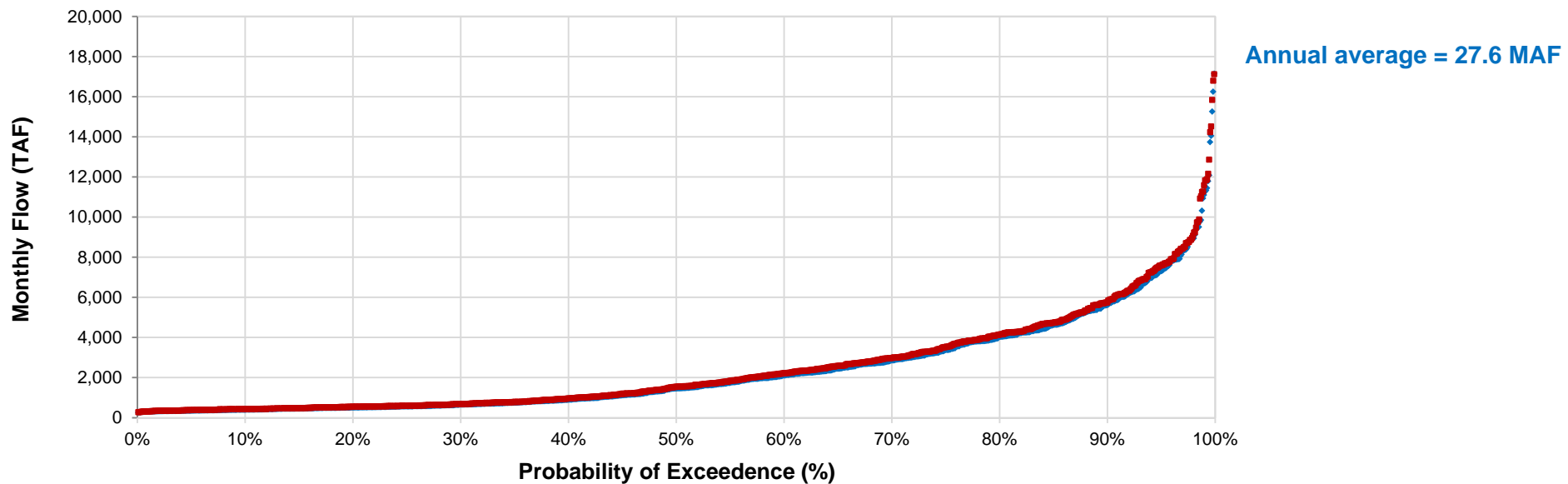


Rim Watersheds

- 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.

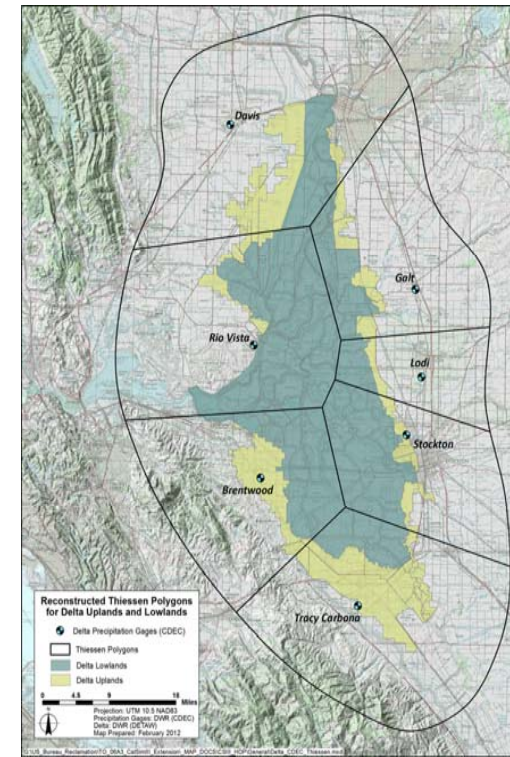


Rim Watersheds



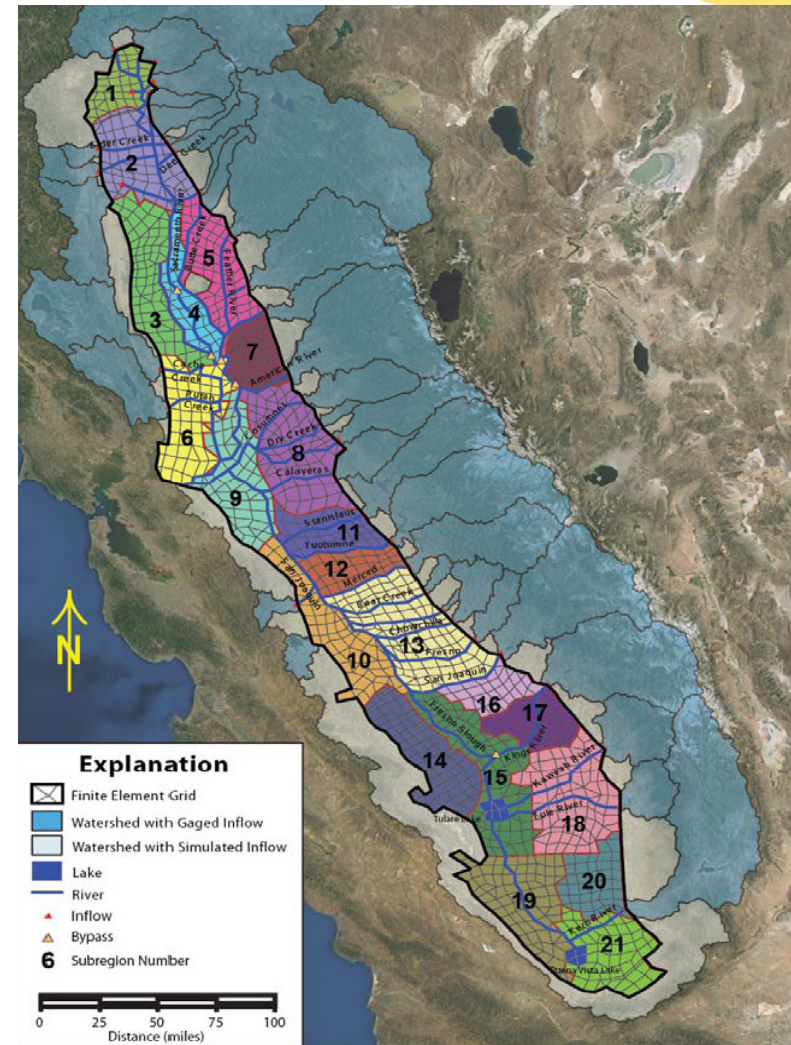
Sacramento-San Joaquin Delta

- 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.



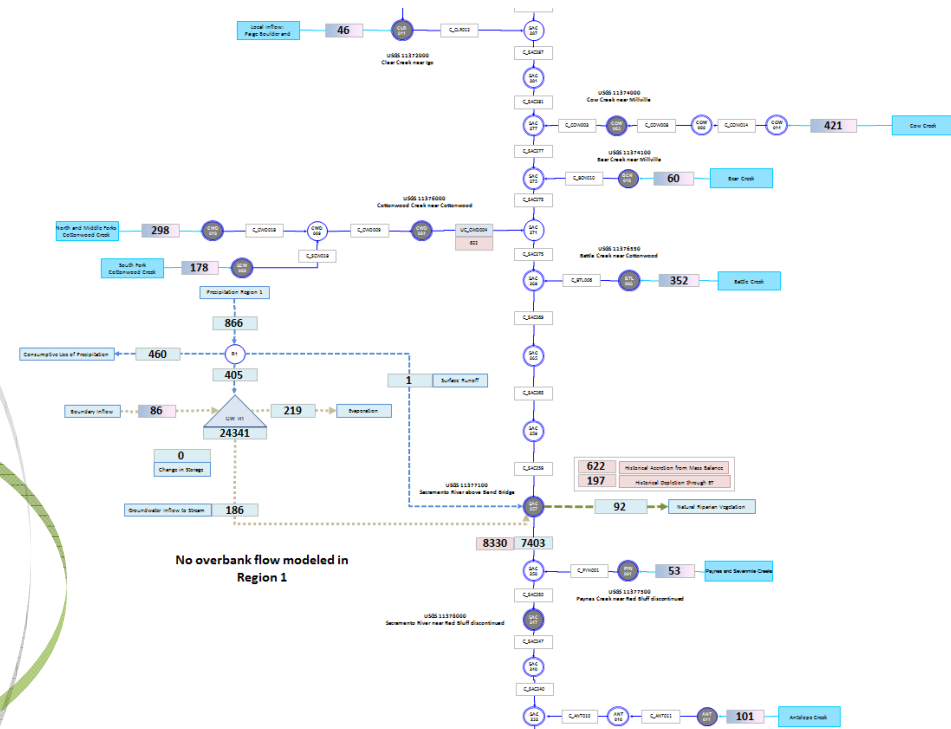
Valley Watershed Subregions

- 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.



4. Groundwater

- Lateral and vertical recharge
- Storage
- Capillary rise/ET
- Discharge to stream system



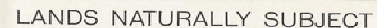
1. Stream System - Channel Capacity

- 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

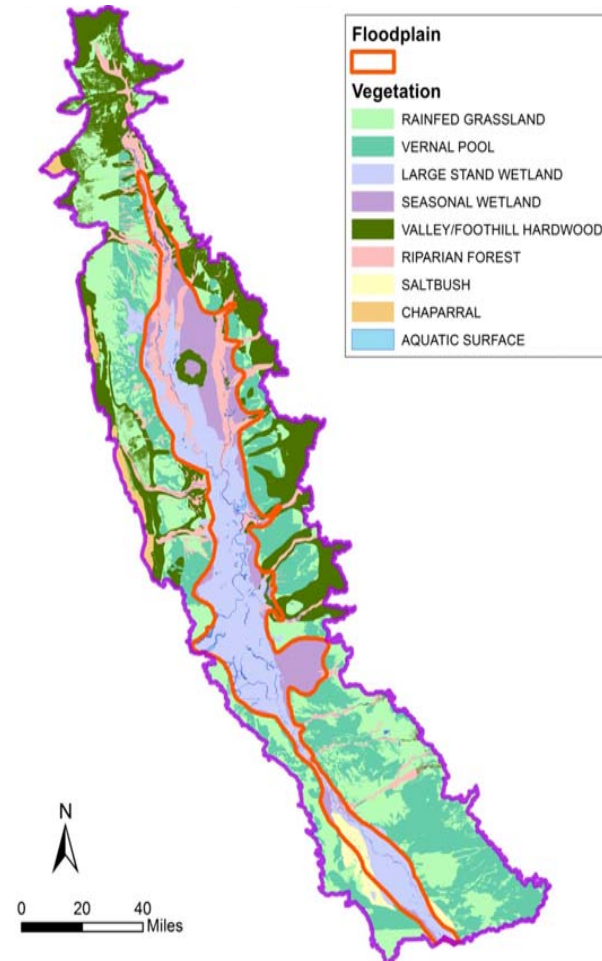


- Bankfull flows are important for forming and maintaining stream channel cross-sectional area in alluvial streams. Bankfull flow is subject to minimum flow resistance and transports the most sediment over time.
- Bankfull events have been determined to have a recurrence interval of approximately 1.5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



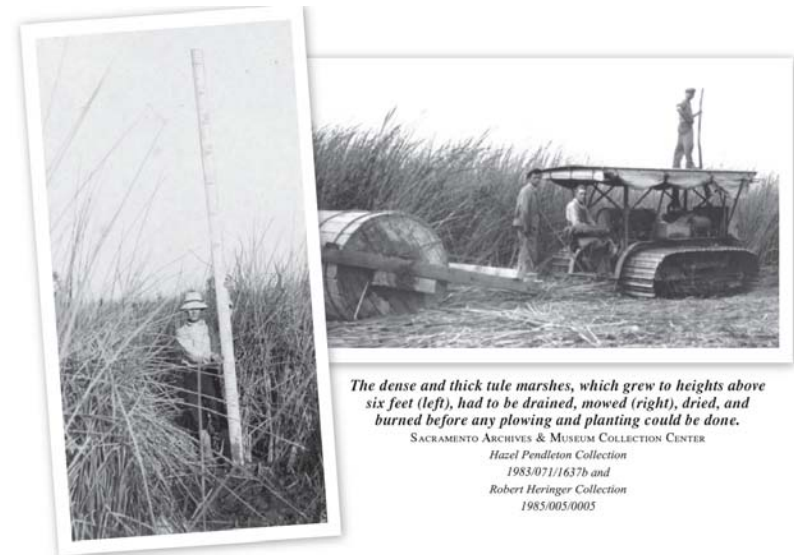
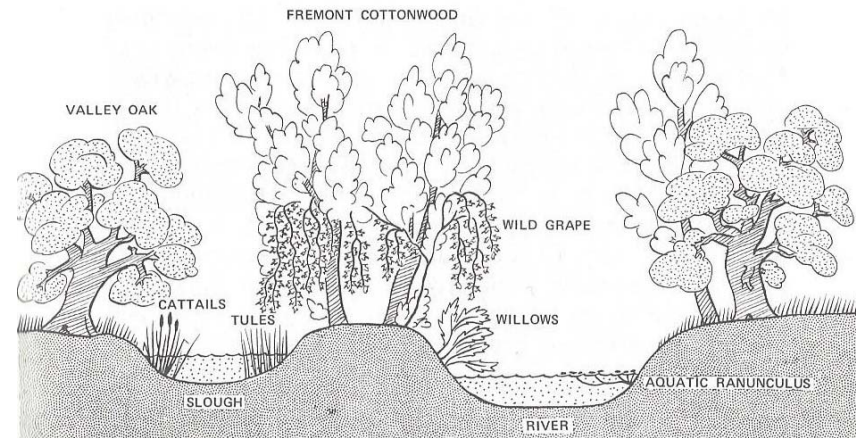
2. Land Surface/Root Zone

- 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



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)

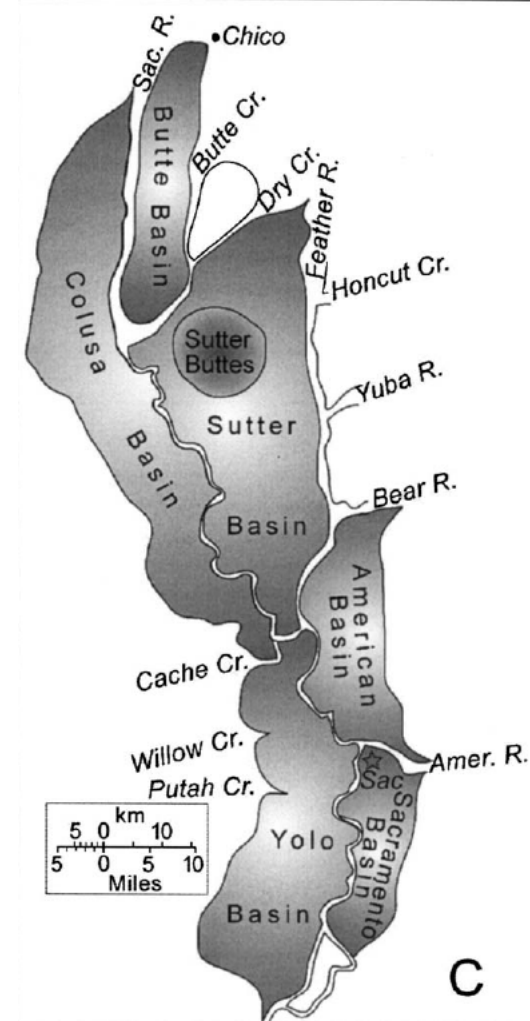
3. Flood Basins

• Sacramento Valley

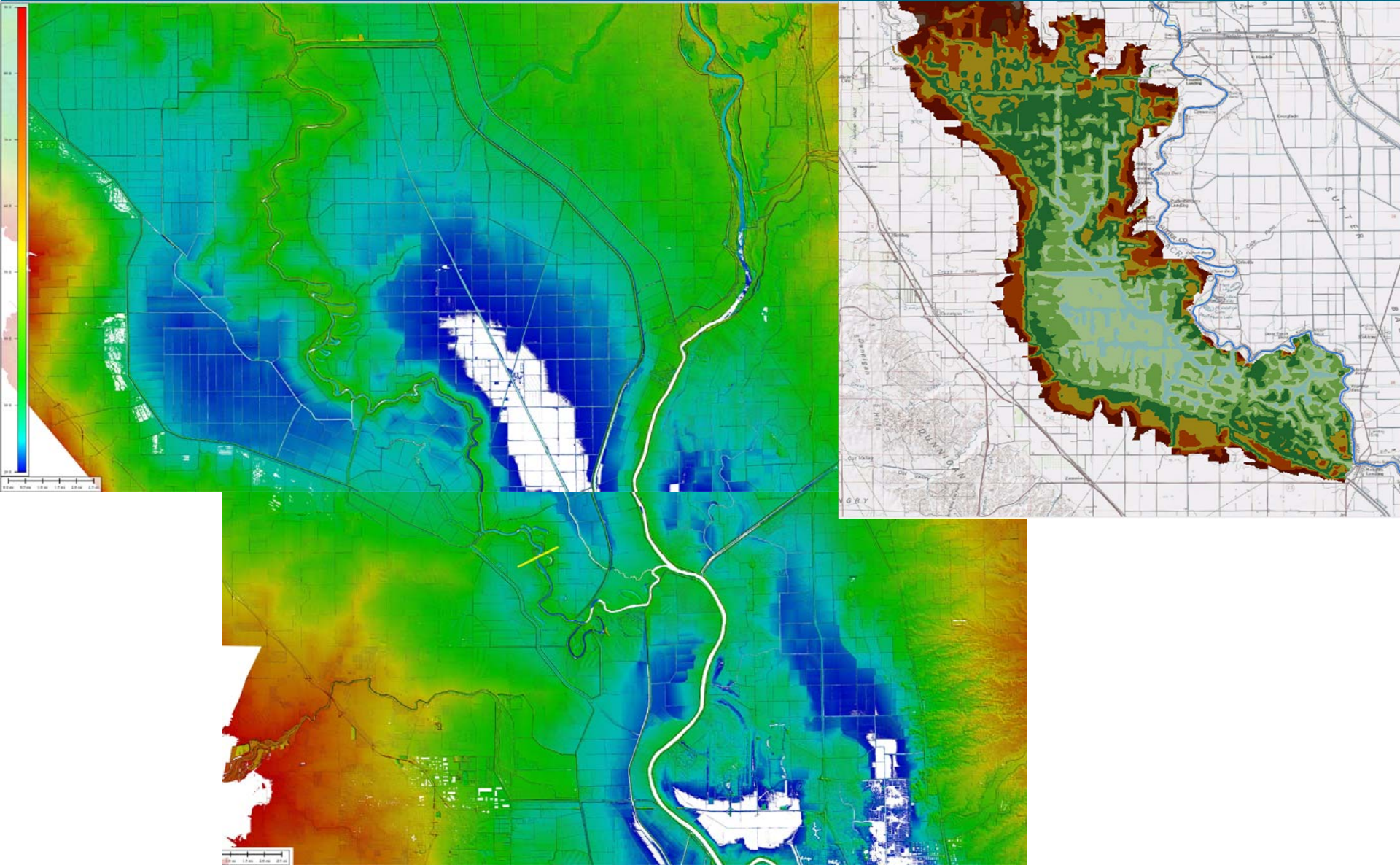
- Approximately 1 million acres or nearly 40 percent of lands within the Sacramento Valley were subject to flooding.
- Colusa, Sutter, American Basins
 - *Assume outflow controlled by river stage*
- Butte Basin
 - *Assume outflow controlled by channel constriction*
- Yolo Basin
 - *No detention storage,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

• San Joaquin Valley

- *No detention storage, flooded area based on steady-state flow analysis*

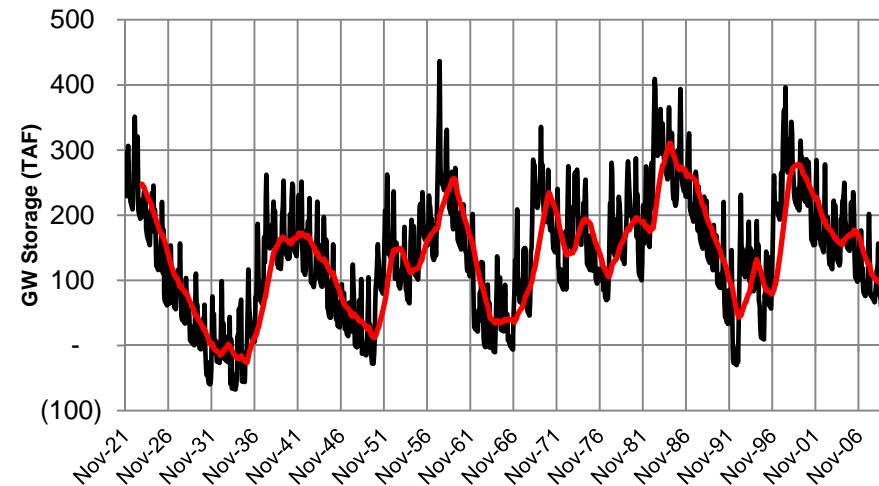
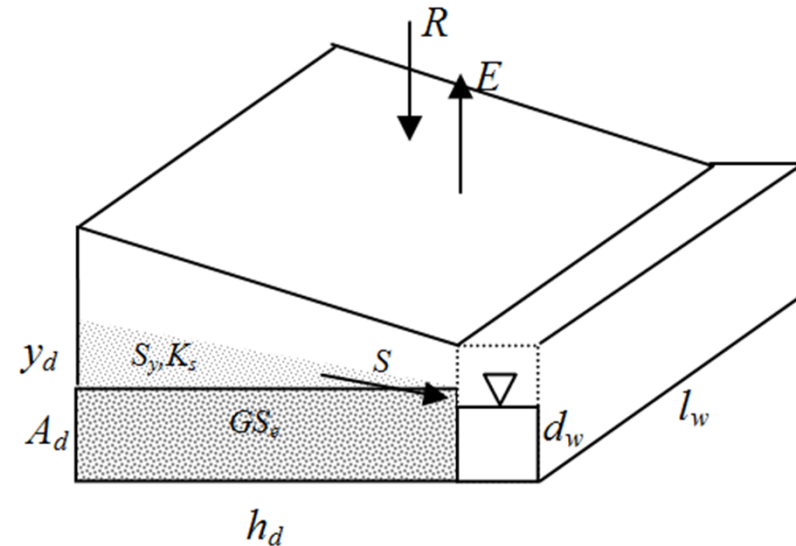


3. Flood Basins



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



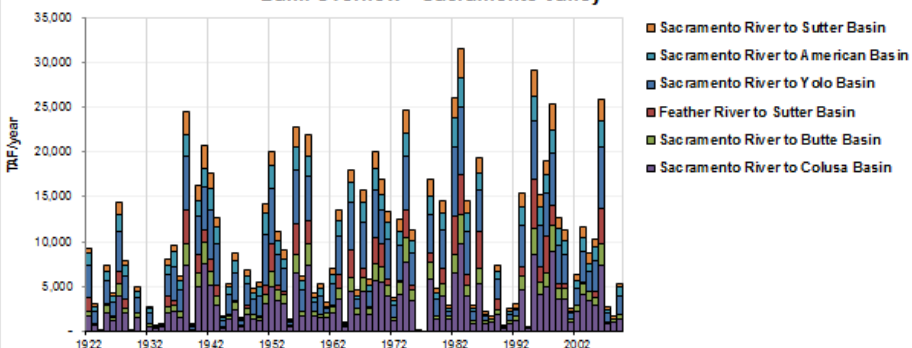
Model Input Parameters

Channel Capacity - Bank Overflow

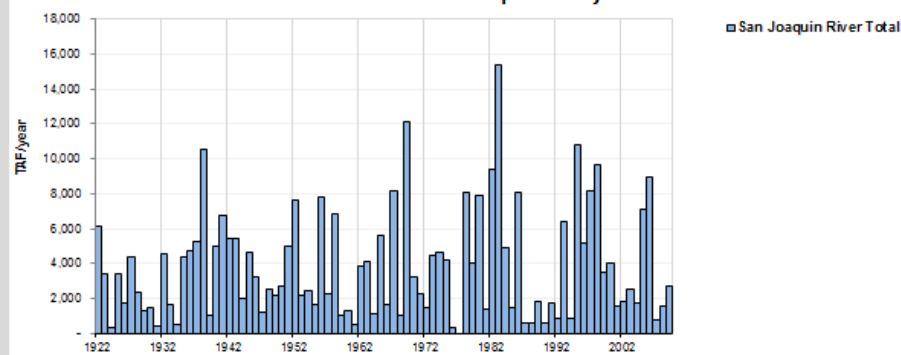
Channel	Where Referenced in Routing	Description
10,000	column= 20, column = 30, column = 56	Sacramento River channel capacity between Old Ferry and Knights Landing
25,000	column= 74, column = 76	Sacramento River channel capacity between Knights Landing and Sacramento
20,000	column = 54	Feather River 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



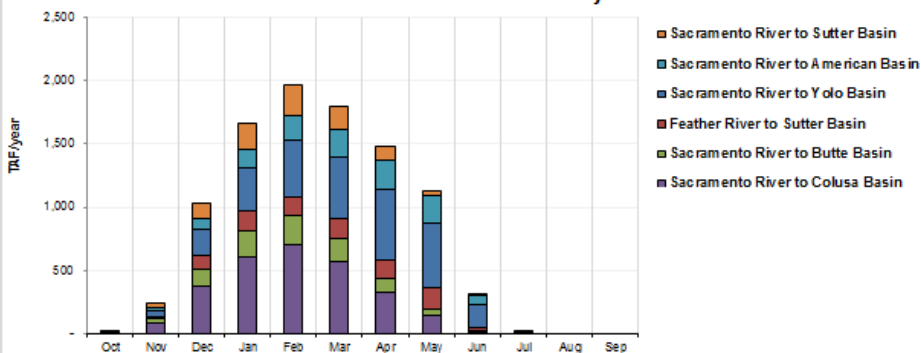
Bank Overflow - Sacramento Valley



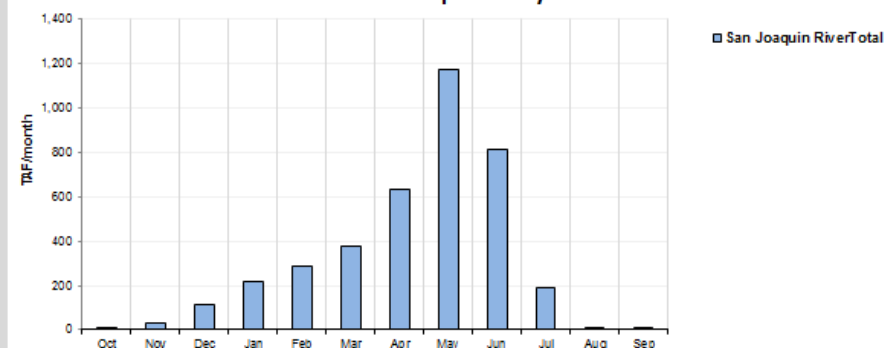
Bank Overflow - San Joaquin Valley



Bank Overflow - Sacramento Valley



Bank Overflow - San Joaquin Valley



Sensitivity Analysis

2

5

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

Sensitivity Analysis

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

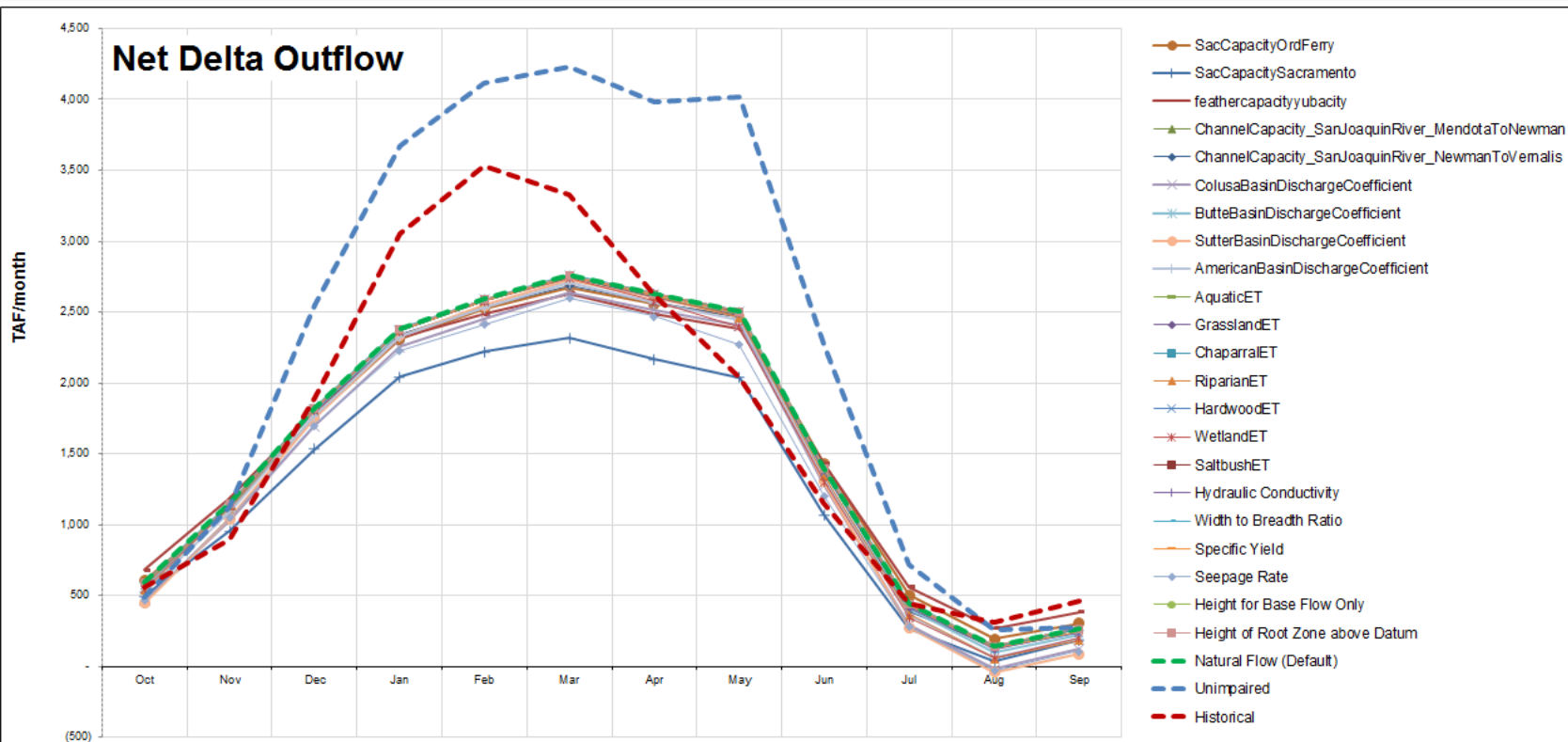
In the sensitivity analysis the input parameter defined in the worksheet **User Defined Input Assumptions** will be multiplied by the values in this column.

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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 Only
Height of Root Zone above Datum

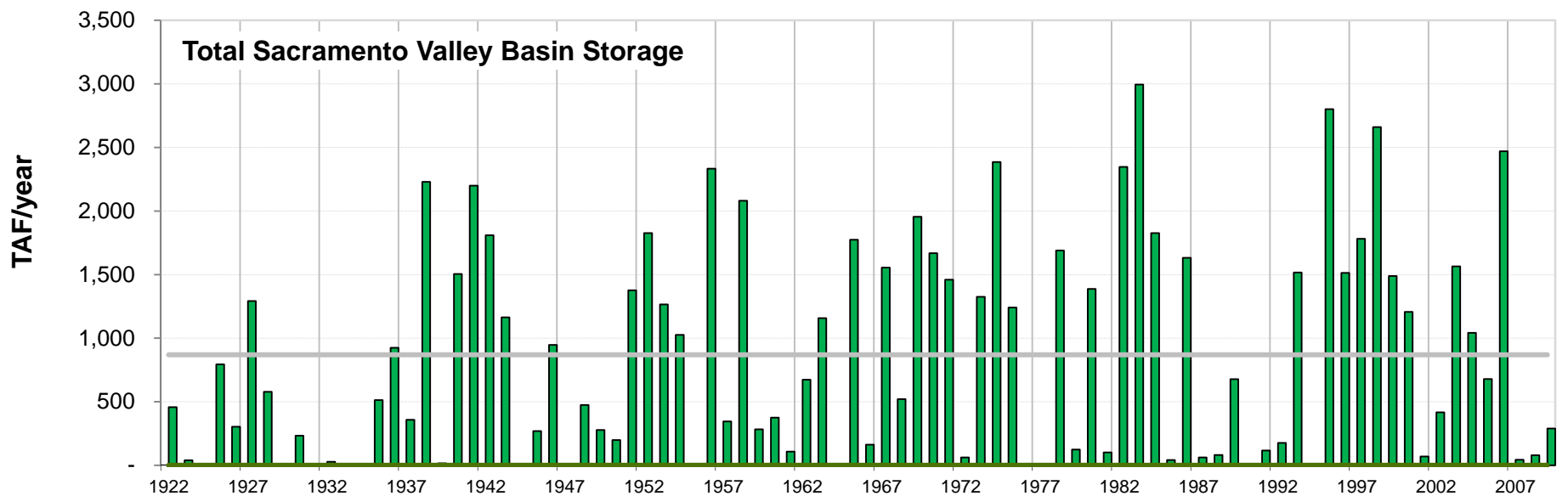
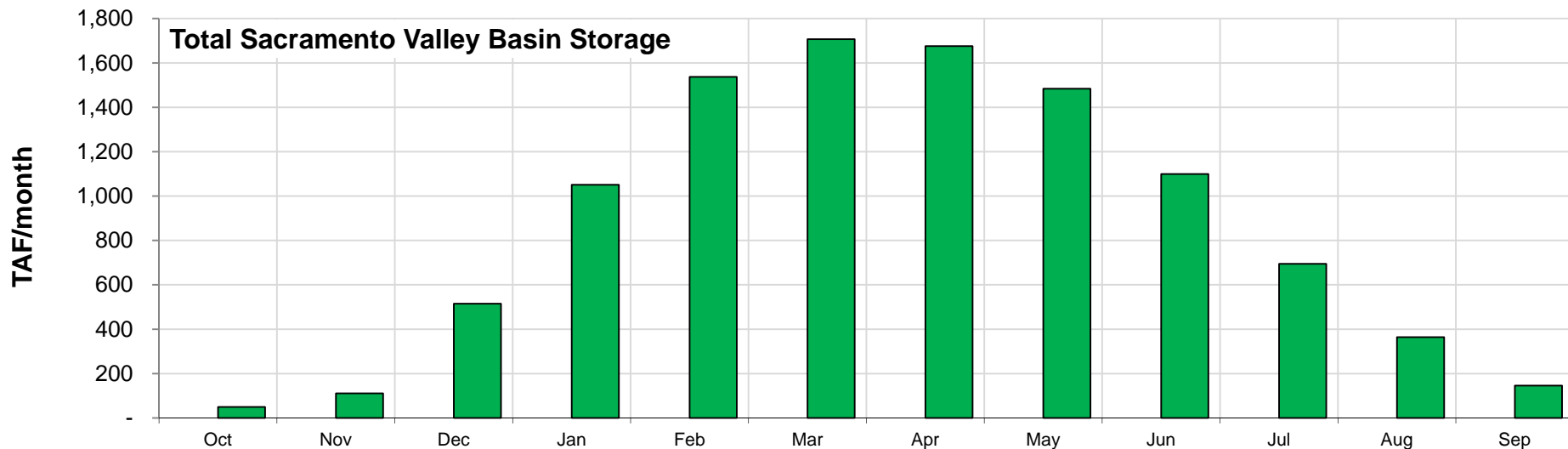
Default Settings
Unimpaired Flows
Historical Flows



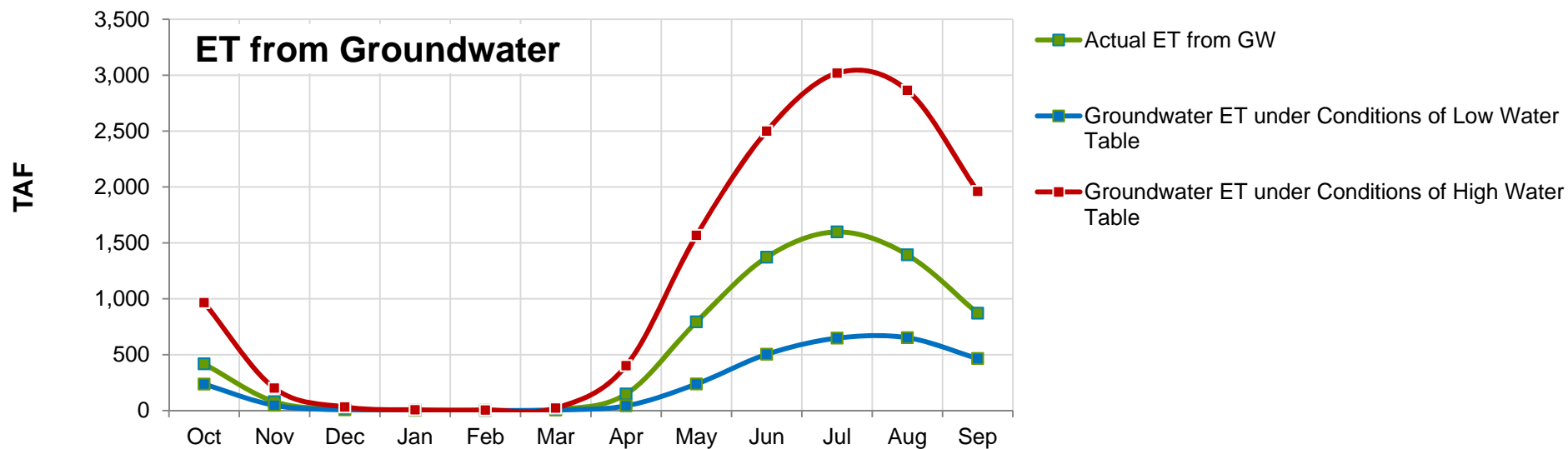
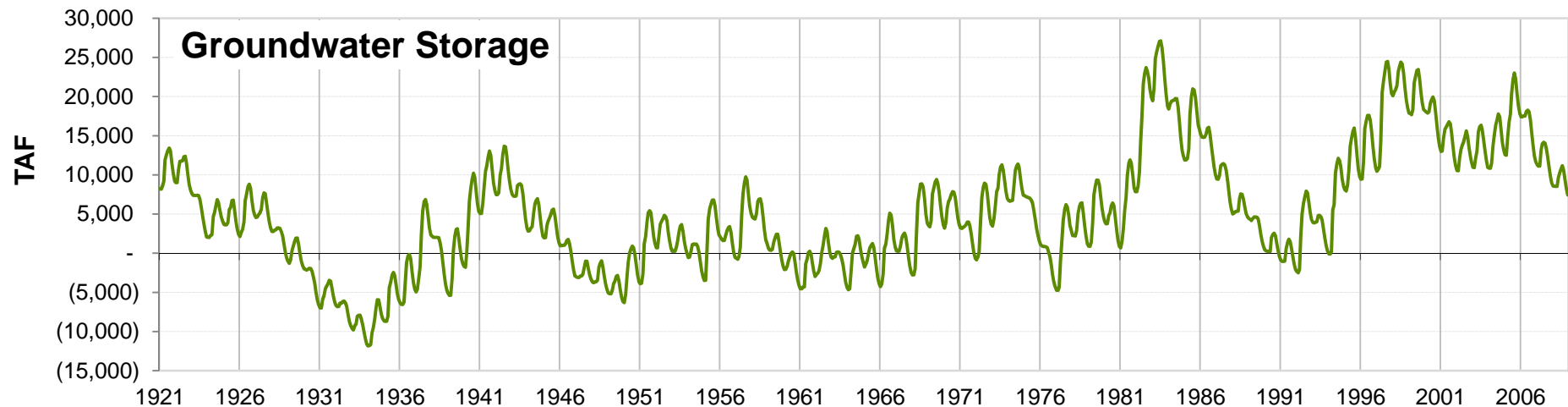
Key Model Drivers

- 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

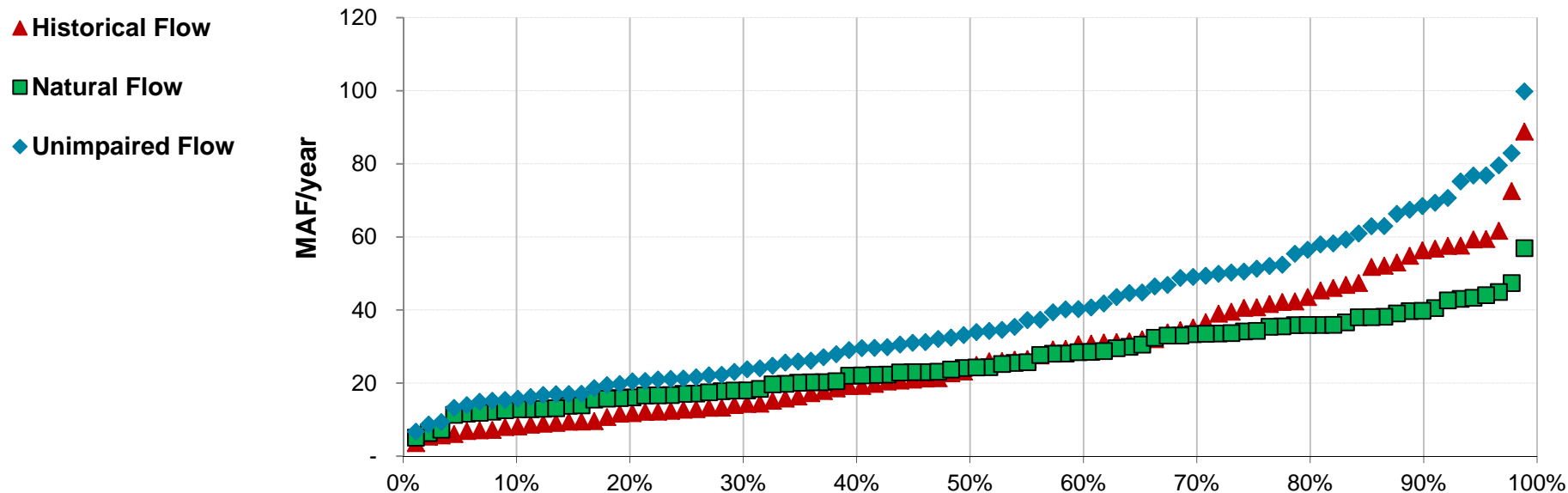
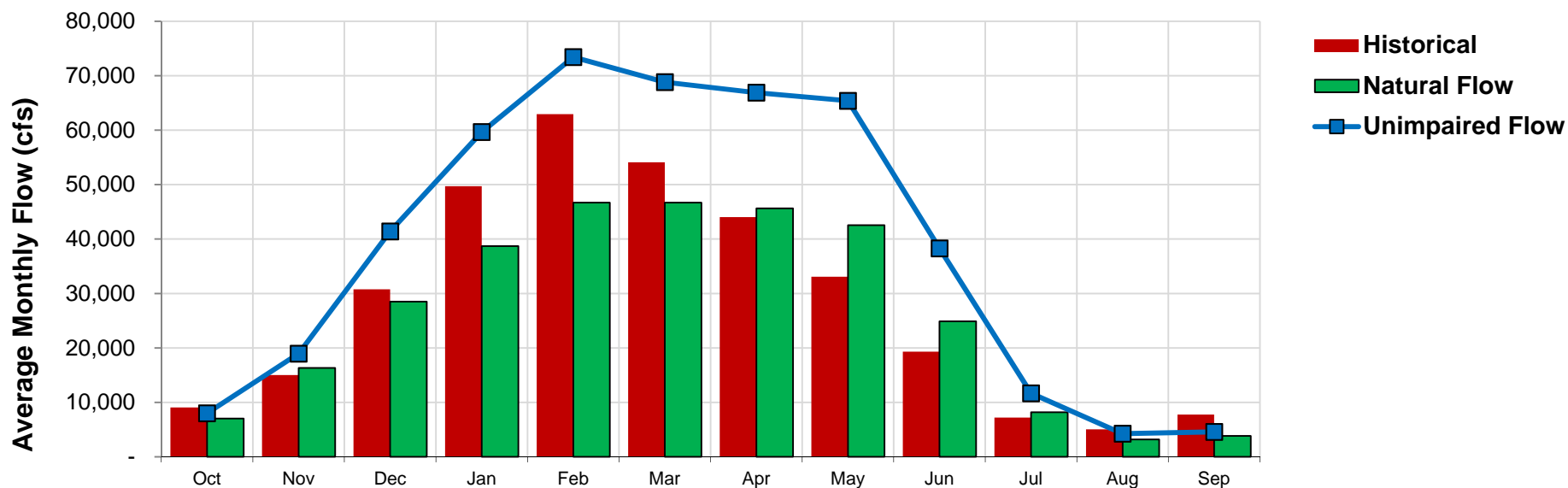
Model Results: Detention Storage



Model Results: Groundwater

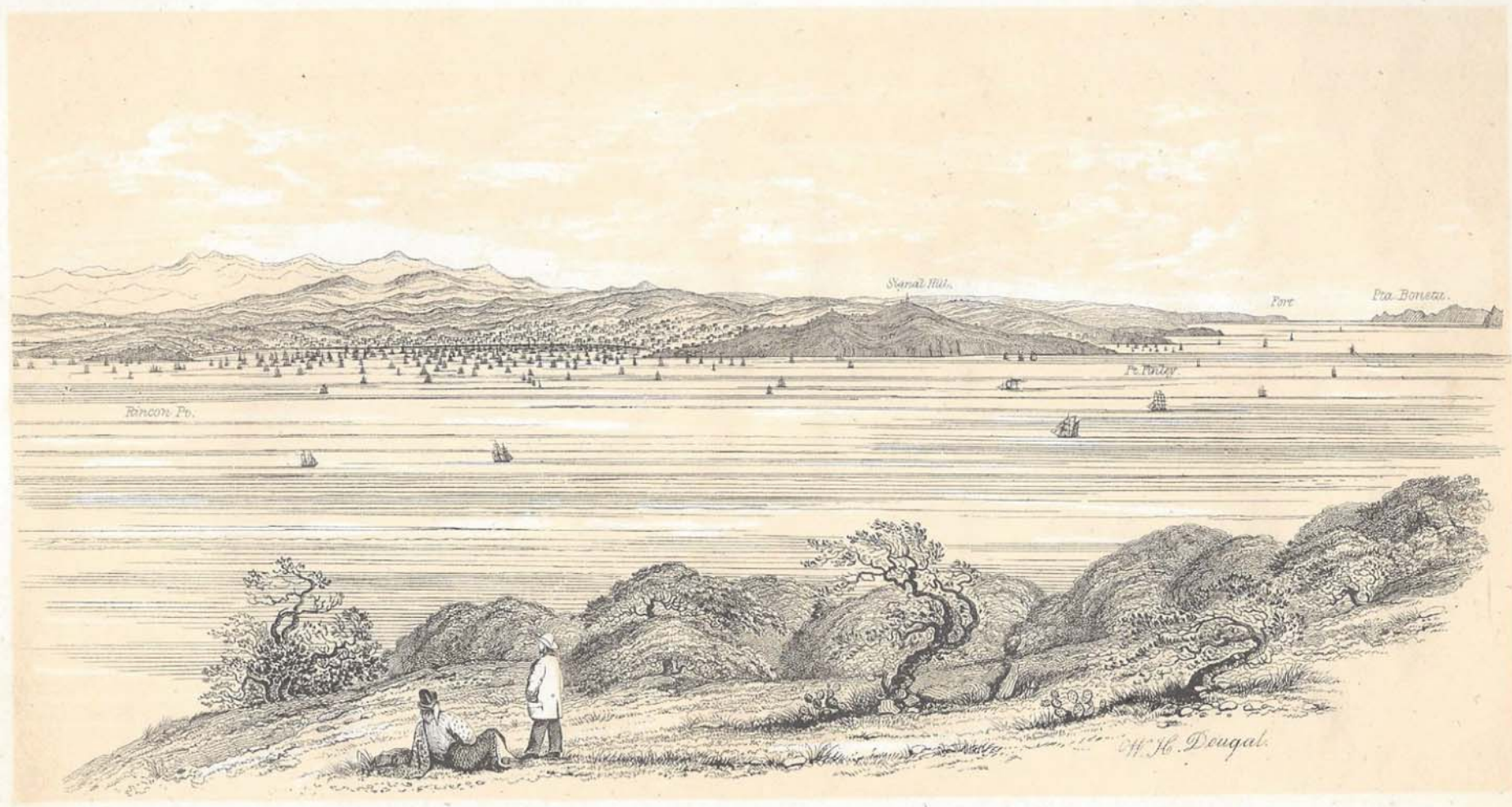


Model Results: Net Delta Outflow



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 groundwater 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.

