Unimpaired Flows vs. Natural Flows to the Sacramento – San Joaquin Delta: What's the Difference?

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Outline

- Unimpaired flow and natural flow (California)
- Unimpairment process and limitations
- DWR Natural Flow Simulations (Central Valley)
- Comparison of unimpaired flows and natural flows
- Sensitivity Analyses
- Lakes and wetlands animation
- Final comments and work under way

Interest

- Interested in an “index” to reflect the water supply of the areas in the Central Valley tributary to the Sacramento – San Joaquin Delta for a given hydrological (precipitation) trace

- Computing inflows into and outflows from the Sacramento – San Joaquin Delta after removing impacts of human development (land use based demands and land use alterations) for a given hydrological (precipitation) trace

Definitions

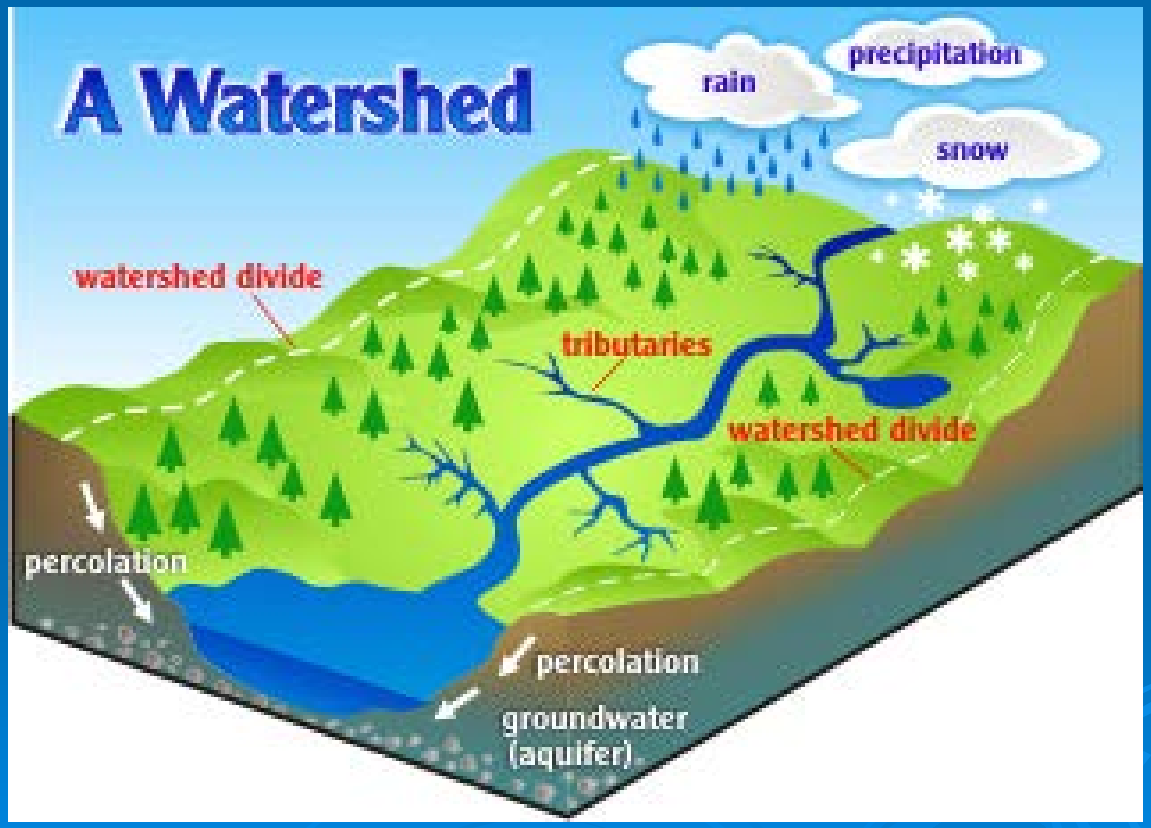
As defined in Wikipedia

Unimpaired runoff, also known as *full natural flow*, is a hydrology term that is used to describe the natural runoff of a watershed or waterbody that would have occurred prior to anthropogenic or human influences on the watershed. Flow readings from river gauges are influenced by upstream diversions, impoundments, and many other alternations of the land that drains into a watershed or of alternatives of a river channel itself. Engineers estimate unimparied or natural runoff by estimating all of the effects of human "impairments" to flow and then removing these effects. Since these calculations involve many assumptions, they tend to be more accurate for either smaller watersheds or when expressed as longer period averages

As defined by DWR (Division of Flood Management – Snow Surveys)

Flow readings from river gages are influenced by upstream diversions, impoundments, and other manmade alterations. The natural runoff at a gage is reconstructed by removing the effects of these "impairments." This calculation is done on a monthly basis for all major rivers in the state, and on a daily basis for a subset. The result is the "full natural flow,"

An Upper Watershed with No Development



A Watershed with Ag and Urban Development

Unimpairment Process

- For an upstream (uppermost) undeveloped watershed a good measure of the water supply (index) is precipitation/snowmelt runoff that shows in a watershed is the runoff that shows up at the outflow point

- In this case the runoff = stream flow measured/computed at the outflow location

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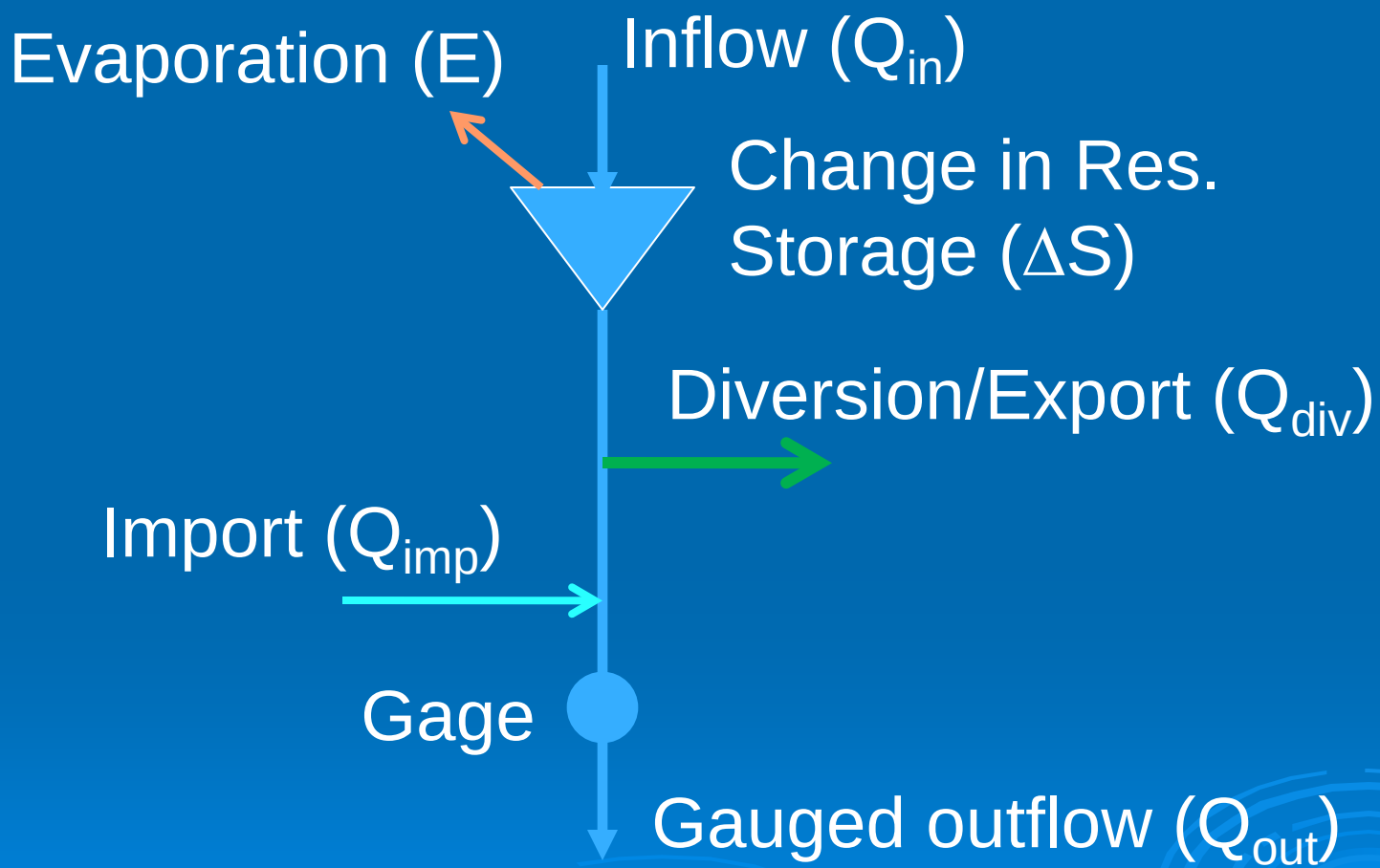
- For an upstream (uppermost) developed watershed impacts of the development (reservoirs, diversions, returns, imports/exports, etc) have to be removed from the measured outflow to get the unimpaired flow

- There are two approaches to the unimpairment process: from the supply side perspective or from the demand sideperspective

- Both approaches have common elements. Main difference is in the unimpairment of depletions: Diversions vs. Land Use (crop acreages, unit ETc, soil moisture accounting)

Conceptual UF Estimation Procedure
(Supply Side Perspective)



$$UF = Q_{out} - Q_{imp} + Q_{div} + \Delta S + E$$

Example: San Joaquin River at Millerton

Flow category	Adjustment	Flow description	Source
Observed flow	+	San Joaquin River below Friant Dam	USGS gage
Diversion	+	Friant-Kern Canal	MI2
	+	Madera Canal	MI1
Storage gain	+	Millerton Lake	MIL (RECL.)
	+	Florence Lake	FLR
	+	Lake Thomas A. Edison	TAE
	+	Huntington Lake	HNT
	+	Shaver Lake	SHV
	+	Mammoth Pool	MPL
	+	Redinger Lake	RDN
	+	Crane Valley (Bass Lake)	CNV
	+	Kerckhoff Reservoir	KRH
Evaporation	+	Millerton Lake	MIL (RECL.)
Unimpaired flow	Sum	San Joaquin River below Friant Dam	SJF

IMPORTANT: Removed diversions are not replaced with native vegetation! Outflow may be overestimated.

Unimpairment Process (Demand Side Perspective)

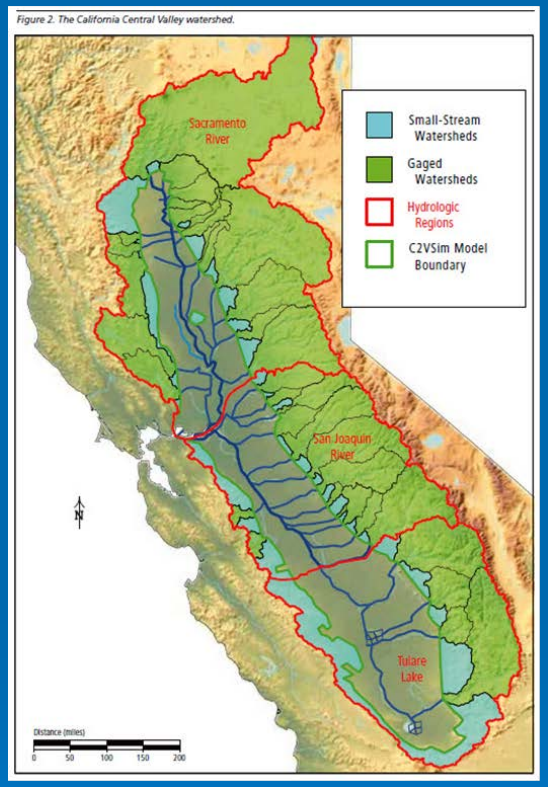
- This approach was used by DWR in developing the hydrological inputs for DWRSIM, CalSim-I and CalSim-II

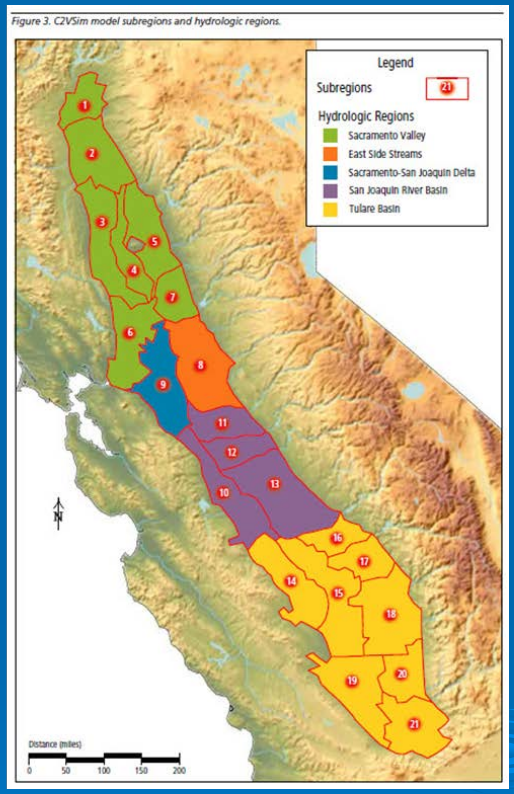
- Starting with the outflow flow, the impairment “builds back into the flow” the impact of the agricultural and urban development from the using land use based estimation of consumptive use or depletions (reservoir storages, imports/exports are handled from the supply side point of view

- A key element in the procedure is that any land use (ag/urban) “removed” is then “replaced” with equal area native vegetation (which would have occurred had the land not been developed).

Watersheds Impact Downstream Areas

In the Central Valley upper watersheds are connected to other areas below: not independent from each other

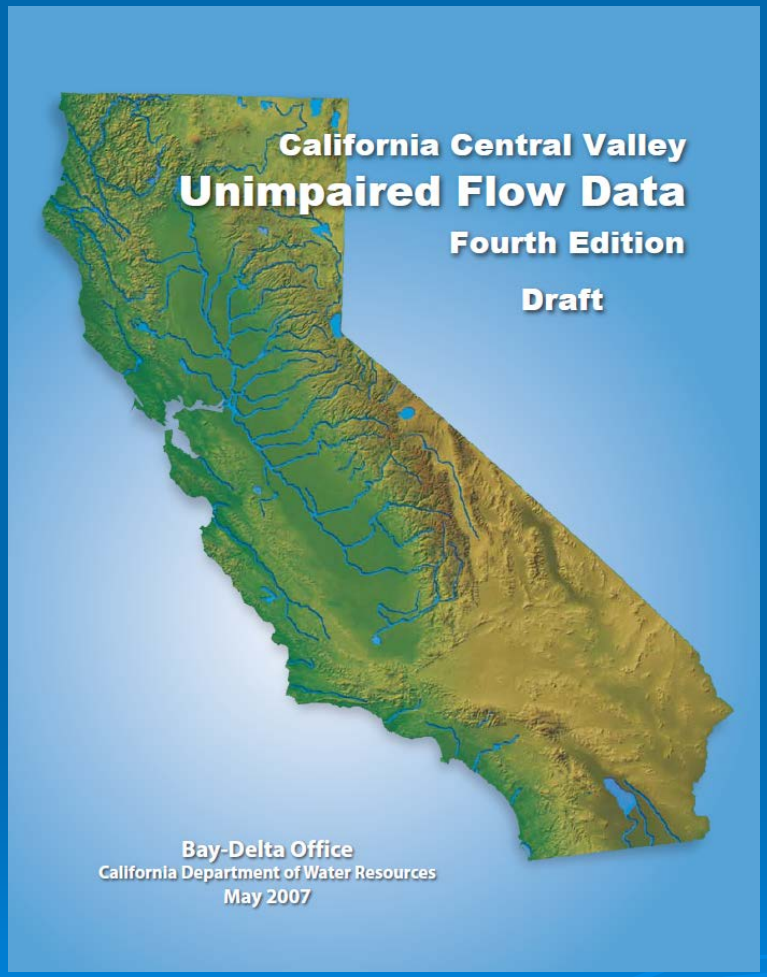




Issues to Consider

- Does the unimpairment process build back in native vegetation over developed ag/urband areas?
- If the outflow from the upper watershed becomes an inflow to a “downstream” watershed or area, that flow is a supply that can meet consumptive demands in the downstream area
- How is ground water and stream – aquifer interaction handled?
- In addition to land use development, human-made levees built on top of natural levees “channelize” water downstream instead of over topping into adjacent areas

Published Unimpaired Flow Data



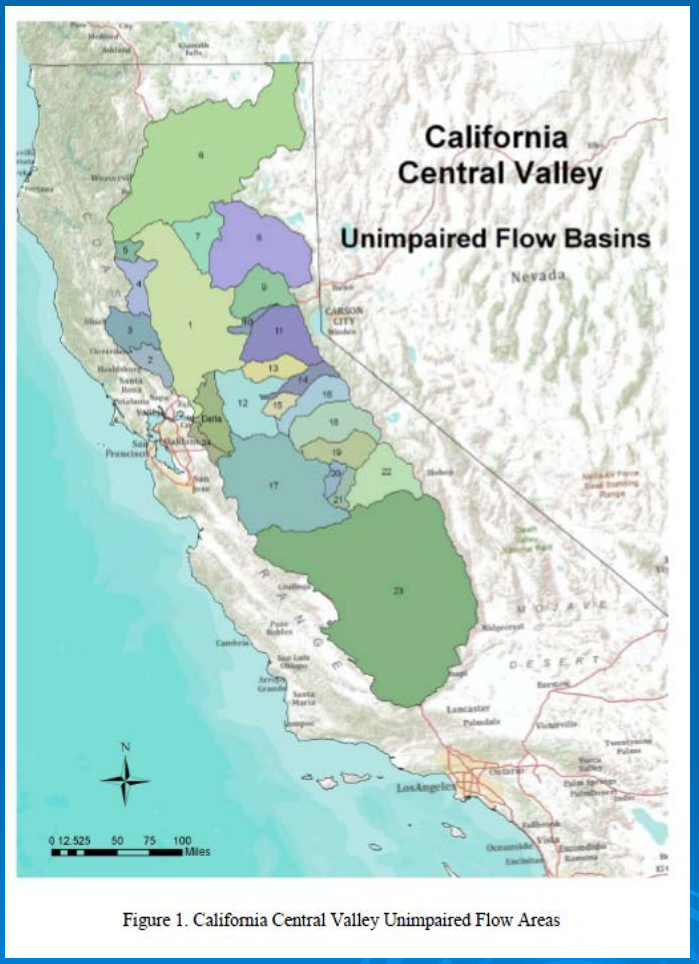


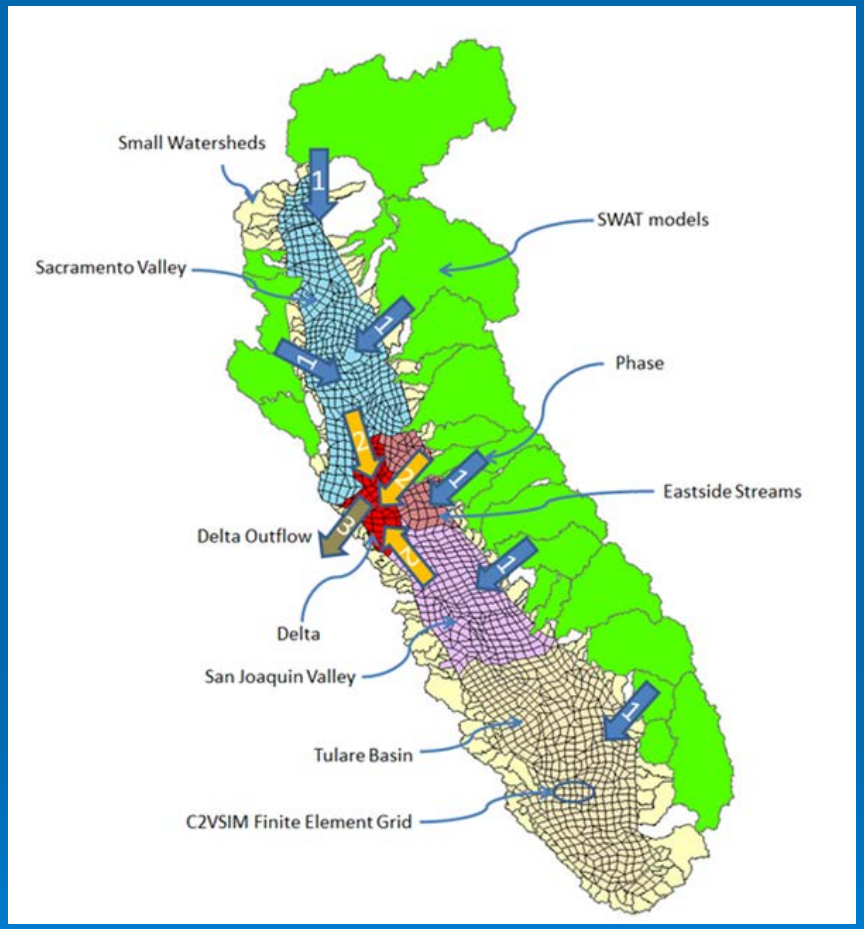
Figure 1. California Central Valley Unimpaired Flow Areas

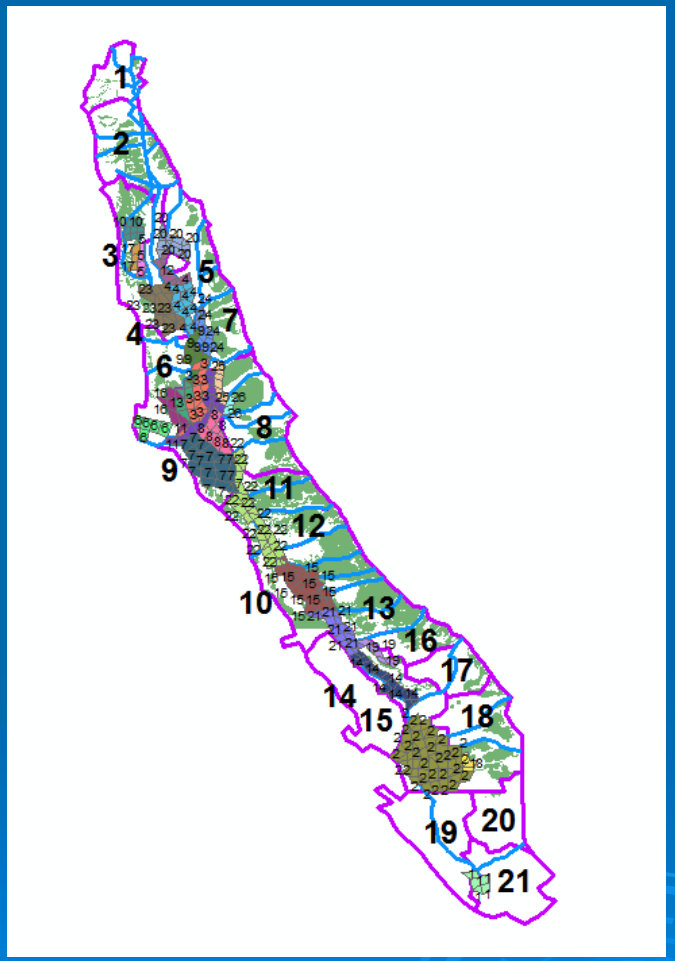
Natural Flow Simulation (Proposed Approach by DWR)

- For a given precipitation trace, if all anthropogenic influences (agricultural and urban development, reservoirs, levees, etc) are removed ***upstream of a location***, and the landscape is replaced with native vegetative classes as existed prior to land use development, and allowances are made for overtopping of streams, and the physical processes of runoff, infiltration, stream-aquifer interaction, lakes are accounted for, the resulting flow will be an approximation of natural flow at that location.

- Objective is to compute stream flows under natural vegetative conditions for both upstream watersheds and downstream (valley floor) areas into and through the Delta

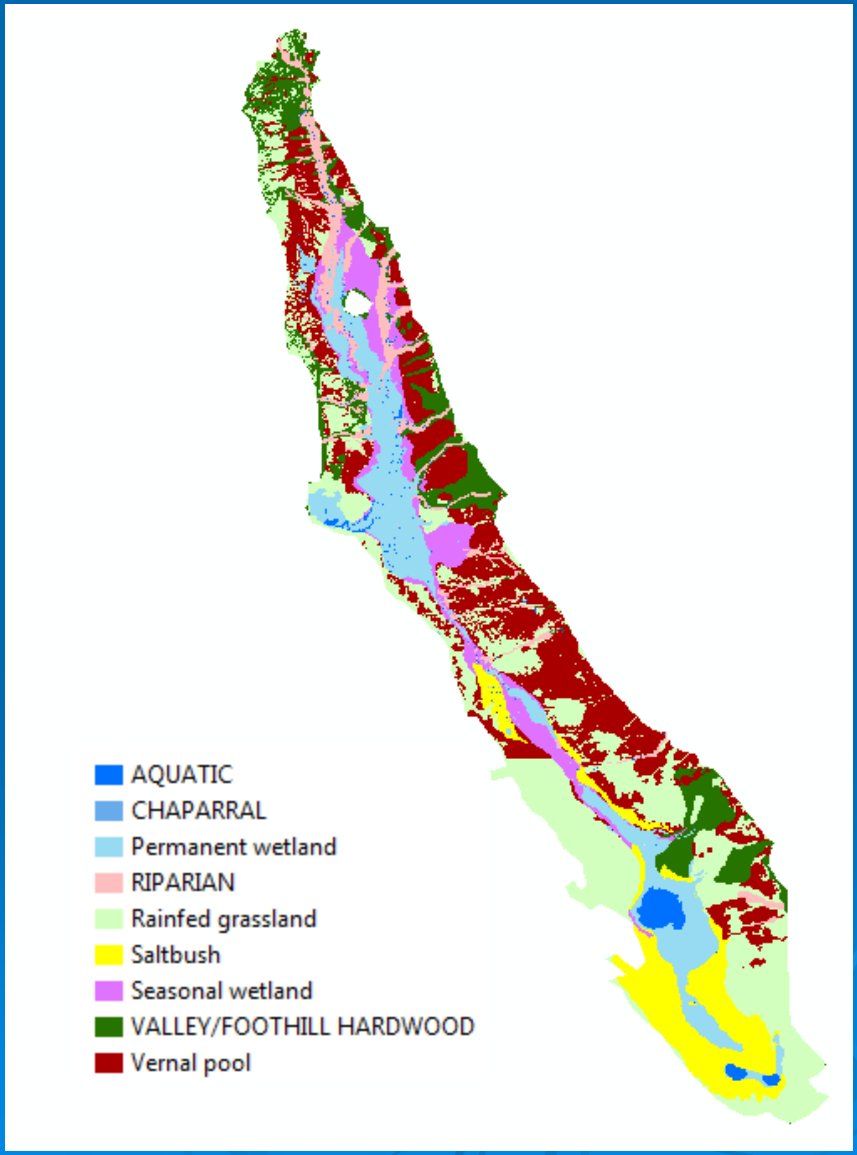
Simulating Natural Flows





Three Phases of Flow: Upper watershed outflows, route through valley floor, route through the Delta

Native Vegetative Classes



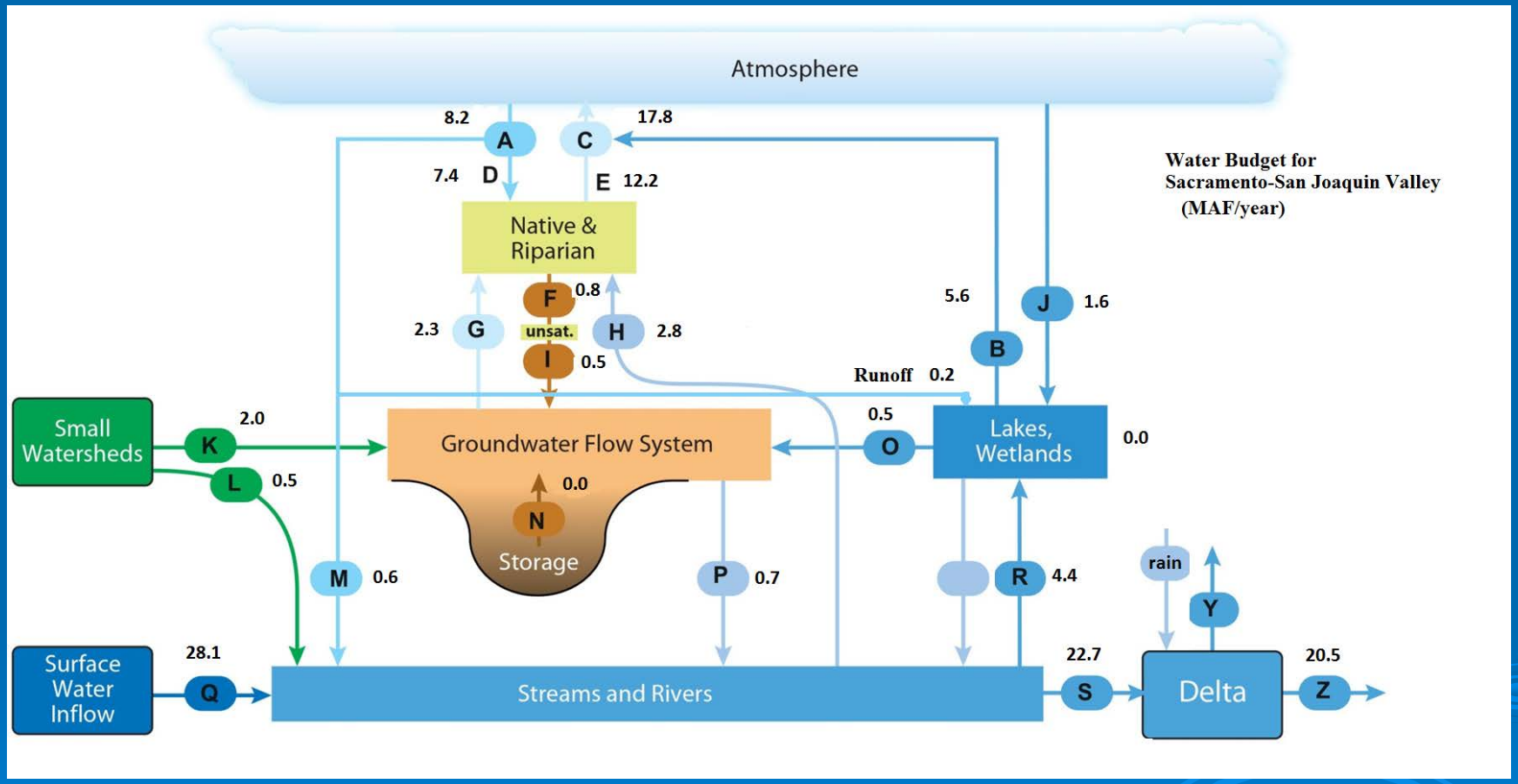
Approach

1. SWAT daily models for 23 major upper watersheds calibrated and verified for 1922-2013 with observed/computed data (monthly, spot check for daily). Minor upper/boundary watersheds modeled within C2VSIM. Compute daily runoffs = outflows.

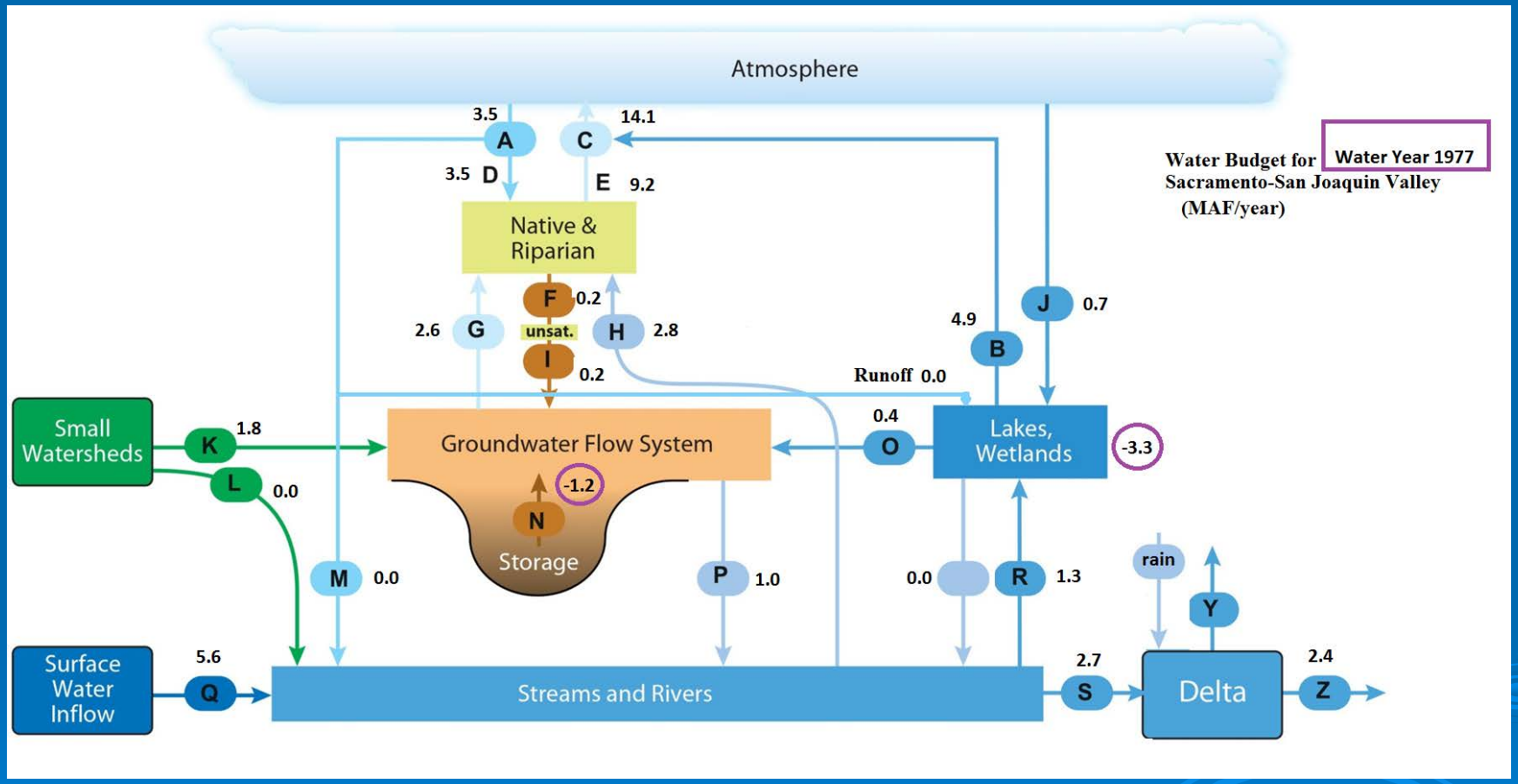
2. Route upper watershed outflows to the Delta using daily C2VSIM:
   - Land use: Native vegetation, riparian vegetation, wetlands and lakes (work by CSU and consultants for MWD)
   - DEM: coarse grid (~ 5miles x 5 miles)
   - Rating curves to allow water flow from streams to lakes/wetlands
   - Connected lakes and wetlands (< 10 ft depth max) with flow back to streams
   - Use ETc estimates (consultants for MWD)
   - Carry out sensitivity runs by varying selected parameters

IWFM version used allows for ground water uptake, riparian/vernal pools access to streams, interconnected lakes, and kinematic wave for routing in streams

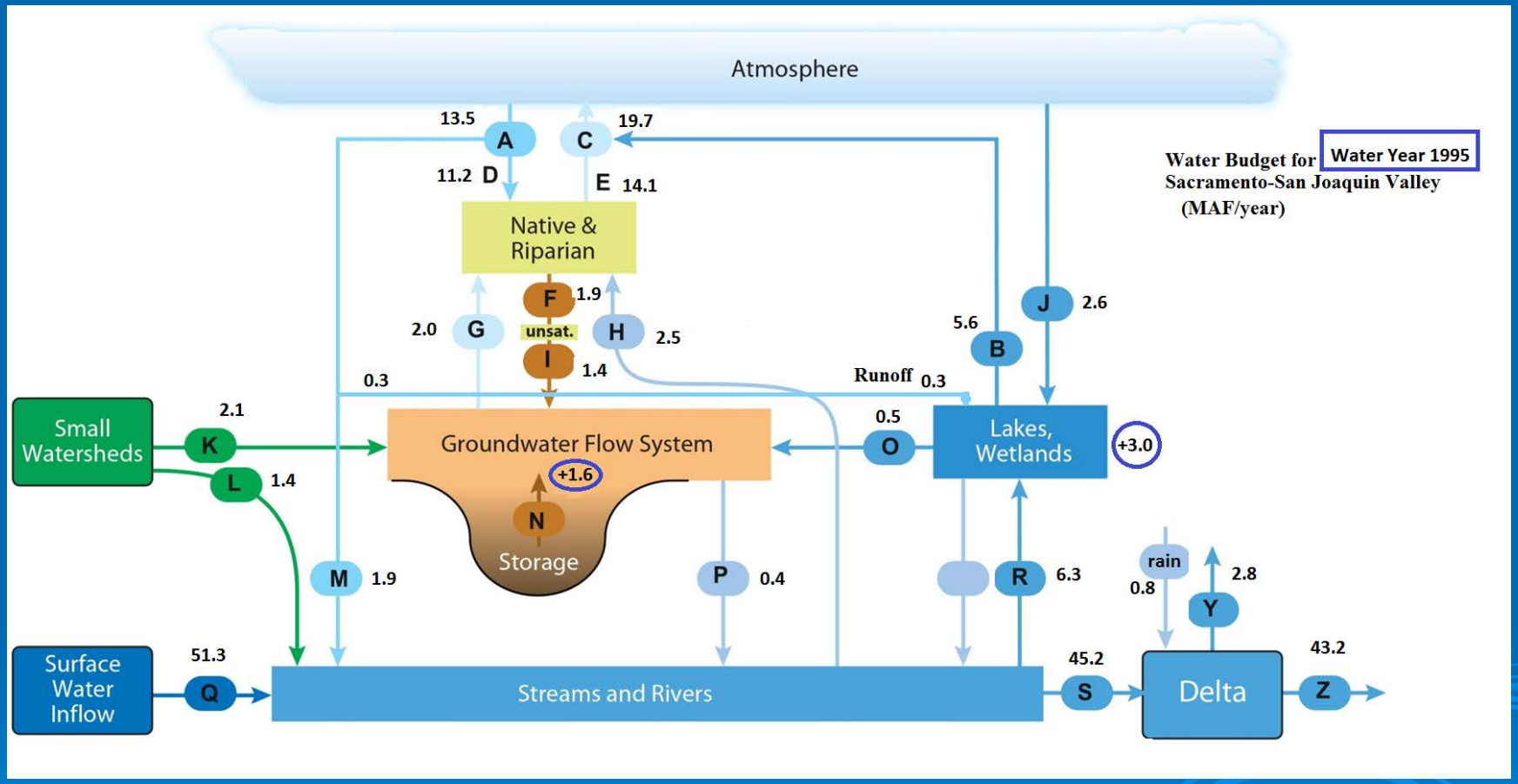
Annual Water Budget (WY1922-2013)



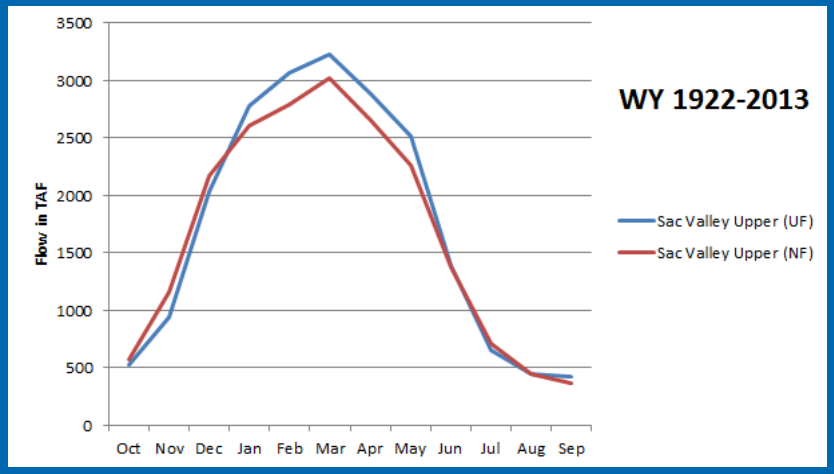
Annual Water Budget (WY 1977 Dry)

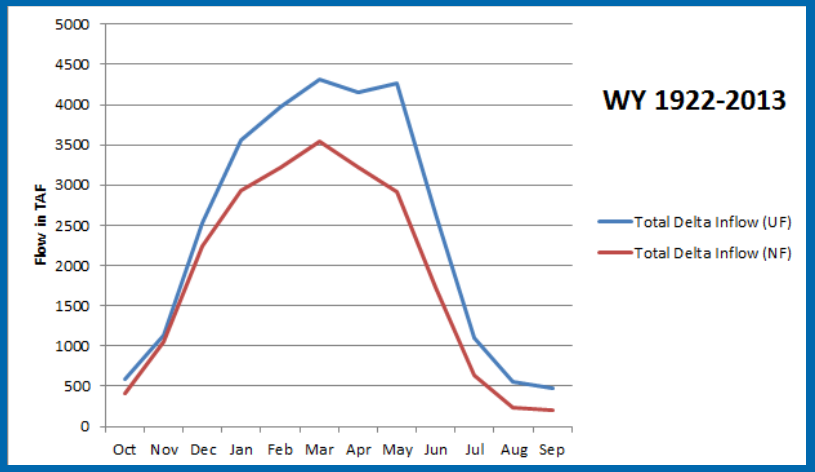


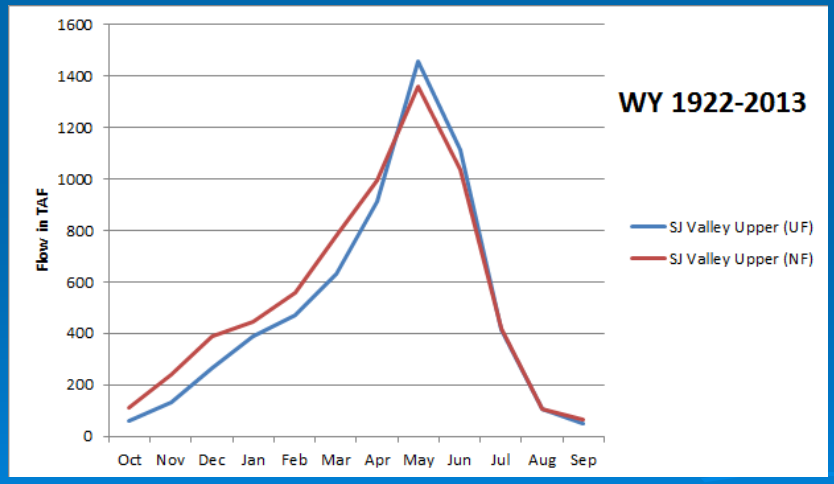
Annual Water Budget (WY 1995 Wet)

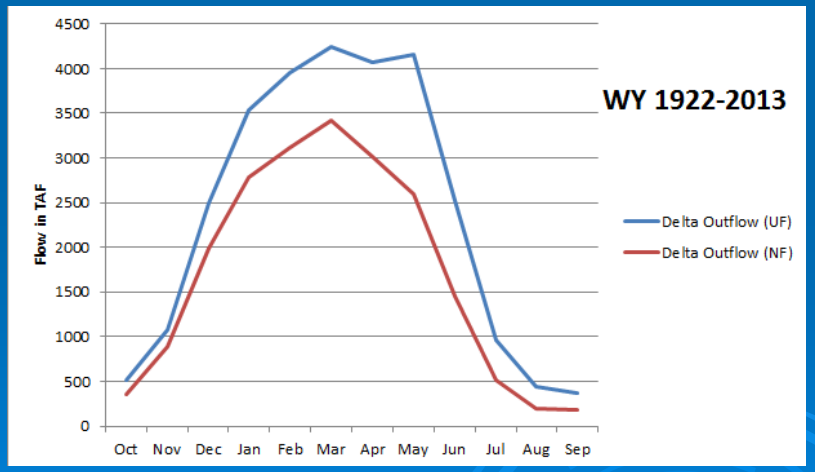


Comparison of Unimpaired Flows vs Simulated Natural Flows









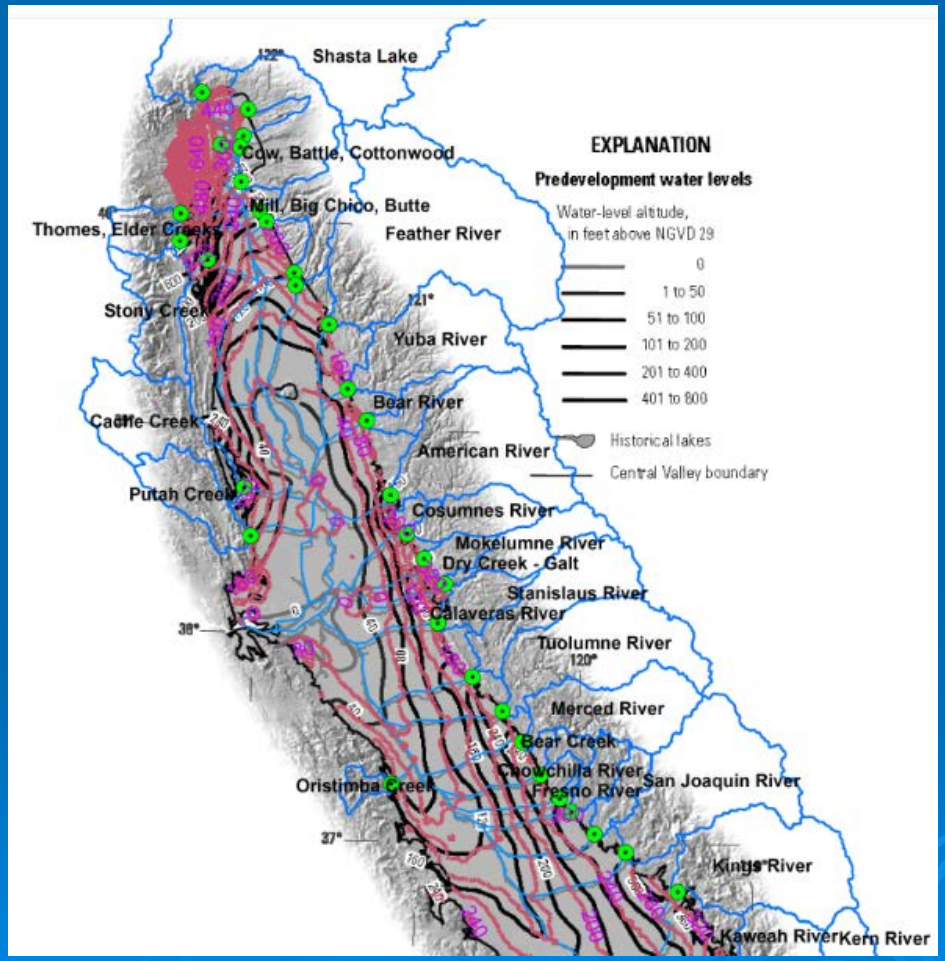
Sensitivity Runs

- Combination of varying parameters and vernal pool simulations:
  - ETc multiplier: 0.9 (1.0) 1.1 1.2
  - Riparian vegetation extinction depths: (20 ft) 40 ft
  - Vernal pools extinction depths: (15 ft)
  - Vernal pools simulations:
    - Access to only nearby streams
    - Access to all streams in the vicinity
    - No access to streams

- Summary results (1922-2013 MAF/yr):

	Lower Bound	Base	Upper Bound
Delta Inflow	21.1	22.5	23.5
Delta Outflow	18.0	20.5	21.4

Comparison of Predevelopment Ground Water Elevations to USGS CVRASA1 (1989)



Animation of Lakes Simulation Results

- This animation is only approximate; assumption is “only if all nodes of the grid element is under water then element is animated as a covered with water (under representation)”
- Link to lakes animation

Concluding Remarks and Future Work

- There is a difference between unimpaired flow and natural flow
- Natural flow simulations provide a better and more reliable estimates of stream flows at locations when upstream land use is under native vegetative conditions (for a given precipitation trace)
- DWR has developed upper watershed SWAT models to compute daily outflows for 1922-2013, and routes the water through the valley floor using C2VSIM and simulates inflows into the Delta and outflow from the Delta
- SWAT and C2VSIM models allow applications of future conditions to study impacts of climate change (precipitation, rising temperatures, Etc)
- Work is under way to prepare a report summarizing all unimpaired flows (WY1922-2013), simulated natural flows, and the listing the differences between them (Draft Spring 2015)

Thank you

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