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Updates of Unimpaired and Natural Flows for Central Valley of California by Bay-Delta Office Extended Through Water Year 2020

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Outline

- Background
- Methods
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- Results
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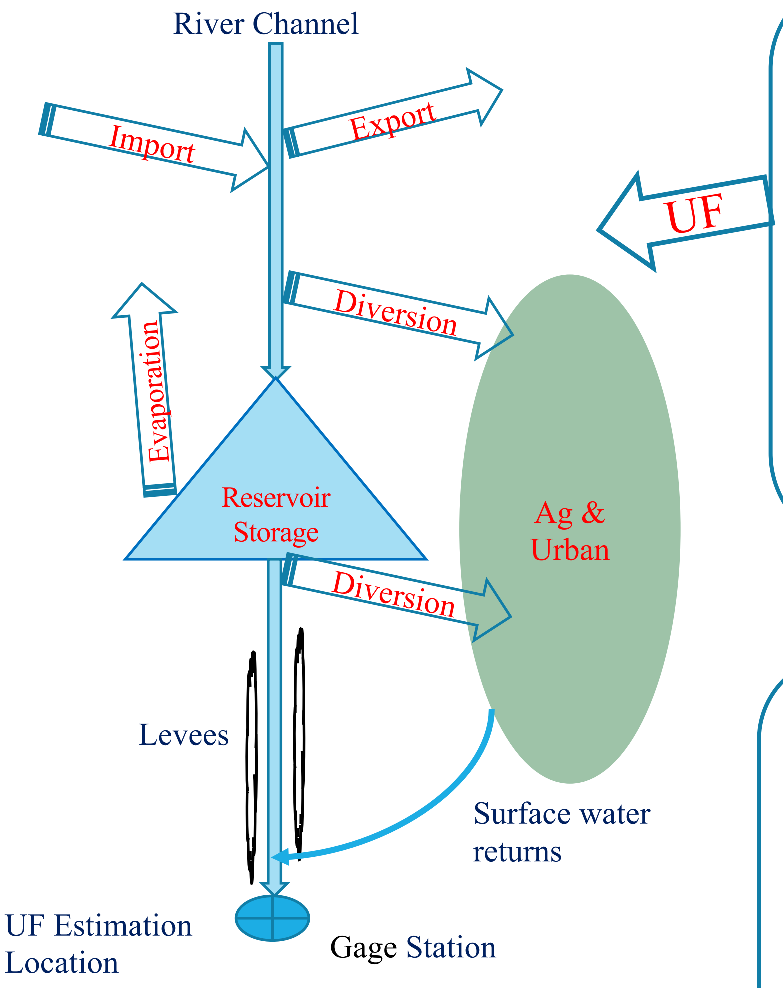
Background-UF and NF Differences



UNIMPAIRED FLOW

Definition: The natural water production of a river basin, unimpaired by upstream diversions, storage, or by export/import of water to/from other watersheds.

Assumption: Current land use, levees, flood bypasses and weirs are all assumed to exist and stream gain/losses do not change.

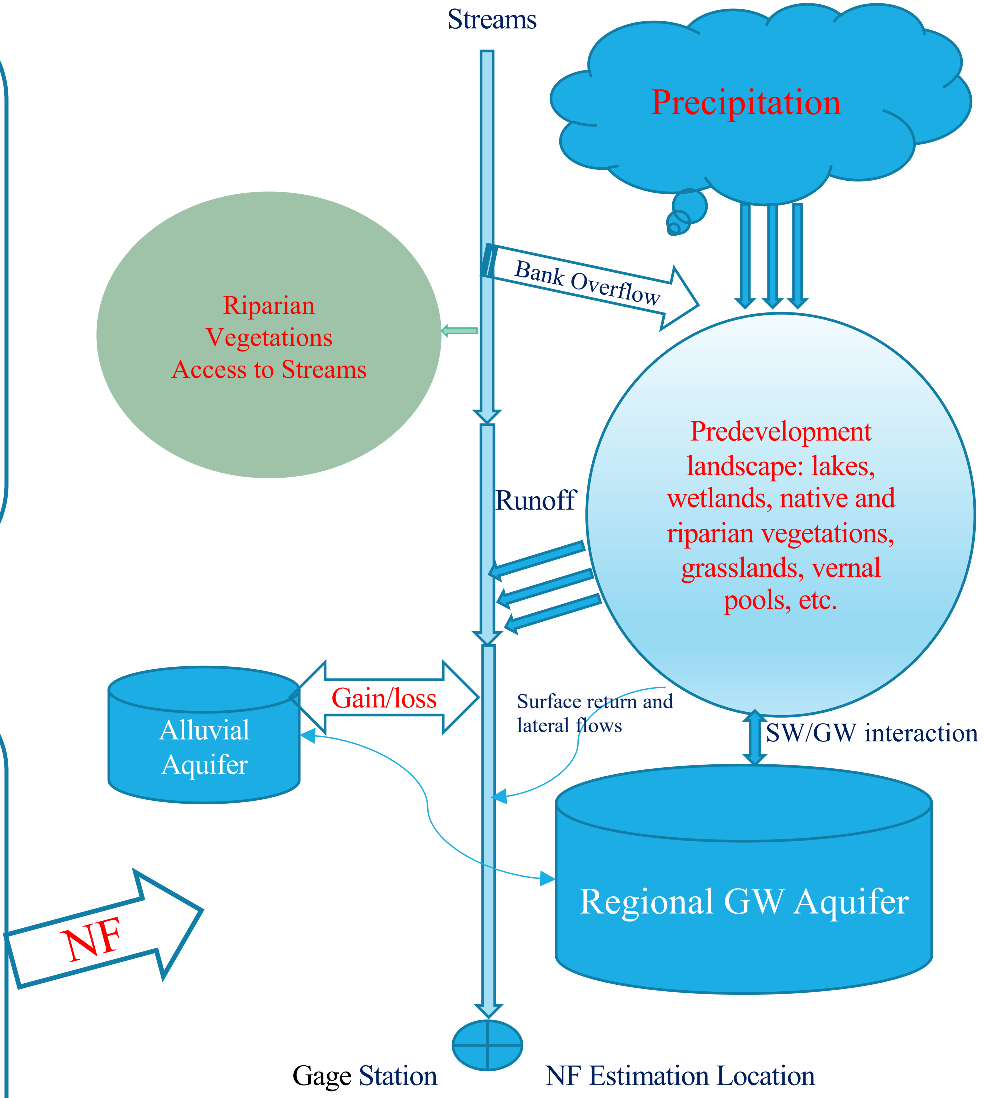
Estimation: Explicit Mass Balance Equation:
Unimpaired Flow = Observed@Gage Station +Diversion + Reservoir Storage + Reservoir Evaporation + Exported Water – Imported Water – Surface water returns (if measured)

NATURAL FLOW

Definition: Theoretical flow that would have occurred in absence of all anthropogenic influences, as in predevelopment landscape or pristine state.

Assumption: Predevelopment lands use stays unchanged, no human alterations to the hydrologic system.

Estimation: Can be simulated with the aid of computer by using machine learning techniques or physically-based hydrological models.



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Background-History of DWR UF/NF Reports

1980- 1st Ed

California Central Valley *Natural Flow* *Data* (WY 1920-1978)

1987-2nd Ed

California Central Valley Unimpaired Flow Data (WY 1920-1983)

1994-3rd Ed

California Central Valley Unimpaired Flow Data (WY 1920-1992)

2007-4th Ed

California Central Valley Unimpaired Flow Data Fourth Edition -Draft (WY 1920-2003)

2018-Draft

Estimates of *Natural Flows* *and Unimpaired Flows for Central Valley of California: Water Years 1922-2015*

Present-

Draft UF Memo
Draft NF Memo
Report is underway (WY 1922-2020)

UNIMPAIRED FLOW | **2017** | + NATURAL FLOW

Background-UF/NF Products in California

Historical and Current Unimpaired and Natural Flow Estimates Available in California

Flow	Computing Agency	Time Scale	Update Frequency	Geographic extent	Statistics	Main Applications	Methods	Calculation Difficulty	Hydrologic Components and Assumptions	Interpretably	Data Availability	Limitations
Unimpaired Flow	DWR-DFM	Monthly	Once a Month	36 Locations Statewide, Mostly Upper Watersheds	Deterministic	Flood Management	Mass-Balance	Simple, even can be calculated by a calculator	Reservoir Storage, Evaporation, Diversions, Imports/Exports, and others that data available; Assumptions: no changes in stream-groundwater interaction, current land use, current river channel configuration	Explicit, can be written as mathematical formula	1900s - present	Statistical Regressions and Expert knowledge needed to estimate unavailable or missing data
	DWR-BDO	Monthly	Every Few Years	14 Locations Central Valley Watersheds	Deterministic	Water Management and Planning					Water Years 1922-2020	
	DWR-DFM and Local Irrigation Districts	Daily	Mostly Daily (not on weekend)	19 Locations Statewide, Mostly Upper Watersheds	Deterministic	Flood Management					1980s - present	
	SWRCB	Monthly	Every Few Years	Sacramento Valley and Delta	Deterministic	Water Management and Planning	Accounting with addition of rainfall runoff from CalSimHydro and Stream Gain/Loss from C2VSim	Accounting with Sacramento Valley Unimpaired Flow Model (SVUFM) , need a computer	Include stream/groundwater interaction and local rainfall runoff to the system using outputs from other models		Water Years 1922-2015	Uses DWR' UF at Rim Inflow Locations; Rely on outputs from other models
Natural Flow	The Nature Conservancy and USGS	Monthly	Every Few Years	Entire California River Basins	Mean, Median, Min, Max	Ecosystems, Environmental Flow	Statistical Models (Machine Learning)	Must use computer simulation or learning	Physical watershed characteristics (geology, soils and elevation) and climate (precipitation and temperature)	Implicit (black box), hardly interpretable	1950-2021	No daily data; lacked physical interpretation;
	DWR-BDO	Monthly Daily	Every Few Years	Up to 36 Locations in Upper Watersheds, 74 Reaches in Valley and Delta	Best Simulation Value	Water Management and Planning, Climate Change Studies	Combination of Semi-Distributed Hydrologic Model (SWAT) and Integrated Surface and Groundwater Model (C2VSim)		Vegetative consumptive use, overbank flows from streams, stream/groundwater interaction, infiltration, runoff, return flows, and uptake from groundwater, so on.	Physically-based, Hydrologically interpretable	Water Years 1922-2020	Complex, computationally intensive

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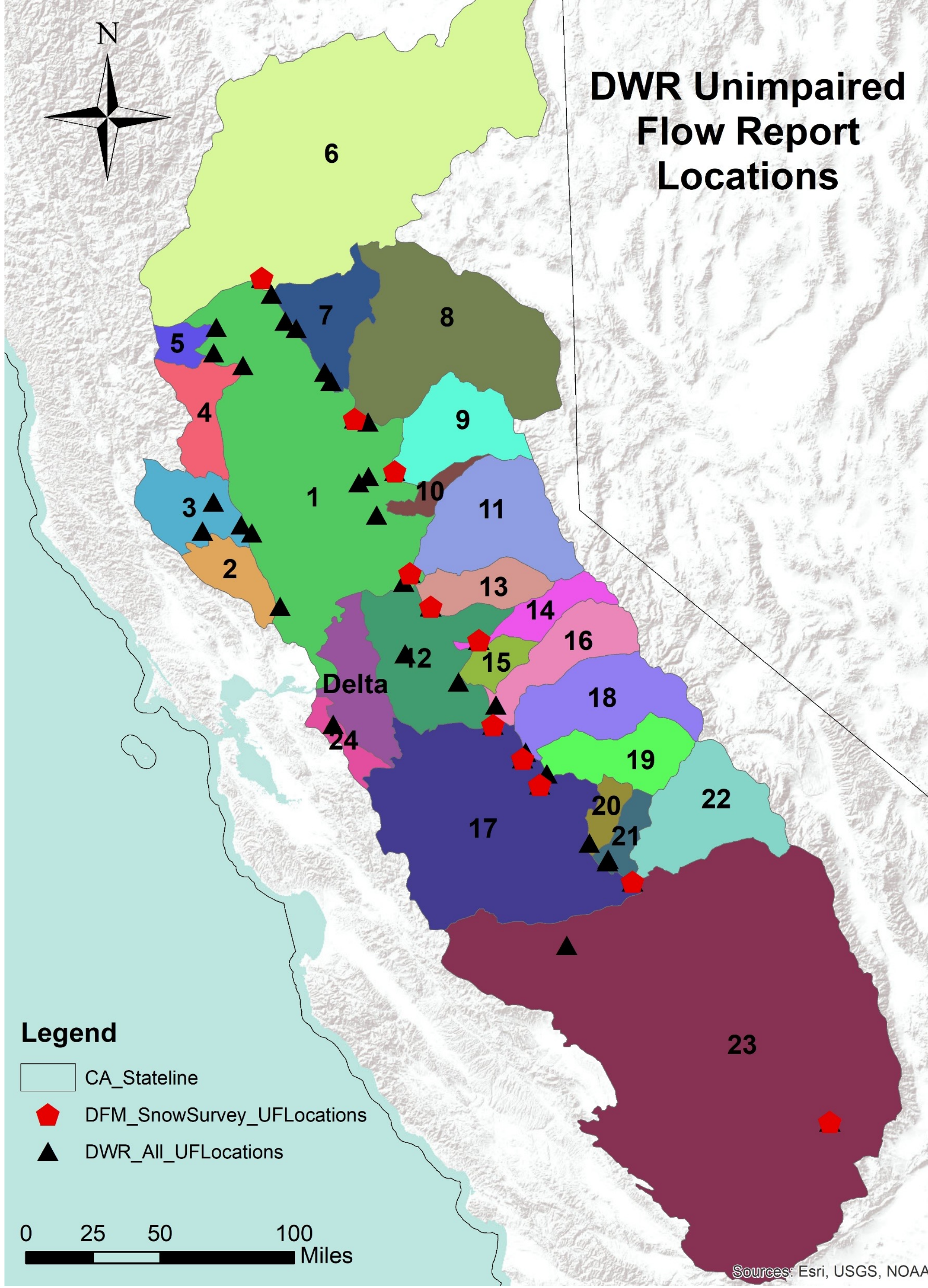
Methods-Unimpaired Flow

- UF estimation procedures in ***"Estimates of Natural Flows and Unimpaired Flows for Central Valley of California: Water Years 1922-2015"*** *(DWR, 2018).*

- **24** unimpaired flow data locations/subbasins reported by DWR
  - **10** of them are for major subbasins published in CDEC and maintained by DFM
  - **14** subbasins are for coastal rim watersheds or Sierra Nevada minor streams and Valley floor, the estimation is provided by BDO.

- Each location has explicit mass balance equation. Some missing data gaps are filled by regression methods using data from nearby watersheds.

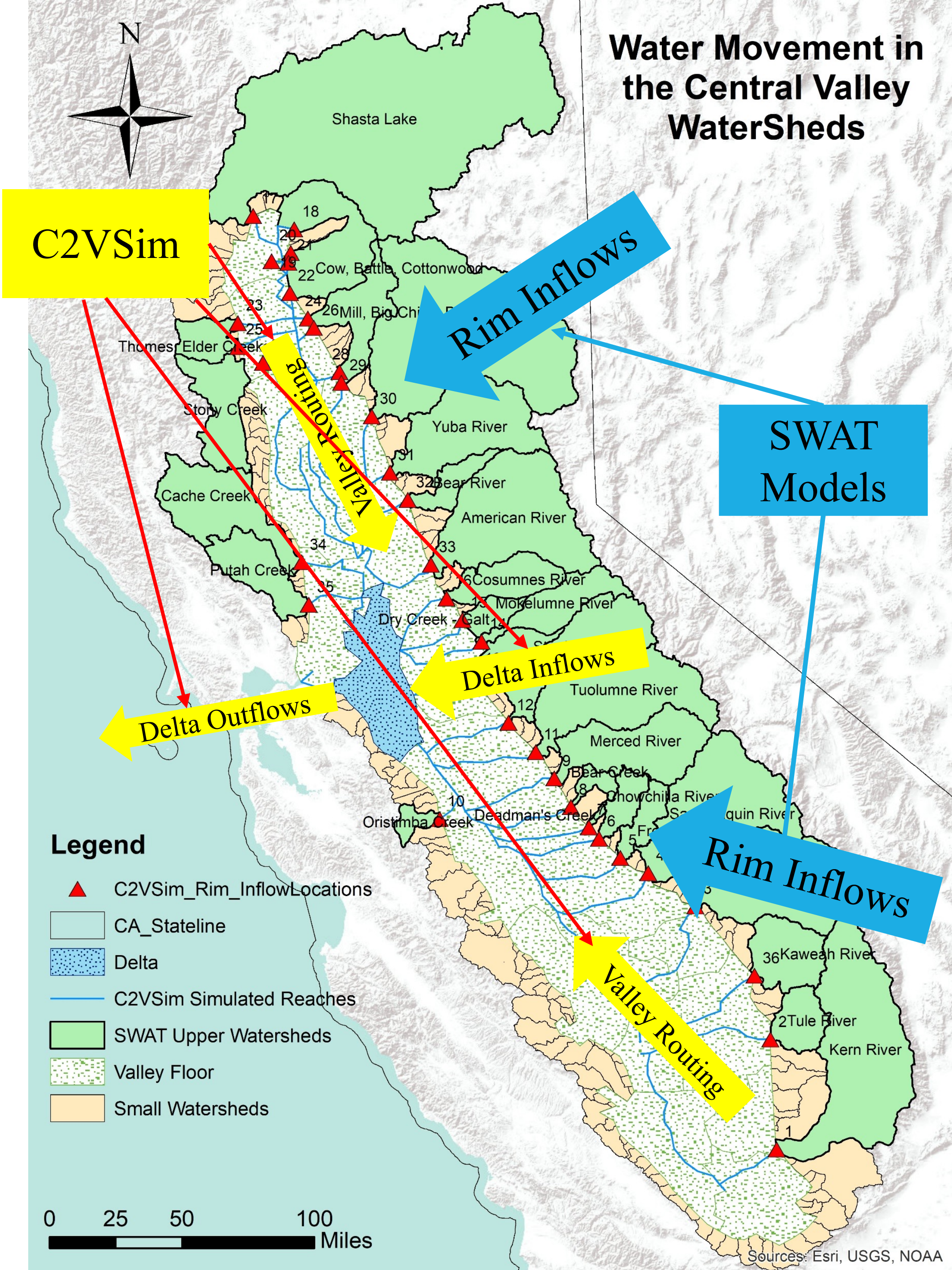


Methods-Natural Flow

- Three phases of water movement from the Sierra mountains to the ocean:
  - Upper watershed outflows
  - Route through valley floor
  - Route through the Delta

- The upper mountainous watersheds: Precipitation-runoff models – **SWAT** (**25** SWAT models for **36** Rim inflow locations)

- The Central Valley floor including Delta: Integrated Hydrologic Model - **C2VSim** Daily Model for pre-development natural conditions – native land cover , no man-made features, no diversions, no groundwater pumping



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Methods-Natural Flow

Native Vegetation and Spatial Distribution

- The backbone of C2VSim daily model for predevelopment natural conditions.
- Compiled and developed from multiple sources of historical maps.
- Circa 1850, Pre-development conditions, no agriculture or urban; no water facilities;
- Nine land coverage types; grassland, vernal pools and hardwood outside of historical flood plains.

References: *CSU Chico (2003), Fox et al. (2015), Küchler (1977).*

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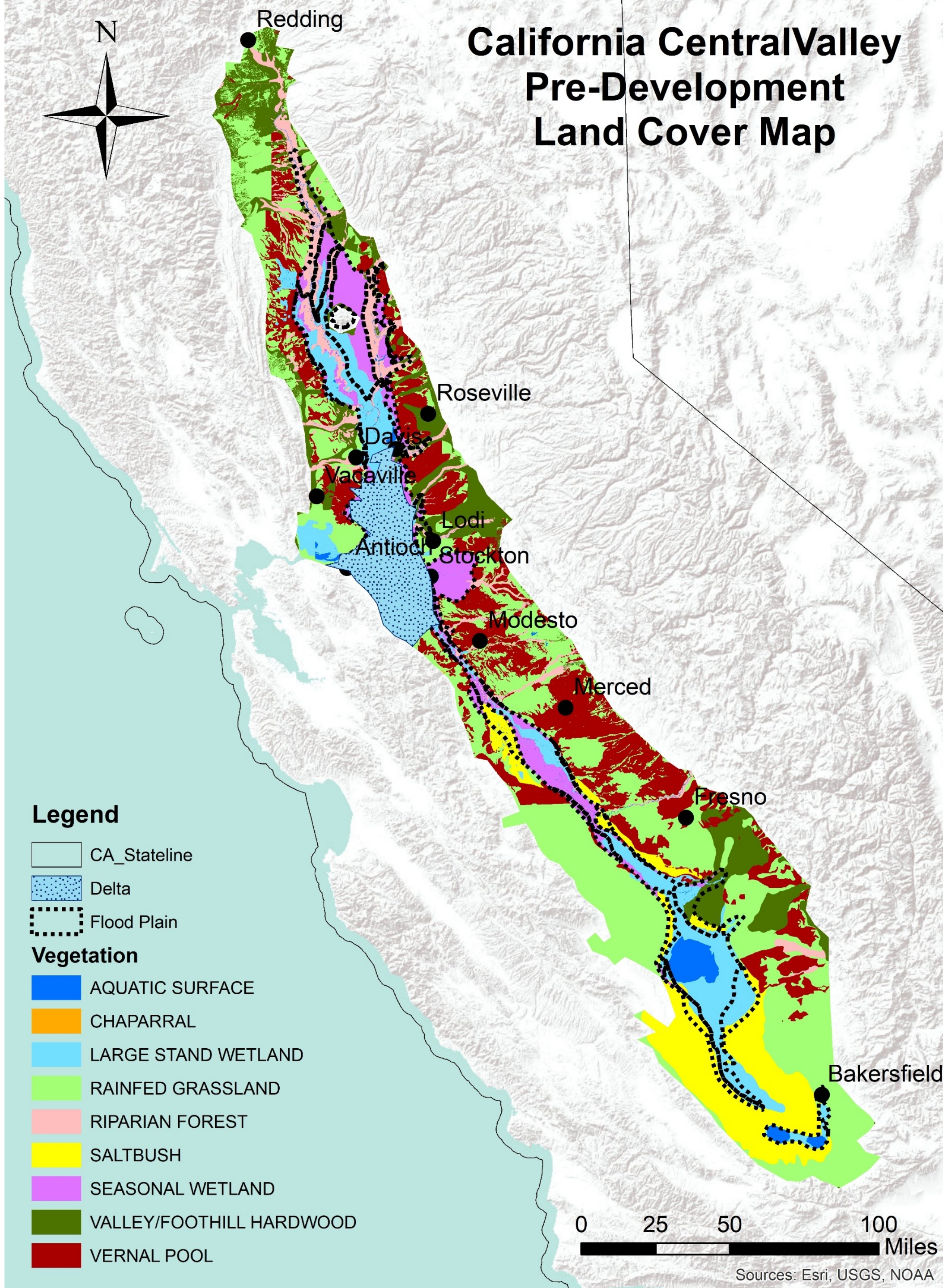


Methods-Extension of SWAT and C2VSim

- Modified, updated and extended SWAT models by extending Precipitation, Maximum and Minimum Temperature at SWAT subbasin level using daily PRISM data for WY 2016-2020.

- Extended C2VSim Daily Model by extending Precipitation using PRISM daily data at each model element; Reference ET and Vegetation ET using CAL-SIMETAW 4x4 km gridded data (*Orang et al., 2013*) and monthly vegetation coefficients (*Kv*) (*Howes, et al., 2015*) at subregion level for WY2016-2020.

- IWFM 2015 features : Root zone groundwater uptake, Riparian vegetation access to stream water, Kinematic wave stream routing, Lake option inflow/outflow rating tables.

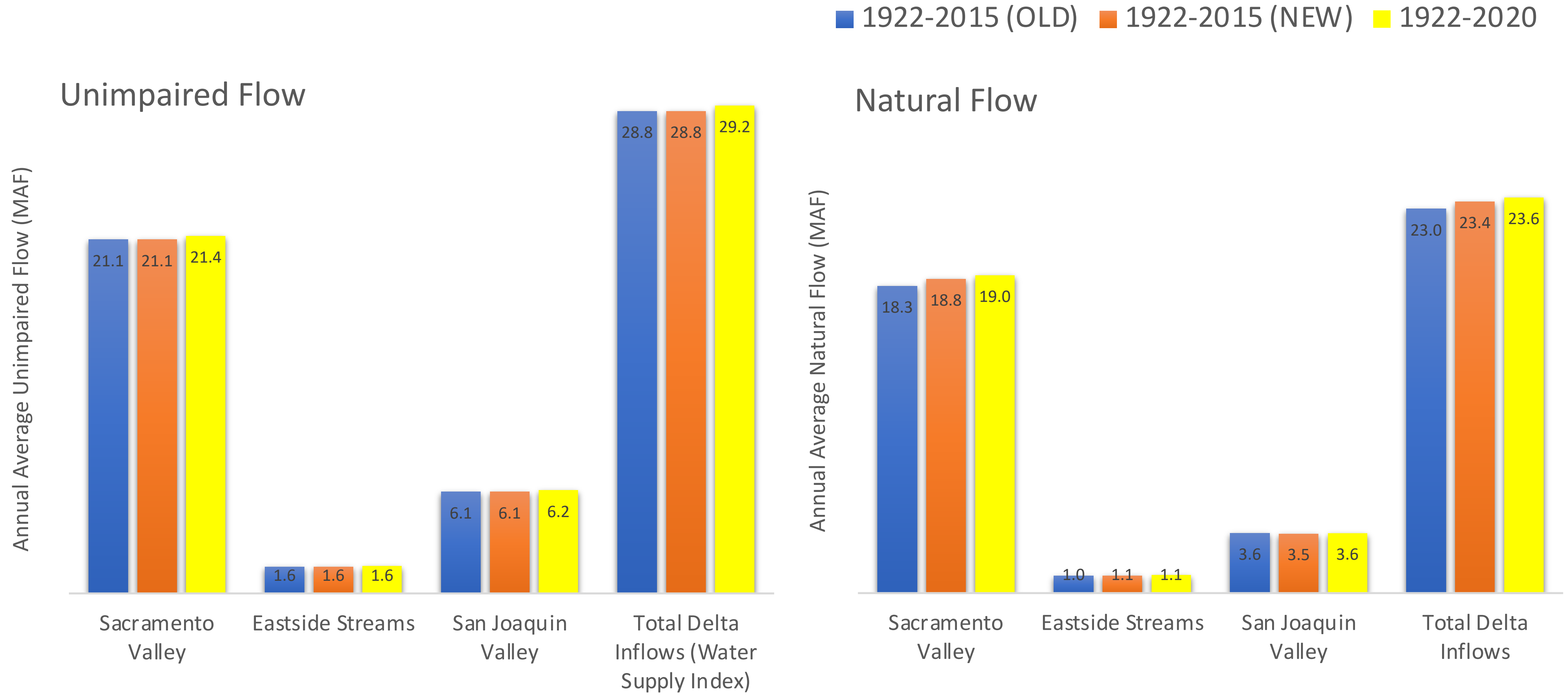
- All the model runs compared and verified at daily, monthly and annual time scales to published UF and NF data of the previous report (WY 1922-2015).

Results-Performance of SWAT models

SWAT Calibration and Validation Statistics Summary:
Sacramento River and Eastside Streams (WY 1922-2020)

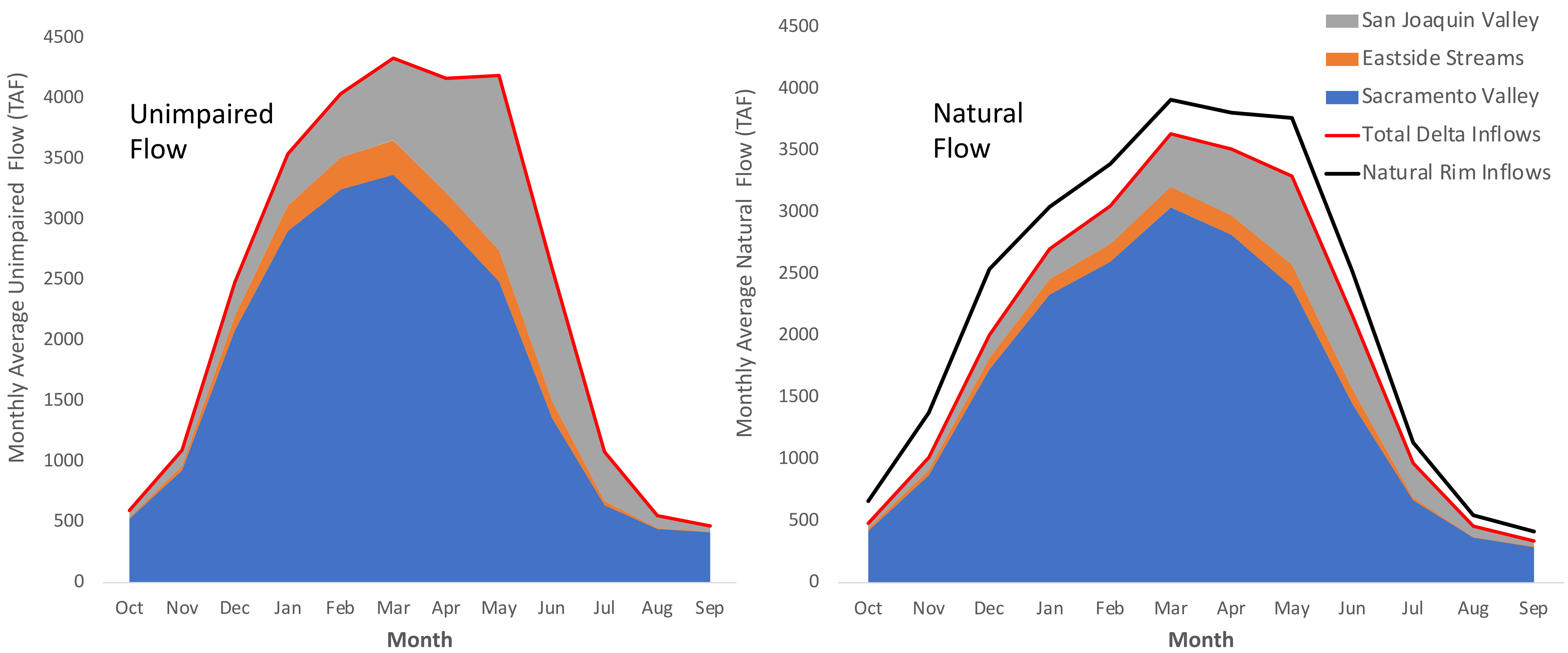
Watershed	No. of Subbasins	No. of HRUs	Drainage Area (km^2)	R^2	Nash-Sutcliffe Efficiency
Sacramento River at Shasta	25	98	16,261	0.90	0.90
Feather River	64	99	9,335	0.91	0.91
Yuba River	39	122	3,174	0.85	0.84
American River	31	200	4,943	0.89	0.88
Bear River	19	46	752	0.88	0.84
Putah Creek	27	51	1,506	0.88	0.84
Cache Creek	25	45	2,440	0.83	0.80
Stony Creek	29	63	1,963	0.70	0.69
Thomes Creek	36	156	699	0.73	0.73
Elder Creek				0.70	0.69
Sacramento East Side Minor Streams (Deer Creek)	324	1221	51,528	0.84	
Cosumnes River	38	132	1,387	0.85	0.85
Mokelumne River	23	77	1,502	0.80	0.79
Calaveras River	25	117	933	0.87	0.87

Results-Consistency Check for Delta Inflows



Comparison of extended annual average UF/NF Delta inflows to previously published UF/NF data (in Million Acre-Feet (MAF))

Results-UF/NF Delta Inflows



Monthly Average UF/NF Inflows to Delta for WY 1922-2020 (in Thousand Acre-Feet (TAF))

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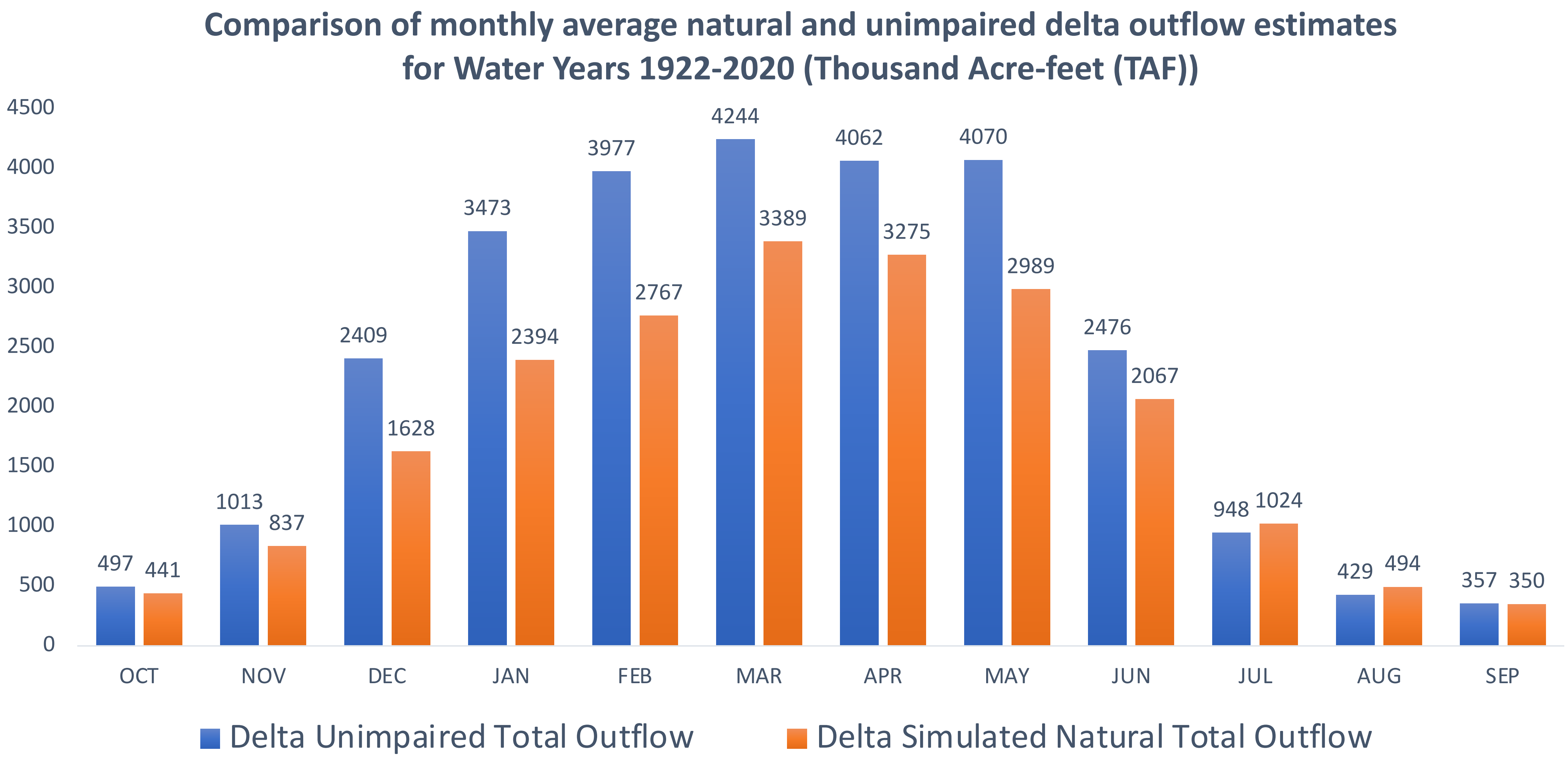
Results-Monthly UF/NF Delta Outflows



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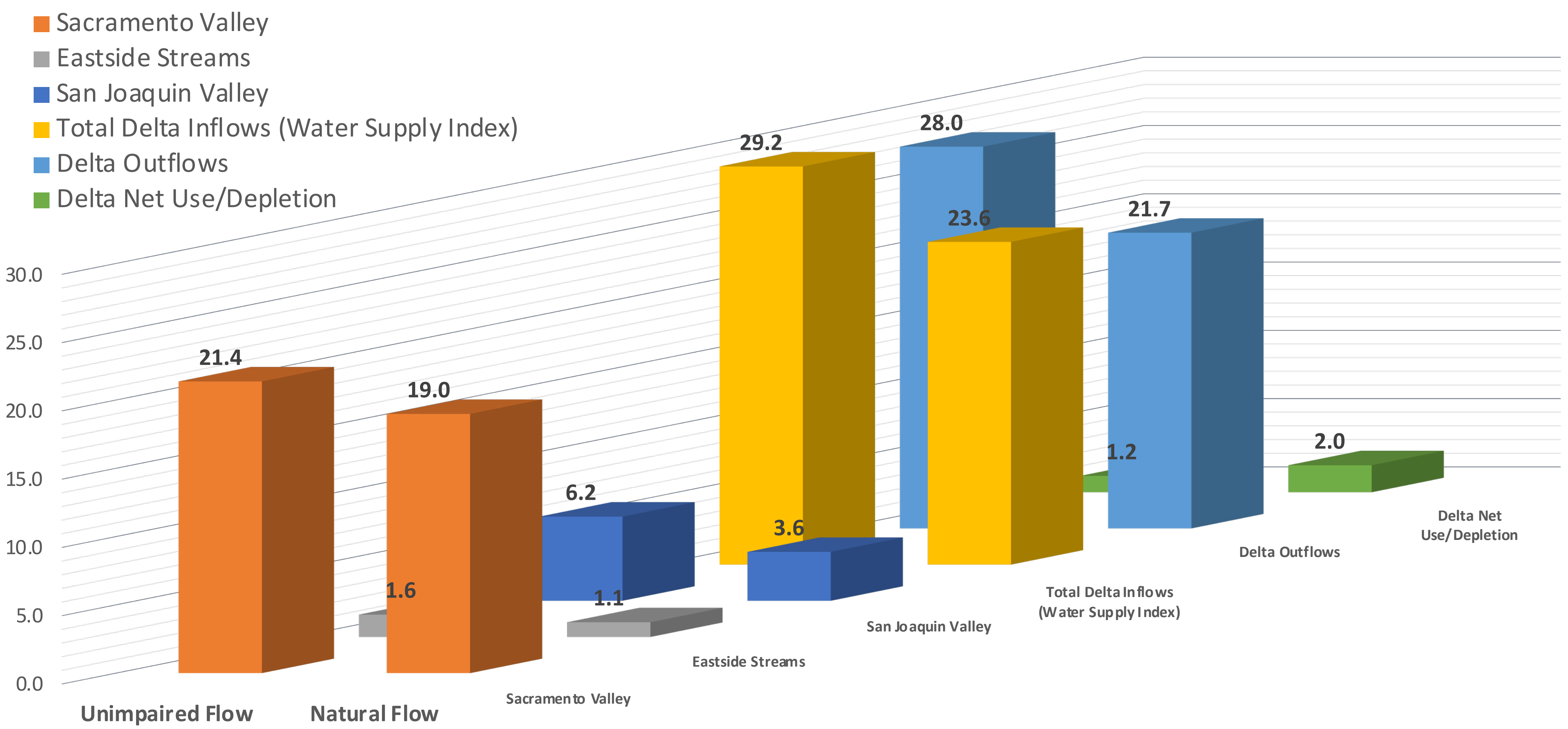
Results-Annual UF/NF Delta Inflows/Outflows

Contributions to Delta Natural Inflow:

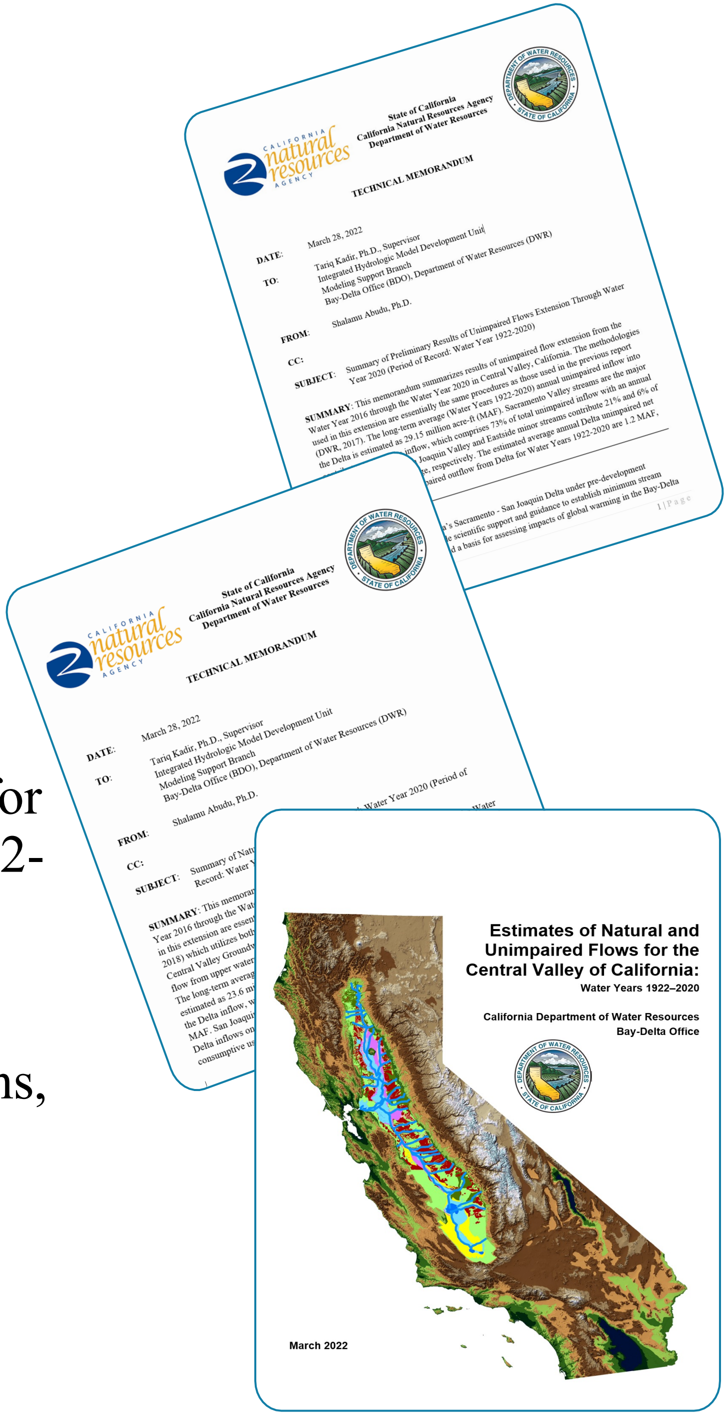
- Sacramento Valley: 80 %
- San Joaquin Valley: 15 %
- East Side Streams: 5%



Annual Average UF/NF Estimates for Water Years 1922-2020 (in Million Acre-Feet)

Summary

- For Delta inflow, UF is better described as water supply index, and NF is streamflow simulated by combination of physically-based hydrologic models, and better represent the Delta inflow under natural conditions.
- We have modified, enhanced and extended 25 upper watershed SWAT models and C2VSim Daily model for the period of WY 1922-2020.
- We have completed the extension of monthly UF, daily and monthly NF data for another 5 years in the Central Valley watersheds. Now the data covers WY1922-2020 and are available for sharing.
- We have completed drafts of two separate Memorandums for UF/NF extensions, and they currently are under review. We are currently drafting the final comprehensive report, and hopefully, we will publish it in the coming months.



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Thank You

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