Sierra Valley Groundwater Model Workshop

University of California Davis

Hydrologic Research Laboratory

March 31, 2017

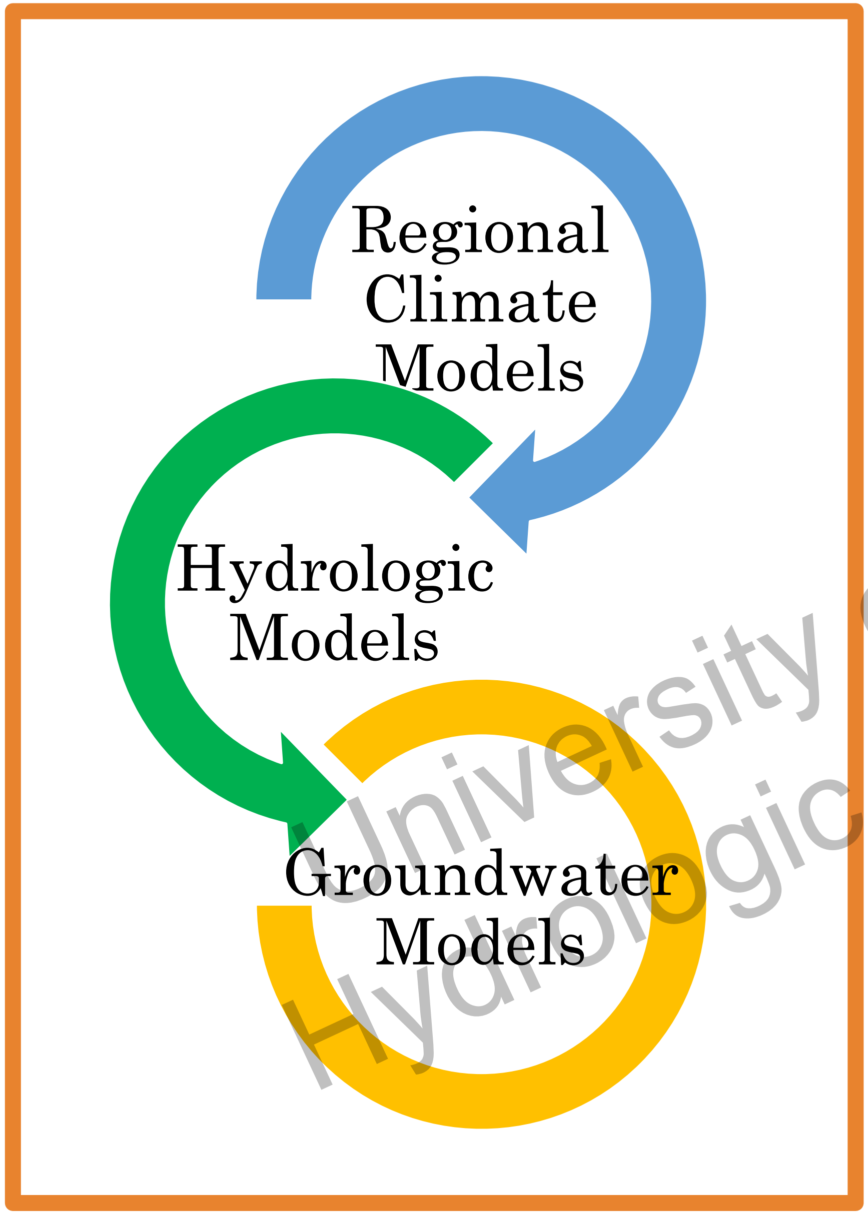
Beckwourth

Outline

- Introduction
- Integrated Hydrological Modeling
- Sierra Valley Groundwater Model
- Historical Simulations (WY2000-WY2010)
- Future Simulations (WY2010-WY2100)
- Questions from SVGMD

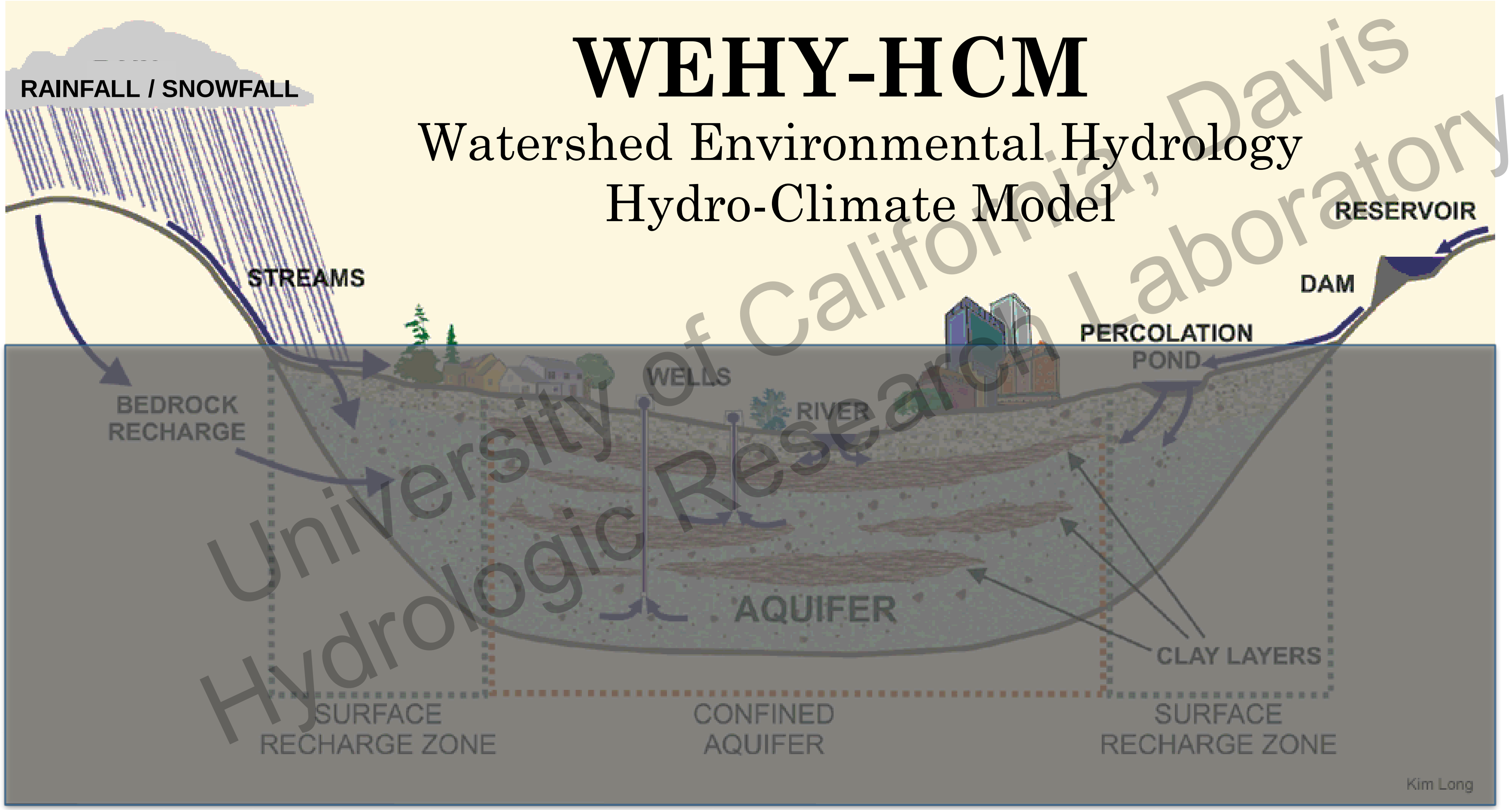
Introduction

- Project: Hydrological Modeling of the Upper Middle Fork Feather River (UMF) Basin
- Goal: Assessment of the hydrological conditions in the UMF Basin during the 21st century.
  - UMF Basin
  - Lake Davis
  - Sierra Valley Groundwater Basin
- Project Period: 2013 – 2016
- Funded by: Prop 50



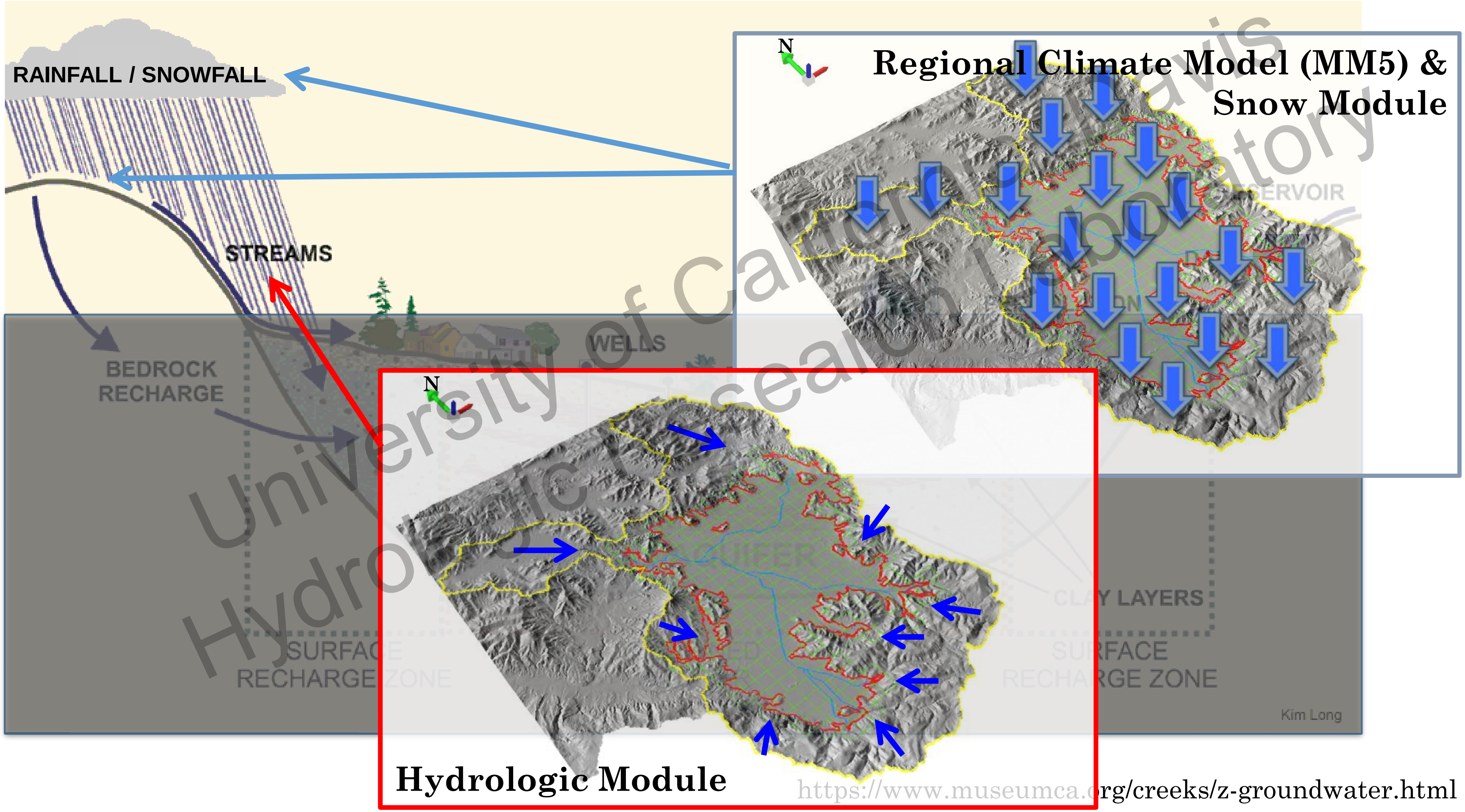
Integrated Hydrological Modeling

Sierra Valley Basin - Foothills



https://www.museumca.org/creeks/z-groundwater.html

Sierra Valley Basin - Foothills

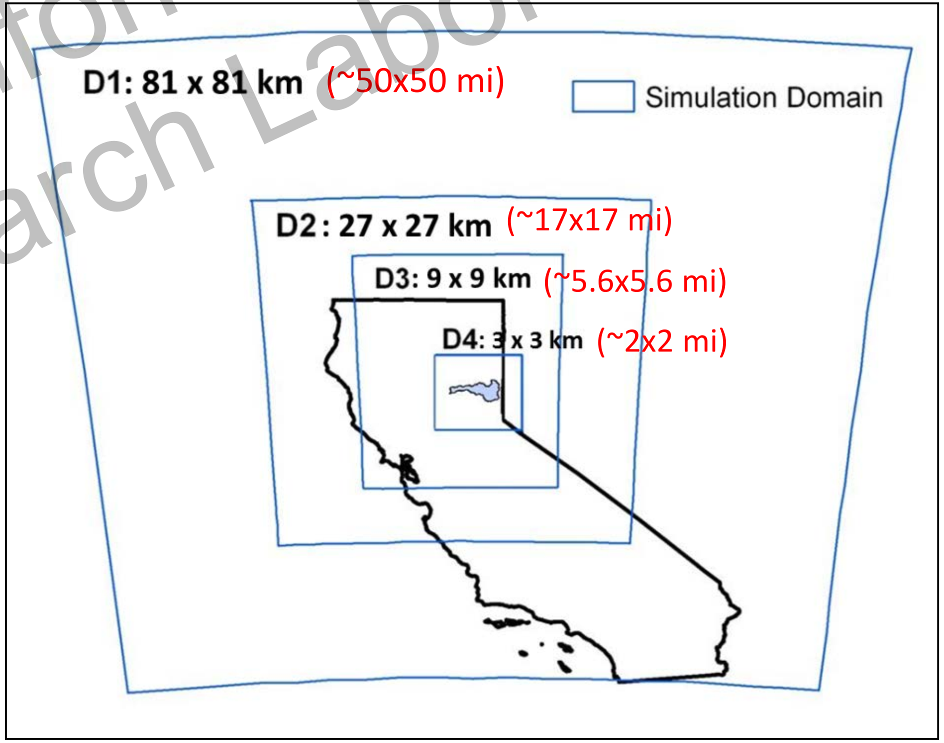


https://www.museumca.org/creeks/z-groundwater.html

Dynamical Downscaling

- Global data downscaled from ~130-mi resolution to a ~2-mi resolution over the basin at hourly time intervals
- Downscaling done for
  - Historical period from 1951 to 2013 using NCEP/NCAR Reanalysis data
  - Future period from 2010 to 2100 using 13 different climate projections

Use of one-way nesting of four domains, where each nest's resolution being one-third of its parent domain resolution:



Reconstructed Historical Climate

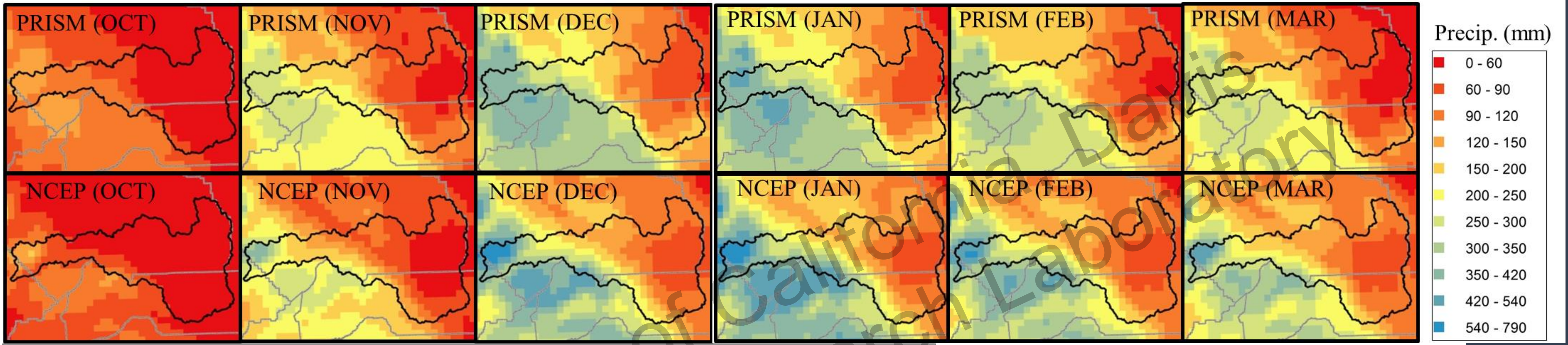
- Dynamical downscaling of historical NCEP/NCAR Reanlysis data
  - Reconstructing historical climate over study basin at a fine resolution

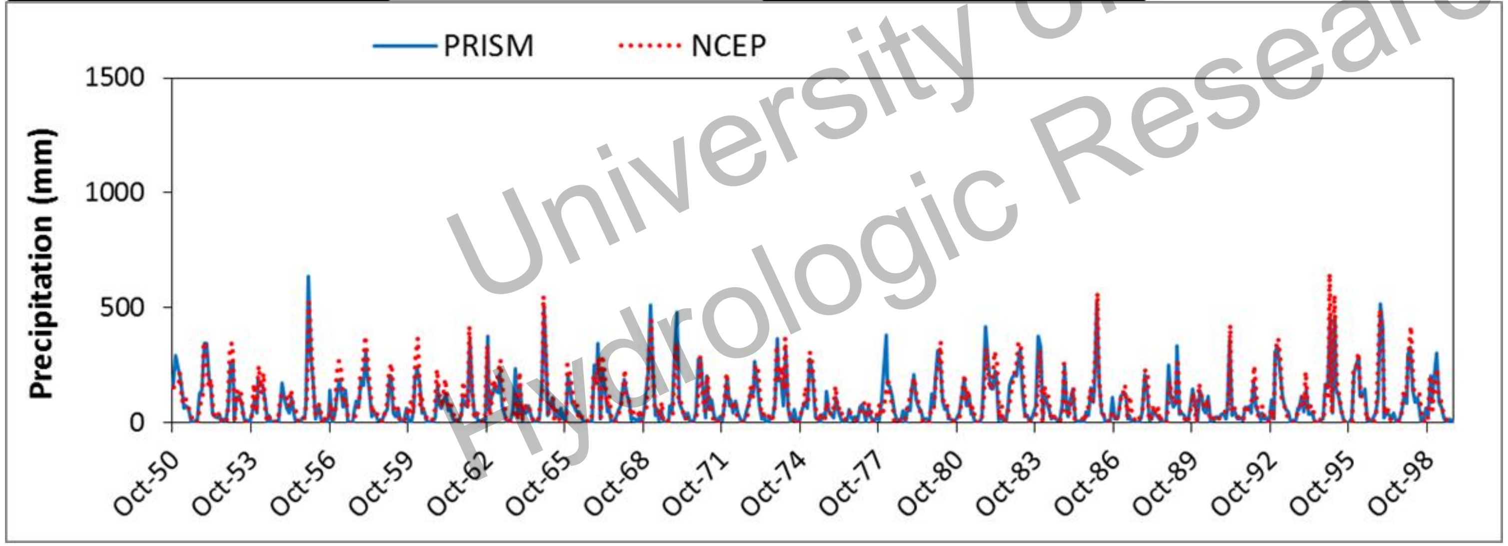
- Gain confidence in the performance of the dynamical downscaling technique and the Regional Climate Model

- Check validity of this downscaling method by validating the reconstructed historical climate

- Compare reconstructed historical precipitation against observation data
  - PRISM (Parameter-elevation Relationships on Independent Slopes Model)
  - Considered as one of the most reliable and comparable datasets for model calibration or validation

Validation of the Reconstructed Historical Climate



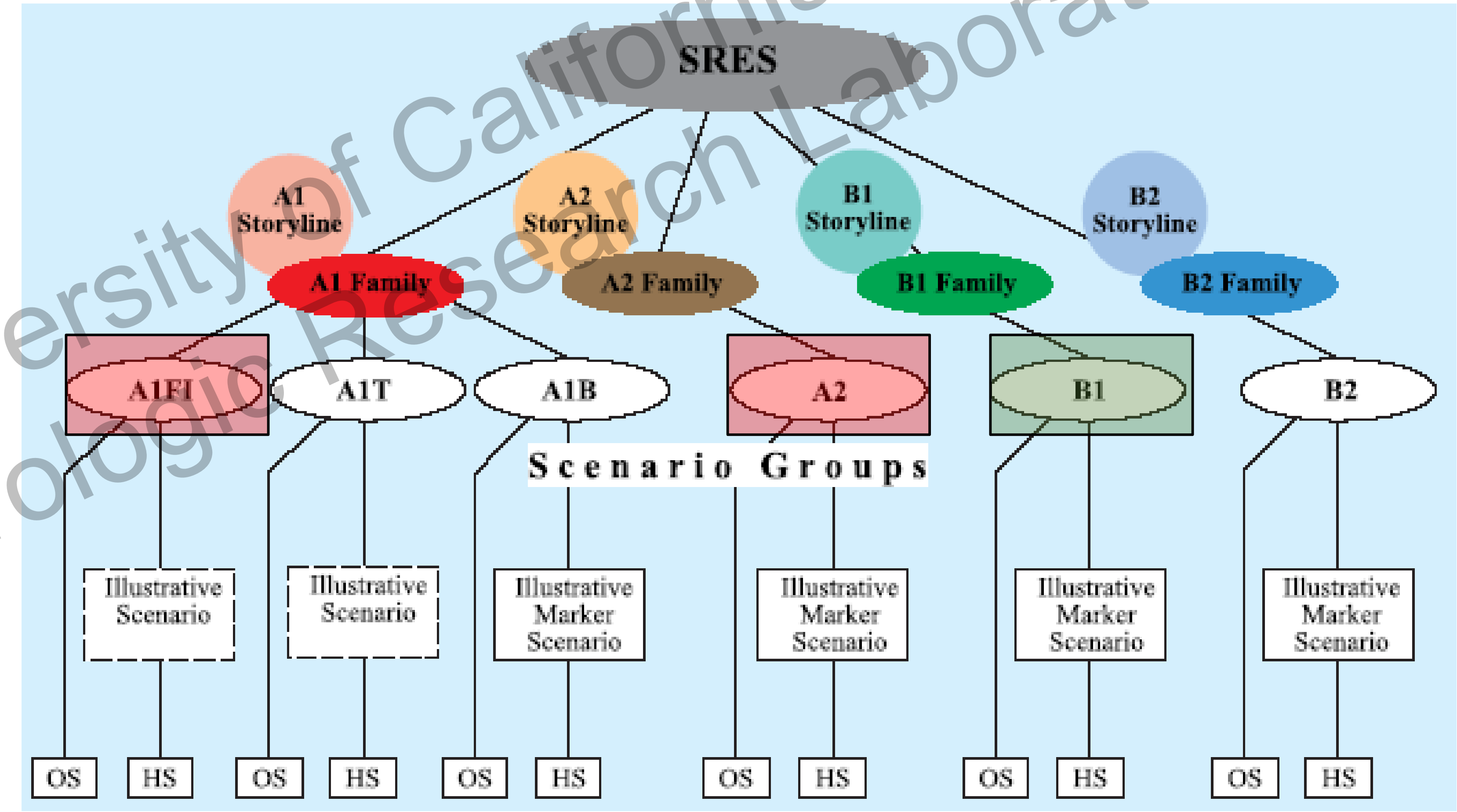


	PRISM	NCEP
MEAN (mm)	83.98	90.12
ST DEV (mm)	100.49	105.44
RMSE	37.28	
NASH	0.86	
CORR.	0.94	

100 mm ≈ 4 in

Future Climate Projections

- Obtained from Global Climate Models (GCMs), which provide projected outputs of temperature, precipitation, and other climatic variables for future years
- Emission scenarios are the driving force; they describe how CO_2 concentrations may evolve in future years
- Emission scenarios grouped into four different families (or storylines): A1, A2, B1, B2
- Groups divided based on the underlying assumptions regarding demographic, economic and technological developments
- Other storylines have their own assumptions which differ from each other
  - A1FI considered most severe, followed by A2
  - B1 considered as most environmentally friendly storyline among the rest
- Differences in assumptions reflected in climate variables from GCMs (e.g., temperature)



Future Climate Projections

Scenarios

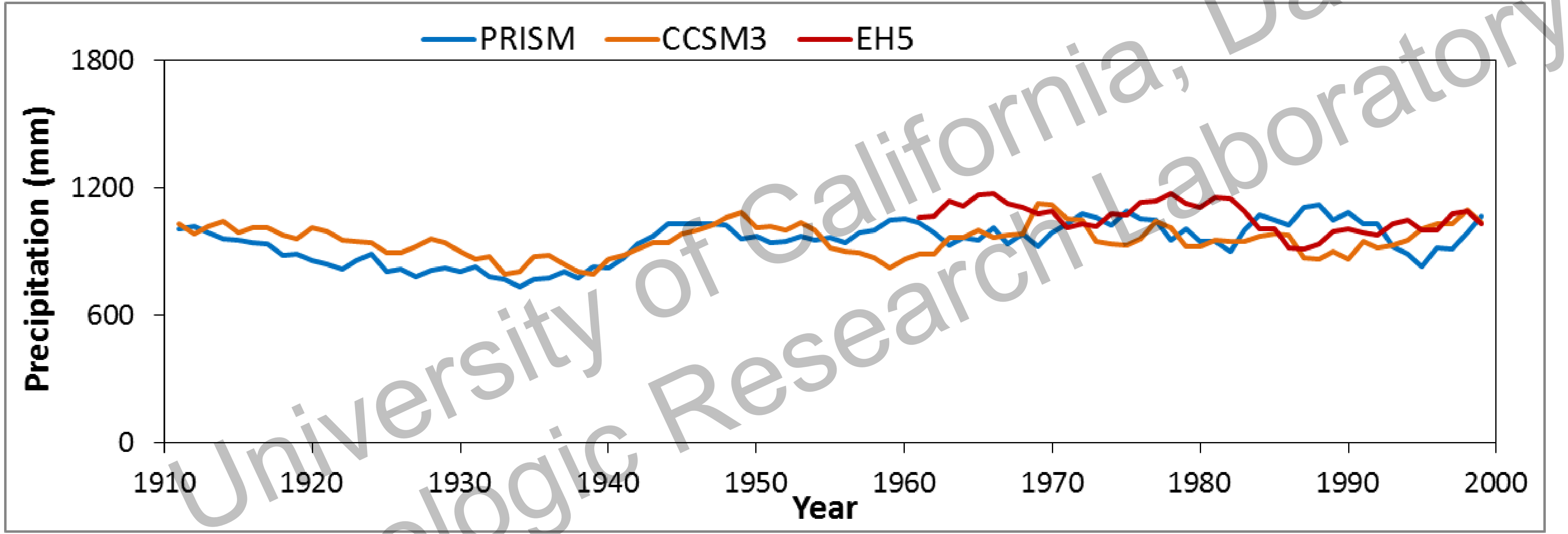
Models

	A1B	A2	B1	A1FI
CCSM3	CCSM3 – A1B	CCSM3 – A2	CCSM3 – B1	CCSM3 – A1FI
ECHAM5	ECHAM5 – A1B-1 ECHAM5 – A1B-2 ECHAM5 – A1B-3	ECHAM5 – A2-1 ECHAM5 – A2-2 ECHAM5 – A2-3	ECHAM5 – B1-1 ECHAM5 – B1-2 ECHAM5 – B1-3	

	CCSM3	ECHAM5
Control runs	1901 – 1999	1951 – 2000
Future Projections	2000 – 2100	2001 – 2100

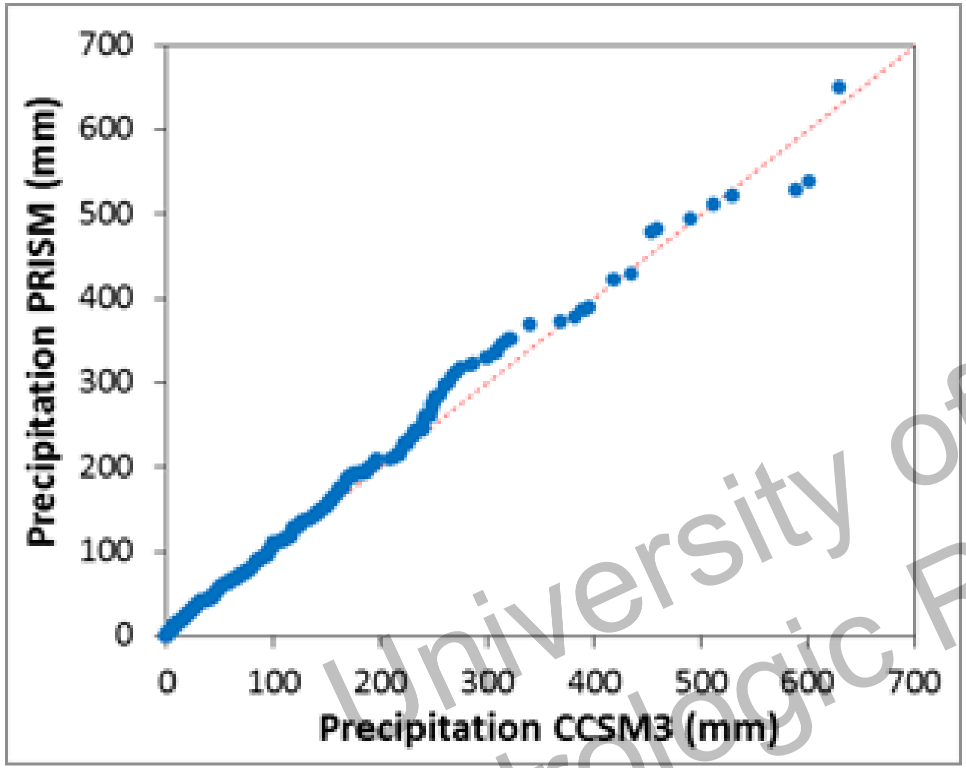
Historical Climate Simulations (Control Runs)

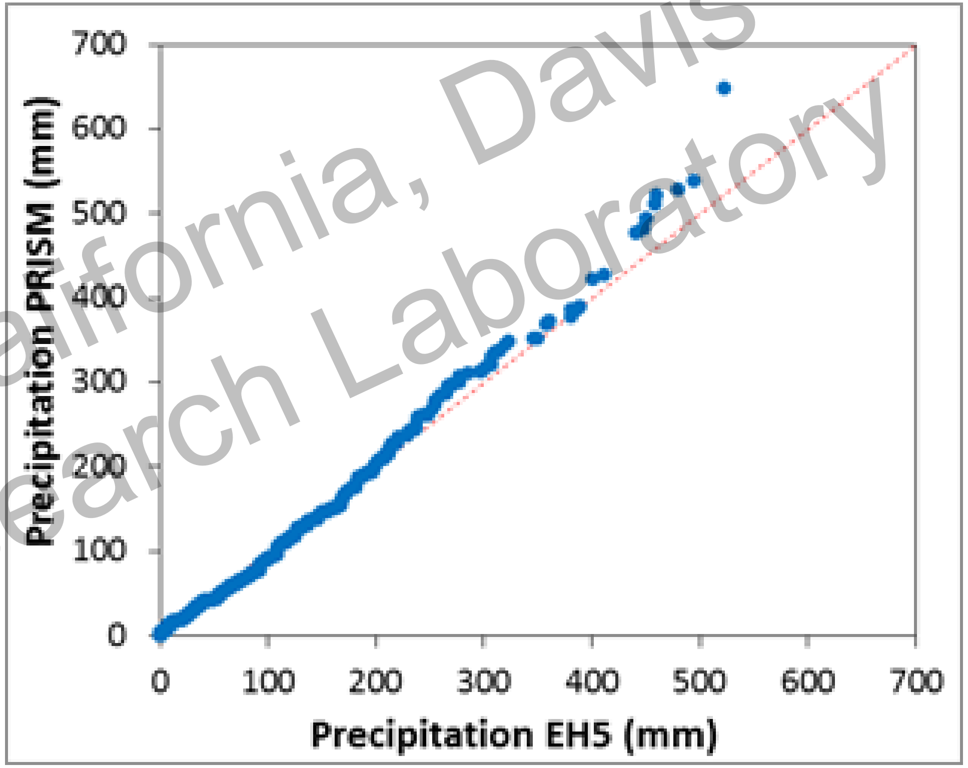
100 mm ≈ 4 in



- 10-year moving average of the basin average precipitation obtained from the CCSM3, EH5 and the PRISM observation data over the historical period
- CCSM3 and EH5 models show similar behavior to the PRISM data in the average sense

Historical Climate Simulations (Control Runs)





- Plotted points are along or very close to dotted red line
- Distribution of model and observed values is similar
  - Model and observed values are statistically similar

100 mm ≈ 4 in

- Models can simulate the average climate conditions well.

Streamflow from Foothills

WEHY Hydrologic Module – Input Data

■ Elevation data

- Digital Elevation Model (DEM)

National Elevation Dataset (NED); 1 arc-second resolution

Topography, Slope, Aspect

■ Soil data

- Soil Survey Geographic Database (SSURGO)

USDA-National Resources Conservation Service; 100-m resolution ≈330 ft

8 Parameters (Soil depth, porosity, mean and variation of Ksat, etc…)

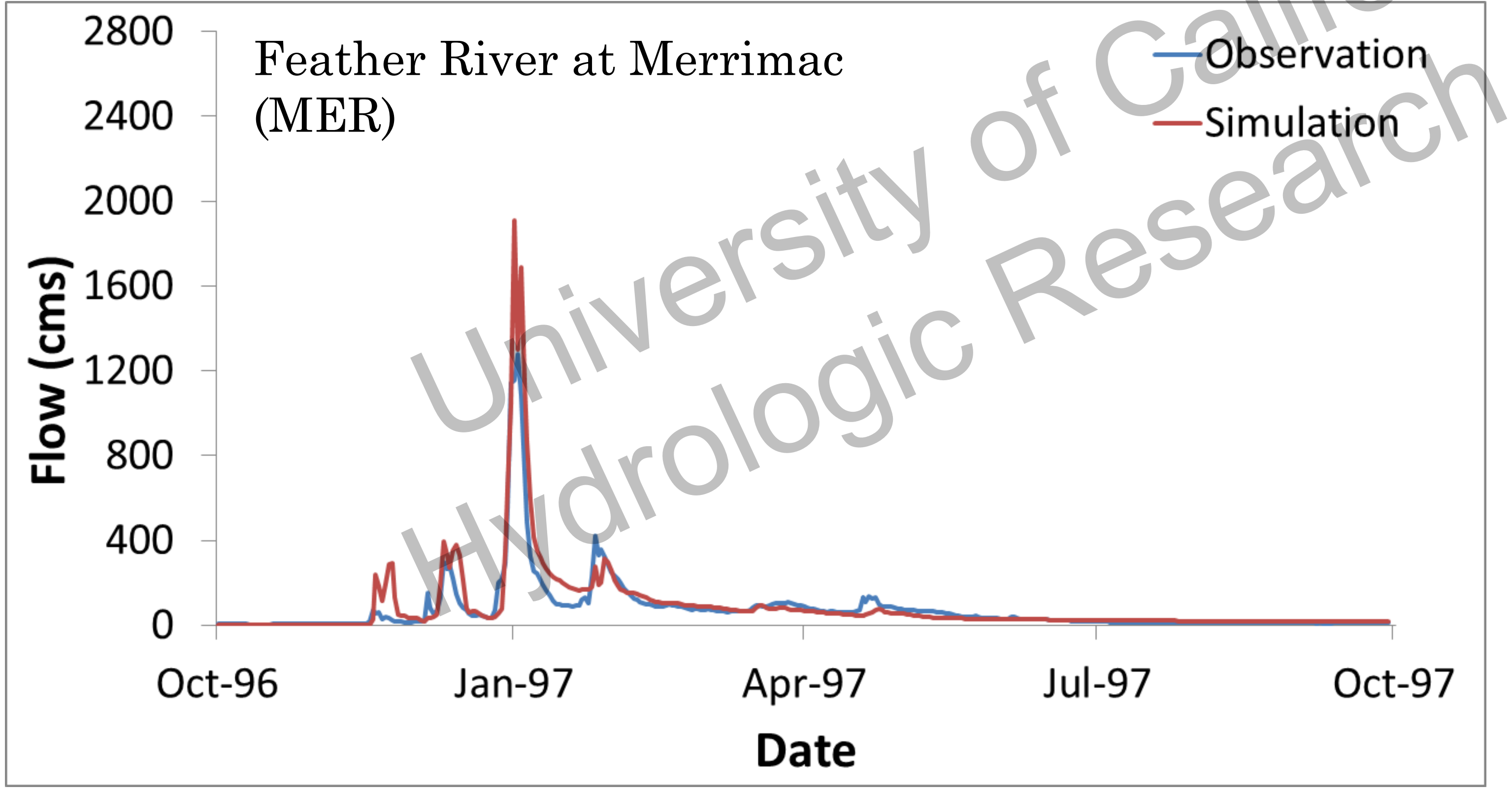
■ Land use/land cover and vegetation data

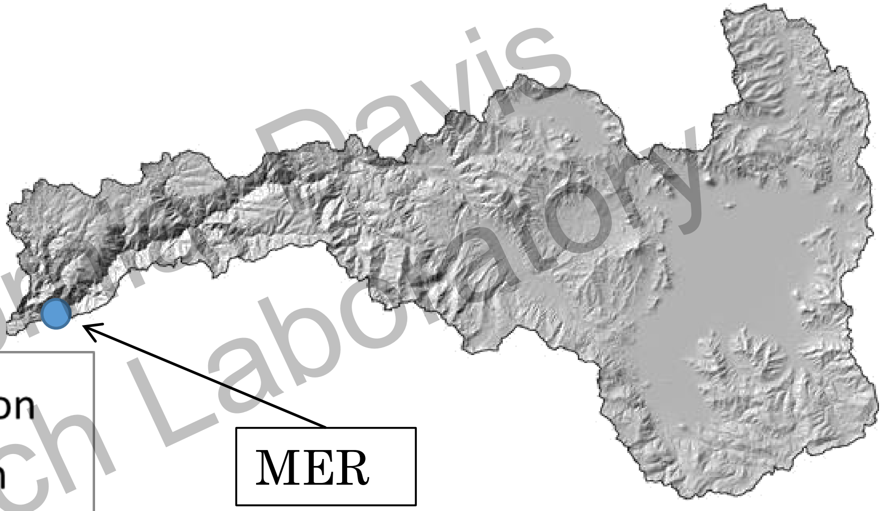
- Multi-source land cover data — CA Spatial Information Library; 100-m resolution ≈330 ft
- Satellite remote sensed data (MOD15) — NASA; 1-km resolution ≈0.6 mi

Land cover types, leaf area index, vegetation root depth, roughness height

Results of the Hydrologic Module

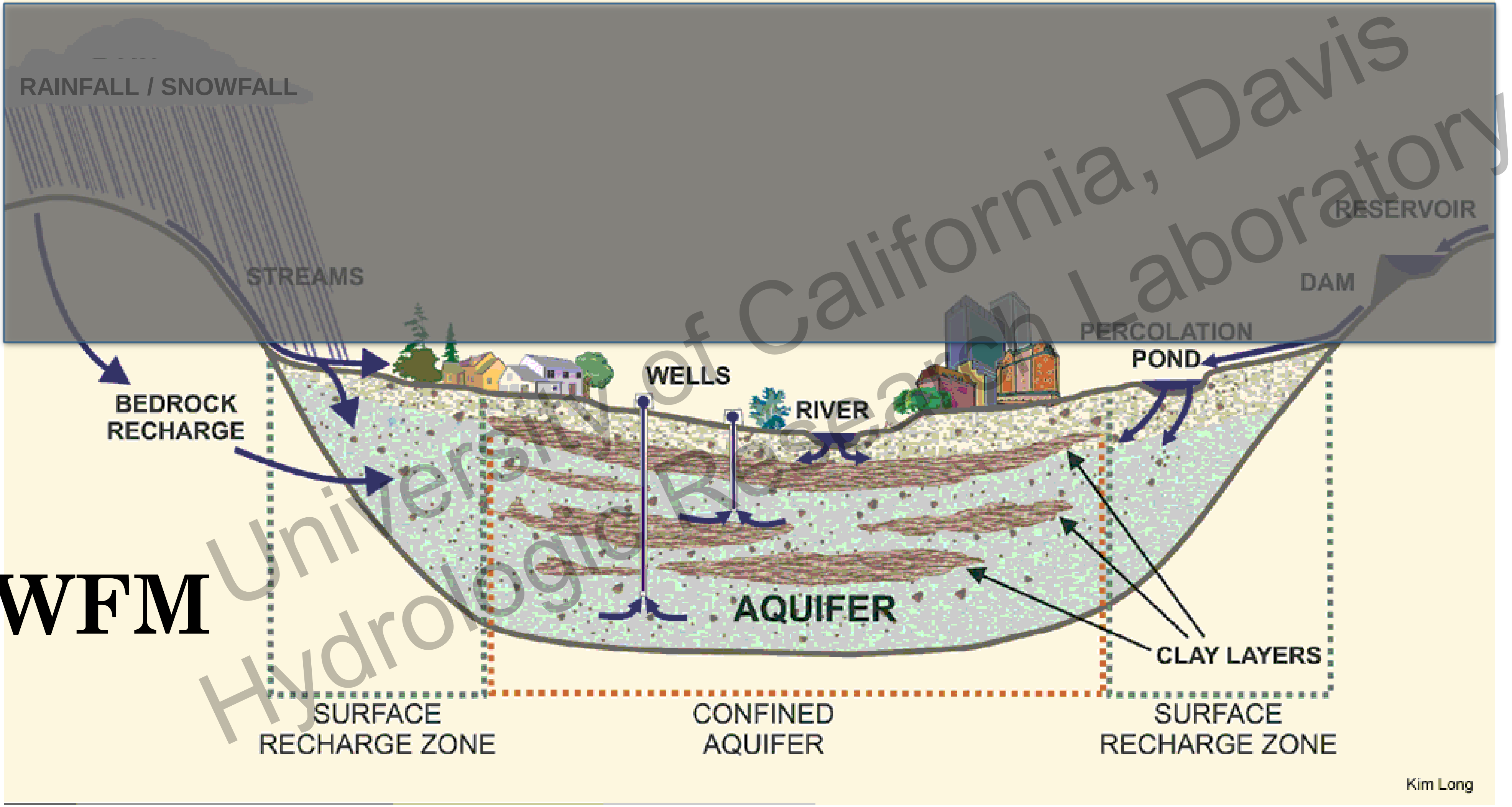
1 cms ≈ 35 cfs





	OBS	SIM
MEAN (cms)	75.53	87.19
ST DEV (cms)	142.56	188.88
RMSE	77.21	
NASH	0.71	
CORR.	0.94	

Sierra Valley Basin – Aquifer



IWFM

https://www.museumca.org/creeks/z-groundwater.html

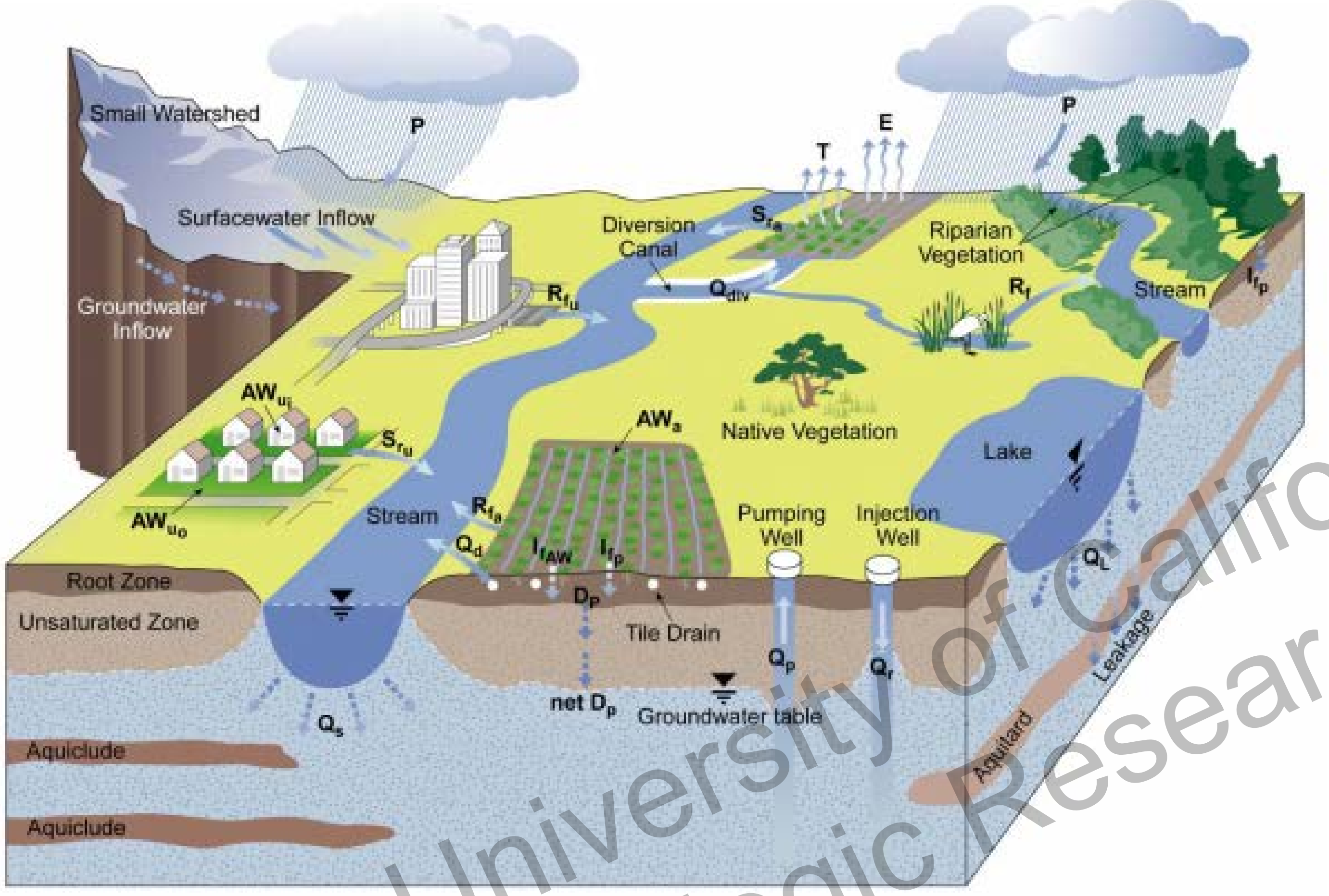
Groundwater Model

IWFM: Integrated Water Flow Model

- Developed by CA DWR, Bay-Delta Office
- Version: IWFM-2015
- From IWFM Website:
  - User manual,
  - Theoretical documentation,
  - Source code (Open Source),
  - Tutorials and examples,
  - Support tools,
  - Publications,
  - Users Group.

IWFM: Integrated Water Flow Model

- Mainly a groundwater flow model that also simulates:
  - Stream-aquifer interaction,
  - Root zone processes (IDC),
  - Vadose zone flow,
  - Agricultural, urban and vegetation water demand,
  - Supply from imported, surface- and/or ground-water,
  - Land subsidence.



LEGEND

P.......... Precipitation
AW_a..... Water applied to agricultural lands
AW_{u_i}.... Water applied to indoor urban lands
AW_{u_o}... Water applied to outdoor urban lands
E.......... Evaporation
T.......... Transpiration
I_{f_p}......... Infiltration of precipitation
$I_{f_{AW}}$...... Infiltration of applied water
Q_{div}...... Surface water diversion
S_{r_a}........ Agricultural runoff
S_{r_u}........ Urban runoff
R_f.......... Return flow
R_{f_a}........ Agricultural return flow
R_{f_u}........ Urban return flow
D_p......... Deep percolation of water to the unsaturated zone
net D_p... Recharge to the groundwater aquifer
Q_p......... Pumping from groundwater aquifer
Q_r......... Recharge to groundwater aquifer
Q_s......... Stream-groundwater interaction
Q_L......... Lake-groundwater interaction
Q_d......... Tile drainage flow

Figure 1.1 Hydrologic processes modeled in IWFM

Components:

- Stream, Lakes
- Surface Water Diversions, Canals, Tile Drains
- Pumping / Injection Wells
- Applied Water / Irrigation
- Native, Riparian Vegetation and Ponded and Non-Ponded Crops
- ~~Small Watersheds~~ (Used WEHY instead)

IWFM Theoretical Documentation

IWFM – Input Data

Discretization

Surface Waters

Domain Initial & Boundary Conditions

Aquifer Hydraulic Parameters

Soil Hydraulic Parameters

Atmospheric Variables
- Precipitation
- Evapotranspiration

Vegetation
- Areas
- Root Zone Depth
- Water Demand (ET)
- Runoff Generation

Pumping Wells
- Location
- Pumping Rate
- Radius & Perforation
- Delivery Destination

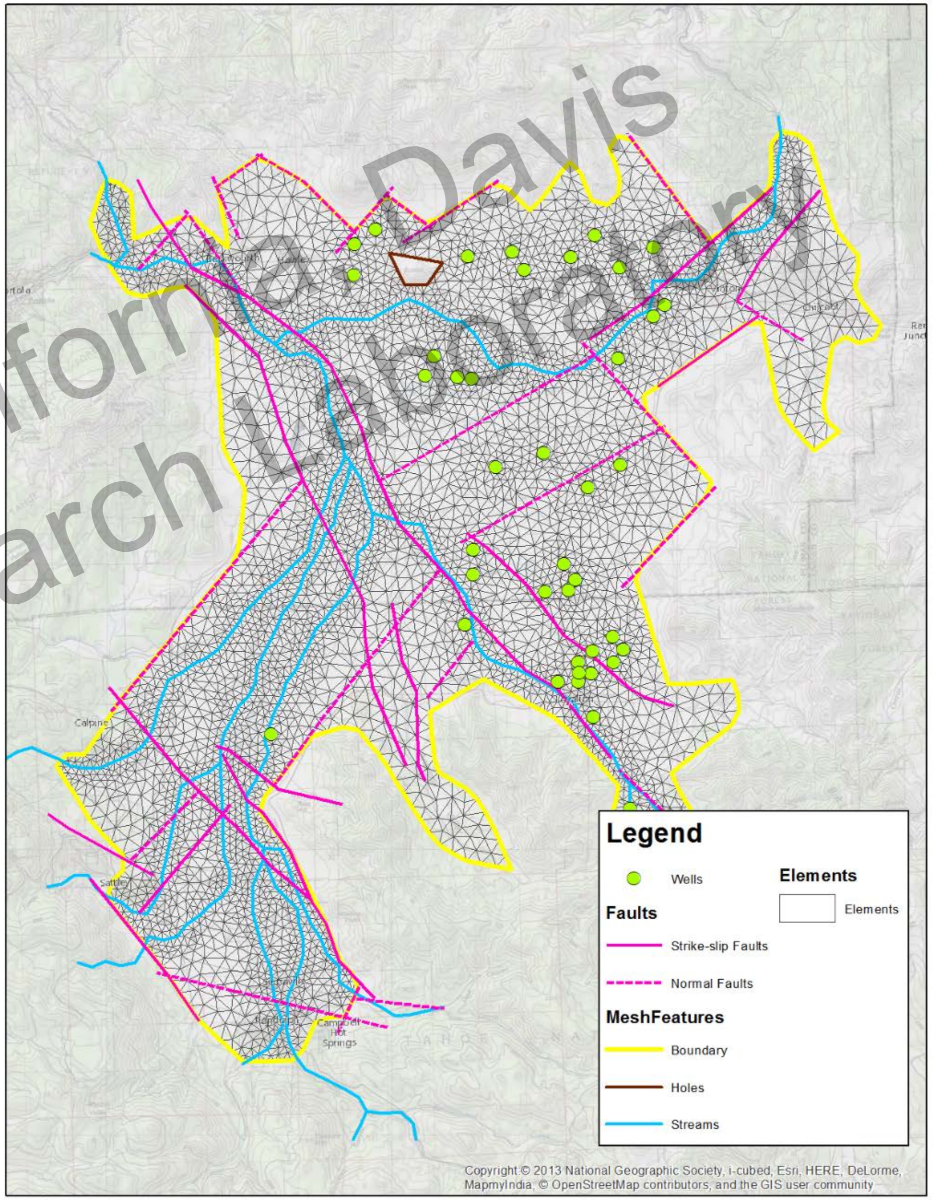
Surface Water Diversions
- Location
- Diversion Rate
- Delivery Destination

Irrigation Specifications
- Irrigation Period
- Irrigation Efficiency
- Minimum Moisture

IWFM – Input - Discretization

- Horizontal
  - 8700 cells,
  - 4560 nodes.
  - Refined near streams and pumping wells.

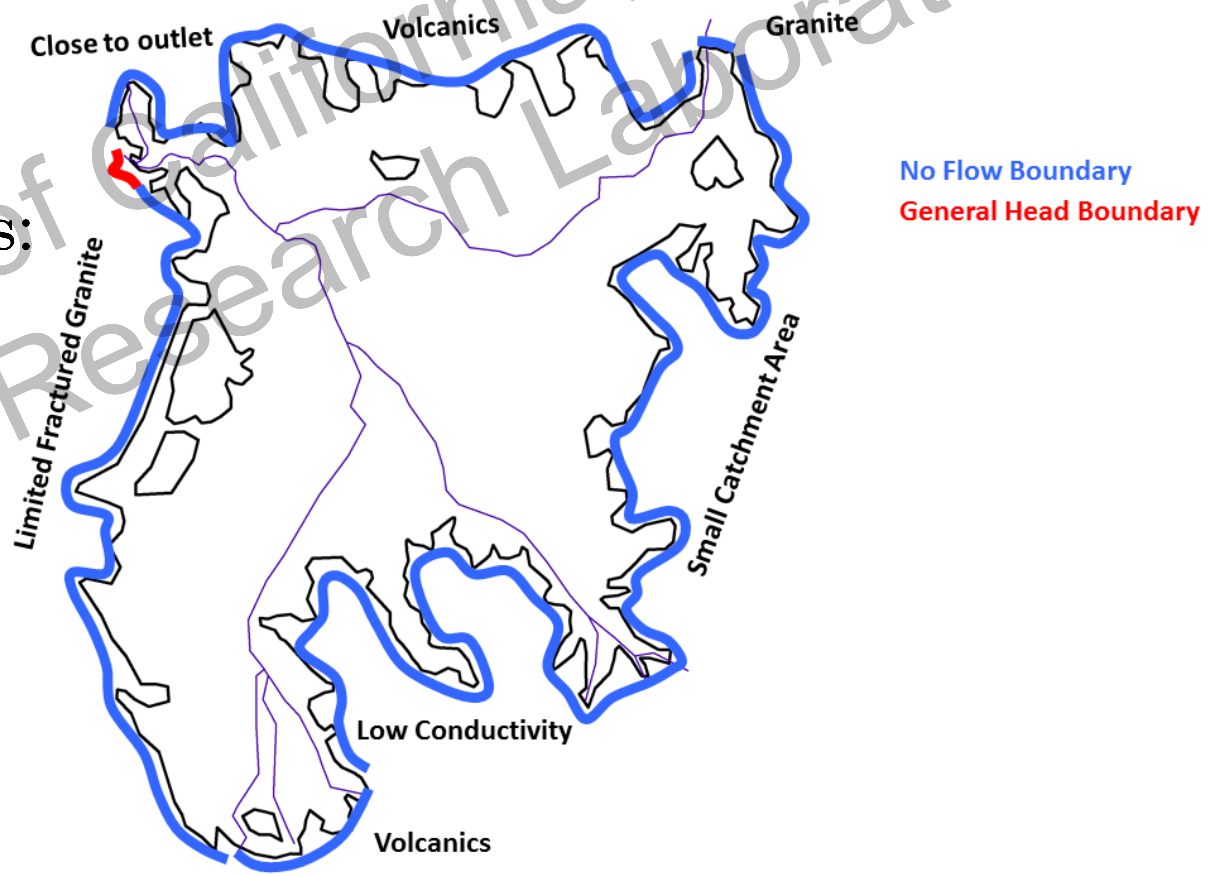
- Vertical (Stratigraphy)
  - 5 layers
  - 1 Shallow Unconfined Aquifer
  - 2 Confined Aquifers
  - 2 Aquitards Layers
  - Impermeable Bedrock Layer



IWFM – Input – Initial and Boundary Conditions

- Initial water table conditions are spatially interpolated from Fall average of available CDEC observation stations.

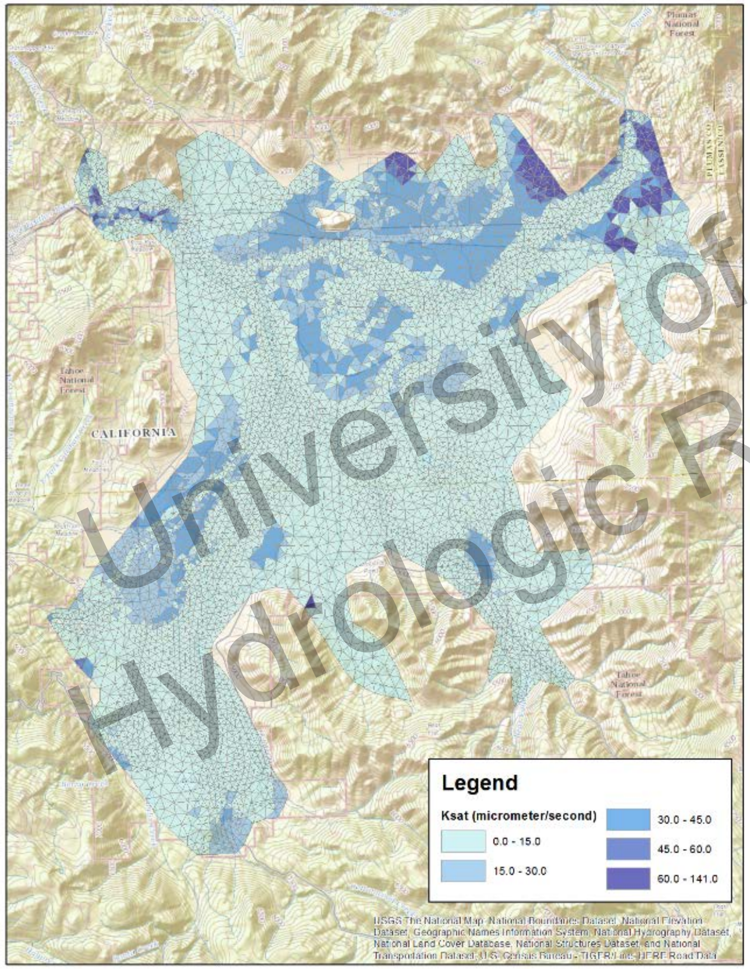
- Domain Boundary Conditions:



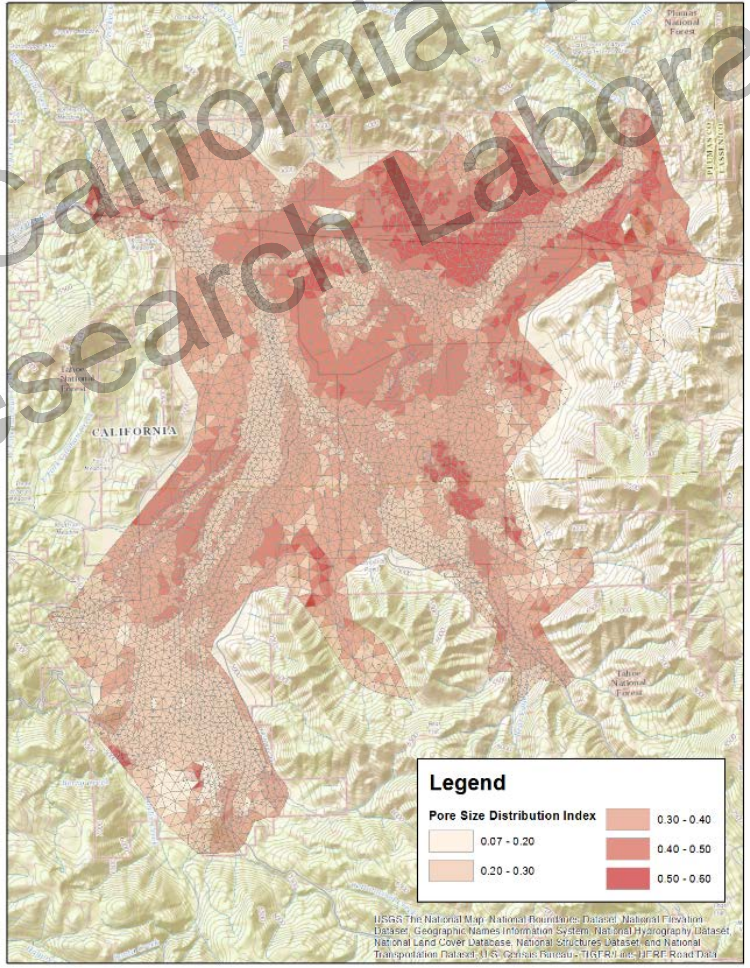
IWFM – Input – Soil Hydraulic Parameters

- Soil Hydraulic Parameters are estimated from SSURGO (USDA-NRCS) databases.
  - Hydrologic Soil Group, Wilting Point, Field Cap., Tot. Porosity, Sat. Hydraulic Con., PSDI

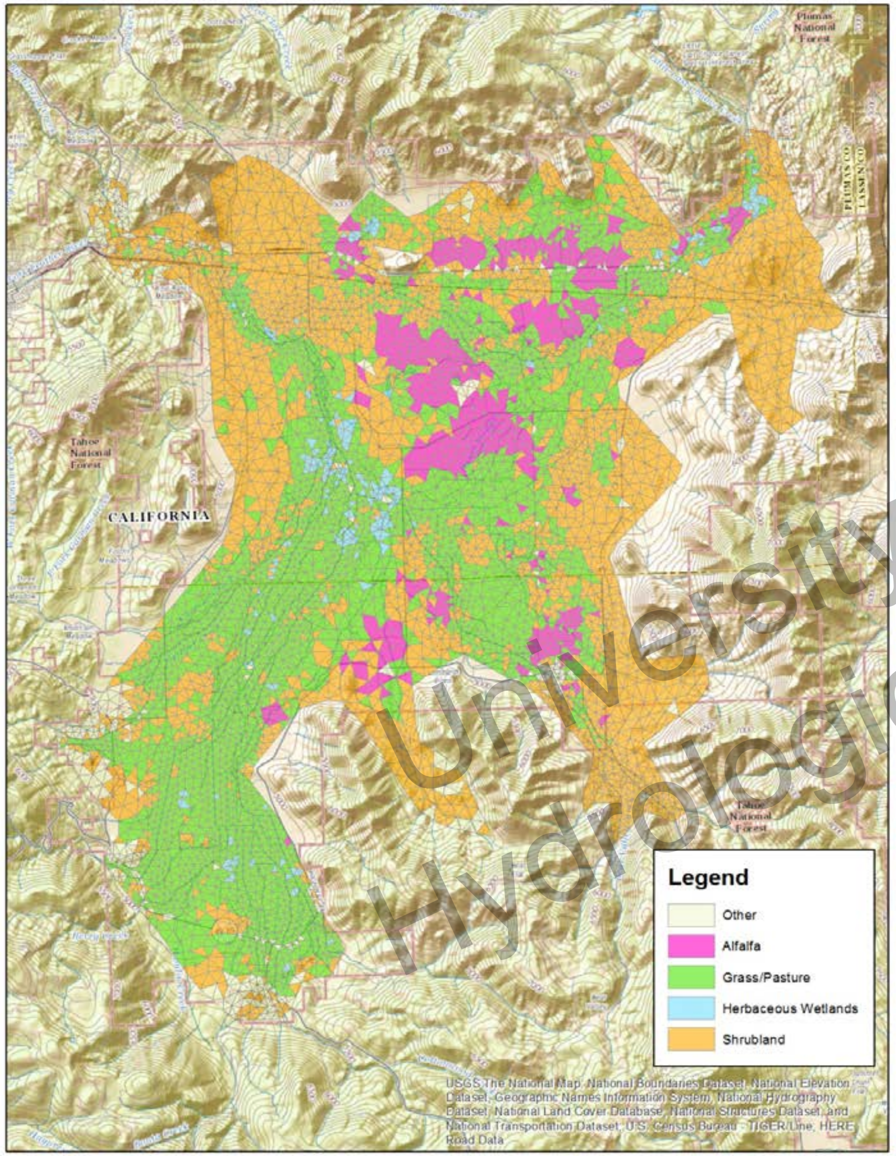
Saturated Hydraulic Conductivity



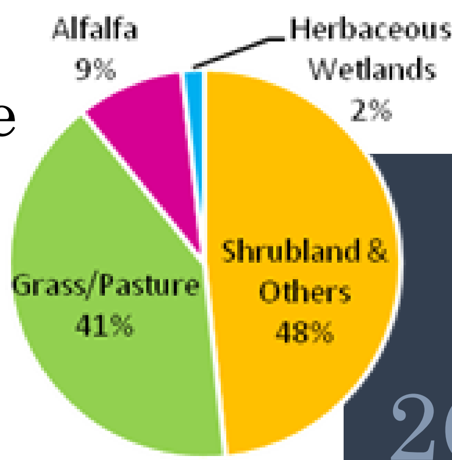
Pore-Size Distribution Index



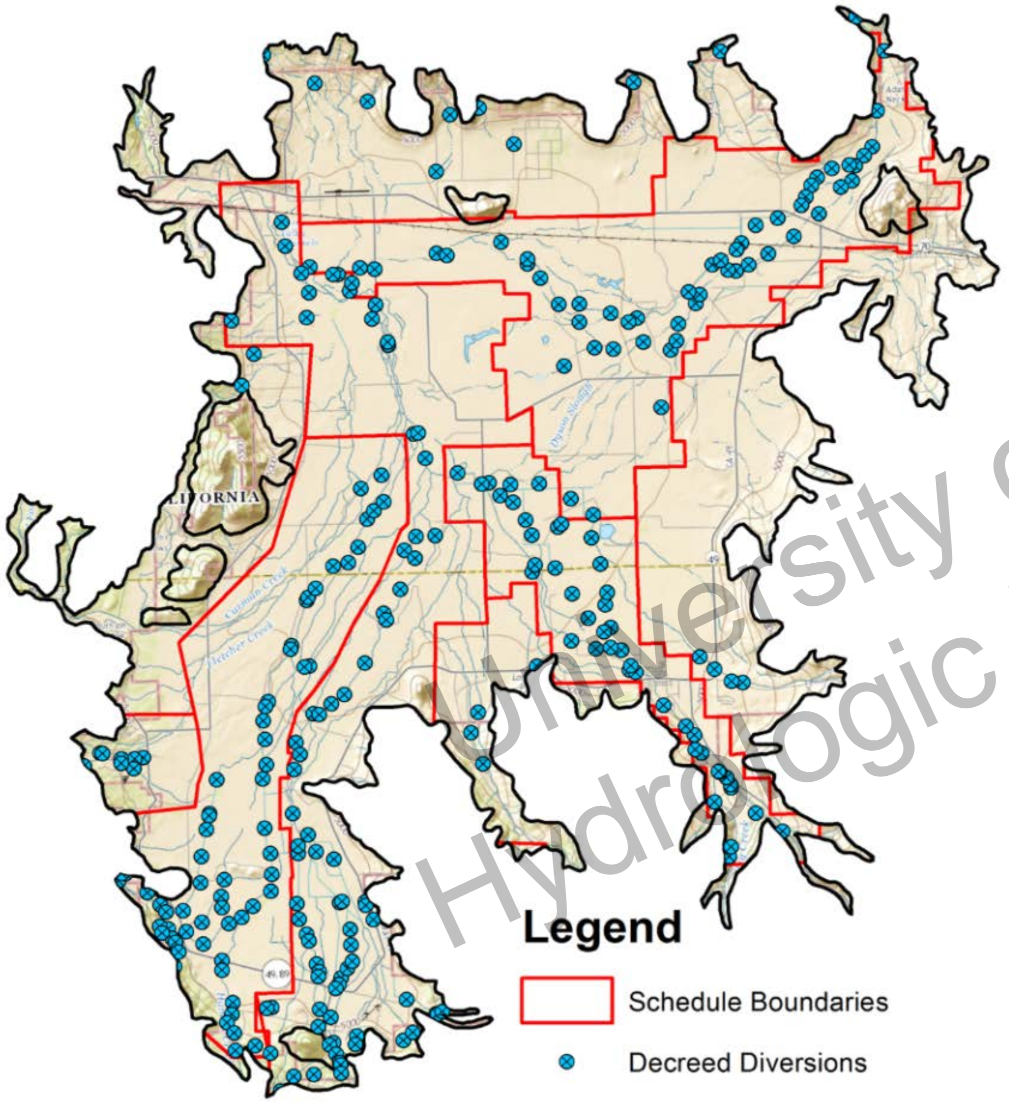
IWFM – Input – Vegetation



- Vegetation Areas from Cropscape Satellite Data, annual starting from 2007.
- Potential ET is calculated by FAO56 method using the atmospheric output from the WEHY-HCM climate model.
- Other information such as root zone depth, growth periods, curve number etc. are determined from literature.



IWFM – Input – Diversions



- Diversion locations were digitized from the Water Master maps.
- Diversion allotments were digitized from the 1949 Decree.
- Each diversion is assumed to be supplying the demand for the DWR Tract area in which it is located.

IWFM – Input – Irrigation Specifications

- Irrigation period was chosen as from May to October.
- Default suggested values are used for the irrigation efficiency and the minimum moisture that triggers irrigation.
- Irrigation is stopped when the soil moisture reaches to the field capacity. (This can be changed to simulate deficit irrigation)

IWFM – Output Data

Land,

Root Zone,

Aquifer,

Agricultural

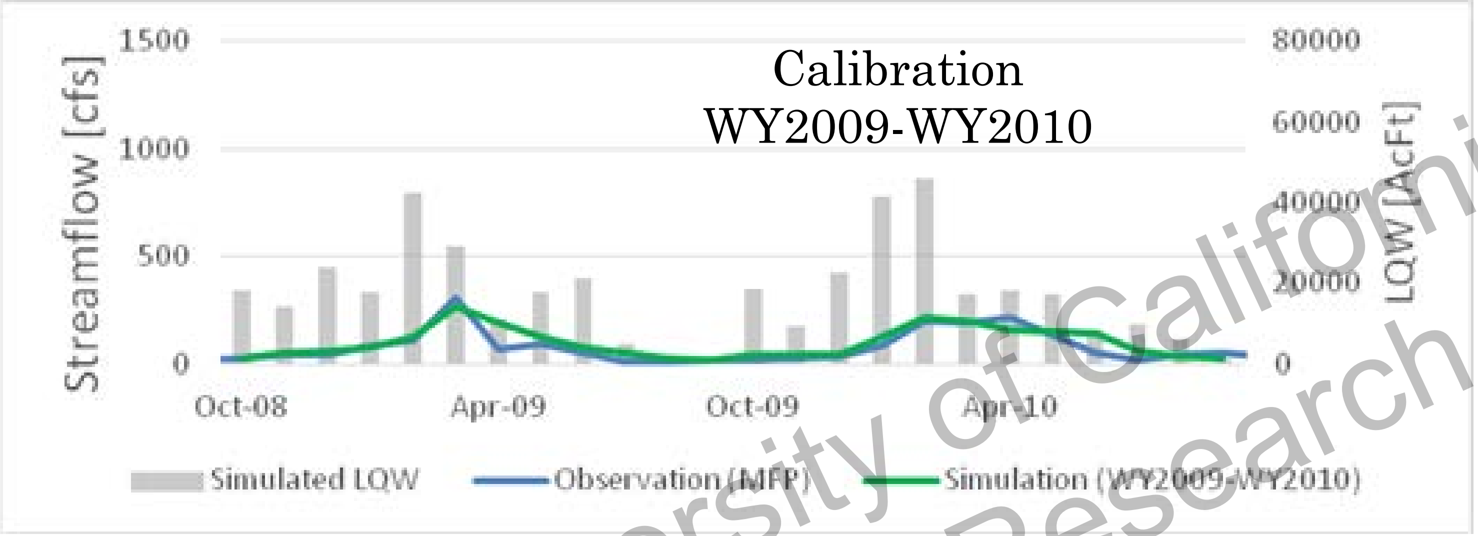
Water budget for

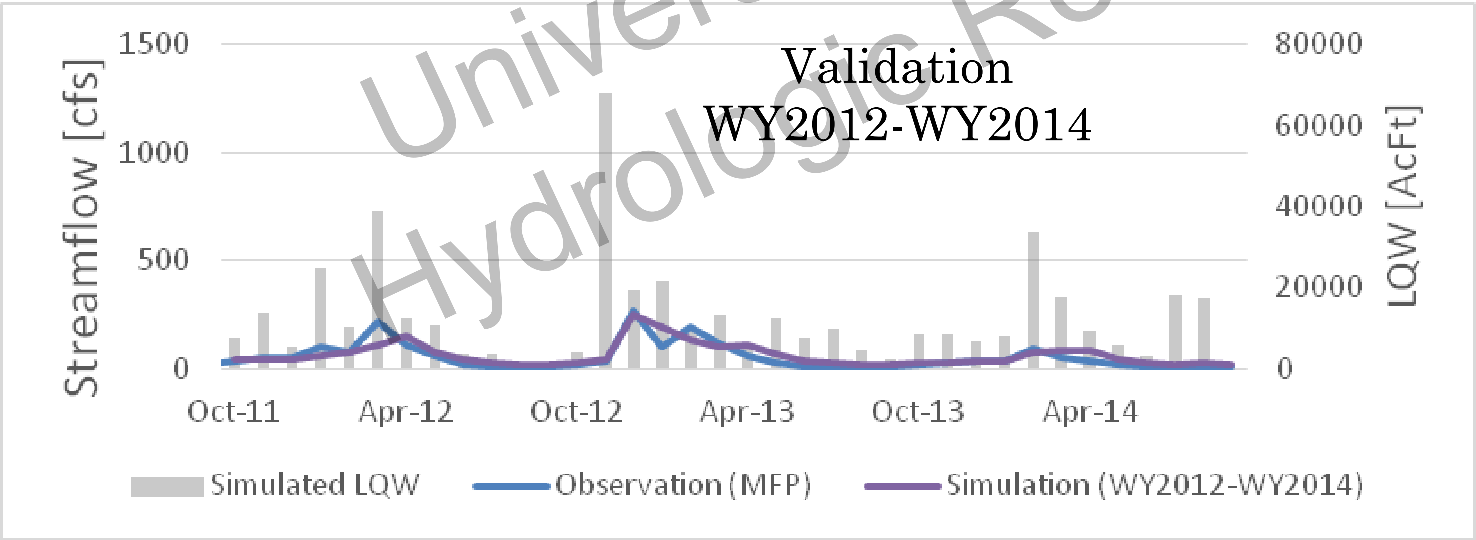
The whole Domain (i.e. Sierra Valley),
or
Regions (e.g. Schedule Areas),
or
Zones (e.g. Individual Farms)
defined by the user.

- Stream water budget at desired stream reaches and streamflow at desired stream locations.
- Groundwater level at every node, or at desired point locations.
- Root zone and aquifer storage.

Validation of the IWFM Results

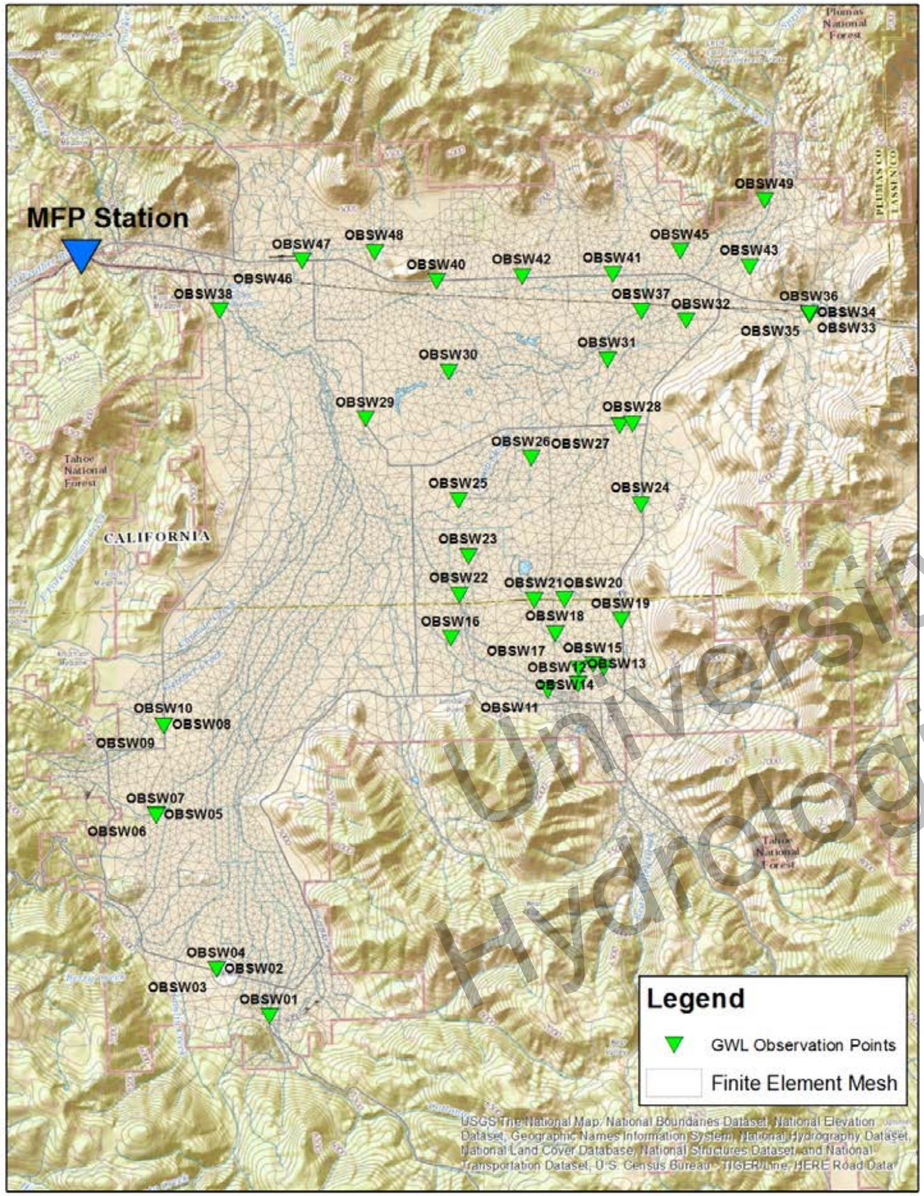
Streamflow at MFP:

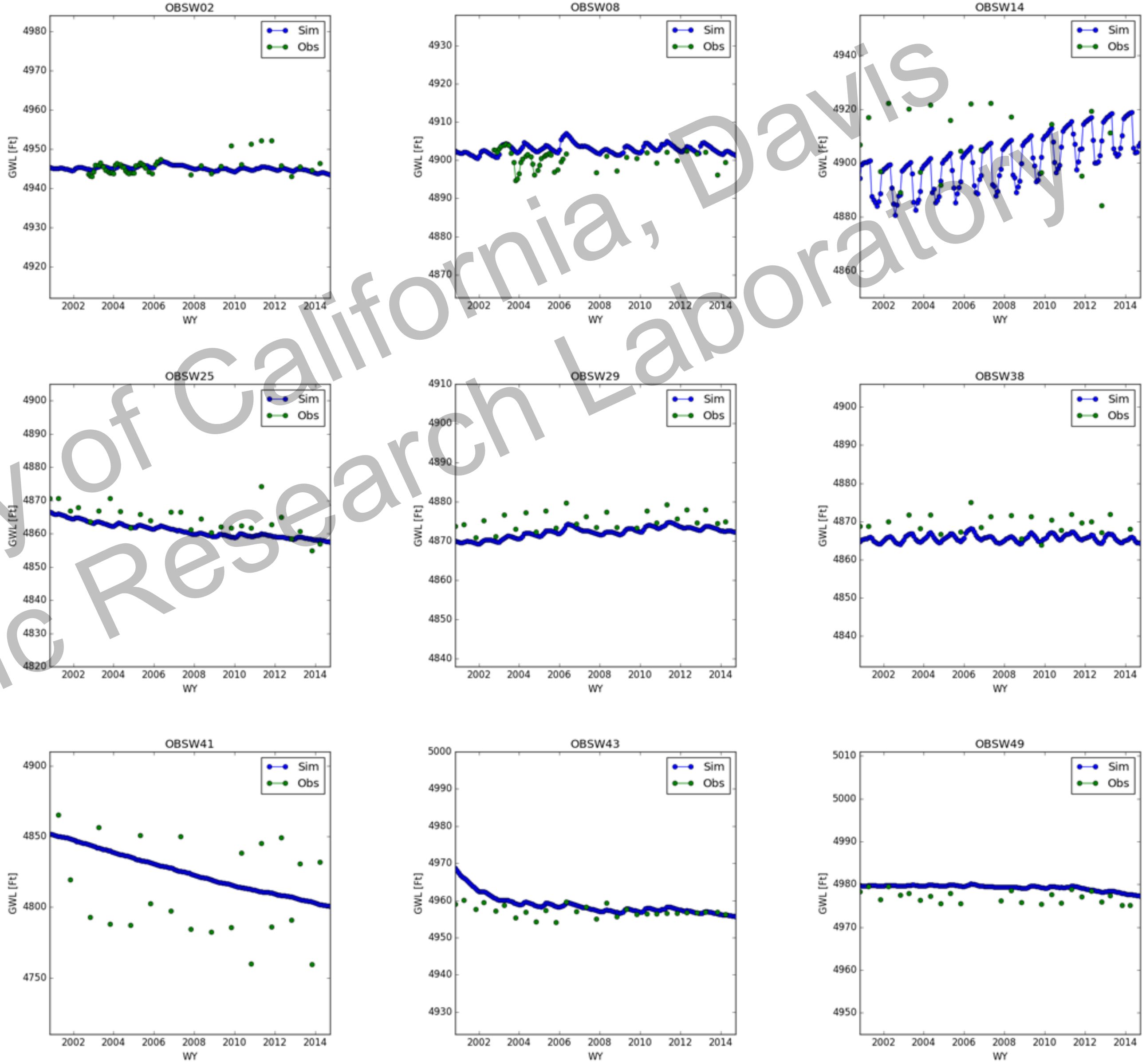




PARAM.	CALIB.		VALID.	
	OBS	SIM	OBS	SIM
MEAN (cfs)	78.61	96.03	53.08	60.38
STDEV (cfs)	77.52	70.52	61.73	53.82
RMSE	40.08		33.57	
NASH	0.72		0.70	
CORR	0.88		0.84	

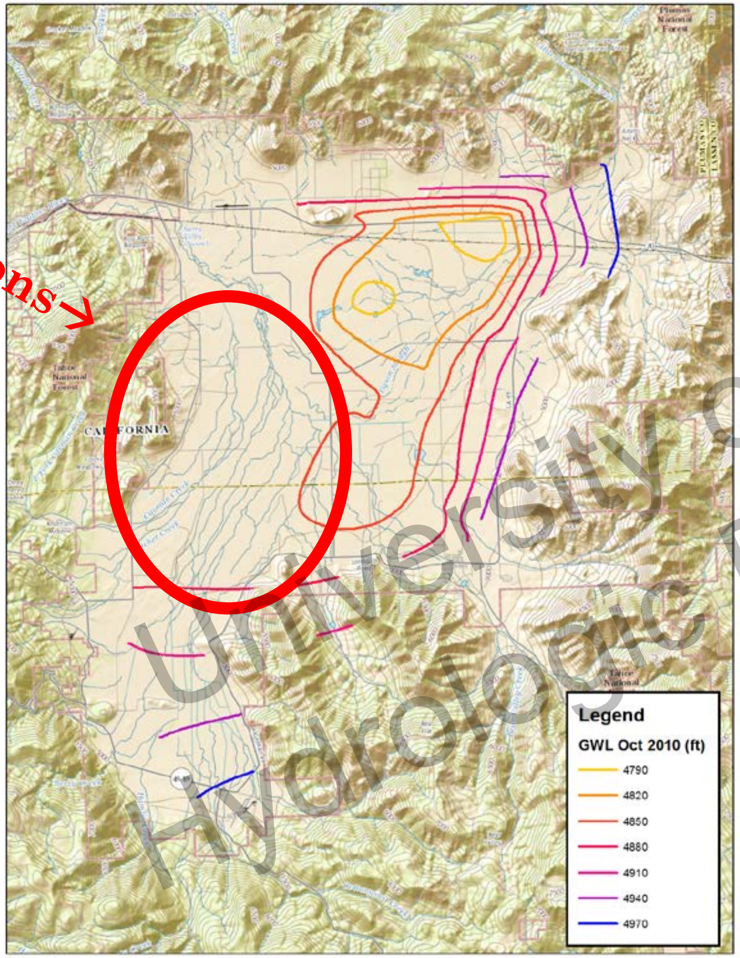
Validation of the IWFM Results

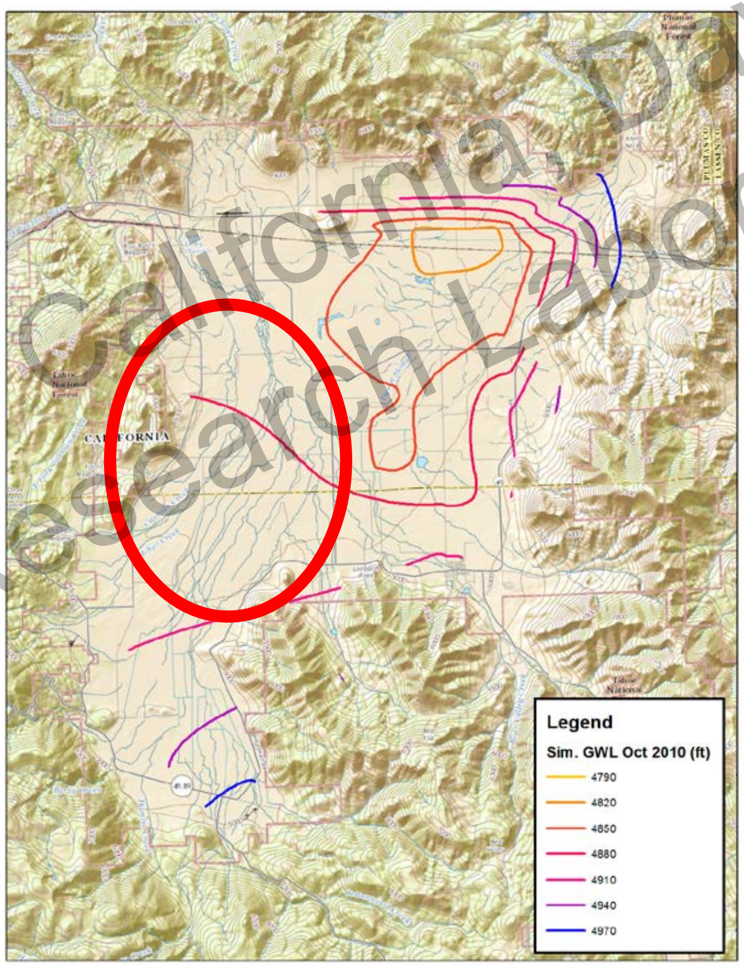




Validation of the IWFM Results

No observations→



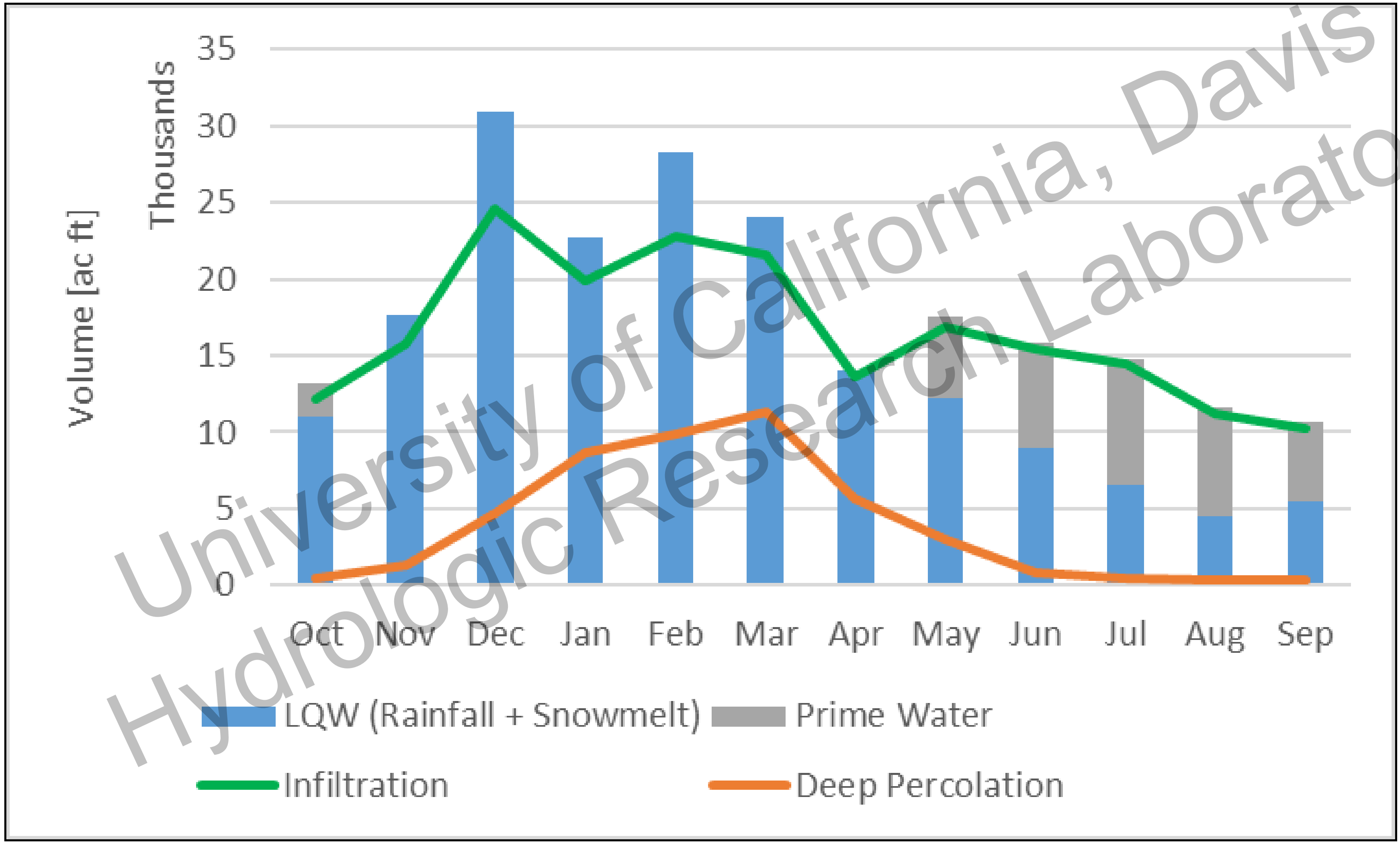


Historical Results

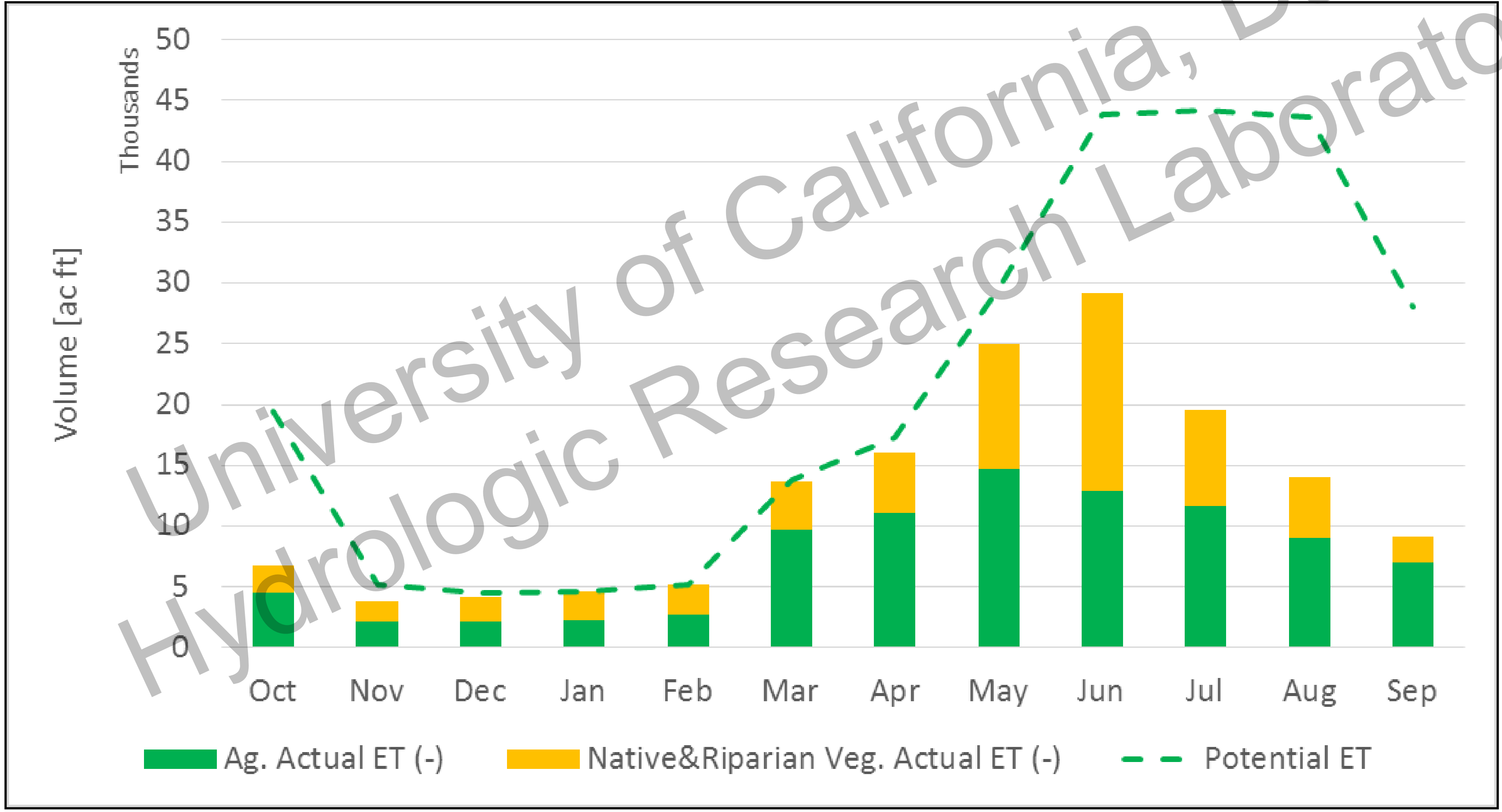
Mean Annual Water Budget between WY2000 and WY2010

Water budget component	Percentage [%]
Liquid Water (LQW)	84
Irrigation Water	16
Total Input on the Ground Surface (LQW + Irrigation)	100
Direct Runoff	10
Infiltration	90
Potential Evapotranspiration	
Actual Evapotranspiration	68 (75 of Inf.)
Deep Percolation	22 (25 of Inf.)
Streamflow in from foothills	
Streamflow out at MFP	

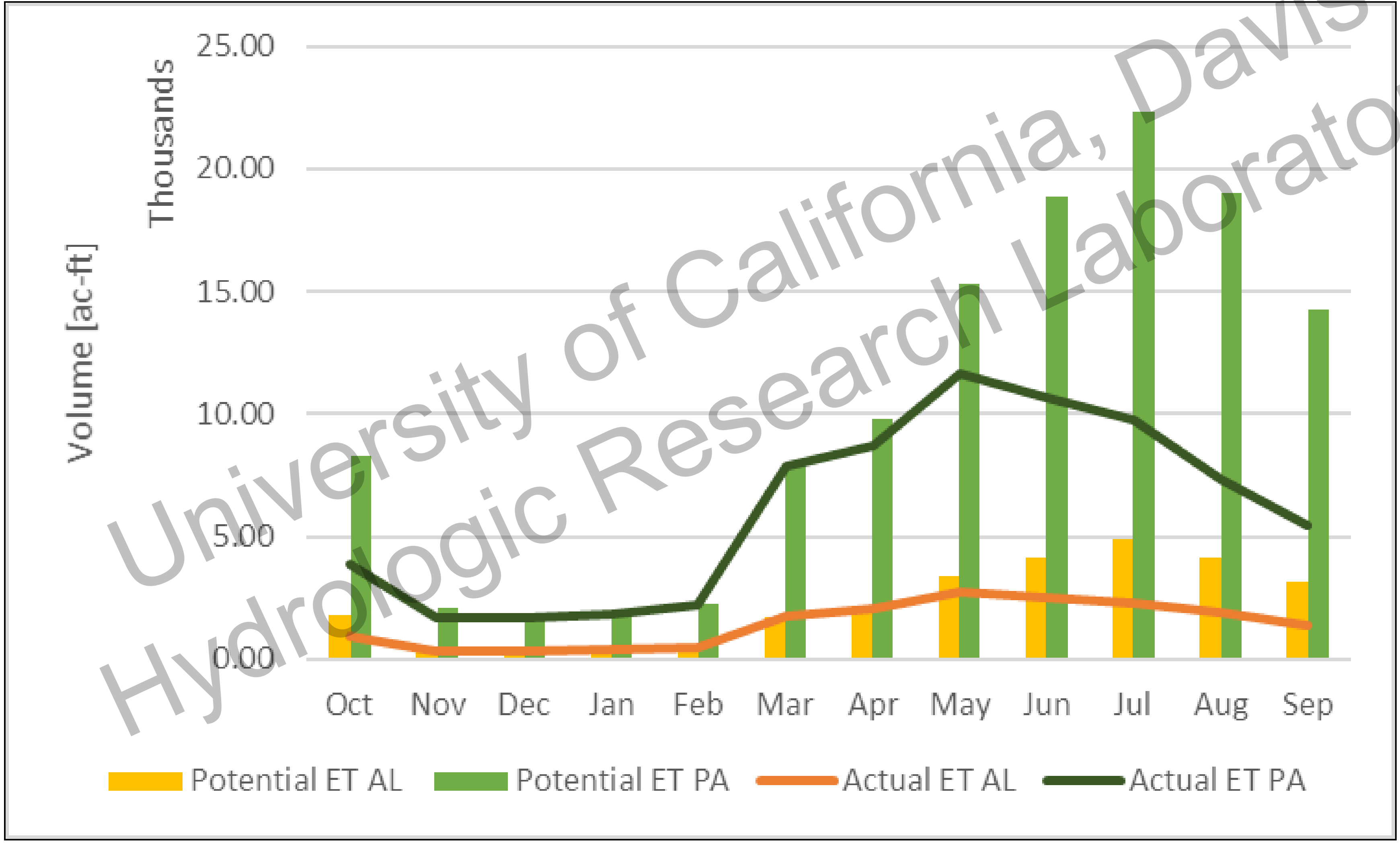
Mean Monthly Deep Percolation (Aquifer Recharge) Between WY2000 and WY2010



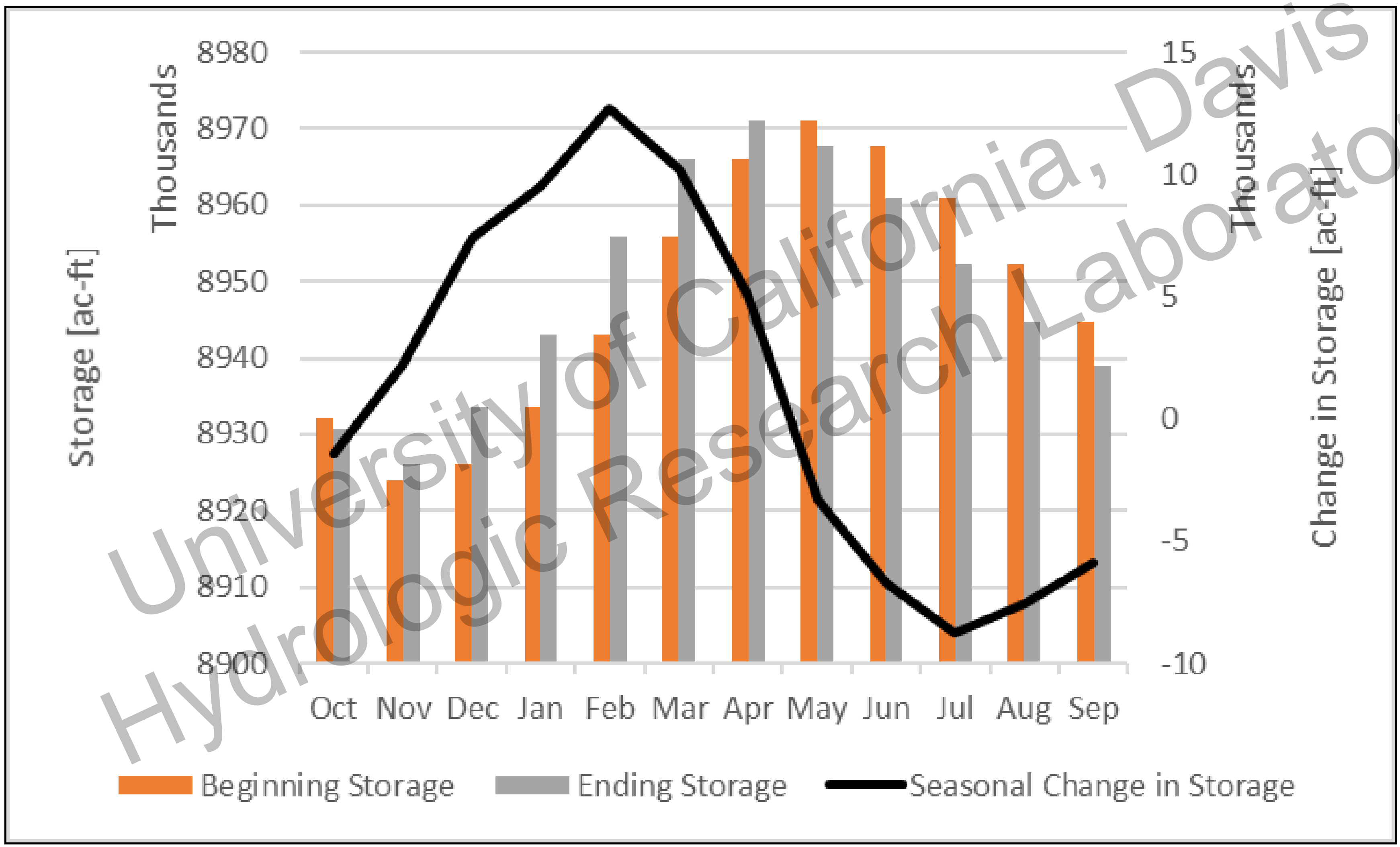
Mean Monthly Water Consumption of Irrigated Vegetation (Alfalfa & Pasture) vs. Non-Irrigated Vegetation (Native & Riparian Vegetation) Between WY2000 and WY2010



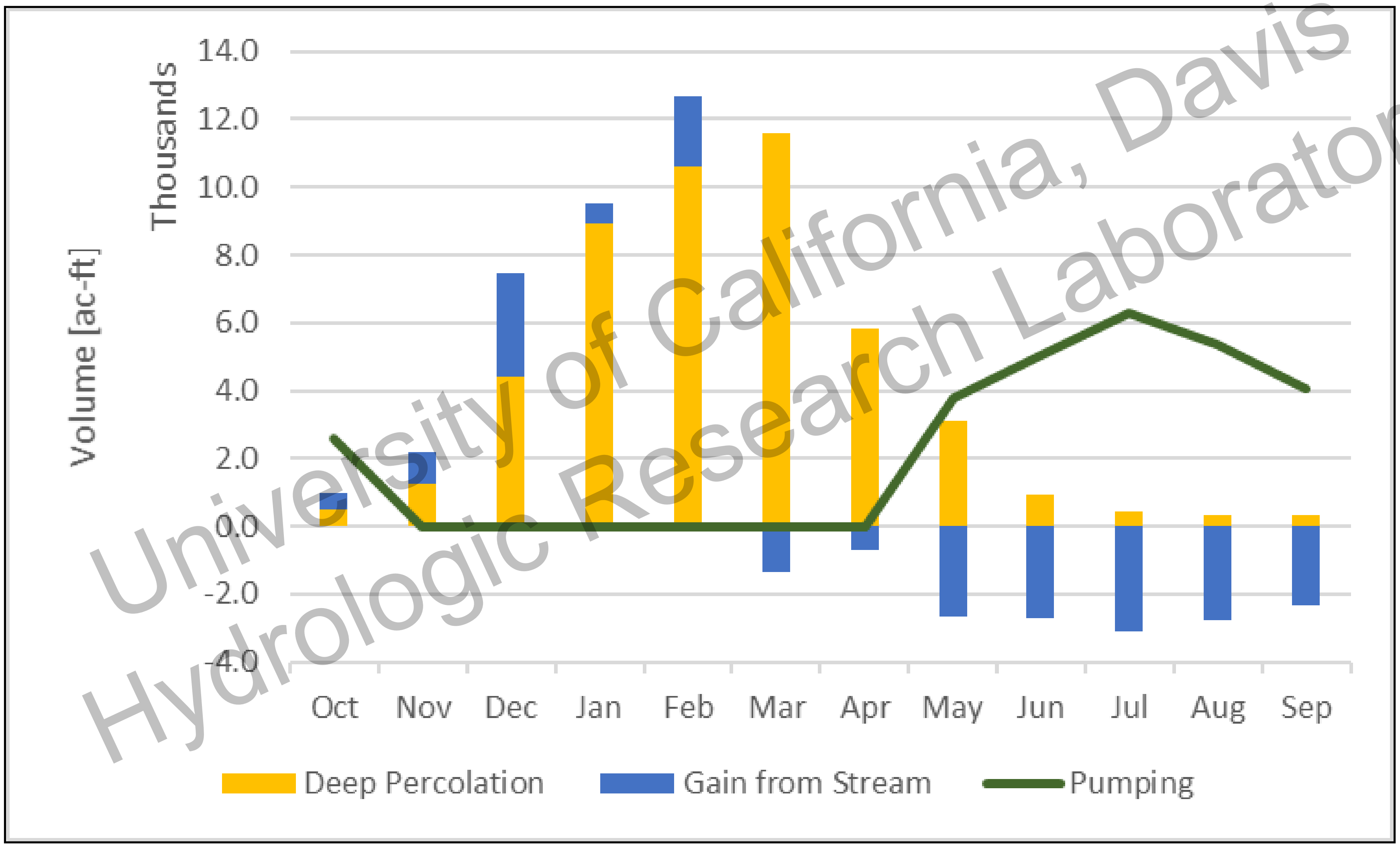
Mean Monthly Water Consumption of Irrigated Crops, Alfalfa vs. Pasture Between WY2000 and WY2010



Mean Monthly Change in Groundwater Storage Between WY2000 and WY2010



Mean Monthly Groundwater Budget Components Between WY2000 and WY2010

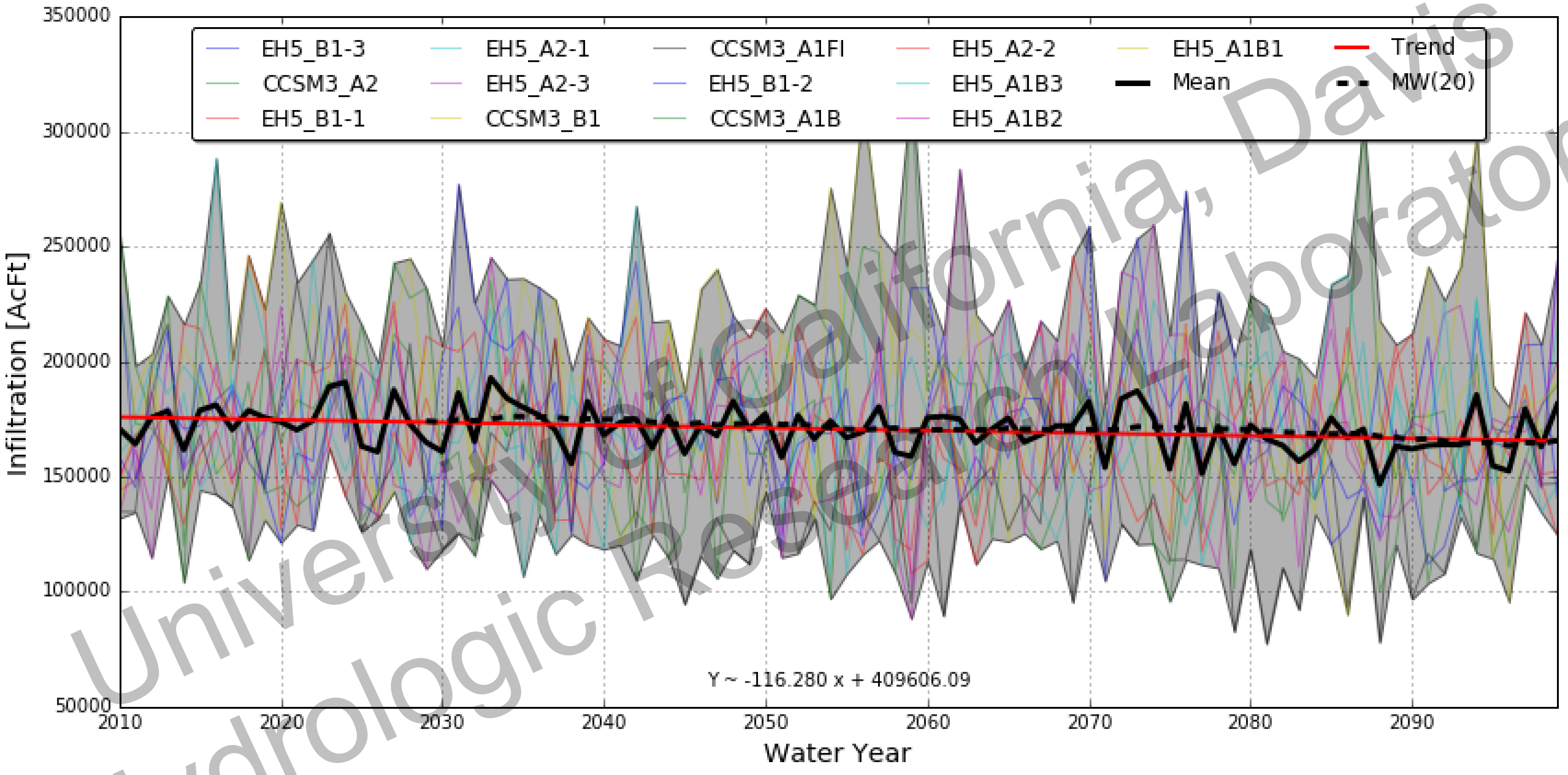


Future Results

How is it expected to change?

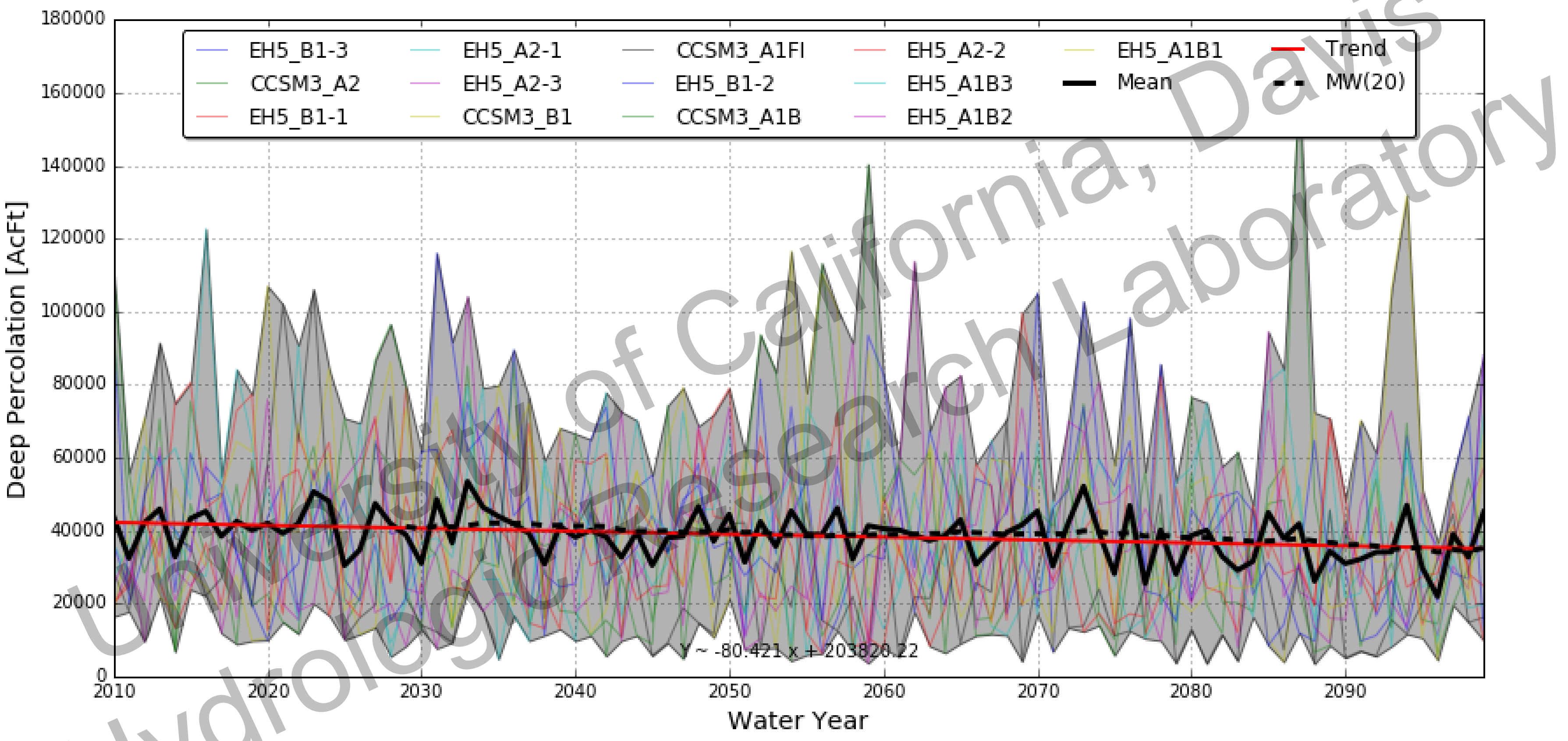
- Rainfall + Snowmelt
- Infiltration
- Direct Runoff
- Deep Percolation (Aquifer Recharge)
- Potential and Actual ET
- Total Irrigation Amount
- Groundwater Pumping
- Stream-Groundwater Interaction

Annual Infiltration



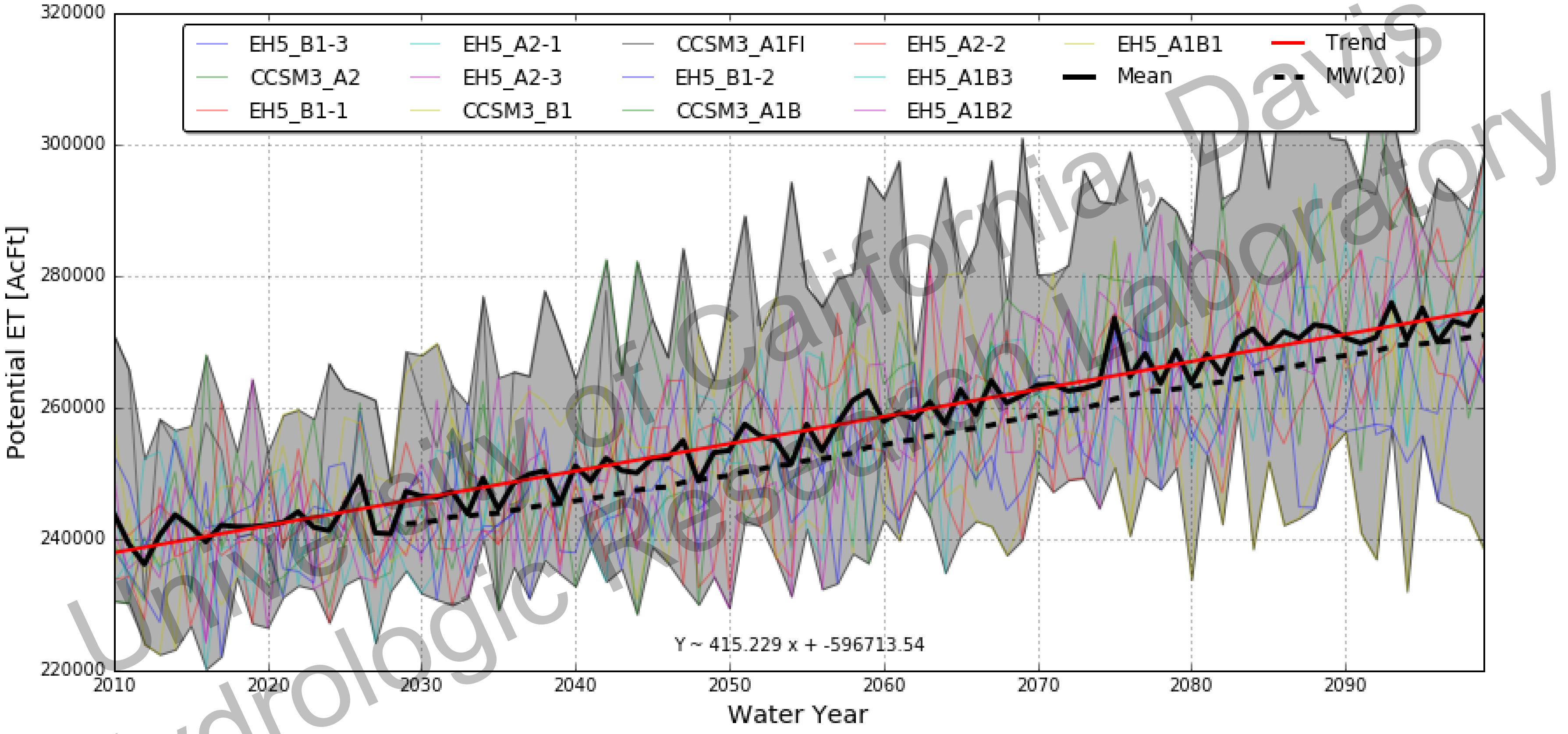
Ensemble mean is significantly decreasing between WY2010-WY2100.

Annual Deep Percolation (Aquifer Recharge)



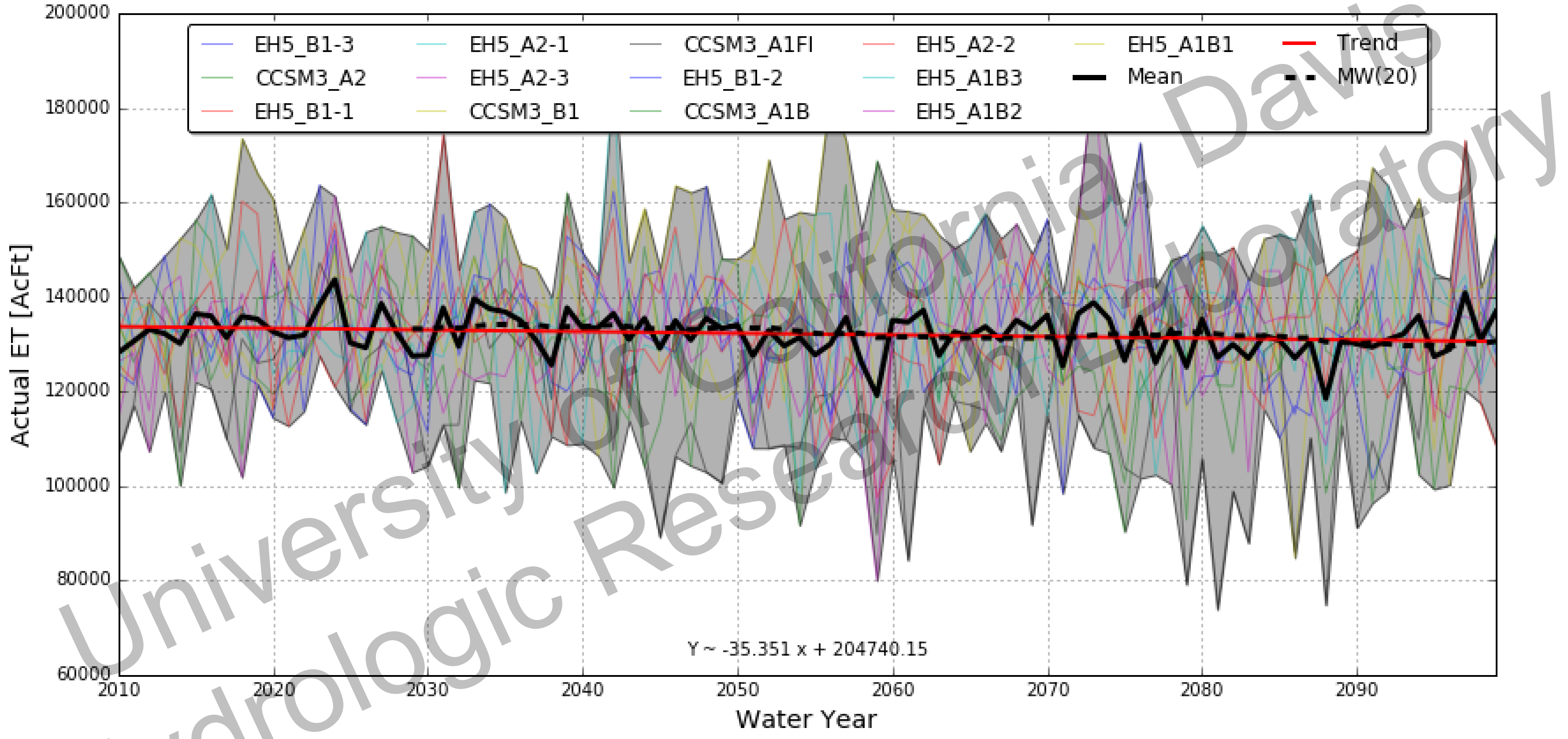
Ensemble mean is significantly decreasing between WY2010-WY2100.

Potential Evapotranspiration



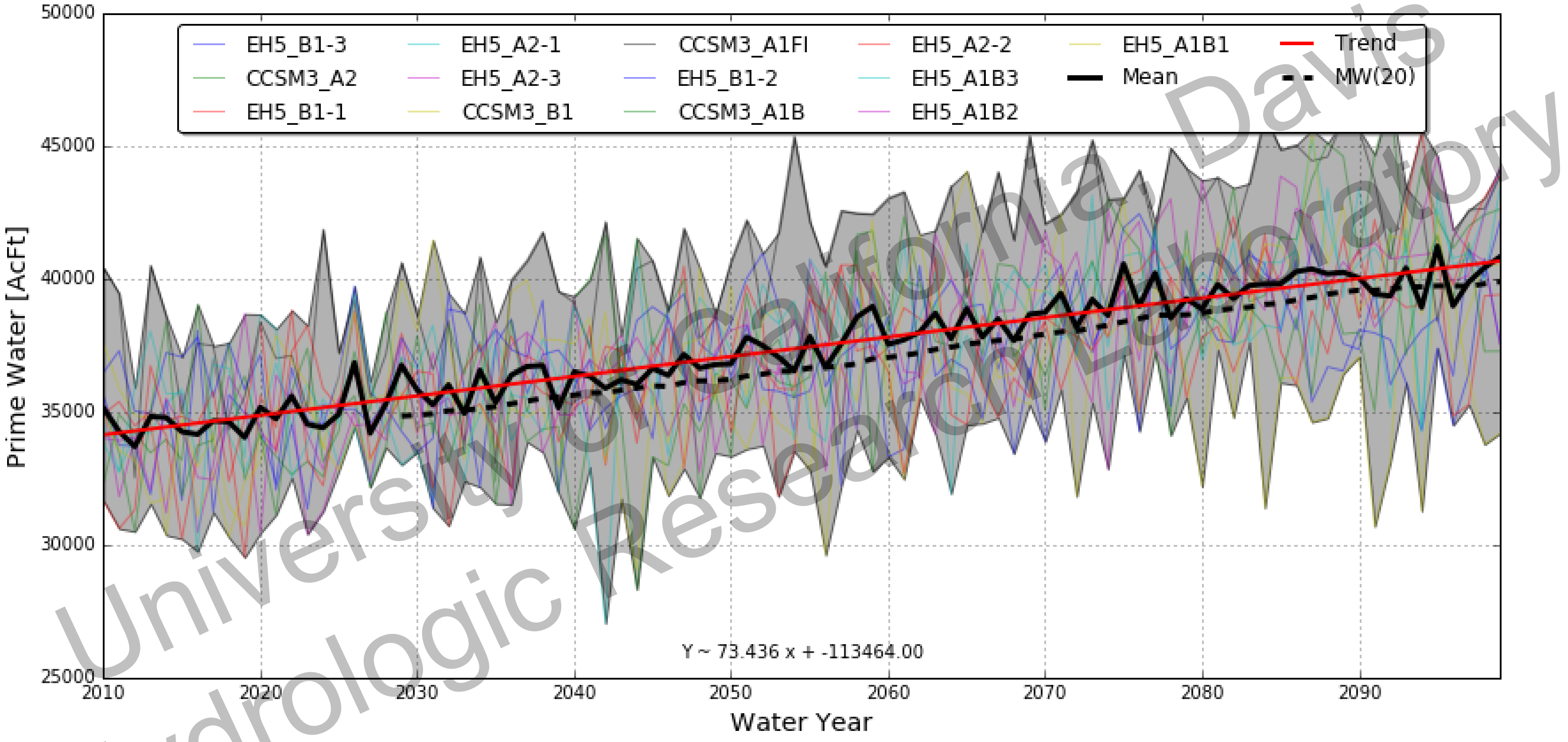
Ensemble mean is significantly increasing for each period and between WY2010-WY2100.

Actual Evapotranspiration



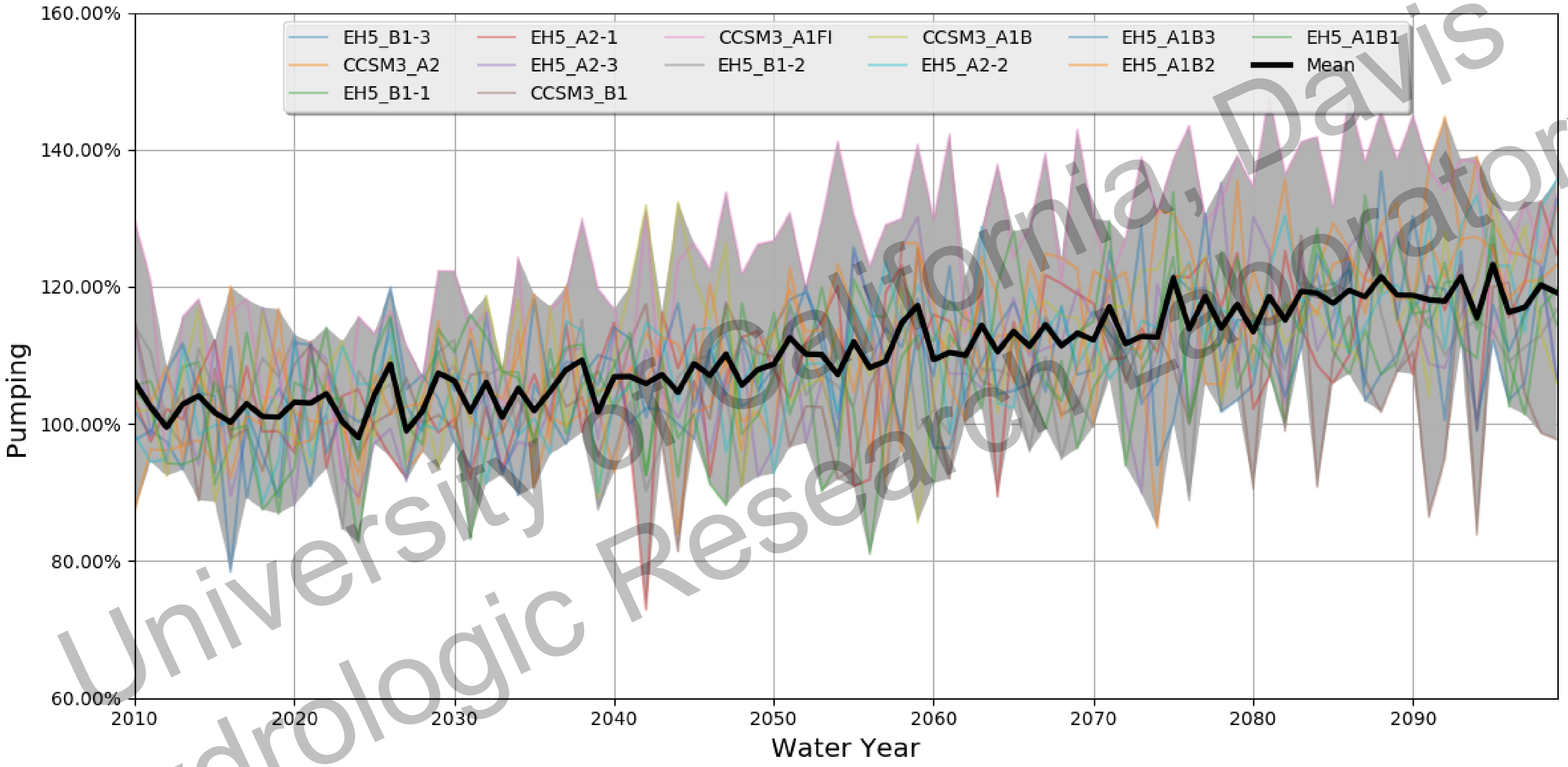
Ensemble mean is not significantly changing.

Total Irrigation



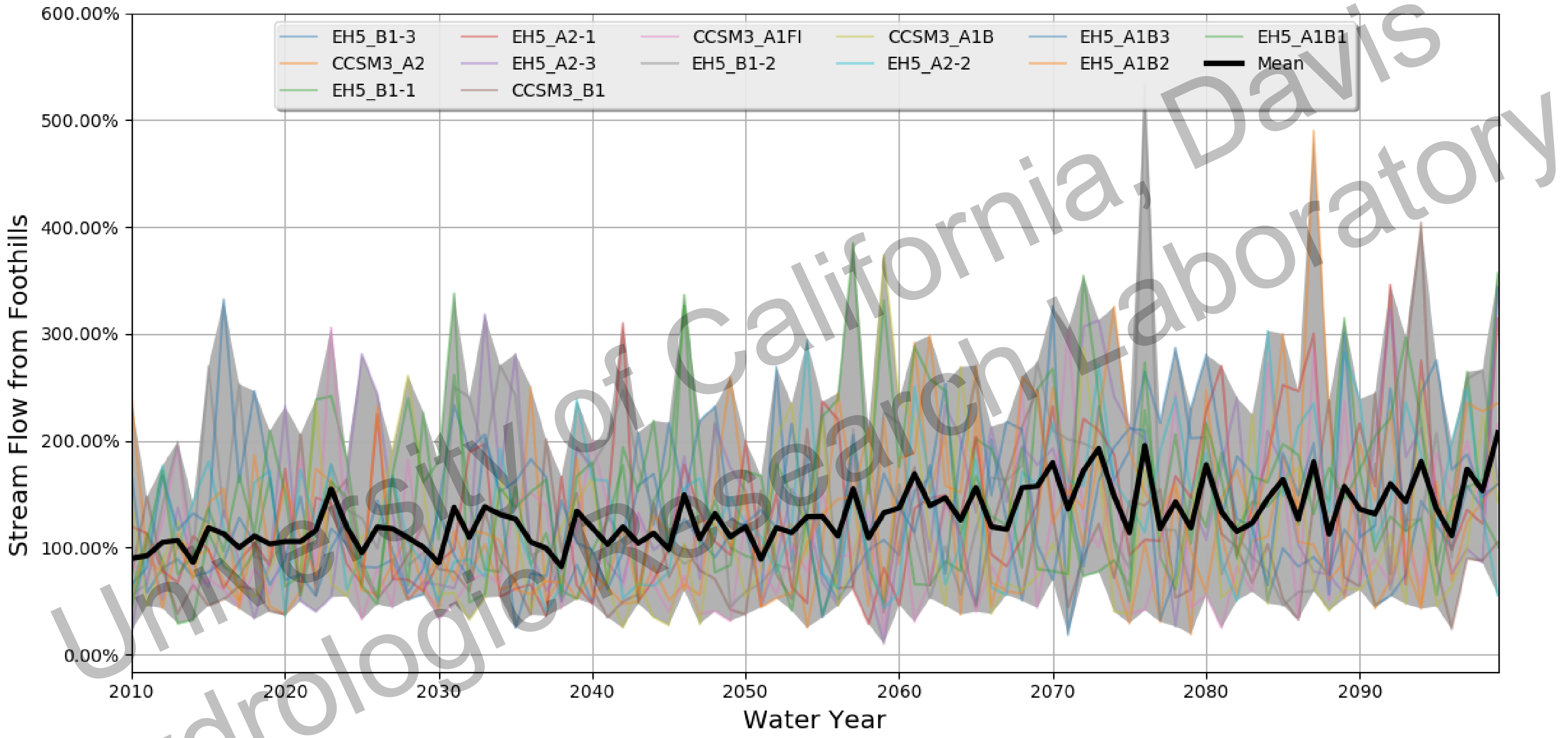
Ensemble mean is significantly increasing for each period and between WY2010-WY2100. ~15-20%

Groundwater Pumping



Ensemble mean is significantly increasing for each period and between WY2010-WY2100.
~ 20%

Streamflow from the Foothills



Ensemble mean is significantly increasing for the 2nd period and between WY2010-WY2100.

Increase in the streamflows coming from the foothills > Increase in pumping