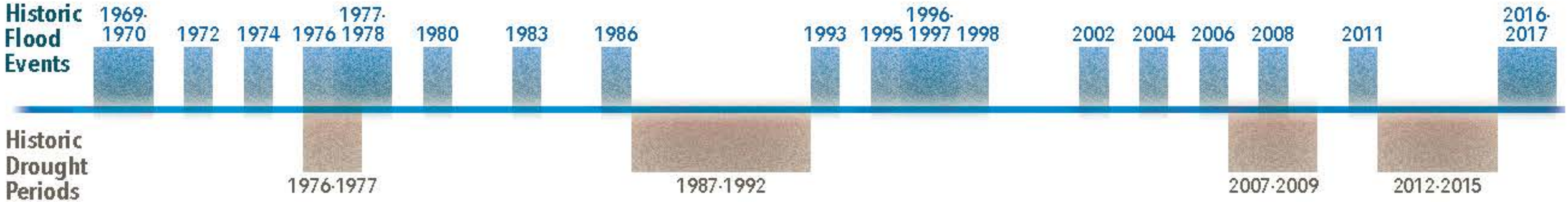
Flood Managed Aquifer Recharge
Merced Watershed Study

California Water Commission

October 21, 2020

California's Water Management
A Tale of Extremes



Sustainability Requires Big Collaboration, Agency Alignment & Sector Co-Management

Integrated Watershed Management

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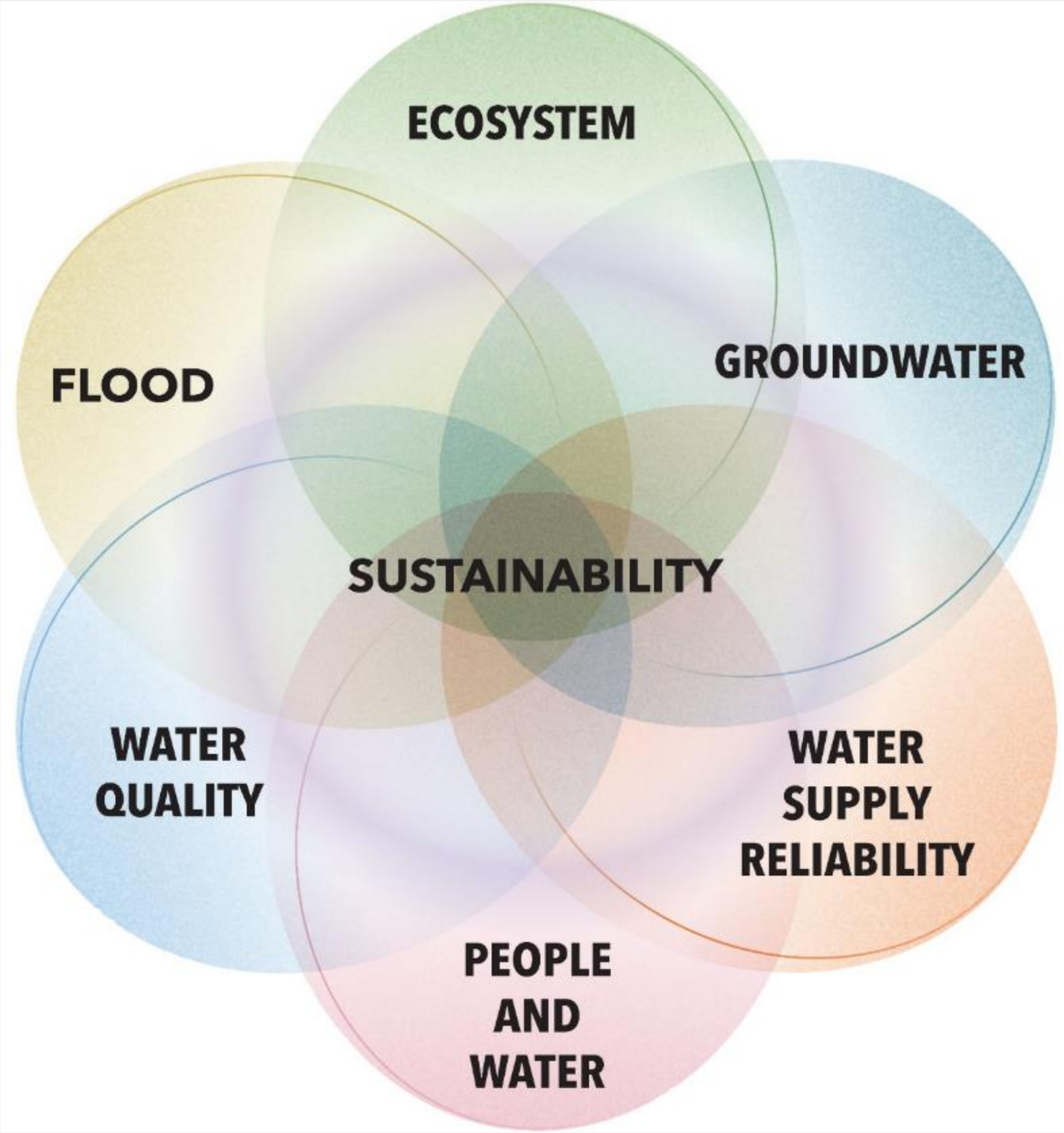
Multi-Sector Collaboration

Multi-Discipline Planning

Multi-Benefit Projects

Multi-Fund Investments

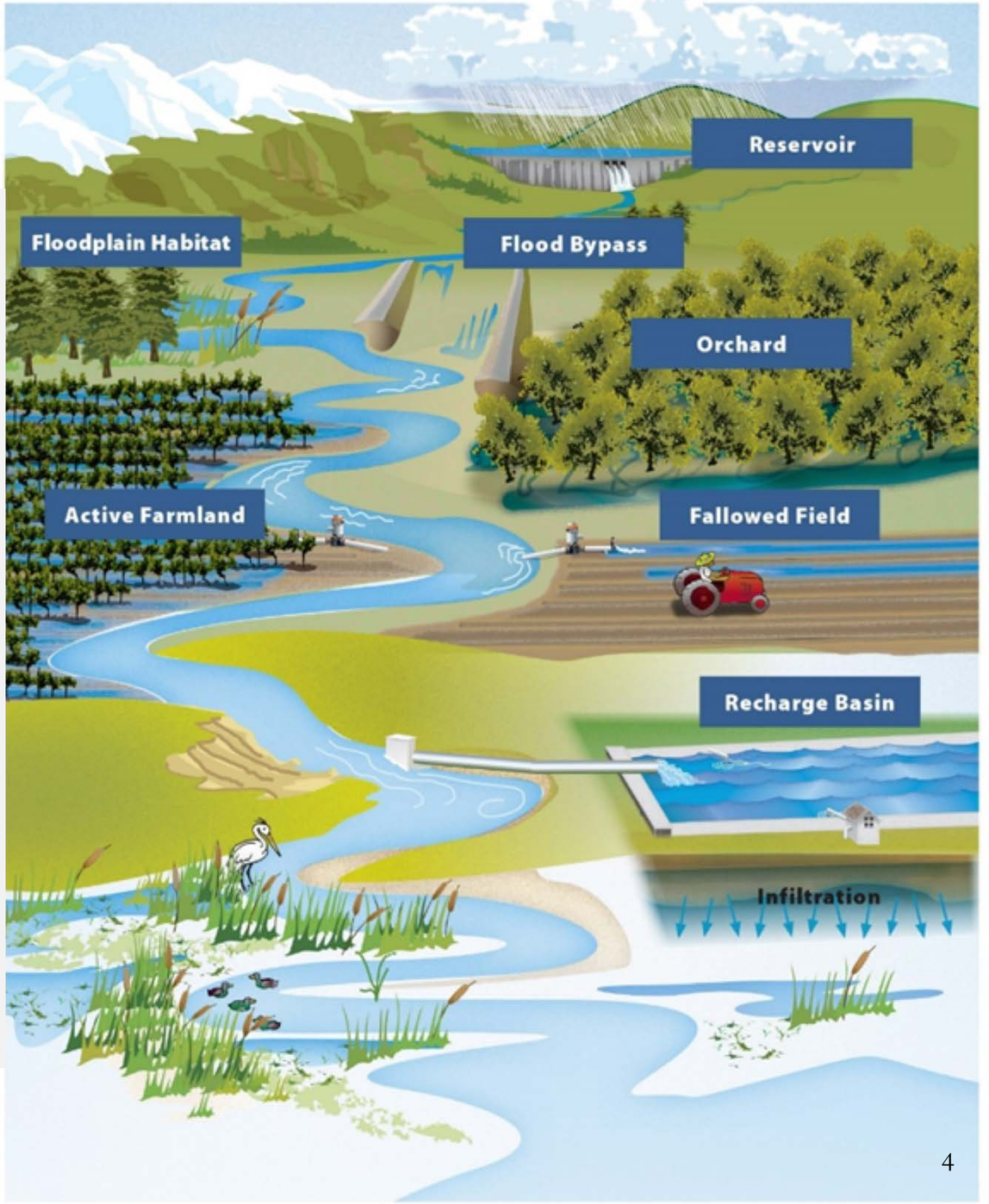


Flood-MAR Epitomizes IWM

An integrated strategy to manage water resources for sustainability & climate resiliency …

… using high flows from (or in anticipation of) rainfall or snowmelt for managed aquifer recharge …

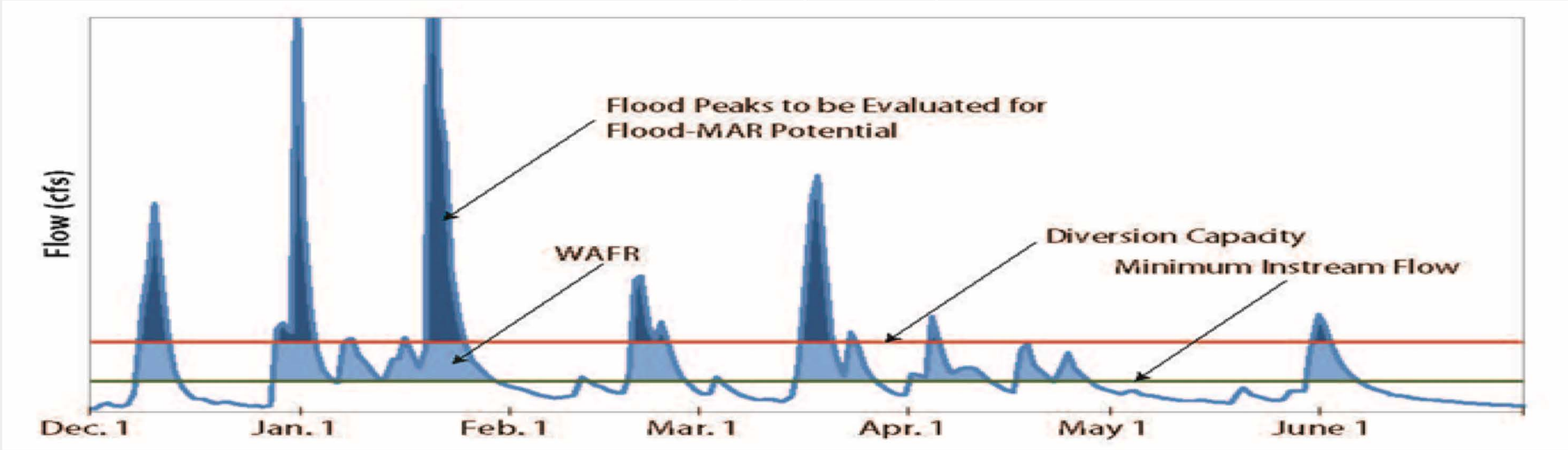
… on agricultural lands, working landscapes, and natural managed lands



CALIFORNIA DEPARTMENT OF WATER RESOURCES

State Recommends Flood-MAR

- 2017 CV Flood Protection Plan Update (Aug. 2017)
- System Reoperation Study Phase 3 Report (Aug. 2017)
- State Board of Food & Agriculture letter (May 2018)
- Final CA Water Plan Update 2018 (July 2019)
- Final Water Resilience Portfolio (July 2020)



Flood-MAR is …

- … **voluntary** (public-private partnerships among private landowners, public agencies, and governments)
- … **multi-sector** (co-management of flood, surface & groundwater, ecosystem & quality)
- … **scalable** (on-farm, GSA, basin, region, watershed)
- … **multi-faceted** (reoperation, conveyance, storage, recharge, banking, transfers, cultivation, restoration, etc.)
- … **untapped** part of California's water portfolio

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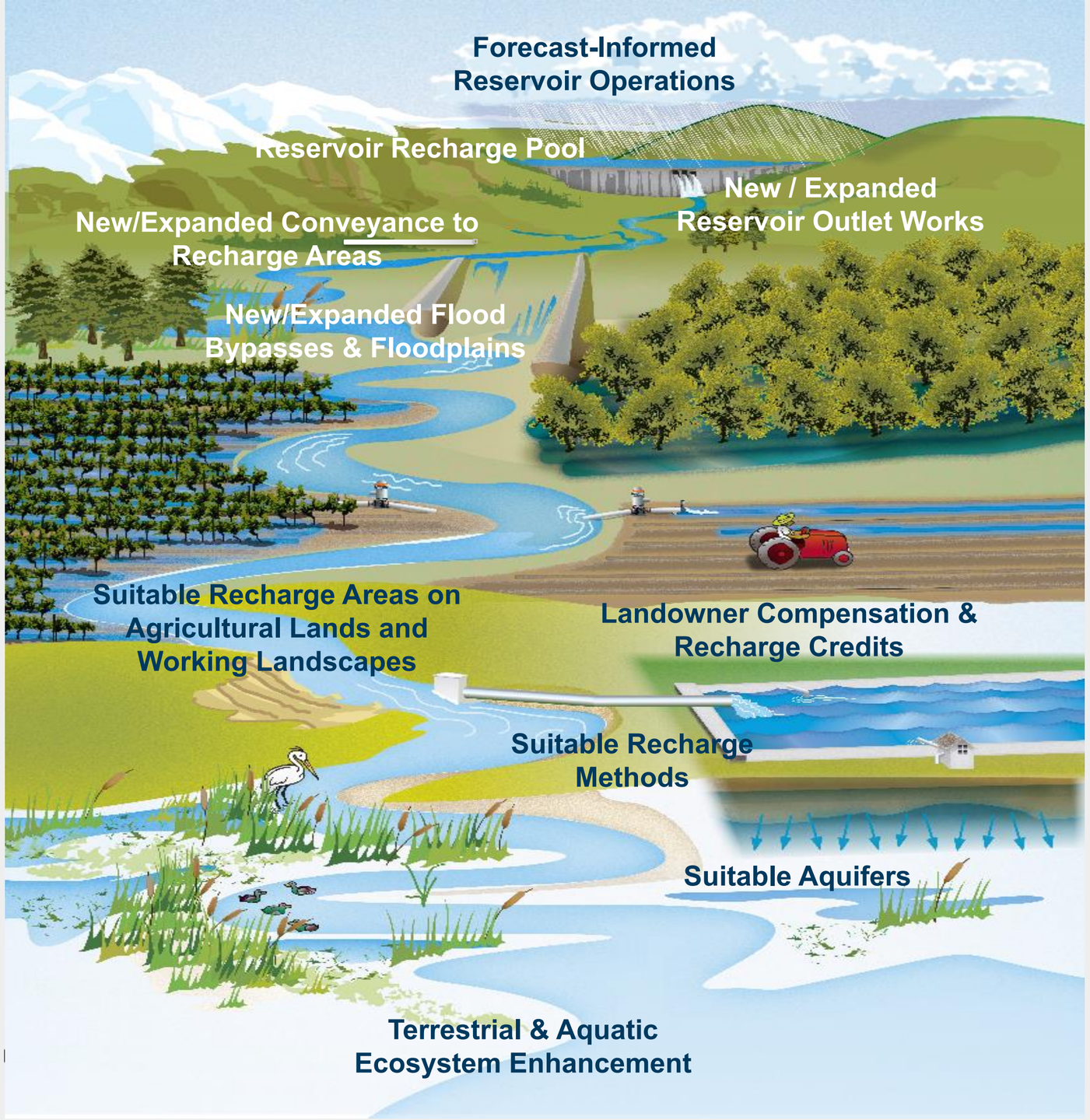

A Headwater to Groundwater Strategy

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Example Flood-MAR Projects & Activities
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2019 Flood-MAR Forum

Actions to Move from Concept to Implementation

1. Create partnerships & opportunities for collaboration
2. Increase agency cooperation & alignment
3. Increase flexibility for water managers
4. Design pilot projects & research studies to fill data gaps
5. Increase technical support & streamline funding for landowners & local agencies

Flood-MAR Activities at DWR

Watershed Studies
- Merced Study
- Tuolumne Study

Flood-MAR Network

Guidance
- White Paper
- R&DD Plan
- Technical Memos

Pilot Projects
- Watershed
- GSA / District
- On-Farm

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Merced River Watershed Flood-MAR Reconnaissance Study

David Arrate

October 21st, 2020

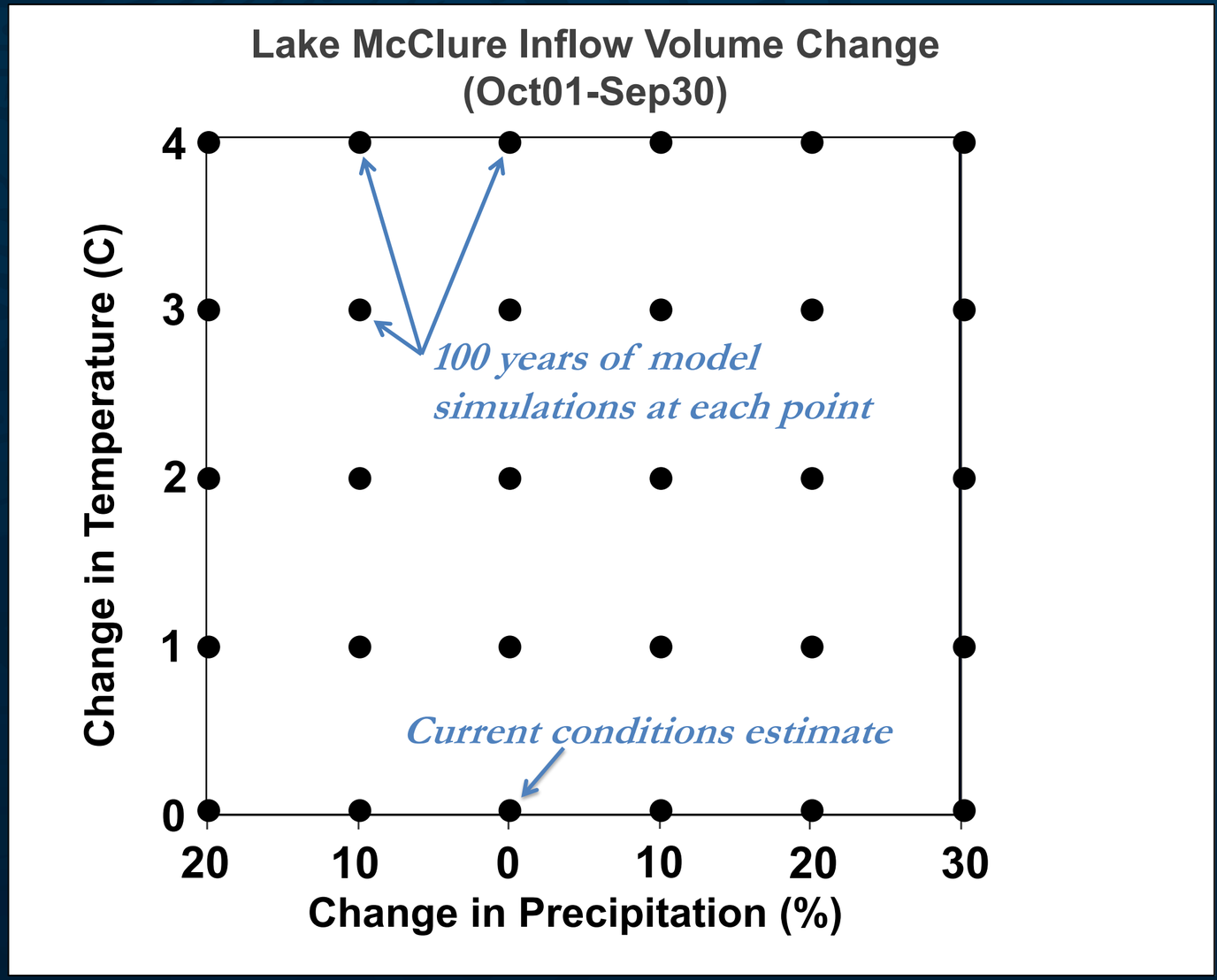
Study Purpose & Goals

- Proof of concept study: Investigate Flood-MAR concepts on a watershed scale
- Integrated Watershed Modeling – Integrated headwater to groundwater toolset and analyses
- Assess multi-benefits, economics, and climate change towards Sustainable & Integrated Resource Management
- Template for future studies and projects - Document the process of planning, modeling, and analyzing a Flood-MAR project of this scale

Climate Change

Annual Average Lake McClure Inflow Volume = 1.0 MAF

- Decision Scaling Methodology
- 30 climate scenarios
  - 0° to 4° Celsius increase in temperature
  - -20% to +30% change in precipitation
- 100 years of hydrology
  - 1900 to 1999

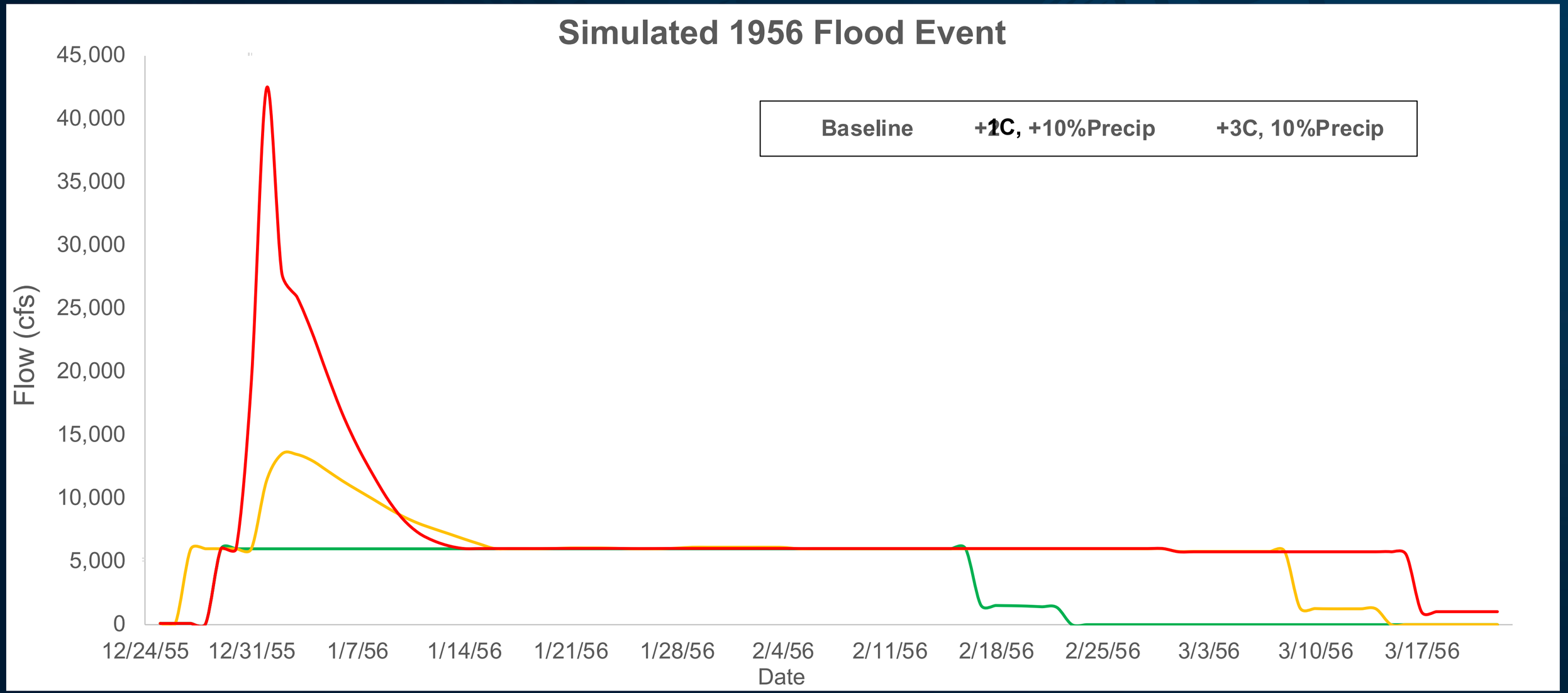


Baseline & Flood-MAR Implementation Levels

- Baseline Climate Vulnerability Analysis
- Level 1 – Existing Infrastructure & Existing Operations
- Level 2 – Existing Infrastructure & Reservoir Reoperations
- Level 3 – New/Expanded Infrastructure & Reservoir Reoperations

Climate Vulnerability Analysis

- Example Result – Peak Merced River Flow



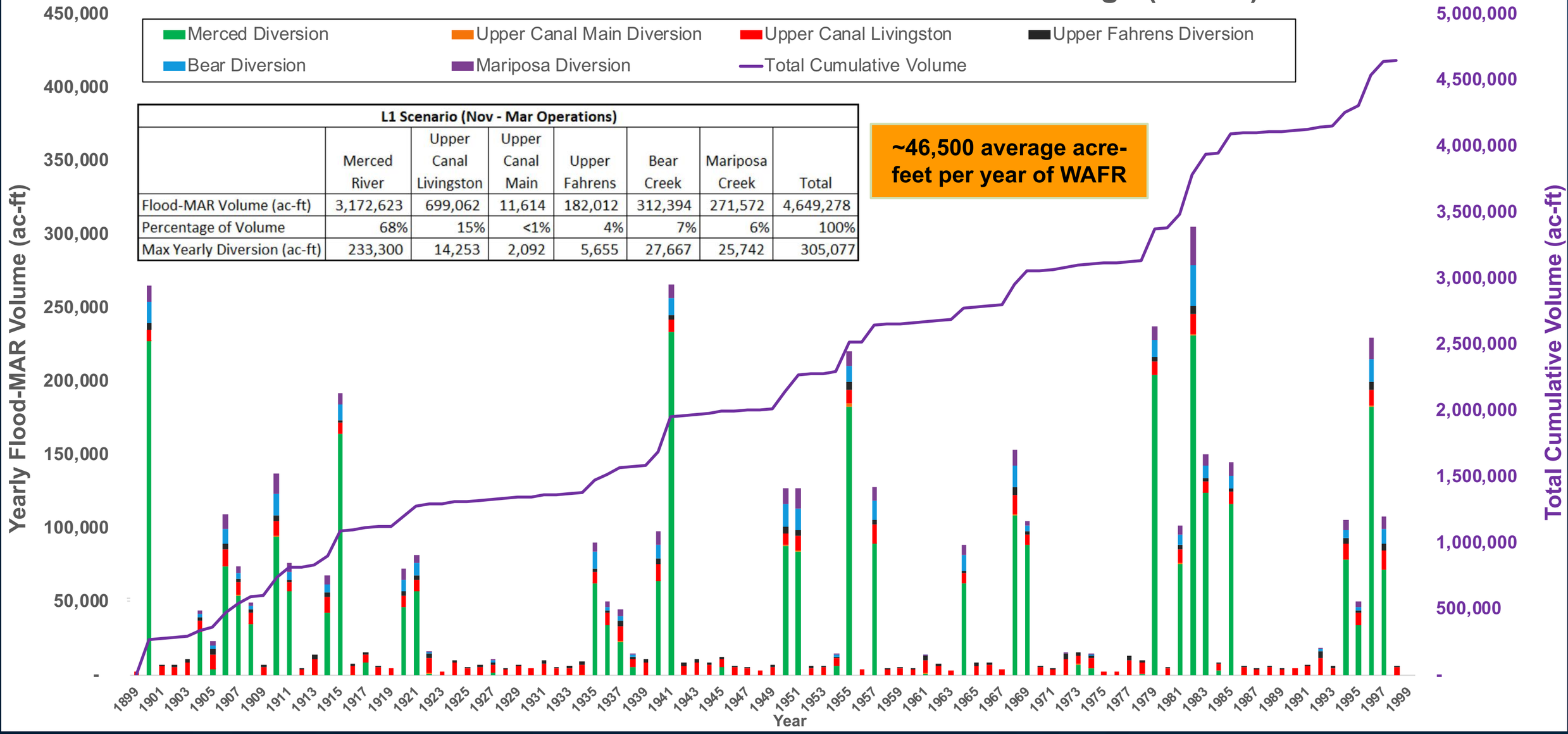
Flood-MAR Level 1 Scenarios

	Initial	Intermediate	Robust
Description	SWRCB Streamline Permitting Guidelines	Expanded Initial Scenario	Max bookend scenario
Flow Trigger	Daily 90th% Flow	Monthly 90th% Flow	Minimum Instream + Buffer
Diversion Amount	Up to 20% of total flow	Any flow above trigger	Any flow above trigger
Timeframe	December to March	November to March	November to March
Recharge Type	Canal-Only	Canal & On-Farm	Canal & On-Farm

- Delta Conditions Check – Flood-MAR triggers when Delta is in excess conditions
- Maximize Flood-MAR recharge while assessing multiple benefits

Level 1 - Intermediate Scenario Results

L1 Intermediate Flood-MAR Water Available For Recharge (WAFR)



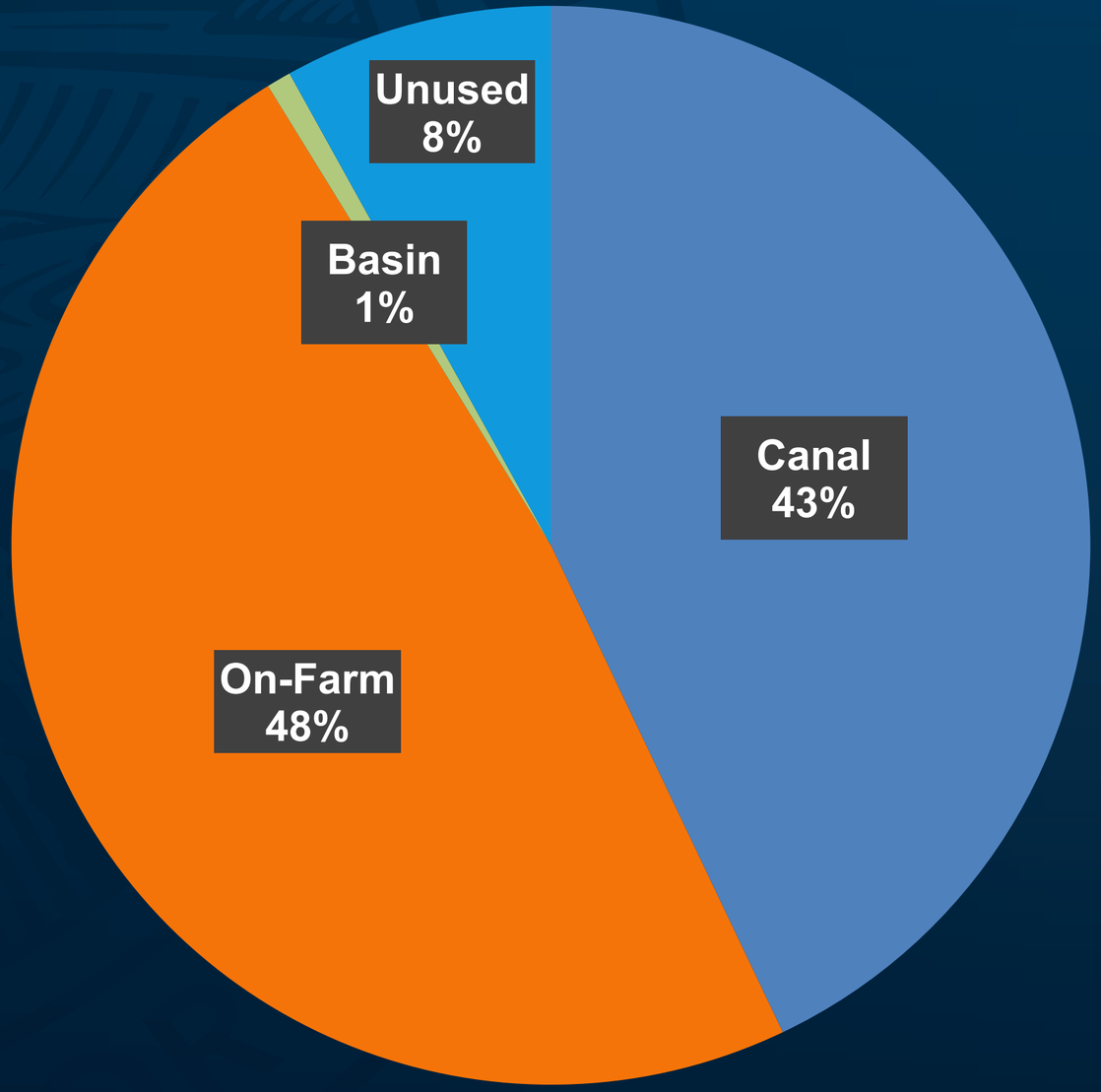
L1 Scenario (Nov - Mar Operations)							
	Merced River	Upper Canal Livingston	Upper Canal Main	Upper Fahrens	Bear Creek	Mariposa Creek	Total
Flood-MAR Volume (ac-ft)	3,172,623	699,062	11,614	182,012	312,394	271,572	4,649,278
Percentage of Volume	68%	15%	<1%	4%	7%	6%	100%
Max Yearly Diversion (ac-ft)	233,300	14,253	2,092	5,655	27,667	25,742	305,077

~46,500 average acre-feet per year of WAFR

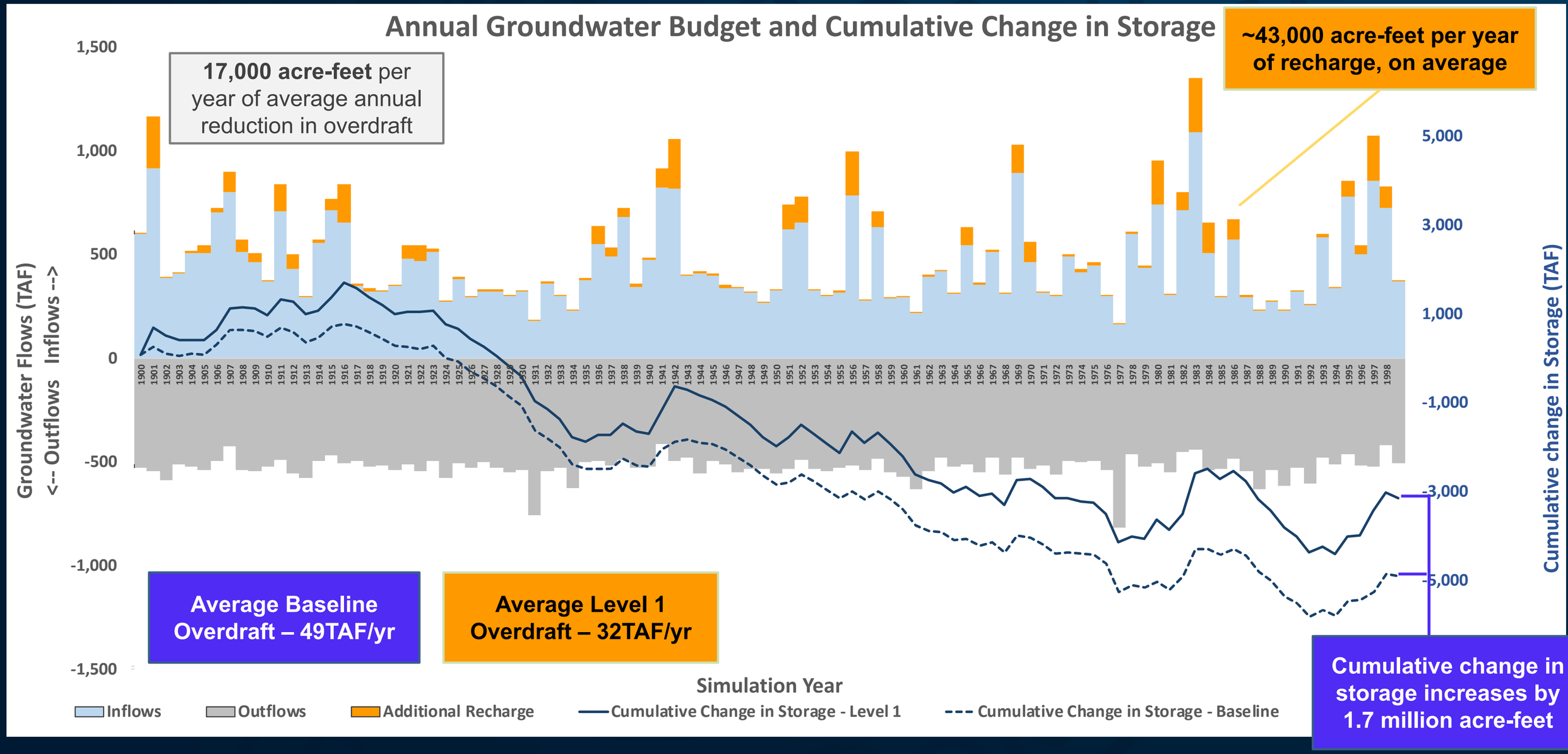
Level 1 - Intermediate Scenario Results

Total Flood-MAR for 100yr study period

Flood-MAR WAFR:	**4,649,278 AF**
Canal Seepage:	**1,995,855 AF**
Recharge Basins:	**34,098 AF**
On Farm:	**2,244,905 AF**
Unused WAFR:	**374,420 AF**
Total Recharge:	**4,274,858 AF**
Avg Annual Recharge:	**~43 TAF/yr**



Fate of Recharge – Change in Storage



Modeling Beyond Study Area

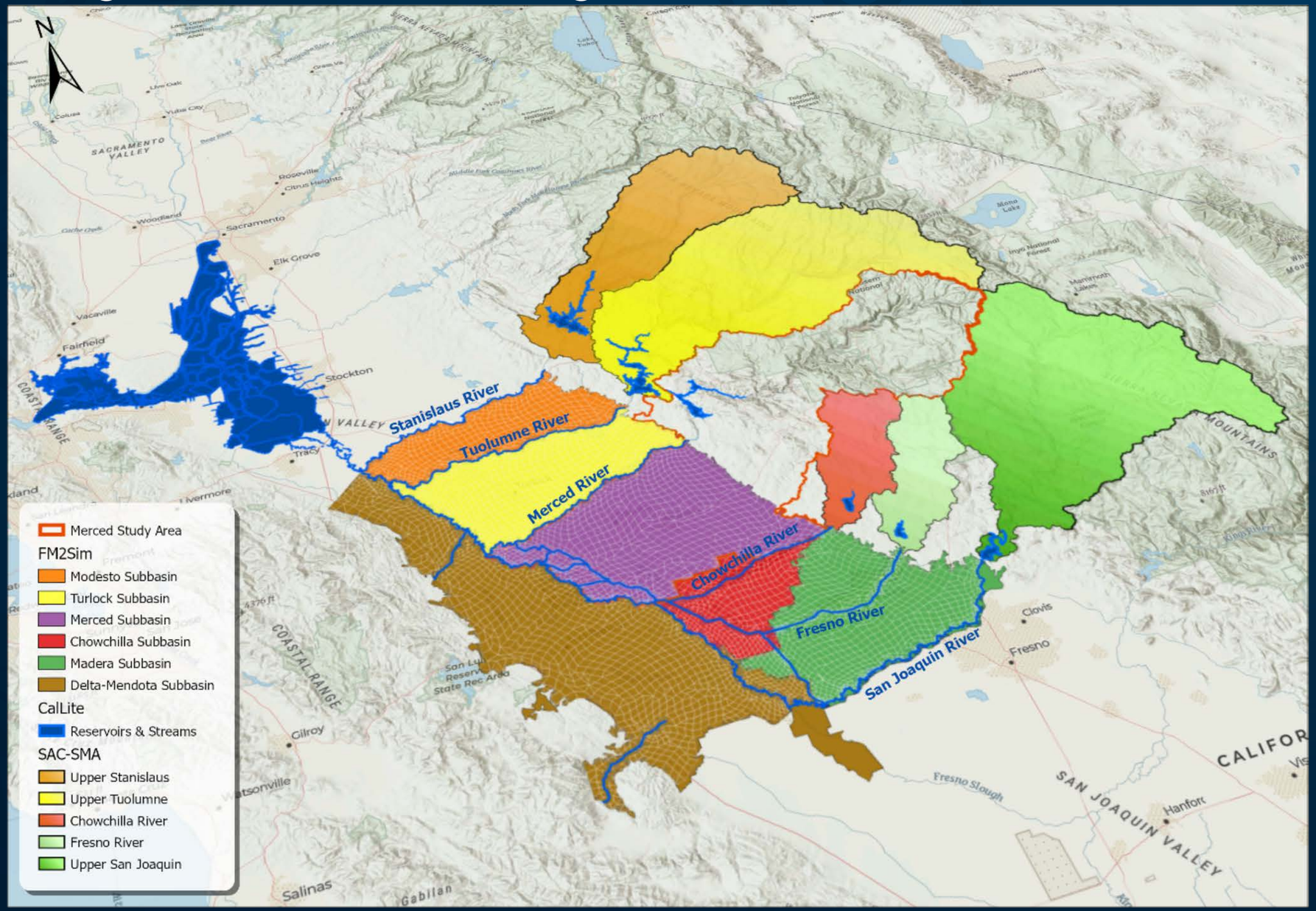
Rainfall Runoff
Sac-SMA

↓

System Operations
CalLite

↓

Groundwater Operations
FM2SIM



Watershed Scale Modeling

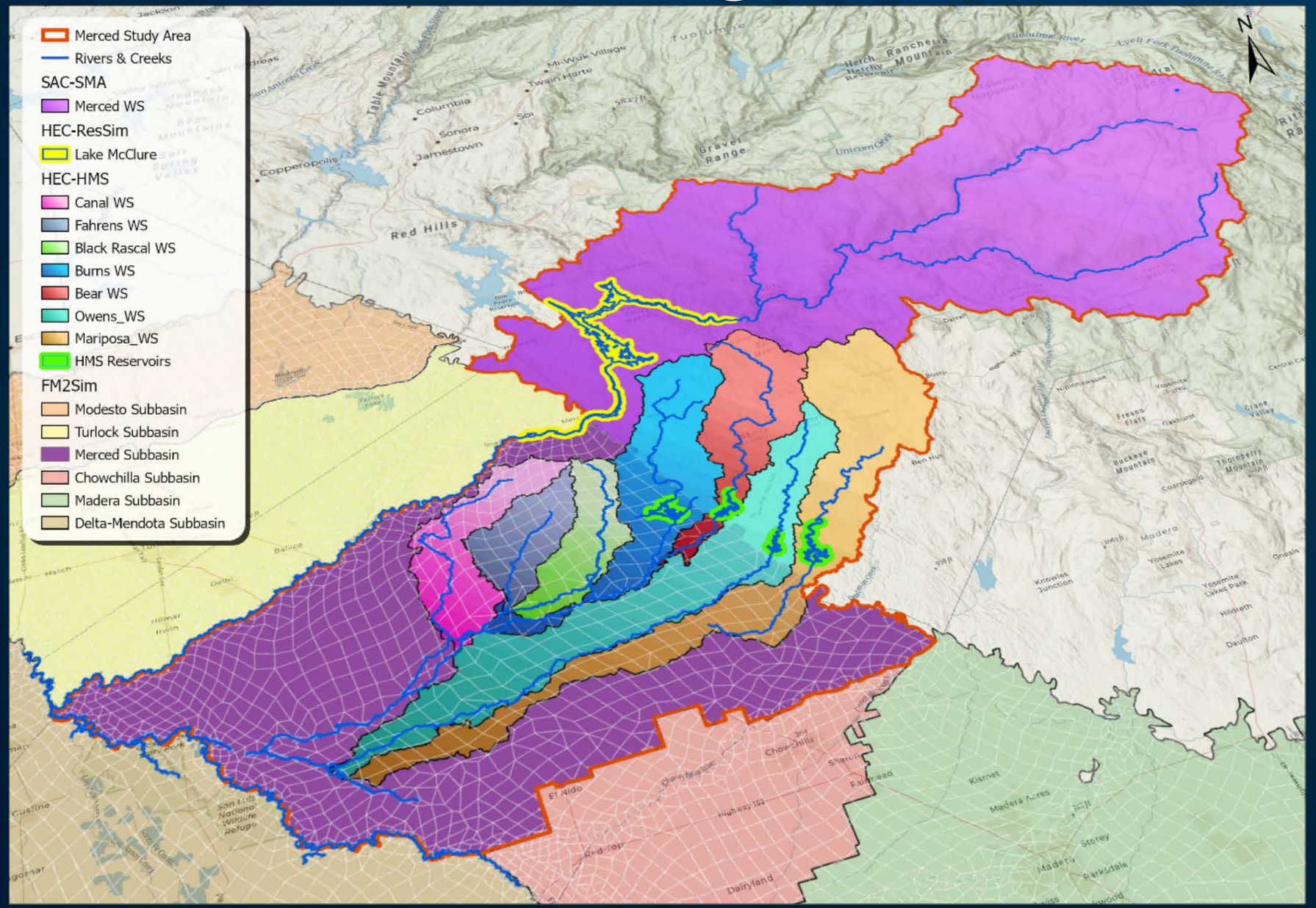
Rainfall Runoff
Sac-SMA

Reservoir Operations
HEC-ResSim (MIDH2O)

Rainfall Runoff (Creeks)
HEC-HMS (MIDH2O)

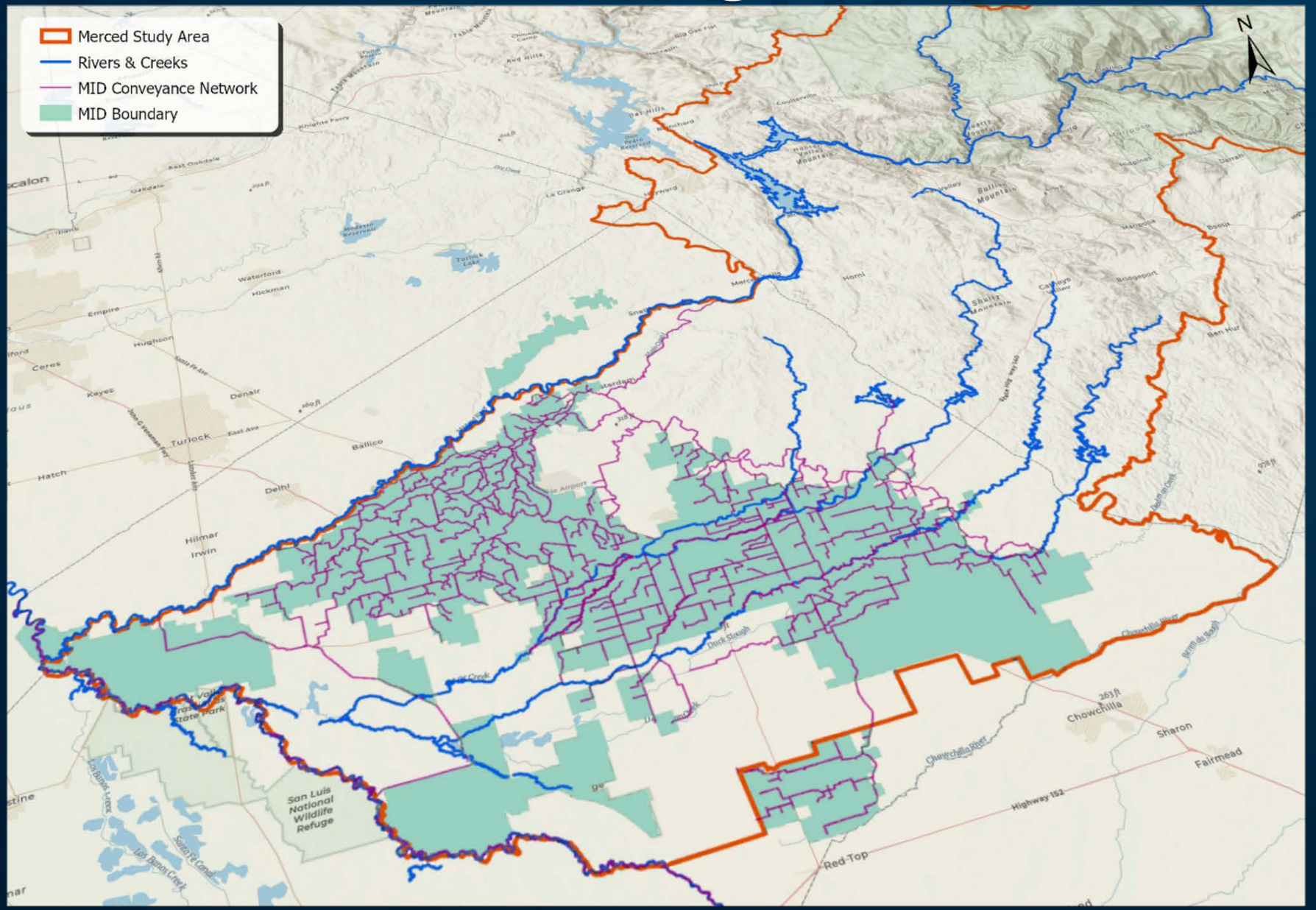
Recharge Optimization
GRAT

Groundwater Operations
FM2SIM



Watershed Scale Modeling

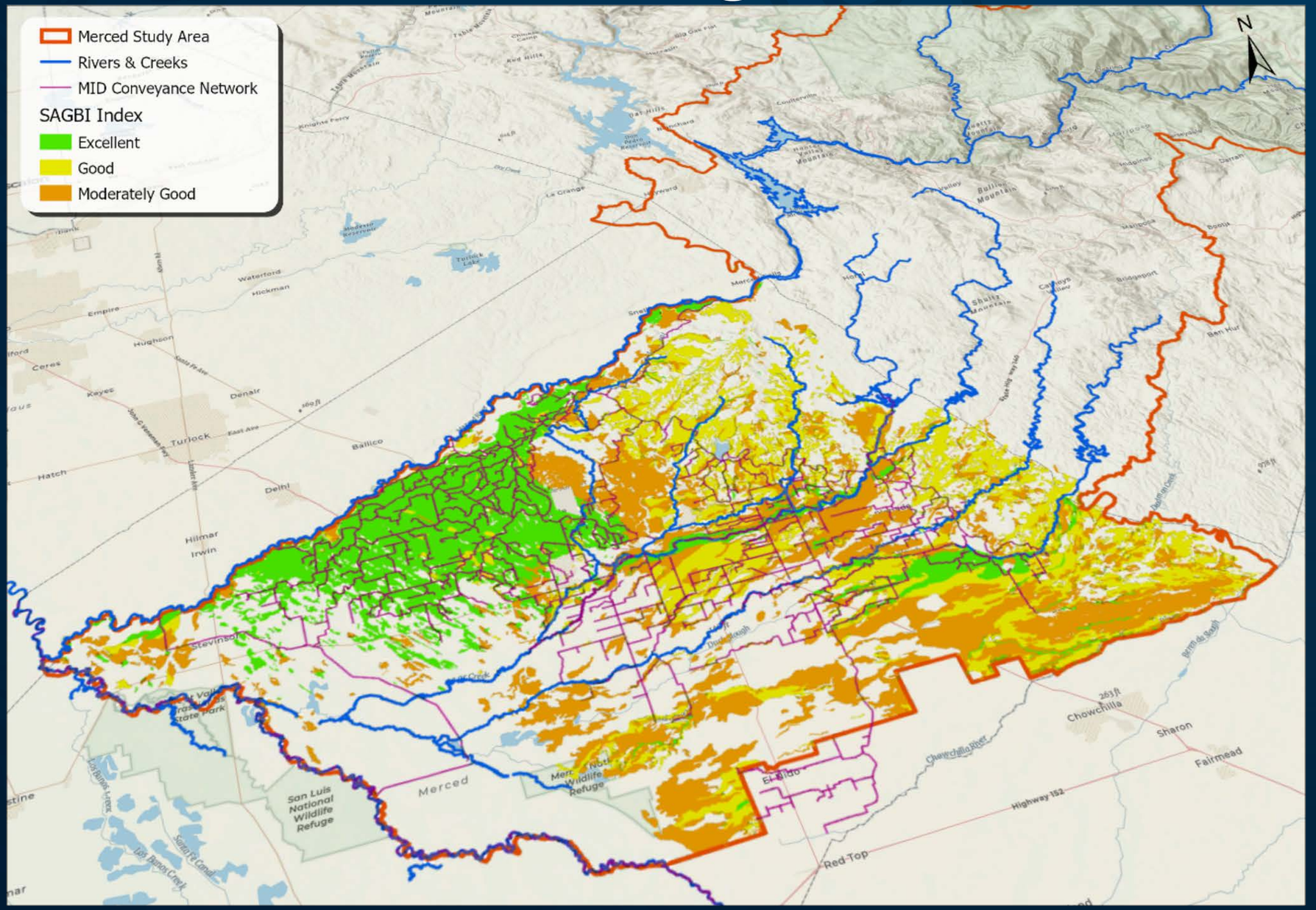
District Service Area



Recharge Optimization
GRAT

Watershed Scale Modeling

Soil Suitability



Recharge Optimization
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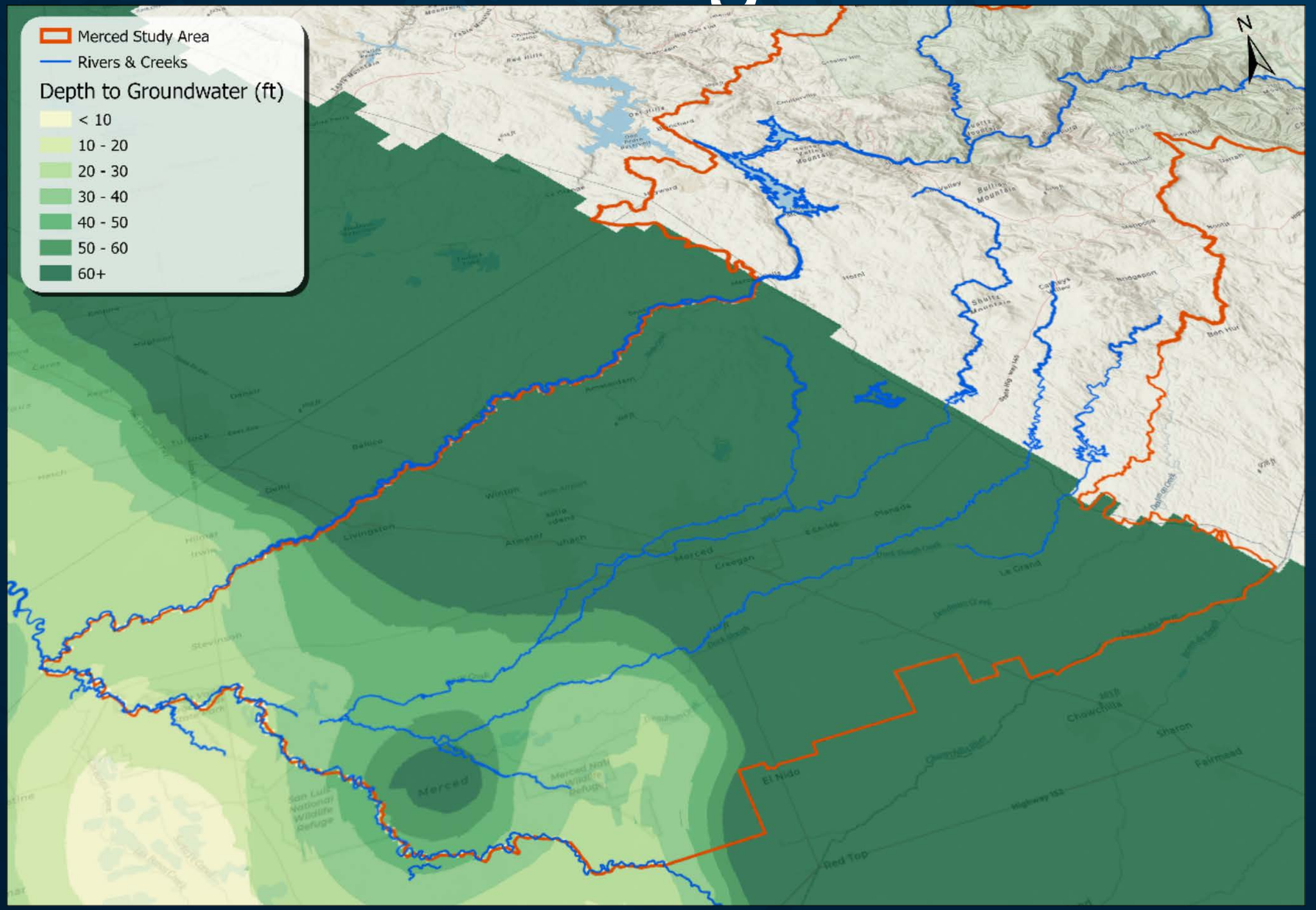
Watershed Scale Modeling

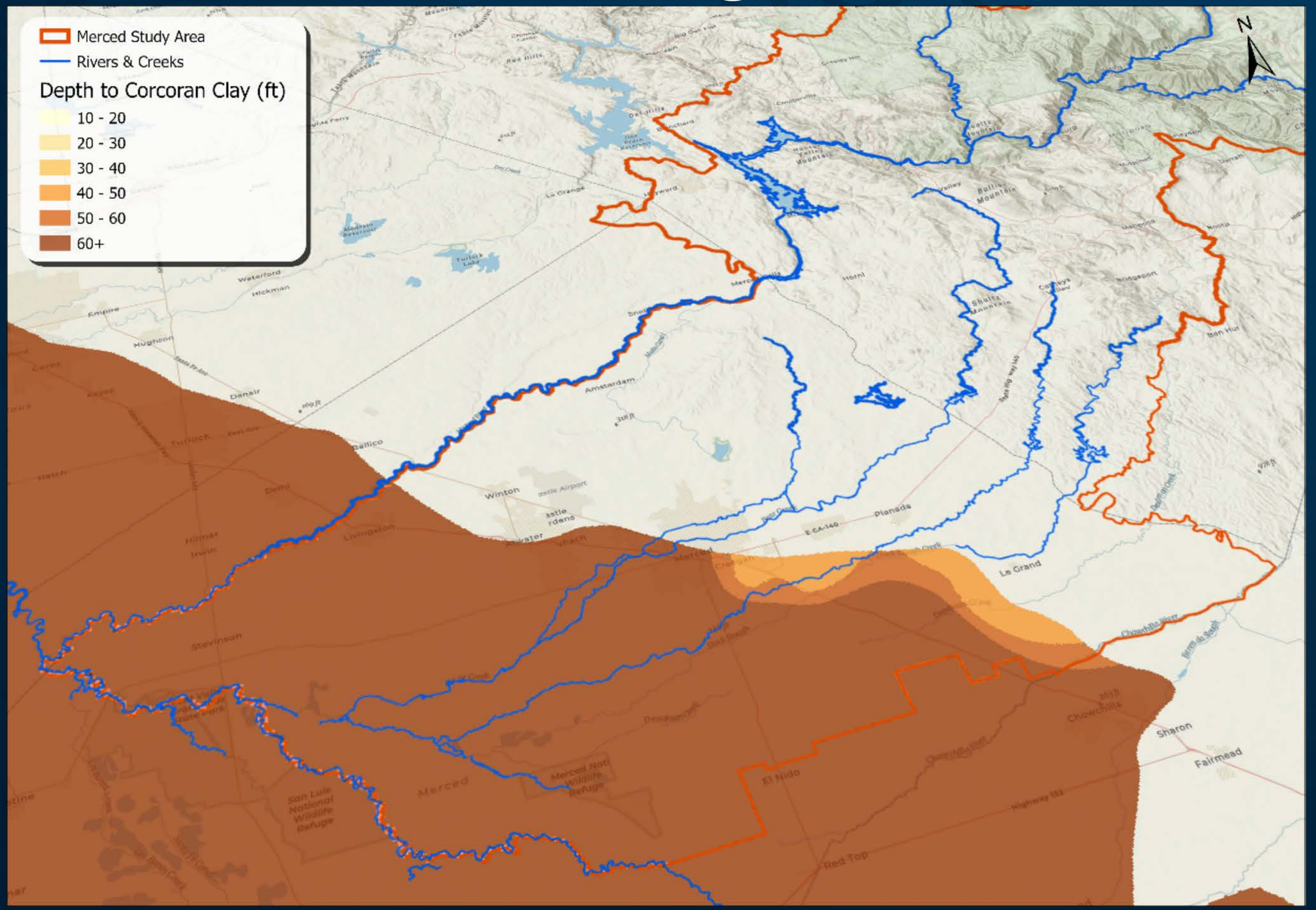
Depth to Groundwater



Recharge Optimization
GRAT

Watershed Scale Modeling

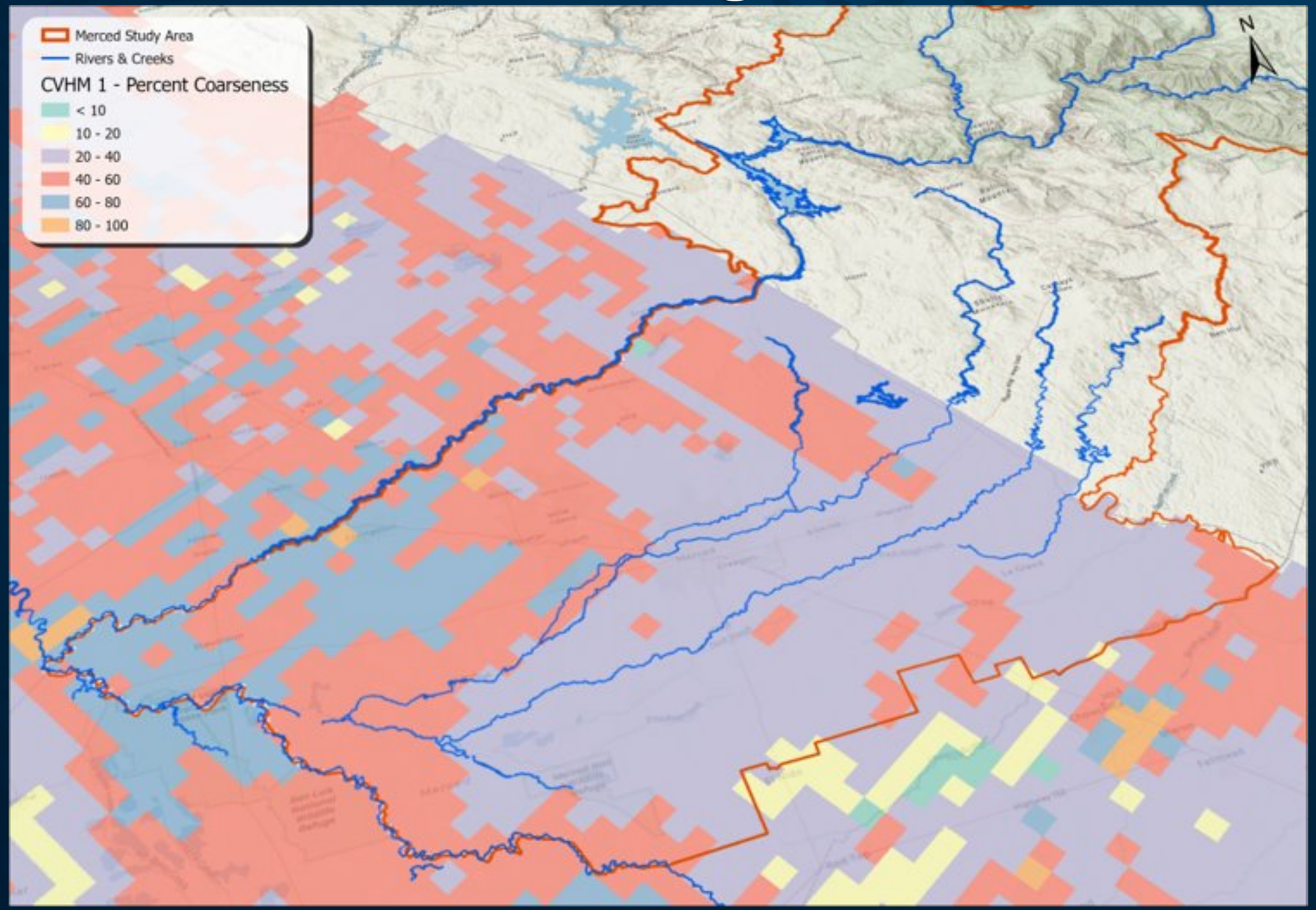
Depth to Corcoran Clay



Recharge Optimization
GRAT

Watershed Scale Modeling

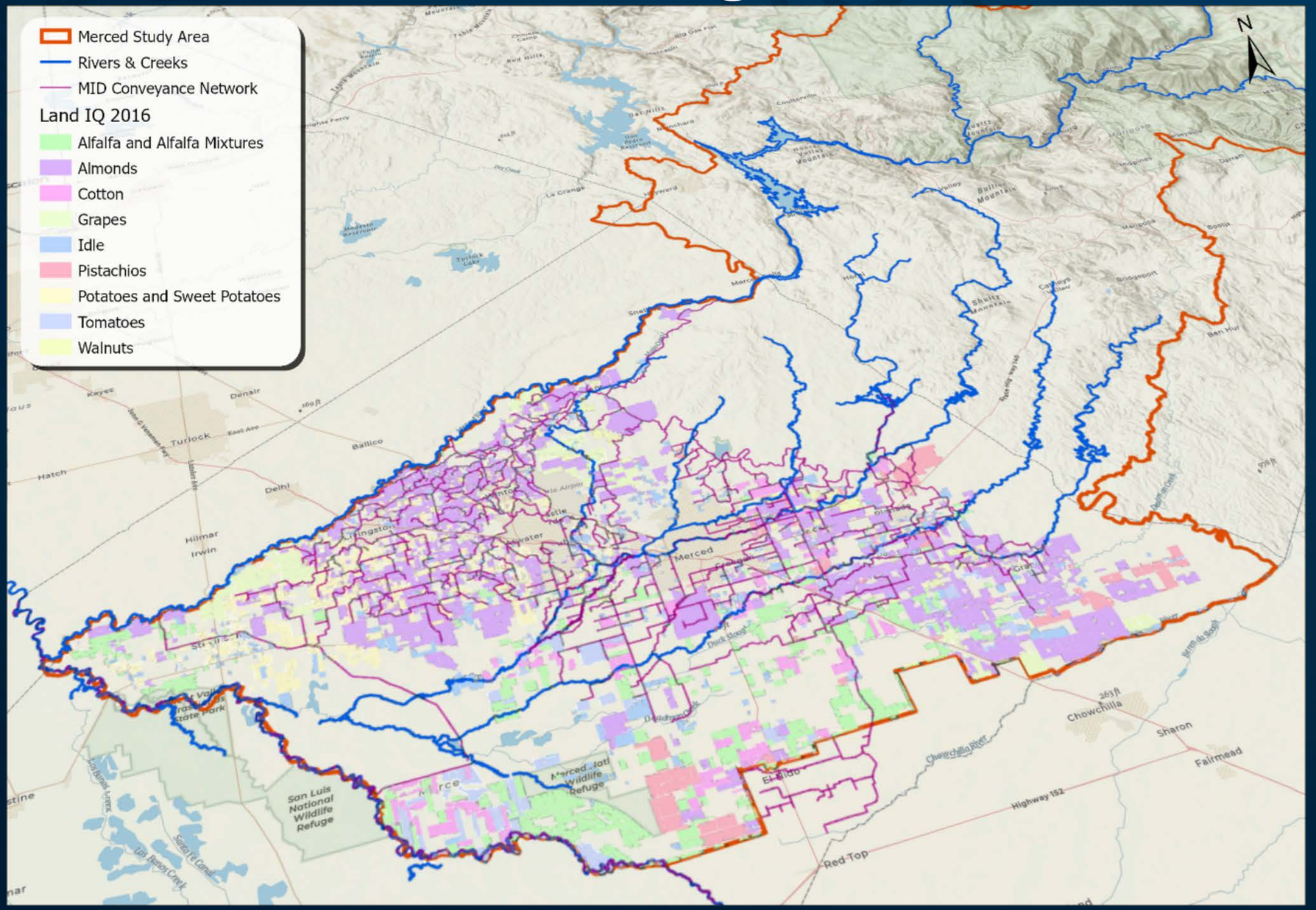
Subsurface Permeability



Recharge Optimization
GRAT

Watershed Scale Modeling

Land Use



Recharge Optimization
GRAT

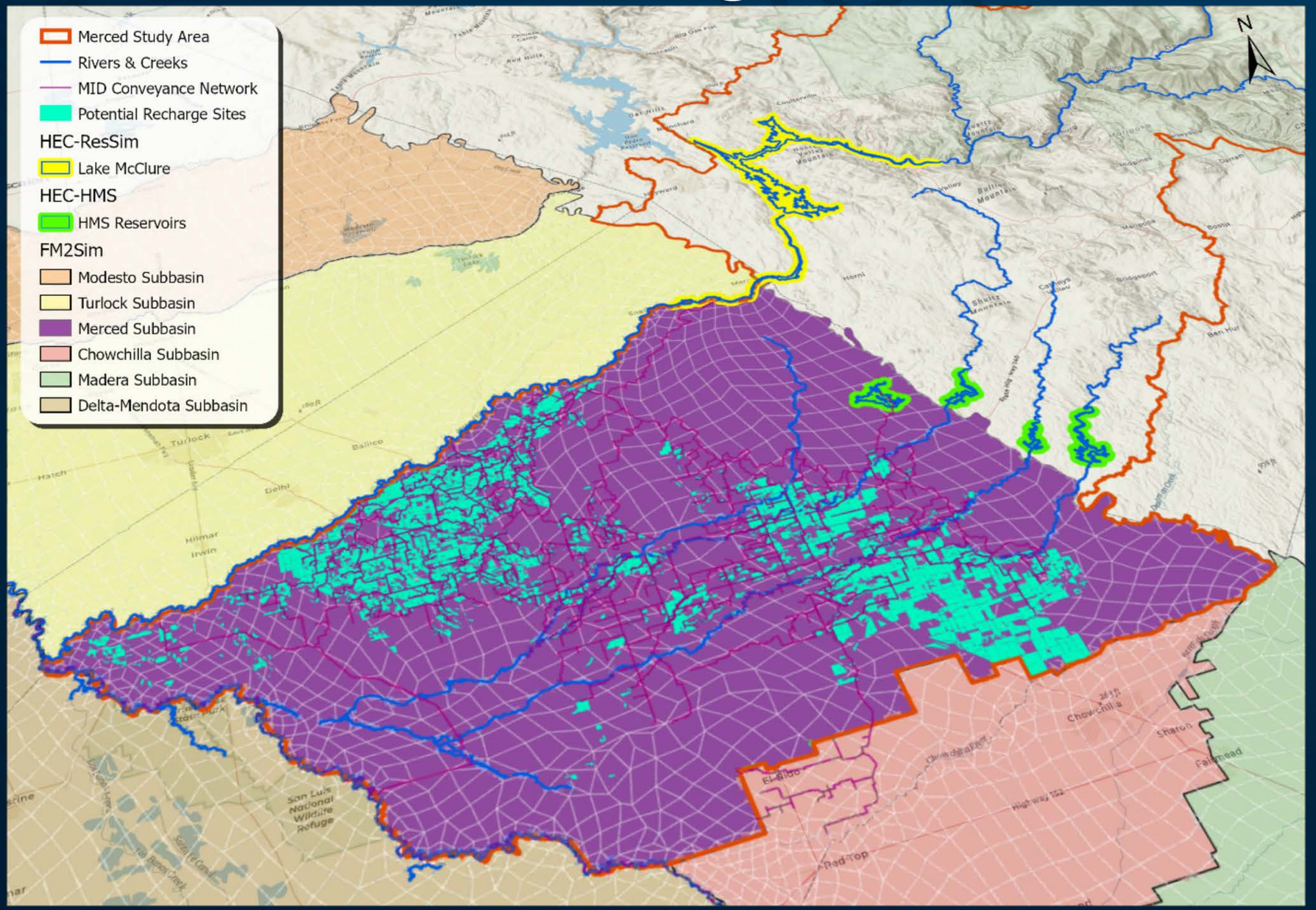
Watershed Scale Modeling

Potential Recharge Sites

Flood-MAR WAFR
ResSim & HMS

Recharge Optimization
GRAT

Groundwater Operations
FM2SIM



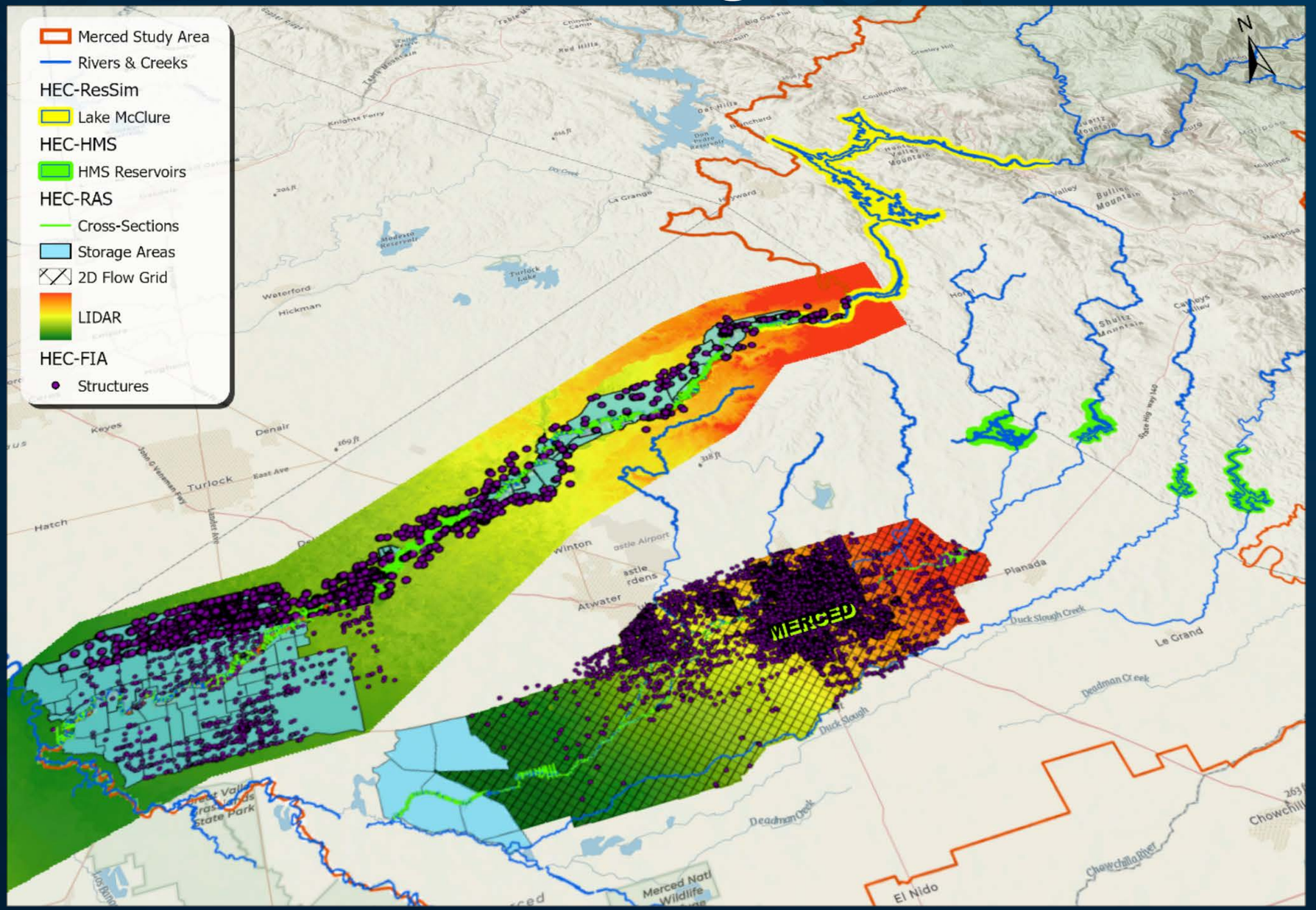
Watershed Scale Modeling

Reservoir Operations
HEC-ResSim (MIDH2O)

Rainfall Runoff (Creeks)
HEC-HMS (MIDH2O)

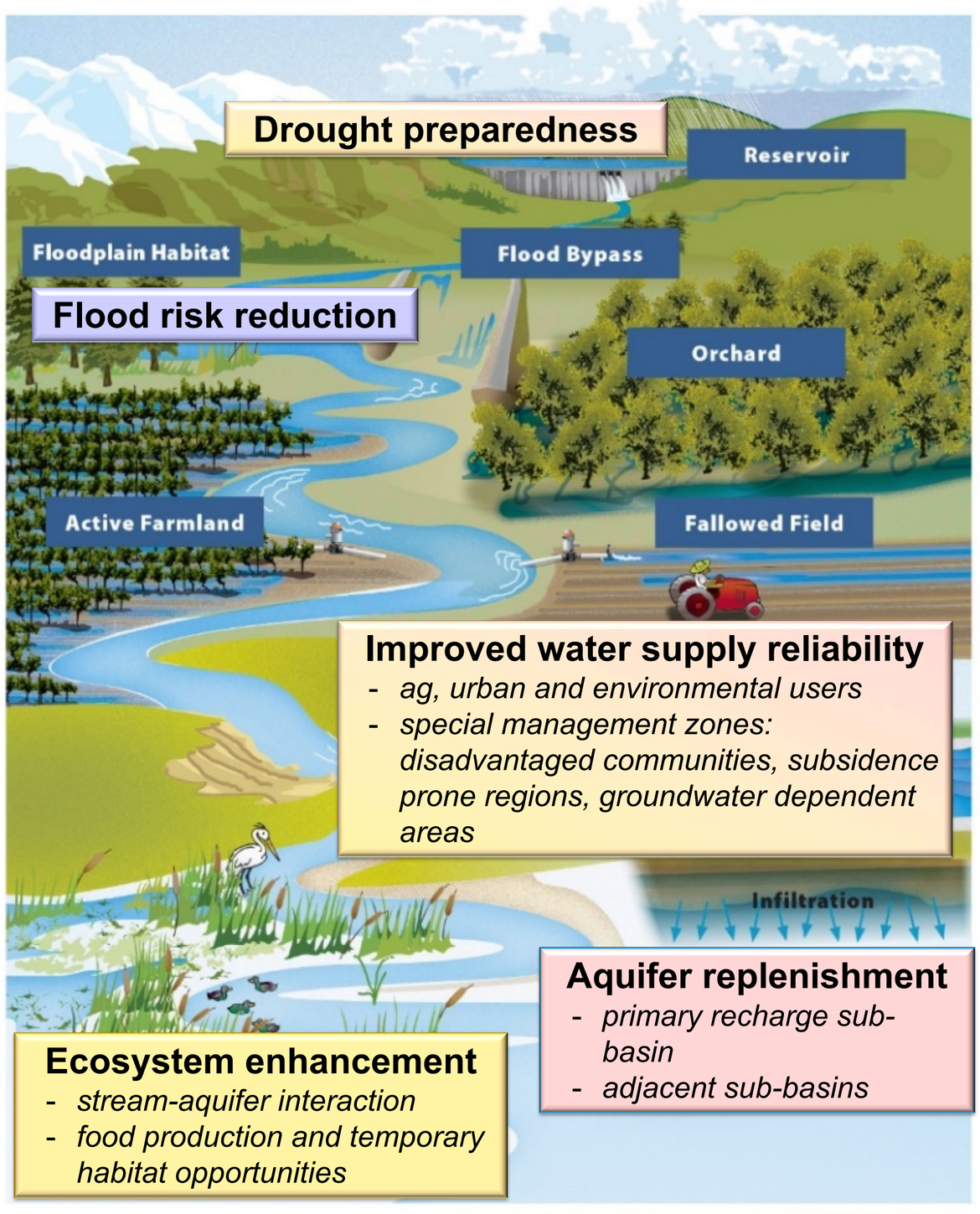
Streamflow
HEC-RAS (MIDH2O)

Flood Damage
HEC-FIA



METRICS

- Evaluate basin-wide performance under current and future climates
  1. flood risk
  2. water supply
     - surface water conditions
     - groundwater conditions
  3. ecosystem management
- Vulnerability to climate change
- Assess benefits of Flood-MAR projects
- Determine effectiveness of Flood-MAR strategies (**adaptation & mitigation potential**)



SUMMARY DASHBOARD EXAMPLE

CATEGORY	METRIC	INDICATOR	Units
Flood Risk Reduction	Merced River flow at Shaffer Bridge	Number of days above 6000 cfs	Days
		100-year peak flow	CFS
	Flood space at Lake McClure	100-year maximum flood space encroachment	TAF
Water Supply	Upper watershed runoff into Merced River basin	Average annual runoff	TAF
		Average seasonal runoff between November 1st and March 31st.	TAF
		Average seasonal runoff between April 1st and October 30th.	TAF
	Agricultural applied water demand	Average annual demand	TAF
		Met by surface water deliveries	TAF
		Met by groundwater pumping	TAF
	Storage at Lake McClure	March 1st - Beginning of the irrigation season	TAF
		June 30th - End of snowmelt runoff season	TAF
		October 31st - End of the irrigation season	TAF
	Merced ID's Allocation	Number of drought years (allocation below 80%)	Years
	Basin-wide annual change in GW storage	Average annual	TAF

Merced River Flow
Lake McClure flood space encroachment

Flood Risk

Upper watershed runoff

Agricultural applied water demand

Surface Water Conditions
Reservoir storage
MID's Allocation

Groundwater conditions

Water Supply

SUMMARY DASHBOARD EXAMPLE

CATEGORY	METRIC	INDICATOR	Units	Absolute Values: Baseline	Absolute Values: Level 1 Initial	Absolute Values: Level 1 Intermediate	Change Relative to Current Conditions: Level 1 Initial	Change Relative to Current Conditions: Level 1 Intermediate	Percent Change Relative to Current Conditions: Level 1 Initial	Percent Change Relative to Current Conditions: Level 1 Intermediate
Flood Risk	Merced River flow at Shaffer Bridge	*Merced River Flow*								
	Flood-space reduction at Lake McClure	*Lake McClure flood space encroachment*								
Water Supply	Upper watershed runoff into Merced River basin	**Upper watershed runoff**								
	Agricultural applied water demand	**Agricultural applied water demand**								
	Storage at Lake McClure	**Surface Water Conditions** *Reservoir storage*								
	Merced ID's Allocation	*MID's Allocation*								
	Basin-wide annual change in GW storage	**Groundwater conditions**								

ABSOLUTE VALUES

CHANGE RELATIVE TO THE BASELINE SCENARIO UNDER CURRENT CLIMATE CONDITIONS.

Effect of **climate change** on baseline scenario under current climate conditions.

CATEGORY	METRIC	INDICATOR	Units	Absolute Values: Current Conditions	Absolute Values: 2040	Absolute Values: 2070	Change Relative to Current Conditions: 2040	Change Relative to Current Conditions: 2070	Percent Change Relative to Current Conditions: 2040	Percent Change Relative to Current Conditions: 2070
Flood Risk Reduction	Merced River flow at Shaffer Bridge	Number of days above 6000 cfs	Days	0	48	180	48	180		
		100-year peak flow	CFS	6,0[illegible]	[illegible]	10,330	[illegible]	[illegible]	[illegible]%	222%
	Flood space at Lake McClure	100-year maximum flood space encroachment	TAF	212	268	291	56	79	26%	37%
Water Supply	Upper watershed runoff into Merced River basin	Average annual runoff	TAF	1,123	1,138	1,161	15	38	1%	3%
		Average seasonal runoff between November 1st and March 31st.	TAF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]%	[illegible]%
		Average seasonal runoff between April 1st and October 30th.	TAF	689	610	542	-79	-147	-11%	-21%
	Agricultural applied water demand	Average annual demand	TAF	798	833	857	35	59	4%	7%
		Met by surface water deliveries	TAF	355	359	359	4	4	1%	1%
		Met by groundwater pumping	TAF	466	494	515	28	49	6%	11%
	Storage at Lake McClure	March 1st - Beginning of the irrigation season	TAF	578	576	574	-2	-4	0%	-1%
		June 30th - End of snowmelt runoff season	TAF	813	776	734	-37	-79	-5%	-10%
		October 31st - End of the irrigation season	TAF	518	479	436	-39	-82	-8%	-16%
	Merced ID's Allocation	Number of drought years (allocation below 80%)	Years	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]%	[illegible]%
	Basin-wide annual change in GW storage	Average annual	TAF	-49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]%	[illegible]%

1 Flood risk increases s[illegible]ificantly with climate change.

2 No change in average annual runoff. However, expect to see a shift in runoff ti[illegible]g from spring/ summer months to winter months.

3 4 5 Assuming 2015 land-use is maintained, agricultural consumptive de[illegible]nd increases by 4 – 7%.

4 Surface water deliveries can be maintained at the current levels diversions at the detriment of reservoir storage.

5 Assuming no land is taken out of production, any increase in demand is met by additional groundwater pumping which will exacerba[illegible]e existing overdraft issues.

Effect of **climate change** on baseline scenario under current climate conditions.

CATEGORY	METRIC	INDICATOR	Units	Absolute Values			Change Relative to Current Conditions		Percent Change Relative to Current Conditions	
				Current Conditions	2040	2070	2040	2070	2040	2070
Flood Risk Reduction	Merced River flow at Shaffer Bridge	Number of days above 6000 cfs	Days	0	48	180	48	180		
		100-year peak flow	CFS	6,000	12,497	19,339	6,497	13,339	108%	222%
	Flood space at Lake McClure	100-year maximum flood space encroachment	TAF	212	268	291	56	79	26%	37%
Water Supply	Upper watershed runoff into Merced River basin	Average annual runoff	TAF	1,123	1,138	1,161	15	38	1%	3%
		Average seasonal runoff between November 1st and March 31st.	TAF	434	528	619	94	185	22%	43%
		Average seasonal runoff between April 1st and October 30th.	TAF	689	610	542	-79	-147	-11%	-21%
	Agricultural applied water demand	Average annual demand	TAF	798	833	857	35	59	4%	7%
		Met by surface water deliveries	TAF	355	359	359	4	4	1%	1%
		Met by groundwater pumping	TAF	466	494	515	28	49	6%	11%
	Storage at Lake McClure	March 1st - Beginning of the irrigation season	TAF	578	576	574	-2	-4	0%	-1%
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		October 31st - End of the irrigation season	TAF	518	479	436	-39	-82	-8%	-16%
	Merced ID's Allocation	Number of drought years (allocation below 80%)	Years	7	10	13	3	6	43%	86%
	Basin-wide annual change in GW storage	Average annual	TAF	-49	-80	-103	-31	-54	63%	110%

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Questions & Comments

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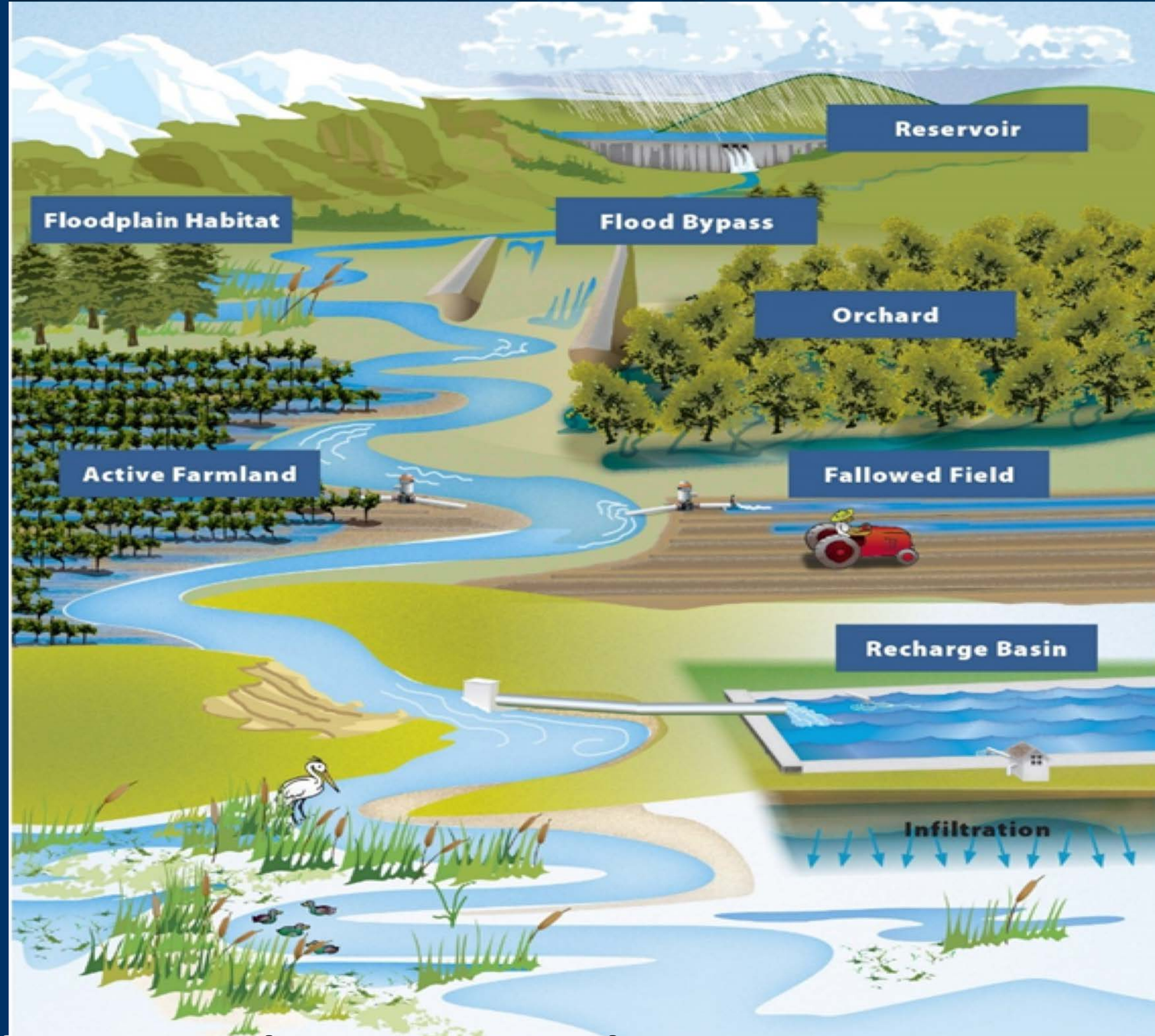

www.water.ca.gov/Programs/All-Programs/Flood-MAR