From Groundwater to Streamflow: Scaling Up Strategies, Models, and Datasets for Salmonid Success
Afternoon Session

A Concurrent Session at the 42nd Annual Salmonid Restoration Conference
Santa Cruz, California, April 29 - May 2, 2025

Session Coordinators: David Dralle, *US Forest Service Pacific Southwest Research Station*, and Monty Schmitt, *The Nature Conservancy*

Groundwater plays a vital role in keeping streams flowing during the dry season, especially in watersheds that support salmon. With growing pressures from land use changes, groundwater pumping, and climate variability, it's more important than ever to manage the connection between groundwater and surface water to protect these critical flows.

This session will focus on practical tools and strategies for managing groundwater to maintain streamflows that salmon rely on. We'll cover the latest advancements in large-scale groundwater models that can help predict and address streamflow depletion. We'll also look at regional groundwater management plans that are successfully safeguarding water resources through thoughtful planning and regulation. In addition, we'll explore new research on why some streams dry up and how this affects fish, alongside a discussion on the global issue of aquifer decline and what it means for local water management.

By sharing case studies, management approaches, and the latest research, this session aims to provide practitioners, researchers, and policymakers with actionable insights and tools to support salmon restoration efforts through effective groundwater and surface water management.

Presentations

- **Democratizing California's Water Future: Tools For Advancing Inclusive And Integrated Groundwater-Surface Water Management In The Central Valley**
  Ted Grantham, Ph.D., UC Berkeley……………………………………………………………………….Slide 4

- **Beyond Surface Water and Groundwater: Successful Flow Enhancement and Climate Change Adaptation Requires a Holistic Approach to Managing the Entire Hydrologic Cycle**
  Jeremy Kobor, PG, OEI, Inc.…………………………………………………………………………....Slide 31

- **Response Diversity to Acute Climate Conditions Among Streams with Variable Flow Permanence Stabilizes Habitat Availability for Spawning Salmonids**
  Skylar Rousseau, Stillwater Sciences..……………………………………………………………….Slide 51
  .

- **Addressing Streamflow Depletion Due to Groundwater Pumping - Unified Modeling Approaches and Process Uncertainty**
  Nicholas Murphy, Ph.D., The Nature Conservancy…………………………………………………....Slide 92

- **The California Environmental Flows Framework: Integrating groundwater and Surface Water Management**
  Kris Taniguchi-Quan, Ph.D., Southern California Coastal Water Research Project……………………Slide 128

- **Panel Discussion and Interactive Q&A**……………………………………………………………….n/a

DEMOCRATIZING CALIFORNIA'S WATER FUTURE: tools for advancing inclusive and integrated groundwater-surface water management

Salmonid Restoration Federation

Groundwater to Streamflow: Scaling Up Strategies

May 2, 2025

Ted Grantham

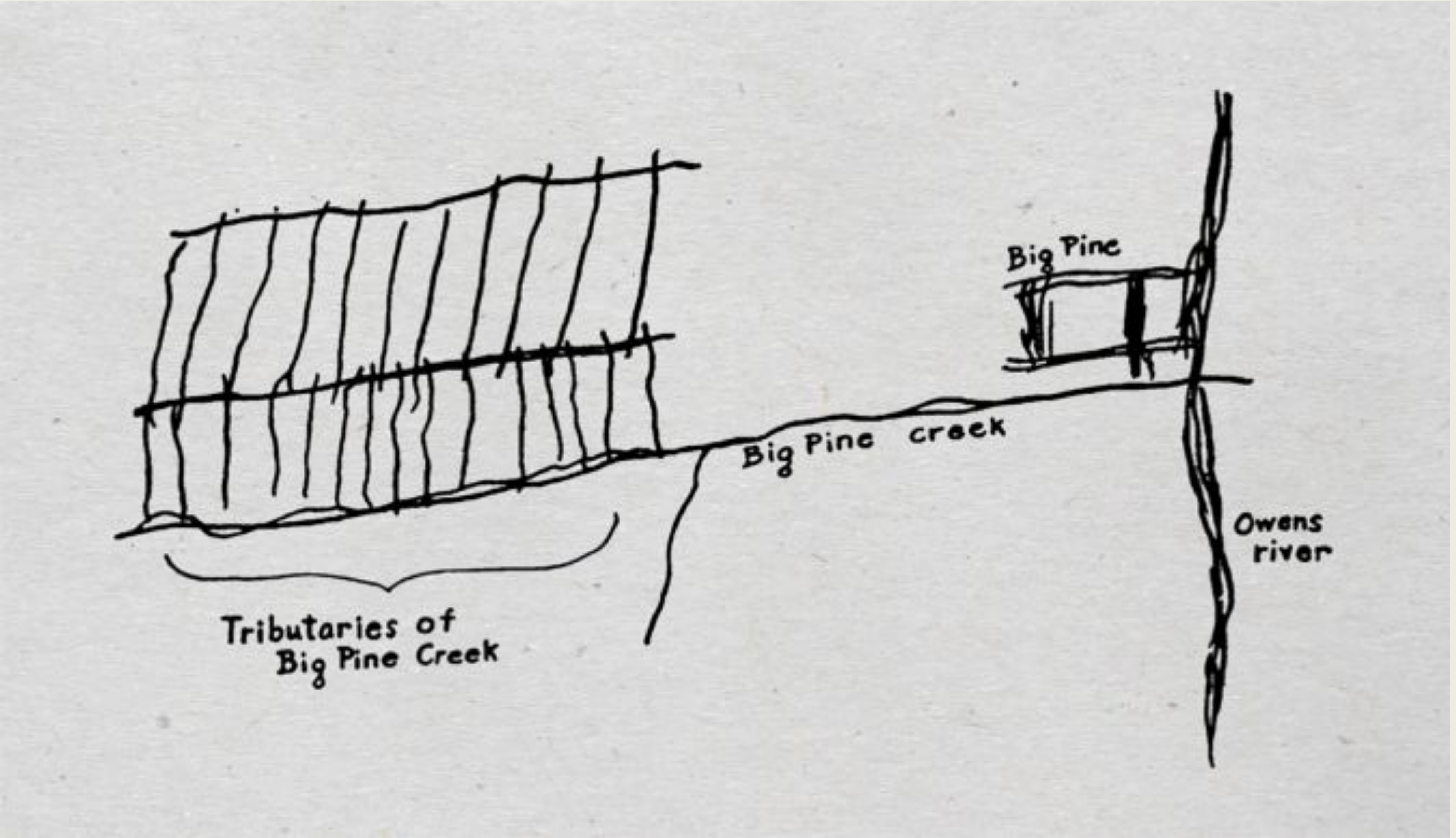
Dept. Environmental Science, Policy, and Management

University of California, Berkeley

OUTLINE

- A brief history of California water management
- Collaboratory for Equity in Water Allocation (COEQWAL)
- Preliminary results of groundwater management scenarios

INDIGENOUS LAND AND WATER STEWARDSHIP



Tributaries of Pine Creek (Jack Stewart 1933, UC Berkeley Anthropology Library)

Owens Valley
(Owens Valley Indian Water Commission)

EUROPEAN COLONIZATION

Sluice mining for gold, 1850 (USGS)

Hydraulic mining at French Corral Mine, 1867 (Houseworth)

LAND "RECLAMATION"

Artesian well in Kern County, 1880-1890 (Carleton E. Watkins)

Clamshell Dredge near Sherman Island, 1907 (National Maritime Museum, San Francisco)

COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

DAMS AND CANALS


Friant Dam, San Joaquin River (DWR)


California Aqueduct near Palmdale (DWR)

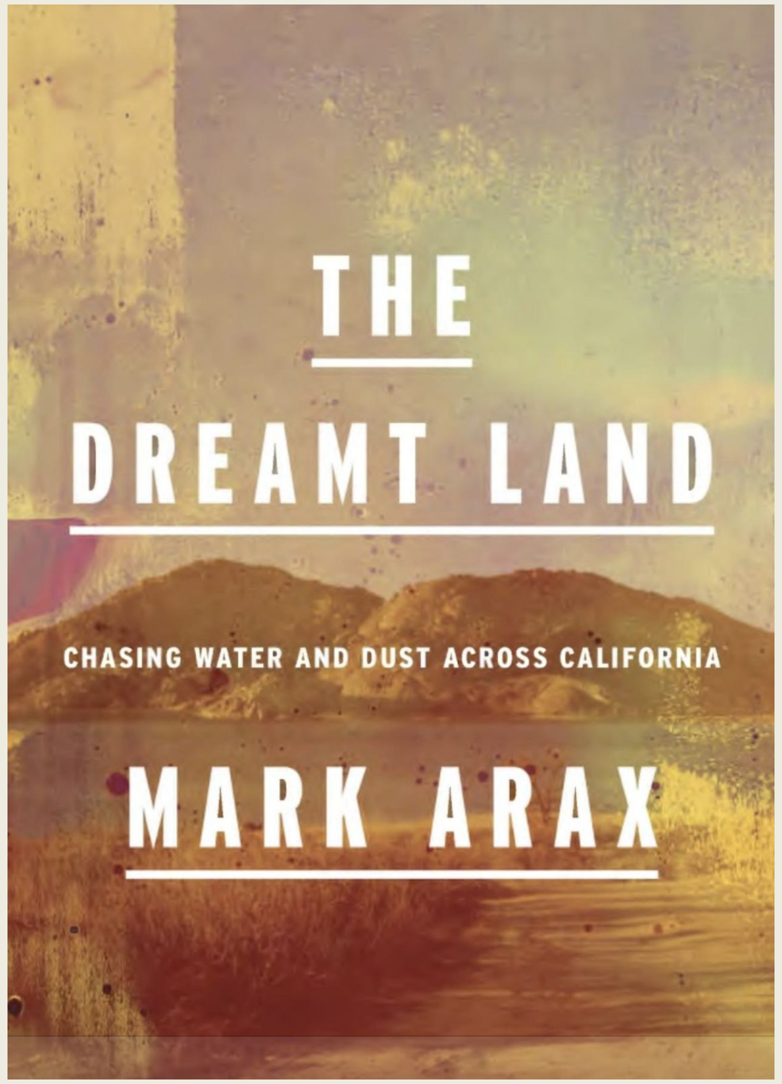
WATER DEMAND PARADOX

demand for more surface water

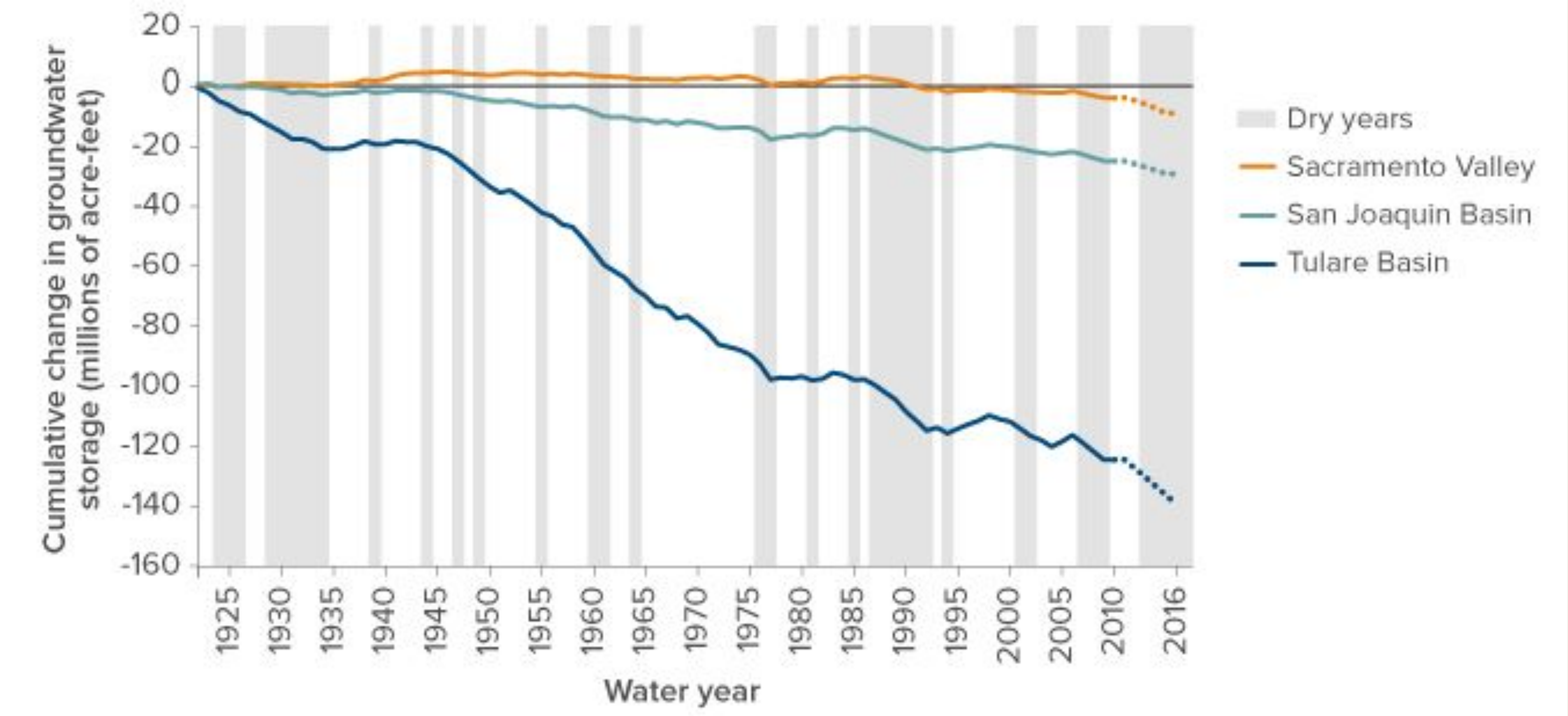
agricultural expansion

exhaustion of local water supplies

water scarcity



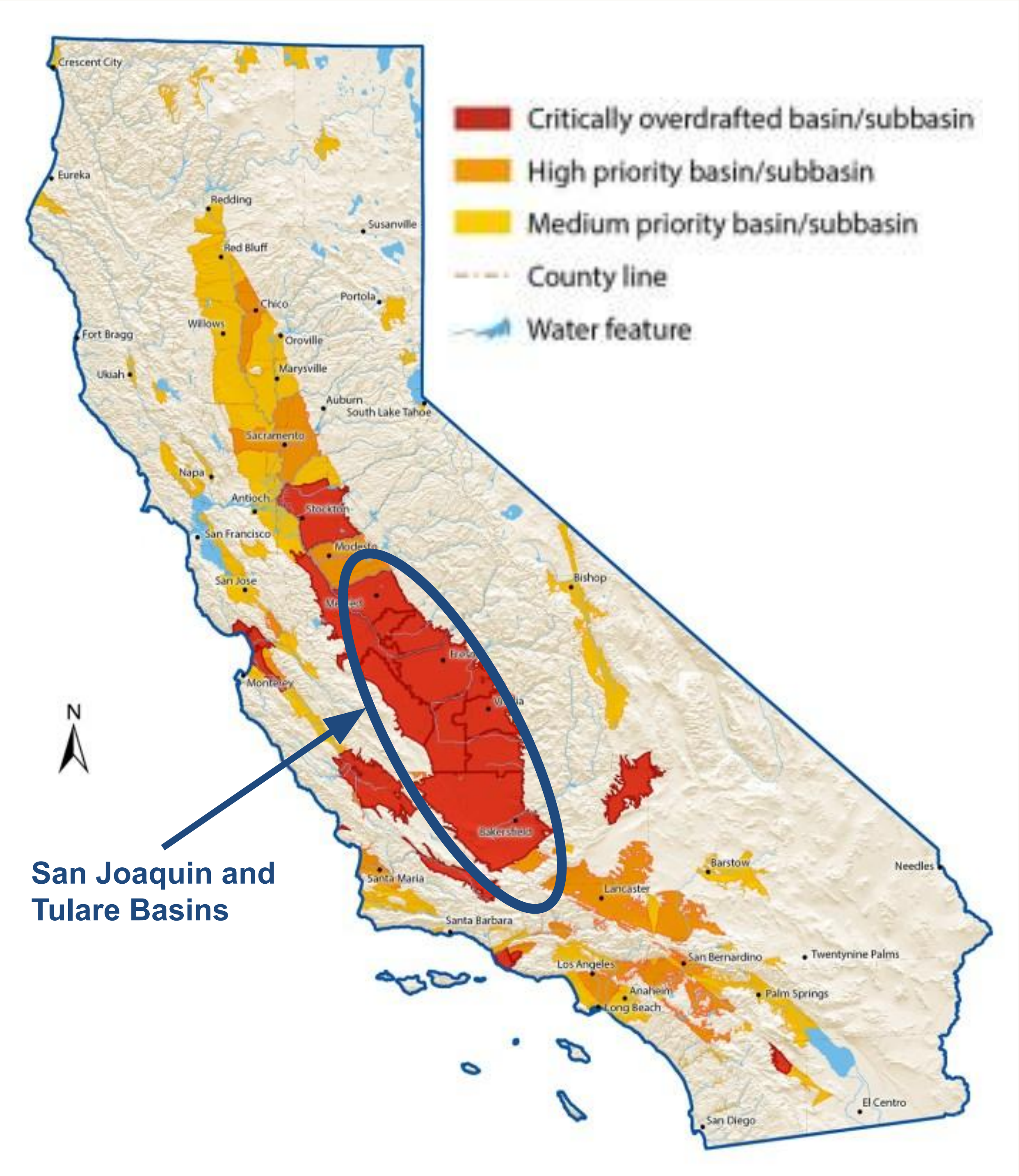
GROUNDWATER OVERDRAFT



PPIC

COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

SUSTAINABLE GROUNDWATER MANAGEMENT ACT



Implementation timeline

Step one
Form Groundwater Sustainability Agency
June 30, 2017

Step two
Develop Groundwater Sustainability Plan (GSP)
January 31, 2022

Step three
Achieve Sustainability
20 years after GSP adoption

AGRICULTURAL LAND “REPURPOSING"

- By 2040, average annual supplies could decline by 20% (3.2 million acre feet/year)

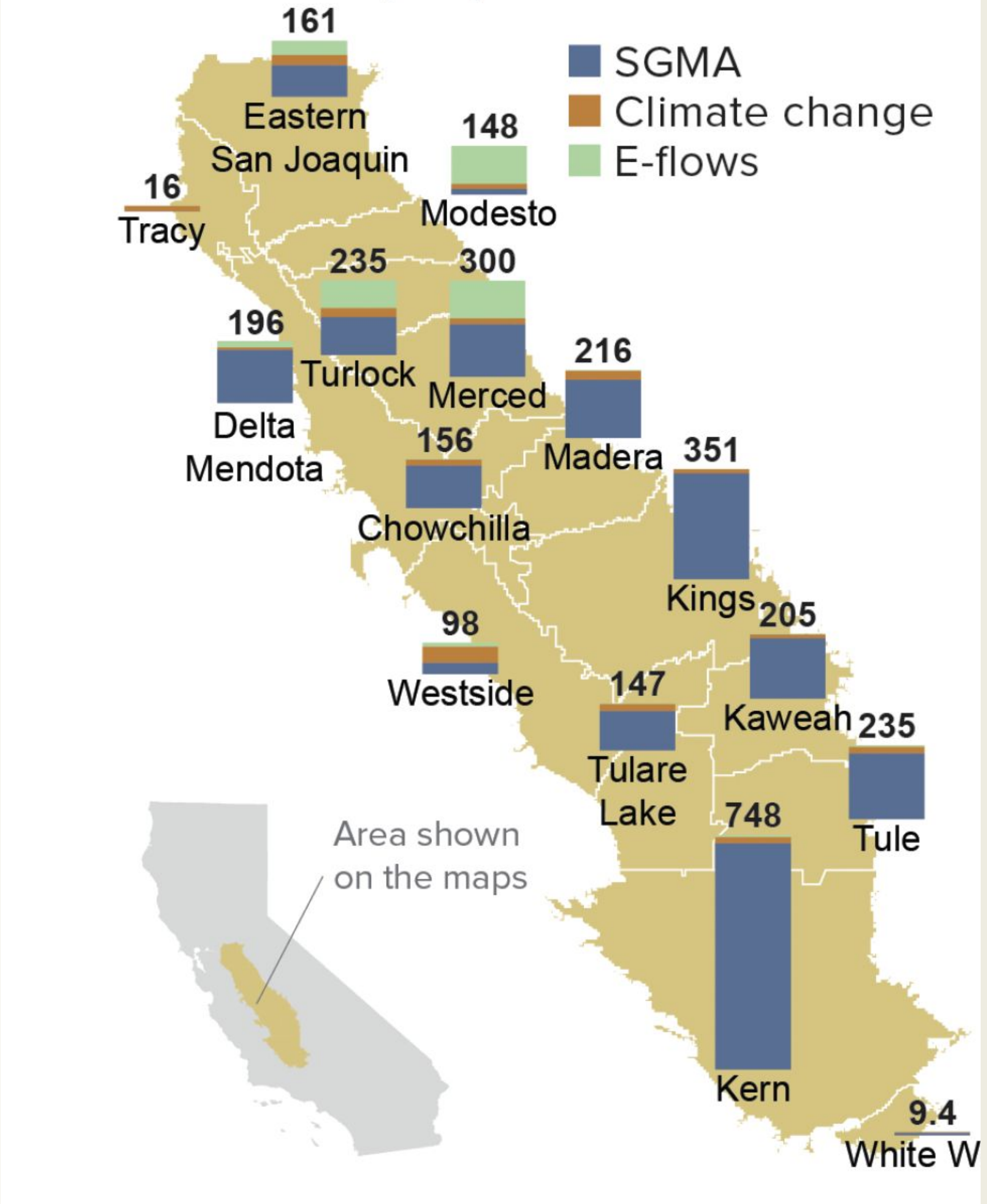
- Without adaptation, this could translate to:

  ~900,000 acres of irrigated land fallowed

  ~50,000 jobs list

  ~2.3% decline in GDP

- Uncertain impacts on other water uses, including the environment



Escriva-Bou 2023. Future of San Joaquin Valley. PPIC

CALIFORNIA’S WATER FUTURE?

COEQWAL

COLLABORATORY FOR EQUITY IN WATER ALLOCATION

COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

COEQWAL

COLLABORATORY FOR EQUITY IN WATER ALLOCATION

DEMOCRATIZE CALIFORNIA'S WATER FUTURES through an inclusive, participatory process that diversifies and enhances engagement in water planning and stewardship

UPLIFT PERSEPCTIVES, needs, and values of communities that have been historically marginalized from water decision-making through intentional outreach and engagement

PROVIDE ACCESS to knowledge, data, and tools used by agencies and decision-makers

COLLABORATORS

Agency/Water Utility

NOAA

Delta Stewardship Council

Metropolitan Water District of California

Department of Water Resources

State Water Resources Control Board

Interagency Ecological Program

Academic

UC Berkeley (lead)

UC Santa Cruz

UC Davis

UC San Diego

UC Merced

UC Los Angeles

Sacramento State

California Institute for Water Resources

Community

Shingle Springs Band of Miwok Indians

Buena Vista Rancheria of Me-Wuk Indians

Karuk Tribe

The Nature Conservancy

Restore the Delta

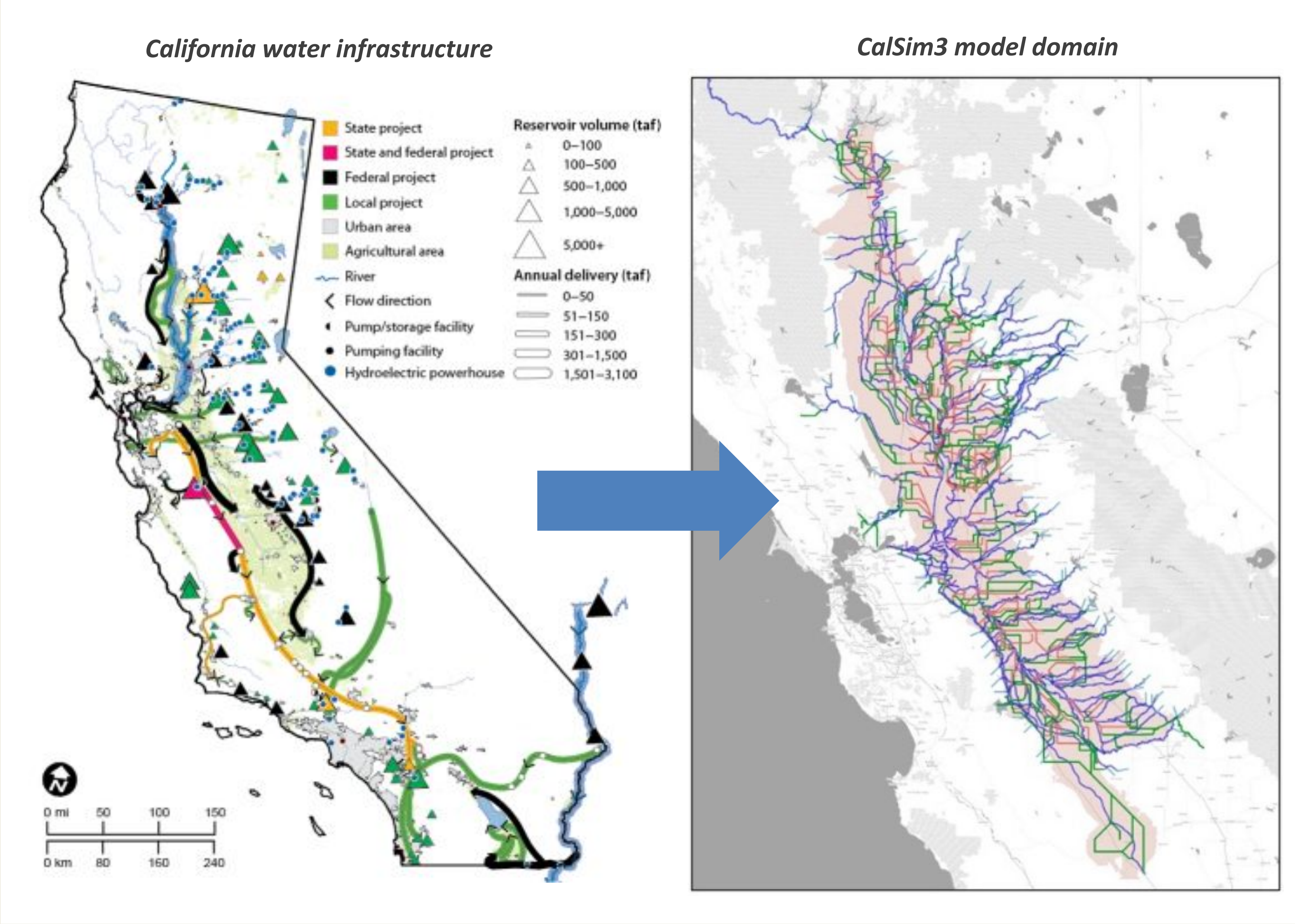
Public Policy Institute of California

Alliance for Global Water Adaptation

SCENARIO EXPLORATION WITH CALSIM3

CalSim3 - water allocation and planning tool for the Central Valley and interconnected basins

Developed by the California Department of Water Resources and US Bureau of Reclamation



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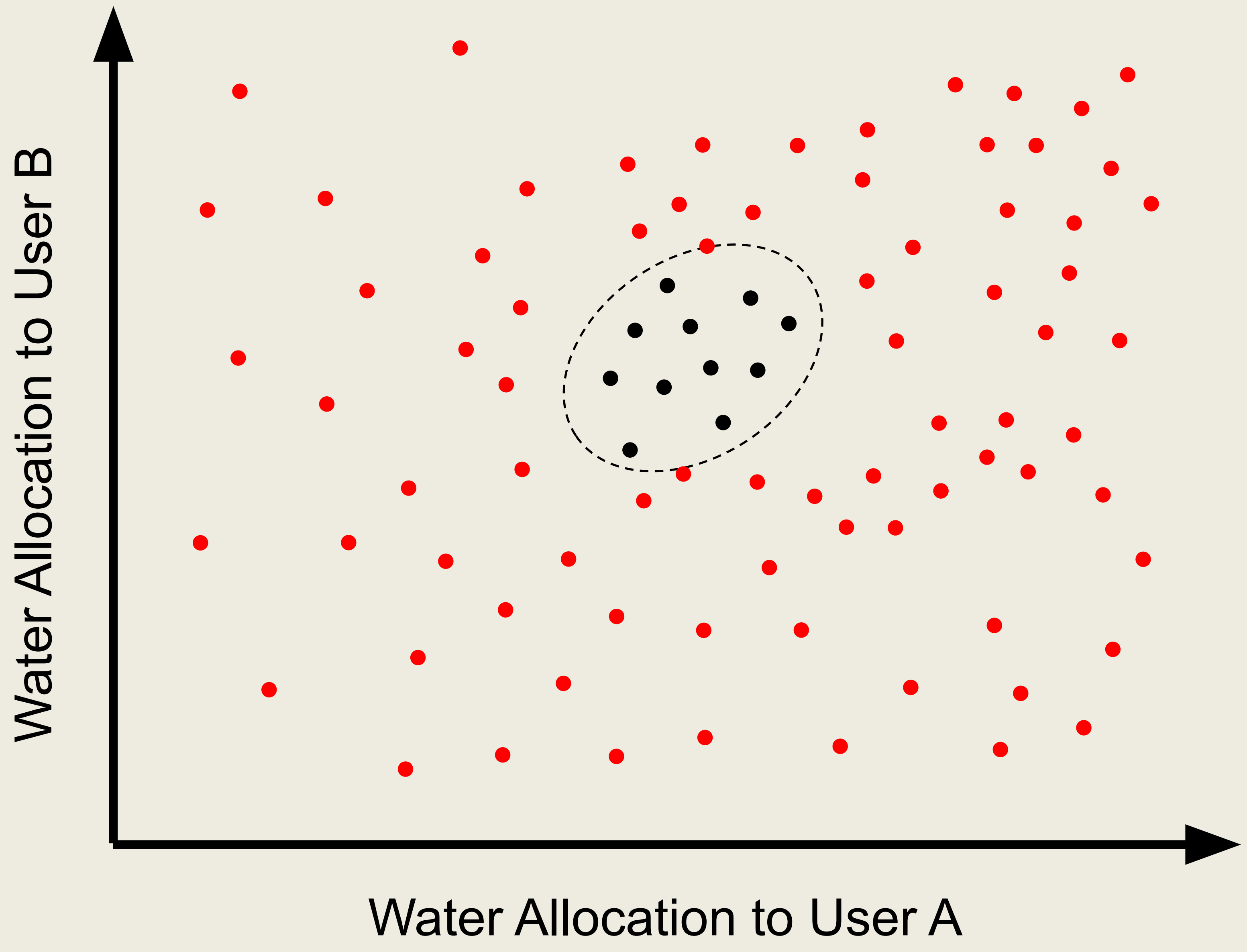
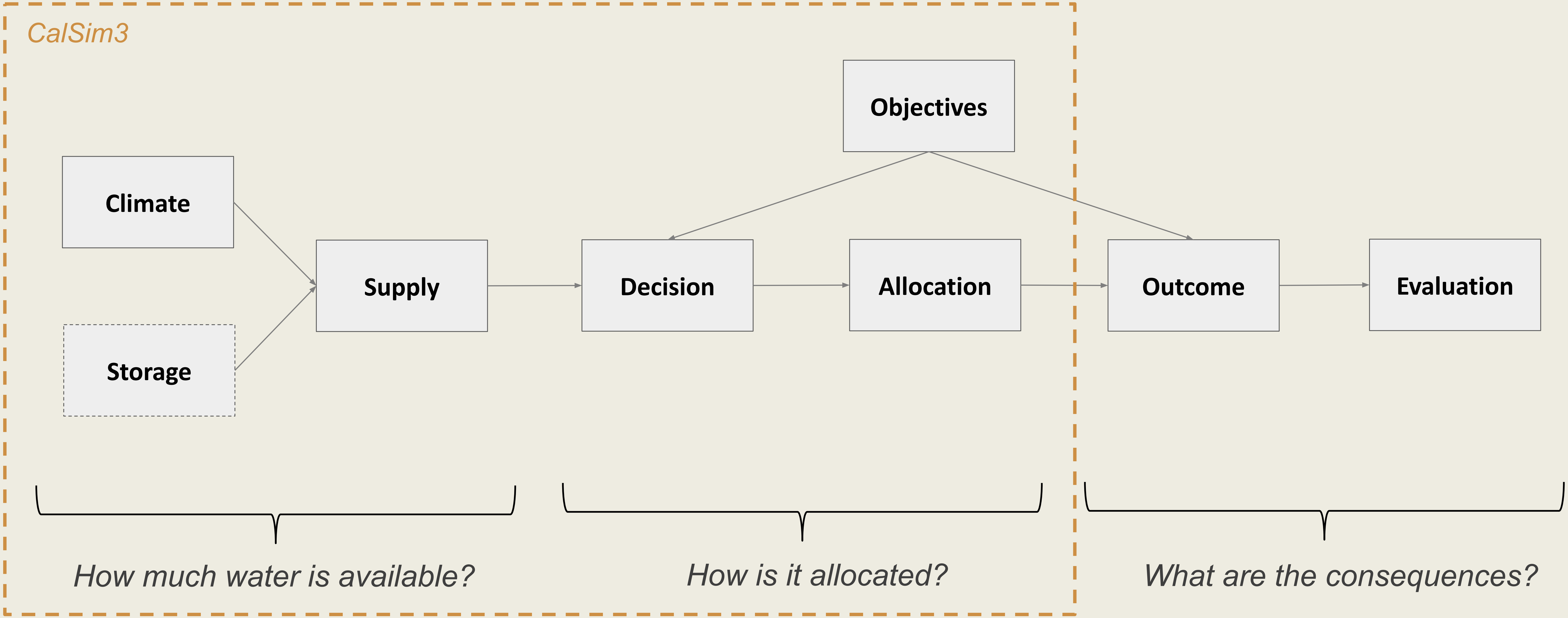
SCENARIO EXPLORATION



Typical assessments of water management alternatives explore limited range of variability

We intentionally **expand the scope of scenarios** analyzed to consider possible operational changes depart from “business as usual”

WHAT IS A SCENARIO?



WHAT IF?

What if no changes in operations are made? (business as usual)

What if more natural flows are restored to rivers and the Delta?

What if drinking water for communities are prioritized?

What if new infrastructure is built?

What if groundwater is sustainably managed?

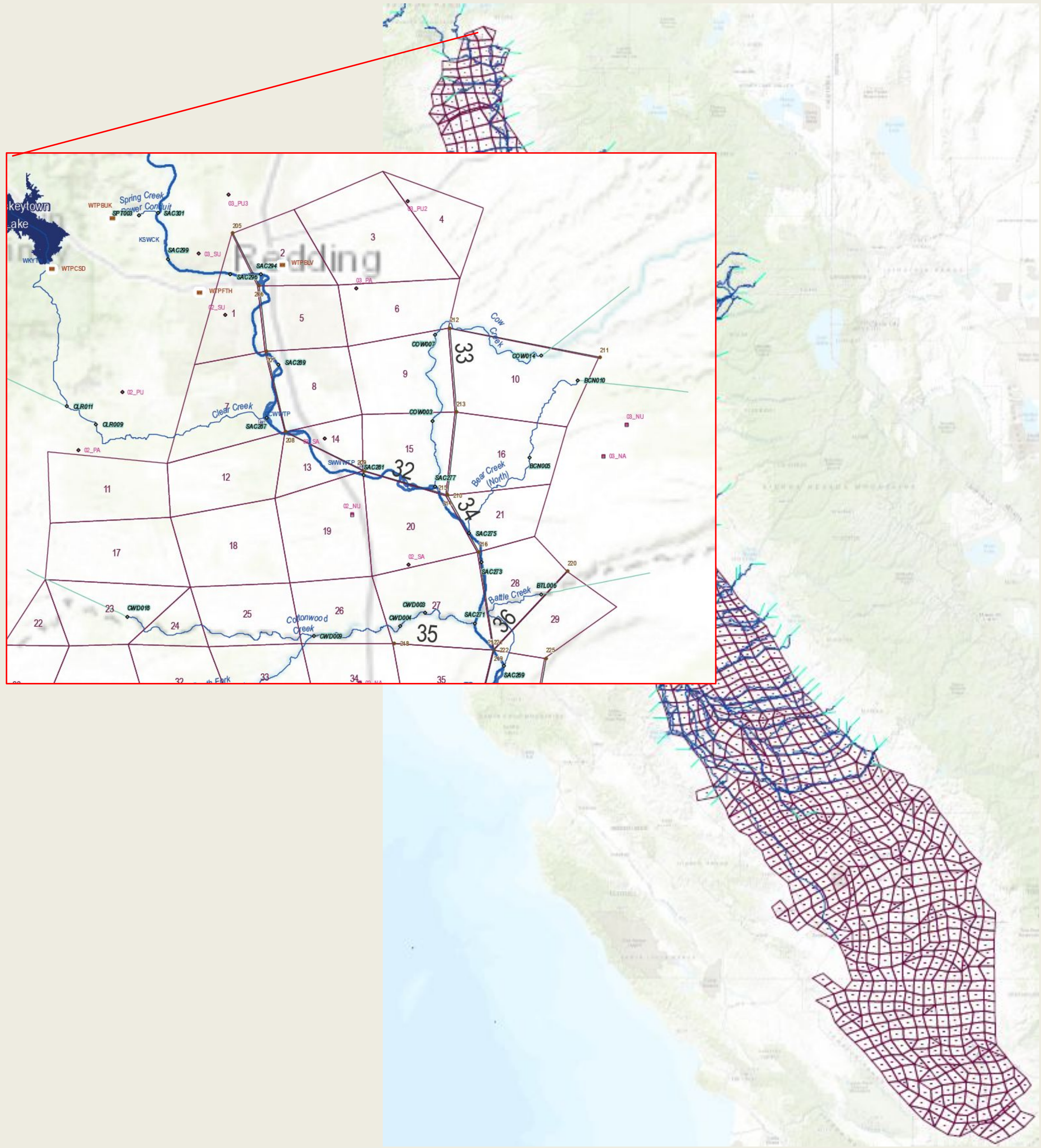
GROUNDWATER MANAGEMENT SCENARIOS

CalSim3 surface water allocation model coupled with ground water model (C2VSim)

Accounts for pumping, recharge, and stream-GW interactions

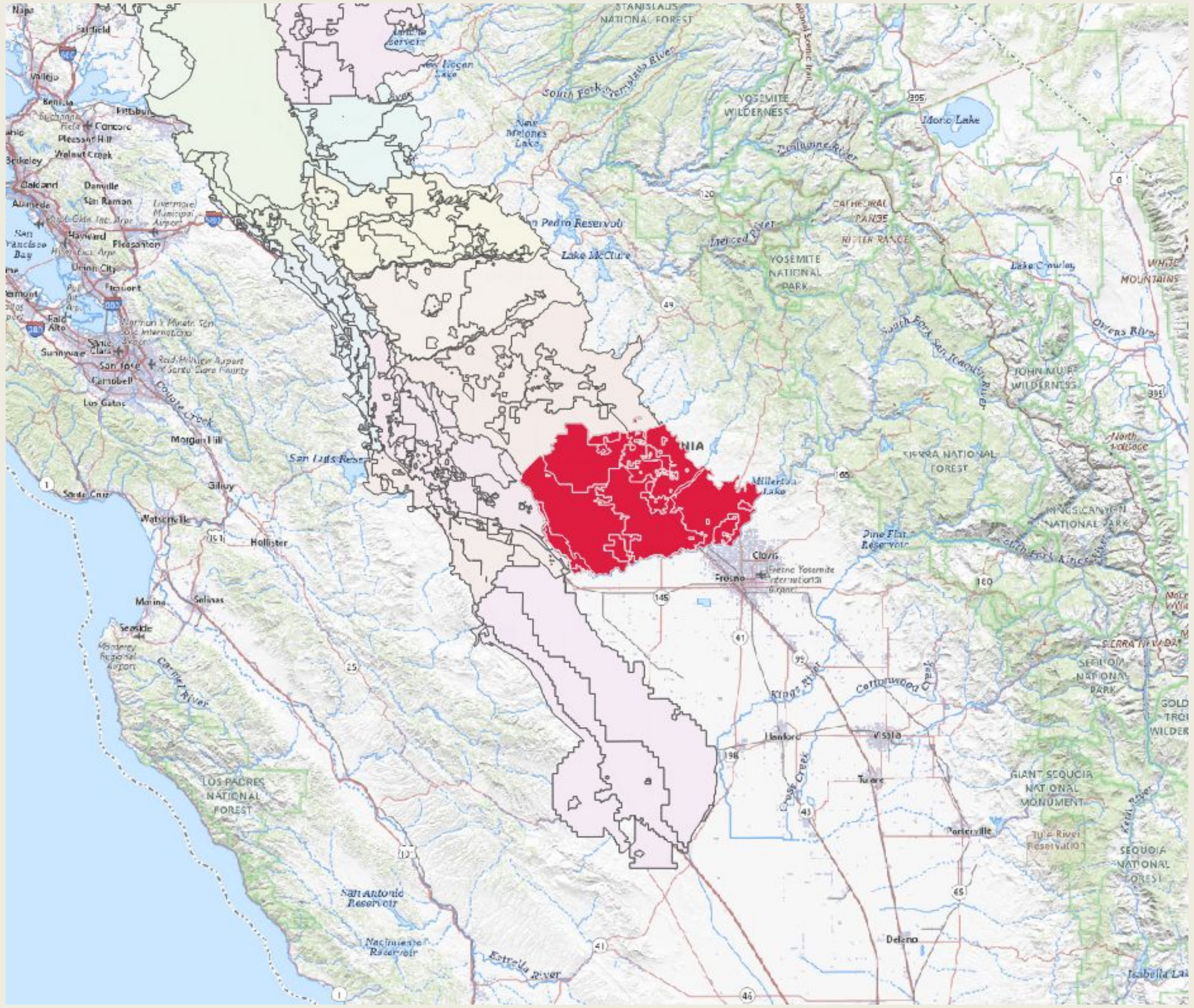
Demand not met by surface water is pumped from groundwater

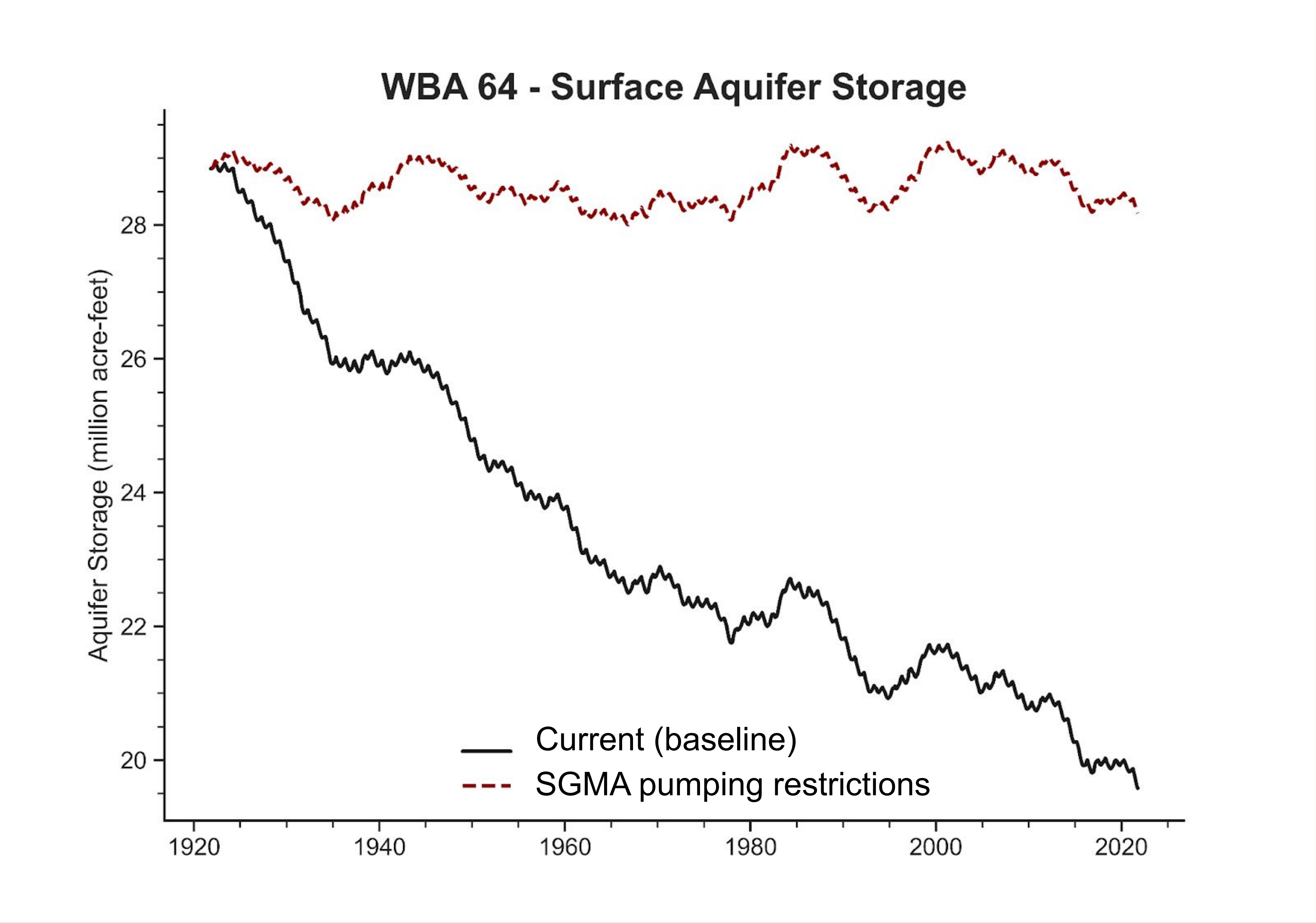
To approximate SGMA, groundwater pumping at “demand units” is limited to long-term sustainable levels



COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

RESULTS: GROUNDWATER STORAGE





COEQWAL
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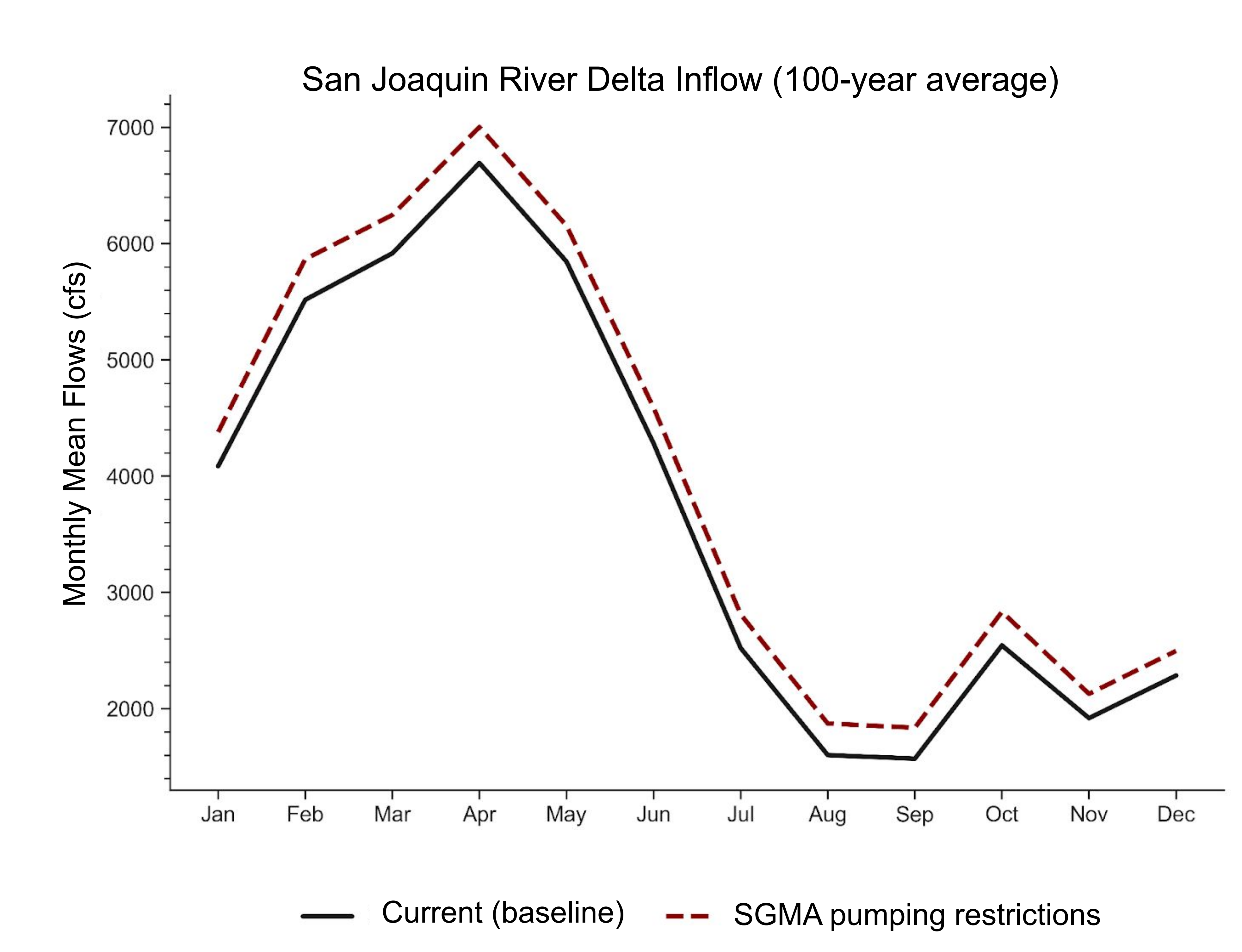
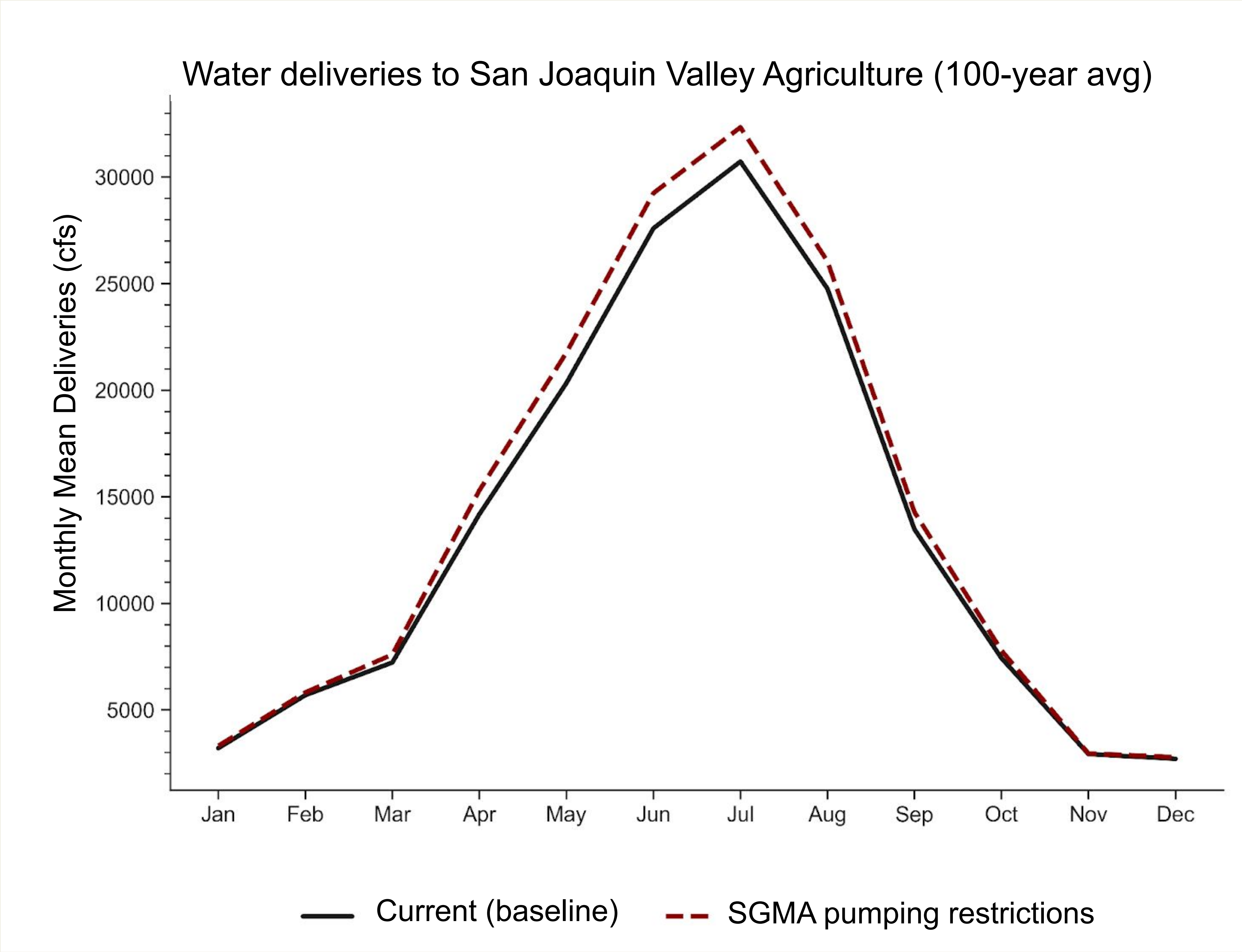
RESULTS: INCREASED RIVER FLOWS



Flows from San Joaquin into the Delta increase by 7% on average, 10% in drought years, relative to current conditions

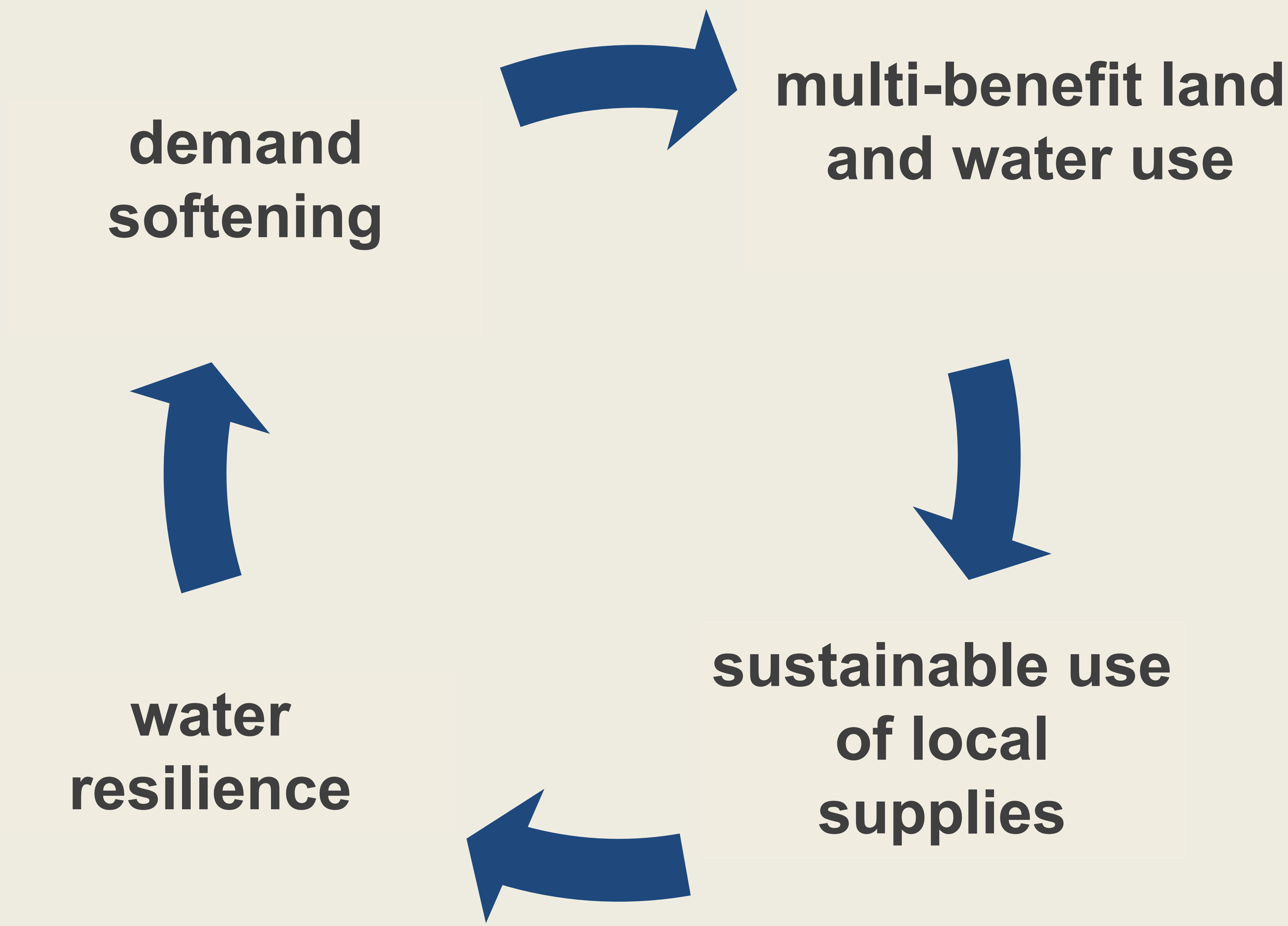
COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

RESULTS: MORE SURFACE WATER FOR AG



Water deliveries for agriculture in San Joaquin Valley increases, on average, by 3% (and 10% in drought years)

WATER PARADOX TO VIRTUOUS CYCLE?



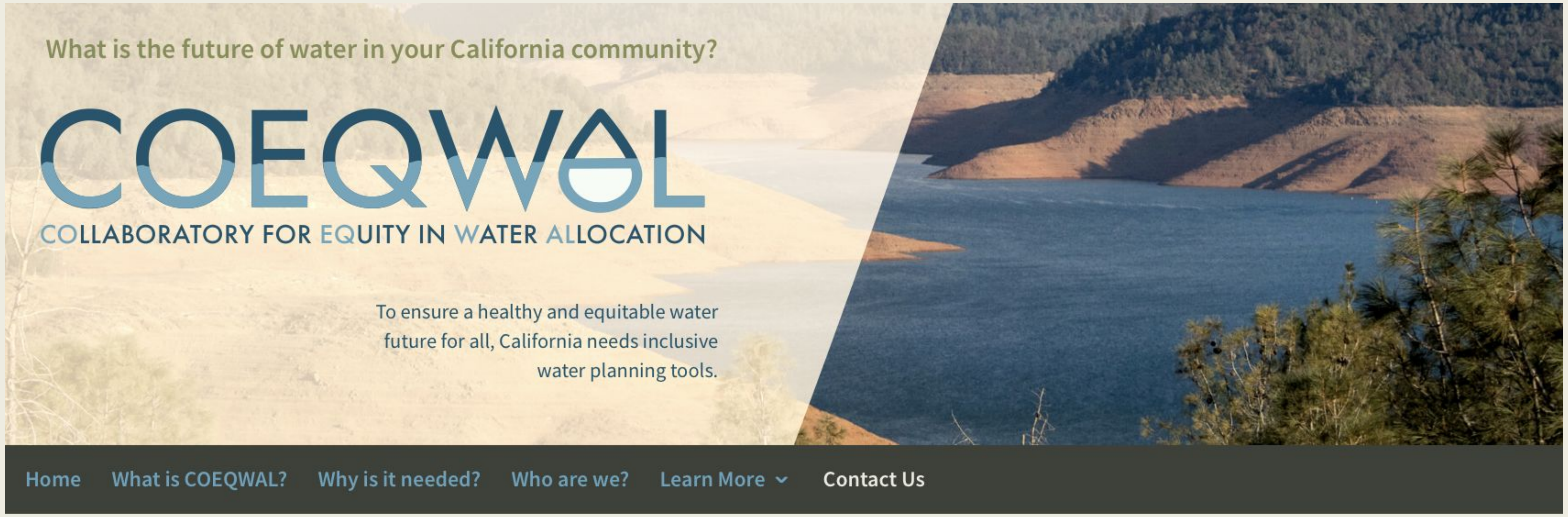
COEQWAL
COLLABORATORY FOR EQUITY IN WATER ALLOCATION

CONCLUSIONS

- SGMA implementation will have big impact on ag
- Groundwater recovers when pumping is limited, improving river flows AND surface water supplies
- Integrated systems models needed to understand nature of trade-offs
- Collaborative modeling approaches can build trust and engagement in water stewardship

DWR

https://coeqwal.berkeley.edu



VOICE
DATA
TOOLS
KNOWLEDGE
ACTION

WHAT IS COEQWAL?

A new resource empowering all Californians to envision a more equitable solution to California's diverse water needs.

Collaborative research that advances science to explore new possibilities for water management.

Accessible, online tools to help understand how California can support critical water needs in a changing climate.

A network of diverse water users collaborating to explore more equitable water allocation balance.

NEWS

The 2025 UC Water Academy course will start on January 21st. **Learn more.**

Read our 2024 Project Brief: **The Future of California Water.**

Maven's Notebook reports on **COEQWAL.**

Beyond Surface Water and Groundwater:

Successful Flow Enhancement & Climate Change Adaptation Requires a Holistic Approach to Managing the Entire Hydrologic Cycle

April 2025

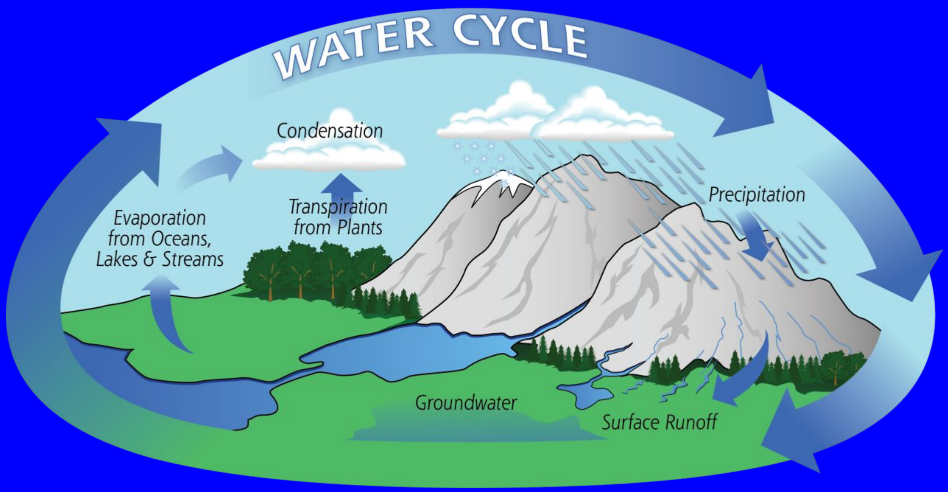
Jeremy Kobor, PG

Mike Sherwood, PG

Compartmentalization

<u>Nature</u>

Everything is interconnected



<u>Humans</u>

Different disciplines, tools & regulations for each process

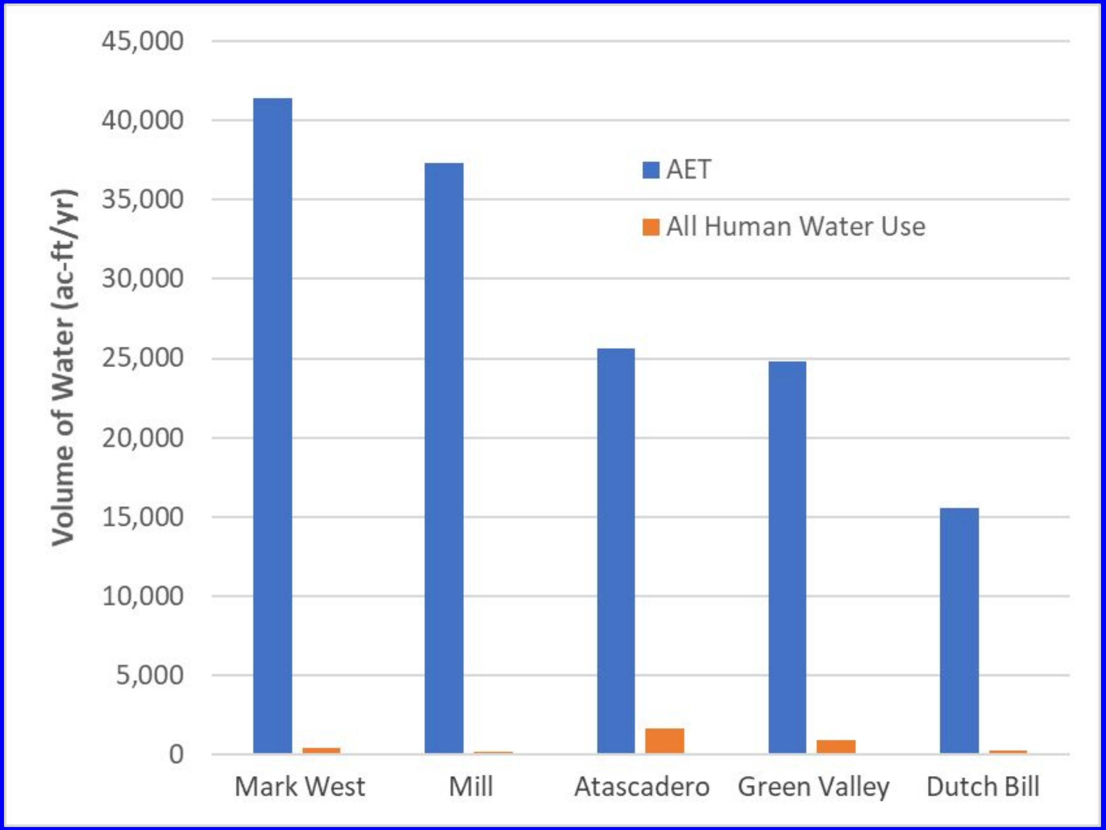
surface water

groundwater

landuse & ET

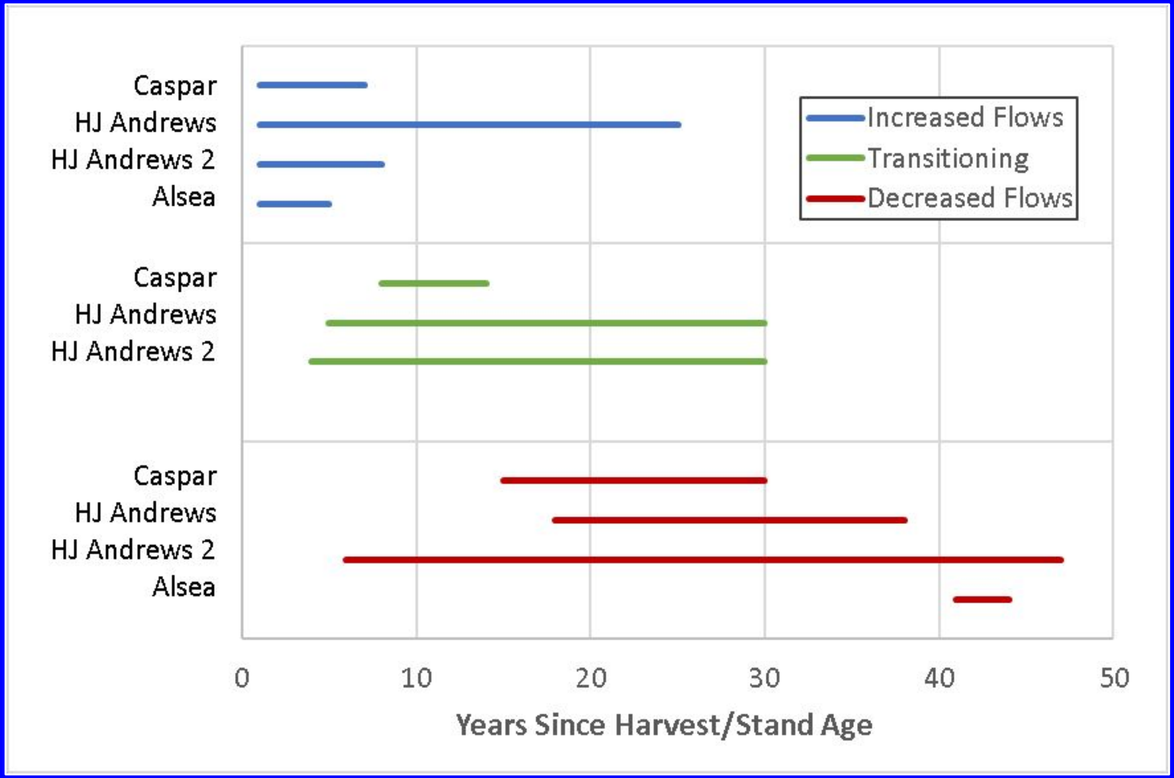
AET > Human Water Use

- AET 15-160 times greater than all human water use in Russian River tributaries
- Intensive study/scrutiny of diversions & wells
- Limited oversight of forest management or land cover conversion



Forest Management & Streamflow

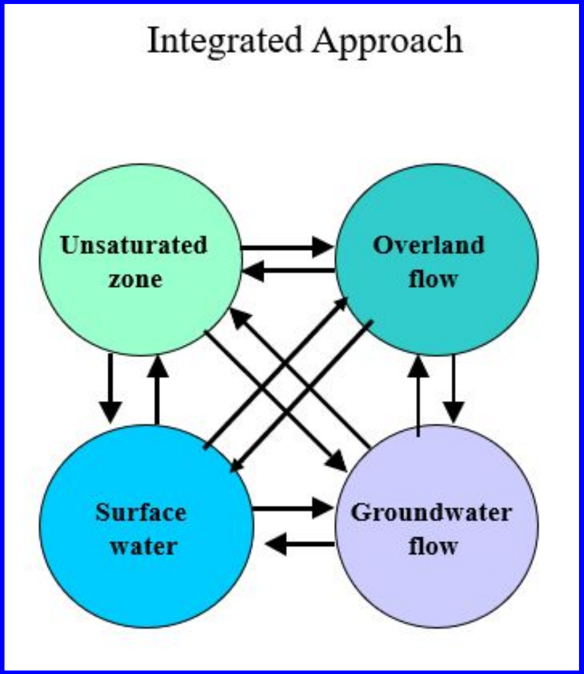
- Experimental watershed results indicate short period of increased streamflow followed by decades of decreased streamflow (25-60%)
- Indicates mature/old growth forests use much less water than young regenerating forests

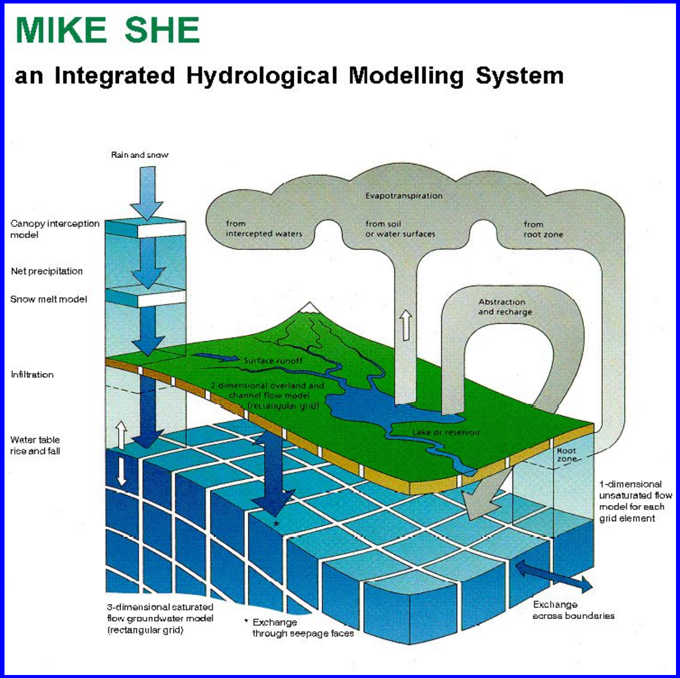


data from Coble et al. (2020)

Is Your Integrated Model Truly Integrated?

- Many model codes are a legacy of compartmentalization
- Many SGMA models only include one-way coupling
  - May be blind to important process feedbacks
- Example:
  - Groundwater pumping lowers the water table resulting in reduced riparian ET & increased groundwater recharge

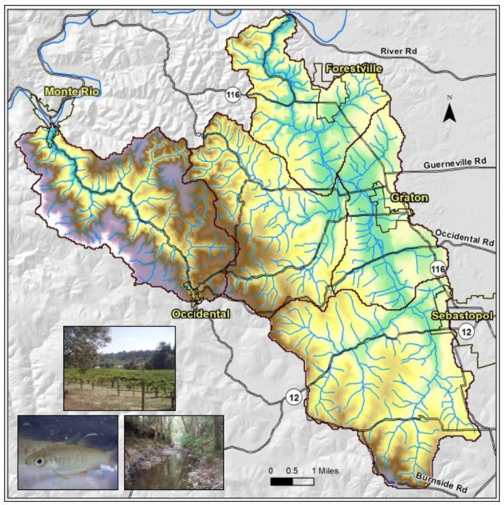




Existing Integrated Numerical Models

Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning:

Green Valley\Atascadero and Dutch Bill Creek Watersheds, Sonoma County, California



March 2016

Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Upper Mark West Creek Watershed, Sonoma County, CA

Wildlife Conservation Board Grant Agreement No. WC-1996AP
Project ID: 2020018

November 2020

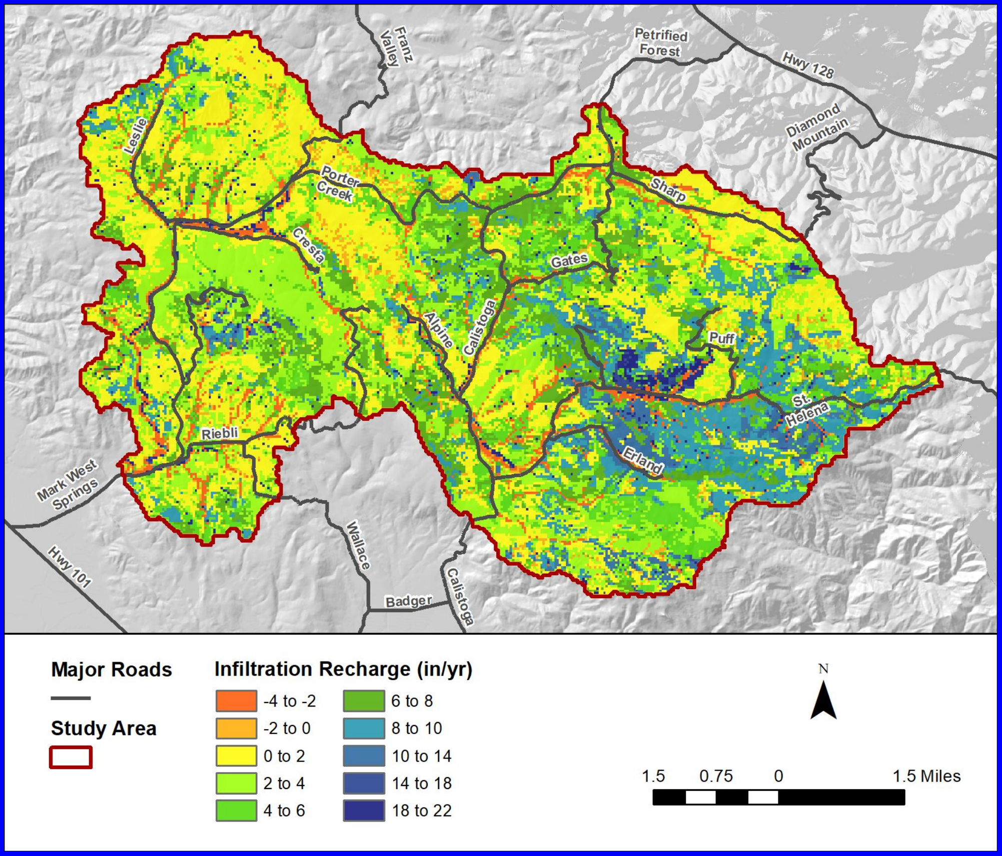
Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Mill Creek Watershed, Sonoma County, CA

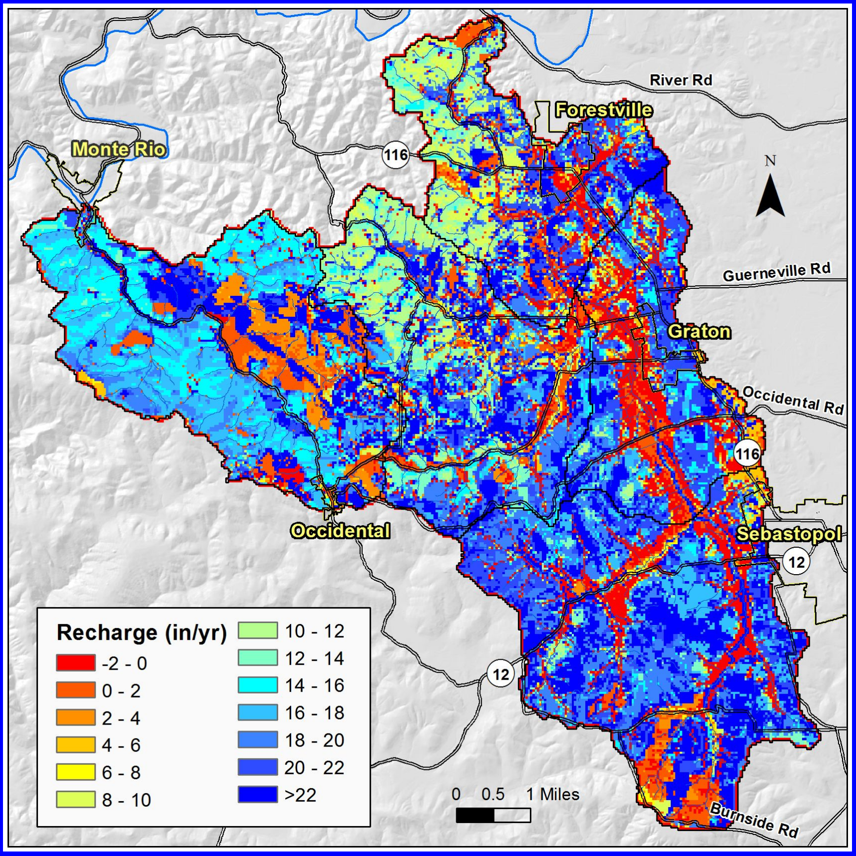
Wildlife Conservation Board Grant Agreement No. WC-1659EH
Project ID: 2017033

June 2021

- CDFW & WCB Funded
- Coast Range Watershed Institute, Sonoma RCD, Gold Ridge RCD, Pepperwood Preserve, Trout Unlimited, FMWW, County Parks

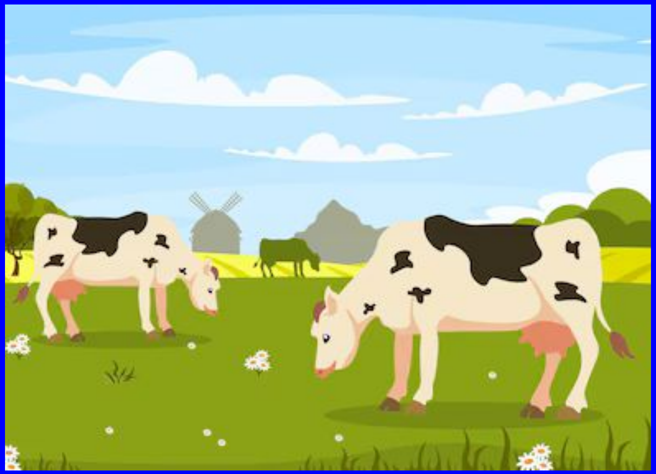
Heterogeneity





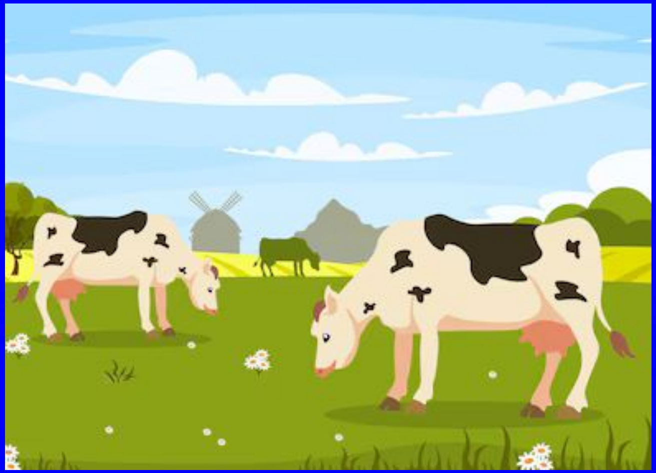
- Heterogeneity in hydrology suggests different flow enhancement strategies will be effective in different areas

What do you see happening in these images?


What do you see happening in these images?

Answer: workers & animals changing streamflow conditions



Reducing canopy interception & evapotranspiration demand

Compacting soils & increasing runoff

Increasing soil moisture holding capacity and groundwater recharge

Reducing soil infiltration rates & increasing runoff

Implementing BMPs to enhance recharge

Alternative Flow Enhancement Strategies

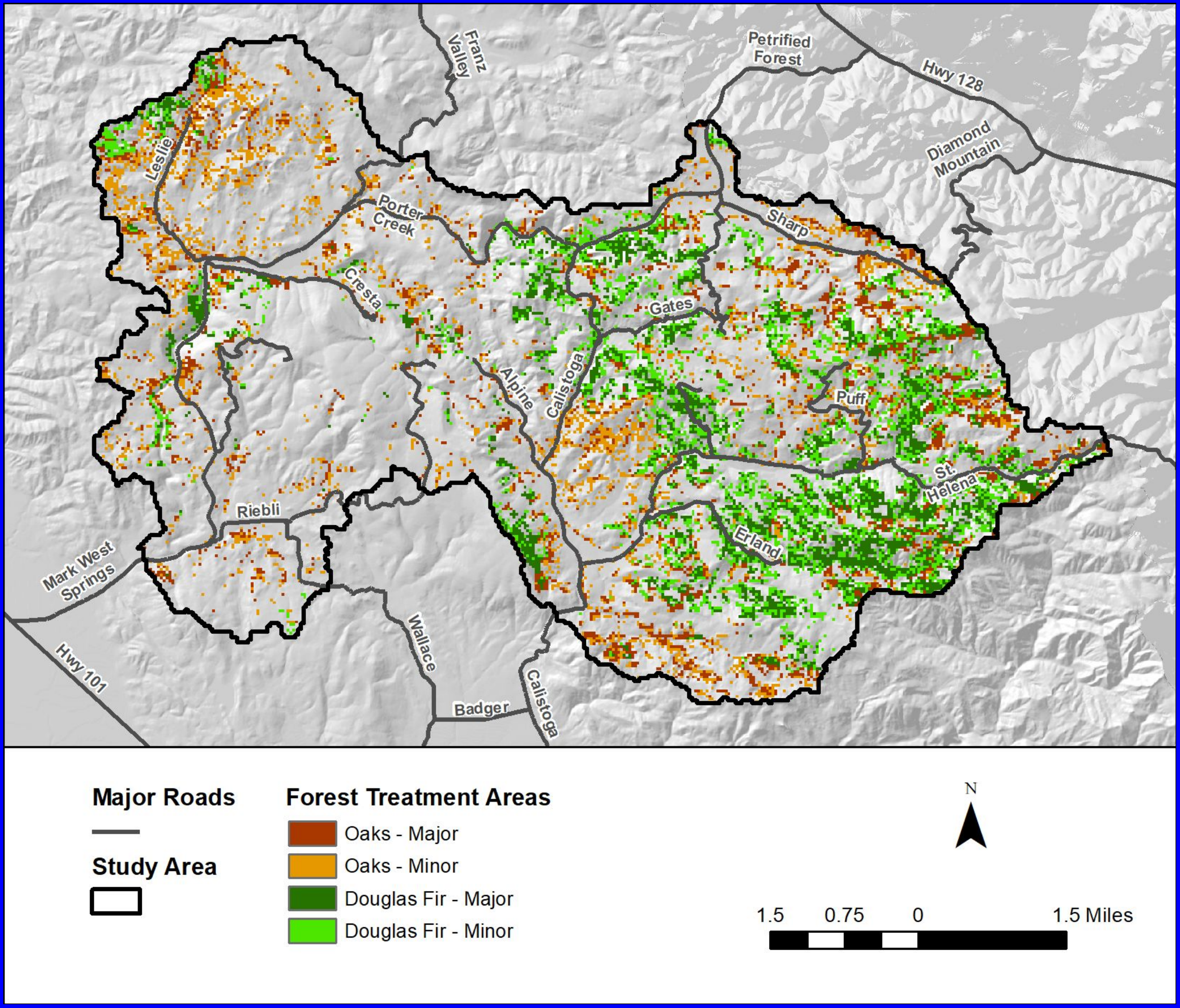
"Any action that alters landscape conditions (soils, vegetation), affects various aspects of the water cycle and may influence the availability of streamflow and salmonid habitat"

-Jeremy Kobor

- Forest management
  - Huge opportunity for synergy with wildfire risk reduction efforts
- Grassland management
  - Grazing practices influence infiltration rates which in turn influences recharge and streamflow
- Runoff management
  - Slow it, spread it, sink it vs. collect it, discharge it

Scenario Analysis – Forest Fuel Management

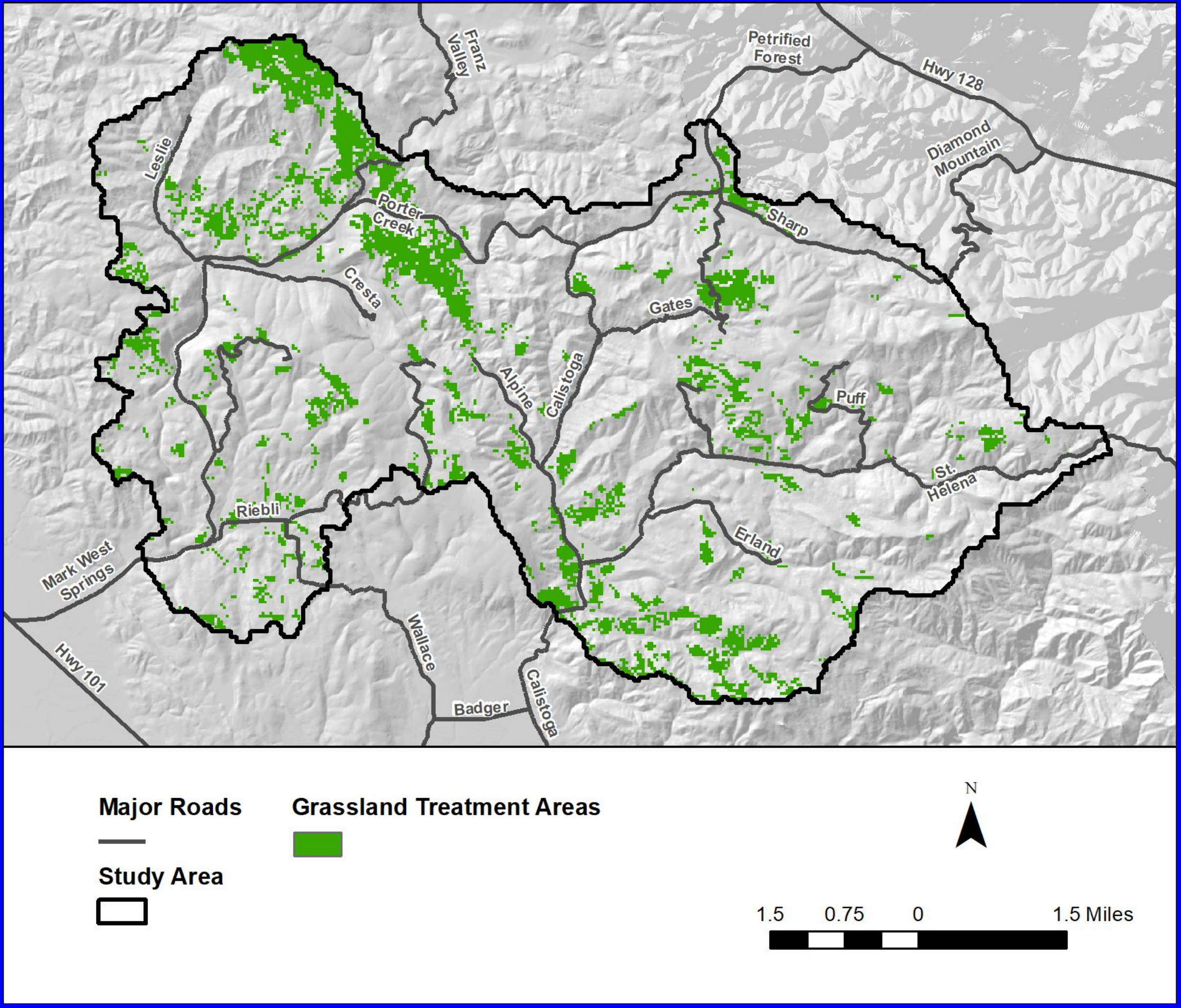
- Forest condition mapping at Monan's Rill, regional LAI and ladder fuels mapping (7,100 acres treated)



Scenario Analysis – Grassland Management

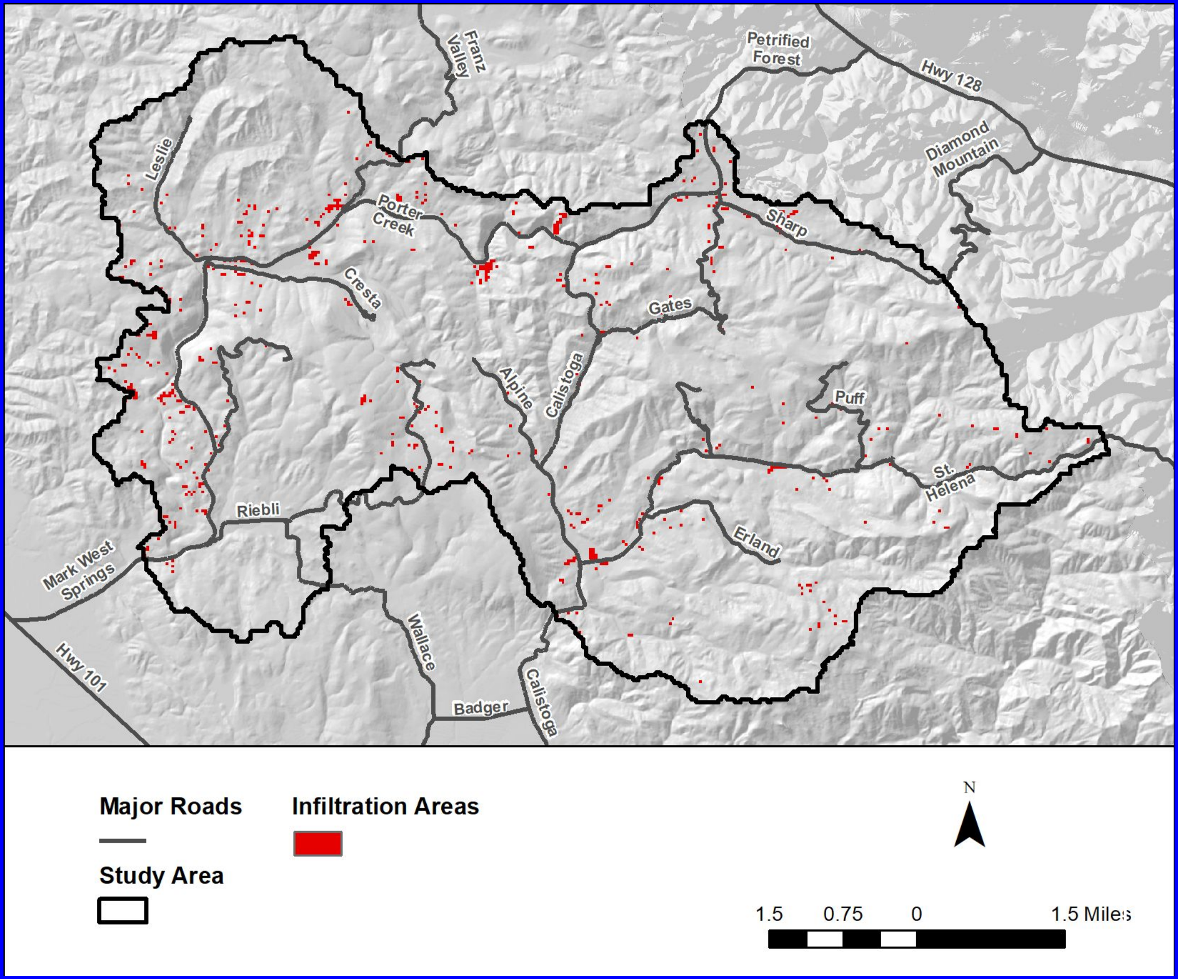
- Represents implementation of large-scale compost applications to increase soil organic matter & soil water storage

(2,875 acres)

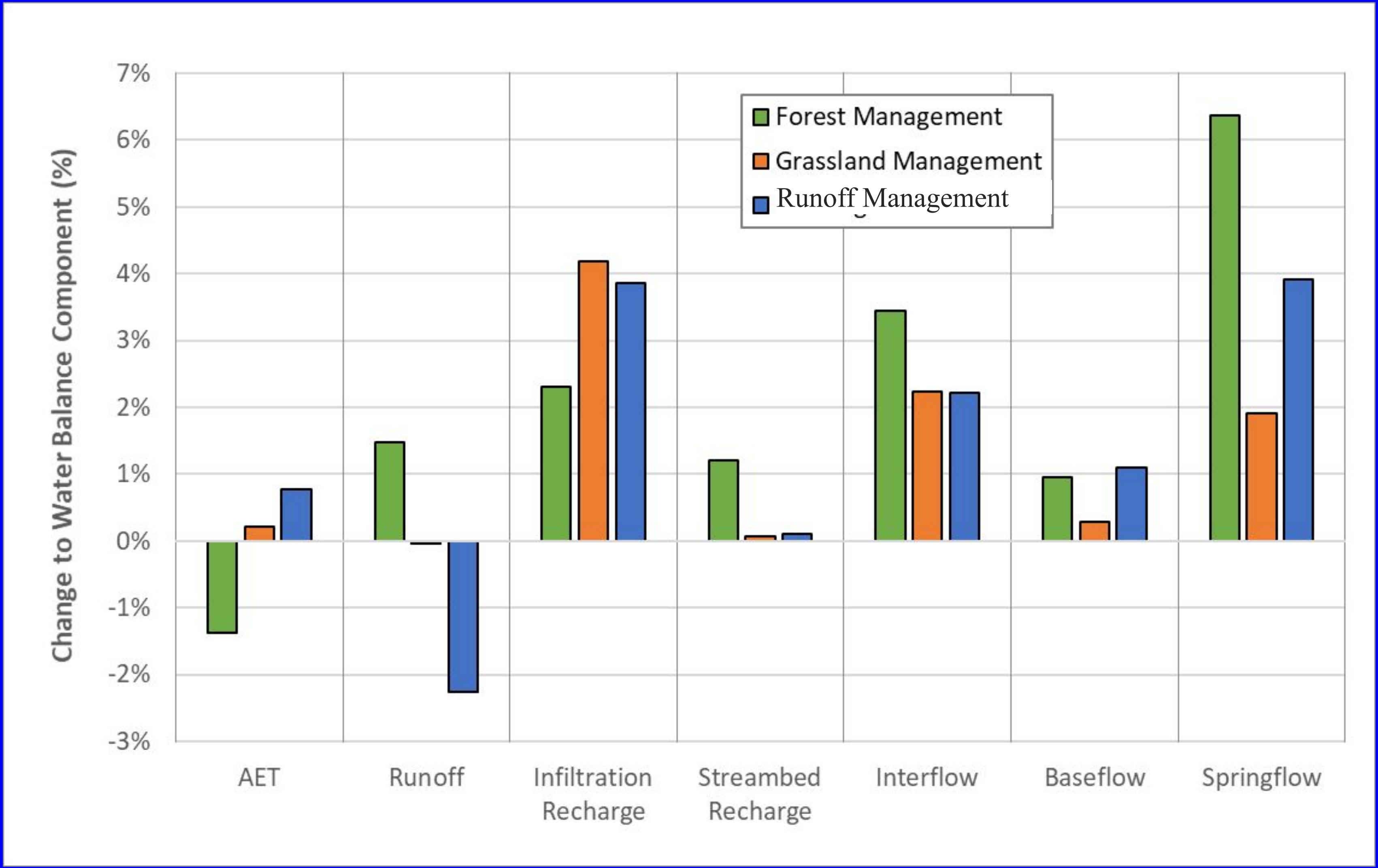


Scenario Analysis – Runoff Management

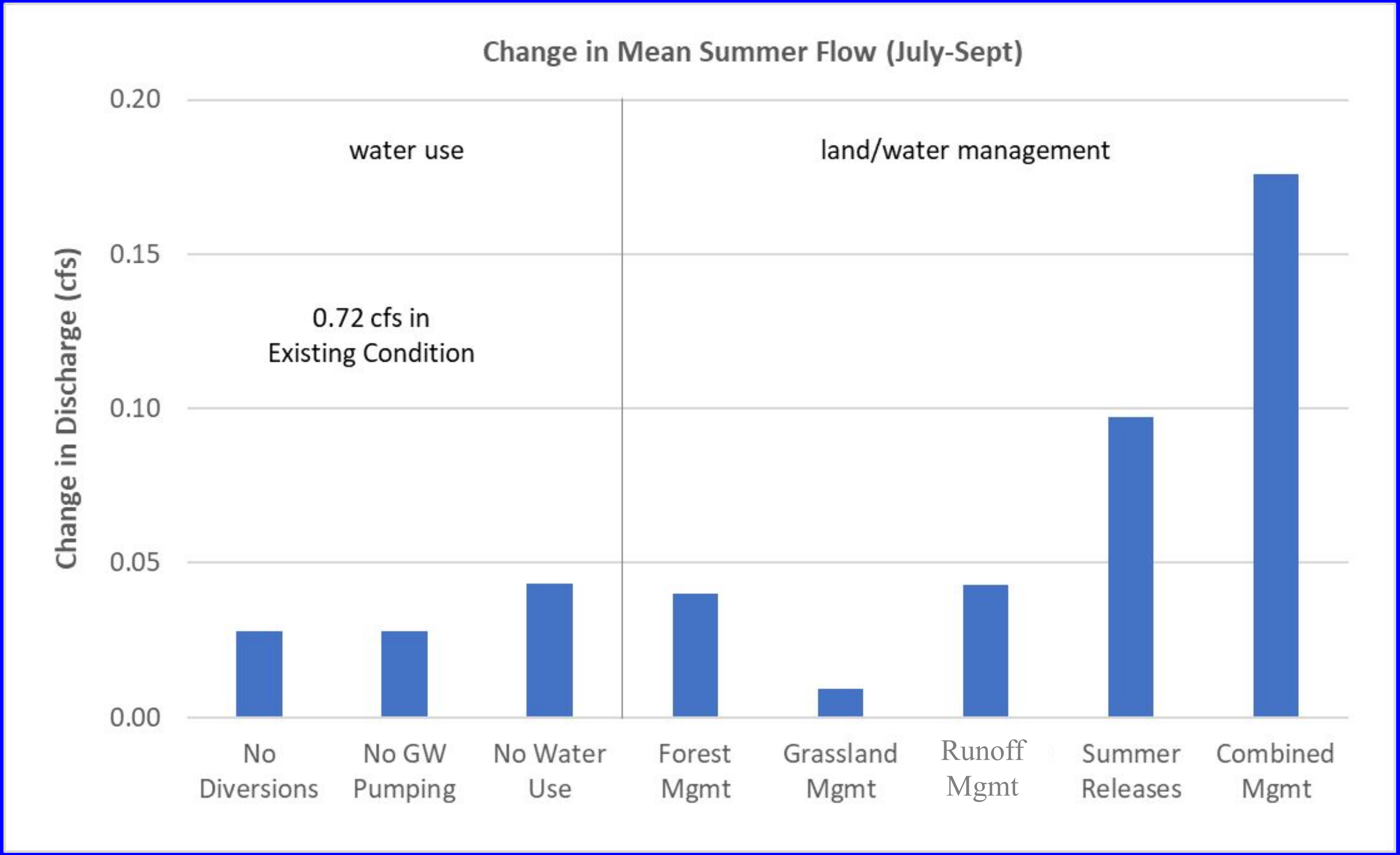
- Represents implementation of large-scale stormwater management best practices
- Assumes runoff from developed lands is infiltrated (310 acres)



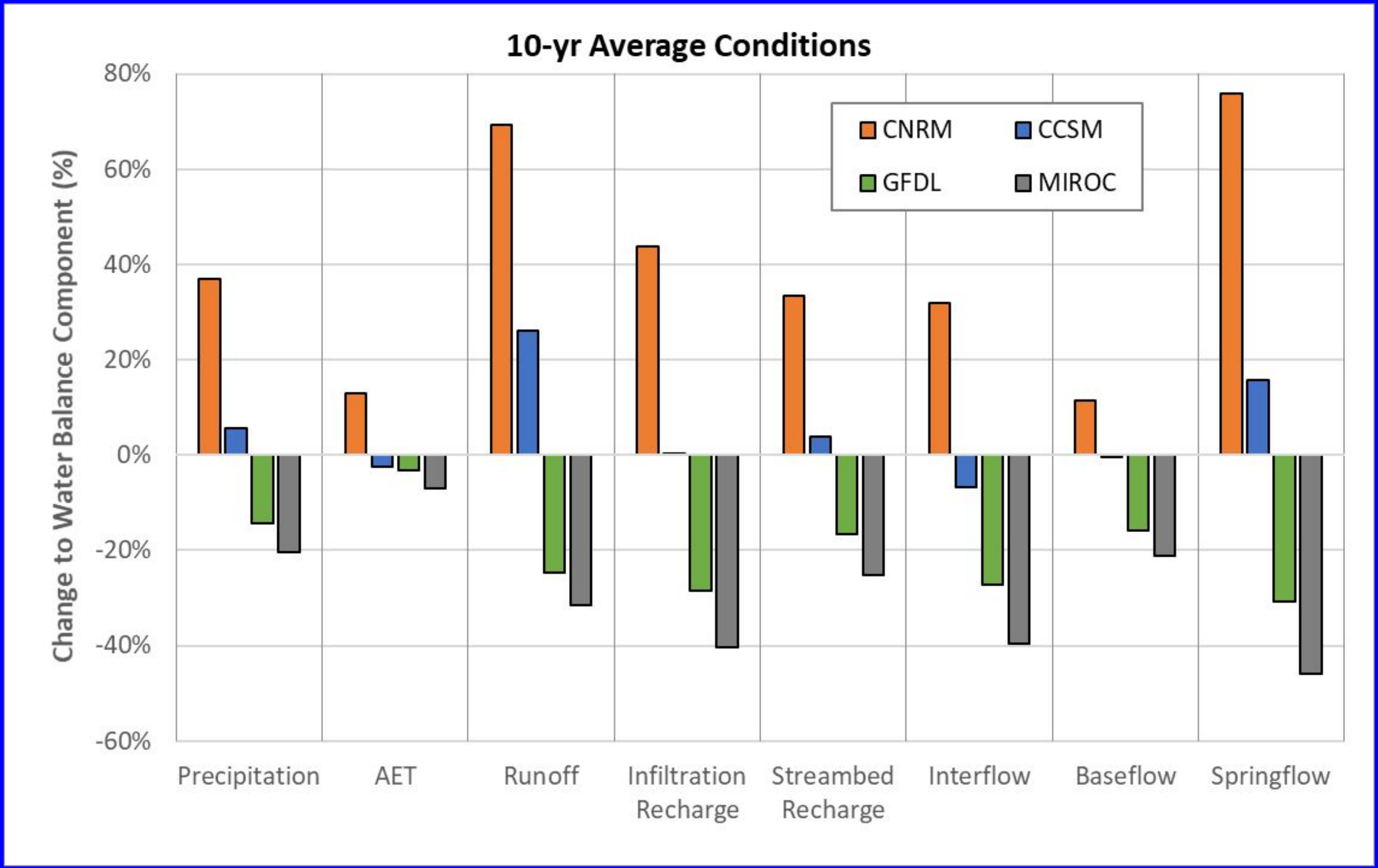
Scenario Analysis – Land/Water Management



Scenario Summary – Summer Streamflow

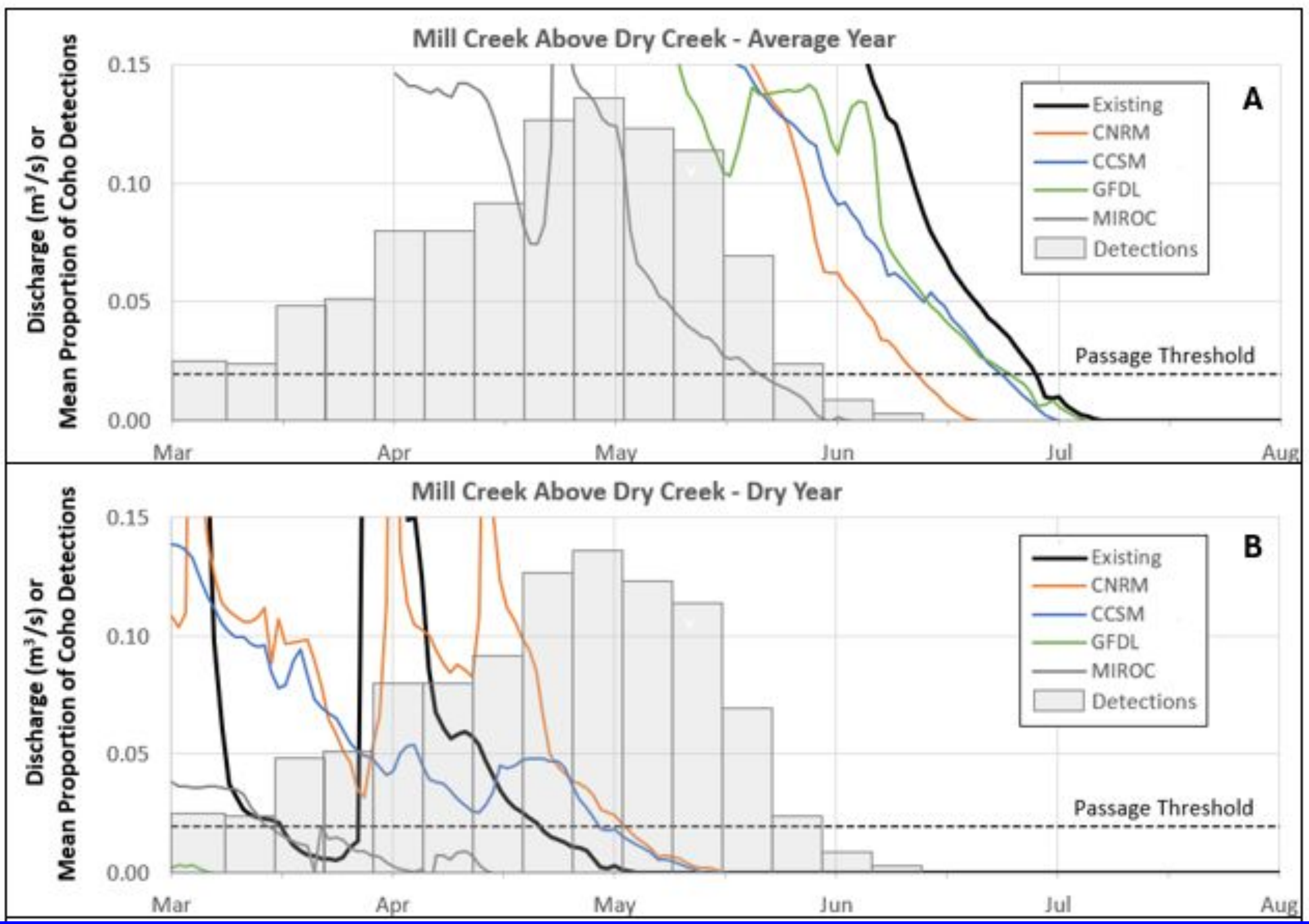


Climate Change Impacts



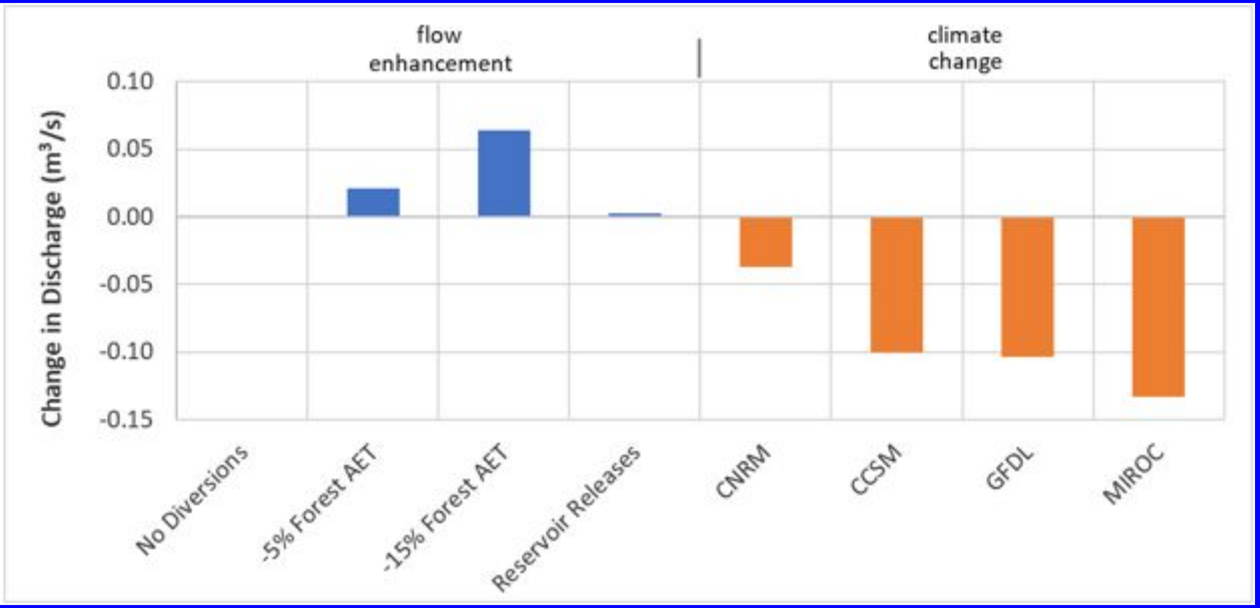
Climate Change Impacts

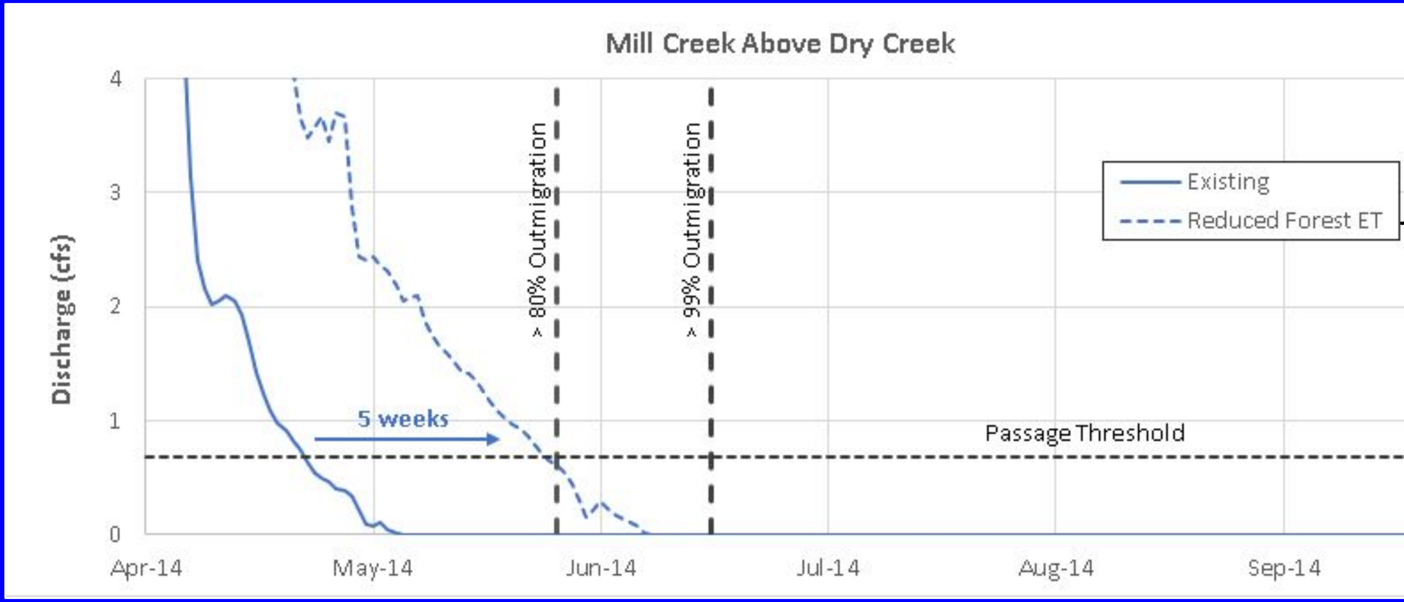
- Increases precipitation seasonality will result in earlier spring flow recessions – risks to outmigrating smolts



Climate Change Mitigation

Mill Creek





-15%

Summary

- Move towards management of the entire water cycle
  - relationships between land use decisions, AET & streamflow are particularly important/neglected
- Integrated water management requires use of models capable of representing process feedbacks
- Forest, grassland, & runoff management are key flow enhancement strategies
  - more work needed to tie specific management actions to anticipated streamflow outcomes
- Climate change poses a threat to smolt outmigration through increased precipitation seasonality
  - Water use modifications are unlikely to be an effective mitigation strategy – landscape level management of key hydrologic processes is required

Thank You

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www.coastrangewater.org/projects

Developing Effective Flow Enhancement Strategies for Salmonid Recovery and Climate Change Adaptation in Central California's Coastal Watersheds, River Research & Applications, In Review

Response Diversity Among Streams With Variable Flow Permanence Stabilizes Habitat Availability for Spawning Salmonids

Skylar Rousseau

Timothy Walsworth

SRF Conference

May 2, 2025

Habitat Mosaics

- Dynamic resource patches
- Temporary aquatic habitat (TAH)
  - Discrete
  - Creates patch diversity
  - Form & function

Non-Permanent Streams

- Common form of TAH
- Cease to flow at some point in hydrograph
- 59% of stream length
- Snowmelt driven
  - Intermountain West
- Flow and dry seasonally

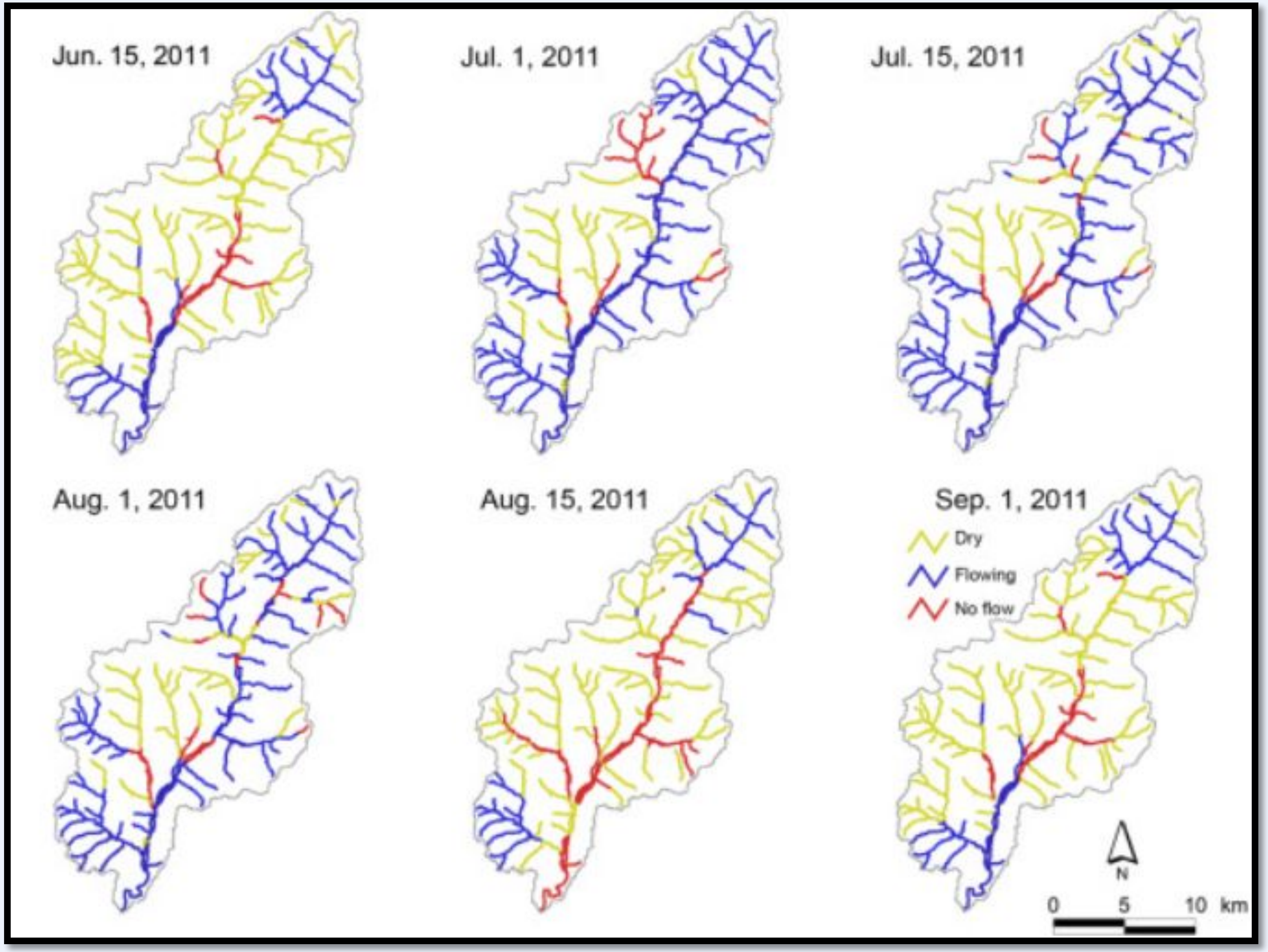
May

June

Little White Pine Creek - 2022

Habitat Mosaics

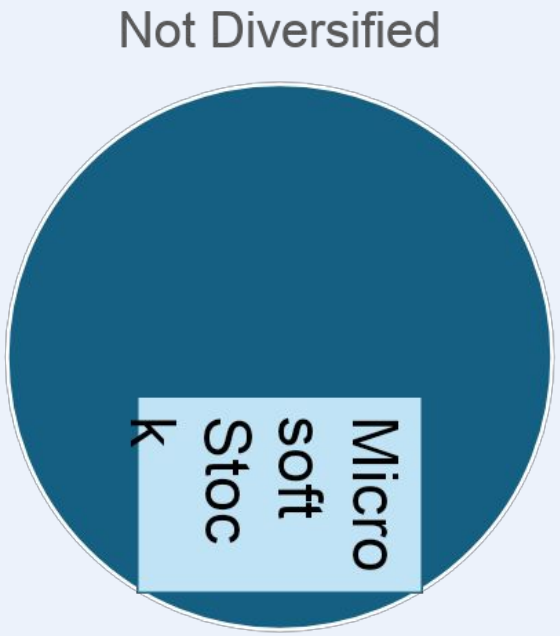
- Watershed scale
  - Wet dry cycles
  - Shifting mosaic of heterogeneous habitat patches
- Flows shift through time and space
- Dynamic flow patterns
  - Habitat expansion/contraction
  - Connectivity

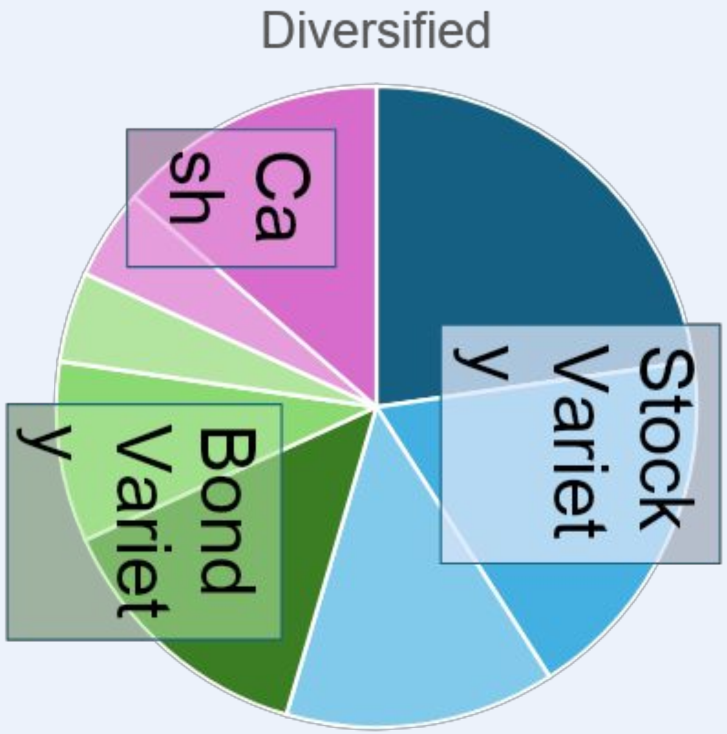


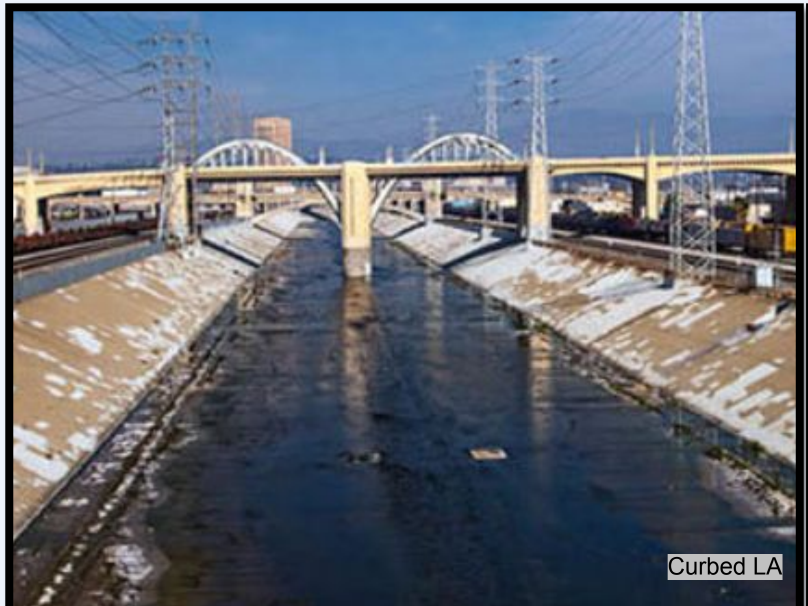
Datry *et al.*, 2017

Portfolio Effects

- Response diversity
- Local conditions decoupled from regional drivers
- Complexity reduces risk of climate change and disturbance



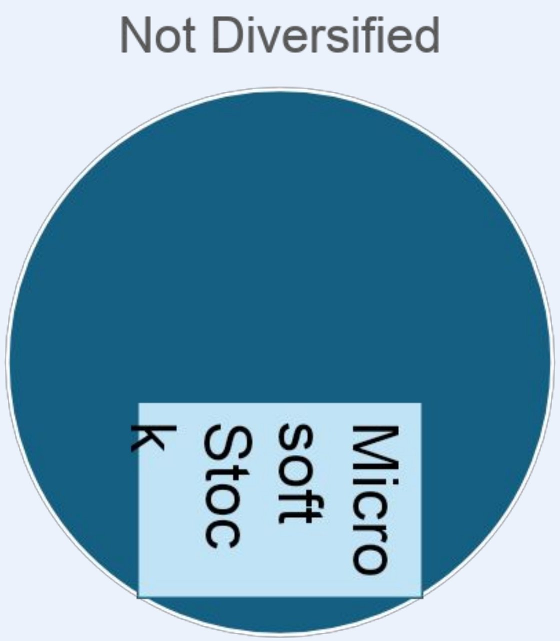


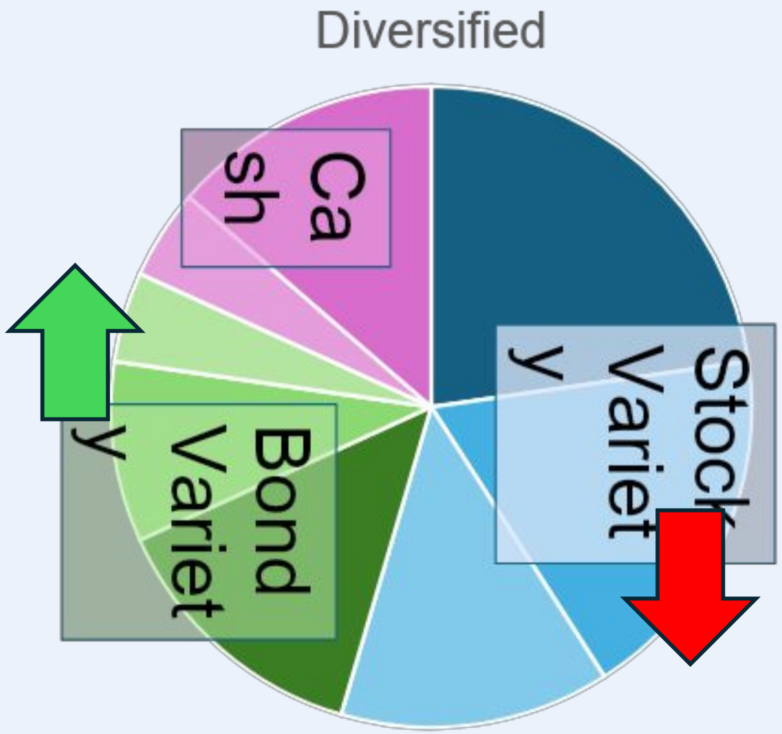

Curbed LA

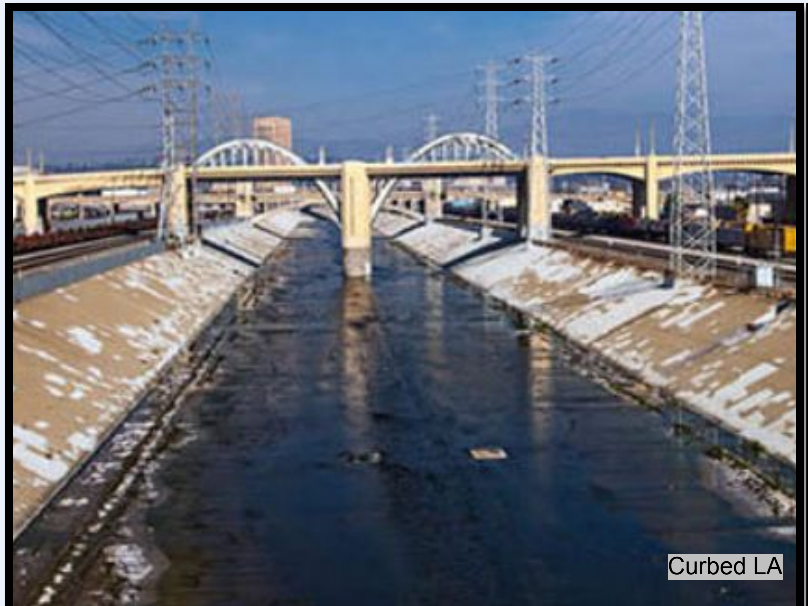

Jonathan Armstrong

Portfolio Effects

- Response diversity
- Local conditions decoupled from regional drivers
- Complexity reduces risk of climate change and disturbance



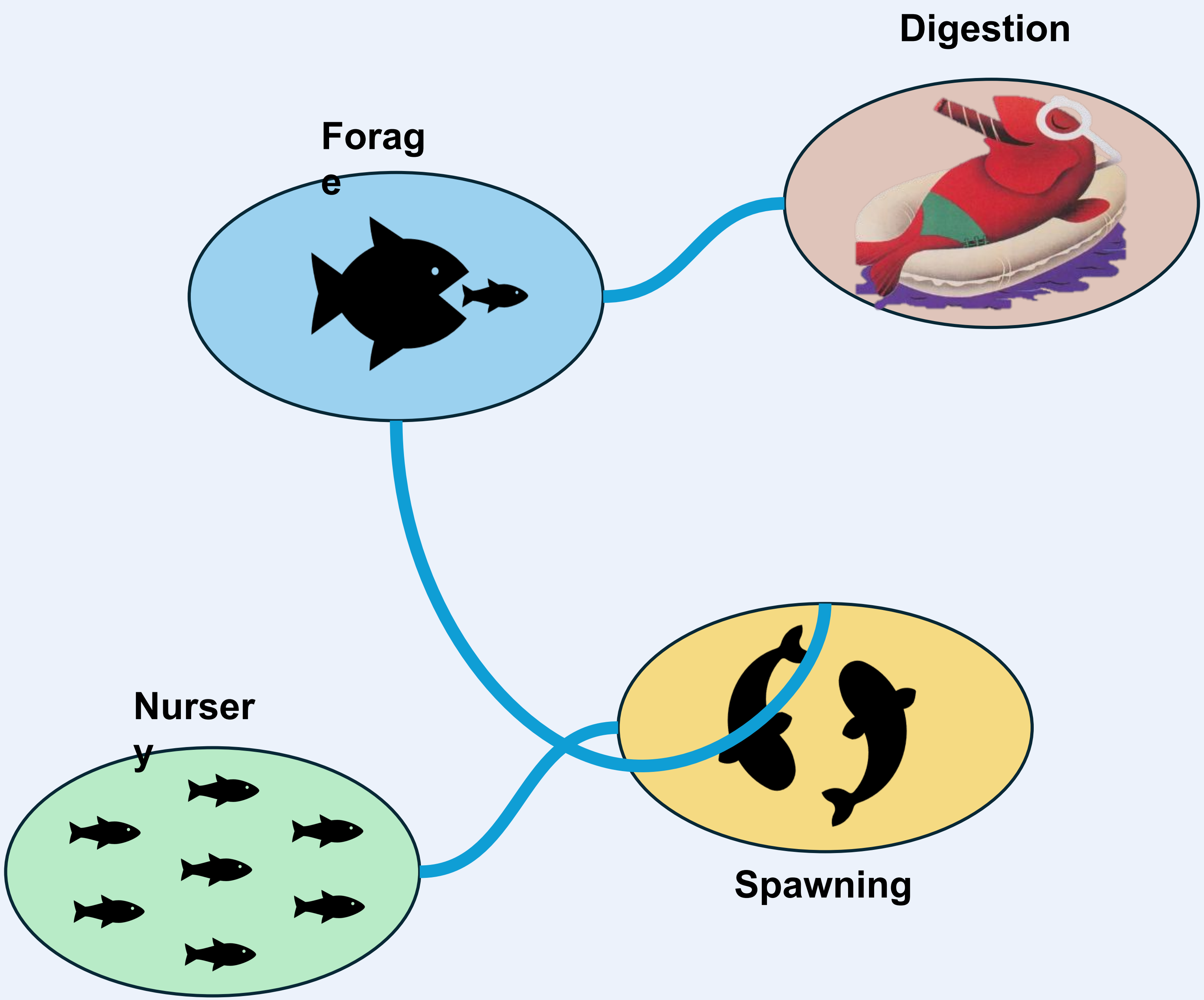




Habitat Mosaics:

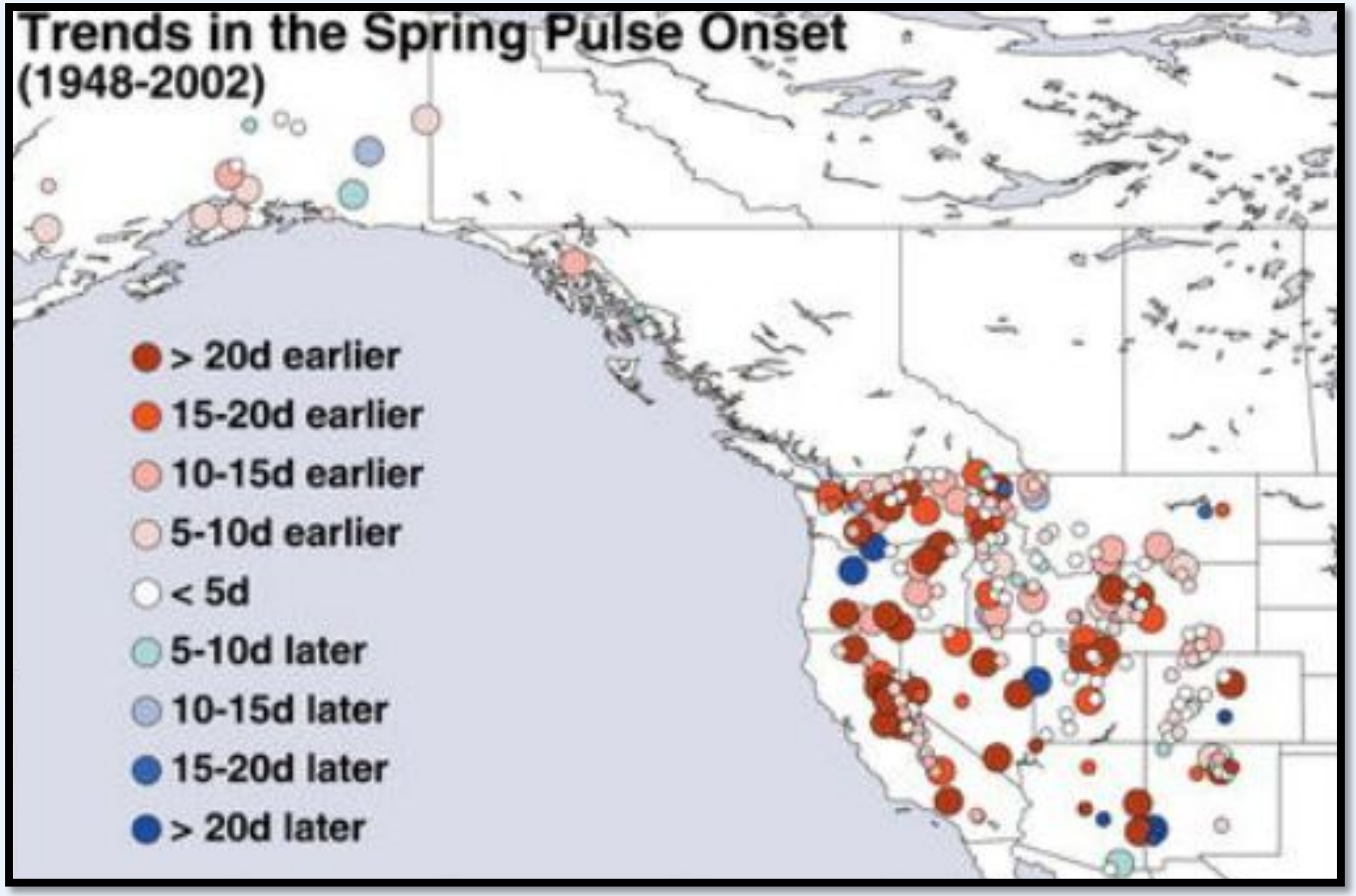
Fitness benefit

- Tailored life history
- When available
- Alternative, complementary habitats
  - Benefit different life stages and life history expressions



Increasing Impermanence

- Natural, global phenomenon
  - Frequency and duration of no-flow
- Higher winter/spring temperatures
- More precipitation coming as rain
- Earlier peak runoff and streamflow
  - Earlier drying for non-permanent
- Permanent streams now go dry



Stewart *et al.*, 2005

Knowledge Gaps

- Despite increasing presence

- Poor understanding of their role in aquatic species life history

Knowledge Gaps

- Non-permanent tributary availability overlaps with spring spawn

- Spawning habitat in certain years and conditions

Question:

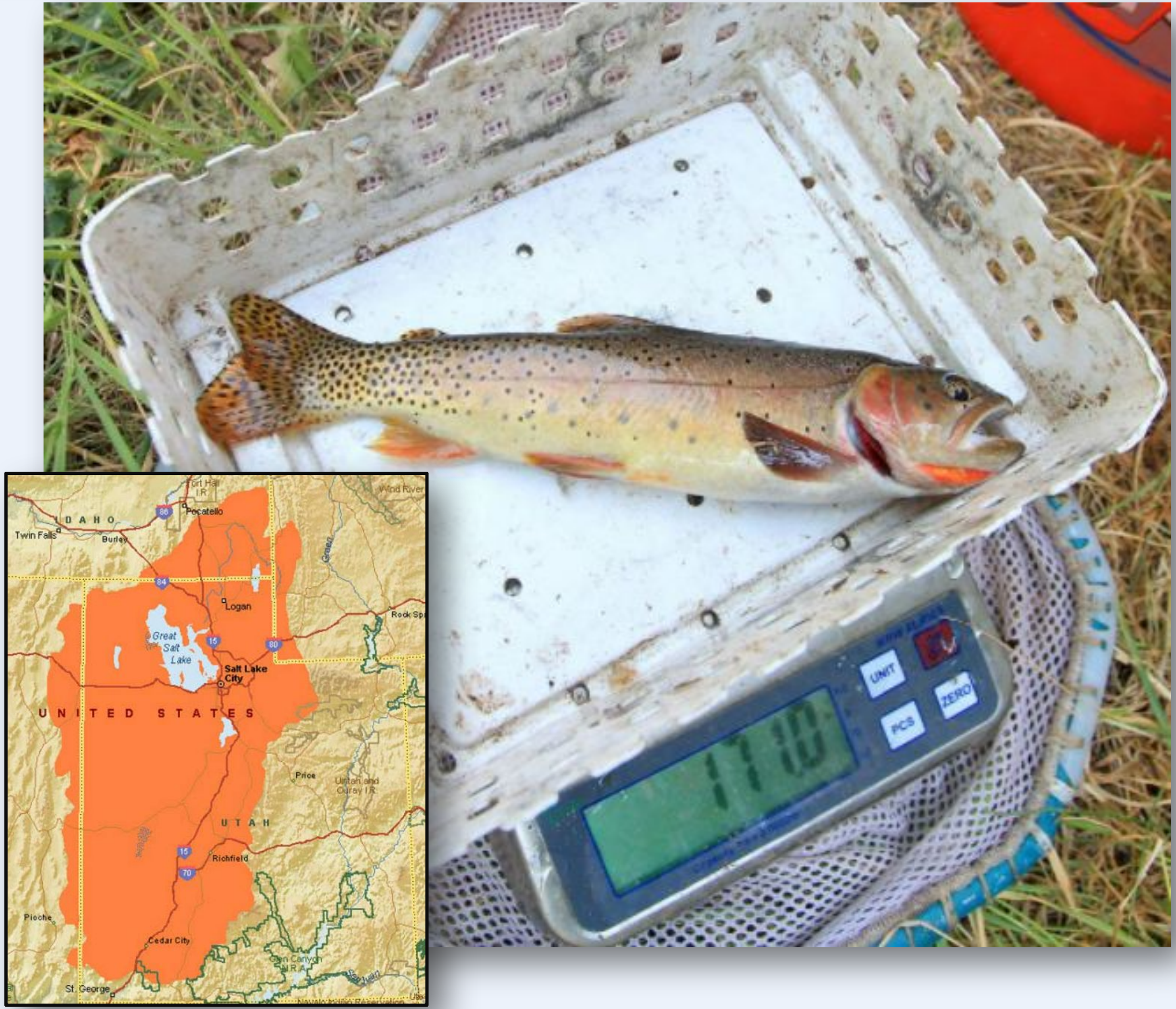
1. Potential and realized ability of non-permanent streams to support spawning and early life history of cutthroat trout
    a) Mediated by local climate conditions

Suitable Conditions

- Requirements for spawning
  - Stream must flow long & warm enough
  - Fertilization, emergence, and migration
  - Timing of stream drying is critical

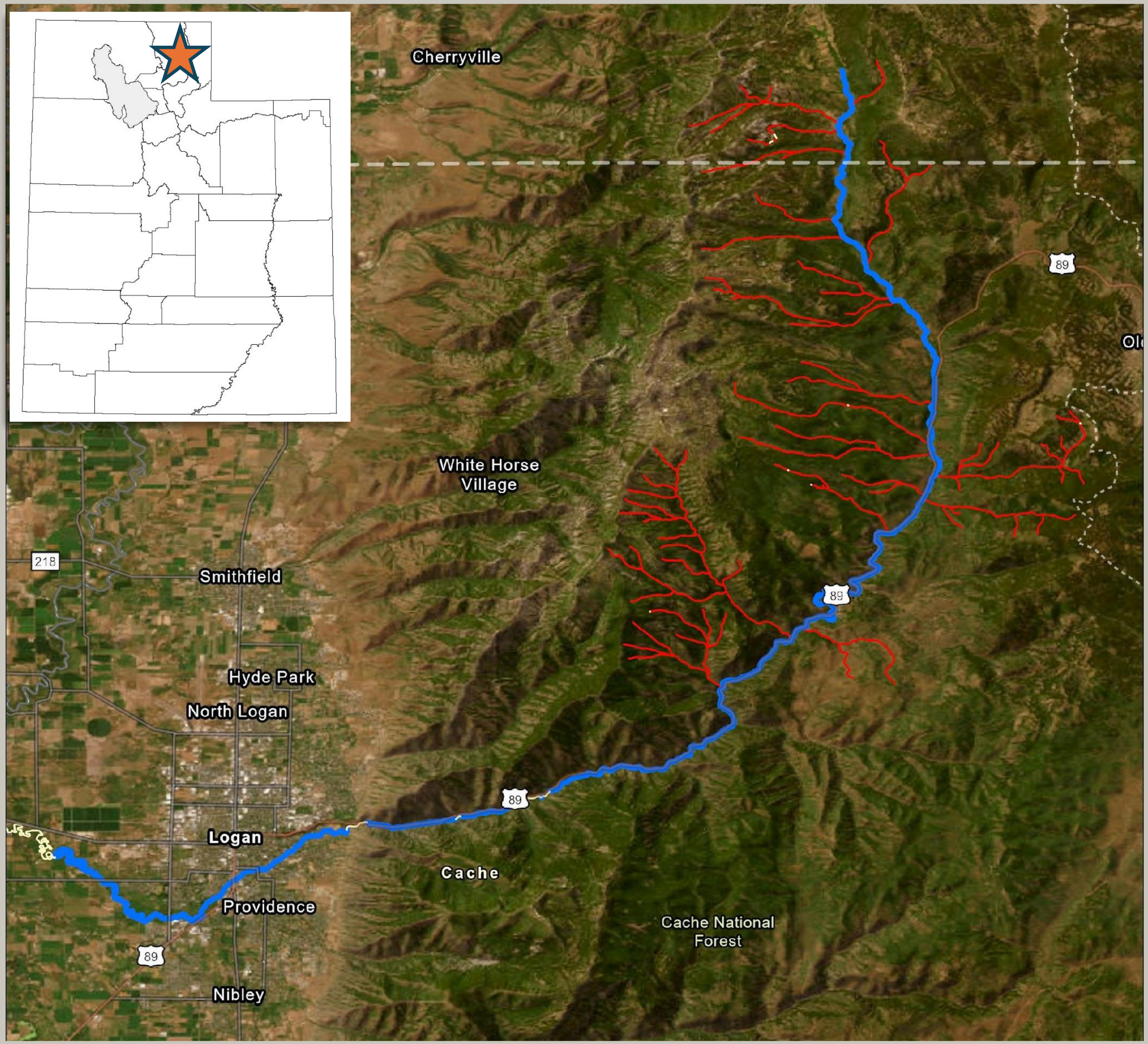
Bonneville Cutthroat Trout

- Bonneville Basin
- Segregate habitat use by life history needs
- Multiple movements in one watershed
- Spring spawn



Logan River

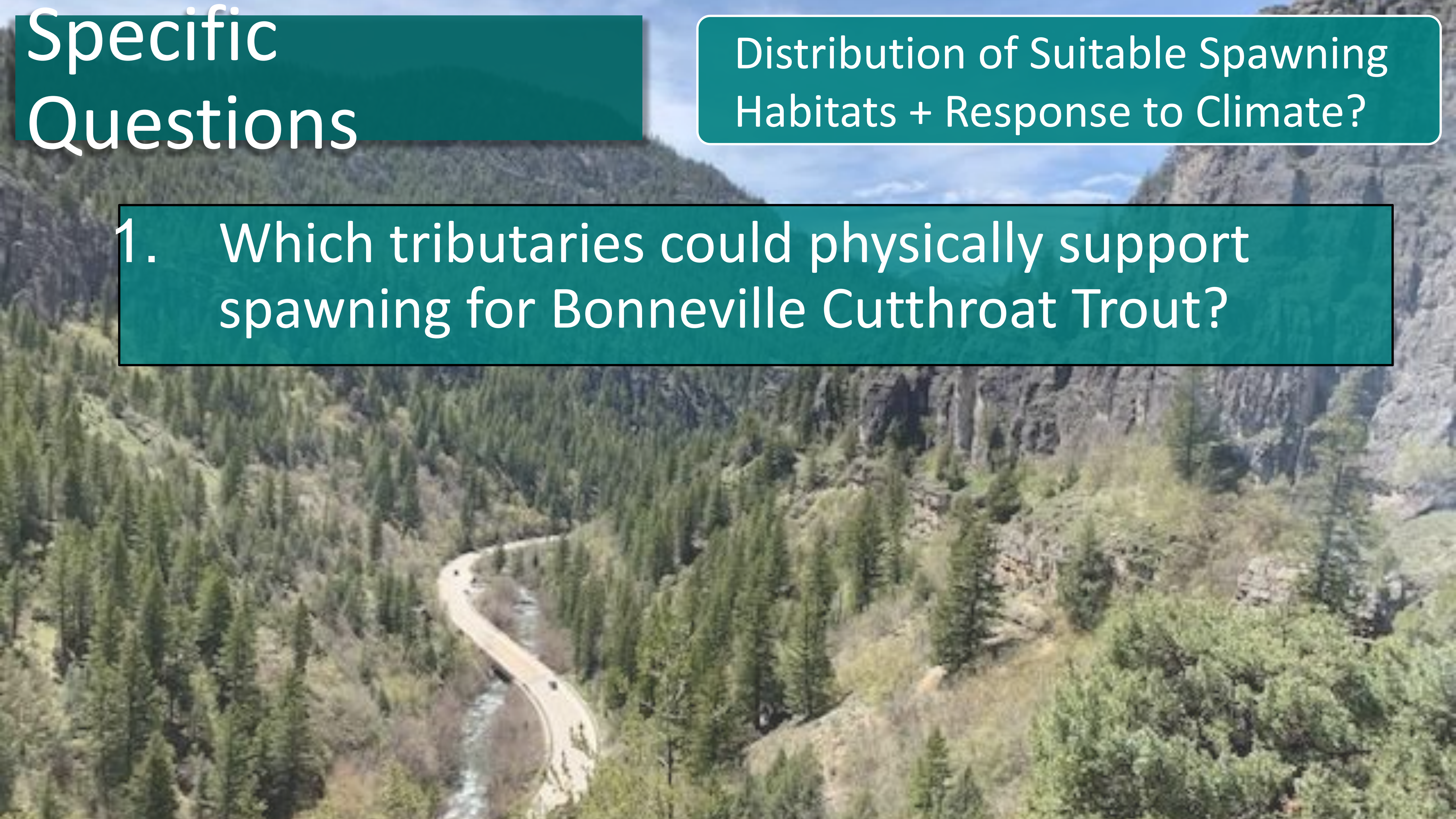
- BCT population stronghold
- Hydrograph driven by snowmelt in spring
  - Inundates dozens of tributaries
- Documented spawning in spring fed creeks
- One historic record of use
- Habitat suitability and use change?



Specific Questions

Distribution of Suitable Spawning Habitats + Response to Climate?

1. Which tributaries could physically support spawning for Bonneville Cutthroat Trout?



Spawning Suitability

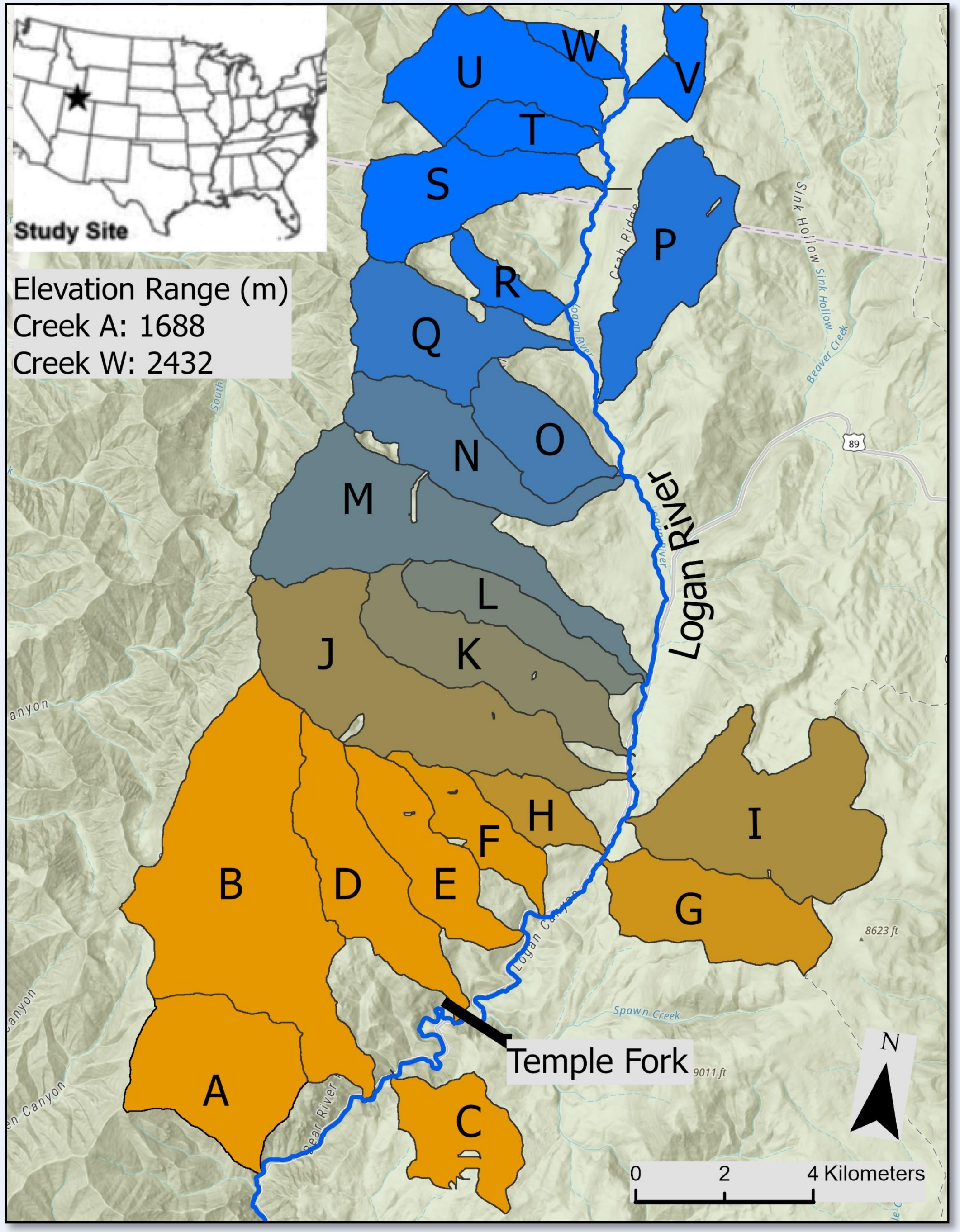
- Determining suitability
  - Degree Day (DD)
  - Integrated metric of time*temperature
  - Embryo development to emergence
- DD accumulated before drying
  - ∑ (Daily average temperature) across flow period
  - Emergence (479 DD) benchmark

Spawning Suitability

- Determining suitability
  - Degree Day (DD)
  - Integrated metric of time*temperature
  - Embryo development to emergence
- DD accumulated before drying
  - ∑ (Daily average temperature) across flow period
  - Emergence (479 DD) benchmark
- **What we need:**
  - **Daily average temperature**
  - **Start / stop dates continuous flow**

Tributary Sites

- Deployed temperature and water level loggers
- 23 ungauged tributaries
- Mid Elevation ⇨ Headwaters
  - 5300 – 8000 feet
- Flow permanence gradient
  - Flashy, seasonal, permanent



Deploy Loggers

- Time series of daily average temperatures and flow duration

Degree Days

- Calculate for each potential spawn date (May 1st, May 2nd,…)

Emergence Probability

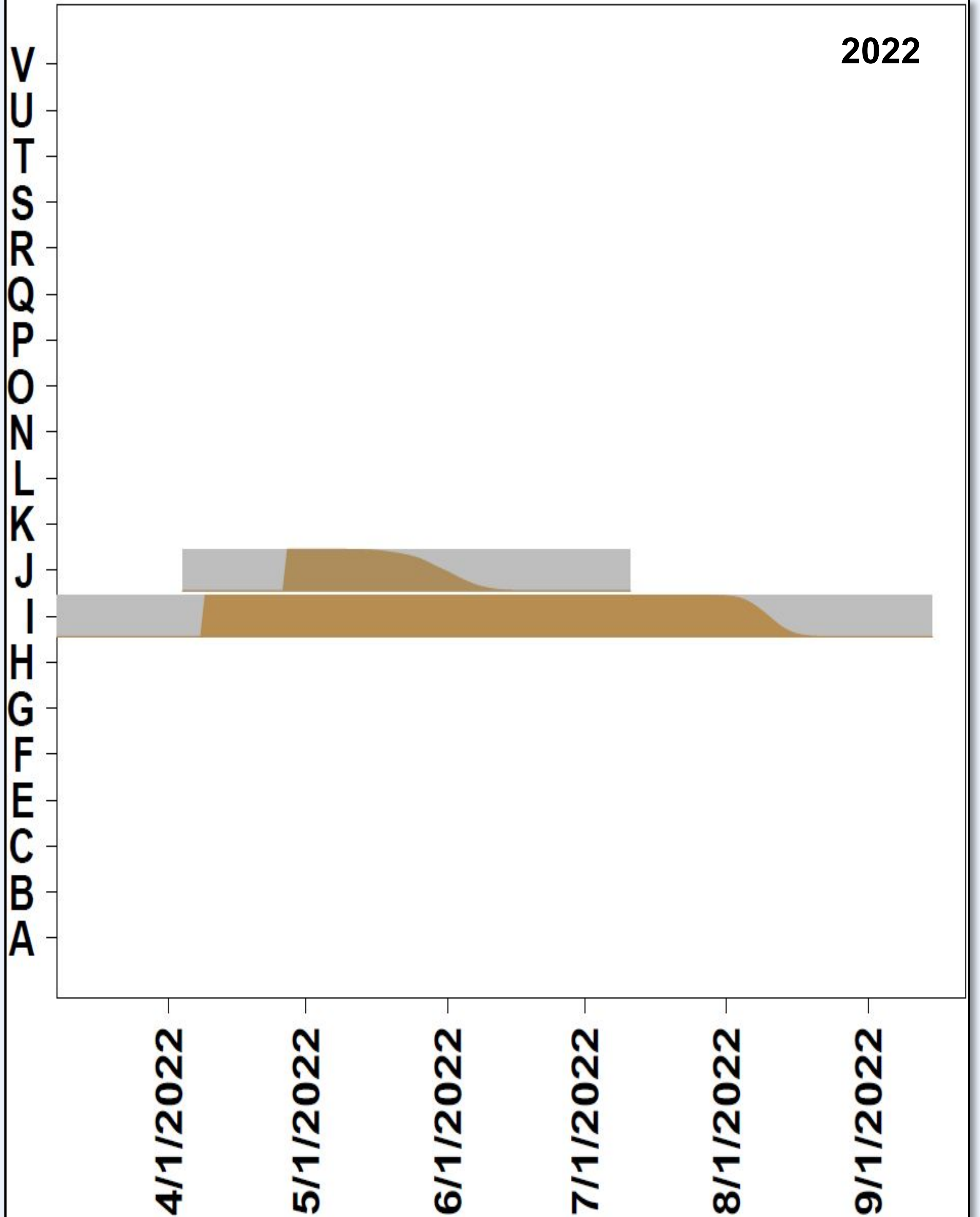
- Spawn on day x, probability accumulate enough DD?

Spawn Window

- Sum across all flow days for comparisons

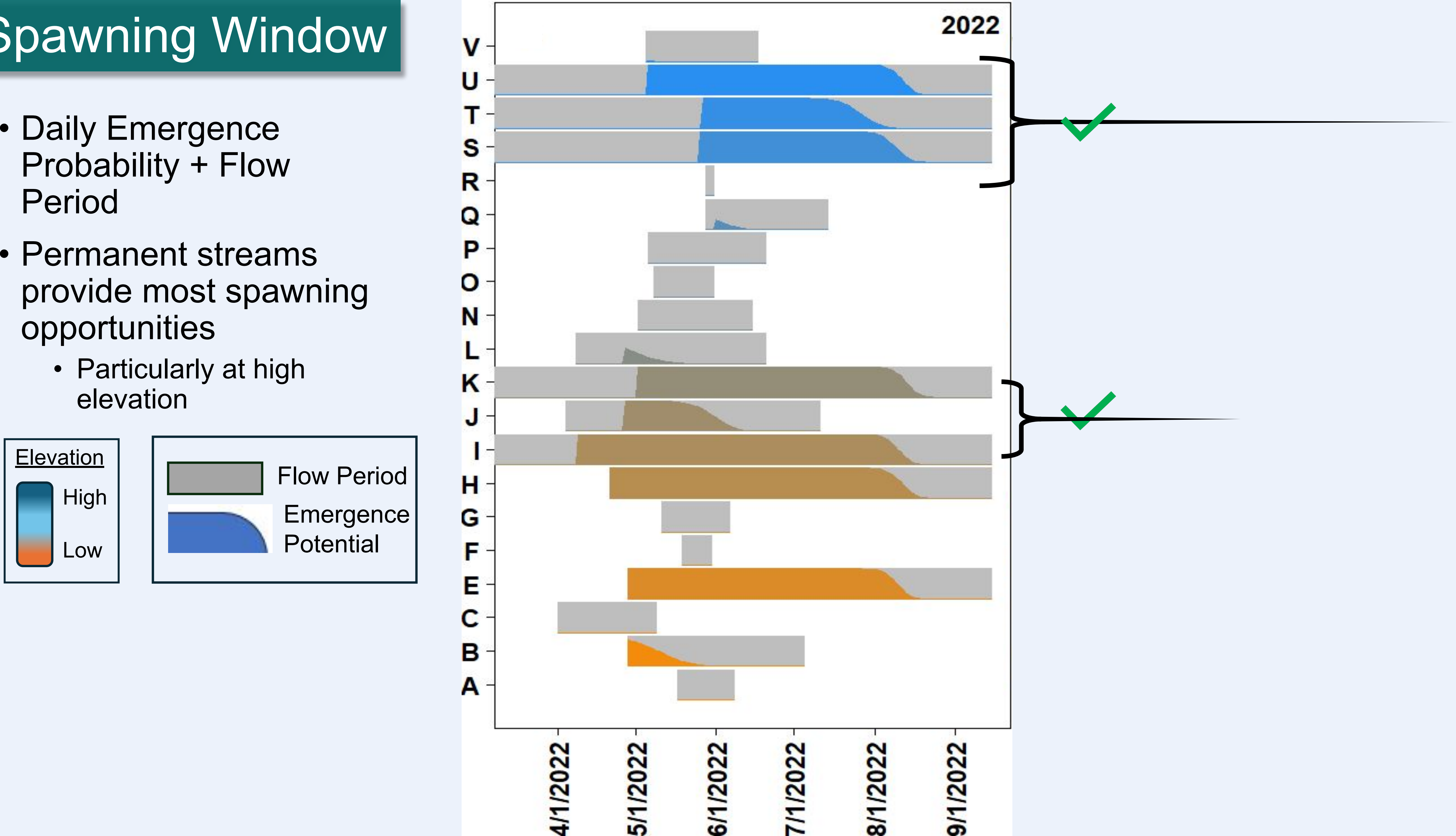
Spawning Window

- Daily Emergence Probability + Flow Period
- Creek I
  - Permanent
  - April 10th – August 1st
  - 5°C on April 10th
  - September 15th cutoff
- Creek J
  - Non-permanent
  - May 1st – June 1st



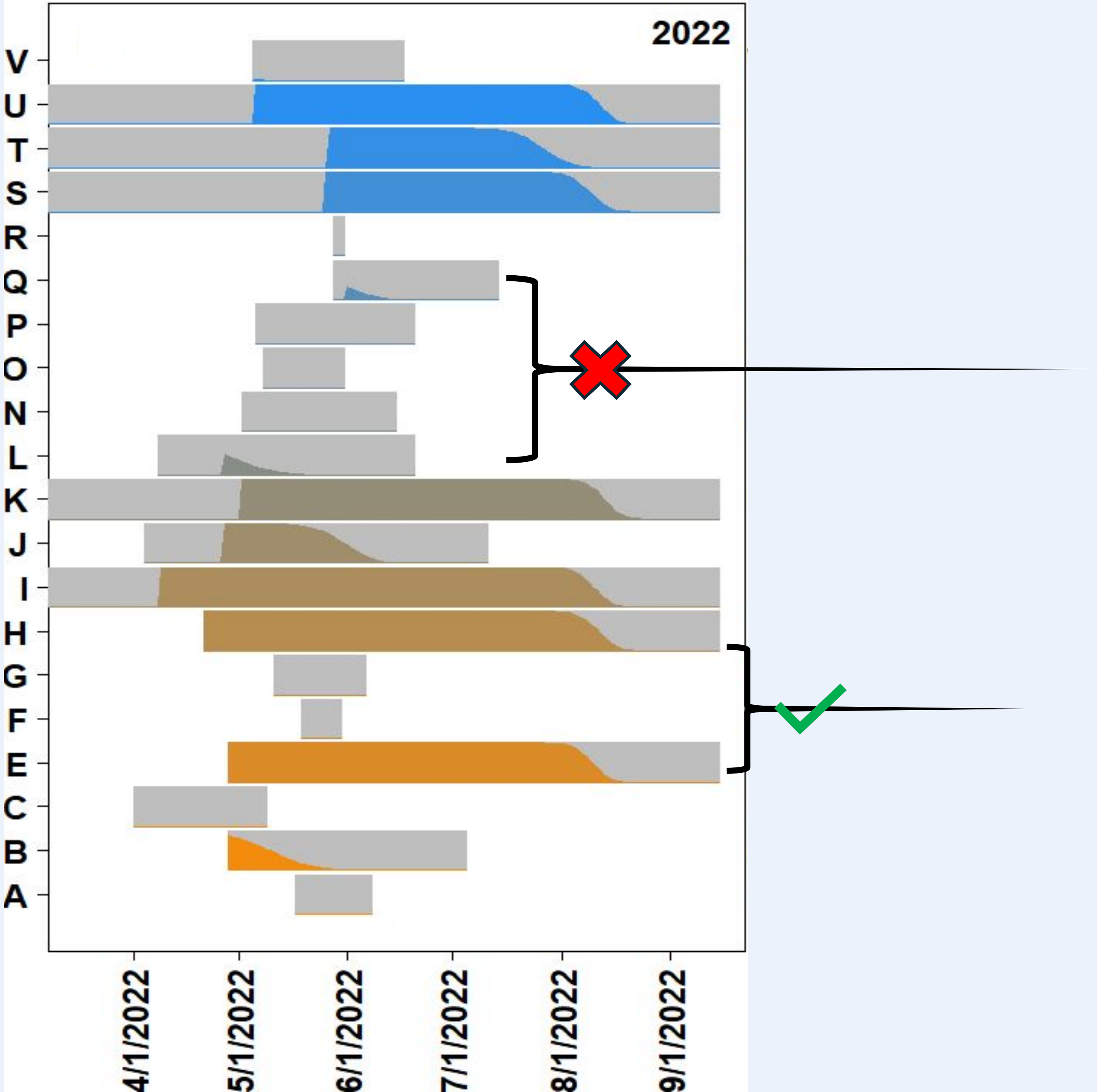
Spawning Window

- Daily Emergence Probability + Flow Period
- Permanent streams provide most spawning opportunities
    - Particularly at high elevation



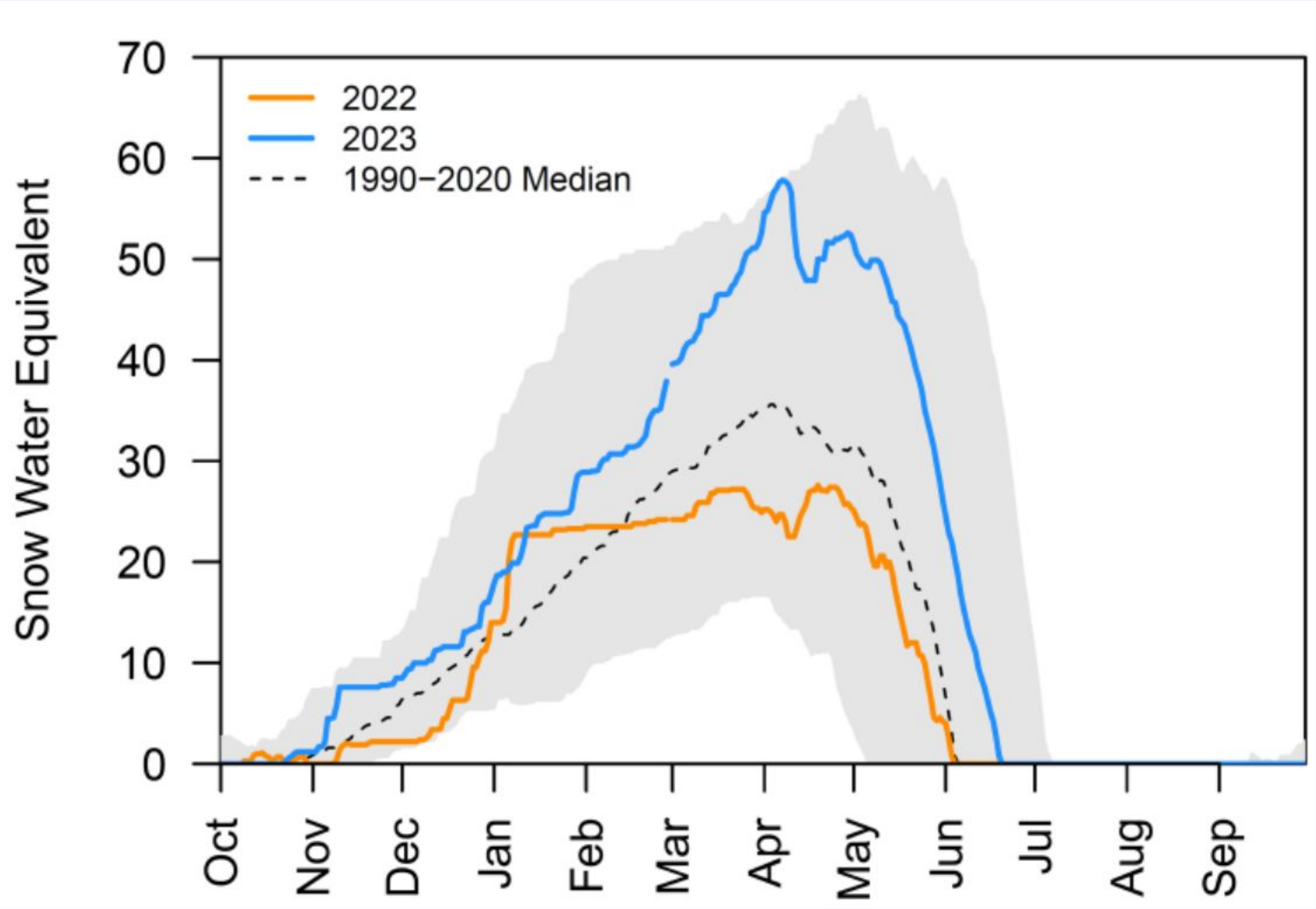
Spawning Window

- Daily Emergence Probability + Flow Period
- High elevation, permanent streams provide much spawning habitat
- **Non-permanent streams support some spawning**
    - Most don't flow long enough



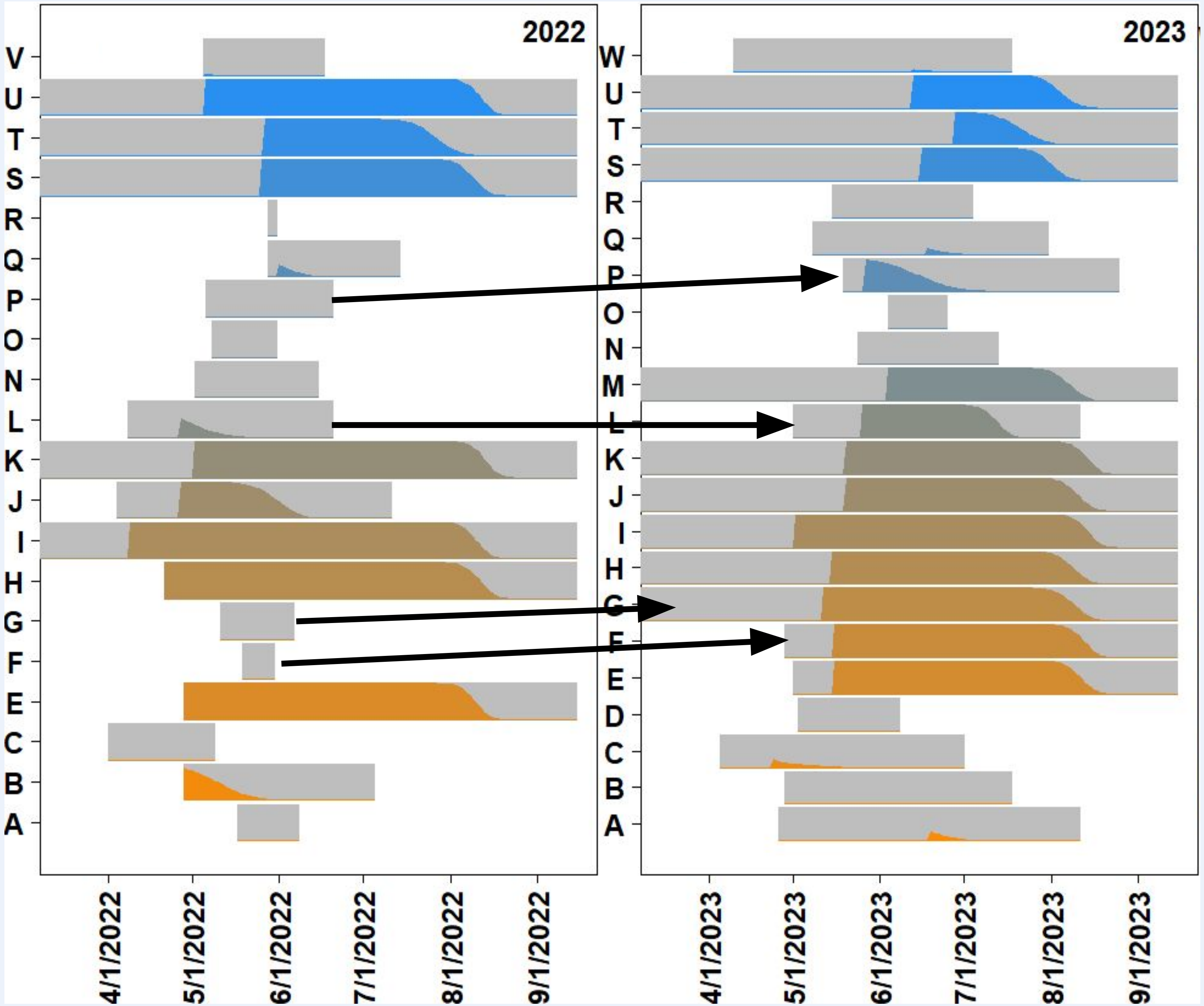
Spawning Window

- Importance of climate
- 2022 = end of prolonged drought
- 2023 = record snowpack year
- Peak snow water equivalent increased by 132% in the basin



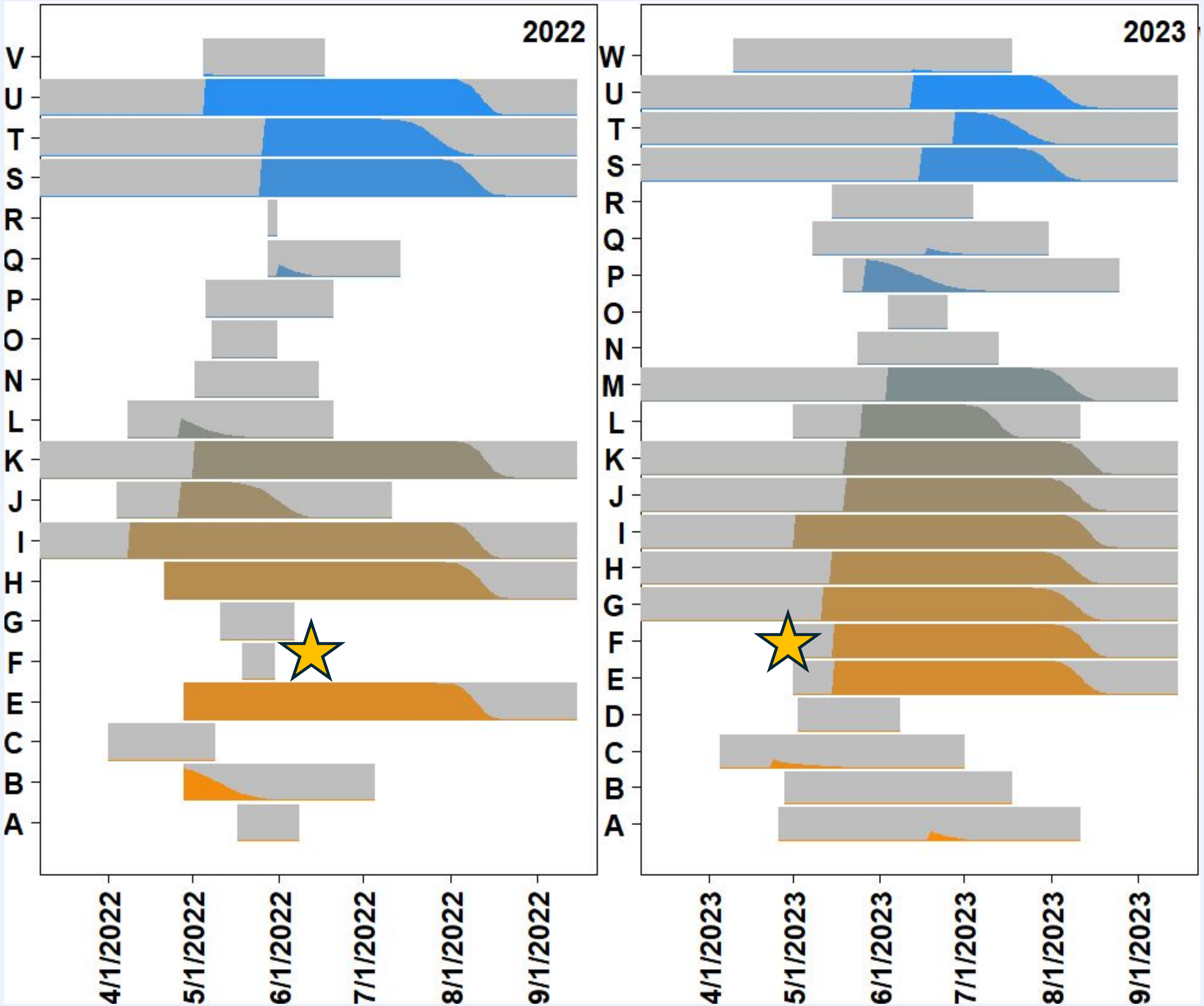
Spawning Window

- Spatial shifts
- Record snowpack extends flow period
- More DDs = higher probability of emergence
  - Longer spawning window
- F, G, L, P supported no spawning in 2022, 100% probability of emergence in 2023



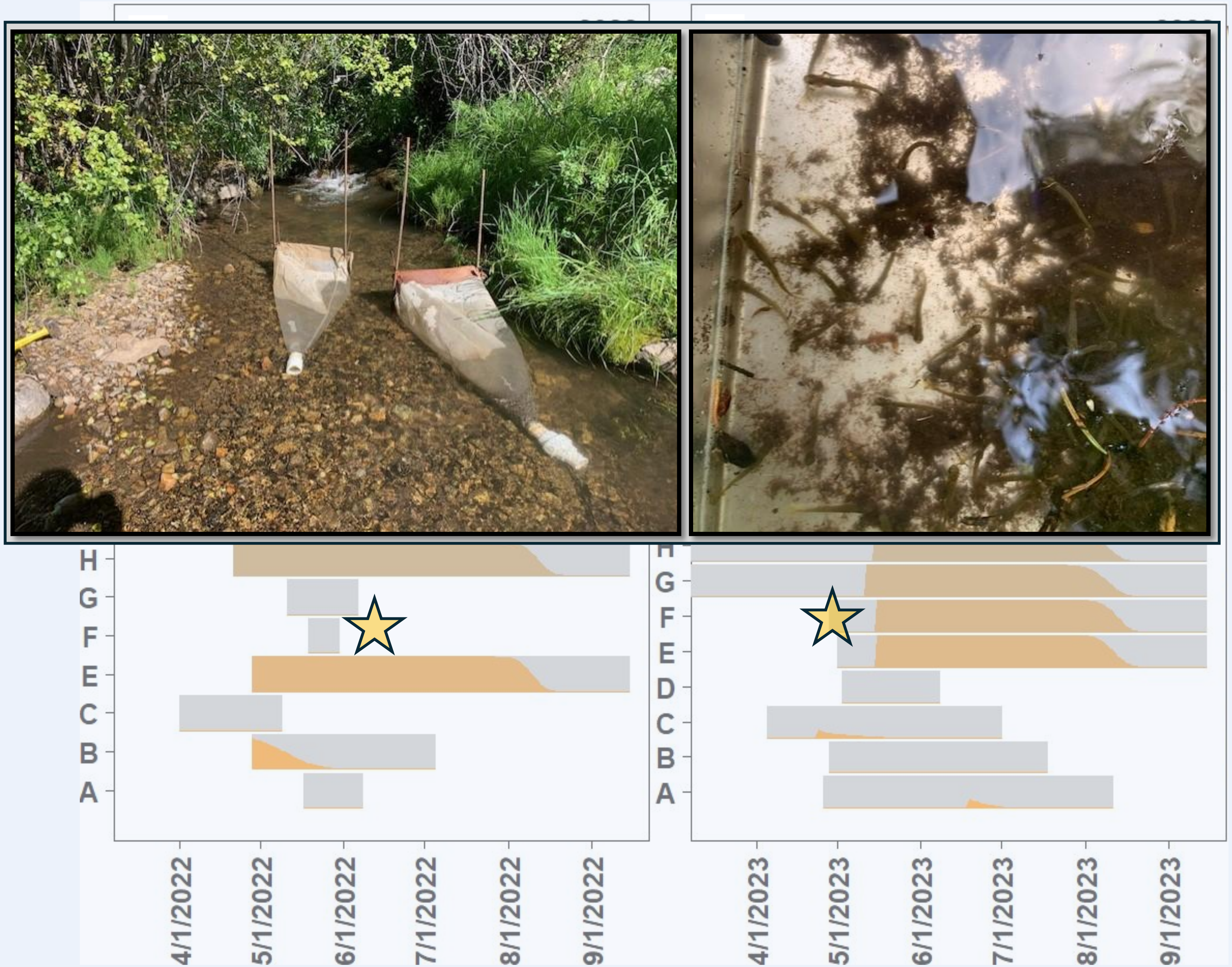
Spawning Window

- Non-permanent streams provide suitable conditions
  - Theoretical
  - Successfully spawn
- Migrating fry captured
  - Flow varied
- Twin creek (F)
  - < 5 days 2022
  - Flowed enough to support fry production 2023



Spawning Window

- Non-permanent streams support suitable conditions
  - Theoretical
  - Successfully spawn
- Migrating fry captured (n=234) in one night
- Twin creek (F)
  - < 5 days 2022
  - Flowed enough to support fry production 2023



Adult (> 150mm)

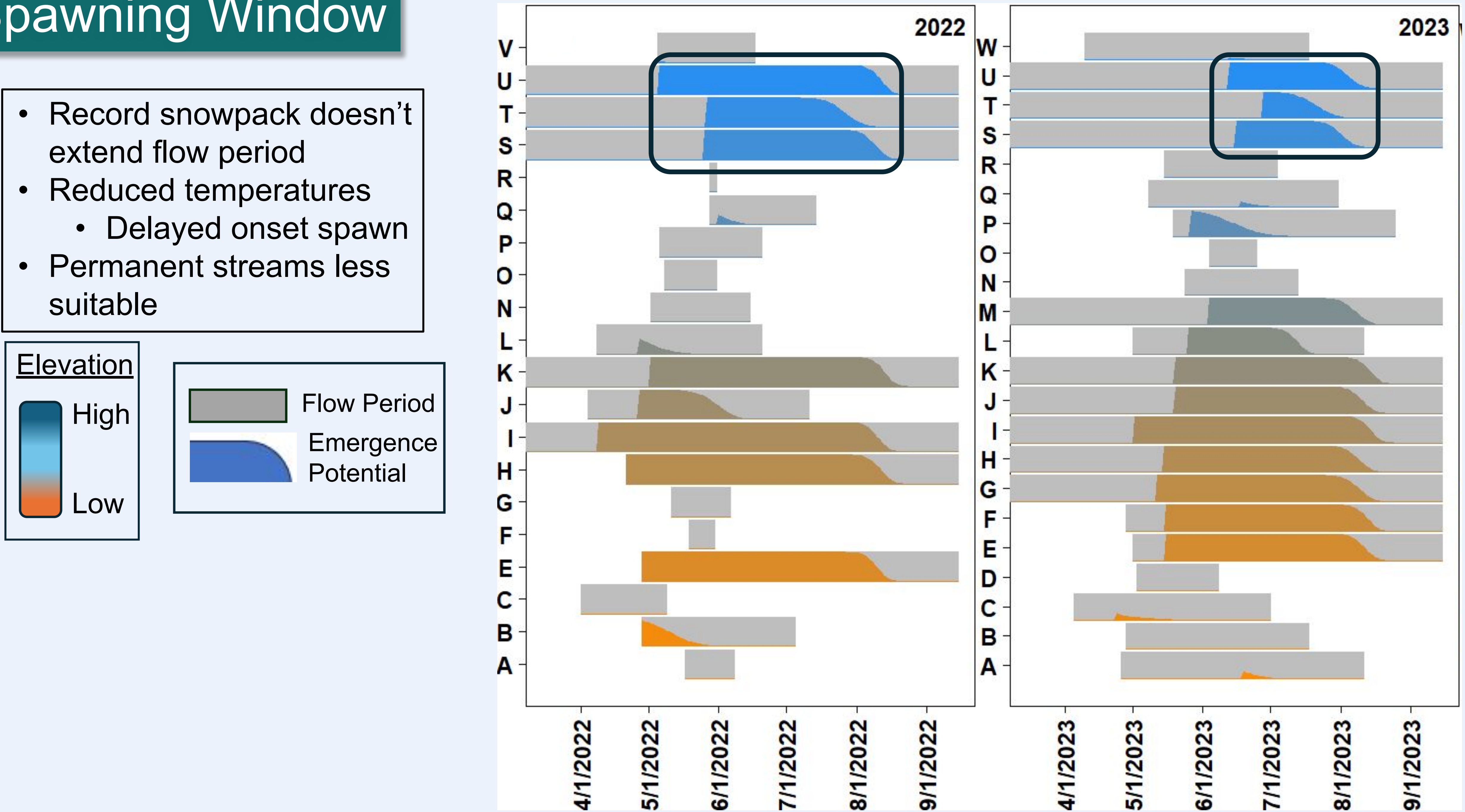
Juvenile (< 150mm)

Fry (< 50 mm)

Bear Hollow (Creek E), 2023 (n=234)

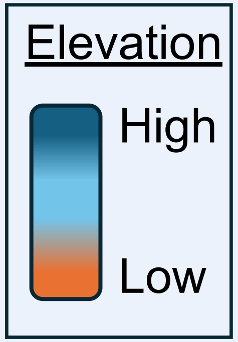
Spawning Window

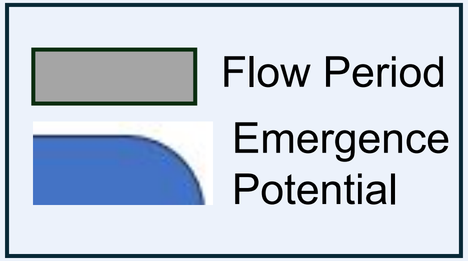
- Record snowpack doesn't extend flow period
- Reduced temperatures
  - Delayed onset spawn
- Permanent streams less suitable

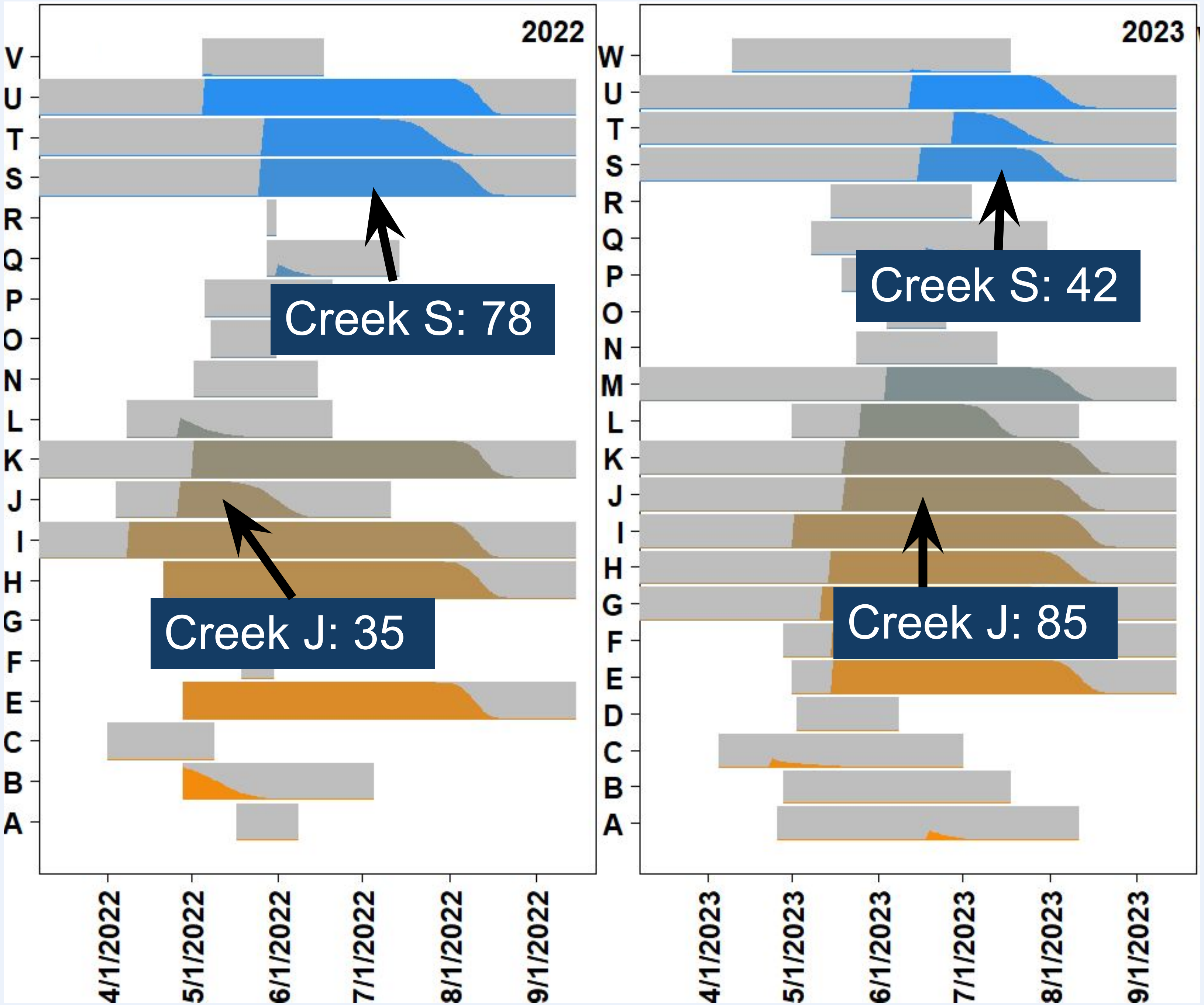


Spawning Window

- Area under emergence probability curve
- Duration of spawning window
  - Single value
- Direct comparisons across years





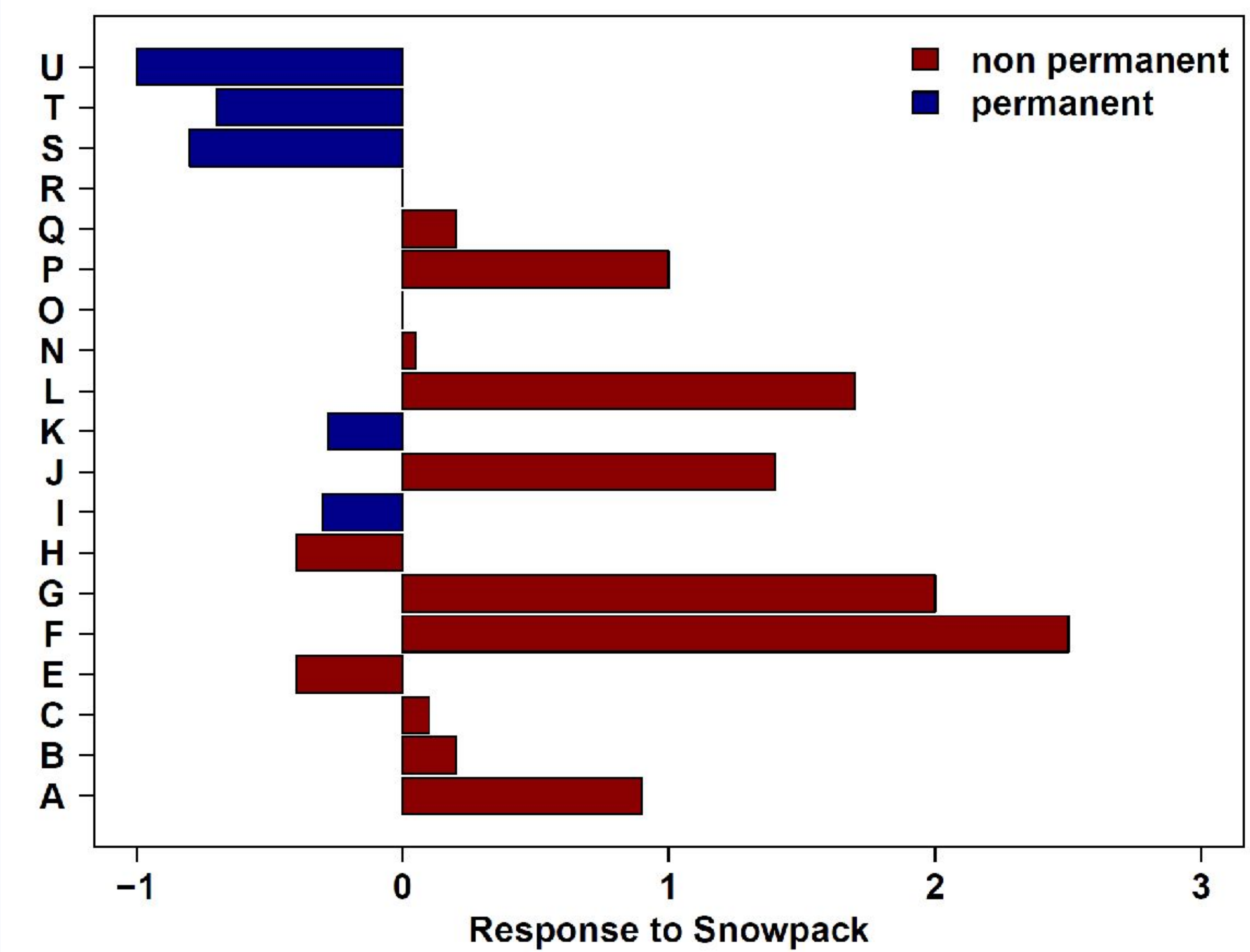


Spawning Window

Preliminary Data 2024

- 2022 - 2024 (low, high, normal snowpack)

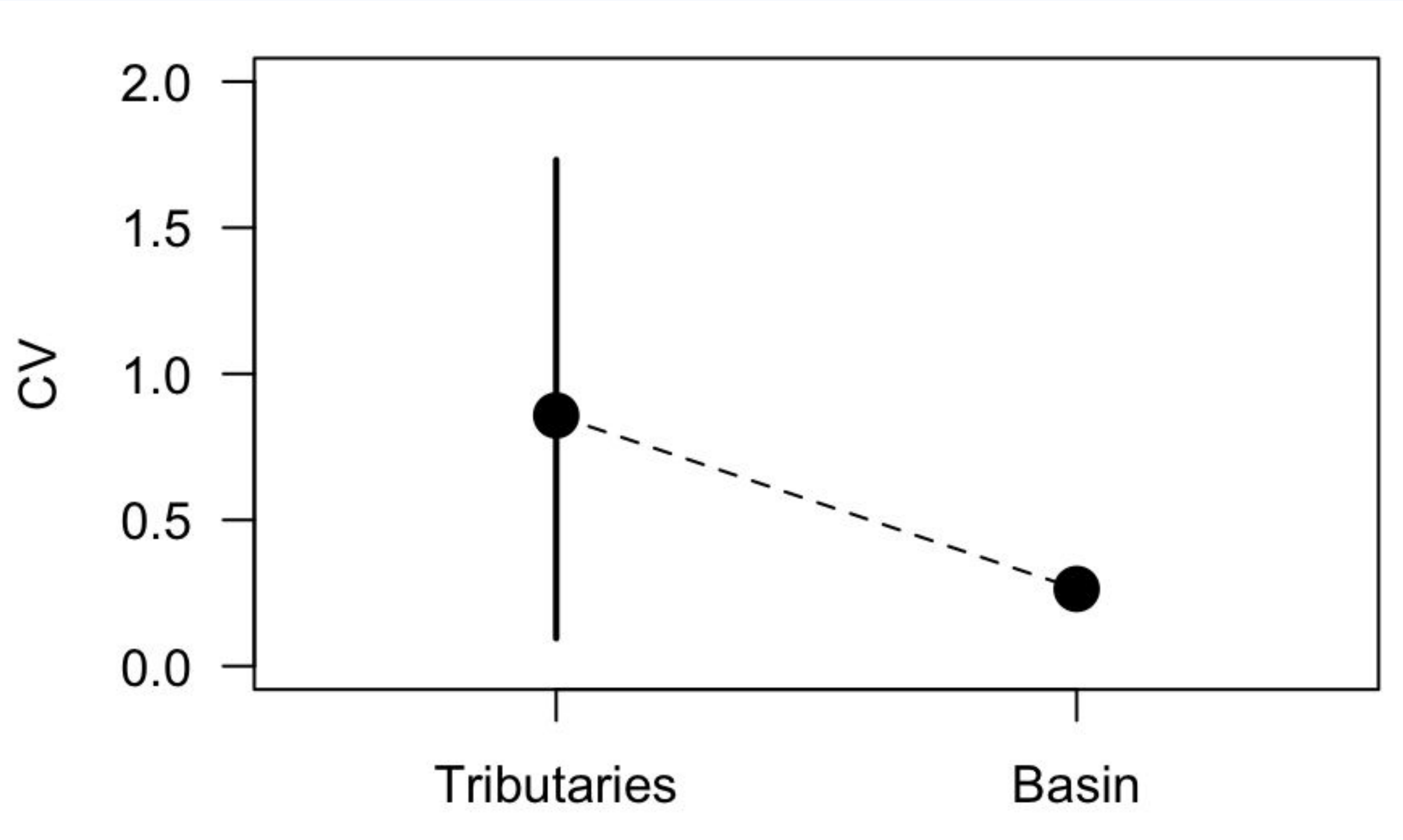
- 3 years of data
- Catchment specific relationships spawning window ~ snowpack
  - Non-permanent streams increase
  - Permanent streams decrease



Spawning Window

Preliminary Data 2024

- 3 years of data
- Despite variability in spawning window within and among tributaries
  - In response to climate
- Basin wide spawning opportunities are conserved



Discussion

- Mosaic of viable spawning habitat shifts in response to snowpack
  - Drought years
    - High elevation, permanent streams are best
    - Retain flow when non-permanent streams are dry
  - Wet years
    - Mid-elevation, non-permanent streams are better
      - Warmer; flow into fall
    - Cold temperatures in permanent streams delay onset of spawning

Discussion

- Mosaic of viable spawning habitat shifts in response to snowpack
  - Drought years
    - High elevation, permanent streams are best
    - Retain flow when non-permanent streams are dry
  - Wet years
    - Mid-elevation, non-permanent streams are better
      - Warmer; flow into fall
    - Cold temperatures in permanent streams delay onset of spawning

- Response diversity creates portfolio effects and buffers habitat against climate volatility

- Despite major changes in hydrologic conditions, network wide spawning opportunities change very little

Discussion

- Mosaic of viable spawning habitat shifts in response to snowpack
  - Drought years
    - High elevation, permanent streams are best
    - Retain flow when non-permanent streams are dry
  - Wet years
    - Mid-elevation, non-permanent streams are better
      - Warmer; flow into fall
    - Cold temperatures in permanent streams delay onset of spawning

- Plans identify + protect coldest permanent streams for refugia under warming
  - Variable precipitation
  - Conserve greatest diversity of stream types, including warmer non-permanent, stabilizes habitat

Discussion

- BCT use non-permanent streams for spawning when they are available

- Streams that don't support surface flow in some years support substantial fry production in others
  - Contribute to diversity of fluvial life history expressions

- **<u>Next steps</u>**: understand contribution to population productivity and stability

Discussion

- BCT use non-permanent streams for spawning when they are available
- Streams that don't support surface flow in some years support substantial fry production in others
  - Contribute to diversity of fluvial life history expressions
- **<u>Next steps</u>**: understand contribution to population productivity and stability

- BCT do not occupy some streams that support them
- Physical barriers to migration (sedimented culverts)
- Restoration opportunity

Questions

srousseau@stillwatersci.com

Stillwater Sciences

S.J. & JESSIE E. QUINNEY COLLEGE of NATURAL RESOURCES

UtahStateUniversity DEPARTMENT OF WATERSHED SCIENCES

OFFICE OF RESEARCH UtahStateUniversity

ECOLOGY CENTER

USDA Forest Service U.S. DEPARTMENT OF AGRICULTURE

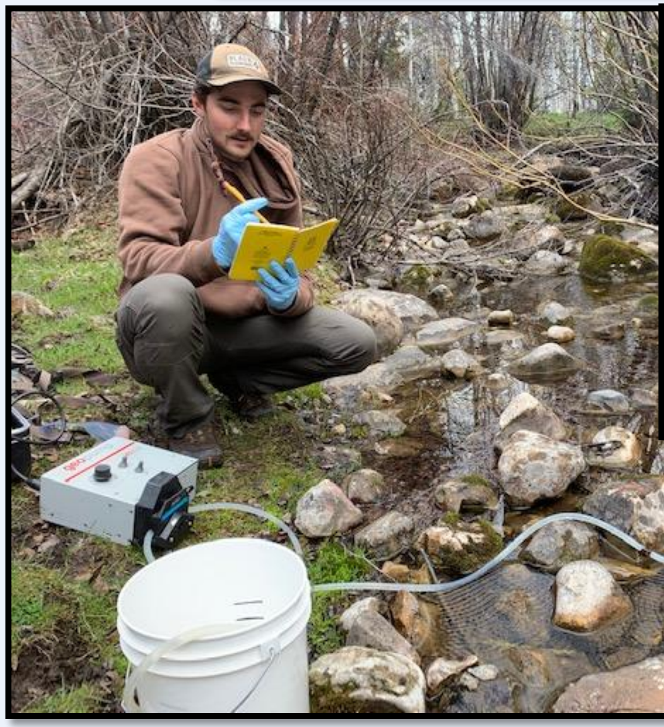
Detection

2022 eDNA

- Presence/absence and timing of fish using tributaries during the spawning window

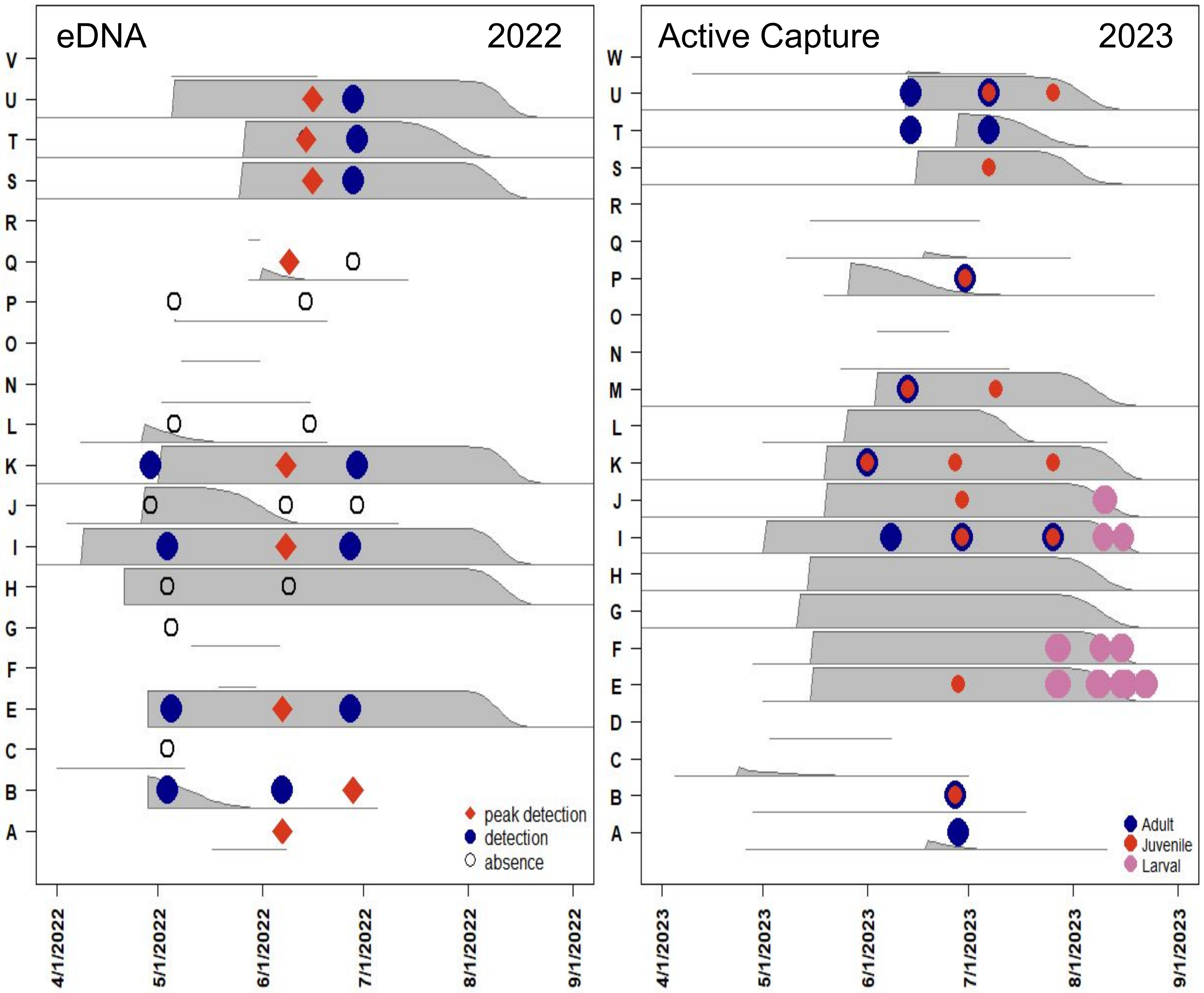
2023: eDNA + Active capture (stage structure)

- Electro-fish
- Snorkel
- Drift nets

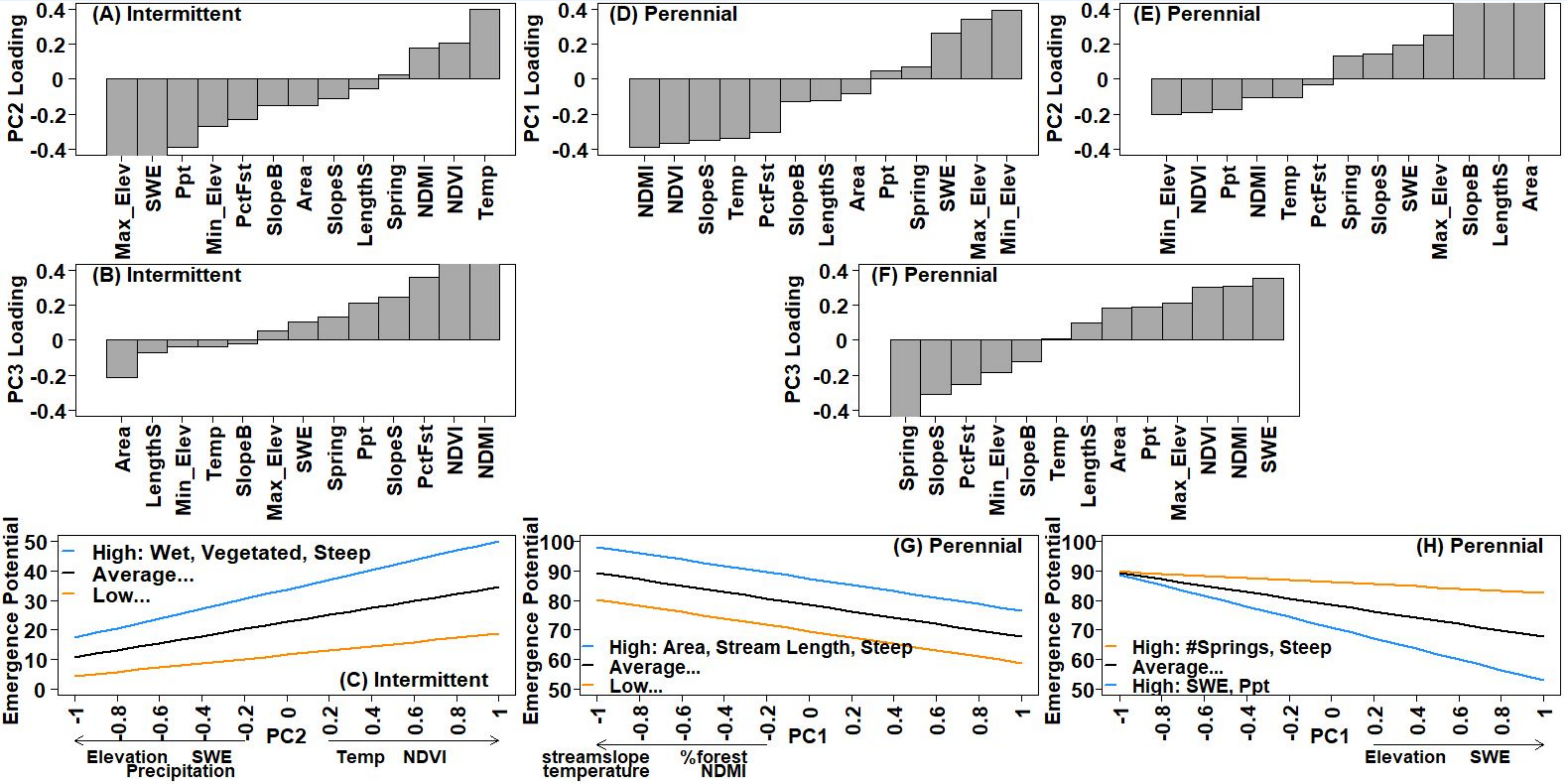


Fish Detection

- BCT occupy streams that support them
- Occupation timing aligns with known spawn window
  - April 26th – July 7th
- Migrating fry captured
  - (n=234)



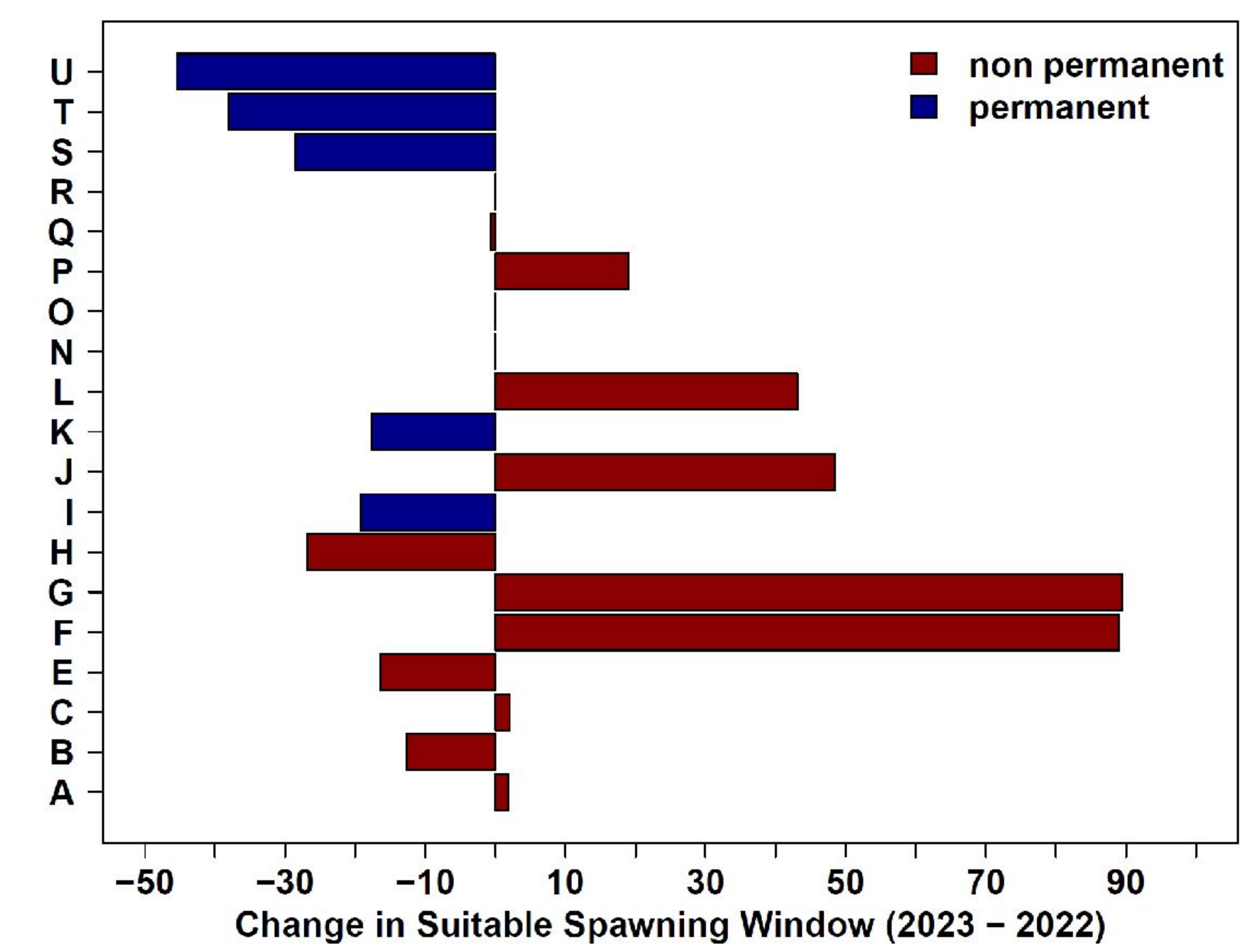
PCA + PCR


(A) Intermittent
PC2 Loading
Max_Elev
SWE
Ppt
Min_Elev
PctFst
SlopeB
Area
SlopeS
LengthS
Spring
NDMI
NDVI
Temp
(D) Perennial
PC1 Loading
(E) Perennial
PC2 Loading
(B) Intermittent
PC3 Loading
(F) Perennial
PC3 Loading
(C) Intermittent
Emergence Potential
High: Wet, Vegetated, Steep
Average...
Low...
PC2
Elevation SWE
Precipitation
Temp NDVI
(G) Perennial
High: Area, Stream Length, Steep
Average...
Low...
PC1
streamslope %forest
temperature NDMI
(H) Perennial
High: #Springs, Steep
Average...
High: SWE, Ppt
PC1
Elevation SWE

Spawning Window

- Tributaries respond differently

- Permanent streams decline
- Offset by suitability gains in non-permanent streams



The Nature Conservancy

Addressing streamflow depletion due to groundwater pumping – emerging modeling approaches and process uncertainty.

The Nature Conservancy, University of Kansas, O’Connor Environmental Inc., Foundry Spatial, University of California - Davis

NICHOLAS MURPHY, PHD – 05/02/25

THE SOURCE OF WATER DERIVED FROM WELLS—ESSENTIAL FACTORS CONTROLLING THE RESPONSE OF AN AQUIFER TO DEVELOPMENT

“

All water discharged from wells is balanced by a loss of water somewhere.”

Charles V. Theis, 1941

The Nature Conservancy

Why do we care?

Image Credit © DAVID VARGAS F/TNC Photo Contest 2022

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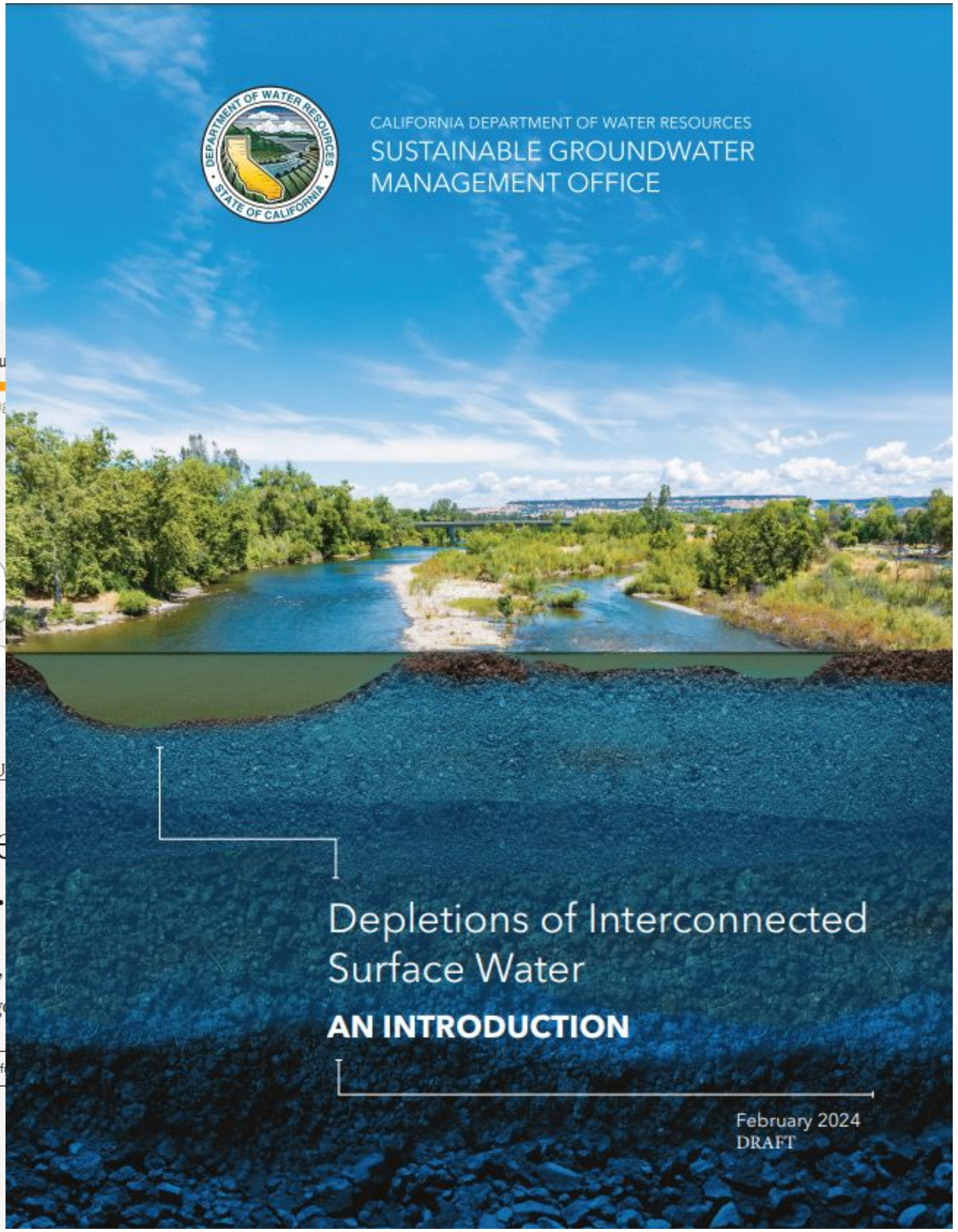

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Groundwater Management in Ca

2014 Sustainable Groundwater Management

SANTA CRUZ COUNTY
ENVIRONMENTAL HEALTH

About Us | Programs

Well Ordinance Upd

NEW HOME > PROGRAMS > WATER RESOURCES > WELL ORDINANCE UPDATE

Meeting Materials

Meeting 3

Agenda

Stream and Well Impact Considerations Memo

Public Trust Protection Comments and Response

Santa Cruz County Environmental Health staff are convening (Well TAC) to provide County Staff with guidance, recommer policy matters pertaining to the update of the Water Wells a Cruz County Code:

- Water Wells Chapter (7.70)
- Individual Water Systems Chapter (7.73)

Goal and Objectives

The goal of the TAC is to help staff develop an ordinance tha well construction and use, while not creating an undue burd

FOR IMMEDIATE RELEASE

Board of Supervisors gives initial approval to Well Ordinance update

Santa Rosa, CA | April 05, 2023

The Board of Supervisors on Tuesday gave initial approval to amendments to the county's Well Ordinance, which would create a new regulatory process for approving well permits.

Under the amendments, before a well permit may be approved, potential adverse impacts on public trust resources in navigable waterways, such as the Russian River, would be analyzed and mitigated to the extent feasible. The amendments were created to reflect the county's responsibilities under California's public trust doctrine regarding natural resources such as waterways.

See full Press Release on Permit Sonoma Website>>

Russian Riverkeeper (RRK) and our state association, California Coastkeeper Alliance, recently filed a challenge to the Sonoma County Well Ordinance update. While the new ordinance started the conversation around what is needed, the final amendment is too vague and has not analyzed whether it will protect fish and other resources as claimed. The stakes are too high to not take the time to get this policy right.

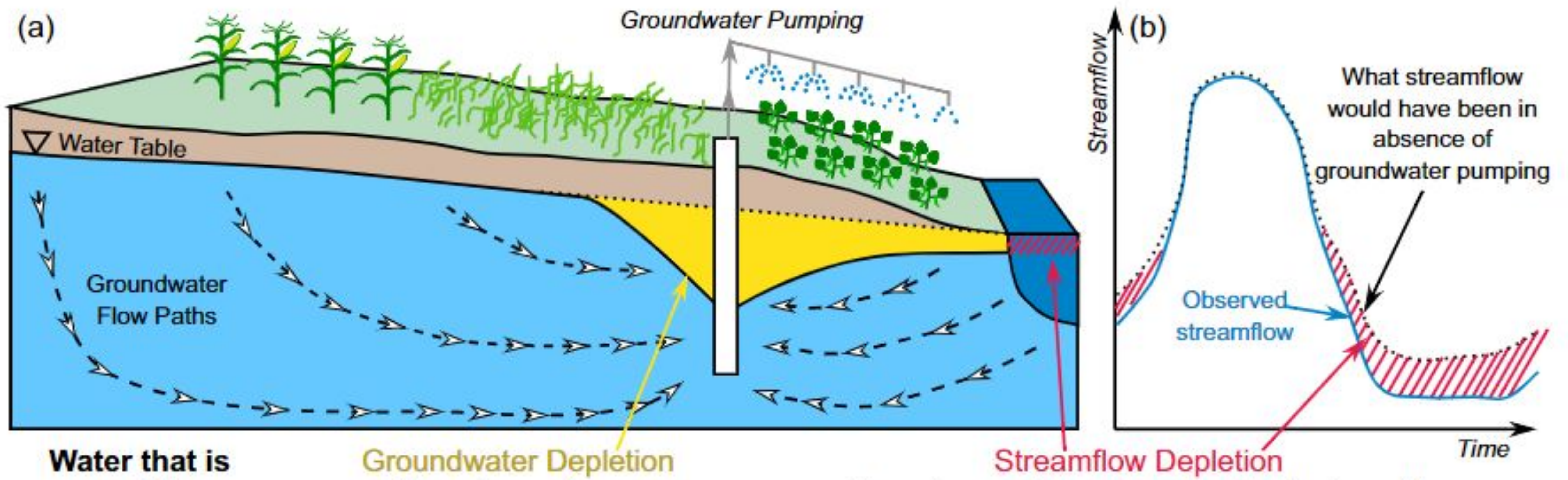
The Well Ordinance update was in response to a prior lawsuit against the County for failing to protect endangered fish and other resources from county-permitted wells. Existing wells are known to pump streams so low, and oftentimes even dry, that fish and other species become trapped and die. Beyond fish impacts, many families and small farms have had their wells go dry and are experiencing reduced water quality due to the recent drought and increased groundwater use. It is clear we have an issue now —unrestrained groundwater pumping cannot continue as it has.

Search...

Categories

- Advocacy (33)
- Climate Change (11)
- Education (14)
- Environmental Justice (12)
- Events (3)
- Featured (80)

Streamflow Depletion



Water that is pumped from a well comes from two sources:

Groundwater Depletion
Pumping reduces groundwater storage.
This can be quantified by measuring changes in groundwater levels.

Streamflow Depletion
Pumping captures groundwater that would have flown into the stream and/or induces infiltration from the stream into the aquifer.
This cannot be directly measured and is challenging to estimate.

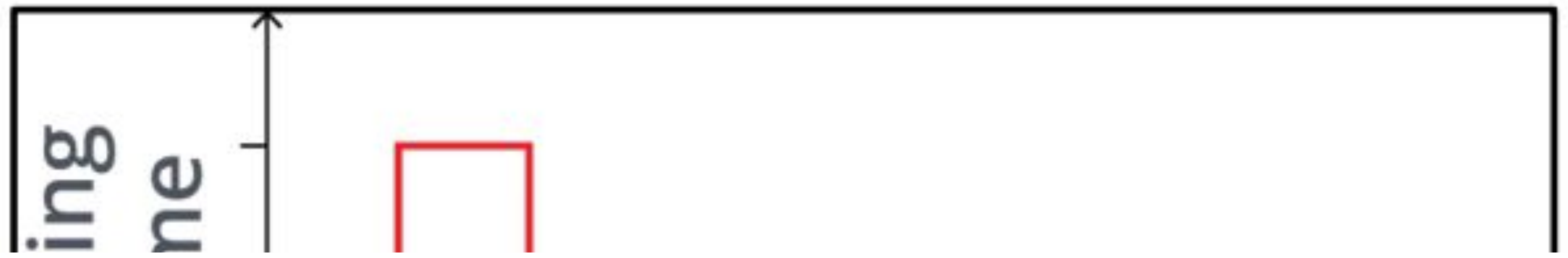
Zipper et al. 2022

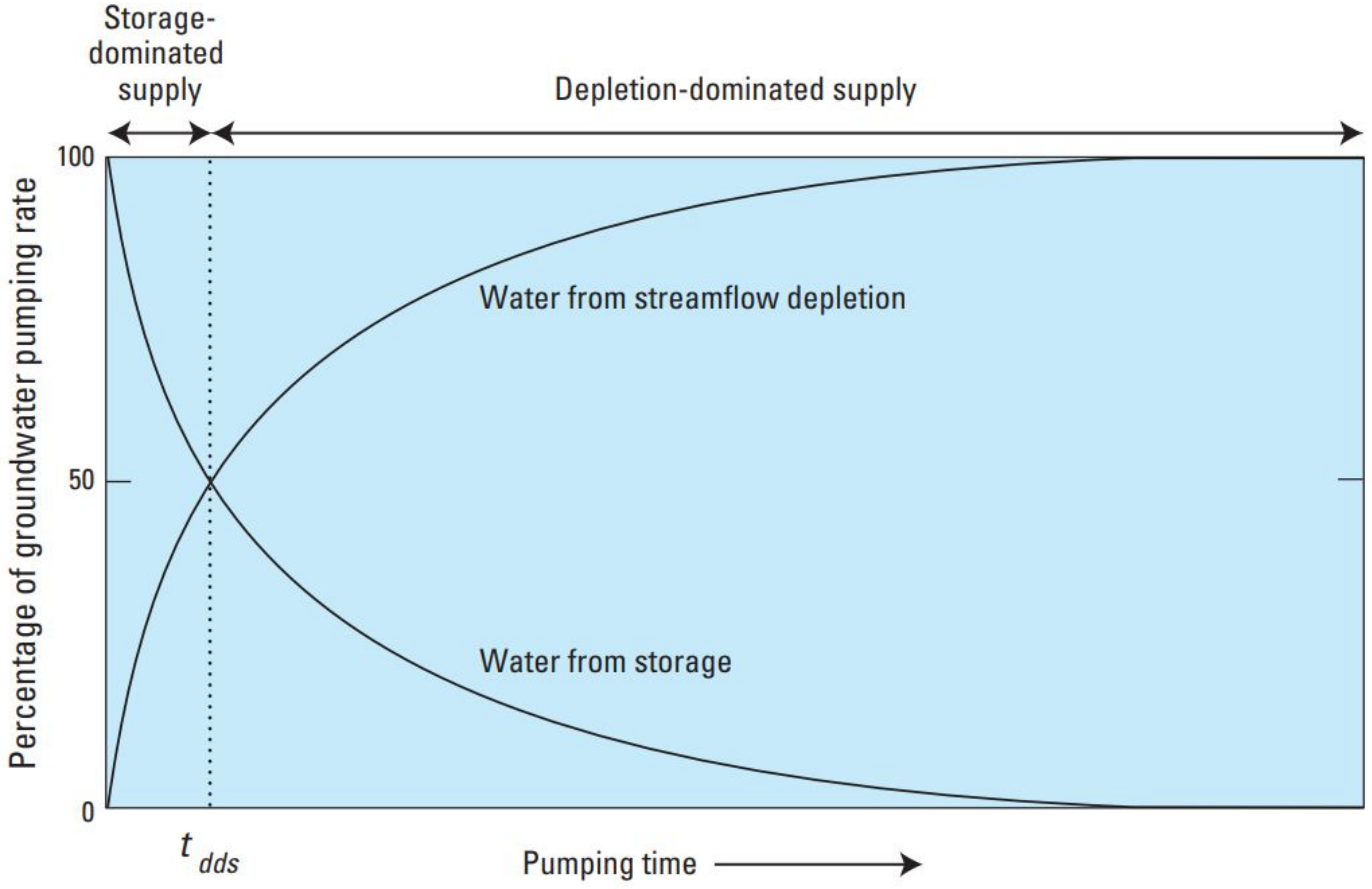
Streamflow Depletion

- Over long timescales, a majority of pumped water comes from streamflow depletion

- Hydraulic properties of the aquifer systems influence system response to groundwater pumping

- Timing, location and magnitude of groundwater pumping is key to our understanding of streamflow depletion dynamics





The Nature Conservancy

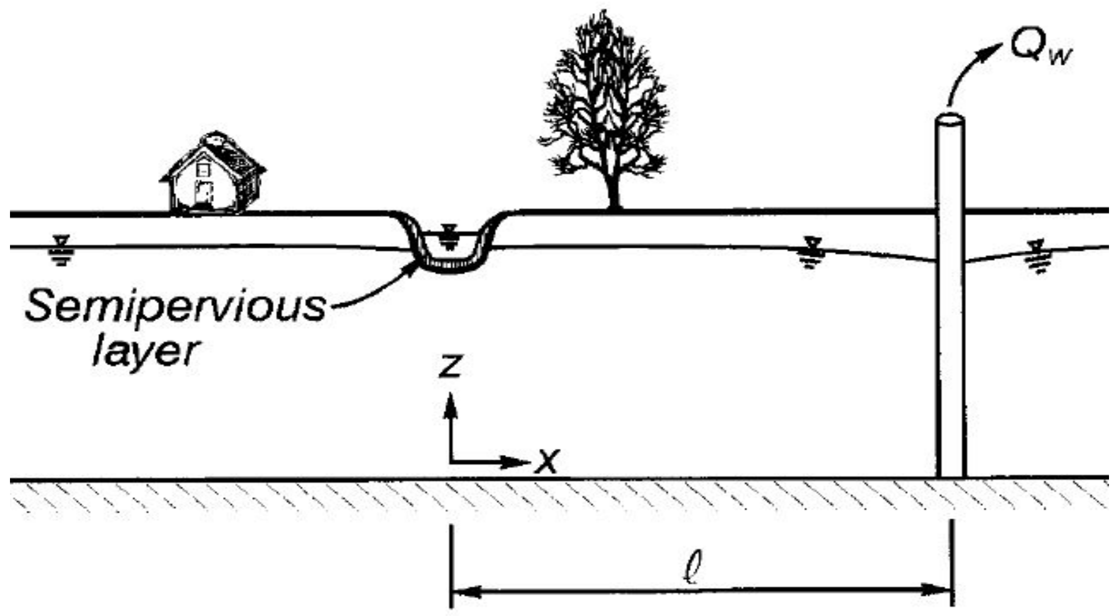
Barlow & Leake 2012, DWR 2024

“

Streamflow depletion cannot be measured directly…”

Zipper et al. 2022

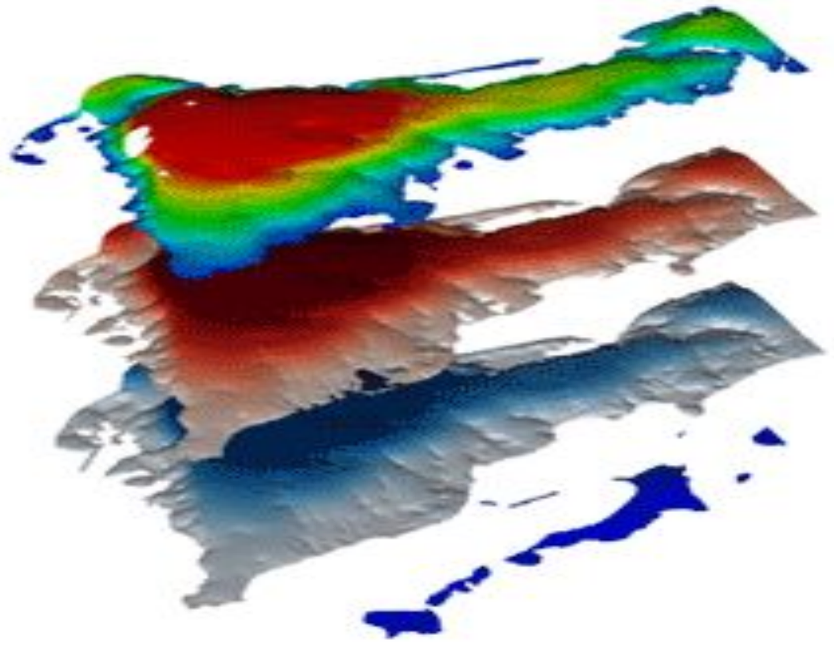
Analytical Models



Faster to implement, but lots of assumptions

Real World

Numerical Models



More realistic, but cost time/effort/$$$

What are we doing?

Image Credit © Bridget Besaw

The Nature Conservancy

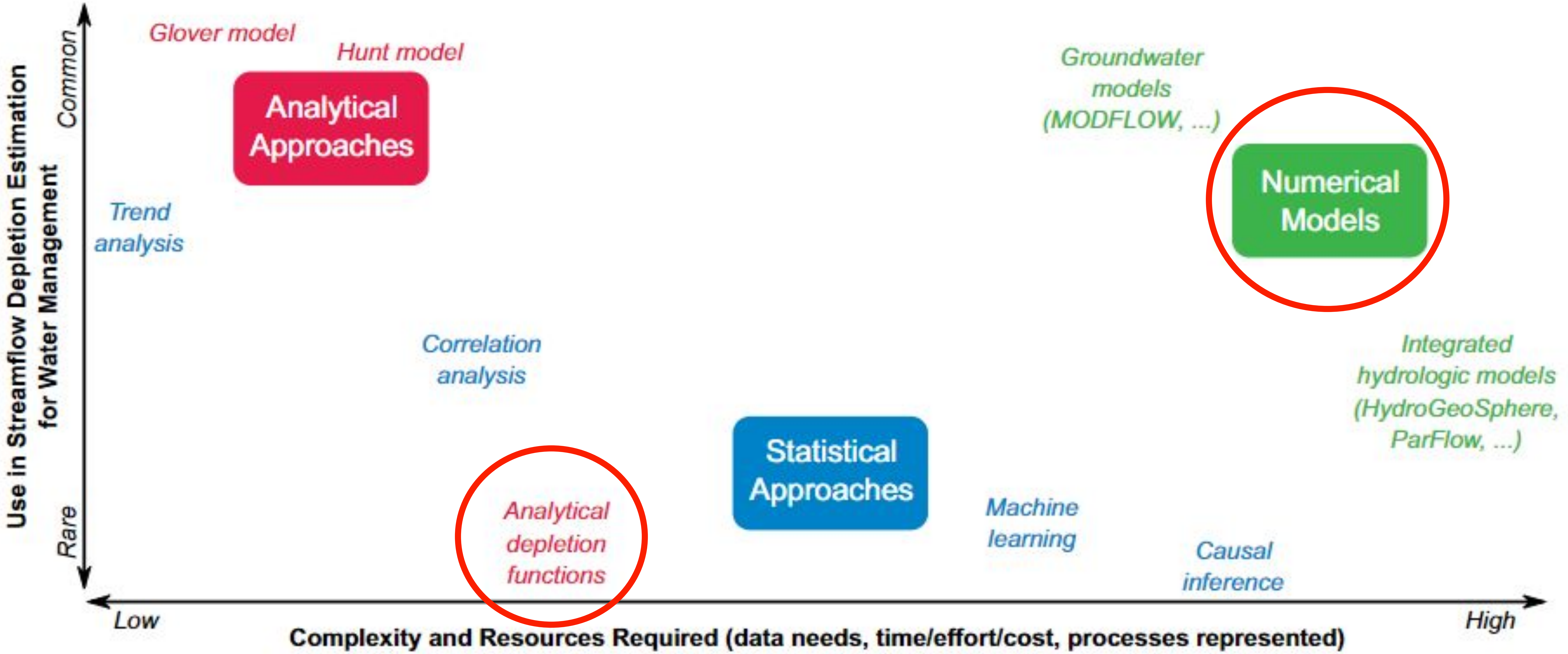
Ongoing Streamflow Depletion Modeling Work

Modeling Approaches & Decision-Support tools

Goal: Advance modeling tools and develop decision-support frameworks to assess streamflow depletion impacts due to groundwater pumping, across diverse geologic settings.

- ADF Model Development across two geographies
  - Scott Valley
  - Sonoma County
- Comparison to existing numerical models
- Technical guidance for modeling streamflow depletion

Modeling Streamflow Depletion



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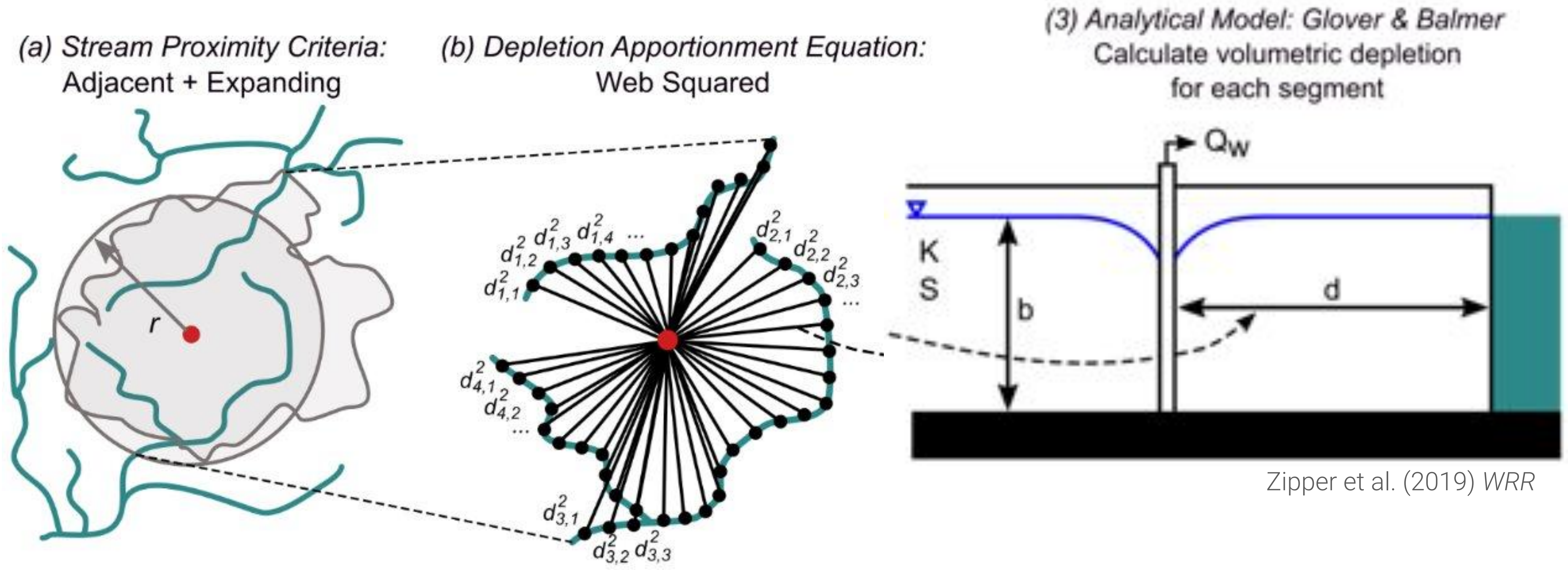
Zipper et al. 2022

What is an Analytical Depletion Function?



Zipper et al. (2019) *WRR*

(a) Stream proximity criteria – determines which stream segments may be affected by a well

(b) Depletion apportionment equation – calculates relative depletion among stream segments

(c) Analytical model – estimates *depletion potential* (reduction in streamflow as % of pumping rate) for each segment

In simple terms – ADF models are *spatially distributed analytical models*

The Nature Conservancy

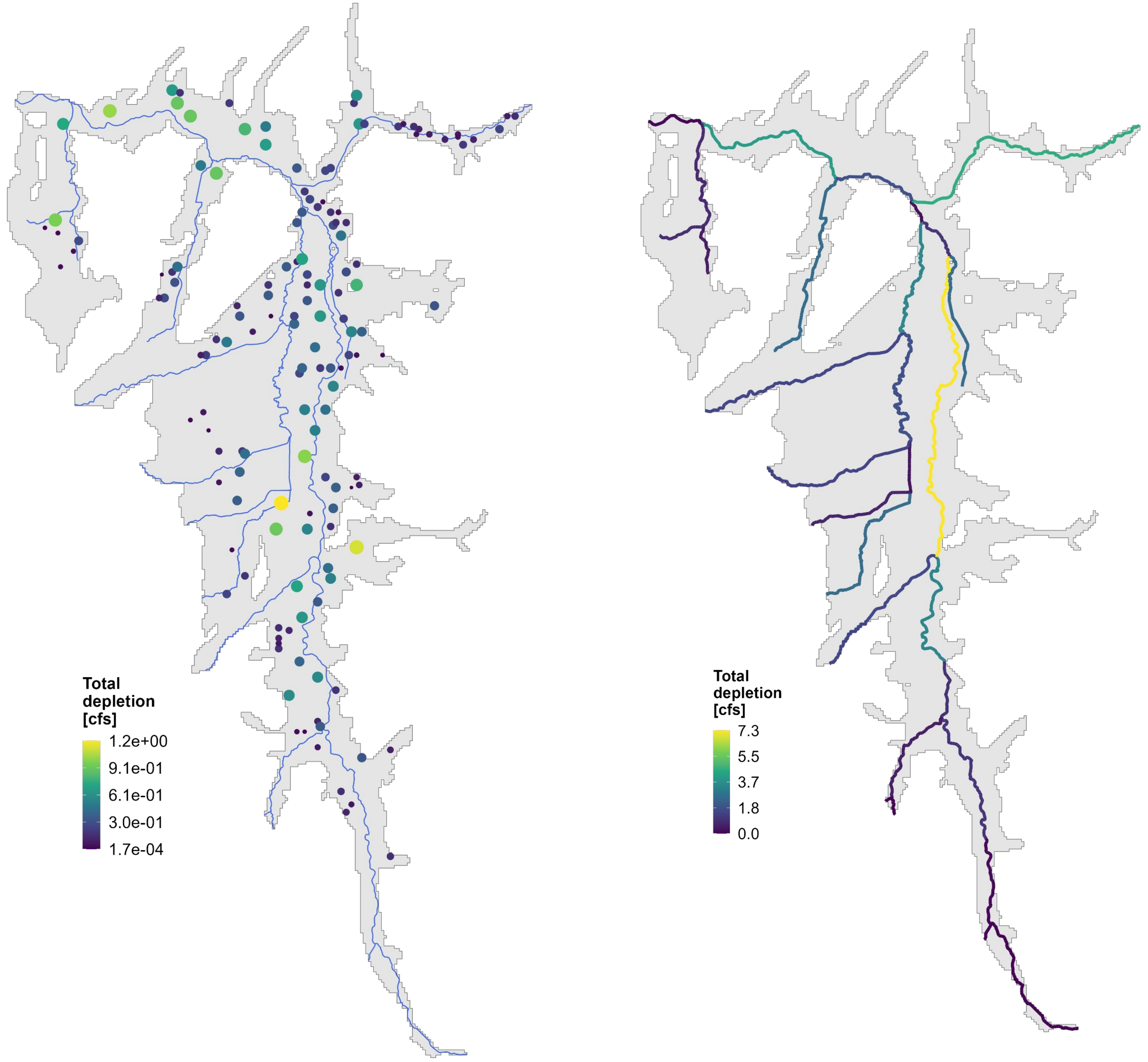
Scott Valley – ADF Results & Comparison with SVIHM

Image Credit © Daniel Potter/KQED

The Nature Conservancy

Spatially distributed estimates of streamflow depletion across the Scott Valley

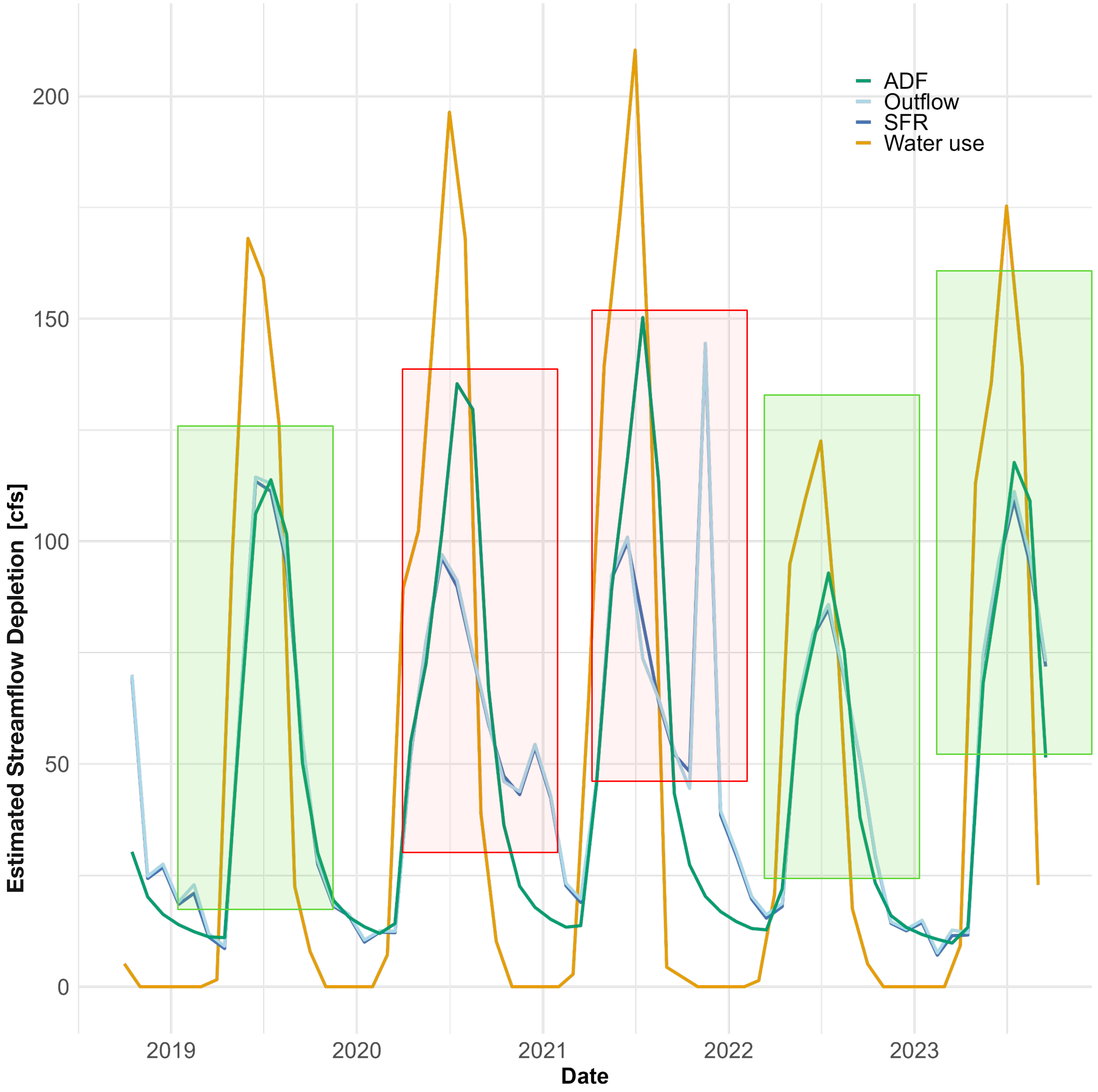
- 148 wells, 30 stream segments
- Calculation of well-resolution (cause) and stream-resolution (effect) depletion
- Most depletion in the center of the valley. Depletion accumulates at watershed outlet.

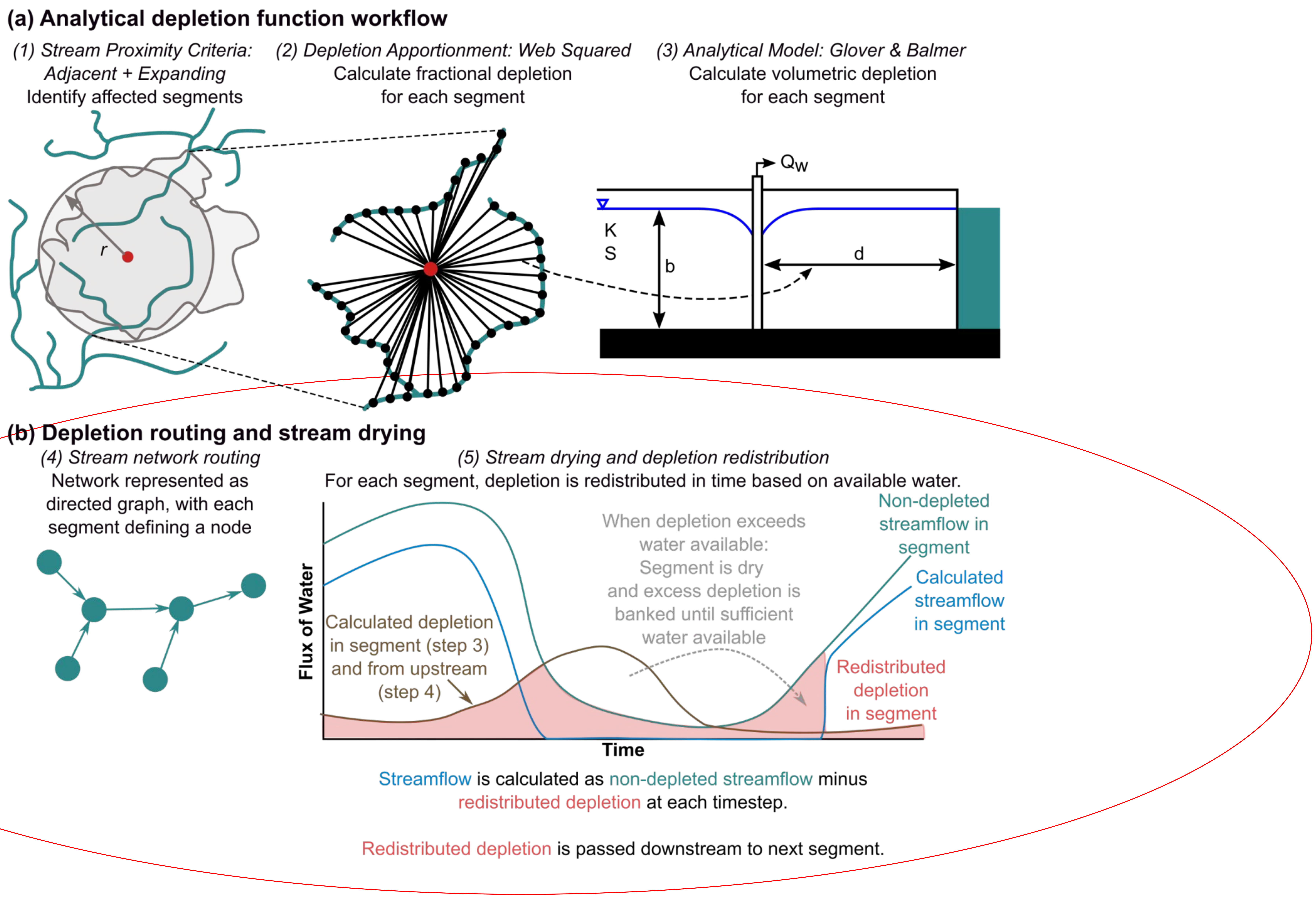


Zipper et al. *In Prep*

Comparison: Monthly Depletion at Outlet

- ADF and SVIHM agree in both timing and magnitude in most years
- SVIHM simulates ‘double peaks’ in some years
  - Cause: Streams dry in SVIHM so some depletion happens later in fall/winter when streams rewet





Zipper et al. *In Prep*

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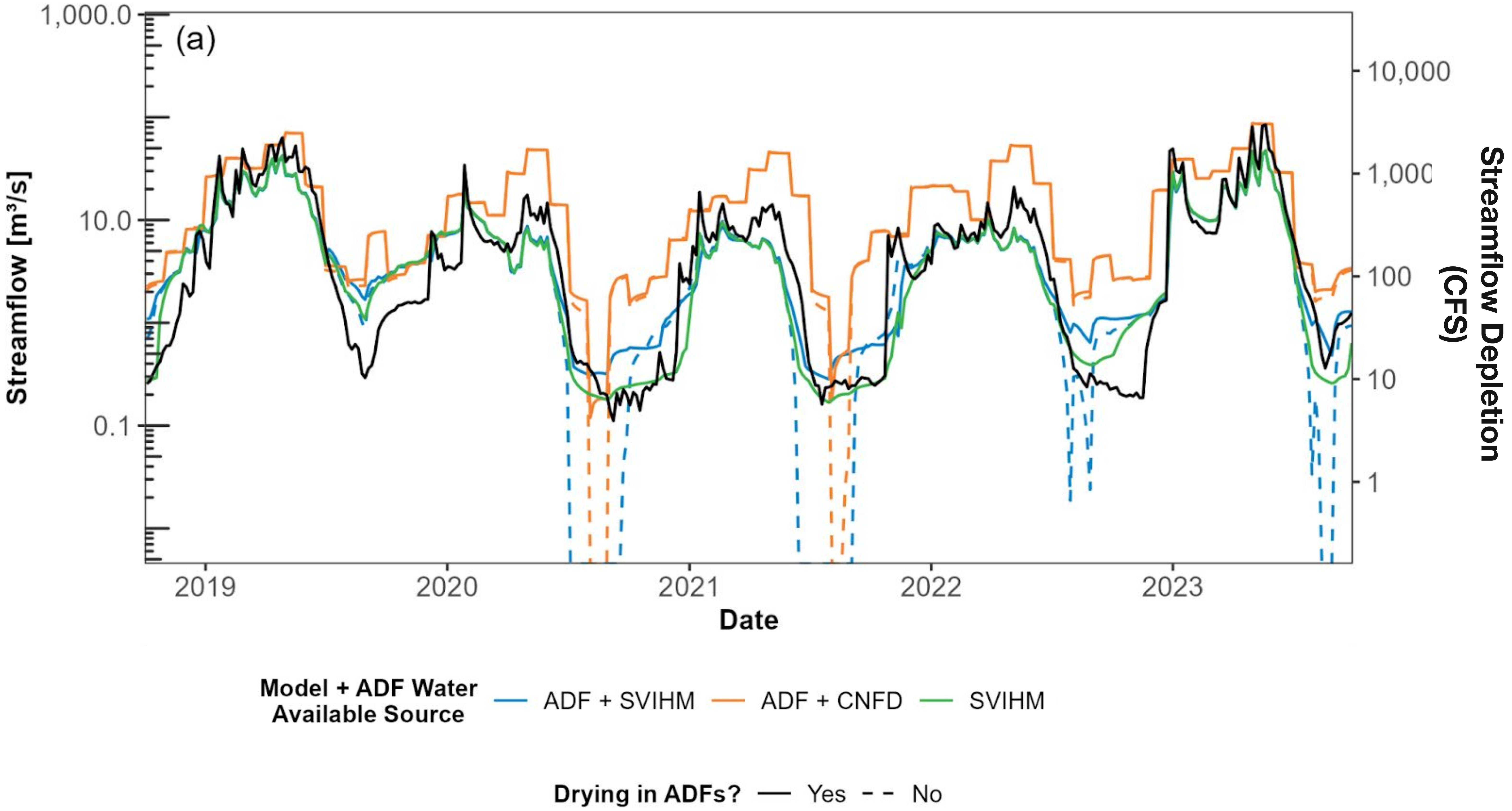
Model Performance

- Comparable model performance between ADF and numerical modeling approaches

- Incorporation of ‘drying’ considerations allows for model comparison to real-world stream gage data

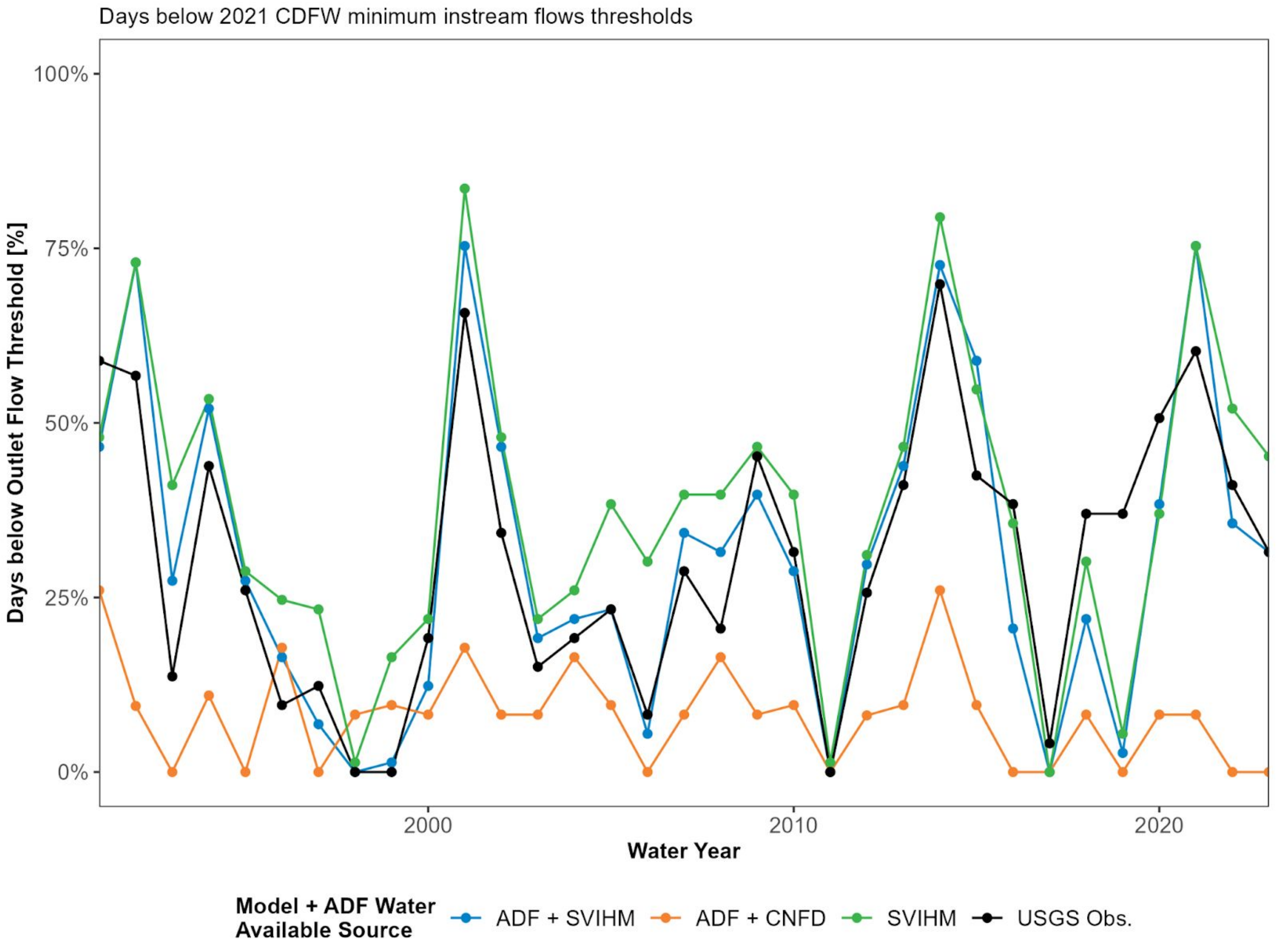


Zipper et al. *In Prep*

Model Performance

- Comparison to real-world streamflow data allows for evaluation of different management approaches

- Can simulate management scenarios to meet regulatory requirements



Zipper et al. *In Prep*

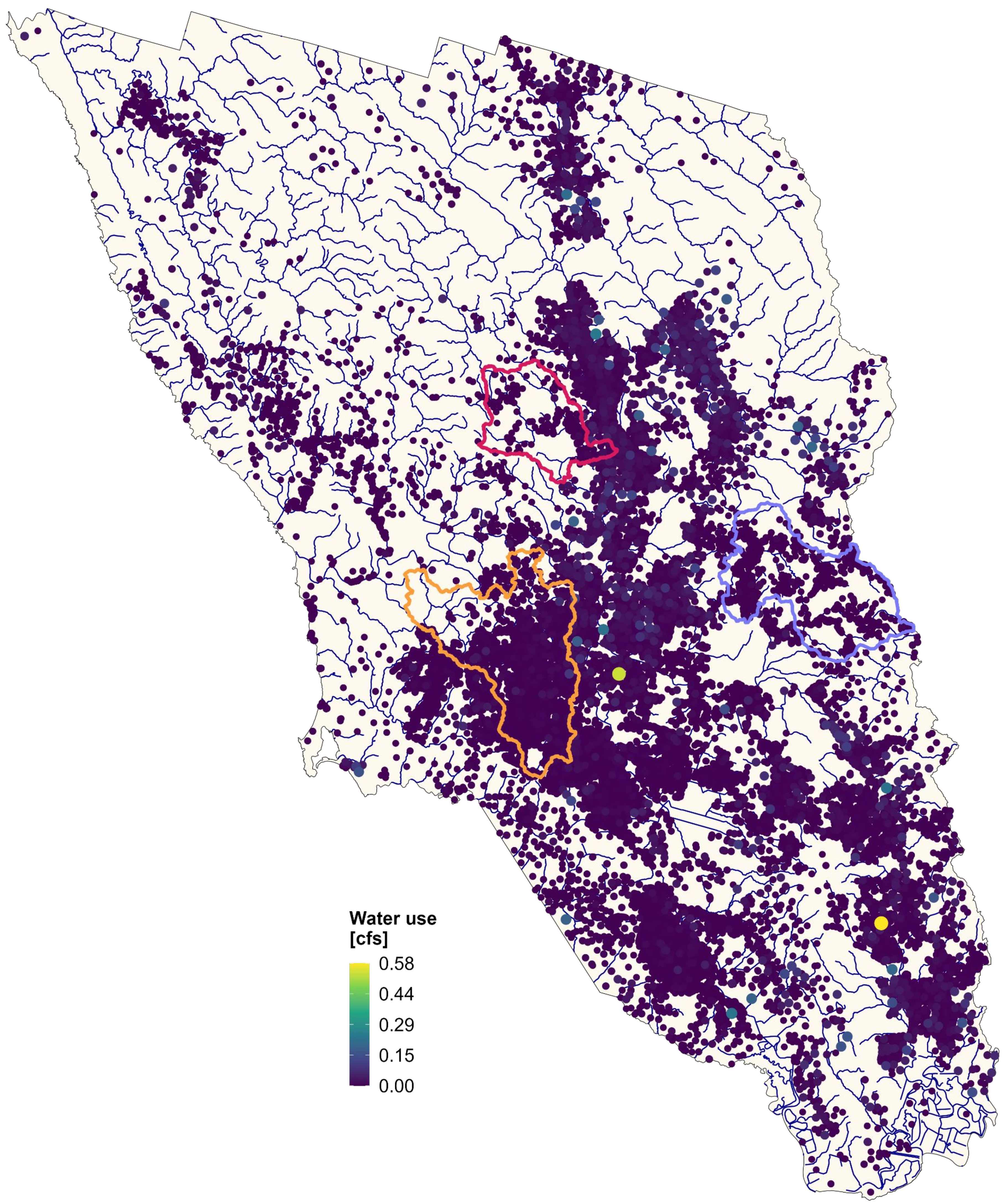
Sonoma County: County-wide ADF Analysis

Image Credit © Daniel Potter/KQED

The Nature Conservancy

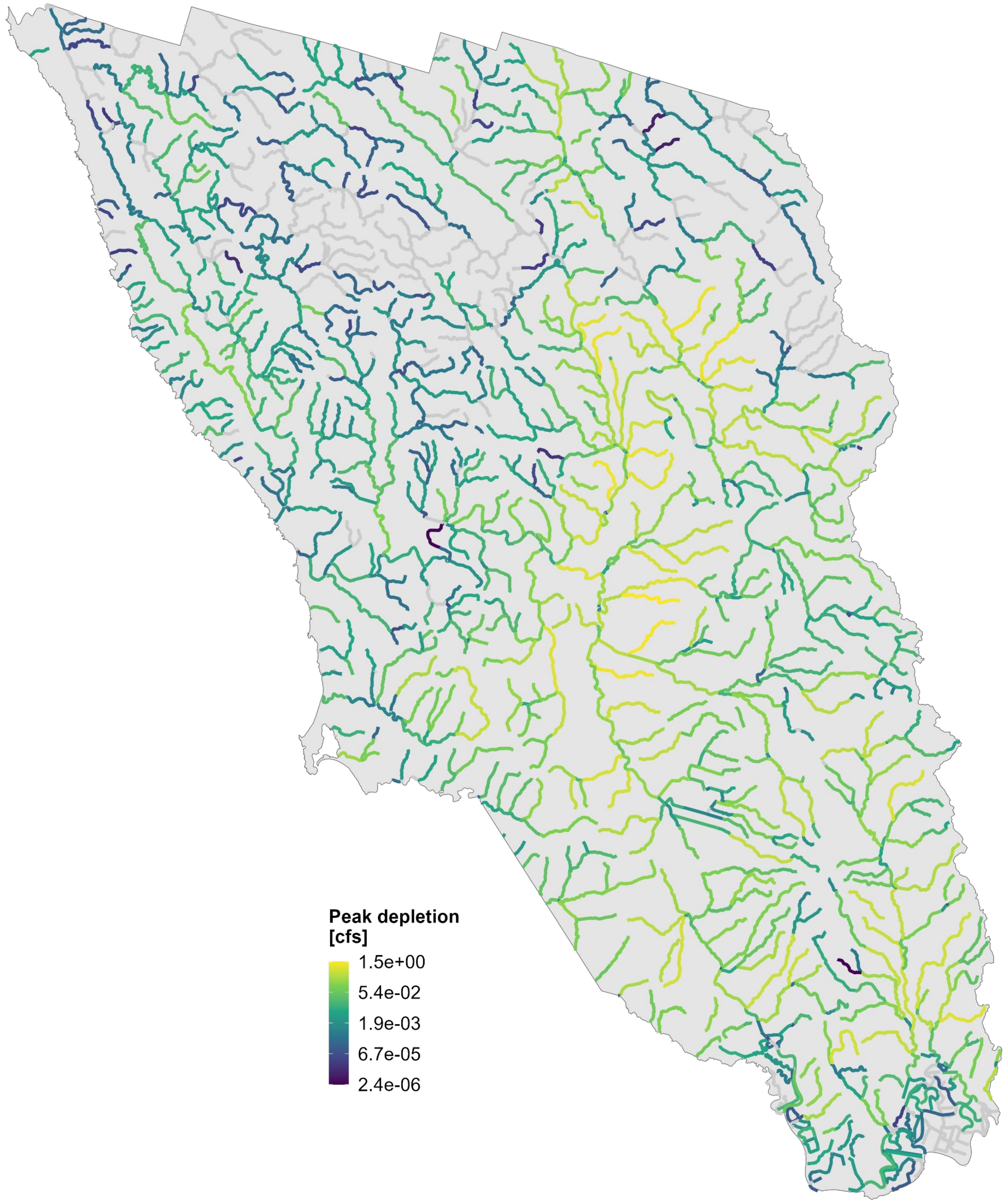
Sonoma County

- Much bigger domain: ~26k wells, 1651 stream segments
- Simulated depletion for all wells and streams in county
- Comparison in three focus domains, to existing MIKE-SHE models
  - Mark West
  - Mill Creek
  - Green Valley/Dutch Bill



Results: Stream Resolution

- Streamflow depletion at the reach-scale ranges from 0 – ~1.5 cfs
- Biggest impacts in central, alluvial portion of Sonoma County.
  - Reminder: segment-resolution impacts, not accumulated impacts
- Some non-impacted segments in northern portion of domain
  - Headwater, rural stream reaches
  - No pumping in area

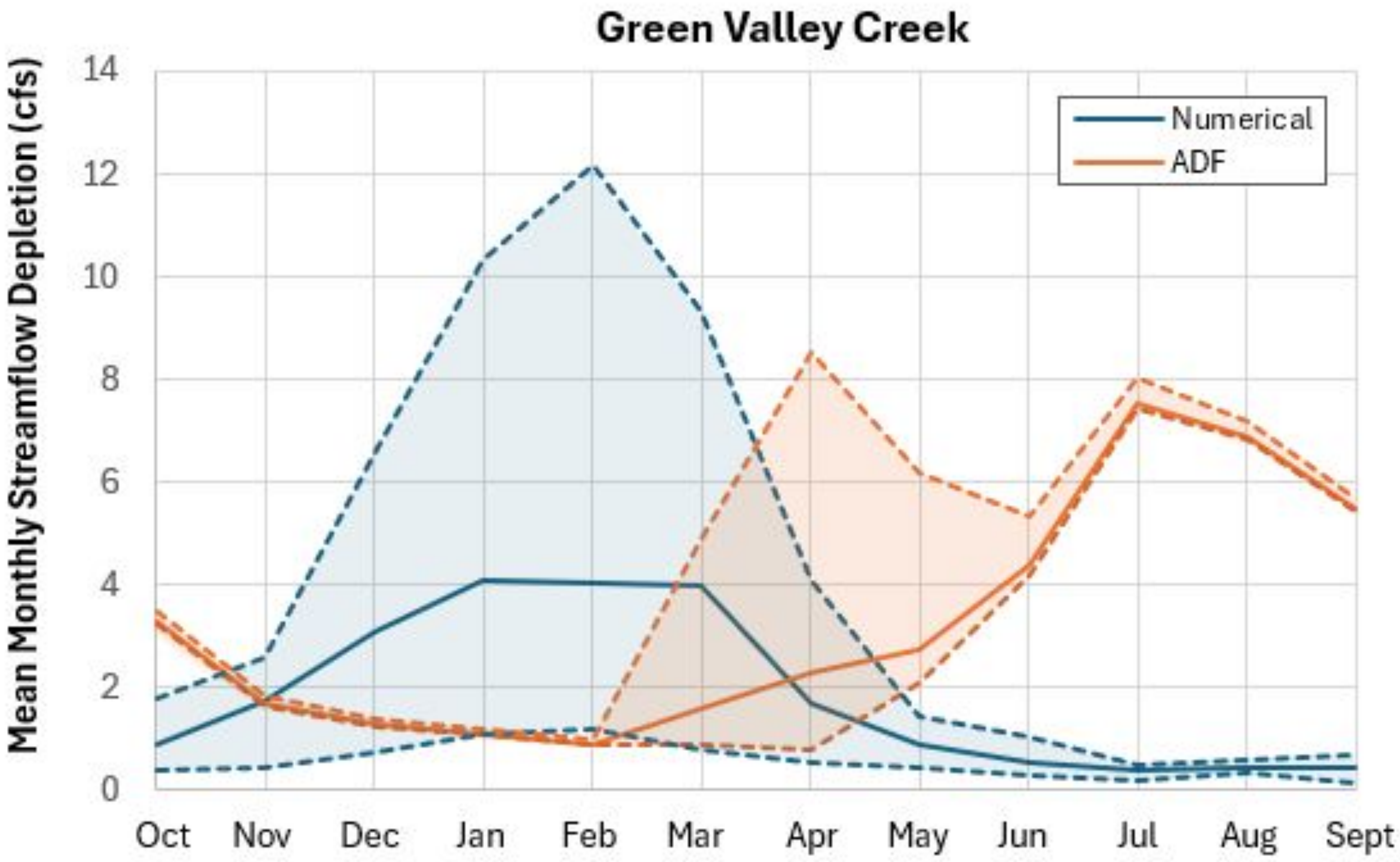


Comparison: Average Monthly Depletion at Watershed Outlet

- Discrepancy between ADF & numerical approaches on timing of peak estimated streamflow depletion

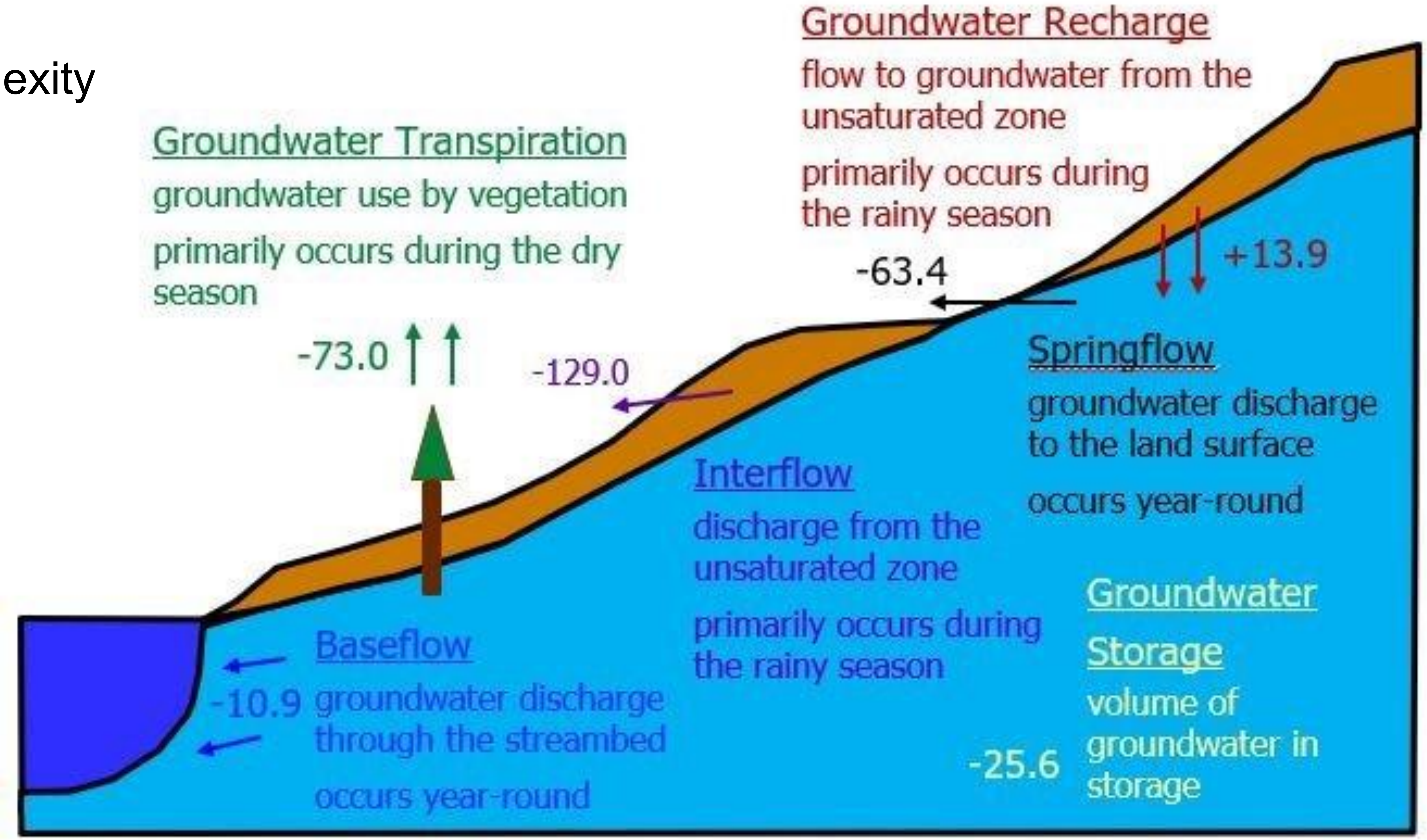
- What factors influence timing and spatial distribution of streamflow depletion?

- Uncertainty in…
  - Complex Hydrologic Processes
  - Well Connectivity (depth/screened interval)
  - Stream wetting/drying dynamics
  - Slope & topographic considerations



Mark West Creek – Sonoma County (numerical model)

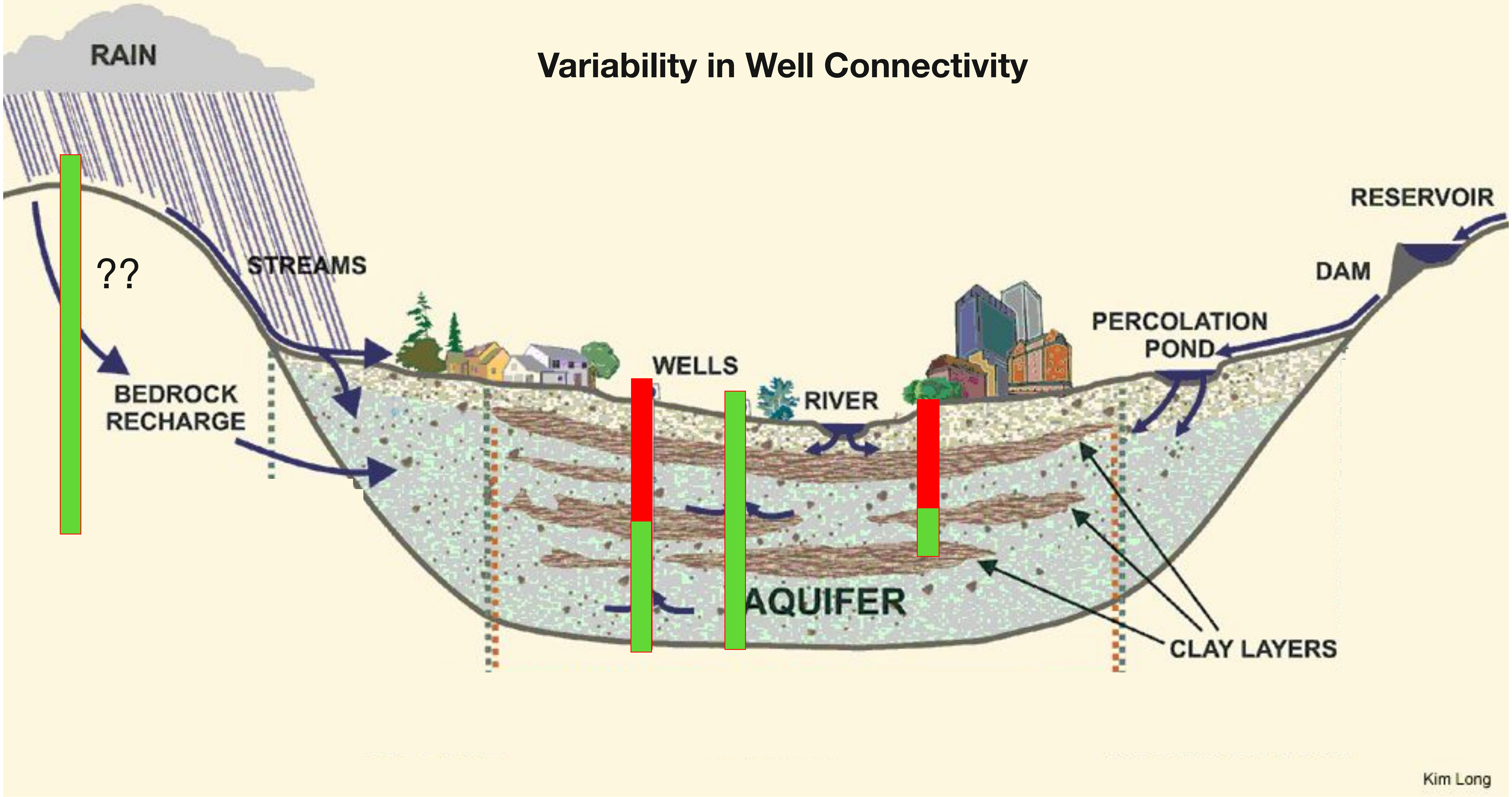
- Models represent varying levels of hydrologic complexity
- Analytical models don't currently incorporate transpiration or recharge dynamics, only represent baseflow exchange



O'Connor Environmental Inc, 2024

The Nature Conservancy

Variability in Well Connectivity



Conclusions & Next Steps

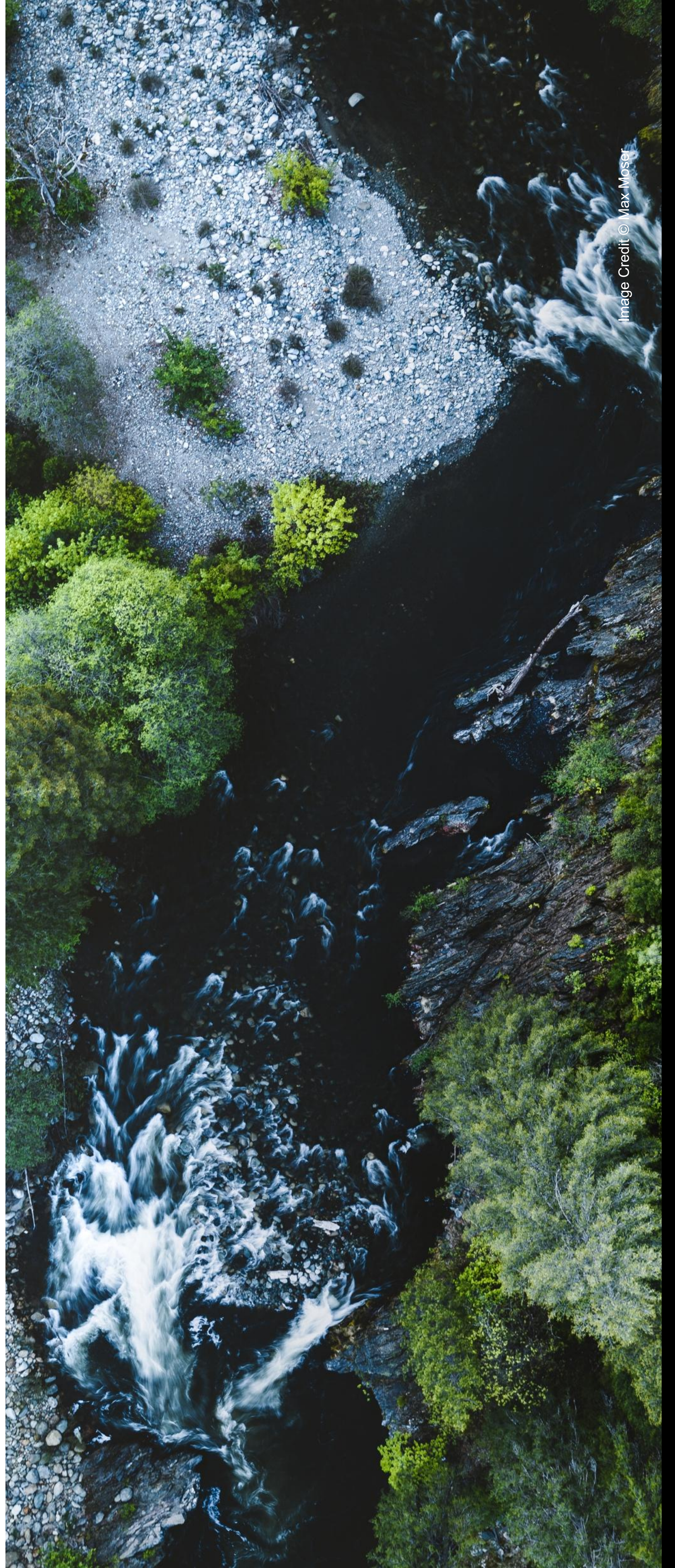
Streamflow depletion management is complex, modeling using appropriate tools can help us unravel system dynamics.

In alluvial systems…

• ADF models show promise as cost-effective decision-support tools

In fractured bedrock systems…

• Hydrologic process complexity introduces uncertainty into streamflow depletion estimates. Additional research is ongoing.



Acknowledgements

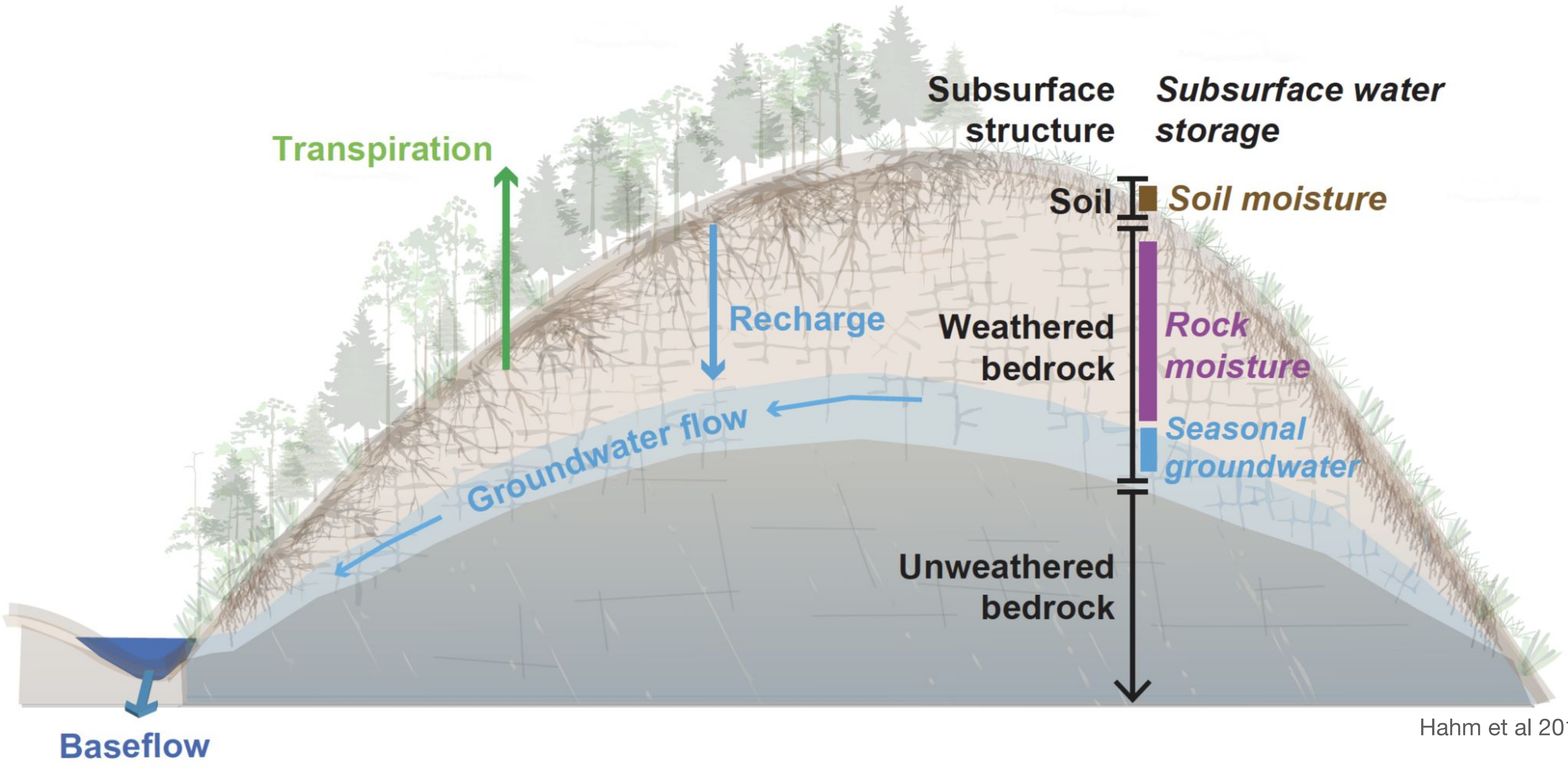
Partners –

- University of Kansas – Zipper Lab
- University of California, Davis – Harter Lab
- O'Connor Environmental Inc.
- Foundry Spatial
- Salmon and Steelhead Coalition (The Nature Conservancy, CalTrout, Trout Unlimited)

The Nature Conservancy


Thank You
The Nature Conservancy
Image Credit © Bridget Besaw

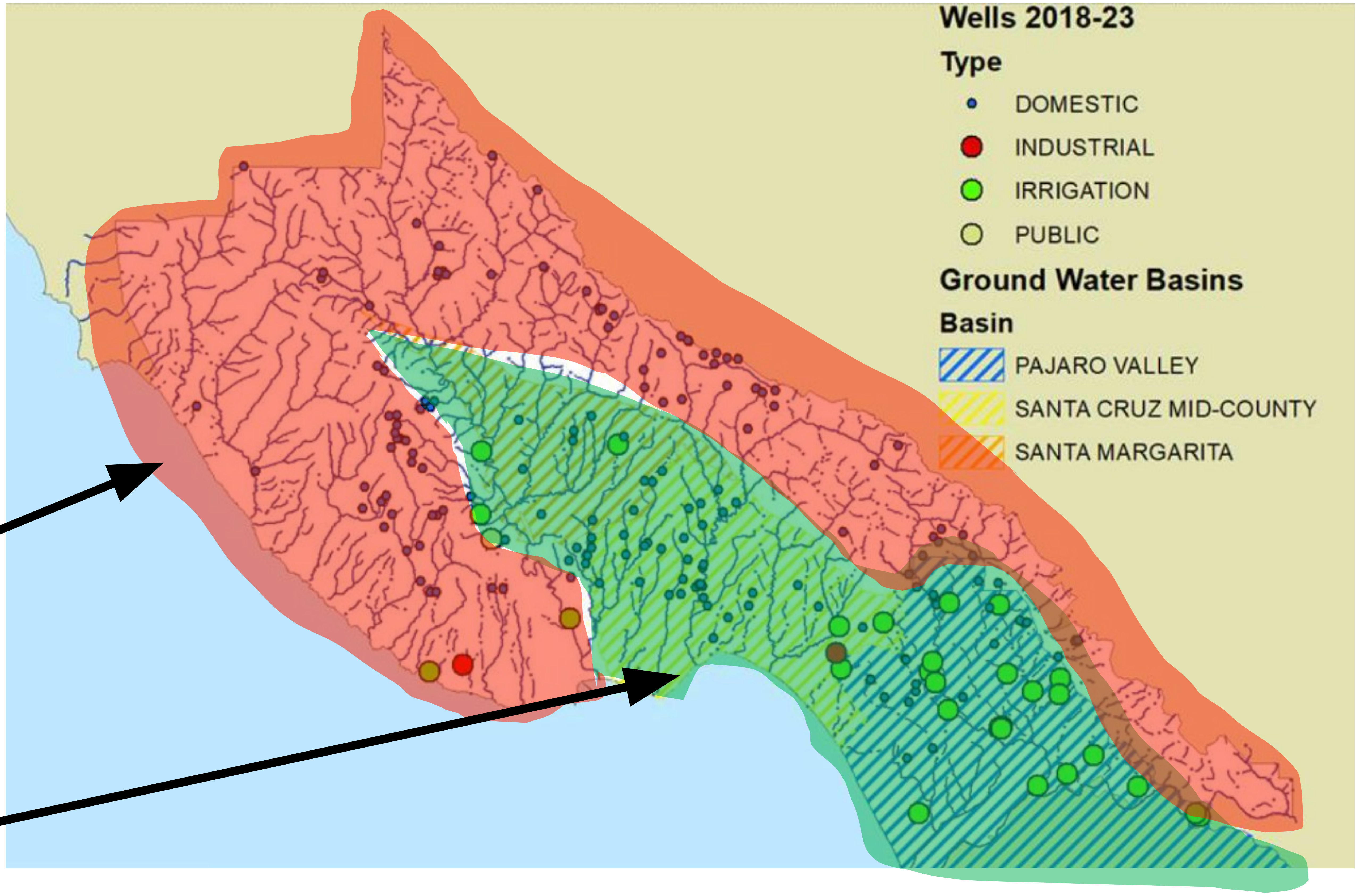
Groundwater in coastal watersheds is the primary source of summer baseflows.



Hahm et al 2019

Why a ‘unified modeling approach’ ?

Fill in the gaps!

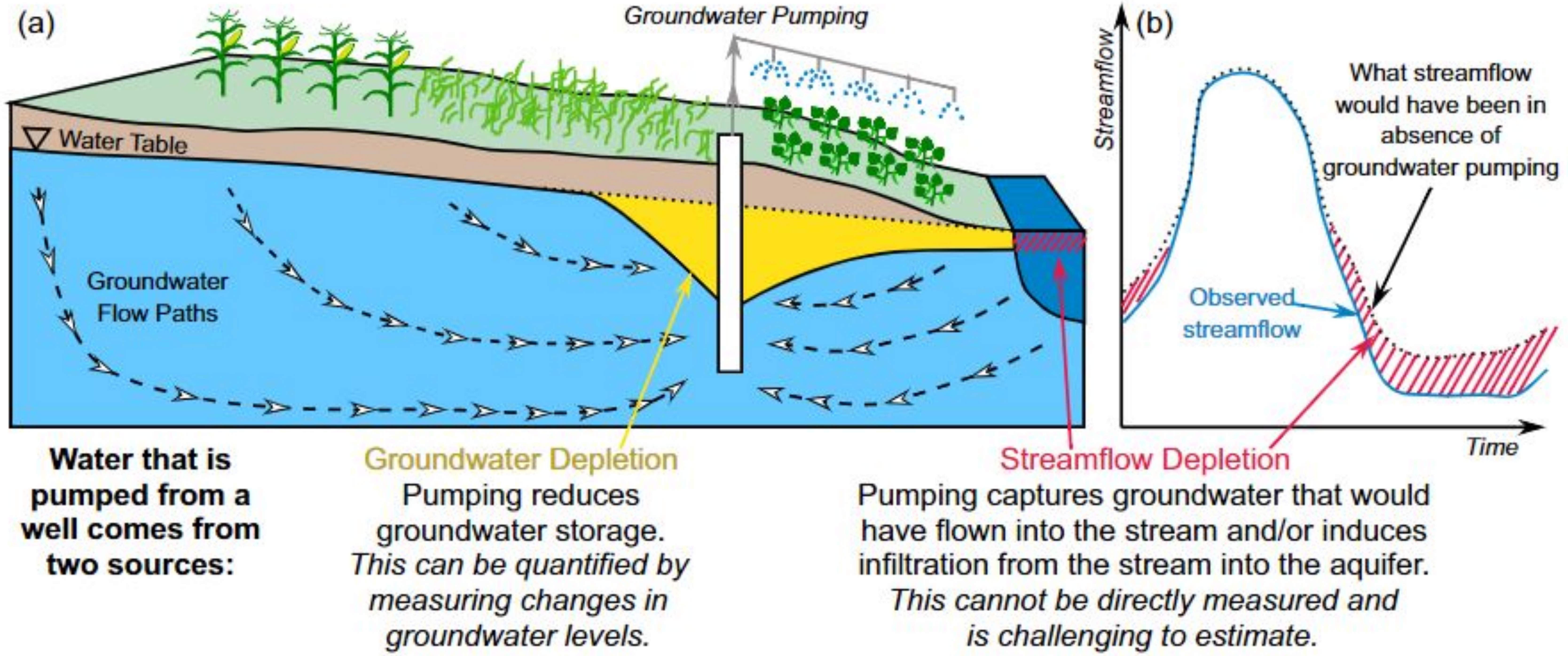


Analytical Approaches

Numerical Models

The Nature Conservancy

Streamflow Depletion

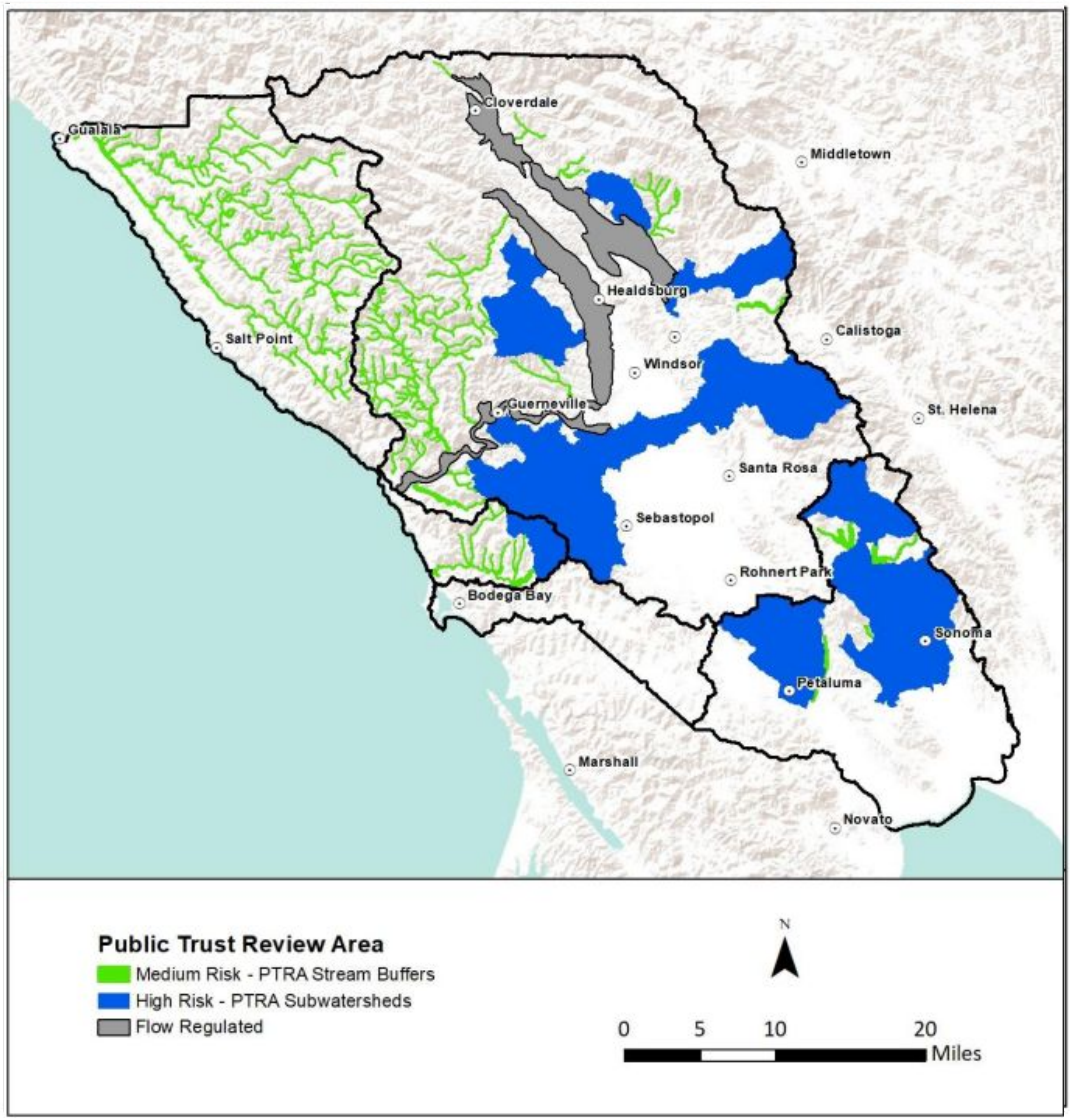


Sonoma County

Public trust resource impact analysis requires –

- Mapping habitat value
- Mapping existing and potential streamflow depletion impacts
- Development of a well-permitting framework based upon the best available science, informing policy

Working with partners on adaptive management plants to improve the protection of public trust resources

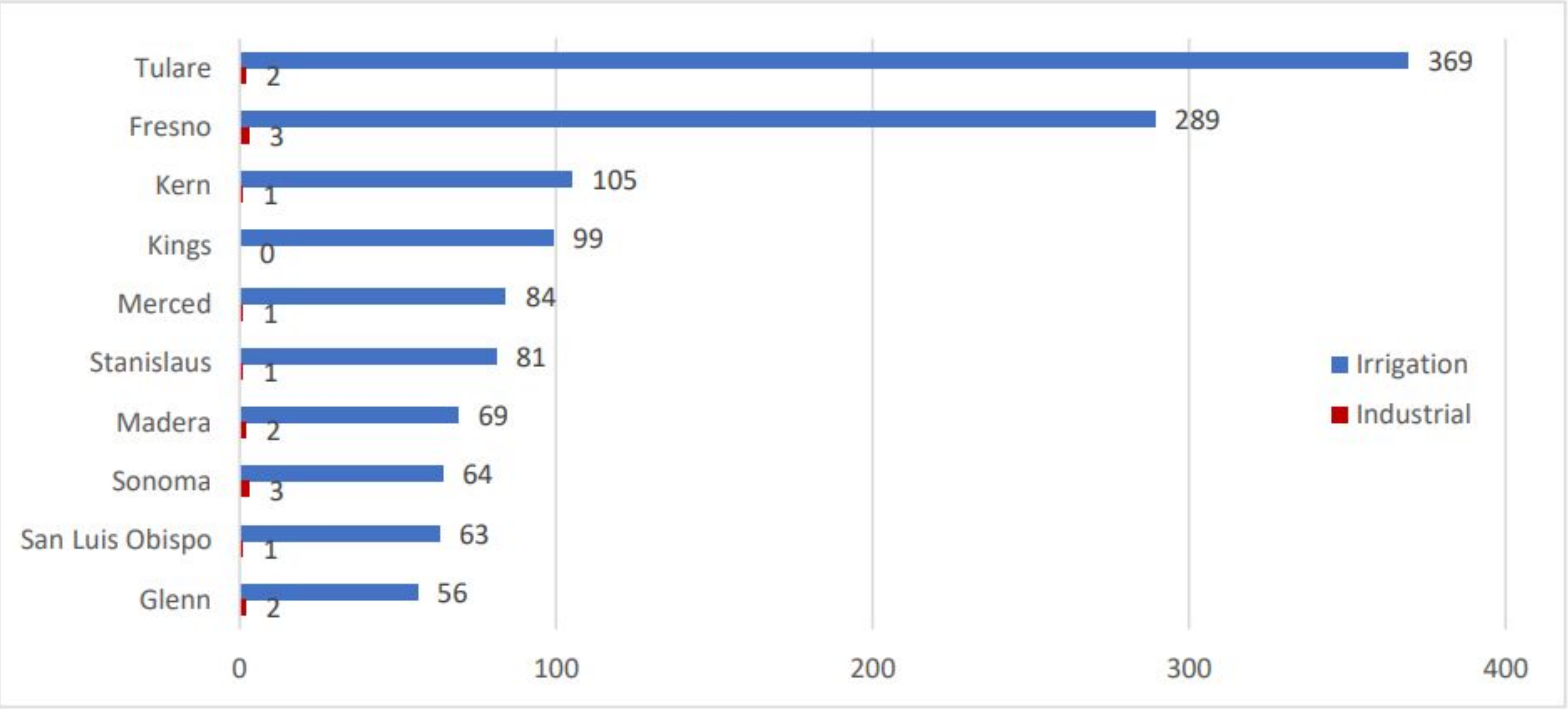


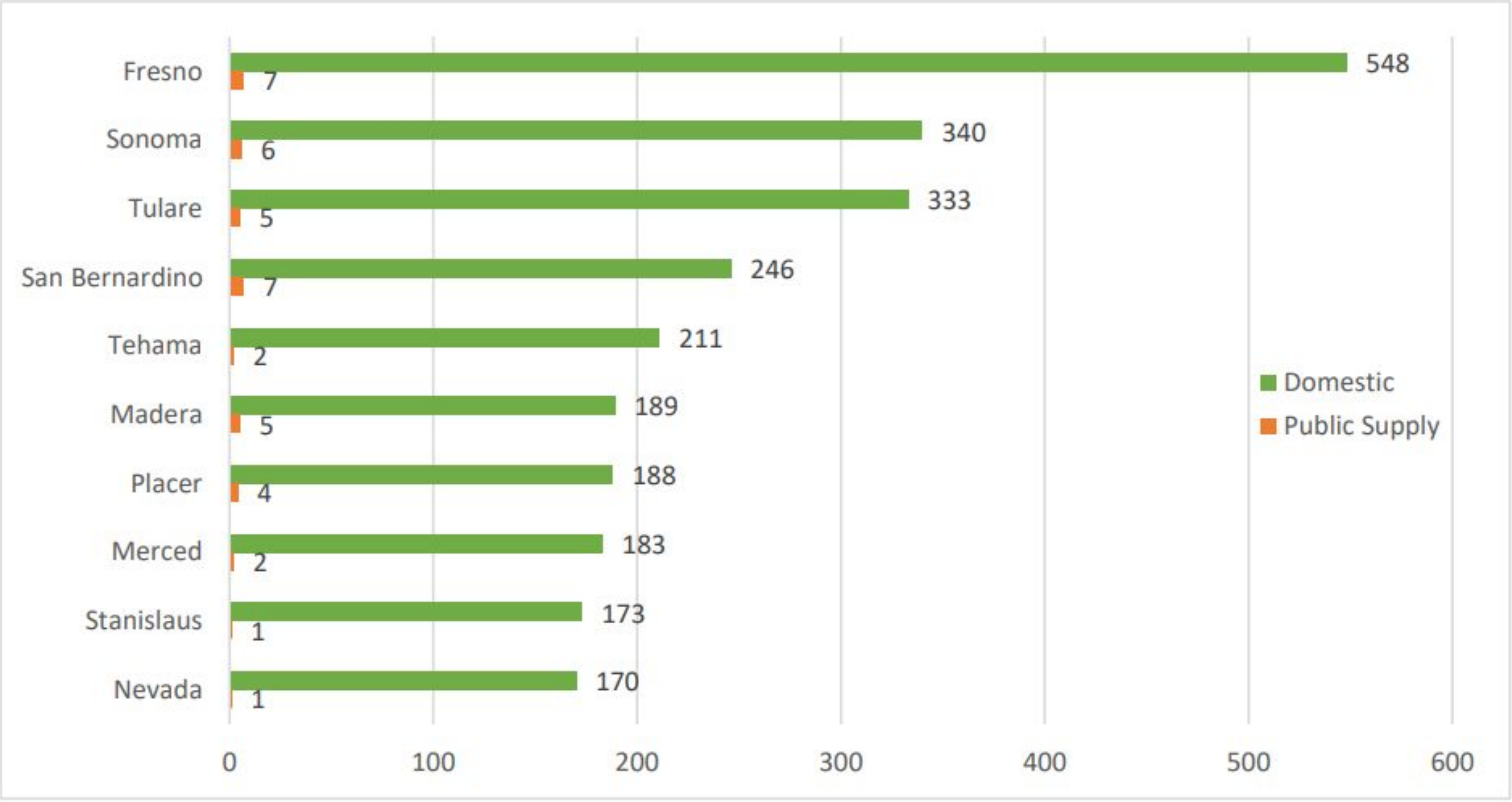
OEI & Permit Sonoma, 2023

Sonoma County

Top 10 counties statewide – wells installed since 3/28/22

Sonoma County
8th most irrigation wells installed
2nd most domestic wells installed

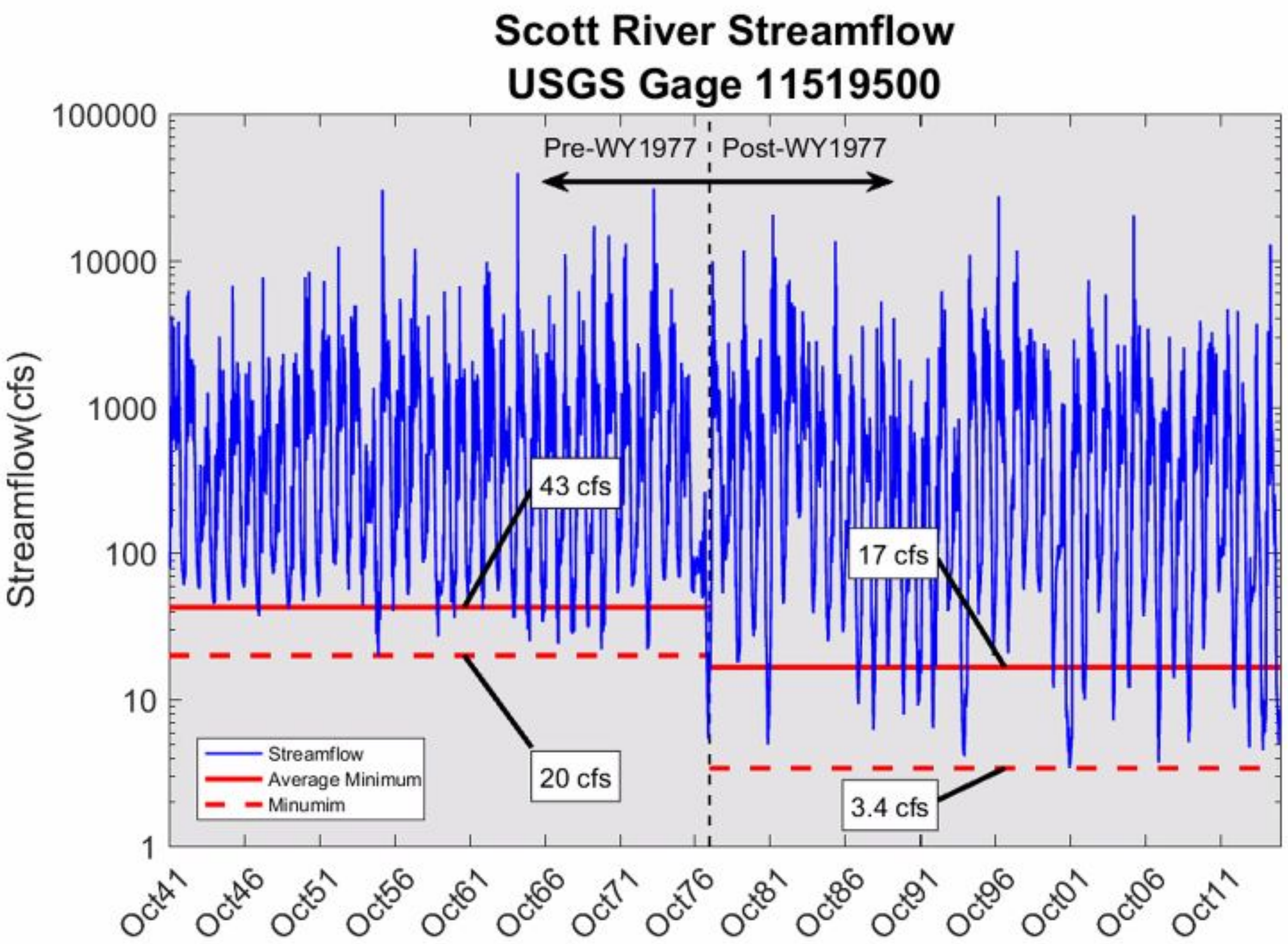




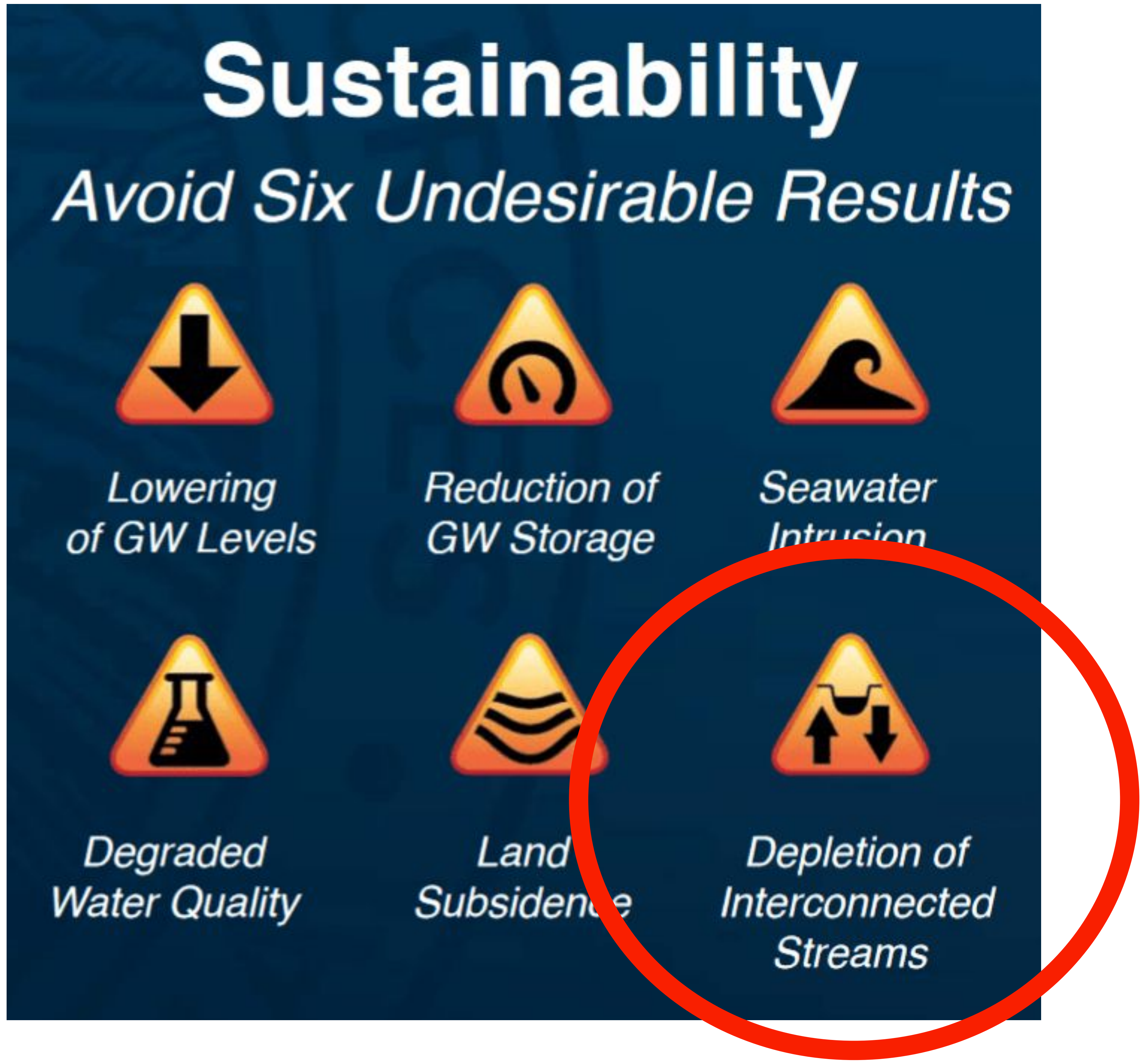
DWR, 2024

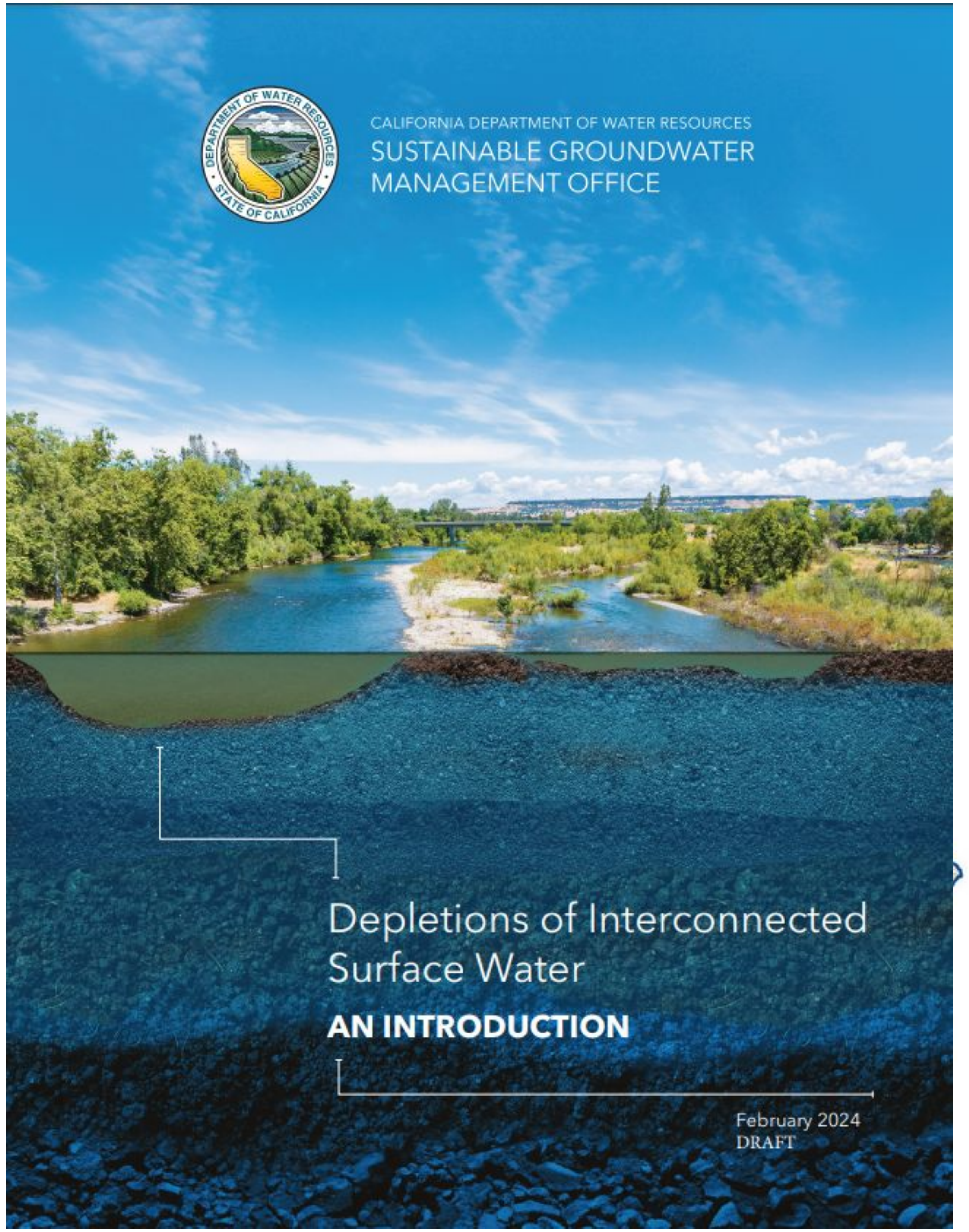
Siskiyou County

- Mid-summer to fall streamflow depends on baseflow from the valley aquifer
- In the 1970s, late-summer streamflow decreased by ~50%
- Likely driving factors -
  - Switch from surface water to groundwater irrigation
  - Additional cutting of alfalfa



Statewide – Sustainable Groundwater Management Act (SGMA) Implementation

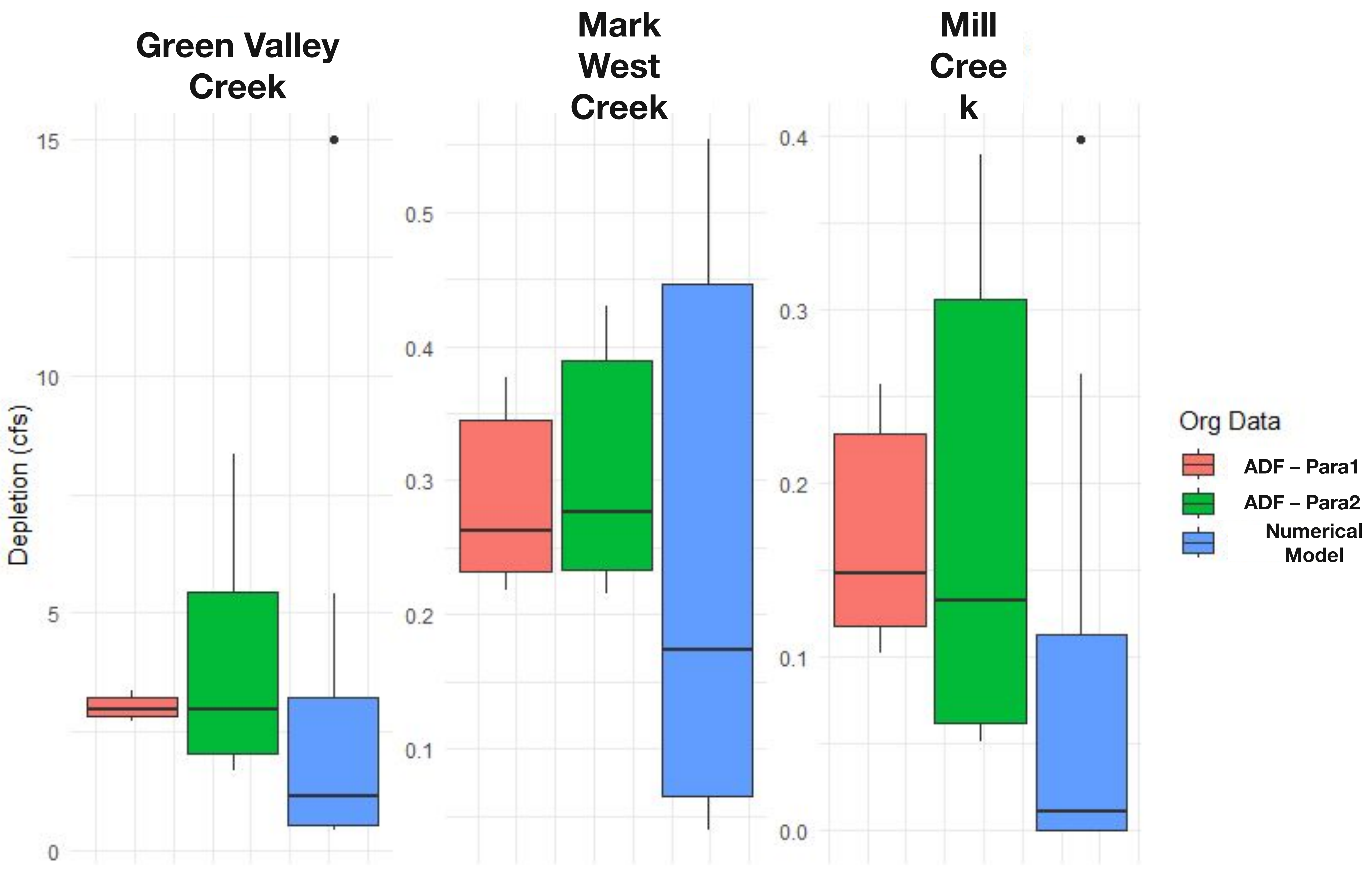




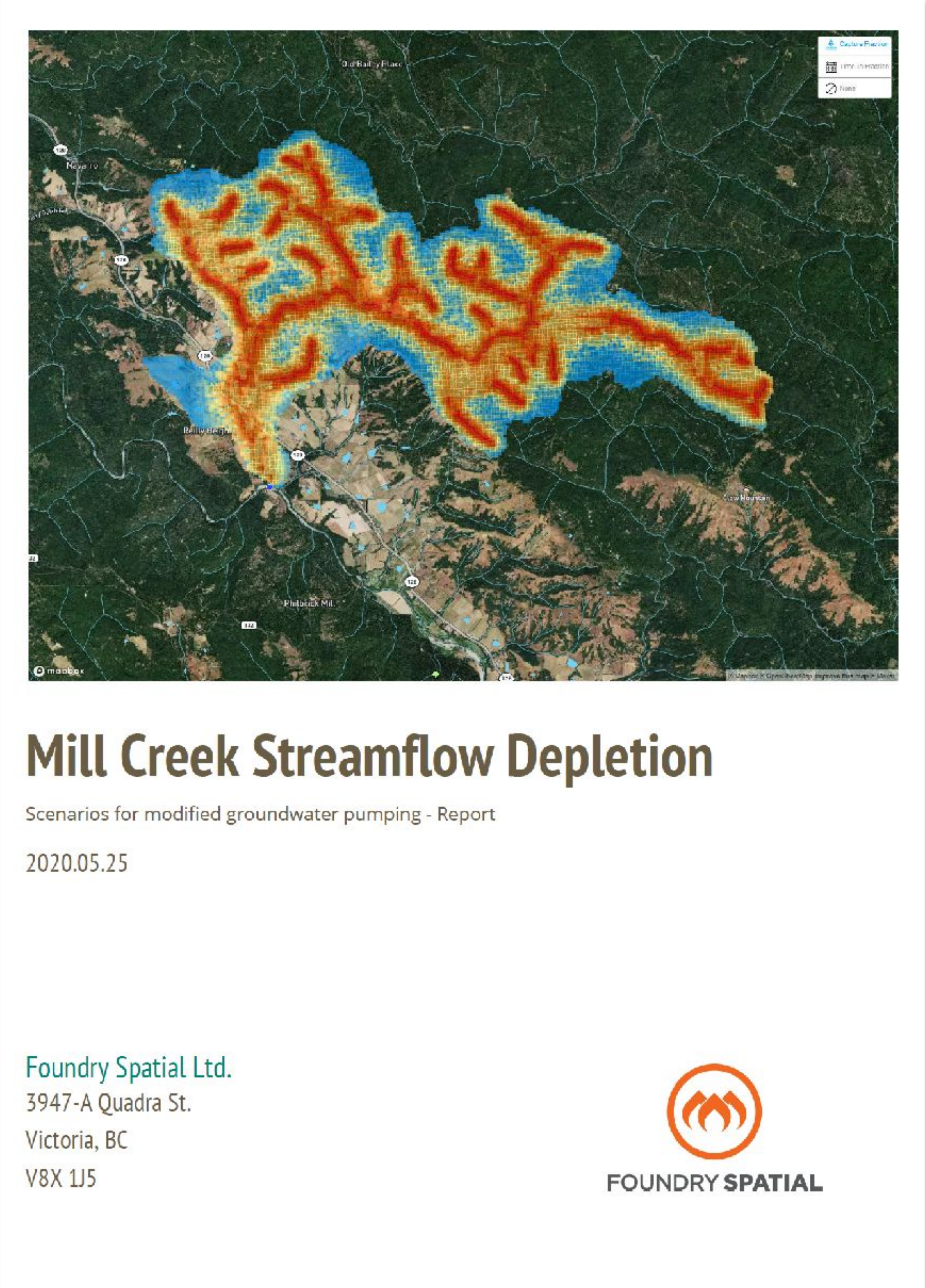
The Nature Conservancy

Comparison: Yearly Depletion at Watershed Outlet

- Annual scale streamflow depletion estimate is comparable



Wells are depleting flows in coastal rivers

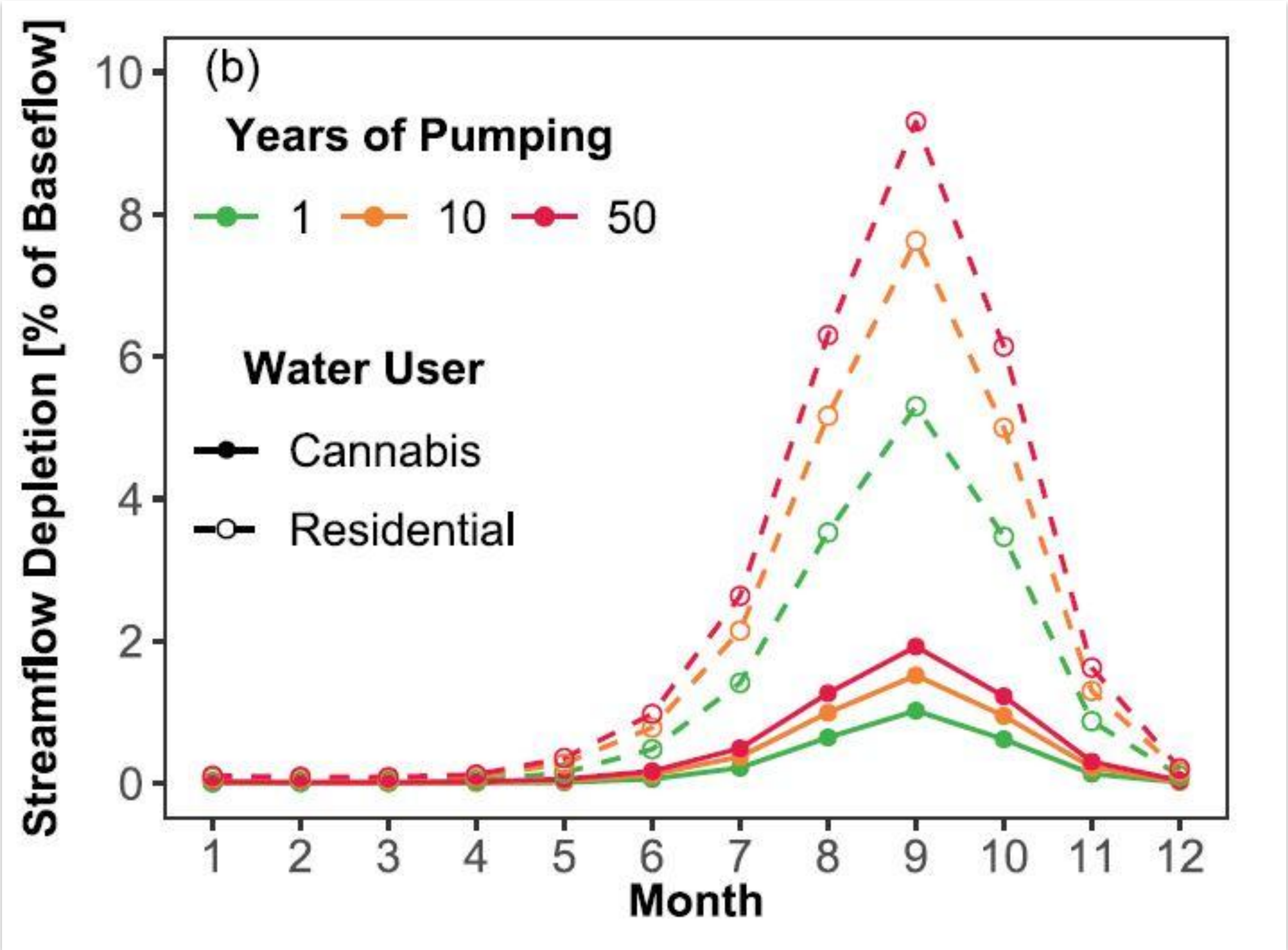

Mill Creek Streamflow Depletion

Scenarios for modified groundwater pumping - Report

2020.05.25

Foundry Spatial Ltd.
3947-A Quadra St.
Victoria, BC
V8X 1J5

FOUNDRY SPATIAL



Streamflow depletion can occur anywhere that groundwater pumping occurs

Photo: Carson Jeffres

CA Environmental Flows Framework (CEFF):
Integrating Groundwater and Surface Water Management

Kris Taniguchi-Quan, Bronwen Stanford, Sarah Yarnell, Alex Milward, Eric Stein, Ted Grantham

Outline

- Overview and goals of CEFF
- What we have developed so far (framework, tools, case studies)
- Nexus with sustainable groundwater management

Numerous Policy Drivers that Demand Solutions

California Salmon Strategy

Cannabis Cultivation Policy

California Water Action Plan

Sustainable Groundwater Management Act

Water Resilience Portfolio

Recycled Water Policy

How much water should be left in streams?

How much groundwater should be pumped?

How much wastewater should be recycled?

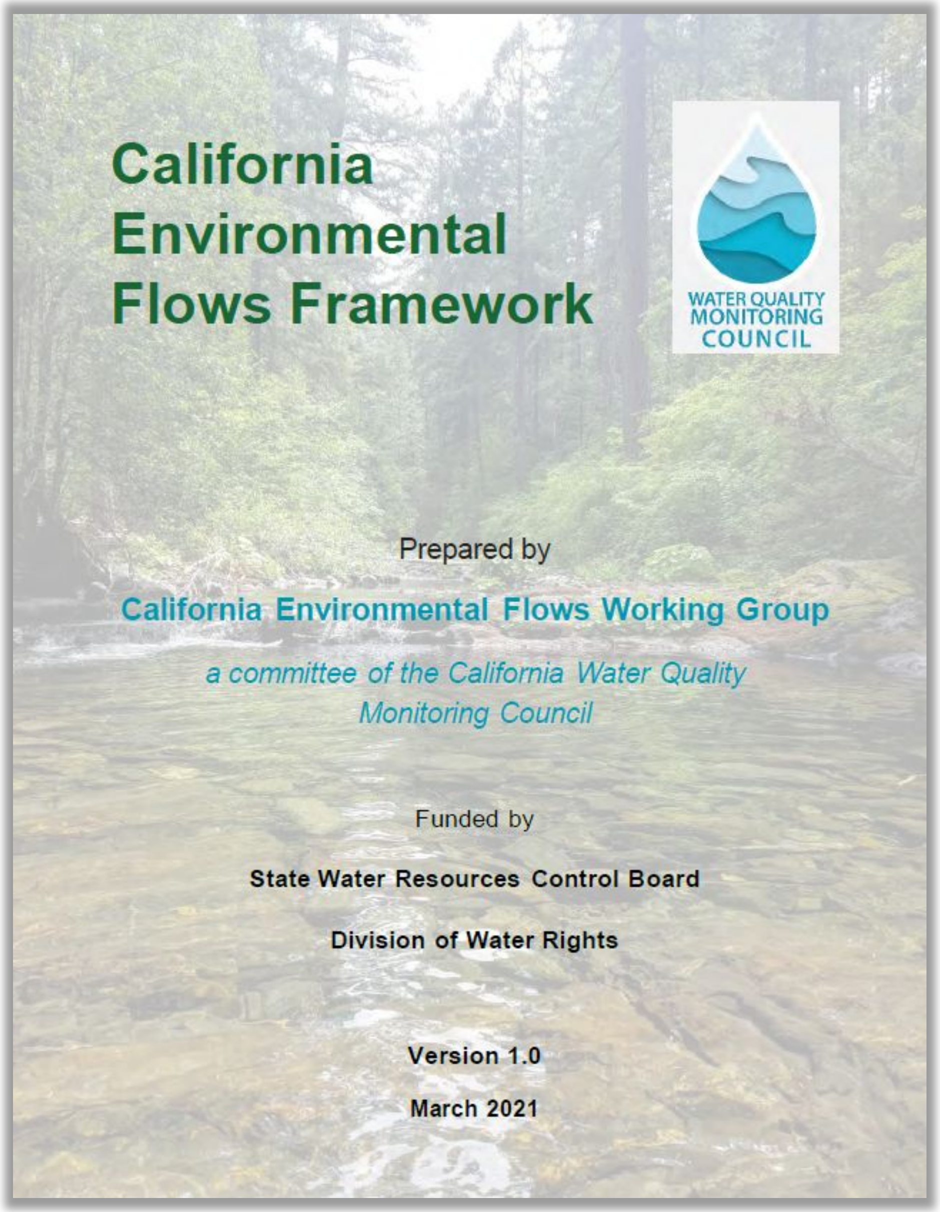
How much stormwater should be captured?

The Need for a Coordinated Framework

- Many programs are attempting to set environmental flows, however,
  - California is diverse and has a variety of systems with different ecological endpoints and broad range of water demands
  - Management needs vary across these systems

- Other challenges include:
  - Coordination between programs and groups
  - Sharing data
  - Uncertainty in which methods are most appropriate
  - Inefficiencies and redundancy in developing requirements
  - Communicating with the public

Process can take a long time



https://ceff.ucdavis.edu/

California Environmental Flows Framework

- Co-developed by agencies of the California Environmental Flows Working Group
- Provides statewide technical guidance for managers to develop scientifically defensible environmental flow recommendations
- Currently being implemented in several programs across the state

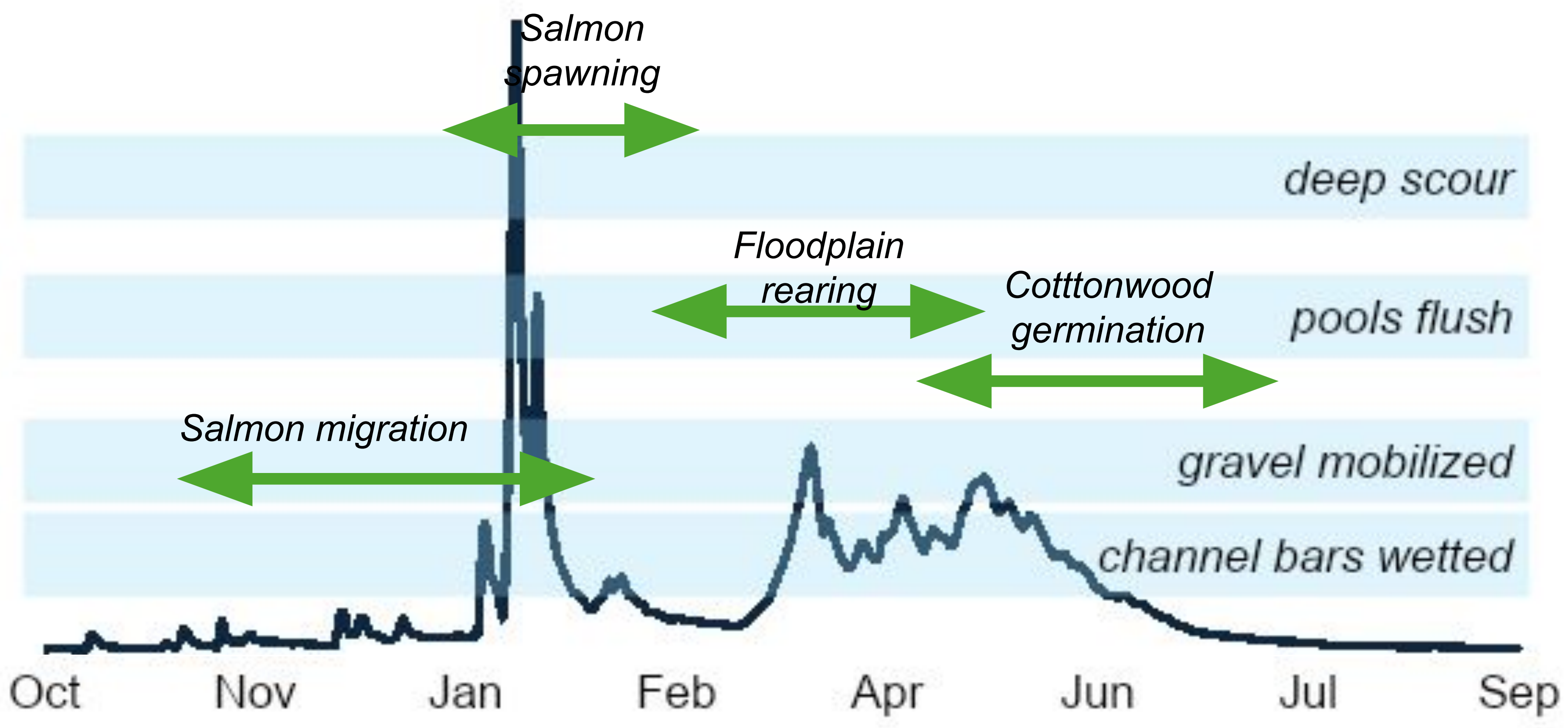
California Environmental Flows Framework

- Multi-step process to define:
  - **Ecological flow criteria:** metrics that describe the range of flows that must be maintained within a stream and its margins to support the natural functions of healthy ecosystems

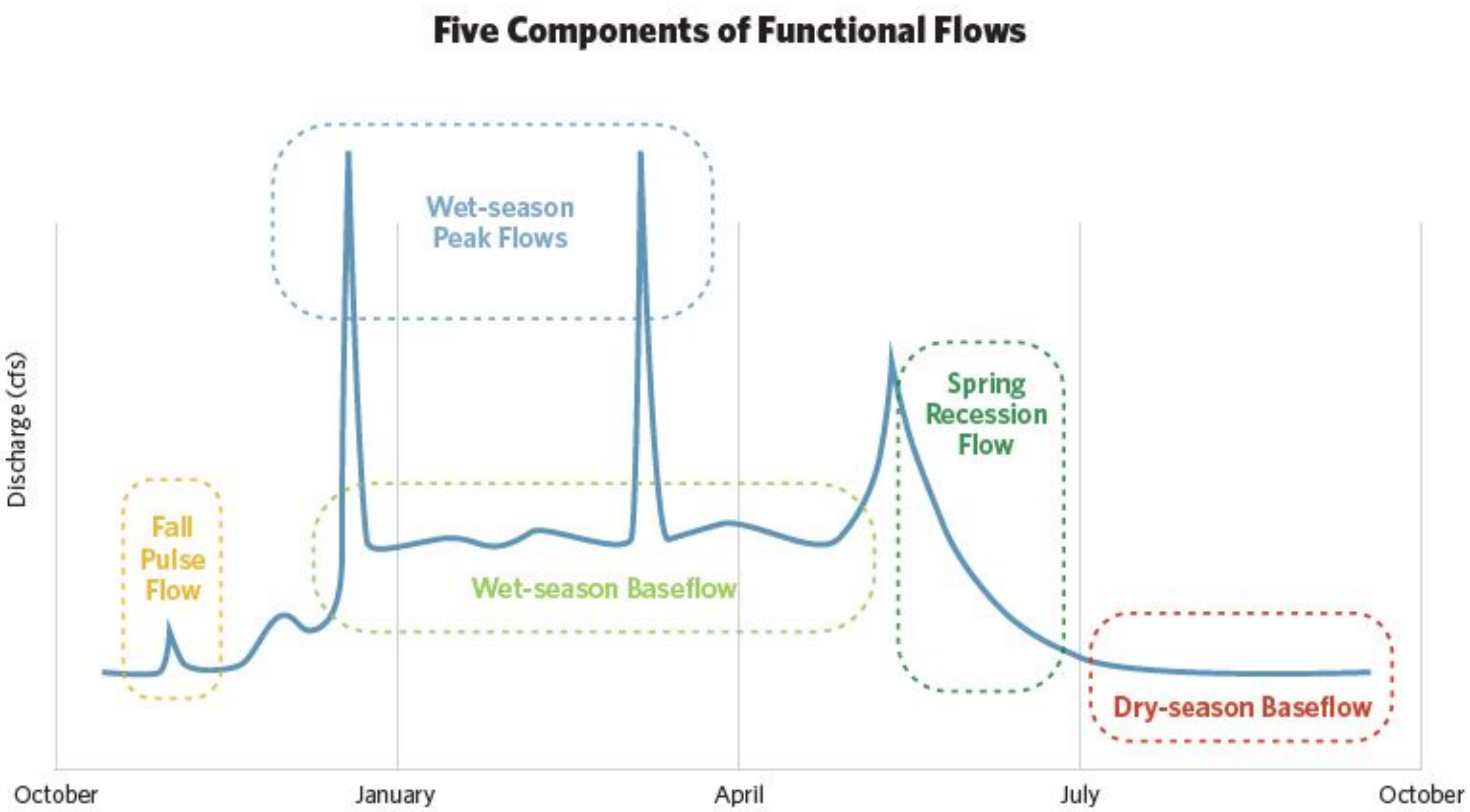
  - **Environmental flow recommendations:** metrics that consider human uses and other management objectives along with ecological flow criteria

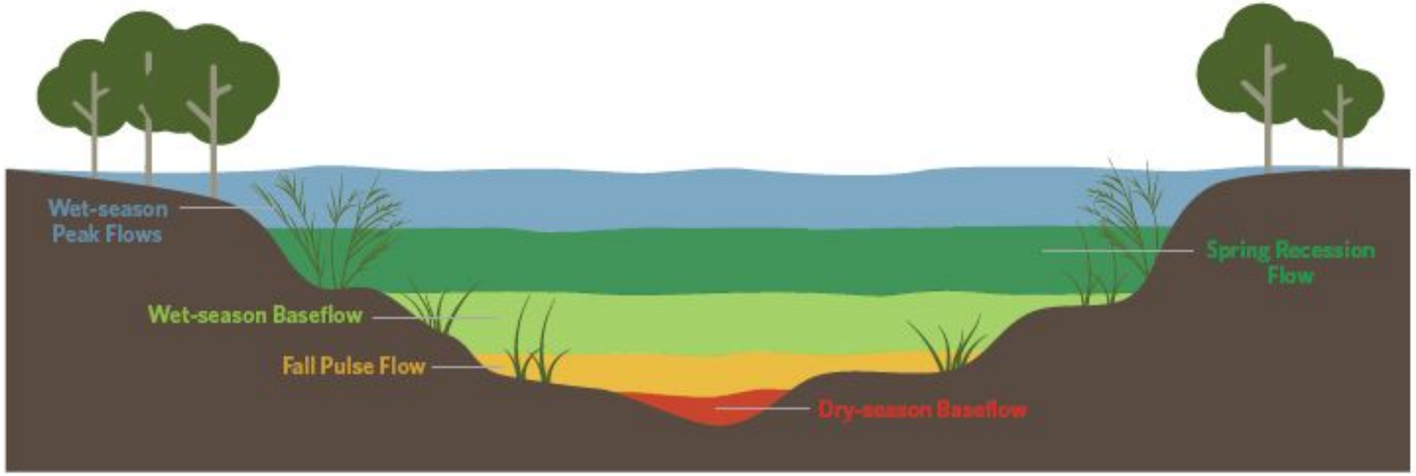
- Guidance document available: https://ceff.ucdavis.edu/

Flow Functions



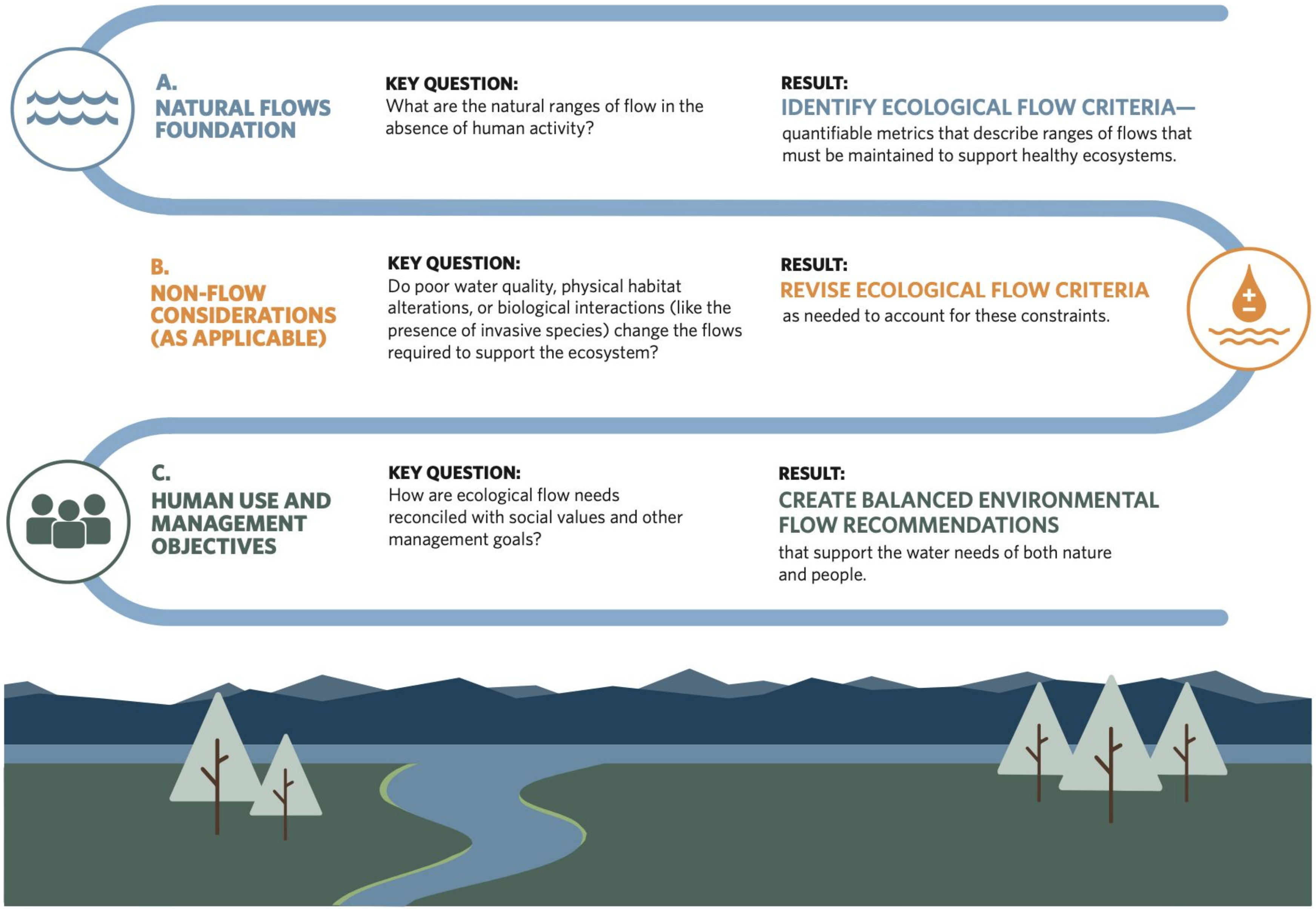
Credit: Sarah Yarnell





Flow Component	Flow Metrics
Fall pulse flow	Magnitude (cfs)
	Timing (date)
	Duration (days)
Wet-season base flow	Magnitude (cfs)
	Timing (date)
	Duration (days)
Wet-season peak flow	Magnitude (cfs)
	Duration (days)
	Frequency
Spring recession flow	Magnitude (cfs)
	Timing (date)
	Duration (days)
	Rate of change (%)
Dry-season base flow	Magnitude (cfs)
	Timing (date)
	Duration (days)

California Environmental Flows Framework



CEFF Tools

California Environmental Flows Framework

Home | The Framework › | Resources › | About

Fact Sheet and FAQs

California Environmental Flows Framework • Resources • Fact Sheet and FAQs

In response to comments received throughout the development of the Framework, the CEFF Technical Team has developed resources to help users understand the Framework and answer common questions.

A fact sheet describing the Framework is available for download here.

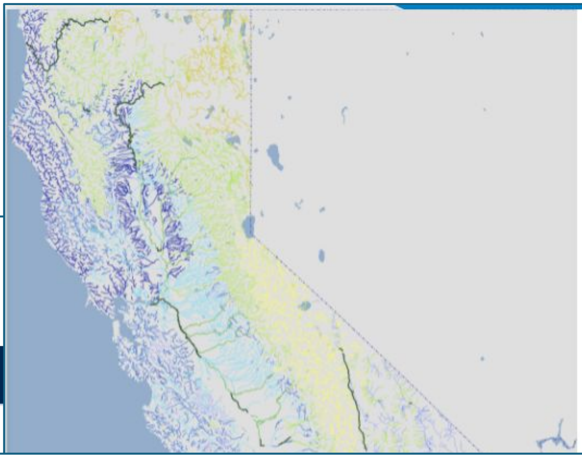
The FAQs provided below detail responses to questions that arose during public review of the California Environmental Flows Framework version 1.0. They have been grouped into the following categories based on sim

analys

Fac

Pres

Arti



Explore and visualize California's unimpaired streamflow patterns, including natural stream classes and functional flow metrics

EXPLORE HYDROLOGY | HOW DOES IT WORK?

Stream

Dimensionless Observed

Functional Flow
trics

w metrics quantify
aspects of the
ural flow regime
ed to critical
system functions.

R Package for Obtaining Functional Flow Metrics

An R package has been developed that allows users to access the Functional Flows Calculator directly via an API. The package allows users to:

- Retrieve streamflow data automatically from USGS or transform user-uploaded streamflow timeseries and run them through the functional flow calculator online,
- Obtain modeled functional flow m
- Create plots of dimensionless hy
- Compare observed and natural fu

The package is available on GitHub.

California Natural Flows Database

Water is essential for California's people, economy, and environment. Centuries of water diversion have altered the flows in many streams and rivers, which can harm the freshwa Conservancy and the United States Geological Survey (USGS), and other partners have (expected streamflow in the absence of human modification) in all the streams and rivers present.

Explore the Data

Science

Understanding natural flows and patterns of flow alteration is an important first step in improving the management of California's rivers and streams for human and ecosystem

Map

Explore, visualize, and download the natural flows data with a map-based application. Search for stream segments, visualize estimated flow rates, and download flow data

Data download and API

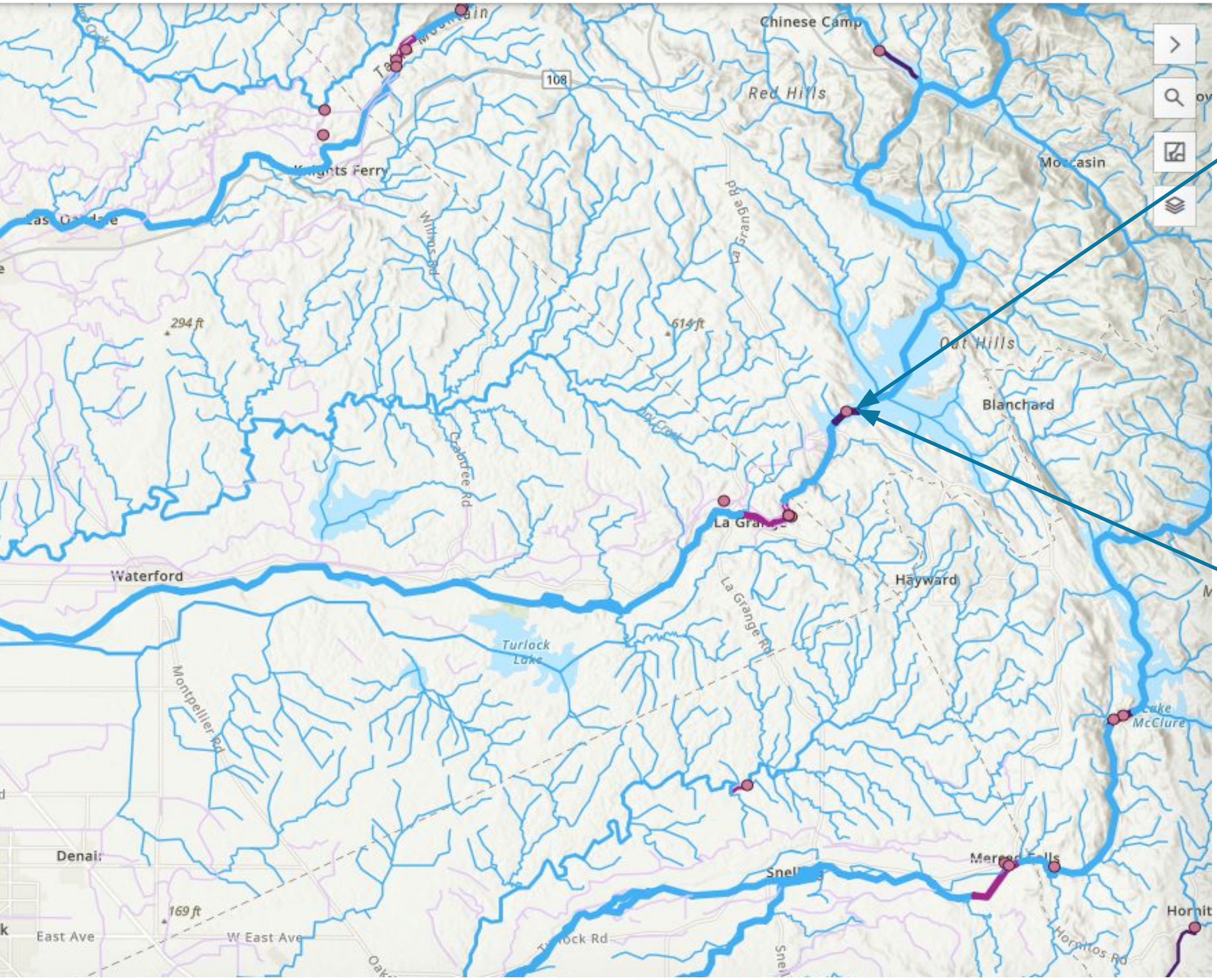
Feel more comfortable at the command line? Query the data directly using a REST API. Follow the link below for detailed documentation and code samples in R,

Umbrella Species and Functional Flow Needs

Umbrella fish species and their functional flow requirements were identified for California. Access the map here, or begin using the map below by clicking "OK". The map displays the umbrella species for California; users may click on a watershed to view regional fish species assemblages (where each assemblage is represented by a different color), the umbrella species associated with each assemblage, and the HUC 12 distributions that comprise these assemblages outlined in gray. Functional flow needs for each umbrella species are available in the attached Excel workbook. For further details on how umbrella species were identified, see Obester et al. 2021.

Natural Flows Web Tool

rivers.codefornature.org

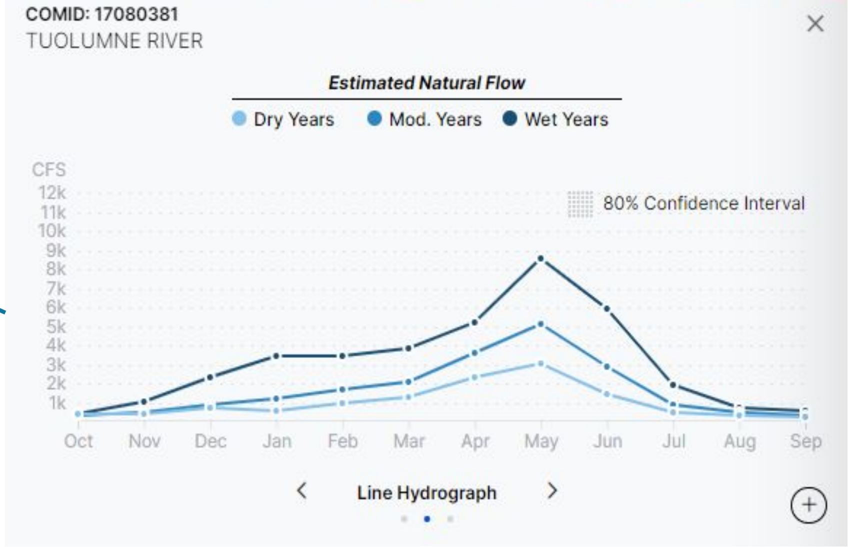


COMID: 17080381
TUOLUMNE RIVER

Flow Component	Year Type	Recurrence Interval
Wet-season base flow	All Years	2-year

FLOW METRIC	10th pctl	50th pctl	90th pctl	Observed Med.
Wet-season baseflow	659 CFS	1,100 CFS	1,750 CFS	-
Wet-season median baseflow	1,810 CFS	3,130 CFS	5,220 CFS	-
Wet-season start	Nov. 17	Jan. 2	Feb. 14	-
Wet-season duration	71.2 DAYS	127 DAYS	186 DAYS	-

Functional Flow Metrics



How CEFF Moves the Ball Forward

- Provides tools to identify protective flow ranges for <u>all stream reaches in the state</u>
  - Year-round flow targets that address all functional flow components
- Provides a structured approach to developing region-specific target ranges
  - Provides a mechanism for local refinement of targets
- Provides process for evaluating human vs. ecological demands
- Is an agreed upon approach co-developed by multiple agencies

Case Study Applications

DAM OPERATIONS

- San Joaquin tributaries
- Putah Creek

INSTREAM FLOW & RESTORATION

- Navarro River
- Deer Creek
- Mill Creek
- Little Shasta River
- South Fork Eel River

URBAN RUNOFF PROVISIONS

- Aliso Creek
- San Juan Creek
- Spring Valley Creek

WASTEWATER CHANGE PETITIONS

- LA River
- San Gabriel River

GROUNDWATER PLANNING

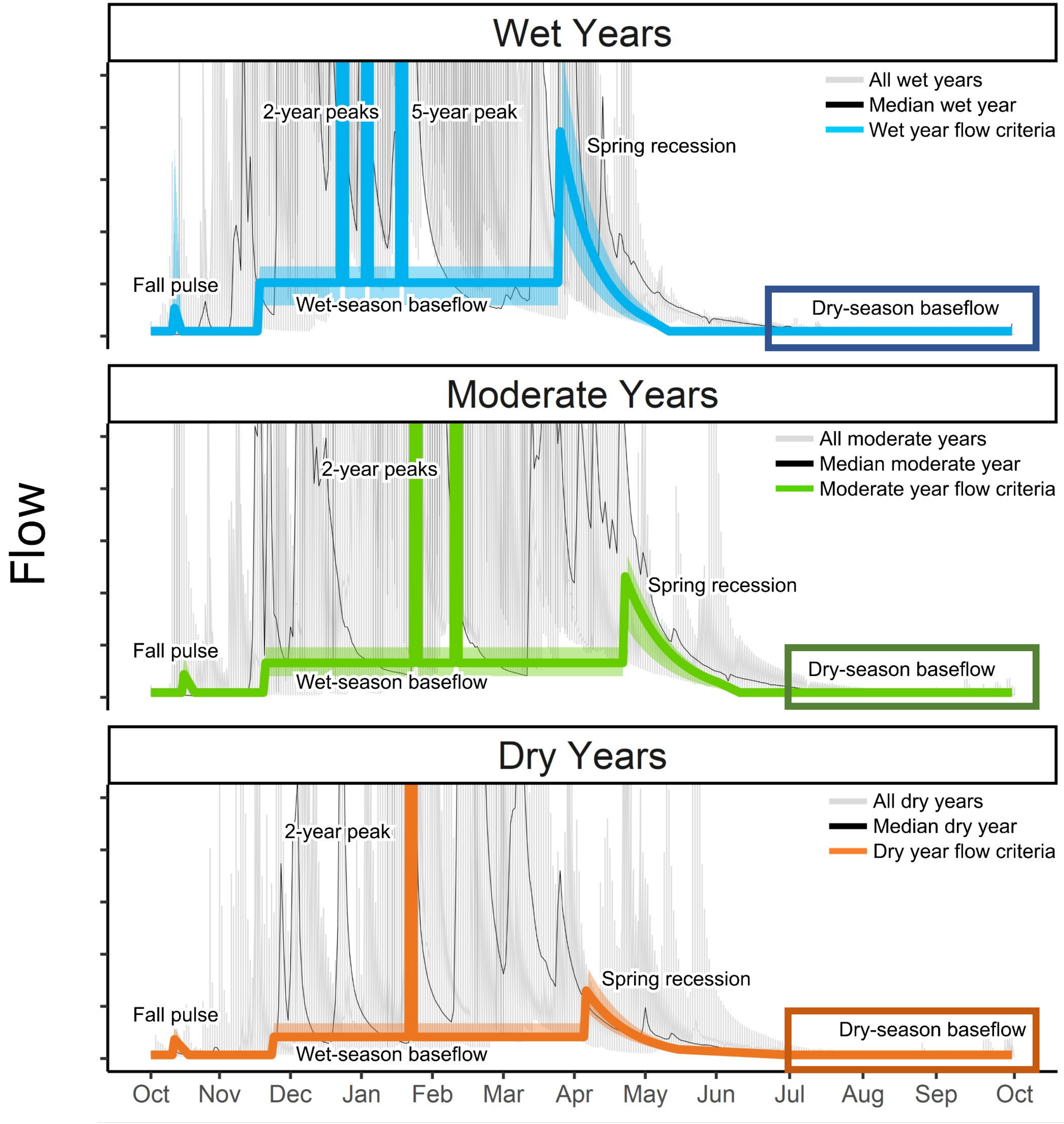
- Upper Santa Clara River
- Napa River
- Scott River

Growing Interest from Groundwater Community

- Water districts and groundwater agencies are starting to use CEFF
  - Water reuse, SGMA, MAR, and well ordinance applications

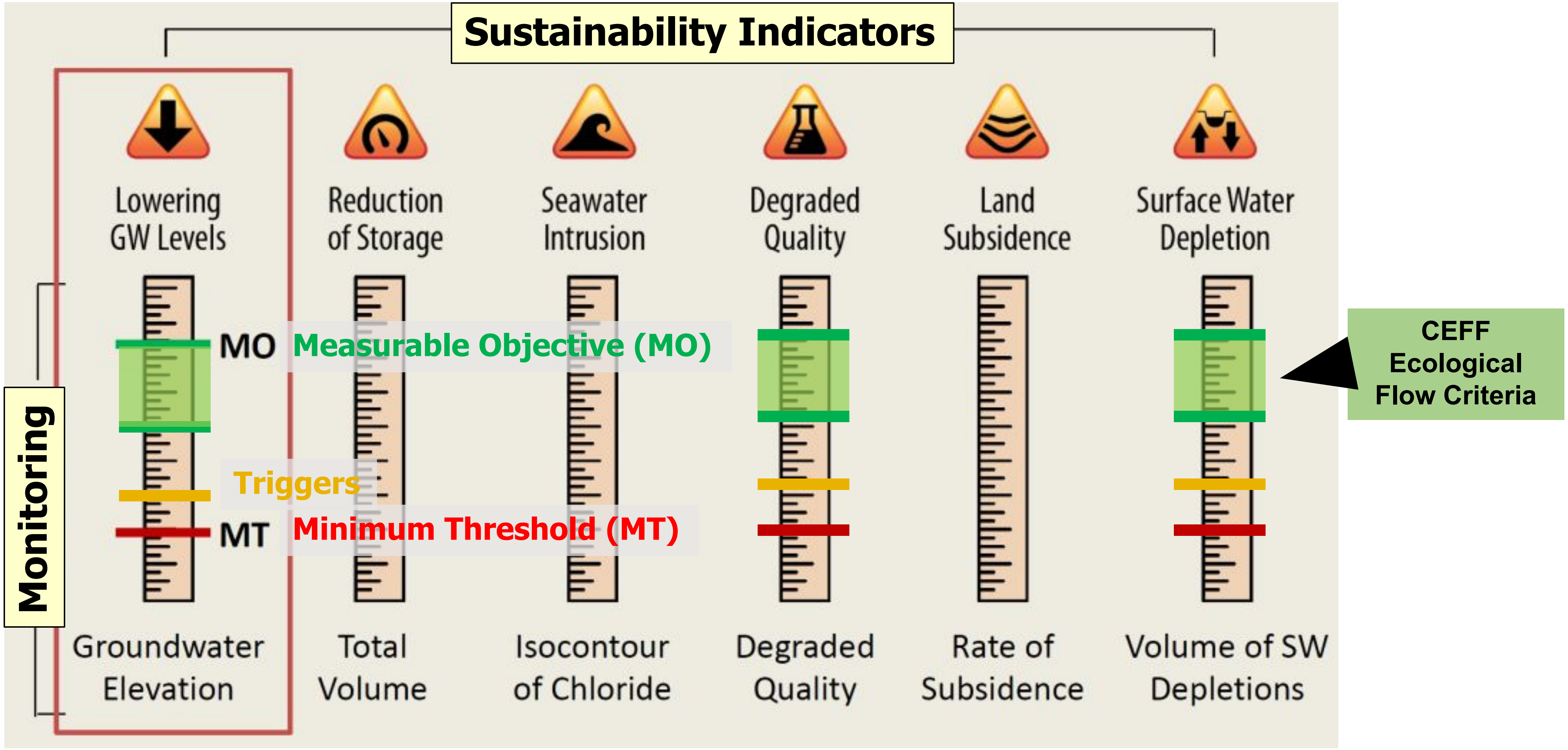
- CEFF tools and datasets can:
  - Inform tradeoff analysis on water for environment and other uses
  - Identify measurable objectives for interconnected surface waters
  - Inform managed aquifer recharge that provides co-benefits to ecosystems and humans

- Case studies needed to serve as future templates
  - Opportunity to test and enhance CEFF for new applications



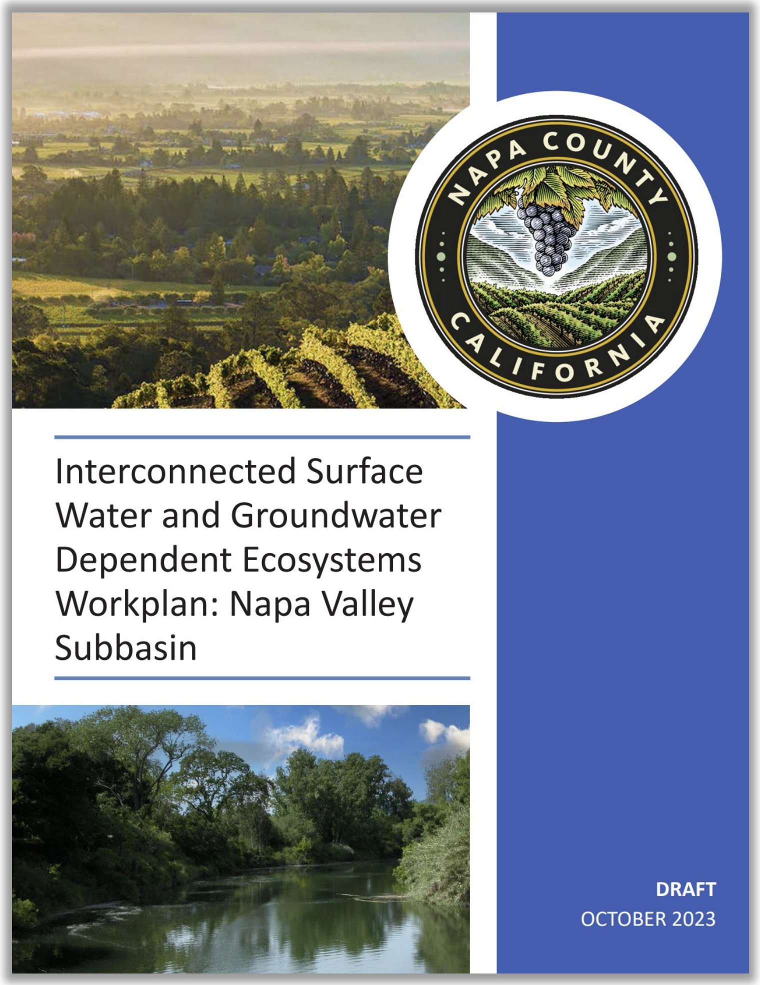
CEFF Flow Criteria can serve as measurable objectives that can vary by water year type

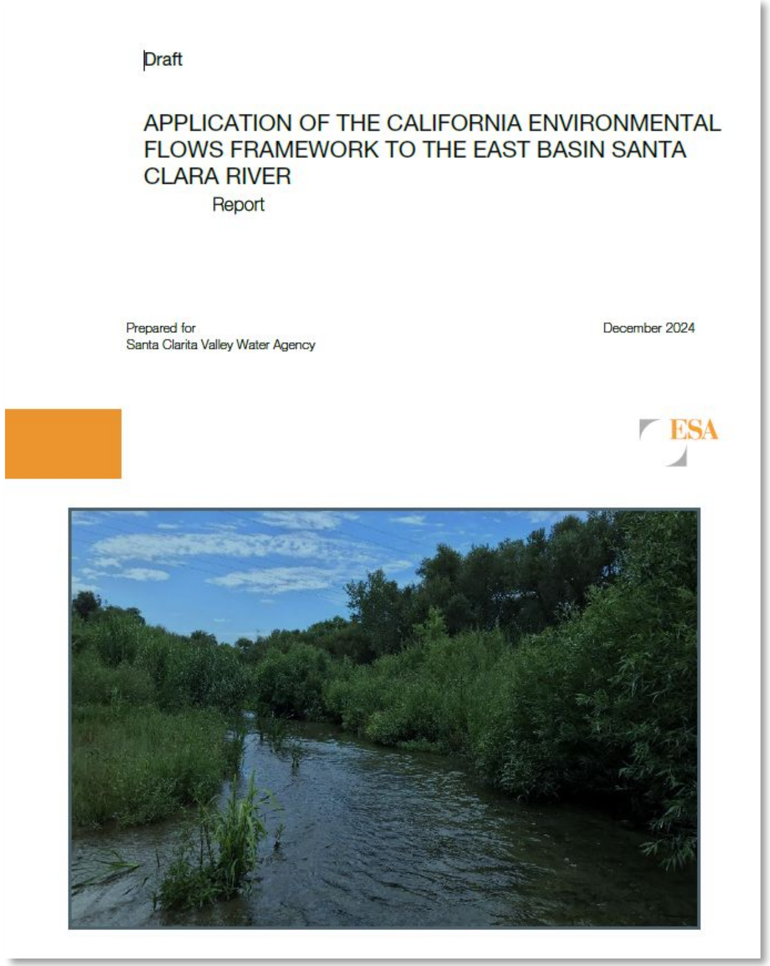
CEFF can Inform Monitoring and Managing Sustainability



modified from CADWR 2016

CEFF Informs Groundwater Sustainability Planning



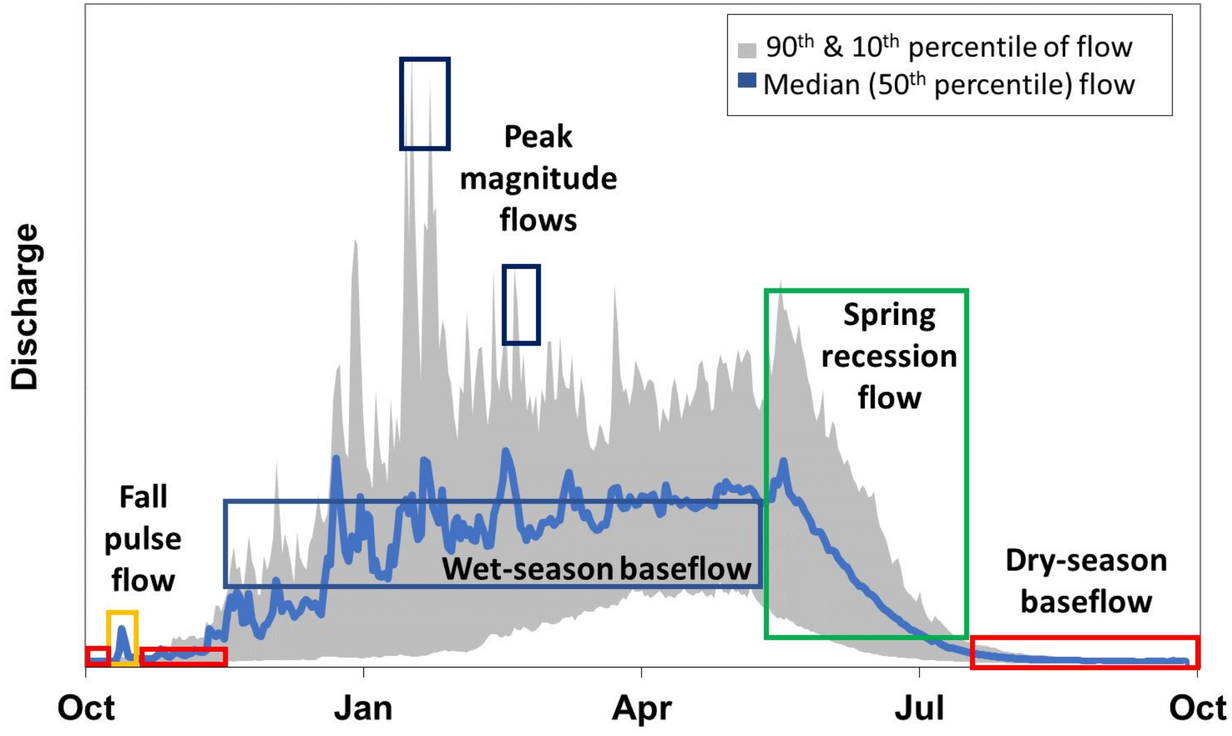


MAR and Wet-Season Functional Flows

Wet-season baseflow
- Connectivity for migration
- Water quality
- Hyporheic exchange

Peak flow
- Channel maintenance
- Floodplain access

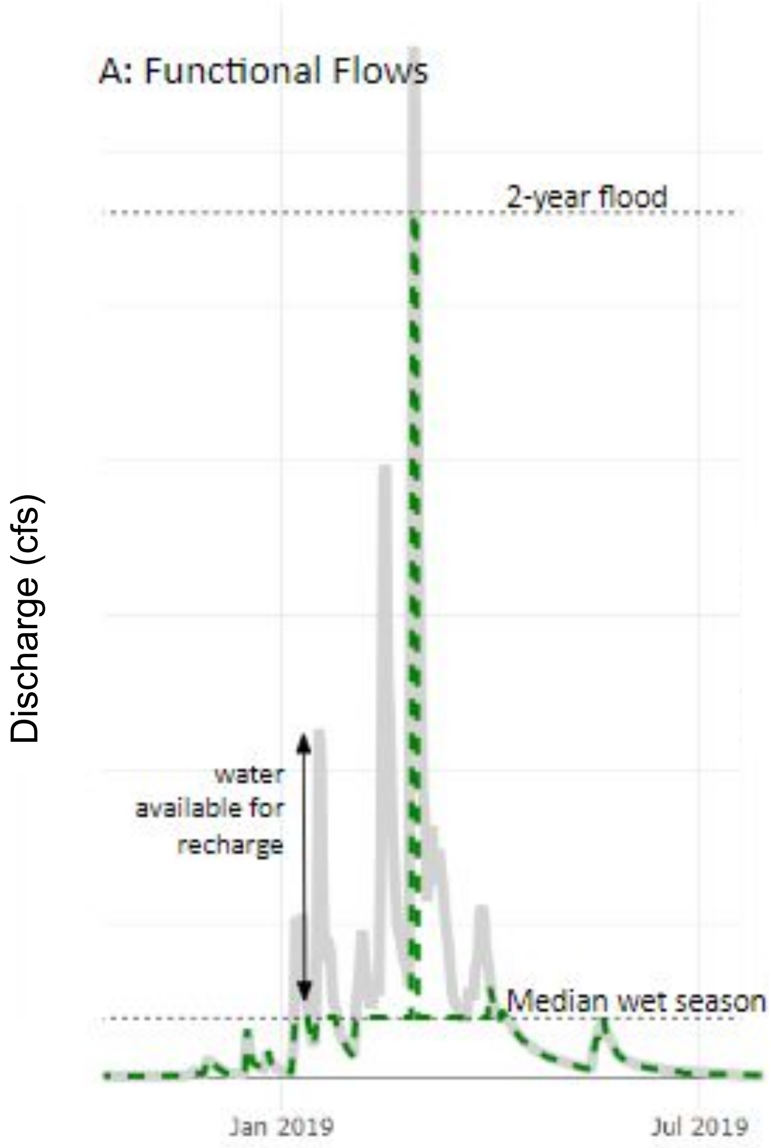
Spring recession flow
- Connectivity
- Water quality
- Sediment redistribution
- Reproductive and migratory cues



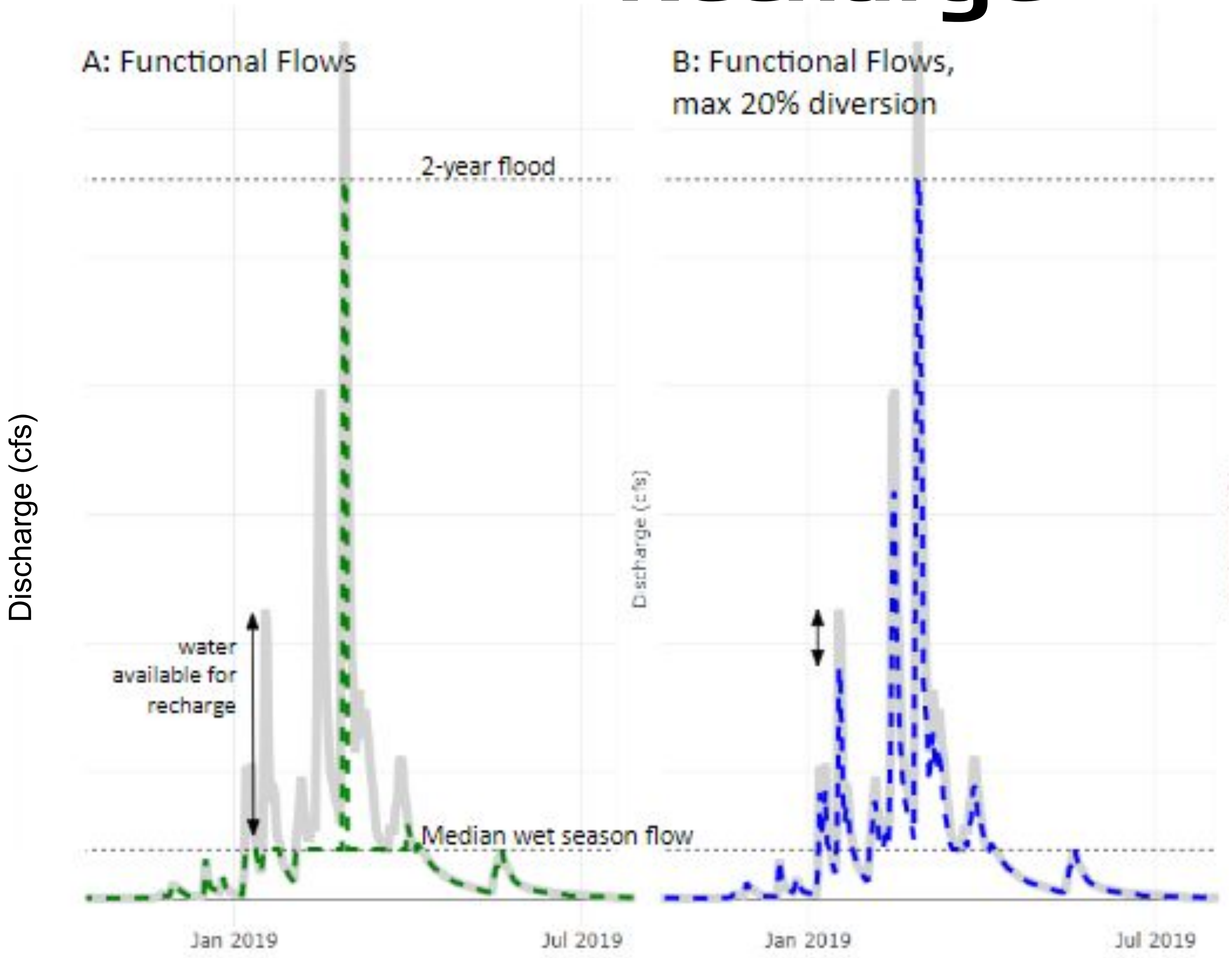
+Potential to restore dry season baseflow

https://californiawaterblog.com/2024/01/08/a-functional-flows-approach-to-implementing-flood-mar/

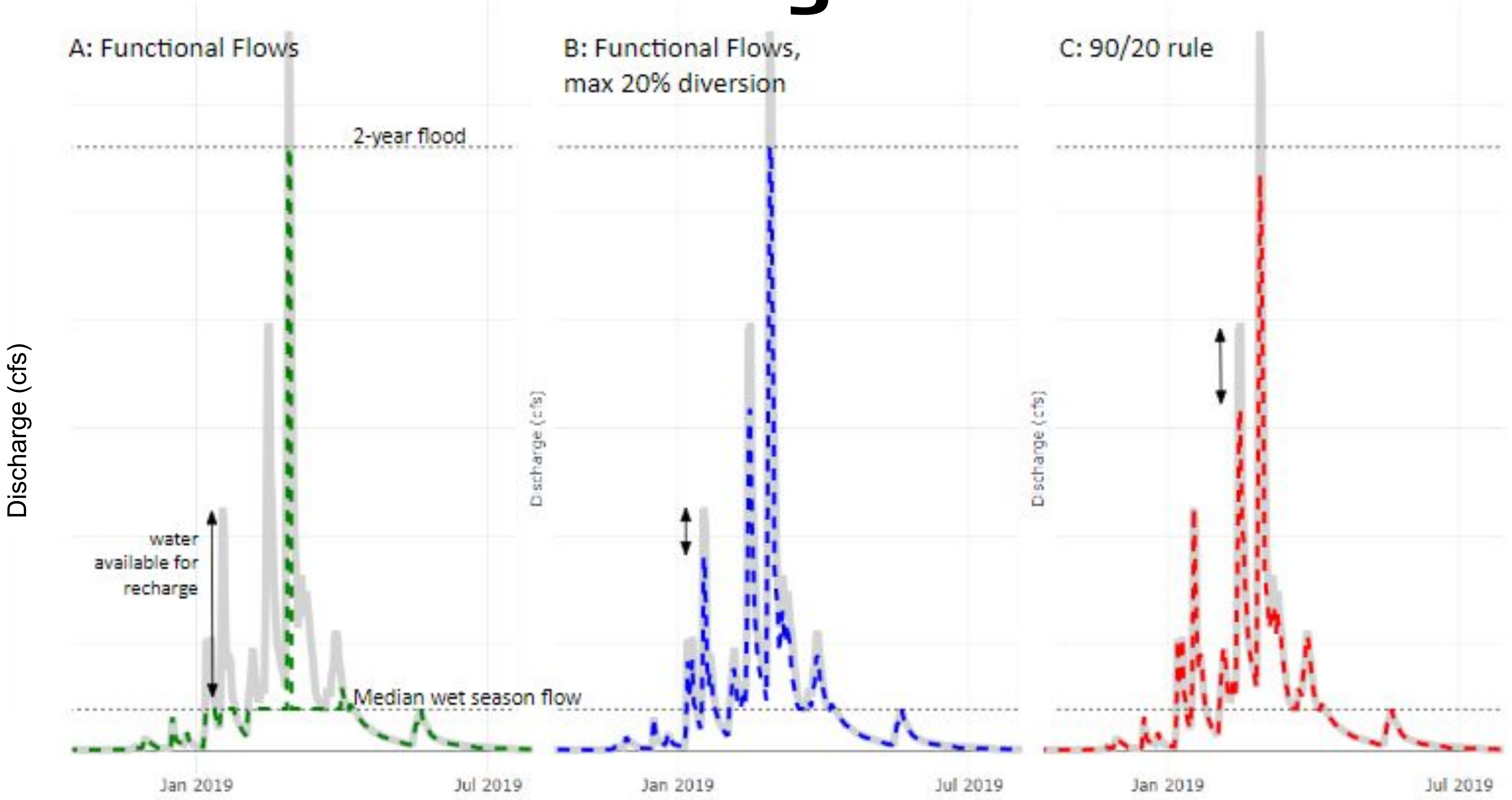
CEFF can Inform Water Available for Recharge



CEFF can Inform Water Available for Recharge



CEFF can Inform Water Available for Recharge



Flooding in the Floodplain → More Benefit

Multiple benefits of flooding within the riparian zone/floodplain:

- recharge
- habitat access
- food production
- vegetation maintenance

Restoration of connected floodplains can provide multiple

Operationalizing CEFF: Groundwater Applications

- Modeling approach to account for groundwater depletion effects on surface flows
  - Using hillslope Boussinesq approach (Dralle et al., 2014)
- Case study and integration of GW models with CEFF to set protective flows
- CEFF implementation guidance and workshop training series

Take Home Messages

- CEFF is a fully developed method that has been agreed upon by multiple agencies
- There are numerous successful applications of CEFF across the state
- Opportunities exist to expand CEFF for groundwater applications
- We are looking for partnerships to test and possibly enhance CEFF for new applications

Questions

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SCCWRP
kristinetq@sccwrp.org

https://ceff.ucdavis.edu/

https://mywaterquality.ca.gov/environmental-flows/

What does it mean to apply CEFF?

Functional flows for ecology

Section A
- Begin with metrics from CEFF tools and management objectives

Section B
- Refine with local information (if necessary)

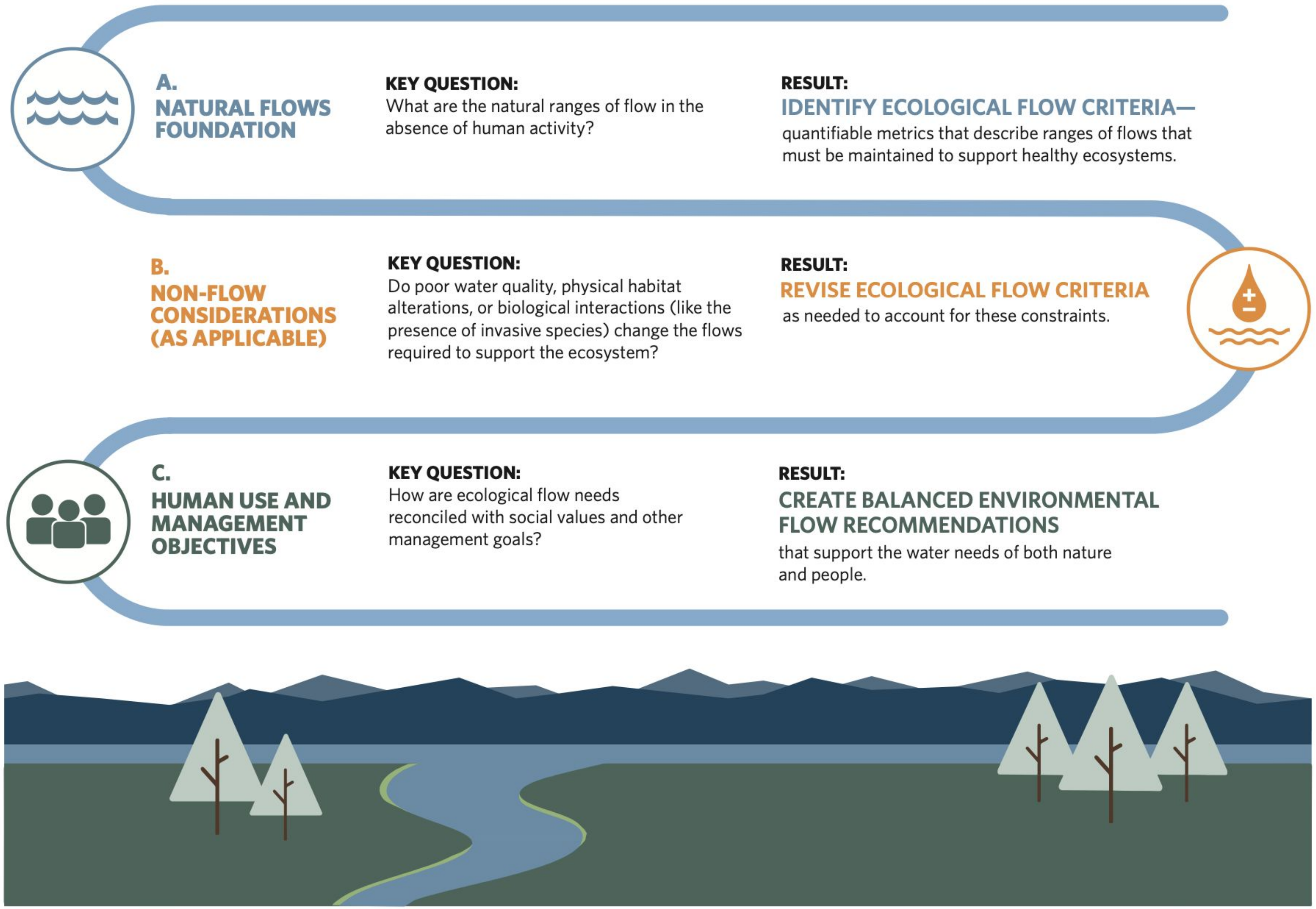
Outcome 1
- Year-round flow criteria to address all 5 functional flow components for planning, restoration and/or starting point for a regulatory process

Flows considering non-ecological uses

Section C
- Use local or regional information to inform risk categories to support trade-off analysis (if necessary)

Outcome 2
- Compromised flow regime that trades some degree of ecological function to support non-ecological uses

California Environmental Flows Framework



Modeled Natural Functional Flows

- Predictions of natural functional flow metric ranges at every stream in the state
- Hydrologic model predictions used for 16 metrics and observed, reference-gage data used for 8 metrics
- Ranges reported by water-year type for most metrics

Grantham et al. 2022 FES