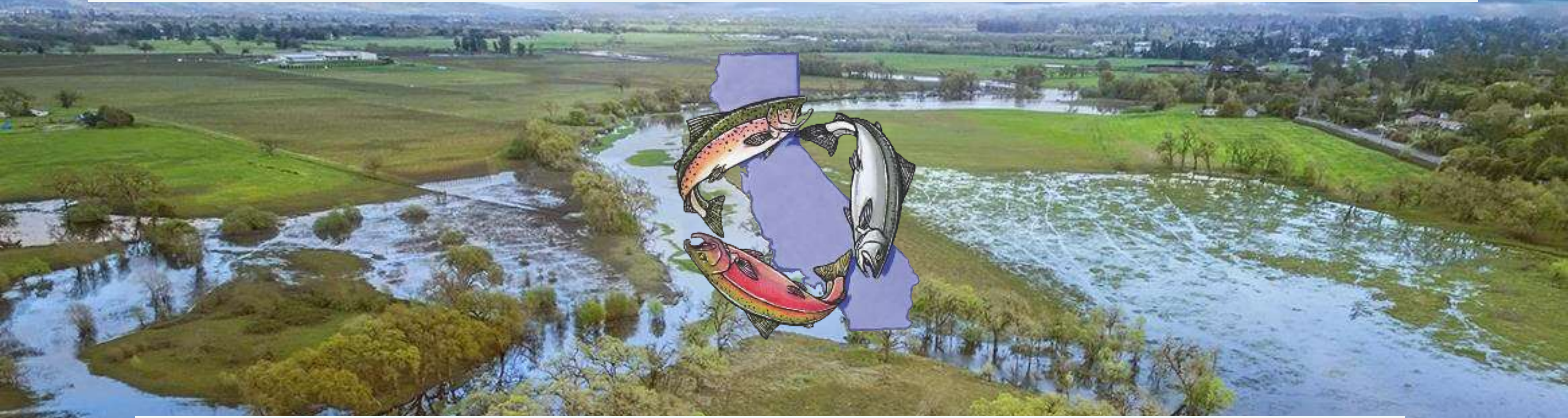
From Groundwater to Streamflow: Exploring the Science, Projects, and Policies to Manage Groundwater Resources to Support Streamflows for Salmon and Public Trust Resources



A Concurrent Session at the 41st Annual Salmonid Restoration Conference
Santa Rosa, California, March 26-29, 2024

Session Coordinators: Monty Schmitt, The Nature Conservancy; **Matt Clifford**, JD, Trout Unlimited; and **David Dralle**, Ph.D., U.S. Forest Service, Pacific Southwest Research Station

Groundwater contributions to instream flows, particularly in the dry season, are essential for the restoration of rivers and the recovery of salmonid populations. Historic logging practices, changes in land use, the legacy of fire exclusion, and increasing well diversions have all contributed to depleted streamflows. Efforts to manage groundwater resources, like the Sustainable Groundwater Management Act and recent efforts by county planning departments, have yet to address the complex technical and regulatory issues associated with avoiding or mitigating existing cumulative impacts and permitting for new wells. Additionally, existing state-wide legislation manages groundwater only in large groundwater basins like the Central Valley, neglecting the essential role of hillslope groundwater systems in the small headwater watersheds that support salmon populations. Increasingly, groundwater infiltration and recharge projects are being proposed, but securing permits for restoration actions and predicting the benefits of actions are not always straightforward. This session will address three main challenges and explore solutions regarding groundwater modeling of streamflow depletion in diverse (geology, biome, etc.) landscapes; designing and permitting infiltration and flood recharge projects; and efforts to develop county groundwater well ordinances to protect public trust resources.

Presentations

Evaluating the Hydrologic Effects of Scott and Shasta River Irrigation Curtailments Using Remote Sensing and Streamflow Gages

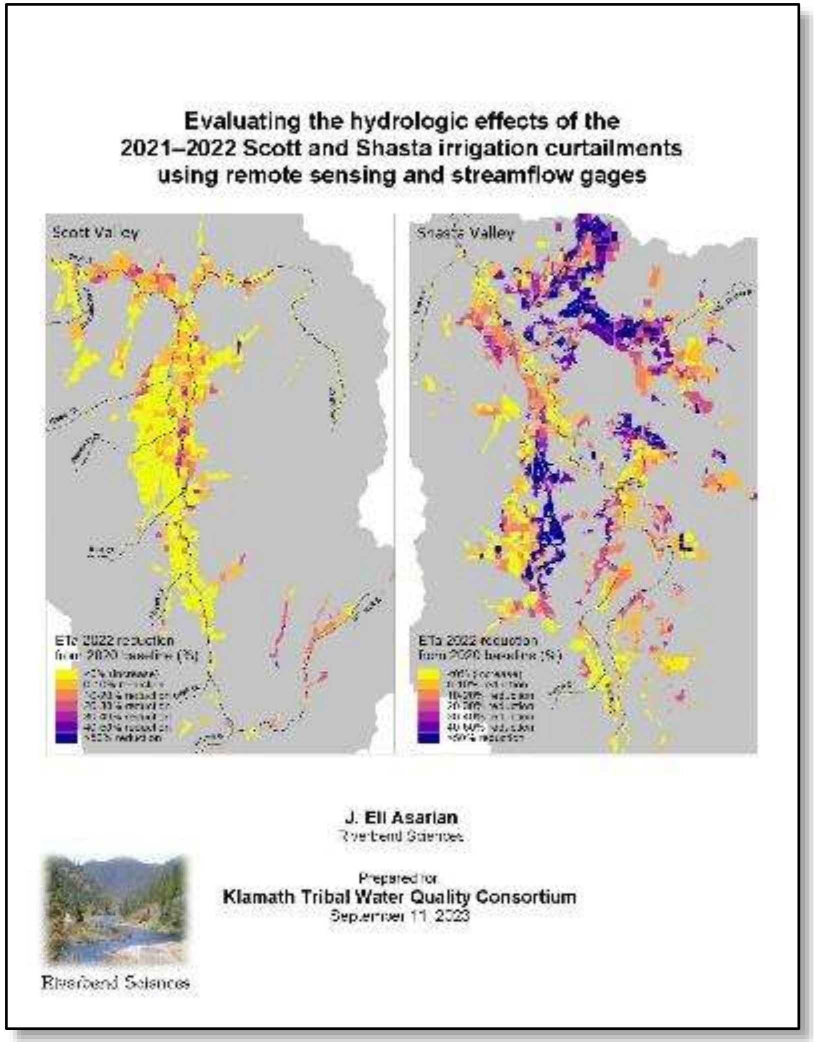
Bronwen Stanford &
Nicholas Murphy
The Nature Conservancy

Eli Asarian
Riverbend Sciences

Michael Pollock
NOAA Fisheries

SRF Conference
3/28/2024, Santa Rosa, CA

Technical report
completed 9/11/2023
https://www.riverbendsci.com/reports-and-publications

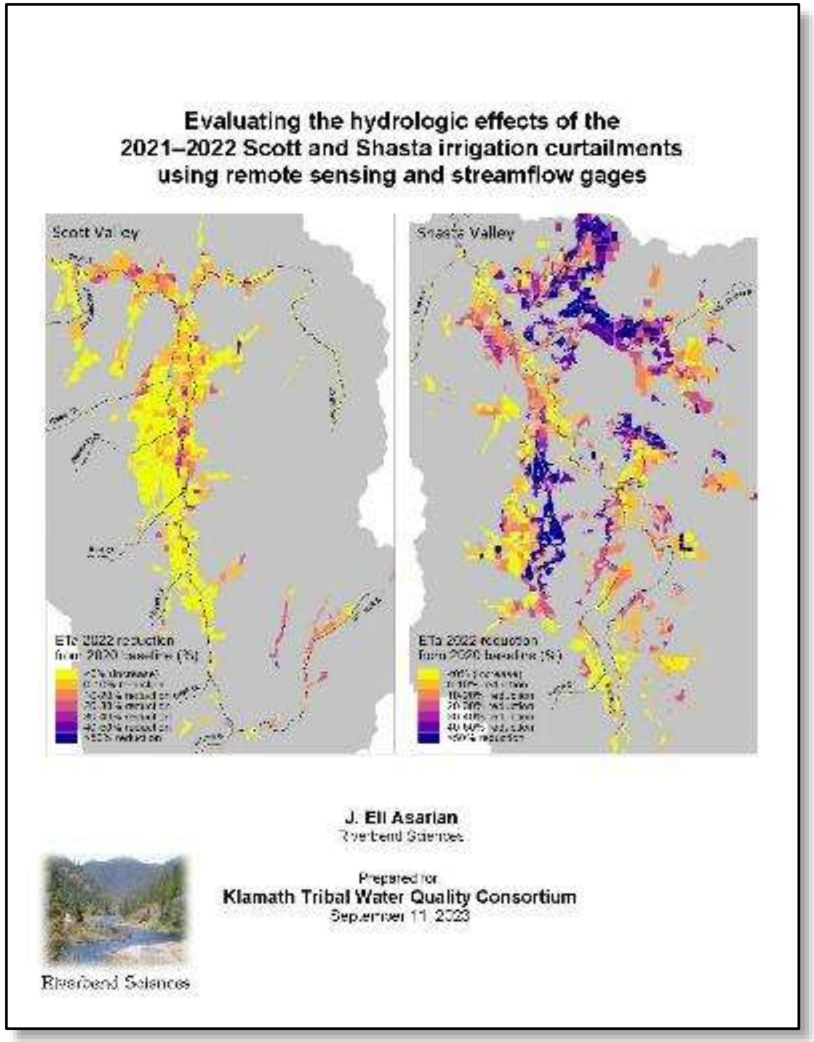

Evaluating the hydrologic effects of the
2021–2022 Scott and Shasta irrigation curtailments
using remote sensing and streamflow gages

J. Eli Asarian
Riverbend Sciences

Prepared for
Klamath Tribal Water Quality Consortium
September 11, 2023

Riverbend Sciences

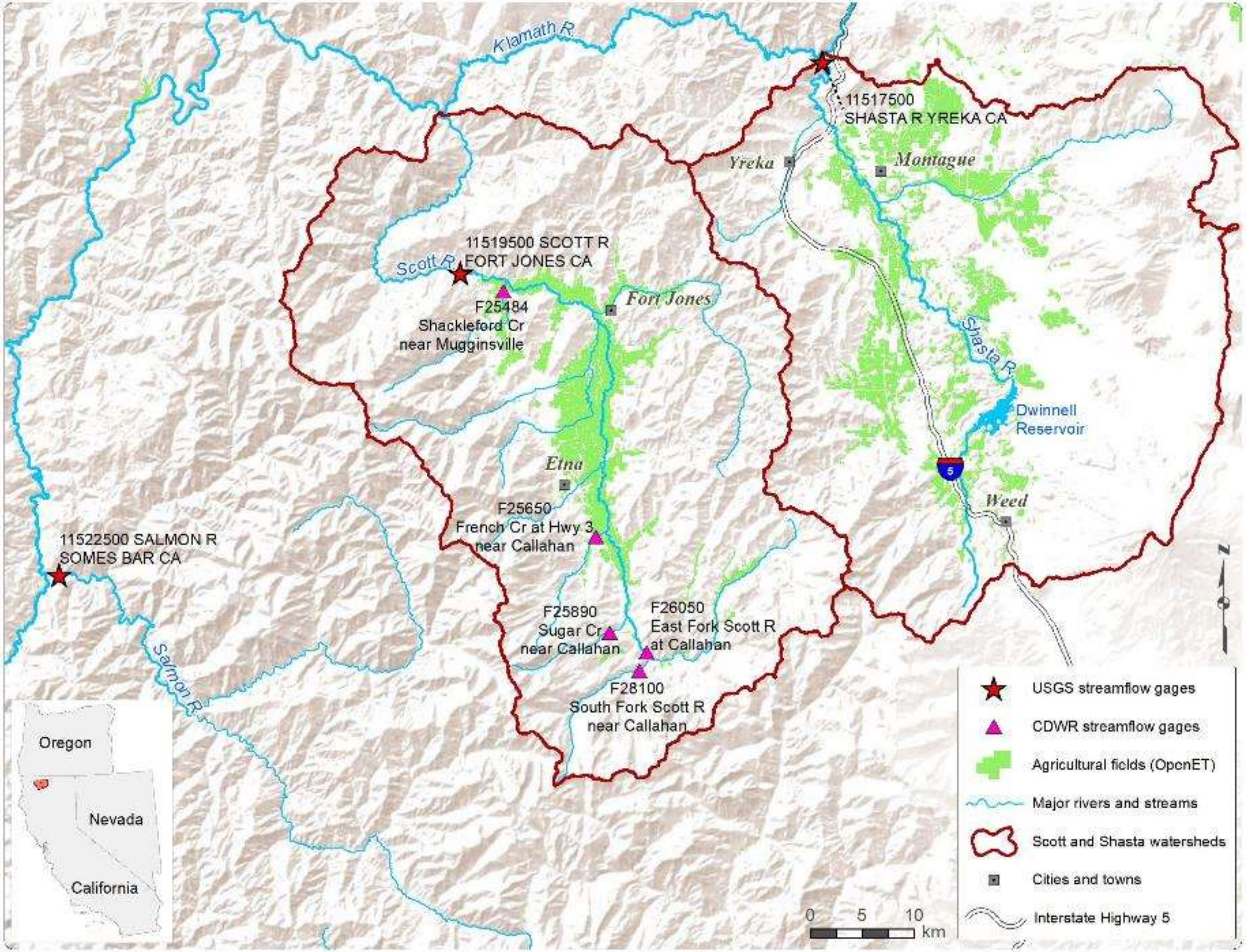
Technical report
completed 9/11/2023
https://www.riverbendsci.com/reports-and-publications



Peer-review manuscript in prep

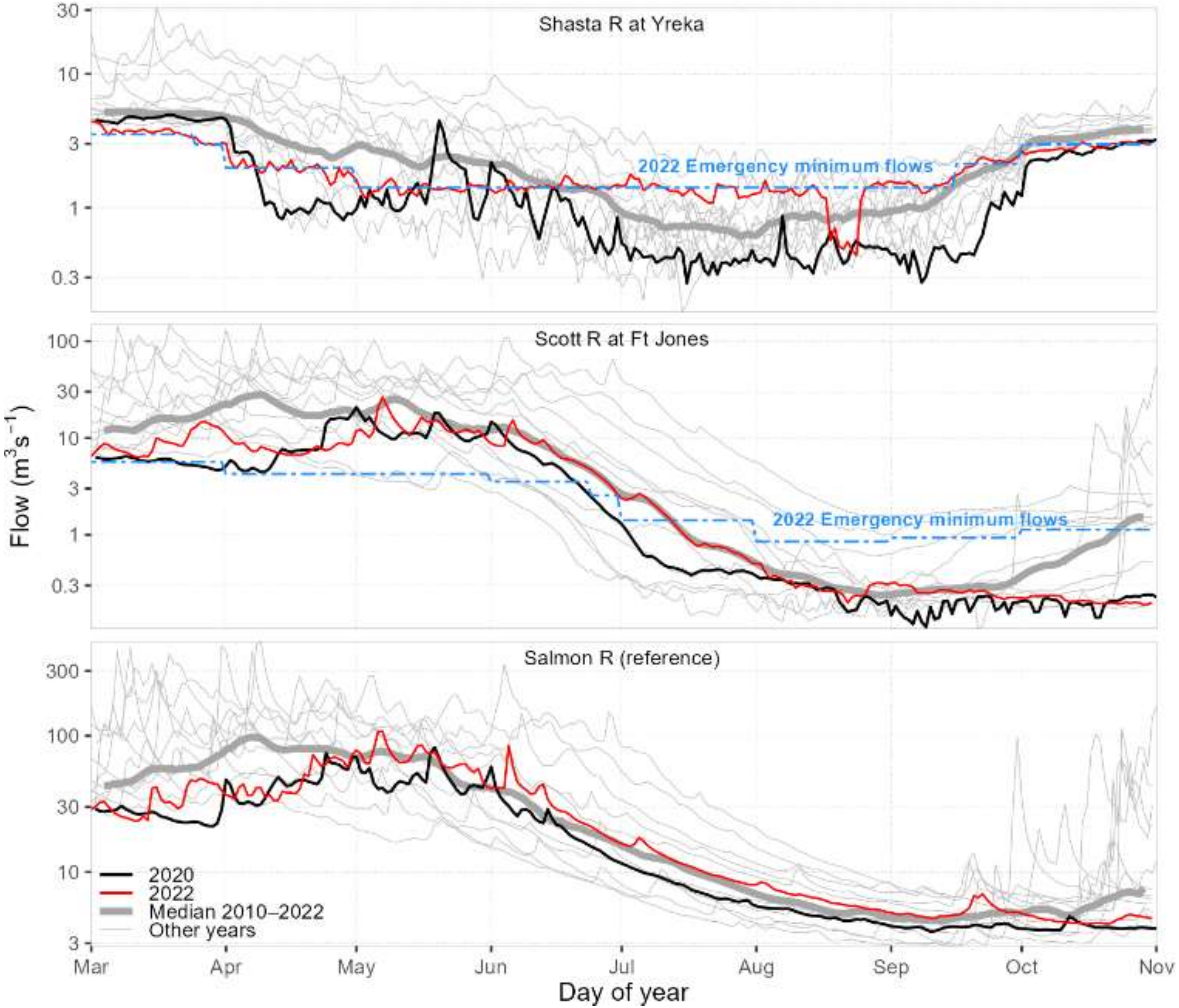
Authors:
Eli Asarian, Riverbend Sciences
Bronwen Stanford and Nicholas Murphy, The Nature Conservancy
Michael Pollock, NOAA Fisheries

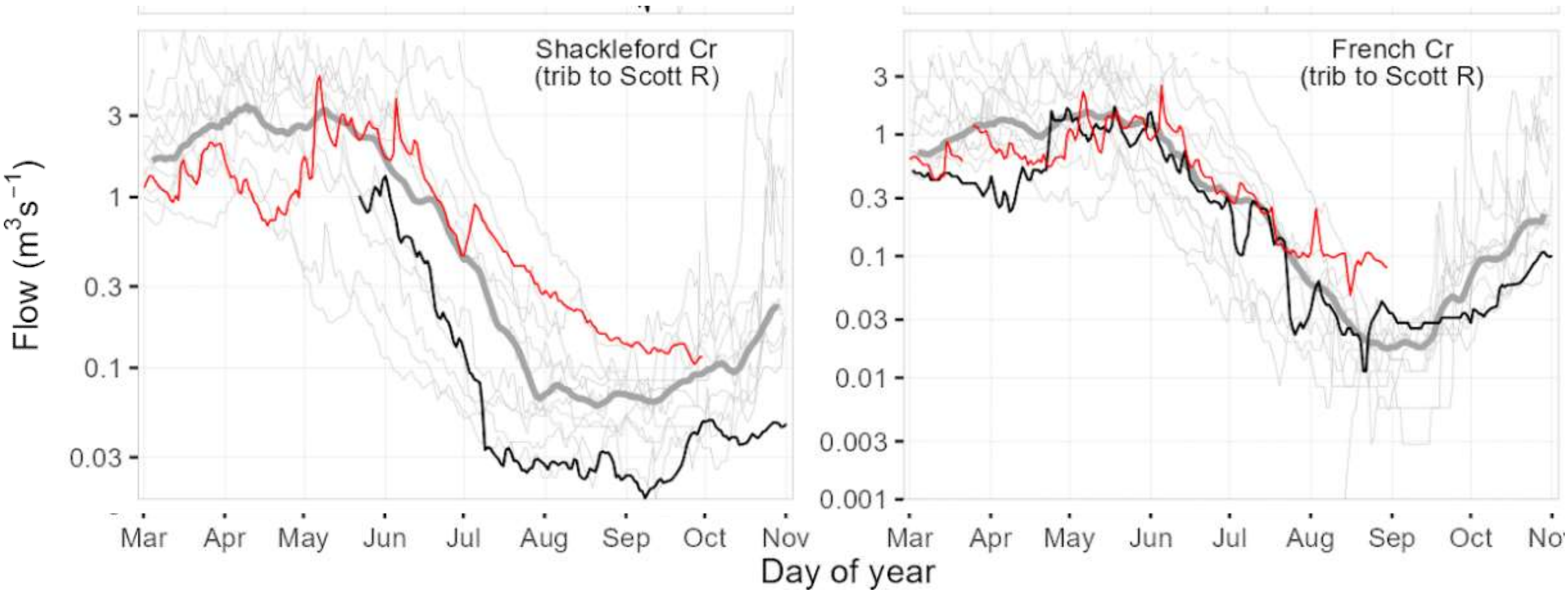
RESULTS PROVISIONAL!



Klamath R
11517500
SHASTA R YREKA CA
Yreka
Montague
11519500 SCOTT R
FORT JONES CA
Scott R
F25484
Shackleford Cr
near Mugginsville
Fort Jones
Shasta R
Dwinnell
Reservoir
5
Etna
Weed
F25650
French Cr at Hwy 3
near Callahan
11522500 SALMON R
SOMES BAR CA
F25890
Sugar Cr
near Callahan
F26050
East Fork Scott R
at Callahan
F28100
South Fork Scott R
near Callahan
Salmon R
Oregon
Nevada
California
USGS streamflow gages
CDWR streamflow gages
Agricultural fields (OpenET)
Major rivers and streams
Scott and Shasta watersheds
Cities and towns
Interstate Highway 5
0 5 10 km

- Drought emergency
- SWRCB emergency regs
- 2022 Shasta curtailment
  - By priority date
- 2022 Scott curtailment
  - Surface water July 1
  - Groundwater July 14
    - Continued pumping with water conservation agreements

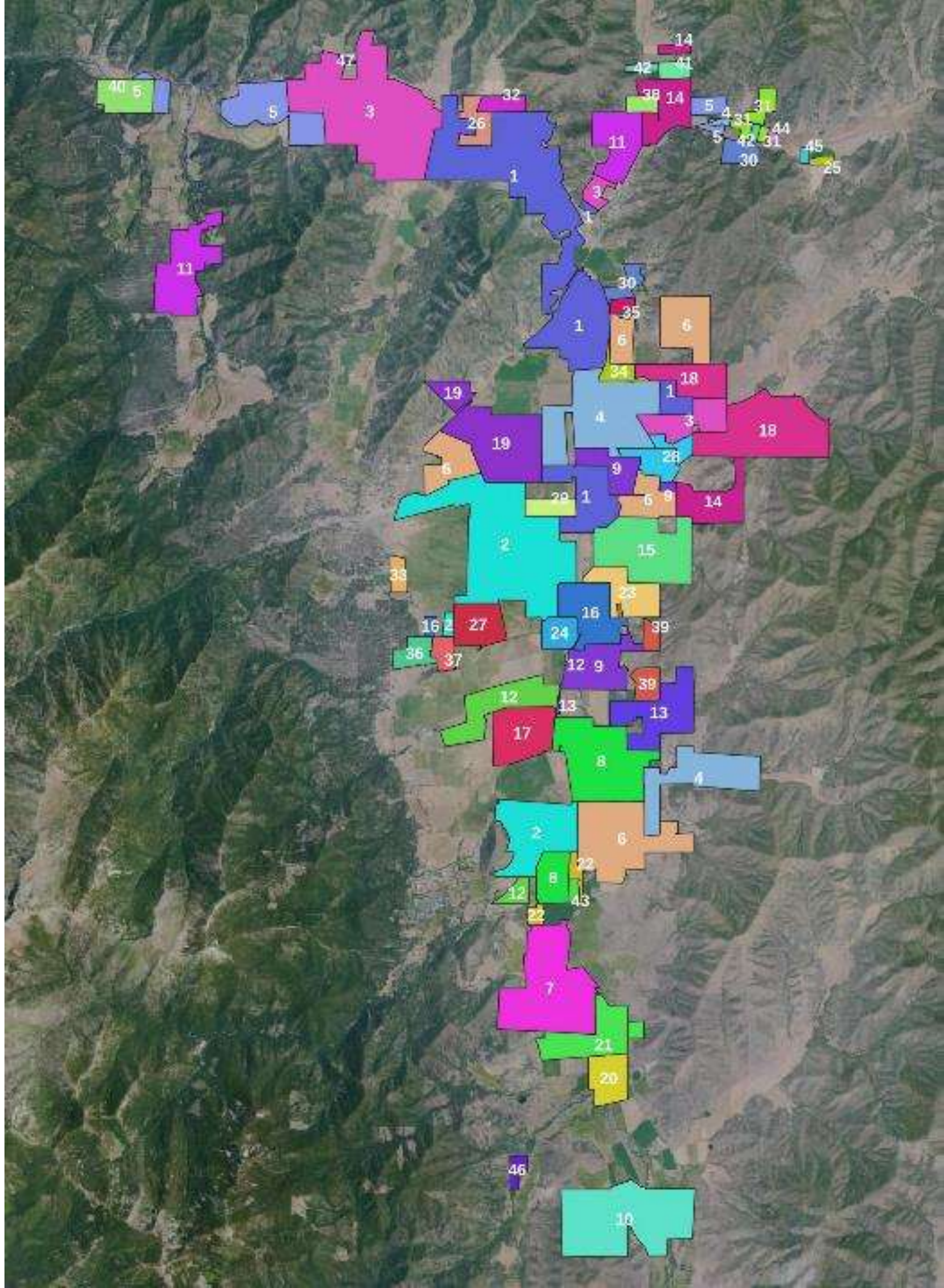




Shackleford Cr
(trib to Scott R)
French Cr
(trib to Scott R)
Flow (m^3s^{-1})
3
1
0.3
0.1
0.03
0.01
0.003
0.001
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Day of year

2022 Water Conservation Agreements

- 47 of 50 are Scott groundwater
- Reduce 2022 pumping from 2020 by 30% during irrigation season:
  - Irrigation efficiency
  - Alfalfa → grain
  - Fallow fields/corners
  - Reduced cuttings
- Self-reported pumping, some oversight
- ≥90 percent of groundwater acres



Remote Sensing

Remote sensing tools

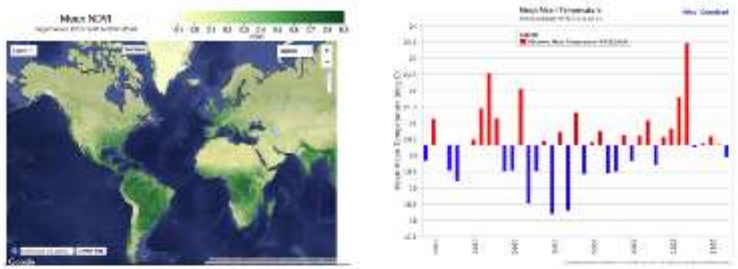
(See tutorials at https://www.riverbendsci.com/projects/remote-sensing)

OPENET

https://openetdata.org/

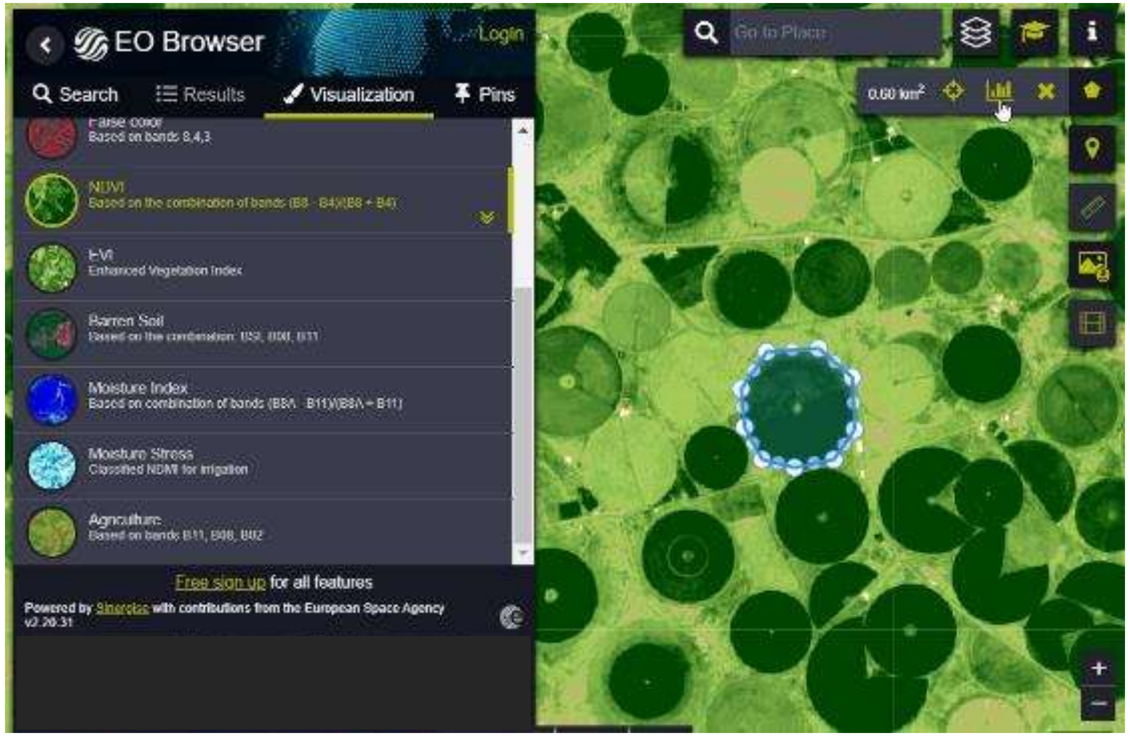
ClimateEngine.org

Cloud Computing of Climate and Remote Sensing Data



sentinelhub

https://apps.sentinel-hub.com/eo-browser




USDA
NAIP aerial
1-3 years
≤1m resolution

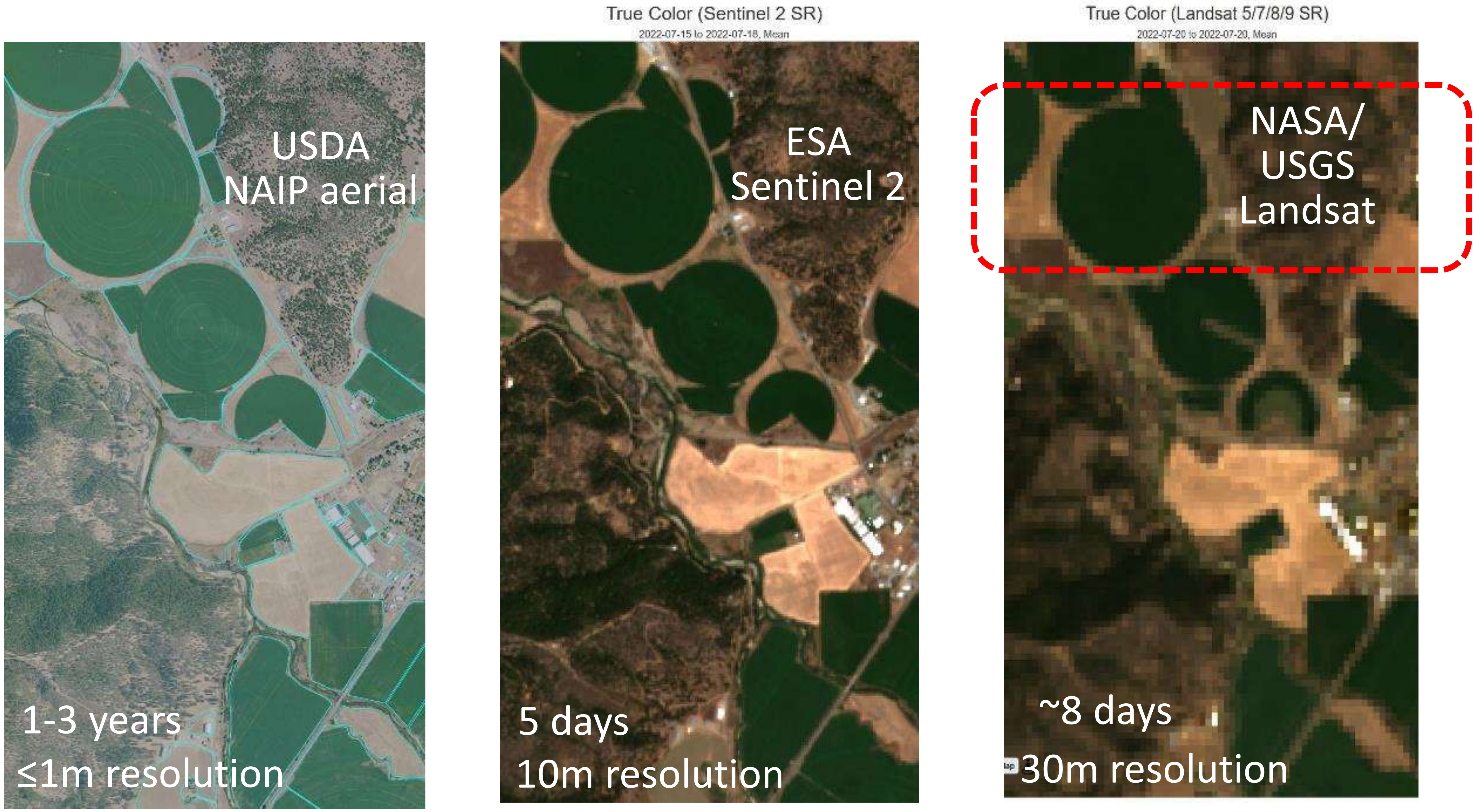

USDA
NAIP aerial
1-3 years
≤1m resolution


True Color (Sentinel 2 SR)
2022-07-15 to 2022-07-18, Mean
ESA
Sentinel 2
5 days
10m resolution


USDA
NAIP aerial
1-3 years
≤1m resolution


True Color (Sentinel 2 SR)
2022-07-15 to 2022-07-18, Mean
ESA
Sentinel 2
5 days
10m resolution


True Color (Landsat 5/7/8/9 SR)
2022-07-20 to 2022-07-20, Mean
NASA/
USGS
Landsat
~8 days
30m resolution



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True Color (Sentinel 2 SR)
2022-07-15 to 2022-07-18, Mean
ESA
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5 days
10m resolution
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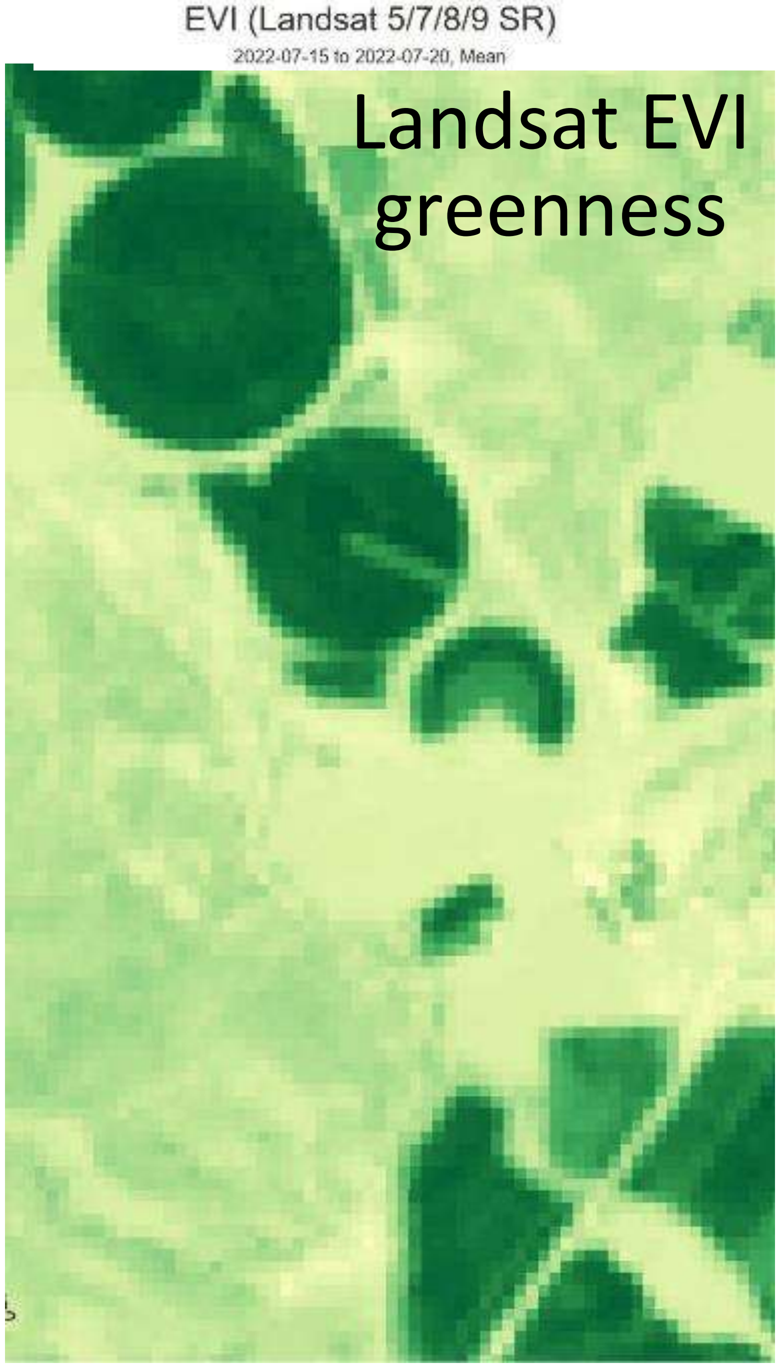
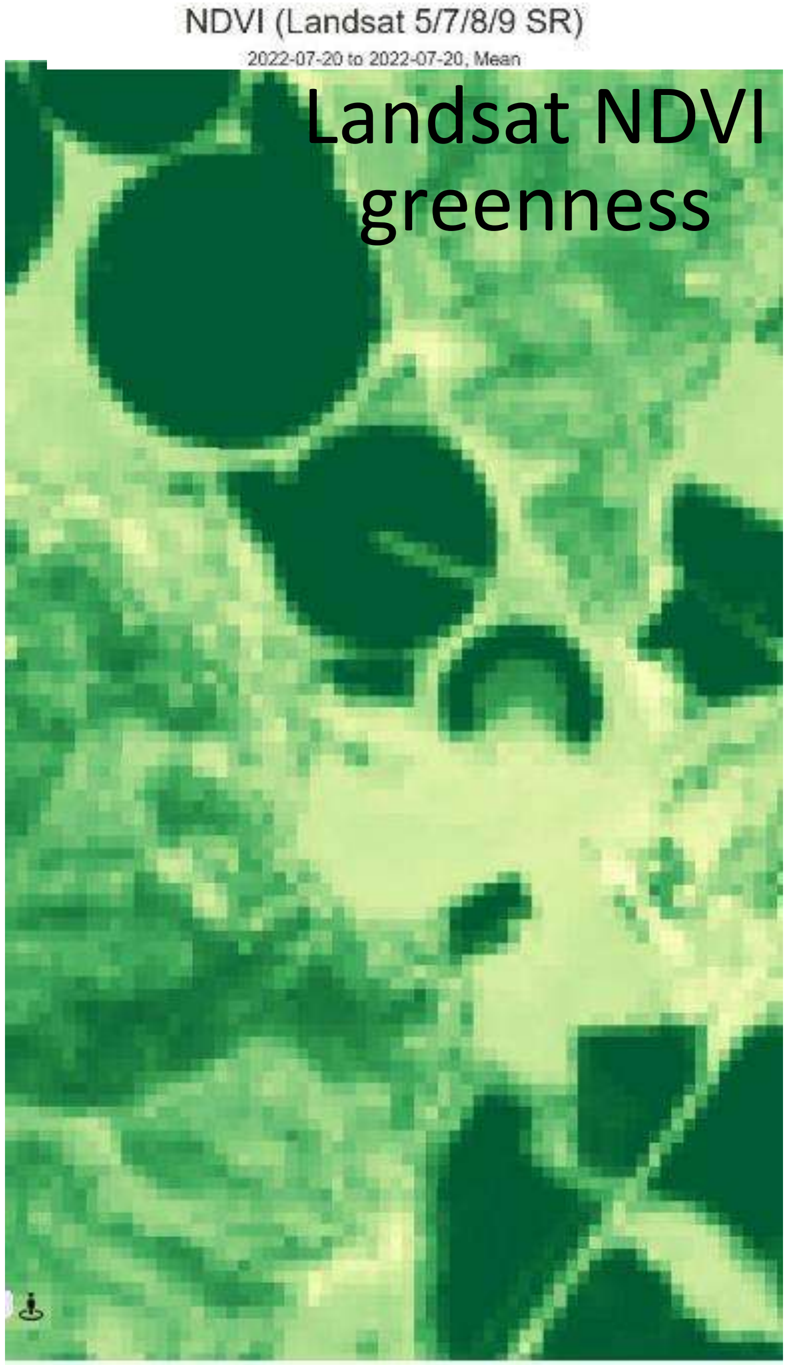
~8 days
30m resolution

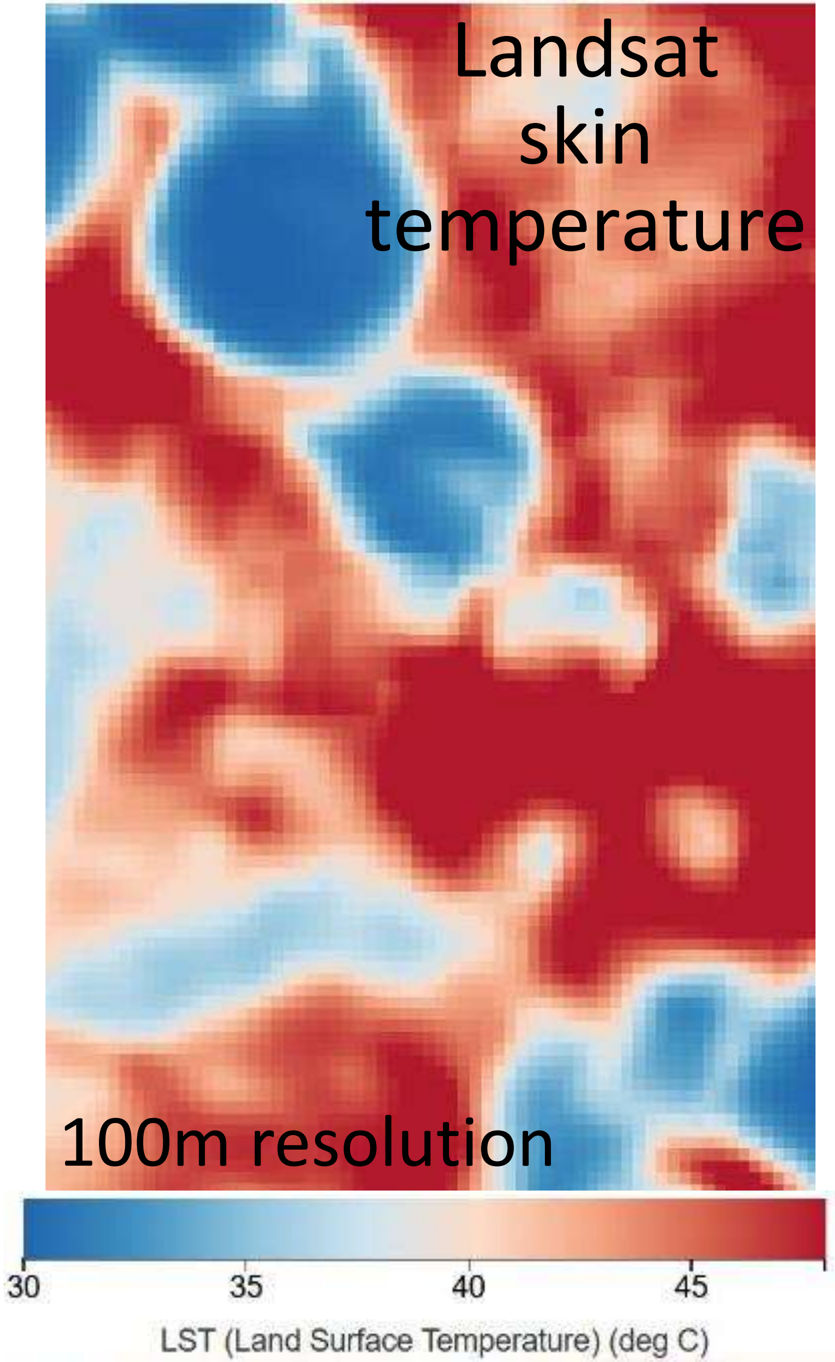
True Color (Landsat 5/7/8/9 SR)

2022-07-20 to 2022-07-20, Mean

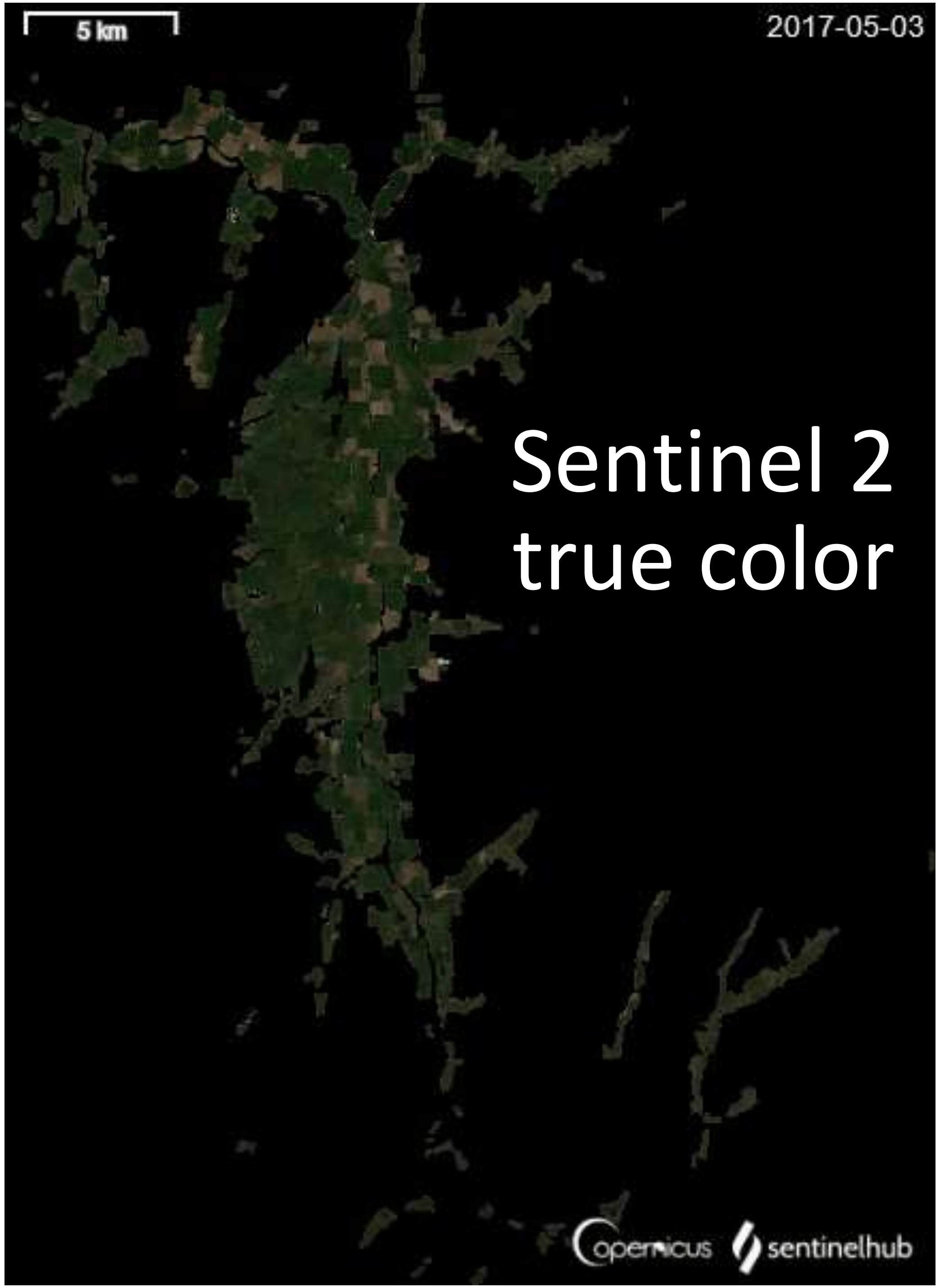

EVI (Landsat 5/7/8/9 SR)
2022-07-15 to 2022-07-20, Mean
Landsat EVI greenness

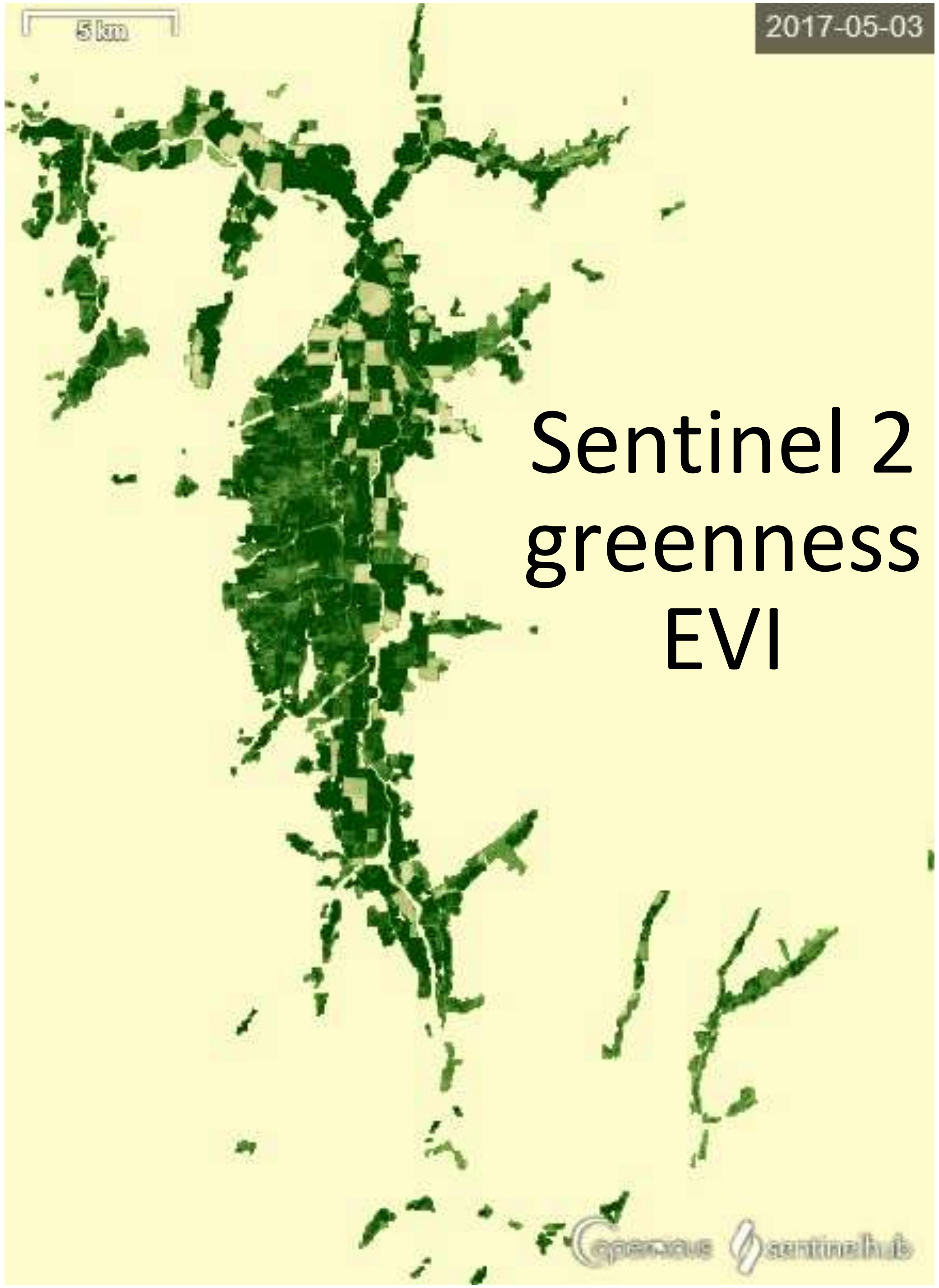

NDVI (Landsat 5/7/8/9 SR)
2022-07-20 to 2022-07-20, Mean
Landsat NDVI greenness

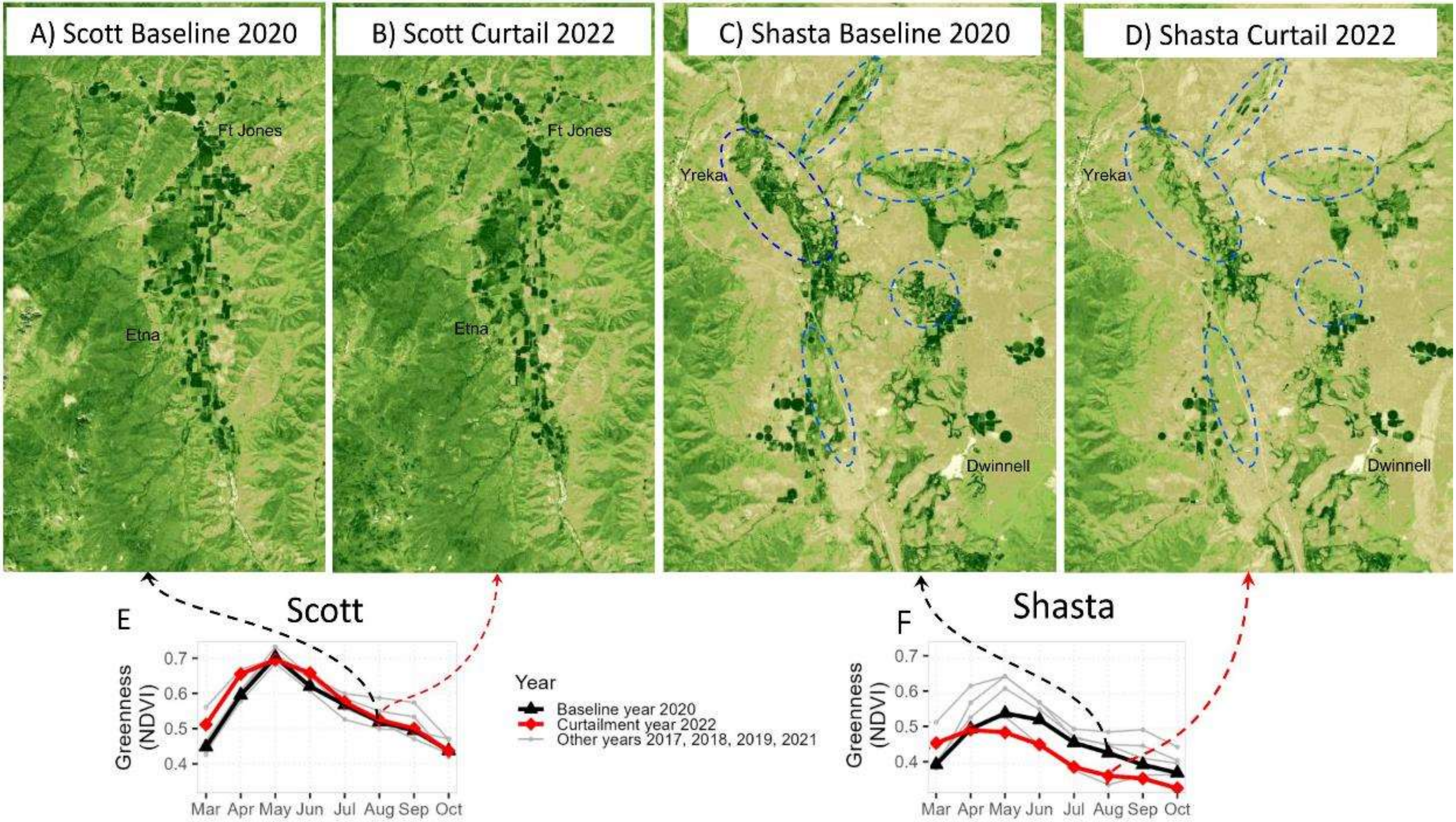

True Color (Landsat 5/7/8/9 SR)
2022-07-20 to 2022-07-20, Mean
Landsat True Color

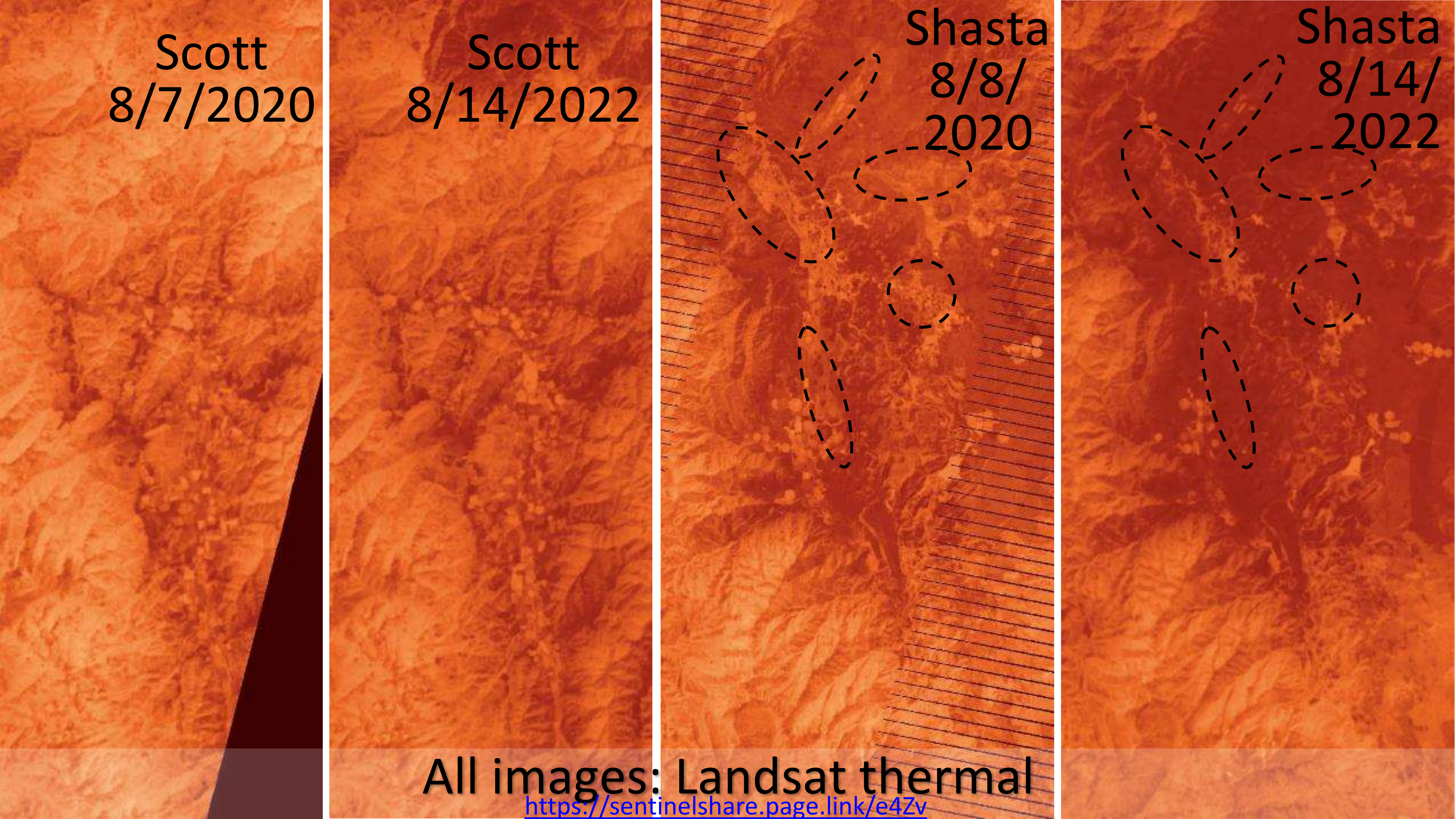

Landsat
skin
temperature
100m resolution
30
35
40
45
LST (Land Surface Temperature) (deg C)


True Color (Landsat 5/7/8/9 SR)
2022-07-20 to 2022-07-20, Mean
Landsat
True Color
30m resolution


5 km
2017-05-03
Sentinel 2
true color
sentinelhub


5 km
2017-05-03
Sentinel 2
greenness
EVI


A) Scott Baseline 2020
B) Scott Curtail 2022
C) Shasta Baseline 2020
D) Shasta Curtail 2022
Ft Jones
Etna
Yreka
Dwinnell
E
Scott
F
Shasta
Greenness (NDVI)
0.7
0.6
0.5
0.4
Mar Apr May Jun Jul Aug Sep Oct
Year
Baseline year 2020
Curtailment year 2022
Other years 2017, 2018, 2019, 2021


Scott
8/7/2020
Scott
8/14/2022
Shasta
8/8/
2020
Shasta
8/14/
2022
All images: Landsat thermal
https://sentinelshare.page.link/e4Zv

What are:

Evapotranspiration (ET),

Consumptive use,

& Irrigation efficiency?

How do they affect water budgets?

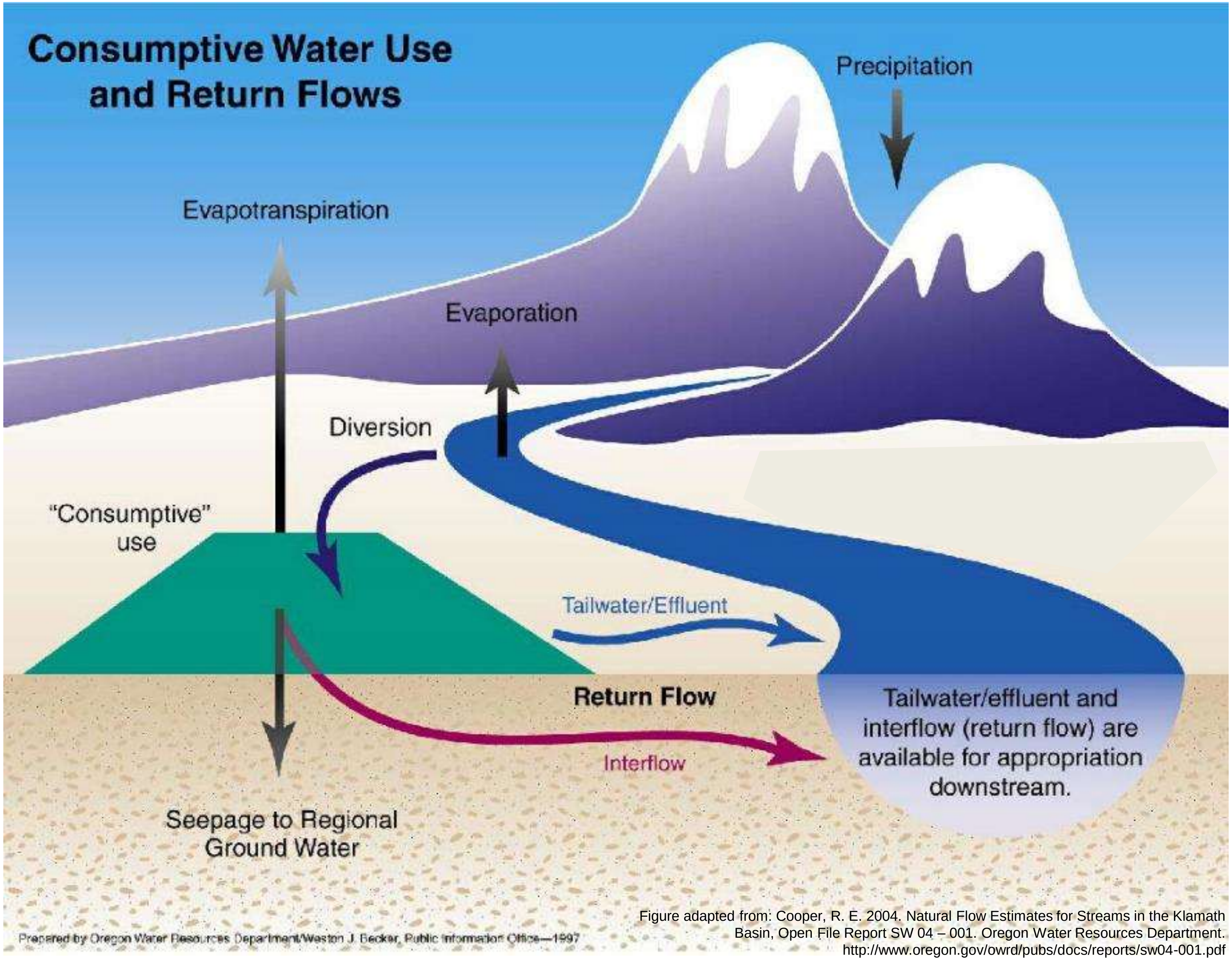
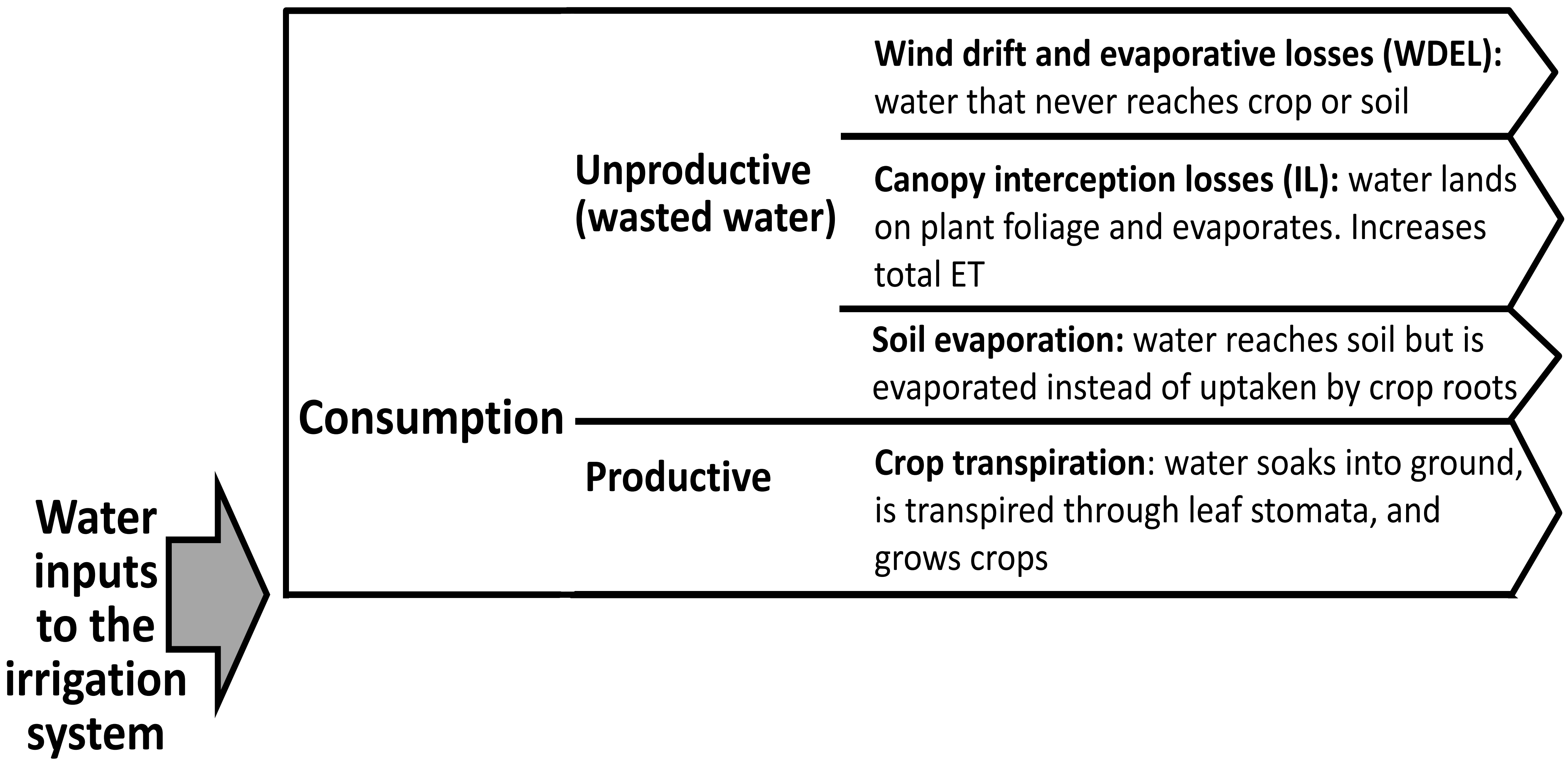
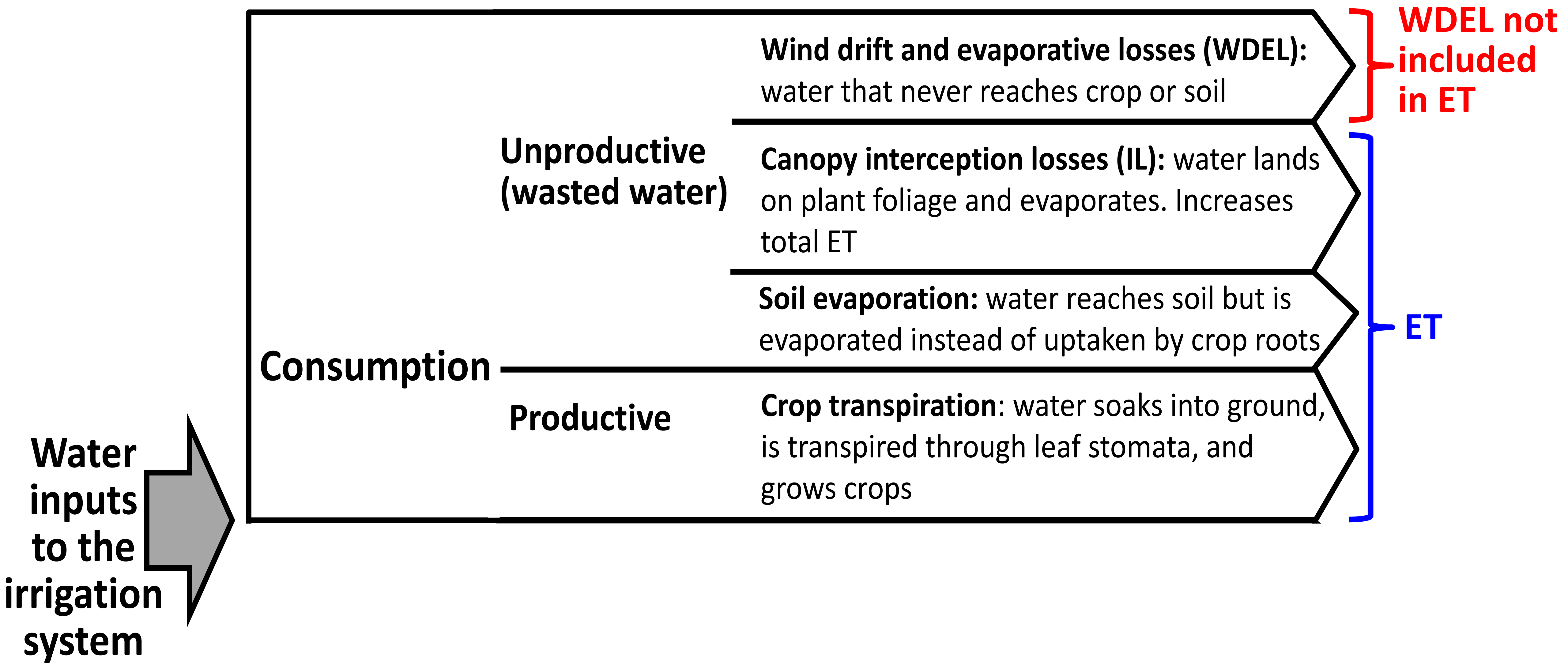


Figure adapted from: Cooper, R. E. 2004. Natural Flow Estimates for Streams in the Klamath Basin, Open File Report SW 04 – 001. Oregon Water Resources Department. http://www.oregon.gov/owrd/pubs/docs/reports/sw04-001.pdf


Wind drift and evaporative losses (WDEL): water that never reaches crop or soil
Unproductive (wasted water)
Canopy interception losses (IL): water lands on plant foliage and evaporates. Increases total ET
Soil evaporation: water reaches soil but is evaporated instead of uptaken by crop roots
Consumption
Productive
Crop transpiration: water soaks into ground, is transpired through leaf stomata, and grows crops
Water inputs to the irrigation system



Wind drift and evaporative losses (WDEL): water that never reaches crop or soil
WDEL not included in ET
Unproductive (wasted water)
Canopy interception losses (IL): water lands on plant foliage and evaporates. Increases total ET
Soil evaporation: water reaches soil but is evaporated instead of uptaken by crop roots
ET
Consumption
Productive
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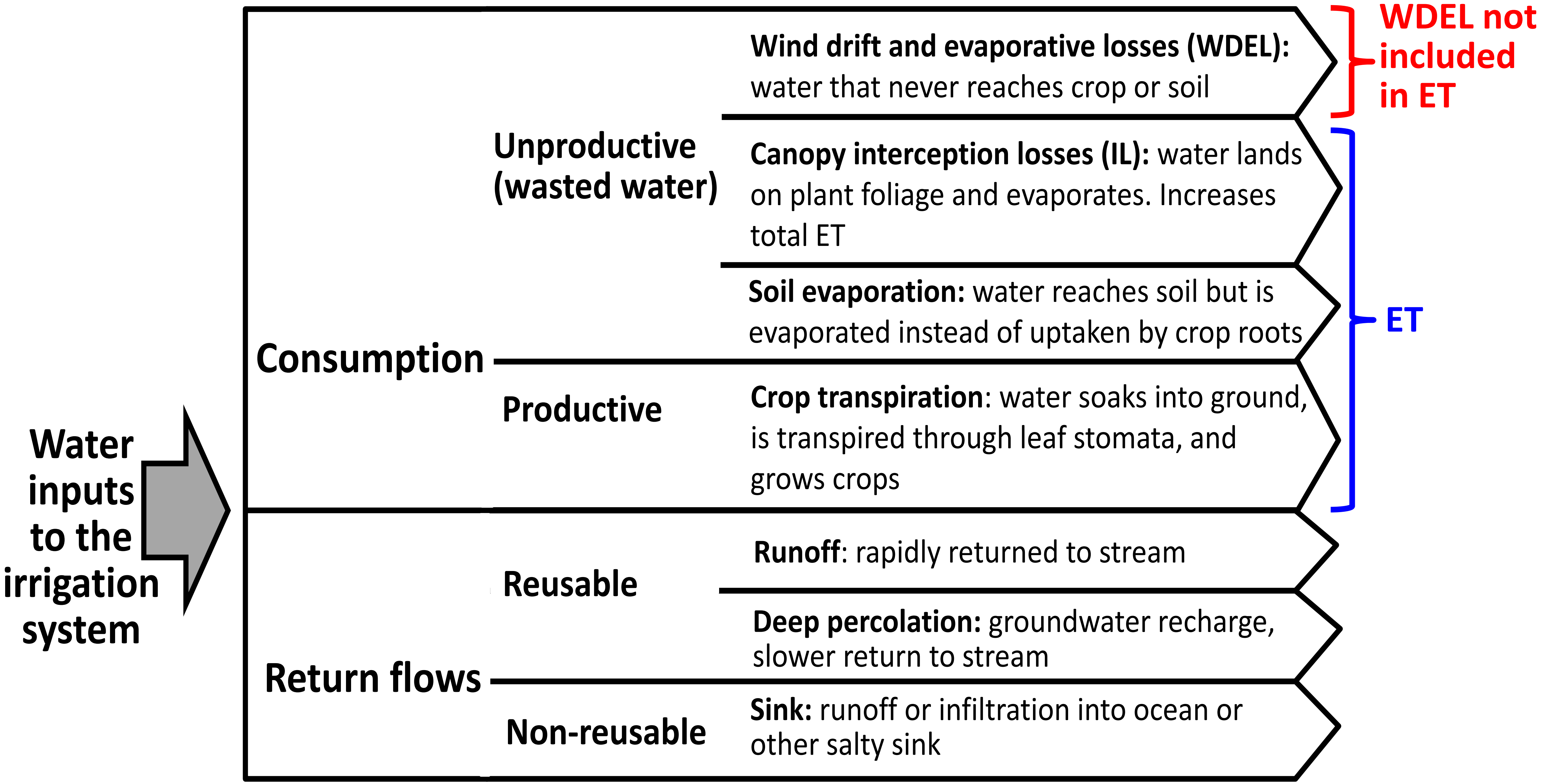
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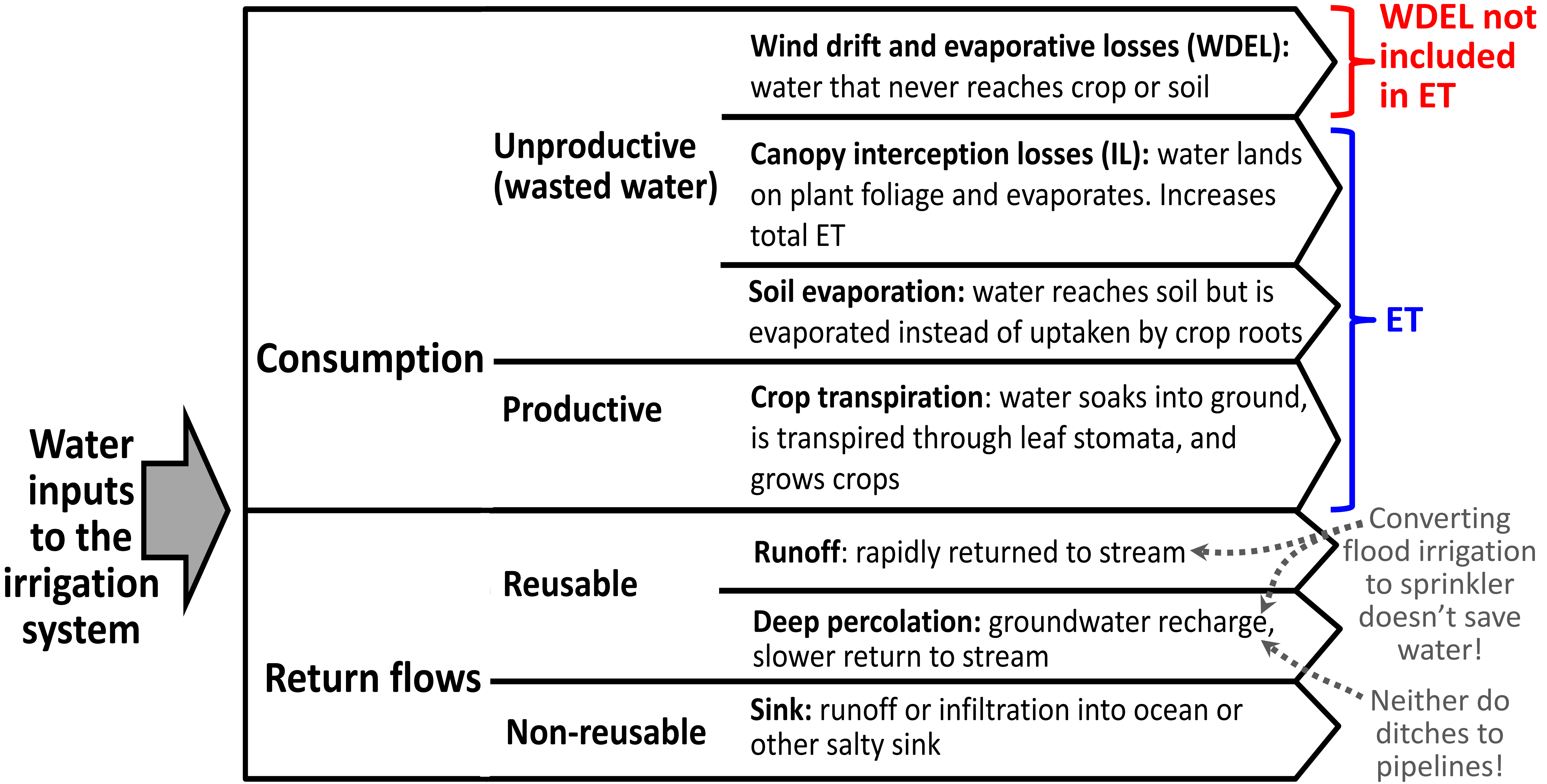
Soil evaporation: water reaches soil but is evaporated instead of uptaken by crop roots
Productive
Crop transpiration: water soaks into ground, is transpired through leaf stomata, and grows crops
Return flows
Reusable
Runoff: rapidly returned to stream
Deep percolation: groundwater recharge, slower return to stream
Non-reusable
Sink: runoff or infiltration into ocean or other salty sink
WDEL not included in ET
ET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Non-reusable
Sink: runoff or infiltration into ocean or other salty sink
WDEL not included in ET
ET
Converting flood irrigation to sprinkler doesn't save water!
Neither do ditches to pipelines!

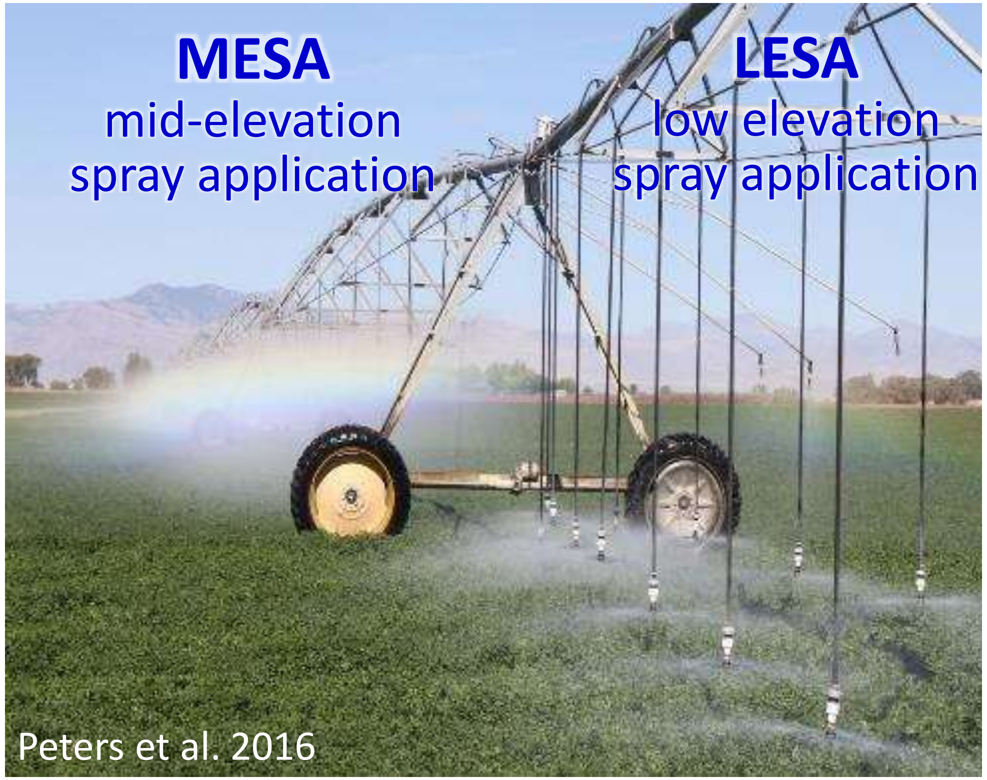
The More You Expose, the More You Lose:
Limiting Center Pivot Irrigation Water Losses

Sarwar and Peters

~5-20%?

More consumptive use → **Less consumptive use**

High-pressure impact sprinkler



LEPA
Low energy precision application

Move sprinklers as close to the ground as possible

Decrease pressure

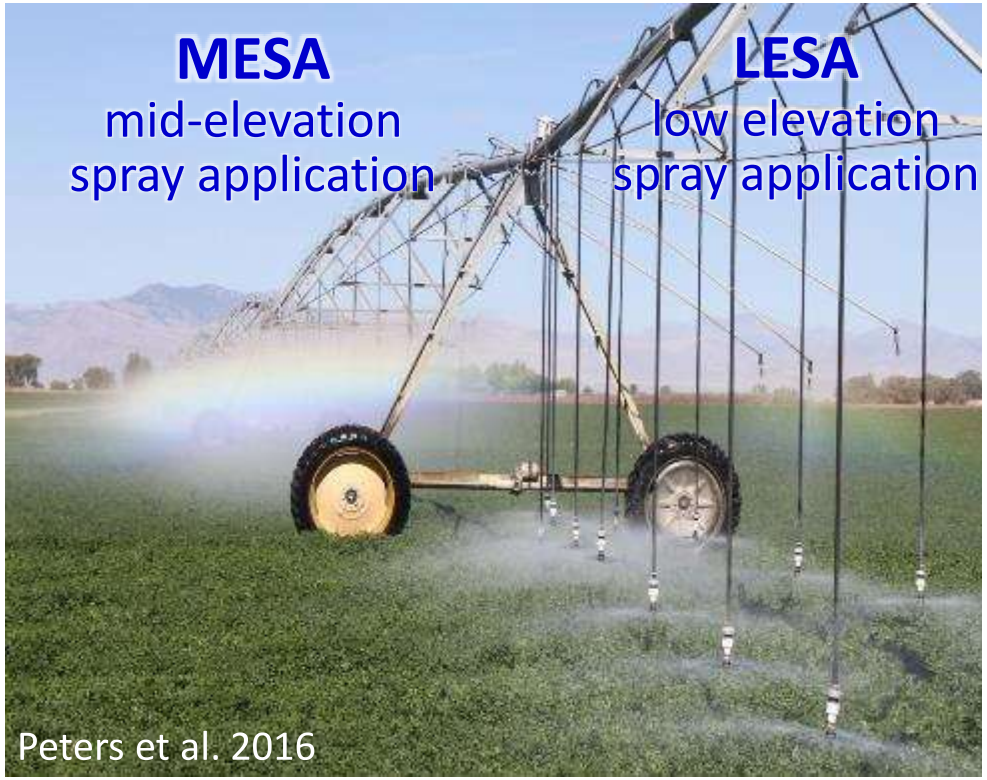
Increase nozzle sizes

Large droplets, but don't compromise water distribution uniformity and runoff

~5-20%?

More consumptive use → **Less consumptive use**

High-pressure
impact sprinkler



LEPA
Low energy precision application

Estimating “actual evapotranspiration” (ETa)

Field measurements (hard)

Assuming fully-watered field: calculate reference evapotranspiration (ET_0 or ET_r, aka “evaporative demand”) from weather data, then multiply by crop coefficient

Remote sensing

OPENET

https://openetdata.org/

EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

Google Earth Engine

NASA

DRI

USGS

UNIVERSITY of NEBRASKA–LINCOLN

HabitatSeven®

USDA ARS

University of Idaho

UNIVERSITY OF MARYLAND 1856

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

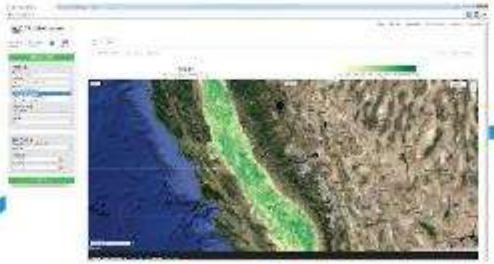
California State University
MONTEREY BAY

UFRGS
UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

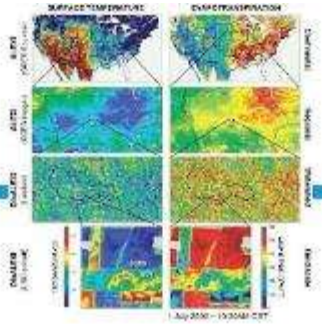
OPENET

https://openetdata.org/

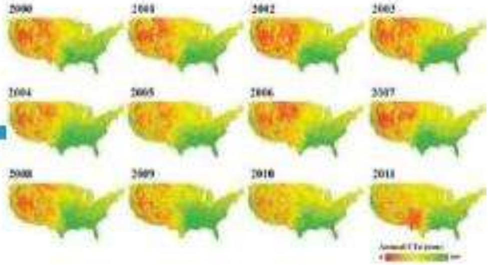
Ensemble average of 6 models



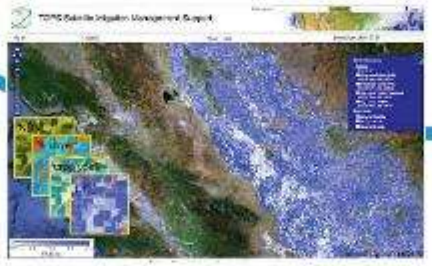
EE METRIC
University of Nebraska, University of Idaho



ALEXI/DisALEXI
USDA, NASA, University of Maryland, University of Wisconsin

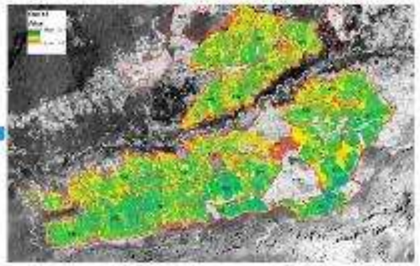


SSEBop
USGS

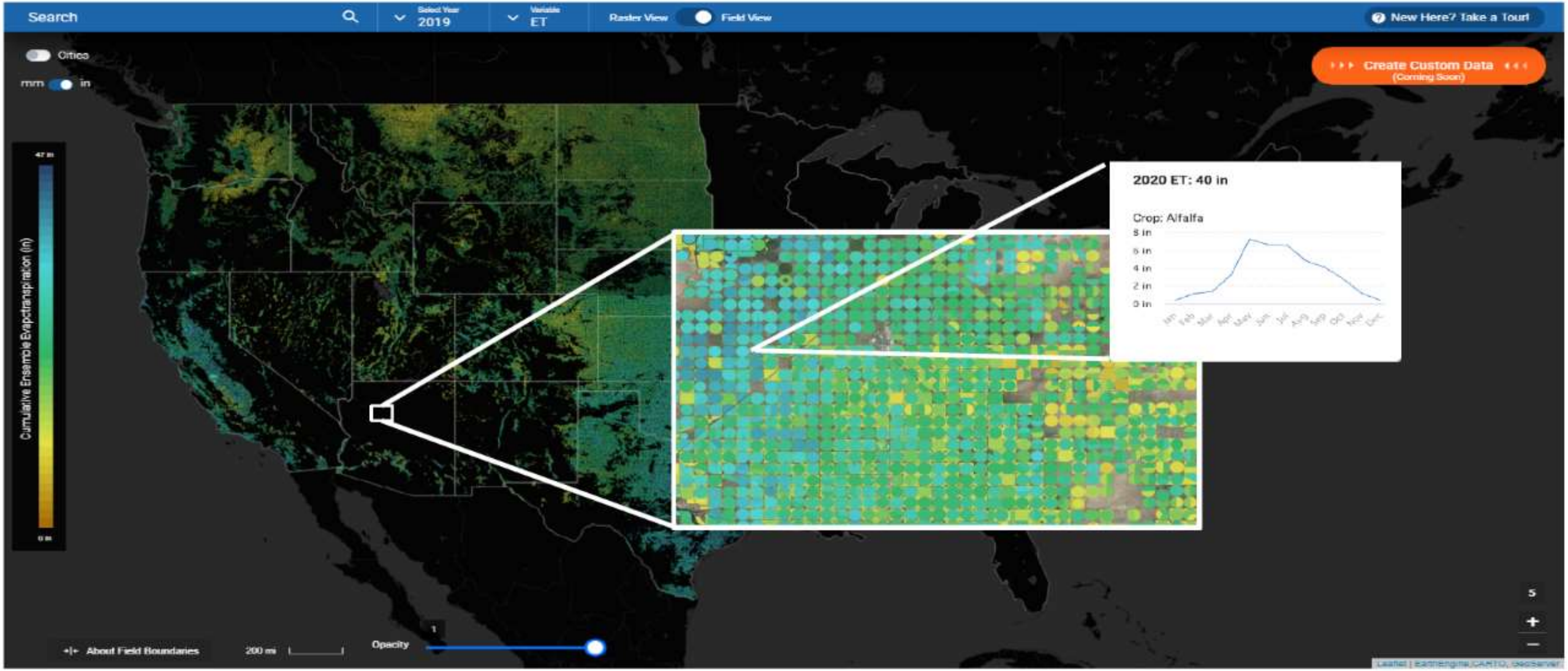


SIMS
NASA, CSUMB, Stanford University

PT-JPL
NASA



SEBAL



Time series for Scott/Shasta fields provided by OpenET’s Will Carrara

OPENET methods

Gridded weather data:
(mostly spatial CIMIS)

reference ET
(assumes fully watered crop)

OPENET methods

Satellites (mostly Landsat):
mostly skin temperature
(& greenness)

Gridded weather data:
(mostly spatial CIMIS)

% of reference ET
(including gap-filling)

reference ET
(assumes fully watered crop)

OPENET methods

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(including gap-filling)

reference ET
(assumes fully watered crop)

ET_a for each
30-meter pixel

OPENET methods

Satellites (mostly Landsat):
mostly skin temperature
(& greenness)

Gridded weather data:
(mostly spatial CIMIS)

GIS boundaries of
agricultural fields

% of reference ET
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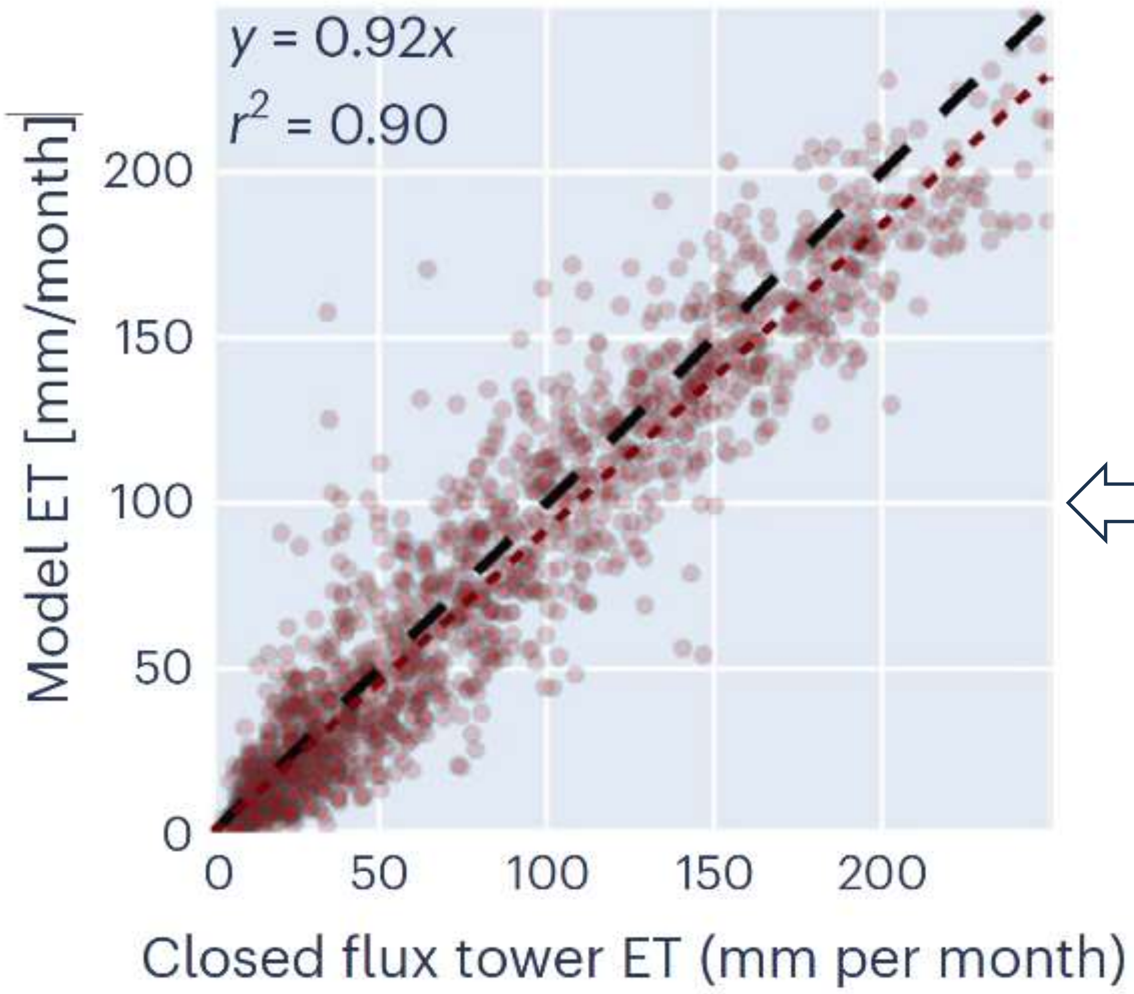
ET_a for each
30-meter pixel

ET_a for each
agricultural field

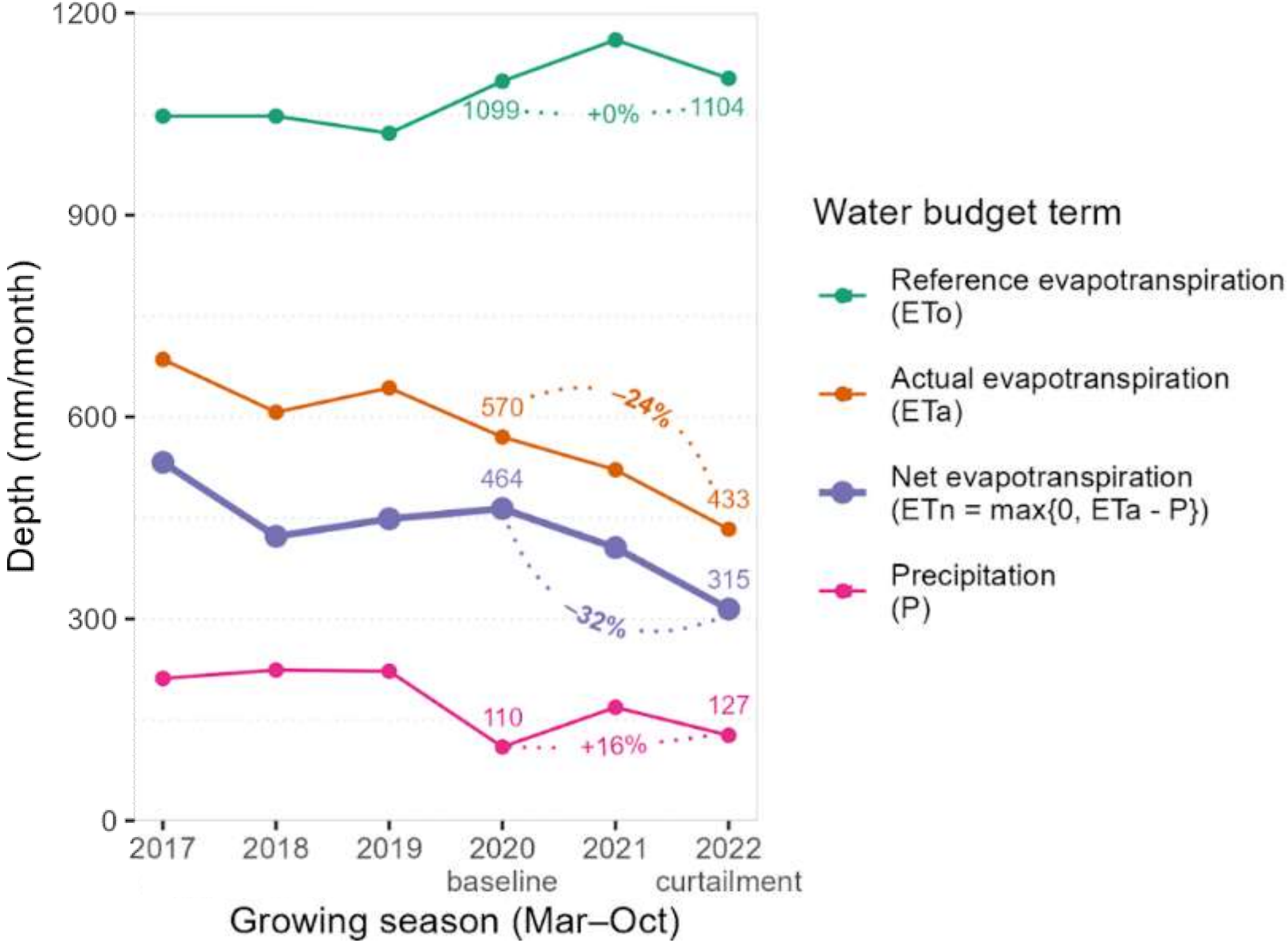
OPENET ETa validation: 53 cropland sites

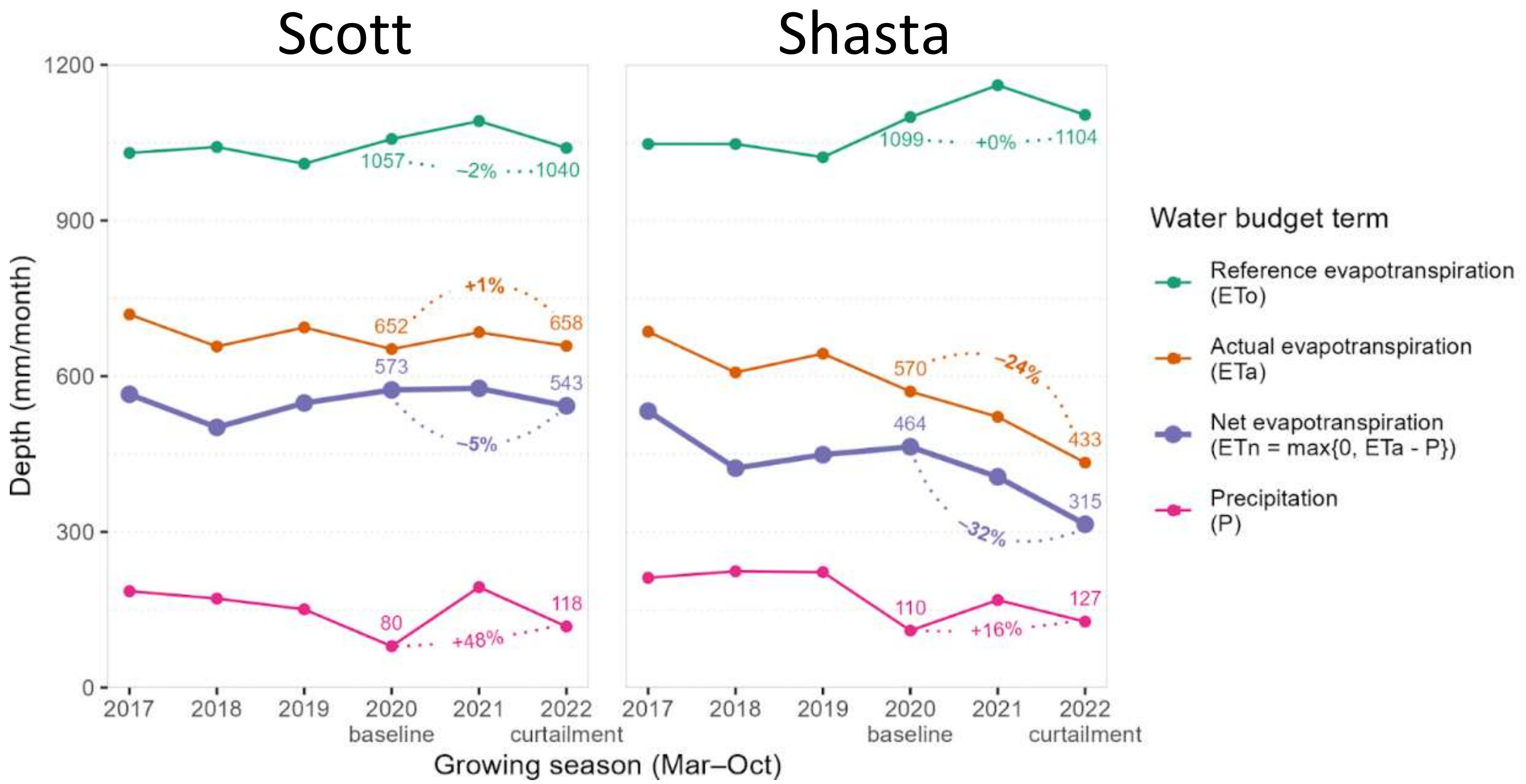


Time period	Average error (MAE)
Monthly	17%
Growing season	13%

Volk et al. 2024: https://doi.org/10.1038/s44221-023-00181-7

Shasta


1200
900
600
300
0
Depth (mm/month)
1099
+0%
1104
570
-24%
433
464
315
-32%
110
+16%
127
2017
2018
2019
2020
baseline
2021
2022
curtailment
Growing season (Mar–Oct)
Water budget term
Reference evapotranspiration (ETo)
Actual evapotranspiration (ETa)
Net evapotranspiration (ETn = max{0, ETa - P})
Precipitation (P)



Scott
Shasta
Depth (mm/month)
1200
900
600
300
0
1057
-2%
1040
1099
+0%
1104
+1%
652
658
570
-24%
433
573
543
-5%
464
315
-32%
80
+48%
118
110
+16%
127
2017
2018
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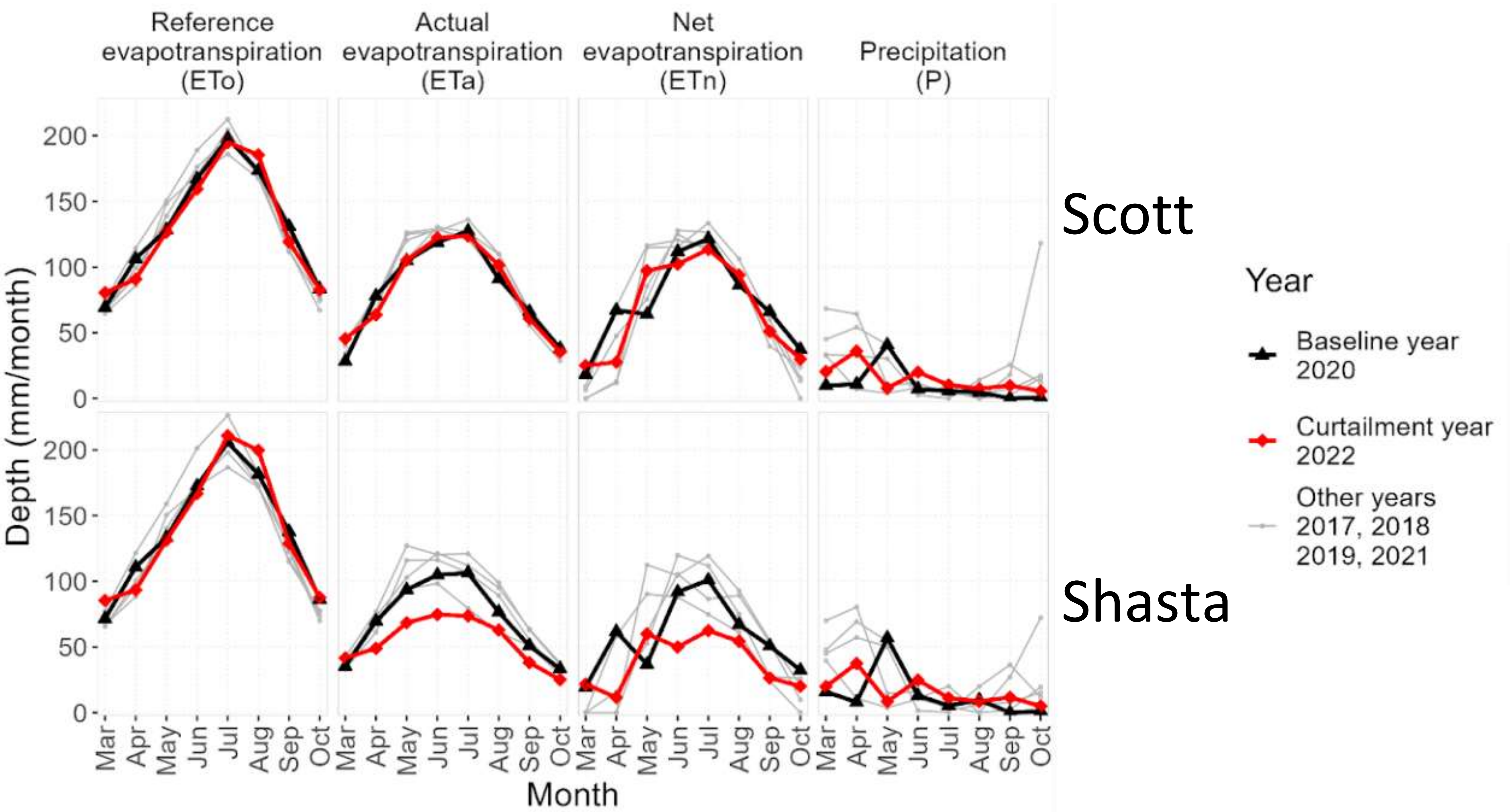
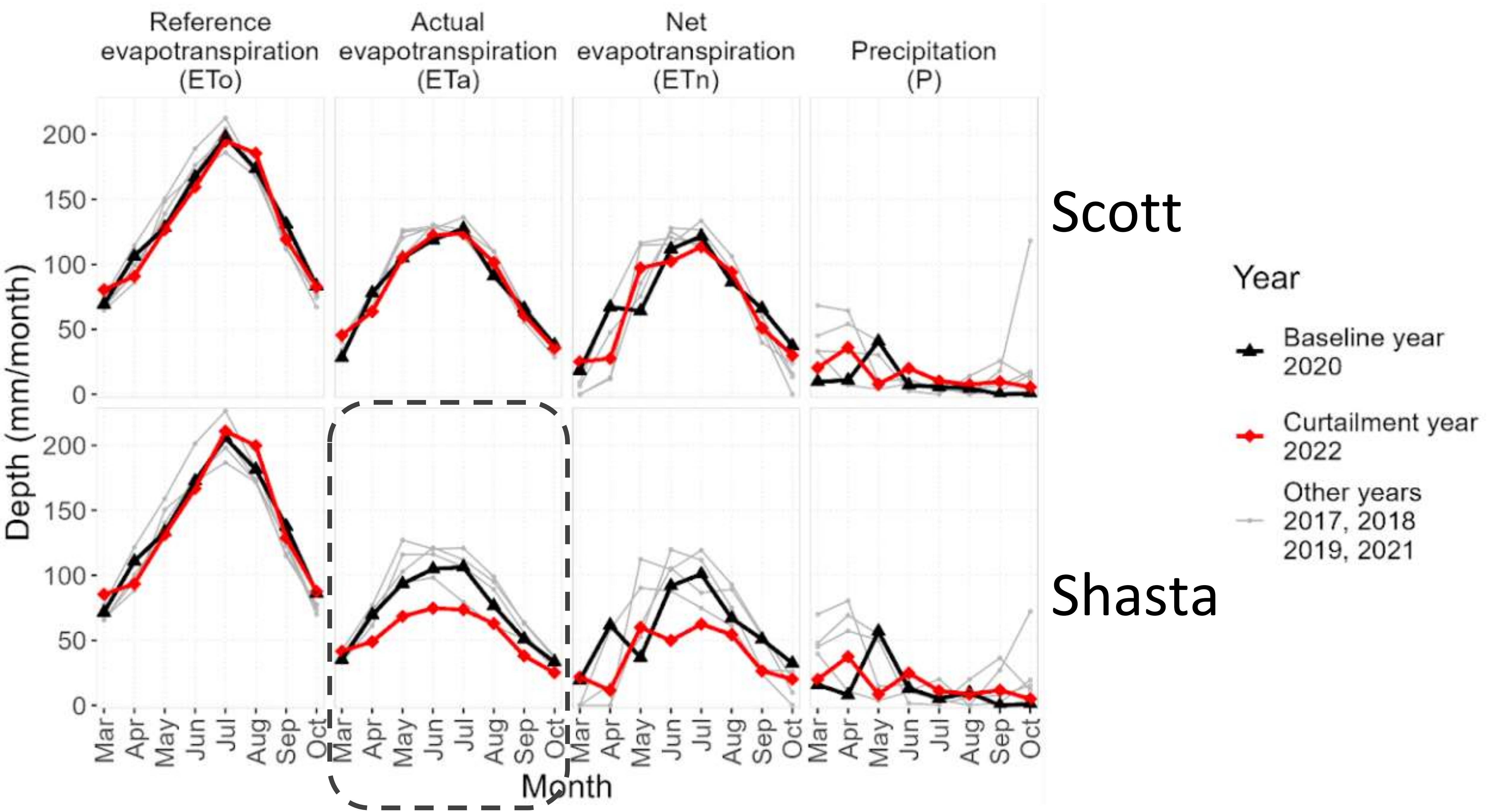
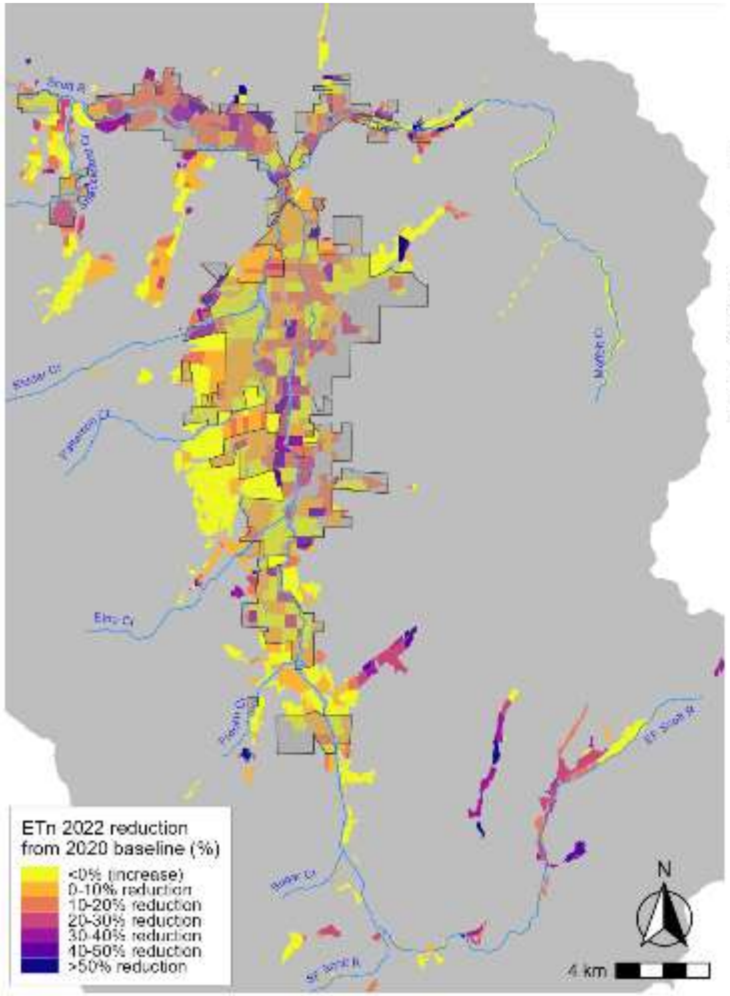
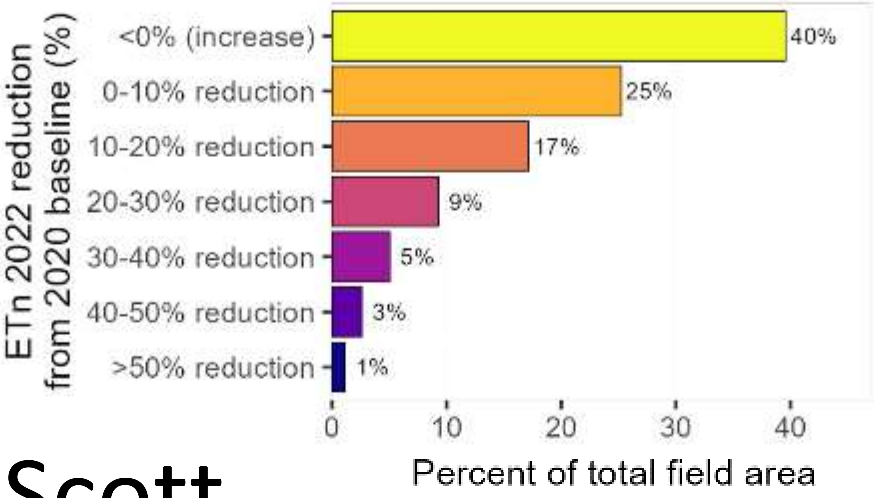

Reference evapotranspiration (ETo)
Actual evapotranspiration (ETa)
Net evapotranspiration (ETn)
Precipitation (P)
Depth (mm/month)
0
50
100
150
200
Scott
Shasta
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Month
Year
Baseline year 2020
Curtailment year 2022
Other years 2017, 2018 2019, 2021



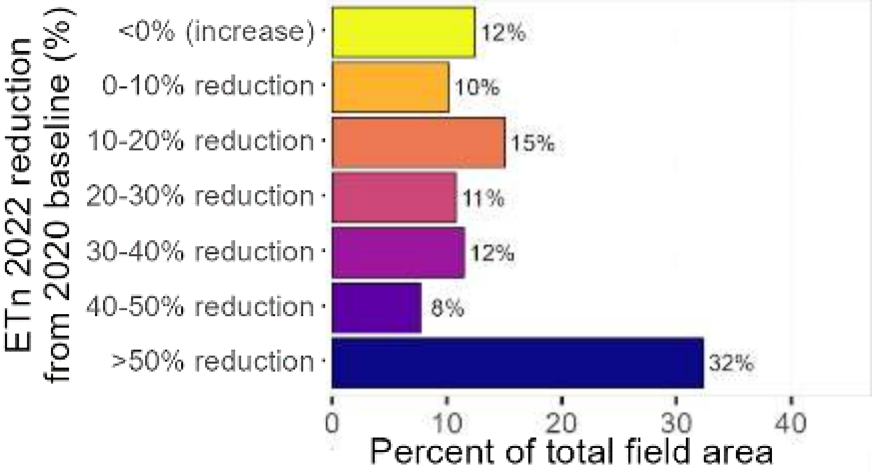
Reference evapotranspiration (ETo)
Actual evapotranspiration (ETa)
Net evapotranspiration (ETn)
Precipitation (P)
Depth (mm/month)
0
50
100
150
200
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Month
Scott
Shasta
Year
Baseline year 2020
Curtailment year 2022
Other years 2017, 2018 2019, 2021

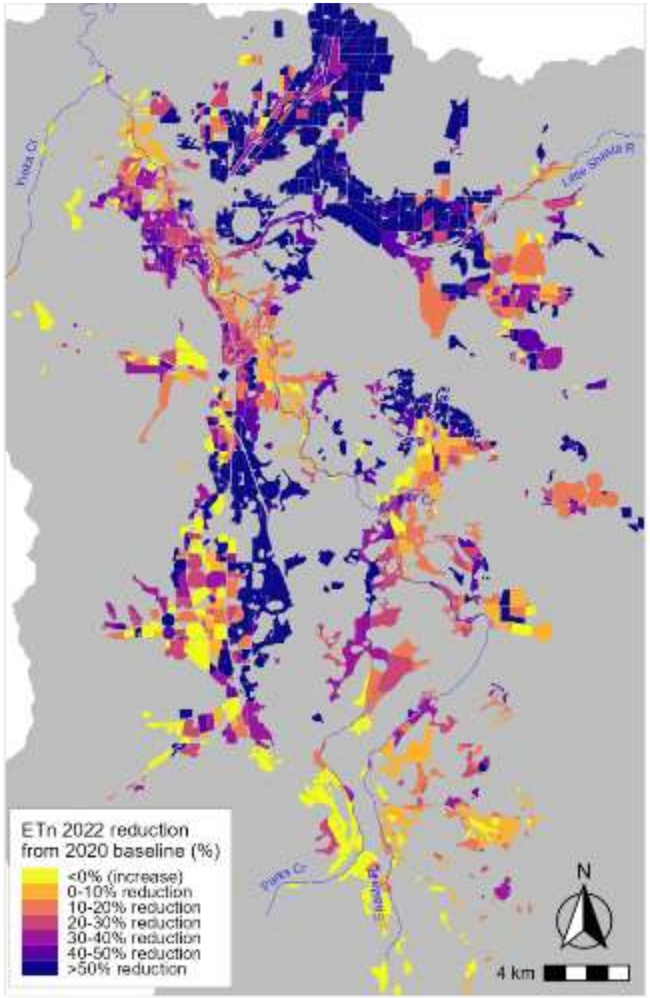


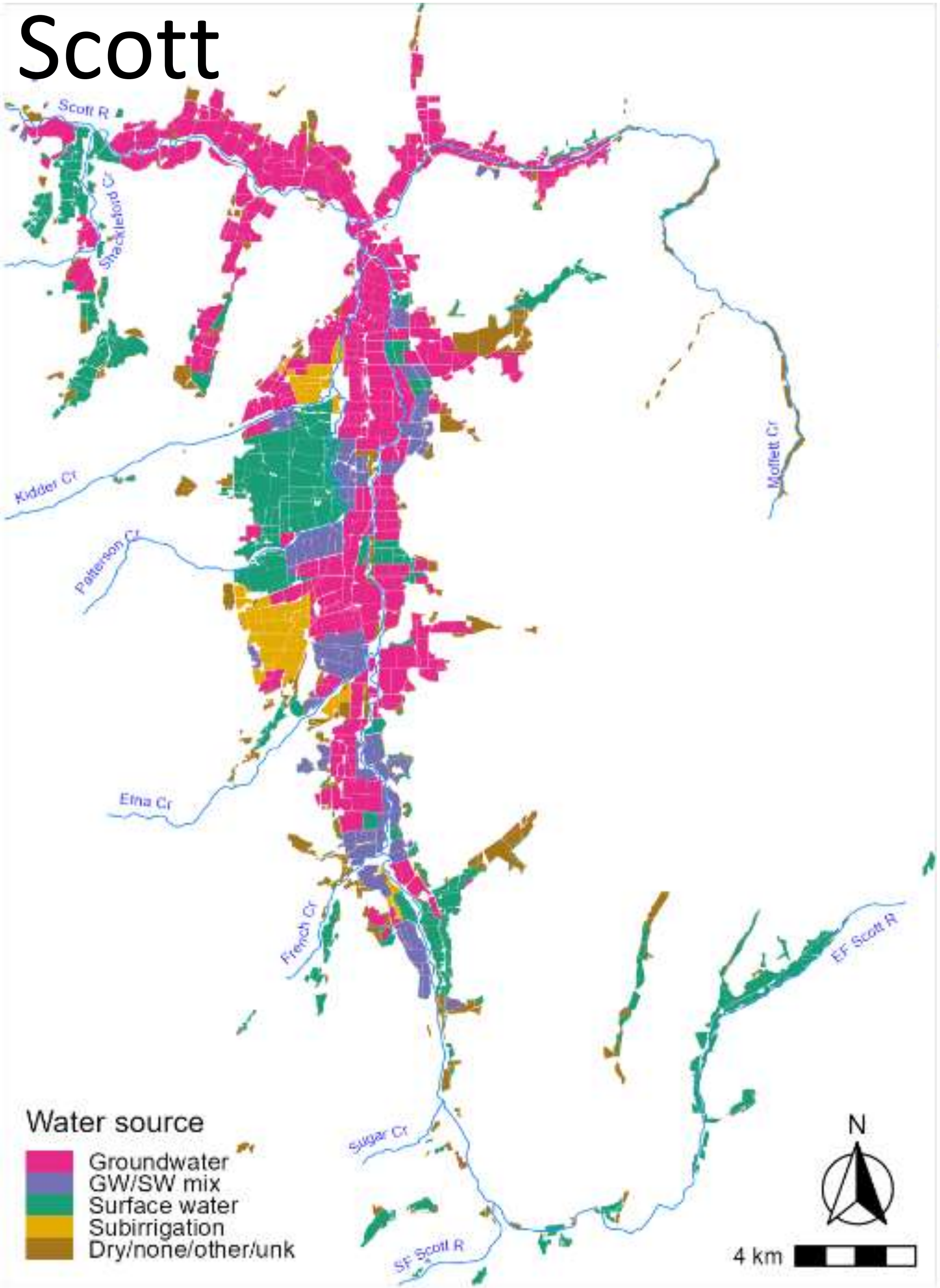


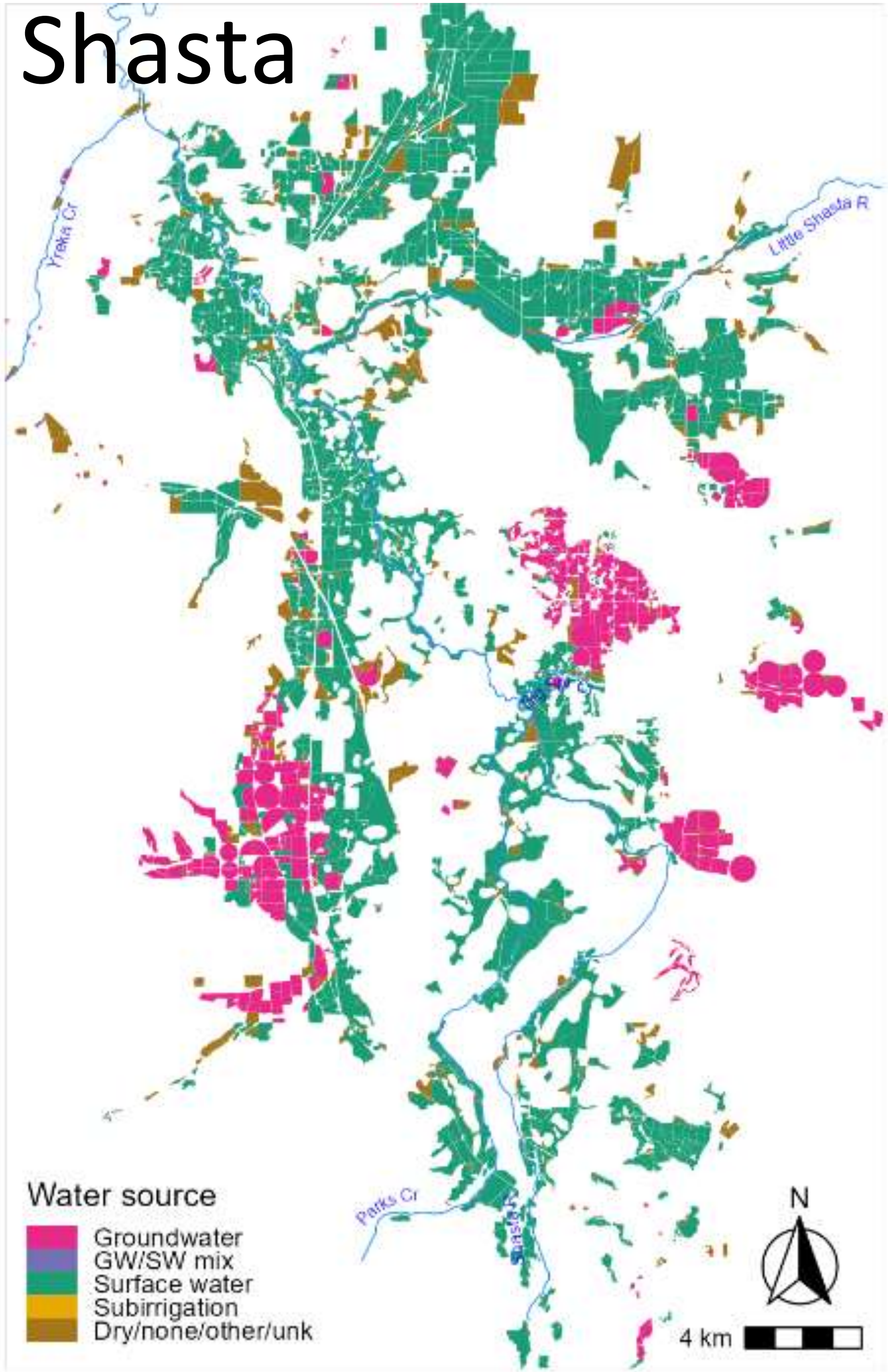
Scott

Shasta

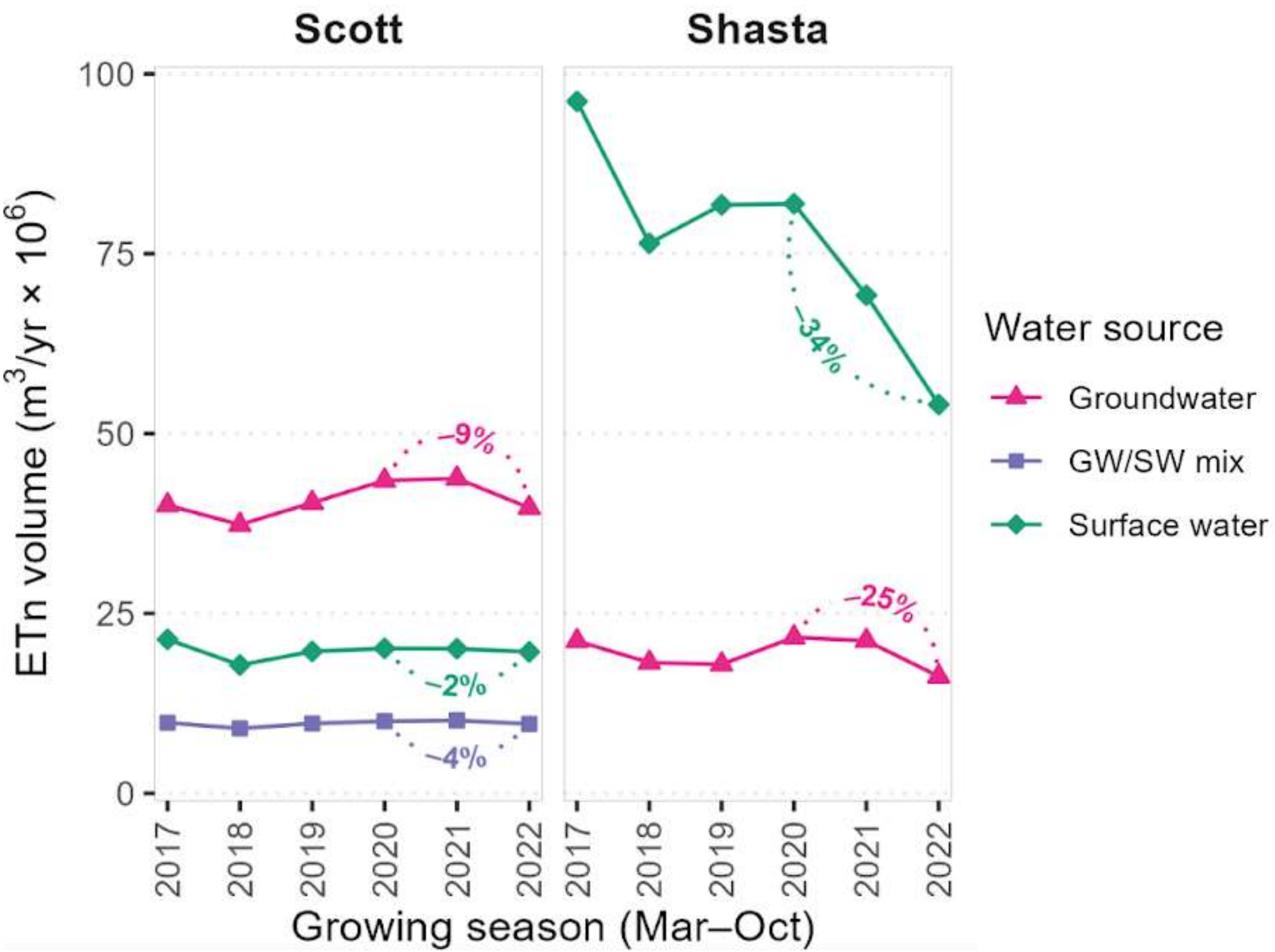






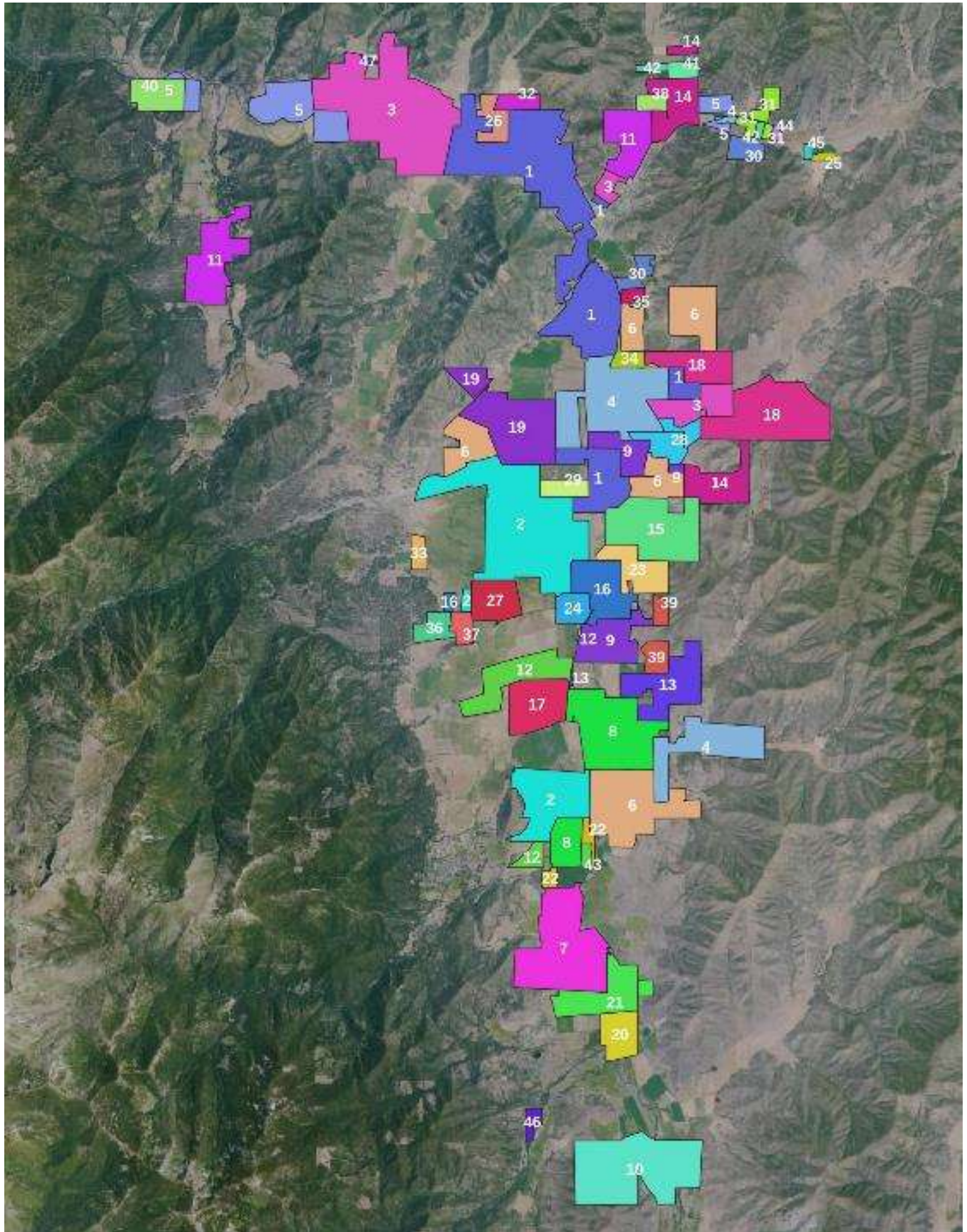


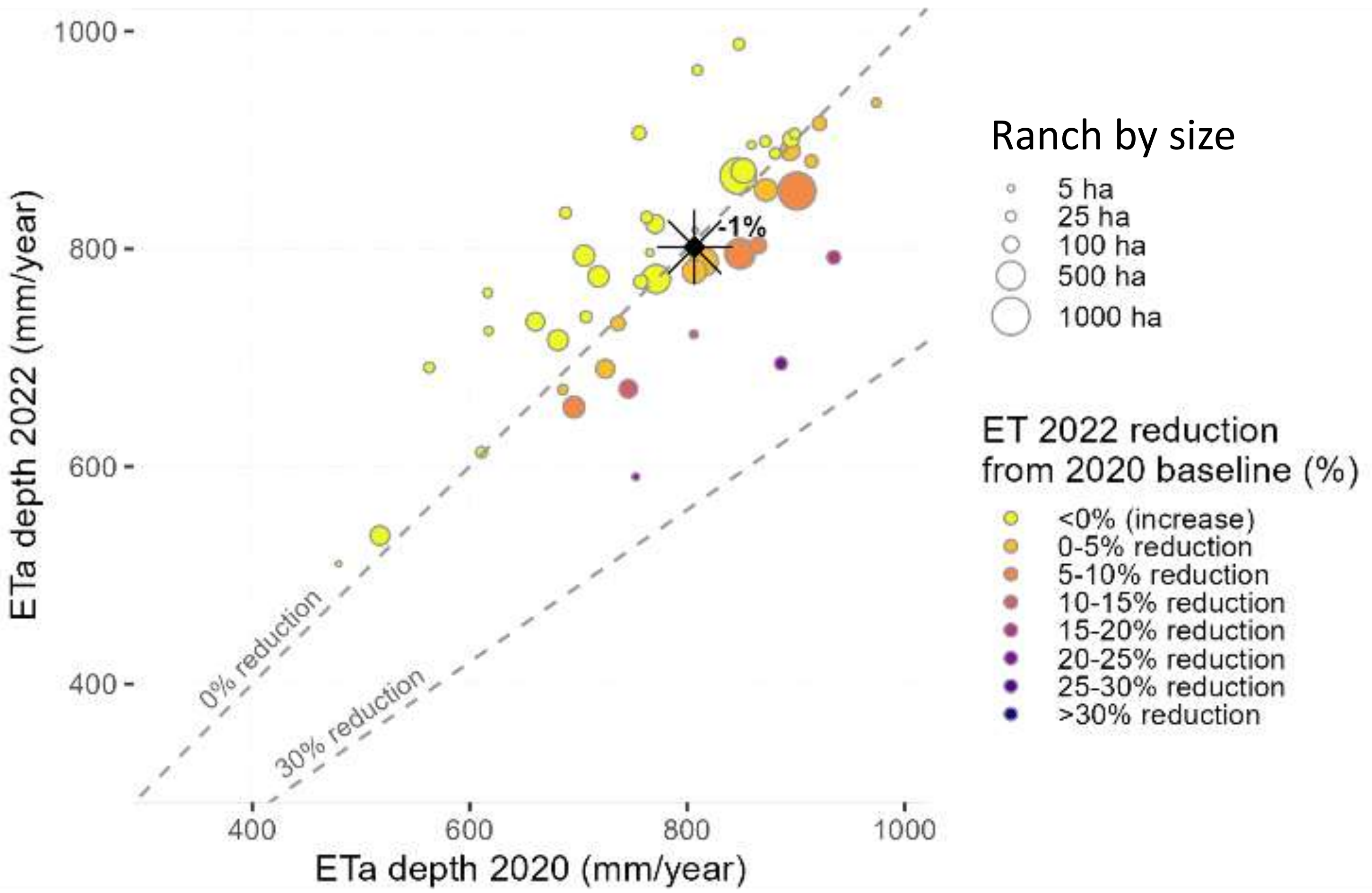
Irrigation sources:
Groundwater
Surface water



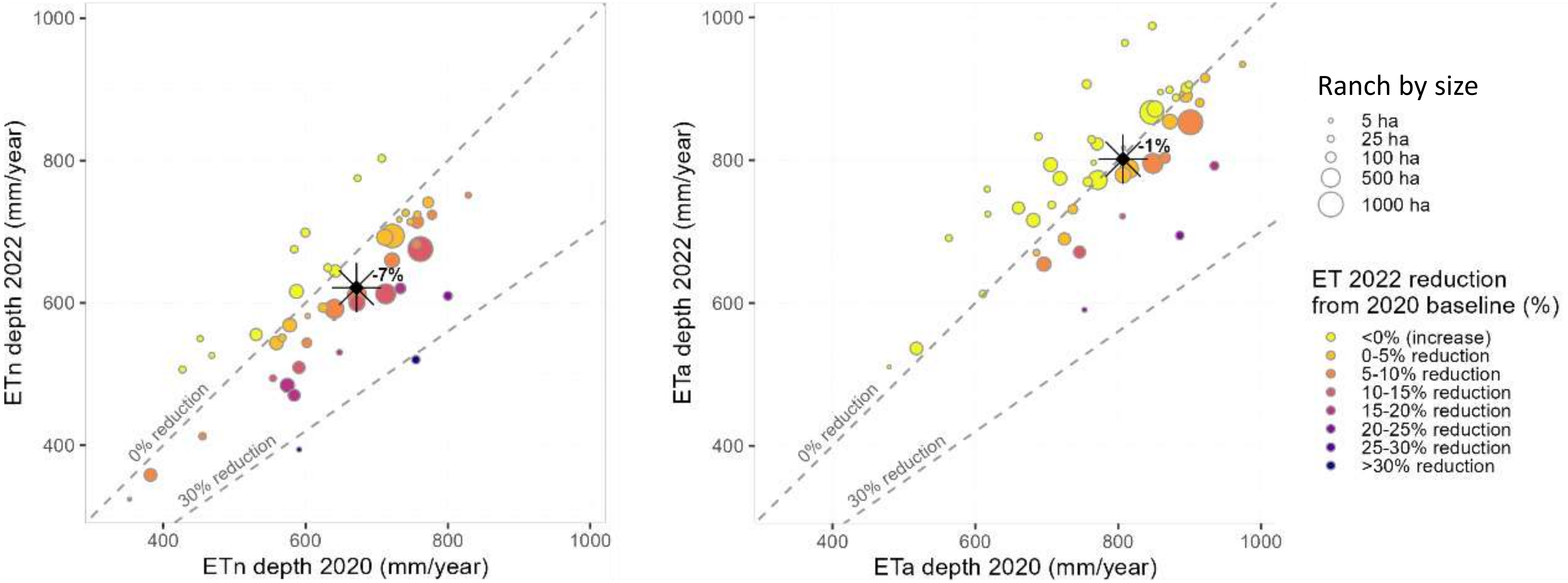
Scott
Shasta
ETn volume (m3/yr × 106)
100
75
50
25
0
−9%
−2%
−4%
−34%
−25%
2017
2018
2019
2020
2021
2022
Growing season (Mar–Oct)
Water source
Groundwater
GW/SW mix
Surface water

2022 Water conservation agreements





Ranch by size
5 ha
25 ha
100 ha
500 ha
1000 ha
ET 2022 reduction
from 2020 baseline (%)
<0% (increase)
0-5% reduction
5-10% reduction
10-15% reduction
15-20% reduction
20-25% reduction
25-30% reduction
>30% reduction
ETa depth 2022 (mm/year)
ETa depth 2020 (mm/year)
400
600
800
1000
0% reduction
30% reduction
-1%



1000
800
600
400
ETn depth 2022 (mm/year)
-7%
0% reduction
30% reduction
400
600
800
1000
ETn depth 2020 (mm/year)
ETa depth 2022 (mm/year)
-1%
ETa depth 2020 (mm/year)
Ranch by size
5 ha
25 ha
100 ha
500 ha
1000 ha
ET 2022 reduction from 2020 baseline (%)
<0% (increase)
0-5% reduction
5-10% reduction
10-15% reduction
15-20% reduction
20-25% reduction
25-30% reduction
>30% reduction

Inflated Baselines

Source	Applied irrigation (in)
v1 groundwater model (Foglia et al. 2013)	30.3
v2 groundwater model (Foglia et al. 2018)	22.6

Inflated Baselines

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Water conservation agreements baseline 2020	44.1
Water conservation agreements reporting 2022	29.2

Inflated Baselines

Source	Applied irrigation (in)
v1 groundwater model (Foglia et al. 2013)	30.3
v2 groundwater model (Foglia et al. 2018)	22.6
Water conservation agreements baseline 2020	44.1
Water conservation agreements reporting 2022	29.2

Too low?

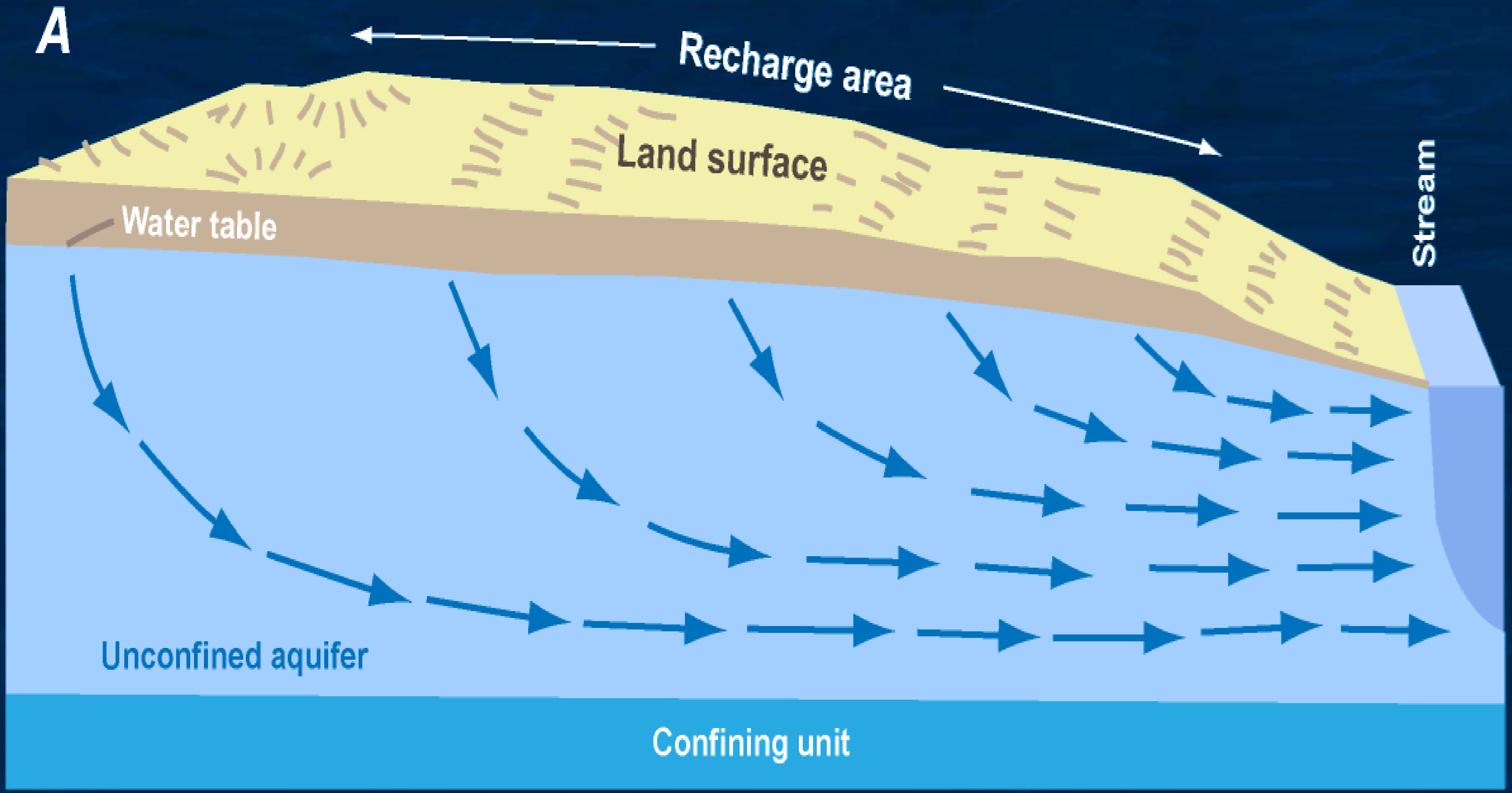
Too high?

Conclusions

- 2022 curtailments
  - Shasta: reduction in ETa and Etn, increase in flow
  - Scott: no ETa reduction, but precip reduced Etn. No flow increase
- Irrigation systems
  - Shasta mostly watermastered surface water
  - Scott mostly groundwater
- Water conservation agreements ineffective at reducing pumping
  - Inflated baselines
  - No metering
  - Little independent verification

Legal tools for Protecting Surface Flows From Groundwater Extraction in California

Matt Clifford, California Director, Trout Unlimited



A
Recharge area
Land surface
Water table
Stream
Unconfined aquifer
Confining unit

Water Code Section 2500

As used in this chapter, “stream system” includes stream, lake, or other body of water, and tributaries and contributory sources, **but does not include an underground water supply . . .**

Water Code Section 1200

[T]he terms stream, lake or other body of water . . . refer[s] only to surface water . . .

Water Code Section 2500

As used in this chapter, “stream system” includes stream, lake, or other body of water, and tributaries and contributory sources, but does not include an underground water supply . . .

Water Code Section 2500

As used in this chapter, “stream system” includes stream, lake, or other body of water, and tributaries and contributory sources, but does not include an underground water supply other than a subterranean stream flowing through known and definite channels.

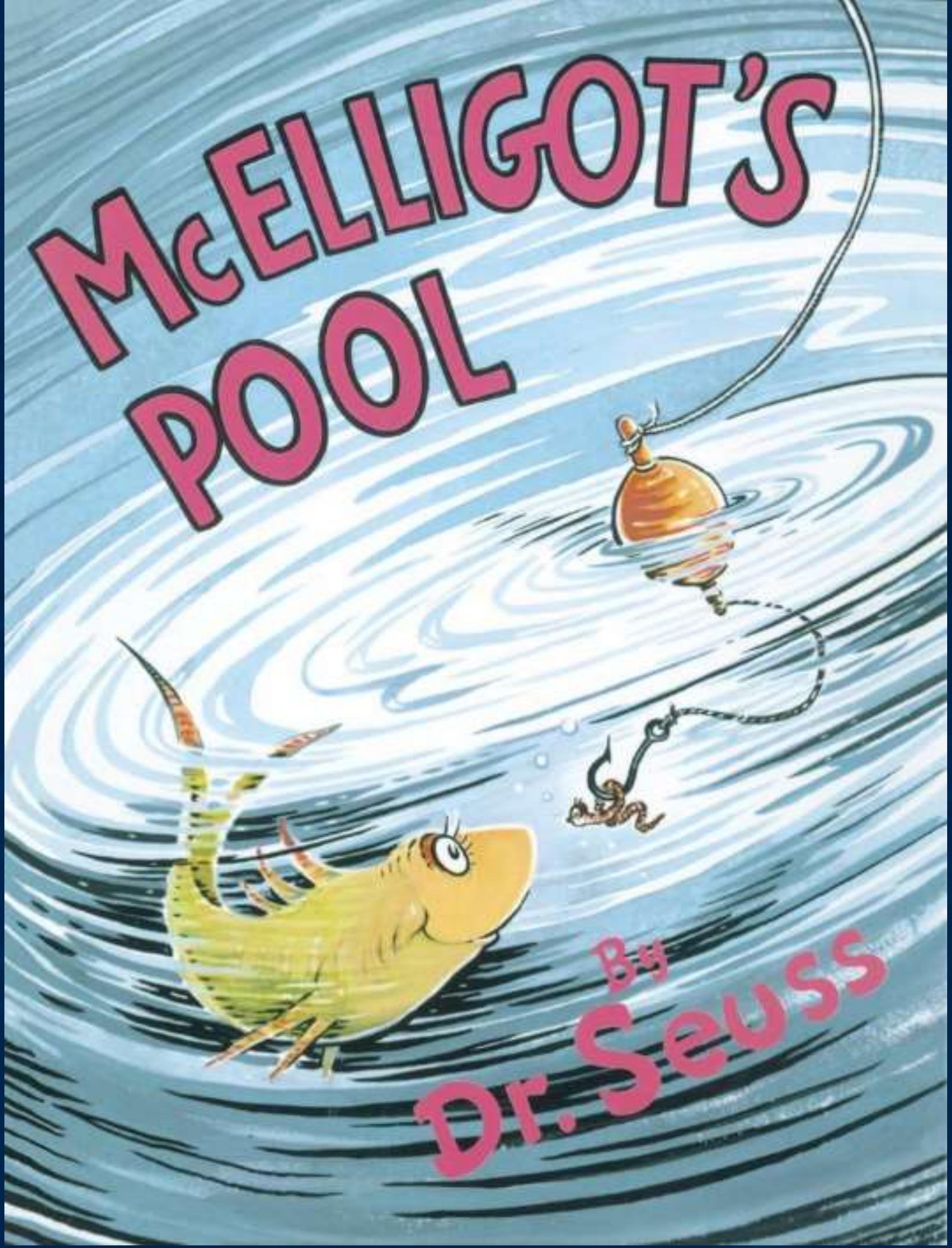
Water Code Section 1200

[T]he terms stream, lake or other body of water . . . refer[s] only to surface water . . .

Water Code Section 1200

[T]he terms stream, lake or other body of water . . . refer[s] only to surface water, and to subterranean streams flowing through known and definite channels.

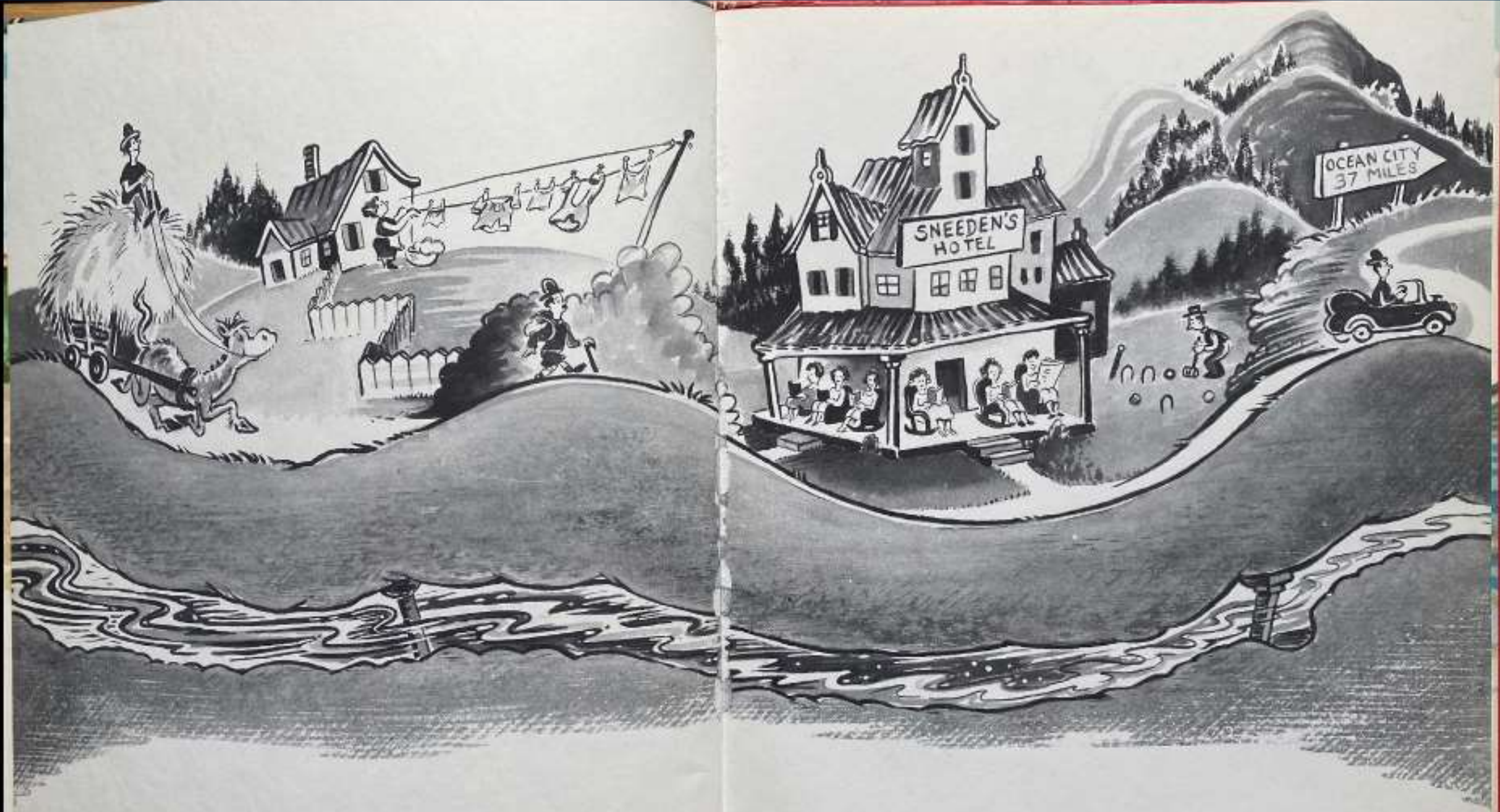

WIND
BLOWS


McELLIGOT'S
POOL
By
Dr. Seuss

This MIGHT be a pool, like I've read of in books,
Connected to one of those underground brooks!

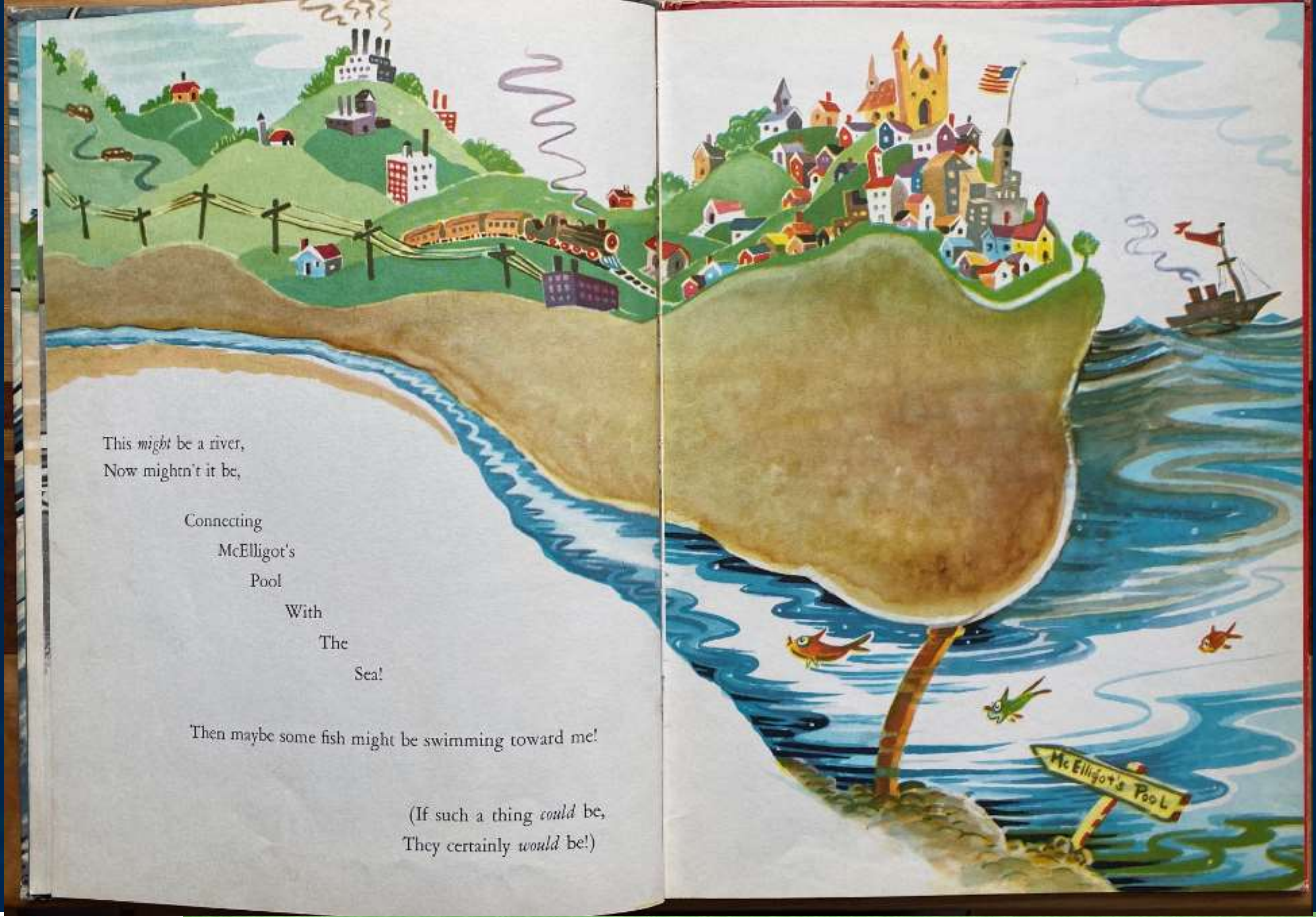
An underground river that starts here and flows
Right under the pasture! And then...well, *who knows?*

TROUT UNLIMITED



It *might* go along, down where no one can see,
Right under State Highway Two-Hundred-and-Three!
Right under the wagons! Right under the toes
Of Mrs. Umbroso who's hanging out clothes!

It *might* keep on flowing…perhaps…who can tell?…
Right under the people in Sneeden's Hotel!
Right under the grass where they're playing croquet!
Then under the mountains and far, far away!



This *might* be a river,
Now mightn't it be,

Connecting
McElligot's
Pool
With
The
Sea!

Then maybe some fish might be swimming toward me!

(If such a thing *could* be,
They certainly *would* be!)

"To put the matter as simply as possible, the above categories do not accord with scientific understanding of the occurrence and distribution of water on and in the earth."

-- Professor Joseph L. Sax, *Review of the Laws Establishing the SWRCB's Permitting Authority Over Appropriations of Groundwater Classified as Subterranean Streams and the SWRCB's Implementation of Those Laws*

Subterranean Streams: 4-Part Test

(1) a subsurface channel must be present

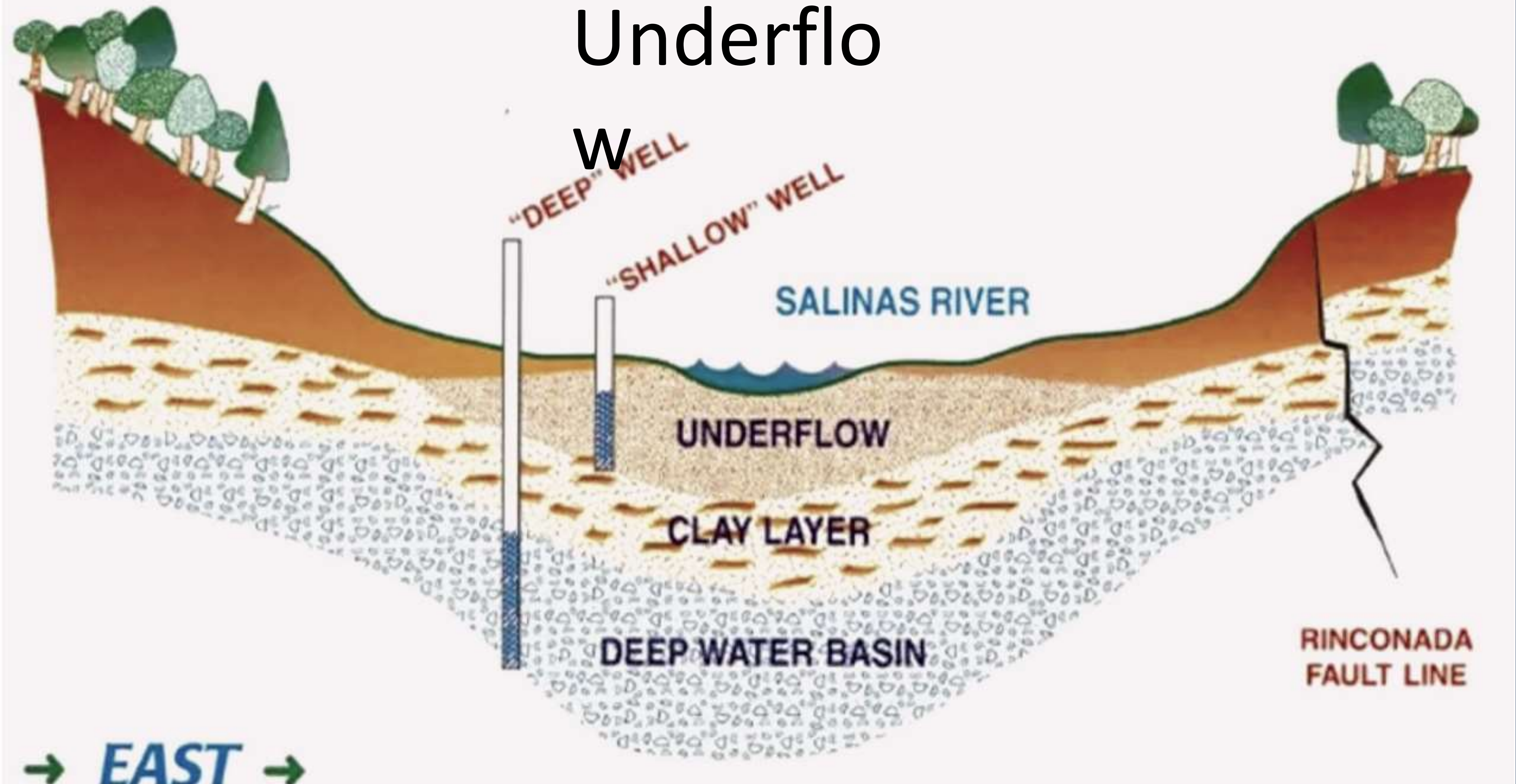
(2) the channel must have a relatively impermeable bed and banks

(3) the course of the channel must be known or capable of being determined by reasonable inference

(4) groundwater must be flowing in the channel.

North Gualala Water Company v. State Water Resources Control Board, 139 Cal.App.4th 1577

Underflow


"DEEP" WELL
"SHALLOW" WELL
SALINAS RIVER
UNDERFLOW
CLAY LAYER
DEEP WATER BASIN
RINCONADA
FAULT LINE
→ EAST →

"The underflow or subflow of a surface stream consists of water in the soil, sand, and gravel immediately below the bed of the open stream, which supports the surface stream in its natural state or feeds it directly."

-- Wells A. Hutchins, The California Law of Water Rights (1956)

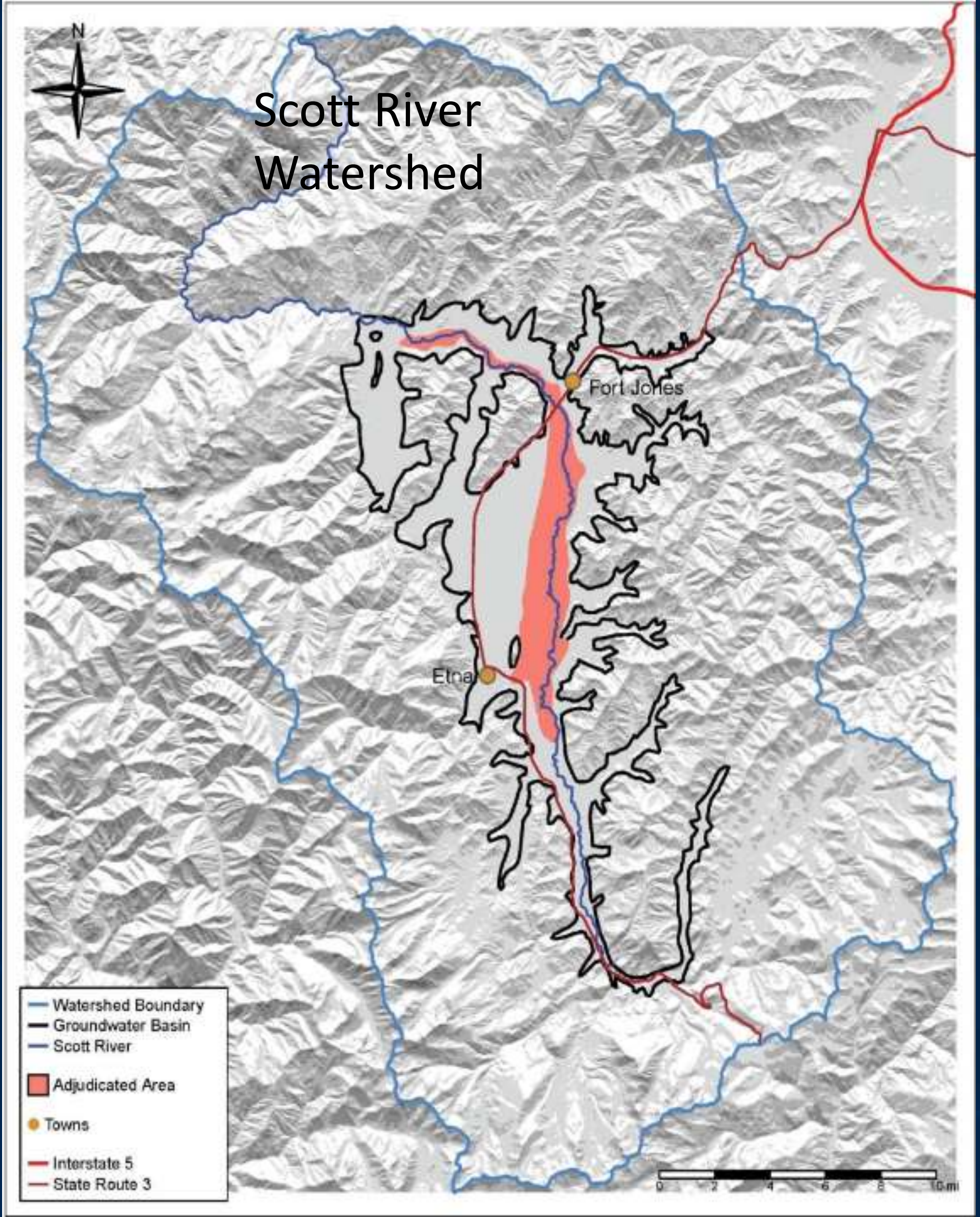
"There will always be great difficulty in fixing a line, beyond which the water in the sand and gravels over which a stream flows and which supply or behold the stream, ceases to be part thereof and becomes what is called percolating water."

Hudson v. Dailey, 156 Cal. 617, 627-28 (1909)

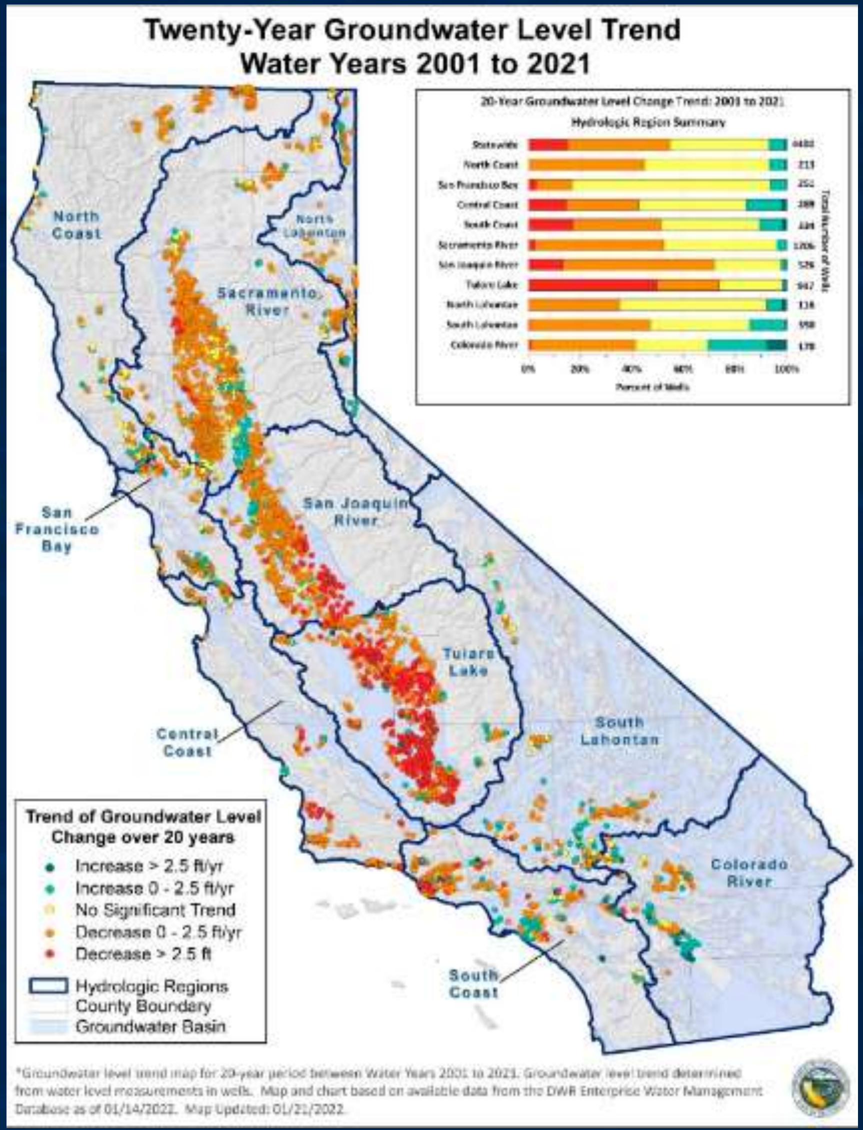
Scott River

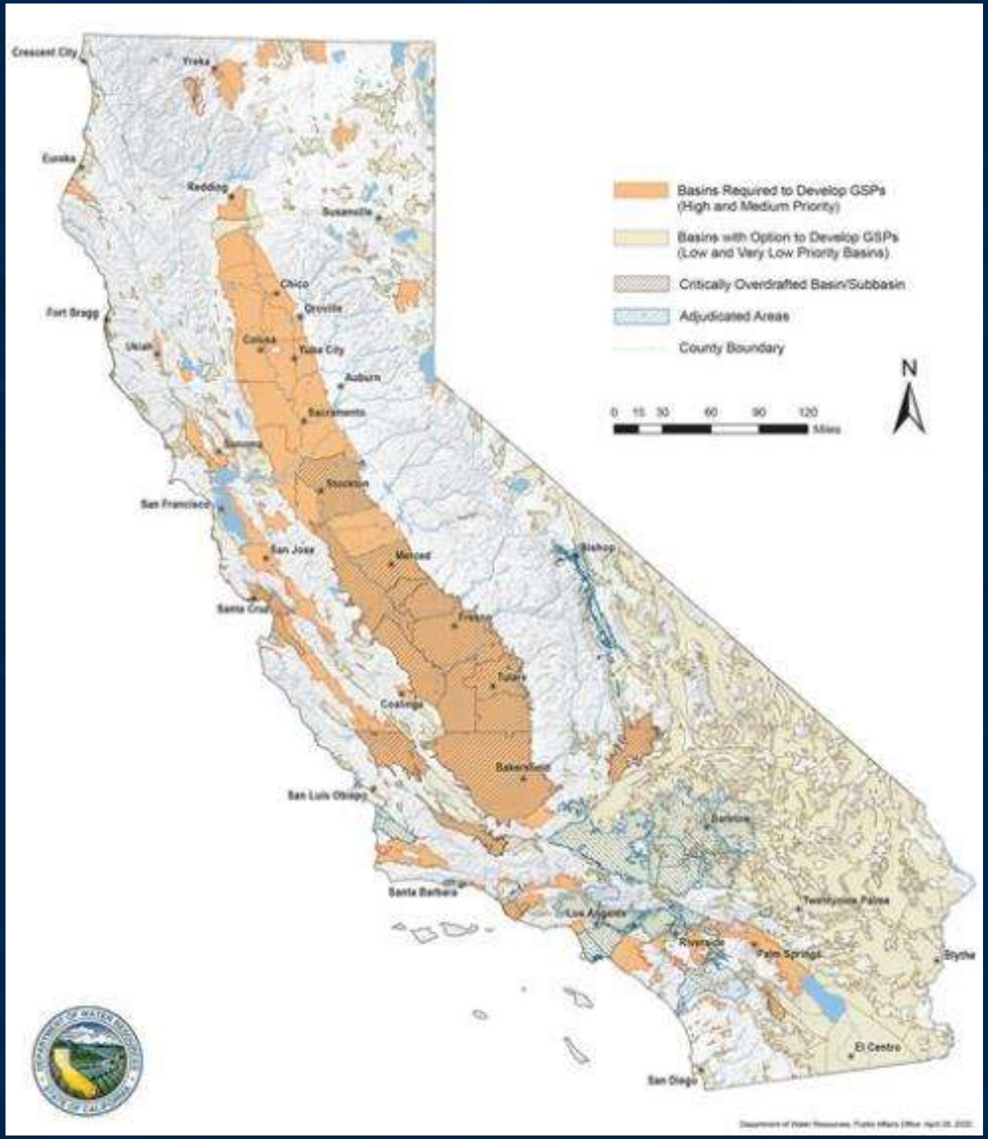
Water Code Section 2500.5

(a) As used in this chapter with respect to the Scott River in Siskiyou County, “stream system” includes ground water supplies which are interconnected with the Scott River, but does not include any other underground water supply.


N
Scott River Watershed
Fort Jones
Etna
Watershed Boundary
Groundwater Basin
Scott River
Adjudicated Area
Towns
Interstate 5
State Route 3
0 2 4 6 8 10 mi

Sustainable Groundwater Management Act (SGMA)





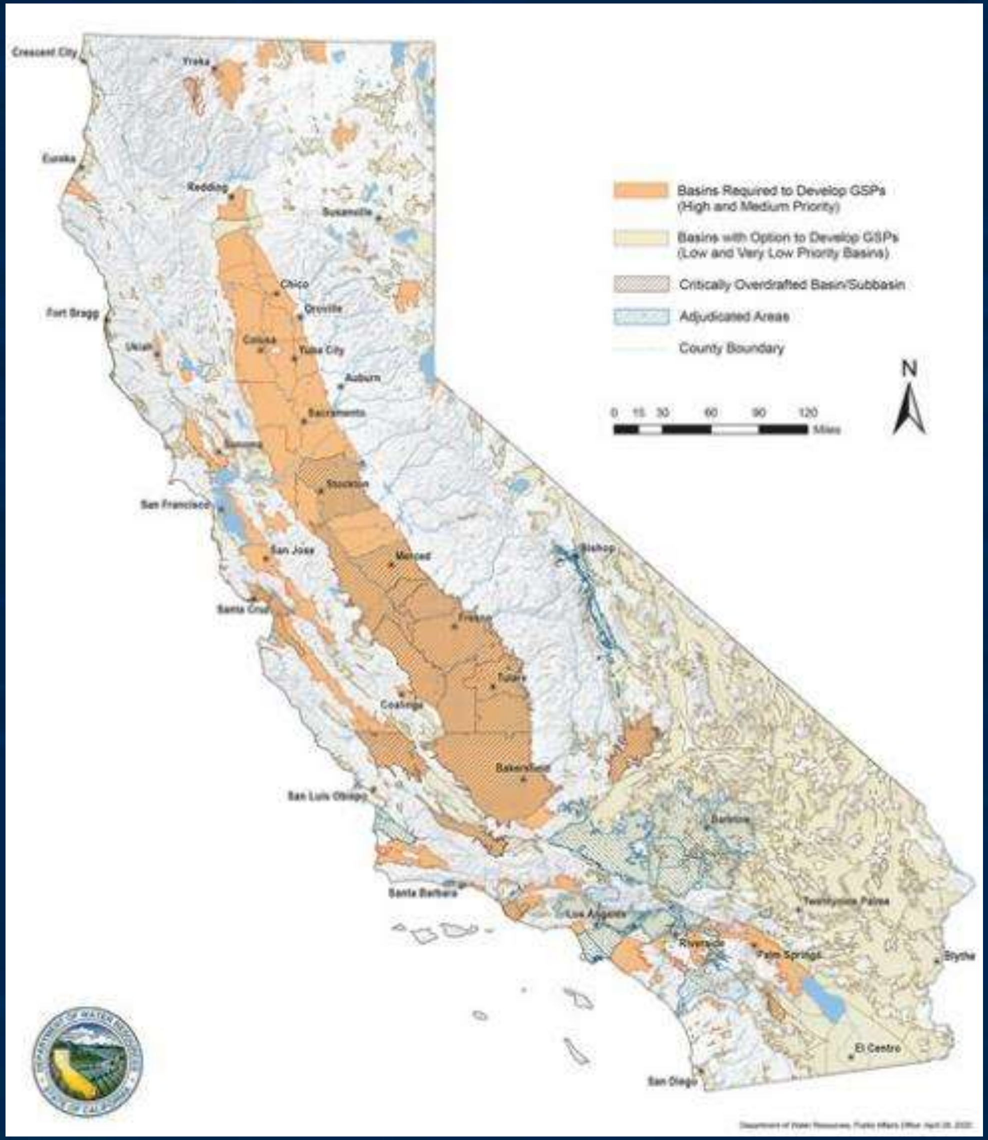
SGMA Basins

Priority basins – high/ medium/ low

Local agencies formed (GSAs)

Charged with developing sustainability plans (GSPs)

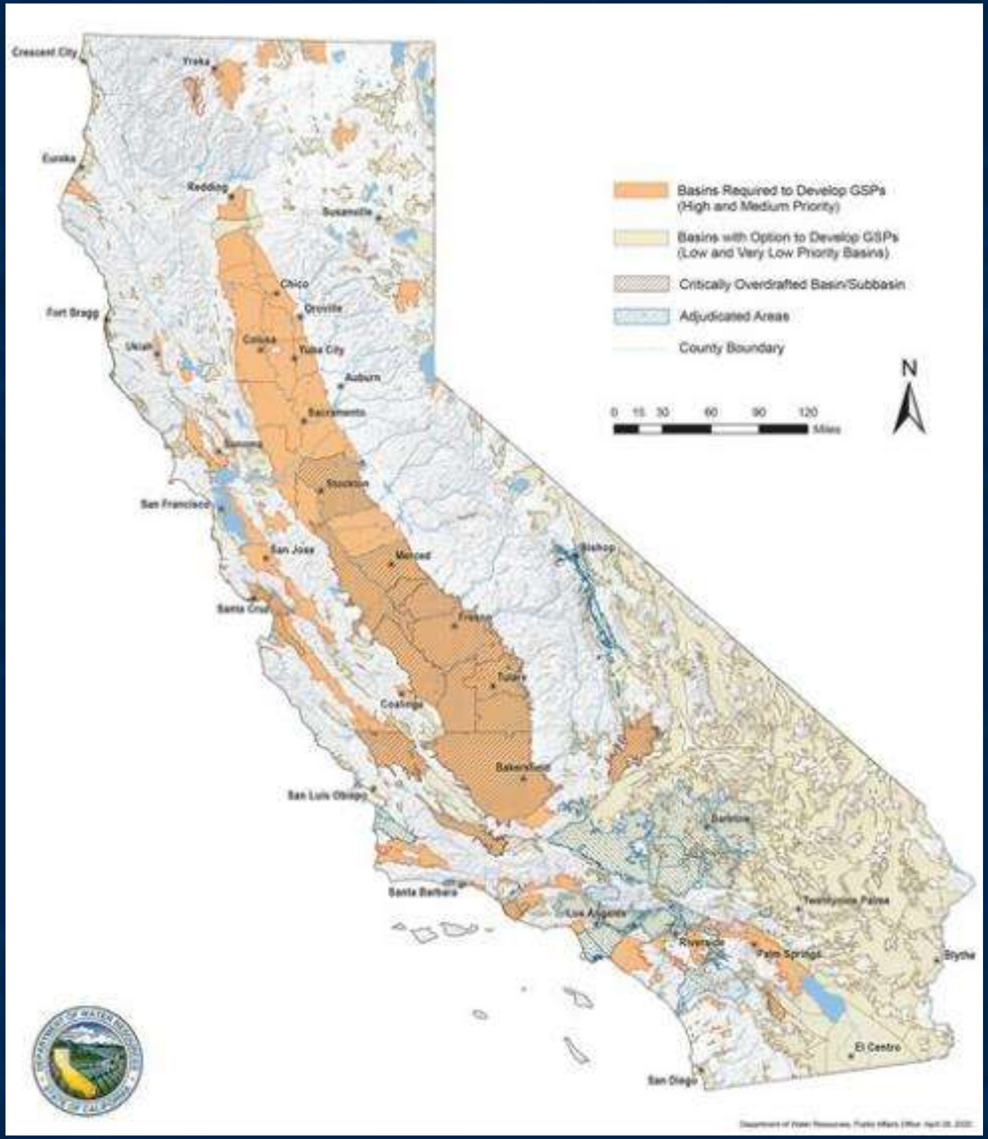
6 things to avoid:



GSPs Must Avoid:

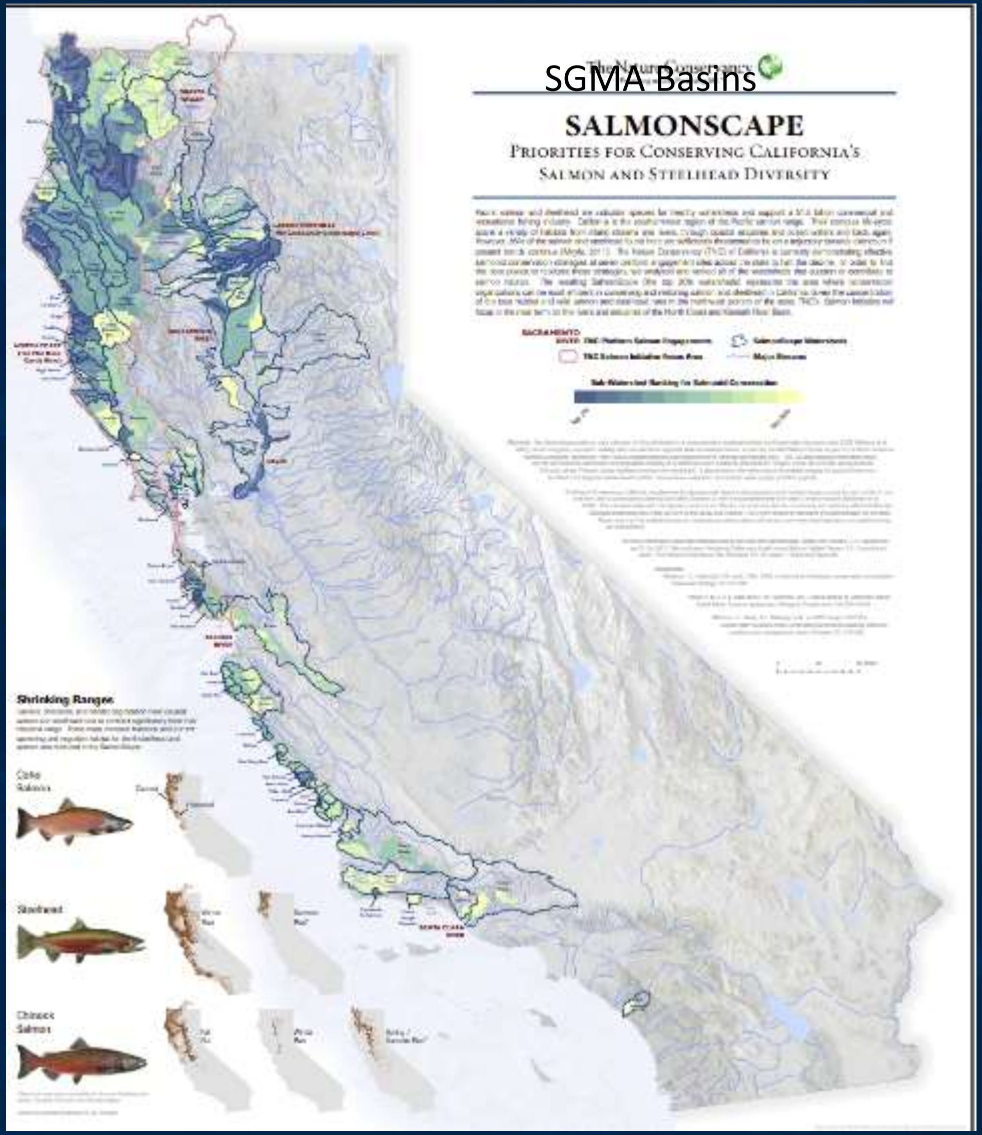
SGMA Basins

- Chronic lowering of groundwater levels
- Significant and unreasonable reduction of groundwater storage
- Significant and unreasonable seawater intrusion
- Significant and unreasonable degradation of water quality
- Significant and unreasonable land subsidence
- Significant and unreasonable impacts on beneficial uses of surface water



Crescent City
Yreka
Eureka
Redding
Susanville
Chico
Oroville
Fort Bragg
Colusa
Yuba City
Ukiah
Auburn
Sacramento
Sonoma
Stockton
San Francisco
San Jose
Merced
Bishop
Santa Cruz
Fresno
Tulare
Coalinga
Bakersfield
San Luis Obispo
Barstow
Santa Barbara
Los Angeles
Twentynine Palms
Riverside
Palm Springs
Blythe
El Centro
San Diego
Basins Required to Develop GSPs (High and Medium Priority)
Basins with Option to Develop GSPs (Low and Very Low Priority Basins)
Critically Overdrafted Basin/Subbasin
Adjudicated Areas
County Boundary
N
0 15 30 60 90 120 Miles

SGMA Basins



SALMONSCAPE
Priorities for Conserving California's Salmon and Steelhead Diversity
Shrinking Ranges
Coho Salmon
Steelhead
Chinook Salmon

The Public Trust Doctrine

The Public Trust Doctrine

Institutes of Justinian (4th Century Rome)

Illinois Central Railroad Co. v. Illinois, 146 U.S. 387 (1892))

National Audubon Society v. Superior Court, 33 Cal.3d 219 (1983) (Mono Lake case)

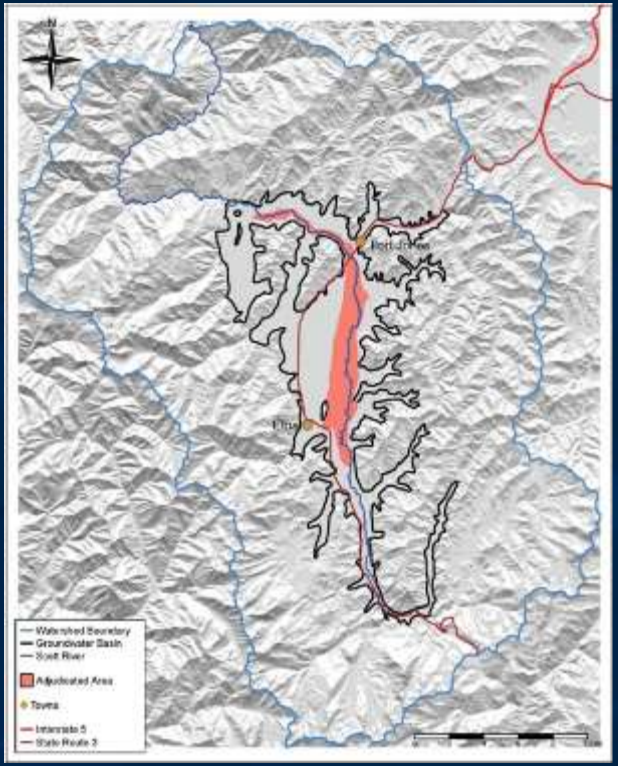
The Public Trust Doctrine

- State holds all **navigable waters** in **trust** for the benefit of the people
- Protects public trust **uses**: navigation/commerce/ fishing (and in modern times, **ecosystems)**
- State decisions affecting navigable waters must consider effects on public trust uses
- Applies to **State Water Board** decisions to issue **water rights**

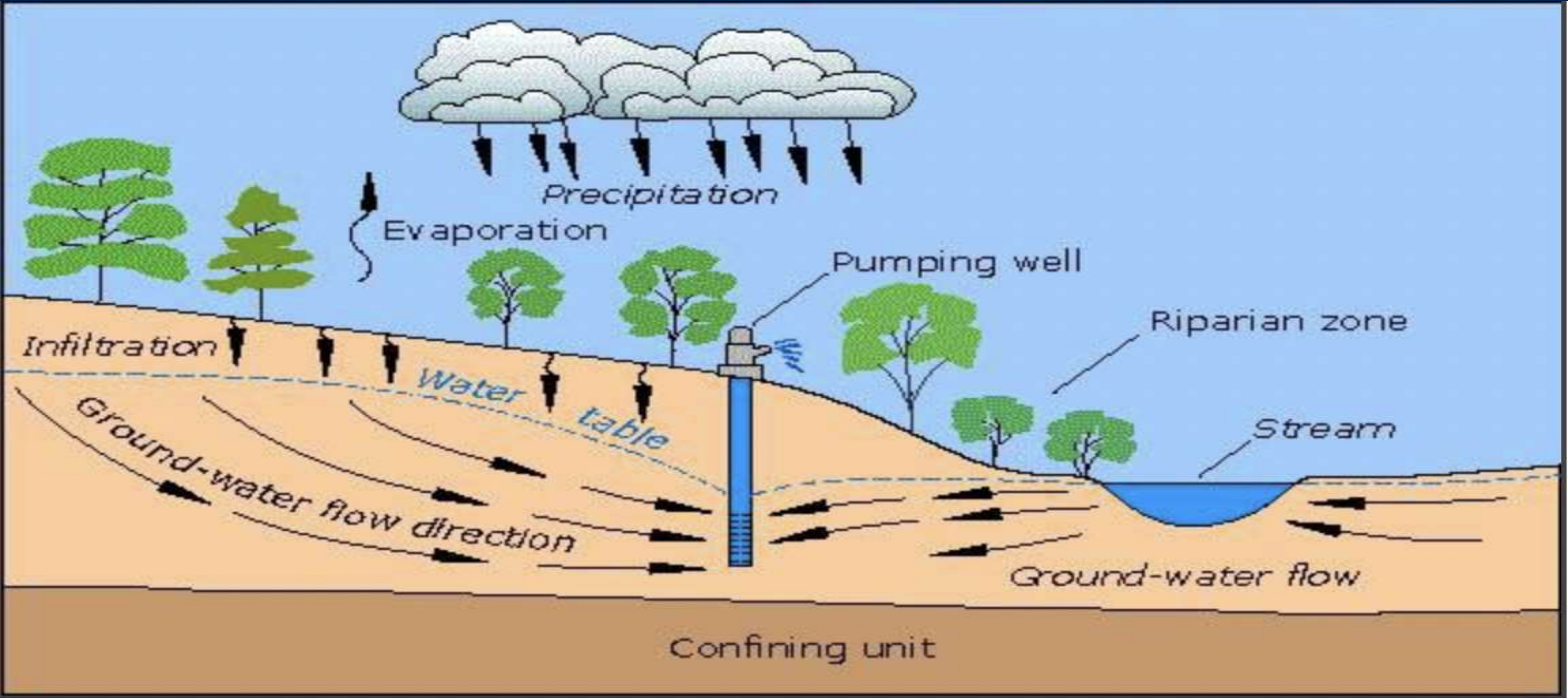
Non-navigable tributaries

Environmental Law Foundation (ELF) v. SWRCB 2018 26 Cal.App.5th 844

Public trust doctrine applies to county well drilling permits



Aquifers are tributary to navigable streams



Sonoma County Well Ordinance (2023)

Suit by CA Coastkeeper

Scope of Ordinance:

- Wells that affect flow in navigable streams
- Wells that affect flow in **non-navigable** streams that are used by species that migrate from navigable waters

Other counties – Santa Cruz, Mendocino(?)

Cities

Legal tools for Protecting Surface Flows From Groundwater Extraction in California

Matt Clifford, California Director, Trout Unlimited

Groundwater into Streamflow

Principles and Guidelines for Cities and Counties to Develop Well Ordinances to Protect Streamflow for Salmon Habitat

Presentation to the

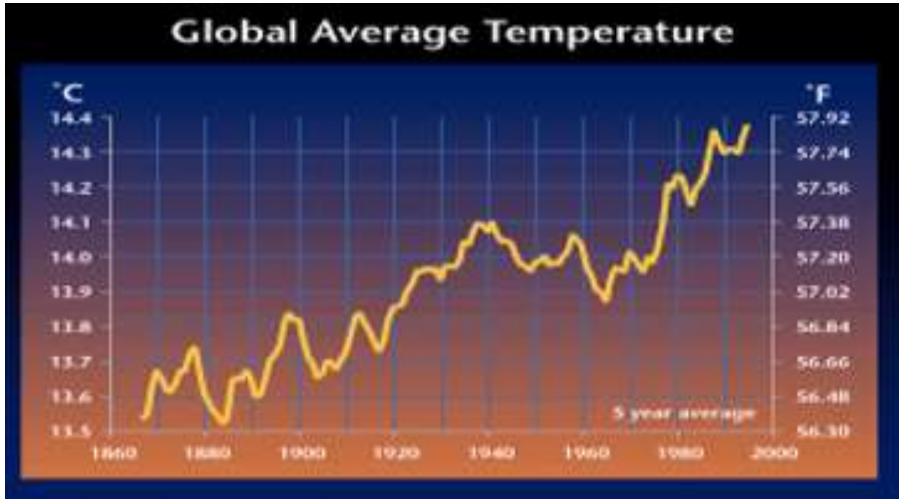
40th Annual Salmonid Restoration Federation Conference

Santa Rosa, CA

March 29, 2024

Monty Schmitt
Water Program Sr. Project Director
The Nature Conservancy

Coastal Rivers, Salmon and Groundwater



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Coastal Rivers, Salmon and Groundwater

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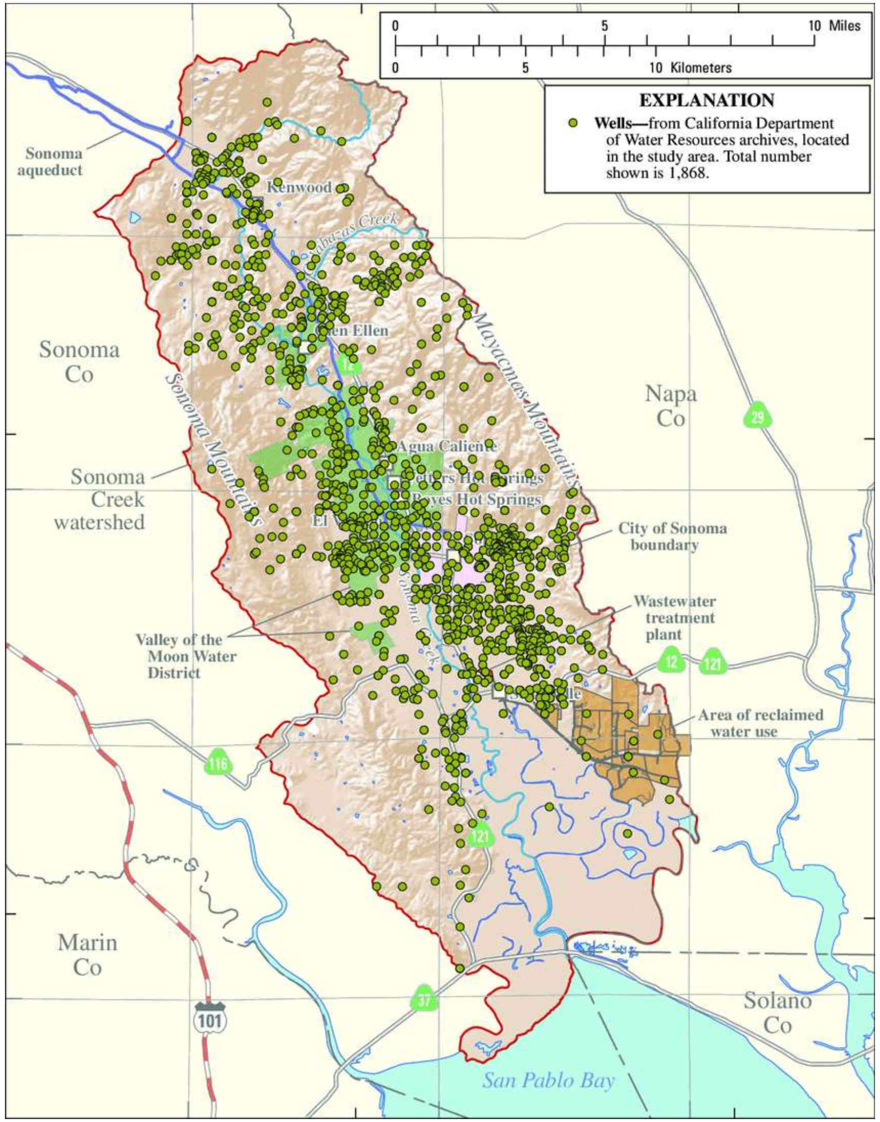
Coastal Rivers, Salmon and Groundwater



Farrar. 2006. USGS Scientific Investigations Report 2006-5092

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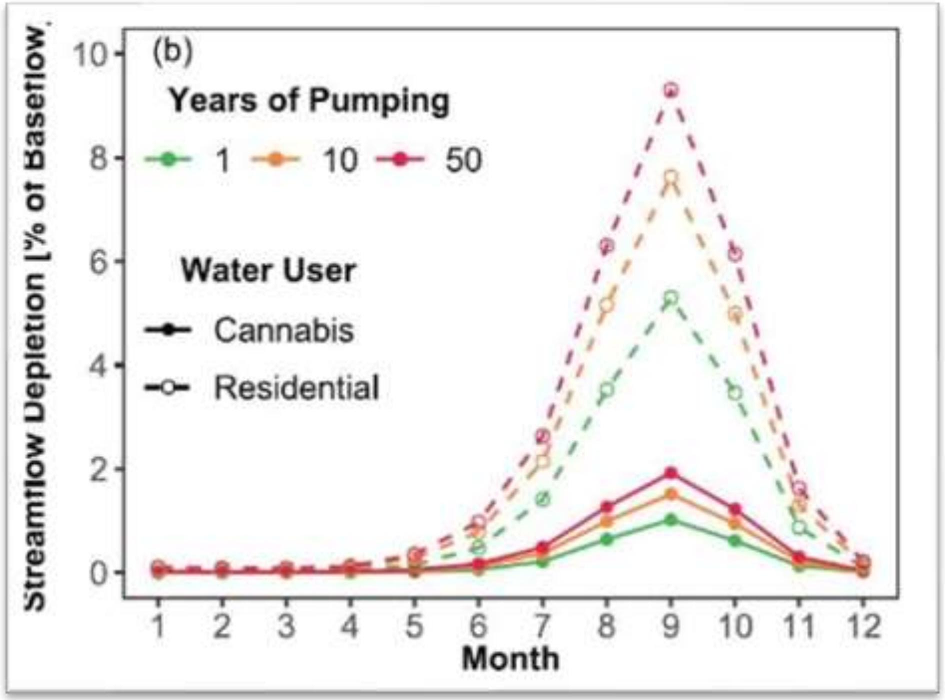
Coastal Rivers, Salmon and Groundwater



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Coastal Rivers, Salmon and Groundwater

Is this the new normal?

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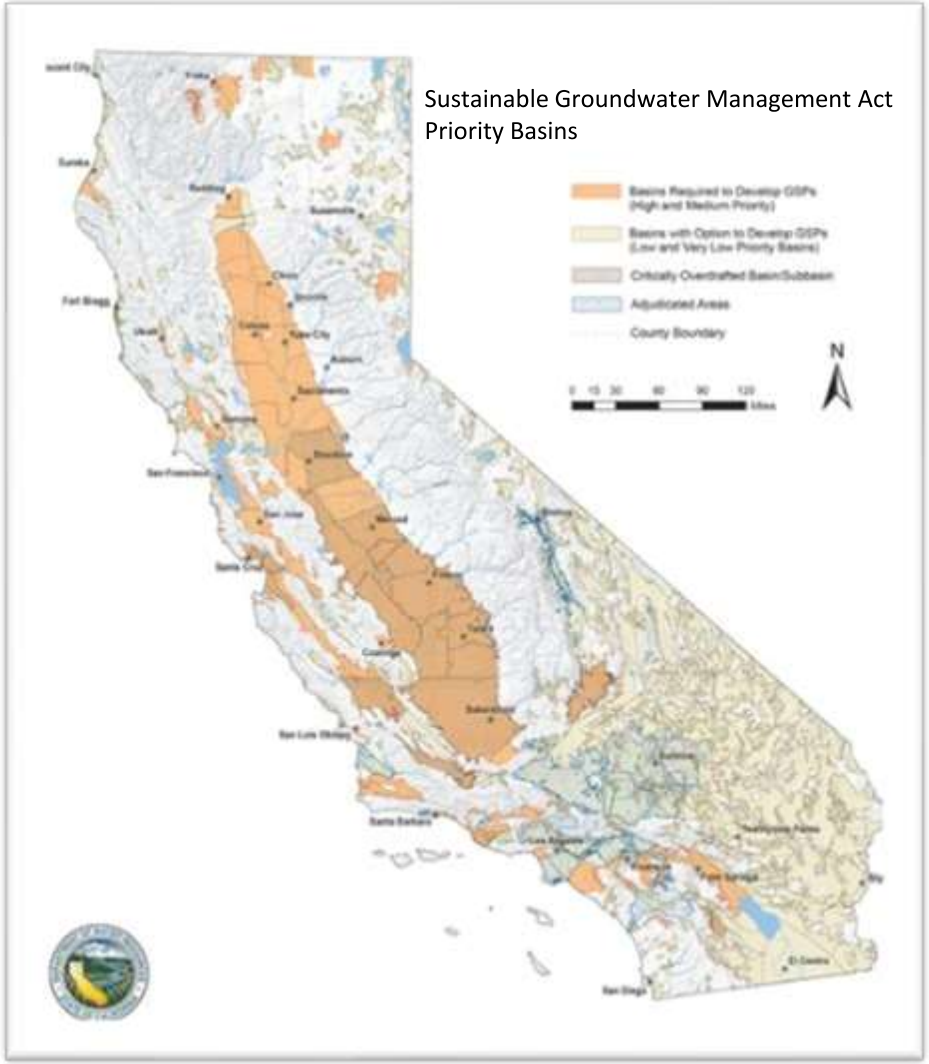
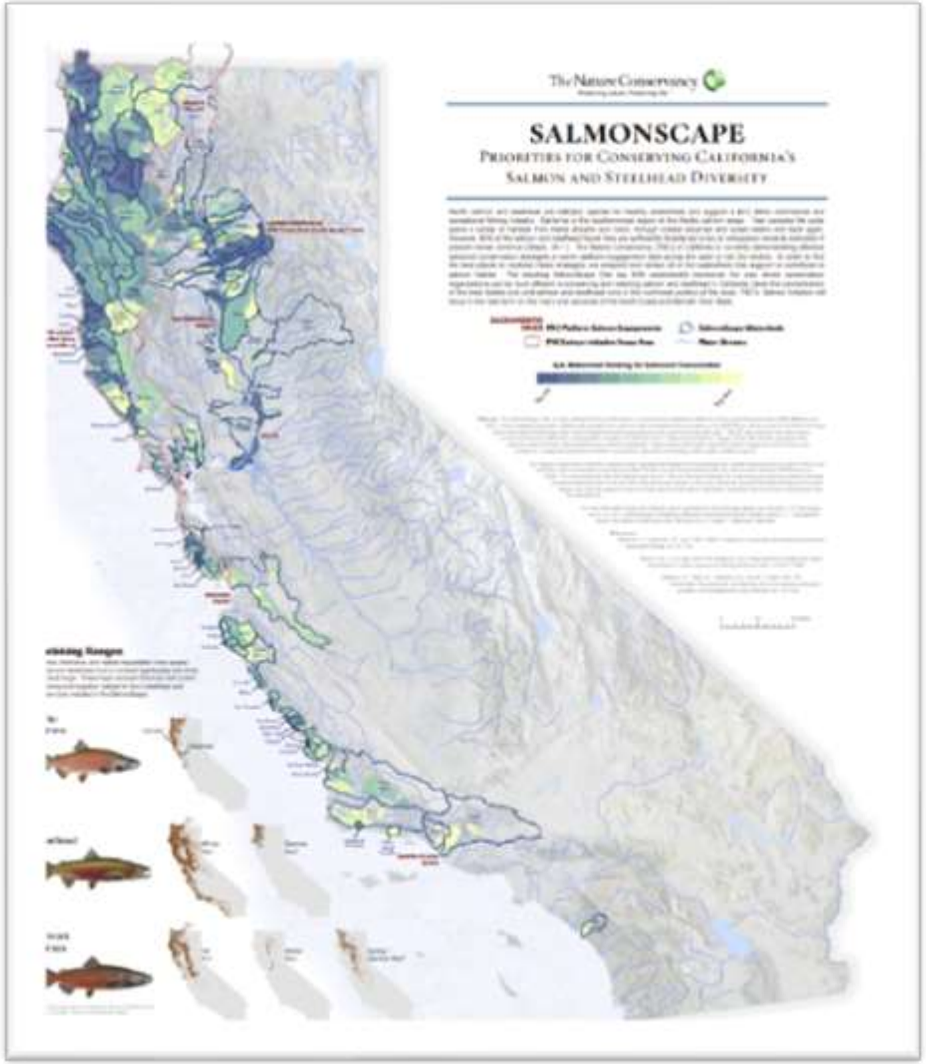
Coastal Rivers, Salmon and Groundwater





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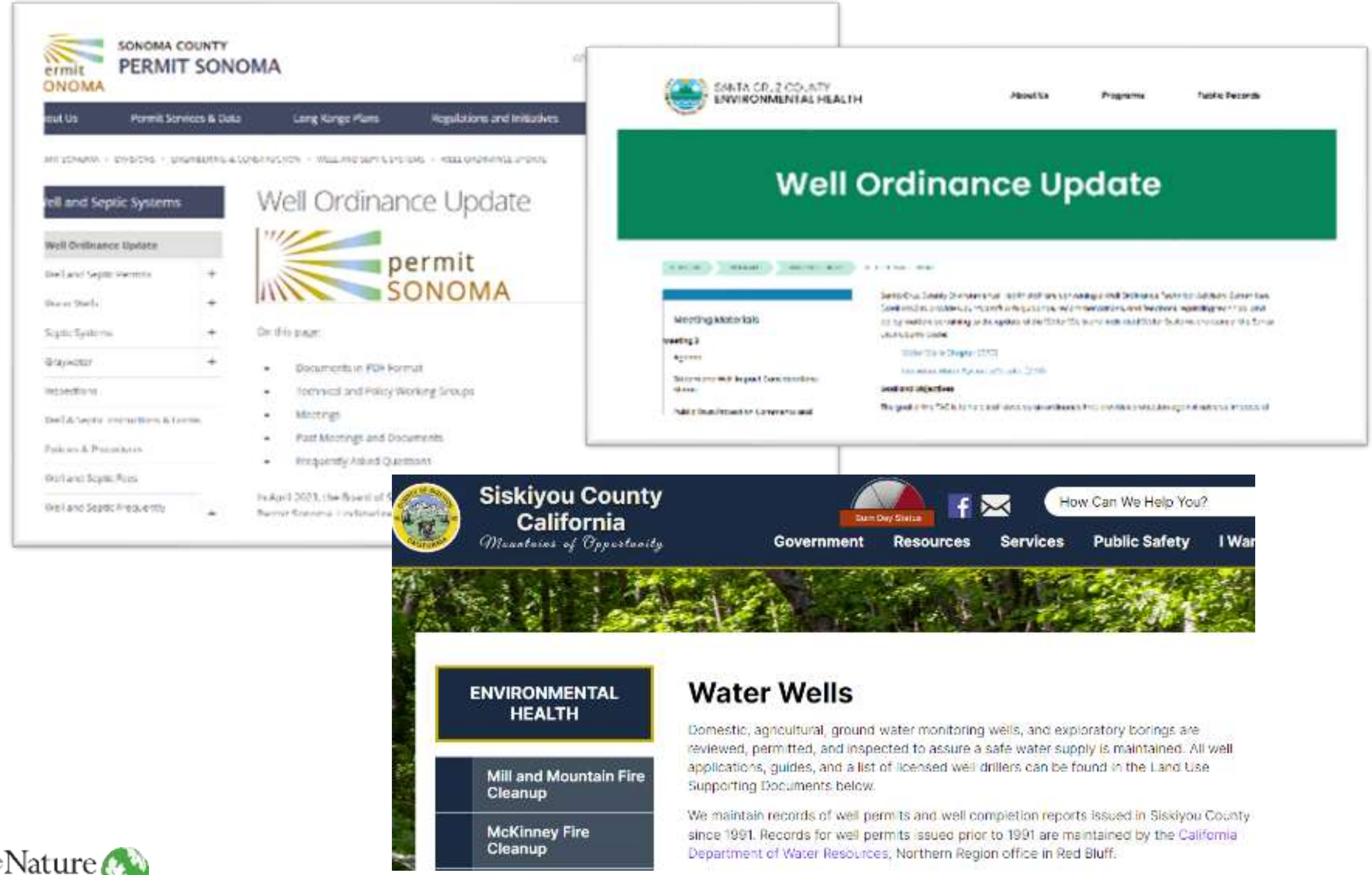
Principles and Guidelines for Well Ordinances



Principles and Guidelines for Well Ordinances

- **Element 1**: Identify and map the Public Trust Review Area
- **Element 2**: Assess baseline streamflow and groundwater conditions
- **Element 3**: Identify ecologically protective streamflow thresholds to assess risk and impacts
- **Element 4**: Develop a PTR risk assessment matrix and maps to inform appropriate permitting pathways.
- **Element 5**: Define permitting thresholds, reporting requirements, and mitigation measures.
- **Element 6**: Establish monitoring and adaptive management measures.

Principles and Guidelines for Well Ordinances

Element 1: Identify and map the Public Trust Resources

a) Navigable waters within the planning area including streams which contribute flows to those reaches.

b) Identify target PTR species and habitats

   a) Salmon and steelhead

   b) Seasonal wetlands

   c) Groundwater dependent ecostems

c) Map Public Trust Resources

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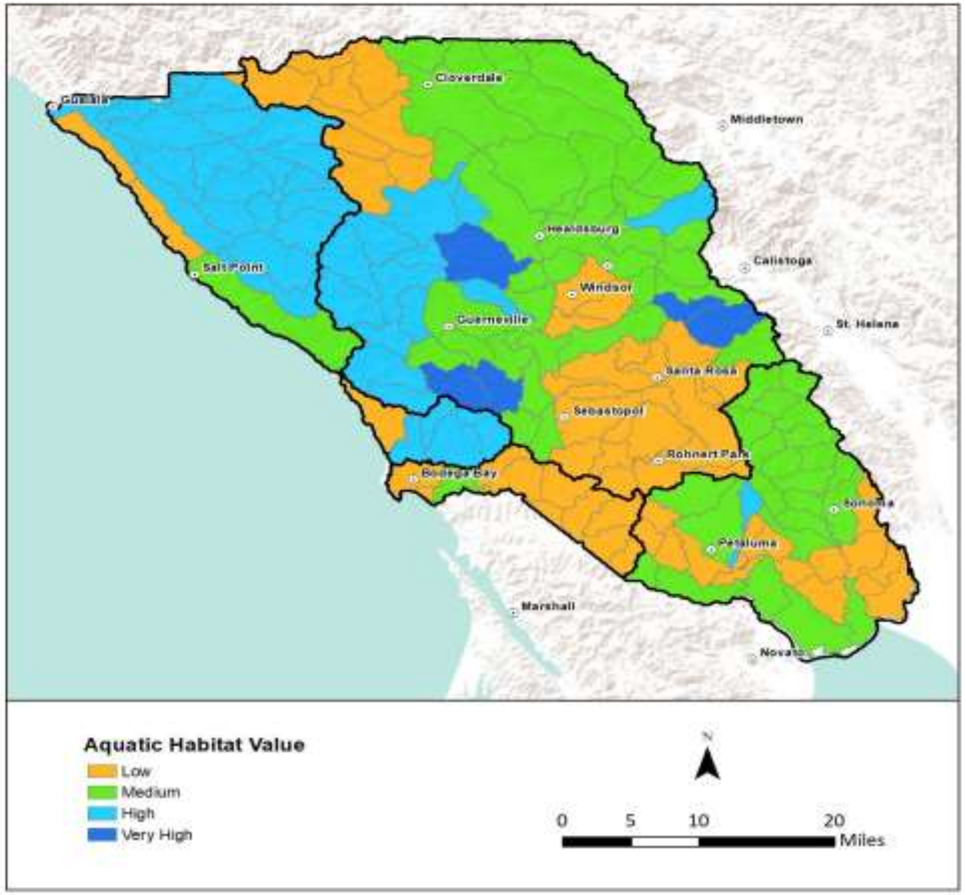
Principles and Guidelines for Well Ordinances

Element 1: Identify and map the Public Trust Resource



Credit Permit Sonoma

Example: Sonoma County Aquatic Habitat Value

- Coho and steelhead used as indicator species
- Focused on existing summer rearing habitat and priority recovery habitat for Coho
- Assessment of specific habitat conditions based on input fisheries experts.

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Principles and Guidelines for Well Ordinances

Element 2: Assess baseline streamflow and groundwater conditions

a) **Identify existing streamflow conditions for a range of water-year types to provide a baseline for risk and impact analyses.**
   1. Unimpaired and impaired flows
   2. Natural Flows Database, USGS, DWR or other gaging data

b) **Assess risk of streamflow depletion related existing surface water rights.**
   1. Use EWRIMS and other available data to quantify existing water rights demand

c) **Estimate existing, cumulative streamflow depletion impacts due to groundwater pumping.**
   1. Utilize or develop appropriate modeling tools (e.g.; statistical, analytical, numerical) based on risk and need for resolution.

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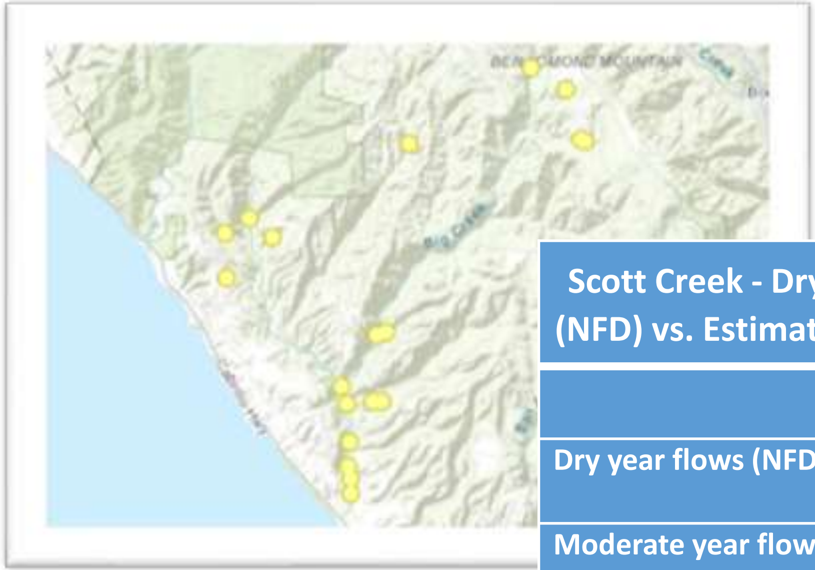
Principles and Guidelines for Well Ordinances

Element 2: Assess baseline streamflow and groundwater conditions

b) Assess risk of streamflow depletion impacts due to current surface water diversions related to existing surface water rights.



Scott Creek - Dry Season Base Flow (June to November) from Natural Flows Database (NFD) vs. Estimated cumulative water right diversions demand from EWRIMS database

	June	July	Aug	Sep	Oct	Nov	Units
Dry year flows (NFD)	4.9	4.5	3.0	2.8	3.1	8.6	cfs
Moderate year flows (NFD)	11.4	6.8	3.9	3.7	4.7	14.6	cfs
Estimated daily cumulative water right demand (max reported or face value)	1.2	1.2	1.2	1.2	1.2	1.2	cfs
Diversion impacts as a percent of unimpaired flows in a dry year	25%	27%	41%	45%	39%	14%	
Diversion impacts as a percent of unimpaired flows in a moderate year	11%	18%	31%	33%	26%	8%	

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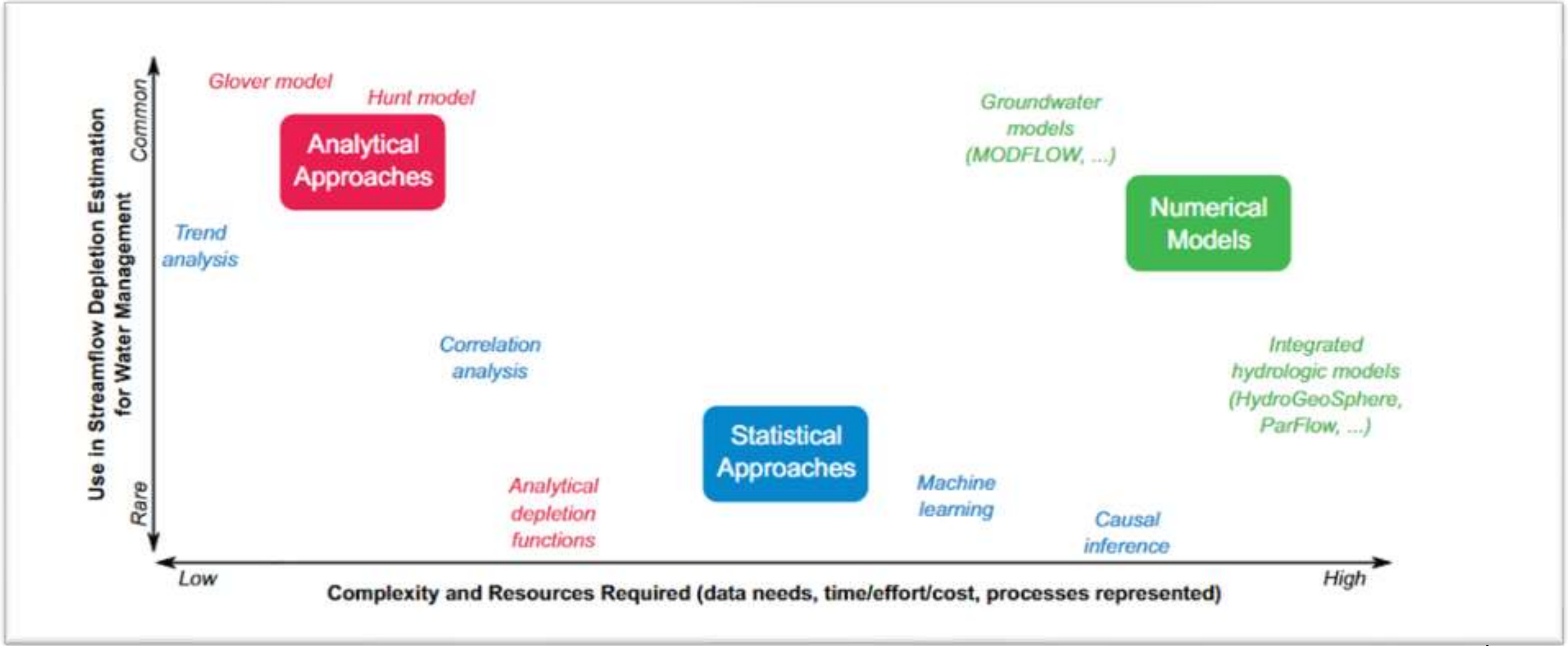
Principles and Guidelines for Well Ordinances

Element 2: Assess baseline streamflow and groundwater conditions

c) Estimate existing, cumulative streamflow depletion impacts due to groundwater pumping.

1. Utilize or develop appropriate modeling tools (e.g.; statistical, analytical, numerical) based on risk and need for resolution.



Zipper et al. 2022

Principles and Guidelines for Well Ordinances

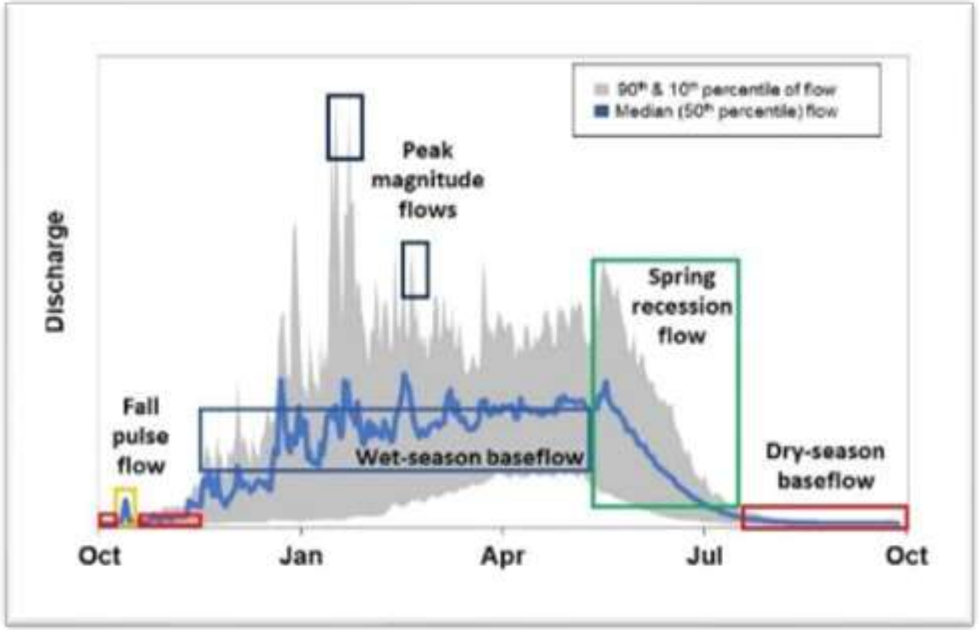
Element 3: **Identify ecologically protective streamflow thresholds to assess risk and impacts.**

a) Existing streamflow and habitat analyses, established flow requirements.

b) Generalize approaches such as the Richter (2012), North Coast Instream Flow Policy, California Environmental Flows Framework (CEFF), etc.

Example: Sonoma County

- Developed a presumptive standard for environmental flow protection based on Richter (2012)
  - 0-10% Depletion= High level of ecological protection
  - 11-20% = Moderate depletion.
  - > 21%= High level of Streamflow depletion



California Environmental Flow Framework. Yarnell et al. 2020

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Principles and Guidelines for Well Ordinances

Element 4: **Develop a PTR risk assessment matrix and maps to inform appropriate permitting pathways.**

a) **Low-risk area** –
   1. Areas where streamflows are not already ecologically impaired,
   2. Significant streamflow depletion of new wells is unlikely to impact PTR

b) **High-risk area** –
   a) Where streamflows are approaching or exceeding unacceptable levels of ecological impairment;
   b) Where new wells could have significant streamflow depletion impacts
   c) There is elevated risk of future impacts due to development pressure
   d) The presence of particularly sensitive resources

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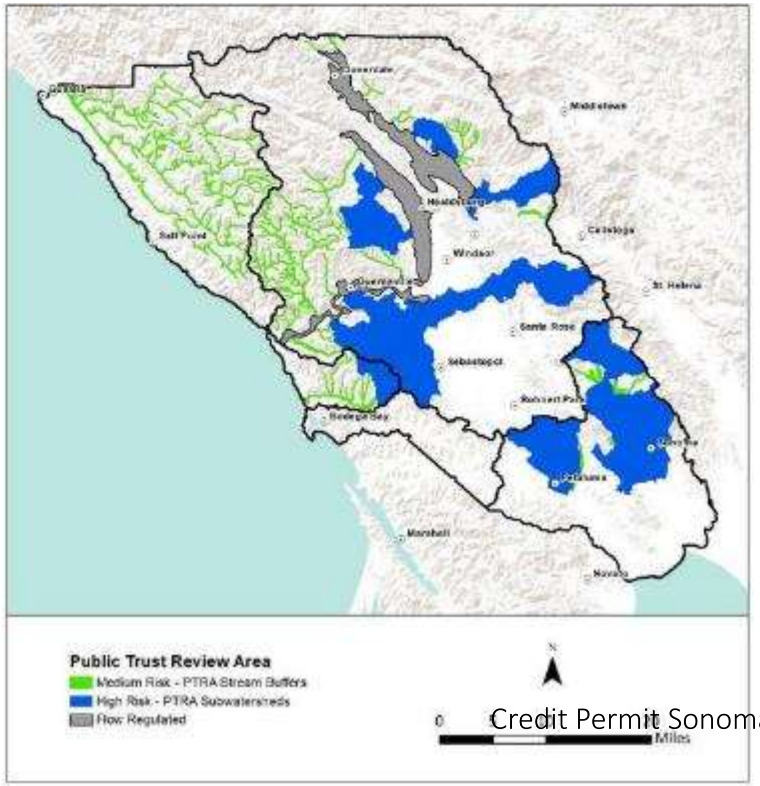
Principles and Guidelines for Well Ordinances

Element 4: Develop a PTR risk assessment matrix and maps to inform appropriate permitting pathways.



Credit Permit Sonoma

	Low SFD (0 – 10%)	Medium SFD (10 – 20%)	High SFD (>20%)
Low Habitat Value	Low Risk Area Not included in PTRA	Low Risk Area Not included in PTRA	Low Risk Area Not included in PTRA
Moderate Habitat Value	Low Risk Area Not included in PTRA	Moderate Risk Area Stream buffers	High Risk Area Sub-watershed
High Habitat Value	Moderate Risk Area Stream buffers	High Risk Area Sub-watershed	High Risk Area Sub-watershed
Very High Habitat Value	High Risk Area Sub-watershed	High Risk Area Sub-watershed	High Risk Area Sub-watershed

Stream buffers – Moderate Risk Areas

- Stream Depletion Factor (SDF) was used in defining stream buffer distances
- A relative measure of how rapidly streamflow depletion occurs in response to new pumping
- ~100 ft for the Franciscan Complex, ~250 ft for the Sonoma Volcanics, and ~750 ft for Wilson Grove Formation / alluvial sediments

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Principles and Guidelines for Well Ordinances

Element 5: Define permitting thresholds, reporting requirements, and mitigation measures

a) Define categories of low and high-risk wells

   a) Location (risk area, proximity to stream or habitat), size (af/yr).

b) Permitting

   a) Ministerial – Low risk location and well.

   b) Discretionary – High risk location or well

c) Conservation and mitigation measures

   a) Water efficiency requirements, conservation plans for ag and commercial,

   b) Net Zero impacts for high risk wells.

d) Replacement Wells

   a) Same depth and rate, mitigation measures.

e) Reporting requirements.

   a) All discretionary - non de minimis – wells

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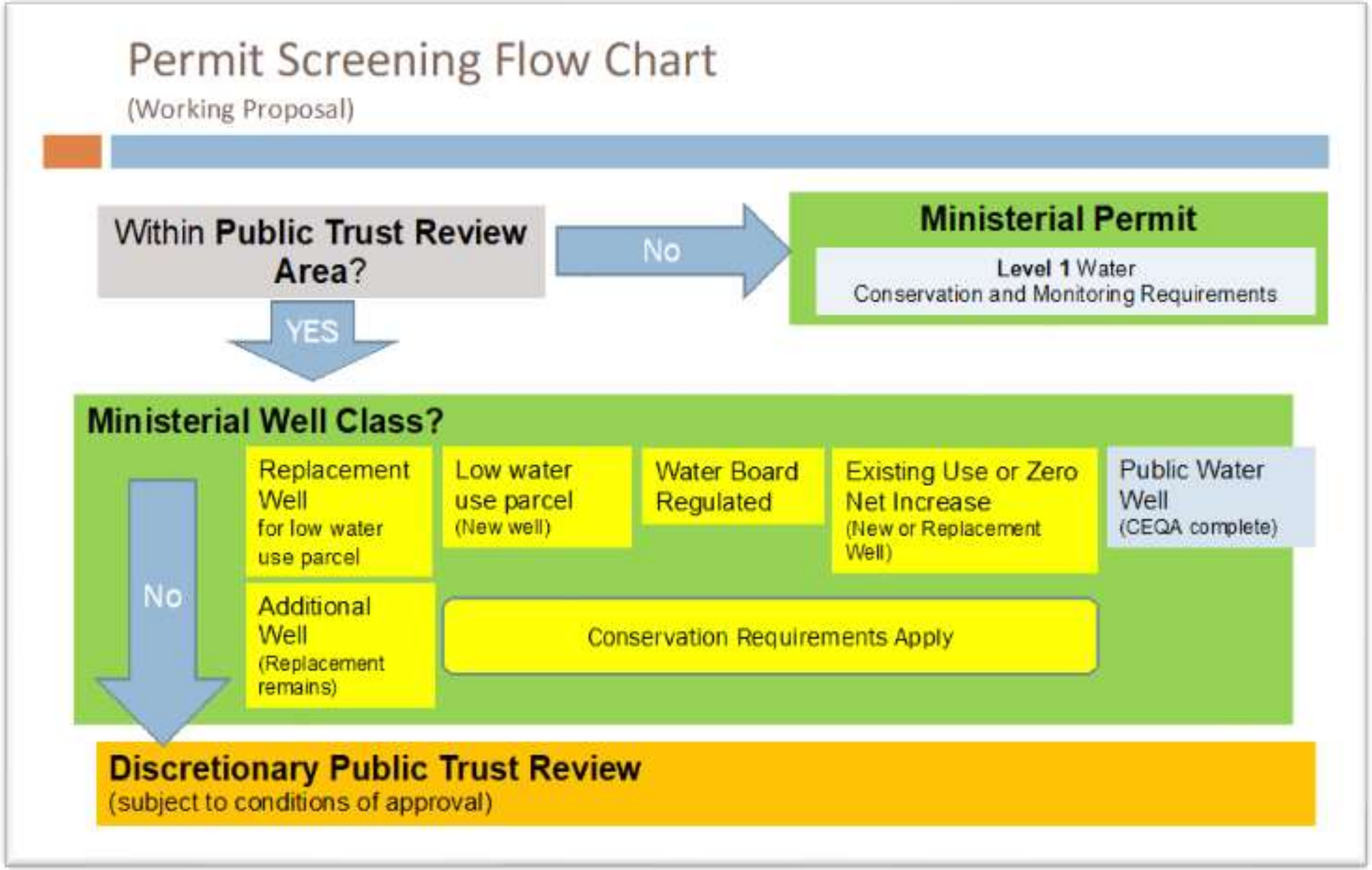
Principles and Guidelines for Well Ordinances

Element 5: Define permitting thresholds, reporting requirements, and mitigation measures.



Credit Permit Sonoma

Principles and Guidelines for Well Ordinances

Element 6: **Establish monitoring and adaptive management measures.**

a) Establish groundwater and surface water monitoring programs to assess and avoid impacts on PTRs.

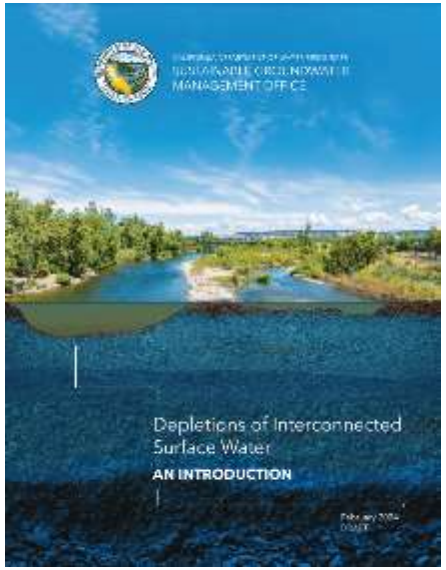
b) Develop methods to monitor, and report groundwater extraction volumes, rates, and timing.

c) Develop adaptive management measures to mitigate climate change impacts.

d) Reassess cumulative streamflow depletion impacts and remap county-wide risk assessments every five years.

Next Steps

- Well Ordinance Principles and Guidelines Report
- City and county efforts to develop well ordinances
  - Sonoma (adaptive management plan)
  - Santa Cruz, Siskiyou, San Luis Obispo, others?
- SGMA
  - DWR Interconnected Surface Water Guidance
- State Water Board / DWR
  - Update statewide well ordinance guidelines



The Nature Conservancy

Groundwater into Streamflow

Principles and Guidelines for Cities and Counties to Develop Well Ordinances to Protect Streamflow for Salmon Habitat

Questions?

Monty Schmitt
Water Program Sr. Project Director
The Nature Conservancy

Incorporating Site Characterization into Natural Landscape Engineering and Streamflow Enhancement Projects: Case Studies from the Upper Mattole Watershed

Wyeth Wunderlich, MS, GIT

Project Geologist, EBA Engineering

wwunderlich@ebagroup.com

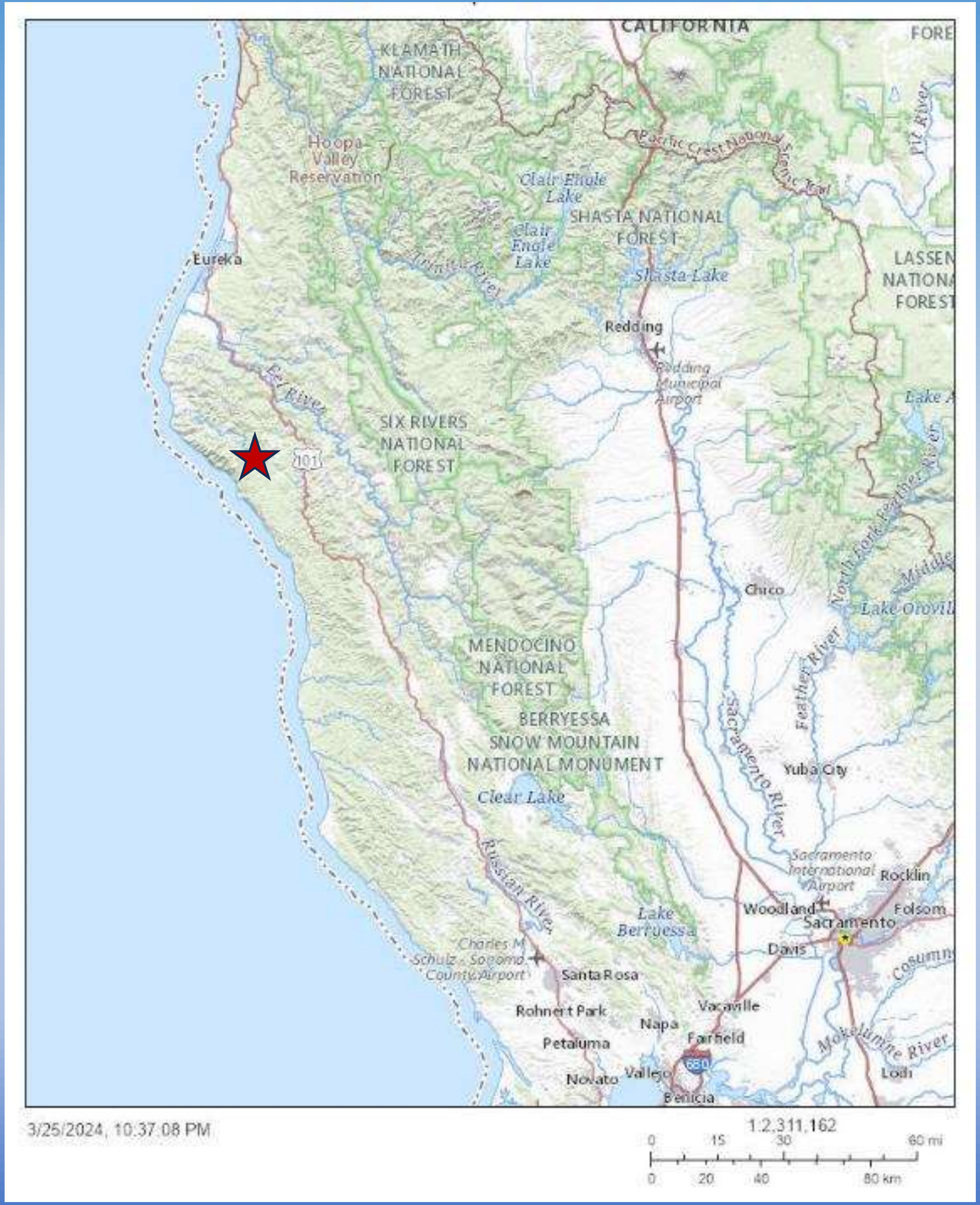
Tasha McKee

Water Program Director, Sanctuary Forest

tasha@sanctuaryforest.org

EBA ENGINEERING

Sanctuary Forest



CALIFORNIA
KLAMATH NATIONAL FOREST
Hoopa Valley Reservation
Clair Engle Lake
SHASTA NATIONAL FOREST
Shasta Lake
Eureka
Redding
Redding Municipal Airport
LASSEN NATIONAL FOREST
Eel River
SIX RIVERS NATIONAL FOREST
101
Chico
Lake Oroville
Feather River
MENDOCINO NATIONAL FOREST
BERRYESSA SNOW MOUNTAIN NATIONAL MONUMENT
Clear Lake
Sacramento River
Yuba City
Sacramento International Airport
Rocklin
Woodland
Sacramento
Folsom
Davis
Russian River
Lake Berryessa
Charles M Schulz - Sonoma County Airport
Santa Rosa
Rohnert Park
Napa
Vacaville
Fairfield
Petaluma
Novato
Vallejo
Benicia
Lodi
Mokelumne River
3/25/2024, 10:37:08 PM
1:2,311,162
0 15 30 60 mi
0 20 40 80 km

The Mattole Watershed
101
Rainbow Ridge
Taylor Peak
North Fork Mattole
Petrolia
Mattole River
Prosper Ridge
Mattole River
Honeydew
Gilham Butte
Wilder Ridge
King Peak
Ettersburg
Telegraph Ridge
Garberville
Briceland
King Range National Conservation Area
Thorn Junction
Shelter Cove
Whitethorn
Chemise Mountain
Humboldt Co.
Mendocino Co.
Elevation in feet
> 2500
1501 - 2500
1001 - 1500
501 - 1000
251 - 500
< 250
Peaks
Critical Coastal Areas
Mattole Watershed Boundary
Humboldt State Redwoods Park
King Range National Conservation Area
Punta Gorda Marine Potection Area
Area of Special Biological Significance
0 2.5 5 Miles

Land Acknowledgement

Sanctuary Forest acknowledges and appreciates that the Mattole River watershed is situated within the greater Tribal Territories of the Indigenous Sinkyu-ne (“Sinkyone”), Mattole, Bear River, and Wailaki peoples who have stewarded this land for many thousands of years. We pledge to collaborate with the native peoples on whose unceded ancestral land we live and work while respecting their right to self-determination and the sanctity of their cultural lifeways.

Streamflow Enhancement Strategies

- Changing human use – storage and forbearance, community outreach, and collaborative water management.

- Groundwater recharge – instream and upslope projects with “passive” streamflow benefits.

- Upslope ponds with metered flow to the stream.

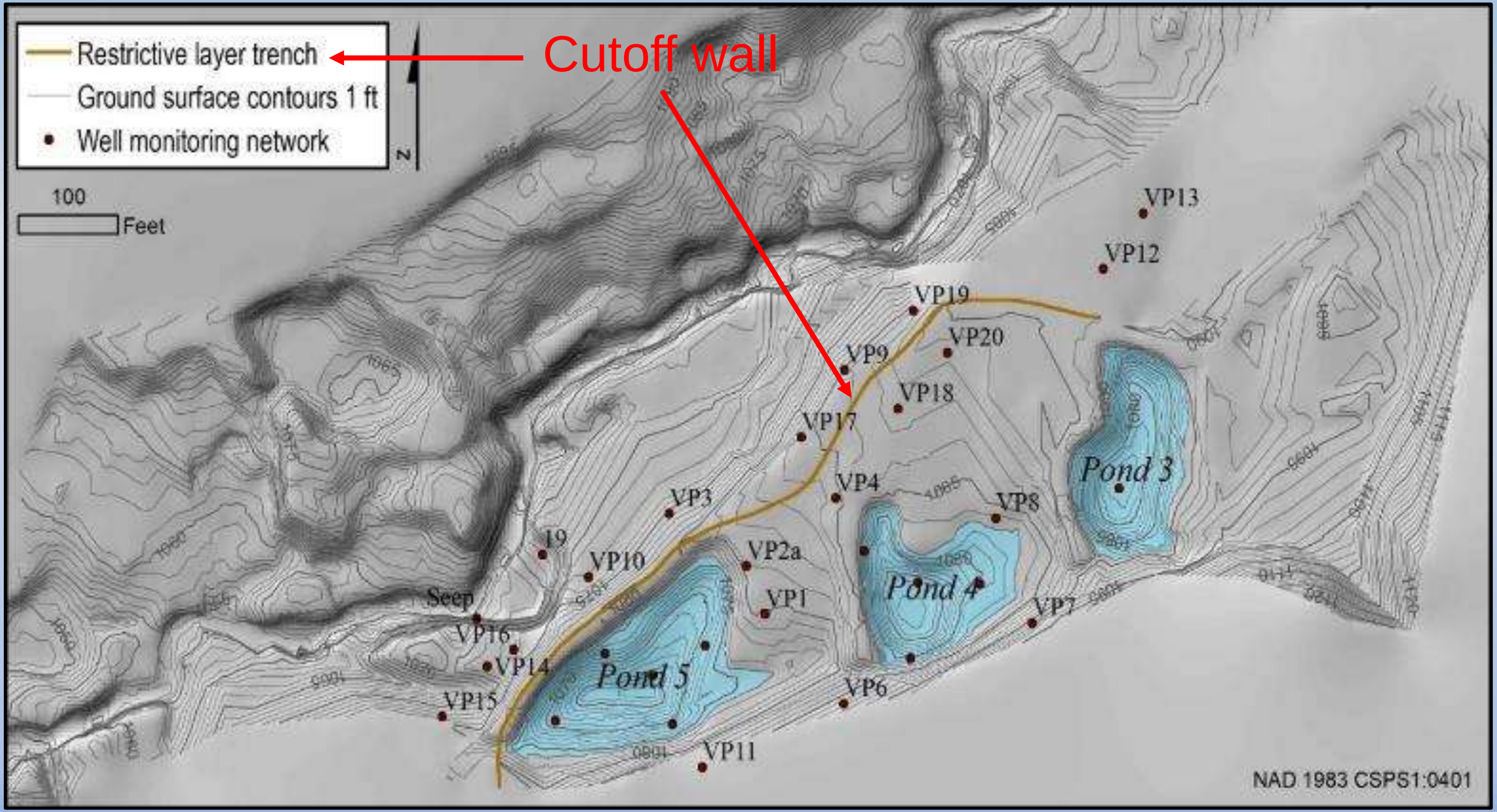
- Forest thinning for stewardship and to reduce evapotranspiration.

Baker Creek String of Pearls

Groundwater Recharge Ponds

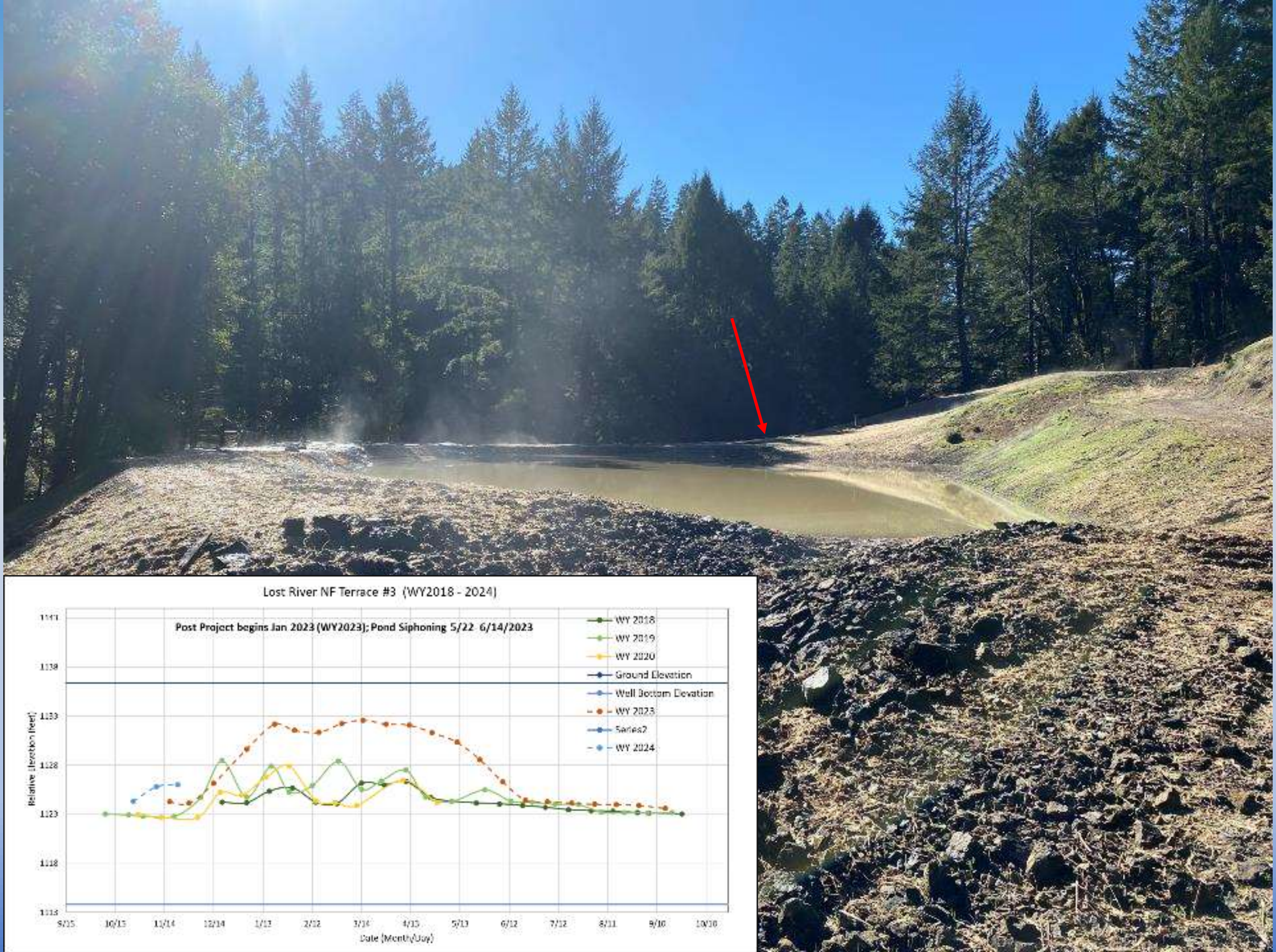
(2.8 million gallons of surface water & up to 7 million gallons of groundwater)

(Approx. 370,000 CF & 936,000 CF)



*Project designed and implemented by Sanctuary Forest and Stillwater Sciences.
EBA Engineering was not involved in the Baker Creek String of Pearls Project.

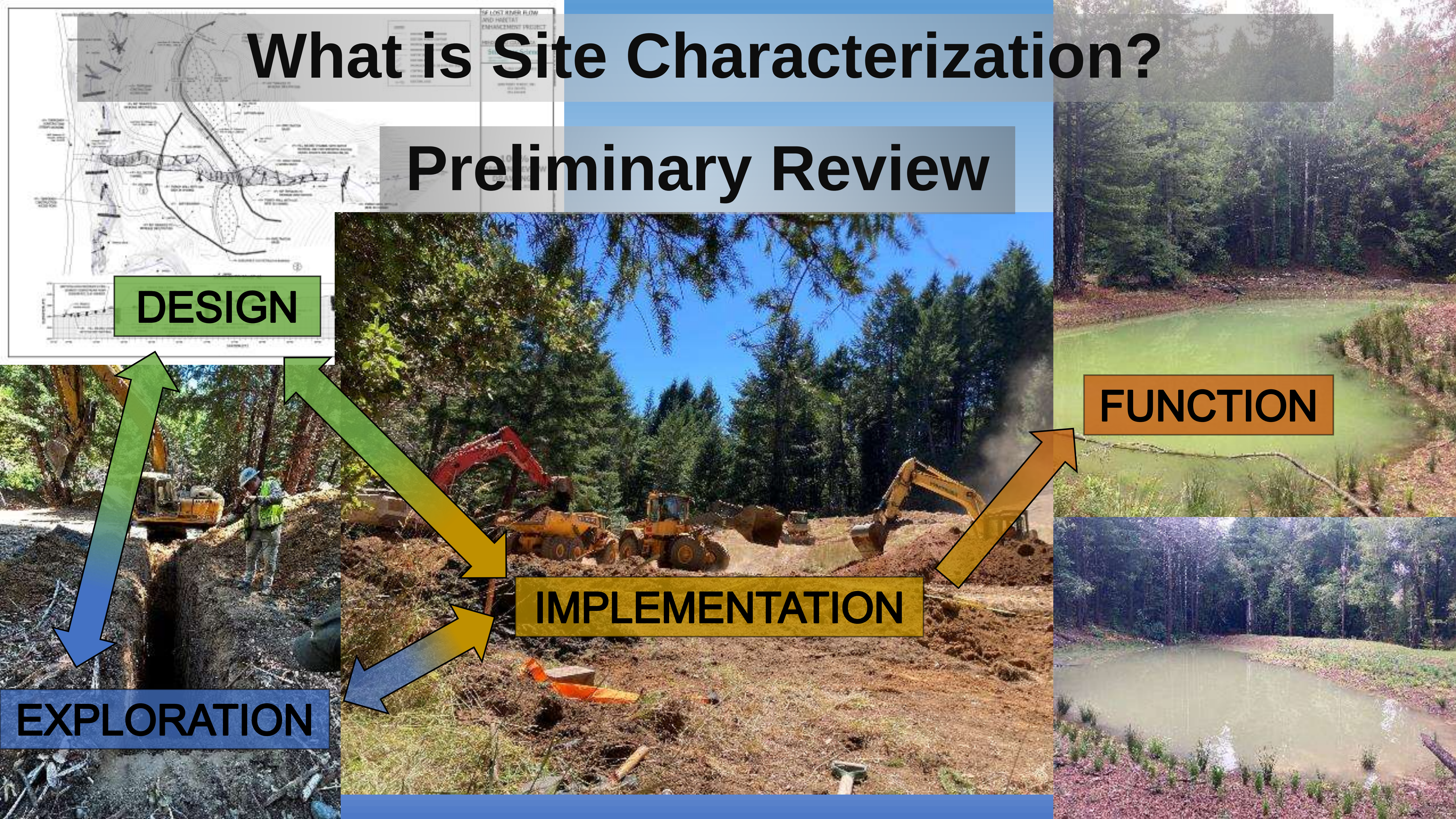
Building the Subsurface Restrictive Barrier (‘Cutoff Wall’)



Lost River NF Terrace #3 (WY2018 - 2024)
Post Project begins Jan 2023 (WY2023); Pond Siphoning 5/22-6/14/2023
WY 2018
WY 2019
WY 2020
Ground Elevation
Well Bottom Elevation
WY 2023
Series2
WY 2024
Relative Elevation (feet)
1143
1138
1133
1128
1123
1118
1113
9/15
10/15
11/14
12/14
1/13
2/12
3/14
4/13
5/13
6/12
7/12
8/11
9/10
10/10
Date (Month/Day)

What is Site Characterization?

Preliminary Review



What are some methods used to characterize site conditions?

Published Resources

- Geologic maps, ideally 7.5-minute (1:24,000) scale (USGS, CGS, academic studies, etc.).
- Fault/fold map databases (USGS, CGS).
- Regional geologic studies (academic, industry, etc.).
- NRCS Web Soil Survey.
- Landslide Inventory Database (CGS).
- FEMA Flood Maps.

Monitoring/Data Collection

- Water balance/hydrologic analysis
  - Precipitation (PRISM - daily timestep).
  - Streamflow (USGS/NOAA).
  - Evapotranspiration (CIMIS, RAWS, etc.).
- Topographic survey and analysis
  - LiDAR, drone photogrammetry, topographic survey
- Groundwater
  - Monitoring wells, wetlands, streams, water quality, slug tests, etc.).
- Local bedrock geology
  - Composition, structural orientations, extents.
- Geophysical surveys
  - Seismic, electrical resistivity, downhole, etc.

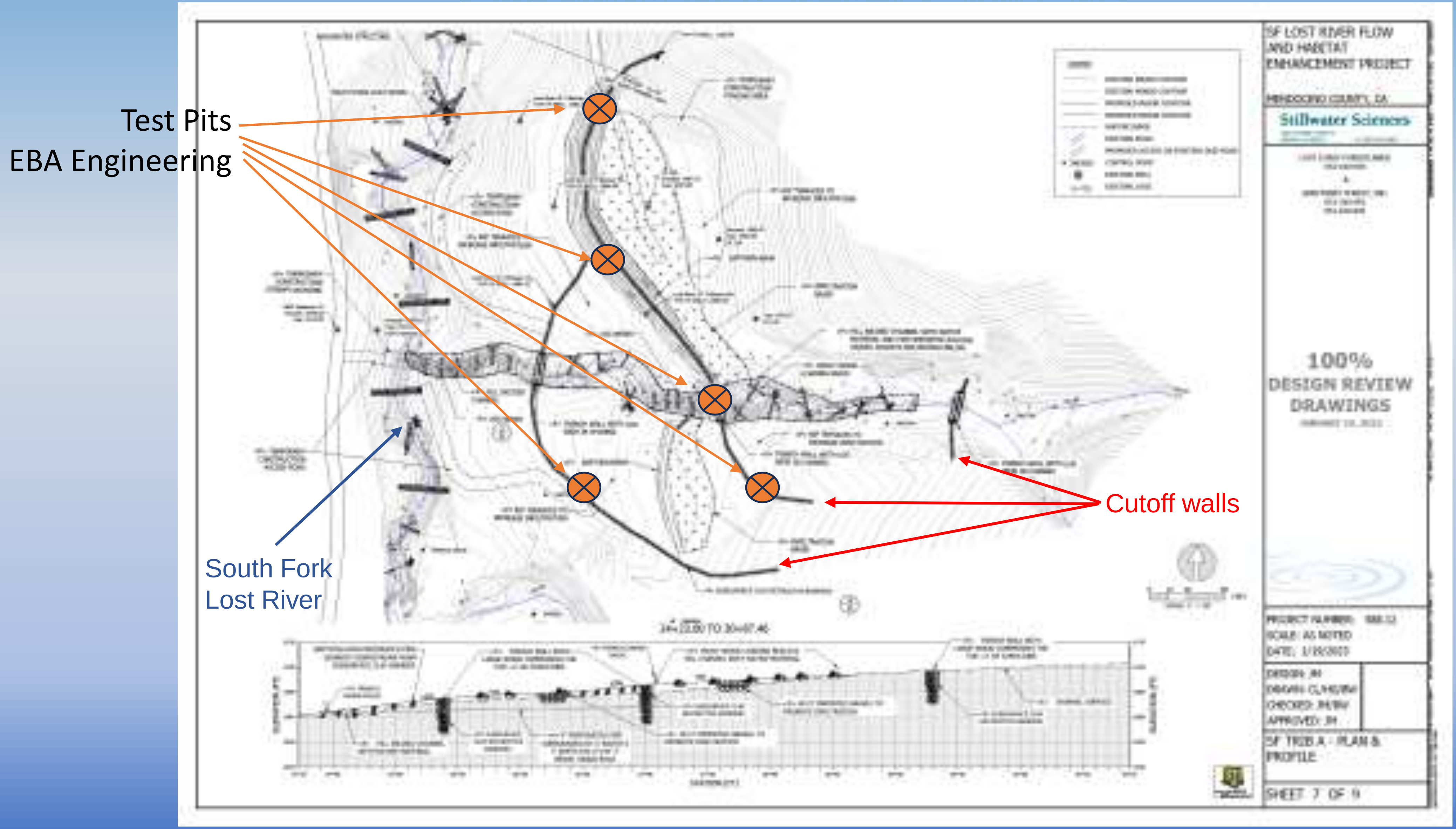
Direct Observation

- Test pits.
  - Subsurface strata, continuity, samples, and presence/depth of groundwater.
- Borings
  - Direct push technology (DPT), hollow stem auger.
- Cone penetrometer test (CPT)
  - Lithological classification and soil behavior.
- Laboratory analysis – soil/rock
  - Sieve analysis, permeability, Atterberg Limits, Expansion index, Strength test, compaction test, etc.

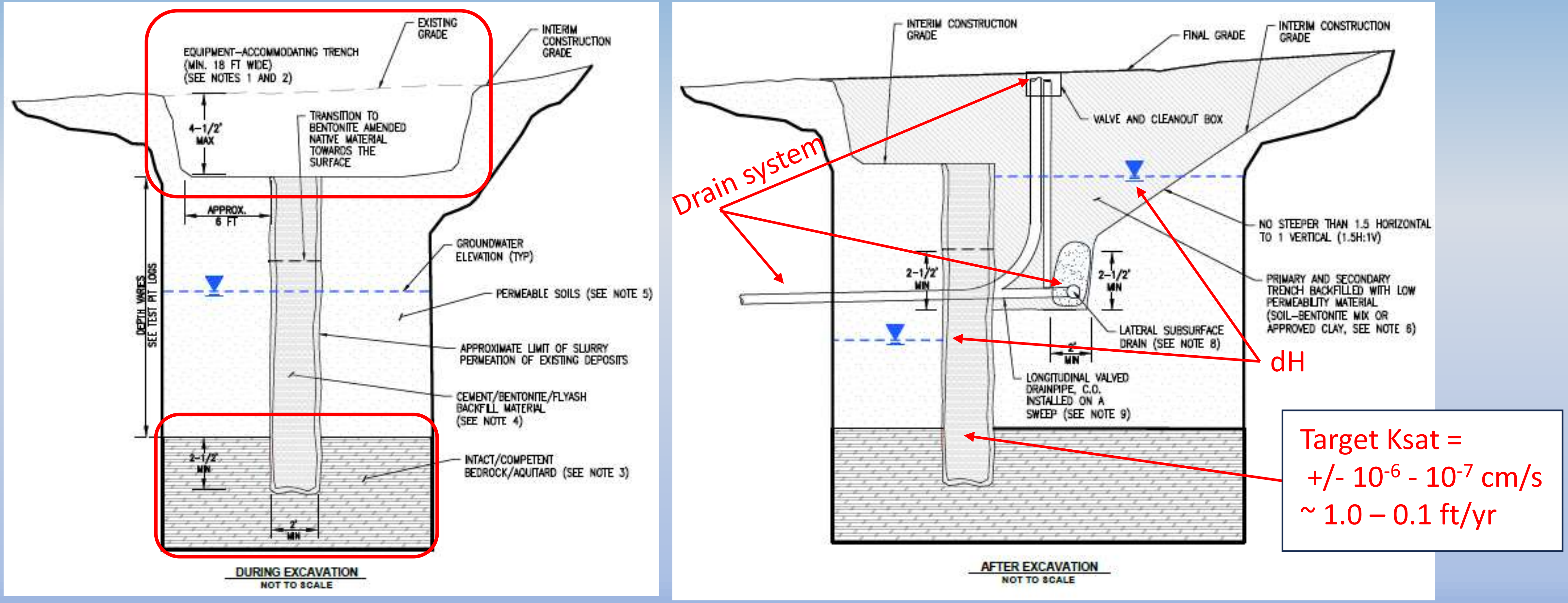
South Fork Lost River

Subsurface clay restrictive barriers for Terrace storage

(Estimated 1.1 million gallons & avg streamflow benefit of 6.5 gpm over 122 days June 15- Oct 15)



Conceptual Construction X-Section Details



*Schematic produced by EBA Engineering Senior Engineering Geologist, Bret McIntyre, PG, CEG

Key Takeaways

- Project design is an iterative process which should work backwards from the intended project function and site constraints.

- Site characterization should incorporate a review of published resources, design limitations, collection of monitoring data, and direct observations of site conditions and constraints.
  - Site assessments and prescriptions will vary per site, with some generic, and others unique to the site conditions.

- Surprises = $$$ - Proper site characterization reduces the risks and magnitude of encountering unexpected site conditions.
  - Investment - Requires budget allocation to the pre-construction site characterization phase.
  - Greater chances of successful outcomes!


2020/08/27


2020/08/27




Sanctuary Forest

Thank You to Our Partners!

With acknowledgement to our <u>many</u> mentors and partners including (but not limited to!):

- Joel Monschke, Stillwater Sciences
- Campbell Thompson, Mattole Salmon Group
- Sam Flanagan, Bureau of Land Management
- Randy Klein, Consulting Hydrologist
- EBA Engineering, Wyeth Wunderlich and Bret McIntyre
- Conor Shea, US Fish & Wildlife Service
- Charnna Gilmore, Scott River Watershed Council
- Dr. Michael Pollock, NOAA Fisheries
- Chris Maser, research scientist
- Implementation subcontractors, community volunteers and working group/technical advisory committees, 2010 – present
- California Dept. of Fish & Wildlife (Forbearance Program Development)
- Regional & State Water Quality Control Boards (Permitting & Water Rights Pathways)

Sanctuary Forest

Thank You to Our Funders!

- California Wildlife Conservation Board
- California Department of Water Resources
- California Department of Fish and Wildlife
- California State Water Resources Control Board
- National Fish and Wildlife Foundation
- National Oceanic and Atmospheric Administration
- Bella Vista Foundation
- California State Coastal Conservancy
- Bureau of Land Management
- US Fish and Wildlife
- Humboldt Area Foundation
- Department of Water Resources
- Kenny Brothers Foundation
- Fish America Foundation
- Firedoll Foundation
- McLean Foundation
- Patagonia Foundation
- Weeden Foundation
- Cereus Fund
- Anadromous Fund
- Pacific Coast Joint Venture
- Grace Us Foundation
- Resources Legacy Fund
- Scott Evans Foundation
- Sanctuary Forest Donors
- Participating Landowners

Projects and Services

- Environmental
  - Wide variety of site remediation, monitoring, and reporting.
  - Environmental Site Assessments (ESAs), permitting, CEQA, and regulatory support.
- Hydrogeologic and Geologic Services
  - Water availability analyses, well siting, groundwater modeling and geotechnical services.
- Civil
  - Water infrastructure, (supply, treatment, design), restoration, civil improvements, and construction management services.
- Survey

For Questions, Project, and Partnership Inquiries:

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Project Geologist, EBA Engineering

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David Noren,

Vice President, EBA Engineering

dnoren@ebagroup.com


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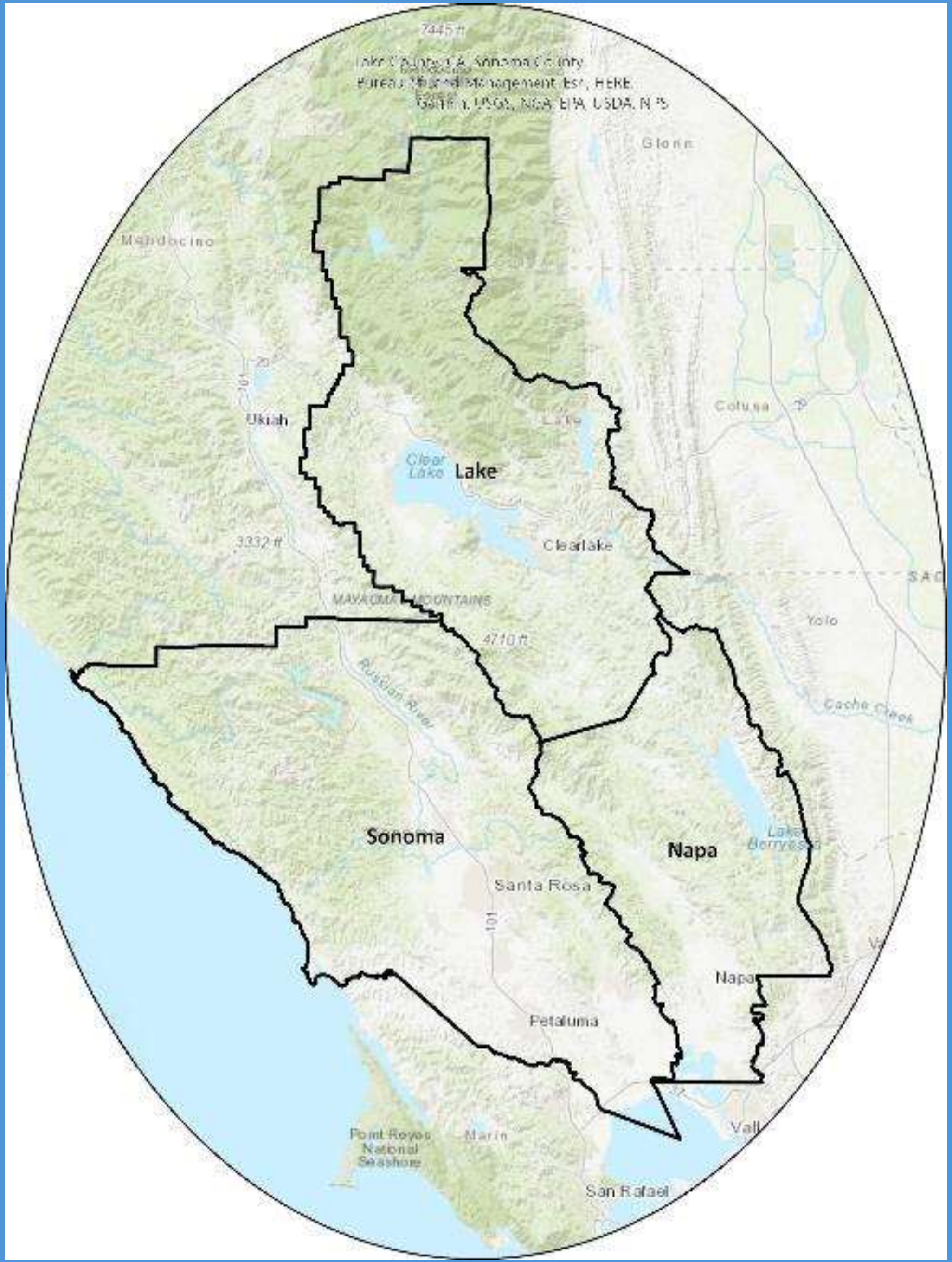
wwunderlich@ebagroup.com
Tasha McKee
Water Program Director, Sanctuary Forest
tasha@sanctuaryforest.org
EBA ENGINEERING
Sanctuary Forest

Regional Approaches for Groundwater Management to Mitigate Streamflow Depletion

Matthew O’Connor, PhD, CEG
O’Connor Environmental, Inc.
Healdsburg, California

Salmonid Restoration Federation Annual Conference

Santa Rosa, California March 29, 2024



Streamflow Depletion…

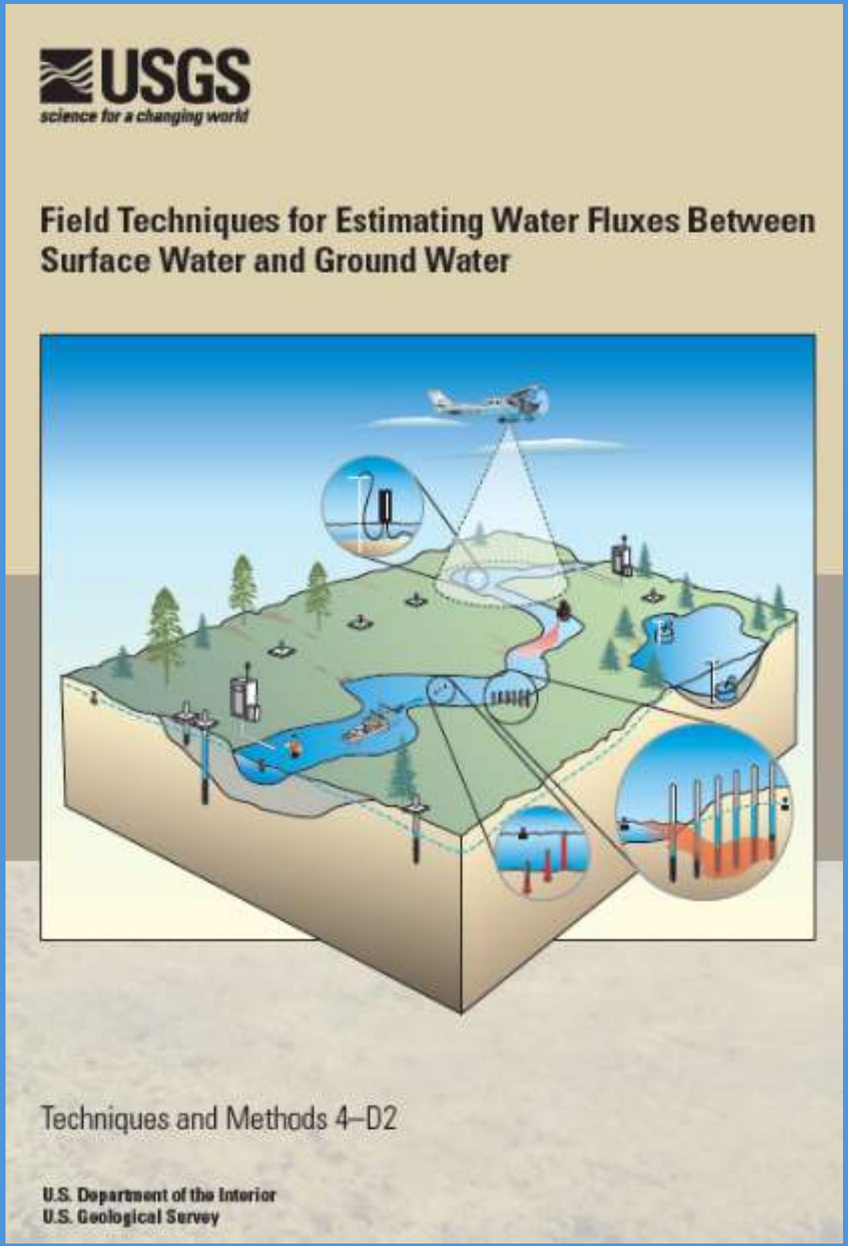
- Diminishes habitat for coho salmon in Central Coastal ESU & other aquatic species
- Severity scales with human use of water and climate
- Hydrologic processes in upland/bedrock tributary watersheds differ from lowland/alluvial rivers & streams
- Dry season streamflow is inflow from groundwater and may be lost to groundwater
- Groundwater pumping reduces inflows to streams and increases losses from streams
- Long term average streamflow depletion is “equivalent” to long term groundwater use
- “Equivalent” with much spatial/temporal variation in hydrogeologic processes that control streamflow
- Reducing groundwater use likely benefits streamflow; it is uncertain when, where and by how much
- County/State governments have enacted policies to manage groundwater and <u>begin</u> to address SD
- Numerical models are the state of the art for managing groundwater
- Models of interaction between surface water and groundwater require extra effort
- Obtaining data to calibrate and validate models is difficult and critical
- Significant time and effort required to validate & quantify streamflow benefits of groundwater management

Overview

- Methods for estimating streamflow depletion
- Existing County-level policies and procedures
- Typical groundwater analysis for County permits
- Strengths, weaknesses and insights

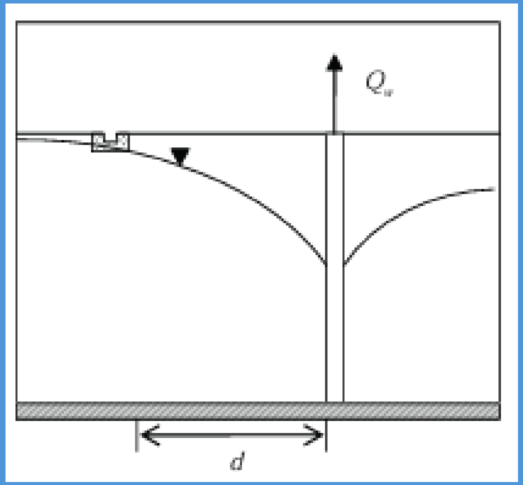
Quantifying Streamflow Depletion

Site specific intensive field measurement techniques



Quantifying Streamflow Depletion

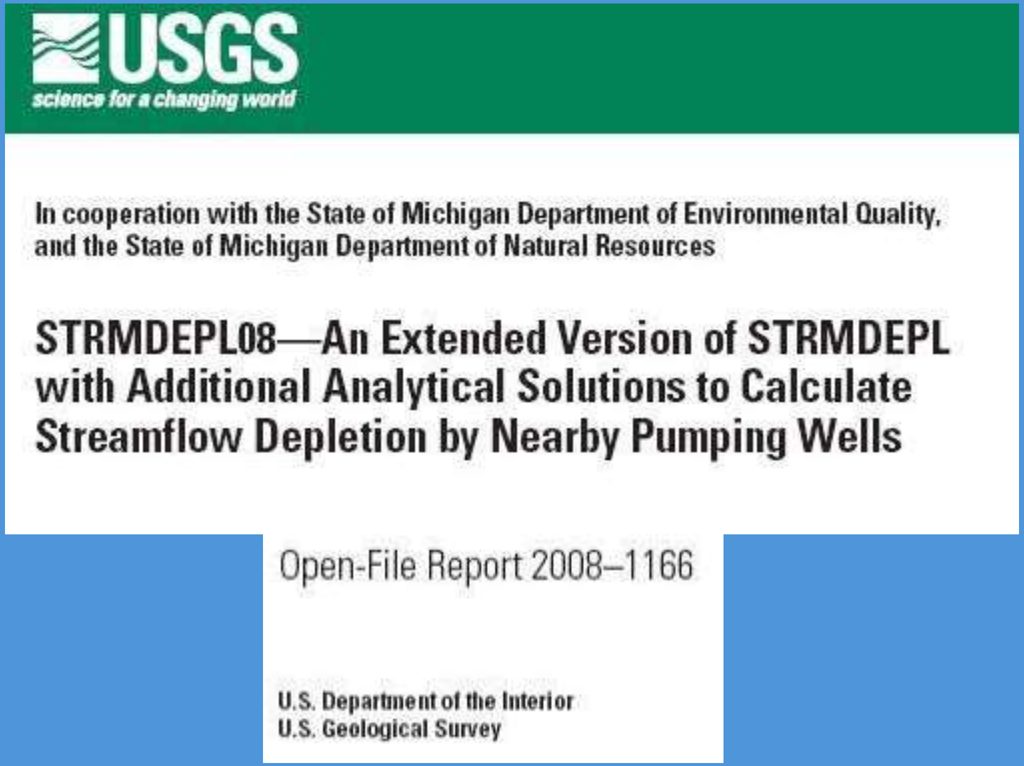
- Single well empirical well functions




Partially penetrating stream with streambed resistance (Hunt, 1999)

Distance (ft):
Transmissivity (ft2/day):
Storage Coefficient:
Streambed Conductance (ft/day):
Pumping Rate (gpm):
Days of Pumping:

Reset Submit


USGS
science for a changing world

In cooperation with the State of Michigan Department of Environmental Quality, and the State of Michigan Department of Natural Resources

STRMDEPL08—An Extended Version of STRMDEPL with Additional Analytical Solutions to Calculate Streamflow Depletion by Nearby Pumping Wells

Open-File Report 2008–1166

U.S. Department of the Interior
U.S. Geological Survey

Quantifying Streamflow Depletion

JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

Vol. 58, No. 2 AMERICAN WATER RESOURCES ASSOCIATION April 2022

Quantifying Streamflow Depletion from Groundwater Pumping: A Practical Review of Past and Emerging Approaches for Water Management

Samuel C. Zipper, William H. Farmer, Andrea Brookfield, Hoori Ajami, Howard W. Reeves, Chloe Wardropper, John C. Hammond, Tom Gleeson, and Jillian M. Deines

Quantifying Streamflow Depletion

Spatially distributed analytical models

Environ. Res. Commun. 1 (2019) 125005

S C Zipper *et al*

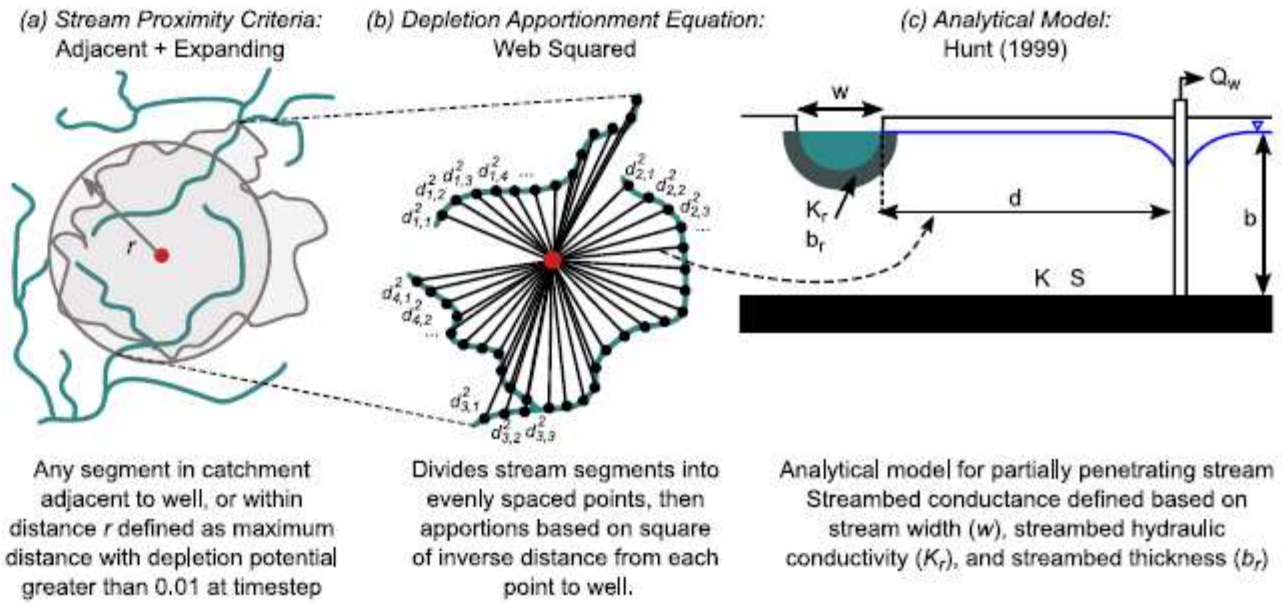
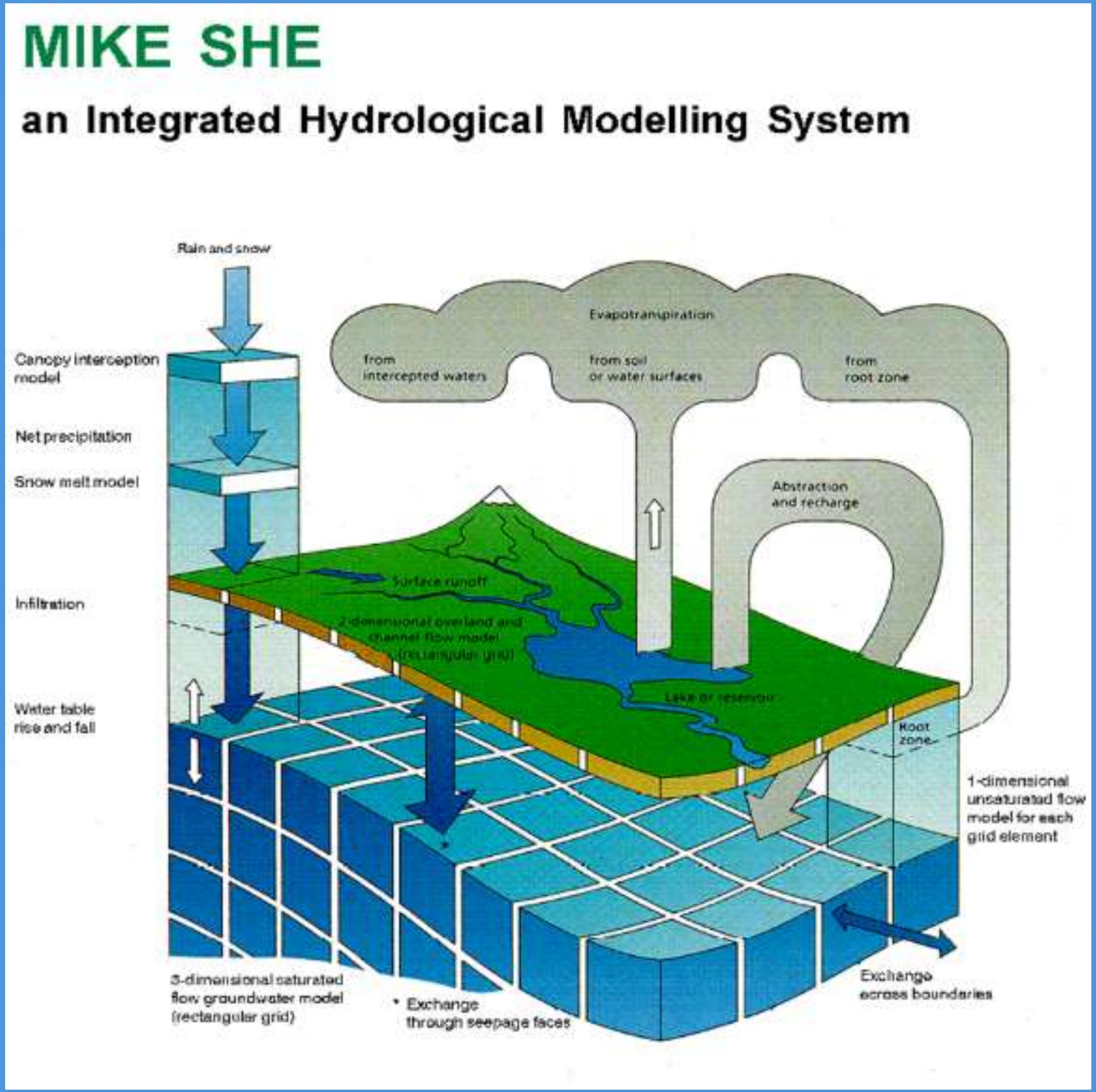


Figure 2. Diagram showing components of analytical depletion function: (a) stream proximity criteria, (b) depletion apportionment equations, and (c) analytical model.

Quantifying Streamflow Depletion

- Physically based spatially distributed Numerical models
- Numerical models + AI/ML



Disclaimer

County of Sonoma

- General Plan water resources element
  - ~2004-Policy RC-3h
  - ~2017-Policy WR-2e
    - Expanded & formalized
    - SGMA basins
    - Critical coho salmon watersheds
- Applicability
  - Depends on location
  - Discretionary permits-subdivisions, use permits, building permits, septic systems
  - Ministerial permits when a groundwater performance standard applies
  - Does not apply to most agricultural use
- Consistency with GSP's 2021
- Revised Well Ordinance adopted 2023 specifically to address potential SD

Permit and Resource Management Department

POLICY AND PROCEDURE **Number 8-1-14**

Procedures for Groundwater Analysis and Hydrogeologic Reports

PURPOSE

This policy outlines requirements for hydrogeologic reports, including well pump tests, for discretionary and ministerial projects performed for the purpose of complying with General Plan Policy WR-2e and sustainable groundwater management.

> ***Policy WR-2e (formerly RC-3h):*** *Require proof of groundwater with a sufficient yield and quality to support proposed uses in Class 3 and 4 water areas. Require test wells or the establishment of community water systems in Class 4 water areas. Test wells may be required in Class 3 areas. Deny discretionary applications in Class 3 and 4 areas unless a hydrogeologic report establishes that groundwater quality and quantity are adequate and will not be adversely impacted by the cumulative amount of development and uses allowed in the area, so that the proposed use will not cause or exacerbate an overdraft condition in a groundwater basin or subbasin. Procedures for proving adequate groundwater should consider groundwater overdraft, land subsidence, saltwater intrusion, and the expense of such study in relation to the water needs of the project.*

GENERAL

The Groundwater Availability Map classifies four areas of the County based on water yield, natural recharge and major groundwater basins within the County of Sonoma. Since adoption of the Sustainable Groundwater Management Act the groundwater availability map also identifies priority groundwater basis as identified by the Department of Water Resources Bulletin 118.

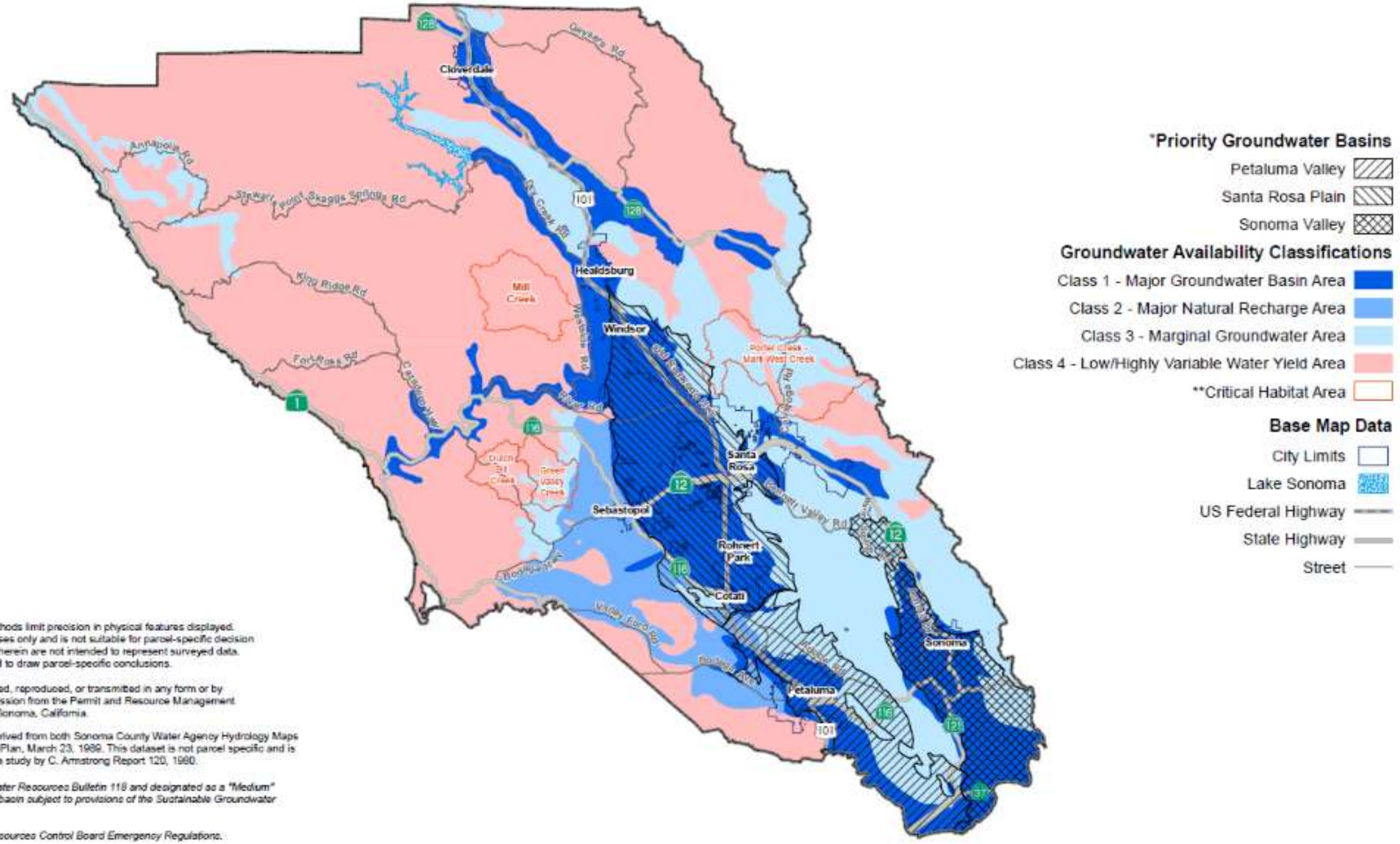
A hydrogeologic report will be required when a project is located in a Class 3 and or Class 4 groundwater availability area and also within priority groundwater basins. Hydrogeologic reports must be prepared by a qualified professional and include all information and analysis required in the Permit and Resource Management Department (Permit Sonoma) checklist (attached) for groundwater studies. Include impacts of the project with existing development and cumulative impacts from future development, and evaluate impacts to neighboring wells and interconnected surface waters.

AUTHORITY

Section 25-17q, Section 25-56c, and Section 7-12 of the County Code

1 of 5 02/23/2017

Groundwater Availability



Map scale and reproduction methods limit precision in physical features displayed. This map is for illustrative purposes only and is not suitable for parcel-specific decision making. The parcels contained herein are not intended to represent surveyed data. Site-specific studies are required to draw parcel-specific conclusions.

The original boundaries were derived from both Sonoma County Water Agency Hydrology Maps and County of Sonoma General Plan, March 23, 1989. This dataset is not parcel specific and is based on surface geology from a study by C. Armstrong Report 120, 1980.

**As defined in Department of Water Resources Bulletin 118 and designated as a "Medium" or a "High" priority groundwater basin subject to provisions of the Sustainable Groundwater Management Act.*

*** As defined by State Water Resources Control Board Emergency Regulations.*

permit SONOMA

Permit and Resource Management Department
2550 Ventura Avenue, Santa Rosa, California 95403
707-565-1900 FAX 707-565-1103

Groundwater Report

- Qualifications and scope specified
- Local project “impact area”
- Hydrogeologic conditions
- Water balance
  - Compare recharge to use
  - Future build-out scenario
- Additional impacts considered
  - Interconnected surface water
  - Aquatic habitat
  - Water quality

SONOMA COUNTY HYDROGEOLOGIC REPORT CHECKLIST

Compliance with Guidelines

YES	NO		
		1.	Was the report prepared by a Registered Geologist, Certified Engineering Geologist or Certified Hydrogeologist?
		2.	Is the impact area identified in the report and projected development consistent with that mutually agreed on by the geologist, the REHS, and the planner?
		3.	Are geologic formations correctly identified and delineated on a map?
		4.	Does the map have a scale and reference points?
		5.	IS the type of aquifer identified and described?
		6.	Is a geologic cross section included?
		7.	Are well depths in the area documented?
		8.	Is the yield of wells in the area known and well documented?
		9.	Was an effort made to learn of well failures or unsuccessful attempts to develop water in the impact area?
		10.	Is this effort well documented?
		11.	Were local property owners consulted, where appropriate?
		12.	Were well drillers contacted, where appropriate?
		13.	Is a water balance provided?
		14.	Is storage capacity calculated?
		15.	Is the water in storage calculated for the impact area?
		16.	Are the methods used described?
		17.	Are the calculations shown?
		18.	Does the report discuss current quantities and projected (cumulative) quantities of groundwater pumped?
		19.	Have other WR-2e reports been conducted in the area?
		20.	Is this report consistent with those reports?
		21.	Does the report discuss impacts to interconnected surface waters and aquatic habitat?
		22.	Are known water quality issues, including saline water intrusion, discussed?

The report indicates that:

	23.	The size of the cumulative impact areas (CIA) (acres)
	24.	The size of the project property (acres)
	25.	Proposed annual use (acre-feet)
	26.	Depth of proposed well (feet)
	27.	Estimated projected annual use by existing and potential development in the cumulative impact area (acre-feet)
	28.	Number of active wells in the cumulative impact area
	29.	Depth of wells in cumulative impact area (feet)
	30.	Distance to nearest well (feet)
	31.	Distance of ground water supply well to nearest surface water body (feet)
	32.	(P) Average annual rain fall (tenths of a foot)
	33.	(ETo) is lost to evapotransporation (tenths of a foot)
	34.	(Qout) % runs off

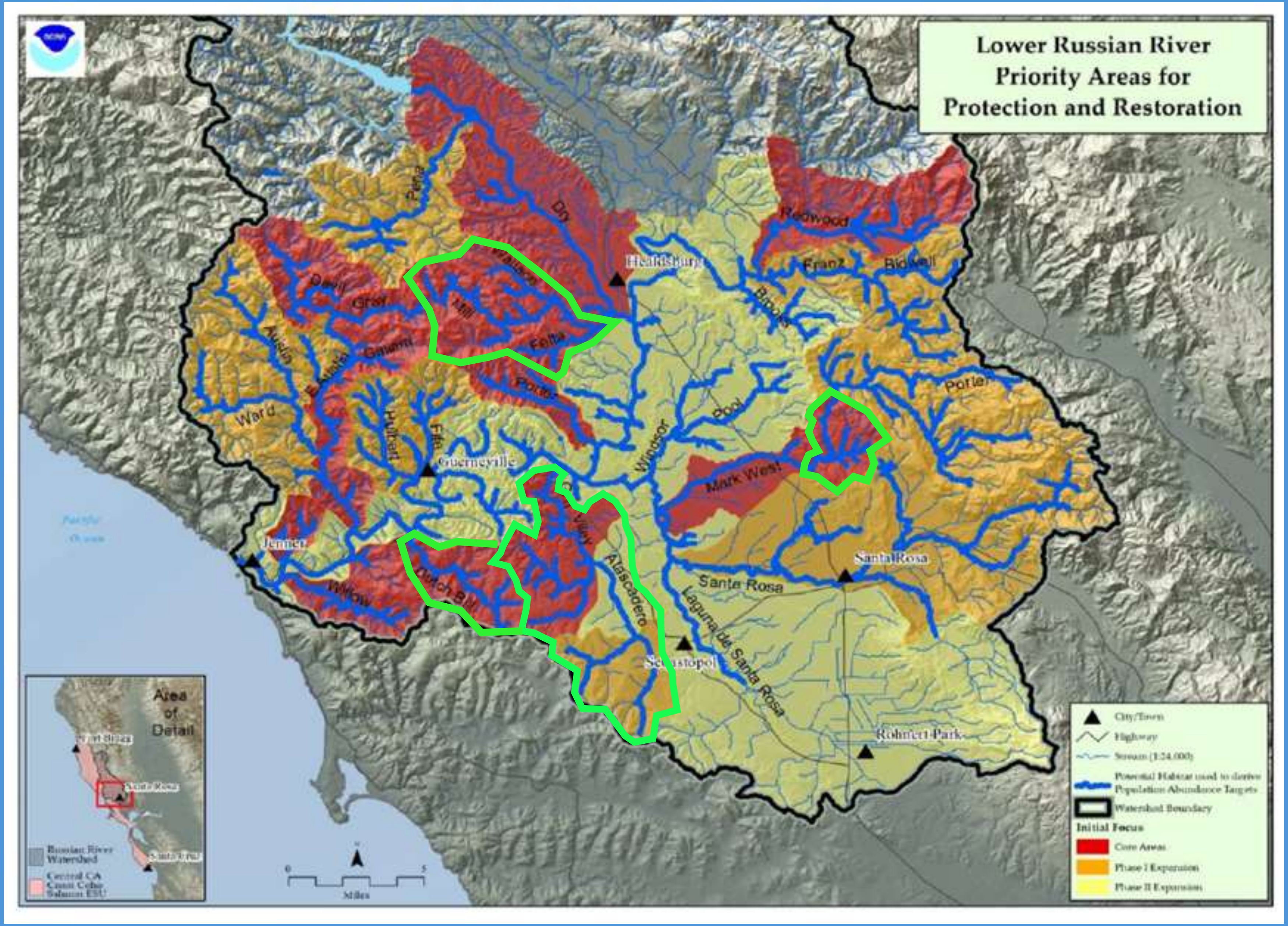
permit SONOMA

Sonoma County Permit and Resource Management Department
2550 Ventura Avenue Santa Rosa CA 95403-2859 (707) 565-1900
www.PermitSonoma.org

Criteria for Approval

Established by Gen. Plan Policy Specified in P&P 8-1-14

1. Groundwater quality and quantity are adequate and will not be adversely impacted by the cumulative amount of development and uses allowed in the area
2. The proposed use will not cause or exacerbate an overdraft condition in a groundwater basin or subbasin
3. The proposal [will] not result in groundwater overdraft, land subsidence or saltwater intrusion.
4. Groundwater use must not result in critical reduction in flow in directly connected surface waters or adverse impacts to groundwater dependent ecosystems

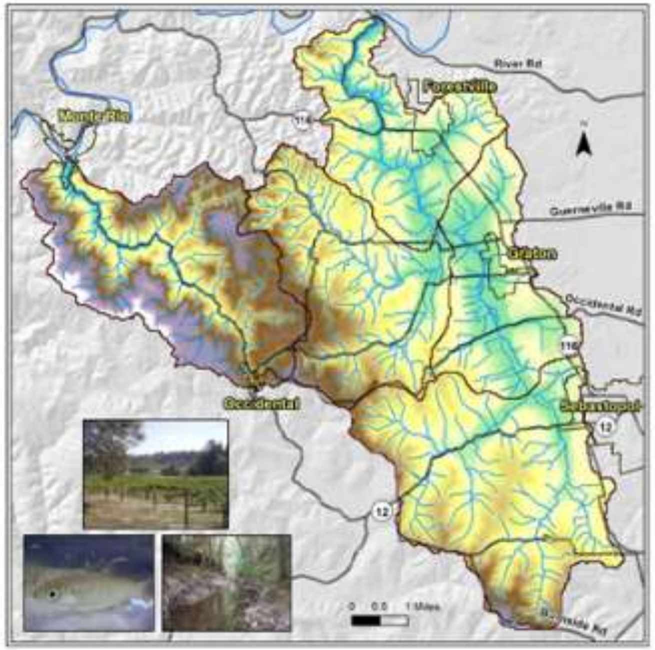


Priority Watersheds for Coho Salmon

- Recovery Plan 2012
- County of Sonoma 2017
  - Green Valley, Atascadero & Dutch Bill Creeks
  - Mark West Creek
  - Mill Creek
- Numerical hydrologic 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

December 2020

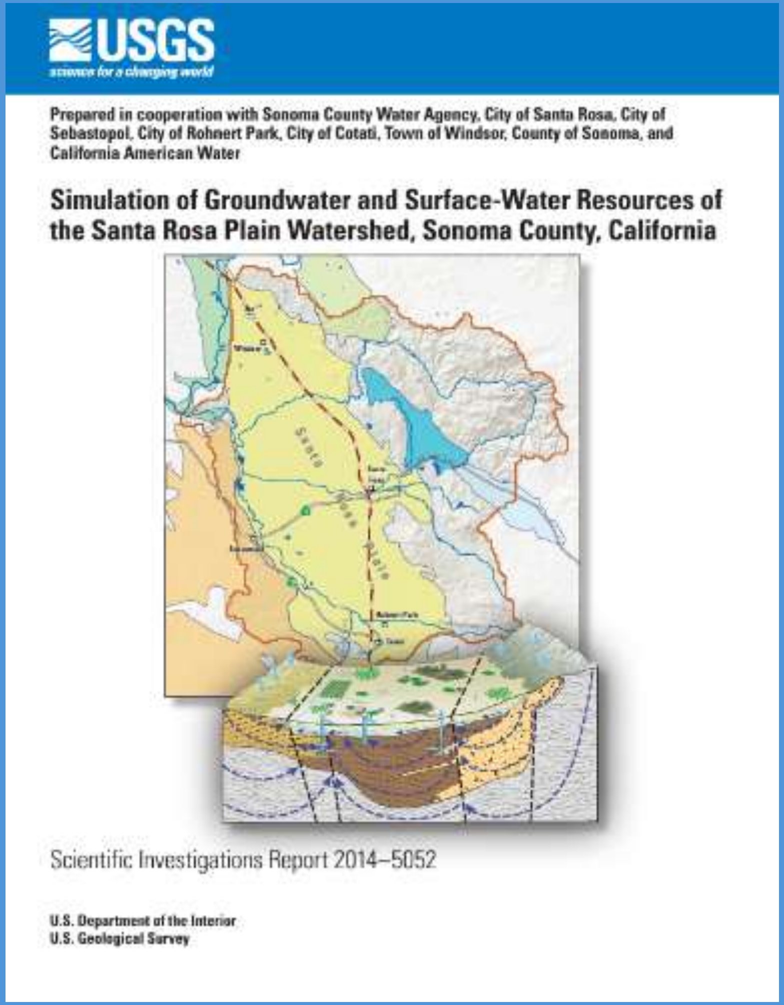
Integrated Surface and Groundwater Modeling and Flow Availability Analysis for Restoration Prioritization Planning, Mill Creek Watershed, Sonoma County, CA

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

June 2021

www.oe-i.com/news

www.coastrangewater.org/projects



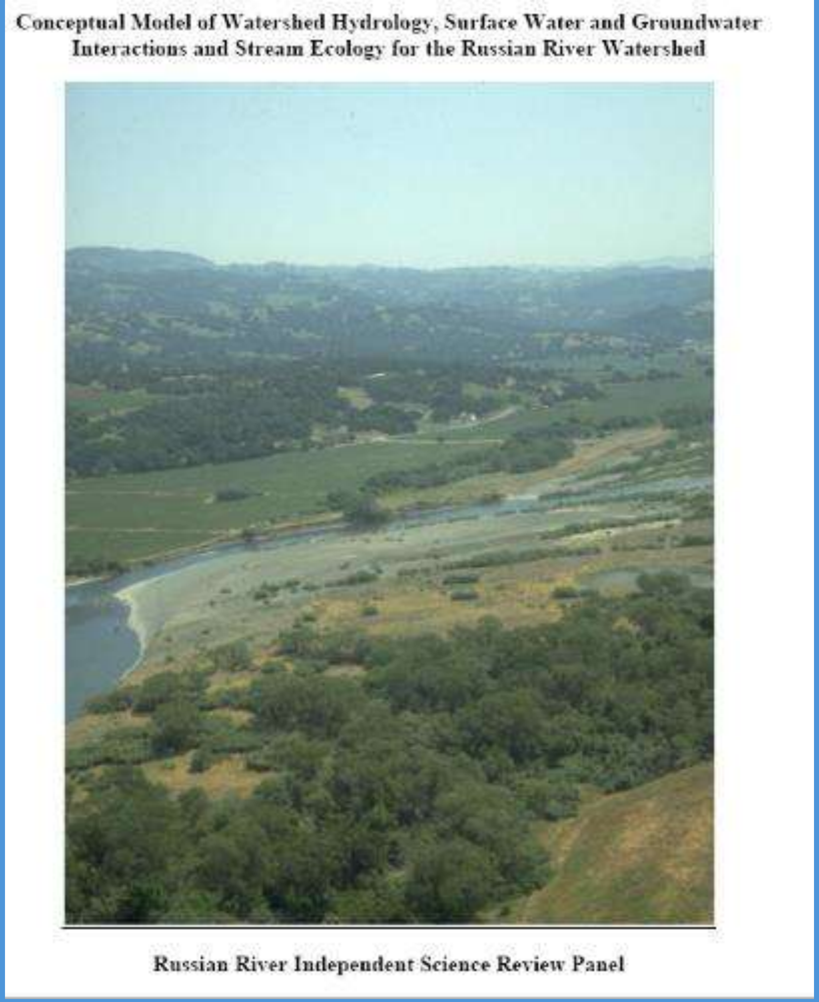
USGS
science for a changing world

Prepared in cooperation with Sonoma County Water Agency, City of Santa Rosa, City of Sebastopol, City of Rohnert Park, City of Cotati, Town of Windsor, County of Sonoma, and California American Water

Simulation of Groundwater and Surface-Water Resources of the Santa Rosa Plain Watershed, Sonoma County, California

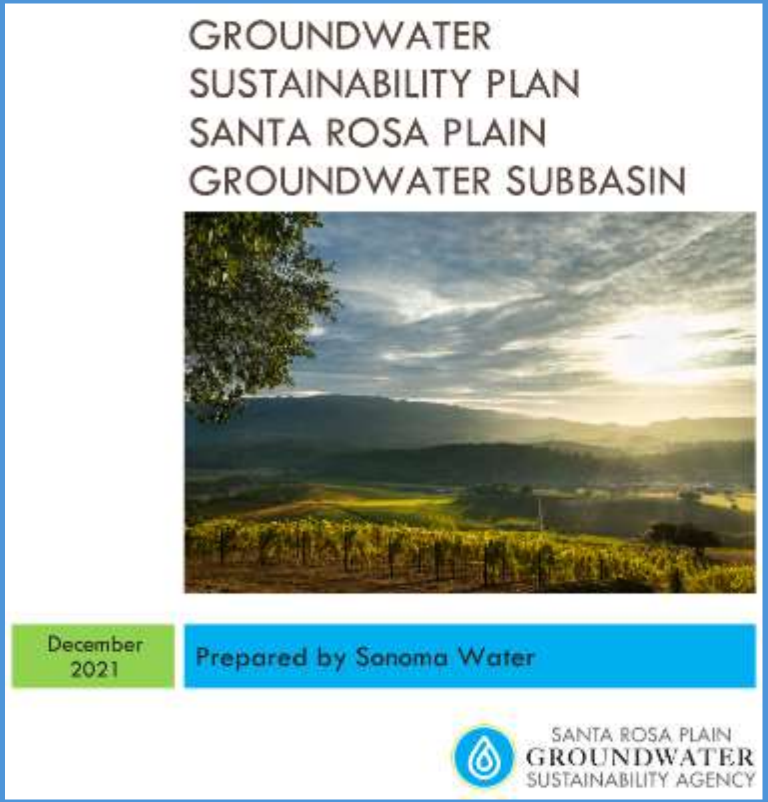
Scientific Investigations Report 2014–5052

U.S. Department of the Interior
U.S. Geological Survey



Conceptual Model of Watershed Hydrology, Surface Water and Groundwater Interactions and Stream Ecology for the Russian River Watershed

Russian River Independent Science Review Panel



GROUNDWATER SUSTAINABILITY PLAN SANTA ROSA PLAIN GROUNDWATER SUBBASIN

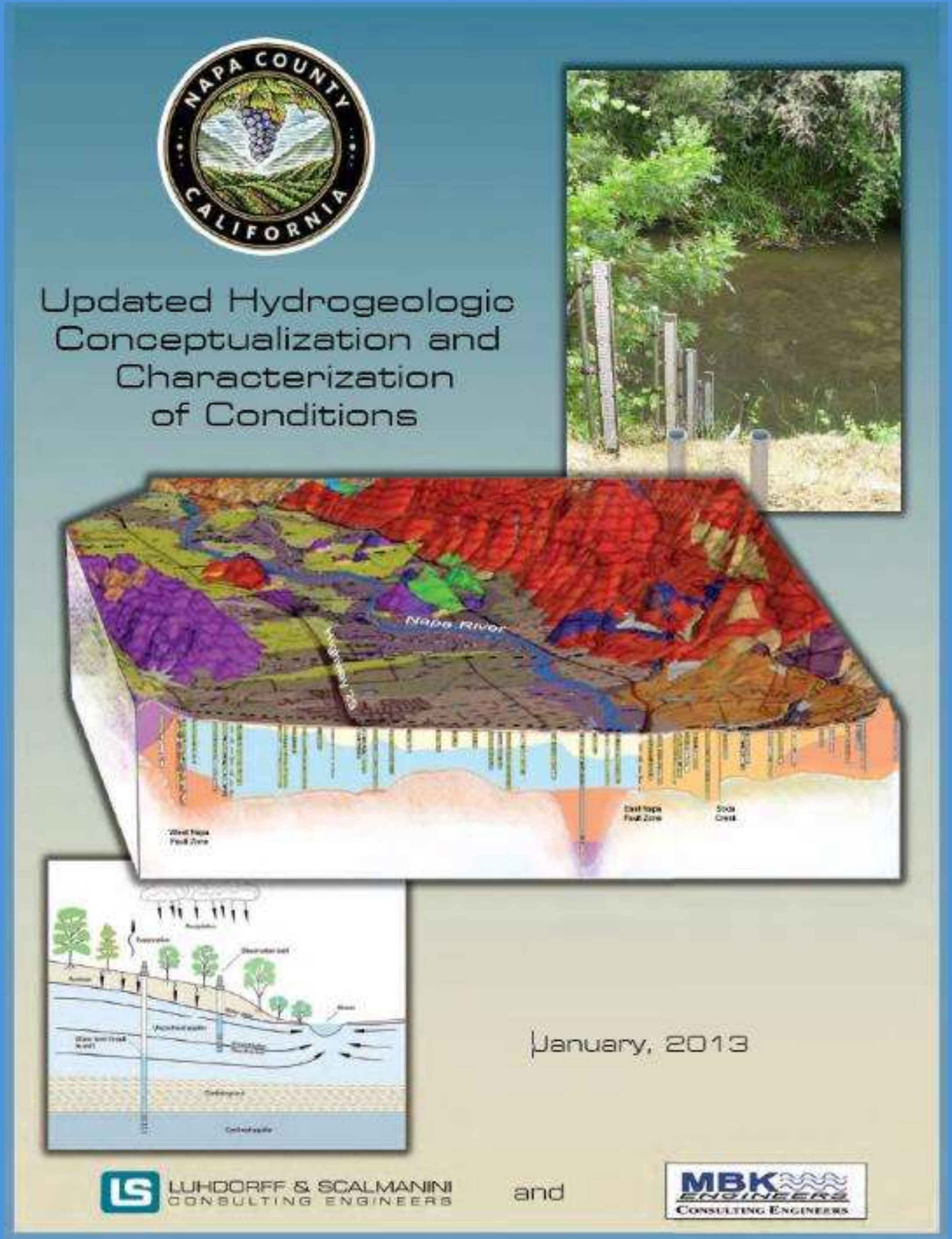
December 2021

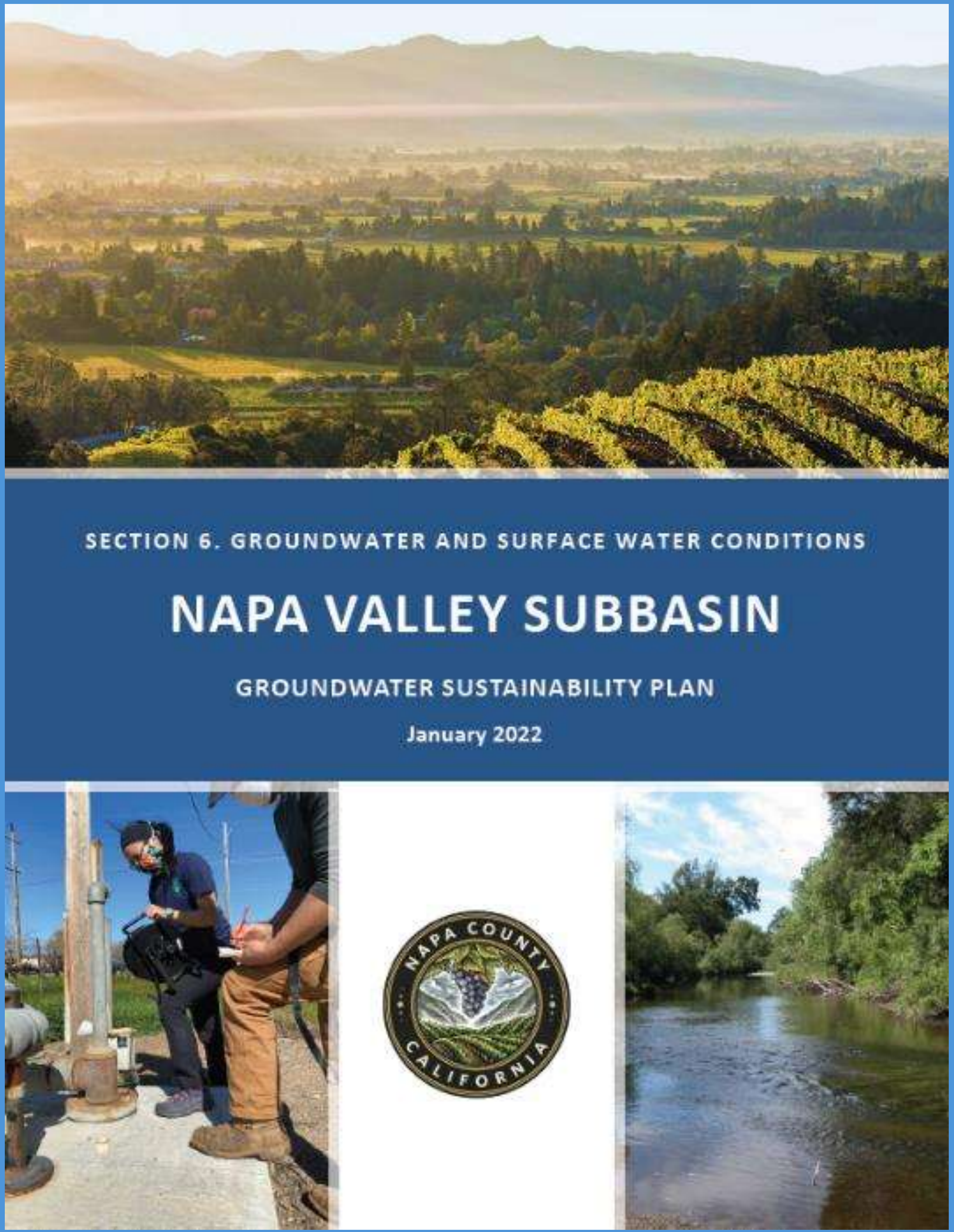
Prepared by Sonoma Water

SANTA ROSA PLAIN GROUNDWATER SUSTAINABILITY AGENCY

County of Napa

- Water Availability Analysis (WAA) guidelines adopted May 2015
- Driven by California Environmental Quality Act (CEQA) analysis of discretionary permits
- “Would the project substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level?”
- Example of a substantial problem: “the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted”
- Qualifications not specified; scope is specified


NAPA COUNTY
CALIFORNIA
Updated Hydrogeologic Conceptualization and Characterization of Conditions
Napa River
January, 2013
LUHDORFF & SCALMANINI
CONSULTING ENGINEERS
and
MBK ENGINEERS
CONSULTING ENGINEERS


SECTION 6. GROUNDWATER AND SURFACE WATER CONDITIONS
NAPA VALLEY SUBBASIN
GROUNDWATER SUSTAINABILITY PLAN
January 2022
NAPA COUNTY
CALIFORNIA

WAA Applicability

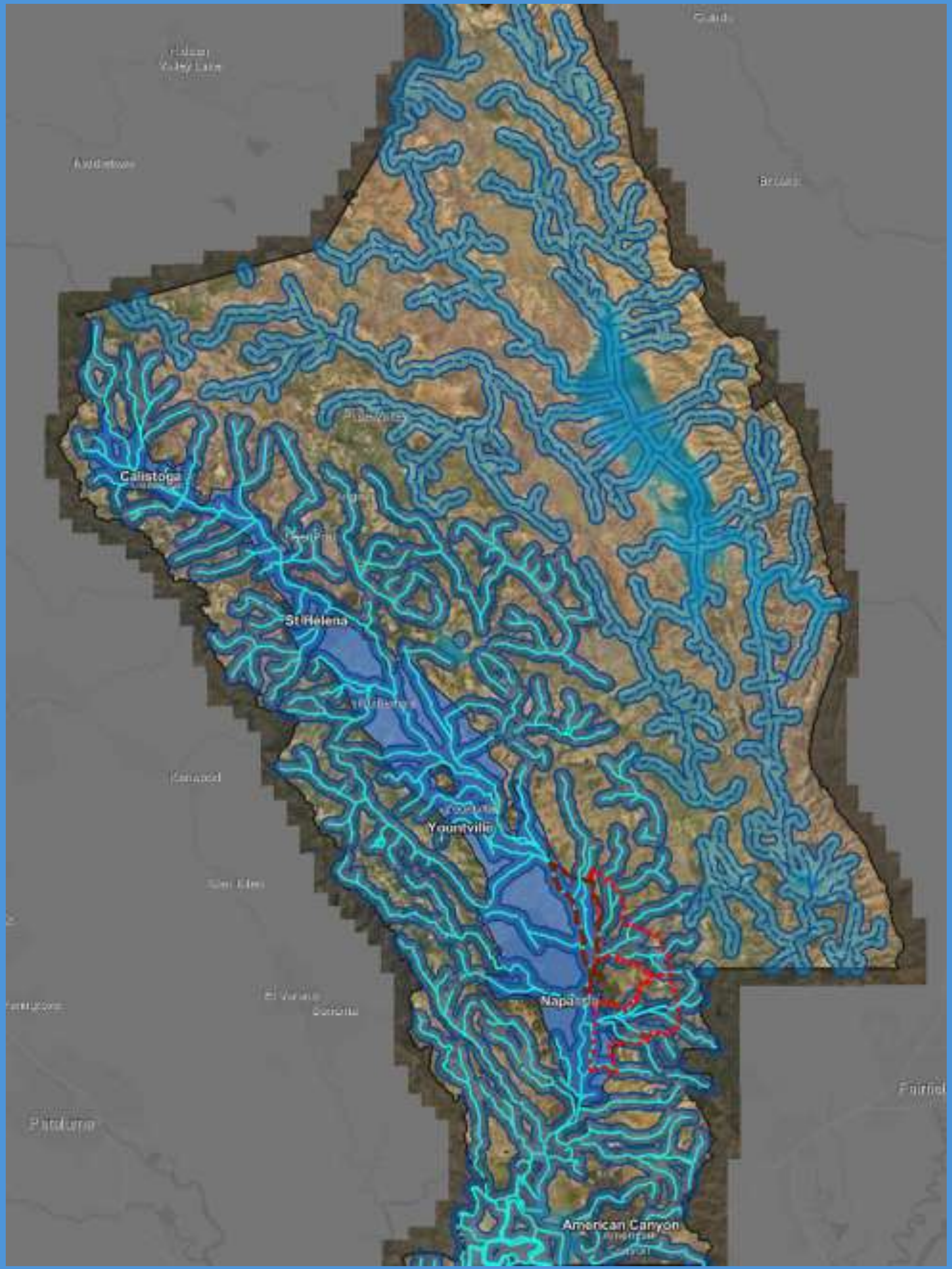
<u>Groundwater Sub-areas</u>

- Groundwater Deficient Area
- Groundwater Study Area
- Napa Valley Floor/Napa Valley Groundwater Subbasin (SGMA)
- “Hillside” areas-Napa River watershed
- Outside Napa River watershed

<u>Projects requiring a County permit</u>

- New vineyards and some replanting projects
- Wineries
- Some residential projects

<u>Governor’s Drought Emergency Executive Order N-7-22</u>



WAA Elements

Tier 1-Water Use Criteria

- Use of 0.3 ac-ft/ac/yr or less allowed in some areas
- For site-specific allowances > 0.3 ac-ft/ac/yr: water balance analysis
- Compare recharge to use
- Parcel v. "impact area"

Tier 2-Well & Spring Interference

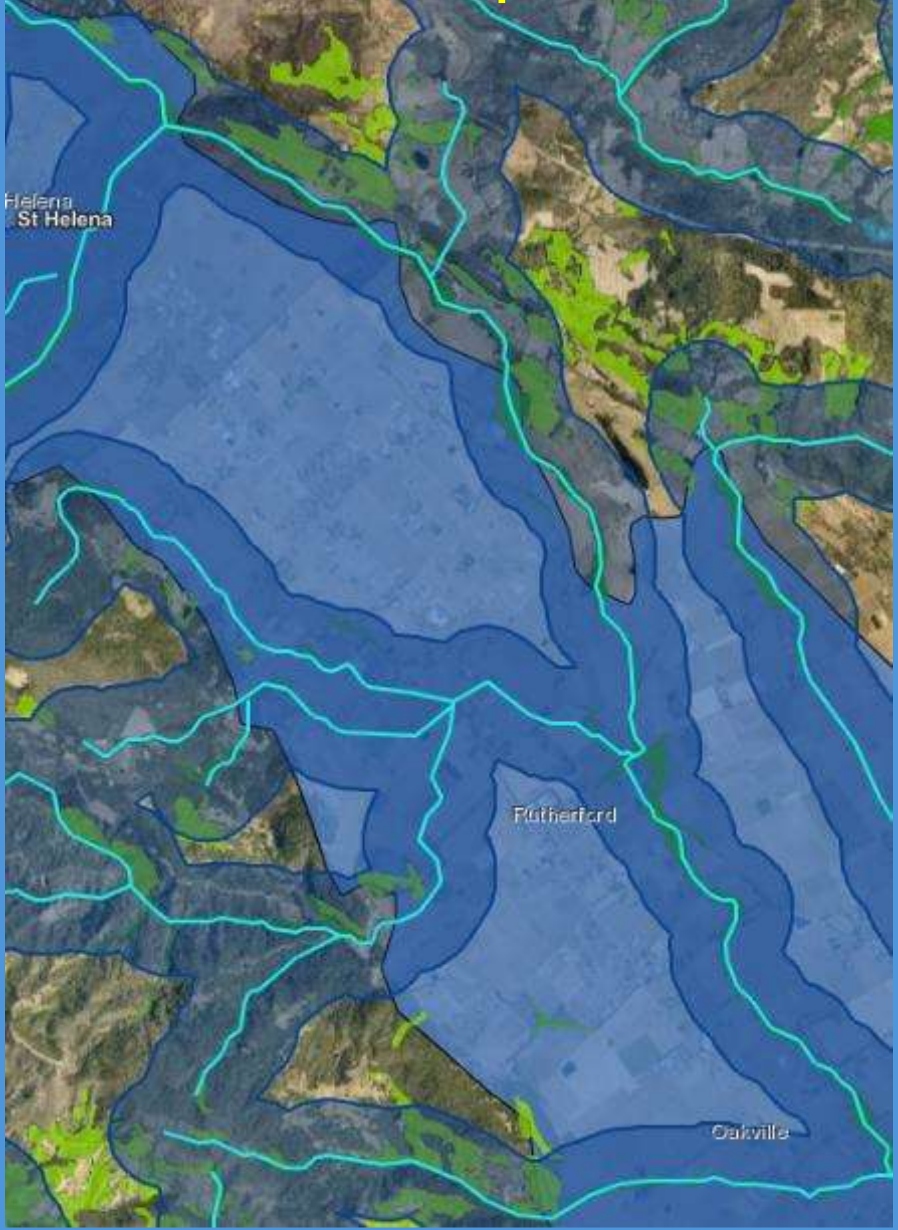
- Wells < 500 ft and Springs < 1,500 ft require analysis
- Drawdown analysis for affected wells; threshold is 10 to 15 ft

Tier 3-Groundwater/Surface Water Interaction

- Wells < 1,500 ft from streams require analysis
- Evaluate connectivity to streams
- Criteria for wells with potential connectivity

Contents

Criteria for Impact on Surface Waters



Pumping Rate
< 10 gpm

Table 3. Well Distance Standards and Construction Assumptions; Very low capacity pumping rates (i.e., less than 10 gpm), constructed in unconsolidated deposits in the upper part of the aquifer system (unconfined aquifer conditions).

Aquifer Hydraulic Conductivity (ft/day)	Acceptable Distance from Surface Water Channel			Minimum Surface Seal Depth (feet)	Depth of Uppermost Perforations (feet)
	500 feet	1000 feet	1500 feet		
80	✓			50	100
50	✓			50	100
30	✓			50	100
0.5	✓			50	100

Pumping Rate
10 to 30 gpm

Table 4. Well Distance Standards and Construction Assumptions; Low capacity pumping rates (i.e., between 10 gpm and 30 gpm), constructed in unconsolidated deposits in the upper part of the aquifer system (unconfined aquifer conditions).

Aquifer Hydraulic Conductivity (ft/day)	Acceptable Distance from Surface Water Channel			Minimum Surface Seal Depth (feet)	Depth of Uppermost Perforations (feet)
	500 feet	1000 feet	1500 feet		
80			✓	50	150
50			✓	50	150
30			✓	50	100
0.5		✓		50	100

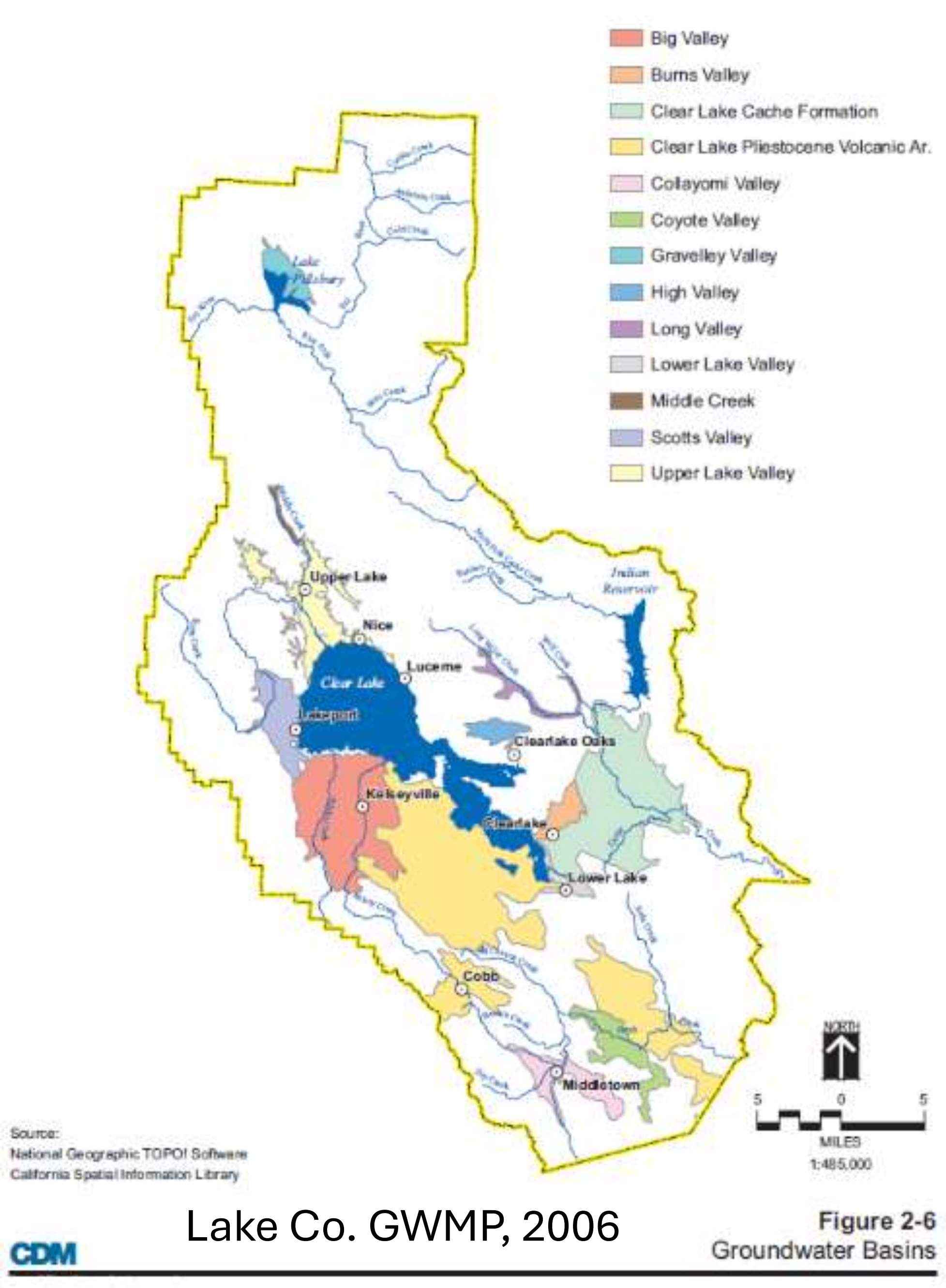
Pumping Rate
> 30 gpm

Table 5. Well Distance Standards and Construction Assumptions; Moderate to high capacity pumping rates (i.e., greater than 30 gpm), constructed in unconsolidated deposits in the upper part of the aquifer system (unconfined aquifer conditions).

Aquifer Hydraulic Conductivity (ft/day)	Acceptable Distance from Surface Water Channel			Minimum Surface Seal Depth (feet)	Depth of Uppermost Perforations (feet)
	500 feet	1000 feet	1500 feet		
80			✓	50	150
50			✓	50	150
30			✓	50	100
0.5			✓	50	100

County of Lake

- General Plan water resources element
- Well permit requirements address public health standards for well construction
- ~25 years of County-led management planning and studies of the Big Valley Groundwater Subbasin + long-term groundwater monitoring
- SGMA GSP Report completed for Big Valley Subbasin 2021
- Drought emergency-Governor's Exec. Order N-7-22
- .



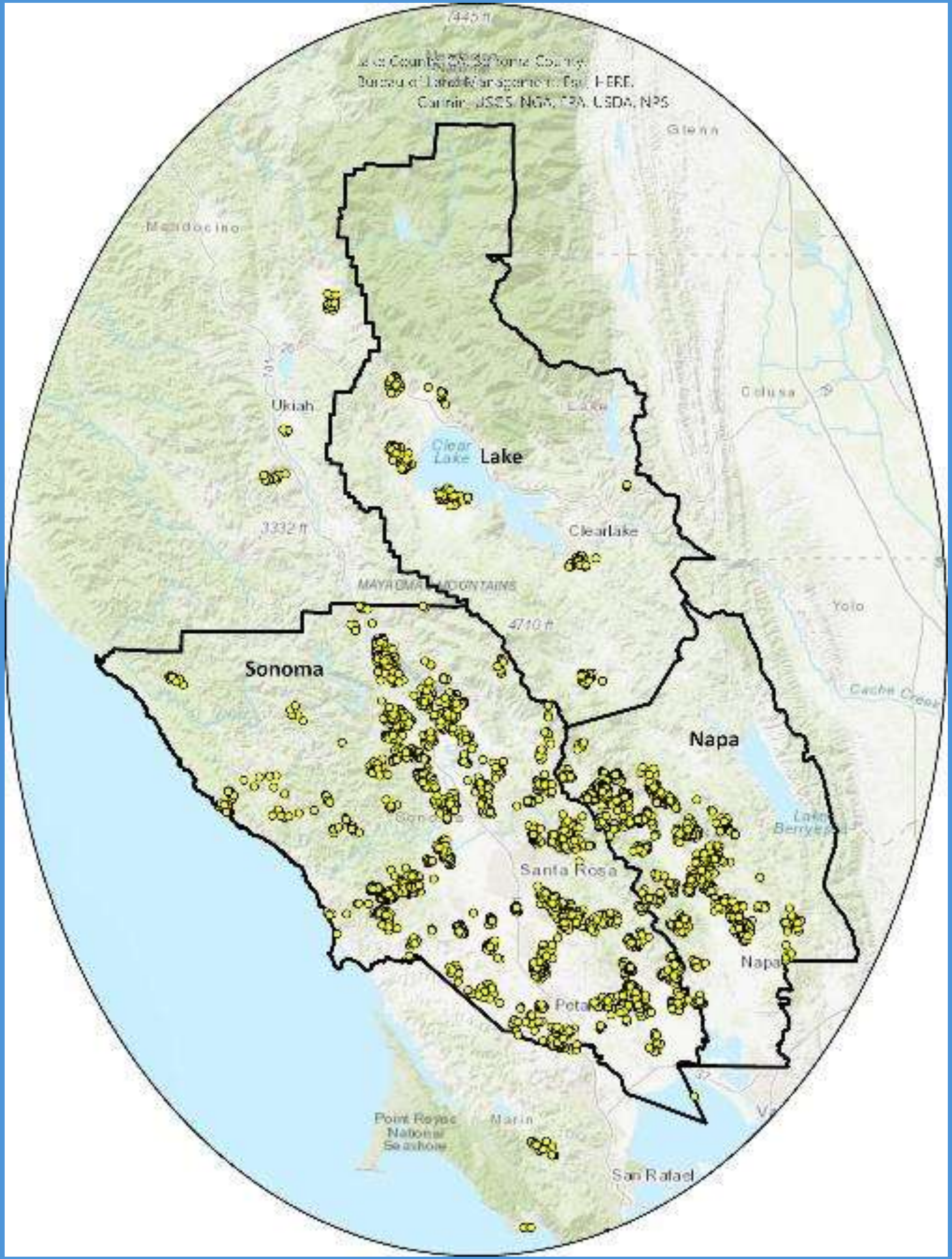
Lake Co. GWMP, 2006

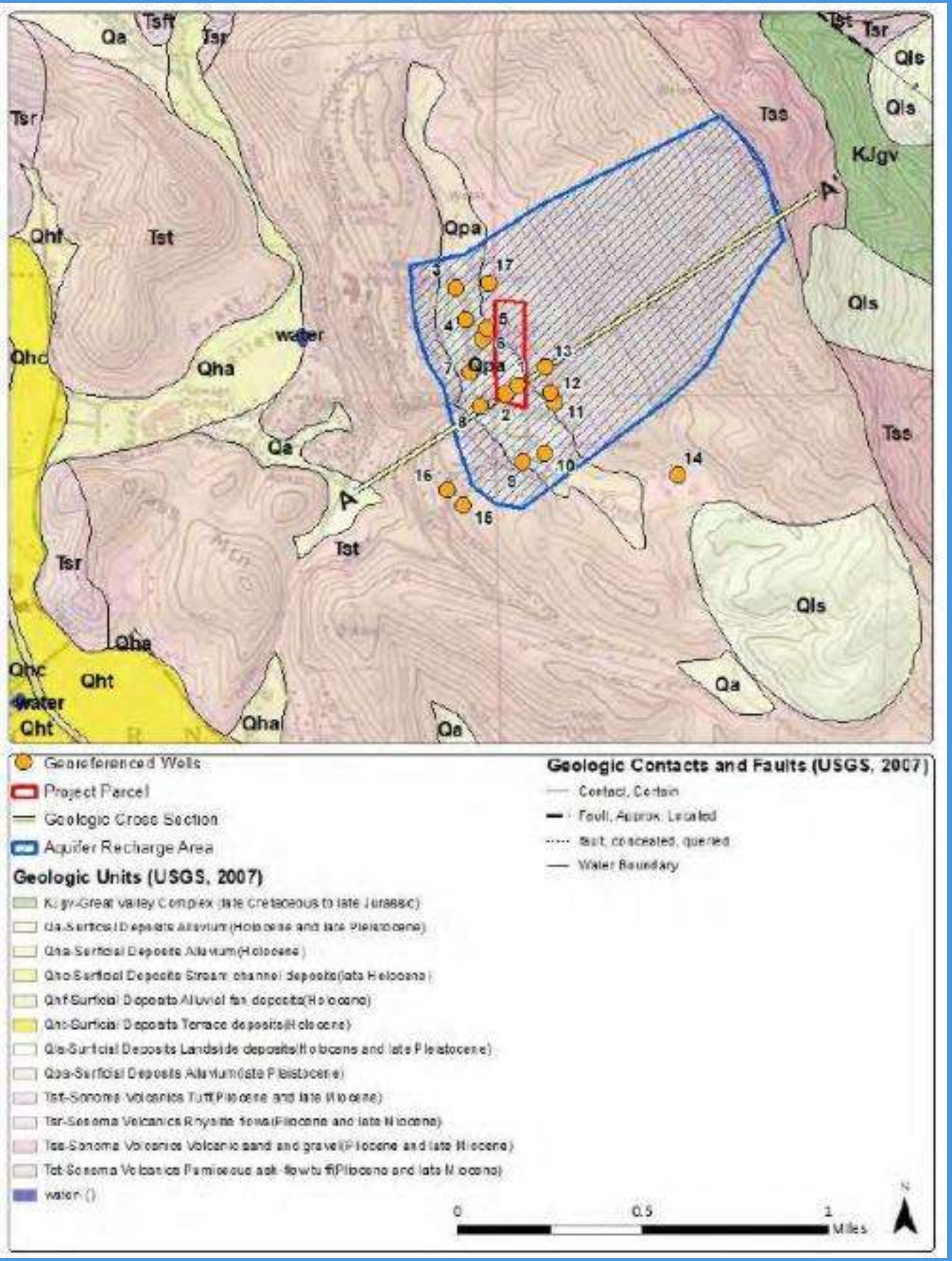
County of Lake

- Big Valley Band of Pomo Indians + other tribal groups have long been concerned about the health of the Clear Lake Hitch (chi), a minnow species endemic to Clear Lake and its tributaries
- BVB Pomo have been conducting habitat and hydrologic monitoring studies of the chi population **www.bvrancheria.com/epa**
- Clear Lake hitch was designated as a threatened species under the California Endangered Species Act in 2014.
- Governor Newsom has recently directed the State Water Board to evaluate minimum instream flows, work with water users and Tribes (Pomo), and consider emergency regulations to protect this unique fish.
- Federal, State & Tribal agencies are collecting data on the chi population and environmental conditions affecting habitat in Clear Lake and its tributaries
- SWRCB Division of Water Rights Order 2024-0003-Information Order and Reporting Requirements in the Matter of Water Use in the Clear Lake Watershed
- SWRCB is leading a comprehensive hydrogeologic analysis to evaluate conditions and potential effects on chi habitat

Project-Scale Water Balance Analyses

- ~200 projects in past 20 years
- Key components
- Well Completion Reports
- Conceptual hydrogeologic model
- Recharge estimate-Soil Water Balance model
- Estimates of groundwater use
- Ratio of use to recharge





Well ID	1	2	3	4	5	6	7	8
	Project Well							
Year Completed	2022	1991	2003	1982	1987	2006	1973	1979
Depth (ft)	608	515	420	430	272	385	325	350
Static Water Level (ft)	128	150	0	93	Unk.	110	110	80
Estimated Yield (gpm)	110	40	50	25	38	60	25	10
Top of Screen (ft)	148	160	120	230	212	195	Unk.	230
Bottom of Screen (ft)	588	515	420	430	272	385	Unk.	350
Geologic Map Unit	Tst	Tst	Tst	Tst	Tst	Tst	Tst	Tst
DWR WCR No.	WCR2022-003034	371073	901100	119523	195751	938179	72969	103344

Well ID	9	10	11	12	13	14	15	16	17
Year Completed	1991	2006	2009	2009	2004	2000	1992	1991	1991
Depth (ft)	430	377	250	420	400	430	400	550	260
Static Water Level (ft)	80	60	76	96	46	50	300	180	40
Estimated Yield (gpm)	30	Unk.	10	5	80	200	50	50	100
Top of Screen (ft)	160	120	110	357	80	70	300	150	80
Bottom of Screen (ft)	430	377	250	417	400	430	400	550	260
Geologic Map Unit	Tst	Tst	Tst	Tst	Tst	Tst	Tst	Tst	Tst
DWR WCR No.	384905	N/A	e0102104	e0103207	e012093	710221	384930	384904	284997

Well 2

Parcel # 21-330-013

RECEIVED FEB 28 1991 DEPT. OF ENVIRONMENTAL MANAGEMENT

3/7/91 #3042

QUADRUPLICATE
Use to comply with local requirements

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
WATER WELL DRILLERS REPORT

Do not fill in

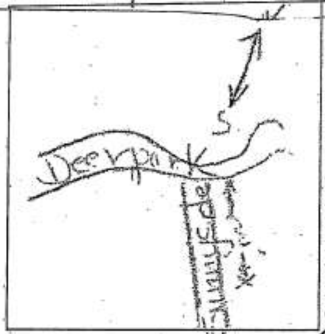
No. 371073

State Well No. ______
Other Well No. ______

Notice of Intent No. ______
Local Permit No. or Date D27479

(1) OWNER: Name [redacted]
Address [redacted]
City [redacted] ZIP

(2) LOCATION OF WELL (See instructions):
County 28 Owner's Well Number ______
Well address if different from above Same
Township 21 Range 330 Section 013
Distance from cities, roads, railroads, fences, etc. 800 ft So. of Deerpark Rd. on Sunnyside rd.



WELL LOCATION SKETCH

(3) TYPE OF WORK:
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

(4) PROPOSED USE:
Domestic ☒
Irrigation ☐
Industrial ☐
Test Well ☐
Municipal ☐
Other ☐
(Describe)

(5) EQUIPMENT:
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

(6) GRAVEL PACK:
Yes ☒ No ☐ Size ______
Diameter of bore 9
Packed from 26 to 515

(7) CASING INSTALLED:
Steel ☐ Plastic ☒ Concrete ☐

(8) PERFORATIONS:
Type of perforation or size of screen

From ft.	To ft.	Dia. in.	Gage or Wall	From ft.	To ft.	Slot size
0	515	5"	200	160	515	Factory

(9) WELL SEAL:
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 26 ft.
Were strata sealed against pollution? Yes ☐ No ☐ Interval ______ ft.
Method of sealing ______

(10) WATER LEVELS:
Depth of first water, if known ______ ft.
Standing level after well completion 150 ft.

(11) WELL TESTS:
Was well test made? Yes ☒ No ☐ If yes, by whom? Driller
Type of test Pump ☐ Bailer ☐ Air lift ☒
Depth to water at start of test 150 ft. At end of test 490 ft.
Discharge 40 gal/min after 6 hours Water temperature ______
Chemical analysis made? Yes ☐ No ☒ If yes, by whom? ______
Was electric log made Yes ☐ No ☒ If yes, attach copy to this report

(12) WELL LOG: Total depth 520 ft. Completed depth 515 ft.
from ft. to ft. Formation (Describe by color, character, size or material)

0 - 60 brown ash
60 - 140 blue clay
140 - 165 hard black rock
- with blue clay
165 - 170 soft brown ash
- with hard black ash
170 - 235 hard black rock
- with blue clay
235 - 260 hard brown ash
260 - 280 black rock with
280 - 325 hard red ash with
- red clay
325 - 335 black rock
335 - 405 hard purple rock
- with brown & green
405 - 420 soft black ash
- gray ash
420 - 440 gray ash with
- black ash
440 - 475 hard purple rock
- with brown rock
475 - 500 brown clay with
- hard purple rock
500 - 505 soft black ash
505 - 520 brown clay with
- hard rock

Work started 11-30-1990 Completed 12-7 1990

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

Signed Tom Pulliam (Well Driller)
NAME Pulliam Well Drilling (Person, firm, or corporation) (Typed or printed)
Address 3277 Pic Ranch Rd
City St. Helena ZIP 94574
License No. 426777 Date of this report 1-11-91

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

DWR 188 (REV. 12-86)

Well 6

DUPLICATE
Requirements
Page ___ of ___
Owner's Well No. ______
Date Work Began 12/07/2006, Ended 12/21/2006
Local Permit Agency Napa County
Permit No. E06-01553 Permit Date 11/09/2006

STATE OF CALIFORNIA
WELL COMPLETION REPORT
Refer to Instruction Pamphlet
No. 0938179

DWR USE ONLY — DO NOT FILL IN
STATE WELL NO./STATION NO.
LATITUDE LONGITUDE
APN/TRS/OTHER

GEOLOGIC LOG

ORIENTATION (✓) X VERTICAL ___ HORIZONTAL ___ ANGLE ___ (SPECIFY)
DRILLING METHOD Rotary FLUID Air/mud

DEPTH FROM SURFACE Ft. to Ft.		DESCRIPTION Describe material, grain size, color, etc.
0	12	Brown Ash & Clay
12	105	Hard Gray & Green Clay
105	170	Hard Gray Rock
170	210	Brown, Gray & White Ash
210	225	Red Ash
225	260	Purple with Hard Gray Rock
260	275	Brown Ash
275	340	Gray & Red Ash
340	370	Gray Brown & Red Ash
370	385	Gray Brown & Red Ash

RECEIVED
JUN 22 2007
DEPT. OF ENVIRONMENTAL MANAGEMENT

TOTAL DEPTH OF BORING 385 (Feet)
TOTAL DEPTH OF COMPLETED WELL 385 (Feet)

WELL OWNER
Name [redacted]
Mailing Address [redacted]
CITY [redacted]

WELL LOCATION
Address 669 Deer Park Road
City Saint Helena
County Napa
APN Book 021 Page 184 Parcel 001-000
Township ______ Range ______ Section ______
Lat ___ N Long ___ W
DEG. MIN. SEC.

LOCATION SKETCH
NORTH

WEST EAST SOUTH

Illustrate or Describe Distance of Well from Roads, Buildings, Fences, Rivers, etc. and attach a map. Use additional paper if necessary. PLEASE BE ACCURATE & COMPLETE.

ACTIVITY (✓)
✓ NEW WELL
MODIFICATION/REPAIR
___ Deepen
___ Other (Specify)
DESTROY (Describe Procedures and Materials Under "GEOLOGIC LOG")
USES (✓)
WATER SUPPLY
✓ Domestic ___ Public
___ Irrigation ___ Industrial
MONITORING ___
TEST WELL ___
CATHODIC PROTECTION ___
HEAT EXCHANGE ___
DIRECT PUSH ___
INJECTION ___
VAPOR EXTRACTION ___
SPARGING ___
REMEDIATION ___
OTHER (SPECIFY) ___

WATER LEVEL & YIELD OF COMPLETED WELL
DEPTH TO FIRST WATER UK (Ft.) BELOW SURFACE
DEPTH OF STATIC WATER LEVEL 110 (Ft.) & DATE MEASURED 12-21-06
ESTIMATED YIELD * 60 (GPM) & TEST TYPE Air lift
TEST LENGTH 16 (Hrs.) TOTAL DRAWDOWN UK (Ft.) GPM at Day 08 test
* May not be representative of a well's long-term yield.

DEPTH FROM SURFACE Ft.	to Ft.	BORE-HOLE DIA. (Inches)	TYPE (✓) BLANK	SCREEN	CON-DUCTOR	FILL PIPE	MATERIAL / GRADE	INTERNAL DIAMETER (Inches)	GAUGE OR WALL THICKNESS	SLOT SIZE IF ANY (Inches)
0	26	11	✓				Plastic	5	F480	
26	195	8 3/4	✓				"	"	"	
195	385	8 3/4		✓			"	"	"	.032

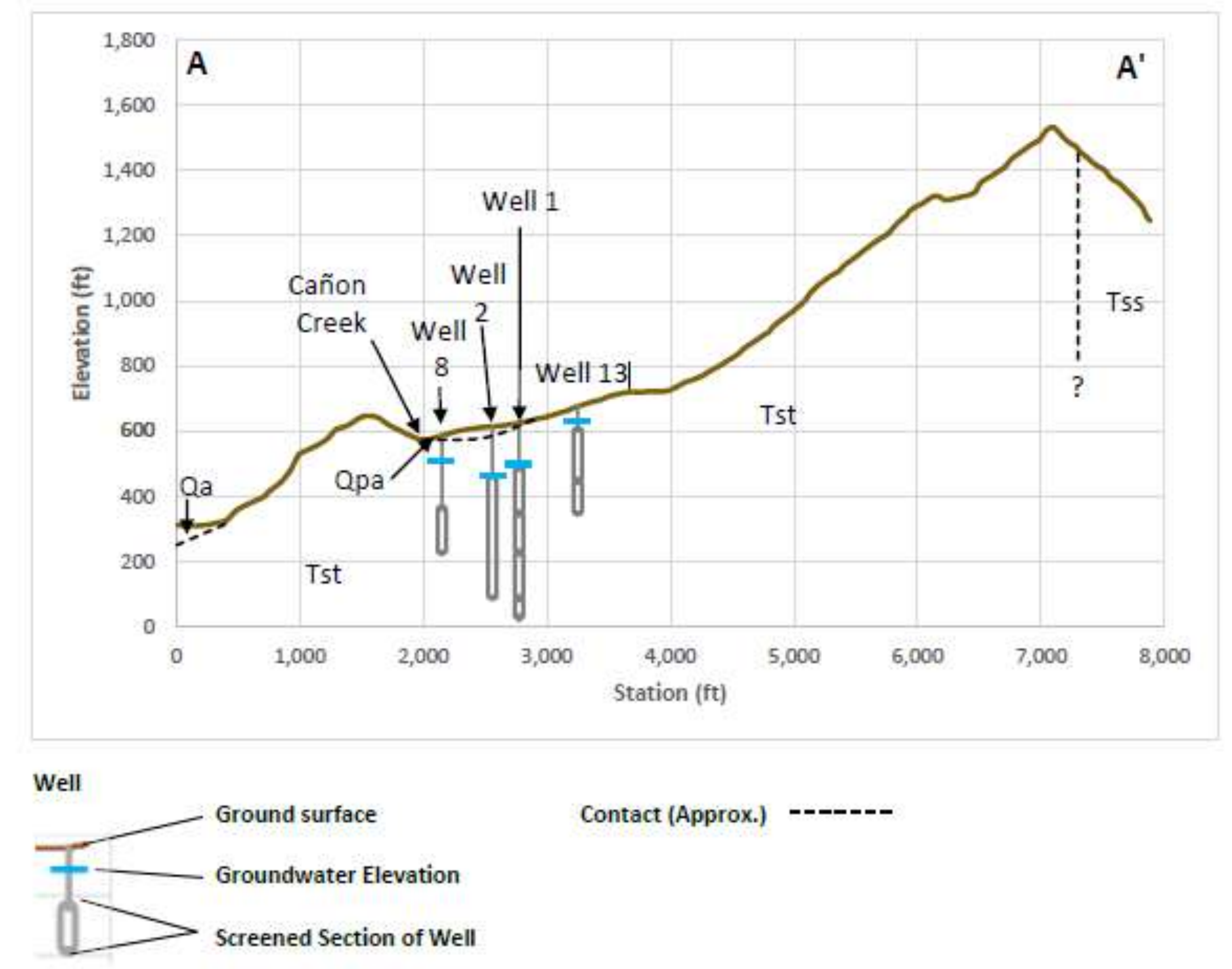
DEPTH FROM SURFACE Ft.	to Ft.	CE-MENT (✓)	BEN-TONITE (✓)	FILL (✓)	FILTER PACK (TYPE/SIZE)
0	26	✓			
26	385				Well Pack Gravel

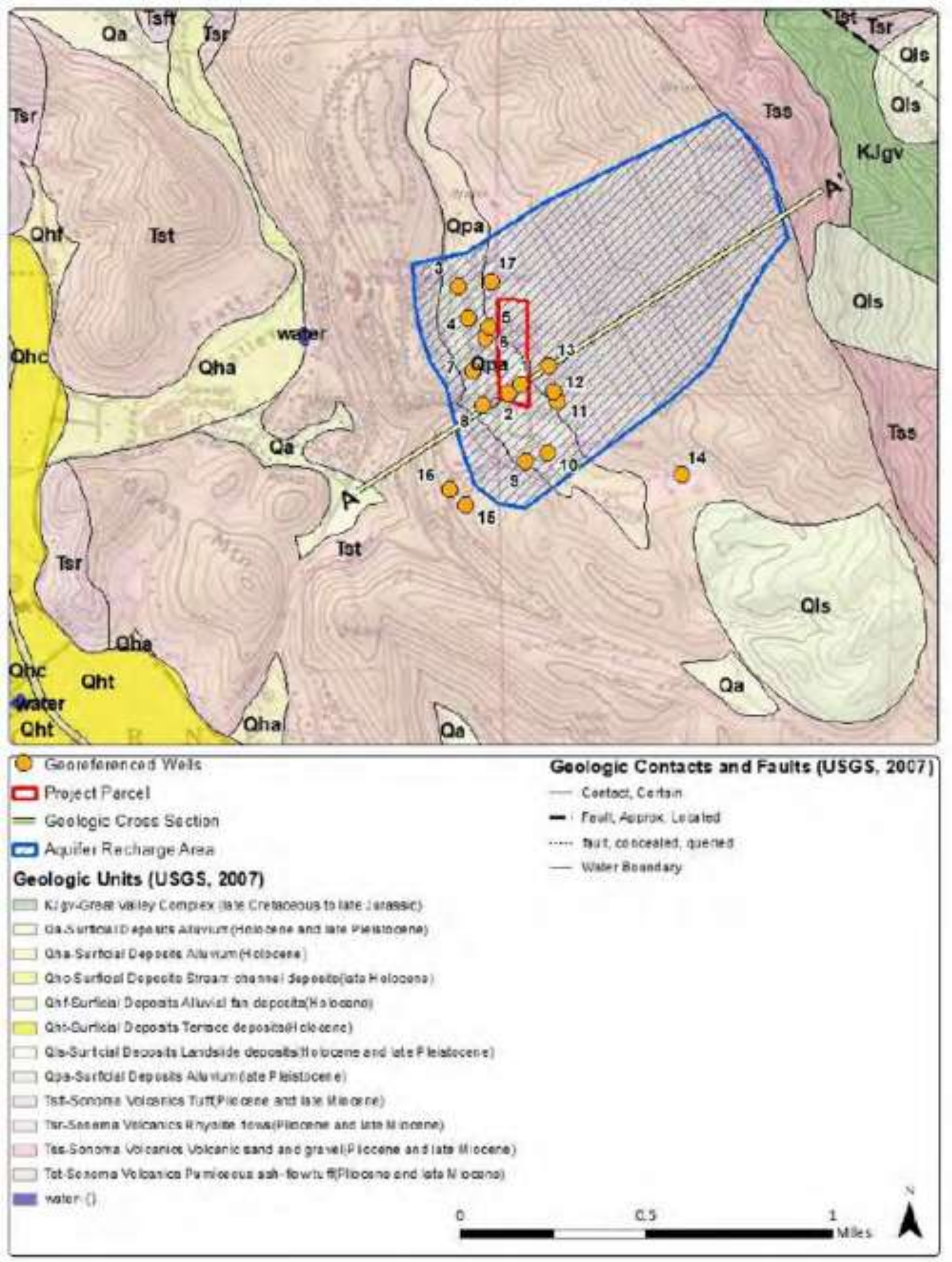
ATTACHMENTS (✓)
___ Geologic Log
___ Well Construction Diagram
___ Geophysical Log(s)
___ Soil/Water Chemical Analyses
___ Other
ATTACH ADDITIONAL INFORMATION, IF IT EXISTS.

CERTIFICATION STATEMENT
I, the undersigned, certify that this report is complete and accurate to the best of my knowledge and belief.
NAME Pulliam Well Exploration (PERSON, FIRM, OR CORPORATION) (TYPED OR PRINTED)
ADDRESS 5110 Highway 128 CITY Napa STATE CA ZIP 94558
Signed Tom Pulliam C-57 LICENSED WATER WELL CONTRACTOR DATE SIGNED 1-7-07 C-57 LICENSE NUMBER 808-508

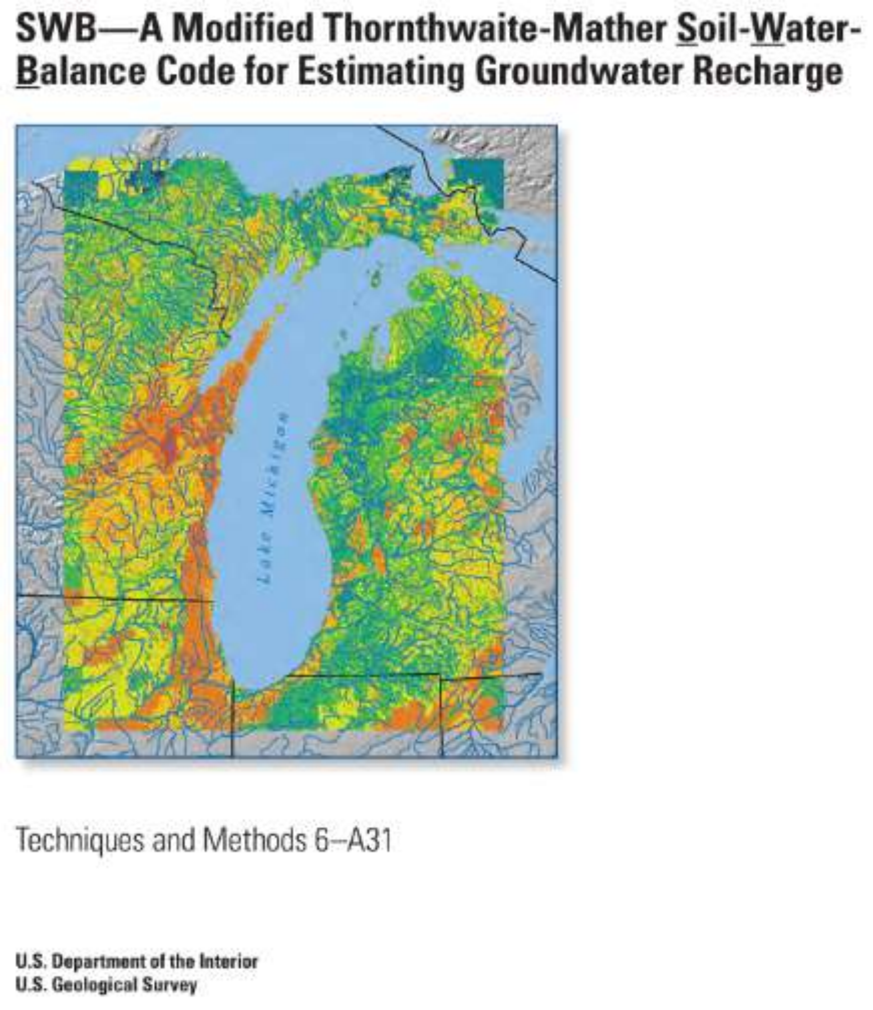
DWR 188 REV. 05-03

IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM


A
A'
Elevation (ft)
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Station (ft)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Well 1
Well 2
Well 8
Well 13
Cañon Creek
Qa
Qpa
Tst
Tss
?
Well
Ground surface
Groundwater Elevation
Screened Section of Well
Contact (Approx.)


Qa
Tsft
Tsr
Tss
Qls
KJgv
Tst
Qpa
Qhf
Qha
Qhc
Qht
Qhal
water
A
A'
Georeferenced Wells
Project Parcel
Geologic Cross Section
Aquifer Recharge Area
Geologic Units (USGS, 2007)
Geologic Contacts and Faults (USGS, 2007)
Contact, Certain
Fault, Approx. Located
fault, concealed, queried
Water Boundary
Qa-Surficial Deposits Alluvium (Holocene and late Pleistocene)
Qha-Surficial Deposits Alluvium (Holocene)
Qhc-Surficial Deposits Stream channel deposits (late Holocene)
Qhf-Surficial Deposits Alluvial fan deposits (Holocene)
Qht-Surficial Deposits Terrace deposits (Holocene)
Qls-Surficial Deposits Landslide deposits (Holocene and late Pleistocene)
Qpa-Surficial Deposits Alluvium (late Pleistocene)
Tsft-Sonoma Volcanics Tuff (Pliocene and late Miocene)
Tsr-Sonoma Volcanics Rhyolite flows (Pliocene and late Miocene)
Tss-Sonoma Volcanics Volcanic sand and gravel (Pliocene and late Miocene)
Tst-Sonoma Volcanics Pumiceous ash-flow tuff (Pliocene and late Miocene)
water ()
0
0.5
1
Miles

SWB for Estimating Groundwater Recharge


SWB—A Modified Thornthwaite-Mather Soil-Water-Balance Code for Estimating Groundwater Recharge

Techniques and Methods 6–A31

U.S. Department of the Interior
U.S. Geological Survey

Recharge = Sources – Sinks

(precip + inflow) –

(interception + outflow + ET)
– Δ soil moisture

Calculated for each grid cell on daily time step

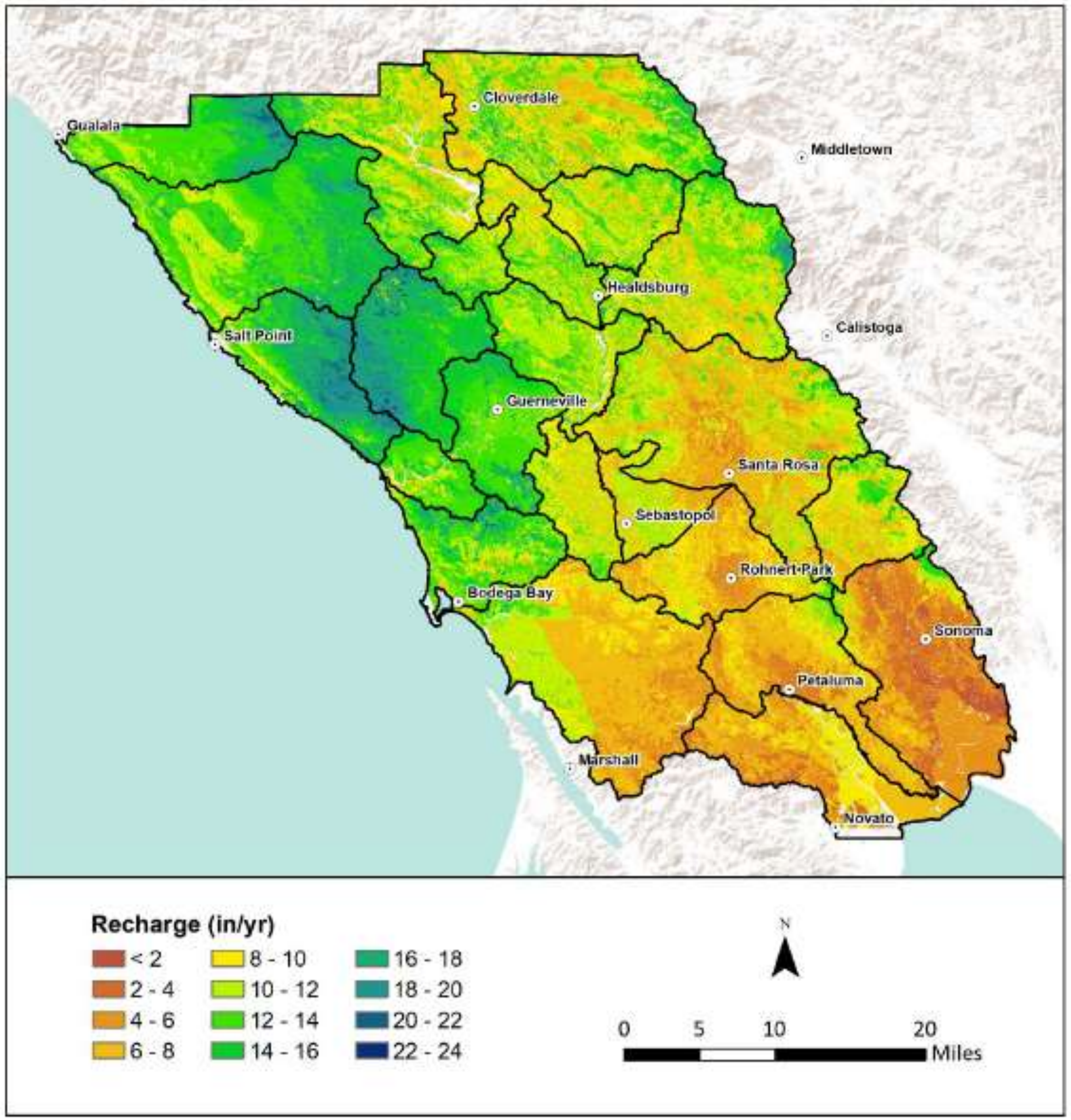


Figure 15: Water year 2010 Recharge simulated with the Sonoma County SWB model.

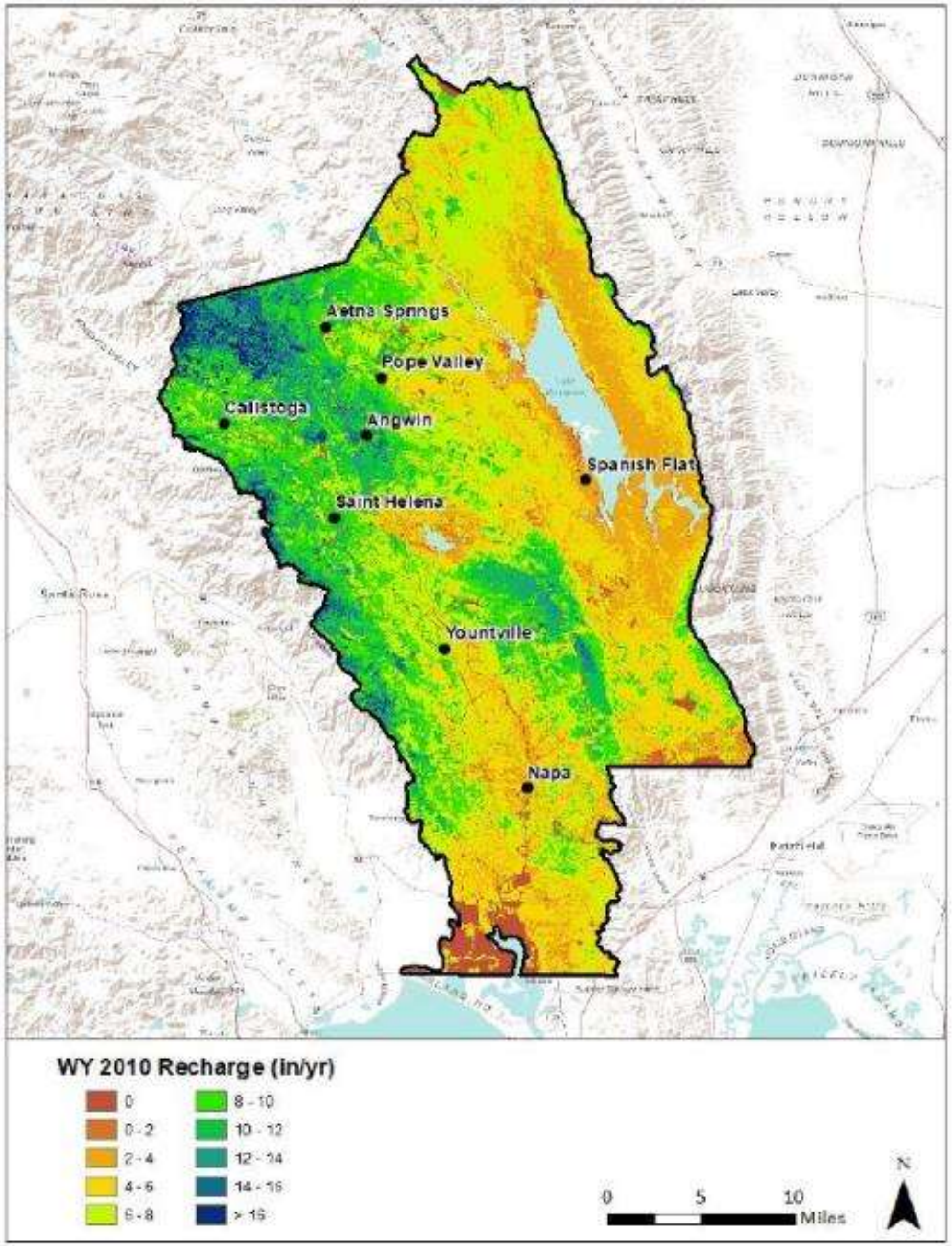


Figure 13: Water Year 2010 recharge simulated with the Napa County SWB model.

Estimated Groundwater Use

Table 3: Estimated groundwater uses on neighboring parcels within the project recharge area in the existing and proposed conditions.

	# of Units	Use per Unit	Annual Water Use (AF/yr)
Residential Use			**72.6**
Residences, Primary	83 Residences	0.75 AF/Residence	62.3
Residences, Secondary	27 Residences	0.35 AF/Residence	9.45
Pools	5 Pools	0.10 AF/Pool	0.50
Lawn, Additional	2000 sq. ft.	0.10 AF/1,000 sq. ft.	0.20
Other Landscaping, Addtl.	4000 sq. ft.	0.05 AF/1,000 sq. ft.	0.20
Agricultural Use			**7.45**
Vineyard	14.9 Acres	0.50 AF/acre/yr	7.45
Miscellaneous			**10.9**
Community Hall	1 Hall	7.50 AF/Hall	7.50
Thrift Store	5 Employees	15 gal/shift @ 365 shifts/yr	0.08
School (Teachers & Students)	41 Persons	15 gal./day w/ 180 days/yr	0.47
School Ball Field	28,000 sq. ft.	0.1 AF/1,000 sq. ft.	2.80
Total			**90.9**

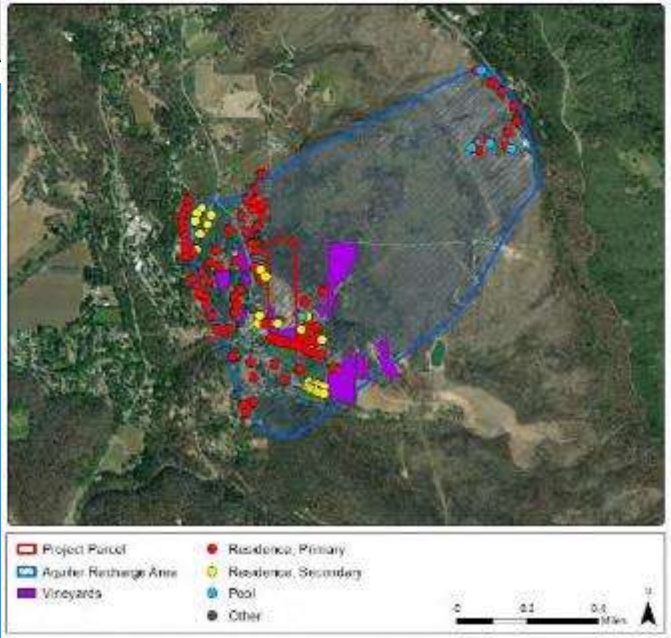


Figure 4: Existing water uses identified in the project recharge area.

Table 4: Estimated groundwater use within the project recharge area in the existing and proposed conditions.

	Existing Condition (acre-ft/yr)	Proposed Condition (acre-ft/yr)
Project Parcel	**2.35**	**4.15**
Residential Use	1.10	0.75
Irrigation Use	1.25	3.40
Neighboring Parcels	**90.9**	**90.9**
Residential Use	72.6	72.6
Irrigation Use	7.45	7.45
Miscellaneous Use	10.9	10.9
Total	**93.3**	**95.1**

Groundwater Recharge & Ratio of Use to Recharge

Table 6: Summary of water balance results estimated by the SWB model for Water Year 2010 and calculated average of 2012-2021 WYs.

	2010 Normal Year		2014 Dry Year		2012 - 2021 WY Average	
	inches	% of precip	inches	% of precip	inches	% of precip
Precipitation	42.0	-	22.2	-	32.2	-
AET	23.9	57%	17.6	79%	-	-
Runoff	8.7	21%	5.9	27%	-	-
Δ Soil Moisture	-0.5	-1%	-3.8	-17%	-	-
Recharge	9.9	24%	2.5	11%	5.7	18%

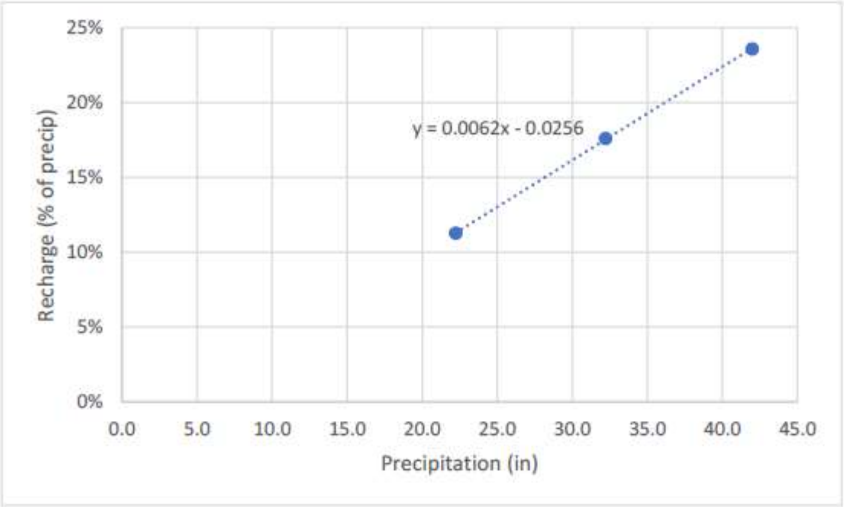
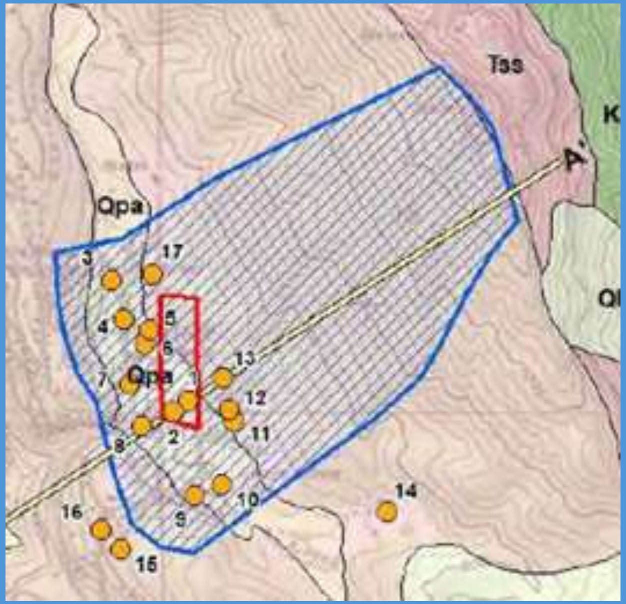


Figure 5: Relationship between precipitation and estimated groundwater recharge as a percent of precipitation.

Table 7: Comparison of proposed water use to average annual groundwater recharge for the project recharge area and for the project parcel.

Domain	Total Proposed Demand (ac-ft/yr)	Average 2012-2021 Water Years		
		Recharge (ac-ft/yr)	Recharge Surplus	Demand as % of
Project Recharge Area	95.1	184.3	89.2	52%
Project Parcel	4.15	6.4	2.3	65%



Strengths & Weaknesses of Project-scale Assessment

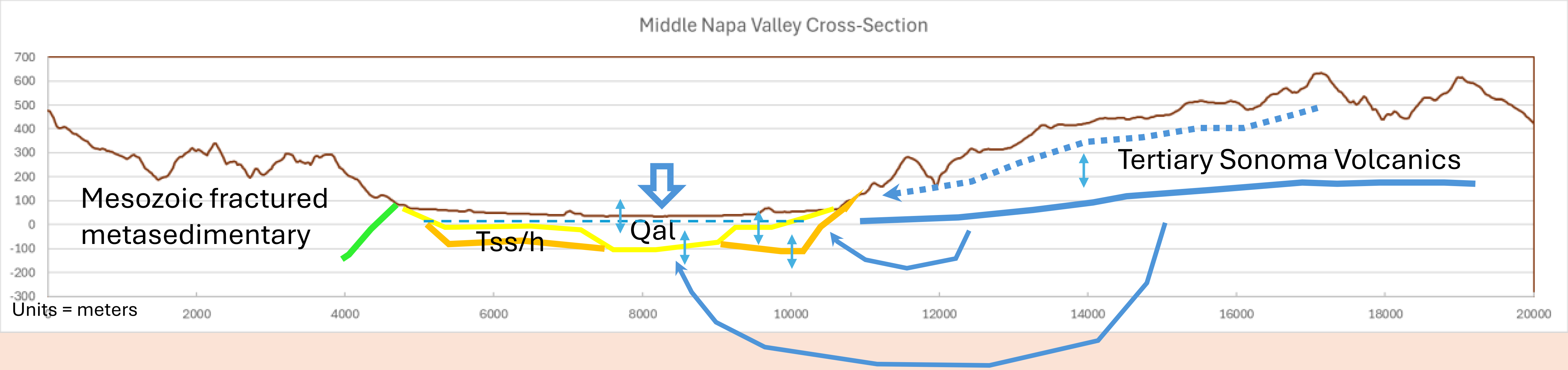
<u>Strengths</u>

- Water balance method-long-standing, accepted, comprehensible
- Practical use of available data
- Defensible quantitative estimates of use and recharge
- Basis for limits on some groundwater uses
- Hydrogeologic perspective from numerous project-scale studies

<u>Weaknesses</u>

- Recharge estimate (SWB) does not account for aquifer capability
- Groundwater flow processes are not quantitatively analyzed
- Complexity of aquifer material not well represented
- Potential effect on streamflow is qualitative and indirect
- Larger-scale, longer-term hydrogeologic processes not represented

Insights-Regional Hydrogeology



Insights-Approaches to Mitigation

Accumulated wisdom

- Project scale case studies
- County-scale Soil Water Balance models
- Numerical models

Approach to Sonoma County Well Ordinance update 2023-
Jeremy Kobor's presentation this afternoon

Data for Numerical Modeling

- Accurate Well Completion Reports
- Groundwater elevation monitoring
- Stream gages rated for discharge
- Aquifer pumping tests to sample aquifer hydraulic parameters

Small-scale groundwater recharge opportunities for streamflow augmentation, Little Mill Creek, Navarro River watershed

Christopher J. Woltemade, PhD

Prunuske Chatham, Inc.

christopher@pcz.com

PCI ECOLOGICAL

Acknowledgements

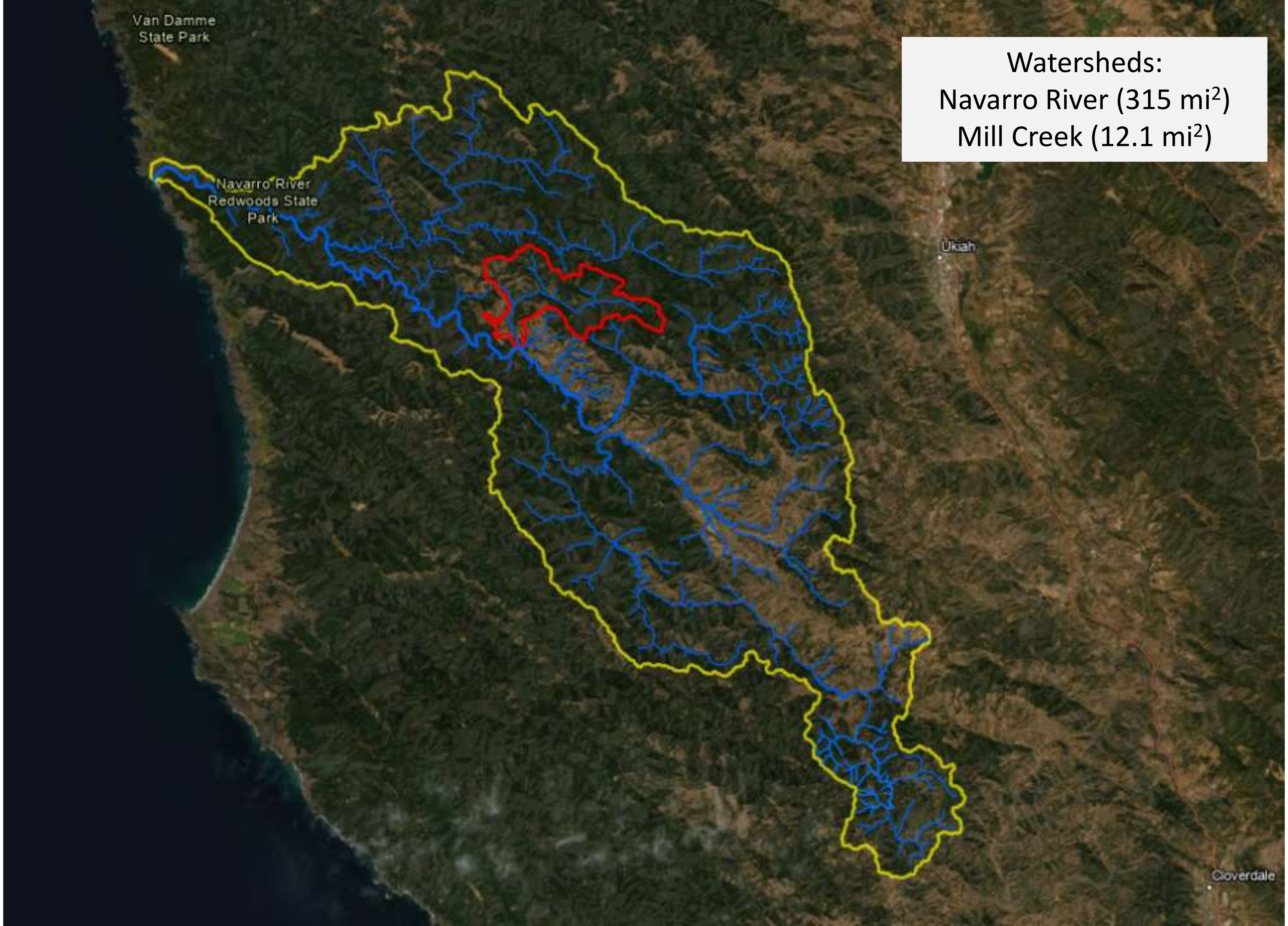
Little Mill Creek
Landowners

Karen Jamgochian
Ellen Cox
Mike Jensen

California Department of Fish & Wildlife
The Nature Conservancy
Trout Unlimited
Mendocino County Resource Conservation District
PCI Ecological

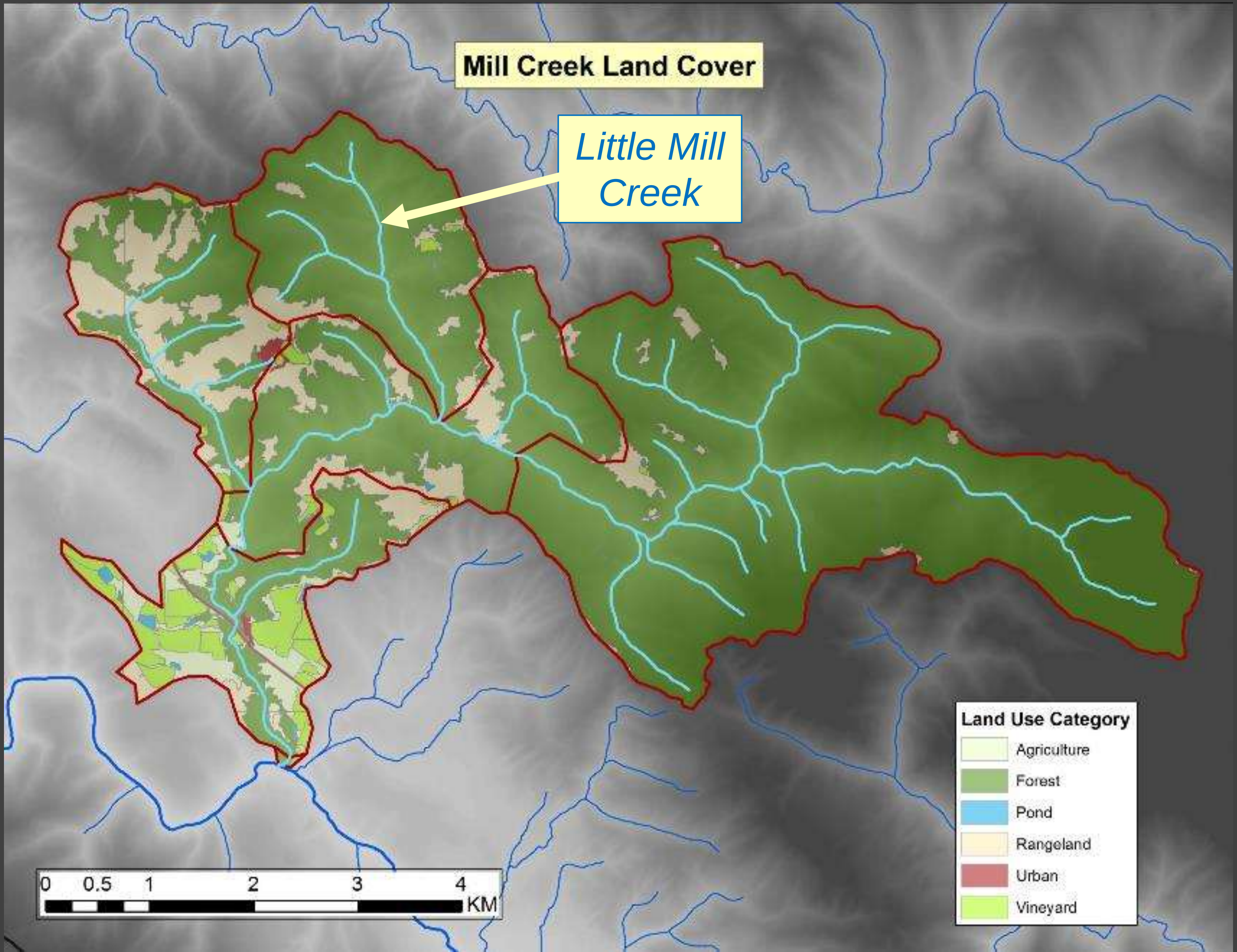
Outline:

- Watershed introduction: Navarro River and Mill Creek
- Groundwater recharge landscape assessments
- Projects selected for concept designs
- Pond release & incised channel repair project
- Questions and discussion



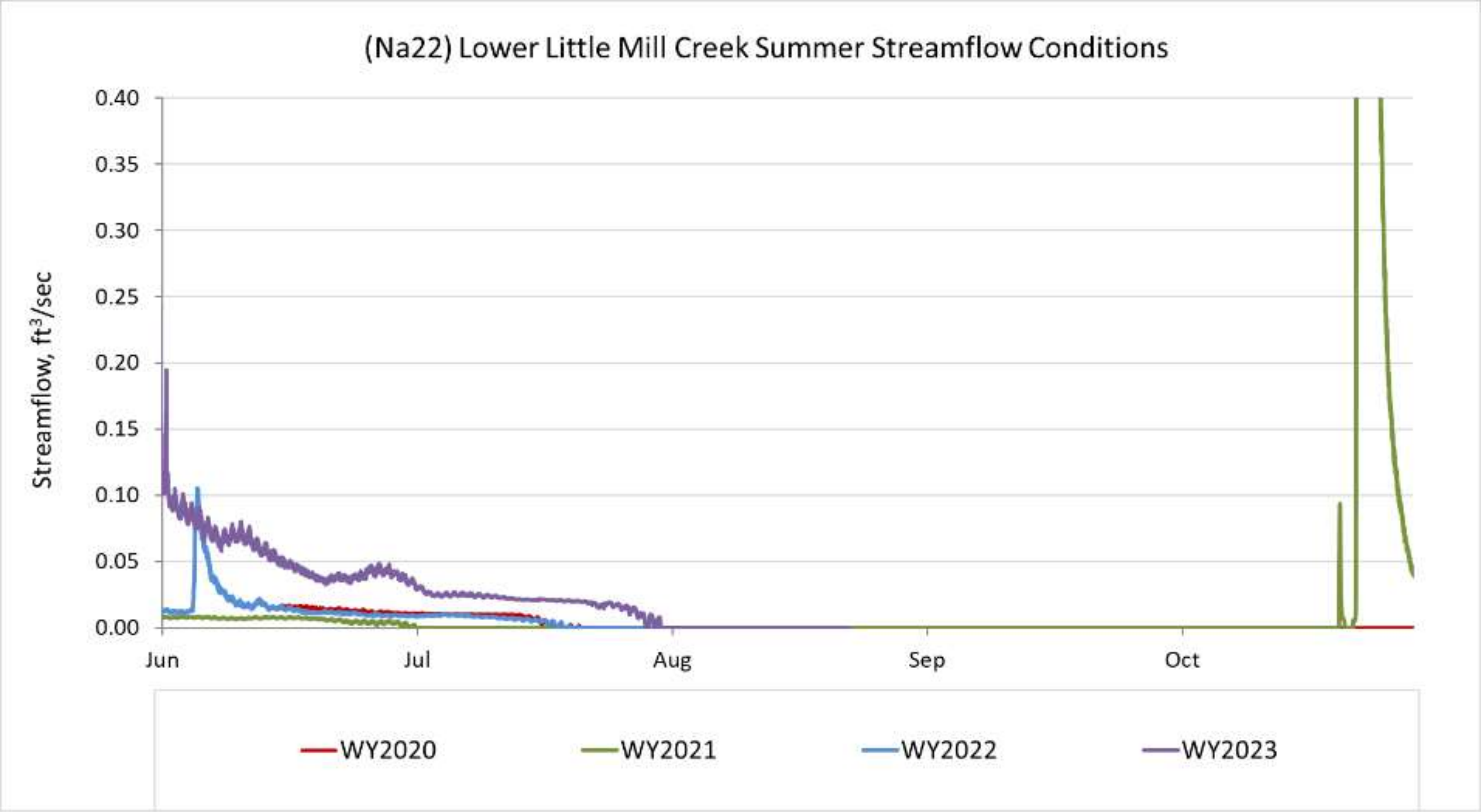
Watersheds:
Navarro River (315 mi^2)
Mill Creek (12.1 mi^2)

Mill Creek Watershed: 12.1 mi^2 Little Mill Creek: 1.6 mi^2



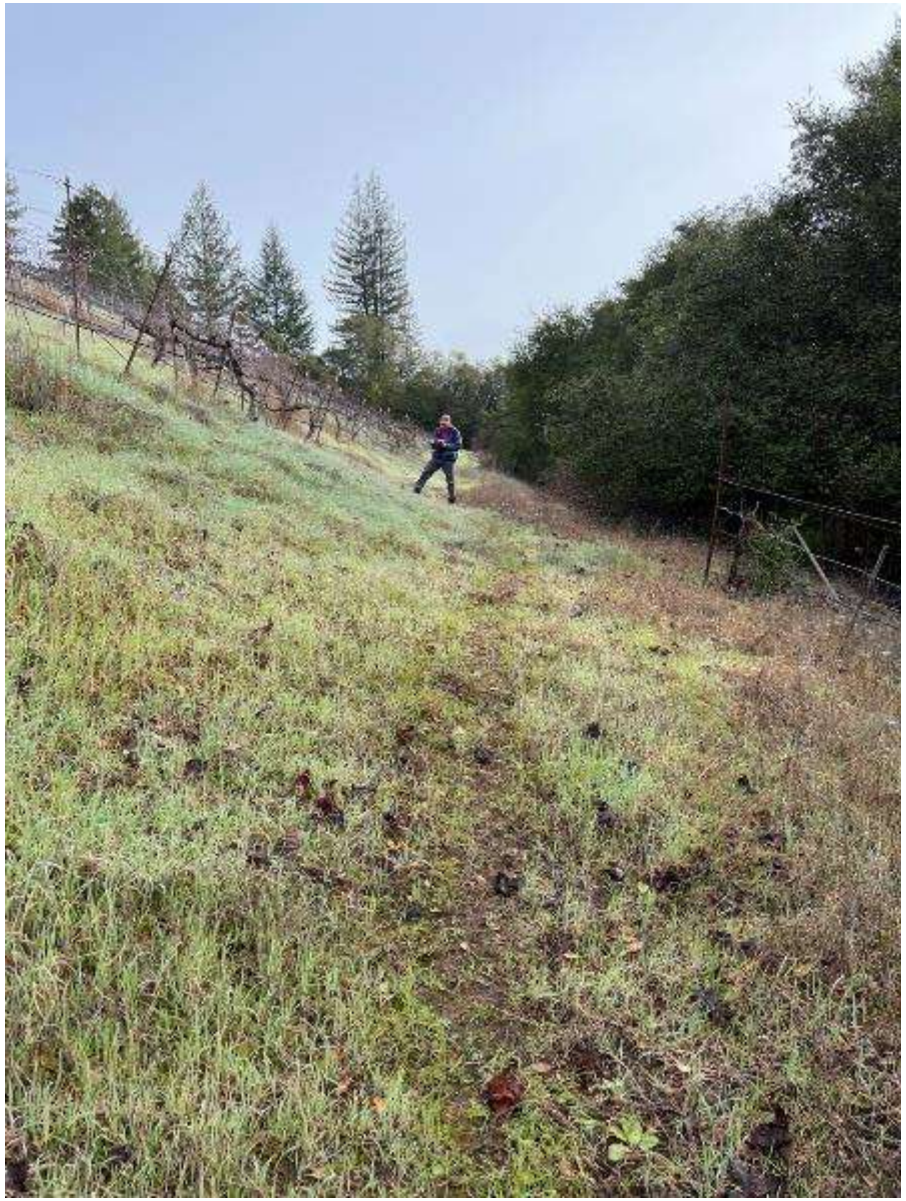
Context: Hydrologic challenges to salmonid recovery in California

Hydrologic monitoring data (TU)



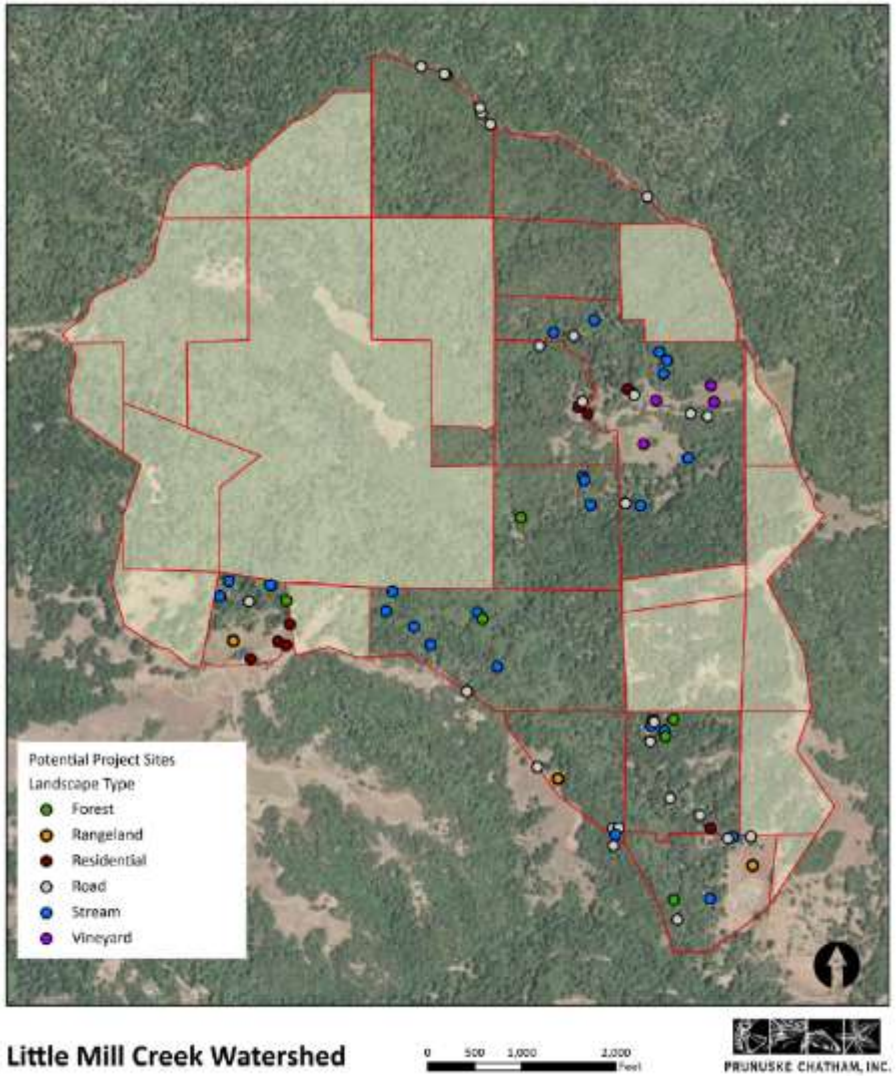
Little Mill Creek
Groundwater Recharge
Field Assessments

- 8 property parcels
- 465 acres

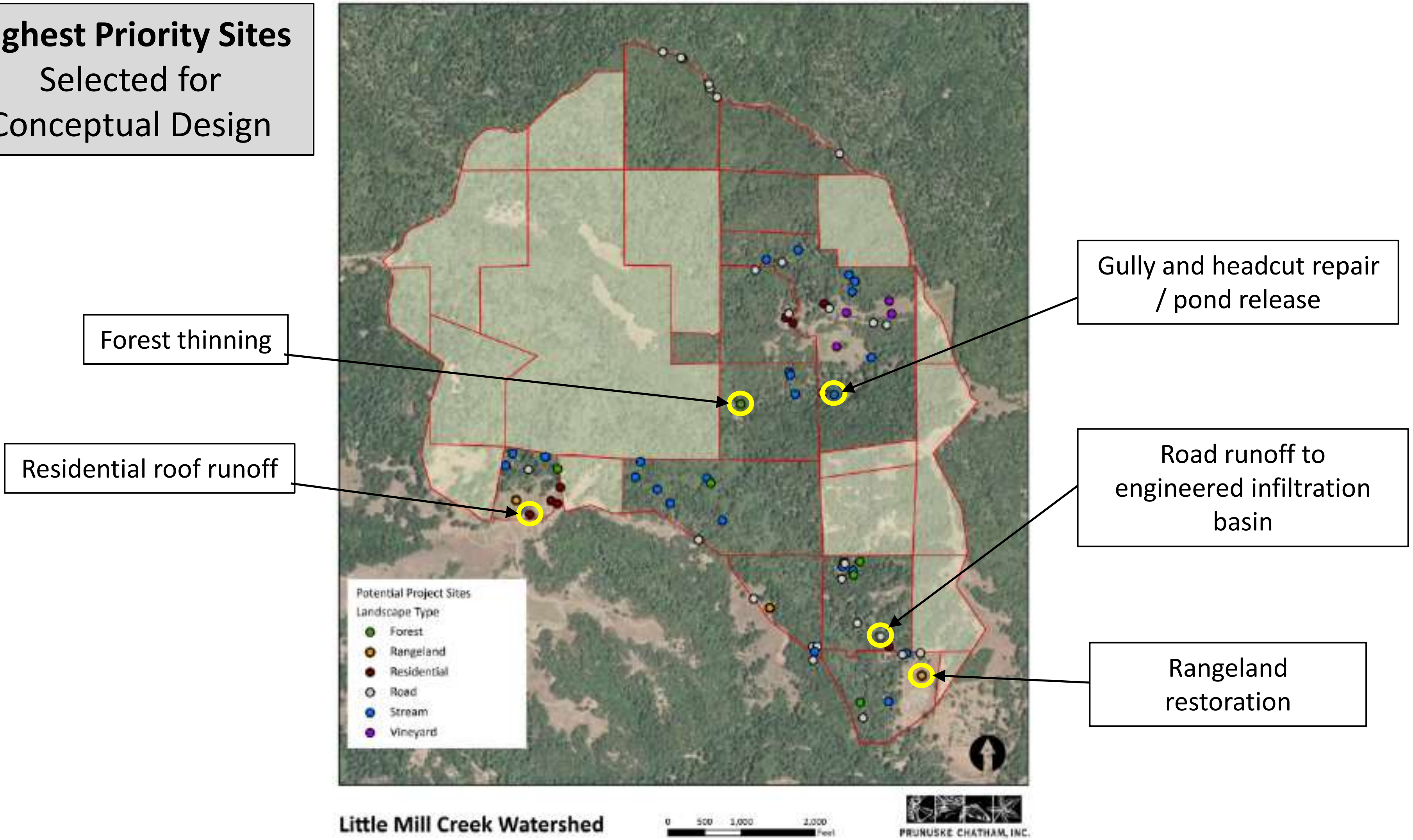


Potential Groundwater Recharge Projects

Landscape	Potential Project Sites
Forest	6
Rangeland	2
Residential	8
Road	24
Stream / Riparian	21
Vineyard	3
TOTAL	64



Highest Priority Sites
Selected for
Conceptual Design



Little Mill Creek Watershed

Hydrologic Benefits Summary

Recommended Treatment	Runoff Area Treated	Potential groundwater recharge by precipitation year (acre-feet)		
		Average	Dry	Very Dry
Residential runoff to tanks, raingarden	0.3 ac	0.3	0.2	0.1
Infiltration basin for road, upland runoff	0.1 ac road; 7.5 ac watershed	1.6	1.1	0.9
Rangeland soil health and infiltration trenches	10.2 ac	11.4	6.4	0.9
Forest thinning	4.7 ac	1.2	1.2	0.0
Strategic pond release, repair incised channels	420 ft stream; 24.6 ac watershed	0.2*	0.2*	0.2*

Cumulative Benefits

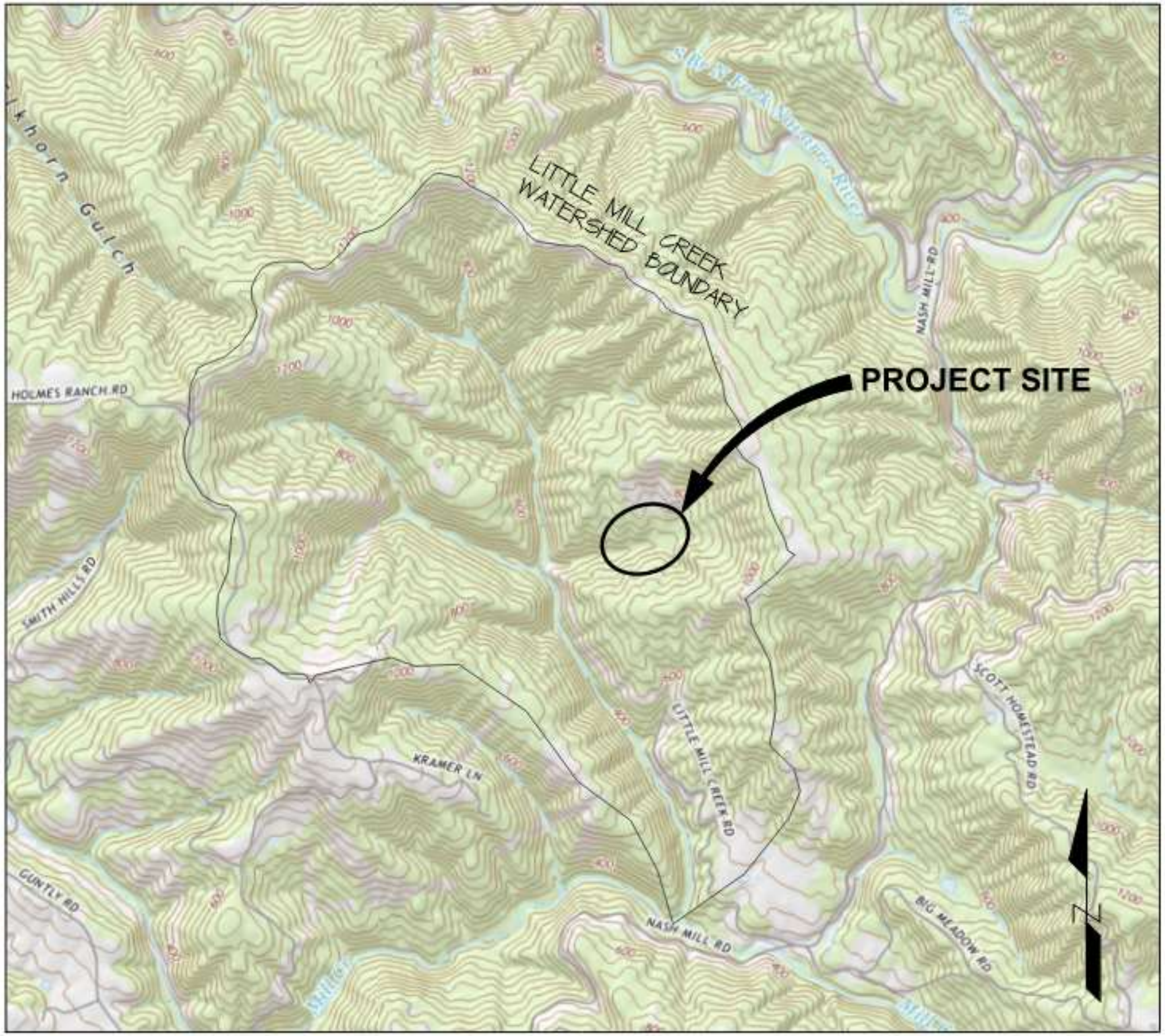
Dry Season Streamflow Increases

Implementing groundwater recharge projects:

Average years:	0.03 – 0.04 cfs
Dry years:	0.01 – 0.03 cfs
Very dry years:	0.01 – 0.02 cfs

These small increases can be ecologically significant

Restoration design



Project location

Strategic release for flow augmentation

Pond total volume = **4.2 AF**

Leakage **(2.1 AF) (Multiple cycles?)**

Spike rush

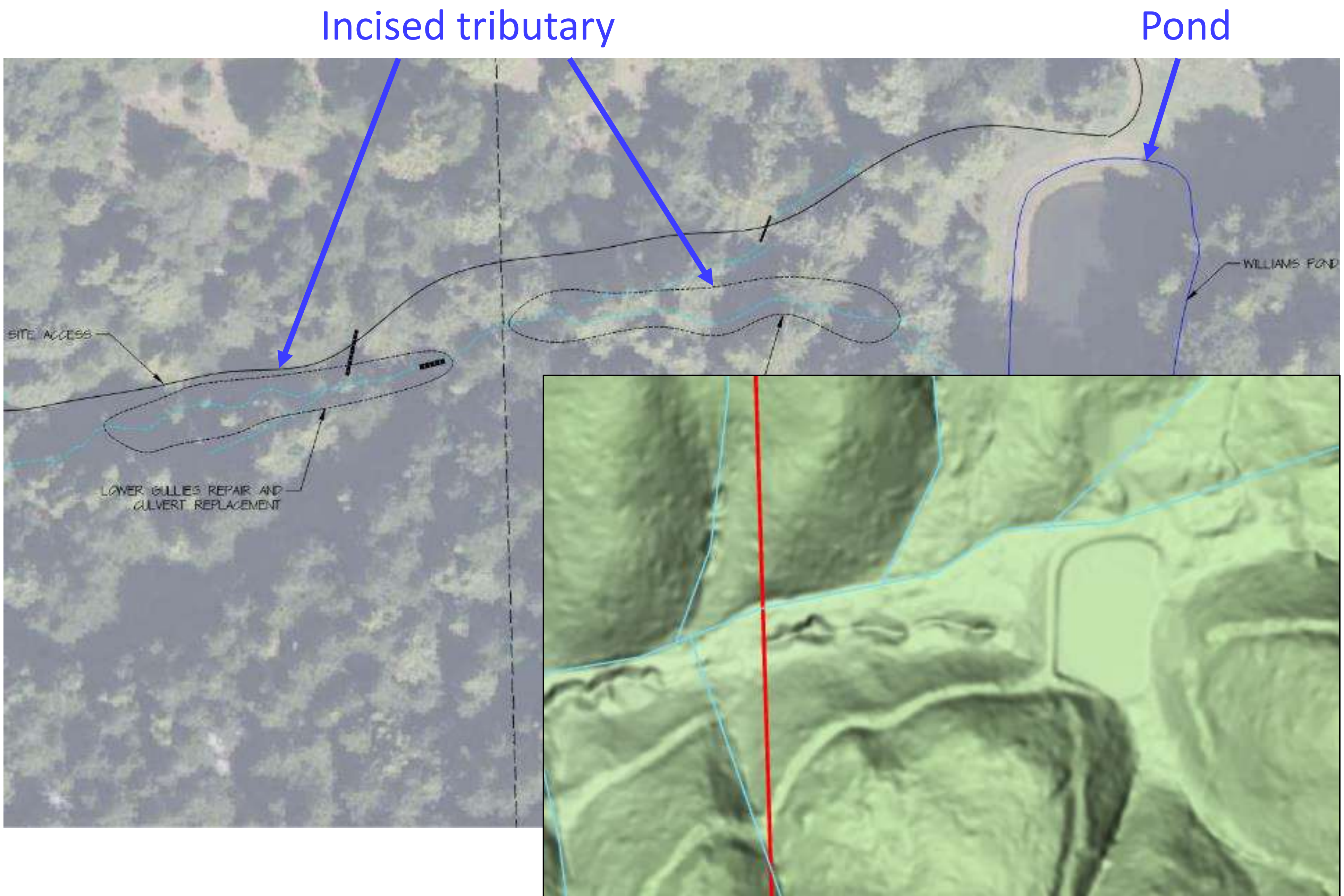
Retained volume	**2.1 AF**
(Reserve for use)	**0.3 AF**
Available volume	**1.8 AF**

Release @ 0.1 cfs (45 GPM) for 9 days

Cumulative Evaporation **(AF)**

April	**0.1**
May	**0.2**
June	**0.4**
July	**0.6**
August	**0.8**
September	**1.0**

Channel Restoration Design

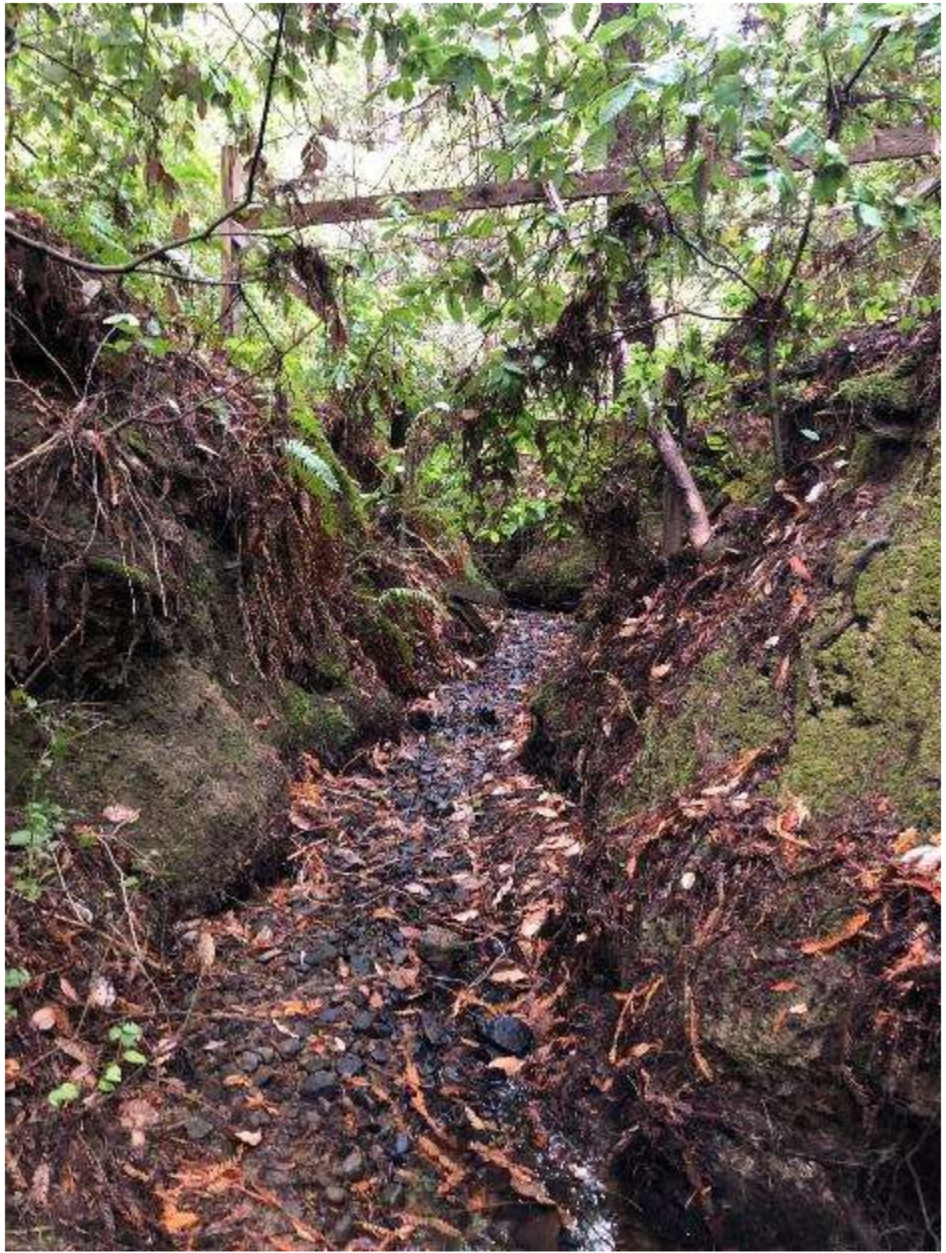


Tributary Geomorphology: Lack of floodplain, steep hillslopes (30-75%), steep long profile (11%)

Headcuts and incision - up to 14 feet

Headcuts and incision - up to 14 feet

Incised channel lowers local water table

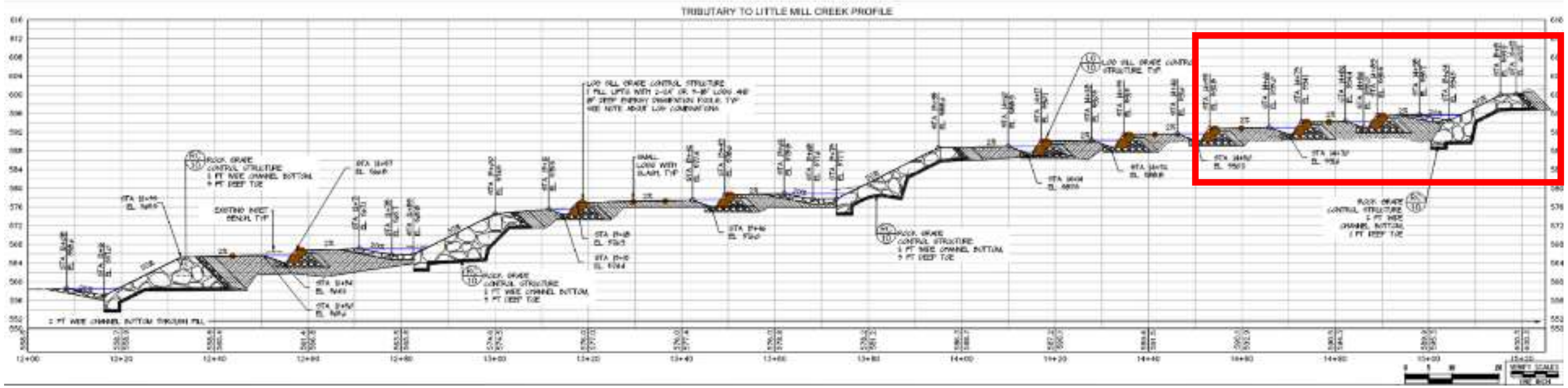


Groundwater seeps maintain flow well into dry season

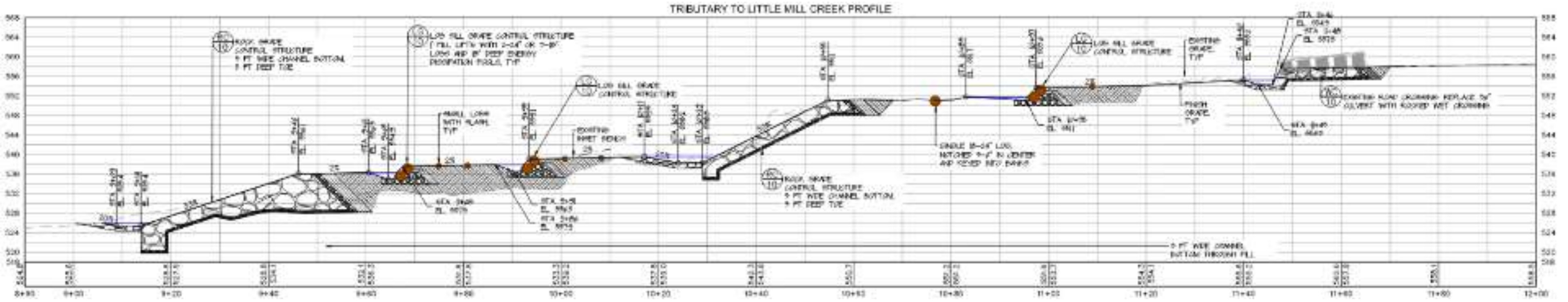
Common inset benches

Restore profile for infiltration and groundwater retention

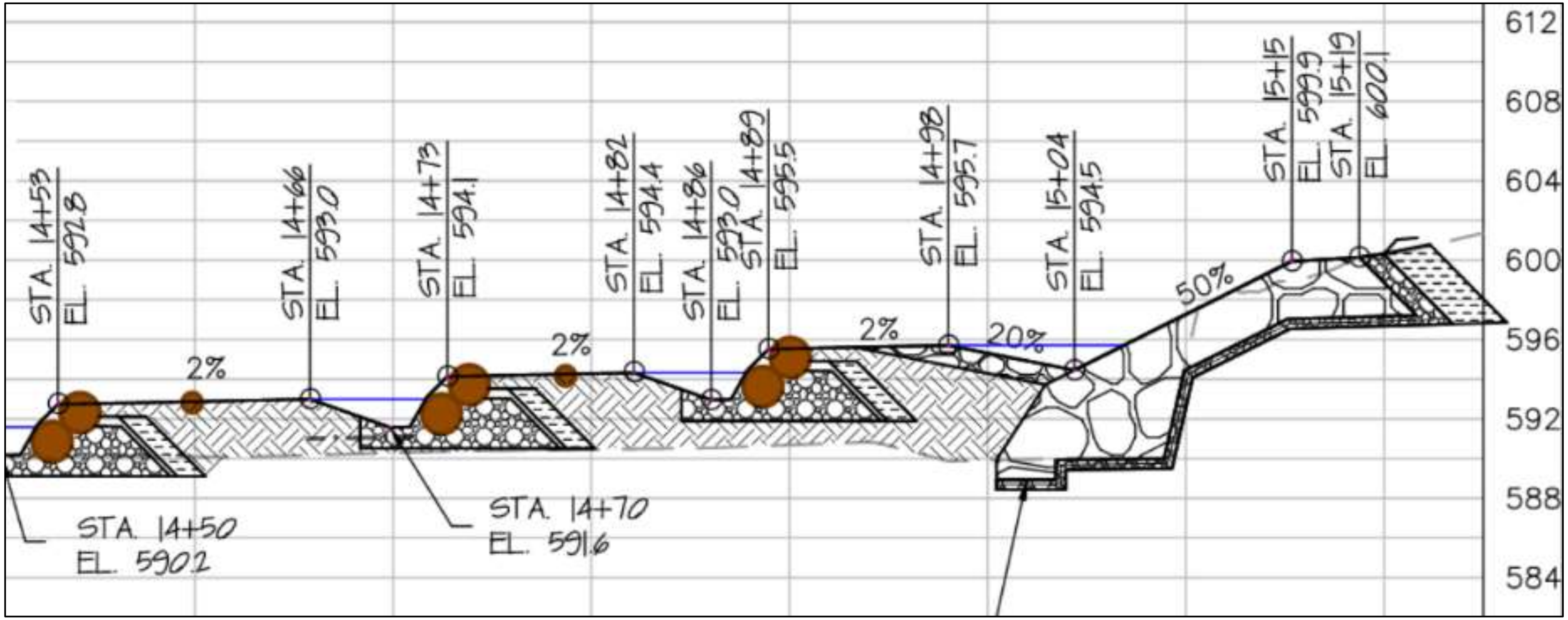
Upstream Reach



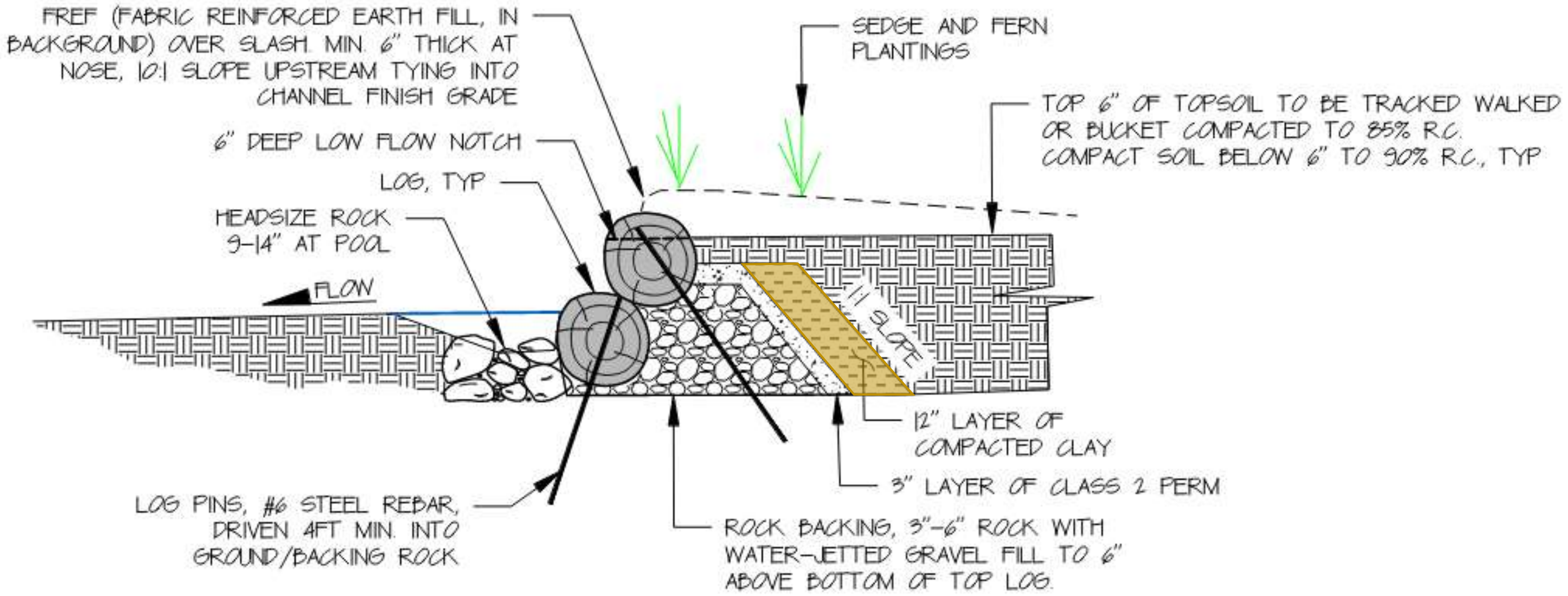
Downstream Reach



Restore profile for infiltration and groundwater retention

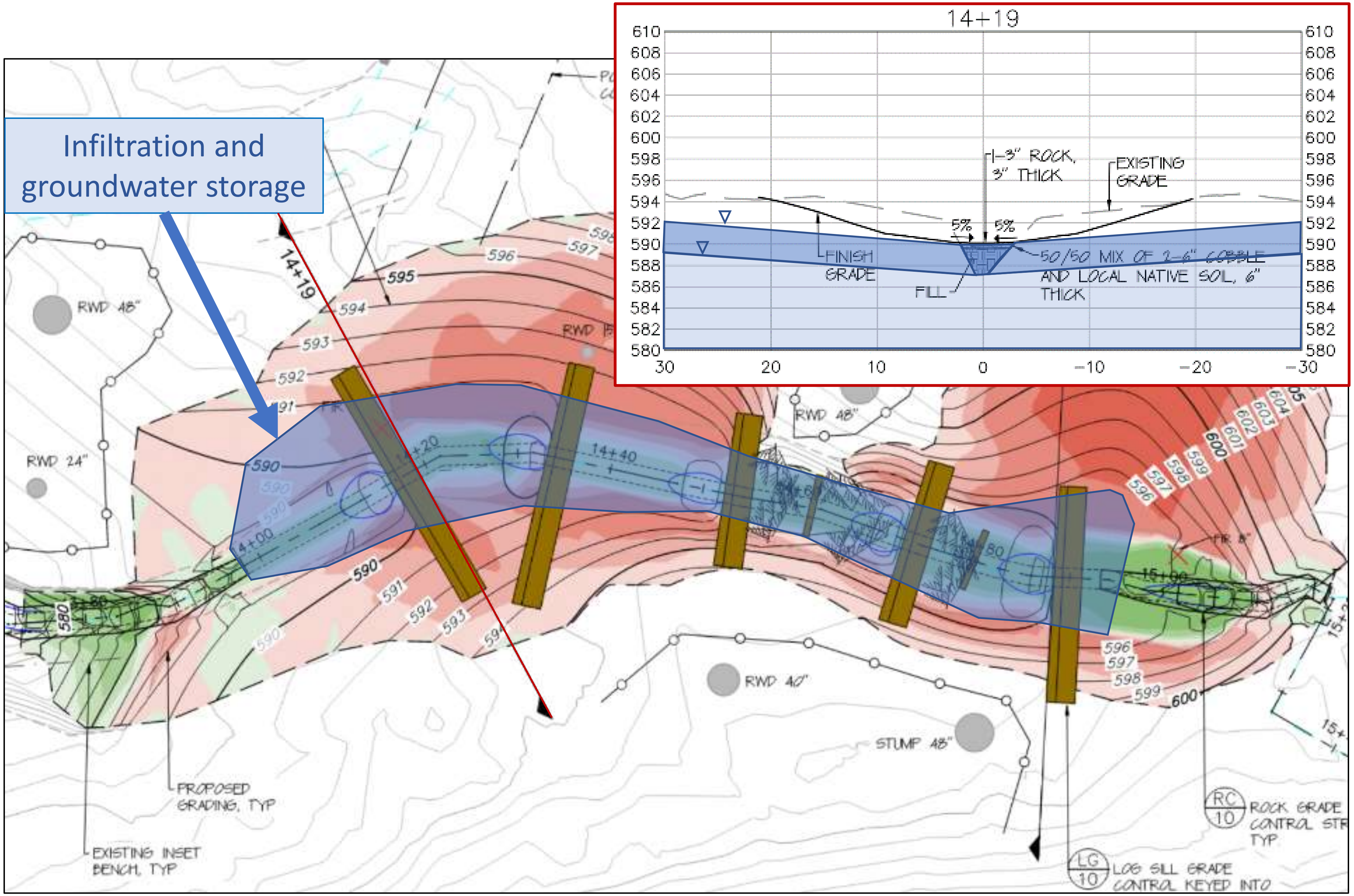


Log Sill Grade Control

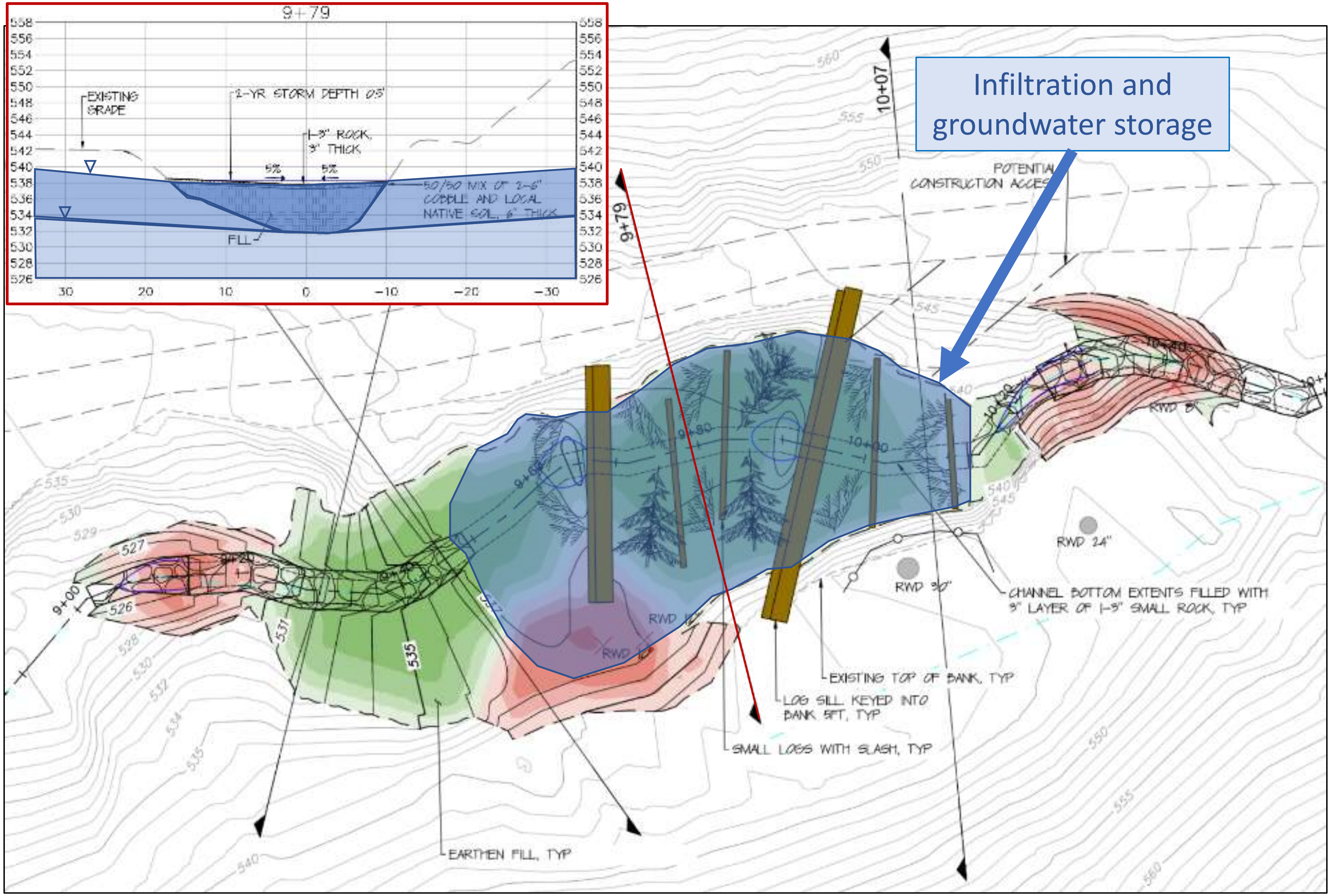


Plan view: Log sills, rock grade control, infiltration zones

Infiltration and groundwater storage

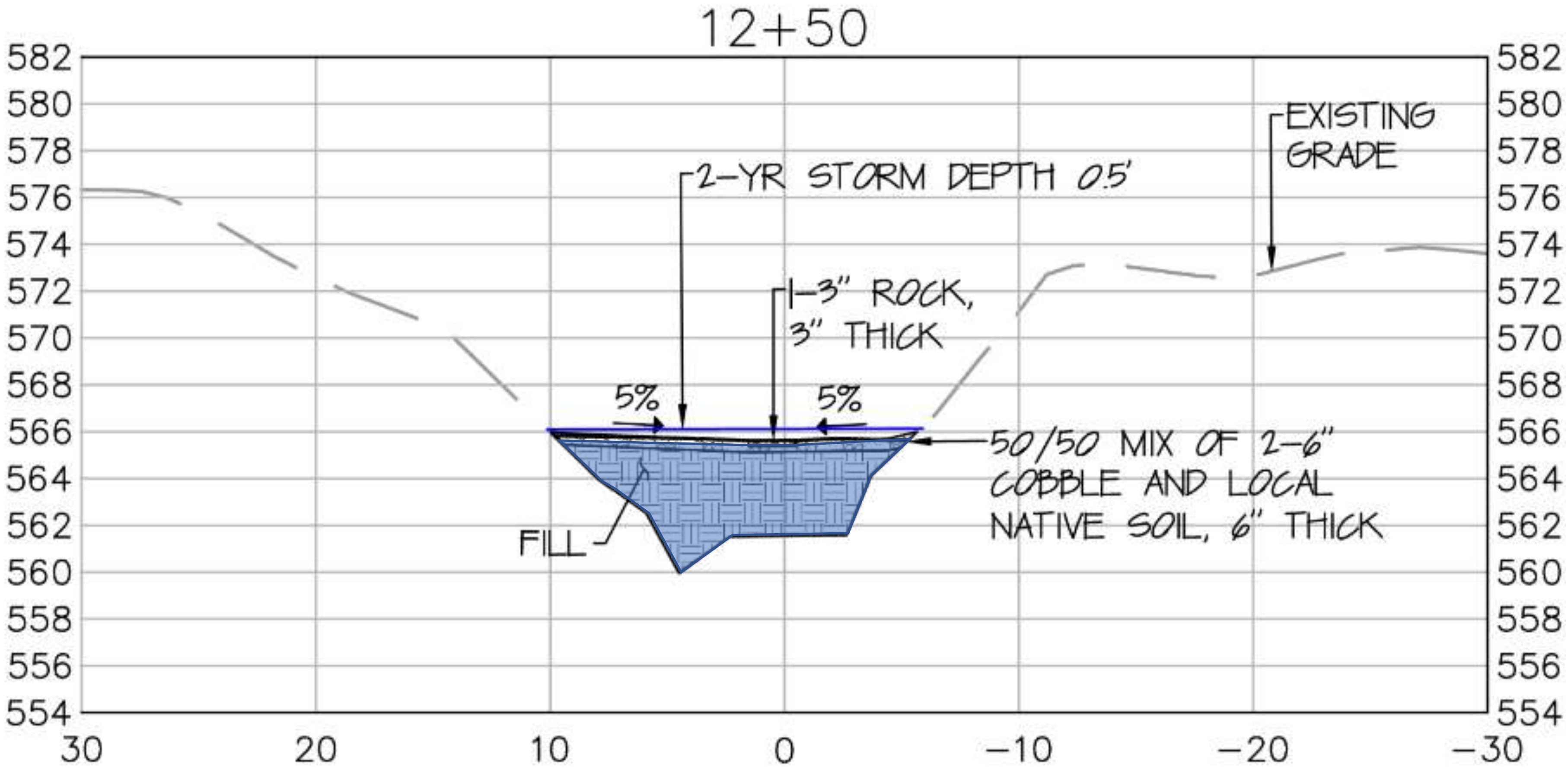


Plan view

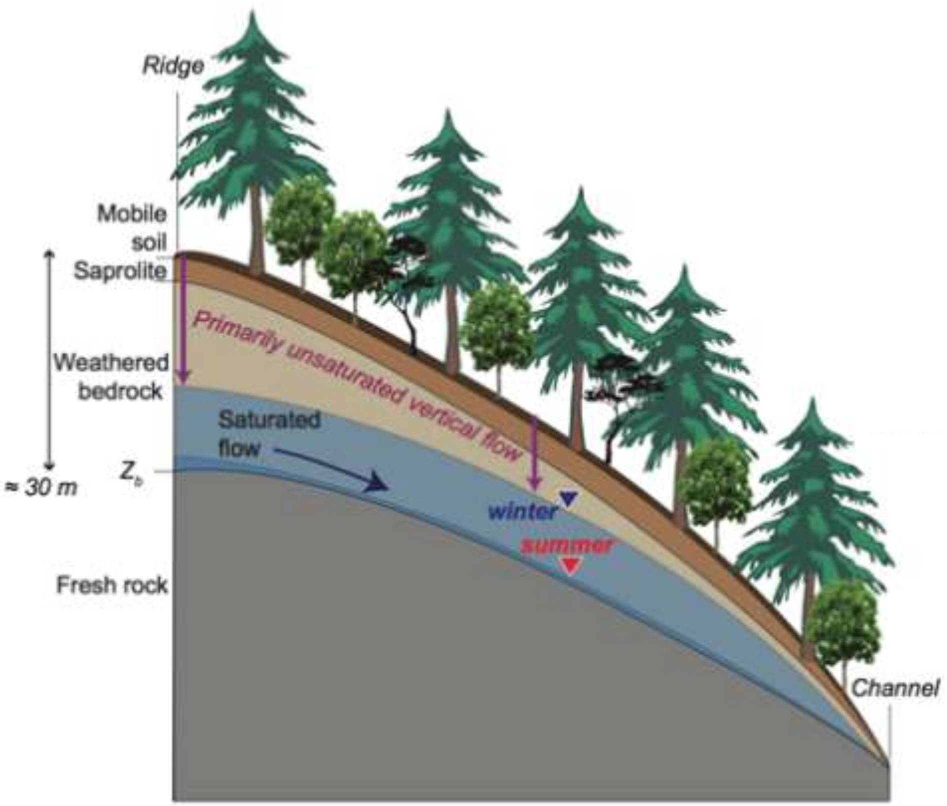

9+79
EXISTING GRADE
2-YR STORM DEPTH 0.5'
1-3" ROCK, 3" THICK
5%
5%
50/50 MIX OF 2-6" COBBLE AND LOCAL NATIVE SOIL, 6" THICK
FILL
Infiltration and groundwater storage
10+07
POTENTIAL CONSTRUCTION ACCESS
9+00
9+60
9+80
10+00
RWD
RWD 30"
RWD 24"
CHANNEL BOTTOM EXTENTS FILLED WITH 3" LAYER OF 1-3" SMALL ROCK, TYP
EXISTING TOP OF BANK, TYP
LOG SILL KEYED INTO BANK 5FT, TYP
SMALL LOGS WITH SLASH, TYP
EARTHEN FILL, TYP

Hydrologic benefits summary

Raise tributary channel profile ~4 ft over 420 foot length
→ Groundwater retention: 8,316 cubic feet (0.2 AF)

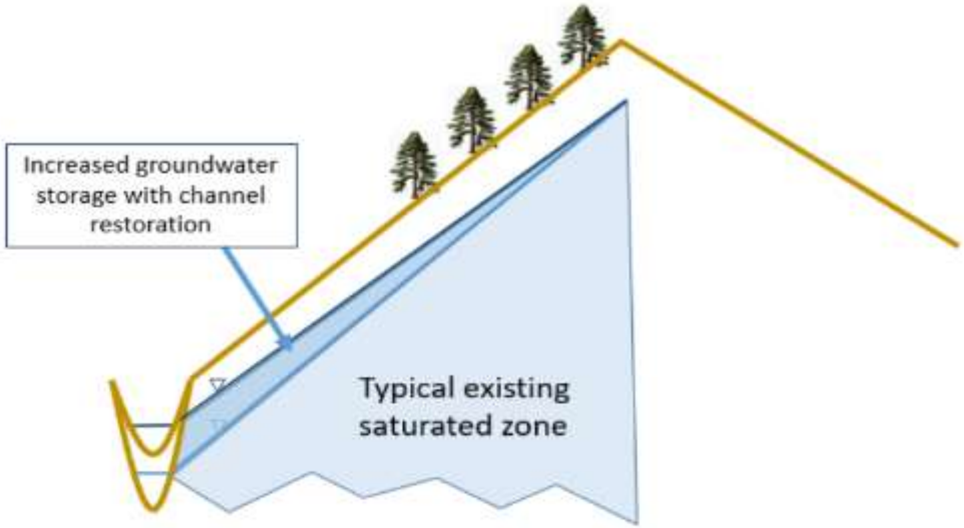


Potential to raise water table in adjacent hillslopes



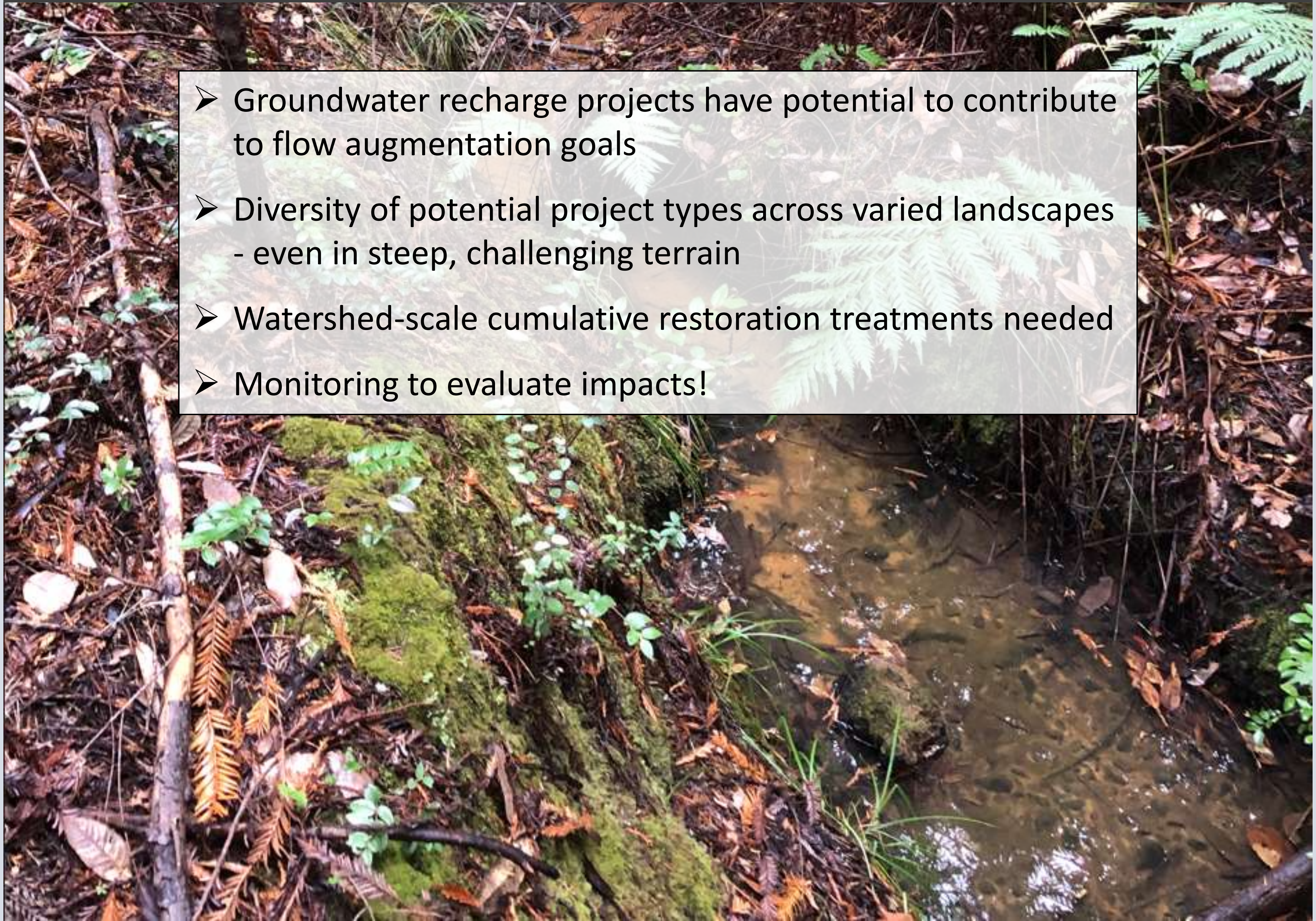
Hahm et al., *WRR, 2019.*

Hydrologic Benefits Summary



Retain additional groundwater within ~25 ac adjacent hillslopes
Baseflow contribution later into the spring/summer

Conclusions and Discussion



- Groundwater recharge projects have potential to contribute to flow augmentation goals
- Diversity of potential project types across varied landscapes - even in steep, challenging terrain
- Watershed-scale cumulative restoration treatments needed
- Monitoring to evaluate impacts!

Small-scale groundwater recharge opportunities for streamflow augmentation, Little Mill Creek, Navarro River watershed

Thank you!

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