The Role of Meadows in Water-Fire-Fish Processes Across the Landscape

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

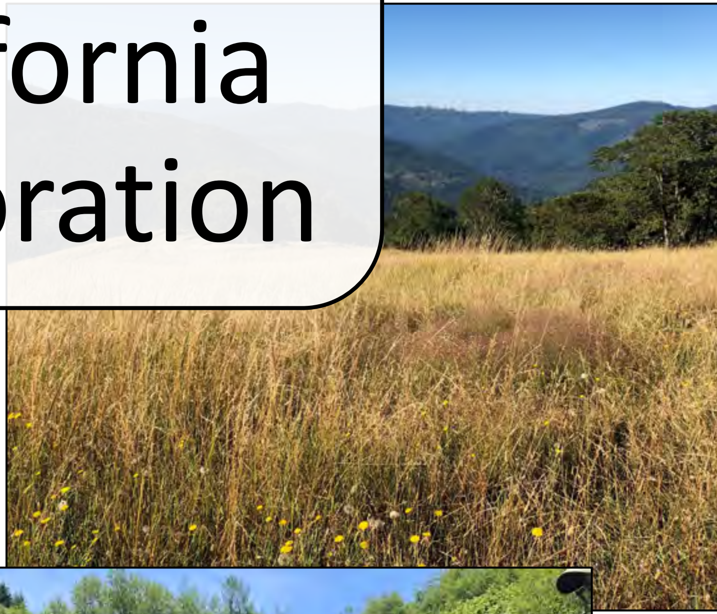
Session Coordinators: *Emily J. Cooper-Hertel*, *Klamath Meadows Partnership Coordinator, WRTC; and* ***Jay Stallman****, Senior Geomorphologist, Stillwater Sciences*

Despite their relatively small coverage of area across the landscape, meadows have a landscape scale impact when they are able to retain and slowly release water to lower watershed areas during the dry season. Many wet meadows in the Klamath, North Coast, and Sierra Mountain Ranges are important not only for their connection to fish habitat downstream, providing cold water refugia required by summer rearing salmonid species, but also for their wildfire refugia capabilities throughout upland areas. This session explores the role of meadows in holistic watershed stewardship, from wildfire resilience in forests to water security in streams. Meadows can act as a geomorphic hydraulic control at the watershed scale; however, altered hydrologic and fire disturbance regimes have impaired the ability of meadows to hold water that supports specific plant and animal communities locally as well as those farther downstream with seasonal water release.

This session is intended to explore the effects on eco-hydrologic processes at the watershed scale in response to fuels, fire, and instream restoration locally within and around meadows. A better understanding of meadow distribution, condition, and restoration across the landscape can help inform the role and need for meadows as integral components of watershed processes. We would like to explore knowledge of the dynamics between groundwater and surface water from geologic, geomorphologic, vegetation, and climatic conditions. How does upland fire and fuels management pair with meadow restoration regarding surface and groundwater availability? Can targeting upland forest restoration where there are high densities of meadows maximize potential increases and durations in water yields due to the natural water storage characteristics of meadows in the watershed? Do dry meadows and grasslands treated with beneficial burning improve forest and stream health? Do healthy meadows improve seasonal fish habitat? What meadow restoration strategies have worked or are desired with integrated forest and instream management? How can traditional ecological knowledge of watershed stewardship highlight the role of meadows in forest and stream health?

Presentations

Understanding and Restoring Meadows of Northern California through Meaningful Collaboration

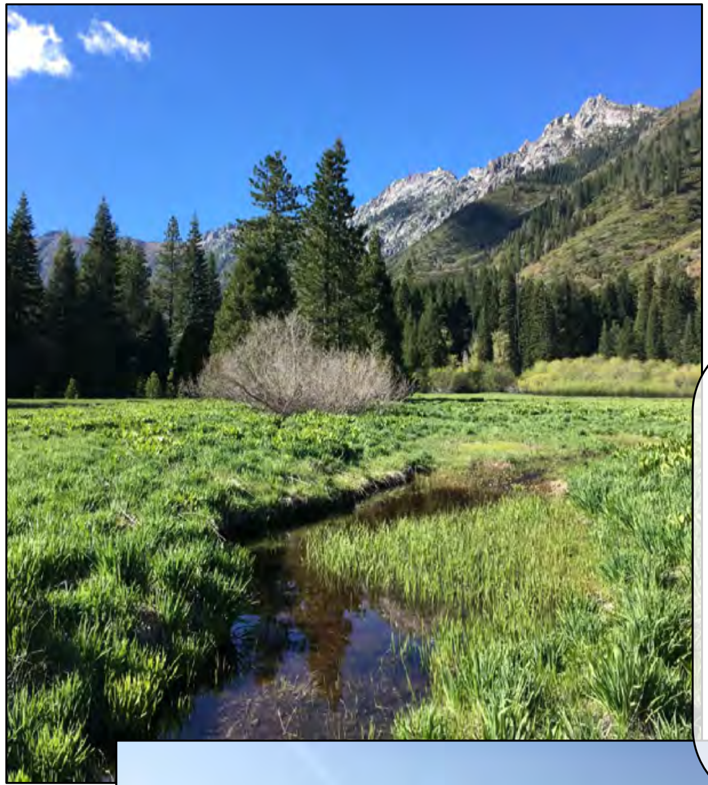


Emily Cooper-Hertel

Klamath Meadows Partnership Coordinator

Watershed Research & Training Center

What is a Meadow?

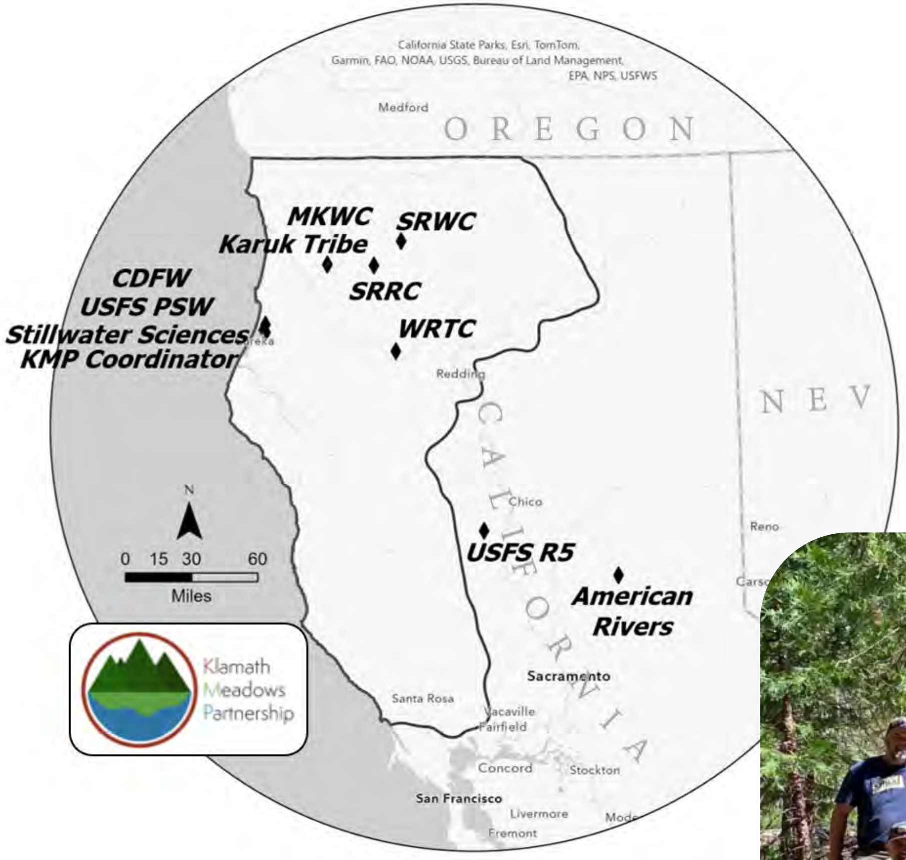


- Open, treeless area dominated by grasses and forbs
- Depositional zones for sediment and water storage
- A place for beaver, bear, elk
- A place for gathering food, fiber, and medicine
- A fire break
- A type of wetland
- An extension of a riparian zone; a floodplain

Why Meadows?

- Hydrologic, biological, and cultural significance
- Meadows have a high intrinsic potential for supporting wildfire resilience and water security
- Anthropogenic impacts to hydrologic and beneficial fire regimes have degraded meadows, resulting in symptomatic channel incision and forest encroachment
- Studies estimate that meadows now make up a small portion of their historical extent

Klamath Meadows Partnership



Partners: 15 representatives from 9 organizations that steer the KMP vision, goals, and action

Members: Over 120 individuals from organizations including non-profits, federal and state agencies, tribes, private companies, academics, and meadow enthusiasts

KMP Mission:

To better understand, highlight, and restore meadows of Northern California through meaningful collaboration

- **Capacity Building & Outreach**
- **Meadow Mapping**
- **Meadow Restoration Project Development**

Meadow Mapping

KMP Regional Assessment

Meadow Mapping

KMP Regional Assessment

- Ancestral lands of over 28 tribes

Meadow Mapping

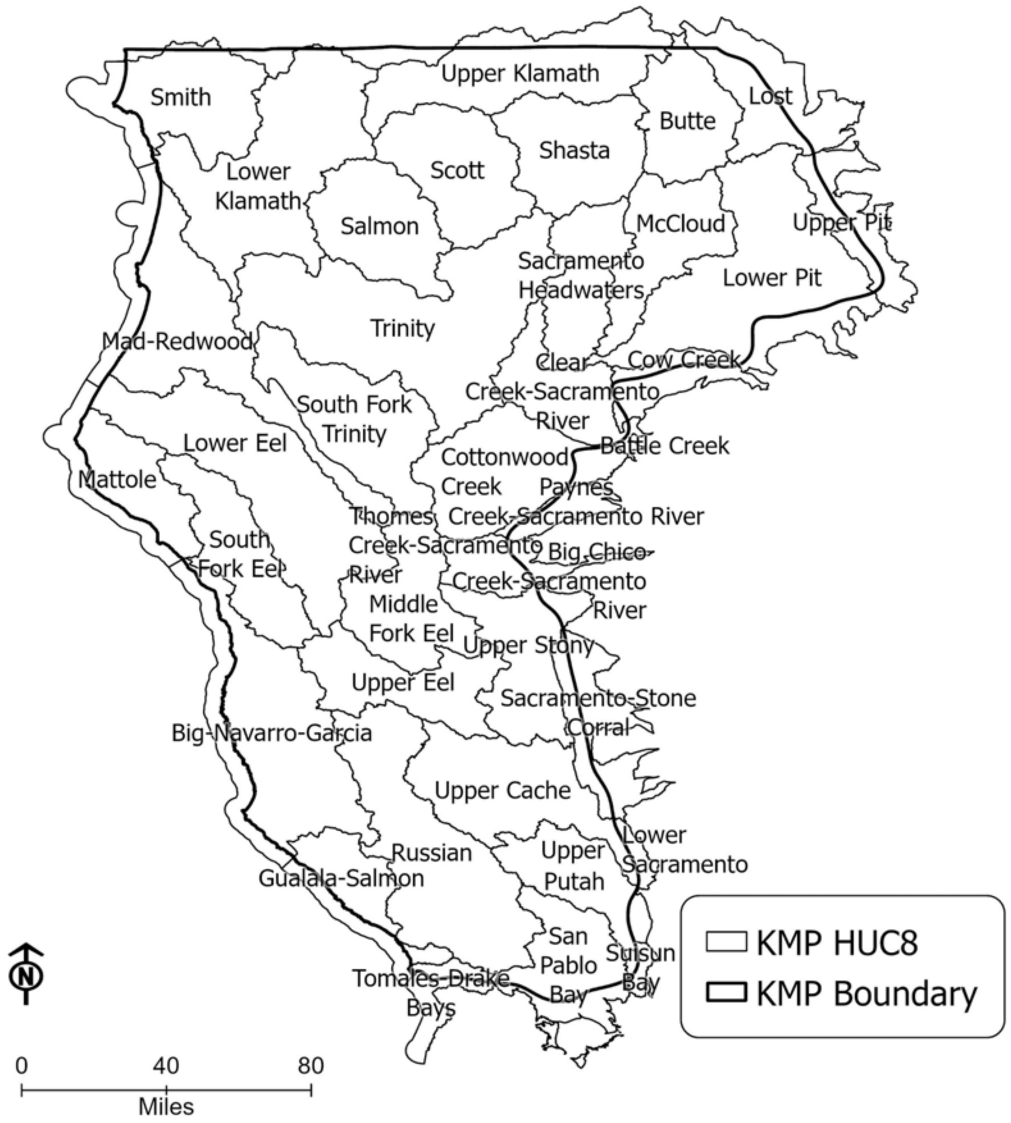
KMP Regional Assessment

- Ancestral lands of over 28 tribes
- Myriad private and public present-day landownership
- 17 counties
- 4 National Forests

Meadow Mapping

KMP Regional Assessment

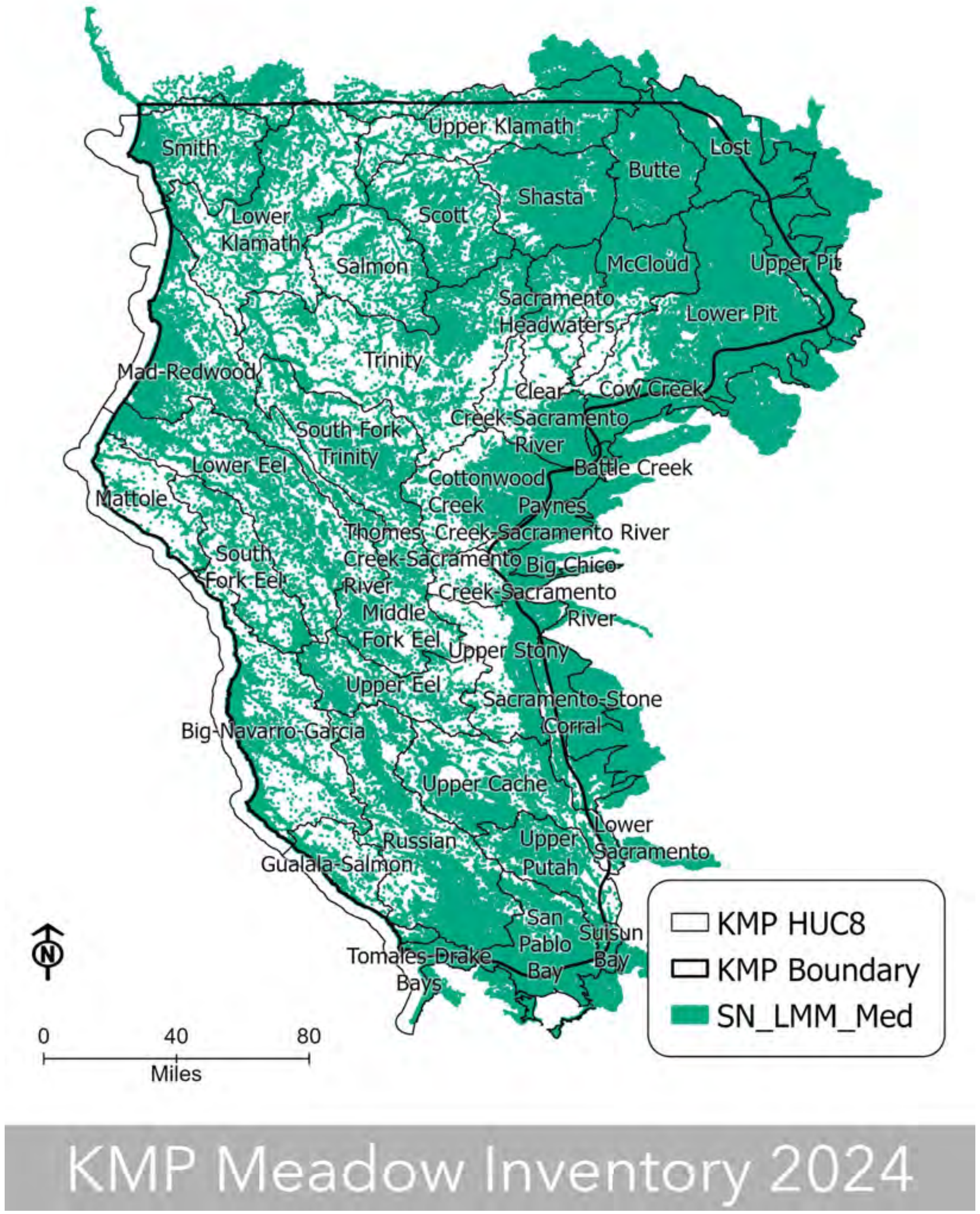
- Over 100,000 sq. km
- Klamath, Eel, Russian, coastal watersheds, and west-side Sacramento watersheds



Meadow Mapping

Meadow Modeling

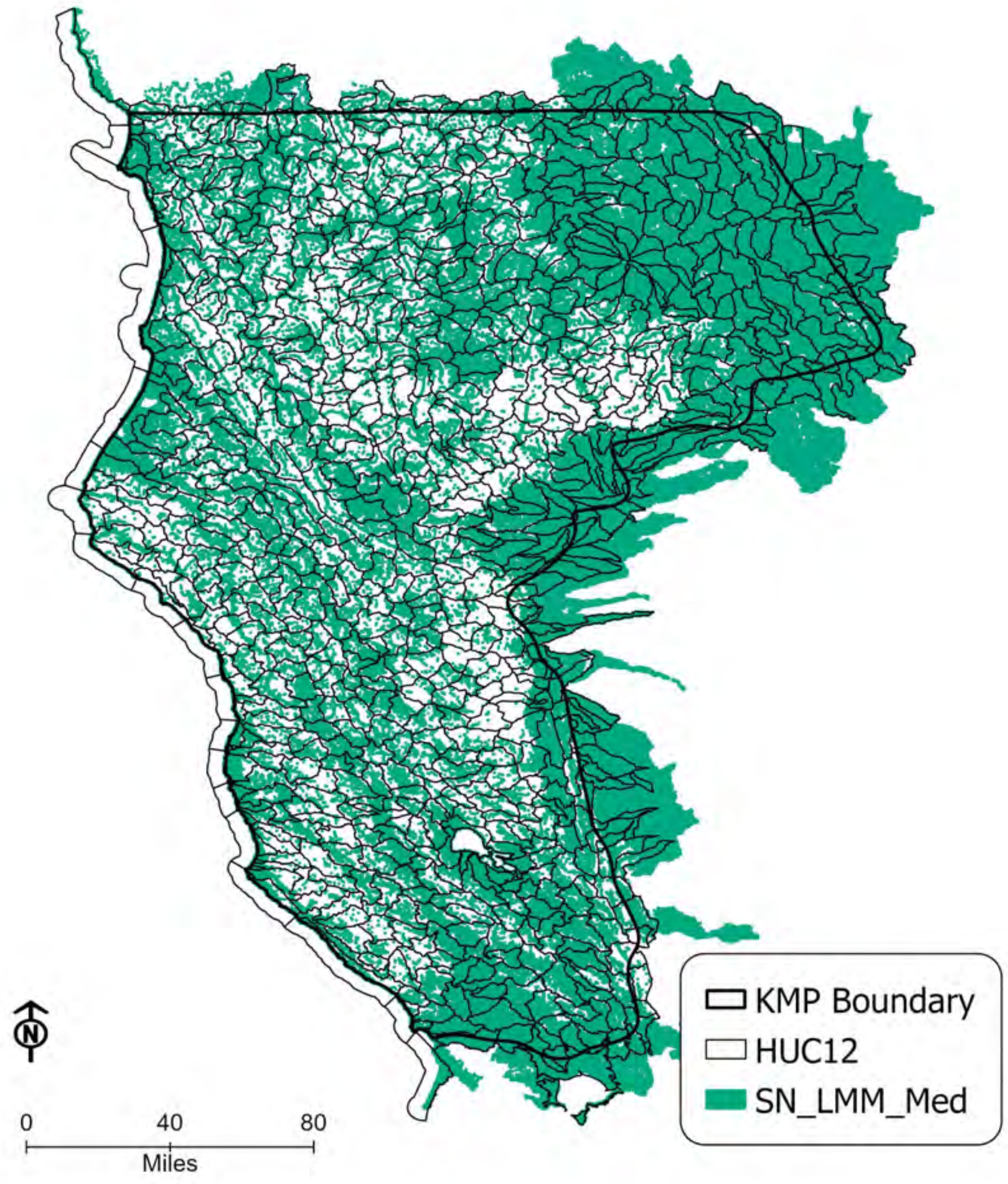
- Lost Meadow Model (Pope and Cummings 2023)



Meadow Mapping

Remotely Assessed Existing Data for Field Sampling Site Selection

- Lost Meadow Model (Pope and Cummings 2023)
- Meadow Delineation datasets (UC Davis 2020, SRRC 2024)
- CDFW wetland frog habitat
- USFS Existing Vegetation
- National Wetlands Inventory
- State Lake Dataset
- iNaturalist meadow associated plant data
- National Hydrography Dataset streams, springs, seeps



KMP Meadow Inventory 2024

Meadow Mapping

Remotely Assessed Existing Data for Field Sampling Site Selection

- Lost Meadow Model (Pope and Cummings 2023)
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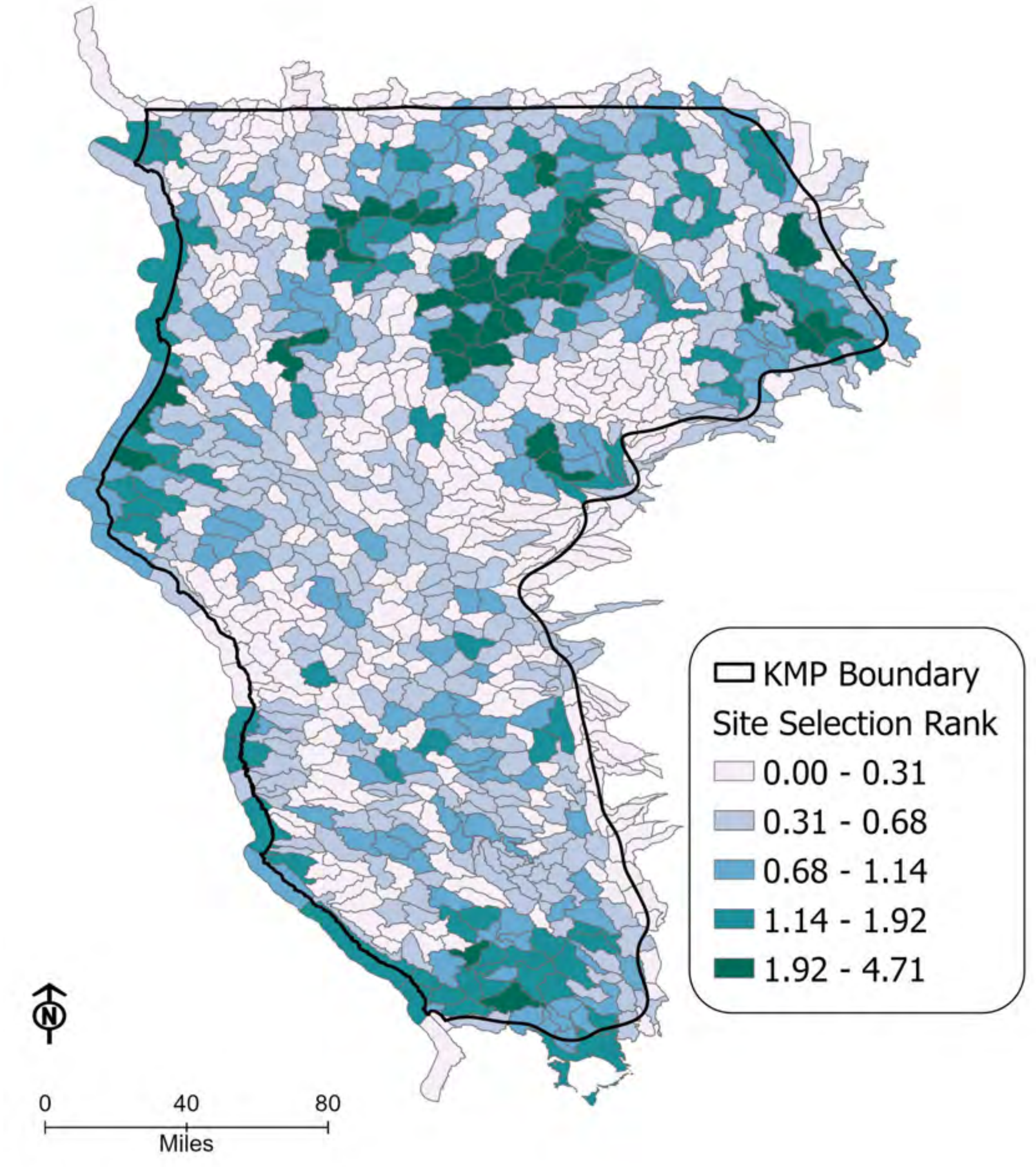


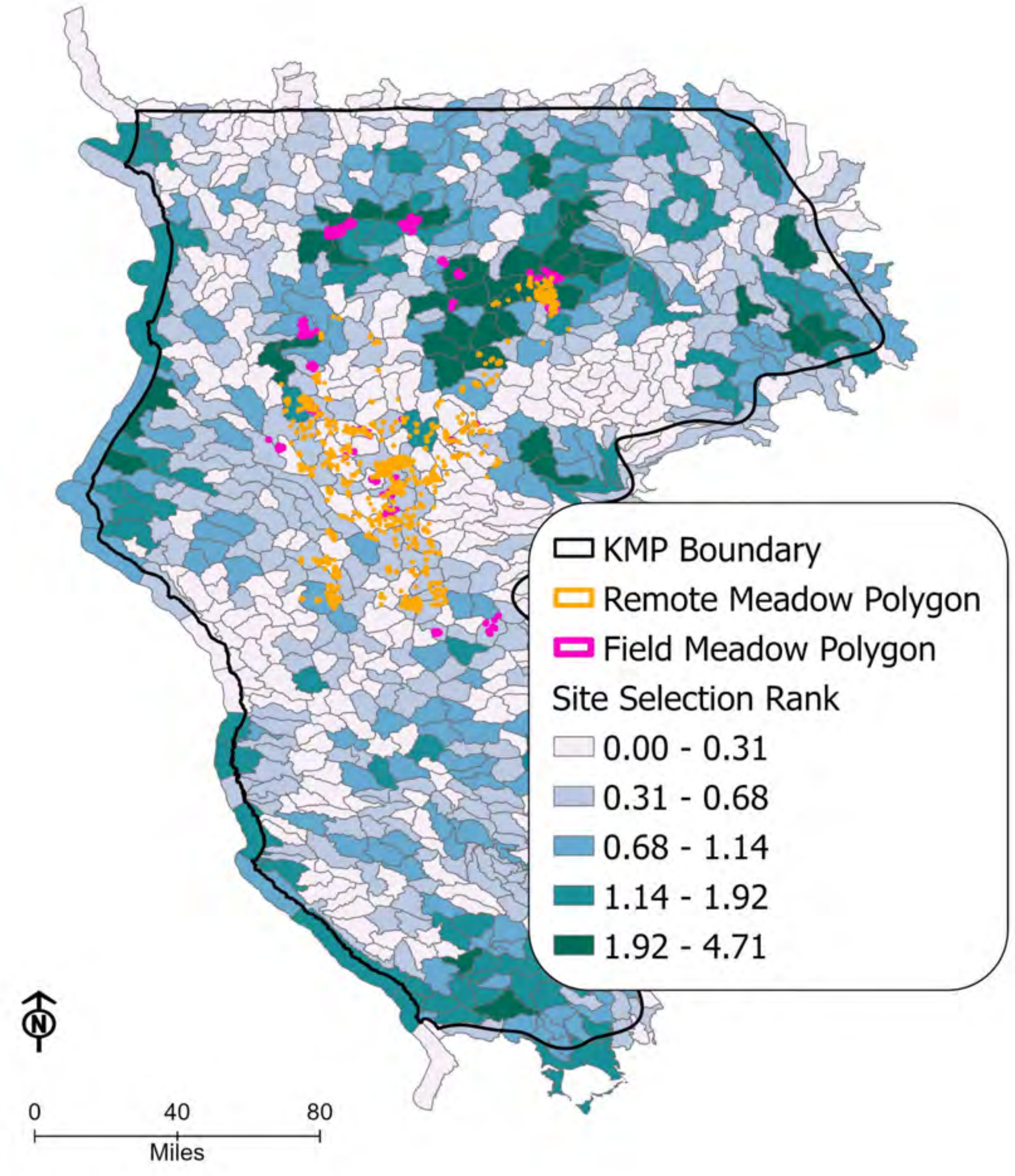
KMP Meadow Inventory 2024

Meadow Mapping

Data collection for developing Klamath Lost Meadow Model and meadow assessments

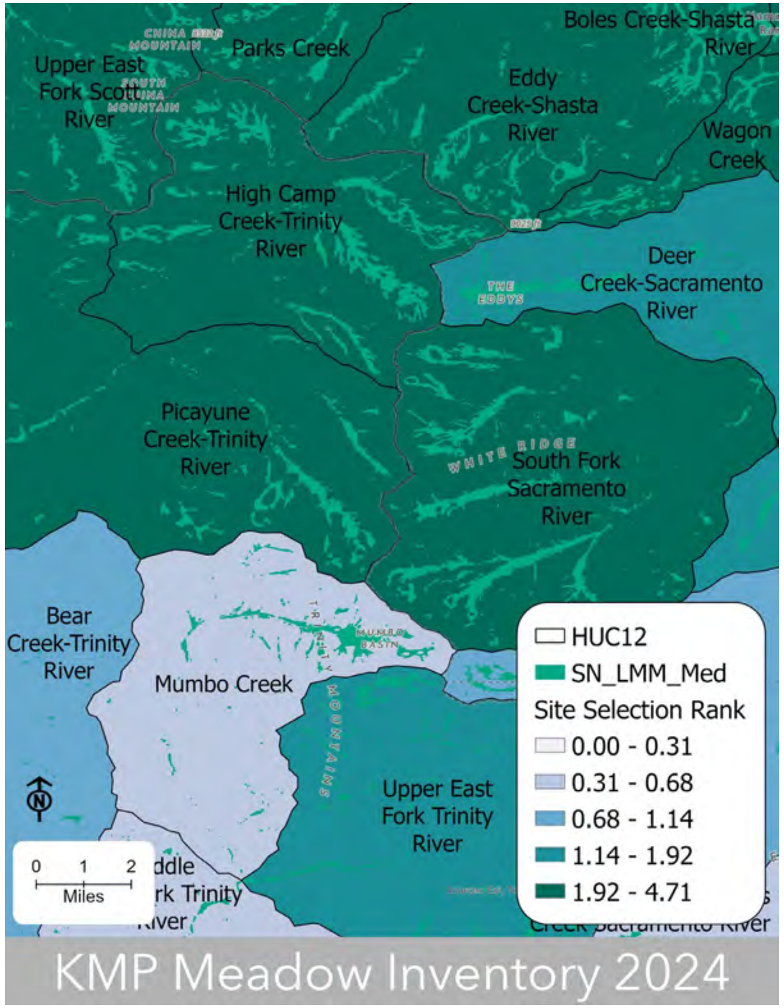
Field
- 5 crews from different organizations
- 673 site visits
- 498 Positive Meadows (1,523 Acres)
- 175 Negative Meadows

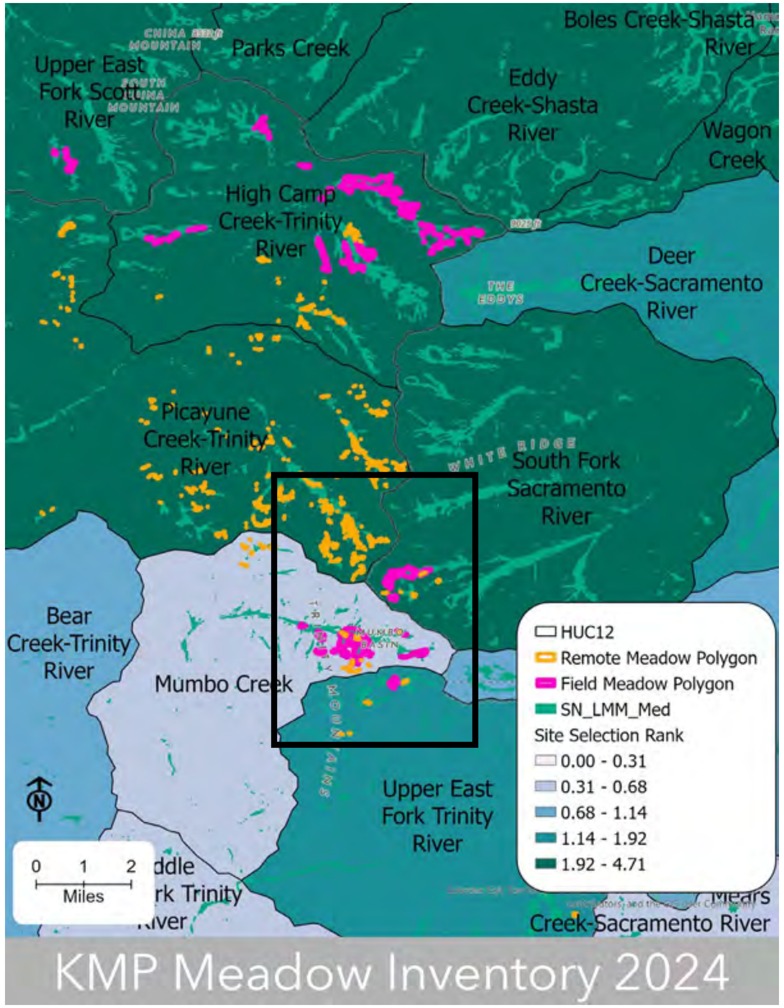
Remote (field-informed)
- 1,281 Meadows (6,960 Acres)

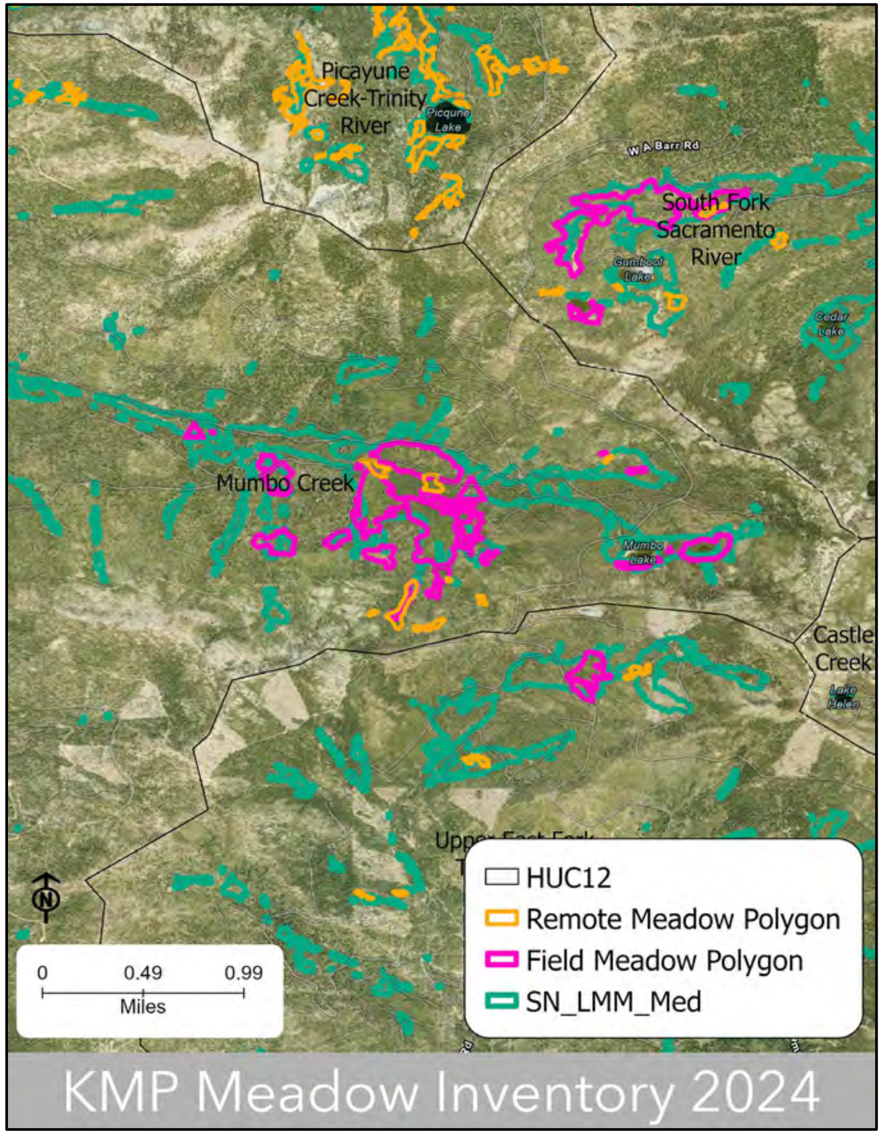


KMP Meadow Inventory 2024

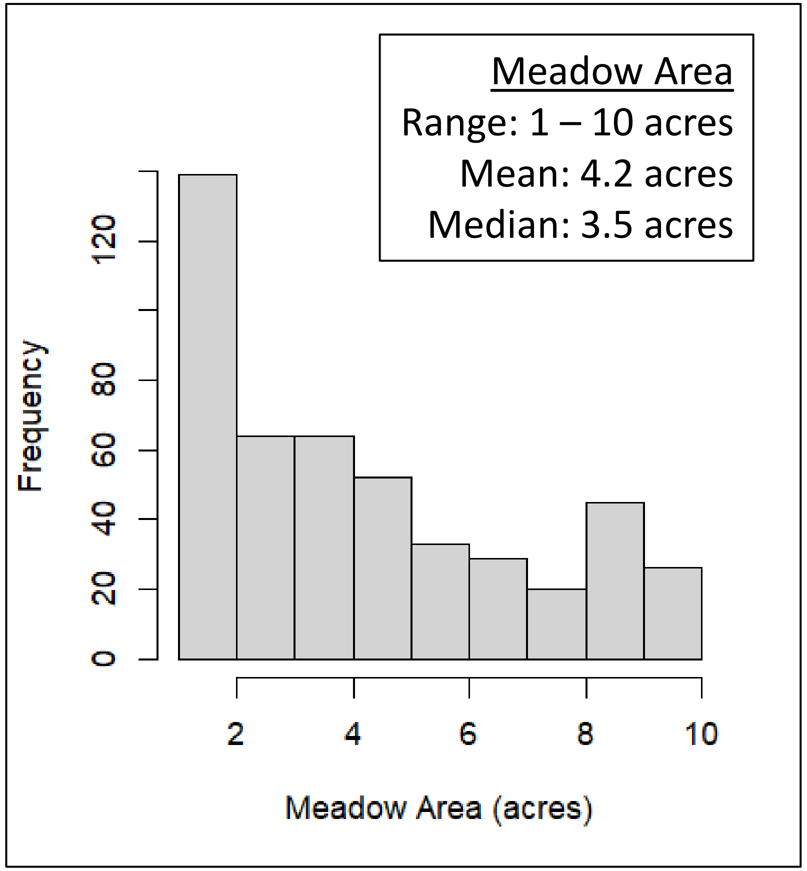
Meadow Mapping

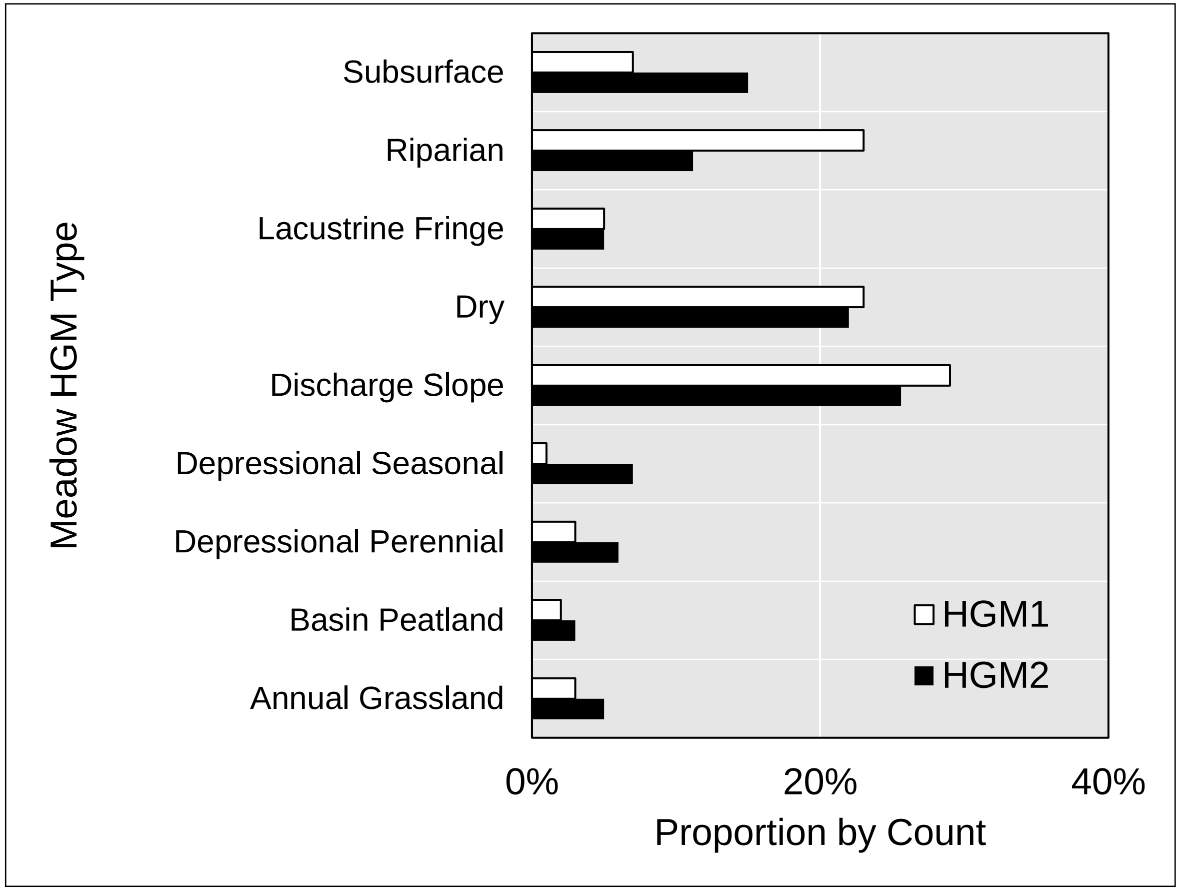






Meadow Areas & Hydrogeomorphic Types



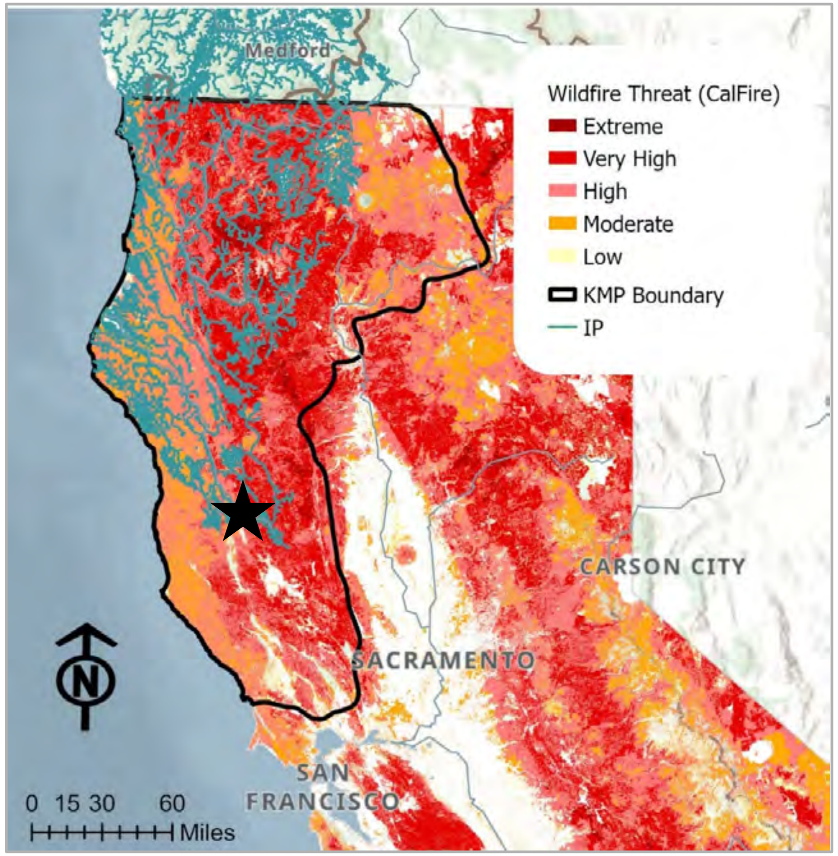


Meadow Areas & Hydrogeomorphic Types

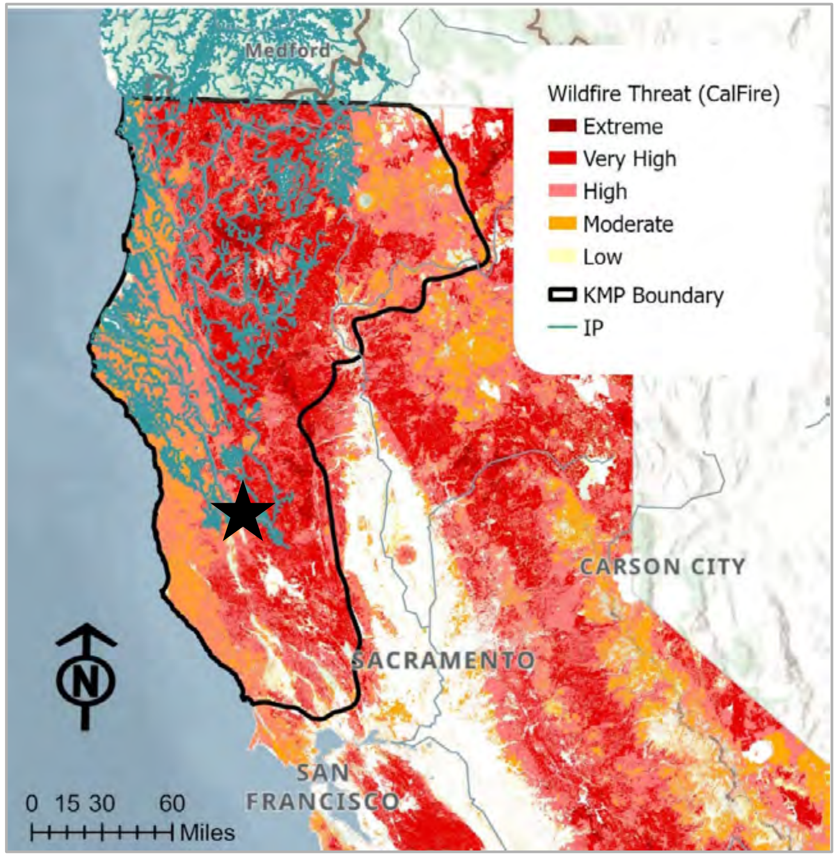
Meadow Areas & Hydrogeomorphic Types

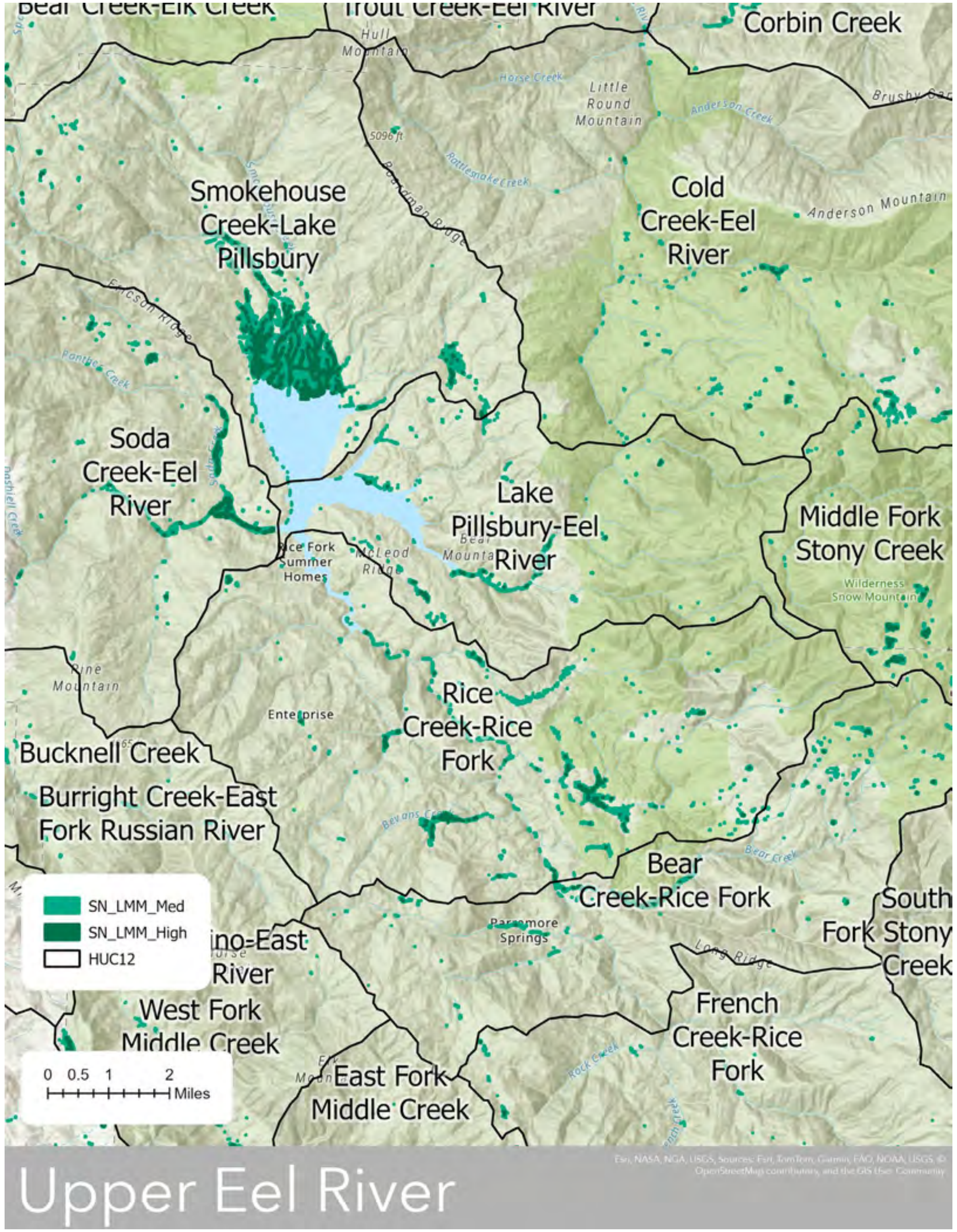
Discharge Slope Meadow,
Bear Creek Basin

Restoration Prioritization & Project Development: Landscape, Watershed, & Site Scale Perspectives



Restoration Prioritization & Project Development: Landscape, Watershed, & Site Scale Perspectives





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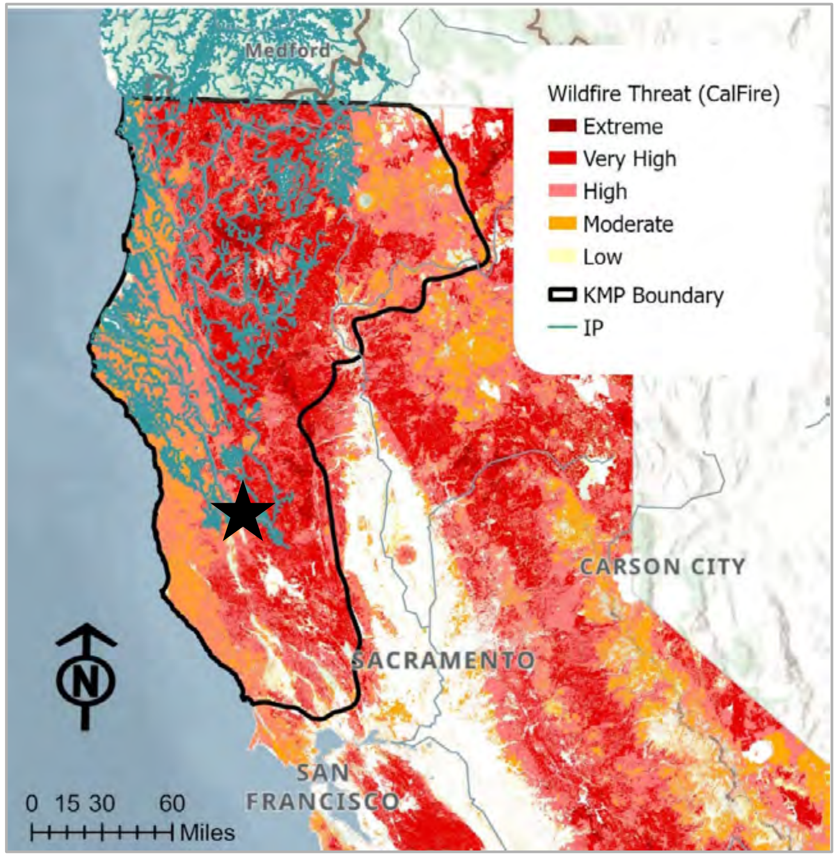

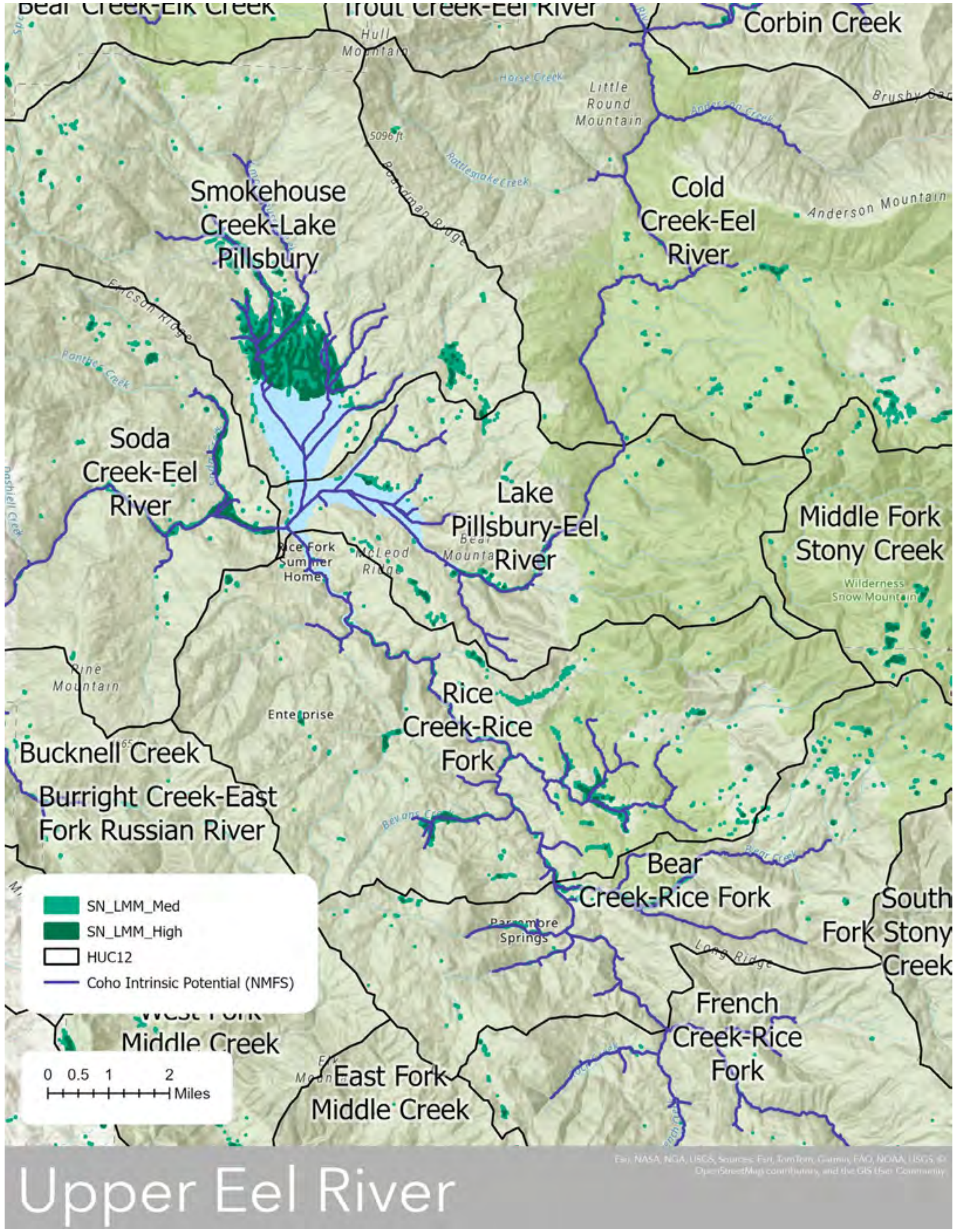

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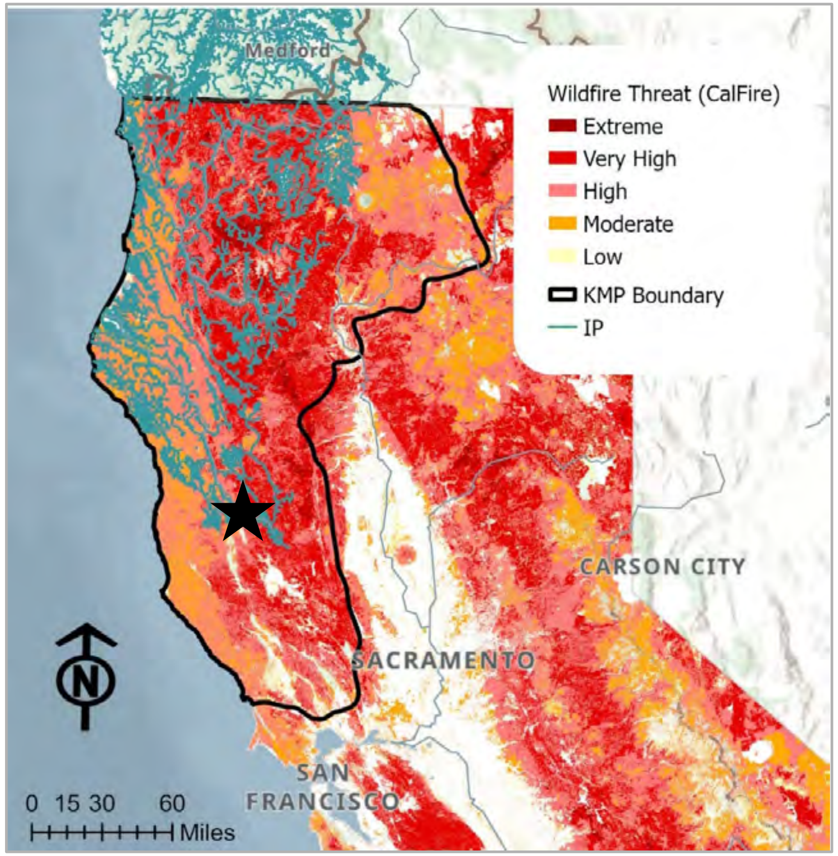

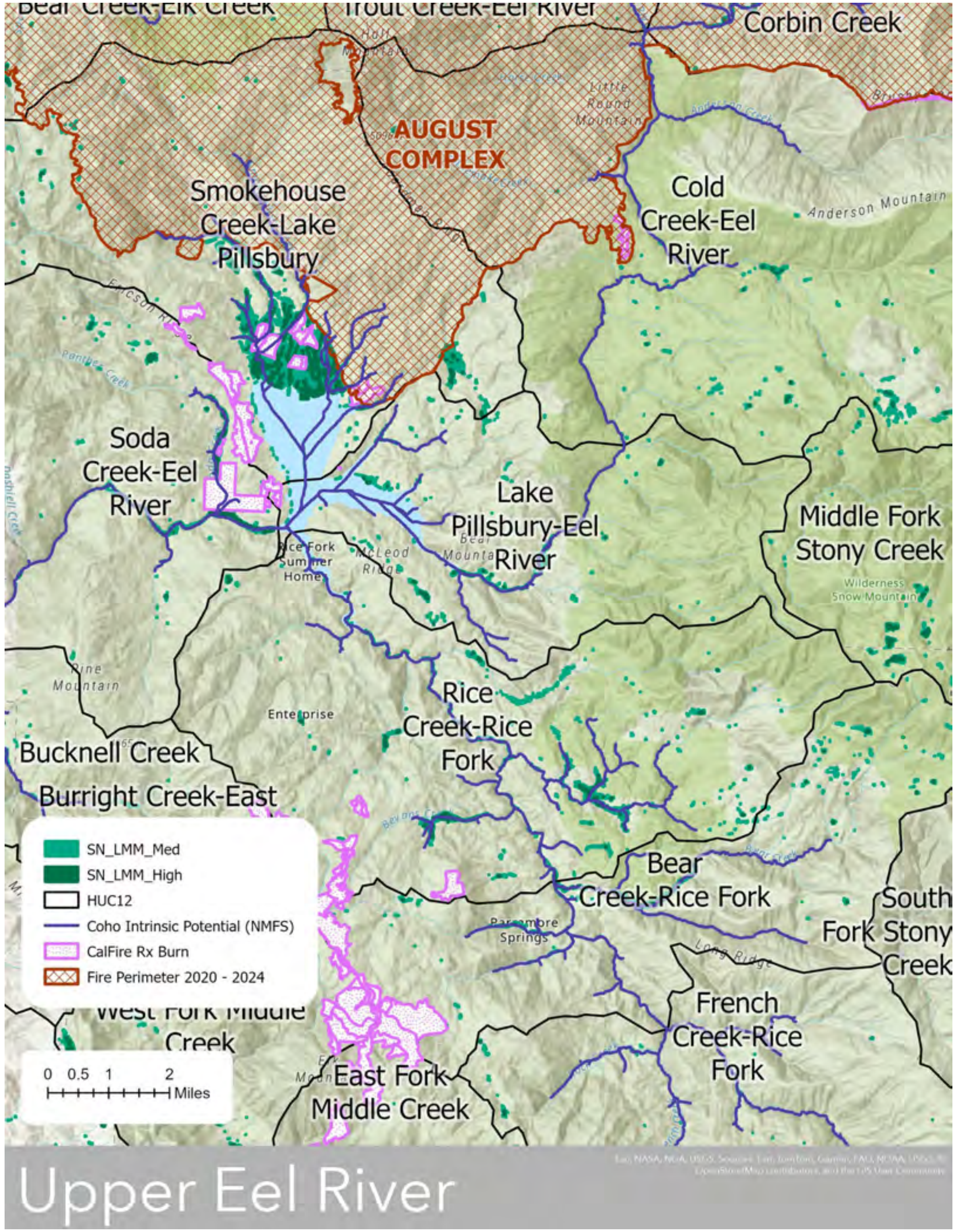

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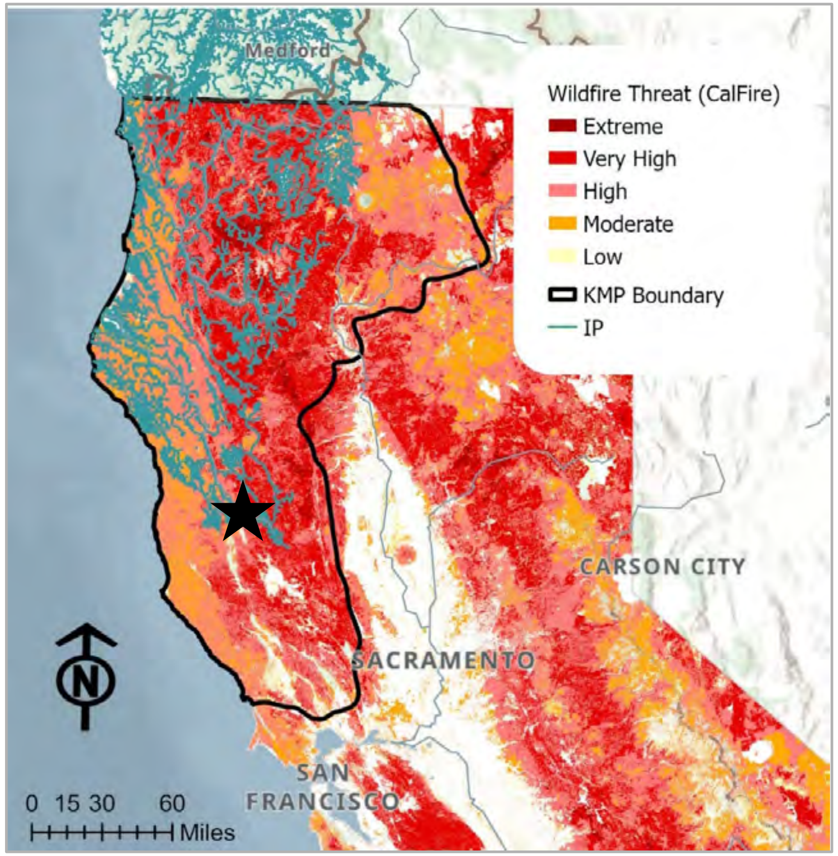

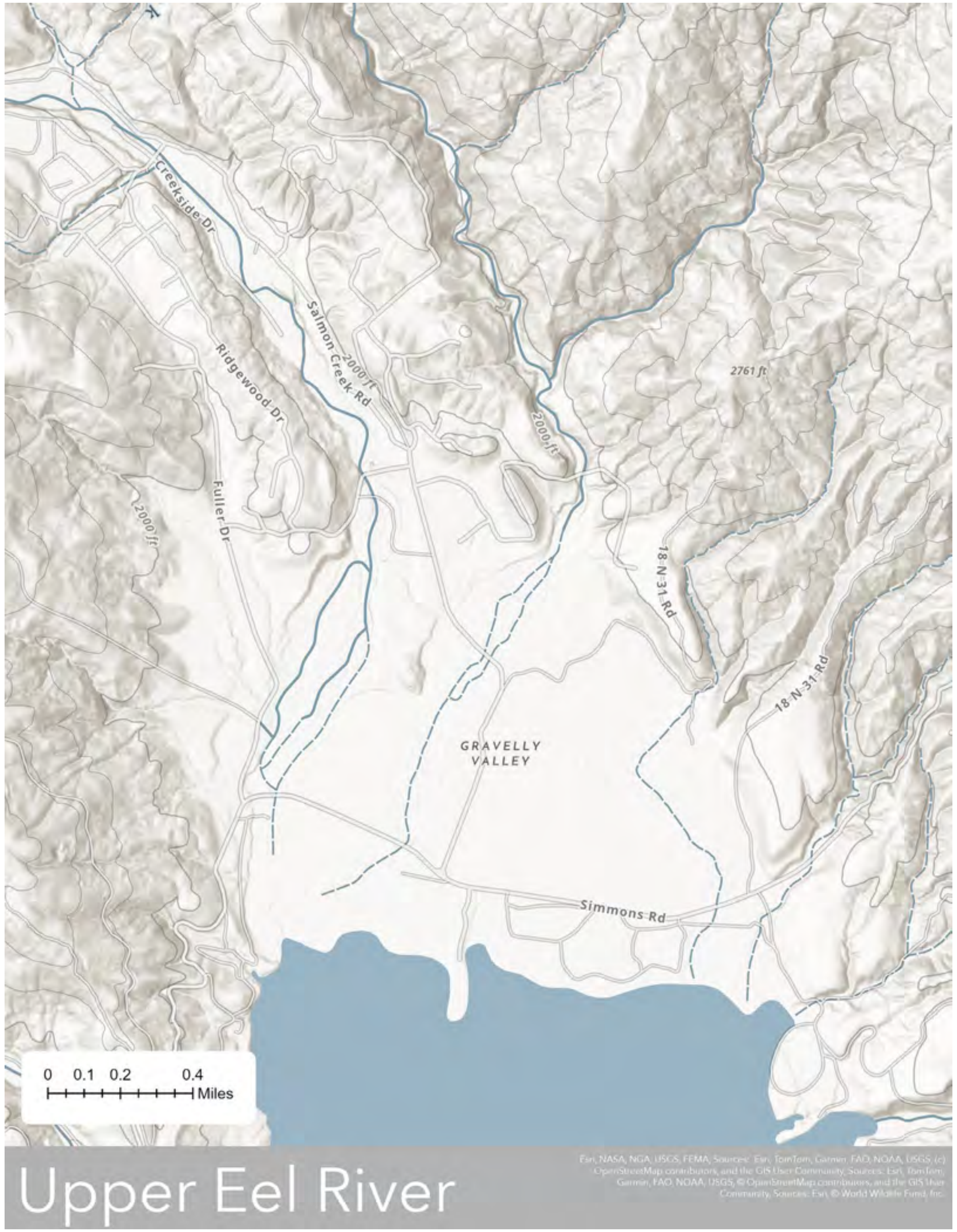

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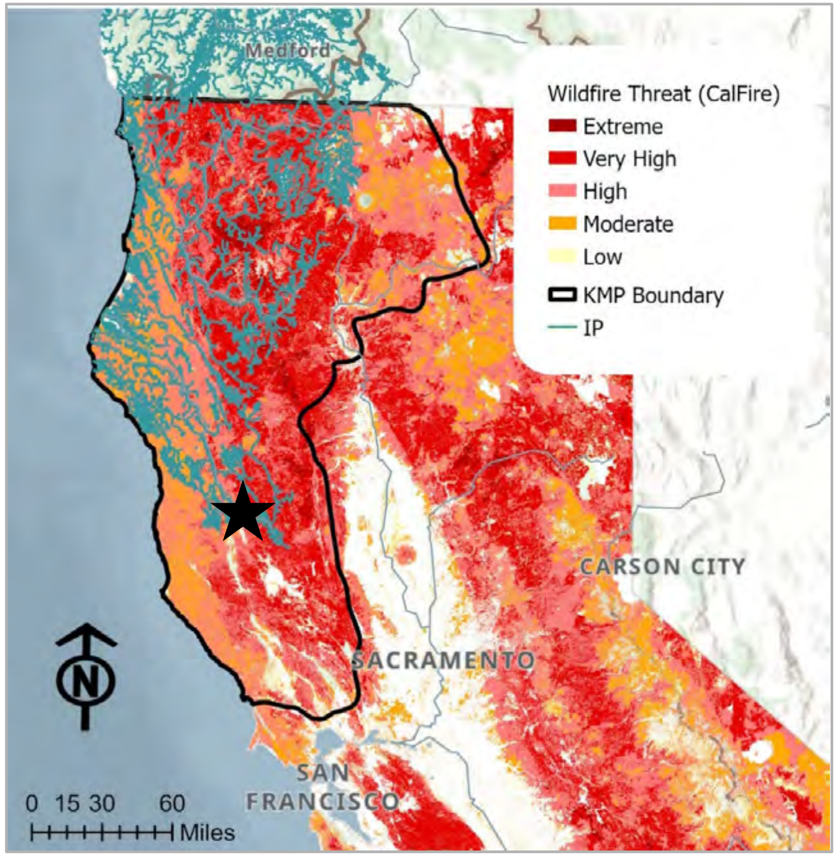

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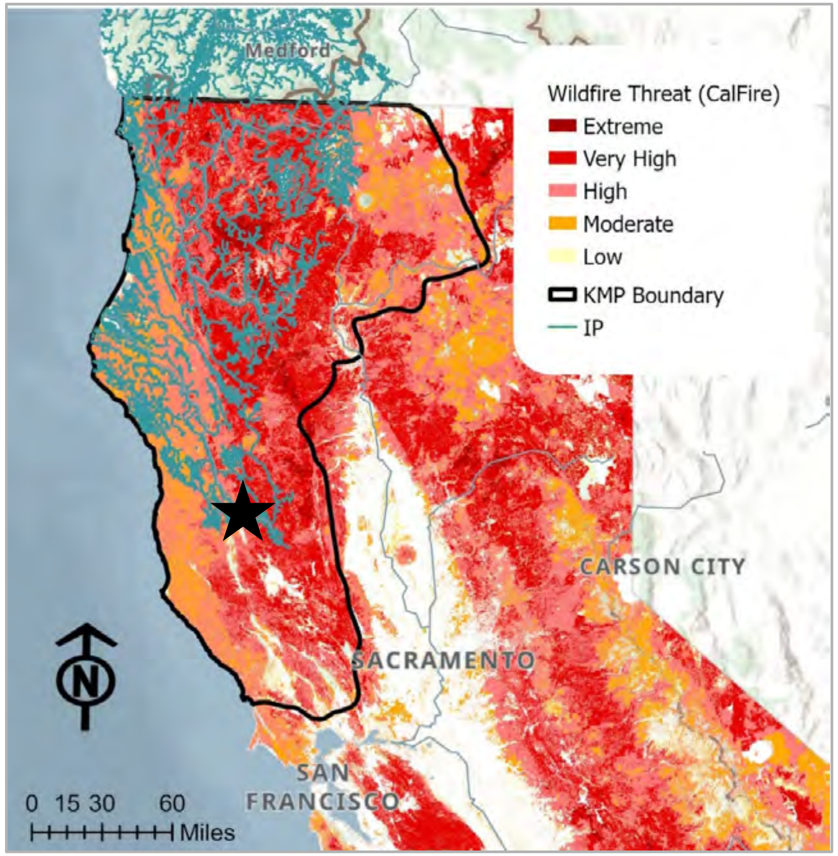

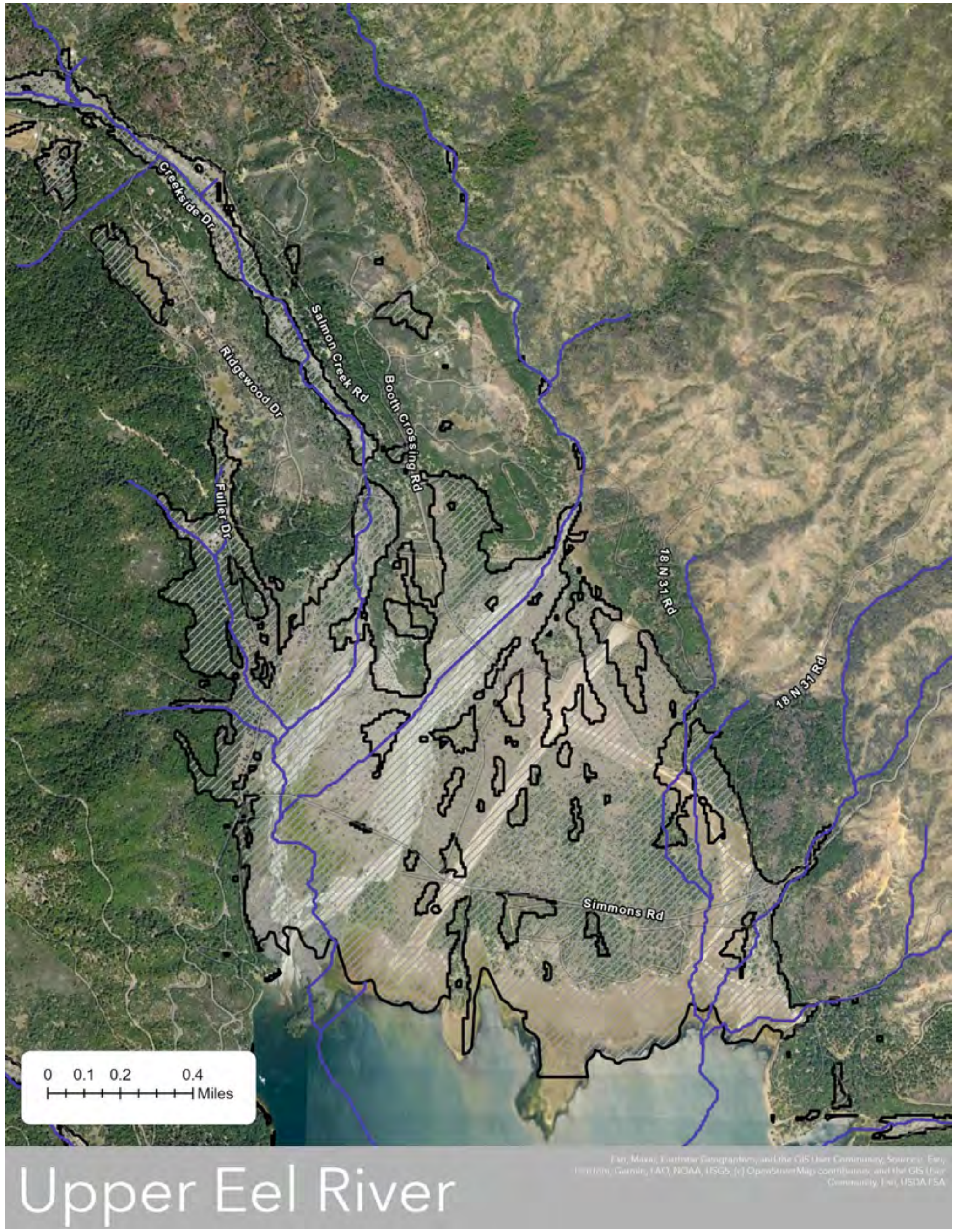

Scaling Up to Integrated Aquatic & Fire Restoration

- Programmatic Environmental Compliance Strategies
  - Sub-regional efforts: Six Rivers NF NEPA, TRRP NEPA, Scott River Watershed Council & Klamath NF NEPA, WRTC Trinity Watershed CEQA
  - KMP's work with Forest Service Region 5 NEPA efforts

Restoration & Stewardship

- Restoring the hydrologic and fire regimes in and around meadows is key to realizing their full potential.
- Collaboration is key.
  - Tribes have long managed meadows with fire and known the connection between meadows and fish
  - Beaver have been catching water for millions of years.
  - Local groups have been restoring meadows with various techniques.
- What role do meadows and integrated restoration play in sustaining streamflows for salmonids?

FISH AND FIRE WORKSHOP INSIGHTS

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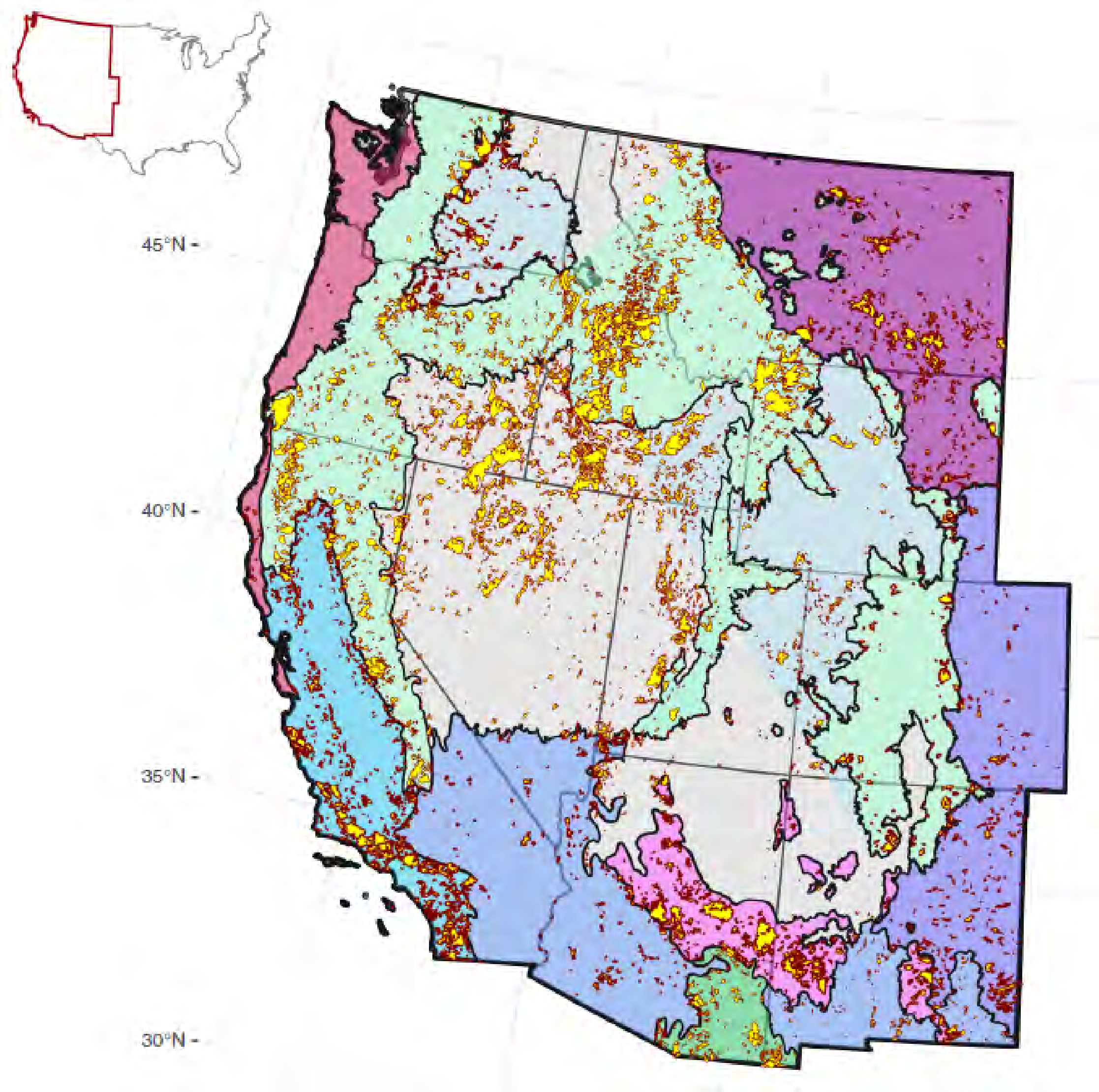
josh@thewatershedcenter.com

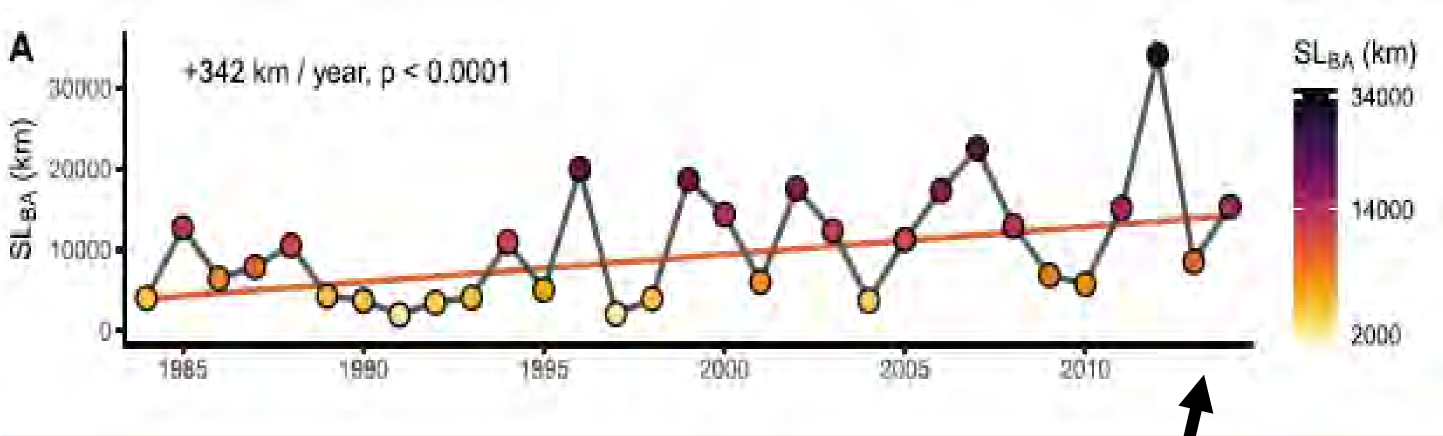
Josh Smith
Director – Watershed Stewardship Program
Watershed Research and Training Center

UC ANR FIRE NETWORK

THE WATERSHED CENTER
HAYFORK, CALIFORNIA

WILDFIRES ARE INCREASINGLY AFFECTING AQUATIC SYSTEMS





Total stream length affected by fire

Ball et al. 2021

WATER

Park Fire jeopardizing one of California's most iconic species: 'This species could blink out'

BY RACHEL BECKER
JULY 31, 2024

THE KLAMATH DAMS FELL, NOW LET'S GET TO WORK RESTORING FIRE FOR THE FISH!

FIRE ECOLOGY - CARL SKINNER

- Basic fire ecology (fire scars → fire return interval). 5-15 yr FRI
- We can expect more fire. We are going to see fire burning, the choice is what kind of fire do you want to get.
- Carl’s intro to fish: Deer Creek and Mill Creek were most frequently burned watersheds in Sierra Nevada Ecosystem study area, but also had the most intact fish and amphibian faunas, still governed by natural processes” (Moyle)

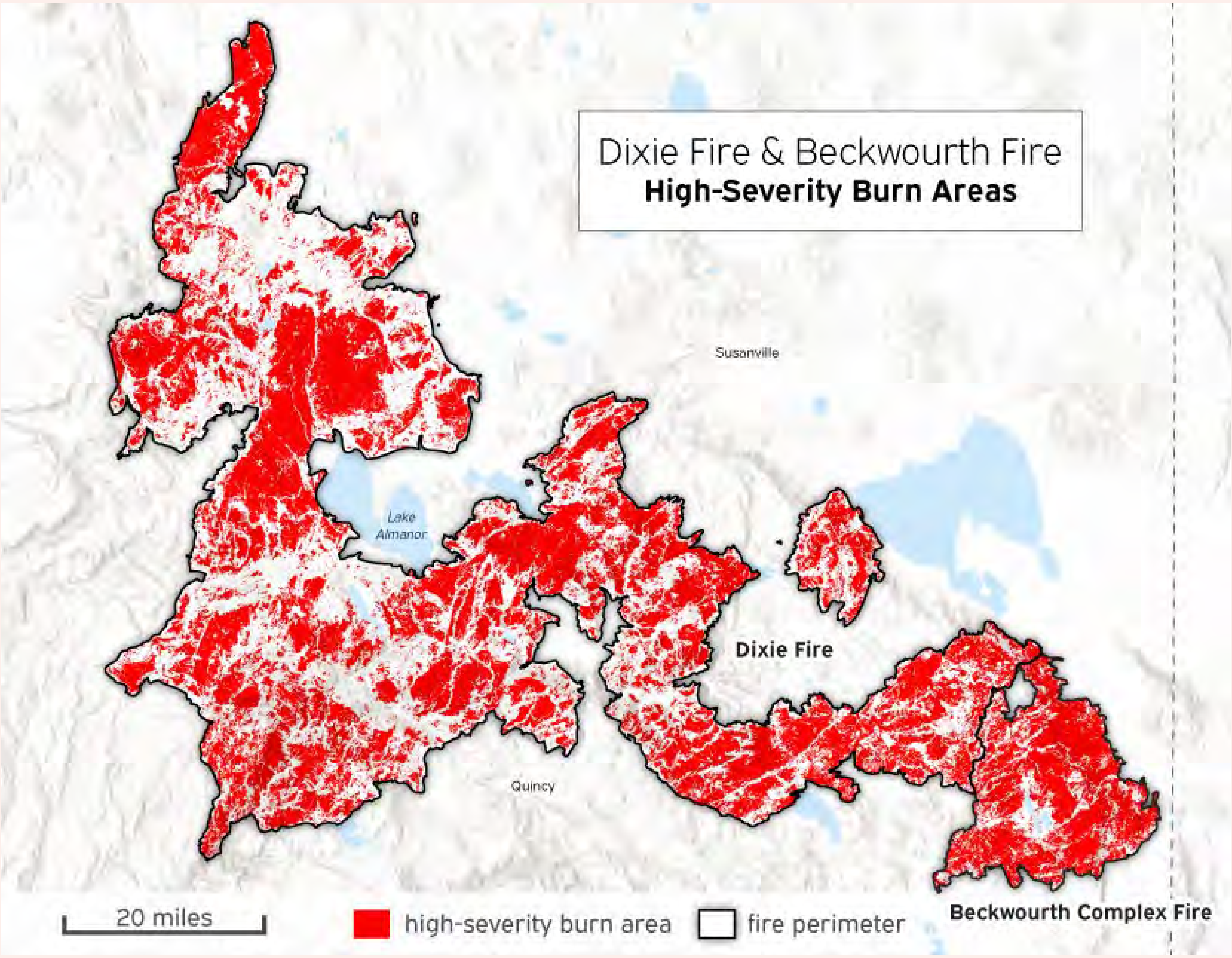
"Fires … have been ground fires, and easily controlled. A trail will sometimes stop them."

R.B. Wilson

1904

Township descriptions of the lands examined for the proposed Trinity Forest Reserve, California.

US Department of Agriculture, Bureau of Forestry, Washington, D.C.



Dixie Fire & Beckwourth Fire
High-Severity Burn Areas
Susanville
Lake Almanor
Dixie Fire
Quincy
Beckwourth Complex Fire
20 miles
high-severity burn area
fire perimeter

nature communications

Article https://doi.org/10.1038/s41467-024-46702-0

Fire suppression makes wildfires more severe and accentuates impacts of climate change and fuel accumulation

Received: 14 June 2023

Accepted: 7 March 2024

Published online: 25 March 2024

Check for updates

Mark R. Kreider[1], Philip E. Higuera[2], Sean A. Parks[3], William L. Rice[4], Nadia White[5] & Andrew J. Larson[1,6]

Fire suppression is the primary management response to wildfires in many areas globally. By removing less-extreme wildfires, this approach ensures that remaining wildfires burn under more extreme conditions. Here, we term this the "suppression bias" and use a simulation model to highlight how this bias fundamentally impacts wildfire activity, independent of fuel accumulation and climate change. We illustrate how attempting to suppress all wildfires neces-

CALIFORNIA LANDSCAPES NEED FIRE


(Photo Don Hankins)

PATHWAYS LINKING FIRES AND FISH (DAVID ROON)

Whole-ecosystem approaches needed to synthesize pathways and identify driving mechanisms

The interactions are very complicated!

It comes with both “good and bad”.

Fire = heterogeneity.

good processes outweigh bad?

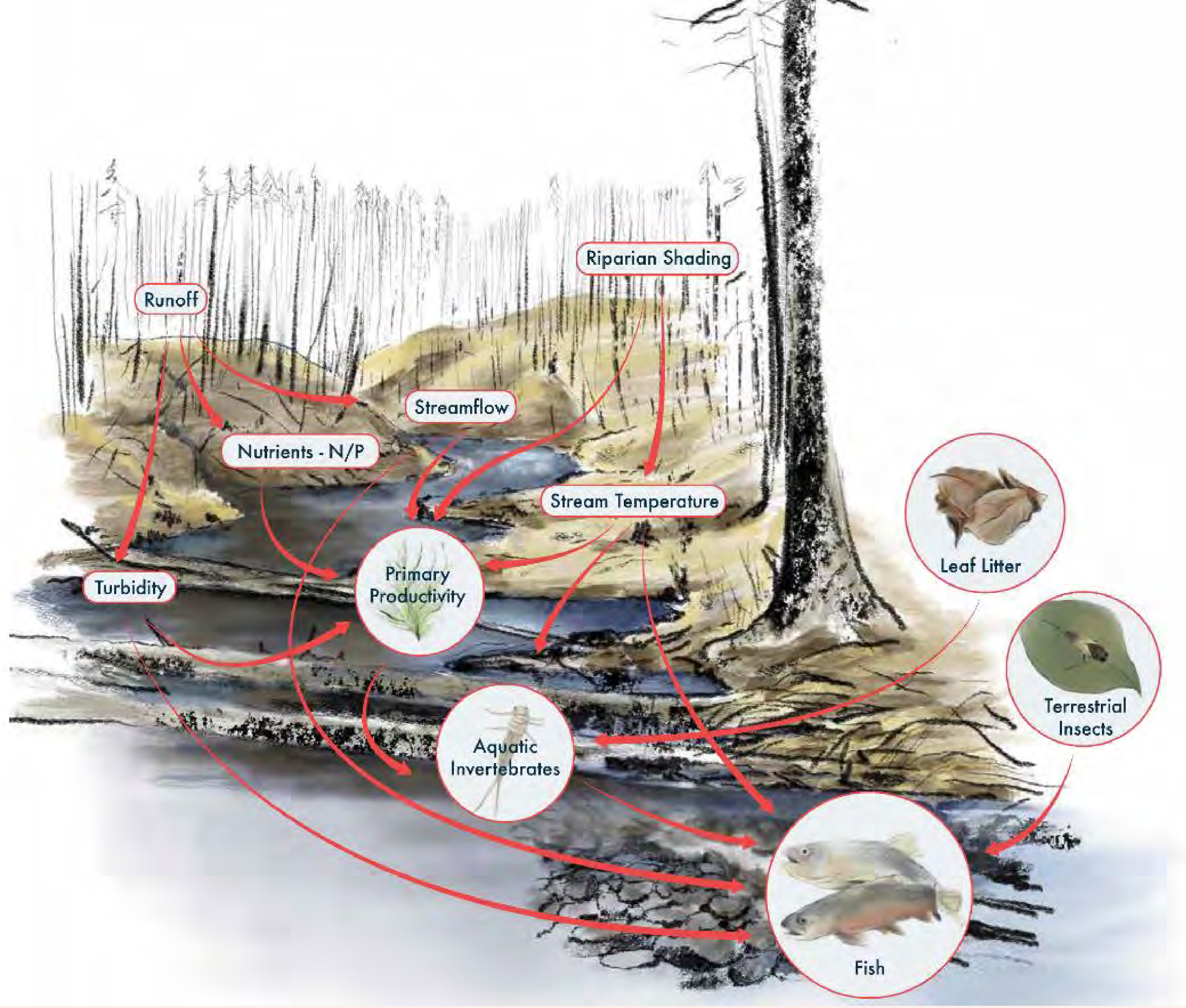


Illustration by Cecil Howell

MCKINNEY FIRE
TOZ SOTO

"Bad fire" example:

Hottest day of the year, fast moving (30,000 acres in 8 hours). Decomposed granite. 5-10 inches of rain in just a few hours.

Dozens of debris flows → 1,000 ntu turbidity.
DO was at 0 for 2 hours - killed everything (not just a single species like disease does)

Even in this terrible event:
- sediment and wood → good geomorphic changes
- Intermittent streams → flowing year round

The New York Times

California Fire and Floods Turn a River to 'Sludge,' Killing Thousands of Fish

Dead fish found on a stretch of the Klamath River in Northern California on Saturday.
Karuk Tribe Department of Natural Resources, via Associated Press

FISH AND FIRE – GORDIE REEVES

Wildfire is a natural process

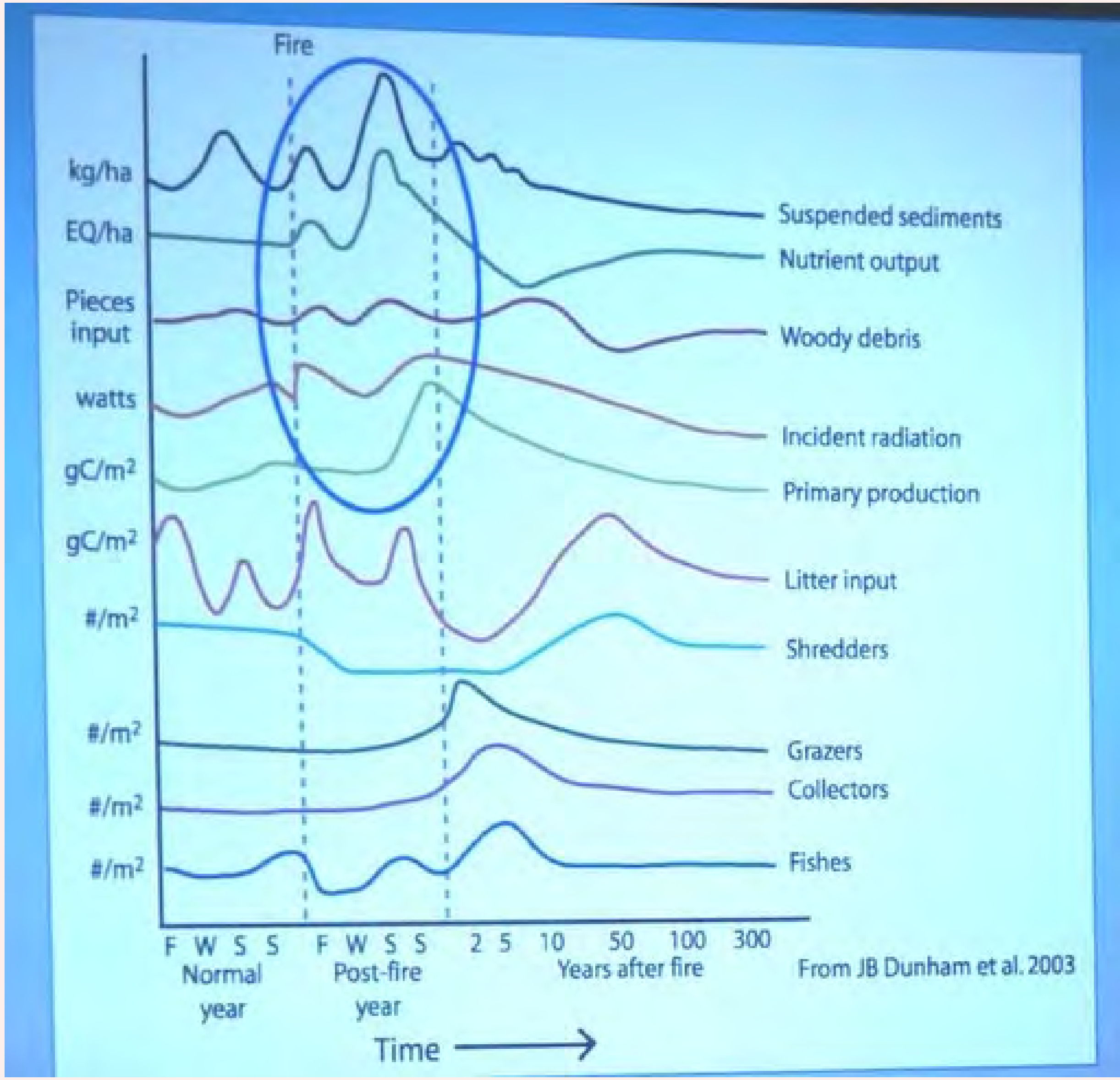
not the boogieman we often think it is.

Ecosystems are not static, particularly aquatic.

Fish populations have persisted for millennia in fire prone landscapes.

"Looking at the entirety of the salmonid life history stages, the overall post fire responses are positive for fish."

Primary production is up, woody debris is up, fish production (growth) is up, overall fish abundance numbers often go up   native fish typically outcompete invasive post fire.



WILDFIRE BENEFITS

- Stream flow ↑
- Stream temperature ↓
- BMI changes ↑
- Wood ↑
- Spawning gravels ↑
- *Oak woodlands/ grasslands*
- *Recent fire = best protection*

STREAMFLOW AND FIRE (EVAPOTRANSPIRATION)

Fire exclusion = dense forests

-10x more forest biomass than 100 years ago

Burning creates more open spaces: less biomass → less evapotranspiration

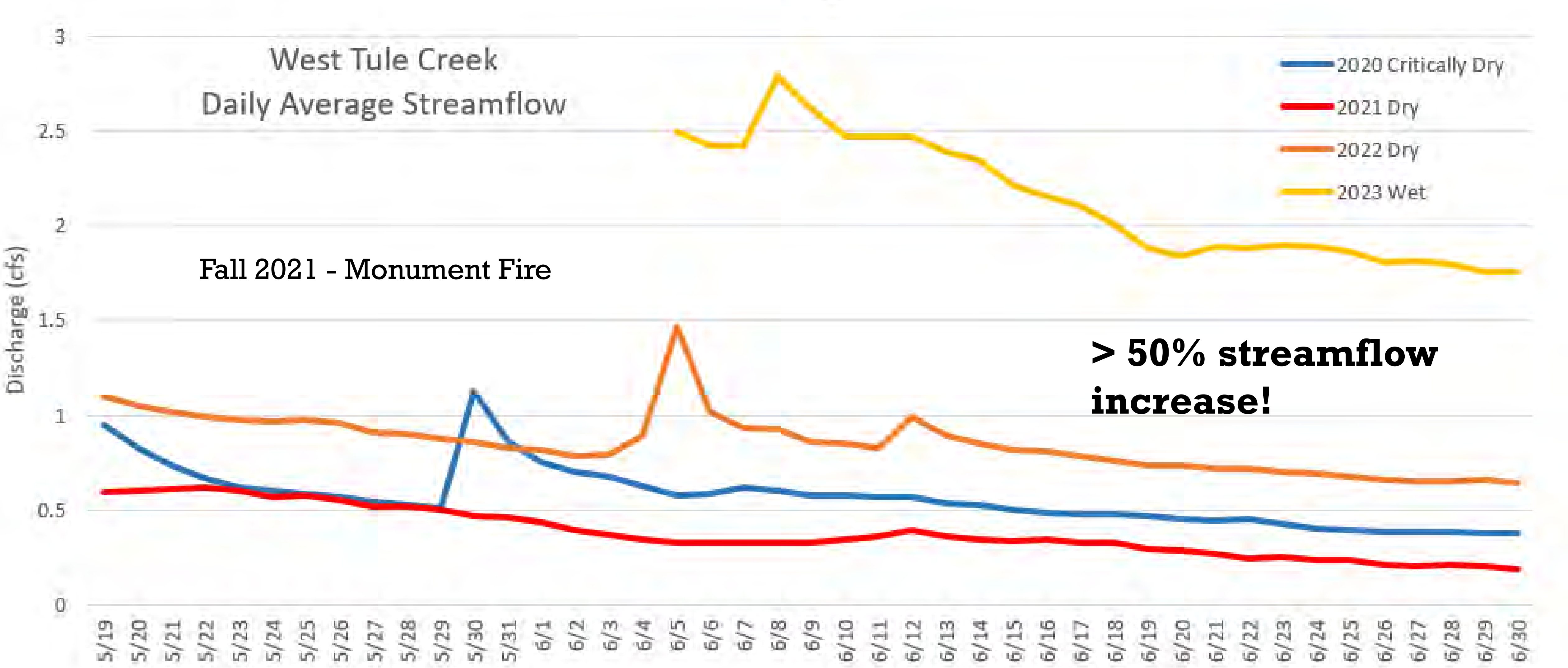
(less pulling of water from the ground and evaporating to atmosphere)

2020 August Complex - Forest Glen (SFTR) ~ 10 + cfs flow improvement

Toz Soto - Indian Creek post slater fire increase 42% overnight)

Leaf Hillman's examples

TULE CREEK STREAMFLOW



SMOKE AND STREAMFLOW

Inversion/Smoke during 2015 Fire Complexes

USGS gage ~ 30% increase in streamflow

Also – Obvious corresponding decreases in stream temperature

SMOKE AND STREAM TEMPERATURES

- Eli Asarian

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

RESEARCH ARTICLE

10.1029/2018WR022964

Key Points:

- Wildfire smoke cools river and stream water temperatures by reducing solar radiation and cooling air temperatures
- For both air and water, smoke has a greater cooling effect on daily maximum temperatures than daily mean temperatures
- This smoke-induced cooling has the potential to benefit cold-water adapted species in fire-prone watersheds

Wildfire Smoke Cools Summer River and Stream Water Temperatures

Aaron T. David[1], J. Eli Asarian[2], and Frank K. Lake[3]

[1]U.S. Fish and Wildlife Service, Arcata, CA, USA, [2]Riverbend Sciences, Eureka, CA, USA, [3]U.S. Forest Service, Pacific Southwest Research Station, Orleans Ranger Station, Orleans, CA, USA

Abstract To test the hypothesis that wildfire smoke can cool summer river and stream water temperatures by attenuating solar radiation and air temperature, we analyzed data on summer wildfire smoke, solar radiation, air temperatures, precipitation, river discharge, and water temperatures in the lower Klamath River Basin in Northern California. Previous studies have focused on the effect of combustion heat on water temperatures during fires and the effect of riparian vegetation losses on postfire water temperatures, but we know of no studies of the effects of wildfire smoke on river or stream water

2015 Steinacher Fire in Wooley Creek

2013 Salmon River at Mouth of Crapo Creek

FIRE AND SNOWPACK

Fire reduces vegetation which reduces interception and melting

DON HANKINS: RIPARIAN BURNING (NOT JUST PROTECTION)

(Photo Don Hankins)


(Photo Don Hankins)

LESS FOREST CANOPY ~

Benthic macro-invertebrate changes

~ Greater salmonid production

~ Greater plant diversity


(Photo Will Harling)

CATASTROPHIC FIRE?

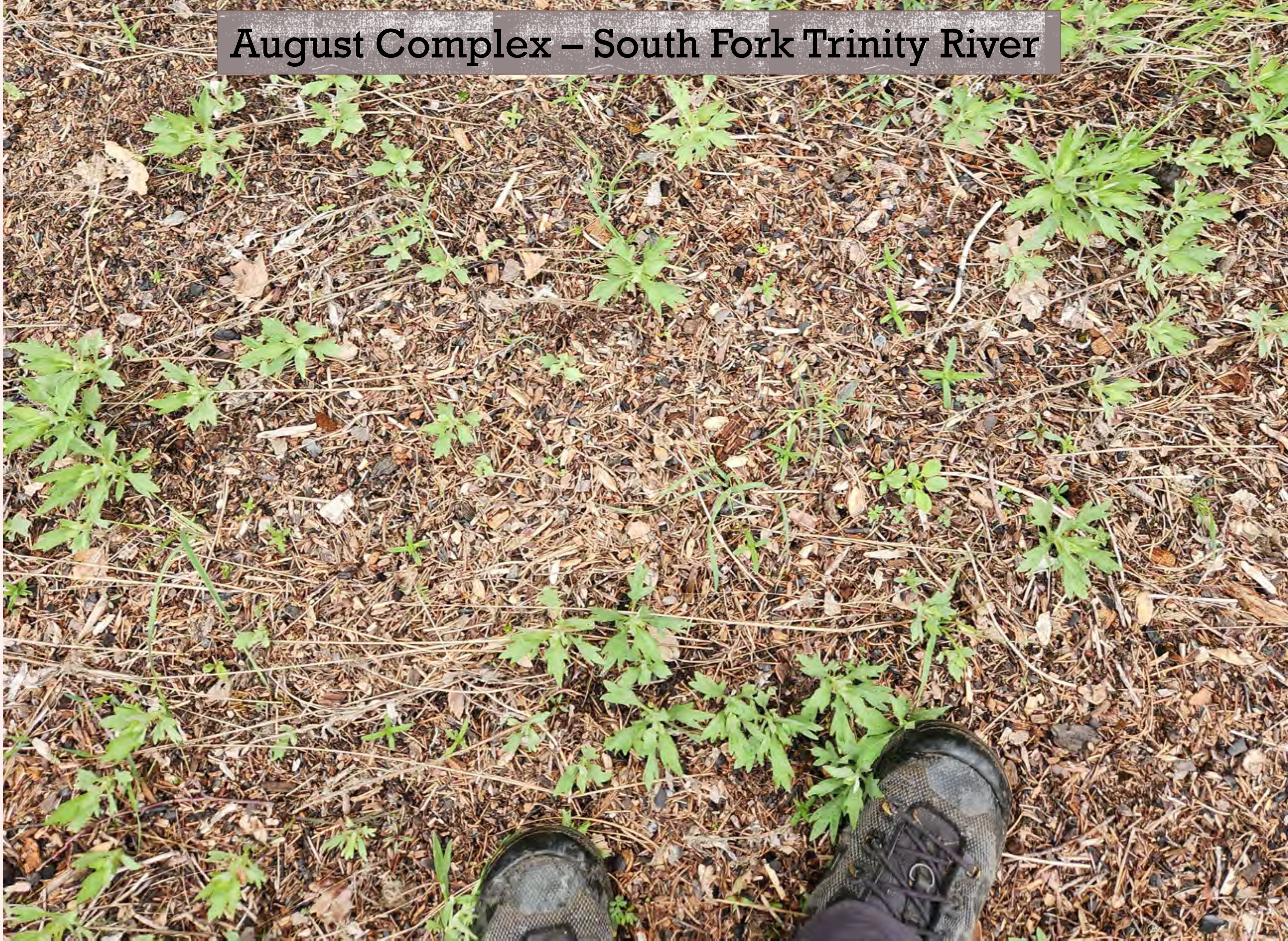
OR…

Large Wood Inputs

Spawning Gravel Inputs

August Complex wildfires and associated mass wasting:

TOPSOIL SEDIMENT AND BIOCHAR INPUTS = RIPARIAN GROWTH



INSTREAM RESTORATION FOR POST-WILDFIRE SEDIMENT CAPTURE

Karen Pope, Adam Cummings, Kate Wilcox, Jordin Jacobs, Joe Wagenbrenner, David Dralle

USDA Forest Service, Pacific Southwest Research Station

Wildfire Suppression Impacts

Roadside berms

Dozer-line accidents

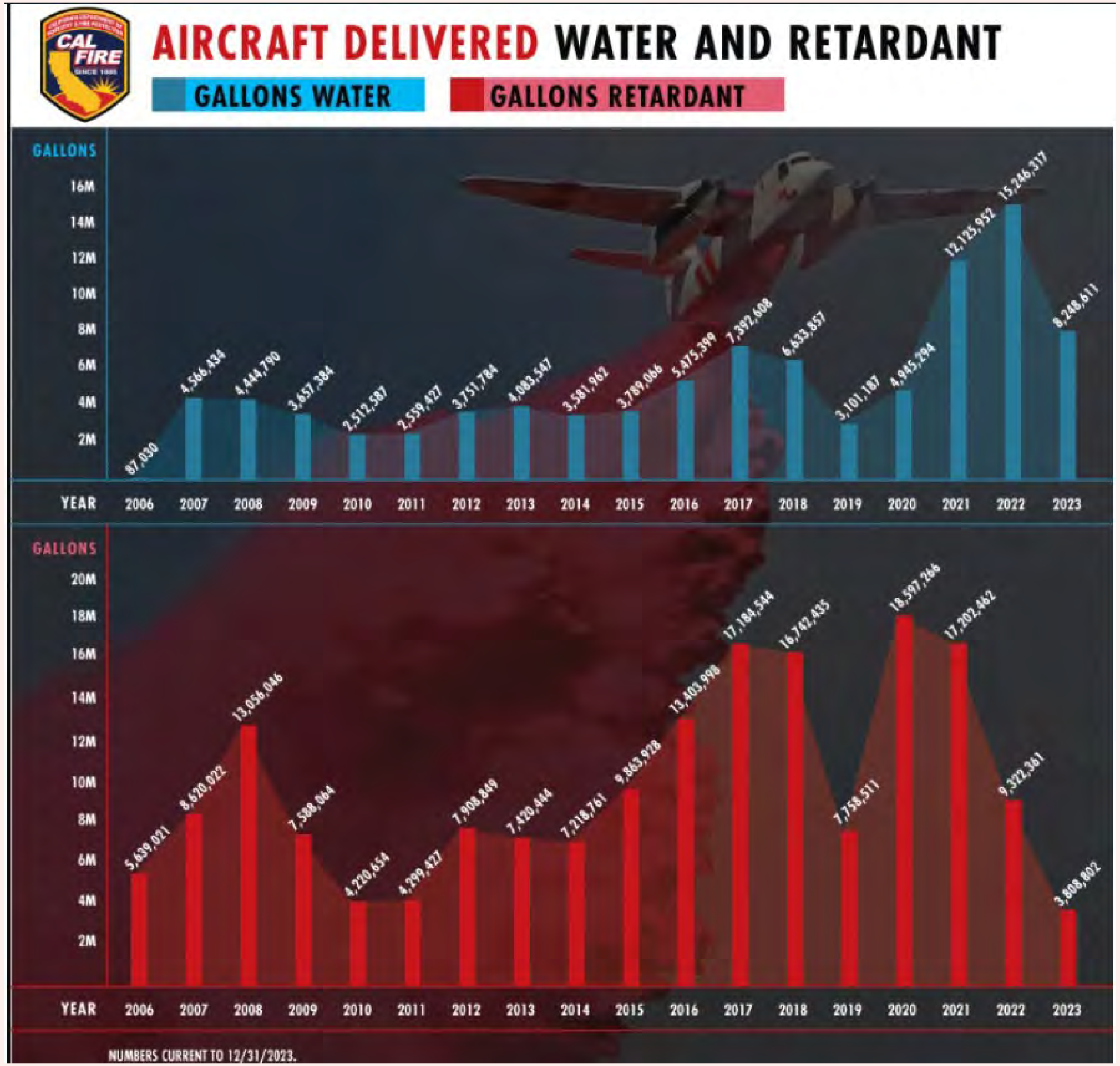
Too busy to repair after fires

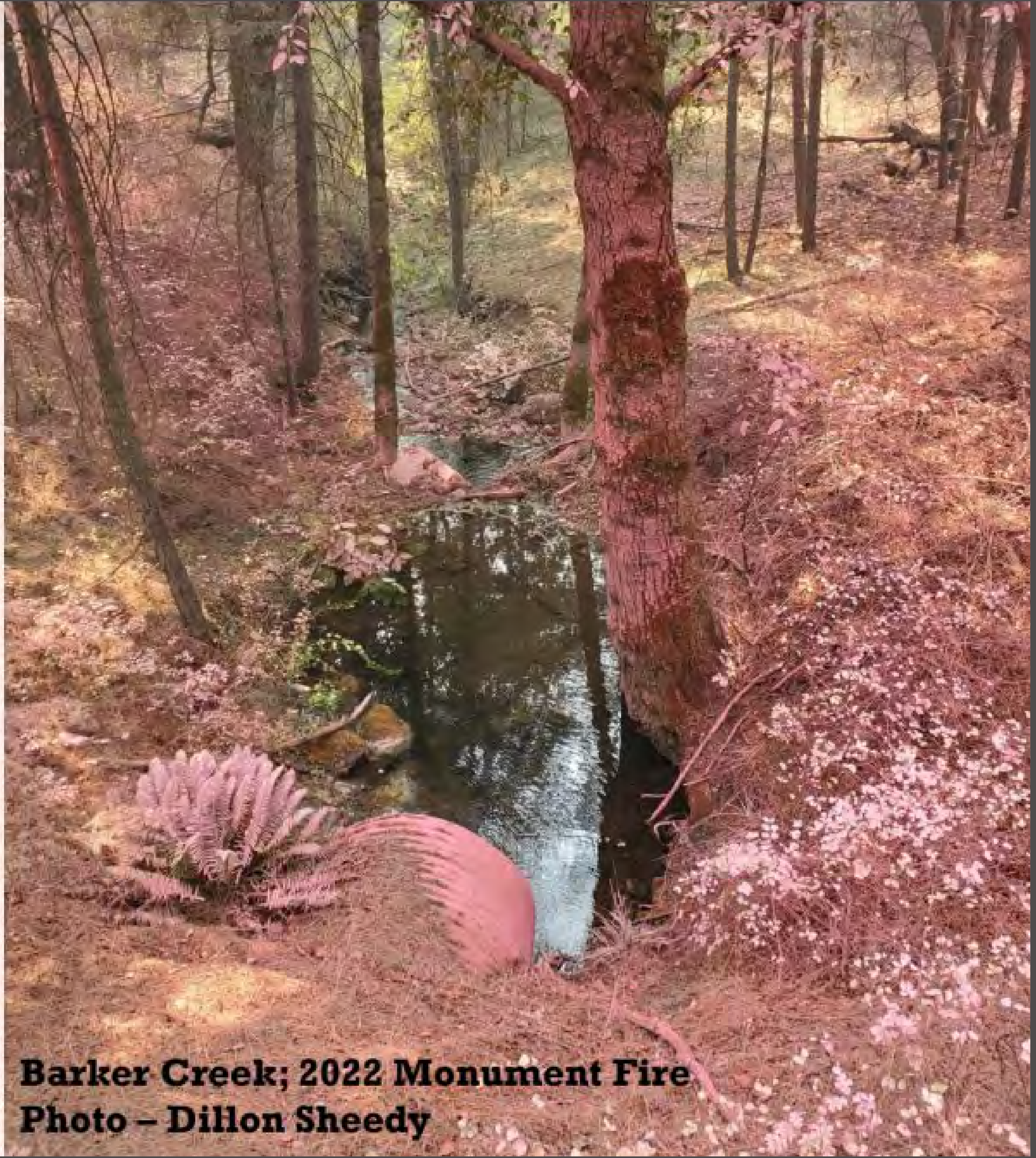
Wildfire Suppression Impacts

Wildfire Suppression Impacts

Dewatering
Dams
Fuel

Fire Retardant Use

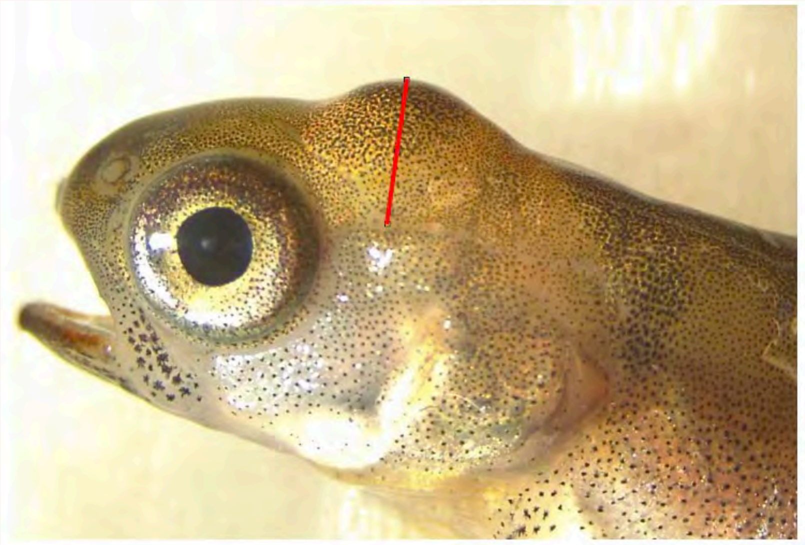




Barker Creek; 2022 Monument Fire
Photo – Dillon Sheedy

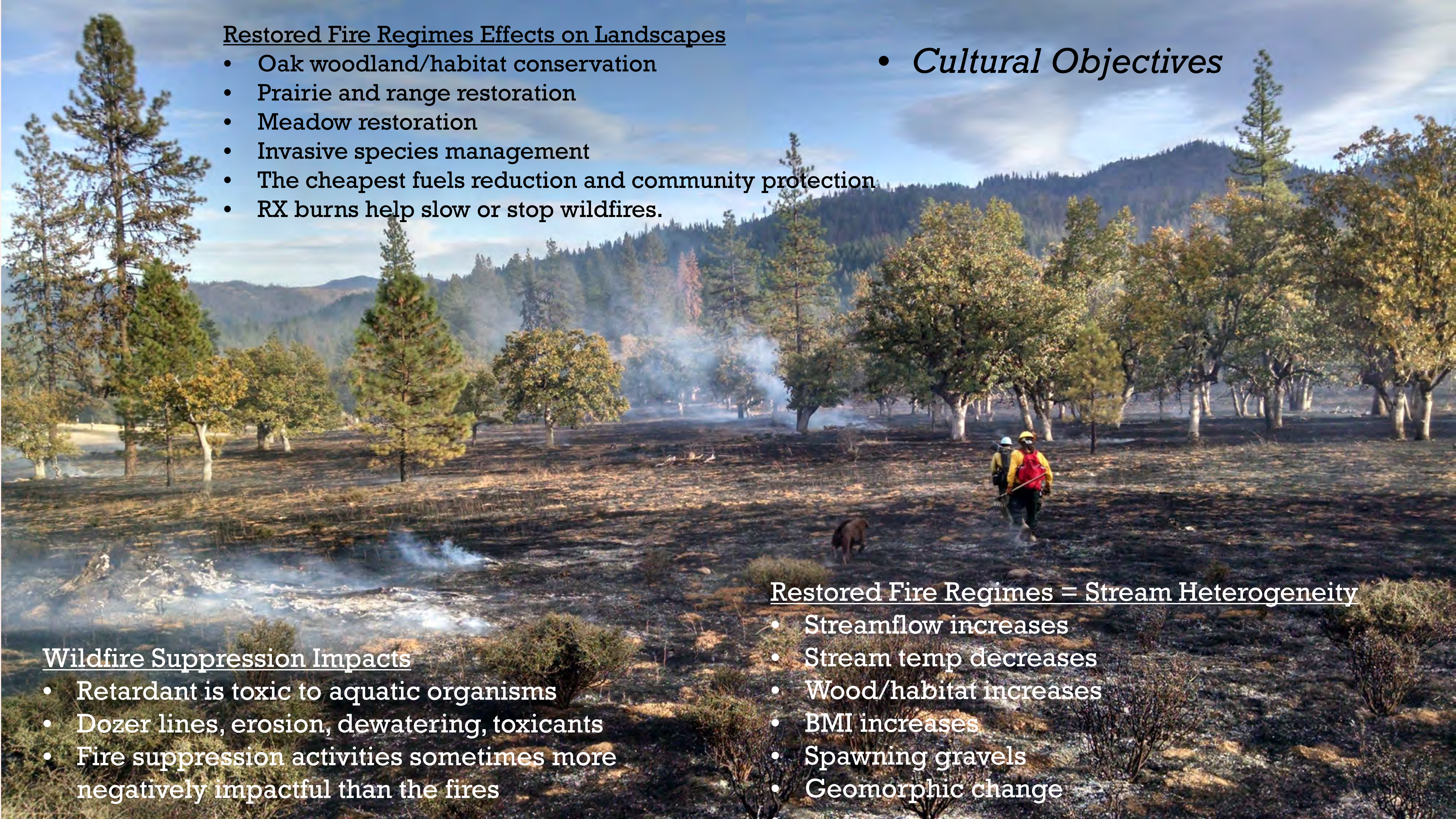
Toxicity of fire retardant on juvenile salmonids

Louise Cominassi
UC Davis



Cranial expansion in Rainbow trout increased with higher concentrations

- Active ingredient = **ammonia phosphate.** Changes in water pH. Recent research highlight **presence of metals.**
- Toxicity is **species specific, Rainbow trout embryos are more sensitive** to fire retardant than Chinook Salmon
- Toxicity: **weathered** Phos-Chek is more **toxic** than **non-weathered**
- **Surprising mortalities** after 96h **"sublethal exposure"** in concentrations that were 10x lower than concentration used for LC50. The 96 h-LC50 might underestimate mortality.
- Sublethal effect: Behavioral effect were observed at concentration 200x lower than their LC50. **Anxiety-like behavior and alteration in locomotion.**


Restored Fire Regimes Effects on Landscapes
• Oak woodland/habitat conservation
• Prairie and range restoration
• Meadow restoration
• Invasive species management
• The cheapest fuels reduction and community protection
• RX burns help slow or stop wildfires.
• Cultural Objectives
Restored Fire Regimes = Stream Heterogeneity
• Streamflow increases
• Stream temp decreases
• Wood/habitat increases
• BMI increases
• Spawning gravels
• Geomorphic change
Wildfire Suppression Impacts
• Retardant is toxic to aquatic organisms
• Dozer lines, erosion, dewatering, toxicants
• Fire suppression activities sometimes more negatively impactful than the fires

Bringing fire back to the landscapes and to the people!

Photo by Will Harling

Cultural Fire Management Council

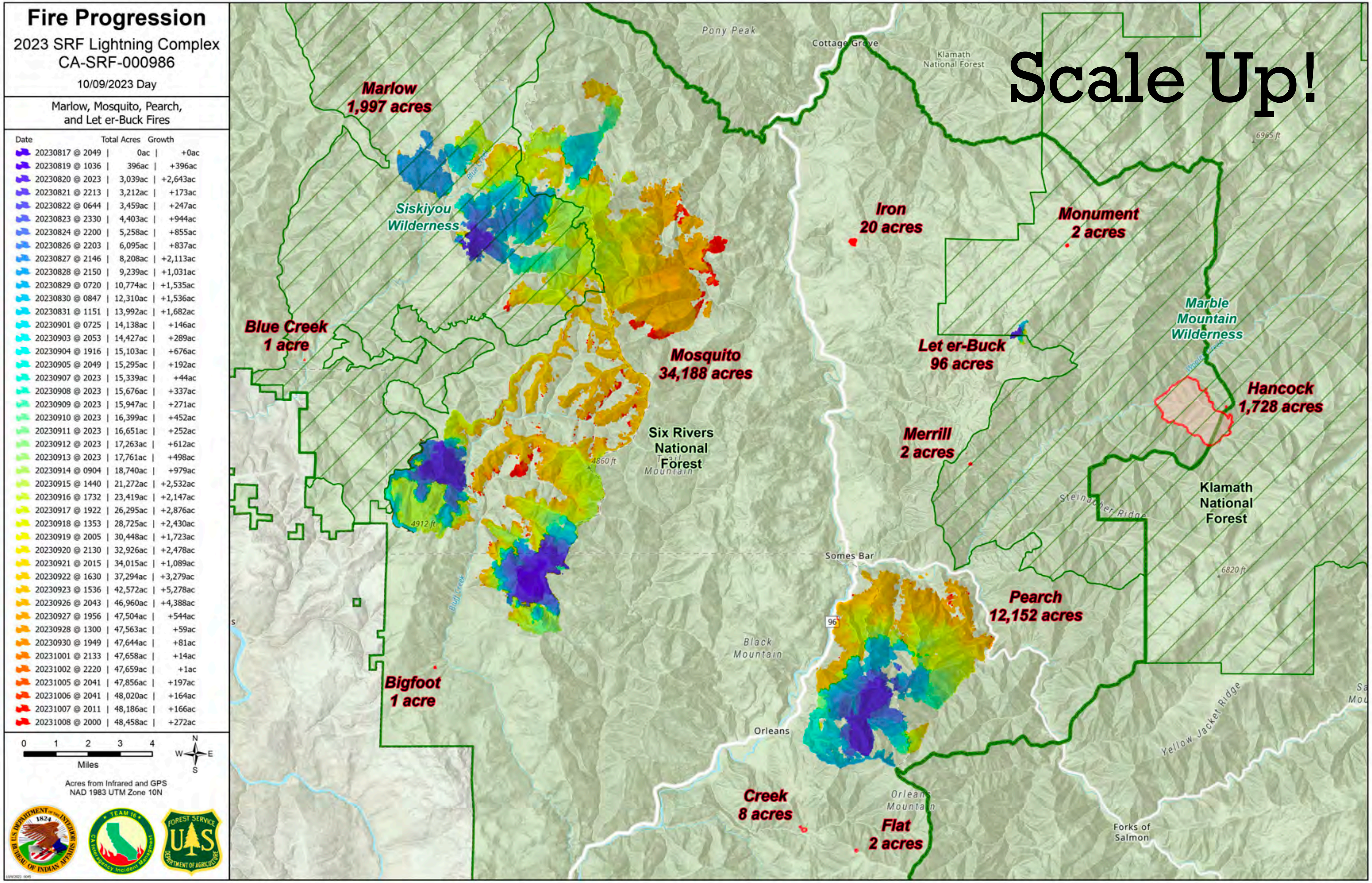
Photo by Zeke Lunder

Photo by Miller Bailey

PBAs/community-based prescribed fire in California

www.calpba.org

Scale Up!


Fire Progression
2023 SRF Lightning Complex
CA-SRF-000986
10/09/2023 Day
Marlow, Mosquito, Pearch, and Let er-Buck Fires
Date | Total Acres | Growth
20230817 @ 2049 | 0ac | +0ac
20230819 @ 1036 | 396ac | +396ac
20230820 @ 2023 | 3,039ac | +2,643ac
20230821 @ 2213 | 3,212ac | +173ac
20230822 @ 0644 | 3,459ac | +247ac
20230823 @ 2330 | 4,403ac | +944ac
20230824 @ 2200 | 5,258ac | +855ac
20230826 @ 2203 | 6,095ac | +837ac
20230827 @ 2146 | 8,208ac | +2,113ac
20230828 @ 2150 | 9,239ac | +1,031ac
20230829 @ 0720 | 10,774ac | +1,535ac
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20231008 @ 2000 | 48,458ac | +272ac
0 1 2 3 4
Miles
N W E S
Acres from Infrared and GPS
NAD 1983 UTM Zone 10N
Marlow 1,997 acres
Siskiyou Wilderness
Blue Creek 1 acre
Mosquito 34,188 acres
Six Rivers National Forest
Bigfoot 1 acre
Pony Peak
Cottage Grove
Klamath National Forest
Iron 20 acres
Monument 2 acres
Let er-Buck 96 acres
Marble Mountain Wilderness
Hancock 1,728 acres
Merrill 2 acres
Steinacher Ridge
Klamath National Forest
Somes Bar
Pearch 12,152 acres
Black Mountain
Orleans
Creek 8 acres
Flat 2 acres
Orleans Mountain
Forks of Salmon
Yellow Jacket Ridge
96
4860 ft
4912 ft
6965 ft
6820 ft

THANKS FOR YOUR TIME

Josh Smith & Lenya Quinn-Davidson
Watershed Research and Training Center & Univ. of CA Ag and Natural Resources


How do we get there?

Building a Meadow Restoration Program

Scott River
Watershed Council

Scott River Watershed Council began with a Focus on Coho


Charnna Gilmore

Betsy Stapleton

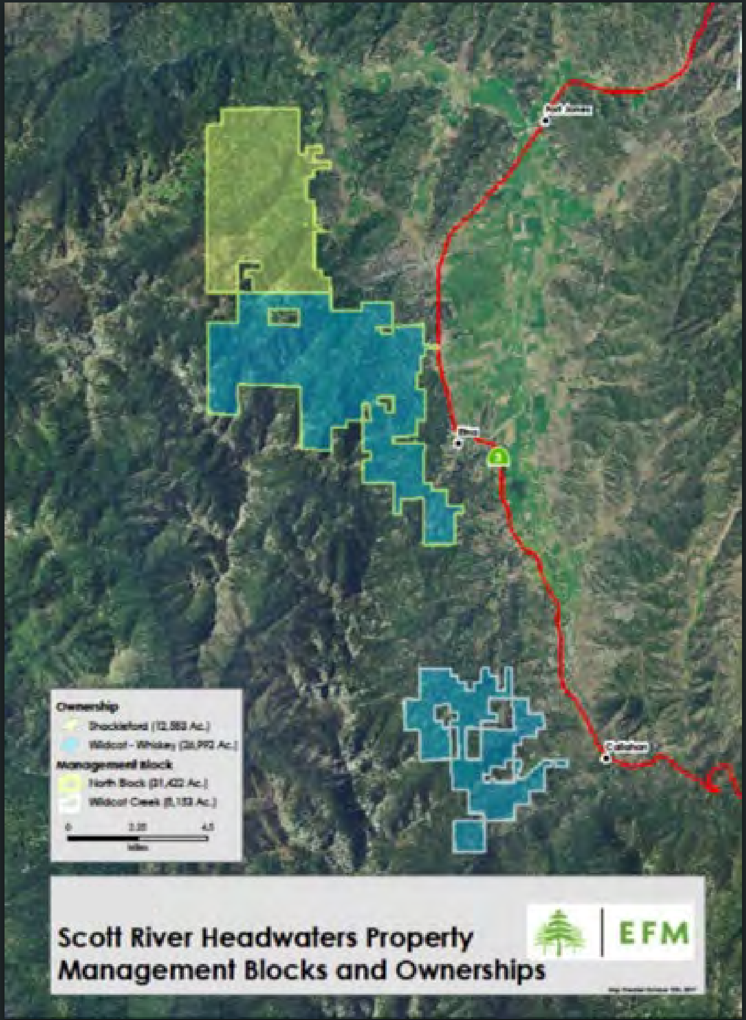

First Foray into Mountain Meadows

Meeks beaver dam in 2004

Meeks beaver dam in 2016


Meeks Meadow and Lake
2012
Meeks Meadow Creek
Google Earth


Meeks Meadow and Lake
2016
Meeks Meadow Creek
Google Earth


Ownership
Management Block
Scott River Headwaters Property
Management Blocks and Ownerships
EFM


Big Meadows 2020
Google Earth
Image © 2025 CNES / Airbus


07.02.2018 11:11



07.02.2018 11

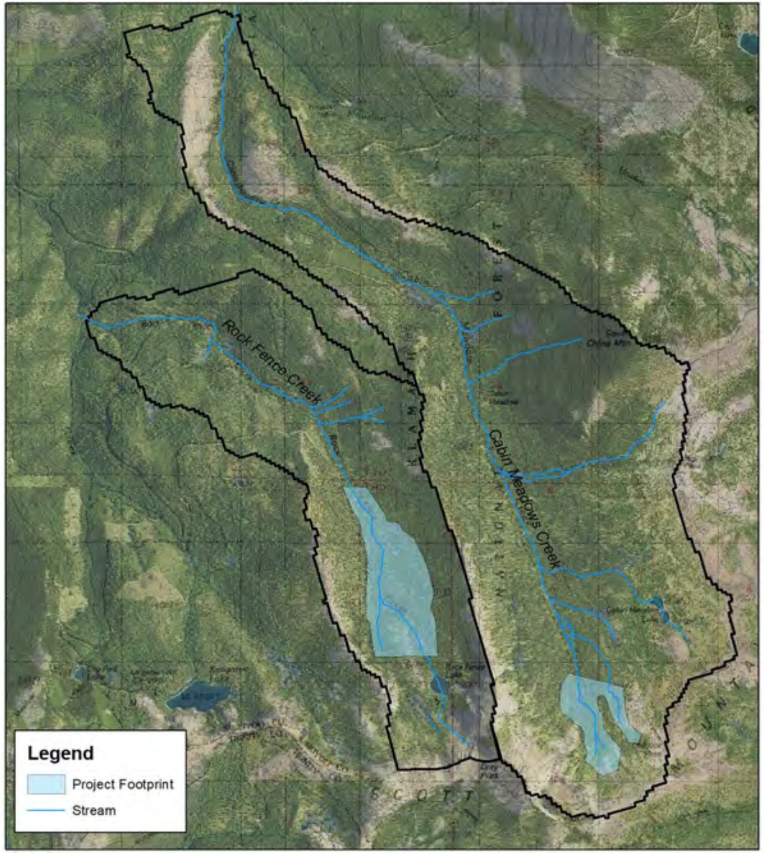

Date & Time: Wed, Sep 04, 2024 at 14:24:11 PDT
BMAT1 start: 249
Big Meadows Aspen Transects

2018 vs 2024


Big Meadows 2020
Google Earth
Image © 2025 CNES / Airbus


Big Meadows 2023
Google Earth
Track 1

CMRF Meadow Restoration Project Footprint

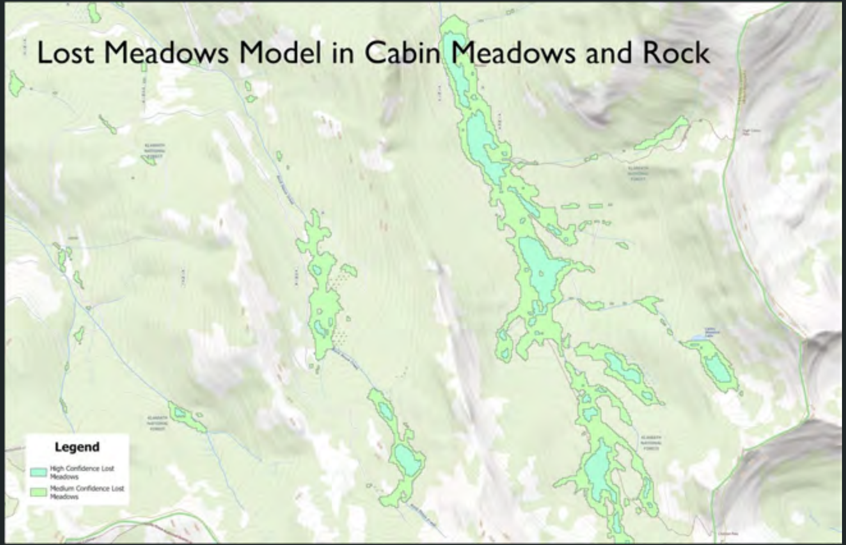


0 1,250 2,500 5,000 Feet

E. Yokel - 5/19/2023






Lost Meadows Model in Cabin Meadows and Rock
Legend
High Confidence Lost Meadows
Medium Confidence Lost Meadows


Klamath Meadows Partnership

Discharge slope fen in Cabin Meadows, Nov 2023

Klamath Meadows Partnership

Klamath Meadows Partnership - Kickoff call

Thursday, April 16th

12:30pm - 2:00pm

Agenda

1. Introductions (name, affiliation, brief background on work in meadows)
2. Vision for this partnership – what role should it play?
3. Current meadow mapping effort – example of an effort this partnership could benefit
4. Next steps - Who should be engaged moving forward? Frequency of calls?

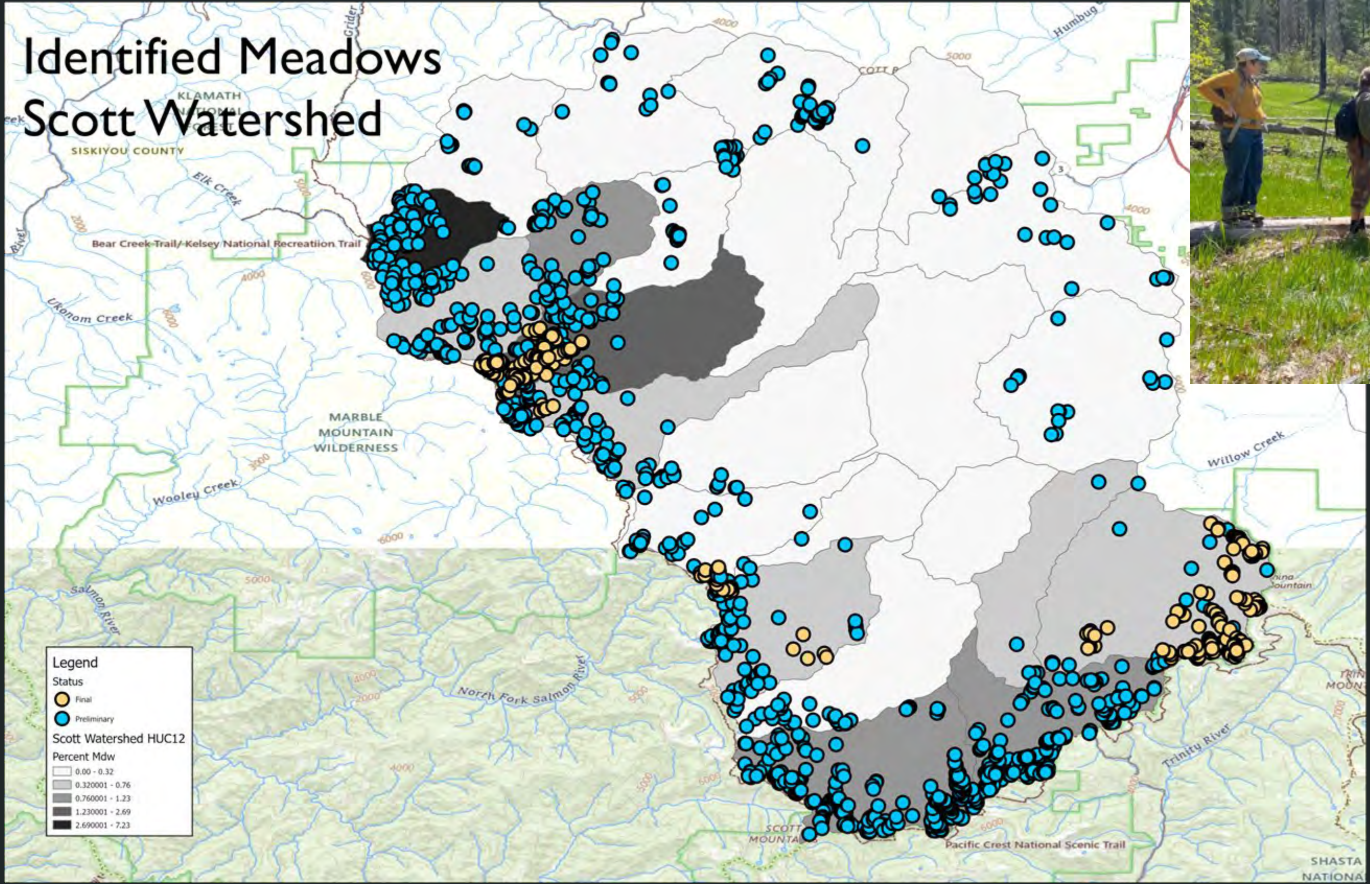
Attendees

Gabrielle Bohlman (USFS, Ecology Program)
Bobbie Miller (USFS, Klamath NF)
Betsy Stapleton (Scott River Watershed Council)
Charna Gilmore (Scott River Watershed Council)
Don Flickinger (NOAA)
Ryan Peek (UC Davis - Center for Watershed Sciences)
Karen Pope (PSW)
Adam Cummings (PSW)
Damion Ciotti (USFWS)
Dave Powers (EFM)
Kyle Pritchard (USFS - Klamath NF)

Vision for Partnership

- Collaboration between public and private land managers and researchers focused on meadows
- Develop a clear and articulate vision statement that highlights the importance of restoration, protection, and conservation of meadows in the Klamath Mountains
- Coordinate efforts to inventory meadows and prioritize restoration needs

Identified Meadows
Scott Watershed



1955 CDFG Lake Survey

CALIFORNIA DEPARTMENT OF FISH AND GAME LAKE SURVEY

NAME MEEKS MEADOW LAKE

TRIBUTARY TO Meeks Meadow Creek

OTHER NAMES Meeks Lake

by M. Coots. 9-17


scottriver.org
megan@scottriver.org

Integrating Forest Health with Meadow Restoration in the Middle Truckee River Basin

foriver
TRUCKEE RIVER WATERSHED COUNCIL

Balance Hydrologics

TRUCKEE DONNER LAND TRUST

FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE

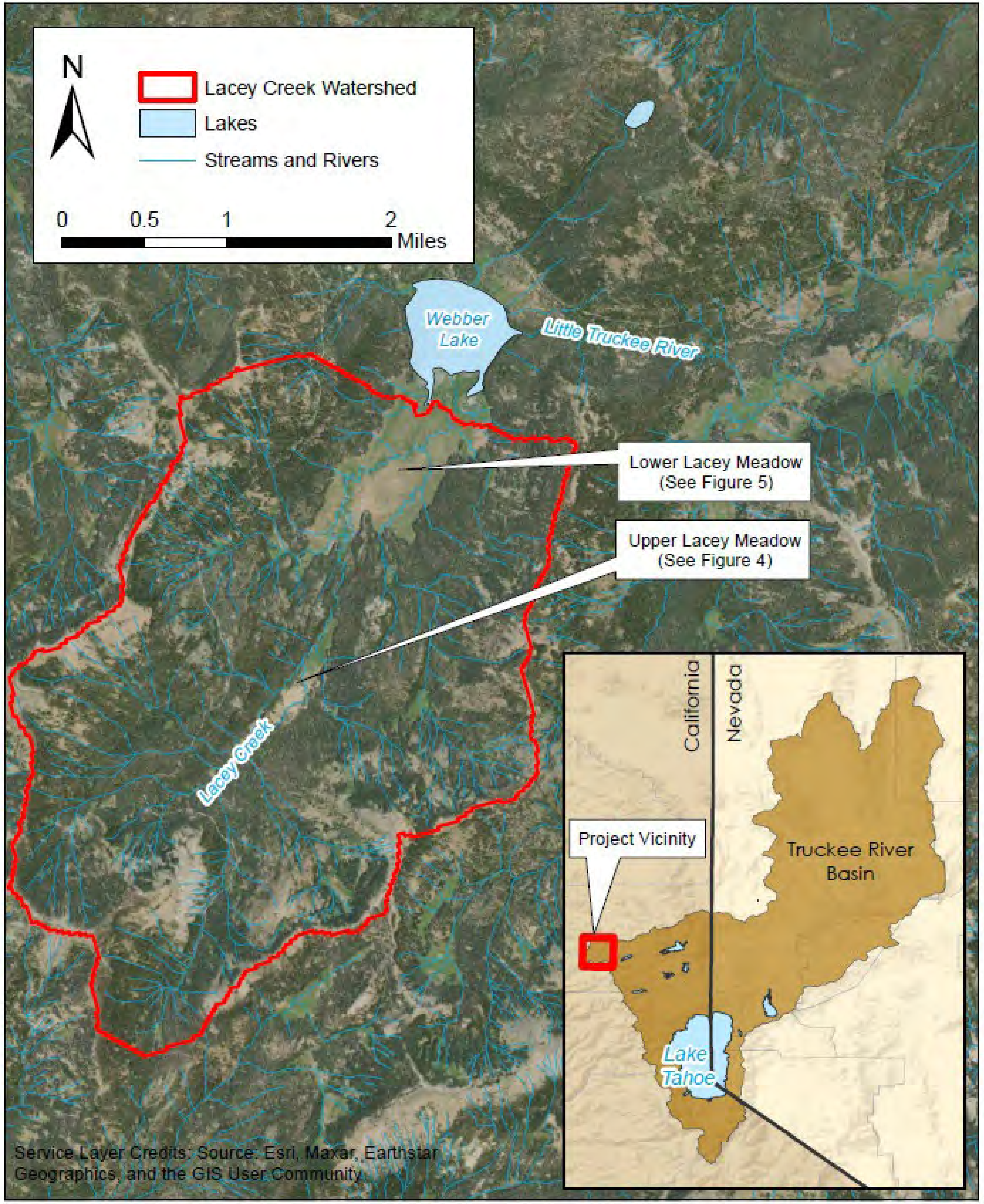
May 2, 2025

Lacey Meadows Watershed

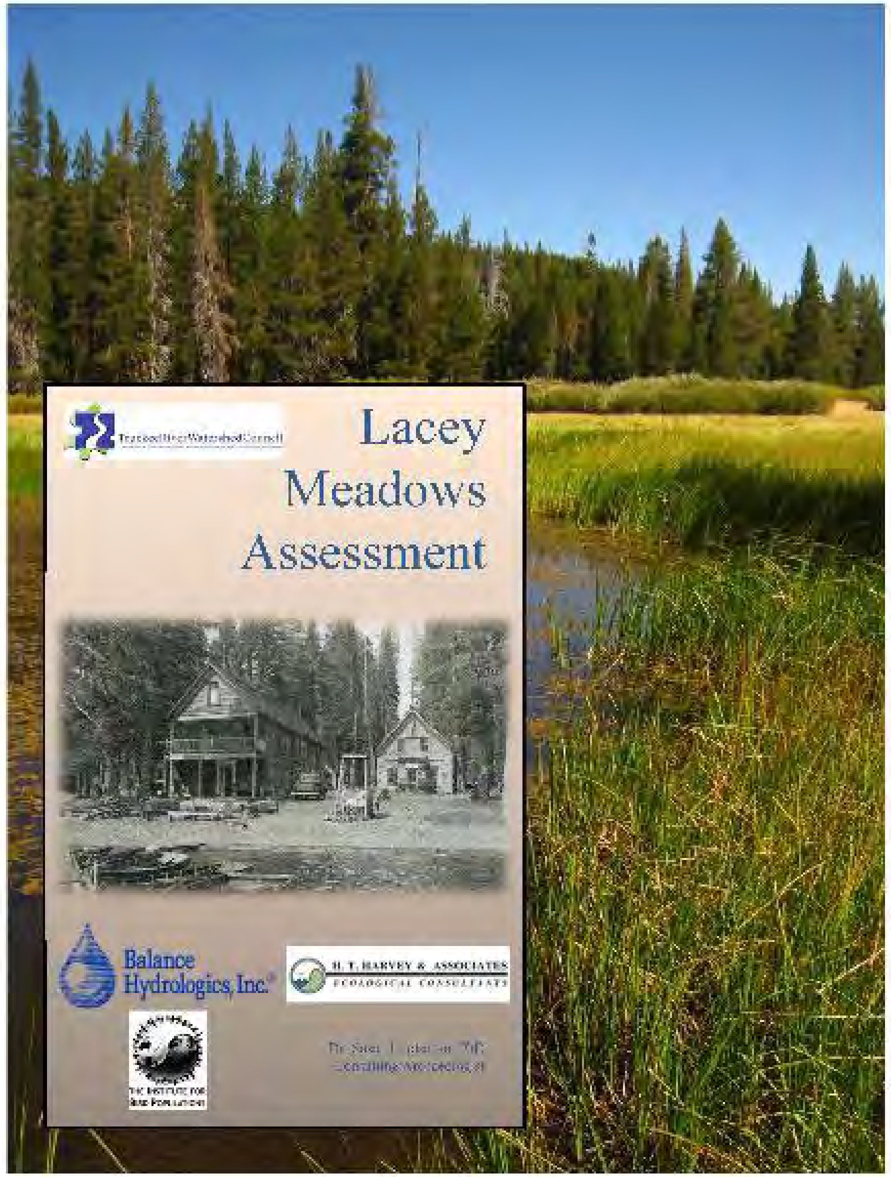
Watershed Area: 9 square miles
Elevations: 6,800 – 8,200 feet
Annual Precipitation: 44.9 inches
Snow Depths: >150 inches

Roughly 550 acres of montane meadow

Headwaters of the Little Truckee River



Lacey Meadows Restoration Timeline



2012 Truckee Donner Land Trust acquires Lacey Meadows/Webber Lake

2012-2013 Watershed Assessment

2018-2020 Watershed Improvements

2019 Meadow Restoration Design and Baseline Monitoring

2023 Phase 1 THP and Upper Meadow Restoration Implemented

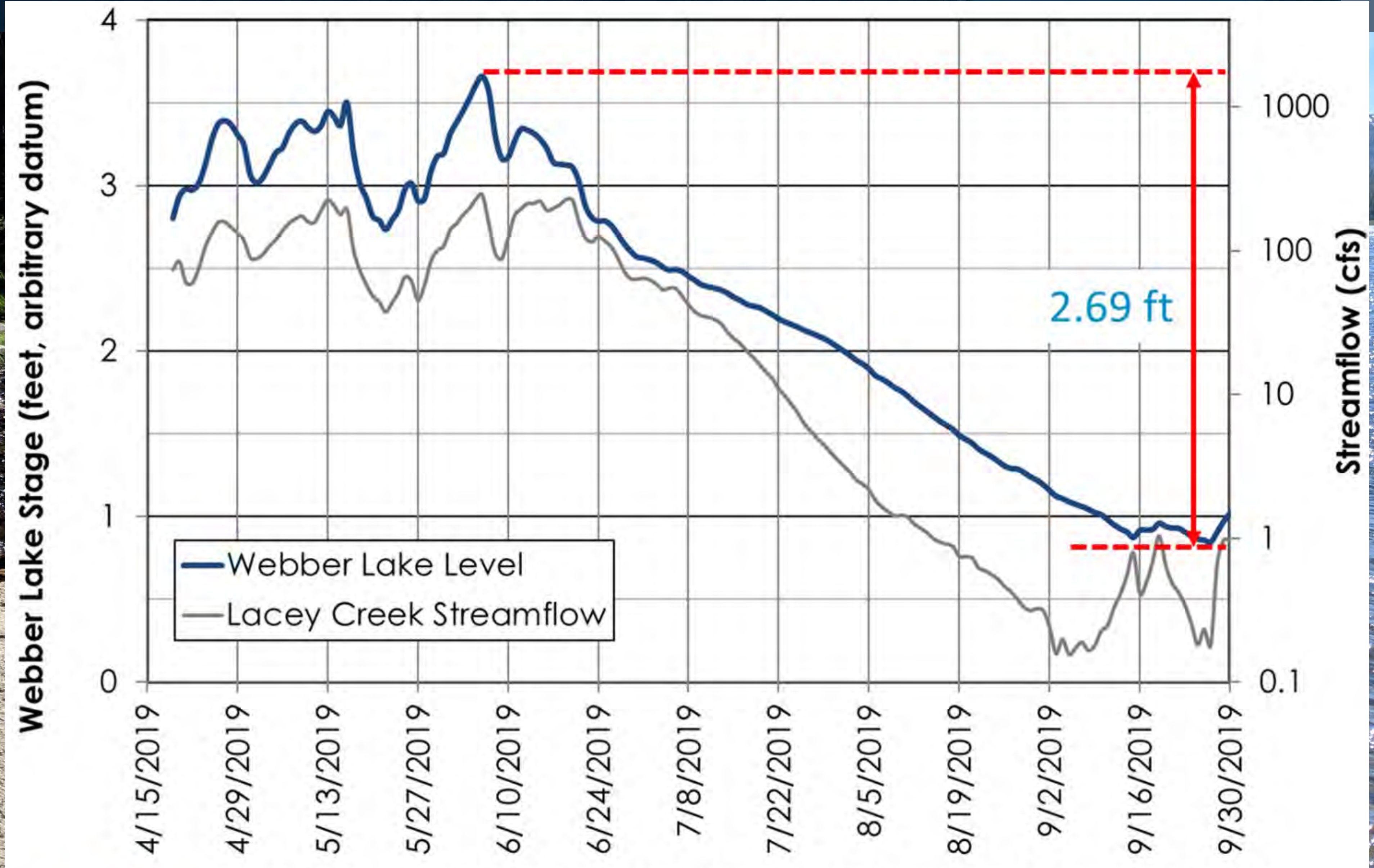
2024 Phase 2 THP and Lower Meadow Restoration Implemented

Background: Land Use History

- Sheep grazing 1850s thru current
- Cattle grazing (old dairy adjacent) 1940s, 1950s
- Logging 1950s-1970s

Drivers of Meadow Degradation?

Driver: Baselevel Changes

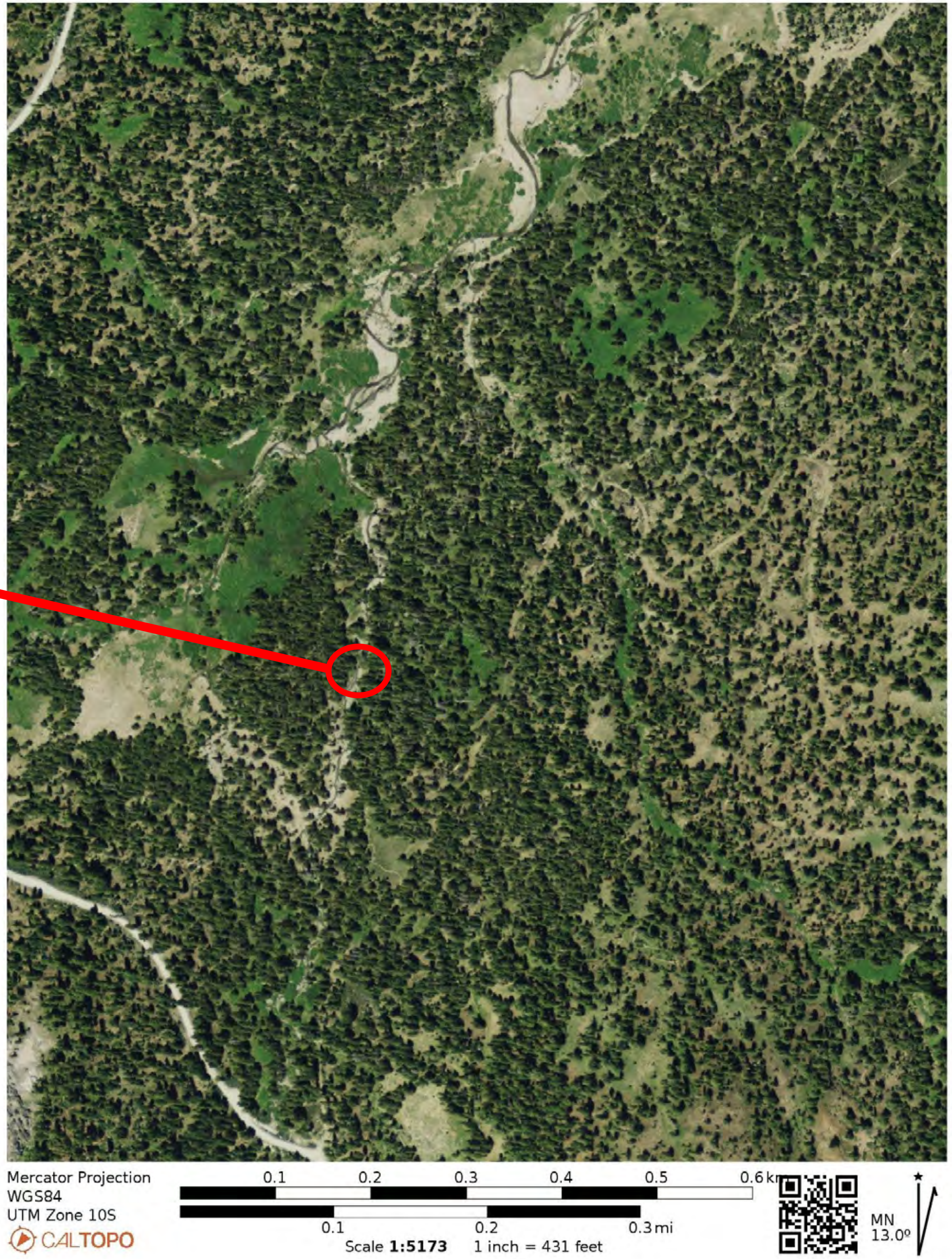


Balance Hydrologics™

Figure 4. **Webber Lake daily mean and maximum water levels, April 19 - September 30, 2019, Sierra County, California**
Lacey Creek Streamflow shown for context

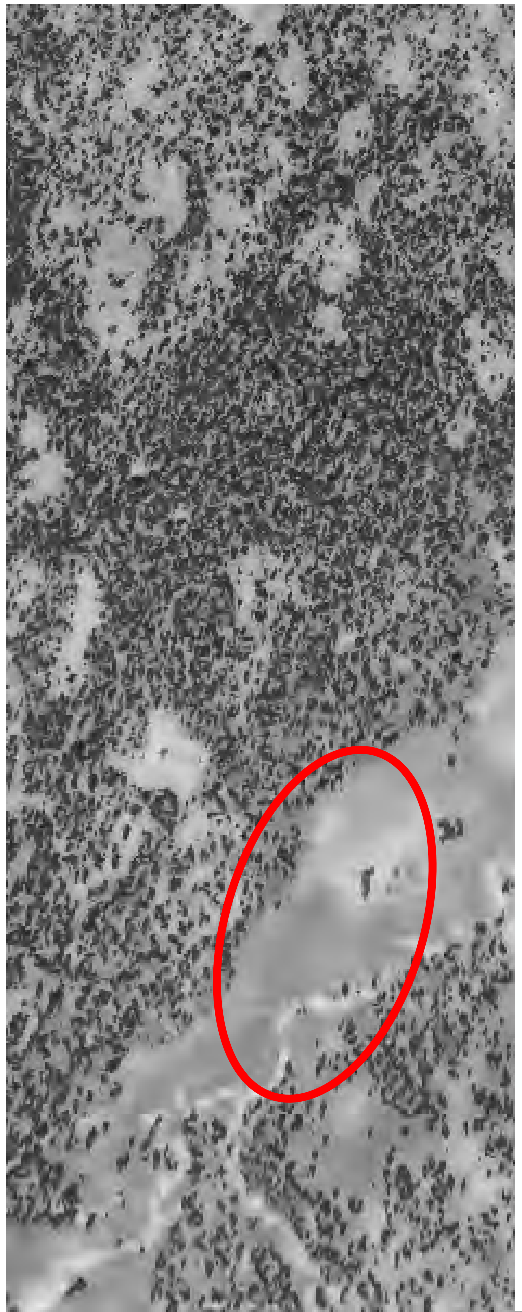
Driver: Baselevel Changes

Driver: Roads



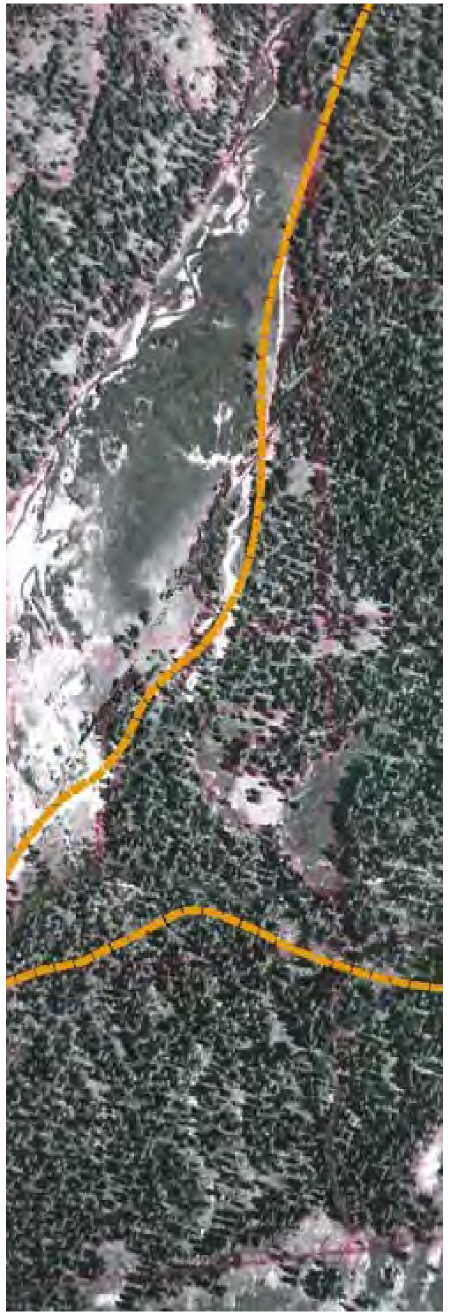
Driver: Channel Modifications

1939

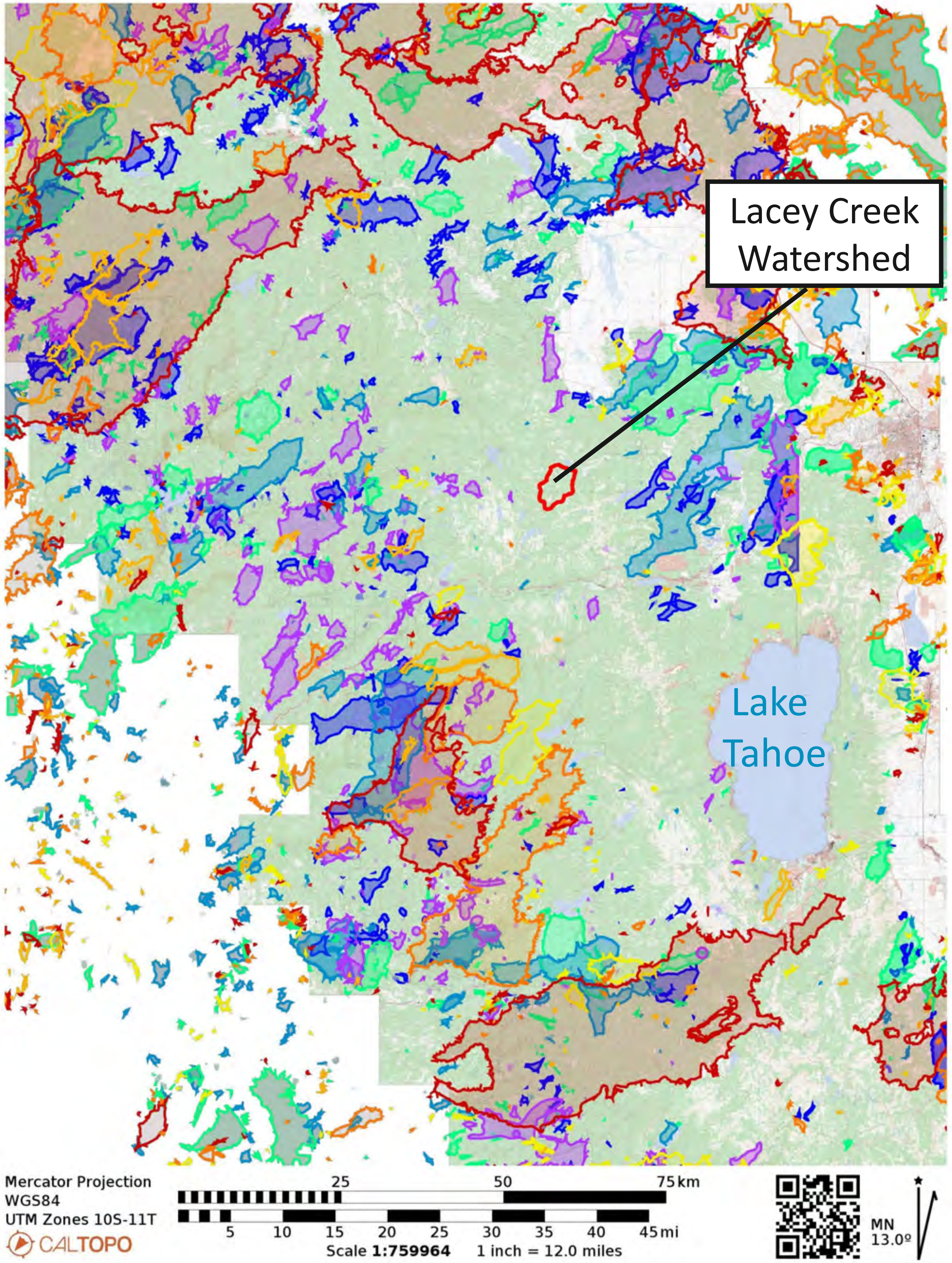


1952

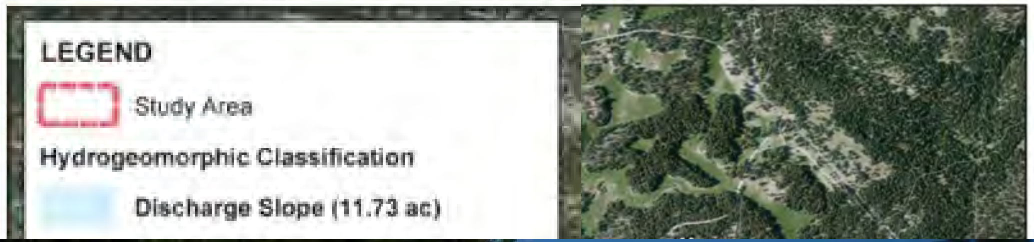
1966



Conditions: Forest Health



Current Meadow Conditions



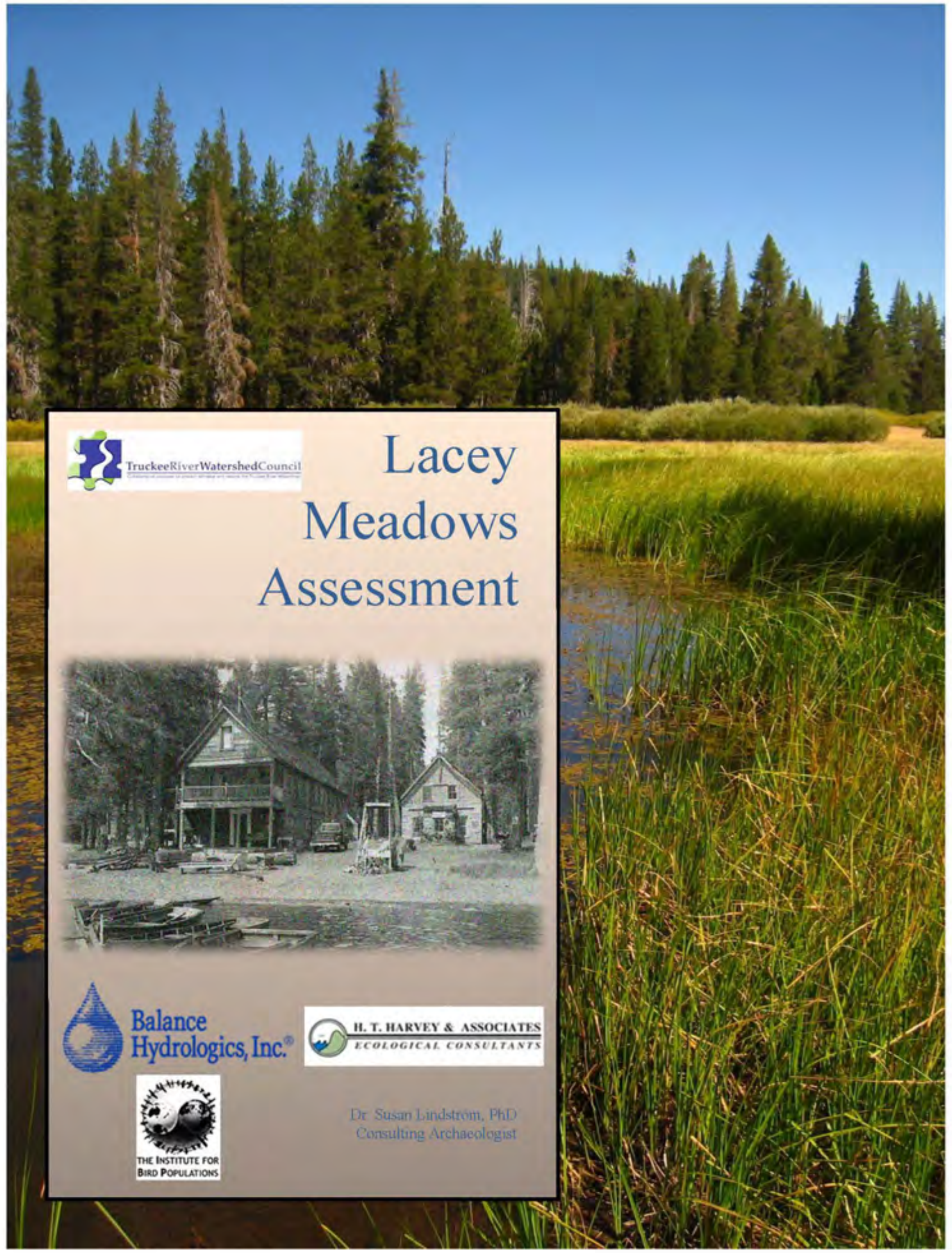
Meadow Condition Assessment
(2012)

Dry Montane Meadows
(historically wetter)

Conifer Encroachment
Bare Ground
Low Ecological Status

Watershed Improvements

- Lake Level Management Plan
- Road Drainage Improvements
- Grazing Plan
- Timber Harvest Plan



H. T. HARVEY & ASSOCIATES
Ecological Consultants
50 years of field notes, exploration, and excellence

Webber Lake and Coppins Meadow Livestock Grazing Management Plan

Project # 3407-02

Prepared for:

Beth Christman
Truckee River Watershed Council
10418 Donner Pass Road
Truckee, CA 96161

Prepared by:

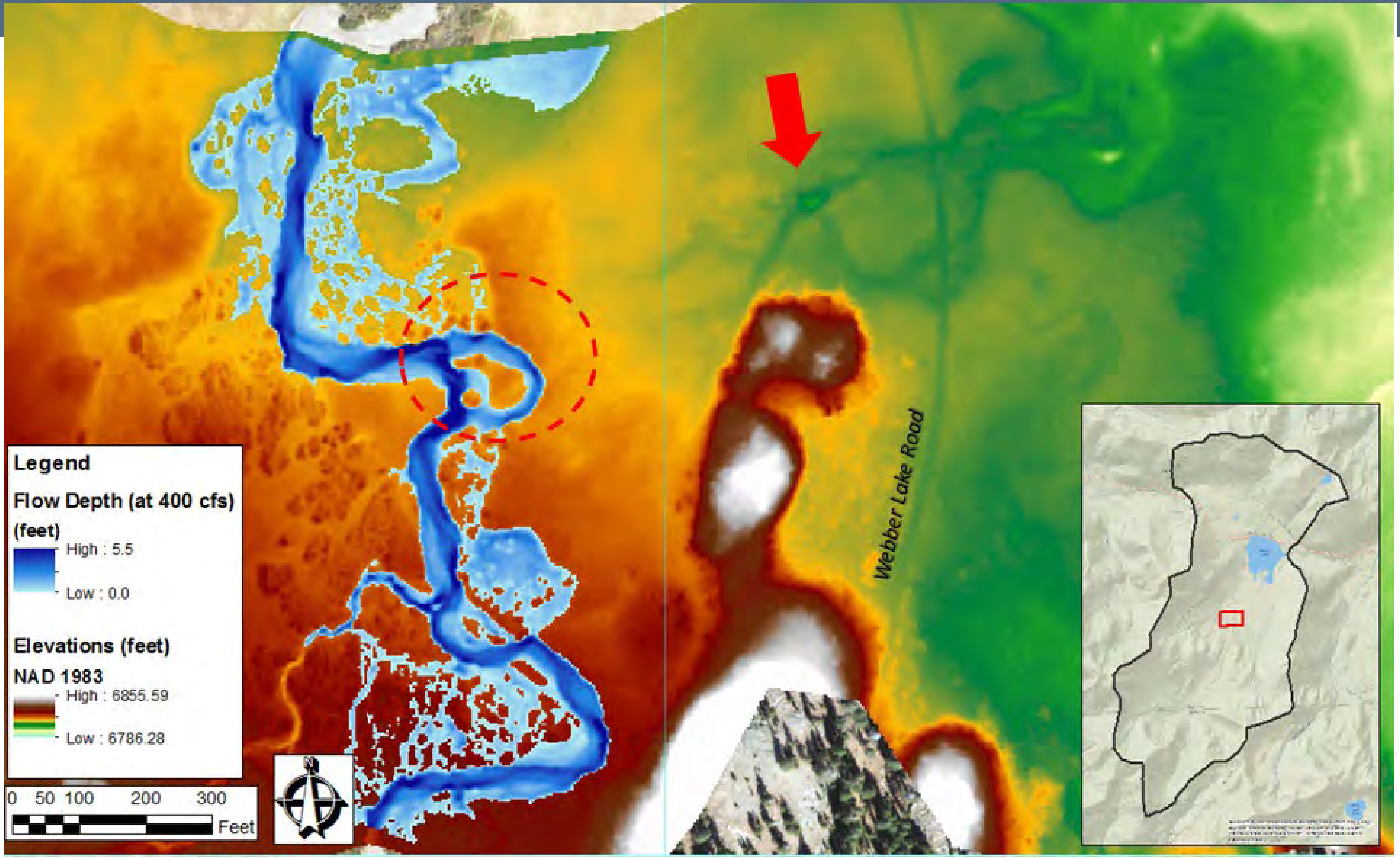
H. T. Harvey & Associates

November 2020

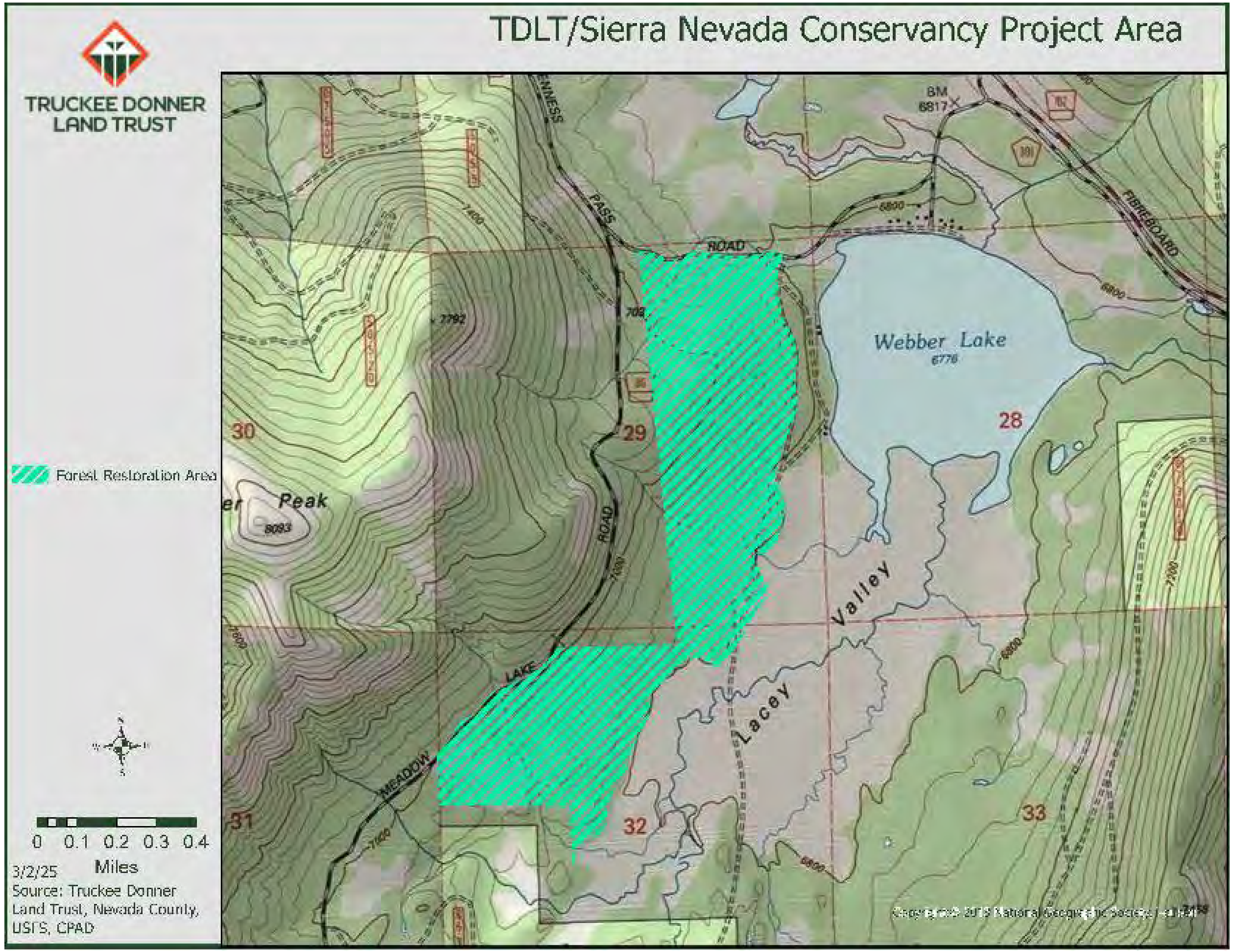
1331 Garden Hwy, Suite 310 • Sacramento, CA 95833 916.779.7350 • www.harveyecology.com

Meadow Restoration Design

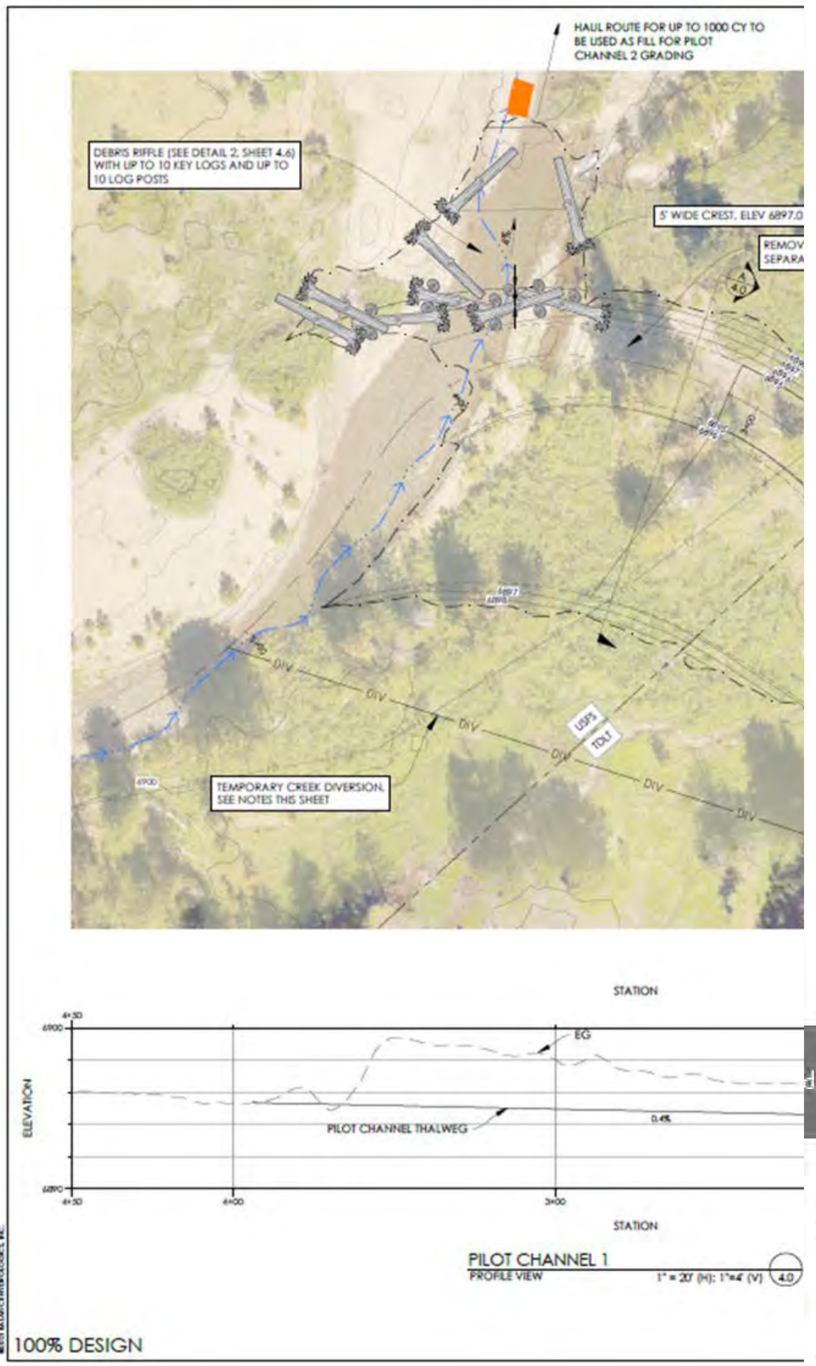
Meadow Restoration Design

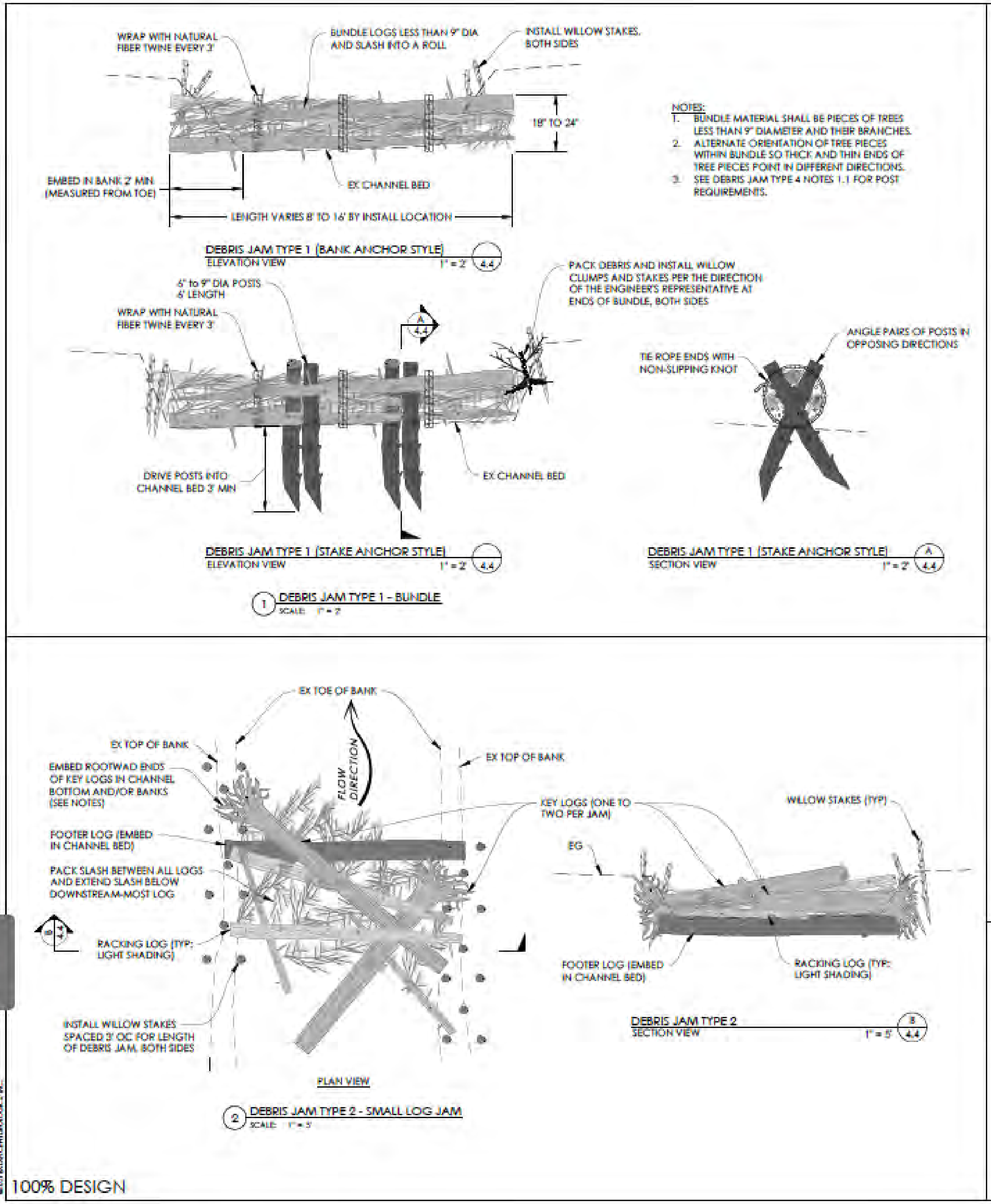


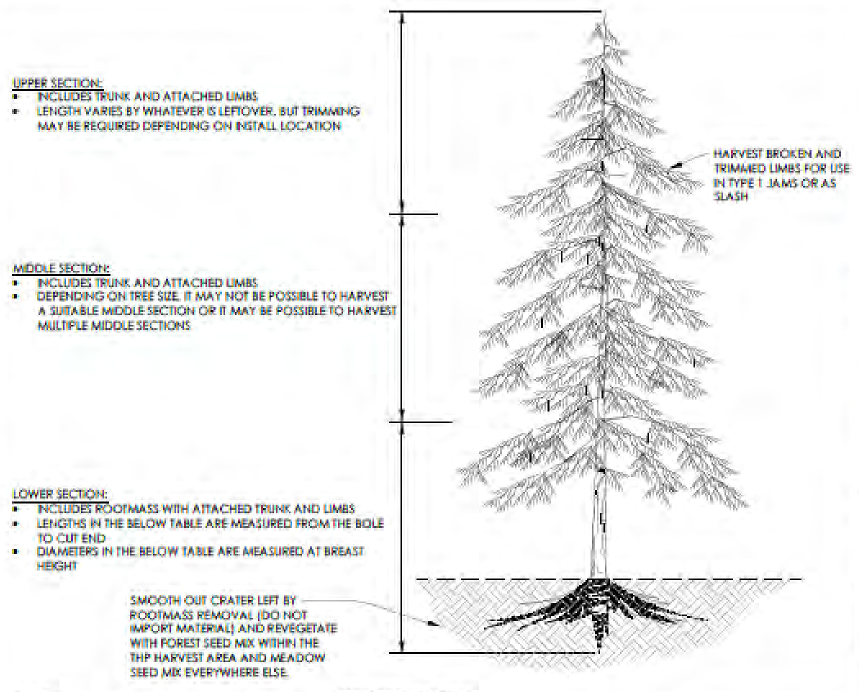
Meadow Restoration Design



Meadow Restoration Design







GENERAL:
- ALL LOGS TO BE USED AS KEY LOGS OR RACKING LOGS SHALL BE SOUND, FREE FROM ROT OR INFESTATION BY INSECTS, AND FREE OF ADHERED DIRT, LITTER, OR OTHER MATERIAL.
- LOGS SHALL HAVE NO WEAKNESSES SUCH AS CRACKS AND SPLITS THROUGH MORE THAN 25 PERCENT OF THE LOG DIAMETER.
- LOGS NOT MEETING THE ABOVE CRITERIA MAY BE FURTHER DISSECTED AND USED AS SLASH, OR CHIPPED AND DISPERSED IN UPLAND AREAS PER THE DIRECTION OF THE ENGINEER'S REPRESENTATIVE.

TREE PIECE SIZING TABLE:

TREE SECTION	LOG TYPE	DETAIL REFERENCE (DETAIL #/SHEET#)	DIAMETER (INCHES)	LENGTH (FEET)
UPPER	SLASH	1/4.4, 2/4.4, 3/4.5	N/A	N/A
	TYPE 1 JAM BUNDLE MATERIAL	1/4.4	< 9"	8' TO 16'
MIDDLE	KEY LOG - TYPE 2 JAM	2/4.4	12" TO 15"	> 0.75 BFW
	RACKING LOG - TYPE 2 OR 3 JAM	2/4.4, 3/4.5	> 9"	> 0.5 BFW
	LOG POST TYPE B	2B/4.6	9" TO 12"	12' TO 20'
	LOG 3-STACK	1/4.3	> 18"	20'
	TYPE 1 JAM BUNDLE MATERIAL	1/4.4	< 9"	8' TO 16'
LOWER	KEY LOG - TYPE 2 JAM	2/4.4	12" TO 18"	>0.75 BFW
	KEY LOG - TYPE 3 JAM	3/4.5	> 18"	>1.0 BFW
	LOG POST TYPE A	2A/4.6	> 15"	10' TO 15'
	LOG GRADE CONTROL	2/4.3	> 15"	18'

BFW = BANKFULL WIDTH (TO BE PROVIDED BY THE ENGINEER'S REPRESENTATIVE

3 TREE DISSECTION FOR DEBRIS JAMS
SCALE: NTS

DEBRIS JAM TYPES 1, 2, AND 3 NOTES:
1. THE ENGINEER'S REPRESENTATIVE SHALL FLAG LOCATIONS FOR DEBRIS JAMS. THE CONTRACTOR AND ENGINEER'S REPRESENTATIVE SHALL COORDINATE FOR THE INSTALLATION OF EACH DEBRIS JAM TO AGREE ON CONFIGURATIONS OF KEY LOGS AND RACKING LOGS, SOURCE TREES FOR LOGS, AND HAUL ROUTES.
2. TREES FOR DEBRIS JAMS SHALL BE SOURCED FROM EITHER EXISTING LIVE TREES WITHIN 50' OF THE STRUCTURE ("TREES TO BE HARVESTED AND REUSED" NOTED ON THE PLANS) OR FROM THE THP HARVEST AREA SHOWN ON SHEET 3.3.
3. THE ENGINEER'S REPRESENTATIVE SHALL MARK ALL TREES FOR REMOVAL. TREES SHALL BE LODGEPOLE PINE TO THE EXTENT PRACTICABLE.
4. FOR TYPE 2 AND TYPE 3 DEBRIS JAMS:
   - 4.1. INSTALL LOG POSTS CONCURRENT WITH THE DEBRIS JAMS WHERE THE PLANS INDICATE LOG POSTS ARE REQUIRED.
   - 4.2. ORIENT ROOTWAD ENDS OF LOGS WITH THE ROOTWAD POINTING IN THE DOWNSTREAM DIRECTION, AS SHOWN ON THE PLANS.
   - 4.3. KEY ROOTWAD ENDS INTO THE CHANNEL AND/OR BANKS TO FIRMLY SECURE THE KEY LOG IN PLACE. EXCAVATE A TRENCH JUST LARGE ENOUGH TO ACCEPT THE ROOTWAD FAN.
   - 4.4. PLACE ROOTWAD AND BACKFILL BY HYDRAULICALLY JETTING RIVERBED MATERIAL (IF WATER SOURCE IS AVAILABLE WITHIN 300' OF THE INSTALL LOCATION). IF WATER IS NOT AVAILABLE WITHIN 300', BACKFILL TRENCH WITH RIVERBED MATERIAL. BUCKET COMPACT IN 12" LIFTS, AND STIR MATERIAL WITH BUCKET TEETH BETWEEN LIFTS TO MINIMIZE VOIDS.
   - 4.5. SLASH IN EXCESS OF WHAT CAN BE INCORPORATED INTO THE DEBRIS JAMS SHALL BE CHIPPED AND DISPERSED IN UPLAND AREAS PER THE DIRECTION OF THE ENGINEER'S REPRESENTATIVE.

Balance Hydrologics, Inc.
12020 Donner Pass Road
Truckee, CA 96161

SUBMITTALS / REVISIONS: 11/15/19 BKH 30% DESIGN; 7/15/20 BKH 65% DESIGN; 7/18/22 PK 100% DESIGN

DEBRIS JAM TYPICALS 1
UPPER LACEY MEADOW RESTORATION DESIGN
SIERRA AND NEVADA COUNTIES, CALIFORNIA

PROJECT NUMBER 218199
SCALE (AT 22" X 34") AS SHOWN
SHEET 4.4

Implementation

Project Results: Upper Lacey Meadow

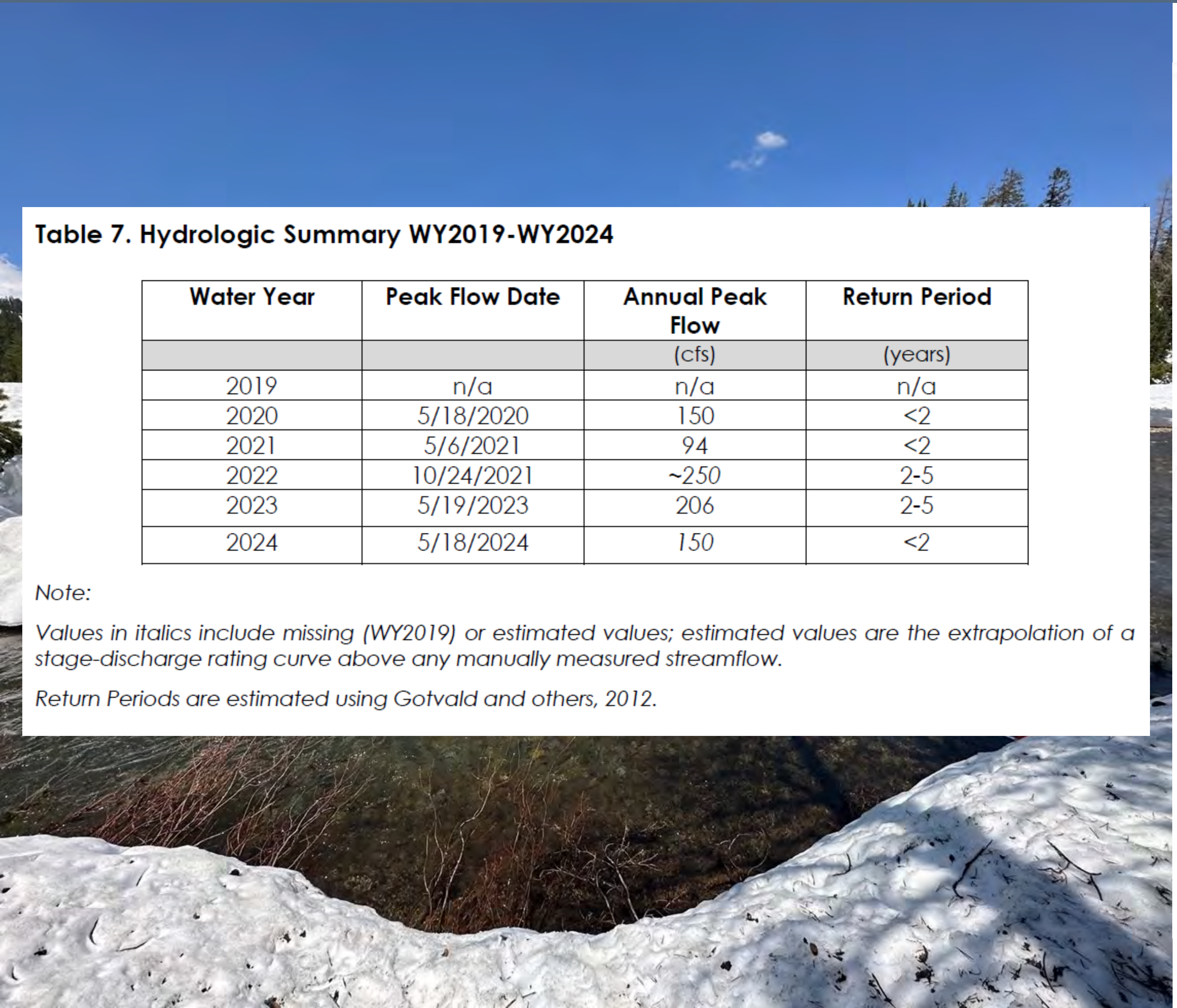


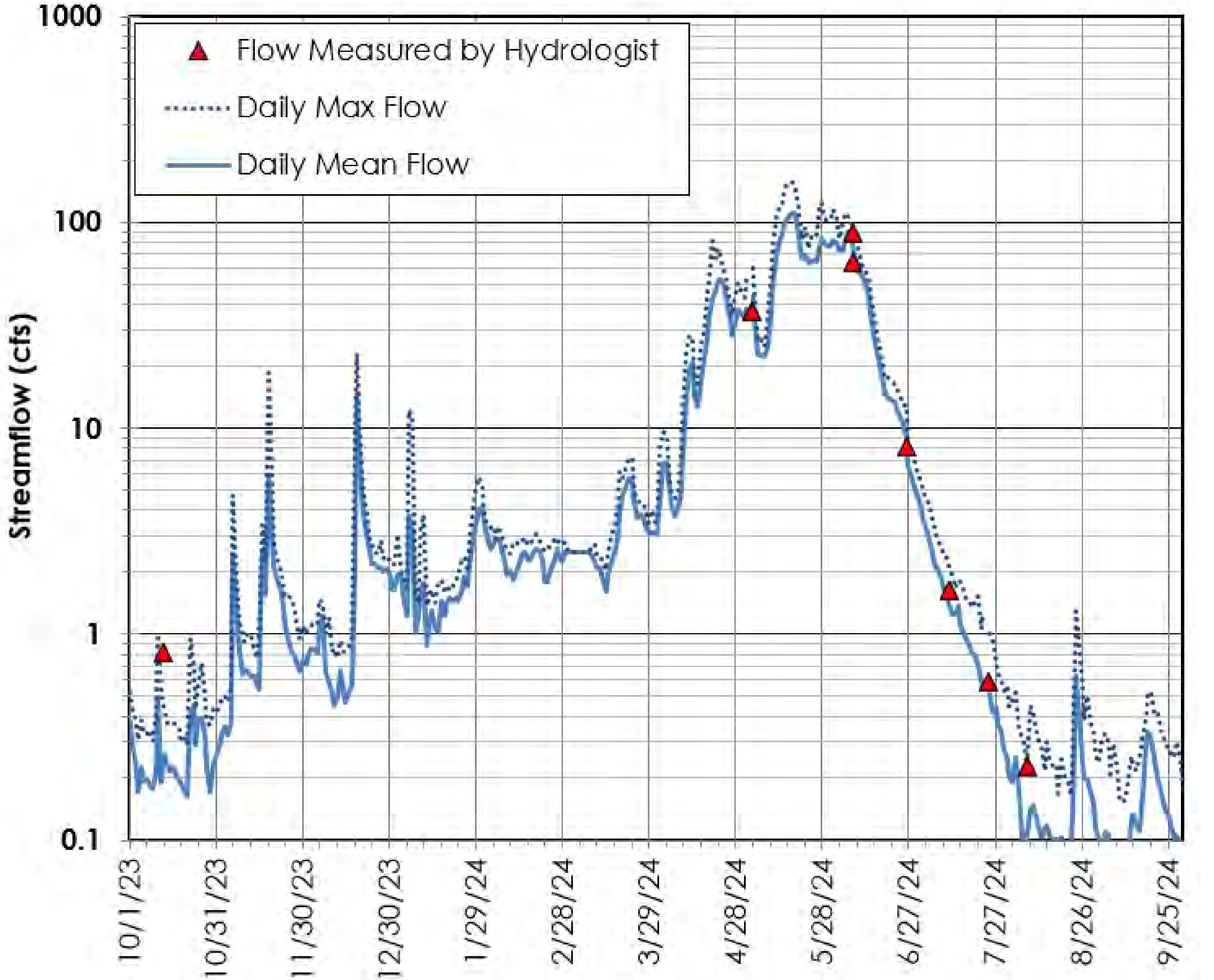
Table 7. Hydrologic Summary WY2019-WY2024

Water Year	Peak Flow Date	Annual Peak Flow	Return Period
		(cfs)	(years)
2019	*n/a*	*n/a*	*n/a*
2020	5/18/2020	150	<2
2021	5/6/2021	94	<2
2022	10/24/2021	*~250*	2-5
2023	5/19/2023	206	2-5
2024	5/18/2024	*150*	<2

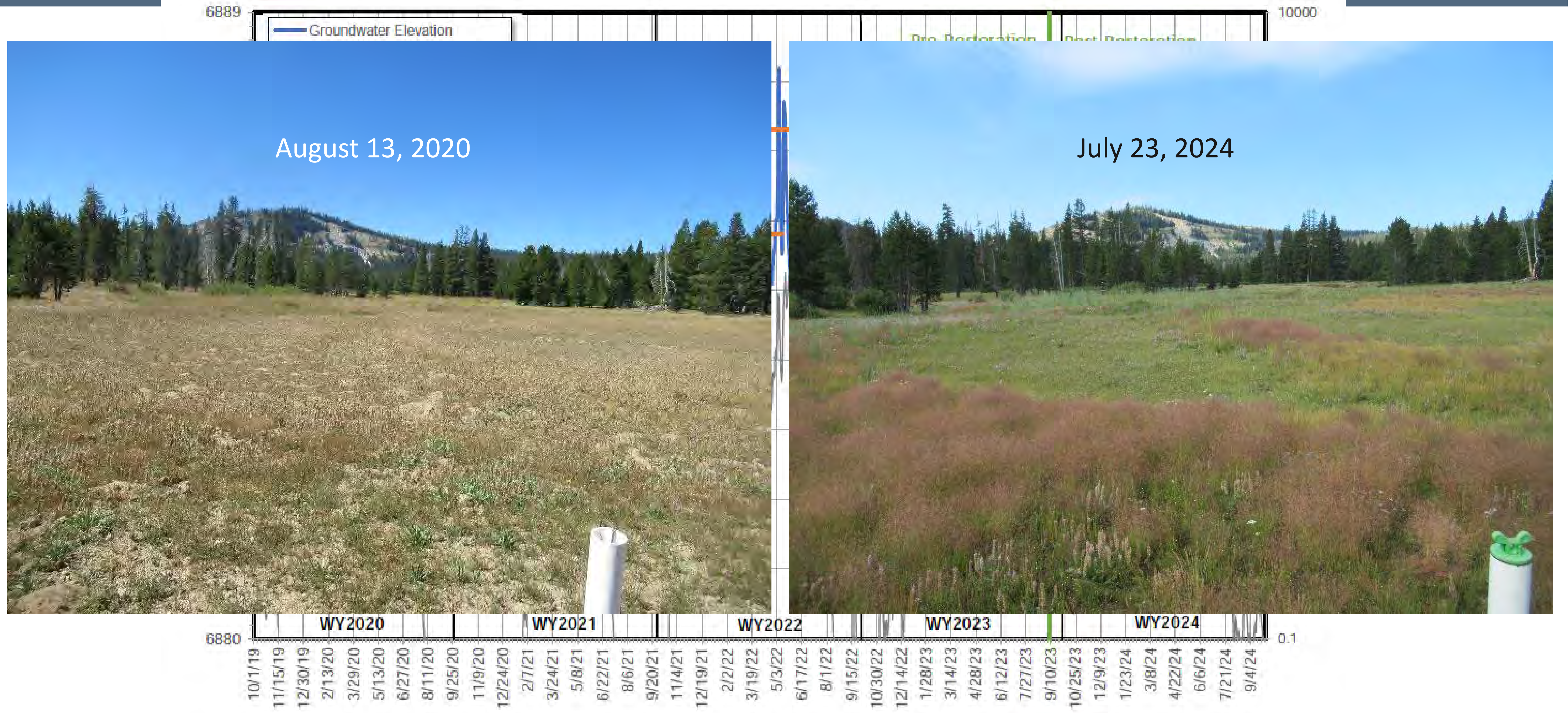
Note:

Values in italics include missing (WY2019) or estimated values; estimated values are the extrapolation of a stage-discharge rating curve above any manually measured streamflow.

Return Periods are estimated using Gotvald and others, 2012.



Project Results: Upper Lacey Meadow



Project Results: Upper Lacey Meadow

Google Earth Image: August 4, 2016
(Near to Below Average Water Year)

UAV image: July 27, 2024
(Near to Above Average Water Year)

Project Results: Upper Lacey Meadow

Project Results: Upper Lacey Meadow

Lower Lacey Meadow

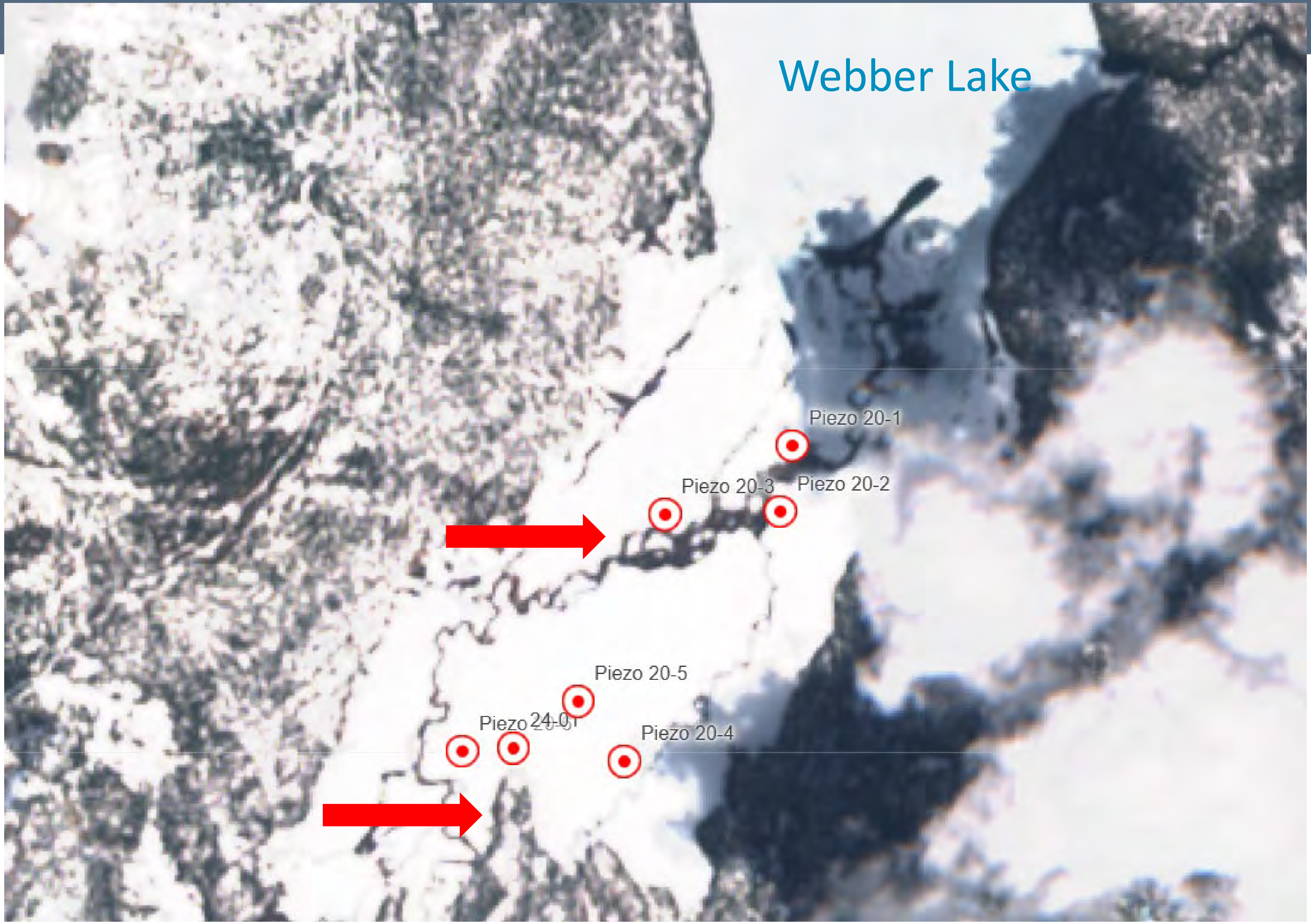
Lower Lacey Meadow

Lower Lacey Meadow

Lower Lacey Meadow

Sentinel Satellite Image:

April 30, 2025



Funding and Acknowledgements

Partners:

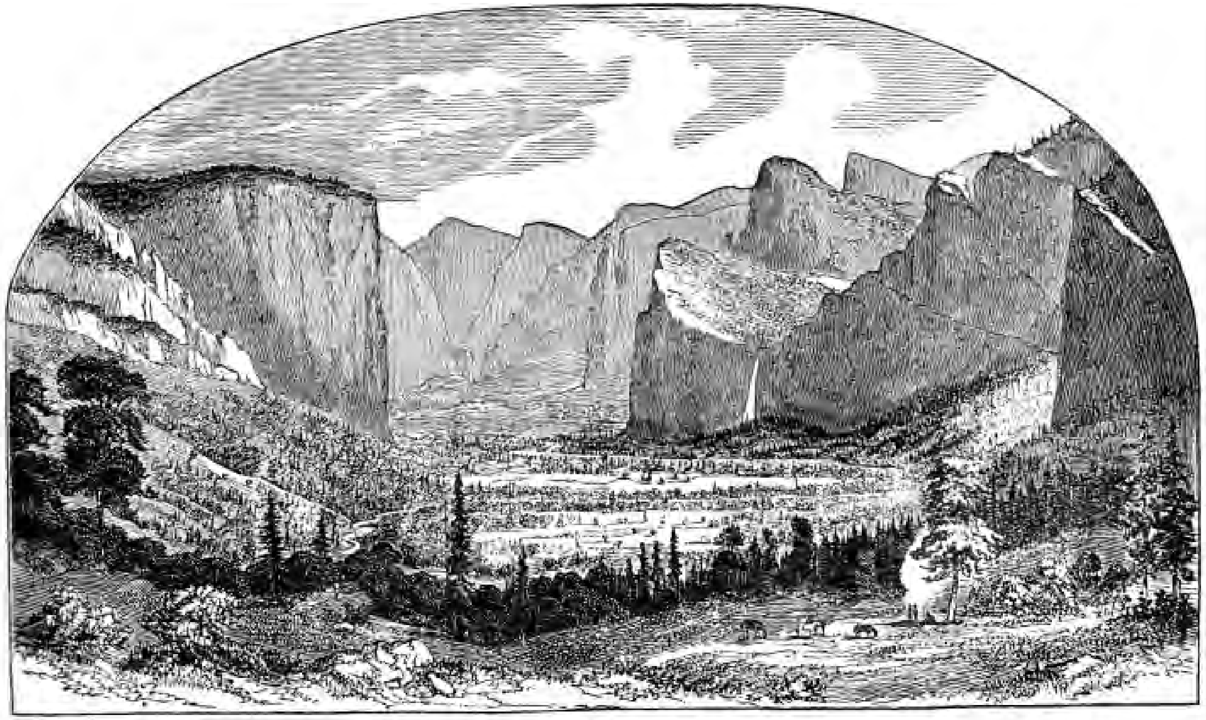
- Truckee Donner Land Trust
- U.S. Forest Service

Funders:

- Donors to the Truckee River Watershed Council
- CA Department of Fish and Wildlife
- CA Wildlife Conservation Board

Questions

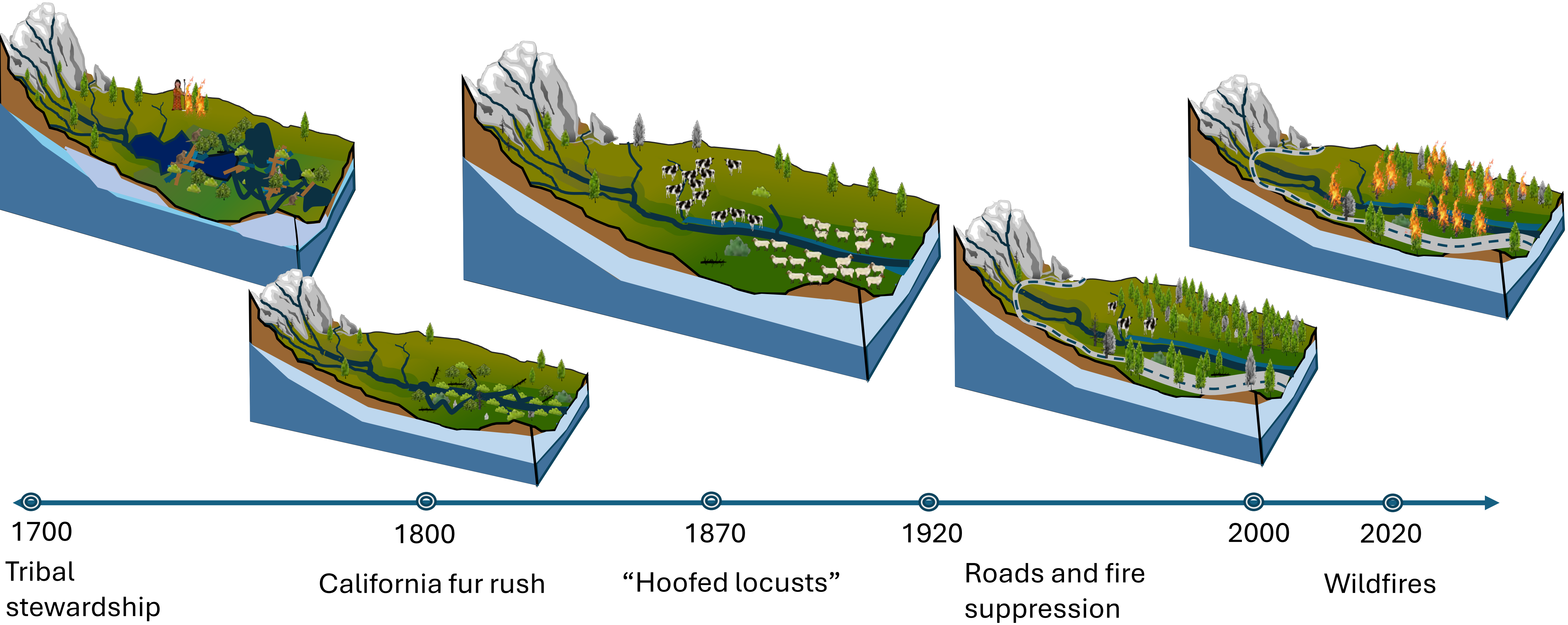
Wet, open valleys are disappearing



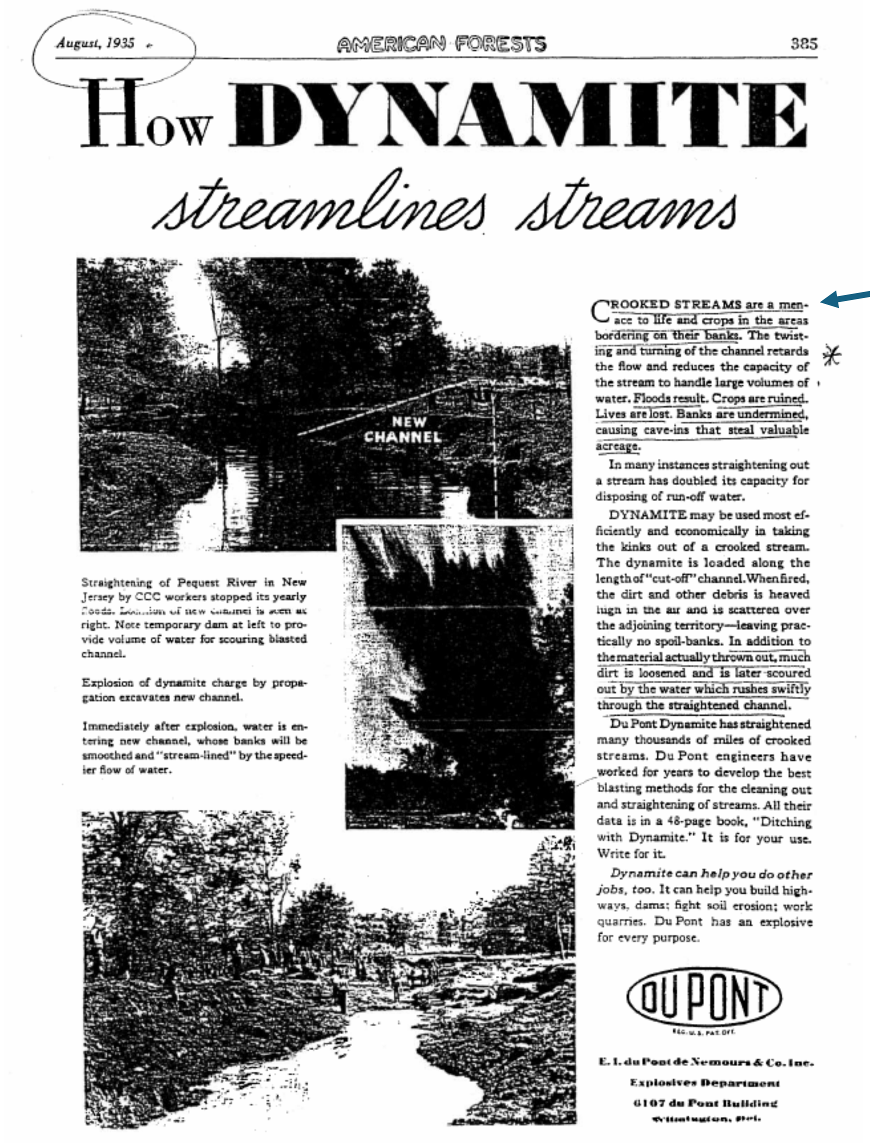
THE FIRST PICTURE OF YOSEMITE VALLEY
Sketched by Thomas A. Ayres, June 20, 1855 [Editor's note: the correct date is June 27, 1855.—DEA]

June 2022

A Brief History of Meadows



The old perspective: "Crooked streams are a menace to life... "



How DYNAMITE *streamlines streams*

CROOKED STREAMS are a menace to life and crops in the areas bordering on their banks. The twisting and turning of the channel retards the flow and reduces the capacity of the stream to handle large volumes of water. Floods result. Crops are ruined. Lives are lost. Banks are undermined, causing cave-ins that steal valuable acreage.

In many instances straightening out a stream has doubled its capacity for disposing of run-off water.

DYNAMITE may be used most efficiently and economically in taking the kinks out of a crooked stream. The dynamite is loaded along the length of "cut-off" channel. When fired, the dirt and other debris is heaved high in the air and is scattered over the adjoining territory—leaving practically no spoil-banks. In addition to the material actually thrown out, much dirt is loosened and is later scoured out by the water which rushes swiftly through the straightened channel.

Du Pont Dynamite has straightened many thousands of miles of crooked streams. Du Pont engineers have worked for years to develop the best blasting methods for the cleaning out and straightening of streams. All their data is in a 48-page book, "Ditching with Dynamite." It is for your use. Write for it.

Dynamite can help you do other jobs, too. It can help you build highways, dams; fight soil erosion; work quarries. Du Pont has an explosive for every purpose.

Straightening of Pequest River in New Jersey by CCC workers stopped its yearly floods. Location of new channel is seen at right. Note temporary dam at left to provide volume of water for scouring blasted channel.

Explosion of dynamite charge by propagation excavates new channel.

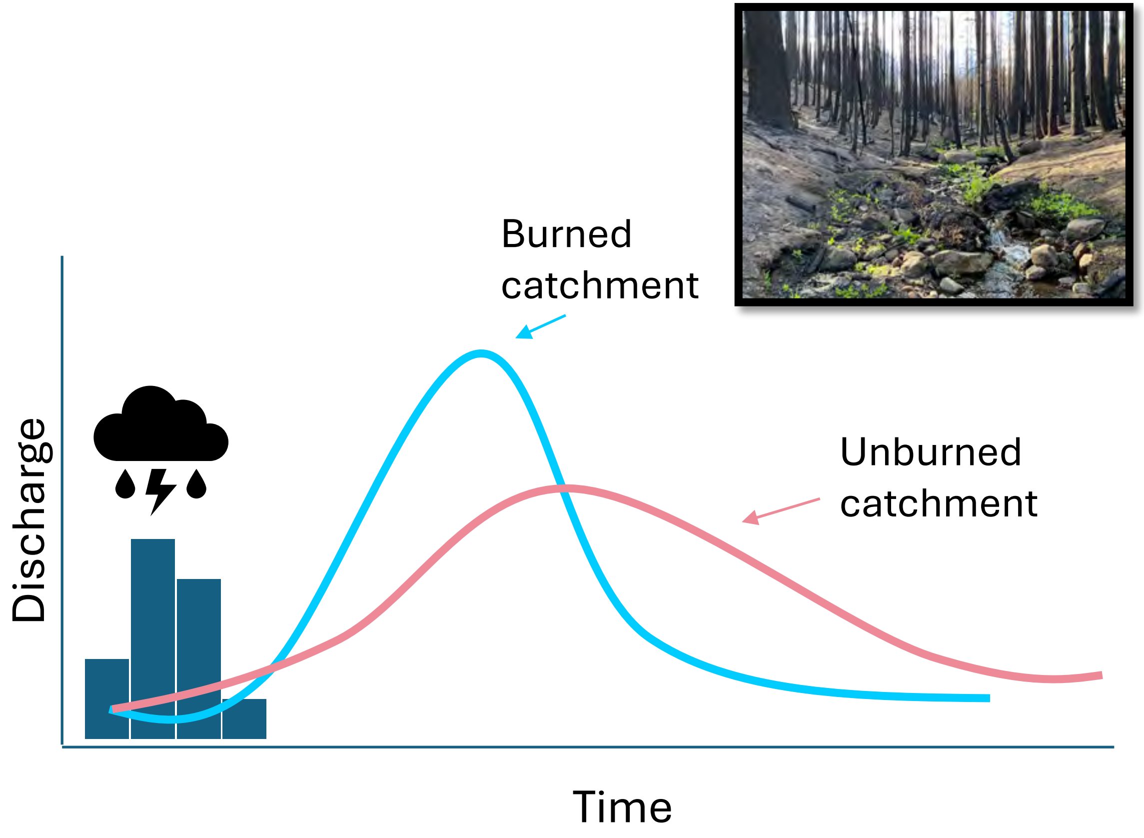
Immediately after explosion, water is entering new channel, whose banks will be smoothed and "stream-lined" by the speedier flow of water.

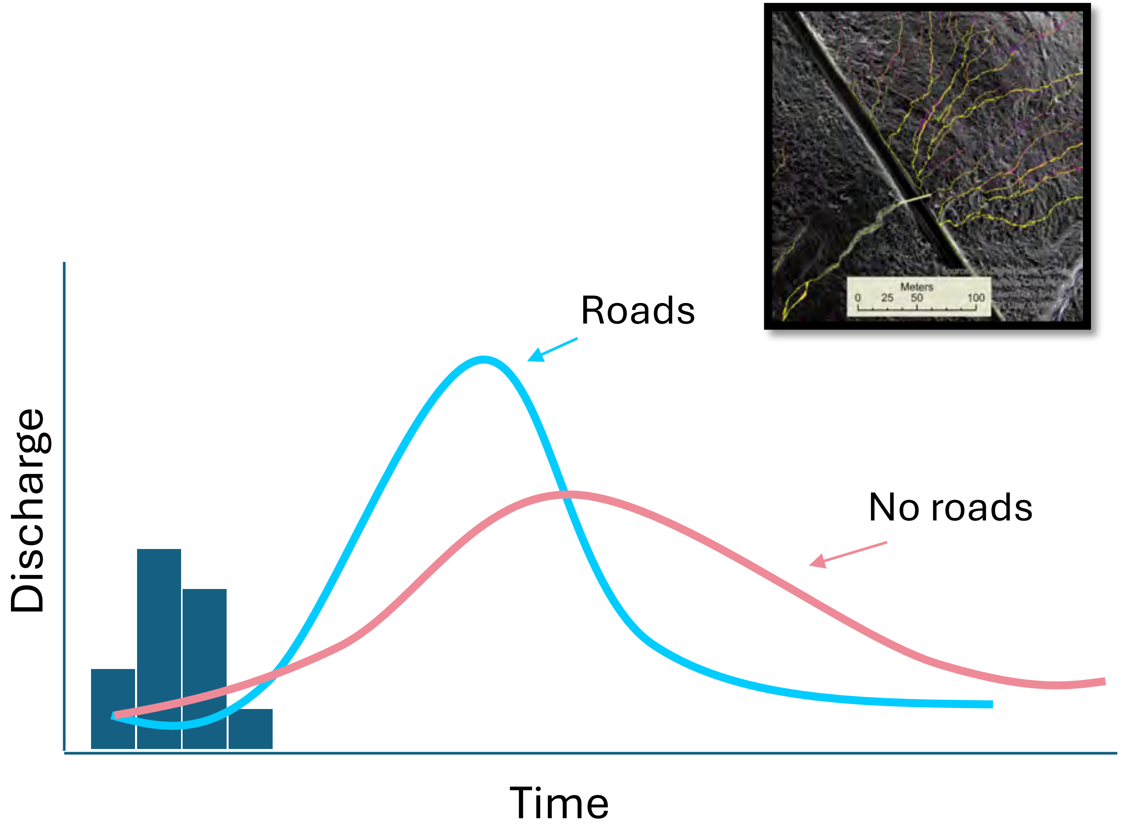
DU PONT

E. I. du Pont de Nemours & Co. Inc.
Explosives Department
6107 du Pont Building
Wilmington, Del.

- "straightening out a stream has doubled its capacity for disposing of run-off water."
- "DuPont Dynamite has straightened many thousands of miles of crooked streams."
- "Do it yourself. All their data is in a 48-page book, Ditching with Dynamite"

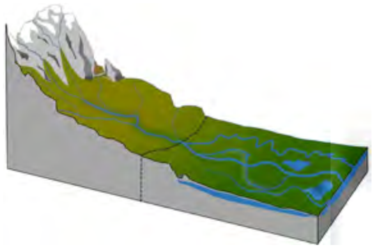
Altered upland forest hydrology





Wildfire: Scott 1997; Moody et al. 2008; Leopardi & Scorzini 2015; Kean et al. 2016; Havel et al. 2018; Srivastava et al. 2018; Williams et al. 2022. **Roads**: Wemple & Jones, 2003; Dymond et al. 2014; Wemple et al. 2016; Surfleet & Marks 2021.

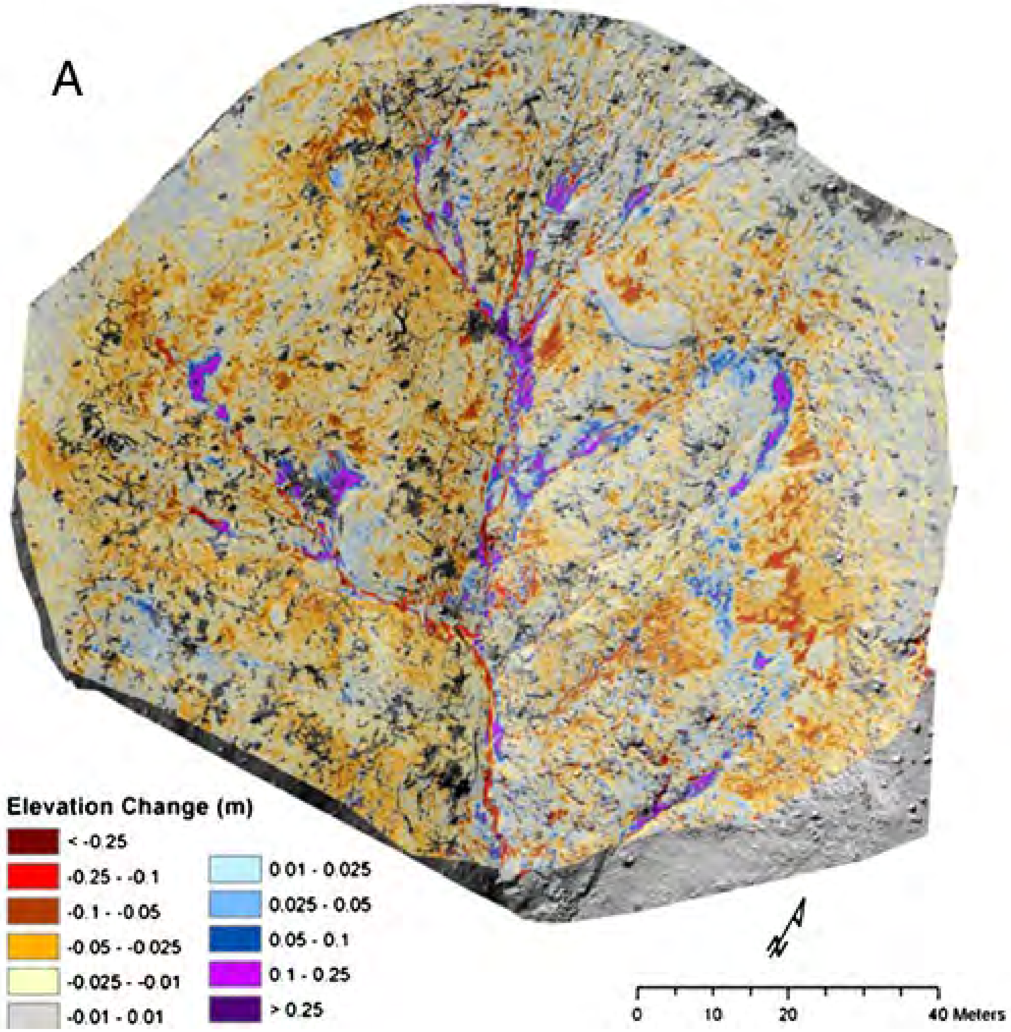
Where should we focus restoration efforts?



Low-gradient streams and meadows with high potential to:

- Retain water
- Capture sediment
- Attenuate peak flows, extend low flows
- Keep water cool
- Improve water quality

J.A. Moody et al. / Earth-Science Reviews 122 (2013) 10–37



Human-moderated meadow evolution, last 150 years

Human-moderated meadow evolution, next 50 years

Can we apply low-tech, nature-based restoration approaches to increase scale?

- Use locally sourced materials (wood, rock, sod) to add structure to initiate hydrological and biological processes.
- Work with the system (e.g., stream energy to deliver sediment, plant roots to lock in the sediment, beavers to develop complexity and storage).
- Apply a conscious effort to use cost-effective, minimal disturbance treatments (such as beaver dam analogs).
- Engage with local communities.

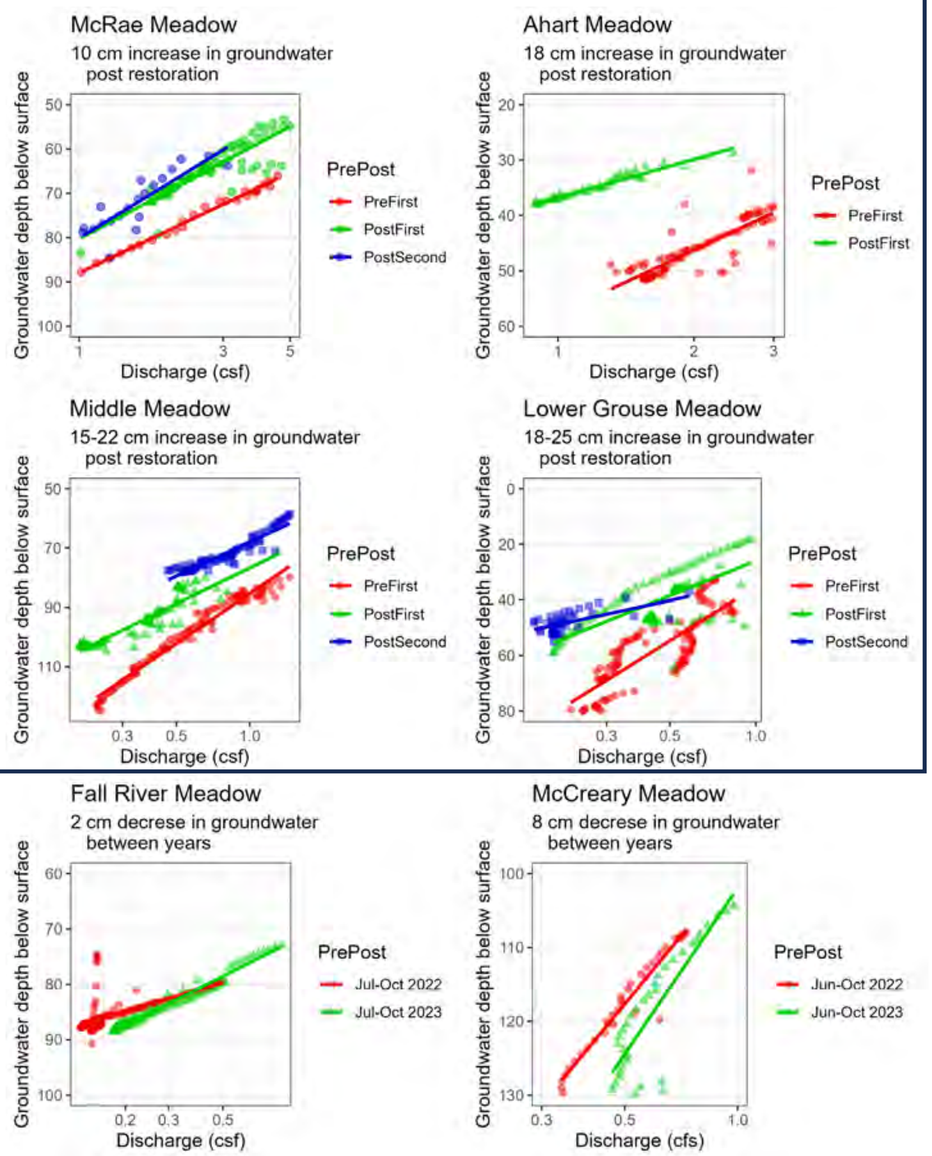
Experiment to test effects of low-tech process-based restoration in burned and unburned forests

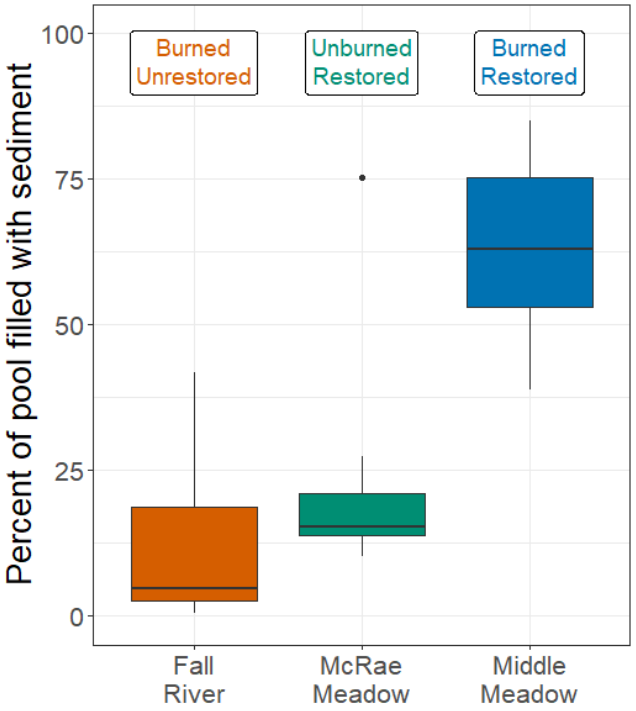
- Six meadows in the Plumas and Sierra National Forests
- Compared burned and unburned and treated vs. untreated
- Joined forces with Cal Poly Humboldt and Fresno State
- 2021-2025

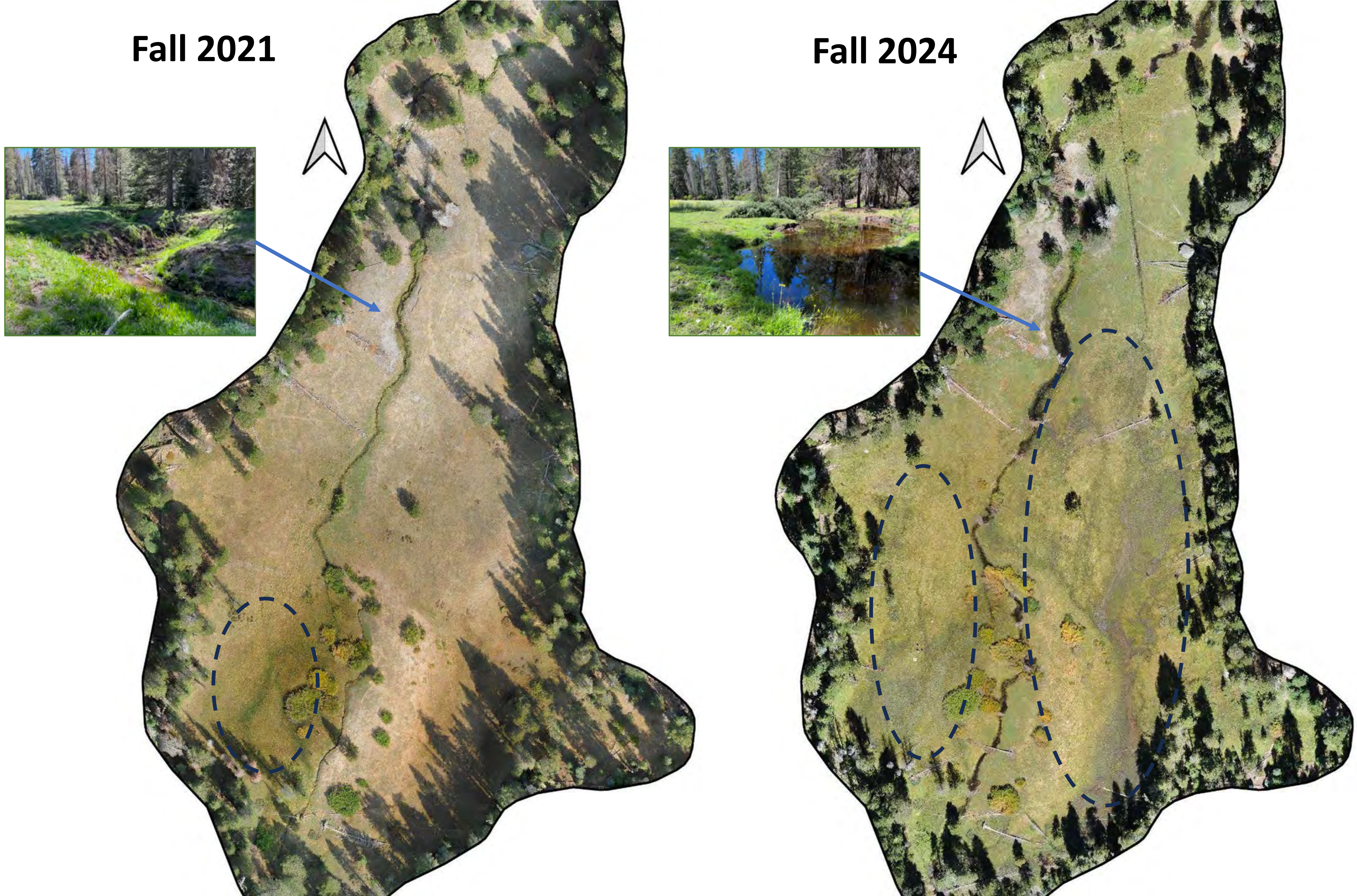
What is success?

- Increase surface water retention and complexity
- Raise groundwater elevation
- Capture sediment
- Increase wet meadow vegetation area and productivity

Rapid and persistent hydrological response following restoration

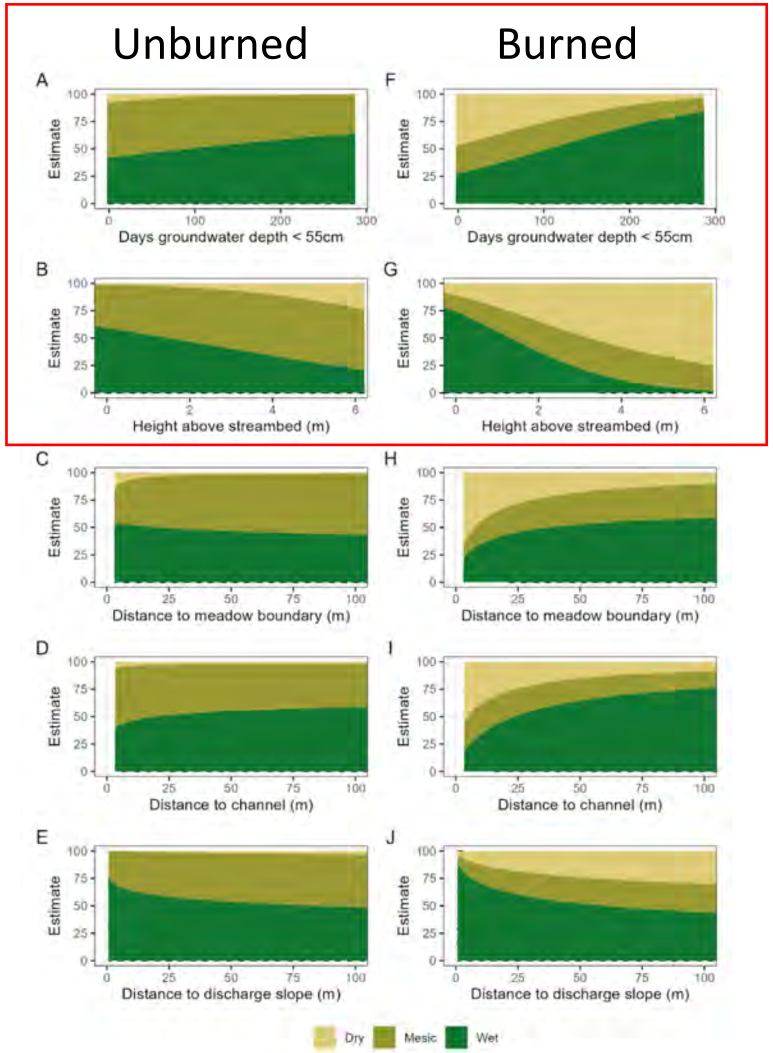


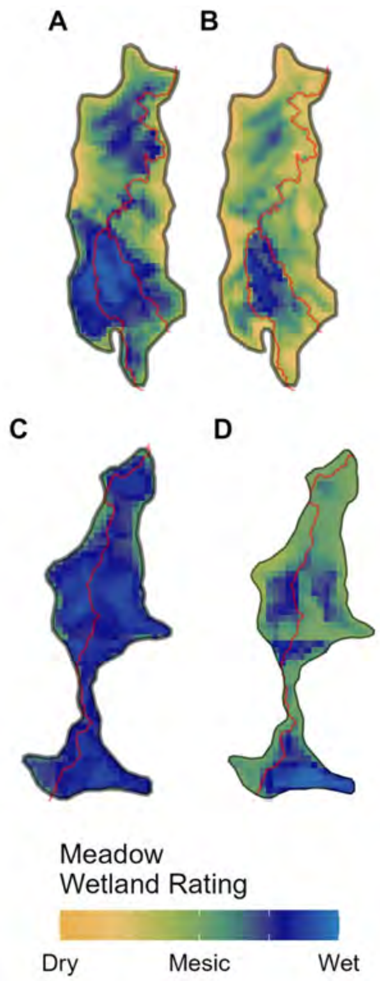




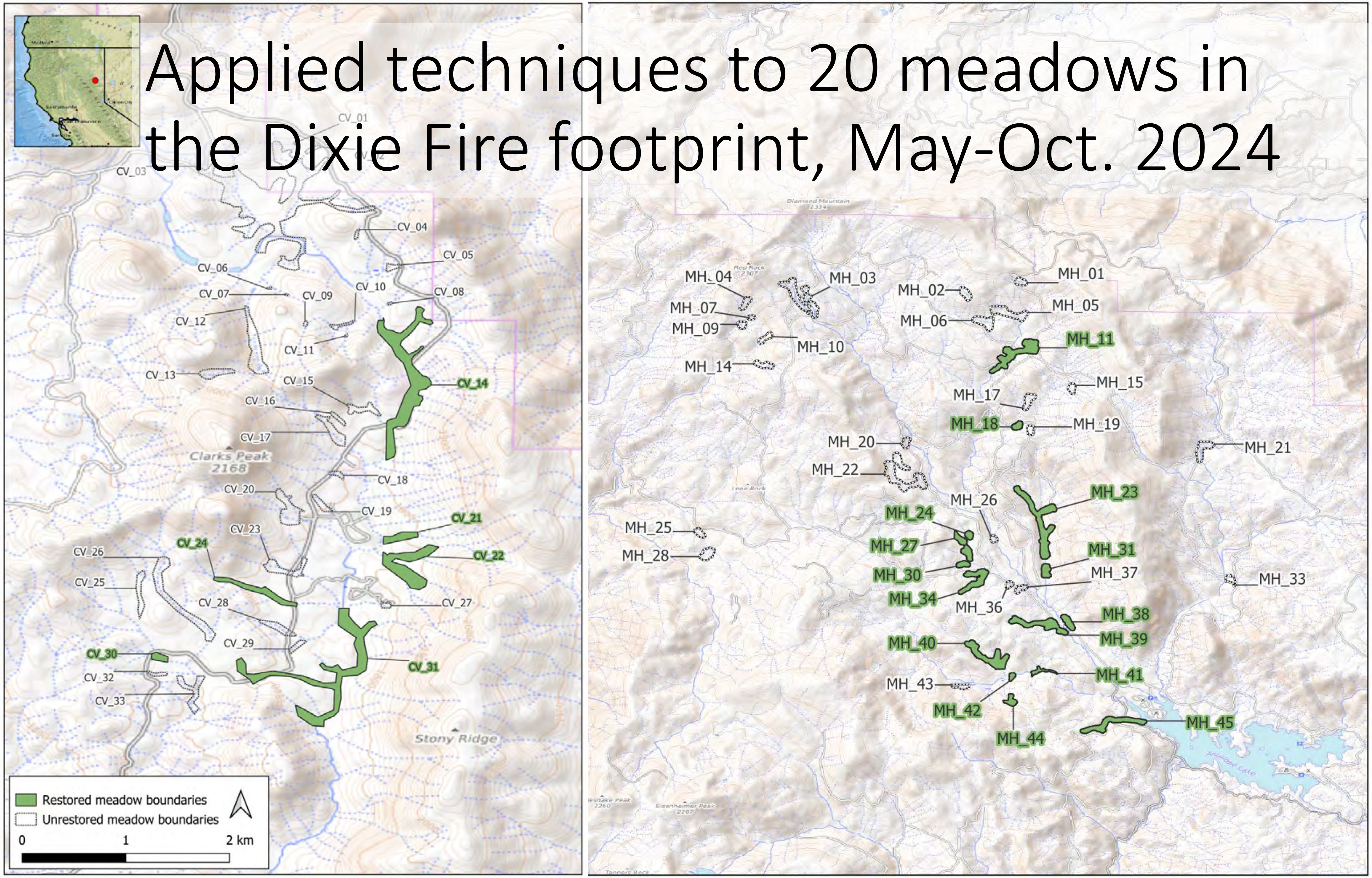
Fall 2021
Fall 2024

Post fire without treatment, meadows loose ground to upland vegetation

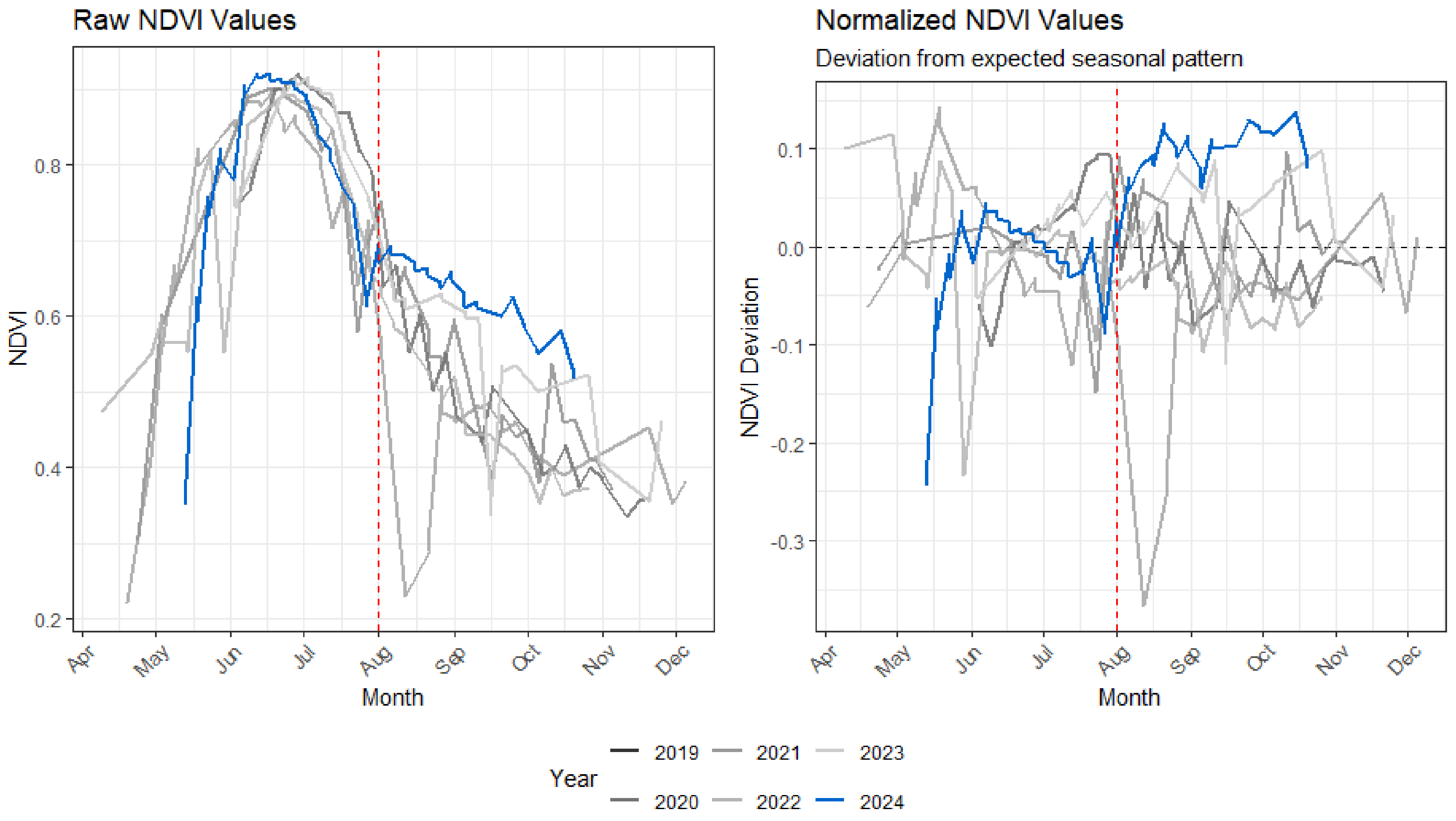




Applied techniques to 20 meadows in the Dixie Fire footprint, May-Oct. 2024



Boost in late season vegetation greenness following restoration



Key Takeaways

- It is easy to forget what we've lost.
- Resetting the baseline presents opportunities for landscape scale restoration efforts.
- Low-tech process-based restoration can rapidly increase groundwater storage and activate channel aggradation, especially in burned landscapes.
- The scale of degradation necessitates working with nature and with communities.
- It is possible to ramp up restoration efforts.

Conclusions & Implications

- Time to act, not just stare into the abyss
- Possible to achieve:
  - Local benefits
    - Species specific
    - Biodiversity
    - Fuel break
    - Climate and wildfire refugia
  - Landscape potential
    - Create safer and more fire-resistant landscapes
    - Protect sources of drinking water
    - Healthier forests
- Imperative to build strong collaboration across disciplines and communities

Collaborators/Colleagues

PSW: Adam Cummings, Joe Wagenbrenner, David Dralle
ORISE Fellows: Kate Wilcox, Jordin Jacobs, Matt Berry
Cal Poly Humboldt: Margaret Lang, Emma Sevier, Christa Meingast
Fresno State
Kevin Swift, Swift Water Design
Sierra NF, Plumas NF

Join the fun!

CALIFORNIA PROCESS BASED RESTORATION NETWORK

CalPBR.org

The Sierra Meadows Partnership

sierrameadows.org

klamathmeadows.org

Additional Materials

Scientific Manuscript describing the model:
Cummings, Adam K., Karen L. Pope, and Gilbert Mak. **"Resetting the baseline: using machine learning to find lost meadows."** *Landscape Ecology*

Scientific Manuscript describing applications of the model:
Pope, Karen L., and Adam K. Cummings. **"Recovering the lost potential of meadows to help mitigate challenges facing California's forests and water supply."** *California Fish and Wildlife Journal.*

A 2 hour recorded workshop that describes the Lost Meadows Model, how to access the data, and example applications.

Restoring Meadows and Flows for Eagle Lake Rainbow Trout

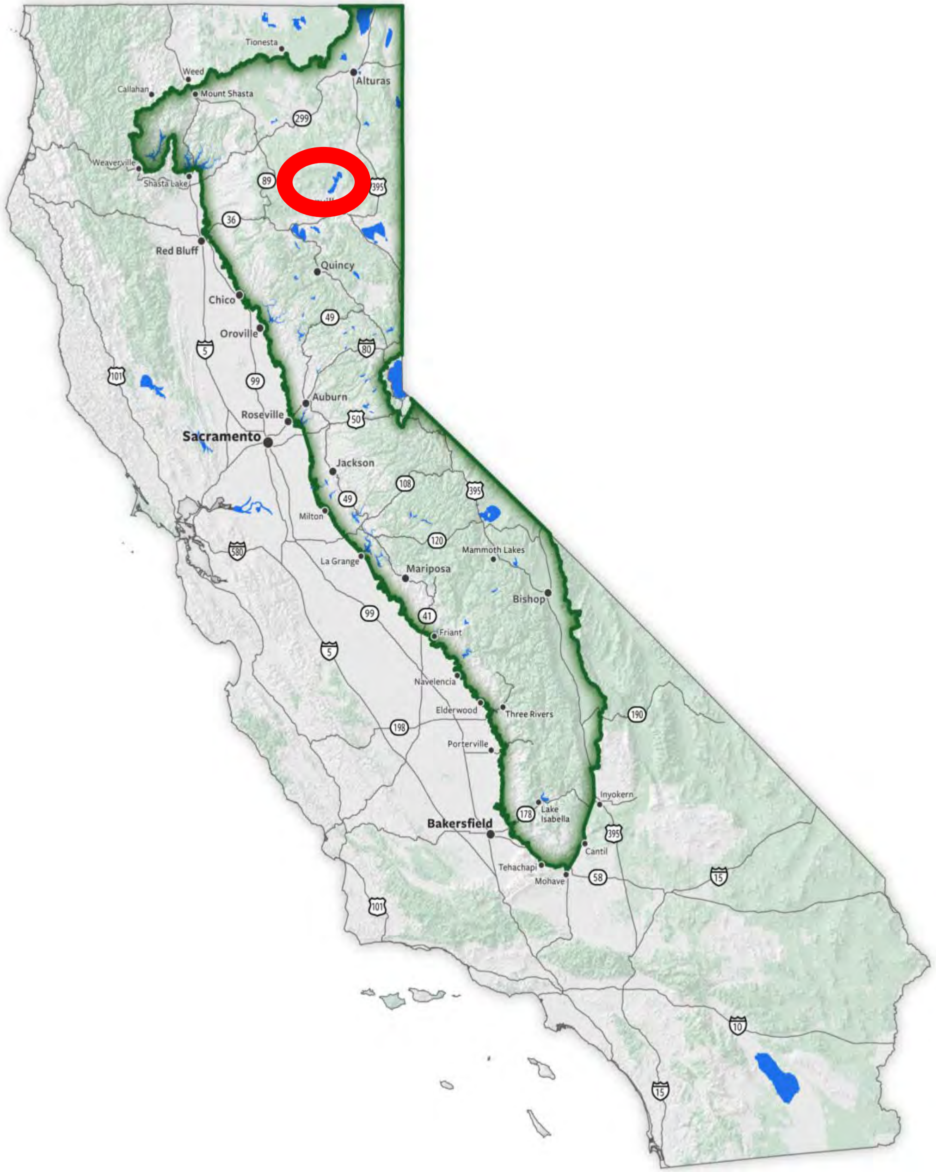
May 2, 2024

Michael Cameron
Trout Unlimited

TROUT UNLIMITED

Eagle Lake and Pine Creek

- **Eastside, terminal, alkaline lake, 5,000' elevation.**
- **At the geological convergence of Cascades, Sierra Nevada & Great Basin.**
- **Home of Eagle Rainbow Trout.**



Eagle Lake Rainbow Trout (ELRT)

- Only trout that survives in Eagle Lake
- Commercially fished in the late 1800s
- Nearly extirpated in 1940s

- Decline due to:
  - Partial draining of the lake for irrigation.
  - Degradation of Pine Creek spawning habitat through logging, road building and overgrazing.
  - Non-native brook trout.
- Now completely dependent on hatcheries.
- Petitioned several times for ESA listing.

Pine Creek

- 40-mile long, ephemeral stream.
- **Meadows essential for ELRT reproduction:**
  - **Duration of flow**
  - **Habitat – spawning and rearing**
- Legacy alterations of landscape processes – decreased duration of flows (~ avg. 90-110 days/year).
- **Reduced flow duration primary barrier to spawning.**

75 Years of Conservation Effort

- 1950 – Hatchery production begins
- 1987 – Coordinated Resources Planning Mgt. Group
- 2007 – ELRT Conservation Plan
- 2015 – ELRT Conservation Agreement
- 2015 – Meadow assessments & prioritization
- 2019 – McKenzie Meadow restored
- 2021 – Confluence Meadow restored
- 2024 – Logan Springs Meadow restored
- 2024 – Champs & McCoy Meadow design started

Pine Creek Coordinated Resources Management Planning Group (CRMP)

Since 1987

75 Years of Conservation Effort

Partial List of Leading Contributors

- Steven Young
- W.S. Platt
- Sherman Jensen
- Peter Moyle
- Teresa Pustejovsky
- Lisa Thompson
- David Lile
- Sabra Purdy
- Todd Sloat
- Matt Kiese
- Matt Weld
- Bobette Jones
- Paul Divine
- Rene Henery


Pine Creek Geomorphic Assessment and Trend Analysis

River Run Consulting
P. O. Box 68
Cedarville, CA 96104

And:

Todd Sloat Biological Consulting, Inc.
P.O. Box 125
McArthur, CA 96056

Prepared for: Pine Creek Coordinated Resource Management Planning group

September 1,2015

TERESA PUSTEJOVSKY
Under Contract with Honey Lake Valley Resource Conservation District
Funded by Lassen County Resource Advisory Council
At Recommendation of Pine Creek Coordinated Resources Management Planning Group
June 2007


Pine Creek Watershed:
Prioritization of Meadow Restoration Opportunities

Prepared By:
Todd Sloat Biological


Conservation Agreement
for the
Eagle Lake Rainbow Trout
(*Oncorhynchus mykiss aquilarum*)
Lassen County, California

California Department of Fish and Wildlife
Northern Region

USDA Forest Service, Pacific Southwest Region
Eagle Lake Ranger District, Lassen National Forest

U.S. Fish and Wildlife Service, Pacific Southwest Region
Sacramento Fish and Wildlife Office


American Rivers
Rivers Connect Us

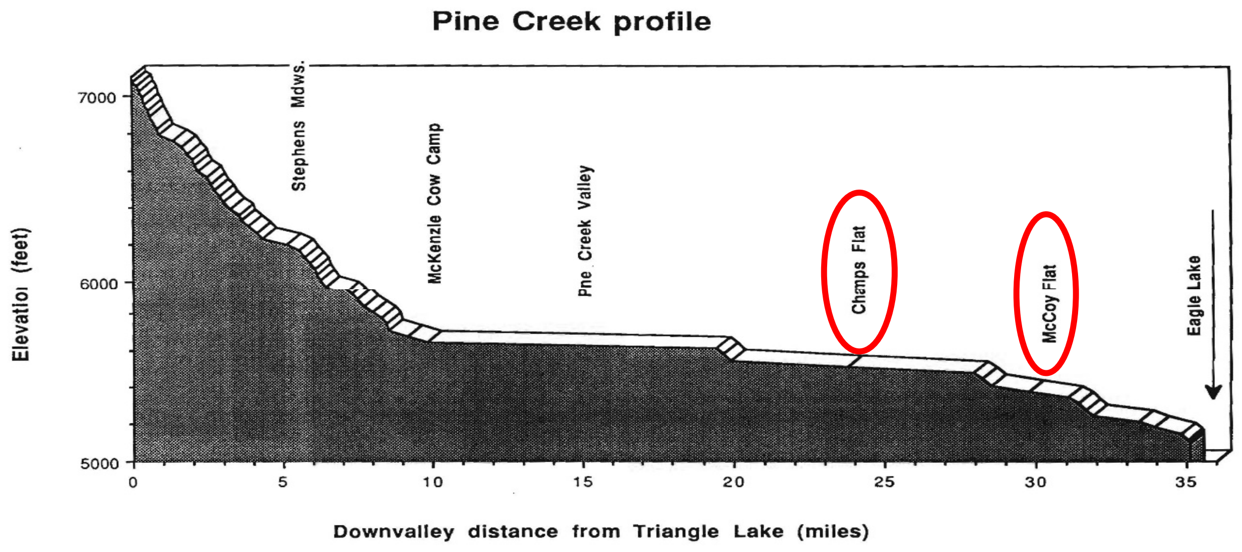
PINE CREEK MEADOW ASSESSMENT

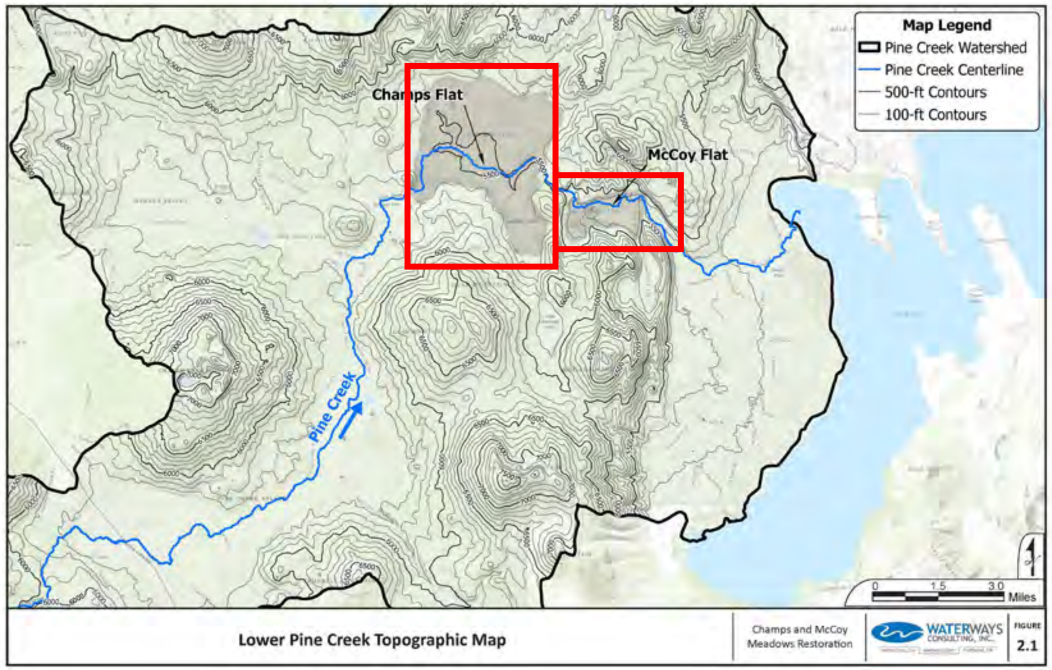
Champs Flat & McCoy Flat Restoration Design Project

Two most important Pine Creek meadows

Champs Flat Meadow ~ 3,000 acres

McCoy Flat Meadow – 700 acres





Champs Flat & McCoy Flat Restoration Design Project

Pre-Disturbance Conditions

- Anabranching multi-thread channel pattern.
- Smaller channel spread water over floodplain, low erosive force.
- Geomorphology – dynamically stable.
- Net sediment storage.
- High vertical & lateral connectivity between the channel & floodplain.
- Wetland vegetation, especially deep-rooted wetland graminoids.

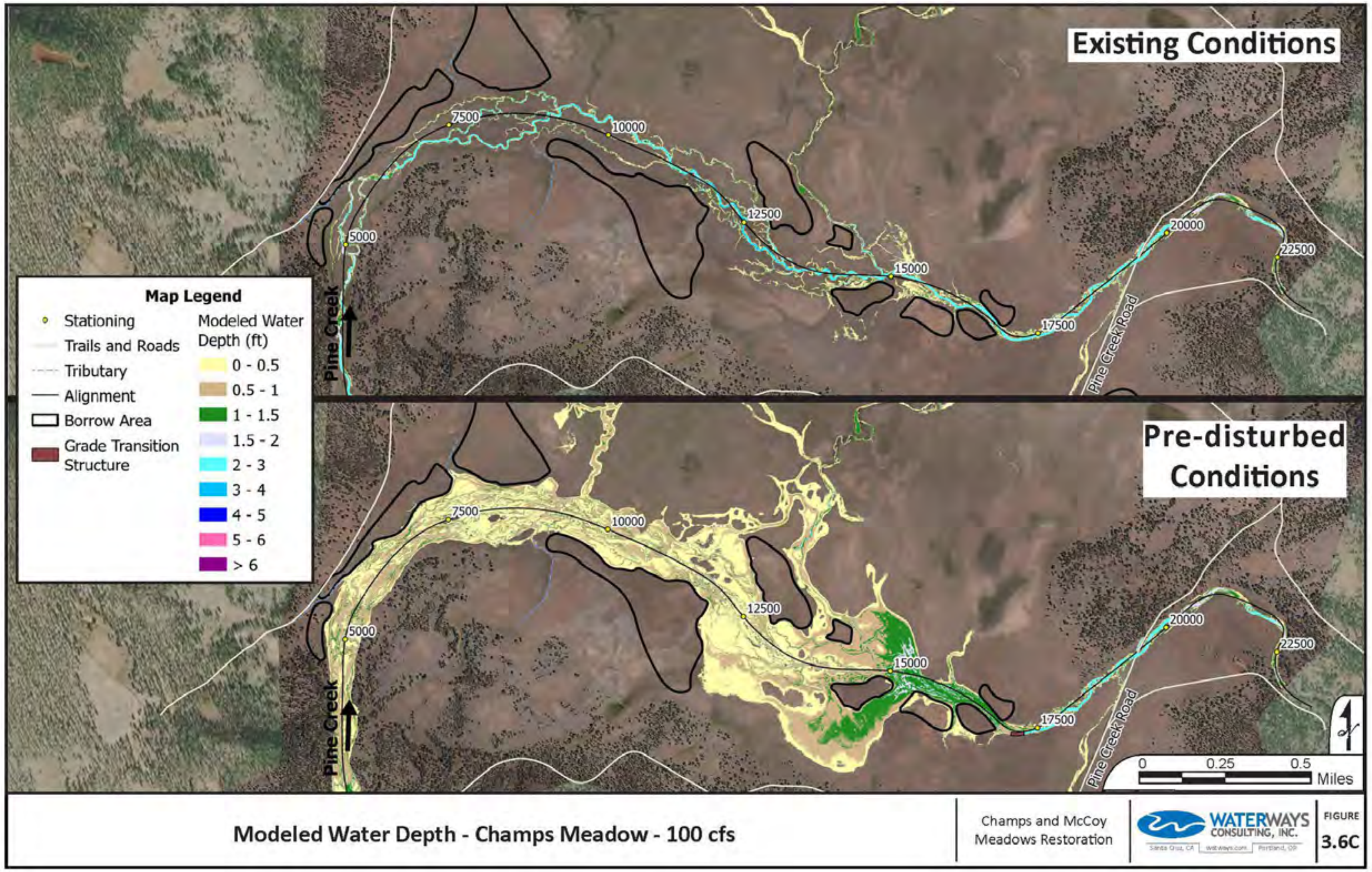
Restored – Confluence Meadow

Champs Flat & McCoy Flat Restoration Design Project

Post-Disturbance Conditions

- Deeply incised > 6 feet.
- Disconnected from floodplain.
- Active eroding banks.
- Oversized, single channel.
- Shear stress 2-3 times pre-disturbance values.
- Low groundwater levels.
- Vegetation converted to annual grassland.
- Inset floodplain is still developing, but most high-quality habitat is gone.

Champs Flat & McCoy Flat Restoration Design Project

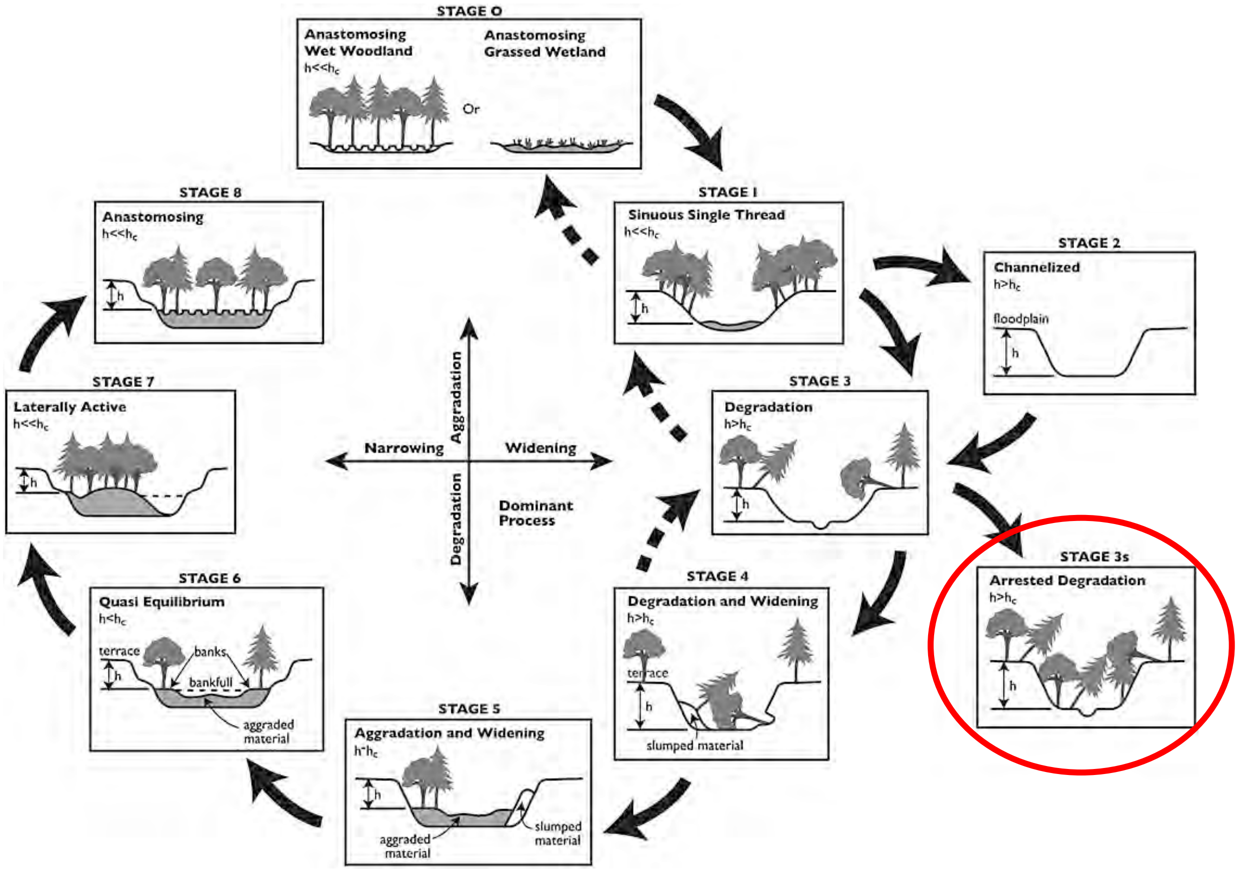


Modeled Inundation

- Existing conditions – flows access floodplain between 150 – 250 cfs.
- Pre-disturbance conditions – flows access floodplain between 10 – 50 cfs.

Champs Flat & McCoy Flat Restoration Design Project

Channel Evolution Model used for Development of Alternatives



Cluer and Thorne (2014)

- Channel has reached Stage 3/3s (Arrested Degradation).
- High design complexity.
- Floodplain vegetation is poor.
- High risk of re-incision.
- Hydrogeomorphic function, ecosystem and habitat benefits less than about 25% of potential.

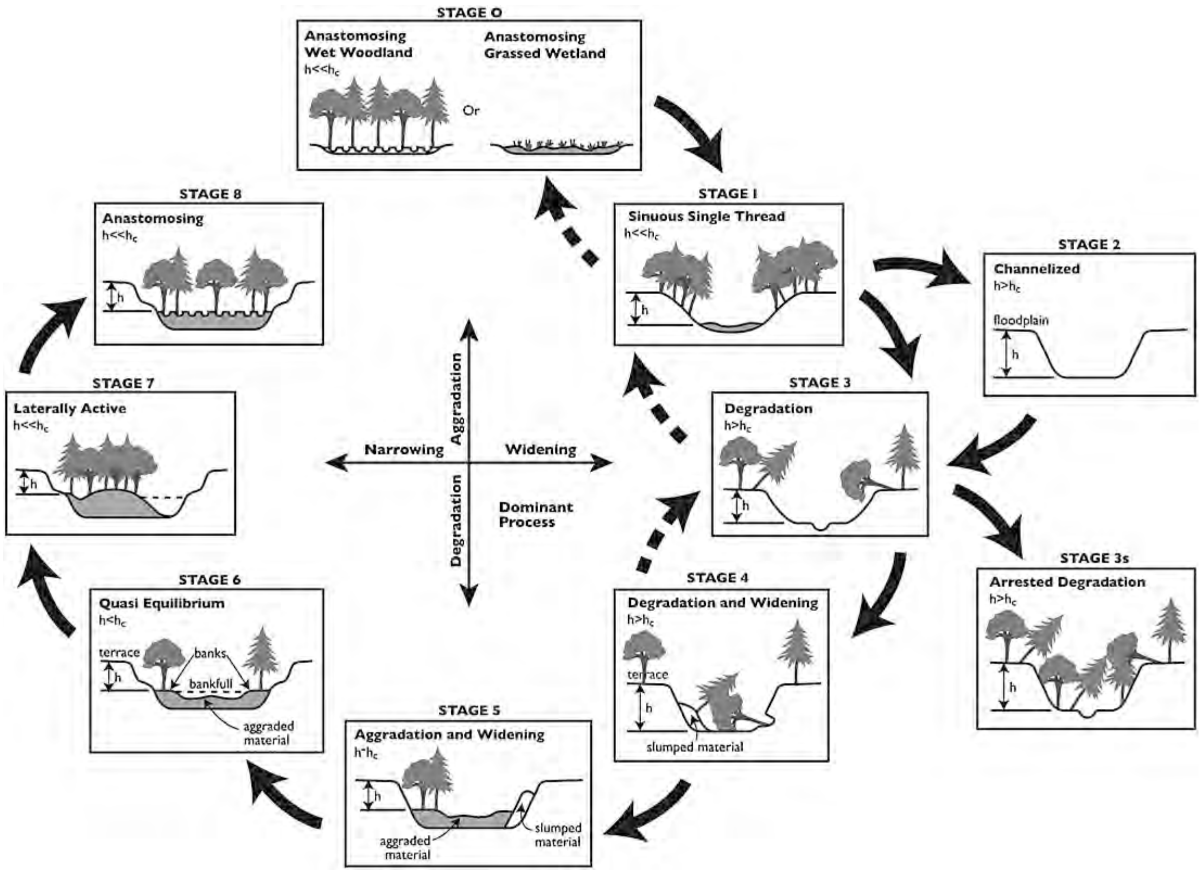
Champs Flat & McCoy Flat Restoration Design Project

Design Objectives – Improve:

- Geomorphic and hydrologic function.
- Aquatic habitat function.
- Meadow ecosystem function.
- Resistance and increase recovery capacity to flood, fire & drought.

Alternatives Developed for Each Stage.

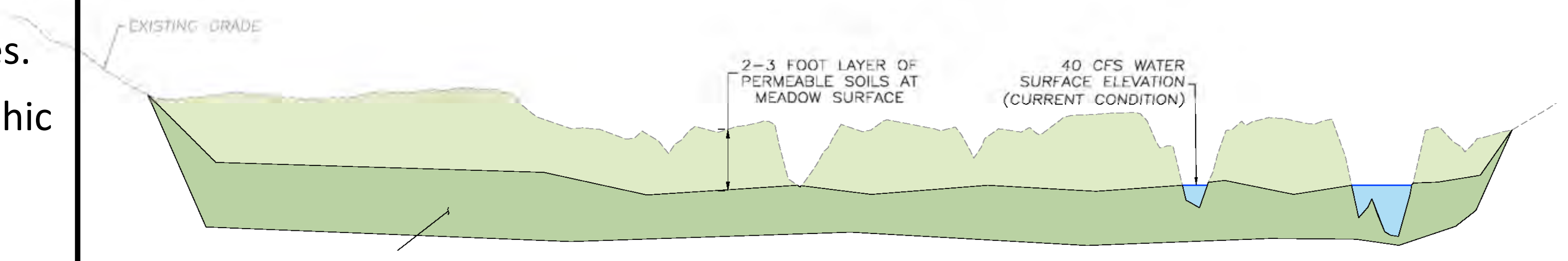
- Without significant external forcing, Champs and McCoy Flats will progress slowly through SEM due to erosion-resistant streambanks and lack of coarse sediment supply.
- Stage 0 deemed most likely to succeed.



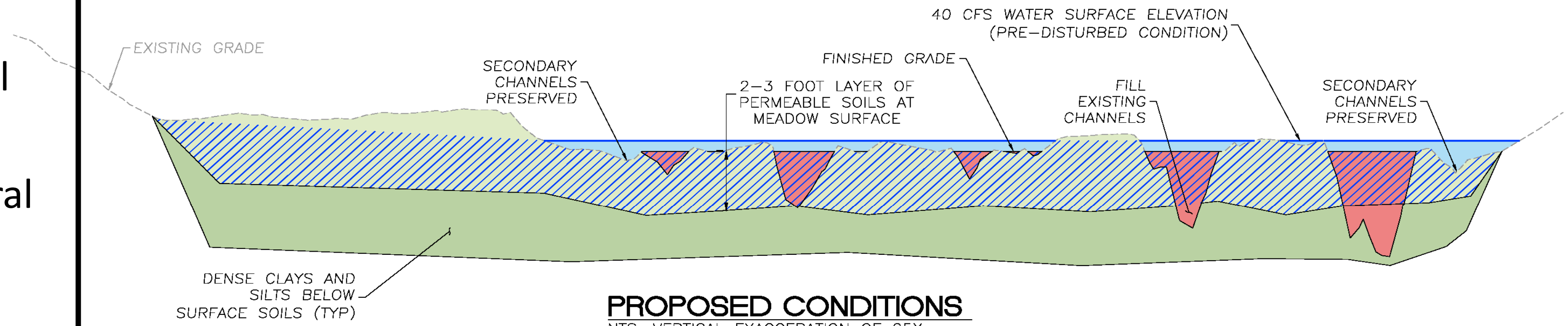
Champs Flat & McCoy Flat Restoration Design Project

Recommended Alternative - Complete Channel Fill with Borrow From Terraces

- Fill all major incised channels - material obtained from terraces.
- Most likely to restore geomorphic and ecosystem processes.
- Focus not on site-specific floodplain and channel form.
- Channel will undergo a period of adjustment post-project.
- Result in anabranching channel pattern.
- Result in high vertical and lateral floodplain connectivity.
- Manage re-incision risk by promoting flow access to the floodplain below 1.5 to 2-year recurrence interval.



Existing Conditions



PROPOSED CONDITIONS
NTS: VERTICAL EXAGGERATION OF 25X

Champs Flat & McCoy Flat Restoration Design Project

Next Steps

- Progress from 30% to 65% to 90% Design Stages – Spring 2026
- NEPA and Permitting completed by Winter 2026
- Construction – funding dependent – as early as fall 2027

Acknowledgements

- California Department of Fish and Wildlife
- United State Forest Service
- Matt Weld - Waterways Consulting
- Todd Sloat
- Sabra Purdy
- Matt Kiese