Klamath Dam Removal - Lessons Learned as a River is Reborn

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

Session Coordinators: Bob Pagliuco, *Marine Habitat Resource Specialist, NOAA Fisheries Restoration Center*; and Mike Belchik *Sr. Water Policy Analyst, Yurok Tribe*

This session will highlight the current state of post-dam removal restoration, dam removal lessons learned, science and monitoring, and what the future holds following implementation of the largest river restoration project in the world.

Free flowing Klamath River post-dam removal.
Photo: Swiftwater Films

Presentations

- **Planning, Implementation, and Lessons Learned for the Removal of the Four-Dam Complex of the Lower Klamath Project**
  Mort McMillen, *Executive Vice-President, McMillen Inc.*……………………………………………………..…....Slide 4

- **From Reservoirs to Rivers: A Look at the Past Year of the Klamath River Renewal Project Restoration Journey**
  Dan Chase, *Director, Fisheries, Aquatics & Design – Western Region, RES*……………………………….......Slide 87

- **Water Quality Conditions During Klamath Dam Removal Drawdown**
  John R. Oberholzer Dent, *Biologist, Karuk Tribe Department of Natural Resources* ………………………...….Slide 132
  .

- **Mapping a New River – First Aerial Surveys of the Klamath River After a Century of Dams**
  DJ Bandrowski, P.E., *Senior Civil Engineer/Program Manager; Yurok Tribe*………………………………......Slide 173

- **Factors Limiting Filamentous Algae and Rooted Macrophyte Growth During Dam Removal in the Klamath River**
  Isabelle Tang, MS Student, *Oregon State University*……………………………………………..………...….Slide 199

- **Quantifying Benthic Macroinvertebrate Responses to Klamath Dam Removal During Juvenile Salmonid Outmigration Season**
  Rosa Cox, Masters Student, *Cal Poly Humboldt*………………………………………………….……….....….Slide 229

- **Evaluating the Effectiveness of Dam Removal on the Klamath River Using SONAR and Radio Telemetry**
  James Whelan, *Project Manager, California Trout* and Alex Corum, *Sr. Fisheries Biologist, Karuk Tribe*…..…..…....Slide 268

Planning, Implementation, and Lessons Learned for the Removal of the Four-Dam Complex of the Lower Klamath Project

McMillen

Morton D. McMillen, Executive VP, McMillen Inc.

MAY 1, 2025

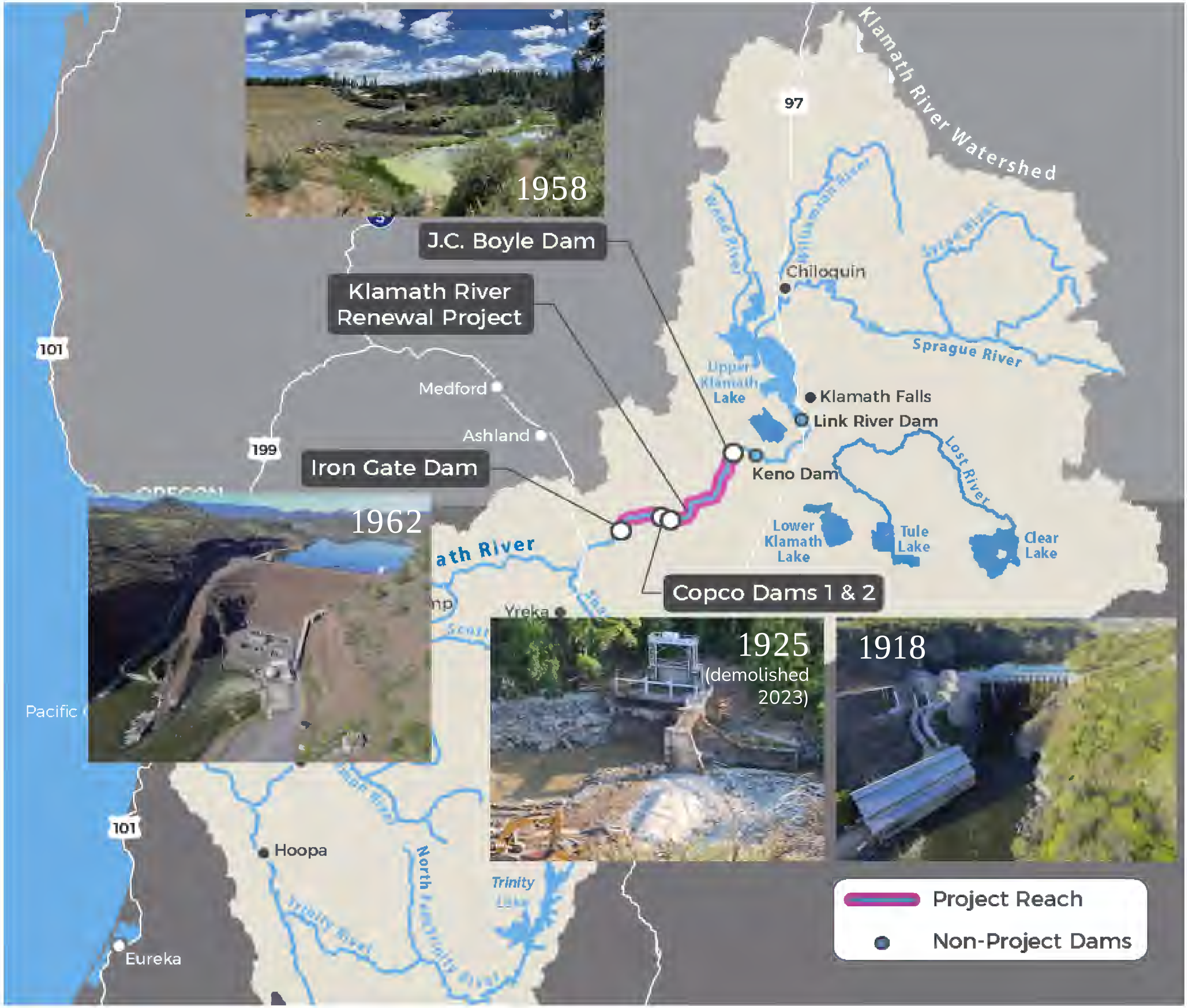
Agenda

- General Project Overview
- Dam Removal Approach
- Dam Safety Program
- Lessons Learned
- Questions

WARNING

“Presentation by pocket protector wearing introverted old school civil engineer.”

Project Vicinity Map



Project Purpose

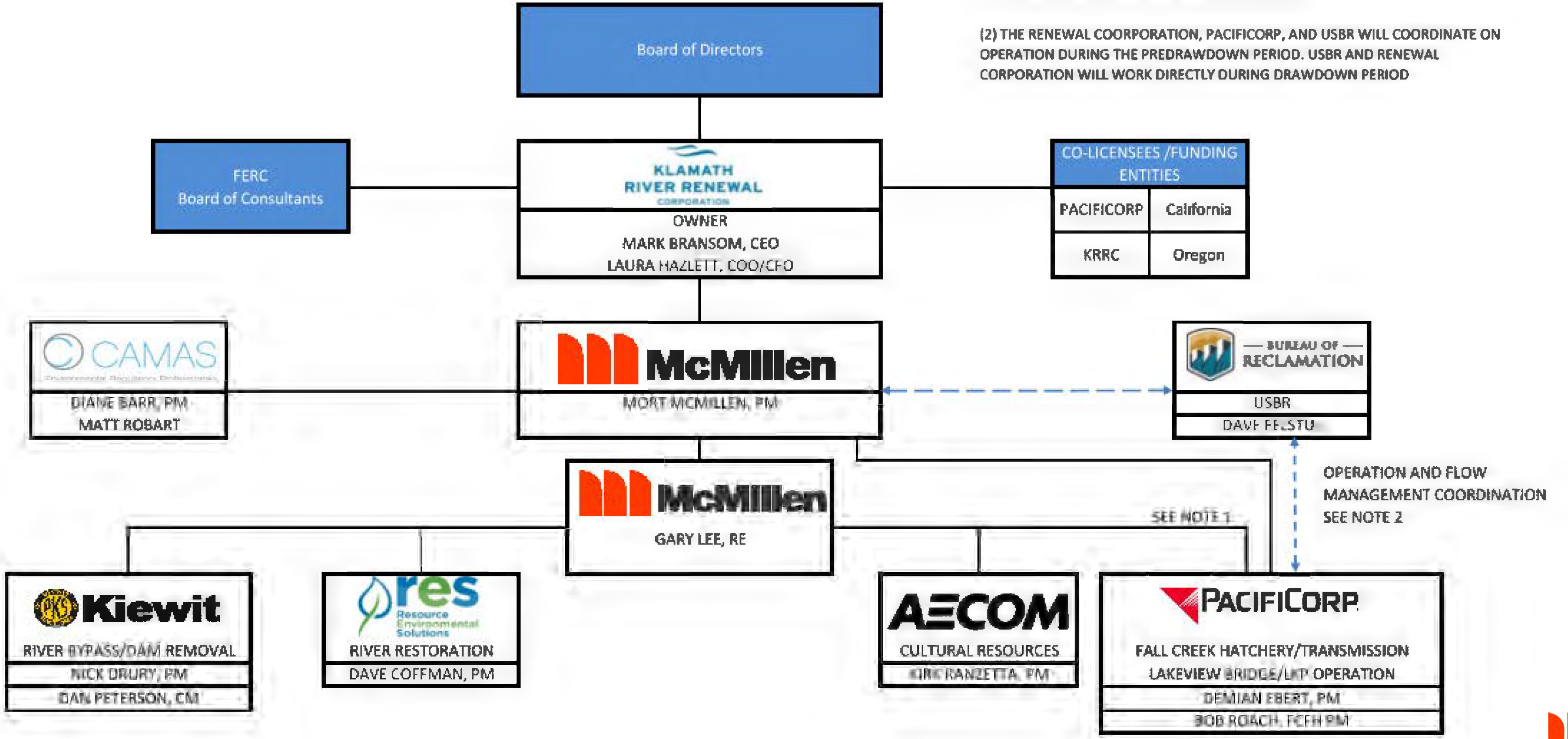
Achieve dam removal, a free-flowing condition on the Klamath River, and volitional fish passage.

KRRC Organization Chart—Implementation Phase

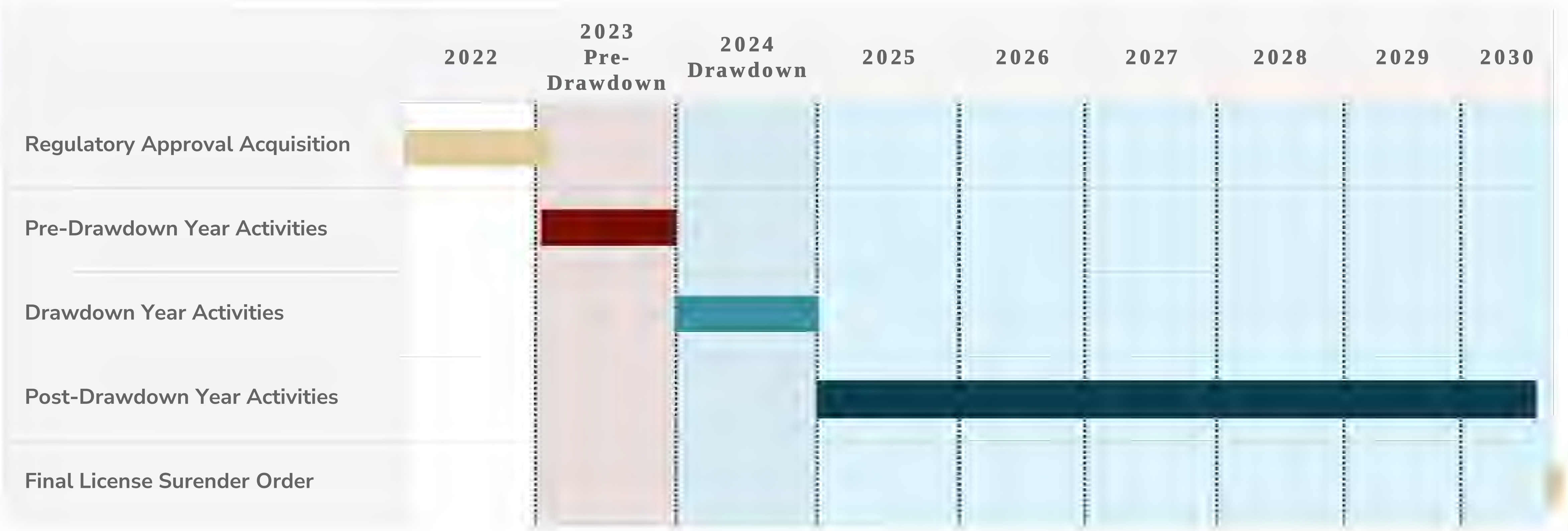
NOTES:

(1) OPERATING LKP UNDER AN O&M AGREEMENT WITH THE RENEWEL COORPORATION DURING PRE-DRAWDOWN PERIOD.

(2) THE RENEWAL COORPORATION, PACIFICORP, AND USBR WILL COORDINATE ON OPERATION DURING THE PREDRAWDOWN PERIOD. USBR AND RENEWAL CORPORATION WILL WORK DIRECTLY DURING DRAWDOWN PERIOD



Dam Removal Project Timeline



Pre-Drawdown Year:

- Dam/tunnel modifications
- Road/bridge improvements
- CoY Waterline Replacement
- Fall Creek Hatchery Construction
- Water Quality/Quantity Monitoring
- Copco No. 2 Dam Removal

Drawdown Year:

- Dam and infrastructure removal
- Initial reservoir restoration

Post-Drawdown Years:

- Site Restoration
- Monitoring/Adaptive Management

Observations and Lessons Learned

How do you Approach Large Dam Removal?

Review the Original Dam Construction

- Construction drawings
- Construction photos
- Construction manager reports
- Identify original borrow sources, cofferdam and diversion plans, temporary works, and material placement records
- Look for field adjustments during construction – why did they do this?

Main Engineering Considerations for Dam Removal

- Hydrologic and river flow conditions
- Means and methods for lowering reservoirs – low level outlets
- Cofferdam and water diversion requirements
- Construction access
- Means and methods for dam removal
- Dam safety during construction
- Disposal sites
- Site restoration
- Regulatory and permitting requirements – how do you get the dams out AND meet these conditions

Regulatory: 70 + Approvals/Agreements

FEDERAL

15+

FERC, USACE, USFWS, NMFS, NEPA (3), NPS, BLM, EPA

STATE

30+

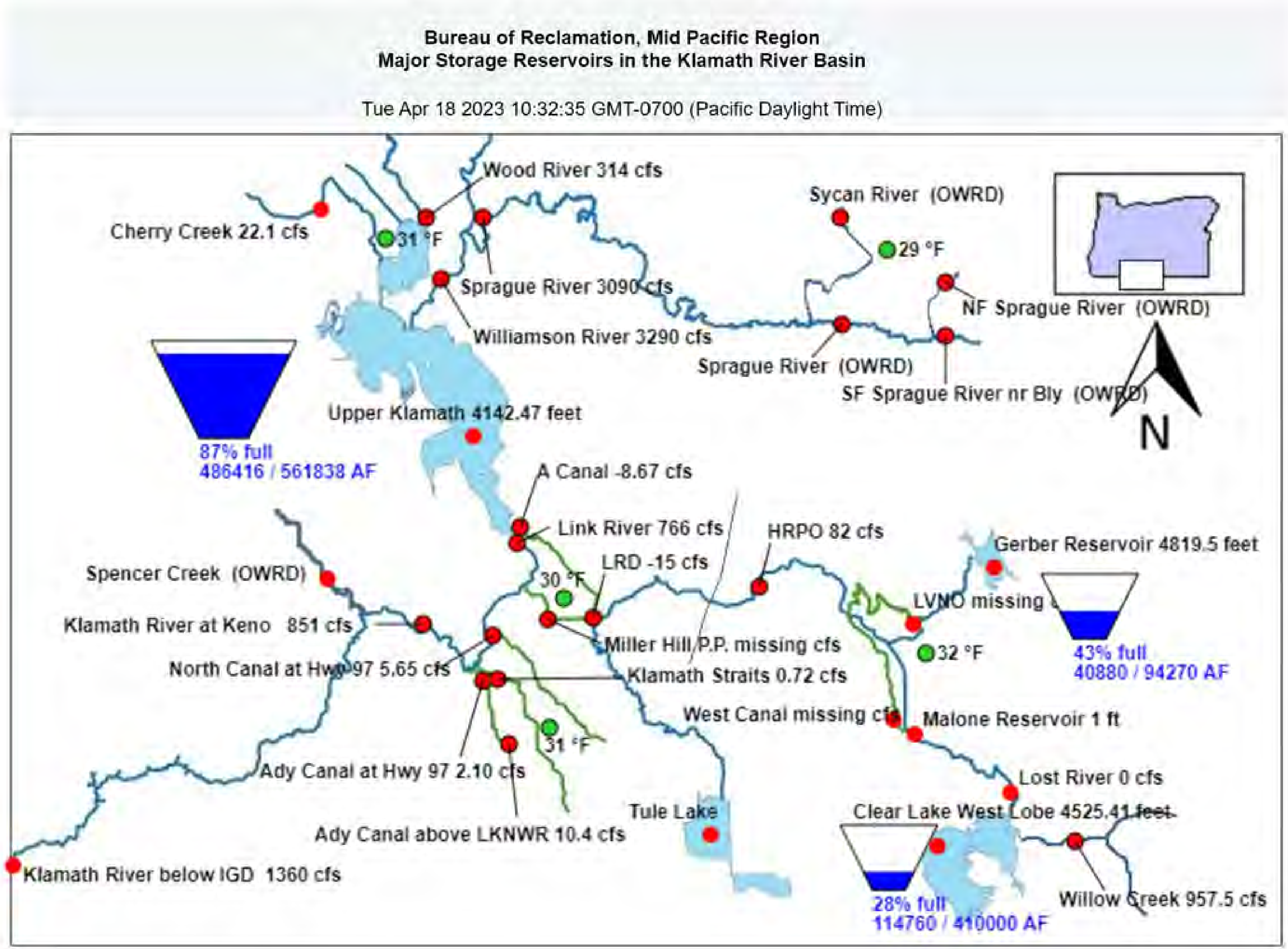
401s, DSOD, S106, NPDES, DSL, Clean Fill, Haz Waste, Coastal Comm, Fire, Dust, Air Quality, WQ Plans

COUNTY

25+

MOU’s, Drilling, Haz Waste, Signs, Septic, Encroachments, Demo, Bridges, Wells, Waterlines

Upper Klamath Basin



Flow Management and Operations Coordination

Pre-Drawdown Period

- Monitor spring runoff to determine timing for initiating Pre-Drawdown construction activities
- Coordinate peaking flow operation at JC Boyle to support whitewater community recreation
- Manage flow releases from Keno and Lower Klamath Reservoir operations to support shutting down Copco No. 1 to remove Copco No. 2 dam, install access, and remove trees from Ward Canyon
- Maintain flows to meet BiOp requirements in Klamath River below Iron Gate Dam

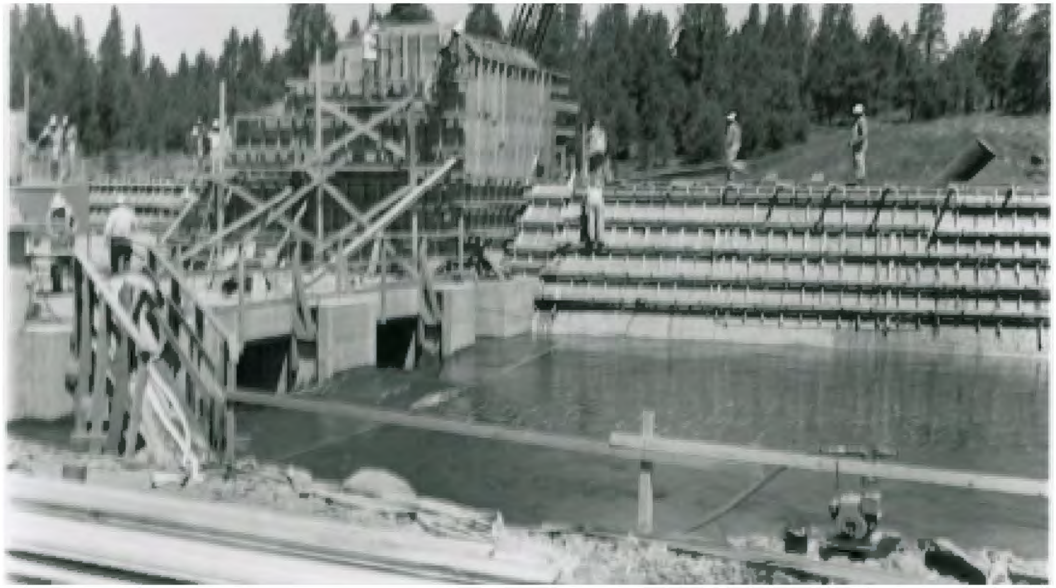
Drawdown Period

- Determine start date for dam removal
- Reduces flow from Keno to support low-level outlet final opening
- Reduces flow from Keno to support final Iron Gate Dam cofferdam breach
- Control flood flows out of Klamath Lake
- Maintain flows to meet BiOp requirements in Klamath River below Iron Gate Dam

J.C. Boyle Dam

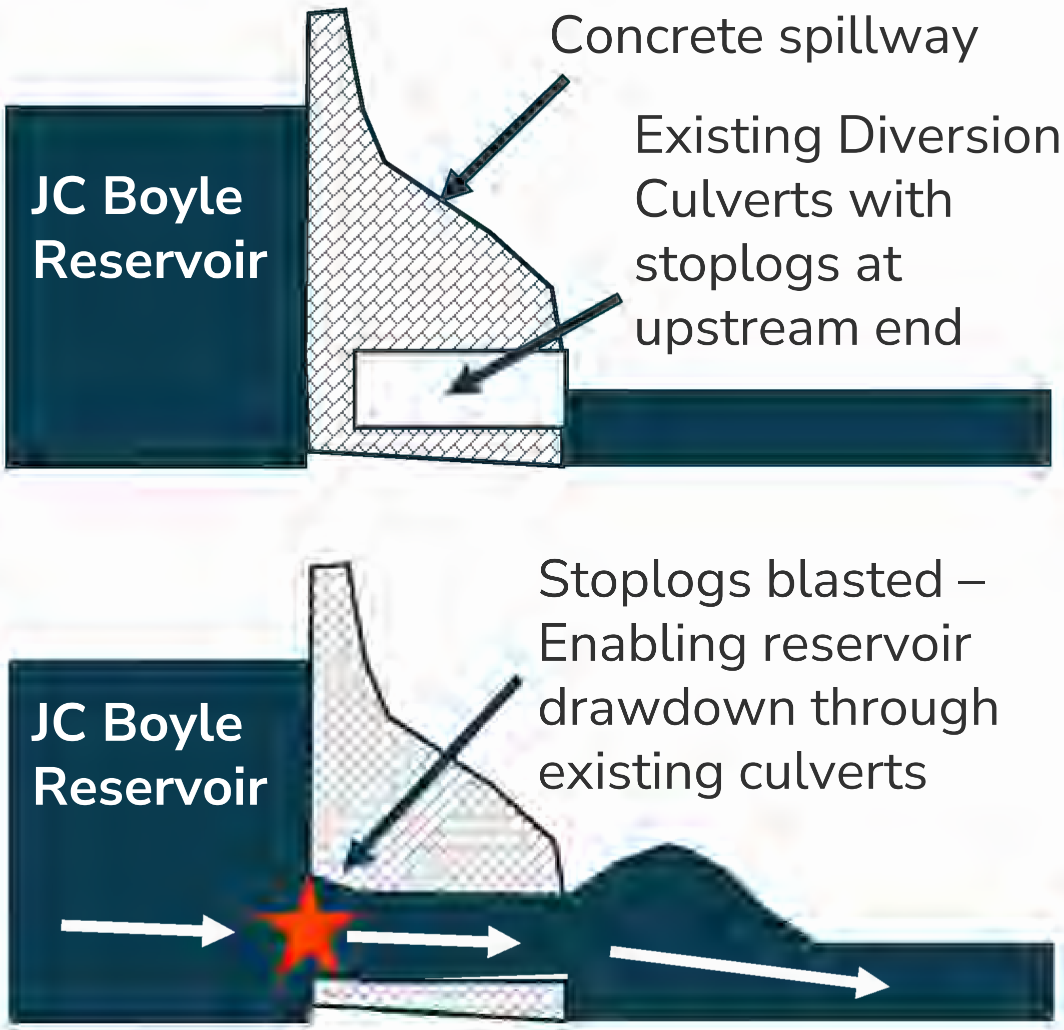
JC Boyle original approach channel and spillway low-level conduits under construction.

JC Boyle original approach channel with river bypassed through low-level outlets under the spillway



JC Boyle Reservoir Drawdown & Dam Removal

1) JC Boyle reservoir was drawn down in January 2024. Existing culverts underneath the dam (which were used to divert water during original construction) were opened to provide a low-level outlet at the spillway.
2) Stoplogs (a thin concrete wall) that were at the upstream end of the diversion culverts were blasted out, allowing the reservoir to drawdown with water passing beneath the existing spillway.

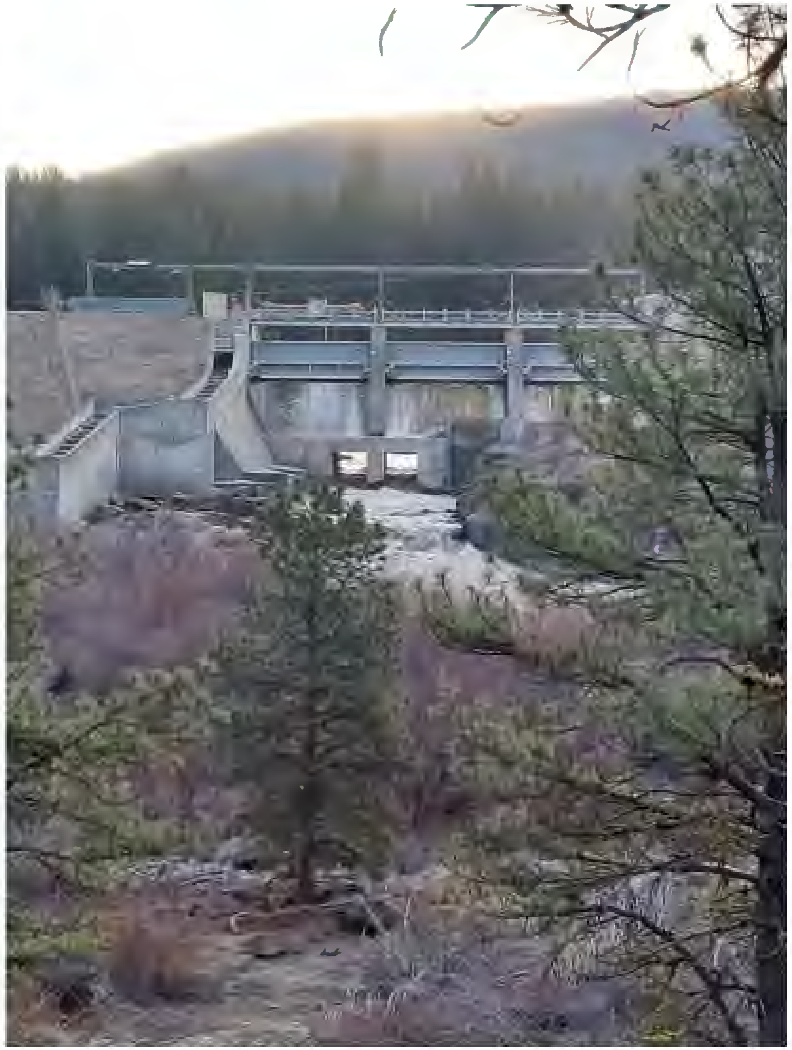


JC Boyle Drawdown

Reservoir drawdown initiated after blasting the first diversion culvert.

16 January 2024

JC Boyle Drawdown



JC Boyle reservoir drawdown complete. Spillway conduits fully open.

February 2024

JC Boyle Drawdown

JC Boyle reservoir drawdown complete. Historic cofferdam located in the center of the image. 1200 cfs flushing flow in progress.

24 January 2024

J.C. Boyle Dam Removal

JC Boyle cofferdam breach.
30 July 2024

J.C. Boyle Dam Removal

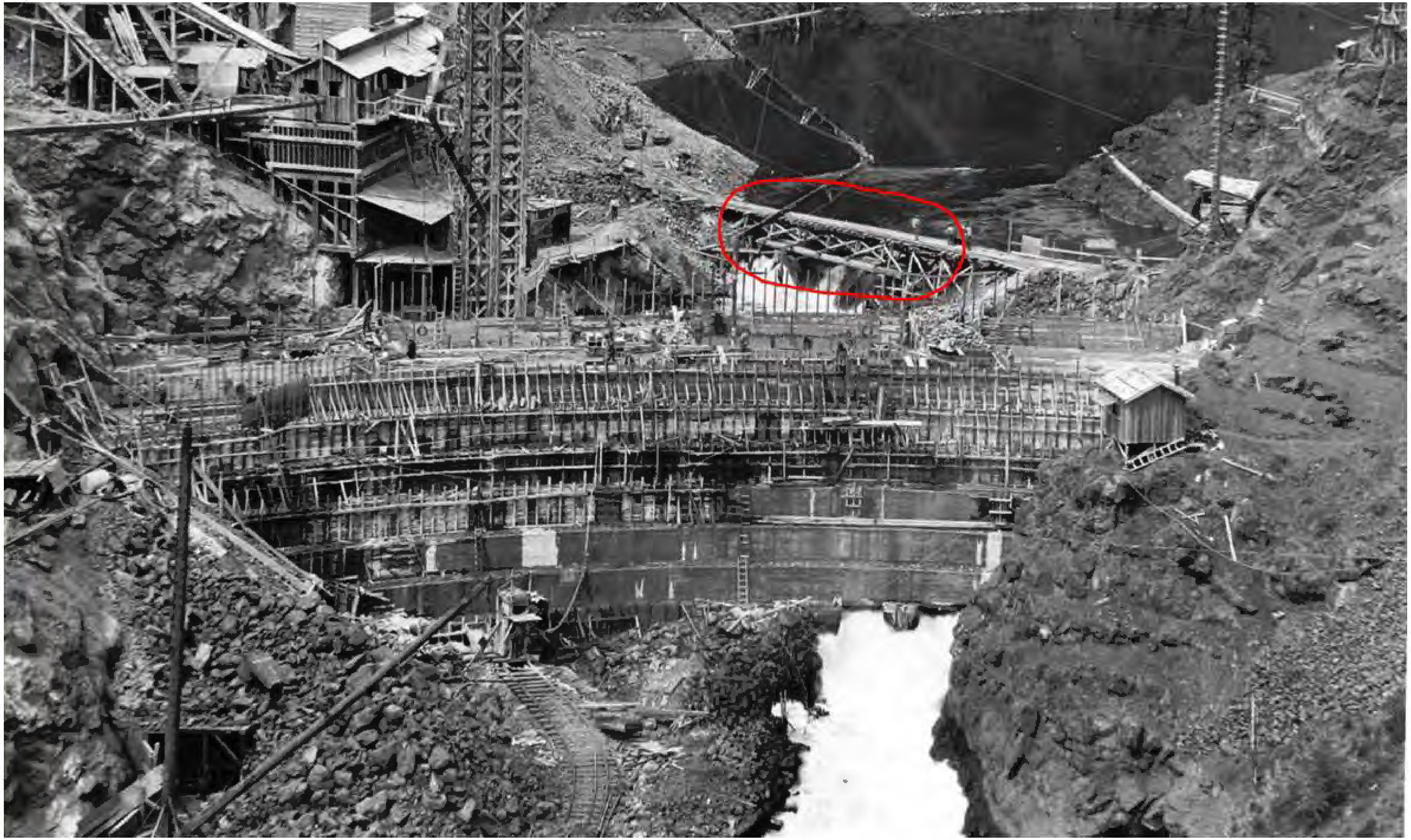
JC Boyle new river channel through dam footprint.
29 September 2024

J.C. Boyle Power Canal Removal

JC Boyle power canal
site restoration.
29 September 2024

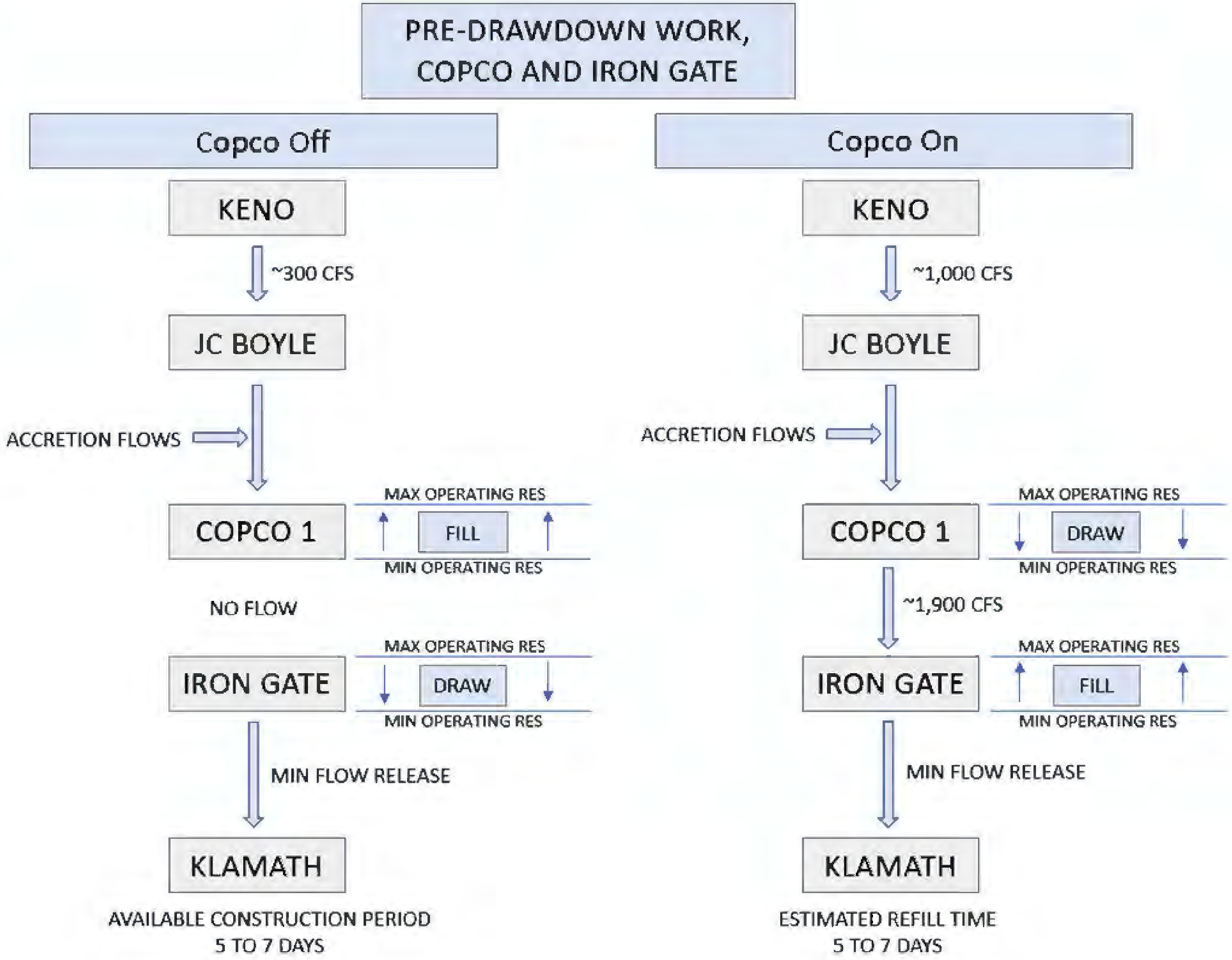
Pre-Drawdown: Copco Complex

Copco No. 1



Copco No. 2

Lower Klamath Project – Reservoir Operations Schematic



Copco Reservoir – Drawdown Schematic

Copco No. 2 Demolition – Dam

Copco No. 2 Drawdown

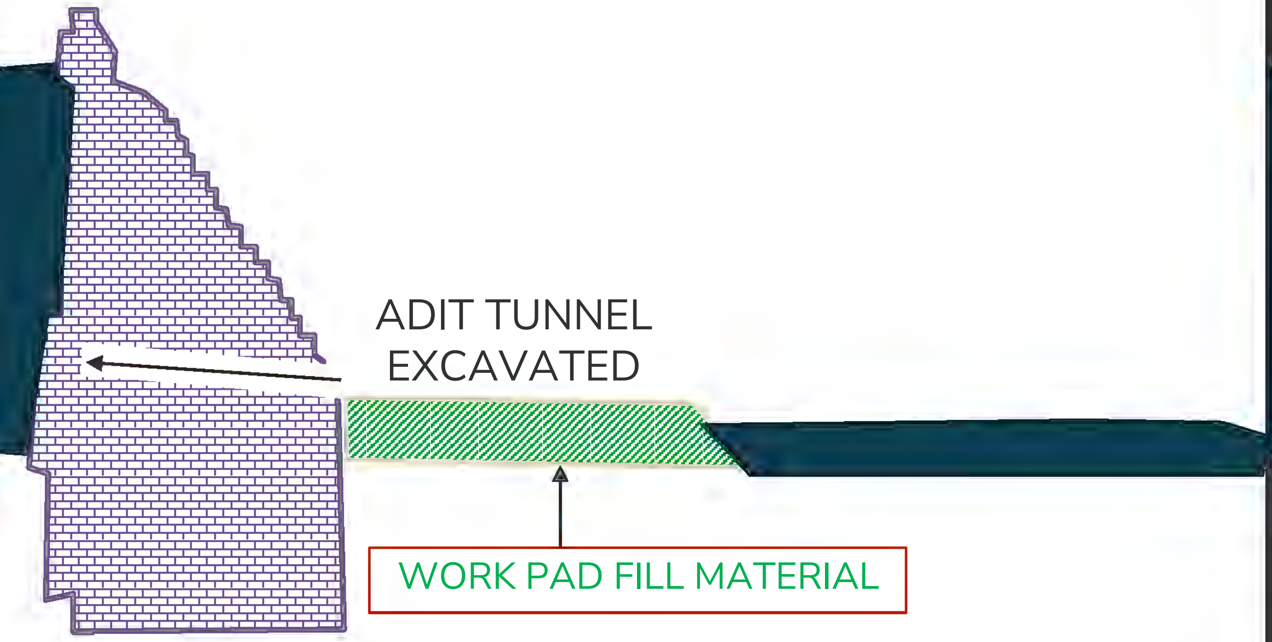
Copco 2 dam site before demolition.
13 June 2023

Completed Copco 2 dam site.
23 January 2024

2023 Pre-Drawdown: Copco No. 1 Dam Adit Tunnel

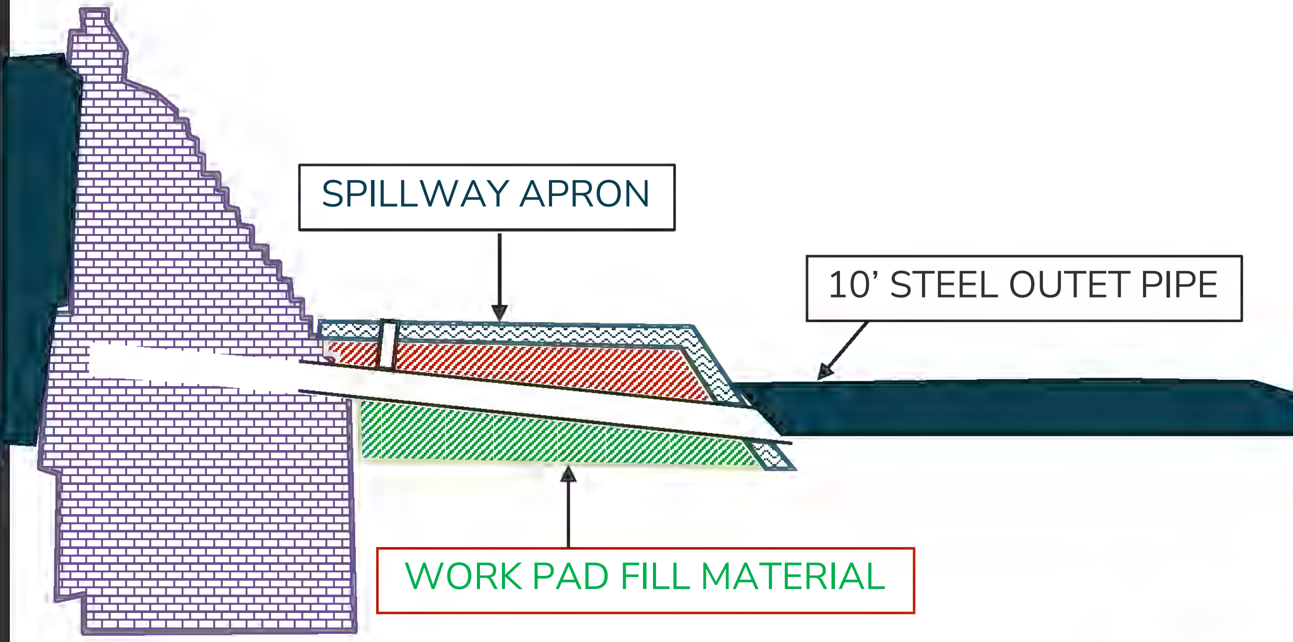
1) Green work pad constructed on downstream side at base of dam.

2) 10’ diameter adit tunnel excavated through base of dam. Plug left in place at upstream end.



3) 10’ diameter extension pipe installed downstream of tunnel.

4) Extension pipe covered with spillway apron earthen material and grouted in place.



2024 Facilities Removal: Copco No. 1

- Concurrent with dam removal, existing structures at the Copco 1 facility will be decommissioned and removed.
- Facilities include the existing hydro-power generation equipment, the powerhouse structure itself, and several other buildings in the vicinity of the dam.

Copco No. 1 – Adit and Forebay Dredging


COPCO 1 LOW LEVEL ADIT


DREDGING IN COPCO 1 FOREBAY

Copco No. 1 - Adit

First section of steel extension pipe set in place at the Copco 1 low-level adit.

10 October 2023

Copco No. 1 - Adit

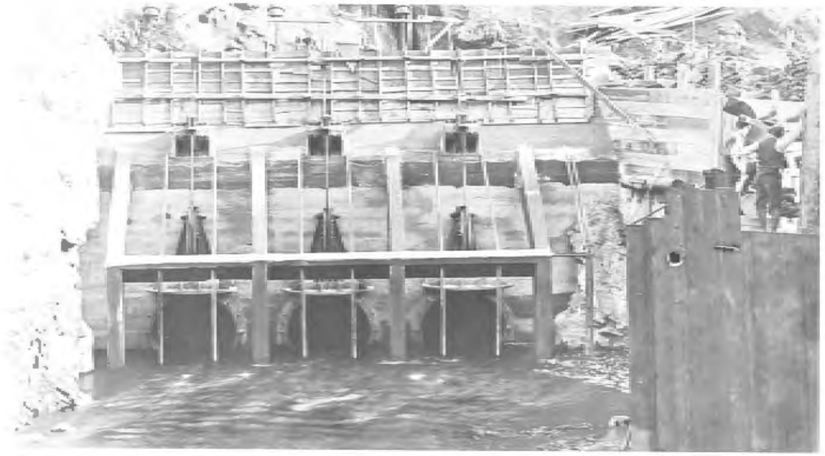
General view of Copco 1 dam and powerhouse with progress on grouted riprap placement over the steel extension pipe.
8 November 2023

Copco No. 1 Drawdown

View of Copco No. 1 Powerhouse and river channel after adit plug blasted.
23 January 2024

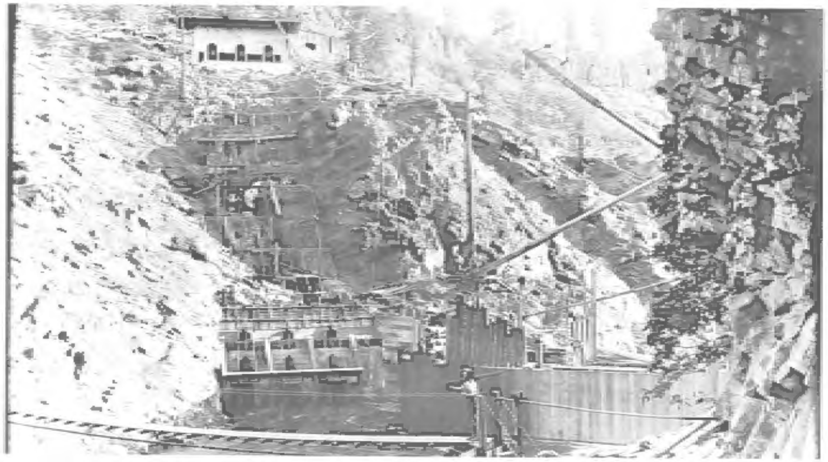
Copco No. 1

n and reservoir site looking upstream from the new dam site. *(Left center)* Working on original dam site.



First water turned through Copco No. 1 diversion tunnel, October 12, 1912.

nd Gauging Station on Klamath River at Copco No. 1, May 1911.



Headworks Copco No. 1 diversion tunnel, October 12, 1912.

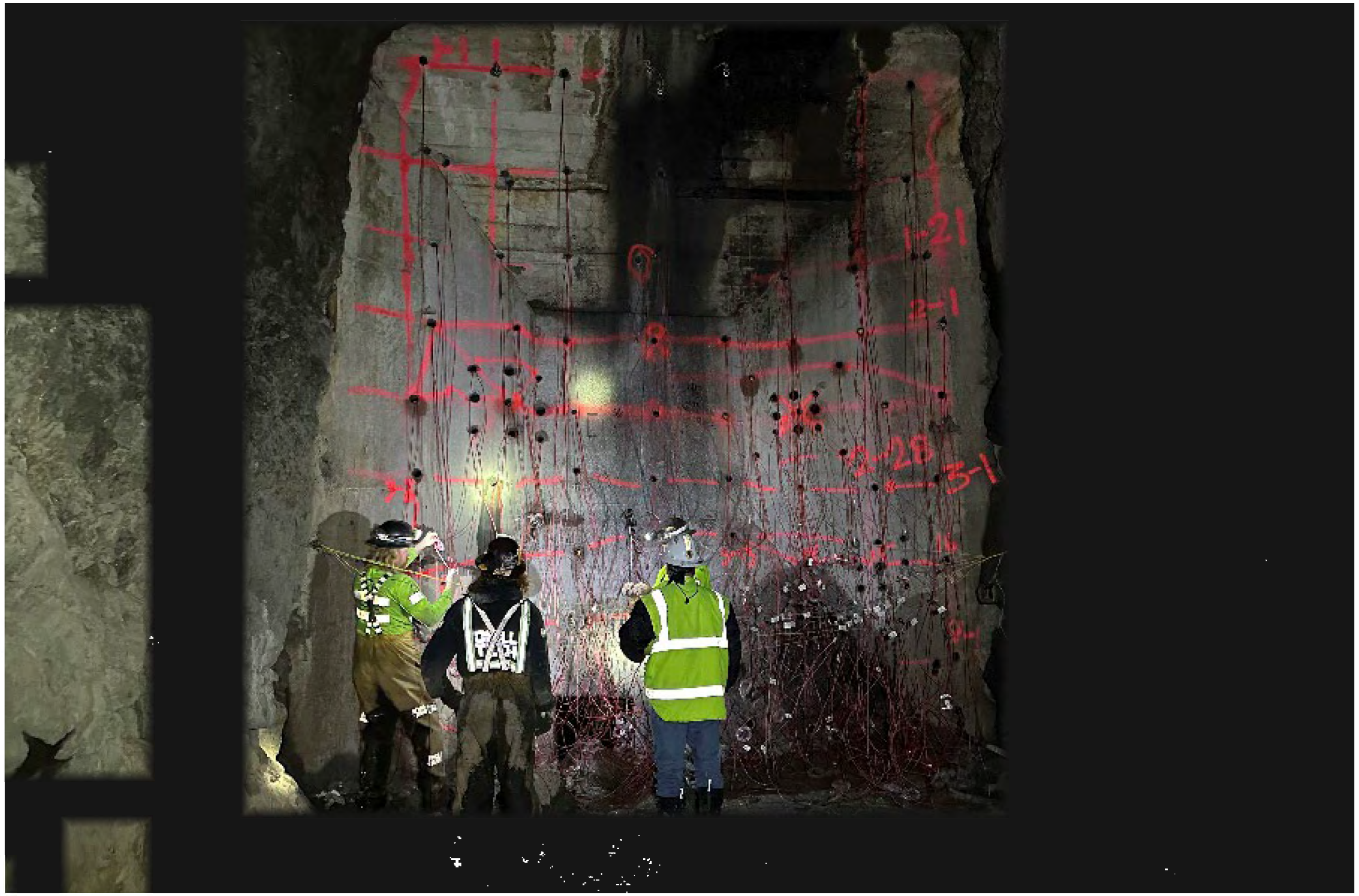
Copco No. 1 Dam Removal

Traction line winched excavator removing diversion tunnel gate operator concrete piers at Copco 1.
6 February 2024

Copco No. 1 Drawdown

View of Copco No. 1 Dam and reservoir after drawdown.
31 January 2024

Copco No. 1 Diversion Tunnel



Copco 1 diversion tunnel plug loaded and tied in.
1 March 2024

Copco No. 1 Diversion Tunnel

Copco 1 diversion tunnel after blasting the plug.
1 March 2024

Copco Complex Construction Site

Overview of Copco 1 and 2 sites and the Klamath River between Copco 1 and 2.
15 March 2024

Copco No. 1 Dam Removal

Copco No. 1 dam
Phase 4 Blast.
18 June 2024

Copco No. 1 Dam Removal

Copco No. 1 upstream excavation and powerhouse backfill.
12 July 2024

Copco No. 1 Dam Removal

Concrete rubble from Phase 5B blast partially removed.
9 August 2024

Copco No. 1 Dam Removal

Breaching historic cofferdam.
28 August 2024

Copco No. 1 Dam Removal

Klamath River flowing through the dam site.
13 September 2024

Copco No. 1 Dam Removal

Dam removal complete and site restoration in progress.
19 September 2024

Iron Gate Dam

View of Iron Gate dam and reservoir before drawdown.
20 December 2023

Iron Gate Dam

Iron Gate Dam diversion tunnel intake with cofferdam across Klamath River

Iron Gate Dam diversion tunnel intake with three sides of trashracks

Iron Gate Outlet Tunnel Modifications

Iron Gate Drawdown

Klamath River at Low Level Outlet tunnel.
5 February 2024

2024 Reservoir Drawdown & Dam Removal: Iron Gate

- Drawdown of Irongate Reservoir used the existing low level outlet diversion tunnel.
- Beginning in May, Large trucks and excavation removed the dam embankment from the top down
- Approximately 1 million cubic yards were excavated in total
- The existing spillway was be filled in with earthen materials
- The powerhouse equipment was removed and the powerhouse demolished
- Once the dam and facilities were removed, a new river channel was built in the dam footprint. Channel grading was completed in October 2024

Iron Gate Construction

Exposed diversion tunnel intake structure trash racks at Iron Gate.
12 March 2024

Iron Gate Drawdown

Iron Gate project site including dam (upper right), haul road (center), and waste disposal area (upper left). Note high water level due to ESA geomorphic releases.
15 March 2024

Iron Gate Dam Removal

Waste Disposal Site.
7 July 2024

Iron Gate Dam Removal

Embankment removal progress – looking downstream.
12 August 2024

Iron Gate Dam Removal

Waste Disposal Site.
12 August 2024

Iron Gate Dam Removal

Embankment removal from upstream.
3 September 2024

Iron Gate Dam Removal

Embankment removal and spillway fill.
29 September 2024

Dam Safety Program

Dam Safety Considerations

- Required developing plans specific to the planned construction activities and dam removal nature of the Lower Klamath Project
- Considered FERC license transfer from the original licensee, PacifiCorp, to the new co-licensee, KRRC, State of CA, and State of OR
- Addressed anticipated operation and dam safety risks during the project implementation phases: Pre-Drawdown, Drawdown, and Post-Drawdown
- Required well-developed plans and implementation by the new licensee to ensure effective public safety throughout the dam removal process

Pre-Drawdown Phase (2023) Plans

- Owners Dam Safety Program (ODSP)
- Dam Safety Surveillance and Monitoring Program (DSSMP)
- Emergency Action Plan
- Public Safety Plan
- Temporary Construction Surveillance Monitoring Plan (TCSMP)
- Temporary Construction Emergency Action Plan (TCEAP)
- Operations and Flow Management Plan
- Slope Stability Monitoring Plan
- Quality Control and Inspection Plan (QCIP)
- Copco No. 2 Final Facility Termination Plan

Drawdown Phase (2024) Plans

- Owners Dam Safety Program (ODSP)
- Dam Safety Surveillance and Monitoring Program (DSSMP)
- Emergency Action Plan
- Public Safety Plan
- Temporary Construction Surveillance Monitoring Plan (TCSMP)
- Temporary Construction Emergency Action Plan (TCEAP)
- Operations and Flow Management Plan
- Slope Stability Monitoring Plan
- Quality Control and Inspection Plan (QCIP)
- Debris Management Plan
- Copco No. 1, Iron Gate, and JC Boyle Final Facility Termination Plan

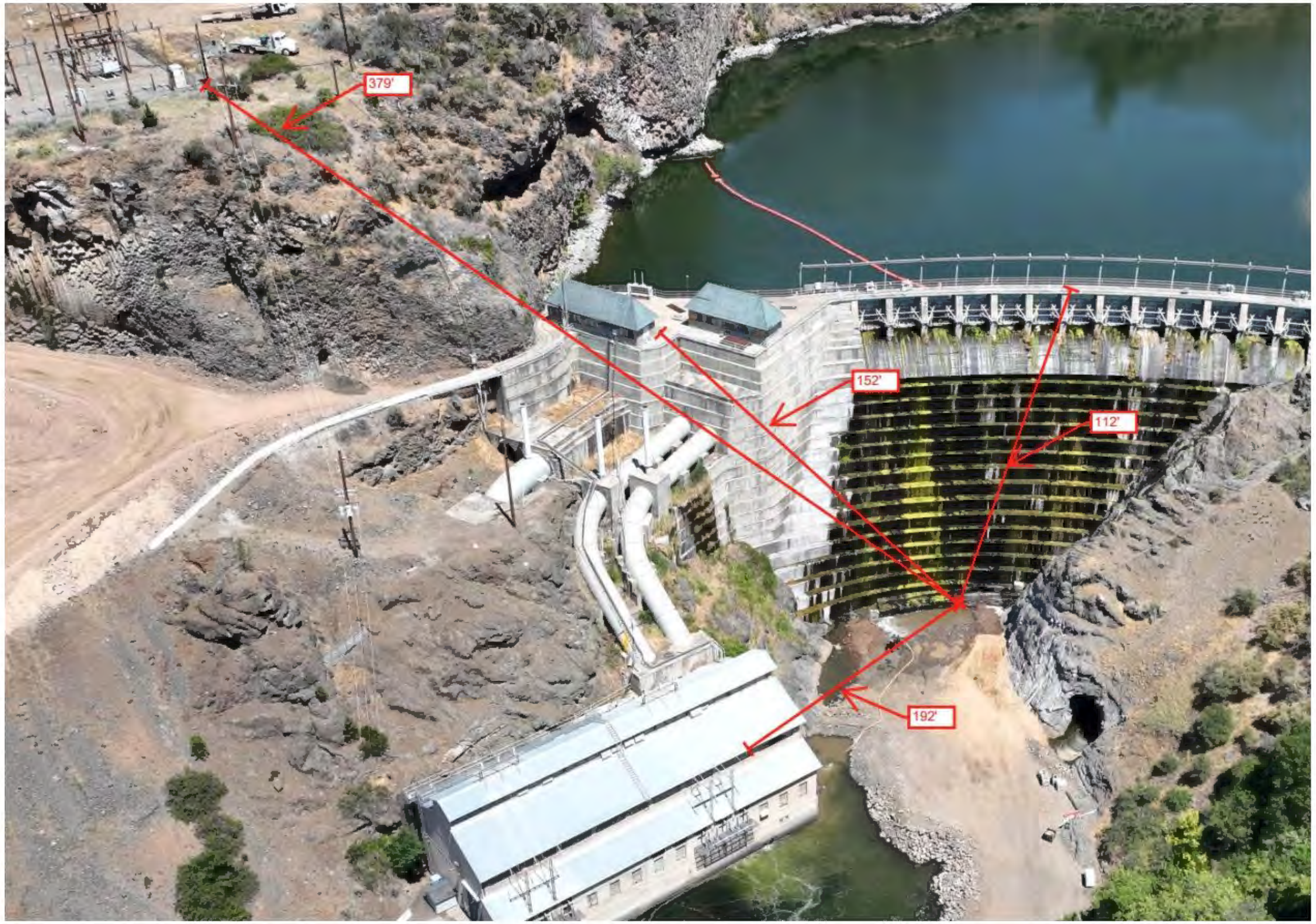
Pre-Drawdown Phase (2023)

- Plan focused on monitoring activities at Copco No. 1, Copco No. 2, and Iron Gate
- No work activities at JC Boyle
- KRRC contracted O&M of the plants to PacifiCorp during the Pre-Drawdown Period
- Active operation and flow management with PacifiCorp and USBR to support construction
- Completed modifications to Copco No. 1 and Iron Gate to facilitate final drawdown
- Removed Copco No. 2 diversion dam

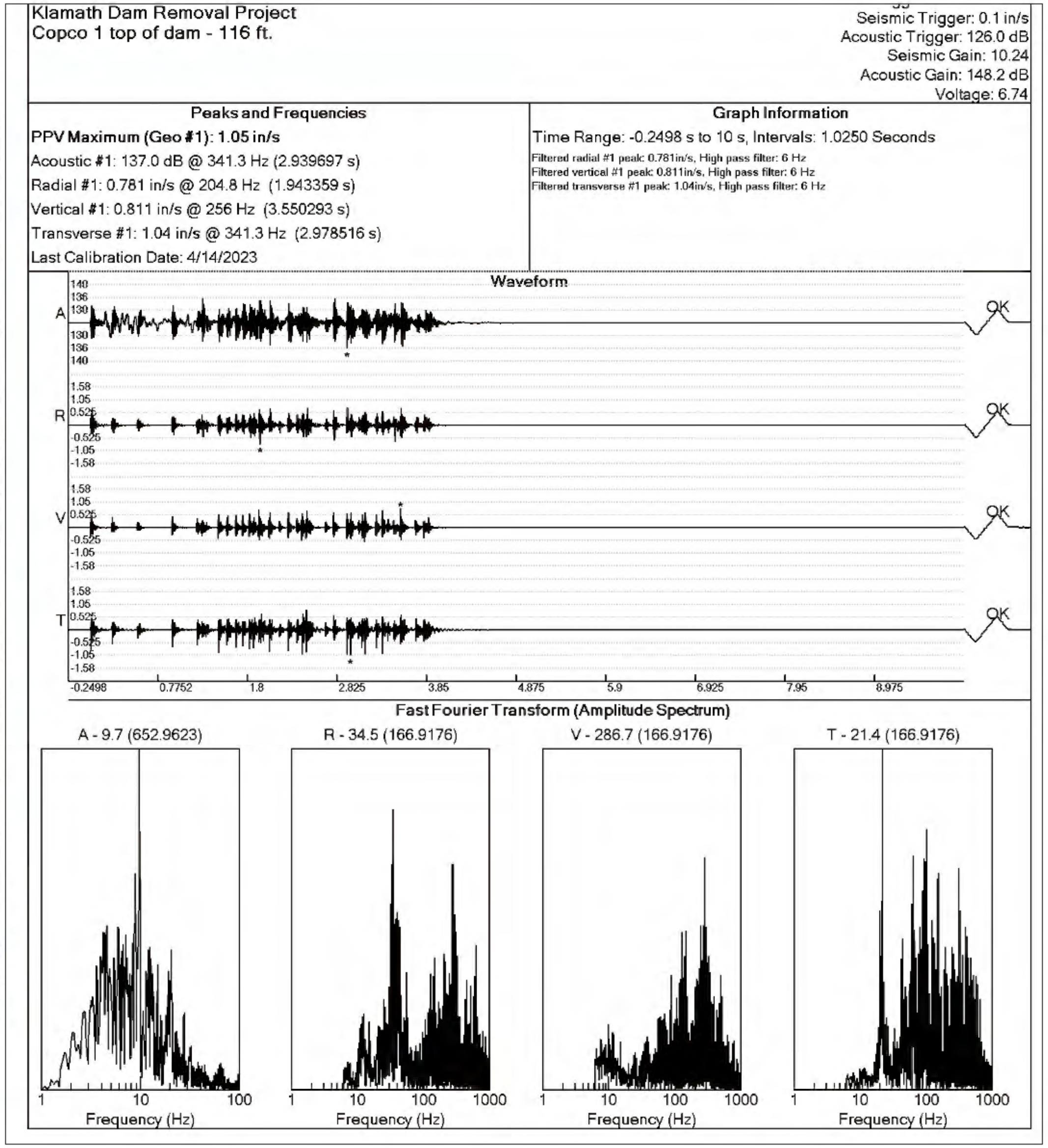
Drawdown Phase (2024)

- Implemented site-specific Drawdown Phase Dam Safety Surveillance and Monitoring Plan
- Plan focused on monitoring activities at JC Boyle, Copco No. 1, and Iron Gate Dams
- Copco No. 2 dam already removed
- Completed final facility termination at each remaining plant to initiate final drawdown – PacifiCorp no longer providing operation support
- Active operation and flow management with USBR/Agencies/Tribes to support construction
- Active dam removal activities initiated in February 2024 with final dams removed by October 1, 2024.

Copco No. 1 Adit Blasting Monitoring



Copco No. 1 Adit Blasting Monitoring



Drawdown Phase Primary Monitoring

- JC Boyle Dam embankment stability during reservoir drawdown and dam removal
- Scour Hole slope stability during construction
- Copco Lake Reservoir Rim Slope Stability during Reservoir Cycling
- Copco No. 1 Dam stability during blasting and removal
- Iron Gate reservoir rim slope stability during drawdown
- Iron Gate Dam embankment stability during drawdown
- Iron Gate Tunnel condition during reservoir drawdown

Iron Gate Reservoir
Slope Stability Monitoring

Lessons Learned

Definition of Lessons Learned

- “Knowledge or understanding gained from experience”

Pre-Drawdown Phase (2023)

- Copco No. 1 adit blasting approach
- Iron Gate Diversion Tunnel as-built conditions

Drawdown Phase (2024)

- Iron Gate Diversion Tunnel Cavitation
- Copco No. 1 Over Blasting
- Sediment Transport Characteristics

Copco No. 1 Adit Blasting

Issue: Steel rails placed in the original dam concrete placement caused the blast to vary depending on the number and location of the rails. This resulted in a delay in advancing the adit construction as well as high fly rock debris in the first two blasts.

Lesson Learned: Blasting schedule should be developed to accommodate multiple test blasts and "dialing-in" of blasting program to accommodate site specific conditions. Data from the field blasting was required in order to determine the appropriate powder factor to shear off steel rails and reach the full blast depth but stay below a safe threshold for vibration. More fly rock guarding was required than anticipated.

Copco No. 1 Adit Blasting

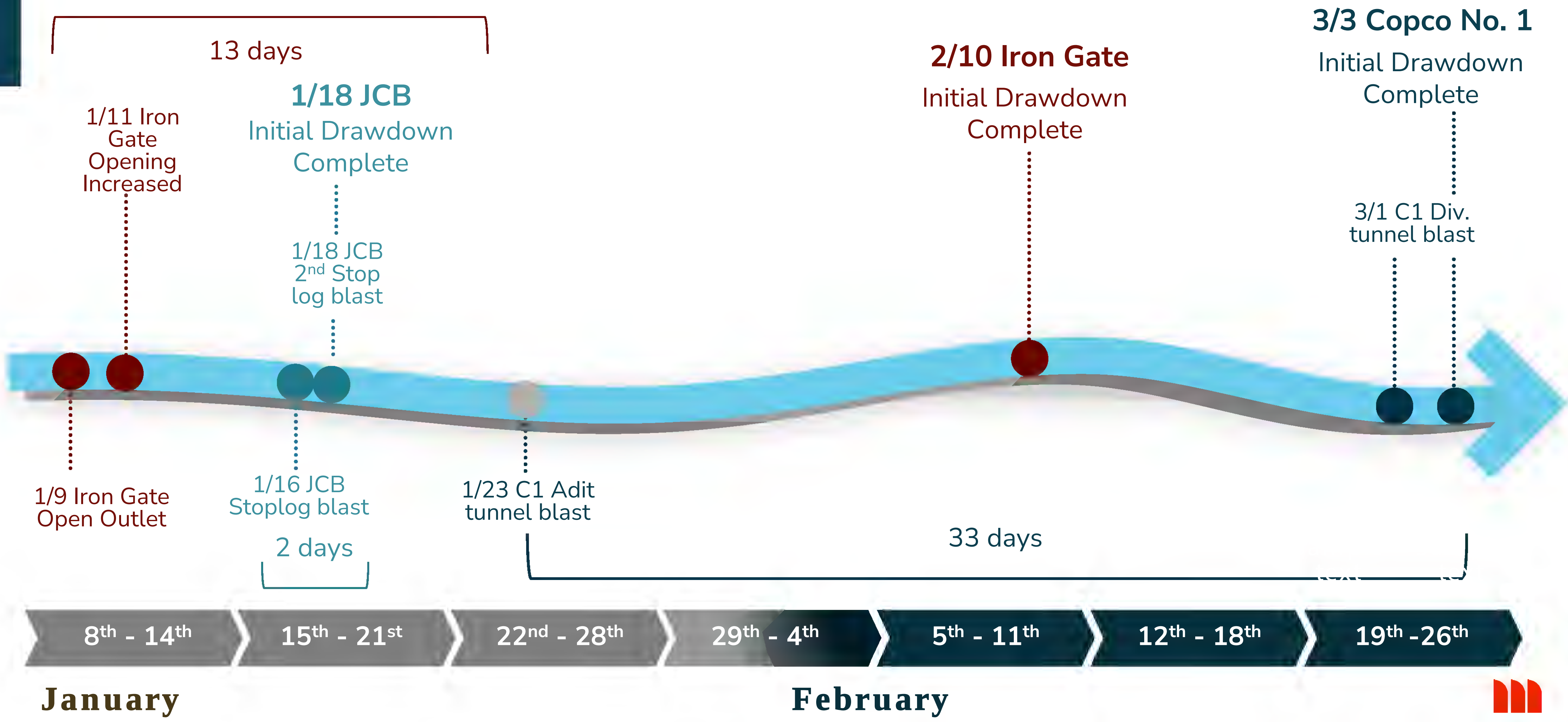
Picture shows at least 7 pieces of rail at random angles that kept the shot from breaking to full depth.

Sediment Transport Characteristics

Issue: Project planning called for flushing the reservoir sediment out of the dam reservoirs and out to the ocean. Sediment characteristics resulted in variation in sediment movement by reservoir and flow management to optimize the sediment movement.

Lesson Learned: Extensive sediment modeling was used to determine the sediment transport mechanism and volumes moved out of the reservoirs. Maintaining the ability to supplement water flows to help move sediment during critical times was invaluable in meeting the overall sediment flushing and transport objectives of the Lower Klamath Project.

Initial Drawdown Schedule



Sediment Transport Characteristics

Sediment Transport Characteristics

Thank you.

McMillen

Mort McMillen, PE,
mortmcmillen@mcmillen.com

Copco No. 1 Dam Intake Blasting Overbreak

Issue: Blasting of the penstock intake resulted in significant overbreakage and large of block of concretes impacting and partially damaging the outlet conduit. This resulted in significant work to remove the concrete and restore full diversion pipe flow.

Lesson Learned: Contractor was pushing the schedule using as large of concrete blasts as possible. The penstock intake was set up as a single blast to facilitate a single removal activity. A smaller blast area would have been more appropriate controlling the extent of the concrete removal and overbreakage, protecting the diversion pipe, and minimizing any potential impact to schedule. Lesson learned is that bigger is not always better in the world of blasting.

Copco No. 1 Intake Blasting Overbreak

Iron Gate Diversion Tunnel Anchors

Issue: Super cavitation blocks were installed at the end of the existing concrete lined section of the diversion tunnel downstream from the gate structure. During installation, placement of the rock anchors tying the baffles to the concrete was delayed due to a void and unsuitable material beneath the existing concrete liner. This resulted in a construction delay and redesign during a critical outage period.

Lesson Learned: As-constructed drawings did not reflect the conditions under the slab and resulted in a significant construction delay. Required field probing, design modifications, and approval from FERC, BOC, and DSOD before the work could progress. Verification of as-builts should be completed in advance of critical schedule work to minimize unforeseen conditions and associated delays.

Iron Gate Diversion Tunnel Anchors

Iron Gate Diversion Tunnel Cavitation/Venting

Issue: During the initial opening of the existing diversion tunnel gate, significant cavitation noise was observed. Soon after, the newly installed vent pipe in the outlet tunnel failed. This caused significant concern about the level of damage occurring in the tunnel due to cavitation and potential lack of aeration.

Lesson Learned: Though the aeration issue was identified and evaluated in the design, cavitation subsequently occurred and resulted in significant damage to the newly installed vent pipe. Several different options for increasing the air flow to the downstream side of the gate were evaluated, and a design approach used which utilized the easiest access to install the pipe. In hindsight, new vent lines should be been routed down the inside face of the tower to supply the gate where damage due to flowing water would be eliminated.

Iron Gate Diversion Tunnel Cavitation/Venting

From Reservoirs to Rivers: A Look at the Past Year of the Klamath River Renewal Project Restoration Journey

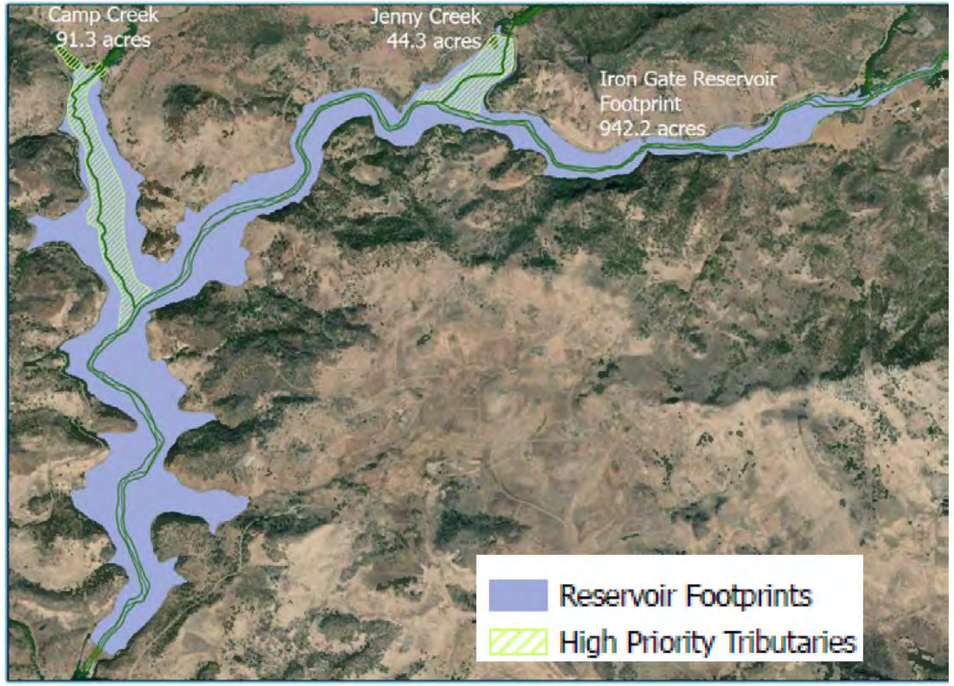
Salmonid Restoration Federation

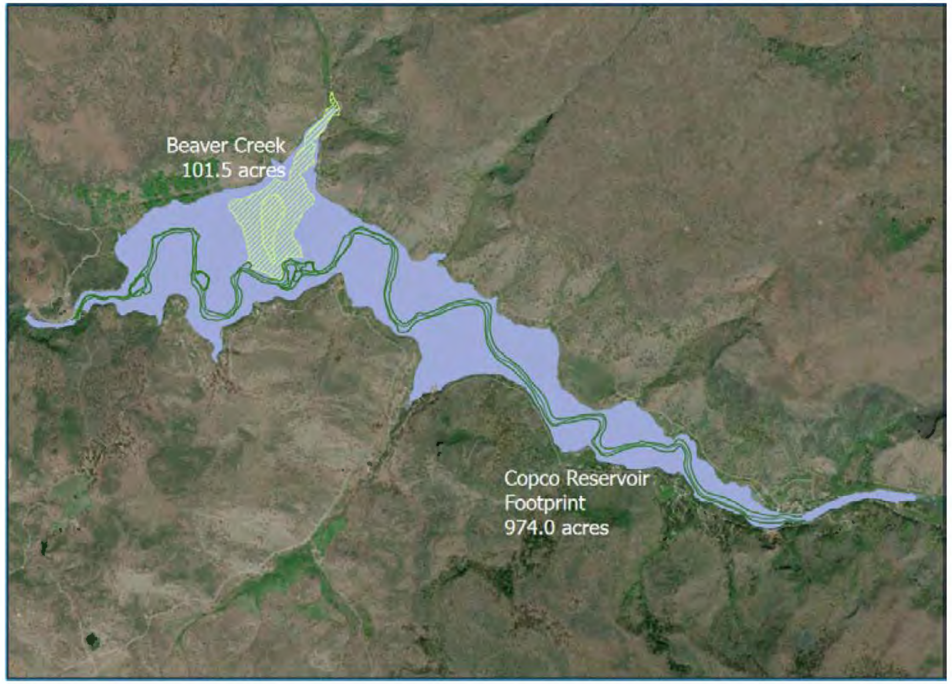
May 1, 2025

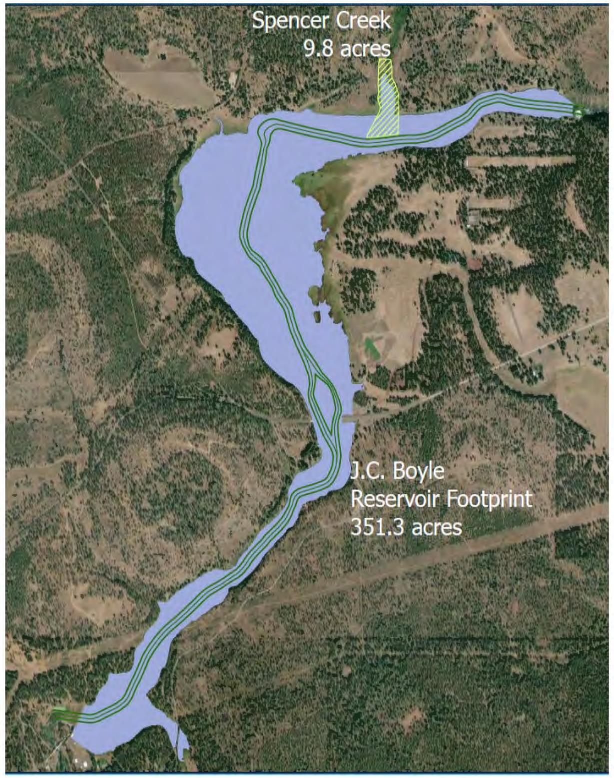
res Restoring a resilient earth for a modern world

Presenter: Dan Chase
Director, Fisheries and Aquatics

Dams, Tributaries, and Reservoir Footprints







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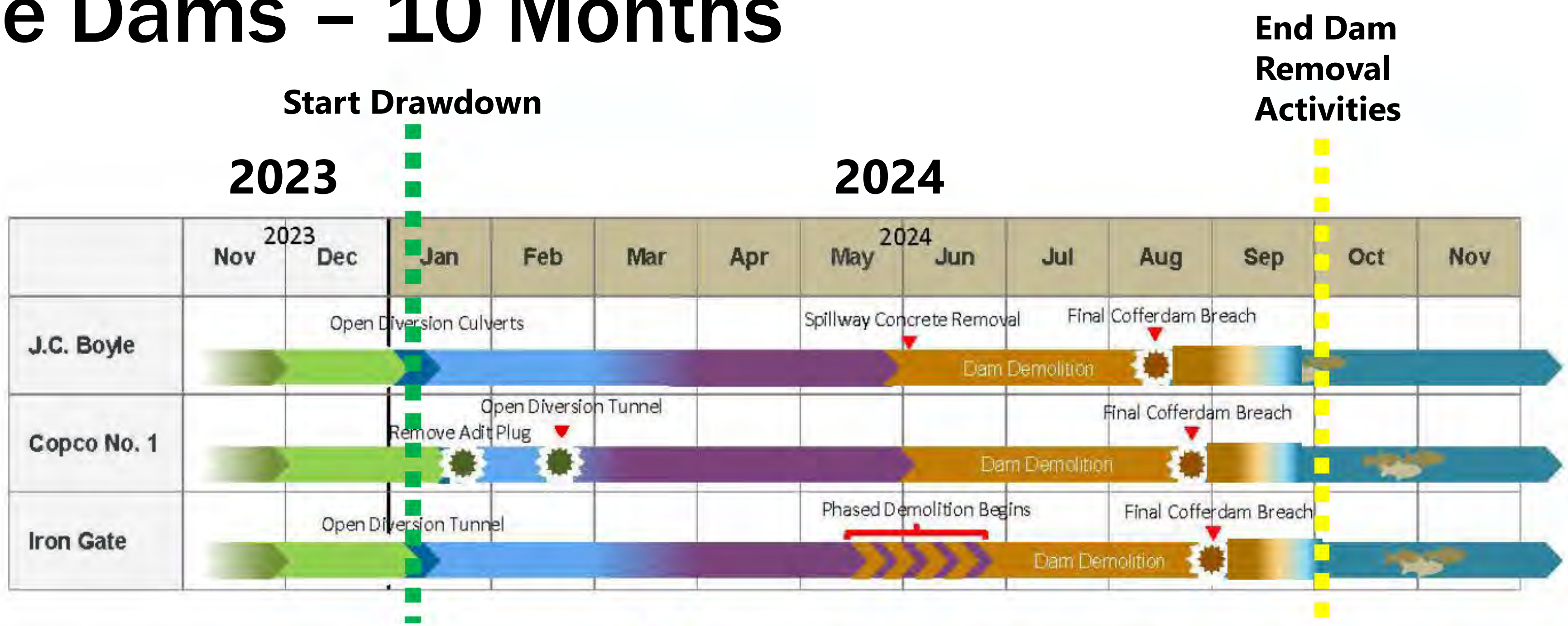
Three Dams – 10 Months



1. Operational Drawdown:
Lowering reservoir to its minimum operating level

2. Initial Drawdown:
Reservoir water evacuation below the Operational Drawdown limits

3. Reservoir Refilling and Releasing Period:
Inflows exceed outflow capacity periodically, causing reservoir levels to rise and fall

4. Dam Demolition:
Reservoir water elevation remains at the top of the historic cofferdam while dam concrete and embankments are removed

5. Klamath River Reconnection:
Breaching of the historic cofferdam, allowing the river to permanently flow in a riverine condition

Copco Dams 2 & 1 – Klamath River – June 2023

Copco Dam 1 – Klamath River – January 2024

Camp Creek - February 2024

Photo: Matt Mais, Yurok Tribe

Photo: Matt Mais, Yurok Tribe

Photo: Sarah Wood, Resource Environmental


Copco Valley - Klamath River - October 2024
Copco Dam 1 - March 2024
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Photo: Swiftwater Films

Jenny Creek - April 2024

Iron Gate – Klamath River - May 2024

Iron Gate Dam - June 2024

Copco Valley – Klamath River - October 2024

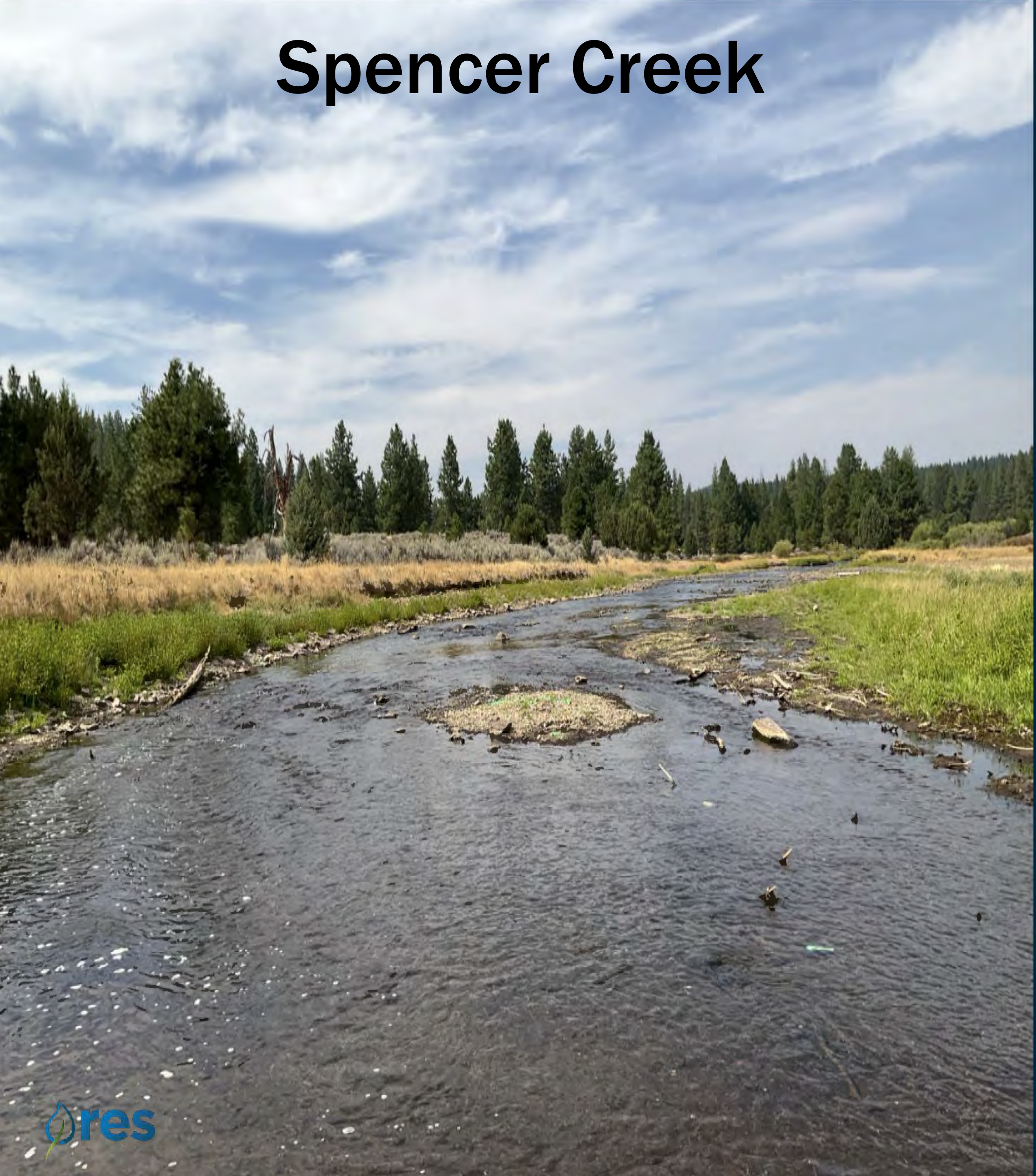
JC Boyle Dam Breach - July 2024

Photo: Swiftwater Films

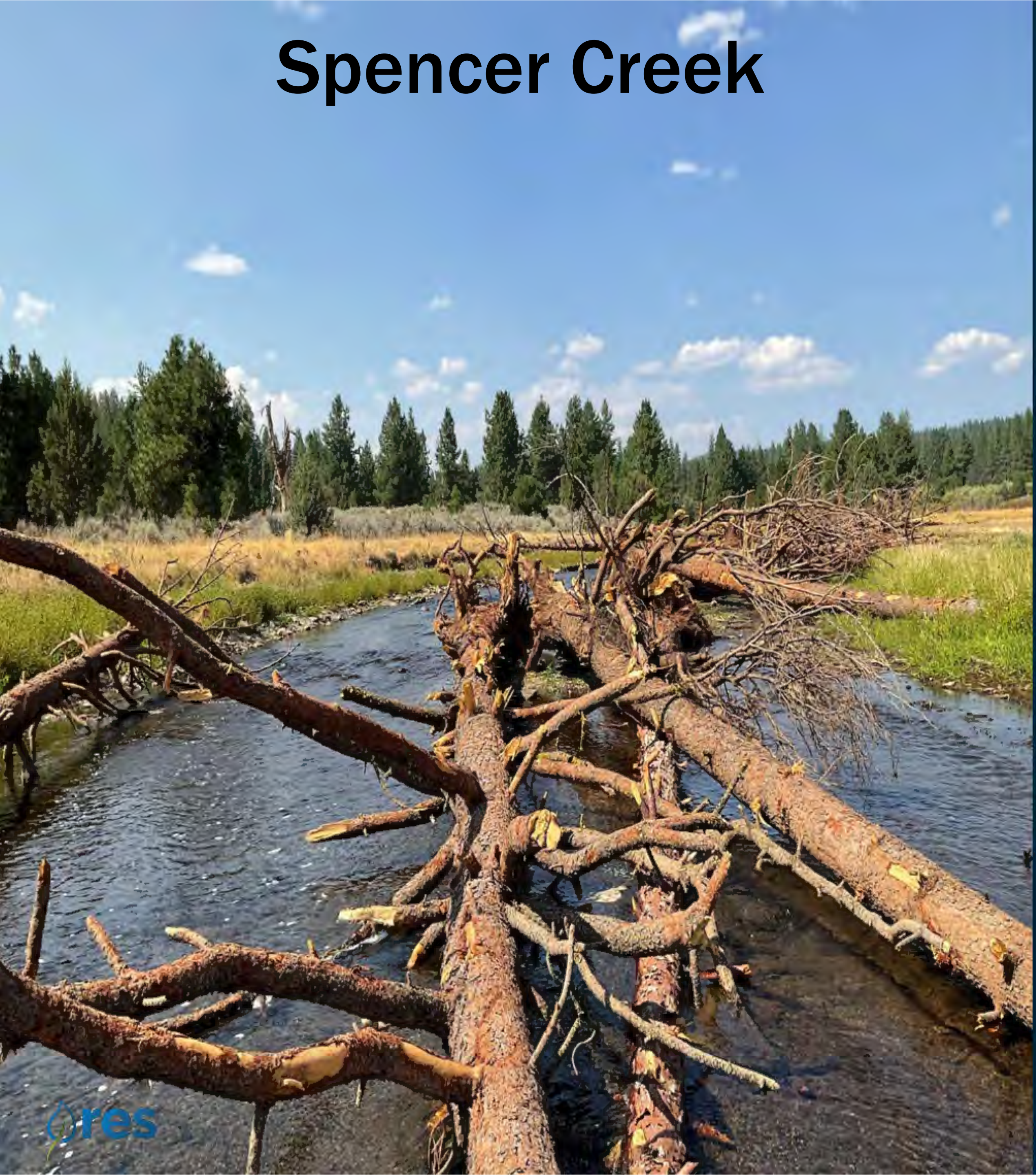
Also July 2024… Iron Gate – Klamath River

Spencer Creek – Klamath River – August 2024

Spencer Creek July 2024



Spencer Creek August 2024



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Copco 1 Dam - September 2024

JC Boyle – Klamath River - October 2024

JC Boyle – Klamath River - June 2023

JC Boyle – Klamath River - October 2024

Copco Valley – Klamath River - October 2024

Copco Dam 1 and Reservoir - September 2023

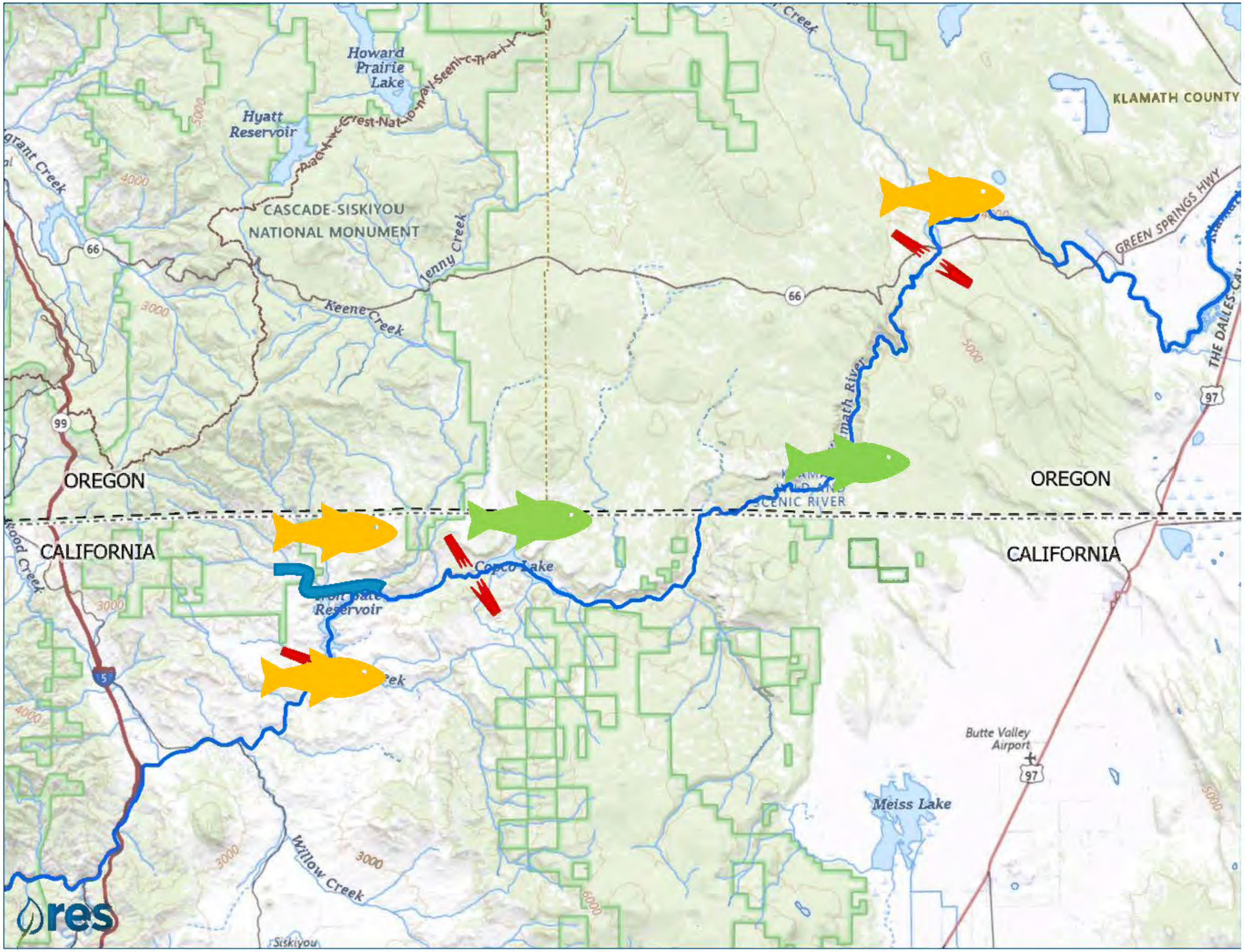
Copco Valley – Klamath River - October 2024

Iron Gate Dam Upstream View - January 2024

Former Iron Gate Dam Upstream View - October 2024

Jenny Creek – October 2024

Photo: Swiftwater Films



10/2 In-water work complete

10/1 Pacific lamprey detected in Jenny Creek

10/3 first Chinook passed Iron Gate

10/15 Chinook detected in Jenny Creek

10/16 Chinook detected in Spencer Creek, OR

12/5 Coho detected in Beaver Creek

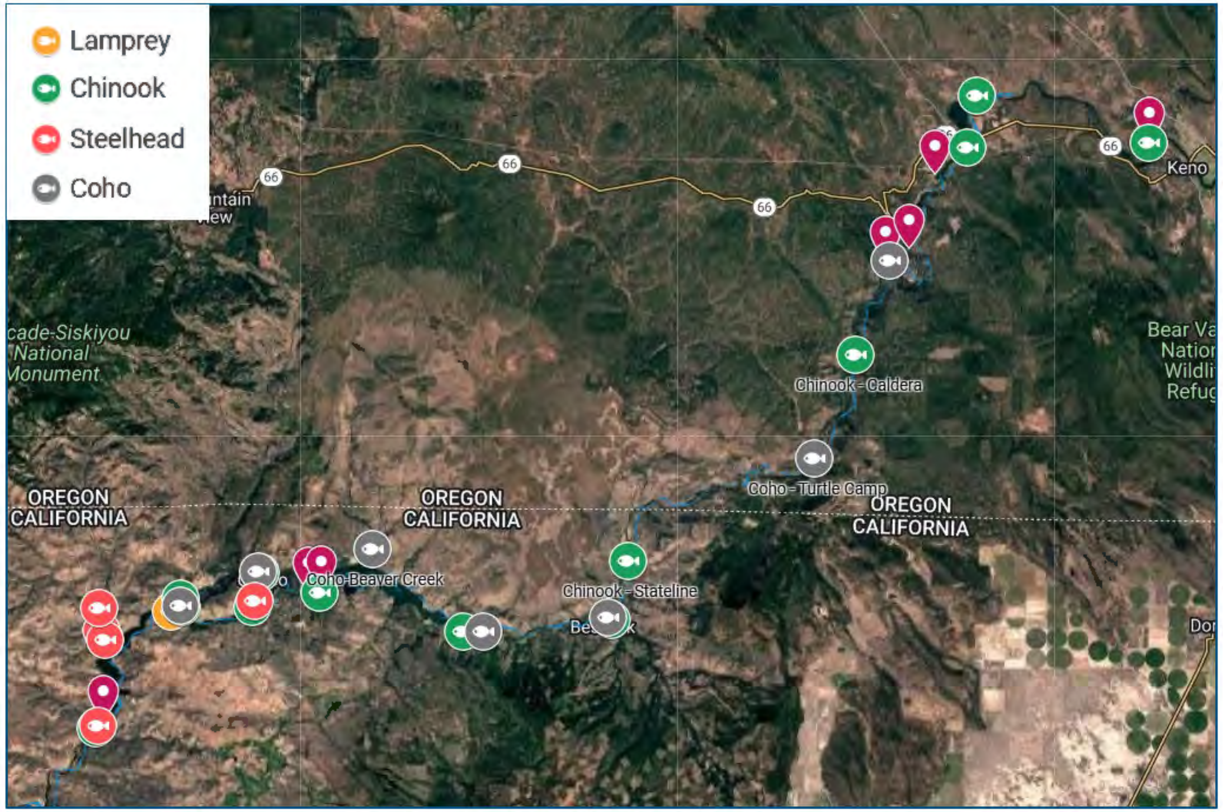
12/19 Coho detected spawning in Oregon

Fisheries Monitoring

Primary objective: Inform volitional fish passage through the LKP footprint.

Population monitoring conducted by Yurok Tribe, Karuk Tribe, Klamath Tribes, CDFW, ODFW, NMFS, USFWS, CalTrout, university partners.

- **Fish passage monitoring**
- **Fish presence monitoring – Fall/Winter spawning surveys**
- **eDNA**



res

Water Quality & Aquatics Program – Data Collection

- Over a dozen regulatory authorizations related to fisheries and aquatics that require an extensive monitoring program

Fish passage monitoring

Telemetered monitoring location

Restoration Underway in Tributaries and Reservoir Footprints

Sediment Evacuation and Fish Passage Impediment Removal

Revegetation Efforts

Large Wood Loading

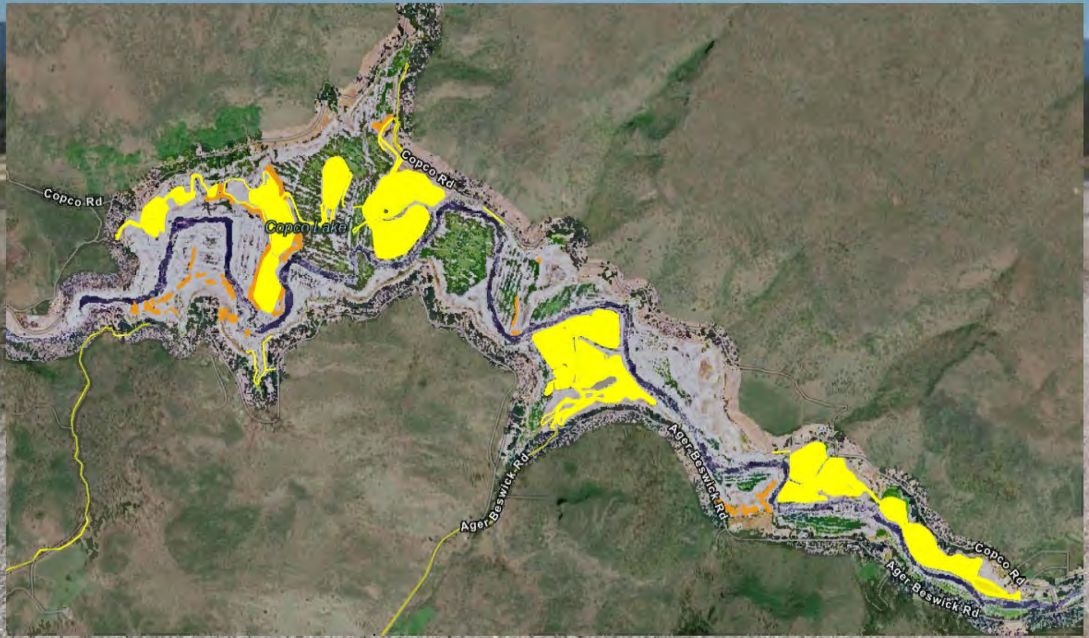
Beaver Creek Valley – Copco Footprint

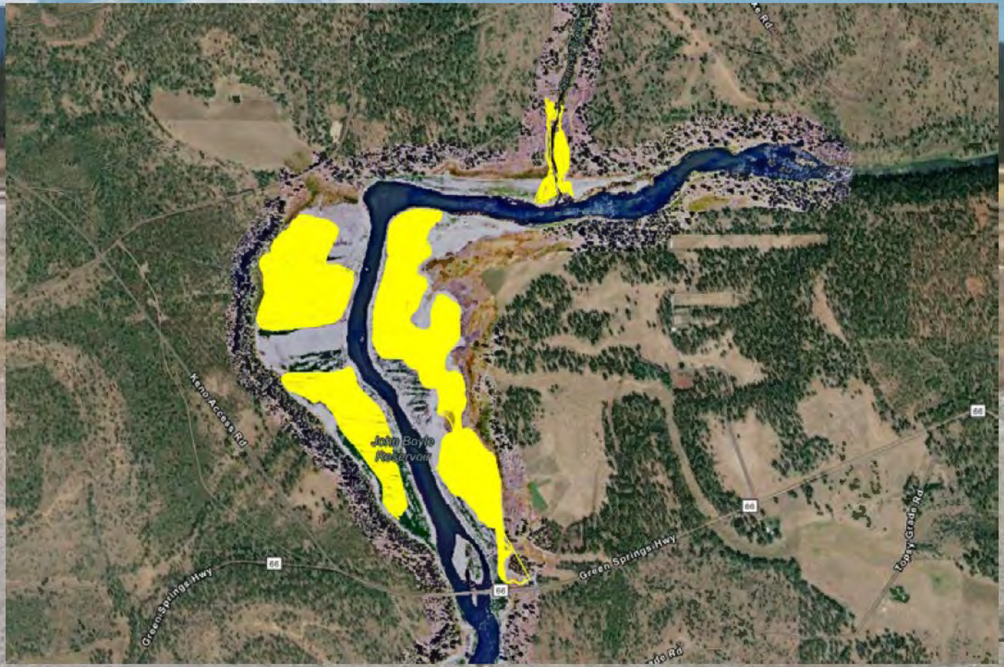
Photo: John Lang

Klamath River - Copco Valley – Copco Lake Footprint

Photo: Joel Ophoff

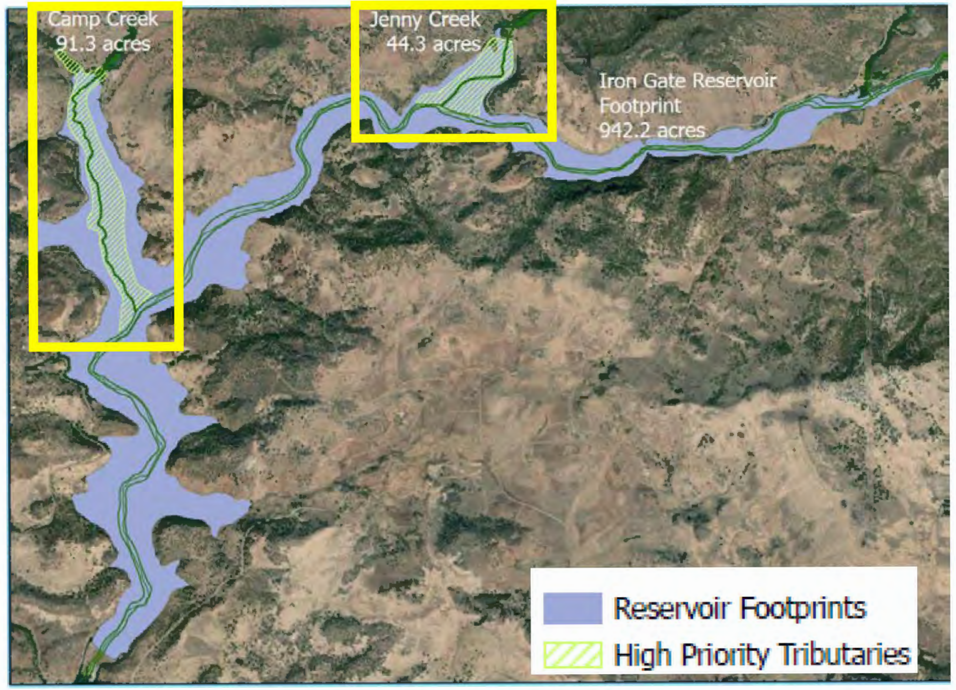
Seedbed Preparation

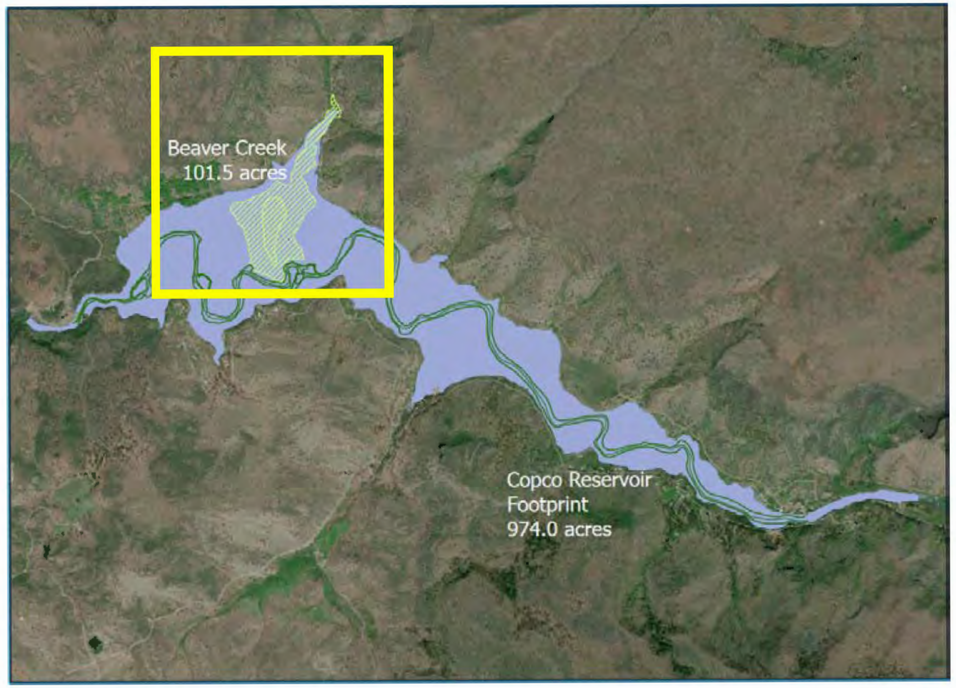


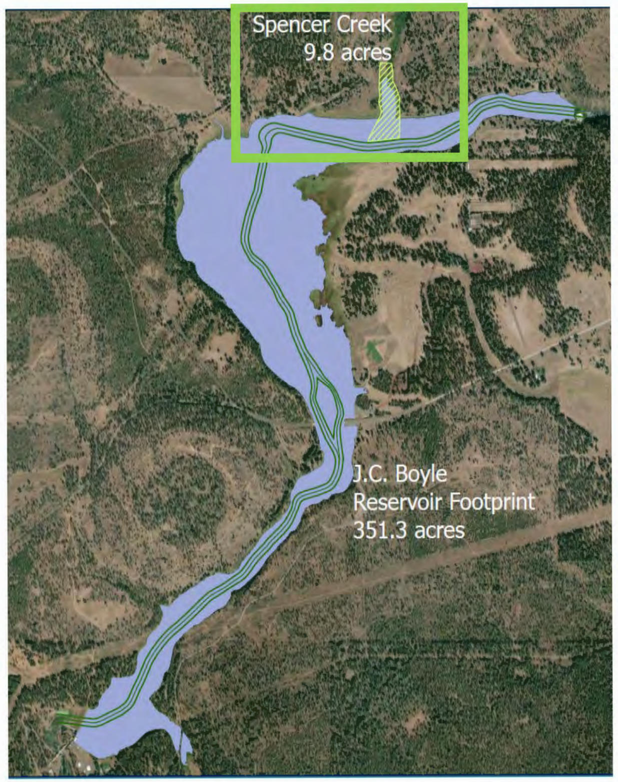


Seedbed Preparation at JCB, September 2024 Photo: Nathan McCanne

Tributaries and Reservoir Footprints







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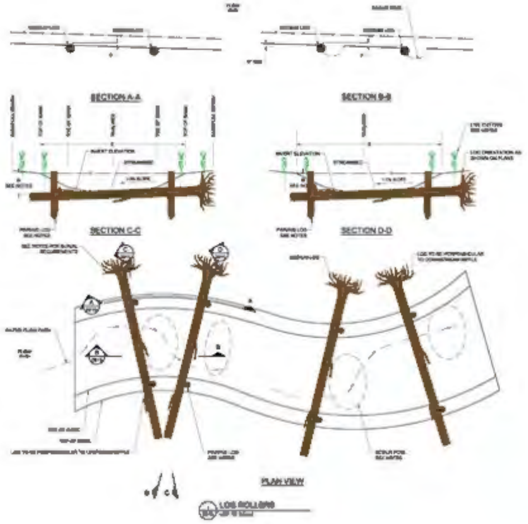
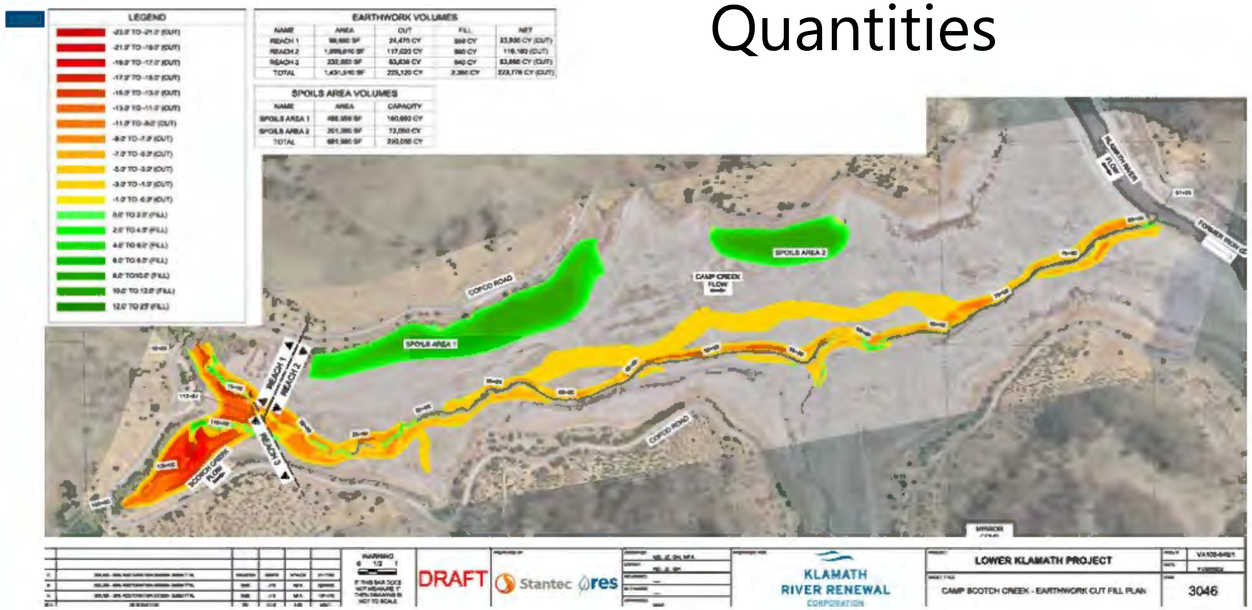
Design Progression

Features



Quantities



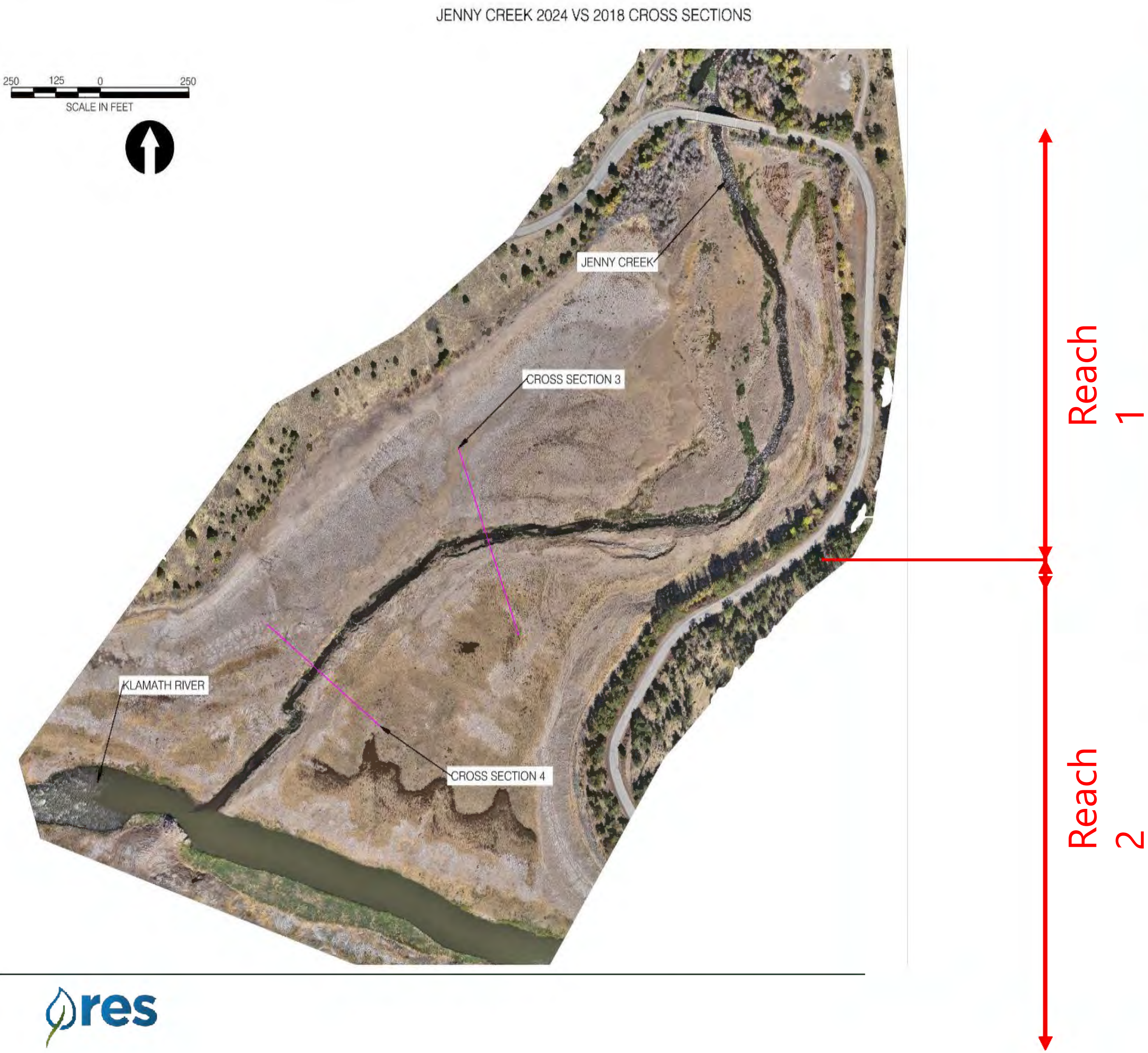
Placement

Sourcing

Verifcation

res

Jenny Creek Adaptive Design



Adaptive Design Approach

By Improving and then Monitoring:

- Fish Passage
- Bank Stability
- Floodplain Connectivity
- Floodplain Roughness
- Channel Fringe Complexity

Upcoming Restoration Work

2025

- Data collection and field surveys
- Restoration work in priority tributaries
    - Floodplain grading
    - In-channel work
- Fall revegetation effort
- IEV management

RES Project Partners

KLAMATH RIVER RENEWAL CORPORATION

McMillen

Kiewit

THE KLAMATH TRIBES · KLAMATH · MODOC · YAHOOSKIN

GREAT SEAL OF THE KARUK TRIBE

SHASTA INDIAN NATION

CAMAS

Stantec

TROUT UNLIMITED

USGS

RDG RIVER DESIGN GROUP

Ross Taylor & Associates

CROMAN CORP

cbec eco-engineering

res

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Biologist
dchase@res.us

Dave Meurer
Director of
Community Affairs
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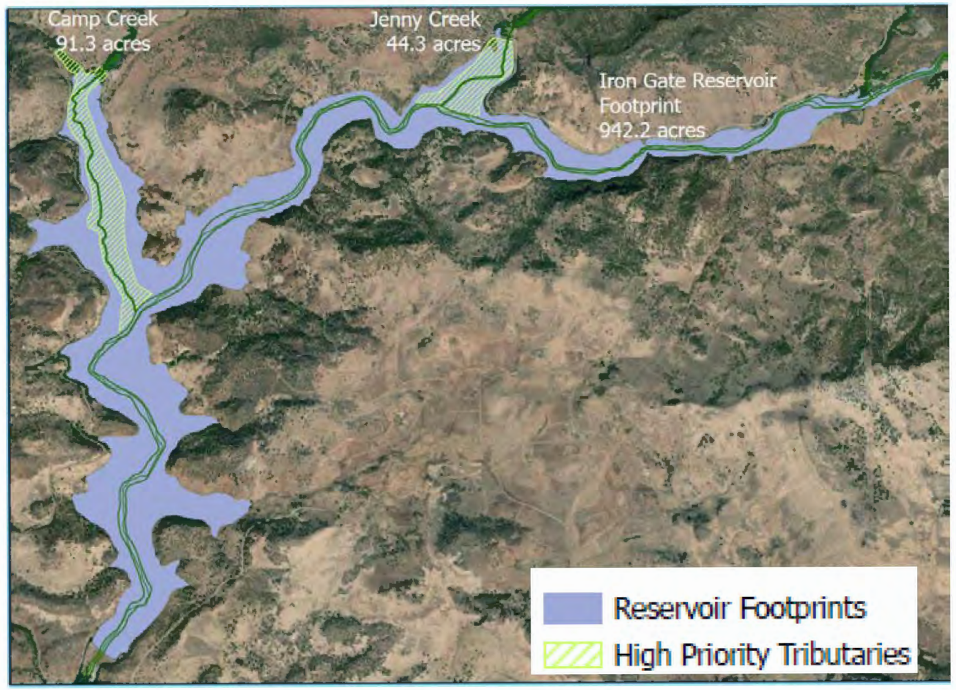
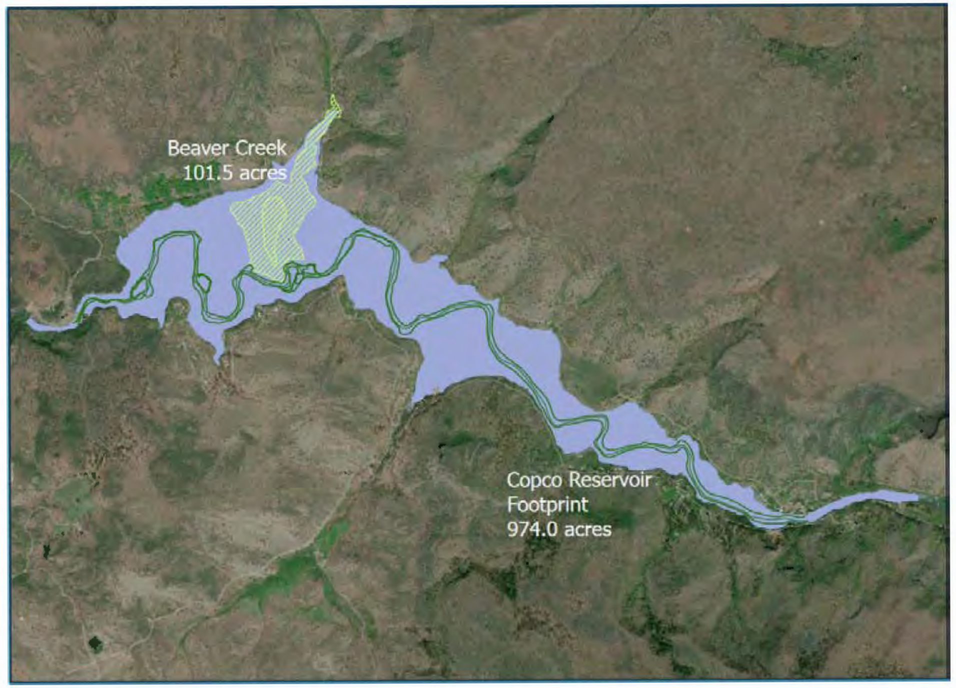
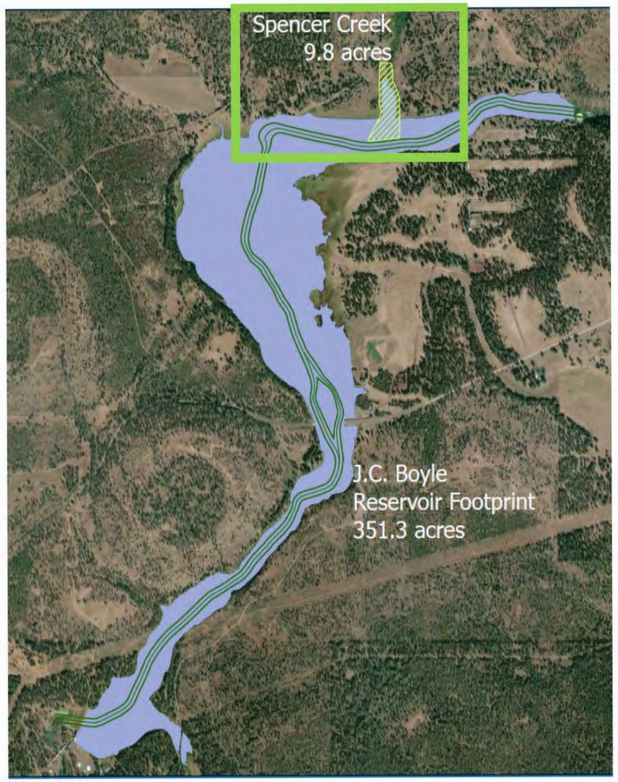
RES Klamath Story Map

Tributaries and Reservoir Footprints







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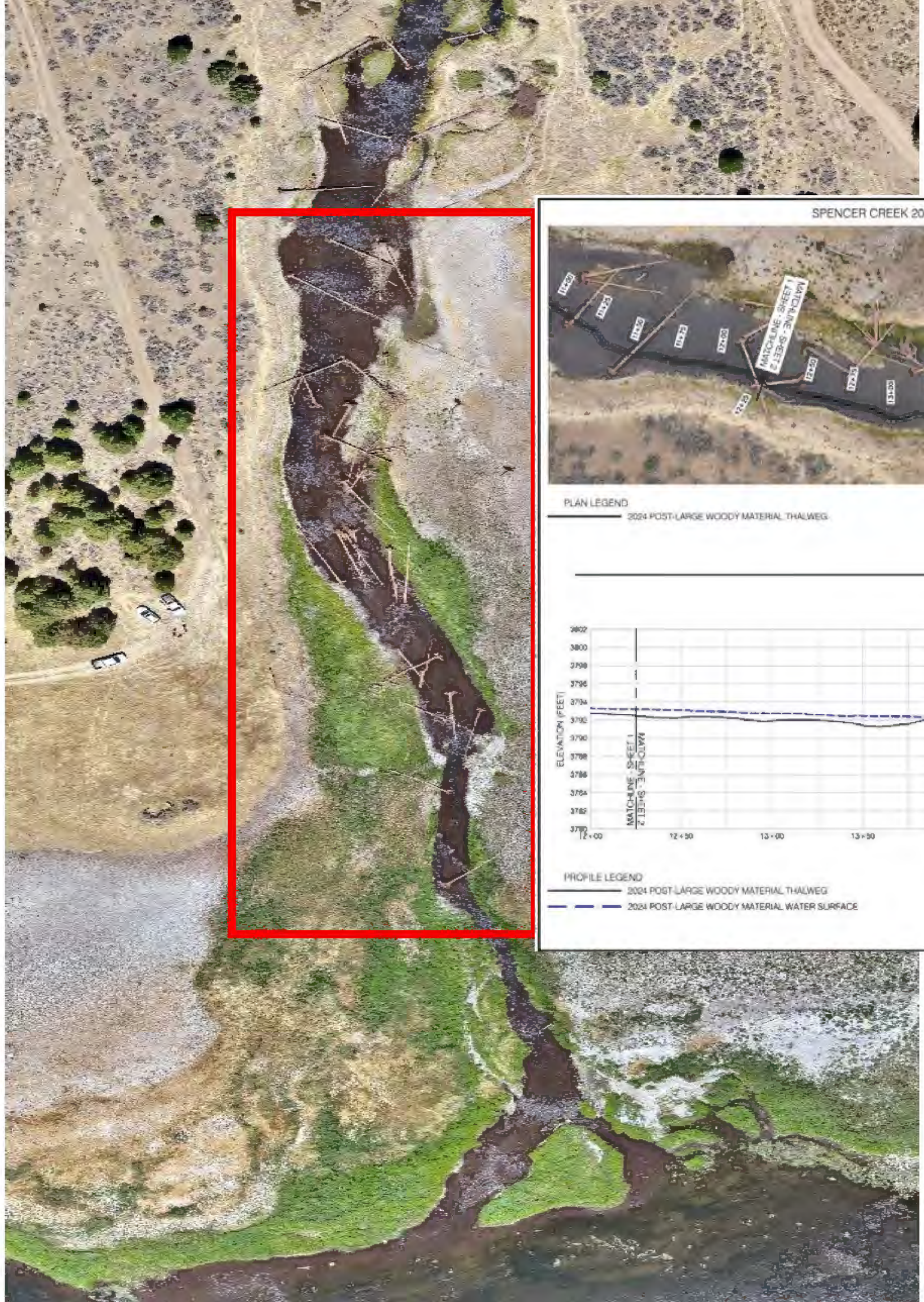
Spencer Creek

July 2024

res

Spencer Creek

Aug 2024



res

Spencer Creek

Aug 2024

Spencer Creek

Jan 2025

Spencer Creek

Aug 2024

SPENCER CREEK 2024 POST-LARGE WOODY MATERIAL PLACEMENT PLANFORM AND LONGITUDINAL PROFILE

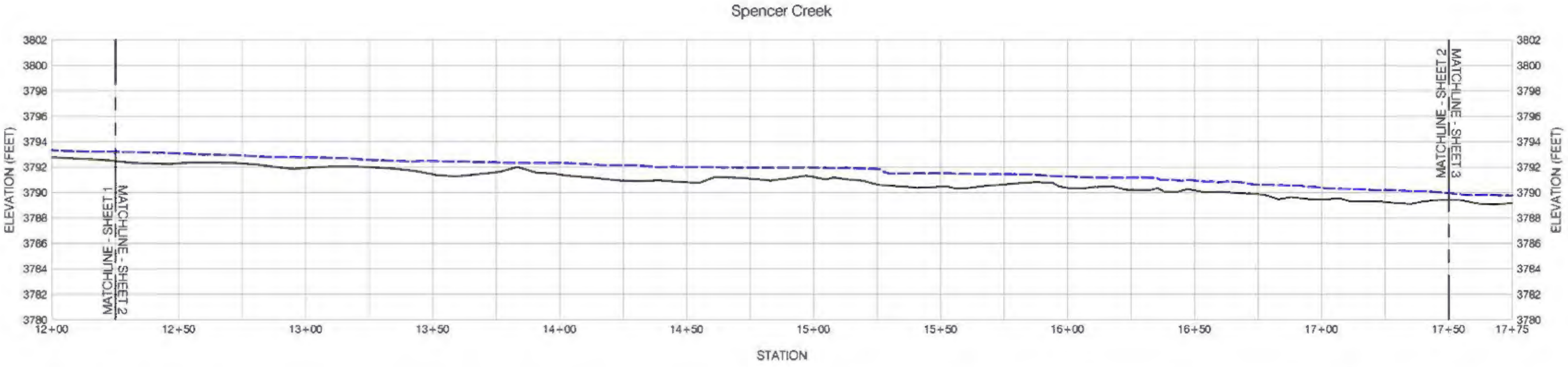
SOURCE: BASE MAP IMAGERY FROM DRONE FLIGHT ON AUGUST 12, 2024

PLAN LEGEND

2024 POST-LARGE WOODY MATERIAL THALWEG

40 20 0 40

SCALE IN FEET



PROFILE LEGEND

2024 POST-LARGE WOODY MATERIAL THALWEG

2024 POST-LARGE WOODY MATERIAL WATER SURFACE

SCALE: HORIZONTAL 1" = 40'
VERTICAL 1" = 8'

SPENCER CREEK 2024 POST-LARGE WOODY MATERIAL PLACEMENT PLANFORM AND LONGITUDINAL PROFILE

STAMP/SEAL:

HGS, LLC. A RES COMPANY
2125 19TH STREET, SUITE 200
SACRAMENTO, CA 95818
P: 804.353.6017
WWW.RES.US

REVISED DATE: 10-24-2024 | DRAWN BY: LEW

Peeshkeesh hûut kích?

Water Quality Conditions During Klamath Dam Removal Drawdown

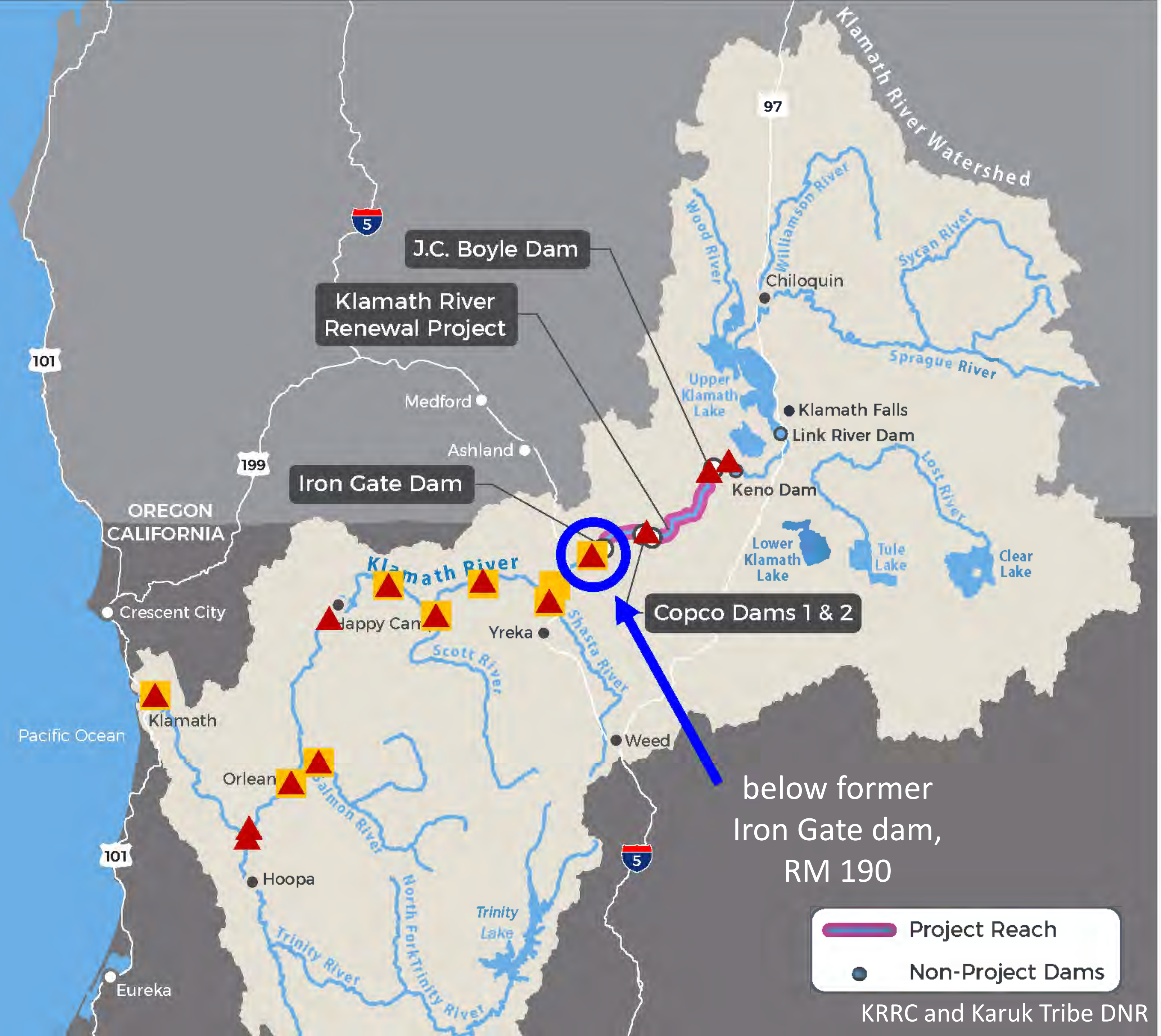
John R. Oberholzer Dent
Biologist
Karuk Tribe Water Quality Program

Klamath Dam Removal

- 4 dams
- 425 ft. combined height
- 420 miles of spawning habitat upriver
- 4.2 million tons sediment (dry weight) in reservoirs


Drained Copco reservoir


Iron Gate dam (left) and partially drained reservoir during 2024 drawdown



Water Quality Monitoring by Karuk Tribe, Yurok Tribe, USGS, and RES

- 9 continuous monitoring stations (temperature, conductivity, dissolved oxygen, pH, turbidity)
- 14 grab sampling locations (nutrients, sediment, microcystin, heavy metals)
- Other monitoring data not presented here includes continuous monitoring in the reservoir reach (USGS)

KTDNR
WQ Staff

Temporary Impairments

("Short-term pains")

- Turbidity/suspended sediment, dissolved oxygen sags, minimal contaminants

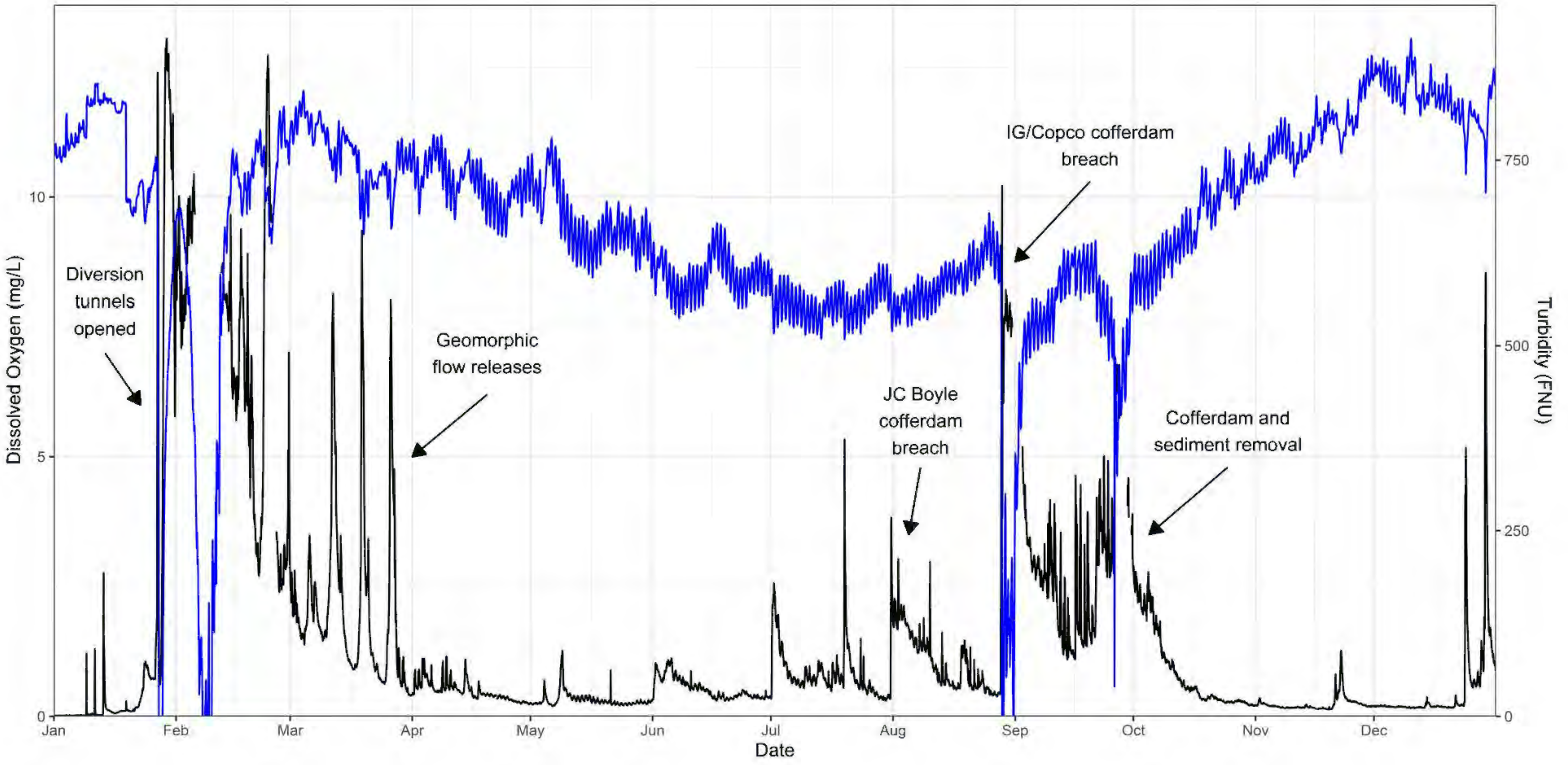
Immediate, Long-Term Improvements

("for long-term gains")

- Temperature, dissolved oxygen, pH, algal toxins, disturbance, fish disease, fish migration

All photos by author unless noted

A year of drawdown: turbidity and DO below the former Iron Gate Dam in 2024



Dam Removal in Perspective: Larger Historic Disturbances

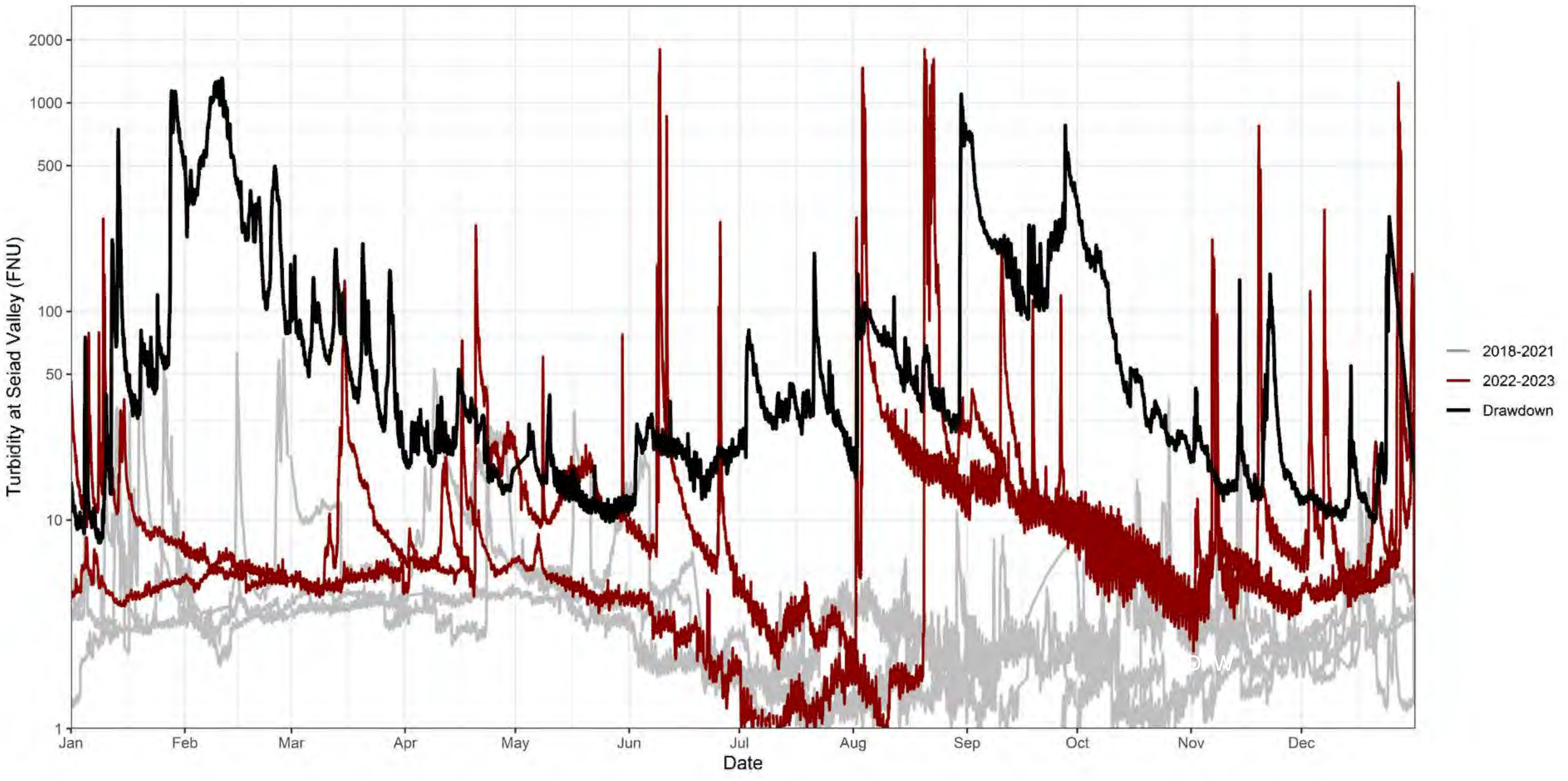
Hydraulic mining during gold rush

USGS

Christmas Flood of 1964

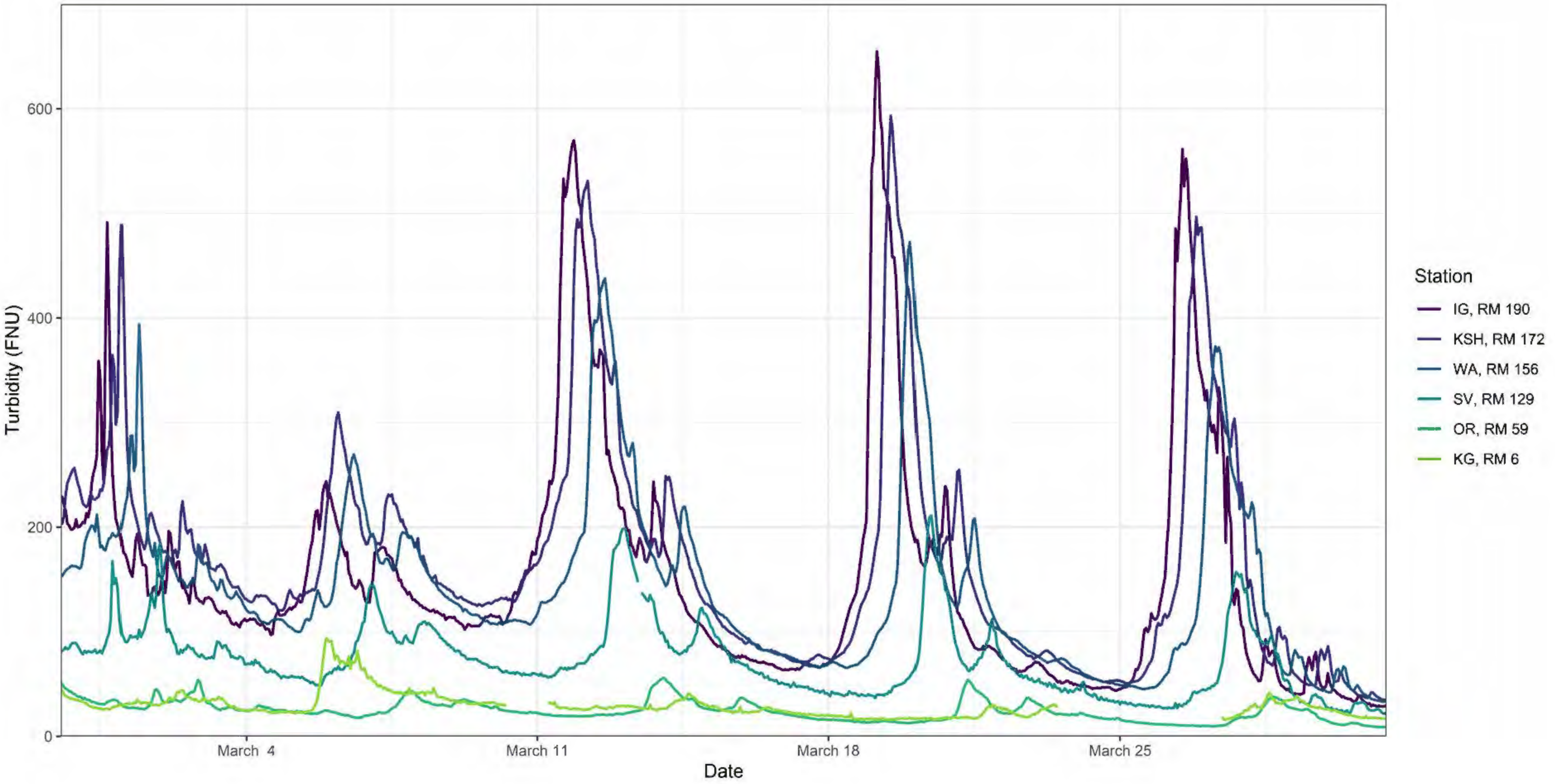
Eureka Newspapers

2022 McKinney Fire and impacts of catastrophic wildfire (log scale)



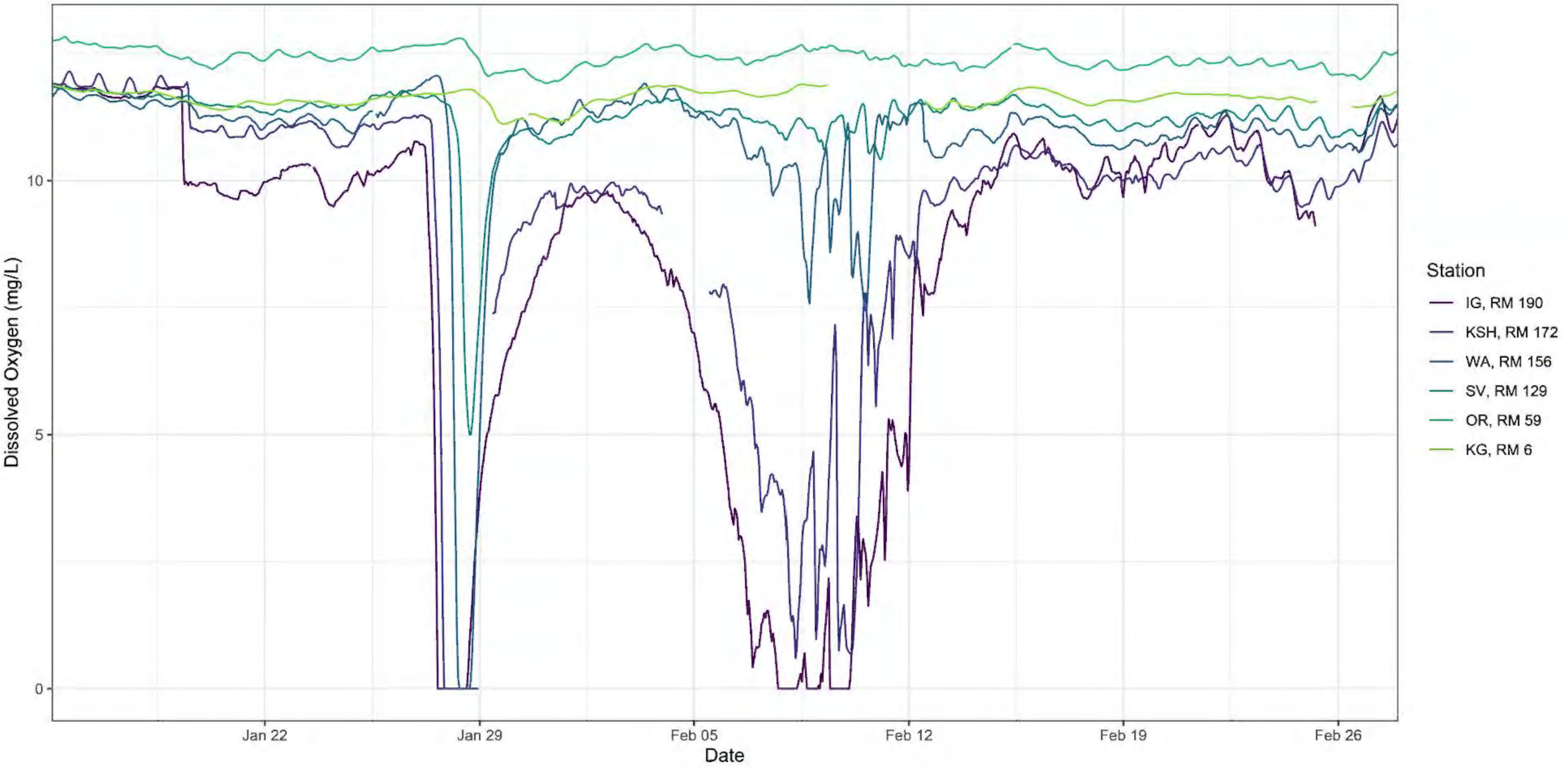
Dilution and Improvement of Water Quality Downriver

Dilution of turbidity from storms and geomorphic flow releases (March 2024)

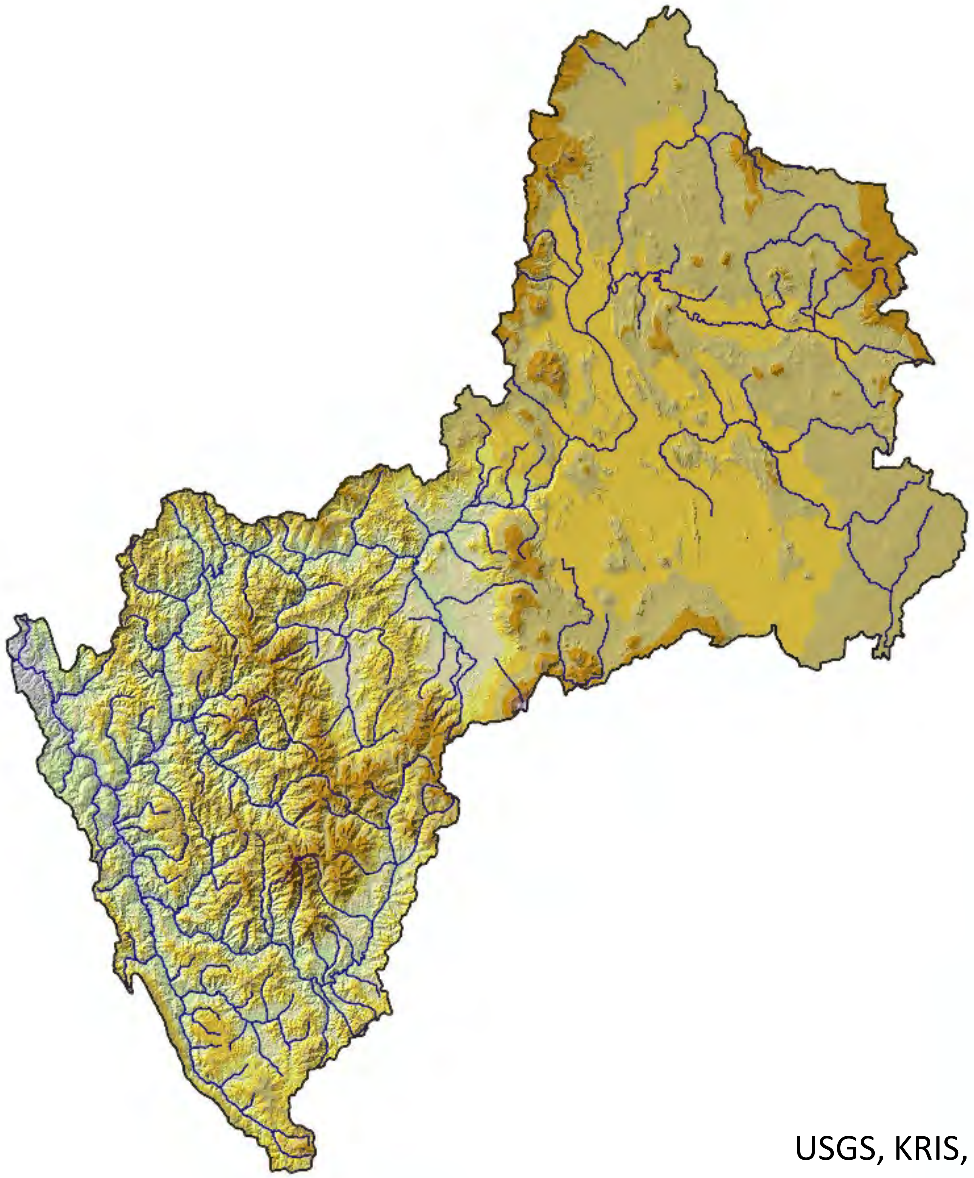


Dilution of suspended sediment concentration samples

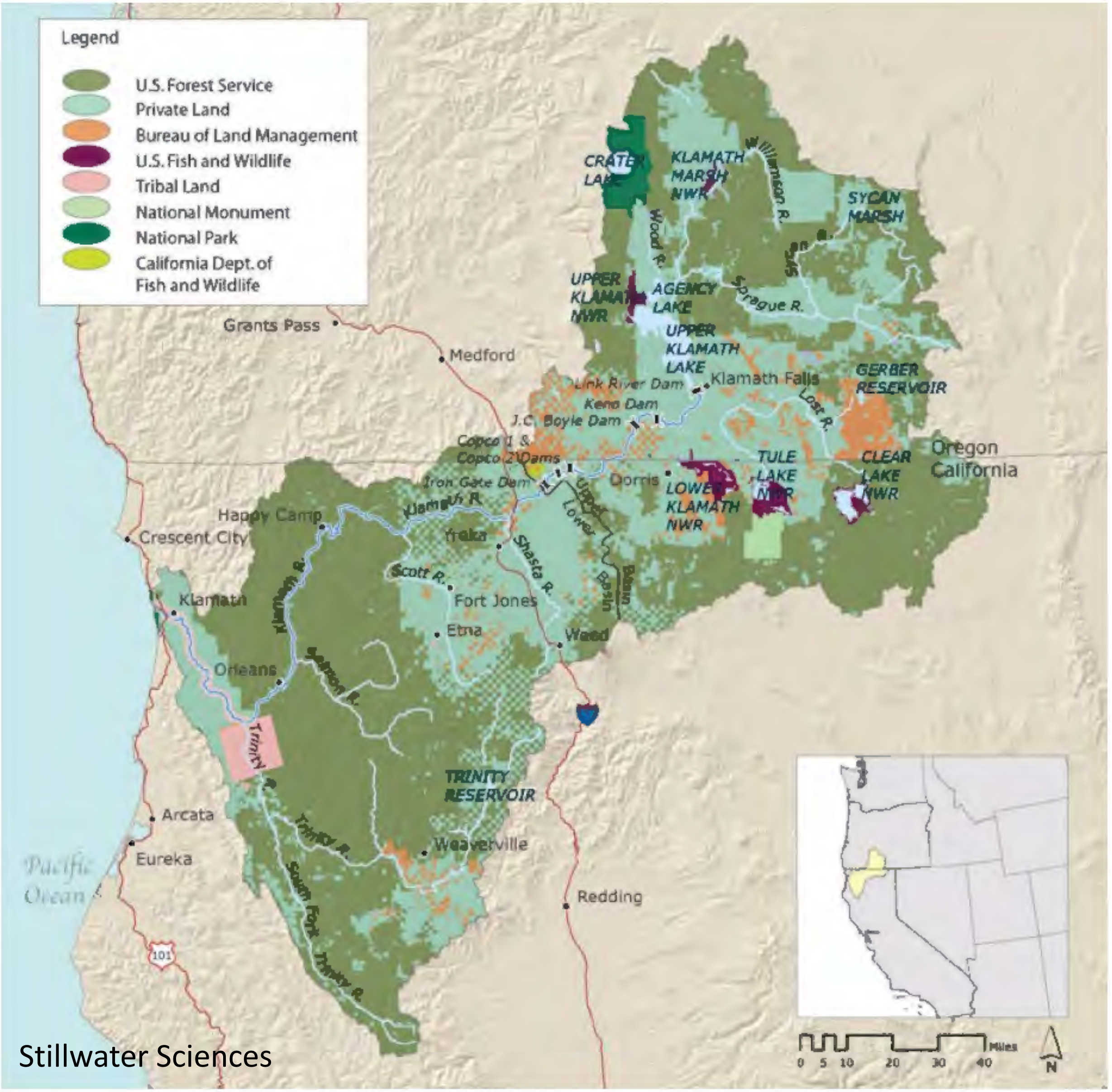
Recovery of dissolved oxygen sags (January-February 2024)



The “upside-down” river



USGS, KRIS, NWS



Stillwater Sciences


Dillon Creek dilutes Klamath River, February 27, 2024
Klamath River
Dillon Creek


Klamath River dilutes Trinity River, December 15, 2024
Trinity River
Klamath River

Misinformation about Klamath Dam Removal

~~“river of death”~~

~~“superfund site”~~

~~“collapse of the Klamath River ecosystem”~~

~~“conditions of disaster or extreme peril”~~

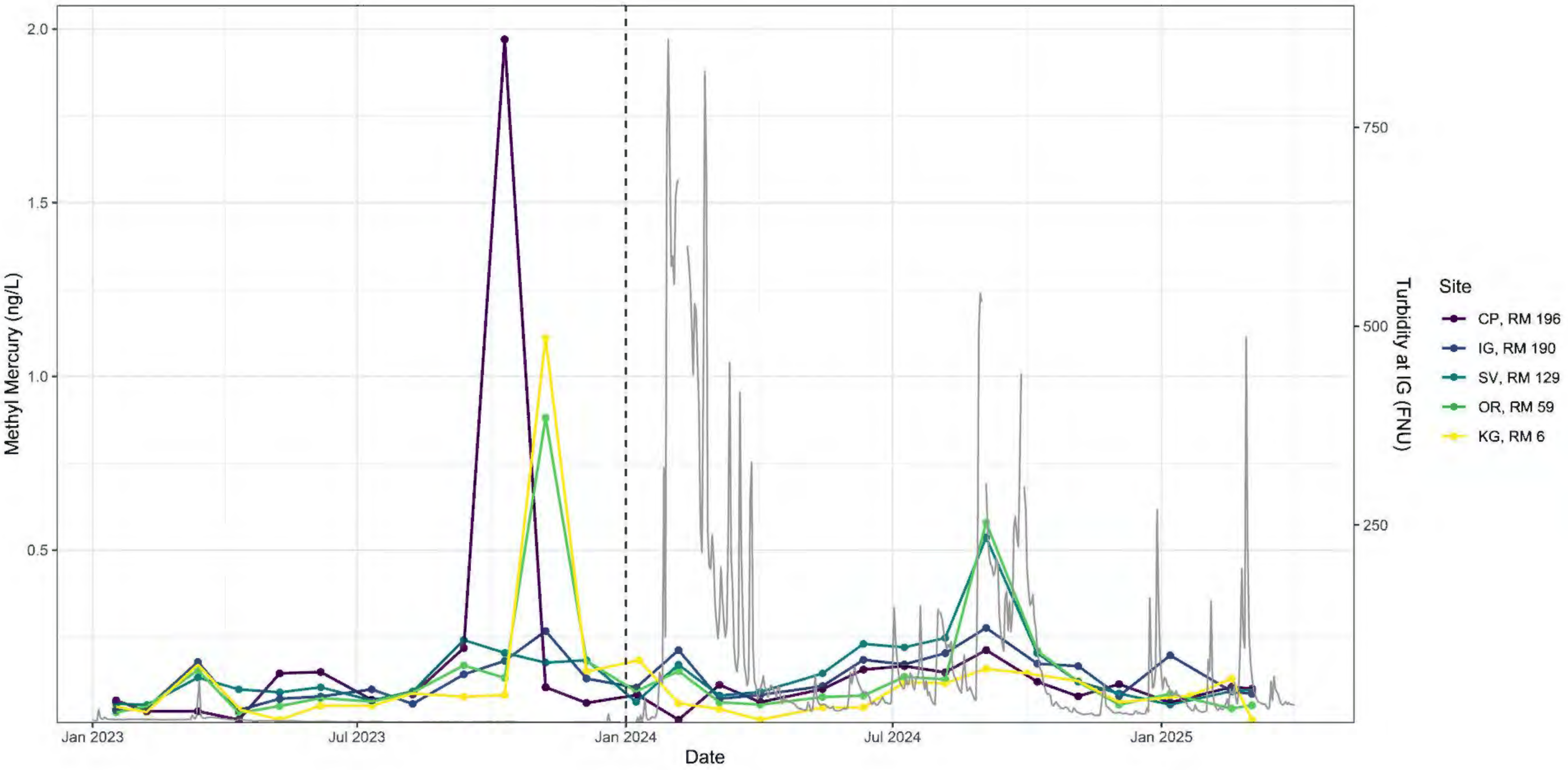
Facts about Klamath Dam Removal

- The Klamath River is used for drinking water in only one location, a rest stop on I-5. It was supplied with water by KRRC for the duration of the project.
- Drawdown was timed for winter to avoid recreation impacts as well as salmonid impacts. With winter water temperatures that reach 3 °C, recreation is… limited.
- Volcanic geology creates naturally high background levels of heavy metals.
- Other ongoing water quality concerns (i.e., catastrophic wildfire) have greater long-term impacts.

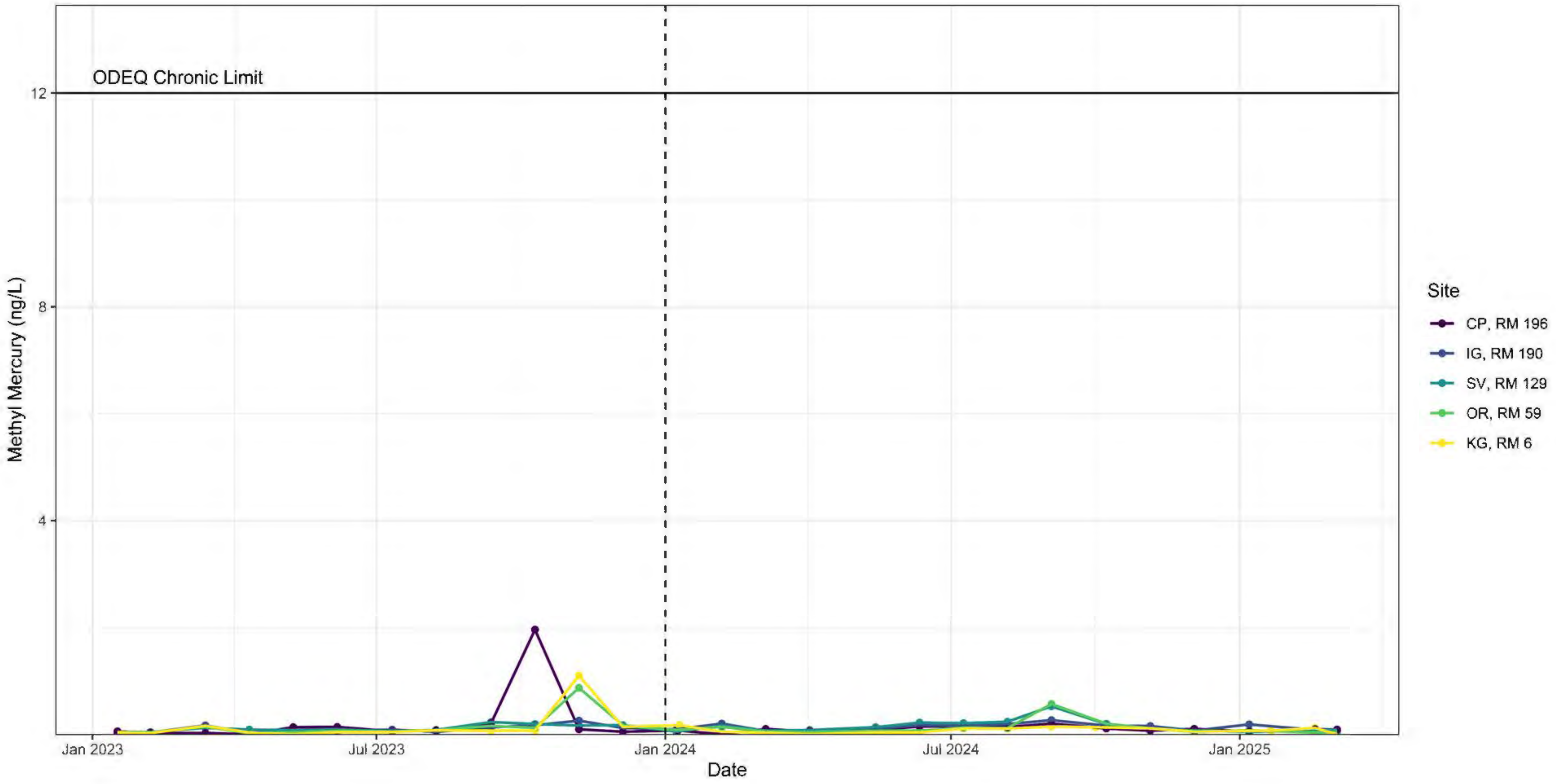
Fish Mortality

- Nearly 250 overwintering juvenile Coho were rescued from the mainstem Klamath and relocated to off-channel ponds by Tribal and RES staff prior to drawdown
- Some juvenile salmonid and sucker mortality observed during anoxic events caused by initial drawdown (January, extending 40 miles downriver) and cofferdam removal (September, extending 15 miles downriver)
- Hatchery juvenile mortality event was not caused by water quality (still produced more than the scheduled 3.25 million for last year)
- Majority of mortality observed was non-native reservoir fishes (e.g., perch)

Methylmercury before and during drawdown

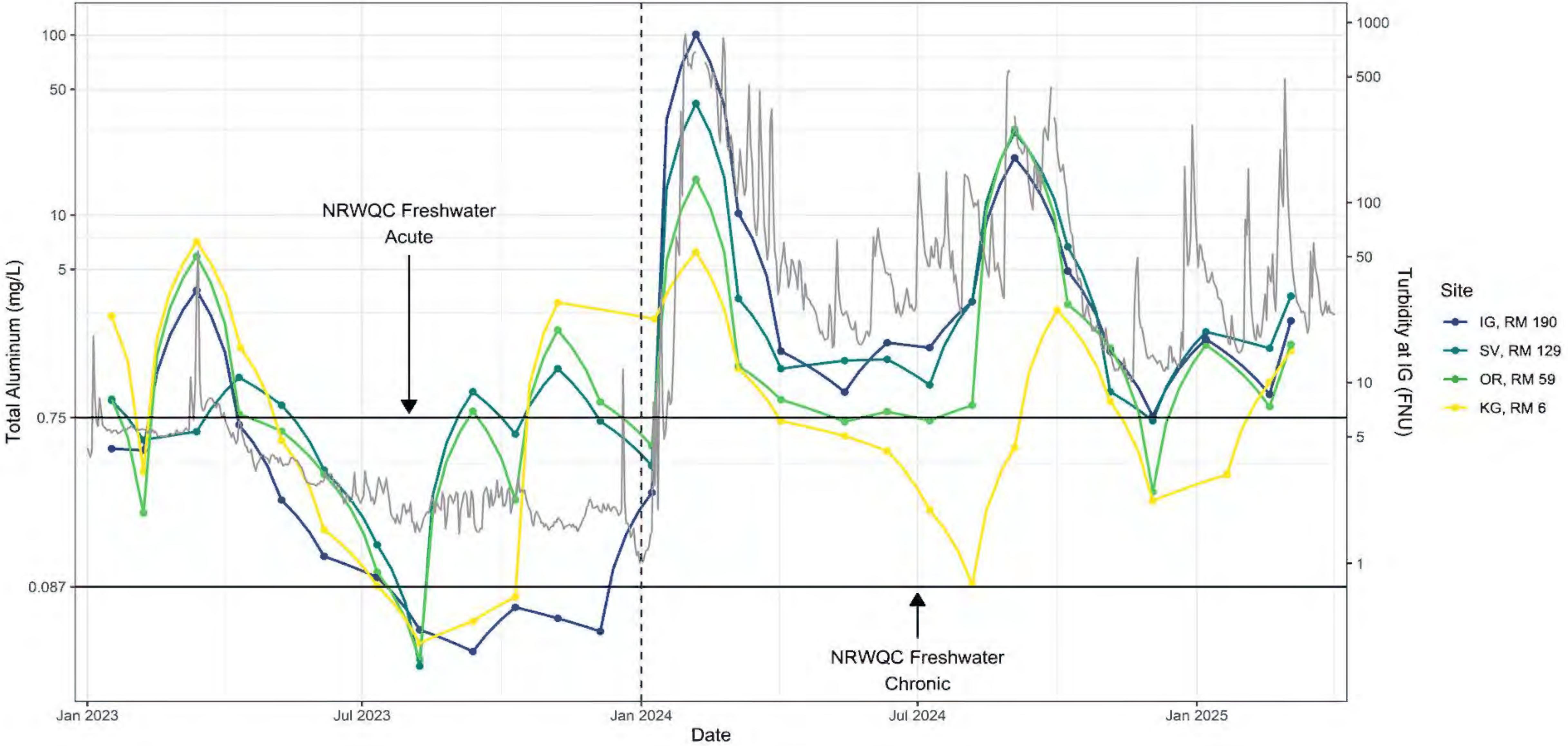


Methylmercury compared to lowest applicable water quality standard



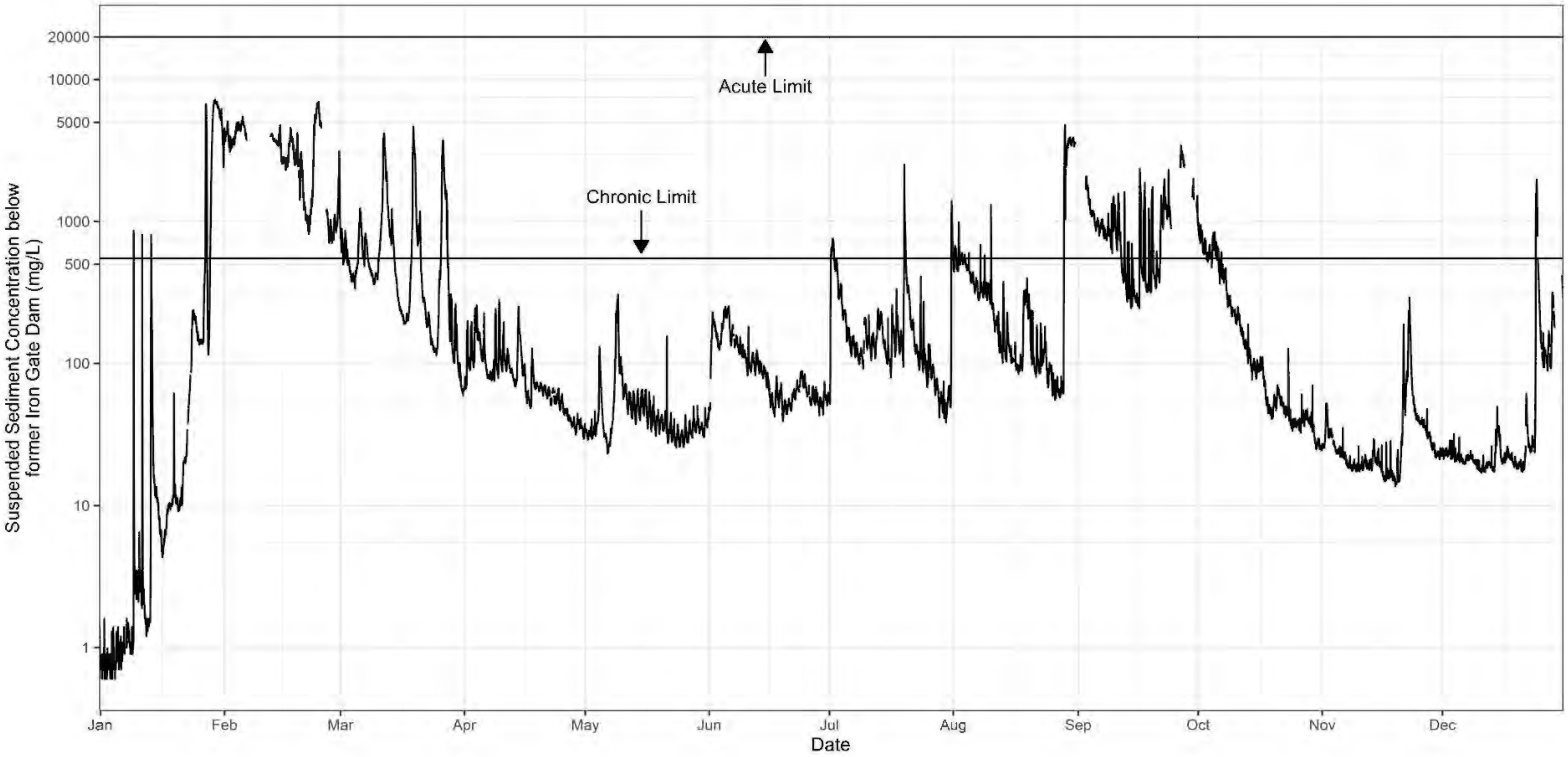
Total aluminum before and during drawdown (log scale)

*Klamath, Shasta, Scott, and Trinity Rivers are already on the 303(d) list as impaired by aluminum pollution (NCRWQCB)

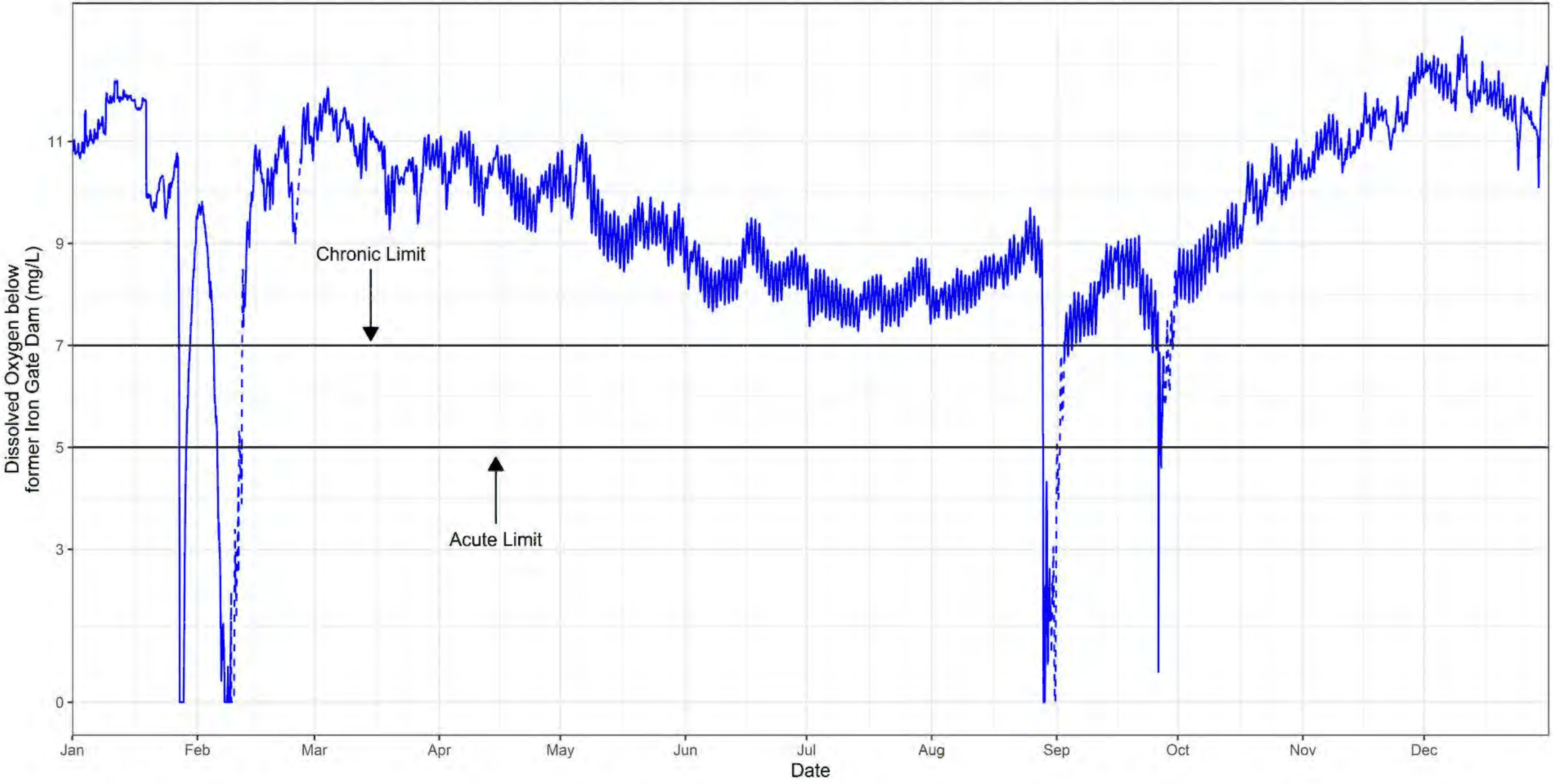


Modeled max SSC: **~20,000** mg/L vs. actual: **7,290** mg/L (log scale)

Turbidity to SSC regression by USGS



Modeled DO < 7 mg/L: **53** days vs. actual: **6** days



Modeled Expectations vs. Measured Results

Parameter	Modeled	Actual
Maximum SSC (mg/L)	15,000-30,000	**7,290**
Days above 1,000 mg/L SSC	56	**52**
Days above 5,000 mg/L SSC	14	**4.3**
Days below 7 mg/L DO	53	**6.2**
Days below 5 mg/L DO	12	**3.6**


2024


2021
Reconnect Klamath

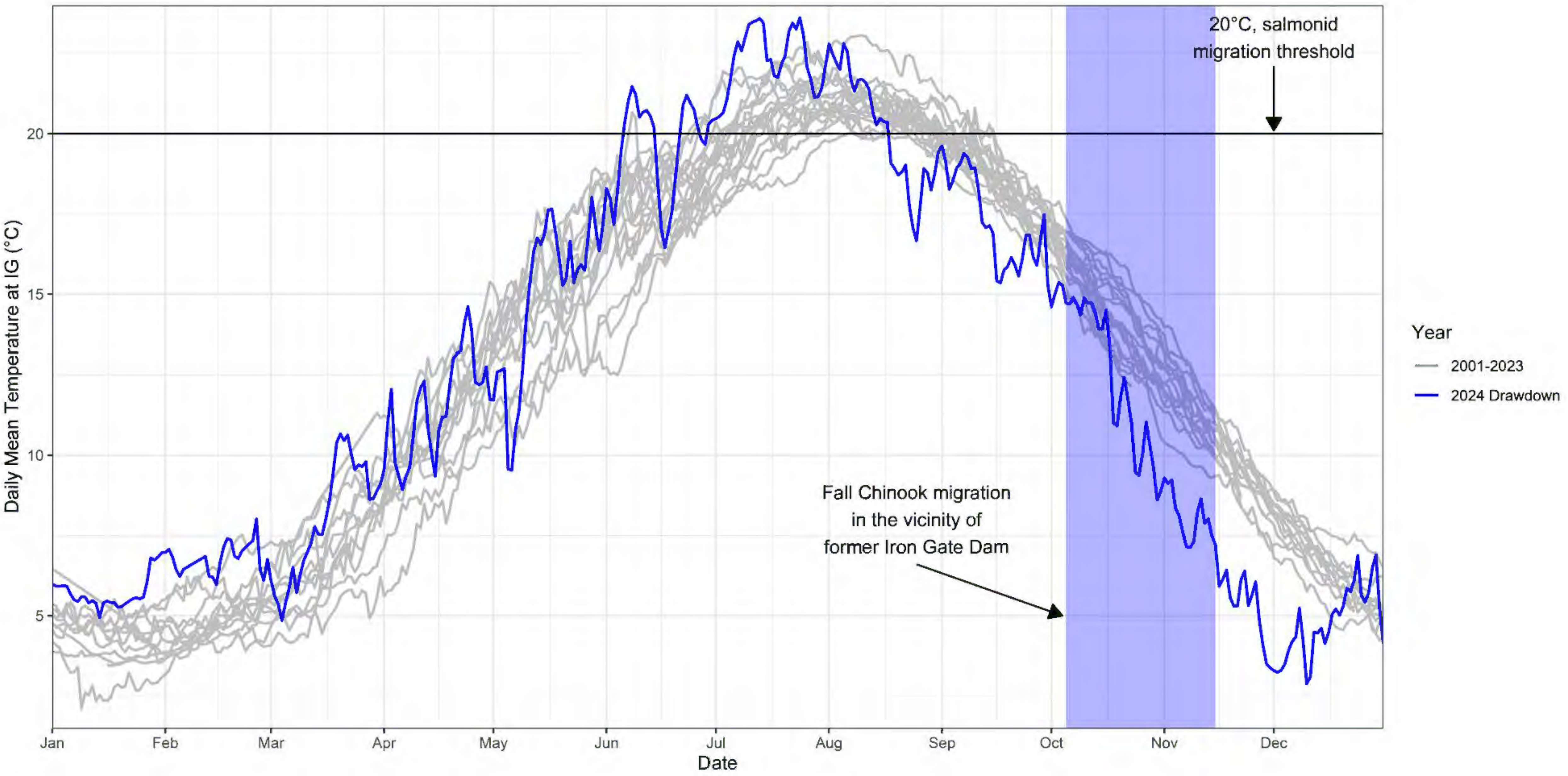

2025

Short-Term Drawdown WQ Impacts

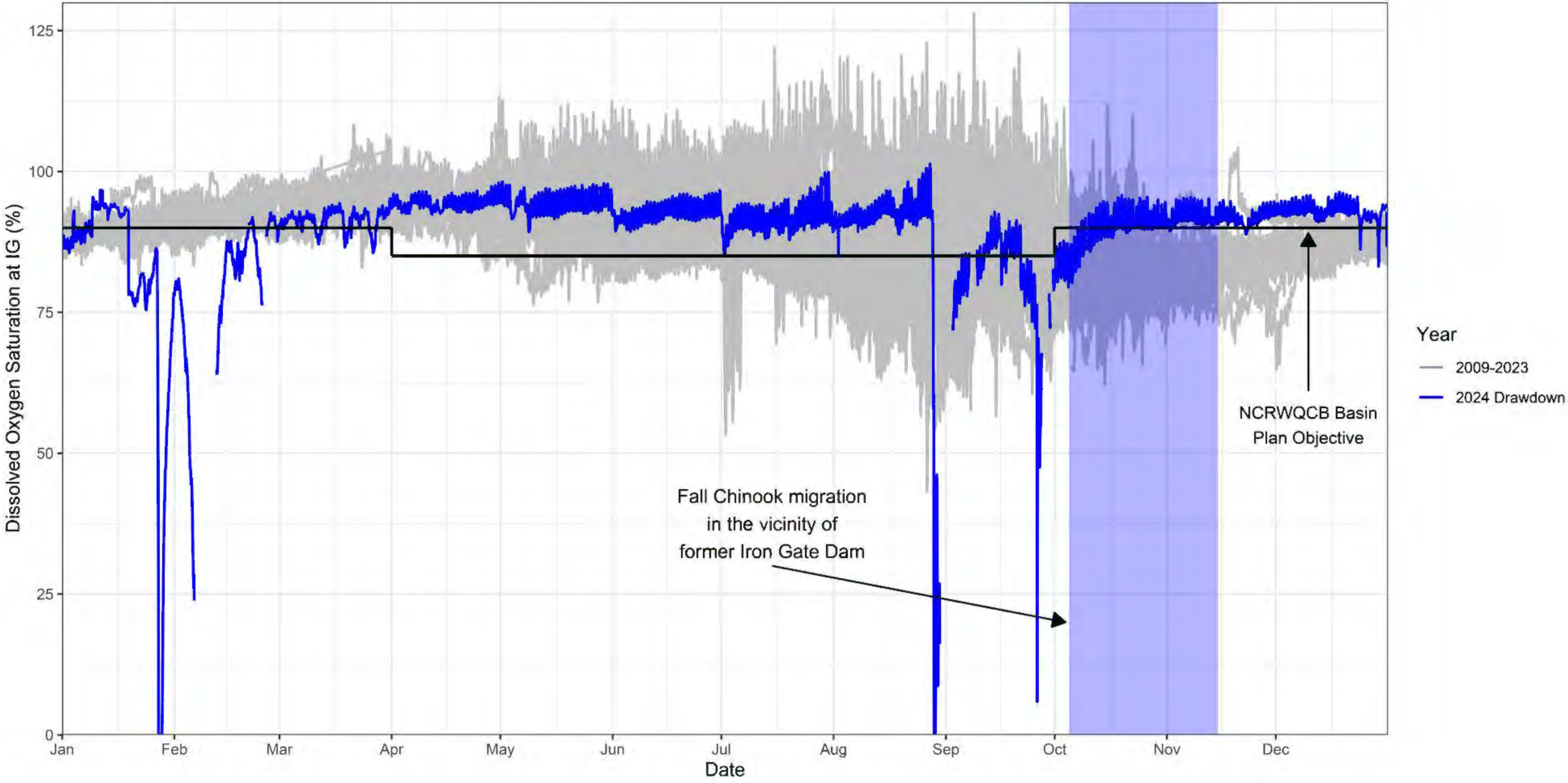
- DO sags, including several hours of anoxia, during initial drawdown, cofferdam breach, and cofferdam removal
- SSC below salmonid stress thresholds during 86% of the year
- DO above salmonid stress thresholds during 98% of the year
- SSC and DO impairments much less severe than modeled

What’s ahead for a free(-er) Klamath?

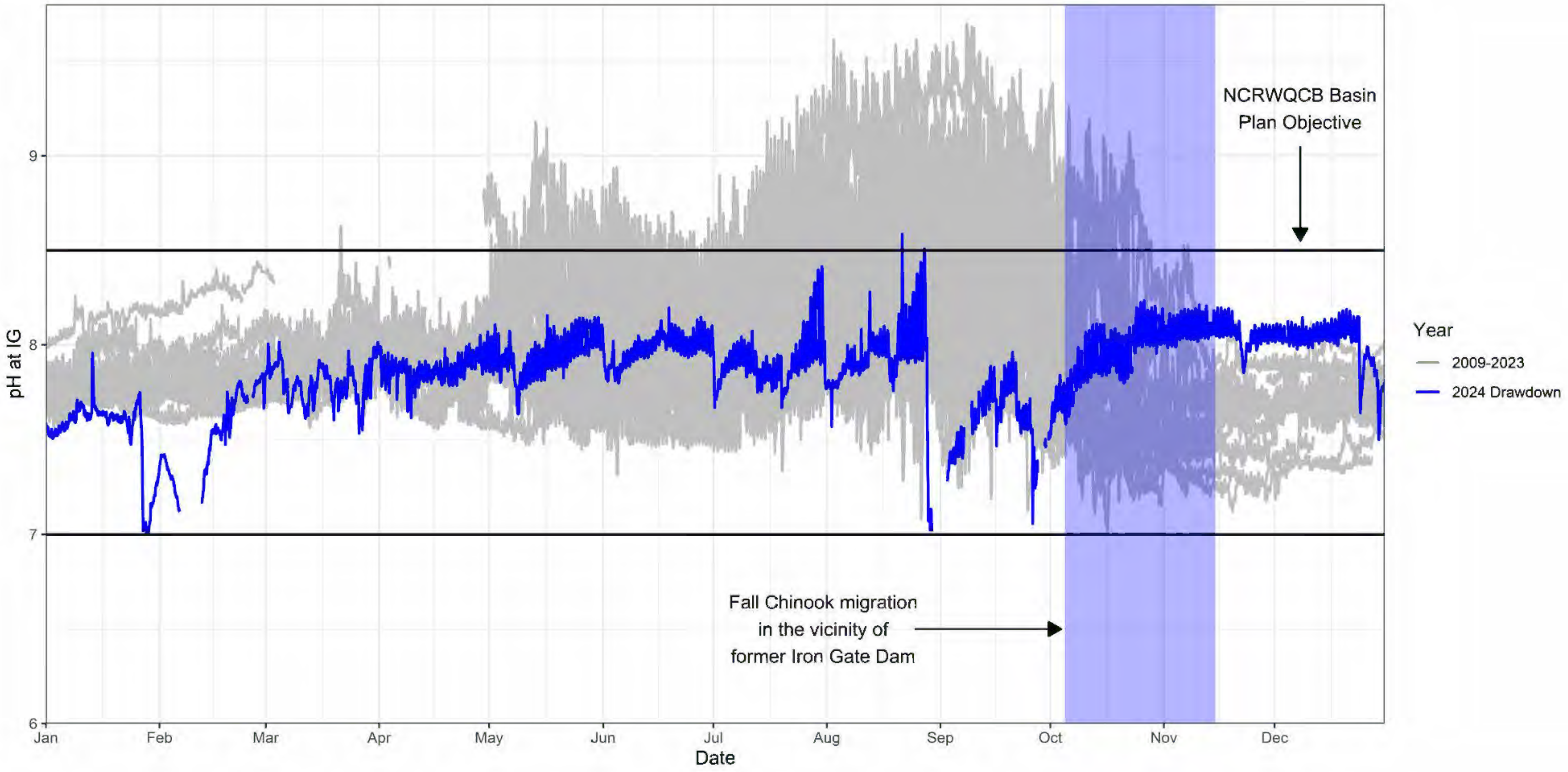
Immediate improvements in temperature



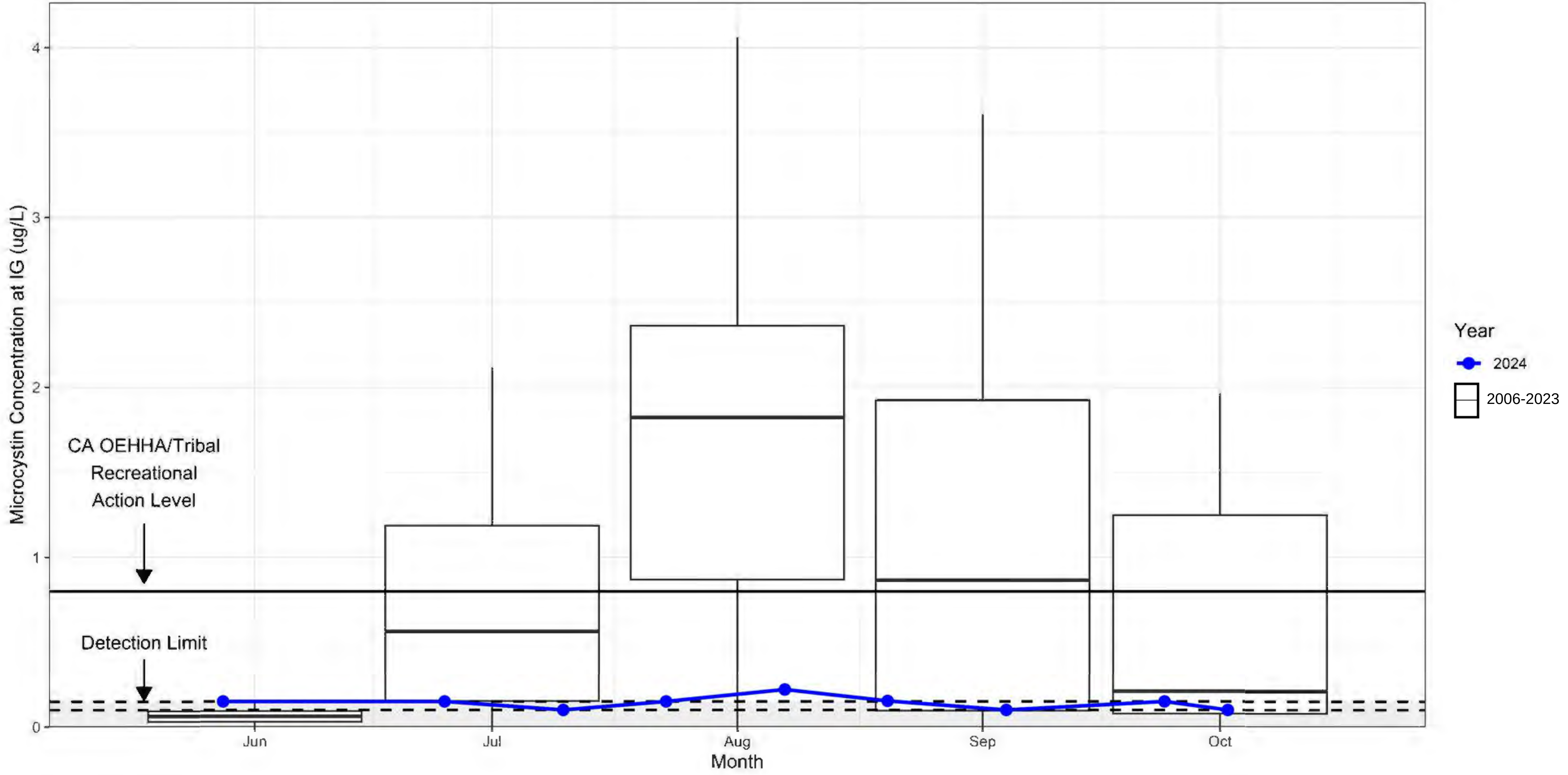
Immediate improvements in dissolved oxygen



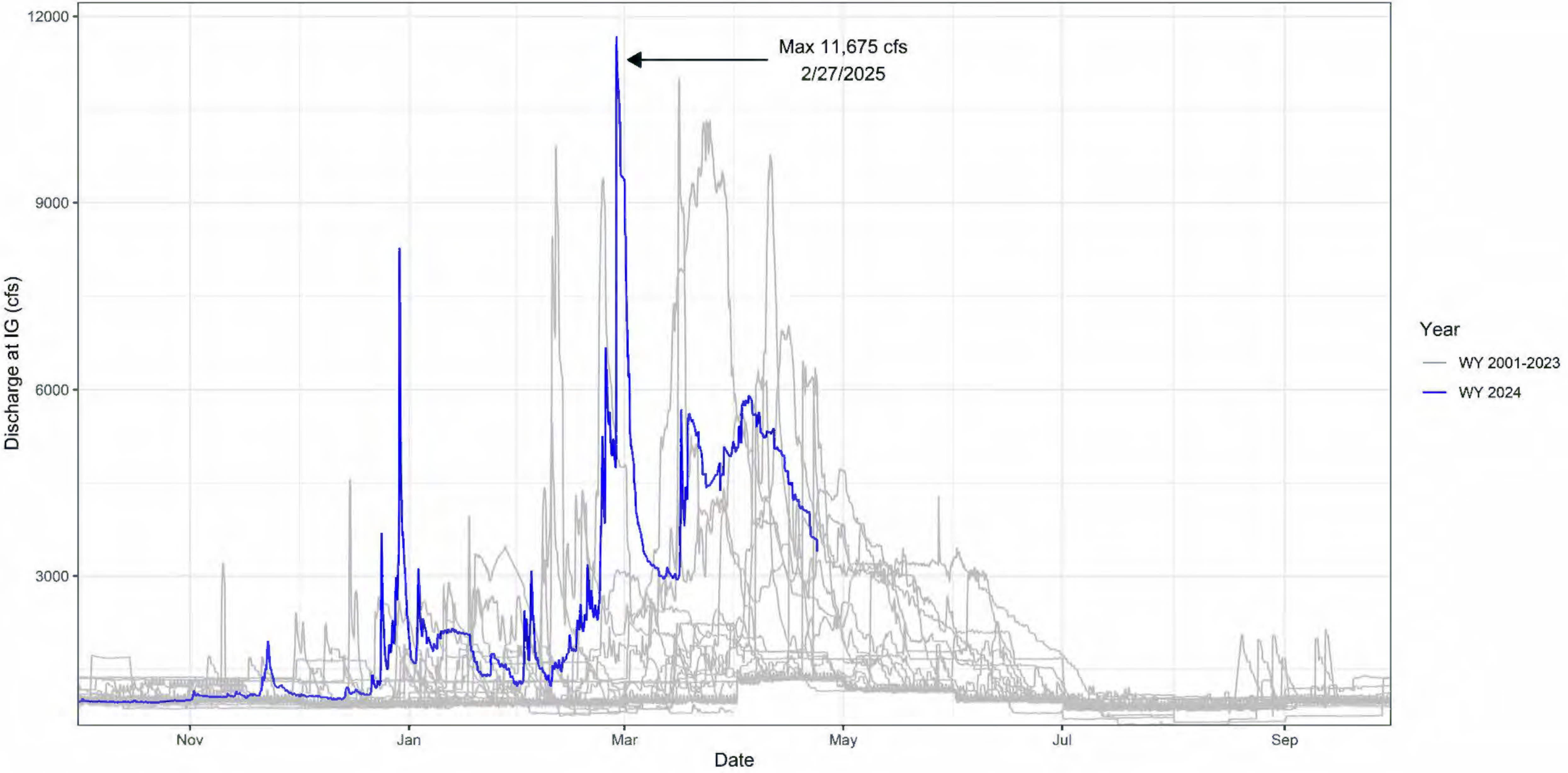
Immediate improvements in pH



Microcystin samples mostly nondetect in 2024



Increased disturbance in free-flowing reaches (data from USGS)



Before and After June-October Water Quality
% of continuous data below former Iron Gate dam

Parameter	2001-2011[1]	2012-2023[2]	2024
DO Sat. < 90%	33	62	**40**
DO Sat. < 85%	22	41	**19**
pH > 8.5	23	24	**<1**
pH > 9.0	2	7	**0**
Temp. > 22 °C	9	1	**19**

1 Asarian, E., & Kann, J. 2013. Synthesis of Continuous Water Quality Data for the Lower and Middle Klamath River, 2001-2011. Prepared by Kier Associates and Aquatic Ecosystem Sciences for the Klamath Basin Tribal Water Quality Work Group. 50 pp. + appendices.

2 Iron Gate curtain used starting 2015 (water released from lower in the reservoir)

Long-Term Dam Removal Water Quality Improvements

- Lower late summer and fall temperatures
- Higher dissolved oxygen
- Lower and less variable pH
- Almost no microcystin detected
- Restored flow regime and sediment transport regime


Klamath River at Seiad Valley

Water Quality Leads to…

- Reduced fish disease
- Habitat availability, diversity
- Safety for cultural, ceremonial, and recreational use
- Access to healthy traditional foods and other cultural resources
- Healthy communities and economies

Ron & Jason Reed dipnet fishing at Ishi Pishi Falls
(Photo: Noel DiBenedetto)

1. The Klamath River is resilient in the face of dam removal impacts.

2. Water quality impairments were far less severe than predicted.

3. Striking water quality improvements are already being realized.


Peeshkeesh hûut kích?
Yêeship!

"Mapping a New River"

First Surveys of the New Free Flowing Klamath River After a Century of Dams

Salmon Restoration Federation (SRF)

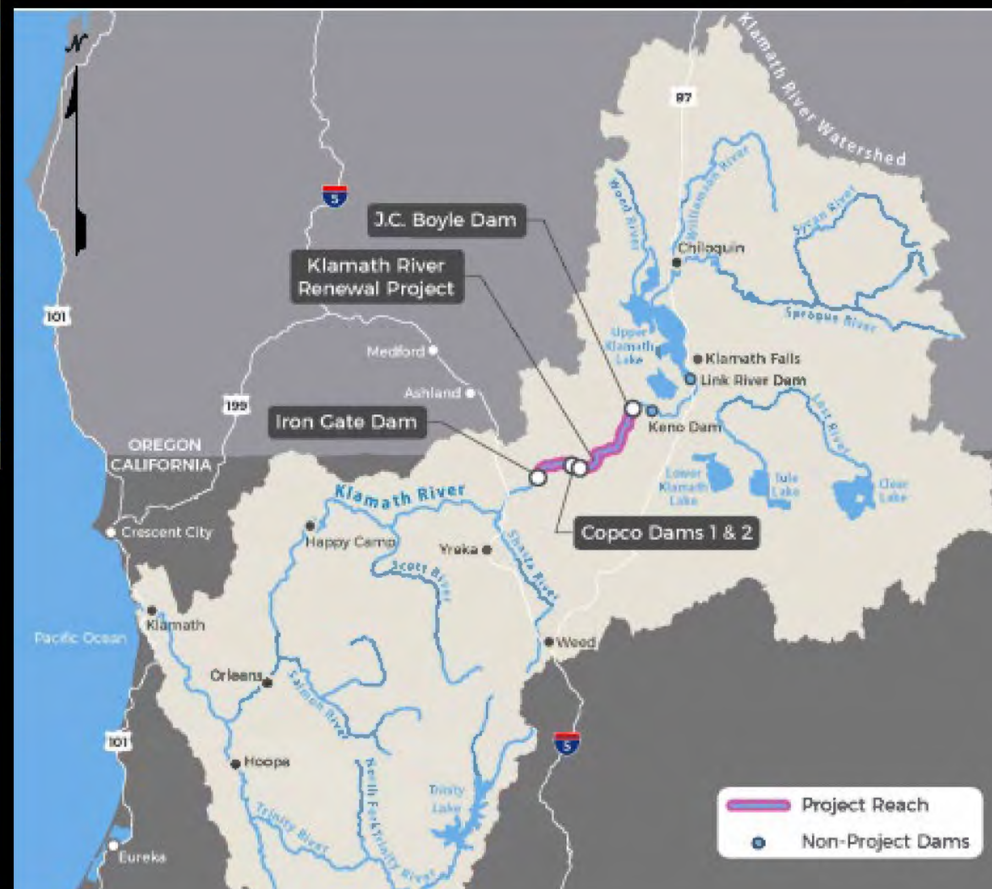
May 1st, 2025

Yurok Tribe Fisheries Department
Design and Technical Services Program (TSP)
Condor Aviation Program

David (DJ) Bandrowski P.E.; Senior Civil Engineer
Cort Pryor; Survey Manager
Geomatics Branch Staff and Fisheries TSP Team

STANDING ON THE SHOULDERS OF GIANTS… A TRIBUTE TO THE FIGHT

STEWARDSHIP ACROSS THE KLAMATH BASIN – RESTORING BALANCE
THE KLAMATH RIVER IS THE LIFEBLOOD OF THE YUROK TRIBE



The Next Generation - Capacity Building in Action
Restoration isn't Just About Rivers… But About People

Learning from Those that Came Before us – The Elwha

The Elwha River flows into the Strait of Juan de Fuca, carrying sediment once trapped behind dams. The gradual release has rebuilt riverbanks and created estuary habitat for Dungeness crabs, clams, and other species.

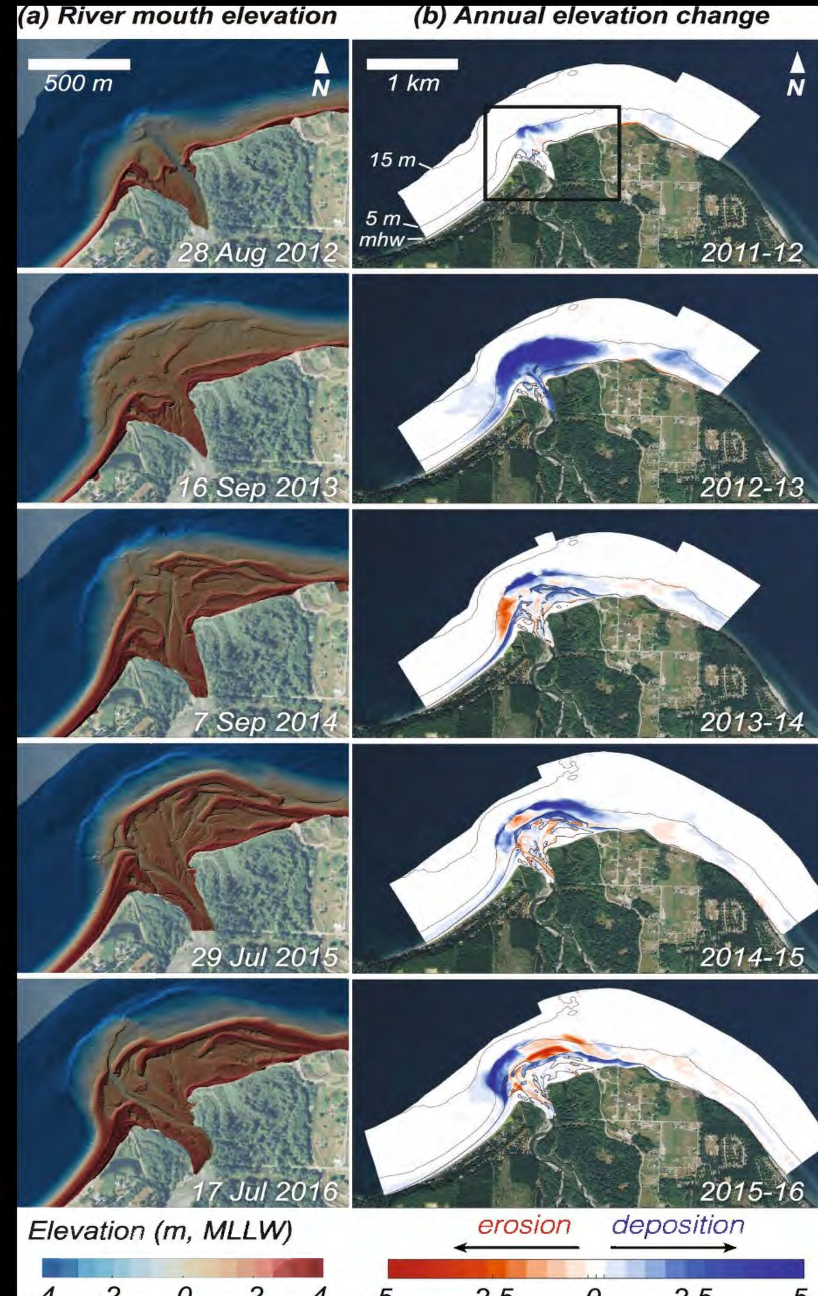
PHOTOGRAPH BY ELAINE THOMPSON, ASSOCIATED PRESS

World's Largest Dam Removal Unleashes U.S. River After Century of Electric Production

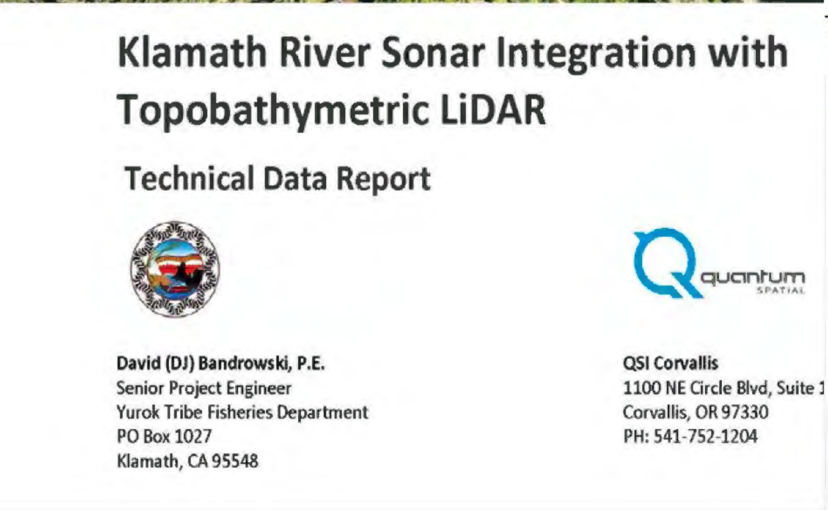
As Washington State's Elwha River runs free, a habitat for fish and wildlife is restored.

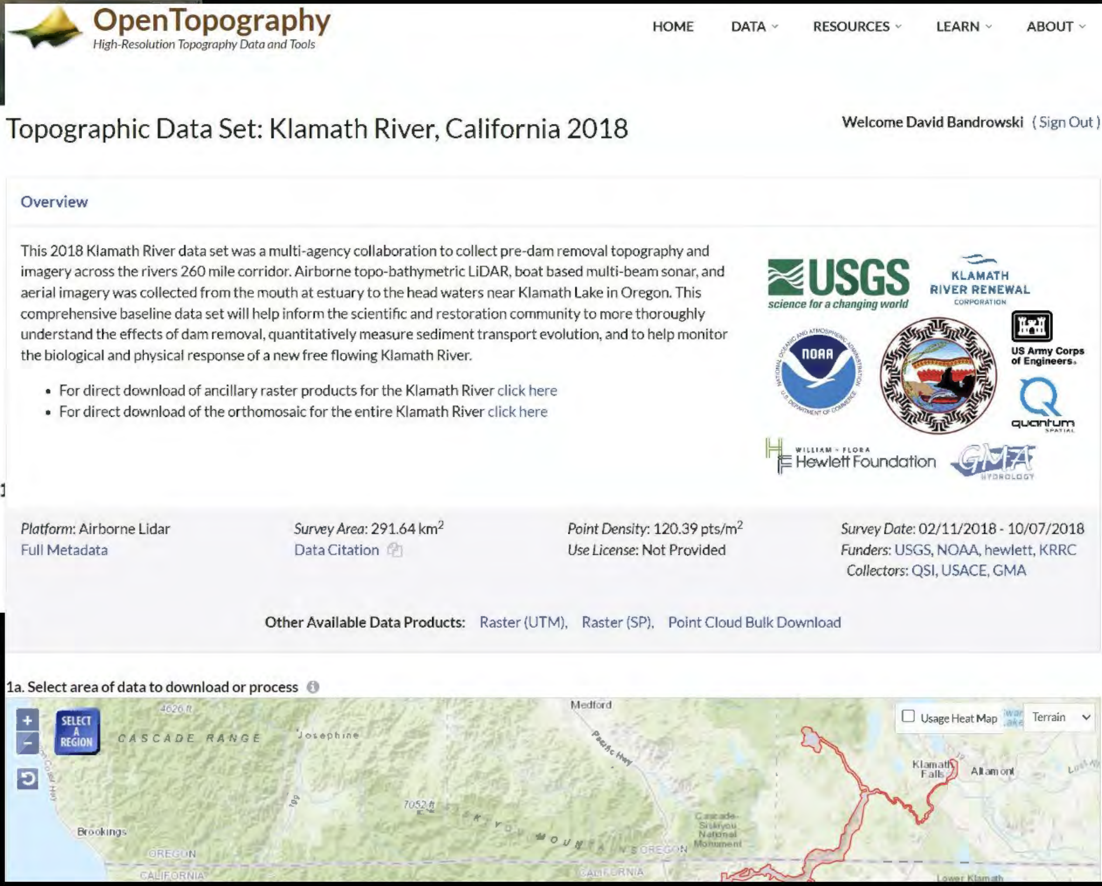
8 MINUTE READ

BY **MICHELLE NIJHUIS**, FOR NATIONAL GEOGRAPHIC



Mapping of the Klamath River (2018)
Base Line Data Set for Pre-Dam Removal Conditions
Approx. 72,000 acres; 250 miles / 400 kilometers



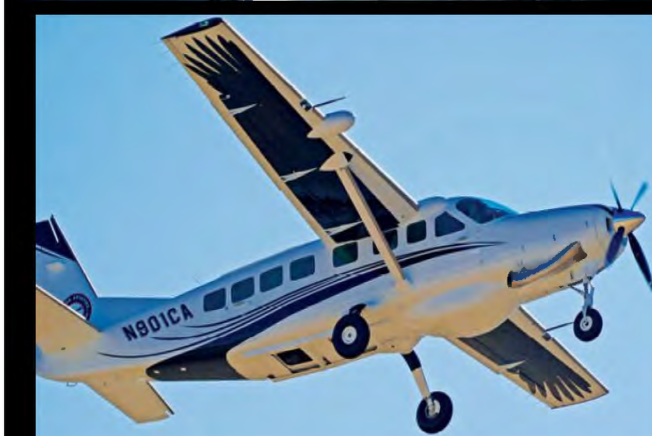


THE CONDOR AVIATION GEOSPATIAL PROGRAM TAKES FLIGHT

LoCO Staff / Tuesday, June 27, 2023 @ 10:01 a.m. / Wildlife

Yurok Tribe Acquires Badass, LIDAR-Equipped, Condor-Wing-Bedecked Airplane for Scientific Research and Land Management Purposes

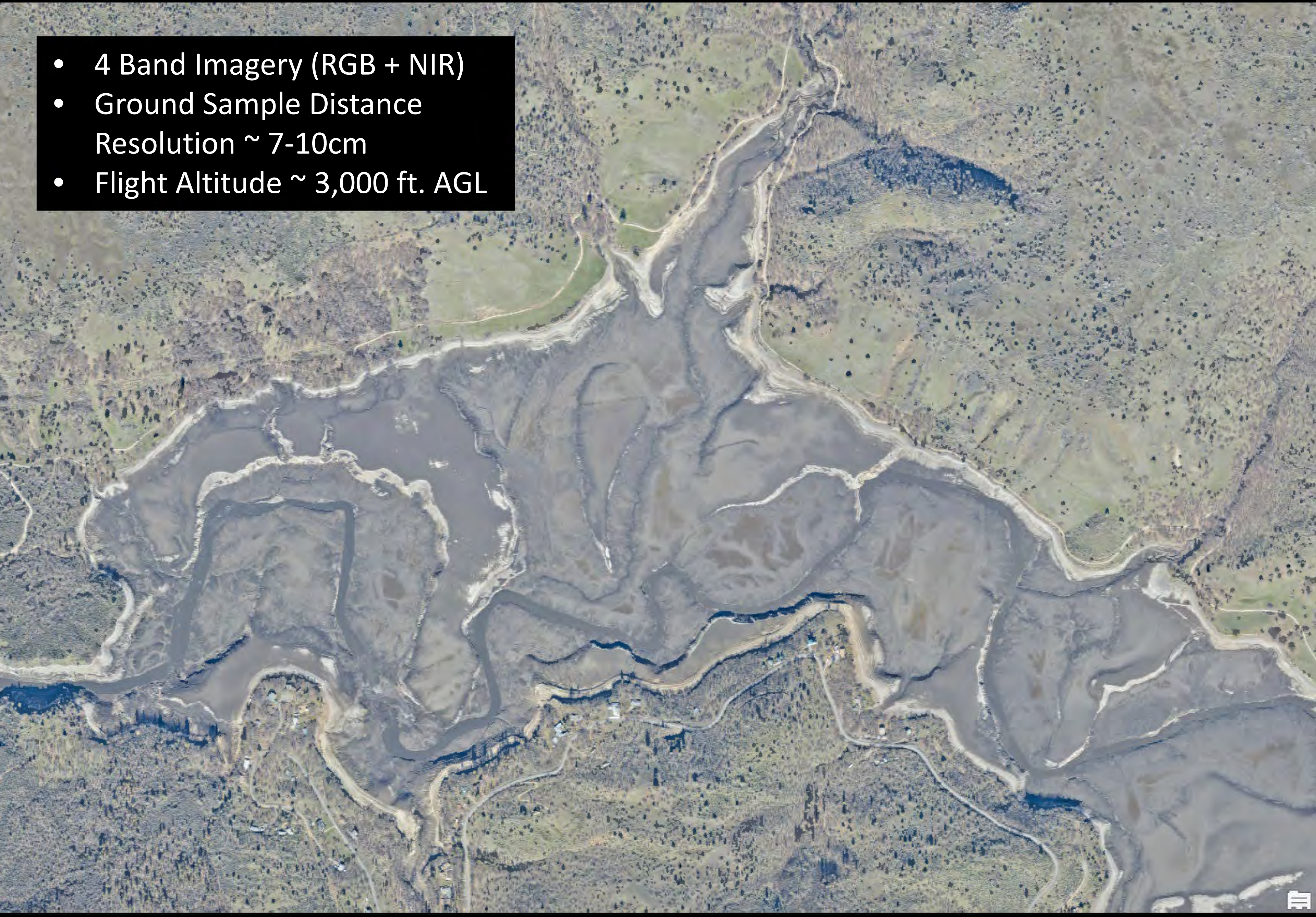
The Yurok Tribe's Cessna Grand Caravan EX aircraft is adorned with condor wings and a traditional basket design. Photo courtesy the tribe's Condor Aviation unit.



Drawdown Begins Mapping a New River After a Century of Dams and Restoring the Homeland of the Shasta Indian Nation

AERIAL IMAGERY OF *COPCO VALLEY* – JANUARY 2024

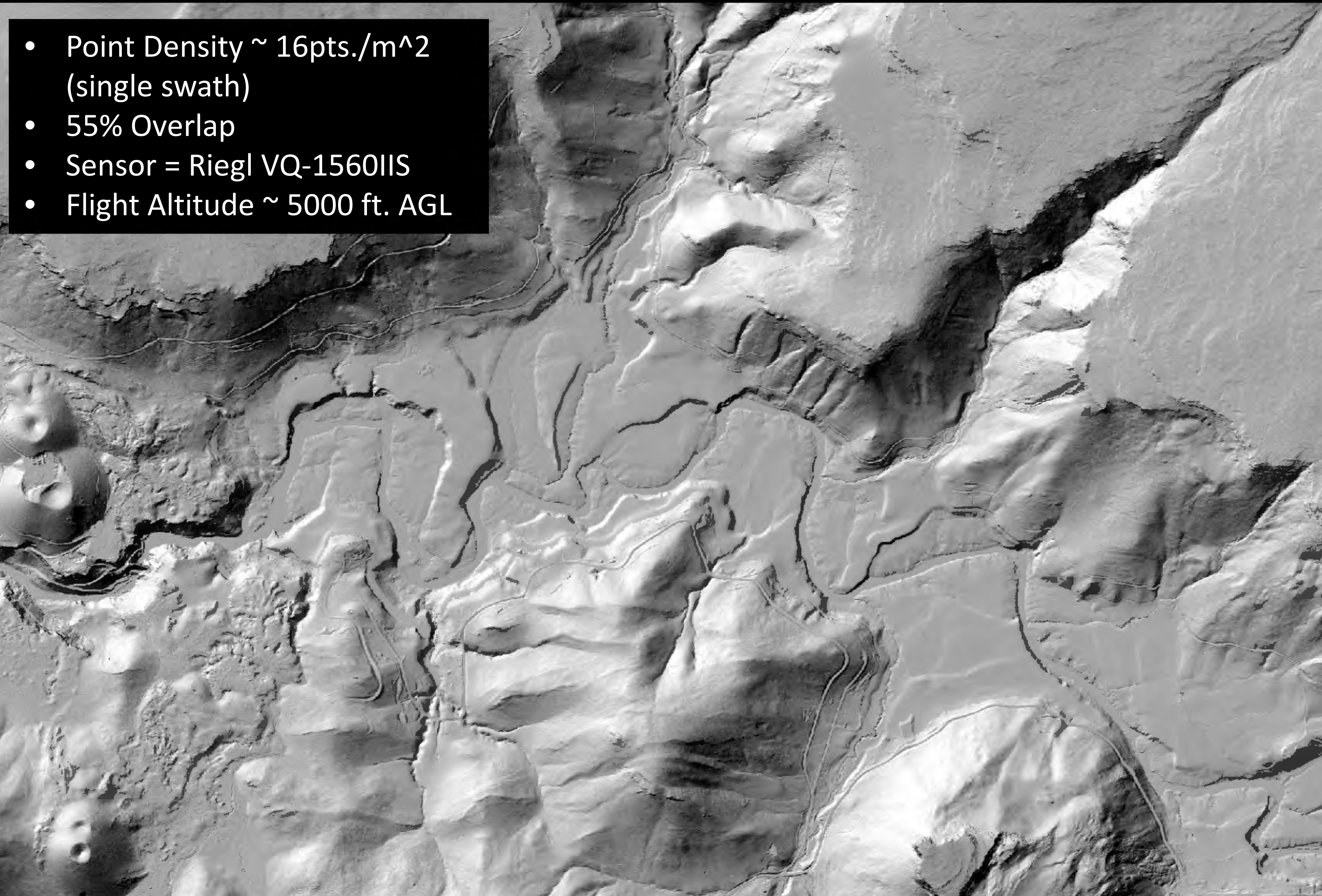
AERIAL IMAGERY OF *COPCO VALLEY* – FEBRUARY 2024



AERIAL IMAGERY OF *COPCO VALLEY* – APRIL 2024

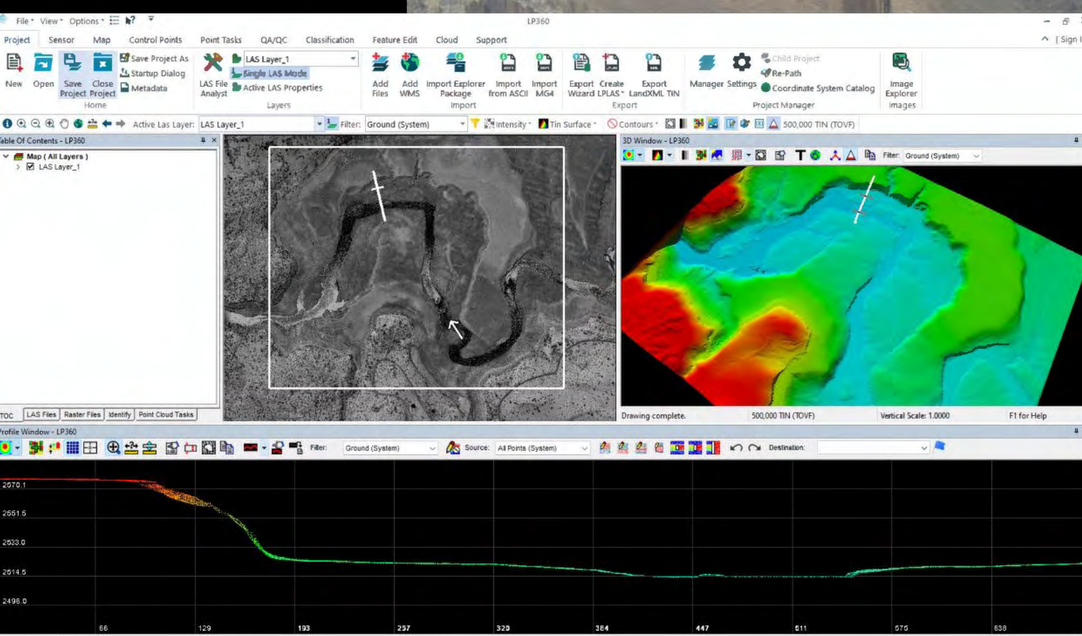
2024 LiDAR Surveys – Developing Digital Terrain Models

- Point Density ~ 16pts./m^2 (single swath)
- 55% Overlap
- Sensor = Riegl VQ-1560IIS
- Flight Altitude ~ 5000 ft. AGL

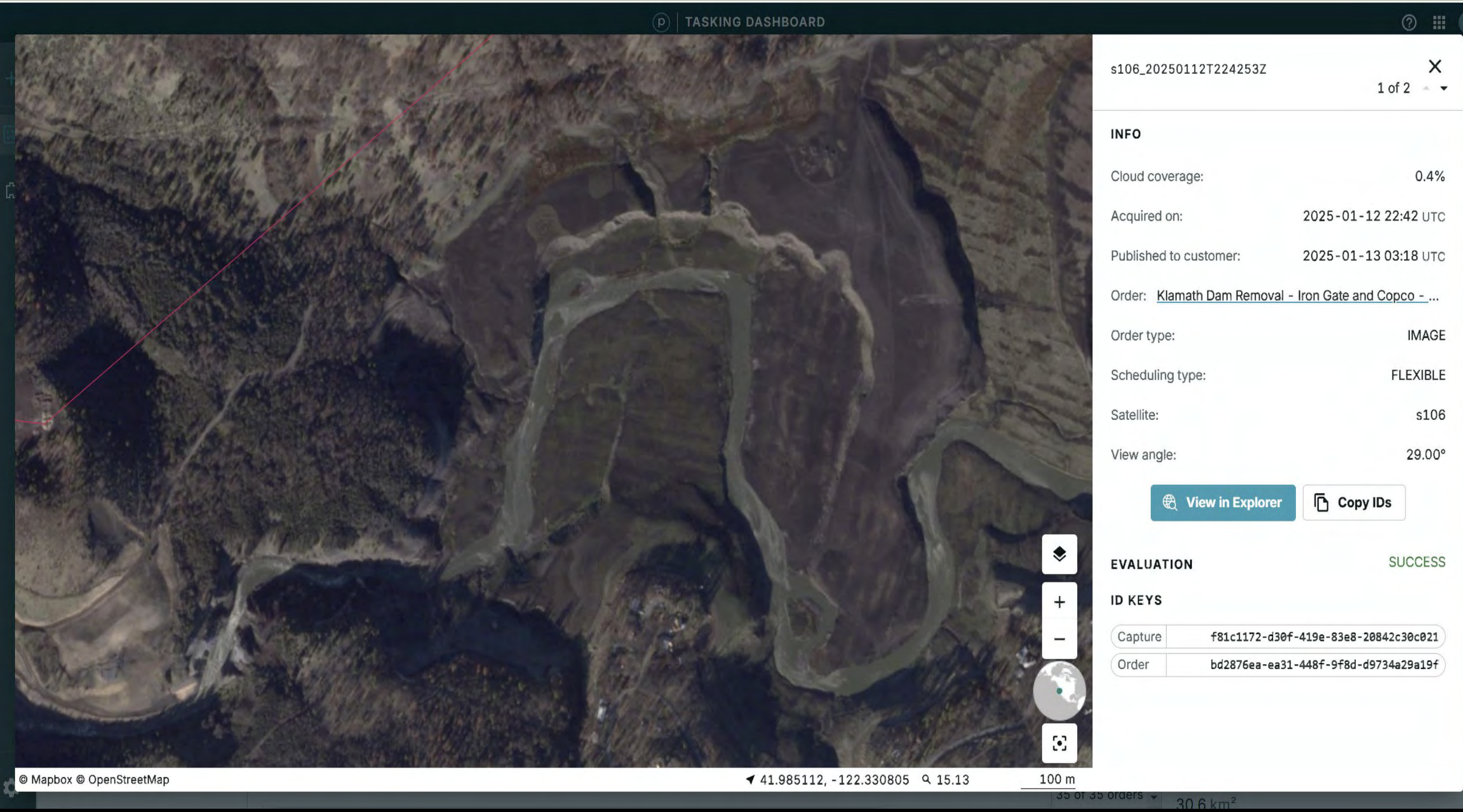


Putting a New River on the Map (*Literally*), Digitizing the Klamath and its Tributaries After more Than a 100 Years

Geospatial Analysis using 3D Modeling form Imagery/LiDAR

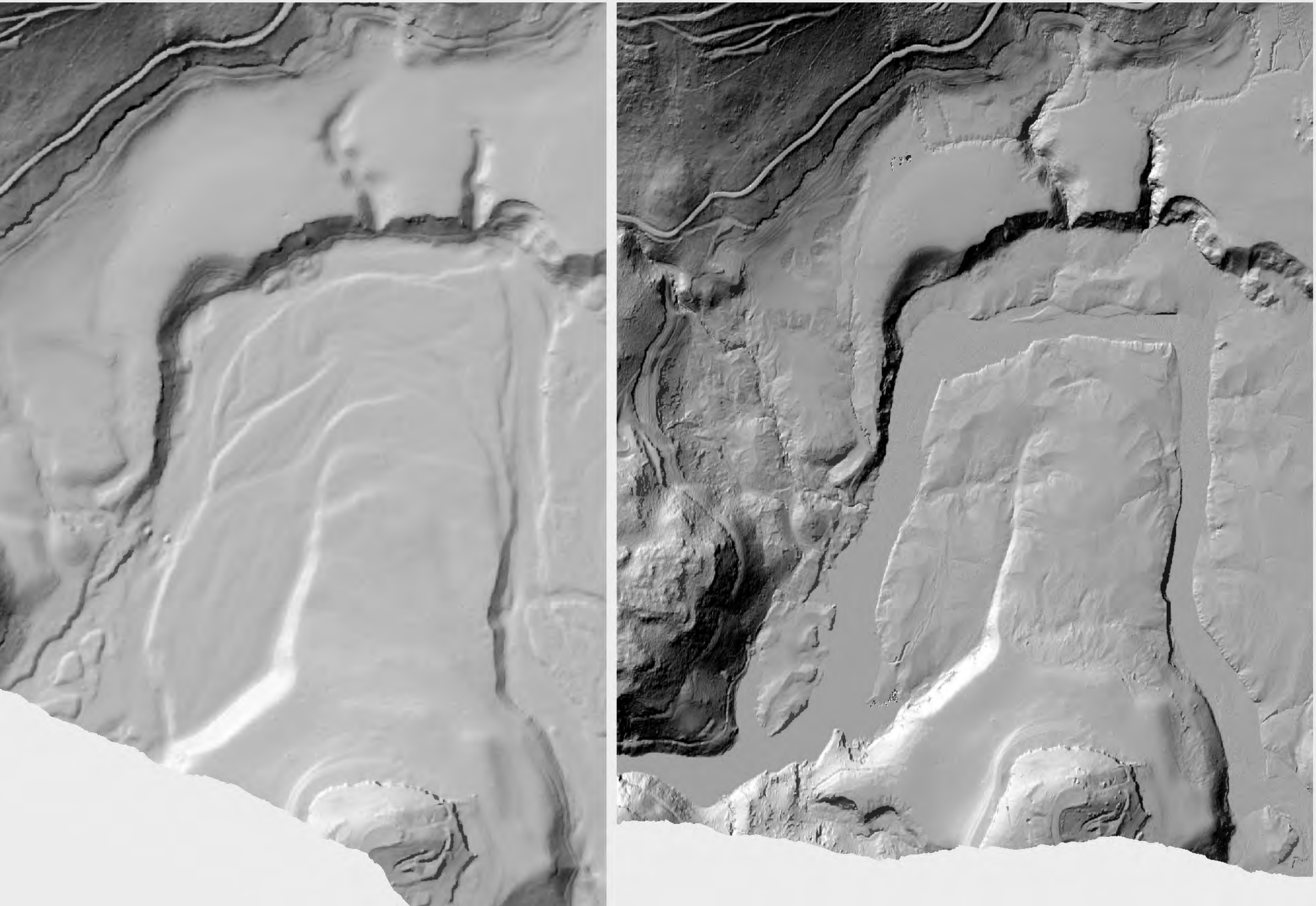


2025 Satellite Imagery – Planet Labs (~1M Resolution)



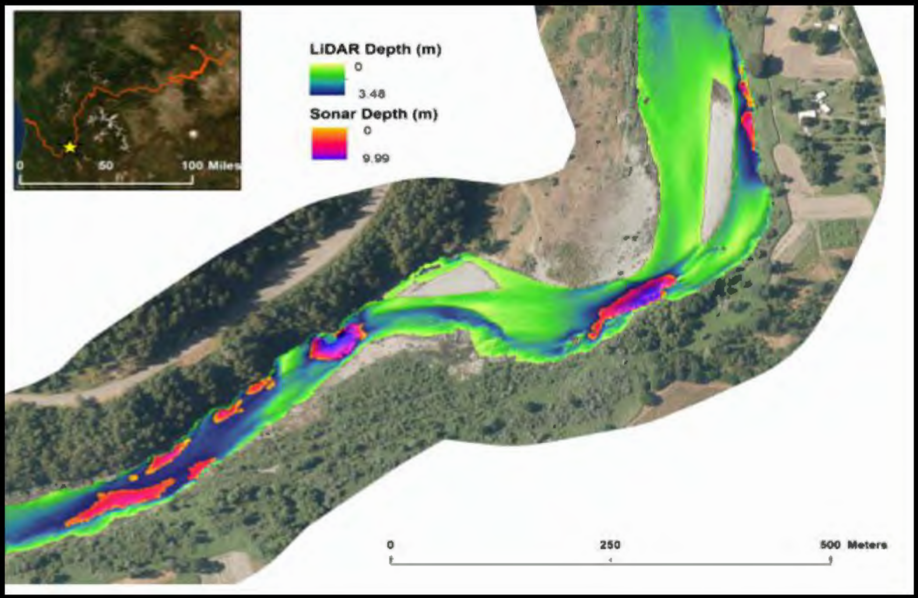
BATHYMETRIC MAPPING – BOAT BASED SONAR DATA COLLECTION

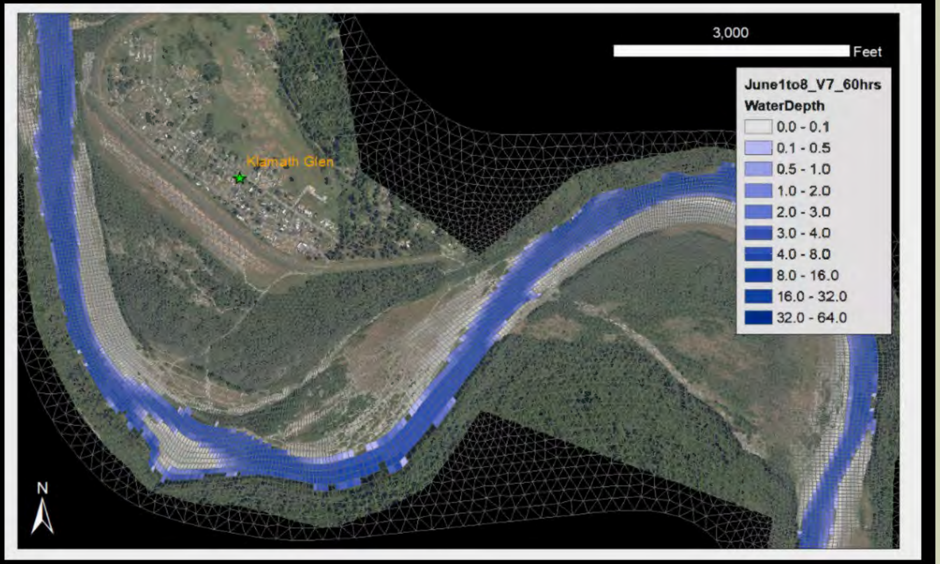
DTM Comparative Analysis 2018 vs. 2024

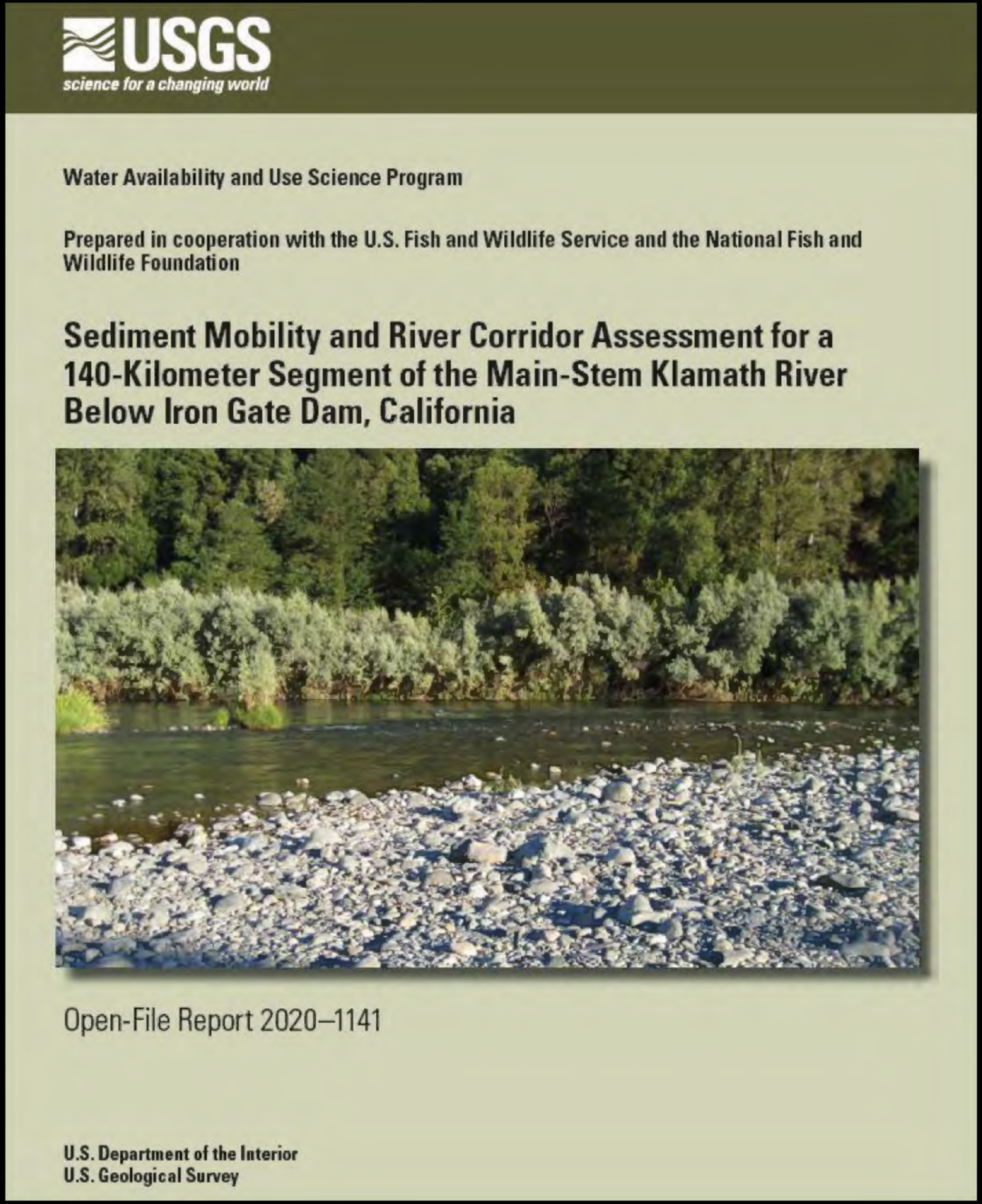


Next Steps – How will the LiDAR and Imagery Be Used:

Hydrodynamic Models; Habitat Assessment; Sediment Transport; Geomorphic Change Detection, Monitoring Vegetation, etc.







USGS
science for a changing world

Water Availability and Use Science Program

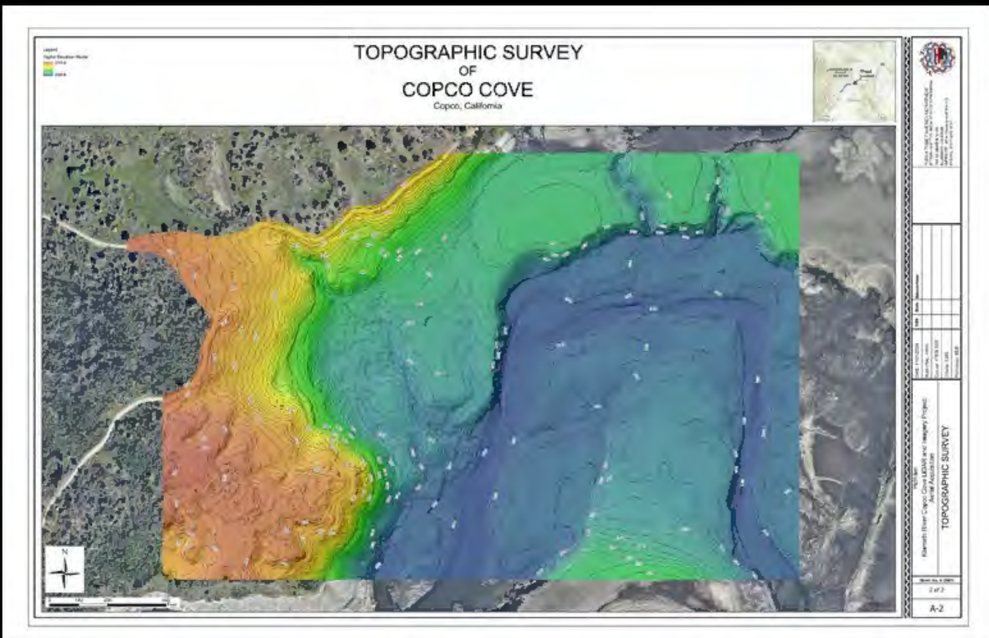
Prepared in cooperation with the U.S. Fish and Wildlife Service and the National Fish and Wildlife Foundation

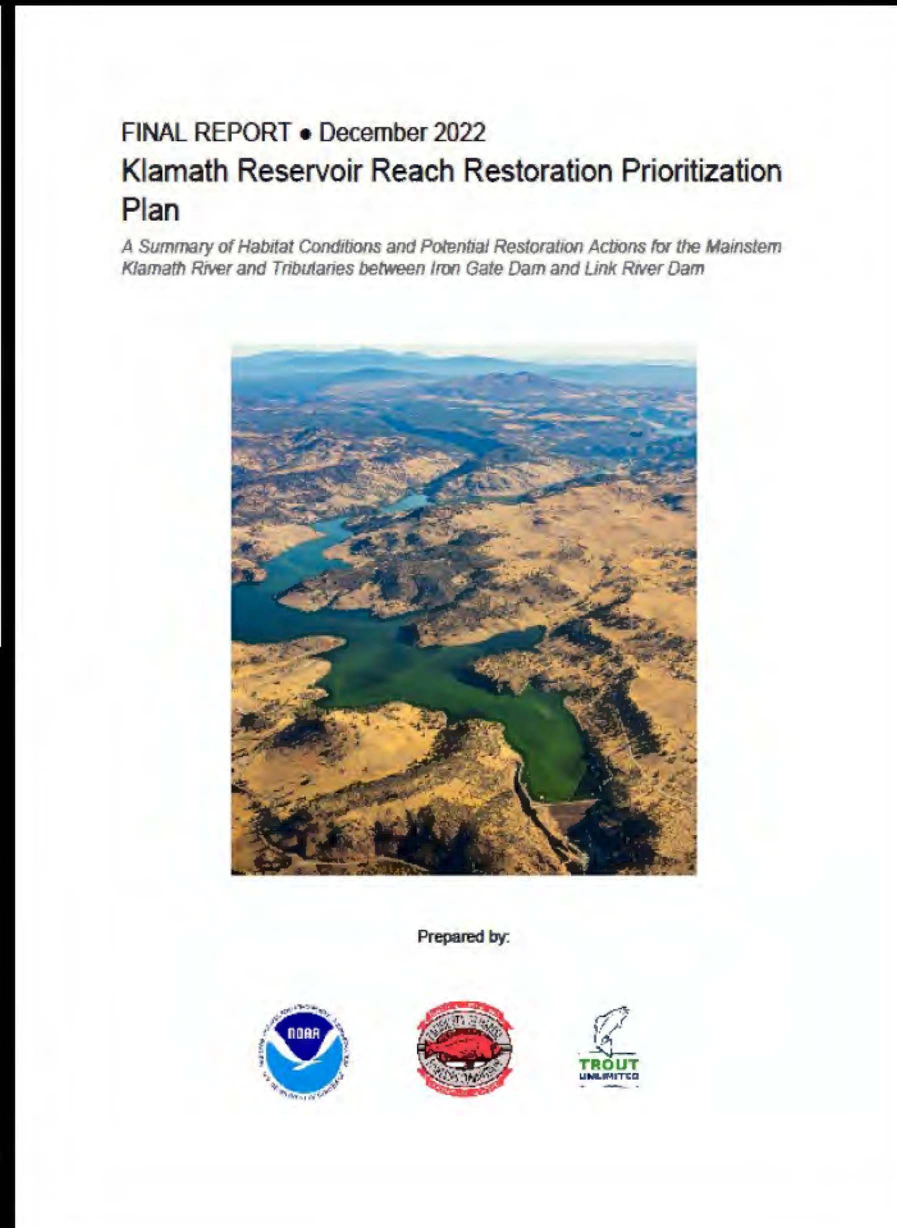
Sediment Mobility and River Corridor Assessment for a 140-Kilometer Segment of the Main-Stem Klamath River Below Iron Gate Dam, California

Open-File Report 2020–1141

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

Supporting Tributary Restoration Designs and Future Projects Across the Basin





Supporting Revegetation Operations During Dam Removal

Seeding and Planting Statistics

7 seed mixes

- 6 mixes were from custom-grown seed

High diversity

- 28 species in total
- 11-20 species per mix

Seed Mix	Lbs Sown	Acres
Rocky Wake Zone	11,128.1	286.0
Wild RWZ*	30.3	-
Grassland-Chaparral	2,769.3	83.5
Oak woodland	1,349.0	70.8
Riparian (low)	102.9	3.0
Ponderosa Pine	1,090.0	30.6
Riparian (high)	175.0	4.3
Native Mix 9	105.0	2.9
TOTALS	**16,749.6**	**481.1**

*Supplemented the Rocky Wake Zone mix on 33 acres in Copco only.

- 106,656 plants planted (25 species)
- 320 Oregon white oak acorn clusters
(25,585 acorns)
- 39 showy milkweed rhizome clusters
(*Asclepias speciosus/* 1,173 rhizomes)
- 75,898 bare root, container/plug plants

Restoration is About a Relationship to the Land and The People Who Steward and are the Caretakers






When the River is Restored… The People Will Be Healed
The Work is Just Beginning…




Tell me and I'll forget. Show me, and I may not remember. Involve me, and I'll understand.

- Native American Saying -

DJ Bandrowski P.E., Senior Project Engineer
Program Manager
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THE FIGHT FOR DAM REMOVAL… PROTECTING THEIR EXISTENCE


Copco No. 1 | CA


Copco No. 2 | CA


JC Boyle | OR


Iron Gate | CA

THE KLAMATH - FREEING A RIVER AFTER A CENTURY OF DAMS

IRON GATE

The Klamath - Freeing a River After a Century of Dams

Copco 1

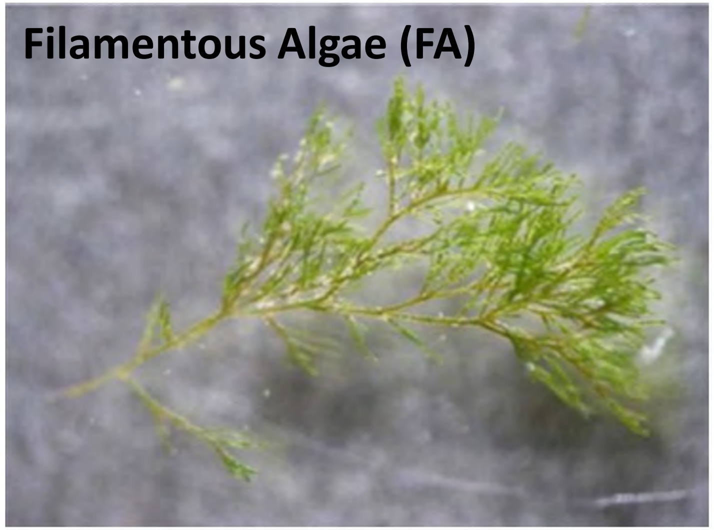
Factors Limiting Filamentous Algae and Rooted Macrophyte Growth During Dam Removal in the Klamath River

Isabelle Tang, *Oregon State University*; Desirée Tullos, *Oregon State University*; Laurel Genzoli, *University of Nevada, Reno*;
Ryan Bellmore, *USFS Pacific Northwest Research Station*; John R. Oberholzer Dent, *Karuk Tribe Department of Natural Resources*

Salmonid Restoration Federation
May 1, 2025

Excessive algae and macrophytes can cause a nuisance in rivers

- Filamentous Algae (FA) and rooted aquatic plants (macrophytes) are essential primary producers in a river
- Excessive accumulation of FA and macrophyte biomass can be a nuisance and impact dissolved oxygen
- Light and discharge are potential limiting factors for growth



The factors that drive the growth and senescence of FA and macrophytes are not well understood

- A large sediment pulse through the basin was anticipated during reservoir drawdown and deconstruction
- The Klamath River has high rates of primary production
- Dam removal provided an opportunity to study the impacts of a large sediment pulse on FA and macrophyte growth


Michael Wier / CalTrout

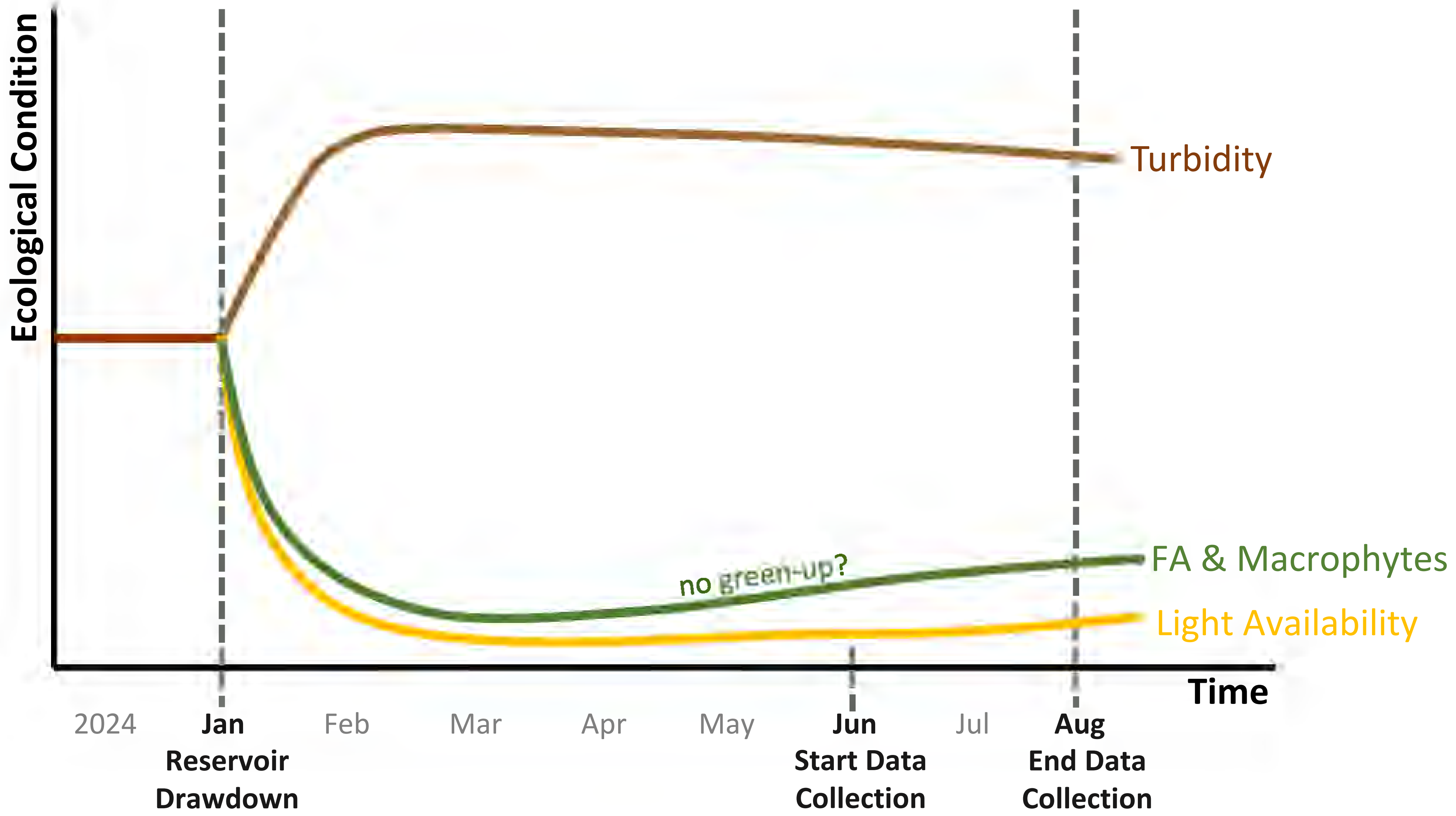

Swiftwater Films

How does FA and macrophyte growth timing, biomass accumulation, and senescence vary with changes in peak discharge, baseflow hydraulics, light availability, and temperature?

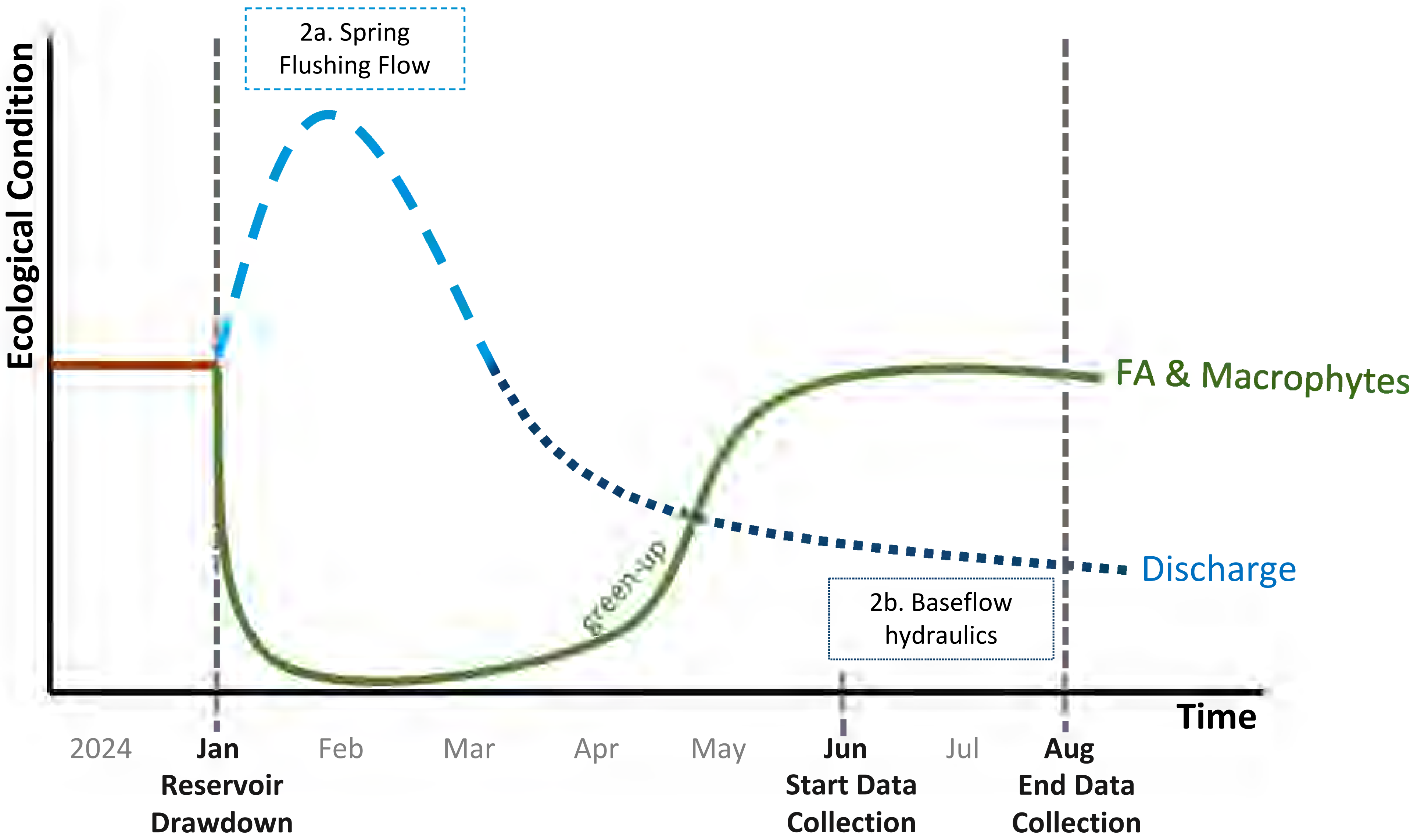
(1) Field surveys before and during dam removal

(2) Mechanistic Model

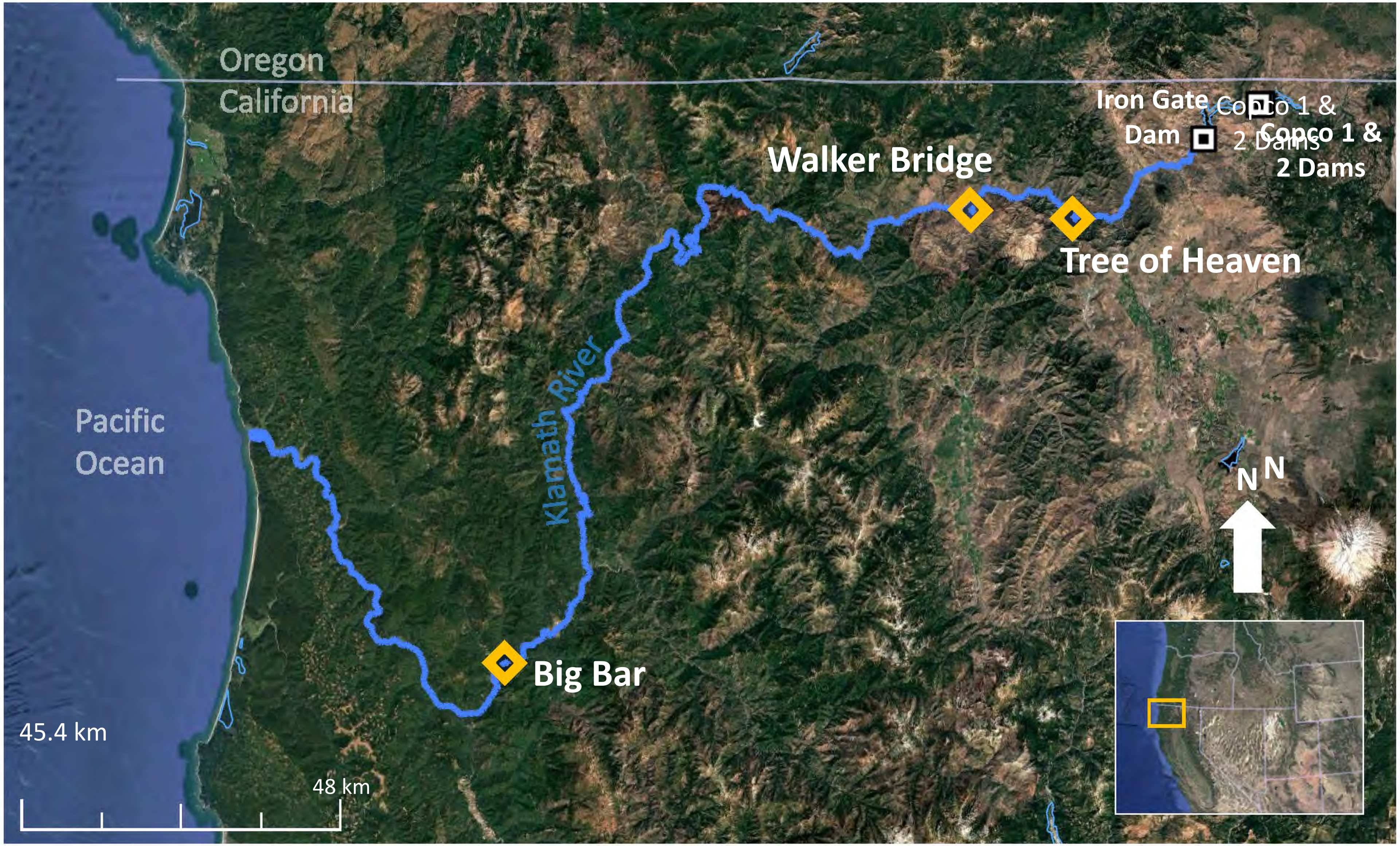
Hypothesis 1: Light controls biomass accumulation.



Hypothesis 2: Discharge controls biomass.



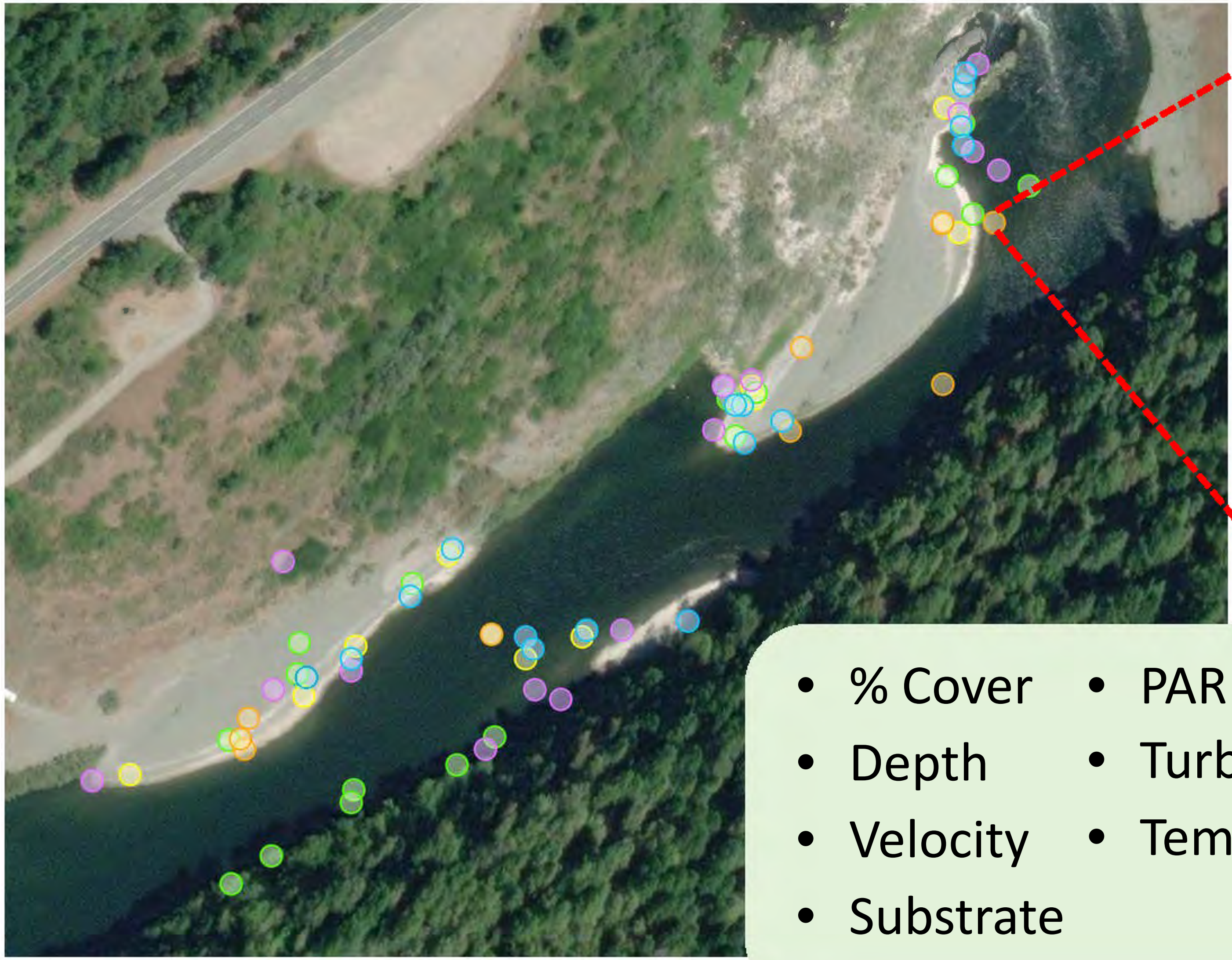
Field Methods

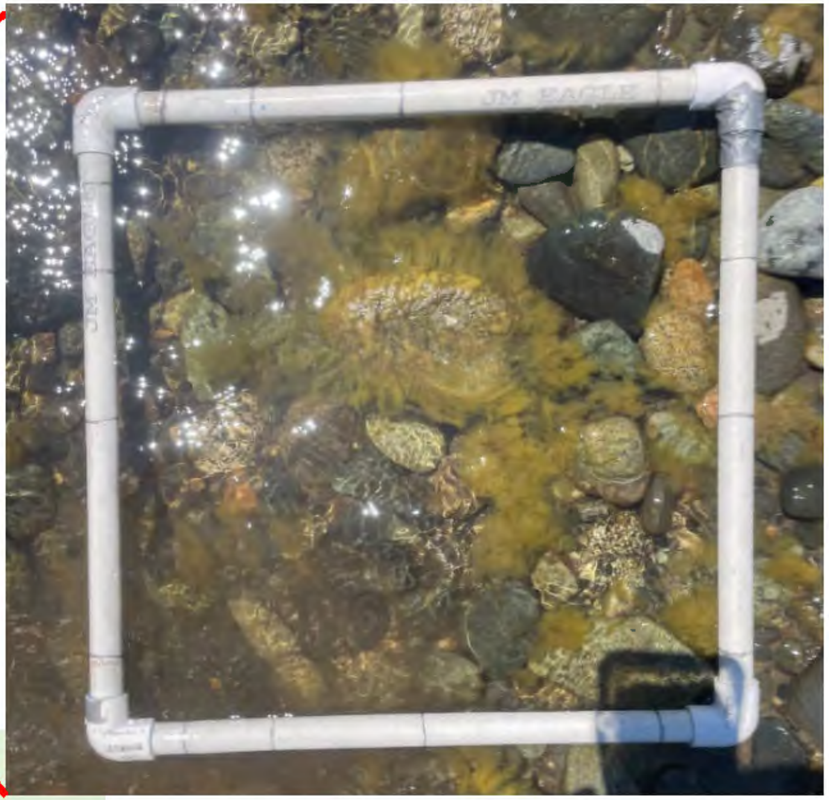


Map data: Google, LDEO-Columbia, NSF, NOAA, SIO, U.S. Navy, NGA, GEBCO
River data: Samantha Adams, U.S. Fish and Wildlife

- Macrophytes dominate upriver.
- FA dominates downriver.

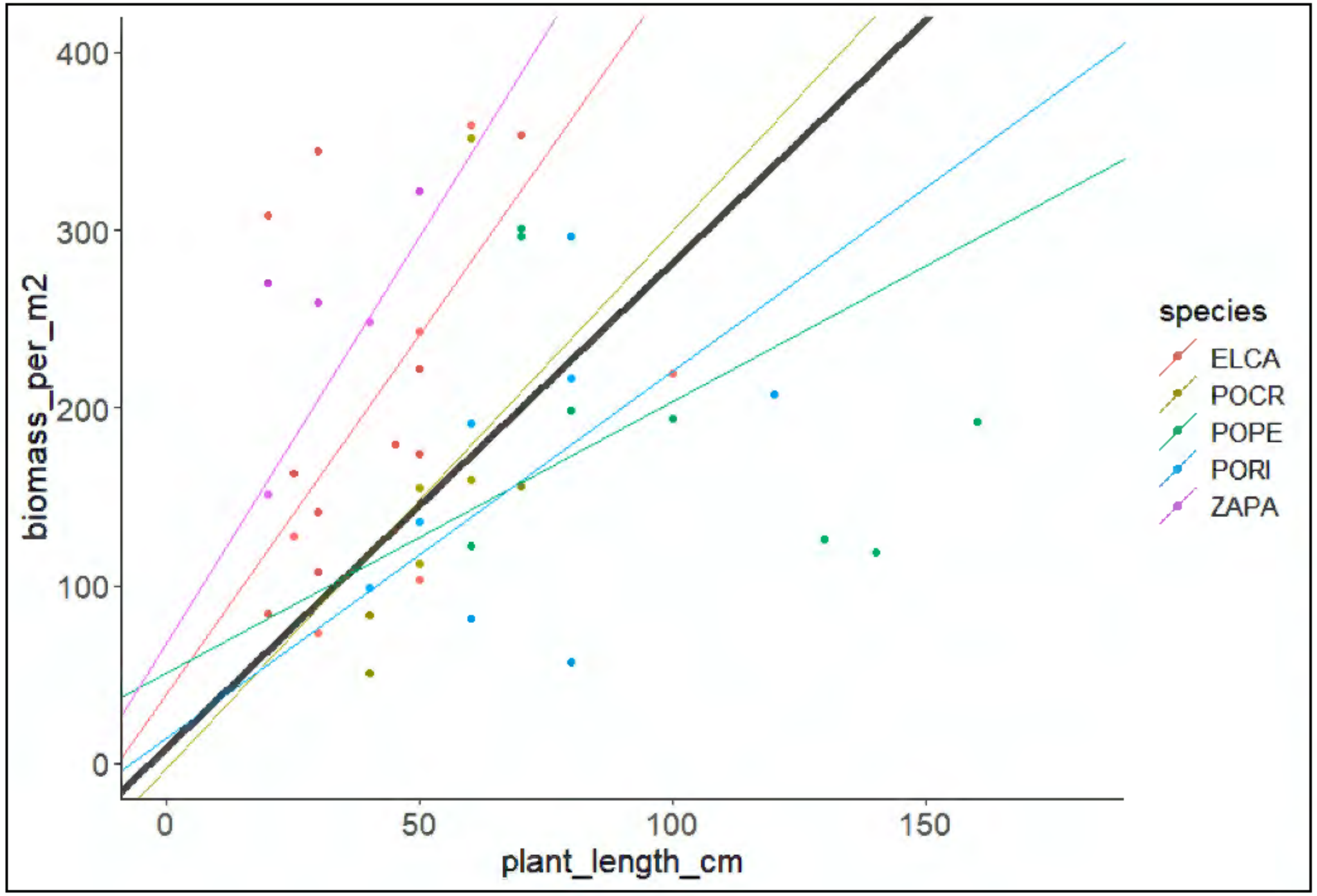
Data Collection – Field Surveys

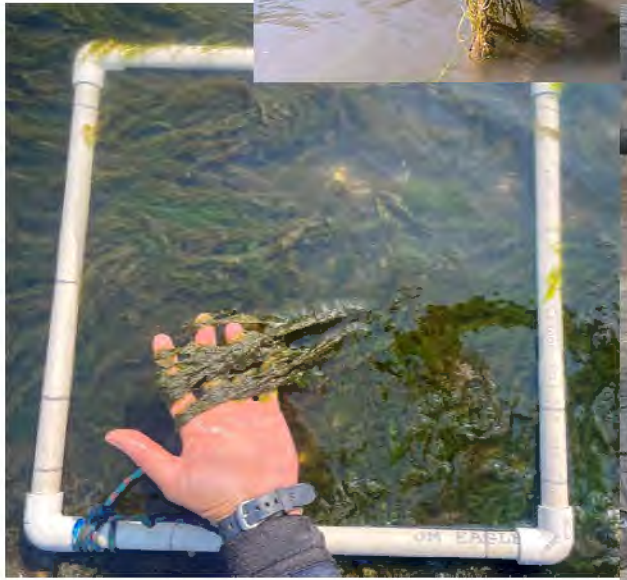




- % Cover
- Depth
- Velocity
- Substrate
- PAR
- Turbidity
- Temperature

We converted % cover of FA and macrophytes to Biomass/m^2





(Genzoli and Hall in Review)

Field Results

Photo: Sean Nealon

Upriver

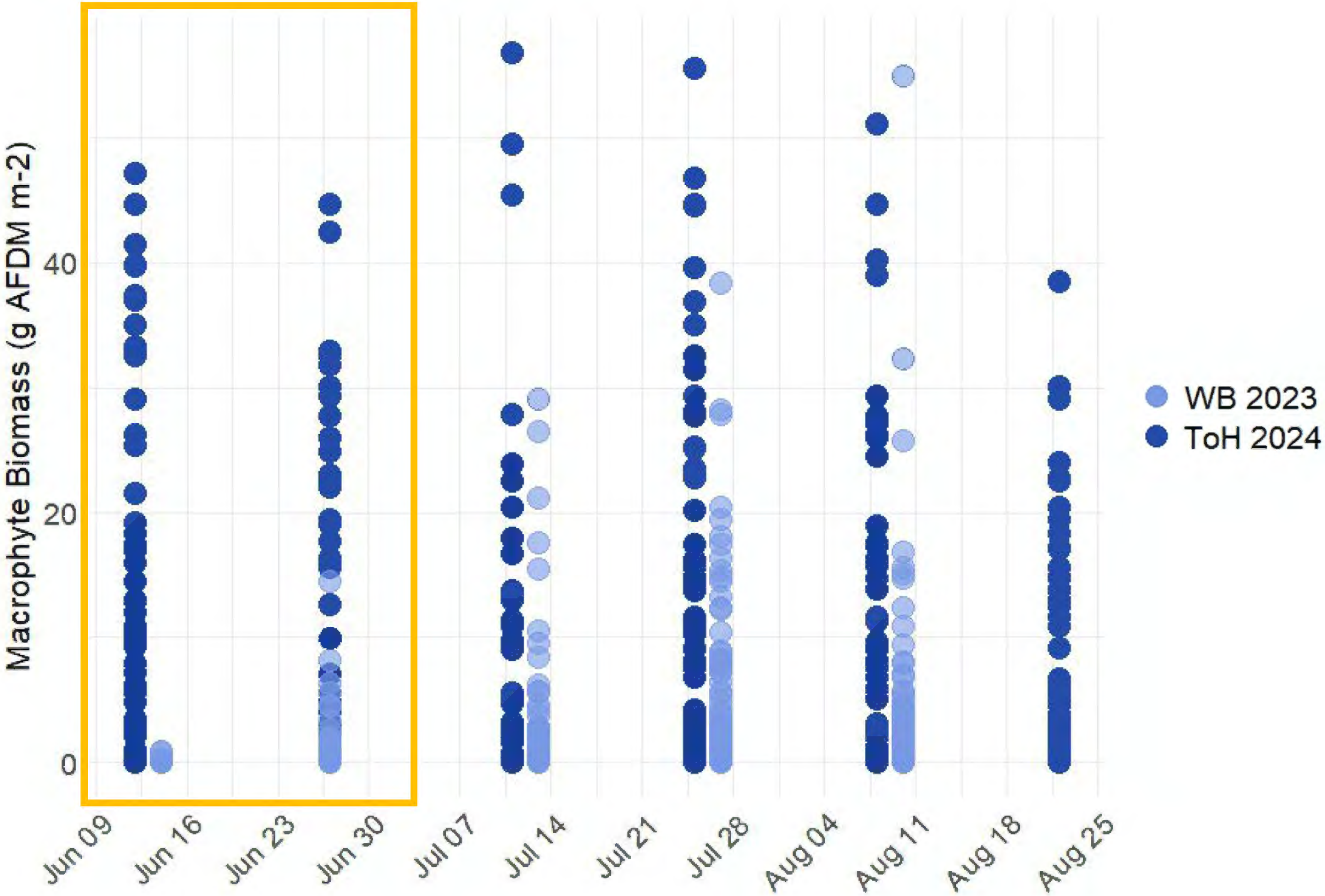
Year	Median Summer Turbidity (FNU)*	Spring Peak Flow (cfs)
2023	4	6500
2024	48	3430

Downriver

Year	Median Summer Turbidity (FNU)*	Spring Peak Flow (cfs)
2023	2	34,300
2024	13	51,600

- Median turbidity was higher in 2024 than 2023 at both sites.
- Peak flows were lower at the upriver site, but higher at the downriver site in 2024.

Macrophytes were established much earlier in 2024 than 2023

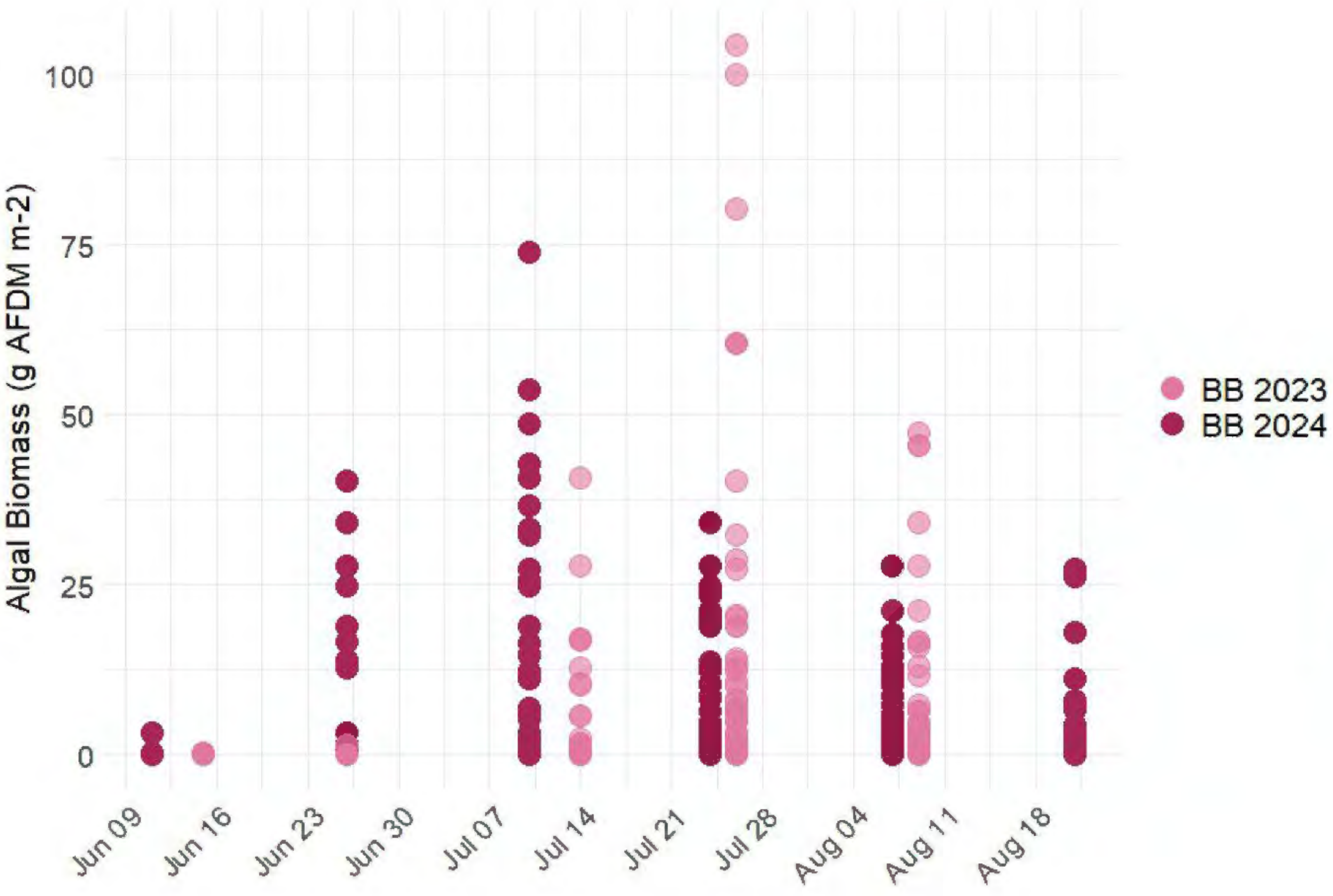


Upriver Sites

Year	Median Summer Turbidity (FNU)*	Spring Peak Flow (cfs)
2023	4	6500
2024	48	3430

**turbidity data courtesy of the Karuk Tribe*

Max FA biomass was lower and earlier in 2024 than 2023

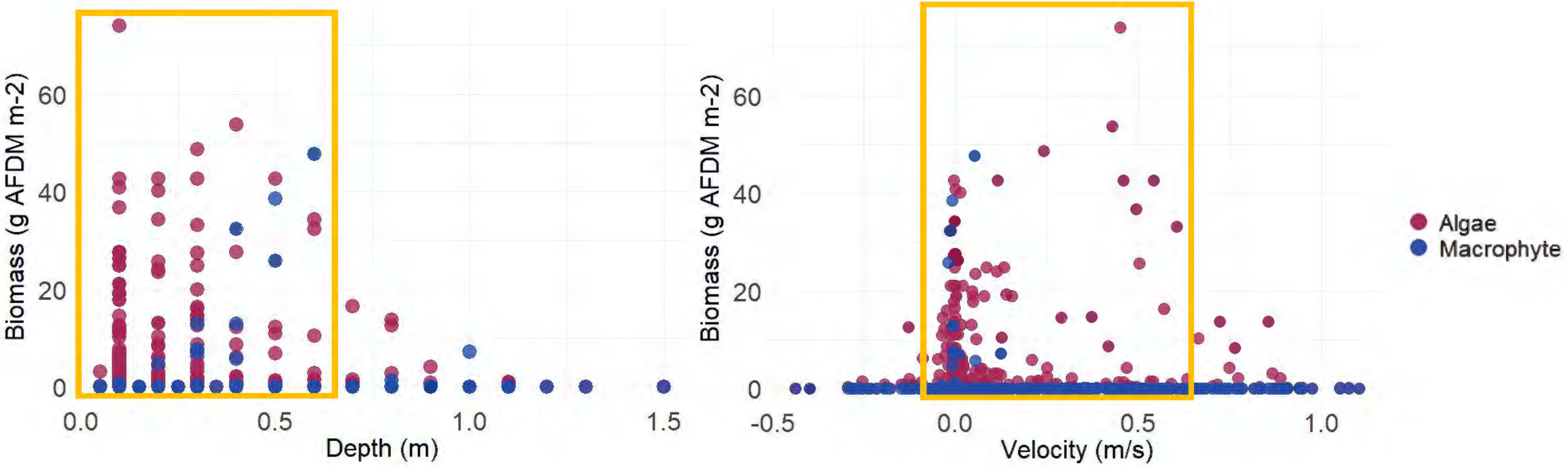


Downriver Sites

Year	Median Summer Turbidity (FNU)*	Spring Peak Flow (cfs)
2023	2	34,300
2024	13	51,600

**turbidity data courtesy of the Karuk Tribe*

FA and macrophytes persisted in shallow, slow moving water.



Macrophytes overcame low light conditions from sediment pulses.

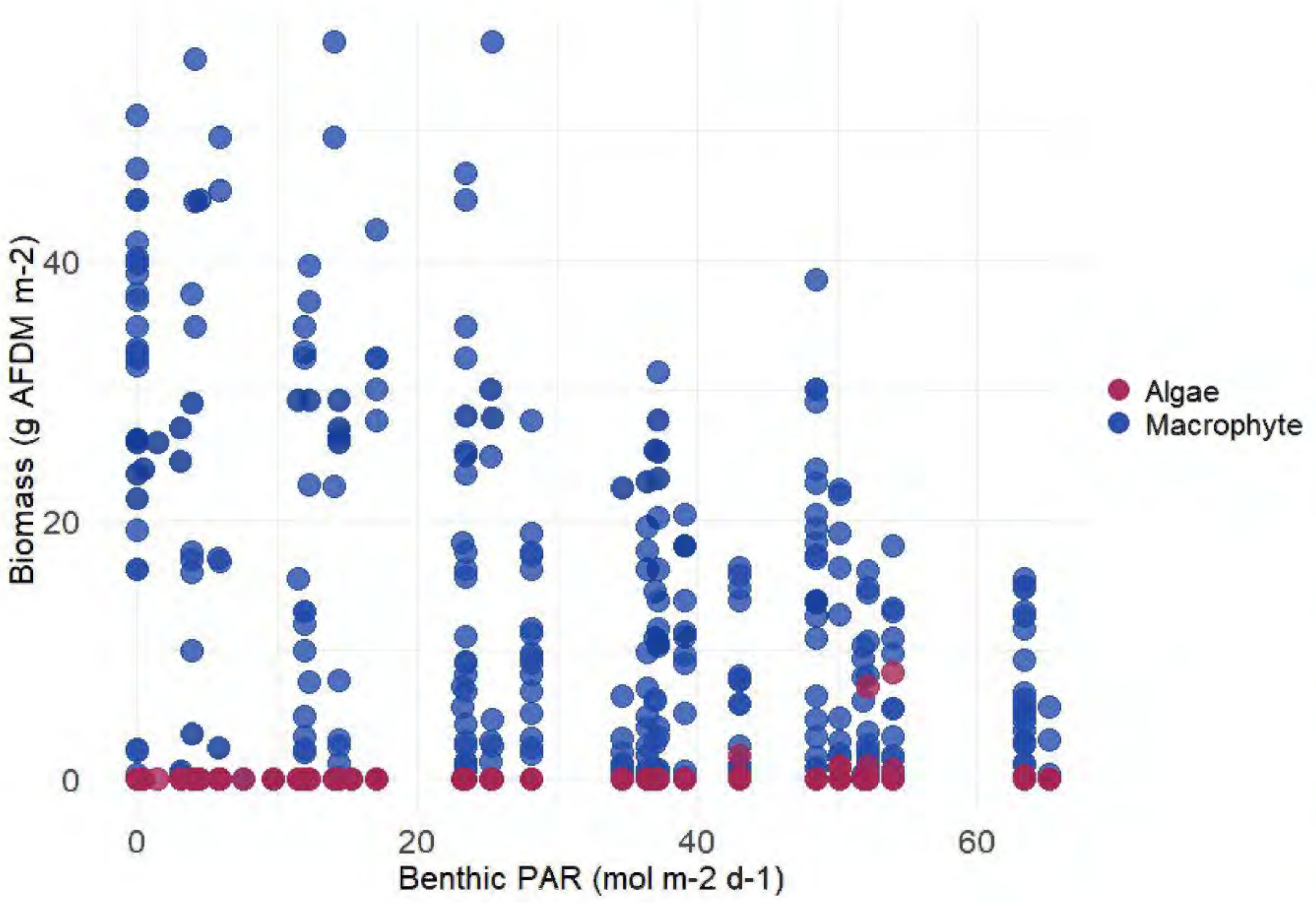
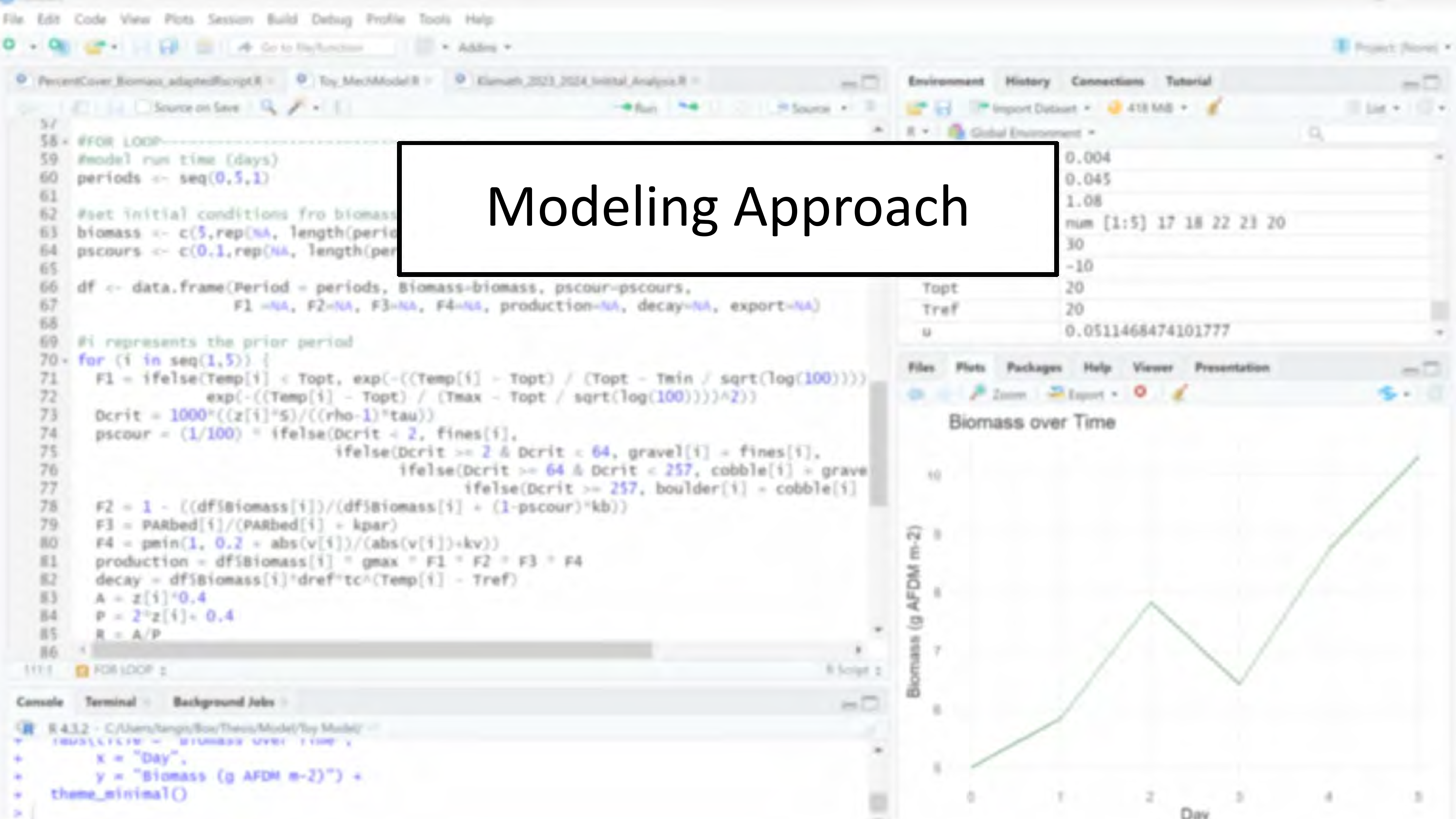


Photo: Sean Nealon

Algae are more sensitive to light than macrophytes.

Modeling Approach



Mechanistic Simulation Model

$$\frac{\Delta\, Biomass}{\Delta\, time} = production_i - decay_i - export_i$$

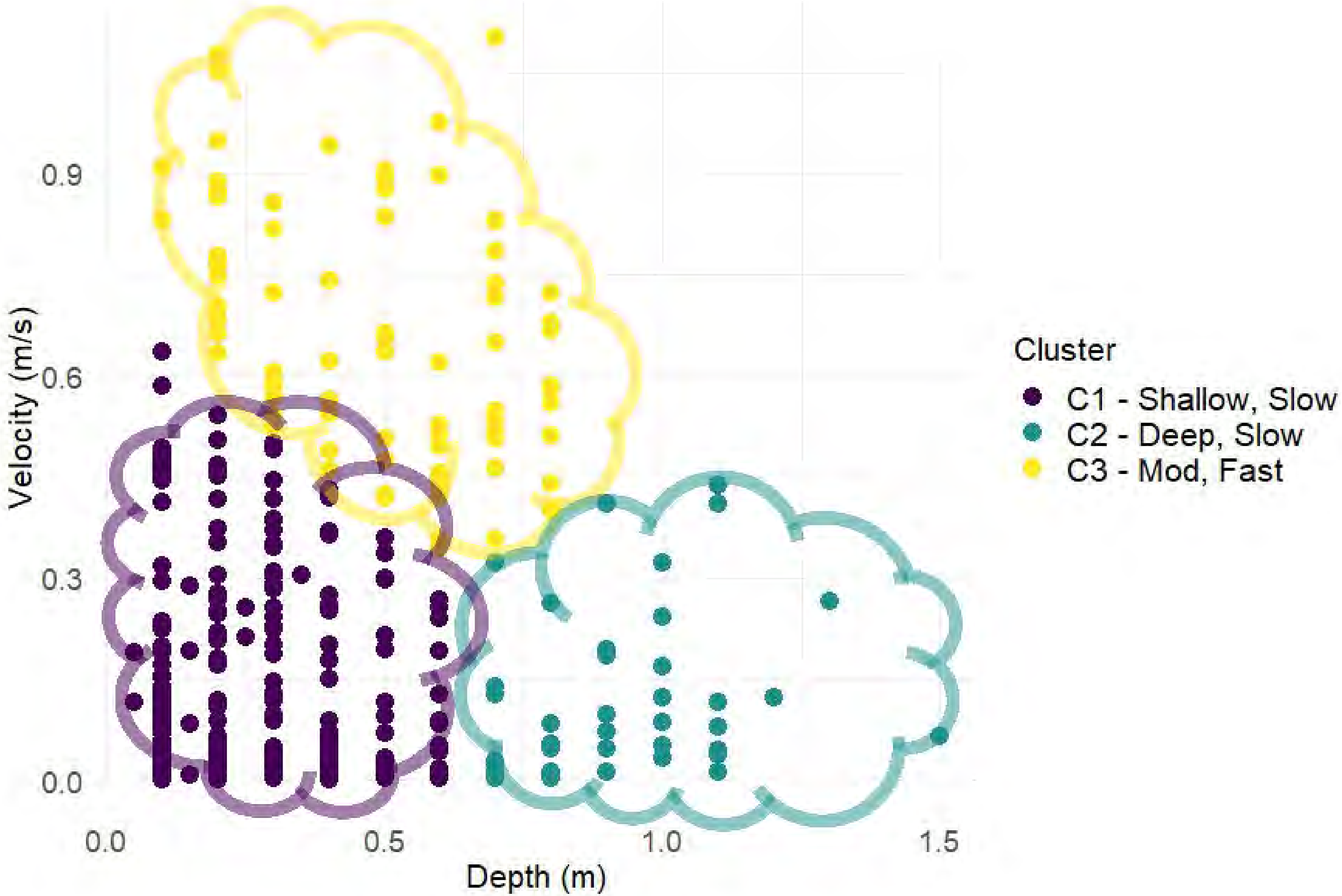
$$f(temperature, density, light, velocity)$$

$$f(temperature)$$

$$f(scour, bed\ mobilization)$$

(Adapted from Bellmore et al. 2017)

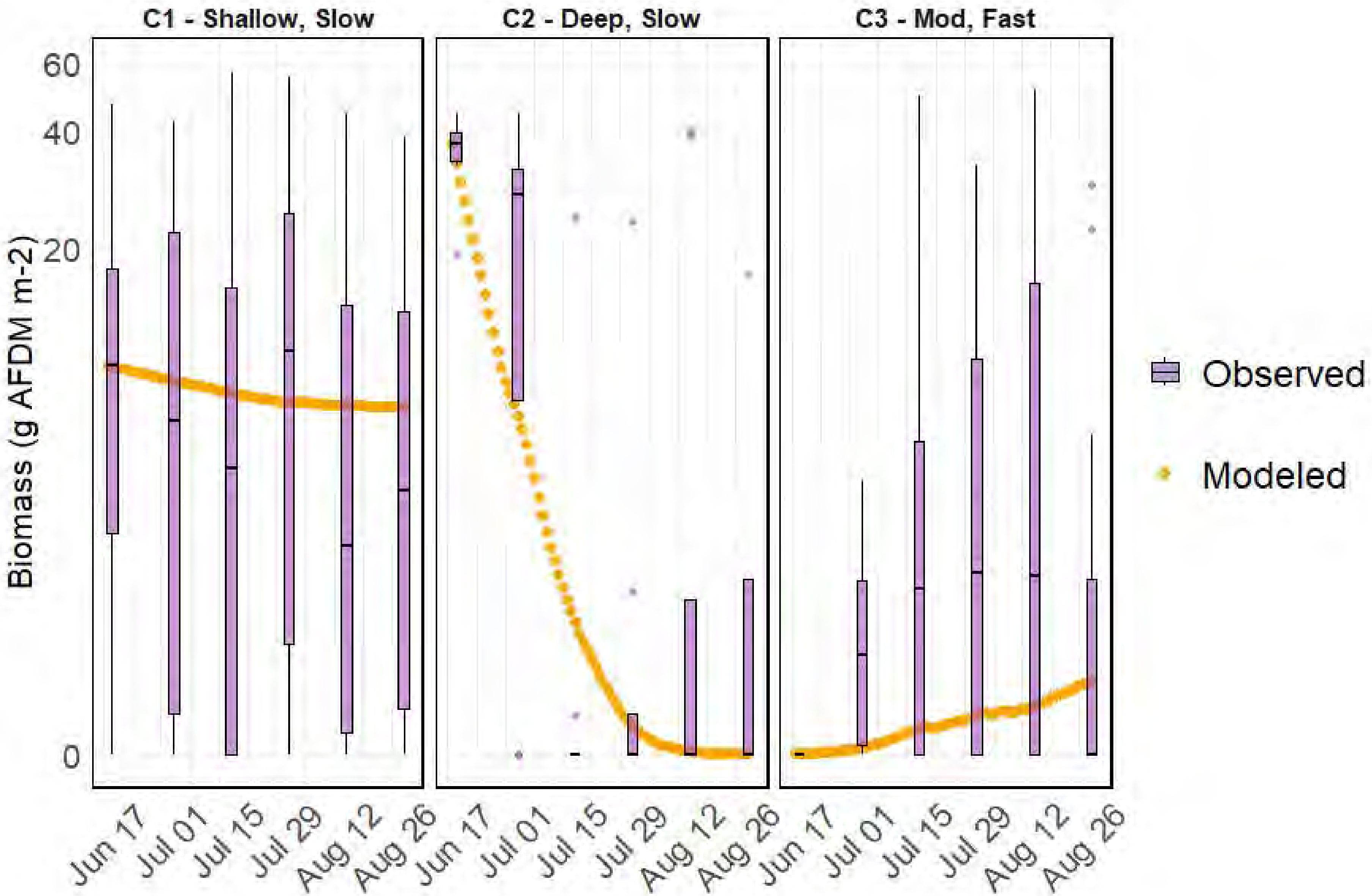
Data were clustered based on depth and velocity.



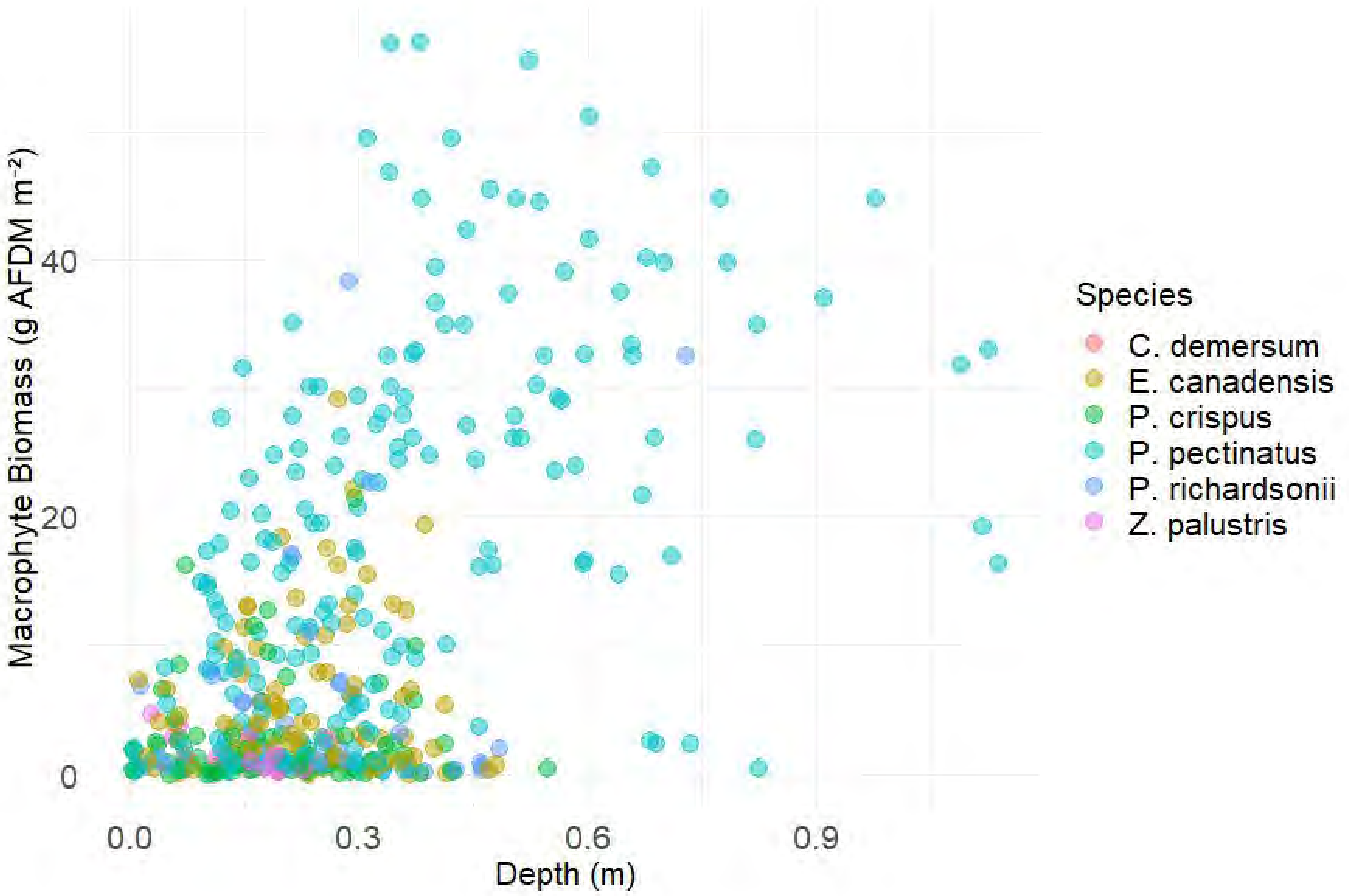
Modeling Results



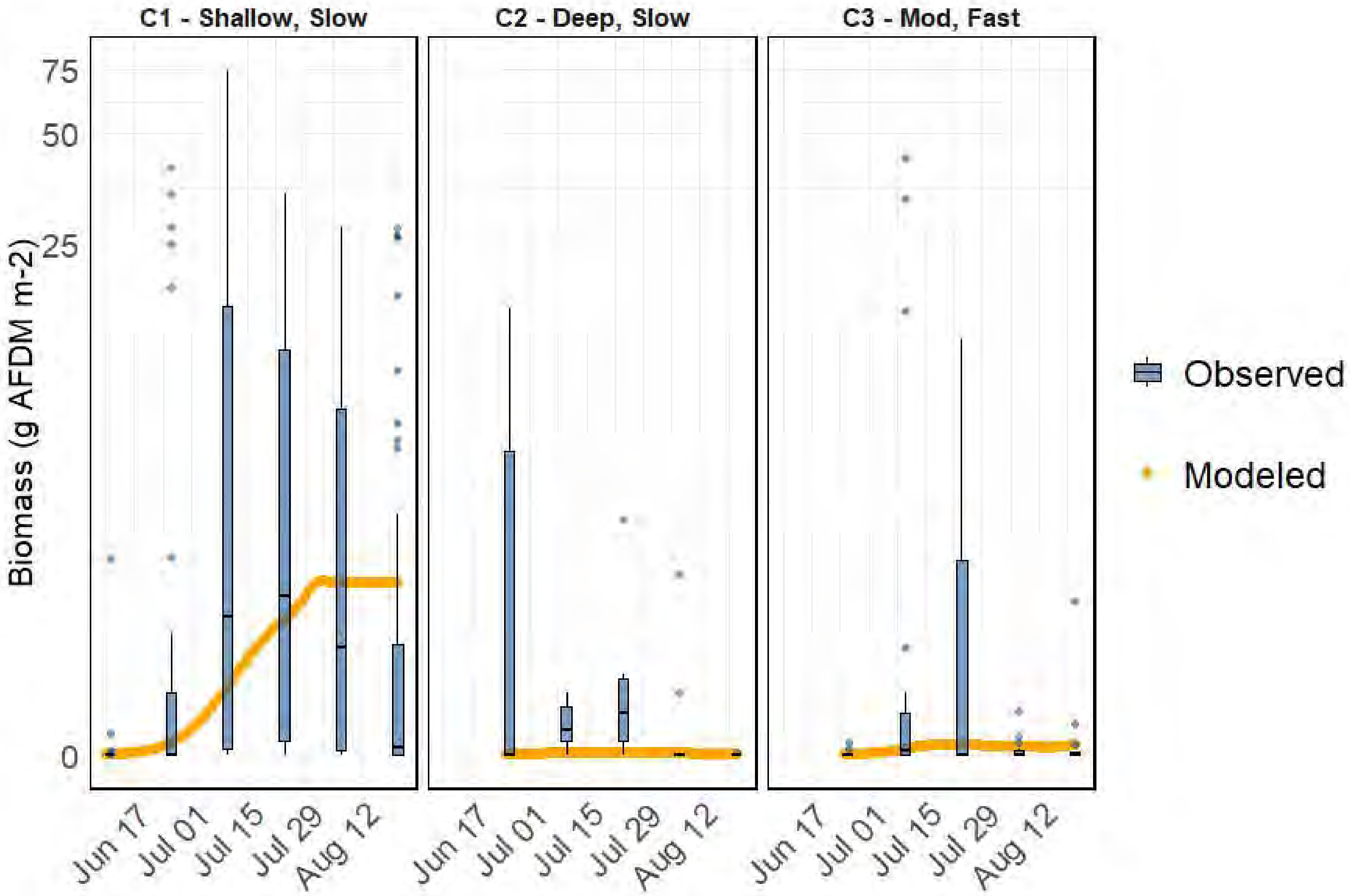
Macrophyte dynamics can be roughly reproduced by discharge, light, and temperature



Potential improvement: Incorporate species dynamics



Algae dynamics are likely more complex than the model processes.



Potential improvement: Incorporate limitation via self shading

Future Work

- Summer 2025 Field Surveys
- + Data, Update Model Processes

Thank you!

- Co-Authors
- Field Crew
  - Lily Bell
  - Emelyn Keller
  - Kristine Alford
  - Rebecca Wheaton
  - Grace Boisen
  - Whitney Packard
- Yurok Tribal interns
- John Bolte
- Ciana David
- Karuk Tribe Water Quality Department

Questions or comments?

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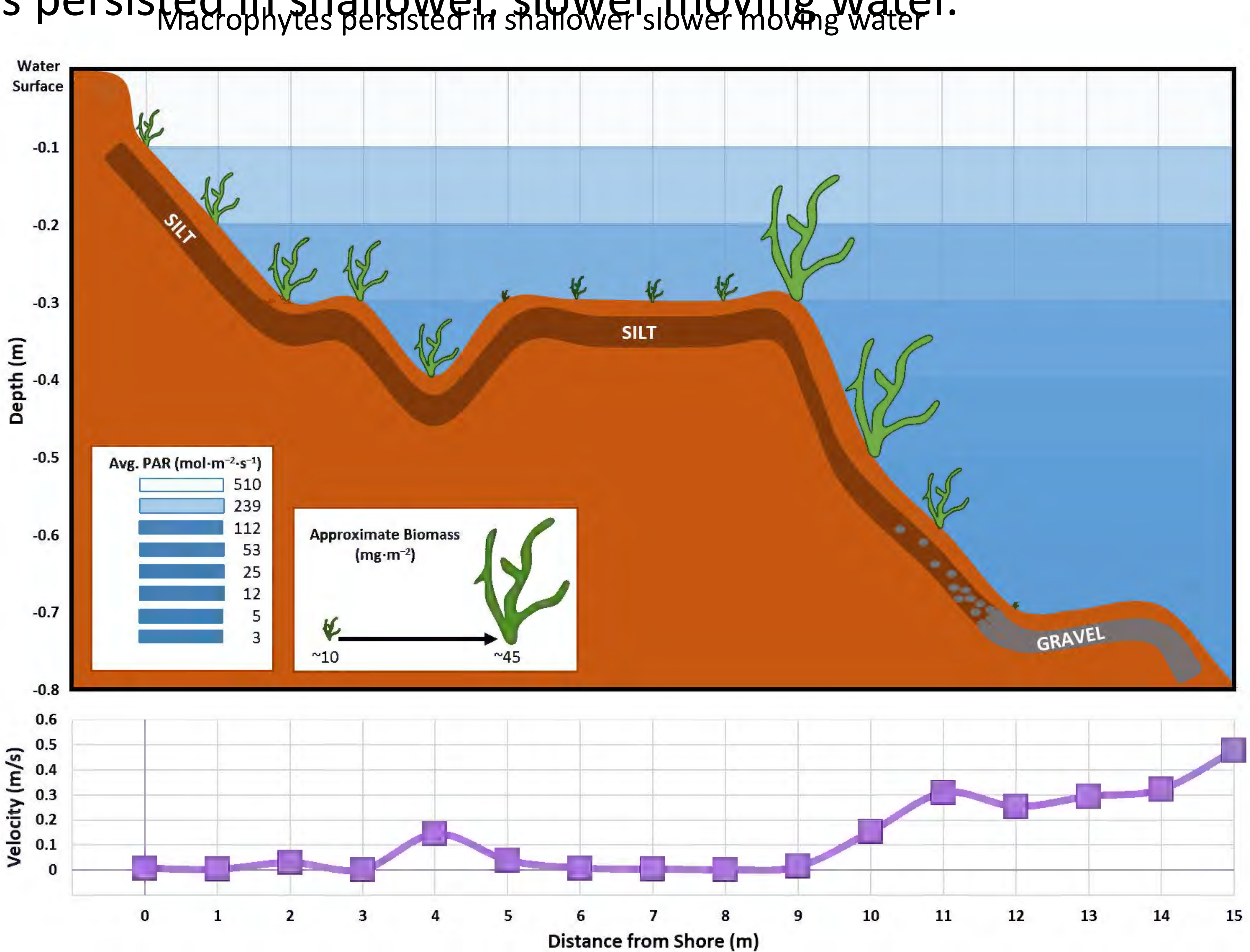
Sea Grant OREGON

Oregon State University

Macrophytes persisted in shallower, slower moving water.



Macrophyte Model Parameters and Results

Cluster	Habitat Type	Growth Rate (gmax)	Decay Rate (dref)	Decay Shape Coeff (ai)	Density Half Saturation (kb)	PAR Half Saturation (kpar)	Velocity Half Saturation (kv)	RMSE - Train (g AFDM/m^2)	RMSE - Test (g AFDM/m^2)
1	Shallow, Low Velocity	0.20	0.01	5.00	7.15	2.50	0.14	0.14	3.00
2	Deep, Low Velocity	0.20	0.09	10.00	3.00	5.00	0.18	0.07	8.50
3	Mod Depth, High Velocity	0.20	0.01	9.87	3.35	2.50	0.15	0.50	1.55

Algae Model Parameters and Results

Cluster	Habitat Type	Growth Rate (gmax)	Decay Rate (dref)	Decay Shape Coeff (ai)	Density Half Saturation (kb)	PAR Half Saturation (kpar)	Velocity Half Saturation (kv)	RMSE - Train (g AFDM/m^2)	RMSE - Test (g AFDM/m^2)
1	Shallow, Low Velocity	0.55	0.12	10.38	3.61	9.00	0.14	0.63	1.23
2	Deep, Low Velocity	0.36	0.12	9.96	2.55	2.50	0.14	0.31	0.25
3	Mod Depth, High Velocity	0.35	0.12	15.00	1.00	9.00	0.15	0.21	0.09

Macrophytes and FA occupy specific depth and velocity habitat ranges.

Macrophytes are driven by discharge and can ~~adapt~~ overcome ~~to~~ low light.

Filamentous algae is more sensitive and less adaptable to low light ~~but more robust to~~ independent-peak flows.

Macrophyte dynamics can be roughly reproduced with peak flow, baseflow hydraulics, light availability, and temperature.

Algae dynamics are more complex than the processes represented in the model.

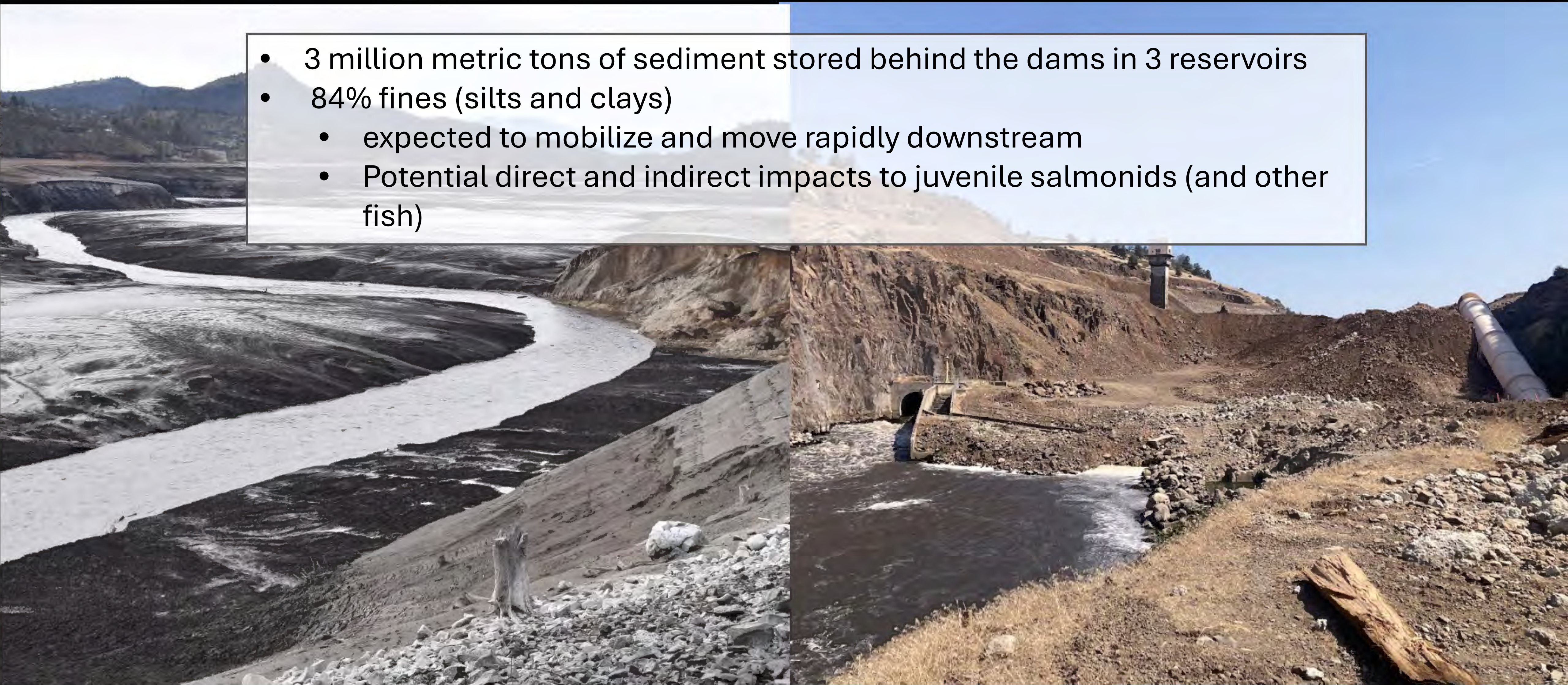
Quantifying short-term food web responses to dam removal on the Klamath River

Rosa Cox
Dr. Alison O'Dowd
Toz Soto

INTRODUCTION:

Dam Removal – short term impacts

- 3 million metric tons of sediment stored behind the dams in 3 reservoirs
- 84% fines (silts and clays)
  - expected to mobilize and move rapidly downstream
  - Potential direct and indirect impacts to juvenile salmonids (and other fish)



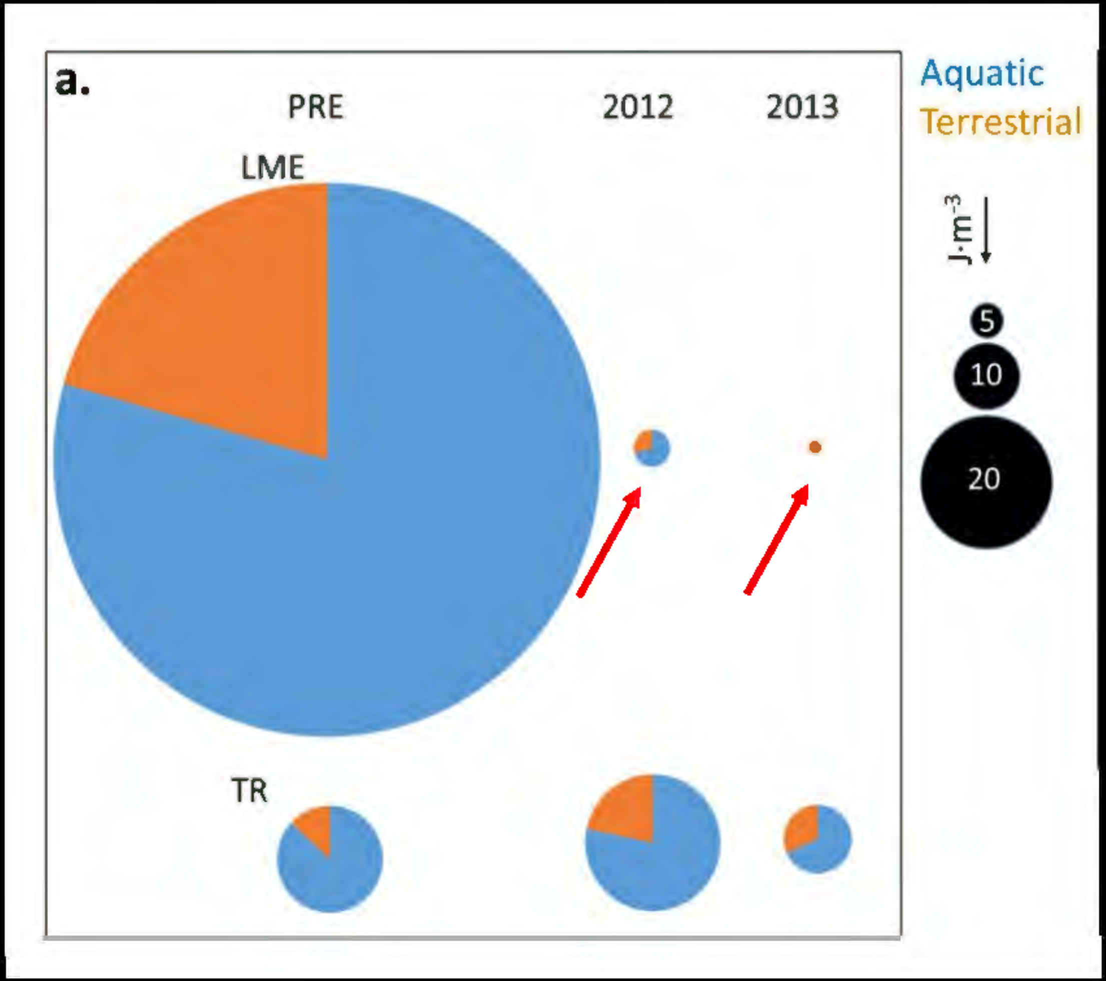
Food webs and benthic macroinvertebrates

- Benthic macroinvertebrates (BMI):
  - High quality fish food
  - Indicators of stream quality/ecosystem health

Elwha dam removal: lessons learned

Spring Drift Samples:

- Decline in invertebrate drift during2 years of dam removal in mainstem between and below dams (LME)



Elwha drift energy densities (J/m^3) by terrestrial vs aquatic origin in sections sections below the dams (LME) with reference sites in Tributaries (TR). Adapted from Morley et al. 2020

Mechanisms for potential impacts from reservoir sediments:

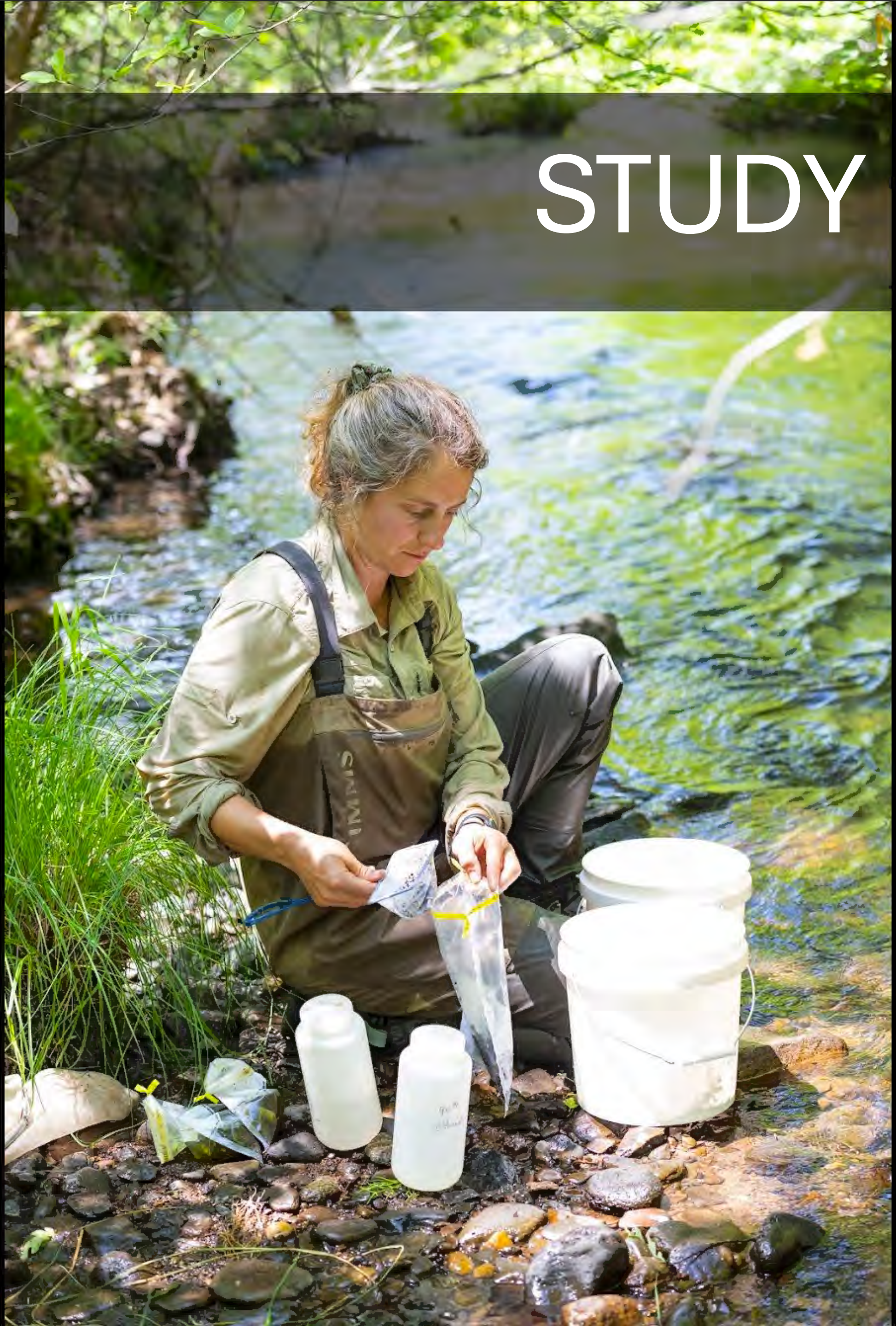
High Suspended Solids Concentration (SSC)

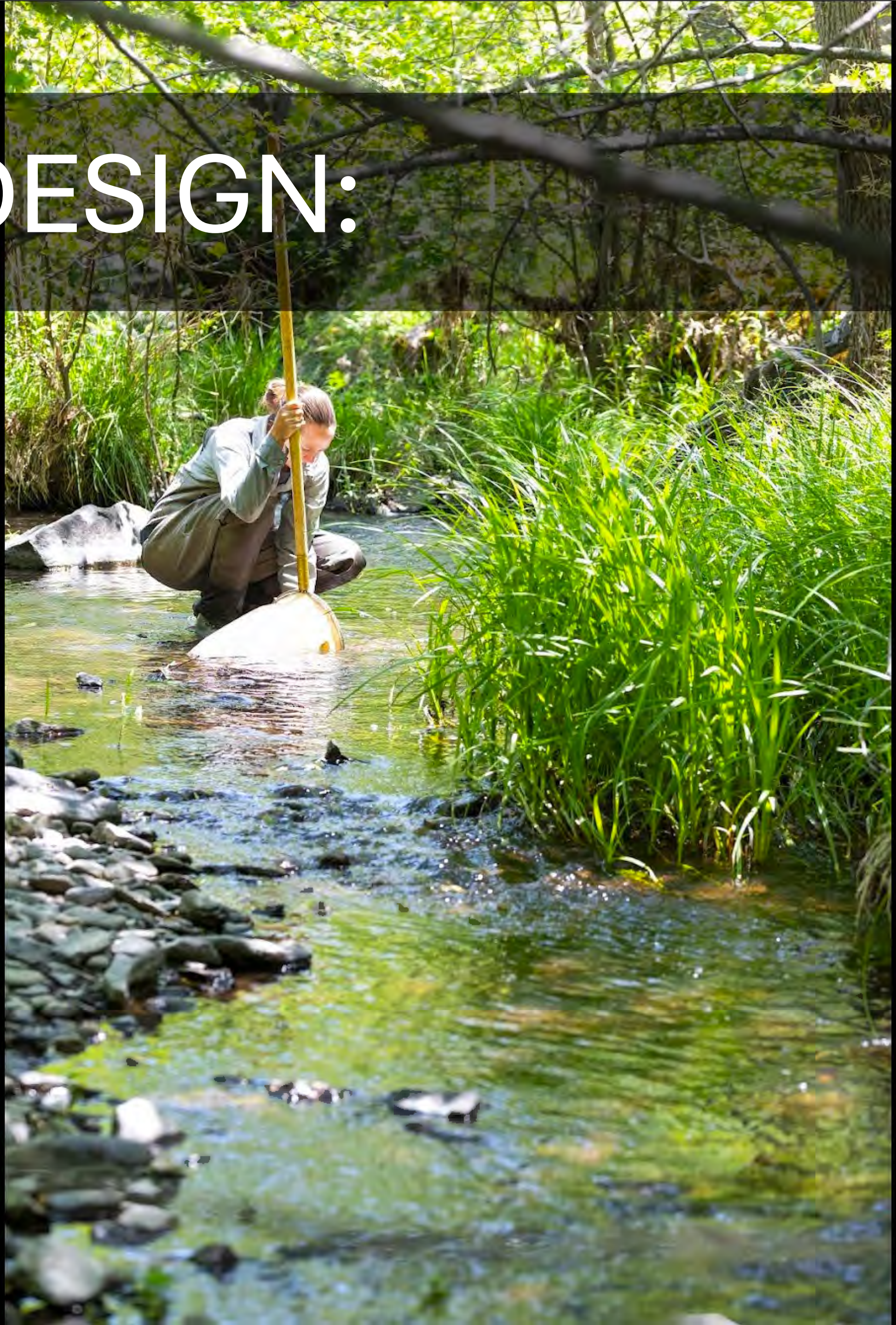
- Low Dissolved Oxygen
- Physical damage:
  - gill/gut clogging
  - abrasion of gills/tissue
- Exposure to toxins/heavy metals**
- Reduced primary productivity resulting from lower light infiltration
- (+) nutrient subsidies

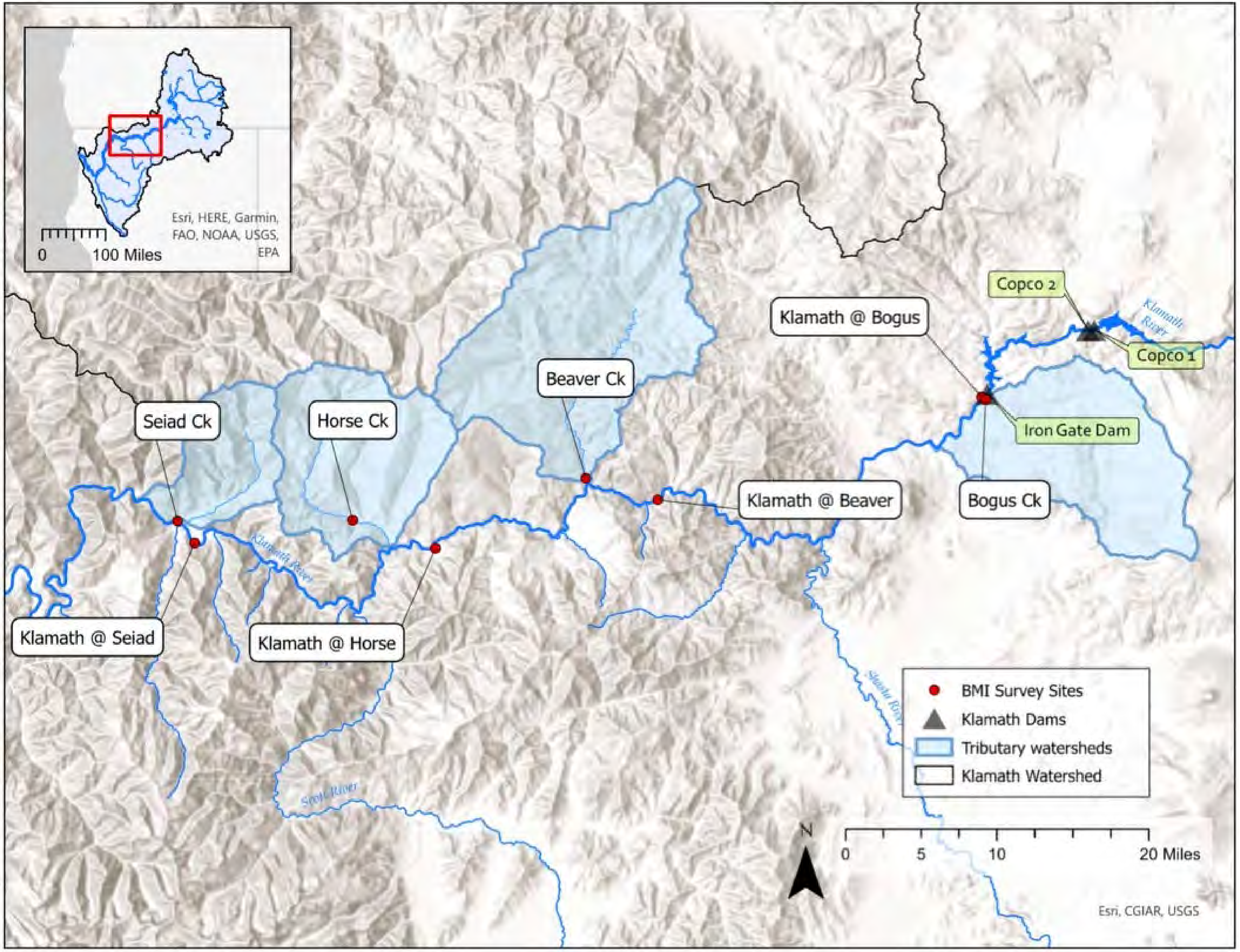
Sediment deposition

- Direct burial
- Loss of habitat in interstitial spaces
- (+) increased habitat for sediment – burrowing taxa

STUDY DESIGN:







Sites:

paired mainstem and tributary

BEFORE

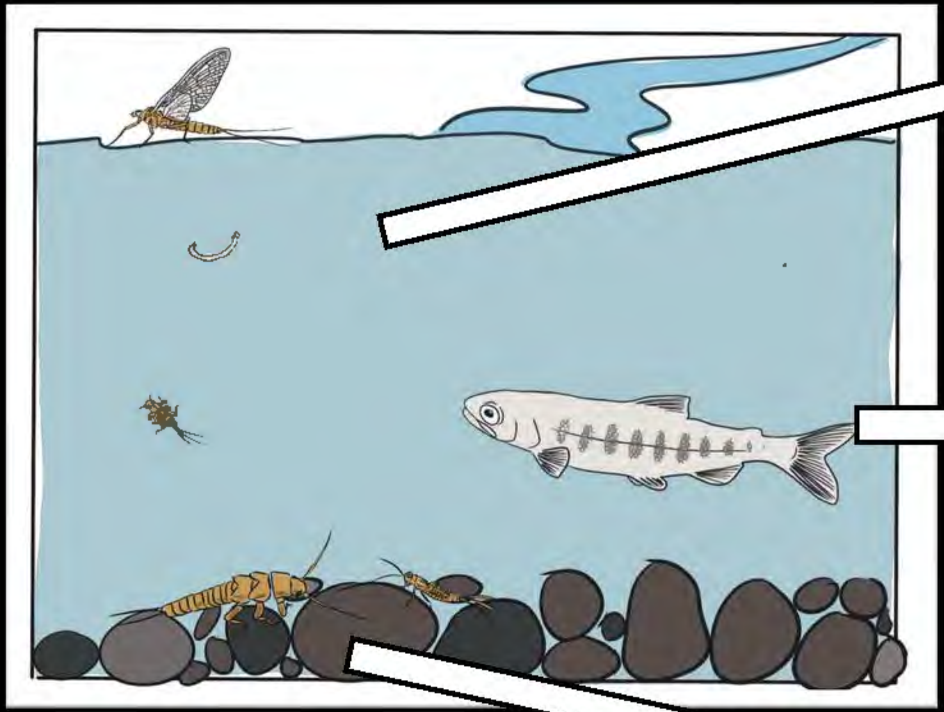
2022 = 4 sites (pilot)

2023 = 8 sites

DURING

2024 = 8 sites

Sampling Methods



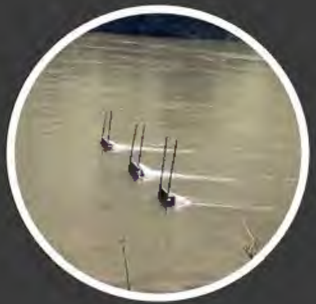
2. Drift (30 min drift)

3. Juvenile salmonid diet (gastric lavage)

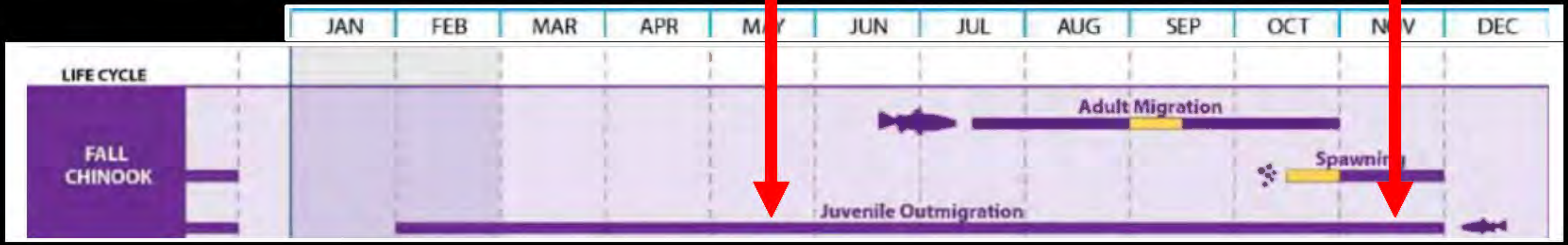
1. Benthic (1min kick)

Sampling Season

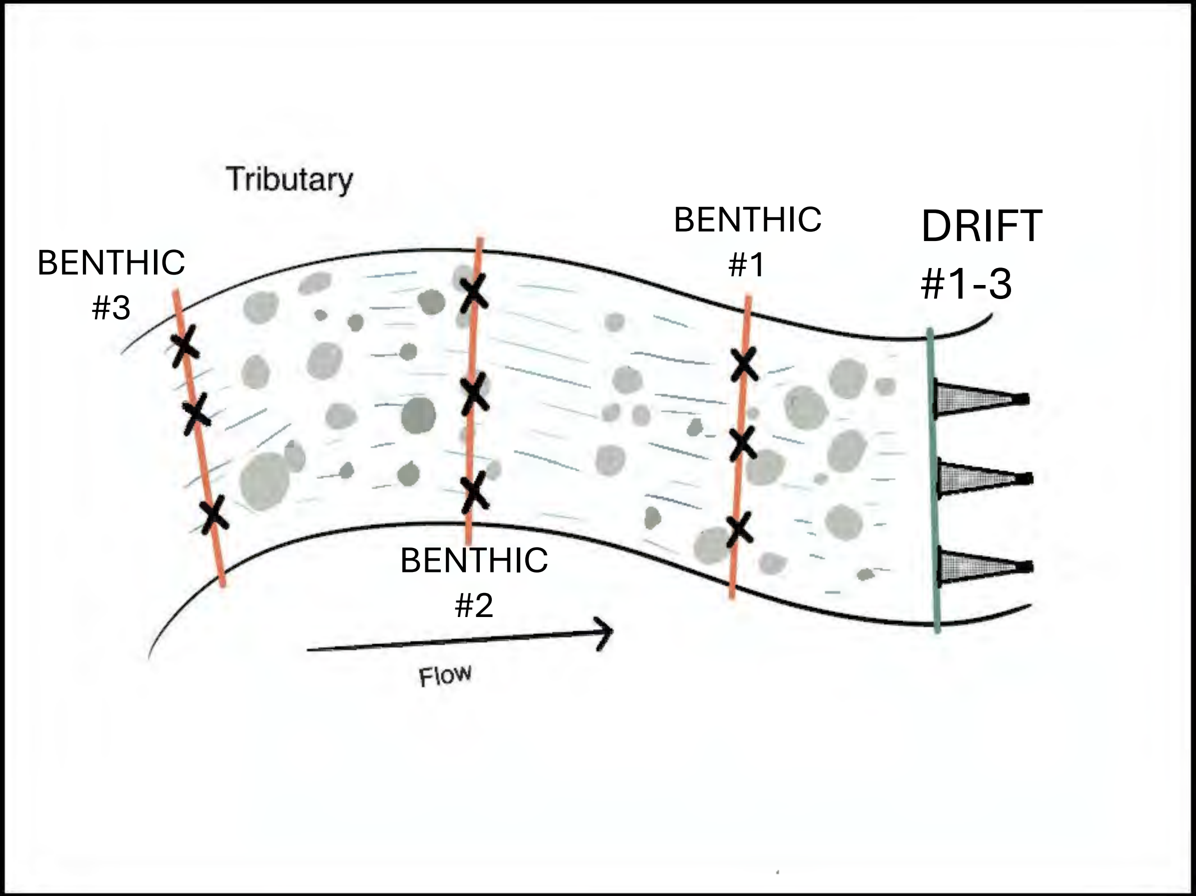
SPRING:
- All sample types and sites
- May-June 2022-2024

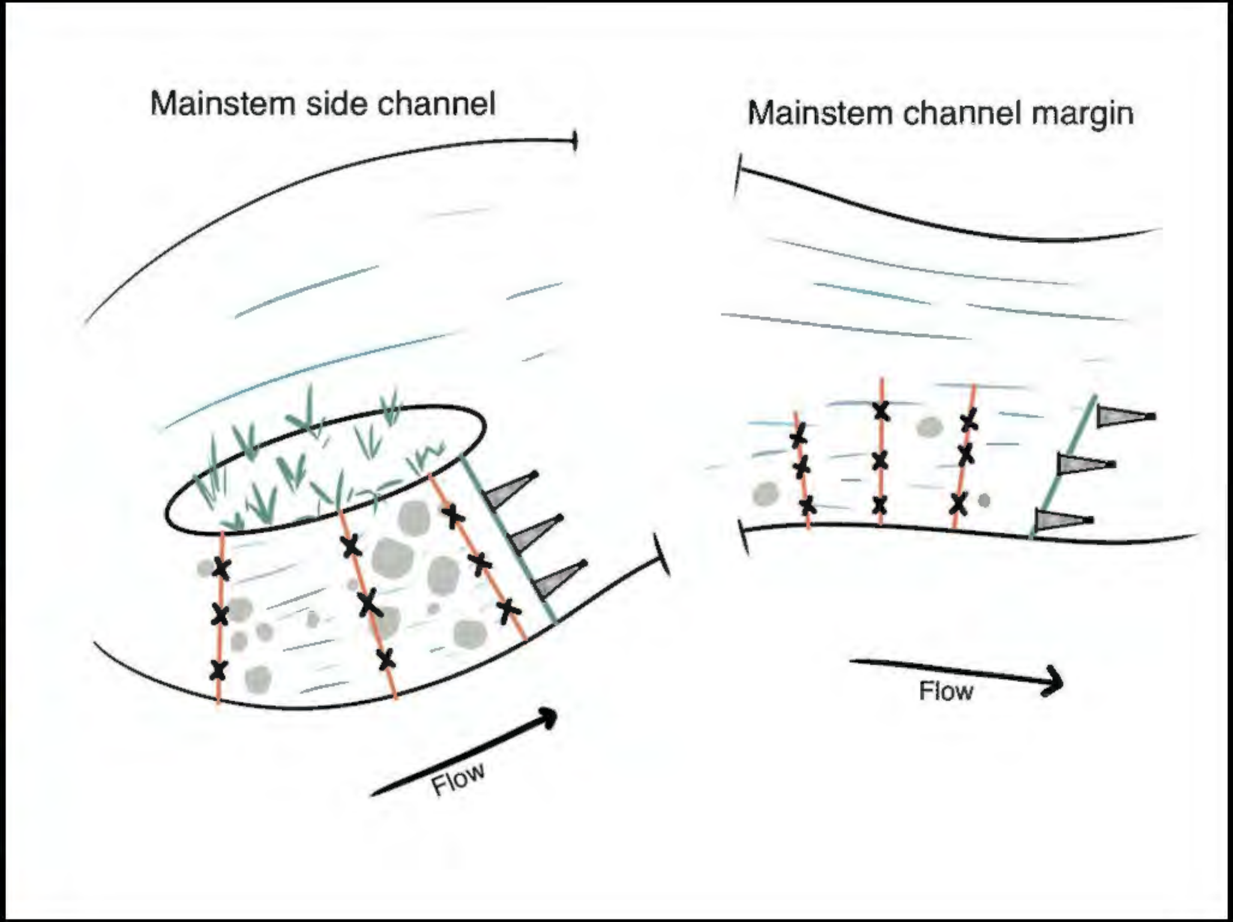

FALL:
- Benthic samples only
- fewer sites
- November 2023 & 2024



Sampling design



Site-specific sampling

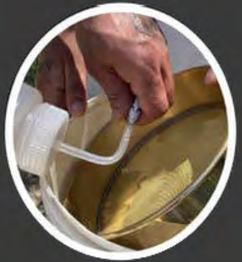


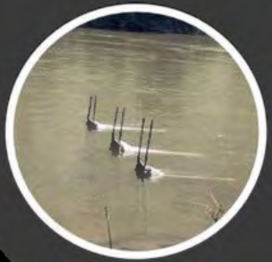
Laboratory methods

Benthic:

- Aquatic insects identified to genus*

*non-insects = class/order
*terrestrial insects = order





Drift and Diet:

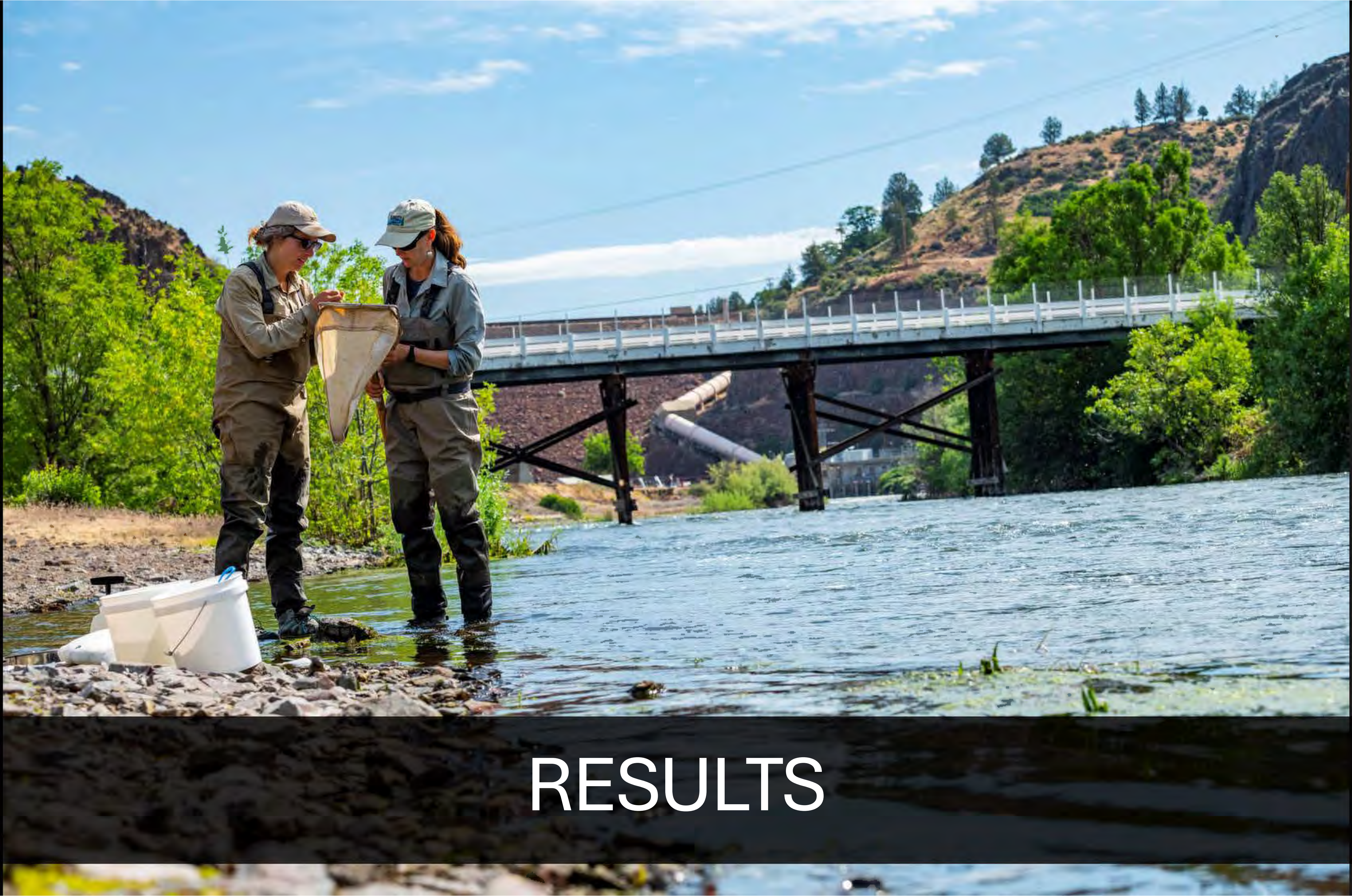
- Aquatic insects identified to family*
- Length measured to nearest mm
  - Biomass estimated using taxonomic specific length-weight regression

203,468 individuals identified and enumerated

(Preliminary) Data Analysis

- Linear mixed effect models
  - Log-transformed responses (counts, biomass, gut fullness)
- 2-way ANOVA, Tukey HSD pairwise comparisons
- $\log(Y_i) = \beta_0 + \beta_1(SiteType_i) + \beta_2(Treatment_i) + \beta_3(Treatment_i * SiteType_i) + \alpha_{site[i]}$

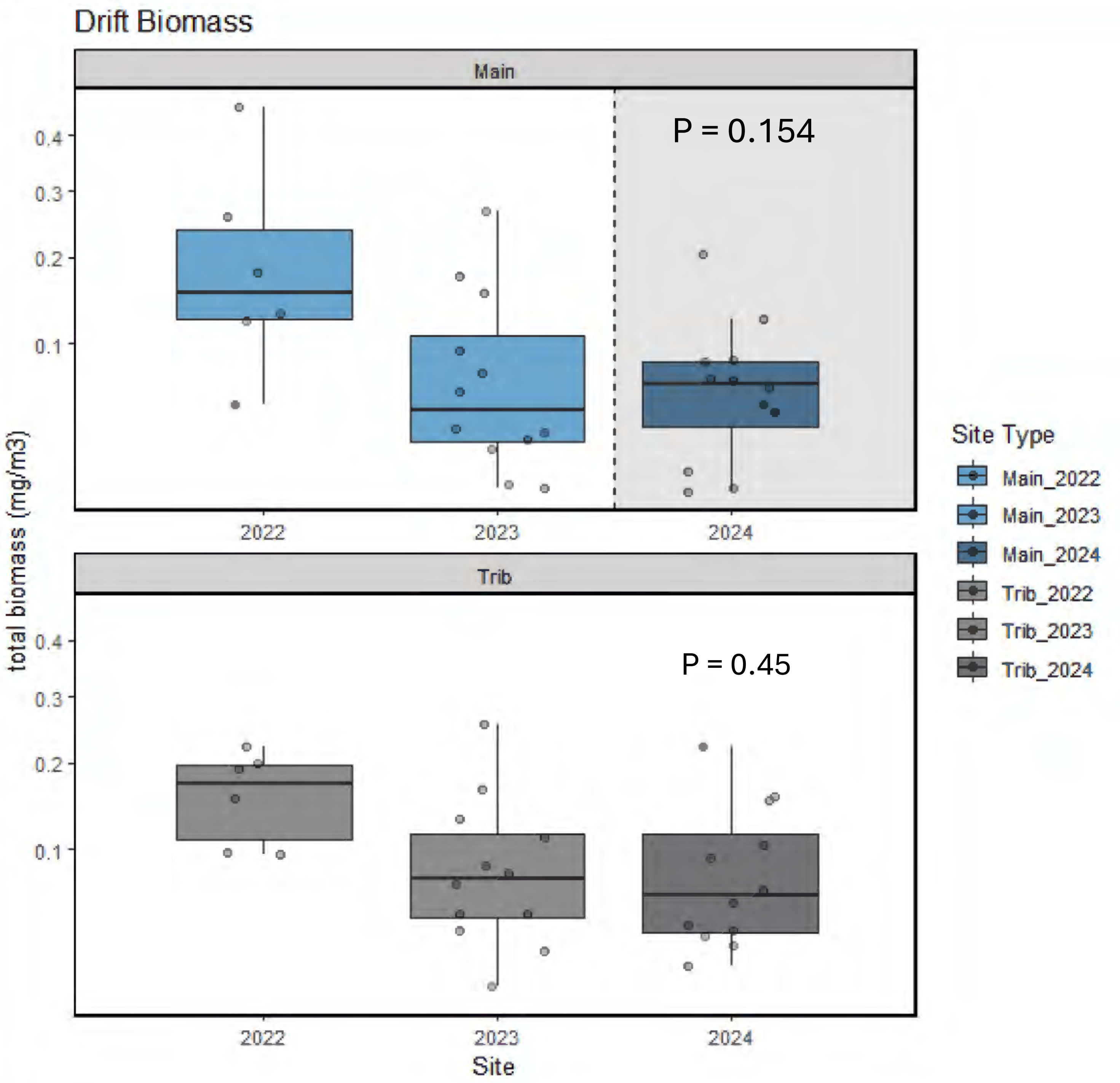
  $\alpha_{site[i]} \sim \mathrm{Norm}(0, \sigma^2_{site})$



RESULTS

DRIFT:

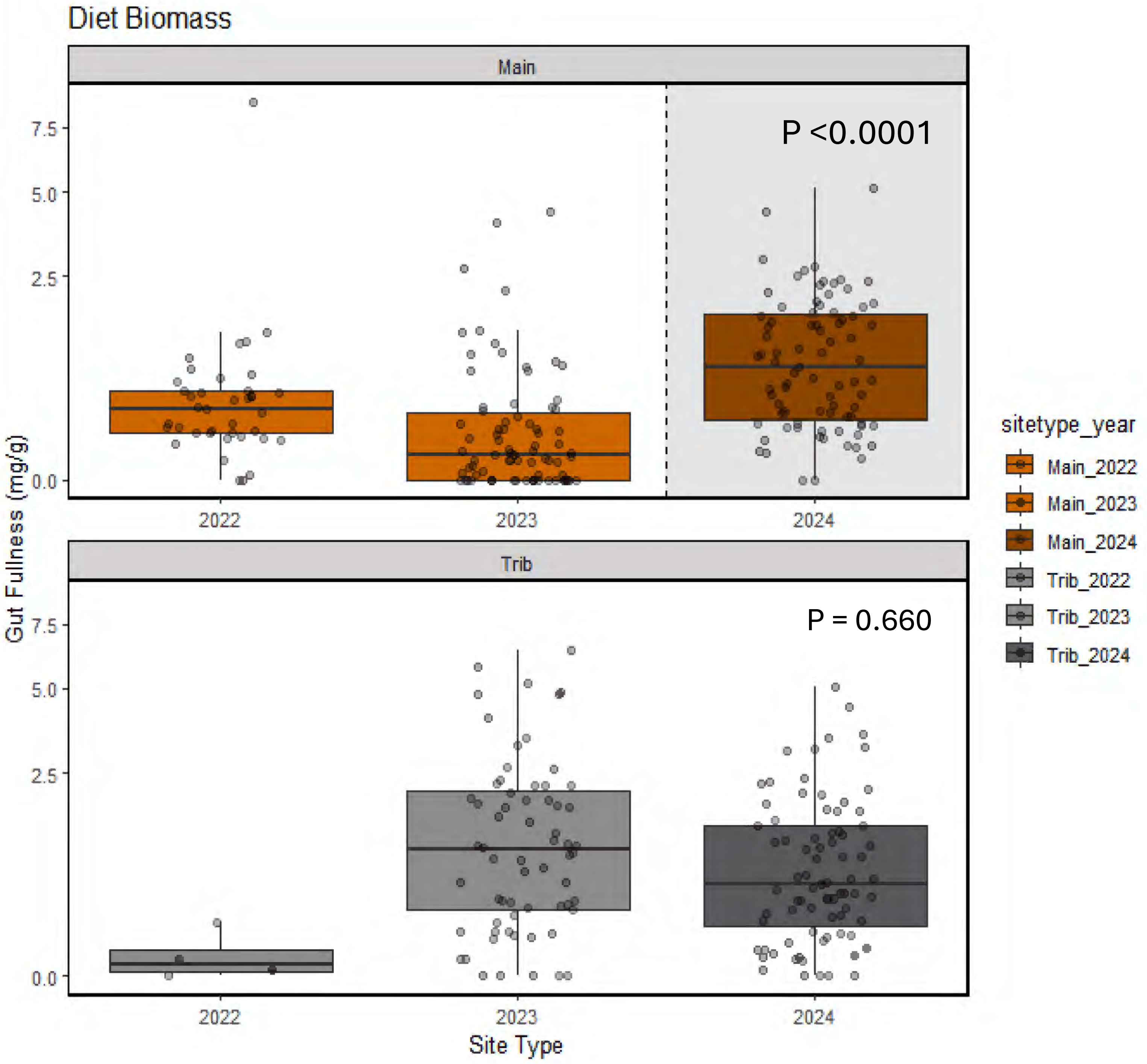
No significant shifts in **biomass density (mg/m3)** or **abundance (counts)**



DIET :

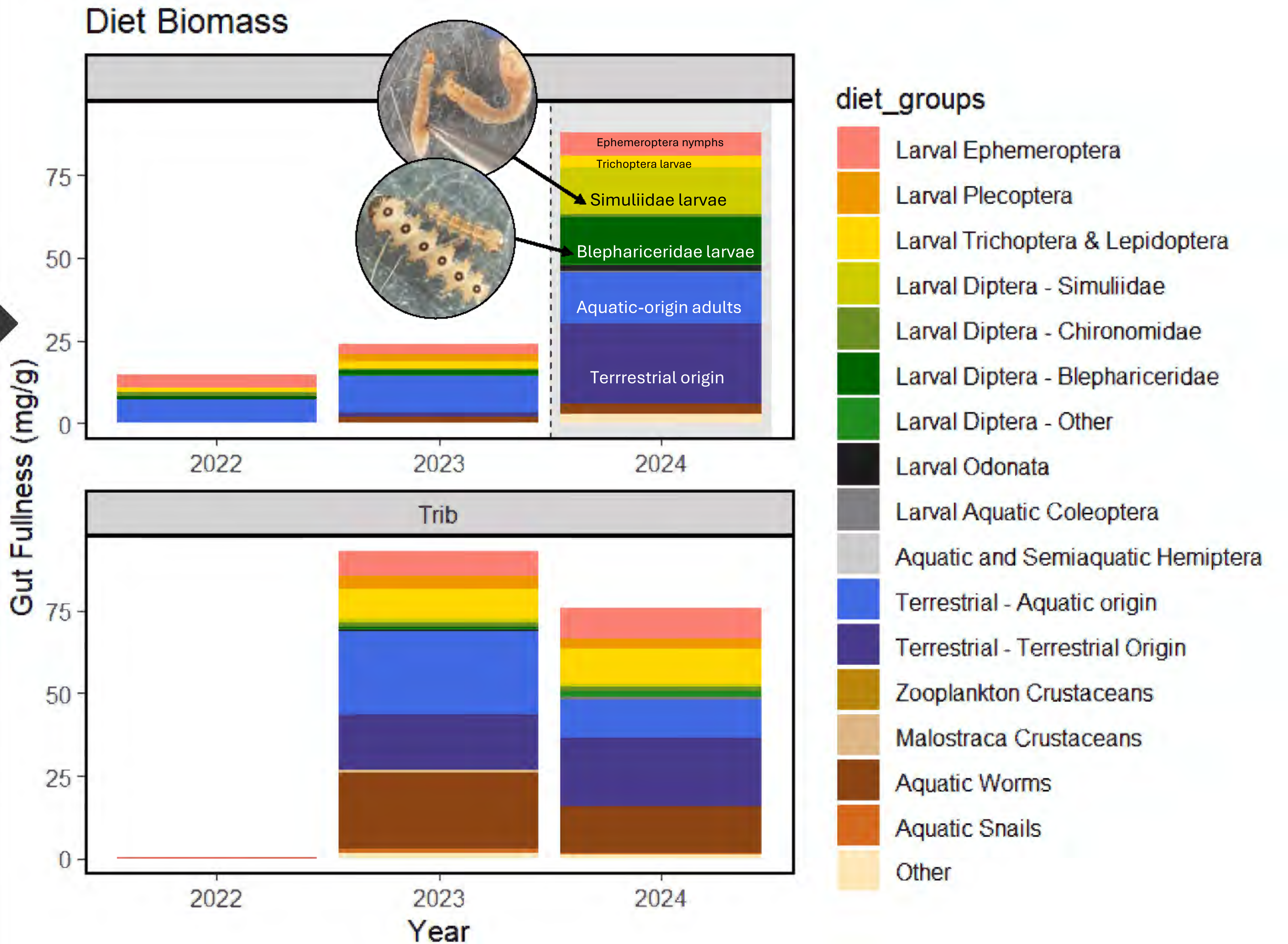
Significant increase in total abundance and biomass **(gut fullness)**

Site	year	# samples	# empty stomachs
KL_BB	2023	19	10
KL_BB	2024	23	1
KL_GT	2022	20	4
KL_GT	2023	20	8
KL_GT	2024	20	0



DIET :

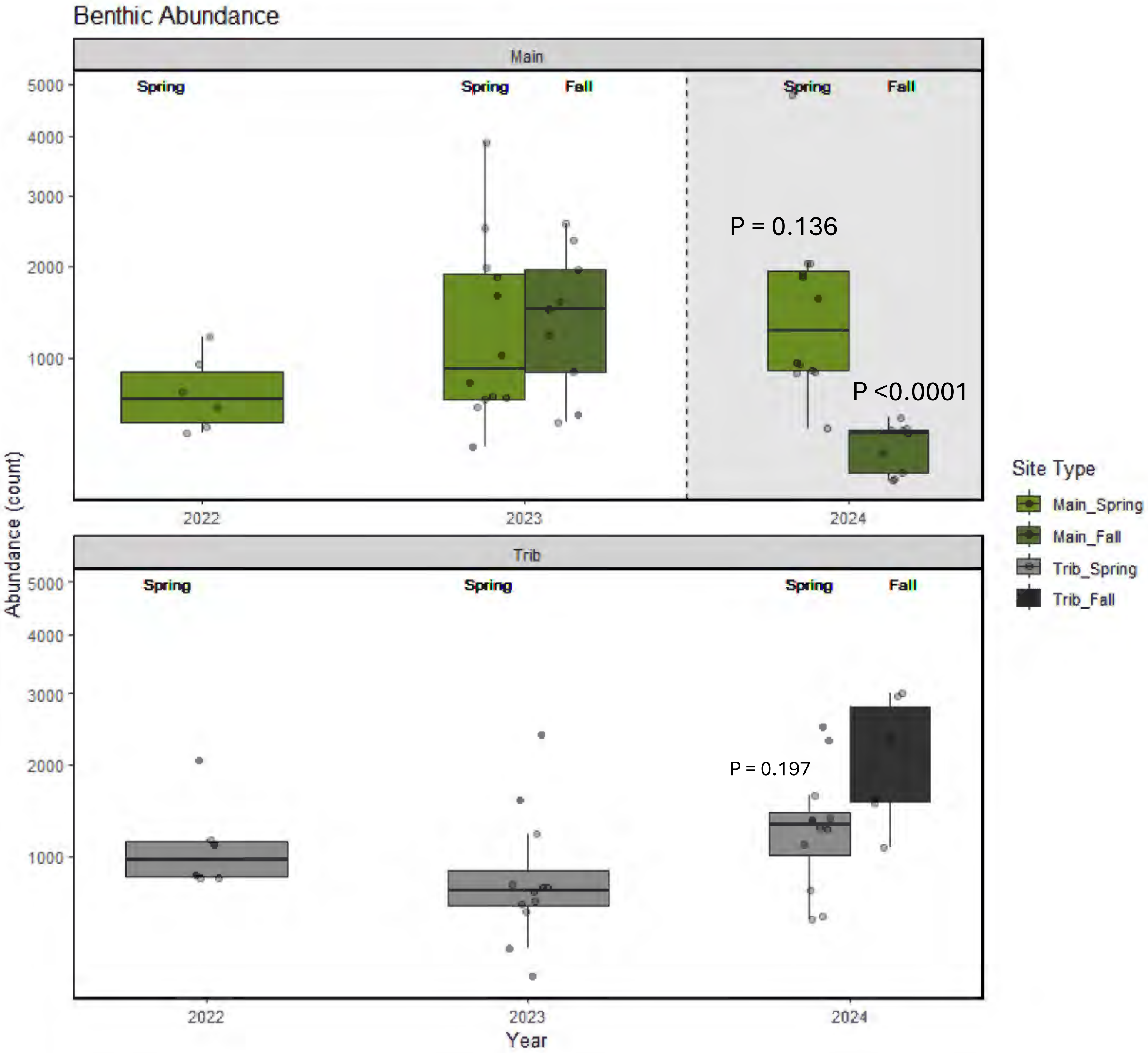
Taxonomically diverse, no clear winners



BENTHIC:

No change in abundance between **Spring** samples

Abundance declined significantly in **2024 Fall**

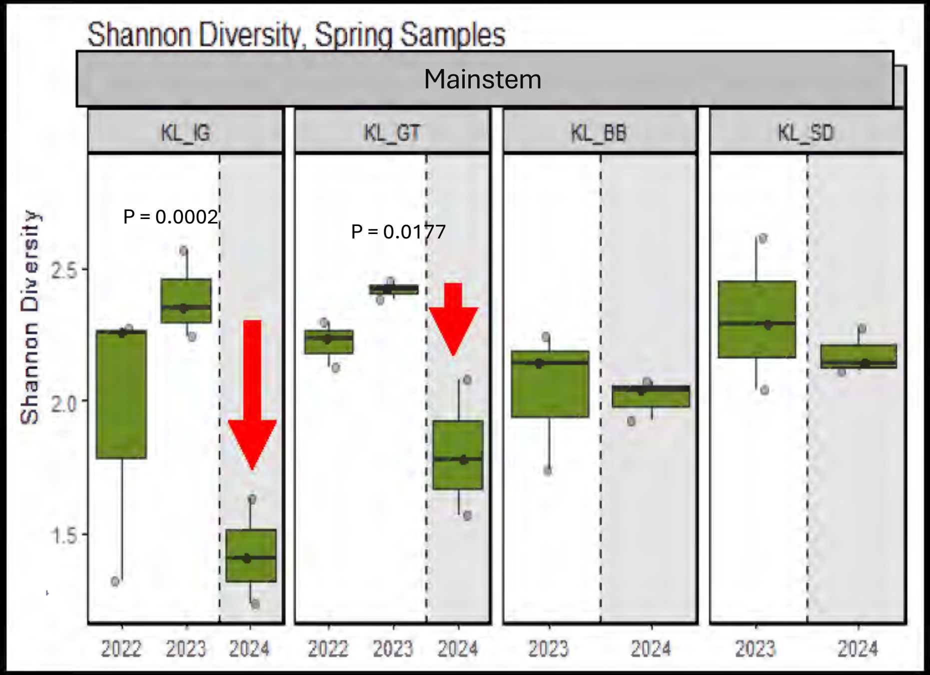


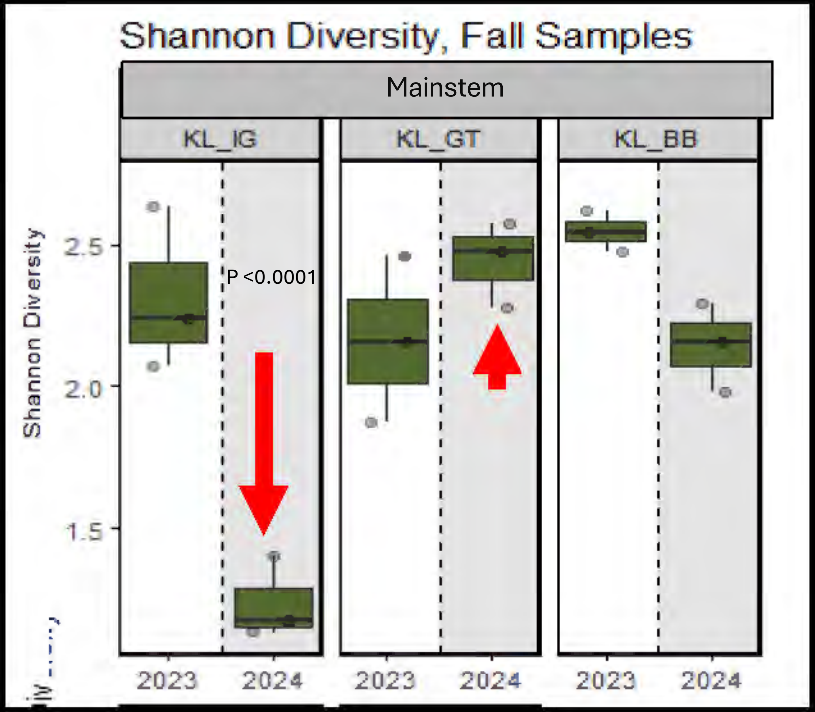
BENTHIC (SPRING):

Shannon diversity declined at 2 sites closest to Iron Gate Dam

BENTHIC (FALL):

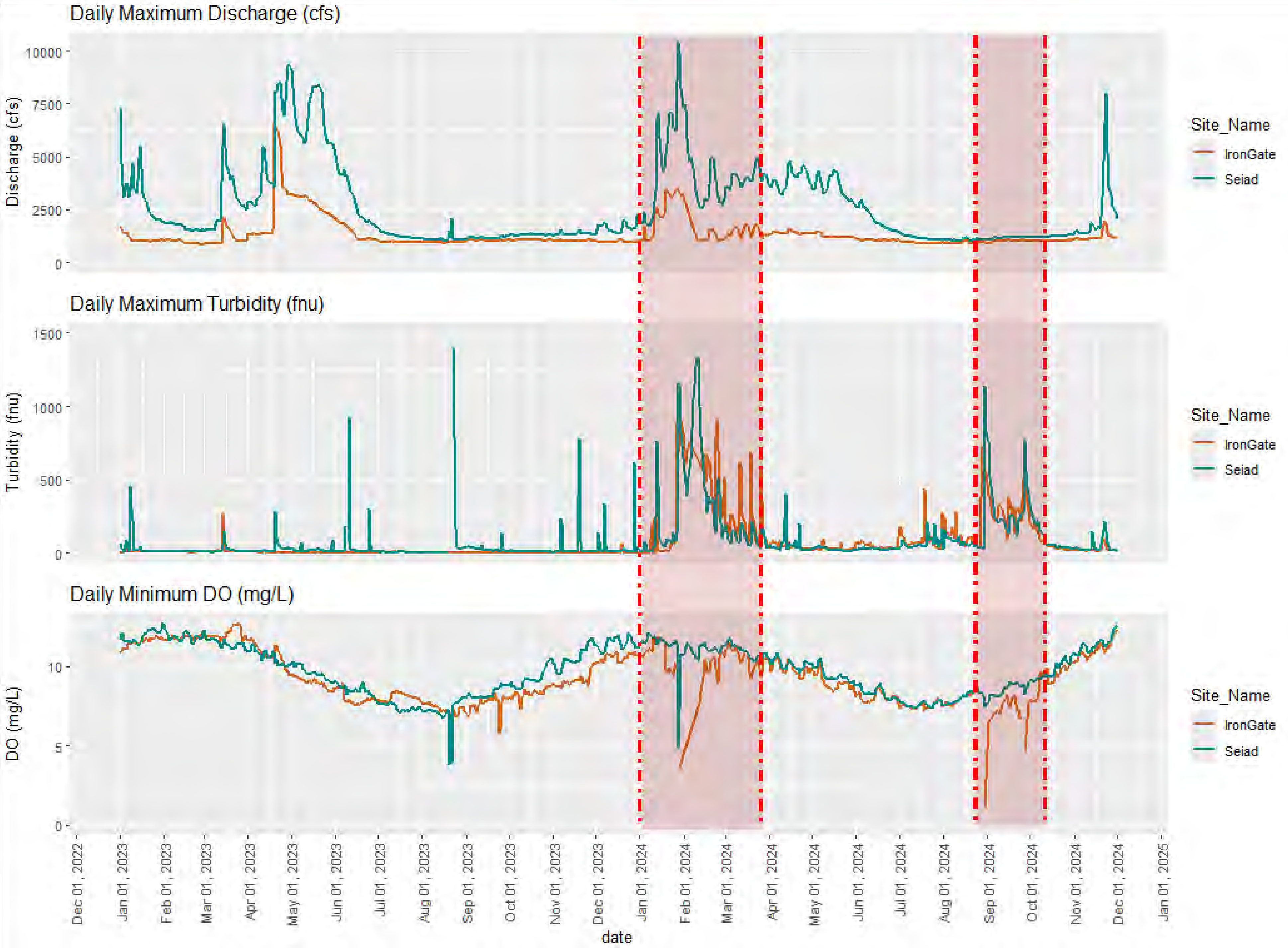
Shannon diversity declined only at Iron Gate





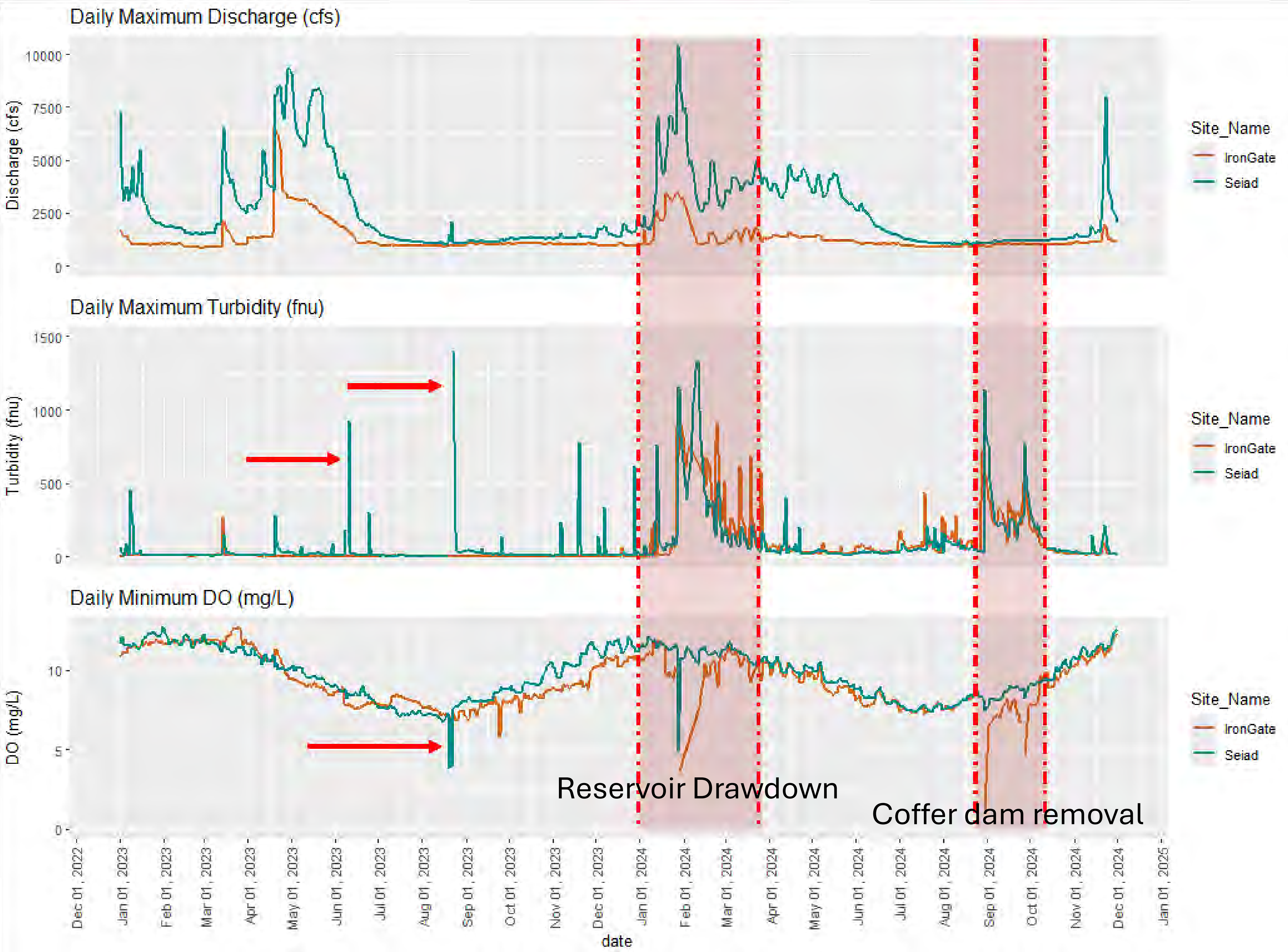
Initial drawdown vs coffer dam removal

Drawdown and coffer dam removal sediment pulses



Continuous water quality data from RES

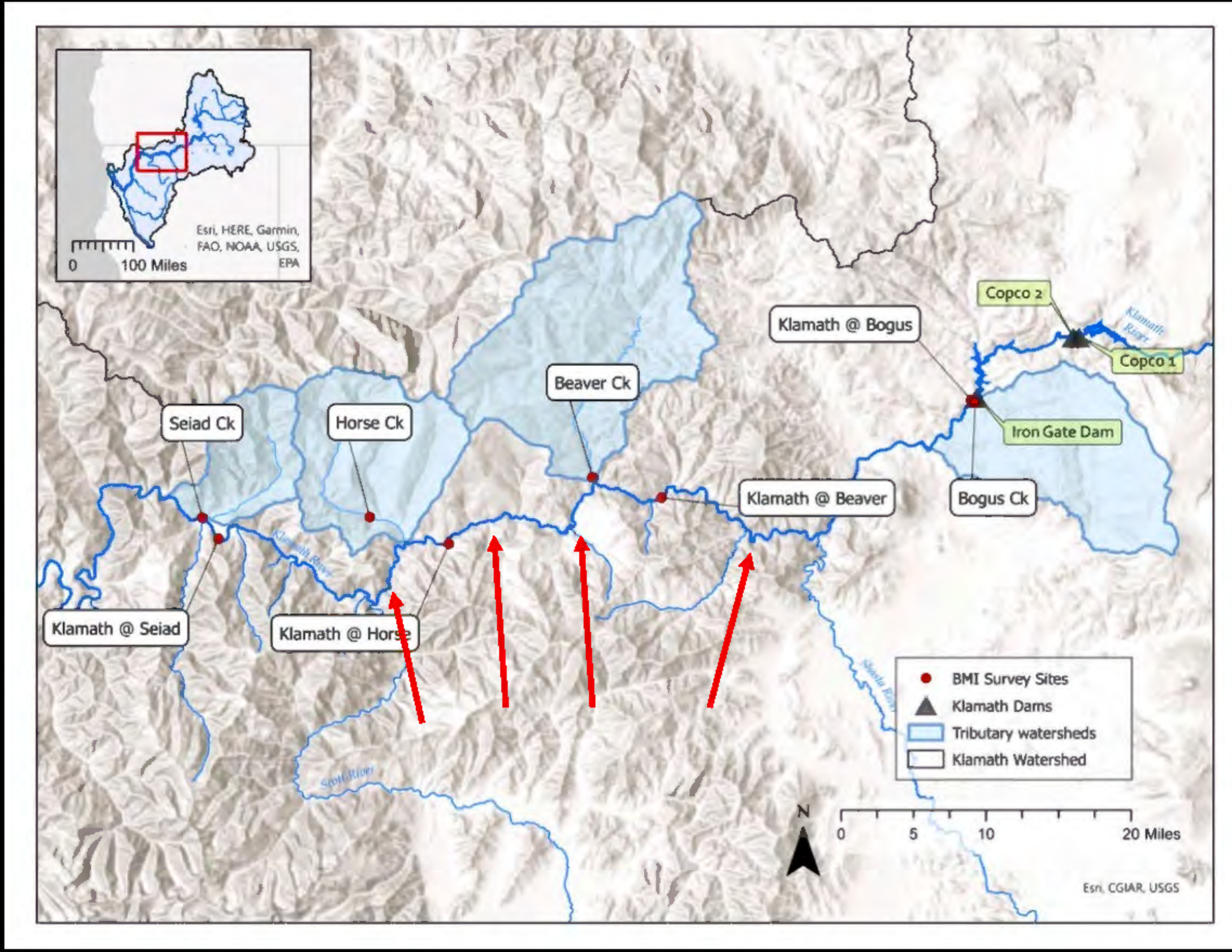
McKinney Fire sediment pulses



Continuous water quality data from RES

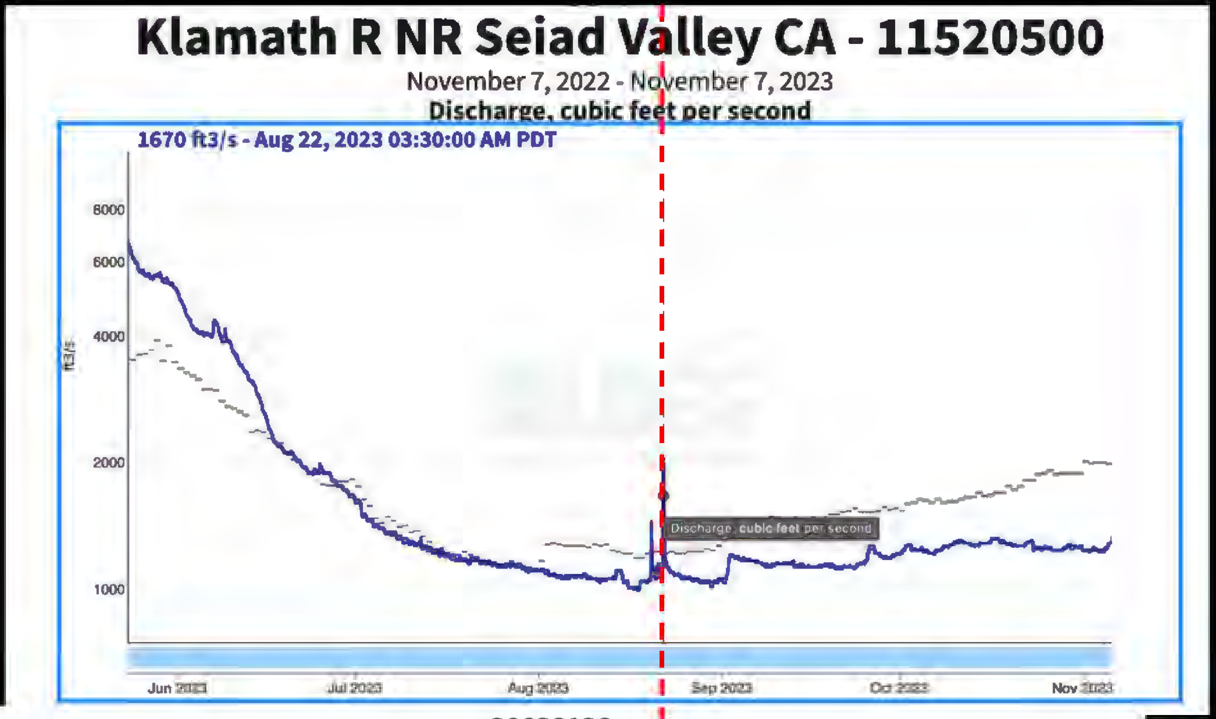
Already lots of extra sediment in the river

- McKinney Fire between 2022 and 2023 sampling seasons

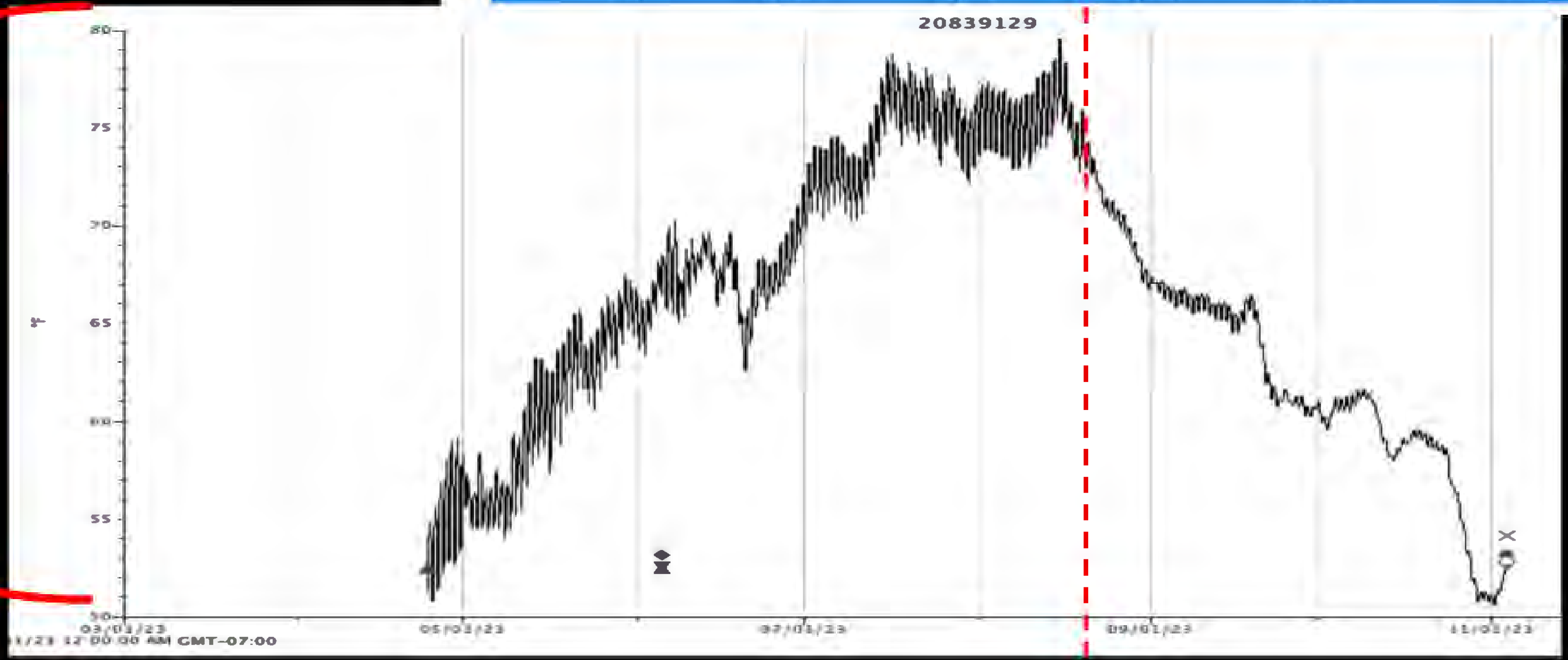


McKinney fire sediment

Discharge (CFS)



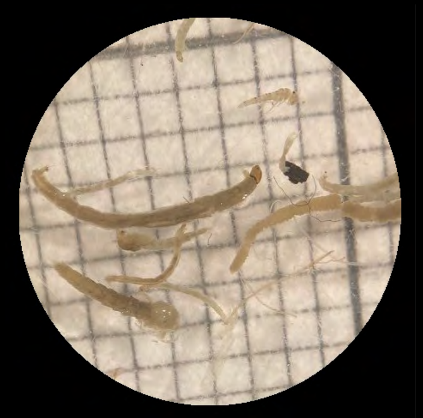
Temp C



Take homes:

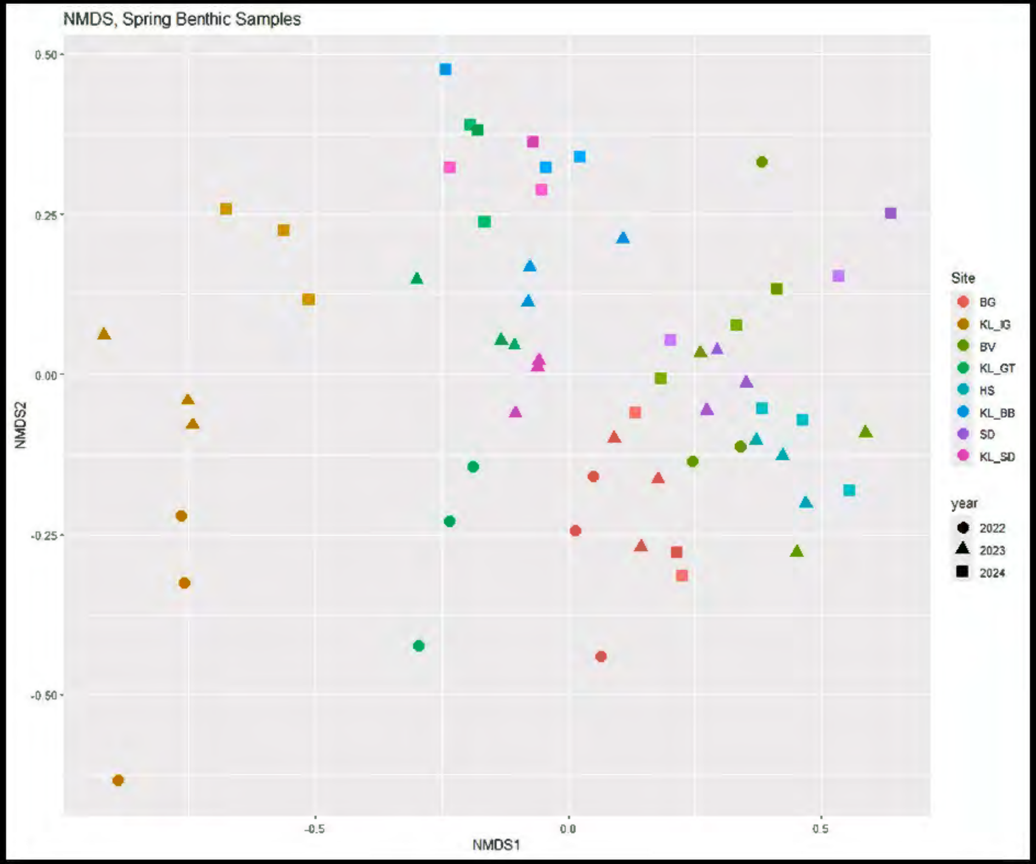
- Dam removal didn't cause dramatic changes in SPRING juvenile salmonid diet availability

- Timing of sediment flushes (relative to flow in the river and water temperature) may be important for mitigating impacts



Next steps:

- GLMM in Bayesian framework
  - Spatial trends (distance from dam)
  - Parse out McKinney Fire vs dam removal?
- Multivariate community analyses
- Taxonomic variability in response
  - Who is driving the decline in diversity?
- Monitor future trends
  - Next graduate student



Acknowledgements

- **Thesis committee**: Dr. Alison O’Dowd, Dr. Nicholas Som, Dr. Darren Ward
- **Karuk Tribe Fisheries**: Toz Soto, Clayton Tuttle, Ben Harrison, Aaron Tuttle
- **O’Dowd Lab**: Elizabeth Uemura, King Baptista, Amanda Podkomorka, Michael Paige, Kelly Corcoran, Andre Giraldi, Theo Murphy, Blake Gonzales, Victoria Budke, Ben King, Julia Nehl
- **U.C. Davis Lusardi lab**: Rob Lusardi, Brandi Goss, Sarah Howe

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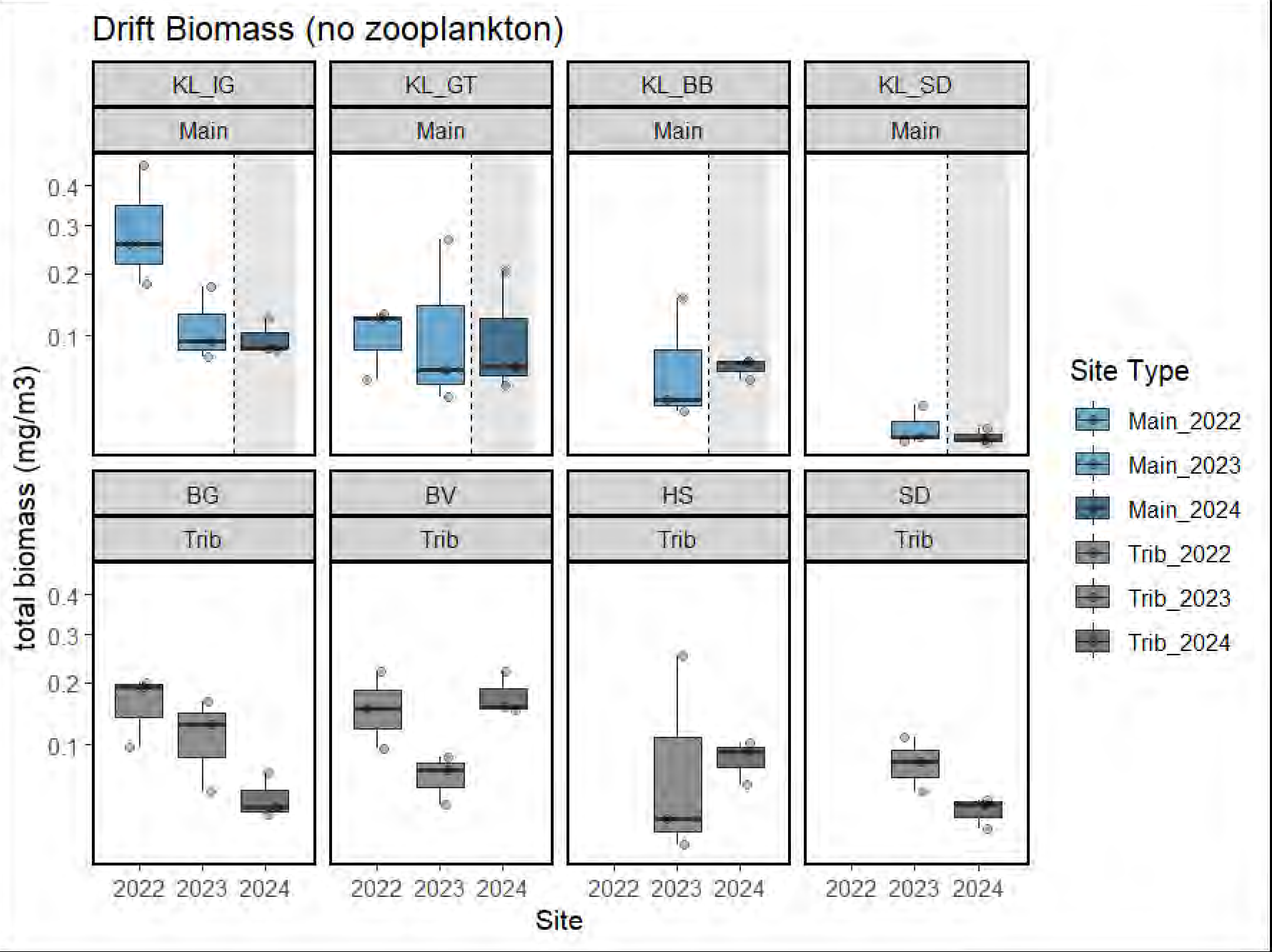
GREAT SEAL OF THE KARUK TRIBE

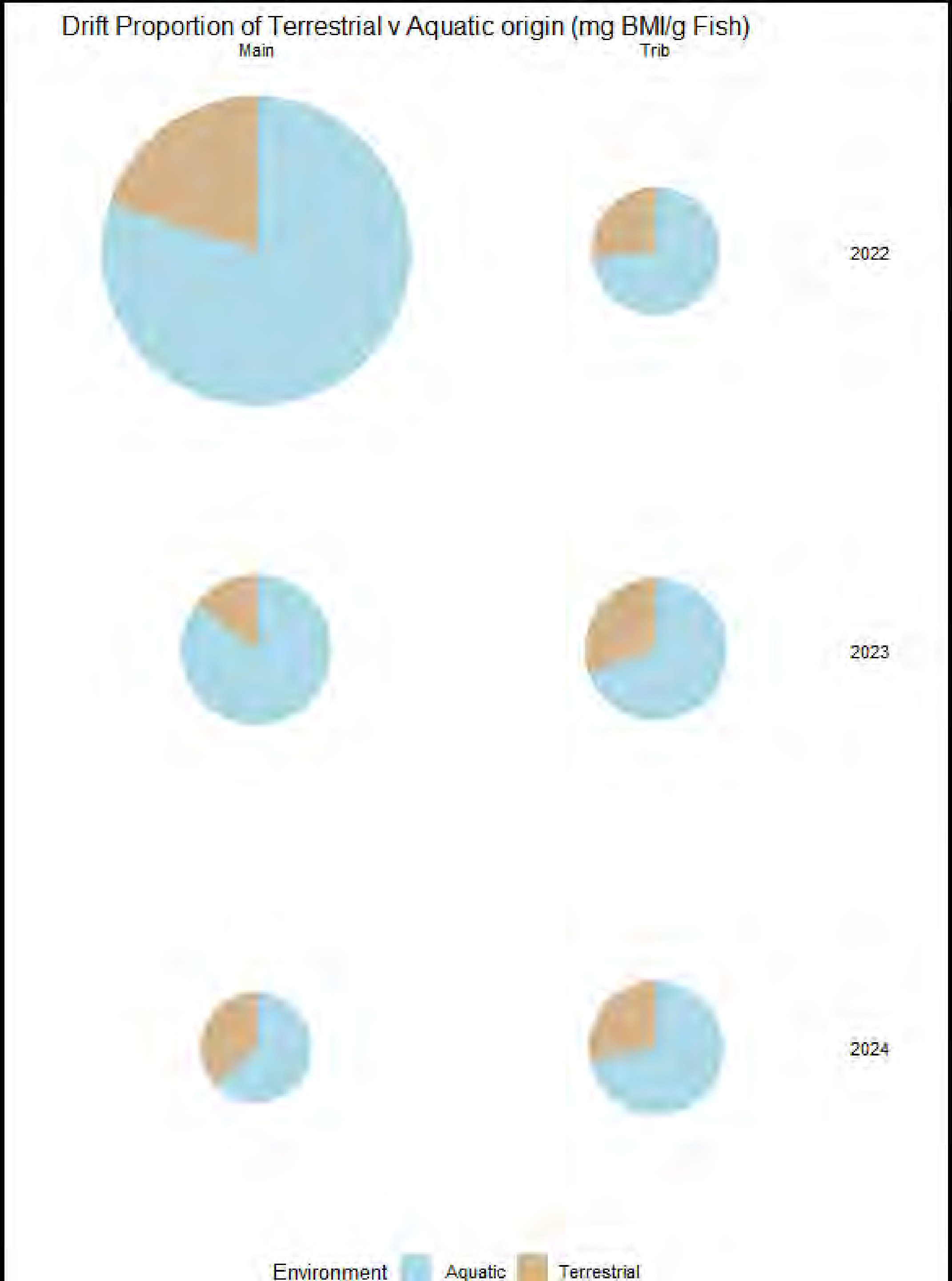

Questions?



Drift Biomass (no zooplankton)
KL_IG
KL_GT
KL_BB
KL_SD
Main
BG
BV
HS
SD
Trib
total biomass (mg/m3)
0.4
0.3
0.2
0.1
2022 2023 2024
Site
Site Type
Main_2022
Main_2023
Main_2024
Trib_2022
Trib_2023
Trib_2024

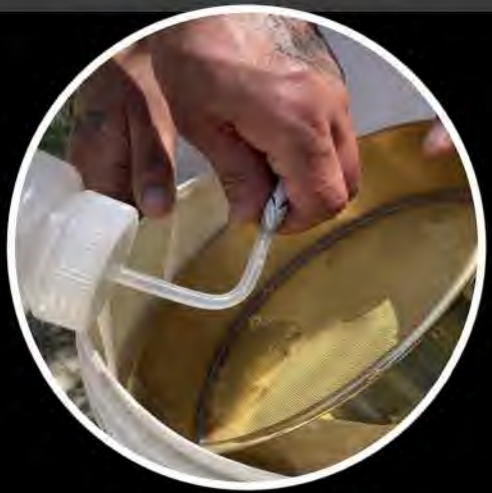
DRIFT:

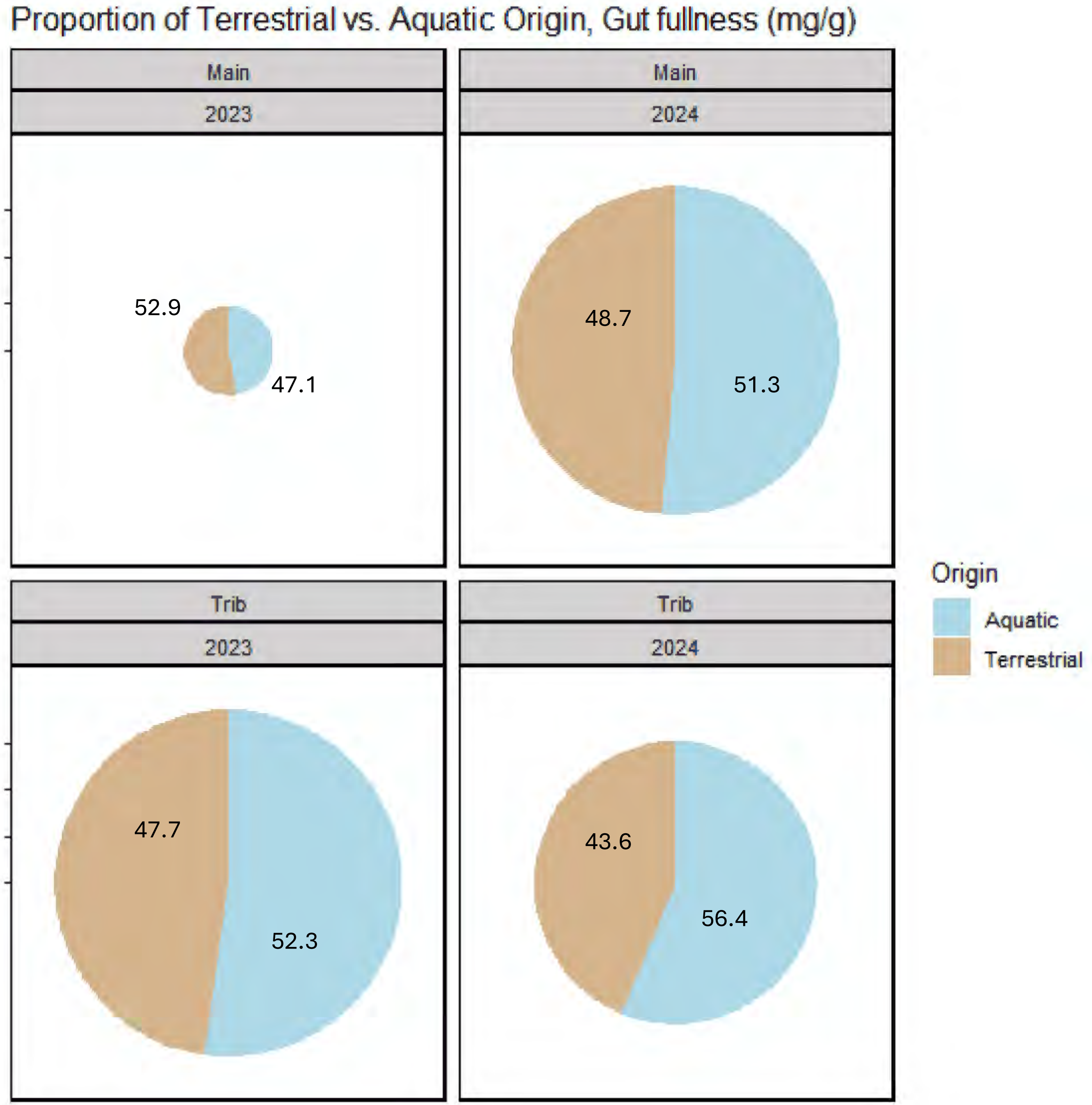
No significant change in proportion of terrestrial vs. aquatic origin



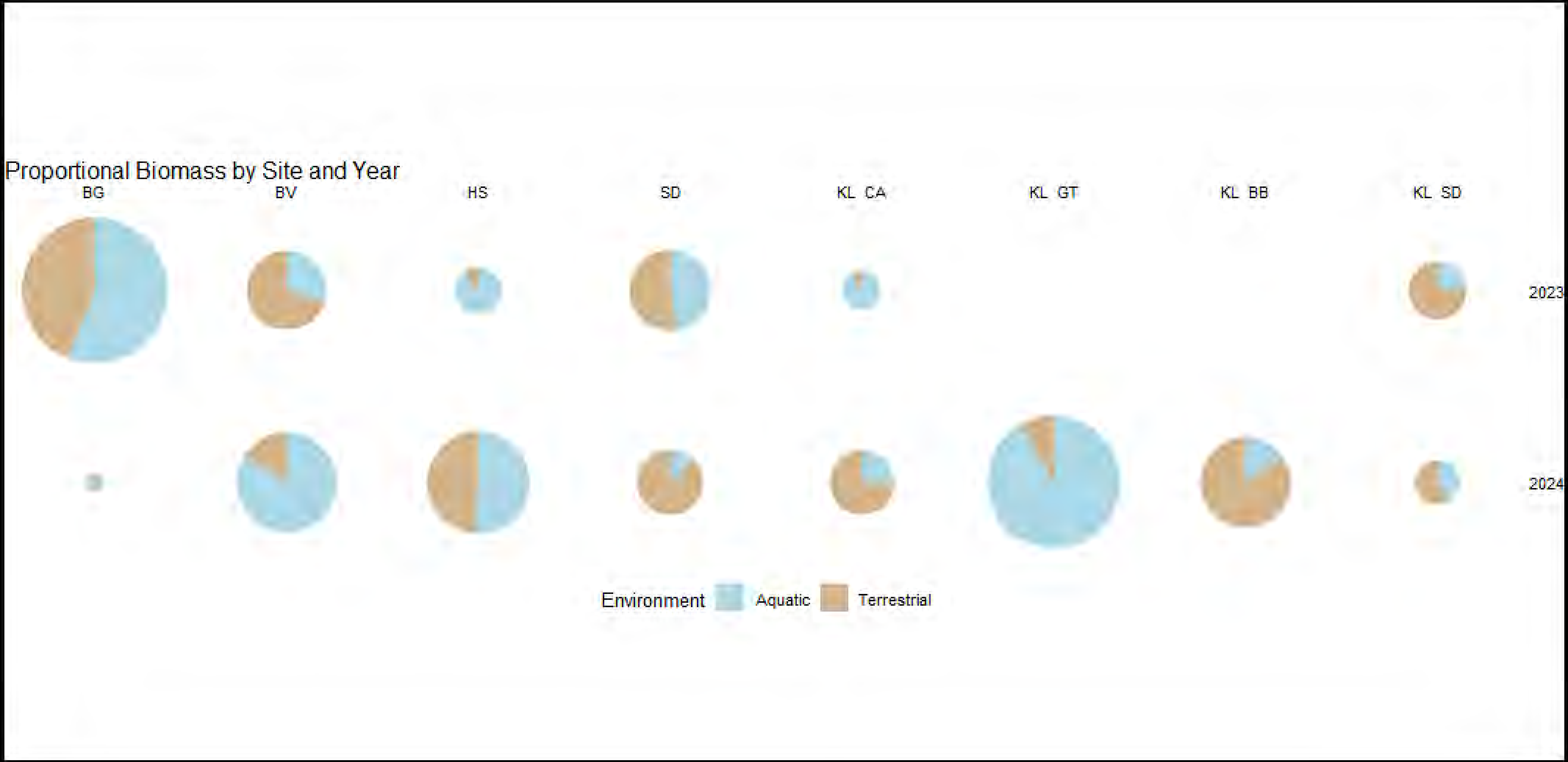
DIET :

No significant change in proportion of terrestrial vs. aquatic origin

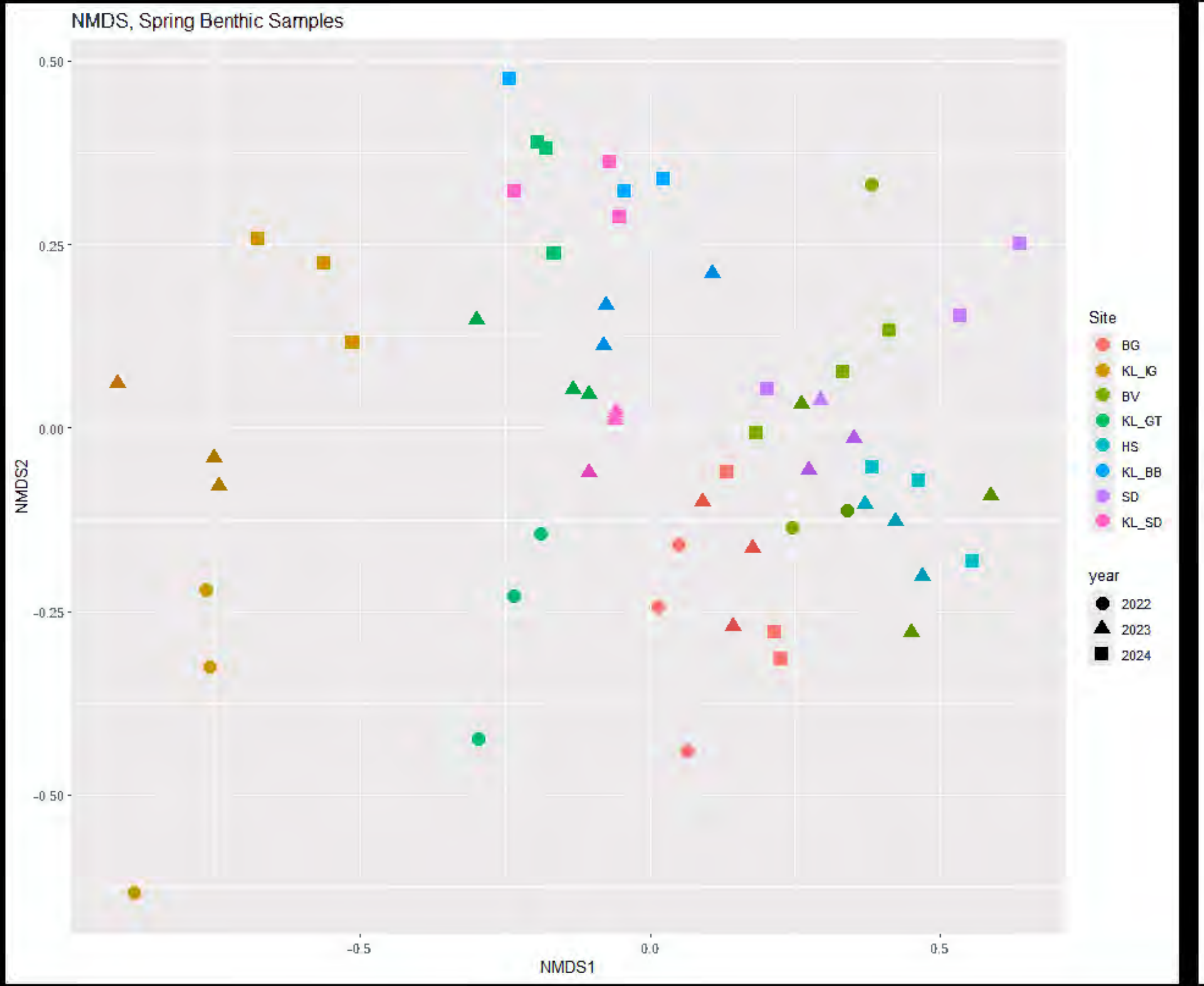


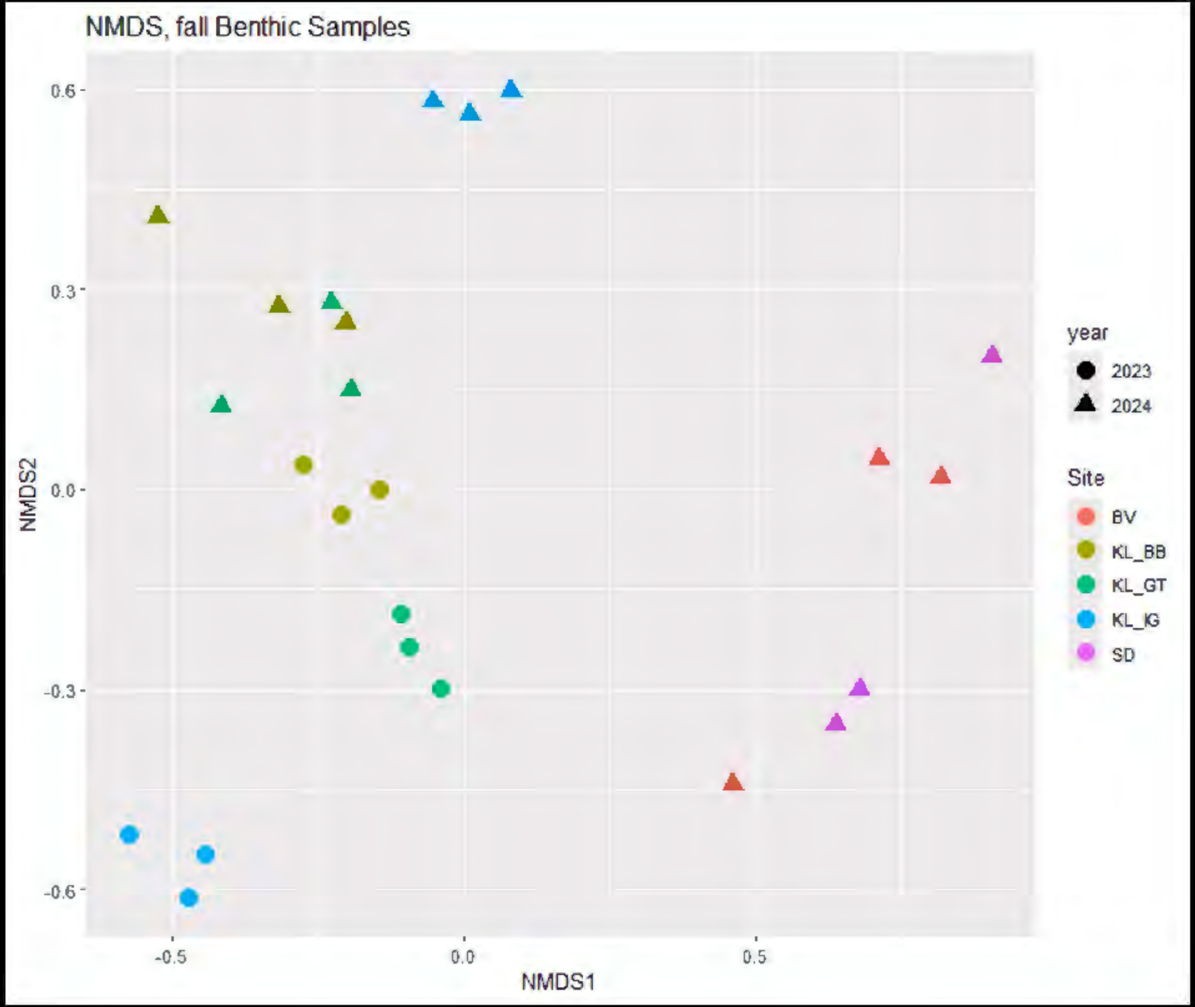


Diet site specific shifts in terr v aquatic



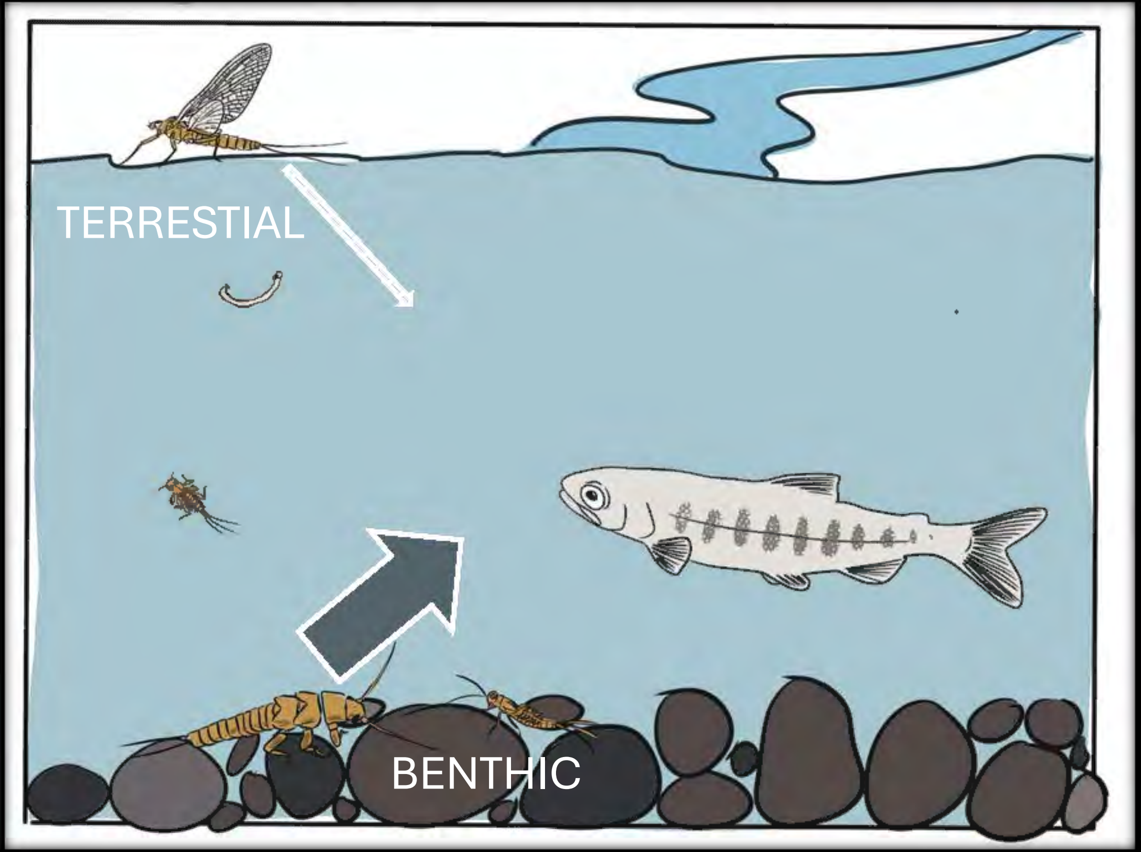
BENTHIC community shifts – fall v spring for each sitetype/year



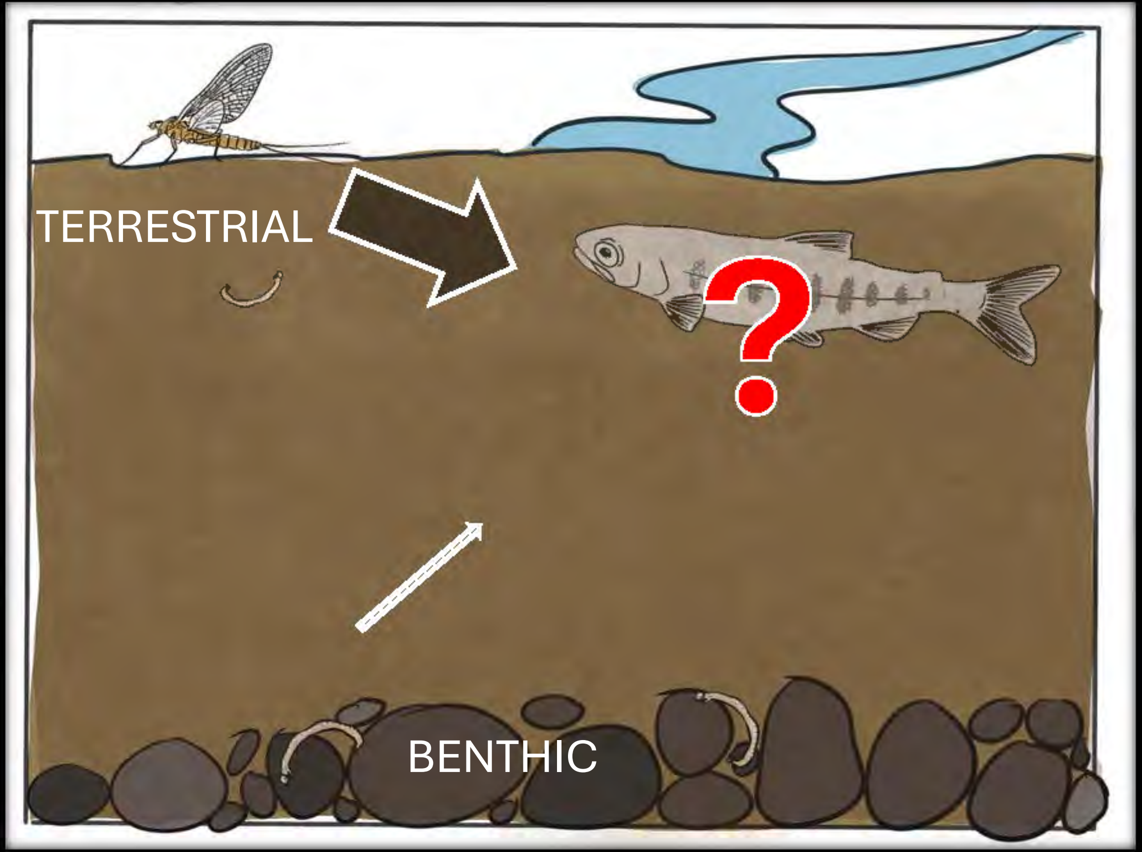


Klamath expectations: shifts in fish diet availability

Before sediment pulse

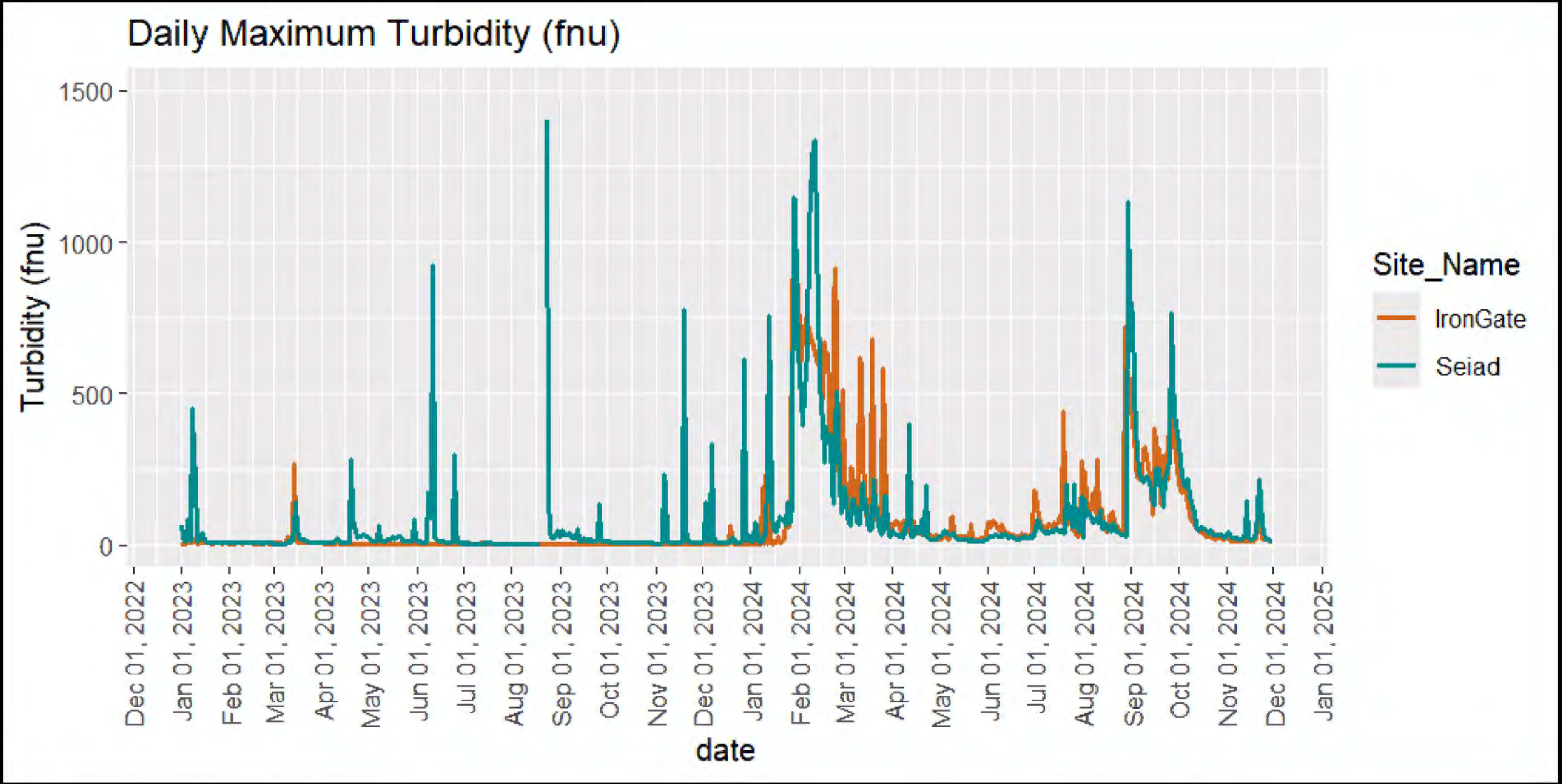


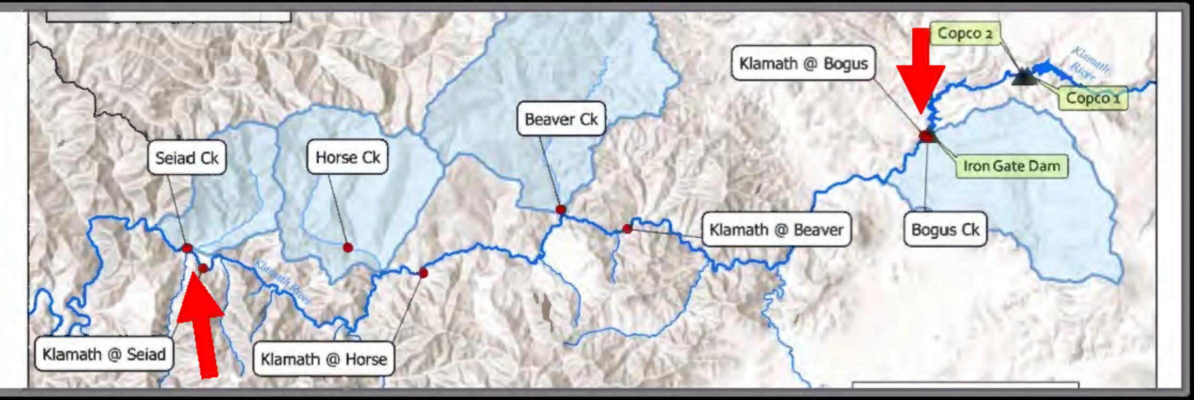
During sediment pulse



flow

WQ (RES data)

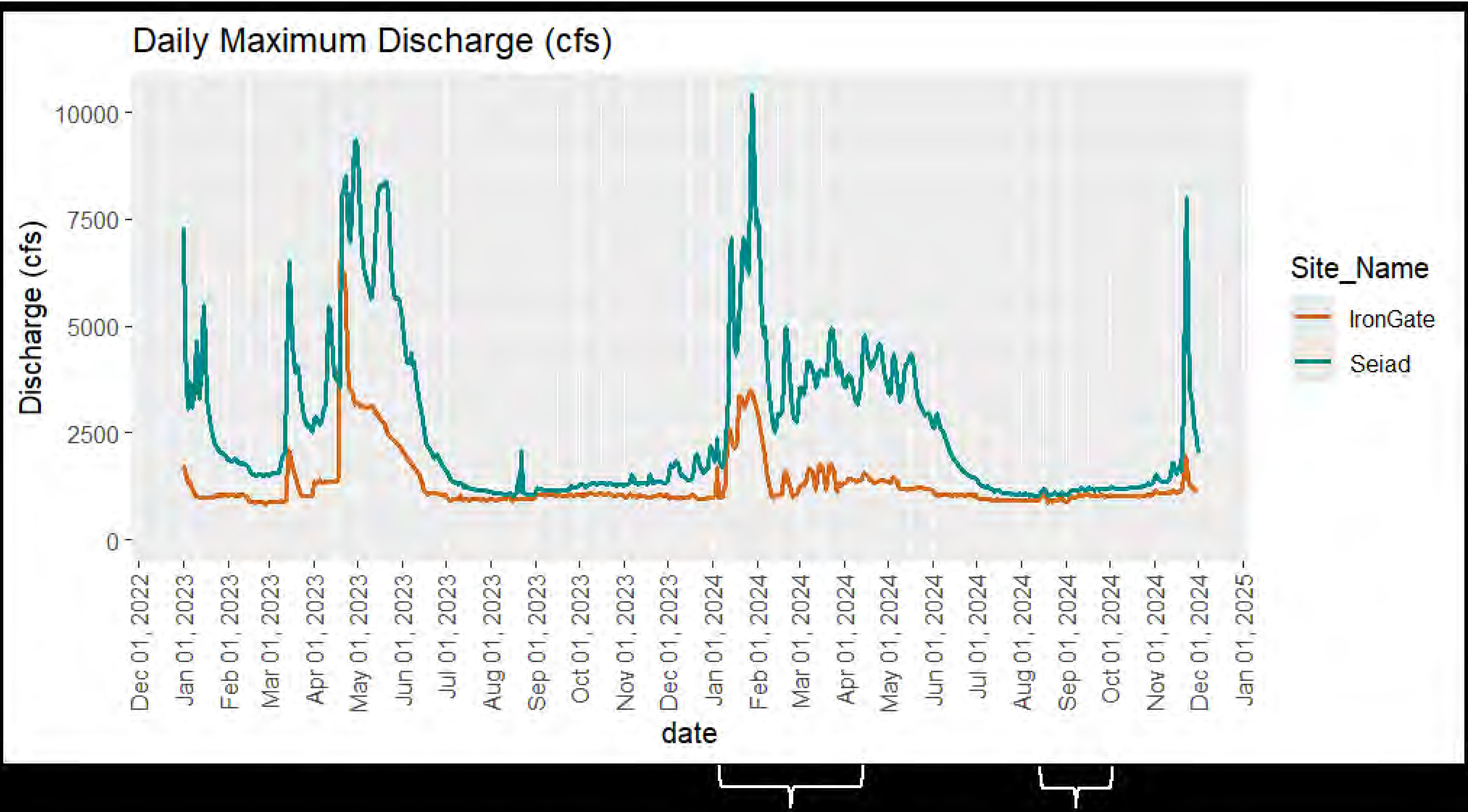




Reservoir Drawdown

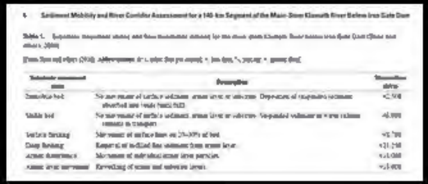
Coffer dam removal

WQ (RES data)

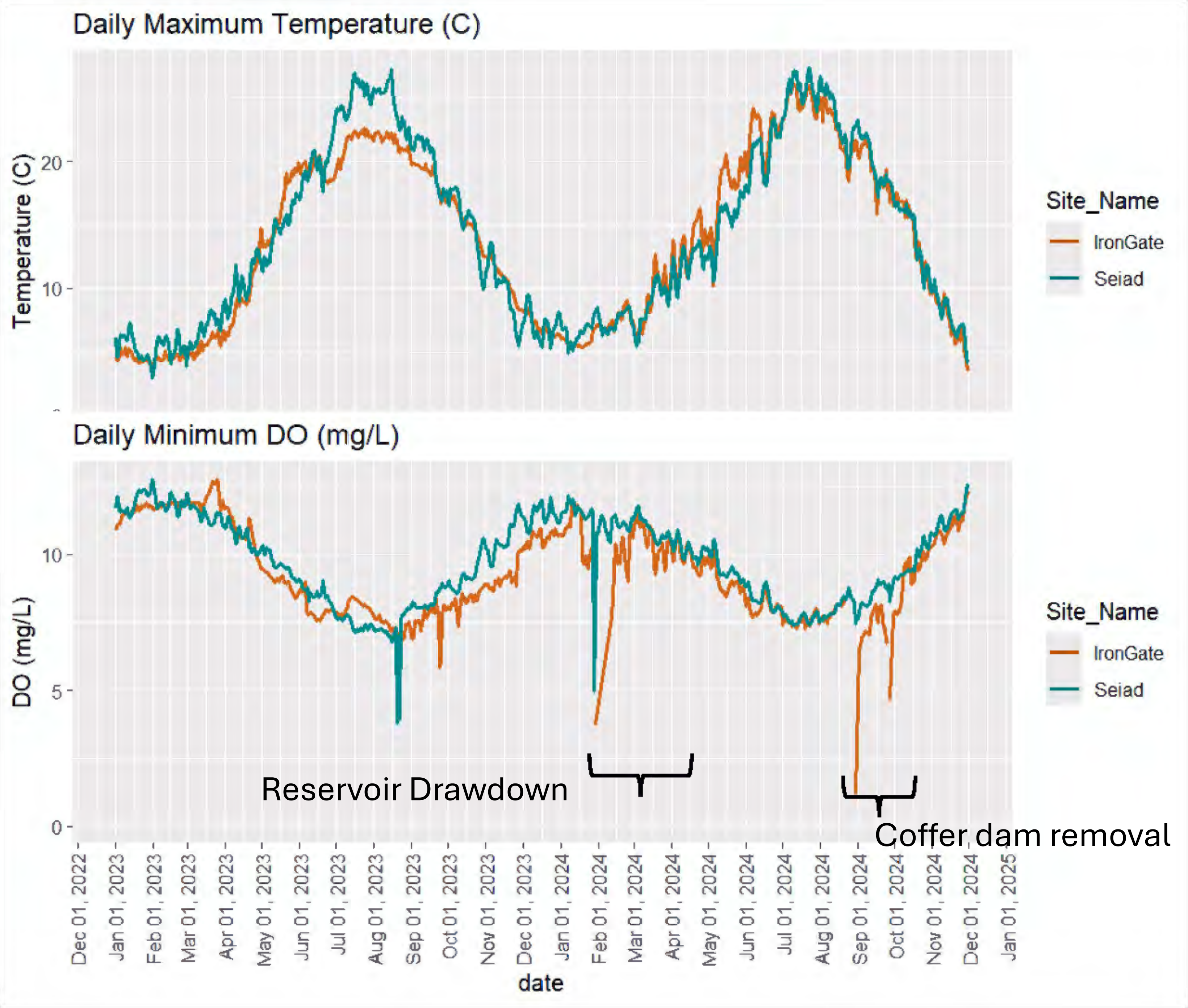


Daily Maximum Discharge (cfs)
Discharge (cfs)
10000
7500
5000
2500
0
Dec 01, 2022
Jan 01, 2023
Feb 01, 2023
Mar 01, 2023
Apr 01, 2023
May 01, 2023
Jun 01, 2023
Jul 01, 2023
Aug 01, 2023
Sep 01, 2023
Oct 01, 2023
Nov 01, 2023
Dec 01, 2023
Jan 01, 2024
Feb 01, 2024
Mar 01, 2024
Apr 01, 2024
May 01, 2024
Jun 01, 2024
Jul 01, 2024
Aug 01, 2024
Sep 01, 2024
Oct 01, 2024
Nov 01, 2024
Dec 01, 2024
Jan 01, 2025
date
Site_Name
IronGate
Seiad
Reservoir Drawdown
Coffer dam removal

WQ (RES data)



Curtis, J., Poitras, T., Bond, S., and Byrd, K., 2021, Sediment mobility and river corridor assessment for a 140-kilometer segment of the main-stem Klamath River below Iron Gate Dam, California



Elwha dam removal: lessons learned

Spring (May – June) Summer (July – August)

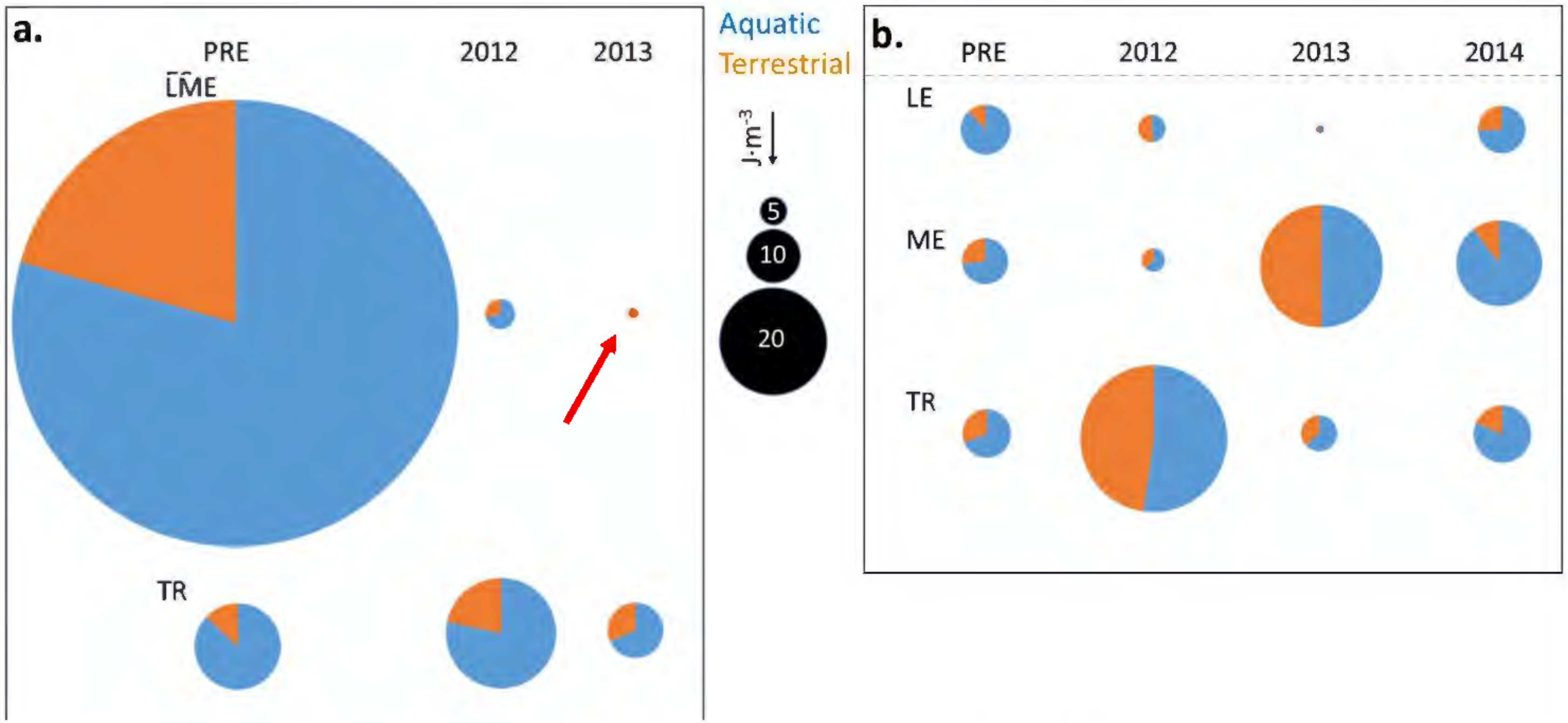


Fig 5. Mean invertebrate energy density by habitat of origin (aquatic or terrestrial). Data are plotted by section and year for (a) spring and (b) summer.

https://doi.org/10.1371/journal.pone.0239198.g005

Elwha drift energy densities by terrestrial vs aquatic origin in sections between dams (ME) and below dams (LE), with reference sites in Tributaries (TR). Adapted from Morley et al. 2020

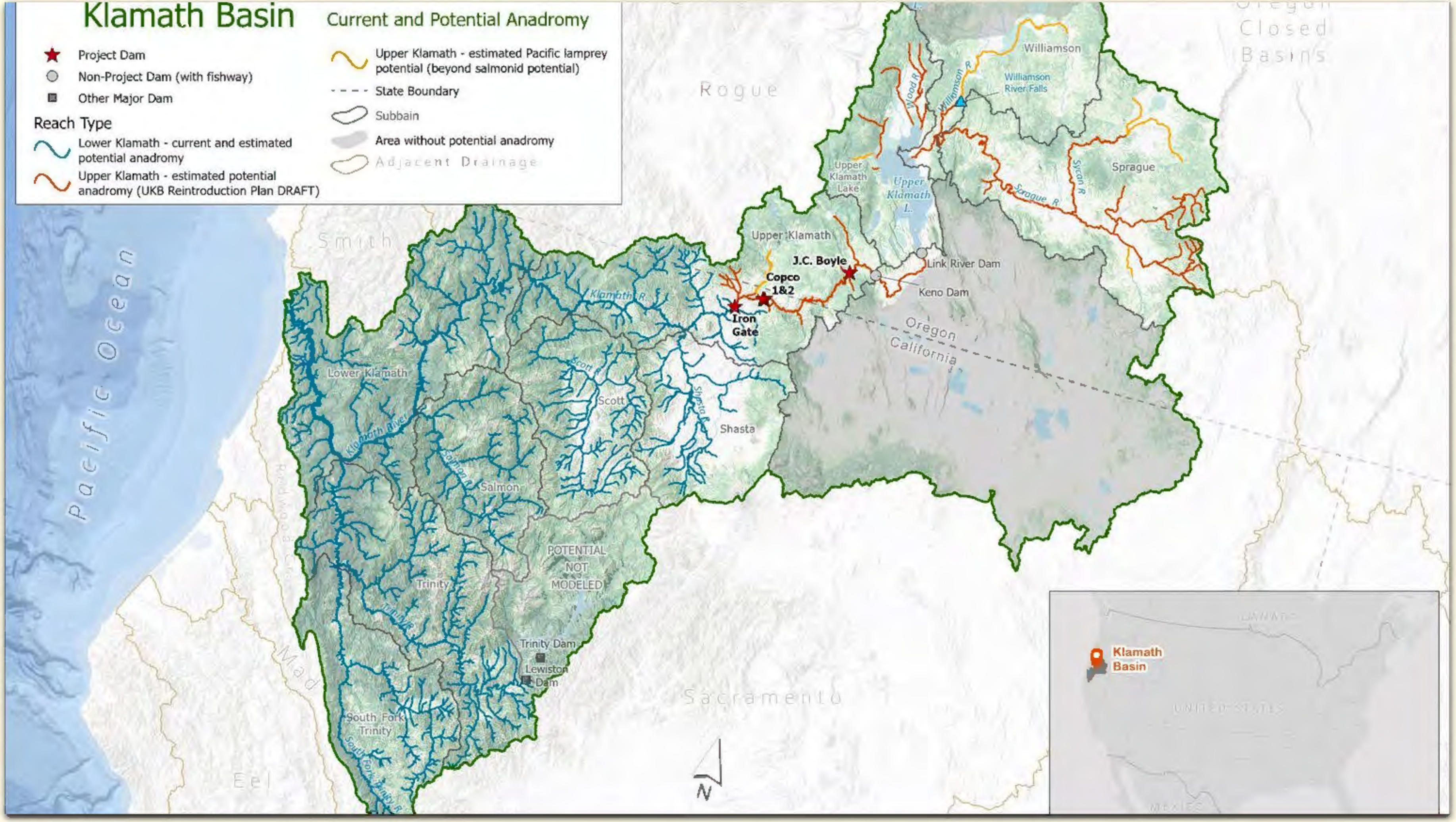
Klamath River Effectiveness Monitoring

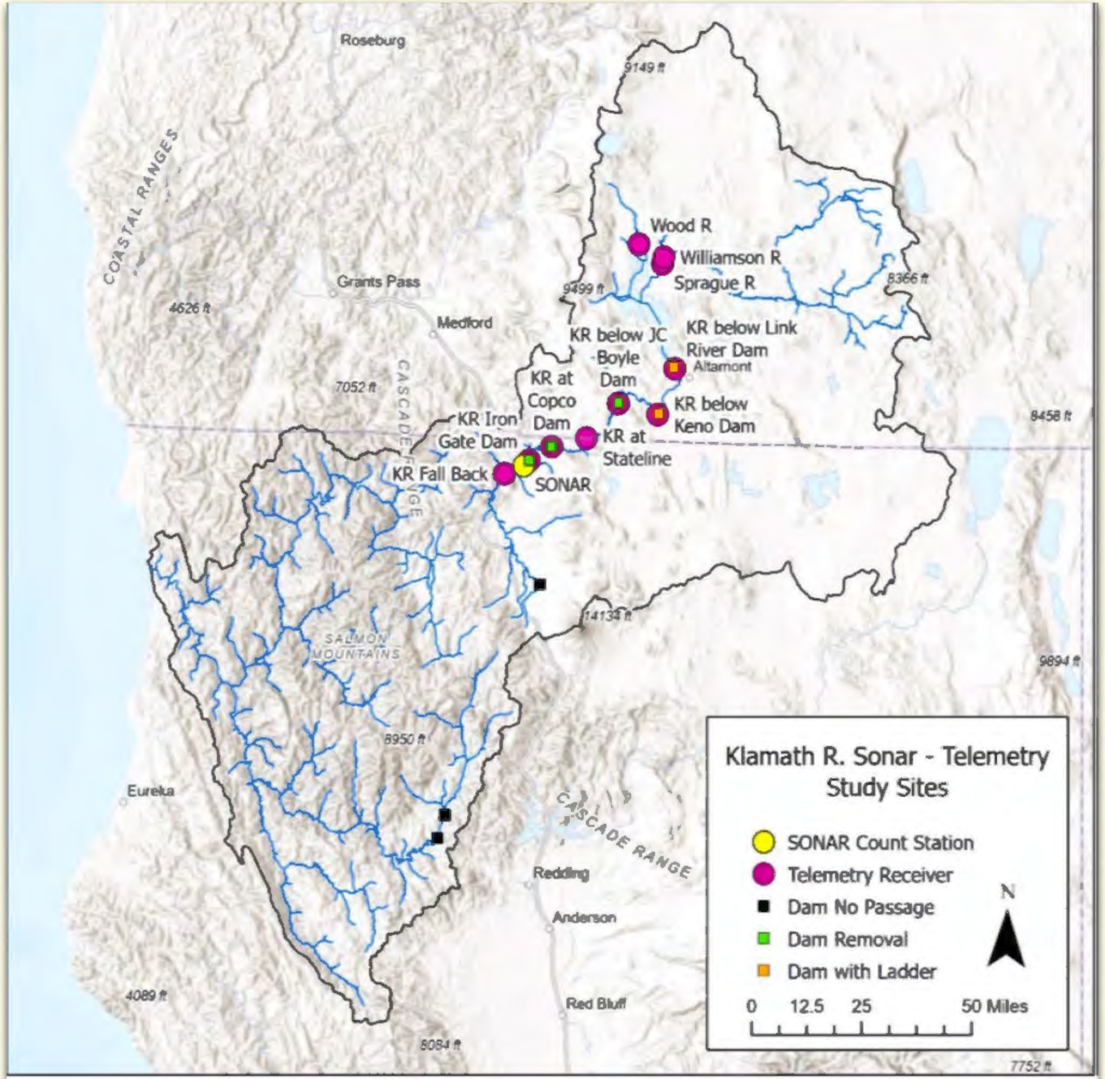
Alex Corum
James Whelan

SRF 2025

Photo by Michael Weir


AFTER
BEFORE


Klamath Basin
Current and Potential Anadromy
Project Dam
Non-Project Dam (with fishway)
Other Major Dam
Reach Type
Lower Klamath - current and estimated potential anadromy
Upper Klamath - estimated potential anadromy (UKB Reintroduction Plan DRAFT)
Upper Klamath - estimated Pacific lamprey potential (beyond salmonid potential)
State Boundary
Subbain
Area without potential anadromy
Adjacent Drainage
Rogue
Closed Basins
Williamson
Williamson River Falls
Sprague
Upper Klamath Lake
Upper Klamath L.
Upper Klamath
J.C. Boyle
Copco 1&2
Iron Gate
Link River Dam
Keno Dam
Oregon
California
Smith
Pacific Ocean
Lower Klamath
Klamath R.
Klamath River
Scott
Scott R.
Shasta
Shasta R.
Salmon
POTENTIAL NOT MODELED
Trinity
Trinity R.
Trinity Dam
Lewiston Dam
South Fork Trinity
Sacramento
Eel
Mad
N
Klamath Basin



Roseburg
Grants Pass
Medford
COASTAL RANGES
CASCADE RANGE
4626 ft
7052 ft
9149 ft
9499 ft
8366 ft
8458 ft
14134 ft
9894 ft
8950 ft
4089 ft
8084 ft
7752 ft
Wood R
Williamson R
Sprague R
KR below JC Boyle Dam
KR below Link River Dam
Altamont
KR below Keno Dam
KR at Copco Dam
KR at Stateline
KR Iron Gate Dam
KR Fall Back
SONAR
SALMON MOUNTAINS
Eureka
Redding
Anderson
Red Bluff
CASCADE RANGE
Klamath R. Sonar - Telemetry Study Sites
SONAR Count Station
Telemetry Receiver
Dam No Passage
Dam Removal
Dam with Ladder
N
0 12.5 25 50 Miles

Phase 1 Monitoring

- **How Many?** – SONAR below Iron Gate
- **What Species?** – Tangle netting for species apportionment
- **Where are they going?** – Radio telemetry tagging fish at tangle net sites and stationary and mobile tracking.

July 15th, 2024
Kickoff Meeting

September 9th, 2024
Initial SONAR Deployment

October 4th, 2024
First Fish Detected by SONAR

October 16th, 2024
First Tangle Netting

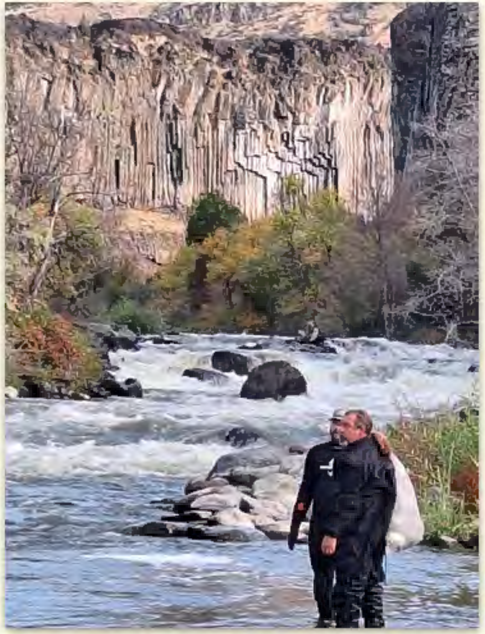
October 22nd, 2024
First Chinook Caught and Tagged

December 4th, 2024
First Coho Caught and Tagged

Monitoring Strategies

SONAR

Tangle Netting

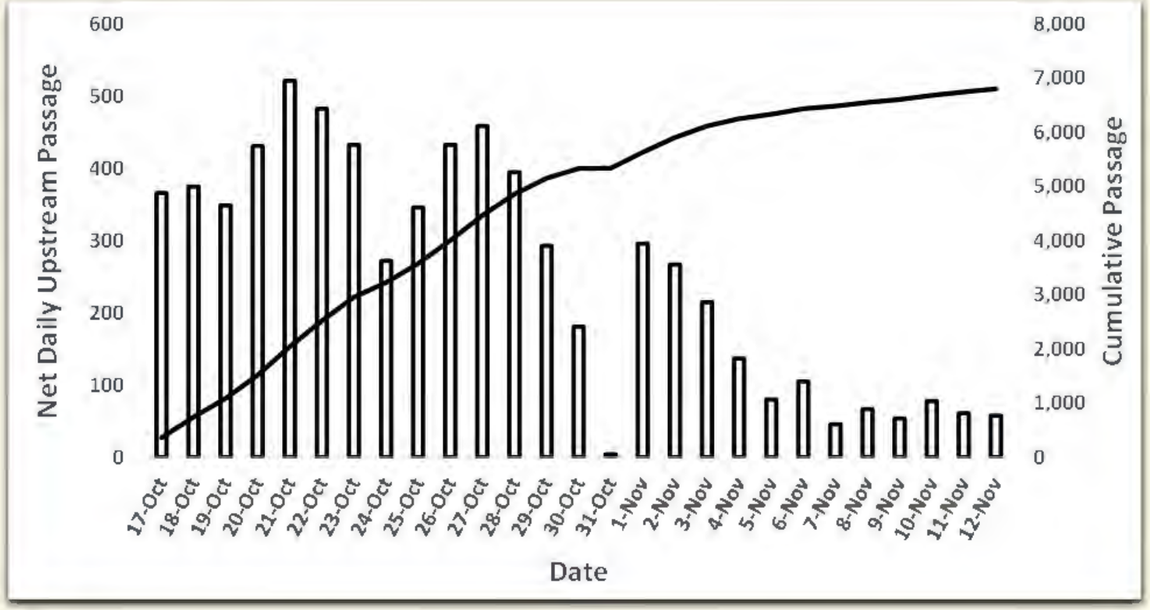


Radio Telemetry

SONAR: ARIS Camera

- Deployed just downstream of the IGD footprint
- Sound waves deploy to show pyramidal cross-section
- Deployed in Sep/Oct, 2024
- Records 24/7

SONAR: ARIS Camera



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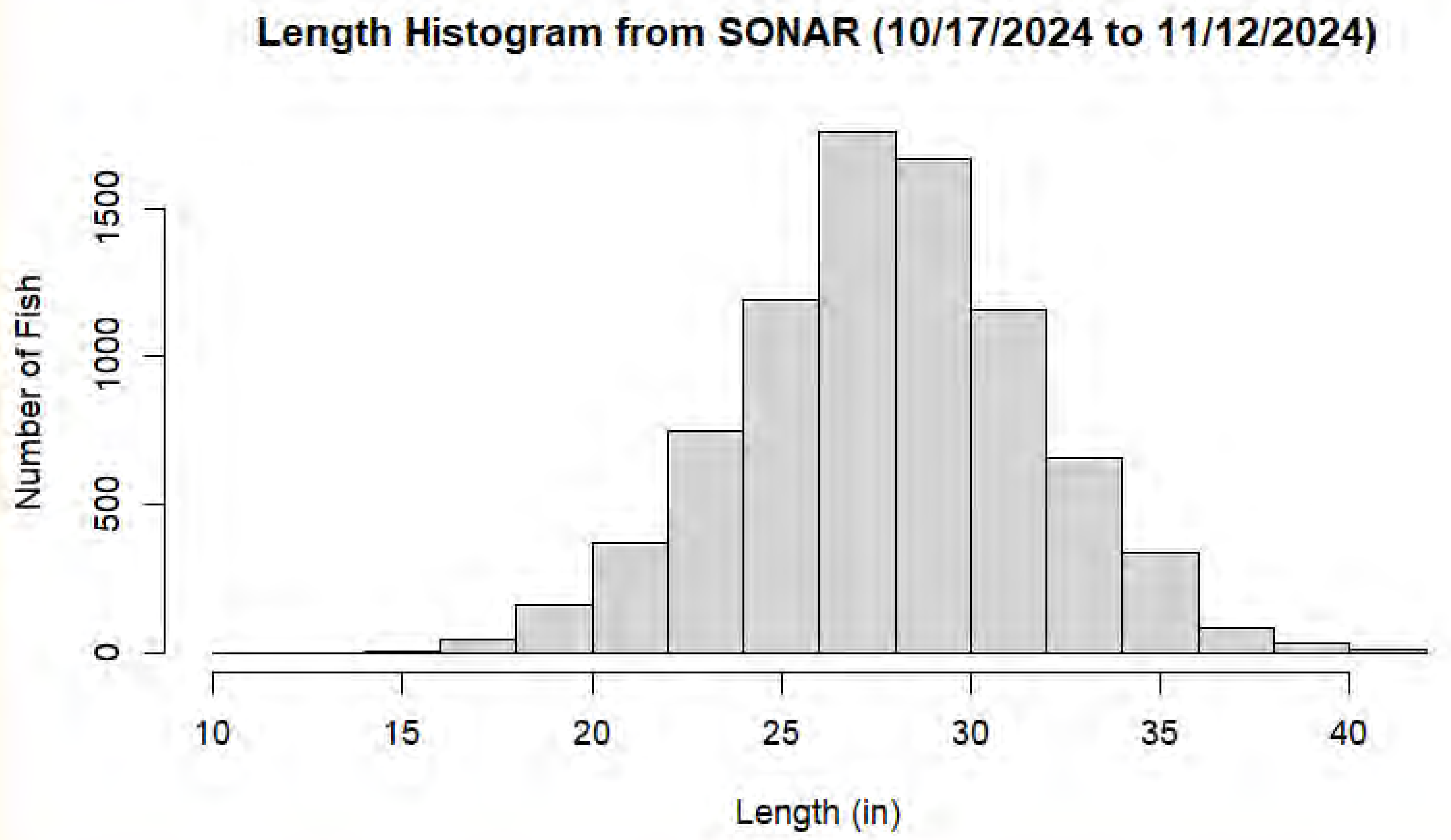
Length Histogram from SONAR (10/17/2024 to 11/12/2024)
Number of Fish
0
500
1000
1500
10
15
20
25
30
35
40
Length (in)

Tangle Netting

- Kick-off effort Oct 16th
- Safely capture and secure fish for tagging
- Physical samples taken for genetics and aging
- Each fish dual tagged with Radio and PIT tags

Tangle Netting

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Capture Summary

- Weeks Netted Up to 1/30/2025
  - 10
- Weeks with Fish Caught up to 1/30/2025
  - 8
- Total Fish Caught up until 1/30/2025
  - 20
- Total Chinook Caught up until 1/30/2025
  - 4
- Total Coho Caught up until 1/30/2025
  - 2
- Total ~~Steelhead~~ ~~*O. mykiss*~~ Sáap caught up until 1/30/2025
  - 14

Radio Telemetry

- Tags deployed externally
- Archival and environmental tags
- Secured to all three species
- Mobile tracked and stationary arrays

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Thank you

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HUMBOLDT AREA FOUNDATION

Wild Rivers COMMUNITY FOUNDATION

GREAT SEAL OF THE KARUK TRIBE

RIDGES TO RIFFLES
INDIGENOUS CONSERVATION GROUP

THE KLAMATH TRIBES
KLAMATH · MODOC · YAHOOSKIN

U.S. FISH & WILDLIFE SERVICE
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