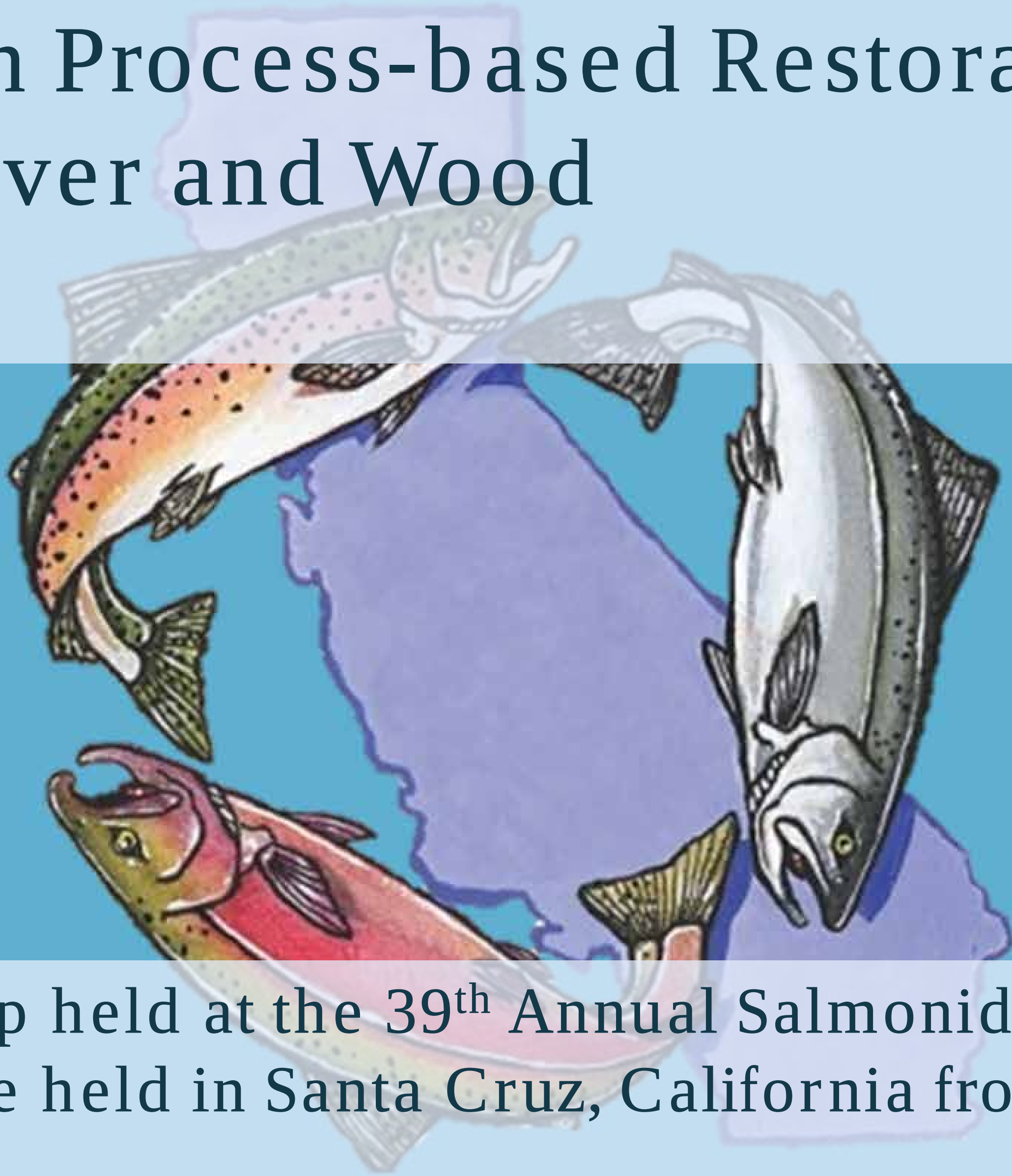
# Low-tech Process-based Restoration with Beaver and Wood



A Workshop held at the 39th Annual Salmonid Restoration Conference held in Santa Cruz, California from April 19 – 22, 2022.

- **Workshop Coordinator:**
  - Eli Asarian, Riverbend Sciences
  - Kate Lundquist, Occidental Arts & Ecology Center
  - Chris Jordan, NOAA, NMFS, and Northwest Fisheries Science Center

The scale and severity of river impairment globally cannot be meaningfully addressed solely using traditional hard-engineering restoration approaches. This workshop will be an opportunity to share recent developments in the evolving science and practice of low-tech process-based restoration (LTPBR) of riverscapes. LTPBR is the practice of adding low unit-cost wood and beaver dams to riverscapes to mimic functions and initiate specific processes that improve river habitats. This workshop will provide an introduction to the LTPBR restoration approach and case-study examples from recent and ongoing LTPBR projects from the Western U.S. including California, Utah, Nevada, Oregon, and Washington. Presentation topics will include:

Overview/introduction to the LTPBR restoration approach

- Effects of LTPBR on geomorphology, hydrology, hydraulics, habitat, water quality, salmonids and other organisms, and ecosystem drought and fire resiliency
- Updated case studies from restoration projects using beavers and wood
- Models and tools for prioritizing LTPBR site selection and evaluating outcomes
- Restoration construction techniques and implementation lessons learned
- Pathways for permitting LTPBR projects and restoring beavers in California

# Presentations

Slide 5 - **Introduction to Low-Tech Process-based Restoration: The Why of the Design Process**, Chris Jordan, Ph.D., *NOAA/NMFS/Northwest Fisheries Science Center*

Slide 78 - **Structural Starvation: Design Examples of Low-Tech Process-based Restoration Across a Diversity of Riverscapes,** Nick Bouwes, Ph.D., *Utah State University*

Slide 149 - **Four Criteria for Process-based Restoration of Streams**, Damion Ciotti, *U.S. Fish and Wildlife Service*

Slide 176 - **Design Tools and Spatial Analysis to Support Low-Tech Process-Based Restoration of Riverscapes**, Chris Jordan, Ph.D., *NOAA/NMFS/Northwest Fisheries Science Center*

Slide 232 - **Planning is Best Done in Advance: LiDAR-based site Assessment Techniques**, Adam Cummings, M.S., *US Forest Service*

Slide 261 – **Dam Satellites: A Quick-start Lesson on Using Free, Publicly Available Remote Sensing Tools to Monitor How Beaver Change Riparian Areas**, Emily Fairfax, Ph.D., *California State University Channel Islands*

# Presentations

Slide 338 - **California's First Beaver Dam Analogues (BDAs) –What Have We Learned Since 2014**, Charnna Gilmore, *Scott River Watershed Council*

Slide 358 - **Use of Process-based Restoration Techniques in a Coastal Tributary of the Klamath River**, Sarah Beesley, M.S., *Yurok Tribe Fisheries Department*

Slide 381 - **Mimicking Beaver Dams in Childs Meadow, California**, Kristen Wilson, Ph.D., *The Nature Conservancy*, and Sarah Yarnell, Ph.D., *UC Davis*

Slide 410 - **PBR The Hard Way—Fear, Hype, and the Reality of Your First 1000 Structures**, Kevin Swift, *Swift Water Design*

Slide 454 - **Update on California Department of Fish and Wildlife Efforts to Provide a Guidance Document for the Use of Low-tech Process-based Stream Habitat Restoration**, Will Arcand, P.G., C.E.G., *California Department of Fish and Wildlife*

Slide 470 - **California Process-based Restoration Network**, Karen Pope, Ph.D., *US Forest Service*

Slide 475 - **Bring Back the Beaver Campaign Updates**, Kate Lundquist, *Occidental Arts & Ecology Center WATER Institute*

# Introduction to LTPBR: The Why of the design process

Chris Jordan – NOAA/NMFS/NWFSC

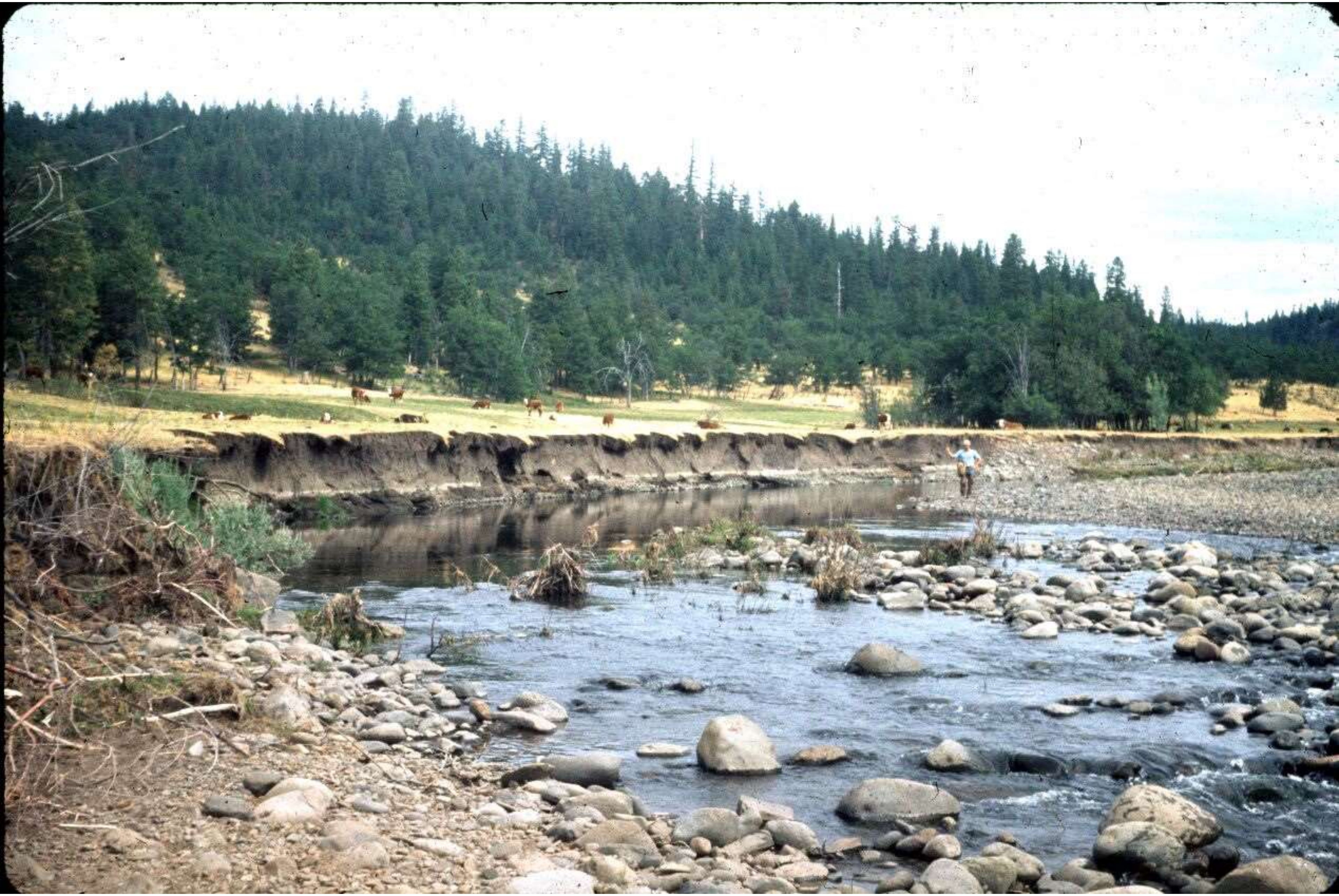


Photo source: BLM Medford Oregon District

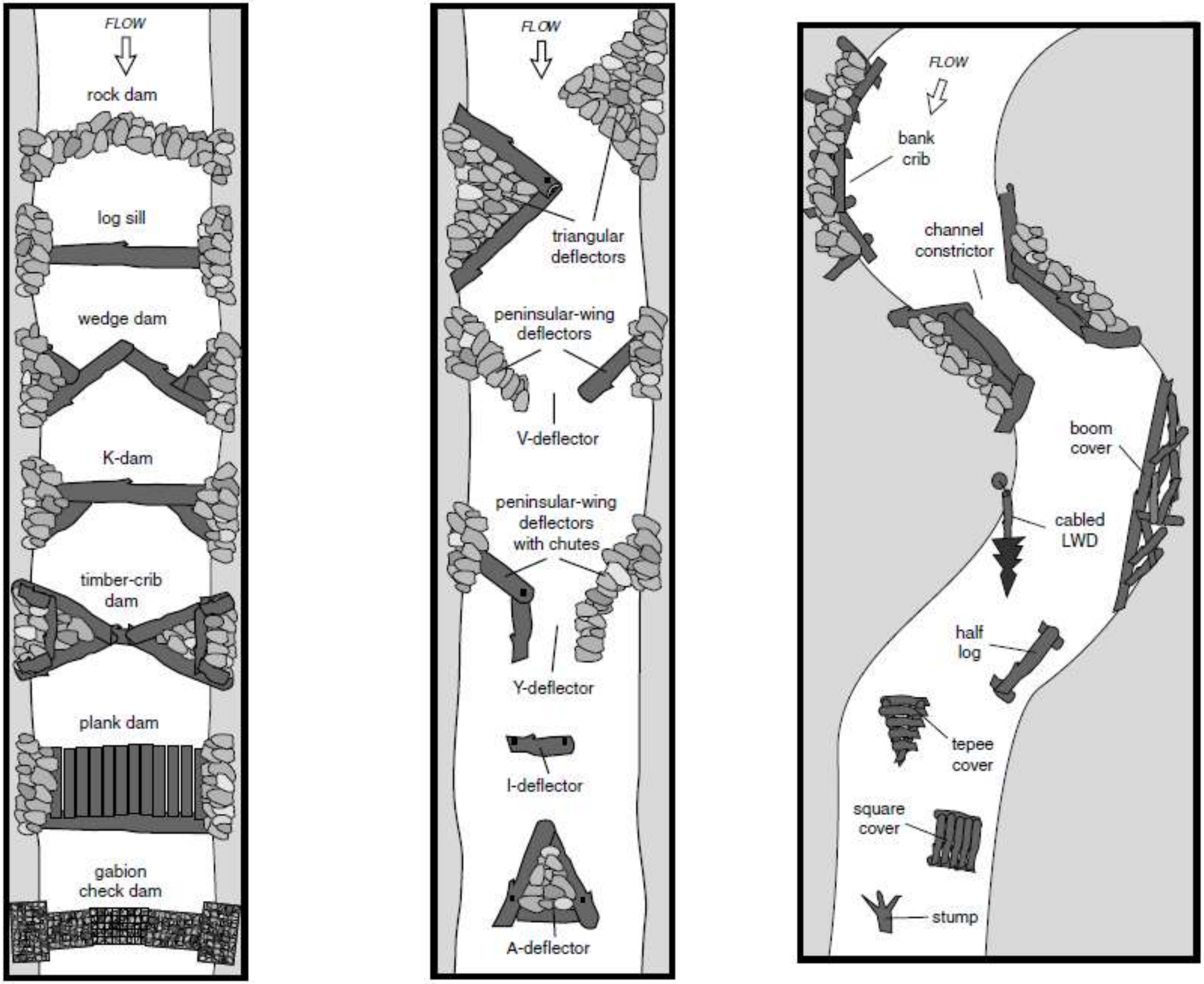

(trekandshoot/shutterstock)

# …to get back to “here”…

# How do we get from A to B?


?


- What does a “good” stream look like?
- What are the dimensions of “good”?
- What are the design characteristics of “good”?


FLOW
rock dam
log sill
wedge dam
K-dam
timber-crib dam
plank dam
gabion check dam
FLOW
triangular deflectors
peninsular-wing deflectors
V-deflector
peninsular-wing deflectors with chutes
Y-deflector
I-deflector
A-deflector
FLOW
bank crib
channel constrictor
boom cover
cabled LWD
half log
tepee cover
square cover
stump


NRTG

Port of Seattle

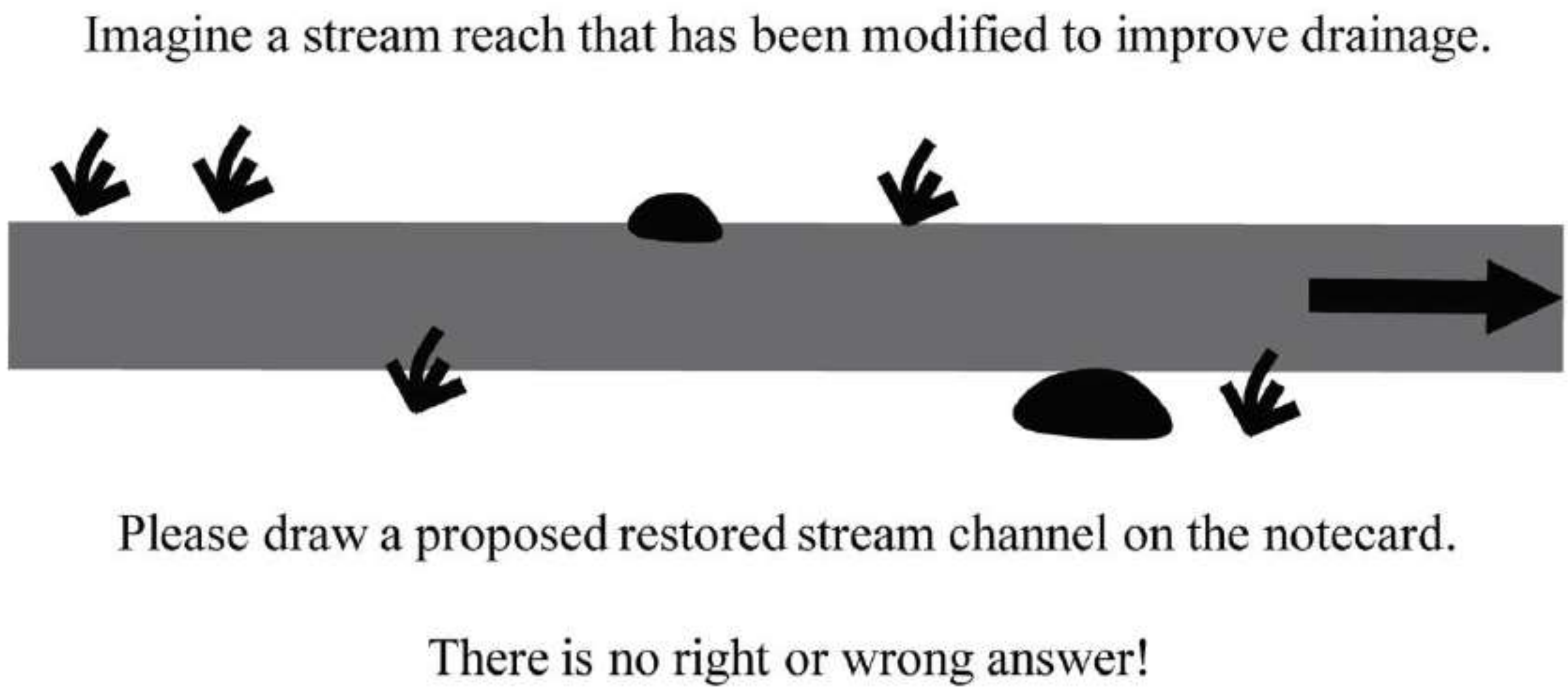
Close your eyes and imagine a healthy stream...

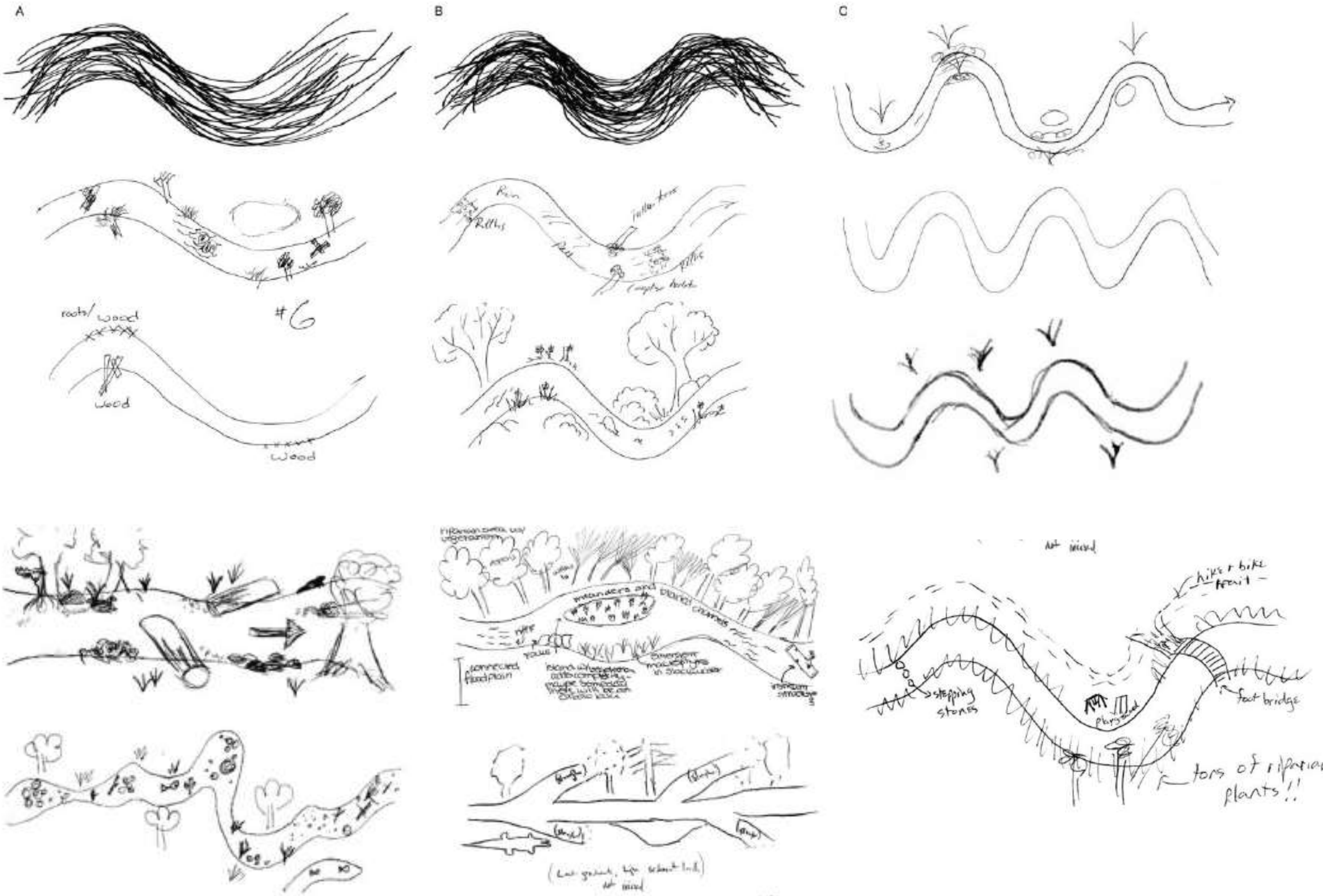
What do you see?

# The ideal meander: Exploring freshwater scientist drawings of river restoration

**Kristen N. Wilson[1,4], Suzanne L. Baker[2,5], and G. Mathias Kondolf[3,6]**

[1]The Nature Conservancy, 201 Mission Street, San Francisco, California 94105 USA
[2]Lawrence Berkeley National Laboratory, Molecular Biophysics and Integrative Bioimaging, 1 Cyclotron Road, Berkeley, California 94720 USA
[3]Department of Landscape Architecture and Environmental Planning, University of California Berkeley, 202 Wurster Hall, Berkeley, California 94720 USA






Wilson et al. 2020


Reimagine what riverscapes can be
Mark Beardsley

# Reimagine what riverscapes can be

# Reimagine what riverscapes can be

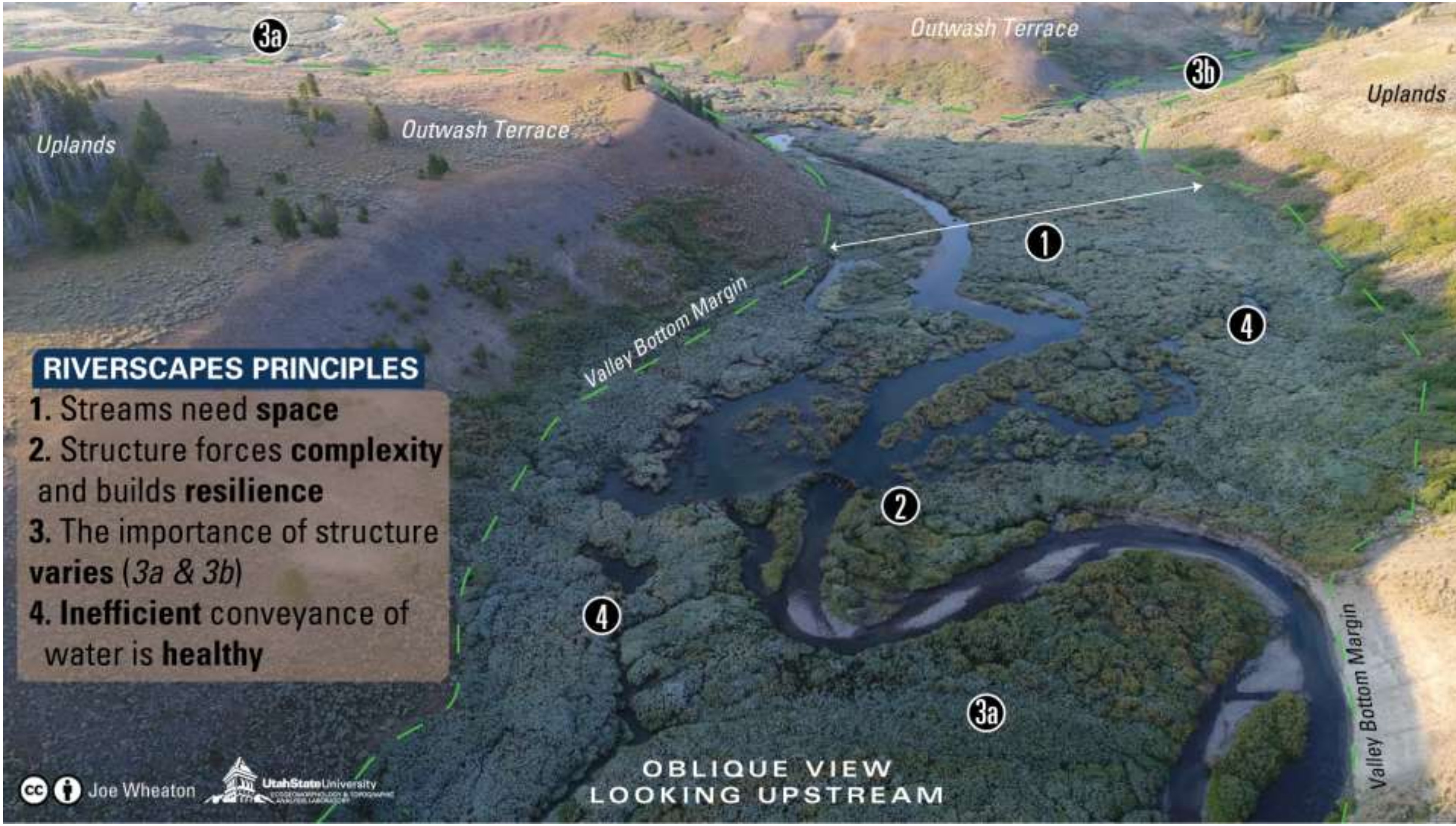
# These are not anomalies


Adapted from Figure 1.7 (p 36) of Shahverdian et al. (2019) – Chapter 1 LTPBR Manual DOI: [10.13140/RG.2.2.14138.03529](https://doi.org/10.13140/RG.2.2.14138.03529)


We’ve forgotten what riverscapes can be
Mark Beardsley

# Biofluvialgeomorphic System

# What constitutes a healthy riverscape?




From pages 3-4 of Pocket Guide; Wheaton et al. (2019)

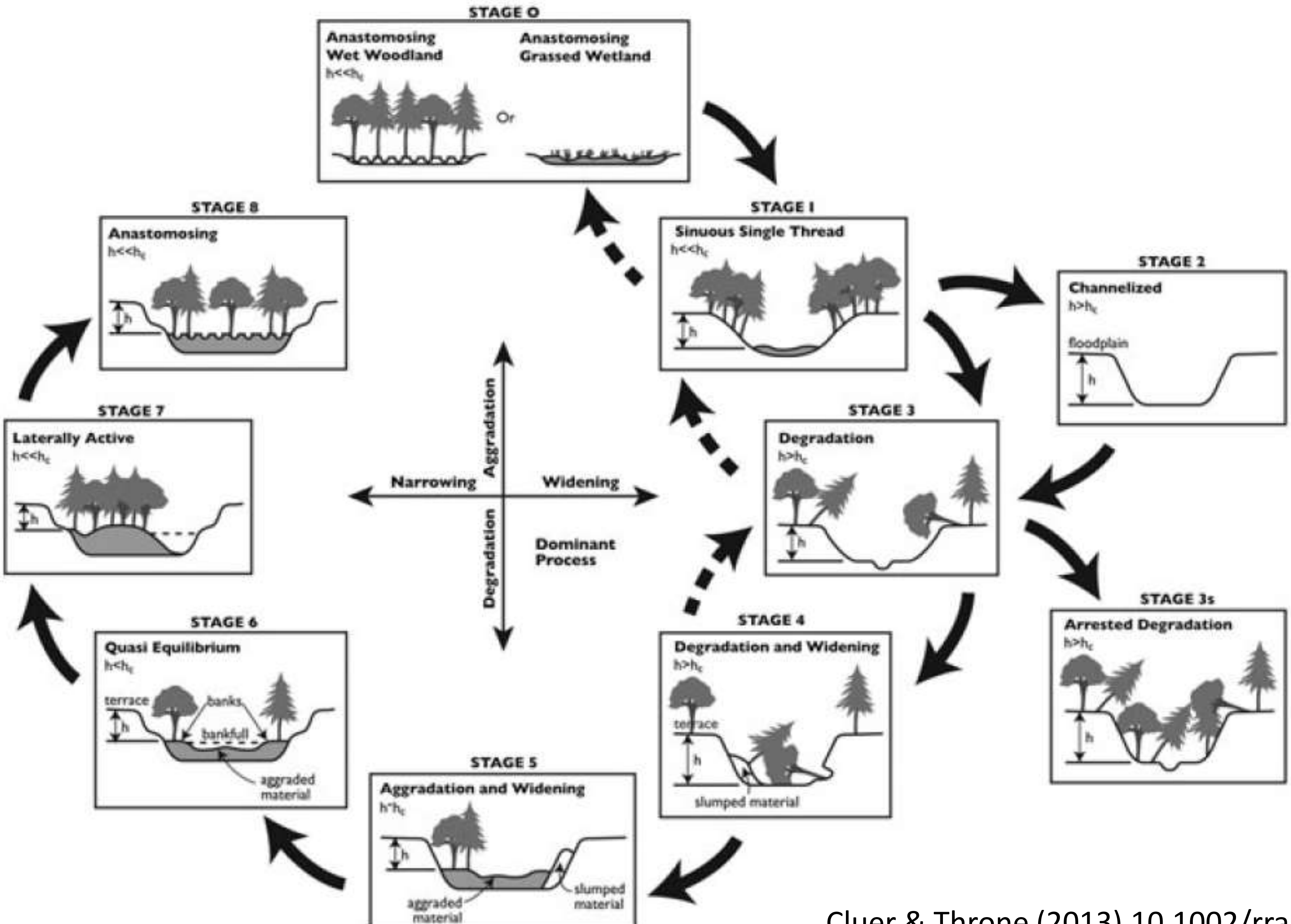
DOI: [10.13140/RG.2.2.28222.13123/1](https://doi.org/10.13140/RG.2.2.28222.13123/1)

See Wheaton et al. (2019, p 60): Chapter 2 LTPBR Manual for Principles

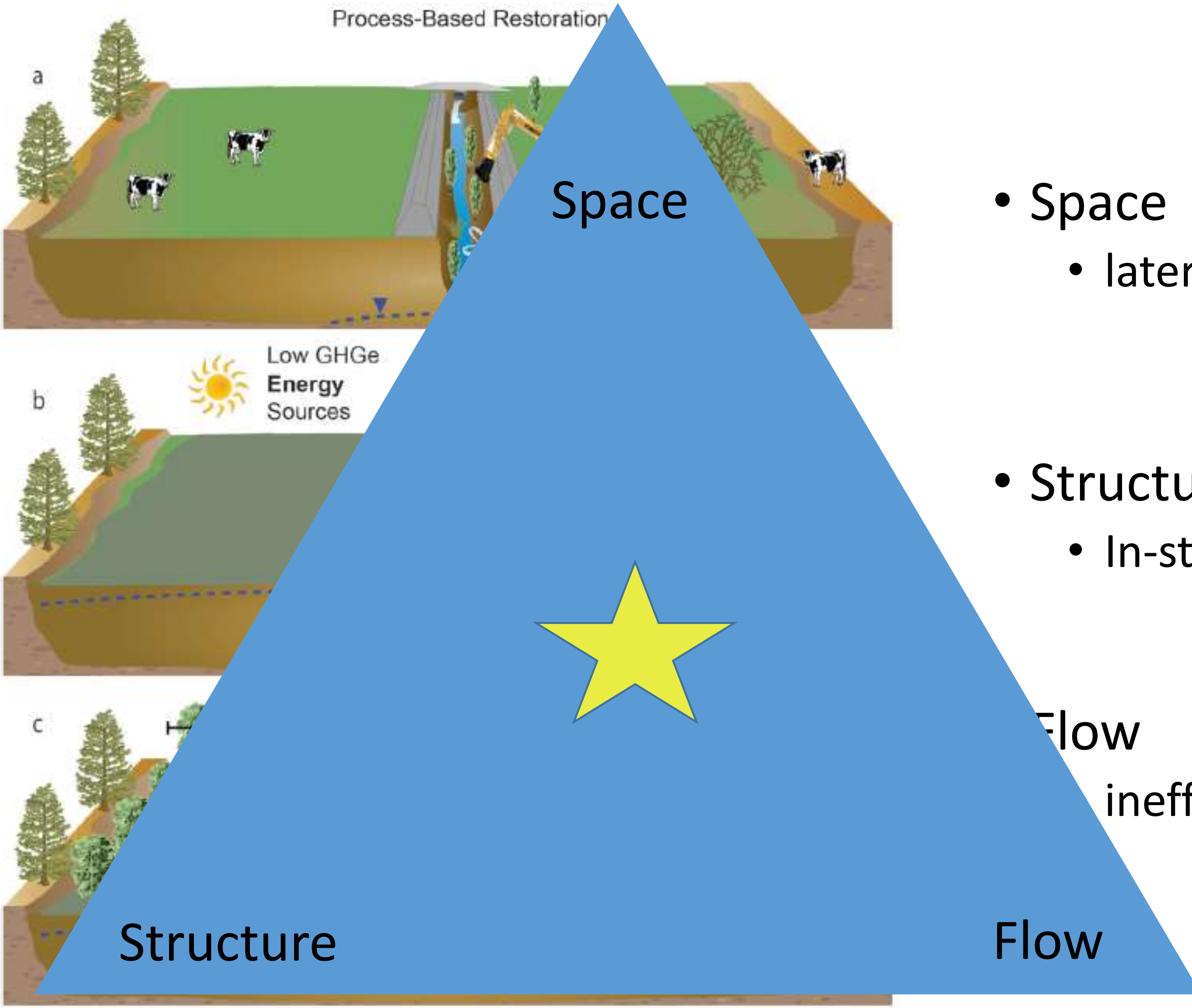
DOI: [10.13140/RG.2.2.34270.69447](https://doi.org/10.13140/RG.2.2.34270.69447)

## Riverscapes Principles

# Cluer & Thorne Channel Evolution Model

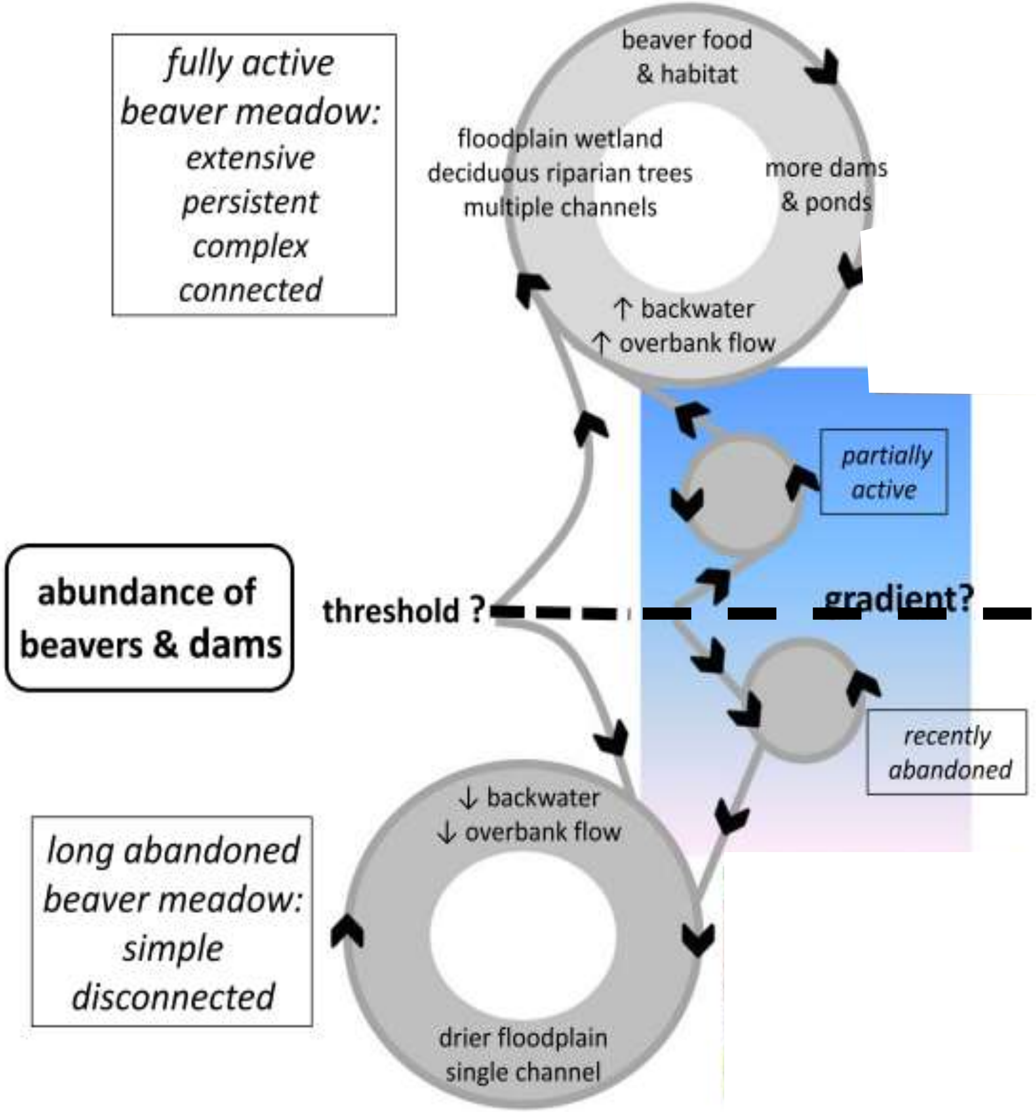



Cluer & Throne (2013) 10.1002/rra.2631

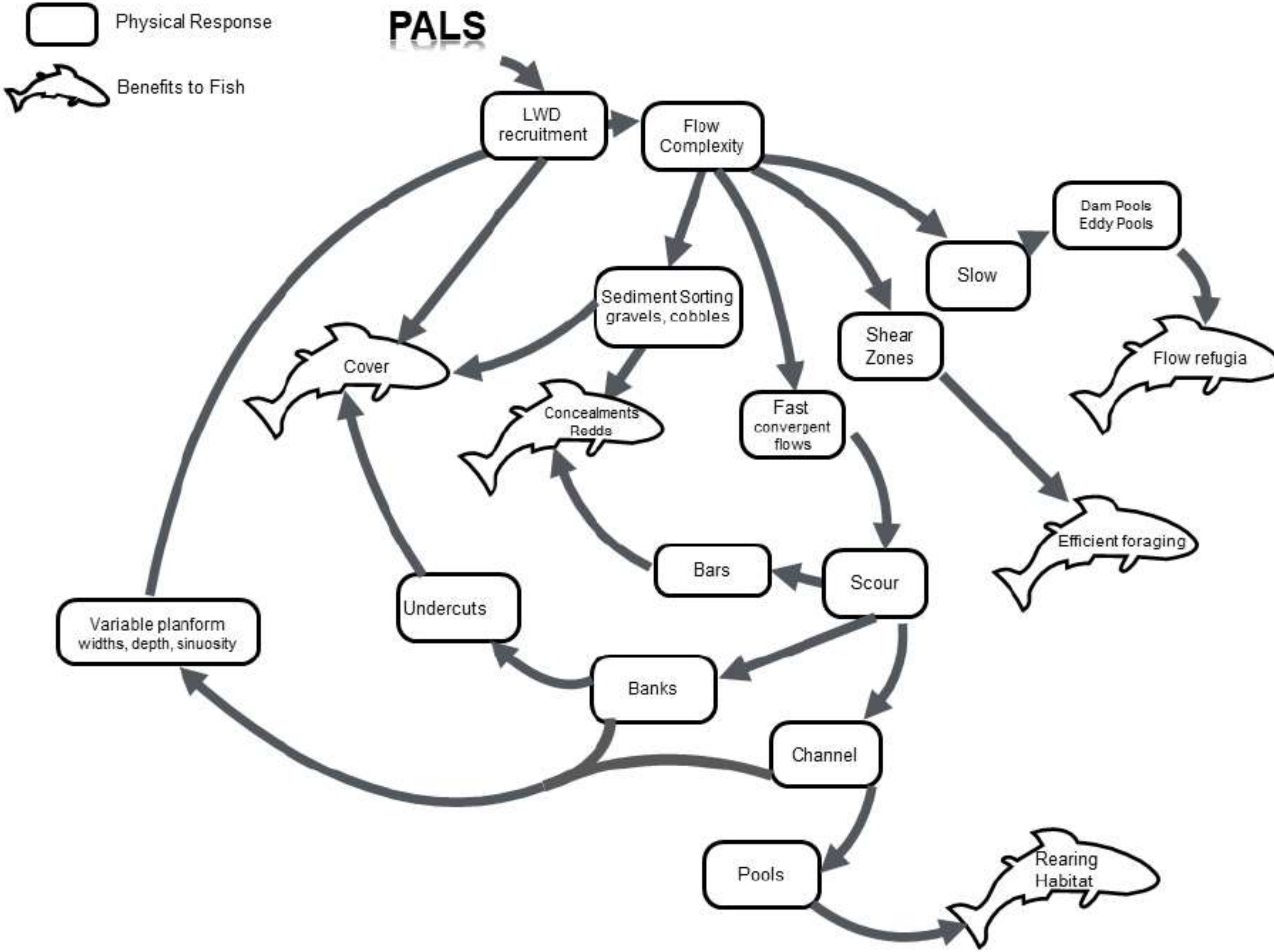



- Space
  - lateral
- Structure
  - In-stream
- Flow
  - inefficiency

Ciotti et al. 2021




Laurel and Wohl (2018) The persistence of beaver-induced geomorphic heterogeneity and organic carbon stock in river corridors. Earth Surf. Process. Landforms. DOI: 10.1002/esp.4486




Shahverdian et al. 2019

# A simple design question – good or bad?


Figure 1.3 (p 32) of Shahverdian et al. (2019) – Chapter 1 LTPBR
Manual DOI: 10.13140/RG.2.2.14138.03529

# Hydraulic Roughness
# or
# Structural Complexity



What are process-based tools to develop hydraulic roughness?

# Post Assisted Log Structures (PALS)


Shahverdian et al. 2019

# Beaver Dam Analogues (BDAs)

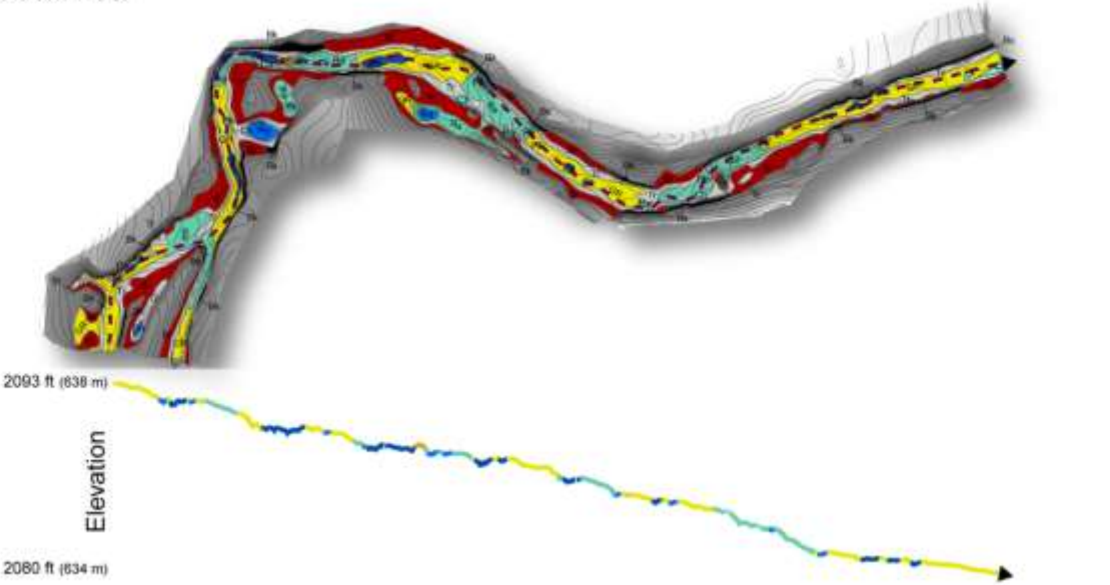

Shahverdian et al. 2019

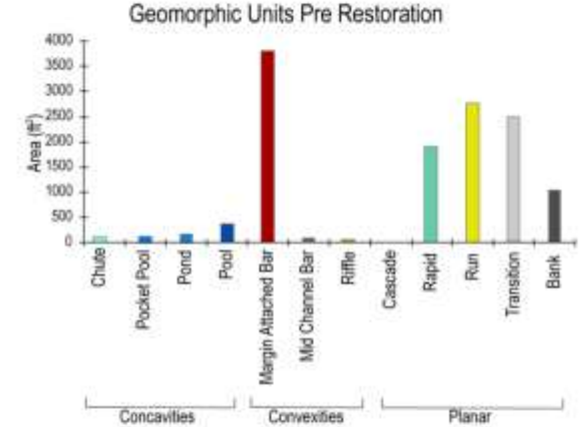
# Adding P.A.L.S. (Wood)

**STRUCTURE FORCES COMPLEXITY & BUILDS RESILIENCE**
RIVERSCAPES PRINCIPLE 2.

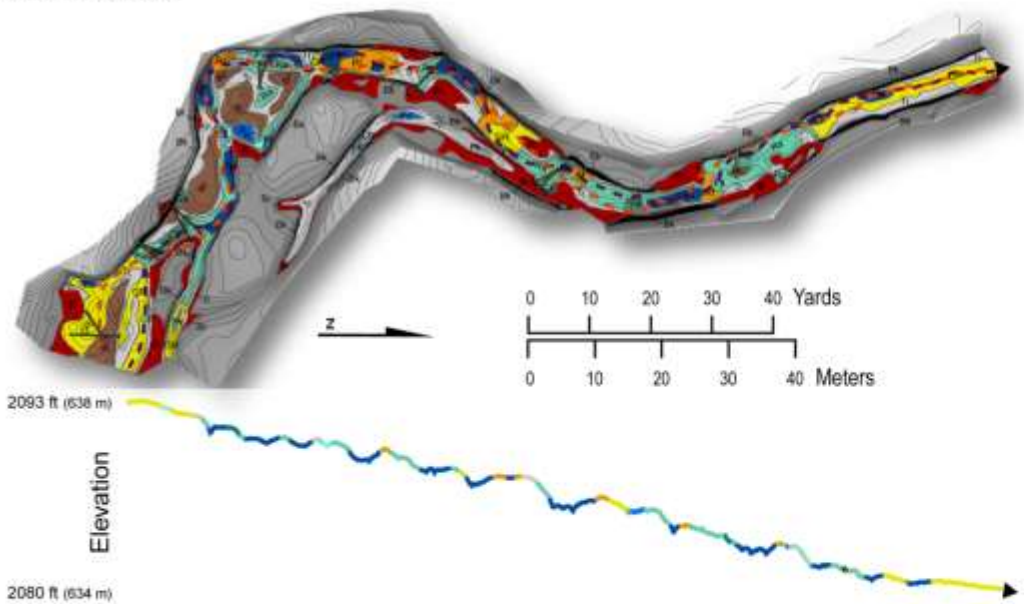
South Fork Asotin Creek: Planformed Controlled with Discontinuous Floodplain Latitude: 46.24869088939191 Longitude: -117.2892015084726

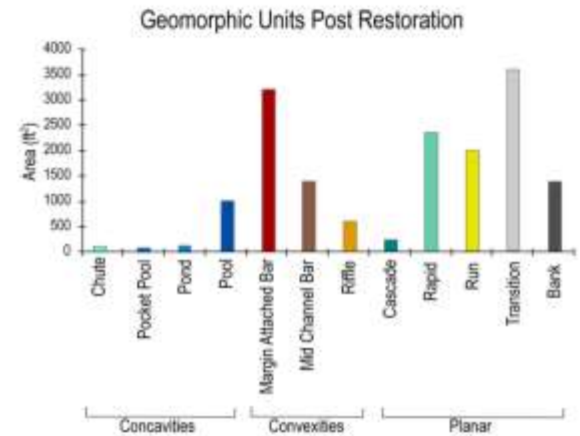
Condition: Poor



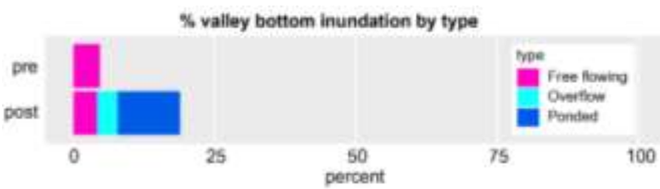




Condition: Moderate



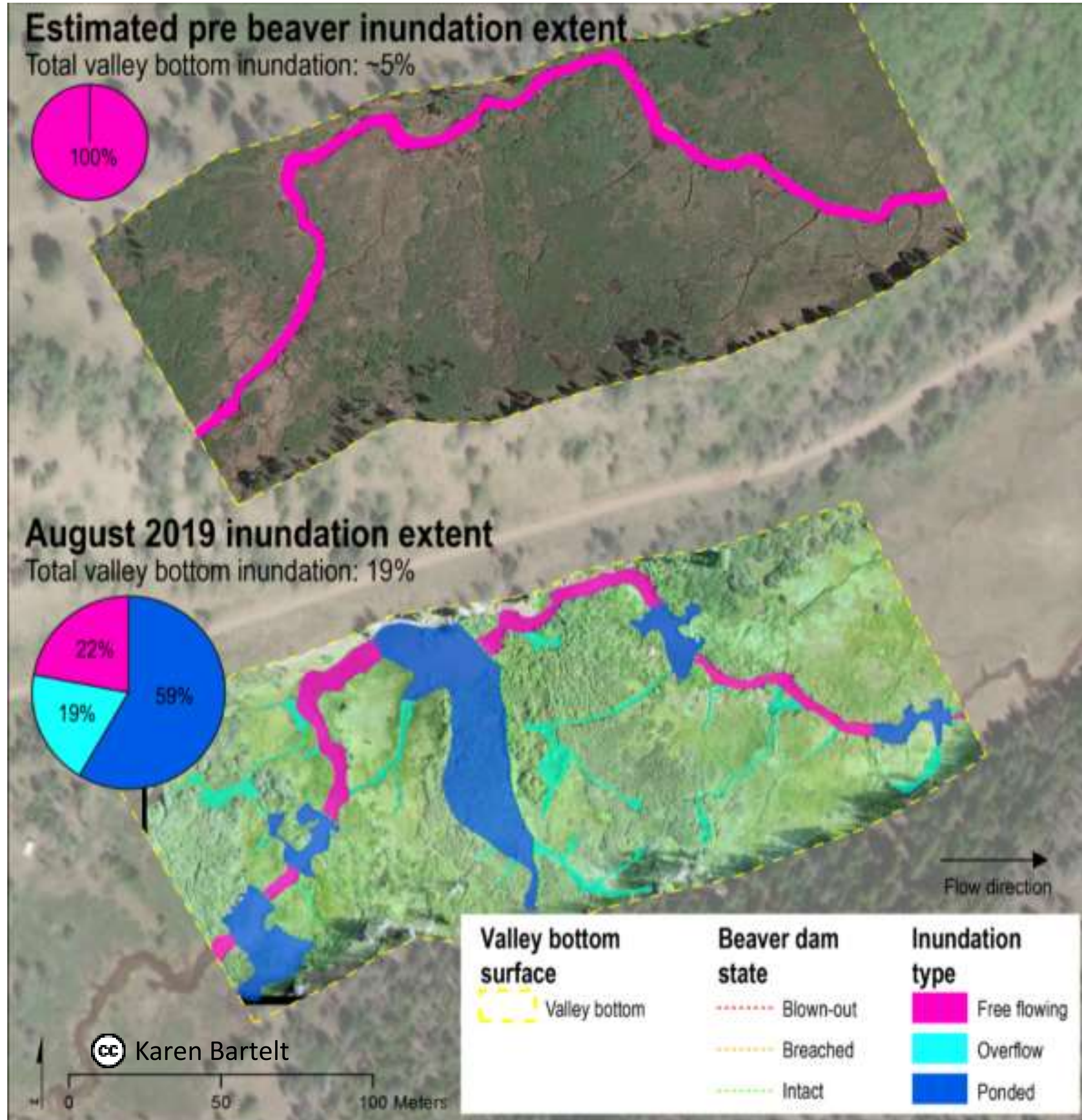

# What Does The Water Tell Us?

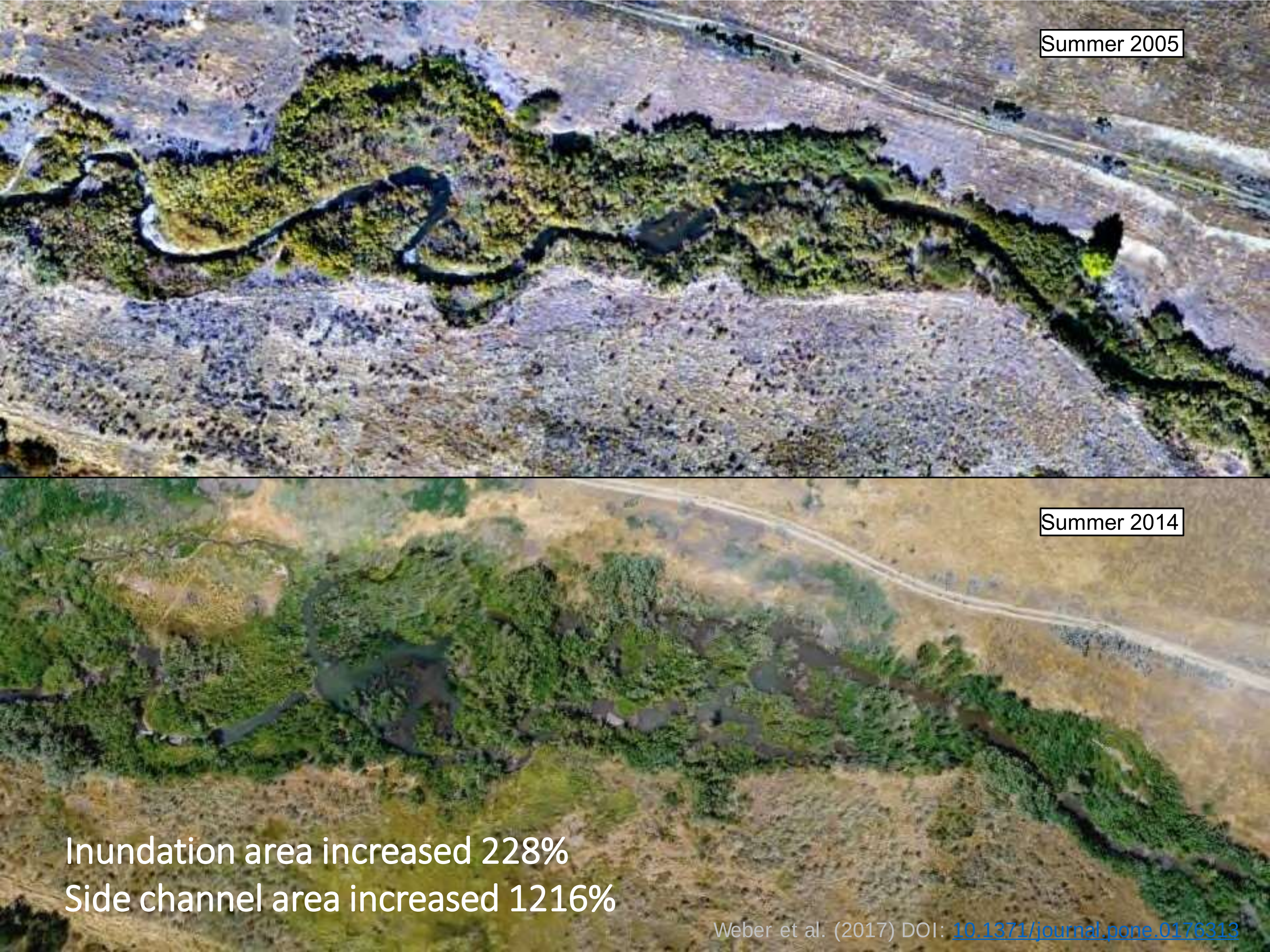



Inundation type diversity

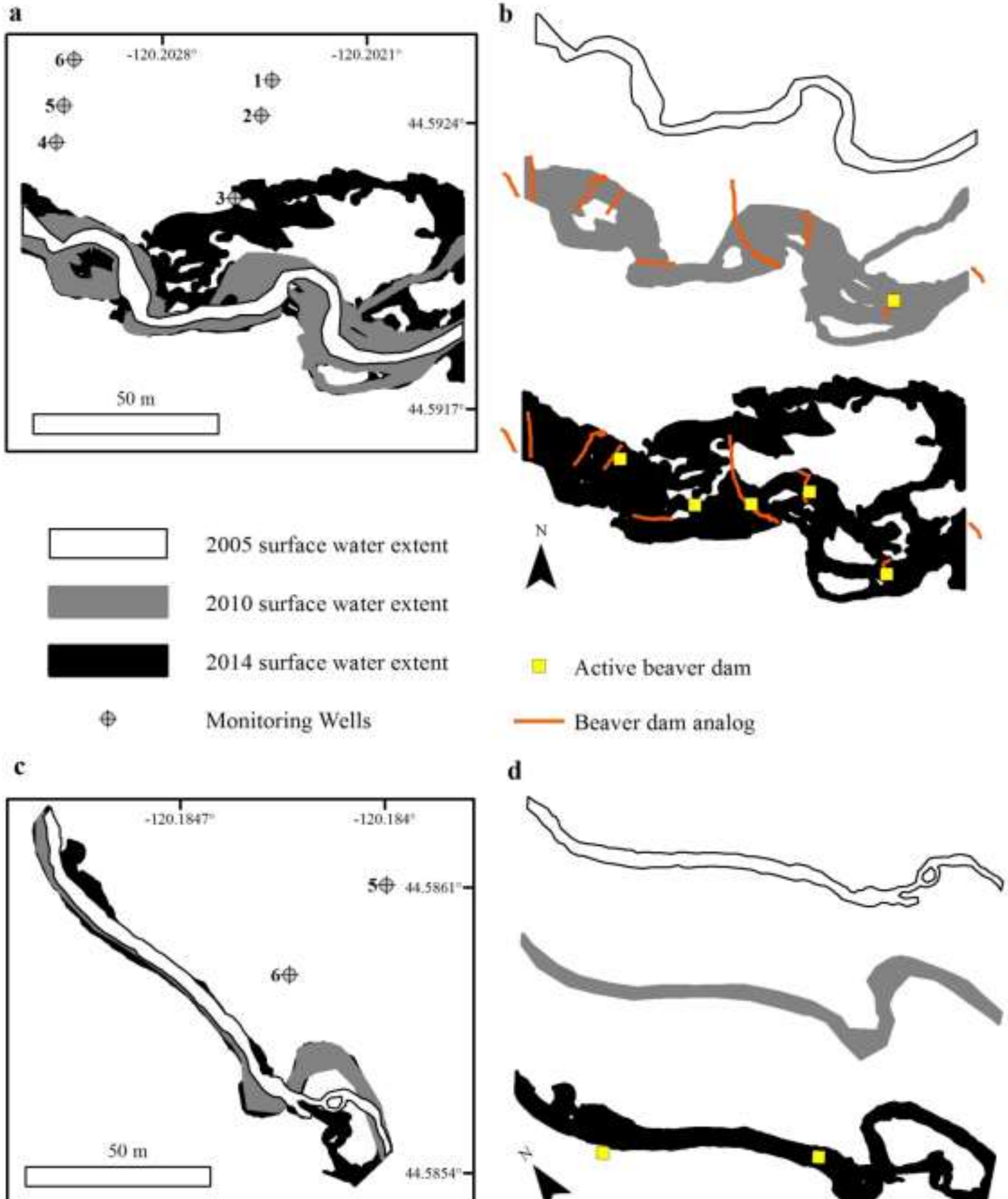
~

residence time




Summer 2005
Summer 2014
Inundation area increased 228%
Side channel area increased 1216%
Weber et al. (2017) DOI: 10.1371/journal.pone.0176313

# Water Surface Extent



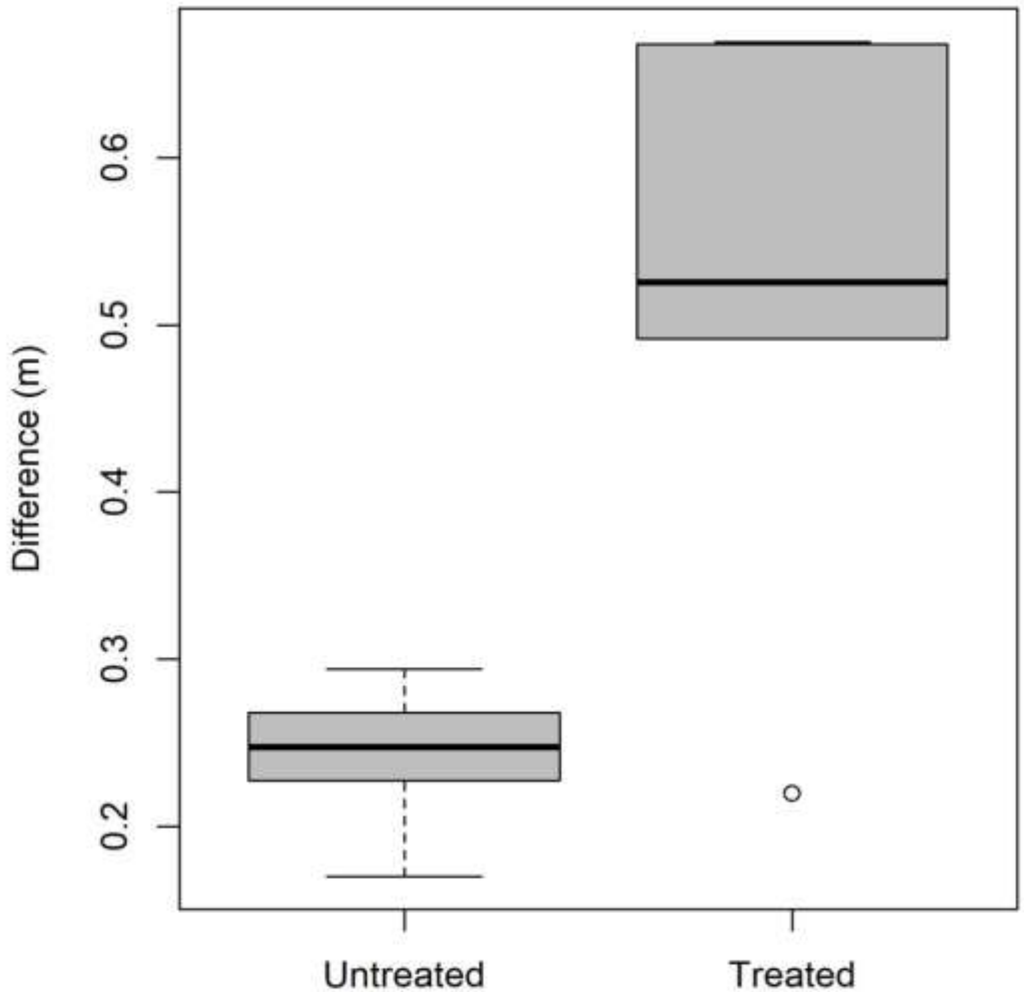

*Volk et al. in review*

# Expansion of the Riparian Zone


- Repeat high resolution (10 cm) imagery before & after 2009 treatment

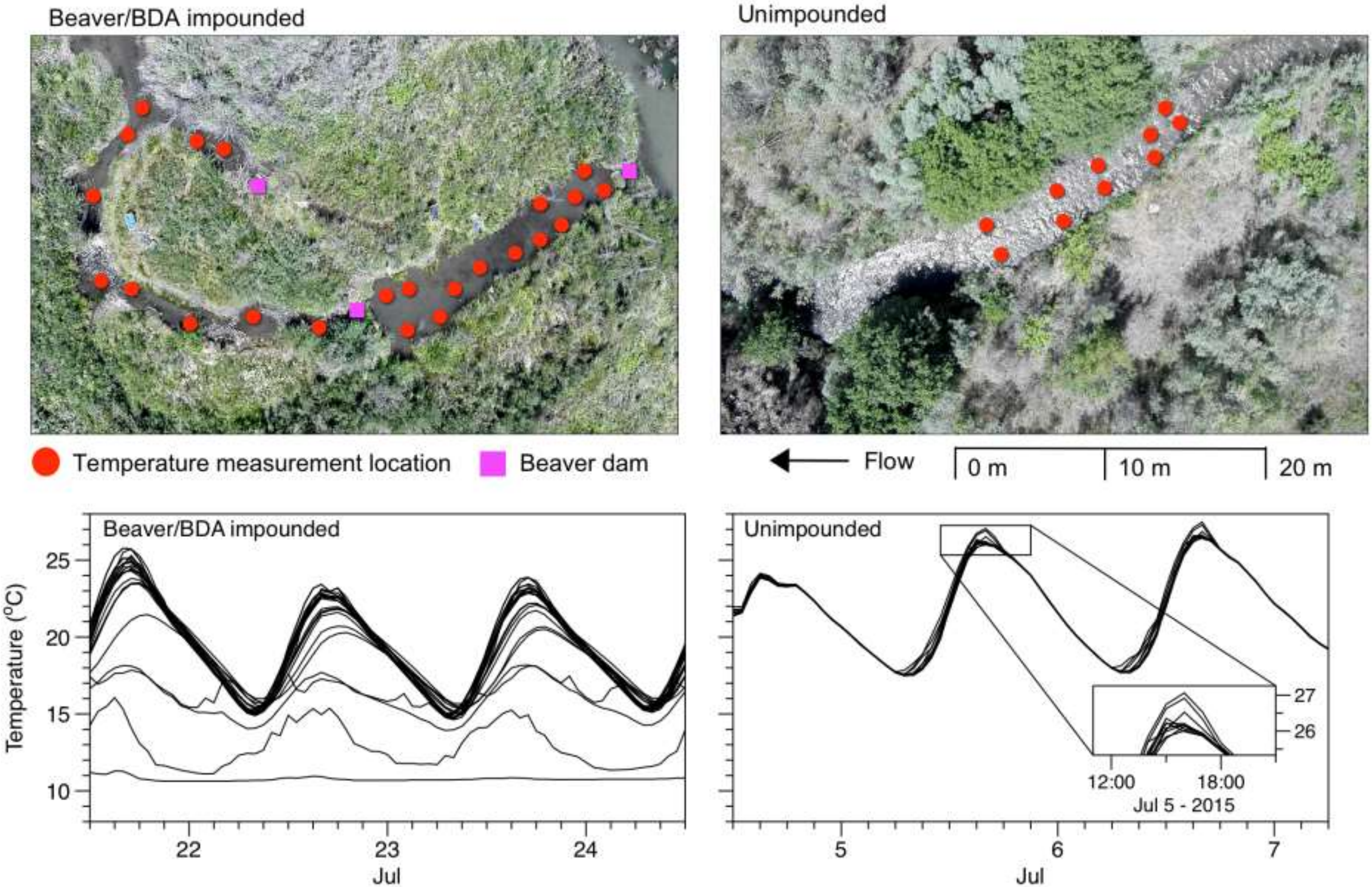
Figure from Carol Volk (South Fork Research)

# Groundwater Elevation

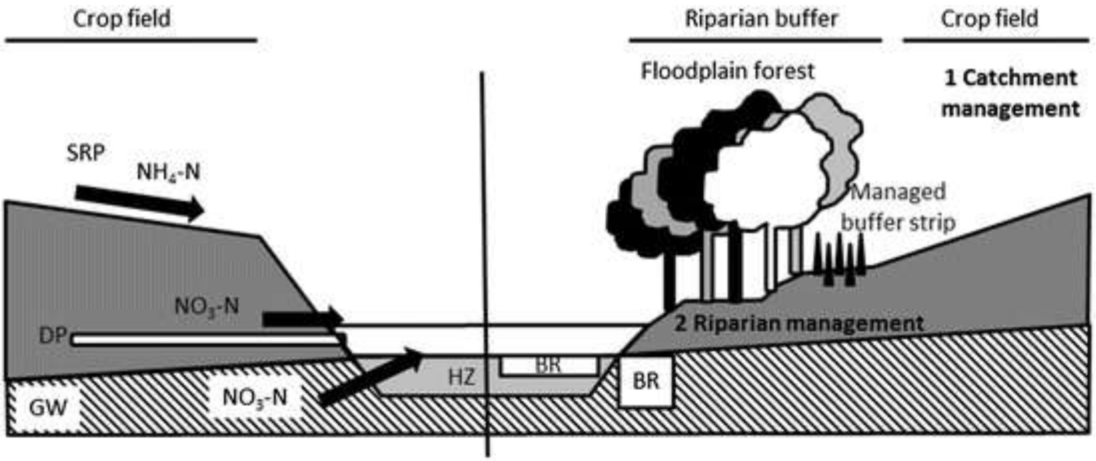


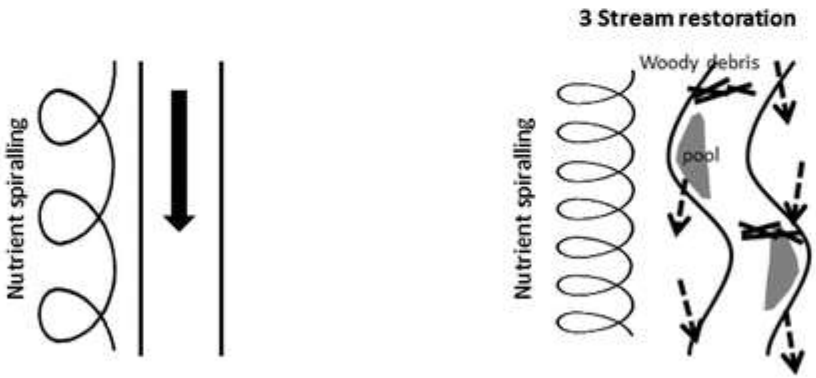

*Volk et al. in review*

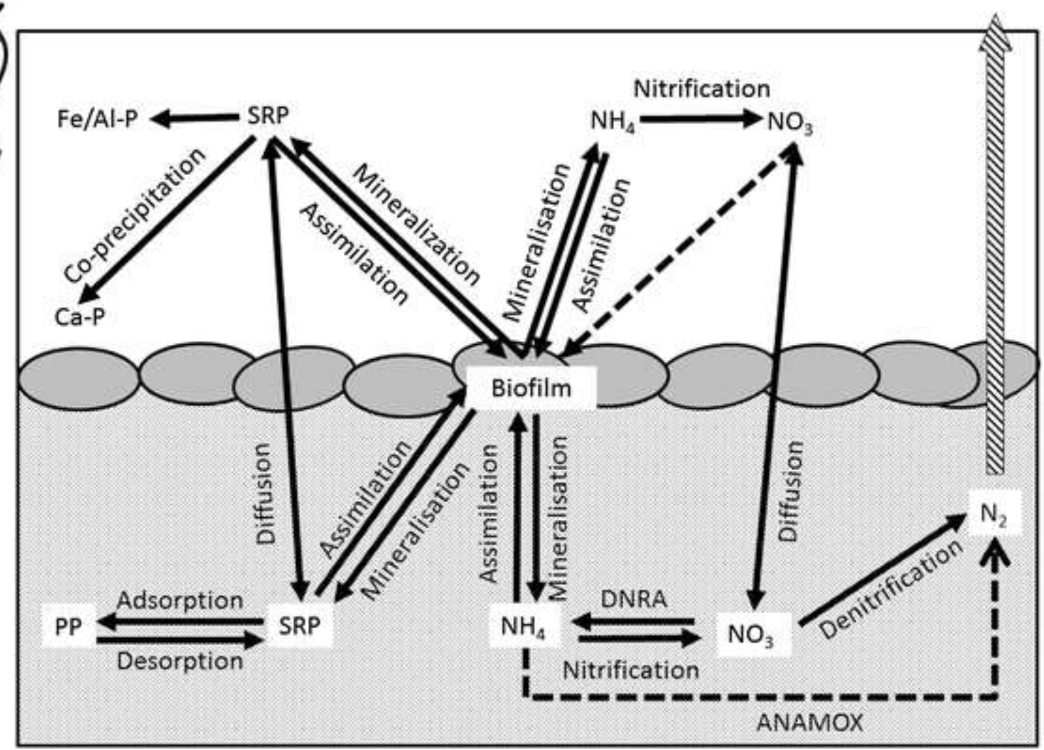
# Channel Temperature Heterogeneity




Weber et al. 2017

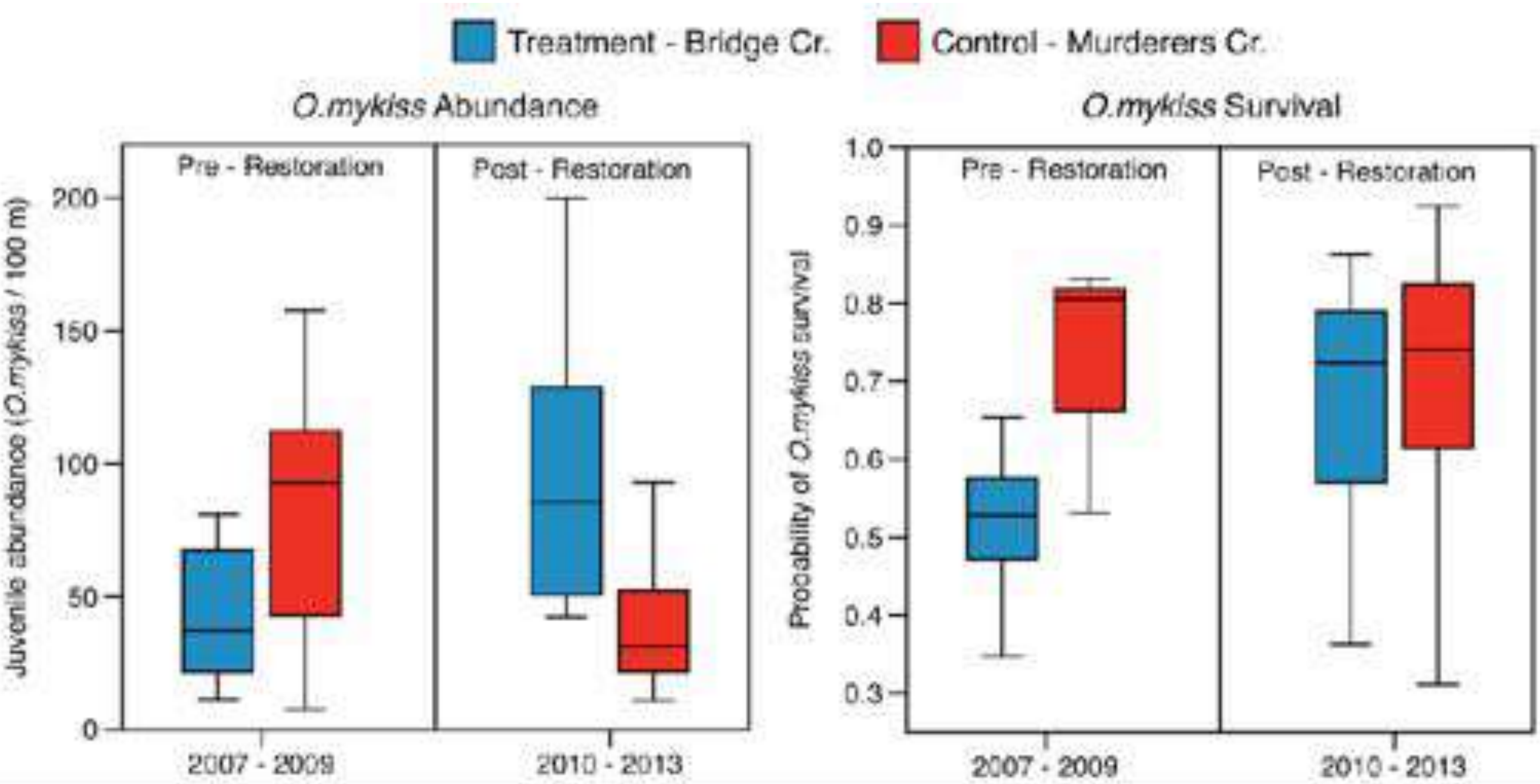



Weigelhofer G., Hein T., Bondar-Kunze E. (2018) Phosphorus and Nitrogen Dynamics in Riverine Systems: Human Impacts and Management Options. https://doi.org/10.1007/978-3-319-73250-3_10

# Juvenile *O. mykiss* Response




Abundance

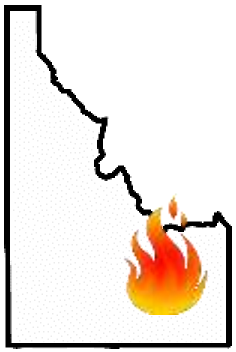
168% increase

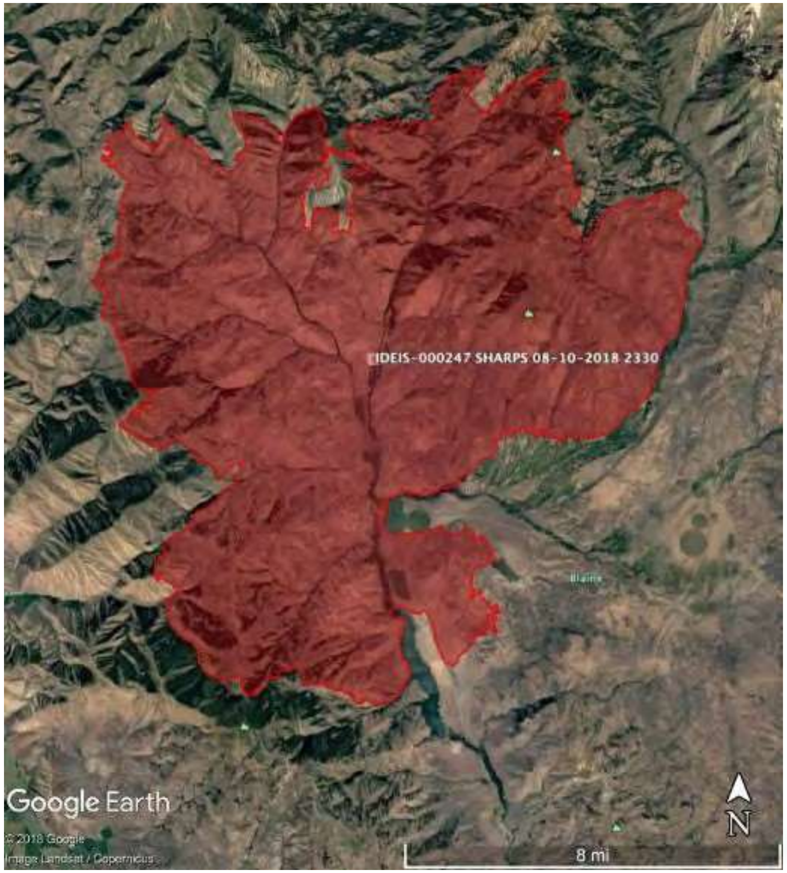
Survival

52% increase

Bouwes et al. 2016 *Scientific Reports*

# Connected floodplains create refugia during fire.





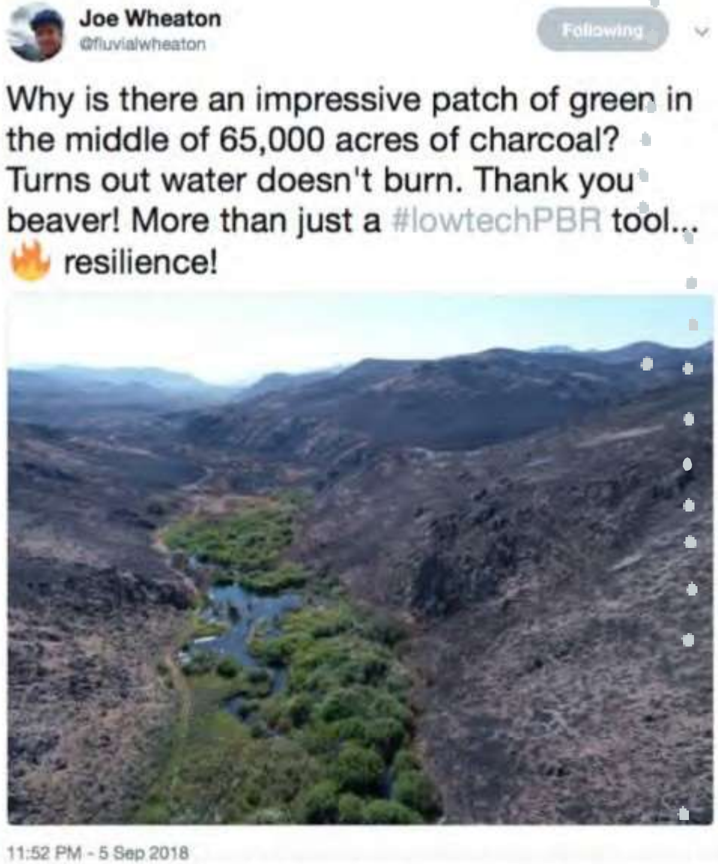




Photo by Joe Wheaton. Baugh Creek, ID

# Process Based Restoration

**IMPLEMENTATION APPROACHES**

**Process-Led** **Process-Reset**

Hand Labor
BDAs / PALS
Raise WSE
Erode Banks

Hand Labor and Light Machinery
Large BDAs / Enlarge Riffles
Breach Levees

Heavy Machinery
Grade Anthropogenic Features
Fill Incised Channels

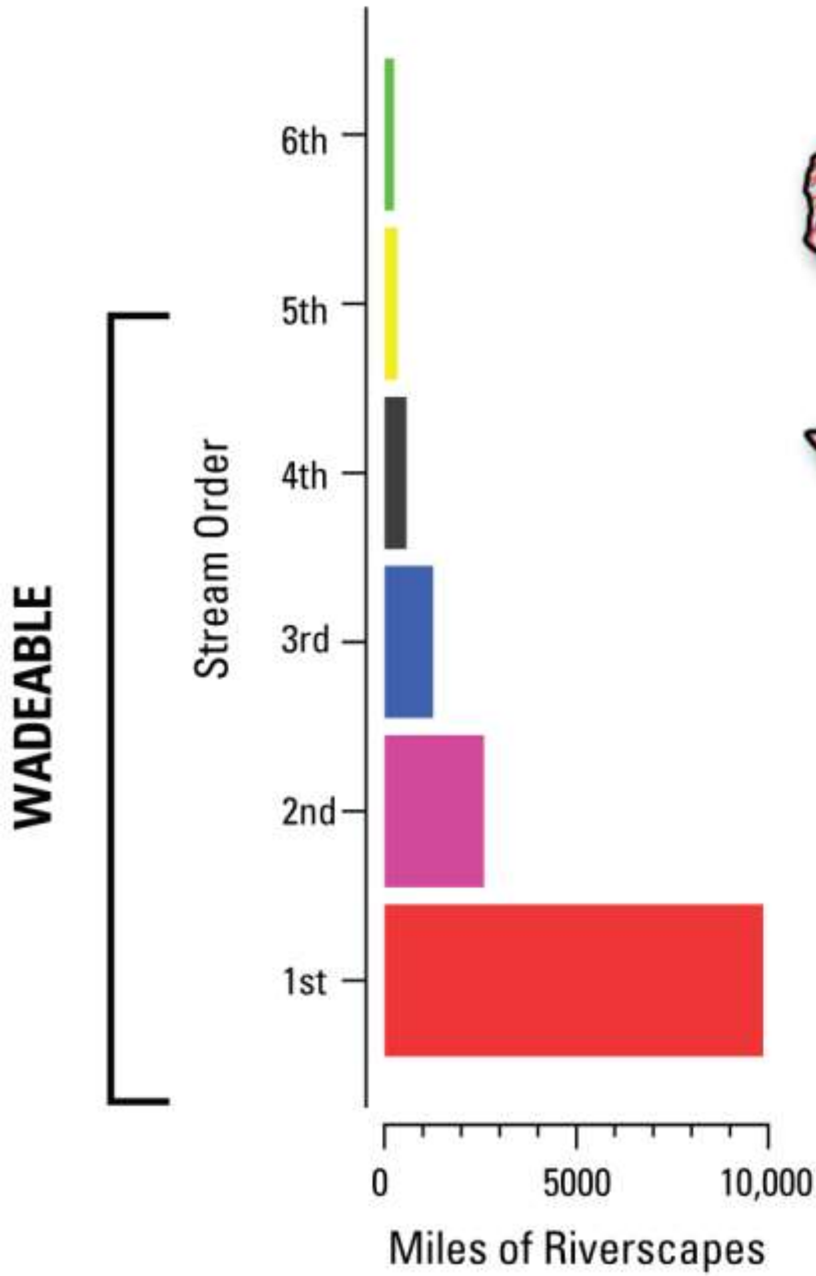
Remove Legacy Sediment

Multiple Interventions

Scale
Problem and Effort
Time to Benefit

One Intervention

# We need scalable solutions… URGENTLY




# RESOURCES

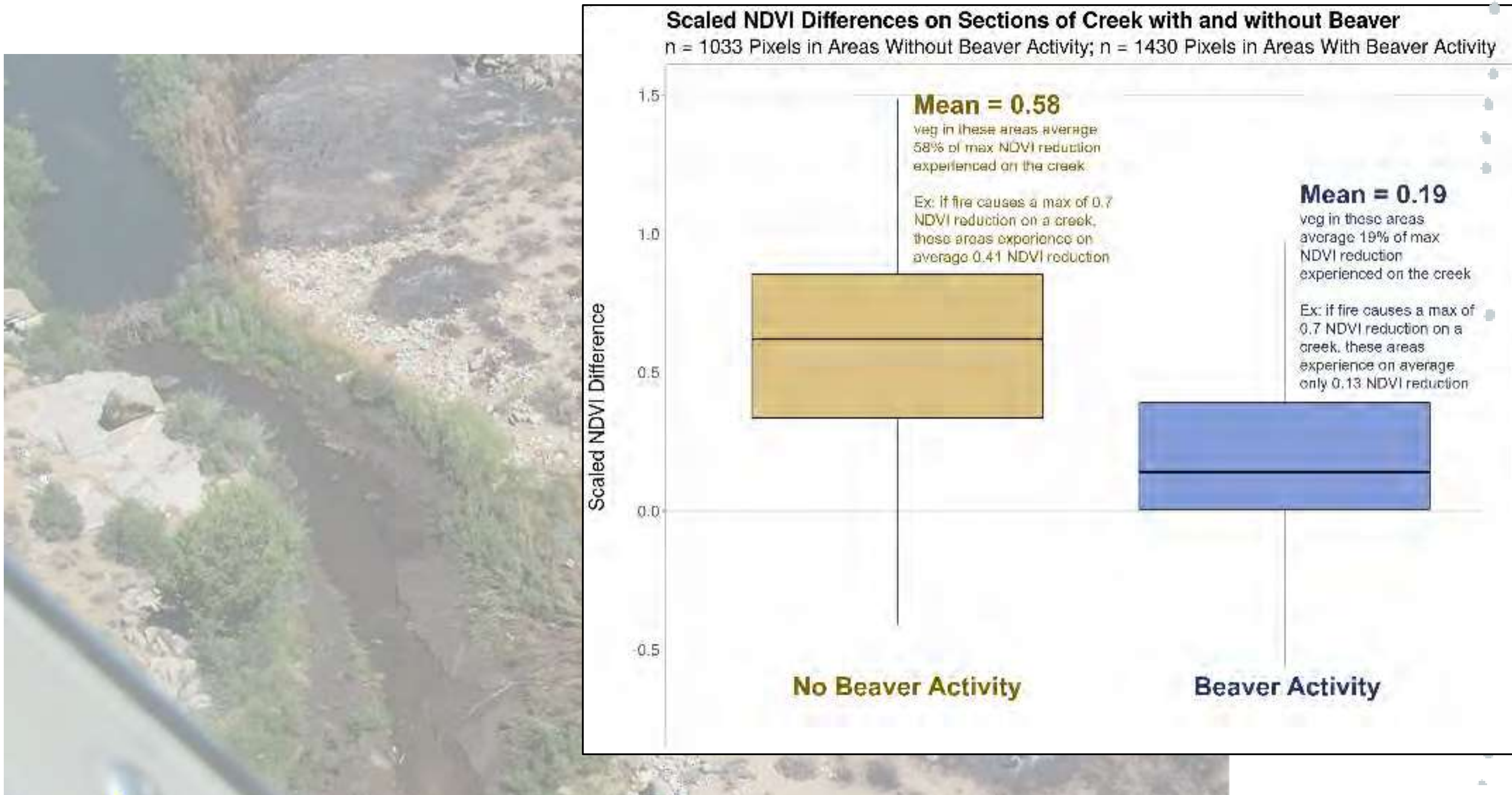


http://lowtechpbr.restoration.usu.edu/manual/

https://www.beavercoalition.org/guidebook


Ciotti et al. 2021

# Beaver connected floodplains repeatedly create refugia during fire.

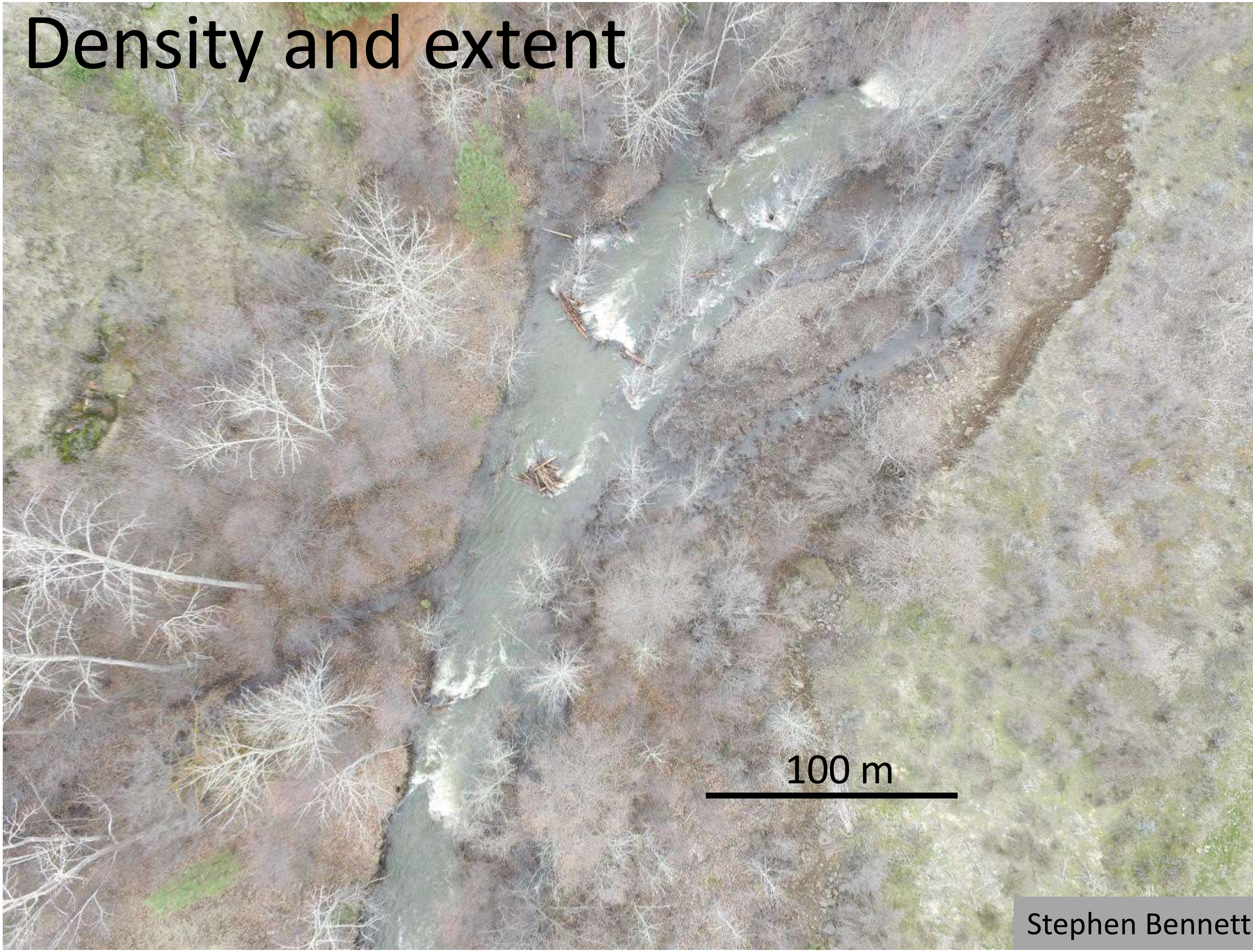



Fairfax and Whittle (2020)

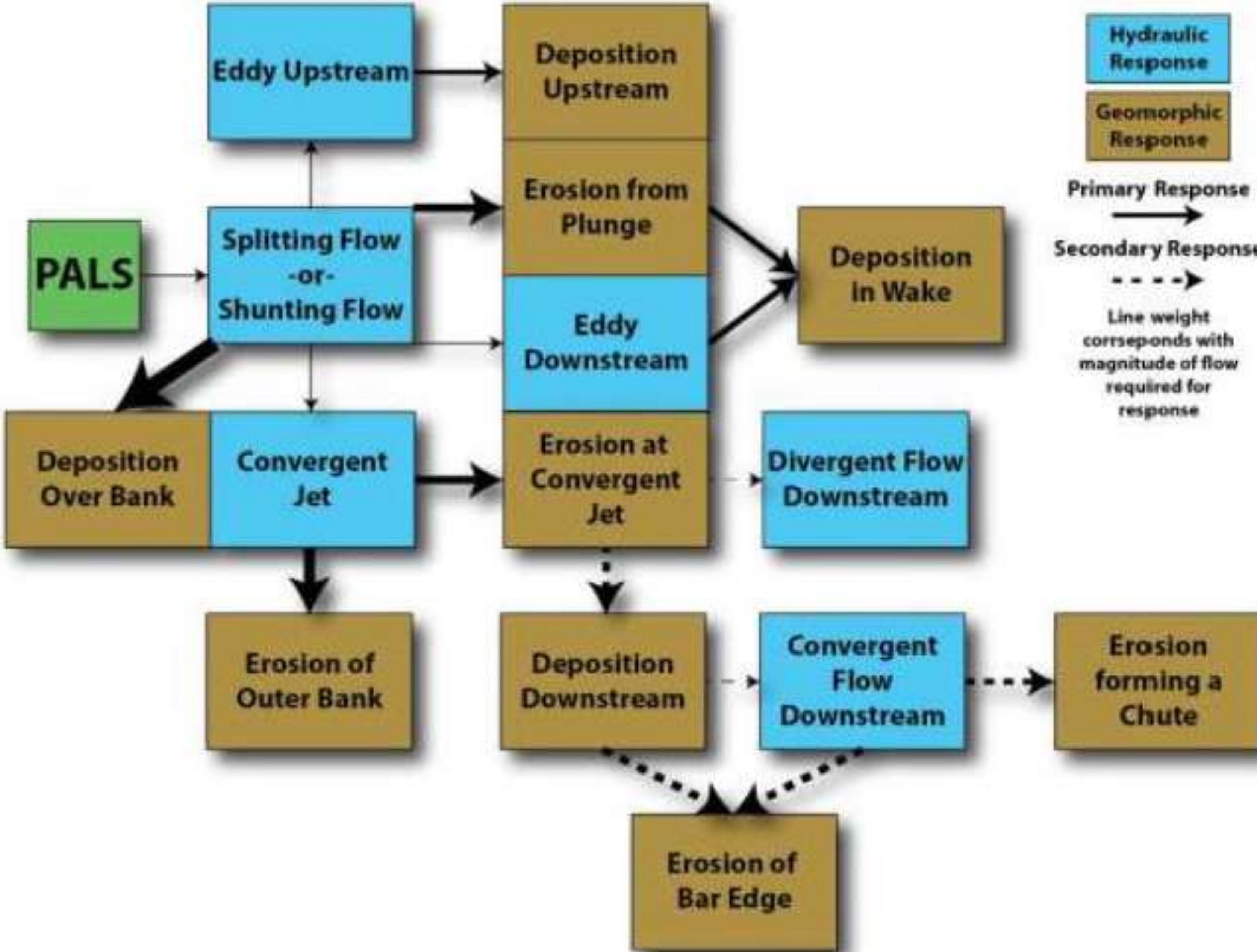
# Traditional Restoration

## Hard engineering – where it makes sense!

# Density and extent

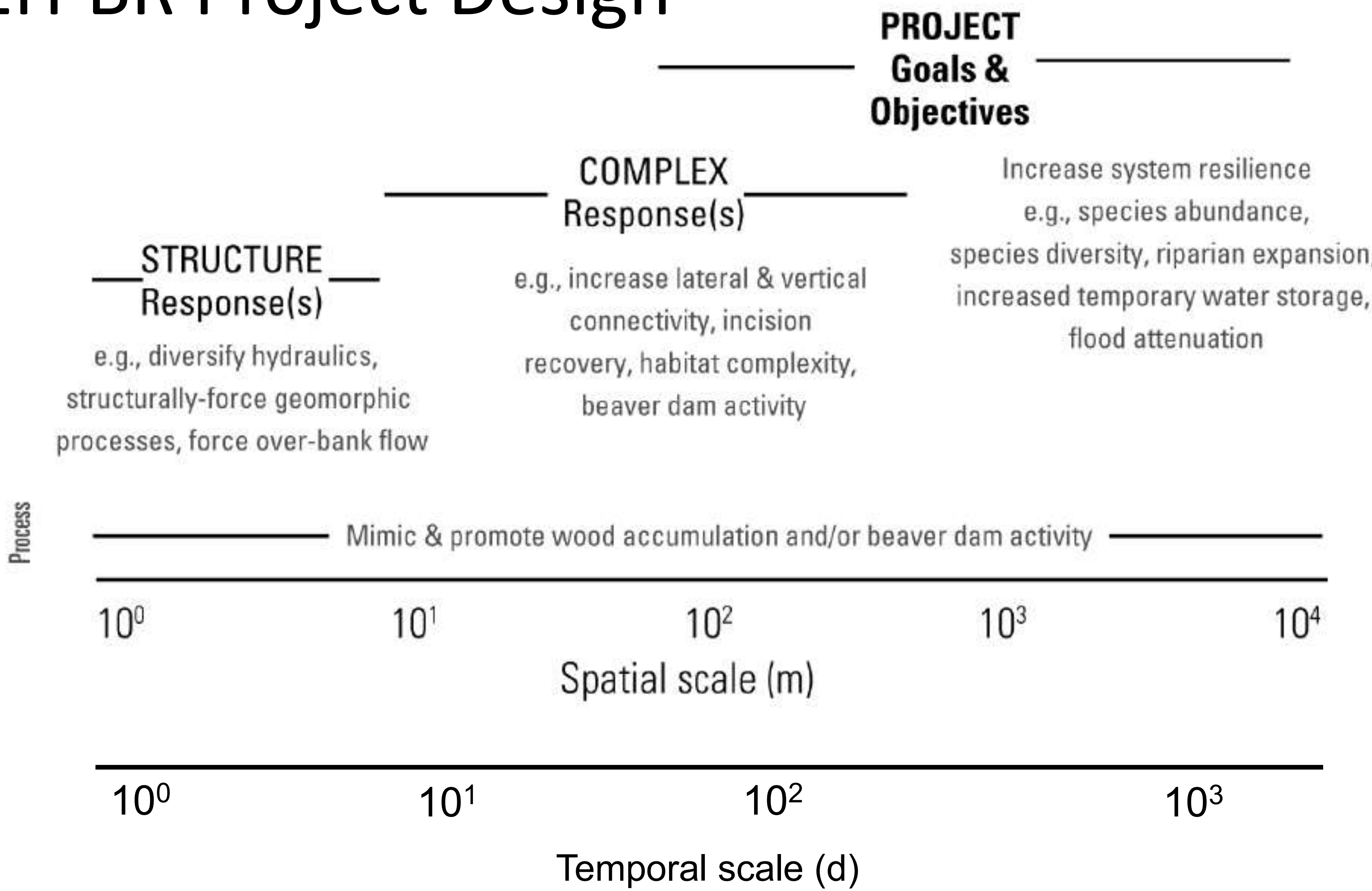


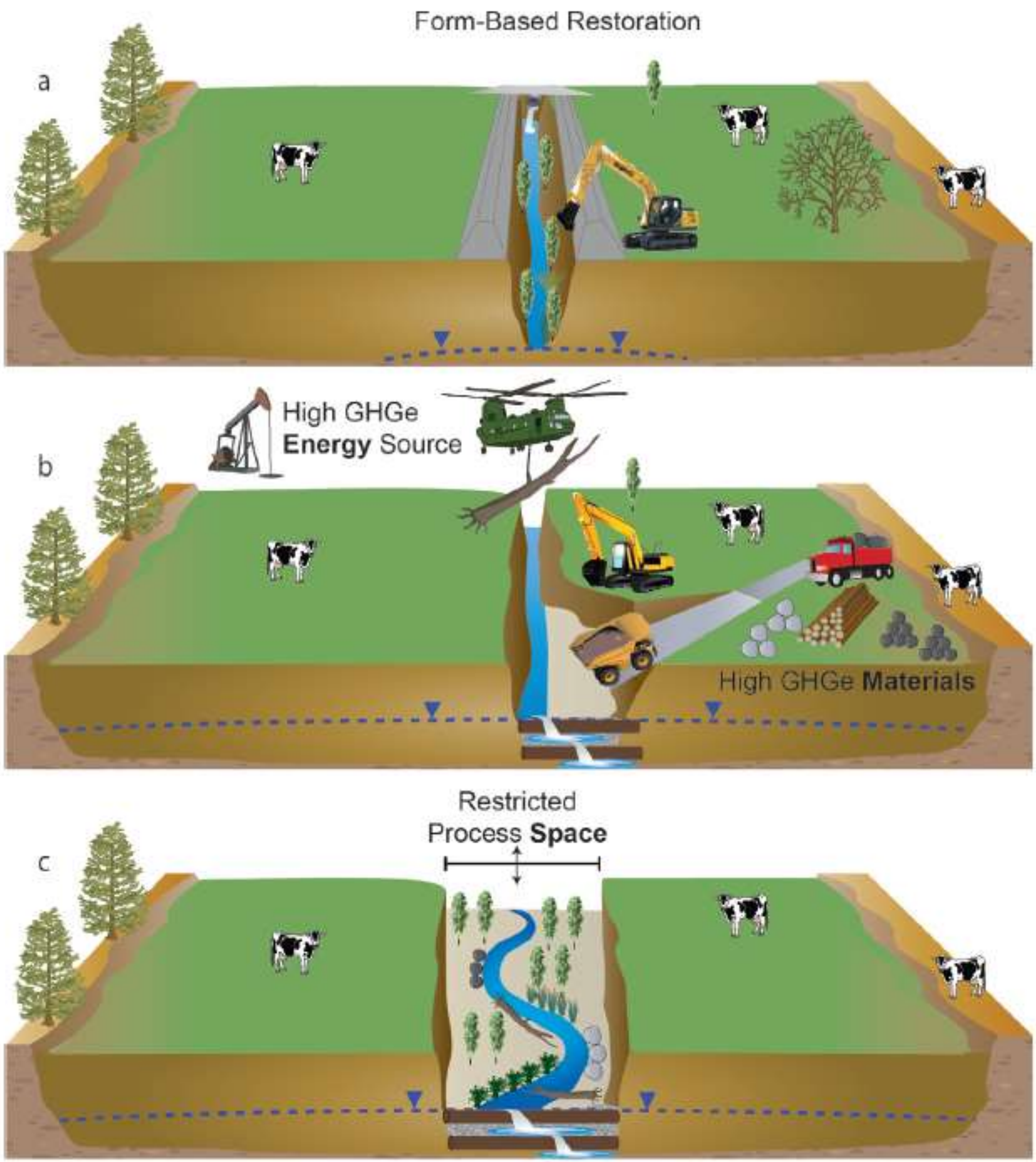
| Type | Hydraulic | Hydrologic | Geomorphic | Biomorphic |
|---|---|---|---|---|
| **PALS Channel-spanning** | create upstream backwater and plunge hydraulics downstream | increase frequency and magnitude of overbank flow, increase hyporheic flows | channel aggradation, channel avulsion, bank erosion, dam and plunge pool formation, bar formation | expand riparian vegetation, in-channel vegetation recruitment |
| **PALS Bank-attached** | force convergent flow, create eddy behind structure | force overbank flows | bank erosion, scour pool formation, bar formation, sediment sorting, channel avulsion | expand riparian vegetation, in-channel vegetation recruitment |
| **PALS Mid-channel** | force flow separation, create eddy behind structure | force overbank flows | bank erosion, scour pool formation, bar formation, sediment sorting, channel avulsion | expand riparian vegetation, in-channel vegetation recruitment |
| **Primary BDA** | create deep slow water | increase frequency and magnitude of overbank flow, increase hyporheic flows | channel aggradation upstream, bar formation, bank erosion sediment sorting | beaver habitat feature formation, reinforcement |
| **Secondary BDA** | create deep slow water | increase frequency and magnitude of overbank flow, increase hyporheic flows | channel aggradation, channel avulsion, bank erosion, dam pool formation, bar formation | beaver habitat feature formation, reinforcement |


Eddy Upstream
Deposition Upstream
Hydraulic Response
Geomorphic Response
Primary Response
Secondary Response
Line weight corrseponds with magnitude of flow required for response
Erosion from Plunge
PALS
Splitting Flow -or- Shunting Flow
Deposition in Wake
Eddy Downstream
Deposition Over Bank
Convergent Jet
Erosion at Convergent Jet
Divergent Flow Downstream
Erosion of Outer Bank
Deposition Downstream
Convergent Flow Downstream
Erosion forming a Chute
Erosion of Bar Edge

Camp 2015

# LTPBR Project Design



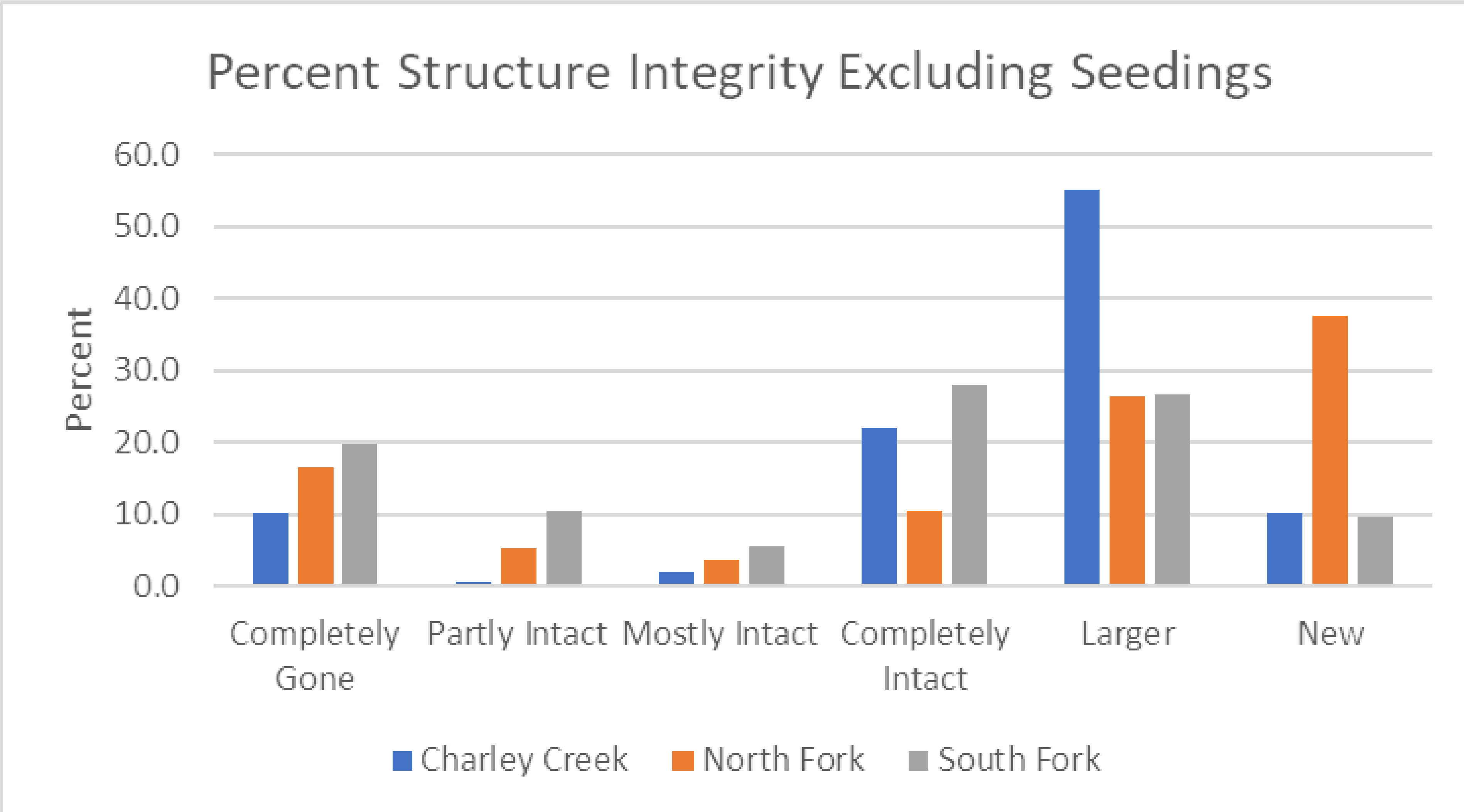



- Detailed designs
- Stability
- Low density
- Constructed habitats
- Prevent erosion

= High cost/mile

Ciotti et al. 2021


Shahverdian et al. 2019




Survey of condition of structures 6 years (South Fork), 5 years (Charley), and 4 years (North Fork) after construction (n = 685).

Bennett et al. 2020

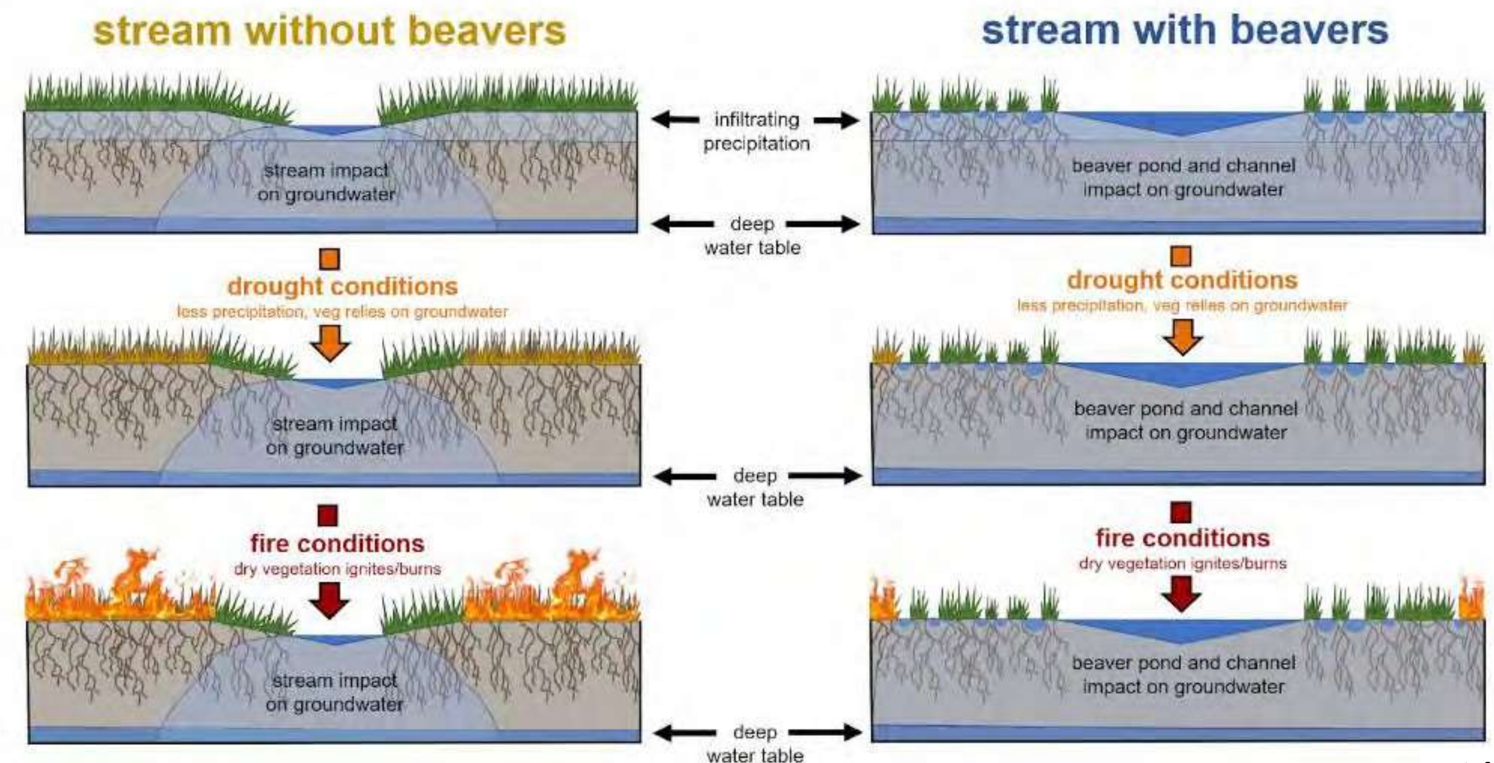

BOGT #1
What's going on here?
What do you notice?
Why do A and B look so different?
Is A or B "natural"?

# Process-based Restoration – the alternative to constructed features

- **Root cause** of the problem
- **Scale** of problem
- **Consistent** with site
- Clearly articulated ecological **outcomes**
  - Dynamic
  - Self-sustaining
  - Resilient
- **Function** over **Form**
  - Resilience comes from the function, not the form

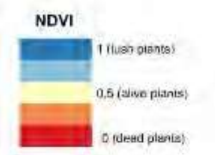
Palmer et al. 2005, Beechie et al. 2010, Ciotti et al. 2021

# Connected floodplains create refugia during fire.

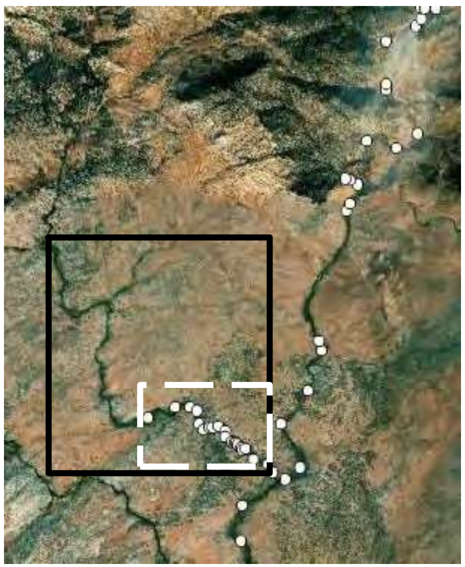



Fairfax and Whittle (2020)

# Look back into the past with satellites



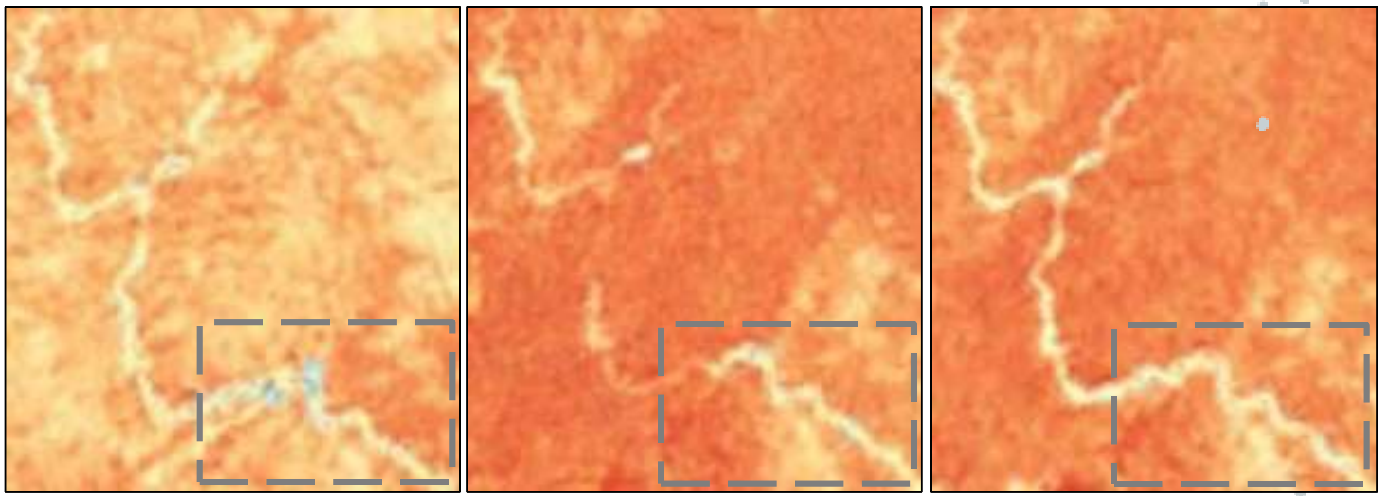

Satellite Image
(dams marked)



July 1999
(before fire)

July 2000
(during fire)

July 2001
(after fire)

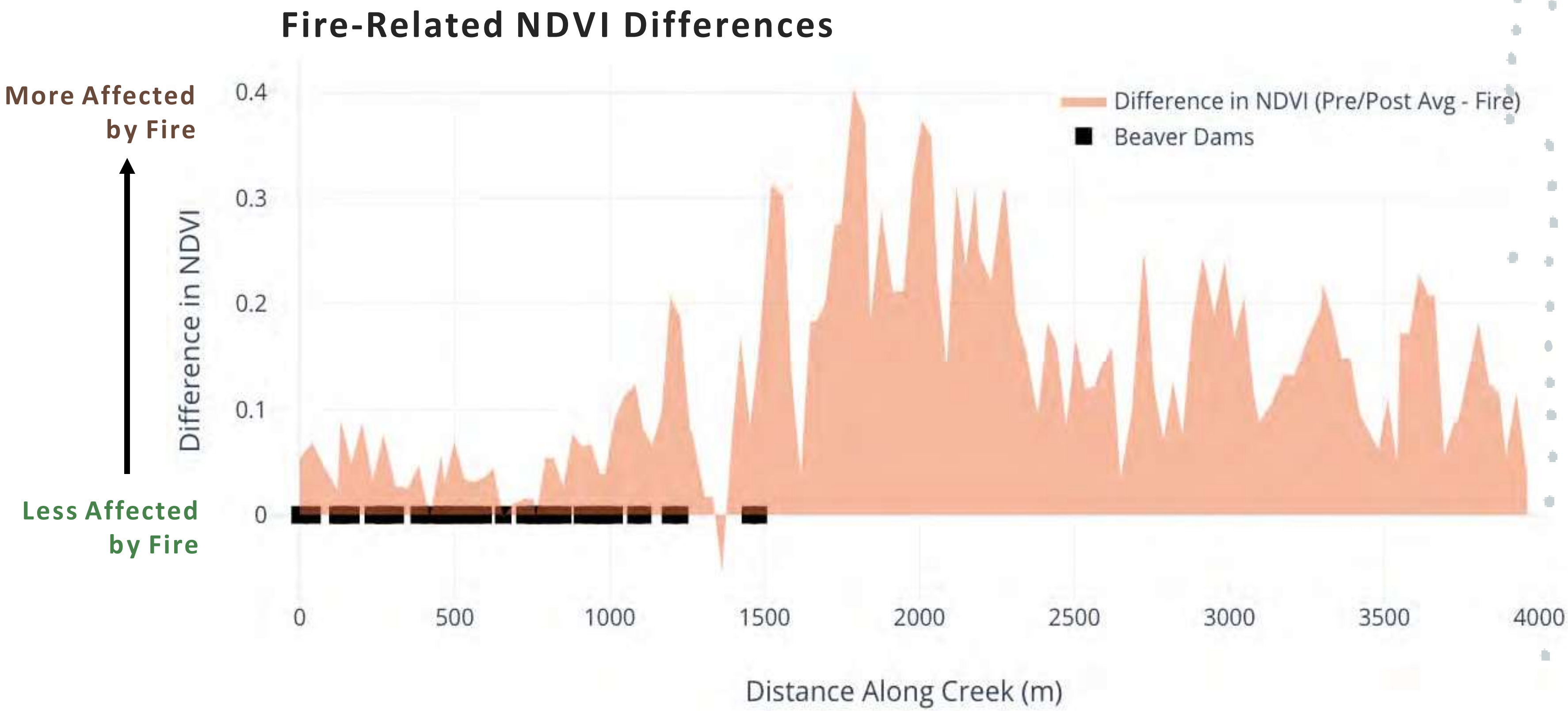


◯ = beaver dams

From Fairfax & Whittle (2020)

From Fairfax & Whittle (2020)

# Beaver dams appear to reduce impact of fire on plants.



# Beaver connected floodplains repeatedly create refugia during fire.

Fairfax and Whittle (2020)

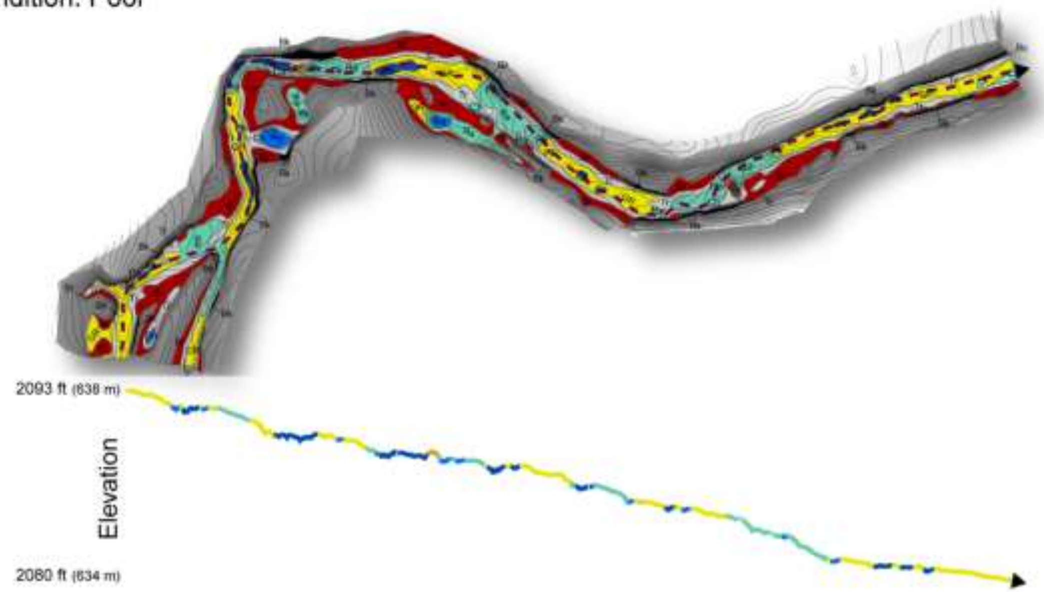
# BOGT #2: What's process based stream restoration got to do with climate change??

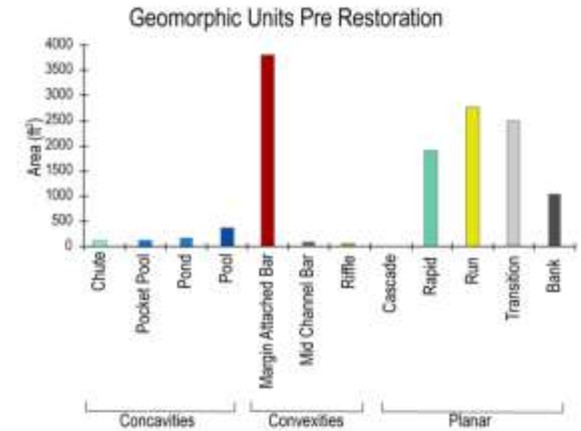

Jordan & Fairfax, 2022. Beaver: The North American Freshwater Climate Action Plan, WIRES Water, https://dx.doi.org/10.13140/RG.2.2.28332.13446

Skidmore & Wheaton, 2022. Can restored riverscapes help us adapt to climate change? Anthropocene, https://doi.org/10.1016/j.ancene.2022.100334

South Fork Asotin Creek: Planformed Controlled with Discontinuous Floodplain Latitude: 46.24869088939191 Longitude: -117.2892015084726

Condition: Poor



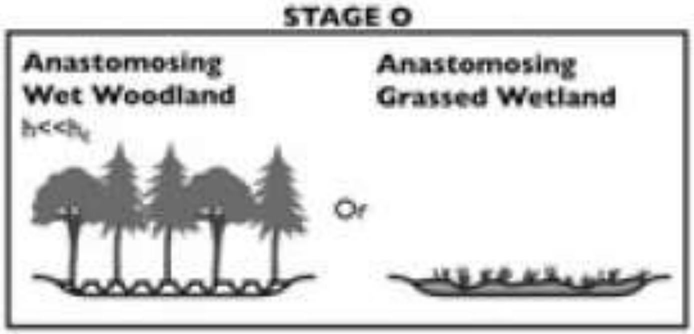



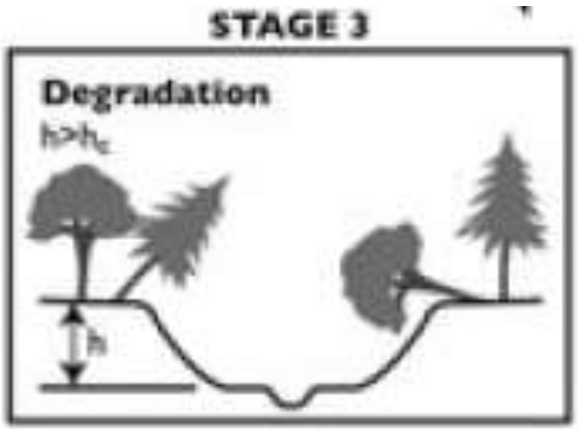

- Plane bed dominated (rapids & runs)
- Starved of wood..
- Limited interaction with floodplain

GUT

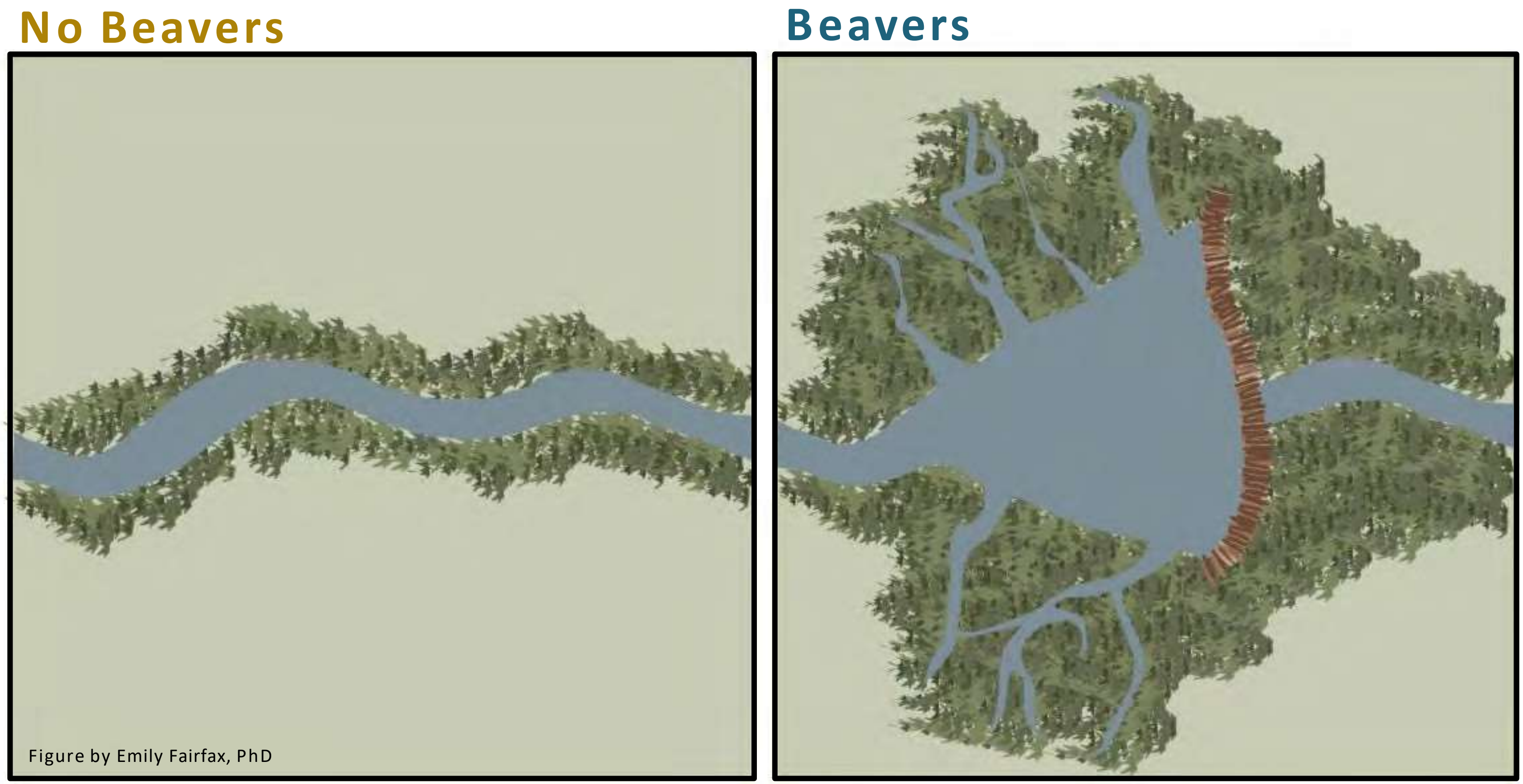
http://gut.riverscapes.xyz

# BOGT #2: What's missing to drive the rehabilitation process?



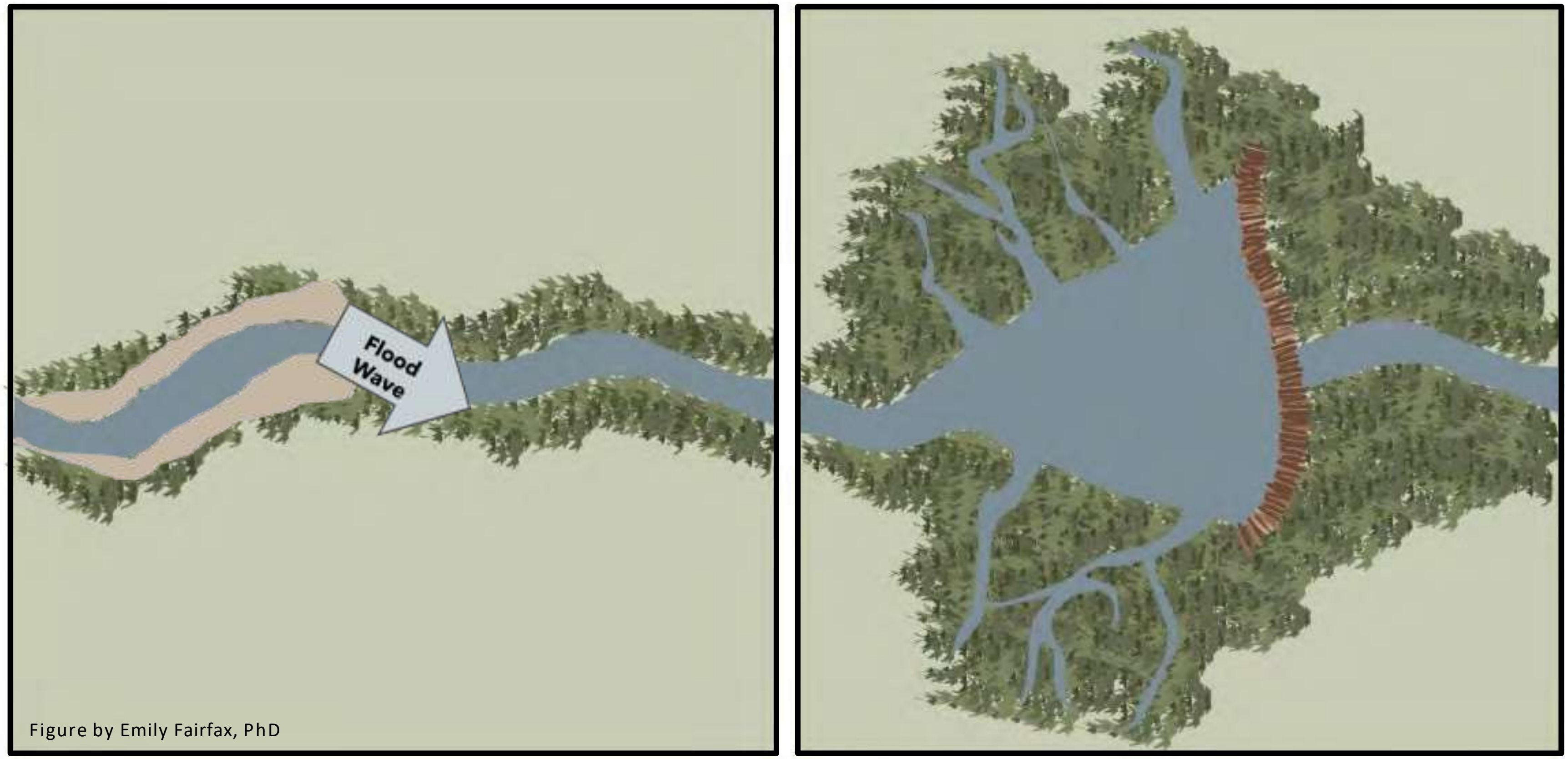



# Connected Floodplains dampen flood pulse

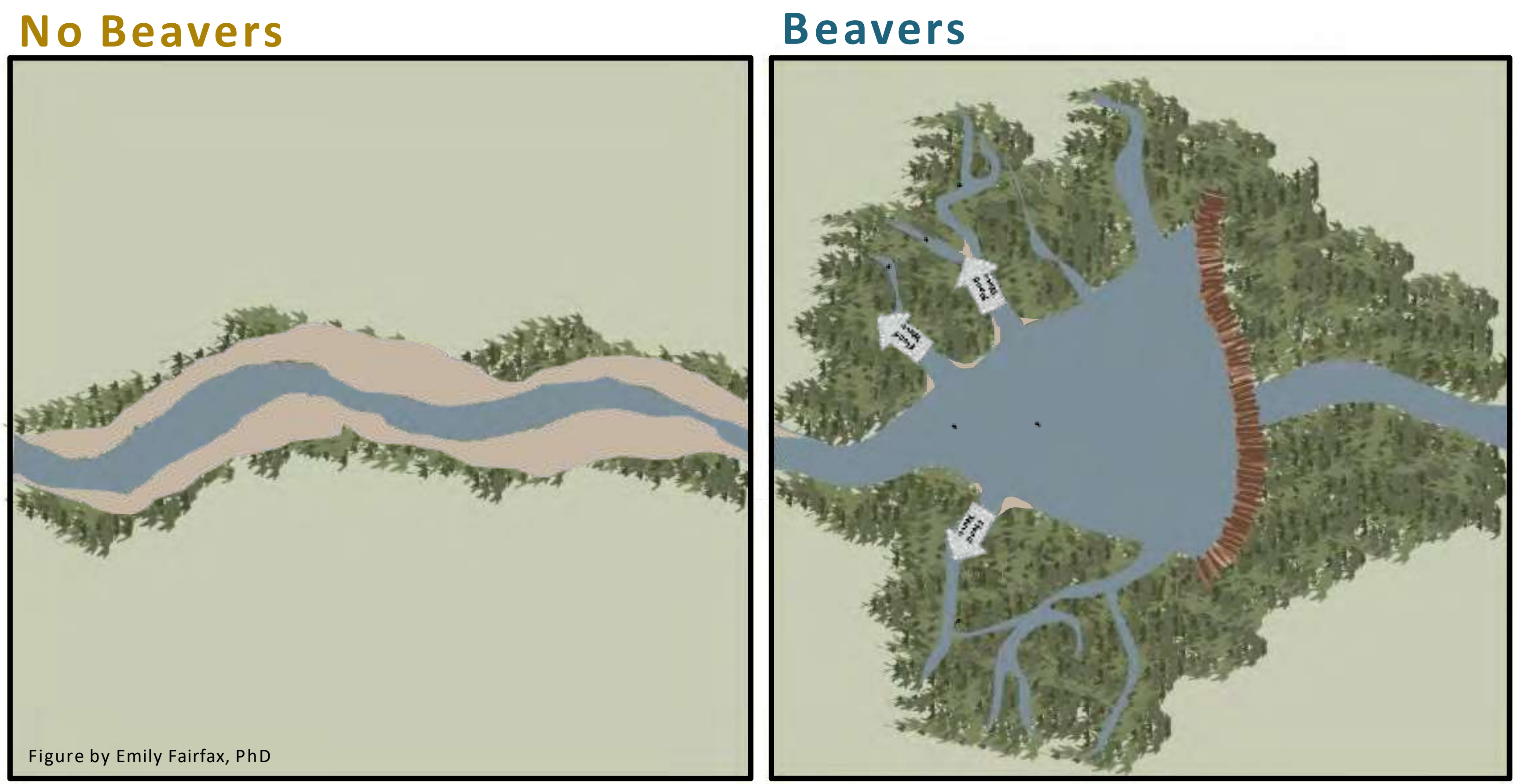


# Connected Floodplains dampen flood pulse

**No Beavers** **Beavers**

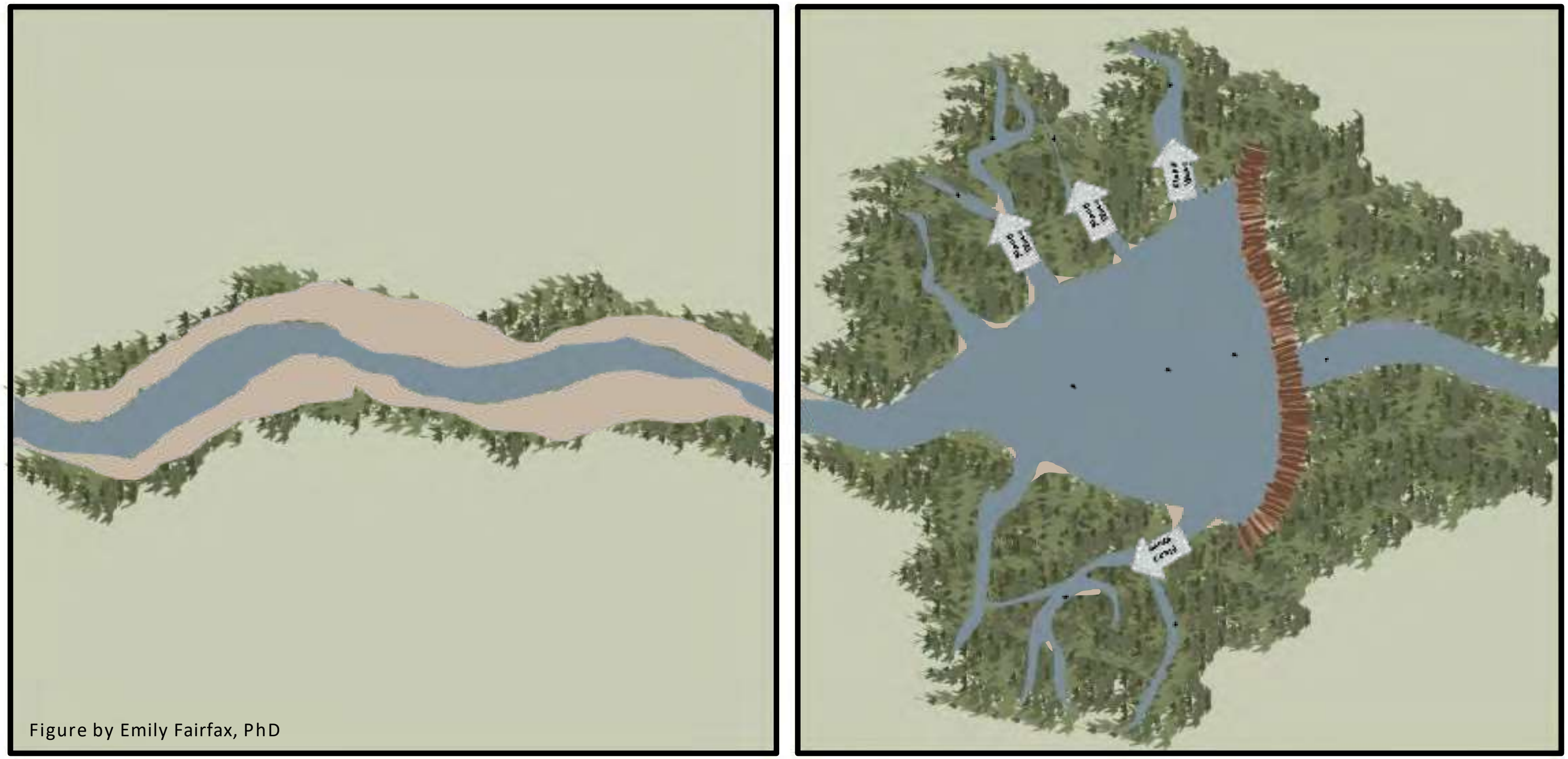


# Connected Floodplains dampen flood pulse



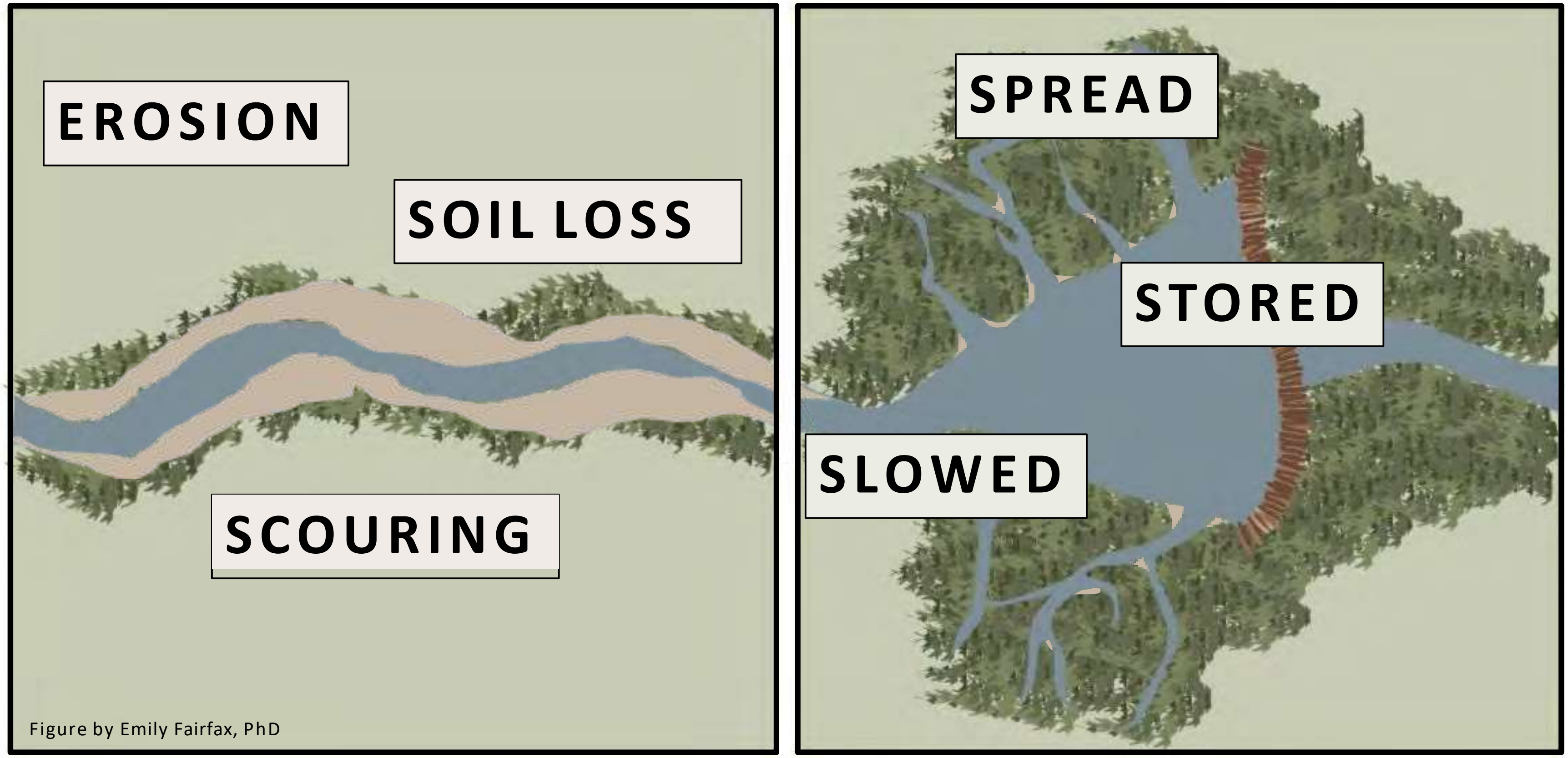
# Connected Floodplains dampen flood pulse

**No Beavers** **Beavers**



# Connected Floodplains dampen flood pulse

**No Beavers** **Beavers**

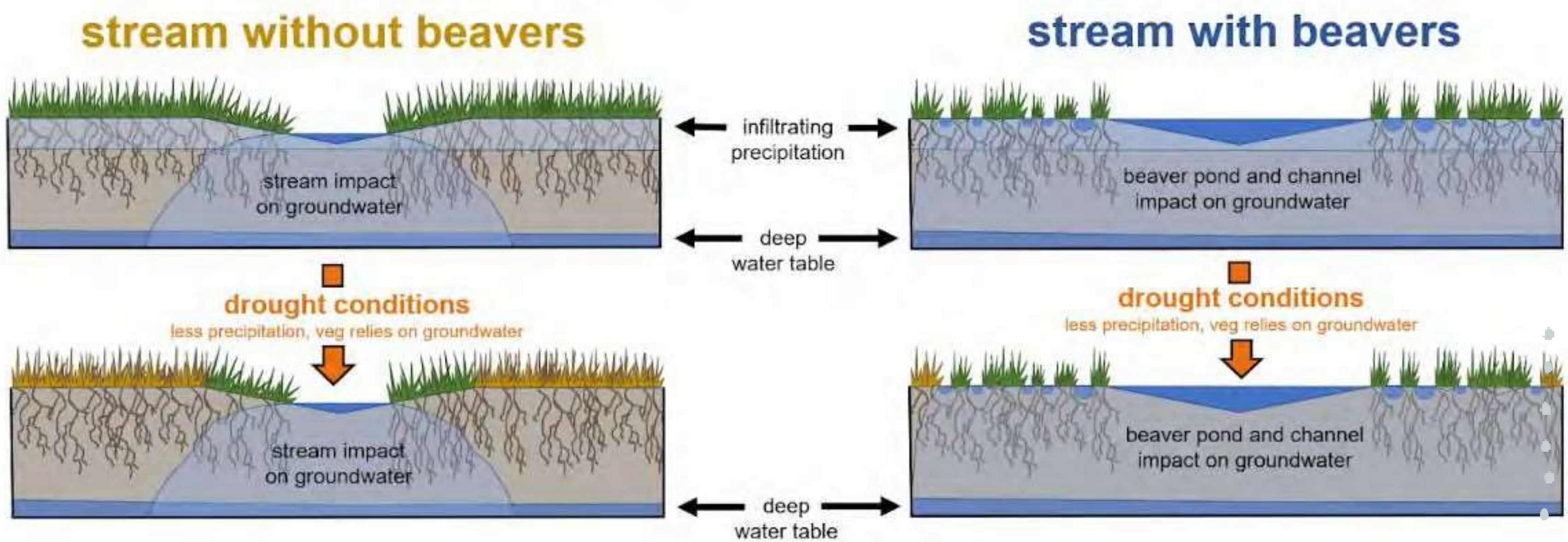


# Conceptual Model: Connected Floodplains and Drought



Fairfax and Small (2018)

# Conceptual Model: Connected Floodplains and Drought




Fairfax and Small (2018)

# STRUCTURAL STARVATION: EXAMPLES OF LOW-TECH PROCESS-BASED RESTORATION ACROSS A DIVERSITY OF RIVERSCAPES


Nick Bouwes –Anabranch Solutions, USU, Eco Logical Research
Stephen Bennett –Anabranch Solutions, USU, Eco Logical Research
Joe Wheaton - Anabranch Solutions, Utah State University
Nick Weber –Anabranch Solutions, Eco Logical Research
Sabra Purdy-Anabranch Solutions, Trout Unlimited
Chris Jordan-NOAA/NMFS/NWFSC

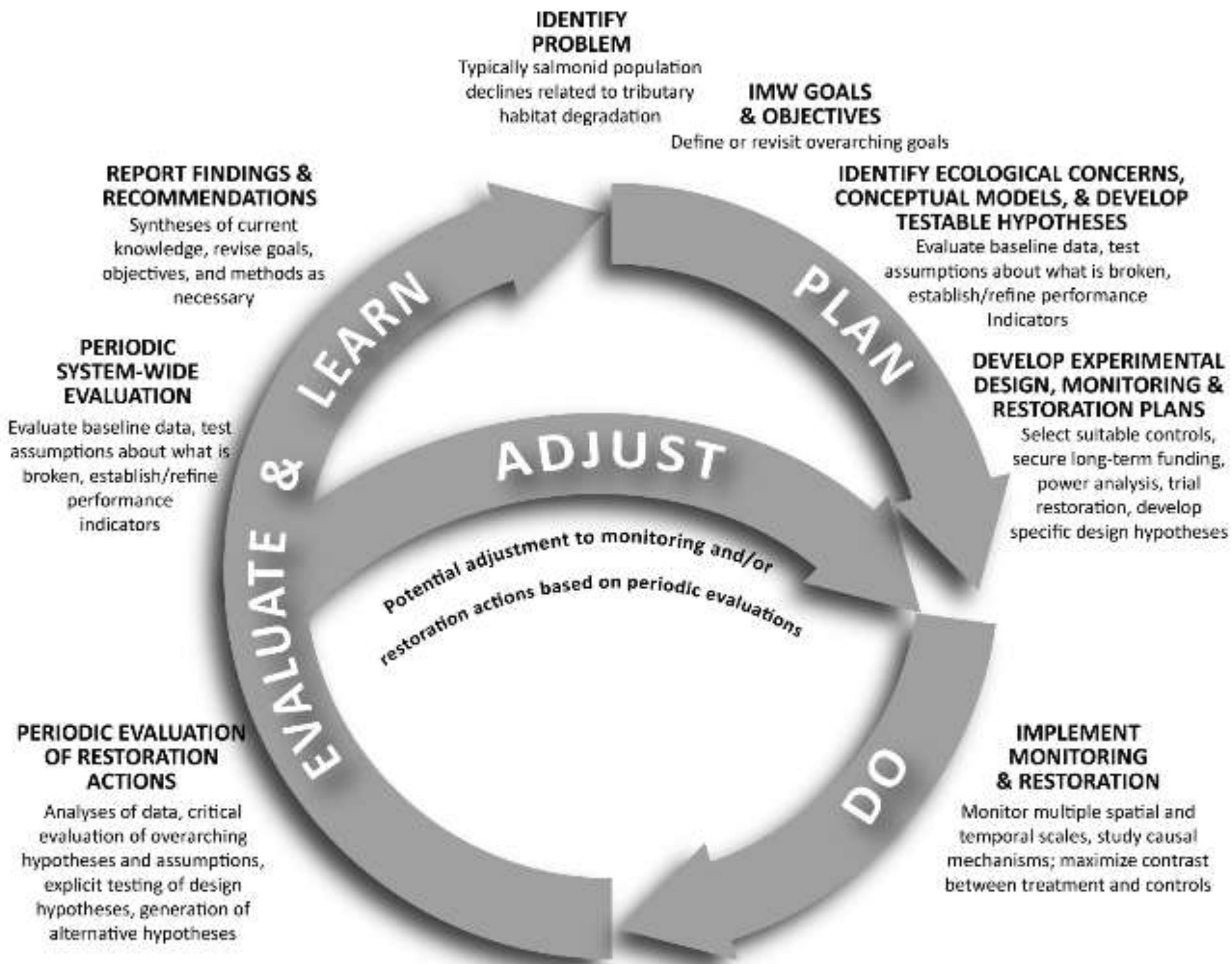
# SOME ECOSYSTEM SERVICES INCREASED BY LTPBR

- Habitat quantity and complexity for fish, amphibians, birds, wildlife,…
- Resilience to floods, drought, fire
- Water storage
- Water quality (sediments, nutrients, temperature)
- Livestock forage

# EXAMPLES OF MEANS OBJECTIVES OF LTPBR

- Increase aggradation
- Increase hydraulic and geomorphic complexity
- Increase water storage
- Increase water quality
- Increase sedge and riparian production

# LTPBR ADAPTIVE MANAGEMENT

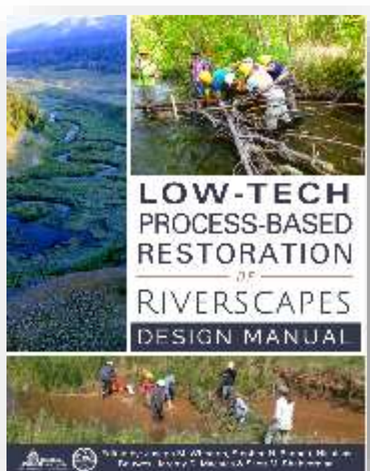


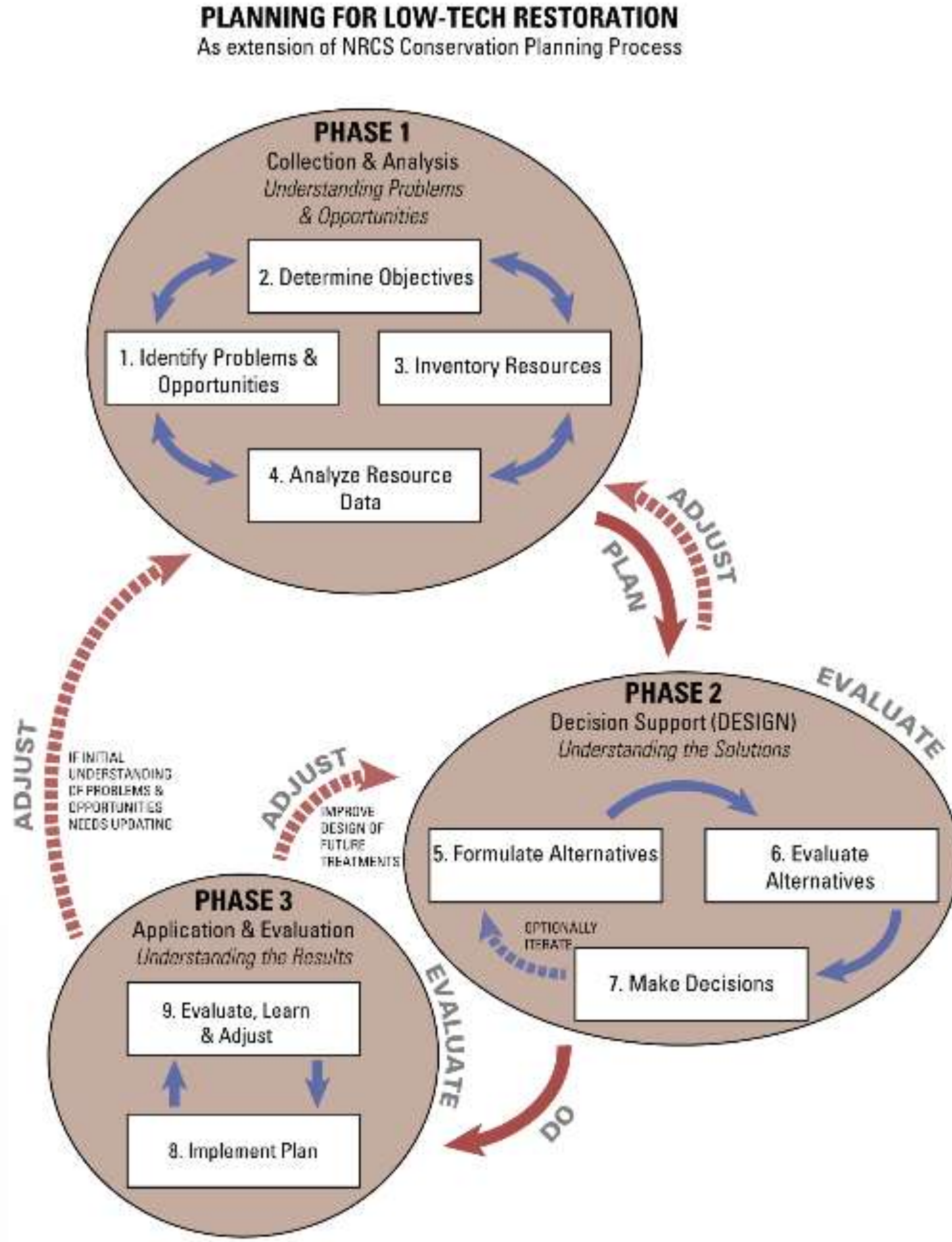


Bouwes et al. 2016 Fisheries

# PROCESS OF ADAPTIVE MANAGEMENT

- Define the problem
- Identify objectives
- Develop alternatives
- Exploring consequences
- Consider trade-offs
- Implement action
- Monitoring
- Evaluation
- Adjustment

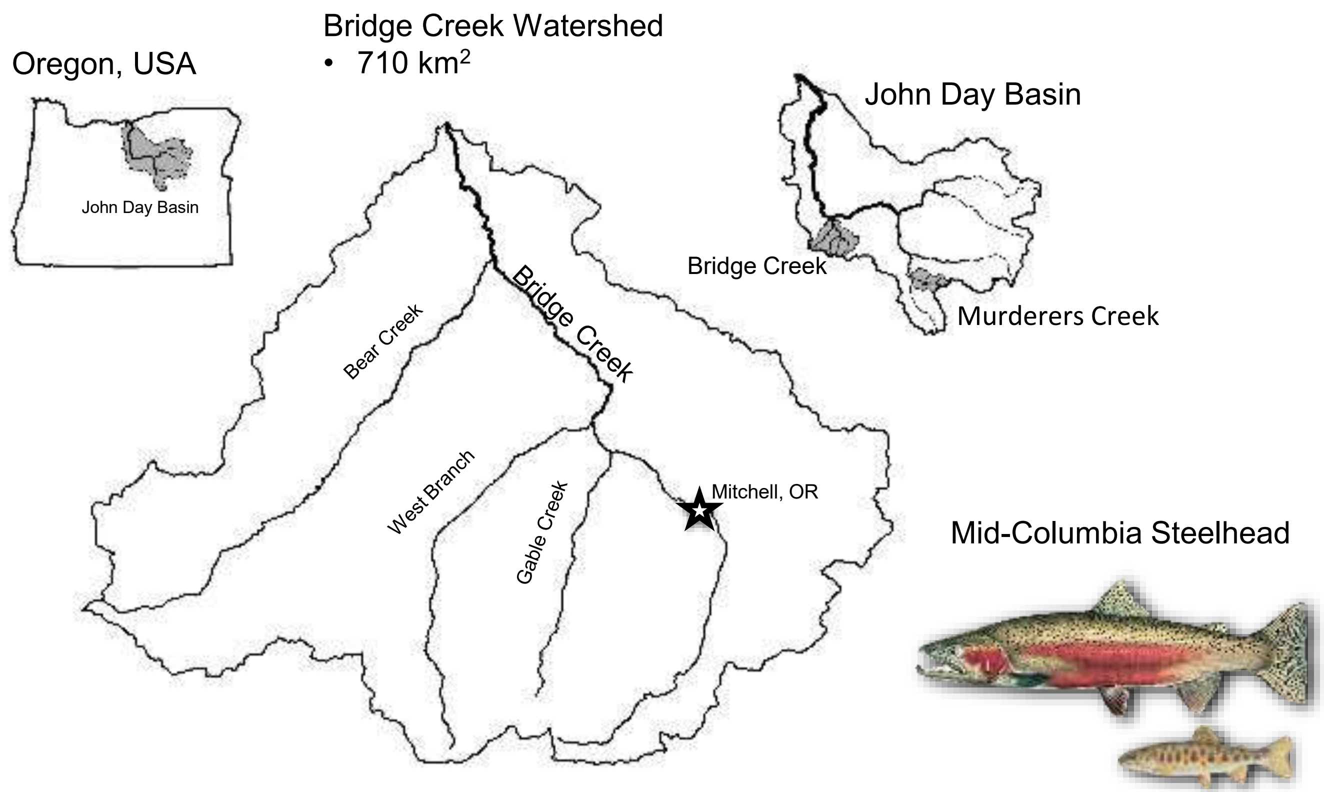


# EXAMPLES OF MEANS OBJECTIVES OF LTPBR

- **Increase aggradation**
- Increase structural and geomorphic complexity
- Increase water storage
- Increase water quality
- Increase sedge and riparian production

# BRIDGE CREEK INTENSIVELY MONITORED WATERSHED AGGRADATION



PRE-RESTORATION

# INCISED

25 YEARS LATER…….

# STILL INCISED

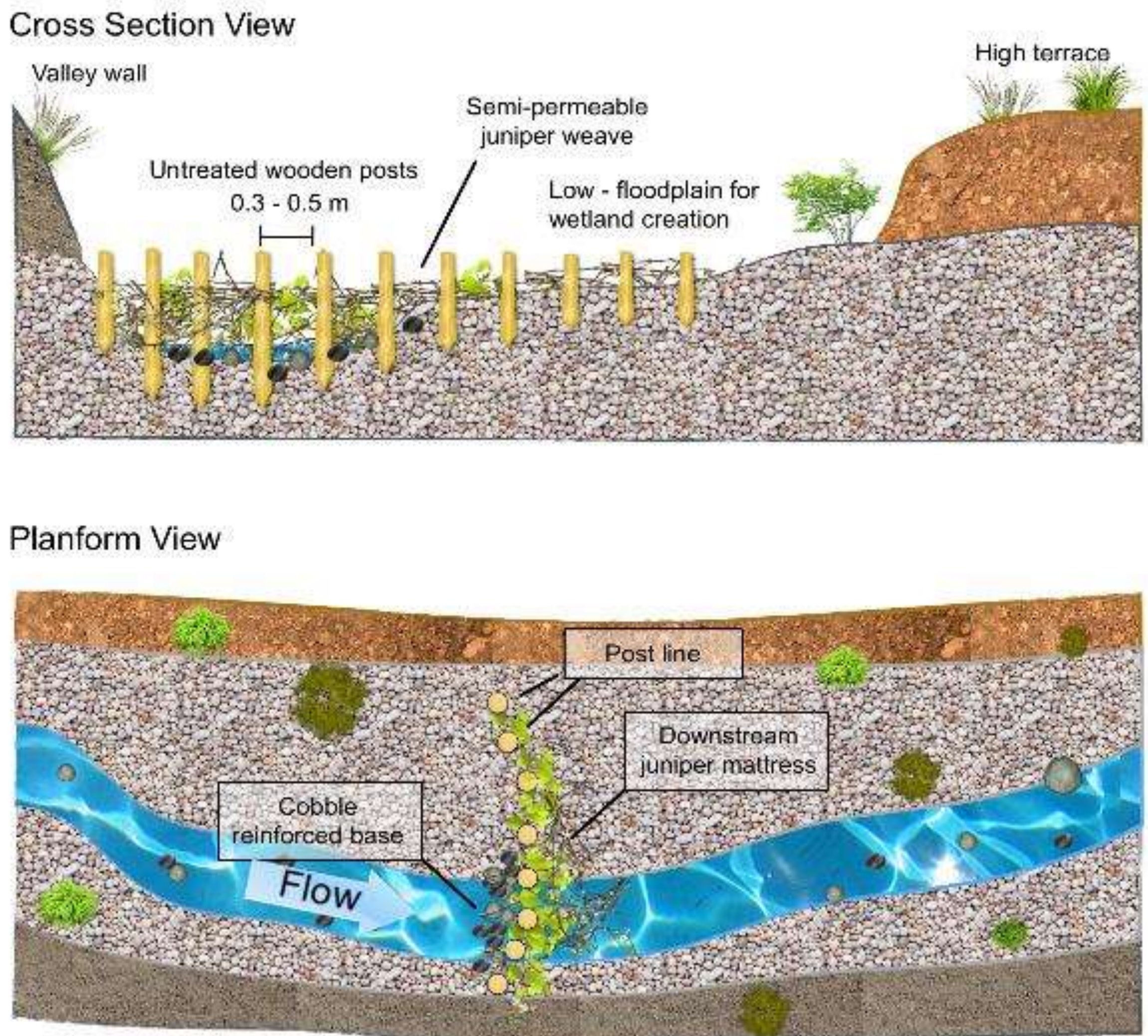
PRE-RESTORATION

# BEAVER PRESENT

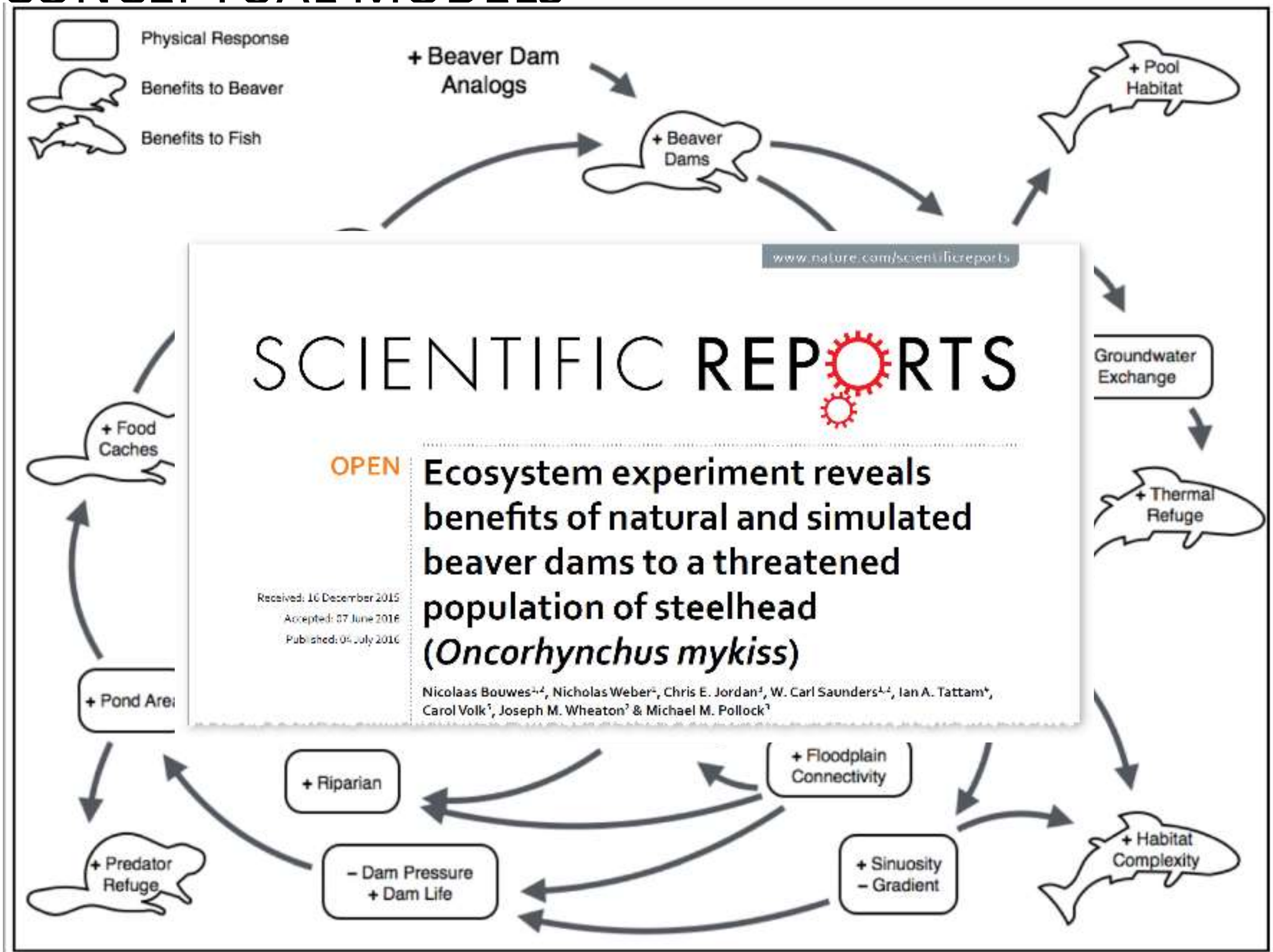
PRE-RESTORATION
# DAM BLOW-OUTS FREQUENT

# RESTORATION APPROACH: MIMIC BEAVER

## Beaver Dam Analogs (BDAs)



# CONCEPTUAL MODELS




www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

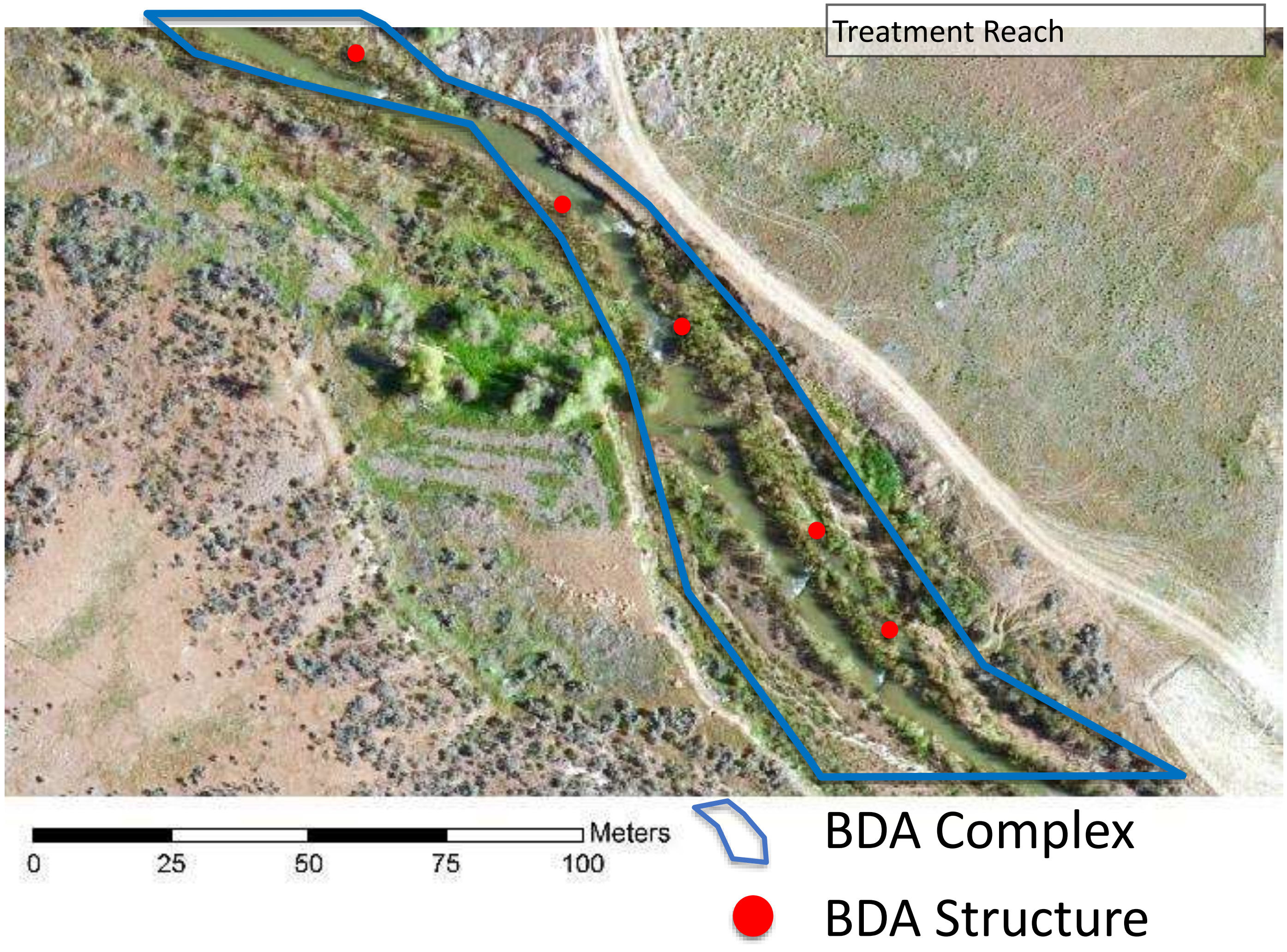
## Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*)


Received: 16 December 2015
Accepted: 07 June 2016
Published: 04 July 2016



Nicolaas Bouwes, Nicholas Weber, Chris E. Jordan, W. Carl Saunders, Ian A. Tattam, Carol Volk, Joseph M. Wheaton & Michael M. Pollock

# MIMIC – BUILD COMPLEXES




4 Treatment Reaches ~ 1 km/each     120 BDAS

POST-RESTORATION

# BEAVER DAMS AND BDAs - PROMOTE

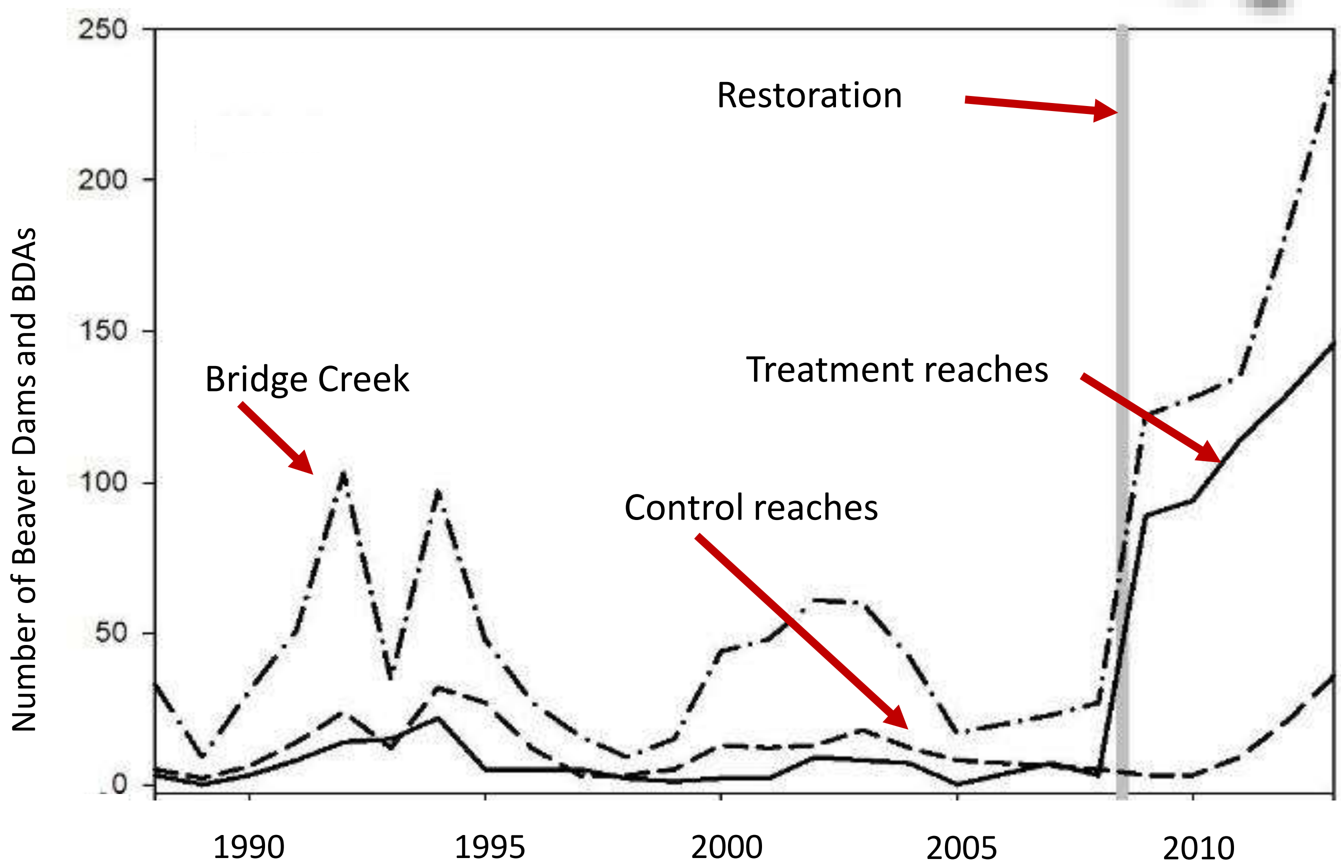



Figure 4 from Bouwes et al (2016) DOI: [10.1038/srep28581](https://doi.org/10.1038/srep28581)

Post-restoration

# AGGRADATION ~1M < 1 YR : PROMOTE

Post-restoration

# FLOODPLAIN FREQUENTLY INUNDATED

POST-RESTORATION

# WATER TABLE ELEVATION CHANGE

1’-3’ increase in the height of the water table


Slide from Nick Weber


Summer 2005
Summer 2014
Inundation area increased 228%
Side channel area increased 1216%

POST-RESTORATION

# FLOODPLAIN CONNECTION : SUSTAIN?

POST-RESTORATION

# BEAVER RESPONSE - SUSTAIN

**<u>ACTIVE BEAVER DAMS</u>**

- 2008 = 22 (pre-BDAs)
- 2016 = 164!

# RESILIENCY- SUSTAIN?

# RESILIENCY-SUSTAIN

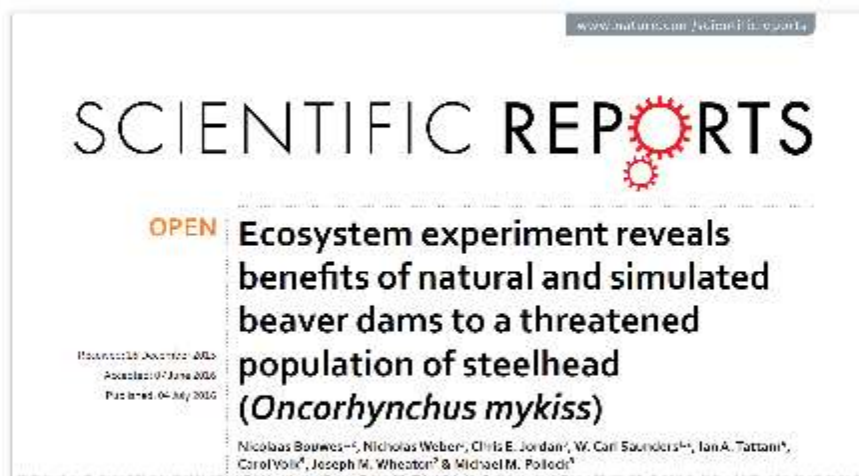
# BRIDGE CREEK FISH POPULATION RESPONSE

- 3 Annual M-R Surveys - 11 yrs
- ~ 100,000 Juveniles Pit-tagged
- 4 Passive Instream Antennas
- Adult Steelhead Trap

168% increase in abundance

52% increase in survival

172% increase in production



SCIENTIFIC REPORTS

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**Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*)**

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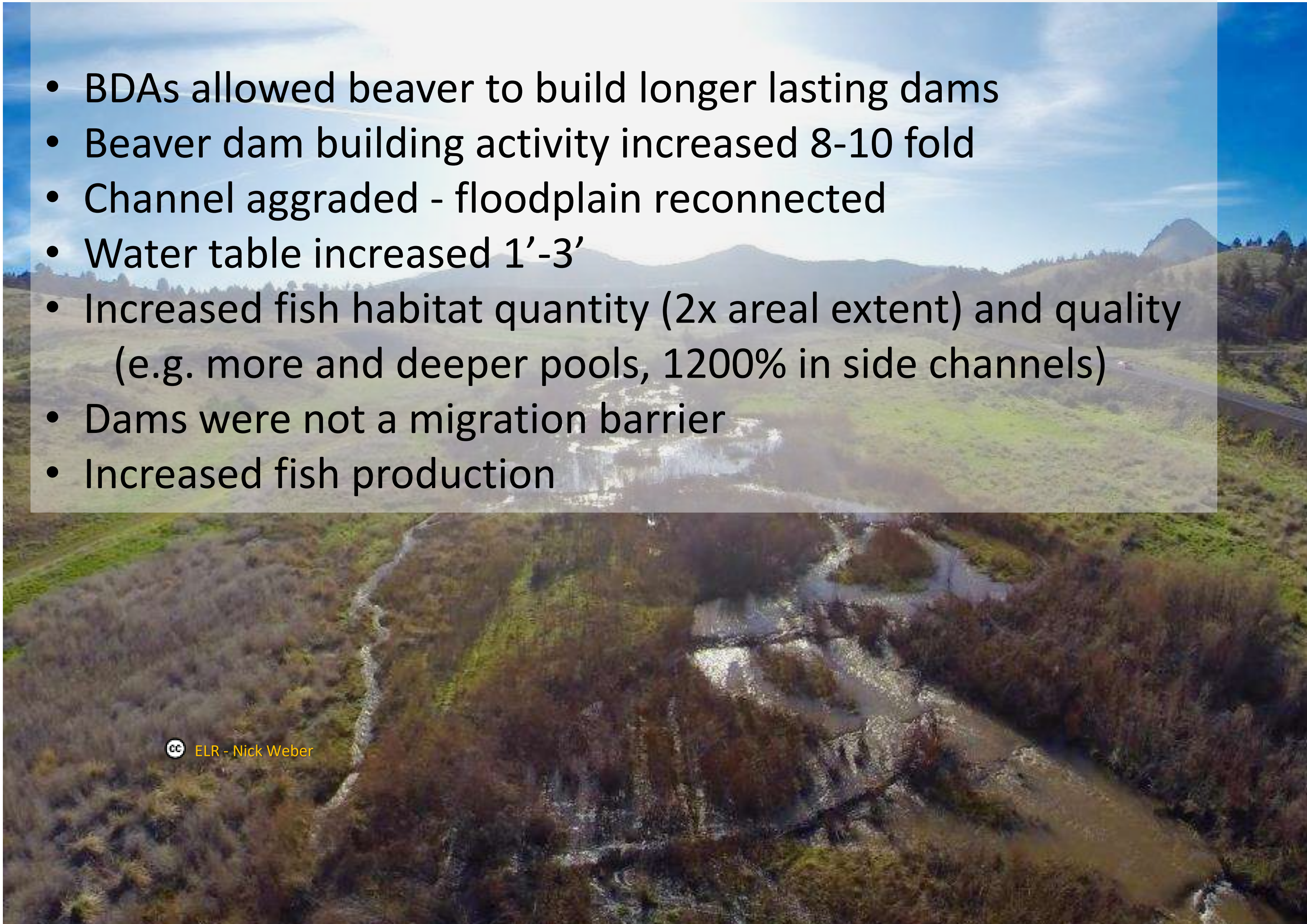
# BRIDGE CREEK CONCLUSIONS

- BDAs allowed beaver to build longer lasting dams
- Beaver dam building activity increased 8-10 fold
- Channel aggraded - floodplain reconnected
- Water table increased 1’-3’
- Increased fish habitat quantity (2x areal extent) and quality (e.g. more and deeper pools, 1200% in side channels)
- Dams were not a migration barrier
- Increased fish production



# STRUCTURALLY-FORCED RESILIENCE TO FIRE


Wheaton et al. (2019) – LTPBR Manual

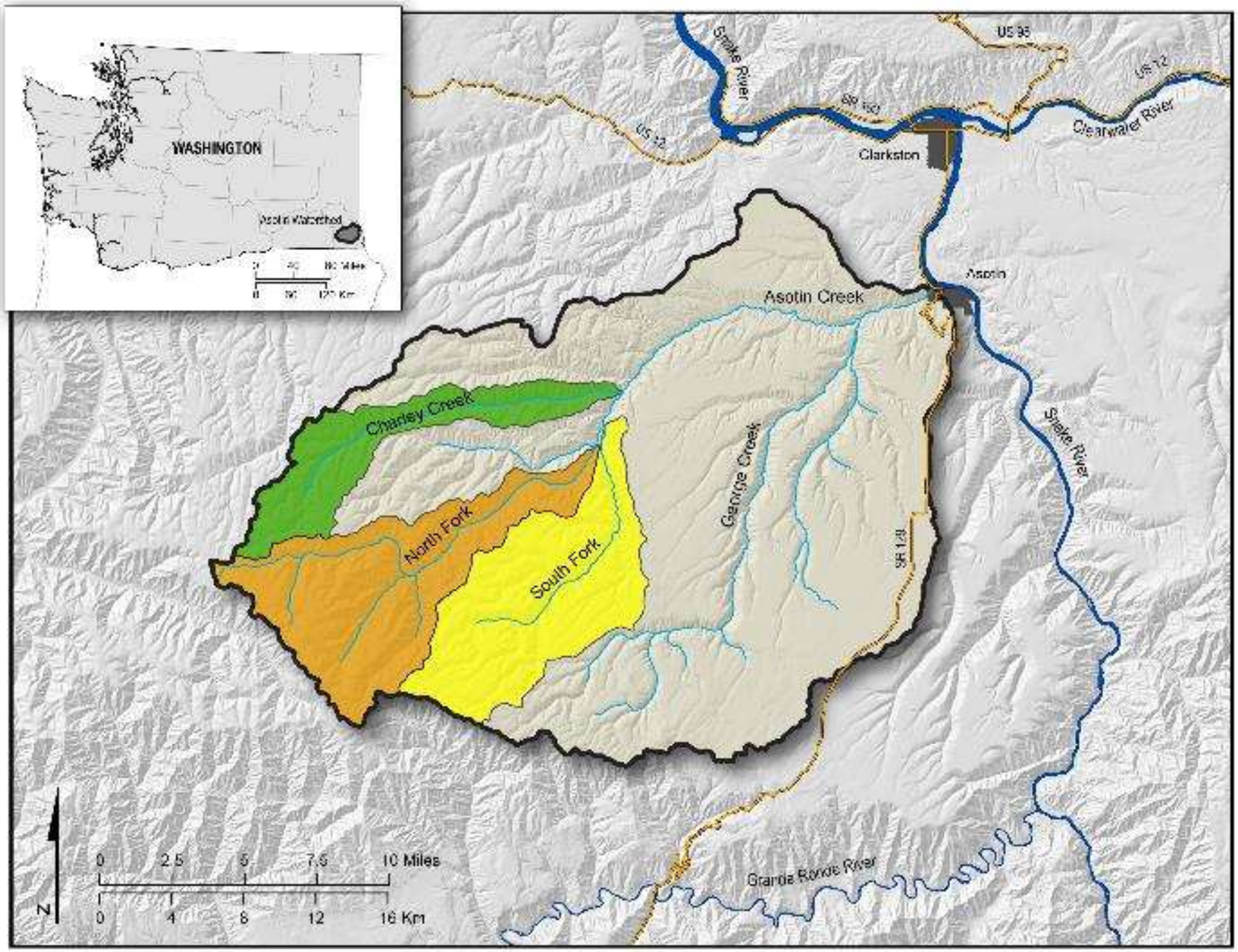
DOI: [10.13140/RG.2.2.19590.63049/1](https://doi.org/10.13140/RG.2.2.19590.63049/1)

# EXAMPLES OF MEANS OBJECTIVES OF LTPBR

- Increase aggradation
- **Increase structural and geomorphic complexity**
- Increase water storage
- Increase water quality
- Increase sedge and riparian production

# ASOTIN INTENSIVELY MONITORED WATERSHED

## HABITAT COMPLEXITY FOR LISTED STEELHEAD




PRE-RESTORATION
STRUCTURALLY STARVED
LOW COMPLEXITY
Serra Bowl
42

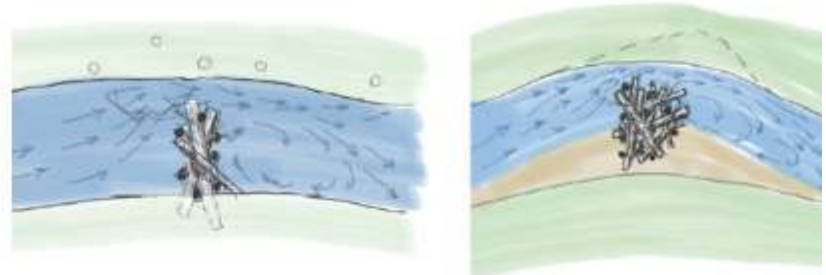
# ASOTIN IMW
## BROADENED OBJECTIVES

- Increase complexity
  - Widen channel
  - Build bars
  - Scour pools
  - Aggrade
- Force overbank flow
- Riparian function

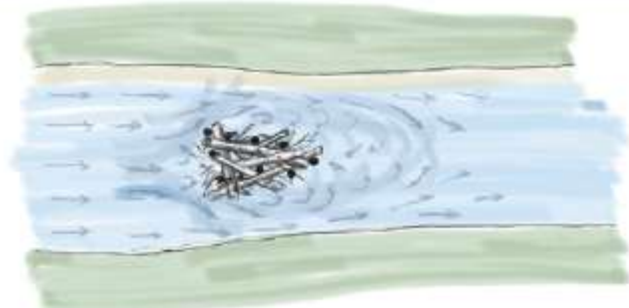
# RESTORATION APPROACH- MIMIC WOOD ACCUMLATION (JAMS)

POST-ASSISTED LOG STRUCTURES (PALS)

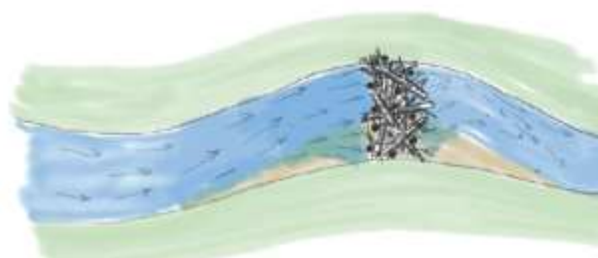
## BANK-ATTACHED PALS



## MID-CHANNEL PALS



## CHANNEL-SPANNING PALS



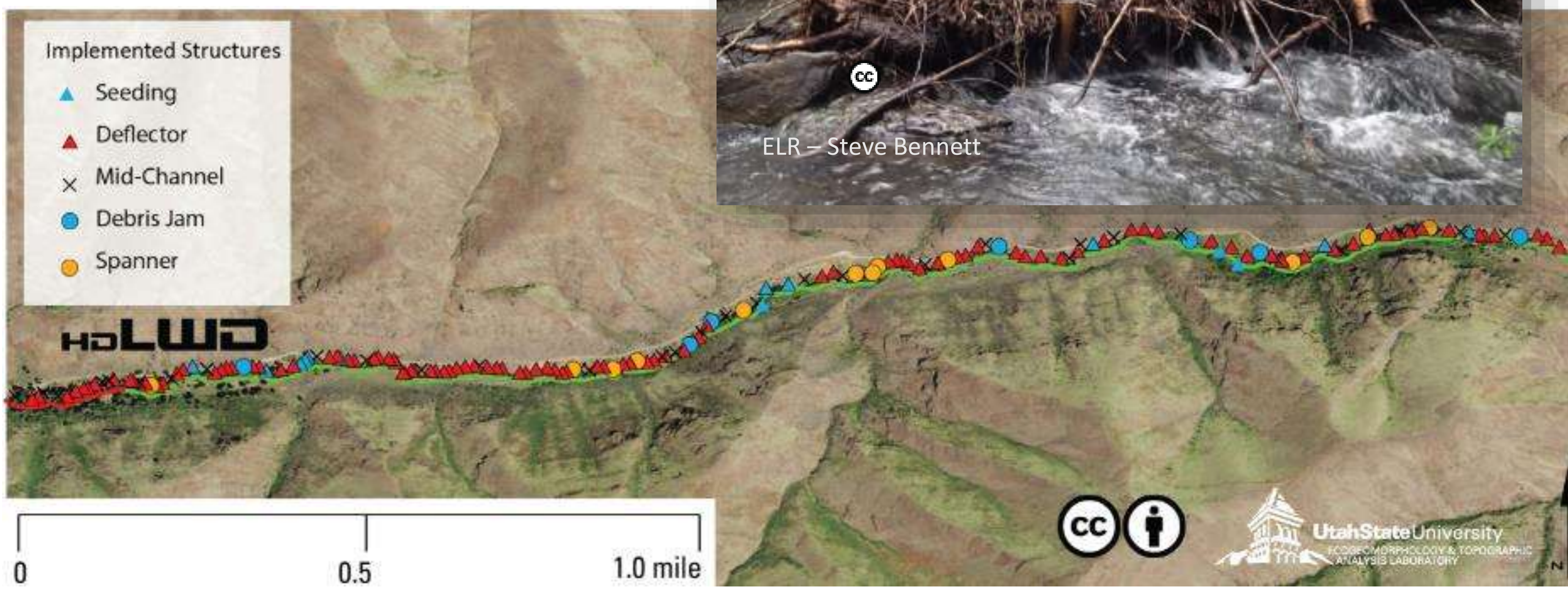
# RESTORATION APPROACH- MIMIC WOOD ACCUMLATION (JAMS)




PALS

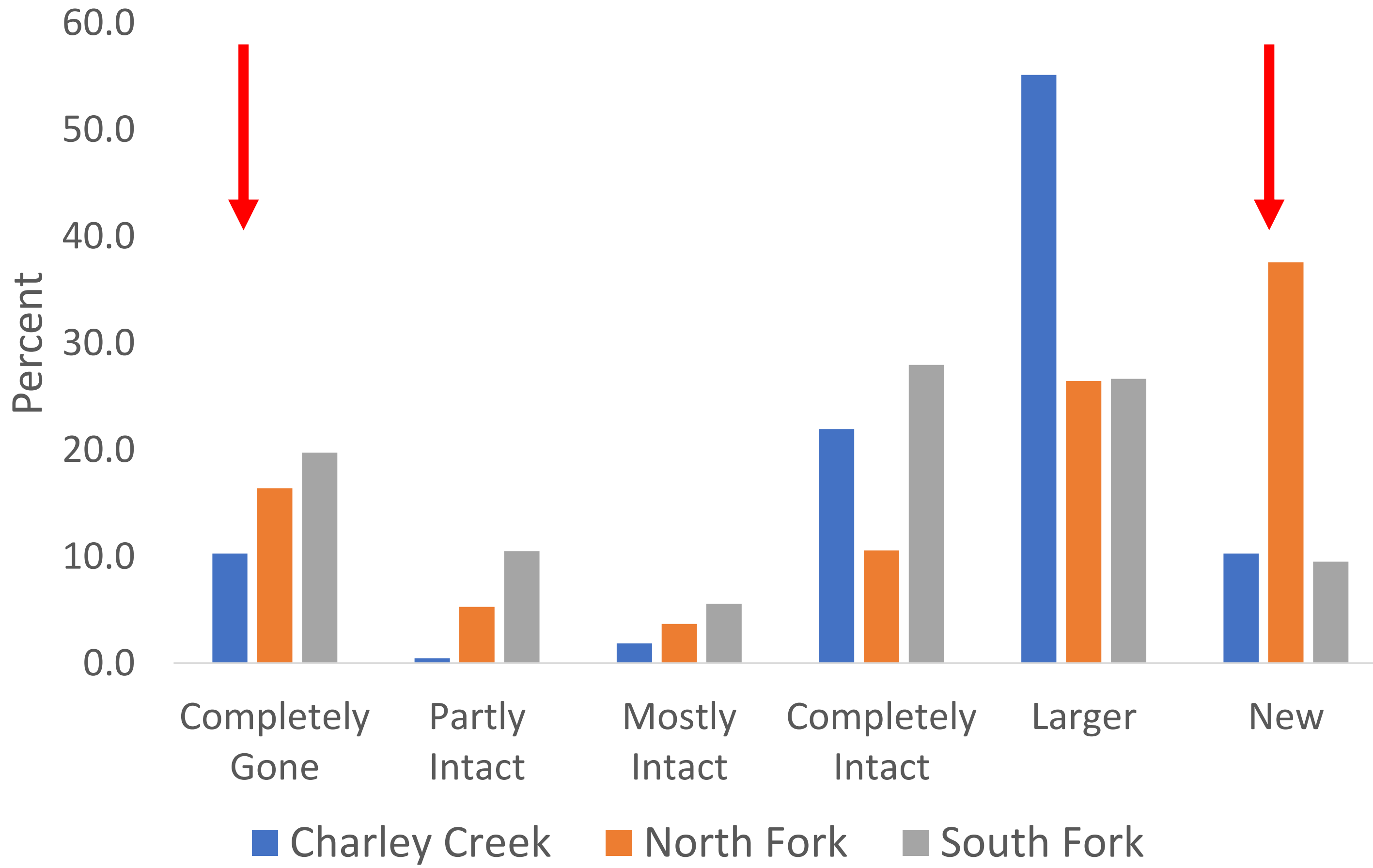
# RESTORATION SCOPE

- ~ 800 PALS
- 14 km/36 km = 40%

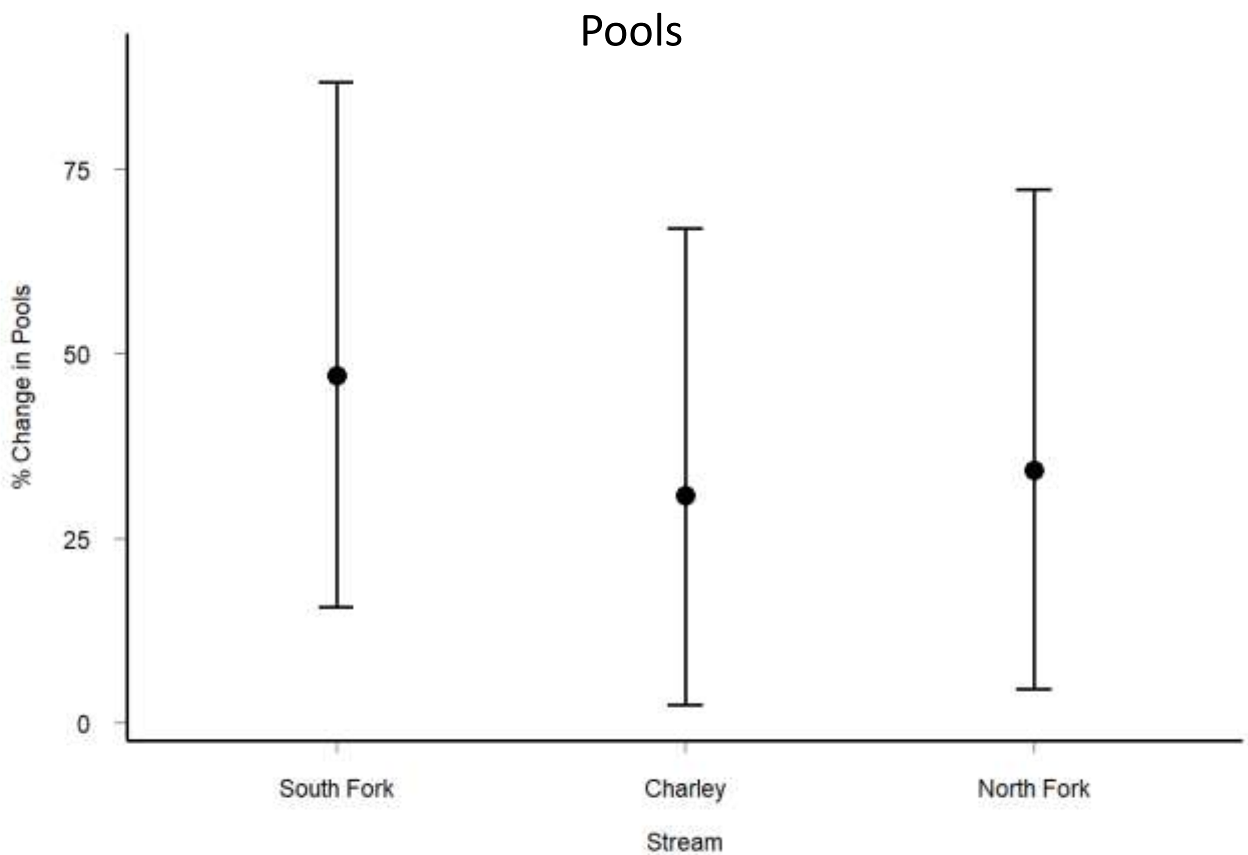
POST-RESTORATION

# PROMOTE WOOD ACCUMULATIONS




Condition of structures 7 years (South Fork), 6 years (Charley), and 5 years (North Fork) after construction (n = 750).

# POST RESTORATION
# INCREASE IN POOLS AND BARS (GEOMORPHIC COMPLEXITY)




Percent change in **pool** frequency (/100 m) in treatment sites relative to control sites in three IMW streams: 2008-2020. Bars = 90% confidence intervals.

# POST RESTORATION
# SUSTAIN

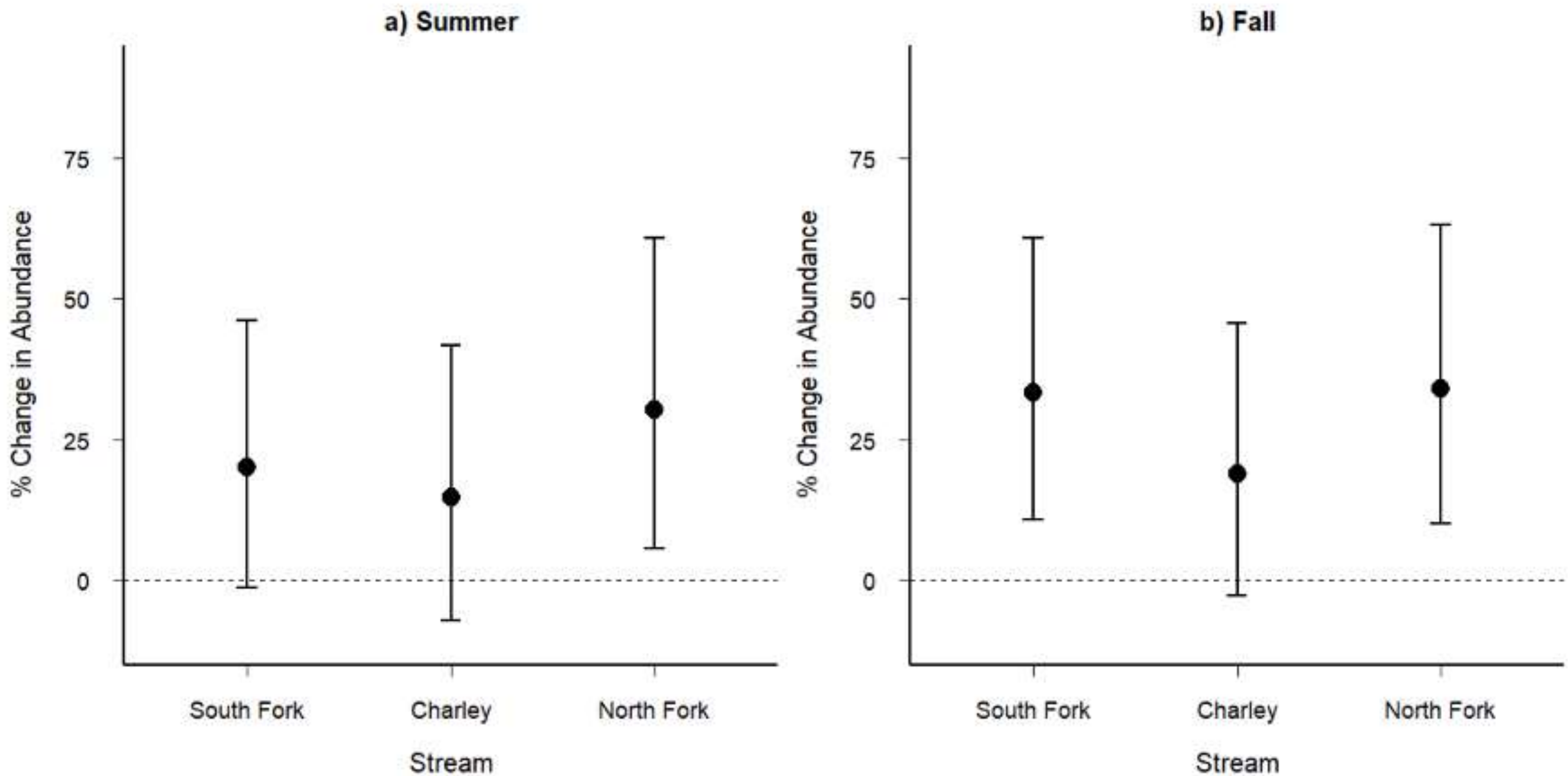
Floodplain Connection

Tree Recruitment

Wood Accumulation & Off-channel Habitat

POST RETORATION

# INCREASE HABITAT COMPLEXITY → FISH ABUNDANCE




Percent change in **abundance** of juvenile steelhead (fish/km) in treatment sites relative to control sections in three IMW streams: 2008-2020. Bars = 90% confidence intervals.

# EXAMPLES OF MEANS OBJECTIVES OF LTPBR

- Increase aggradation
- Increase structural and geomorphic complexity
- **Increase water storage**
- Increase water quality
- Increase sedge and riparian production

# BIRCH CREEK, ID
# WATER STORAGE

**Restoration Goal**

- Restore perennial flow

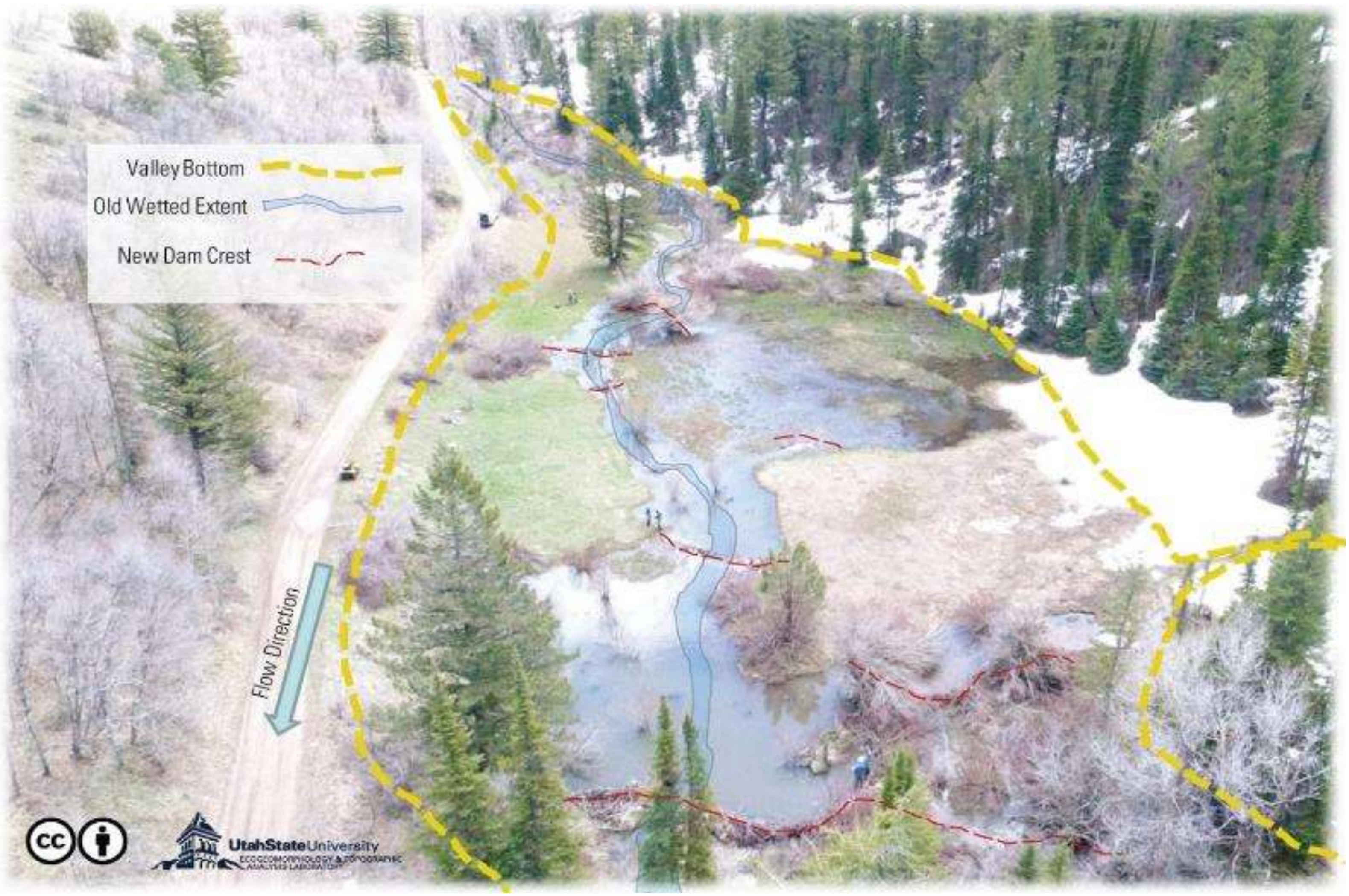
**Setting**

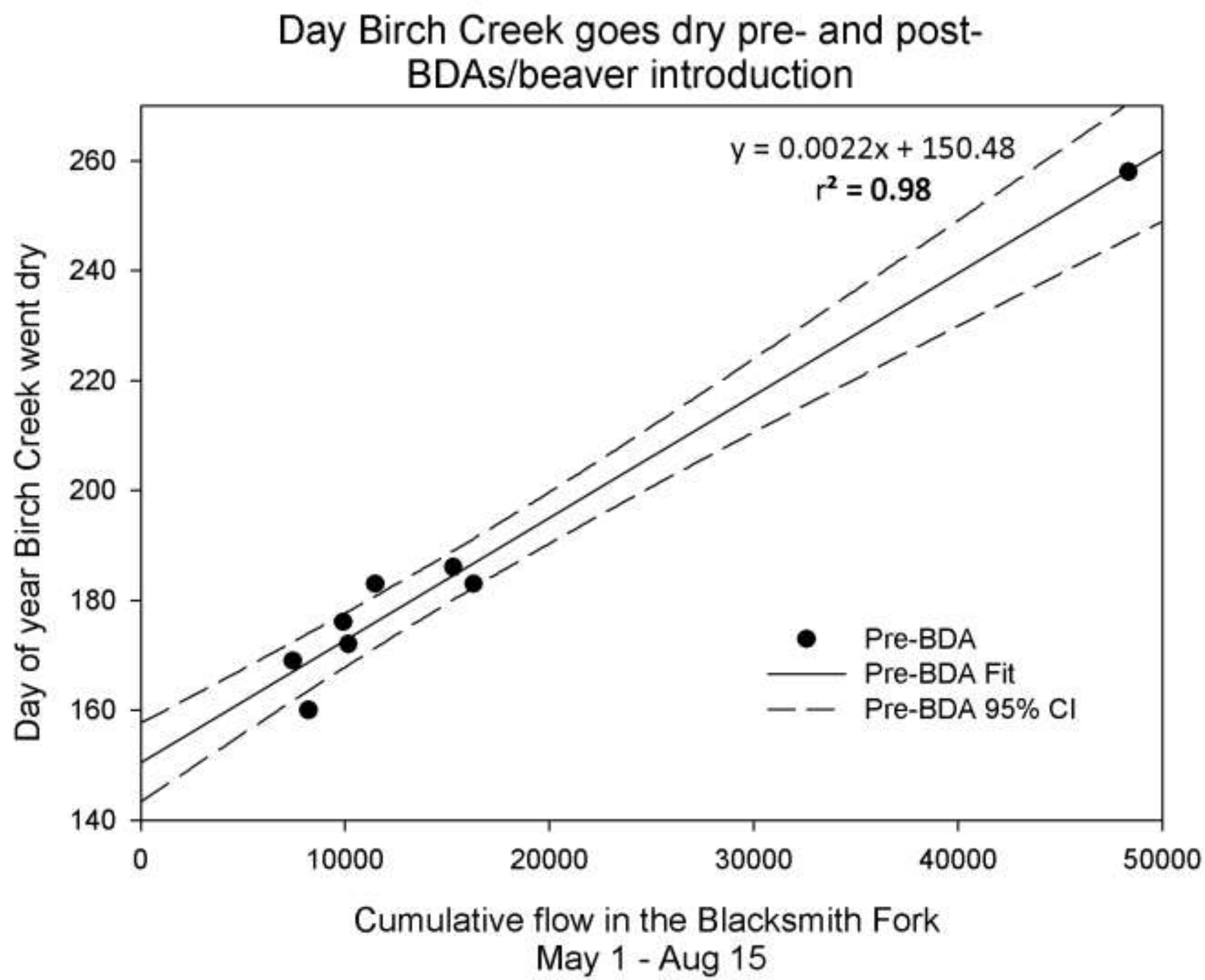
- No Beaver
- Abundant forage for beaver
- Shallow water depth – high risk of predation

**Strategy**

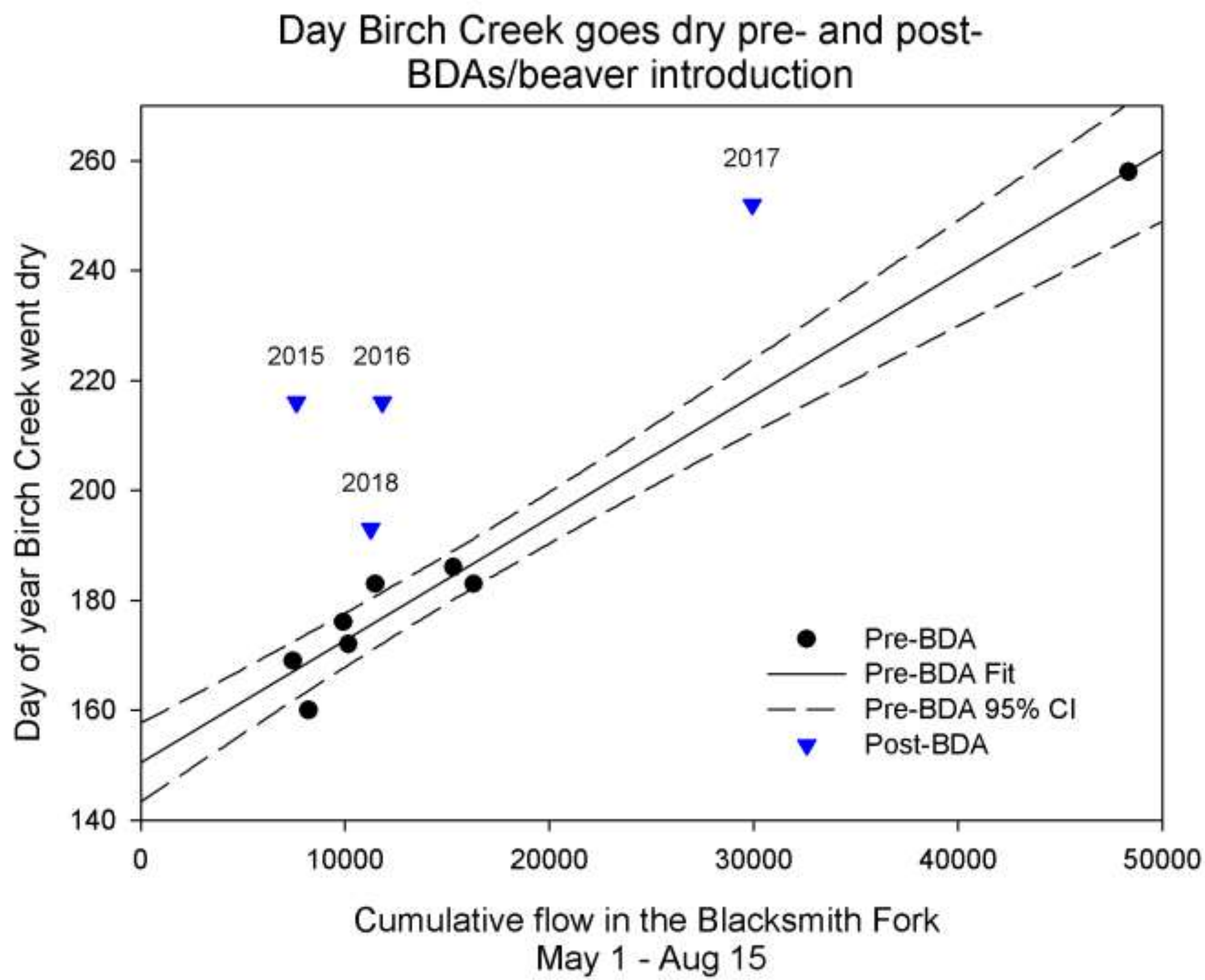
- Build BDAs to provide immediate habitat/refuge for beaver
- In 2015-16 introduced 9 beavers

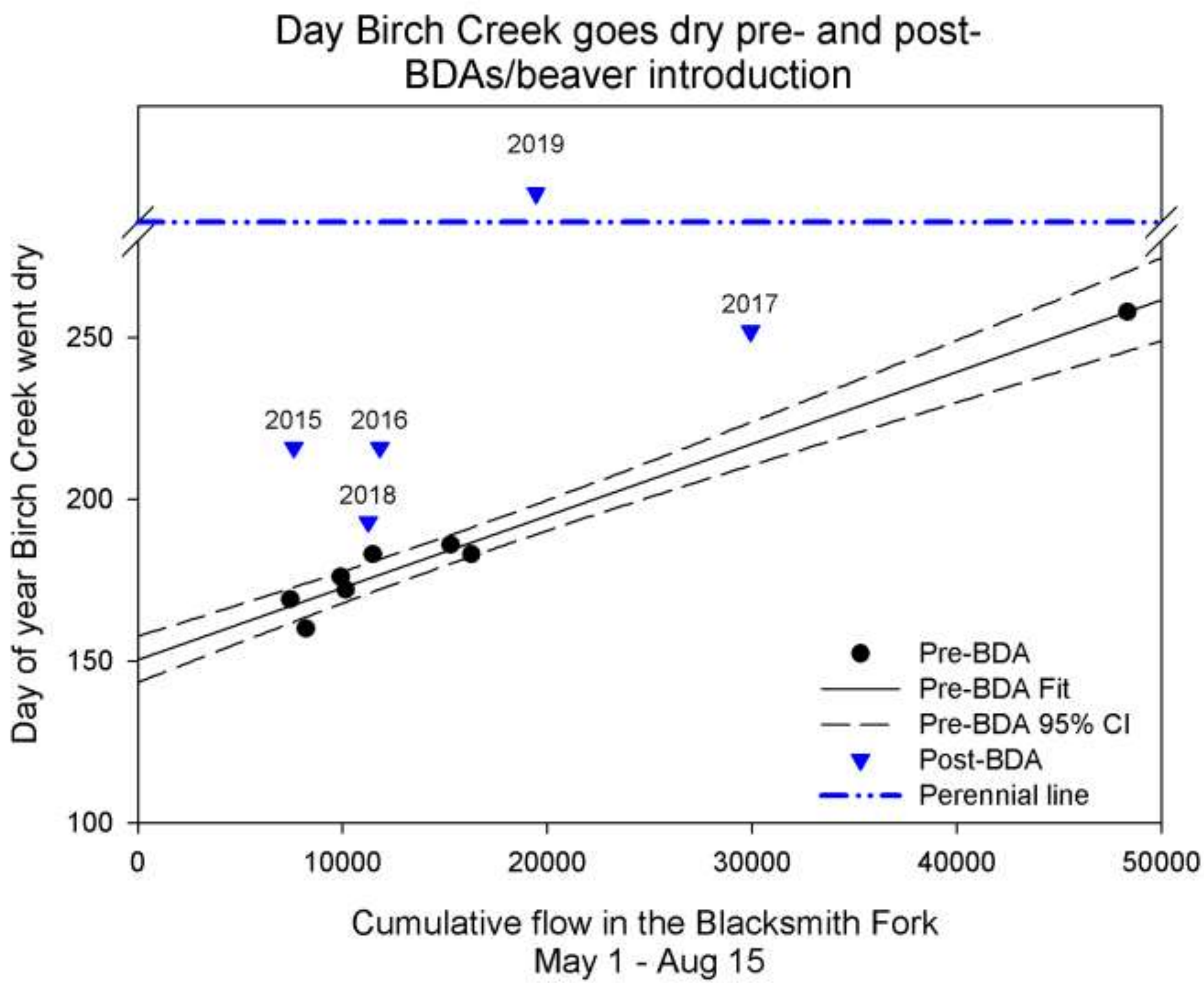
# WATER STORAGE-BIRCH CREEK, ID
## 2019>140 DAMS





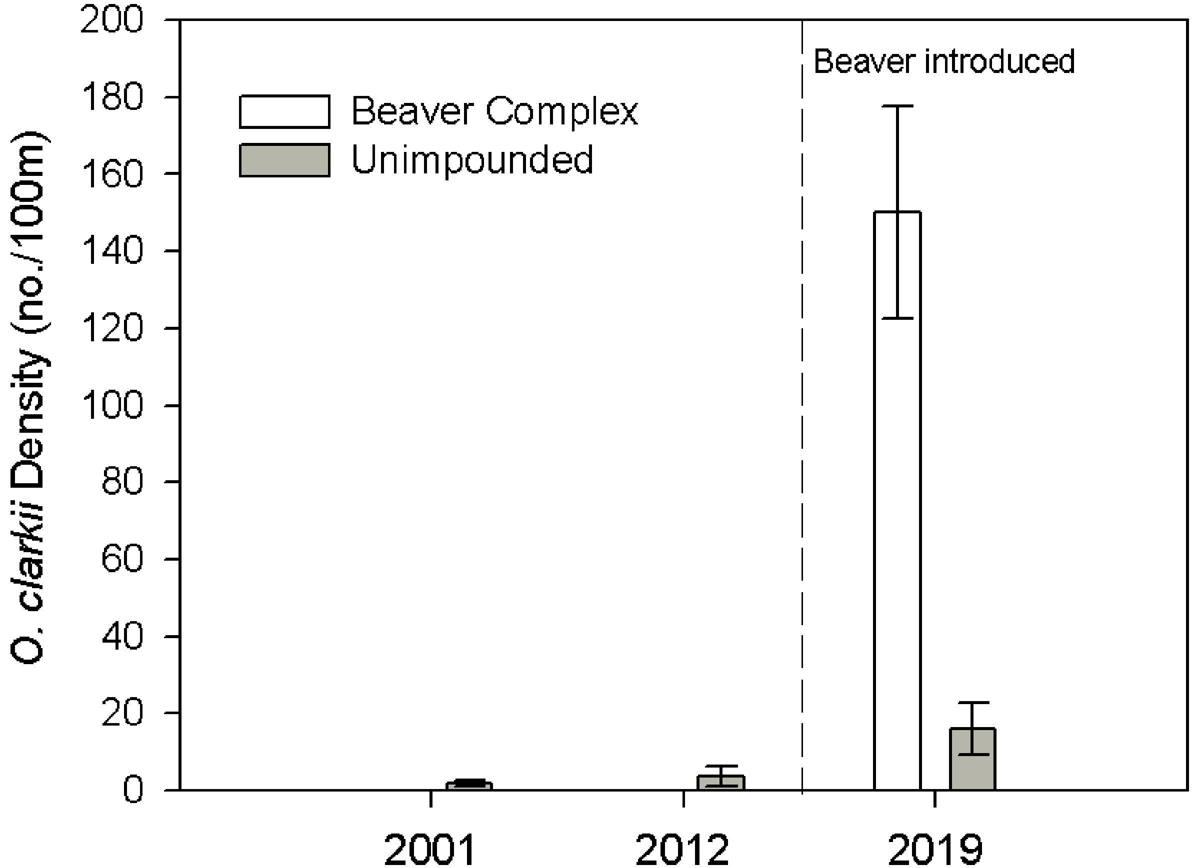
Day Birch Creek goes dry pre- and post-
BDAs/beaver introduction
y = 0.0022x + 150.48
r² = 0.98
Day of year Birch Creek went dry
260
240
220
200
180
160
140
0
10000
20000
30000
40000
50000
Pre-BDA
Pre-BDA Fit
Pre-BDA 95% CI
Cumulative flow in the Blacksmith Fork
May 1 - Aug 15


Day Birch Creek goes dry pre- and post-
BDAs/beaver introduction
Day of year Birch Creek went dry
Cumulative flow in the Blacksmith Fork
May 1 - Aug 15
2015
2016
2017
2018
Pre-BDA
Pre-BDA Fit
Pre-BDA 95% CI
Post-BDA
140
160
180
200
220
240
260
0
10000
20000
30000
40000
50000



Day Birch Creek goes dry pre- and post-
BDAs/beaver introduction
Day of year Birch Creek went dry
Cumulative flow in the Blacksmith Fork
May 1 - Aug 15
100
150
200
250
0
10000
20000
30000
40000
50000
2019
2017
2015
2016
2018
Pre-BDA
Pre-BDA Fit
Pre-BDA 95% CI
Post-BDA
Perennial line

# Cutthroat trout response



# EXAMPLES OF MEANS OBJECTIVES OF LTPBR

- Increase aggradation
- Increase structural and geomorphic complexity
- Increase water storage
- **Increase water quality**
- Increase sedge and riparian production

# CAMPBELL CREEK, OR
# WATER QUALITY

# CAMPBELL CREEK
# WATER QUALITY

| Pesticide | Average (ug/L) | Maximum (ug/L) | AQL (ug/L) | % AQL |
|---|---|---|---|---|
| (RS)-AMPA (Aminomethyl phosphonic acid) | 0.217 | 0.753 | - | - |
| 2,4-D | 0.200 | 0.200 | 299.2 | 0% |
| Azoxystrobin | 0.110 | 0.189 | 44 | 0% |
| Chlorthal monoacid and diacid degradates | 1.000 | 1.000 | - | - |
| Dicamba | 0.500 | 0.500 | 61 | 1% |
| Dimethenamid | 0.375 | 1.300 | 8.9 | 15% |
| Dimethoate | 0.053 | 0.067 | 0.5 | 13% |
| Diuron | 0.033 | 0.084 | 2.4 | 4% |
| Glyphosate | 0.687 | 1.820 | 1800 | 0% |
| Linuron | 0.083 | 0.322 | 0.09 | 358% |
| Metolachlor | 0.049 | 0.049 | 1 | 5% |
| Metribuzin | 0.041 | 0.085 | 8.7 | 1% |
| Metsulfuron-methyl | 0.005 | 0.005 | 0.36 | 1% |
| Prometryn | 0.033 | 0.112 | 1 | 11% |
| Propiconazole | 0.140 | 0.310 | 21 | 1% |
| Sulfometuron methyl | 0.014 | 0.014 | 0.48 | 3% |
| Terbacil | 0.087 | 0.094 | 11 | 1% |

# CAMPBELL CREEK
# CONCEPTUAL MODELS

- **Settling of suspended sediments.**
- Slowing reach-scale water velocity.
- Increasing hyporheic exchange.

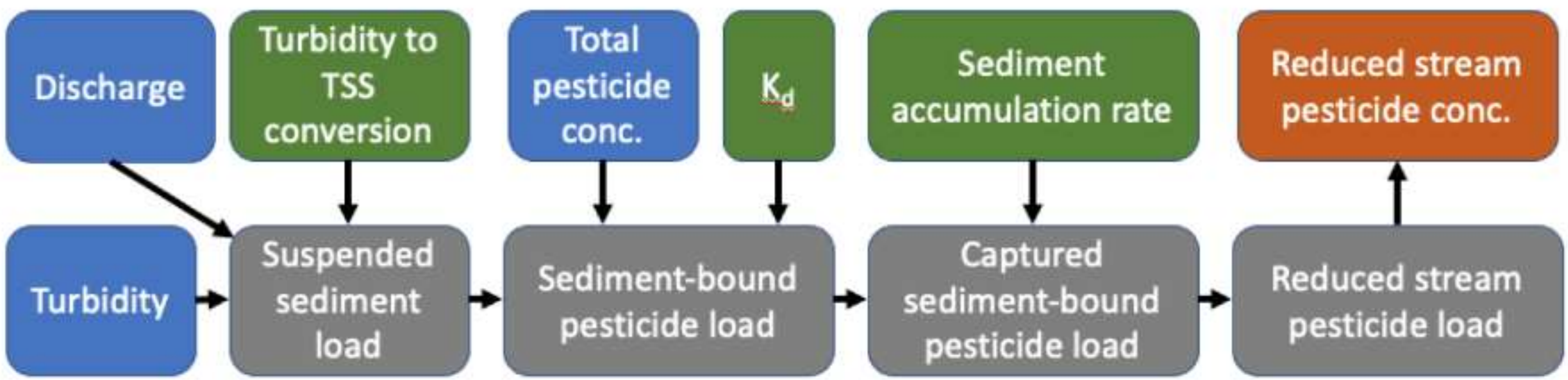



**Figure 3**. Conceptual model of BDA impact on pesticide removal via direct sediment capture. Site data (blue) are combined with literature values or relationships (green) to calculate additional values (gray) and the final performance metric (orange).

# CAMPBELL CREEK
# CONCEPTUAL MODELS

- Settling of suspended sediments.
- **Slowing reach-scale water velocity.**
- Increasing hyporheic exchange.

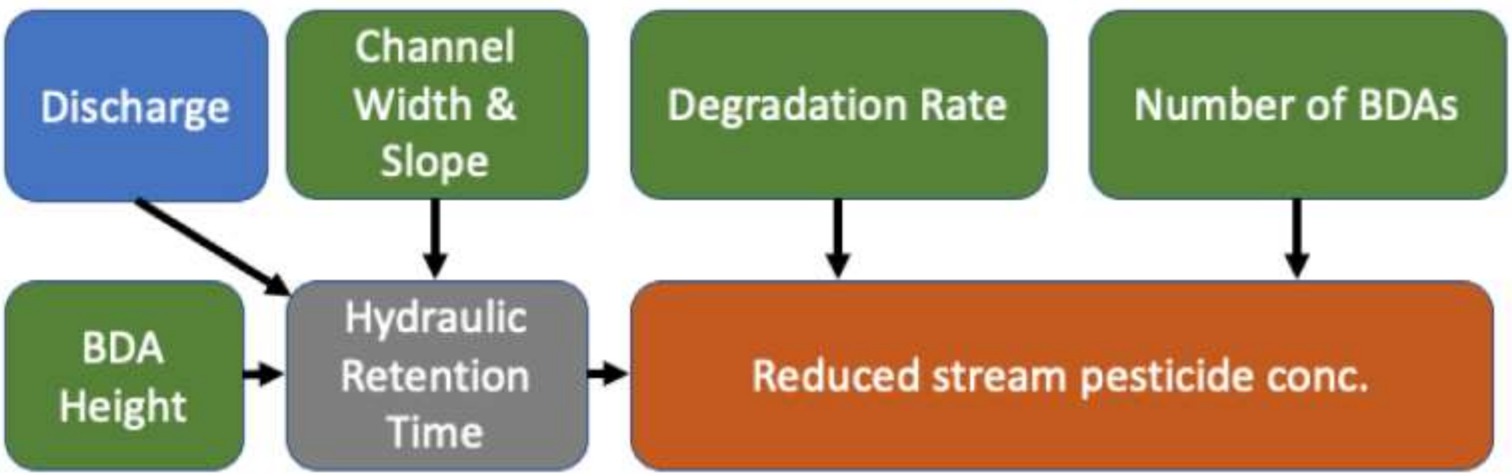



**Figure 4**. Conceptual model of BDA impact on pesticide removal via increased in-stream hydraulic retention time. Site data (blue) are combined with literature values or relationships (green) to calculate additional values (gray) and the final performance metric (orange).

# CAMPBELL CREEK CONCEPTUAL MODELS

- Settling of suspended sediments.
- Slowing reach-scale water velocity.
- **Increasing hyporheic exchange.**

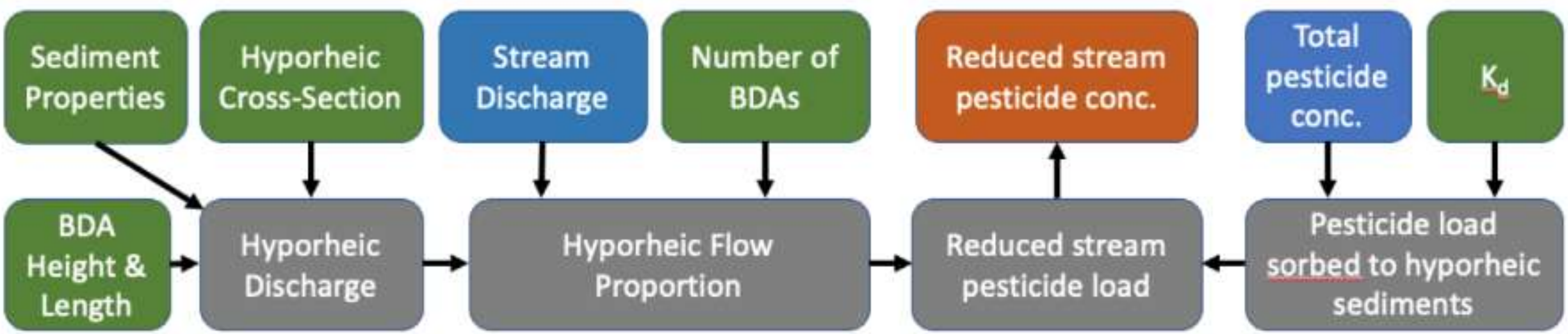



**Figure 5.** Conceptual model of BDA impact on pesticide removal via hyporheic sorption. Site data (blue) are combined with literature values or relationships (green) to calculate additional values (gray) and the final performance metric (orange).

# CAMPBELL CREEK
# WATER QUALITY

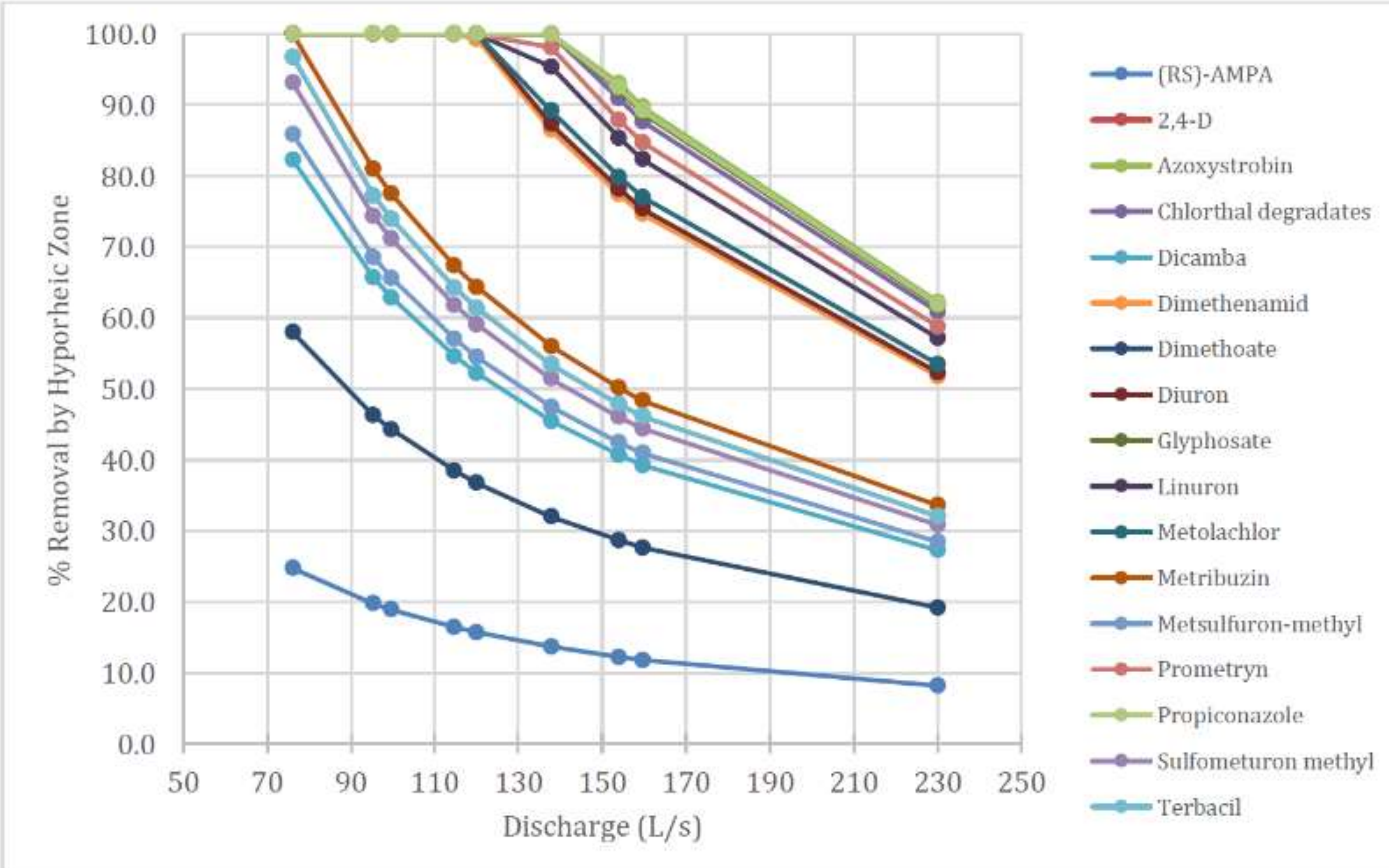


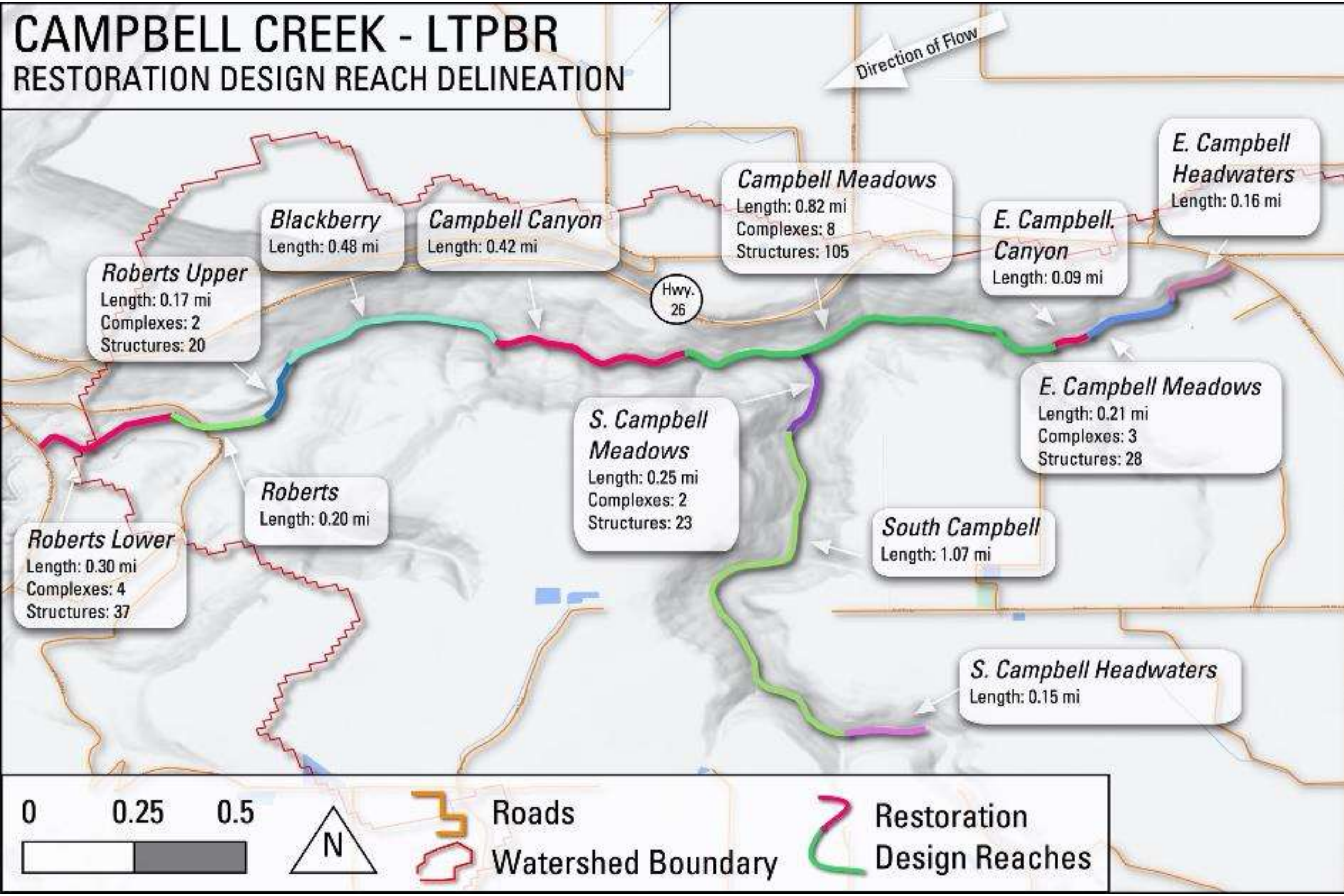

**Figure 6**. Pesticide percent removal by hyporheic exchange across observed stream discharge range. 100 L/s = 0.1 $m^3/s$ = 3.5 cfs.

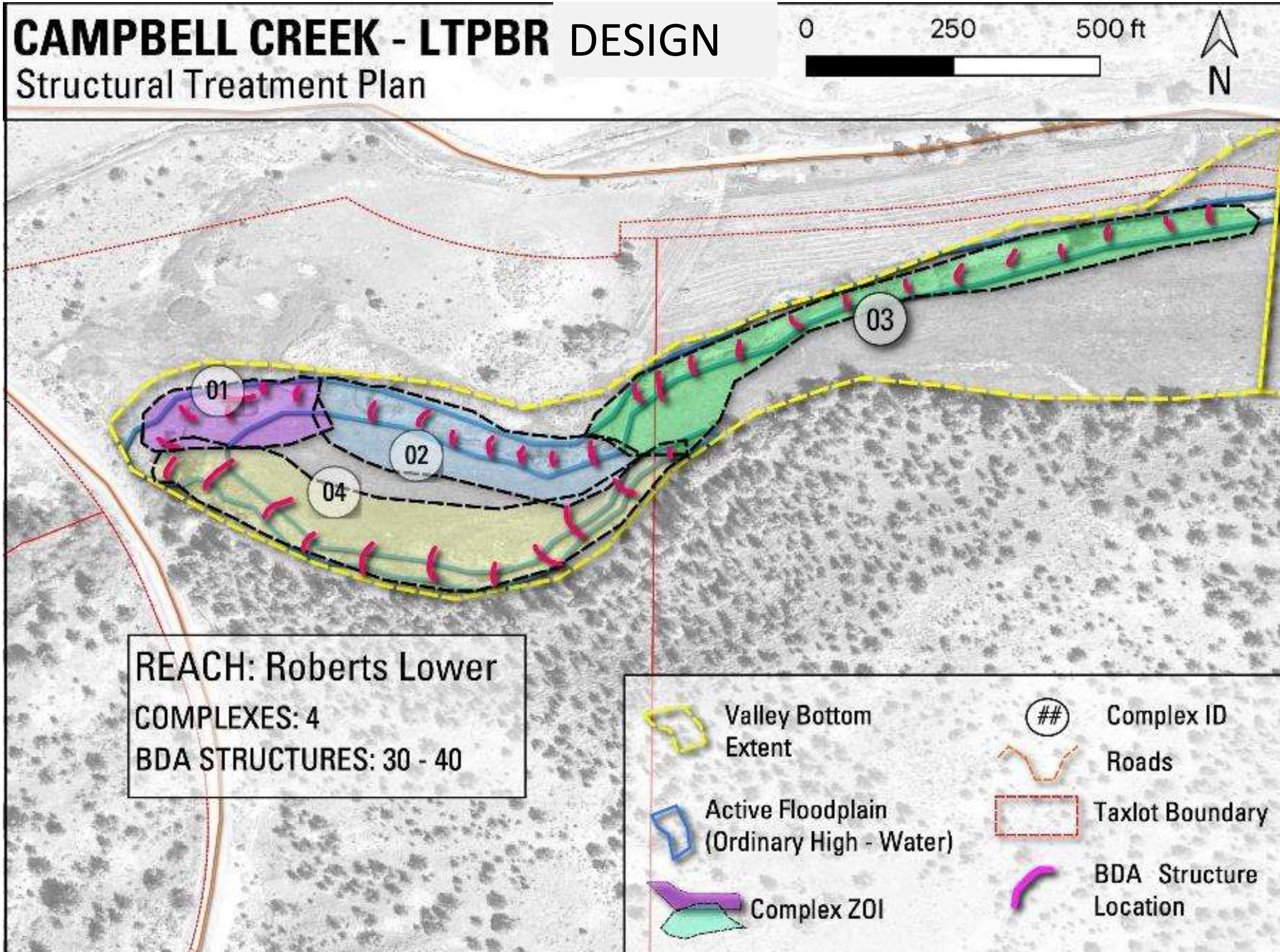
CLEAR CREEK HYDROLOGY, LLC 2021

# CAMPBELL CREEK
## RESTORATION PLAN

*Table 5. Proposed structural treatment phase, flow type, and characteristics of the valley bottom relevant to process based restoration. Limitations to site access are also listed for each restoration reach.*

| REACH | STRUCTURAL TREATMENT PHASE | FLOW TYPE | VALLEY BOTTOM CHARACTERISTICS | VEGETATION | SITE ACCESS |
|---|---|---|---|---|---|
| **ROBERTS LOWER** | Phase 1 | Perennial | Wide valley bottom with some amount of low accessible floodplain and spring fed secondary channel. | Woody riparian vegetation abundant in incised channel. | Vehicle accessible |
| **ROBERTS RESIDENCE** | Untreated | Perennial | Extensive human infrastructural risks limits restoration potential. | Abundant mature woody riparian vegetation. | Vehicle accessible |
| **ROBERTS UPPER** | Phase 1 | Perennial | Confined and simplified channel but potential for large | Largely pasture composed with some large willows. | Vehicle accessible |
| **BLACKBERRY** | Potential Phase 2, 3 | Perennial | Wide channel, pockets of low elevation floodplains. | Dense mature woody riparian vegetation. Extensive blackberry. | Vehicle accessible |
| **CAMPBELL CANYON** | Untreated | Perennial | Highly confined channel, little accommodation space. | Dense mature woody riparian vegetation already acting as source of structure. | Foot access only |


CAMPBELL CREEK - LTPBR
RESTORATION DESIGN REACH DELINEATION
Direction of Flow
E. Campbell Headwaters
Length: 0.16 mi
Campbell Meadows
Length: 0.82 mi
Complexes: 8
Structures: 105
E. Campbell Canyon
Length: 0.09 mi
Blackberry
Length: 0.48 mi
Campbell Canyon
Length: 0.42 mi
Roberts Upper
Length: 0.17 mi
Complexes: 2
Structures: 20
Hwy. 26
E. Campbell Meadows
Length: 0.21 mi
Complexes: 3
Structures: 28
S. Campbell Meadows
Length: 0.25 mi
Complexes: 2
Structures: 23
Roberts
Length: 0.20 mi
South Campbell
Length: 1.07 mi
Roberts Lower
Length: 0.30 mi
Complexes: 4
Structures: 37
S. Campbell Headwaters
Length: 0.15 mi
0
0.25
0.5
N
Roads
Watershed Boundary
Restoration Design Reaches



CAMPBELL CREEK - LTPBR DESIGN
Structural Treatment Plan
0
250
500 ft
N
01
02
03
04
REACH: Roberts Lower
COMPLEXES: 4
BDA STRUCTURES: 30 - 40
Valley Bottom Extent
Active Floodplain (Ordinary High - Water)
Complex ZOI
##
Complex ID
Roads
Taxlot Boundary
BDA Structure Location

# EXAMPLES OF MEANS OBJECTIVES OF LTPBR

- Increase aggradation
- Increase structural and geomorphic complexity
- Increase water storage
- Increase water quality
- **Increase sedge and riparian production**

# Brown Meadow

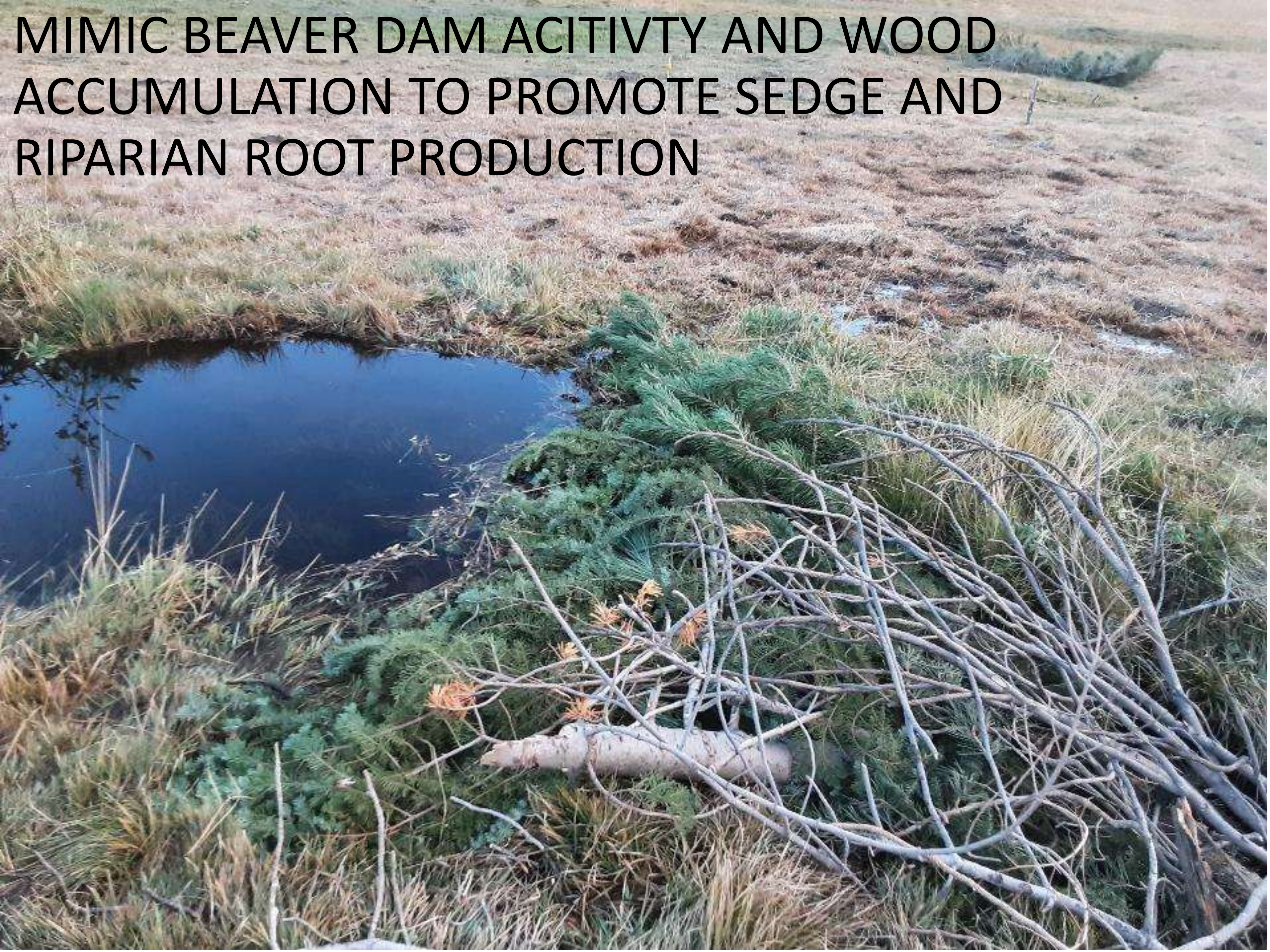
## SEDGE AND RIPARIAN PRODUCTION

# INCISION

PRE-RESTORATION
RECOVERING
INSET
FLOODPLAIN

PRE-RESTORATION SEDGE ROOT MASS AS STRUCTURE

PRE-RESTORATION
SEDGE AS
STRUCTURE


MIMIC BEAVER DAM ACITIVTY AND WOOD ACCUMULATION TO PROMOTE SEDGE AND RIPARIAN ROOT PRODUCTION

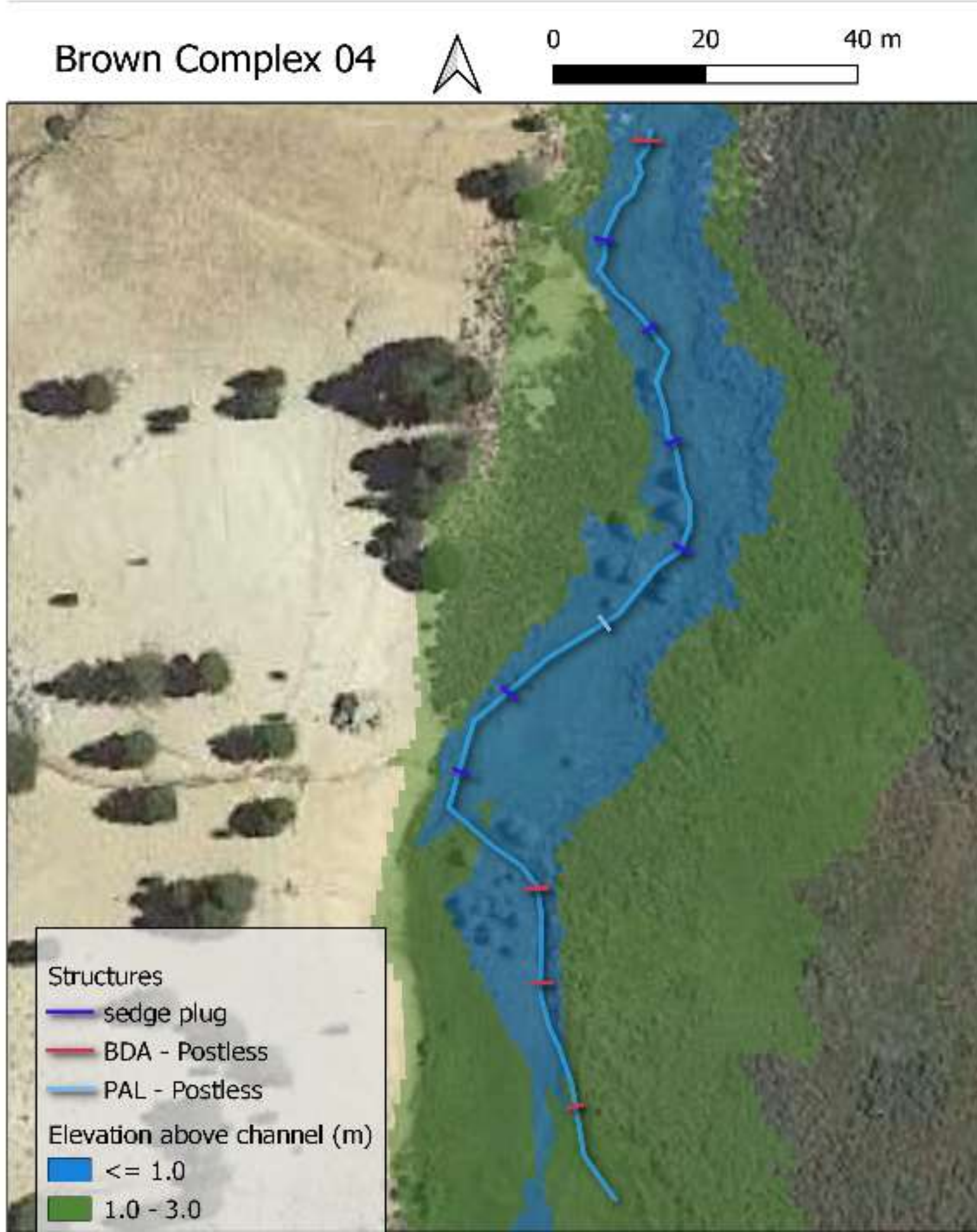
# HABITAT COMPLEXITY FOR AQUATIC SPECIES

| Complex ID | avg. channel depth (m) | avg. channel width (m) | complex length (m) | relief (m) | gradient (%) |
|---|---|---|---|---|---|
| 01 | 0.6 | 2 | 108.3 | 2.24 | 2.1 |
| 02 | 0.6 | 2 | 74.9 | 1.71 | 2.3 |
| 03 | 0.45 | 1 | 189.9 | 2.44 | 1.3 |
| 04 | 0.3 | 2 | 173.3 | 3.23 | 1.9 |
| 05 | 0.3 | 0 | 54.1 | 1.04 | 1.9 |
| 06 | 0.5 | 1 | 167.6 | 3.32 | 2.0 |
| 07 | 0.5 | 1 | 51 | 0.92 | 1.8 |
| 08 | 0.5 | 1.25 | 25.7 | 0.88 | 3.4 |
| 09 | 0.3 | 3 | 32.7 | 0.56 | 1.7 |
| 10 | 0.6 | 1 | 19.7 | 0.5 | 2.5 |
| 11 | 0.5 | 1 | 238.3 | 4.12 | 1.7 |
| 12 | 0.3 | 1 | 20.4 | 0.94 | 4.6 |
| 13 | 0.3 | 5 | 43.4 | 0.94 | 2.2 |
| 14 | 0.5 | 2 | 25.2 | 0.32 | 1.3 |
| 15 | 0.4 | 1.25 | 38.4 | 0.59 | 1.5 |
| 16 | 0.5 | 1 | 40.9 | 0.94 | 2.3 |
| 17 | 0.5 | 1 | 145.9 | 2.54 | 1.7 |
| 18 | 0.75 | 1.5 | 185.2 | 4.48 | 2.4 |
| 19 | 0.9 | 5 | 128.5 | 2.36 | 1.8 |
| 20 | 1.25 | 3 | 27.2 | 0.77 | 2.8 |
| 21 | 0.5 | 2 | 193.7 | 5.07 | 2.6 |
| 22 | 1 | 4 | 45.9 | 1.14 | 2.5 |
| 23 | 0.5 | 1 | 20 | 0.5 | 2.5 |
| 24 | 0.75 | 1.5 | 25.1 | 1.59 | 6.3 |
| 25 | 1 | 3 | 49.6 | 0.79 | 1.6 |
| 26 | 0.3 | 0.75 | 43.3 | 1.1 | 2.5 |
| 27 | 2 | 8 | 113.5 | 2.47 | 2.2 |

| Complex | no. of structures | structure spacing | avg. structure volume ($m^3$) | total complex volume ($m^3$) | ZOI ≤1.0 ($m^2$) | ZOI 1.0-3.0 ($m^2$) | Complex Objectives |
|---|---|---|---|---|---|---|---|
| 01 | 4 | 27.1 | 0.8 | 3.2 | 1403 | 2943 | A, LC/PH |
| 02 | 3 | 25.0 | 0.8 | 2.4 | 1160 | 2791 | LC/PH, A |
| 03 | 5 | 38.0 | 0.2 | 0.8 | 3455 | 7694 | LC/PH, A |
| 04 | 11 | 15.8 | 0.4 | 4.4 | 2395 | 7320 | LC/PH |
| 05 | 3 | 18.0 | 0.1 | 0.3 | 970 | 2601 | LC/PH |
| 06 | 7 | 23.9 | 0.2 | 1.2 | 2469 | 5773 | LC/PH, A |
| 07 | 2 | 25.5 | 0.2 | 0.3 | 748 | 1901 | A, LC/PH |
| 08 | 2 | 12.9 | 0.3 | 0.5 | 398 | 1050 | LC/PH, A |
| 09 | 2 | 16.4 | 0.9 | 1.8 | 516 | 1556 | A, LC/PH |
| 10 | 1 | 19.7 | 0.2 | 0.2 | 208 | 1145 | LC/PH |
| 11 | 8 | 29.8 | 0.2 | 1.3 | 3481 | 10188 | A, LC/PH |
| 12 | 3 | 6.8 | 0.1 | 0.3 | 38 | 236 | LC/PH*, A |
| 13 | 3 | 14.5 | 2.5 | 7.5 | 411 | 1084 | LC/PH*, A |
| 14 | 1 | 25.2 | 0.7 | 0.7 | 229 | 291 | LC/PH |
| 15 | 1 | 38.4 | 0.2 | 0.2 | 356 | 1314 | A, LC/PH |
| 16 | 2 | 20.5 | 0.2 | 0.3 | 620 | 2028 | LC/PH, A |
| 17 | 5 | 29.2 | 0.2 | 0.8 | 2010 | 6002 | SR, W |
| 18 | 6 | 30.9 | 0.6 | 3.4 | 2255 | 6304 | SR, W |
| 19 | 3 | 42.8 | 7.5 | 22.5 | 3376 | 8719 | A*, W |
| 20 | 1 | 27.2 | 3.8 | 3.8 | 120 | 408 | A* |
| 21 | 10 | 19.4 | 0.7 | 6.7 | 4397 | 9020 | A*, LC/PH |
| 22 | 1 | 45.9 | 5.3 | 5.3 | 415 | 1053 | A* |
| 23 | 1 | 20.0 | 0.2 | 0.2 | 68 | 213 | A* |
| 24 | 2 | 12.6 | 0.6 | 1.1 | 85 | 600 | A* |
| 25 | 1 | 49.6 | 3.0 | 3.0 | 616 | 3413 | A |
| 26 | 4 | 10.8 | 0.1 | 0.2 | 564 | 2197 | A |
| 27 | 1 | 113.5 | 0.4 | 0.4 | 1084 | 4578 | SR, W |

*Complex objectives (SR=Sediment Recruitment, W=Widening, A=Aggradation, LC/PH=Lateral Connectivity/Pool Habitat) with the primary objective listed first. *includes headcut mitigation.*

# BROWN MEADOW DESIGN ZOI



Brown Meadow
01
02
05
06
08
10
11
15
16
17
18
19
20
21
23
26

# CONCLUSIONS

- Many streams are structurally starved and disconnected from their floodplain
- Structure and connected floodplains provide many ecosystem services
- LTPBR mimics, promote, and sustain processes of beaver dam building activity, wood accumulation, and vegetation production
- Let's keep documenting either through monitoring or adaptive management the benefits LTPBR provides

ANABRANCH SOLUTIONS
ALTERNATIVE WAYS TO RESTORE RIVERS

TROUT UNLIMITED

Process Based Restoration
LOW-TECH

Eco Logical Research

UtahStateUniversity
RESTORATION CONSORTIUM

NOAA

# Four Criteria for Process-based Restoration of Streams

**Damion Ciotti**
**U.S. Fish and Wildlife Service**

Jared McKee, Karen L. Pope, G. Mathias Kondolf, and Michael M. Pollock

# Restoration Design Criteria

***What will the project achieve? (Performance Criteria)***

***How will it be undertaken? (Prescriptive Criteria)***

Infrastructure  -  Civil Engineering

Form-based Restoration– Geomorphology/Civil engineering

Process-based Restoration – Ecology/Ecological Engineering

# Process-based Design Criteria

## Based on Ecological Science and Ecological Engineering Fundamentals

*Space + Energy + Materials + Time = Ecological Recovery*

Open **SPACE** and connectivity

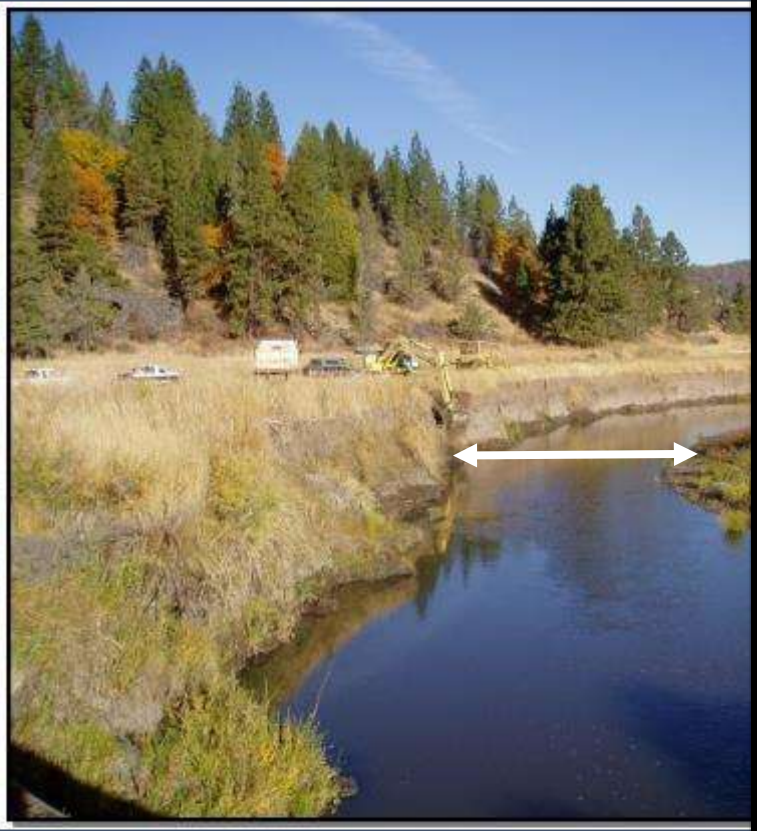
Capitalize on natural **ENERGY**

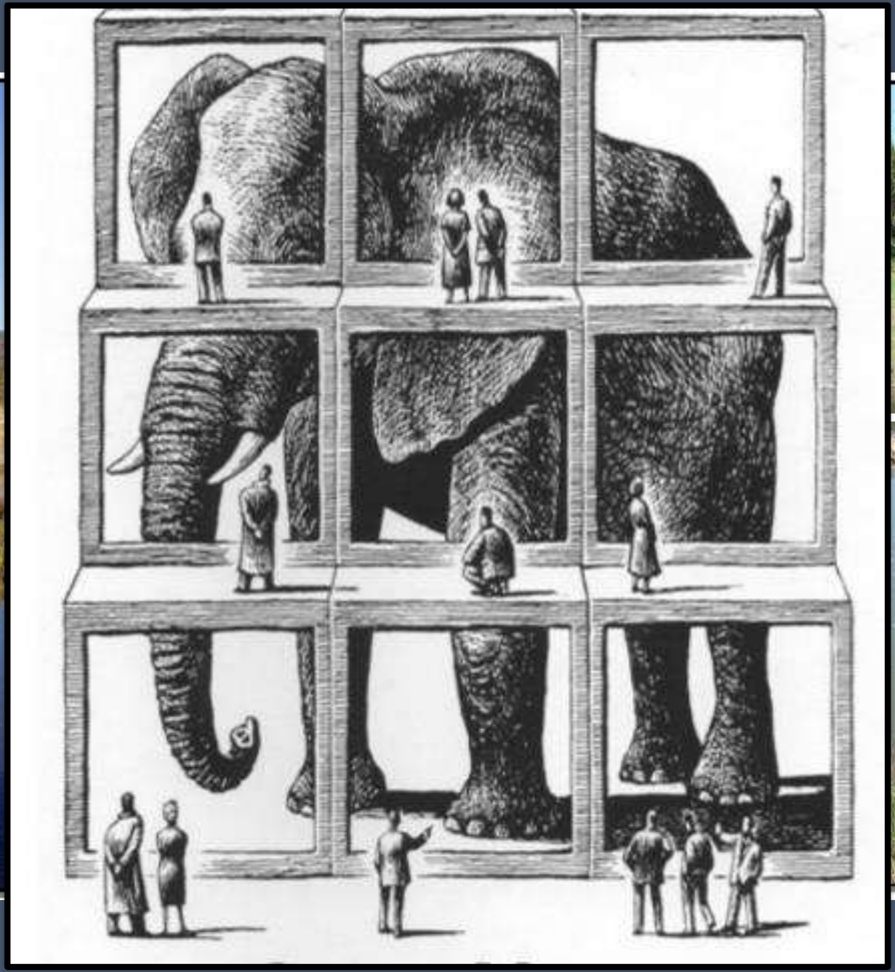
Use natural site **MATERIALS**

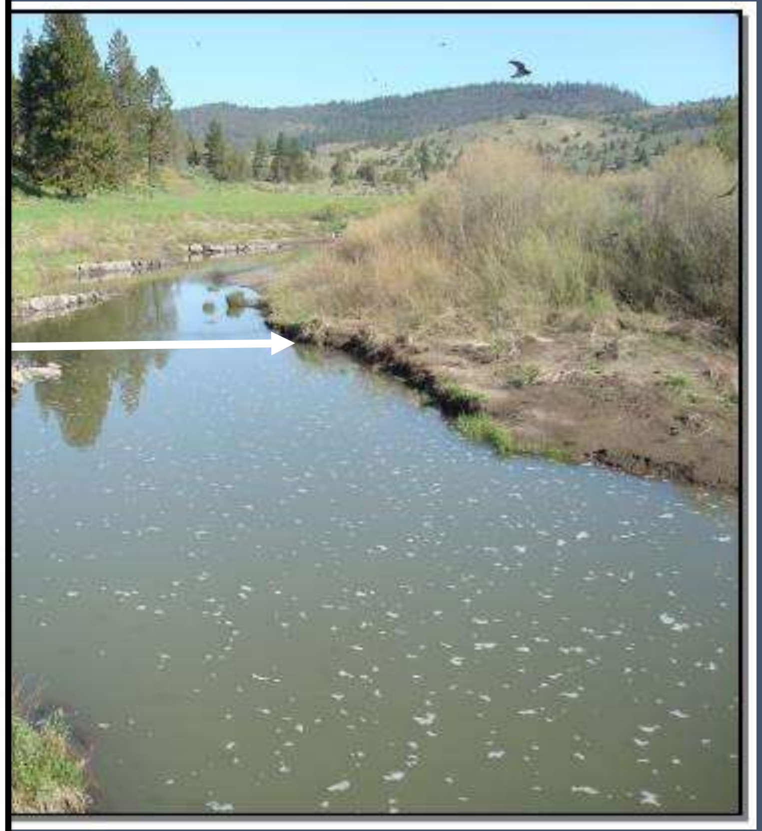
Work adaptively with nature over **TIME**

Form-based Construction

What will the project accomplish? Stabilize a bank and channel



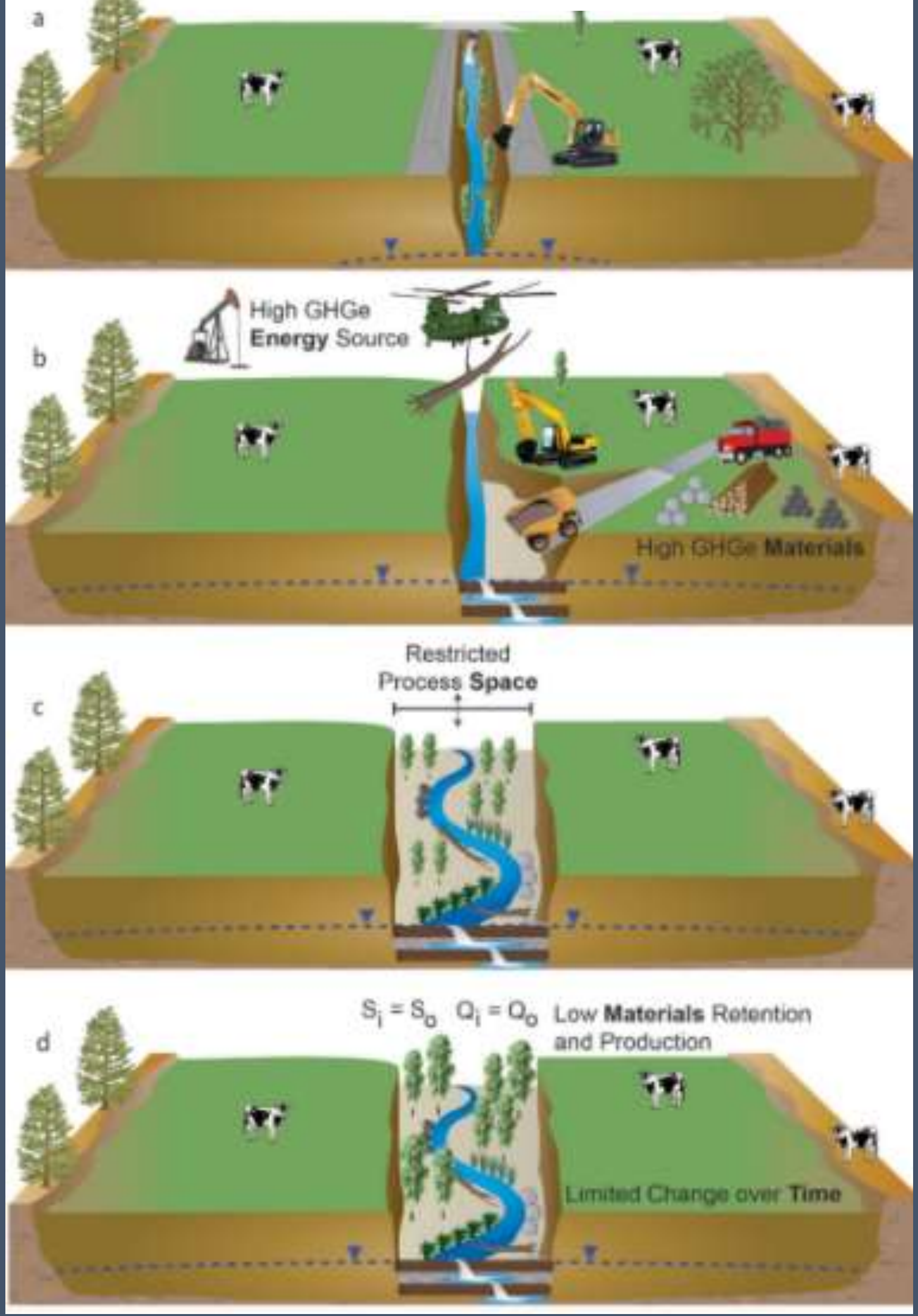




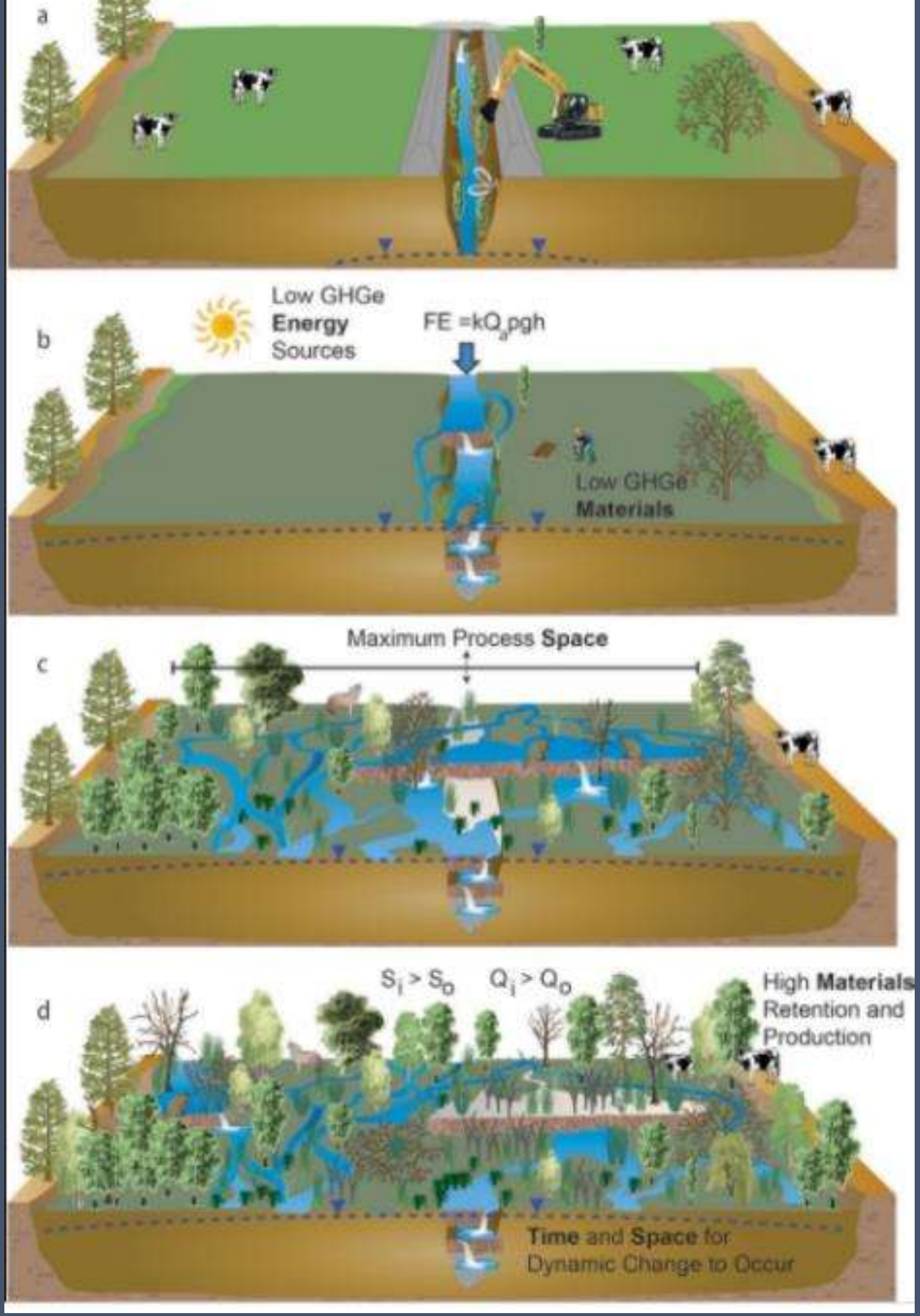
How will project be undertaken? Heavy equipment and rock

# Process-based project – Use natural power and open space

## Form-based Restoration



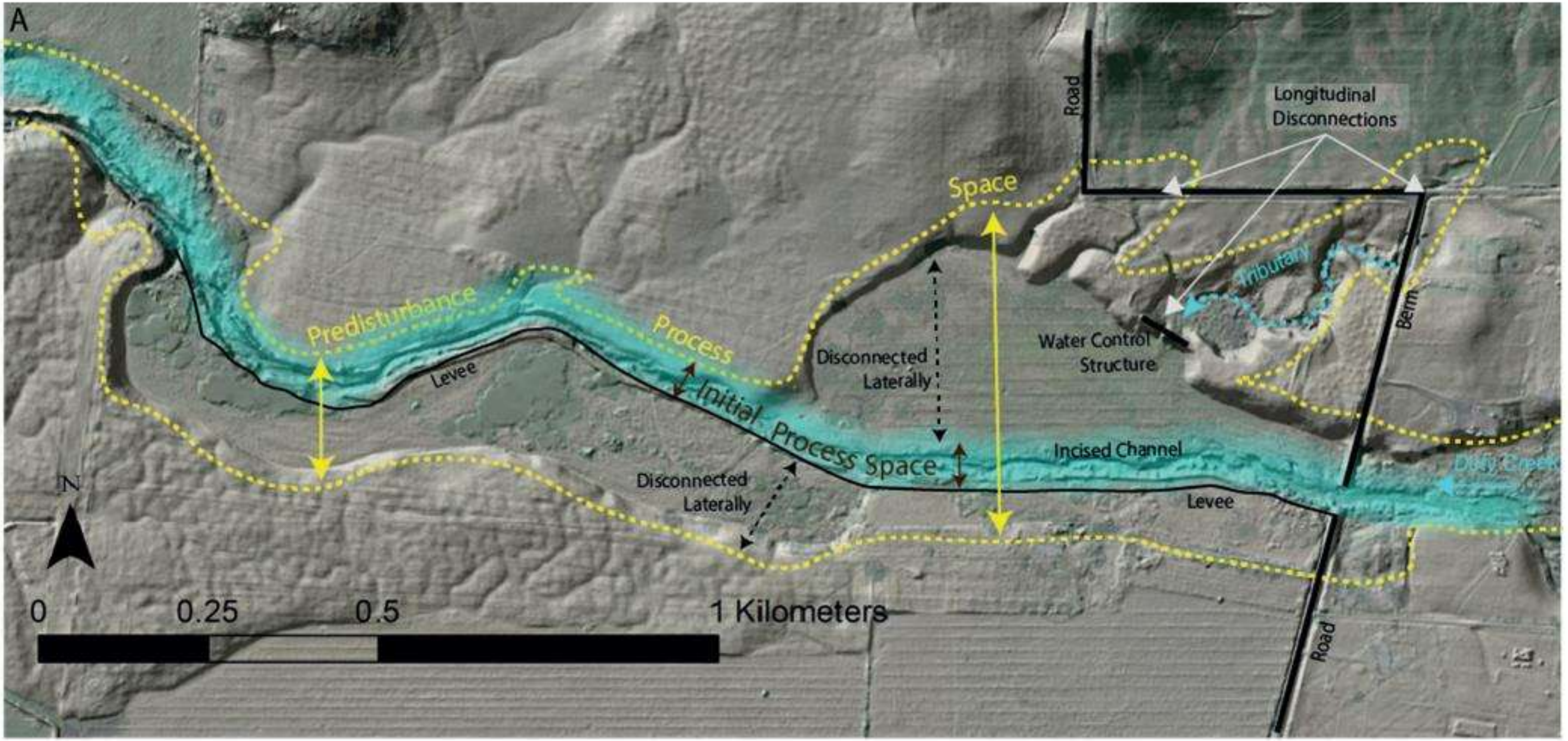

## Process-based Restoration



# Space: Project actions increase the spatial extent of fluvial processes and connectivity lost due to human alterations

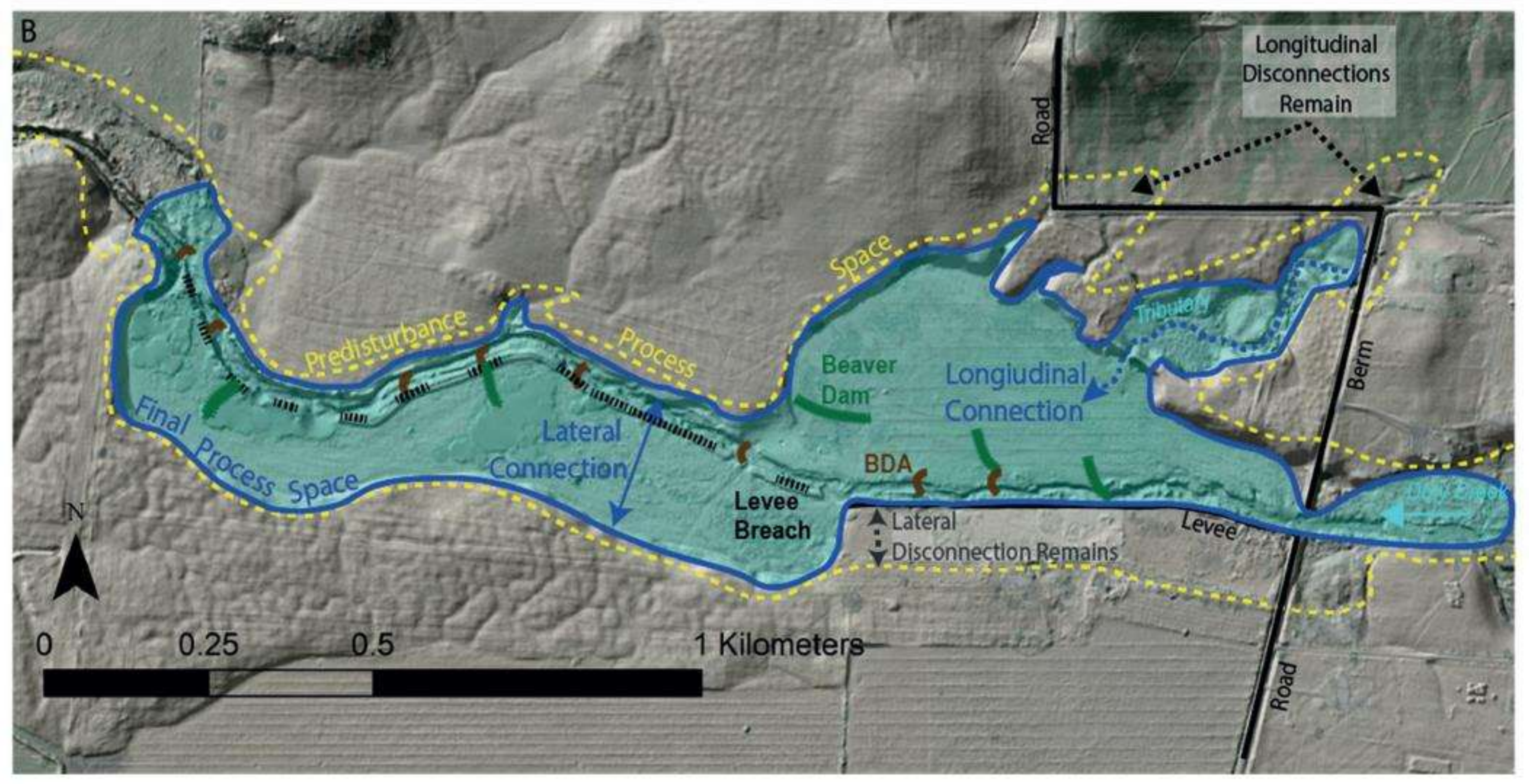

# Space

Starting Process Space 7 acres
Available Process Space 67 acres



# Space

Final project process space 57 acres



# Energy: Project actions capitalize on natural energy within the system to do the work of restoration and minimize the use of external mechanical energy

**Geomorphic work**

Fluvial Energy (Flood pulse)

Solar Energy (Primary production)

**Biological work**

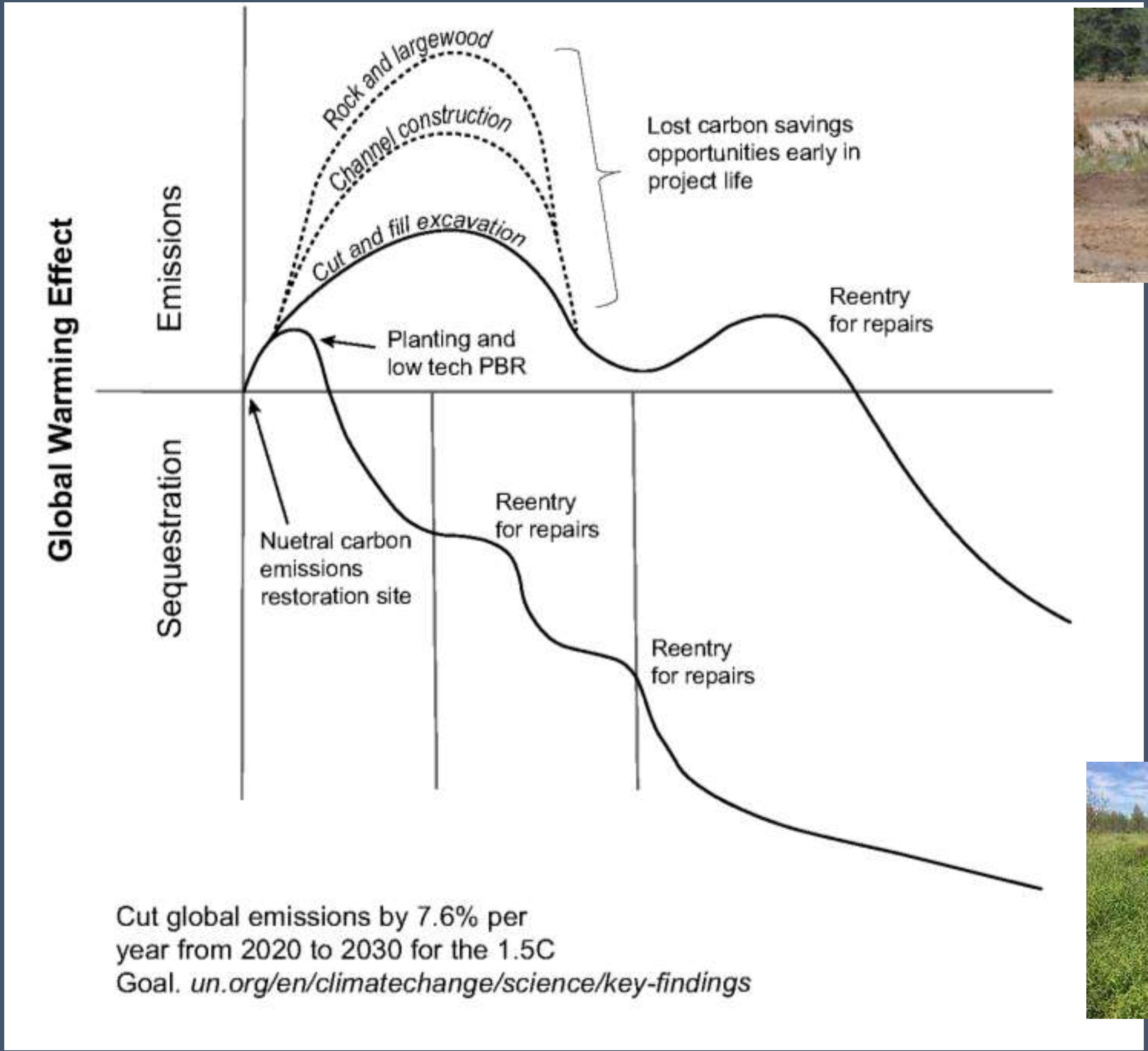
Biological Energy (Beaver, willow, wolves)

**Ecological Engineering**

Self design, energy efficiency, accelerate process, mimicry
(HT Odum; Pollock et al., 2014; Wheaton et al. 2018)

# Energy

2 yr flood event = 21 backhoe days of energy
7.2 tons of carbon.
(McKee et al. 2019 in review)



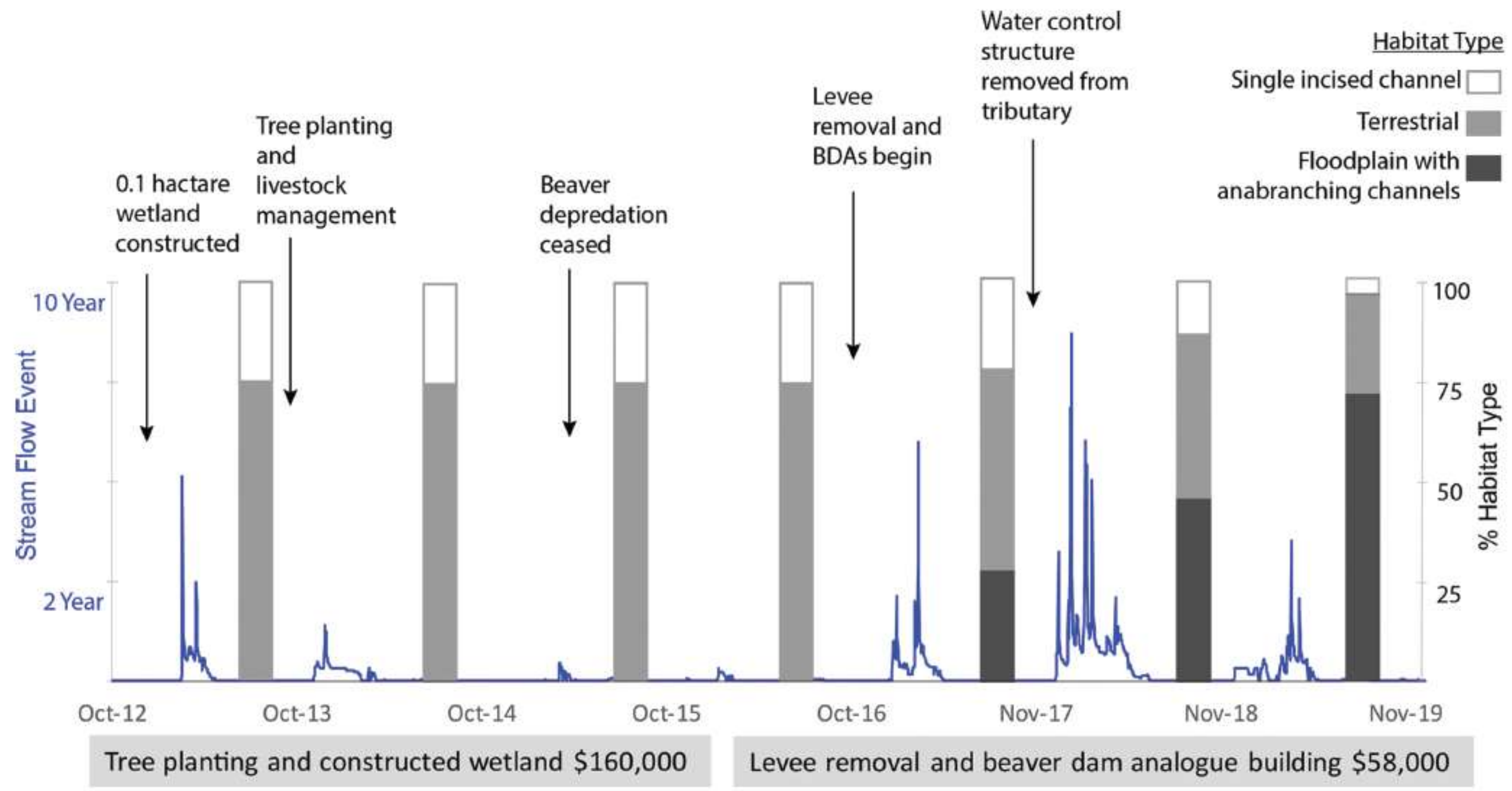

# Reducing the Restoration Project Carbon Footprint

# Materials: Do not over-stabilize project elements or unnaturally constrain channel migration. (Native and geomorphically appropriate)



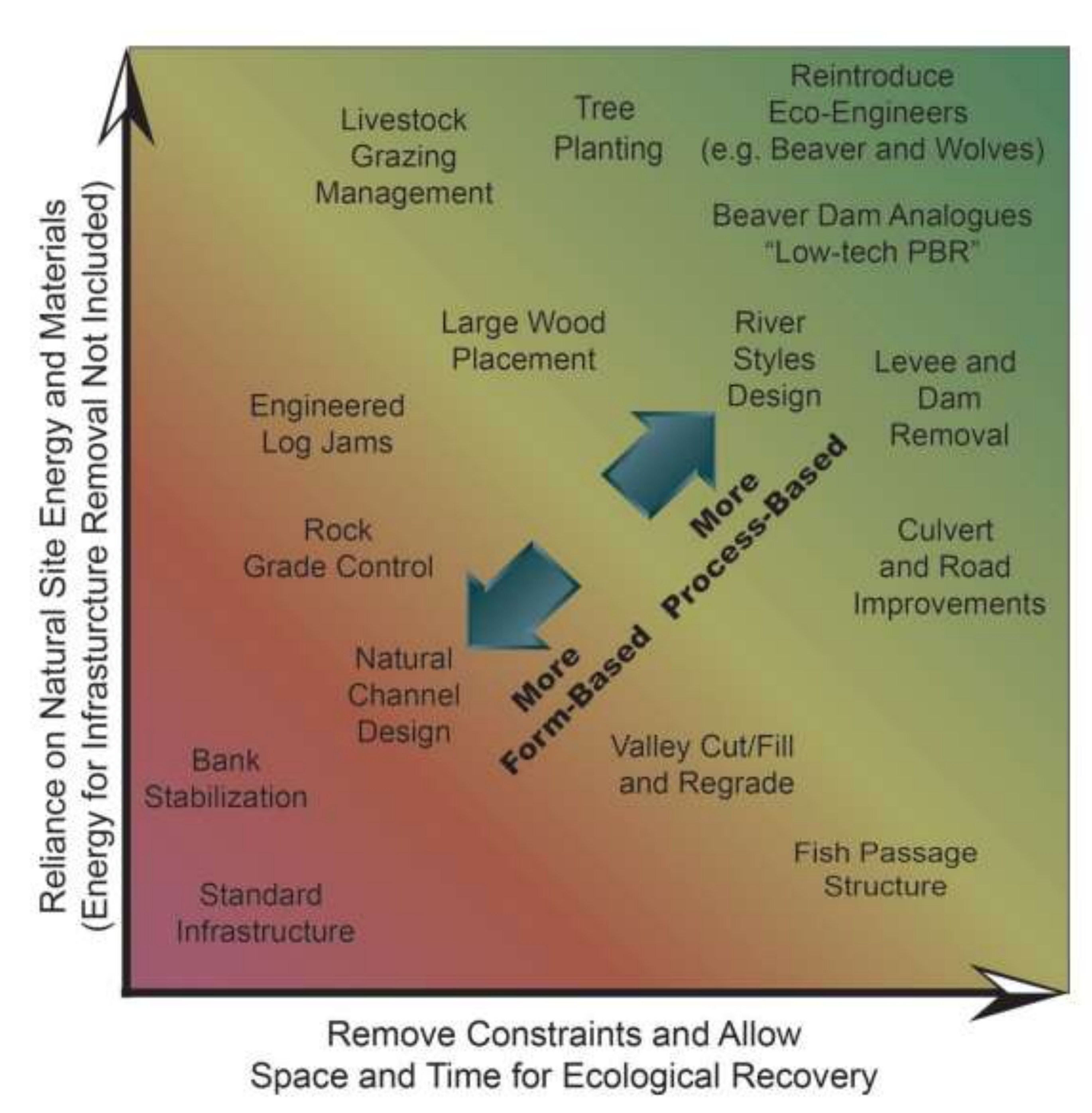


# Time: Achieve habitat objectives over time via restored geomorphic and biologic processes



0.1 hactare wetland constructed
Tree planting and livestock management
Beaver depredation ceased
Levee removal and BDAs begin
Water control structure removed from tributary
Habitat Type
Single incised channel
Terrestrial
Floodplain with anabranching channels
10 Year
2 Year
Stream Flow Event
100
75
50
25
% Habitat Type
Oct-12
Oct-13
Oct-14
Oct-15
Oct-16
Nov-17
Nov-18
Nov-19
Tree planting and constructed wetland $160,000
Levee removal and beaver dam analogue building $58,000


JCB
Permitting

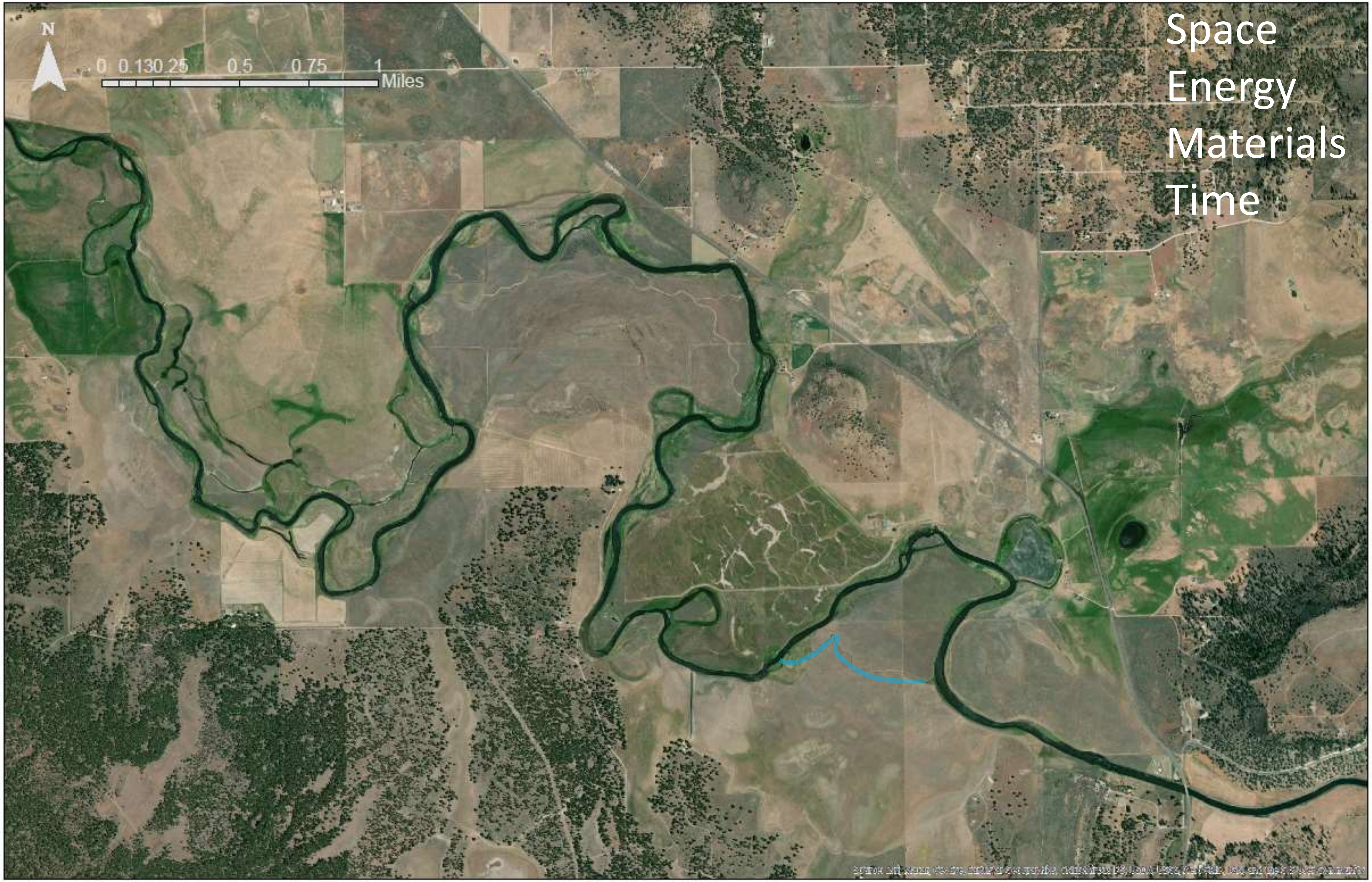


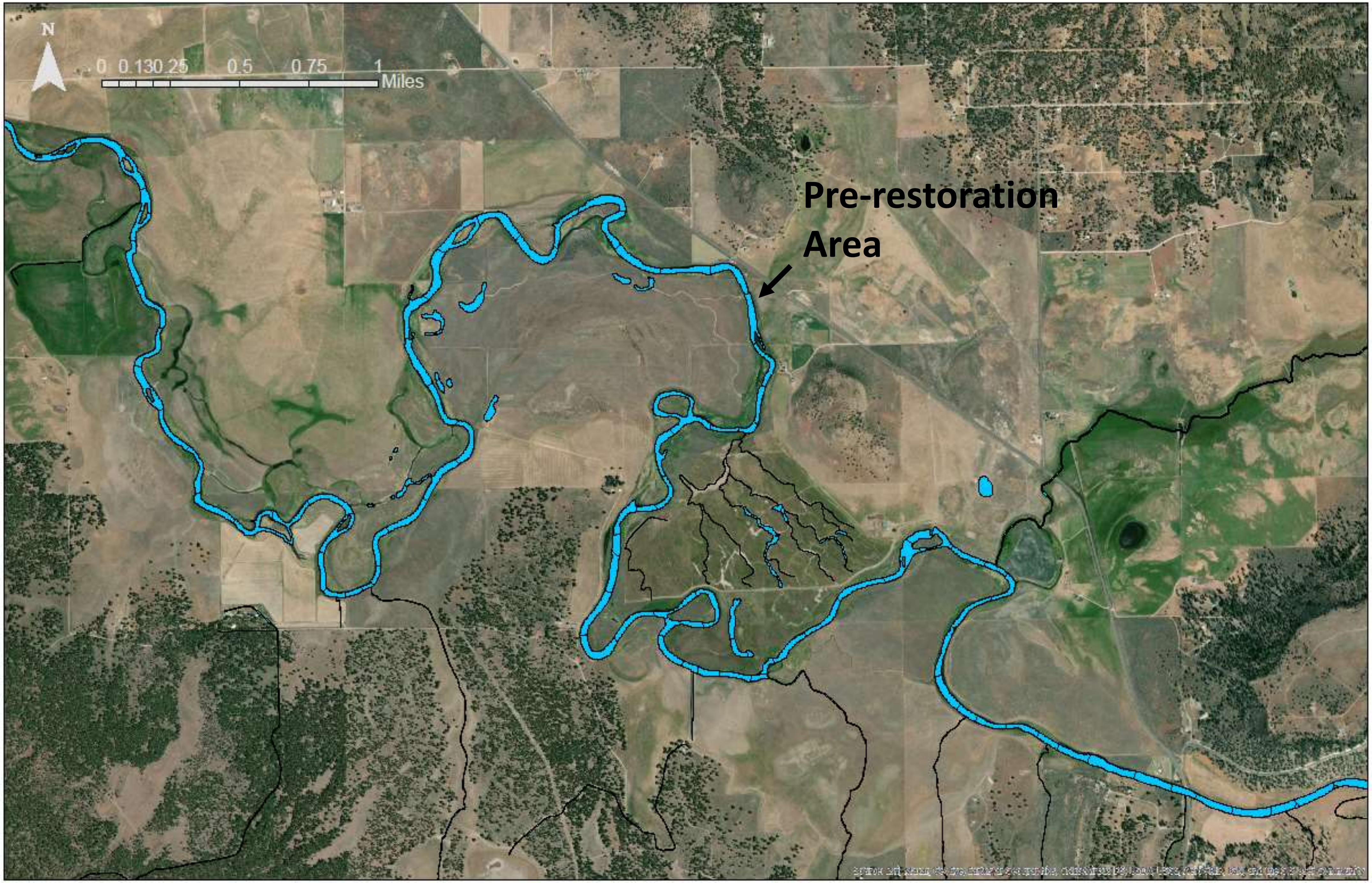
Reliance on Natural Site Energy and Materials
(Energy for Infrastructure Removal Not Included)
Livestock Grazing Management
Tree Planting
Reintroduce Eco-Engineers (e.g. Beaver and Wolves)
Beaver Dam Analogues "Low-tech PBR"
Large Wood Placement
River Styles Design
Levee and Dam Removal
Engineered Log Jams
More Process-Based
Rock Grade Control
Culvert and Road Improvements
Natural Channel Design
More Form-Based
Bank Stabilization
Valley Cut/Fill and Regrade
Fish Passage Structure
Standard Infrastructure
Remove Constraints and Allow
Space and Time for Ecological Recovery

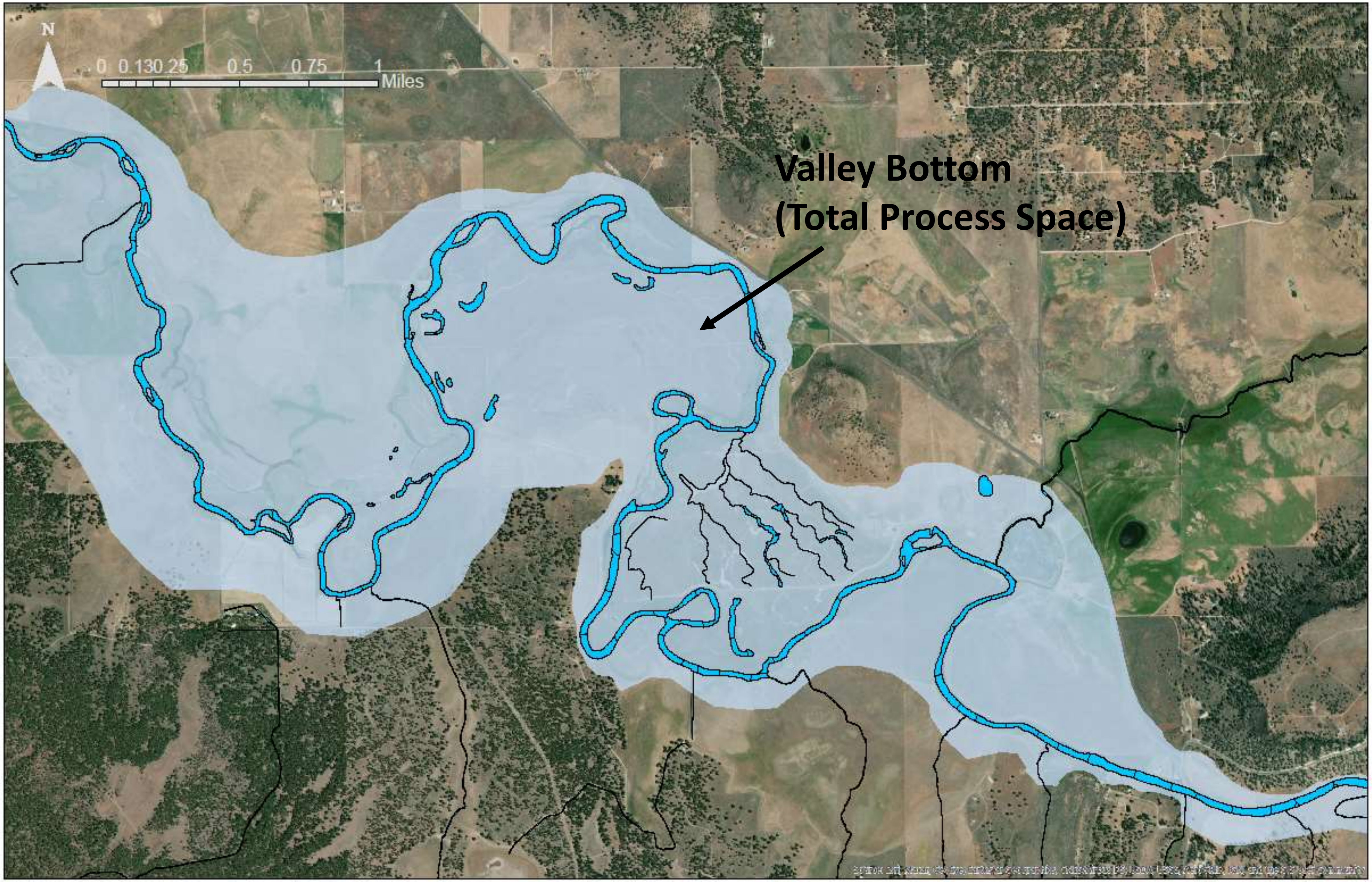
# Process-based Restoration Planning at the Basin Scale

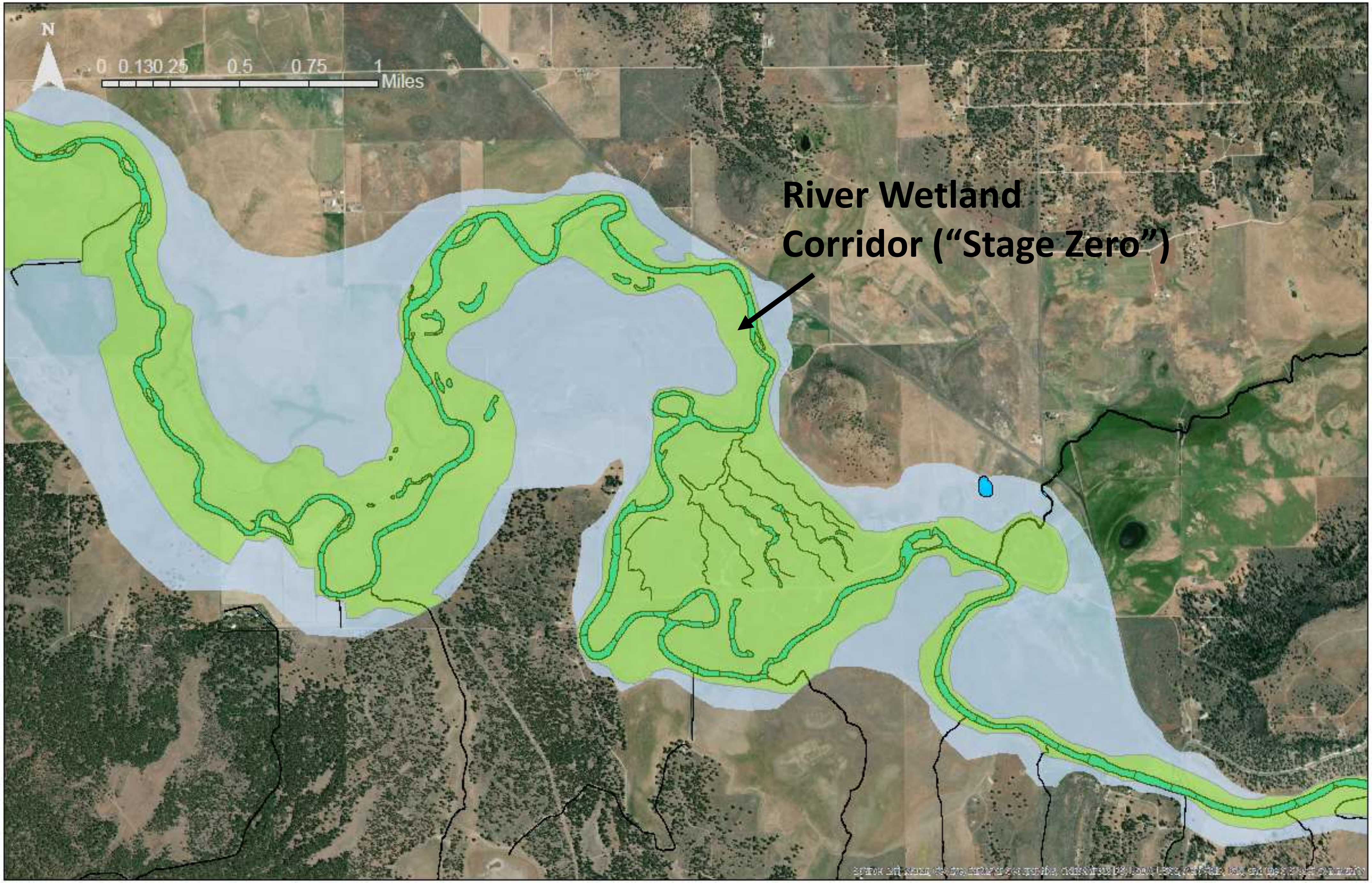
## Sprague River, OR

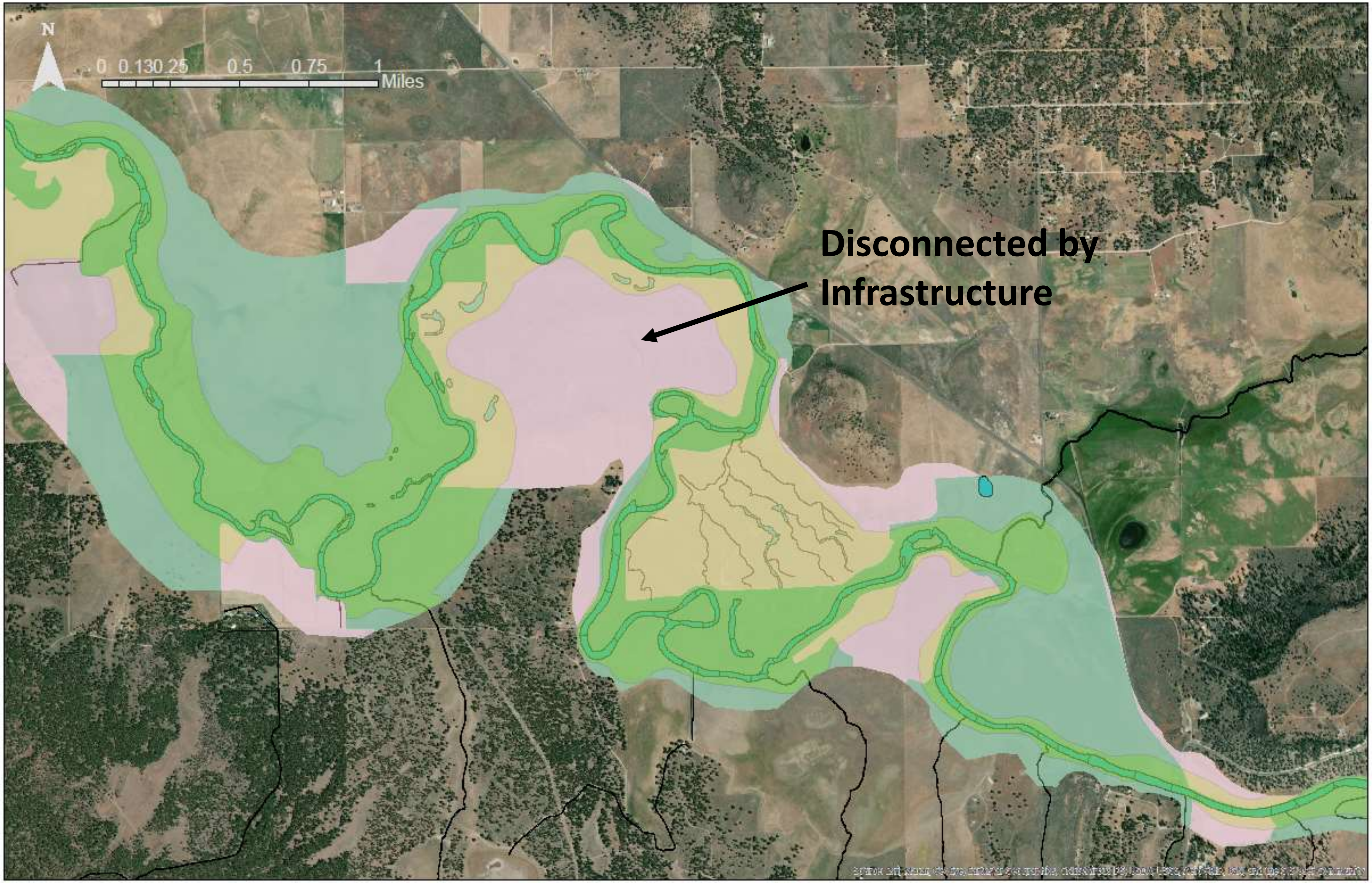
- Space
- Energy
- Materials
- Time

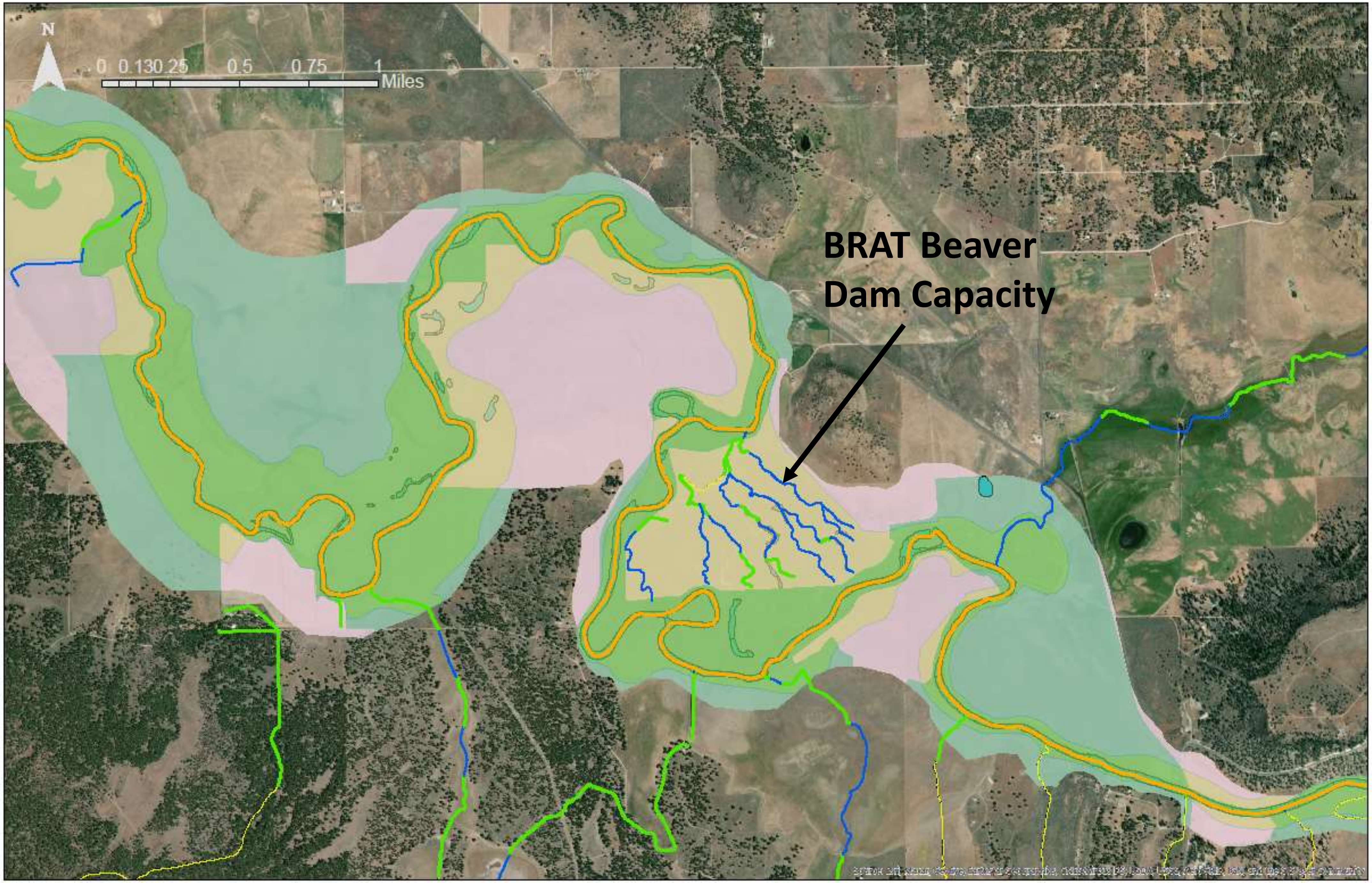

N
0 0.130.25 0.5 0.75 1
Miles
Space
Energy
Materials
Time

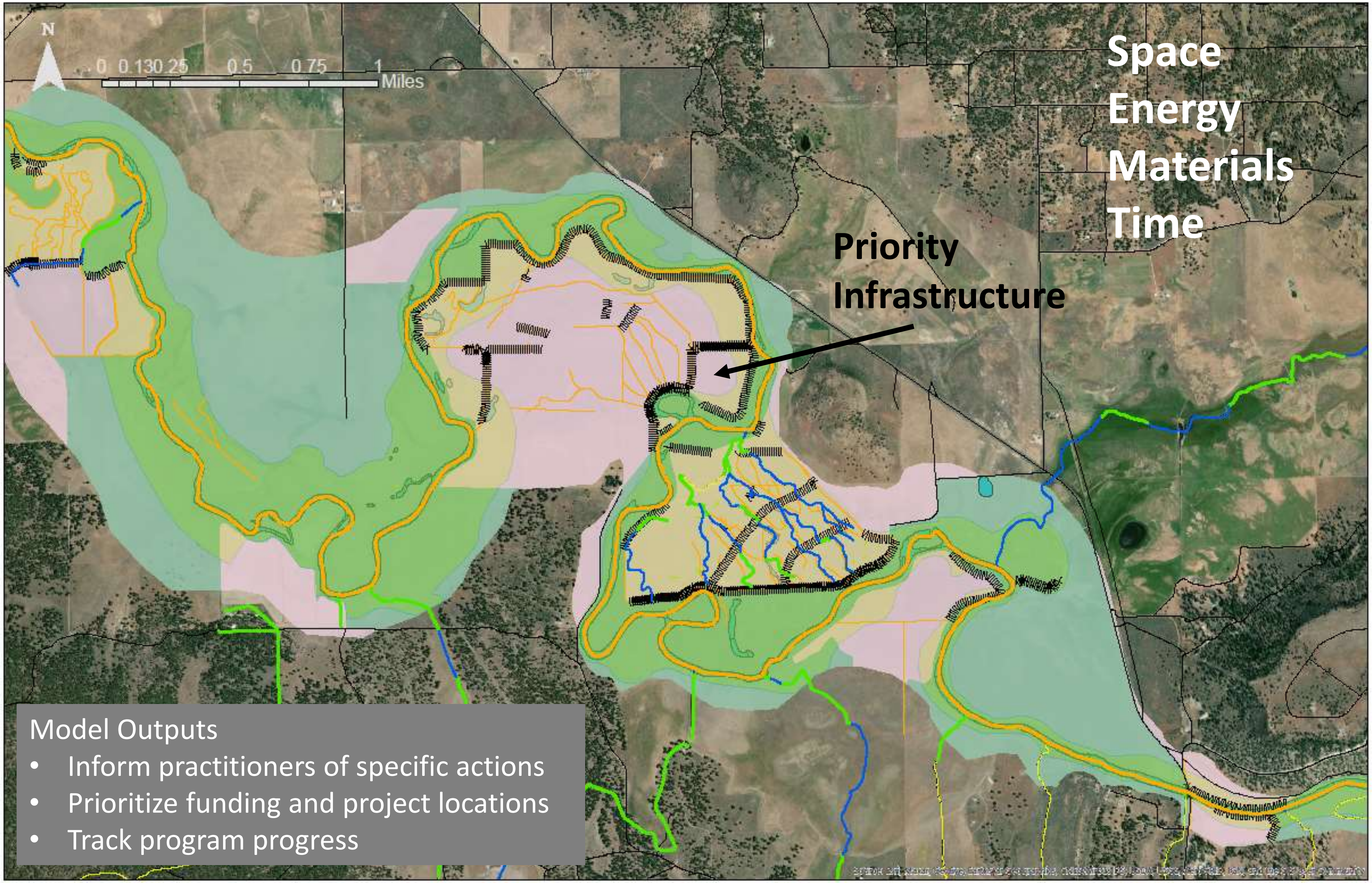

N
0 0.13 0.25 0.5 0.75 1
Miles
Pre-restoration
Area


N
0 0.13 0.25 0.5 0.75 1
Miles
Valley Bottom
(Total Process Space)


N
0 0.130.25 0.5 0.75 1
Miles
River Wetland
Corridor ("Stage Zero")

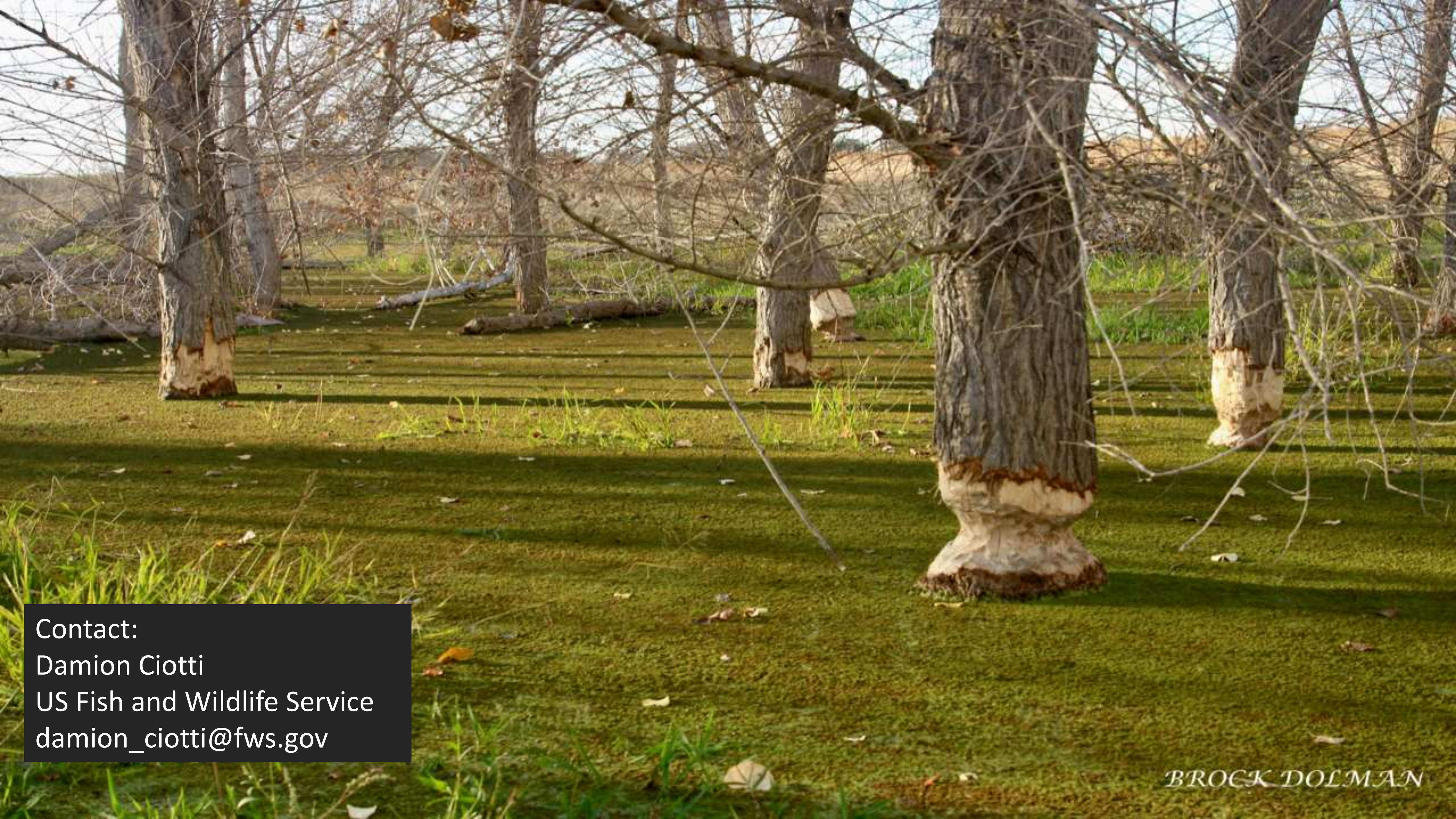

N
0 0.13 0.25 0.5 0.75 1
Miles
Disconnected by Infrastructure


N
0 0.130.25 0.5 0.75 1
Miles
BRAT Beaver
Dam Capacity




Model Outputs

- Inform practitioners of specific actions
- Prioritize funding and project locations
- Track program progress




Contact:
Damion Ciotti
US Fish and Wildlife Service
damion_ciotti@fws.gov

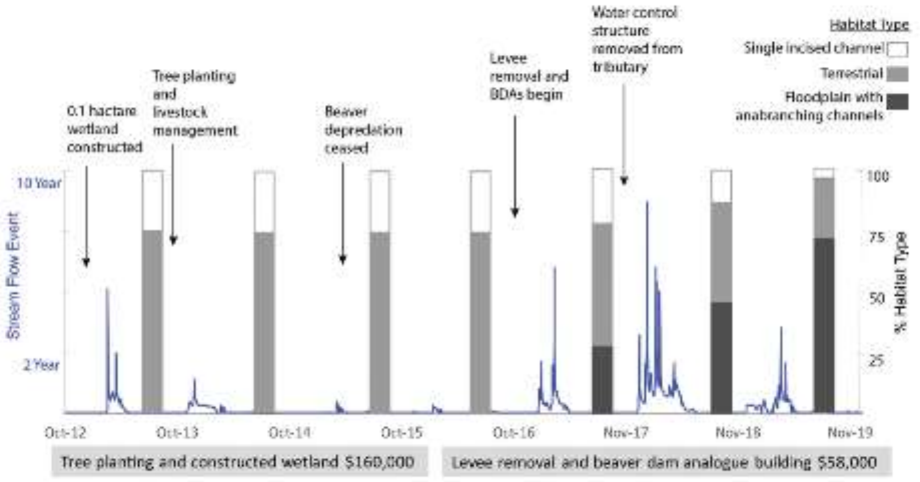



*Figure 7. Assessment of restoration actions for the Doty Ravine project by observing habitat change along the hydrograph from October 2012 to November 2019. Initial restoration attempts (wetland construction and irrigated tree planting) were costly and did not restore fluvial process. Later, process-based restoration actions resulted in dynamic changes in habitat as the floodplain evolved from oak savannah to a wetland and anabranching channel complex.*

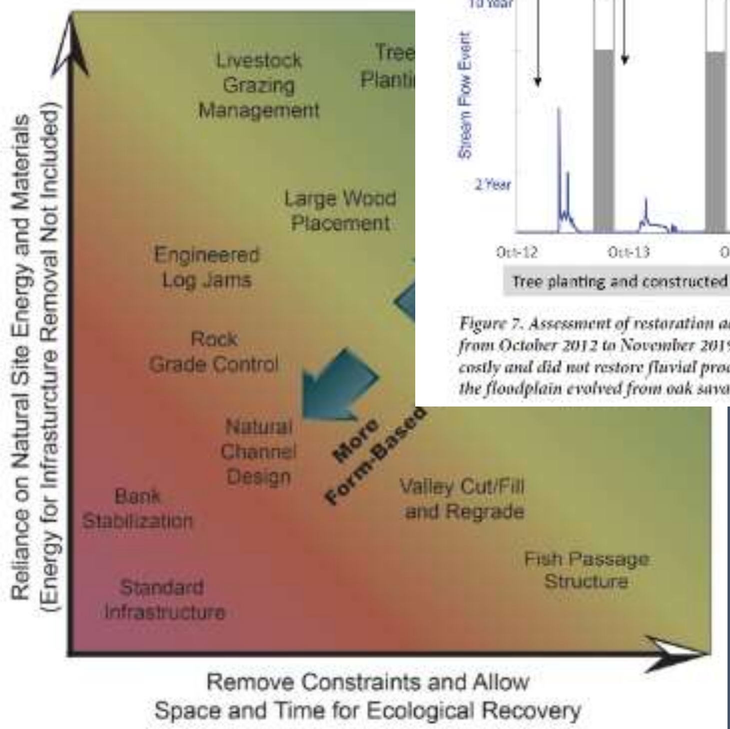


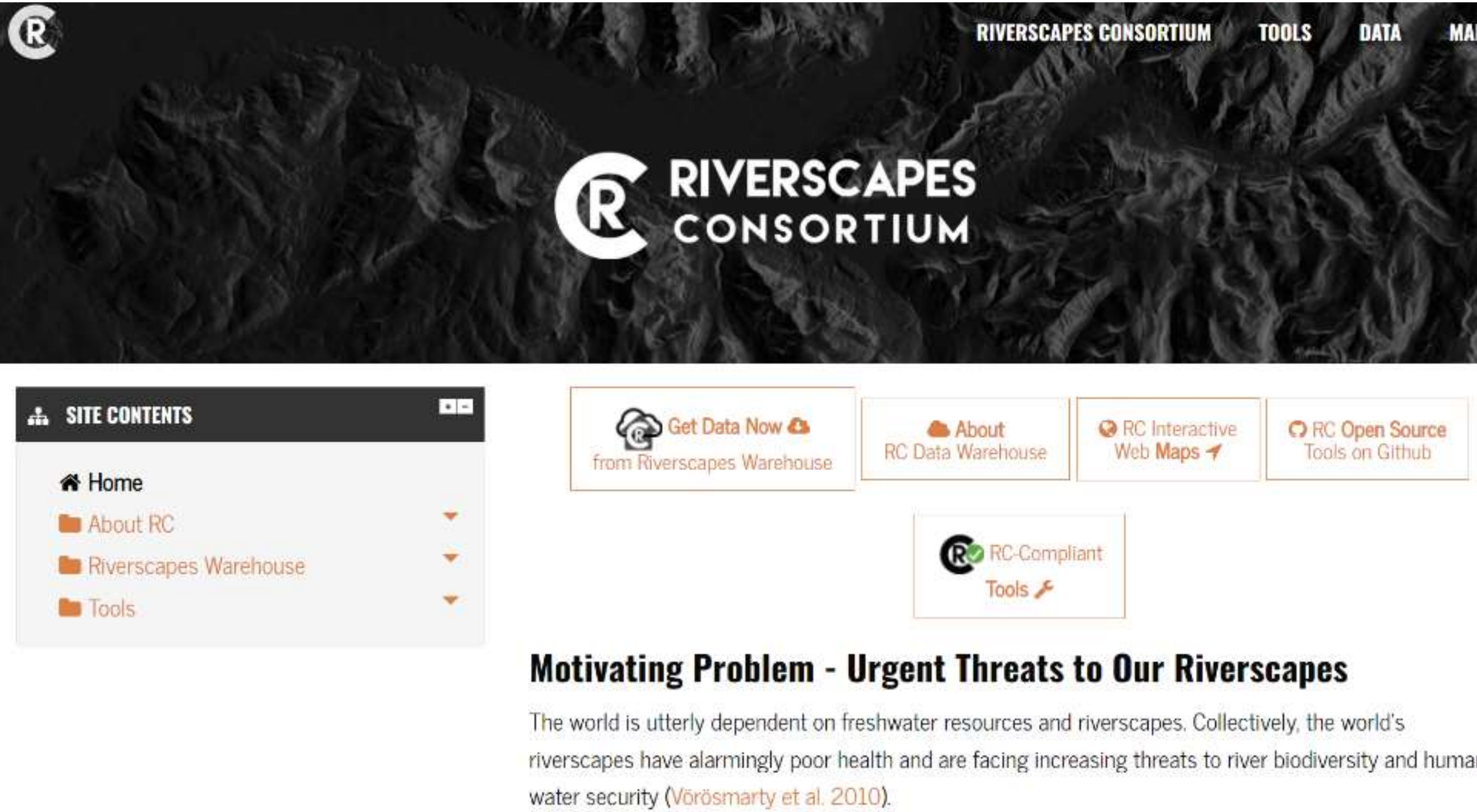

*Figure 8. Conceptual diagram evaluating the relative potential for river management actions to meet process-based restoration objectives. Process-based actions are those that rely on energy and materials of the site and that achieve high levels of connectivity and allow for sufficient time and space for natural processes to restructure and recover habitat complexity.*

# DESIGN TOOLS AND SPATIAL ANALYSIS TO SUPPORT LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES

Nick Bouwes –Eco Logical Research, Anabranch Solutions, USU
Chris Jordan-NOAA/NMFS/NWFSC
Stephen Bennett –Eco Logical Research, Anabranch Solutions, USU
Nick Weber –Eco Logical Research, Anabranch Solutions
Scott Shahverdian, Anabranch Solutions
Joe Wheaton, Utah State University, Anabranch Solutions
Philip Bailey, North Arrow Research, Inc.

# DESIGN TOOLS AND SPATIAL ANALYSIS TO SUPPORT LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES

- Rivescape Consortium
- Planning
  - Riverscape Tools
    - Riverscape Context
    - Valley Bottom Extraction Tool (VBET)
    - Beaver Restoration Assessment Tool (BRAT)
    - TauDEM - HAND
- Design
  - FMLTPBR
  - QRIS
  - Qfield
- Database
  - LT-PBR Explorer
  - Data Warehouse




riverscapes.xyz

Riverscapes Consortium

# TOOLS



The RC has been prolific in developing and vetting the science and theoretical underpinnings essential to understanding and explaining how riverscapes work and are organized across a range of nested hierarchical spatial scales. We have also committed to building open-source algorithms tools to make it easier for researchers, professionals, practitioners and students to apply those concepts to their own riverscapes.

All of RC's tools are based on peer-reviewed, methods. When we have developed the methods ourselves, we aim to have them vetted, published and disseminate in the peer-reviewed literature. We then also make sure to have a well documented website (typically with a URL that will take the form of `sometool.riverscapes.xyz`). For most users, the online help documentation and using the tool 'as is' is as far as they need to take it. However, for those so inclined, all of the underlying source-code for these tools, models and algorithms are available in their own GitHub repository at github.com/Riverscapes. Note that, the `tools.riverscapes.xyz /sometool` convention is used for our predominantly production-grade tools that share the `Riverscapes Commons` Library.

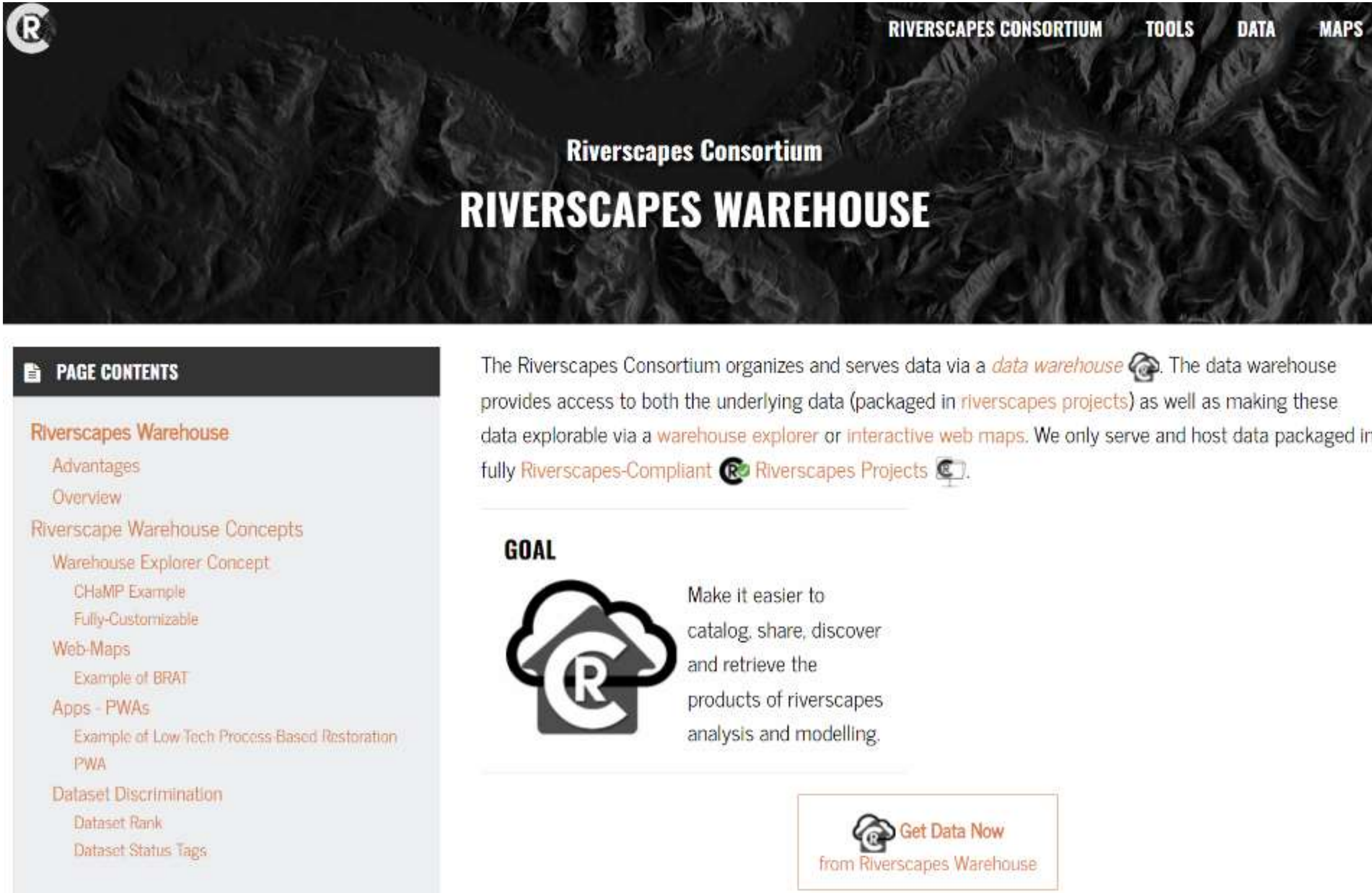
| | | |
|---|---|---|
| Learn more about RC's Production-Grade Network-Scale Tools | RC Open Source Tools on Github | Learn more about RC-Compliant Tool Standards |

## Riverscapes Compliant

Tools are designated as "*riverscapes-compliant*" when they meet the following criteria:

- Tool Status of **Operational-Grade** or Higher
- Code produces riverscapes projects as output of all analyses
- Project Type is registered with `program.xml` in Program Repo
- Has been vetted by the RS Science Committee (i.e. has a "Report Card")

riverscapes.xyz/Tools/




riverscapes.xyz/Data_Warehouses/

# RIVERSCAPES ANALYSIS VISUALIZATION EXPLORER

SITE CONTENTS



The Riverscapes Analysis Viewer and Explorer (RAVE) helps you make maps of rivers. RAVE speeds up the process of adding data related to rivers into your preferred GIS with meaningful layer order and symbology.

There are three versions of RAVE that all work essentially the same way. You start with a riverscapes project that contains a collection of data layers related to rivers. You open the project in the RAVE project explorer that shows all the layers, displayed with meaningful names and icons. Clicking on a layer adds it to the current map in a carefulluy designed order with predefined symbology tailored to the layer in question.

There are three separate versions of RAVE depending on which GIS you prefer:

### WebRAVE

No GIS needed! View riverscapes projects online in a browser.

Learn More

### QRAVE for QGIS

For desktop GIS users with QGIS 3.16.10.

Learn More

### ArcRAVE for ArcGIS

For desktop GIS users with ArcIGS 10.6.1 or higher.

Learn More

# Why RAVE?

River practitioners use lots of disparate geospatial data and need the ability to visualize it quickly.

However, simply adding a dataset to the current map document in desktop GIS can be frustrating for following reasons:

# DESIGN TOOLS AND SPATIAL ANALYSIS TO SUPPORT LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES

- Rivescape Consortium
- Planning
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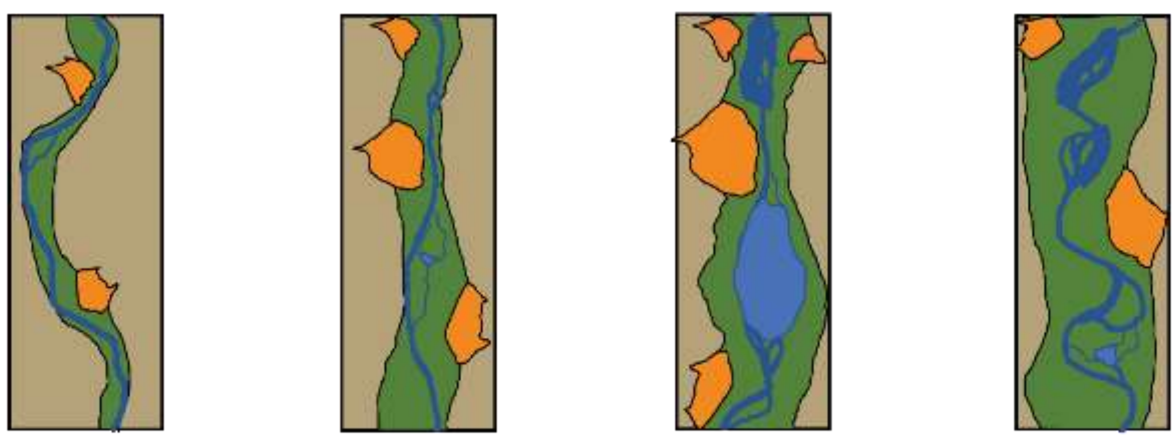
    - TauDEM - HAND
- Design
  - FMLTPBR
  - QRIS
  - Qfield
- Database
  - LT-PBR Explorer
  - Data Warehouse

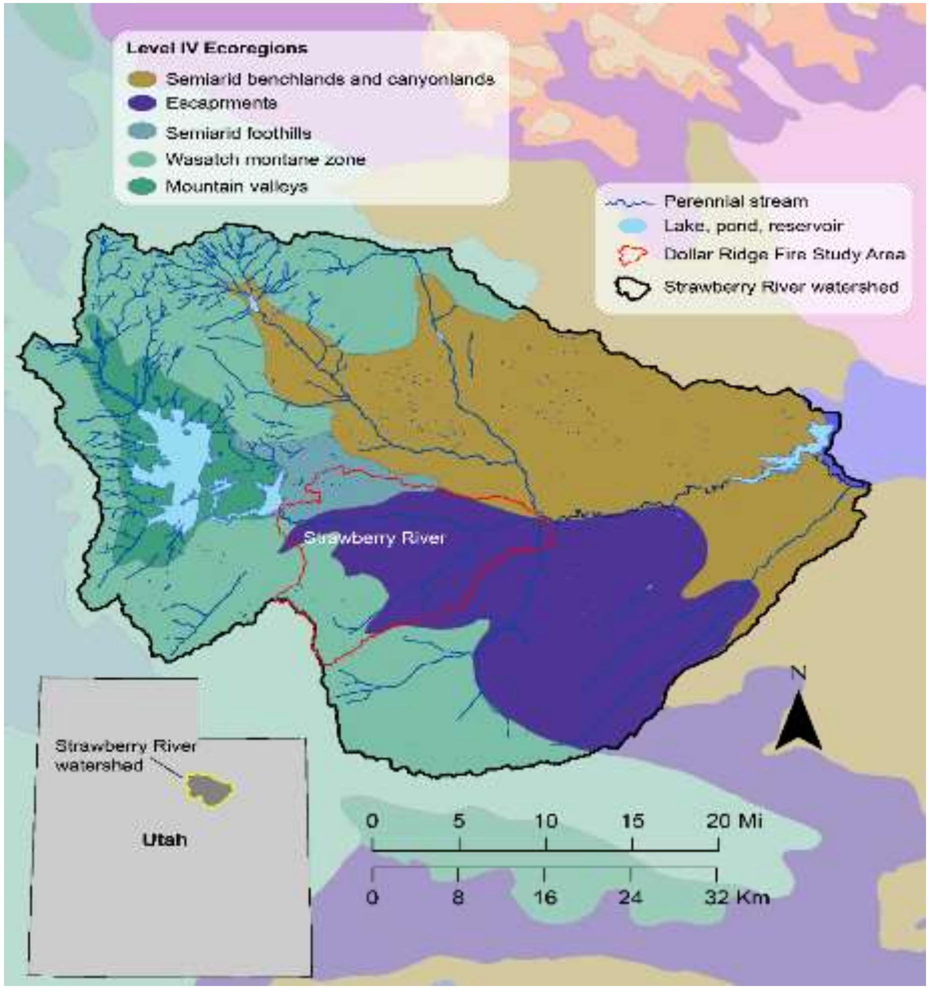
# GEOMORPHIC ASSESSMENT- RIVER STYLES

| | Reach 1 | Reach 2 | Reach 3 | Reach 4 |
|---|---|---|---|---|
| valley setting | confined (hillslopes) | confined (alluvial fans) | partly-confined | partly-confined |
| presence/ extent of floodplain | floodplain pockets | floodplain pockets | discontinuous floodplain | discontinuous floodplain |
| planform | low sinuosity infrequent anabranches | low sinuosity infrequent anabranches | moderate sinuosity frequent anabranches | moderate sinuosity frequent anabranches |
| floodplain geomorphic units | hillslope deposits high-flow channels beaver dams | hillslope deposits high-flow channels beaver dams | high flow channels beaver dams meander cutoffs | high flow channels beaver dams meander cutoffs |
| instream geomorphic units | riffles, pools, runs, point bars, mid-channel bars, islands, rapids, cascades | riffles, pools, runs, point bars, mid-channel bars, islands, rapids, cascades | riffles, rapids, pools, runs, point bars, mid-channel bars, islands | riffles, pools, runs, point bars, mid-channel bars, islands |
| bed material texture | cobbles, gravel, boulder | cobbles, gravel, boulder | gravel, sand, cobble | gravel, sand, cobble |
| structural elements | boulders, LWD, side-channel beaver dams | boulders, LWD, side-channel beaver dams | LWD, side-channel beaver dams | LWD, side-channel beaver dams |
| reach type | confined (hillslopes) with flood-plain pockets, moderate gradient | confined, alluvial fan controlled, floodplain pockets, moderate gradient | partly confined, alluvial fan influenced, low gradient | partly-confined, discontinuous floodplain, moderate sinuosity, low gradient |



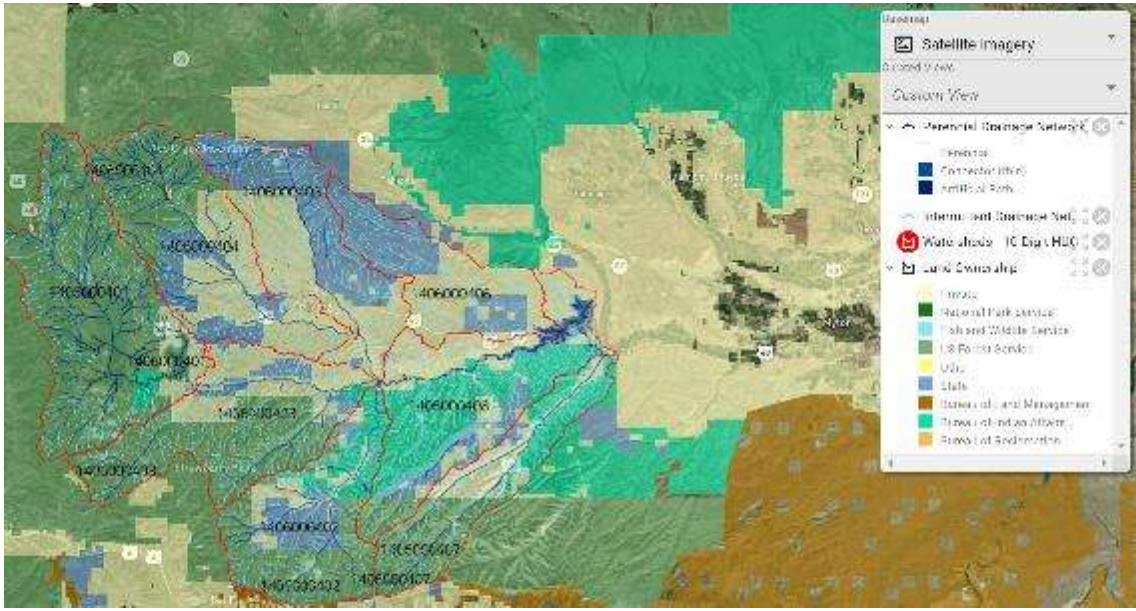
# RIVERSCAPE CONTEXT

- **Ecoregions**:
  - level 1, 2, and 3 Ecoregions from the EPA
- **LANDFIRE** vegetation:
  - Existing vegetation (class, name)
  - Historic vegetation (name)
- **Topography** (Digital Elevation Models)
  - Slope
  - Flow Accumulation
  - Drainage area
  - Detrended DEM
  - Hillshades for context
- **Hydrology**:
  - Hydrography ([NHD HR+]())
  - Watershed boundaries



# RIVERSCAPE CONTEXT

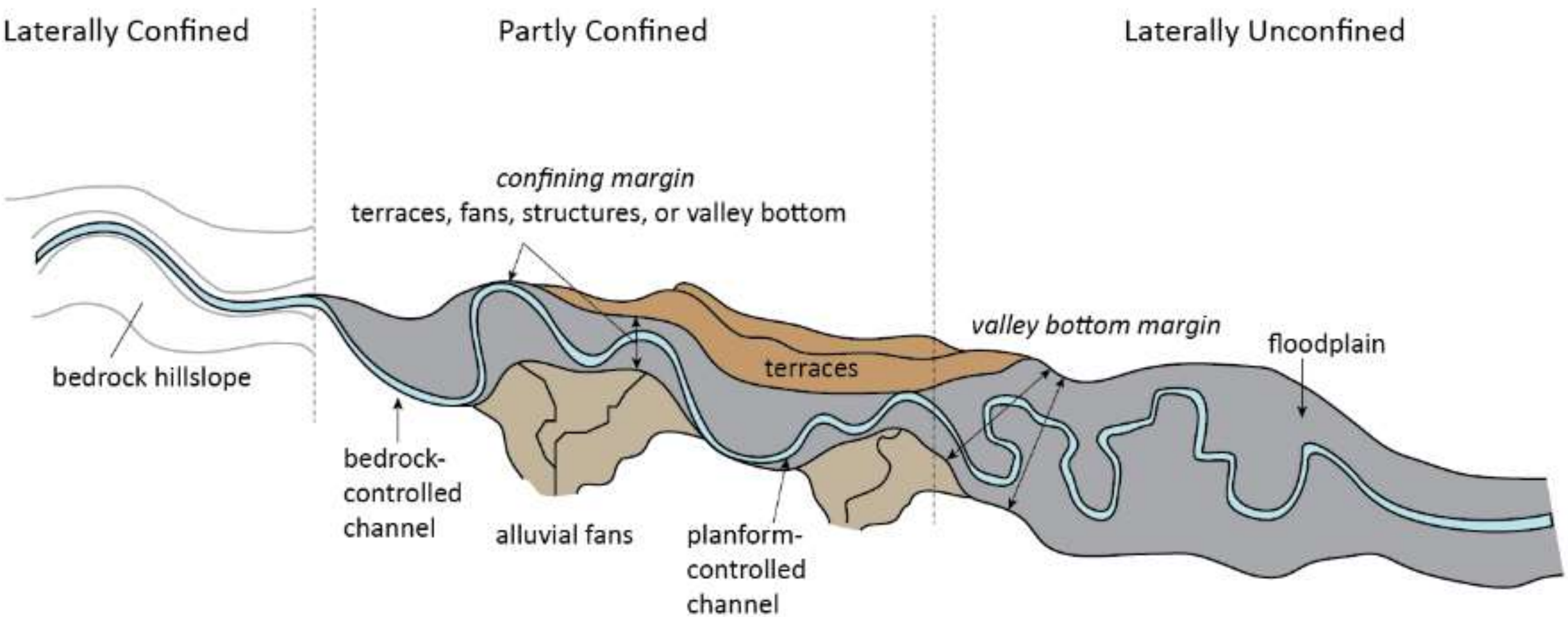
- **Land Management**:
  - Land ownership/agency
  - Fair market value




- **Climate** [(PRISM)]:
  - Mean Annual Precipitation
  - Mean Annual Temperature
  - Minimum Temperature
  - Maximum Temperature
  - Mean Dewpoint Temperature
  - Minimum Vapor Pressure Deficit
  - Maximum Vapor Pressure Deficit
- **Transportation**:
  - Roads
  - Railroads

# VALLEY BOTTOM


What part of valley bottom is available for low-tech restoration?



Valley Bottom margin
Alluvial Fan
Active channel

USU WATERSHED SCIENCES DEPARTMENT LTPBR RIVERSCAPES CONSORTIUM TOOLS DATA MAPS

# VBET - VALLEY BOTTOM EXTRACTION TOOL

**SITE CONTENTS**

- Home
- VBET References
- Getting Started
- Status

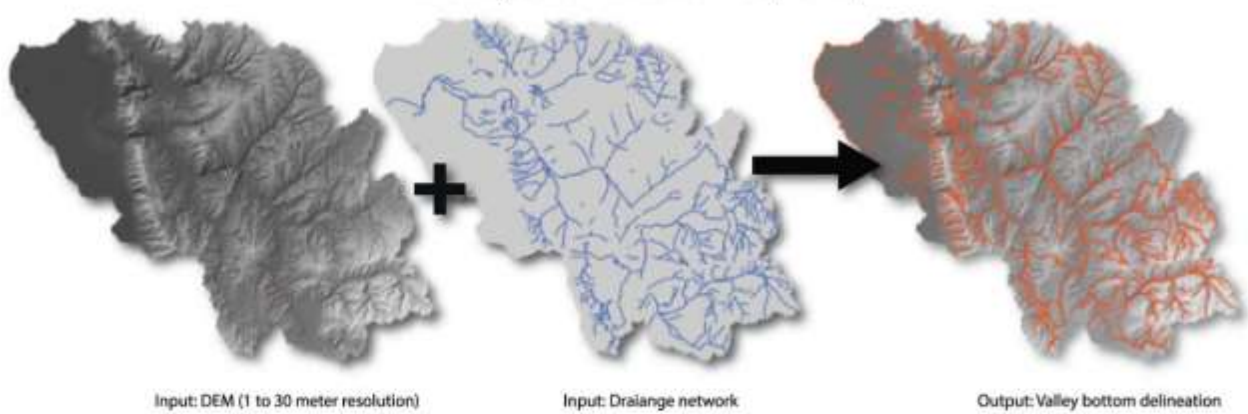
Back to riverscapes tools

## About

The **Valley Bottom Extraction Tool (VBET)** is a tool used to identify the valley bottom of a riverscape, and roughly separate it into geomorphic units (channel, active floodplain, and inactive floodplain). The tool takes a DEM and channel area polygon as inputs. Three different topographic analyses of the DEM are used as lines of evidence in determining what is valley bottom:

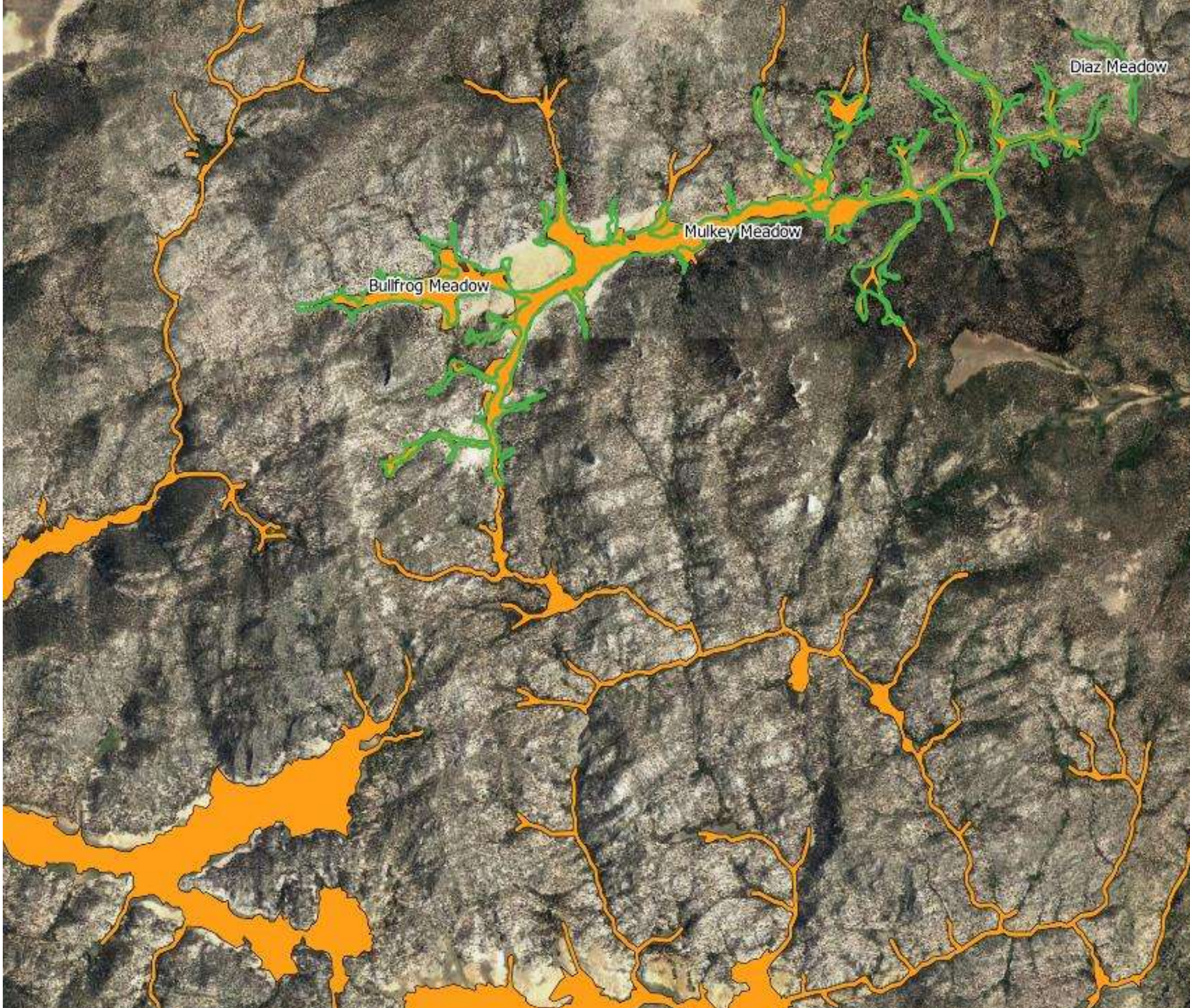
- Slope
- Topographic Wetness Index (TWI)
- Height Above Nearest Drainage (HAND)

**The Valley Bottom Extraction Tool (V-BET)**

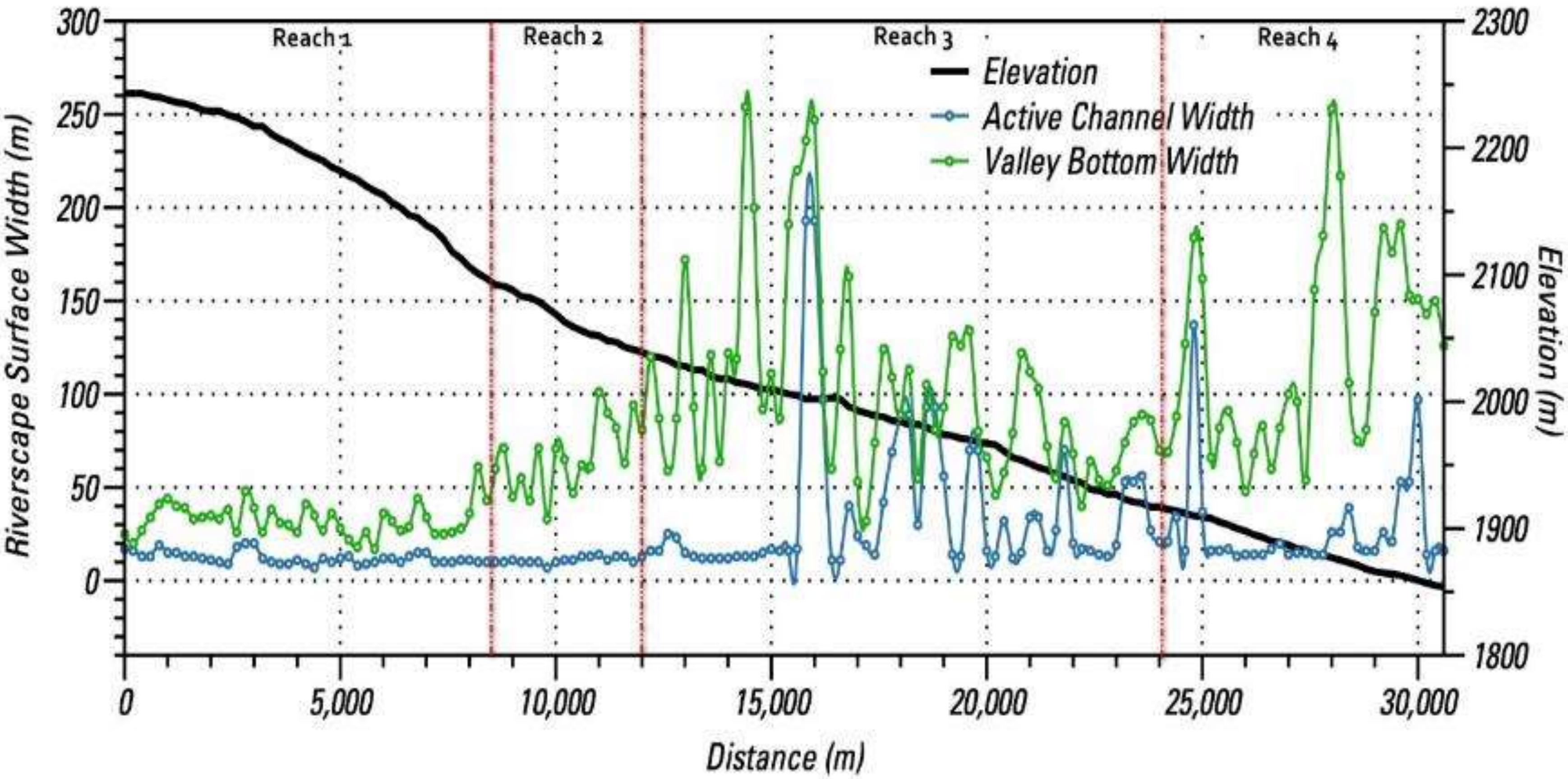



riverscapes.xyz/vbet/

# VBET



# REACH TYPE (RIVER STYLE)



USU WATERSHED SCIENCES DEPARTMENT LTPBR RIVERSCAPES CONSORTIUM TOOLS DATA MAPS

# CHANNEL AREA TOOL

**SITE CONTENTS**

- Home
- Application with NHD
- Status

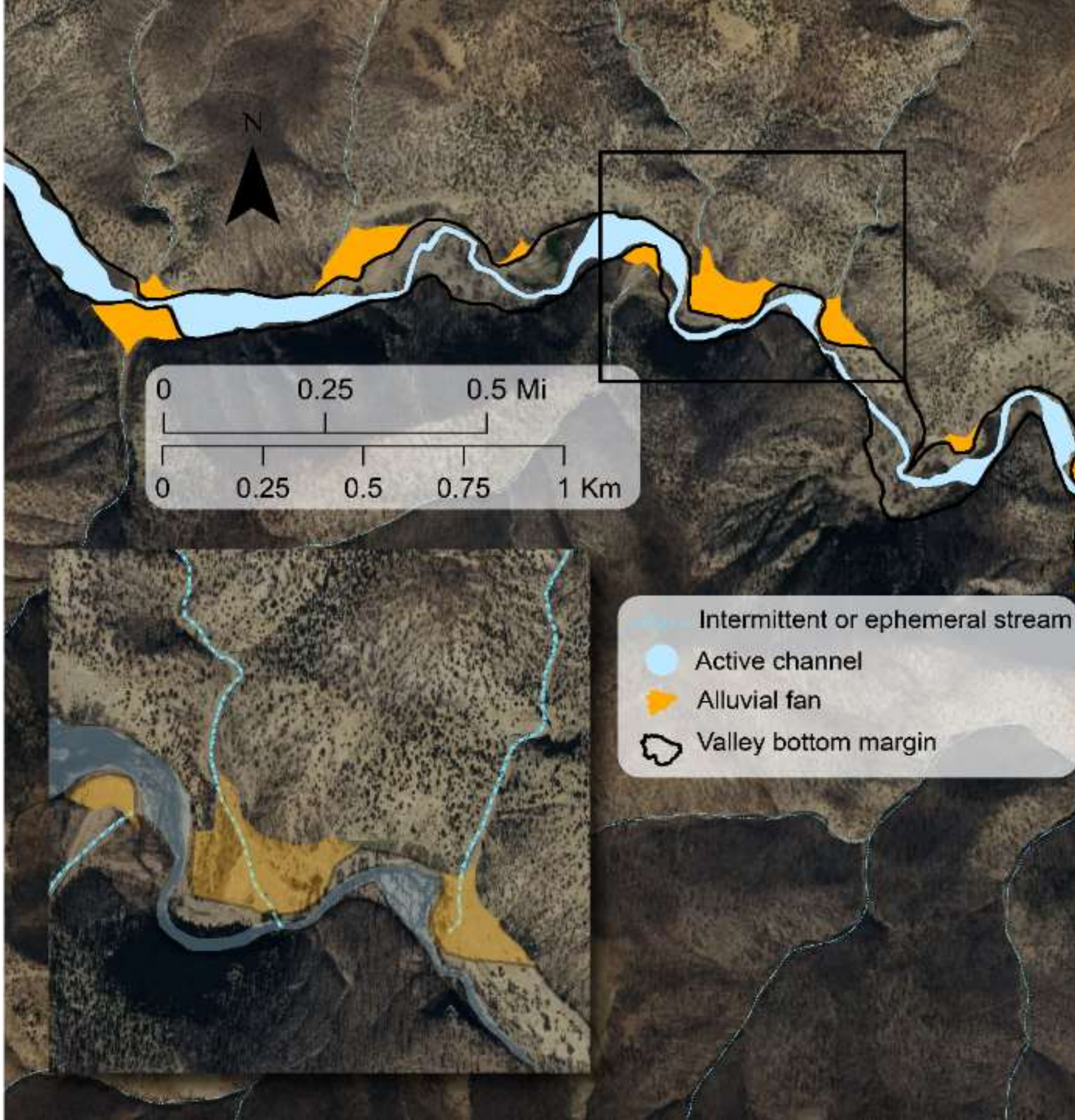
Back to riverscapes tools

## About

The **The Channel Area Tool** is a simple tool for generating polygons representing the spatial extent of the drainage network within a watershed. The primary purpose for the tool is that the outputs it produces are used as *inputs* in other Riverscapes tools. Geospatial tools often use a simple line network to represent


riverscapes.xyz/channel/

# VALLEY BOTTOM MAPPING



# BEAVER RESTORATION ASSESSMENT TOOL
# BRAT

- Beaver need water and wood…
- Type and extent of wood/vegetation matters most
- Flow regime act to potentially limit capacity

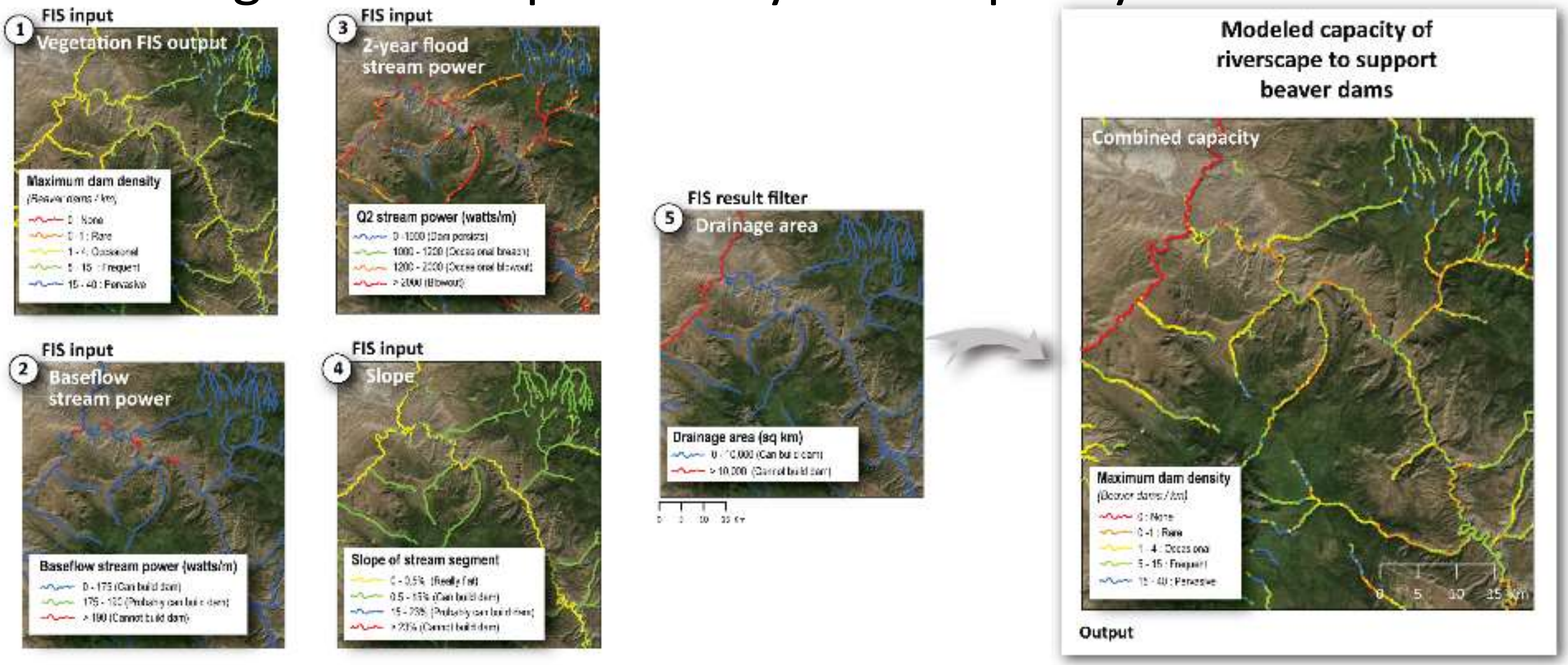
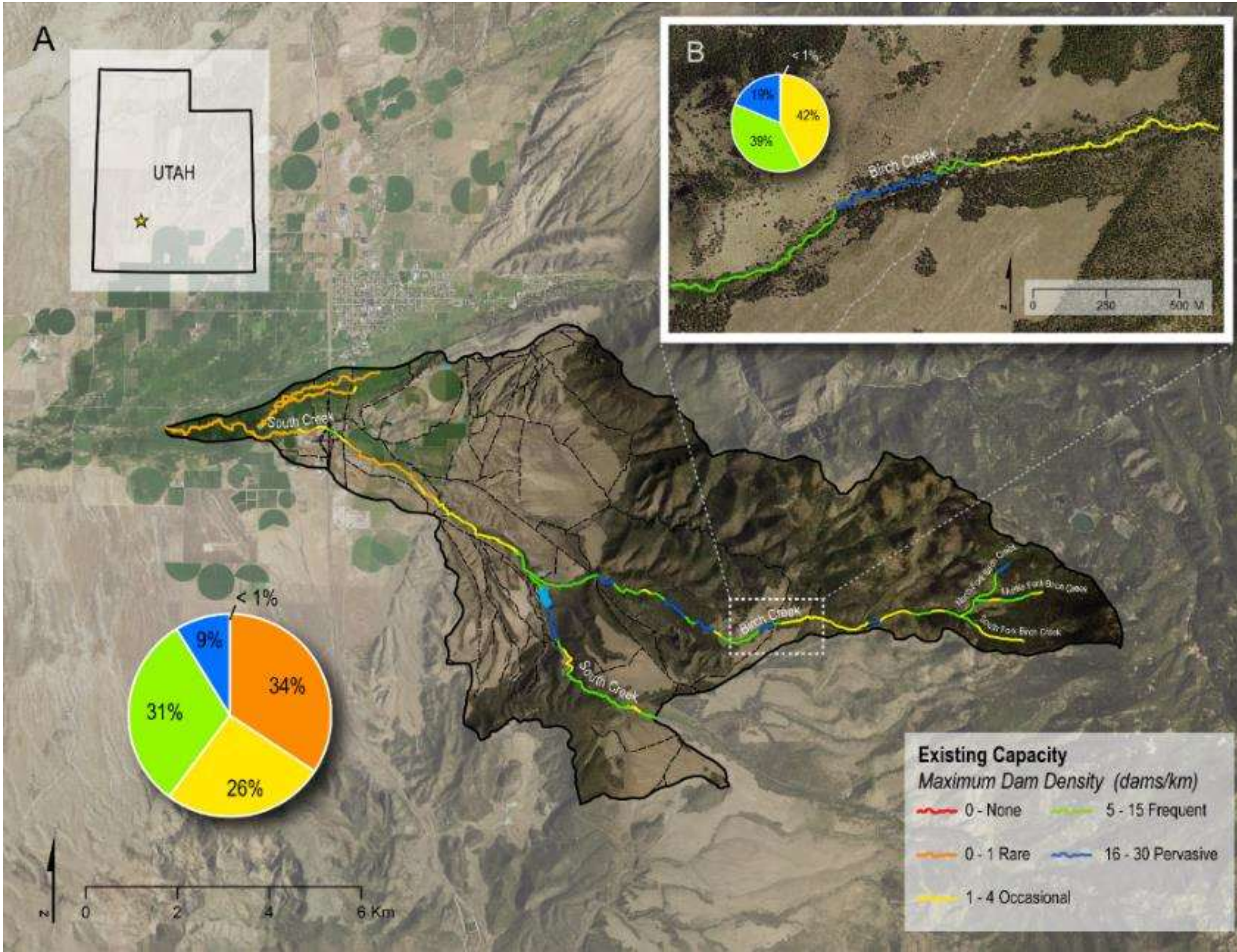
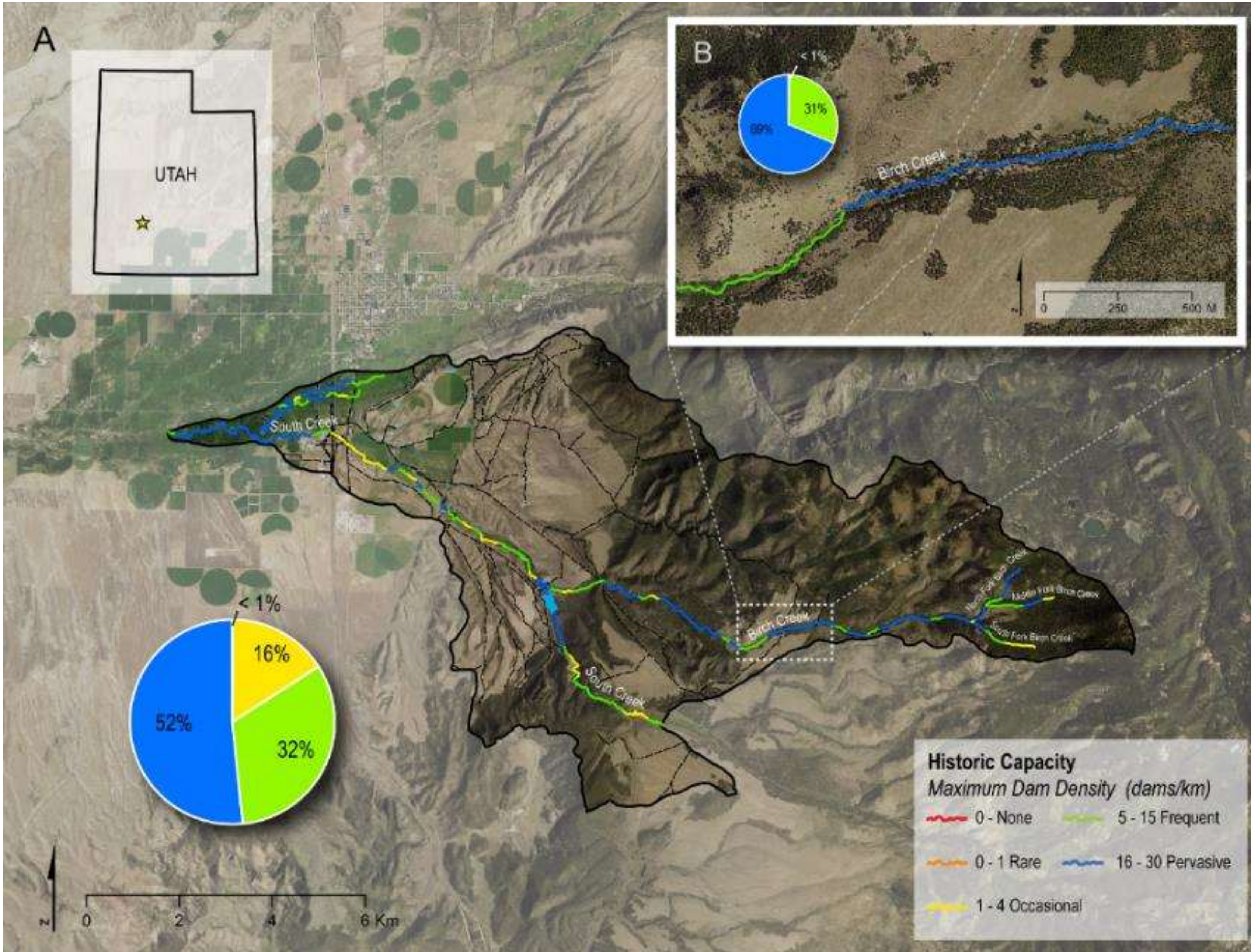



Figure 1 from Macfarlane et al. (2016) DOI: [10.1016/j.geomorph.2015.11.019](https://doi.org/10.1016/j.geomorph.2015.11.019)

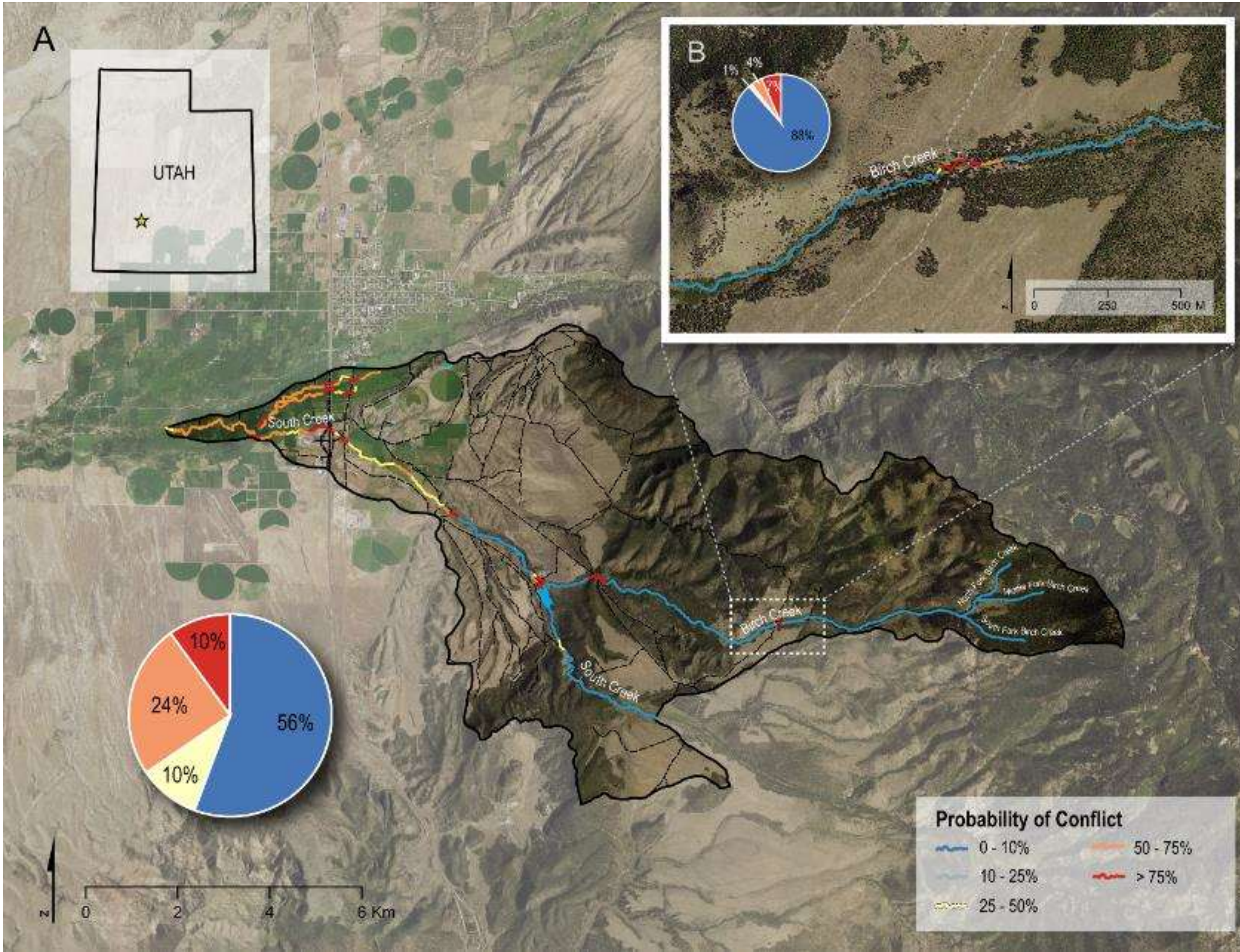
# EXISTING BEAVER DAM CAPACITY



# HISTORIC BEAVER DAM CAPACITY



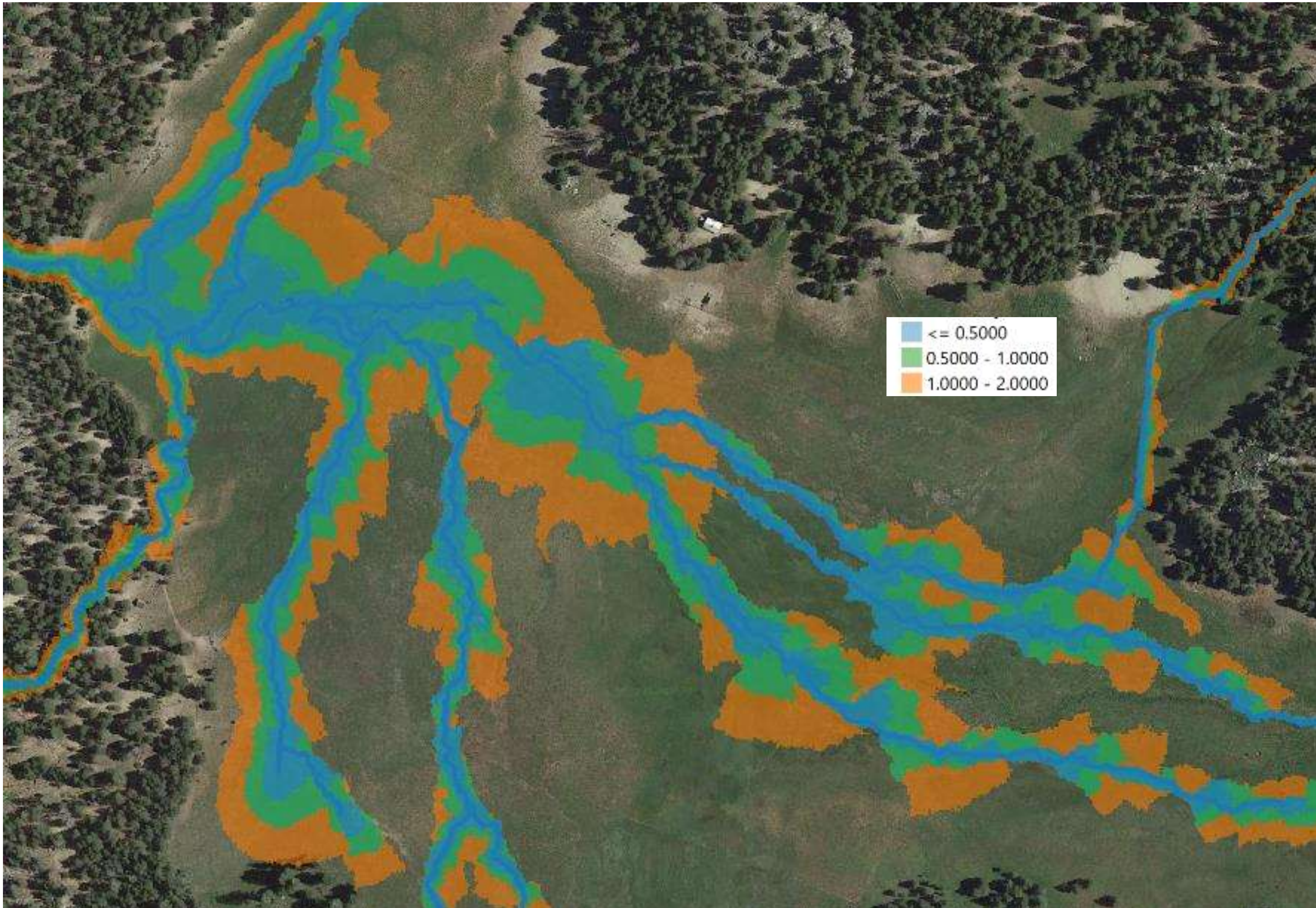
# HUMAN-BEAVER CONFLICT POTENTIAL

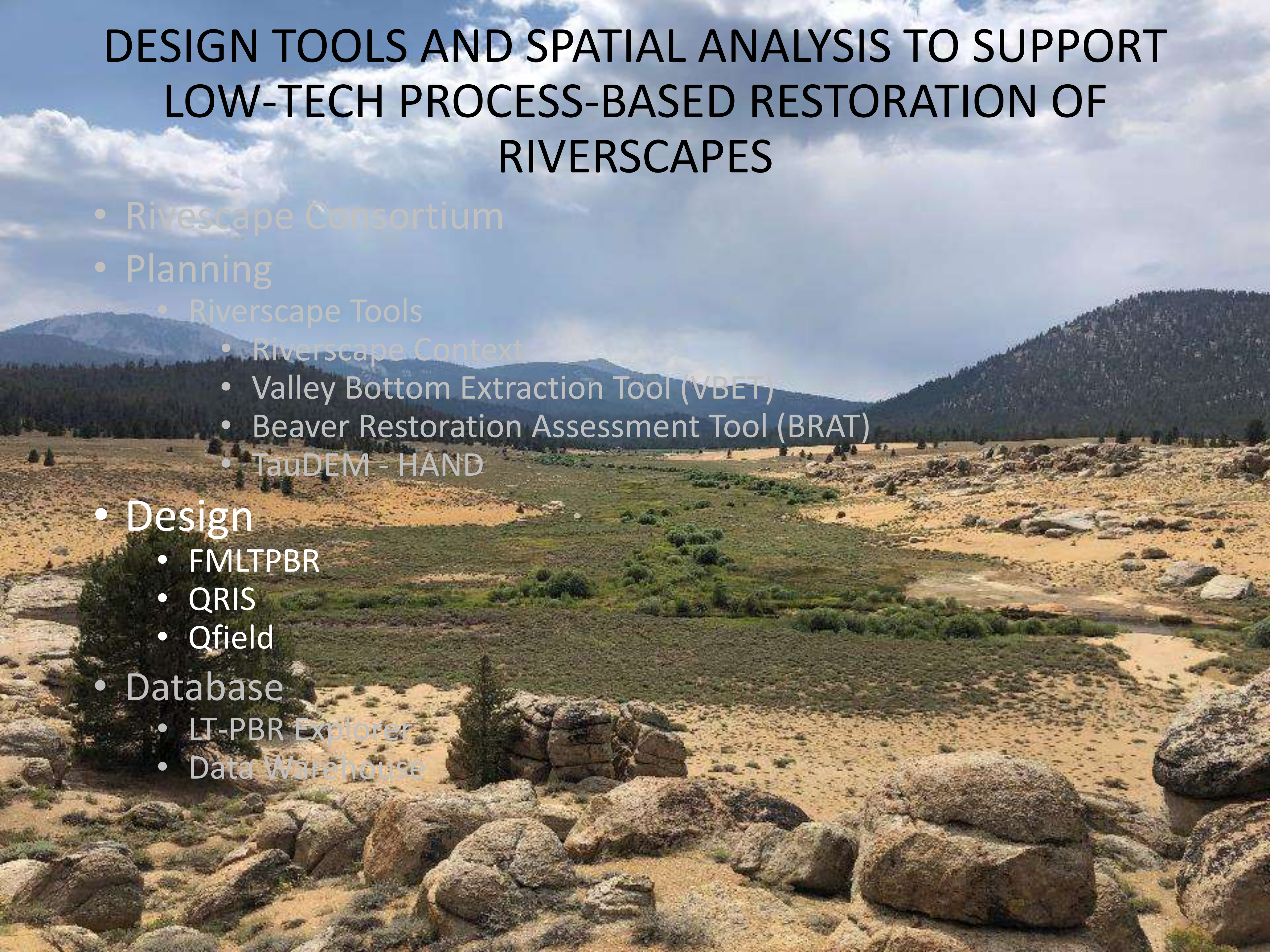


# TERRAIN ANLYSIS USING DIGITAL ELEVATION MODELS
TAUDEM

- Pit-filled DEM
- D-infinity flow direction raster
- D-infinity contributing area raster
- Topographic Wetness Index (TWI)
- D-infinity slope raster (percent)
- D-8 slope raster (degrees) using GDAL
- Height Above Nearest Drainage (HAND) raster

# INUNDATION MAP- RELATIVE DEM





# DESIGN TOOLS AND SPATIAL ANALYSIS TO SUPPORT LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES

- Rivescape Consortium
- Planning
  - Riverscape Tools
    - Riverscape Context
    - Valley Bottom Extraction Tool (VBET)
    - Beaver Restoration Assessment Tool (BRAT)
    - TauDEM - HAND
- Design
  - FMLTPBR
  - QRIS
  - Qfield
- Database
  - LT-PBR Explorer
  - Data Warehouse

# FILE MAKER LTPBR (FMLTPBR)


## FMLTPBR INTENT (GOALS)

1. ***Consistent set of design and implementation attributes and monitoring survey protocols.***
2. ***Efficient data collection and management solution.***
3. ***Advance the science and art of LT-PBR practices.***

# FMLTPBR COMPONENTS

| COMPONENT | DESIGN AND IMPLEMENTATION | MONITORING SURVEY PROTOCOLS | DATA COLLECTION AND MANAGEMENT |
|---|---|---|---|
| **FUNCTION** | Project organization using core set of attributes describing design, objectives, and structure specification. | Series of monitoring surveys capable of generating a diversity of metrics describing ecological outcomes and project effectiveness. | Complete data collection and management solution supporting consistent information capture. |
| **APPLICATION** | Iterative process intended to be edited and updated with new information throughout the lifespan of a project. | Repeat monitoring surveys at discrete survey events | Used throughout design development, implementation, field data collection, or report preparation. |
| **TARGET USERS** | Requires understanding of the restoration design. Project managers, restoration designers, or construction foreman. | Accessible to individuals with a reasonable understanding of fluvial dynamics and taxonomy. Summer research technician or a community volunteer. | All protocol users at appropriate application. |

# PROTOCOL COMPONENTS

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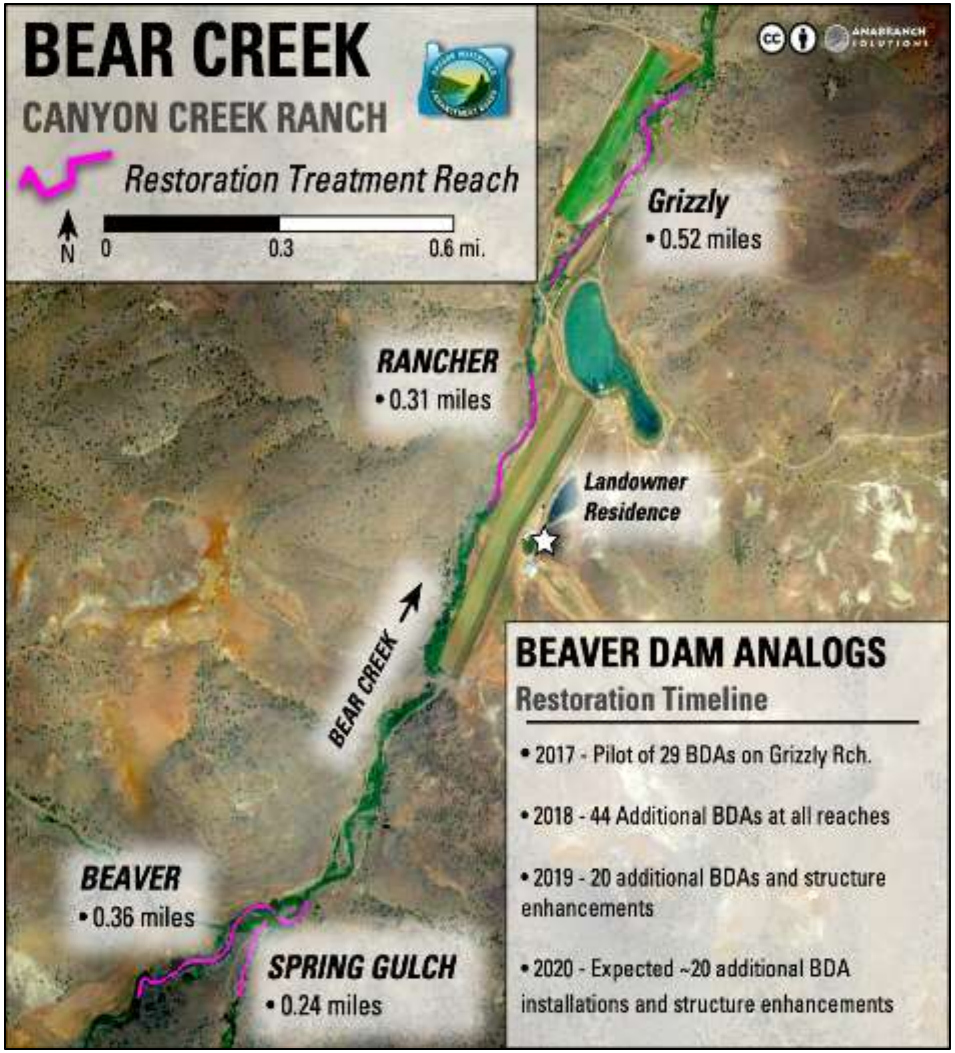
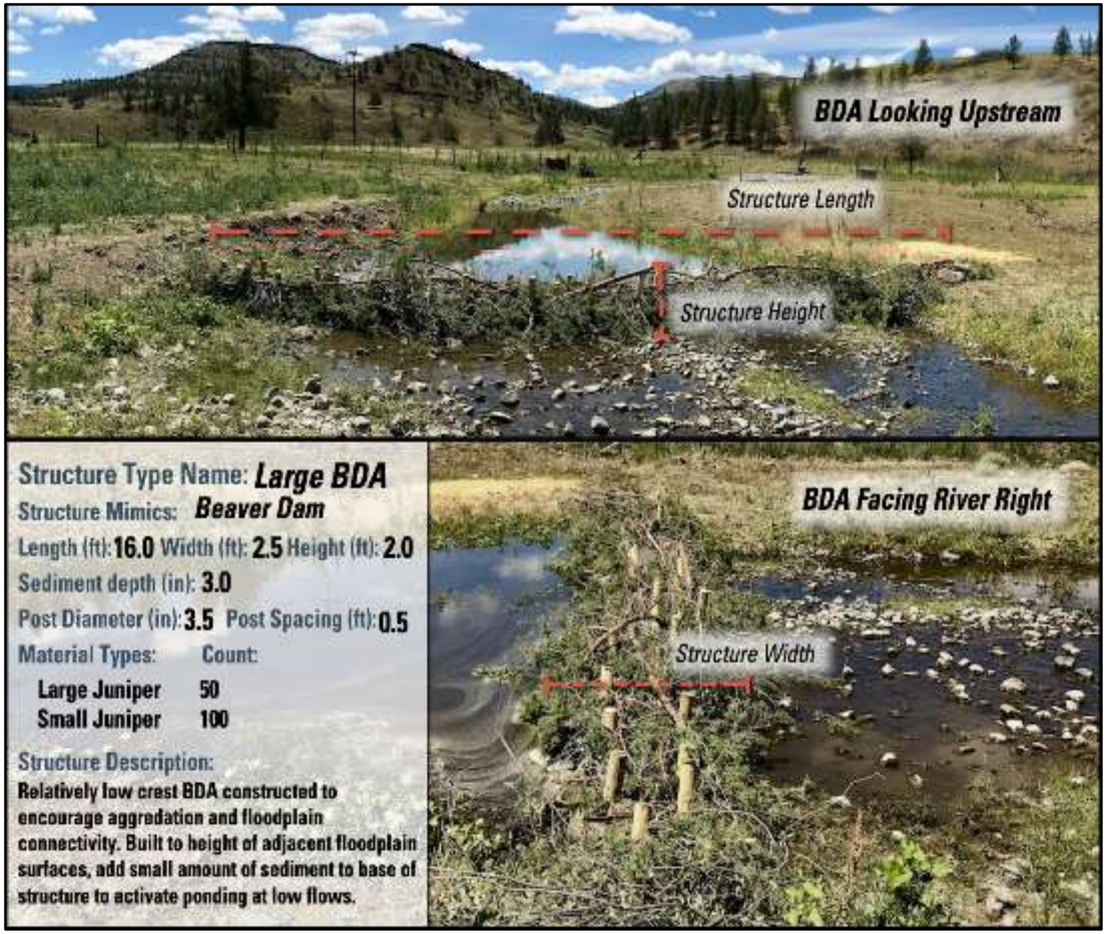
# PROJECT DESIGN AND MANAGEMENT




- CORE SET OF PROJECT DESIGN ATTRIBUTES
- PROJECT SPATIAL AND TEMPORAL ORGANIZATION
  - Multi-year implementation
- EXPLICIT STATEMENTS OF RESTORATION OBJECTIVES
  - Supported by monitoring metrics

# PROJECT DESIGN AND MANAGEMENT




- STRUCTURE DESIGN AND FUNCTION SPECIFICATION
- MATERIAL AND FILL ESTIMATES
- STRUCTURE MODIFICATION AND MAINTENANCE

# PROTOCOL COMPONENTS

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# MONITORING PROTOCOLS

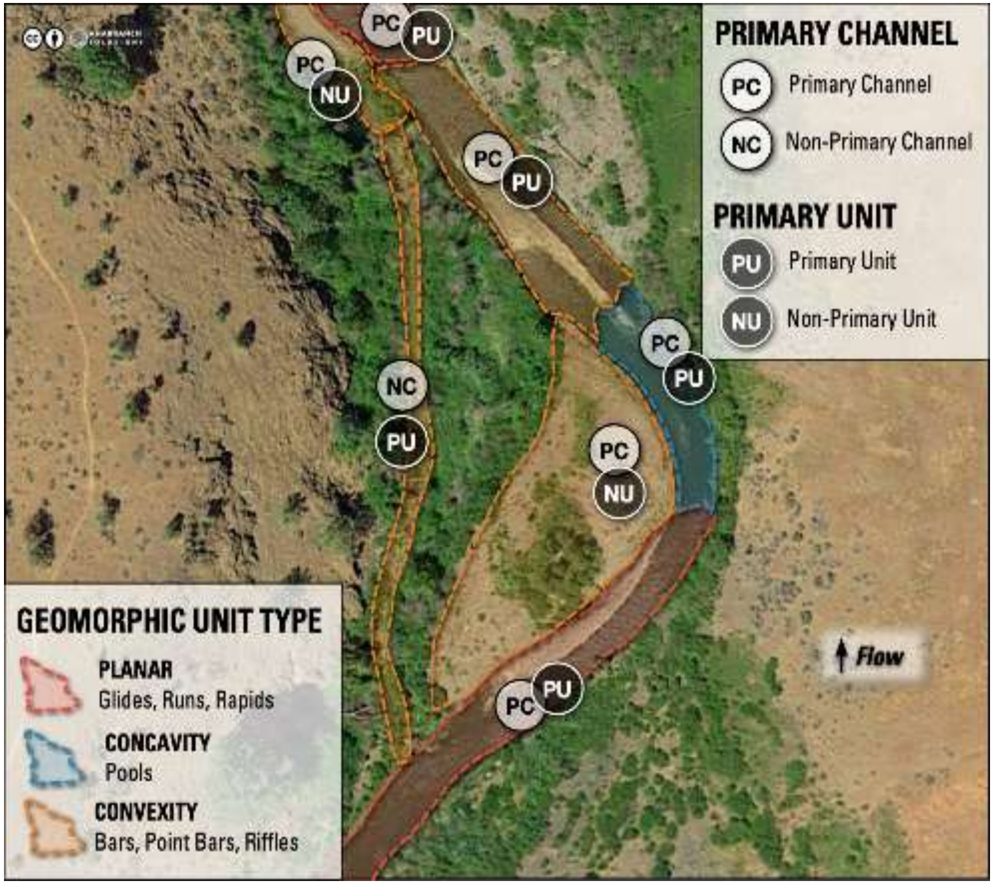
## FIELD STRUCTURE SURVEY

- Structure characteristics, condition, function, and distribution.

# MONITORING PROTOCOLS

## FIELD GEOMORPHIC UNIT SURVEY

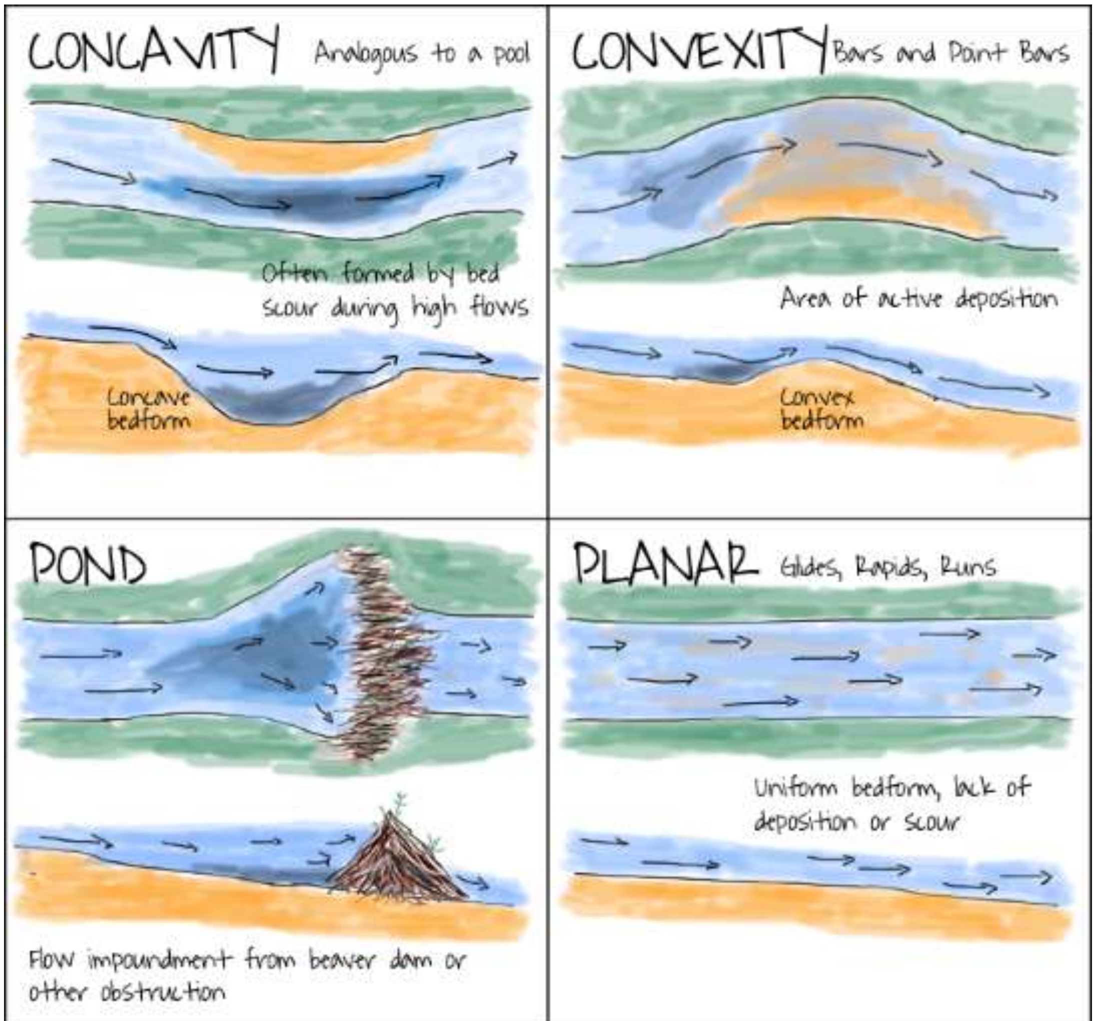
- Distribution and characteristics of habitat units
- Habitat quantity and quality (complexity)
- Geomorphic Change



# MONITORING PROTOCOLS

## FIELD GEOMORPHIC UNIT SURVEY

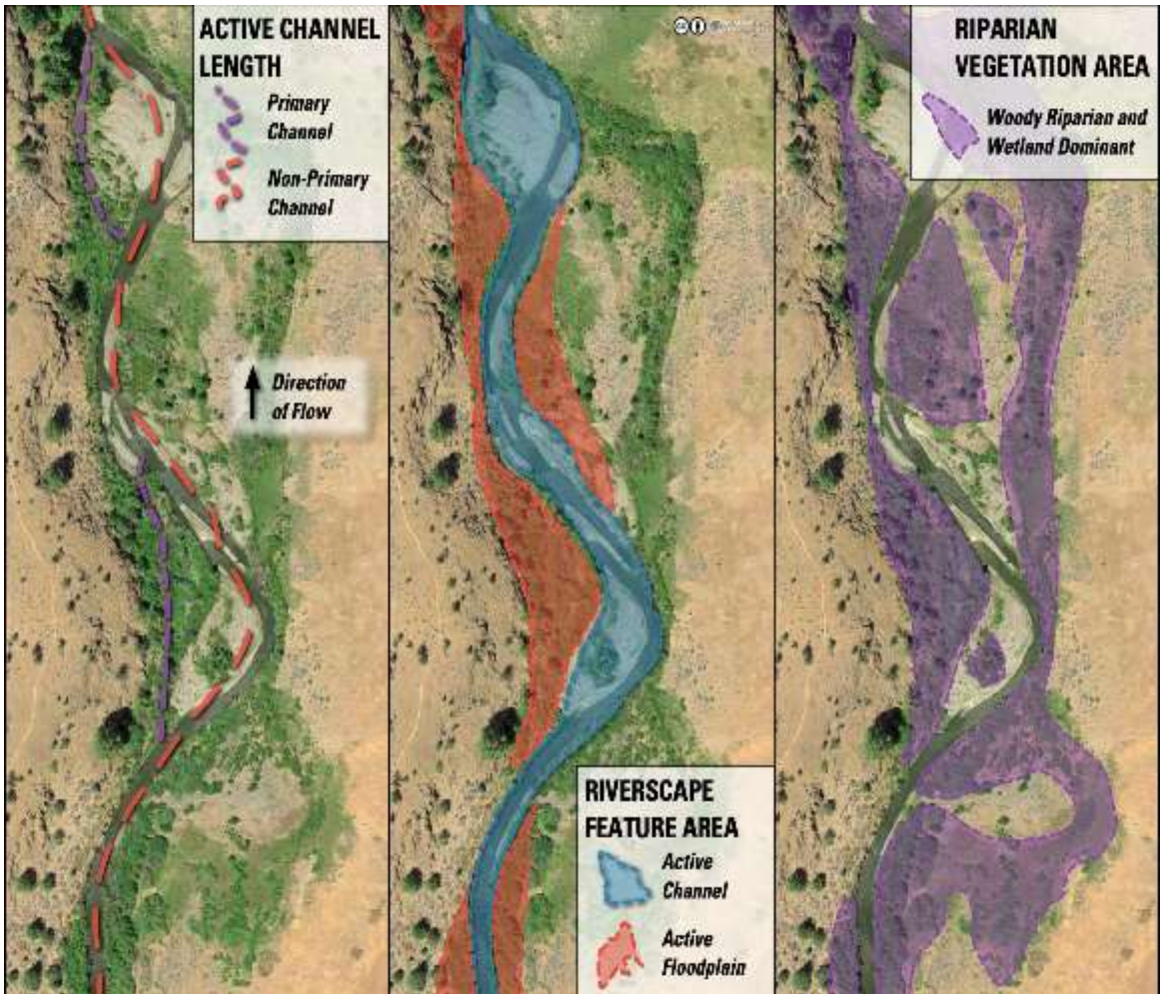
- Simple unit classification schema (Wheaton et al. 2015)



# MONITORING PROTOCOLS

## REMOTE RIVERSCAPE SURVEY

- Desktop digitization of valley bottom features from imagery
- Channel network length, floodplain area, riparian vegetation extent



# OBJECTIVES AND MONITORING

- Explicit link of monitoring survey metrics to reach scale objectives.

### 7.1.4 INDICATORS OF IN-CHANNEL HABITAT QUANTITY AND QUALITY

| METRIC | SURVEY | INTERPRETATION |
|---|---|---|
| **POOL FREQUENCY** | Channel | Increased pool frequency is indicative of a dynamic channel and offers critical cover and holding habitat for fish at all life-stages. |
| **POOL DEPTH RANGE** | Channel | An increased range of pool depths suggests higher habitat complexity. |
| **BAR FREQUENCY** | Channel | Increased occurrence of bars indicates a more dynamic channel and often provides substrate variation critical to adult spawning salmonids. |
| **POND AREA** | Channel | Pond habitat often creates thermal refugia, drought refugia, and slow-water rearing habitat for many aquatic species. |
| **WOODY DEBRIS FREQUENCY** | Structure | Increased woody debris provides cover and flow velocity refugia for many aquatic species. |
| **WETTED CHANNEL AREA** | Channel | Wetted channel area provides a measure of habitat quantity that will increase with pond formation, channel lengthening, and non-primary channel creation. |

# PROTOCOL COMPONENTS

| COMPONENT | DESIGN AND IMPLEMENTATION | MONITORING SURVEY PROTOCOLS | DATA COLLECTION AND MANAGEMENT |
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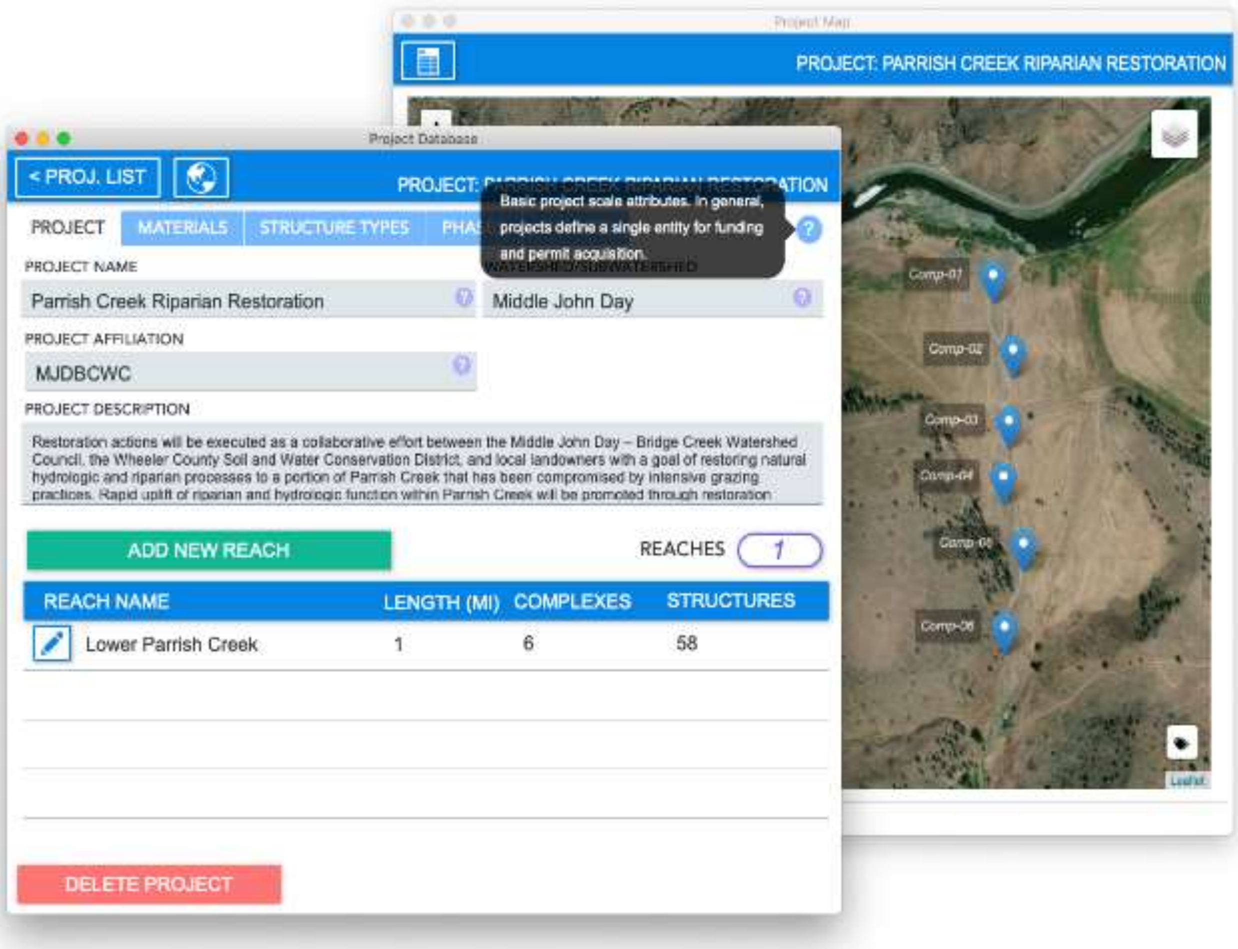
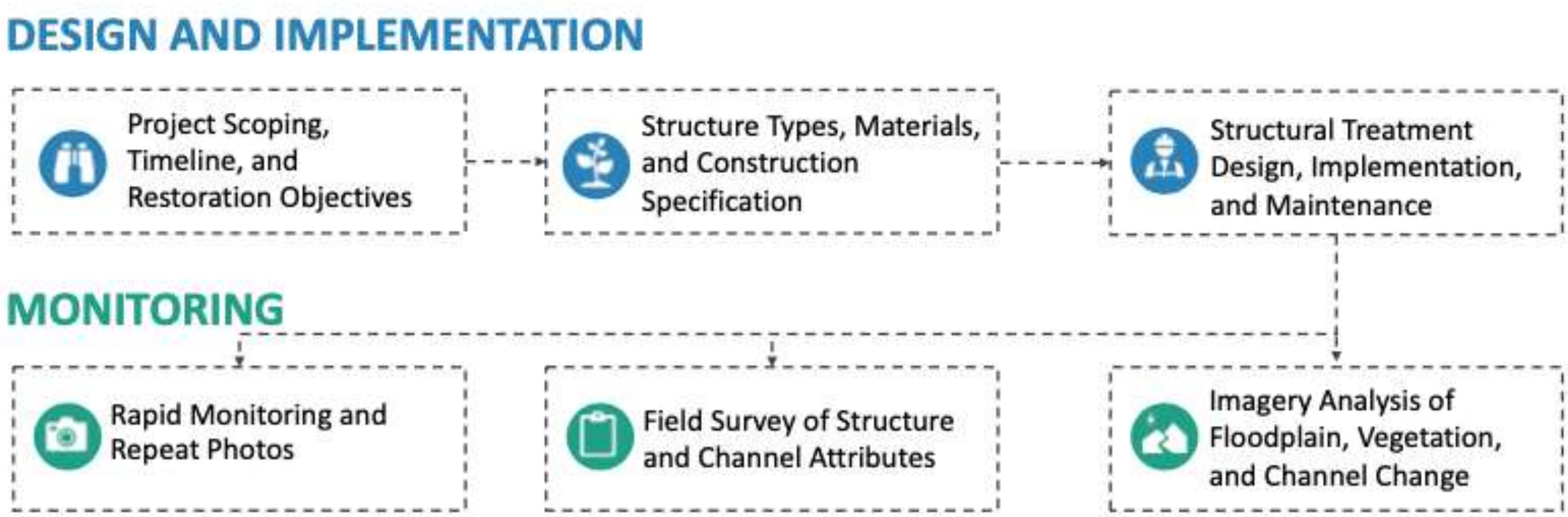
# DATABASE APPLICATION

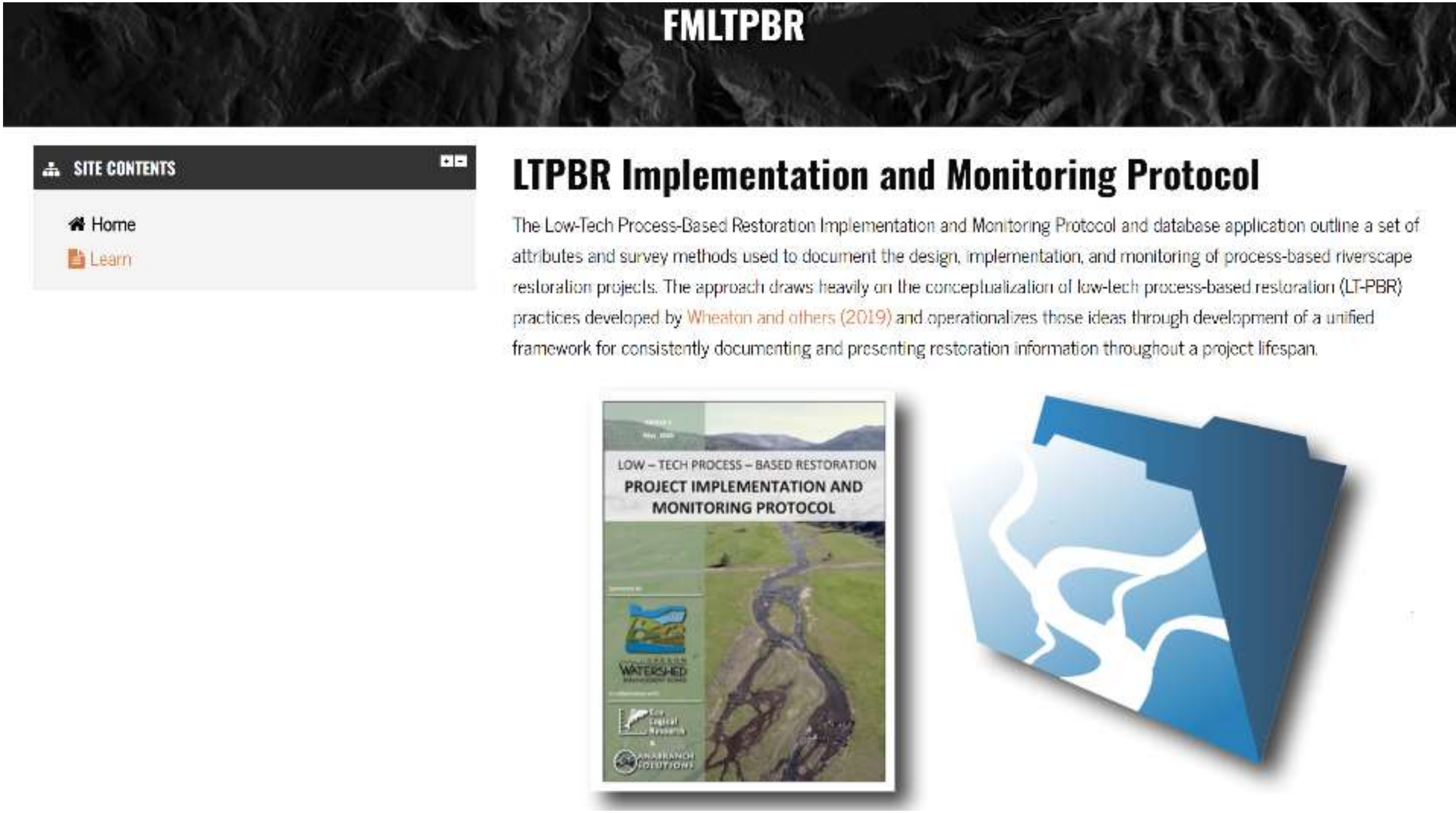
- Filemaker – Windows and Mac
- iPad for field data collection
- iPhones in a pinch – not recommended



# LEARNING VIDEO TUTORIALS

## Design, implement, monitor a mock project






fmltpbr.riverscapes.xyz

QRiS

# Riverscapes Studio

*Open-Source GIS Tools for LTPBR Planning and Design Tools*

LTPBR Planning and Design Template

# QGIS A Gentle Introduction


Free and Open-source GIS – Go get it…

# QGIS PLUGINS

*Extend the Utility of QGIS*

plugins.qgis.org

## *Riverscapes Plugins*

## QRAVE

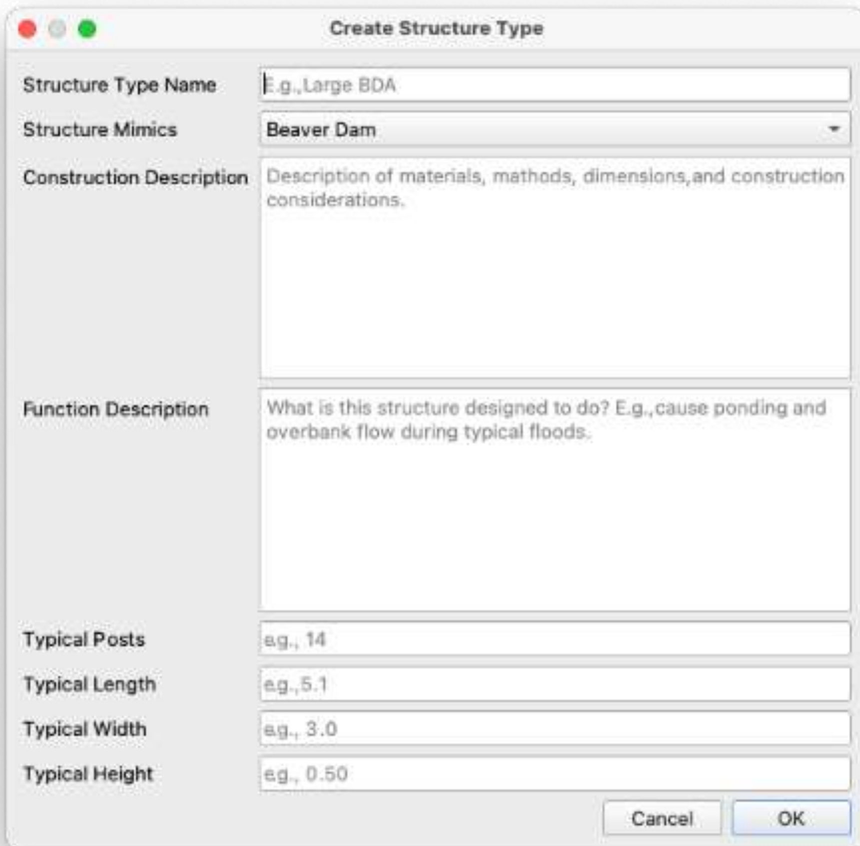
*QGIS Riverscapes Analysis and Visualization Explorer*

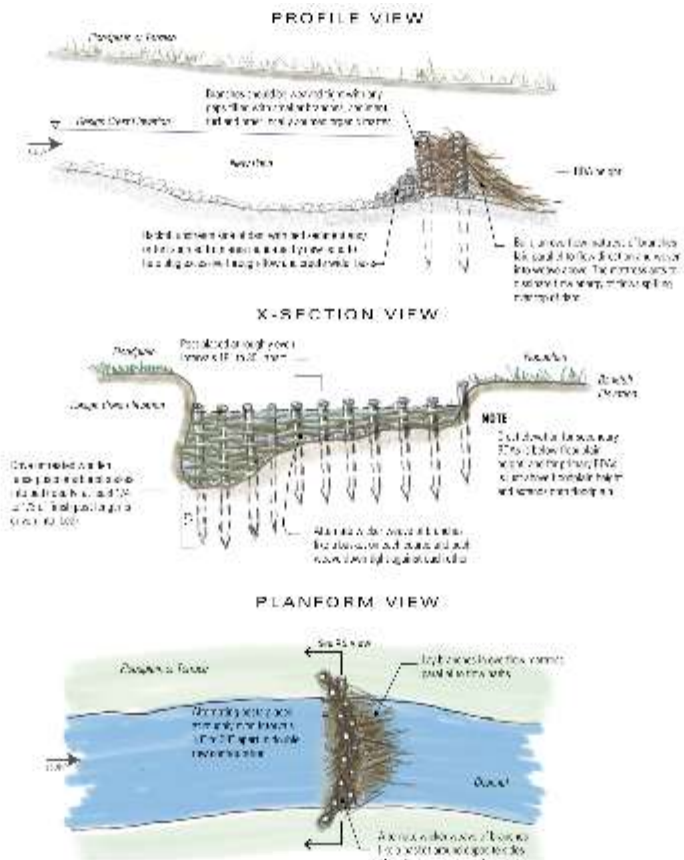
*http://rave.riverscapes.xyz*

## QRiS

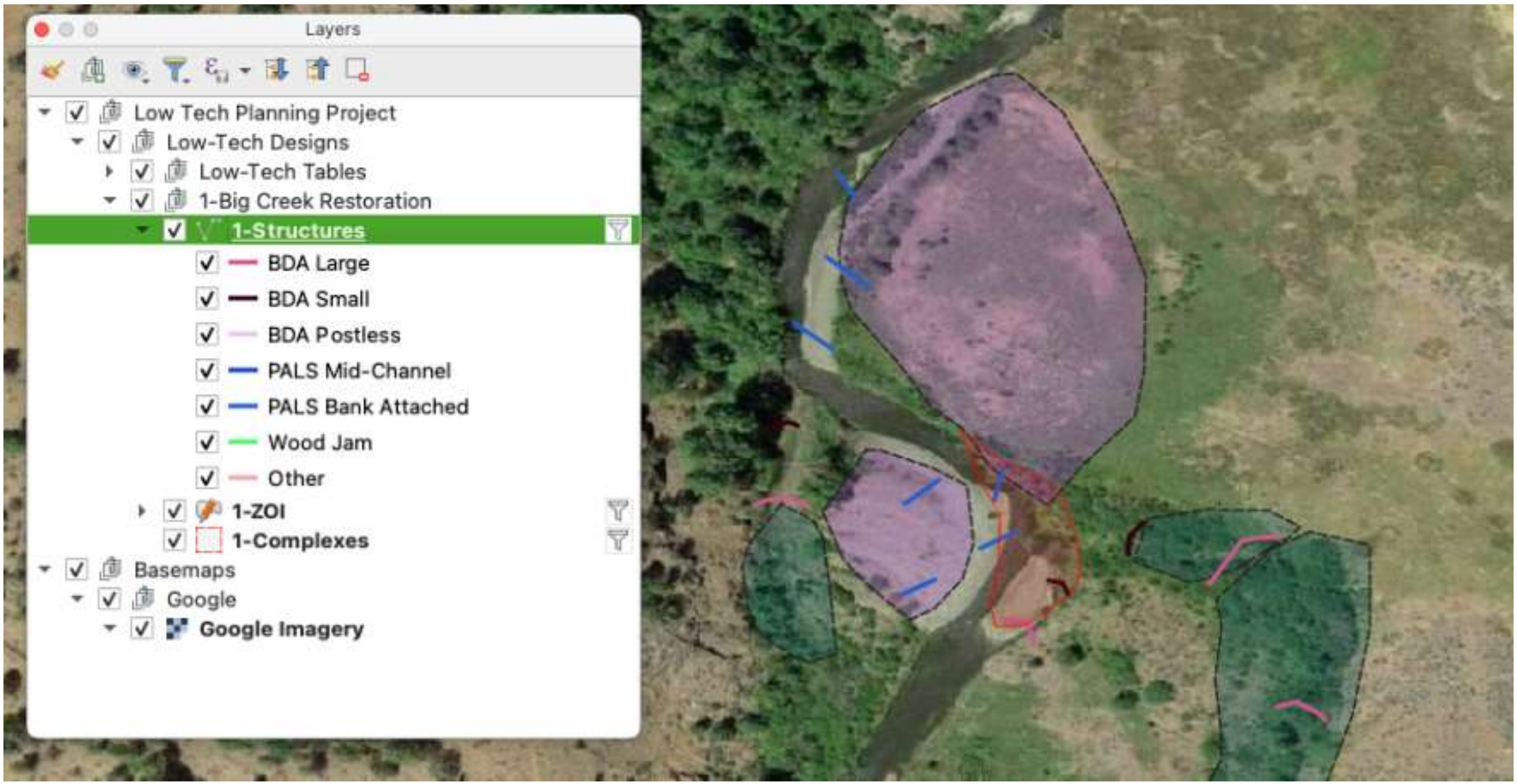
*QGIS Riverscapes Studio*

# Structure Type Specification – Structure Recipes

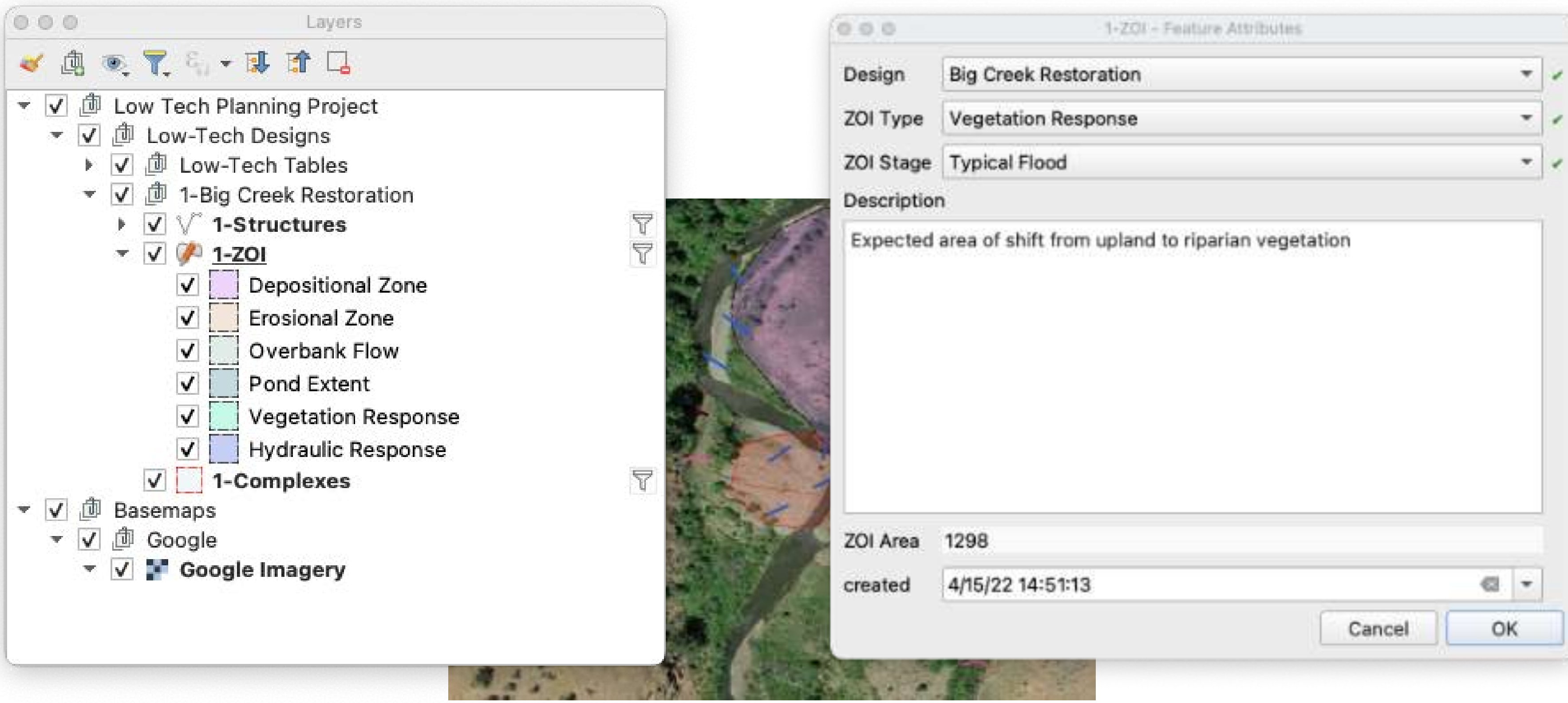


# Structure and Complex Design GIS Standards



# Quantifying Expected Restoration Influence



QRiS

# *Reporting and Summary Data Exports*

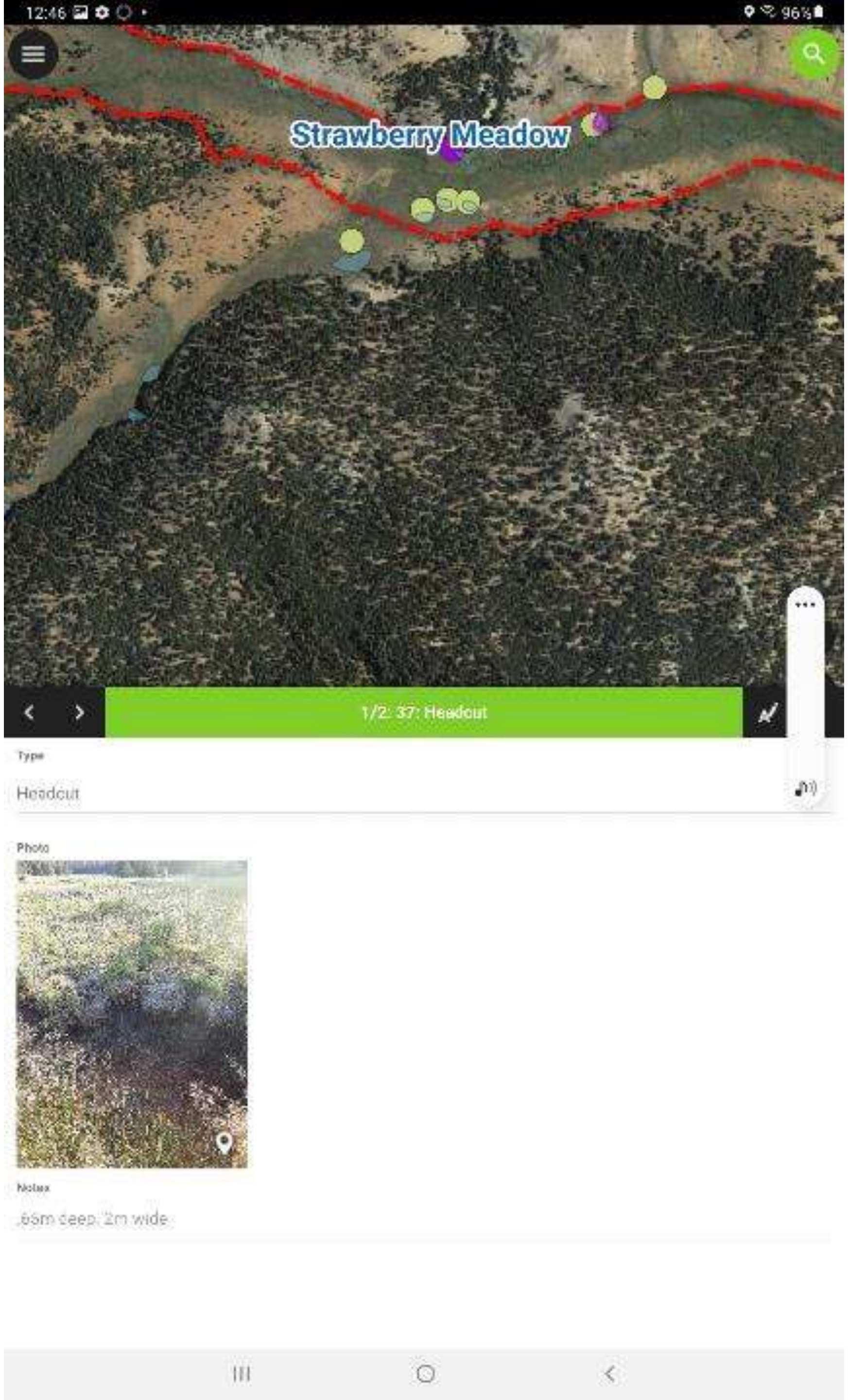
**Structure Summary - Lines — Features Total: 5, Filtered: 5, Selected: 0**

| | na | Design Name | Design Status | Phase Name | Structure Type | Structure Mimics | Structure Count | Total Length |
|---|---|---|---|---|---|---|---|---|
| 1 | | Big Creek Restoration | Specification | Pilot | BDA Large | Beaver Dam | 7 | 122.6 |
| 2 | | Big Creek Restoration | Specification | Pilot | BDA Small | Beaver Dam | 4 | 26.6 |
| 3 | | Big Creek Restoration | Specification | Pilot | PALS Bank Attached | Wood Jam | 11 | 106.7 |
| 4 | | Big Creek Restoration | Specification | Pilot | PALS Mid-Channel | Wood Jam | 6 | 38.8 |
| 5 | | Big Creek Restoration | Specification | Pilot | Wood Jam | Wood Jam | 2 | 12.7 |

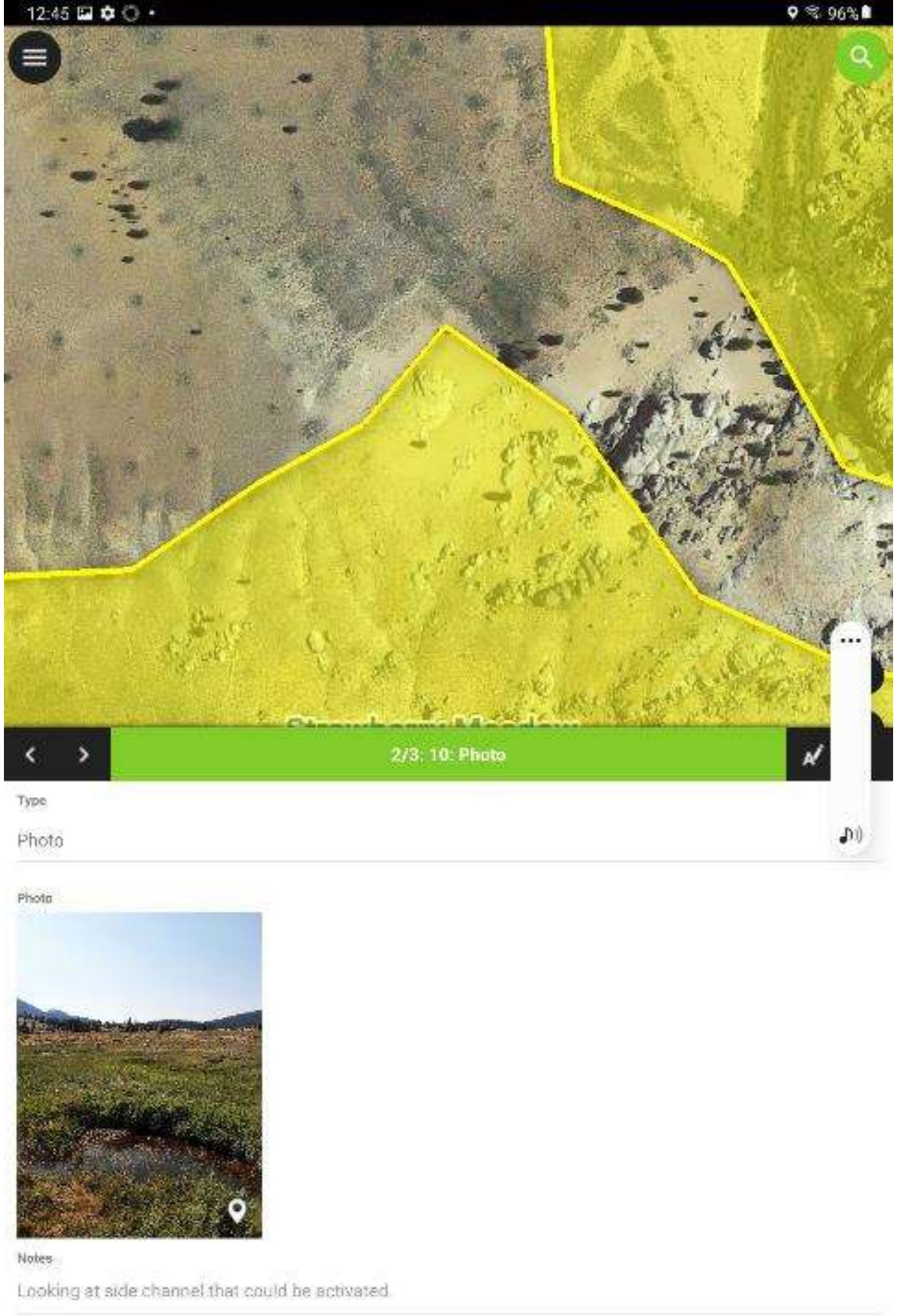
Show All Features

# QFIELD

- Android tablet
- Integrate with QGIS or QRIS
- Record features, photos, etc.



# QFIELD

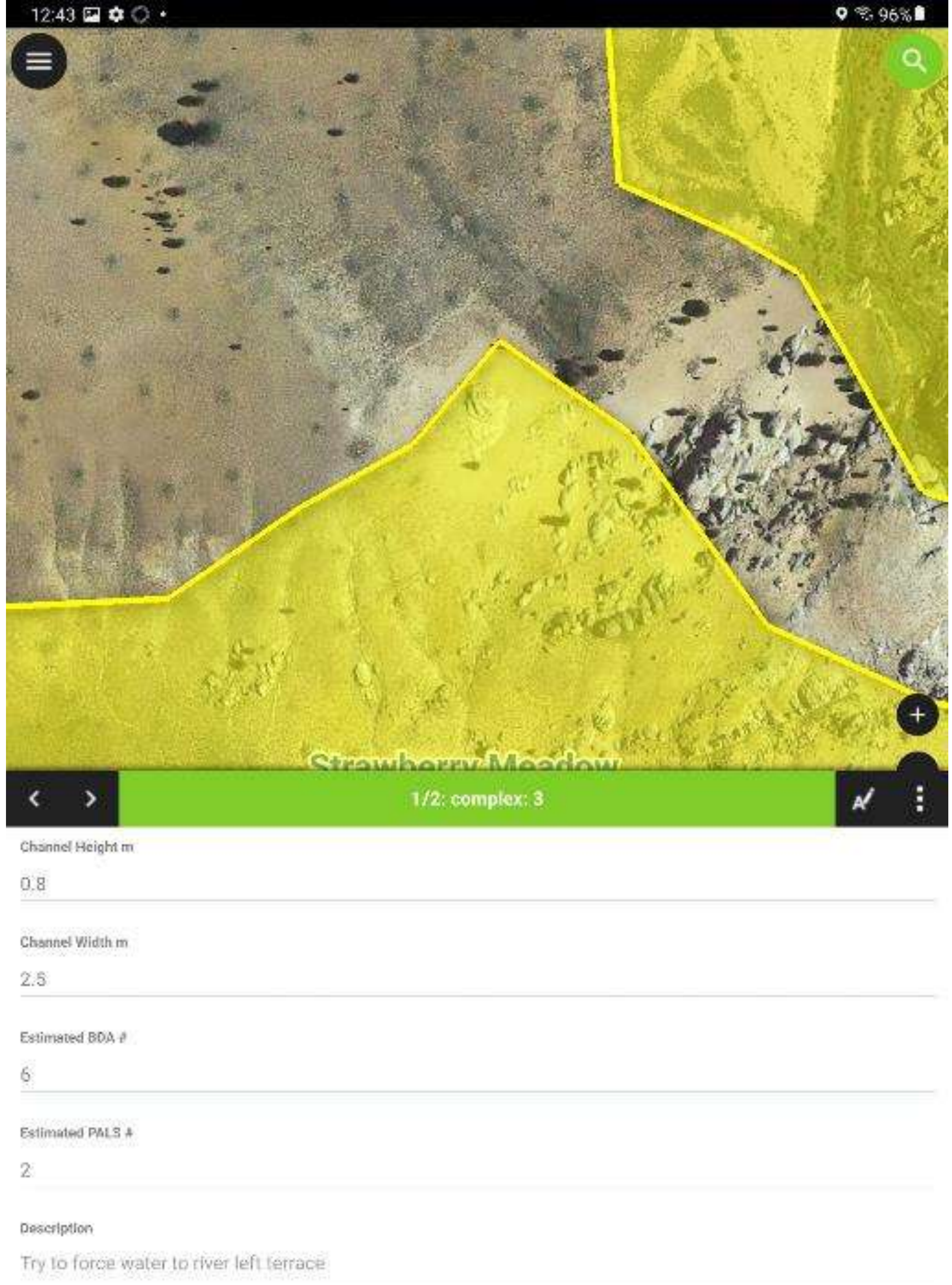


12:45
96%
2/3: 10: Photo
Type
Photo
Photo
Notes
Looking at side channel that could be activated

# QFIELD - Complex design

Complexes

# QFIELD
## Complex design



# DESIGN TOOLS AND SPATIAL ANALYSIS TO SUPPORT LOW-TECH PROCESS-BASED RESTORATION OF RIVERSCAPES

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LT-PBR explorer

About States Projects Sign In Sign Up

# LT-PBR EXPLORER

*Share* and *Discover* Low-Tech Process-Based Restoration Projects

View the Projects Map

Browse the Projects List

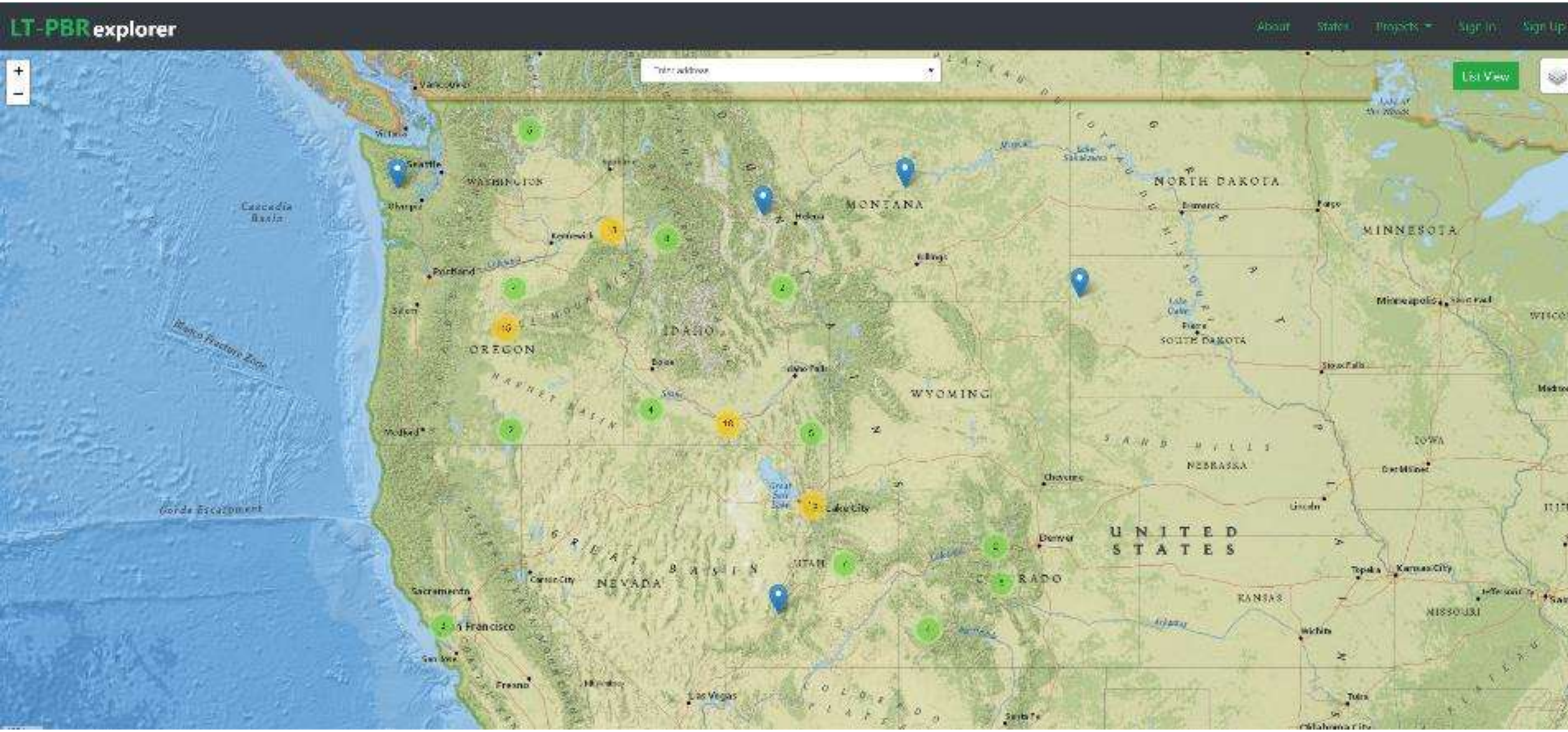
PROJECTS
**132**
Process-based riverscape restoration projects

ORGANIZATIONS
**16**
Number of Organizations represented on BDA-Explorer

LENGTH
**174.6mi**
Total channel length of riverscape restoration implementation

STRUCTURES
**10086**
Beaver dam analog (BDA) and post-assisted log structures (PALS)

STATES
**12**
Number of unique US states containing BDA-Explorer projects




- https://bda-explorer.herokuapp.com/

Enter search terms...
Select organization to match...
Select organization to match...
Filter
Reset Filter

## Parrish Creek Riparian and Hydrologic Enhancement

- Anabranch Solutions — Design and implementation
- Mid John Day - Bridge Creek Watershed Council — Project coordination
- Oregon Watershed Enhancement Board — Funding

John Day
Parrish Creek

## Bear Creek Habitat Enhancement

- Anabranch Solutions — Design and implementation
- Eco Logical Research — Design and monitoring
- Mid John Day - Bridge Creek Watershed Council — Coordination
- NOAA Fisheries — Funding and monitoring
- Oregon Watershed Enhancement Board — Funding
- Wheeler Soil and Water Conservation District — Coordination

John Day
Bear Creek

## Bridge Creek Intensively Monitored Watershed

- Anabranch Solutions — Design and implementation
- Eco Logical Research — Monitoring and design
- NOAA Fisheries — Funding and design
- Oregon Natural Desert Association — Monitoring

John Day
Bridge Creek

## South Fork Crooked River Jake Place

Deschutes
South Fork Crooked River

## South Fork John Day Rapid Riparian Restoration

John Day
South Fork John Day River

# Bear Creek Habitat Enhancement

Anabranch Solutions Design and implementation

Eco Logical Research Design and monitoring

Mid John Day - Bridge Creek Watershed Council Coordination

NOAA Fisheries Funding and monitoring

Oregon Watershed Enhancement Board Funding

Wheeler Soil and Water Conservation District Coordination

State:
Oregon

Stream Name:
Bear Creek

Watershed:
John Day

Project URL:
*None*

Implementation Date:
Jul. 15, 2017

Treatment Length (m):
2000

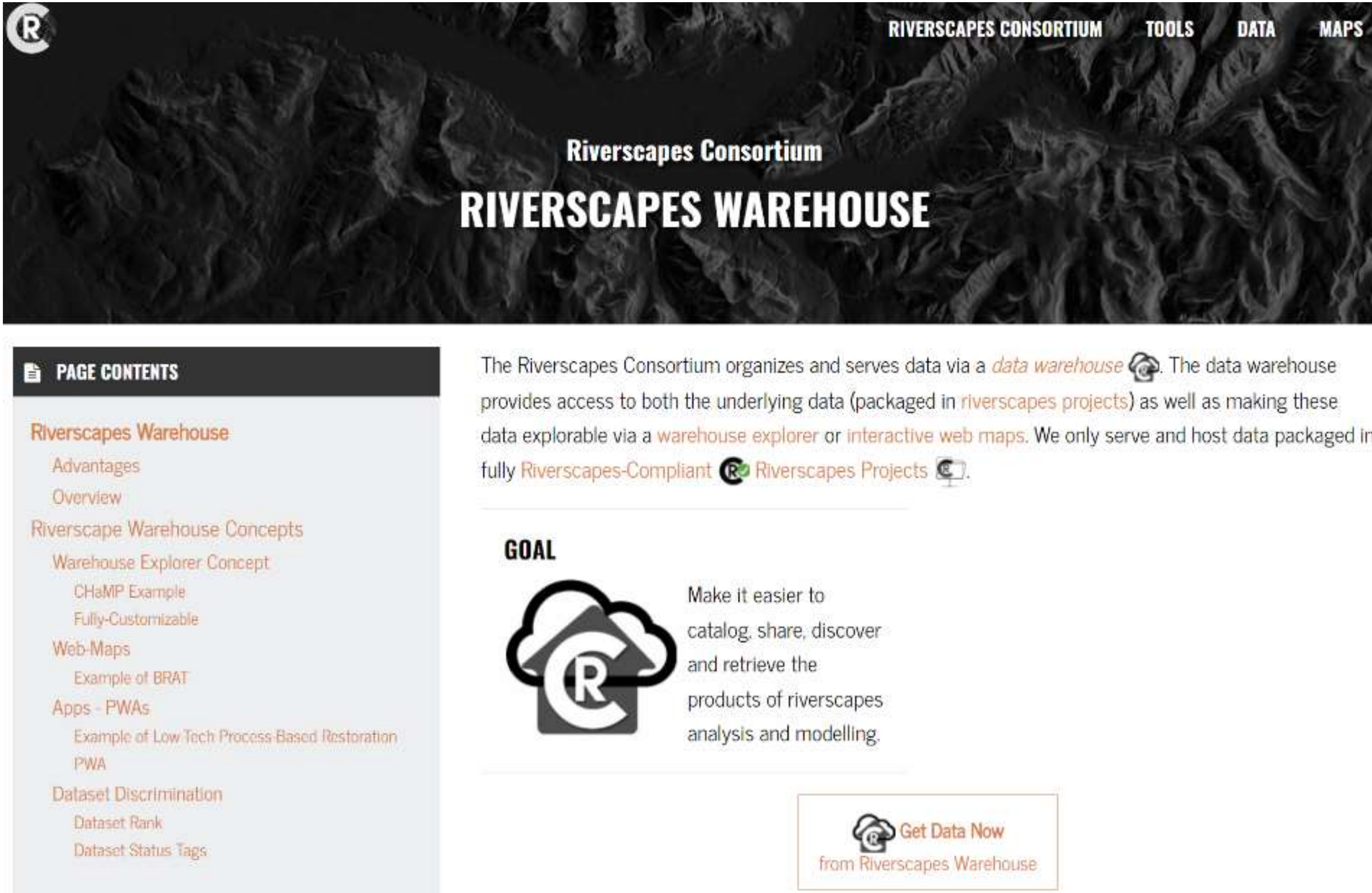
LT-PBR Structures:
90

### Project Goals and Objectives

The primary goal for the project is to increase the abundance of surface flow on intermittent sections Bear Creek during summer. This will provide increased quantity and quality of rearing habitat for juvenile steelhead.

### Structure Construction Elements

BDA structures were largely built by installing post lines across the active channel and applying locally sourced willow with cobble and gravel at the base of


RIVERSCAPES CONSORTIUM TOOLS DATA MAPS

Riverscapes Consortium

# RIVERSCAPES WAREHOUSE

**PAGE CONTENTS**



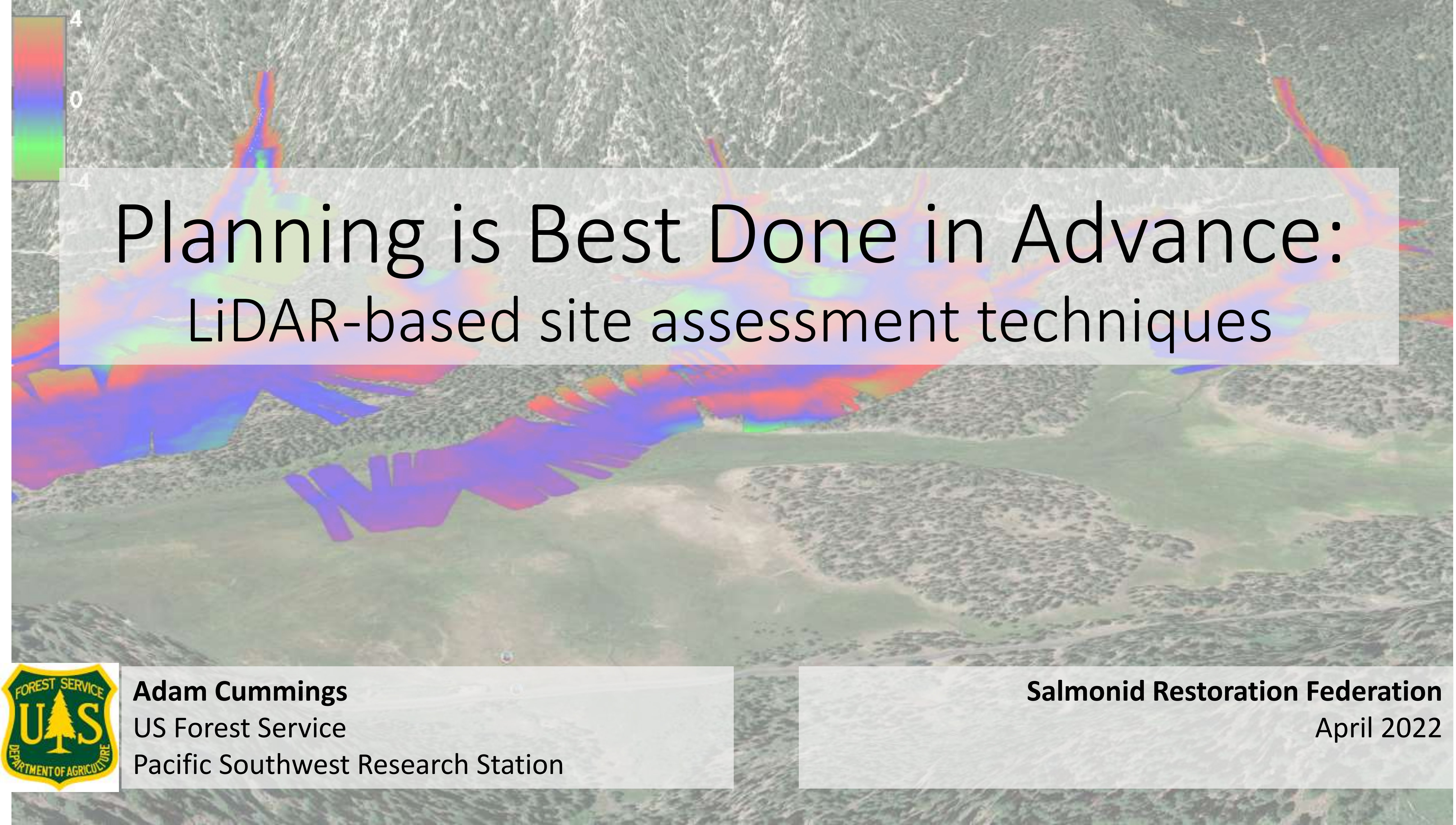
The Riverscapes Consortium organizes and serves data via a *data warehouse*. The data warehouse provides access to both the underlying data (packaged in riverscapes projects) as well as making these data explorable via a warehouse explorer or interactive web maps. We only serve and host data packaged in fully Riverscapes-Compliant Riverscapes Projects.

## GOAL

Make it easier to catalog, share, discover and retrieve the products of riverscapes analysis and modelling.

Get Data Now
from Riverscapes Warehouse

riverscapes.xyz/Data_Warehouses/




# Planning is Best Done in Advance:

## LiDAR-based site assessment techniques

**Adam Cummings**
US Forest Service
Pacific Southwest Research Station

**Salmonid Restoration Federation**
April 2022

# Process Based Restoration?

- Meadows in the Sierra Nevada have self-perpetuated for millennia.

- Meadows in the Sierra Nevada have self-perpetuated for millennia.

- Natural **processes** are responsible for that resilience.

- **Identify and remove source problems** that disturb those self-perpetuating processes.

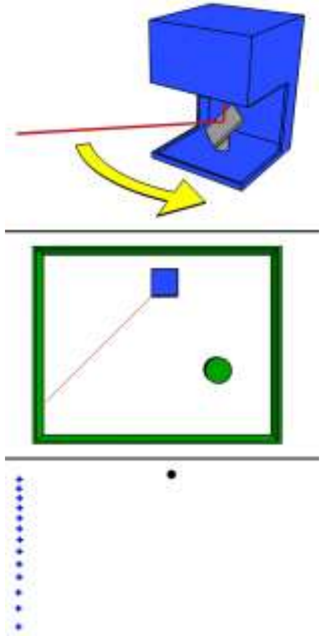
- Using local energy is way less risky than the alternative.

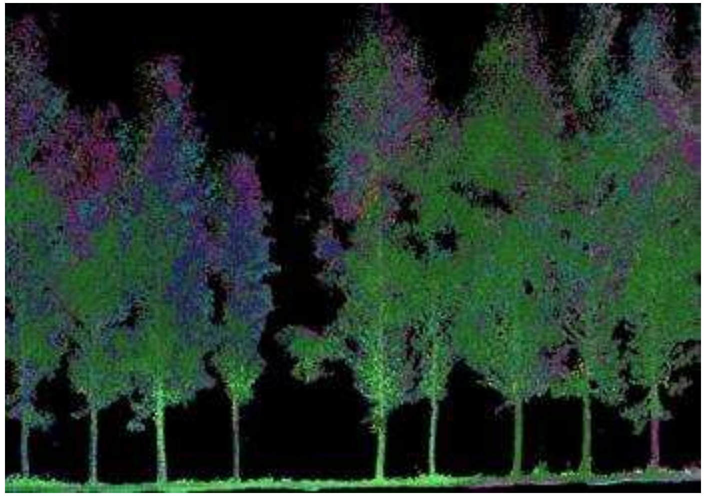
# LiDAR in 20 seconds…

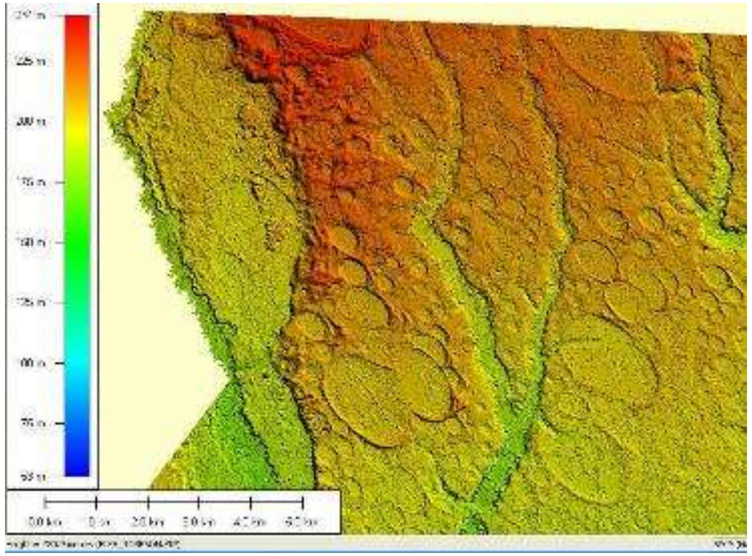
Today's talk:

Lasers + Magic = High-res terrain map

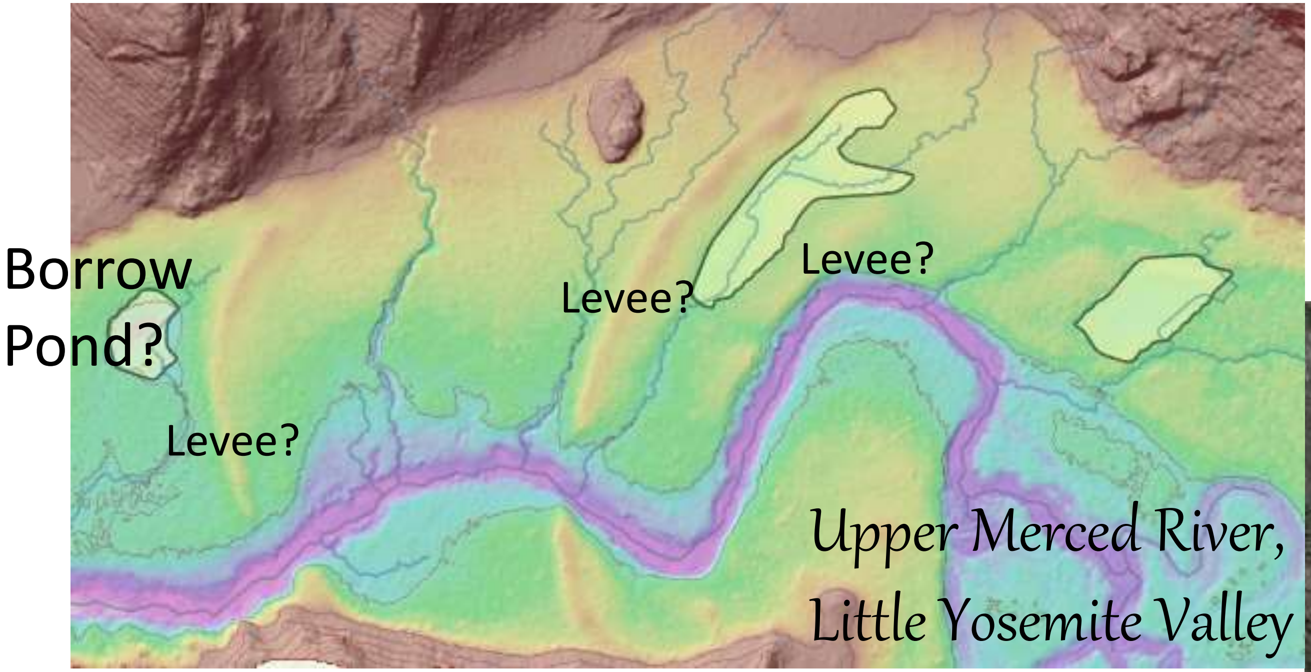
(among other things…)



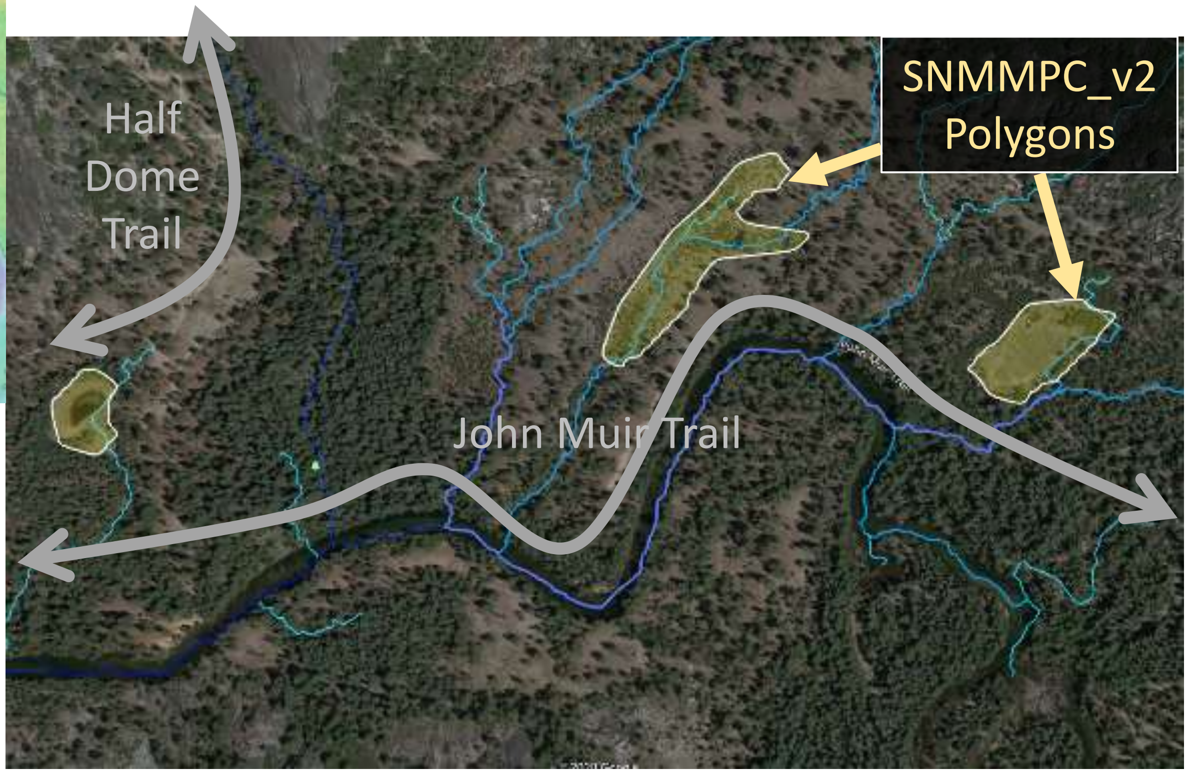




# One application of LiDAR



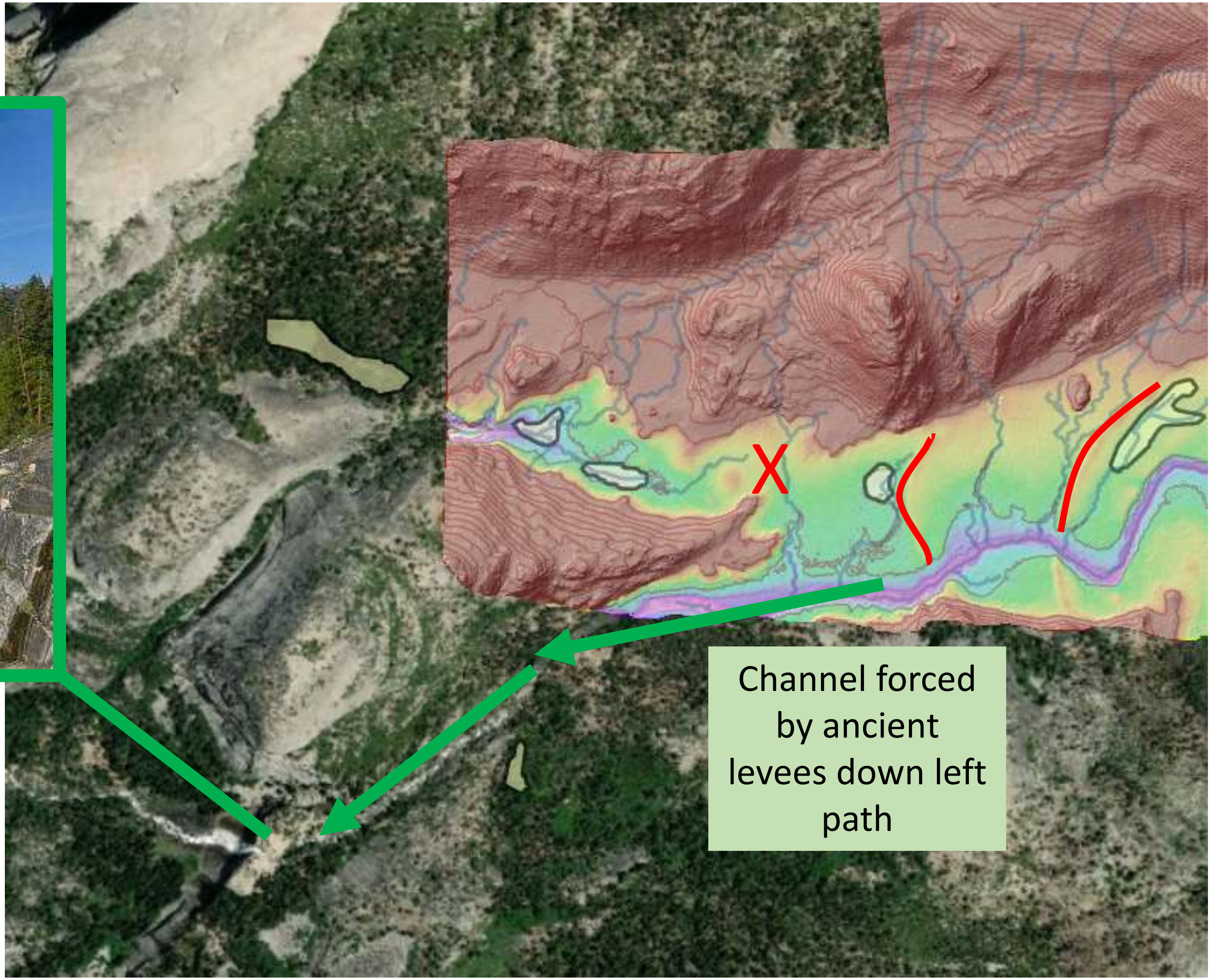

- Have you seen this “borrow pond” before?
- Did you recognize it as such?




LiDAR can reveal ancient disturbance patterns…

# Is Nevada Falls artificial?!

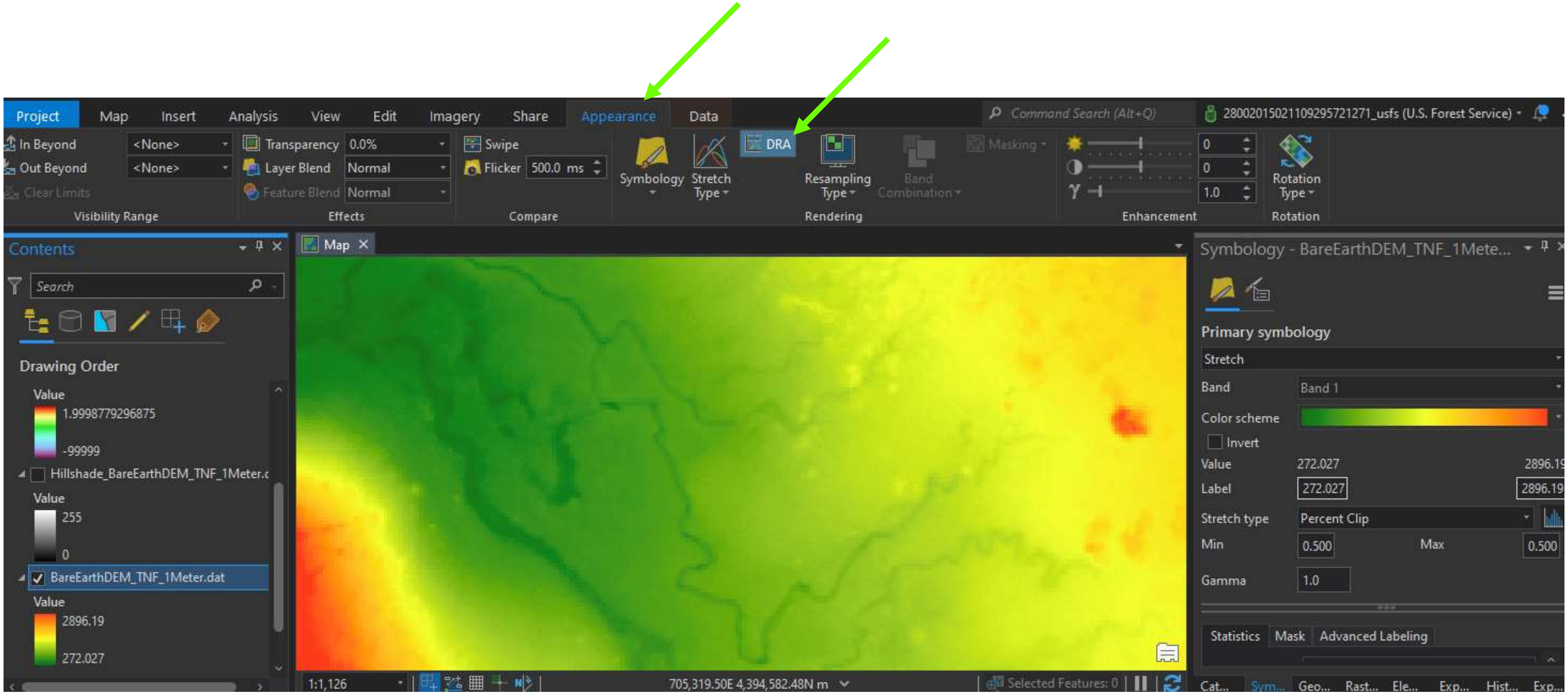
(Disclaimer: Probably not… Please don't let my joke ruin your childhood memories…)



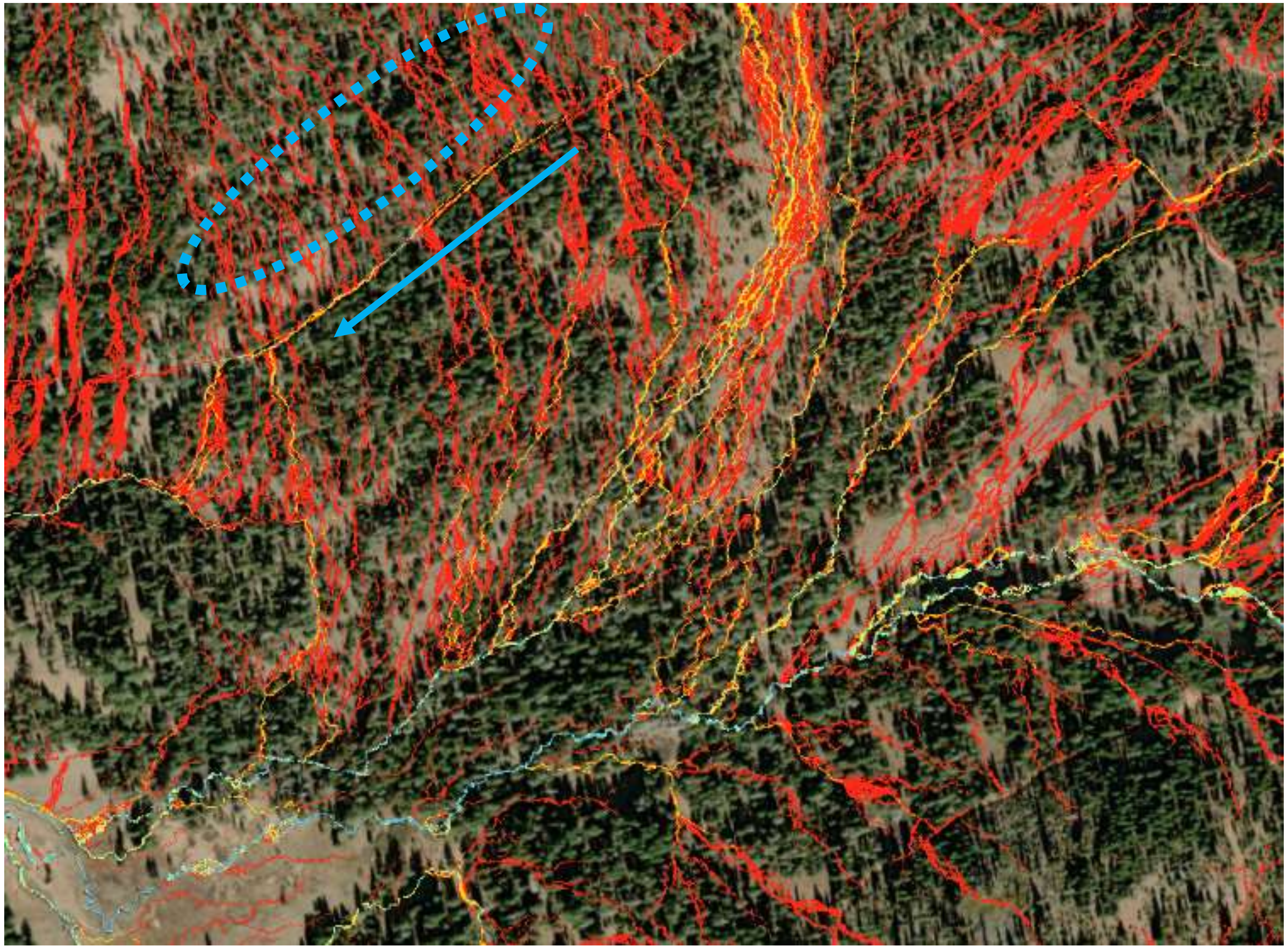
# Take aways from today’s talk:

- Simple
  - Dynamic Range Adjustment
  - Low threshold flow accumulation
- Complicated
  - Detrended Elevation Models

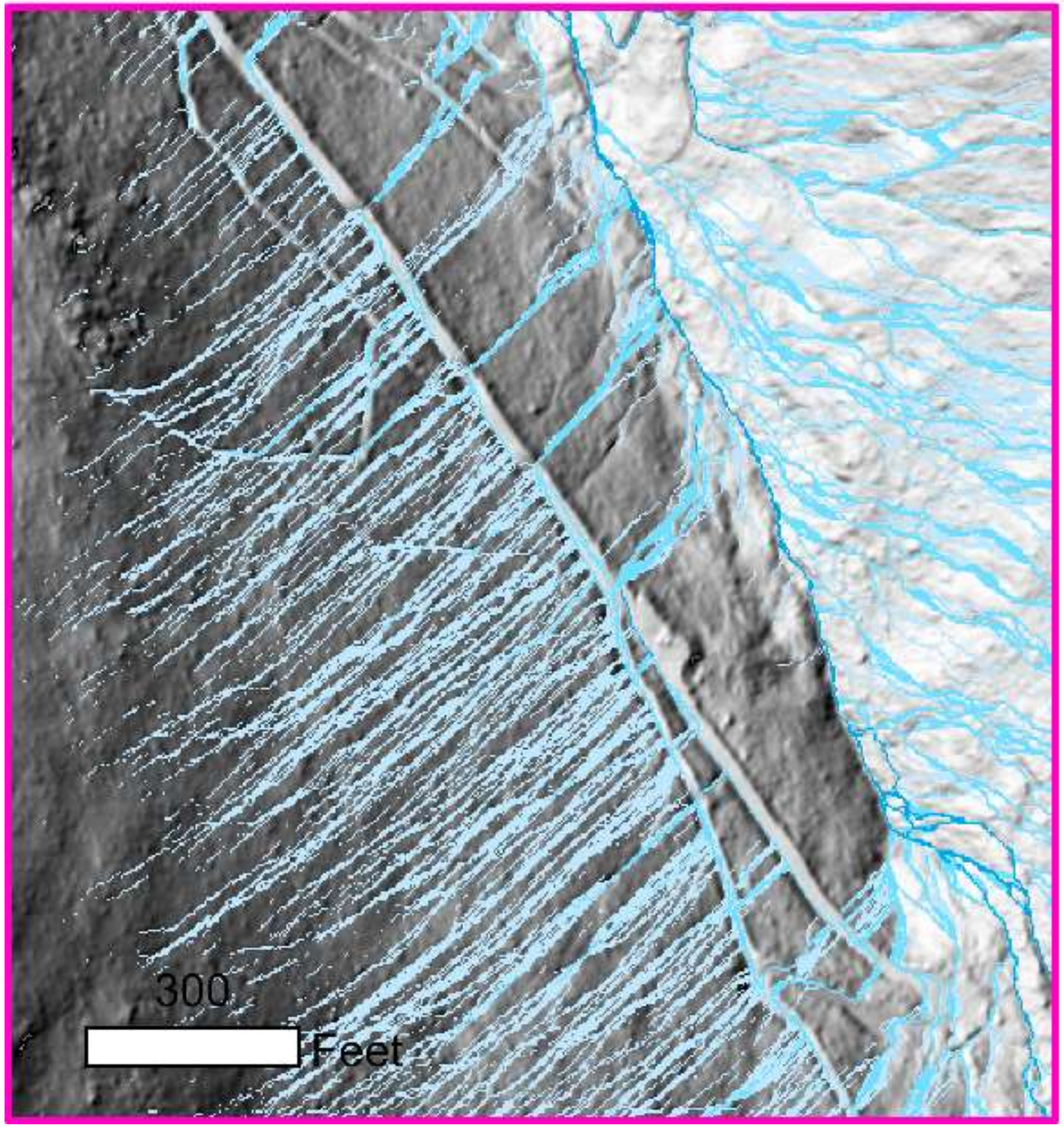
# Dynamic Range Adjustment

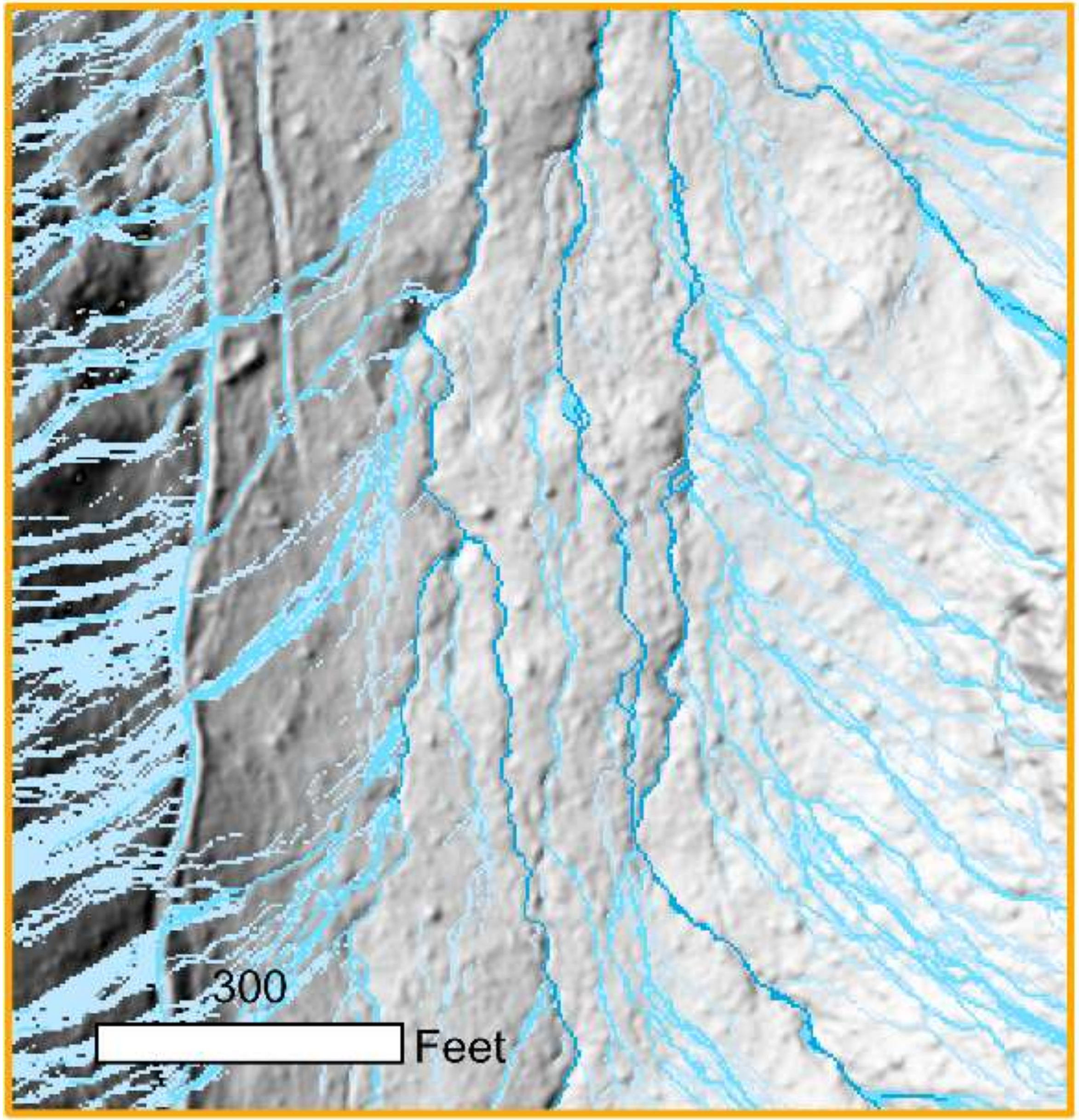


# Low-Threshold Flow Accumulation

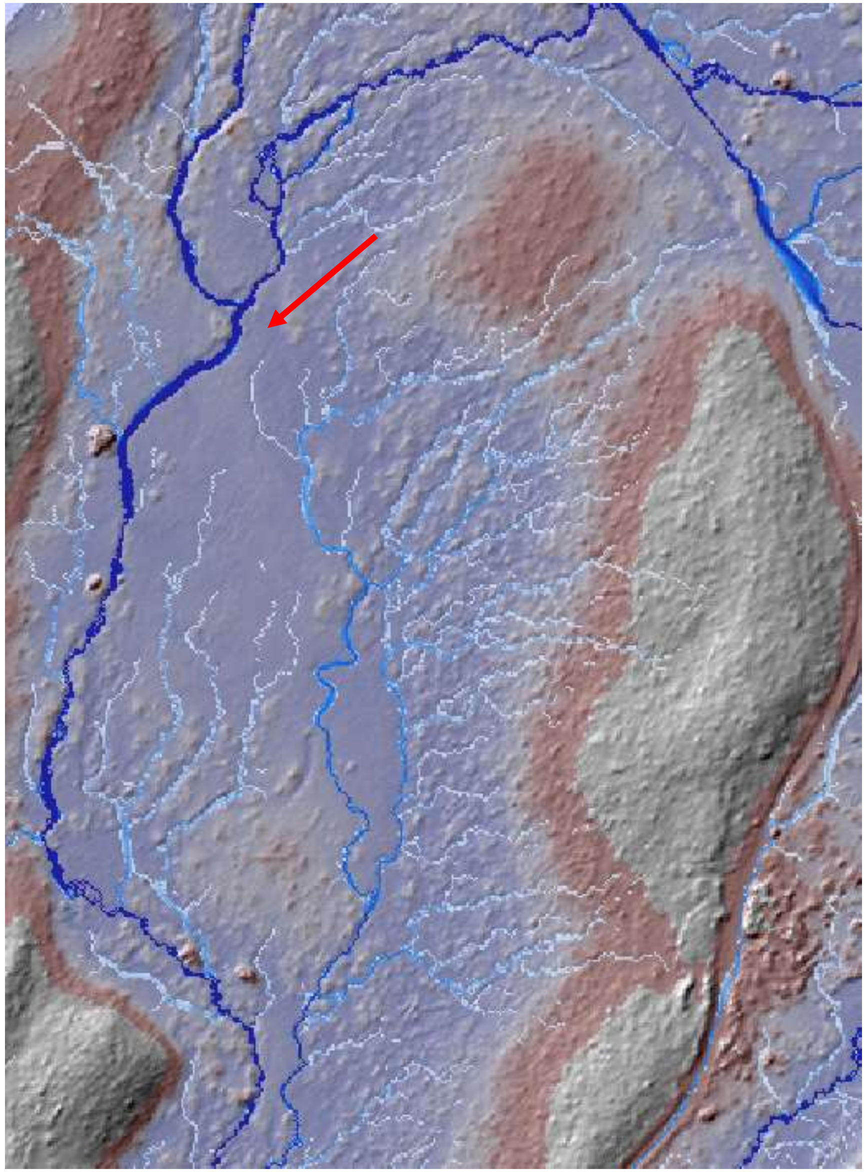


- Roads have dramatic (and often ignored) impacts on groundwater and surface water.


300
Feet


300
Feet

# Low-Threshold Flow Accumulation



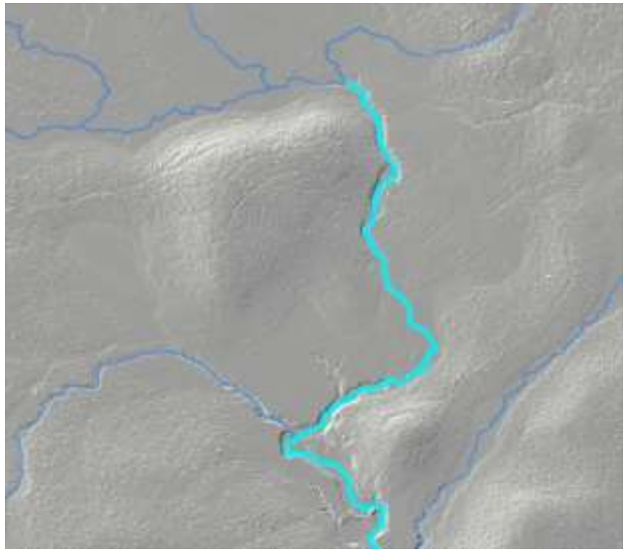
- Flow accumulations can show potential reconnection or switch points

- To make a LTFA:
  - Use your favorite software to make a flow accumulation raster.
  - Then set the symbology to mask values below a low threshold (50? 150? 10000?)

# Detrended Elevation Raster

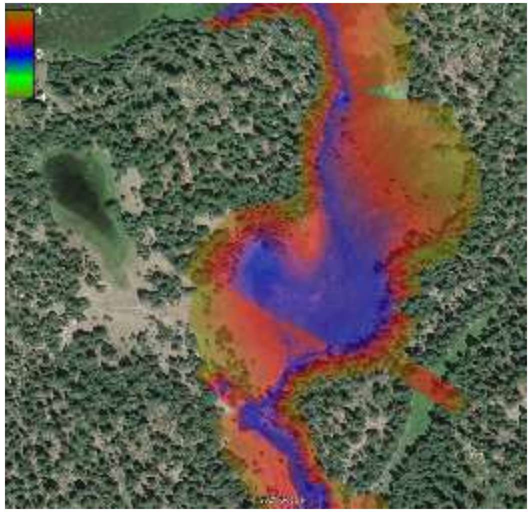
## An R package {ProcessSpace}

### Inputs:



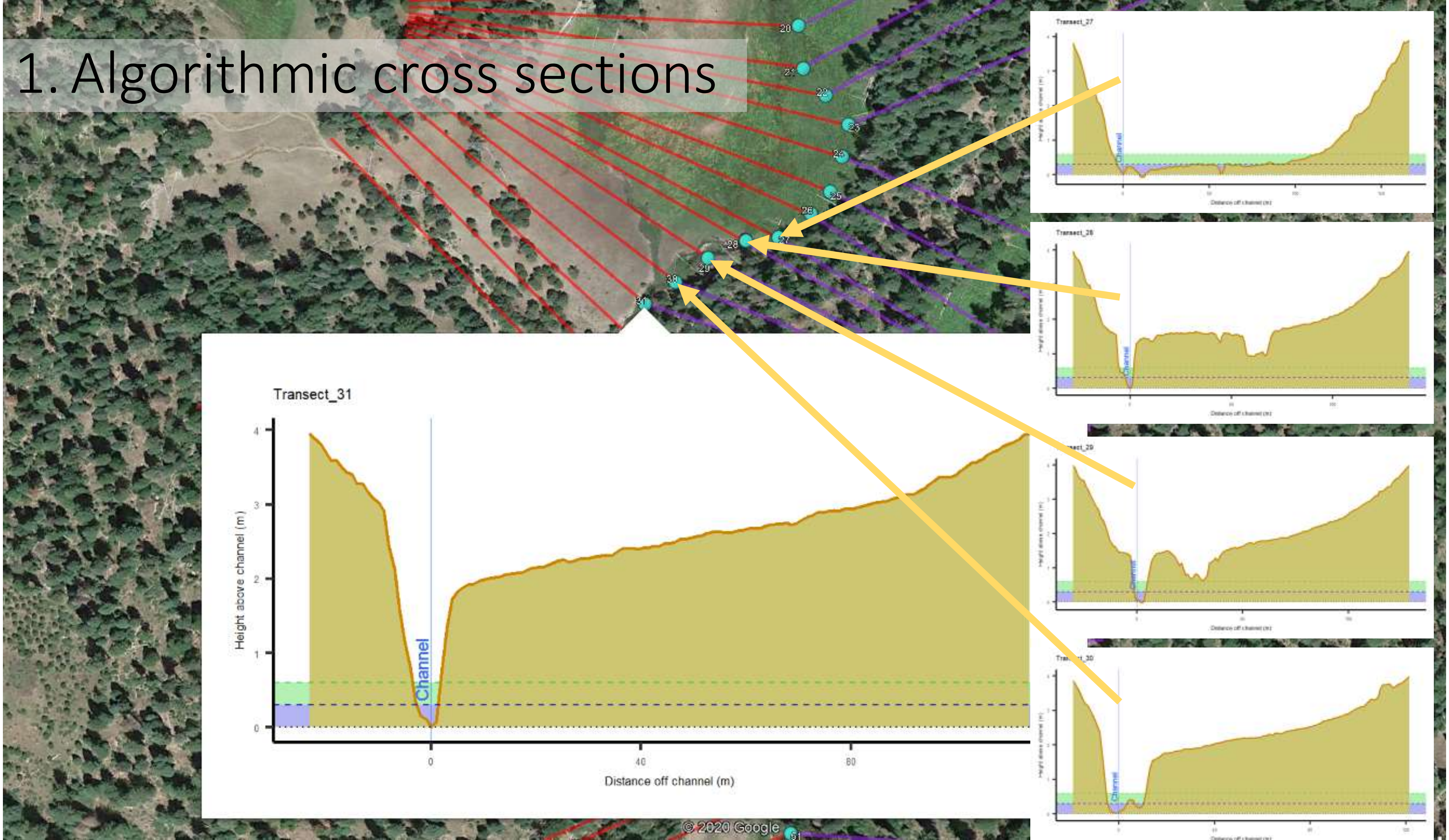
1. Digital Terrain Model
2. Target Stream Reach

### Outputs:

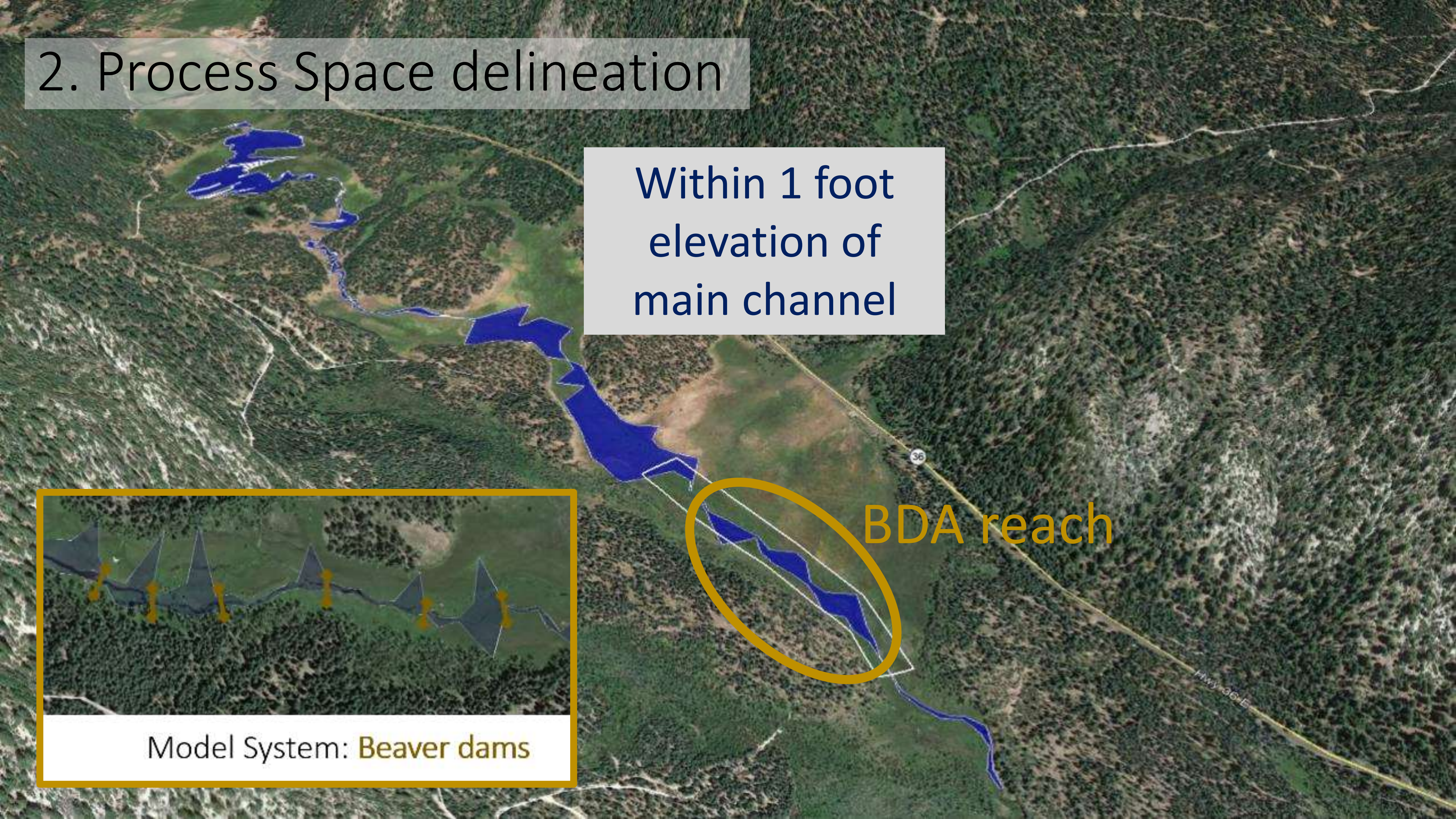


1. Algorithmic cross sections
2. “Process Space” delineation
3. PDF Report
4. Elevations relative to the stream (detrended)
5. **A mindset that extends beyond the meadow surface**

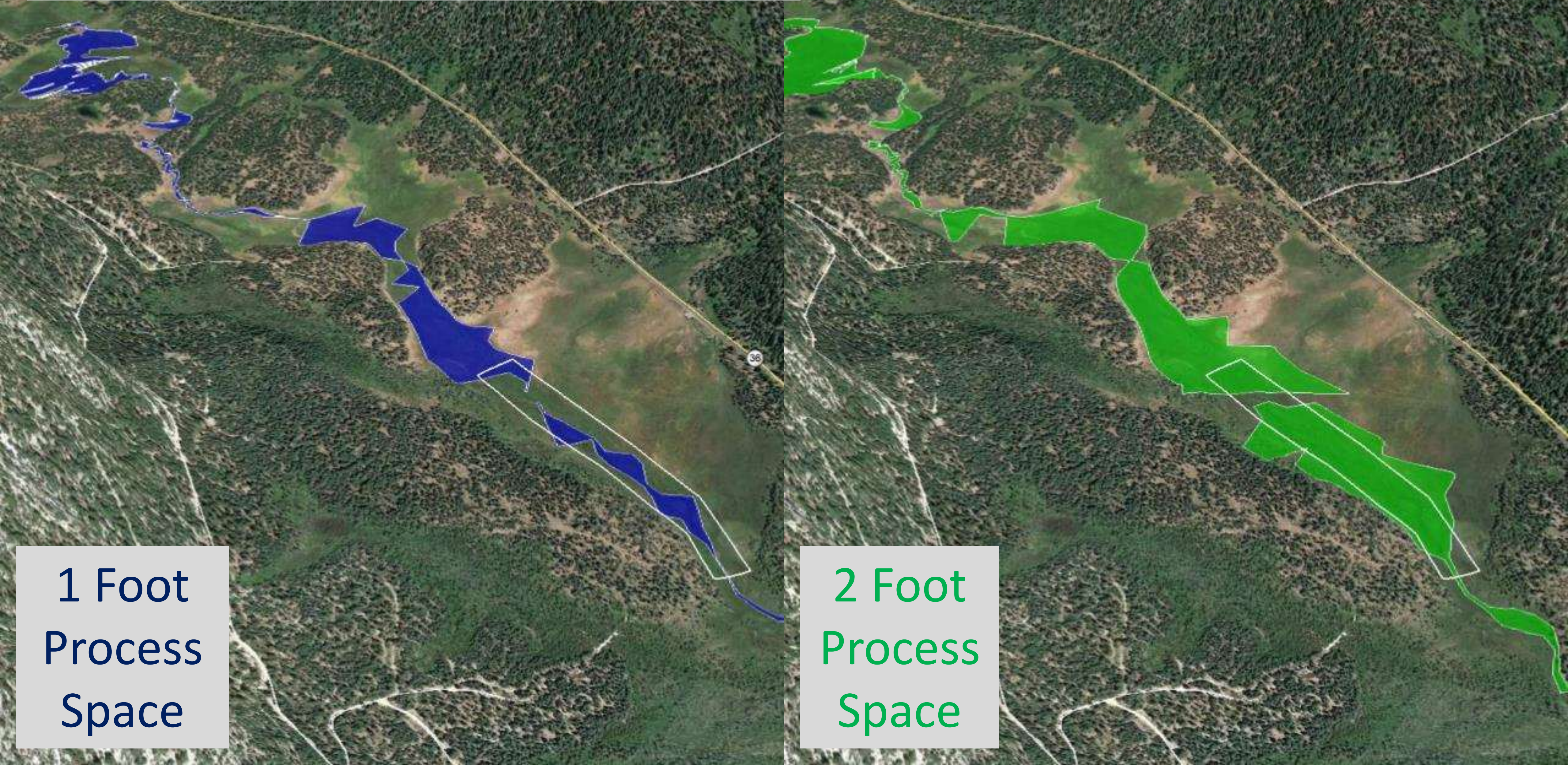
# 1. Algorithmic cross sections



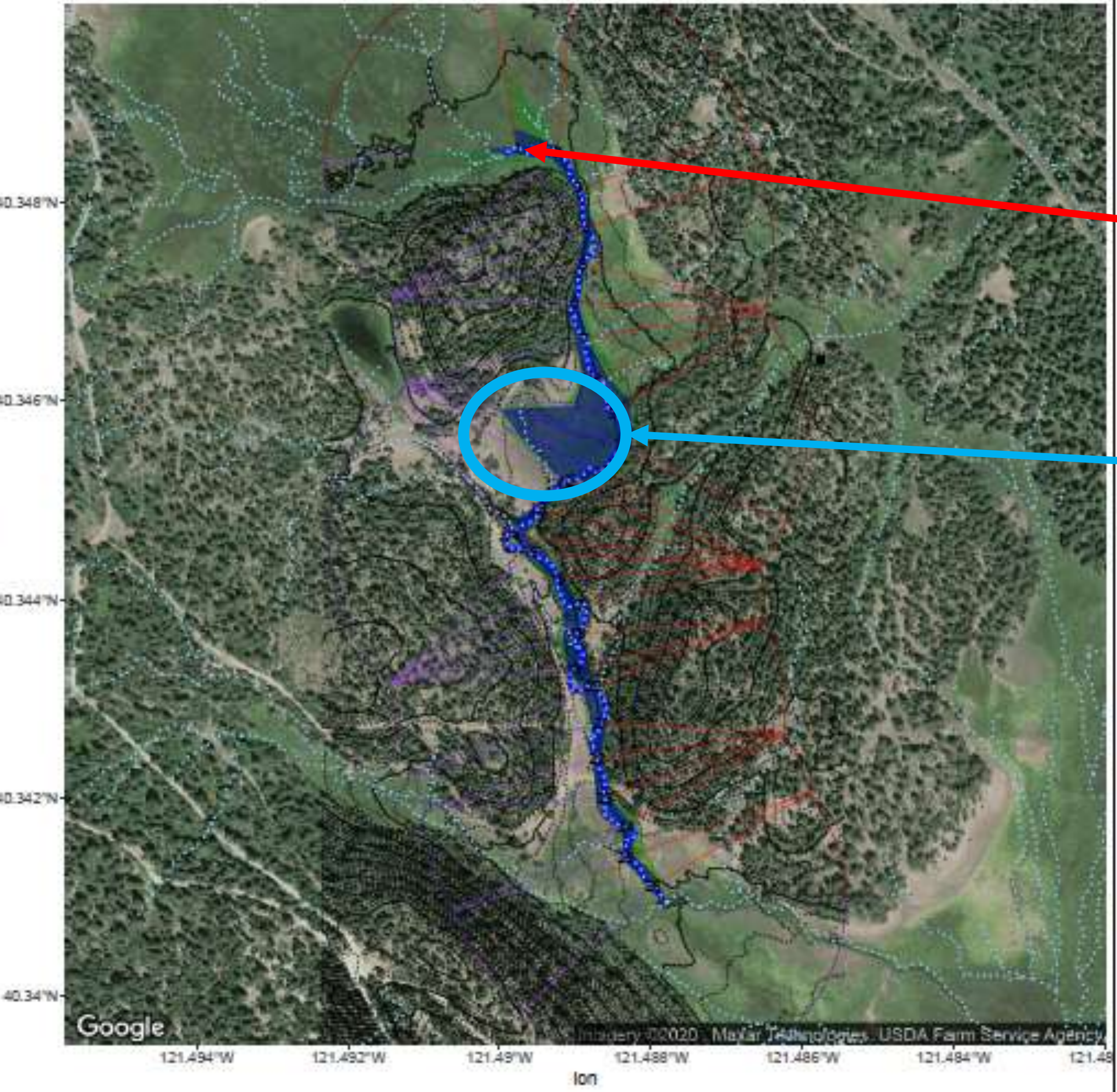
# 2. Process Space delineation

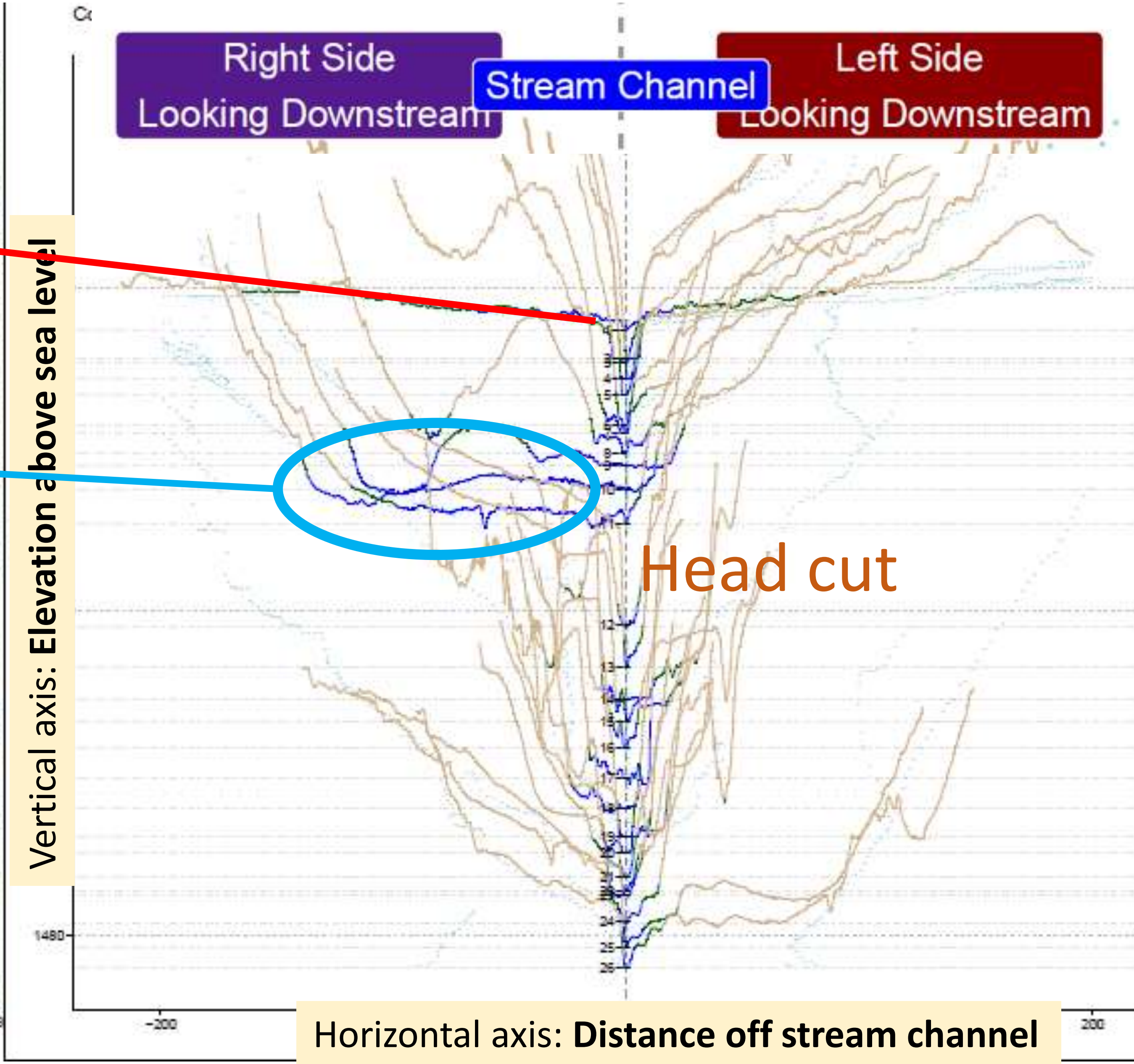


# 2. Process Space delineation



# 3. Report export



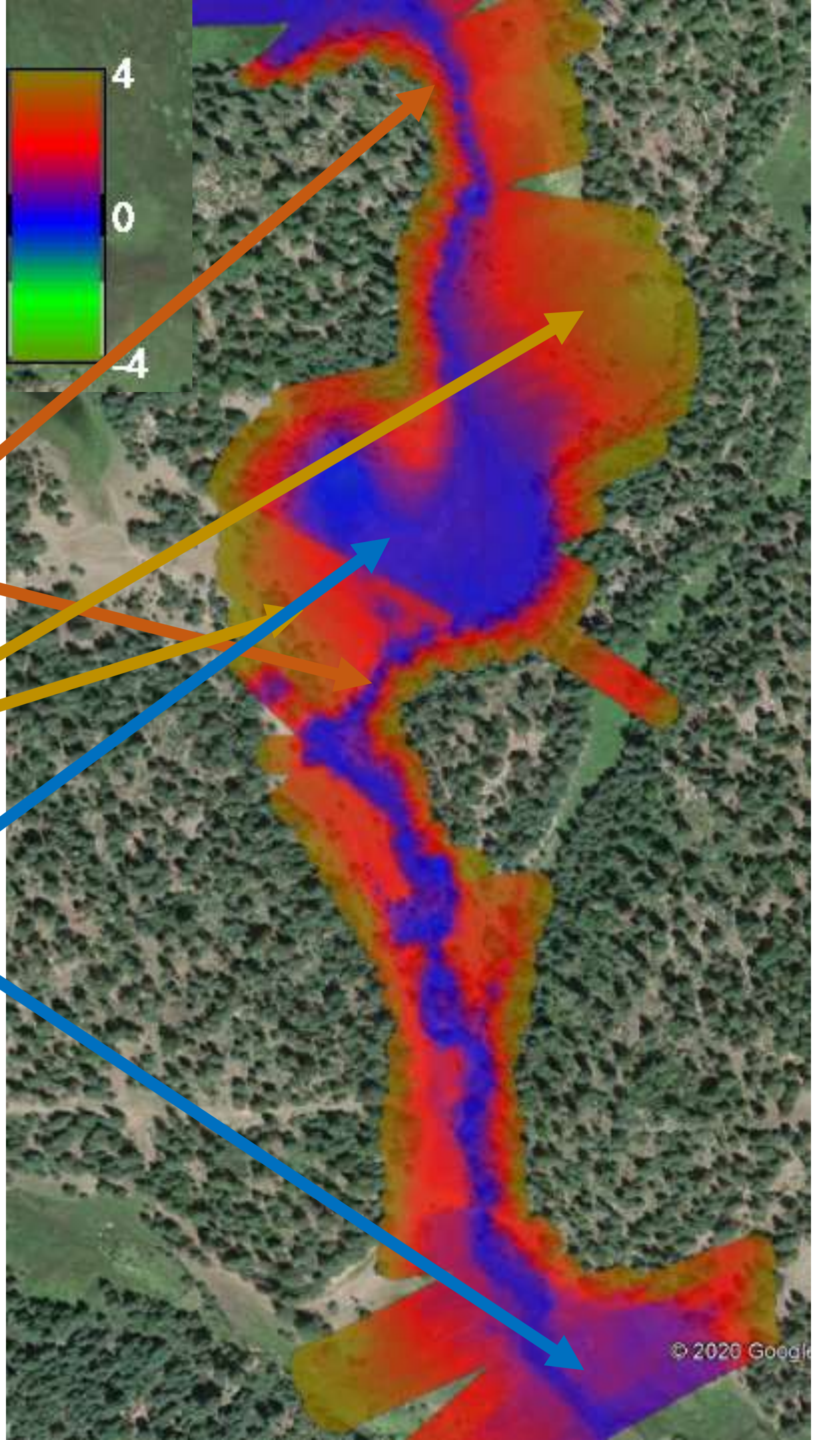
# 4. Elevations relative to stream

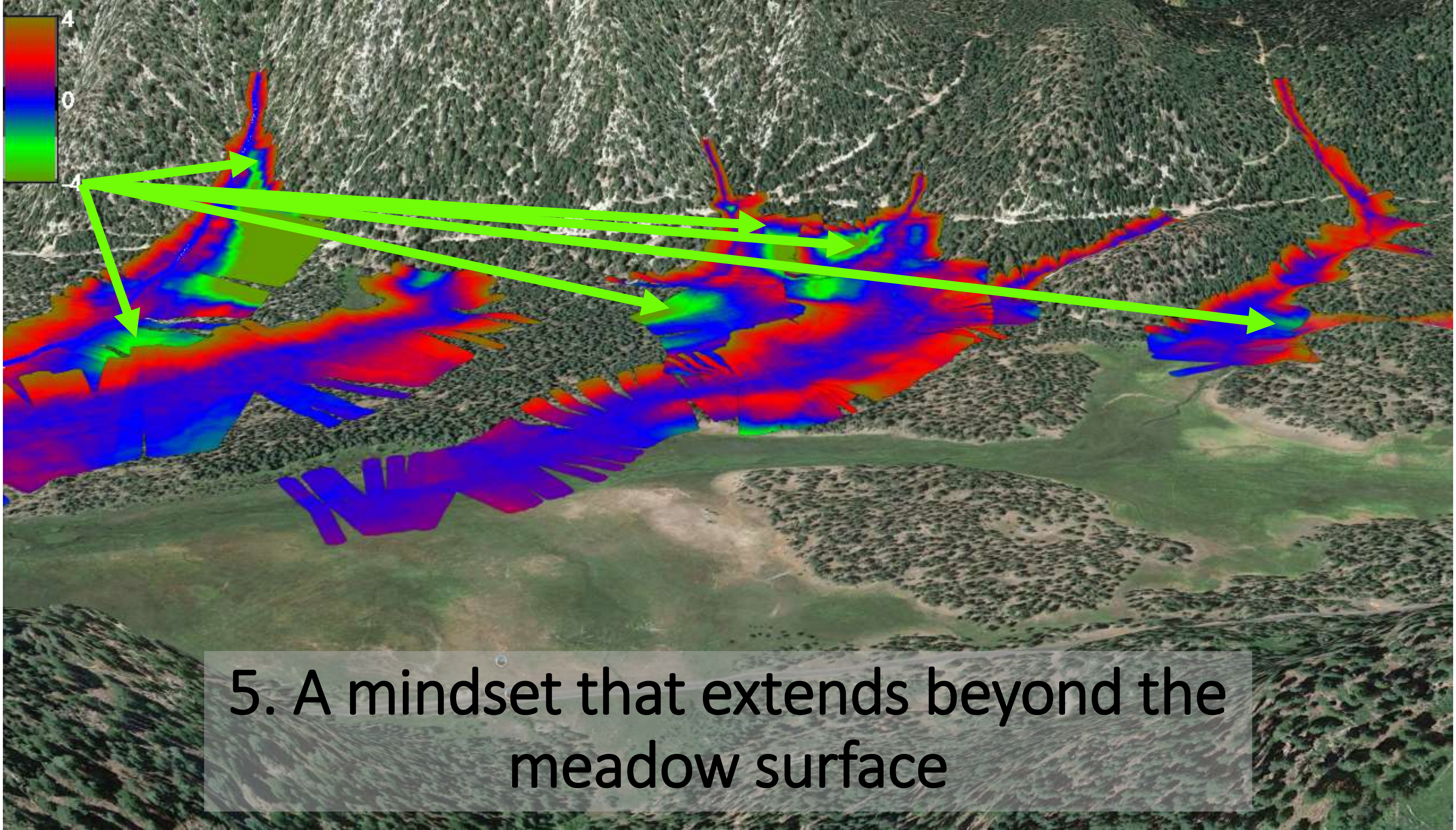
This allows us to see areas of:

Incision

Disconnection

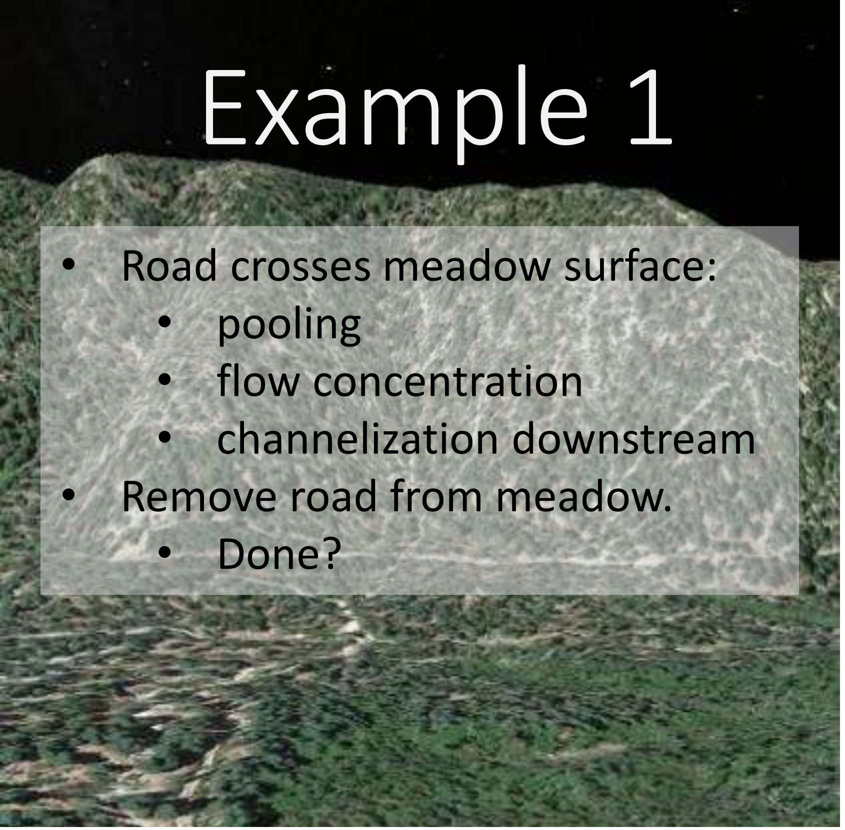
Connection
(potential)

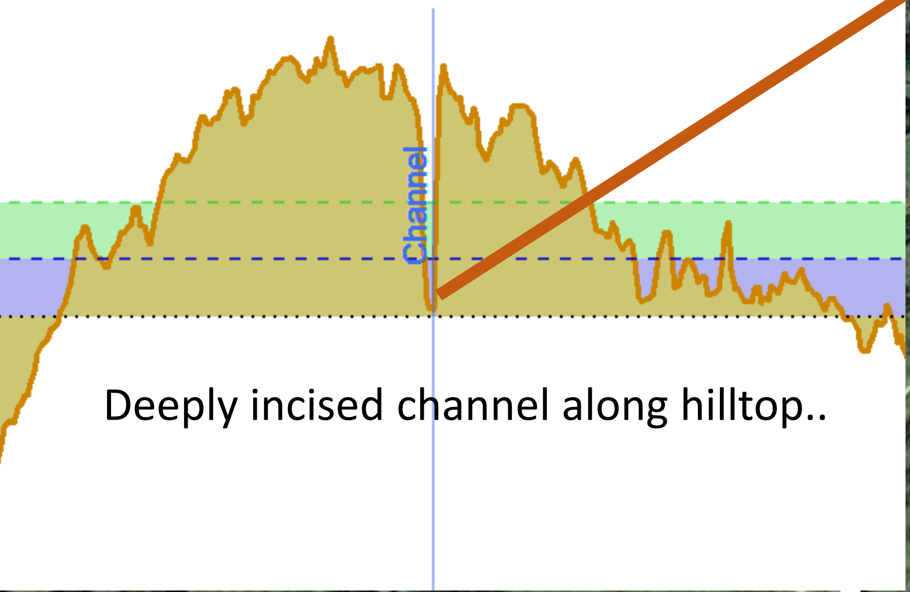



4
0
-4
5. A mindset that extends beyond the meadow surface

# Example 1

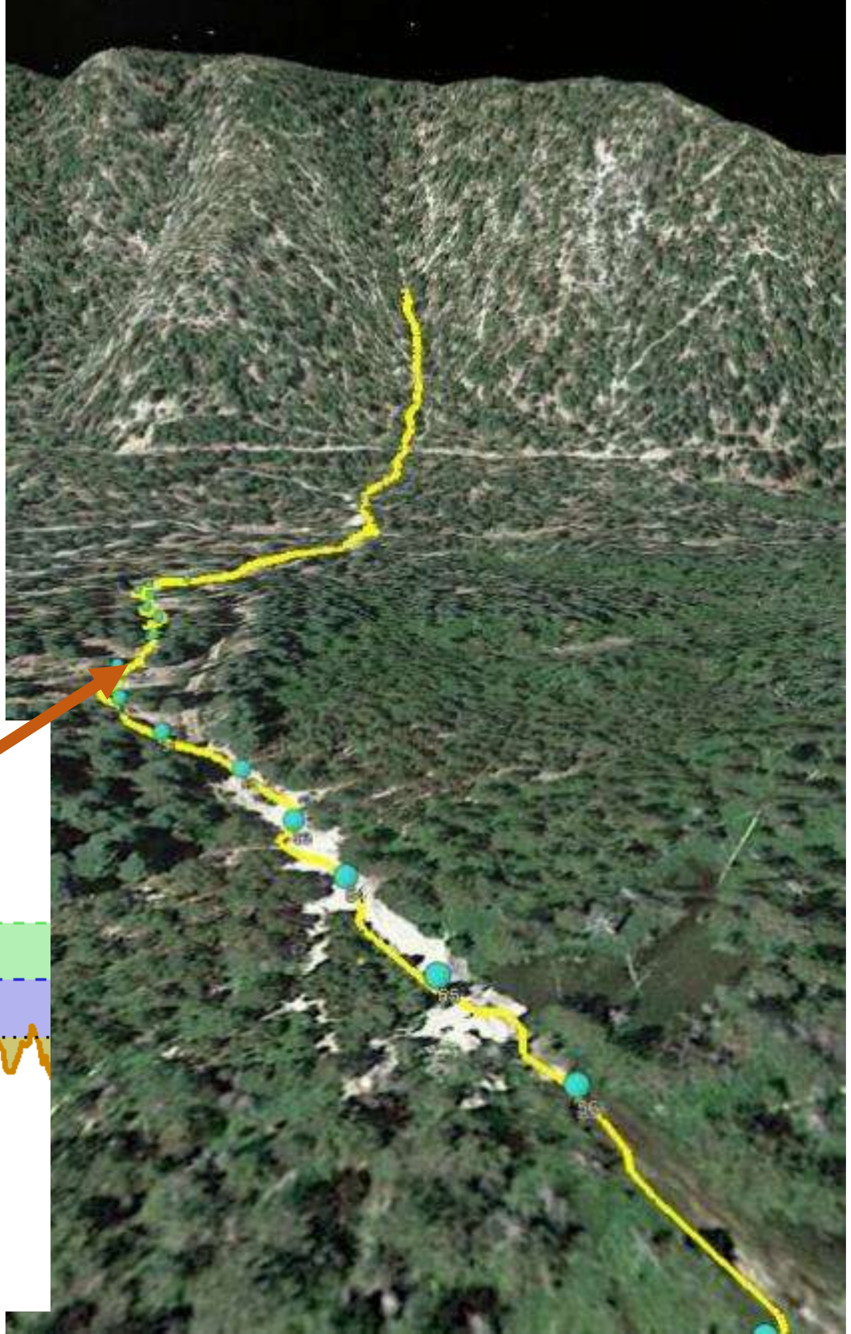
- Road crosses meadow surface:
  - pooling
  - flow concentration
  - channelization downstream
- Remove road from meadow.
  - Done?



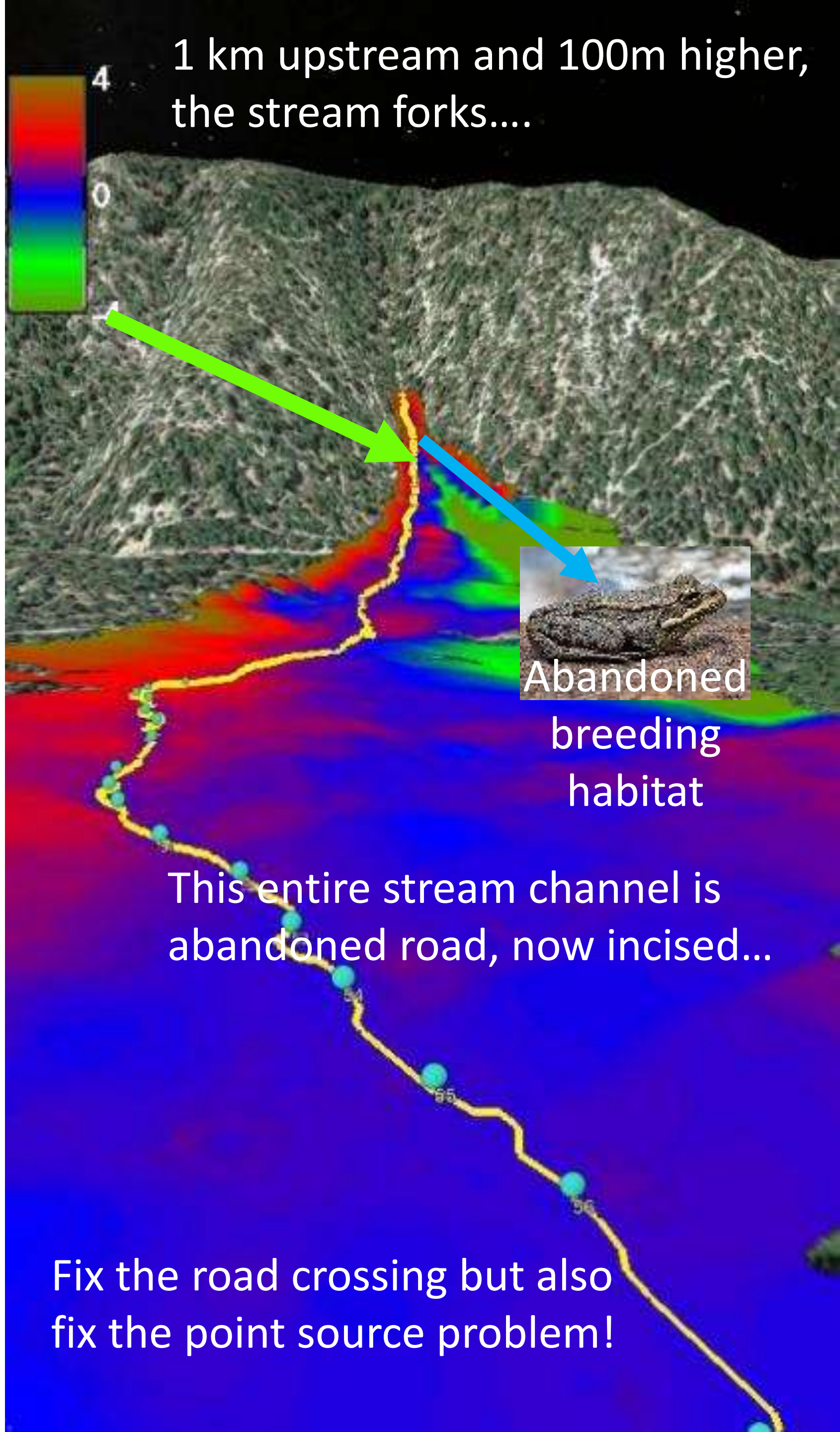



Deeply incised channel along hilltop..

## All roads lead to incision…



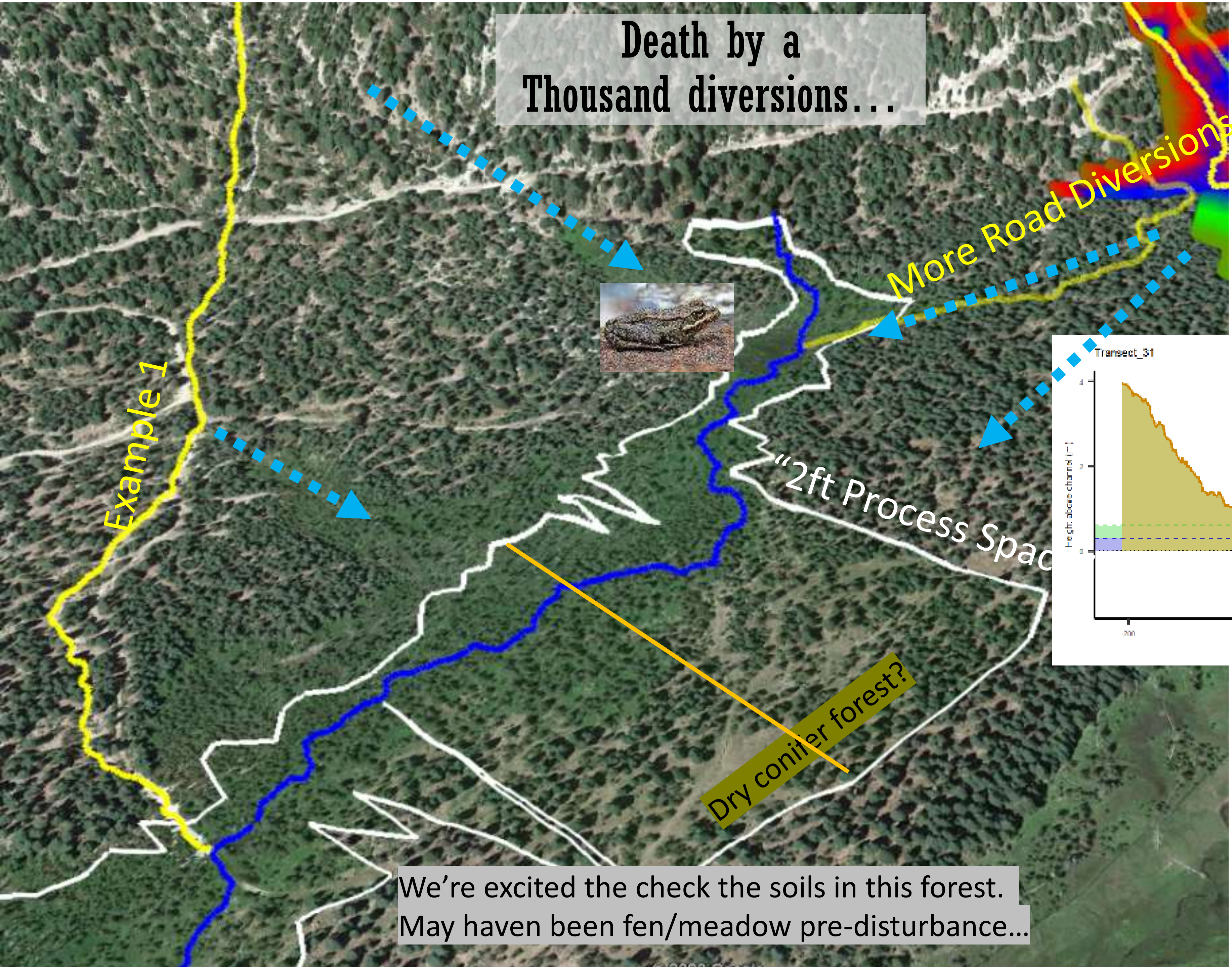
1 km upstream and 100m higher, the stream forks….

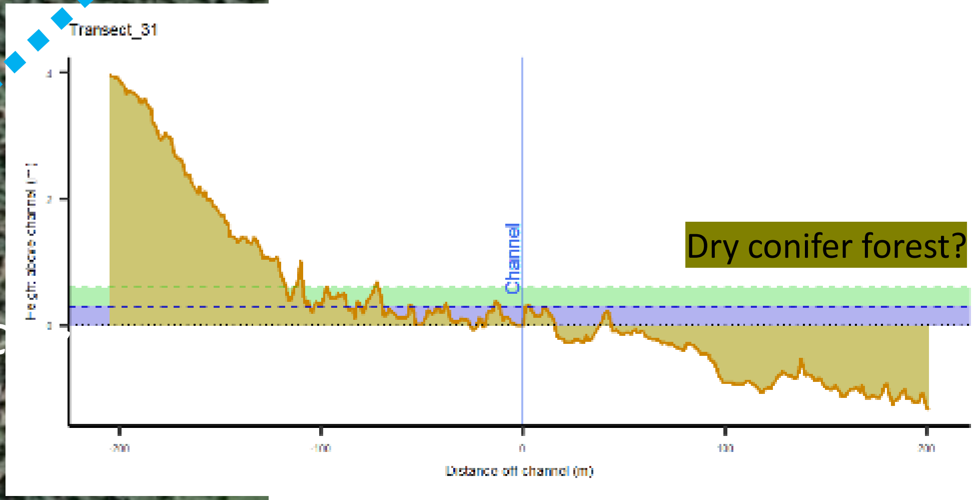



breeding habitat

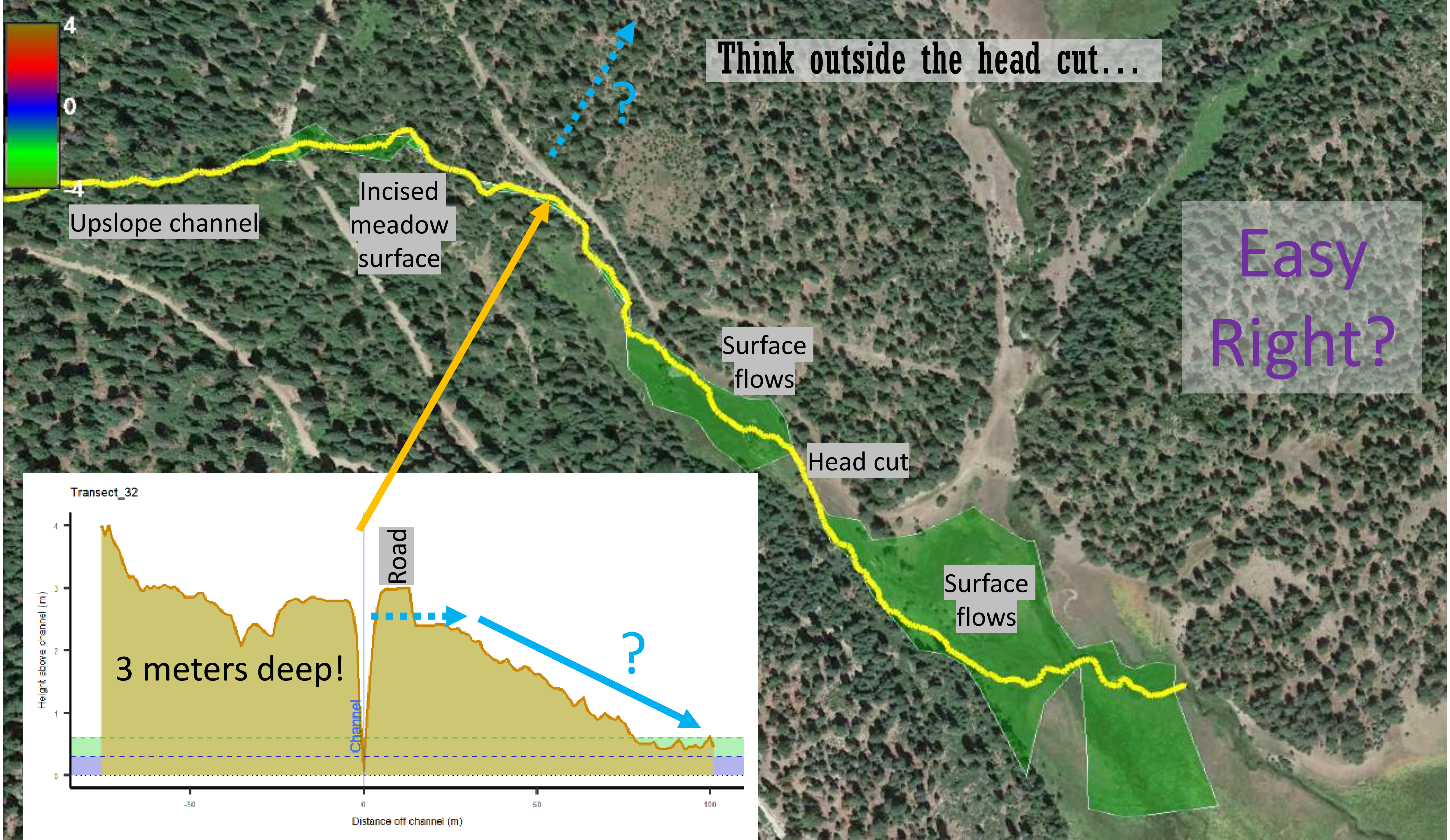
This entire stream channel is abandoned road, now incised…

Fix the road crossing but also fix the point source problem!

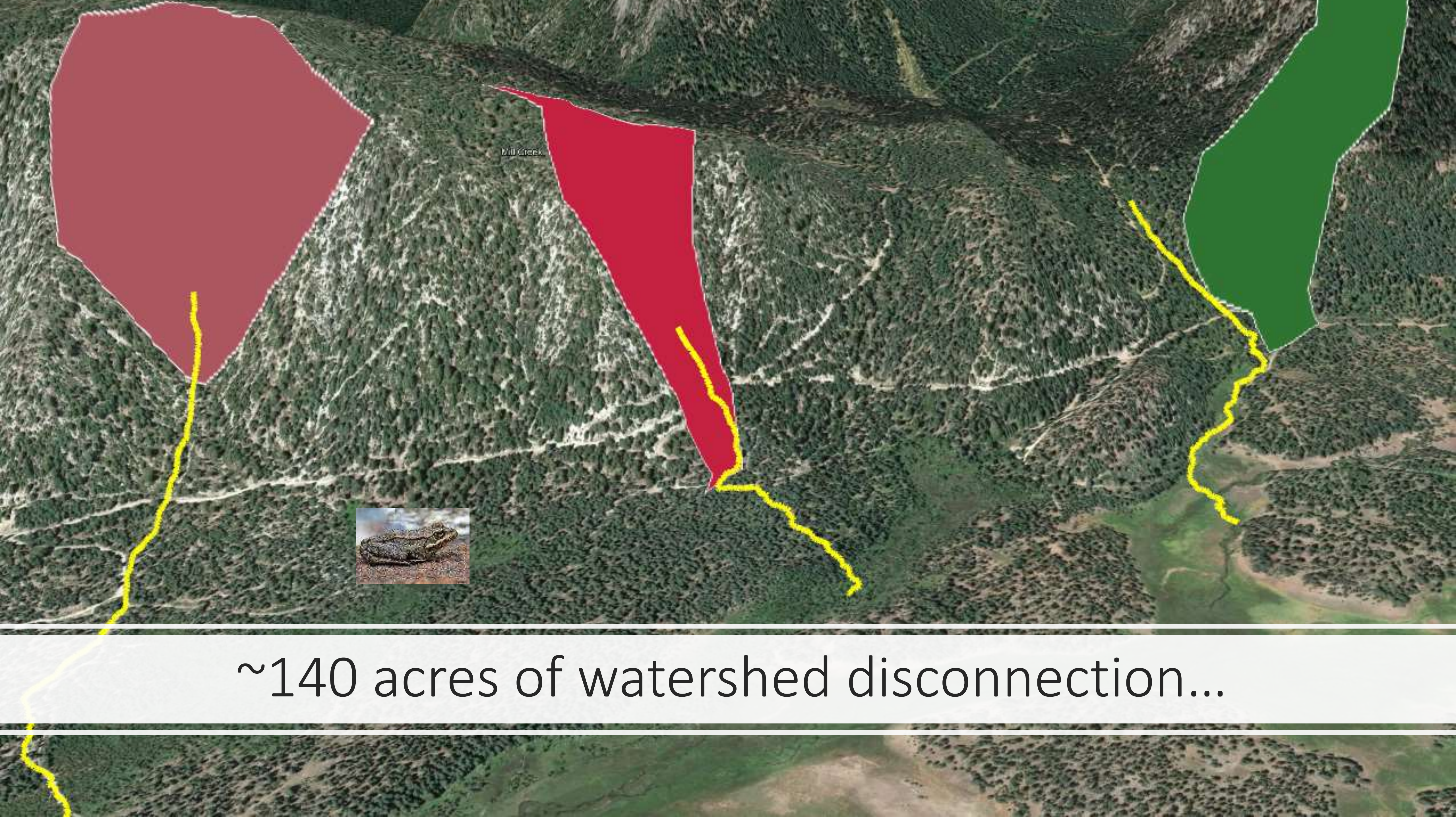



Notice these three examples involved almost zero work in the actual meadow…



4
0
-4
Think outside the head cut…
?
Upslope channel
Incised meadow surface
Surface flows
Head cut
Surface flows
Easy Right?
Transect_32
Road
3 meters deep!
Channel
?
Height above channel (m)
Distance off channel (m)


Mill Creek
~140 acres of watershed disconnection…

# How does it work?

- Stream files generated with **TauDEM** (R Script)
  - (Tarboton, David G. "Terrain analysis using digital elevation models (TauDEM)." *Utah State University, Logan* (2005).)
- Process Space tool built in R
- Free, open source software.

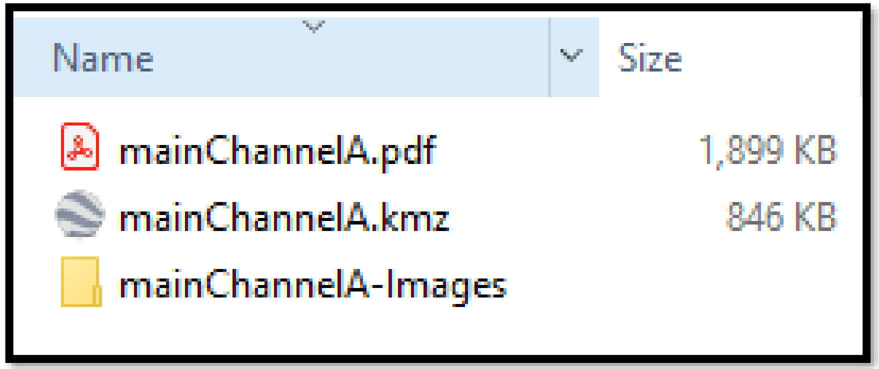
```
finger1 <- sf::read_sf("GeoData/Finger1.shp") %>%
  generateCrossSections(googleZoom=16,
                        xSectionLength = as_units(100,"m"),
                        xSectionDensity =as_units(5,"m")) %>%
  allAtOnce("Finger1.pdf",
            doExportSpatial = TRUE,
            returnObject = TRUE)
```

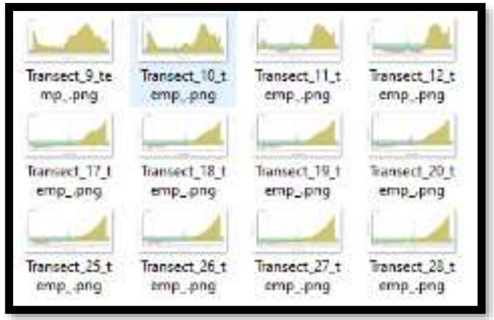
Load a streamline file

Generate cross sections

Do everything else

# And the output?



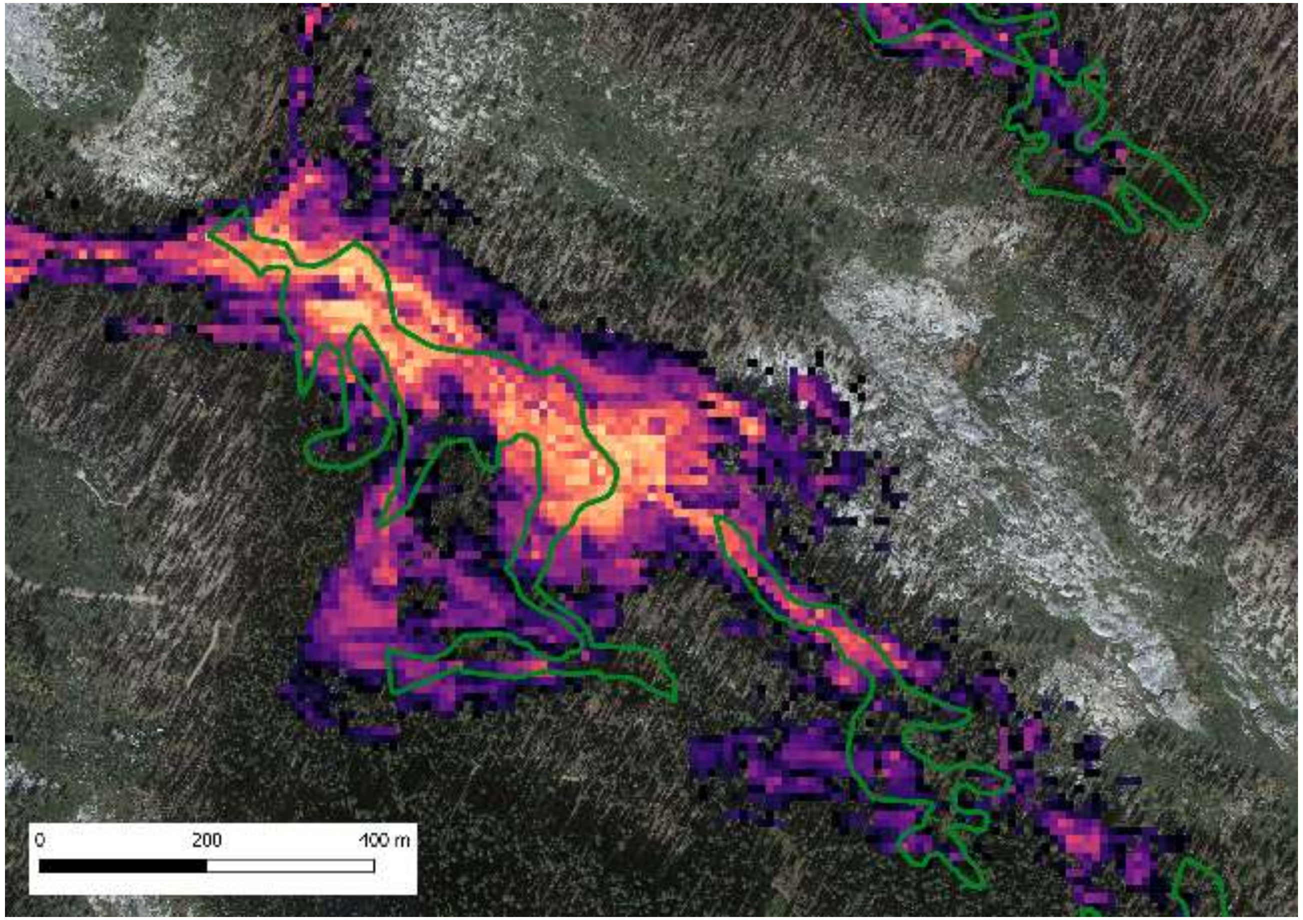




# Is it Available?

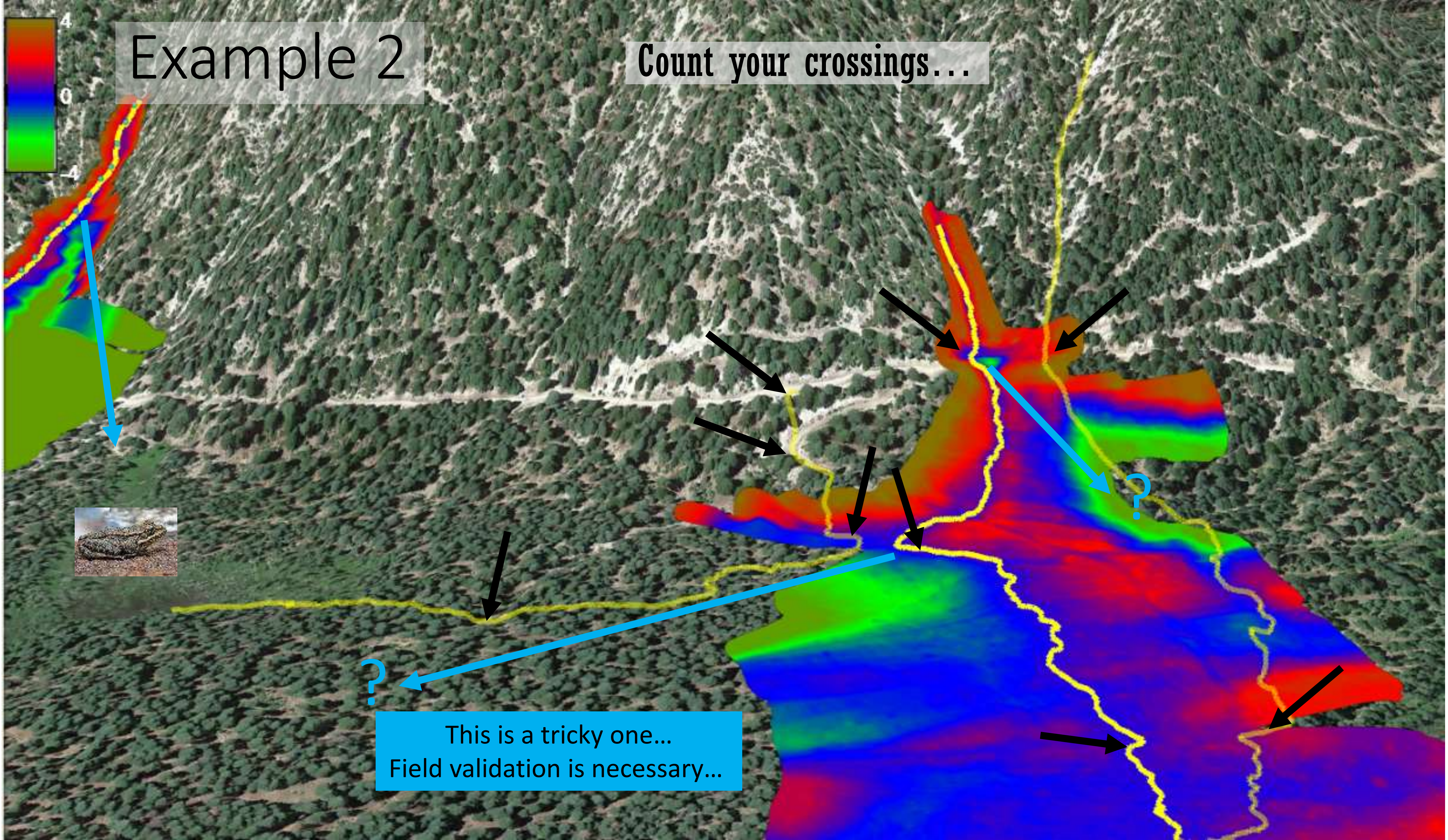
adamcummings.net/ProcessSpace

Or adam.cummings@usda.gov

# See Karen Pope's talk on Friday for more meadow/mind boundary expansion

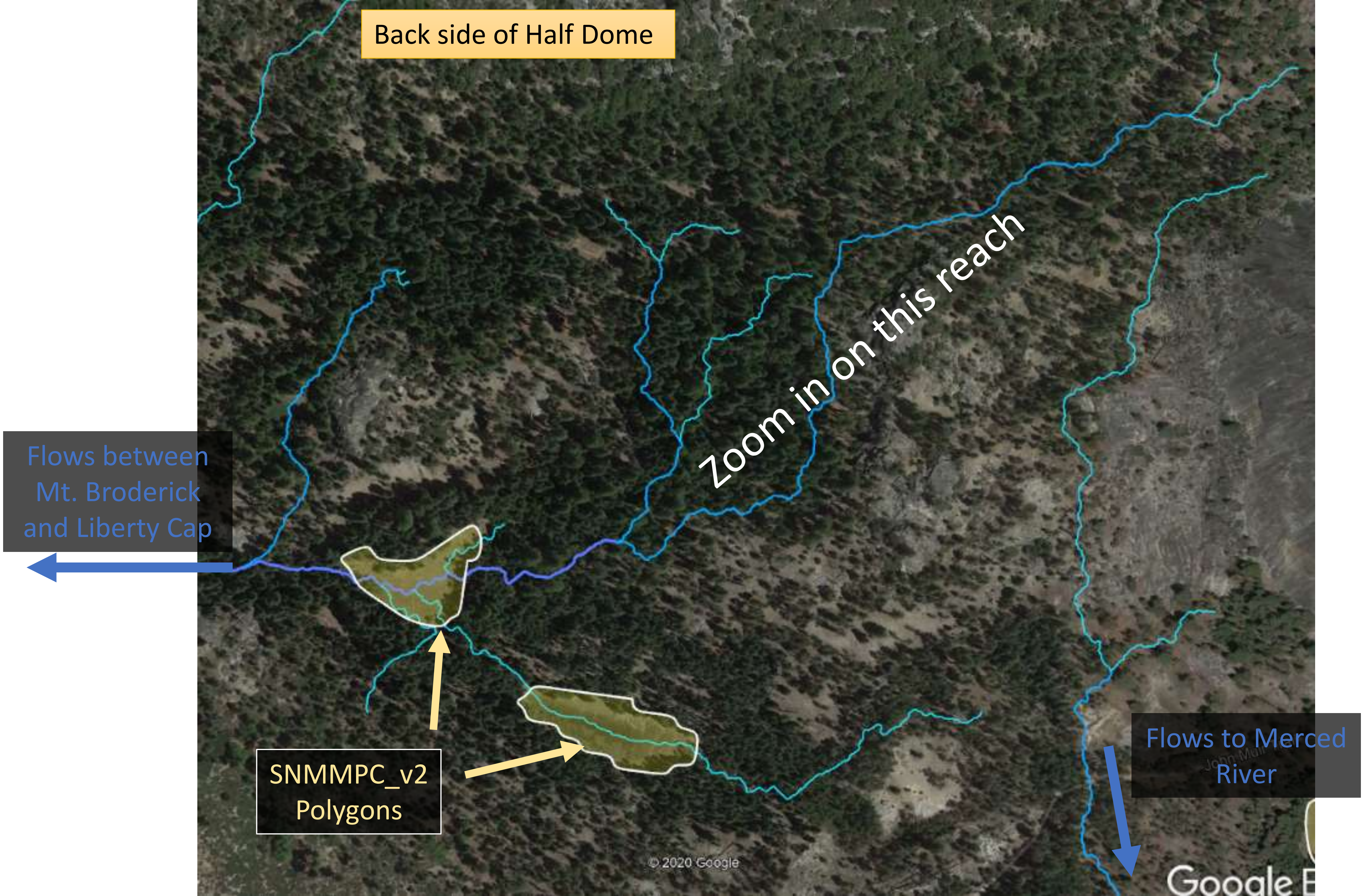


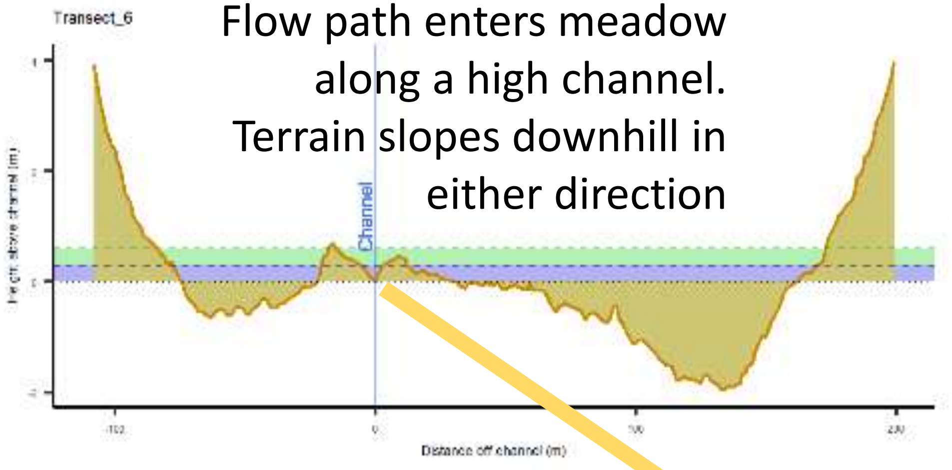
# Questions?


4
0
-4
Example 2
Count your crossings...
?
?
This is a tricky one...
Field validation is necessary...

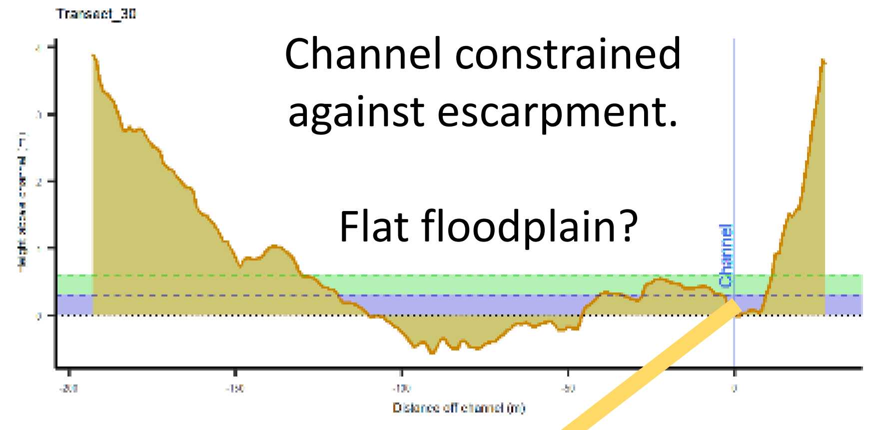
# Can this tool work elsewhere?

Little Yosemite Valley LiDAR


Back side of Half Dome
Zoom in on this reach
Flows between Mt. Broderick and Liberty Cap
SNMMPC_v2 Polygons
Flows to Merced River
© 2020 Google
Google E

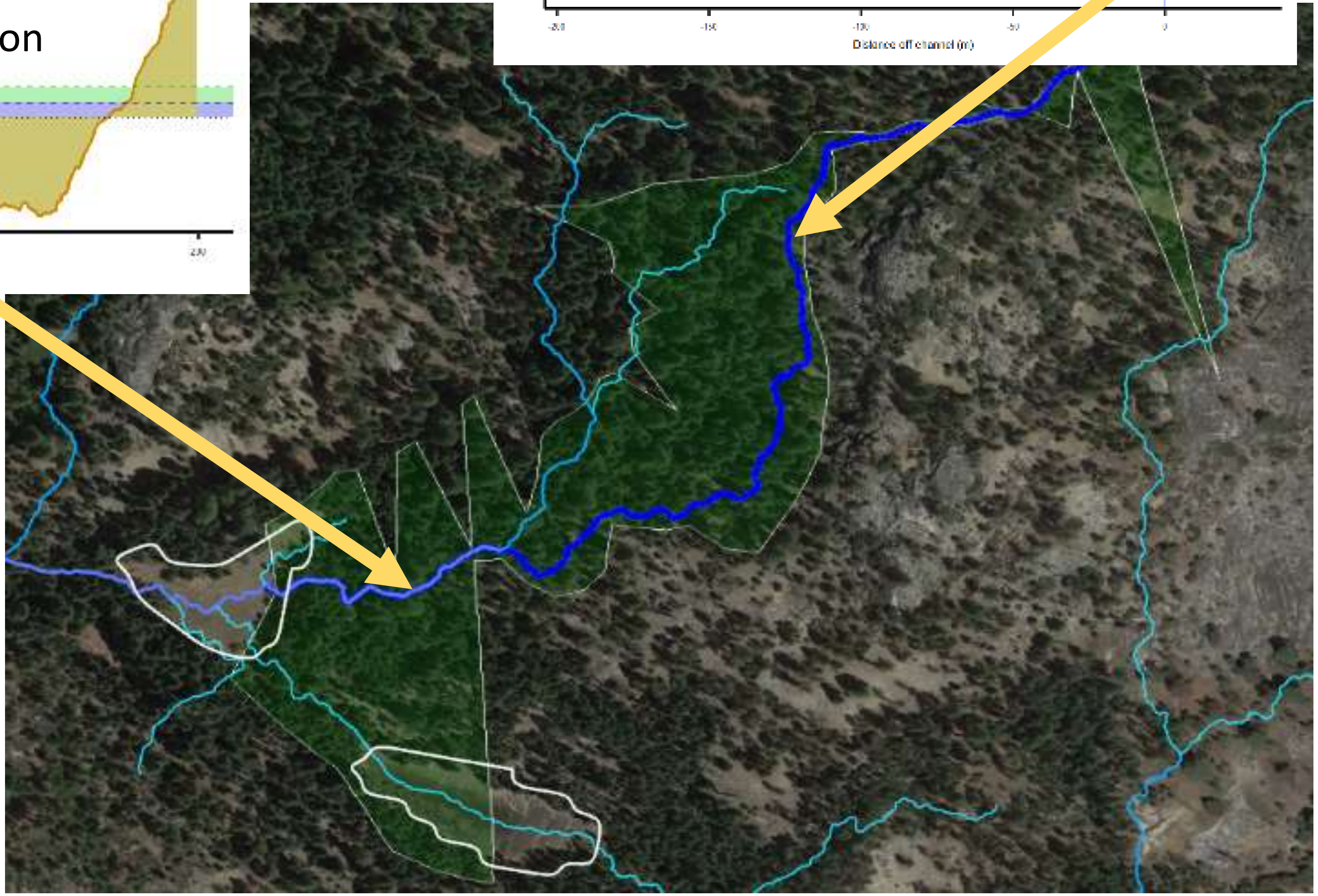



Flow path enters meadow along a high channel. Terrain slopes downhill in either direction




Channel constrained against escarpment.

Flat floodplain?

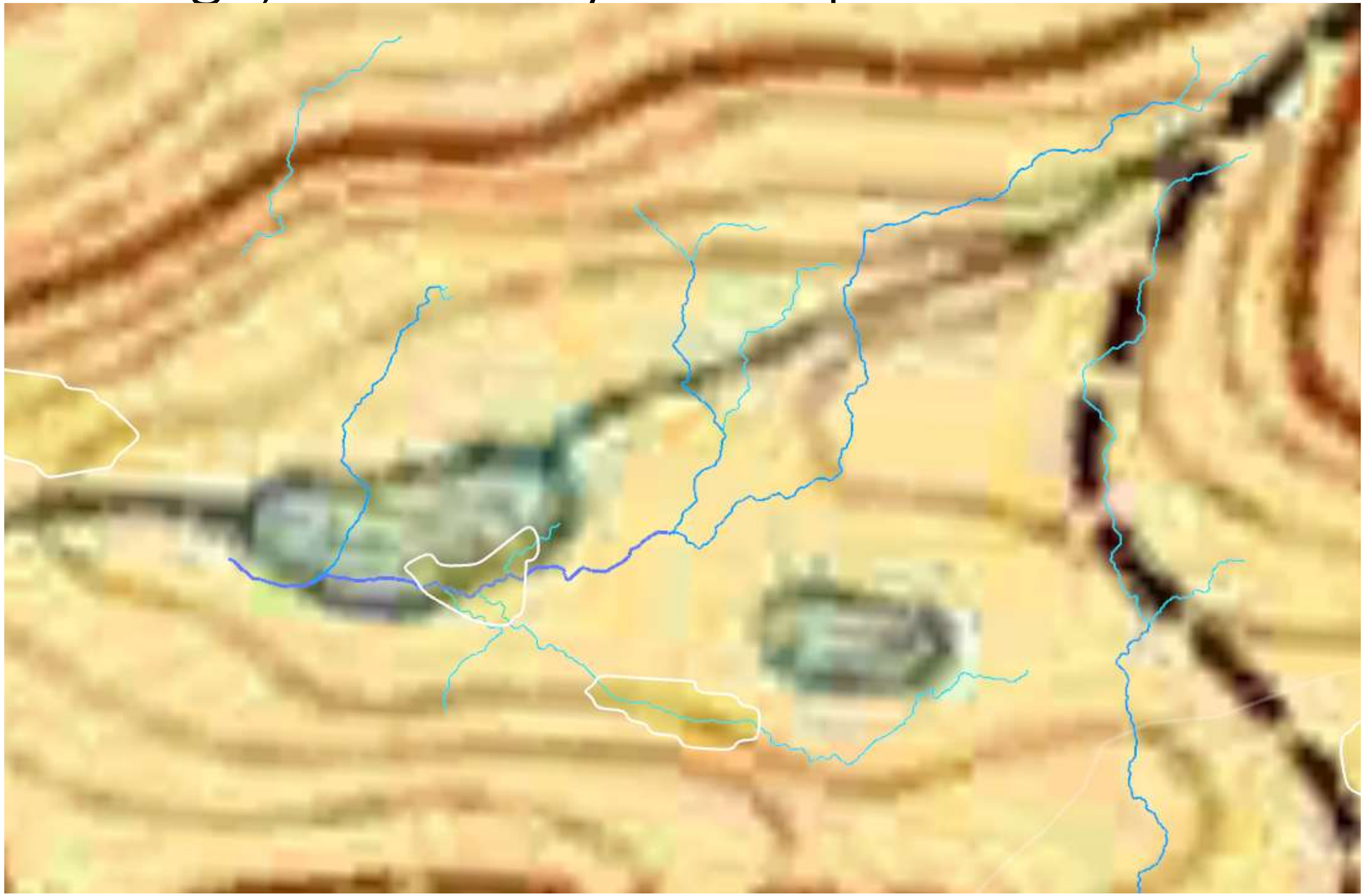


This gives us a good starting knowledge.

- Possible channel confinement immediately upstream of the meadow
- A potential historical meadow now covered by conifers

# 1887 Topo shows considerable wetland …

## Although, not exactly lined up..



# DAM SATELLITES

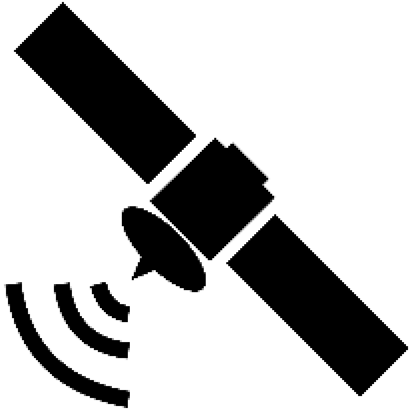
a quick-start lesson on using free, publicly available remote sensing tools to monitor how beavers change riparian areas

Presented by Emily Fairfax, PhD

*Assistant Professor of Environmental Science and Resource Management*

*California State University Channel Islands*

# The Goal of This Presentation



# Why use aerial images in the first place?

How is it better or different than collecting data on the ground?

# Field Visits Are Still Important

But the perspective they offer is fundamentally different than the perspective from above.

Ideally, you do both.

If you have limited time or money, the aerial imagery is quick and free and lets you look over larger space and time scales.

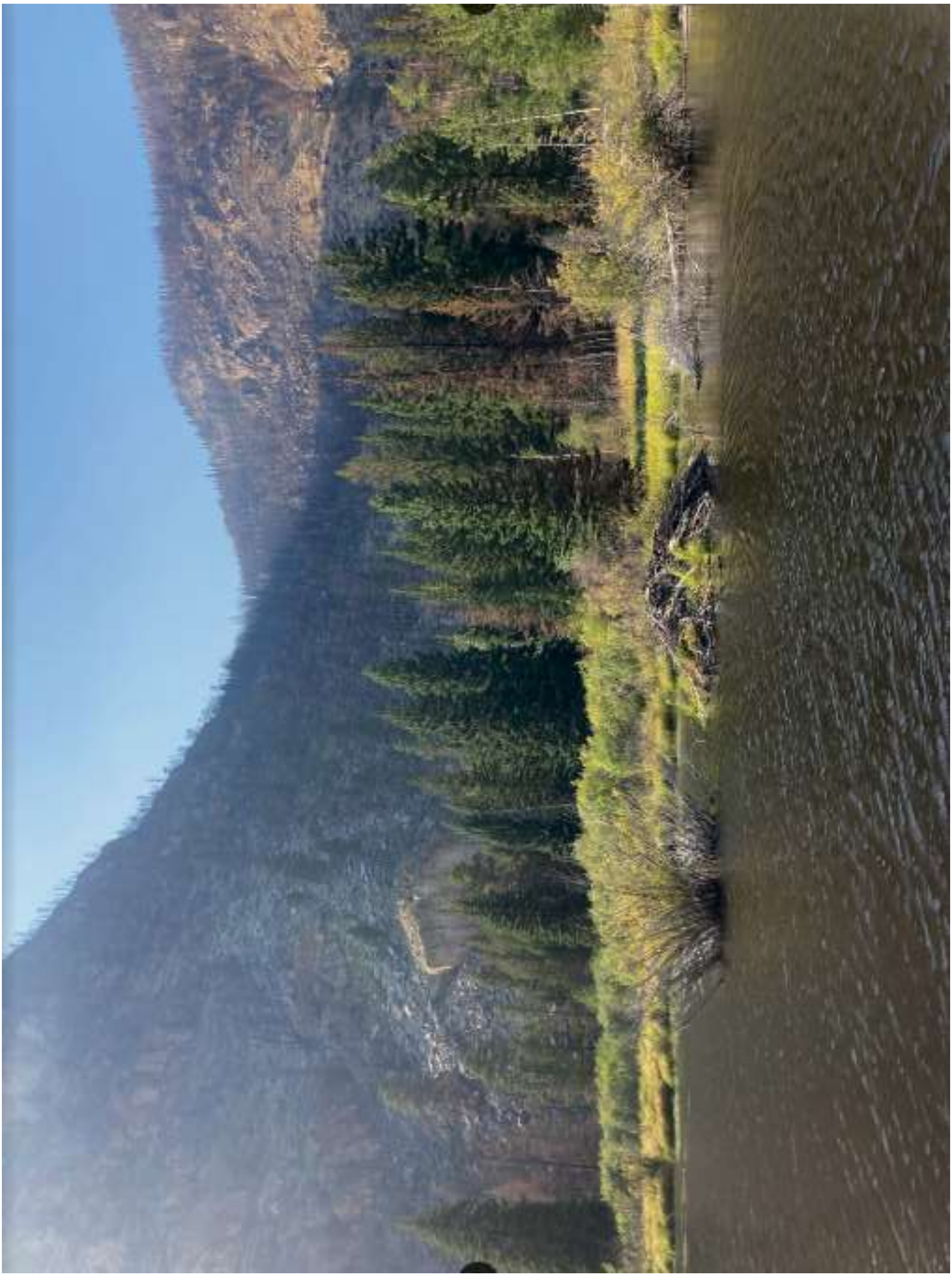
# Field Observations

The finer details are only visible on site.

Field Photographs from Beaver Complex in Colorado, USA within a burn scar.
Photo taken by Emily Fairfax in May 2021

Field Photographs from Beaver Complex in Colorado, USA within a burn scar.
Photo taken by Emily Fairfax in May 2021

Field Photographs from Beaver Complex in Colorado, USA within a burn scar.
Photo taken by Emily Fairfax in May 2021



Field Photographs from Beaver Complex in Colorado, USA within a burn scar.
Photo taken by Emily Fairfax in May 2021

# Publicly Available Imagery

There is more high quality imagery than you might think just sitting on Google Earth Pro.


Aerial and/or Satellite Images of the same area as the field photographs

Imagery sourced from Google Earth Pro publicly available archives.


Aerial and/or Satellite Images of the same area as the field photographs

Imagery sourced from Google Earth Pro publicly available archives.


Aerial and/or Satellite Images of the same area as the field photographs
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Aerial and/or Satellite Images of the same area as the field photographs
Imagery sourced from Google Earth Pro publicly available archives.

# Drone Imagery

The middle ground between fully in situ observations and fully remote, hands off observations.

Audubon » Central Flyway

Urge the Bureau of Land Management to protect sage-grouse habitat | Take action »

# Rockies

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Watch Our 2021 Year-end Video

Beaver wetland in the Cameron Peak Fire perimeter. Photo: Evan Barrientos/Audubon Rockies

Western Rivers Initiative

# Beavers Offer Help for Western Waters

*Beavers are a key partner in protecting and restoring western streams, watersheds, and habitat.*

# So you want to use **aerial images...**

But you're not sure what to look for. Let's talk about beaver dams!

# How to Identify Beaver Features

Beavers and beaver-based structures are increasingly important in the riparian restoration world.

Whether or not you’re explicitly studying them / working with them, you should be able to tell if they’re influencing your project area.

This is a quick-start lesson on how to identify beaver features. Ultimately, it is a skill that needs to be practiced. You can use similar techniques for identifying other significant landforms / features.

# What structures do beavers build?

Beavers build / create several structures that are visible in aerial and (some) satellite imagery.

- Dams
- Lodges
- Canals
- Clearcut Areas
- Flooded Dead Conifers

Think of it like a cumulative checklist, not an either/or list. The more features you see, the more likely it is to actually be beavers. BDAs and beaver based restoration usually do not have lodges or canals visible.

# Beaver Dams

- Linear-ish features, often sinusoidal / curvy that span the entire channel
- Beaver dams usually have very dark, broad patches of ponded water on one side
- The beaver pond usually has feathery / irregular edges except where it is bounded by the dam. Dams in sequence may bound the ponds on two sides
- Vary in size, but can be 1's - 100's of meters long. 10's of meters is typical

# Beaver Lodges

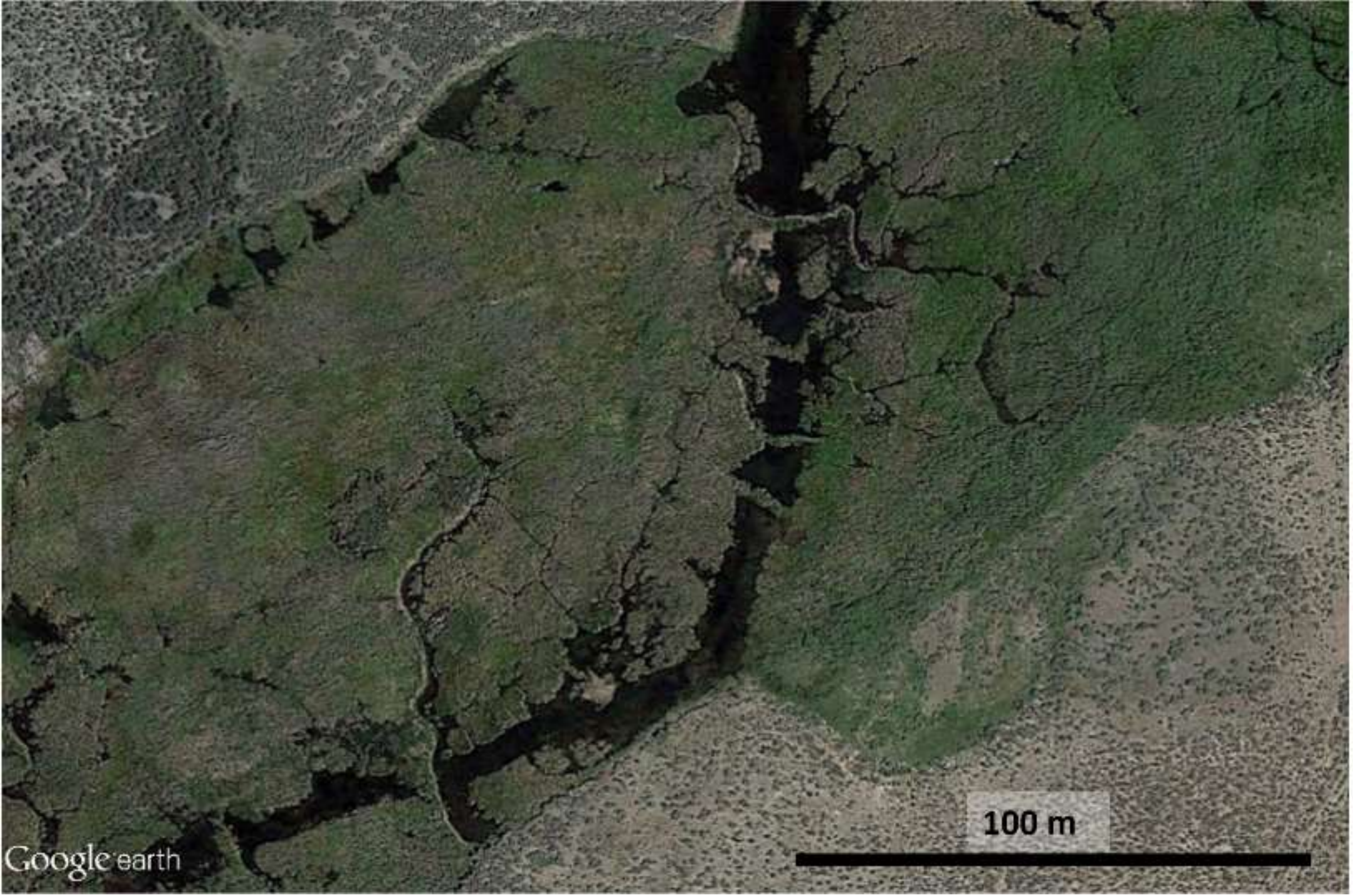
- Round, blobby features, often located on the bank of or in the middle of a beaver pond
- Beige color (sticks, dried out and sunbleached is common) is usually visible and distinct from the surrounding landscape
- Not every beaver pond will have a beaver lodge. The lodges are most often in the biggest ponds (which are usually the “home” pond)
- Vary in size, but can be 1’s - 10’s of meters in diameter. 1-5 meters is typical, but much larger lodges have been seen



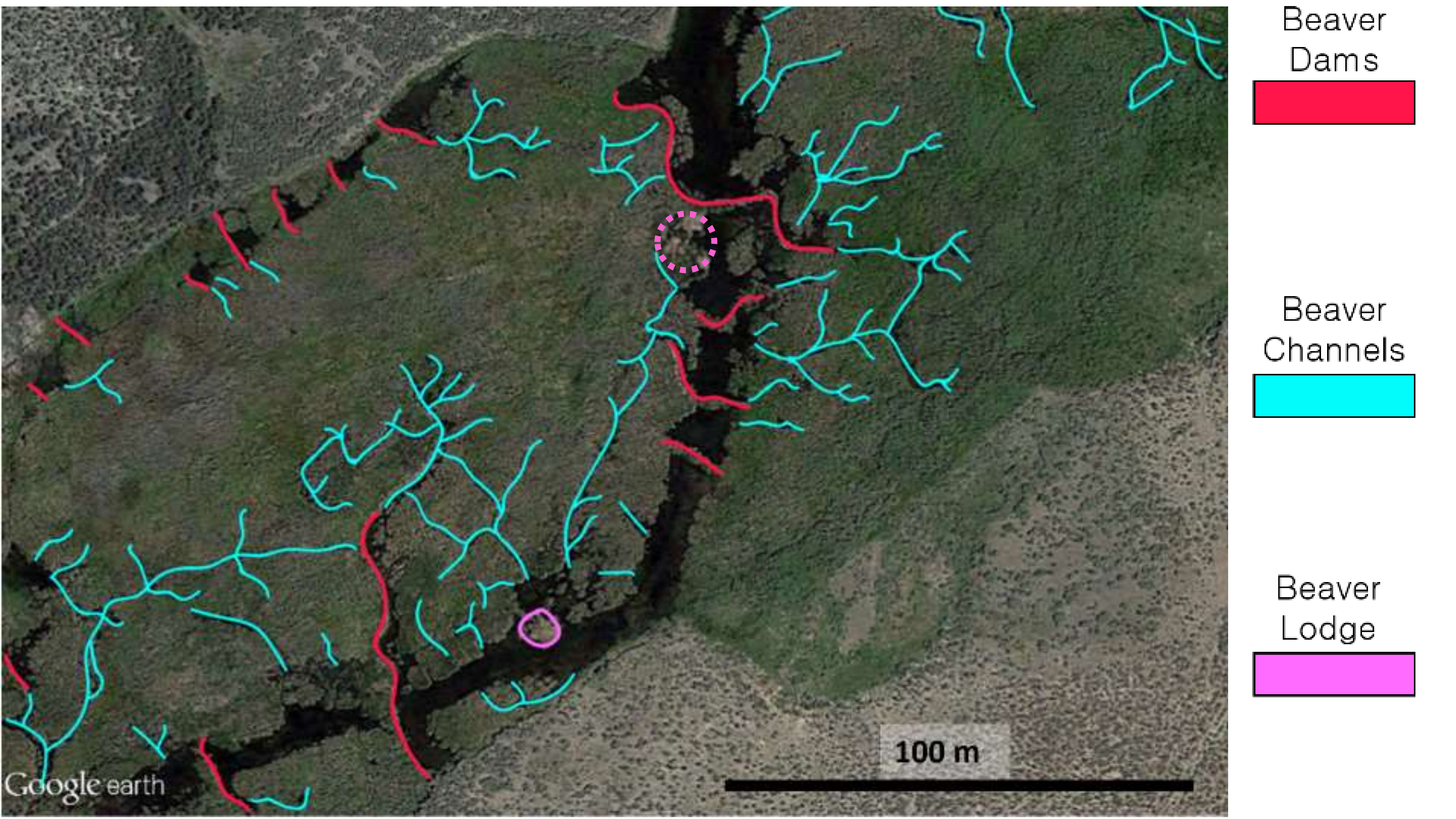
# Beaver Canals

- Long, linear dark water features that radiate out from beaver ponds or river banks into the surrounding riparian zone
- Only the larger beaver canals are visible - tiny canals can only be seen on site or with drone imagery
- Canals are easiest to see in older, well-developed complexes. In newer complexes they can be hidden by tree cover. Can be seen in fully or partially drained ponds too
- Vary in size, but can be 10's - 100's of meters in long.

Think about what those features would look like from above.




Can you find the beaver dams, lodge(s), and canals?



Beaver Dams
Beaver Channels
Beaver Lodge
100 m
Google earth

# Map Using Google Earth Pro

# Let's look at some more examples.

Each one won't all have all of the features. Remember - checklist!

Dams

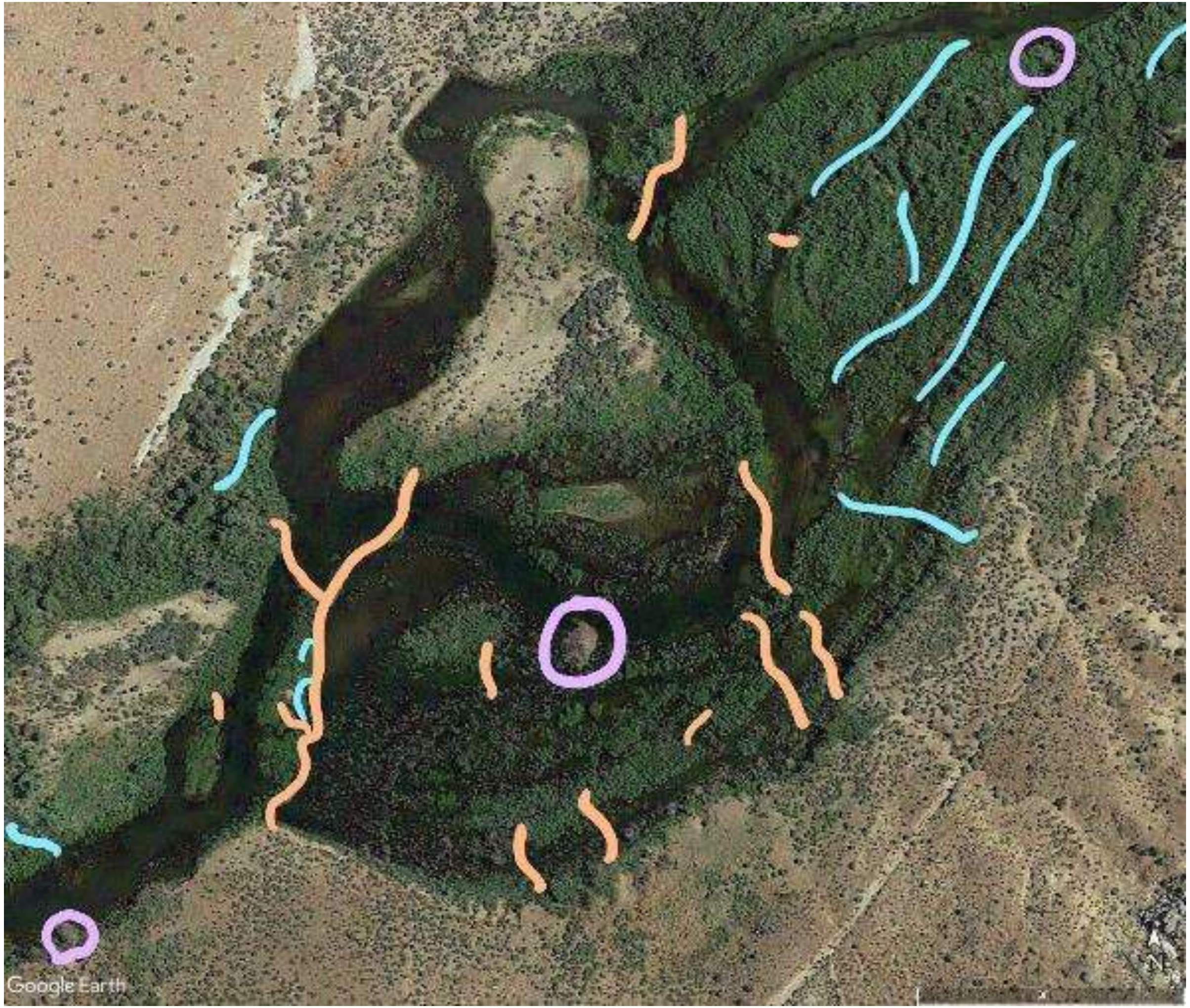
Lodges

Canals


Google Earth


Google Earth

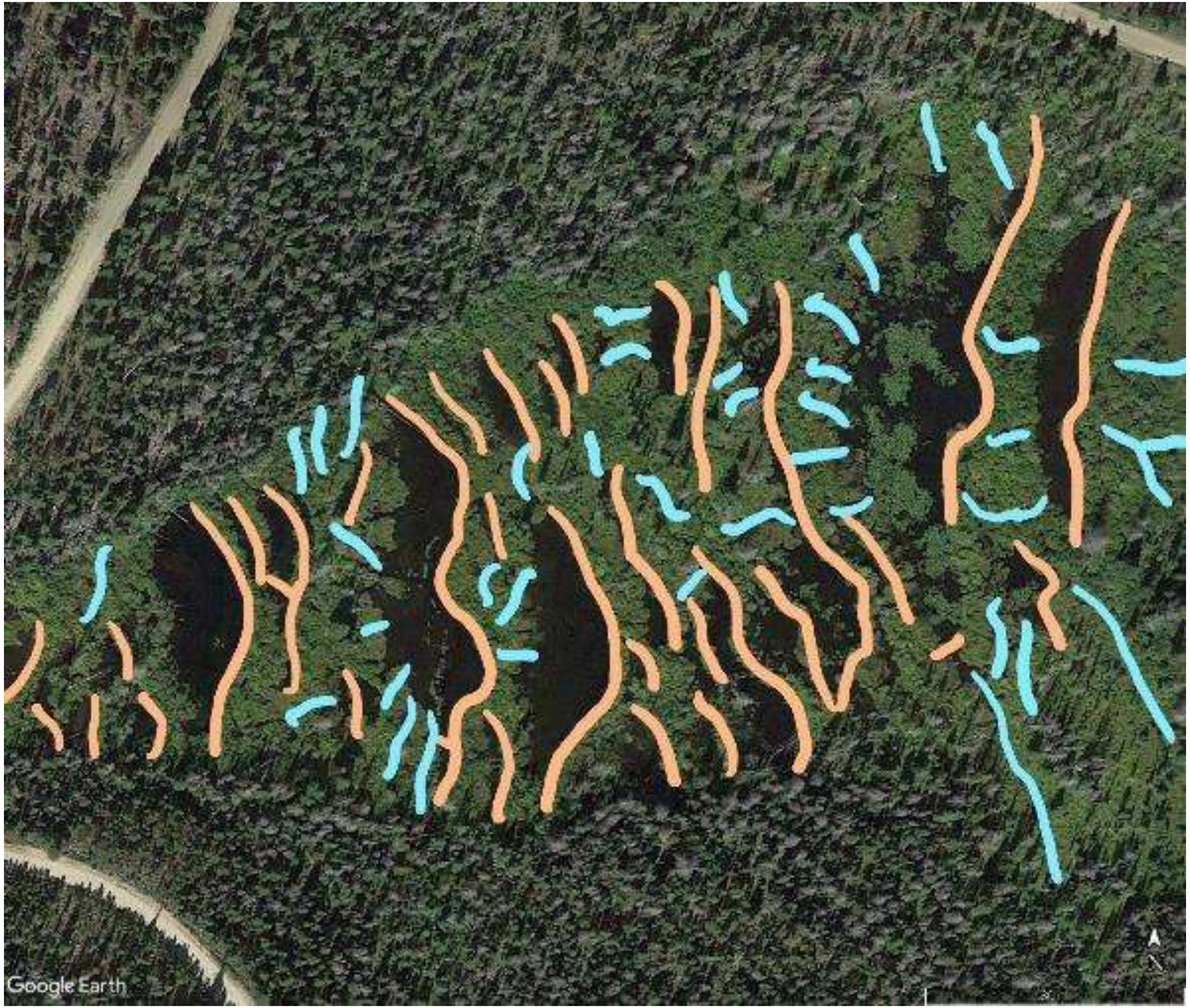

Google Earth


Google Earth


Google Earth
N


Google Earth


Google Earth


Google Earth


Google Earth


Google Earth

# USEFUL GEOSPATIAL DATA TYPES

**You've found your areas of interest and all the beaver dams, now how can you tell if the "treatment" (aka the beavers) actually "worked"?**

# What does a healthy riparian zone look like?

…in remotely sensed data.

# Healthy, Resilient Riparian Areas

Described in words:

- Dense, green vegetation
- Stays green during the summer even if nearby areas do not
- Doesn’t die off or wilt if disturbed
- Wet soil, wet plants, standing water in the stream / pond

# NDVI: a quantitative estimate of plant greenness

NDVI (Normalized Difference Vegetation Index) is a satellite-derived index that goes from 0 to 1 and lets you know about how green your plants are.

It looks at an area (whatever the pixel size is for that data) and determines how green it is. That means it is consider both the absolute greenness of plants and the density of plants in an area

# NDVI: an estimate of plant greenness

High NDVI (closer to 1): many plants, and plants are healthy and photosynthesizing.

Riparian areas should have NDVI > 0.3 in the growing season.

# NDVI: an estimate of plant greenness

Low NDVI (closer to 0): very few plants, even though plants that are there are healthy and photosynthesizing

# NDVI: an estimate of plant greenness

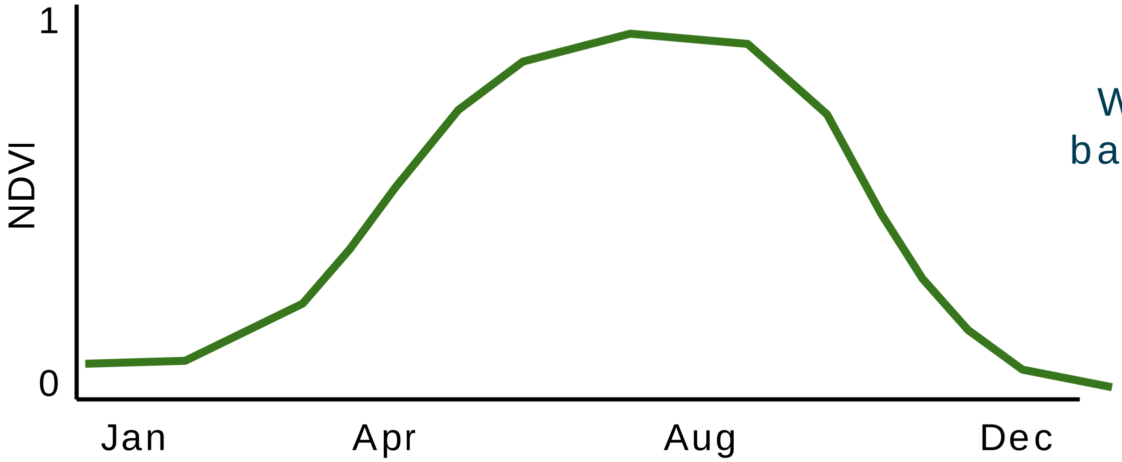
Low NDVI (closer to 0): many plants, but plants are not healthy and are not photosynthesizing due to drought stress or disturbance

# NDVI: an estimate of plant greenness

Low NDVI (closer to 0): many plants, and plants are healthy but are not photosynthesizing due to lack of sunlight (seasonal)

# NDVI of healthy vegetation follows a seasonal arc

It is lowest in the winter because sunlight is limited, and peaks in the summer when there is the most sun (assuming it is well-watered!)




We can calculate it with different bands of light collected by satellites!

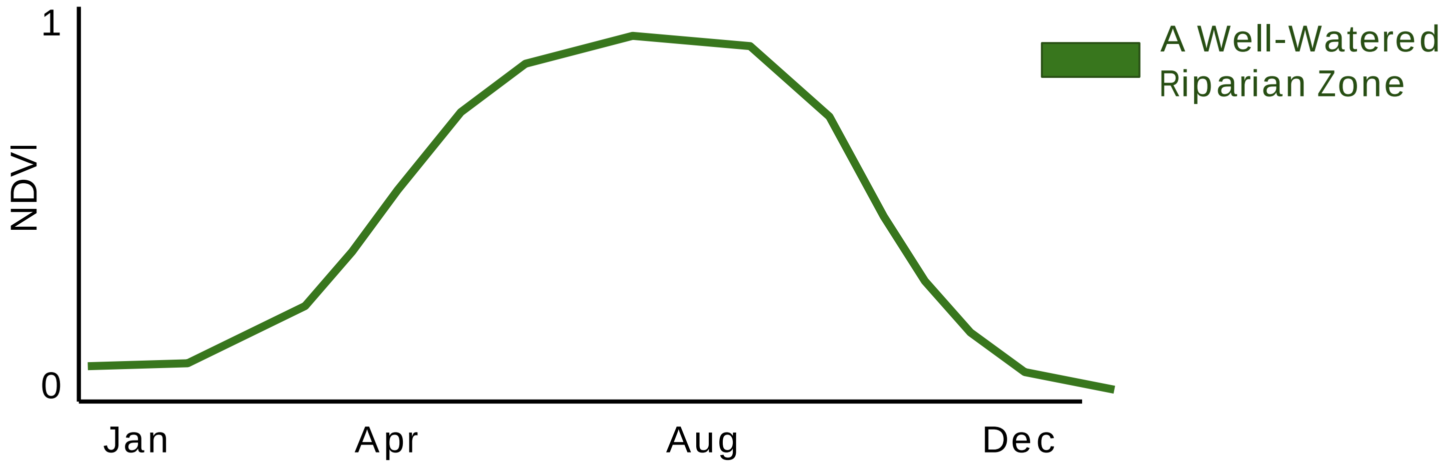
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

# What does drought stress or fire disturbance look like?

…in remotely sensed data.

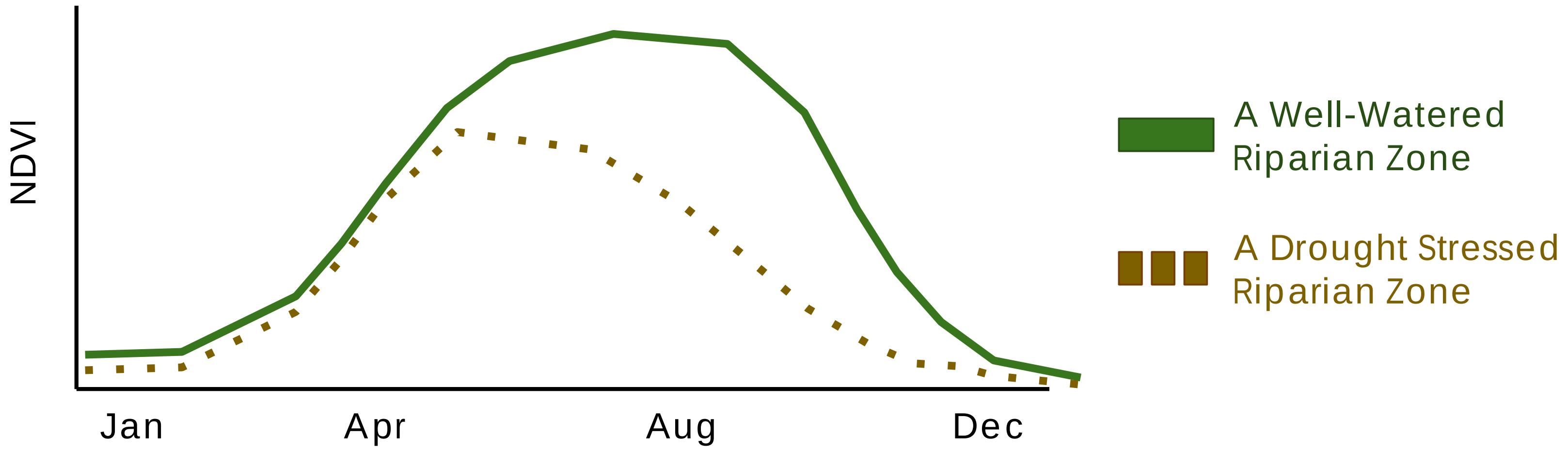
# NDVI of healthy vegetation follows a seasonal arc

It is lowest in the winter because sunlight is limited, and peaks in the summer when there is the most sun (assuming it is well-watered!)



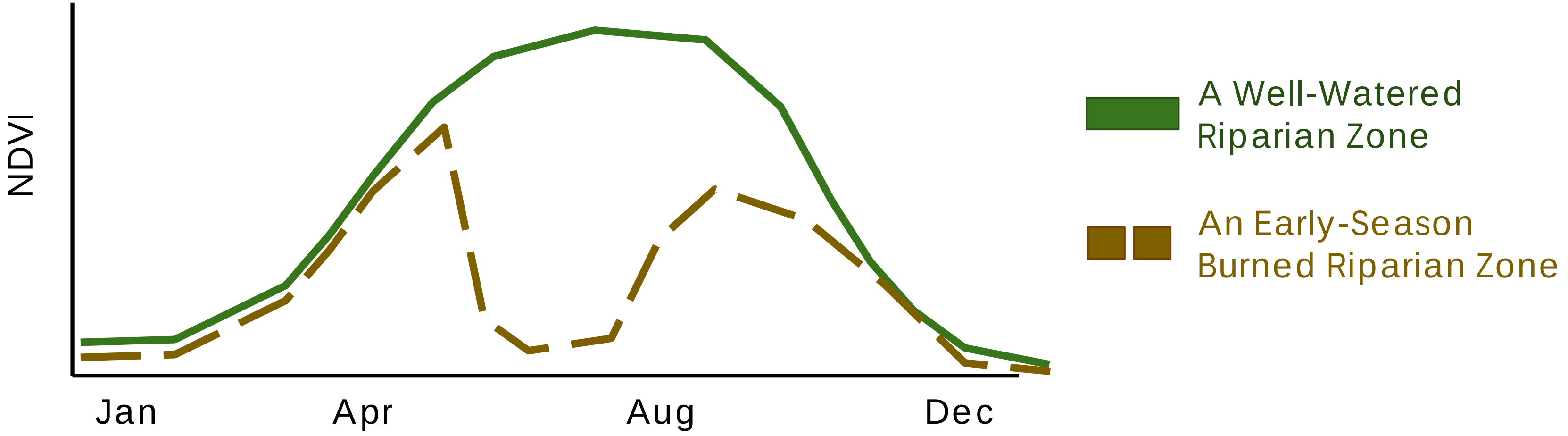
# NDVI of drought stressed vegetation starts decreasing as soon as the drought starts

Once the plants are water-limited, they begin to slow down, and eventually will wilt. This is most visible in the summer when ET and NDVI should be quite high.



# NDVI of fire-impacted vegetation sharply drops as soon as the fire starts, and *may* bounce back after

When the fire burns vegetation, it will immediate stop photosynthesizing. The more severe the burn, the bigger the drop. If it's an early season fire, you may see grasses regrow the same year. If it's a late season fire, you probably won't.



# NDVI of fire-impacted vegetation sharply drops as soon as the fire starts, and *may* bounce back after

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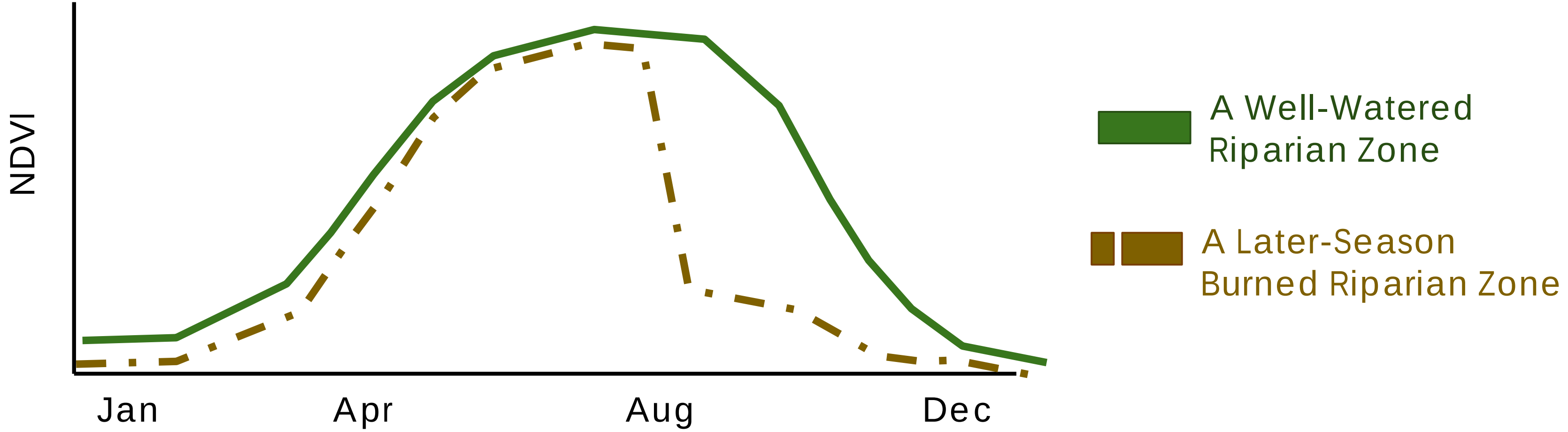
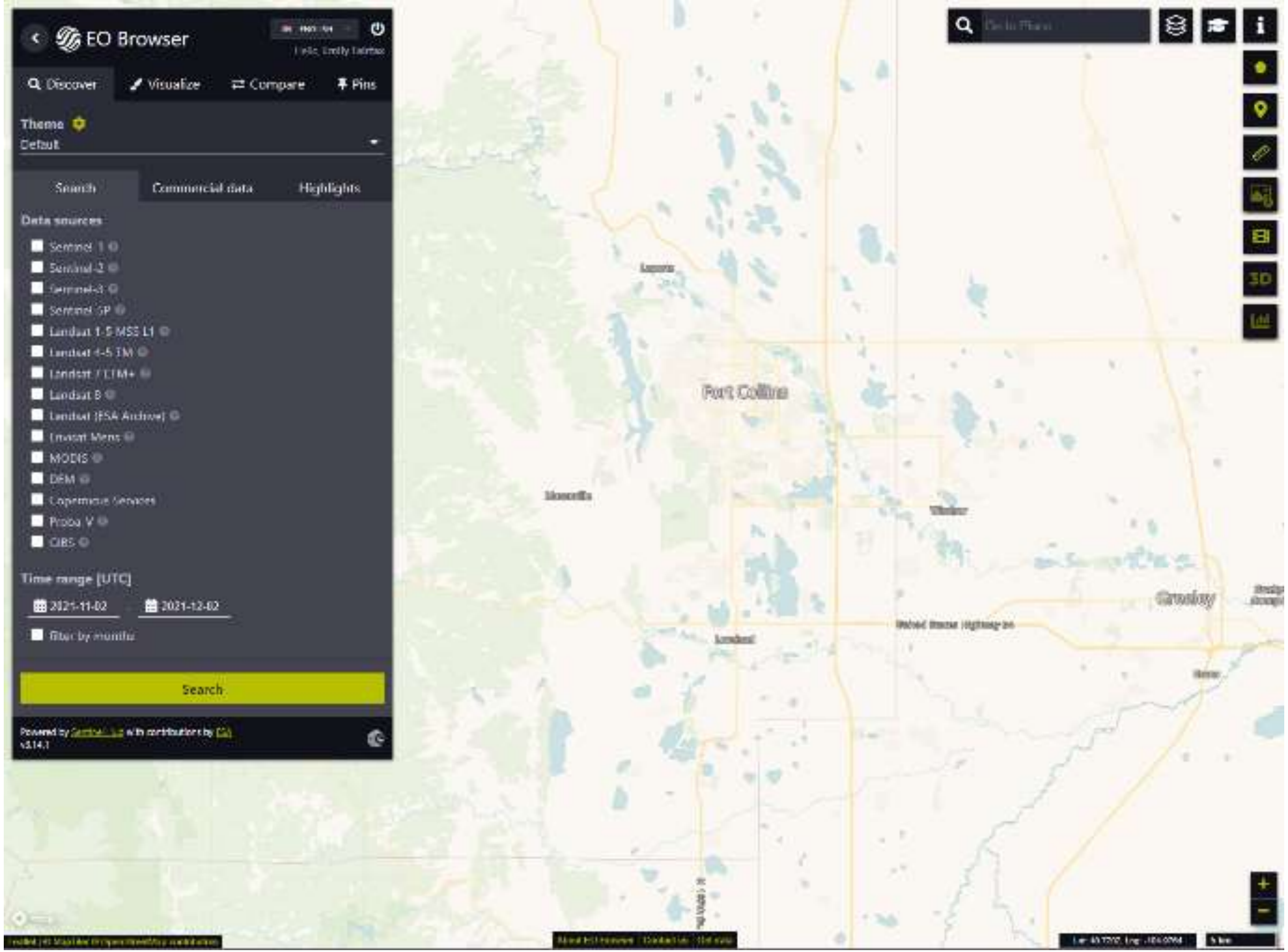


# WHERE TO ACCESS GEOSPATIAL DATA

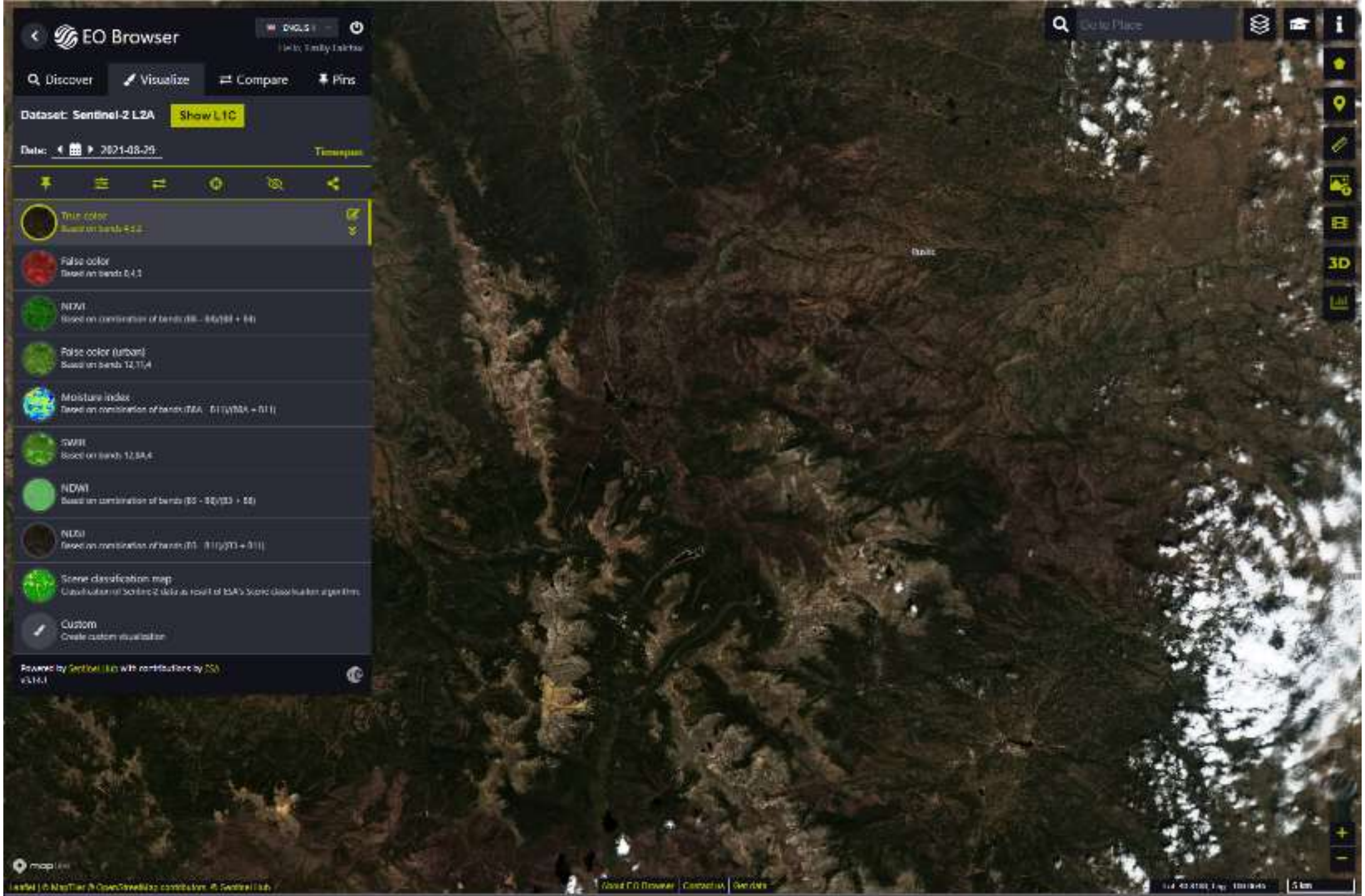
Not just any geospatial data - free, pre-processed, analysis ready geospatial data!

# The Sentinel Hub EO Browser

The free, one-stop-shop for all your satellite data needs.

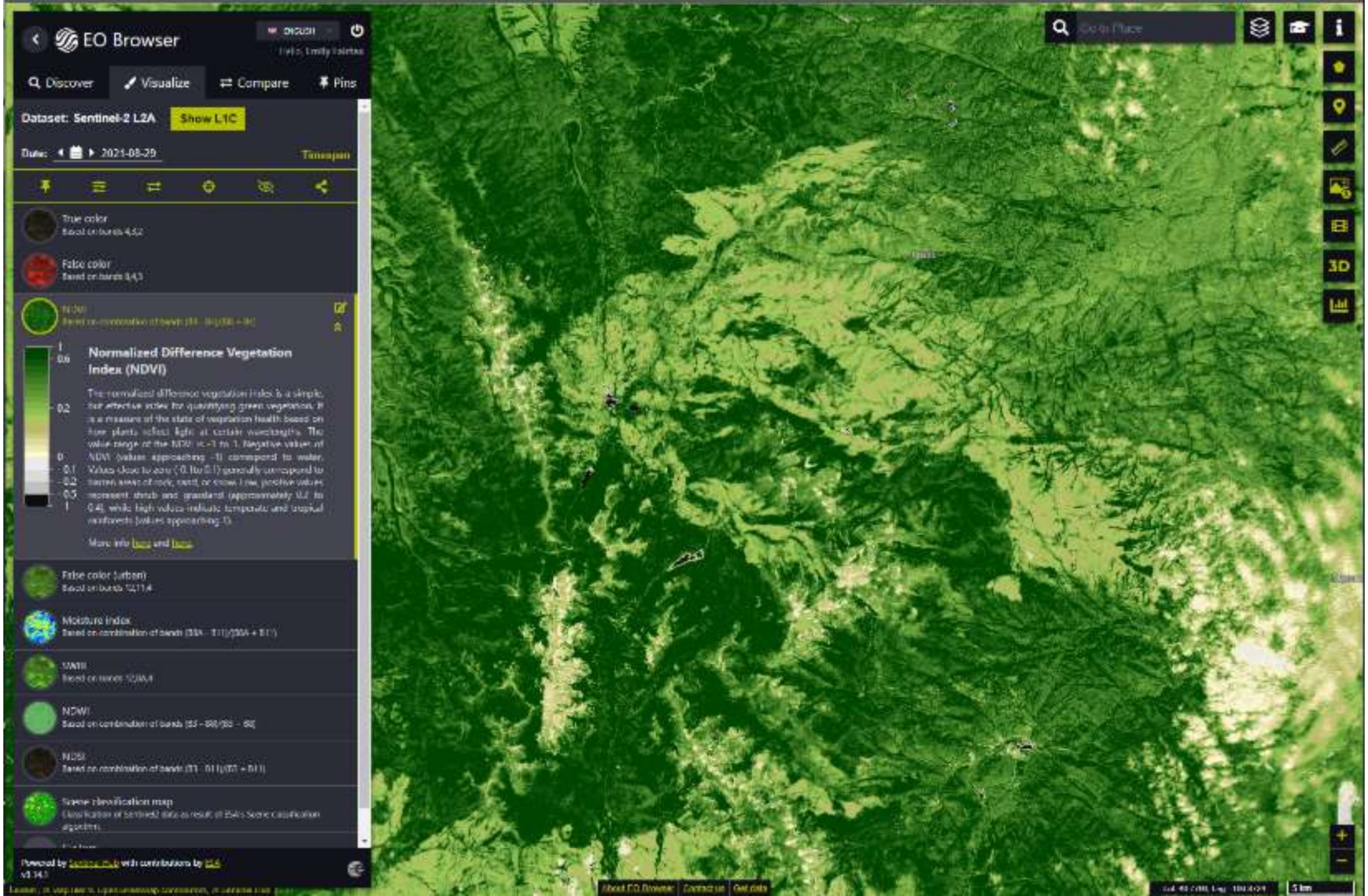


EO Browser
Discover
Visualize
Compare
Pins
Theme
Default
Search
Commercial data
Highlights
Data sources
Sentinel-1
Sentinel-2
Sentinel-3
Sentinel-5P
Landsat 1-5 MSS L1
Landsat 4-5 TM
Landsat 7 ETM+
Landsat 8
Landsat (ESA Archive)
Envisat Meris
MODIS
DEM
Copernicus Services
Proba-V
GIBS
Time range [UTC]
2021-11-02
2021-12-02
Filter by months
Search
Fort Collins
Greeley
Loveland

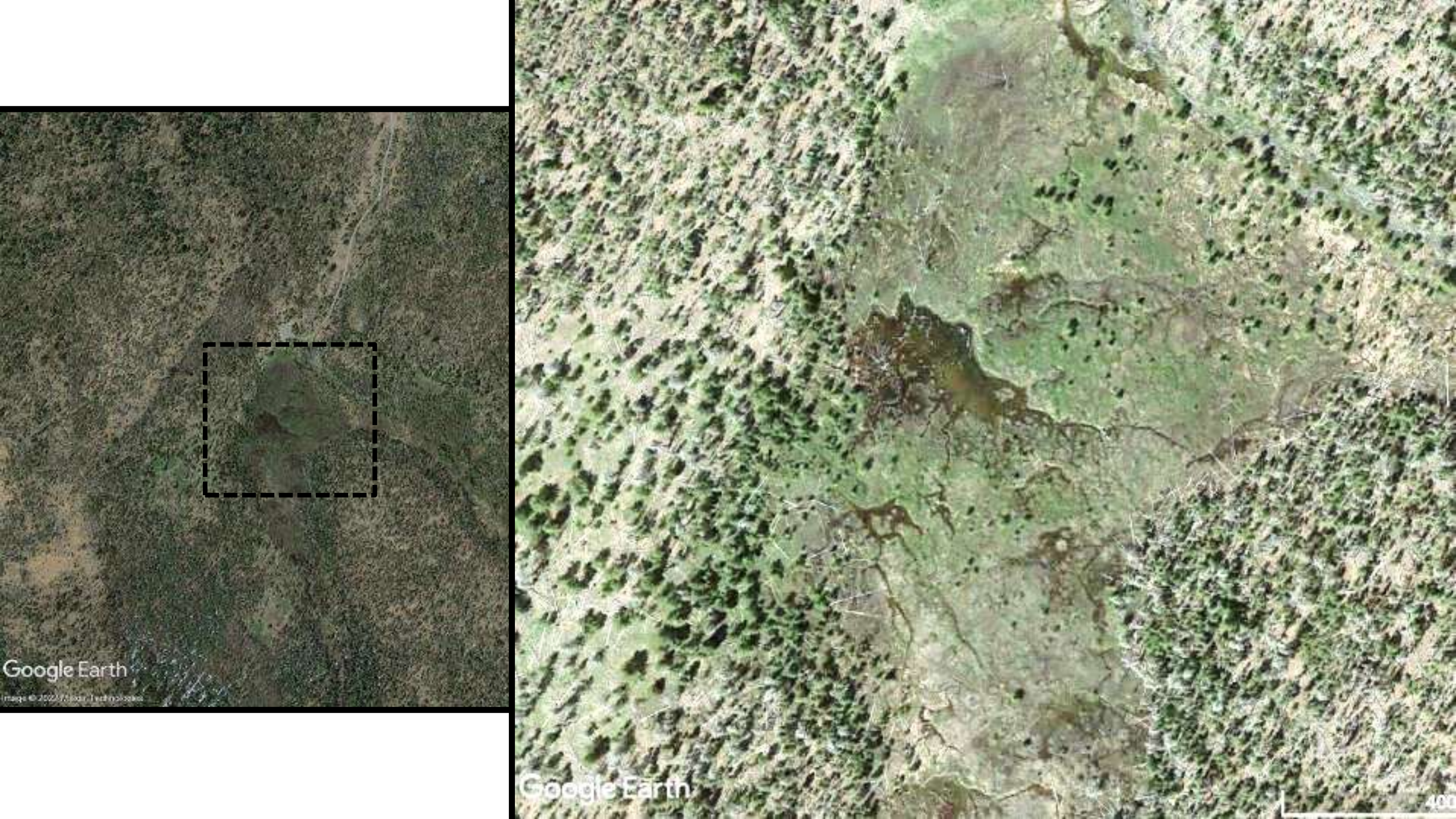


EO Browser
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date:
2021-08-29
Timespan
True color
False color
Based on bands 8,4,3
NDVI
False color (urban)
Based on bands 12,11,4
Moisture index
SWIR
Based on bands 12,8A,4
NDWI
NDSI
Scene classification map
Custom
Create custom visualization
3D


EO Browser
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Timespan
True color
False color composite
NDVI
False color (urban)
Moisture index
SWIR
NDWI
NDSI
Scene classification map
Custom
3D


EO Browser
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date:
2021-08-29
Timespan
True color
Based on bands 4,3,2
False color
Based on bands 8,4,3
NDVI
Normalized Difference Vegetation Index (NDVI)
1
0.6
0.2
0
-0.1
-0.2
-0.5
-1
False color (urban)
Moisture Index
SWIR
NDWI
NDSI
Scene classification map
3D


Google Earth
N
1000 ft


Google Earth
Google Earth


Google Earth

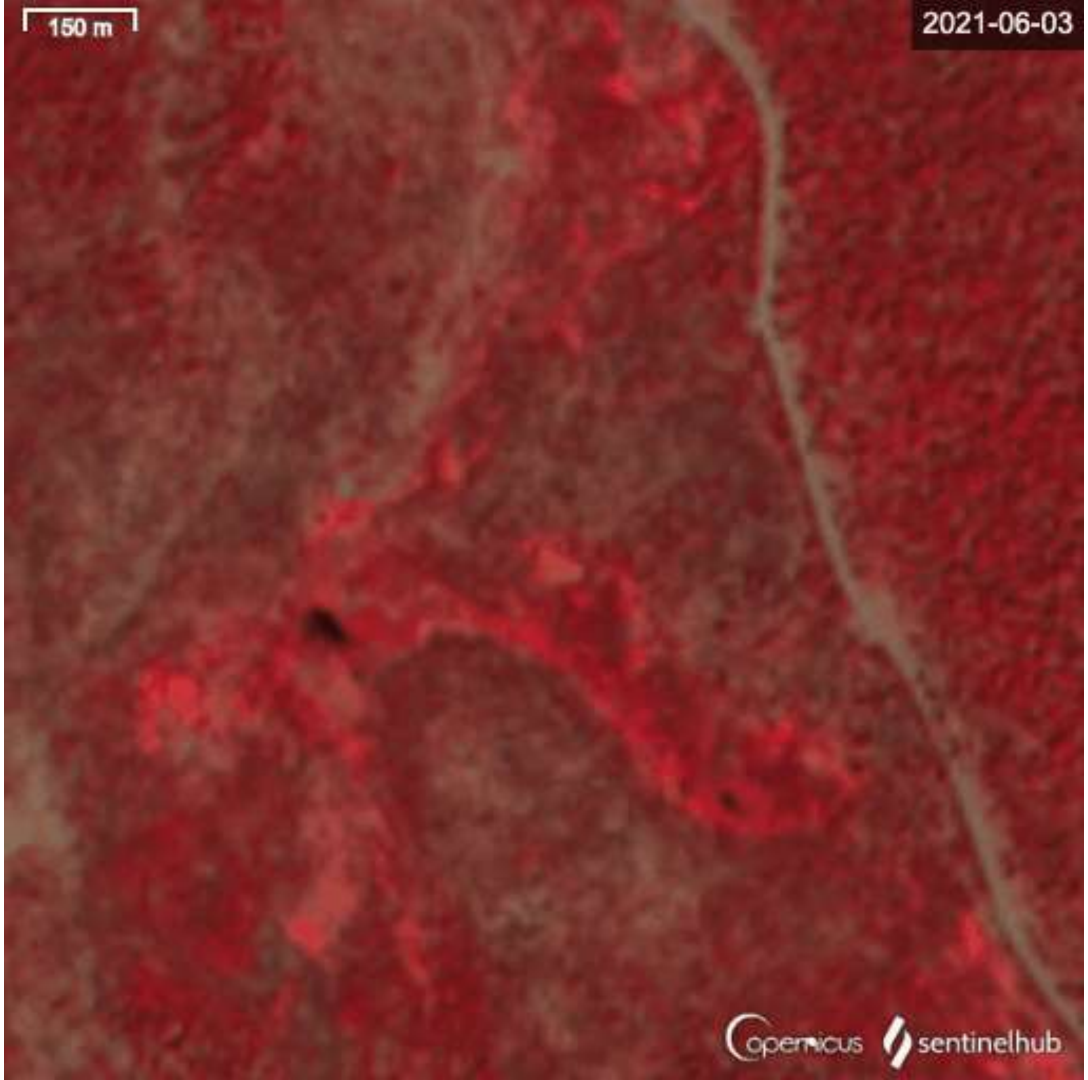
Google Earth

## BEFORE BOOTLEG FIRE


## AFTER BOOTLEG FIRE

TRUE
COLOR

# FALSE COLOR




**Healthy Veg**

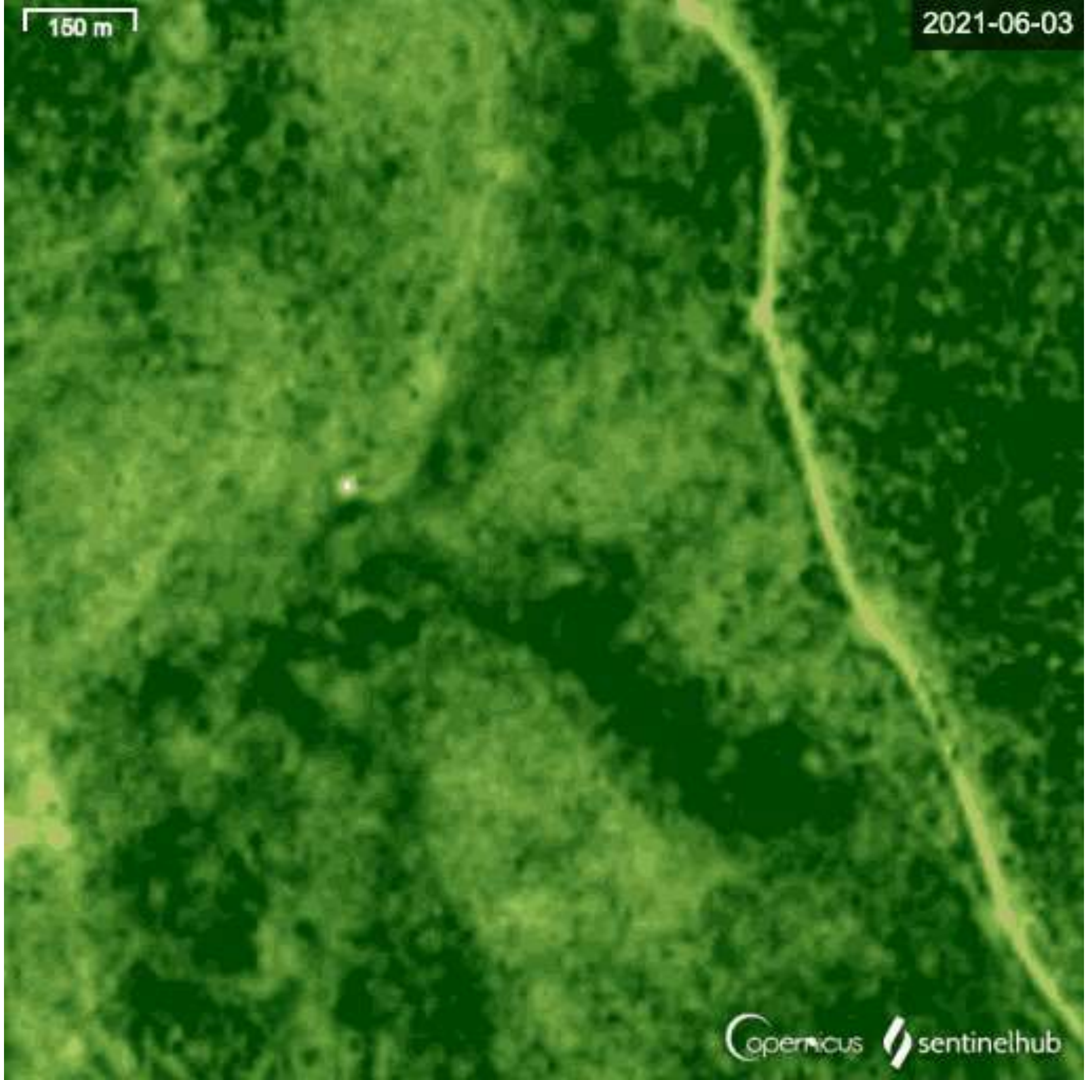
**Burned Veg**

# SWIR COMP


Healthy Veg

Burned Veg

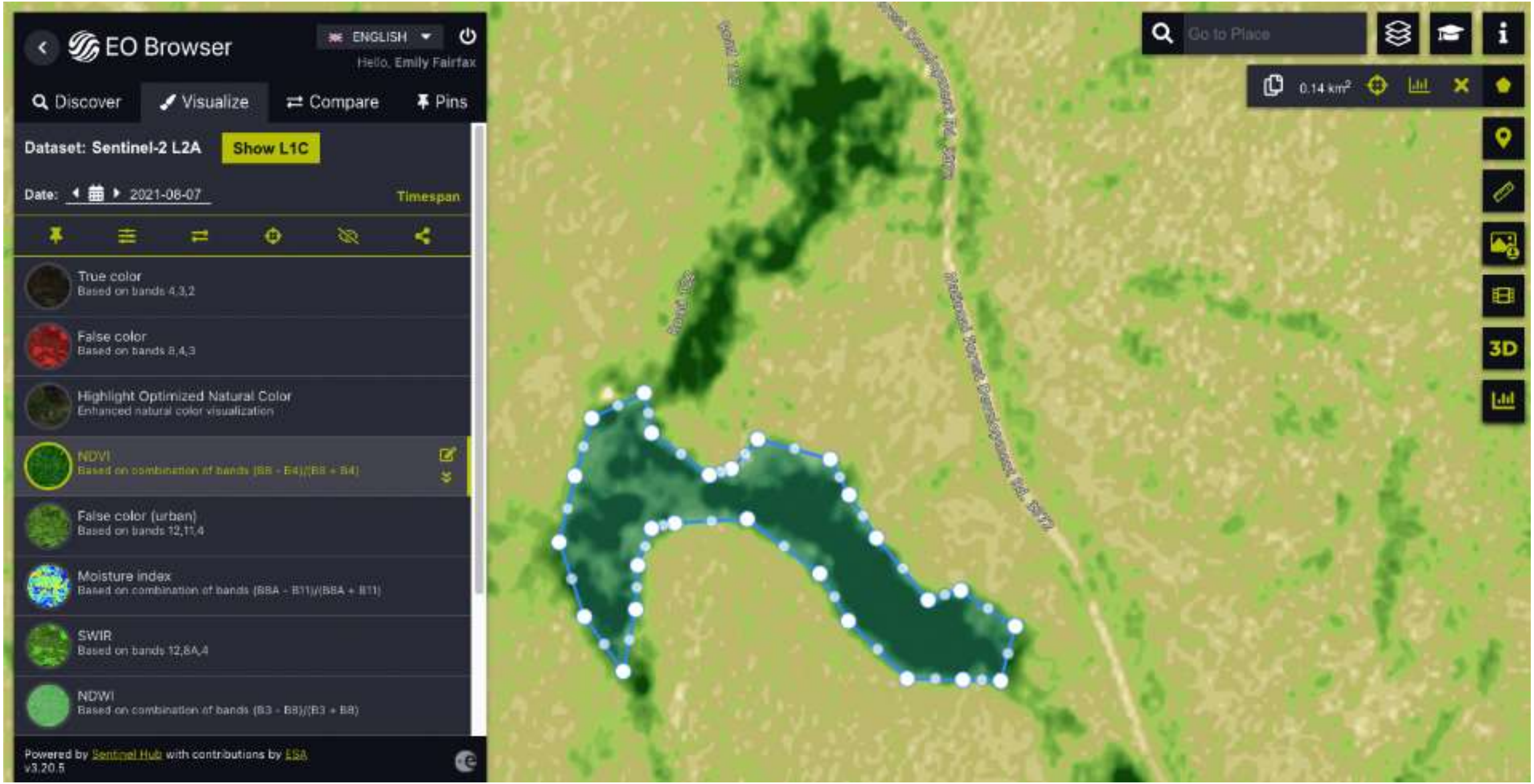
NDVI




Healthy Veg

Burned Veg


EO Browser
ENGLISH
Hello, Emily Fairfax
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date: 2021-08-07
Timespan
True color
Based on bands 4,3,2
False color
Based on bands 8,4,3
Highlight Optimized Natural Color
Enhanced natural color visualization
NDVI
Based on combination of bands (B8 - B4)/(B8 + B4)
False color (urban)
Based on bands 12,11,4
Moisture index
Based on combination of bands (B8A - B11)/(B8A + B11)
SWIR
Based on bands 12,8A,4
NDWI
Based on combination of bands (B3 - B8)/(B3 + B8)
Powered by Sentinel Hub with contributions by ESA
v3.20.5
Go to Place
0.14 km²
3D
Road 122
Road 122
National Forest Development Rd. 3372
National Forest Development Rd. 3372


EO Browser
ENGLISH
Hello, Emily Fairfax
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date: 2021-08-07
Timespan
True color
Based on bands 4,3,2
False color
Based on bands 8,4,3
Highlight Optimized Natural Color
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SWIR
Based on bands 12,8A,4
NDWI
Based on combination of bands (B3 - B8)/(B3 + B8)
Powered by Sentinel Hub with contributions by ESA
v3.20.5
Go to Place
0.14 km²
3D


EO Browser
ENGLISH
Hello, Emily Fairfax
Discover
Visualize
Compare
Pins
Dataset: Sentinel-2 L2A
Show L1C
Date: 2022-04-14
True color
Based on bands 4,3,2
False color
Highlight Optimized Natural Color
Enhanced natural color visualization
NDVI
False color (urban)
Based on bands 12,11,4
Moisture index
SWIR
Based on bands 12,8A,4
NDWI
Sentinel-2 L2A - 3_NDVI
0%
5 years
2 years
1 year
6 months
3 months
1 month
1
0.8
0.6
0.4
0.2
0
13. Jul 17
2. Mar 18
19. Oct 18
8. Jun 19
25. Jan 20
13. Sep 20
2. May 21
20. Dec 21
Export CSV
0.14 km²
3D

# RIPARIAN AREA WITH BEAVERS


# RIPARIAN AREA WITHOUT BEAVERS

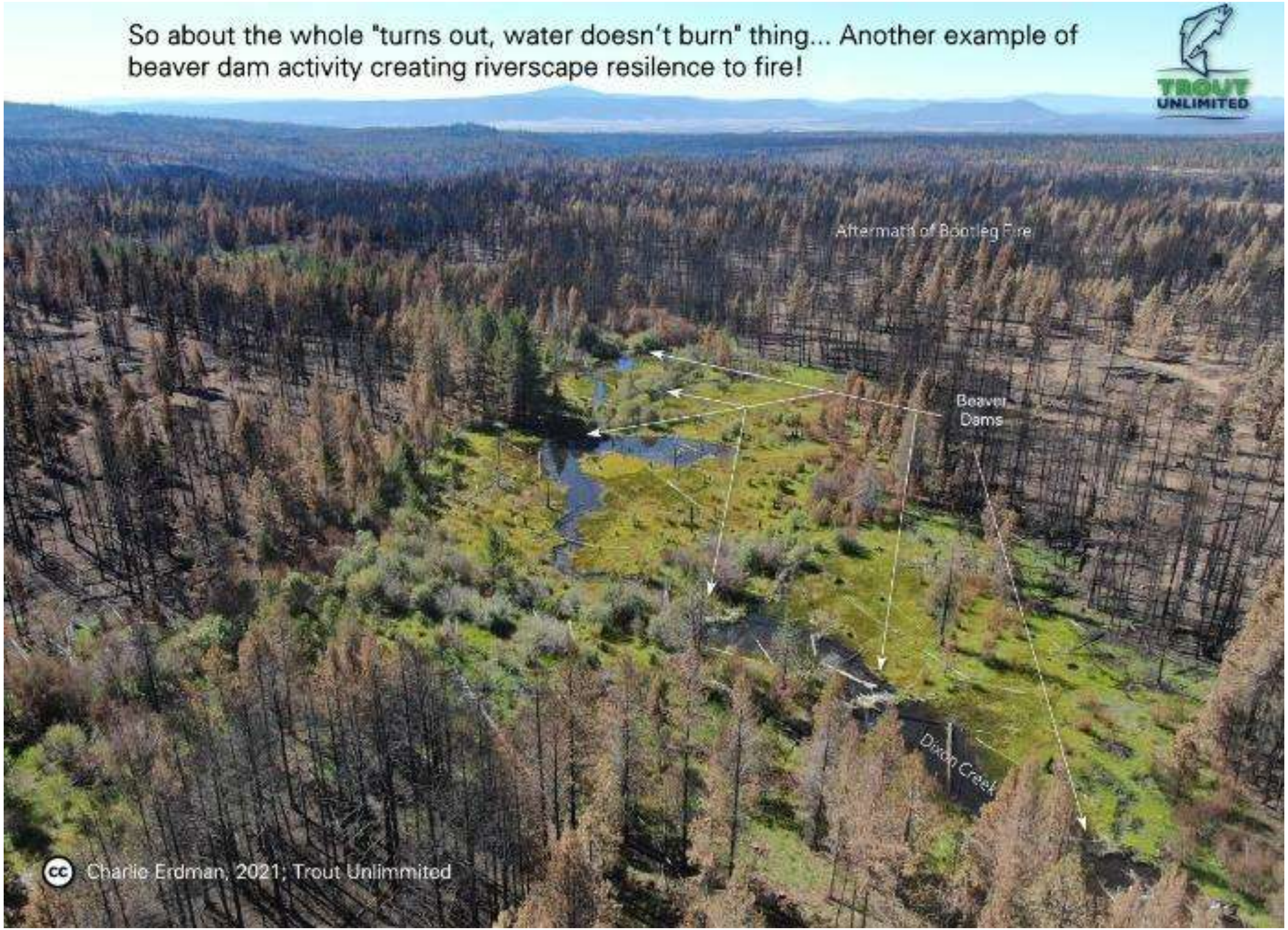



Photo by Charlie Erdman, modified by Joe Wheaton, [CC-by-4.0](CC-by-4.0)

# Questions?

emily.fairfax@csuci.edu

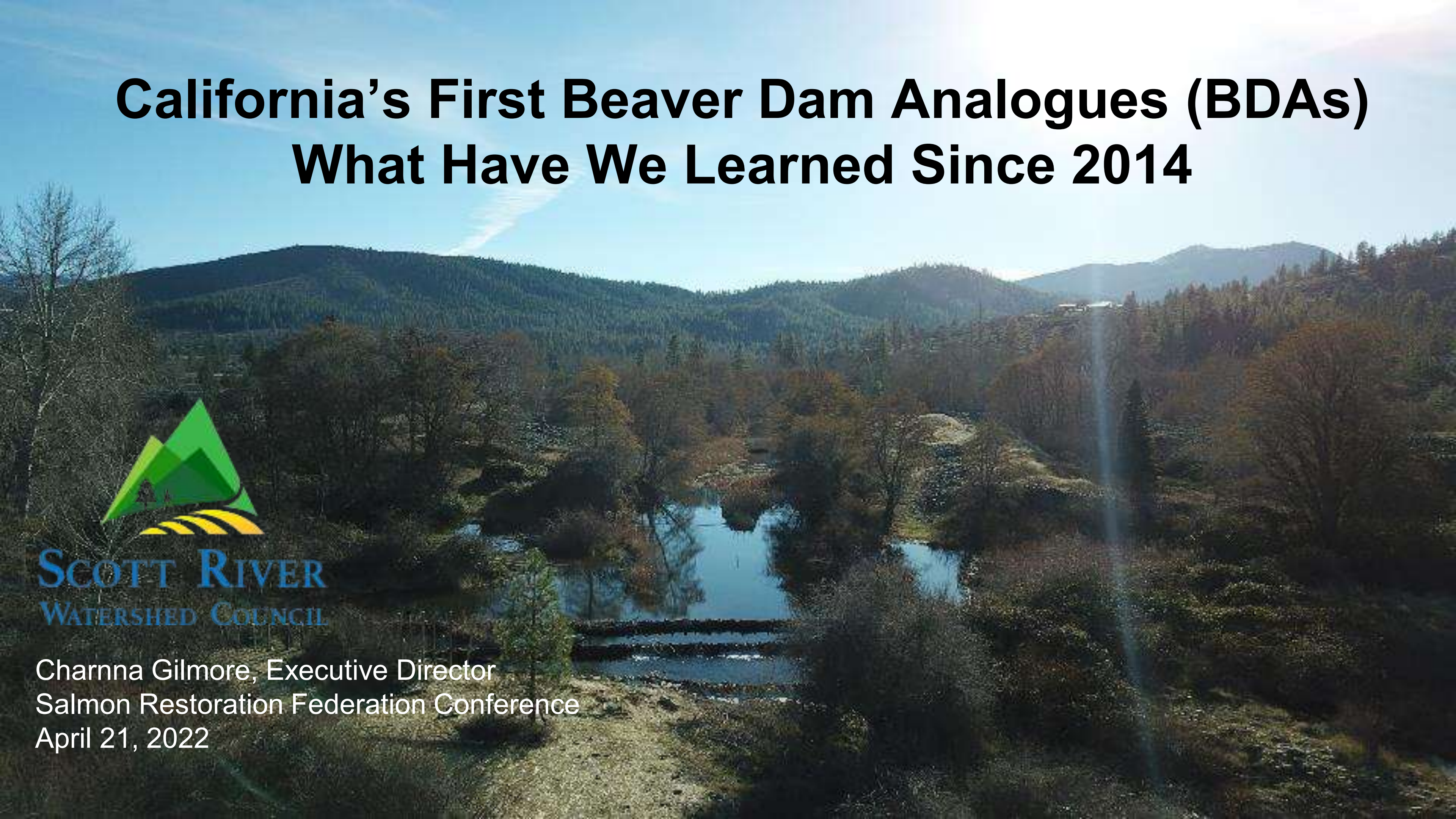
www.emilyfairfaxscience.com

Presented by Emily Fairfax, PhD

*Assistant Professor of Environmental Science and Resource Management*

*California State University Channel Islands*

# California’s First Beaver Dam Analogues (BDAs) What Have We Learned Since 2014

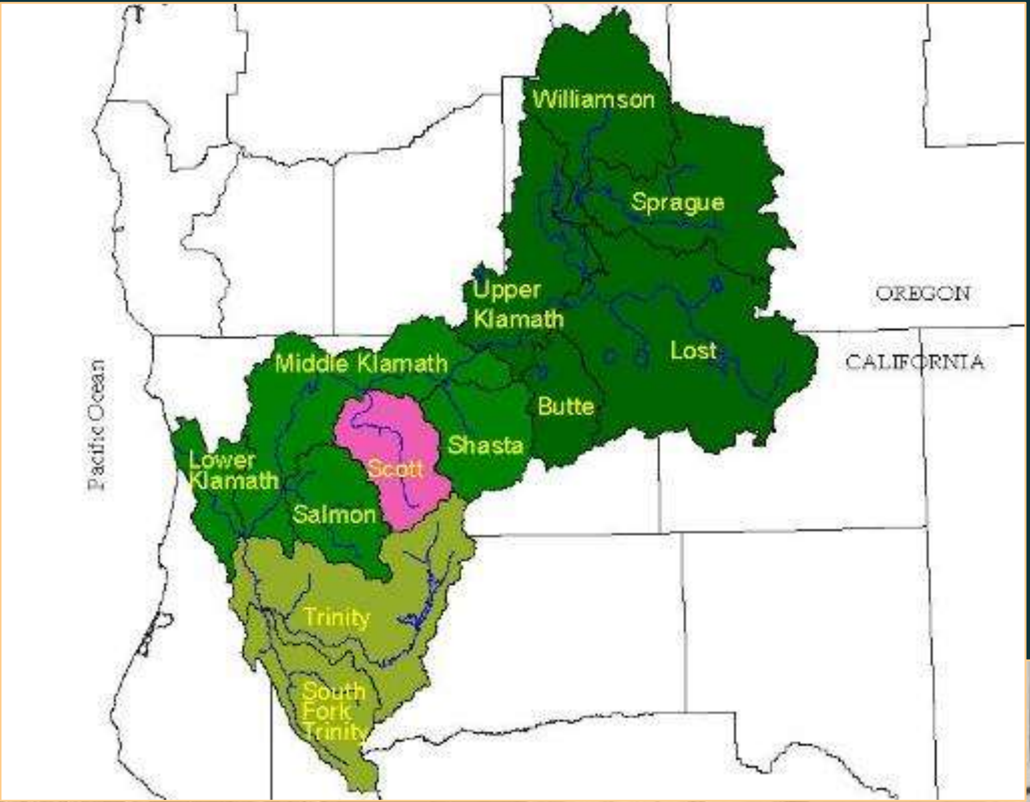


Scott River Watershed Council

Charnna Gilmore, Executive Director
Salmon Restoration Federation Conference
April 21, 2022


30
SECONDS OF
CALM


Sugar Creek BDA Pond 1 - Juvenile Coho Salmon - June 23, 2021
Watch later
Share
MORE VIDEOS
0:37 / 1:45
YouTube



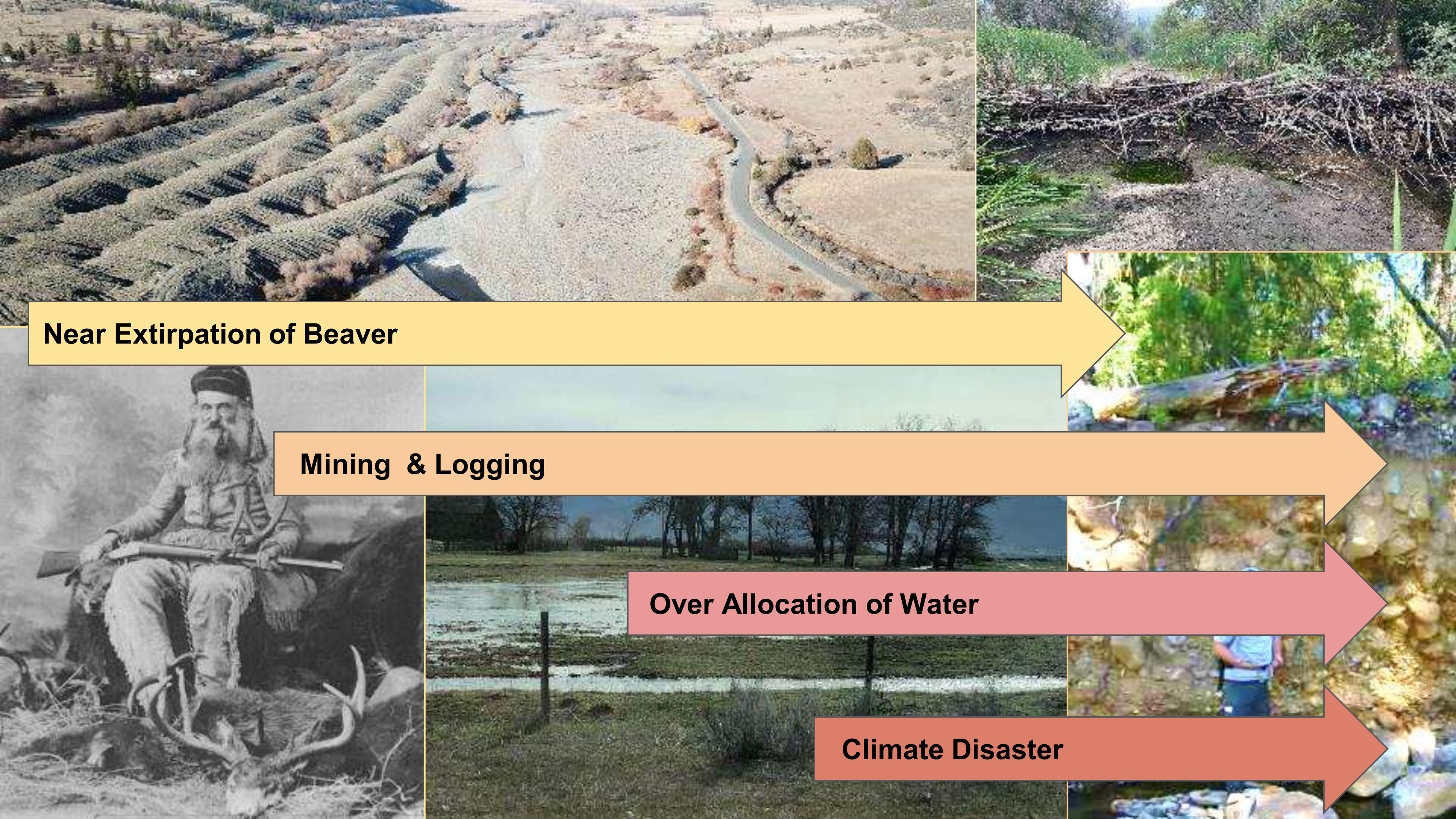

# Scott River Watershed, Siskiyou County

Indigenous Tribes of Shasta and Karuk inhabited the Klamath and Siskiyou Mountains for thousands of years prior to first contact with European settlers

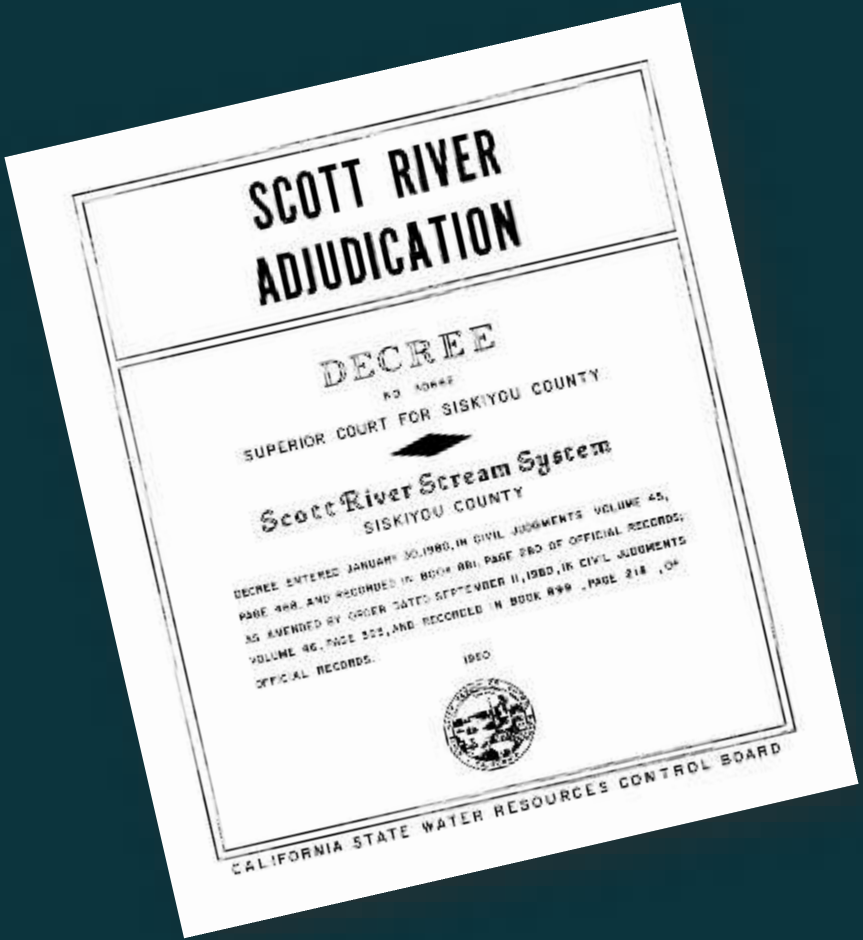
A subbasin to the larger Klamath River basin, the watershed encompassing 813 square miles

Today, 45% in federal and 55% in private lands, <1% now owned by an Indigenous Tribe

Population ~7,000, disadvantaged financially



Near Extirpation of Beaver
Mining & Logging
Over Allocation of Water
Climate Disaster



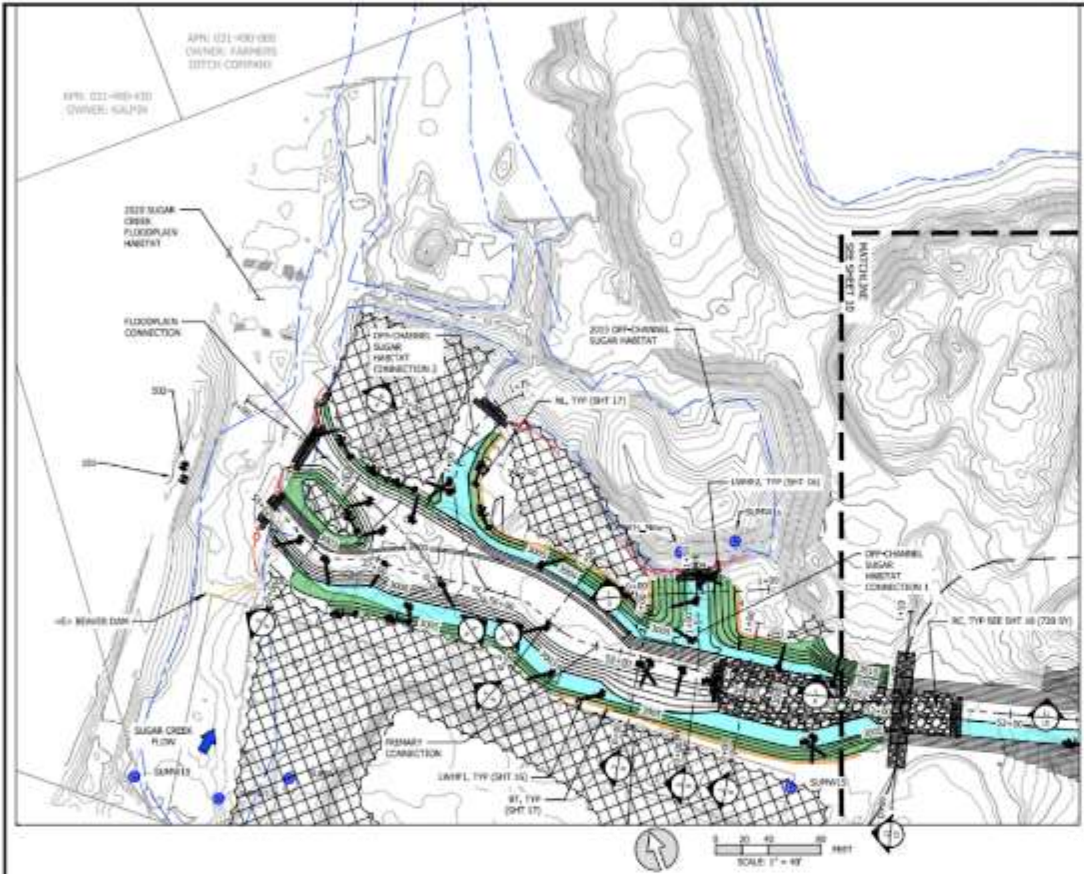

"While solutions for satisfying instream and offstream water needs are seemingly intractable at the present time, answers may probably be had. It will, however, require a cooperative effort between agricultural interests and several resource management agencies at municipal, county, state, and federal levels. "

Stream Flow Needs for Anadromous Salmonids in the Scott River Basin, Siskiyou County – A Summary Report – Dated 6-13-1974

# SRWC has performed stream restoration focused on Coho Salmon and Beaver since 2014

**Objectives:**

- Implement ecological restoration projects to address limiting factors of all life stages of Coho
- Seek solutions that offer multiple ecological services
- Emphasize the role beaver play in stream systems
- Perform physical & biological monitoring to demonstrate effectiveness of restoration, understand environmental condition & gain a better understanding of life strategies of the fishery
- Utilize effectiveness monitoring to guide adaptive management




| HABITAT FEATURE SCHEDULE | | | |
|---|---|---|---|
| TYPE | NORTHING | EASTING | KEY ELEVATION |
| LWHF1 | 2372221.53 | 6335308.66 | 3005.00 |
| LWHF1 | 2372247.04 | 6335274.49 | 3003.00 |
| LWHF1 | 2372313.33 | 6335222.89 | 3004.00 |
| LWHF1 | 2372291.46 | 6335212.35 | 3004.00 |
| LWHF1 | 2372160.59 | 6335196.90 | 2999.00 |
| LWHF1 | 2372273.49 | 6335138.36 | 3005.00 |
| LWHF1 | 2372102.29 | 6335101.07 | 3004.00 |
| LWHF1 | 2372106.28 | 6335118.66 | 2999.00 |
| LWHF1 | 2372179.05 | 6335138.53 | 3004.00 |
| LWHF1 | 2372380.64 | 6335034.43 | 3004.00 |
| LWHF1 | 2372418.01 | 6335034.21 | 2999.00 |
| LWHF1 | 2372449.53 | 6335025.11 | 3000.00 |
| LWHF1 | 2372473.58 | 6335019.85 | 3000.00 |
| LWHF1 | 2372533.06 | 6335014.33 | 3000.00 |
| LWHF1 | 2372380.46 | 6335056.15 | 2999.00 |
| LWHF1 | 2372436.27 | 6334978.43 | 2999.00 |
| LWHF1 | 2372494.25 | 6335056.87 | 3000.00 |
| LWHF1 | 2372485.89 | 6334960.34 | 2999.00 |
| LWHF2 | 2372176.41 | 6335272.22 | 3005.00 |
| LWHF2 | 2372146.27 | 6335219.87 | 2999.00 |
| LWHF2 | 2372324.55 | 6335244.69 | 3004.00 |
| LWHF2 | 2372275.07 | 6335175.43 | 2999.00 |
| LWHF2 | 2372482.19 | 6335082.02 | 3004.00 |
| NL | 2372333.09 | 6335185.66 | 3008.00 |
| NL | 2372180.02 | 6335014.93 | 3005.75 |
| NL | 2372420.67 | 6335104.00 | 3005.25 |
| NL | 2372462.74 | 6335112.38 | 3005.00 |
| NL | 2372396.78 | 6334978.26 | 3007.00 |
| NL | 2372473.99 | 6335056.67 | 3004.00 |
| NL | 2372489.01 | 6335041.24 | 3004.00 |
| NL | 2372462.56 | 6335009.39 | 3004.00 |
| NL | 2372516.70 | 6335025.33 | 3003.00 |

LONG POND HABITAT ENHANCEMENT PROJECT - 100% DESIGN

SISKIYOU COUNTY, CA

Stillwater Sciences

SCOTT RIVER WATERSHED COUNCIL
514 N STATE HIGHWAY 3
P.O. BOX 355
ETNA, CA 96027
530-598-2733

PROJECT NUMBER: 904.00
SCALE: AS NOTED
DATE: 12/3/21

DESIGN: JS/RWK
DRAWN: HLG/RWK
CHECKED: JS/JM
APPROVED: JS/JM

LONG POND REST. STA 51+00 TO 58+00 PLAN

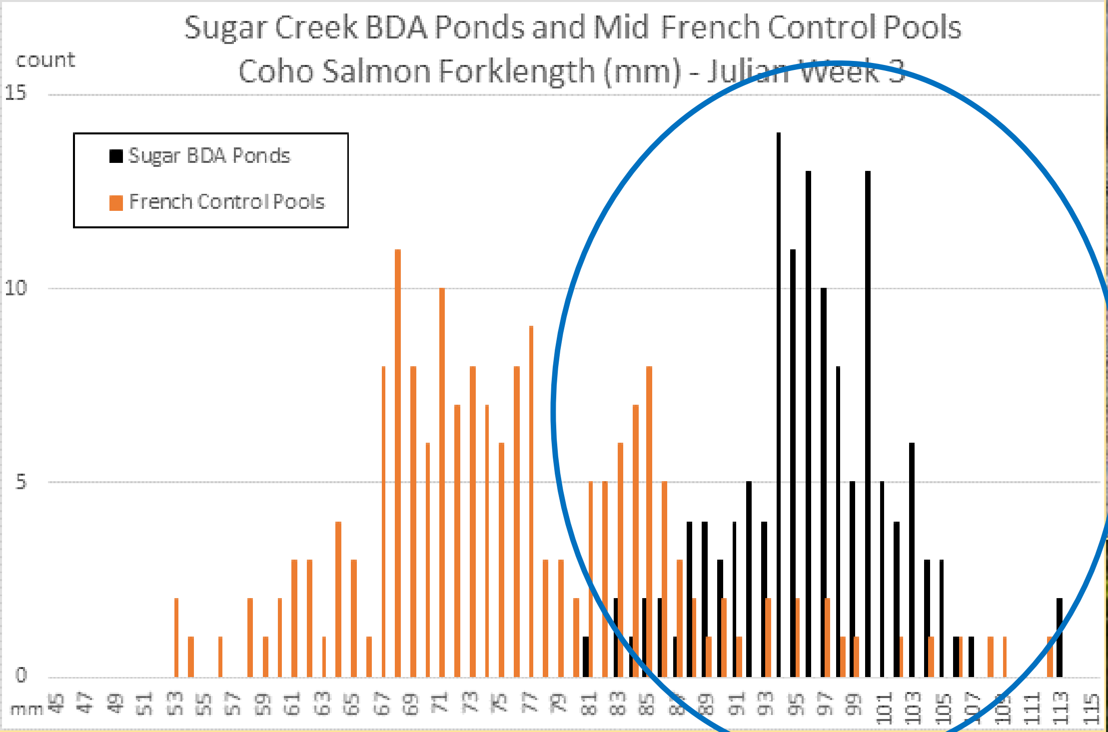
| CUT AND FILL SUMMARY | | | |
|---|---|---|---|
| SITE | CUT (CU YD) | FILL (CU YD) | BALANCE (CU YD) |
| LONG POND PRIMARY CONNECTION WITH OFF-CHANNEL SUGAR HABITAT CONNECTIONS 1 & 2, AND FLOODPLAIN CONNECTION | 7,950 | 50 | 7,900 |
| FILL AREA 1* | 0 | 39,500 | -39,500 |
| TOTAL | 7,950 | 39,450 | -31,500 |
| * SITE LOCATED ON SHEET 12, INCLUDES APPROXIMATELY 2,150 CU YD FILL FROM HABITAT FEATURE AND PLANTING ZONE SOIL AMENDMENT OVER EXCAVATION. | | | |

**GENERAL NOTES**

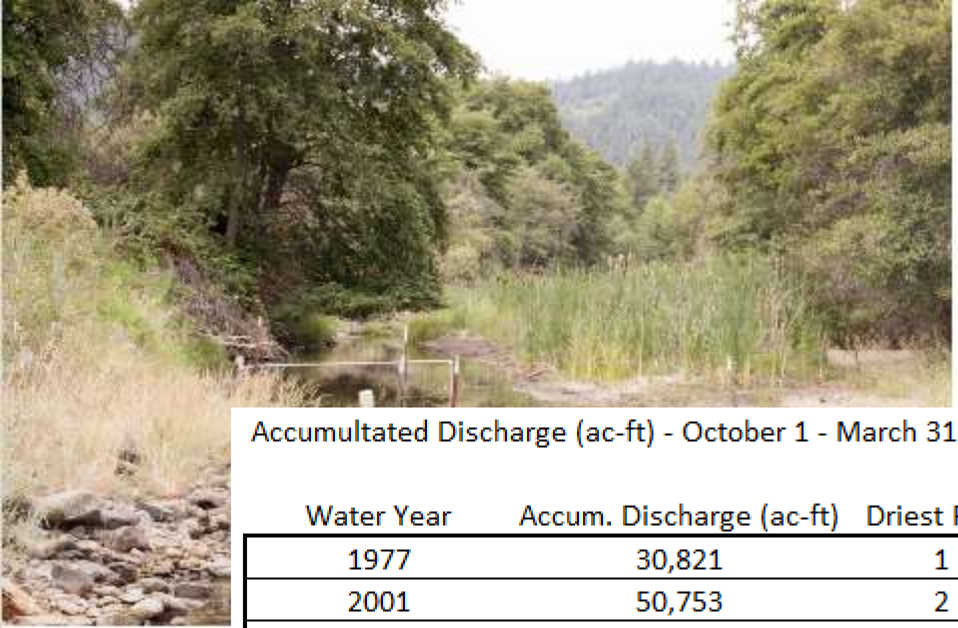
1. CONTRACTOR SHALL LIMIT EARTHWORK TO PERMANENT AND TEMPORARY FEATURES SHOWN ON THE PLANS AND PER DIRECTION OF CAR.
2. DISTURBANCE OUTSIDE THE WORK SHOWN SHALL BE MINIMIZED.
3. THE FILL AREA SHALL BE STABILIZED, WITH A MINIMIZED FOOTPRINT AND MATCHED EXISTING GRADES. TOP ELEVATION OF FILL AREA NOT TO EXCEED HIGHEST EXISTING GRADE TIE-IN PER DIRECTION OF CAR.
4. NEGATIVE VALUES SHOWN IN CUT AND FILL SUMMARY TABLE DENOTE SITE FILL VOLUME DEFICIT. NEGATIVE BALANCE VOLUMES INDICATE SITES REQUIRING MORE FILL VOLUME THAN CUT VOLUME PER PLAN VIEW SHOWN ON SHEET.
5. IF BEDROCK IS ENCOUNTERED ABOVE PROPOSED GRADE SHOWN, CONTRACT TO ADJUST PROPOSED GRADE ELEVATION TO MATCH EXISTING BEDROCK ELEVATION AND PER DIRECTION OF CAR.
6. ESTABLISH PLANTING ZONES FOLLOWING APPROVAL BY CAR AND ENGINEER OF PROPOSED GRADE, SEE SHEETS 14 AND 20, AND SPECIAL PROVISIONS FOR PLANTING ZONE LAYOUT AND DETAILS.

# *Effectiveness Monitoring*

- ➔ Fish Utilization
- ➔ Fish Passage
- ➔ Water Quality
- ➔ Surface/Groundwater Elevations, Stream Flow
- ➔ Geomorphic Change
- ➔ Habitat Characterization
- ➔ Beaver Utilization
- ➔ Riparian Health
- ➔ Food Web


Sugar Creek BDA Ponds and Mid French Control Pools
Coho Salmon Forklength (mm) - Julian Week 3
count
15
10
5
0
Sugar BDA Ponds
French Control Pools
mm
45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99 101 103 105 107 109 111 113 115


07 30 2020



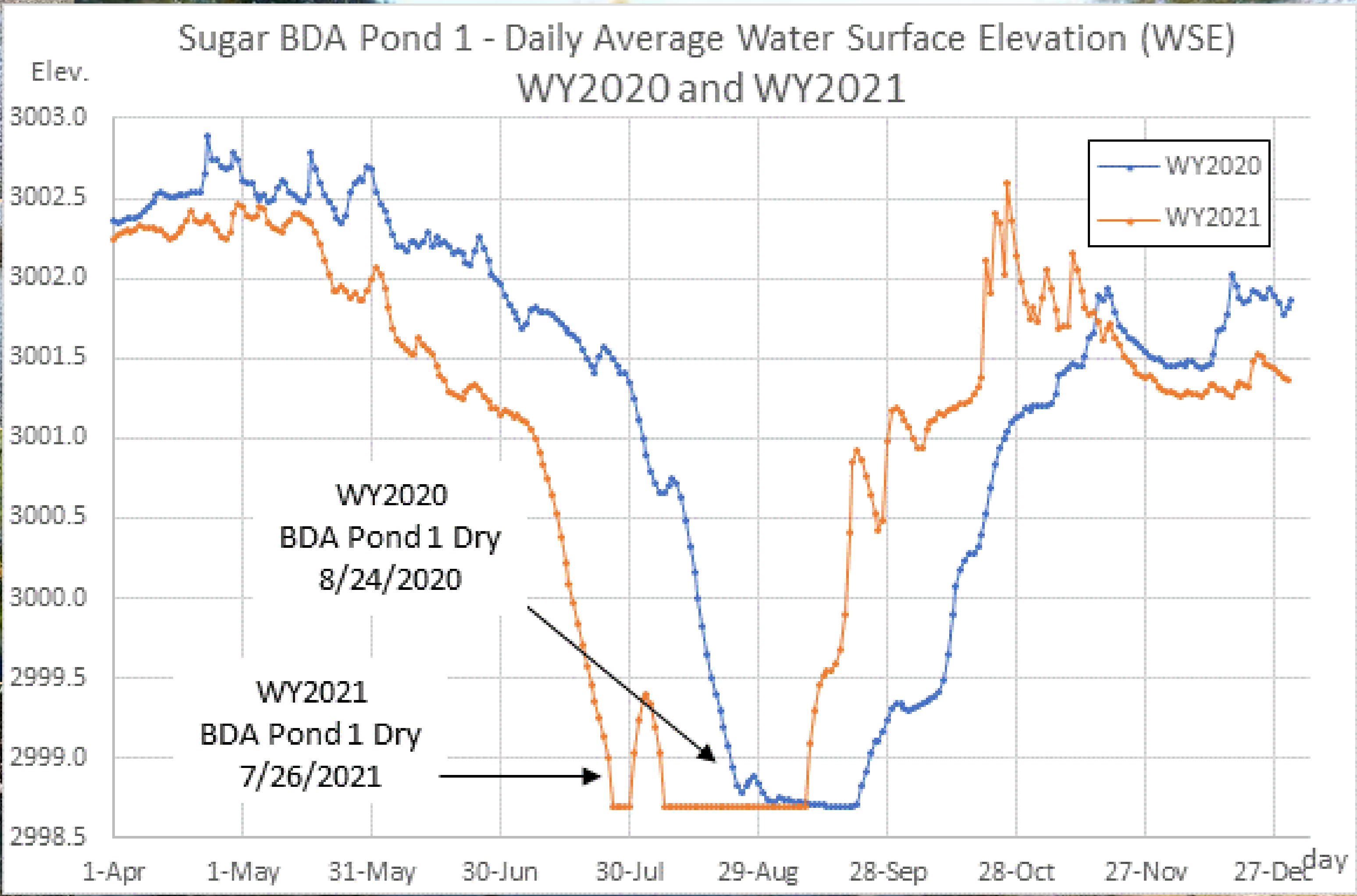
July 24, 2014

July 23, 2020

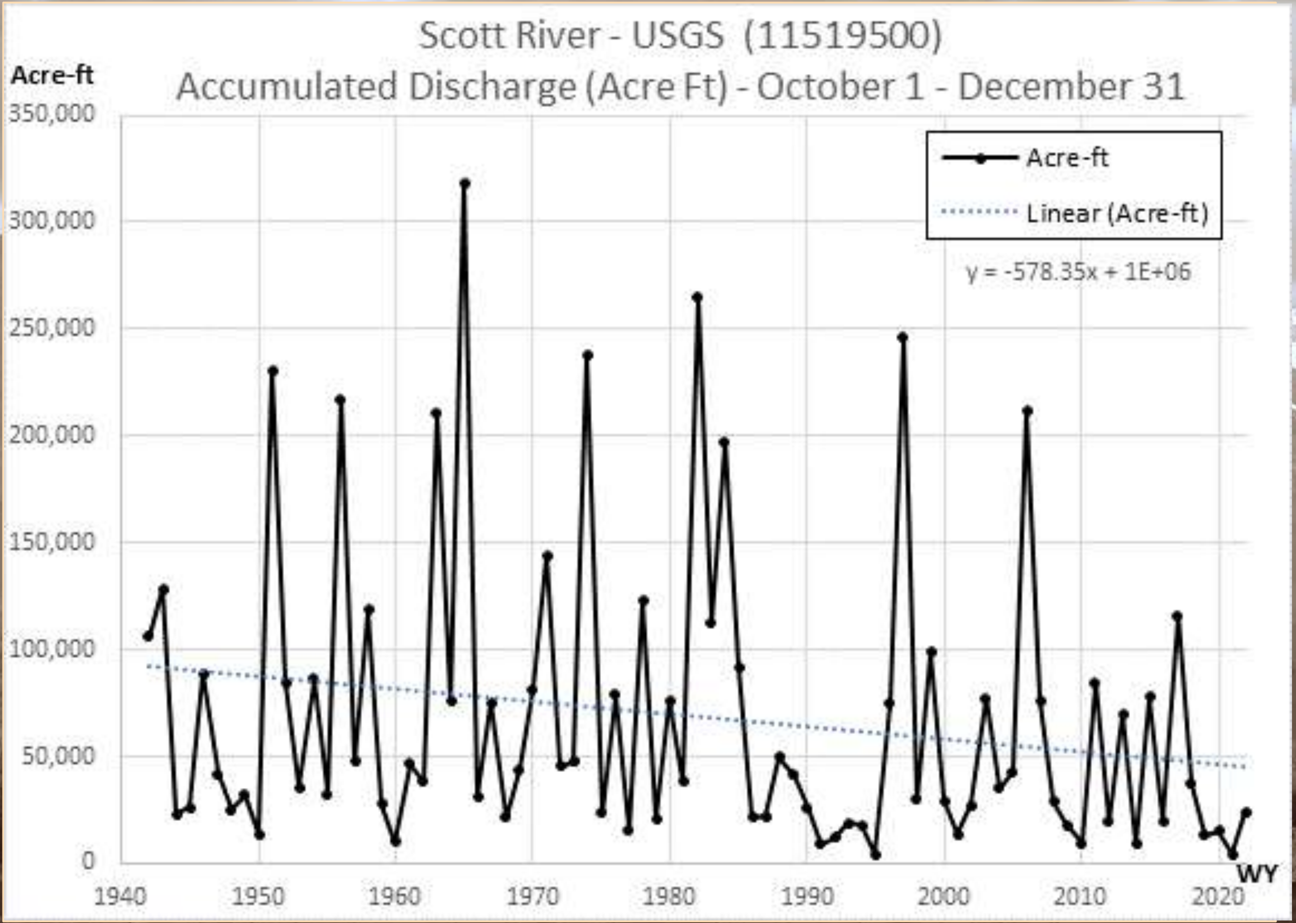
Accumultated Discharge (ac-ft) - October 1 - March 31

| Water Year | Accum. Discharge (ac-ft) | Driest Rank |
|---|---|---|
| 1977 | 30,821 | 1 |
| 2001 | 50,753 | 2 |
| 1991 | 52,981 | 3 |
| 2021 | 60,524 | 4 |
| 2020 | 63,115 | 5 |
| 1992 | 66,029 | 6 |
| 1994 | 66,323 | 7 |
| 1955 | 67,918 | 8 |
| 1944 | 72,172 | 9 |
| 2009 | 86,263 | 10 |
| 2014 | 91,510 | 11 |
| Average (80 years) | 254,525 | |

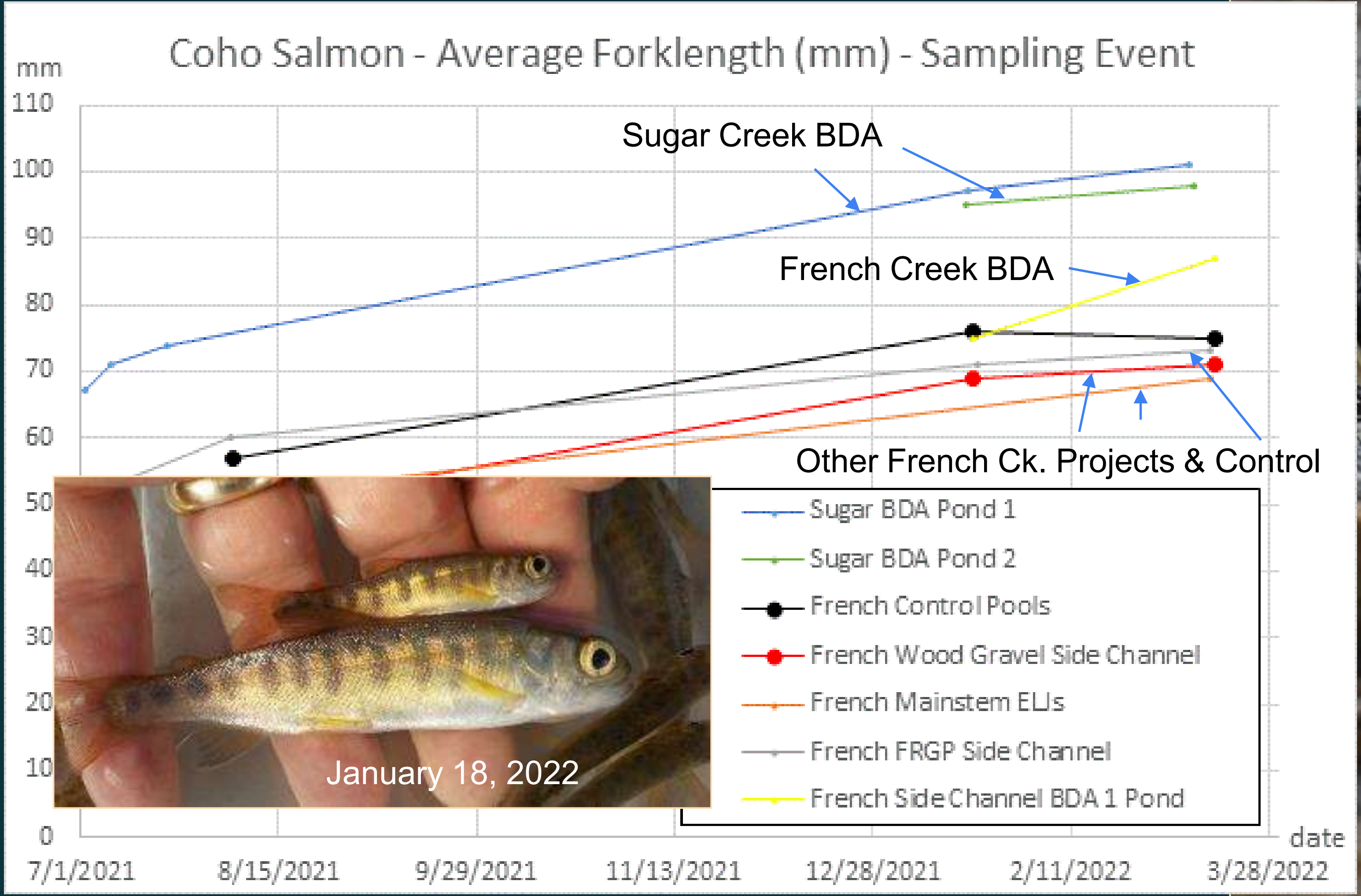
August 24, 2020



Sugar BDA Pond 1 - Daily Average Water Surface Elevation (WSE)
WY2020 and WY2021
Elev.
3003.0
3002.5
3002.0
3001.5
3001.0
3000.5
3000.0
2999.5
2999.0
2998.5
1-Apr
1-May
31-May
30-Jun
30-Jul
29-Aug
28-Sep
28-Oct
27-Nov
27-Dec
day
WY2020
WY2021
WY2020
BDA Pond 1 Dry
8/24/2020
WY2021
BDA Pond 1 Dry
7/26/2021



Scott River - USGS (11519500)
Accumulated Discharge (Acre Ft) - October 1 - December 31
Acre-ft
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1940
1950
1960
1970
1980
1990
2000
2010
2020
WY
Acre-ft
Linear (Acre-ft)
y = -578.35x + 1E+06


Coho Salmon - Average Forklength (mm) - Sampling Event
mm
110
100
90
80
70
60
50
40
30
20
10
0
7/1/2021
8/15/2021
9/29/2021
11/13/2021
12/28/2021
2/11/2022
3/28/2022
date
Sugar Creek BDA
French Creek BDA
Other French Ck. Projects & Control
January 18, 2022
Sugar BDA Pond 1
Sugar BDA Pond 2
French Control Pools
French Wood Gravel Side Channel
French Mainstem ELJs
French FRGP Side Channel
French Side Channel BDA 1 Pond


# Permitting & Funding Evolution

“One and Done” concept

Co-management over time

Adaptive management strategies to adjust to dynamic systems & rapidly changing climate

# Summary

Human use of  land and water is exacerbating climate change impacts

No water or sparce intermittent water - no beavers,  functioning BDAs

Need to tackle the the hard issues - Risk assessment must take into account the risk of doing nothing or more of the same

*“GO BIG OR GO HOME!”*

Look for opportunities to allow riverine systems to occupy the areas that can promote and support large scale process-based restoration

Use our collective voice to continue to make the change necessary to ward off extinction, loss of biodiversity and cultural resources, and Manage water and land for ecosystem needs and for future generations

# Scott Watershed Informational Forum (SWIF) 2023

February 22nd, 23th & 24th

Etna, CA

# Acknowledgements


SRWC Board & Staff

Scott Valley Landowners

NOAA

U.S. Fish & Wildlife Service

California Department of Fish & Wildlife

National Fish and Wildlife Foundation

Humboldt State University

EFM

Forest Service

Rocky Mountain Elk Foundation

California Water Boards North Coast - R1

Bella Vista Foundation

NRCS Natural Resources Conservation Service

California Climate Investments

Wildlife Conservation Society

Center for Watershed Sciences UC Davis

Stillwater Sciences

U.S. Department of the Interior Bureau of Reclamation

North Coast Resource Partnership

Coastal Conservancy

Cascade

Northern California Resource Center

# Questions?

charnna@scottriver.org

www.scottriver.org

Scott River
Watershed Council

# Use of Process-Based Restoration Techniques in a Coastal Tributary of the Klamath River

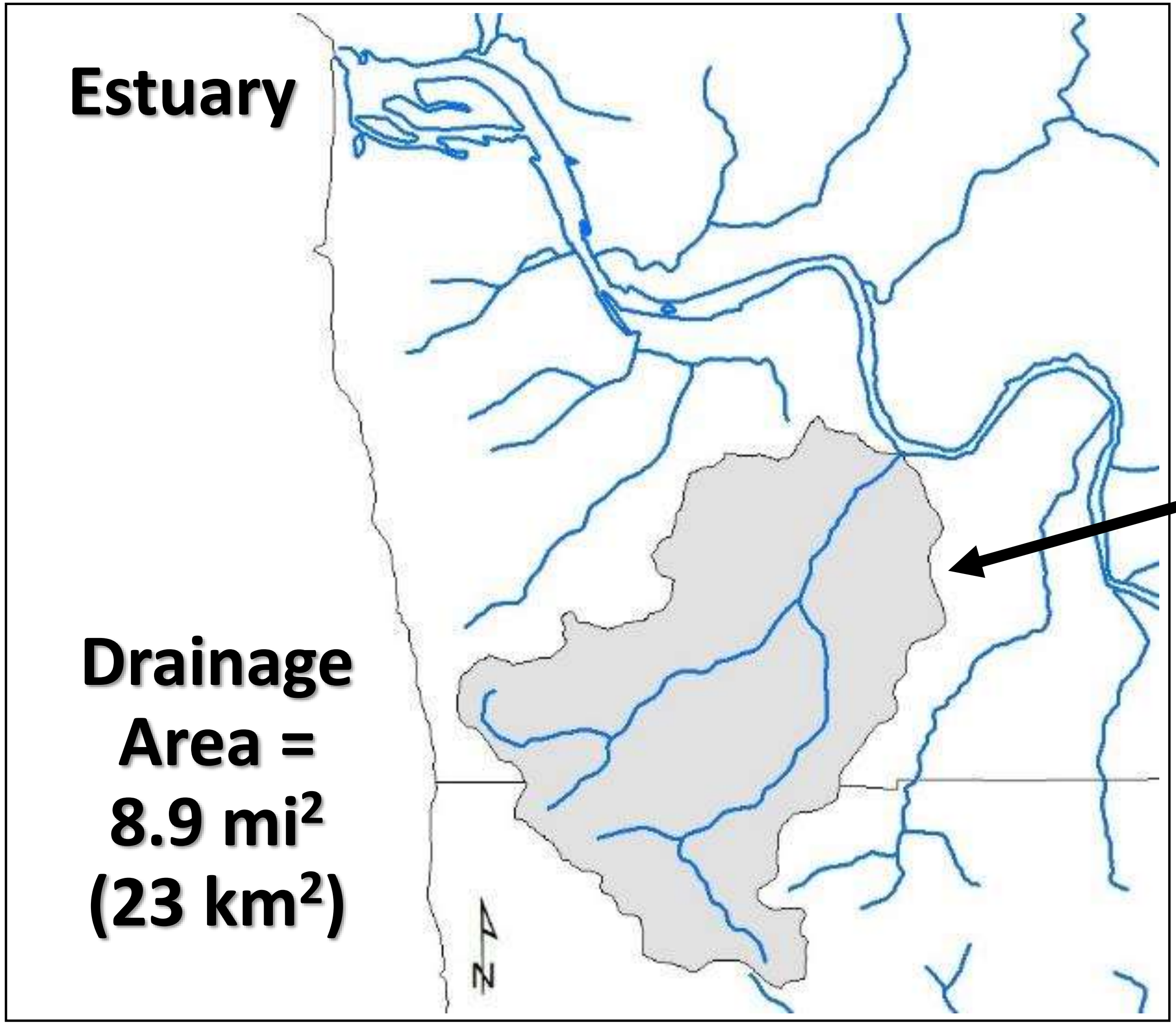
**Yurok Tribal Fisheries Department & Fiori GeoSciences**

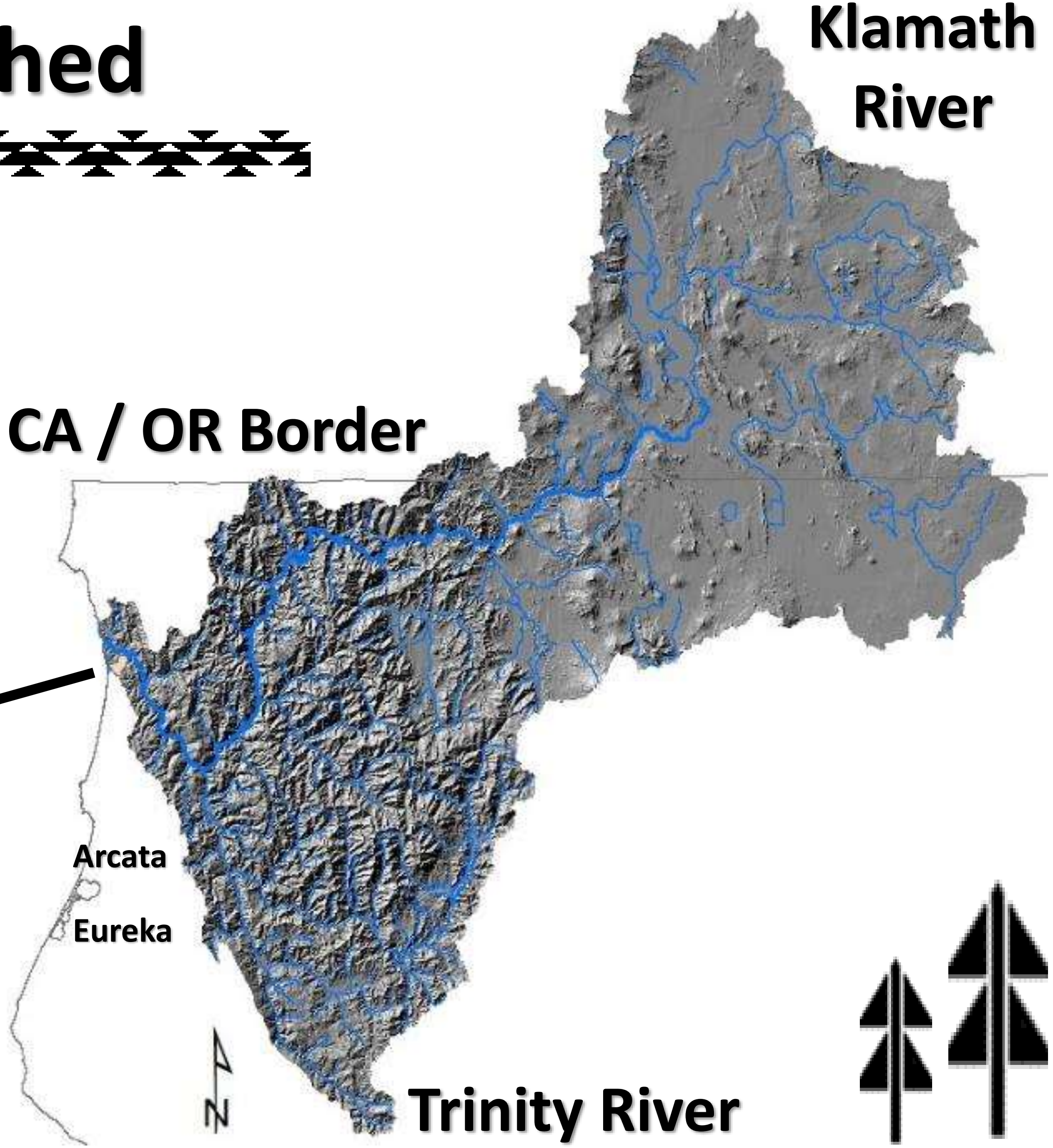
**Salmonid Restoration Federation – April 2022**

# Regenerative Stewardship

- Bio-Mimicry
- Process-Based
- Natural Materials
- Phased / Adaptive
- Long-Term Stewardship

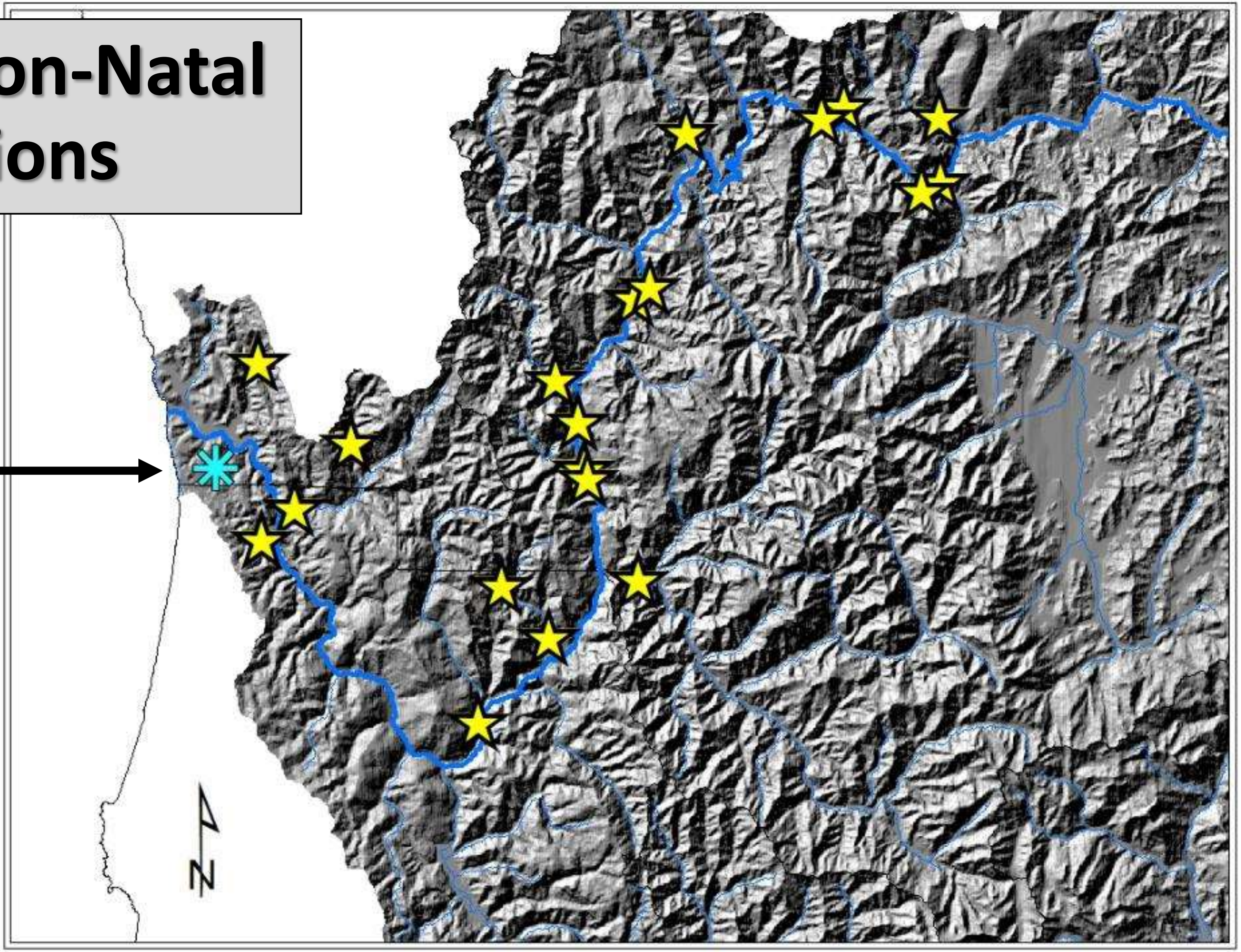
# McGarvey Creek Watershed



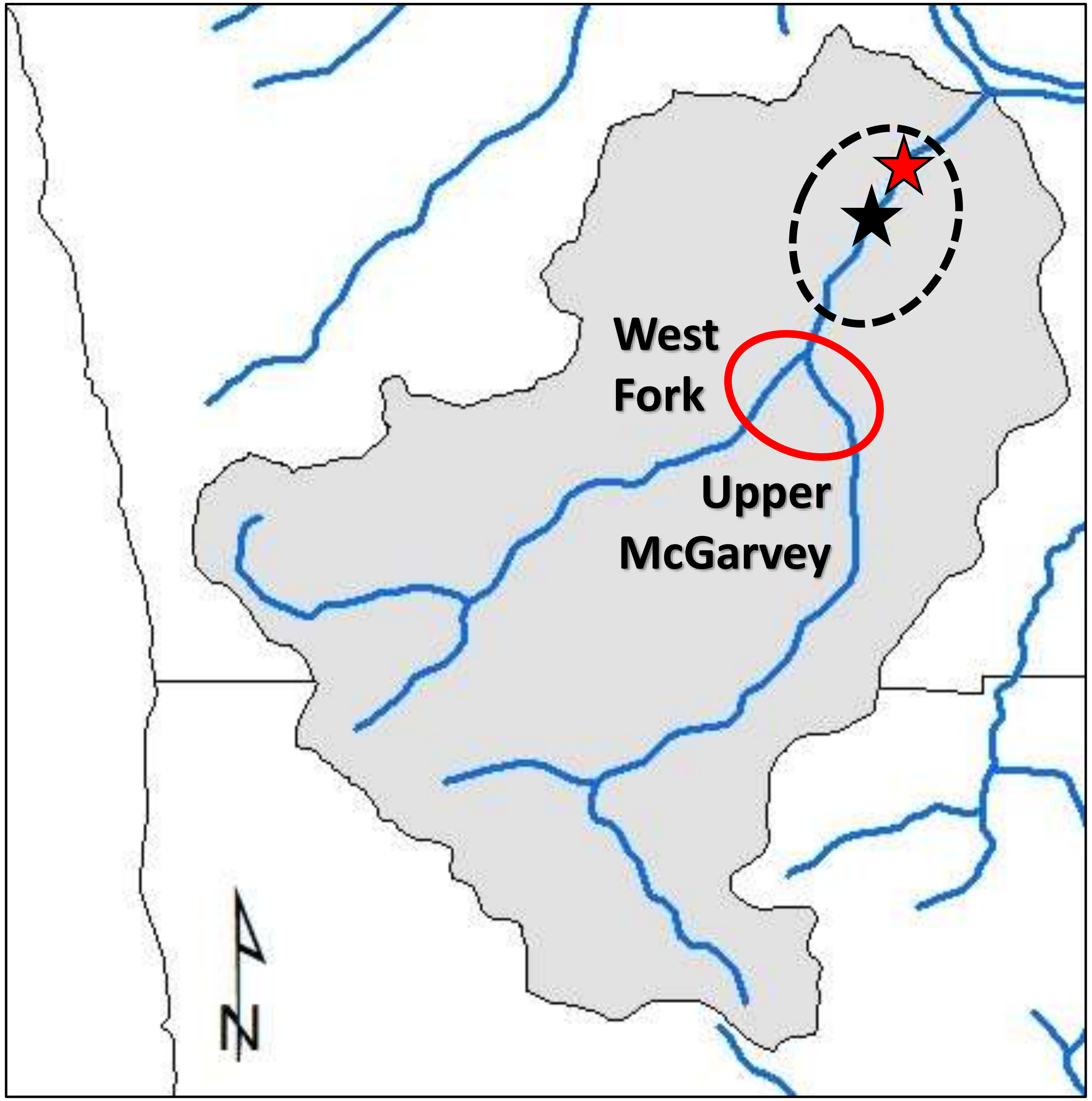



# McGarvey Non-Natal Coho Detections

McGarvey Creek



# McGarvey Creek Stewardship

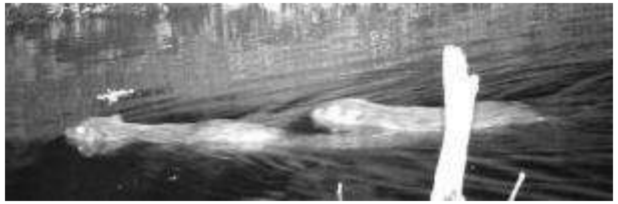



❖ Late 1990s
Road Decommissioning & Riparian Planting

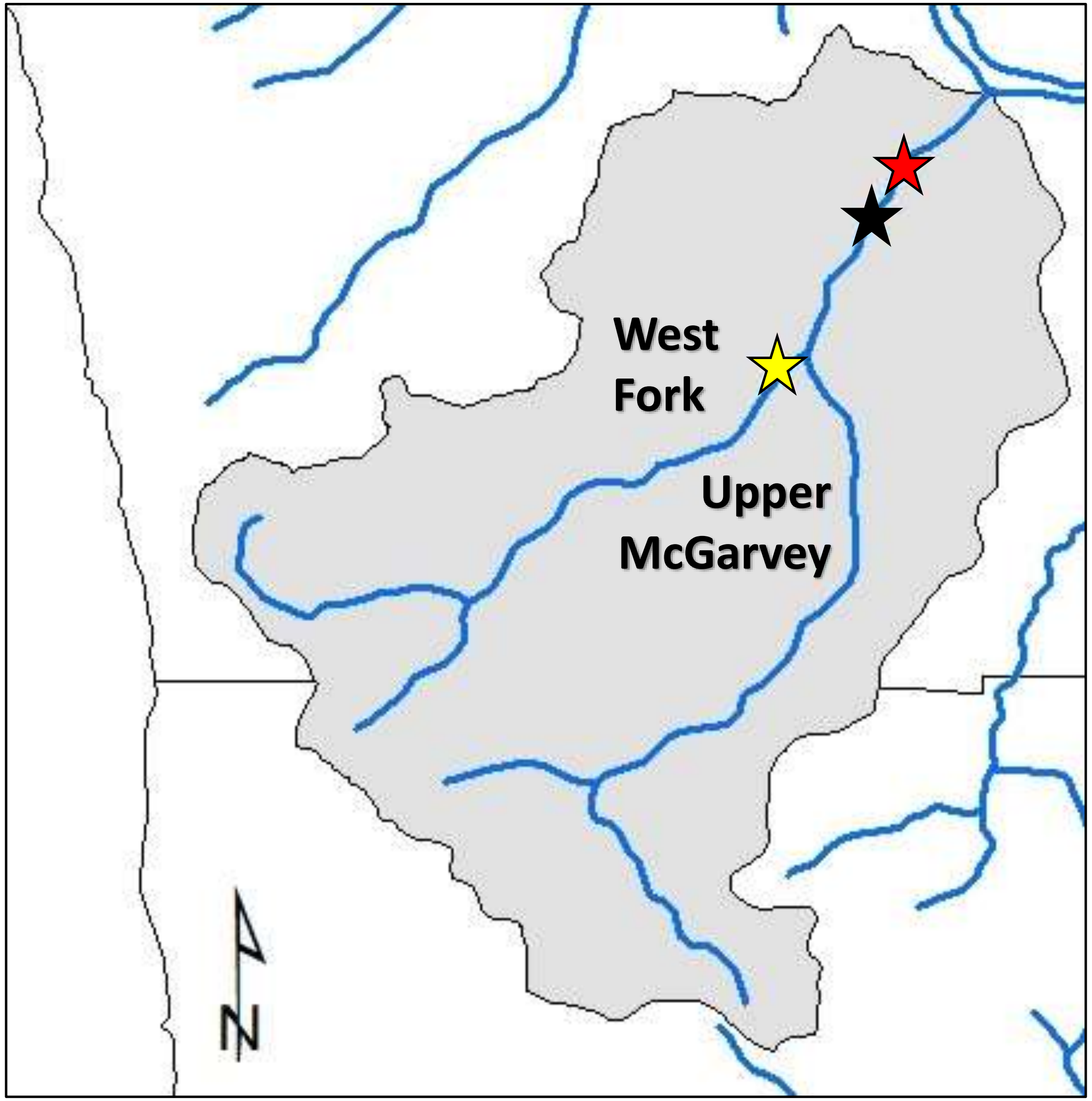
❖ 2007 & 2008
West Fork McGarvey Wood Loading
Upper McGarvey Wood Loading

❖ 2009 – 2014
Mainstem McGarvey Wood Loading
Alcove I-II  Alcove III-IV

# Tes-eer (Beaver) Synergy



# McGarvey Creek Stewardship




Alcove I-II Alcove III-IV

2018 - McGarvey Beaver Dam Analogue (BDA) Sites 1-2

2019 - 2020 - West Fork McGarvey BDA Sites 1-2




# McGarvey Creek BDA Sites 1 - 2

- Constructed Using Heavy Equipment & Hand Labor
- Proposed as Pilot Study

Fish Passage, Seasonal Use, Floodplain Connectivity, Hydro-Period, Beaver Interaction, Site Evolution & Stewardship Needs

# PBR Permitting – McGarvey Creek

## GDRC - Master Agreement of Timber Operations (MATO)

❖CEQA Mitigated Negative Declaration – CDFW Lead Agency

- CWA 401 via GDRC's Forest Management WDR
- CDFW LSAA Coverage

# PBR Permitting – McGarvey Creek

## USFWS – Primary Federal Partner

- NEPA Checklist
- Coordinated NHPA / Section 106 (THPO & SHPO)
- Nexus for USACE 404 & USEPA / YTED CWA 401 Authorizations
- ESA Authorization – USFWS (Consultation) / NOAA (BiOp)

# McGarvey BDA Sites 1-2

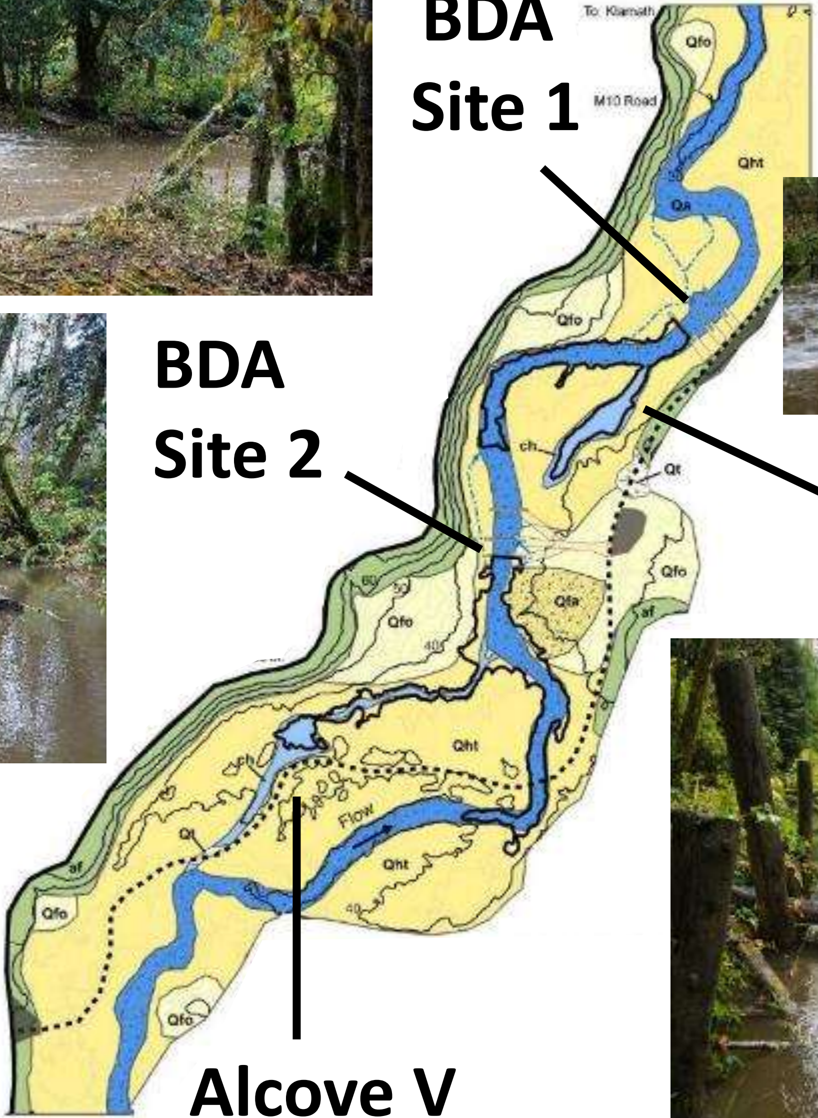
BDA Site 2 - 11/23/18

BDA

Site 1

BDA

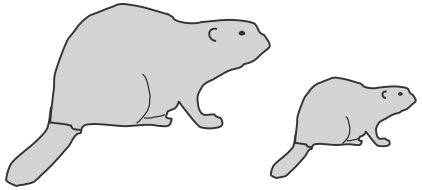
Site 2




Alcove V

BDA Site 1 - 11/23/18

Alcove III 11/23/18



# Key Pilot Study Findings

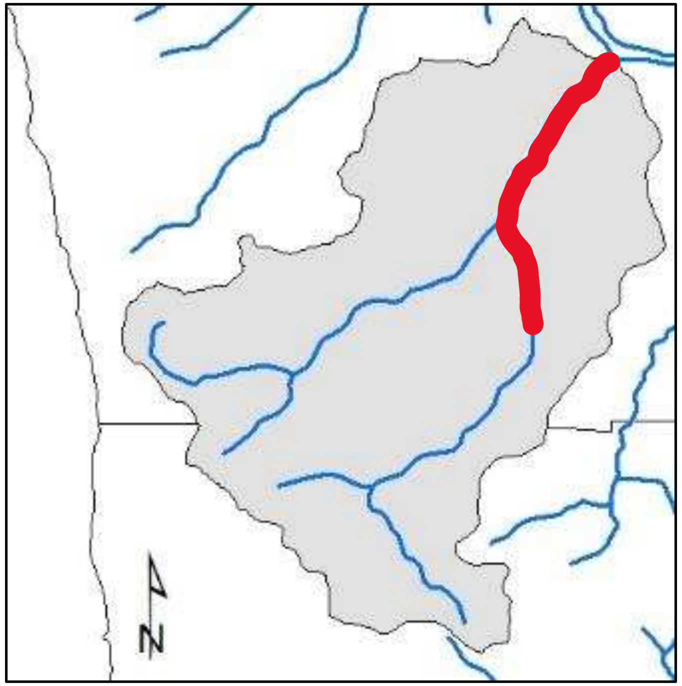



Habitat Response & Site Evolution

Elbow Grease


Hydro-Period

# Channel Drying & Fish Rescue




- Seasonal Channel Drying Occurs in Many Lower Klamath Tributaries (Significant Limiting Factor)
  - McGarvey Creek Conditions & Patterns
    - Drying Occurs Relatively Late (August)
    - Impacts ~40% of Coho Rearing Area
  - Fish Rescue & Relocation (Stewardship)


Photo by M. Mais

Photo by M. Mais

# West Fork McGarvey BDAs

## Pre-Project 06/10/19 vs Post BDAs 07/22/21




# WF McGarvey BDA Site 1



# WF McGarvey BDA Site 2



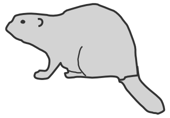
# Creativity, Evolution & Tes-eer

BDA Enhancement

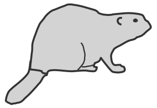
Floodplain Channels

Supplemental Dam Building

Vegetation Coppicing



Tes-
eer



# Wildlife

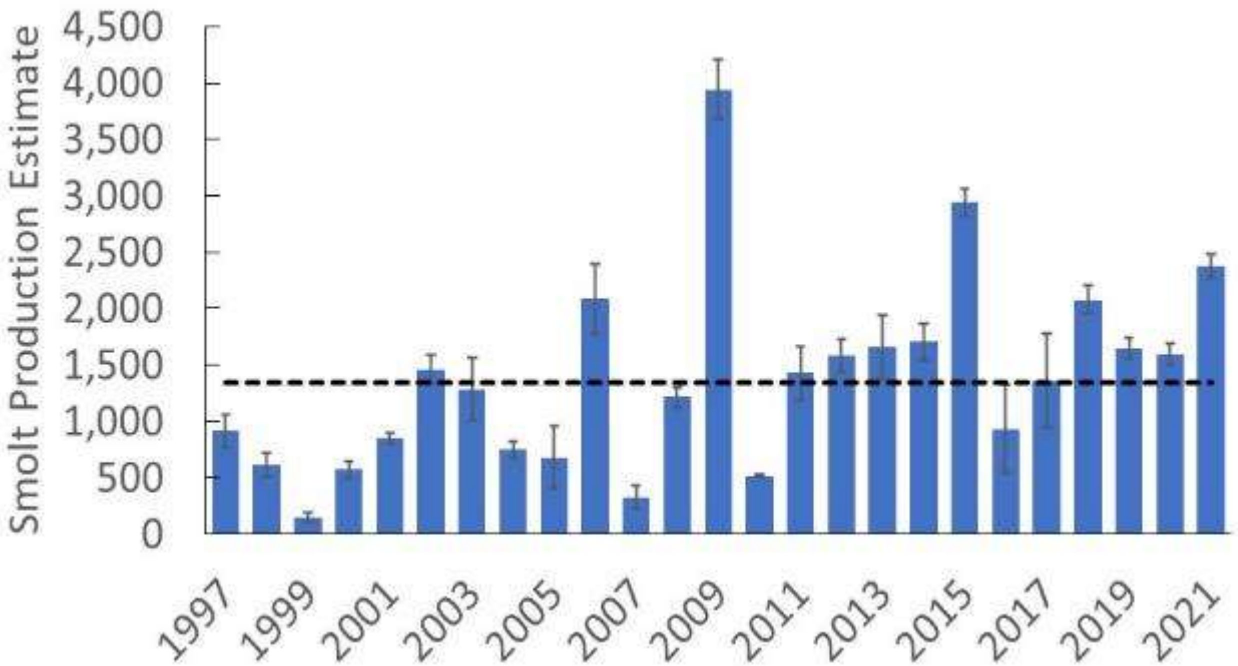
Ducks

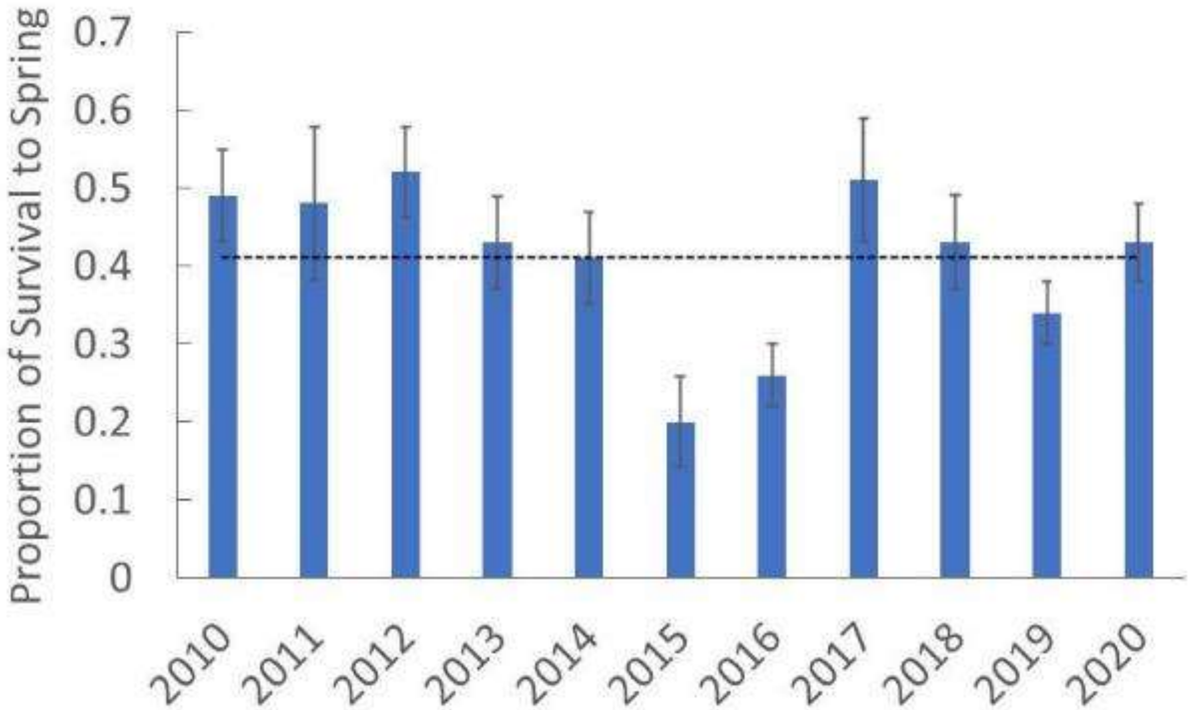
Ducks

so many

**DUCKS!**


# Juvenile Coho Production & Survival



# Next Steps

# Acknowledgements

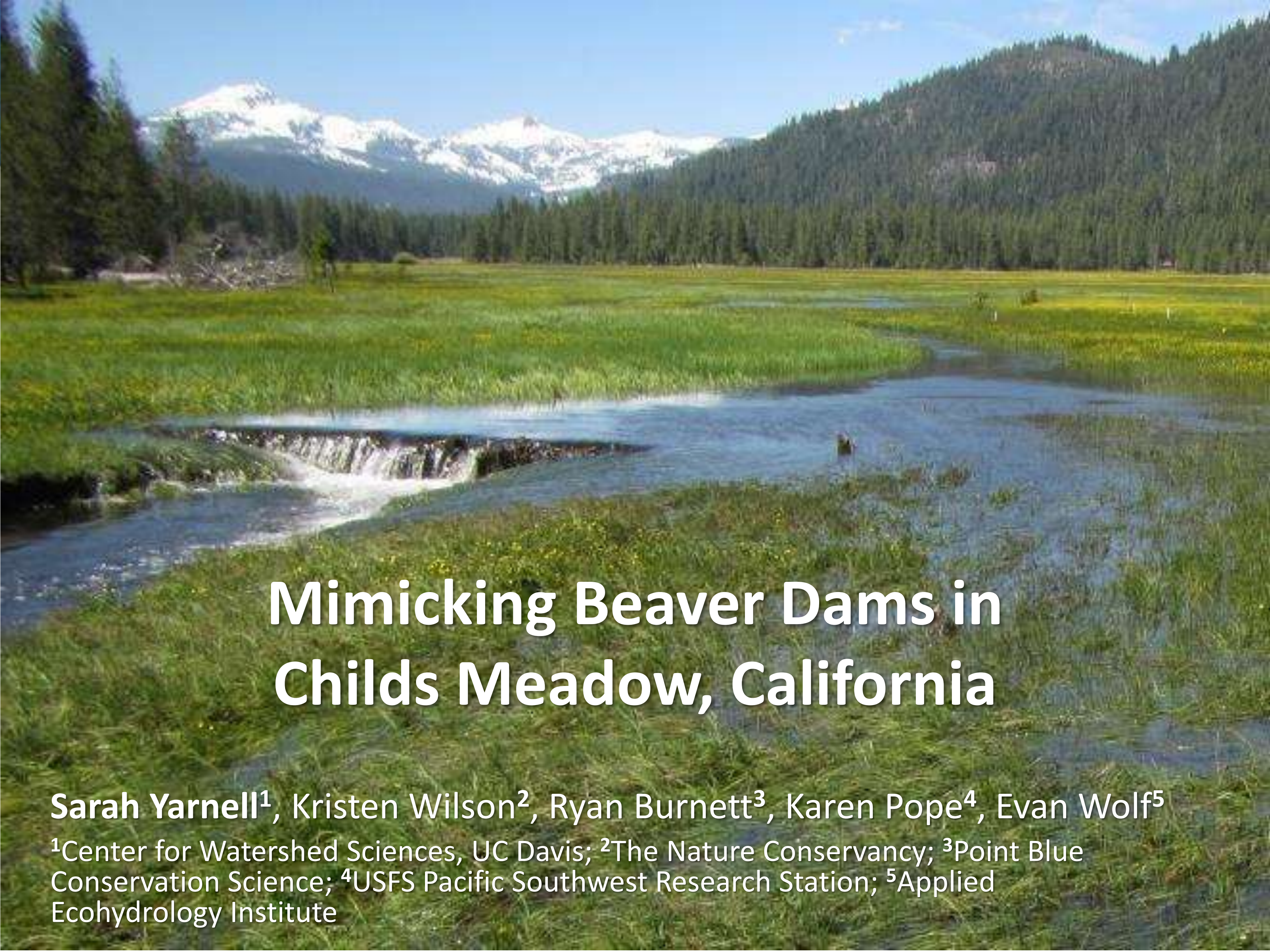
**Co-Authors:**
Rocco Fiori – Fiori GeoSciences
Andrew Antonetti, Jimmy Faukner & Scott Silloway,
Marshal Ownsbey, Logan McKinnon, Eric Schwenk - YTFD

Green Diamond Resource Company
USFWS – Partners Program
Scott River Watershed Council

US BIA – Tribal Resilience Fund
NFWF – Reclamation & PacifiCorp Klamath Coho Funds
NOAA – Pacific Coast Salmon Recovery Funds

# Wok-hlew’

Photo by Ben Laukka
McGarvey Creek Coho



# Mimicking Beaver Dams in Childs Meadow, California

**Sarah Yarnell**[1], Kristen Wilson[2], Ryan Burnett[3], Karen Pope[4], Evan Wolf[5]

[1]Center for Watershed Sciences, UC Davis; [2]The Nature Conservancy; [3]Point Blue Conservation Science; [4]USFS Pacific Southwest Research Station; [5]Applied Ecohydrology Institute

# Childs Meadow Project Partners

**U.S. Fish & Wildlife Service, Partnership Program -**
Jacob Byers and Sheli Wingo

**Plumas Corporation**
Leslie Mink
(Permitting)

**Scott River Watershed Council**
Charna, Leslie, Peter
(BDA Construction)

# Pre-restoration Meadow Conditions

## Pre-treatment Reaches

## Natural Beaver Reach

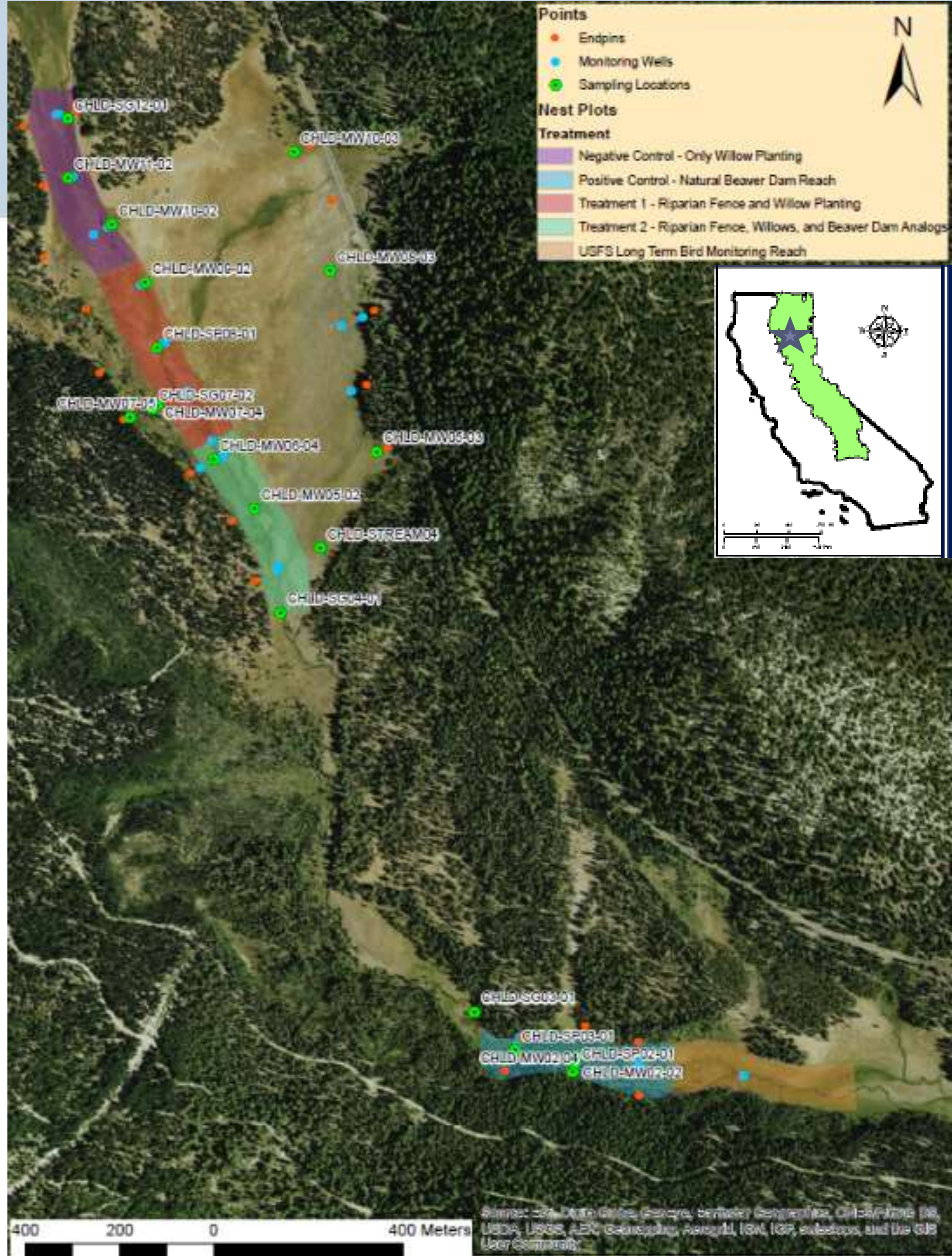
*Images flown same day, Oct. 2014*

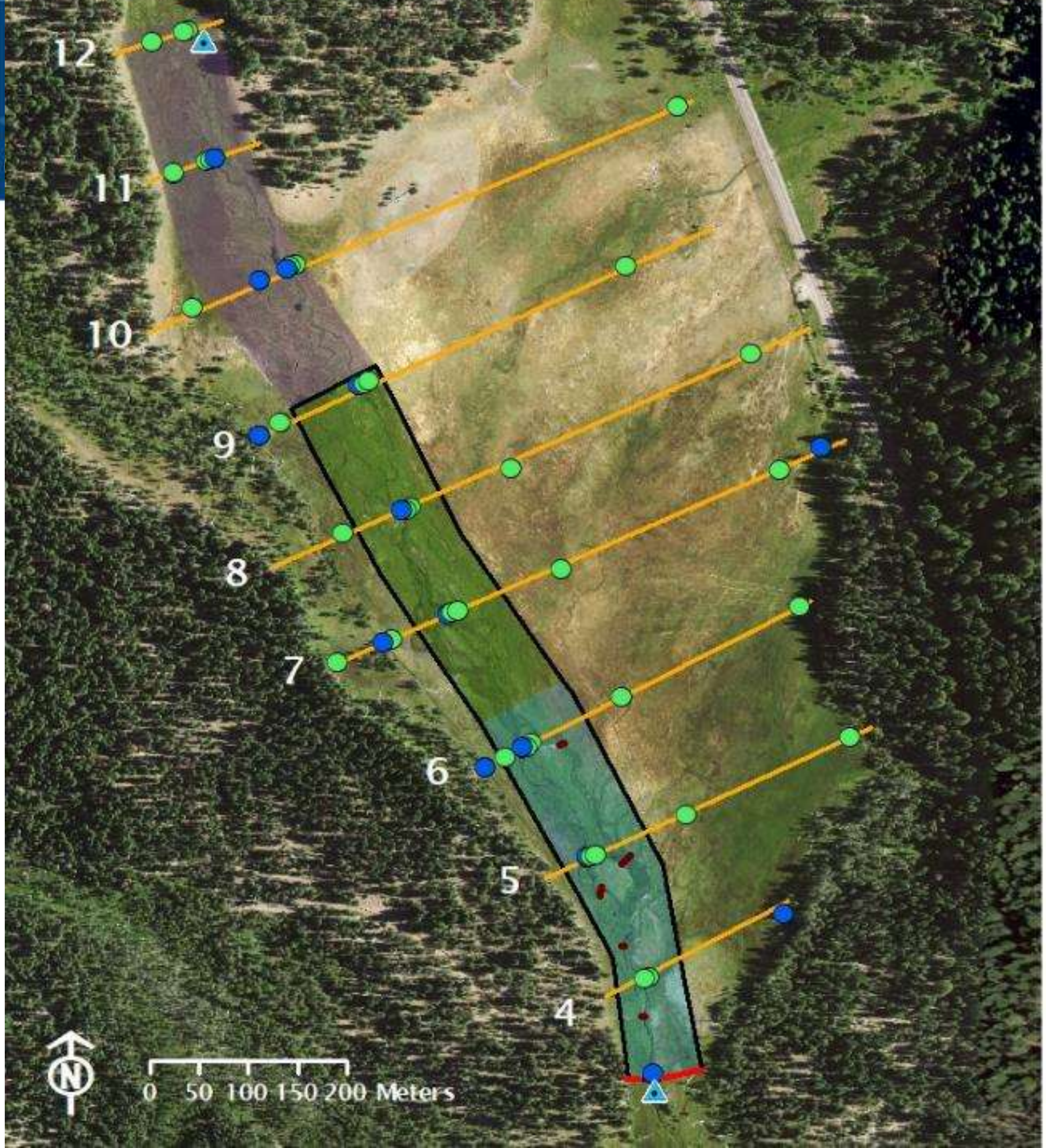
- 100+ years of grazing
- Removal of timber from 1941-1974
- Ditching on edges of meadow by 1974
- Channel incised on average 1.6 ft, lacks woody vegetation

- Beaver present; small family groups
- Cascades Frog population
- Sandhill Crane breeding
- Willow flycatcher habitat, small population

# Study Design

- Before-After-Control-Impact
  - 2 treatments
  - 2 controls
- Surface-groundwater
- Stream channel conditions
- Carbon sequestration
- Response of sensitive species
  - Willow flycatcher
  - Cascades frog






# Upper Childs Meadow Study Site Map

Negative Control: Only Willow Planting

Treatment 1: Riparian Fence & Willow Planting

Treatment 2: Riparian Fence, Willows, & Beaver Dam Analogs

Monitoring Well

Stream Gauge

Staff Plate

Cross-sections

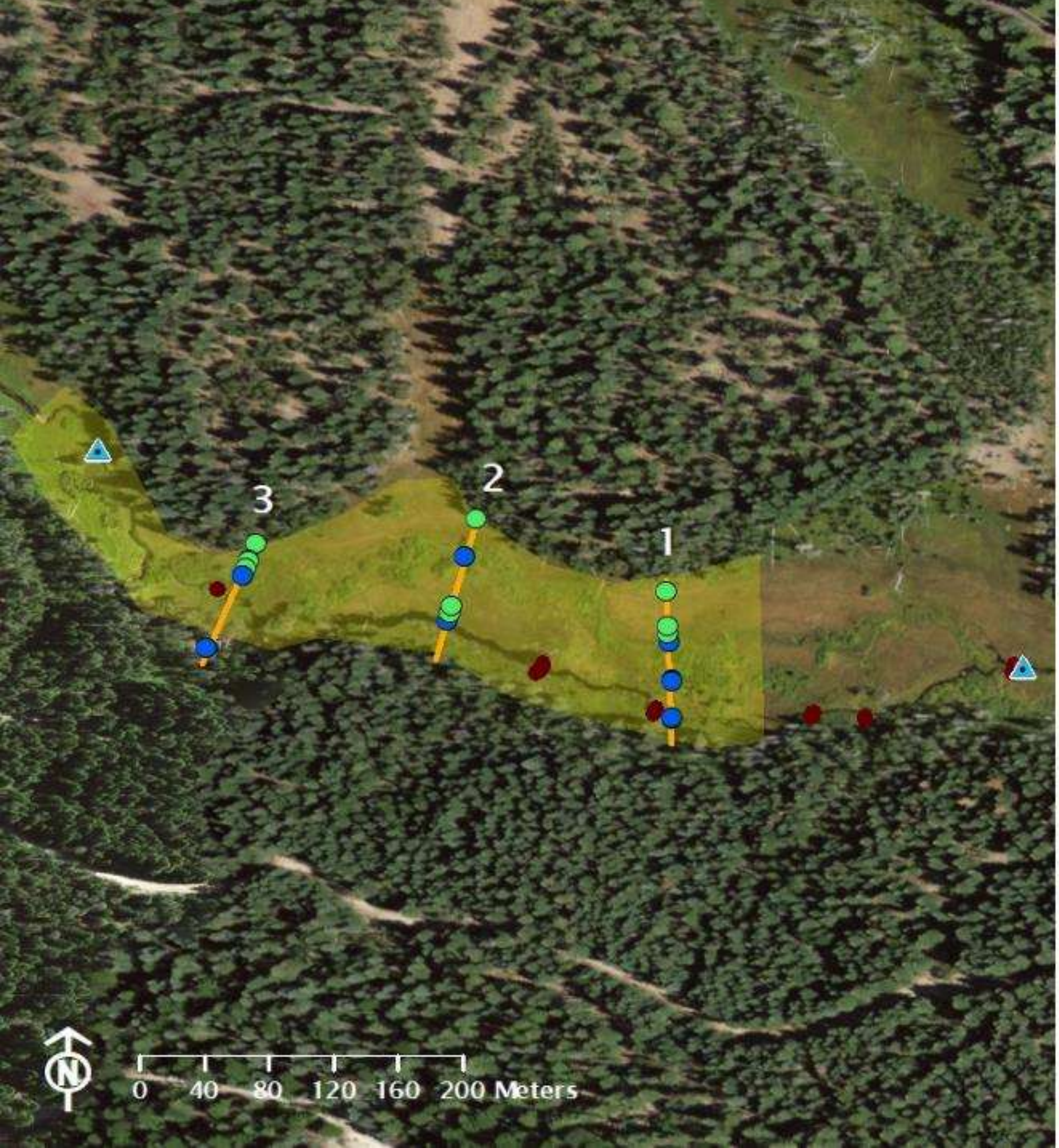
BDA Locations

Split Rail Fence

Treatment Fence

UCDAVIS
CENTER FOR WATERSHED SCIENCES

Projection: WGS 1984 Web Mercator Auxiliary Sphere
Datum: WGS 1984; Data Source: Ersi, ArcGIS Online, & National Agriculture Imagery Program
25 September 2019 Alice Beittel




# Lower Childs Meadow Study Site Map

Positive Control: Natural Beaver Dam Reach

Monitoring Well

Stream Gauge

Staff Plate

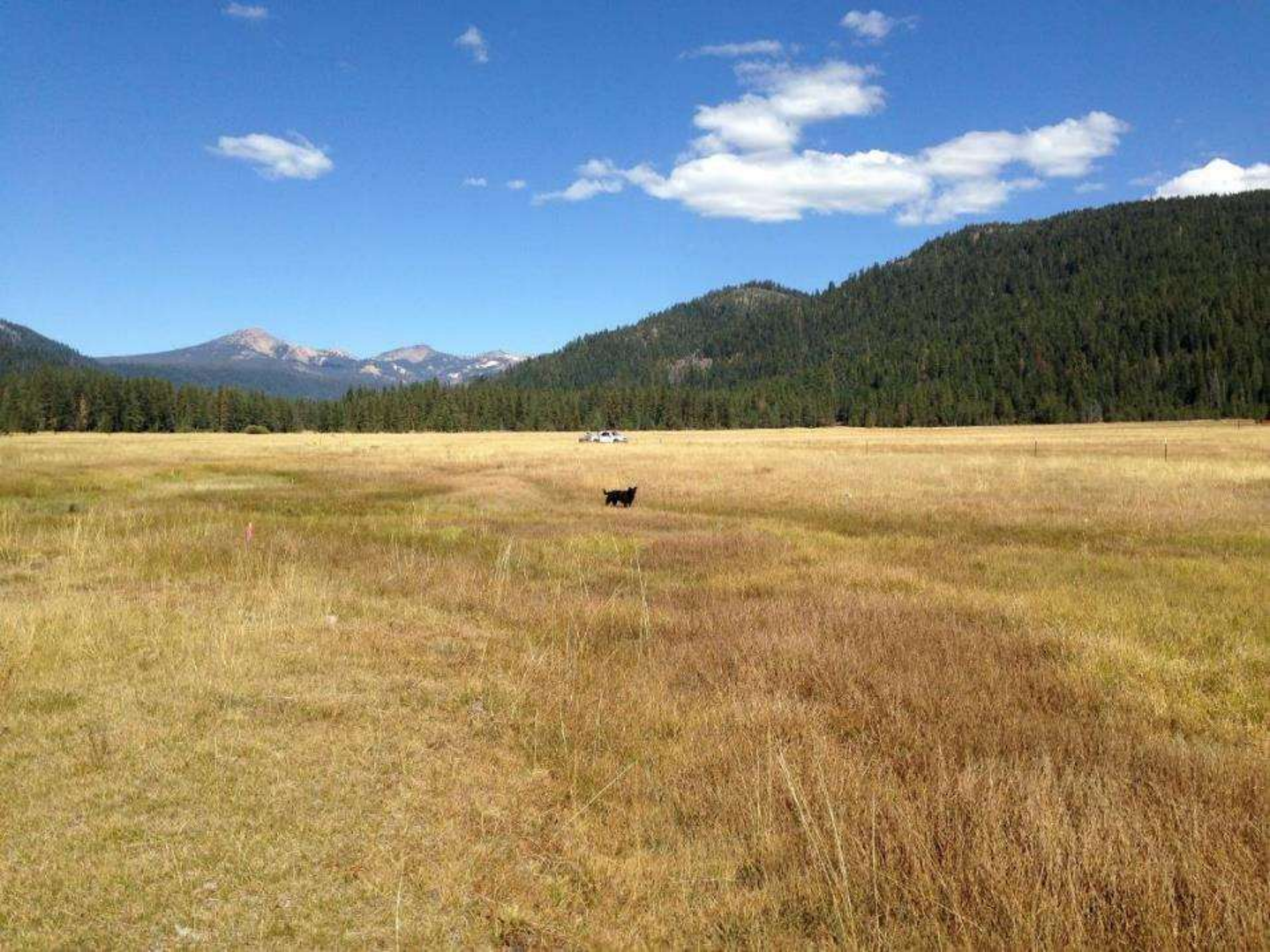
Cross-sections

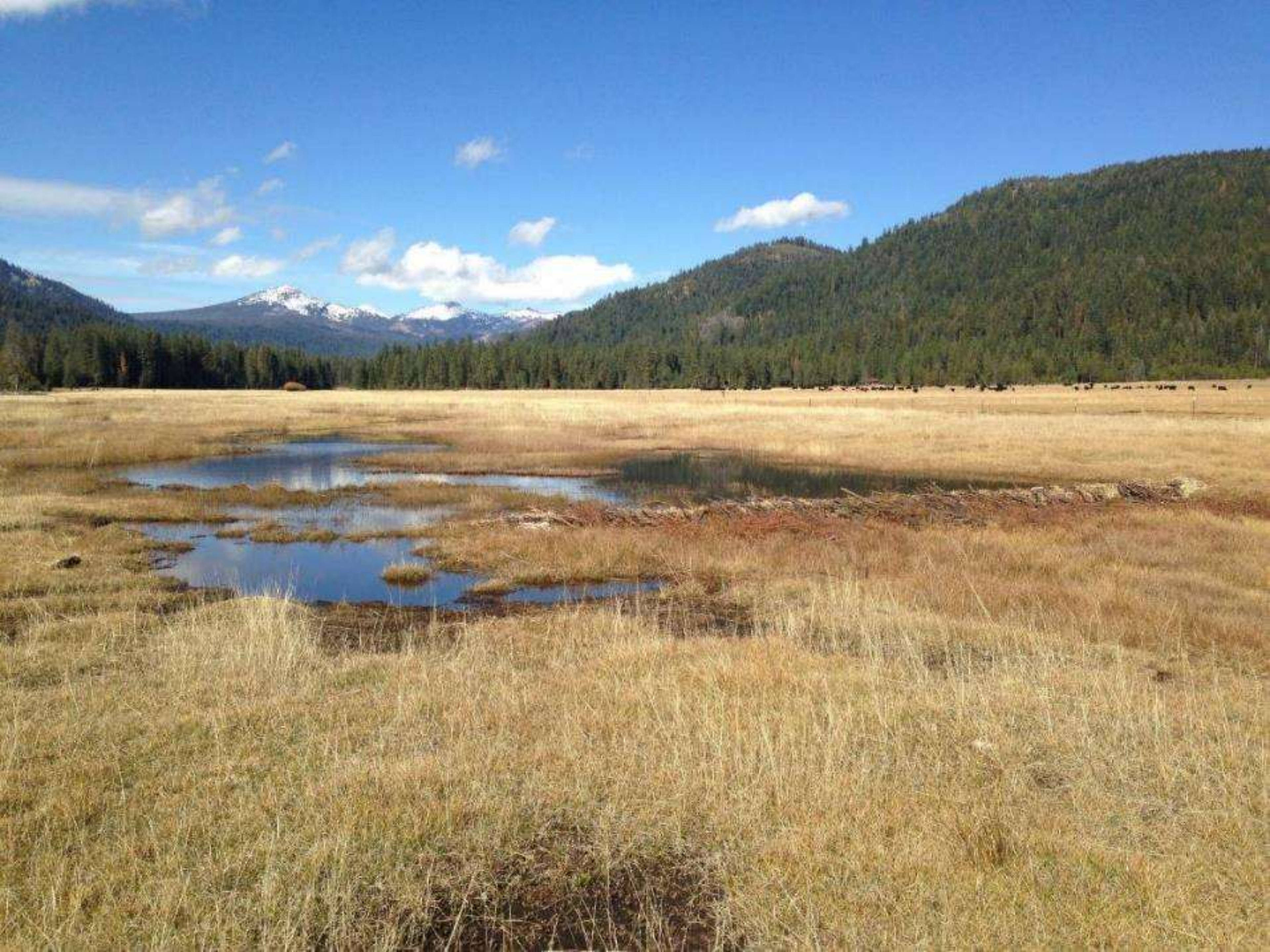
Natural Beaver Dam Locations

UCDAVIS
CENTER FOR WATERSHED SCIENCES

Projection: WGS 1984 Web Mercator Auxiliary Sphere
Datum: WGS 1984; Data Source: Ersi, ArcGIS Online, & National Agriculture Imagery Program
25 September 2019 Alice Beittel

# BDA installation
Oct 2016





# Post-treatment Monitoring



# Post-treatment Monitoring

**Natural beaver dams did not withstand high flows**

- Significant sediment movement downstream
- Dams maintained 2015, 2018, 2019

# September 2017 – Summer Conditions

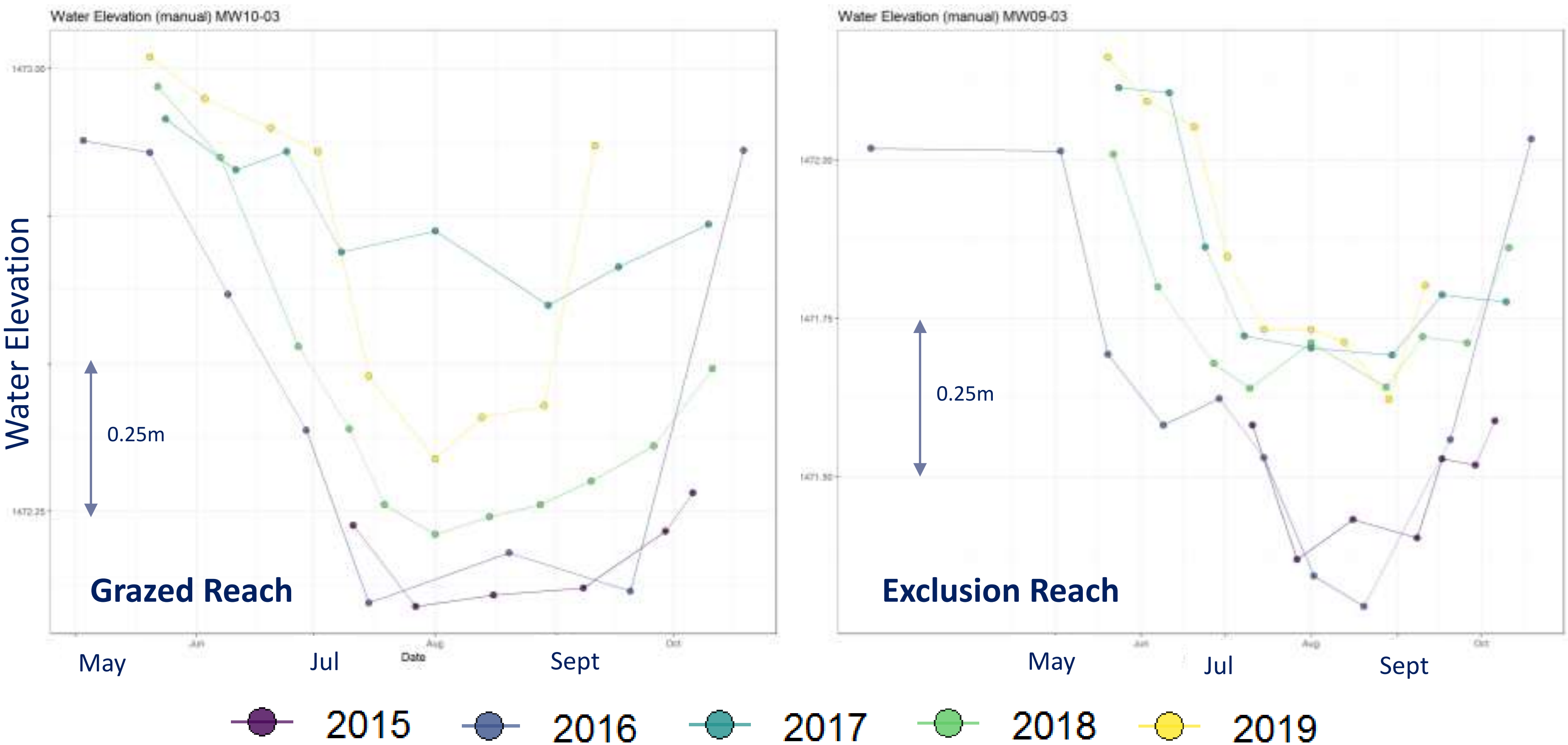
**BDA maintenance - repacked dams from meadow materials**

# October 10 2017 – Fall Conditions

**BDAs at full capacity following maintenance**

# Hydrologic Observations

Water enters the meadow from the main channel and from the meadows edges (hillslopes) – wells near these inputs show **variations with water year type** (2017, 2019 – wet; 2015, 2016 – dry)



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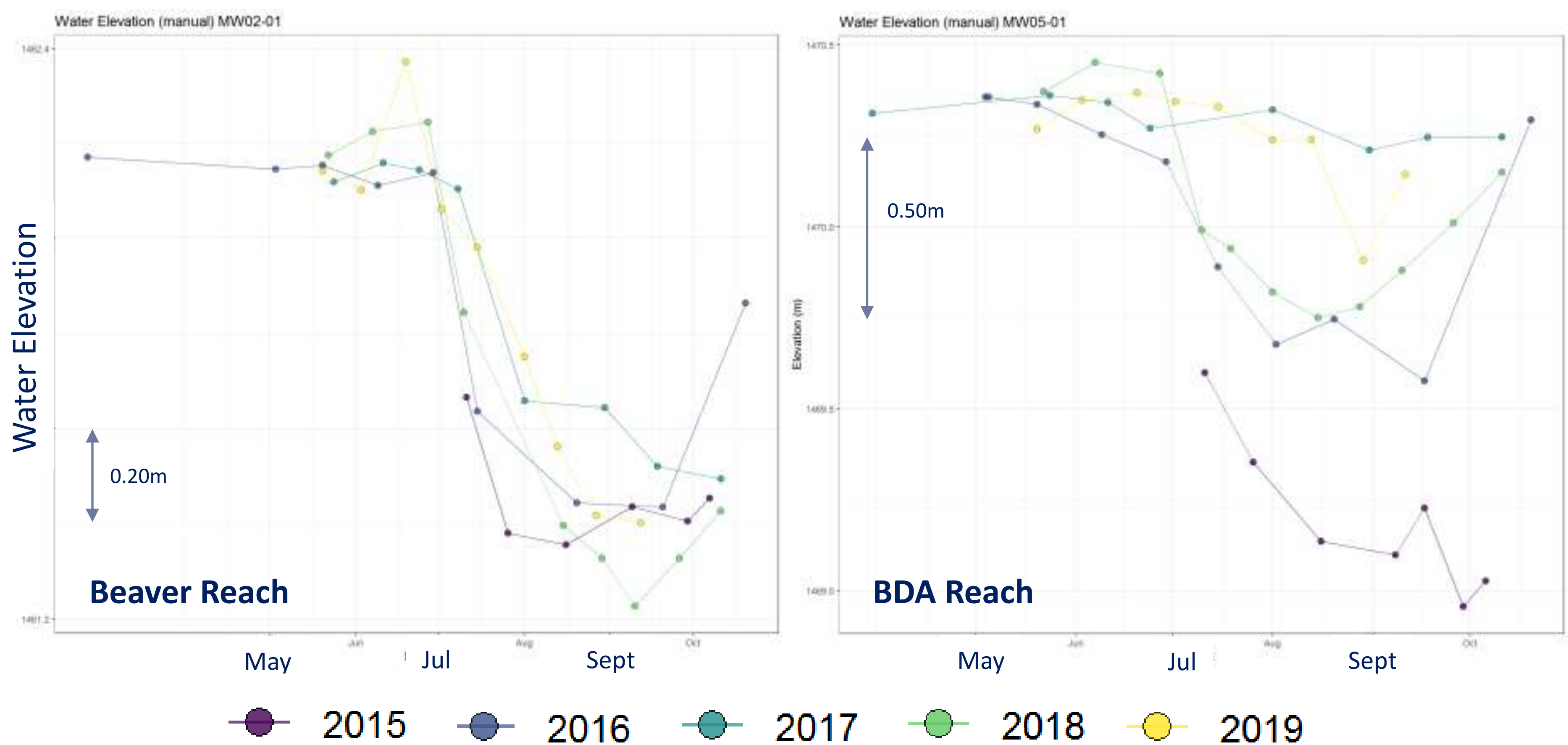
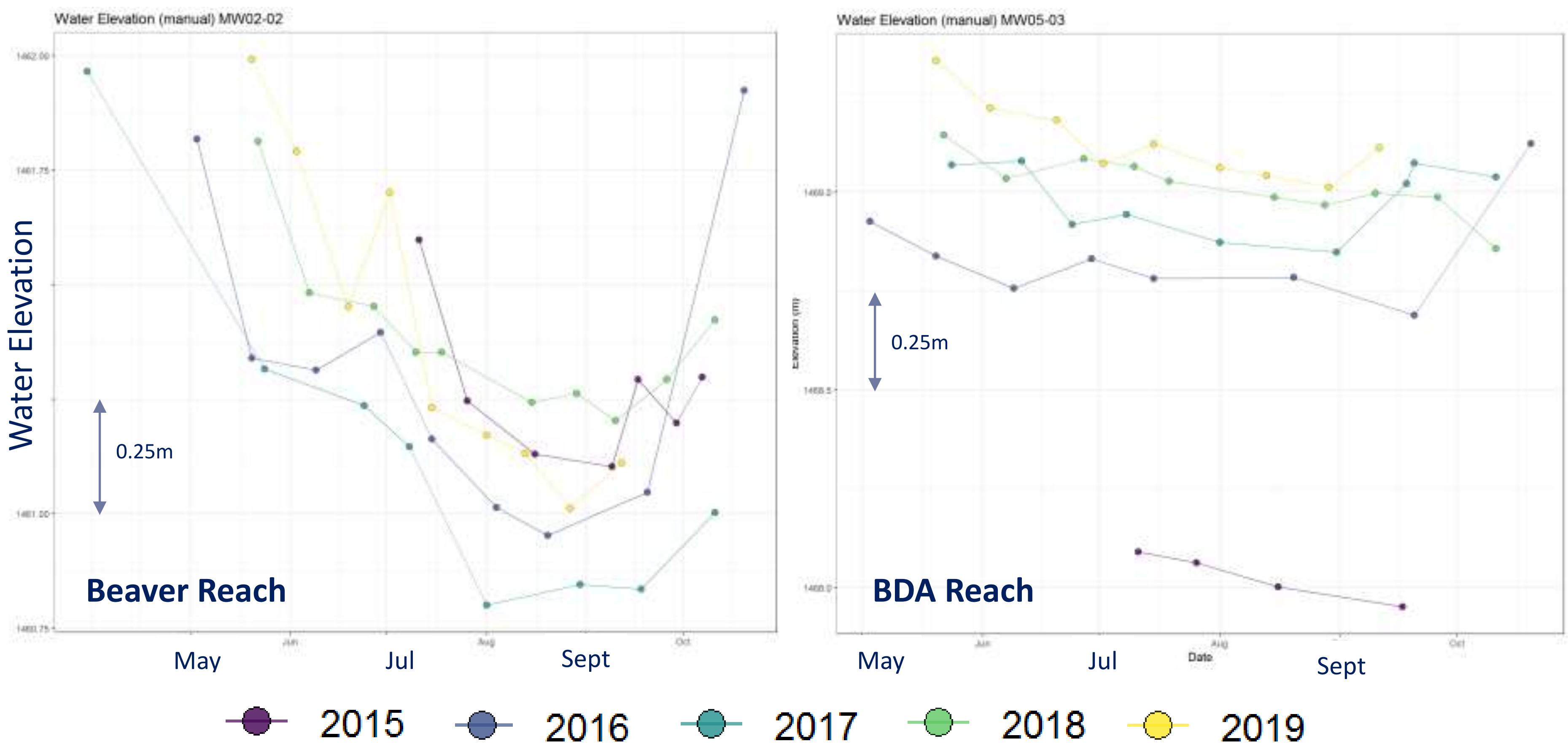


# Hydrologic Observations

Wells by the beaver ponds and BDAs **varied with pond depth** not climate; influence from ponds is localized to within 10-20 m lateral distance from channel



# Hydrologic Observations

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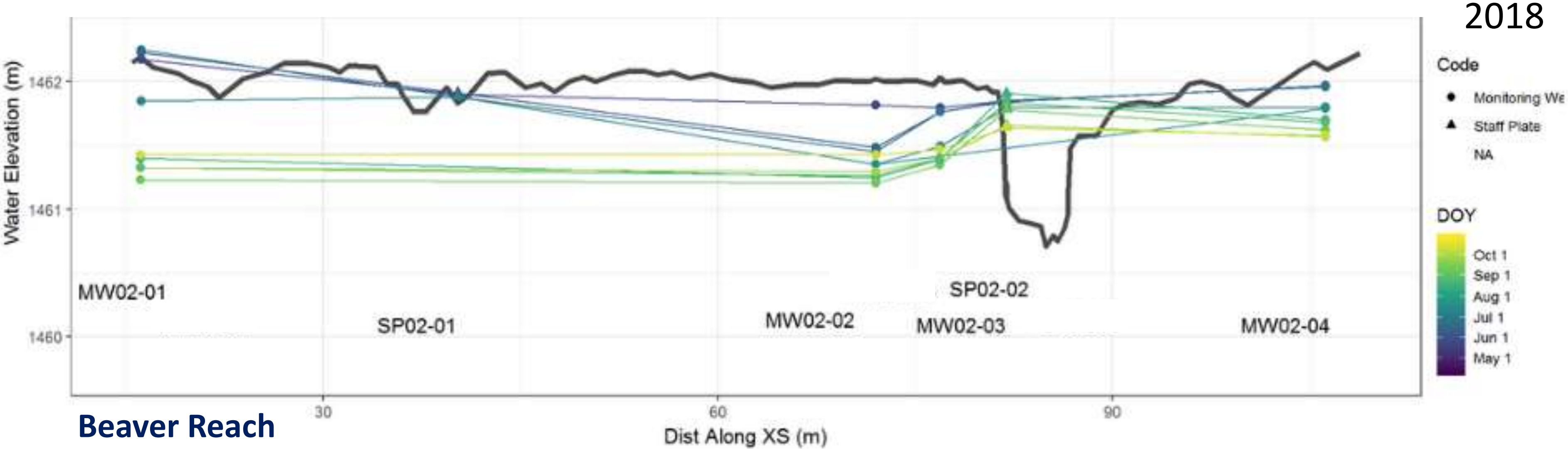
2018



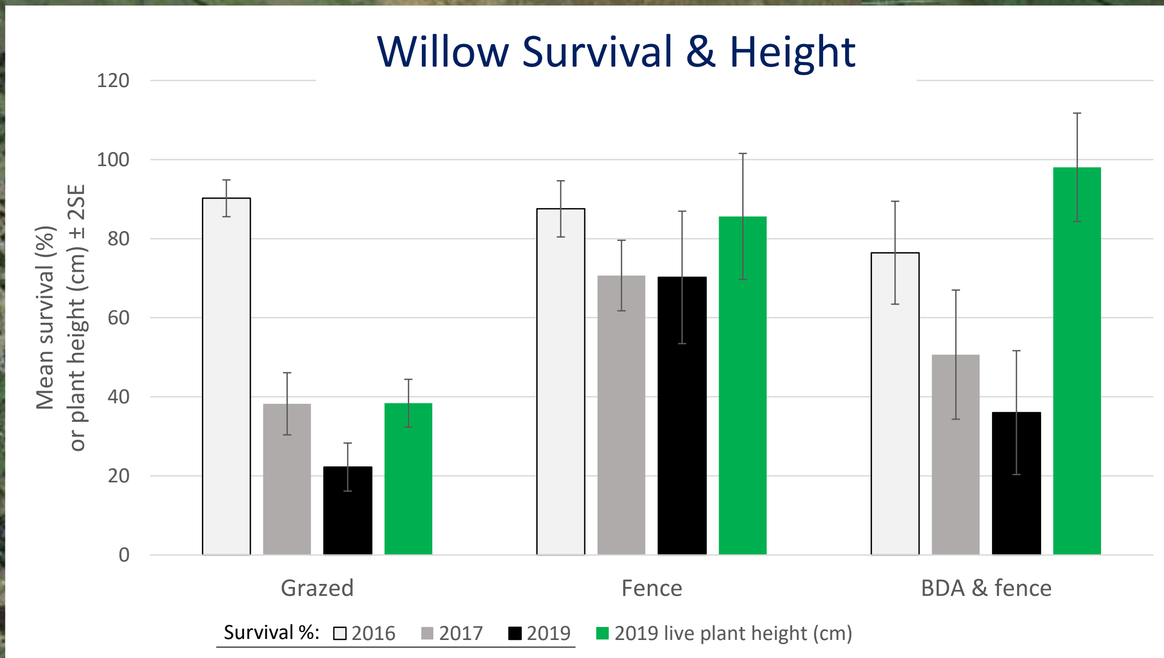

**Beaver Reach**


July 2012
Vegetation
Response


July 2017

July 2012

July 2017

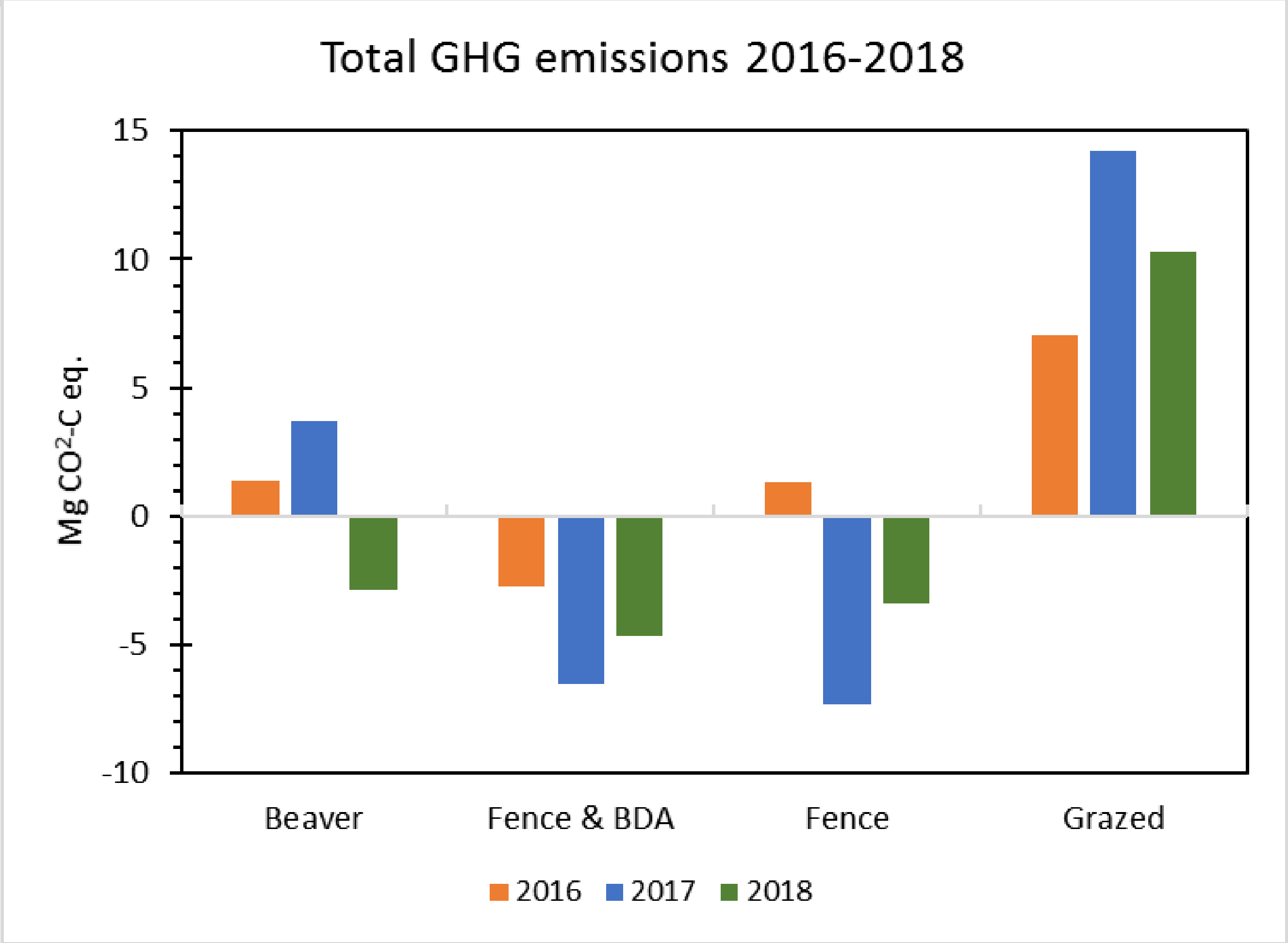



# Vegetation Response

**Fenced vegetation:**

- grew on average 40 cm taller
- contained 1500 lbs/acre more residual dry above-ground biomass

# Carbon Sequestration – Effect of Fencing




Net Restoration Effect Over 3 Years = 1.15 kg $CO^2$-C eq per $m^2$
(10 acres treatment area = 30 metric tons C sequestered per yr)

# Restoration Lessons to Date

- Beavers work hard - Leaky dams require maintenance
- Groundwater levels respond quickly locally
- Willows grow slow: 5+ years to get beaver food
- Cattle exclosure key to vegetation growth, carbon sequestration
- Geomorphic complexity takes time

# Dixie Fire 2021

- Burn impacts in forest in upper meadow complex
- Largest impact on meadow from bulldozer lines
- Mitigation work by USFS to replace sod, scarify mineral soil

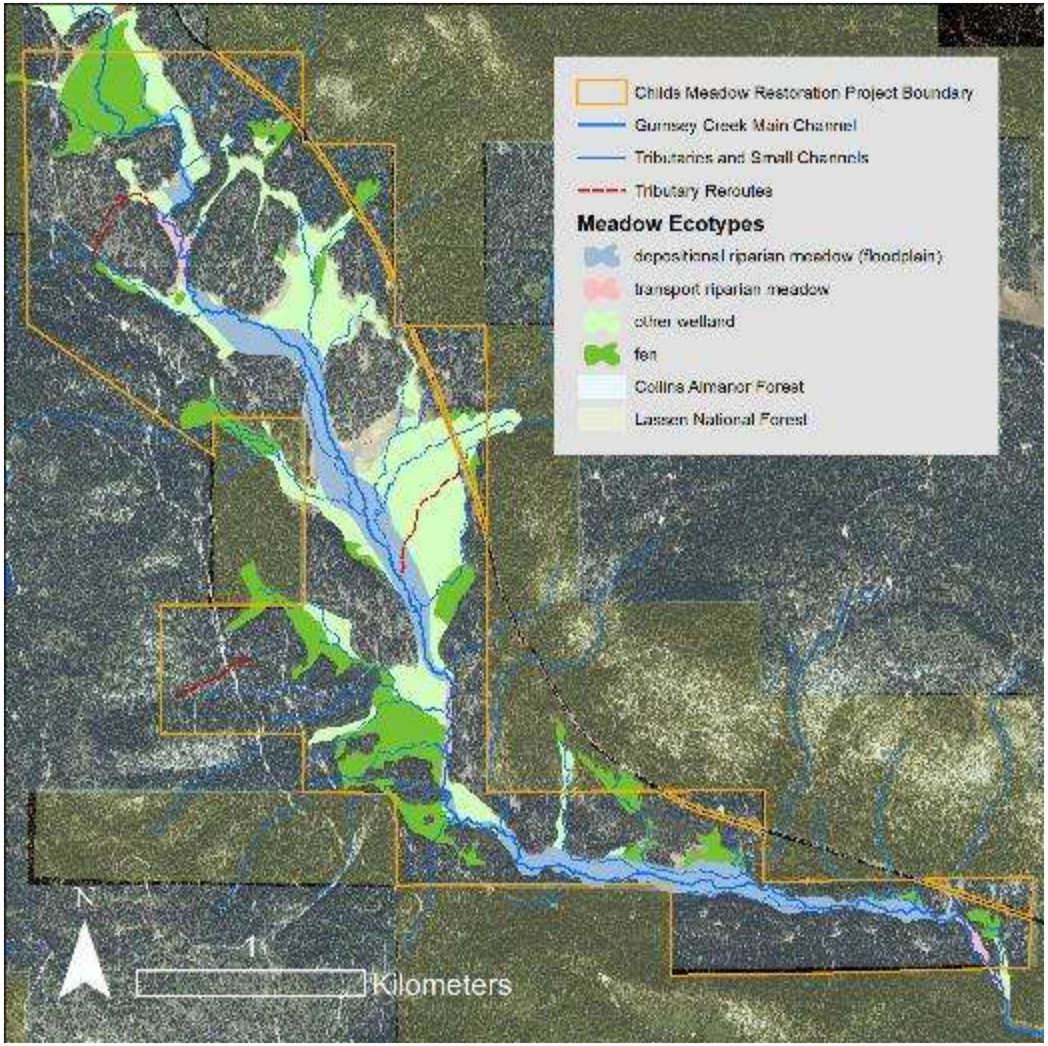
# Dixie Fire 2021

Post-fire Bulldozer line (sept 14)

Mitigation treatment (oct 27)

# Childs Restoration Phase II

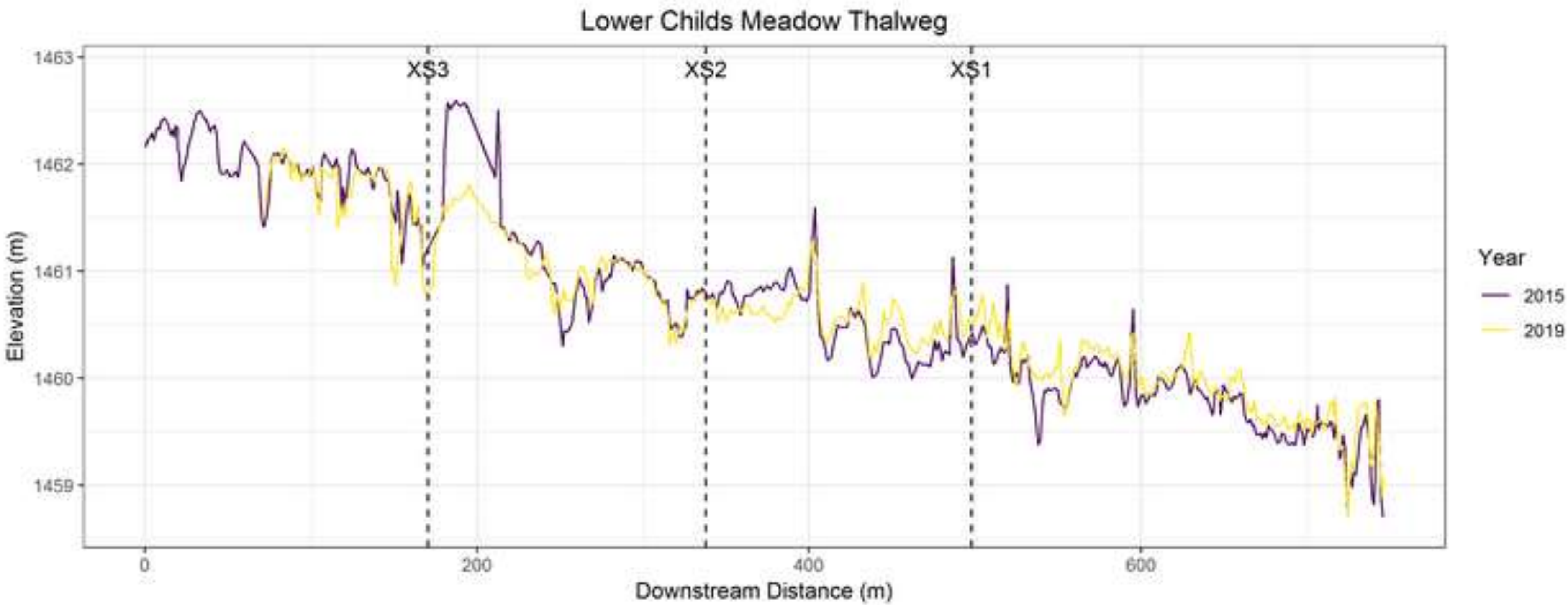
- BDAs to increase floodplain connectivity
- PALs to increase geomorphic diversity
- Hand fill of small ditches and backfill of deep headcut in fens
- Cattle exclusion from fens, eroding channels
- Revegetation (planting)



# Thank you!

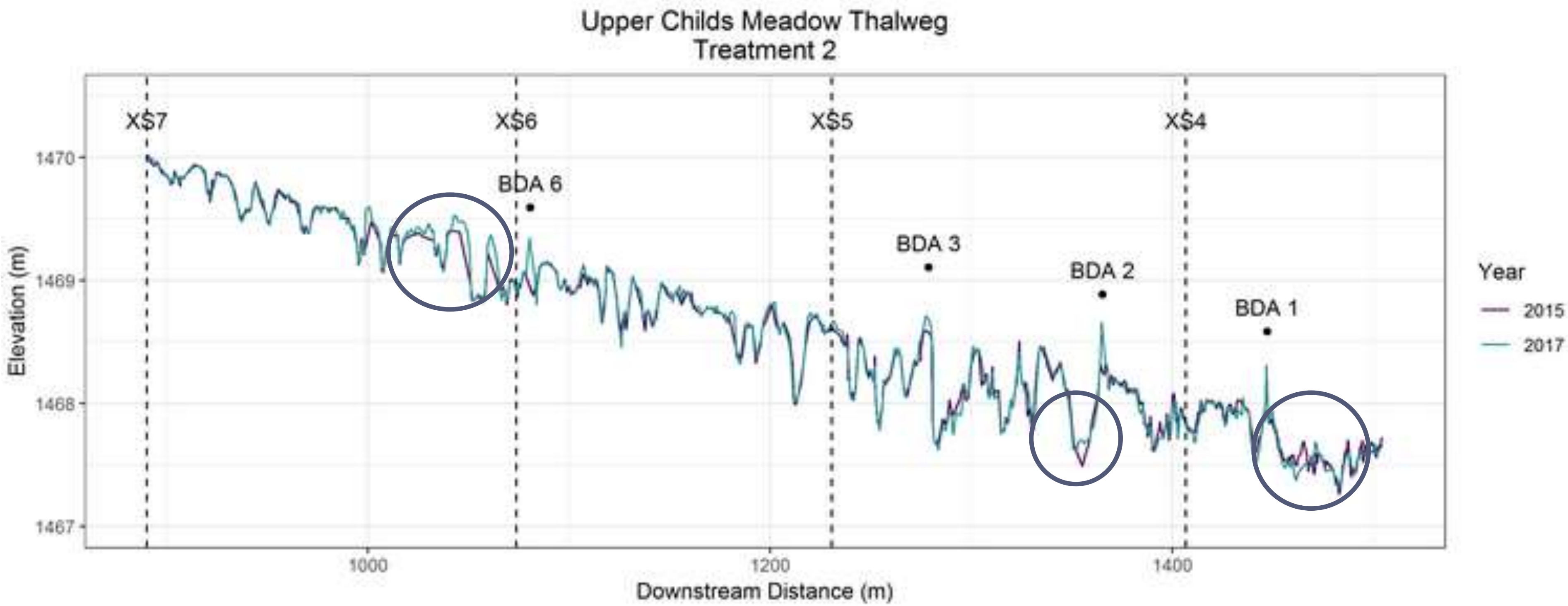
**Sarah Yarnell, smyarnell@ucdavis.edu**

# Geomorphic response – Beaver Reach




- Sediment redistribution following 2017 beaver dam breaches
- Scour of ~1m of sediment depth behind large dam, deposition of ~0.2m sediment throughout lower half of reach

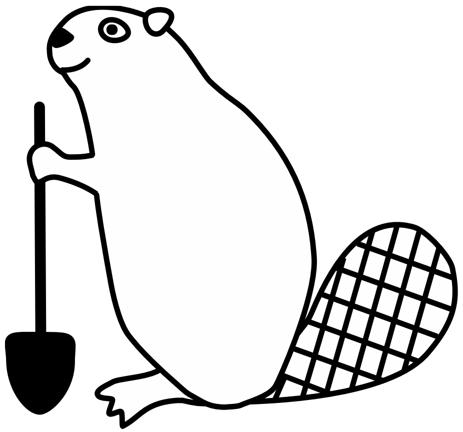
# Geomorphic response – BDA Reach




- Initial signs of deposition and erosion at BDAs (~0.1m depth)
- No changes in channel longitudinal profile in willow or grazed reach
- Geomorphic  response takes time

# PBR The Hard Way—
# fear, hype, and the reality of your first 1000 structures

**Swift Water Design**
**Process Based Restoration**
**and**
**Beaver Coexistence**



Raytheon Technologies

LOCKHEED MARTIN

MONSANTO

Nestlé

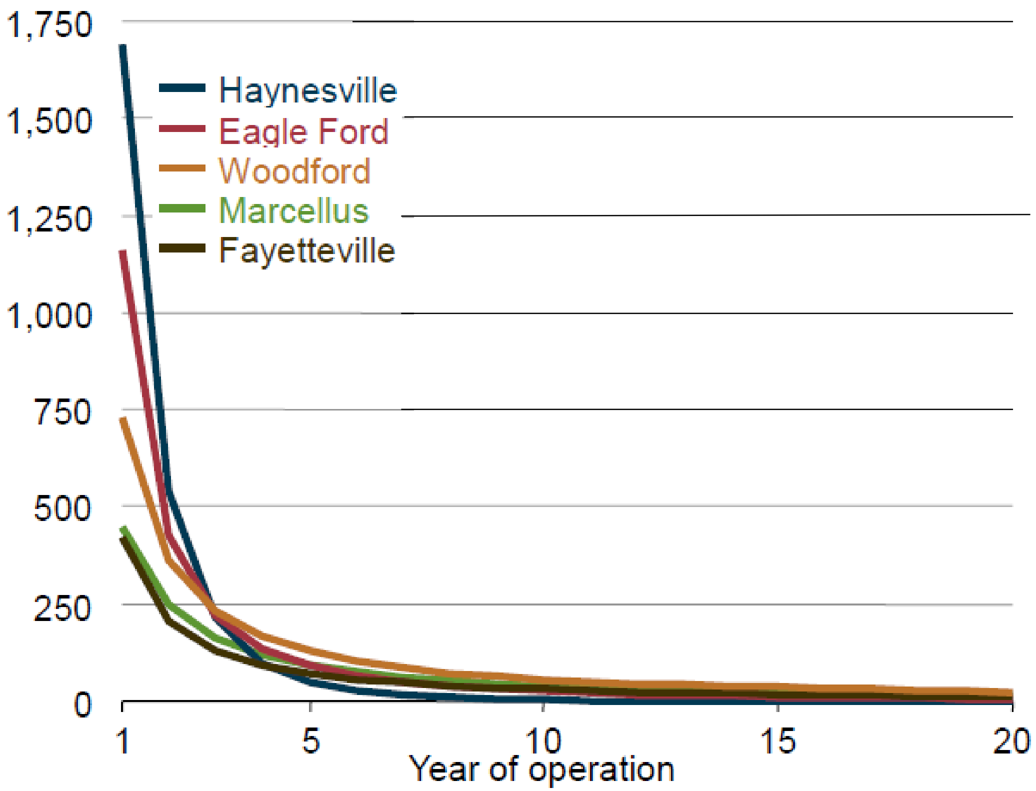
Coca-Cola

WELLS FARGO

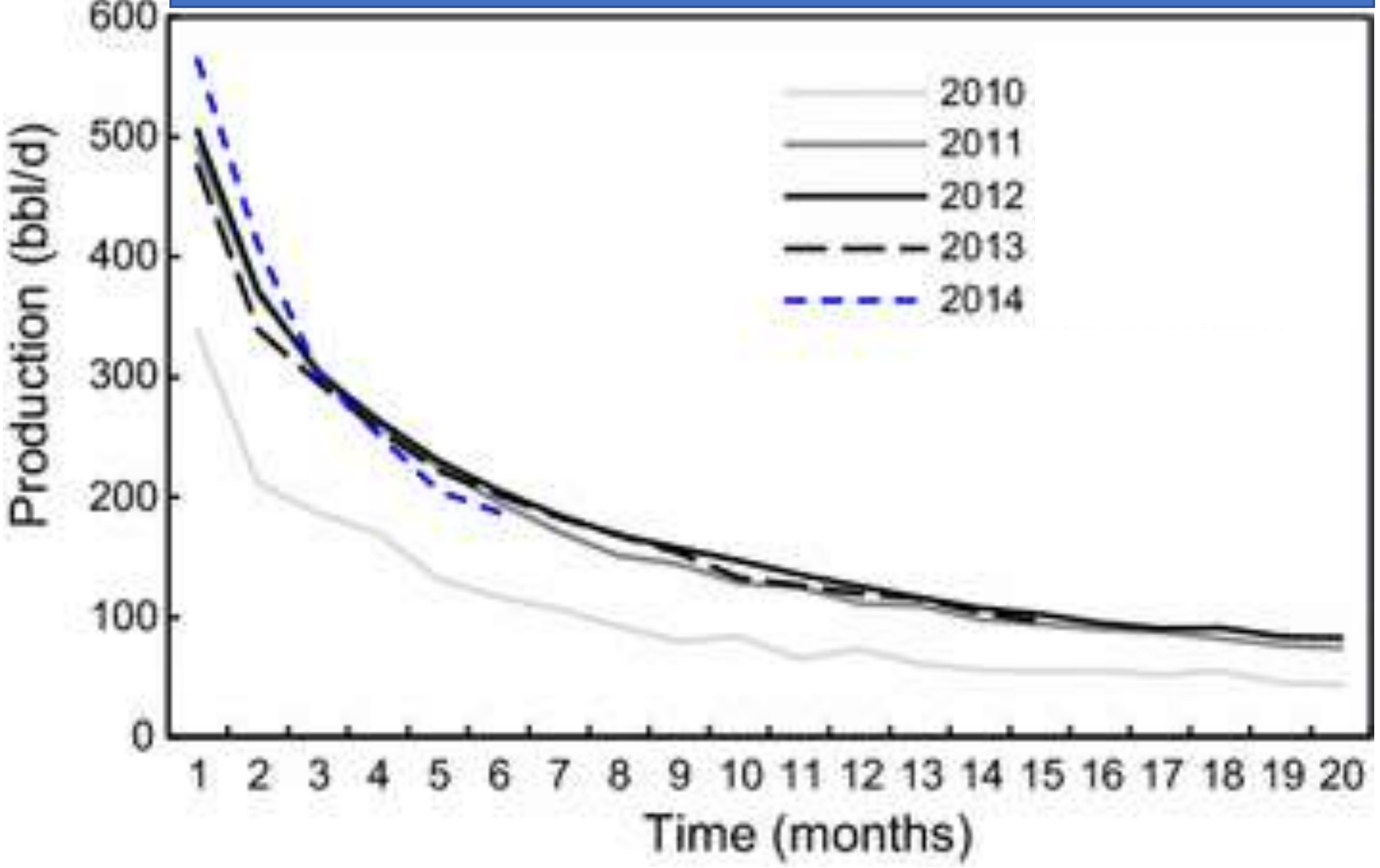
Chevron

# US Fossil Fuel Production

## Shale Gas




## Tight Oil




Relax, we’re all doomed anyway


What the hell?

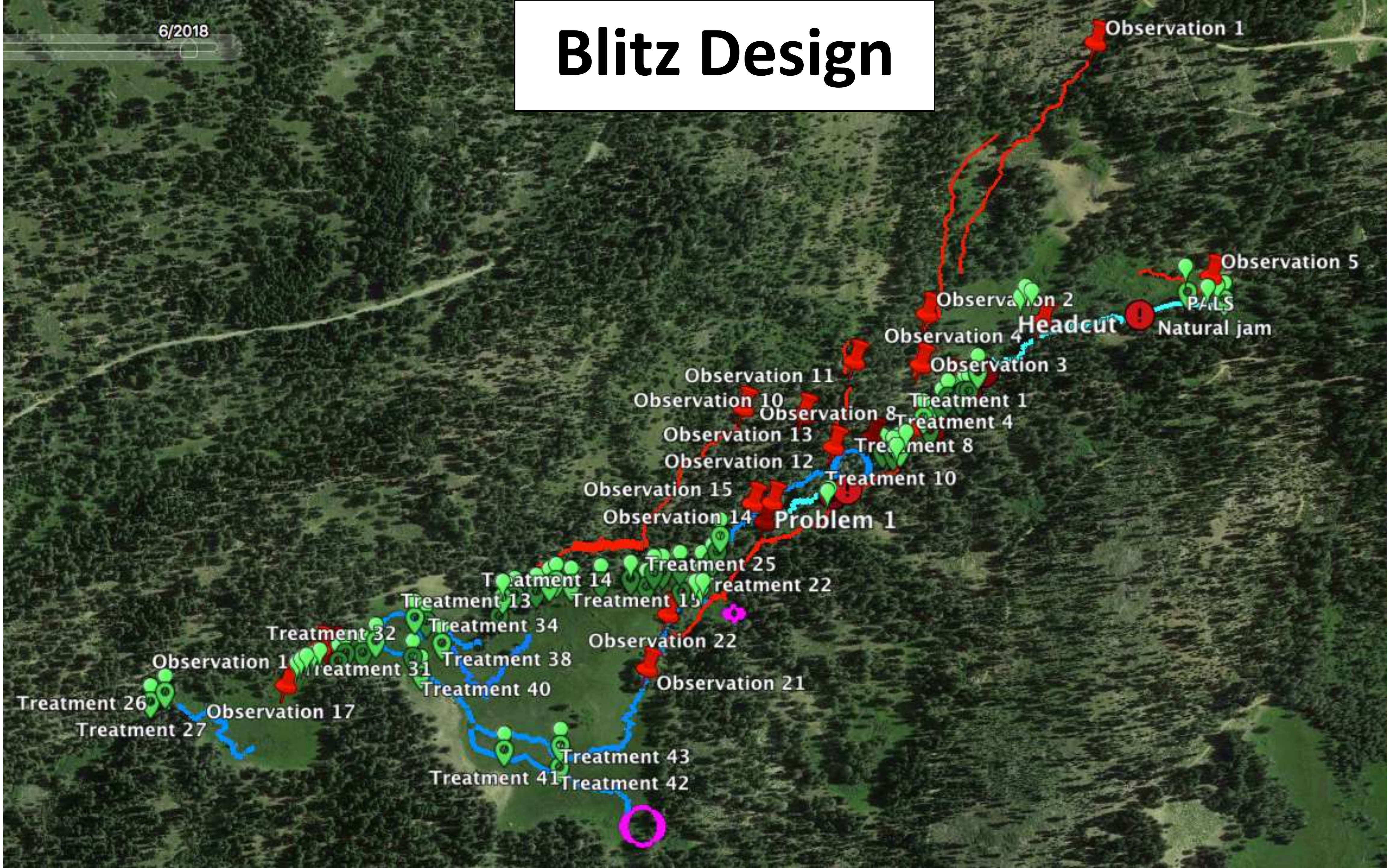
# What’s on your altar?



# The Basics of (not) Planning PBR


# The Basics of Permitting a PBR Project

# Blitz Design



# Blitz Design Equipment Basic


# Blitz Design Equipment Deluxe



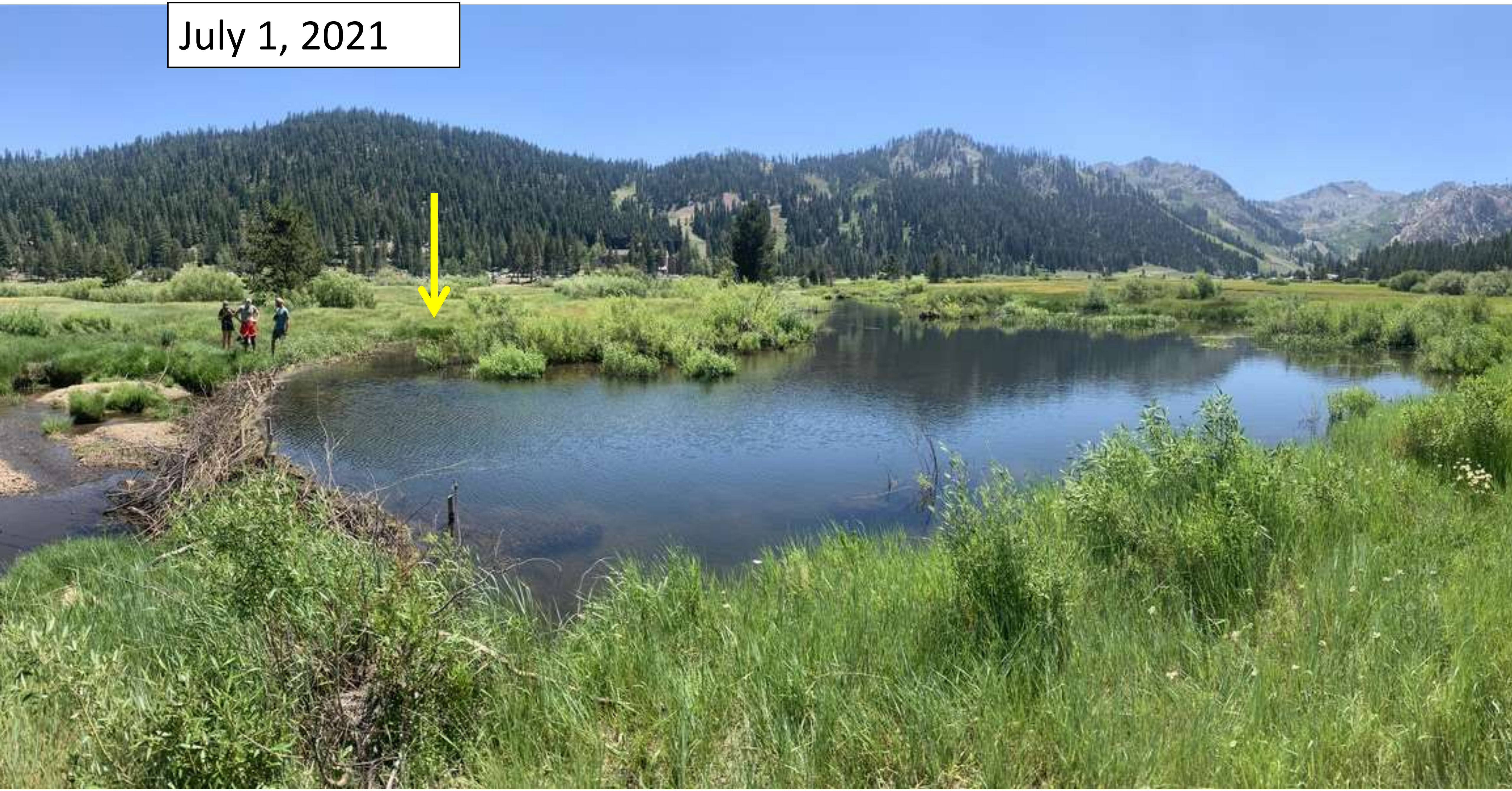

Trimble
GEOMATICS
LAND SURVEYING

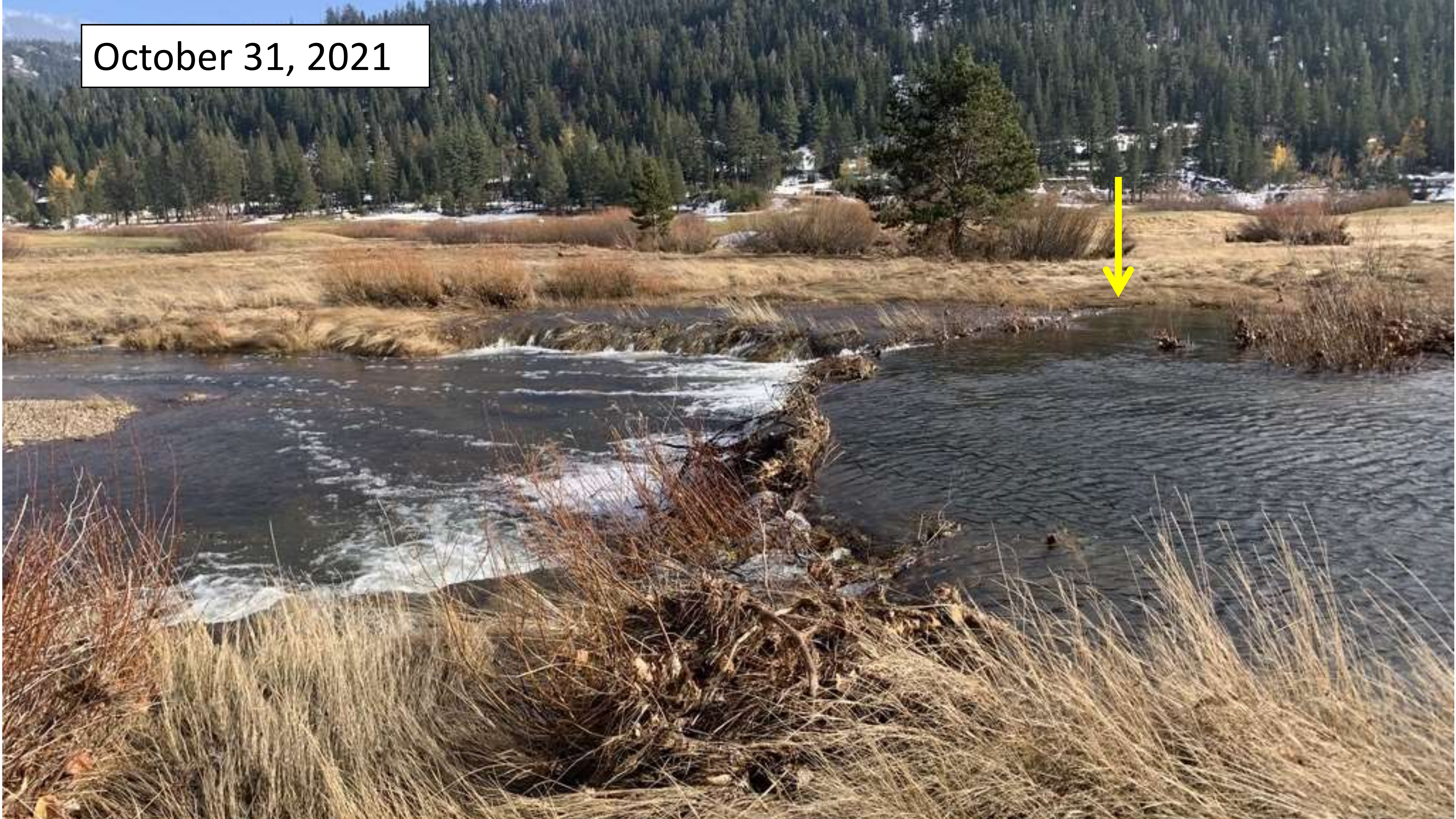

May 24, 2020

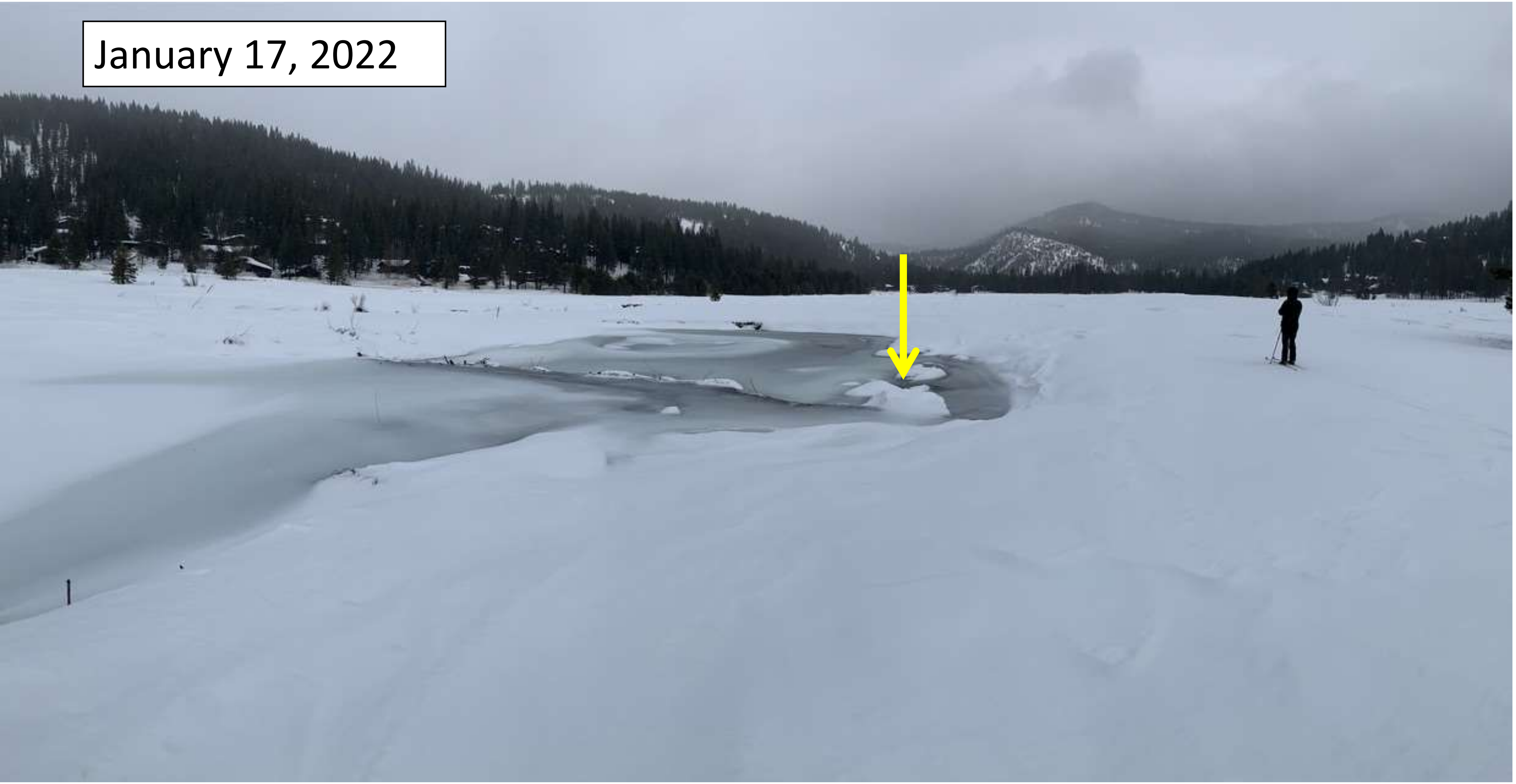

June 20, 2020


August 20, 2020

July 1, 2021

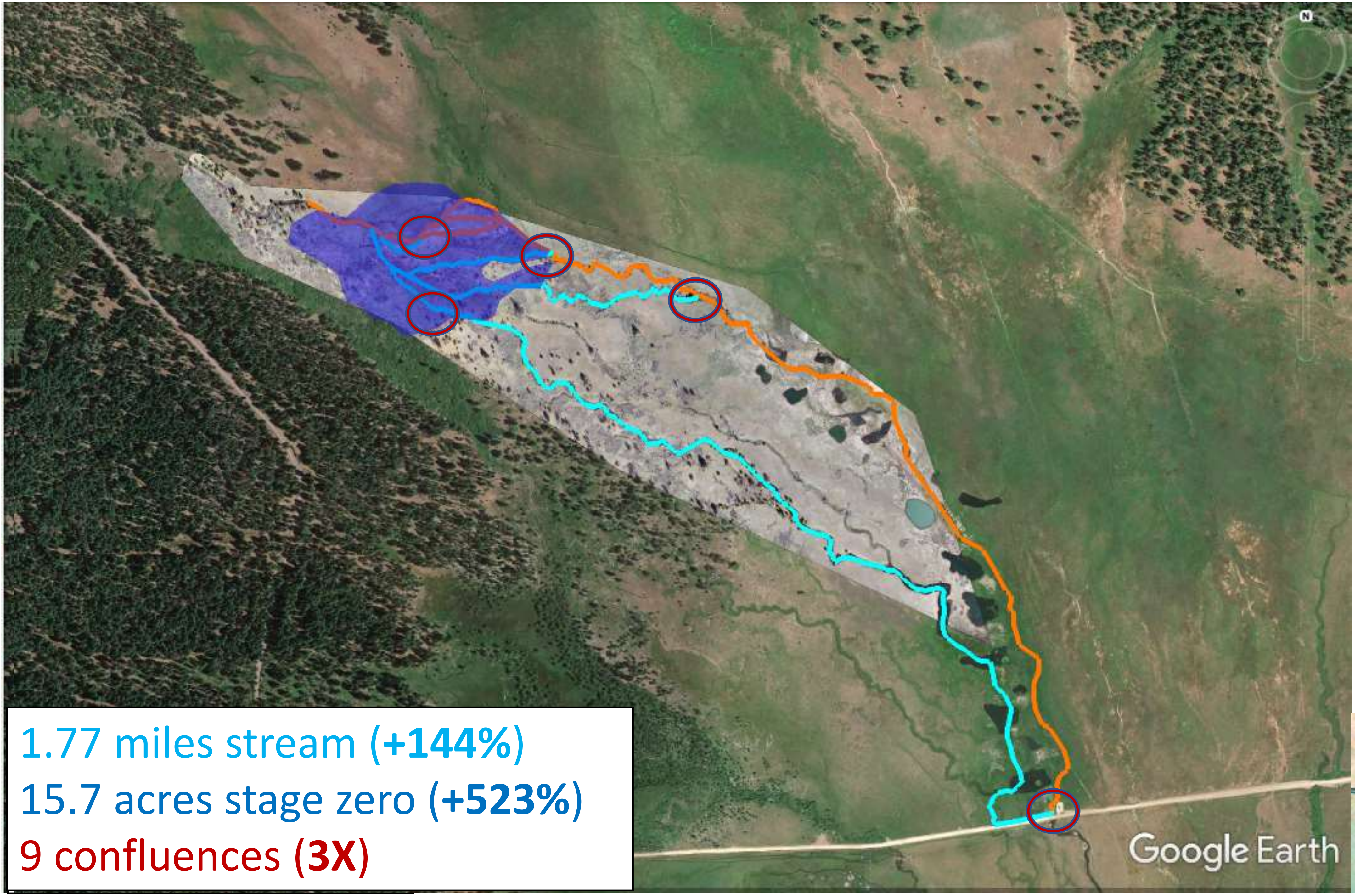



October 31, 2021


January 17, 2022


March 19, 2022

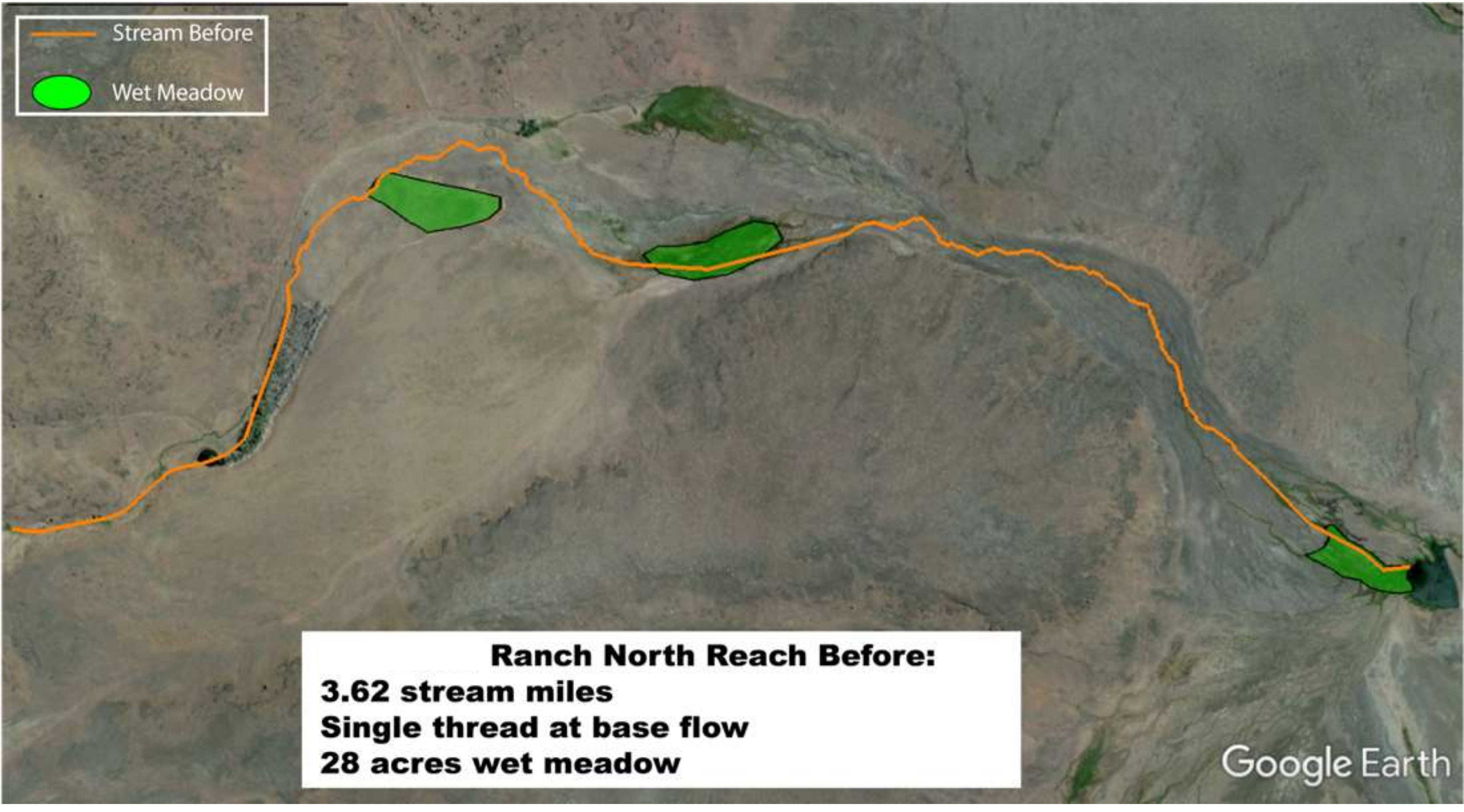





1.77 miles stream (**+144%**)

15.7 acres stage zero (**+523%**)

9 confluences (**3X**)


Stream Before
Wet Meadow
Ranch North Reach Before:
3.62 stream miles
Single thread at base flow
28 acres wet meadow
Google Earth

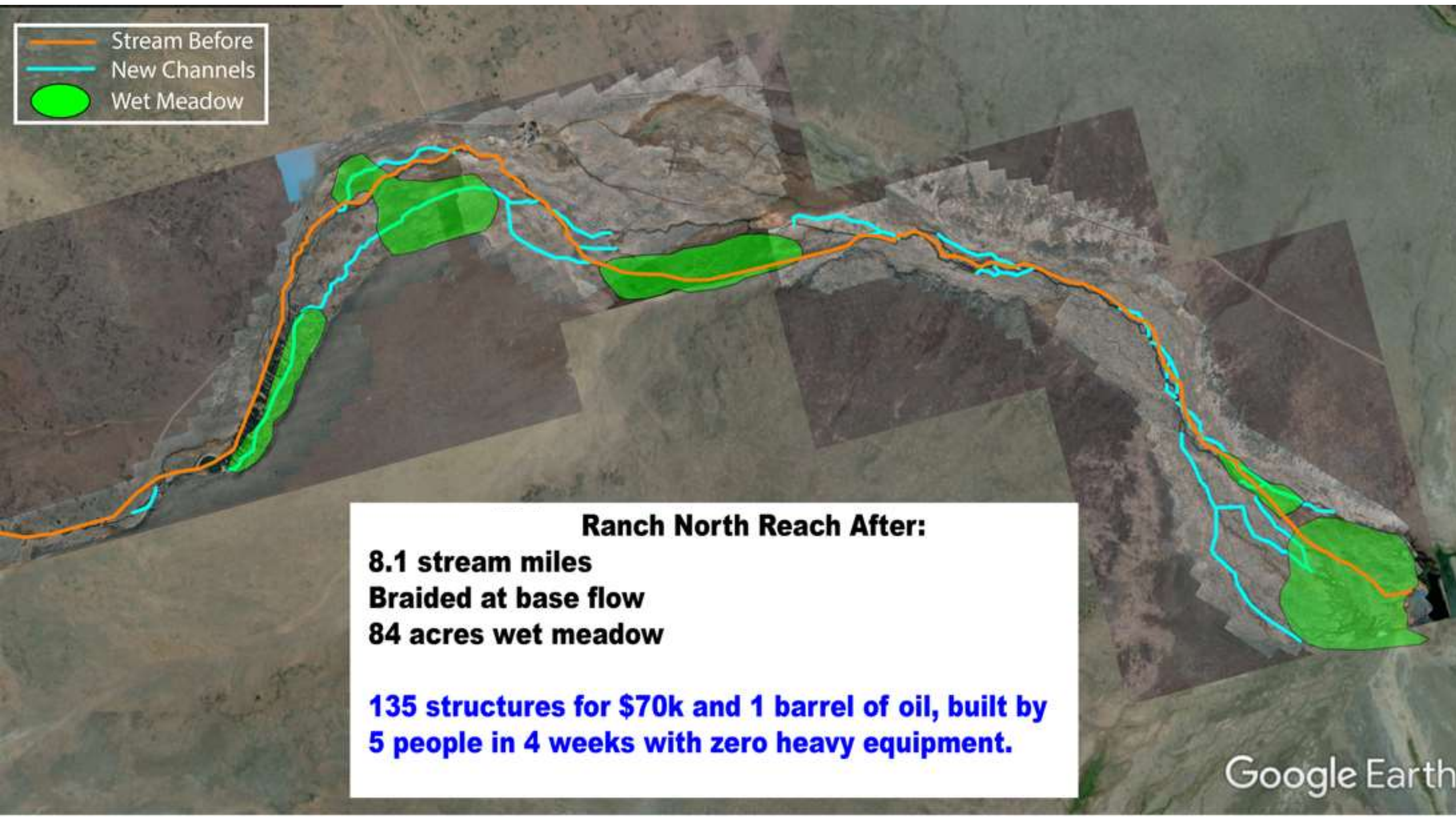


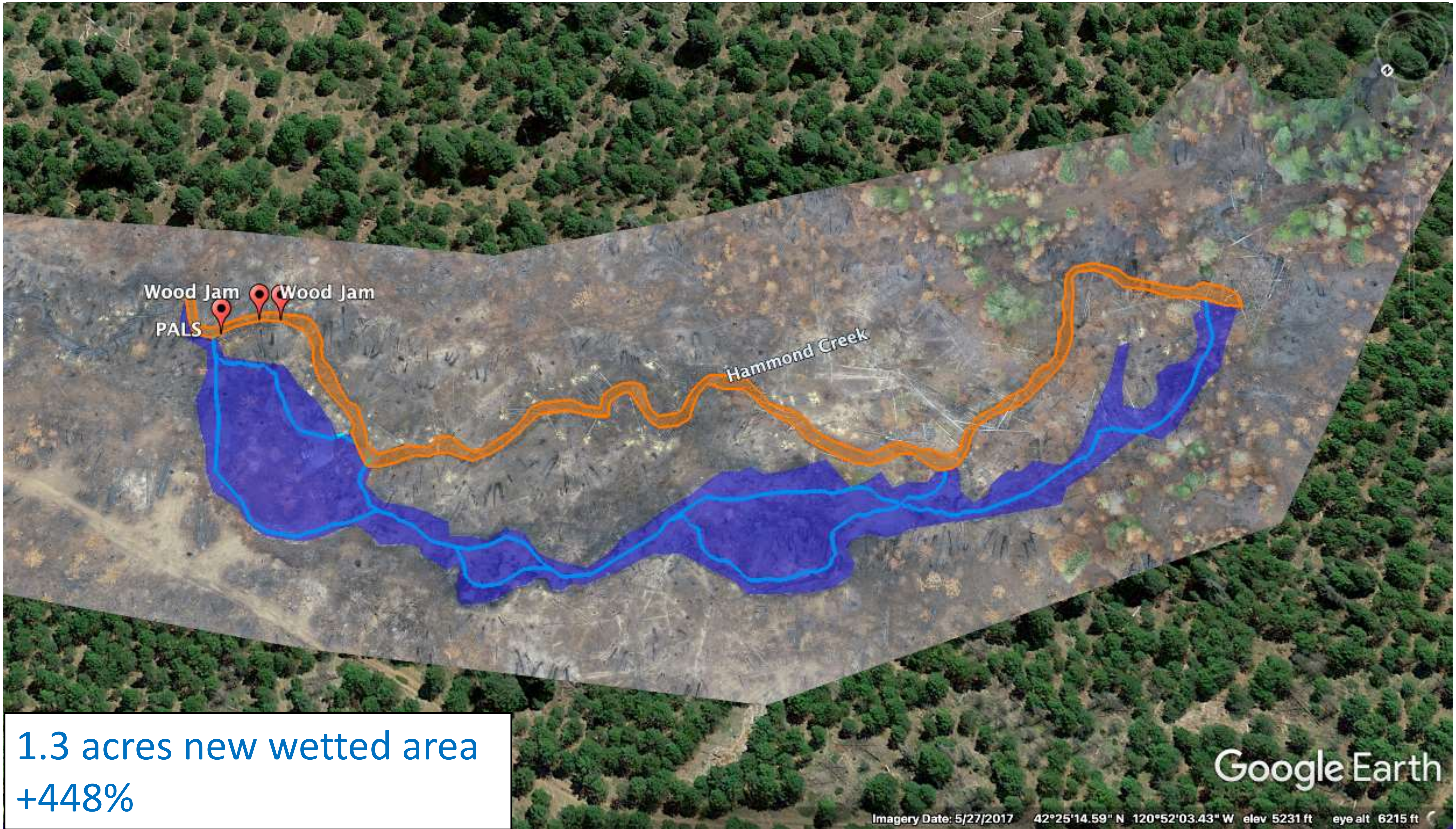









Stream Before
New Channels
Wet Meadow
Ranch North Reach After:
8.1 stream miles
Braided at base flow
84 acres wet meadow
135 structures for $70k and 1 barrel of oil, built by
5 people in 4 weeks with zero heavy equipment.
Google Earth




1.3 acres new wetted area
+448%


FASTER!




24 HOURS LEFT
memegenerator.net

Tiny—ankle deep water and an arm span wide.

Large—chest deep water and 30’ wide.

Medium—waist deep water and 10’—20’ wide.

XXL—swimming depth, 40’ wide, colonized by beavers year one.







LUDICROUS SPEED

# XXL structure

# The Beerometer

## High tech calibration for low tech pbr

# You’re not alone in considering process based restoration.

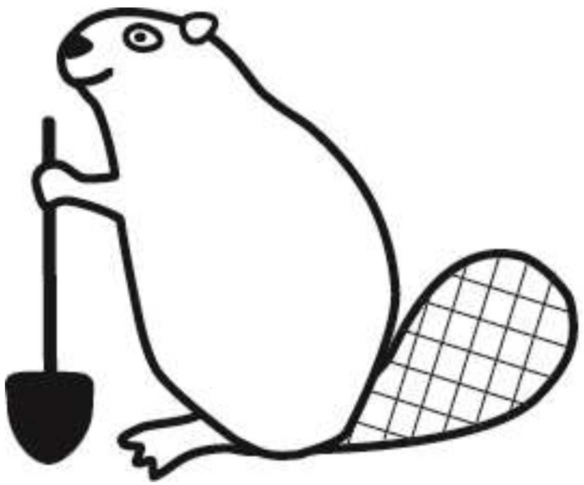
Here are some of the great folks we’ve worked with—many thanks to all of you, and apologies to anyone I’ve forgotten.

# If you have any questions or would like to visit a build, please get in touch.

**Swift Water Design**

**Process Based Restoration**
**and**
**Beaver Coexistence**

**530-416-1907**
**kevin@swiftwaterdesign.com**



# Update on California Department of Fish and Wildlife Efforts to Provide a Guidance Document for the Use of Low-Tech Process-Based Stream Habitat Restoration

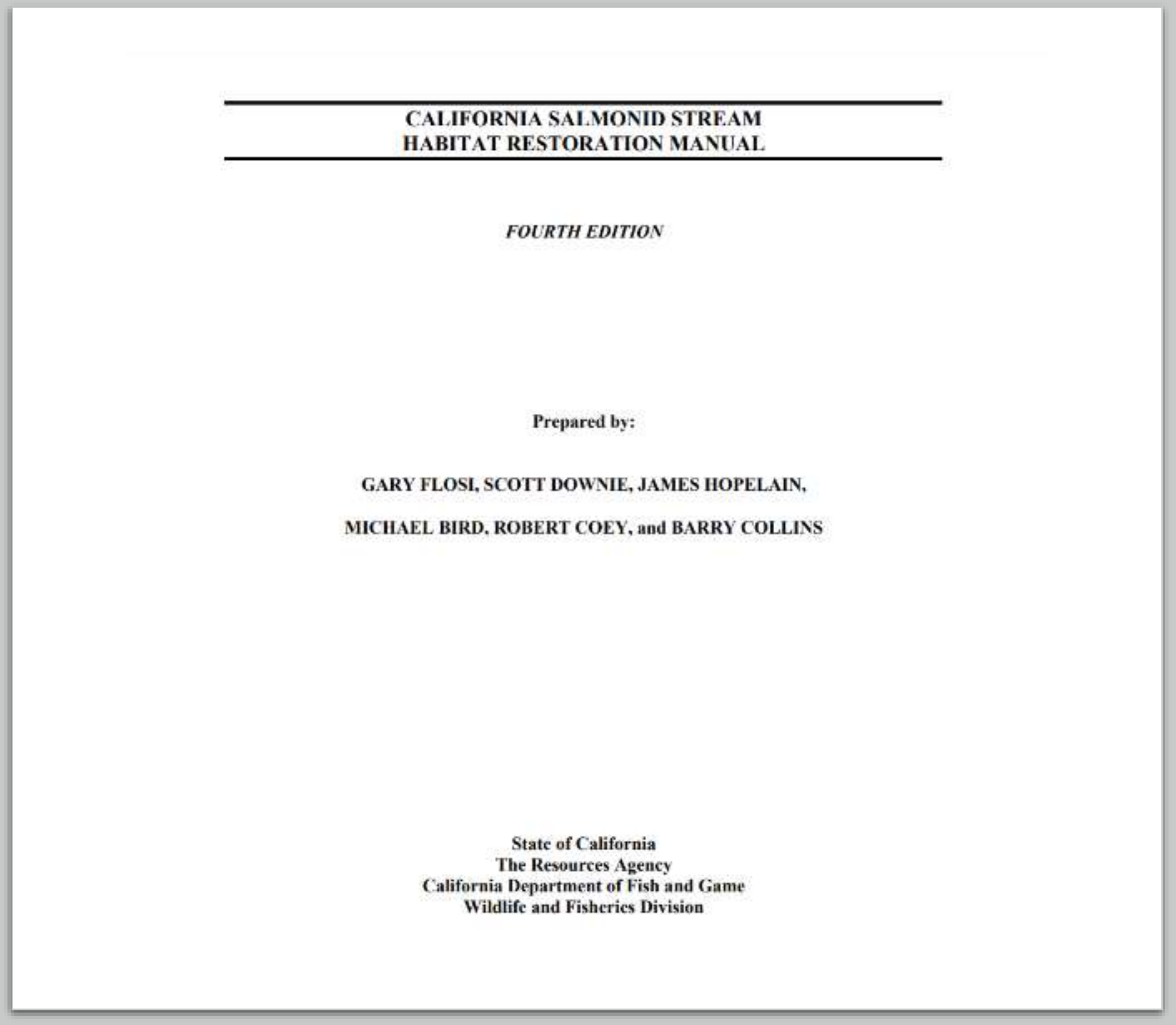
Will Arcand, PG, CEG, California Department of Fish and Wildlife

Elijah Portugal, MS, California Department of Fish and Wildlife

SRF 2022

# Restoration Manual

- First Edition Published in 1991;
- Comprehensive technical guidance document;
- Used extensively by NGOs seeking grant funds, design consultants, stream restoration practitioners;
- Used internally for review of both grant proposals and non-grant LSAA projects.



**CALIFORNIA SALMONID STREAM**
**HABITAT RESTORATION MANUAL**

***FOURTH EDITION***

**Prepared by:**

**GARY FLOSI, SCOTT DOWNIE, JAMES HOPELAIN,**

**MICHAEL BIRD, ROBERT COEY, and BARRY COLLINS**

**State of California**
**The Resources Agency**
**California Department of Fish and Game**
**Wildlife and Fisheries Division**

# 2015 Restoration Manual Update Effort

CDFW identified need to incorporate new chapters supporting contemporary methods of stream restoration.

CALIFORNIA SALMONID STREAM
HABITAT RESTORATION MANUAL

PART XI

RIPARIAN HABITAT RESTORATION

## THE USE OF LOG AND BOULDER WEIRS IN STREAM HABITAT RESTORATION

**California Department of Fish and Wildlife**

**Administrative Report**

Authors:

Gary Flosi

Marjorie Caisley

## THE USE OF LARGE WOOD IN STREAM HABITAT RESTORATION

**California Department of Fish and Wildlife**

**Administrative Report**

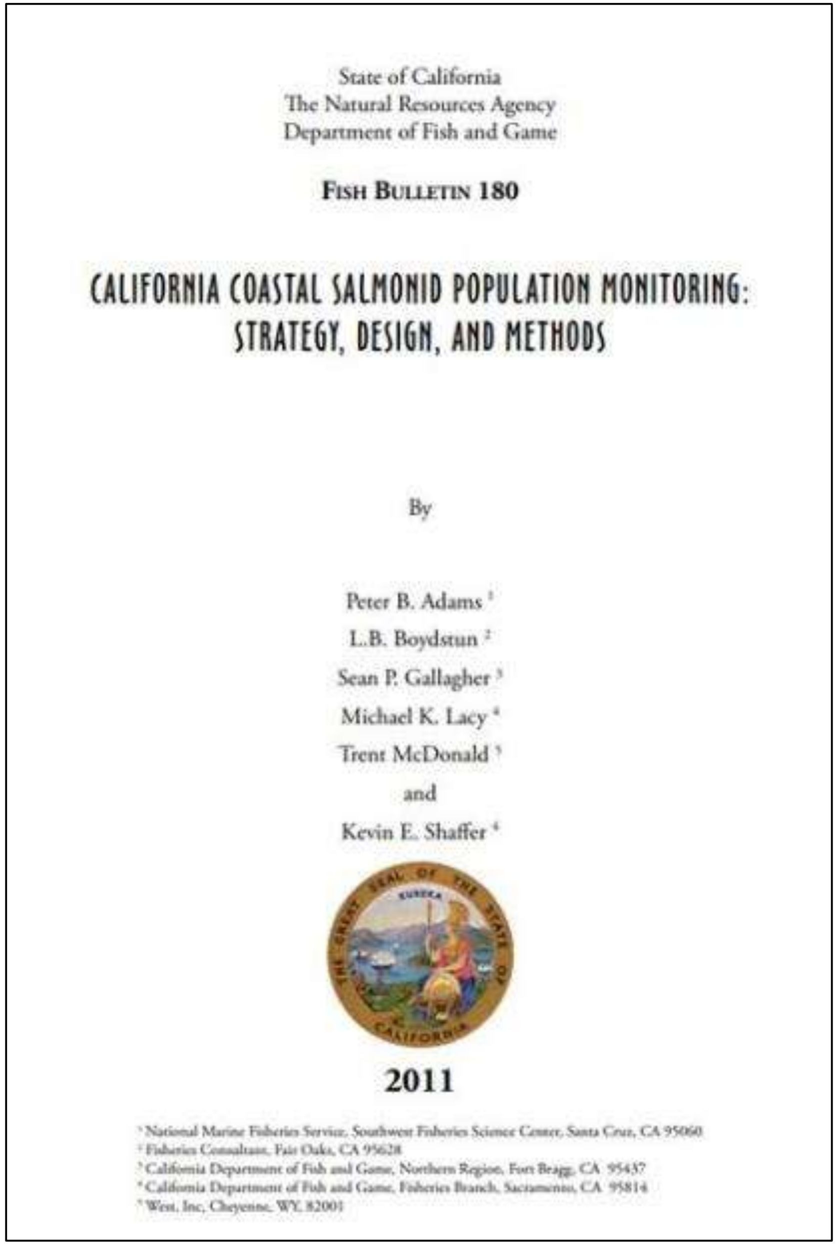
**2021**

Authors:

Gary Flosi
Marjorie Caisley
Mark Smelser

# CDFW Fish Bulletin 180

# California Coastal Salmonid Monitoring Plan (CMP)



State of California
The Natural Resources Agency
Department of Fish and Game

**FISH BULLETIN 180**

**CALIFORNIA COASTAL SALMONID POPULATION MONITORING: STRATEGY, DESIGN, AND METHODS**

By


Peter B. Adams [1]
L.B. Boydstun [2]
Sean P. Gallagher [3]
Michael K. Lacy [4]
Trent McDonald [5]
and
Kevin E. Shaffer [4]

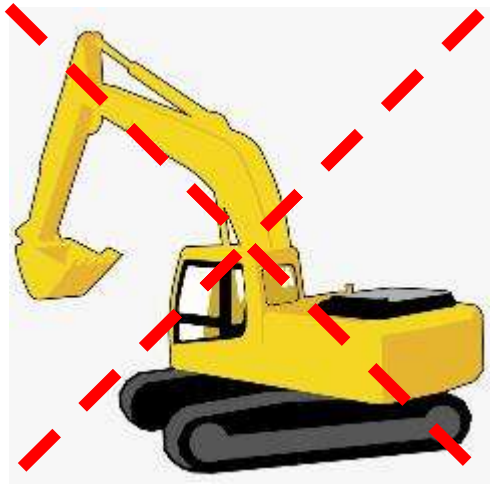


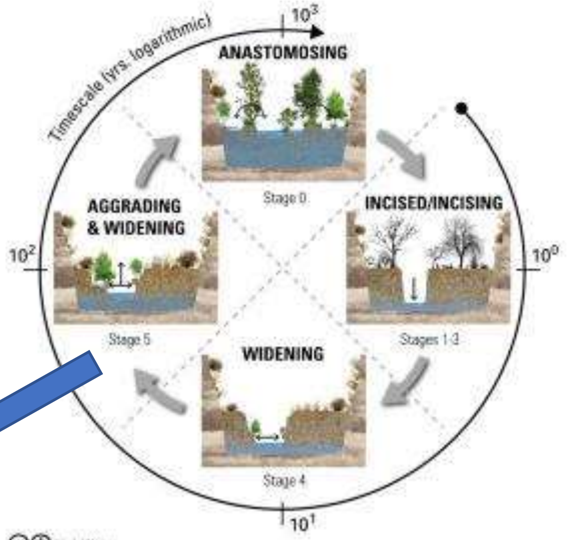

**2011**


[1] National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, CA 95060
[2] Fisheries Consultant, Fair Oaks, CA 95628
[3] California Department of Fish and Game, Northern Region, Fort Bragg, CA 95437
[4] California Department of Fish and Game, Fisheries Branch, Sacramento, CA 95814
[5] West, Inc, Cheyenne, WY 82001

# Third Topic = LTPBR

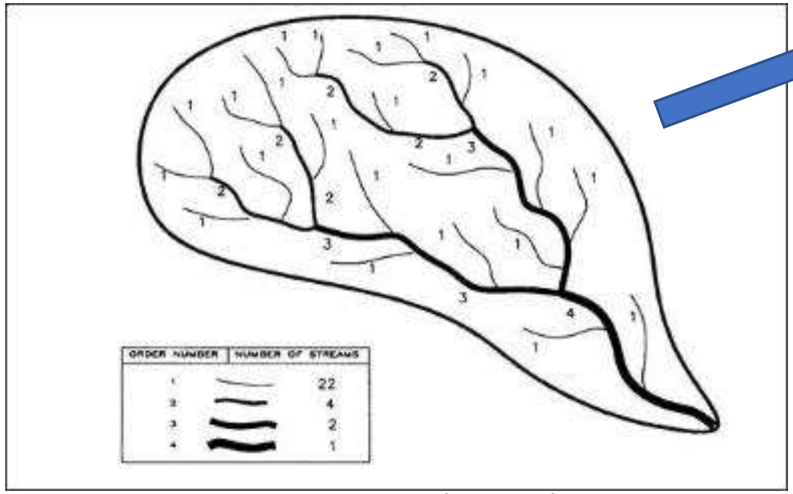
**THE USE OF LOW-TECH PROCESS-BASED STREAM HABITAT RESTORATION**



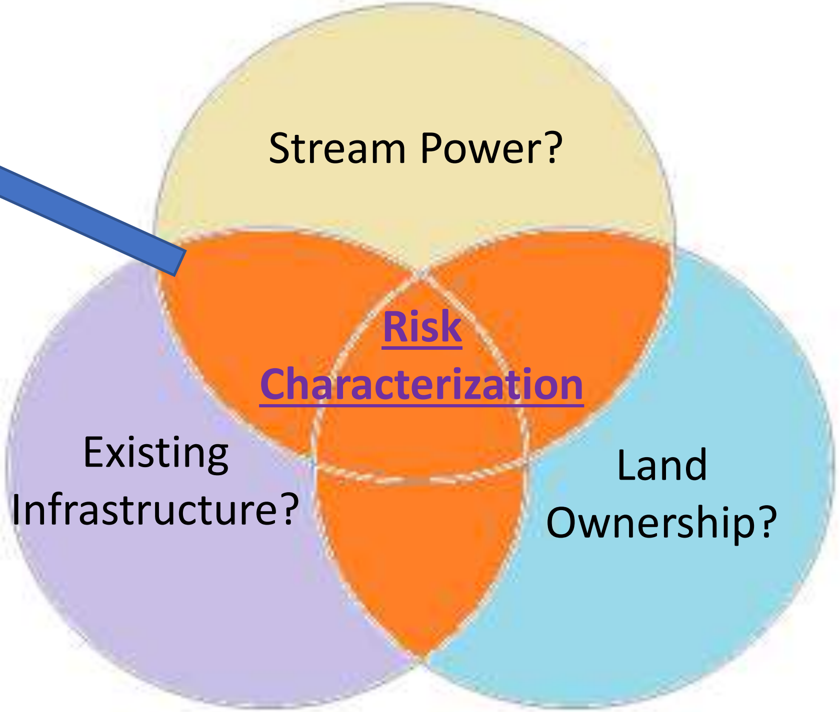


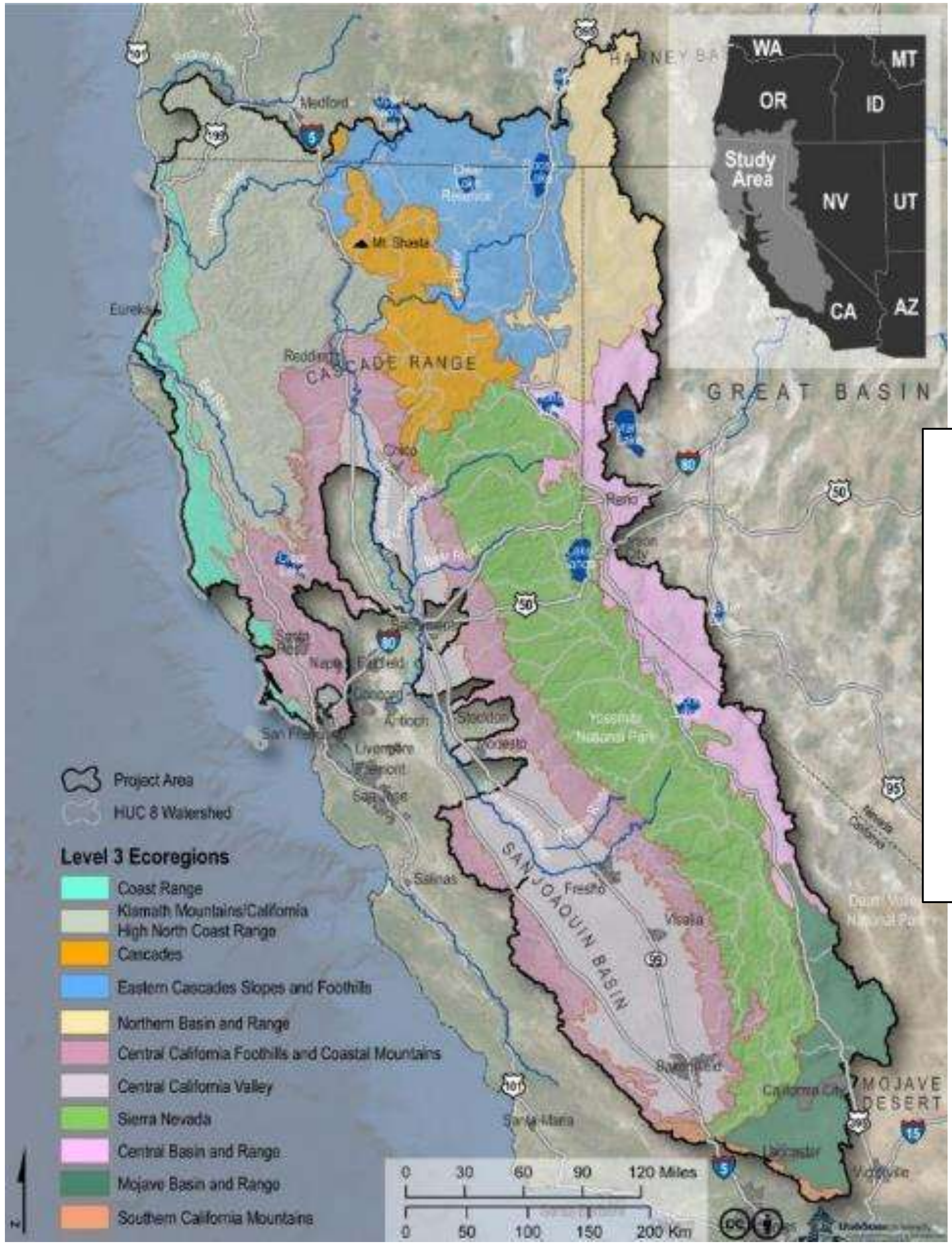

Wheaton et al. (2019)

THE USE OF LOW-TECH PROCESS-BASED STREAM HABITAT RESTORATION



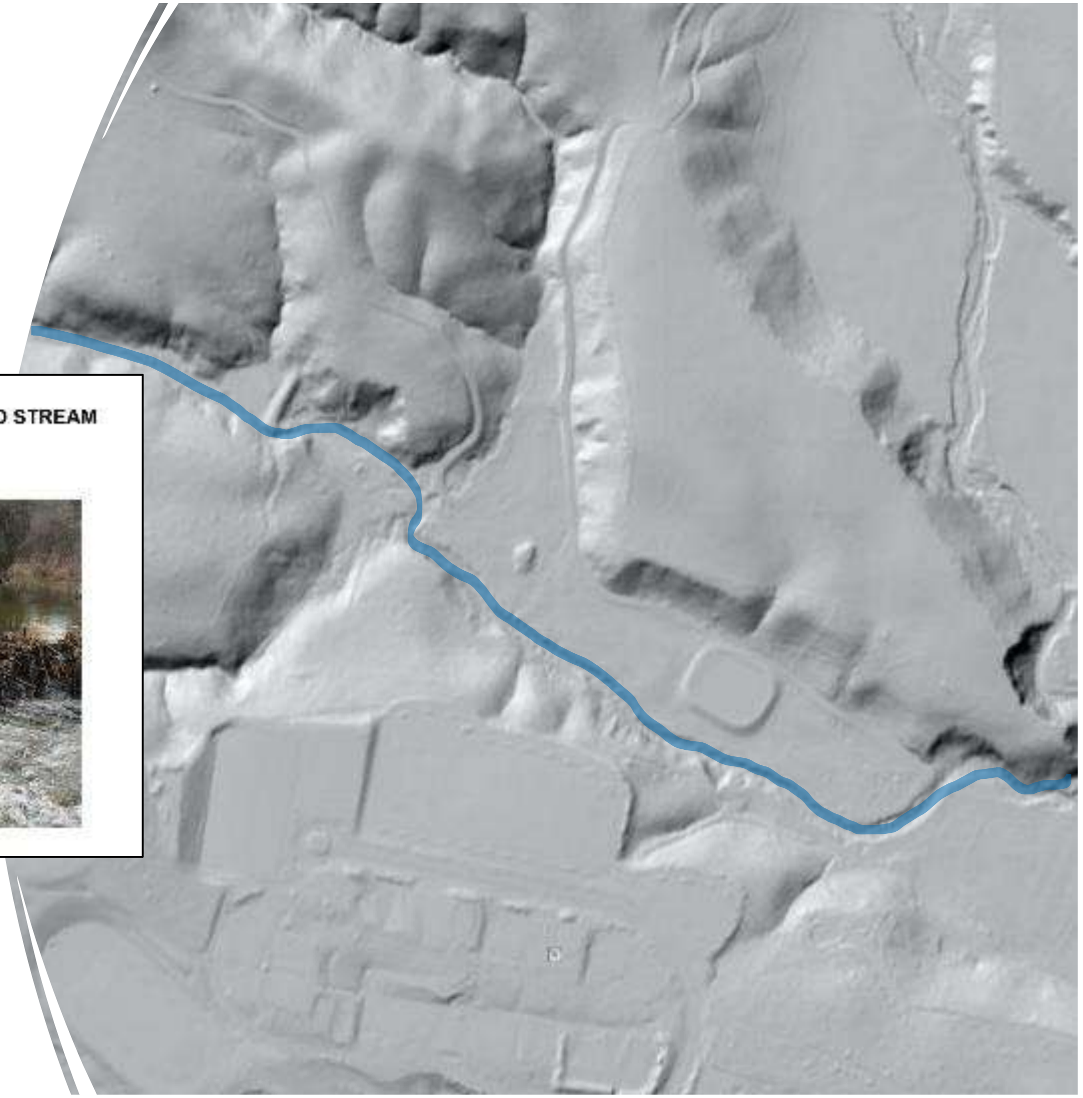

Flosi et al. (1998)

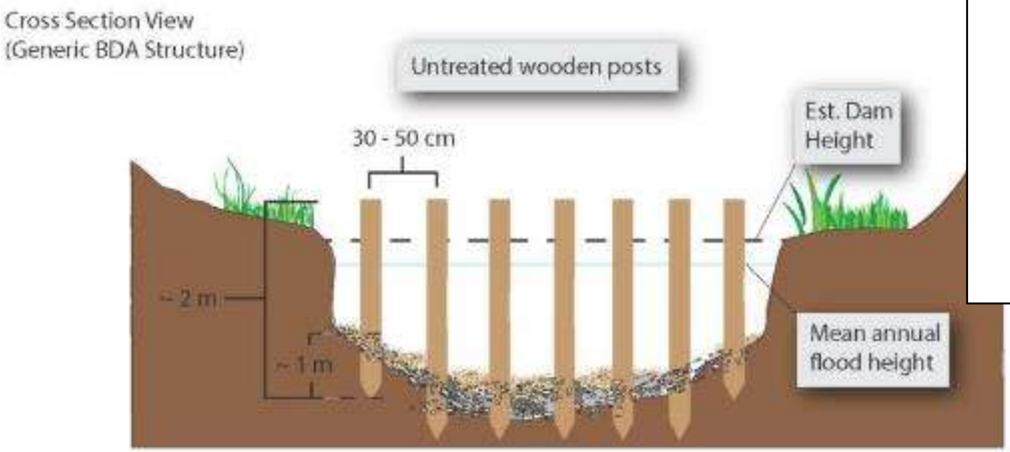


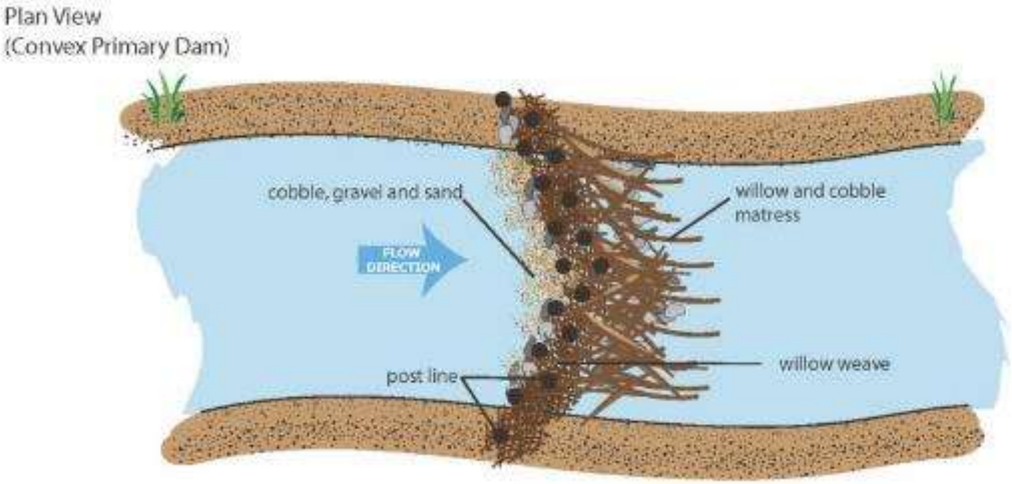


McFarlane et al. (2019)


THE USE OF LOW-TECH PROCESS-BASED STREAM HABITAT RESTORATION

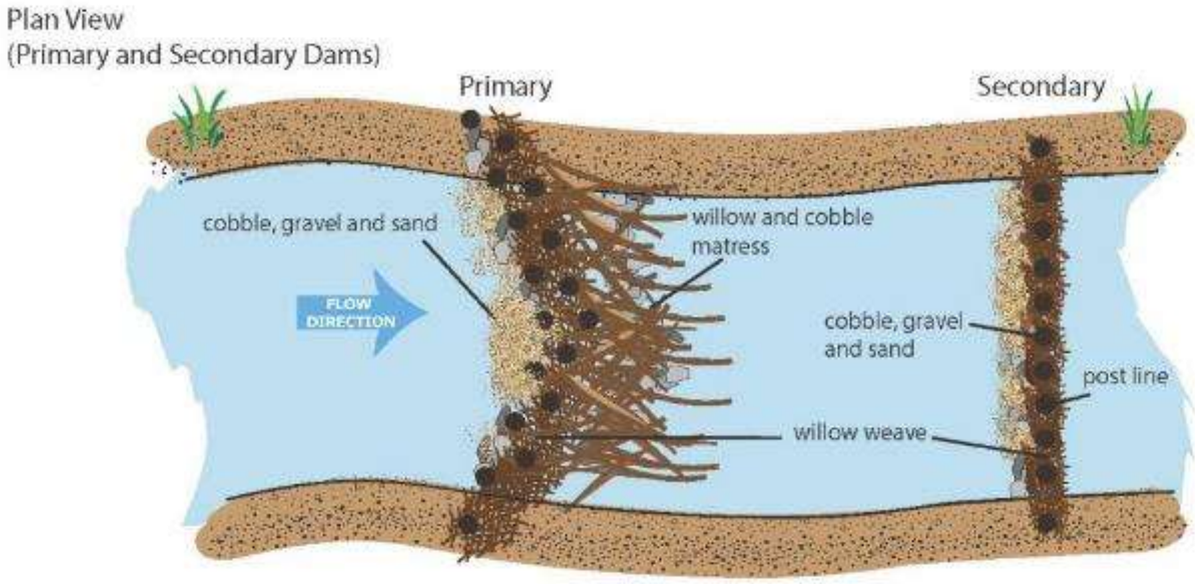

USGS (1988) and USGS (2018)




Portugal et al. (2015)


THE USE OF LOW-TECH PROCESS-BASED STREAM HABITAT RESTORATION

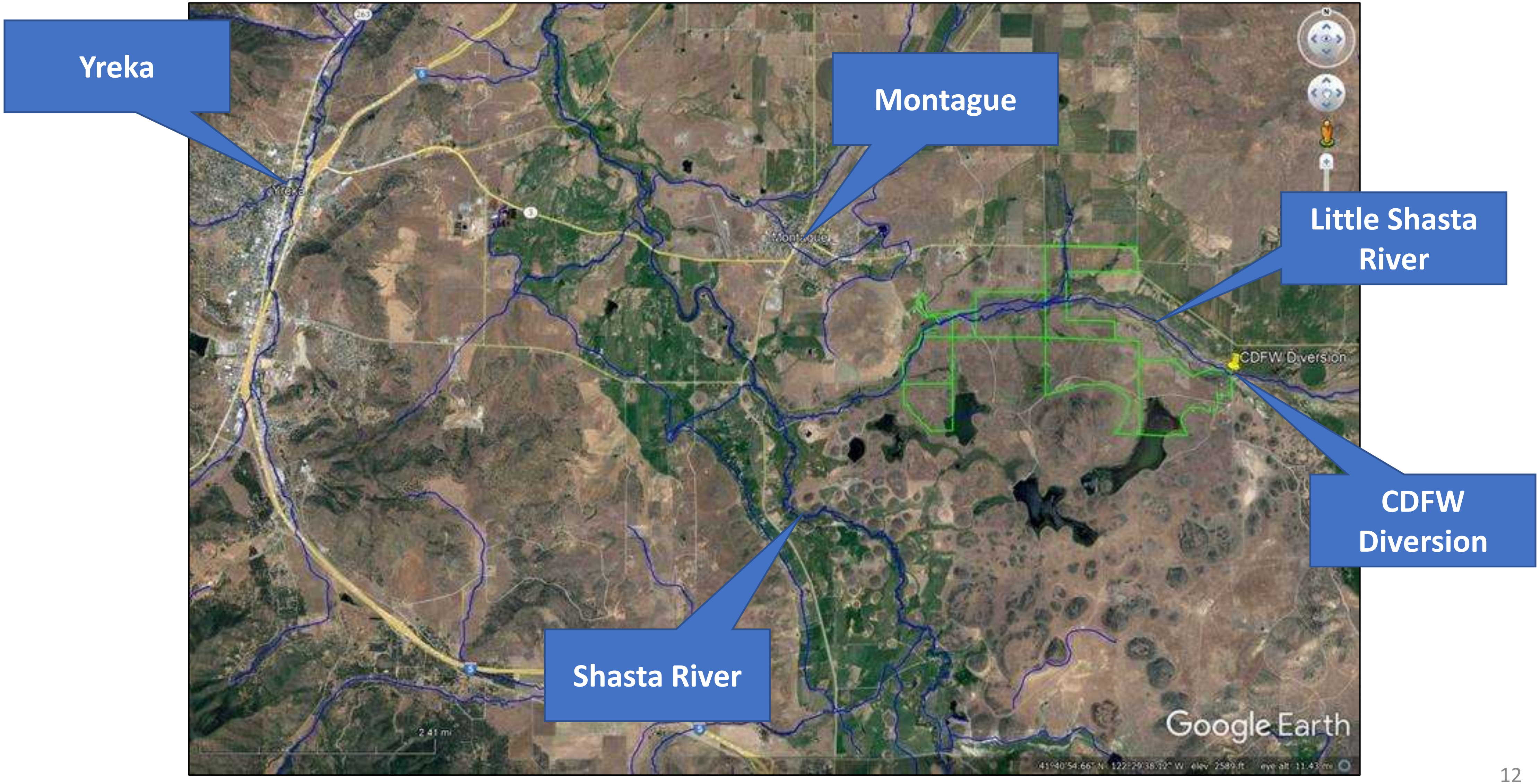


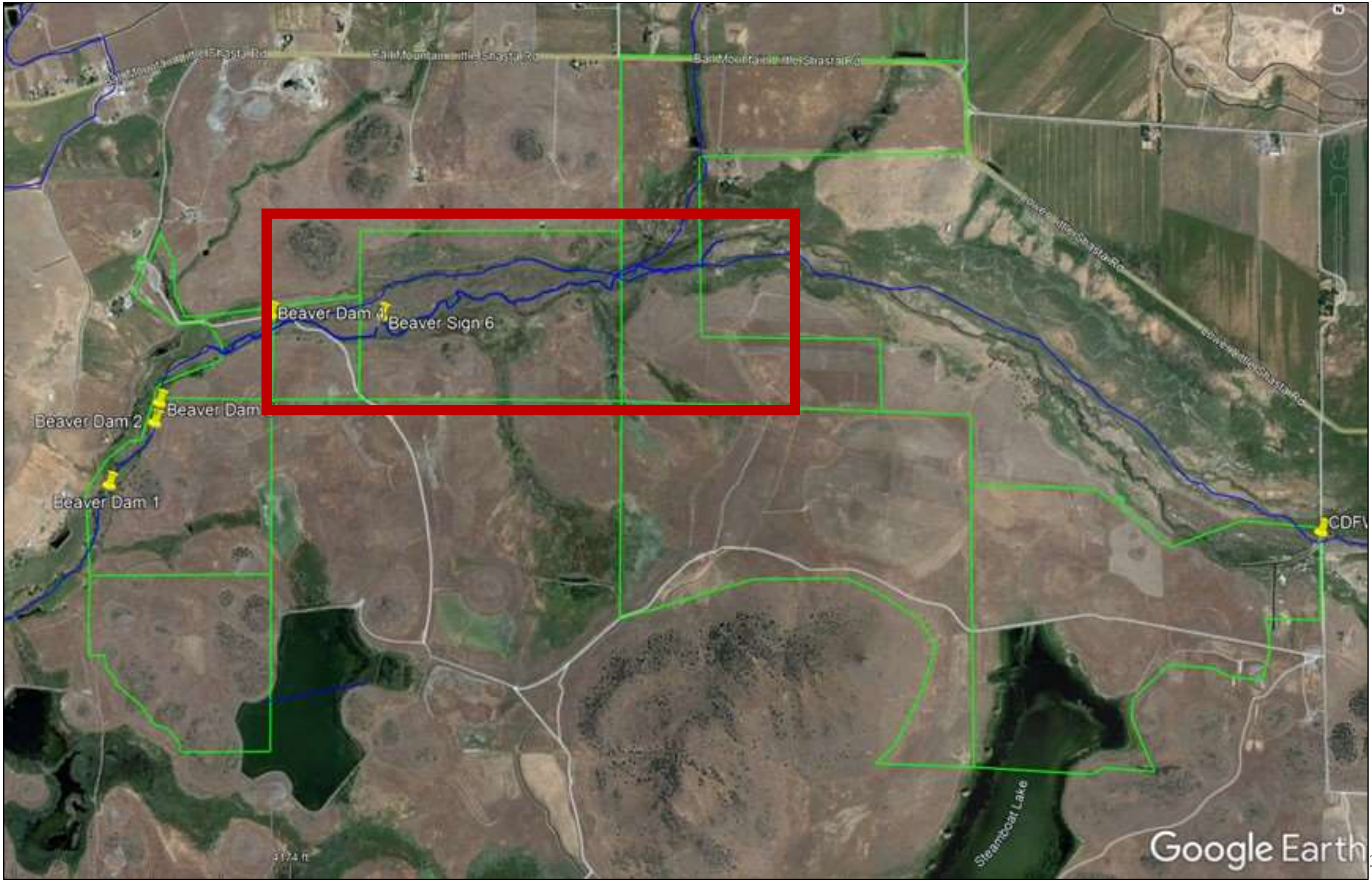

Portugal et al. (2015)

# Pilot Project 1 – Little Shasta River

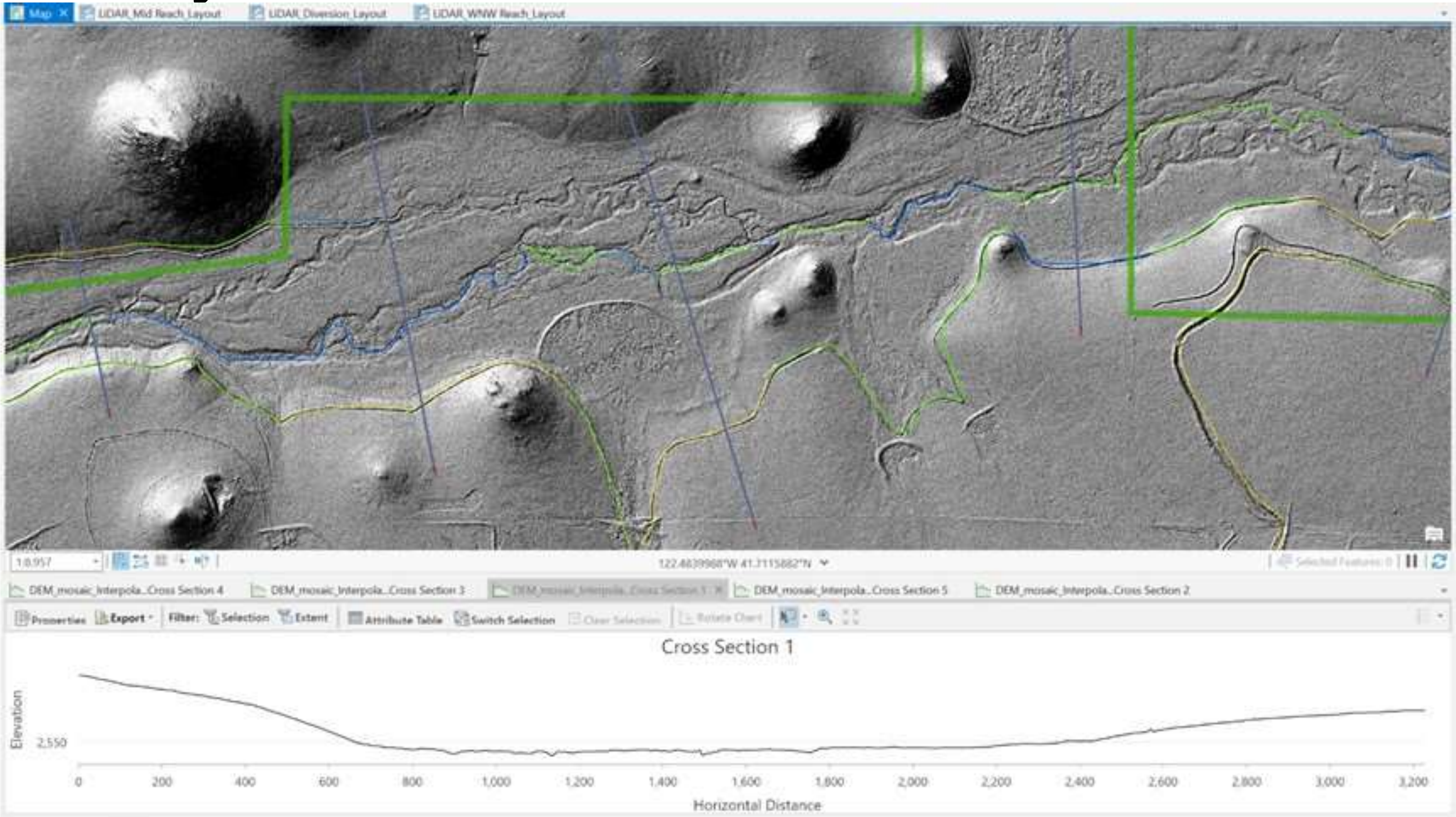
- **LTPBR Pilot Projects to 'field test' site characterization aspects of draft guidance document**
- **Pilot Projects to be located on CDFW lands**
- **First site chosen on lower Little Shasta River where it crosses portions of CDFW's Shasta Valley Wildlife Area (SVWA)**
- **Coho stream**
- **Low seasonal flows**

# Pilot Project 1 – Little Shasta River

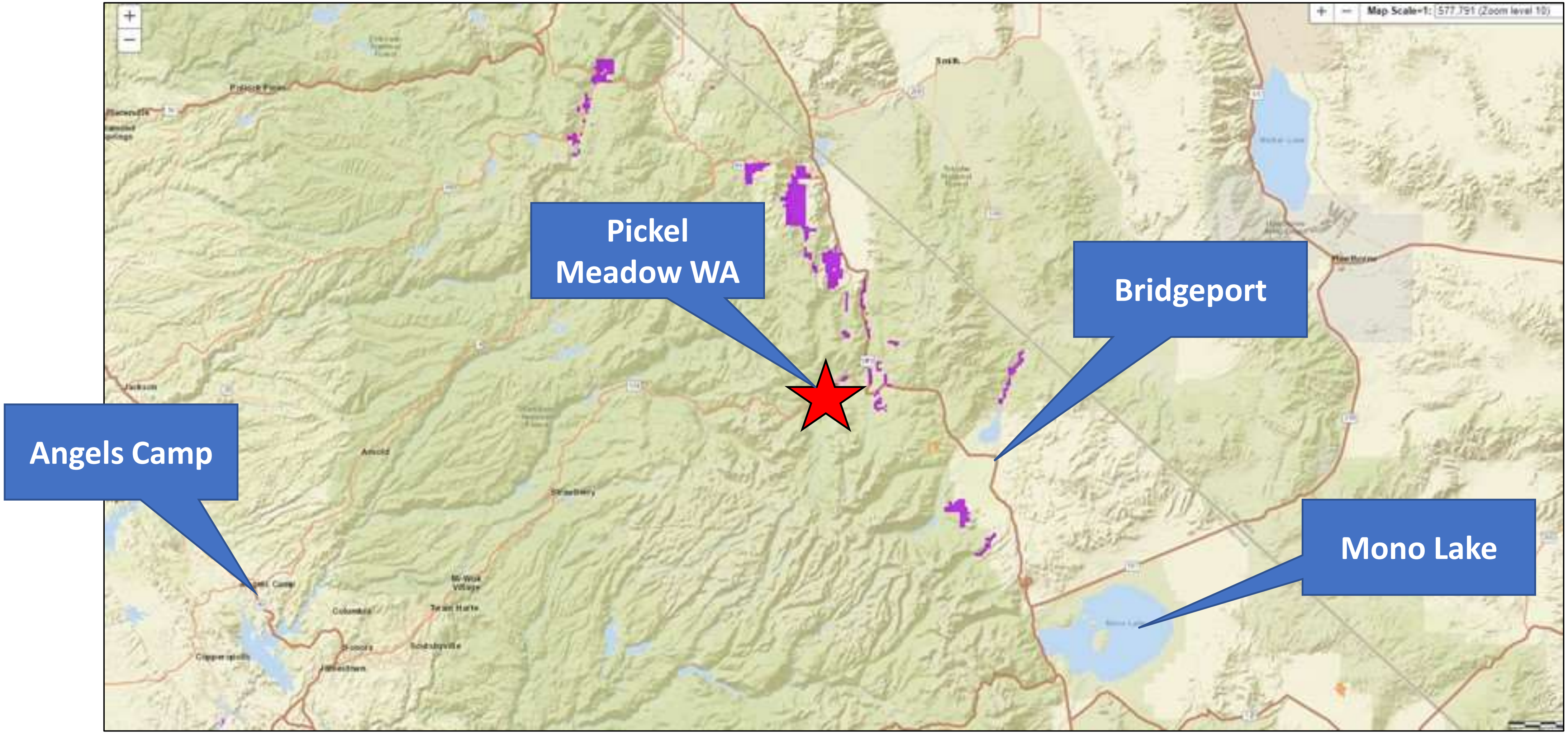



Beaver Dam 4
Beaver Sign 6
Beaver Dam
Beaver Dam 2
Beaver Dam 1
CDFV
Steamboat Lake
Google Earth

# Pilot Project 1 – Little Shasta River



# Pilot Project 2 – West Walker River



# Thank You!

will.arcand@wildlife.ca.gov
elijah.portugal@wildlife.ca.gov

# California Process-Based Restoration Network

To promote nature-based solutions to river, stream and meadow restoration.

# Cal PBR Network

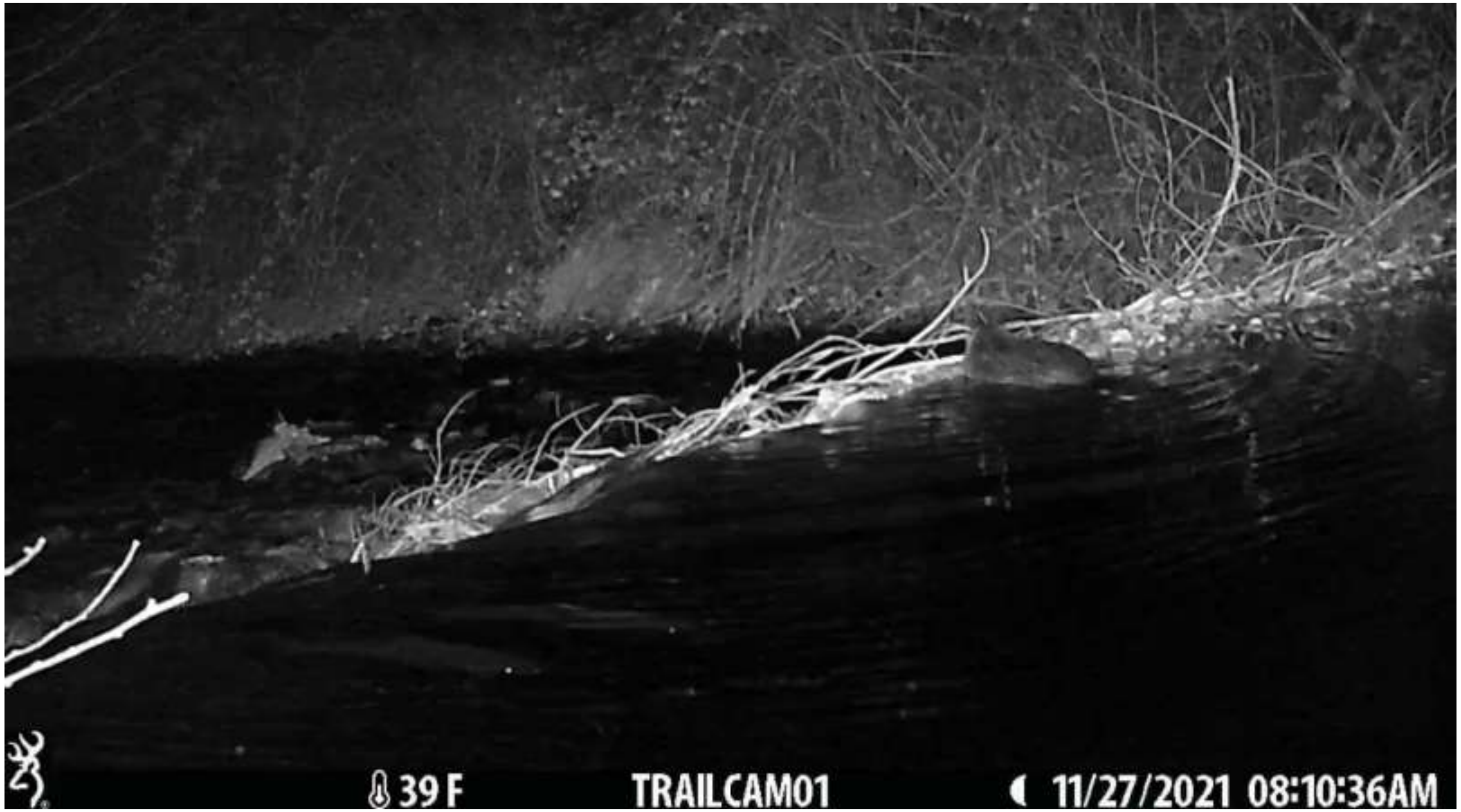
- Encourage information sharing
- Increase restoration capacity through participation and training opportunities
- Provide a collaborative voice in support of PBR

Brock Dolman, OAEC

# Cal PBR Network




- Retain water
- Support biodiversity
- Create fire resiliency
- Adapt to climate change




Scott River Watershed Council

# Cal PBR website – calpbr.org

# Get Involved!

Questions: karen.pope@usda.gov




# BRING BACK THE BEAVER CAMPAIGN UPDATES

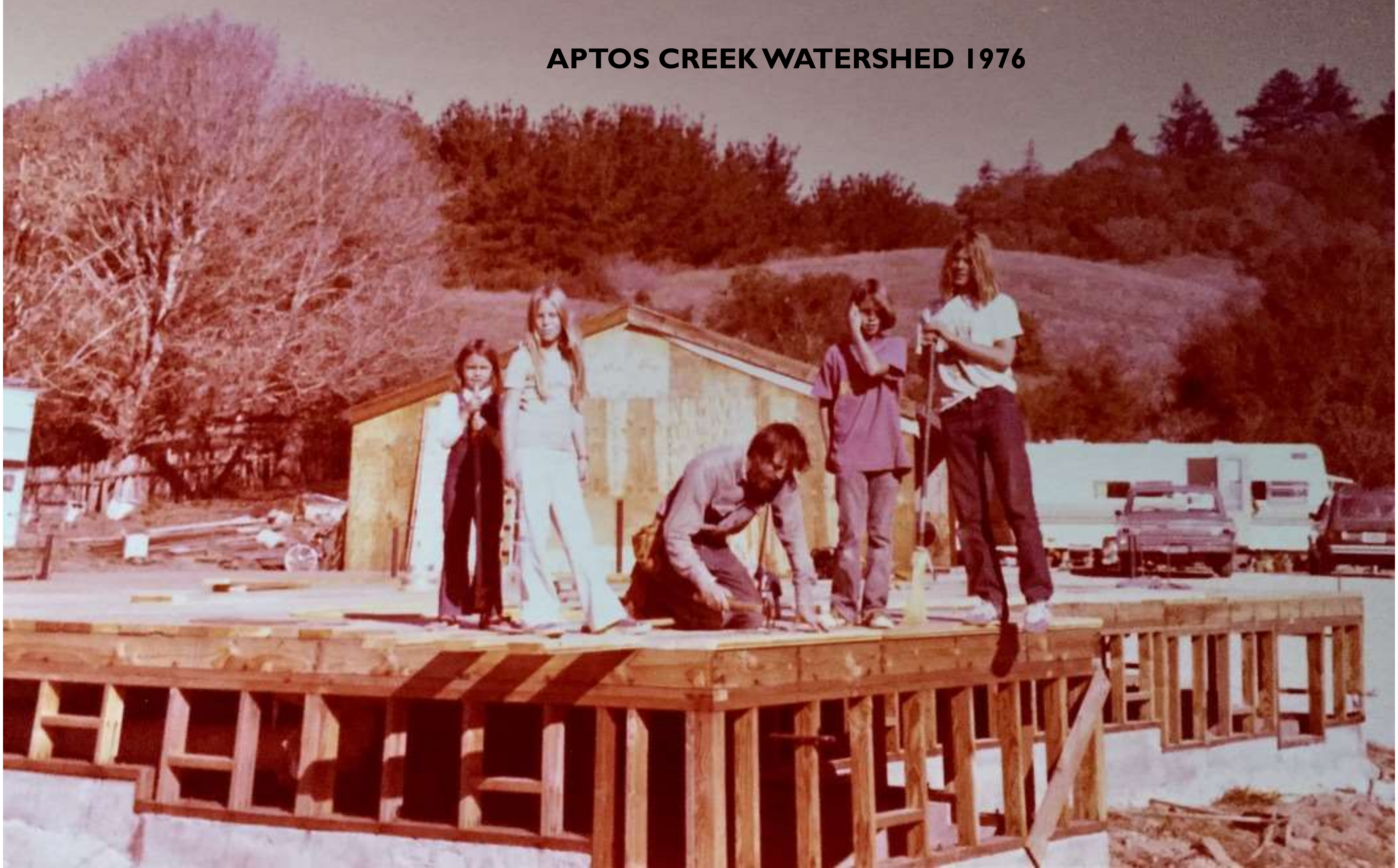
Low-Tech Process-Based Restoration Workshop - Salmonid Restoration Federation Conference - Santa Cruz, CA • April 20, 2022

Kate Lundquist and Brock Dolman • WATER Institute Co-Directors
Occidental Arts & Ecology Center • www.oaec.org/water

WATER INSTITUTE
OCCIDENTAL ARTS & ECOLOGY CENTER

Salmonid Restoration Federation

## APTOS CREEK WATERSHED 1976

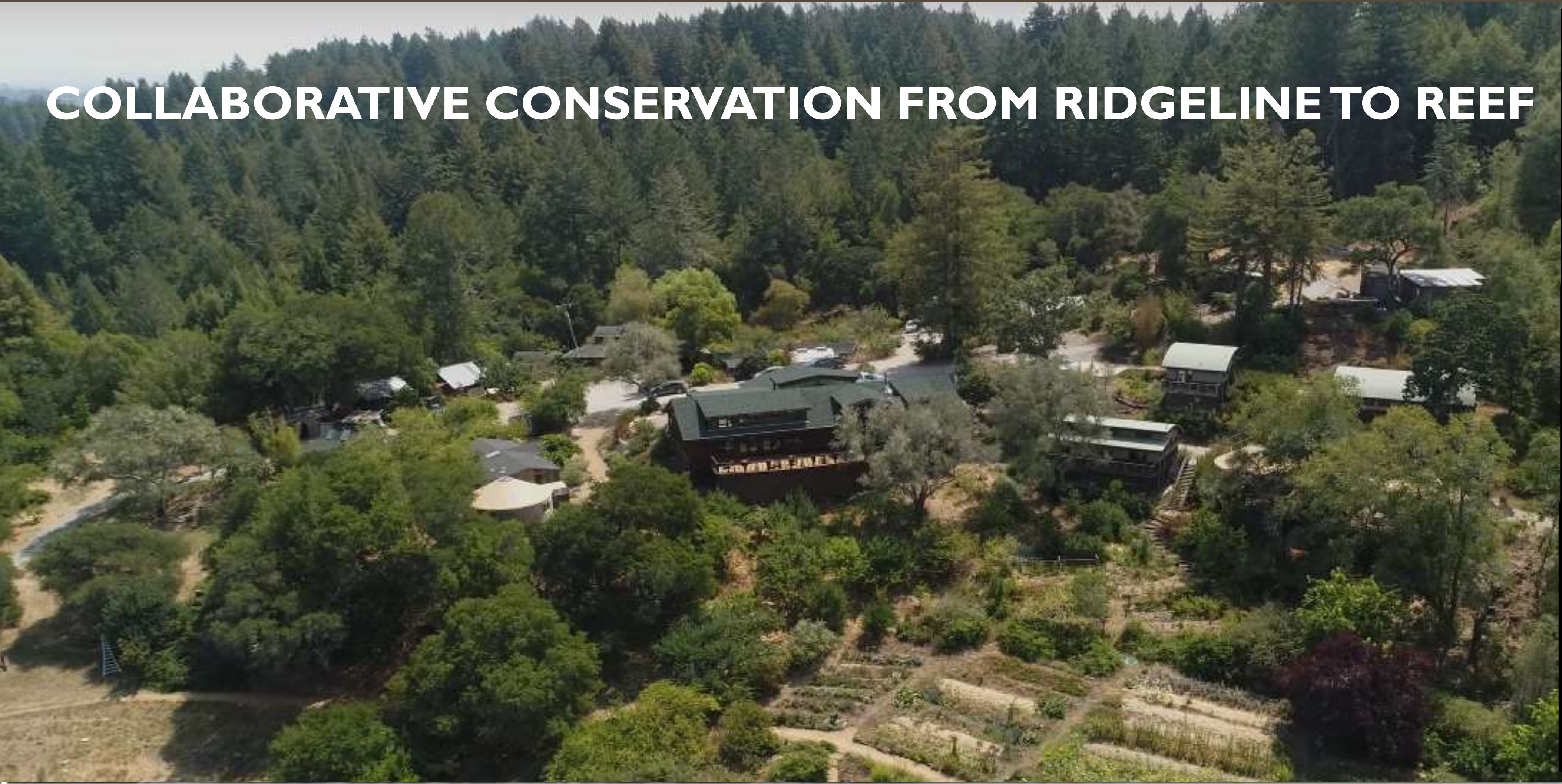


Occidental Arts & Ecology Center

www.oaec.org/water

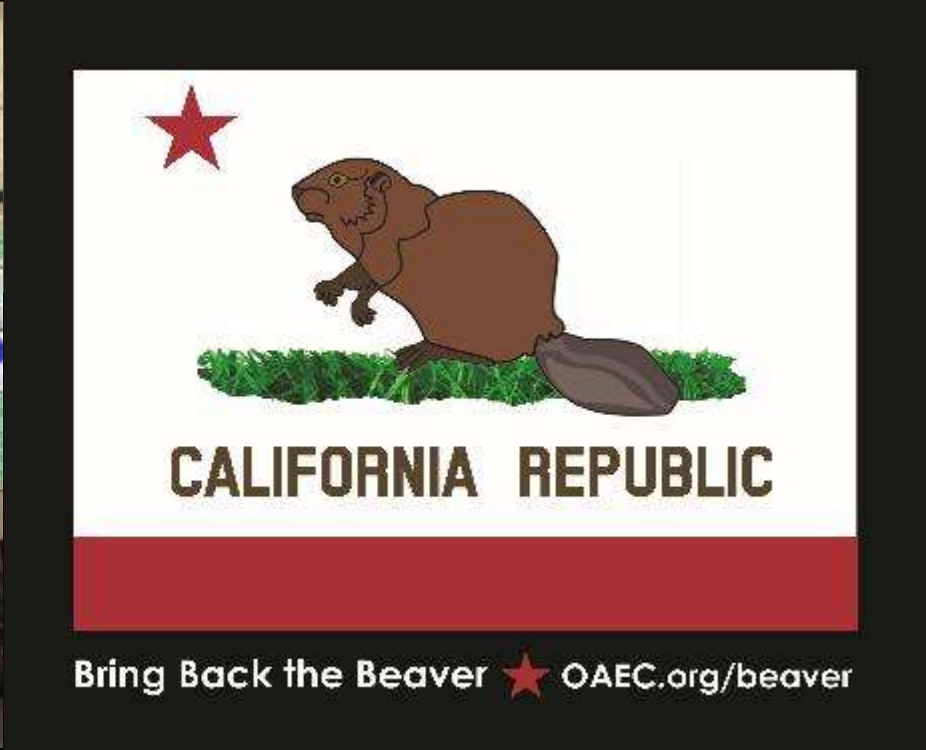
THE WATER INSTITUTE

# COLLABORATIVE CONSERVATION FROM RIDGELINE TO REEF



# BRING BACK THE BEAVER CAMPAIGN

- Education & Outreach
- Citizen Science
- Research & Demonstration
- Policy Change

# BEAVER AND PROCESS-BASED RESTORATION PARTNERSHIPS


# REMEDIATE THE SOURCE PROBLEM: THE "BEAVER BLIND SPOT"

- Co-exist and collaborate with the ones we have

- Identify & resolve historic, social & informational barriers

- Create pathways to return them to their former range

- Modify state policies, regulations, and statutes (if needed) to permit these activities

# POTENTIAL OPPORTUNITIES FOR CO-EXISTENCE AND COLLABORATION


Photo: Rusty Cohn

iNaturalist.org

https://www.inaturalist.org/observations?taxon_id=43794

# MORE ARE EMBRACING THE OPPORTUNITY

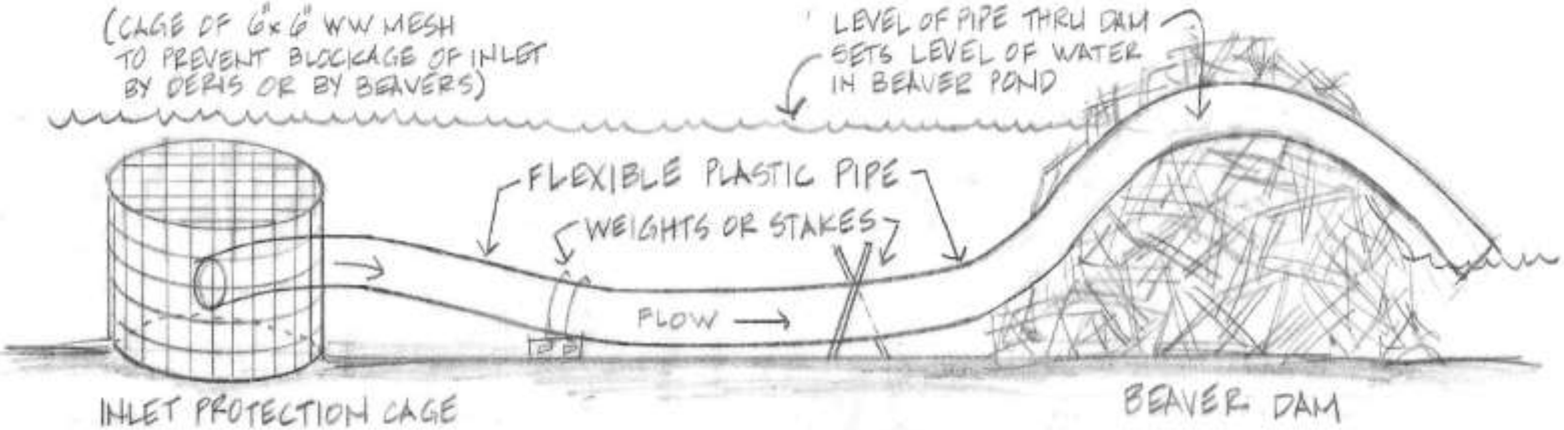
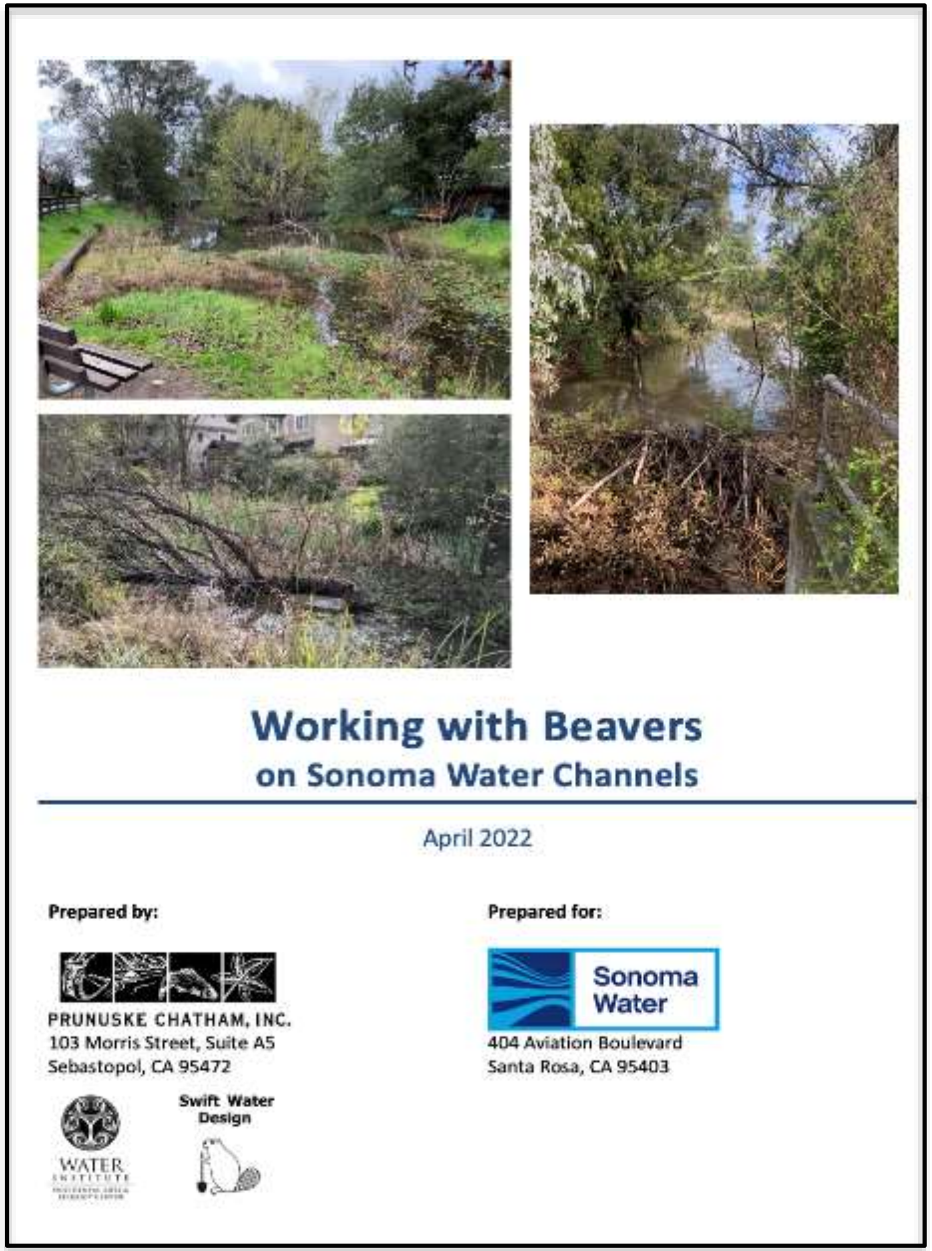




Diagram: Sherry Guzzi / Sierra Wildlife Coalition



Working with Beavers
on Sonoma Water Channels

April 2022

Prepared by:

PRUNUSKE CHATHAM, INC.
103 Morris Street, Suite A5
Sebastopol, CA 95472

WATER INSTITUTE

Swift Water Design

Prepared for:

Sonoma Water
404 Aviation Boulevard
Santa Rosa, CA 95403

# NEW "BEAVER BACK SAVER" DEVICE IS WORKING!

Photos: Brock Dolman/OAEC

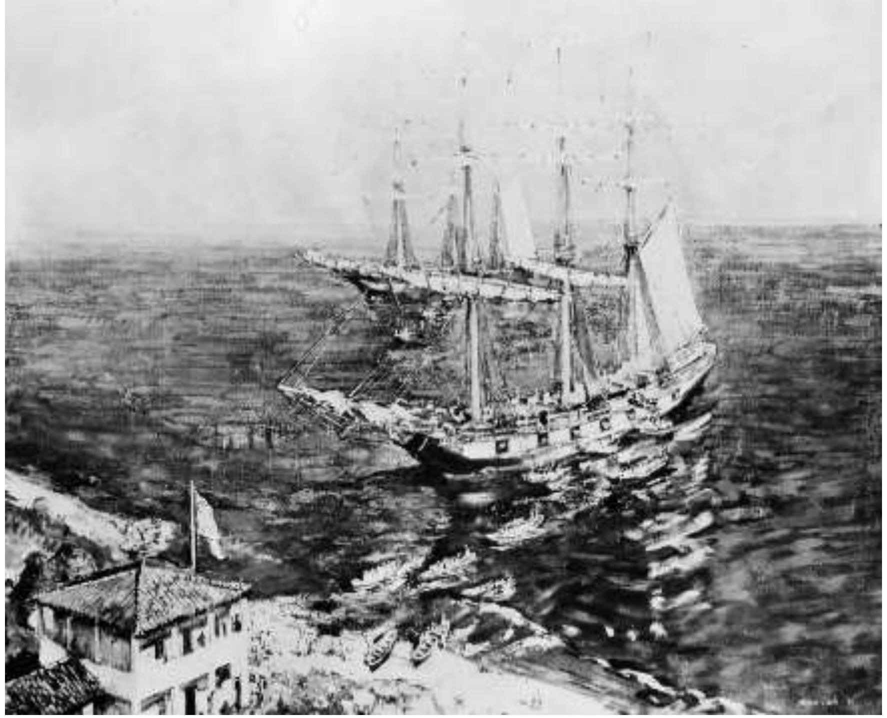
# INFORMATIONAL BARRIERS ARE SLOWLY BEING RESOLVED

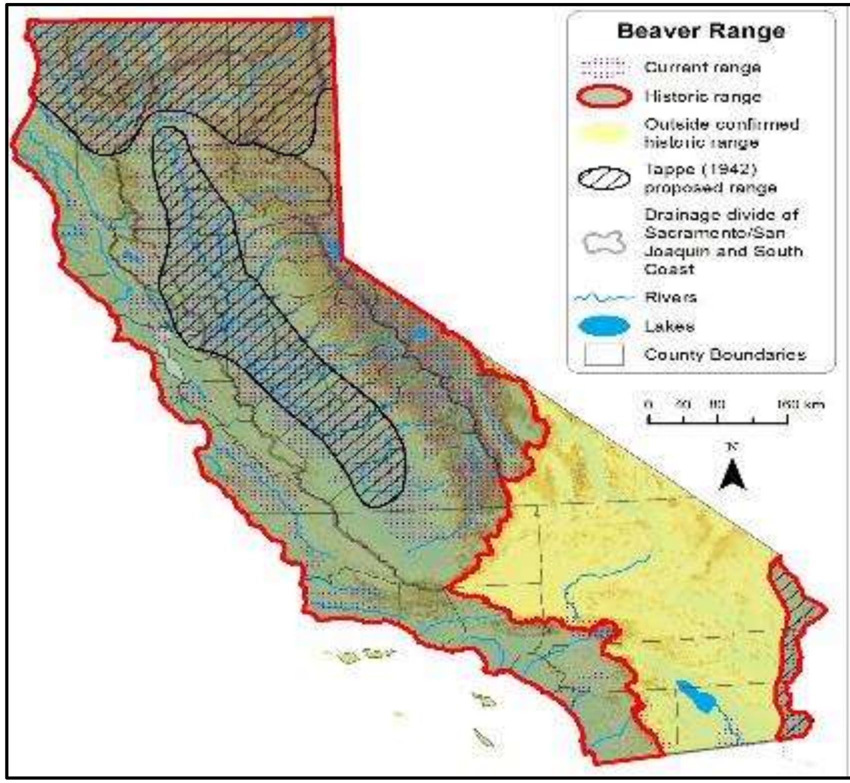
In 2020 remnant beaver dam samples from Yellow Creek in the northern Sierra Nevada were radio carbon dated to:
**749 AD**

https://oaec.org/publications/beaver-recruitment-strategy-for-tasmam-koyom/

HISTORIC ACCOUNT FROM THE MONTEREY BAY:

In October 1818, English explorer Peter Corney sailed into Monterey Bay on the Santa Rosa. He described the fauna of the Monterey area: “There are many bears, wolves, foxes, deer, beavers, etc…” (Corney and Alexander 1896:44).






The Historical Range of Beaver in Coastal California (Update)

Lanman et al. 2013

https://oaec.org/publications/historical-range-of-beaver-update/

# CULTURAL DIVIDES ARE BEING BRIDGED: MARIN RCD RANCHER AND BEAVER PANEL

Jon Griggs,
Ranch Manager
Maggie Creek Ranch
Elko, NV

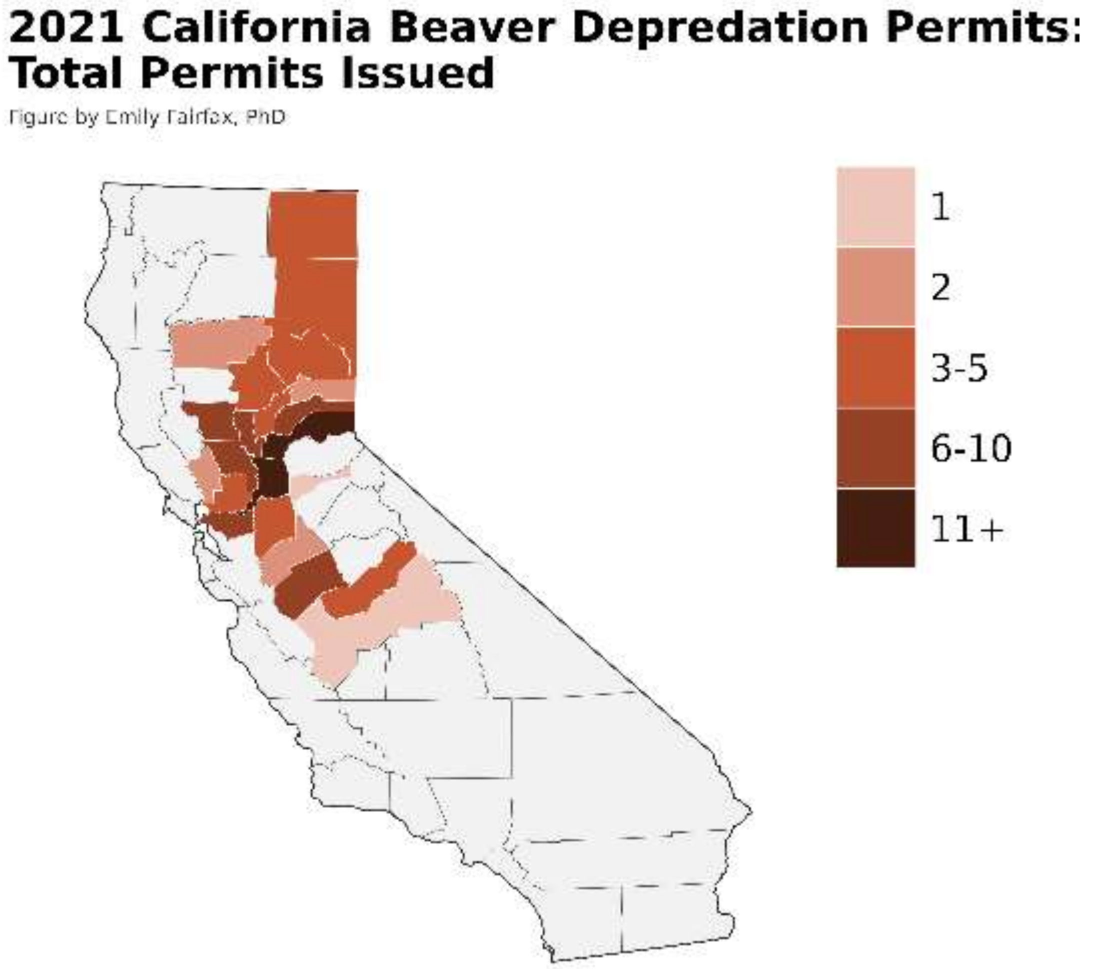
Betsy Stapleton
Rancher
Scott Valley, CA

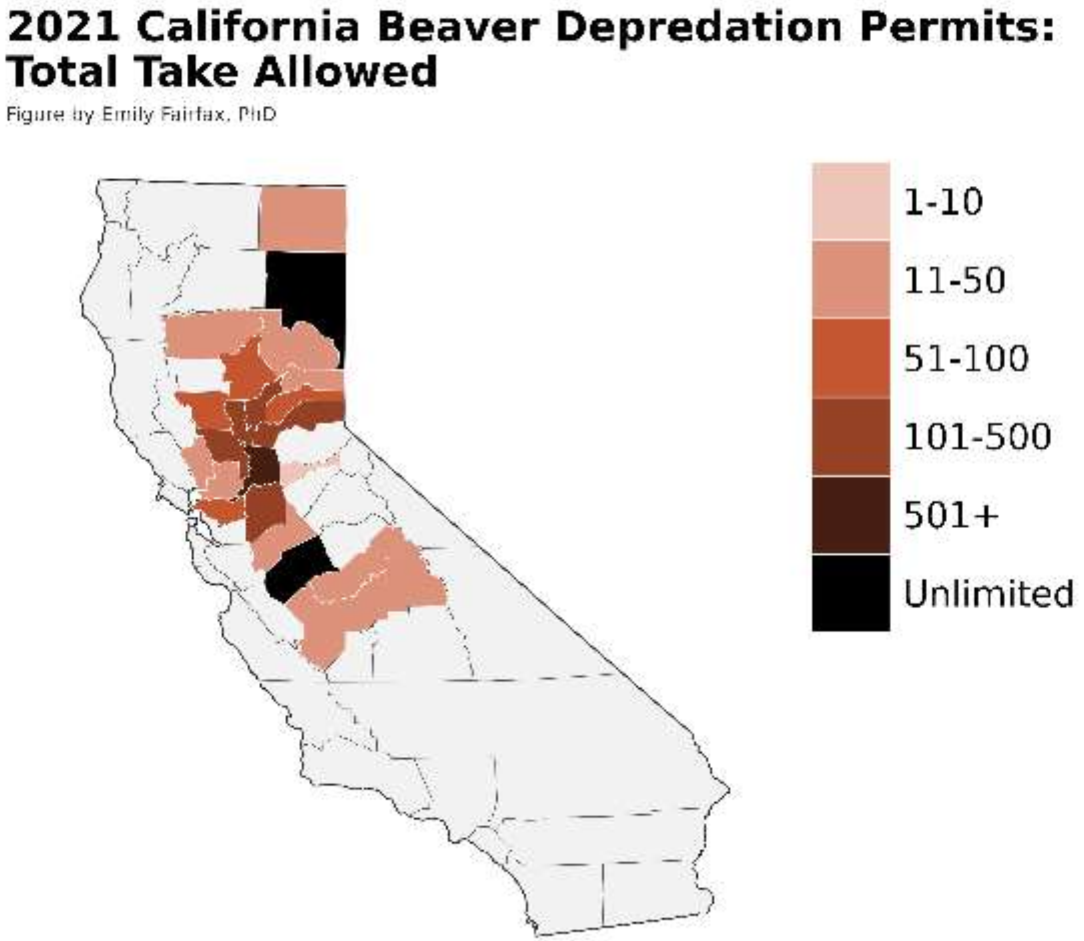
Tracy Schohr, Rancher
Schohr Ranch, Leasee
At Doty Ravine, CA

**Watch recording of panel presentation at:**
**https://youtu.be/4BpLINnaiZM**

See film “Creating Miracles in the Desert”
https://youtu.be/kSctr0aQOso

# WE STILL HAVE WORK TO DO




Fairfax, Emily (2022): Brief Analysis of 2021 Beaver Depredation Permit Data from California, USA. figshare. Presentation. https://doi.org/10.6084/m9.figshare.19452995.v1

# BEAVER DAM REMOVAL GUIDANCE NEEDED TO PREVENT INCIDENTAL TAKE



# BEAVER DEPREDATION REGULATION CHANGE PETITION UPDATE: GUIDANCE IS BEING DEVELOPED

- Increased CDFW budget funds human-wildlife conflict program
- Petitioners working with Vicky Monroe (CDFW) to develop beaver take guidance document similar to mountain lion
- Beaver dam removal to be included
- Still determining what policies, regulations, and statutes will need modifying to support co-existence and return of beaver to their former range

# CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE ADDS NEW BEAVER CONSERVATION RESOURCES TO THEIR WEBSITE

**California Department of Fish and Wildlife**

April 7 at 1:06 PM ·

April 7 is International Beaver Day! This amazing semi-aquatic rodent is native to our state. Throughout California, the North American beaver (Castor canadensis) serves an important role as a keystone species and "ecosystem engineer." Though their natural behaviors – such as felling trees to create dams – may be perceived as negative for some people, beaver activity significantly benefits other native species in California. For example:

- Beaver dams can improve water quality, control water downstream and reconnect streams to their floodplains.
- Beavers can support habitat restoration by expanding wetland, riparian and wet meadow habitats.
- Beavers can increase wildfire resiliency in some areas by creating ponds and flooded areas.
- Beavers can provide habitat for other native species (plants and animals).

CDFW supports a comprehensive approach to beaver management through the implementation of various nature-based solutions, such as restoration projects that support beaver conservation. Learn more about those efforts, as well as science, research, laws and regulations related to beavers on CDFW's Beaver webpage: https://wildlife.ca.gov/Conservation/Mammals/Beaver

Looking for resources and tips about how to address potential human-beaver conflict and prevent property damage? Check out our Human-Wildlife Conflict Program webpage: https://wildlife.ca.gov/.../Wildlife-Health/HWC-Program

# CALIFORNIA RESOURCE AGENCIES ARE RECOGNIZING BEAVER AND PROCESS-BASED RESTORATION AS A CLIMATE SMART NATURE-BASED SOLUTION

ANABRANCH SOLUTIONS
CALIFORNIA TROUT
American Rivers
RIVERS CONNECT US
Google
WATER INSTITUTE
THE YUROK TRIBE
TROUT UNLIMITED
TULALIP TRIBES
COMMUNITY ALLIANCE with FAMILY FARMERS
PLUMAS CORPORATION
ARROYO SECO FOUNDATION
Beaver INSTITUTE
SYRCL
Tuolumne River Trust
PAICINES RANCH
Riverbend Sciences
DEFENDERS OF WILDLIFE
SMOKEY
WORTH A DAM
PACIFIC FOREST TRUST
Salmonid Restoration Federation
CENTER for BIOLOGICAL DIVERSITY
epic
SONOMA ECOLOGY CENTER
SYMBIOTIC RESTORATION
AMERICAN RIVER CONSERVANCY
WHERE THERE ONCE WAS WATER
Sierra Wildlife Coalition
RUSSIAN RIVERKEEPER
CALIFORNIA STATE PARKS FOUNDATION
NHI NATURAL HERITAGE INSTITUTE
STEMPLE CREEK RANCH
Rainfall to Groundwater
CALIFORNIA ACADEMY OF SCIENCES
WILD FARM ALLIANCE
Mattole Salmon Group
SWIFTWATERDESIGN
MARIN RESOURCE CONSERVATION DISTRICT
RESOURCE CONSERVATION DISTRICT GUADALUPE-COYOTE
SAN LUIS OBISPO BEAVER BRIGADE
ECOSYSTEM HERO
The INSTITUTE for BIRD POPULATIONS
CIEA
Sanctuary Forest
SUSTAINABLE ST. HELENA
AN ENVIRONMENTAL ALLIANCE
BLUE FOREST CONSERVATION

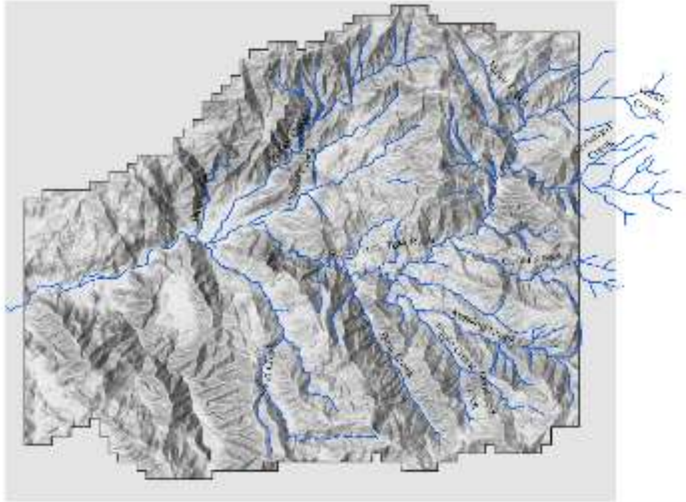
November 9, 2021

Wade Crowfoot, Secretary
Amanda Hansen, Deputy Secretary for Climate Change
California Natural Resources Agency
715 P Street, 20th Floor
Sacramento, CA 95814

*Submitted via email: CaliforniaNature@resources.ca.gov*

**RE: Comments on Draft Climate Smart Strategy - Support inclusion of beaver and process-based restoration in the California Natural and Working Lands Climate Smart Strategy**

# PATHWAYS TO RESTORE BEAVER TO THEIR FORMER RANGE ARE BEING CREATED



# Beaver Recruitment Strategy for Tásmam Koyóm

Prepared for the Maidu Summit Consortium

by Kate Lundquist and Brock Dolman of the Occidental Arts & Ecology Center WATER Institute

with funding from the California Department of Fish and Wildlife, the Resources Legacy Fund and the Patagonia Foundation

June 2020

https://oaec.org/publications/beaver-recruitment-strategy-for-tasmam-koyom/

# BEAVER RESTORATION FEASIBILITY ASSESSMENT - WEST MARIN COUNTY

**WEST MARIN BEAVER ASSESSMENT STEERING COMMITTEE**

**Brock Dolman and Kate Lundquist** – Occidental Arts & Ecology Center
**Jerry Meral** – Natural Heritage Inst./Environmental Action Committee
**Nancy Scolari and Sally Gale** – Marin Resource Conservation District
**Eric Ettlinger** – Marin Municipal Water District
**Preston Brown** – Salmon Protection And Watershed Network
**Gale Seymour** – Retired California Department of Fish and Wildlife


THE ARGYLE SWEATER
BY SCOTT HILBURN
ALMOST AS QUICKLY AS IT HAD STARTED, THE FOOD FIGHT ENDED.

# THANK YOU!

Photo: Rusty Cohn


# QUESTIONS?