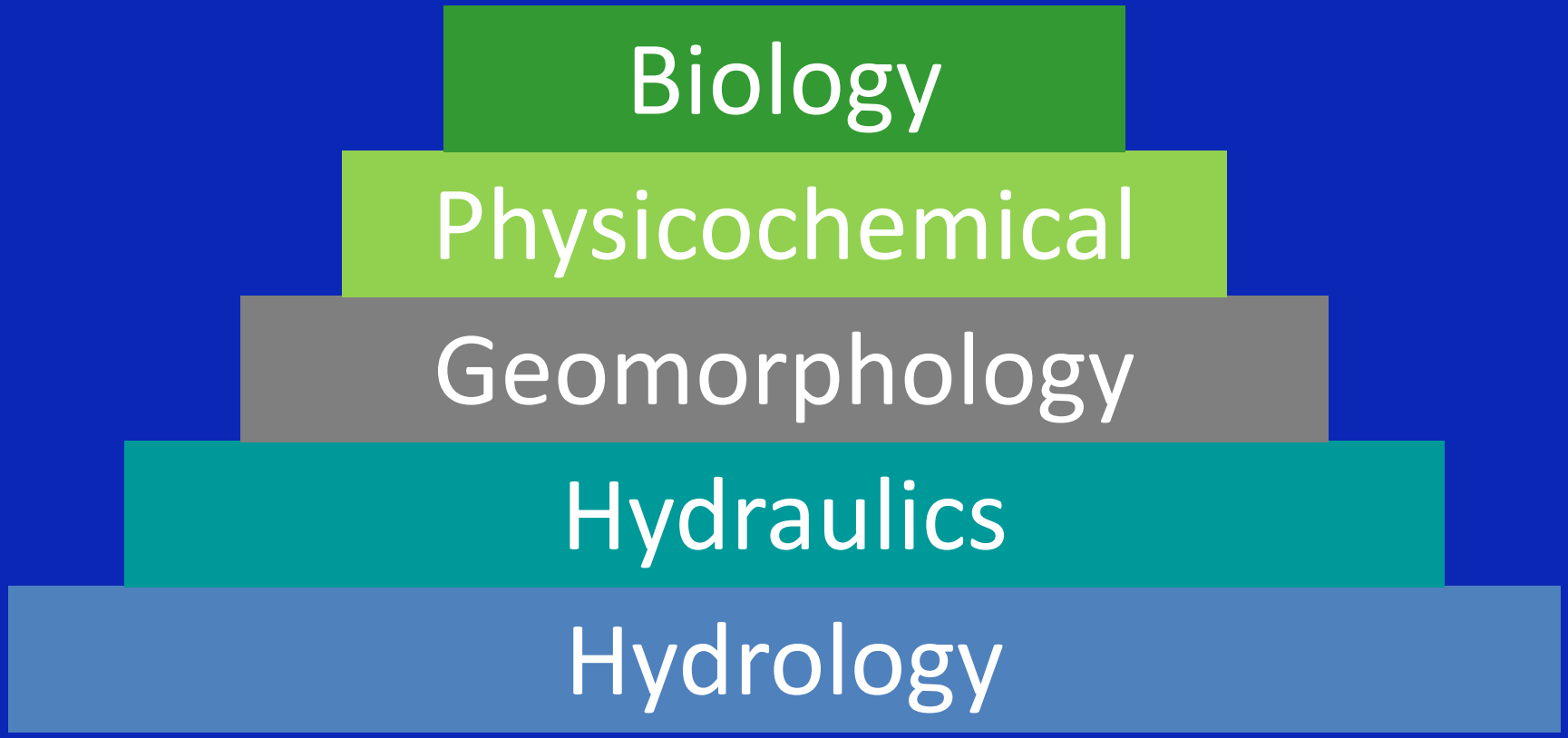
Trick or Treat: Does NCD work to improve stream ecological function?

Matt Kondratieff

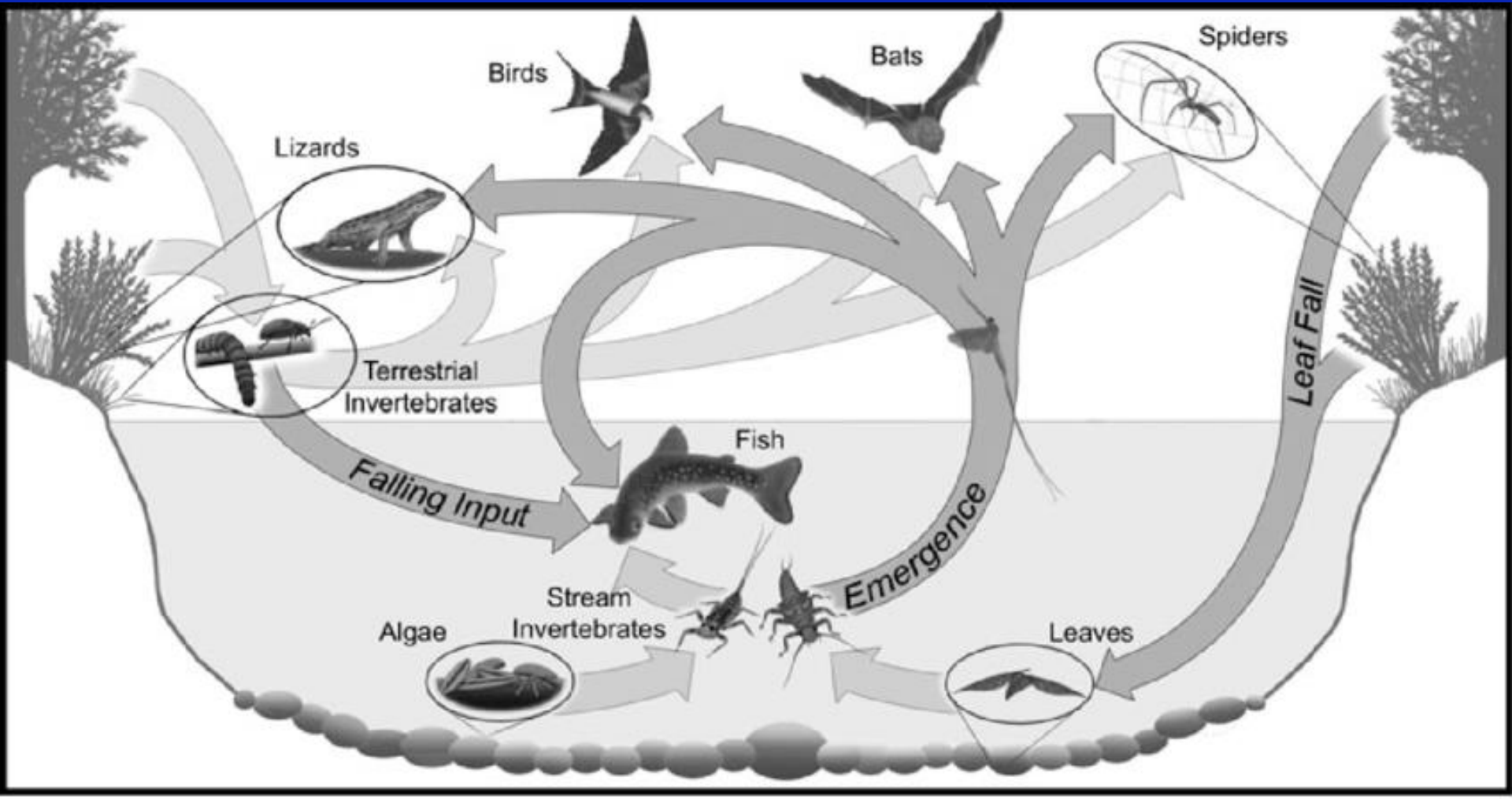
River Restoration 2018
Two Harbors, MN
October 29, 2018

Limiting Factors & Ecological Function



Courtesy Will Harmon, USFWS

Fish populations= Ecological Indicator



Colden et al. 2005

How do you improve a fish population?

Stocking

How do you improve a fish population?

Stocking

Regulations

How do you improve a fish population?

Stocking

Regulations

Habitat

Basics of Stream Habitat

Modified from Schlosser and Angermeier 1995

Basics of Stream Habitat

Modified from Schlosser and Angermeier 1995


CO
COLORADO
PARKS • WILDLIFE

Basics of Stream Habitat

Modified from Schlosser and Angermeier 1995


CO
COLORADO
PARKS • WILDLIFE


CO
COLORADO
PARKS • WILDLIFE


CO
COLORADO
PARKS • WILDLIFE

Basics of Stream Habitat

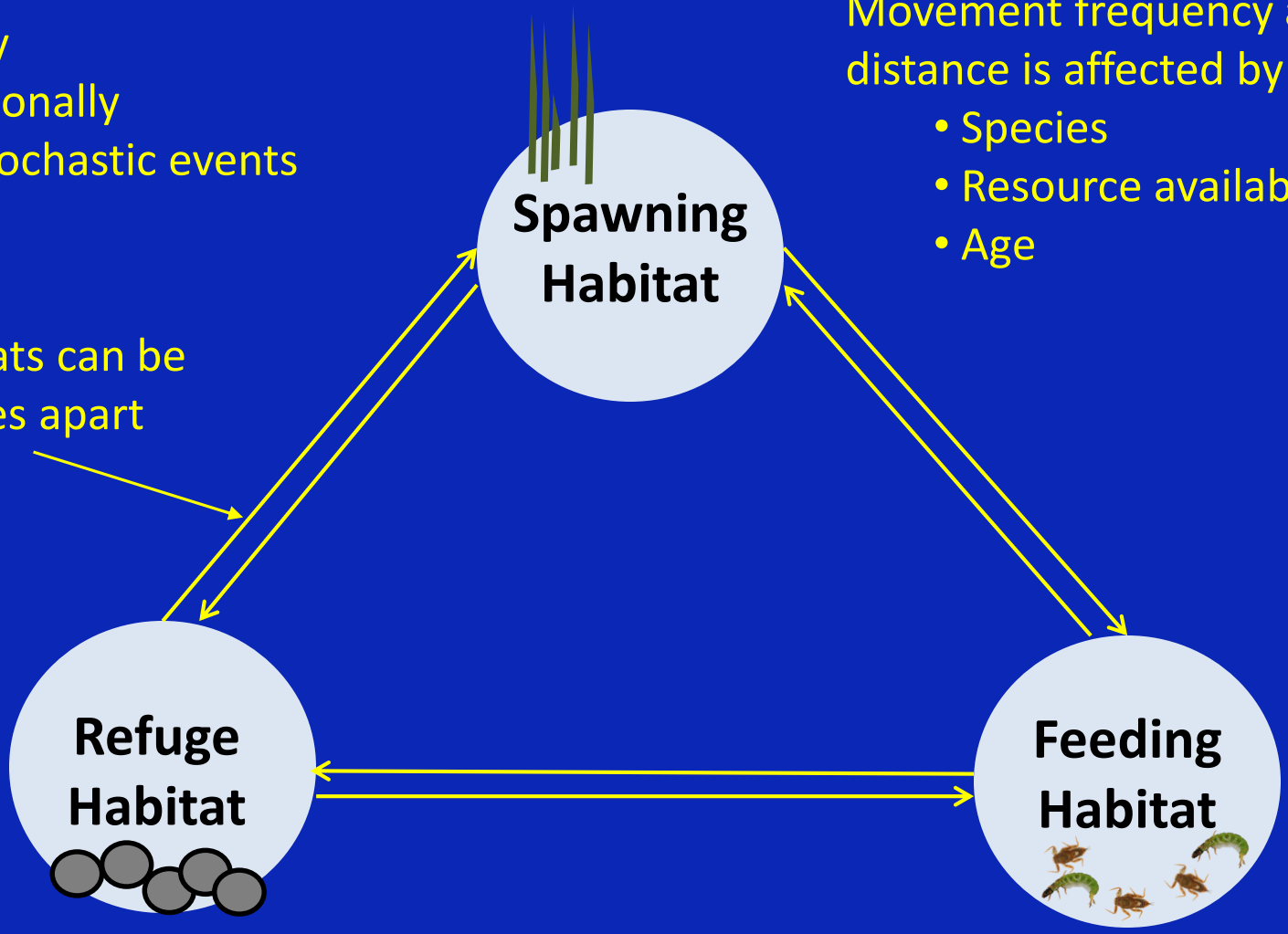
Fish move:

- Daily
- Seasonally
- In stochastic events

Movement frequency and distance is affected by:

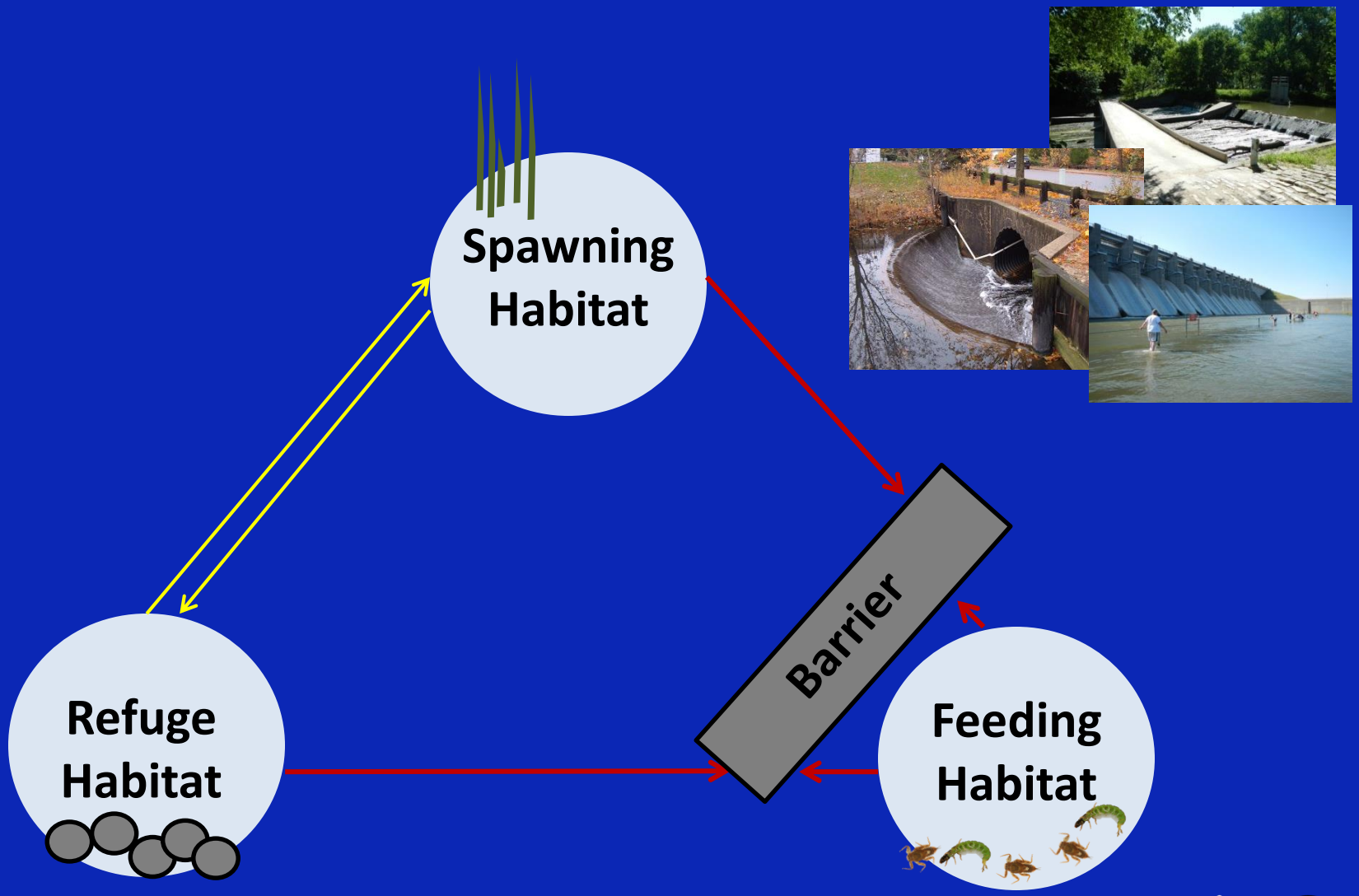
- Species
- Resource availability
- Age

Habitats can be miles apart

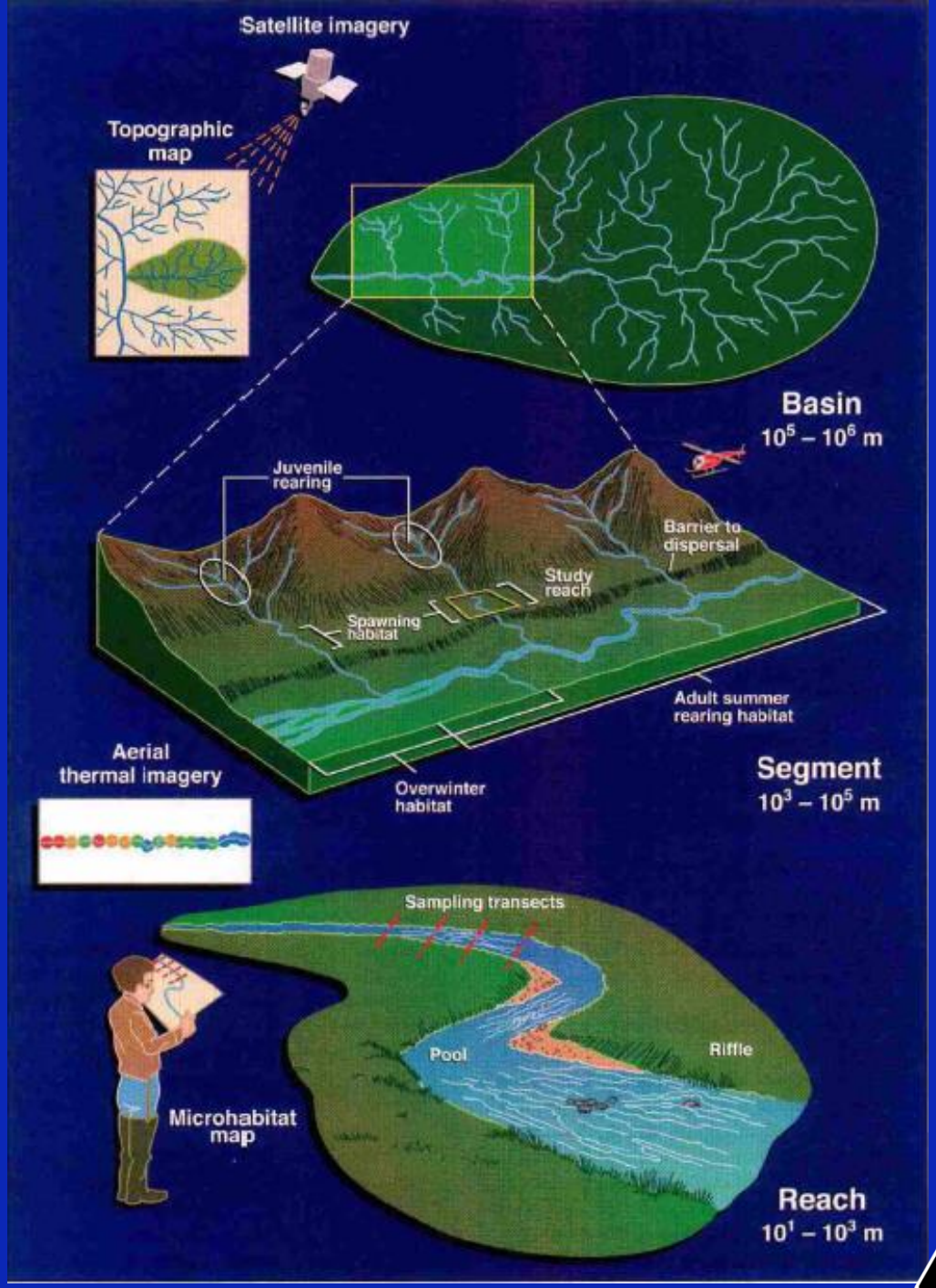


Modified from Schlosser and Angermeier 1995

Basics of Stream Habitat

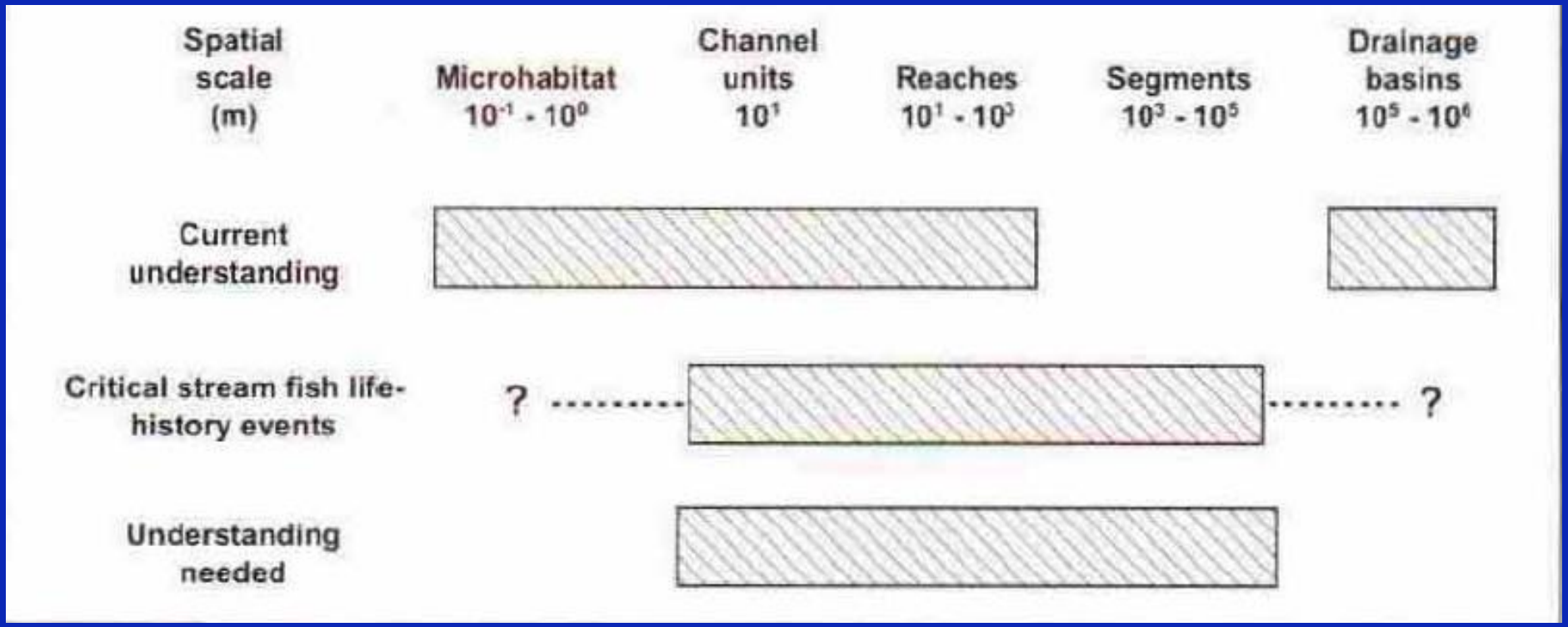


Scale



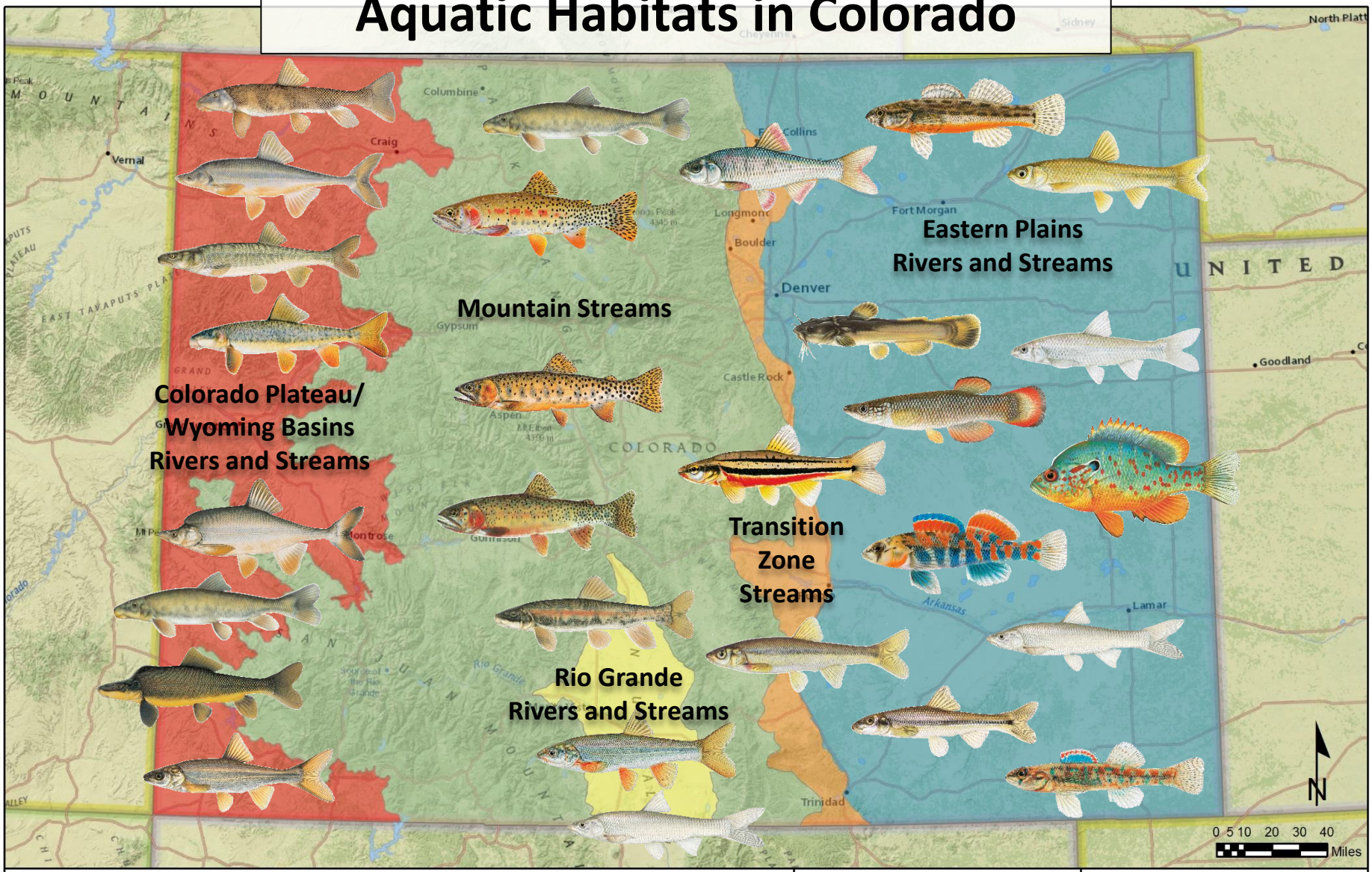
Fausch et al. 2002

Scale



Fausch et al. 2002

Aquatic Habitats in Colorado



- Eastern Plains
- Mountain Streams
- Rio Grande
- Transition Zone
- Wyoming Basin/Colorado Plateau

AQUATIC ZONES	
DRAWN: ERICHER	6/23/2017
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

COLORADO STATE WILDLIFE
ACTION PLAN 2015

Brassy Minnow Vs. Cutthroat Trout

Biology

Physicochemical

Geomorphology

Hydraulics

Hydrology

Courtesy Will Harmon, USFWS

Critical Trout Habitat Functions

8) Connectivity

1) Salmonid Forage Production Areas
2) High Flow Refugia
3) Low Flow & Winter Refugia
4) Spawning Habitat
5) Rearing Habitat
6) Overhead Cover
7) Instream Cover

Courtesy Dave Rosgen, Wildland Hydrology

Departure from Natural Forms:

Channelization

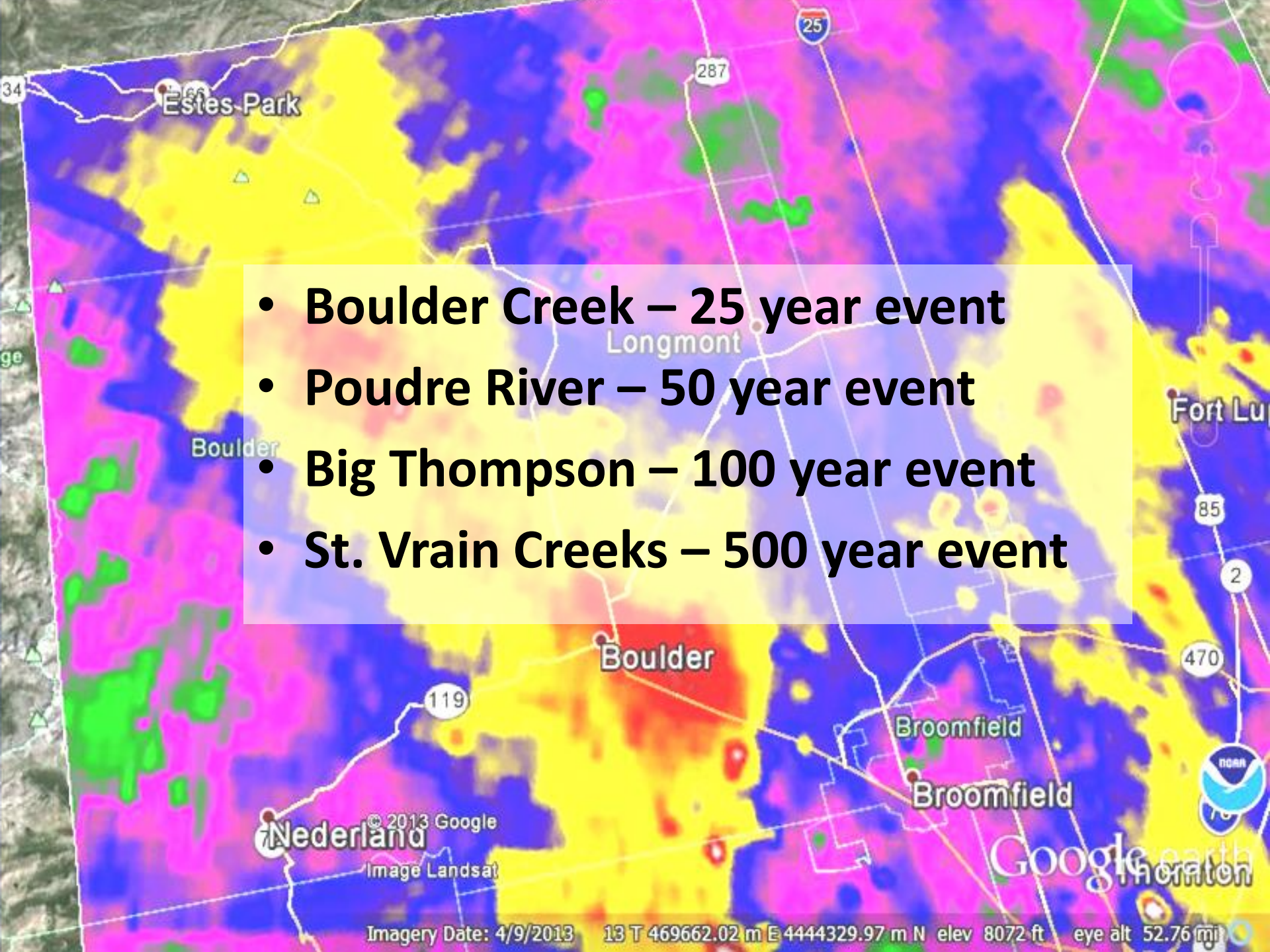
Loss of Floodplain Connectivity

Removal of Wood

Habitat Fragmentation

Altered Hydraulic Conditions

The Flood…



- Boulder Creek – 25 year event
- Poudre River – 50 year event
- Big Thompson – 100 year event
- St. Vrain Creeks – 500 year event

Benefits from Flood?

- Physical Habitat
  - Recruitment of large wood


October, 2013
Woody debris

Benefits from Flood?

- Physical Habitat
  - Recruitment of large wood
  - Geomorphic benefits to habitat and channel stability


South Fork St Vrain Creek
Bohn Park
Pre-flood, April 2012


South Fork St Vrain Creek
Bohn Park
Post-flood, October 2013

Benefits from Flood?

- Physical Habitat
  - Recruitment of large wood
  - Geomorphic benefits to habitat and channel stability
  - Recruitment of inchannel boulders

Benefits from Flood?

- Physical Habitat
  - Recruitment of large wood
  - Geomorphic benefits to habitat and channel stability
  - Recruitment of inchannel boulders
- Biological
  - Disturbance and re-setting vegetative communities

Benefits from Flood?

- Physical Habitat
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- Biological
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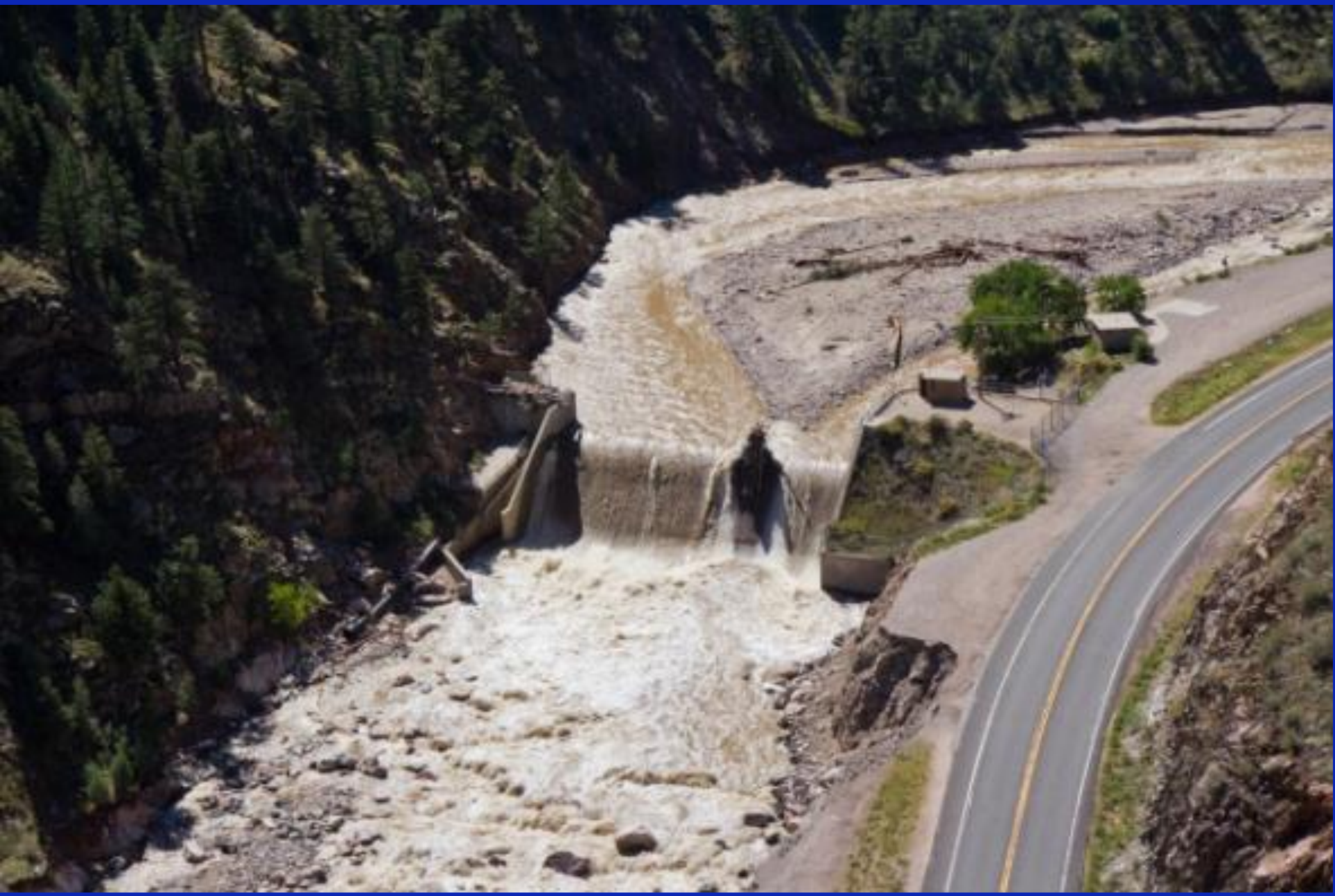
  - Improve connectivity at damaged and destroyed diversions/dams



Benefits from Flood?

- Physical Habitat
  - Recruitment of large wood
  - Geomorphic benefits to habitat and channel stability
  - Recruitment of inchannel boulders

- Biological
  - Disturbance and re-setting vegetative communities
  - Improve connectivity at damaged and destroyed diversions/dams
  - Fish populations

What impact did the flood have on trout populations?

- Post-flood fish surveys conducted at multiples sites in severely impacted locations

- Trout abundance variable ranging from 58% decline to 89% increase over pre-flood population estimates

Fish Monitoring Stations

0 165 330 660 990 1,320 Feet

N

MONITORING LOCATIONS	
DRAWN: ERICHER	10/17/2014
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

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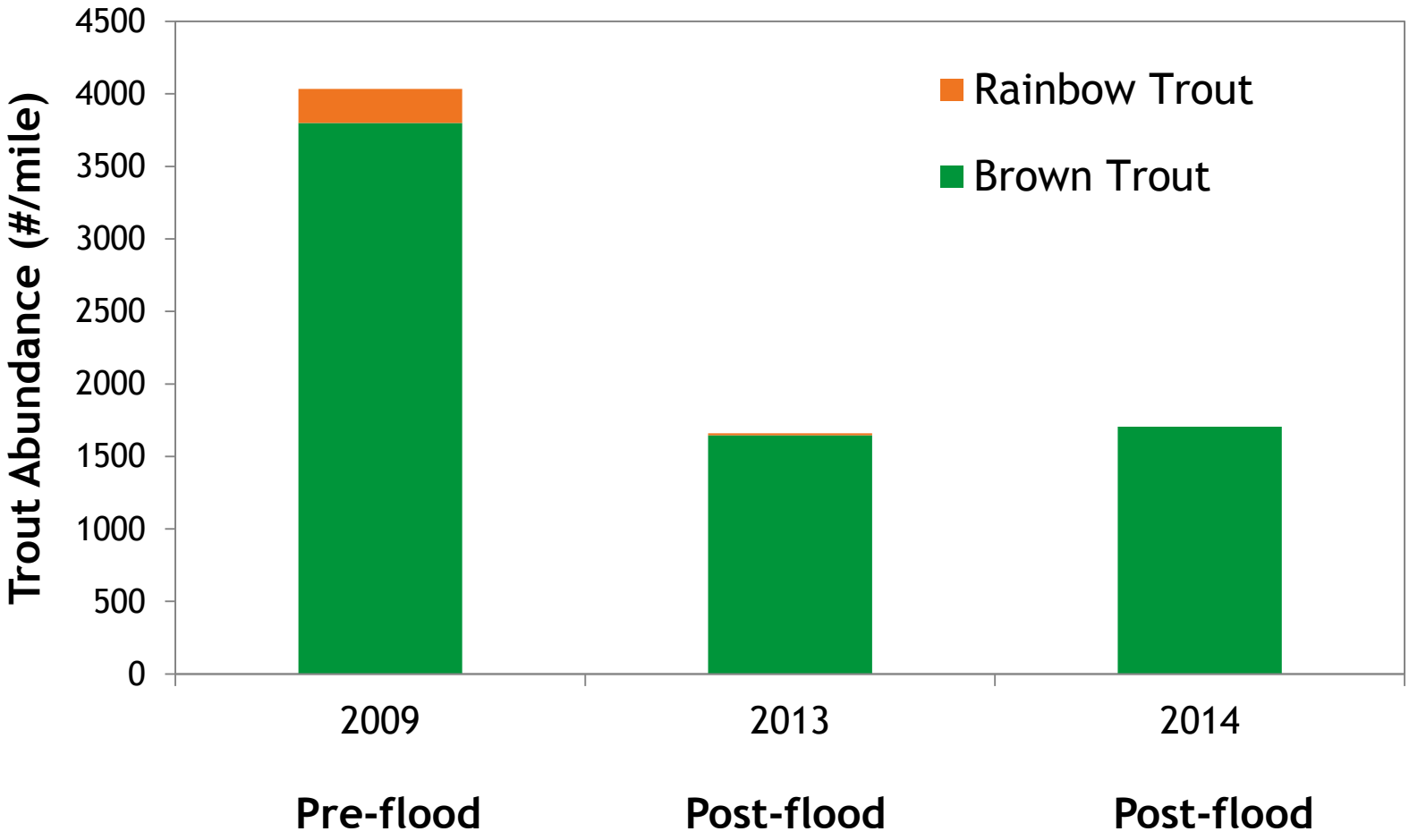
FORT COLLINS, COLORADO

ST VRAIN CREEK
LYONS, COLORADO
PLAN VIEW


North Fork St. Vrain Creek
Meadow Park
Post-flood, September 2013


North Fork St. Vrain Creek
Meadow Park
Post-flood, February 2014

Post-Flood Fishery Assessment: St. Vrain Creek

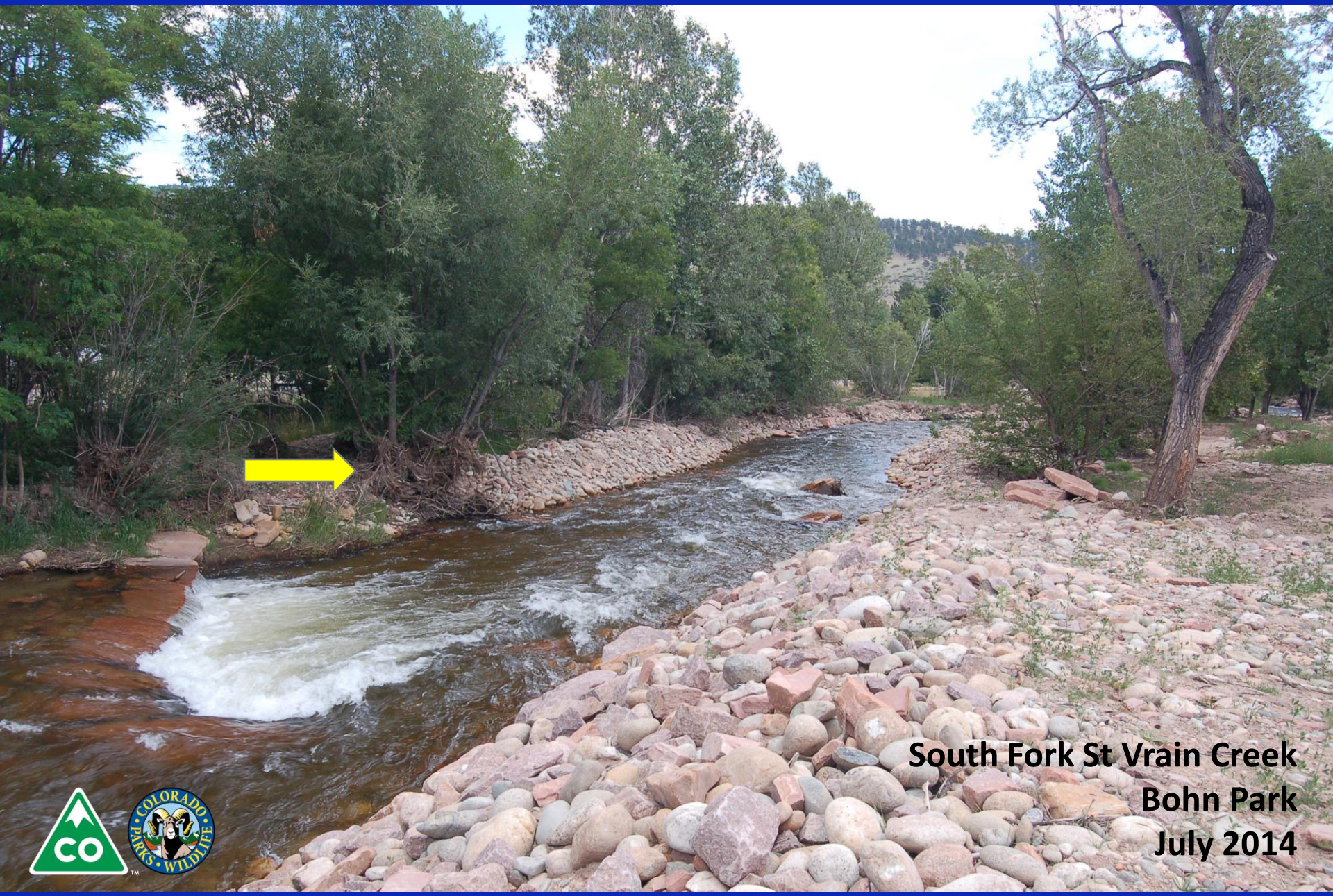


What impact did the post-reconstruction have on trout populations?

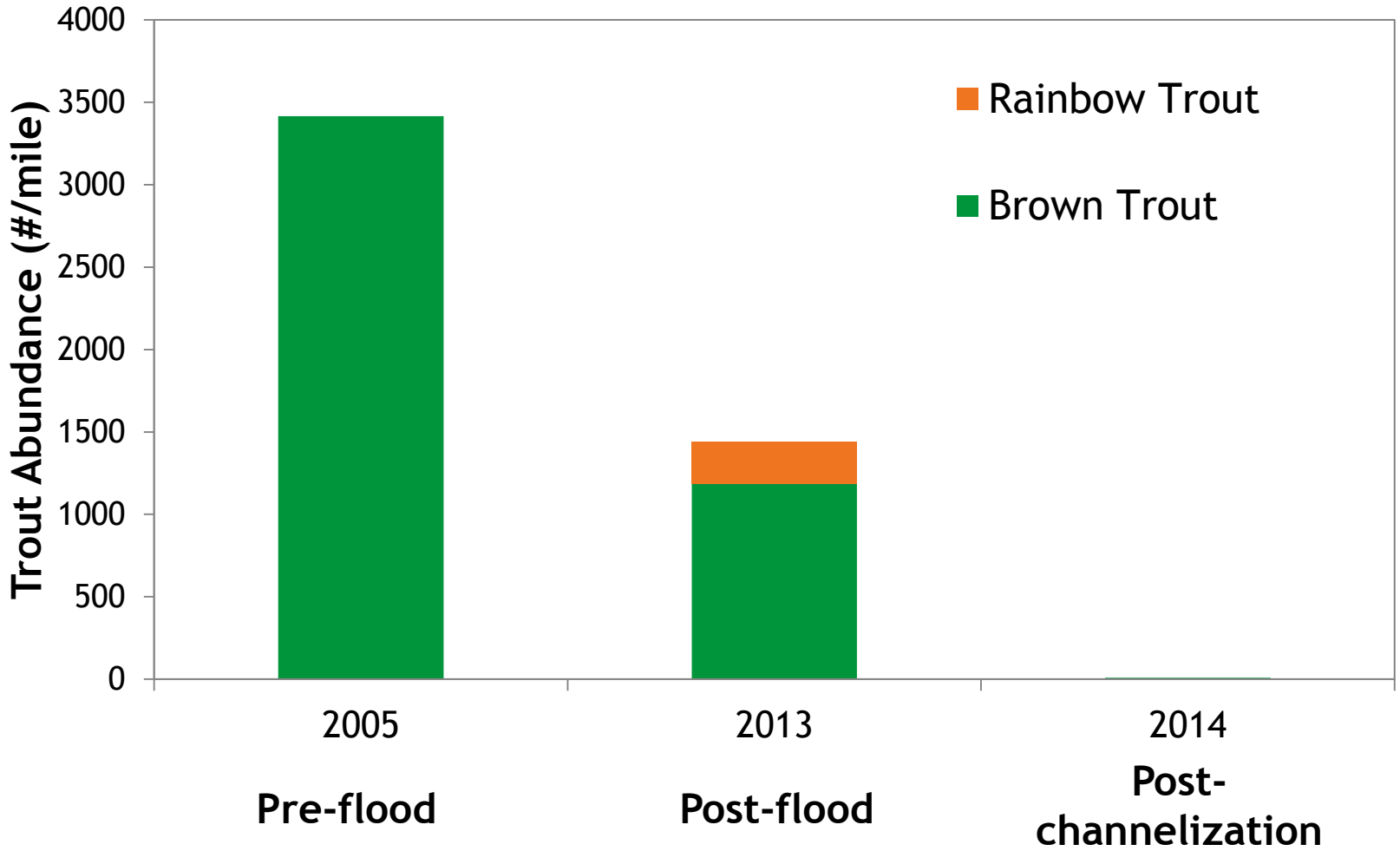
- Post-flood reconstruction sites surveyed after construction activities had ceased
- Trout population abundance declined on average 95% after post-flood reconstruction
- Populations still below pre-flood 3 years after impact from post-flood reconstruction


South Fork St Vrain Creek
Bohn Park
Post-flood, October 2013


South Fork St Vrain Creek
Bohn Park
Post-flood, February 2014


South Fork St Vrain Creek
Bohn Park
July 2014

Post-Flood Fishery Assessment: St. Vrain Creek



The Culprits:

- Channelization
- Armoring

Flood Sites

0 155 310 620 930 1,240 Feet

N

MONITORING LOCATIONS	
DRAWN: ERICHER	10/17/2014
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

STATE OF COLORADO
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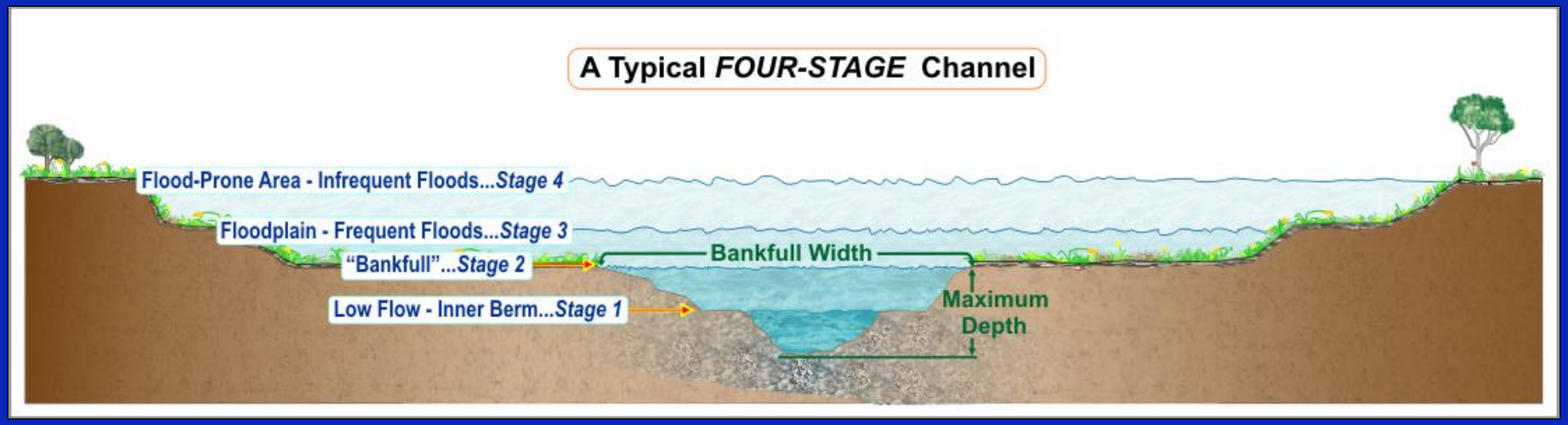
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

LEFTHAND CREEK
PLAN VIEW

Multi-Stage Channel Design



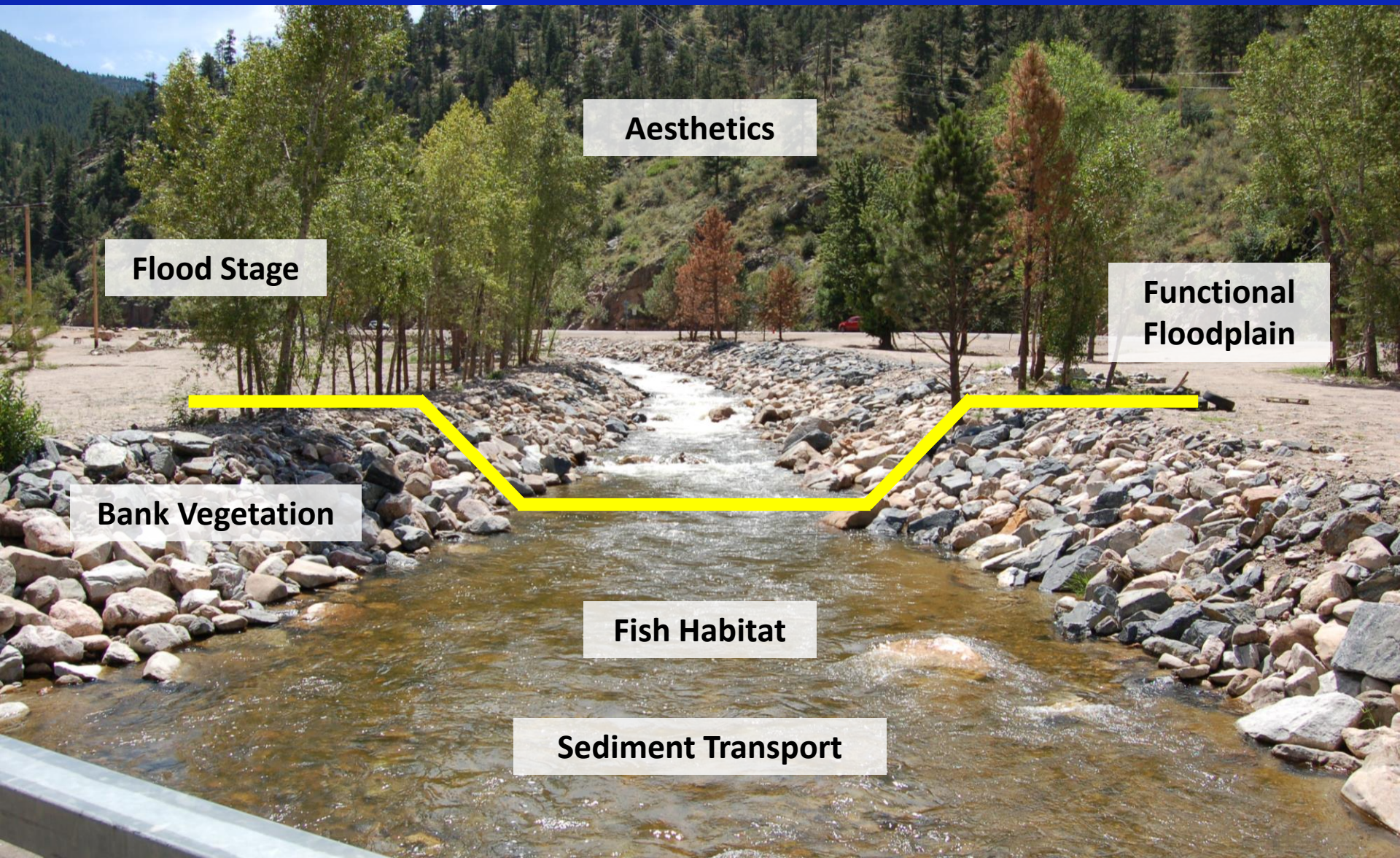
- **Stage 1** – The low flow or inner berm channel
- **Stage 2** – The bankfull stage channel
- **Stage 3** – The active floodplain at the incipient point of flooding
- **Stage 4** – The infrequent but highest flood-level stage

(Used with permission from D.L. Rosgen)


Lefthand Creek
Upstream of HW 119
Post-Flood, 7/7/14


Lefthand Creek
Kanemote Park
Post-Flood, 2/19/14

Trapezoidal Channels



Fish Monitoring Sites

Not Altered

Channelized and Armored

0 0.325 0.65 1.3 1.95 2.6 Miles

N

MONITORING LOCATIONS	
DRAWN: ERICHER	10/17/2014
CHECKED:	
APPROVED:	
SHEET: 1 OF 1	

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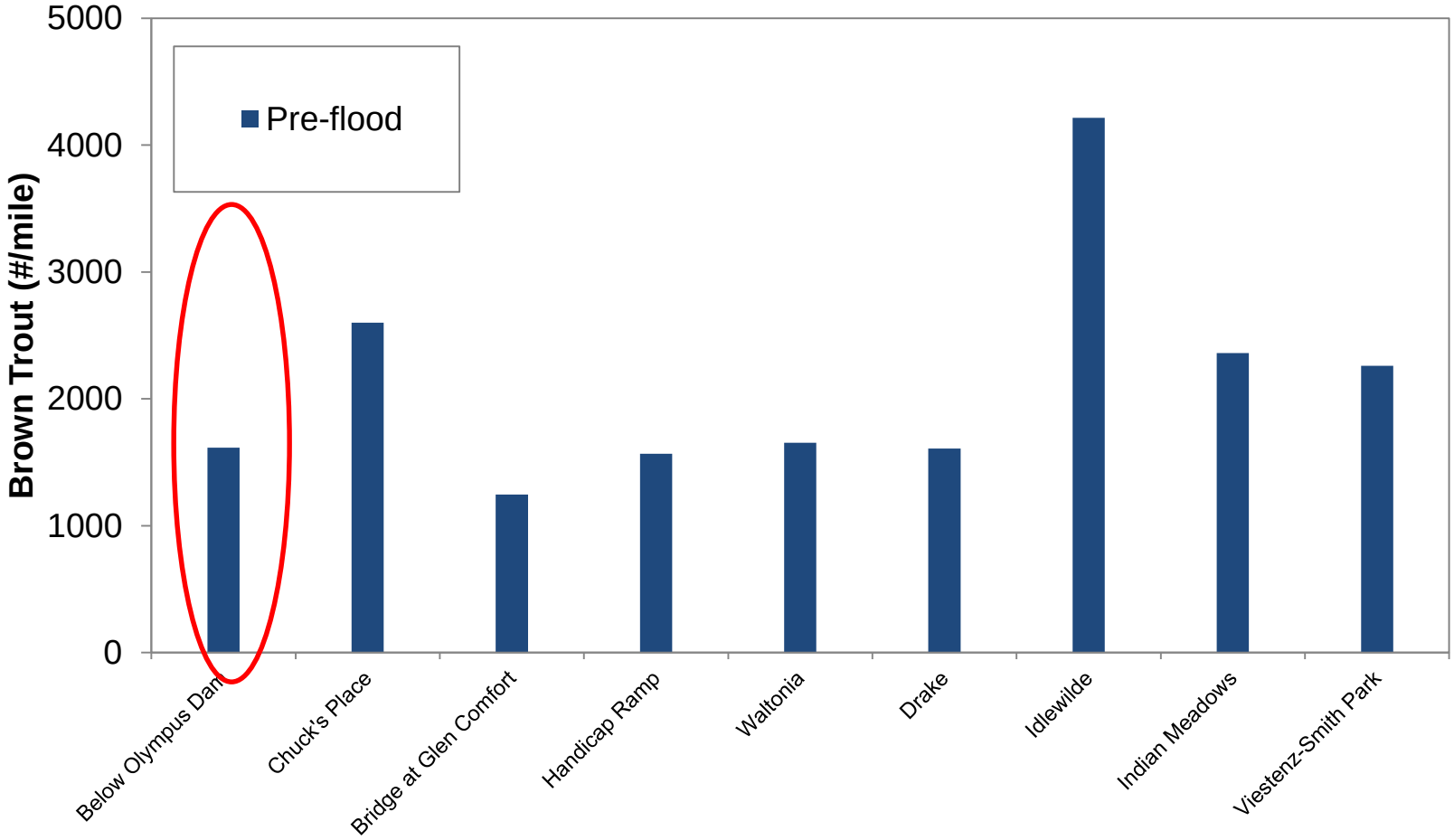
BIG THOMPSON RIVER
PLAN VIEW


Big Thompson River
Below Olympus Dam
1995


Big Thompson River
Below Olympus Dam
September 2013
Parking Area


Big Thompson River
Below Olympus Dam
7/7/2014

Brown Trout : Big Thompson Canyon



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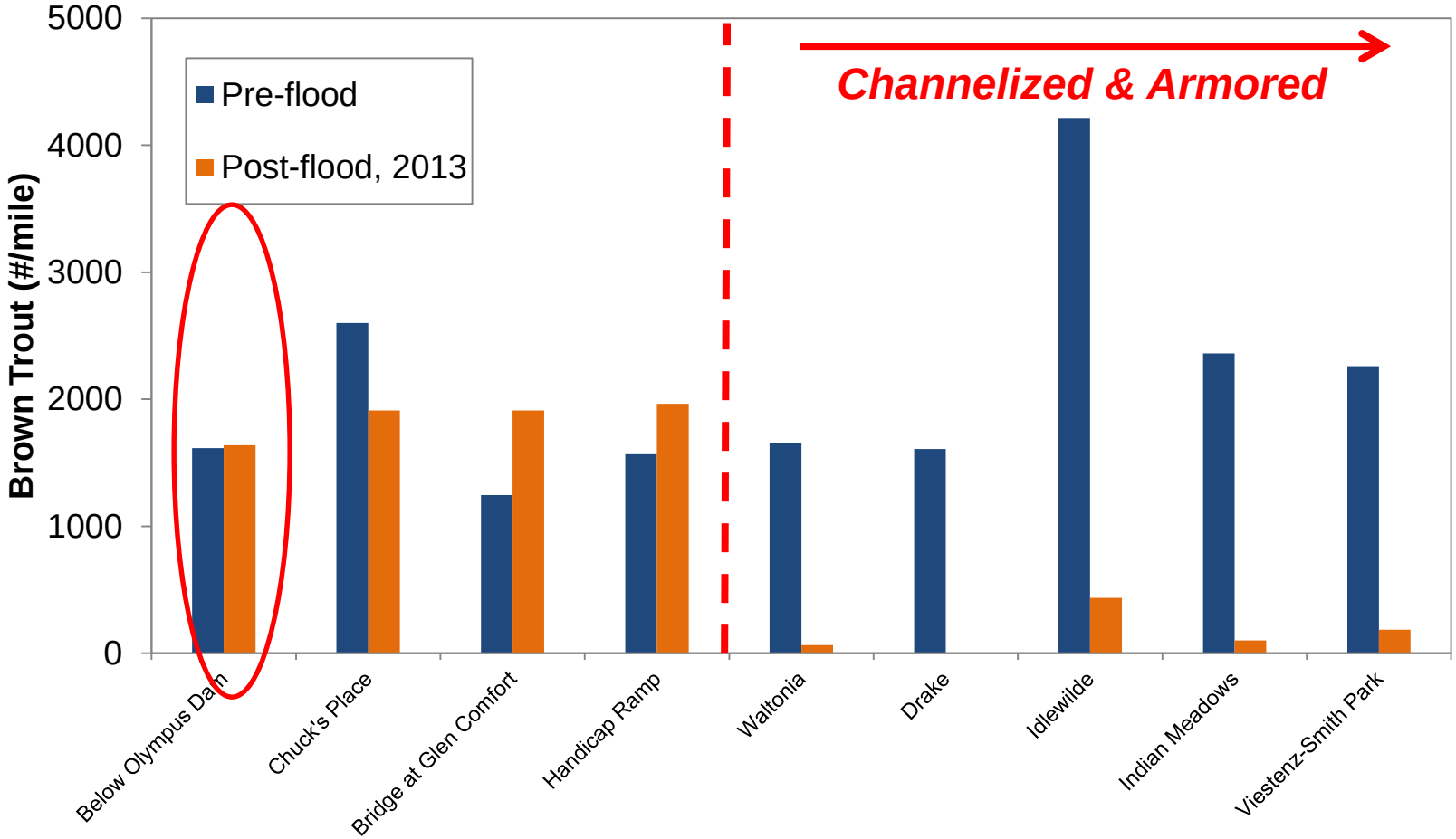
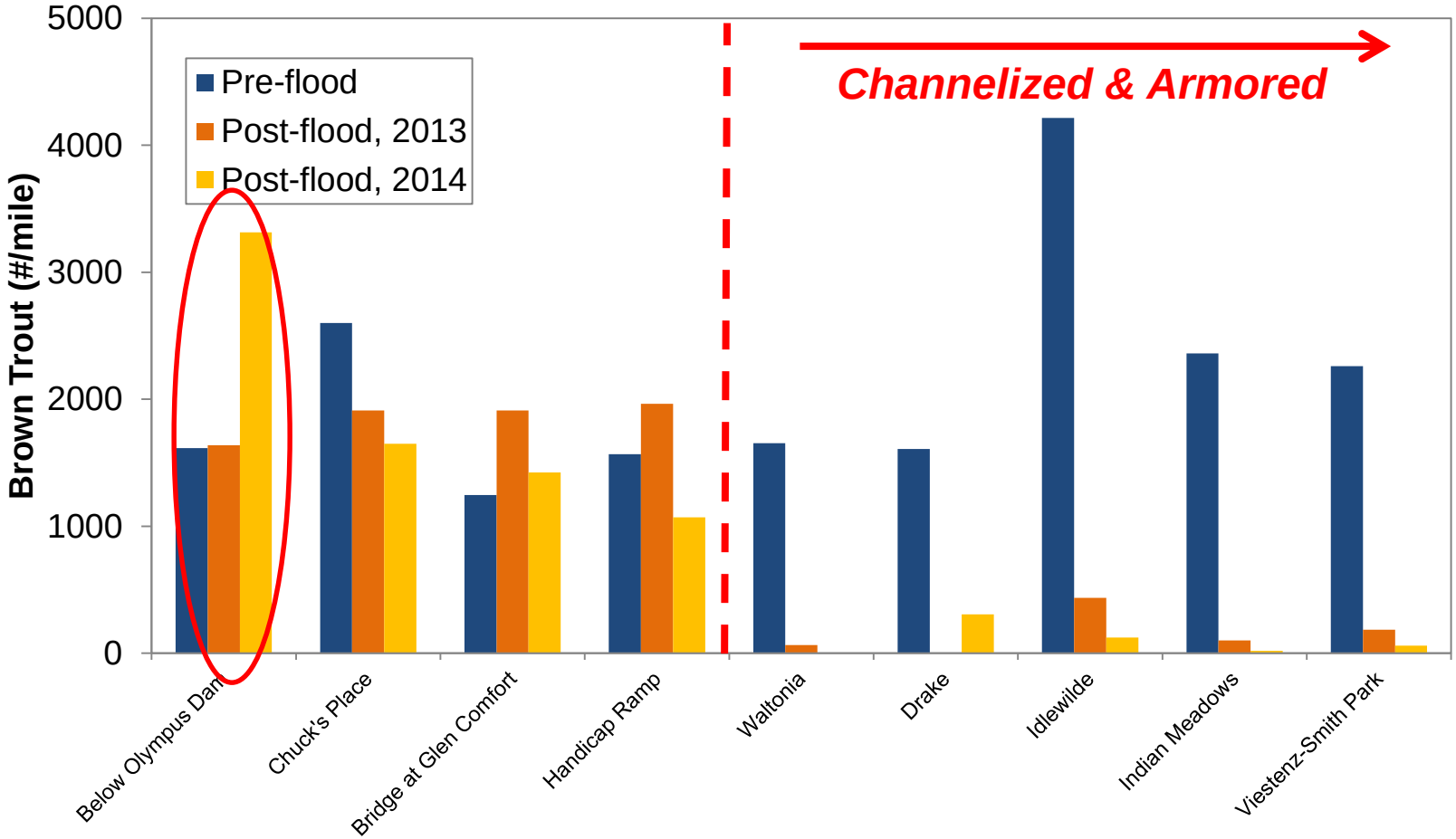


Upstream Sites: 13% increase in abundance
Channelized & Armored: 95% decline in abundance

Brown Trout : Big Thompson Canyon



Upstream Sites: 13% increase in abundance
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Big Thompson River
Drake
11/19/2013


Big Thompson River
Drake
11/19/2013

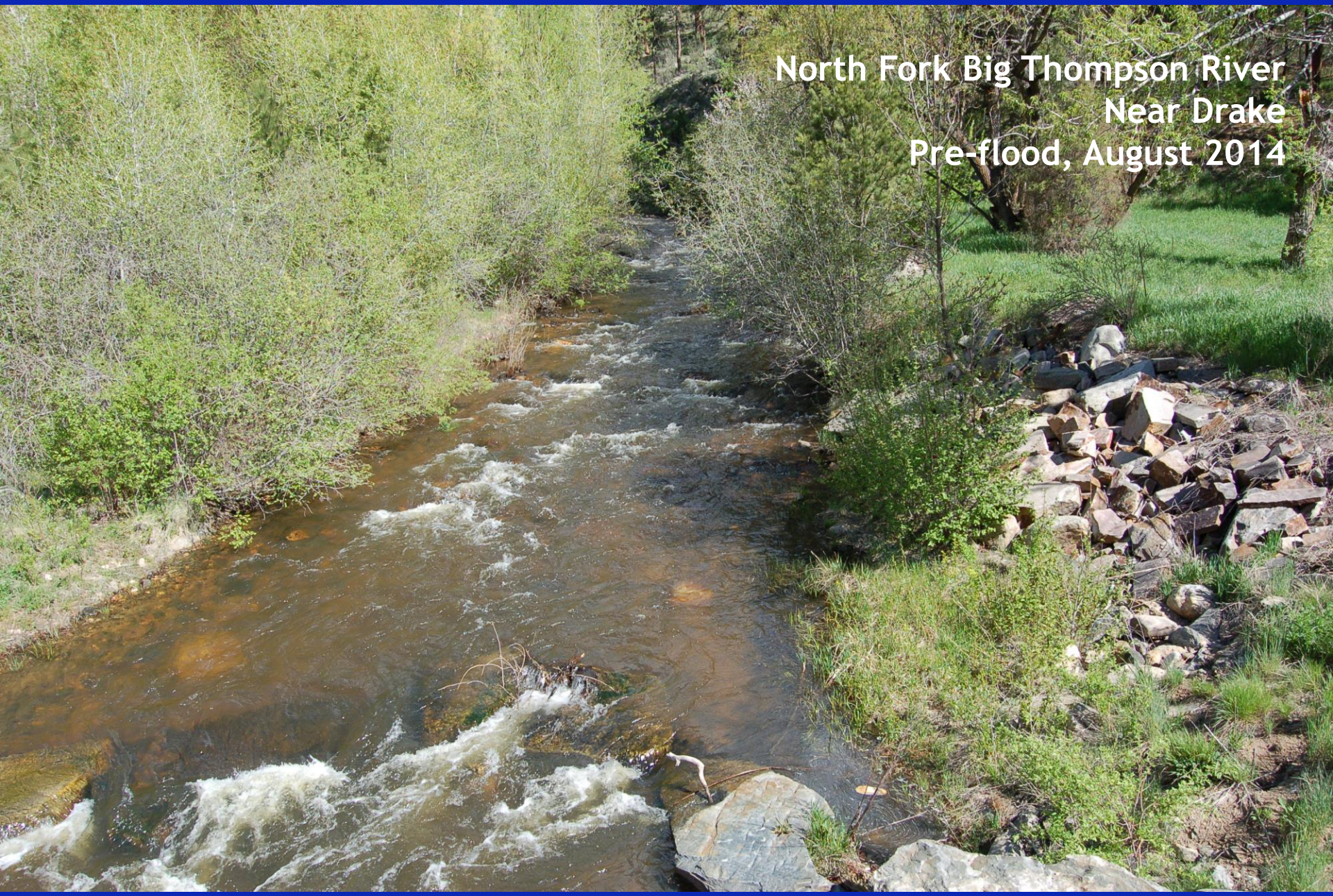

Big Thompson River
Drake
11/19/2013


Big Thompson River
Drake
8/7/2014

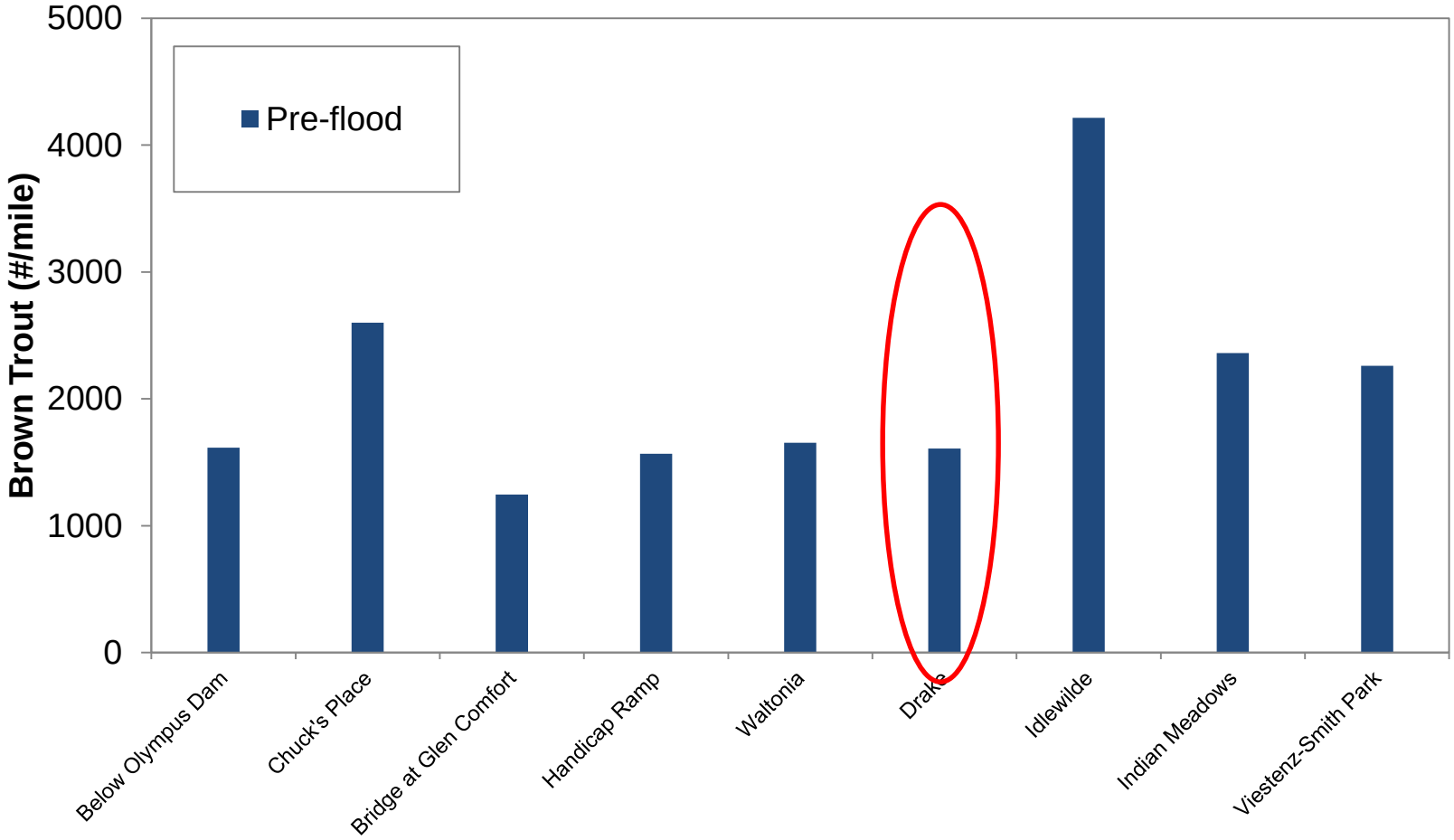

Big Thompson River
Near Drake
Pre-flood, May 2007


Big Thompson River
Near Drake
Post-flood, August 2014


Big Thompson River
Near Drake
Post-flood, August 2015


North Fork Big Thompson River
Near Drake
Pre-flood, August 2014

Brown Trout : Big Thompson Canyon



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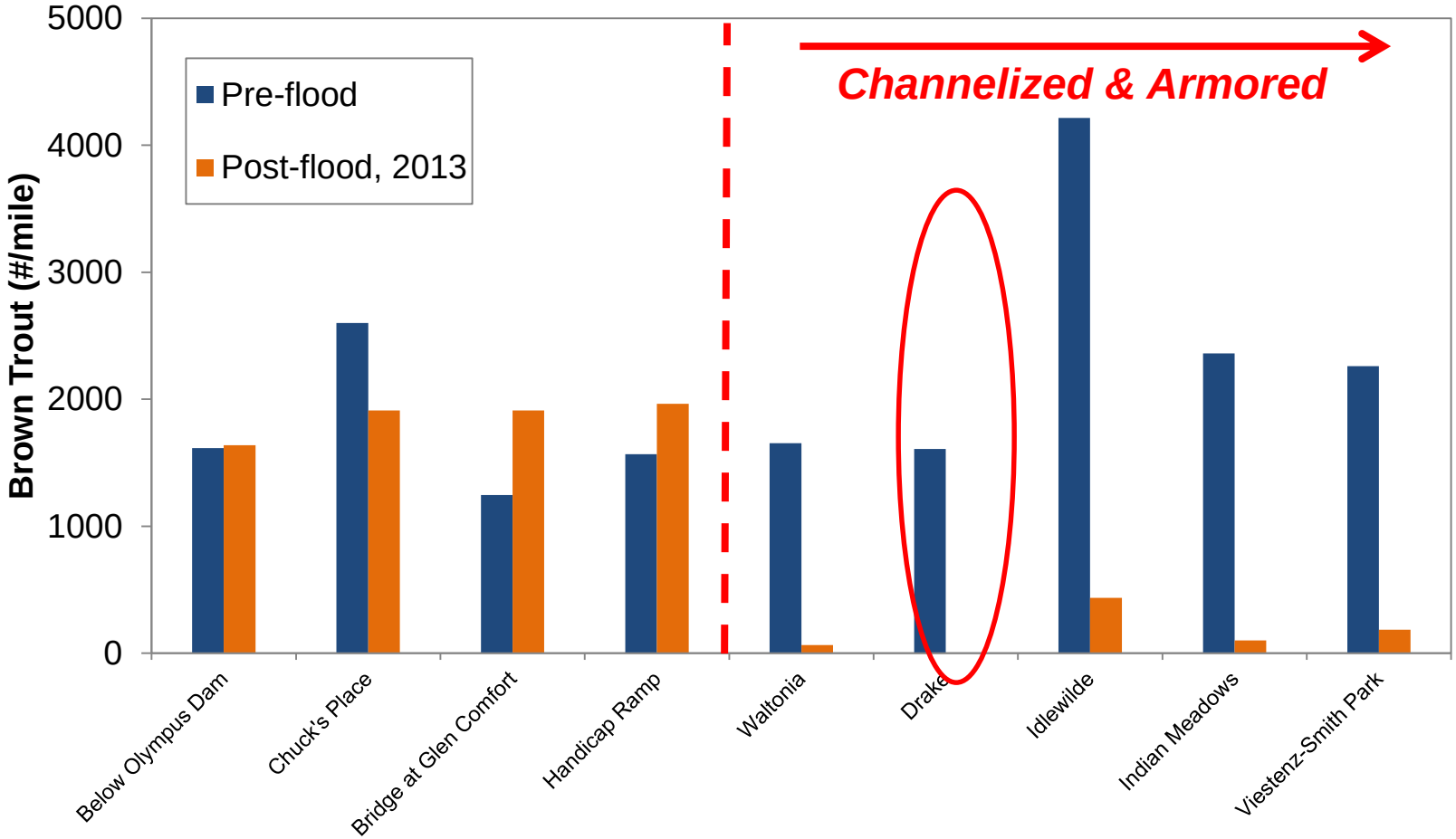

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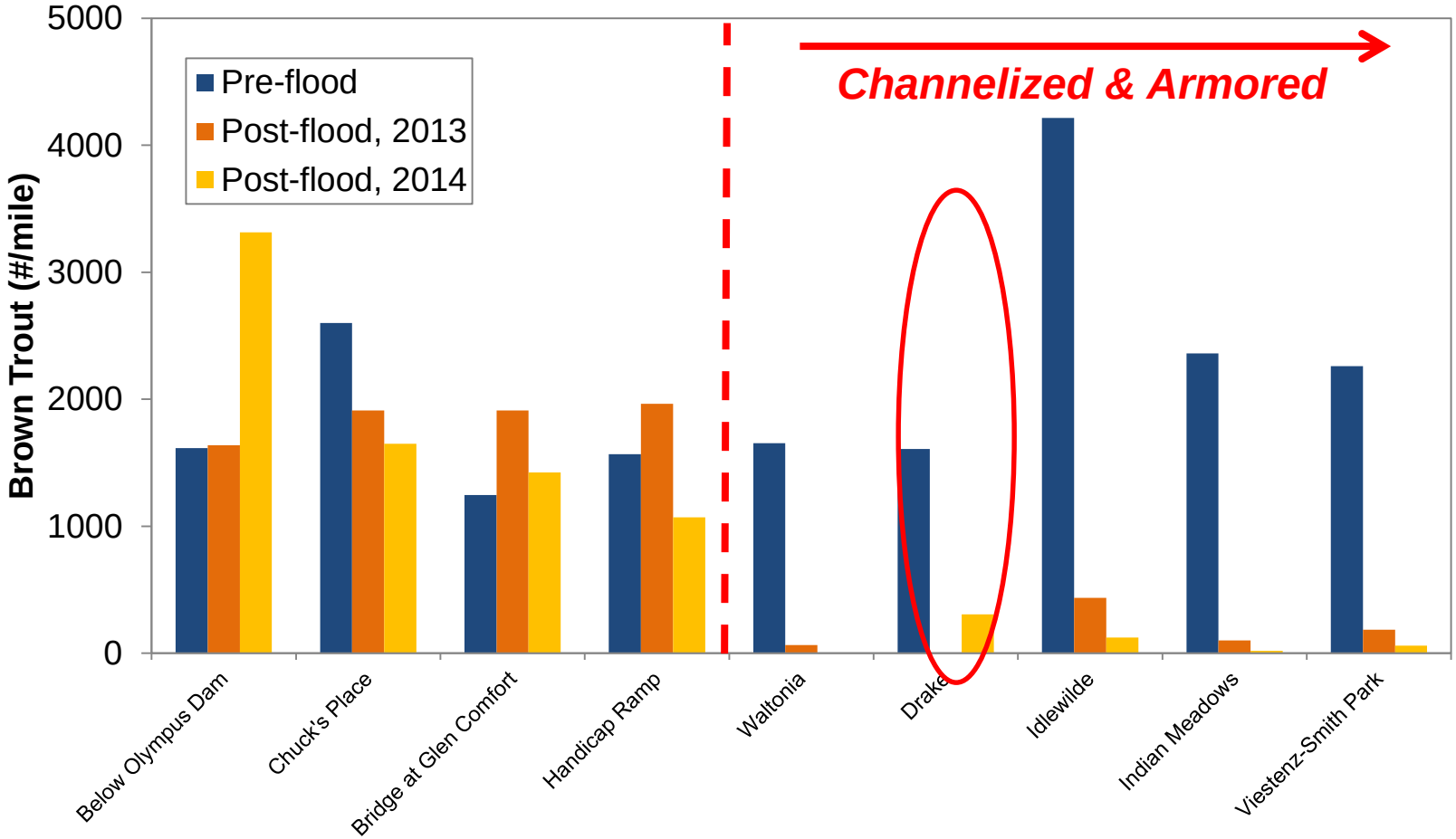


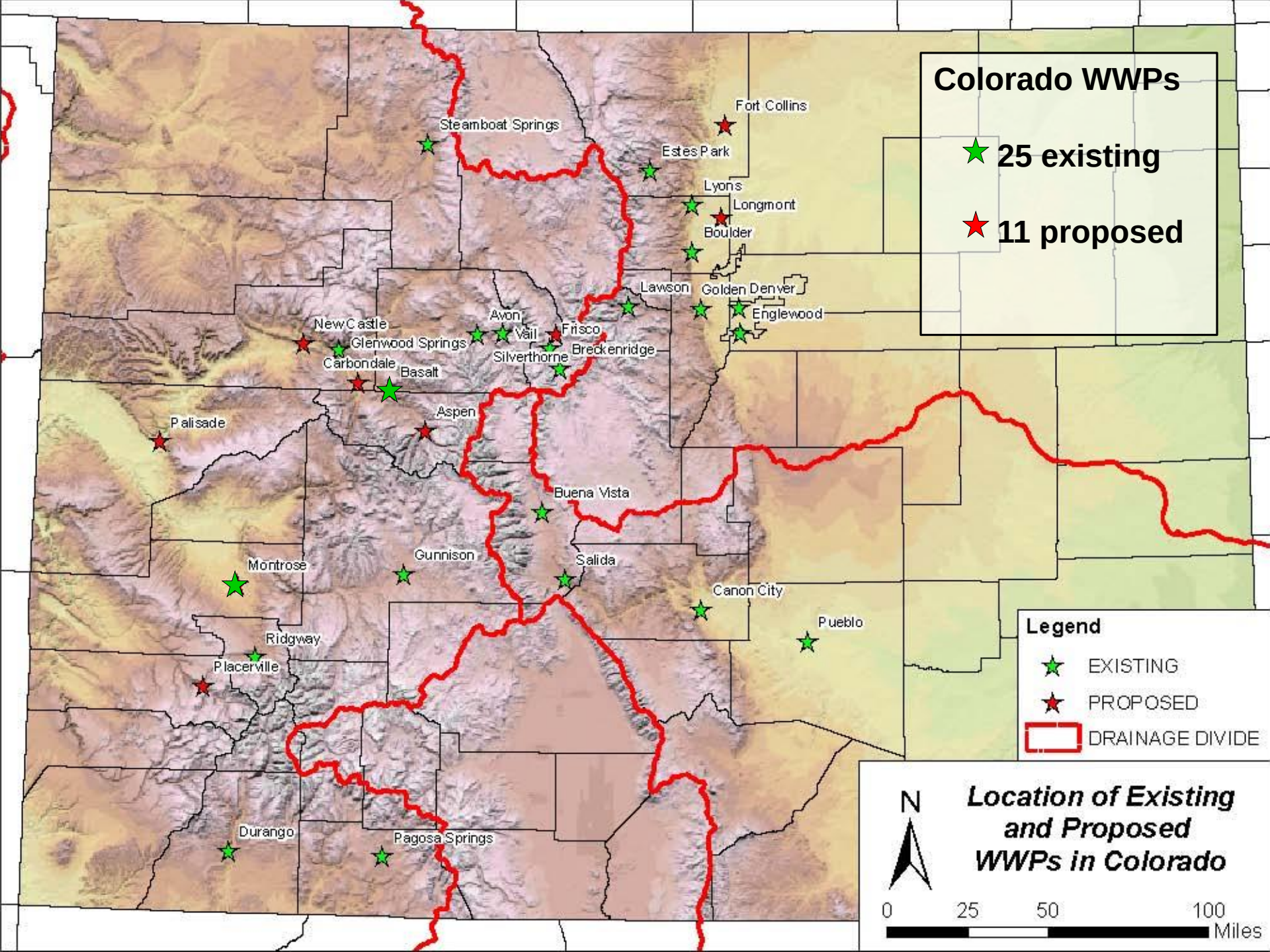
Upstream Sites: 13% increase in abundance
Channelized & Armored: 95% decline in abundance

What is a Whitewater Park?

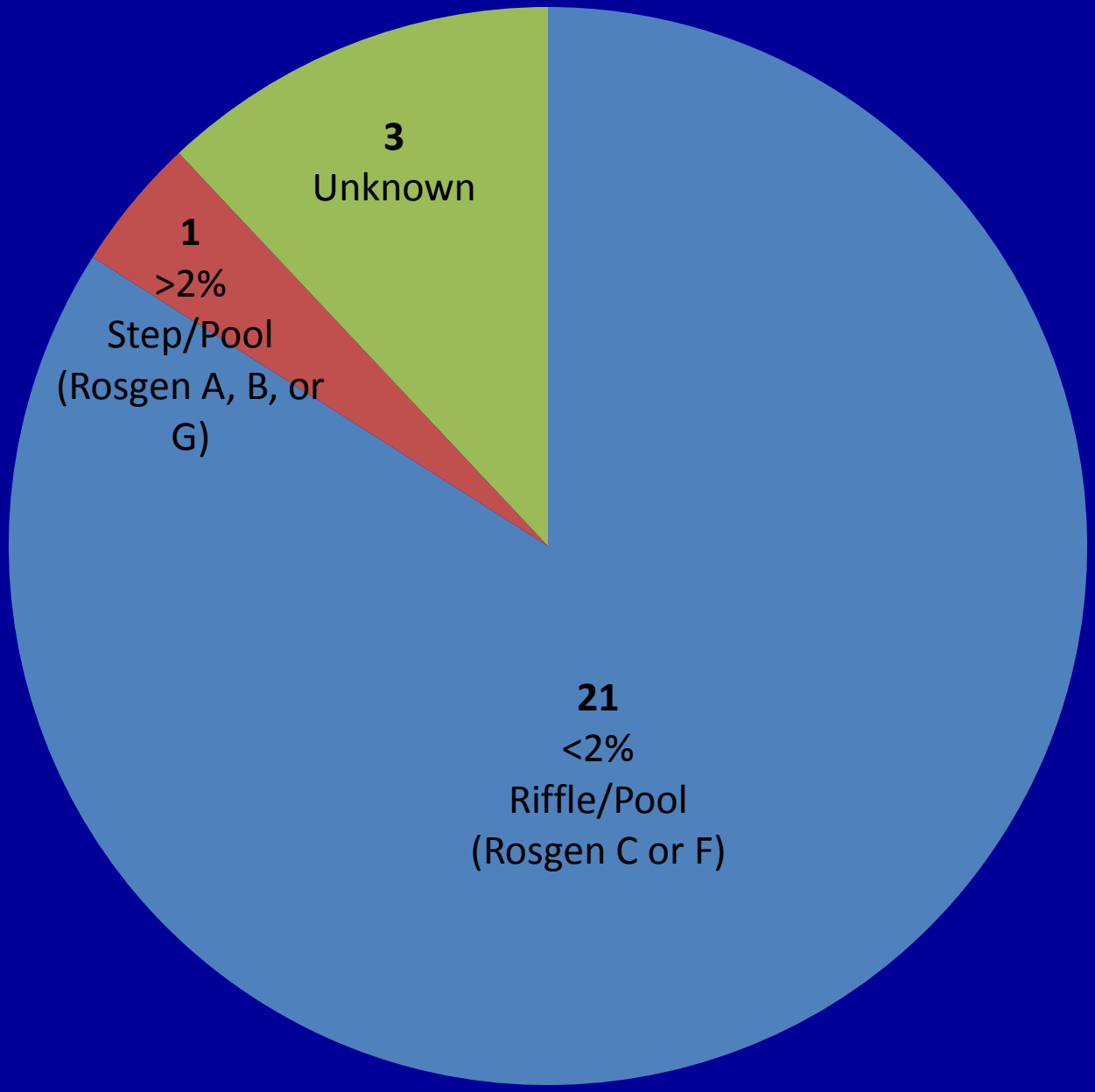
Typical WWP Structures

Chute

Hole

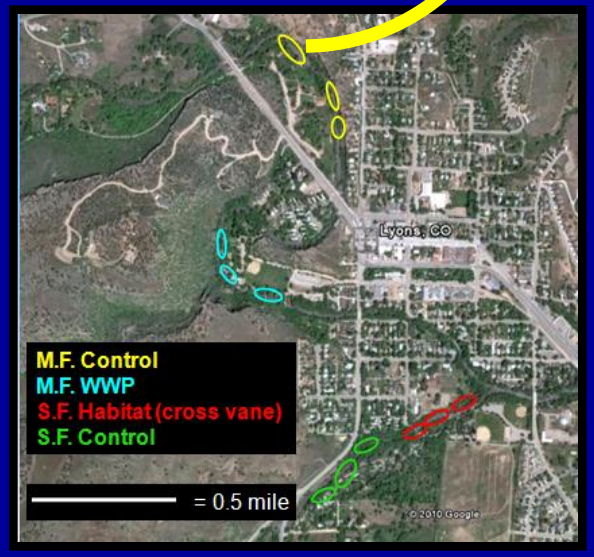

Colorado WWPs
25 existing
11 proposed
Fort Collins
Steamboat Springs
Estes Park
Lyons
Longmont
Boulder
Lawson
Golden
Denver
Englewood
Avon
Vail
Frisco
Breckenridge
Silverthorne
New Castle
Glenwood Springs
Carbondale
Basalt
Aspen
Palisade
Buena Vista
Gunnison
Salida
Montrose
Canon City
Pueblo
Ridgway
Placerville
Durango
Pagosa Springs
Legend
EXISTING
PROPOSED
DRAINAGE DIVIDE
N
Location of Existing and Proposed WWPs in Colorado
0
25
50
100
Miles

WWP Geomorphic Locations

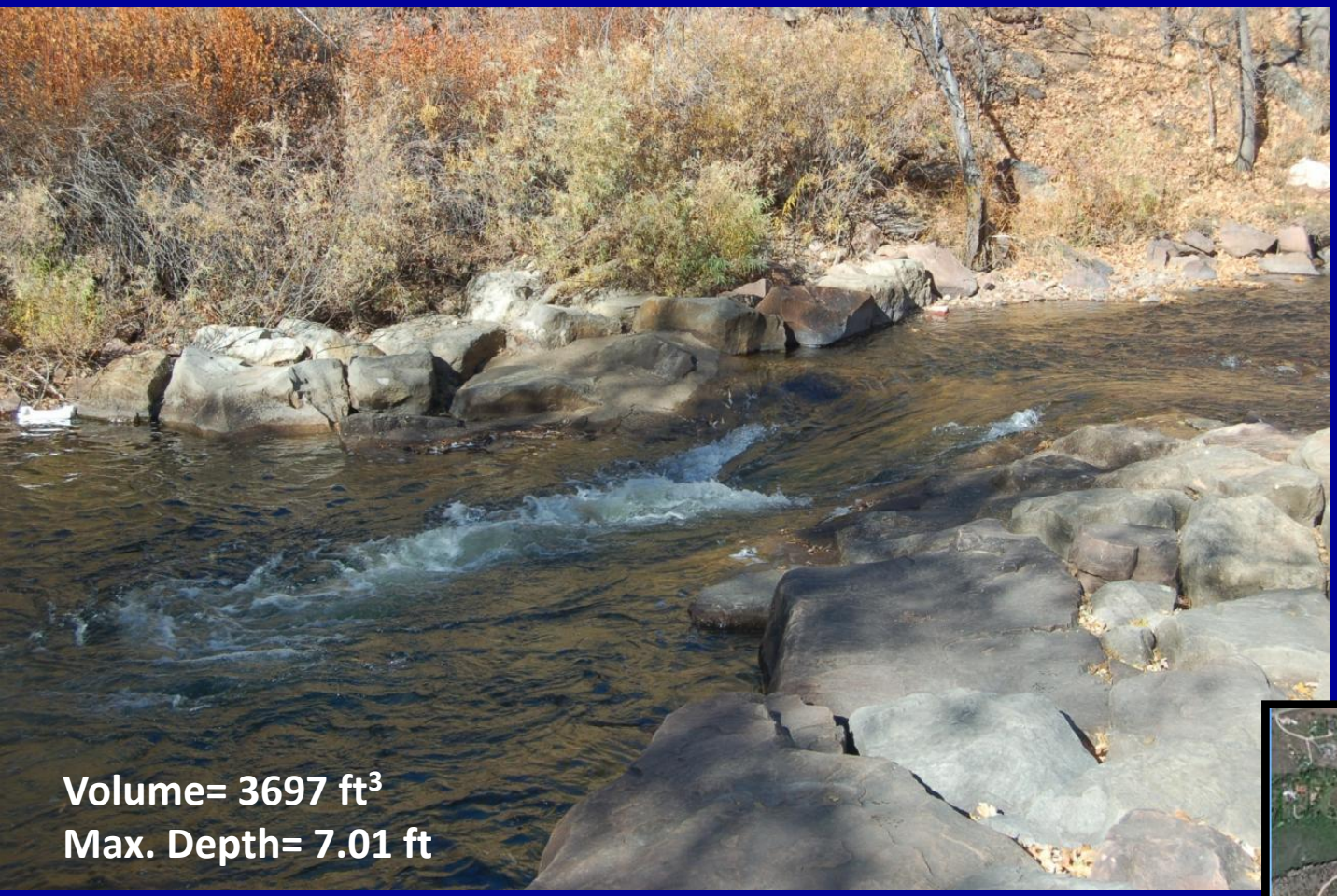


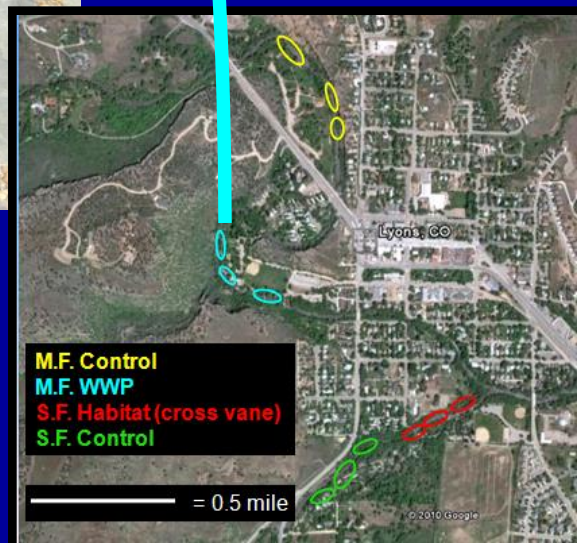
Are WWPs Good Fish Habitat?

Natural Pools

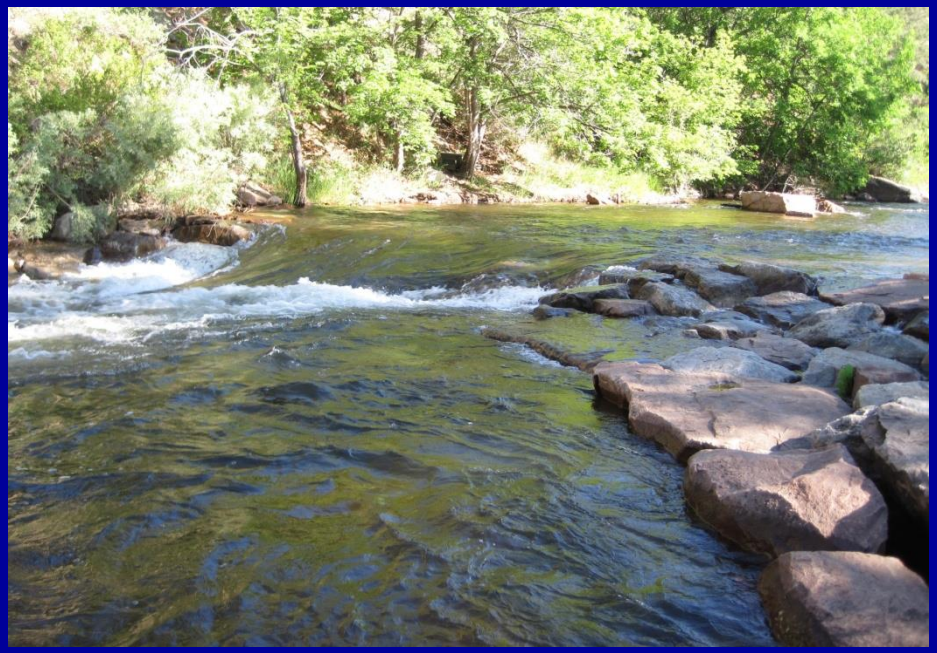


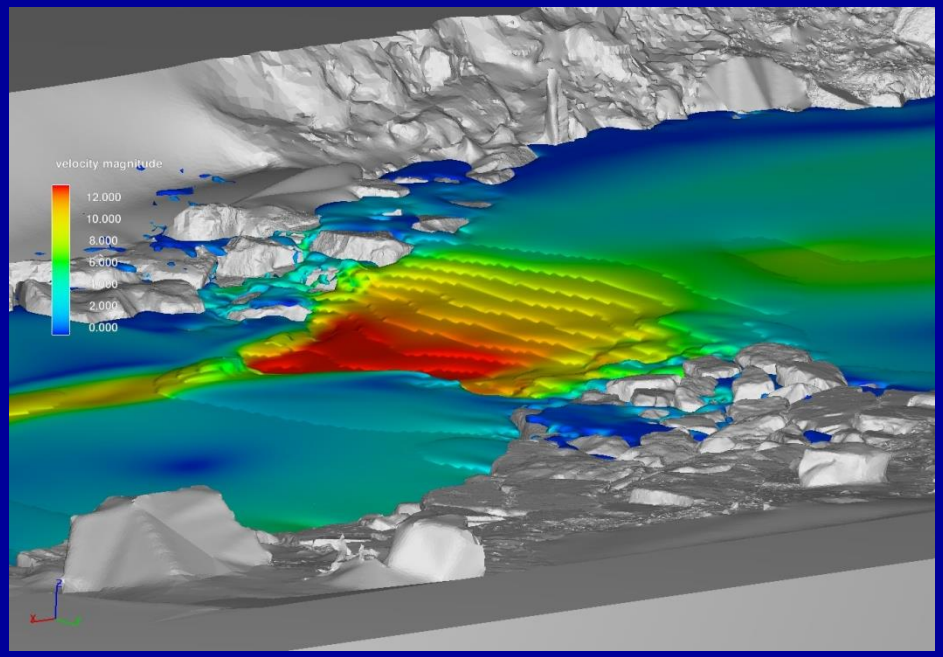
WWP Pools


Volume= 3697 ft³
Max. Depth= 7.01 ft


Lyons, CO
M.F. Control
M.F. WWP
S.F. Habitat (cross vane)
S.F. Control
= 0.5 mile

Fluid dynamics model: FLOW-3D®





Whitewater park drop structure as modeled in FLOW-3D and the actual structure flowing at 173 cfs

Hydraulics: WWP vs Natural Pools

Depth ×2

Velocity ×3

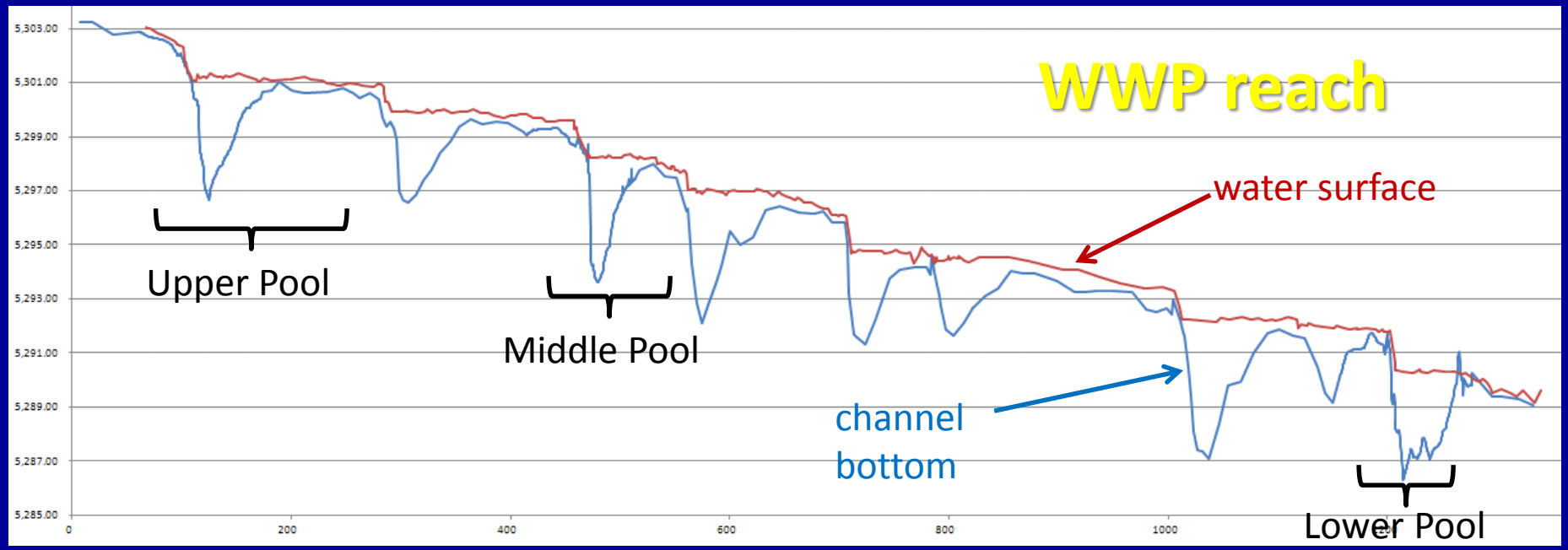
Turbulence ×6

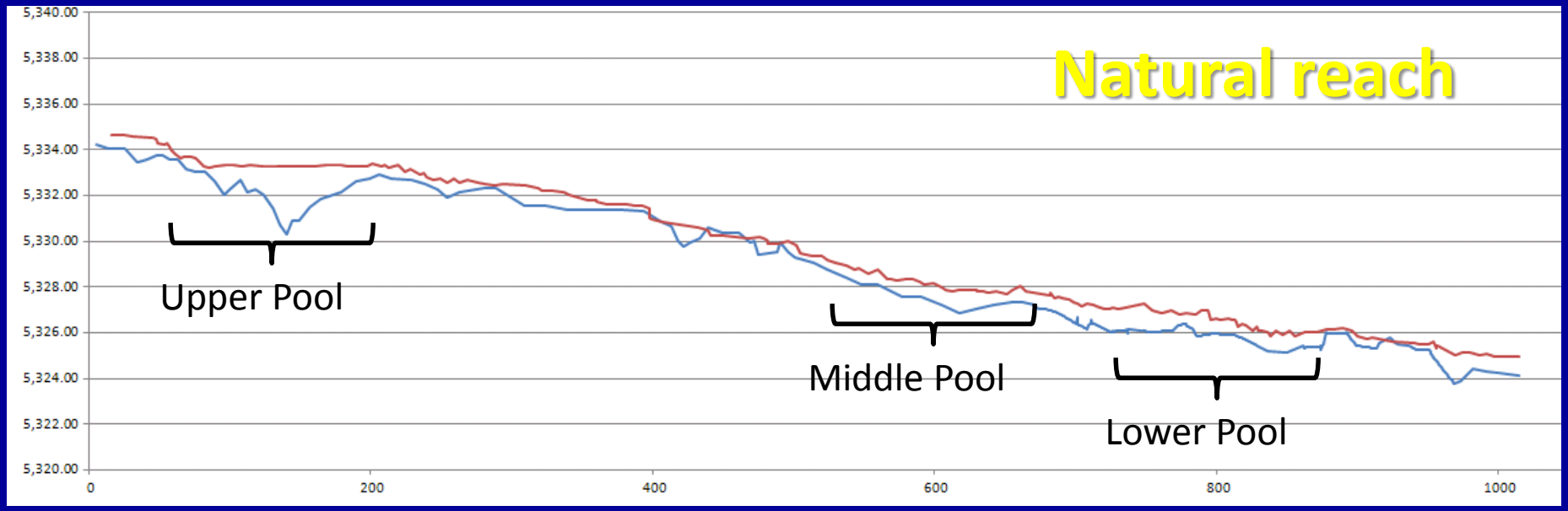
Vorticity ×2

Surging ×40

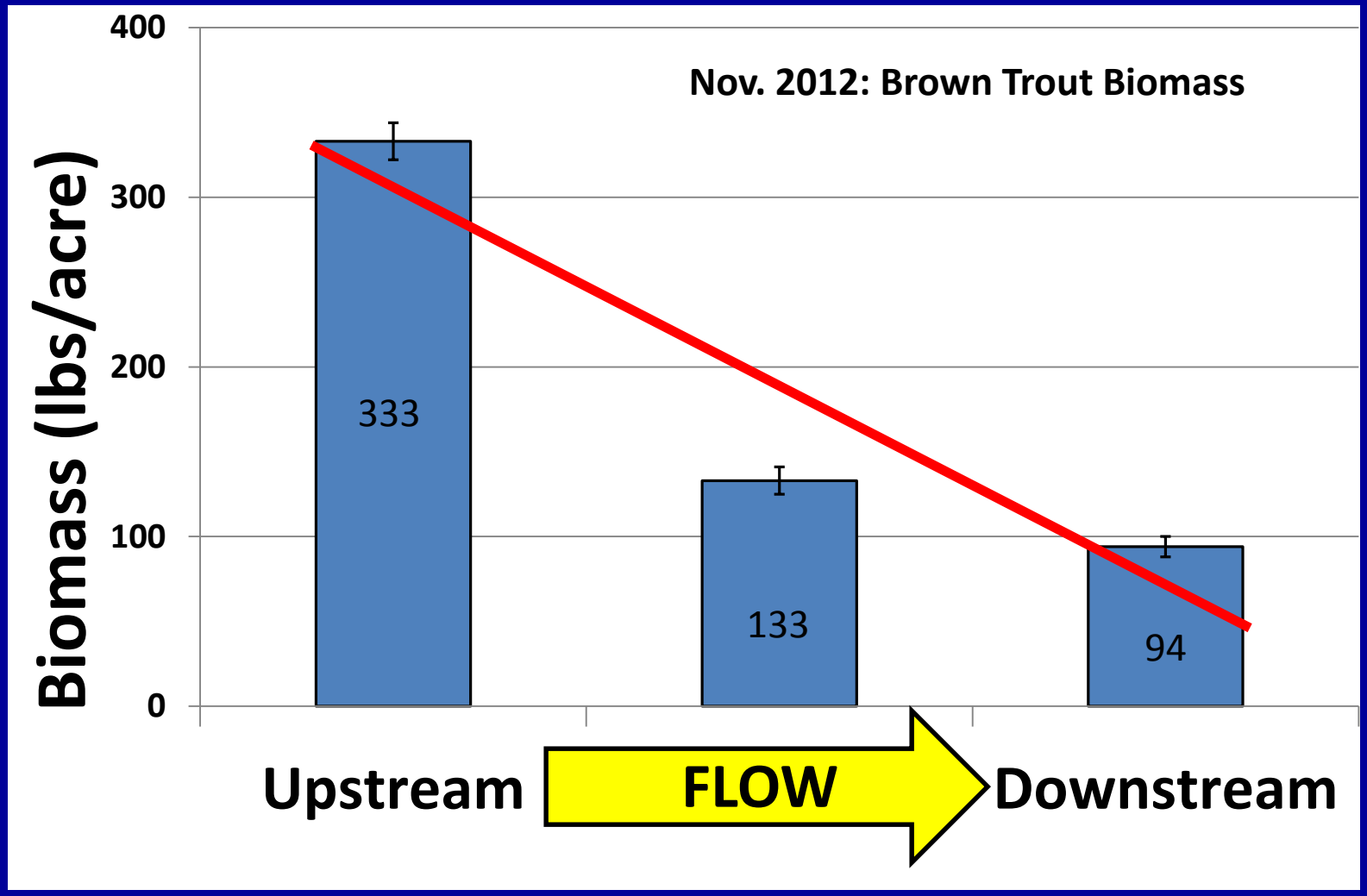
Results - Riffles

Longitudinal Profiles

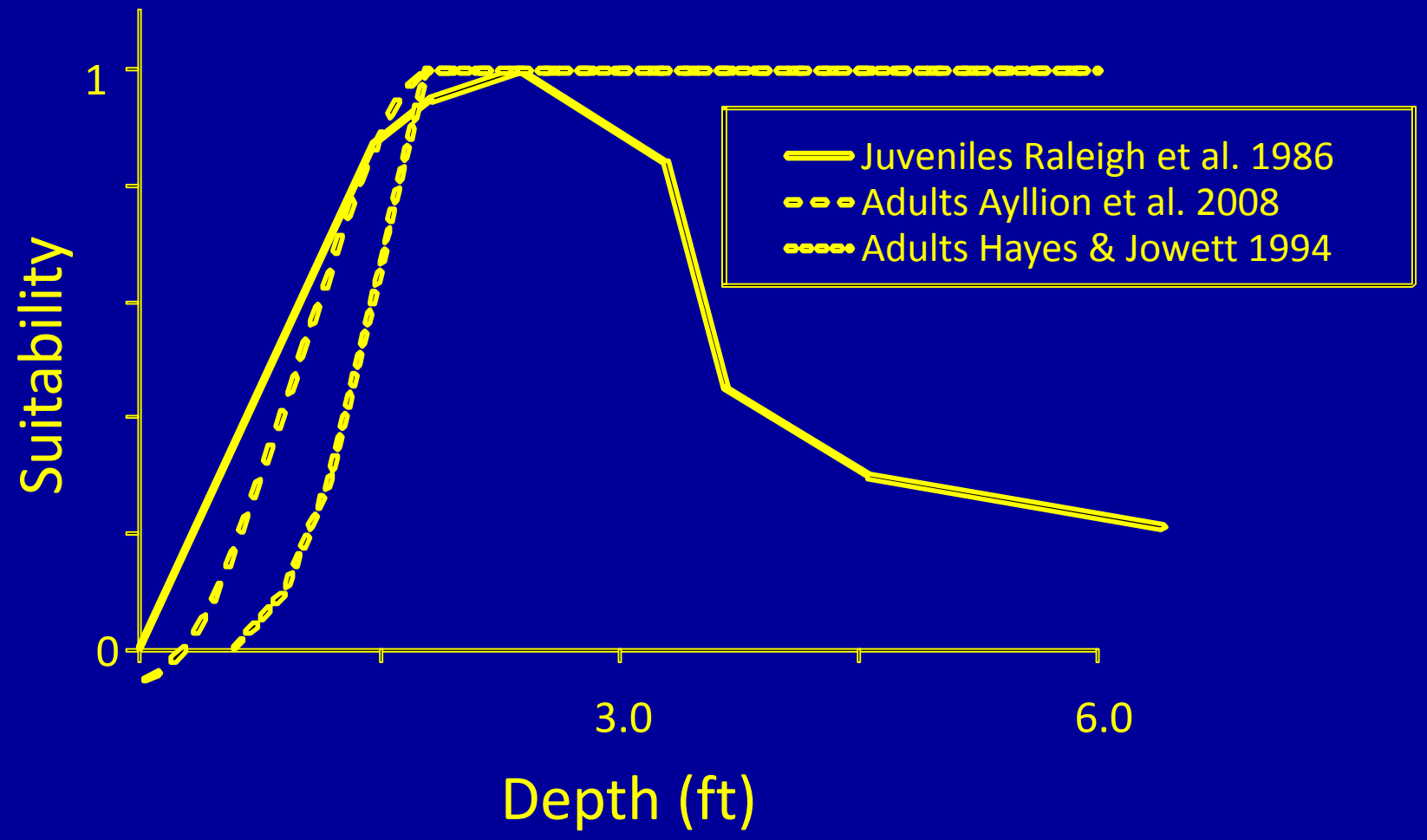


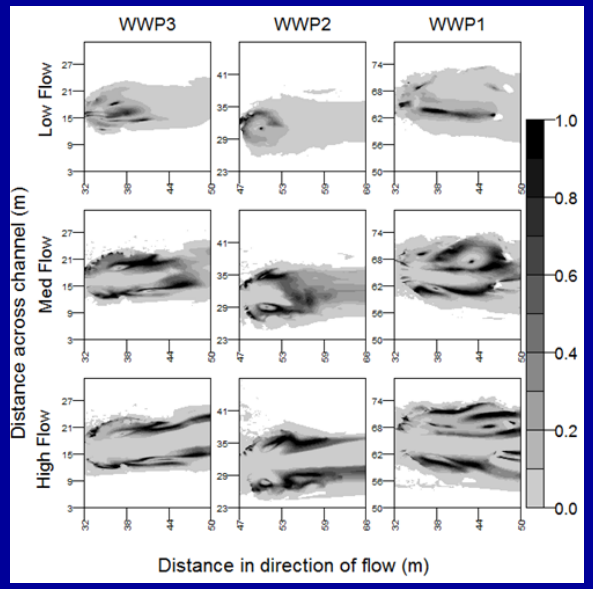


WWP POOLS
What happens when riffles are removed?

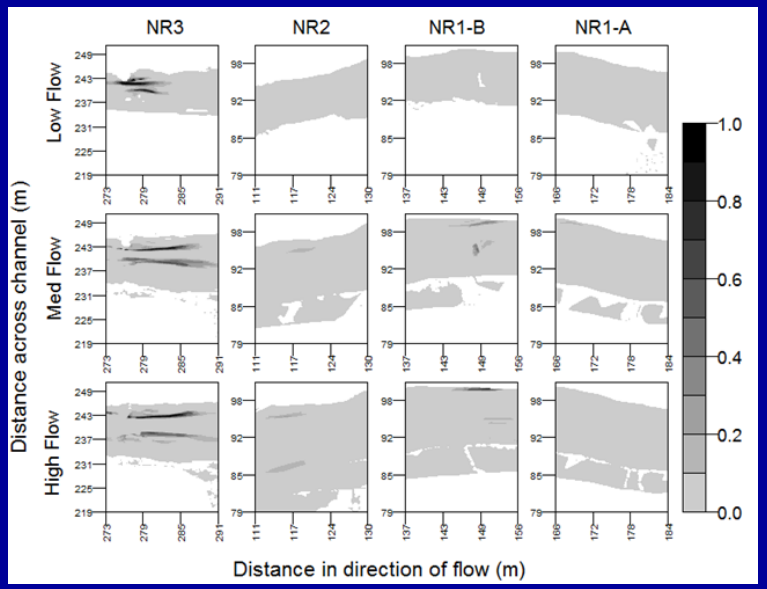


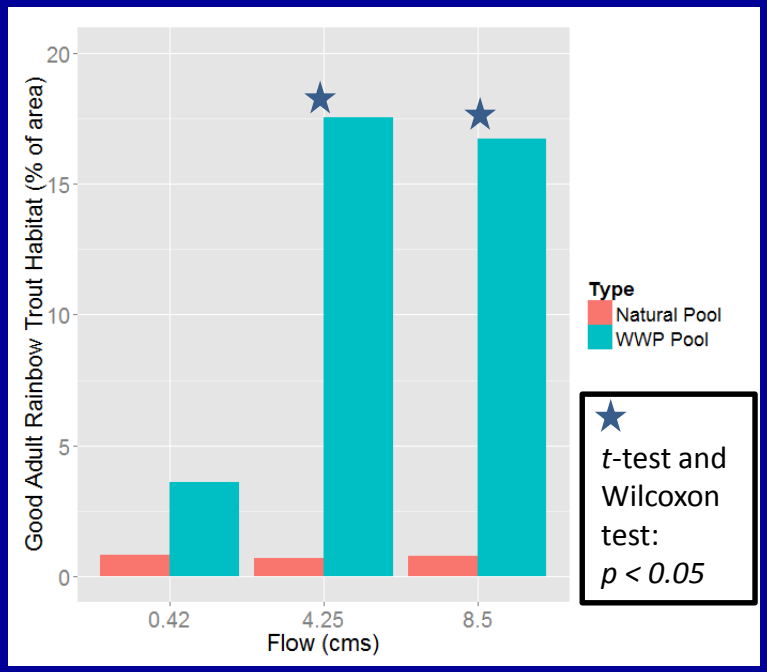
Habitat Suitability Criteria





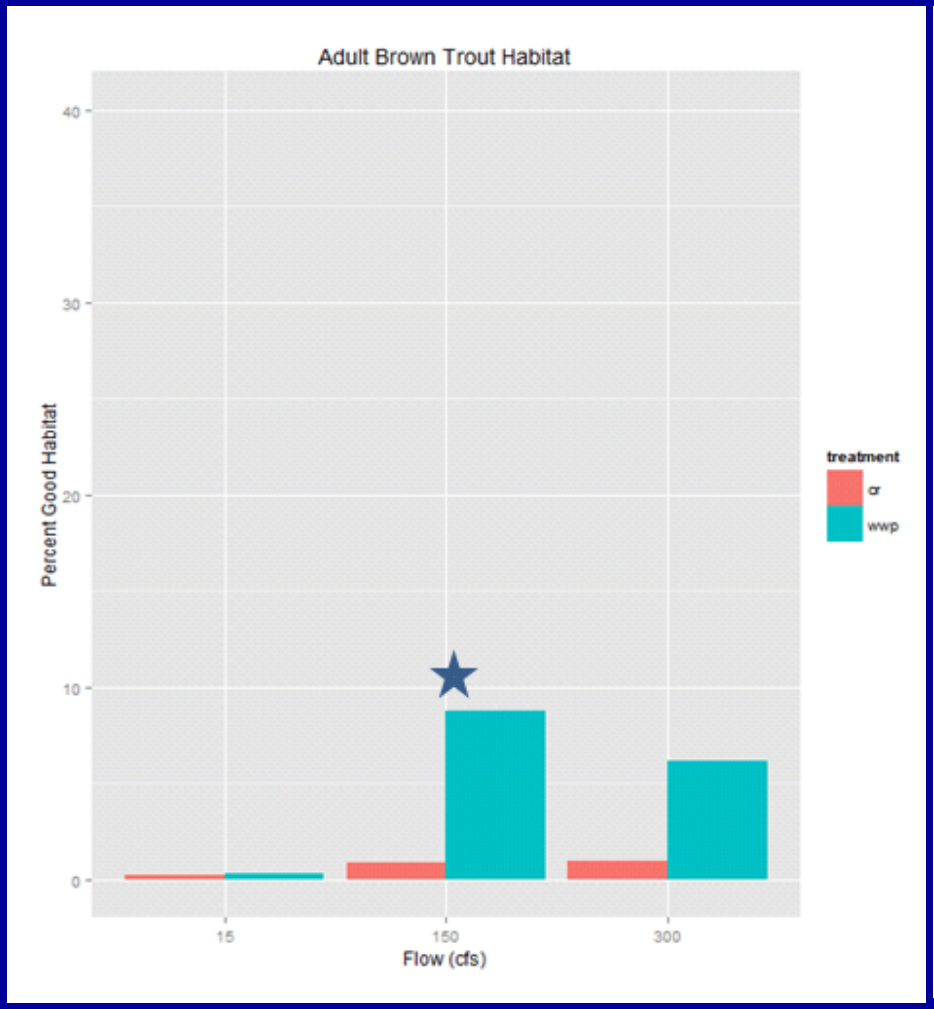
Adult Rainbow Trout



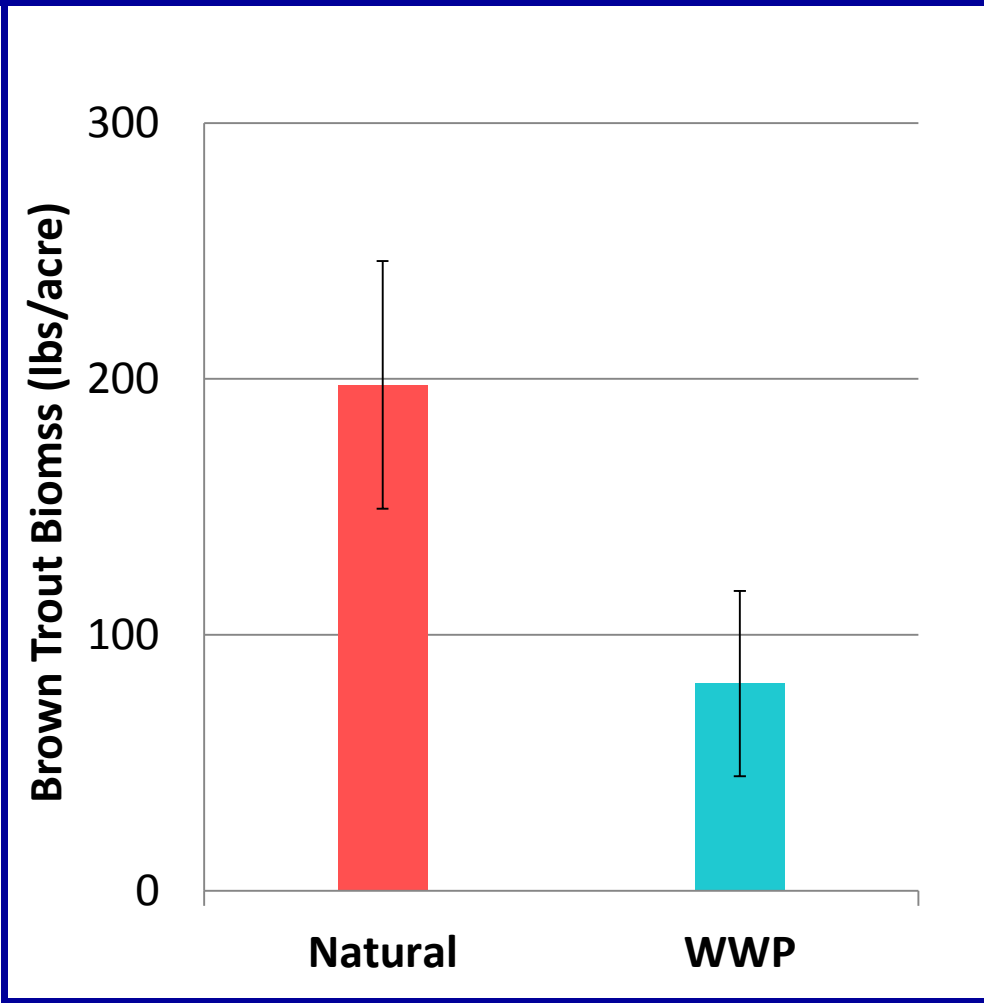


Brown Trout

Predicted

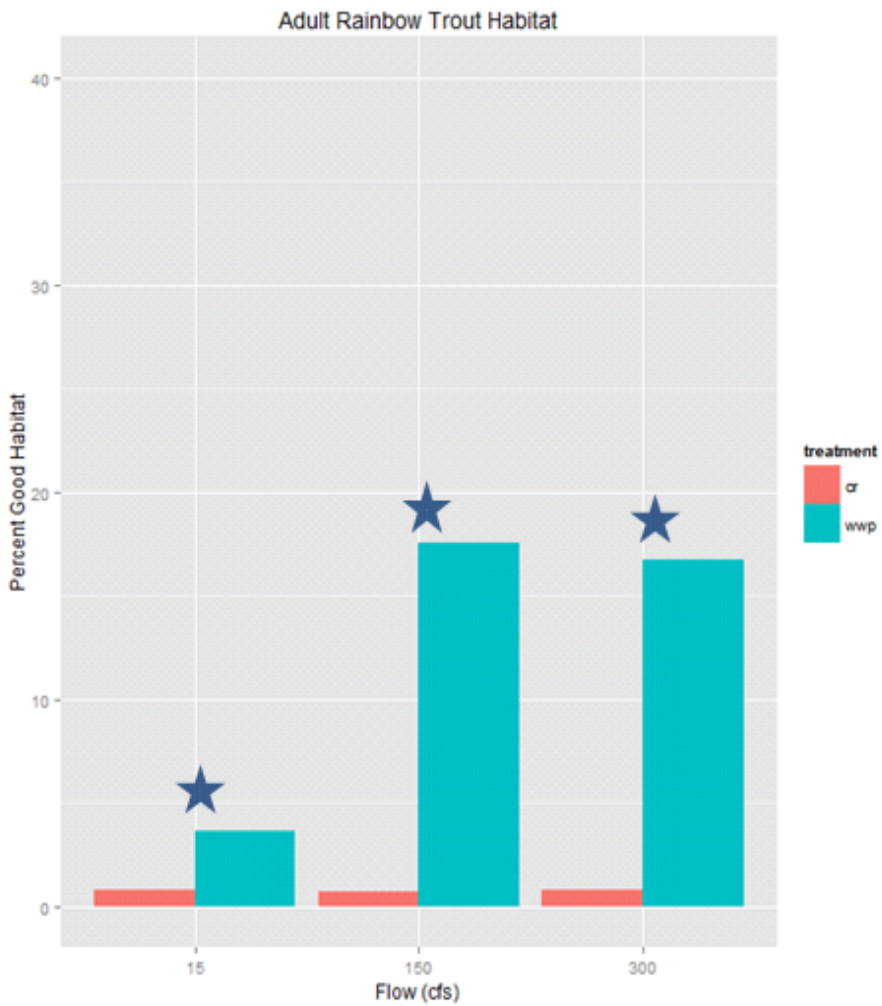


Observed

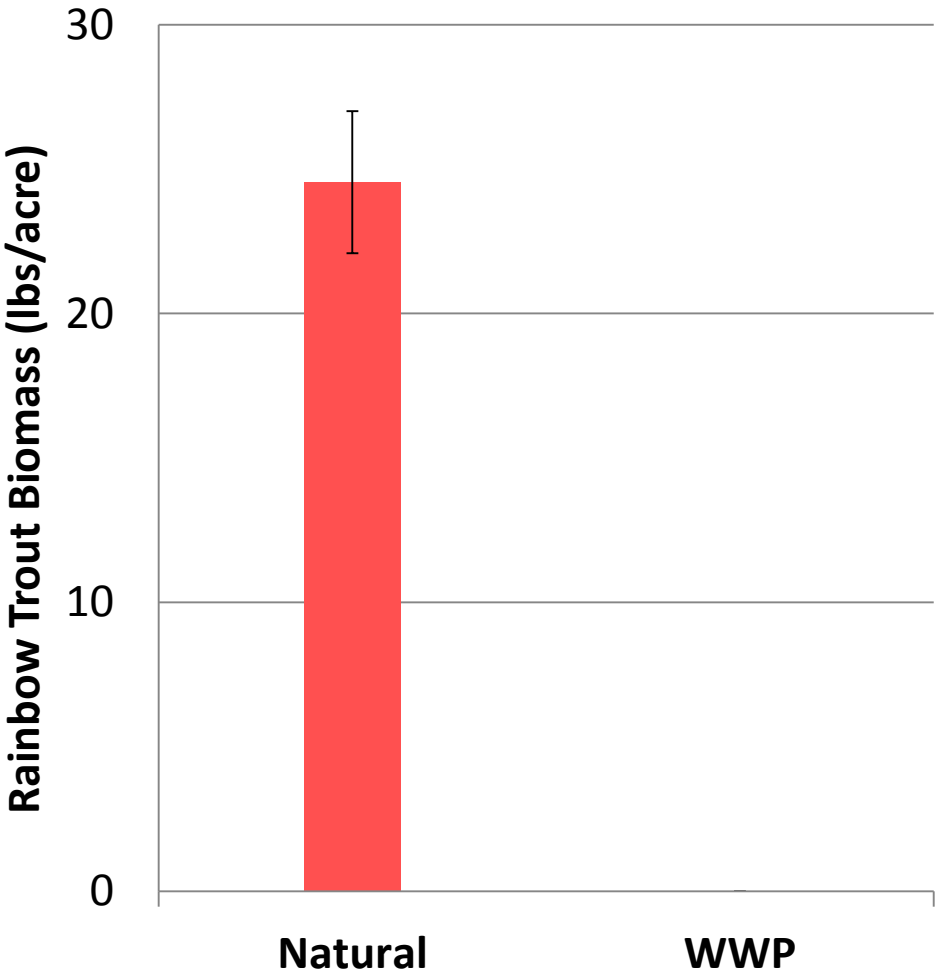


Rainbow Trout

Predicted



Observed



Restoration of Natural Forms:

Conversion of single-stage to multi-stage

Improved Floodplain Connectivity

Addition of Wood

Fish passage

Natural Hydraulic Conditions

Clear Creek

Goals

1) Remove armored rip rap

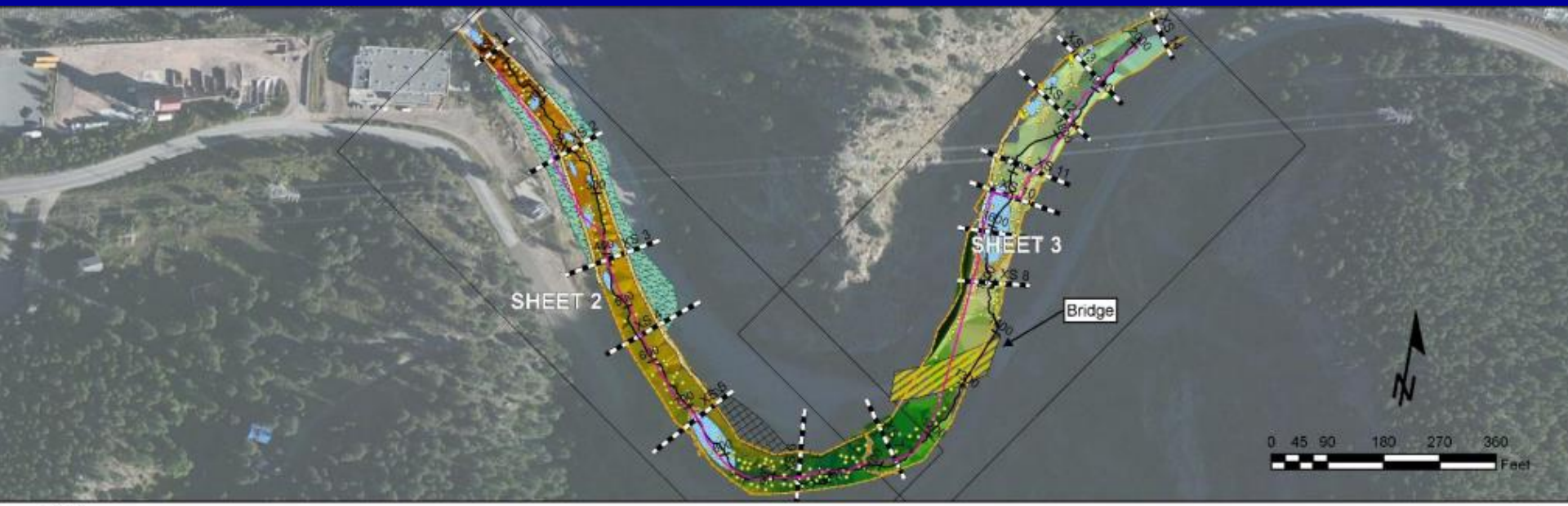
2) Improve floodplain connectivity

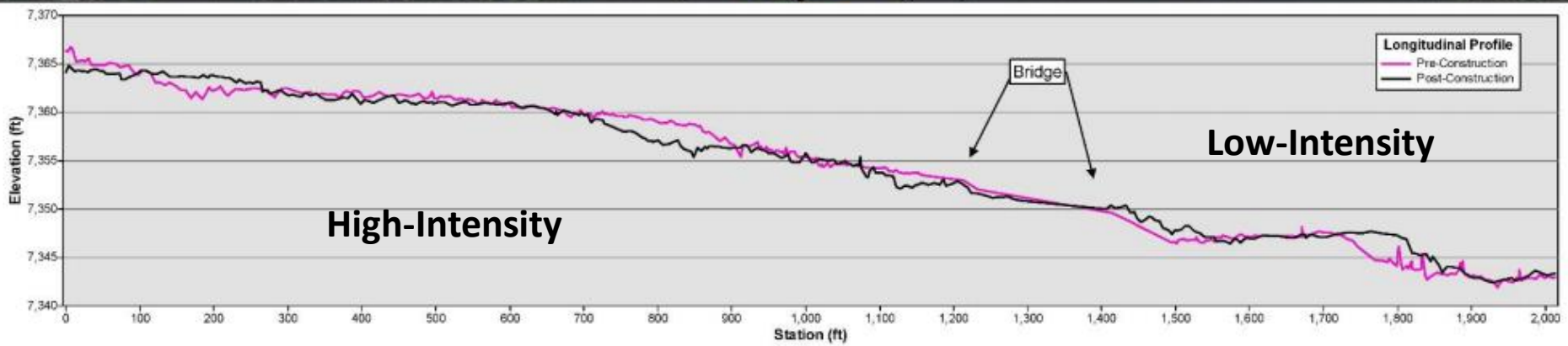
3) Convert single stage to three-stage

4) Establish riparian vegetation

5) Enhance in-channel bedform features (i.e. spawning area development and depth cover)

Overview





Thalweg (Pre-Construction)
Thalweg (Post-Construction)
Channel Alignment
Cross Section
Habitat Boulder
Log Vane
Boulder Structure
Boulder Toe
Pool Development
Riparian Bench
Point Bar Development
Bridge

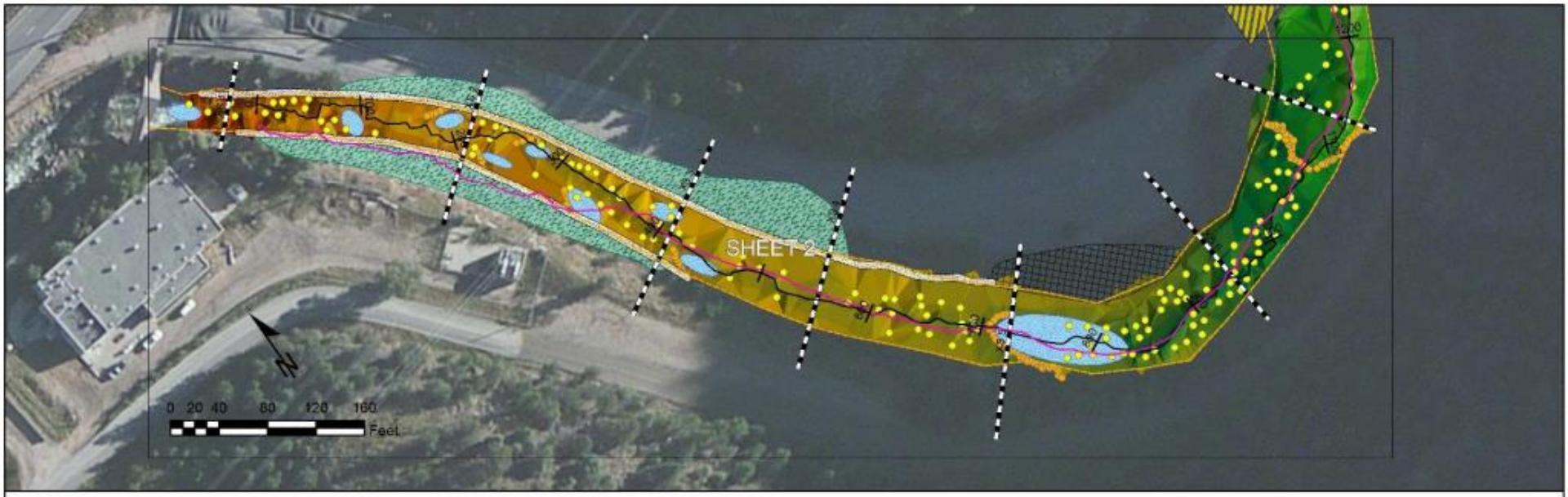
OVERVIEW	
DRAWN: BSTAMPER	8/16/2017
CHECKED: ERICHER	8/23/2017
APPROVED:	
SHEET: 1 OF 8	

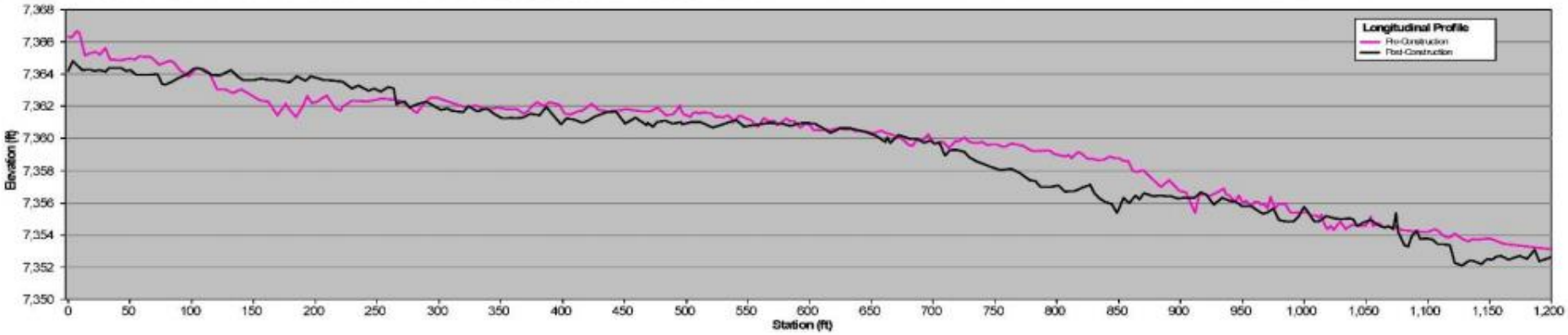
STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

CLEAR CREEK
TWIN TUNNELS
AS-BUILT DRAWINGS


High-Intensity
Before
Single-stage
Confinement=1.2
F-stream type


High-Intensity
After
Three-stage
Confinement=2.0
Bc -Stream Type





Thalweg (Pre-Construction)
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Cross Section
Habitat Boulder
Log Vane
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Pool Development
Riparian Bench
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Bridge

LONGITUDINAL PROFILE

DRAWN: BSTAMPER	8/16/2017
CHECKED: ERICHER	8/23/2017
APPROVED:	

SHEET: 2 OF 8

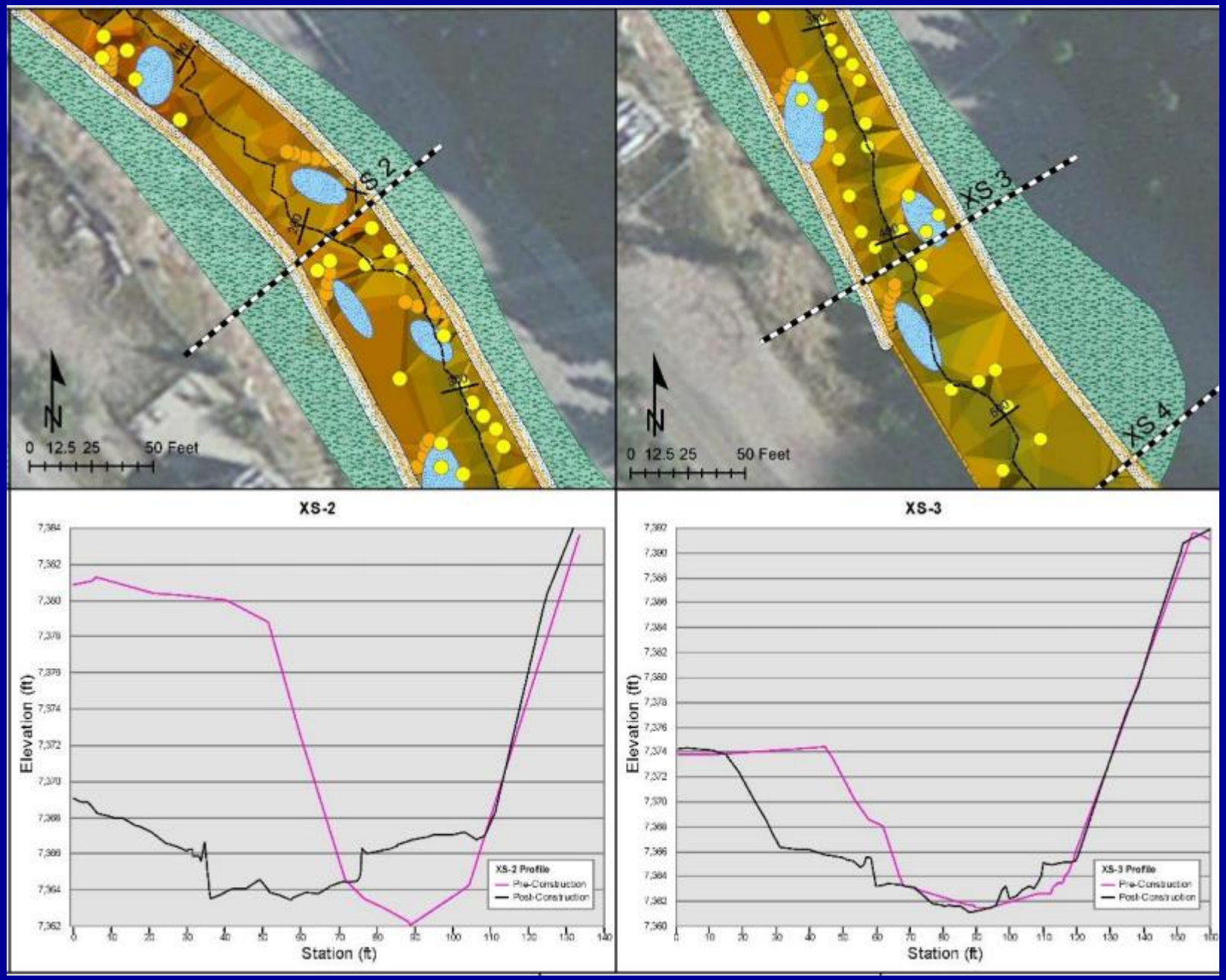
STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

CLEAR CREEK
TWIN TUNNELS
AS-BUILT DRAWINGS


High-Intensity
Before


High-Intensity
After

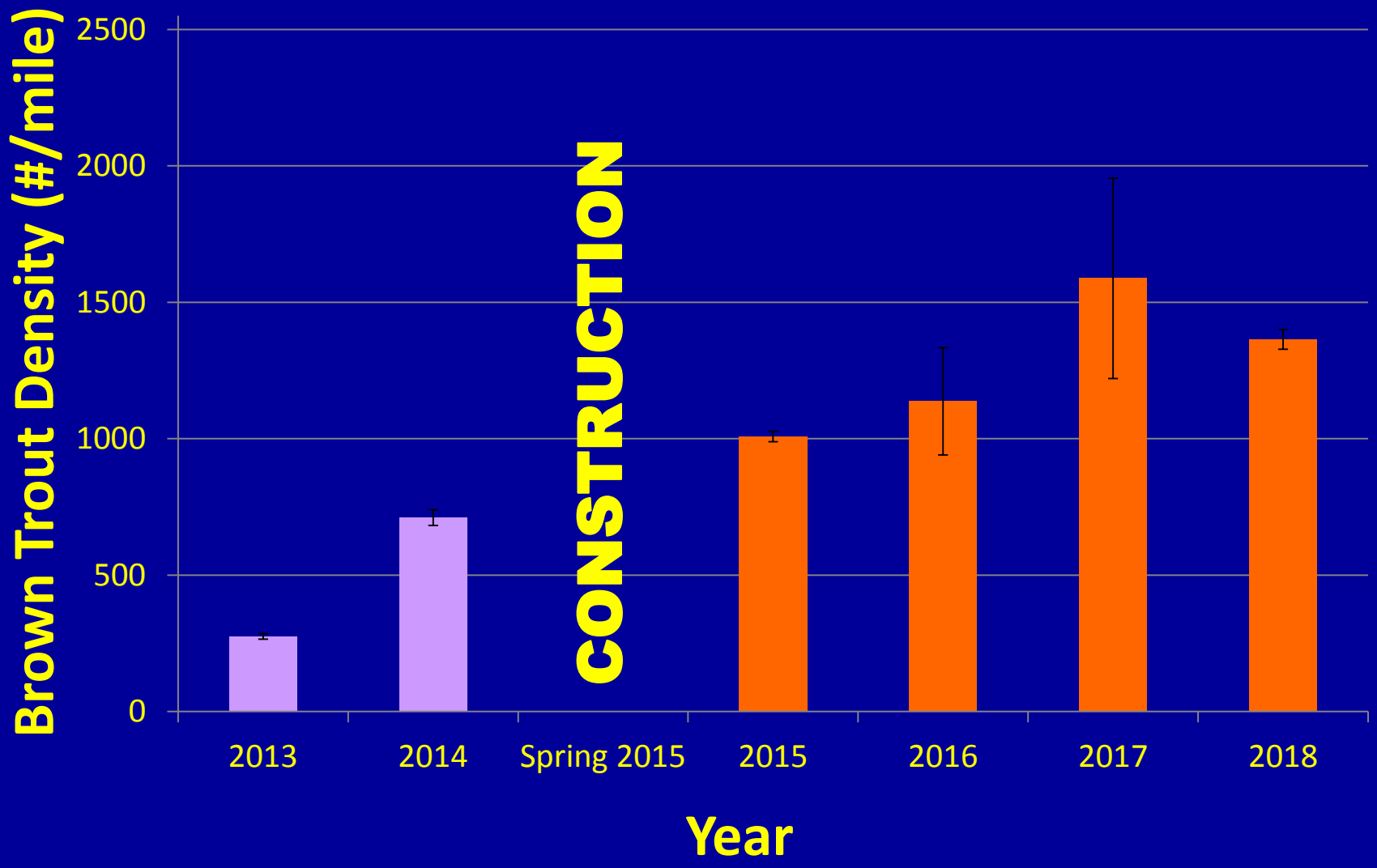

After


XS 2
0 12.5 25 50 Feet
XS 3
XS 4
0 12.5 25 50 Feet
XS-2
Elevation (ft)
Station (ft)
XS-2 Profile
Pre-Construction
Post-Construction
XS-3
Elevation (ft)
Station (ft)
XS-3 Profile
Pre-Construction
Post-Construction

High-Intensity

Treatment	Quantity	Units	Total	% of Total Project
Habitat Boulder	153	Each	234	65%
Boulder Structure	8	Each	9	89%
Boulder Toe	2,458	LF	2,708	91%
Pool Development	10	SF	14	71%
Point-Bar Development	5,420	SF	5,420	100%
Riparian Bench	18,775	SF	18,775	100%

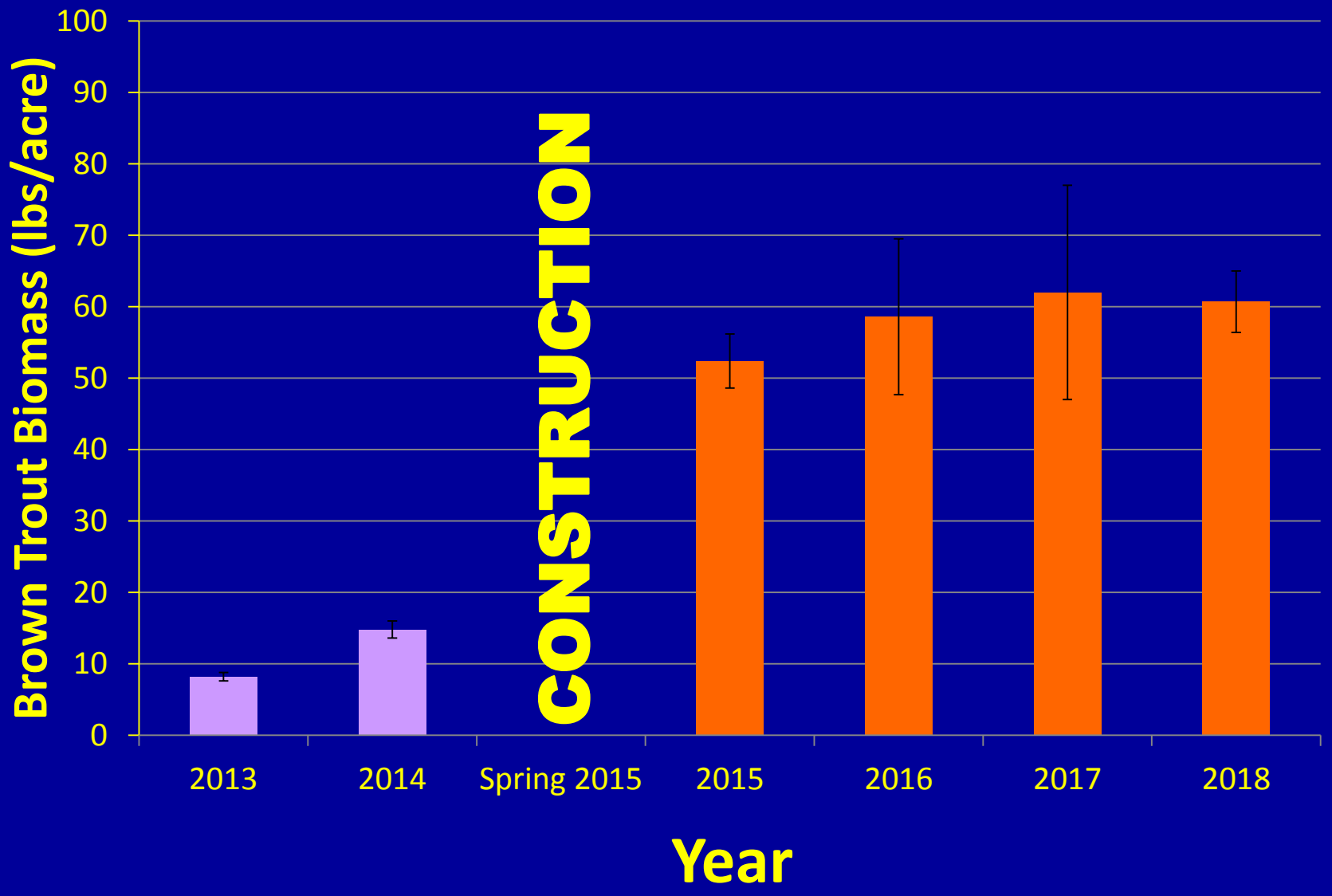
High-Intensity Treatment: Trout Density (#/mile)



High-Intensity Treatment: Trout Density (#/mile)

160% increase

High-Intensity Treatment: Trout Biomass (lbs/acres)



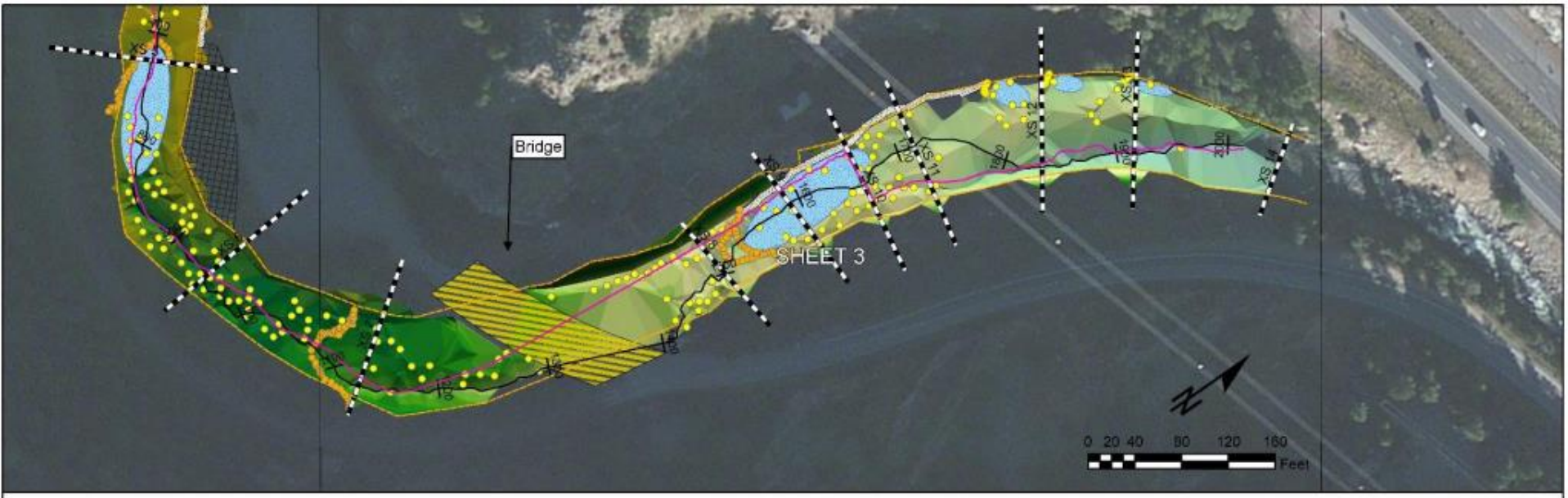
High-Intensity Treatment: Trout Density (#/mile)

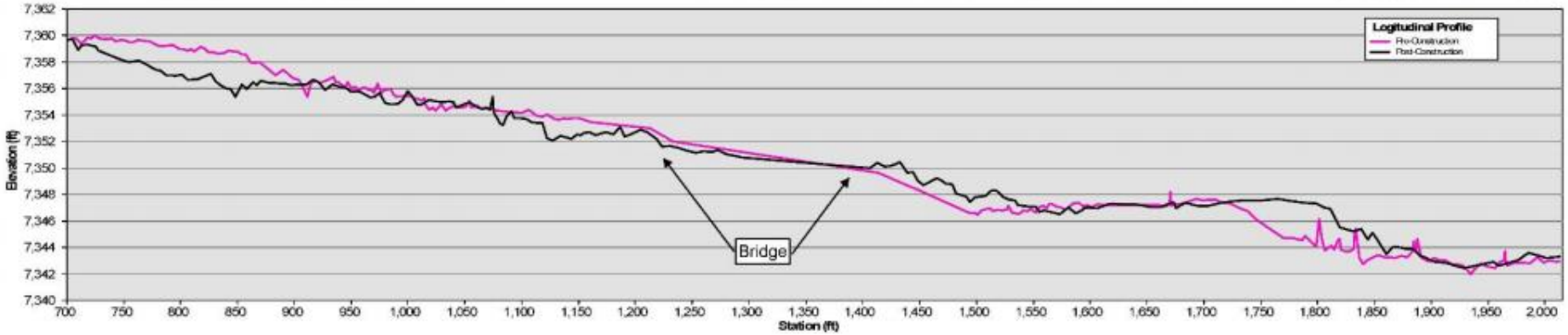
160% increase

High-Intensity Treatment: Trout Biomass (lbs/acres)

408% increase

Low-Intensity





Thalweg (Pre-Construction)
Thalweg (Post-Construction)
Channel Alignment
Cross Section
Habitat Boulder
Log Vane
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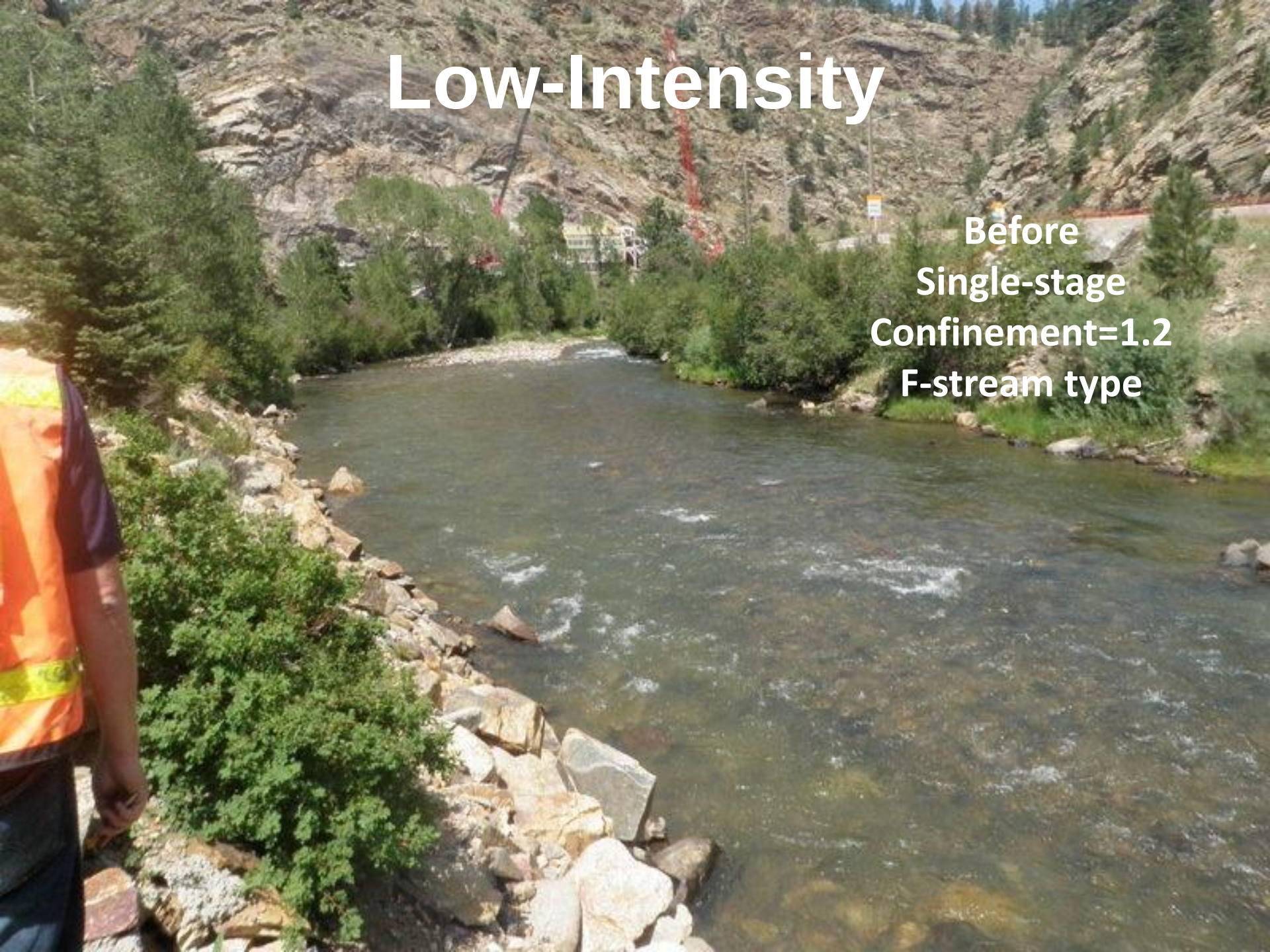
LONGITUDINAL PROFILE	
DRAWN: BSTAMPER	8/16/2017
CHECKED: ERICHER	8/23/2017
APPROVED:	
SHEET: 3 OF 8	

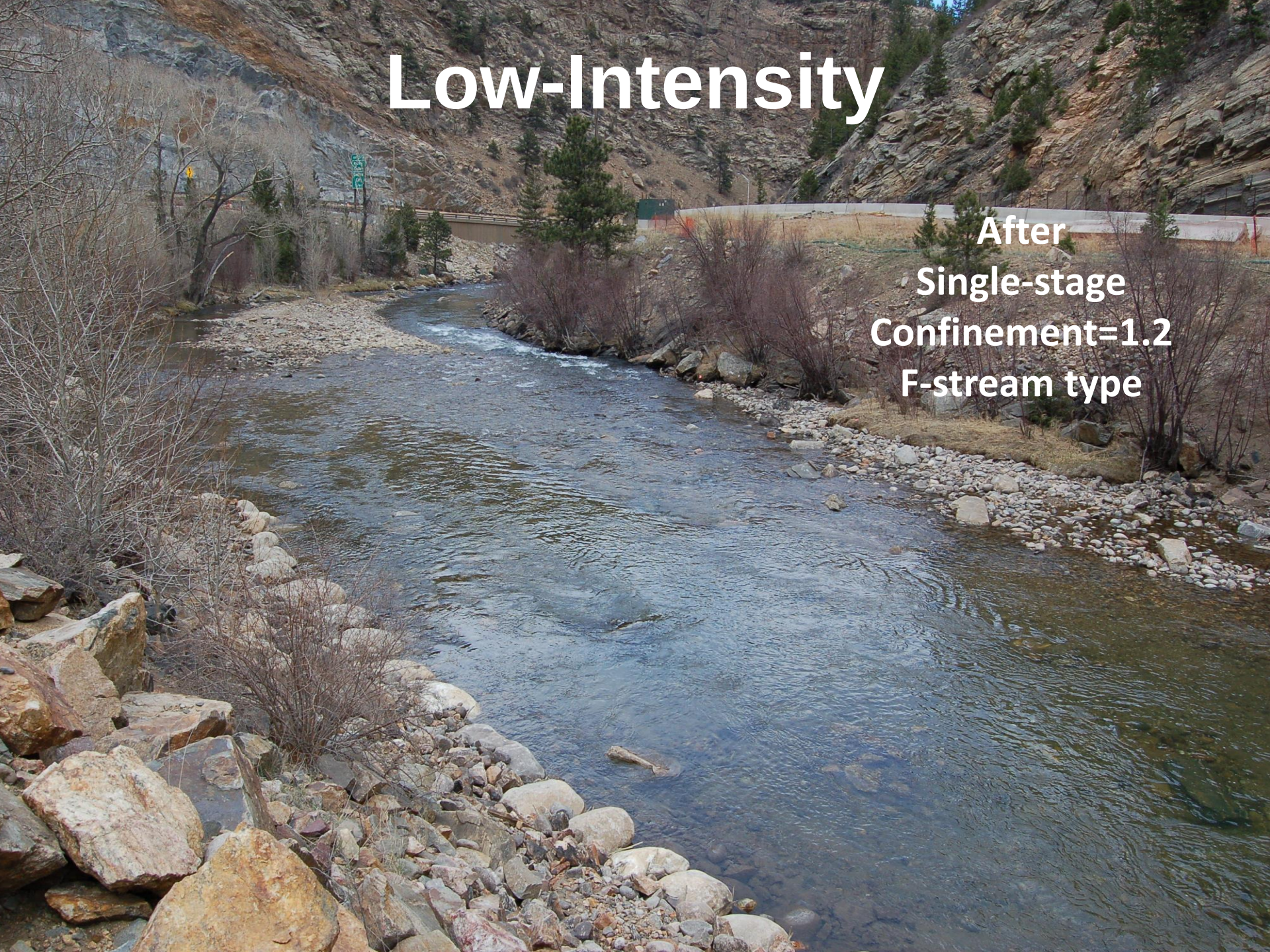
STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
COLORADO PARKS AND WILDLIFE
FORT COLLINS, COLORADO

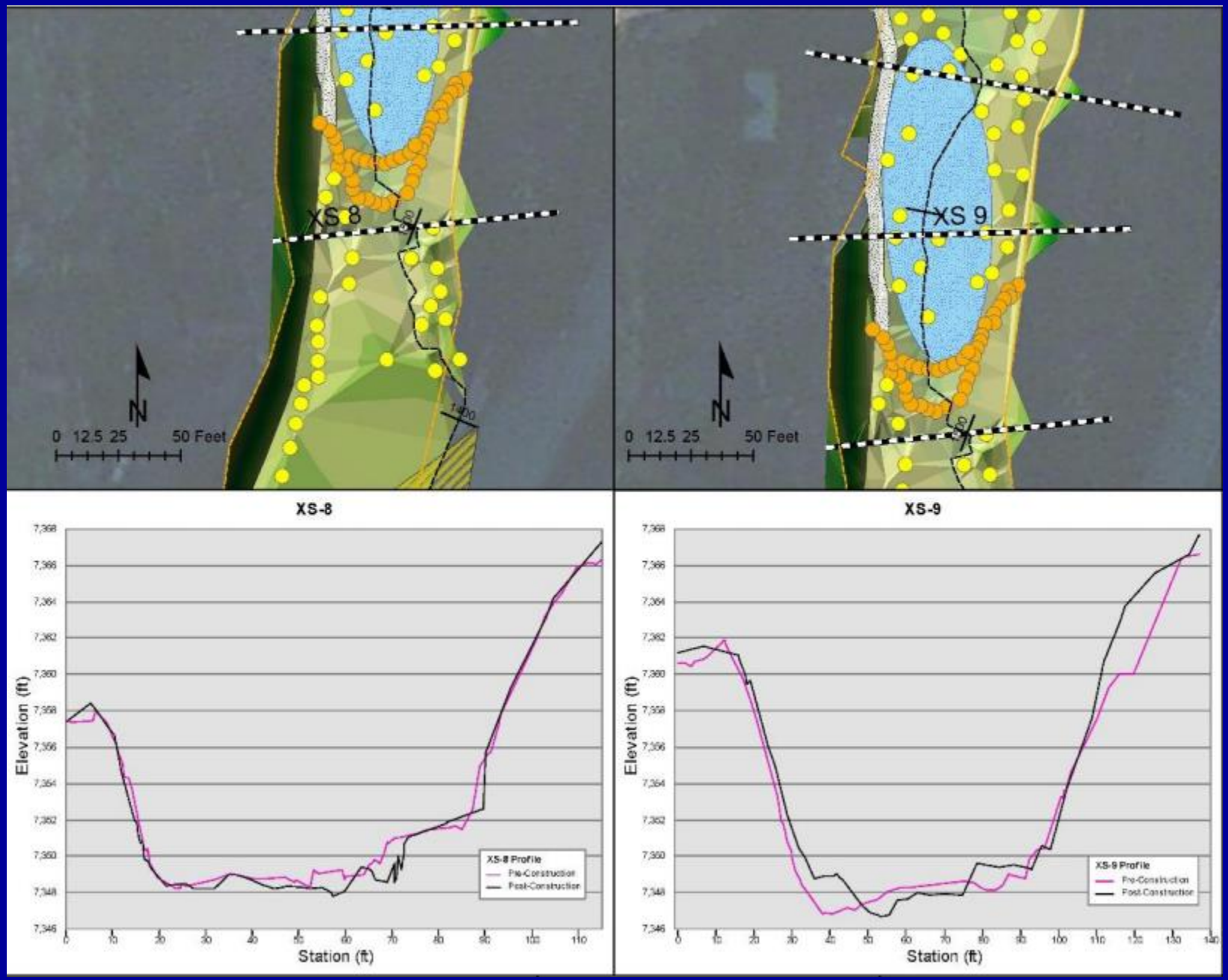
CLEAR CREEK
TWIN TUNNELS
AS-BUILT DRAWINGS

Low-Intensity



Low-Intensity

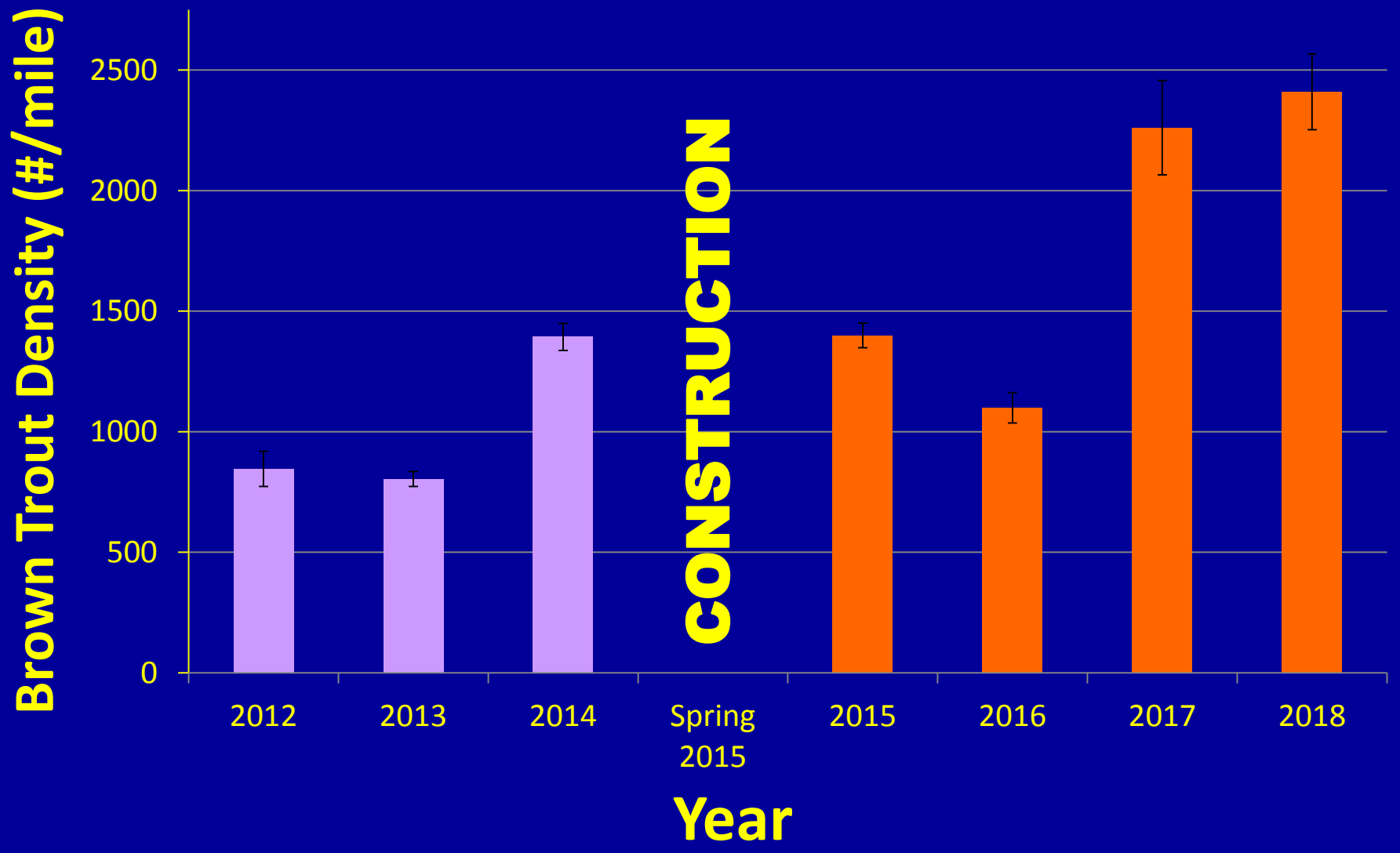



XS 8
0 12.5 25 50 Feet
XS 9
0 12.5 25 50 Feet
XS-8
Elevation (ft)
Station (ft)
XS-8 Profile
Pre-Construction
Post-Construction
XS-9
Elevation (ft)
Station (ft)
XS-9 Profile
Pre-Construction
Post-Construction

Low-Intensity

Treatment	Quantity	Units	Total	% of Total Project
Habitat Boulder	81	Each	234	35%
Boulder Structure	1	Each	9	11%
Boulder Toe	250	LF	2,708	9%
Pool Development	4	Each	14	29%
Point-Bar Development	0	SF	5,420	0%
Riparian Bench	0	SF	18,775	0%

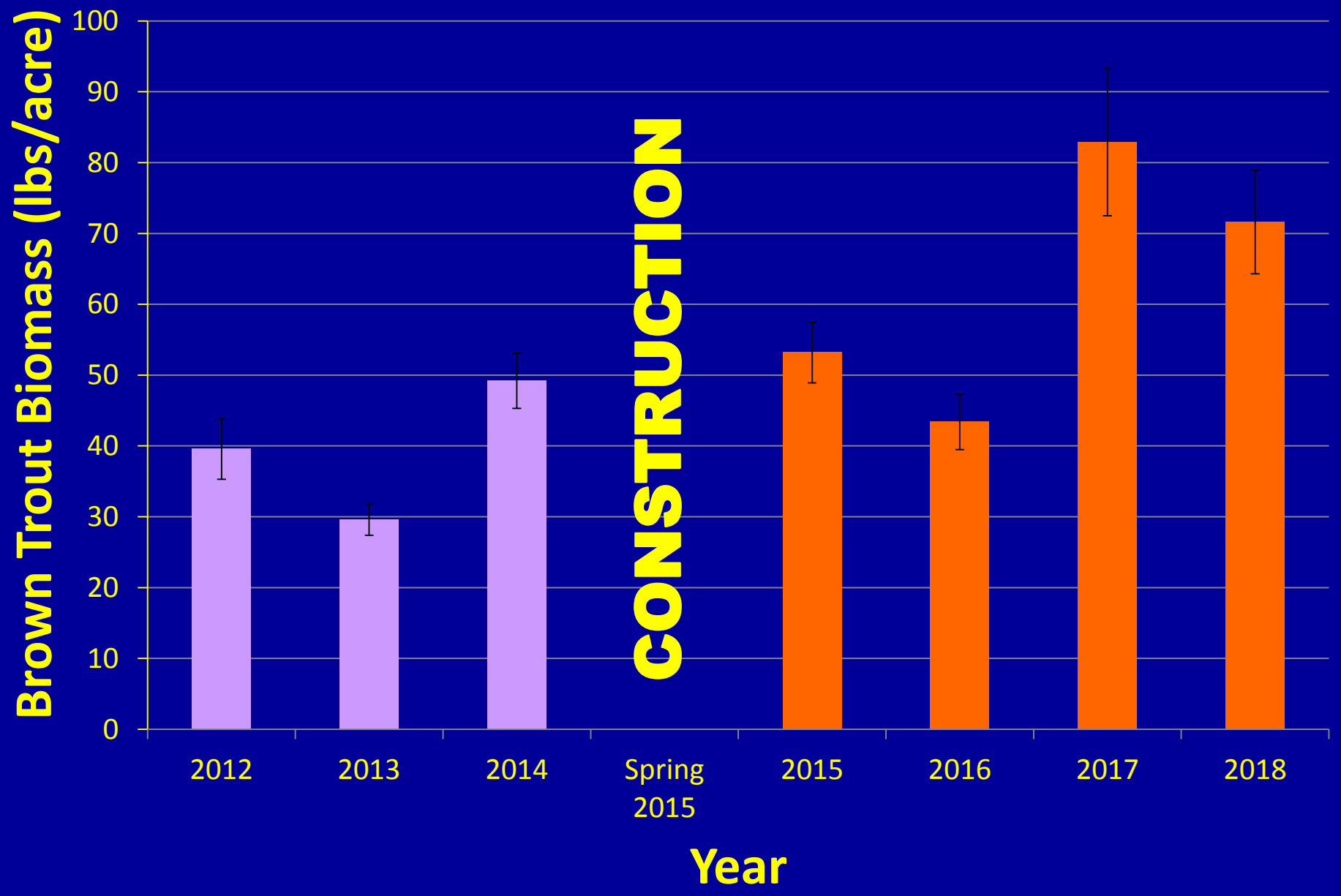
Low-Intensity Treatment: Trout Density (#/mile)



Low-Intensity Treatment: Trout Density (#/mile)

77% increase

Low-Intensity Treatment: Trout Biomass (lbs/acres)



Low-Intensity Treatment: Trout Density (#/mile)

77% increase

Low-Intensity Treatment: Trout Biomass (lbs/acres)

59% increase

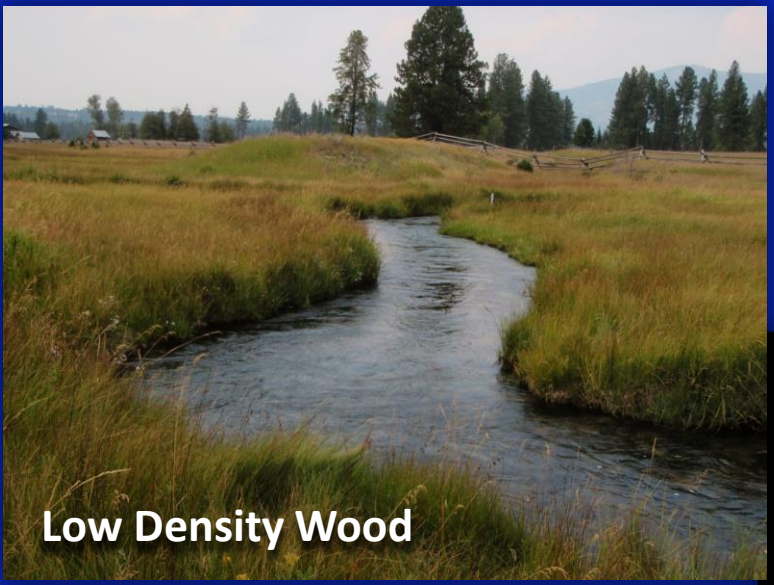
Kleinschmidt Creek - full channel restoration

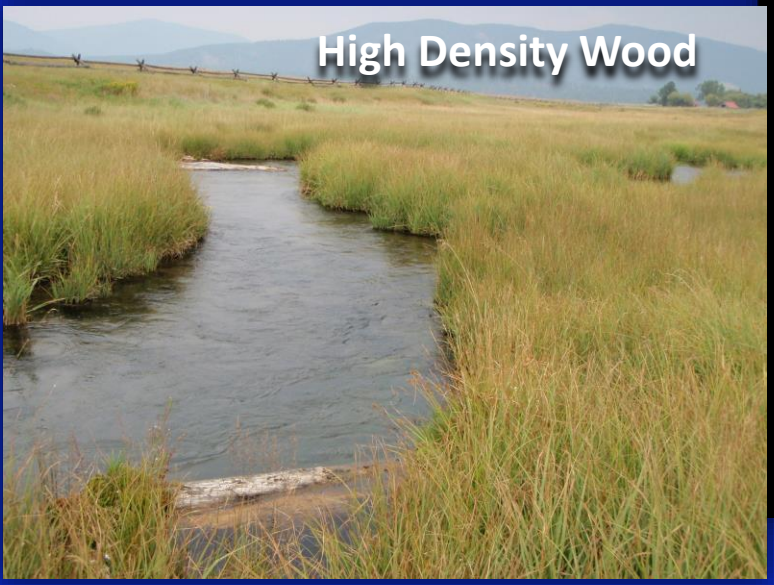
Conversion of a C5 to an E4 stream type

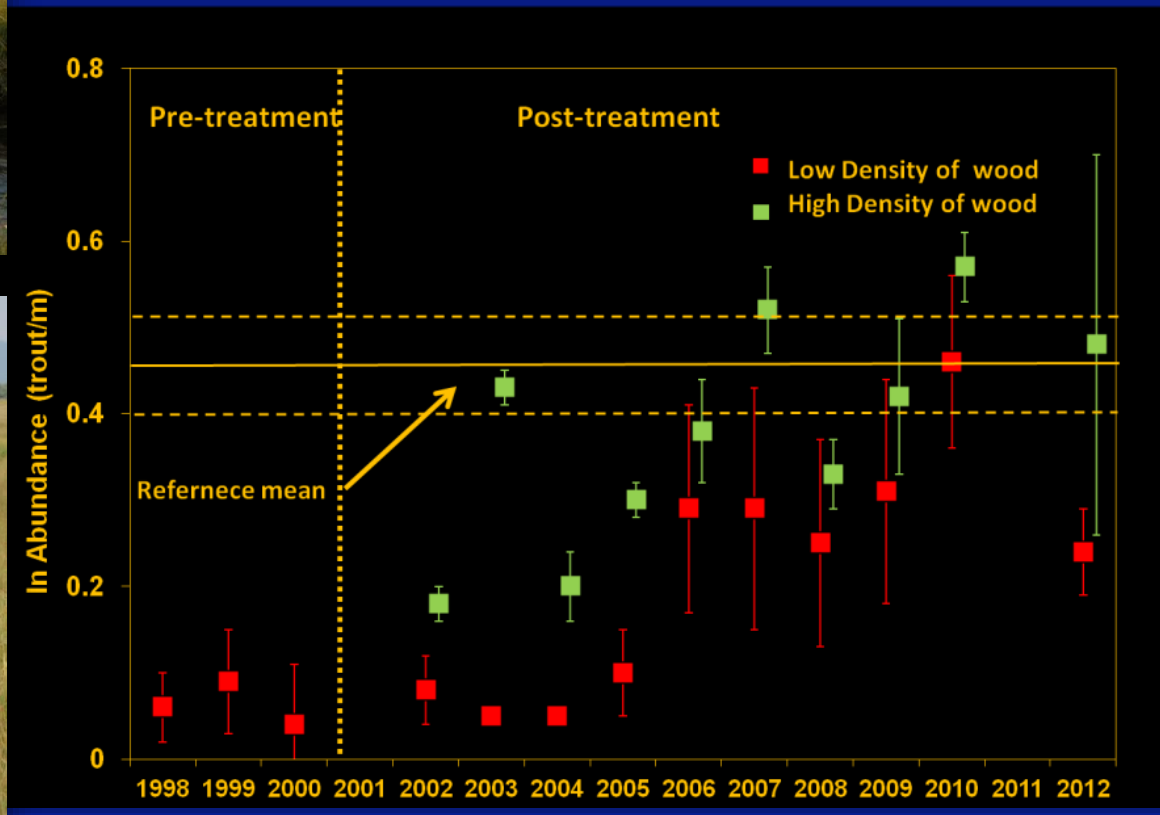
Channel form	Before (C5)	After (E4)
Channel length - (km)	1.97	2.73
Sinuosity	1.1	1.6
Stream slope - (m/m)	0.0058	0.0040
Valley slope - (m/m)	0.0064	0.0064
Bankfull discharge - Q_{bkf} (m^3/s)	0.71	0.71
Bankfull width - W_{bkf} (m)	20.1	3.1
Bankfull depth - d_{bkf} (m)	0.13	0.35
Banfull W/D ratio	150	8.8
Bankfull cross-sectional area - A_{bkf} (m^2)	2.6	1.1
Hydraulic function		
Bankfull mean velocity - $\bar{u}_{bkf}$ (m/s)	0.27	0.67
Bankfull shear stress - T (newtons/m^2)	7.4	13.7
Particle entrainment size (mm)	11	21

Pierce et al., 2015,TAFS, 144, 184–195

Trout response to channel restoration in Kleinschmidt Creek, 1998–2012



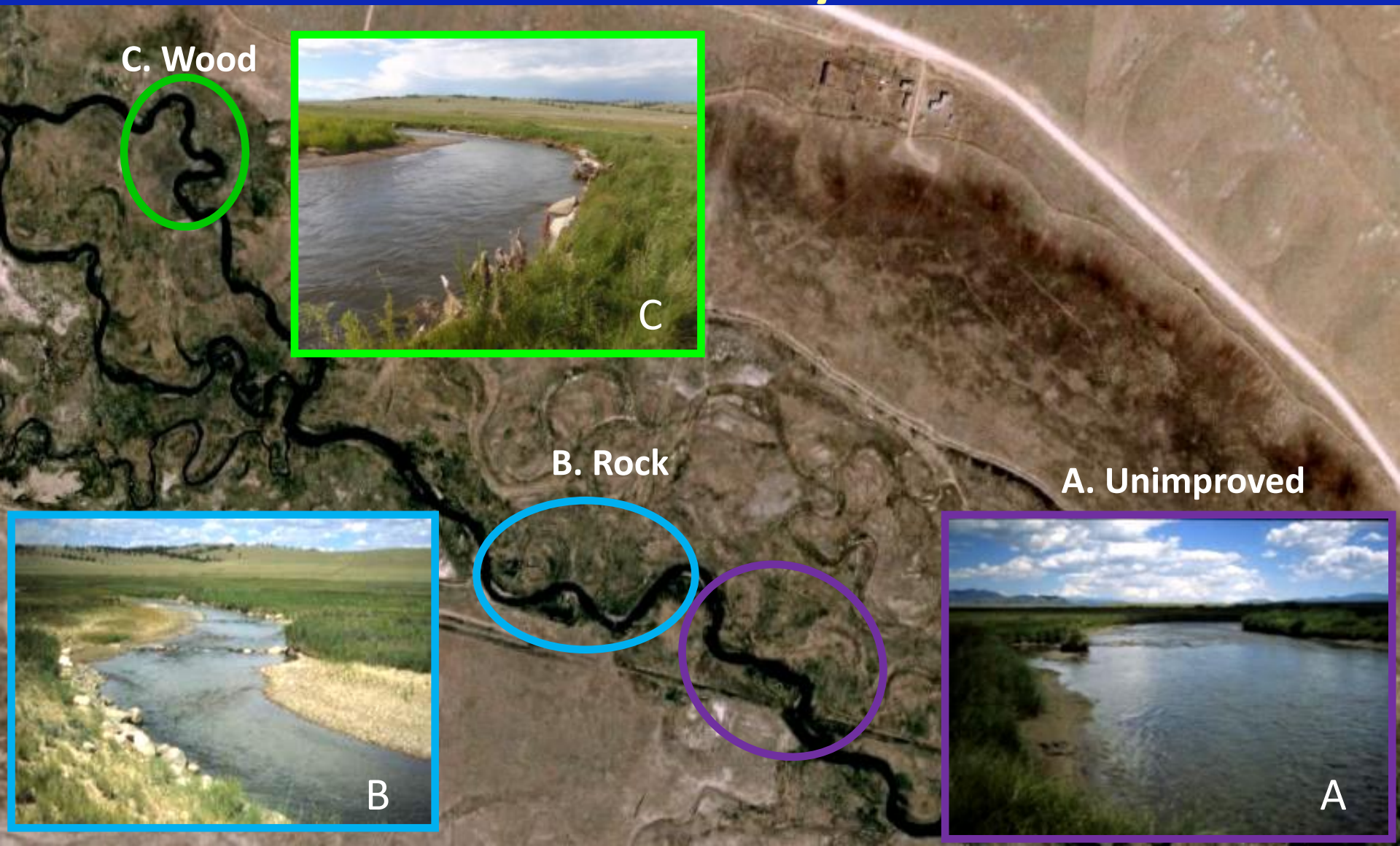




Pierce et al., 2015,TAFS, 144, 184–195

Monitoring Results: Buckley Ranch

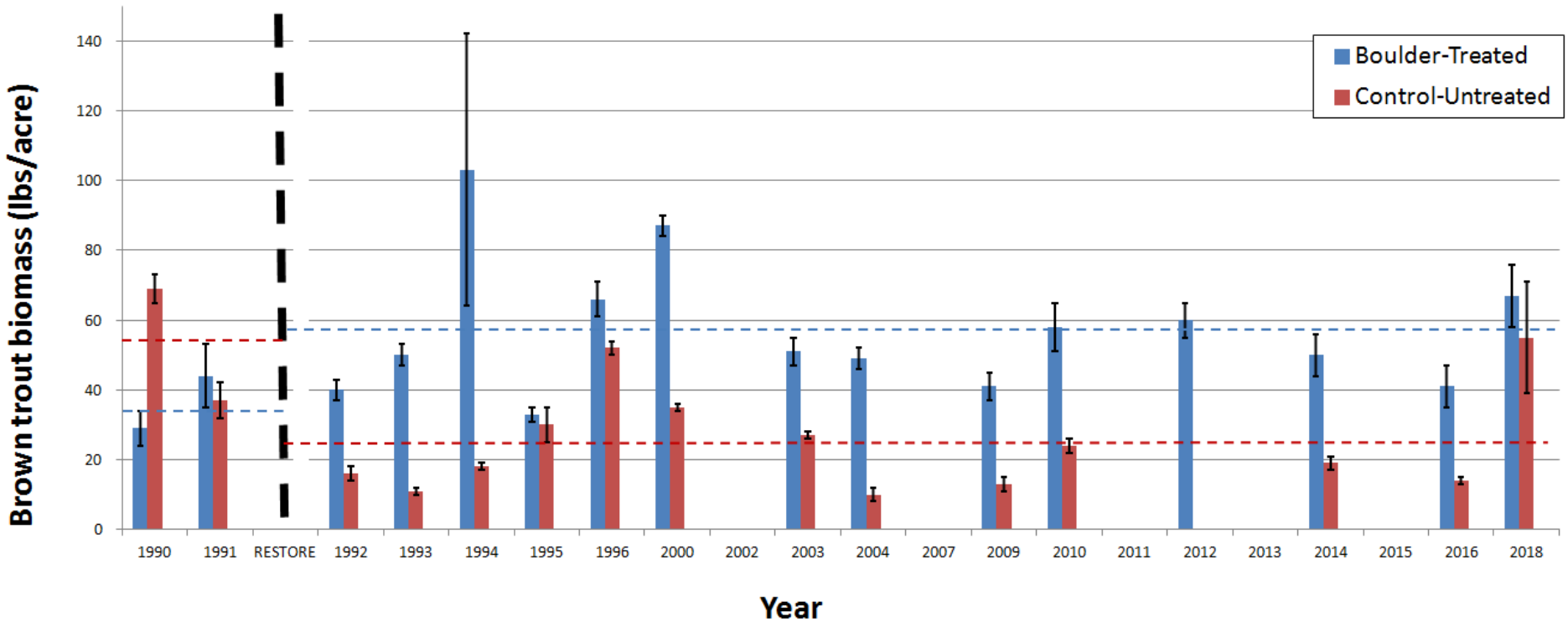
BACI study



Boulder-Treated

Control-Untreated

Boulder-Treated Vs Control-Untreated



Boulder-Treated Vs Control-Untreated

Monitoring Period:

1990-2018: 28 YEARS!

Pre- vs Post:

- Boulder-Treated: 56% increase compared with pre-project baseline.

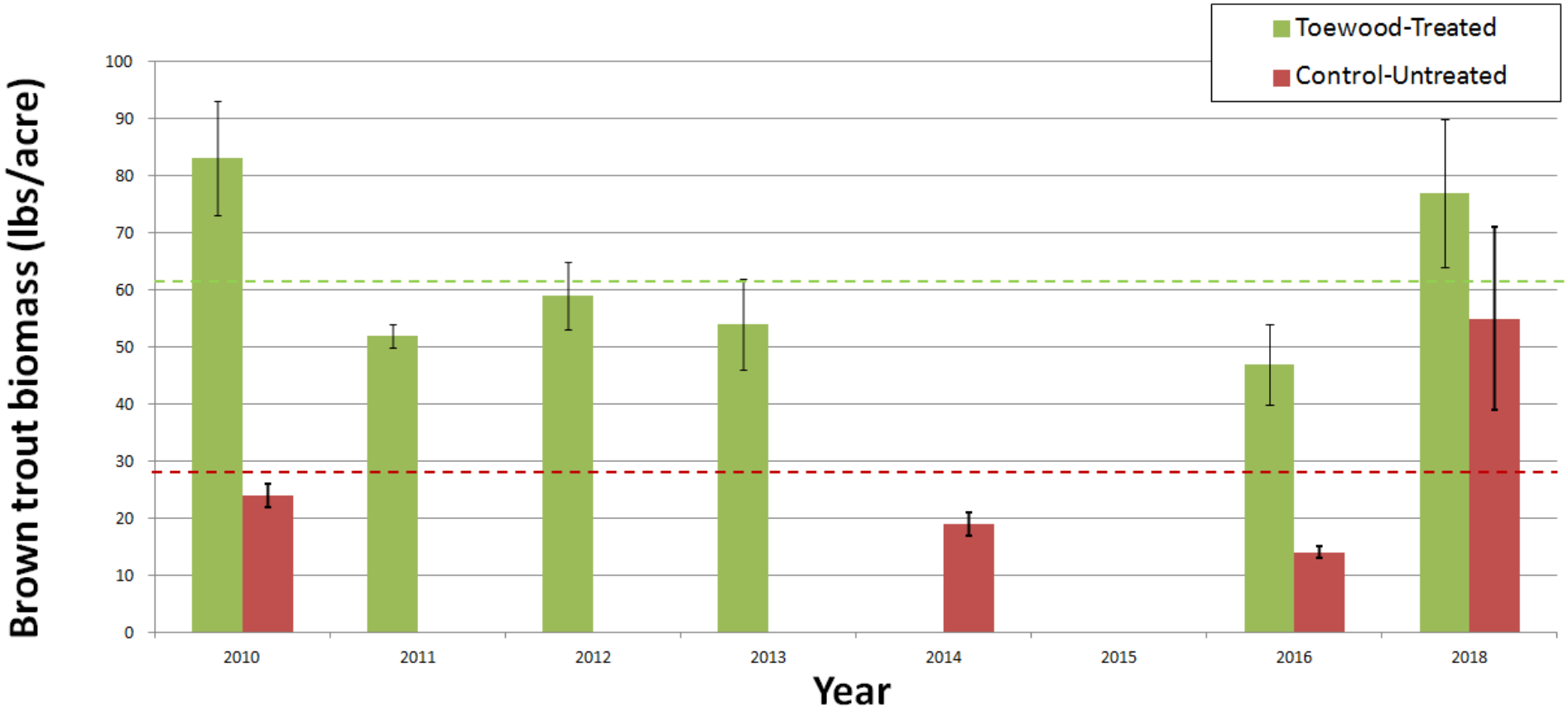
- Control-untreated: 53% decline over the same time period.

Boulder vs Control:

- Brown trout biomass in the boulder -treated reach averaged 32% higher over the control-untreated reach

Toewood-Treated

Toewood-Treated Vs Control-Untreated



Toewood-Treated Vs Control-Untreated

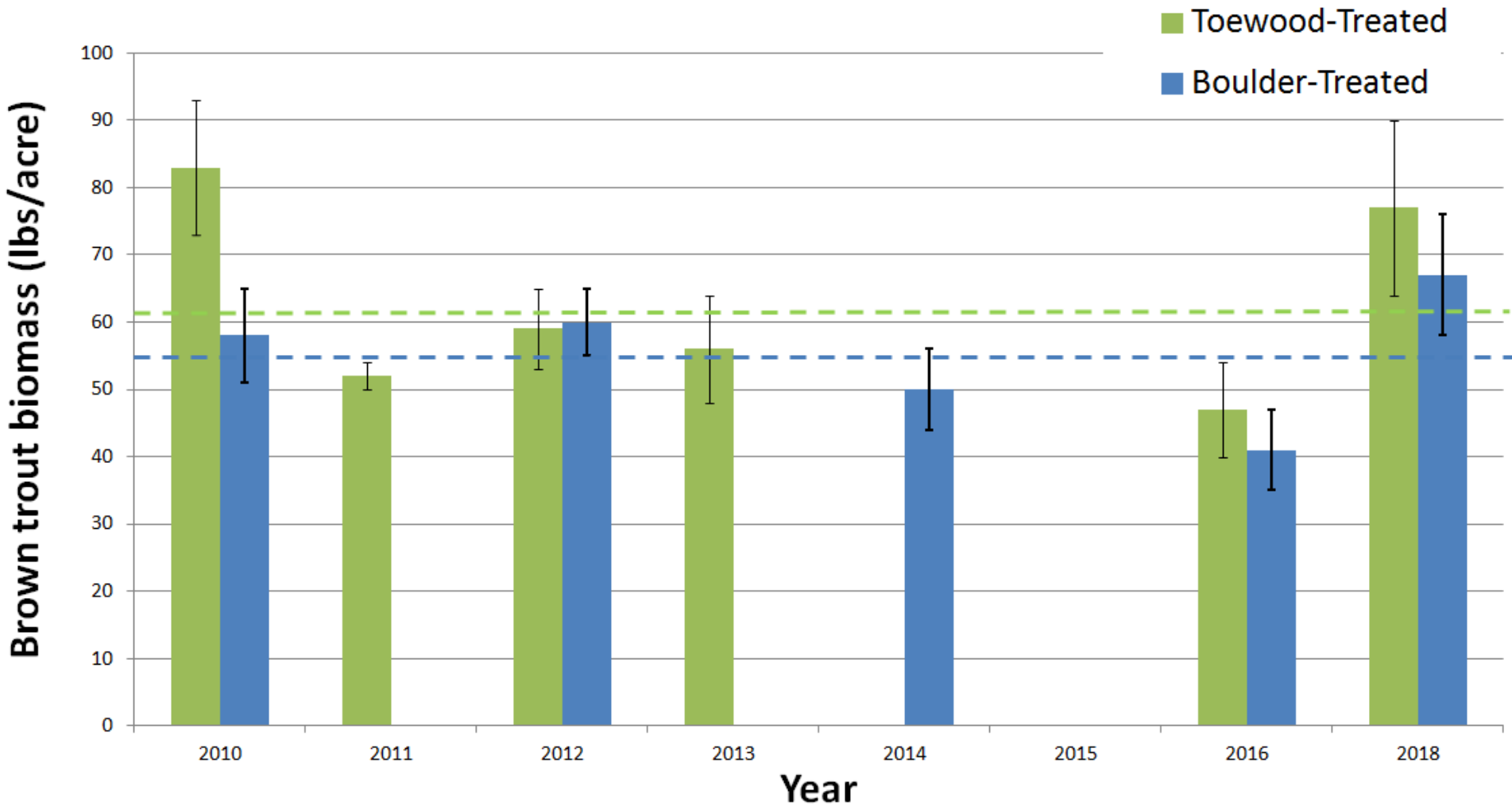
Monitoring Period:

2010-2018: 8 YEARS

Toewood-Treated vs Control:

- Brown trout biomass in the boulder -treated reach averaged 34% higher over the control-untreated reach

Toewood-Treated Vs Boulder-Treated



Toewood-Treated Vs Boulder-Treated

Monitoring Period:

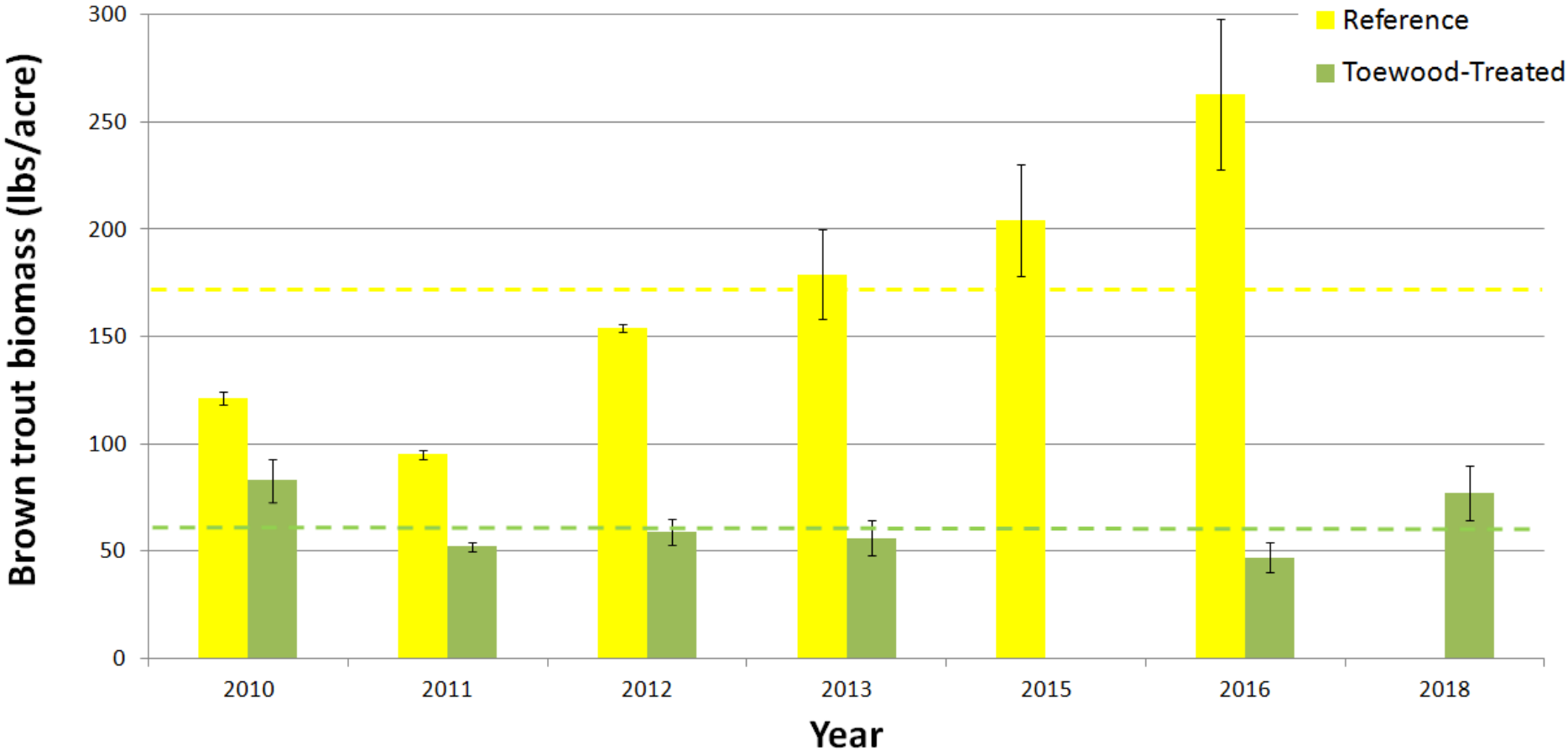
2010-2018: 8 YEARS

Toewood-Treated vs Boulder-Treated:

- Brown trout biomass in the Toewood-Treated reach averaged 7% higher over the Boulder-Treated

Reference

Toewood-Treated Vs Reference



Toewood-Treated Vs Reference

<u>Monitoring Period:</u>

2010-2018: 8 YEARS

- Brown trout biomass in the Reference reach averaged 107% higher over the Toewood-Treated

Summary

- Restoration of natural stream forms (NCD) may restore natural habitats that provide the functions necessary for improving fish populations over time

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- Departure from natural conditions may have negative consequences to fish populations that may not recover without physical intervention

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- Restoration of natural stream forms (NCD) may restore natural habitats that provide the functions necessary for improving fish populations over time
- Departure from natural conditions may have negative consequences to fish populations that may not recover without physical intervention
- Assess limiting factors that may occur outside of geomorphology (channel forms) including departures from natural hydrologic regimes, hydraulics, physicochemical properties, and barriers

Summary

- Not all treatment alternatives are equal. Some treatments will accomplish a “bigger bang for the buck”

Summary

- Not all treatment alternatives are equal. Some treatments will accomplish a “bigger bang for the buck”
- Carefully consider selection of reference reaches for biological monitoring. Use an average of multiple rerference sites if possible