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Alluvial Fans and Salmonid Habitat: The Forgotten and Challenging Landscape In-Between

A Concurrent Session at the 36th Annual Salmonid Restoration Conference held in Fortuna, California from April 11 – 14, 2018.

Session Overview

- Session Coordinators:
  - Michael Love, PE, Michael Love & Associates
  - Jay Stallman, PG, Stillwater Sciences

Although fisheries habitat on alluvial fans may not provide the highest quality, the processes occurring on them is commonly essential to maintaining high quality habitats at their proximal and distal margins. When functioning, they can store and meter sediment loads, recharge groundwater, produce cold water springs and seeps at their bases, and support rich and vibrant wetland ecosystems at their distal ends. When these systems are perturbed, the geomorphic responses are often extreme, sometimes resulting in deeply incised channels, or alternatively, aggrading channels and splays of sediment deposited across working landscapes.

Alluvial fans are often critical zones for salmon and steelhead migration to holding, spawning, and rearing habitats located in upstream reaches. The dynamic network of channels and often complex surface and groundwater interactions creates unique challenges to fish passage, especially where water diversions may limit flow availability and alter sediment transport. This session will focus on the hydraulic and geomorphic processes occurring within alluvial fans relative to fisheries habitat and fisheries access to upstream habitat, the causes and responses of dysfunctional alluvial fan systems, and the importance of restoring these processes to create desirable habitats for salmonid recovery.

Presentations

(Slide 4) The Benefits of Restoring Alluvial Fan Processes after a Century of Neglect
Michael Love, Michael Love & Associates, Inc.

(Slide 26) Alluvial Fan Construction in the Pacific Northwest
Paul Powers, U.S. Forest Service

(Slide 64) Managing Fish Passage Across the Antelope Creek Alluvial Fan
Jay Stallman, Stillwater Sciences

(Slide 85) Debris Basins in Southern Santa Barbara County; Their History and Exciting Future
Seth Shank and Andrew Raaf, Santa Barbara County Flood Control and Water Conservation District

(Slide 139) Expect the Unexpected — Monitoring Geomorphic Changes and Evaluating Overall Effectiveness in Highly Dynamic Alluvial Fan Environments
Ian Mostrenko, Herrera Environmental Consultant

(Slide 173) Salmonid Habitat Use of the Goodell Alluvial Fan: Would Removal of Anthropogenic Features Increase Fish Numbers?
Rick Hartson, Upper Skagit Indian Tribe

Salmonid Restoration Federation 2018 Conference

Alluvial Fans and Salmonid Habitat: The Forgotten and Challenging Landscape In-Between

Session Coordinators:

Michael Love and Jay Stallman

Salmonid Restoration Federation 2018 Conference

The Benefits of Restoring Alluvial Fan Processes after a Century of Neglect

Williams Creek, Eel River Bottoms

Michael Love P.E.
Arcata, California
mlove@h2odesigns.com
707-822-2411

Michael Love & Associates
Hydrologic Solutions

Presentation Outline

1. Definitions, Locations, and Types of Alluvial Fans
2. Geomorphic Processes and Ecosystem Services Provided by Proper-Functioning Fans
3. History of Development on Fans and Maintenance Practices
4. Current Conditions and Need for Action

Alluvial fan activity in New Zealand (courtesy of a Otoga Regional Council)

Typical Alluvial Fan

Tasman River, New Zealand

General Features of Alluvial Fans

- Stream's transition from a confined channel to the unconfined alluvial plain
- Flows emerging onto the fan are free to expand and infiltrate
- Fan is a zone of aggradation from streamflow deposits and/or debris flows
- Channel shifts (avulsions) from blockages (vegetation) and breakout
- Fan shaped from frequent radial shifts in the channel

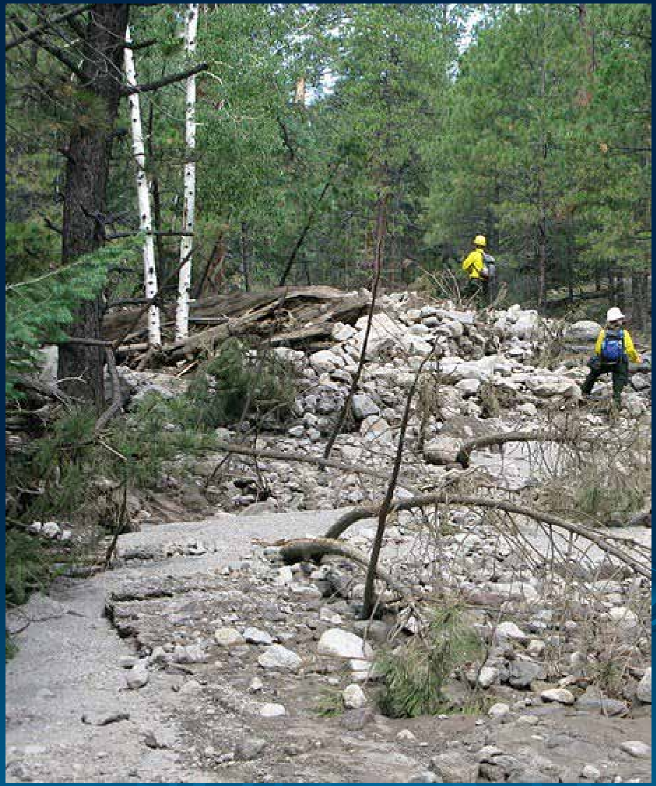
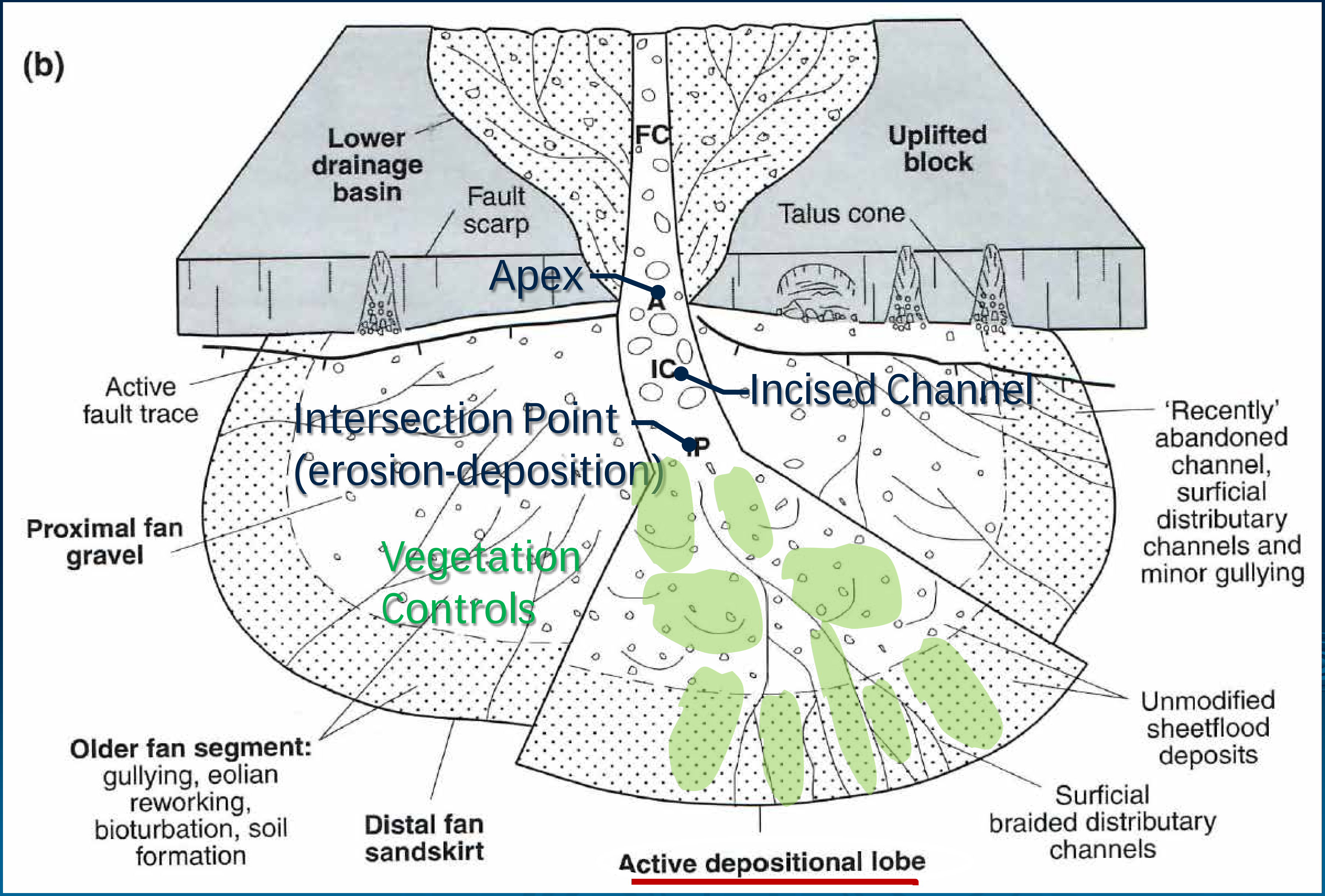


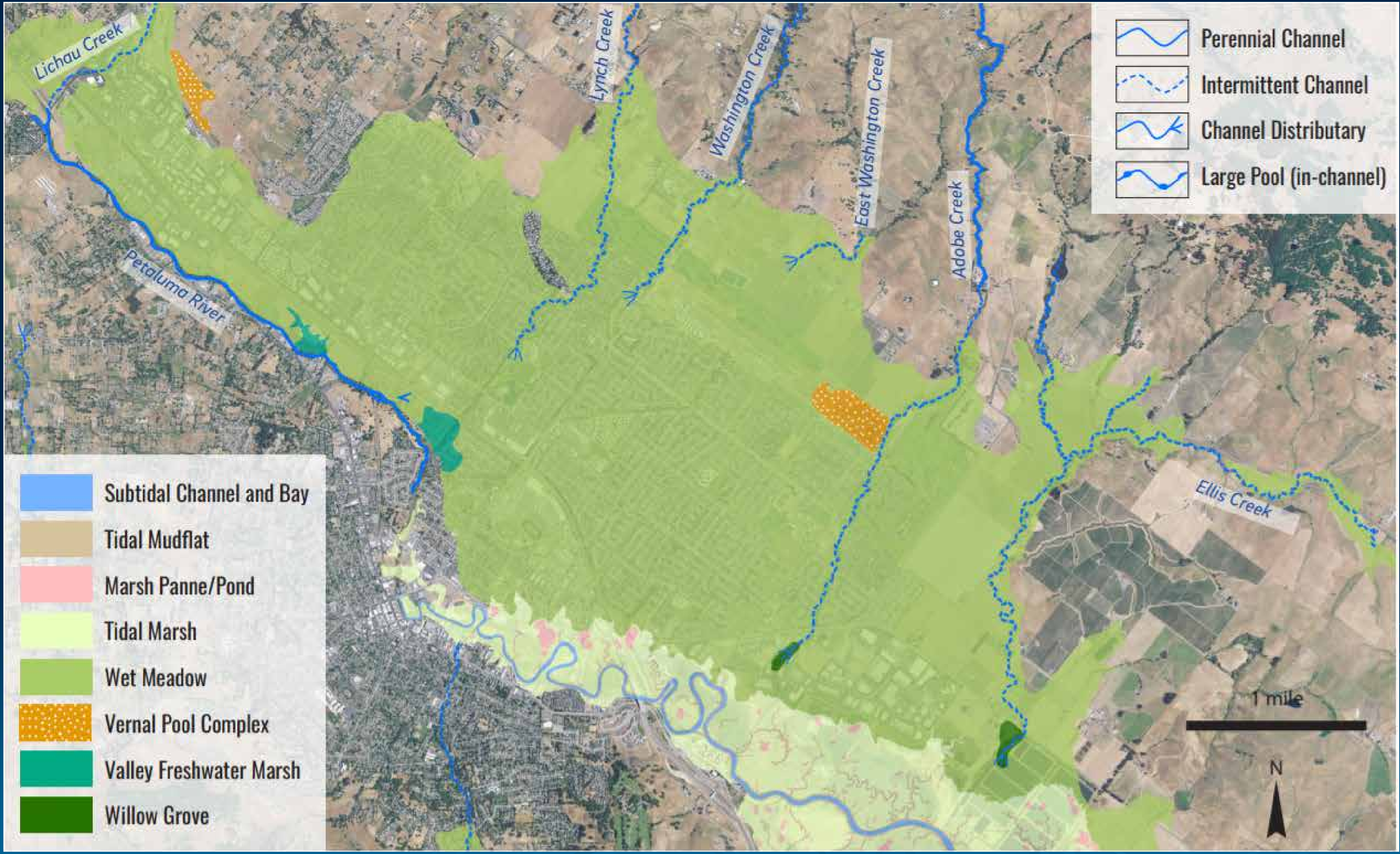
Photo: Ann Youberg, Arizona Geological Survey

Streamflow Dominated Fans



From Blair and McPherson (2009)

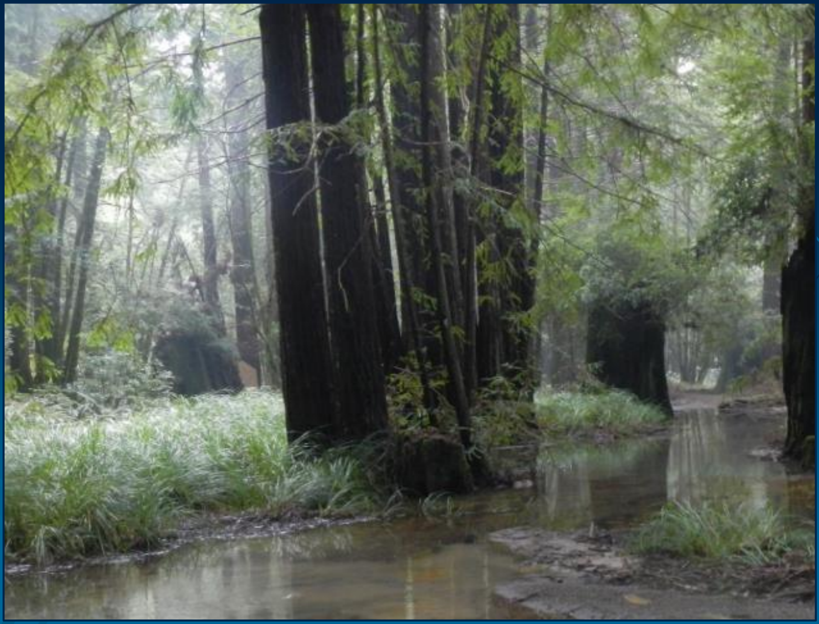
Petaluma River and Tributaries
Mid 19th Century



From Baumgarten et al., 2018, San Francisco Estuary Institute

Role of Alluvial Fans in the Landscape

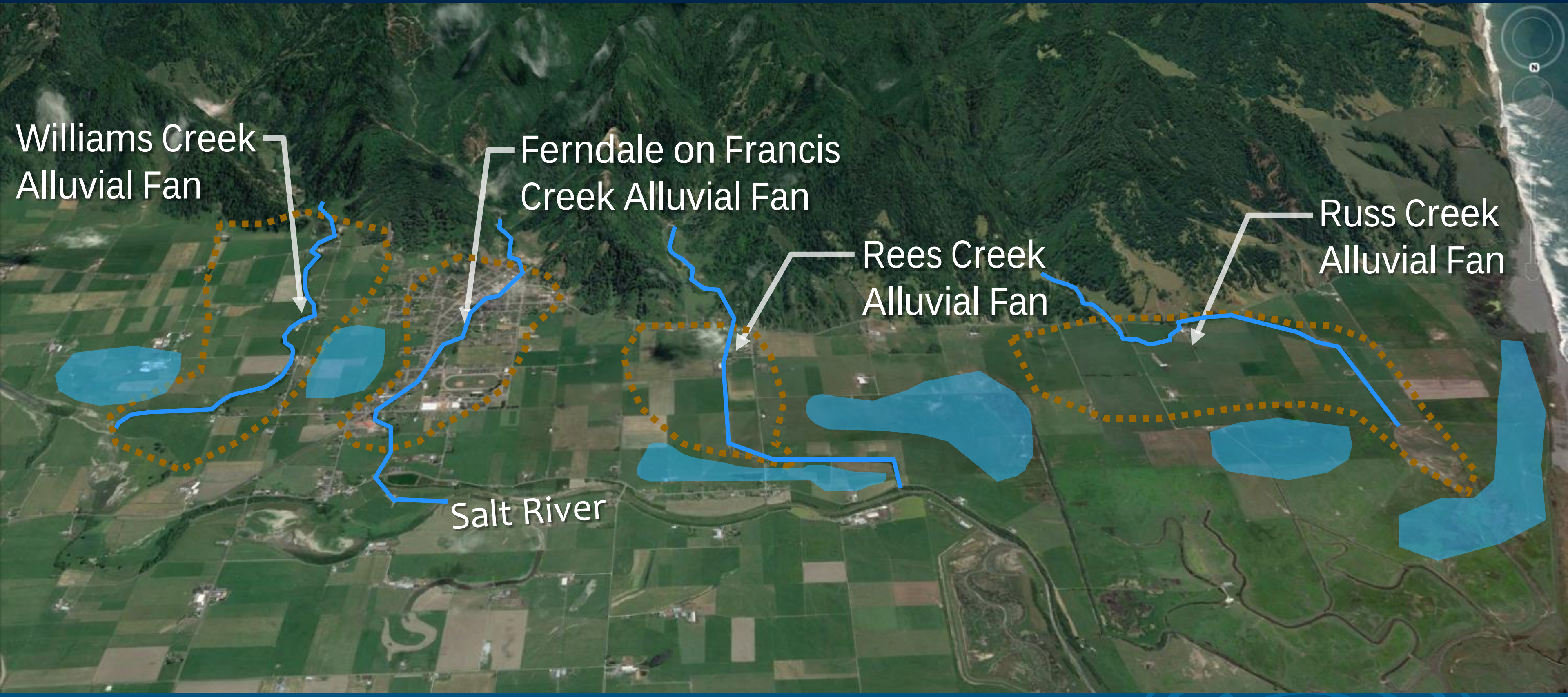
- Linkage between two fluvial systems
- Buffers water and sediment delivery to receiving waterbody
- Recharges groundwater
- Springs, seeps and overbank flows feed wetlands and streams along the fan's distal end



Bear Creek Alluvial Fan
Mattole River Estuary

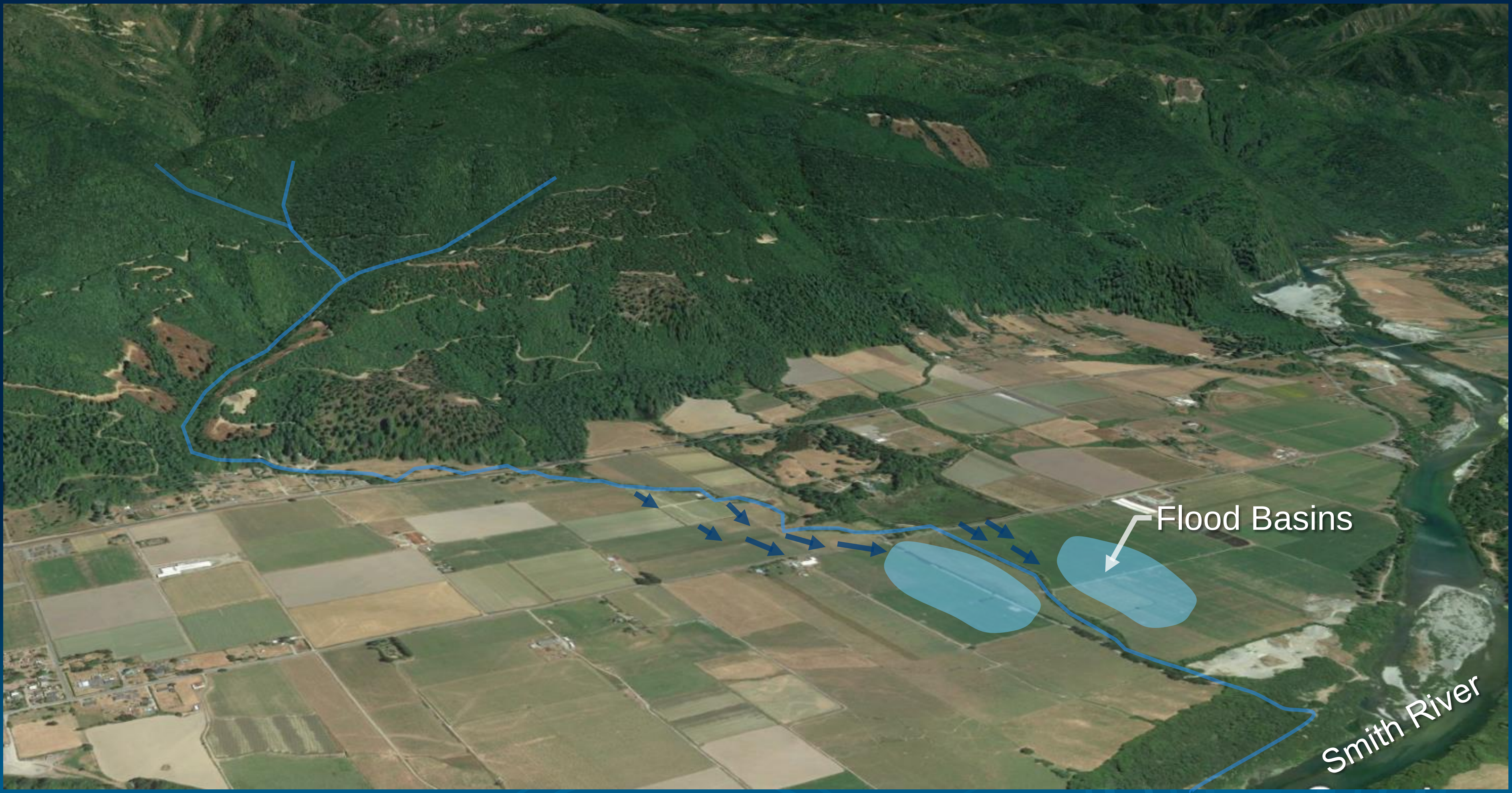
Wetlands at Distal end of Bear Creek Alluvial Fan

Settlement on Alluvial Fans

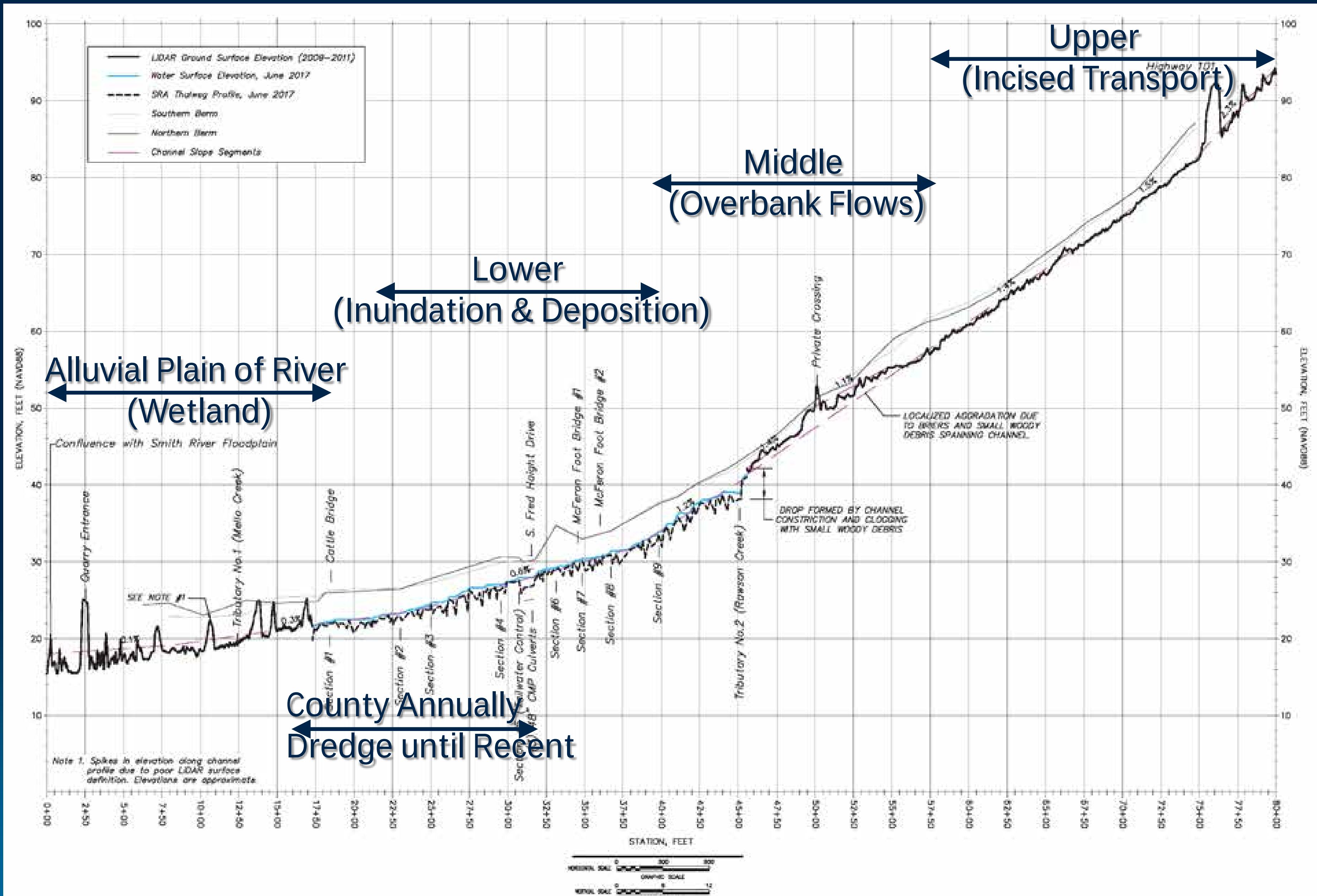


Eel River Bottoms

North Coast Alluvial Fans



Morrison Creek, Smith River, California


Upper
(Incised Transport)
Middle
(Overbank Flows)
Lower
(Inundation & Deposition)
Alluvial Plain of River
(Wetland)
County Annually
Dredge until Recent
LIDAR Ground Surface Elevation (2009–2011)
Water Surface Elevation, June 2017
SRA Thalweg Profile, June 2017
Southern Berm
Northern Berm
Channel Slope Segments
ELEVATION, FEET (NAVD88)
STATION, FEET
Confluence with Smith River Floodplain
Quarry Entrance
Tributary No.1 (Mello Creek)
Cattle Bridge
S. Fred Haight Drive
McFeron Foot Bridge #1
McFeron Foot Bridge #2
Private Crossing
Highway 101
Tributary No.2 (Rawson Creek)
LOCALIZED AGGRADATION DUE TO BRIERS AND SMALL WOODY DEBRIS SPANNING CHANNEL
DROP FORMED BY CHANNEL CONSTRICTION AND CLOGGING WITH SMALL WOODY DEBRIS
Note 1. Spikes in elevation along channel profile due to poor LiDAR surface definition. Elevations are approximate.

Historical Management of Streams on Fans

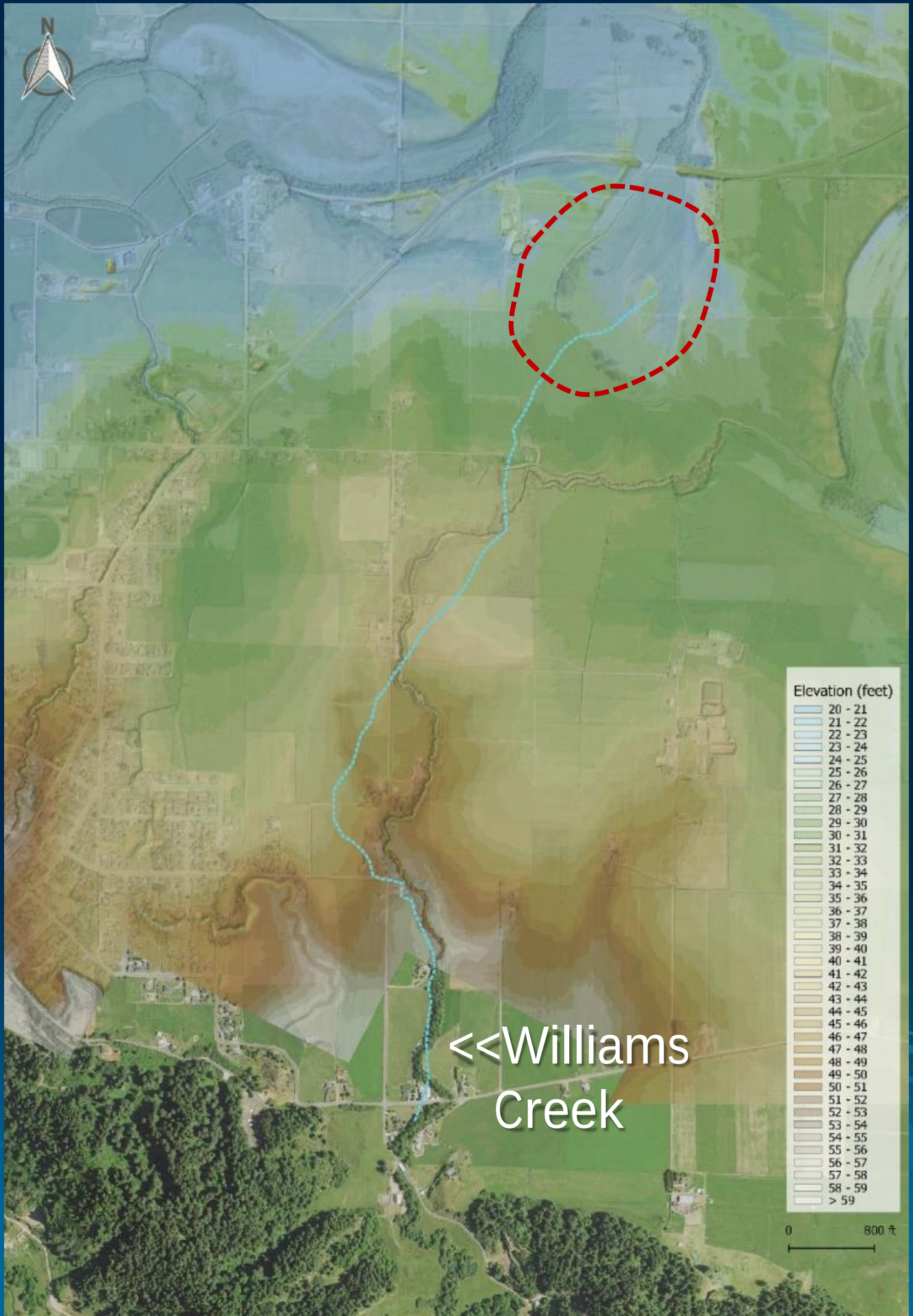
- Channelizing
- Dredging and Berming
- Annual maintenance

Rees Creek

Francis Creek Dredging to Move Depositional Lobe Further Out onto Alluvial Plain

Williams Creek Alluvial Fan

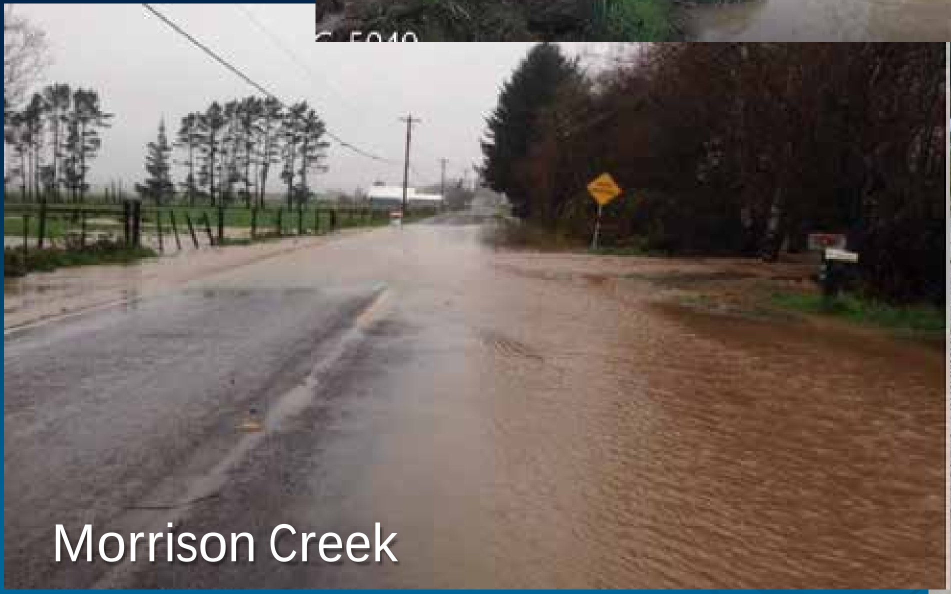
Francis Creek>>



Blue Line = 1916 Alignment

Williams Creek Alluvial Fan
Current Day Depositional Lobe

Living on Fans in Current-Day Regulatory Environment



Morrison Creek

Cummings Creek

Channel Aggradation Leads to Berm Breaching

Cessation of "Channel Maintenance" Leads to Flooding/Avulsions

Cummings Creek, Van Duzen River Tributary, Carlota CA

Debris and Sediment Basins

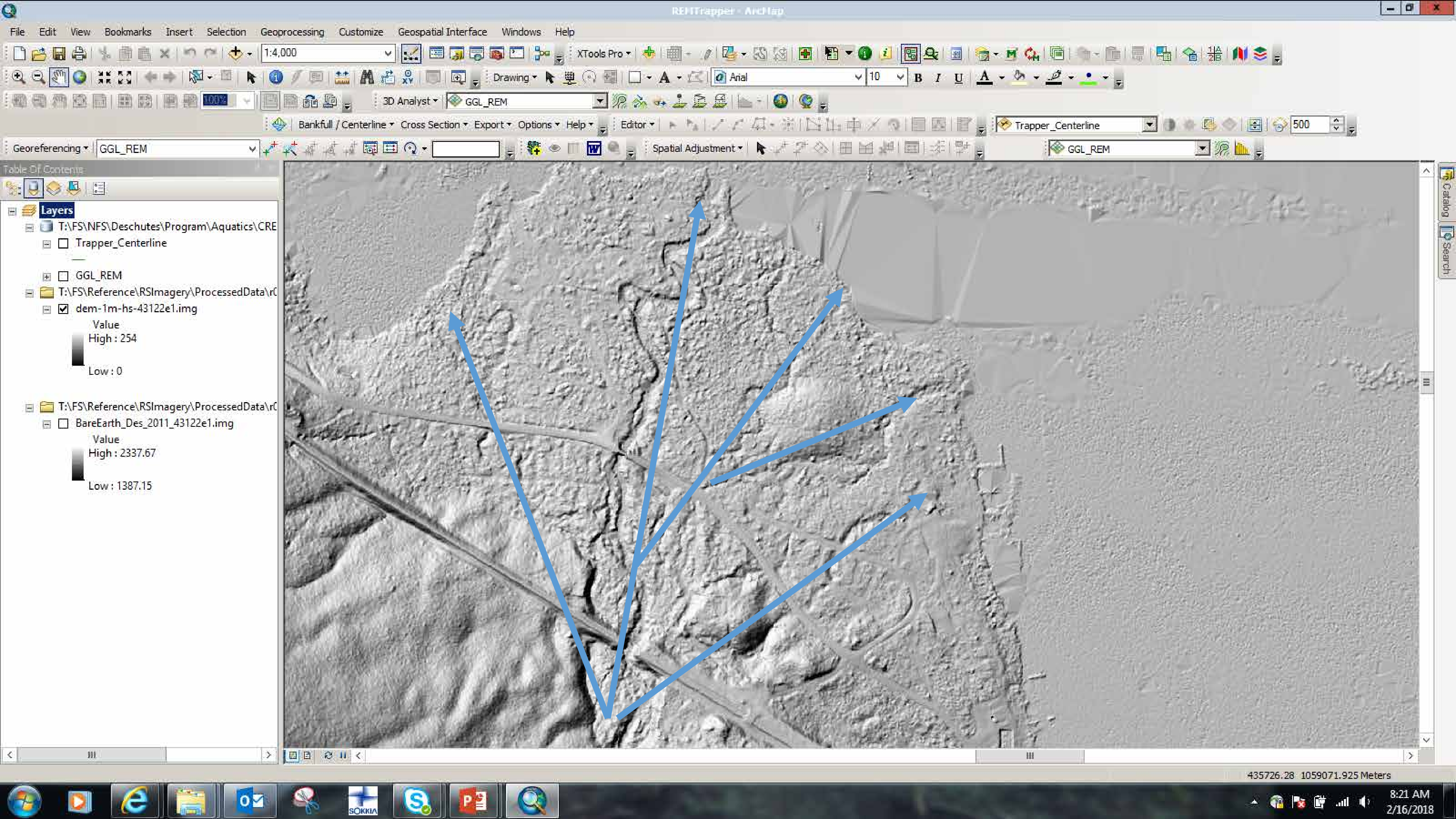
Thinking Forward – Managing Alluvial Fans

- Consider the benefits functioning fans provide at their downstream end:
  - Groundwater recharge
  - Improved water quality
  - Expand wetlands,
  - Backwater habitats
- Rethink the need for single thread channels and “continuous fish passage corridors” across fans
- Aim to restore fluvial processes on alluvial fans
  - Full restoration
  - Containment of active fan corridor
  - Rotational depositional lobes

Questions?

Alluvial Fan Construction in the Pacific Northwest

Paul Powers-Deschutes National Forest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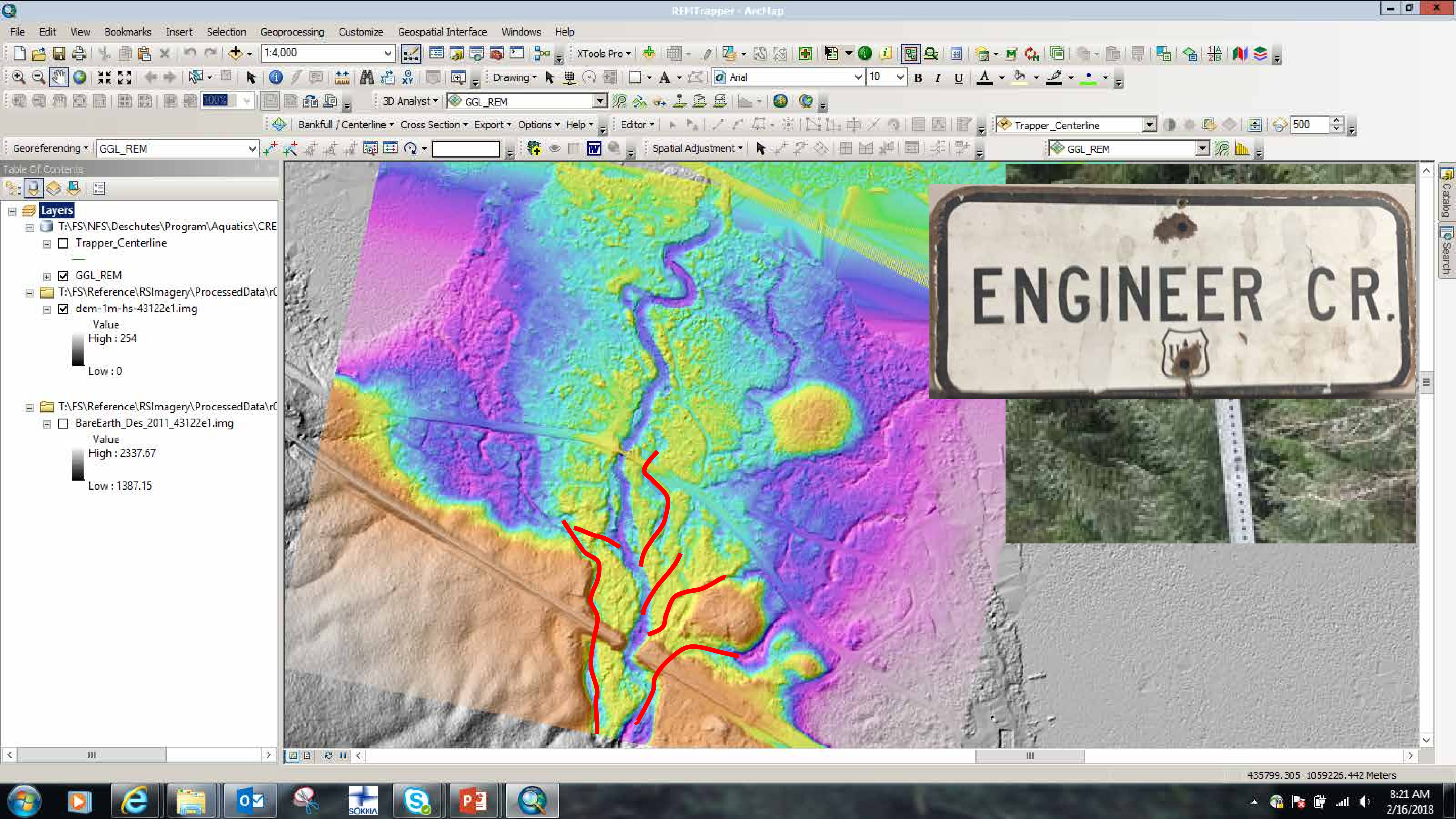
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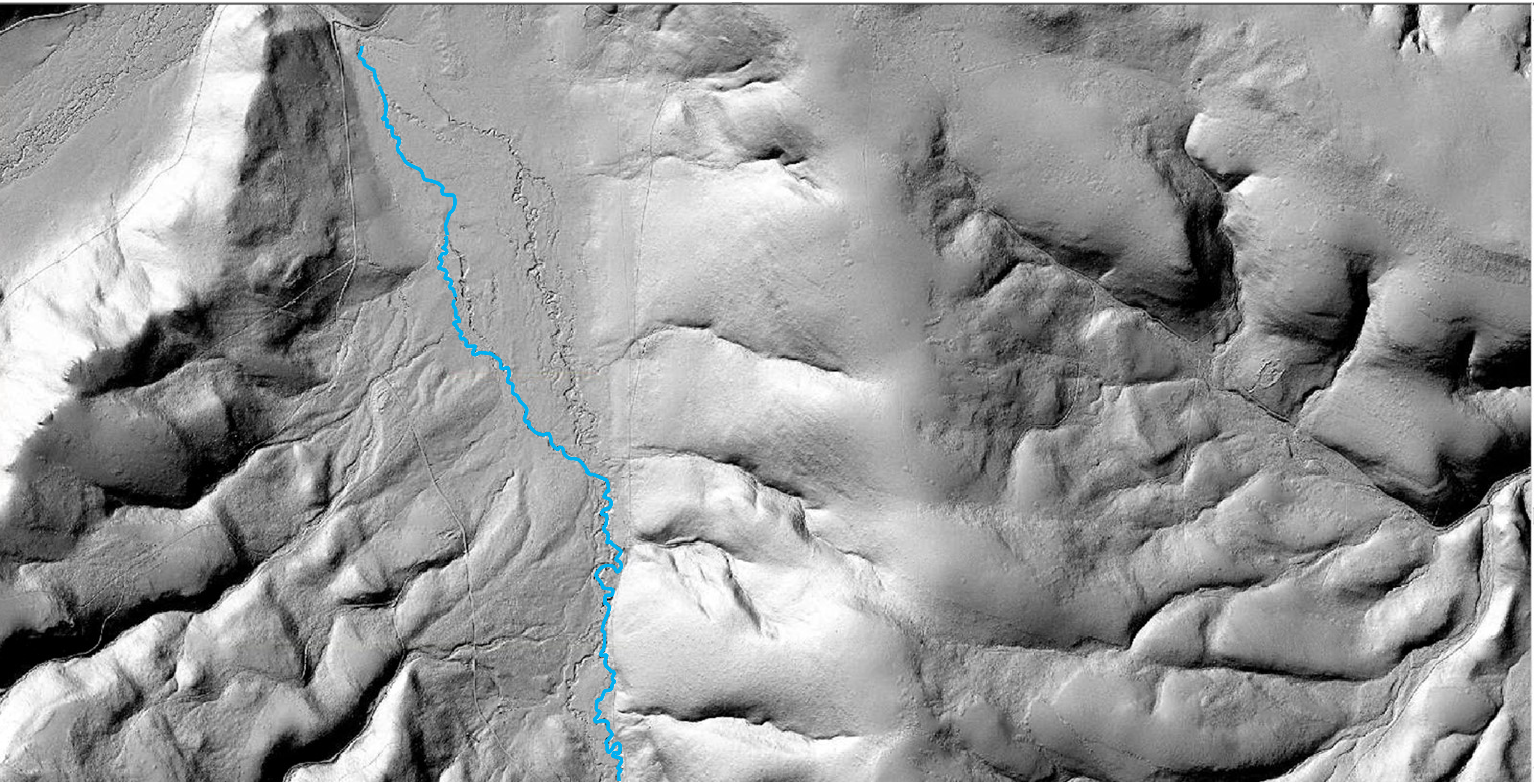
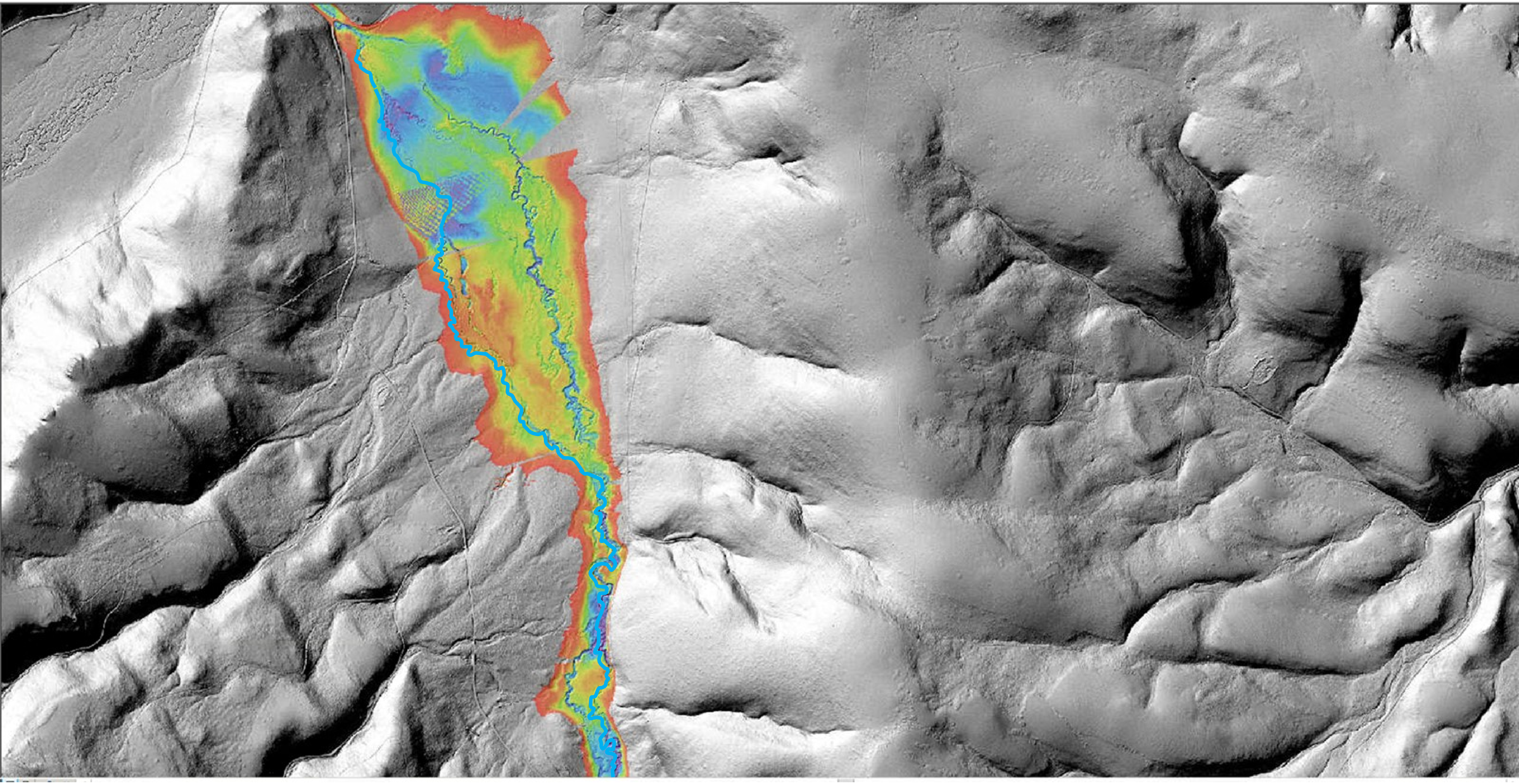
2/16/2018

Separation berm blocking flow into relic channels





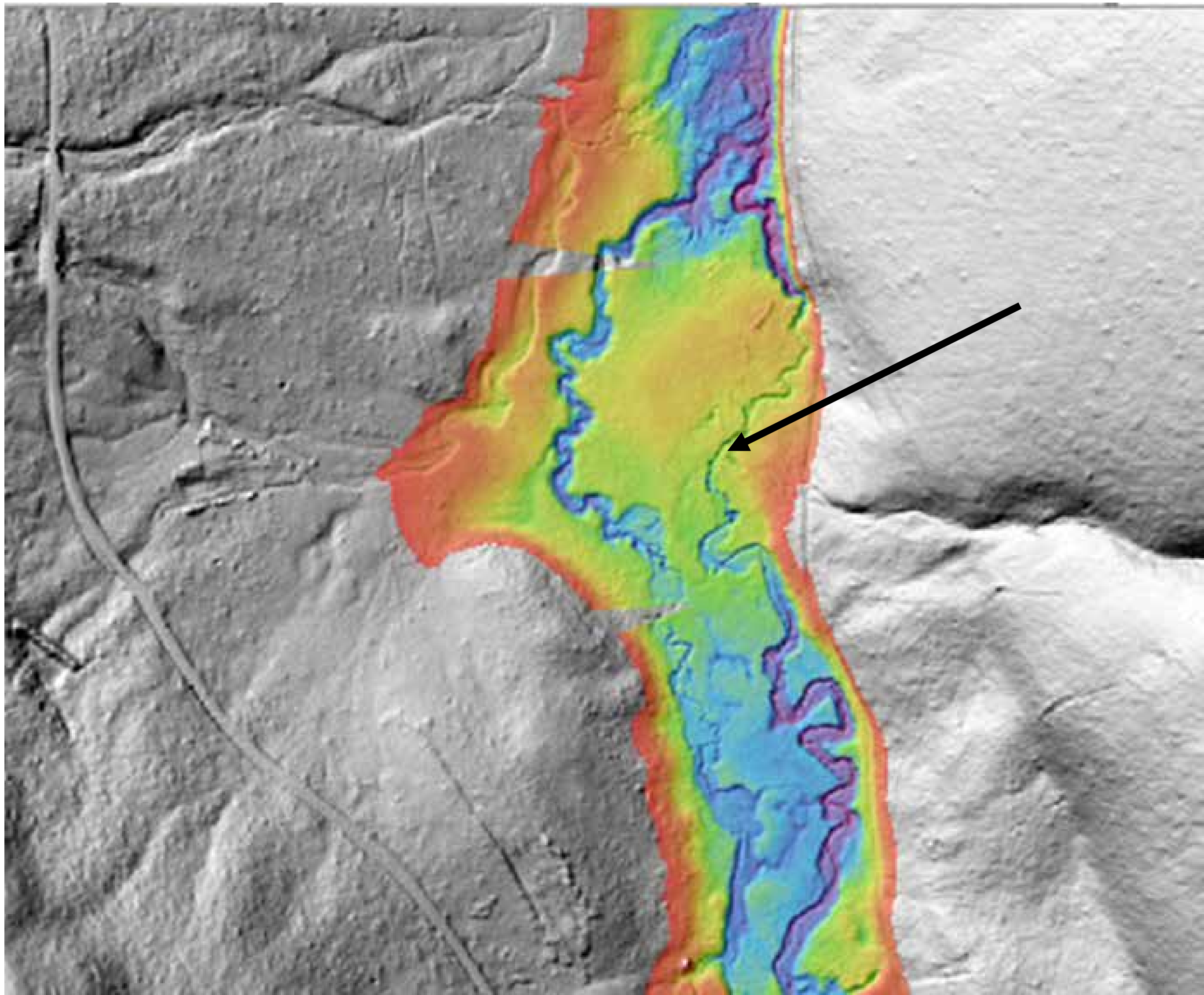


Photo credit: James Pettett

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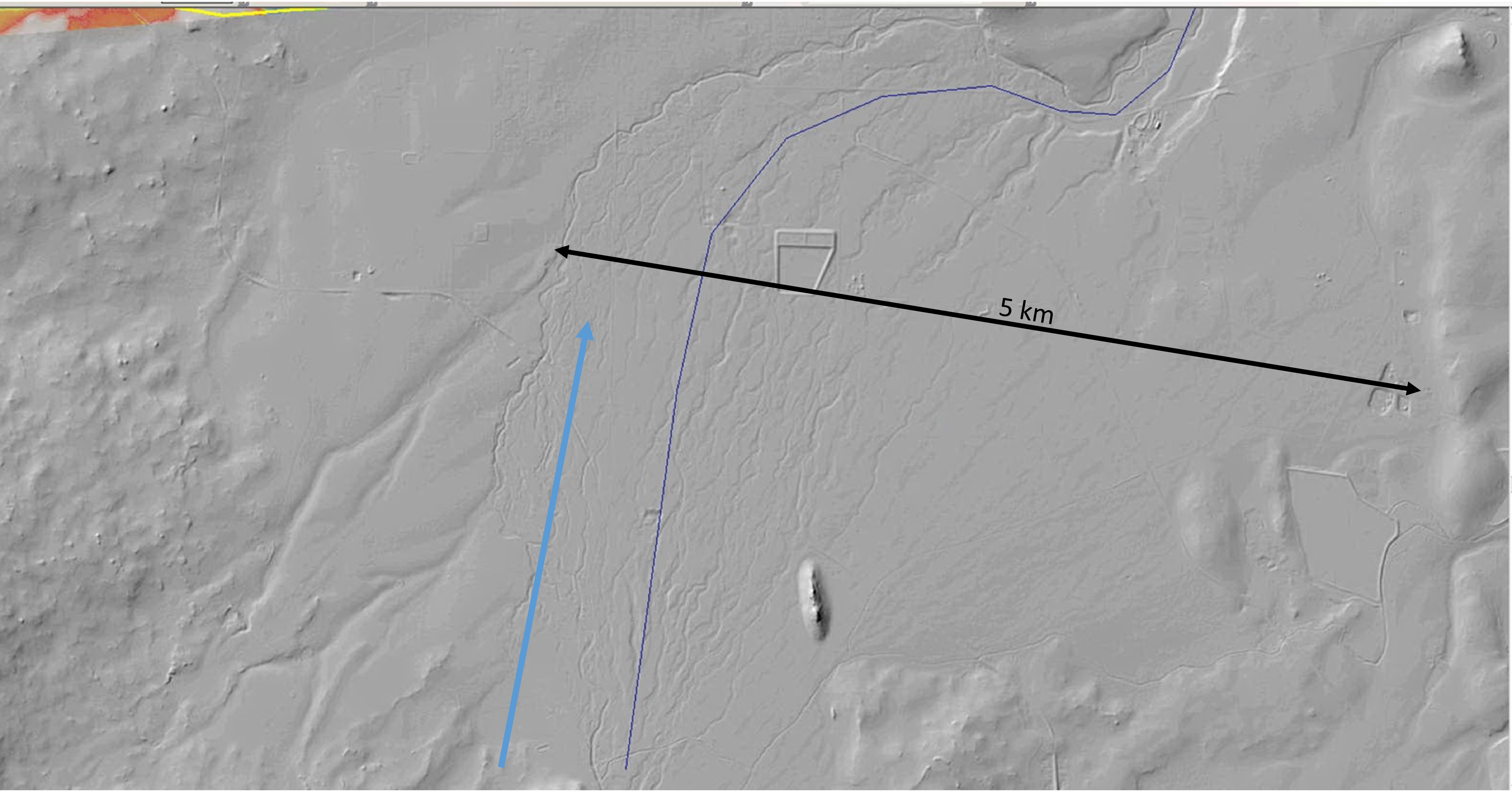
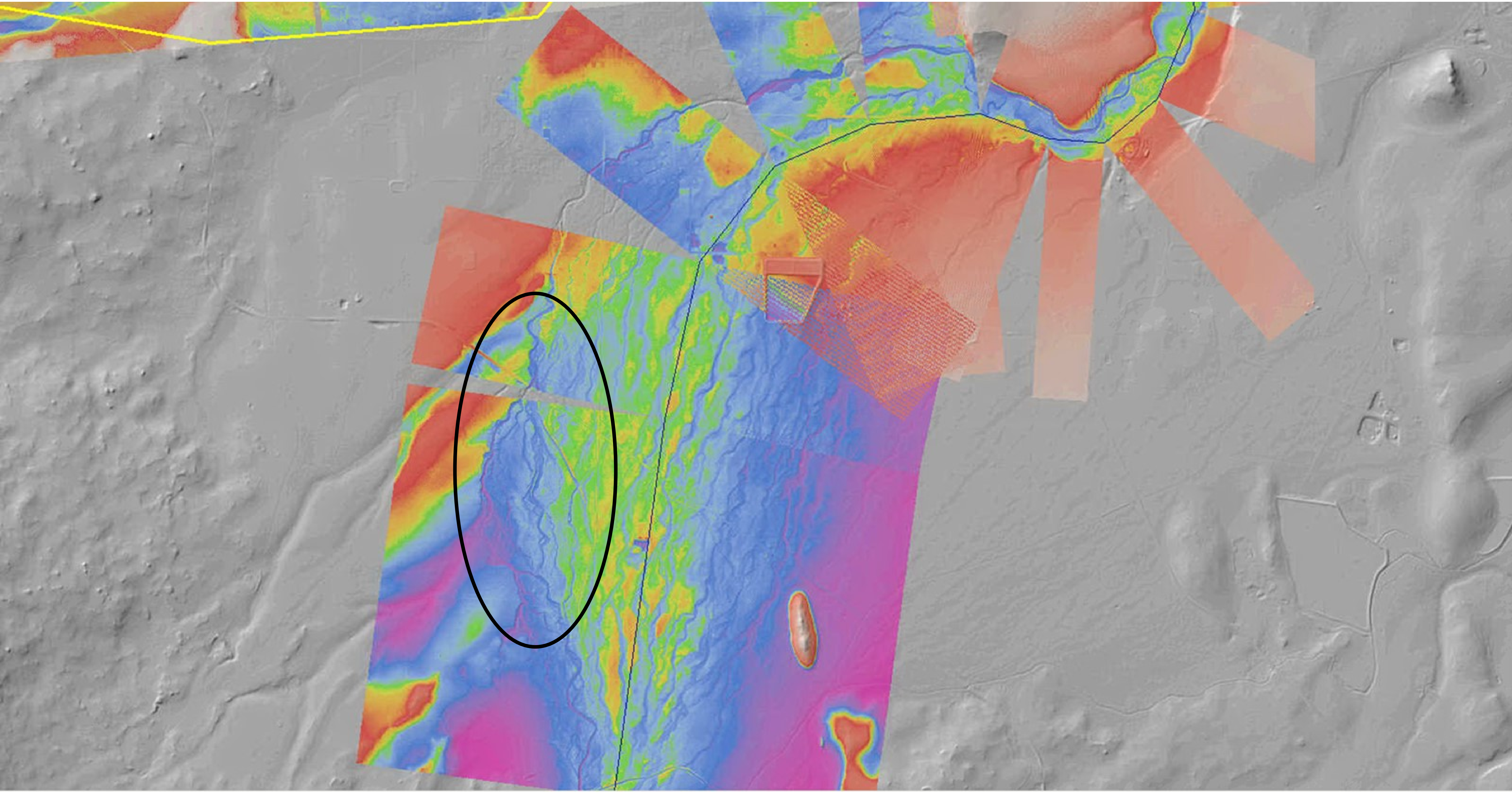
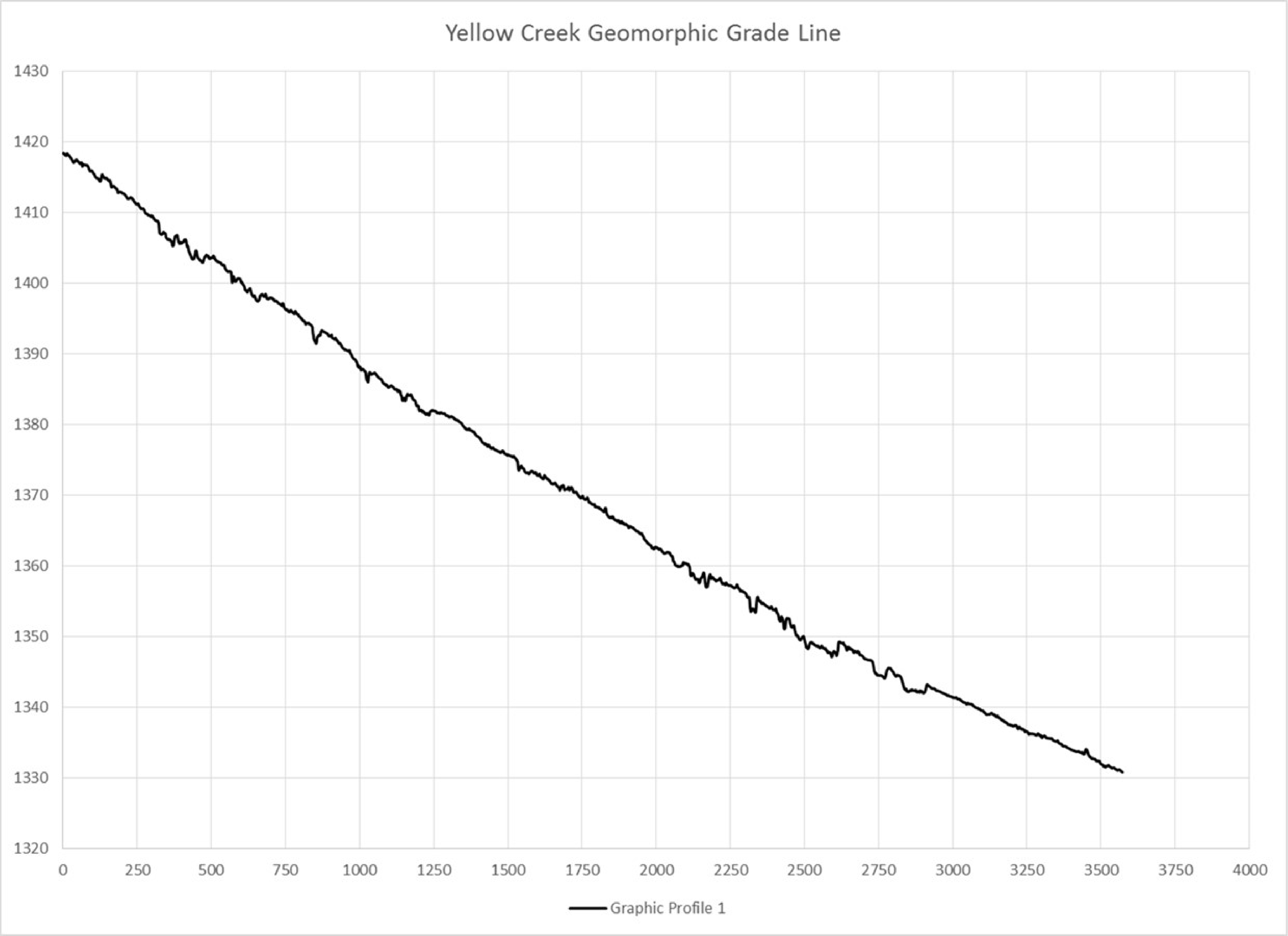
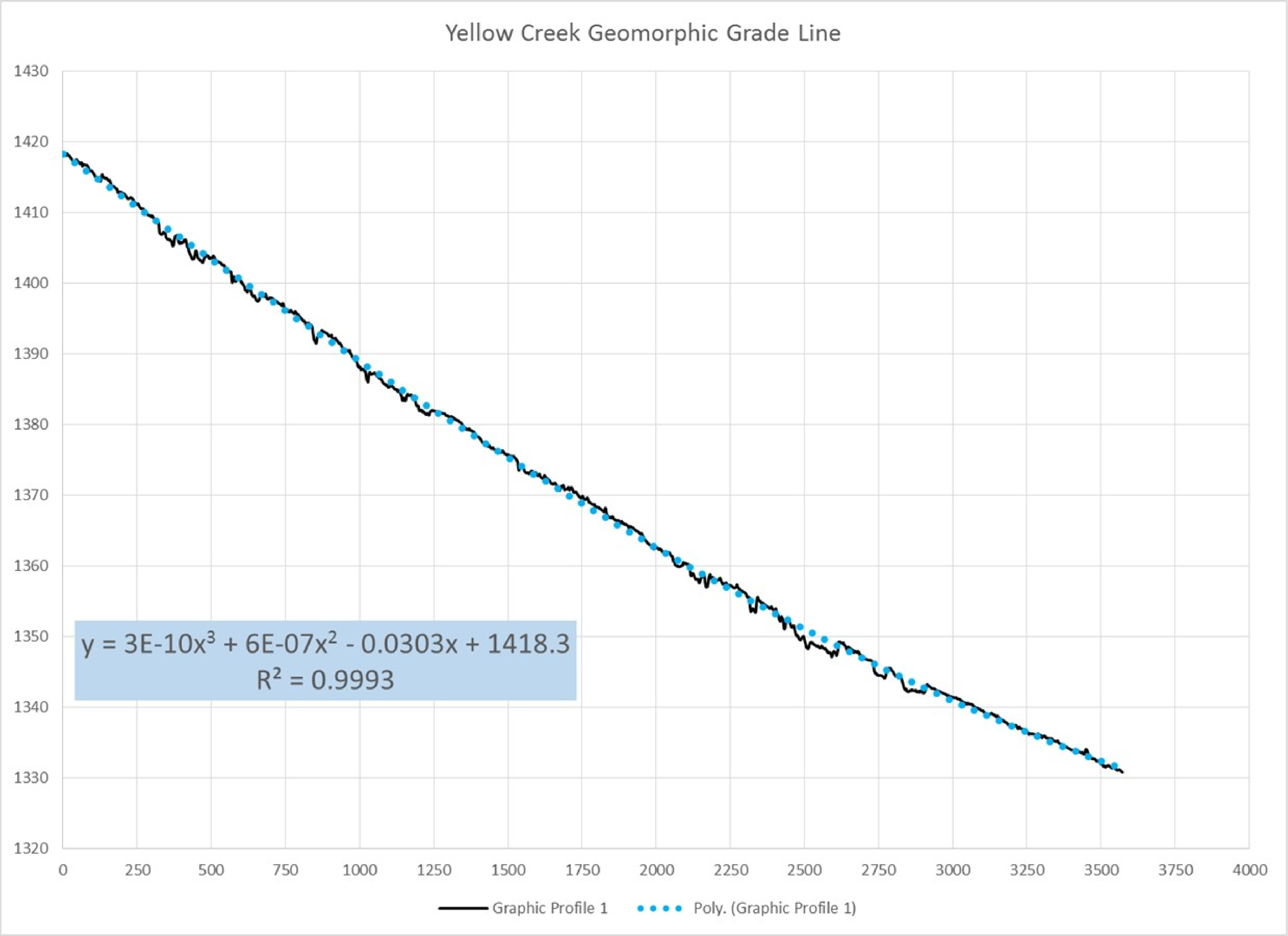

5 km





Yellow Creek Geomorphic Grade Line
1430
1420
1410
1400
1390
1380
1370
1360
1350
1340
1330
1320
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
Graphic Profile 1


Yellow Creek Geomorphic Grade Line
1430
1420
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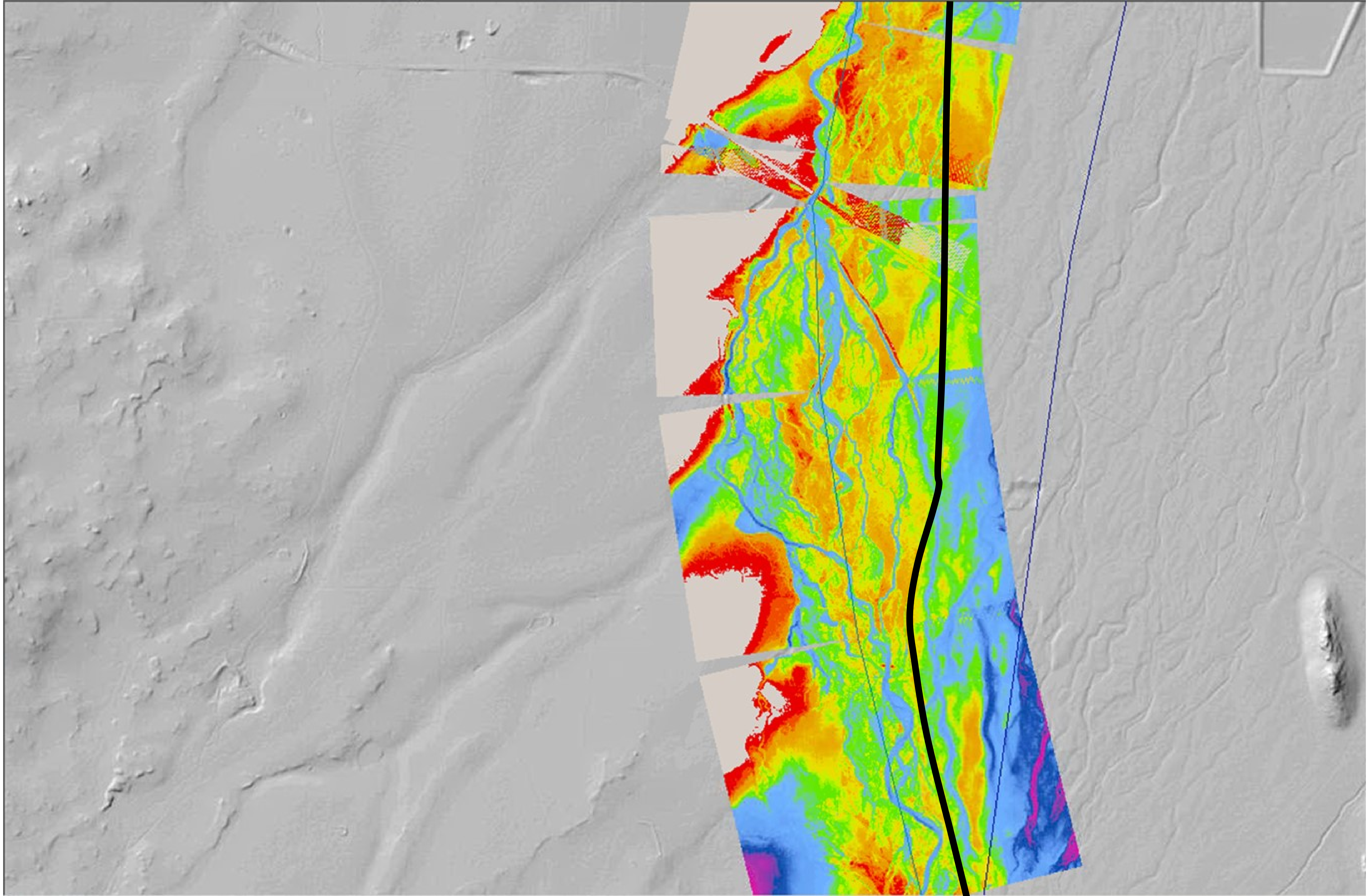
1360
1350
1340
1330
1320
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
3250
3500
3750
4000
y = 3E-10x3 + 6E-07x2 - 0.0303x + 1418.3
R2 = 0.9993
Graphic Profile 1
Poly. (Graphic Profile 1)



Pre

Post

Pre

Post

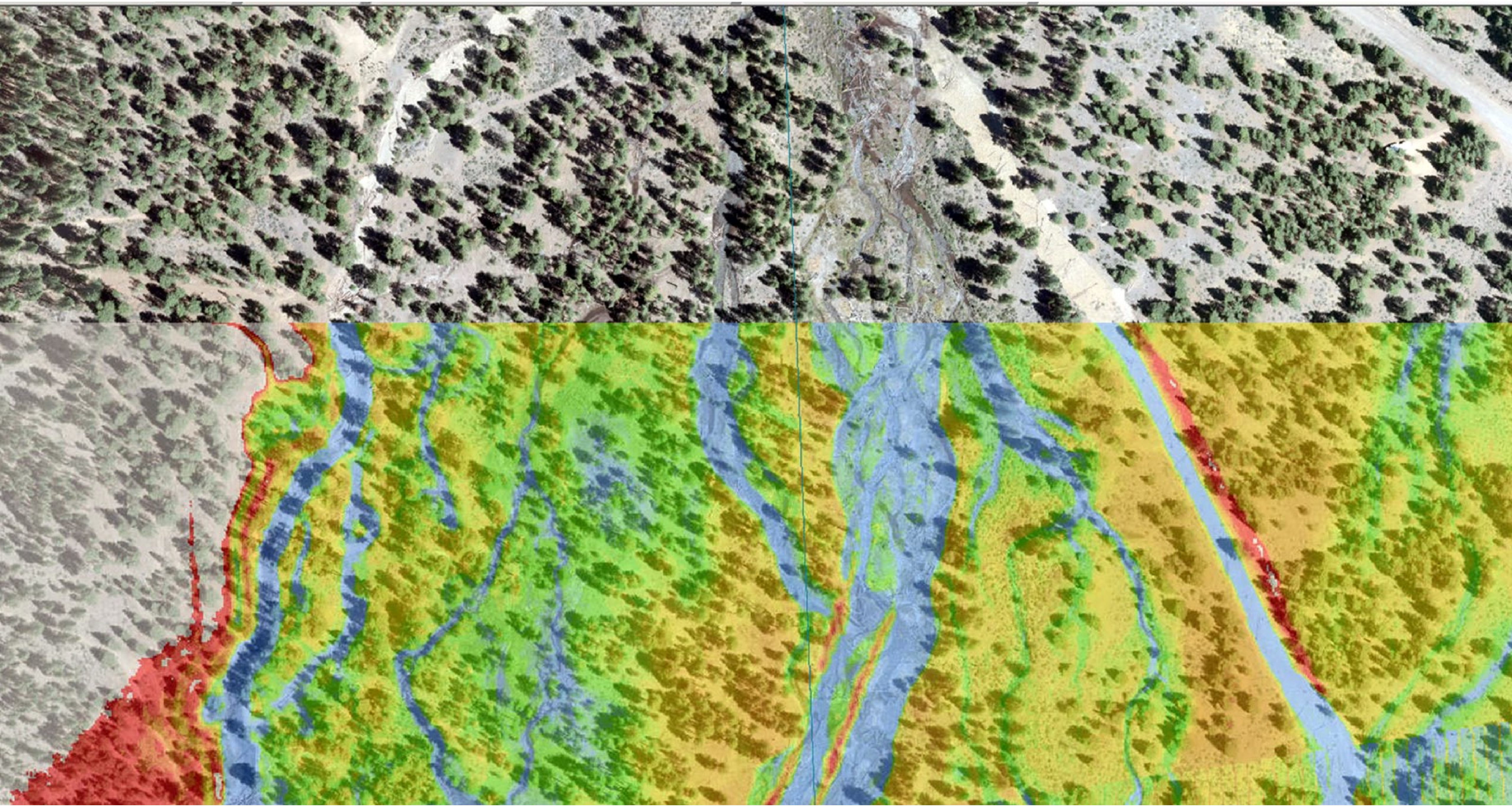
Post


03.22.2015 08:45


03 22 2015 08 44

Post

Post




Pre

Implementation

Implementation

- 25 streamside trees (38-63” dbh) were pulled over using a truck-mounted yarder to serve as large, stable key pieces

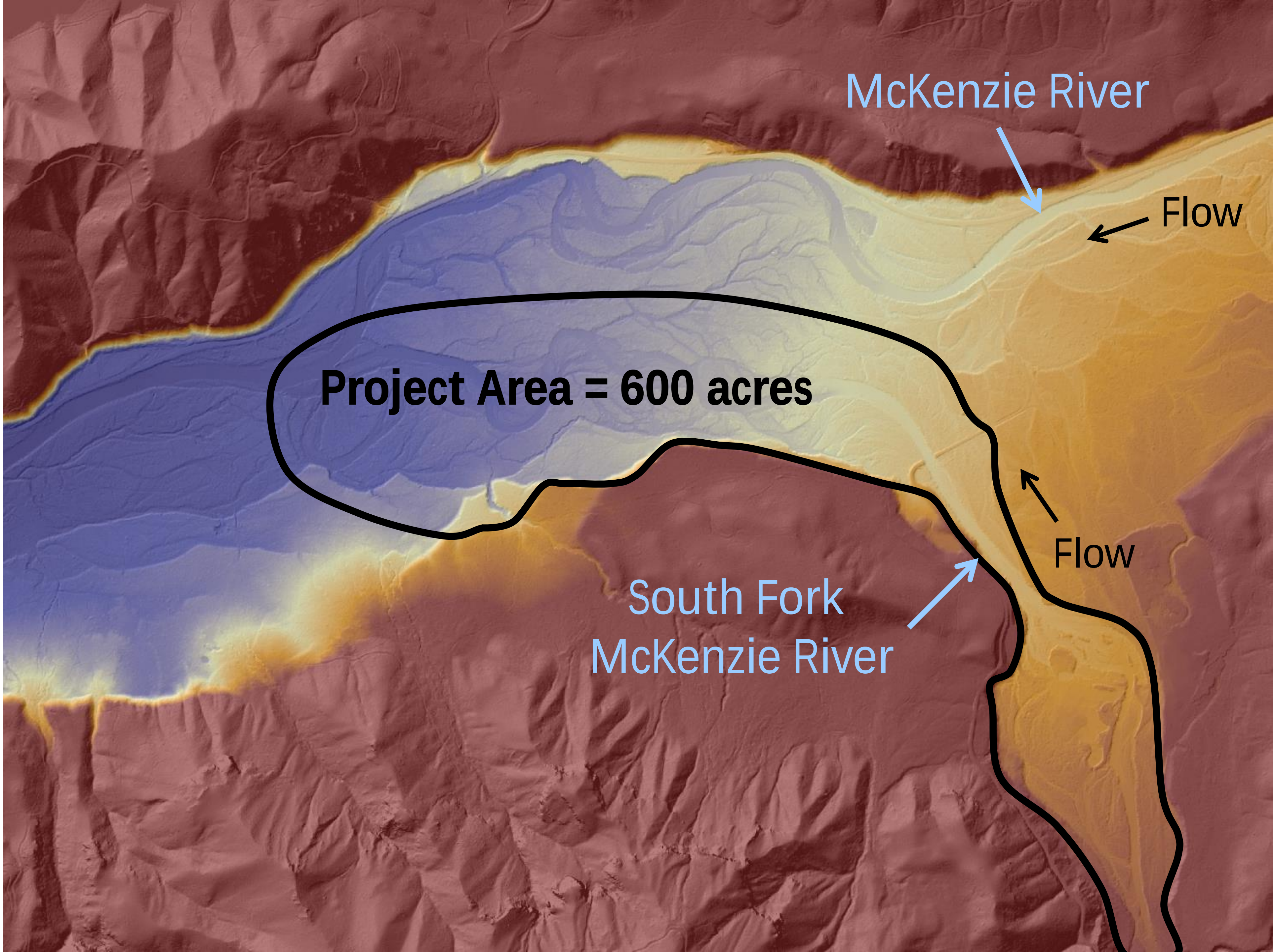
Post

Photo credit: Kate Meyer

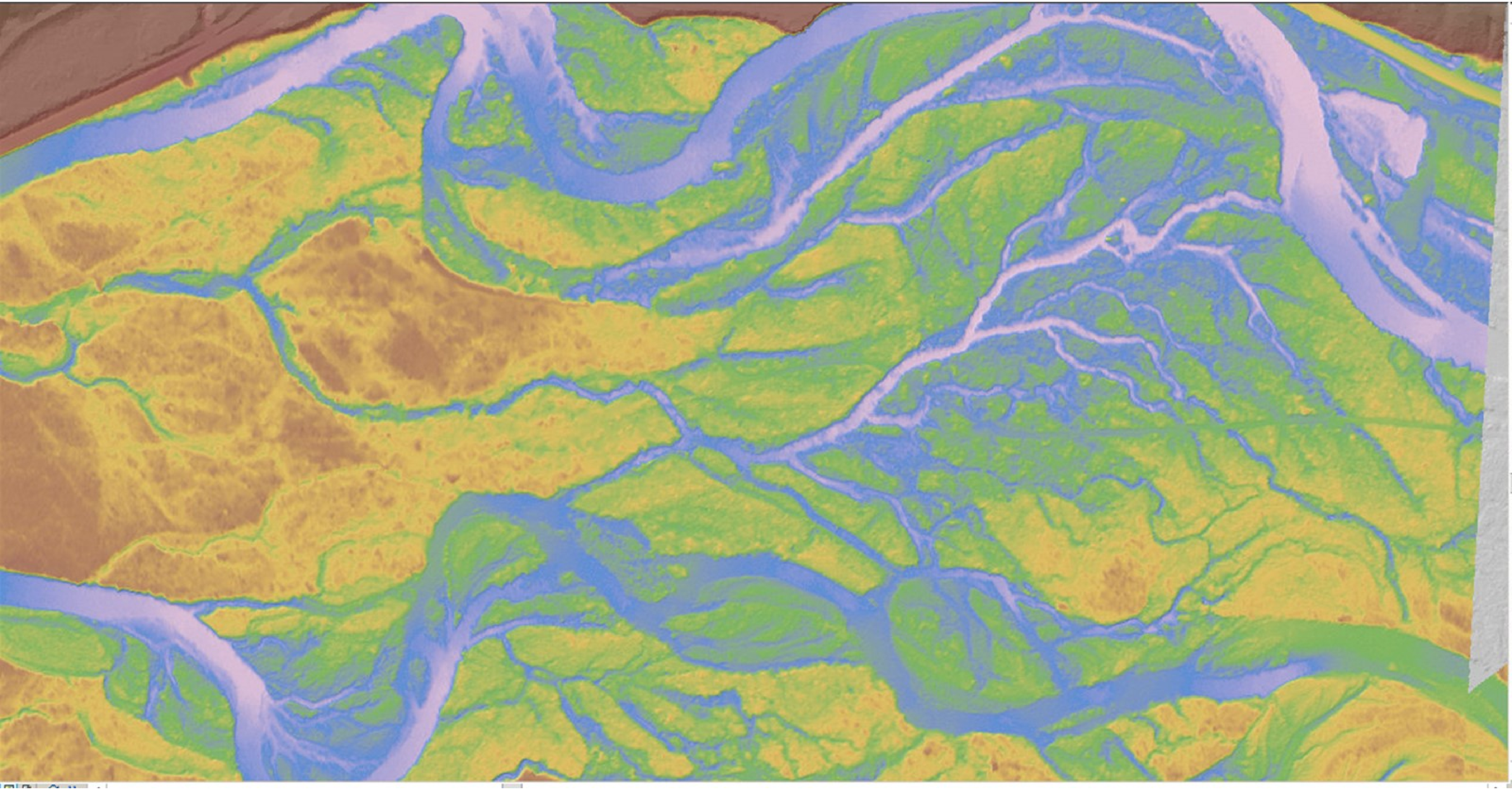
Photo credit: Kate Meyer

Photo credit: Kate Meyer

Photo credit: Kate Meyer


McKenzie River
Flow
Project Area = 600 acres
Flow
South Fork
McKenzie River

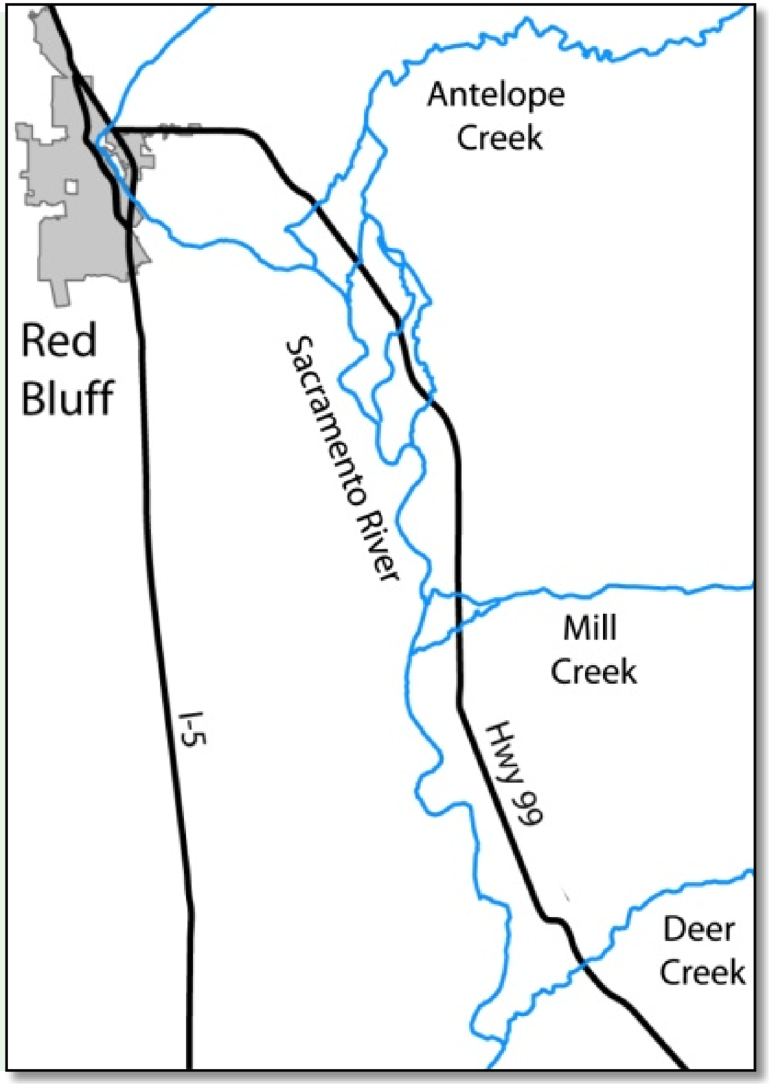
Pre



FISH PASSAGE ACROSS THE ANTELOPE CREEK ALLUVIAL FAN

BACKGROUND

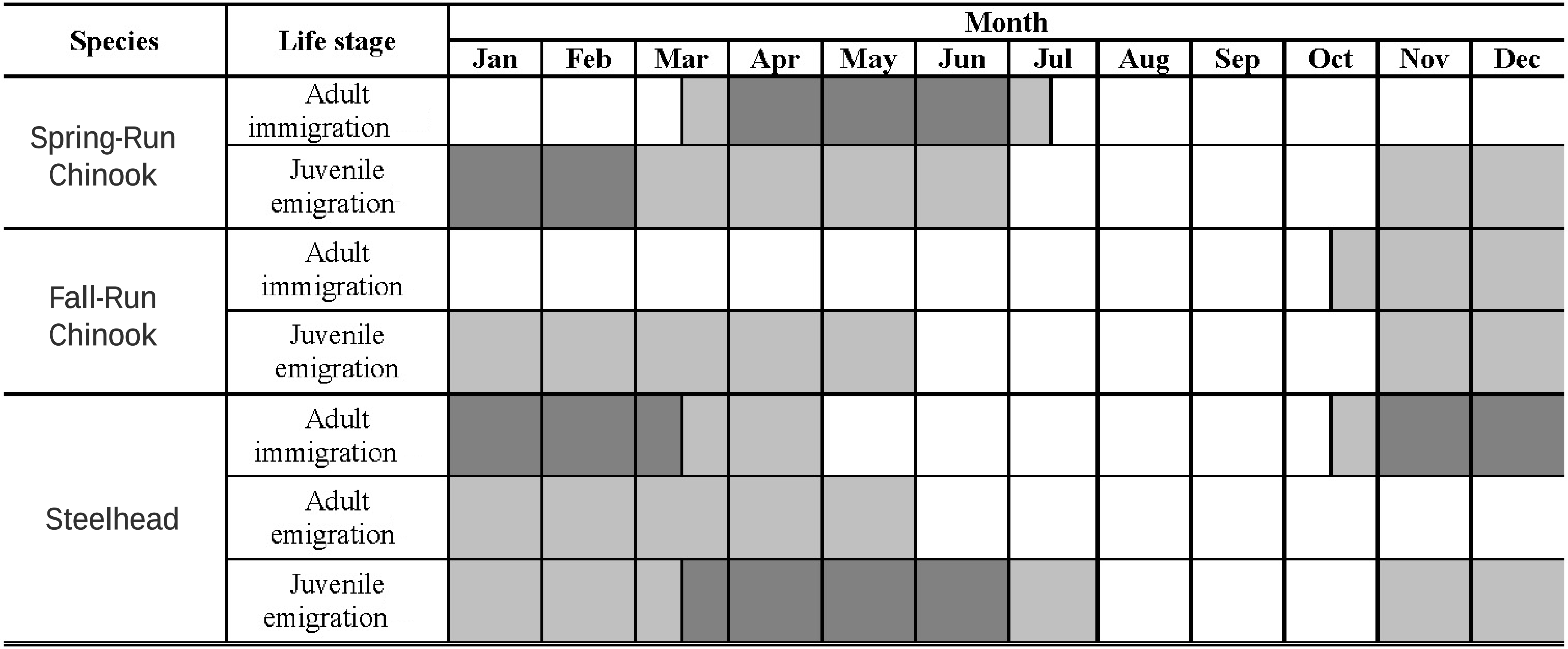
- **35 miles of critical habitat for Chinook salmon and steelhead**
- **5 mile migration across alluvial fan**
- **Reduced flow and elevated temperatures in alluvial fan reaches due to diversion at Edward Diversion Dam**
- **Priority actions (NMFS 2014):**
  - Restore instream flows during migration periods
  - Implement fish passage and entrainment improvement projects to restore connectivity
  - Identify and construct a defined stream channel for upstream and downstream fish migration



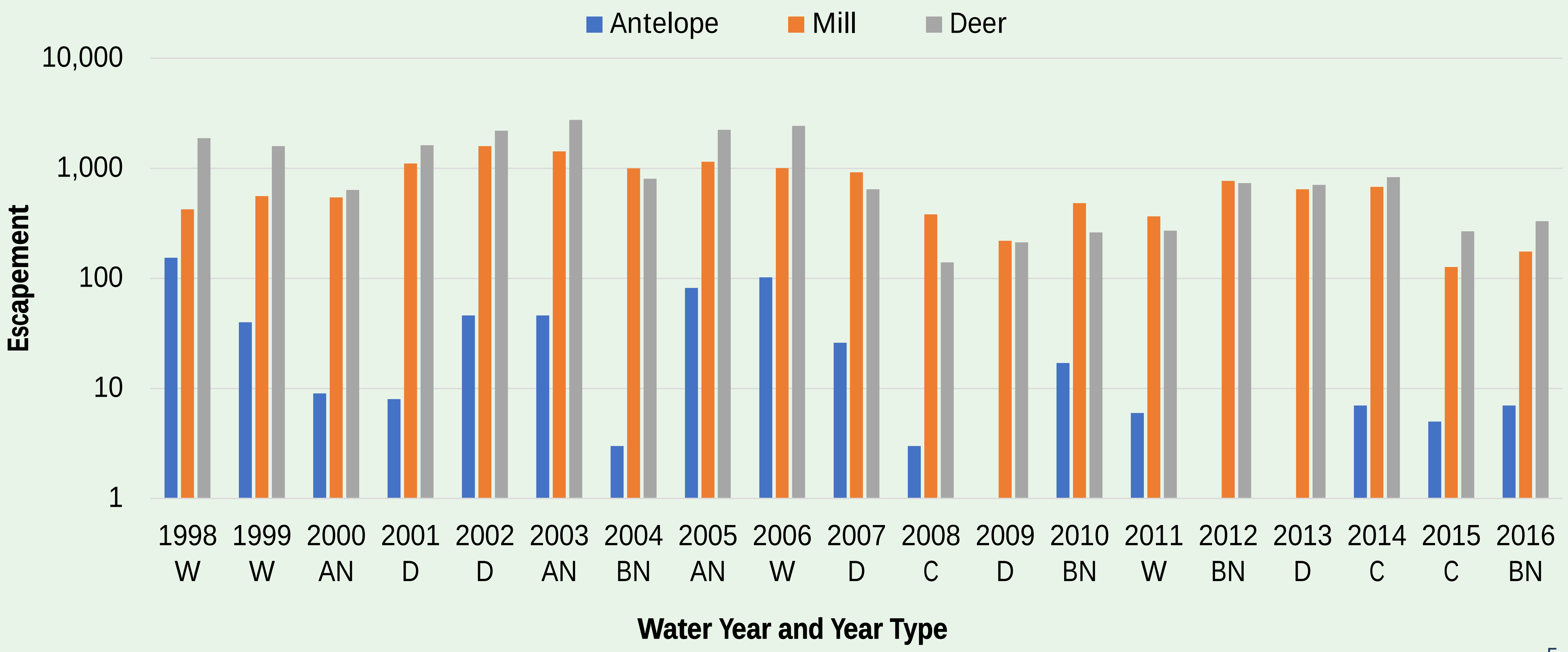
OBJECTIVES

- Occurrence and life histories of Chinook and steelhead
- Geomorphology
- Stream flow and temperature
- Impediments to passage
- Hydraulic conditions at critical passage locations
- Flow recommendations for passage

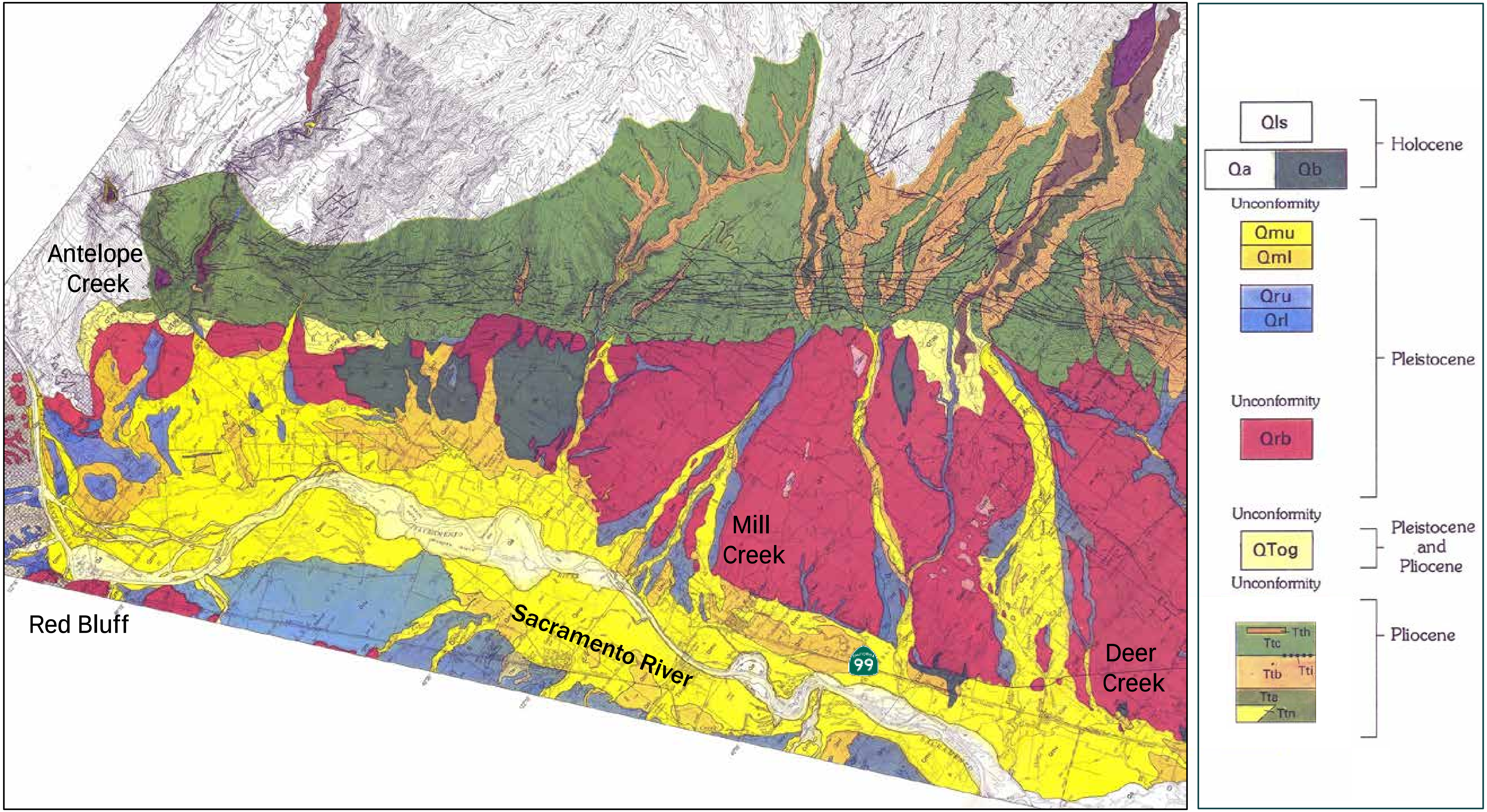
TIMING OF SALMON AND STEELHEAD MIGRATORY LIFE HISTORY



SPRING-RUN CHINOOK ESCAPEMENT

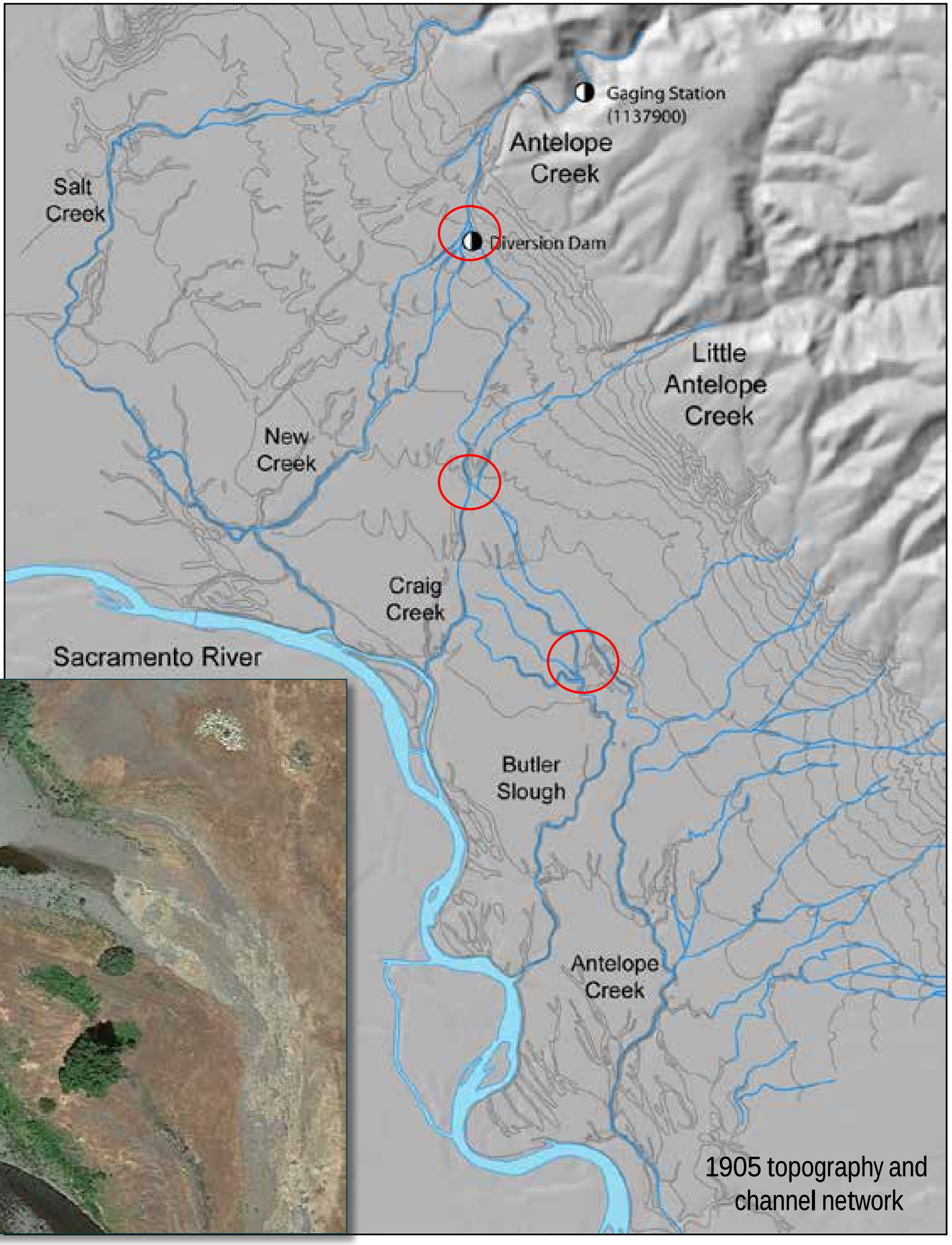


Antelope
Creek
Mill
Creek
36
Sacramento River
Main St
A8
Red Bluff
5
99
Deer
Creek


Antelope Creek
Mill Creek
Deer Creek
Red Bluff
Sacramento River
99
Qls
Qa
Qb
Holocene
Unconformity
Qmu
Qml
Qru
Qrl
Pleistocene
Unconformity
Qrb
Unconformity
QTog
Pleistocene and Pliocene
Unconformity
Tth
Ttc
Ttb
Tti
Tta
Ttn
Pliocene

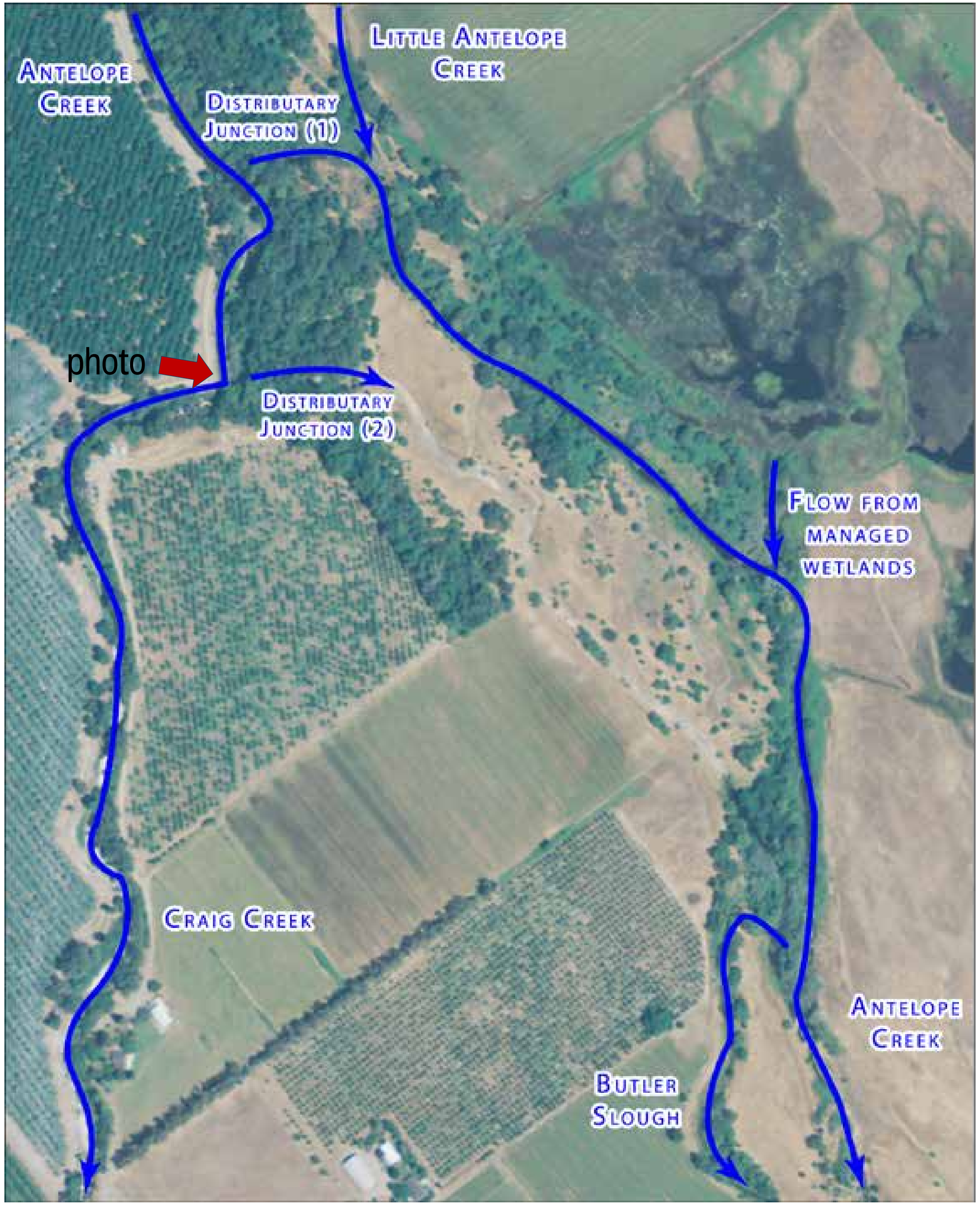
ALLUVIAL FAN CHANNEL NETWORK

- Ø **Dissected alluvial fan**
- Ø **Multiple channels connect Sacramento River to upper basin**
  - New Creek
  - Craig Creek
  - Butler Slough
  - Antelope Creek
- Ø **Flow separation at distributary junctions**

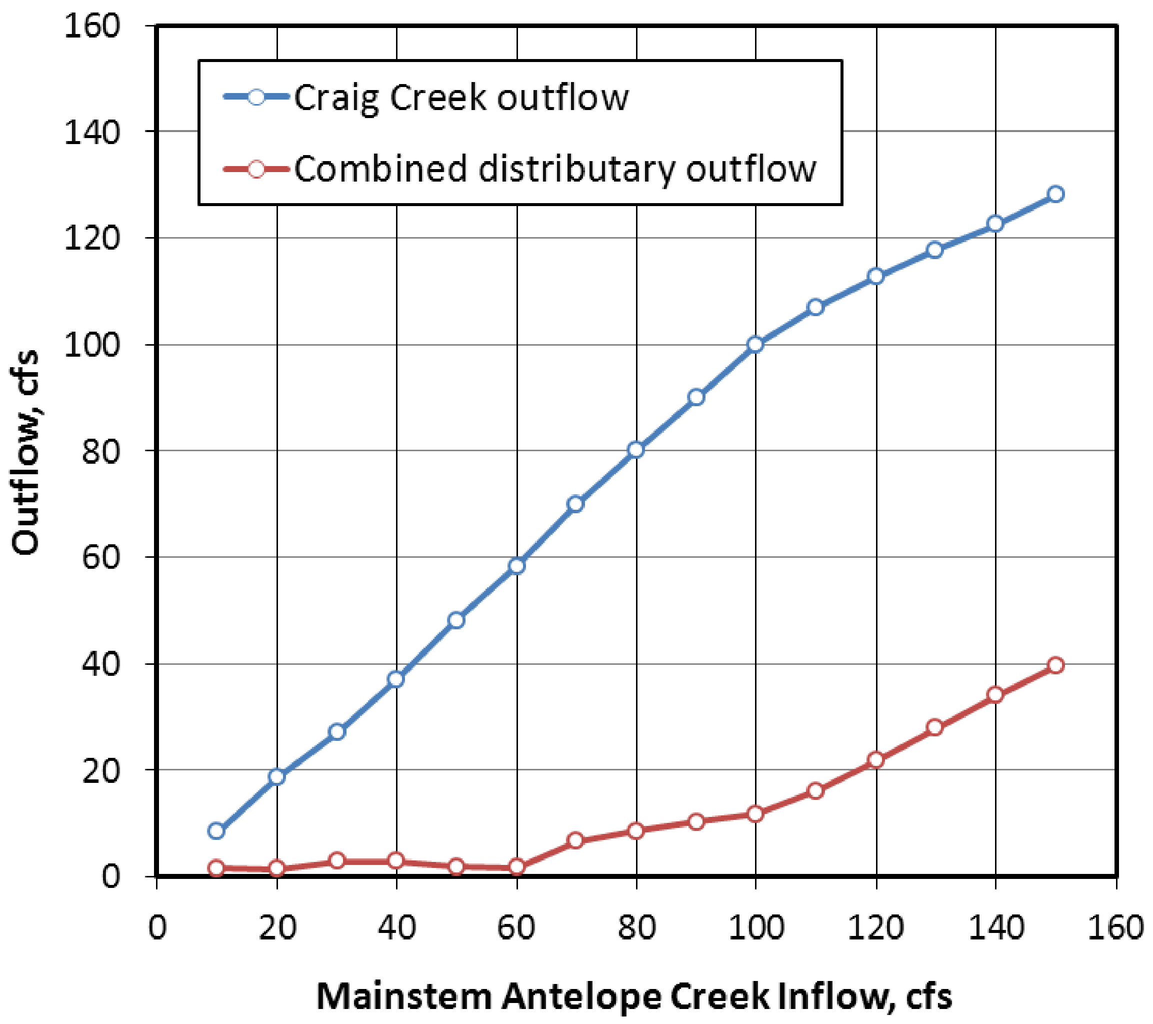


1905 topography and channel network

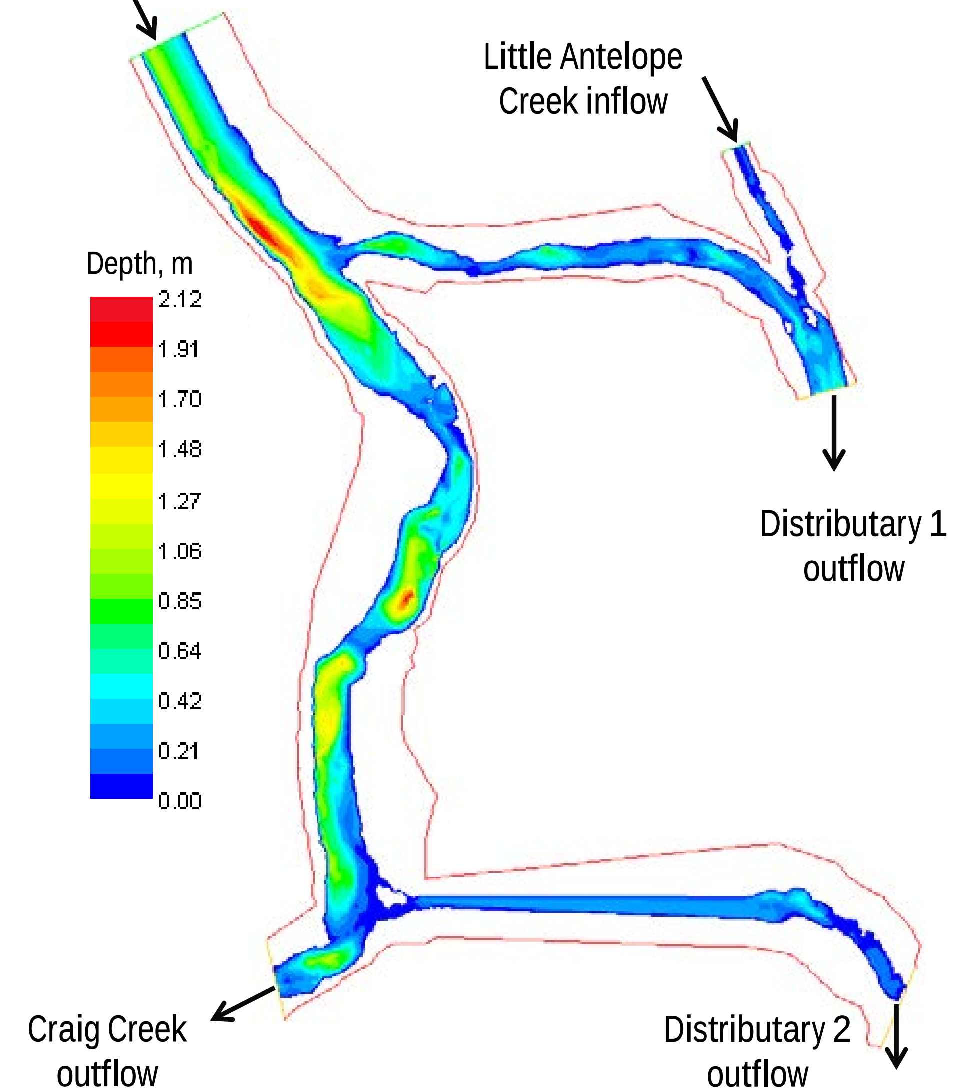
ANTELOPE CREEK–CRAIG CREEK DISTRIBUTARY JUNCTION

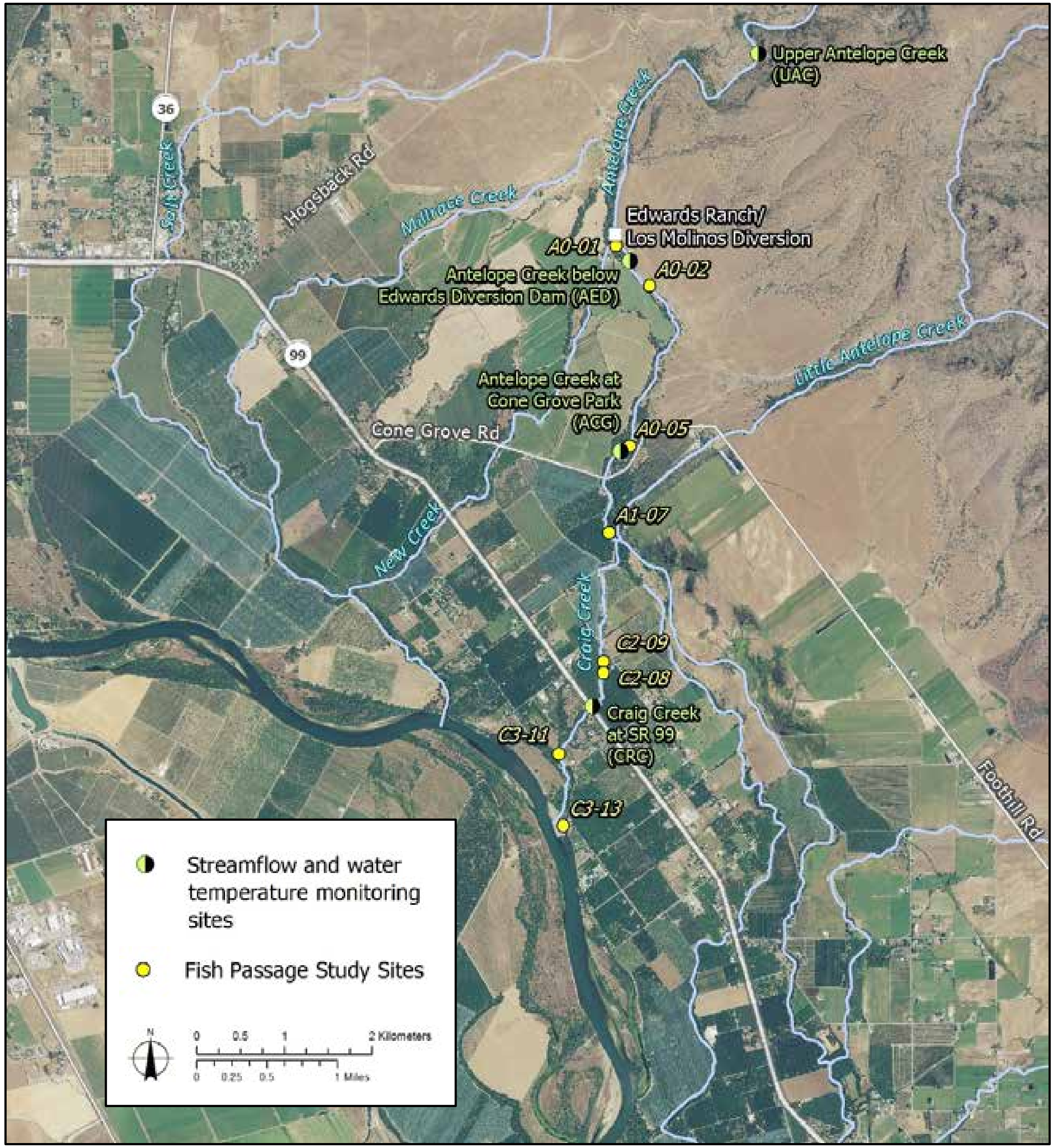


Modeled Inflows and Outflows



Modeled Flow Depths at 40 cfs



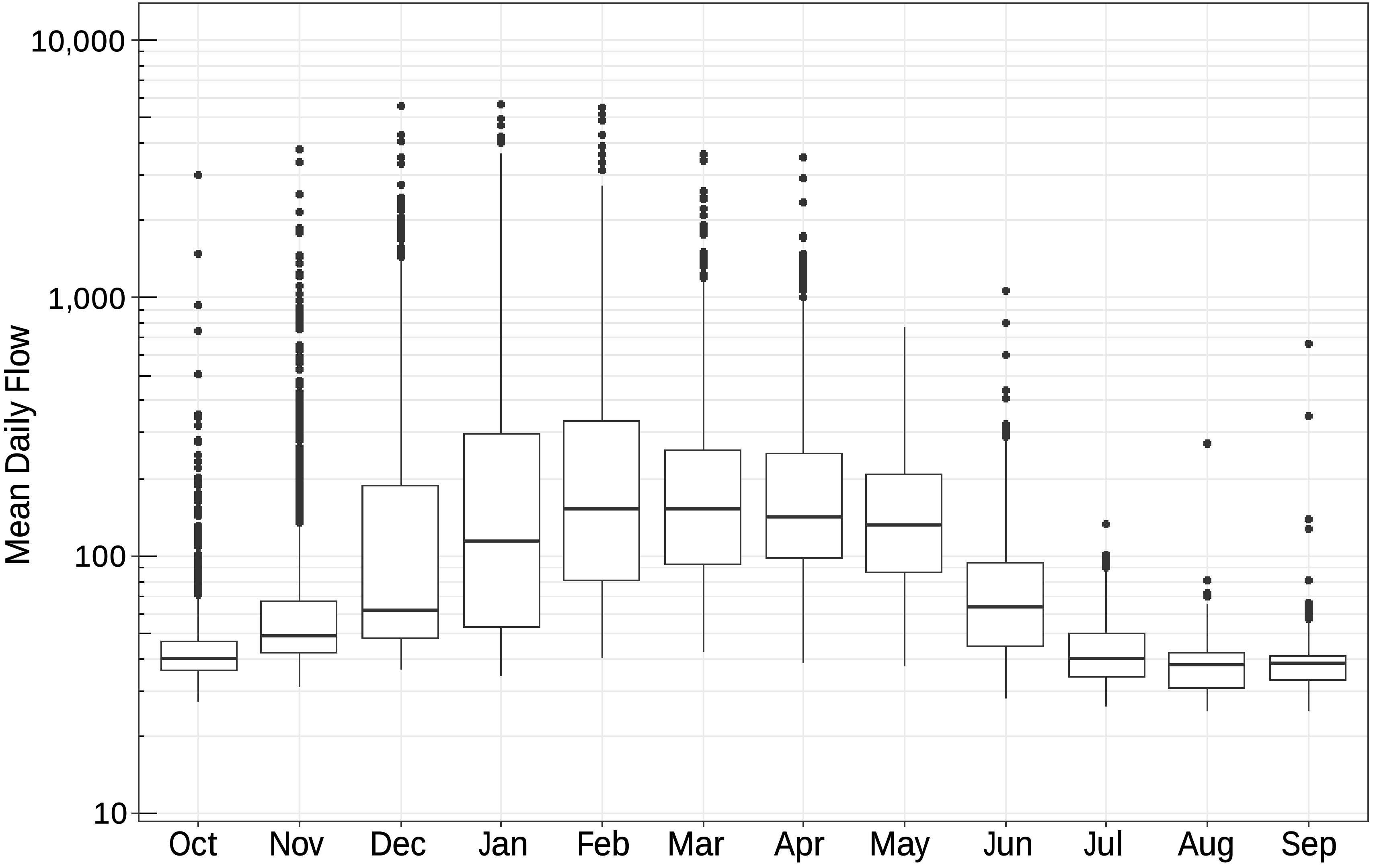


STREAMFLOW AND TEMPERATURE

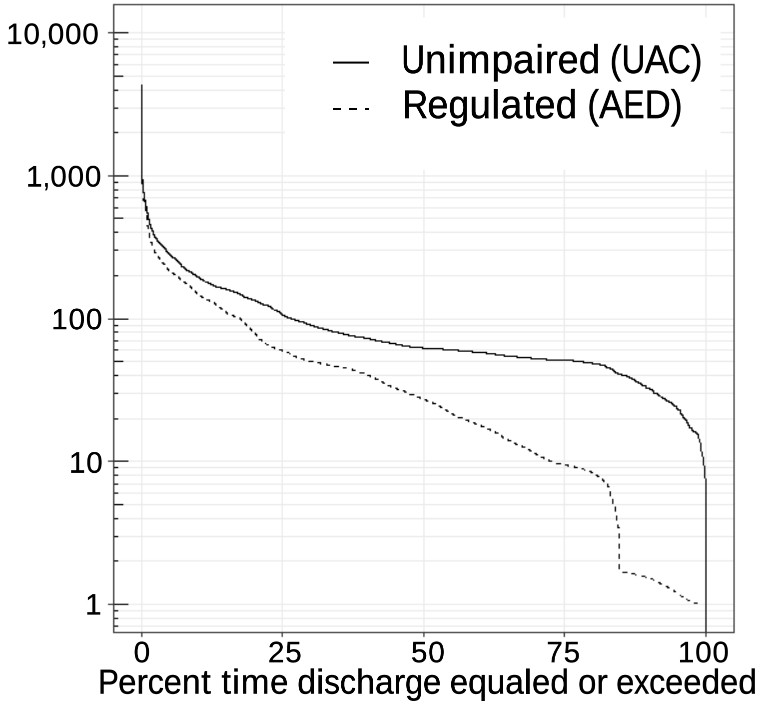
Four Monitoring Sites:

- **UAC – Upper Antelope Creek**
  WY 2010, 2013-2018
- **AED – Antelope Creek below Edwards Diversion Dam**
  WY 2017-2018
- **ACG – Antelope Creek at Cone Grove Park**
  WY 2010, 2013-2016
- **CRC – Craig Creek at State Route 99**
  WY 2010, 2013-2018

UNIMPAIRED FLOW



WY Type	Median Monthly Flow				
	Mar	Apr	May	Jun	Jul
C	64	62	50	37	32
D	97	88	74	41	32
BN	133	126	98	51	37
AN	204	154	138	64	42
W	207	250	214	99	54



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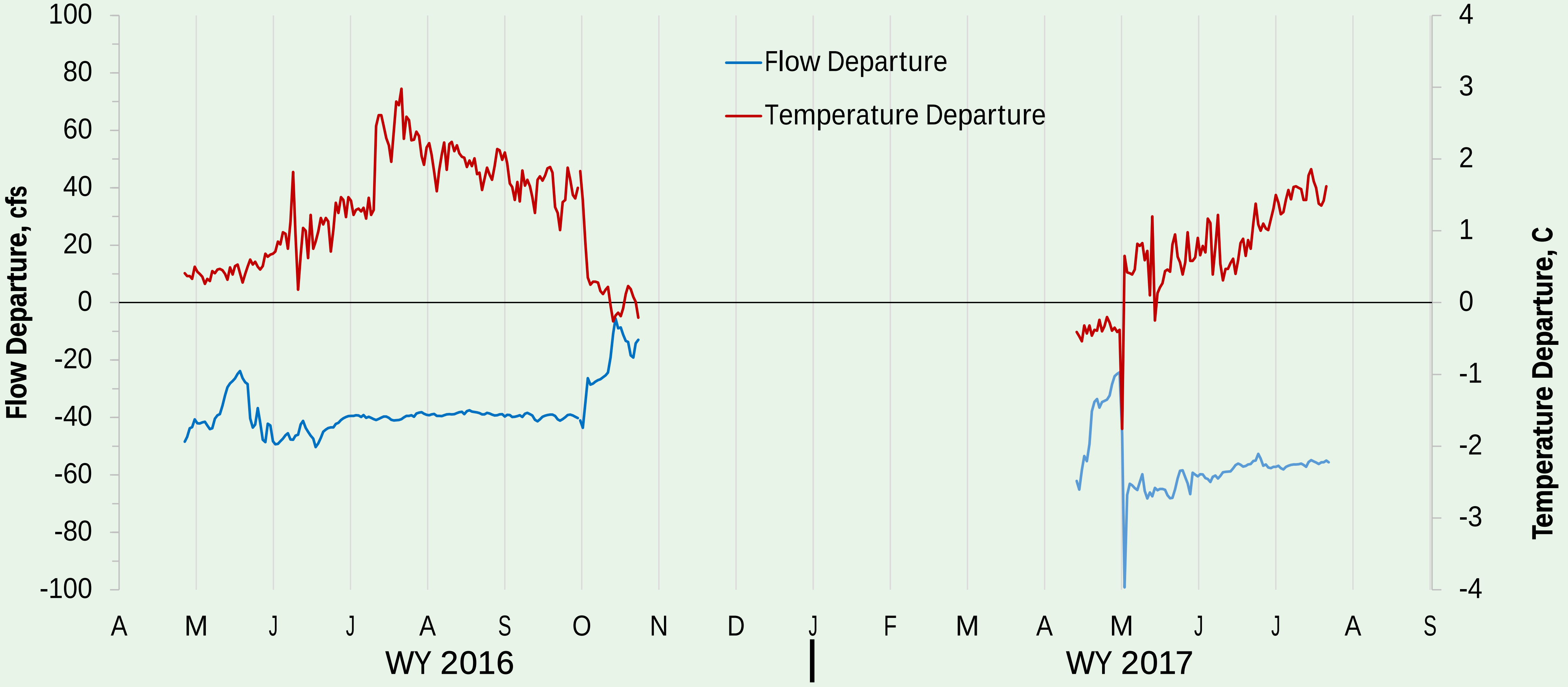
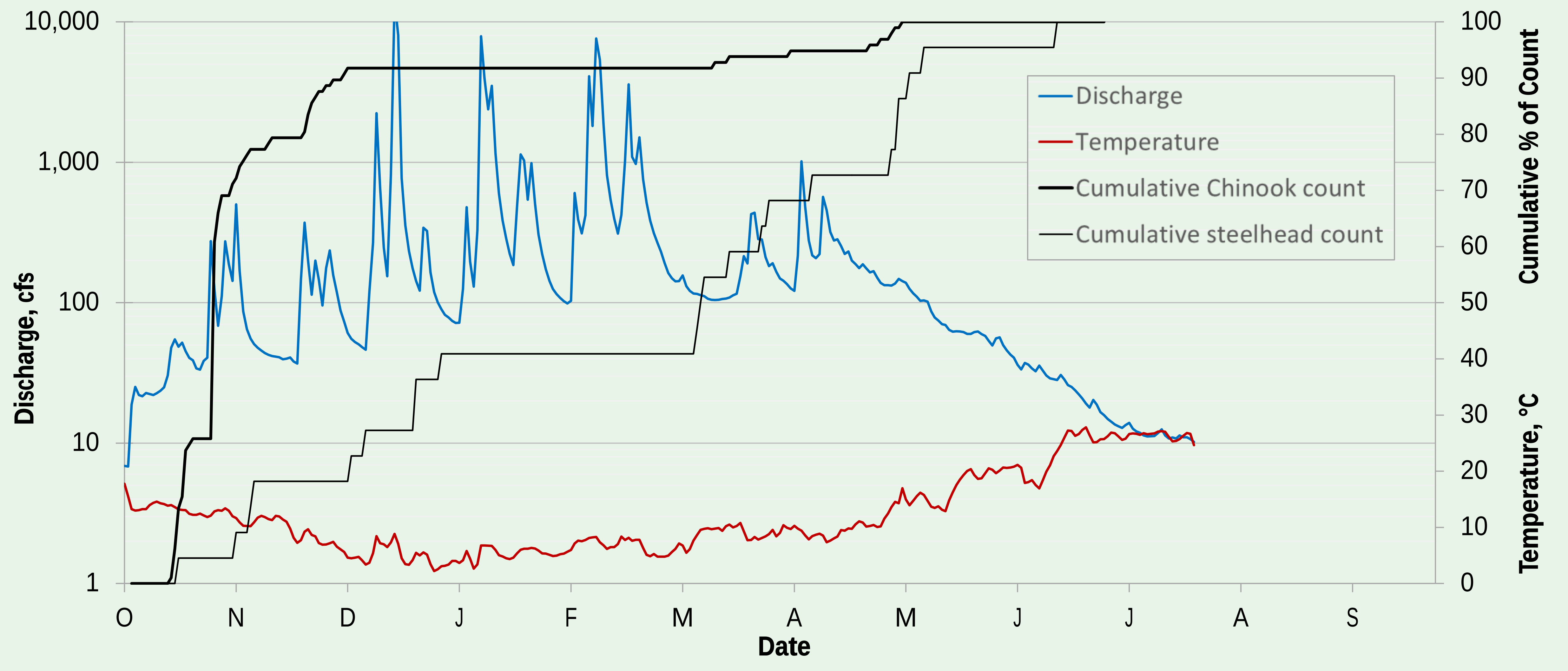
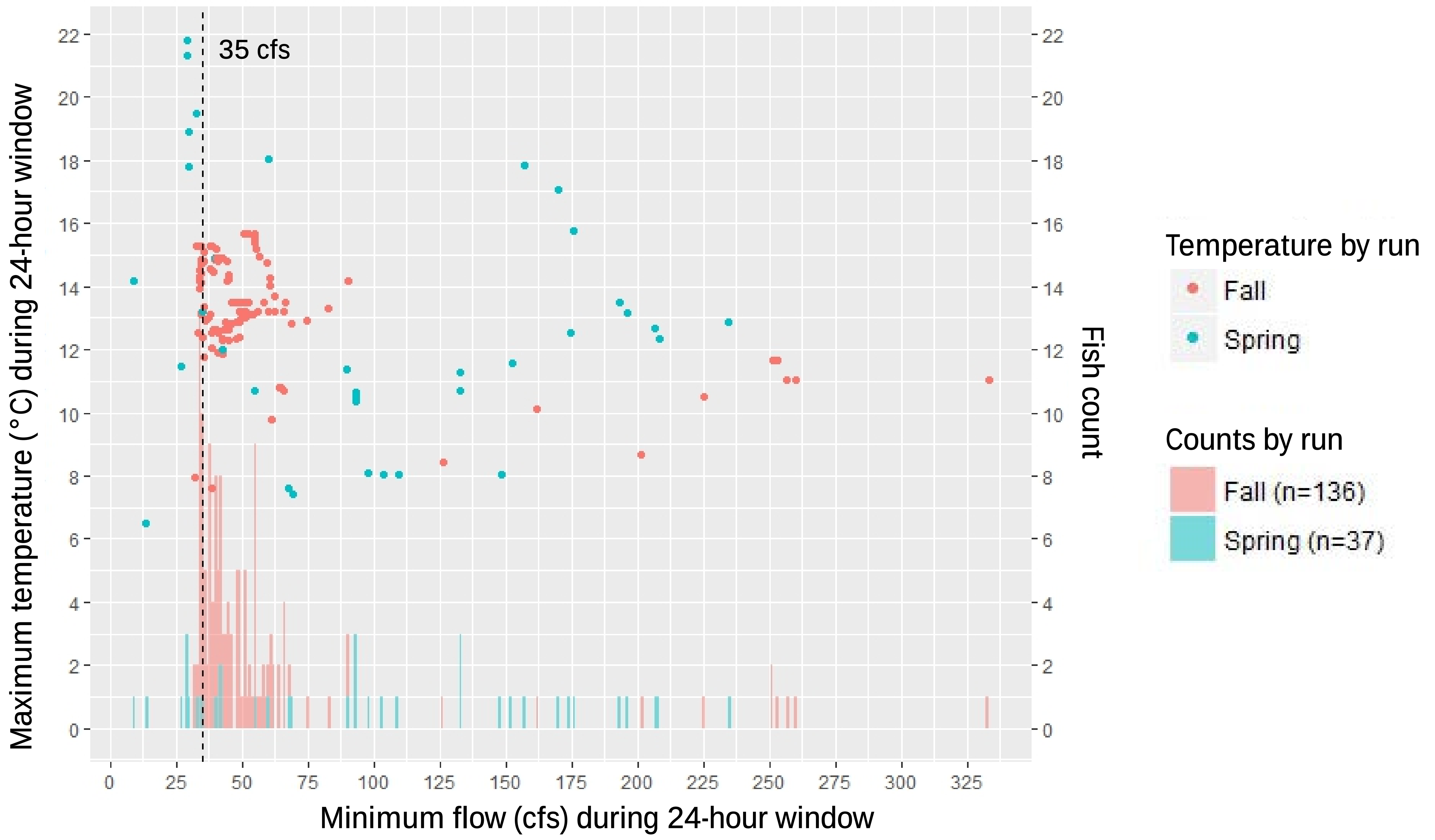
REGULATED FLOW AND TEMPERATURE DEPARTURES FROM UNIMPAIRED CONDITIONS

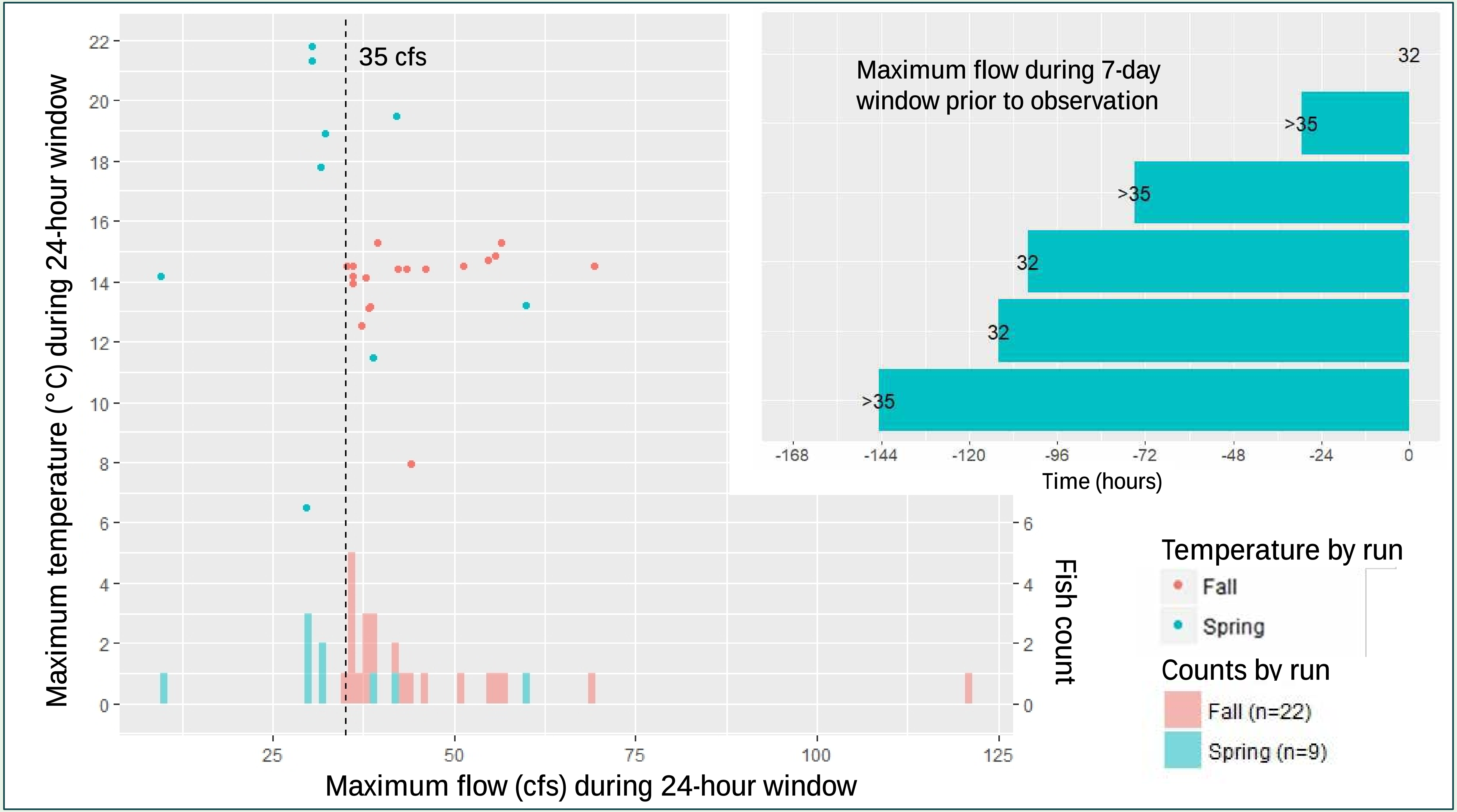


FLOW, TEMPERATURE, AND PASSAGE: WY 2017 (WET YEAR)





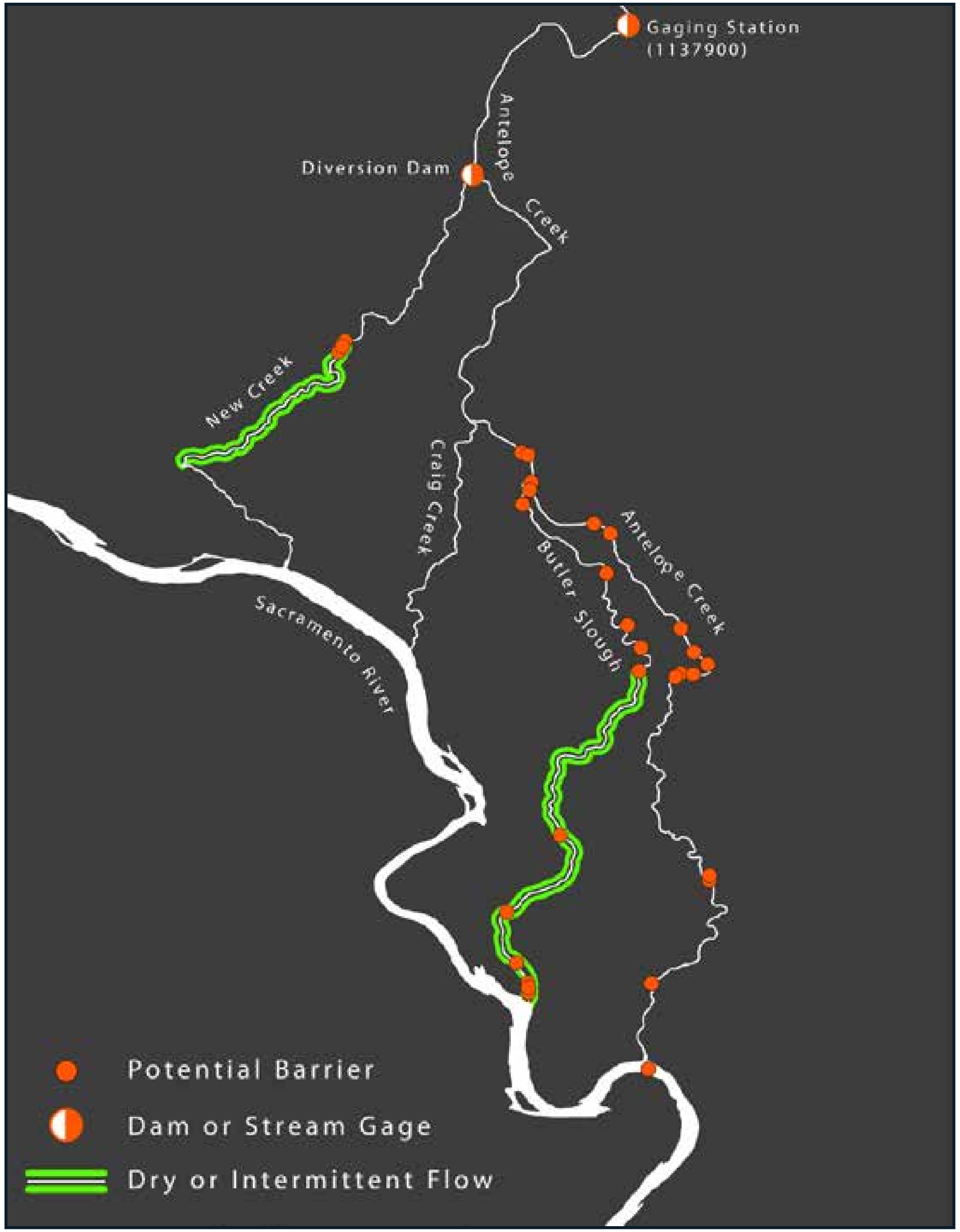
35 cfs
Maximum temperature (°C) during 24-hour window
Fish count
Minimum flow (cfs) during 24-hour window
0
2
4
6
8
10
12
14
16
18
20
22
0
25
50
75
100
125
150
175
200
225
250
275
300
325
Temperature by run
Fall
Spring
Counts by run
Fall (n=136)
Spring (n=37)

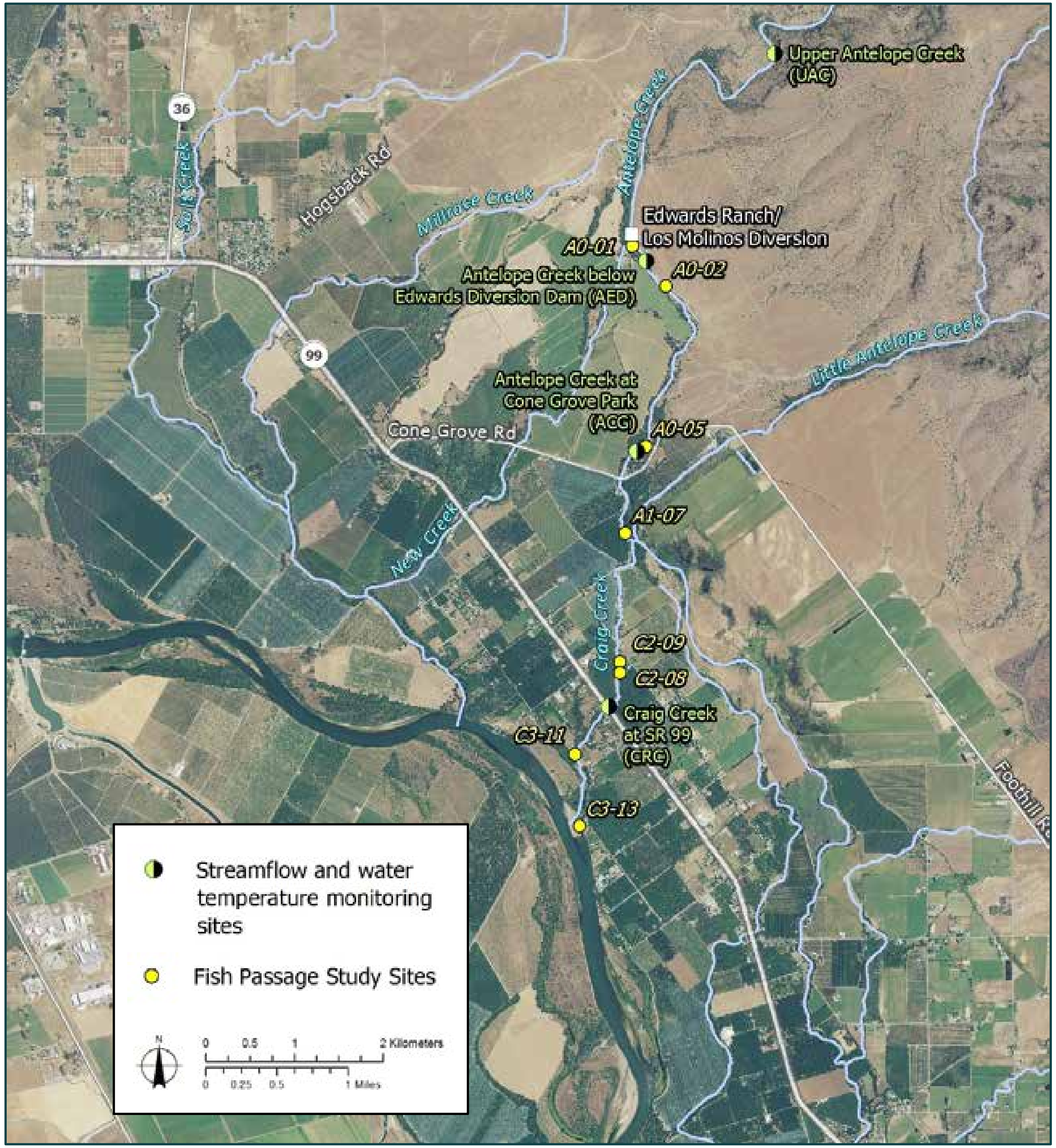


35 cfs
Maximum temperature (°C) during 24-hour window
Maximum flow (cfs) during 24-hour window
Fish count
Maximum flow during 7-day window prior to observation
32
>35
>35
32
32
>35
Time (hours)
-168
-144
-120
-96
-72
-48
-24
0
Temperature by run
Fall
Spring
Counts by run
Fall (n=22)
Spring (n=9)

POTENTIAL PASSAGE BARRIERS

- **Distributaries:**
  - Dry reaches
  - Intermittent flow over bedrock
  - Channel-spanning beaver dams
  - Numerous potential critical riffles
  - Thermal barriers
  - Dense aquatic vegetation at Sacramento River confluence
- **Primary low flow migration corridor:**
  - Unimpeded adult and juvenile passage
  - Numerous potential critical riffles
  - Migration into mainstem influenced by fluvial processes in Sacramento River

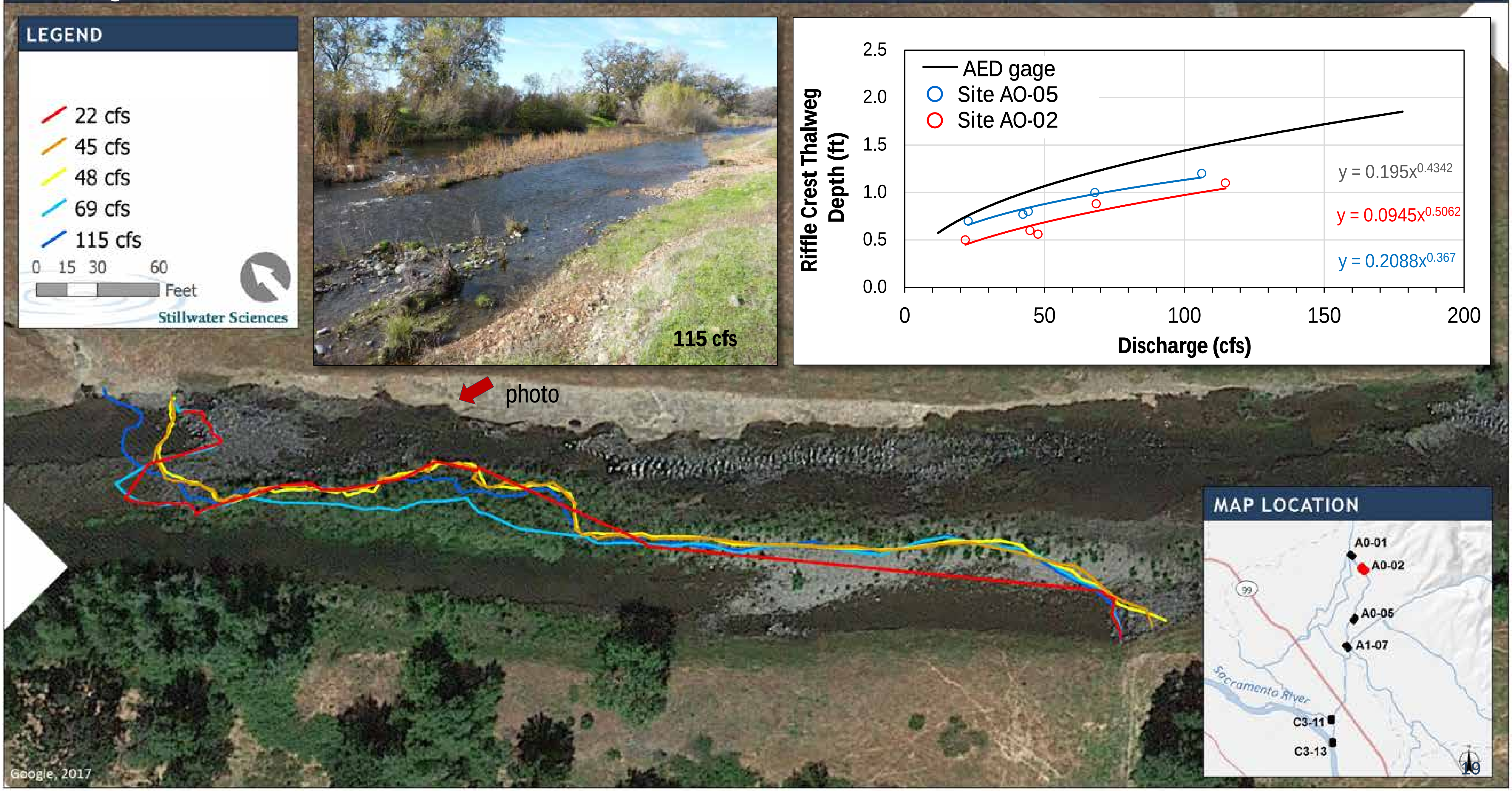




PRIMARY LOW FLOW MIGRATION CORRIDOR

- 13 most restrictive sites identified
- 8 study sites selected

Passage Site AO–02



SUMMARY

- **Antelope Creek alluvial fan**
  - Young fan deposits
  - Multiple distributaries at winter/early spring base flows
  - Dynamic channel at distributary junctions affects flow splits
  - Impediments to adult Chinook immigration in distributaries
- **Primary migration corridor**
  - Adult Chinook migration at flows >32cfs
  - Delayed migration at flows 32-35 cfs
  - 0.9 ft RCT depth at 80 cfs in most restrictive reach
  - >25% unimpaired exceedance flow (flows <100 cfs) most affected by diversion
- **Unimpaired flow availability limited during later months and drier WY types**

ACKNOWLEDGEMENTS

- **Patricia Bratcher**
  Sacramento River Habitat Restoration Coordinator, California Department of Fish and Wildlife
- **Tricia Parker and Brenda Olson**
  Anadromous Fish Restoration Program
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  California Department of Fish and Wildlife
- **Mark Gard**
  USFWS, Restoration and Monitoring Program
- **Tehama County Resource Conservation District**
- **Jim Edwards**
  Edwards Ranch
- **Darrel Mullins**
  Los Molinos Mutual Water Company
- **Dirk Pedersen, Ian Prior, Dylan Caldwell**
  Stillwater Sciences
- **Numerous private landowners**

Santa Barbara County Debris Basins

Their history and exciting future

Andrew Raaf & Seth Shank
Santa Barbara County Flood Control District

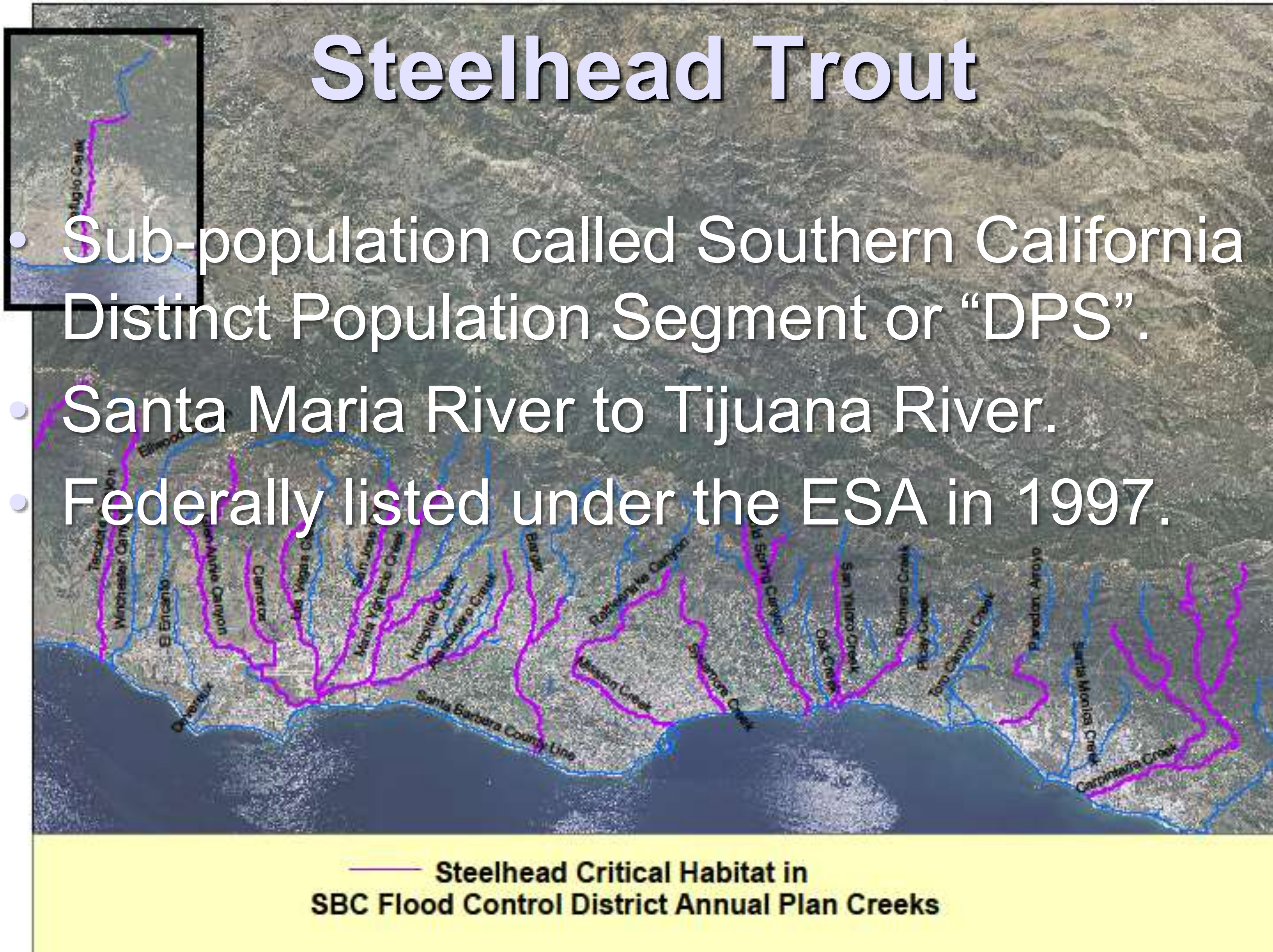
Debris Basins

What are they?

- Built after wildfires to lessen potential flood damage
- Most were built in the 60's/70's
- Earthen fill with concrete/rock cap and 48" culvert pipe
- Designed to catch large debris while passing sediment/water (not the case)
- Built at top of alluvial fan/urban interface
- Built by ACOE/SCS and given to SBCFCD to maintain
- 10 Debris Basins sites within Steelhead creeks
- Now represent fish passage barriers

Steelhead Trout

- Sub-population called Southern California Distinct Population Segment or “DPS”.
- Santa Maria River to Tijuana River.
- Federally listed under the ESA in 1997.



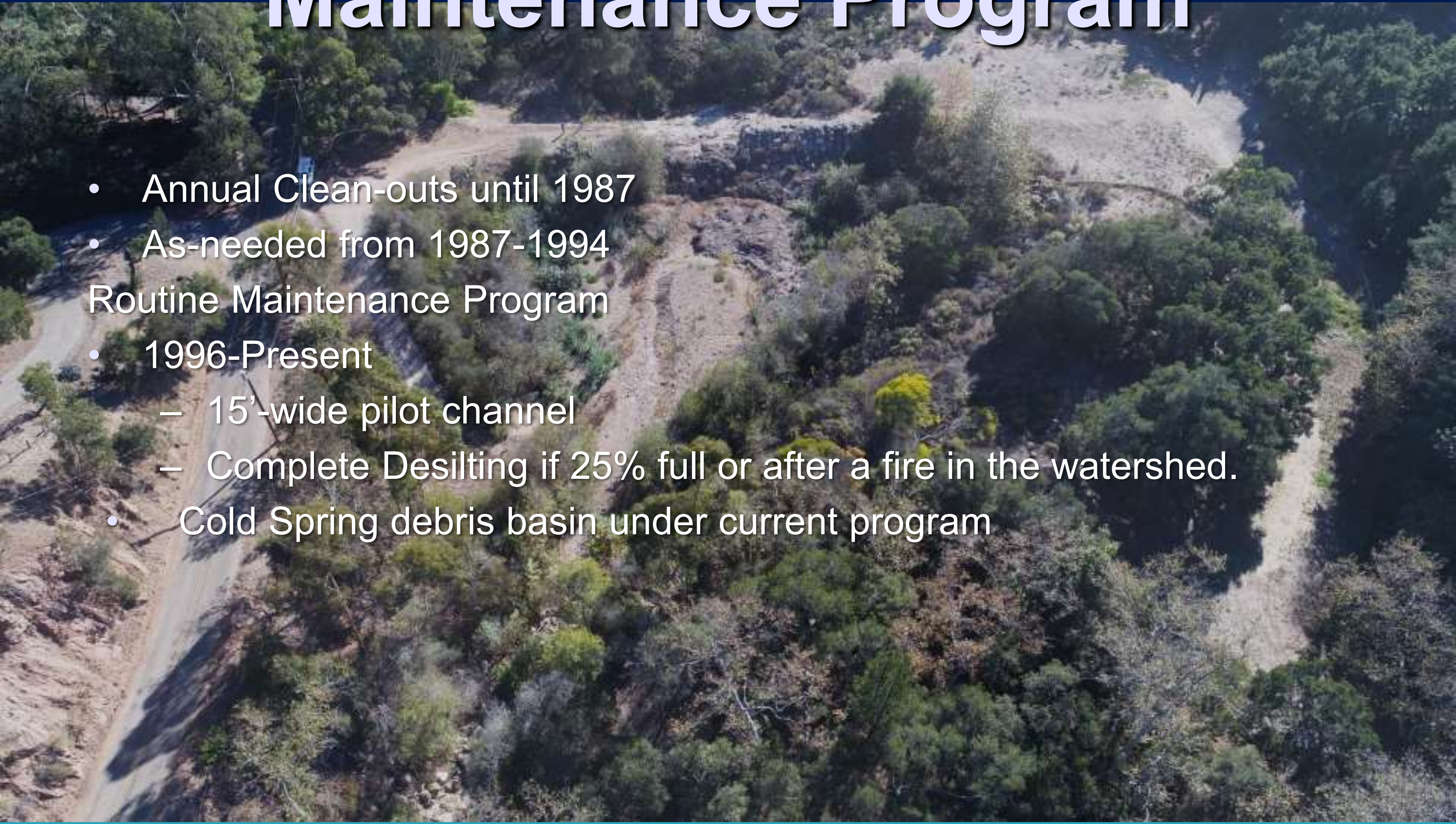
Strategic Basin Locations

Maintenance Program

- Annual Clean-outs until 1987
- As-needed from 1987-1994

Routine Maintenance Program

- 1996-Present
  - 15'-wide pilot channel
  - Complete Desilting if 25% full or after a fire in the watershed.
- Cold Spring debris basin under current program



Biological Opinion

- Physical barriers
- Ops/maintenance alter sediment distribution
- "Jeopardy" determination
- 5 basins to be removed/modified within 10 years
- Submit plans to NMFS along the way

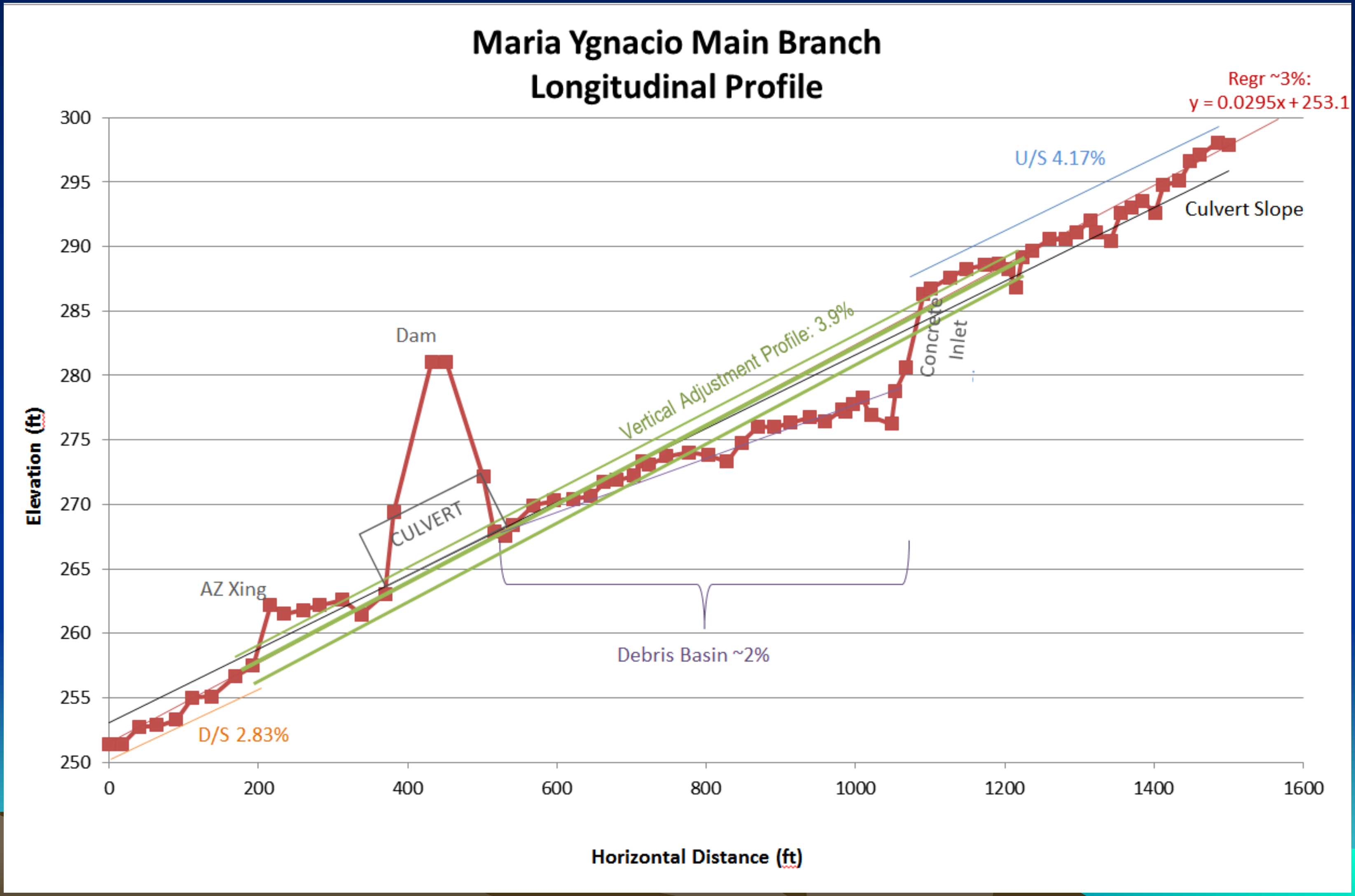
Removal vs Modification

- “Removal” has fewer requirements
- “Modification” involves more criteria
- Bio Opinion favors “Removal” and “Stream Simulation” method

"Stream Simulation" Method

- Measures and mimics a "reference reach"
- Assumes natural processes
- Slope and Bedload are main features

Longitudinal Profile



Progress through Dec 2017

- 95% "stream sim" designs for 2 sites
- 30% designs for remaining 3 sites
- Partial grant funding
- Bids out to contractors
- Pending NMFS approval to begin demolition in 2018…

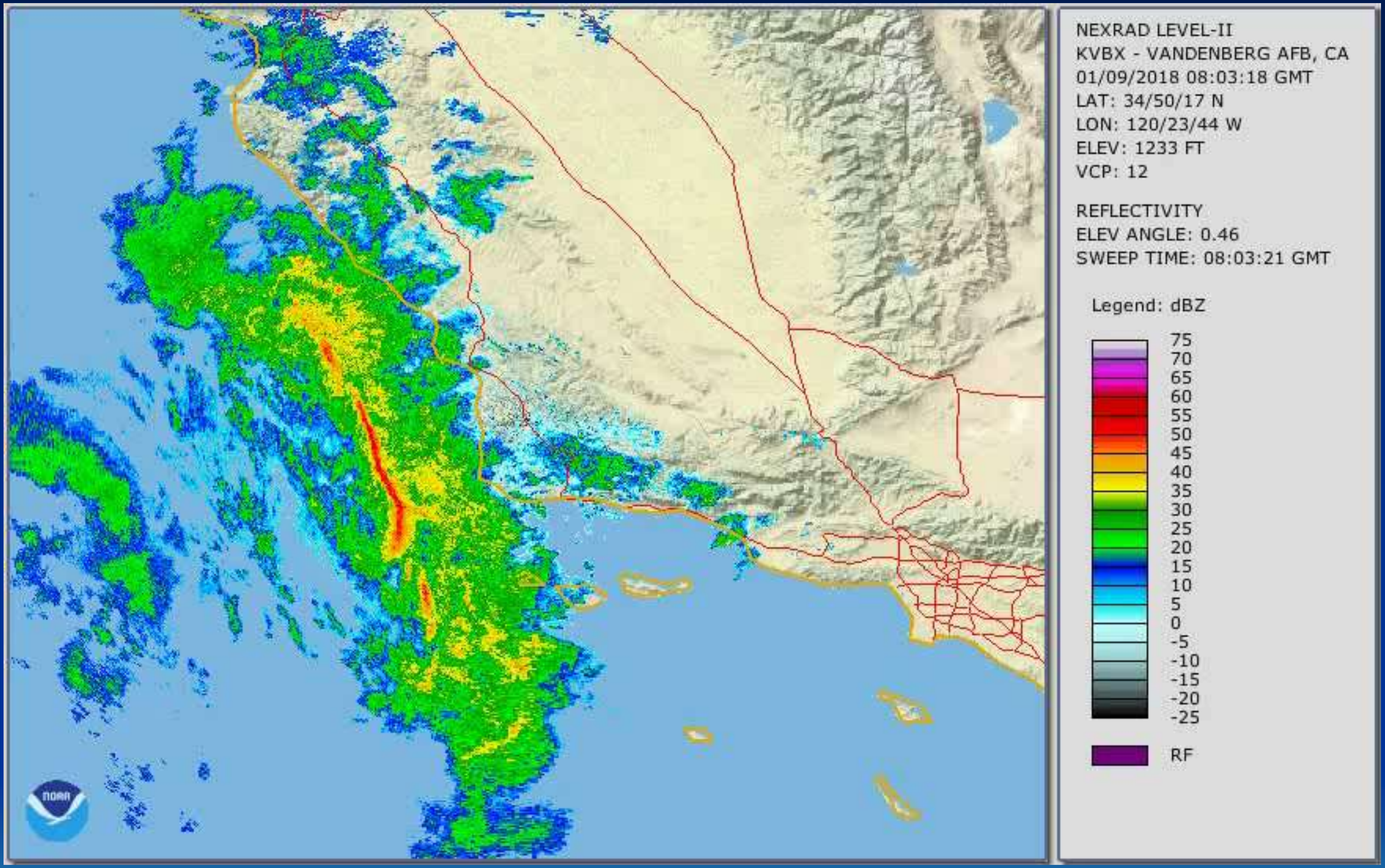
Thomas Fire

Thomas Fire

- Dec 4 – Jan 12
- ~285,000 acres
- Burned ~100% of watersheds above some debris basis

Debris Flow – Jan 9

- ~3:45 am
- 200-yr intensity precipitation
- 0.78 inches / 15 minutes
- Directly impacted burned watersheds


NEXRAD LEVEL-II
KVBX - VANDENBERG AFB, CA
01/09/2018 08:03:18 GMT
LAT: 34/50/17 N
LON: 120/23/44 W
ELEV: 1233 FT
VCP: 12
REFLECTIVITY
ELEV ANGLE: 0.46
SWEEP TIME: 08:03:21 GMT
Legend: dBZ
75
70
65
60
55
50
45
40
35
30
25
20
15
10
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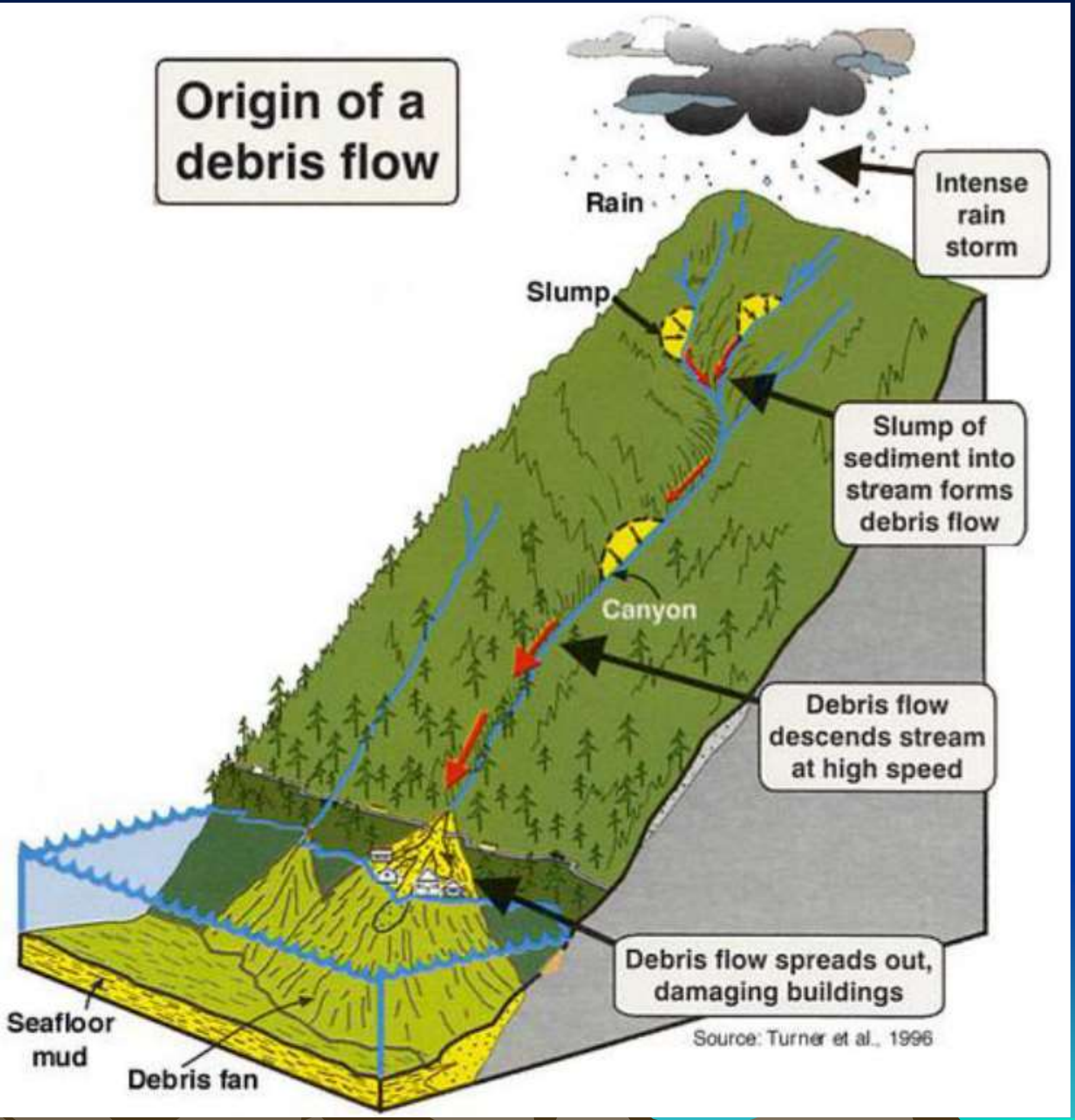
-5
-10
-15
-20
-25
RF
NOAA



Origin of a debris flow
Rain
Intense rain storm
Slump
Slump of sediment into stream forms debris flow
Canyon
Debris flow descends stream at high speed
Debris flow spreads out, damaging buildings
Seafloor mud
Debris fan
Source: Turner et al., 1996

1/9 Debris Flow

- 21 fatalities
- 2 victims still missing
- 107 homes destroyed
- 1,415 homes damaged


SANTA BARBARA
COUNTY
FLOOD
CONTROL
2018/01/11


2018/01/11

Past vs Present

What Happened at the Basins?

- Completely filled with boulders/etc
- Debris volume and speed was reduced
- Max capacity was contained
- Overwhelmed and spilled downstream

Cold Springs Basin

Santa Monica Basin

San Ysidro Basin

Fish-Passage Sites?

- Santa Barbara County has 2 previous dam-removal projects
  - 1 “removal” and 1 “modification”

Lillingston Debris Basin
(complete removal 2010-2013)

- Access constraints
- Resident trout
- Spider excavator
  - Small but nimble
  - Slow
- Phased approach
- 25,000cy material
  - Gradual sediment release
  - Reinforced “cap”
- Debris rack


Debris Rack

- 1000' downstream of basin
- 300' upstream of only bridge access
- Slurry mix
- Temporary
- Catches debris, not sediment…

Phase 1 Complete

Phase 2 Objectives/Concerns

- New thought process
  - <1cy sediment moved year 1
  - Lets move some dirt!!
- D/S pool remains
  - Fish/turtles
- No overland flow upstream
  - No dewatering!
- Regulatory agencies wanted wire mesh covered in fear of animals/fish getting caught


09.17.2012

Phase 3 Objectives/Concerns

- Final Phase
  - Minimal movement previous phases
  - More sediment transport
  - Final channel would be to narrow
  - No further disturbance
  - Downstream pool full of sediment (tracked equipment access?)
  - No creek flow upstream (roughen channel…)

Project Complete

- Flanks broken up and left in place to protect steep slopes
- Rock placed throughout channel to establish new channel , slow and redirect flow
- 8% slope through site


12.12.2016 11:31

February 2017

2018 Debris Flow

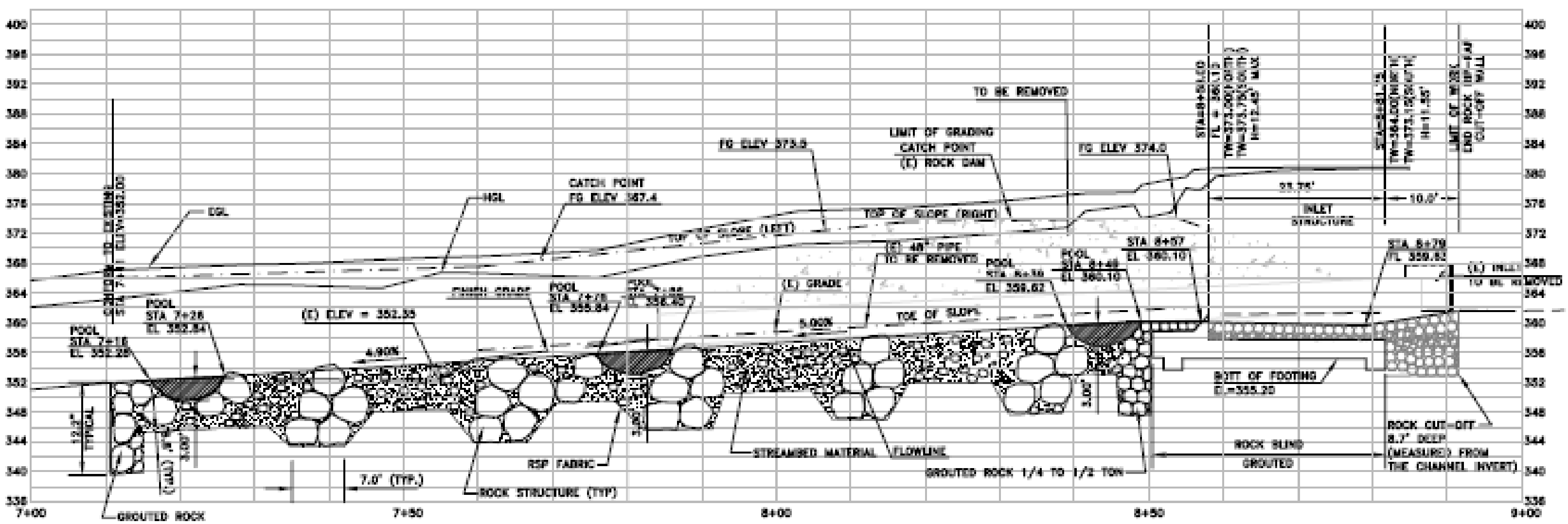

04 04 2018 10:08

Gobernador Debris Basin
(modification 2008)

- District needed to maintain basin function while restoring fish passage and sediment transport
- Easy construction access, no sediment trapped in basin
- 3-3’ deep resting pools with 1’ max jump heights
- Embedded boulder structures with streambed material to maintain ~5% slope
- Longitudinal and transverse cutoff walls to ensure structure stability

Profile

- Grouted rock cutoff walls
- Rock structures (~5% slope)
- Streambed material



HYDRAULIC DATA (Q100 = 8,620 cfs)					
RIVER STATION	HGL (ft)	EGL (ft)	VELOCITY (ft/s)	n CHANNEL	n BANKS
885	380.65	380.91	4.13	0.04	0.06
880	380.68	380.90	3.82		
879.5	380.68	380.90	3.82		
868.5	380.43	380.87	5.35		
868	380.44	380.86	5.21		
859	379.66	380.77	8.47		

PROFILE
SCALE:1"=10'

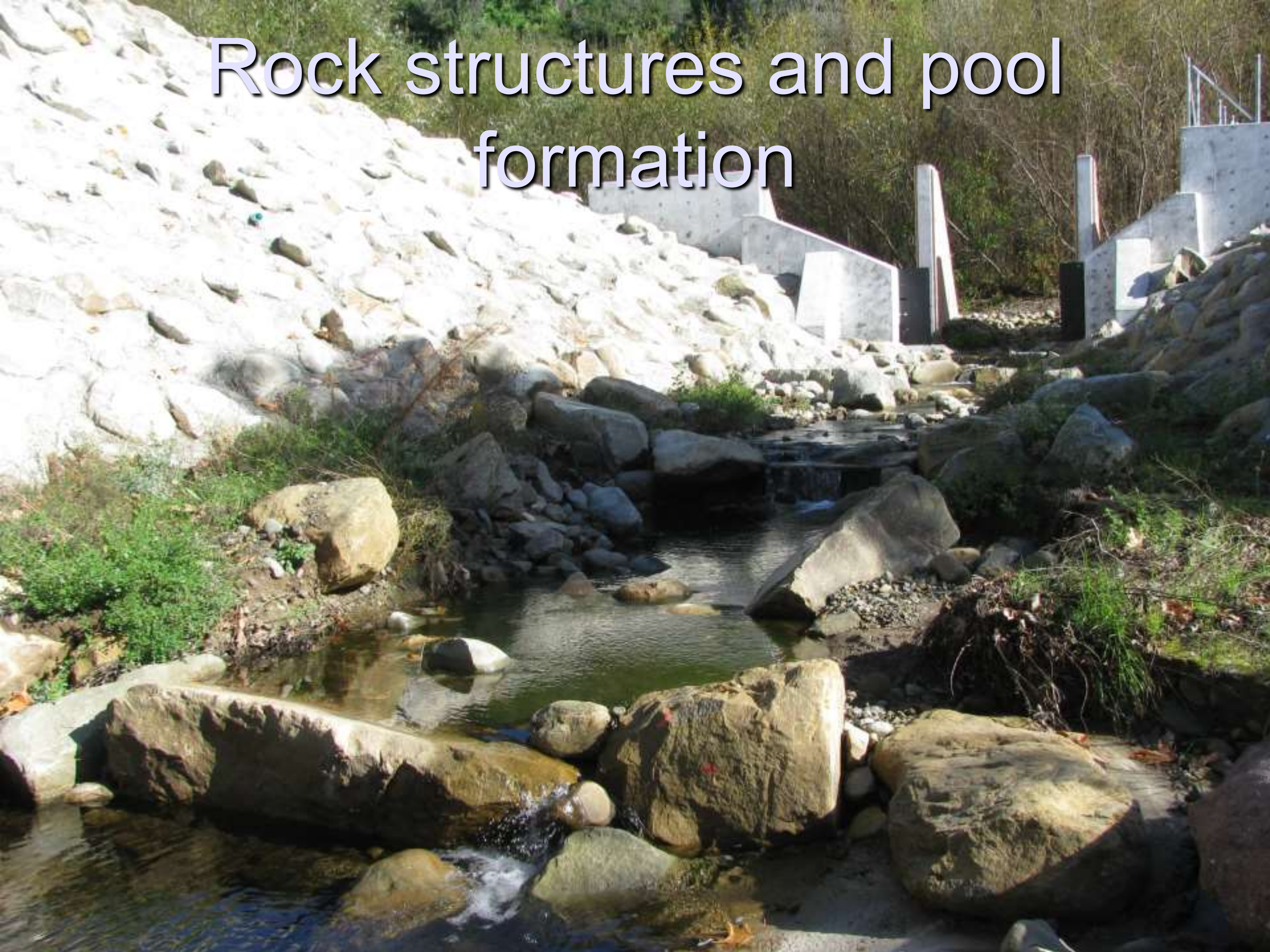
NOTE: THE DEPTH OF CUT-OFF WALLS WILL BE CONFIGURED IN THE FIELD BY THE ENGINEER BASED UPON EXISTING GROUND CONDITIONS.

VORTEX BOULDER WEIR IS LOCATED @ STA 7+28 & STA 7+86

Inlet Structure

- Splitter walls to trap large debris
- Retractable gates
- Equipment access during storm flows

Rock structures and pool formation



2018 Debris Flow

- Transverse cutoff wall visible
- Pools filled with sediment (typical of burned watershed)
- Overall good condition

What's Changed?

- EVERYTHING!
- Hydrology
- Topography
- Vegetation
- Watershed runoff
- Community concern

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the freshest news in Santa Barbara

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Local News

Santa Monica Debris Basin Above Carpinteria Dubbed 'Hero' After Jan. 9 Debris Flow

Project was built after major flooding caused heavy damage to sections of Carpinteria in 1969

Earlier this month, above, the Santa Monica Debris Basin in Carpinteria still held a large quantity of boulders and other materials brought down from the Thomas Fire burn area for a strong storm on Jan. 9. County officials hope to have it completely cleared by March 15. (Tom Fayram photo)

MOST SHARED | LATEST POSTS

1. Famous Santa Barbara Dog Statue, Historical Home For Sale
2. History-Making Night: Dos Pueblos, San Marcos, Santa Barbara Make CIF Water Polo Finals
3. Driver Killed in Fiery Single-Vehicle Crash on Highway 101 in Orcutt
4. Regional Rail Panel Backs Commuter Train to Santa Barbara County's South Coast
5. Falcon 9 Rocket Delivers Spanish Satellite After Vandenberg AFB Liftoff

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15,318 likes

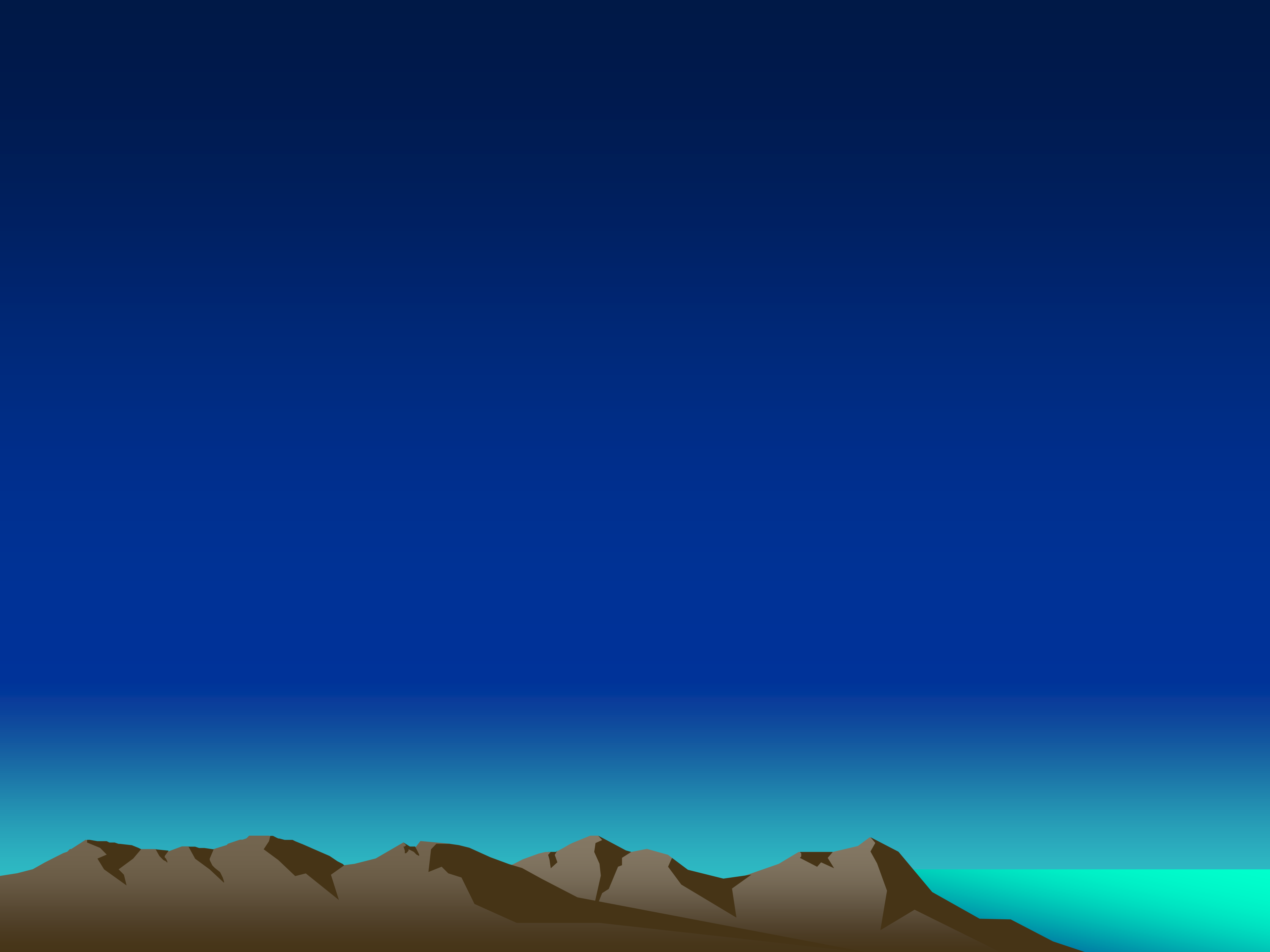
- Debris basins saved lives & property
- Watersheds are not recovered
- Fire season is never-ending

Where Are We Now?

- Emergency cleanup and repair
- Prep for next winter
- Re-Map and survey
- Revisit Debris Basin removal plans
- Community engagement with NMFS
- New options for “Modification”
- Many “Unknowns” remain

Questions/ Acknowledgements

- 1 Korchinski, B. and Barrett,W. 2018 Montecito Debris Flows.
- 2 Turner, A.K., and Schuster, R.L., eds, 1996, Landslides, investigation and mitigation, Transportation Research Board Special Report 247: Washington D.C., National Research Council.



Expect the Unexpected – Monitoring Geomorphic Changes and Evaluating Overall Effectiveness in Highly Dynamic Alluvial Fan Environments – The Hansen Creek Story

Ian Mostrenko
Herrera Environmental Consultants

Acknowledgements

Co-Authors

- Christina Avolio (Herrera)
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- WA-ECY
- WA-SRFB
- SKAGIT COUNTY

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- WA-DNR, Skagit County,
- SCD Watershed Masters, SFEG, PSE
- Skagit Valley College

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Outline

- Background
- Design Concept
- Hydrology
- Geomorphic Changes
- Geomorphic Monitoring
  - Stream Channel
  - LWD Changes
  - Sediment Deposition
- The Unexpected?

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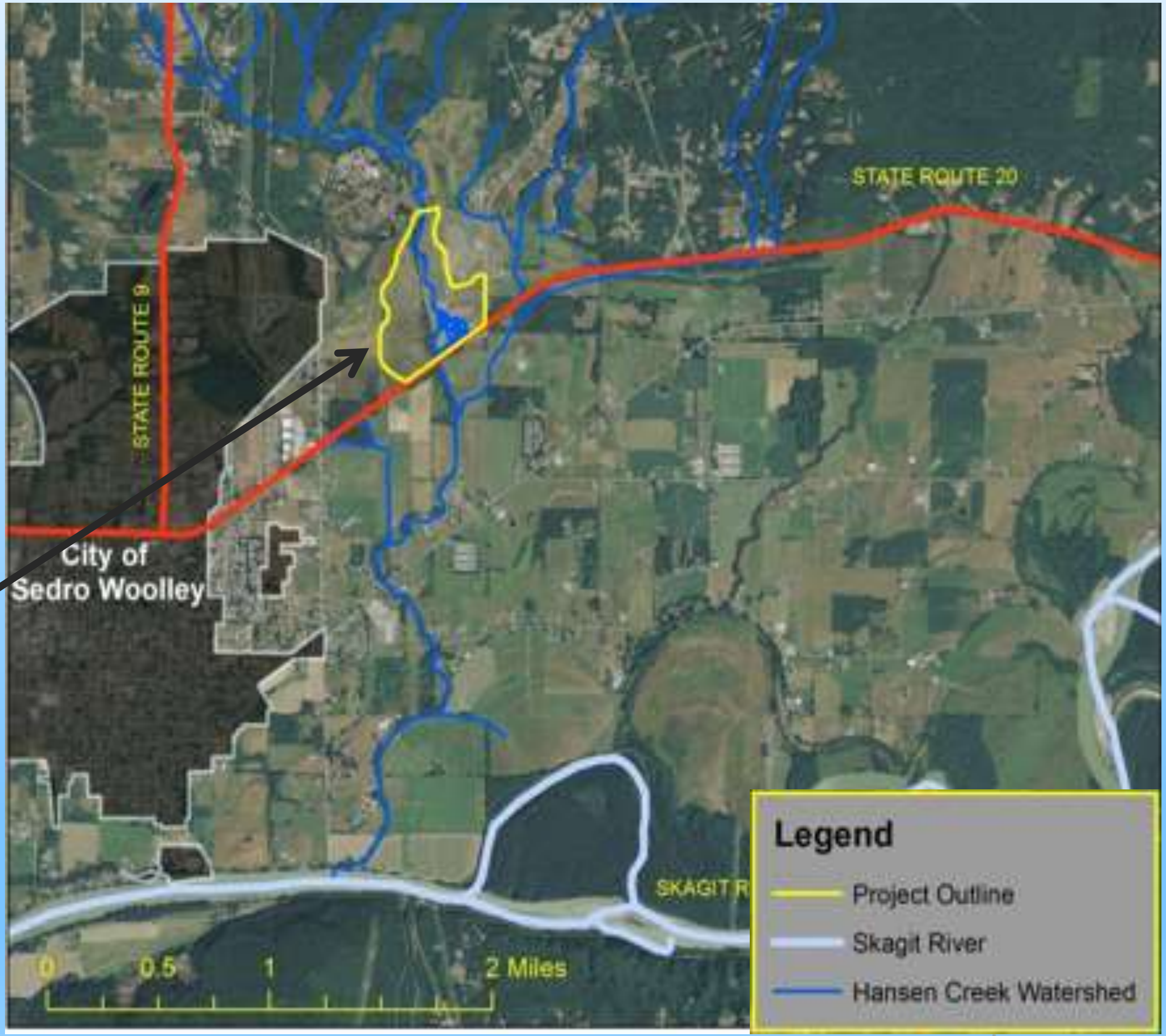
Background

Hansen
Creek
Site

(57 Ha)



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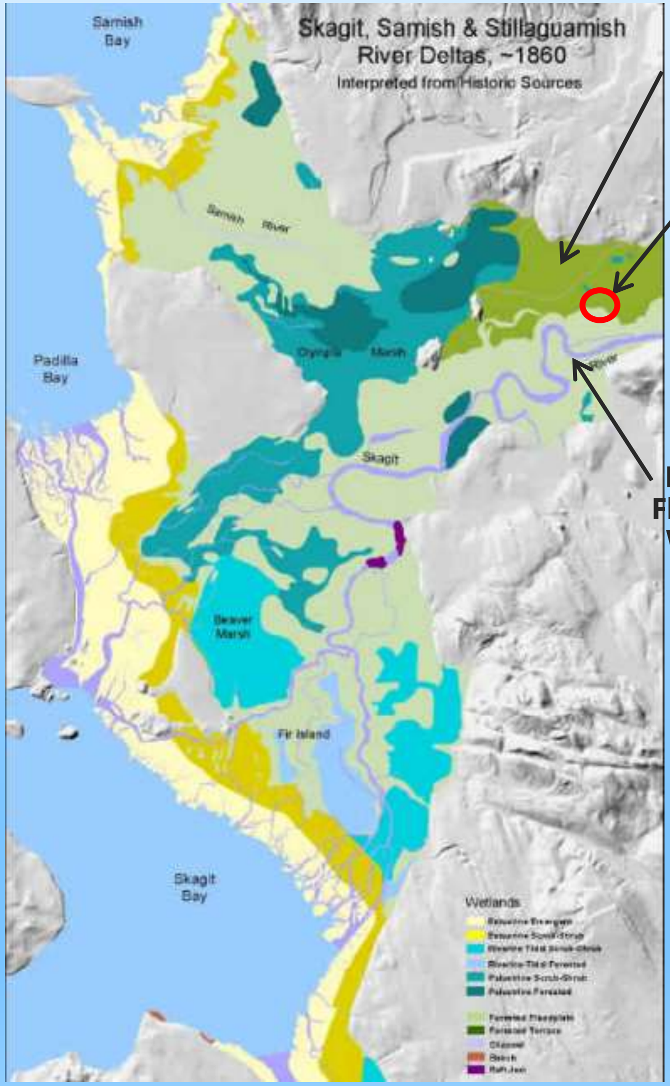
Background

1860



1915

1945

17,730 Ha of Wetlands

Source: B. Collins, 2000

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Background

Channelized

Dredging

Agriculture

Logging

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Background

Objectives:

- Restore natural geomorphic and biological processes
- Alleviate downstream sediment deposition and the need for dredging.
- Promote self-sustaining channel and tributary forms
- Reconnect floodplain
- Enhance fish habitat (off-channel rearing)
- Reduce flooding for nearby properties

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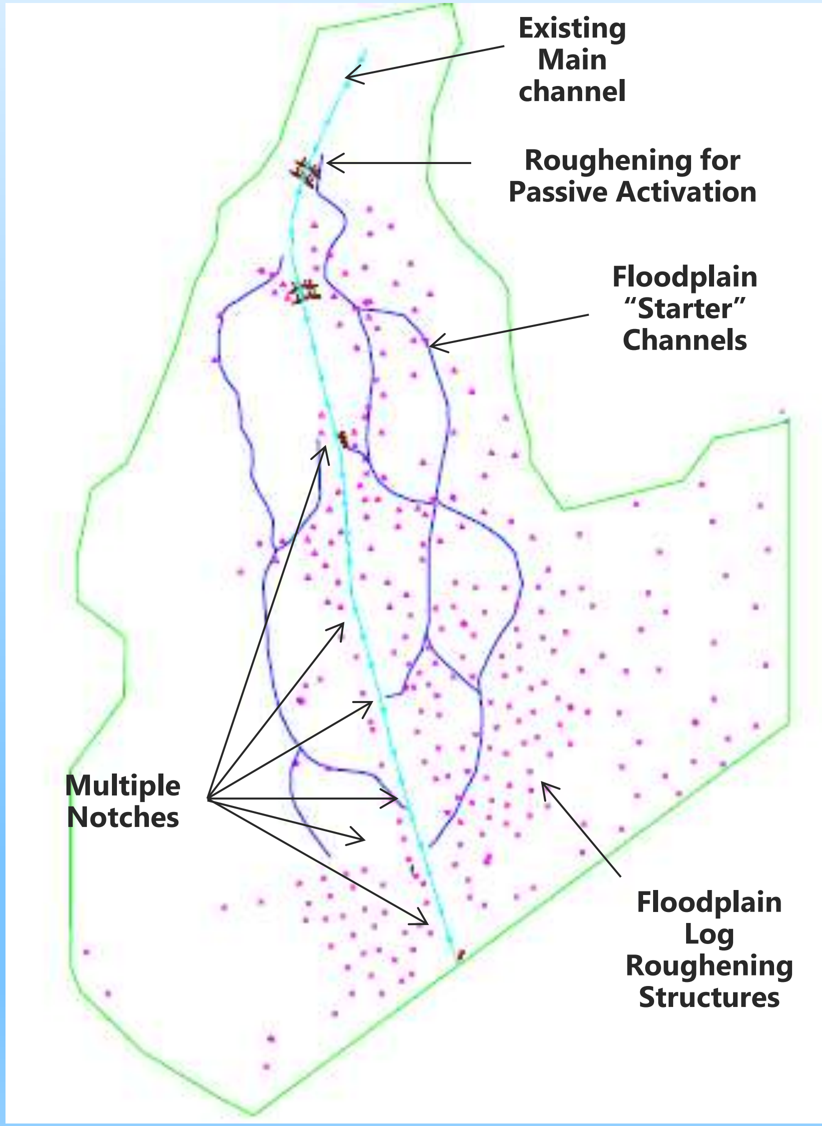
Design Concept

- Passive Activation
- Starter channels
- Notches in existing levee
- Add floodplain structure
  - LWD – Density in areas with high probability of inundation
  - Dense planting for high roughness
- Let natural processes do the work



Hydrology

- Basin size = 20 km^2
- Average Precipitation = 50 inches
- Relief = 4,000 feet
- Flood Flows:

Recurrence interval (years)	Flow (cfs)
100	698
50	644
25	578
10	495
5	413
2	314
1.25	256

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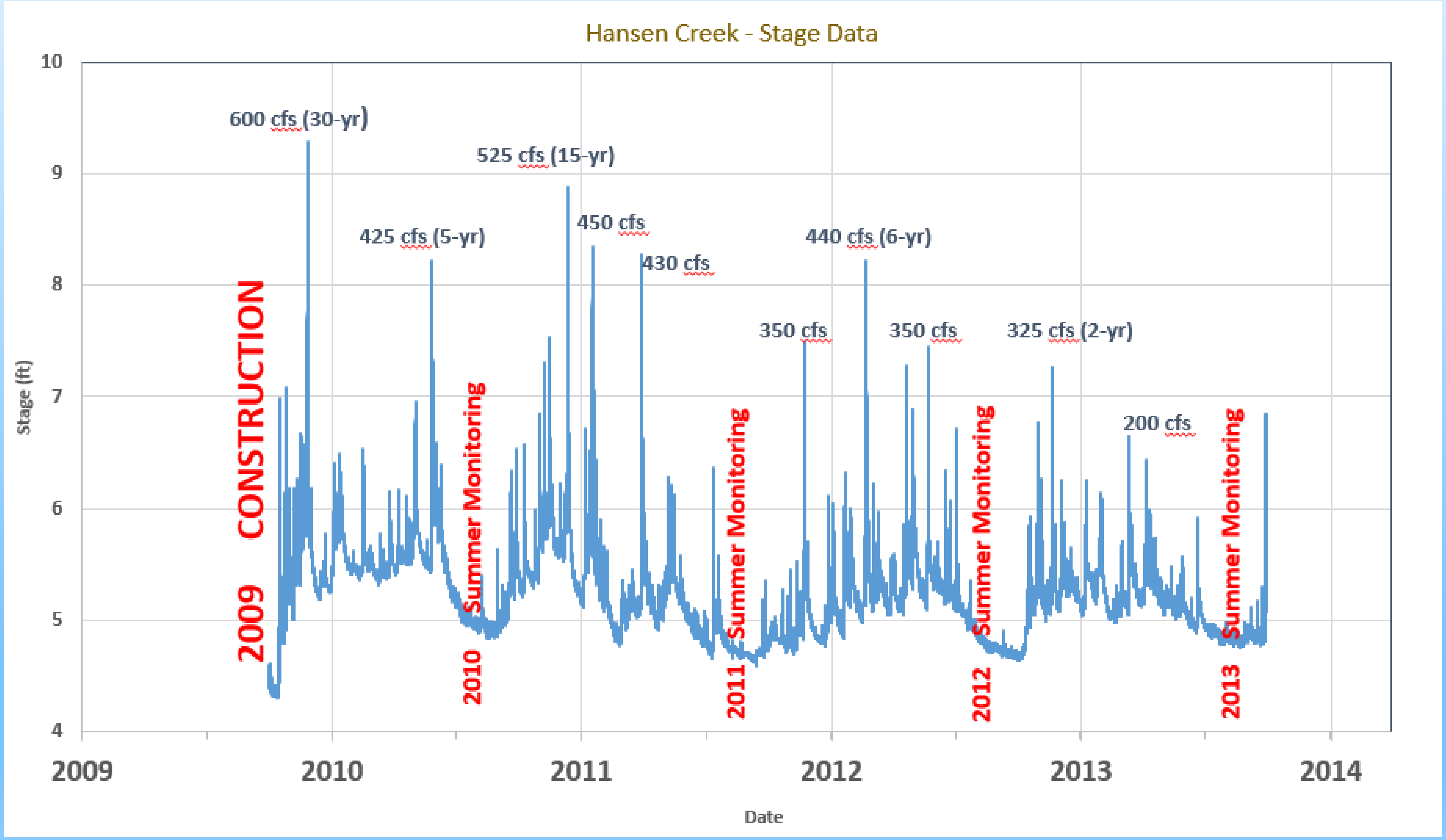
Hydrology



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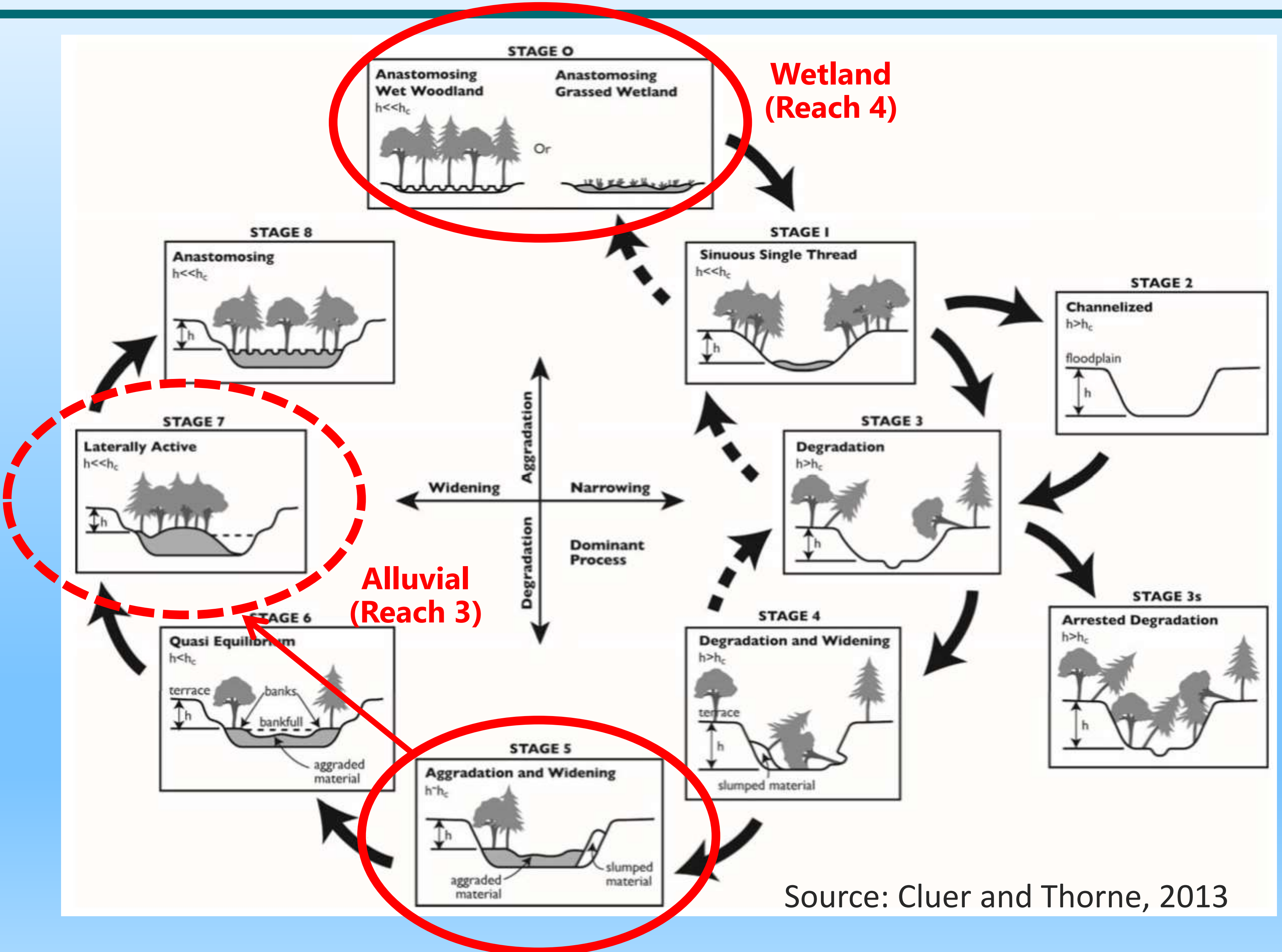
Geomorphic Change



Source: Cluer and Thorne, 2013

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Geomorphic Change

2009

2011

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Geomorphic Change

Anastomosing Channels (Stage 0)

2013

Braided

Transfer Zone

2014

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Geomorphic Change

2015

2017

Lateral Migration (Stage 7)

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Geomorphic Change

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Geomorphic Change

Post Construction (2009)

Geomorphic Change

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Geomorphic Change

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Geomorphic Change

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Geomorphic Change

Geomorphic Change (2012 – year 3)

Pre-Project

Fan

Transition

Wetland

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Monitoring Geomorphic Change

- **Channel Length**
  - Quantitative
- **Large Woody Debris (LWD)**
  - Quantitative
- **Sediment**
  - Qualitative
- **Physical Habitat**
  - Pools and riffles

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Geomorphic Change: Channel Length

	Historic	2010	2011	2012	2013
Main Channel	3,450 feet	5,490 feet	5,890 feet	6,310 feet	4,740 feet
Side Channel	0 feet	0 feet	4,560 feet	3,440 feet	3,970 feet
Total	3,450 feet	5,490 feet	10,450 feet	9,750 feet	8,710 feet

	2010	2011	2012	2013
Increase →	59%	71%	83%	37%
	59%	202%	183%	153%

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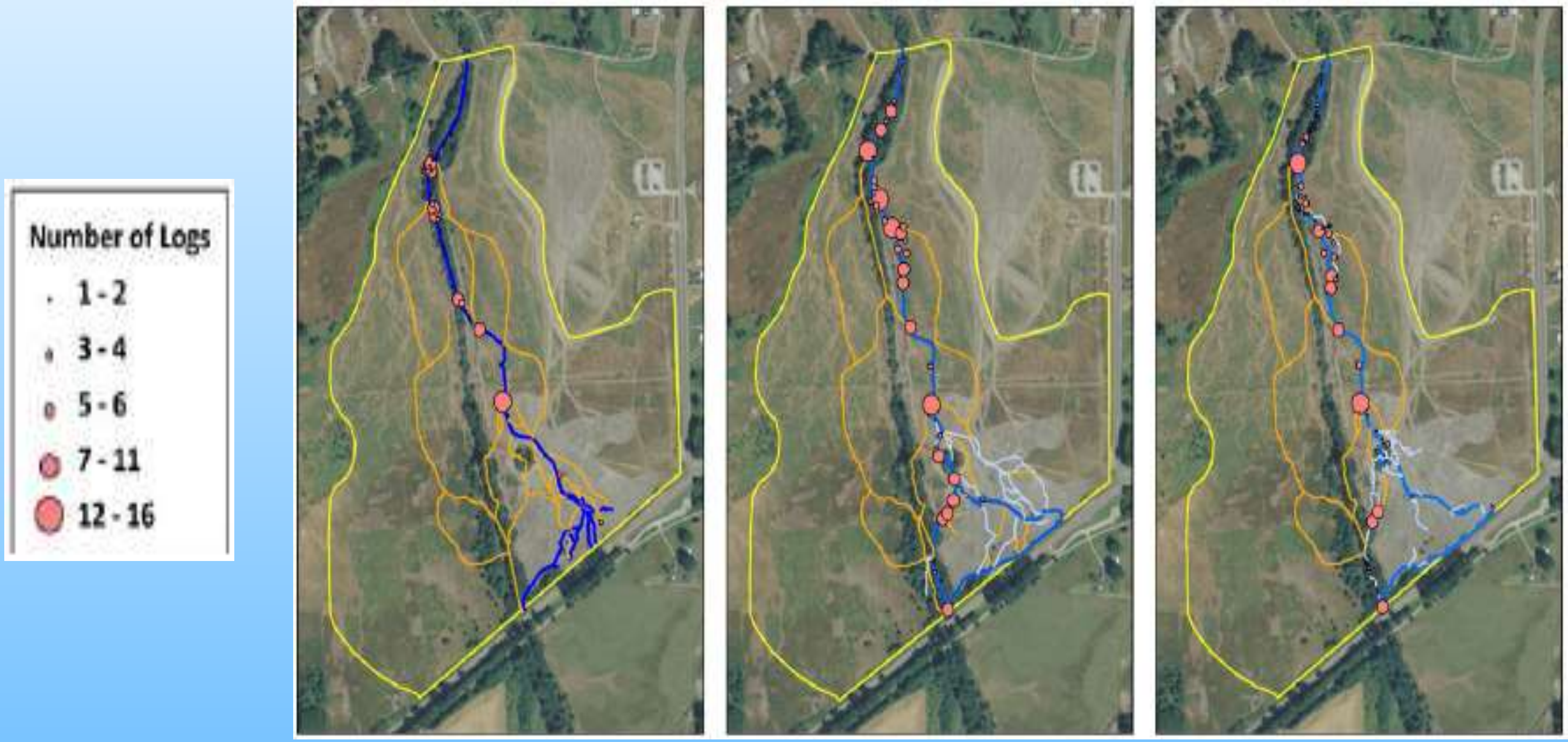
Geomorphic Change: LWD



	2010	2011	2013
	130 Logs	241 Logs	233 Logs
Increase ➡	300%	650%	630%

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Geomorphic Change: Sediment

Typical floodplain roughening logs approx.
4 to 5 feet above grade

2 to 3 feet of deposition at
Floodplain roughening log (2014)

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Geomorphic Change: Sediment

Vegetation in wetland buried in after the March 2011 Flood

0.8m (2.6 ft) cumulative deposition in wetland (measured in winter 2014)

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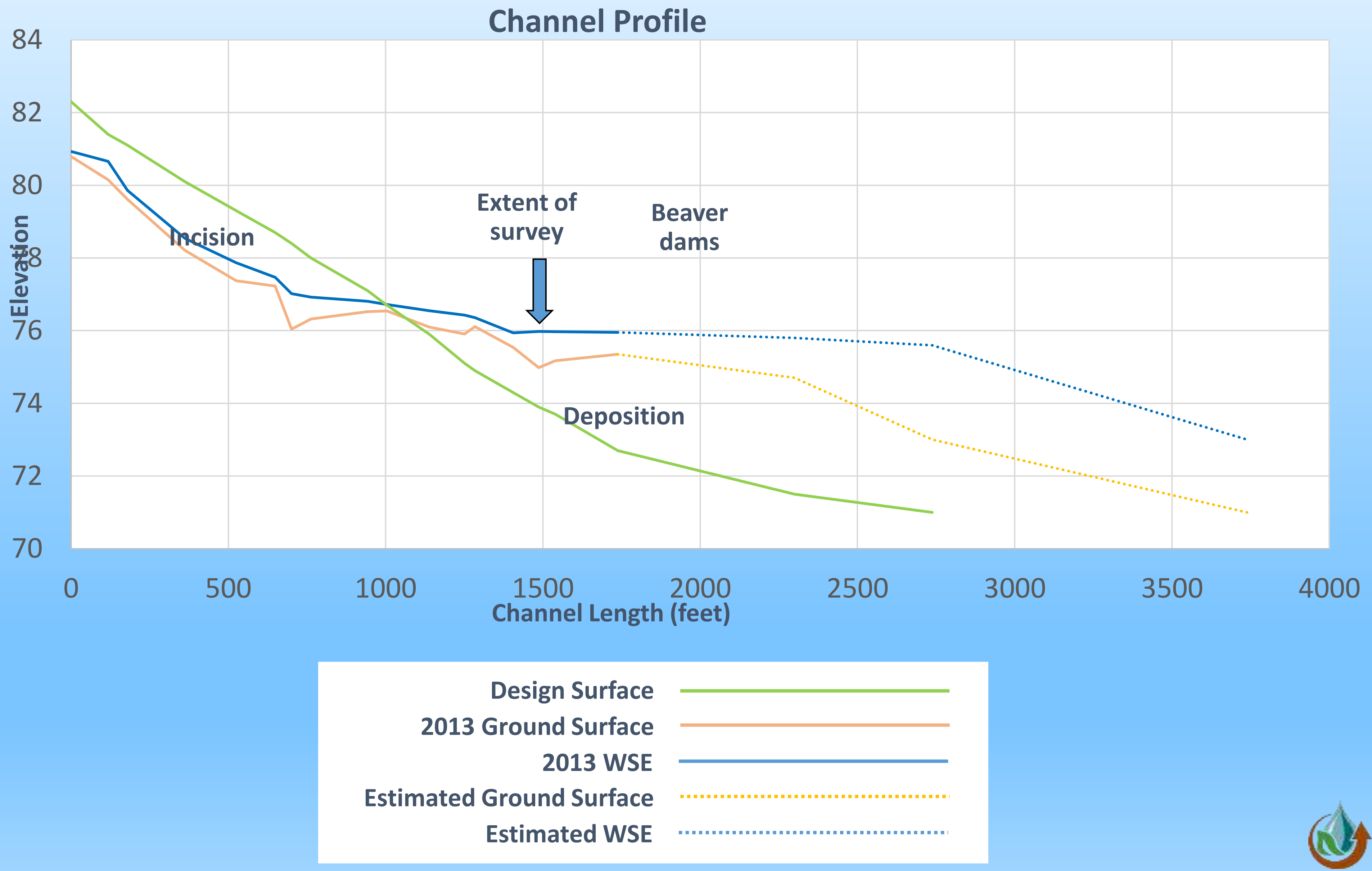
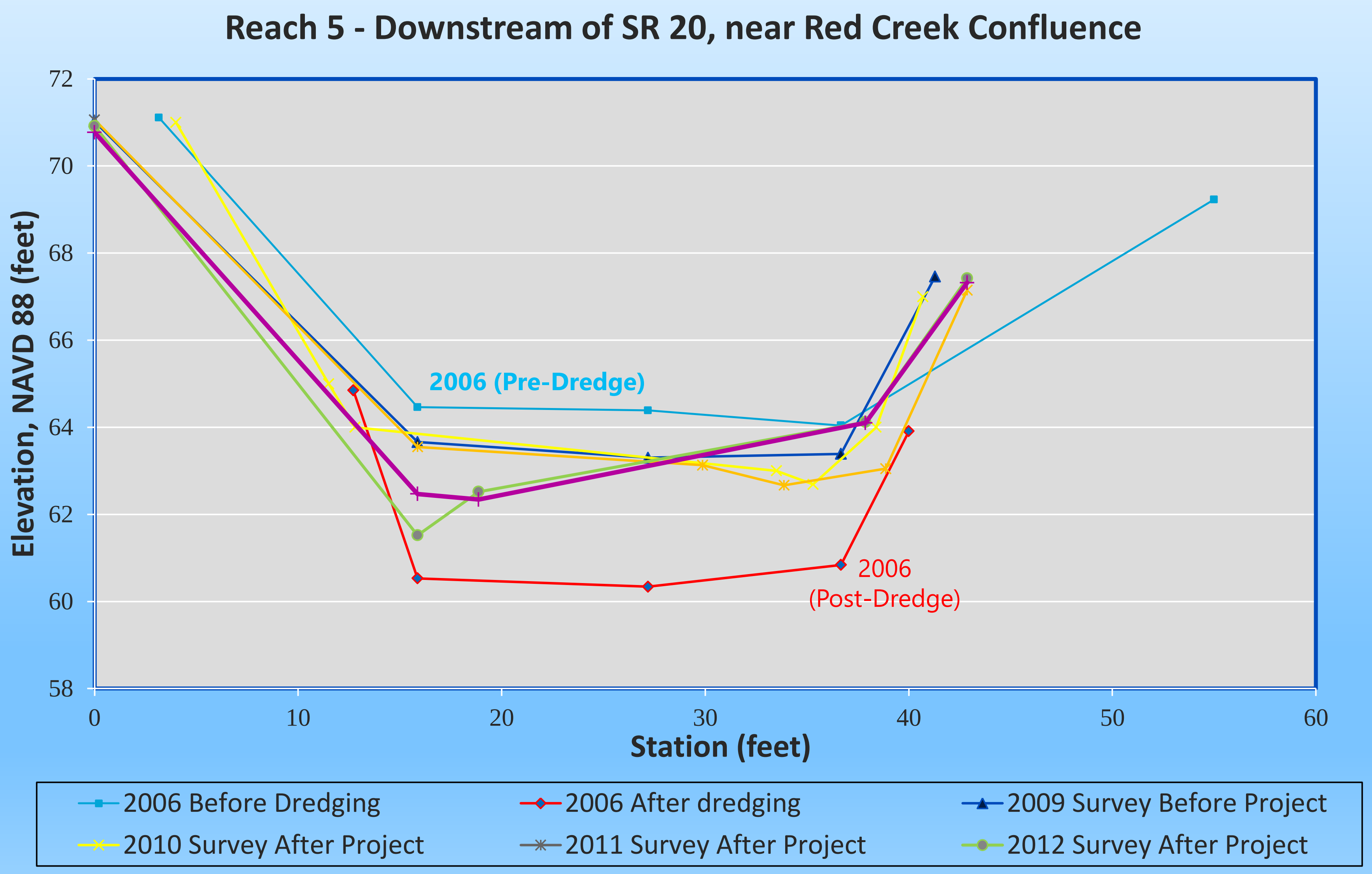
Geomorphic Change: Sediment



Geomorphic Change: Sediment



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Physical Habitat

Table. Habitat Unit Survey data – Pools and Riffles within the fan (Reach 3).

	Pools				Riffles			
	2010	2011	2012	**2013**	2010	2011	**2012**	2013
Number	23	17	20	**26**	23	19	**25**	32
Surface area (m^2) / % surface area	780/ 25%	640/ 20%	1080/ 25%	**1110/ 28%**	2400/ 75%	2460/ 80%	**3170/** 75%	2860/ 72%

Table. Habitat Unit Survey data – Pools and Riffles within the wetland (Reach 4).

	Pools				Riffles			
	2010	**2011**	**2012**	2013	2010	**2011**	**2012**	2013
Number	20	**25**	18	13	16	**17**	15	7
Surface area (m^2) / % surface area	4460/9 4%	3950/ 90%	**5135**/ 90%	3180/ 90%	280 6%	420 10%	**540**/ 10%	200/ 10%

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Lessons Learned

- Expect the unexpected:
  - Hydrology (loss of seeding and plants)

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Lessons Learned

- Expect the unexpected:
  - Hydrology (loss of seeding
  - Beaver

Date	# Dams	Inundated Area (m^2)
7/3/2013	2	601
9/19/2013	6	1,920
9/24/2013	6	3,124
10/22/2013	13	7,686

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Lessons Learned

- Expect the unexpected:
  - Hydrology (loss of seed
  - Beaver
  - Sediment (fine)

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Lessons Learned

- Expect the unexpected:
  - Hydrology (loss of seeding and plants)
  - Beaver
  - Sediment (fine)
  - Neighbor acceptance

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Thank You

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Restoring Tributary Alluvial Fans

Importance to Skagit Chinook Recovery

36th Annual Salmonid Restoration Conference

April 11-14, 2018 Fortuna River Lodge

Rick Hartson
Upper Skagit Indian Tribe

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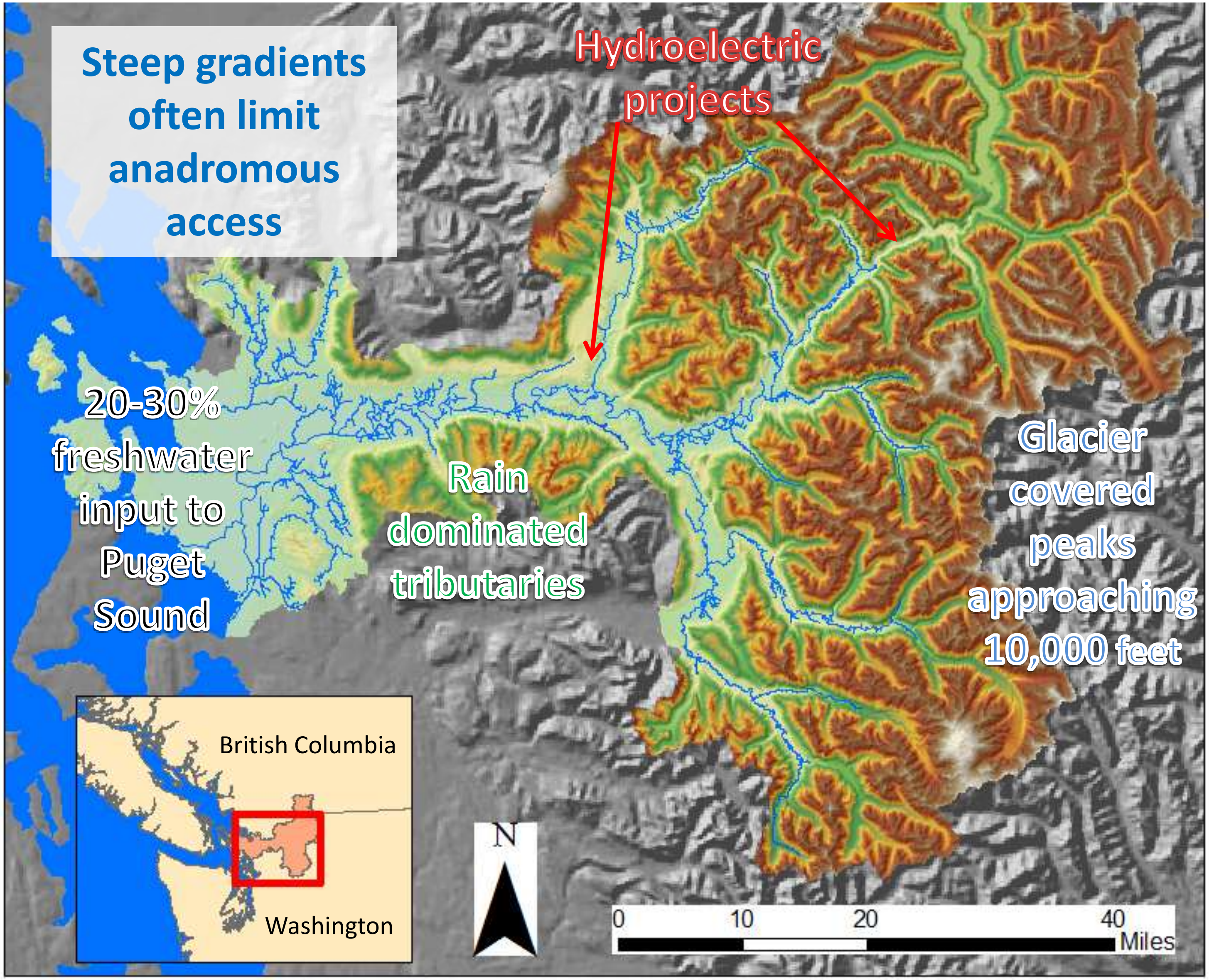
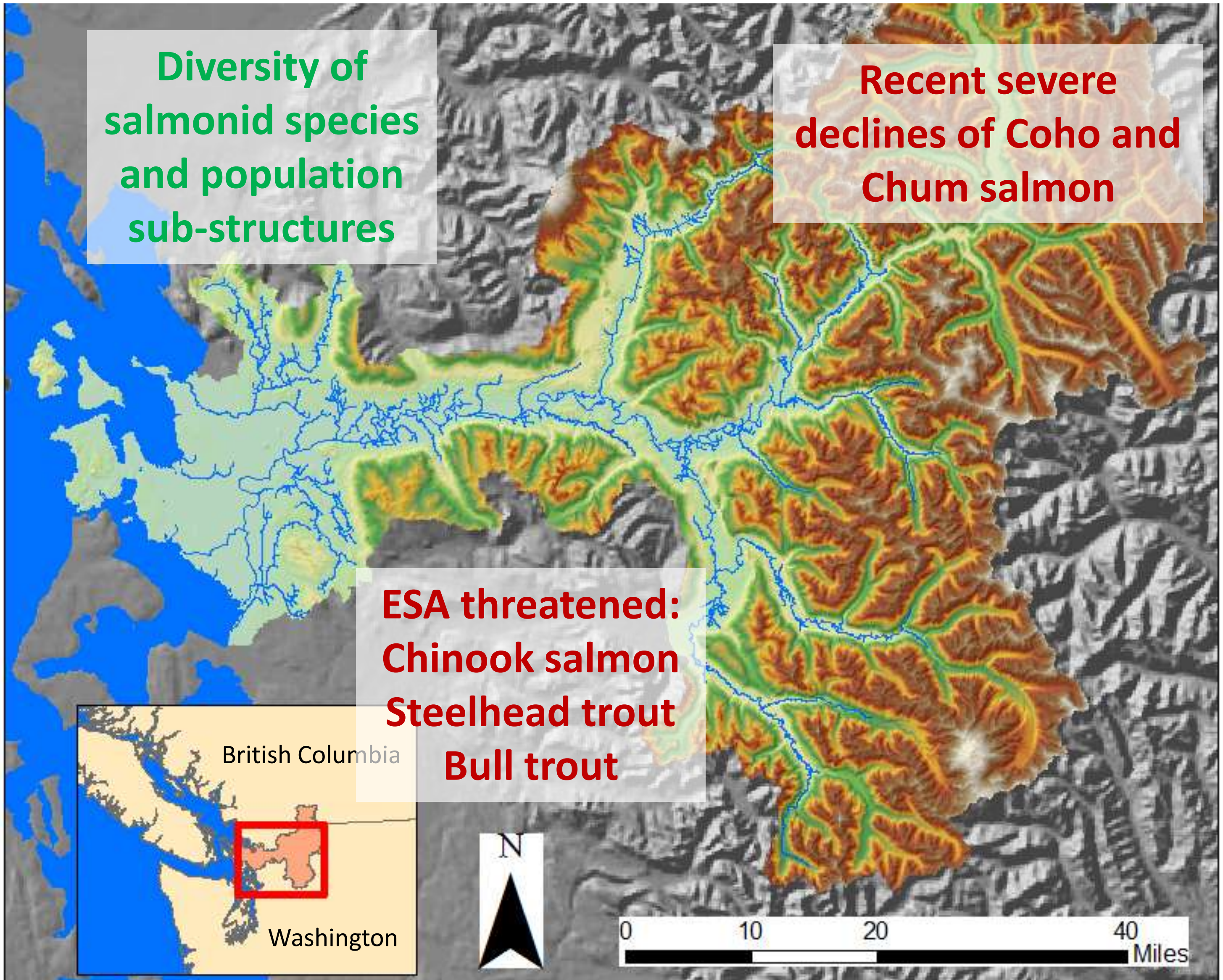
Christina Avolio
Jose Carrasquero

Regional Setting – Puget Sound

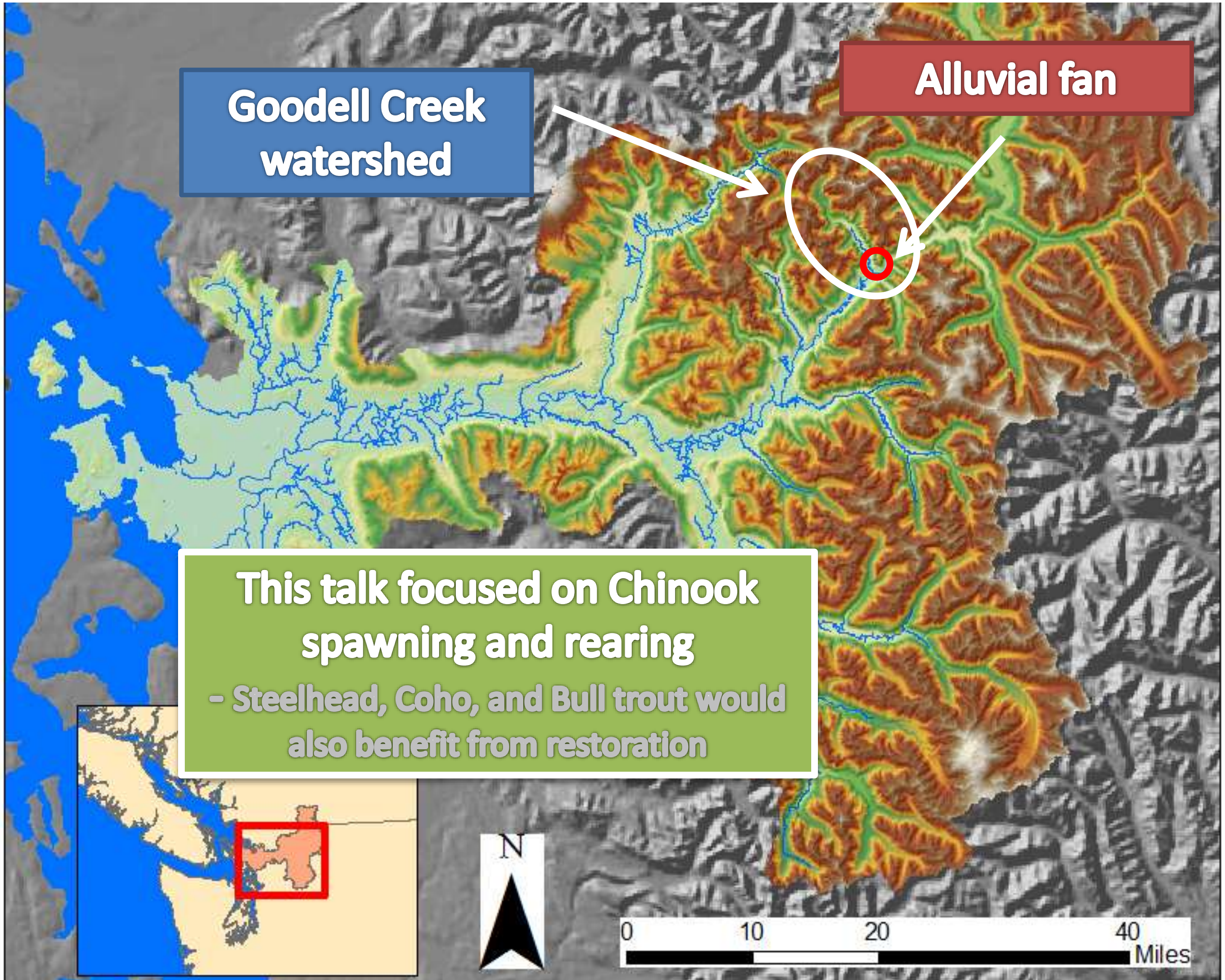
Watershed Setting – Skagit River



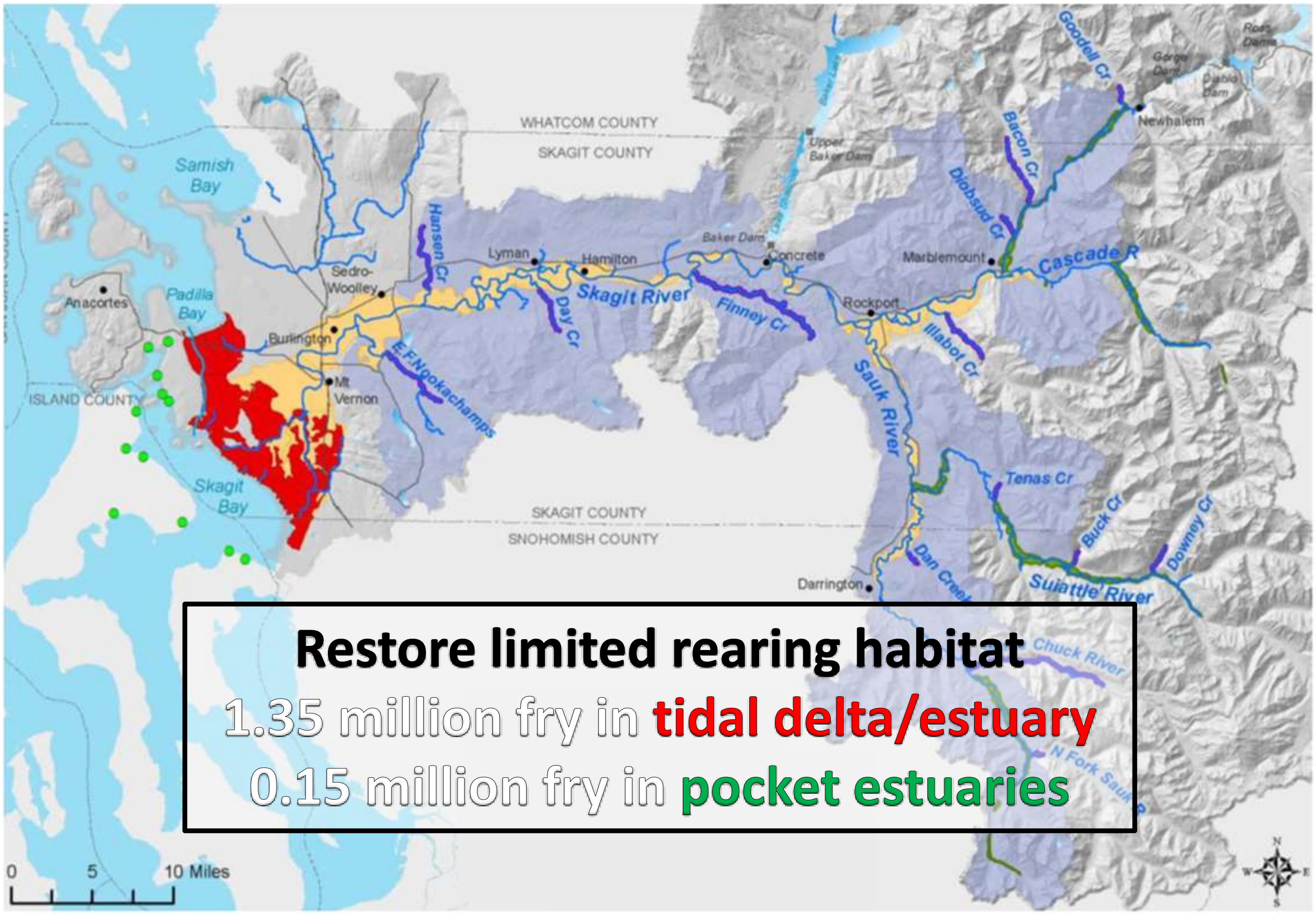
Watershed Setting – Skagit River



Project Setting – Goodell Creek



Chinook Recovery Strategy



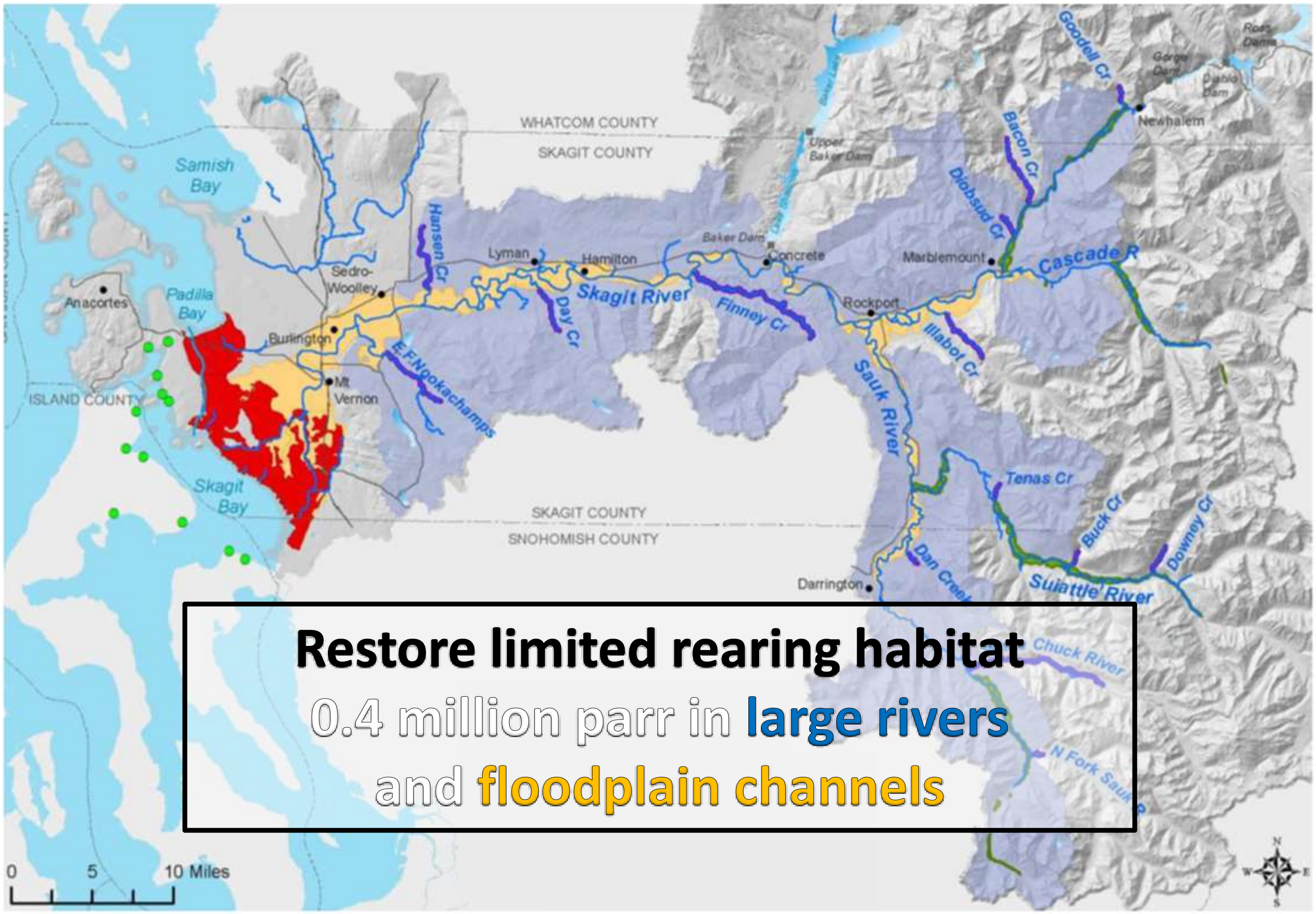
Restore limited rearing habitat

1.35 million fry in tidal delta/estuary

0.15 million fry in pocket estuaries

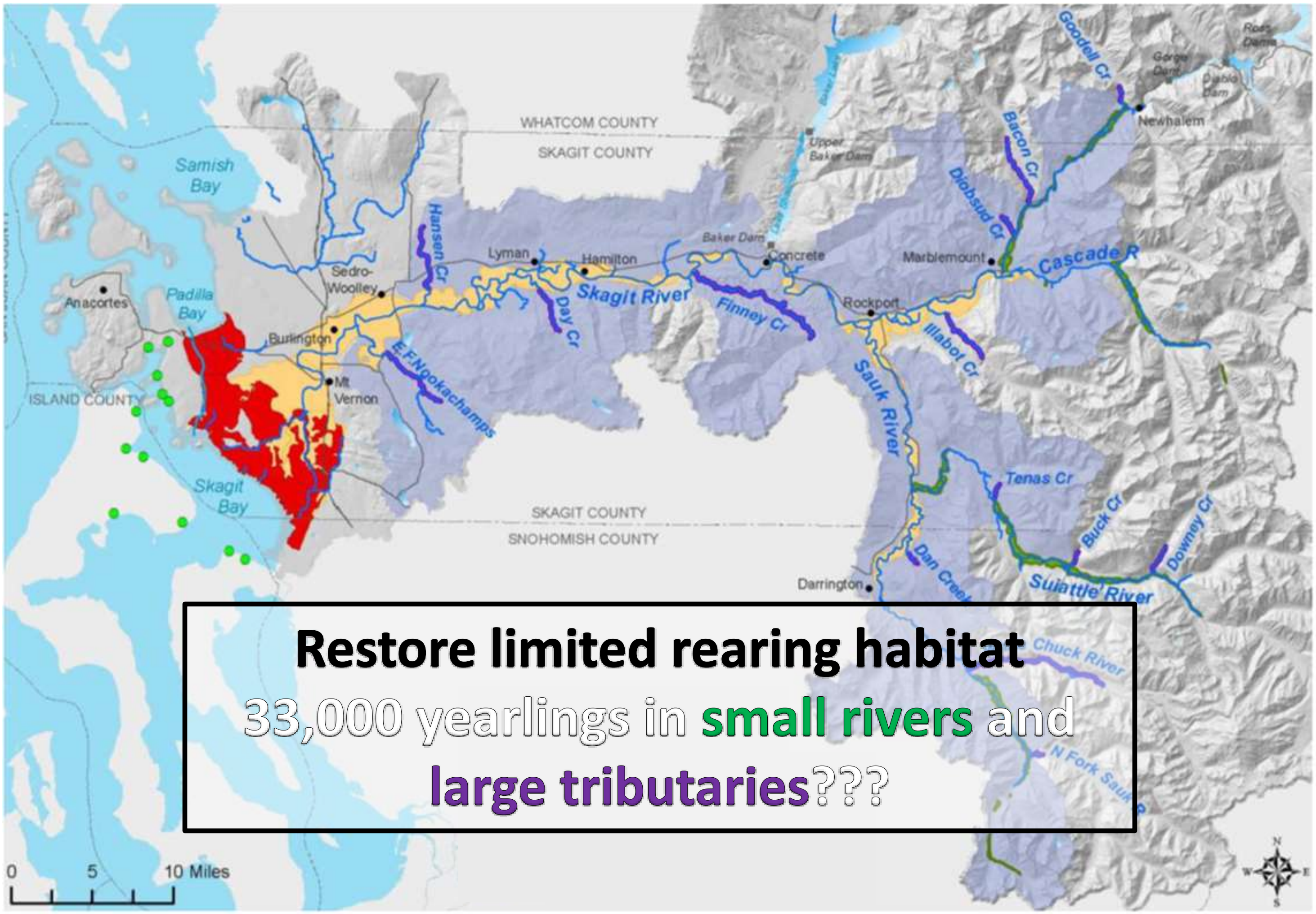
Source: Skagit Watershed Council, Year 2015 Strategic Approach

Chinook Recovery Strategy



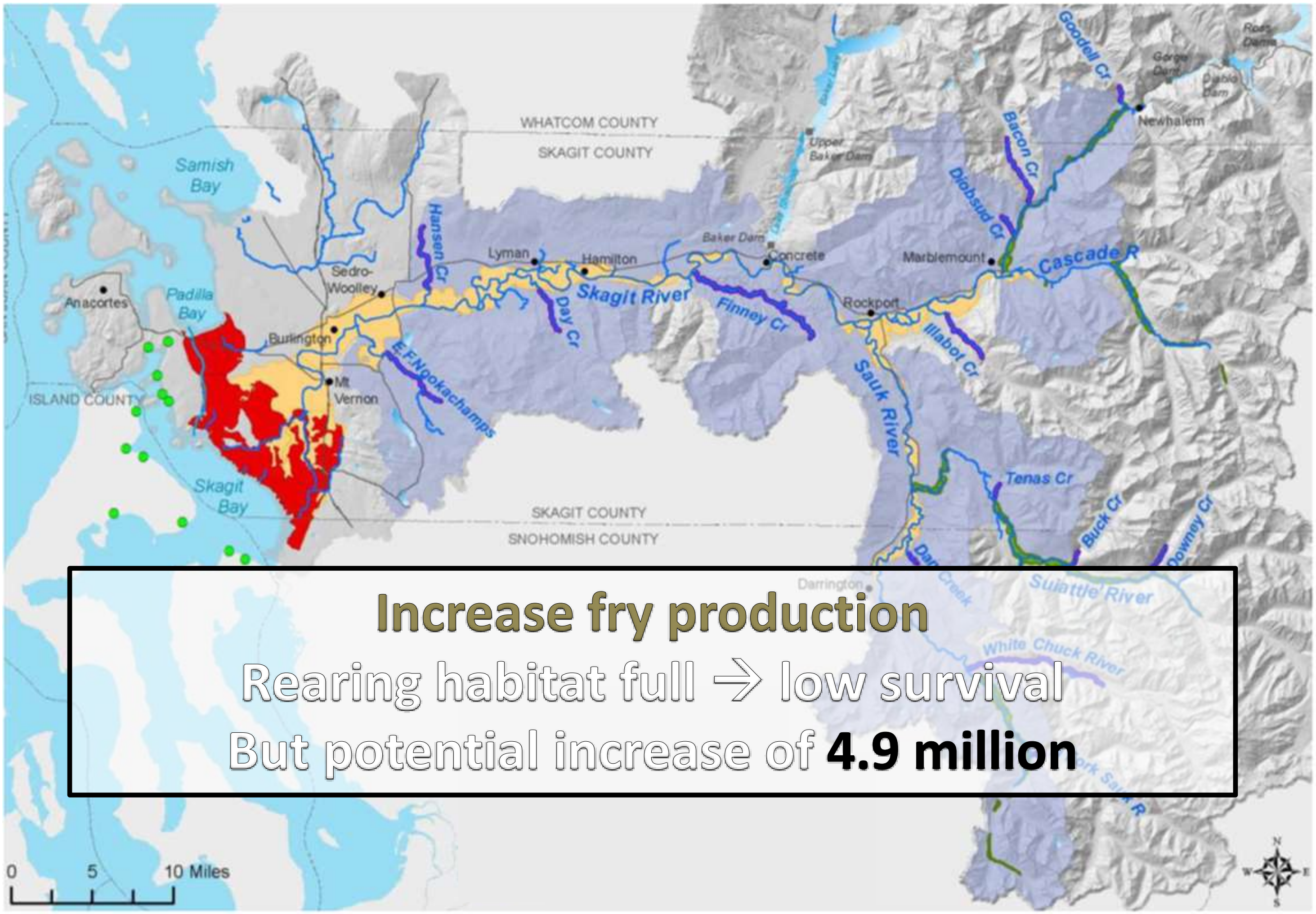
Source: Skagit Watershed Council, Year 2015 Strategic Approach

Chinook Recovery Strategy



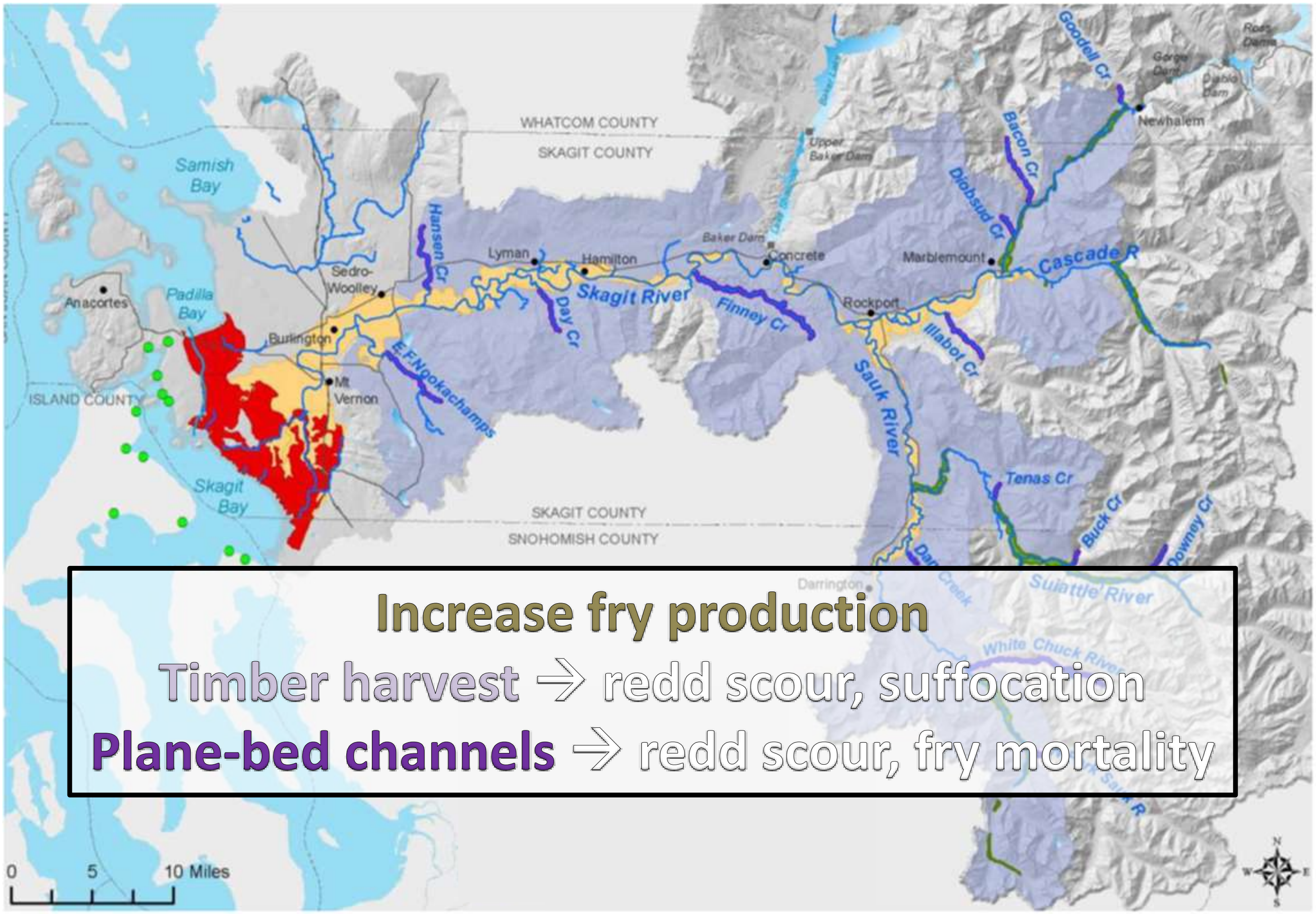
Source: Skagit Watershed Council, Year 2015 Strategic Approach

Chinook Recovery Strategy



Source: Skagit Watershed Council, Year 2015 Strategic Approach

Chinook Recovery Strategy



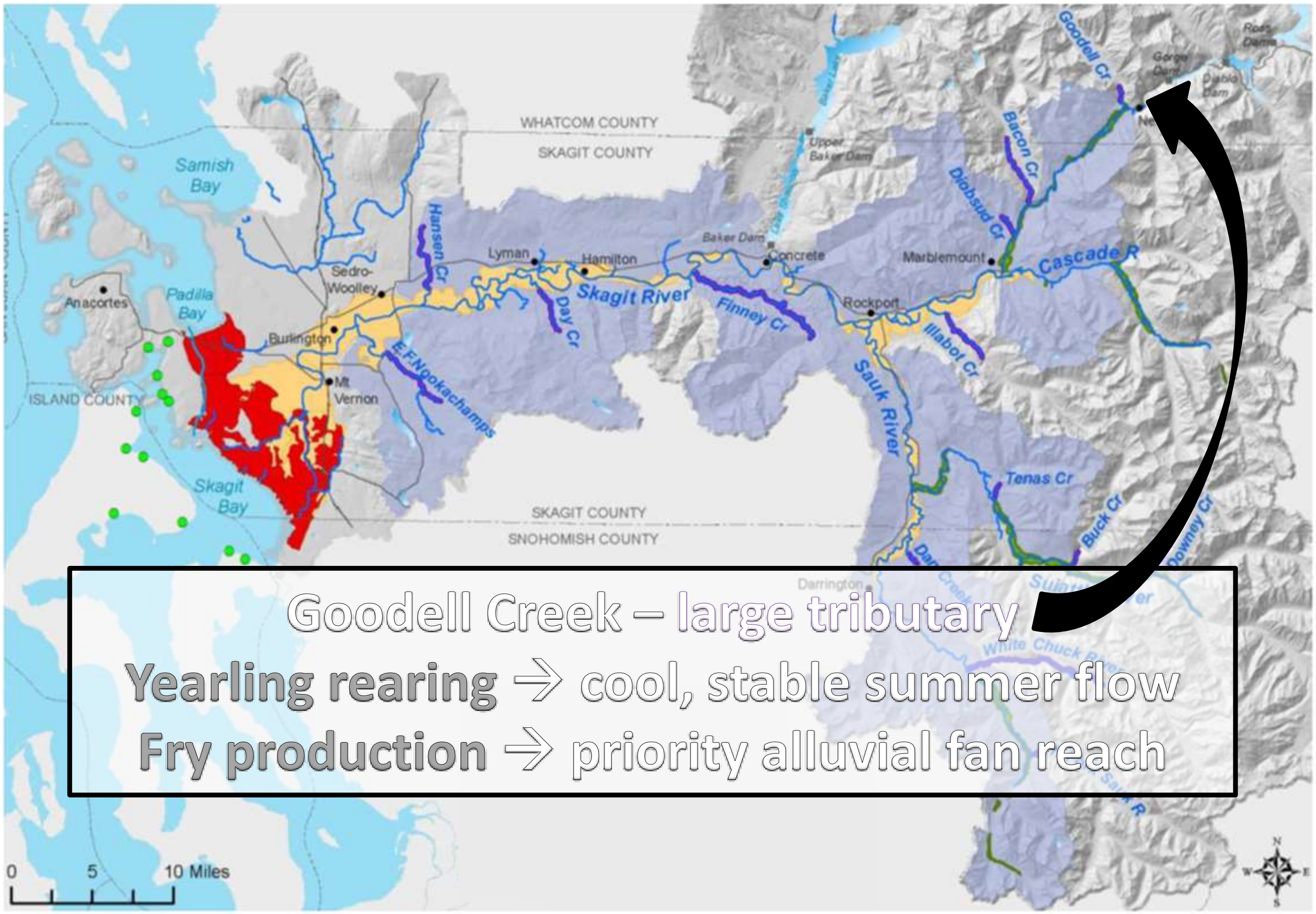
Increase fry production

Timber harvest → redd scour, suffocation

Plane-bed channels → redd scour, fry mortality

Source: Skagit Watershed Council, Year 2015 Strategic Approach

Chinook Recovery Strategy



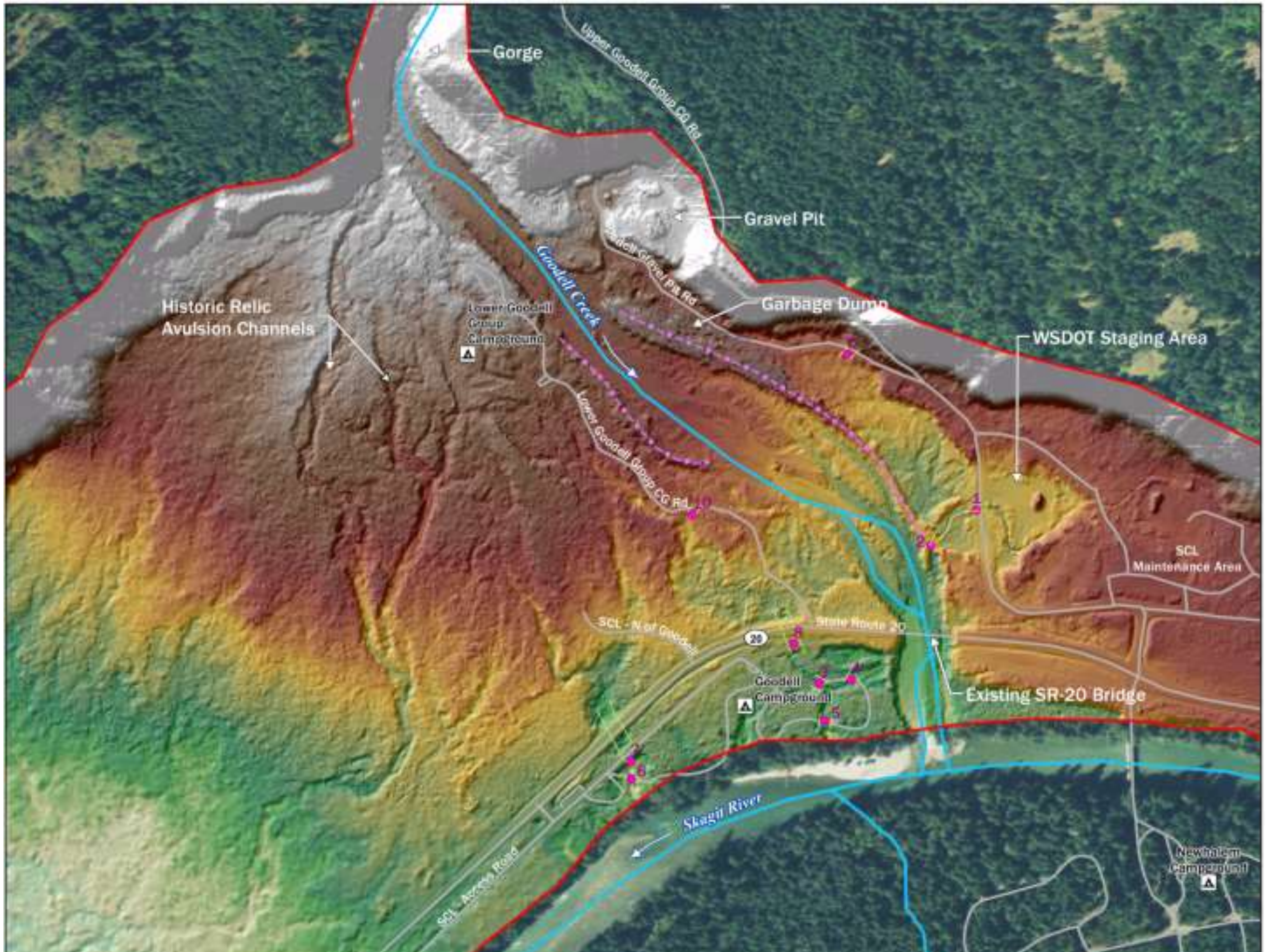
Goodell Creek – large tributary

Yearling rearing → cool, stable summer flow

Fry production → priority alluvial fan reach

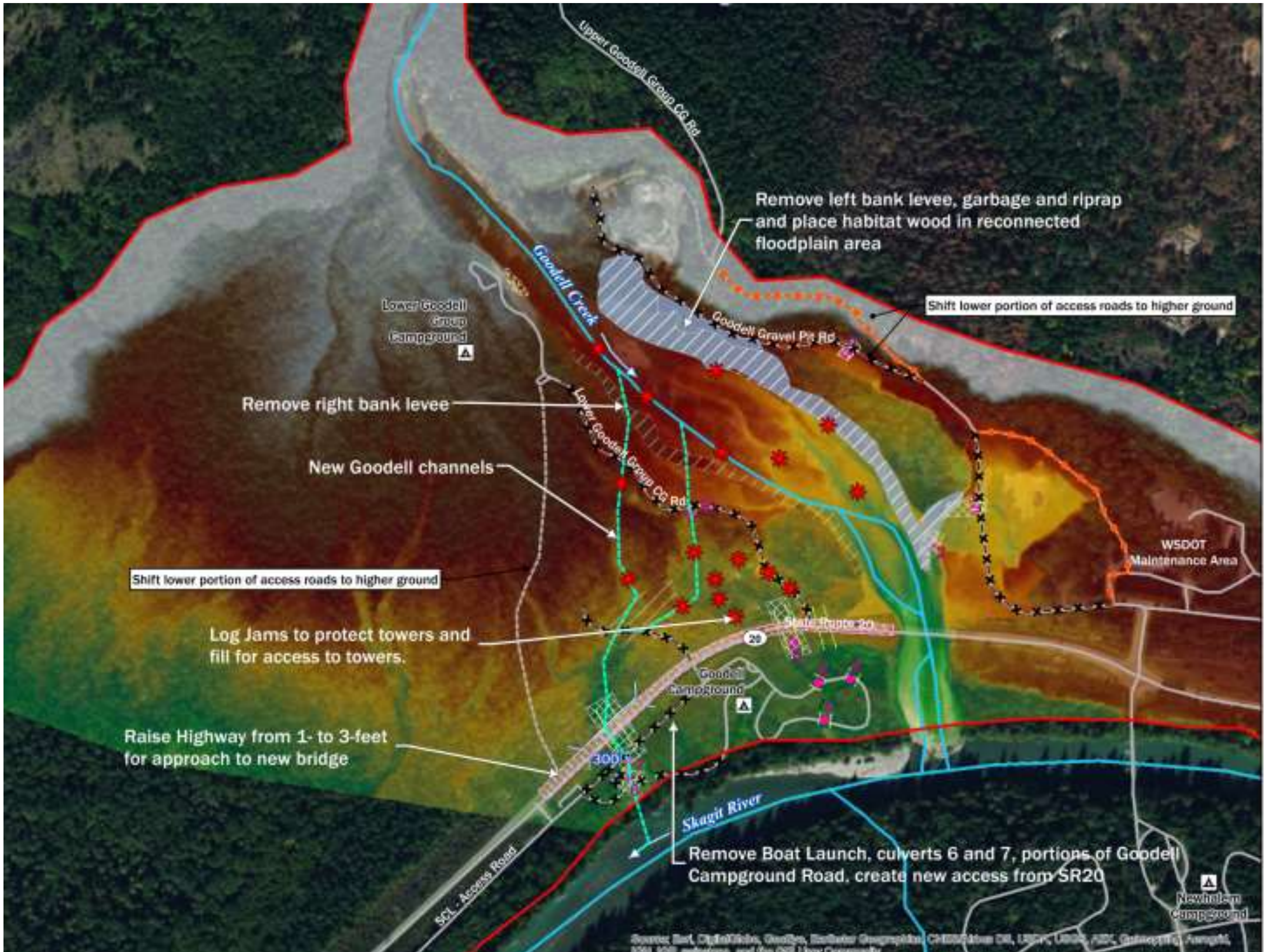
Source: Skagit Watershed Council, Year 2015 Strategic Approach

Goodell Creek - Current Condition



Source: Herrera Environmental Consultants, Inc.

Goodell Creek – Restoration Plan



Source: Herrera Environmental Consultants, Inc.

Assessing Chinook Habitat

Approach:

- Relative comparison: current condition vs. restored

Assessing Chinook Habitat

Approach:

- Relative comparison: current condition vs. restored
- Rearing habitat capacity
  - Habitat types
  - Parr and yearling

Assessing Chinook Habitat

Approach:

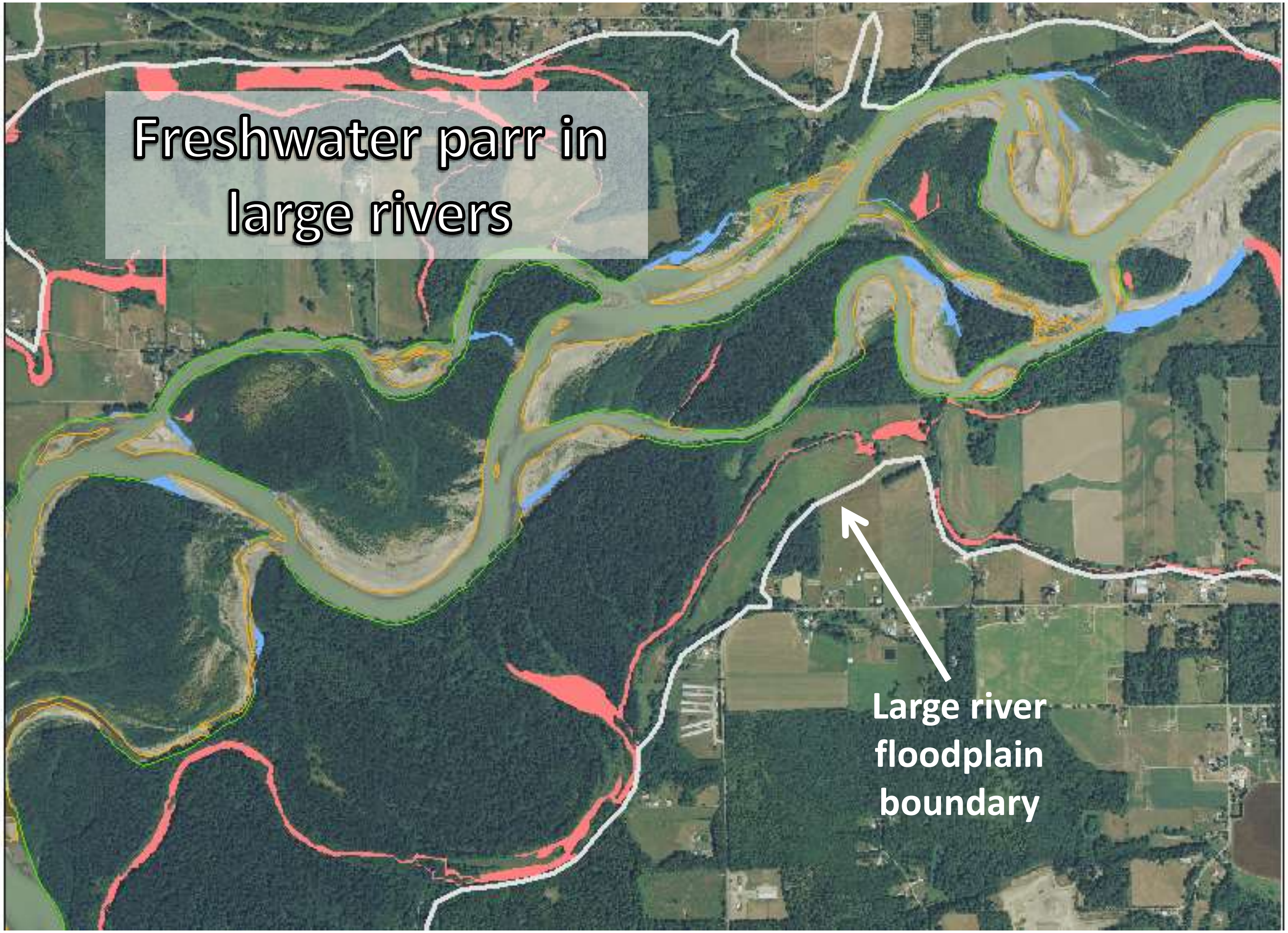
- Relative comparison: current condition vs. restored
- Rearing habitat capacity
  - Habitat types
  - Parr and yearling
- Fry productivity
  - Channel form → redd density and fry survival

Assessing Chinook Habitat

Approach:

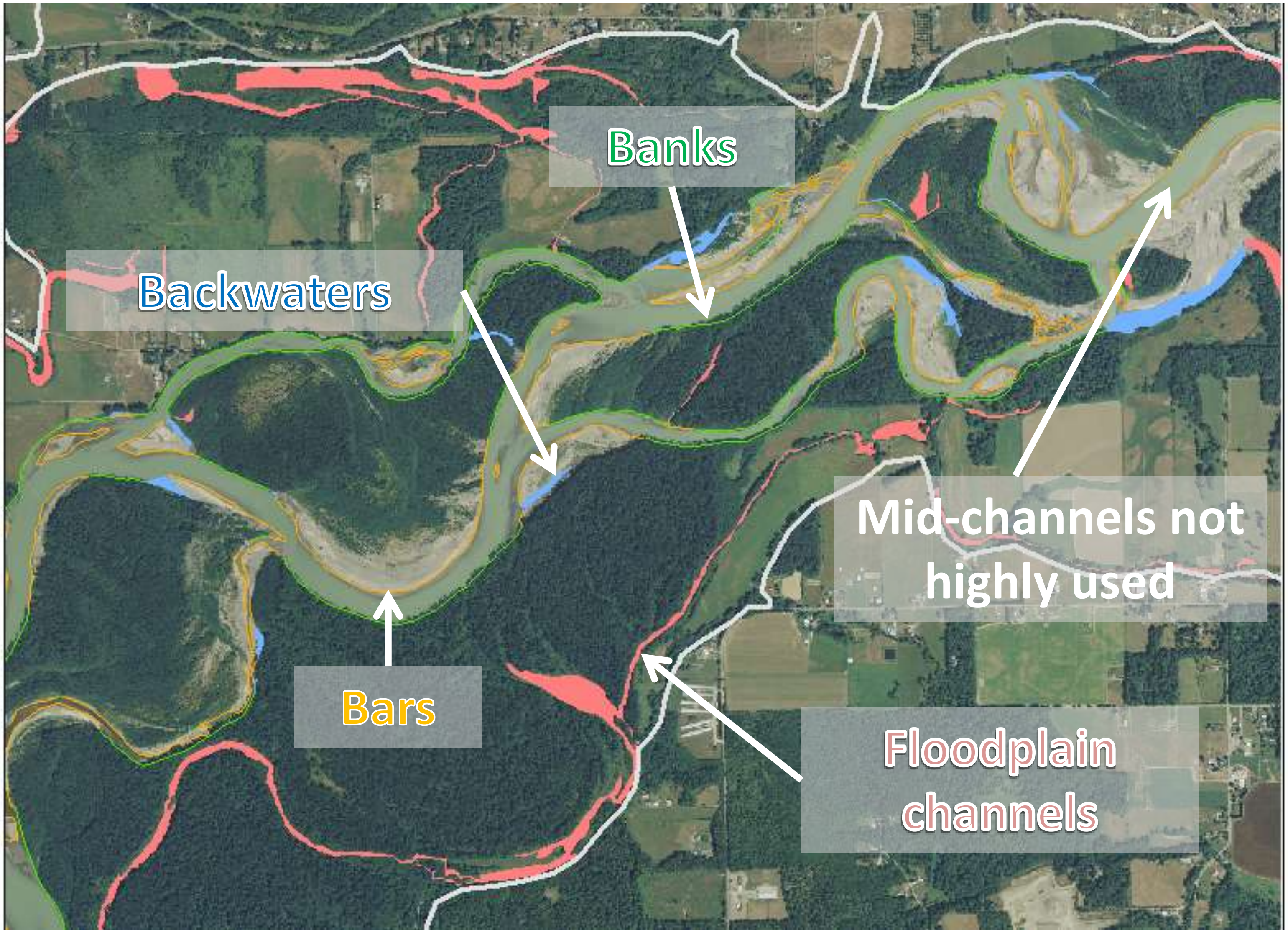
- Relative comparison: current condition vs. restored
- Rearing habitat capacity
  - Habitat types
  - Parr and yearling
- Fry productivity
  - Channel form → redd density and fry survival
- Smolt-to-adult survival to estimate adult abundance

Describing Tributary Habitat



Data source: Skagit Watershed Council; NAIP imagery

Describing Tributary Habitat



Data source: Skagit Watershed Council; NAIP imagery

Describing Tributary Habitat

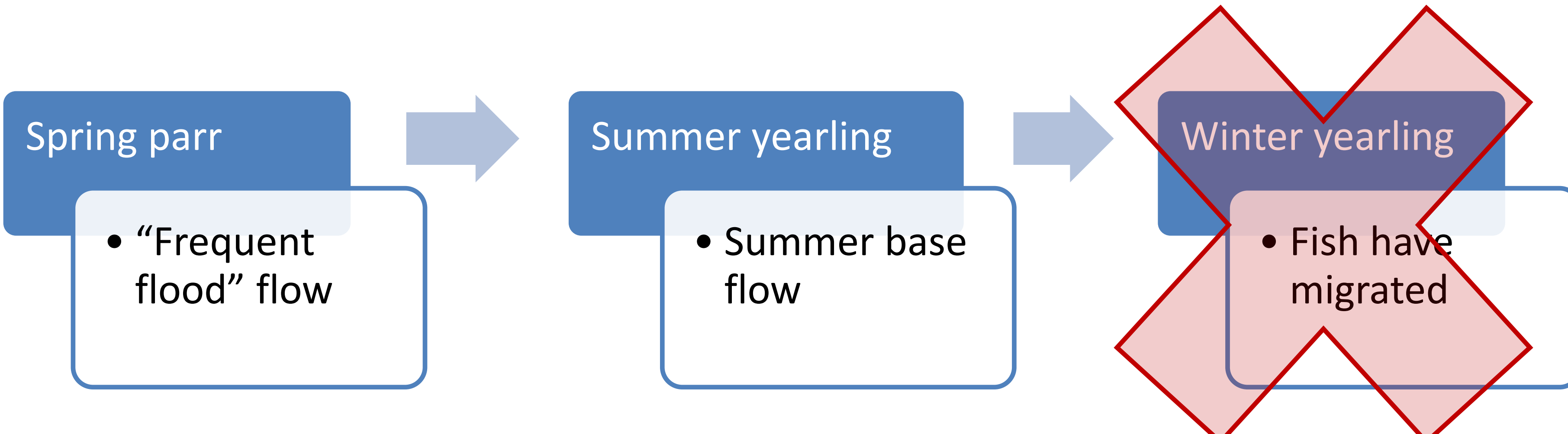
Tributary fish use

- Snorkel survey study
  - Small river and large tributary habitat types

Describing Tributary Habitat

Tributary fish use

- Snorkel survey study
  - Small river and large tributary habitat types
  - Parr and yearling life-history strategies



Describing Tributary Habitat

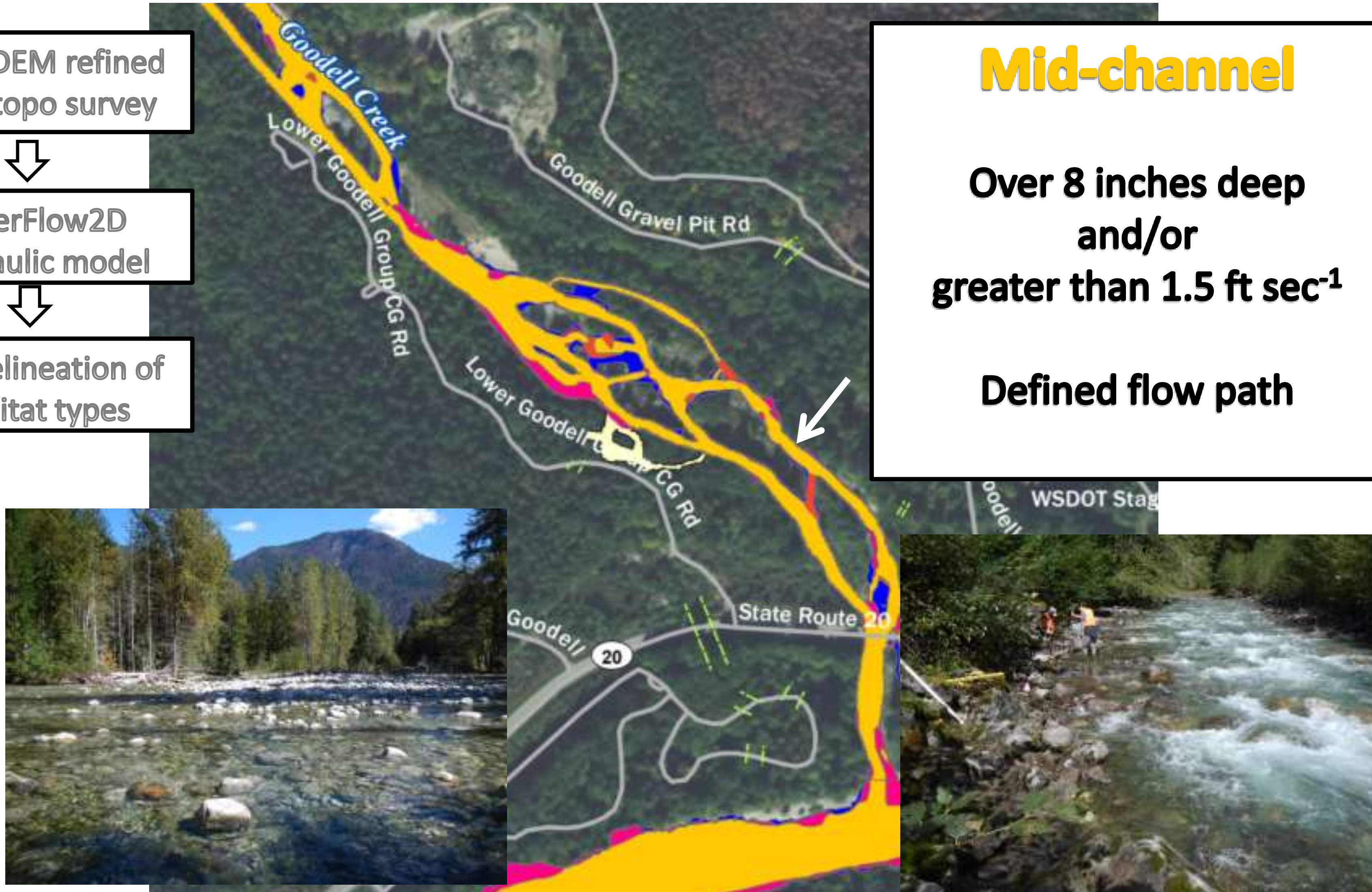
Lidar DEM refined with topo survey

⇩

RiverFlow2D hydraulic model

⇩

GIS delineation of habitat types



Mid-channel

Over 8 inches deep and/or greater than 1.5 ft sec^{-1}

Defined flow path

Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat

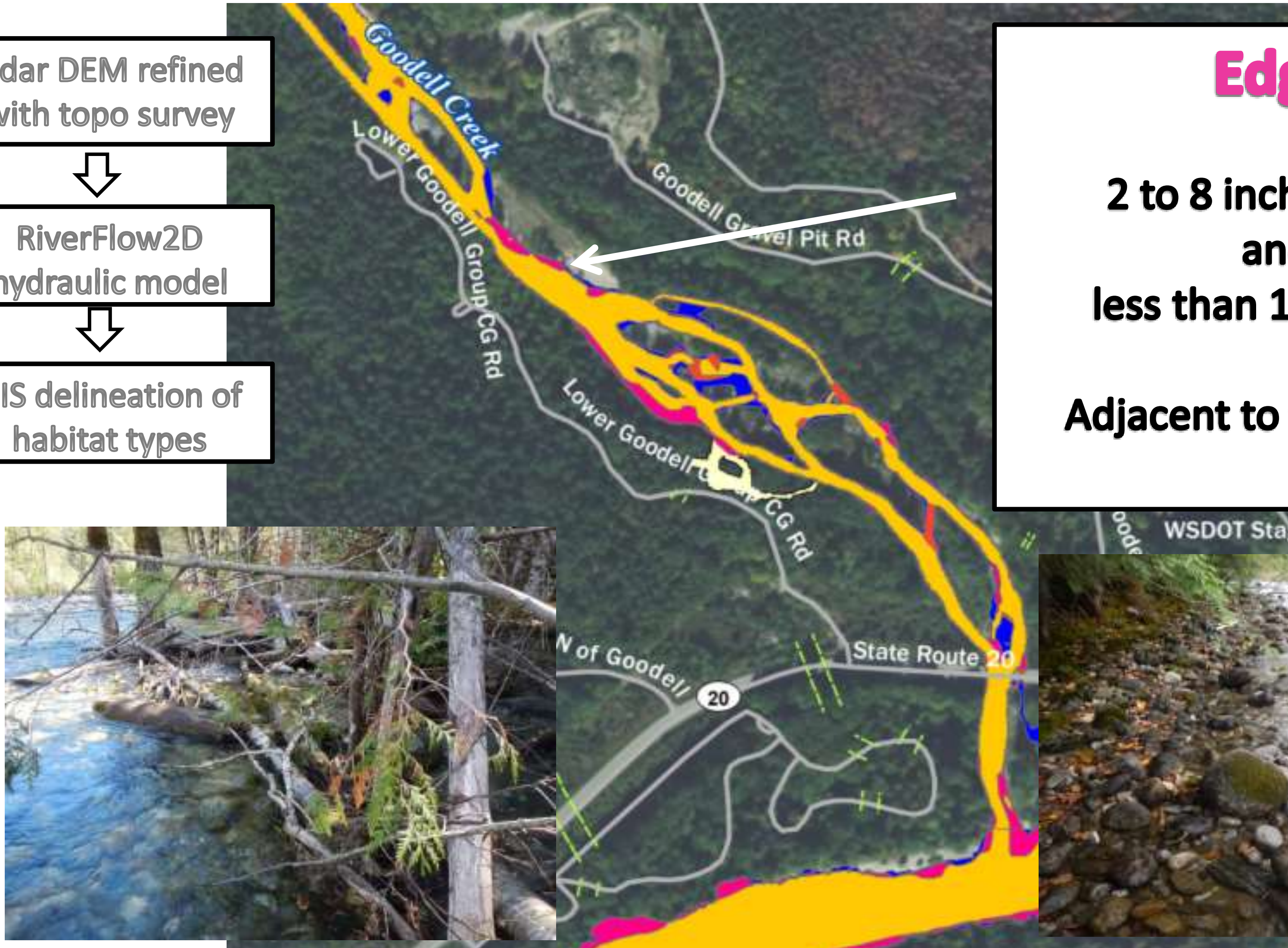
Lidar DEM refined with topo survey

⇩

RiverFlow2D hydraulic model

⇩

GIS delineation of habitat types



Edge

2 to 8 inches deep
and
less than 1.5 ft sec^{-1}

Adjacent to faster flow

Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat

Lidar DEM refined with topo survey

⇩

RiverFlow2D hydraulic model

⇩

GIS delineation of habitat types

Diffuse flow

2 to 8 inches deep
and
less than 1.5 ft sec^{-1}

No adjacent fast flow

Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat

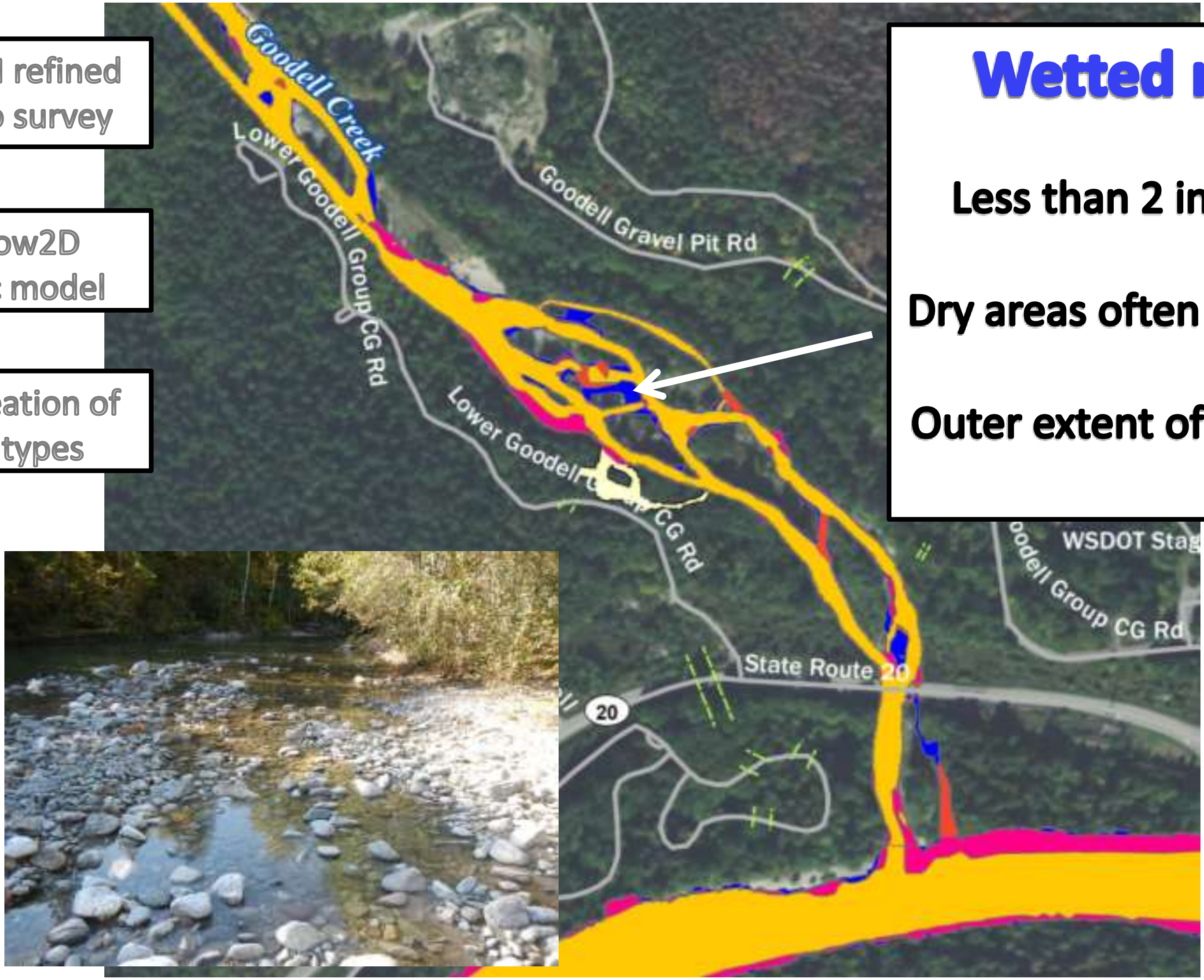
Lidar DEM refined with topo survey

⇩

RiverFlow2D hydraulic model

⇩

GIS delineation of habitat types



Wetted margin

Less than 2 inches deep

Dry areas often interspersed

Outer extent of wetted area

Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat

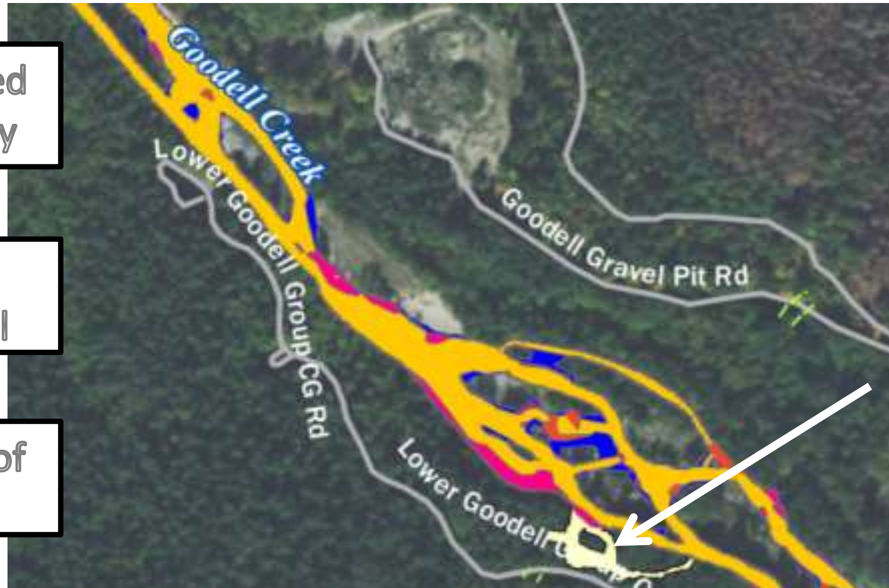
Lidar DEM refined with topo survey

↓

RiverFlow2D hydraulic model

↓

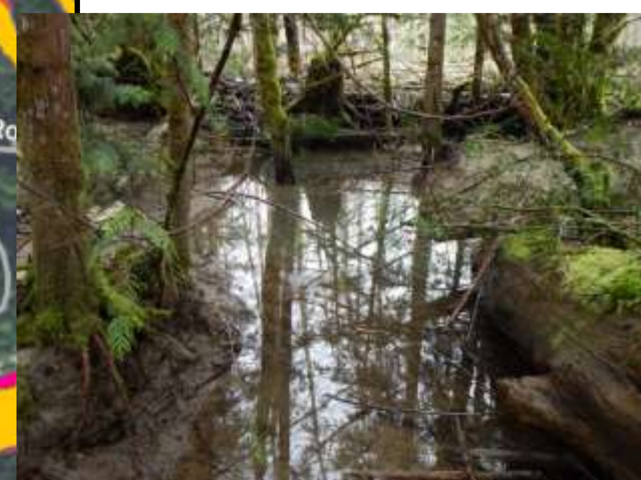
GIS delineation of habitat types



Slough

Relic channels with defined inlet and outlet

1 to 3 ft deep
and
near zero velocity



Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat

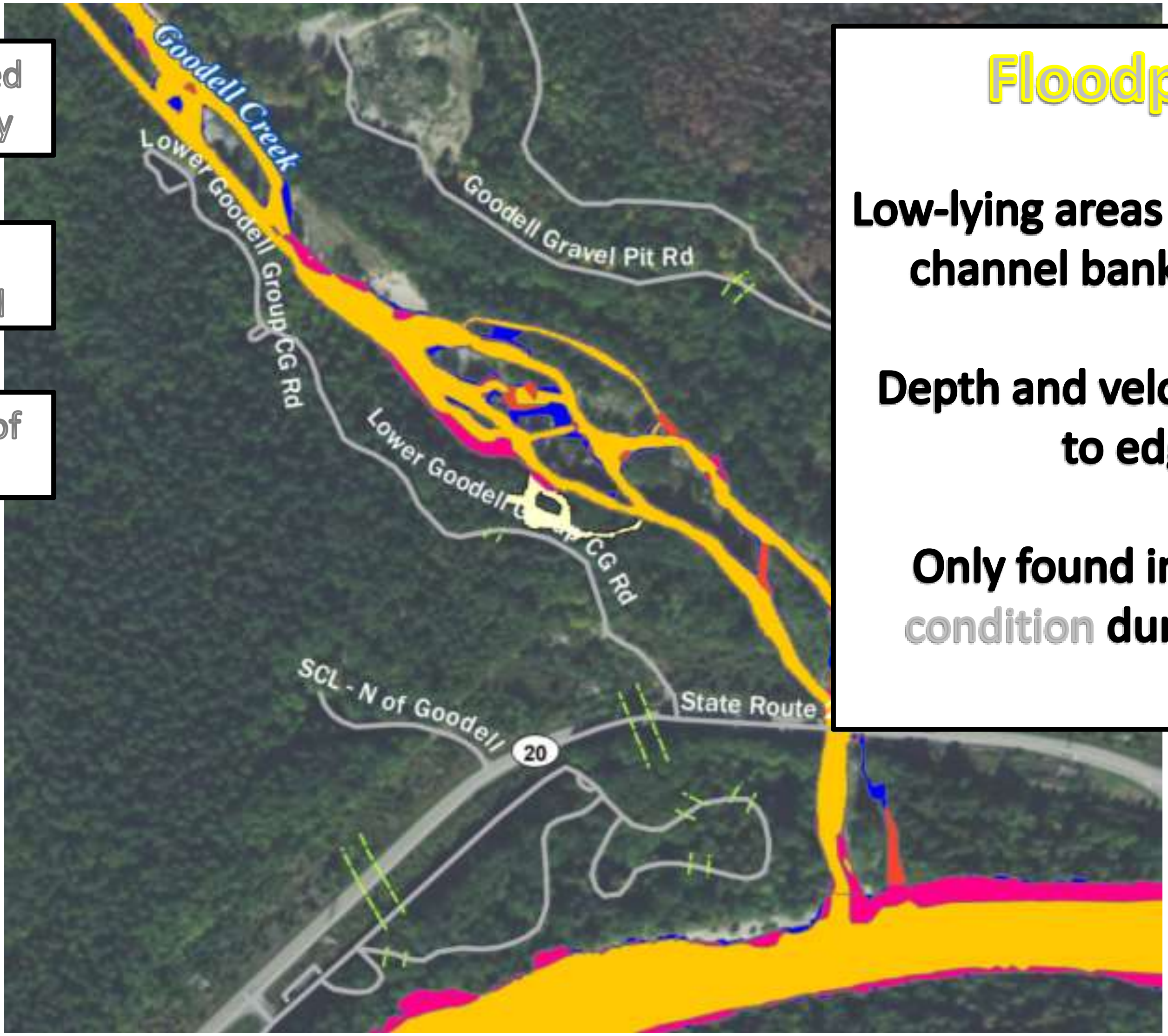
Lidar DEM refined with topo survey

⇩

RiverFlow2D hydraulic model

⇩

GIS delineation of habitat types



Floodplain

Low-lying areas wetted after channel banks overtop

Depth and velocity similar to edge

Only found in restored condition during spring

Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat

Some caveats – habitat area:

Predicting habitat evolution in a dynamic reach

- Side channel progression
- Plan form of reconnected channels
- Hydraulic complexity within channels

Methodological constraints

- Precision of hydraulic model mesh

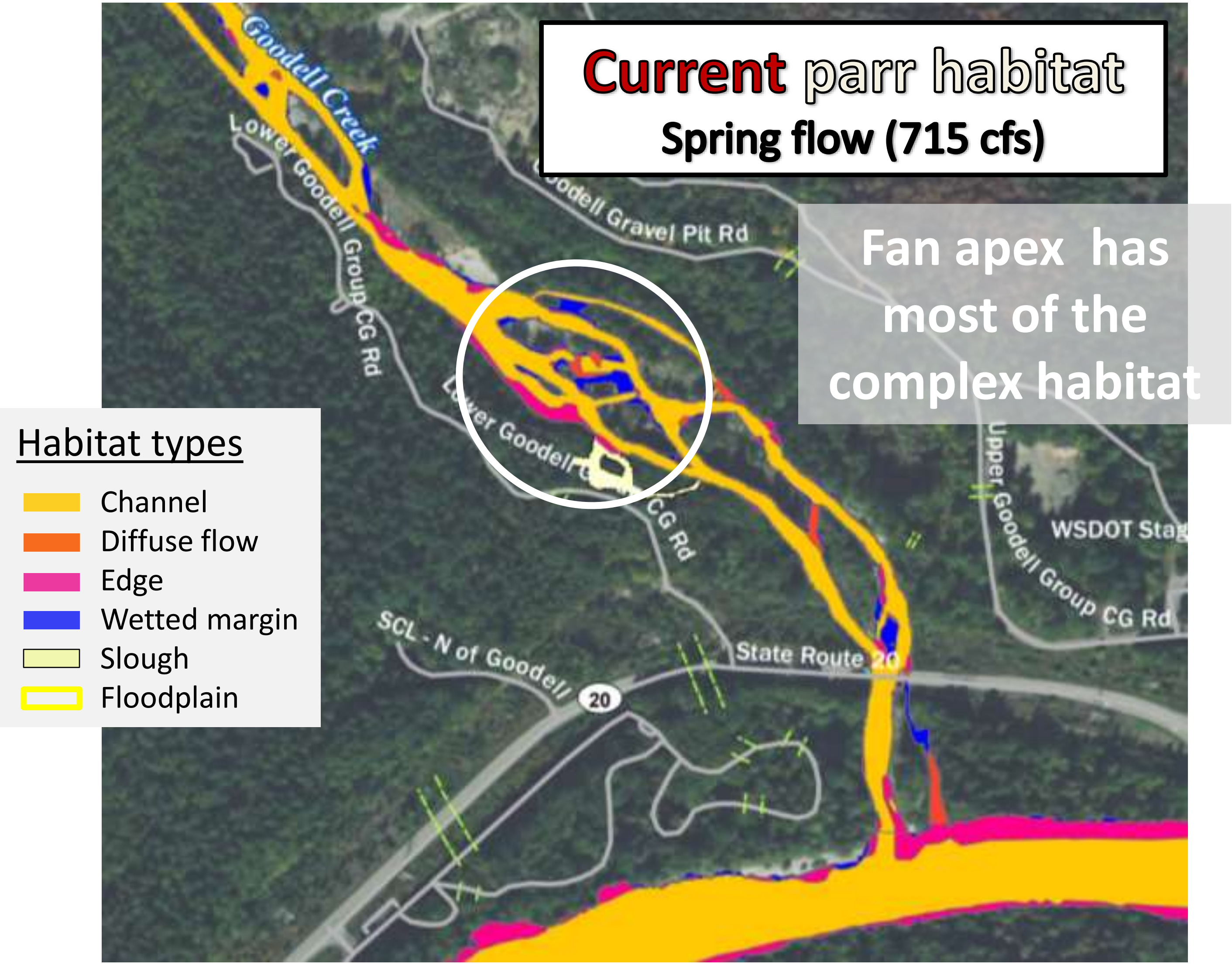
Describing Tributary Habitat

Some caveats – fish density:

Methodological constraints

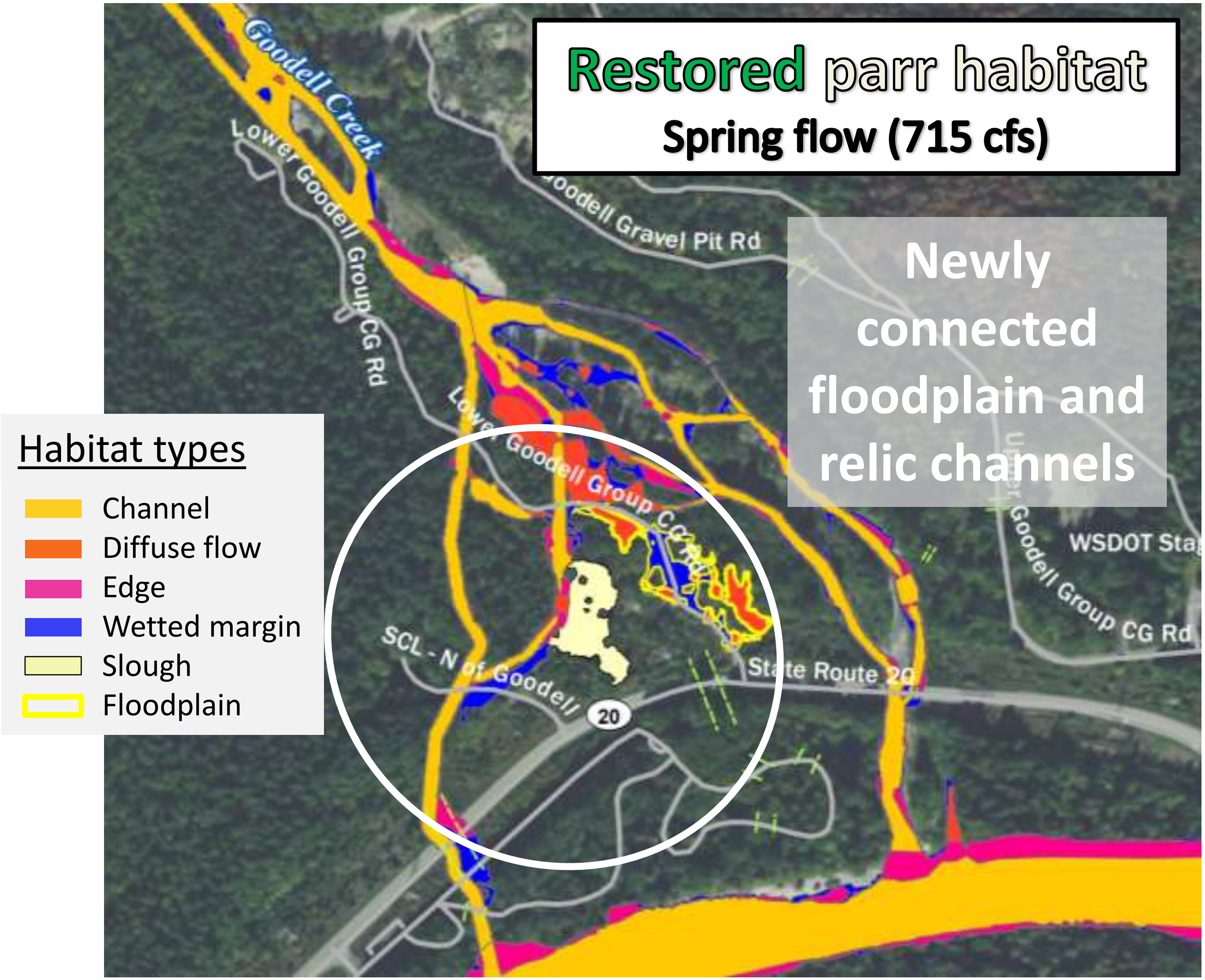
- Sample size for some habitat types
- Representative channel conditions
- Snorkel surveys underestimate density

Describing Tributary Habitat



Source: Herrera Environmental Consultants, Inc.

Describing Tributary Habitat



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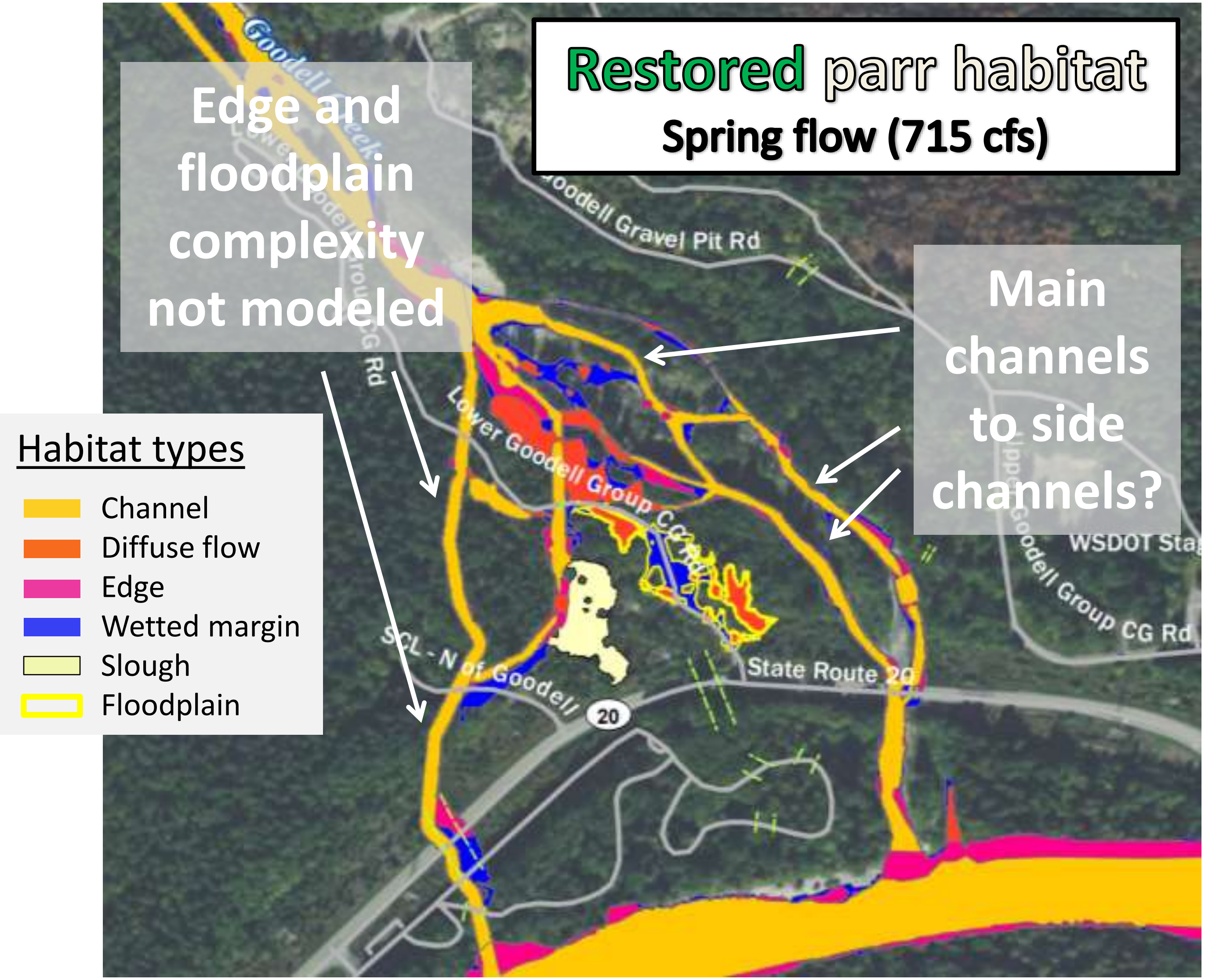
Describing Tributary Habitat



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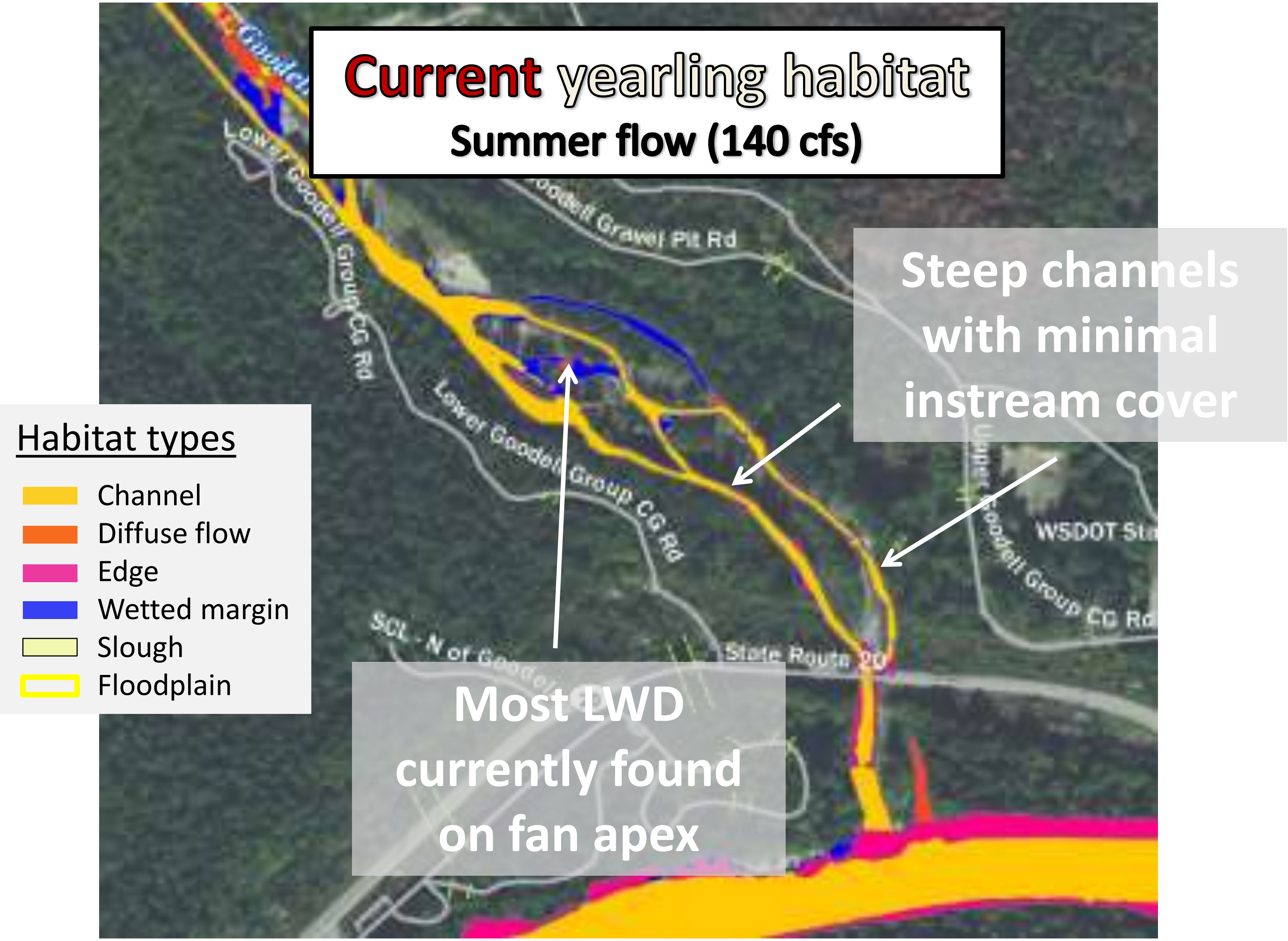
Describing Tributary Habitat



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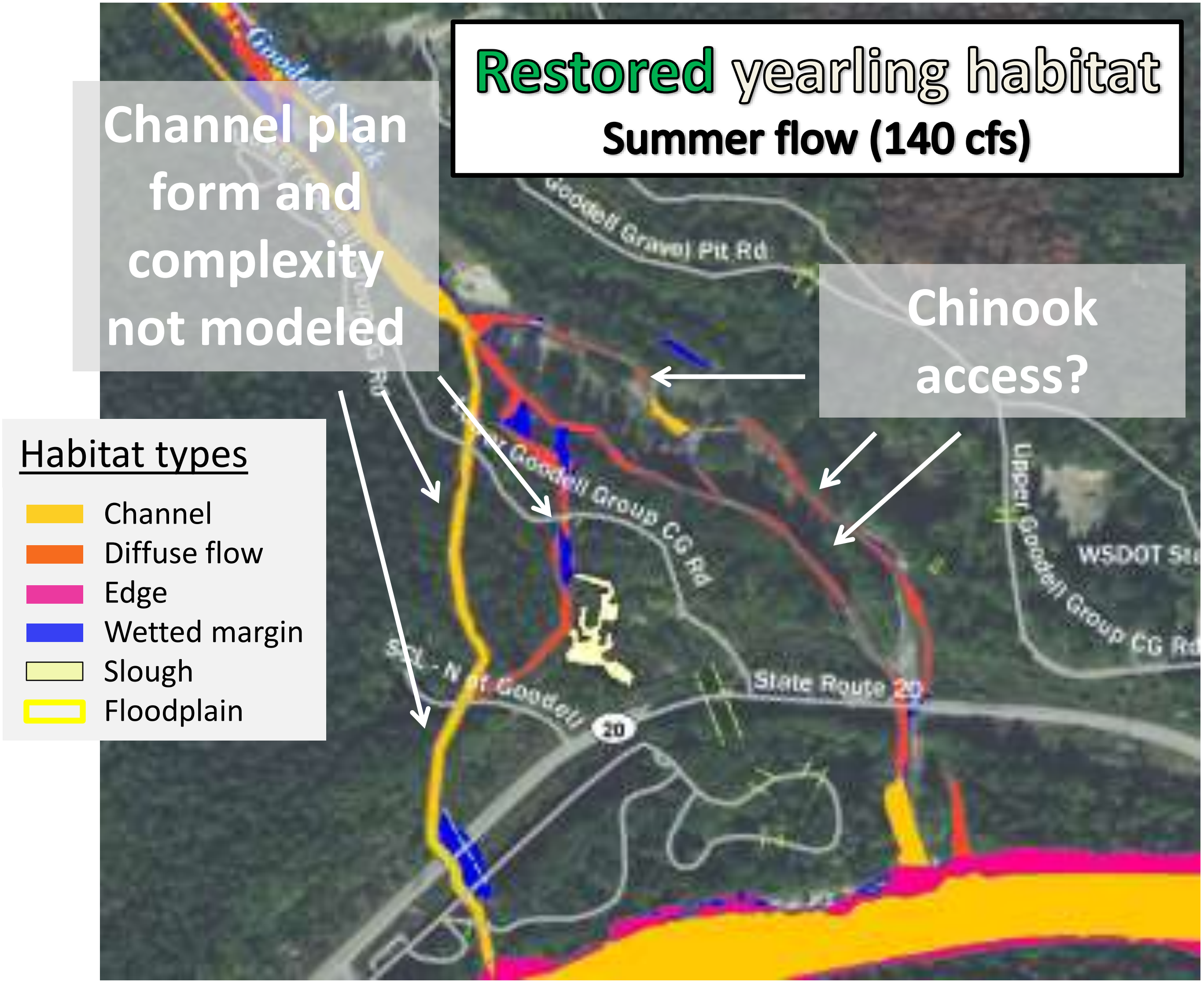
Describing Tributary Habitat

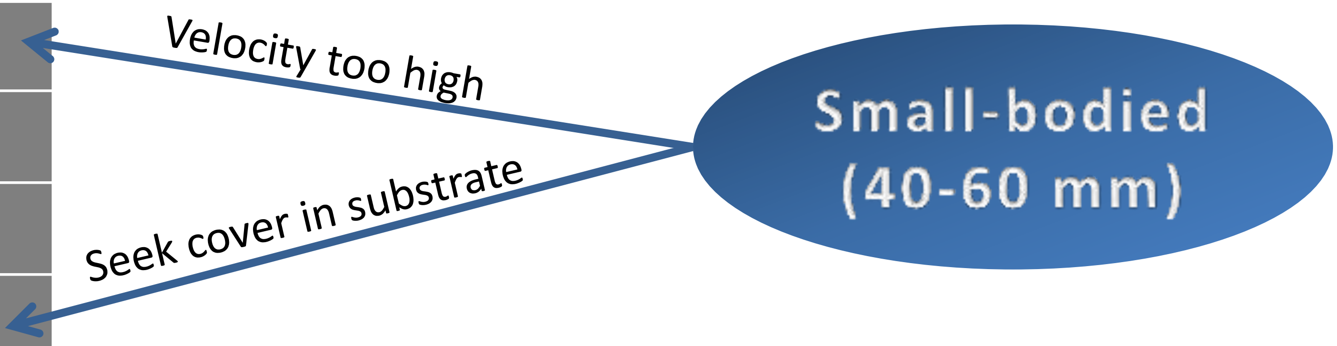


Source: Herrera Environmental Consultants, Inc.

Chinook Habitat Capacity

Parr capacity – spring "frequent flood" (715 cfs)

Habitat type	Density (m^{-2})
Mid-channel	0.000
Edge	0.055
Diffuse flow	0.021
Wetted margin	0.021
Slough	0.086
Floodplain	0.086
Total	**NA**



Chinook Habitat Capacity

Parr capacity – spring “frequent flood” (715 cfs)

Habitat type	Density (m^{-2})	Current area (m^2)	Restored area (m^2)
Mid-channel	0.000	32,861	34,676
Edge	0.055	4,282	5,984
Diffuse flow	0.021	1,365	5,149
Wetted margin	0.021	6,340	10,515
Slough	0.086	1,394	3,175
Floodplain	0.086	0	4,102
Total	**NA**	**46,242**	**63,601**

Largest gains found lateral to channels

Chinook Habitat Capacity

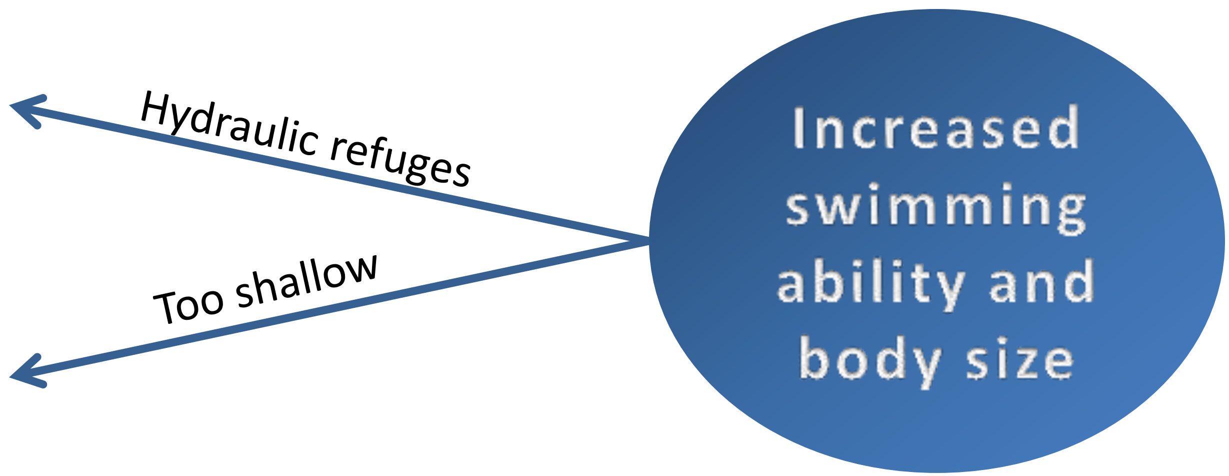
Parr capacity – spring "frequent flood" (715 cfs)

Habitat type	Density (m^{-2})	Current area (m^2)	Restored area (m^2)	Current capacity	Restored capacity
Mid-channel	0.000	32,861	34,676	0	0
Edge	0.055	4,282	5,984	236	329
Diffuse flow	0.021	1,365	5,149	29	108
Wetted margin	0.021	6,340	10,515	133	221
Slough	0.086	1,394	3,175	120	273
Floodplain	0.086	0	4,102	0	353
Total	**NA**	**46,242**	**63,601**	**518**	**1,284**

Chinook Habitat Capacity

Yearling capacity – summer base flow (140 cfs)

Habitat type	Density (m^{-2})
Mid-channel	0.021
Edge	0.088
Diffuse flow	0.046
Wetted margin	0.000
Slough	0.086
Floodplain	NA
Total	**NA**



Chinook Habitat Capacity

Yearling capacity – summer base flow (140 cfs)

Habitat type	Density (m^{-2})	Current area (m^2)	Restored area (m^2)
Mid-channel	0.021	20,353	16,562
Edge	0.088	3,541	2,487
Diffuse flow	0.046	2,251	8,303
Wetted margin	0.000	7,342	9,722
Slough	0.086	0	1,897
Floodplain	NA	0	0
Total	**NA**	**33,487**	**38,971**

Increased channel margin and off-channel area

Chinook Habitat Capacity

Yearling capacity – summer base flow (140 cfs)

Habitat type	Density (m^{-2})	Current area (m^2)	Restored area (m^2)	Current capacity	Restored capacity
Mid-channel	0.021	20,353	16,562	427	348
Edge	0.088	3,541	2,487	312	219
Diffuse flow	0.046	2,251	8,303	104	382
Wetted margin	0.000	7,342	9,722	0	0
Slough	0.086	0	1,897	0	163
Floodplain	NA	0	0	0	0
Total	**NA**	**33,487**	**38,971**	**843**	**1,112**

Chinook Habitat Capacity

Yearling capacity – summer base flow (140 cfs)

Habitat type	De[illegible]	[illegible]	[illegible]tored ar[illegible] (m²)	[illegible]	[illegible]
Mid-channel	[illegible]	[illegible]	6,562	[illegible]	[illegible]
Edge	[illegible]	[illegible]	2,487	[illegible]	[illegible]
Diffuse flow	[illegible]	[illegible]	8,303	[illegible]	382
Wetted margin	0.000	[illegible]	9,722	0	0
Slough	0.086	0	1,897	0	163
Floodplain	NA	0	0	0	0
Total	**NA**	**33,487**	**38,971**	**843**	**1,112**

518 parr inadequate to fill yearling capacity

1,284 parr fill yearling habitat capacity fully

Fry Abundance

Redd density

- Skagit Chinook Recovery Plan
  - Plane-bed channel = 2.7 redds $mile^{-1}$
  - Forced pool-riffle channel = 48 redds $mile^{-1}$

Fry Abundance

Redd density

- Skagit Chinook Recovery Plan
  - Plane-bed channel = 2.7 redds $mile^{-1}$
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Alluvial fan condition	Plane-bed spawning habitat (miles)	Pool-riffle spawning habitat (miles)
Current simplified channel form	1.5	0.1

Small area of braided channels and LWD at fan apex

Fry Abundance

Redd density

- Skagit Chinook Recovery Plan
  - Plane-bed channel = 2.7 redds mile^{-1}
  - Forced pool-riffle channel = 48 redds mile^{-1}

Alluvial fan condition	Plane-bed spawning habitat (miles)	Pool-riffle spawning habitat (miles)
Current simplified channel form	1.5	0.1
Restored channel complexity	1.0	0.6

Naturally steeper and more confined

Reconnect forested floodplain and relic channels

Fry Abundance

Egg-to-fry survival

- Skagit Chinook Recovery Plan
  - Straightened channel lacking LWD = 341 fry $adult^{-1}$

Assume current conditions result in increased redd scour and lack of flood refuge for fry

Fry Abundance

Egg-to-fry survival

- Skagit Chinook Recovery Plan
  - Straightened channel lacking LWD = 341 fry $adult^{-1}$
  - Complex channels with hydraulic refuges = 435 fry $adult^{-1}$

Assume reconnecting forested floodplain and relic channels will increase egg-to-fry survival

Fry Abundance

Combining redd density and egg-to-fry survival to estimate **fry abundance**

Alluvial fan condition	Number of redds	Number of adults	Fry adult^{-1}	Fry abundance
Current **plane-bed** form	8	16	341	**5,456**
Restored **pool-riffle** complexity	31	62	435	**26,970**

5-fold increase

Fry Abundance

Combining redd density and egg-to-fry survival to estimate **fry abundance**

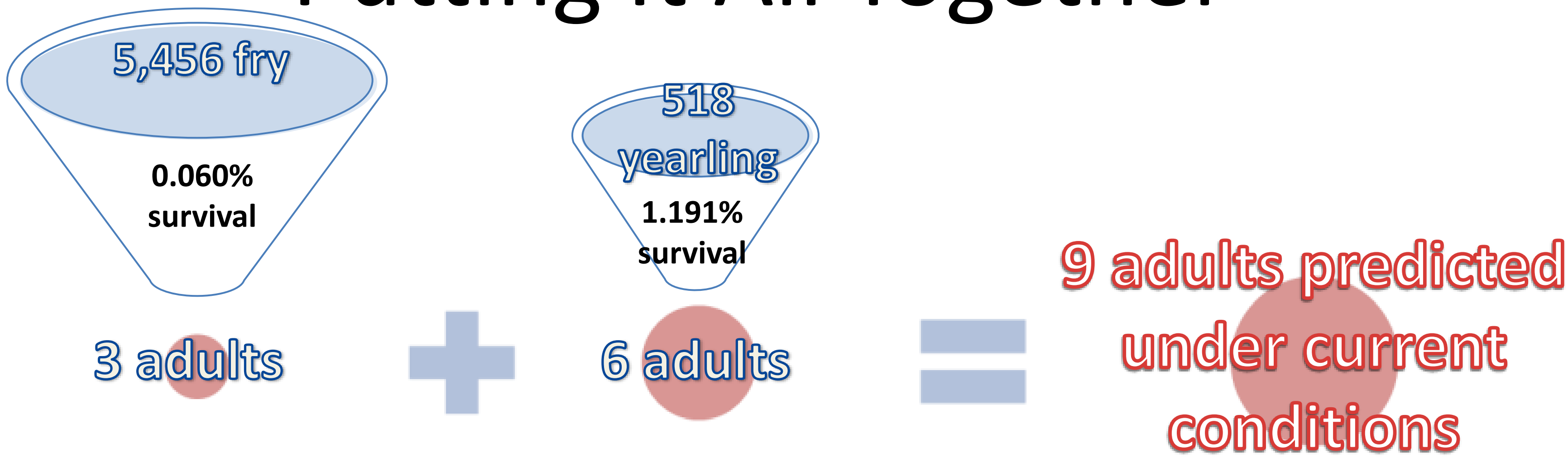
Alluvial fan condition	Number of redds	Number of adults	Fry adult^{-1}	Fry abundance
Current **plane-bed** form	8	16	341	5,456
Restored **pool-riffle** complexity	31	62	435	26,970

Actual redd counts → average 6 per year

Question is:

Can we achieve restoration assumptions?

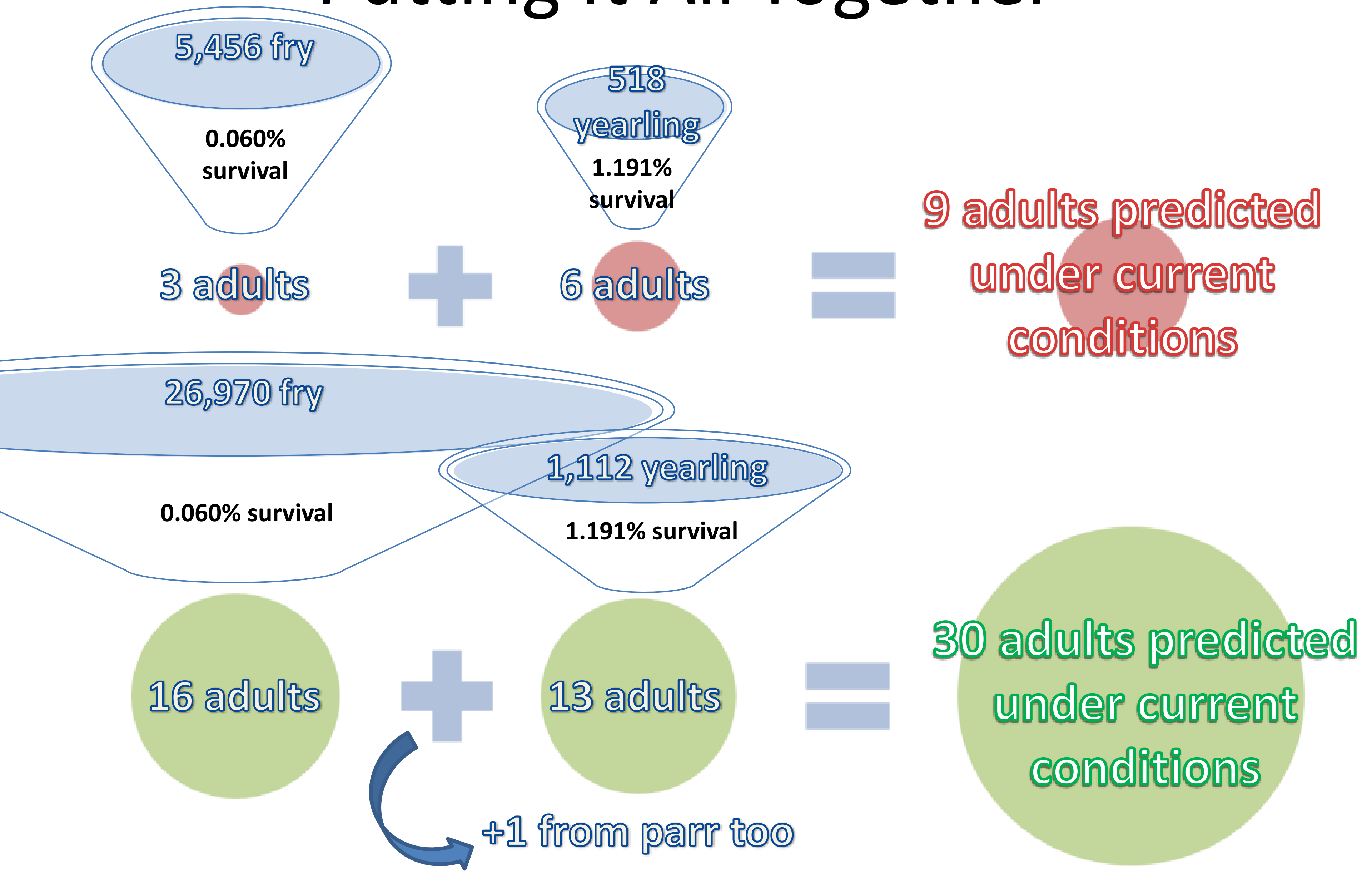
Putting It All Together



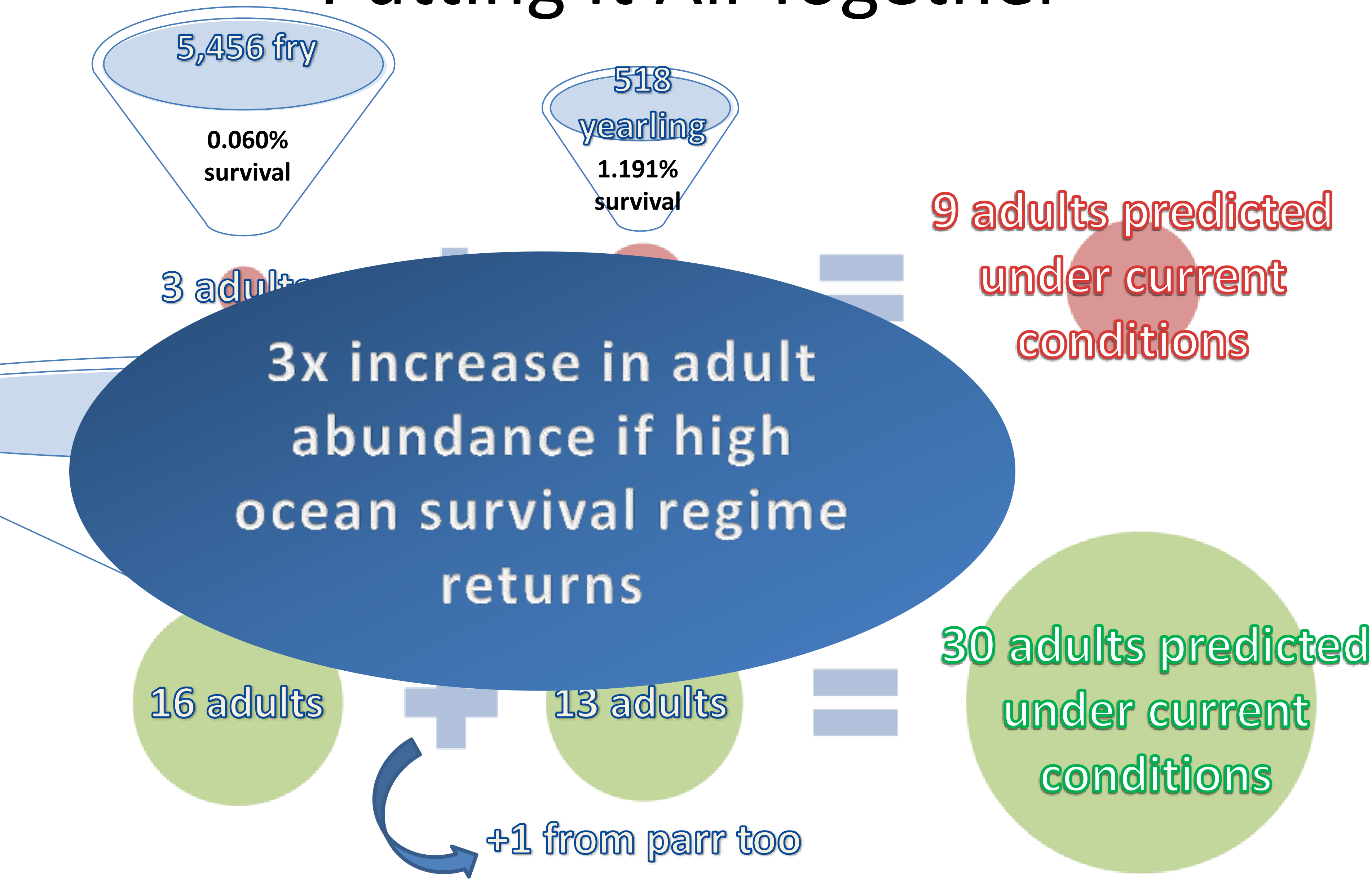
Lost fry production

Yearling habitat degraded, yet still not fully seeded

Putting It All Together



Putting It All Together



Context of Skagit Recovery

Restoring Goodell could achieve (with caveats):

- 0.4% of fry recovery goal
- 1% to 3% of yearling recovery goal
- 0.2% of adult recovery goal

Context of Skagit Recovery

Restoring Goodell could achieve (with caveats):

- 0.4% of fry recovery goal
- 1% to 3% of yearling recovery goal
- 0.2% of adult recovery goal

Percentages may seem small, but consider within context of an ambitious recovery strategy across a large basin with 6 independent populations

Context of Skagit Recovery

- Restoring Goodell could achieve (with caveats):
  - 0.5% of fry recovery goal
  - 1% to 3% of yearling recovery goal
  - 0.2% of adult recovery goal
- NMFS Viable Salmonid Population criteria
  - Spatial structure – upstream spawn extent; large tributary
  - Diversity – yearling life-history; snow-melt hydrology
  - Abundance – redd density; returning adults
  - Productivity – egg-to-fry survival; rearing habitat capacity

Acknowledgements

Partner Organizations

NATIONAL PARK SERVICE

North Cascades National Park Complex

WSDOT

Seattle City Light

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WASHINGTON STATE Recreation and Conservation Office

Salmon Recovery Funding Board,
Puget Sound Acquisition and Restoration Fund

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

National Estuary Program
(PA-01J01601)

Goodell Creek Feasibility Study

(Herrera 2017)

– Contact Rick Hartson, Upper Skagit Indian Tribe
  - rickh@upperskagit.com

– Download from WA RCO website
  - PRISM project search → project number 15-1174