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RESEARCH ARTICLE

WILEY

Evolution of tributary junctions and their capacity for rearing juvenile Chinook salmon (*Oncorhynchus tshawytscha*) on a regulated river

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Abstract

The Trinity River in northern California was adjusting to unregulated flood and mining impacts when it was dammed and flow regulation began in 1960. We examine the subsequent evolution of the river's alluvial channel through 60 years of increases in regulated mainstem flow regimes in an unconfined and confined valley where Rush and Indian creeks respectively join the river 6.9 and 26.7 river kilometres from Lewiston Dam. The resulting capacity of the tributary junctions for rearing Chinook salmon fry in the current flow regime is evaluated with an empirical model developed for the Trinity River. Results indicate that morphologic changes at Indian Creek were relatively minor after damming because mainstem flows were restricted to a narrow channel in comparison to the channel at Rush Creek. Conversely, active channel and bar areas significantly declined at Rush Creek because the mainstem sediment supply was more severely reduced by flow regulation that enabled riparian vegetation to colonize the expansive alluvial surfaces that were present. These changes reduced instream habitat, suggesting salmon populations in large valleys may be at higher risk below dams than in smaller valleys where the reduced flow is confined to an already narrow channel. However, the relatively wide and unconfined valley responded more positively to increases in flow and sediment through the regulatory periods to yield significantly higher capacities for rearing Chinook fry. Therefore, while unconfined reaches may be particularly susceptible to change when a river is dammed, they may also provide the greatest opportunity for restoration of salmon populations.

KEYWORDS
channel morphology, Chinook salmon, flow regulation, river restoration, sediment transport, tributary junction

1 | INTRODUCTION

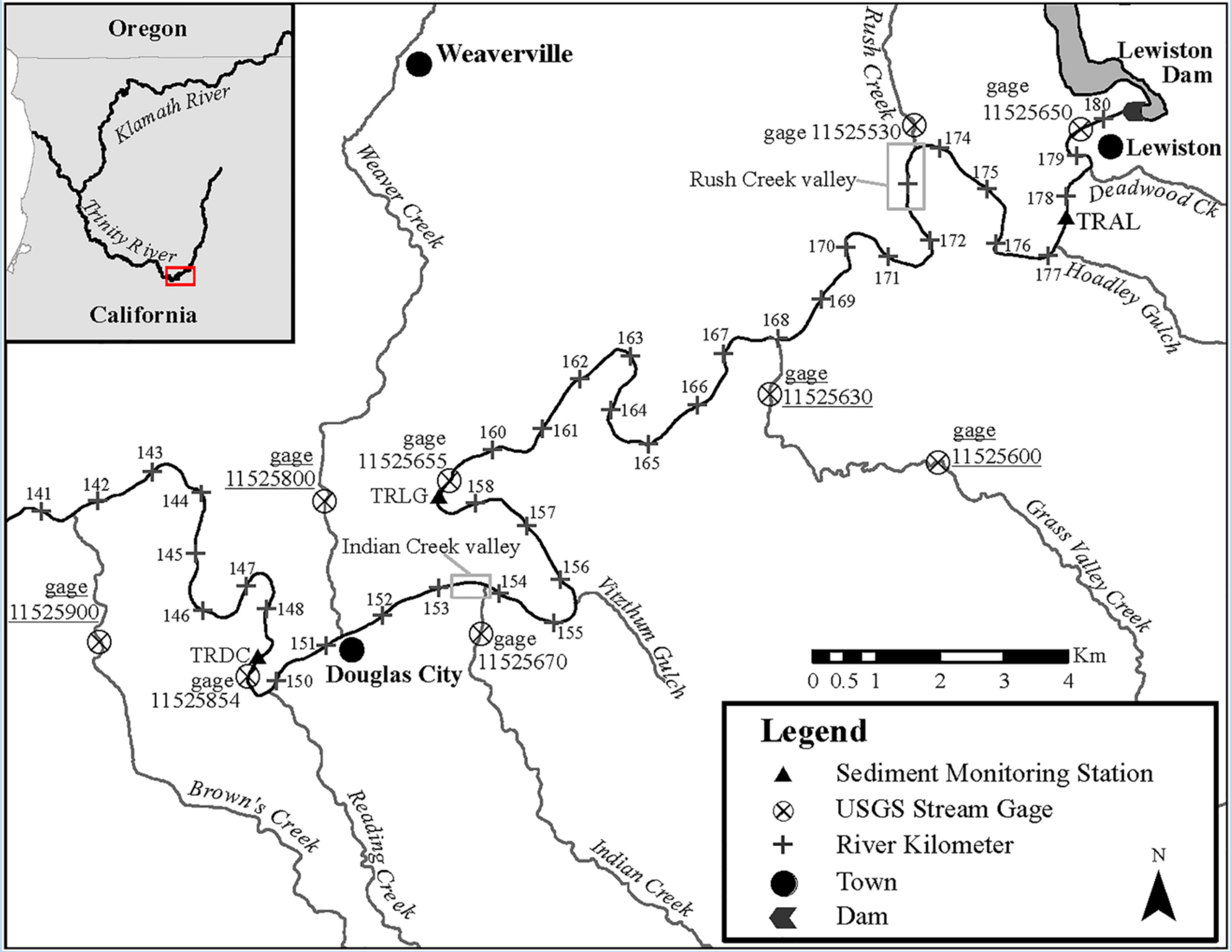
Some of the most biologically active and physically dynamic and complex areas on alluvial rivers occur where tributary streams enter mainstem channels. The dynamics result from abrupt changes in streamflow, sediment supply and grain size by tributary inputs that can alter pathways for flow and sediment transport through the junction (Best, 1988; Imhoff & Wilcox, 2016; Rice et al., 2006). These inputs often result in mainstem adjustments that can include local increases in sediment calibre and downstream channel slope (Rice 1998; Benda et al., 2003), alluvial fan and bar aggradation and erosion (Leenman & Tunnicliffe, 2020), bank retreat and floodplain formation varying channel width and alternating destruction and creation of aquatic habitats, including shear zones, low velocity areas and alcoves.

Evolution of tributary junctions (Rush and Indian Creeks) and their capacity for rearing juvenile Chinook Salmon

Why are tributary junctions important?

- Some of the most biologically active and physically dynamic and complex areas on a river.
- Dynamics result from abrupt changes in flow, grain size, and sediment, wood, and nutrient supplies by tributary inputs.
- River adjustments include changes in channel slope, alluvial fan and bar formation, bank retreat, floodplain formation, and habitat creation (shear zones, alcoves, etc.).
- Habitat complexity and delivery of nutrients and organisms by creeks leads junction areas to be considered biological hotspots for their outsized influence on aquatic productivity.

Study areas


Oregon
Klamath River
Trinity River
California
Weaverville
Weaver Creek
Rush Creek
Lewiston Dam
gage 11525650
Lewiston
gage 11525530
Rush Creek valley
Deadwood Ck
TRAL
Hoadley Gulch
gage 11525630
gage 11525600
Grass Valley Creek
gage 11525800
gage 11525655
TRLG
Indian Creek valley
Vitzthum Gulch
gage 11525900
TRDC
gage 11525854
Douglas City
gage 11525670
Brown's Creek
Reading Creek
Indian Creek
141
142
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174
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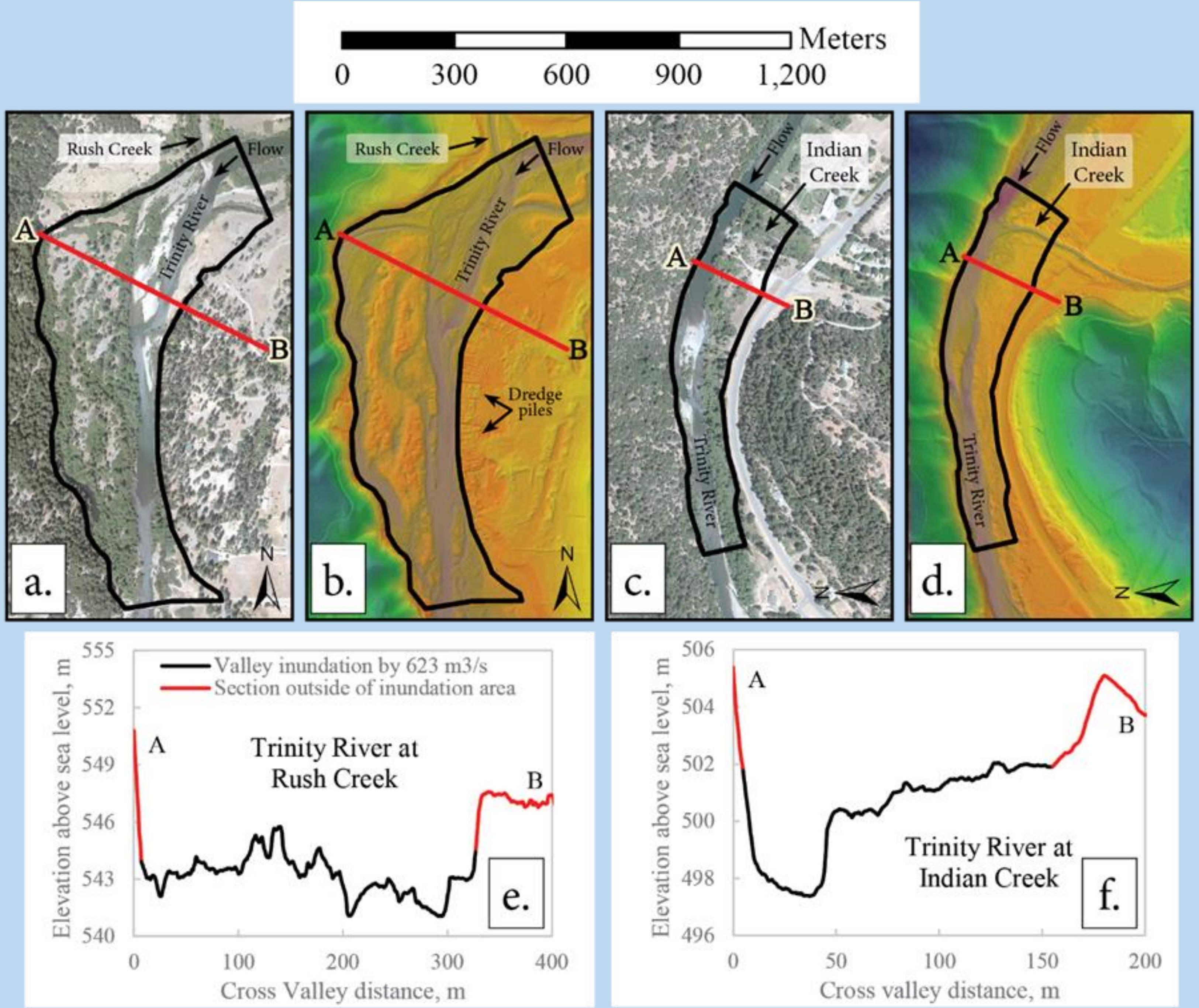
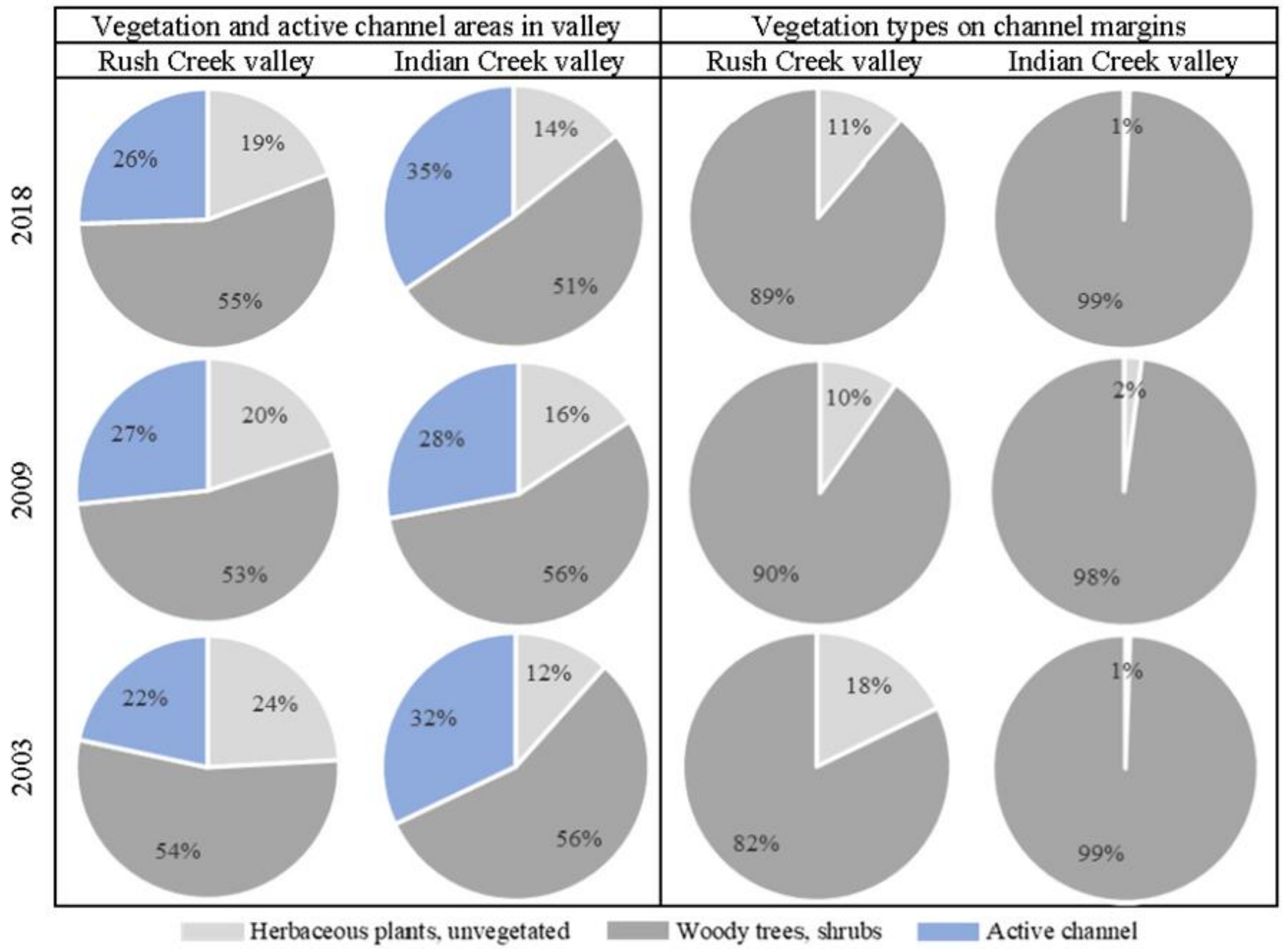
177
178
179
180
0 0.5 1 2 3 4 Km
Legend
Sediment Monitoring Station
USGS Stream Gage
River Kilometer
Town
Dam
N

Study areas

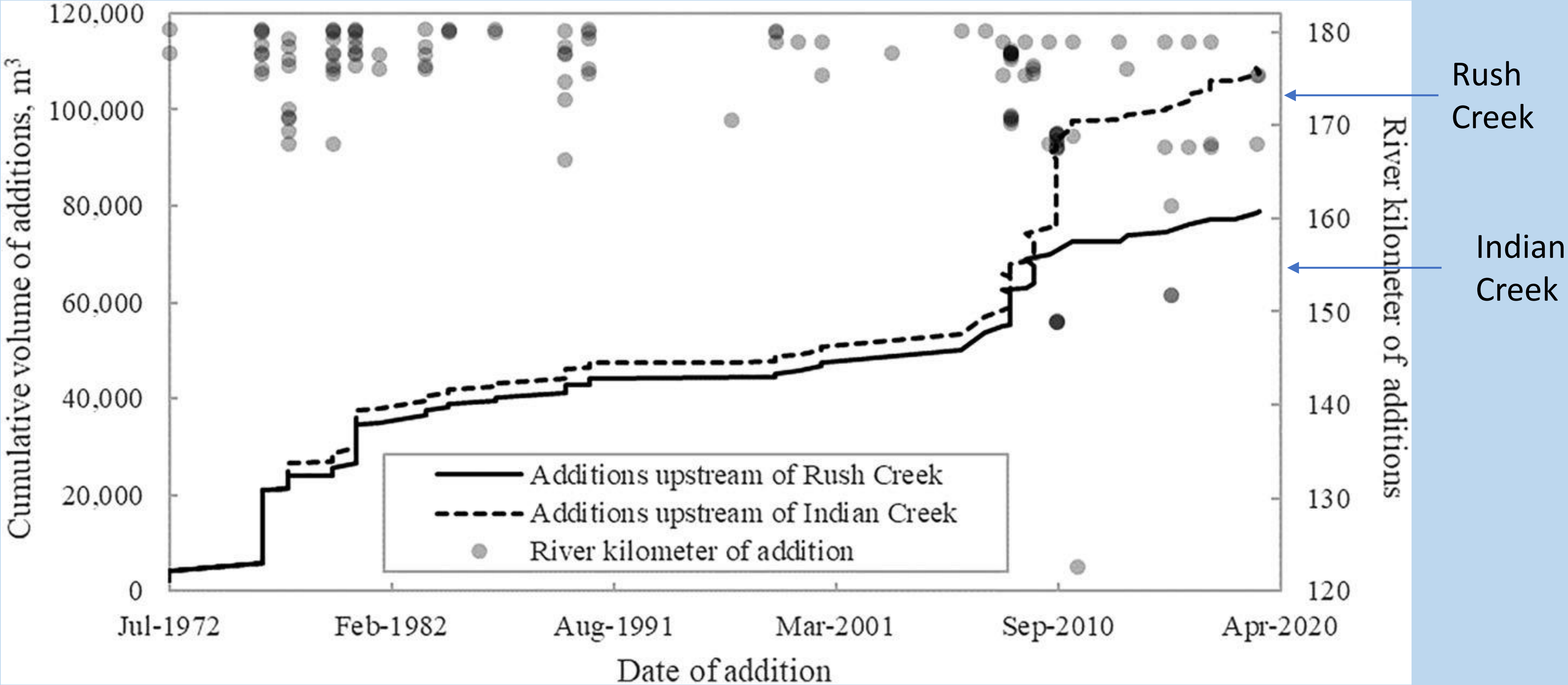


0
300
600
900
1,200
Meters
Rush Creek
Flow
Trinity River
A
B
a.
N
b.
Dredge piles
Flow
Indian Creek
c.
d.
Valley inundation by 623 m3/s
Section outside of inundation area
Trinity River at Rush Creek
Elevation above sea level, m
Cross Valley distance, m
e.
Trinity River at Indian Creek
Cross valley distance, m
f.

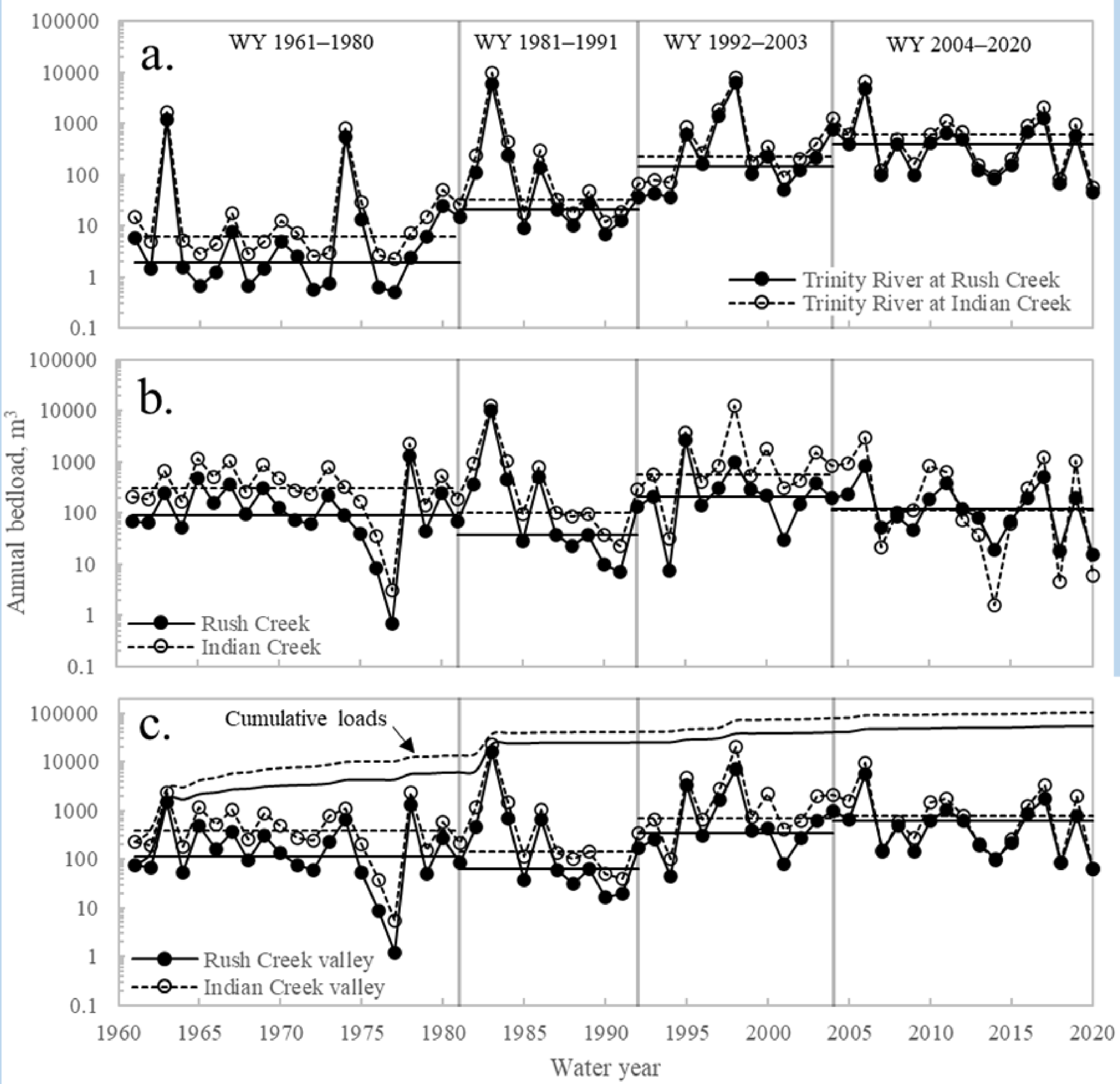
Riparian vegetation



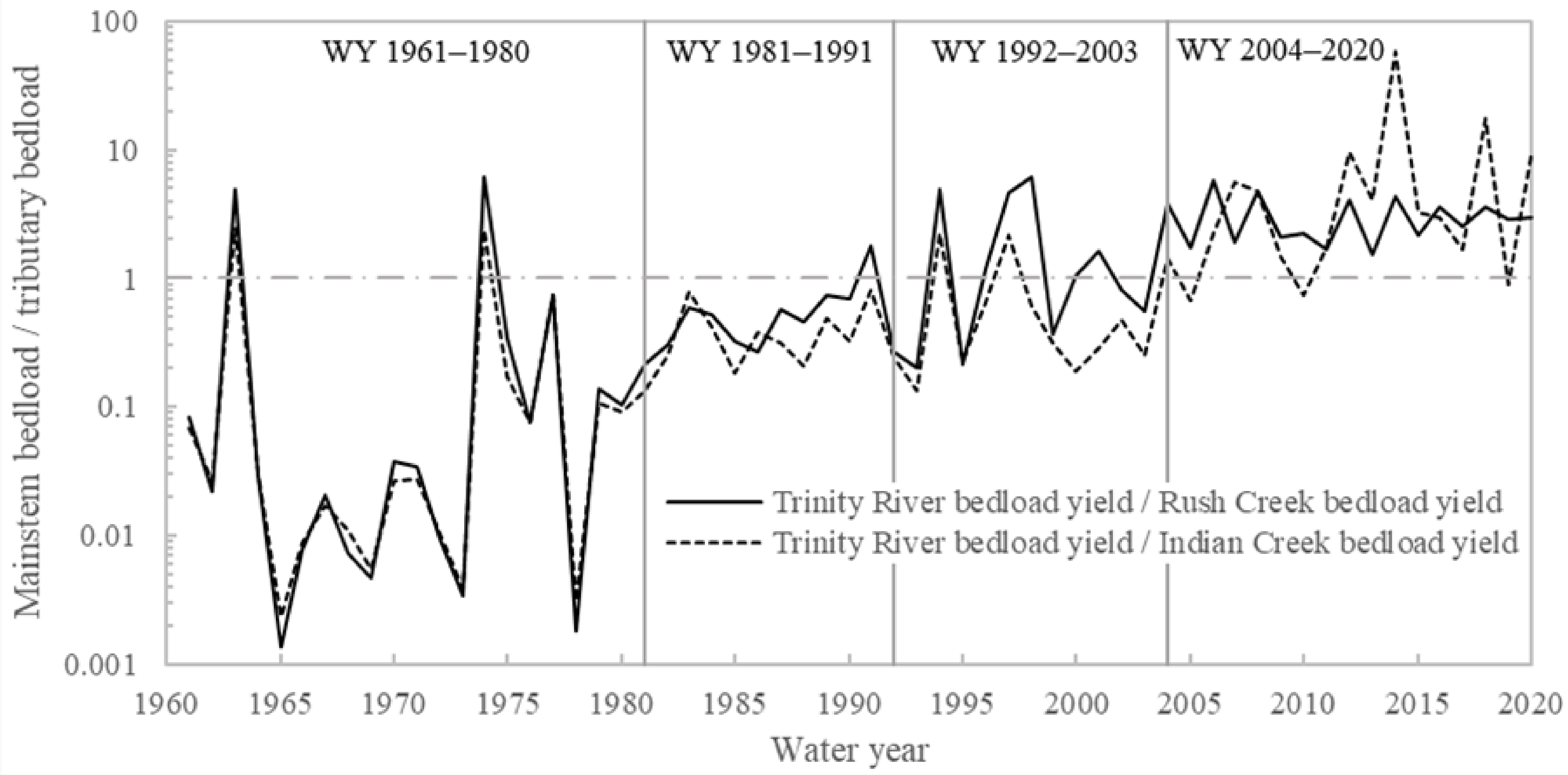
Sediment augmentations



Sediment supply



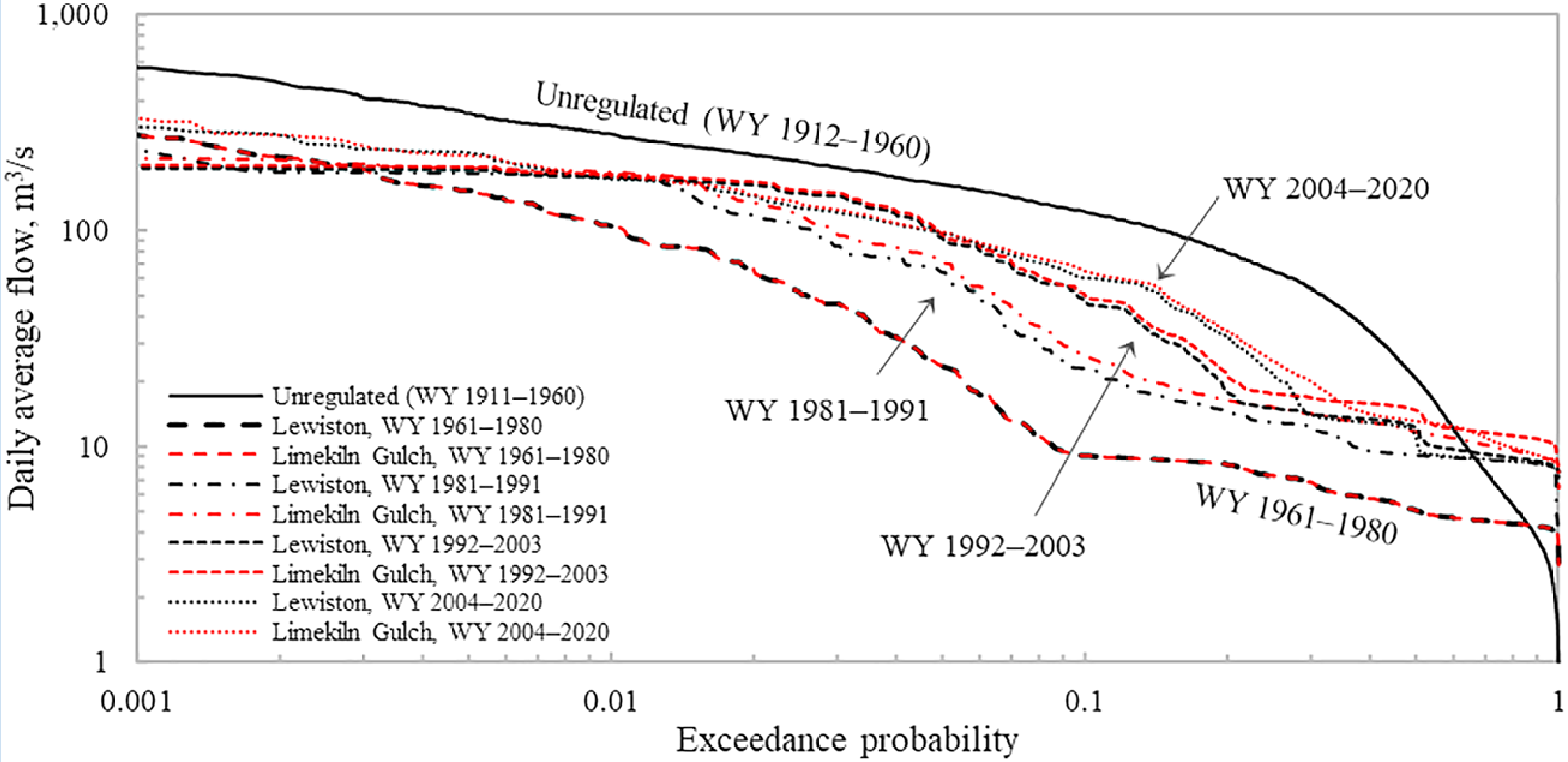
Sediment supply



Flow regulation

Water year	Average annual flood (m^3/s)[1]	Minimum annual flood (m^3/s)[1]	Maximum annual flood (m^3/s)[1]	Authorized annual water volume (ha-m/yr)	Observed average annual water volume (ha-m/yr)	Authorizations
1912–1960	525	87	2,028	—	146,601	—
1961–1980	72	8	184	14,858	29.637	1955 Trinity Division Act
1981–1991	97	18	249	17,262 to 41,922	53,312	1981 Secretarial Decision
1992–2003	135	46	200	>41,922	71,441	1992 Central Valley Project Improvement Act
2004–2020	209	58	348	48,498 to 100,490[2]	76,444	Record of Decision (ROD, 2000)

Flow regulation



Tributary junction responses

Water year	Average annual flood (m^3/s)[1]	Minimum annual flood (m^3/s)[1]	Maximum annual flood (m^3/s)[1]	Authorized annual water volume (ha-m/yr)	Observed average annual water volume (ha-m/yr)	Authorizations
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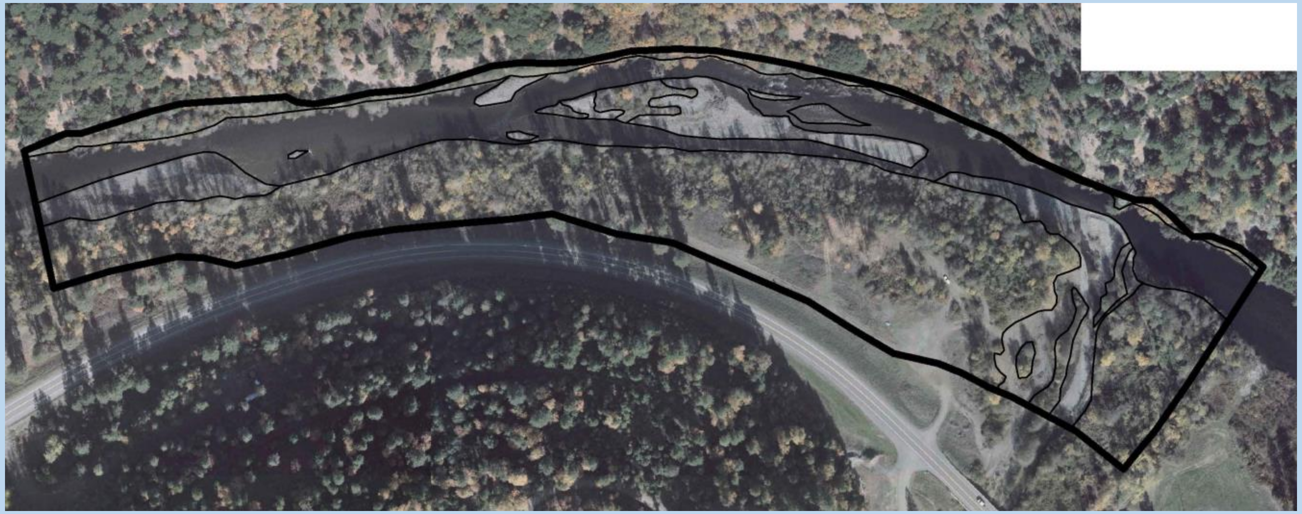
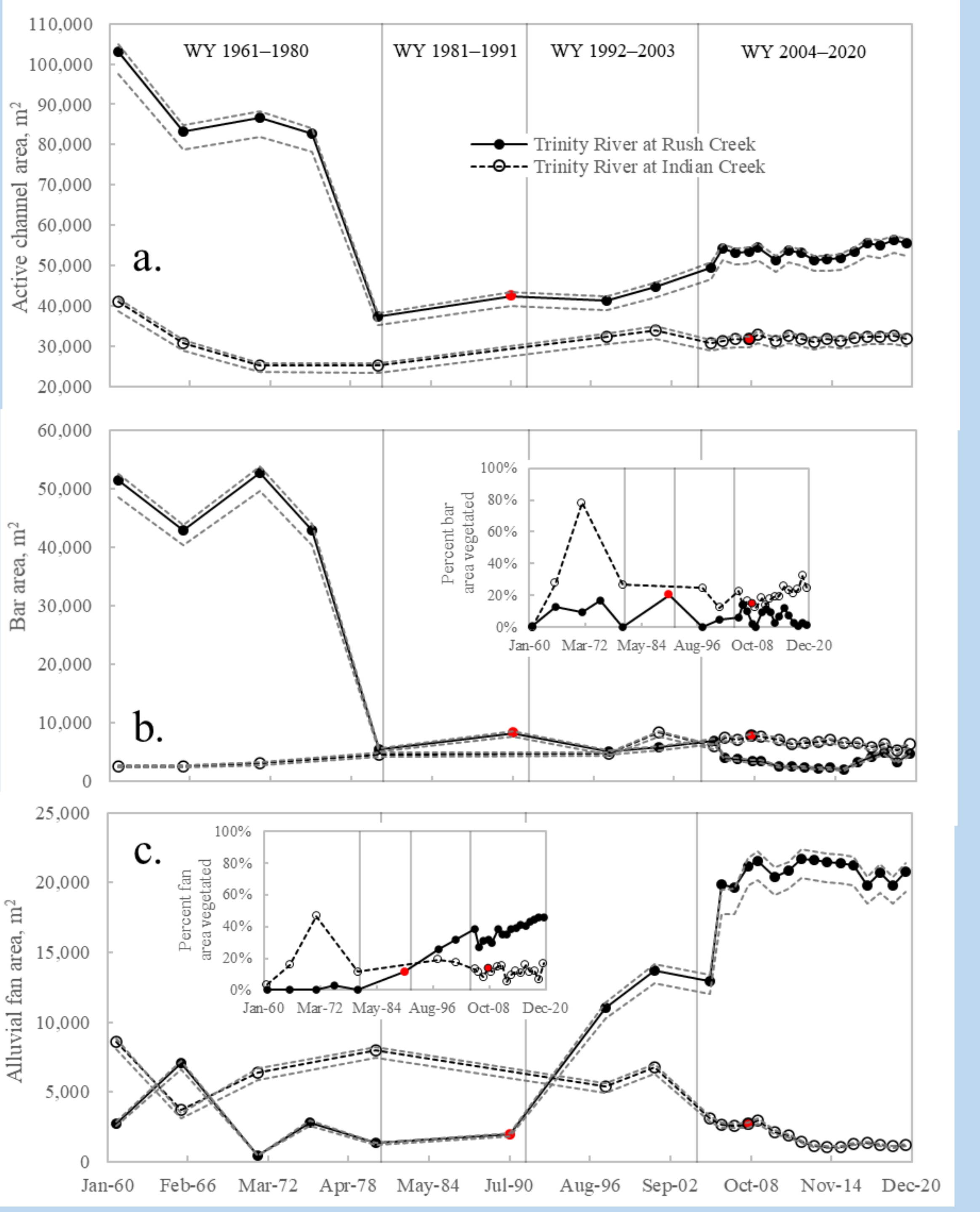
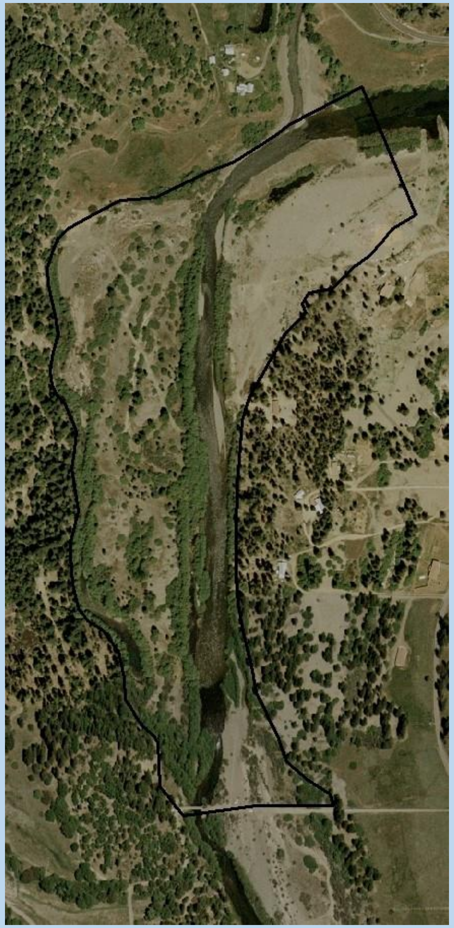


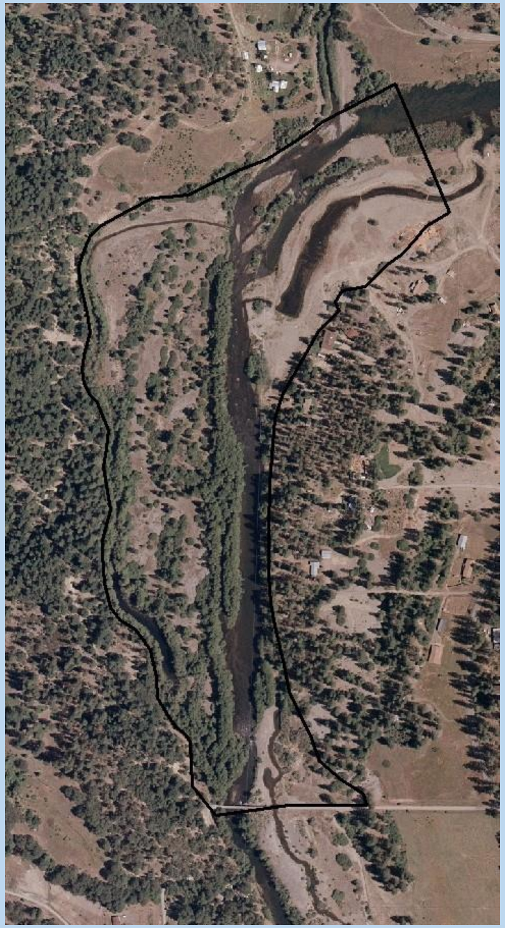


Rush Creek confluence

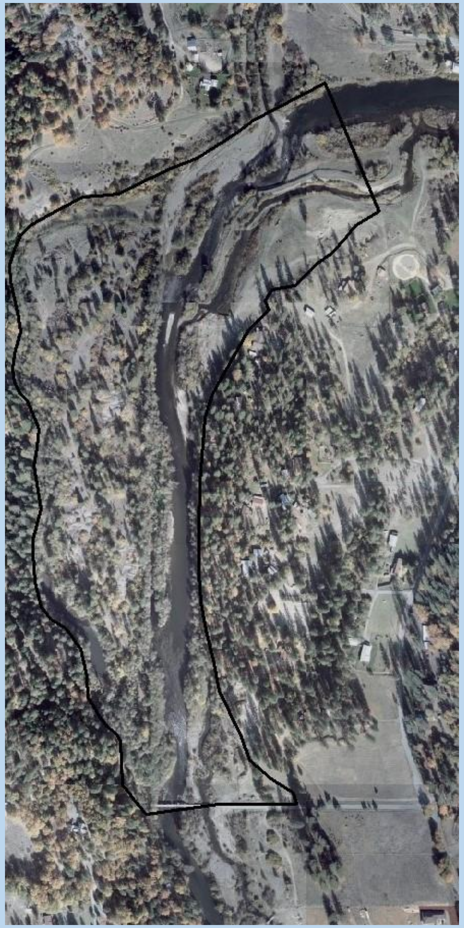
1960



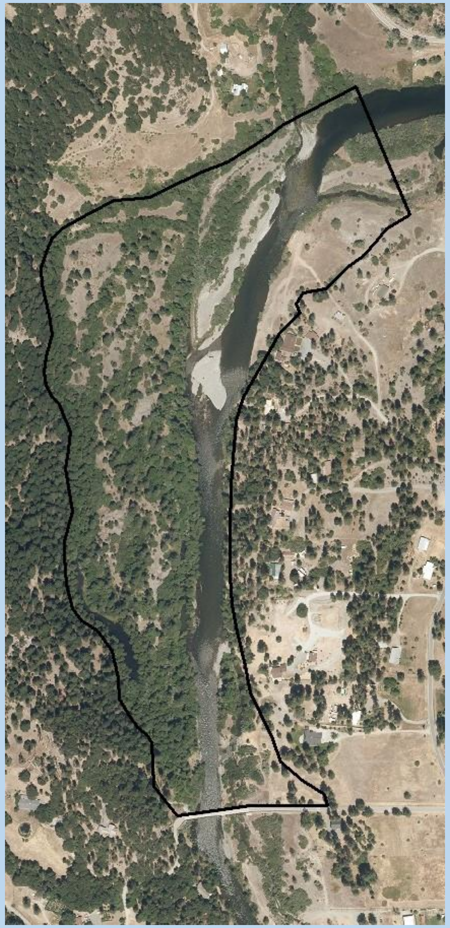
1980



1990



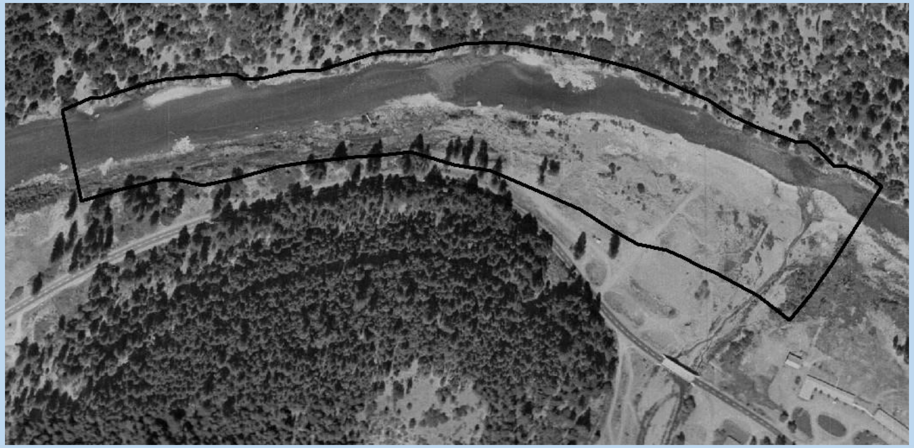
2001



2020

Indian Creek confluence

1960

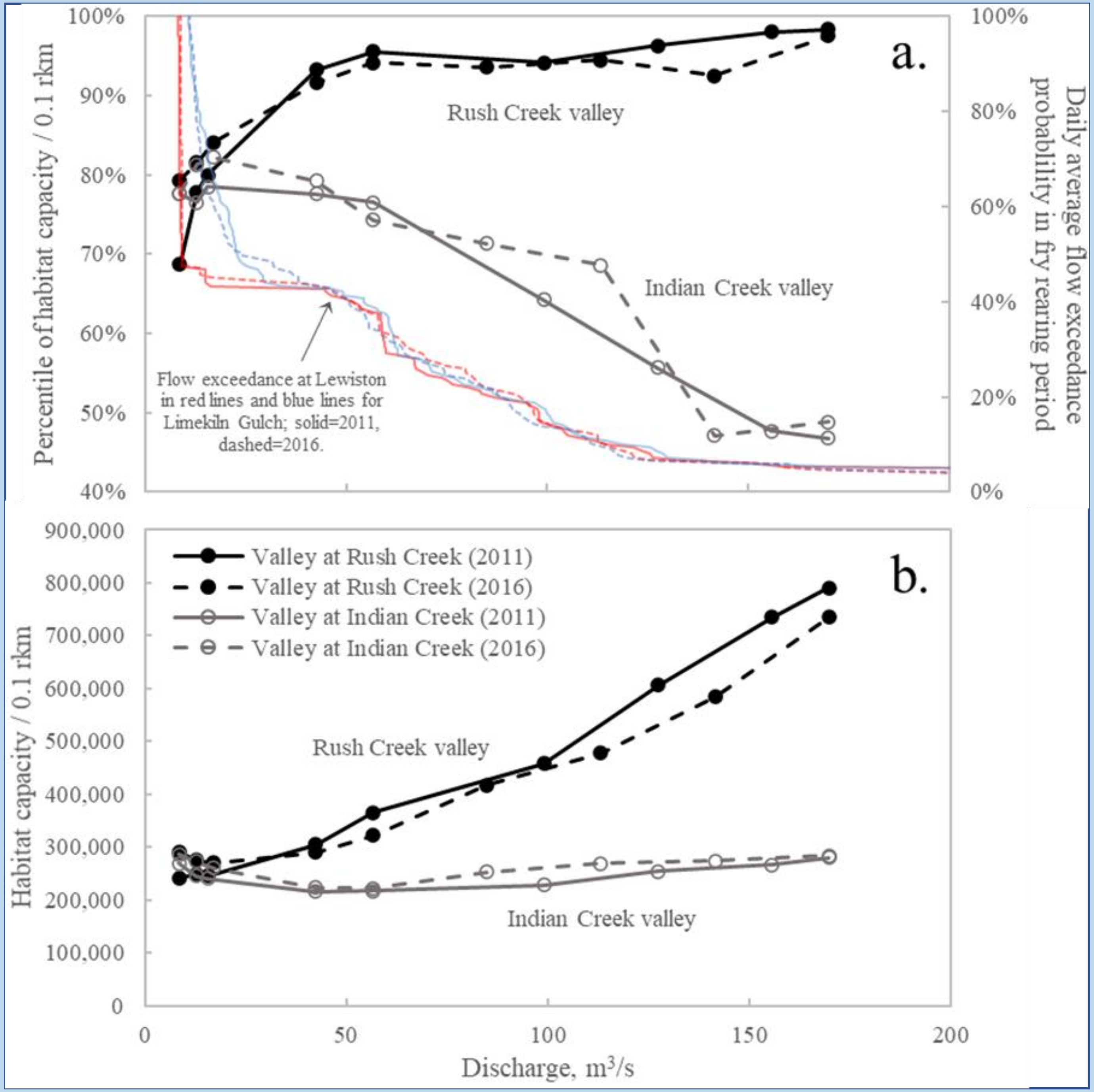


1980

2005

2020

Chinook fry rearing capacity



Major findings

- Wide valleys (Rush Creek) are more affected by flow regulation than narrow valleys (Indian Creek) but recover quicker and display a higher capacity for rearing juvenile Chinook with increases in flow and sediment supply.
  - Restoration should occur in wide valleys first to increase rearing capacity quickest.
- Valley confinement is the primary factor determining the response of tributary junctions to changes in flow regime and sediment supply. Riparian vegetation modulates these effects.
- A wandering mainstem channel constructed at Rush Creek in 1989 increased channel roughness that accelerated fan and bar growth, enabled vegetation patches to form and expand depositional features that was accommodated by erosion of the opposite bank.
- Vegetation removal and channel widening at Indian Creek in 2007 enabled sediment deposition, bar growth, and further widening to accommodate the bar, which continues to expand, increase channel complexity, and provide fish habitat in this otherwise relatively simple reach.