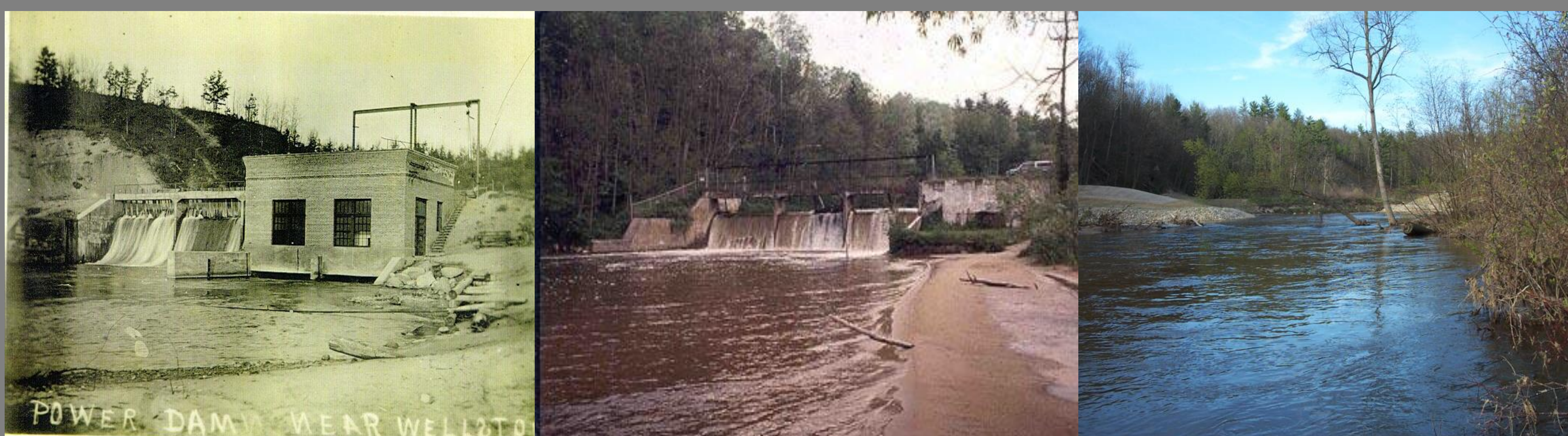
Dam Removal Overview

Modified from a presentation for the

Mio Dam Local Prosperity Group Mtg #2

Bryan Burroughs, Ph.D.
Michigan Trout Unlimited



Presenter Background

- Dr. Bryan Burroughs, Executive Director, Michigan Trout Unlimited
- M.S & Ph.D. Degrees Mich. State- Fisheries & Wildlife – on Dam Removal
- ~25 years working on Michigan Dams & Dam Removal Issues
  - Heinz Center Dialogues (Books on Dam Removal (early 2000's))
  - Stronach Dam Removal Study – publications
  - Boardman River Dams – Feasibility Studies Consultant
  - Golden Lotus – Pigeon R. Dam Removal
  - Involved with ~2 dozen Michigan Dam Removals now
  - MI Dam Safety Taskforce Appointee
  - MI Hydro Relicensing Coalition - Steering Committee
  - Consumer's Dams – MMAC Settlement Agreement participant

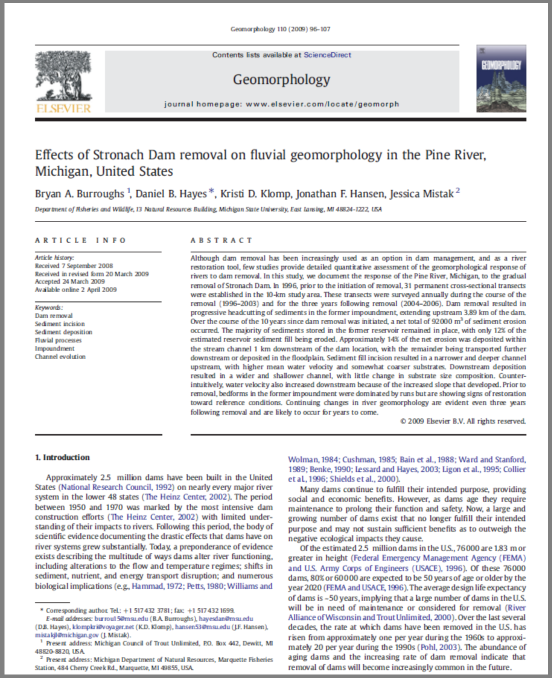
NEWS

Dam task force report: State is heading toward grave situation

Board submits 86 recommendations to Whitmer

Midland Daily News

Feb. 26, 2021



Geomorphology 110 (2009) 96–107

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Effects of Stronach Dam removal on fluvial geomorphology in the Pine River, Michigan, United States

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ARTICLE INFO

Article history:
Received 7 September 2008
Received in revised form 20 March 2009
Accepted 24 March 2009
Available online 2 April 2009

Keywords:
Dam removal
Sediment incision
Sediment deposition
Fluvial processes
Impoundment
Channel evolution

ABSTRACT

Although dam removal has been increasingly used as an option in dam management, and as a river restoration tool, few studies provide detailed quantitative assessment of the geomorphological response of rivers to dam removal. In this study, we document the response of the Pine River, Michigan, to the gradual removal of Stronach Dam. In 1996, prior to the initiation of removal, 31 permanent cross-sectional transects were established in the 10-km study area. These transects were surveyed annually during the course of the removal (1996–2003) and for the three years following removal (2004–2006). Dam removal resulted in progressive headcutting of sediments in the former impoundment, extending upstream 3.89 km of the dam. Over the course of the 10 years since dam removal was initiated, a net total of 92000 m^3 of sediment erosion occurred. The majority of sediments stored in the former reservoir remained in place, with only 12% of the estimated reservoir sediment fill being eroded. Approximately 14% of the net erosion was deposited within the stream channel 1 km downstream of the dam location, with the remainder being transported further downstream or deposited in the floodplain. Sediment fill incision resulted in a narrower and deeper channel upstream, with higher mean water velocity and somewhat coarser substrates. Downstream deposition resulted in a wider and shallower channel, with little change in substrate size composition. Counter-intuitively, water velocity also increased downstream because of the increased slope that developed. Prior to removal, bedforms in the former impoundment were dominated by runs but are showing signs of restoration toward reference conditions. Continuing changes in river geomorphology are evident even three years following removal and are likely to occur for years to come.

1. Introduction

Approximately 2.5 million dams have been built in the United States (National Research Council, 1992) on nearly every major river system in the lower 48 states (The Heinz Center, 2002). The period between 1950 and 1970 was marked by the most intensive dam construction efforts (The Heinz Center, 2002) with limited understanding of their impacts to rivers. Following this period, the body of scientific evidence documenting the drastic effects that dams have on river systems grew substantially. Today, a preponderance of evidence exists describing the multitude of ways dams alter river functioning, including alterations to the flow and temperature regimes; shifts in sediment, nutrient, and energy transport disruption; and numerous biological implications (e.g., Hammad, 1972; Petts, 1980; Williams and Wolman, 1984; Cushman, 1985; Bain et al., 1988; Ward and Stanford, 1989; Benke, 1990; Lessard and Hayes, 2003; Ligon et al., 1995; Collier et al., 1996; Shields et al., 2000).

Many dams continue to fulfill their intended purpose, providing social and economic benefits. However, as dams age they require maintenance to prolong their function and safety. Now, a large and growing number of dams exist that no longer fulfill their intended purpose and may not sustain sufficient benefits as to outweigh the negative ecological impacts they cause.

Of the estimated 2.5 million dams in the U.S., 76000 are 1.83 m or greater in height (Federal Emergency Management Agency (FEMA) and U.S. Army Corps of Engineers (USACE), 1996). Of these 76000 dams, 80% or 60000 are expected to be 50 years of age or older by the year 2020 (FEMA and USACE, 1996). The average design life expectancy of dams is ~50 years, implying that a large number of dams in the U.S. will be in need of maintenance or considered for removal (River Alliance of Wisconsin and Trout Unlimited, 2000). Over the last several decades, the rate at which dams have been removed in the U.S. has risen from approximately one per year during the 1960s to approximately 20 per year during the 1990s (Pohl, 2003). The abundance of aging dams and the increasing rate of dam removal indicate that removal of dams will become increasingly common in the future.

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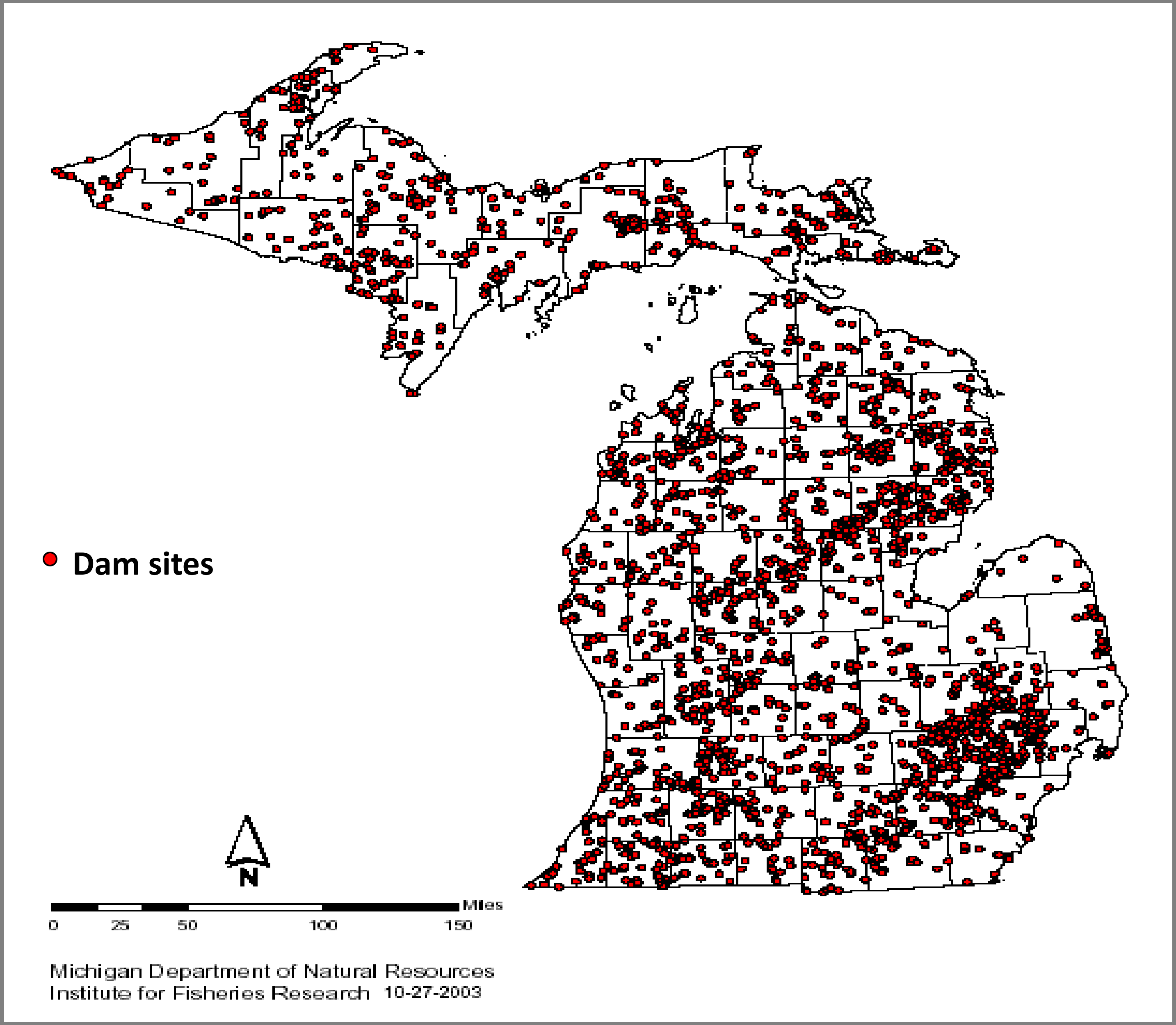
Dams

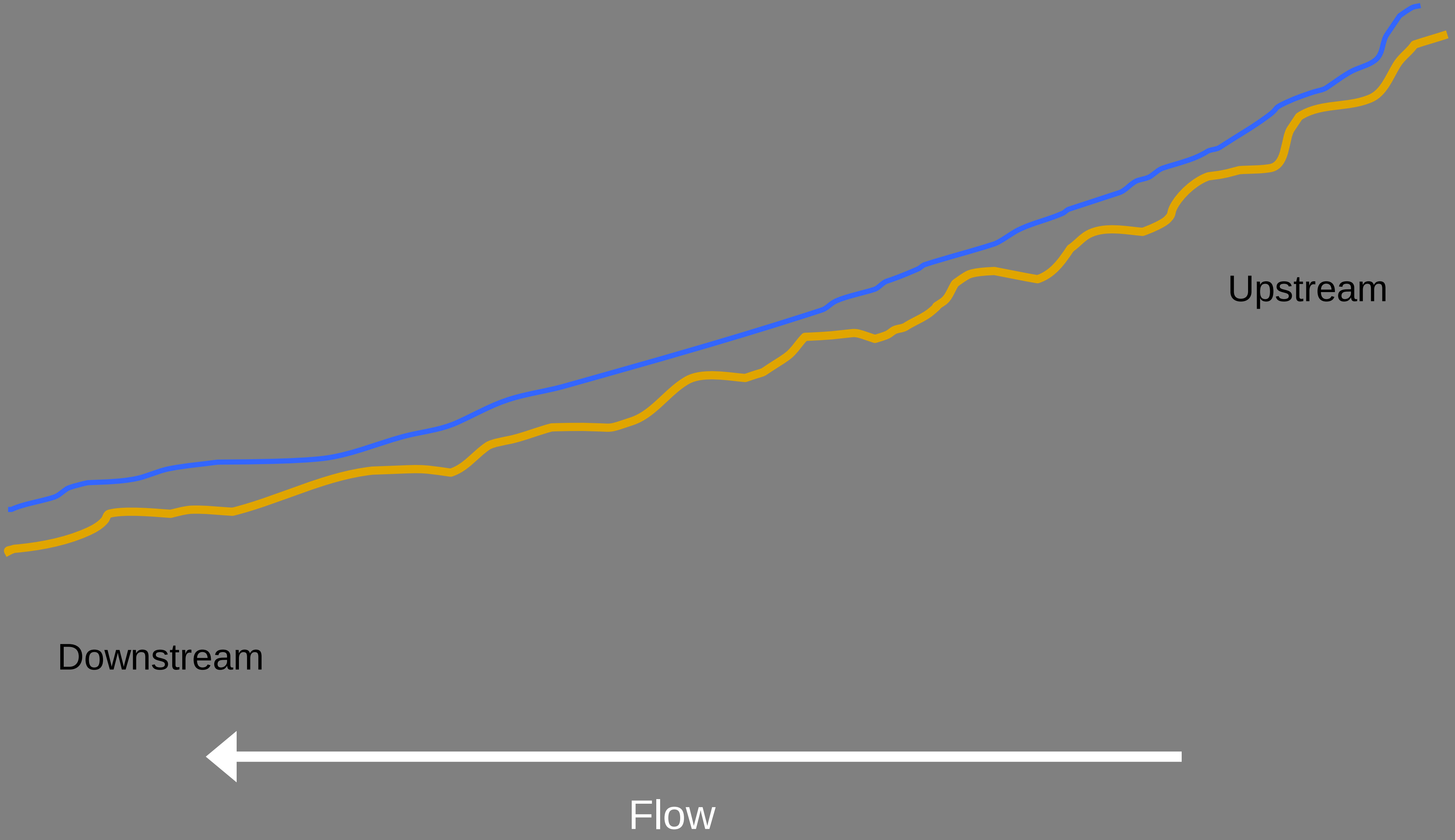
- What: structures that hold back water on rivers/streams
- Why: recreation, fire & farm ponds, flood control, drinking water supply, irrigation, mining waste containment, mechanical and hydroelectric energy generation, navigation and wildlife management
- Where: nearly every major and minor river system in lower 48 states has at least one
- How Many: ~2.5 million dams in the U.S.
  ~76,000 which are >6 ft. tall
  ~3,000 minimum in Michigan
  …and many more undocumented…

Documented Michigan Dams

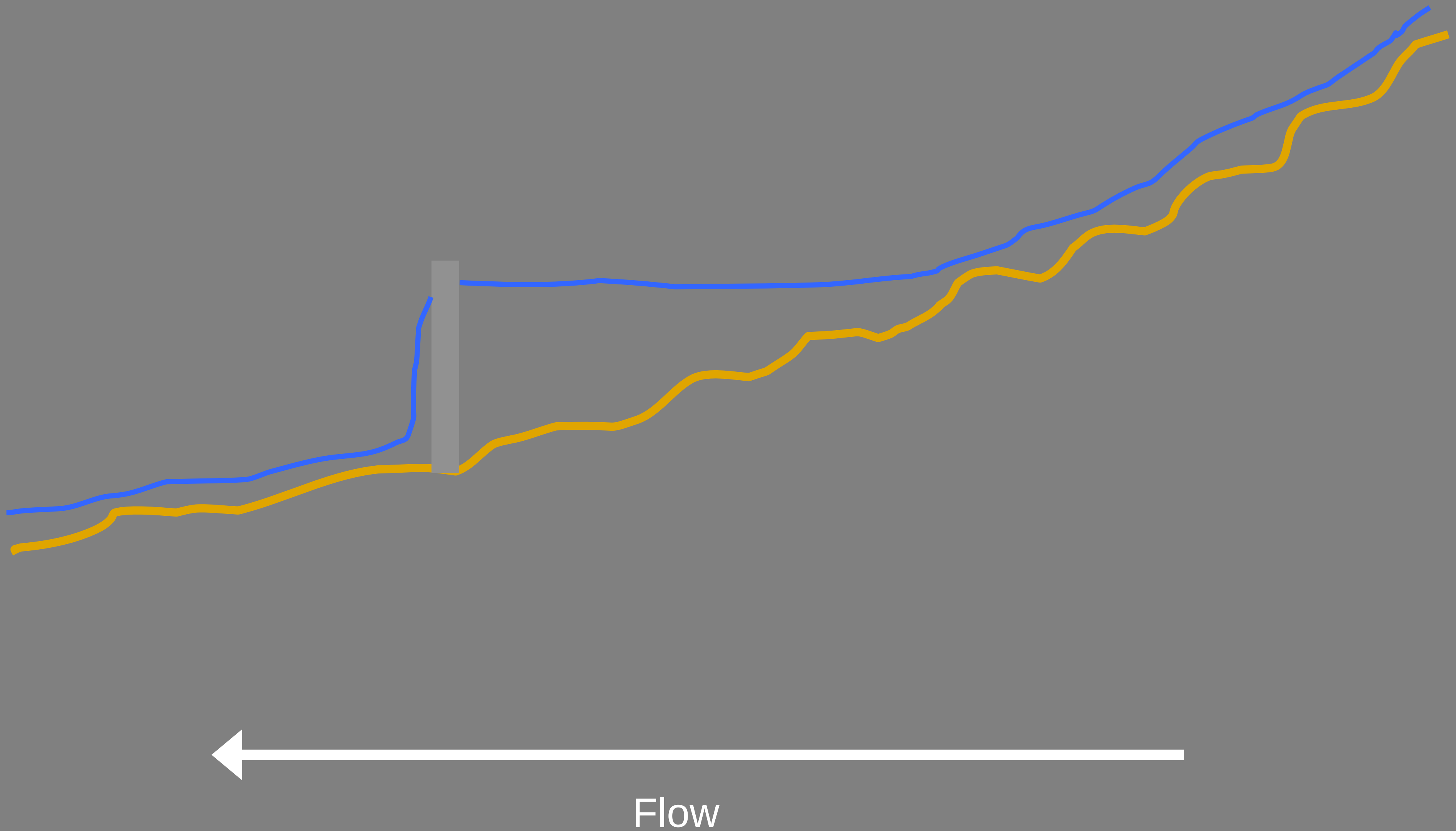


Dams:
What they do to rivers

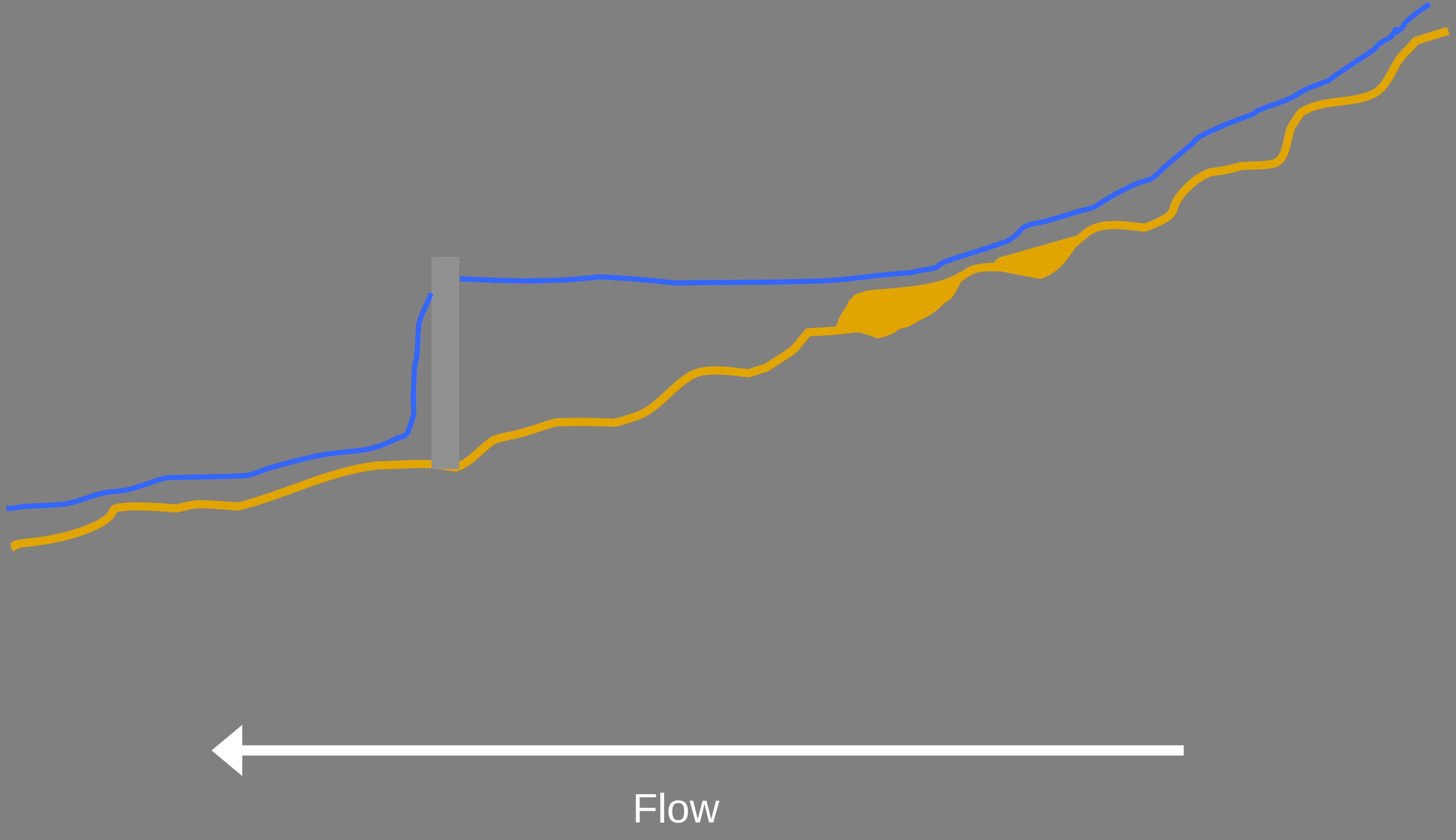
Pre-Dam



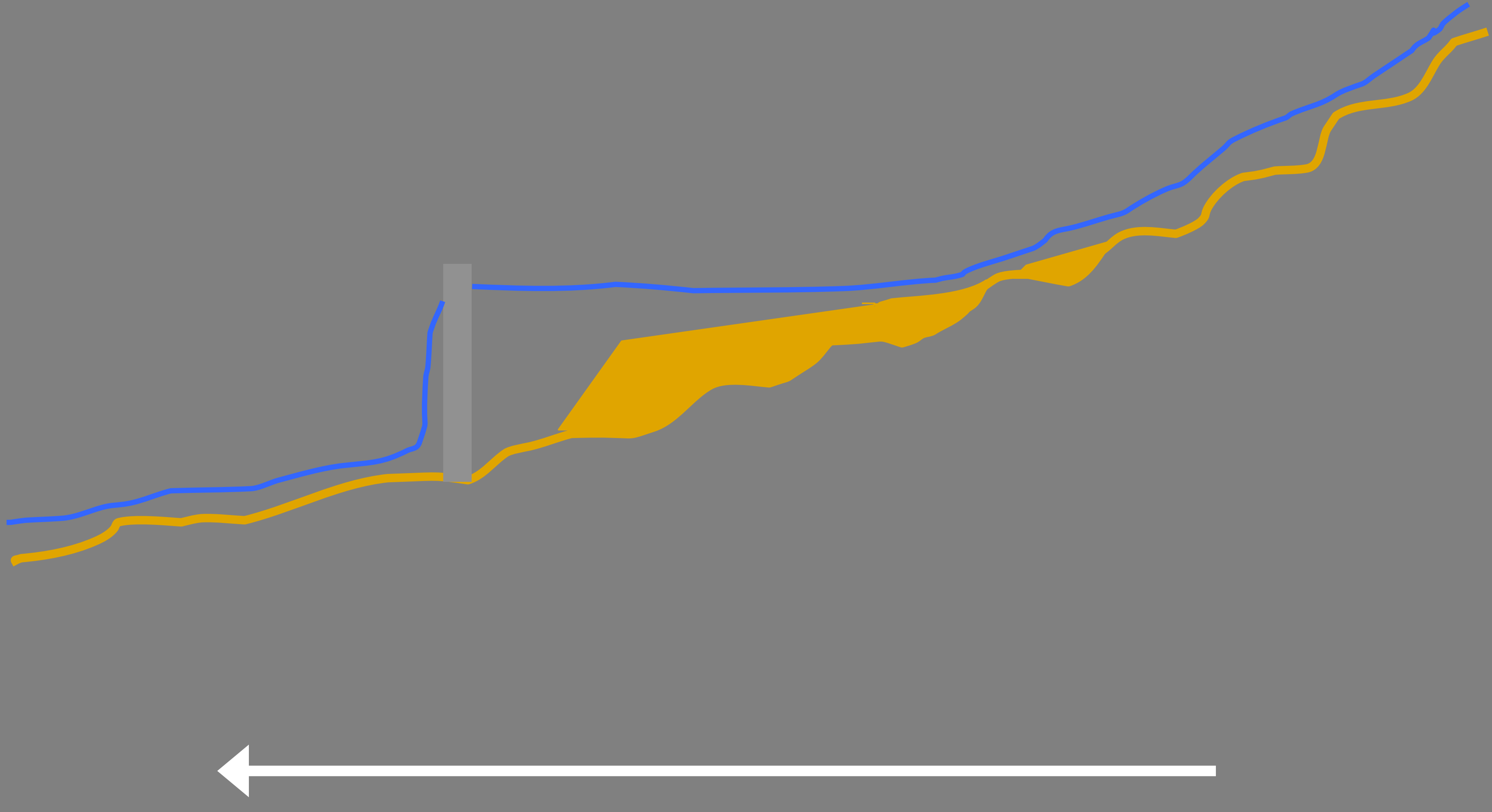
Immediately After Dam Construction



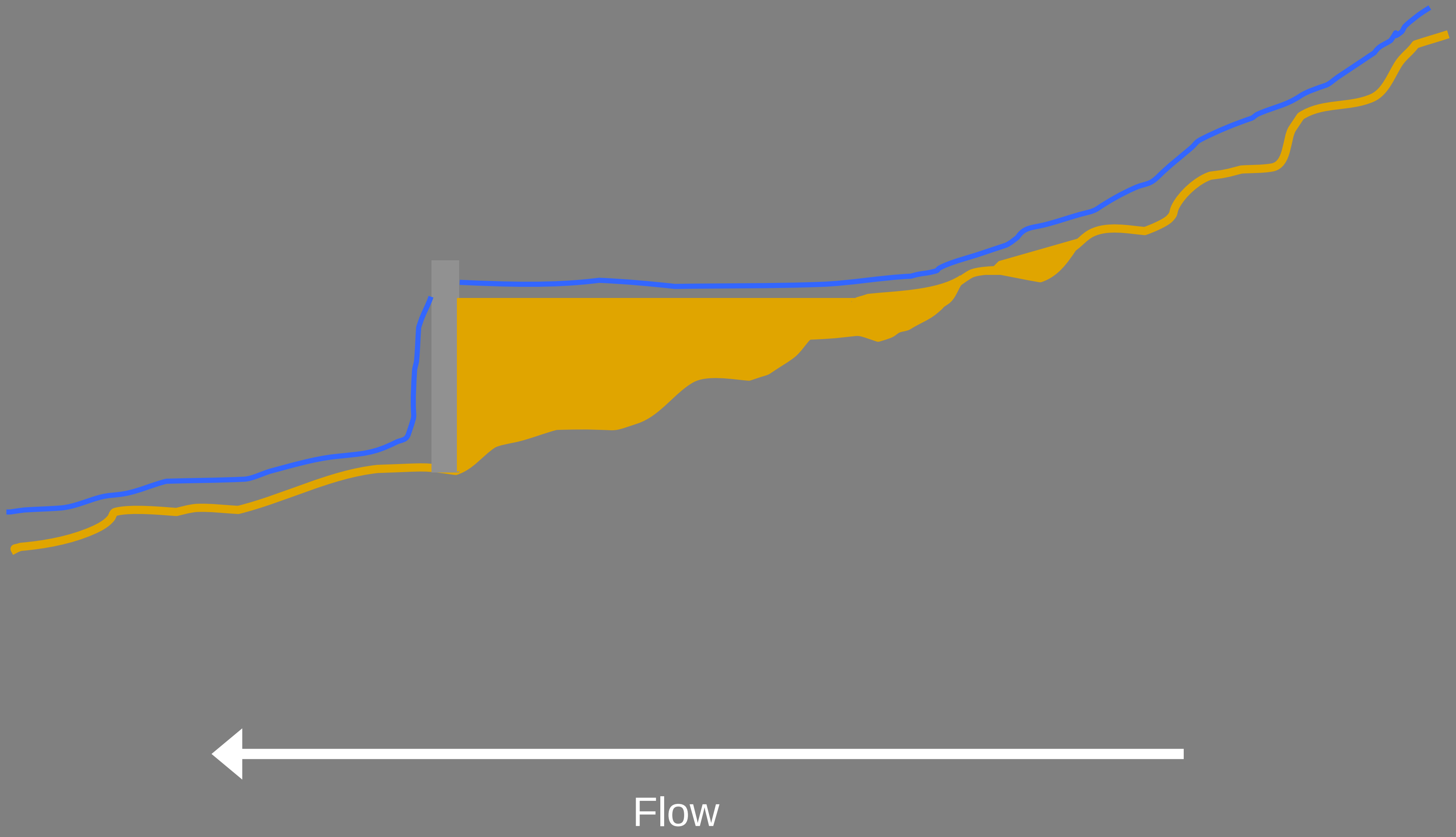
Early Reservoir Sedimentation Phase



Mid Reservoir Sedimentation Phase



Late Reservoir Sedimentation Phase



Effects of Dams

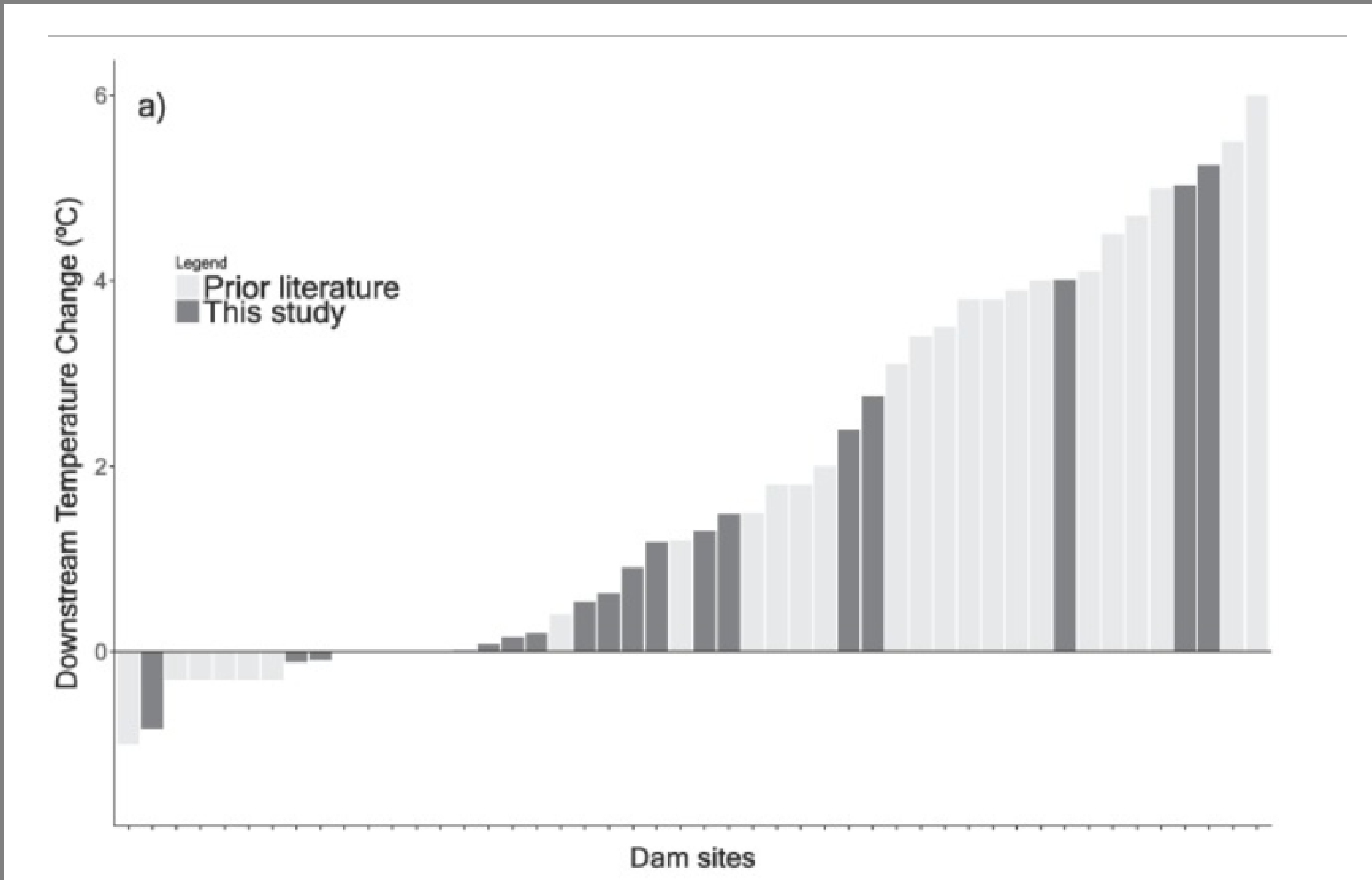
- General: flow of water, sediment, nutrients, & aquatic life interrupted

- Sediment – delivered by river to reservoir and accumulates. Doesn't get delivered downstream, and river changes because of it.

- Water Temperature – slowing, warming. Most Michigan dams warm water temperatures in reservoirs and downstream (the amount varies from subtle to significant).

- Fish – Impacts due to Habitat Alteration & Habitat Fragmentation (i.e. river changed & blocked off)

Water Temperature Effects



From Zaidel et al.2021. Impacts of small dams on temperature. Ecological Indicators, Vol 120.

Fish Densities @ MI Dams

Table 10. Density (fish/ha) and standard error estimates for the five target fish species, above and below the dams, in the ten study streams.

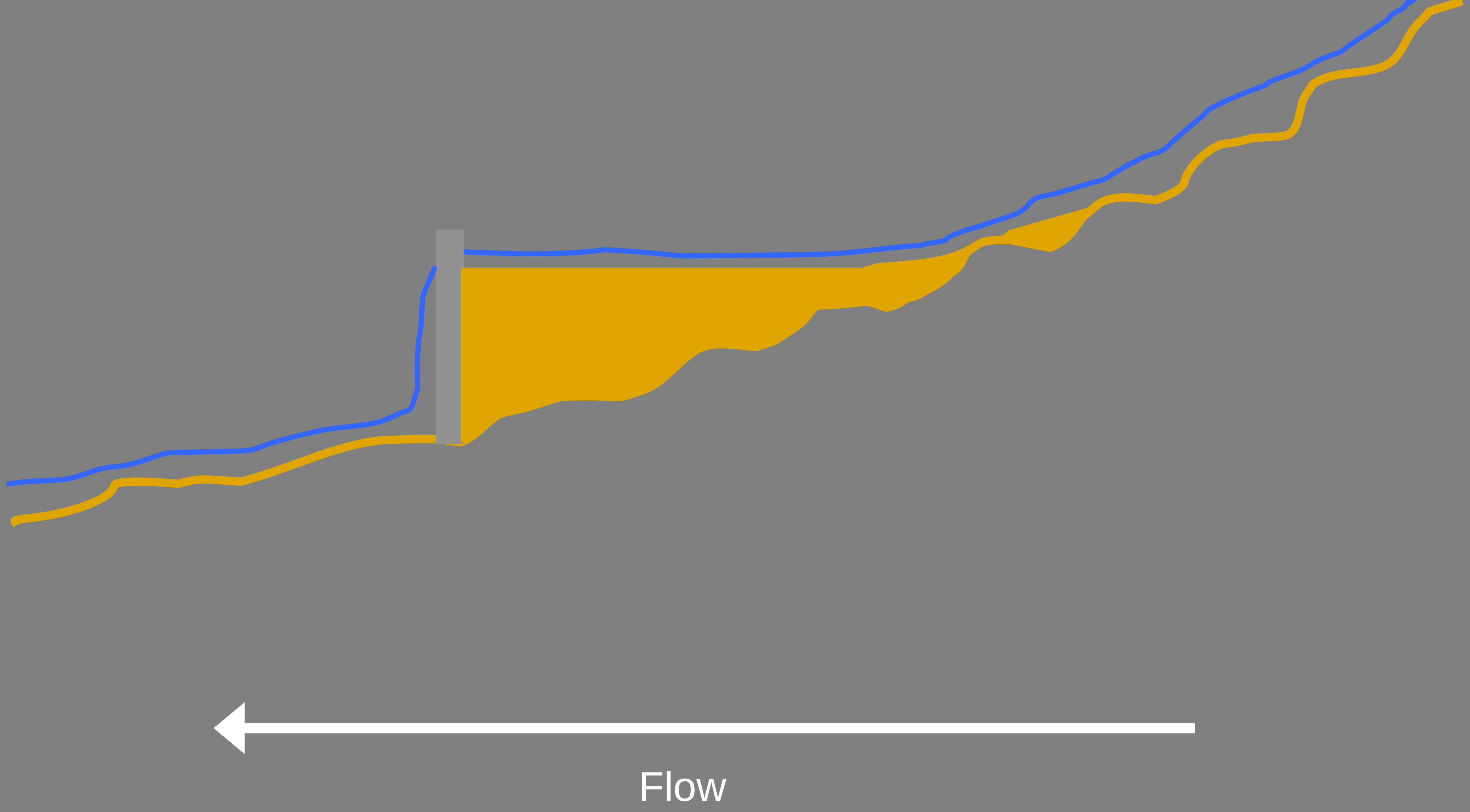
STREAM	BROOK TROUT Above	BROOK TROUT Below	BROWN TROUT Above	BROWN TROUT Below	RAINBOW TROUT Above	RAINBOW TROUT Below	SLIMY SCULPIN Above	SLIMY SCULPIN Below	MOTTLED SCULPIN Above	MOTTLED SCULPIN Below	TOTAL TROUT Above	TOTAL TROUT Below
Boardman	**234**	**18**	**585**	**342**	**0**	**0**	**1124**	**277**	**0**	**0**	**819**	**361**
stderr	44	13	125	111	0	0	432	144	0	0	86	108
Cedar	**191**	**0**	**872**	**0**	**0**	**0**	**2264**	**0**	**0**	**0**	**1064**	**0**
stderr	76	0	185	0	0	0	981	0	0	0	133	0
Dowagiac	**0**	**0**	**73**	**0**	**0**	**0**	**0**	**0**	**1079**	**0**	**73**	**0**
stderr	0	0	67	0	0	0	0	0	540	0	67	0
Fish	**0**	**0**	**23**	**0**	**0**	**0**	**0**	**0**	**52**	**0**	**23**	**0**
stderr	0	0	23	0	0	0	0	0	47	0	23	0
Manton	**2416**	**19**	**2878**	**598**	**0**	**0**	**1475**	**0**	**11**	**22**	**5294**	**617**
stderr	1113	19	466	162	0	0	307	0	11	22	1561	178
Maple	**497**	**84**	**147**	**749**	**23**	**65**	**824**	**990**	**0**	**4**	**668**	**897**
stderr	408	9	147	615	23	29	337	399	0	4	377	648
Middle	**4**	**0**	**214**	**37**	**0**	**0**	**0**	**0**	**556**	**29**	**217**	**37**
stderr	4	0	62	37	0	0	0	0	164	15	65	37
Prairie	**0**	**0**	**76**	**55**	**136**	**47**	**0**	**0**	**482**	**347**	**213**	**103**
stderr	0	0	38	29	71	39	0	0	277	248	107	68
Sugar	**0**	**0**	**558**	**0**	**0**	**0**	**0**	**0**	**60**	**0**	**558**	**0**
stderr	0	0	306	0	0	0	0	0	34	0	306	0
White	**115**	**0**	**170**	**782**	**0**	**0**	**0**	**0**	**1049**	**338**	**284**	**782**
stderr	68	0	59	372	0	0	0	0	186	21	127	372
Mean	346	12	560	256	16	11	569	127	329	74	921	280
stderr	236	8	272	105	14	8	258	100	139	45	497	113

From: J. Lessard, D. Hayes. 2003. Effects of elevated water temperature on fish and macroinvertebrate communities below small dams. River Res. Appl., 19 (2003), pp. 721-732

Dam removals:

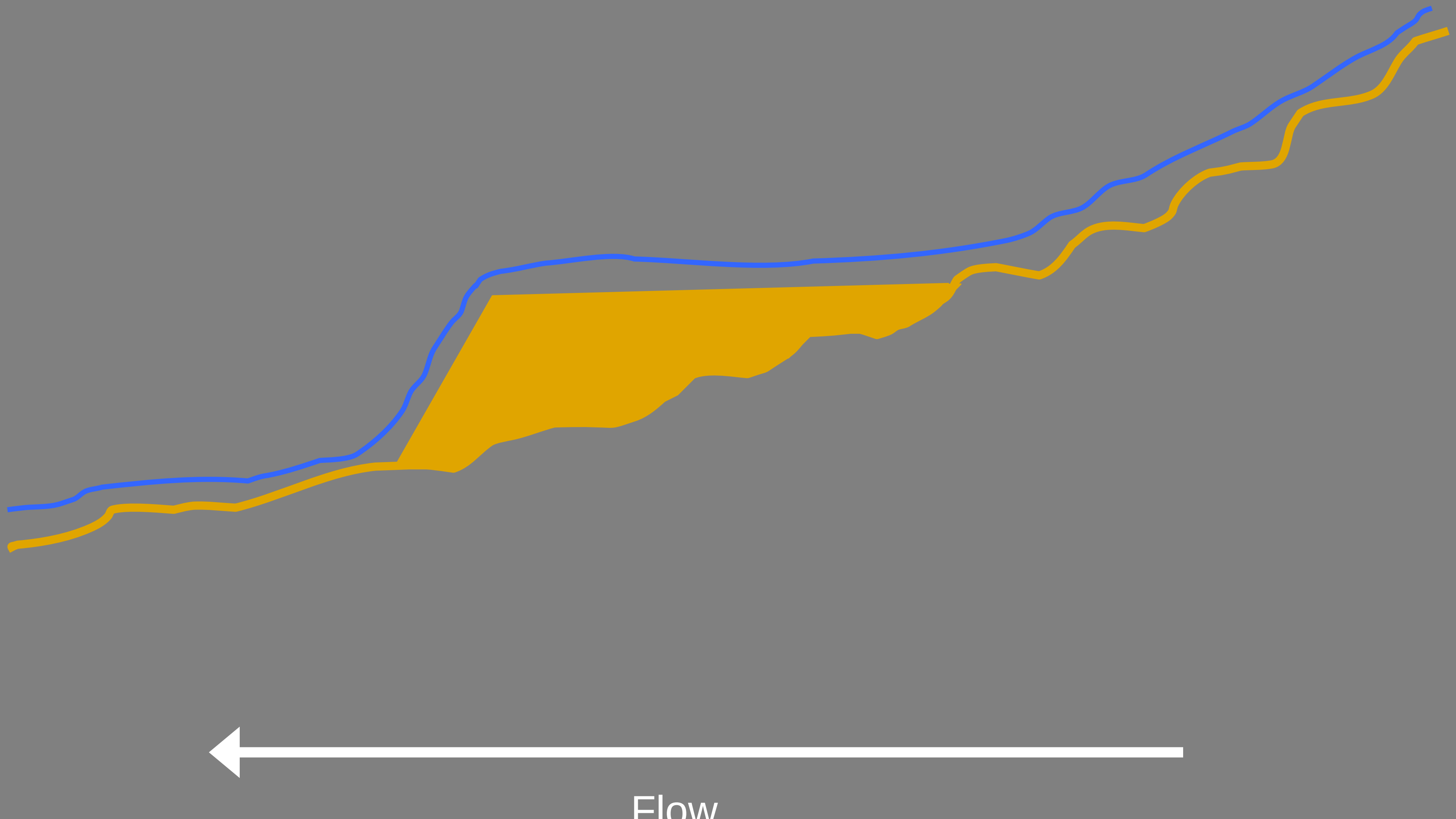
What they do to rivers

Pre-Dam Removal

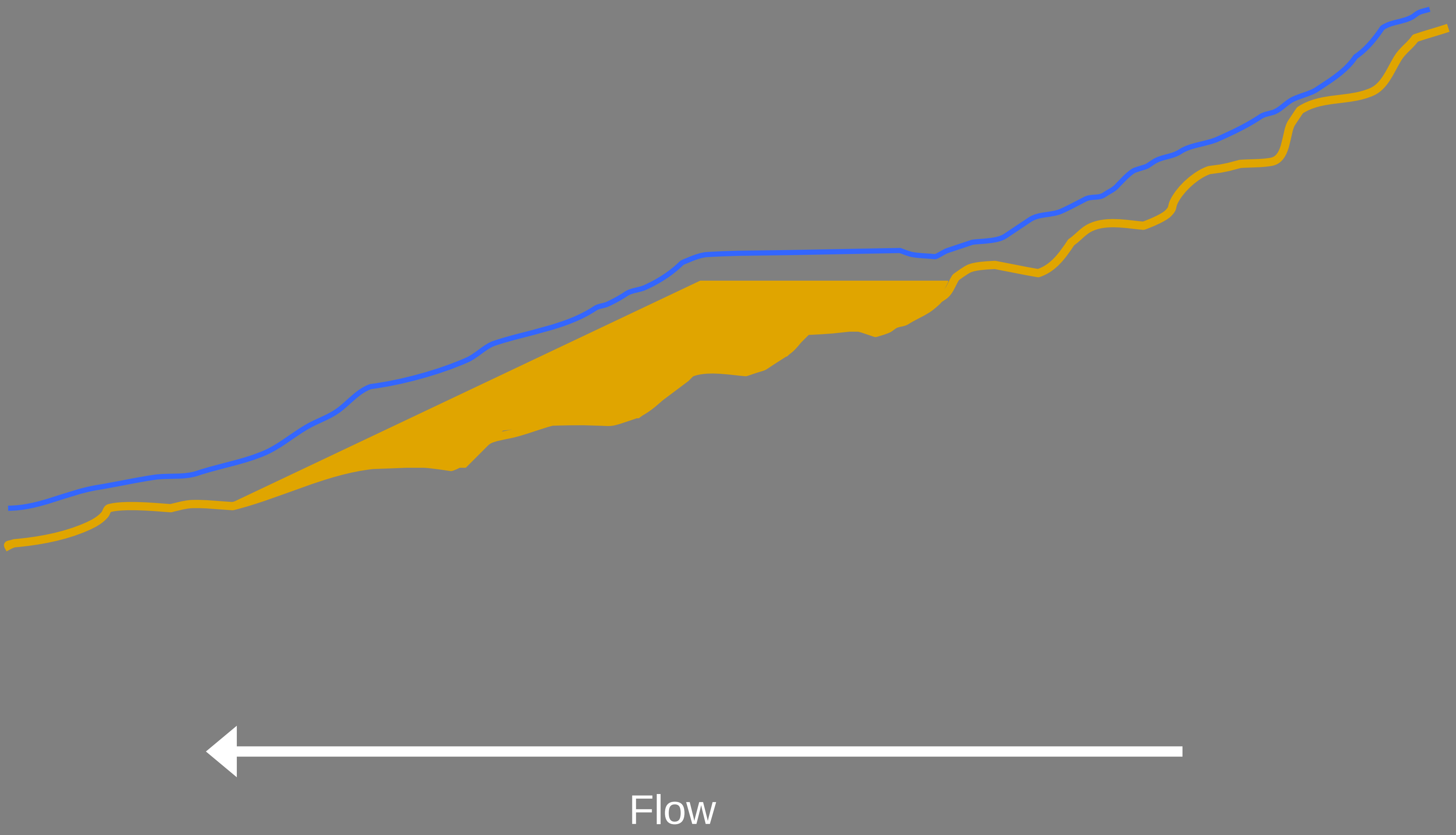


Immediately Post - Dam Removal

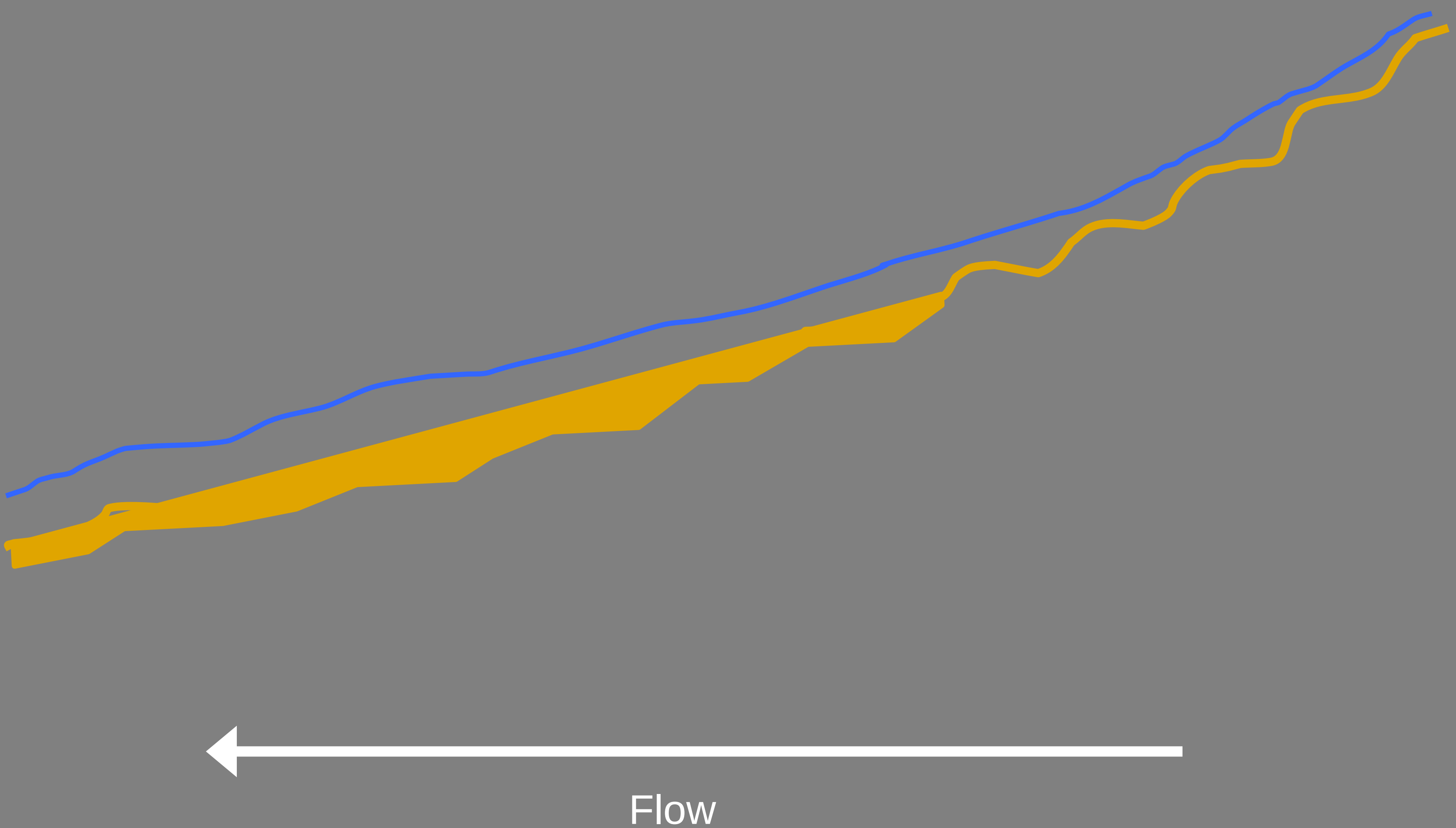
(if sediments are not “dredged”)



Days Post - Dam Removal

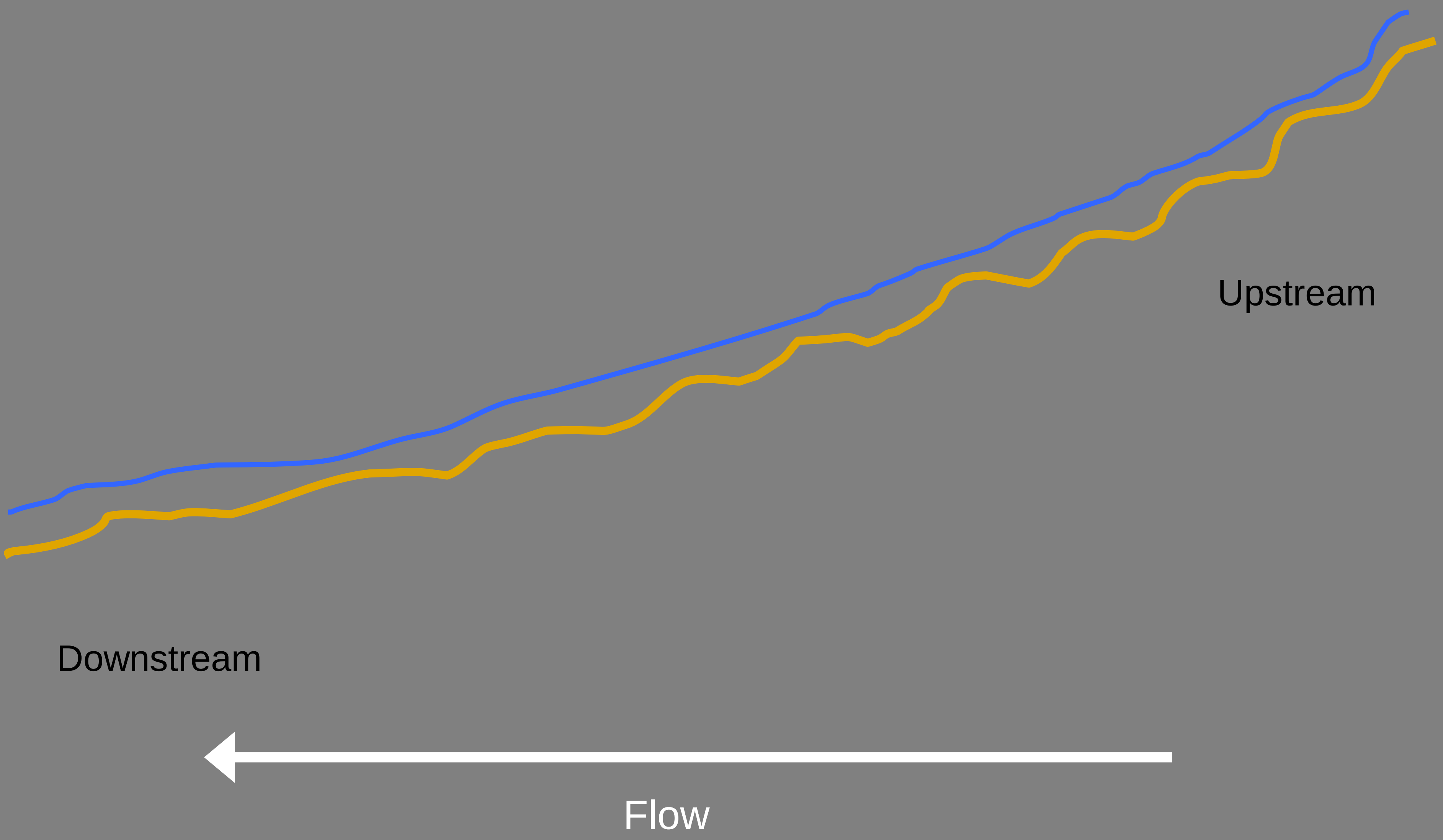


Months Post - Dam Removal

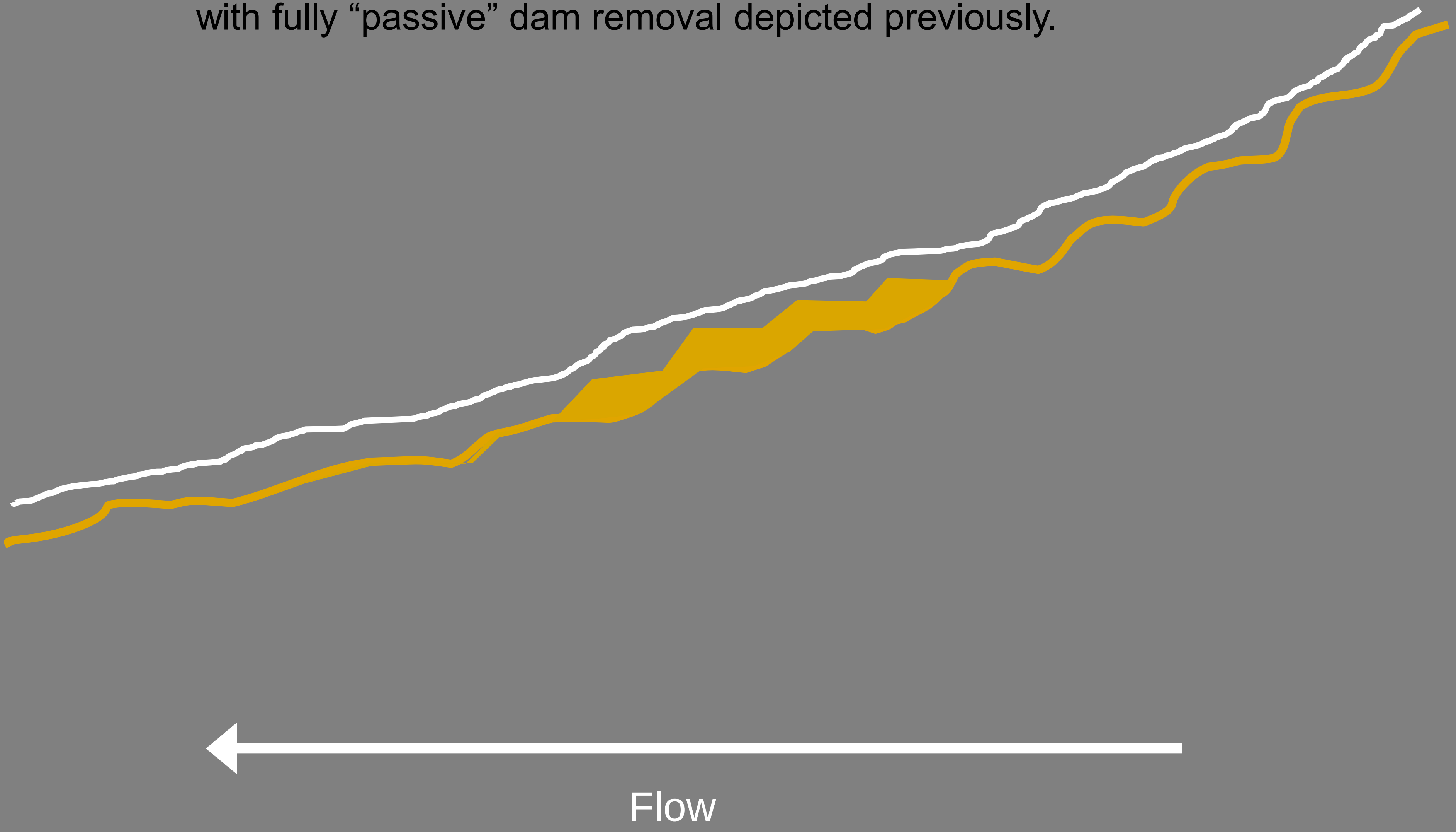


Years - Post-Dam Removal

(if no active restoration measures used)



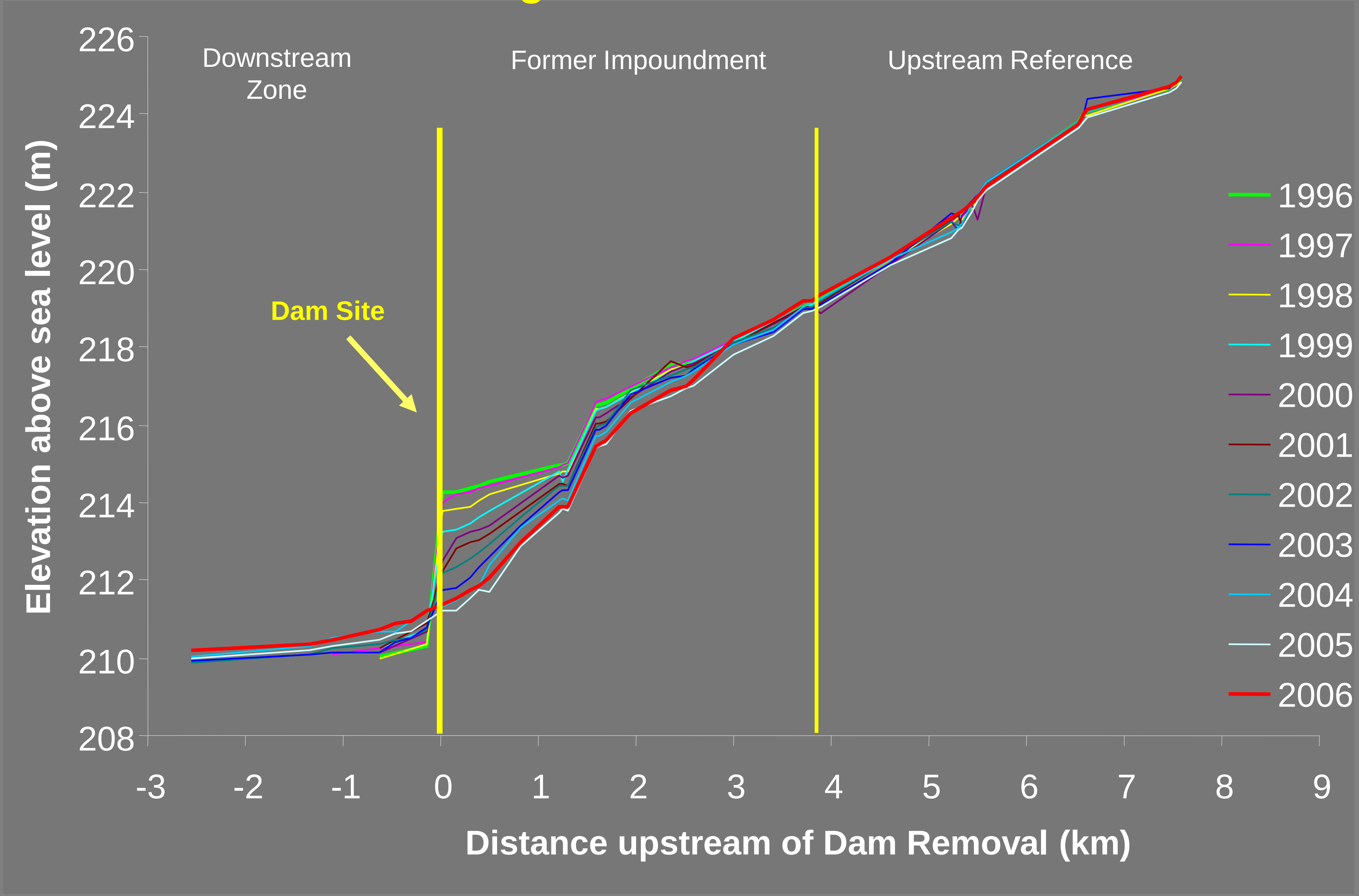
Sometimes, we need to limit sediment erosion (e.g., bridge protection upstream), so we install rock structures in the new stream to limit downcutting, or to speed up new riffle-pool creation). These are considered “active” measures in contrast with fully “passive” dam removal depicted previously.

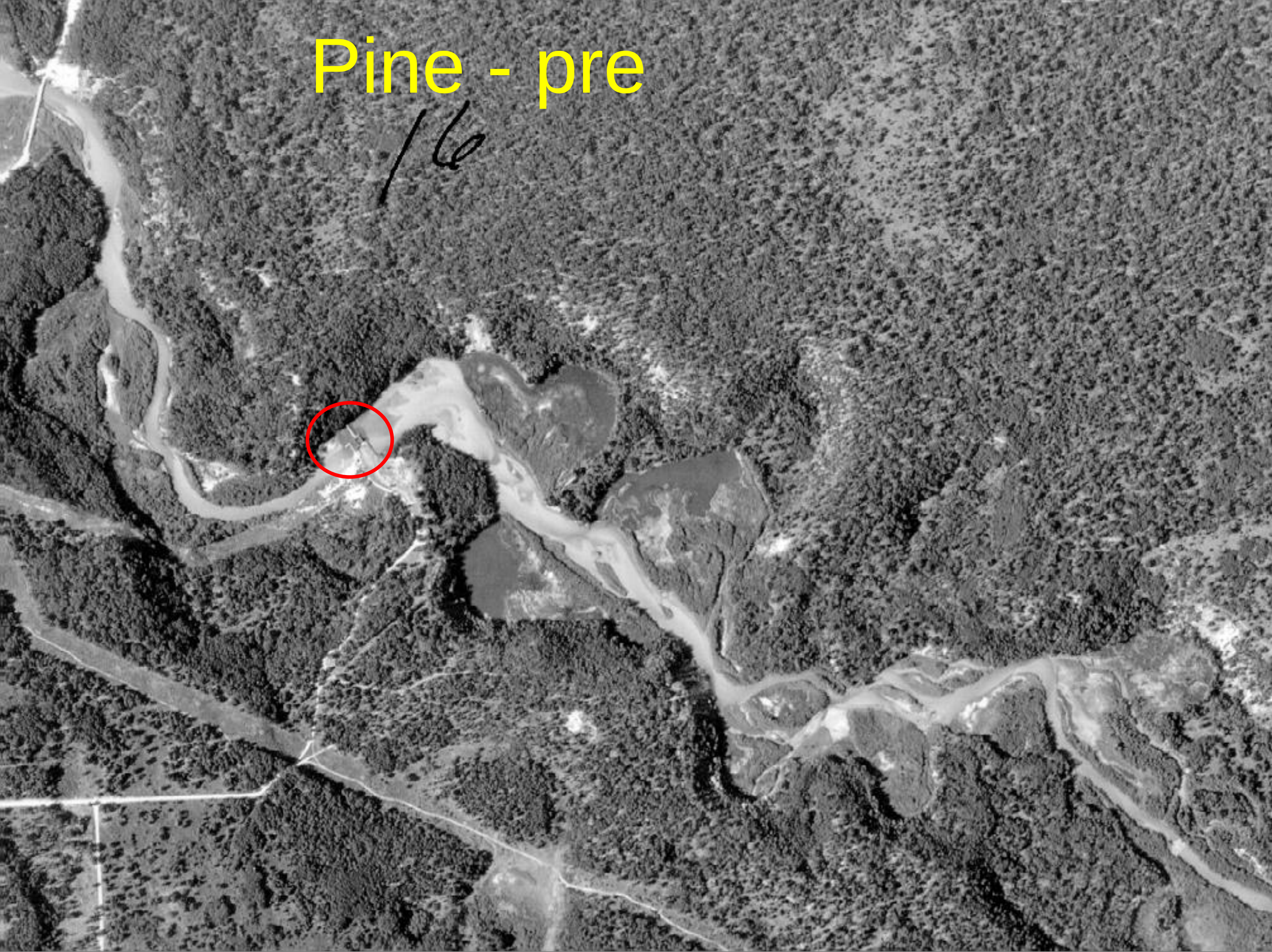



BEFORE a “stage” of a dam removal

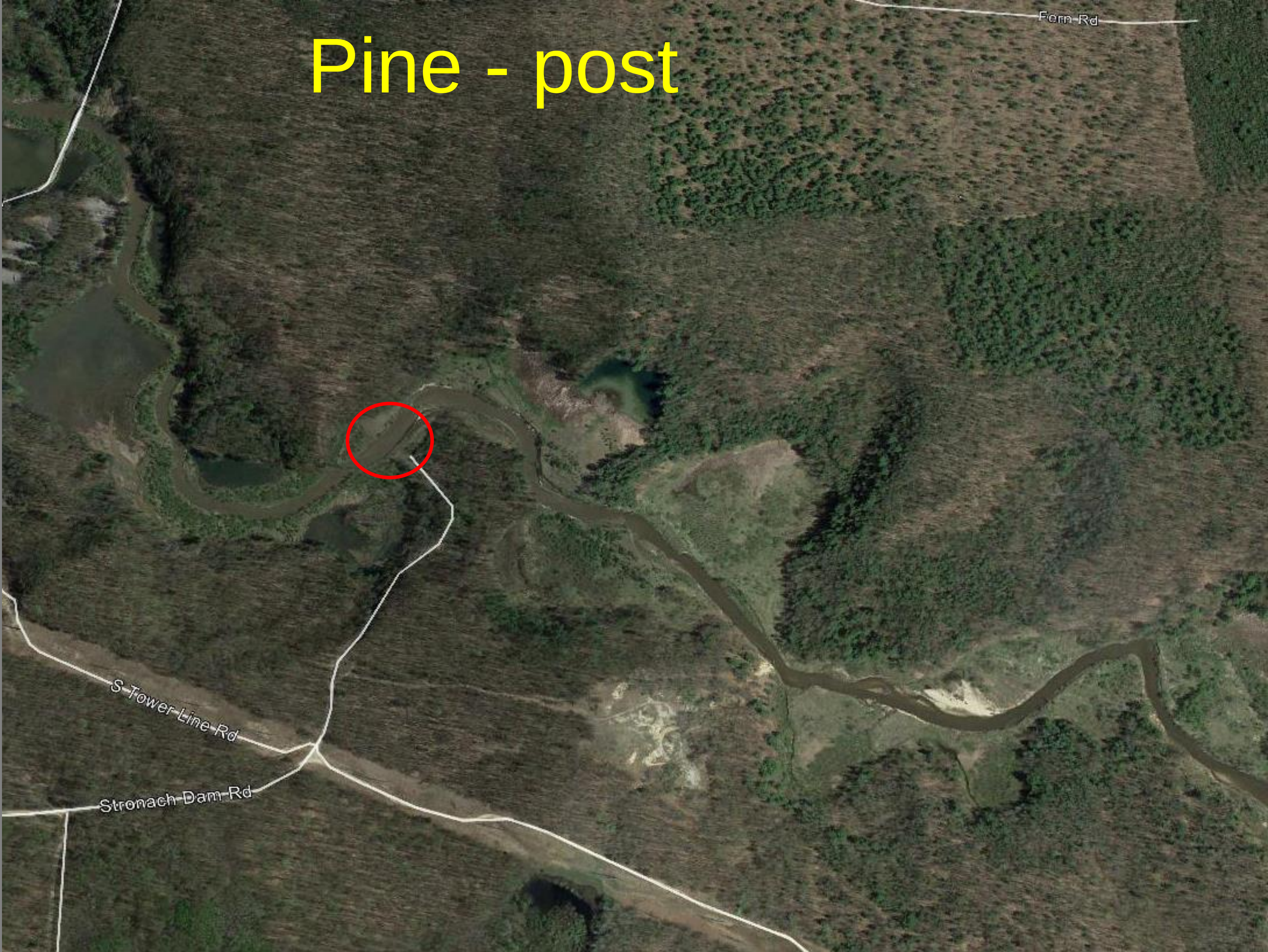

AFTER (2 hours later)

Longitudinal Profile of the Pine River (Water Surface) During Gradual Dam Removal

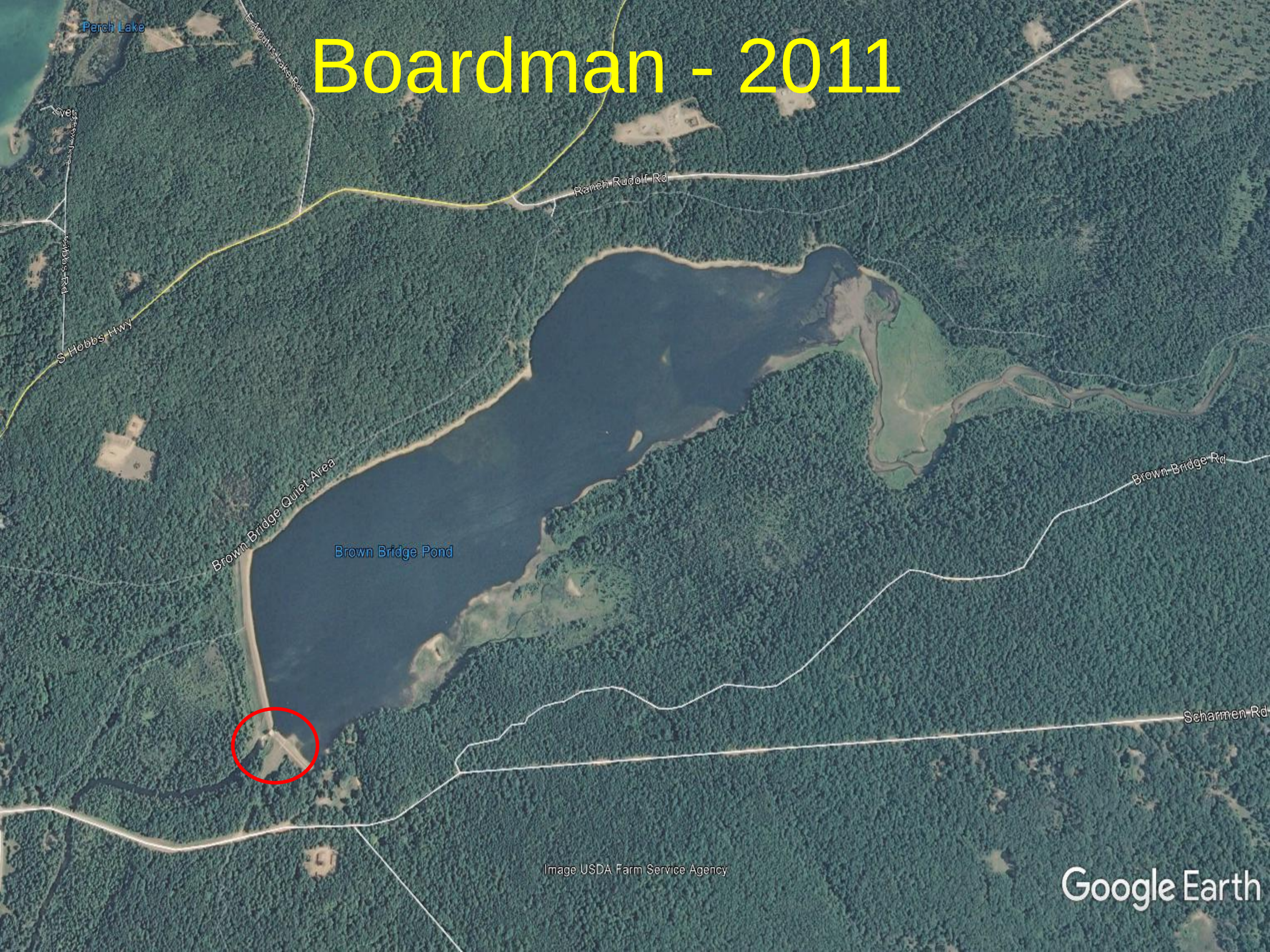



Pine - pre
16

Pine - post



Boardman - 2011



Boardman - 2018

Manton - pre


Mill Pond
Sturtevant St
Fox Rd
Image USDA Farm Service Agency
Google Earth


Manton - post
Mill Pond
Sturtevant St
Fox Rd
Google Earth


Dexter - pre
N Parker Rd
Bent Tree Dr
Boerstro Ct
Sandfield Ct
Dexter Chelsea Rd
Dexter-Pinckney Rd
Island Lake Rd
Boulder Ct
Jeffords
Broad St
Alpine St
Main St
Forest St
Grand St
Dexter
Ann Arbor St
Central St
5th St
Baker Rd
Image U.S. Geological Survey
Google Earth

Dexter - post


Bent Tree Dr
Sandfield Ct
Dexter Chelsea Rd
Island Lake Rd
Dexter-Pinckney Rd
Boulder Ct
Baker Rd
Google Earth

Stream Morphology Summary

Dam Removal: River Slope increases, and everything else follows…

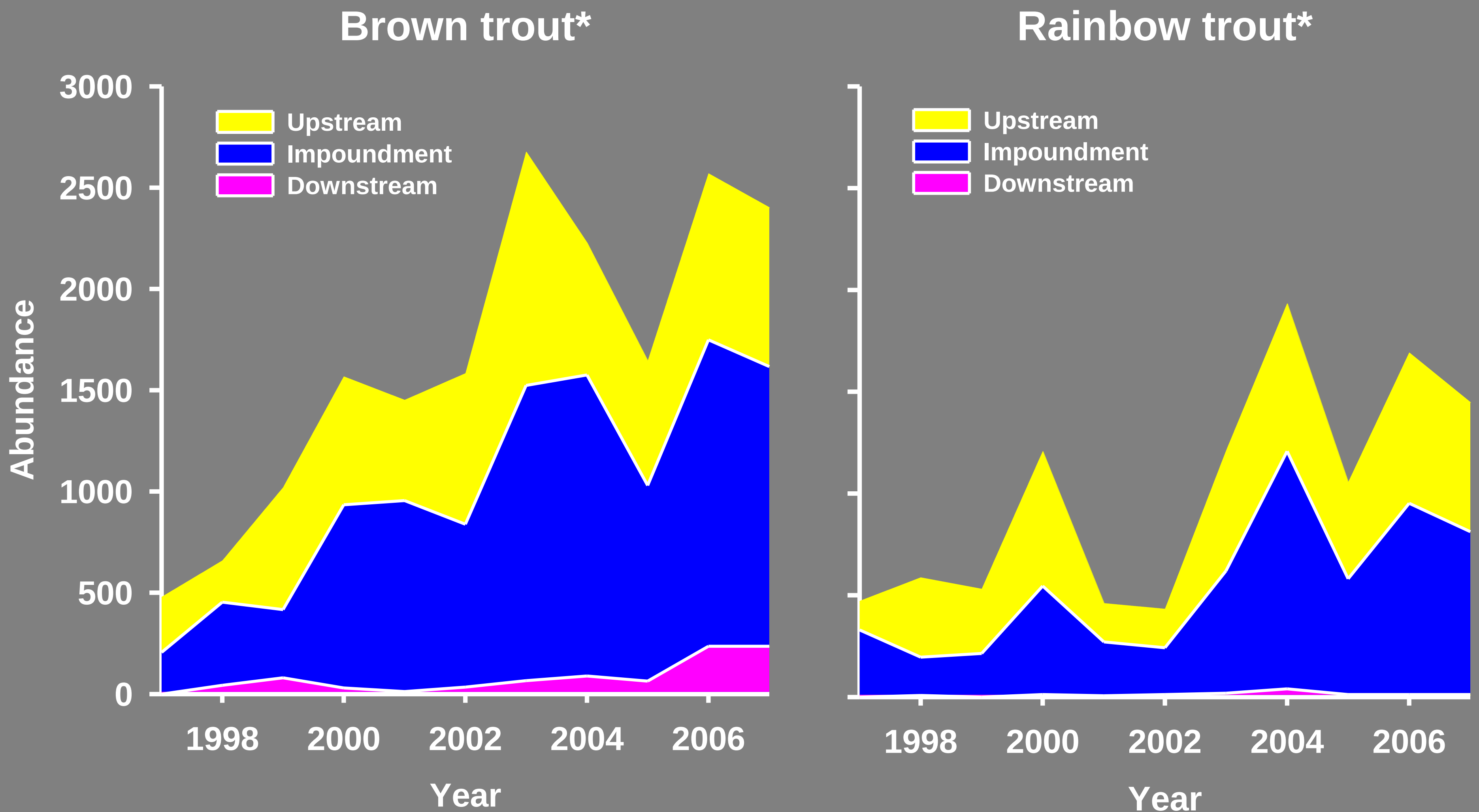
- Sediment erosion occurs & slope increases
  - River cuts down through sediment fill (incision)
- Water Velocity (& diversity) increases
- Water Temperature Impacts alleviated
- Substrate Size Composition – coarsens & diversifies
- Bedform diversity increases (% - runs, riffles and pools)
  - Full restoration requires larger flows, unless active management
- Sinuosity (meanders) – incision path locks – little change

What Dam Removal Does to Fish

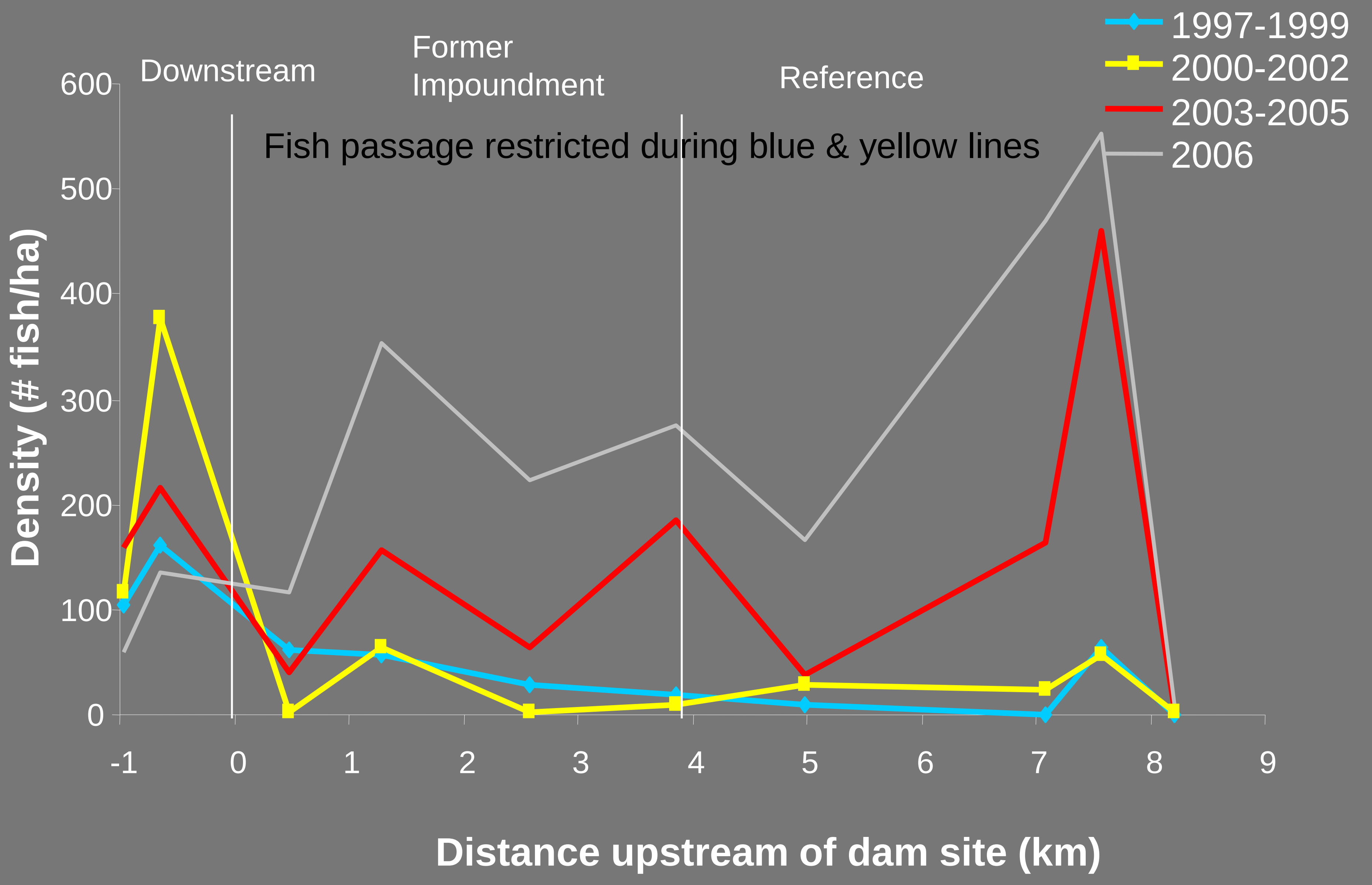
1) Allows fish to move around – accessing all habitats
   -needed for life stages, survival, feeding, reproduction

2) Restores high gradient river habitat and colder temperatures; more and better habitat for river fish

Trout Abundance in the Pine River



White Sucker Density



A recent small dam removal

Prior to Removal

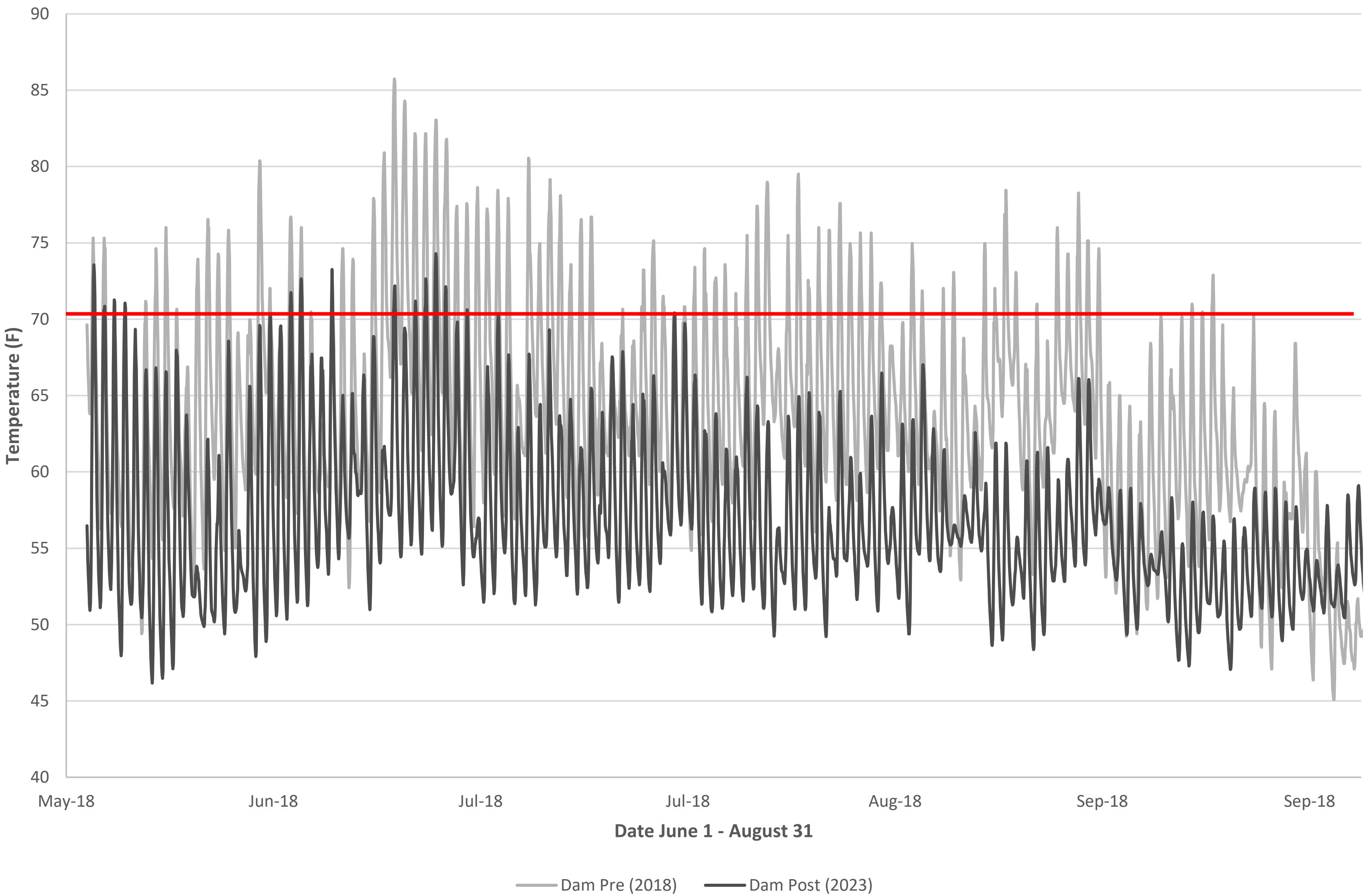
During Removal

Weeks After
Removal

1 year
Later

Water Temperatures – Before (light gray) and After (dark gray), small dam removal shown in previous slides. Measured below the Dam site.

Red line is 70^{0}F, stress level for trout

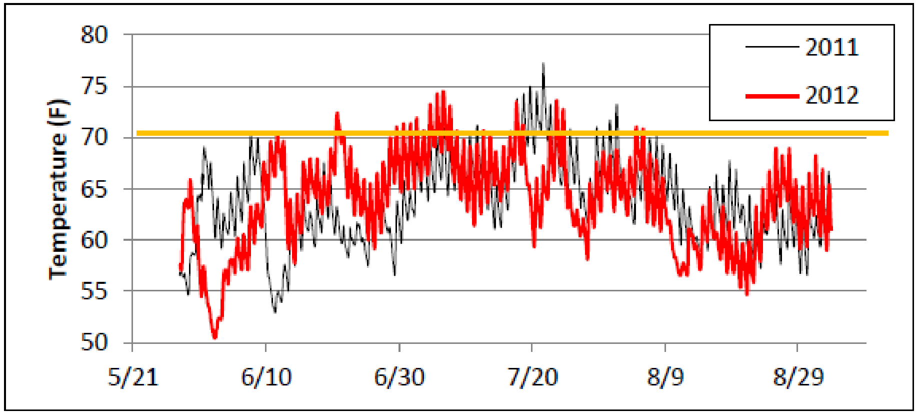


Mio Water Temperatures

Au Sable Above Mio

Mean July Temperature		
Year	**Mean Temperature (F)**	**Classification**
2011	67.4	Cool
2012	66.6	Cold-transitional

June Temperature Summary				Cumulative Hours Over			
	Minimum	**Maximum**	**Average**	**70**	**72**	**74**	**76**
2011	52.9	70.1	61.6	2	0	0	0
2012	50.5	73.4	63.2	33	3	0	0



July Temperature Summary				Cumulative Hours Over			
	Minimum	**Maximum**	**Average**	**70**	**72**	**74**	**76**
2011	61.1	77.2	67.4	147	54	18	5
2012	58.1	74.4	66.6	119	42	6	0

August Temperature Summary				Cumulative Hours Over			
	Minimum	**Maximum**	**Average**	**70**	**72**	**74**	**76**
2011	56.6	73.2	63.0	9	5	0	0
2012	54.7	71.0	62.2	7	0	0	0

*Data collected by the Au Sable Big Water Preservation Association

Mio Water Temperatures

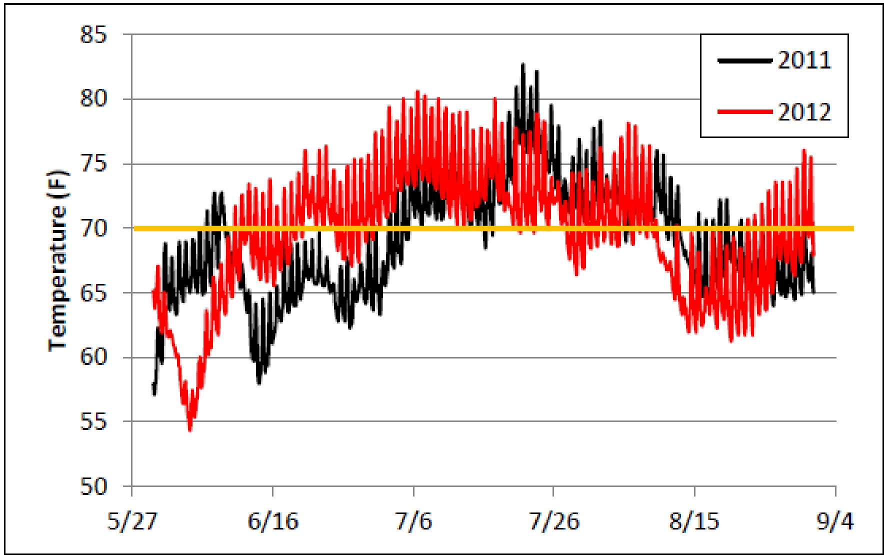
Au Sable Mio to Comins

Mean July Temperature		
Year	**Mean Temperature (F)**	**Classification**
2011	73.3	Warm
2012	73.4	Warm

June Temperature Summary				Cumulative Hours Over			
	Minimum	**Maximum**	**Average**	**70**	**72**	**74**	**76**
2011	58.0	72.7	66.6	39	11	0	0
2012	54.3	77.4	67.5	273	145	52	10

July Temperature Summary				Cumulative Hours Over			
	Minimum	**Maximum**	**Average**	**70**	**72**	**74**	**76**
2011	63.3	82.7	73.3	649	474	313	181
2012	66.4	80.6	73.4	669	489	277	163

August Temperature Summary				Cumulative Hours Over			
	Minimum	**Maximum**	**Average**	**70**	**72**	**74**	**76**
2011	64.0	78.3	69.3	302	169	52	10
2012	61.2	78.1	68.1	216	118	58	22



*Data collected by the Au Sable Big Water Preservation Association

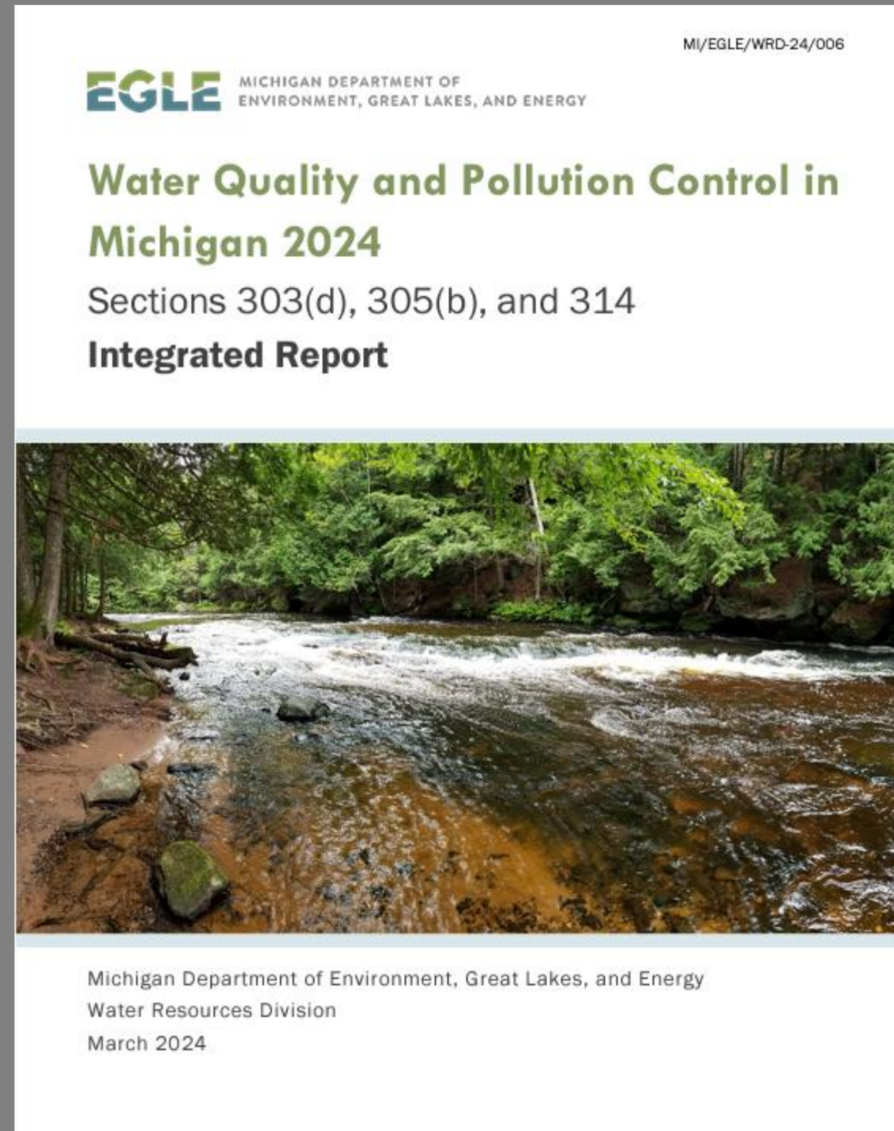
Impairment Status

Coldwater streams have a coldwater fishery designated use within state and federal water quality regulation frameworks.

Dams located on coldwater fisheries, can elevate water temperatures downstream of them past those standards, impairing them, and causing loss of coldwater fisheries

These can be evaluated through data collection, and when found, reported as impairments by EGLE.

Despite the upwelling systems, several of the rivers with Consumers Dams are now listed.


MI/EGLE/WRD-24/006

EGLE MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY

Water Quality and Pollution Control in Michigan 2024

Sections 303(d), 305(b), and 314

Integrated Report

Michigan Department of Environment, Great Lakes, and Energy
Water Resources Division
March 2024

Impairment Status

Mean Monthly Water Temperature based on USGS data (https://waterdata.usgs.gov/mi/nwis/rt)
CWA 401 Water Quality Certification, License Article 405 Standard for June, July, August = 20C, September = 17C

All Rivers	Muskegon River				Manistee River								Au Sable River											
	Croton [1]				Hodenpyl [2]				Tippy [3]				Mio [4]				Alcona [5]				Foote [5]			
	Month				Month				Month				Month				Month				Month			
Year	June	July	August	Sept	June	July	August	Sept	June	July	August	Sept	June	July	August	Sept	June	July	August	Sept	June	July	August	Sept
1995	17.97	20.21																						
1996		20.55	21.68	19.87																				
1997	16.92	20.45	20.02	18.52	16.90	20.48	18.94	16.25			18.87	16.30	19.00		17.45	15.07	19.08	21.27		16.18				20.65
1998	18.03	21.18	21.61	20.27	17.75	21.00	20.58	18.52		21.65	21.06	18.90	17.65	20.95	19.77	16.97	18.58	21.92	20.89	18.30	18.80	23.11	21.76	18.58
1999	18.25	21.32	21.90	19.50	18.78	21.23	20.31	17.45	19.22	21.56	20.51		19.78	21.45	19.45	15.88		22.32		17.32	19.75	23.65	23.35	20.97
2000	17.82	21.00	21.45	19.57	17.82	20.08	19.71	18.00	18.00	20.37			18.48	19.55	19.21	15.85	18.78	20.52	20.24	17.08				
2001	17.63	21.42	21.89	19.37	16.17	20.68	21.18	17.48	16.92	21.11	21.61	17.48		21.13	20.98	15.73		21.95	22.08		20.13			20.15
2002	17.33		21.87	20.63	16.72				17.15	22.40	21.94	19.15	18.23	22.10	20.52	17.70	8.58	23.77	21.81	19.07	18.68	24.52	23.90	21.83
2003	16.43	19.94	21.58	19.32	17.00	20.06	21.32	18.22	17.37	20.50	21.68	18.50	17.85	20.24	21.13	16.37	18.00	21.01	21.51	17.62	18.22	22.44	23.87	20.77
2004		20.48		20.37	16.88	18.79	18.84	18.13	17.25				17.83	19.77	18.44	17.65	18.37	20.56	19.66	19.05	18.92	21.97	21.98	21.37
2005	18.15	20.90	21.26		18.82	21.74	20.84	18.50		22.16			20.20	21.63	20.06	17.48	20.45	22.82	21.47		20.77	24.69	24.37	
2006	18.50		22.67	19.17	18.05	20.26	20.87	16.60	18.25	20.99		17.32	19.53	21.30		14.99	20.27		21.48	16.64	20.72	24.11	24.41	19.62
2007	19.40	21.60	22.16	20.20	19.72	20.65	20.98	17.92		21.06	21.25	18.30	20.23	20.05	20.23	16.99			21.55	18.16	22.21	23.33	23.92	
2008	17.95	21.41	22.36	20.02		20.22	20.75	17.50			21.09	17.79	18.20		19.49	15.83	18.79	21.42	20.92	17.35		23.05	22.98	20.45
2009	*17.80*	*19.79*		*19.93*	16.55	18.76		17.13	16.98		19.47	17.65	*17.68*	*18.56*	*19.17*	*16.07*	17.79	19.84		17.49	18.66	21.61	22.75	20.84
2010	*18.74*	*21.85*	*22.74*	*19.59*	18.96		21.71	17.61	19.24		22.14		*19.13*	*21.82*	*21.09*	*15.77*	20.10	22.63				24.51	24.70	19.75
2011	*18.32*	*21.92*	*22.41*	*19.58*	18.02	20.92	21.32	17.55	18.33	21.42		17.95	*18.32*	*22.52*	*20.39*	*15.79*	19.13	23.19		17.17	19.59	24.47	24.61	20.29
2012	*18.99*	*22.90*	*21.94*	*19.96*	18.75	22.65	20.49	17.88	*19.19*	*23.17*	*21.06*		*19.34*		*19.64*	*16.01*	*19.98*		20.86	17.79	21.11	25.29		20.66
2013	*18.61*	*21.81*	*21.22*		17.75	21.14	19.15	18.05	*17.97*	*21.18*	*19.76*		*18.80*	*21.18*	*19.00*	*16.24*			19.88	17.66	20.09	24.17	22.68	20.58
2014	*18.38*		*21.73*	*19.43*	18.47	19.69	19.38	16.75		*19.71*	*19.76*	*17.05*	*18.56*	*19.31*	*18.46*	*14.82*	*19.47*	20.57	19.46	16.21	20.33	22.74	22.27	19.60
2015	*17.98*	*21.17*	*21.82*	*20.51*	17.70	19.51	20.15	18.04	*17.77*	*19.94*		*18.49*	*17.88*	*20.31*	*19.55*	*16.92*	*18.81*	21.20		18.11	20.07		23.44	21.33
2016	*18.37*	*21.27*	*22.87*	*21.49*	18.81	21.01	21.55	19.00	*18.86*	*21.19*		*19.48*	*19.03*	*21.03*	*21.03*	*17.34*	*20.07*	22.24	22.33		20.91	24.10	25.19	22.48
2017	*18.60*	*21.79*	*21.61*	*20.01*	18.82	20.49	19.96	16.90	*18.72*	*20.70*		*17.72*	*18.89*	*20.40*	*18.84*	*16.77*	*19.62*	21.45	20.35	17.74	20.17	23.35	23.03	
2018	*19.57*	*22.53*	*22.61*	*20.75*	19.50		21.08	18.27	*19.55*	*22.17*	*21.57*	*18.79*	*19.05*	*21.94*	*20.28*	*17.02*	*19.98*	22.94	21.62		21.13	24.88	24.58	21.79
2019	*17.19*	*21.97*	*22.16*	*19.80*	16.92	20.87	20.15	17.36	*16.98*	*20.78*	*20.75*	*17.71*	*17.04*	*20.91*	*19.30*	*16.07*	*17.42*	22.01	20.79		18.25	23.77	23.75	20.04
2020	*19.13*	*23.19*	*23.06*	*19.45*	18.94	21.91	20.65	16.70	*18.97*	*22.15*	*21.21*	*17.26*	*19.35*	*22.05*	*19.97*	*14.90*	*20.22*	23.11	21.32	16.21	21.14	25.39	24.24	19.73
2021	*18.38*	*20.92*	*22.43*	*20.80*	19.08	20.42	20.91	18.13	*19.23*	*20.58*		*18.57*	*19.78*	*20.67*	*20.77*	*16.24*	*20.46*	21.48	21.97	17.78	21.09	23.44	24.70	21.36
Mean (1995-2021)	18.20	21.40	22.00	19.90	*18.00*	*20.60*	*20.50*	17.70	*18.20*	*21.20*	*20.90*	*18.10*	*18.70*	*20.90*	*19.80*	*16.30*	*19.20*	21.80	*21.10*	*17.00*	20.10	23.70	23.60	20.60
Mean Pre-upwelling)	17.86	20.81	21.70	19.73	17.69	20.50	20.36		17.99	21.49	20.96	NA	18.72	20.61	18.15	16.37								
Mean (Post-upwelling;	18.52	21.94	22.22	20.10	18.33	20.67	20.54		18.40	20.98	20.61	NA	18.76	21.10	19.78	16.10								

[1] Upwelling sysgtem installed at Croton in 2009, operates into September

[2] Upwelling sysgtem installed at Hodenpyl in 2007

[3] Upwelling sysgtem installed at Tippy in 2012

[4] Upwelling sysgtem installed at Mio in 2009, operates into September

[5] No upwelling systems installed at Alcona and Foote hydropower projects

Note: yellow highlight indicates exceedance of water quality standard of 20C (and upstream Manistee Sherman and Au Sable Red Oak gauges <20C), italicized figures are post-pwelling system. Orange highlight indicates exceedance of September water quality standard of 17.3C (63F).

From: USGS gage station data, compiled and summarized by Michigan HydroRelicensing Coalition

Sediment Management

- Often the most complicated parts of designing a dam removal
- How much and what types are stored in the reservoir? Are they contaminated?
- Can it be allowed to move downstream, or does some of it need to be removed or collected? (active sediment removal increases costs significantly)
- Can affect what the river there will look like, streambed and banks
- Klamath Dam Removals (largest in US) did little active sediment removal (on purpose).
- Consumers Energy dam removal cost estimates currently include significant active sediment removal.

Dam Removal Process

- Decision to remove or not remove dam – if yes then,
- Preliminary assessments and investigation – answers basic questions, brings into focus what dam removal would look like, and what the project would generally entail.
- *Property Ownership Disposition & Access/Recreational Amenities Planning*
- Full engineering and alternatives development, final design
- Permitting, funding, contracting, project management
- Dam Drawdown – lower water level
- Any active sediment management
- Dam infrastructure removal
- Any active stream restoration measures implemented

Further Learning…

- This was created as a primer of what to expect with dam removals
- It was meant to provide clear illustrations of concepts, with a mix of data from studies to reinforce those
- There now exists a lot of detailed information and studies on all aspects of dam removals available by searching online
- General internet searches on dam removal will yield a lot of information. For searching scientific studies only, Google Scholar is a good starting tool (access to full science papers can be limited, but almost all provide at least the summary abstract to everyone).
- Whether or not you prefer dam removal outcomes, its important to have confidence that you accurately understand what the outcomes would be. We hope this helps get you started towards that.