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Madison River Drainage 2188 Project Monitoring Report 2025

To:

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Introduction

Montana Fish, Wildlife & Parks (FWP) monitors the fisheries in the Madison River Drainage to determine potential effects from operations at Hebgen and Madison dams. This work is funded through an agreement with NorthWestern Energy (NWE), the owner and operator of the dams. The agreement between FWP and NWE is designed to assist NWE in meeting the terms and conditions of the Federal Energy Regulatory Commission (FERC) license issued to NWE in 2000 to operate hydropower systems on the Madison and Missouri rivers (FERC 2000). This license includes Hebgen and Madison dams (Figure 1) and seven dams on the Missouri River collectively referred to by FERC as the 2188 Project. The 2188 license details requirements NWE must follow to operate the dam and hydropower facilities on the Madison and Missouri Rivers.

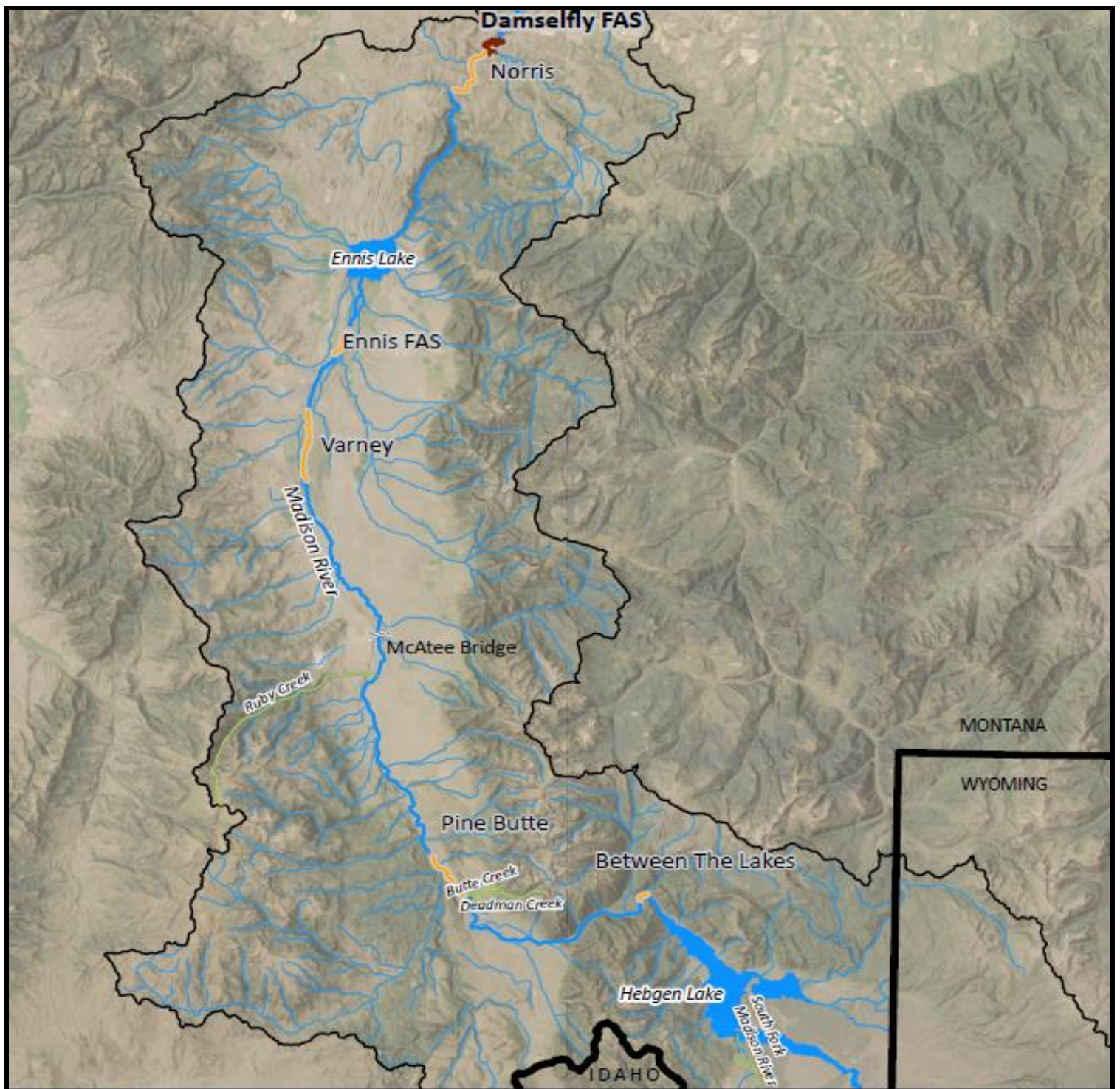
NWE entered a 10-year Memorandum of Understanding (MOU) with state and federal resource management agencies to provide annual funding to implement 2188 license requirements for the protection, mitigation, and enhancement (PM&E) of fisheries, recreation, and wildlife resources. The MOU established Technical Advisory Committees to collectively allocate annual funding to implement PM&E programs and the provisions of the 5-year fisheries and wildlife PM&E plans using adaptive principles. The Madison Fisheries Technical Advisory Committee (MadTAC) comprised of representatives from NWE, FWP, the U.S. Fish & Wildlife Service (USFWS), the U.S. Forest Service (USFS), and the U.S. Bureau of Land Management (BLM) is responsible for the allocation of funds to address fisheries issues related to operations of the Hebgen and Madison Dams under the 2188 license.

This report summarizes work completed by FWP in 2025 with funding provided by the MadTAC to address requirements of the 2188 license, specifically Articles 403, 408, 409, 412, and 419 that pertain to the Madison River fishery. Work included 1) fish abundance estimates in the Madison River, 2) assessment of fish populations in Hebgen reservoir, 3) evaluation of the effects of the 2021 Hebgen gate failure on upper Madison River fisheries 4) conservation and restoration of Arctic Grayling populations, 5) conservation and restoration of Westslope Cutthroat Trout populations, 6) evaluation of opportunities for the enhancement of mainstem and tributary habitats, and 7) implementation of a mainstem habitat project.

Study Area

The Madison River originates in Yellowstone National Park at the confluence of the Gibbon and Firehole rivers and flows north for 180 miles through Southwest Montana to its confluence with the Missouri River near Three Forks, Montana. The Madison transitions from a narrow, forested river valley in the headwaters to a broad valley bounded by the Madison and Gravelly Mountain ranges south of Ennis. North of Ennis the river flows through a steep canyon for 11 miles before it transitions into a broad alluvial valley bottom where it joins the Jefferson and Gallatin rivers, forming the Missouri River (Figure 1).

Two dams impound the Madison River: Hebgen Dam forms Hebgen Reservoir, and Madison Dam forms Ennis Reservoir (Figure 1). Hebgen Reservoir is operated as a water storage facility to control inflow to the downstream Madison Dam, which is a power-generating facility. Madison and Hebgen dam operations are coordinated to provide year-round flows at or above required minimum instream flows and below required maximum rates of flow change; while also mitigating thermal issues in the Madison River below Madison Dam by delivering pulsed flows (Figure 1).






-  Survey Sections
-  State Boundary
-  Watershed Boundary



Figure 1. Locations of NWE dams on the Madison River (FERC Project 2188), FWP annual abundance estimate sections, Ennis and Hebgen Lakes, and project areas discussed in this report.

Monitoring and Projects

Article 403-River Discharge:

Article 403 of the 2188 Project FERC license specifies operational conditions, including minimum and maximum instream flows in various sections of the Madison River. NWE must maintain a minimum flow of at least 150 cfs in the Madison River below Hebgen Dam (gage no. 6-385) and limit the change in the outflow from Hebgen to no more than 10% per day. Additionally, a minimum flow of 600 cfs at Kirby Ranch (USGS gage no. 6-388) and 1100 cfs at USGS gage no. 6-410 below the Madison Dam must be maintained. Flows at Kirby Ranch are limited to a maximum of 3500 cfs under normal conditions to minimize erosion of the Quake Lake outlet. These License requirements necessitated the establishment of the permanent flow gage at Kirby Ranch. FWP and NWE monitor river flow to avoid deviations from operational conditions.

Deviations from Article 403 occurred below Hebgen Dam and at Kirby Ranch on November 30, 2021. The deviations resulted from a broken component on the Hebgen Dam gate that resulted in a 43% change in Madison River discharge between Hebgen and Quake lakes and reduced flows at Kirby Ranch to 395 cfs for approximately 48 hours. To assess the potential impacts of the Hebgen Dam gate failure on the Madison River fishery, a monitoring plan developed by MadTAC and the preparation of a literature review to evaluate the potential effects of low flows were approved by FERC on August 18, 2022. Monitoring completed by FWP and NWE in 2025 is summarized in Appendix A.

Article 408-1) Effects of Project Operations on Hebgen Reservoir Fish Populations:

FWP monitors the Hebgen Reservoir fish assemblage with annual spring gill netting surveys to assess the effects of project operations (Figure 1). Significant changes in the fish assemblage would warrant a review of project operations to address identified issues. We set ten multi-panel, experimental gillnets in Hebgen Reservoir in 2025. Catch-per-unit-effort was calculated as the average number of each species per night:

$$\frac{C}{E}$$

Where C represents the total number of fish and E represents one net night.

The mean catch-per-unit-effort (CPUE) of total trout in Hebgen Reservoir appears stable or slightly decreasing. Standardized gillnetting shows a decrease in CPUE from 21 trout/net in 2024 to 19 trout/net in 2025 (Figure 2). The CPUE of Brown Trout decreased from 16.75 trout/net in 2024 to 13.25 trout/net in 2025, dropping slightly below the management goal of 15.5 Brown Trout/net. Rainbow trout CPUE increased from 4.2 trout/net in 2024 to 5 trout/net in 2025 which remains below the management goal of 7.5 rainbow trout/net. The mean length of Brown Trout decreased from 466 mm in 2024 to 463.4 mm in 2025, remaining above the long-term average of 446.4 mm (Figure 3). The mean length of rainbow trout decreased from 426 mm in 2024 to 414 mm in 2025, which is above the long-term average of 405 mm (Figure 3). Seventy-nine percent of the Brown Trout captured in gill nets were ≥ 406 mm, and 47 % of the rainbow trout captured were ≥ 406 mm.

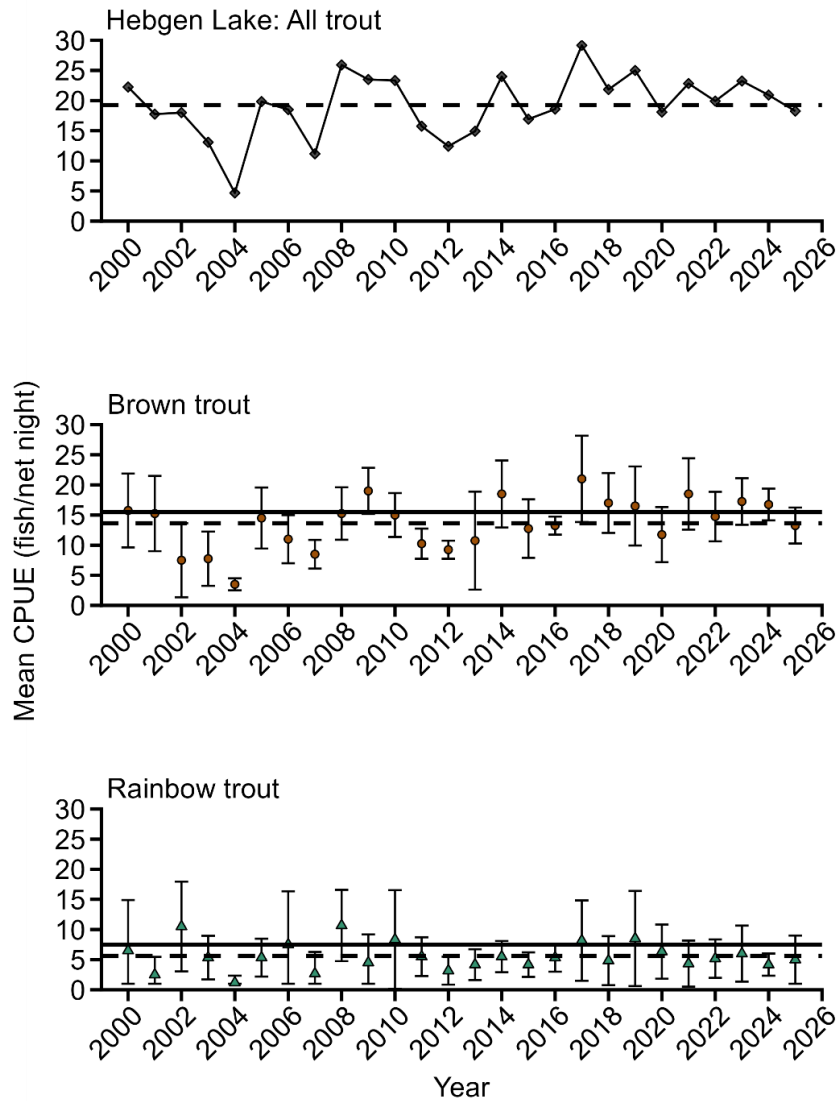


Figure 2. Mean catch-per-unit-effort (CPUE) of all trout combined (black diamonds), Brown (brown circles) and Rainbow Trout (green triangles) captured in Hebgen Reservoir from 2000 to 2025. Catch-per-unit-effort was calculated using catches from both floating and sinking nets. Brown Trout CPUE was calculated from sinking gill nets, and Rainbow Trout CPUE was calculated from floating gill nets to account for behavioral differences of each species. Solid lines represent management goals, dashed lines represent the long-term average CPUE from 2000 to 2025, and error bars represent standard deviations for each year.

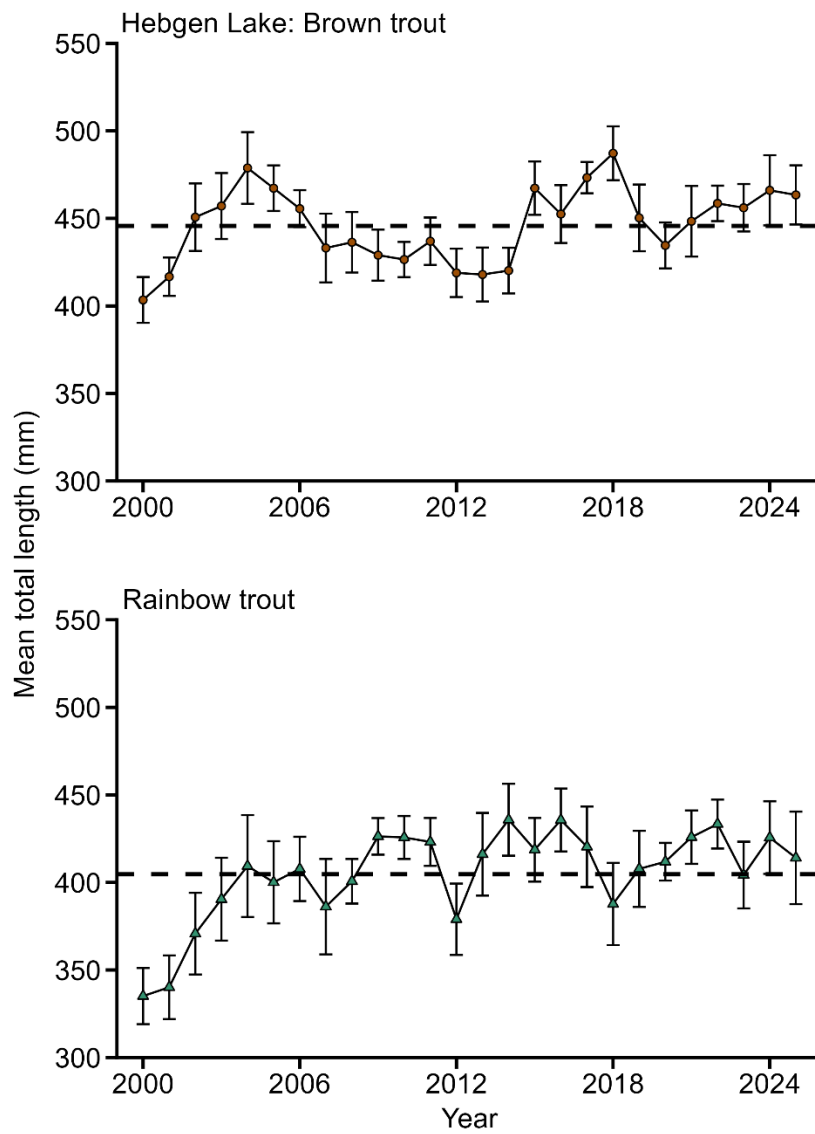


Figure 3. Mean total length (mm) of Brown (brown circles) and Rainbow Trout (green triangles) captured in Hebgen Reservoir from 2000 to 2025. The dashed lines represent the long-term average total length from 2000 to 2025, and error bars represent 95% confidence intervals for each year.

Article 412–1) Effects of Project Operations on Ennis Reservoir Fish Populations:

FWP historically monitored the Ennis Reservoir fish assemblage with biennial fall gill netting surveys on odd years. New gill net locations were established in 2021 to increase sampling efficacy while eliminating gill net sets in shallow habitats with poor capture efficiencies. FWP now sets six multi-panel, experimental gillnets in Ennis Reservoir. Catch-per-unit-effort is calculated as the average number of each species per night:

$$\frac{C}{E}$$

Where C represents the total number of fish and E represents one net night.

In 2024, FWP completed the fourth consecutive year of sampling using the new sampling design. Therefore, FWP reverted to biennial sampling, and the next sampling event will occur in 2026.

the mean catch-per-unit-effort (CPUE) of total trout, brown trout, and rainbow trout were above the long-term averages (Figure 4) in 2024. Total trout CPUE increased from 13 trout/net in 2023 to 18 trout/net in 2024. The mean total length of brown trout decreased from 430 to 419 mm, exceeding the long-term average of 399 mm. The mean total length of Rainbow trout decreased from 390 to 370 mm (Figure 5).

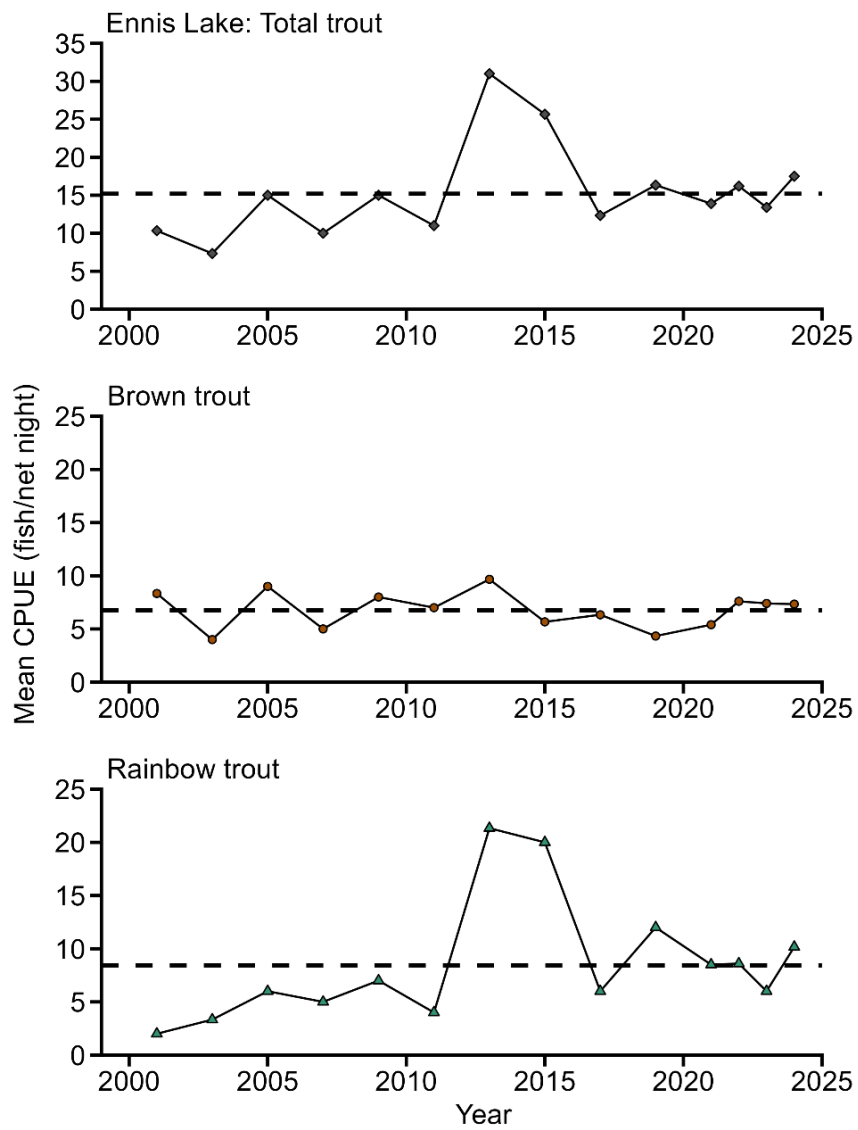


Figure 4. Mean catch-per-unit-effort (CPUE) of total (black diamonds), Brown (brown circles) and Rainbow Trout (green triangles) captured in gill nets set in Ennis Reservoir from 2001 to 2024. Brown and Rainbow Trout mean CPUE and were calculated using all nets set from each year.

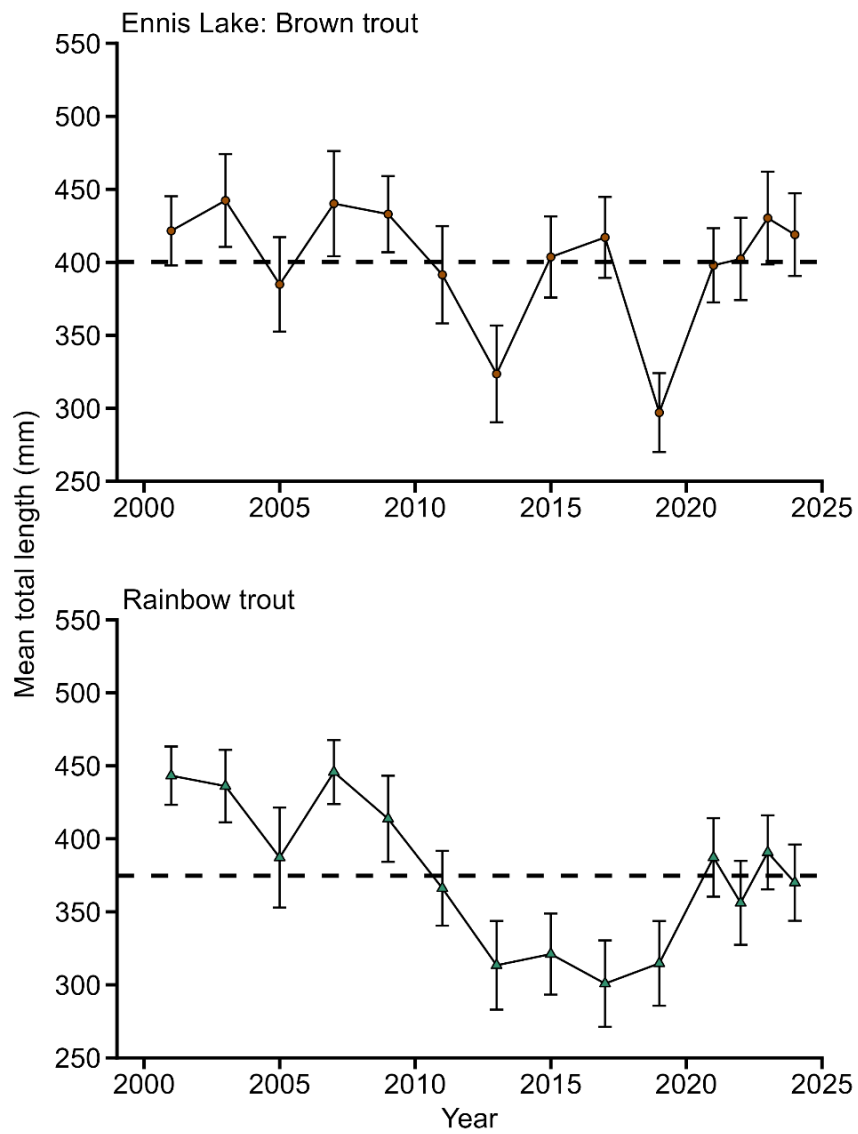


Figure 5. Mean total lengths (mm) of Brown (brown circles) and Rainbow Trout (green triangles) in Ennis Lake from 2001 to 2024. Dashed black lines represent the long-term average total lengths of each species and vertical bars represent the 95% confidence intervals for mean lengths each year.

408-3) Reservoir Draw Down Effects on Fish:

The interactions between Hebgen Reservoir elevation and operations, trophic status, and the trout populations had been assessed annually by FWP from 2006-2020. Sampling occurred in June, July, and August, because these months correspond with the emigration of juvenile trout from natal tributaries to Hebgen Reservoir and their recruitment to the fishery, may be influenced by reservoir conditions at the time of emigration (Watschke 2006, Clancey and Lohrenz 2007, Clancey and Lohrenz 2008, Clancey and Lohrenz 2009). Reservoir elevation may influence juvenile trout growth and recruitment by altering the amount of shoreline habitat and zooplankton abundances. Fluctuating reservoir elevations can impoverish the plankton assemblage through the loss of nutrients, which could limit forage for juvenile trout until they can switch to macroinvertebrates or piscivory (Axelson 1961, Haddix and Budy 2005). Hebgen Reservoir has a full pool elevation of 6534.87 feet (msl) and license article 403 requires NWE to maintain reservoir elevations between 6530.26 feet and 6534.87 feet from June 20 through October 1 and reach full pool elevation by late June or early July. Given the narrow operational range and similarity in reservoir conditions among years, limnological sampling was moved to a biennial schedule in 2020 or when reservoir elevations are outside of normal operational ranges.

Article 403 of the 2188 FERC license requires NWE to maintain Hebgen Reservoir elevation above 6530.26 feet through October 1. Due to low Spring runoff amounts and drought conditions that persisted throughout the summer of 2025, NWE requested a temporary modification to this requirement on September 10, 2025, to drop the reservoir elevation below 6530.26 prior to October 1. The temporary modification was approved by the TAC partners and NWE was able to maintain downstream flows above minimum requirements stipulated in Article 403. Because reservoir elevation was above 6530.26 until September 16, 2025, FWP determined limnological sampling was unnecessary; the deviation occurred too late in the year for comparison to previous years. FWP will next complete limnological sampling in 2026.

408-4) Monitor the Effects of Modified Project Operations on Upper Madison River Fish Populations-Madison River Fisheries Assessment:

Montana Fish, Wildlife & Parks monitors Rainbow and Brown Trout abundances in three long-term trend sections of the Madison River to evaluate the influence of modified project operations at Hebgen and Madison dams on the trout fisheries. This report is limited to a discussion of potential influences of project operations; however, other potential population drivers (e.g., angling pressure, disease) are hypothesized to be influential and thus are evaluated independently by FWP. Crews conducted mark-recapture surveys in three long-term monitoring sections (Pine Butte, Varney, and Norris; Figure 1) to estimate trout abundances. Trout were collected by electrofishing from a drift-boat mounted, mobile anode system. Trout captured in the initial sampling events (marking runs) were anesthetized, weighed (g), measured to total length (mm), marked with a fin clip or tagged, and released. Crews conducted additional sampling events (recapture runs) 7 – 10 days after the marking runs. Trout captured on the recapture runs were measured to total length, examined for existing fin clips or tags, and weighed (if not a recapture). Length-class specific abundance estimates were generated for Brown and Rainbow Trout using an R-based, proprietary FWP fisheries database and analysis tool. Capture histories for the recapture events were generated for each trout i where $y_i = 0$ represented a trout that was not a recapture and $y_i = 1$ represented a trout that was a recapture. We modeled this binary outcome using a generalized linear model with a Bernoulli distribution and a logit link function:

$$y_i \sim \text{Bernoulli}(p_i)$$

where p_i represents the detection probability for fish i . We compared four models for p_i :

- | | |
|--------------------------------------|---|
| 1) Null model: | $\text{logit}(p_i) = \beta_0$ |
| 2) Length linear: | $\text{logit}(p_i) = \beta_0 + \beta_1 \text{length}. \text{bin}_i$ |
| 3) Length quadratic | $\text{logit}(p_i) = \beta_0 + \beta_1 \text{length}. \text{bin}_i + \beta_2 \text{length}. \text{bin}_i^2$ |
| 4) Length quadratic fixed intercept: | $\text{logit}(p_i) = -5 + \beta_1 \text{length}. \text{bin}_i + \beta_2 \text{length}. \text{bin}_i^2$ |

We used Aikikes information criterion to determine the best-fitting model (Akaike 1998) and predicted detection probabilities (p_i) for each length bin i using weighted model averages. We summed the abundance estimates for each length bin to estimate total abundance (\hat{N}). Abundance estimates were standardized to densities using the section length (miles):

$$\frac{\hat{N}}{L}$$

where L represent the section length.

Management Objectives

FWP developed management objectives for total trout densities (trout ≥ 252 mm [$\approx 10''$] per mile) and size structures (percentages of trout ≥ 252 mm that are also ≥ 406 mm [$\approx 16''$]; Table 1) for each long-term monitoring section using the 66th percentiles of data collected from 2000 – 2020. Evaluating PM&E (Protection, Mitigation, and Enhancement) activities and management actions (e.g., flushing flows) in the context of these objectives provides a better understanding of how they influence the Madison River trout fishery relative to other potential population drivers.

Table 1. Montana Fish, Wildlife, and Parks management goals for trout densities and size structures in three long-term monitoring sections of the Madison River.

Site	Management objectives	
	Density (trout ≥ 252 mm /mile)	Size Structure (Proportion of trout ≥ 252 mm that are also ≥ 406 mm)
Pine Butte	2,300	25%
Varney	1,200	35%
Norris	2,500	15%

Pine Butte

The estimate of Rainbow Trout ≥ 152 mm per mile increased from 2,848 in 2024 to 3,300 in 2025 (Figure 6), exceeding the 26-year average of 2,360. Younger age classes composed a large proportion of the sampled 2025 population, with high frequencies of Rainbow Trout ≤ 252 in our catch (Figure 7). The estimate of Brown Trout ≥ 152 mm per mile in Pine Butte decreased from 2,066 in 2024 to 1,620 in 2025, falling slightly below the 26-year average of 1,962 (Figure 6). The high proportion of Brown Trout ≤ 252 observed in 2024 appears to have led to strong recruitment, with slightly higher frequencies of Brown Trout ≥ 252 mm observed in 2025 (Figure 7).

Varney

The estimate of Rainbow Trout ≥ 152 mm per mile decreased from 1,950 in 2024 to 1,513 in 2025 but remains above the 26-year average of 1,311 (Figure 6). High frequencies of Rainbow Trout ≤ 252 mm indicate a strong year class recruited to the sampling gear (Figure 8), indicating strong juvenile trout production in this section. Brown Trout density estimates decreased from 1,425 trout/mile in 2024 to 1,203 trout/mile in 2025 (Figure 6). High frequencies of Brown Trout ≤ 252 mm indicate consistent production in this section.

Norris

Estimates of trout ≥ 152 mm per mile remain at near-historical lows in Norris despite minor increases in both Brown and Rainbow Trout densities (Figure 6). The estimated density of Rainbow Trout ≥ 152 mm increased from 625 trout/mile in 2024 to 768 trout/mile in 2025. The truncated and inconsistent length-frequency histograms of Rainbow Trout in recent years (Figure 13) indicate a decline in Rainbow Trout recruitment and survival compared to populations observed in the 2000s and 2010s. However, a strong year class recruited to the sampling gear in 2025 (Figure 9). Brown Trout densities increased from 625 trout/mile in 2024 to 768 trout/mile in 2025 (Figure 6). Length frequencies of Brown Trout in recent years show a similar pattern to Rainbow Trout, with inconsistent frequencies of trout ≤ 252 mm and ≥ 406 mm occurring between 2024 and 2025 (Figure 9).

These results indicate the need for continued management intervention to increase habitat complexity and refuge for brown and rainbow trout in this section.

Management Objectives

FWP did not meet management objectives for trout densities in any section in 2025. Densities of trout ≥ 252 mm increased in the Pine Butte and Norris sections but decreased slightly in the Varney section (Figure 10). FWP only met size structure objectives for fish ≥ 406 mm in the Norris section; however, Pine Butte and Varney remain only slightly under the size structure objectives (Figure 11).

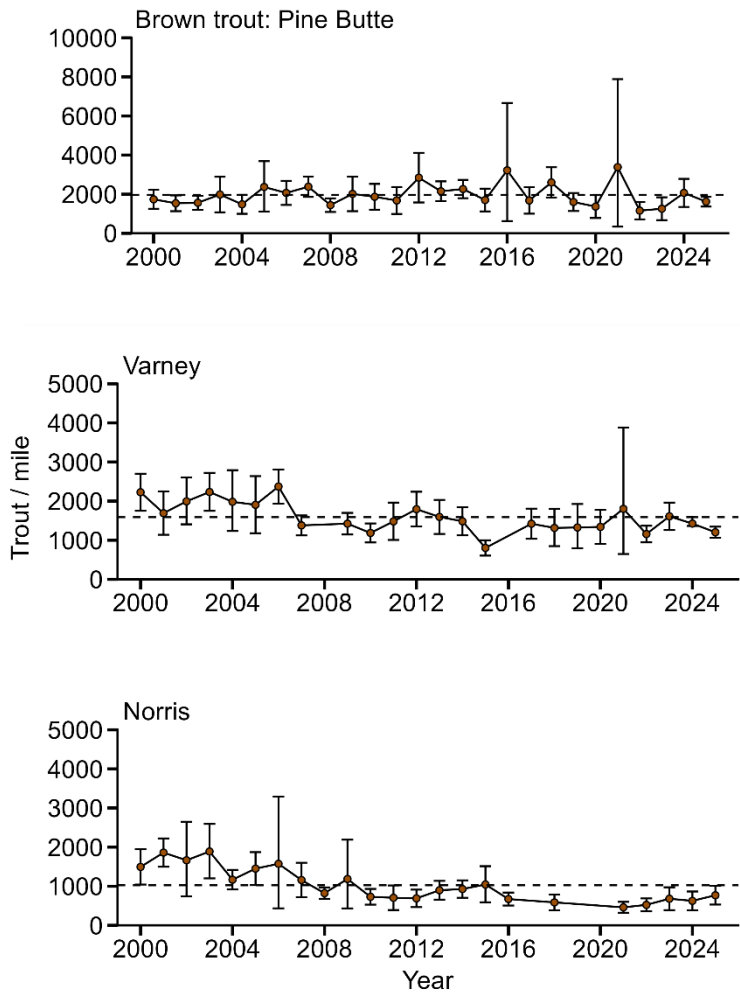
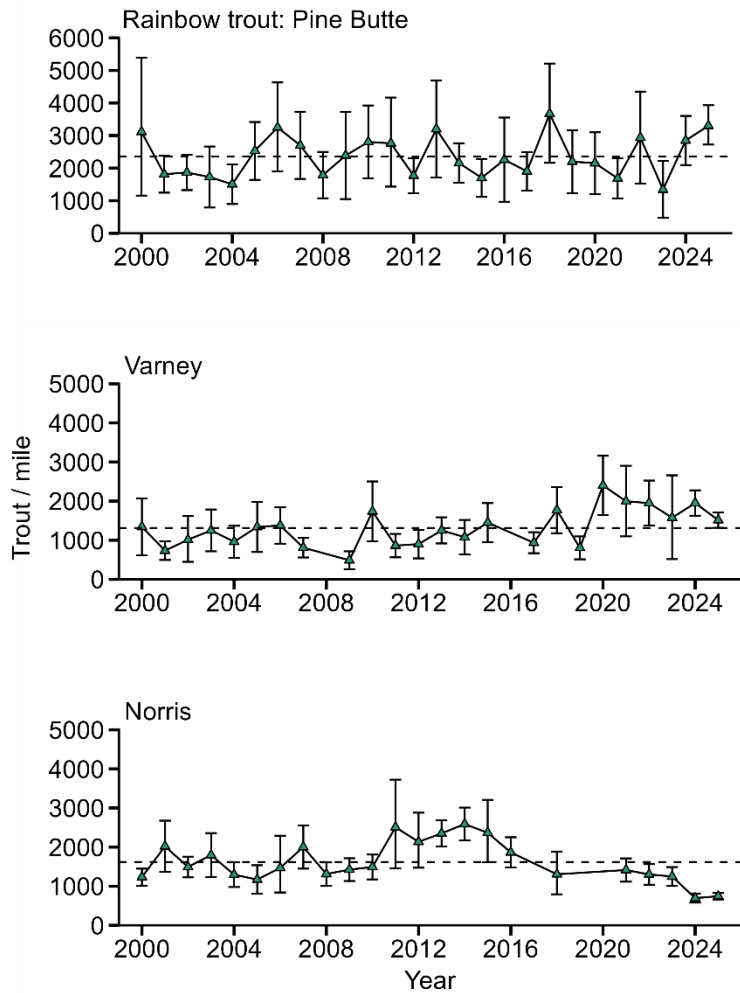


Figure 6. Estimated abundances of Brown (brown circles) and Rainbow Trout (green triangles) ≥ 152 mm ($\sim 6''$) in the three long-term sampling sections of the Madison River. Dashed lines represent the long-term average trout abundance (2000 to 2025), and error bars represent 95% confidence intervals. *We used 200 mm as the minimum size to calculate trout abundances in the Norris reach in 2024.

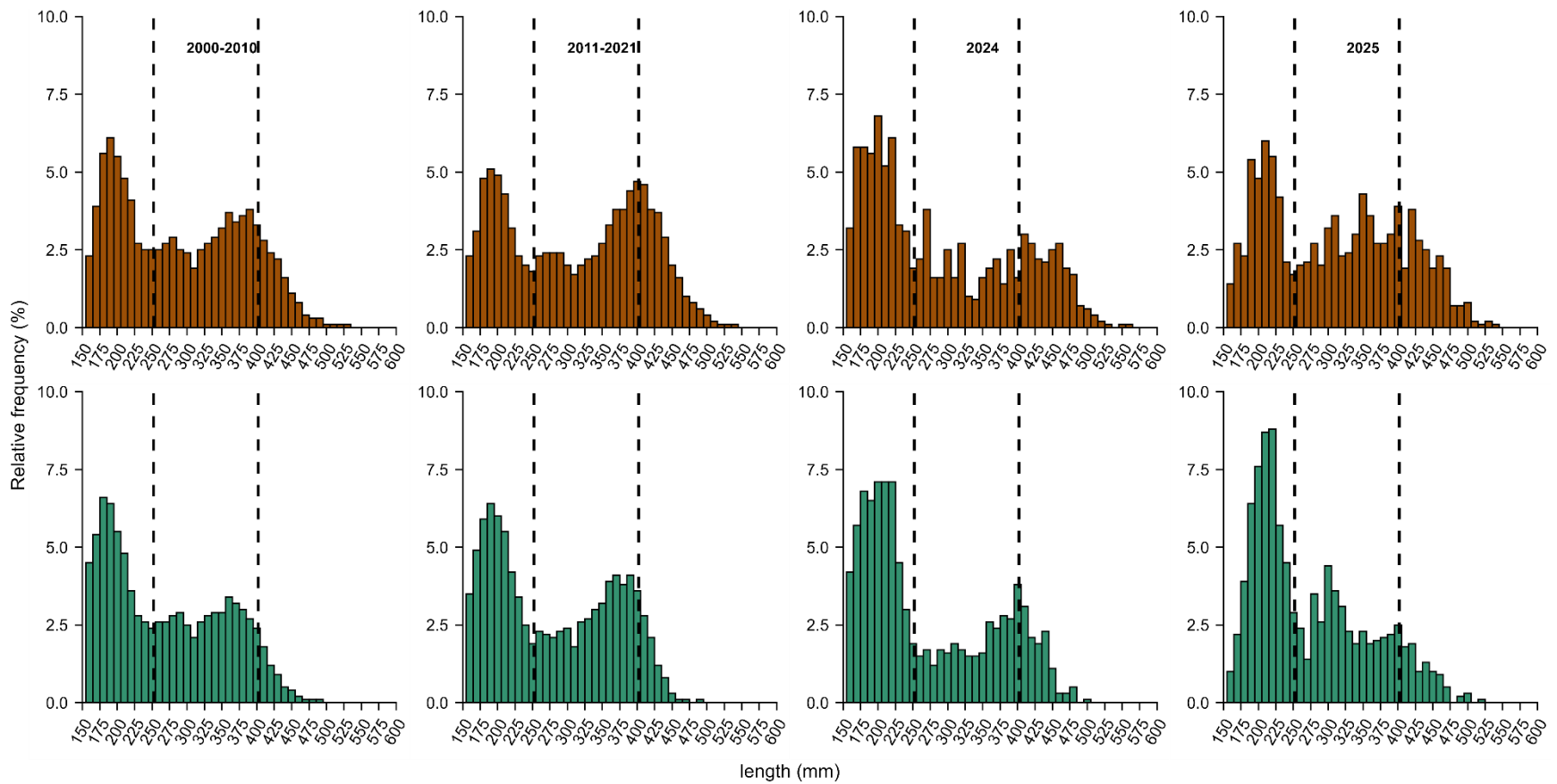


Figure 7. Length frequency histograms of Brown (brown bars) and Rainbow Trout (green bars) ≥ 152 mm ($\approx 6''$) captured in the Pine Butte Section of the Madison River. Black dashed lines delineate 252 mm ($\approx 10''$) and 406 mm ($\approx 20''$).

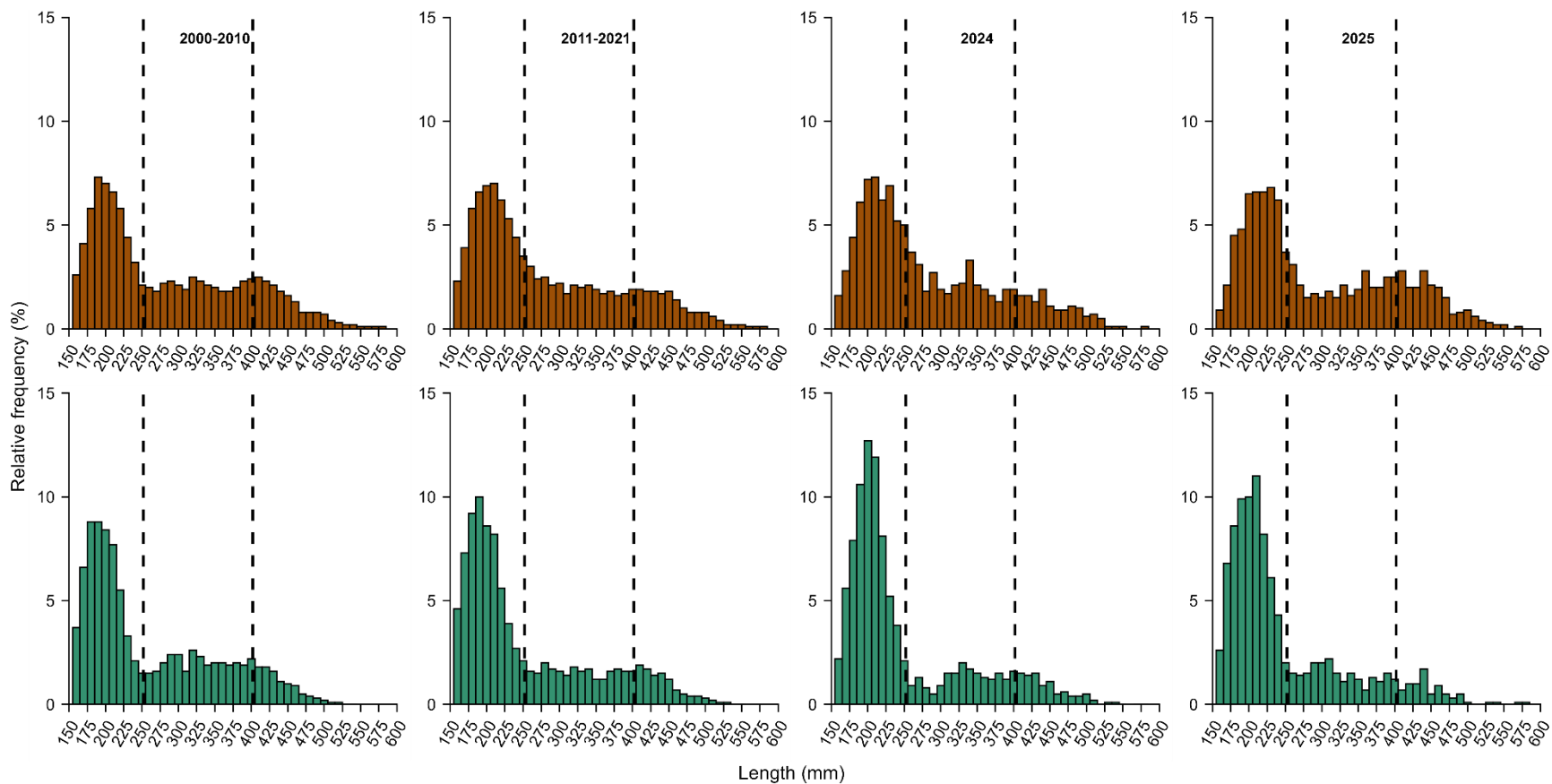


Figure 8. Length frequency histograms of Brown (brown bars) and Rainbow Trout (green bars) ≥ 152 mm ($\approx 6''$) captured in the Varney Section of the Madison River. Black dashed lines delineate 252 mm ($\approx 10''$) and 406 mm ($\approx 20''$).

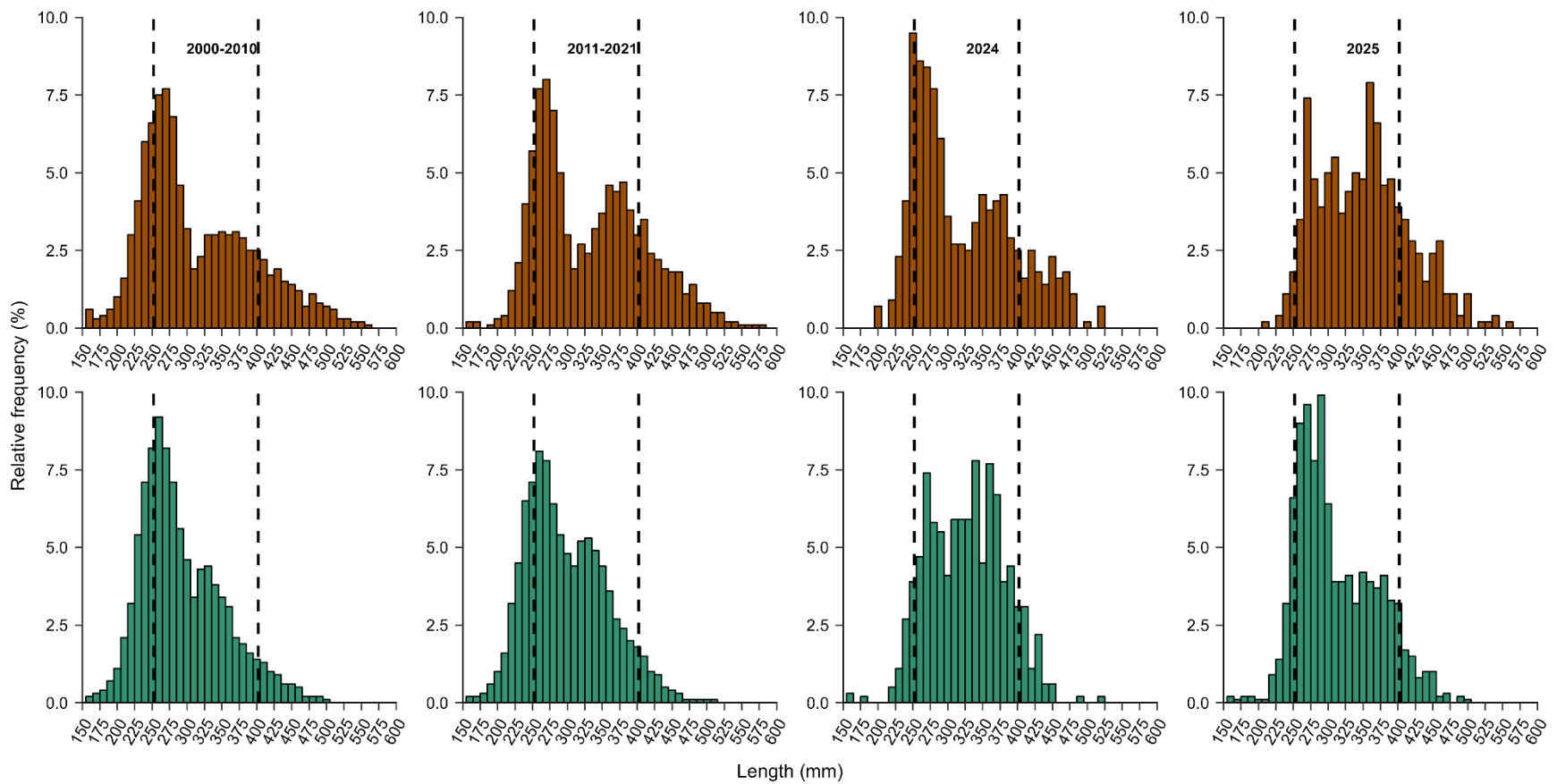


Figure 9. Length frequency histograms of Brown (brown bars) and Rainbow Trout (green bars) ≥ 152 mm ($\approx 6''$) captured in the Norris Section of the Madison River. Black dashed lines delineate 252 mm ($\approx 10''$) and 406 mm ($\approx 20''$).

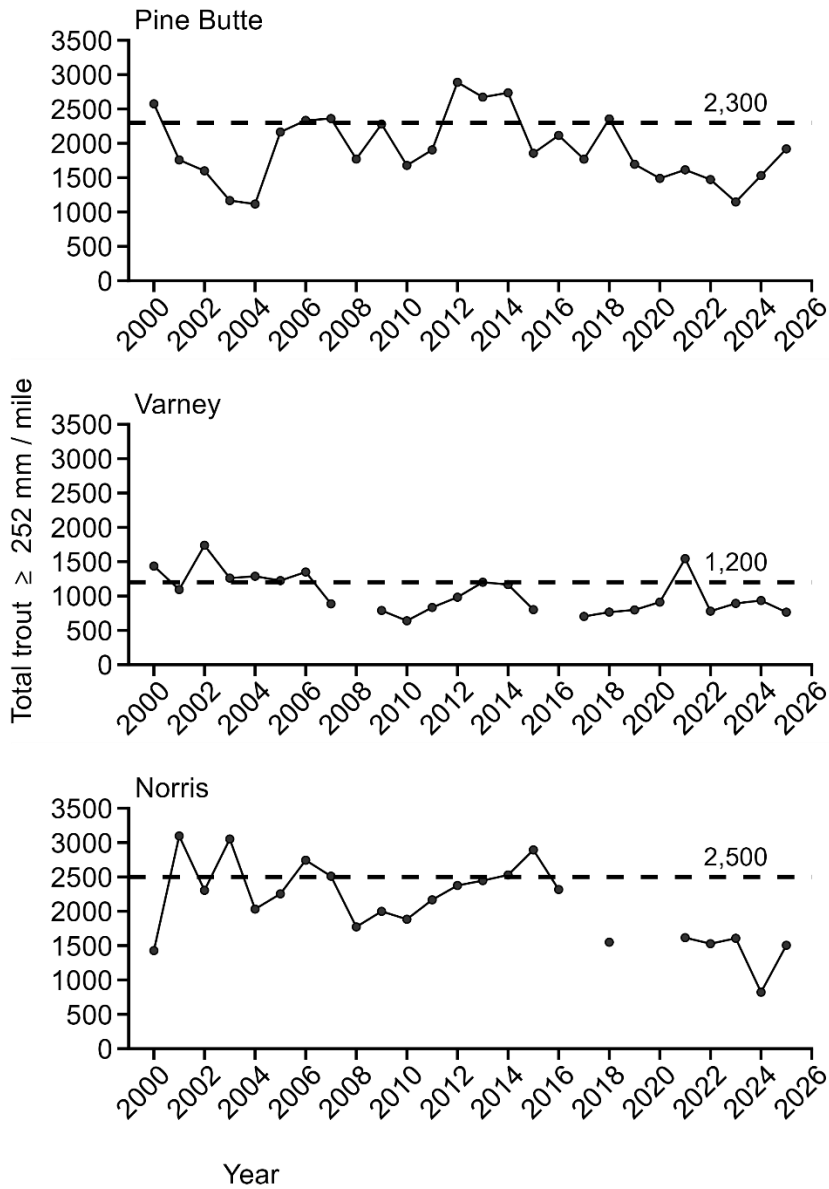


Figure 10. Estimated abundance of all trout ≥ 252 mm (~ 10 ") in three long-term monitoring sections of the Madison River. Black dashed lines represent the management goals for trout abundance in each section.

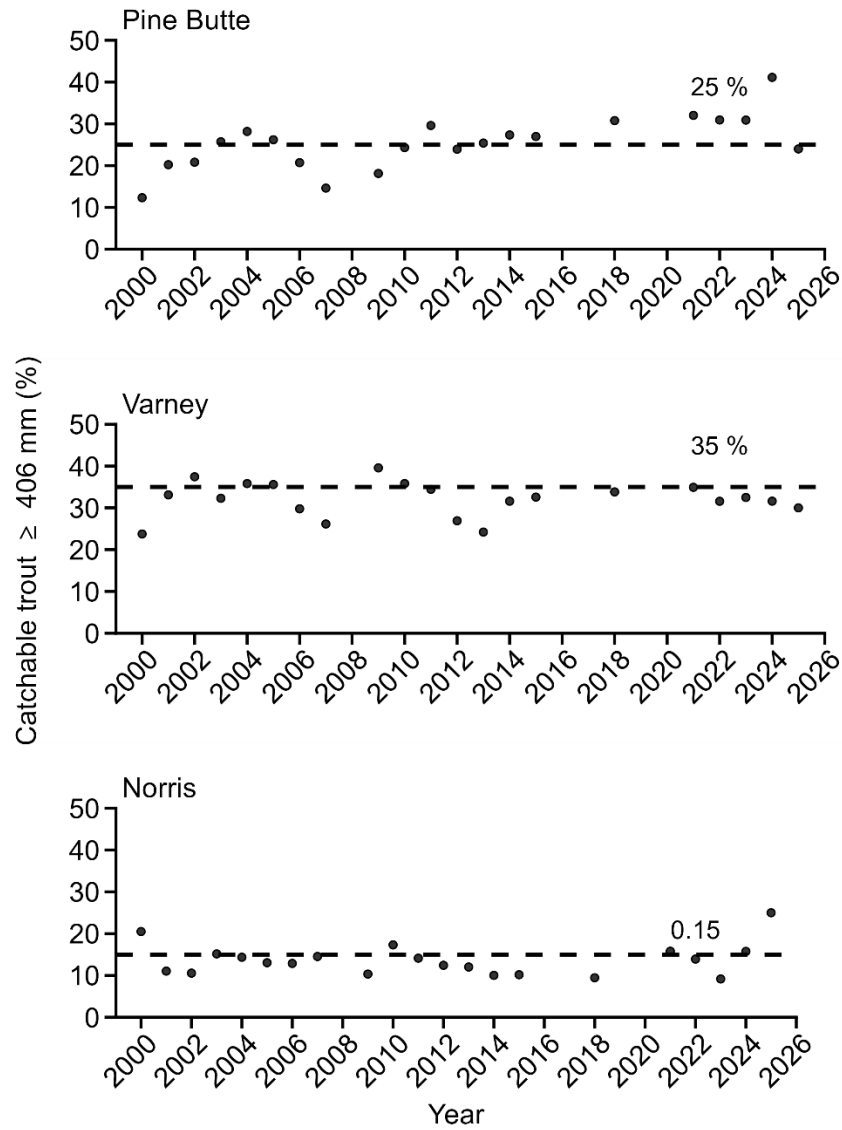


Figure 11. Estimated abundance of all trout ≥ 252 mm ($\sim 10''$) in three long-term monitoring sections of the Madison River. Black dashed lines represent the management goals for trout abundance in each section.

408-7) Monitor Species of Special Concern; Madison Arctic Grayling; Westslope Cutthroat Trout:

Opportunities to recover, conserve, and expand native fish distributions are regularly pursued by FWP and partner agencies. NWE is committed to implementing PM&E measures under Articles 408, 409, and 412 of the 2188 FERC License from Hebgen Reservoir to Three Forks, Montana to mitigate adverse effects to native fish species associated with Madison Project operations (FERC 2000).

Arctic Grayling

Goals and objectives for the conservation and reestablishment of viable Arctic Grayling populations are defined in The Upper Missouri River (UMR) Arctic Grayling Conservation Strategy (MAGWG 2022). The strategy calls for the establishment of two viable grayling populations in Hebgen Reservoir and its tributaries. Previous efforts to reestablish populations in the Madison River below Hebgen Dam have been unsuccessful; however, the removal of non-native fish from Grayling Creek and the Gibbon River, and low densities of Brown Trout in the upper South Fork Madison, present opportunities for the reestablishment of viable populations in the Madison River drainage above Hebgen Reservoir (Figure 12). Reintroduction efforts will require using a minimum of 500,000 grayling embryos and fry per year from fish of primarily Madison genetic ancestry for 3-5 consecutive years.

In 2025, 1.2 million Arctic Grayling embryos were introduced into Black Sand Spring, a tributary to the South Fork Madison River. Since 2021, 2.85 million embryos and 84,000 fry of primarily Madison genetic origin have been introduced in Black Sand Spring (Table 2). Introduction methods have included the use of RSI's (Remote Site Incubators) and simulated broadcast spawning. FWP has been evaluating the differences in embryo survival between the two methods of introduction for the last three years. The complete study design and results are described in Appendix B. FWP will continue to stock Arctic Grayling eggs and fry in Black Sand Spring in 2026.

Table 2. Summary of ARG stocking in Black Sand Spring from 2021-2025. Source is location of ARG used for spawning, eggs are number of eggs collected from spawning, Average-survival to emergence rates are calculated including both spawning methods with 95 CI in (), Fry stocked = (Eggs * Average Survival-to-emergence rate).

Year	Source	Eggs	Average survival-to-emergence	Fry stocked
2021	Axolotl/Green Hollow	150,000		
2022	Axolotl/Green Hollow	500,000		
2023	Rogers/Green Hollow	794,000	0.05 (0.0,0.12)	39,700
2024	Park	218,000	0.32 (0.15,0.49)	69,760
2025	Rogers	1,200,000	0.08 (0.02,0.15)	96,000

In June 2025, FWP Field staff sampled approximately 9 miles of the South Fork Madison River to the mouth of Hebgen and conducted night electrofishing in the South Fork Madison Arm of Hebgen to determine whether Arctic Grayling from previous stocking efforts were present; however, no Arctic Grayling were observed. FWP also collected eDNA samples in October to assess Arctic Grayling presence in Black Sand Spring. The results from the eDNA samples are still pending.

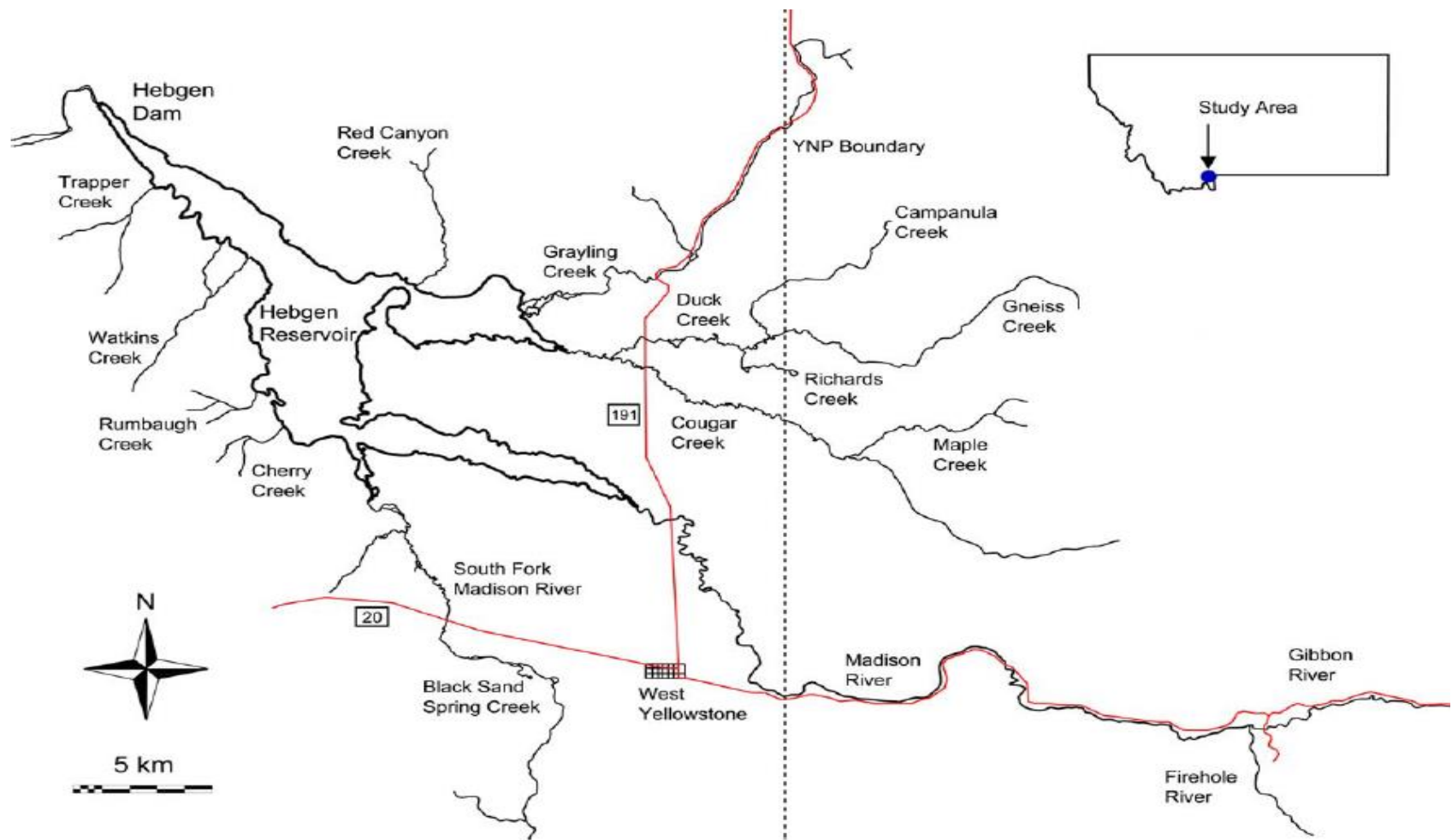


Figure 12. Map of the tributaries to Hebgen Reservoir.

Despite the absence of Arctic Grayling, catch-per-unit-effort (CPUE) of Brown Trout, Rainbow Trout, and Mountain Whitefish was assessed in the South Fork Madison River. The CPUE was 35 fish per mile above Black Sand Springs to Highway 20 (9.9-7.0 RM), while the section from Highway 20 to Hebgen Reservoir (6.2-1.8RM) was 72 fish per mile (Table 3). Brown Trout CPUE was similar between the two sections with 26 fish per mile above and 22 fish per mile below Highway 20. CPUE for Rainbow Trout and Mountain Whitefish was higher in the section downstream of Highway 20 (Table 3). Analysis of relative length frequencies of fish captured during the CPUE sampling showed higher proportions of juvenile trout than older age classes (Figure 13). In contrast, few juvenile Mountain Whitefish were captured, with most Mountain Whitefish ranging in size from 400-500mm.

Table 3. Summary table of Catch-Per-Unit-Effort (CPUE) for sampling conducted on the South Fork Madison River in two sections, Above Black Sand Springs to Highway (9.9-7.0 RM) and Highway to Hebgen Reservoir (6.2-1.8RM). Species are Eastern Brooke Trout (EB), Brown Trout (LL), Rainbow Trout (RB), and Mountain Whitefish (MWF). CPUE was calculated by distance (miles).

Section	Species	CPUE (C/f per mile)
Above Black Sand Springs to Highway 20	LL	26
	RB	8
	MWF	1
Highway 20 to Hebgen	LL	22
	RB	13
	MWF	37

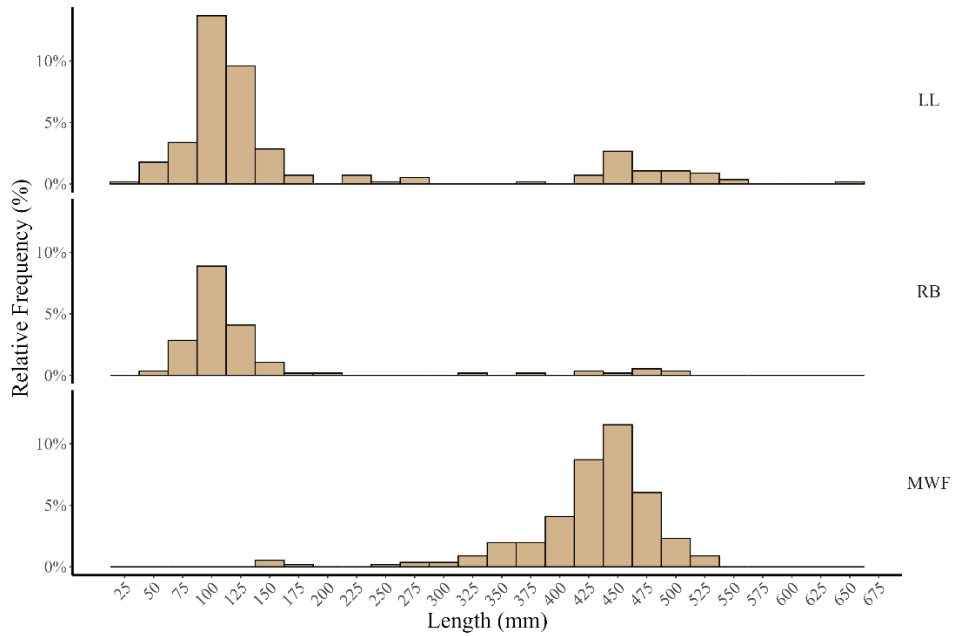


Figure 23. Relative length frequency histograms of Brown Trout (LL), Rainbow Trout (RB), and Mountain Whitefish (MWF) sampled in the South Fork Madison River in June of 2025. Length is measured in millimeters (mm).

Westslope Cutthroat Trout

FWP’s Statewide Fisheries Management Plan calls for the protection and reintroduction of WCT conservation populations (i.e., populations with less than 5% hybridization by non-native fish) to 20% of historically occupied waters (Montana Statewide Fisheries Management Program and Guide 2018). To help facilitate and direct WCT conservation efforts, several state, federal, and non-government agency partners formalized the Westslope Cutthroat Trout Conservation Strategy for the Missouri Headwaters of Southwest Montana in 2022 (Jaeger et al. 2022). The strategy identifies the status and conservation actions needed to protect and restore WCT to 20% of historically occupied tributaries in each of the nine subbasins that comprise the Missouri Headwaters (Beaverhead, Big Hole, Boulder, Gallatin, Jefferson, Madison, Red Rock, Ruby, and Upper Missouri). Revised assessments of WCT conservation populations in the Madison River sub-basin indicate they currently inhabit 14% of historically occupied tributaries and only 23% of the identified populations are considered secure (isolated from non-native fishes, typically by a physical barrier, have a population >2,500 fish >75mm, and occupy enough habitat to ensure long-term persistence).

Westslope cutthroat trout conservation efforts in 2025 included updating the demographic status of the Wall Creek WCT population, Horse Creek WCT population genetic rescue, conducting a non-native fish removal project in Elk Creek, and surveying candidate streams for future WCT expansion projects in the Madison sub-basin.

FWP estimated Wall Creek WCT abundance by conducting 100-meter depletion estimates using a backpack electro-fisher at two sites within the drainage. Successive electrofishing passes were conducted until the number of fish captured during a pass was 50% or less than the number collected during the

previous pass. Fish collected during each pass were held in separate live cars below the sampling reach. Once sampling criteria were met, all fish were enumerated, measured (mm), and a fin clip was taken for genetic analysis. Estimates were produced using an R-based proprietary FWP fisheries database and analysis tool. WCT average abundance in Wall Creek is 21 fish per 100 m (95% CI: 14,19) with an overall population of 2,400 fish.

In October 2025, FWP field staff moved 8 fish from the Ruby Creek WCT population into the Horse Creek WCT population to improve the genetic diversity of the Horse Creek population. The Horse Creek population was recently identified as a core (> 99%) WCT population in danger of extirpation due to small population size, limited habitat, and the threat of hybridization. FWP will continue to monitor population status and needs based on the WCT Strategy.

The first year of piscicide treatment on Elk Creek was conducted in August of 2025 to remove non-native Eastern Brook Trout from the system. A wooden barrier on Elk Creek was constructed in the fall of 2024 with MadTAC funding. The barrier protects 8 miles of habitat for an unaltered WCT population isolated in the headwaters of the Elk Creek drainage (Figure 14). The second year of treatment will occur in 2026.



Figure 14. Elk Creek barrier and detoxification station during a piscicide treatment in August 2025.

In 2024 and 2025, FWP coordinated the evaluation of eighteen streams in the Madison sub-basin identified as potential candidates to restore WCT to 20% of their historic distribution. Population expansion projects typically involve barrier construction, non-native fish removal, and repopulating WCT from donor streams. Currently, 88 miles of WCT restoration is needed to meet the objective of 20% historic distribution.

Article 409- 3) Fish habitat enhancement both in mainstem and tributary streams:

With the development of Hebgen Dam in 1917, gravel recruitment replenish downstream spawning habitats was greatly diminished. The 1959 earthquake and subsequent landslide that impounded the Madison River provided a new source of gravel; however, the river has since incised through the material left by the slide leaving it largely inaccessible to recruitment under normal operations. The scarcity of gravel sources is further exacerbated by the downstream loss of existing gravel into Ennis Lake due to the ability of the river to mobilize the D50 of the active streambed 59 to 364 days a year, a process that typically only occurs 7 to 14 days a year in unregulated systems (Pioneer Technical Services 2022).

Complex habitat features such as islands can serve as reservoirs of gravel for the replenishment and creation of spawning habitat; additionally, the passive edges of islands and side channels provide areas of reduced velocity where spawning gravels are often retained and fish can find refugia from predators and temperature extremes. Habitat or cover (e.g., boulders, large woody debris, undercut banks) have been correlated with trout abundance (Binns and Eiserman 1979; Varley and Gresswell 1988; Molony 2001). An examination of mainstem Madison River habitat features (boulders, islands, and side channels) on trout abundance, conducted by FWP in 2021, showed a suggestive positive relationship between island and side channel density and the abundance of trout >16" (Lohrenz et al. 2021). While the relationship between these features and juvenile trout was not investigated, relative abundances of young-of-the-year and Age-1 salmonid are frequently linked to complex habitats like islands and side channels because they are commonly used for rearing and overwintering (Meehan, W. R. 1991; Swales et al. 1986).

Norris Island and Habitat Enhancement

The Norris Reach is a single-thread channel with interspersed islands that are undergoing a gradual reduction in area (Figure 15). From 1995 to 2021 an estimated net loss of 0.1 acres of island margin habitat has occurred causing an overall reduction in habitat heterogeneity and condition (Pioneer Technical, 2021). Diminishing spawning and rearing habitats have likely contributed to the historically low abundances of trout ≥ 152 mm in the Norris reach. To help mitigate the loss of spawning habitat and improve general habitat conditions for fish production and recruitment to the mainstem fishery, FWP and NWE implemented a habitat enhancement project on the lower Madison River near Warm Spring FAS. Habitat improvements included island expansion and the creation of a 1,000 ft side channel for spawning and rearing trout (Figures 16-22). FWP and its partners anticipate the improvements will help bolster trout abundances in the Norris reach.



Figure 15. Comparison of island loss from the 1950s through 2021 in the Norris reach (Pioneer Technical 2021).



Figure 17. Photo of island before expansion.



Figure 18. Photo of island during expansion.



Figure 19. Photo of island after expansion was completed.



Figure 20. Photo showing side channel construction.



Figure 21. Photo showing a section of the completed side channel.



Figure 22. Photo the completed Norris Island and habitat enhancement project.

Norris Island and Habitat Enhancement Monitoring

To evaluate the success of the Norris Island habitat enhancement project FWP will be implementing a monitoring plan to determine whether 1) juvenile trout abundance increases due to increased shoreline length and improvements to habitat complexity after island and bank construction, 2) island construction improves spawning habitat quality and increases spawner densities, and 3) habitat improvements lead to increased recruitment to the mainstem fishery. FWP anticipates monitoring the project through 2028.

- 1. Determine whether juvenile trout abundance increases due to increased shoreline length and improvements to habitat complexity after island and bank construction.**

To evaluate the effect of the project on juvenile trout abundance, mark recapture estimates at two selected control sites and in the treatment area will be made before and after project implementation. Juvenile trout will be collected using backpack electrofishing gear. During the marking run, captured fish will be marked with a fin clip, PIT tagged, released back into the water and allowed to redistribute for 3 days, after which a recapture run will be made. Fish collected during the recapture run will be examined for a fin clip and their capture history recorded as 0 (not captured during the marking run) or 1 (previously

handled during the marking run). Abundance estimates will be calculated using the Peterson method and estimated to fish/linear foot of streambank using the following equation.

$$N = \frac{M \times C}{R}$$

Where:

- N = estimated total population size
- M = number of individuals initially marked
- C = total number of individuals captured in the second sample
- R = number of individuals recaptured in the second sample

2. Determine whether island construction improves spawning habitat quality and increases spawner densities.

To determine whether spawning habitat quality improves within the project area, five core samples will be taken prior to and following project implementation. Core samples will be collected with a 12-inch McNeil core sampler in substrate identified as spawning habitat. The core sampler will be drilled into the substrate to a depth of 8". Collected substrate will be removed, dried, and sorted using a sieve method. The percent composition of the sample will be calculated according to particle size and percent composition will be compared through time.

Redd counts will be completed in spring and fall to document both Rainbow and Brown Trout use of the area. Redd counts will be completed by walking upstream and identifying streambed disturbances consistent with redd morphology. A typical redd consists of a pit where gravel was excavated with a mound (tail spill) immediately downstream of the pit. The number and location of individual redds within the monitoring section will be recorded and the number of redds per unit area calculated.

3. Determine whether habitat improvements lead to increased recruitment to the mainstem fishery.

Analysis of Brown Trout and Rainbow Trout abundance estimates from long term monitoring data will be used to determine effects of the project on recruitment to mainstem fishery. We will compare abundances through time for the specific subsection that the island enhancement project occurred in and throughout the Norris reach. To determine if fish were produced within the project area, PIT tags will be implanted in young-of-year and juvenile fish during fall abundance estimates and, during annual abundance estimates in the Norris reach, adult trout will be scanned to determine whether they originated from the project area.

Madison River Side Channel Development

FWP and NWE, in partnership with the Madison River Foundation (MRF) and Geum Environmental Consulting, are working towards implementing side channel reconnection and development projects at two sites along the Madison River, Morgan Gulch and Above Hyde Creek (Figures 23) in October 2026. FWP anticipates that the projects will improve spawning and rearing conditions for trout and increase trout recruitment to the mainstem Madison River fishery.

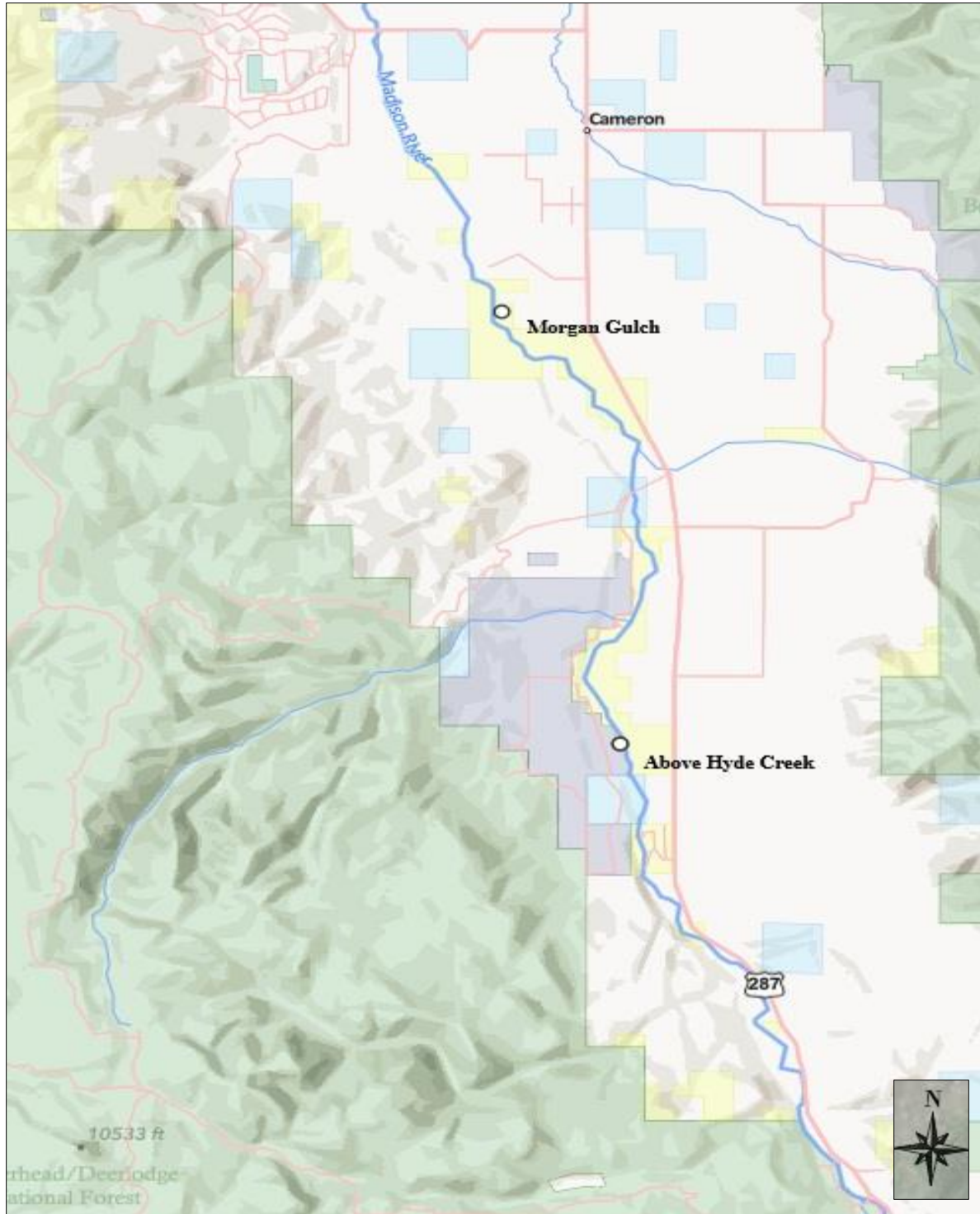


Figure 23. Map depicting the approximate locations of side channel reactivation projects on the upper Madison River scheduled for construction in the fall of 2026.

To evaluate the effects of these projects FWP developed a monitoring plan to determine whether 1) salmonid spawning and juvenile trout abundance increases as a result of increased spawning habitat and habitat complexity created by channel reactivation and 2) side channel reactivation increases trout recruitment to the mainstem Madison River fishery.

1. Determine whether salmonid spawning and juvenile trout abundance increase as a result of increased spawning habitat and habitat complexity created by channel reactivation.

Redd counts will be done in spring and fall after side channel reactivation to document Rainbow and Brown Trout use of the area. Redd counts will be completed by walking upstream and identifying streambed disturbances consistent with redd morphology. A typical redd consists of a pit where gravel was excavated with a mound (tail spill) immediately downstream of the pit. The number and location of individual redds within the monitoring section will be recorded and the number of redds per unit area calculated.

To monitor the effect on juvenile trout abundance, mark recapture estimates at a selected control site and in the treatment areas will occur before and after project implementation. Juvenile trout will be collected using backpack electrofishing gear. During the marking run, captured fish will be marked with a fin clip, PIT tagged, released back into the water and allowed to redistribute for 3 days, after which a recapture run will be made. Fish collected during the recapture run will be examined for a fin clip and their capture history recorded as 0 (not captured during the marking run) or 1 (previously handled during the marking run). Abundance estimates will be calculated using the Peterson method and estimated to fish per linear foot of streambank using the following equation.

$$N = \frac{M \times C}{R}$$

Where:

- N = estimated total population size
- M = number of individuals initially marked
- C = total number of individuals captured in the second sample
- R = number of individuals recaptured in the second sample

Pebble counts will be used to evaluate available spawning habitat in the project area. Suitable Brown Trout and Rainbow Trout spawning habitat particles typically range from 10-32mm in diameter. A 100 particle Wolman pebble count will be conducted in 5 riffles at each project site for 3 years post construction.

2. Determine whether habitat improvements lead to increased recruitment to the mainstem fishery.

FWP will establish a new monitoring section in the Madison River, from Palisades to the Ruby Creek fishing access site, within the area of side channel reactivation. Brown Trout and Rainbow Trout abundances will be estimated prior to side channel reactivation to determine effects of the project on recruitment to mainstem fishery. To assess recruitment from these projects, PIT tags implanted in

young-of-year and juvenile fish in side channels will be subsequently searched for in adult trout captured during abundance estimates in the Palisades to Ruby reach.

Article 413-Pulsed Flows

Temperature affects all aquatic organisms and fish species have specific thermal ranges that are optimal for their persistence. Exposure to extreme temperatures for extended durations can be lethal to fish. In 1988, a fish kill occurred in the Lower Madison River when temperatures reached 82.5°F. FWP and NWE have since implemented monitoring programs to mitigate the effects of high water temperatures on fish. FWP has monitored water and air temperatures throughout the Madison River basin from upstream of Hebgen Reservoir to the mouth of the Madison River at Headwaters State Park since 1993 (Figure 24). Temperature data is used by FWP to implement angling restrictions that reduce adult trout mortality during periods of thermally induced stress. Angling restrictions are implemented when the daily maximum water temperature is $\geq 73^{\circ}\text{F}$ for three consecutive days. Additionally, to mitigate high water temperatures and reduce the risk of a thermally induced fish kill in the Lower Madison River, NWE implemented the Madison Decision Support System (DSS) program. The Madison DSS program is designed to predict a pulse volume of water that will limit thermal gain to keep maximum daily water temperatures $\leq 80^{\circ}\text{F}$ at Sloan and avoid the 82.5°F lethal thermal limit of resident fish in the Lower Madison River. The Madison DSS consists of two methods to determine the pulse volume to be delivered to the Lower Madison River: a thermo-dynamic physics model (physics model) and a manual protocol. Pulsed flows are triggered when the water temperature at the Madison (Ennis) Powerhouse is 68°F or higher and the predicted air temperature at the Sloan Station (River Mile 17) near Three Forks, MT for the following day is 80°F or higher. NWE enters the maximum water temperature recorded at the McAllister USGS gage and the next day's forecasted maximum air temperature at Three Forks to the manual protocol and the physics model to derive the volume of the pulse needed for the following day with each approach (Table 4). NWE conservatively directs operations to release the larger of the two predicted pulses the following day from 6:00 am to noon. The timing of the release considers the travel time so that it arrives in the lower Madison River near Sloan Station during the late afternoon when daily solar radiation is greatest.

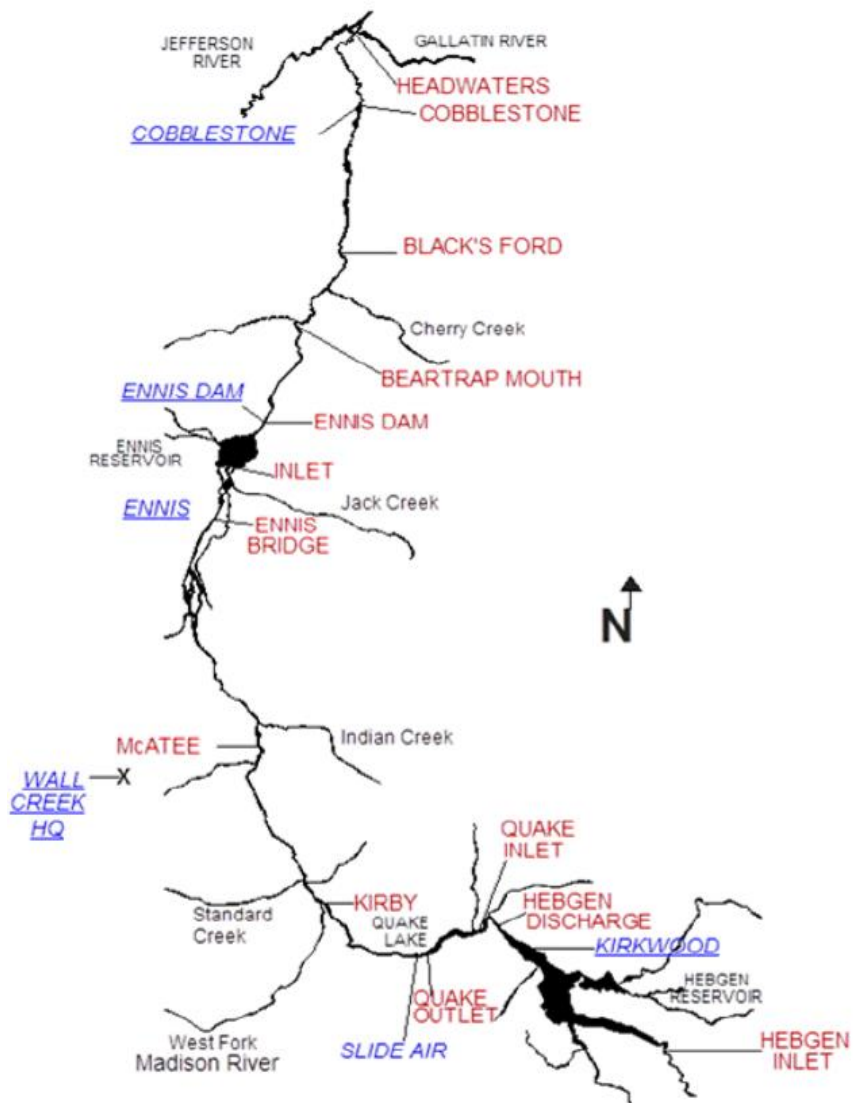


Figure 24. FWP temperature monitoring sites. Air temperature monitoring sites are blue and underlined; water temperature monitoring sites are red.

Table 4. Madison DSS Manual Protocol (Northwestern Energy 2020).

Maximum powerhouse release temperature (°F) at the Madison DSS website or USGS McAllister gage on or after 8:30 p.m.	Predicted maximum air temperature (°F) at Sloan Gage the following day and corresponding pulse flows (cfs).		
	<u>75.0—84.9</u>	<u>85.0—94.9</u>	<u>≥ 95.0</u>
68.0—68.9	1150	1150	1400
69.0—69.9	1150	1400	1600
70.0—70.9	1150	1600	2000
71.0—71.9	1400	1600	2100
72.0—72.9	1450	1800	2400
73.0—73.9	1600	2100	2800
74.0—74.9	1800	2600	3000
≥ 75.0	2600	3200	3200

Daily maximum temperatures were $\geq 73^{\circ}\text{F}$ at the lower river monitoring sites, Blacks Ford and Cobblestone, for 47 and 53 days, respectively (Table 6). Since 2000, maximum daily water temperatures at the Blacks Ford monitoring site have been $\geq 73^{\circ}\text{F}$ an average of 46 times a year causing FWP to regularly implement restrictions that prohibited angling from 2 p.m. to 12 a.m. during summer months.

In 2025, there were 52 calls for a pulse flow, but only 34 resulted in operational changes to accommodate a pulse flow. Maximum daily water temperatures reached 78.5°F at Sloan Station on August 3. Downstream of Sloan Station at the Cobble Stone FAS, water temperatures stayed below 80.0°F . (Table 5; Figure 25). Pulse flows have been implemented an average of 35 days since 2020 and have been effective at moderating maximum daily water temperatures and preventing a thermally induced fish kill in the lower river (Figure 26).

Table 5. Maximum and minimum temperatures (°F) recorded at monitoring sites in the Madison River Drainage, 2025. The mean temperature is the mean daily temperature \pm 95% confidence intervals (CI). Days \geq 73°F are the number of days daily maximum temperatures were at or exceeded 73°F, and days \geq 80°F are the number of days daily maximum temperatures were at or exceeded 80°F. NA denotes that temperature data was unable to be recovered.

Site	Max °F	Min °F	Mean daily temperature \pm 95% CI	Days \geq 73°F	Days \geq 80°F
Hebgen inlet	78.3°	40.8°	59.9° \pm 0.2°	42	0
Hebgen discharge	66.2°	37.0°	53.2° \pm 0.3°	0	0
Quake Lake inlet	NA	NA	NA	NA	NA
Quake Lake outlet	64.3°	37.2°	52.6° \pm 0.3°	0	0
Kirby Bridge	70.0°	35.2°	53.0° \pm 1.1°	0	0
McAttee Bridge	NA	NA	NA	NA	NA
Ennis Bridge	NA	NA	NA	NA	NA
Ennis Reservoir inlet	NA	NA	NA	NA	0
Madison Dam	74.2°	43.3°	60.3° \pm 0.2°	14	0
Bear Trap Mouth	NA	NA	NA	NA	NA
Blacks Ford	79.6°	42.3°	59.6° \pm 1.0°	41	0
Cobblestone	80.4°	39.8°	60.5° \pm 0.3°	42	2

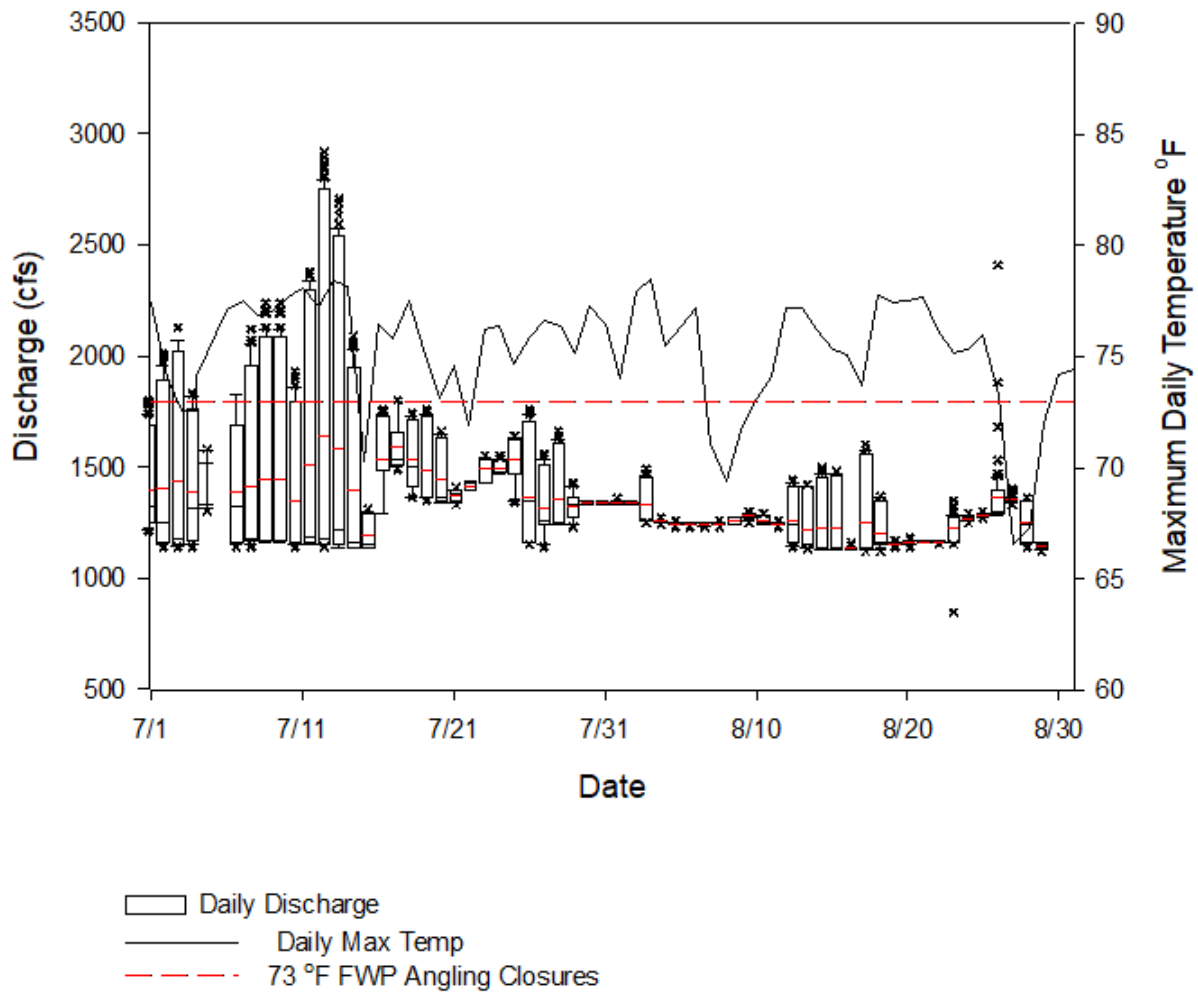


Figure 25. Daily distribution of discharges (left axis) collected every 15 minutes from July 1-Aug 31, 2025(pulse flow season) at USGS gage # 6-410 and daily maximum water temperature at Sloan (right axis). Boxes extend from the 25th to the 75th percentile and whiskers are the 5th and 95th percentile. Horizontal black lines are the median values of the groups' distribution and horizontal red lines are the mean values of the groups' distribution. X's are values outside the 5th and 95th percentiles. The red dashed line denotes the 73°F maximum used by FWP to implement angling closures.

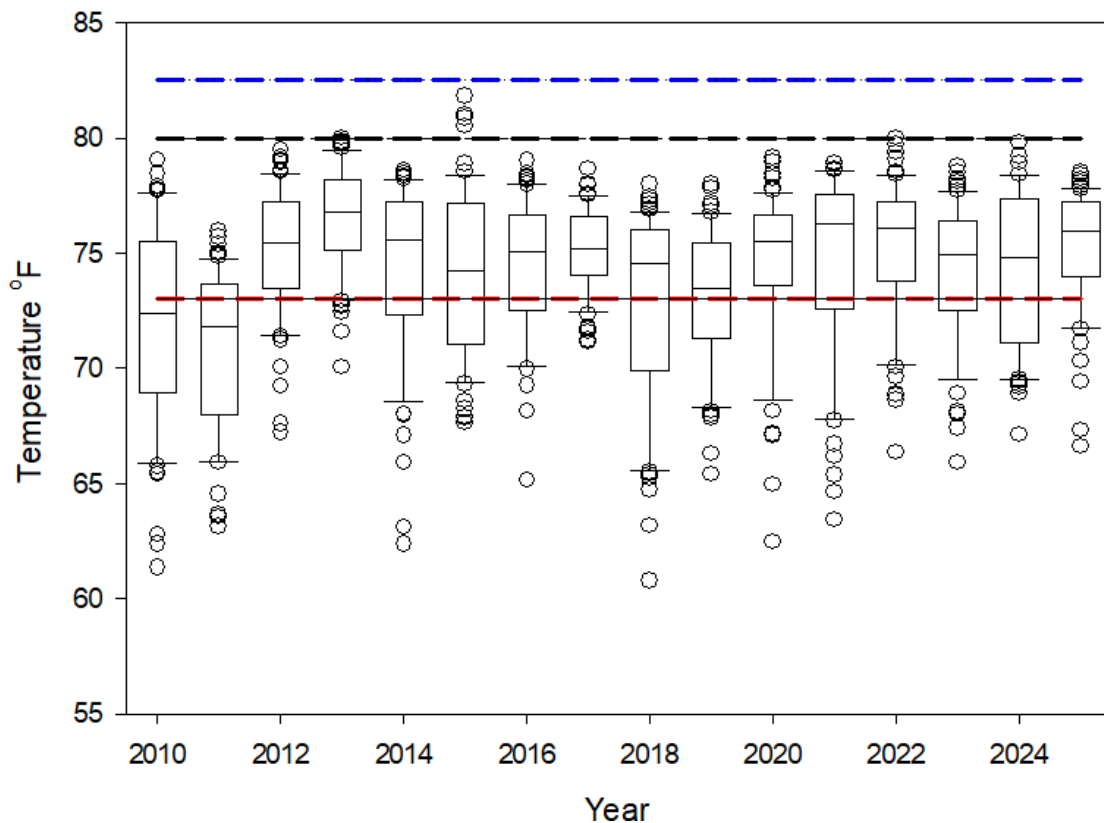


Figure 26. Distribution of daily maximum water temperatures at Sloan from July 1-August 31 from 2010-2025. Boxes extend from the 25th to the 75th (interquartile range) percentile, whiskers are the 5th and 95th percentile and circles are values beyond the 5th and 95th percentiles. The red dashed line denotes the 73°F threshold used by FWP to implement angling restrictions, the black line is the 80°F NWE pulse flow temperature ceiling goal for the lower river, and the blue dashed line denotes the lethal temperature for fish in the lower Madison River of 82.5°F.

To conserve water and meet lower river pulse flow demands NWE, on July 1, 2025, asked for temporary modifications to article 403 of the FERC license. NWE requested operations be temporarily modified to allow for flows from Hebgen Dam to be increased at a rate of 5% hourly instead of 10% daily from June 15 through July 6, and for temporary removal of the 100 cfs per hour flow change limitation in the bypass reach at the Madison Development for flow increases when the bypass flow is less than 600 cfs from July 1 through July 22, 2025.

FWP’s implementation of angling restrictions and NWE’s pulse flow program appear to be effective in limiting thermally induced fish mortality in the lower river. Pulse flows have kept summertime water temperatures below lethal thermal limits for trout in the lower river. However, a negative correlation between the abundances of age-1 and age-2 Rainbow Trout and the frequency of pulses has been observed (Lohrenz et al. 2022). This may be attributable to the lack of habitat complexity in the Norris reach that would provide velocity refugia (Lohrenz et al. 2022). Per recommendations, FWP and NWE implemented a project to improve habitat complexity and diversity in the Norris reach in 2025 (Lohrenz et al. 2023). FWP advocates for the continuation of the NWE pulse flow program.

Article 419-Coordinate and Monitor Flushing Flows:

Article 419 of the 2188 FERC license requires NWE to develop and implement a plan to coordinate and monitor flushing flows in the Madison River downstream of Hebgen Dam. A flushing flow should be large enough to mobilize substrates and produce scour in some locations and deposition in other locations. This is a natural occurrence in unregulated streams and rivers that maintains and creates spawning, rearing, and foraging habitats for fish as well as providing fresh mineral and organic soil for terrestrial vegetation and other wildlife needs (Poff et.al 1997; Reiser, Ramey, and Wesche 1990). Impoundments such as dams interrupt the natural hydrograph of rivers and high flow events responsible for replenishing and cleaning spawning gravels are often reduced in magnitude and duration. These effects may be exacerbated by operational parameters the owner or operators of the dam prefer or must comply with. Streambed embeddedness and excessive amounts of fines (particles ≤ 0.84 mm) in spawning gravels can adversely affect the survival of embryos and the emergence of fry by inhibiting the delivery of oxygenated water and reducing the amount of interstitial space required for development (McNeil and Ahneil 1964; Kondolf 2000). Accordingly, a goal to maintain $\leq 10\%$ fines in the upper Madison River and $\leq 15\%$ in the lower Madison River was established with the understanding that releasing a flushing flow from Hebgen Dam has limited influence on sediment mobility in the lower Madison River. This goal was selected because these targets are known to provide suitable conditions for salmonid spawning.

Operational constraints for Hebgen Reservoir outflow and reservoir elevation limit implementation, magnitude, and duration of a flushing flow. These constraints 1) limit discharge at USGS gage no. 6-388 (Kirby gage) to no more than 3500 cubic feet per second (cfs) to limit erosion of the Quake Lake outlet, 2) limit changes in the outflow from Hebgen Dam to no more than 10% per day for the entire year, and 3) require that snowpack and runoff forecasts allow for the filling of Hebgen to a minimum elevation of 6532.26^{ft} msl by June 20.

Snowpack conditions and runoff forecasts for the spring of 2025 prevented NWE from making operational changes at Hebgen Dam to accommodate a flushing flow. Instead, water was conserved in Hebgen to meet the required volumes for the 2025 pulse flow season and minimum elevation requirements at Hebgen.

Flushing flow and spawning gravel recruitment:

Since 2002, evaluation of the efficacy of flushing flows to recruit spawning gravels and maintain fine sediment thresholds under current operational constraints has primarily been achieved through annual sediment core sampling at four established monitoring sites representative of stream conditions present in the upper (Kirby and Ennis) and lower (Norris and Greycliff) Madison River. Appropriate substrate for sampling was identified by conducting spring and fall redd surveys at each monitoring location. Areas where redds typically occurred contained gravels ranging in size from 10-60 mm with minimal amounts of organic debris and sediment. Core samples from these areas were collected in 2025 with a 12-inch McNeil core sampler manually drilled into the substrate to a depth of 8". Substrate from within the 12" x 8" area was removed, dried, and sorted using a sieve method. The percentage composition of the sample was calculated according to particle size. The results from annual core sampling provide an index of relative spawning habitat suitability (Kleinshmidt 2022). There is no statistical difference in the % fines ≤ 0.84 mm between years when a flushing flow was and was not implemented (Lohrenz et al. 2021; Kleinshmidt 2022). This is consistent with the findings of a 2021 study that examined sediment transport, storage, and spawning gravel recruitment within the range of flows allowed under the current operational conditions (Pioneer Technical Services 2022). The results indicated normal, non-flushing flows can mobilize particles

of the active streambed layer that are $\leq D_{50}$ 59 to 364 days a year and that a flushing flow is not needed to transport spawning gravels (Pioneer Technical Services 2022). Core sample data and results from 2025 will be reported by NWE.

Flushing flow and riparian plant community maintenance and regeneration:

Riparian plant communities are influenced by fluvial processes. These processes are often disrupted on regulated streams through the timing and magnitude of high-water events. In unregulated river systems, high flows typically occur in early summer coinciding with the release of wind and water-dispersed seeds from riparian plant species. Seed germination and seedling establishment occur in areas of fresh alluvial deposition created during high flows, which are critical to the establishment of riparian species, such as cottonwood and willows. The timing of high flows is also critical to riparian plant recruitment. Cottonwoods, for example, disperse their seeds from roughly the end of May through the end of July. Natural or contrived high flows outside of this window would not likely support cottonwood recruitment. Due to its lack of hydrologic complexity as a predominately single-thread channel and operational constraints, processes that support riparian regeneration and expansion are limited throughout much of the Madison River. However, suitable conditions for riparian regeneration and expansion do occur in some reaches of the river, such as Varney and Greycliff, characterized by multi-thread, high-complexity channels that dissipate stream energy and create depositional areas during high flows.

In 2023, FWP, NWE, and Geum personnel assessed whether the timing and magnitude of flushing flows, under current operational constraints, were adequate for cottonwood and willow establishment and maintenance along the Madison River. Geum Environmental Consulting concluded that a flushing flow of 6200 cfs every five to ten years coinciding with the timing of riparian plant seed dispersal (Figure 27), would sustain and promote the regeneration of riparian plant communities along the Madison River (Parker, 2024). This information is being used along with sediment transport and habitat evaluations, conducted over the last five years, to help inform MadTac whether a flushing flow would be beneficial, given year-specific conditions and expected magnitude and duration.

7 days 30 days 1 year

Madison River Near Cameron MT - 06040000

November 6, 2022 - November 6, 2023

Discharge, cubic feet per second



IMPORTANT Data may be [provisional](#)

Discharge, cubic feet per second
This year
— Recorded
— Estimated
Last year
— Recorded
— Estimated
Median: — 1953 - 2023

Figure 27. Hydrograph from USGS gage number 6-400 showing discharge (cfs) for 2022 (red line) and 2023 (blue line) years when a flushing flow on the Madison River occurred. The blue box depicts the recruitment “window” for riparian plant species.

Flushing flows and side channel habitat

Flushing flows in regulated systems are often designed to provide sediment maintenance and not channel and habitat maintenance (e.g., side channels, pools, undercut banks). In many instances, the normal flow regime is adequate to mobilize sand and gravel in the active streambed of the main river channel, and a flushing flow is not warranted (Kondolf 1996; Pioneer Technical 2022). The flushing flow evaluation conducted by Pioneer Technical (2022), showed discharges of ≥ 600 cfs were adequate to mobilize the D_{50} of the active streambed in the Varney and Greycliff reaches 365 days a year, which suggests that even without the implementation of a flushing or pulse flow, base flows would be capable of mobilizing gravel of sufficient size for spawning and keep them relatively free from sediment. However, these calculations only applied to the main river channel and were specific to spawning habitat maintenance within the active substrate layer.

While the focus of the flushing flow program has largely been on the maintenance of spawning gravels, FWP initiated monitoring in 2023-2024 to determine how discharges associated with flushing flows and pulse flows affect side channel habitats. Side channels can be important to the survival of salmonids, as

they have spawning gravels in close proximity to habitats with reduced discharges, complex pools, cobbles, and woody debris commonly used for rearing by young-of-the-year and age-1 trout. FWP's findings indicated the effects of flushing flows on side channel habitat creation and maintenance were greater than those produced by spring runoff or discharges during the pulse flow season (Lohrenz et al. 2025).

Based on the findings of Geum and FWP (2024), FWP recommends implementing a flushing flow in years when conditions allow for the timing of a flushing flow to coincide with riparian seed dispersal and reach discharges of 6,200 cfs at the Varney gage. FWP also recommends that annual MadTac discussions about flushing flow implementation continue, and implementation be considered if there is a high likelihood that pulse flow and drought management needs can also be met.

Literature Cited

- Akaike, Hirotogu. 1998. Information Theory and an Extension of the Maximum Likelihood Principle. In *Selected Papers of Hirotogu Akaike*, 199–213. Springer.
- Bjorn, T.C., D. Reiser. Habitat Requirements of Salmonids in Streams. From: Meehan, W (Ed) 1991. Influence of forest rangeland management of salmonid fishes and their habitat. American Fisheries Society Special Publication 19. 2002 30361, list update reference # 76.
- Byorth, P. A. 2004. Hebgen Reservoir creel survey and contribution of stocked Rainbow Trout to the recreational fishery: June 2000 to June 2001. Montana Department of Fish, Wildlife & Parks, Helena.
- Clancey, P., and T. Lohrenz. 2007. Madison River/Ennis Reservoir fisheries and Madison River Drainage Westslope Cutthroat Trout conservation and restoration program. 2006 Annual Report to PPL Montana, Environmental Division, Butte, and Turner Enterprises, Inc., Bozeman, from Montana Fish, Wildlife, & Parks, Ennis.
- Clancey, P., and T. Lohrenz. 2008. Madison River/Ennis Reservoir fisheries and Madison River Drainage Westslope Cutthroat Trout conservation and restoration program. 2007 Annual Report to PPL Montana, Environmental Division, Butte, and Turner Enterprises, Inc., Bozeman, from Montana Fish, Wildlife, & Parks, Ennis.
- Clancey, P., and T. Lohrenz. 2009. Madison River/Ennis Reservoir Fisheries and Madison River Drainage Westslope Cutthroat Trout conservation and restoration program. 2008 Annual Report to PPL Montana, Environmental Division, Butte, and Turner Enterprises, Inc., Bozeman, from Montana Fish, Wildlife, & Parks, Ennis.
- Lohrenz, T. et al. 2021. Madison River 2188 project monitoring report 2021. Annual Report to NorthWestern Energy Environmental Division. Butte, Montana. From Montana Fish Wildlife and Parks. Ennis, Montana.
- Downing, D.C., T.E. McMahon, and B.L. Kerans. 2002. Relation of spawning and rearing life history of Rainbow Trout and susceptibility to *Myxobolus cerebralis* infection in the Madison River, Montana. *Journal of Aquatic Animal Health* 14:191-203.
- FERC. 2000. Order Issuing New License, Project No. 2188-030. Issued September 27, 2000.
- Feurstein, C., University of Montana, personal communication, 2022.
- Jaeger, M. et al. 2002. Westslope cutthroat trout conservation strategy for the Missouri River headwaters of southwest Montana. Bozeman, Montana.
- Kleinschmidt Associates. 2023. Flushing flow needs in the Madison River, Montana 2018 through 2022. Northwestern Energy, Butte, Montana.
- Klemetsen, A., Amundsen, P-A., Dempson, J.B., Jonsson, B., Jonsson, N., O'Connell, M.F., and Mortenson, E. 2003. Atlantic salmon *Salmo salar* L., Brown Trout *Salmo trutta* L. and Arctic charr *Salvelinus alpinus* (L.): a review of aspects of their life histories. *Ecology of Freshwater Fish*. 12: 1-59.

- Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. *Transactions of the American Fisheries Society* 129: 262-281.
- Kondolf, G.M., and M. Wolman. 1993. The sizes of salmonid spawning gravels. *Water Resources Research*. 29: 2275-2285.
- Kondolf, G.M. et. al. 1991. Distribution and stability of potential salmonid spawning gravels in steep boulder-bed streams of the Eastern Sierra Nevada. *Transactions of the American Fisheries Society* 120: 177-186. 1991.
- Kovach, R., Painter, S., Lodmell, A., and Amish, S. 2023. University of Montana Conservation Genetics Laboratory. Genetics Report Region 3.
- McBain and Trush, 2003. Coarse sediment management plan Lewiston Dam to Grass Valley Creek Trinity River. 8-19. CA.U.S. Bureau of Reclamation. Northern California Area Office. Shasta Lake, California.
- Montgomery, D.R. et. al 1999. Channel type and salmonid spawning distribution and abundance. *Canadian Journal of Fish and Aquatic Science* 56: 377-387.
- Montana Arctic Grayling Workgroup. 2002. Upper Missouri river Arctic Grayling conservation strategy. 28. Bozeman, Montana.
- Montana Fish, Wildlife, & Parks. 2019. 2019-2027 Montana statewide fisheries management program and guide. 446-447. Helena, Montana.
- Parker, T. Geum Consultants, personal communication, 2002.
- Payne, J. Fish Wildlife and Parks, personal communication, 2002.
- Pioneer Technical Services, Inc. 2002. Madison River Sediment Mobility Assessment. 2002. Bozeman, Montana.
- Poff, N.L. et. al. 1997. The natural flow regime a paradigm for river conservation and restoration. *BioScience* 47:769-784.
- Raleigh, R.F., Hickman, T., Solomon, R.C., and Nelson, P.C. 1984. Habitat Suitability Information: Rainbow Trout. Western Energy and Land Use Team, Division of Biological Services, Research and Development, Fish and Wildlife Service. U.S. Department of the Interior, Washington, DC 20240
- Reiser, D.W., M. Ramey, and T. Wesche. 1990. Alternatives in regulated river management. Chapter 4. Gore, P., and G. Petts. Boca Raton, Florida.
- Vincent, R.E., 1978. Fisheries assessment report for the Madison River. Montana Fish, Wildlife and Parks. Bozeman, MT. 59717.
- Watschke, D. 2006. Assessment of tributary potential for wild Rainbow Trout recruitment in Hebgen Reservoir, MT. Master's Thesis. Montana State University, Bozeman.

Appendix A

November 2025

Madison River Fishery Monitoring related to the Hebgen Gate Failure Compliance Report 2025

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For

NorthWestern Energy

Introduction

On November 30, 2021, a mechanical failure of the Hebgen Dam gate resulted in an abrupt decrease in the stage of the Madison River. Madison River flows between Hebgen Dam and Quake Lake declined 370 cfs, from 648 cfs to 278 cfs, within 15 minutes (Figure 1). The decline was more protracted in the 13-mile reach downstream of Quake Lake to Lyons Bridge (Figure 1), with flows decreasing 381 cfs, from 780 cfs to 399 cfs in roughly 48 hours. The rate and volume of water reduction resulted in deviations from NorthWestern Energy's (NWE) Project 2188 Article 403 requirements to: (1) maintain..., a continuous minimum flow of 600 cfs at USGS Gauge No. 6-388 near the Kirby Ranch and (3) limit changes in the outflow from Hebgen Dam to no more than 10 percent per day for the entire year.

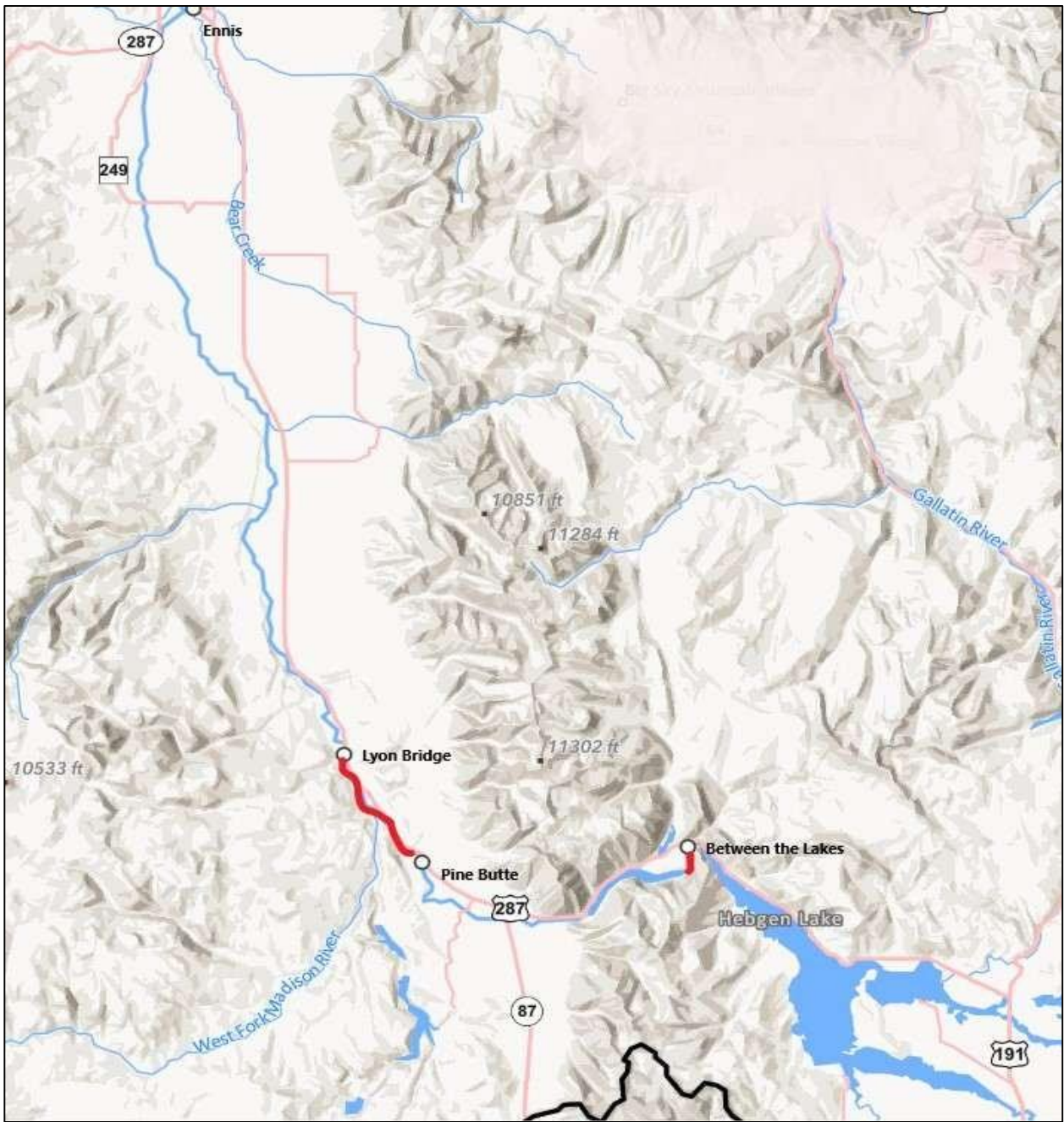


Figure 1. Map of the Madison River and the areas affected by the Hebgen Dam gate failure on November 30, 2021. The areas of focus for monitoring are highlighted in red.

Observed impacts to the fishery immediately following gate failure were greatest between Hebgen Dam and Quake Lake where numerous Brown Trout redds along channel margins (Figure 2) and in side channels were dewatered and adult and juvenile salmonids and sculpins became stranded in disconnected side channels and pools (Figure 3). Below Quake Lake to Lyons Bridge, some Brown Trout redds in shallow side channels were partially dewatered and juvenile salmonids and sculpin were stranded; however, no stranding of adult fish was observed in this reach. There was minimal change in the river stage downstream of Lyons Bridge to the town of Ennis and no dewatered Brown Trout redds or stranded fish were observed in this reach during initial surveys (Figure 1).



Figure 2. A Brown Trout redd in the Madison River between Hebgen Dam and the Quake Lake inlet that became dewatered following the rapid reduction in flow and stage during the Hebgen gate failure.



Figure 3. Juvenile salmonids and Rocky Mountain Sculpin salvaged from a dewatered side channel of the Madison River between Hebgen Dam and Quake Lake inlet following the rapid reduction in flow and stage during the Hebgen gate failure.

Plan to assess impacts

To assess the long-term impacts of the Hebgen Dam gate failure to the Madison River fishery the Madison Technical Advisory Committee, comprised of NWE, Montana Fish, Wildlife & Parks (FWP), United States Forest Service, United States Fish and Wildlife Service, and the Bureau of Land Management suggested the following monitoring plan (Table 1), which was approved by The Federal Energy Regulatory Commission (FERC) on August 18, 2022.

To date, FWP has completed prescribed monitoring (tasks #1-5) and continues to pursue the development of tributary habitat improvement projects as well as an alternative analysis and preliminary engineering report to evaluate the feasibility of implementing projects to improve spawning habitat, gravel recruitment, and embryo survival within the affected reach of the mainstem Madison River as prescribed in task # 6 (Table 1).

This report summarizes the completed monitoring and continuing tasks from 2022 through 2025 to evaluate the effects of the Hebgen Gate failure on Madison River fish populations.

Table 1. Prescribed monitoring plan for the Madison River Fishery and task progress.

Monitoring Plan	Progress
1. Continue developing population estimates in the Pine Butte section (a longstanding electrofishing survey area) on an annual basis to gain information on species ratios and to track cohorts;	Completed 2022-2025
2. Conduct backpack electrofishing surveys in the side channels and margins of the mainstem Madison River (but possibly as far downstream as Kirby) to determine the presence or absence of young-of-the-year (YOY), 1-, and 2-year-old salmonids during the summer of 2022;	Completed-2022
3. Conduct electrofishing surveys between Hebgen Dam and Quake Lake to determine catch-per-unit-effort (C/f) and population structure information (provided that electrofishing remains safe in swift currents) in 2022 and 2025; and,	Completed 2022-2025
4. Conduct fall redd counts in the Madison River between Hebgen Dam and Quake Lake to identify and document key areas of fish use from 2022 through 2025; and,	Completed 2022-2025
5. Preparation of a literature review to evaluate whether impacts from the low flow event could have resulted in a total loss of the population or an individual age class; and,	Completed-2022
6. Development of mitigation measures to benefit the Madison River fishery, with a focus on improving embryo or young-of-the-year survival, developing or enhancing spawning habitat, and/or protecting key habitats from Hebgen Dam to Lyons Bridge (e.g., tributary habitat improvement, an alternative analysis and preliminary engineering report to evaluate alternatives to improve spawning habitat, gravel recruitment, and embryo survival within the affected reach of the mainstem Madison River) will be developed.	Ongoing

1) Pine Butte Cohort Recruitment and Species Ratios

FWP estimated trout abundances using mark-recapture techniques in the Pine Butte monitoring section to evaluate the influence of modified project operations at Hebgen Dam and the gate failure (Figure 1). Trout were collected by electrofishing from a drift boat-mounted mobile anode system. Fish captured in the initial trip (marking run) were weighed in grams and their length measured to the nearest millimeter, marked with a fin clip, observed for hooking scars, and released to redistribute. After seven days, FWP conducted a second trip (recapture run) where fish were examined for marks, measured, and unmarked fish weighed. Species ratios and length-specific mark-recapture log-likelihood closed population abundance estimates by age group were generated and standardized to stream mile for Brown and Rainbow Trout using an R-based proprietary FWP fisheries database and analysis tool. Age classifications were adopted from scale data previously summarized for the Madison River fishery as follows: age 1 (152.0 mm-276.9 mm), age 2 (277.0 mm-376.9 mm), and age 3+ (>377 mm) (Vincent 1973). Through the analysis of otoliths, FWP is working to improve aging precision and update length at age data for the Madison River fishery.

All cohorts of Rainbow and Brown Trout have been observed since 2022; however, the proportional composition and abundance of juvenile Brown Trout in the Pine Butte section were relatively low in 2022 and 2023 (Table 2; Figure 4). The proportion of age 1, 2, and 3+ Brown Trout in 2022 were below the 25th percentile, with the cohorts that were age 0 during the gate failure (age 1 in 2022 and age 2 in 2023) having the lowest proportional composition in the past 20 years (Table 2). The low proportion of age 2 Brown Trout observed in 2023 translated into a lower observed proportional representation of age 3+ Brown Trout in 2024, but age 3+ fish were still at the 20-year median. However, the low proportional representation of age 2 Brown Trout in 2024 (age 0 in 2022 and age 1 in 2023) resulted in a lower proportional representation of age 3+ Brown Trout in 2025, dropping below the 25th percentile (Table 2). From 2022 through 2024, the proportional representation of adult Brown Trout had been comparable to or above the 25th percentile, suggesting that the age 3+ population was able to compensate for low recruitment from during those years (Table 2). The observed proportional decrease of age 3+ Brown Trout in 2025 suggests that compensation for low recruitment of age 2 fish was insufficient. Alternatively, similar results would occur if recruitment from the 2023 and 2024 Rainbow Trout cohorts was above average.

The proportion of age 2 Rainbow Trout in 2023 was below the 25th percentile; however, this same cohort was proportionally above the 75th percentile in 2022, suggesting it was not adversely affected by the gate failure (Table 2). The proportion of age 3+ Rainbow Trout in 2025 was slightly below the 25th percentile.

Table 2. Comparison of the percent composition of Brown Trout (LL) and Rainbow Trout (RB) for the 2022 through 2025 total combined trout estimate and the total combined trout estimated 20-year median and 25th and 75th percentiles by age group in the Pine Butte section. Values with * are below the 25th or above the 75th percentile.

Species	<u>Age 1</u>				<u>Age 2</u>				<u>Age 3+</u>			
	2022	2023	2024	2025	2022	2023	2024	2025	2022	2023	2024	2025
Brown Trout	14%*	21%	26%*	17%*	5%*	4%*	3%*	8%	9%*	25%*	13%	7%*
Rainbow Trout	52%*	38%	44%*	48%*	9%	6%*	7%*	12%	10%	7%	7%	4%*
Brown Trout 20-year median	21% (18%, 23%)				8% (7%, 11%)				13% (10%, 17%)			
Rainbow Trout 20-year median	37% (31%, 43%)				11% (9%, 14%)				6% (5%, 10%)			

The low abundance of age 1 Brown Trout observed in 2022, the cohort expected to be most affected by the Hebgen gate failure, translated to low abundances of age 2 Brown Trout in 2023 (Figure 4). Similarly, low abundance of age 1 Brown Trout in 2023 (embryos in the gravel during the 2021 gate failure) resulted in low abundances of age 2 Brown Trout in 2024 (Figure 4). The below average abundance of age 2 Brown Trout observed in 2022 and 2023 did not translate into weaker age 3+ Brown Trout abundances in 2023 or 2024, with abundances of 3+ Brown Trout remaining above the 20-year average; however, age 3+ Brown Trout abundance fell below the 20-year average in 2025 (Figure 4). It is likely that the number of fish and cohorts in the age 3+ class was previously able to buffer poor recruitment from the age 2 cohorts in 2023 and 2024, but successive years of low age 2 Brown Trout recruitment following the gate failure may have contributed to the observed decline in Age 3+ abundance in 2025. The above average abundance of age 1 Brown Trout in 2024 recruited well into the age 2 class in 2025 and were near the 20-year average (Figure 4).

Age 1 and age 2 cohorts of Rainbow trout were above the 20-year average in 2025. Age 3+ Rainbow trout were at similar abundances as observed since 2020, slightly below or near the 20-year average (Figure 4). The strong 2025 age 2 class could translate into better numbers of 3+ Rainbow Trout in 2026.

Age-specific abundance estimates and proportional age composition suggest the gate failure negatively affected the 2021 Brown and Rainbow Trout cohorts (age 0 during the gate failure) and the 2022 Brown Trout cohort (embryos during the gate failure). There was low proportional representation and absolute abundance of Brown Trout in the affected 2021 and 2022 cohorts. Although the effects of a single weak cohort (2021) matriculating into the adult (age 3+) population was buffered by the overall number of individuals from multiple previous cohorts, compensation for successive weak cohorts did not occur and a decline in abundance in the adult Brown Trout population was realized. The 2021 Rainbow Trout cohort recruited similarly, although poor precision of age 1 abundance estimates precluded inference about cohort strength until they were age 2 in 2023. Subsequent monitoring will elucidate how long it takes for the adult (age 3+) population to recover from the effects of successive weak cohorts coincident with the gate failure.

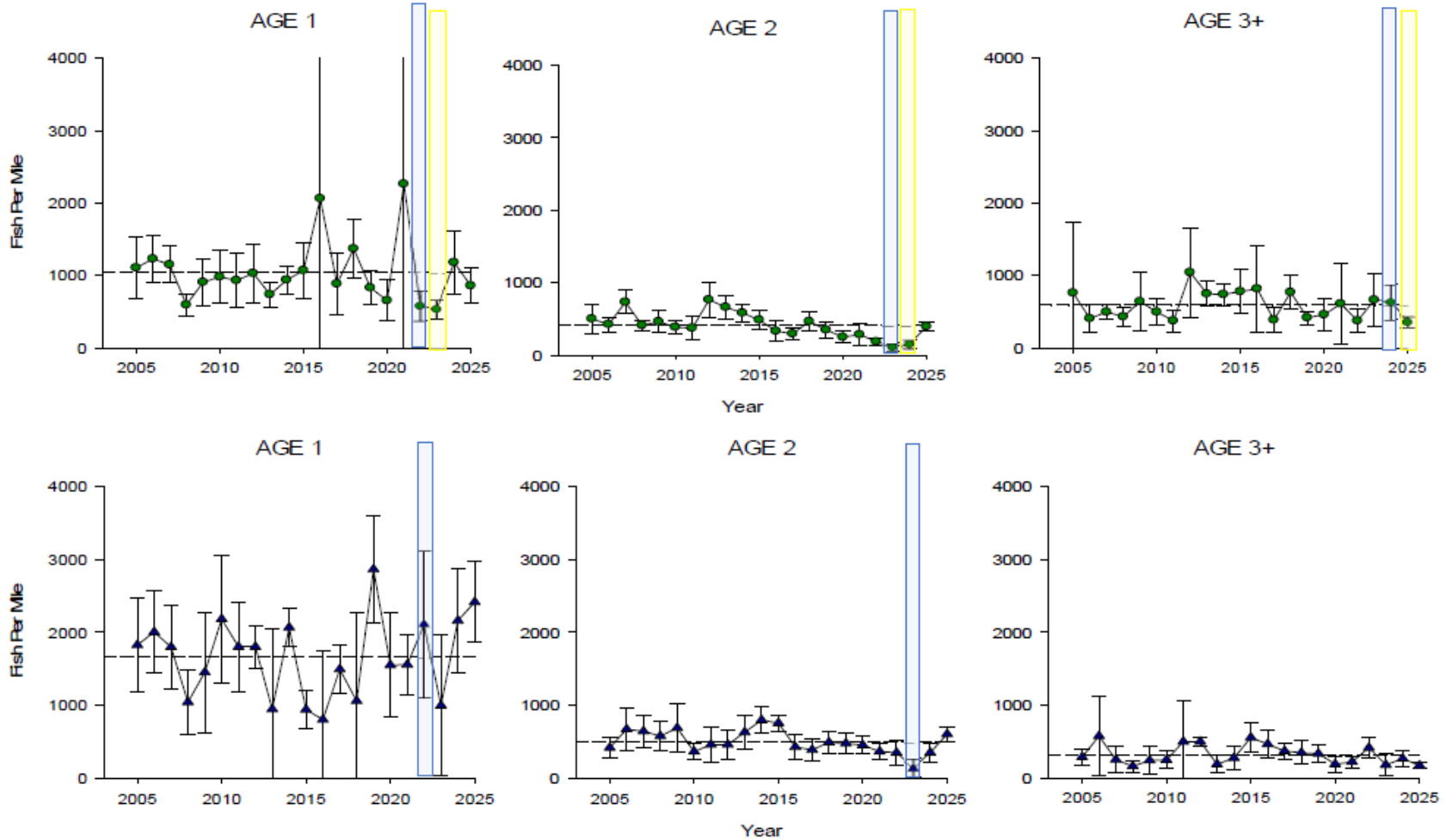


Figure 4. The estimated abundances of Brown and Rainbow Trout by age group in the Pine Butte monitoring section. The dashed lines are the 20-year averages (2005-2025), and the error bars are the 95% confidence intervals. Top panel (Brown Trout) and bottom panel (Rainbow Trout), yellow marker and blue marker represent the cohorts that would have been affected by the 2021 Hebgen gate failure.

2) Juvenile Salmonid Presence Absence Survey

Presence/Absence surveys were completed in 2022 and confirmed that YOY and juvenile salmonids persisted in habitats throughout the reaches of the river most affected by the Hebgen Dam gate failure. Brown Trout YOY were present in 90% of the side channels sampled in June and 95% in July 2022, while YOY Rainbow Trout were present in 90% of the side channels sampled in July 2022. Rainbow Trout YOY absence from the June sample is attributable to emergence timings described by Downing (2001) and resulted in clear size differentiation between Brown and Rainbow Trout YOY; Brown Trout YOY were on average 20mm longer than Rainbow Trout YOY. Age 1 Brown (70% and 75%) and Rainbow Trout (80% and 40%) were present in the majority of side channels during both sampling periods. Age 2 Brown (15% and 35%) and Rainbow trout were present in (10% and 35%) of the side channels sampled. No Mountain Whitefish YOY were observed, age 1 Mountain Whitefish were present in 5% and 20% of side channels, and age 2 Mountain Whitefish were present in 5% of side channels in the respective sampling periods (Lohrenz et. al 2022).

3) Catch-per-unit effort survey of the Madison River between Hebgen Dam and the Quake Lake inlet

FWP performed a catch-per-unit (C/f) survey to collect population structure information for salmonid species in the Madison River between Hebgen Dam and the Quake Lake inlet on September 5, 2025. Fish were collected by electrofishing from a drift boat-mounted mobile anode system. Captured fish were weighed in grams and measured to the nearest millimeter. The sampling section length was used as the measure of effort and age-specific C/f estimates of relative abundance were generated and standardized to stream mile for Brown and Rainbow Trout, and Mountain Whitefish using an R-based proprietary FWP fisheries database and analysis tool.

Catch-per-unit-effort sampling between Hebgen Dam and Quake Lake continues to show lower relative abundances for all fish species and age classes than anticipated, which may be a direct result of the swift and deep river conditions present throughout the section; sampling efficiencies were low and not directly estimated or corrected for. Rainbow Trout and Mountain Whitefish comprised the majority of the fish sampled in 2022, 2023, 2024, and 2025. Brown Trout were at low relative abundances in all years (Table 3). The paucity of Brown Trout observed in the section may be attributable to the lack of habitat features such as undercut banks and large woody debris throughout the sampling reach. As reported previously, YOY, age 1, and age 2 Brown and Rainbow Trout were present in the side channels between Hebgen Dam and Quake Lake; however, only mainstem habitats were sampled during the C/f survey (Lohrenz et.al. 2022).

Table 3. Catch per unit effort (C/f) per mile by age group in millimeters for Brown Trout (LL), Rainbow Trout (RB), and Mountain Whitefish (MWF) below Hebgen Dam to the Quake Lake inlet.

Species	<u>Age 1</u>				<u>Age 2</u>				<u>Age 3+</u>			
	2022	2023	2024	2025	2022	2023	2024	2025	2022	2023	2024	2025
LL	1	0	0	0	0	0	0	0	5	4	2	9
RB	28	4	82	33	12	6	34	31	15	27	34	20
MWF	4	39	34	48	5	82	53	228	70	57	34	108

Data collected in 2025 suggests that MWF and Rainbow Trout continue to recruit well to age 3+ (Table 3). Brown Trout numbers have been similar among years (Table 3). Comparison of the 2025 C/f survey with other C/f surveys following the gate failure show that all species continued to be present and in similar proportions in the river between Hebgen Reservoir and Quake Lake. However, general sampling conditions, normal fluctuations in abundances and the lack of prior data in this section precluded statistically linking observations to the gate failure. Electrofishing surveys in large rivers inherently produce abundance estimates with uncertainty (i.e., relatively large confidence intervals). Estimated Brown and Rainbow trout abundances of fish 152 mm (~6”) or greater in the Pine Butte Section fluctuated on average 28% and 31%, respectively, from year-to-year since 2000. If the trout population downstream of Hebgen Dam has similar variation as the population in the Pine Butte Section, the low and uncertain efficiency associated with C/f sampling may mask potential influence of the dam failure in this reach. C/f surveys will cease to be conducted, unless major operational changes occur at Hebgen Dam and conditions are changed drastically.

4) Fall Redd Counts

In 2025, FWP continued Brown Trout redd counts in the Madison River between Hebgen Dam and Quake Lake to identify and document key areas utilized by Brown Trout for spawning. Redd counts were done by walking in an upstream direction and visually identifying streambed disturbances consistent with redd morphology (Gallagher et al. 2007). A typical redd consists of a defined pit where gravel was excavated with a mound of gravel (tail spill) immediately downstream of the pit (Figure 5). GPS coordinates were recorded and redd locations were mapped using Google Earth (Figure 6).



Figure 5. Brown Trout spawning in a side channel of the Madison River between Hebgen Dam and the Quake Lake inlet Fall 2024.

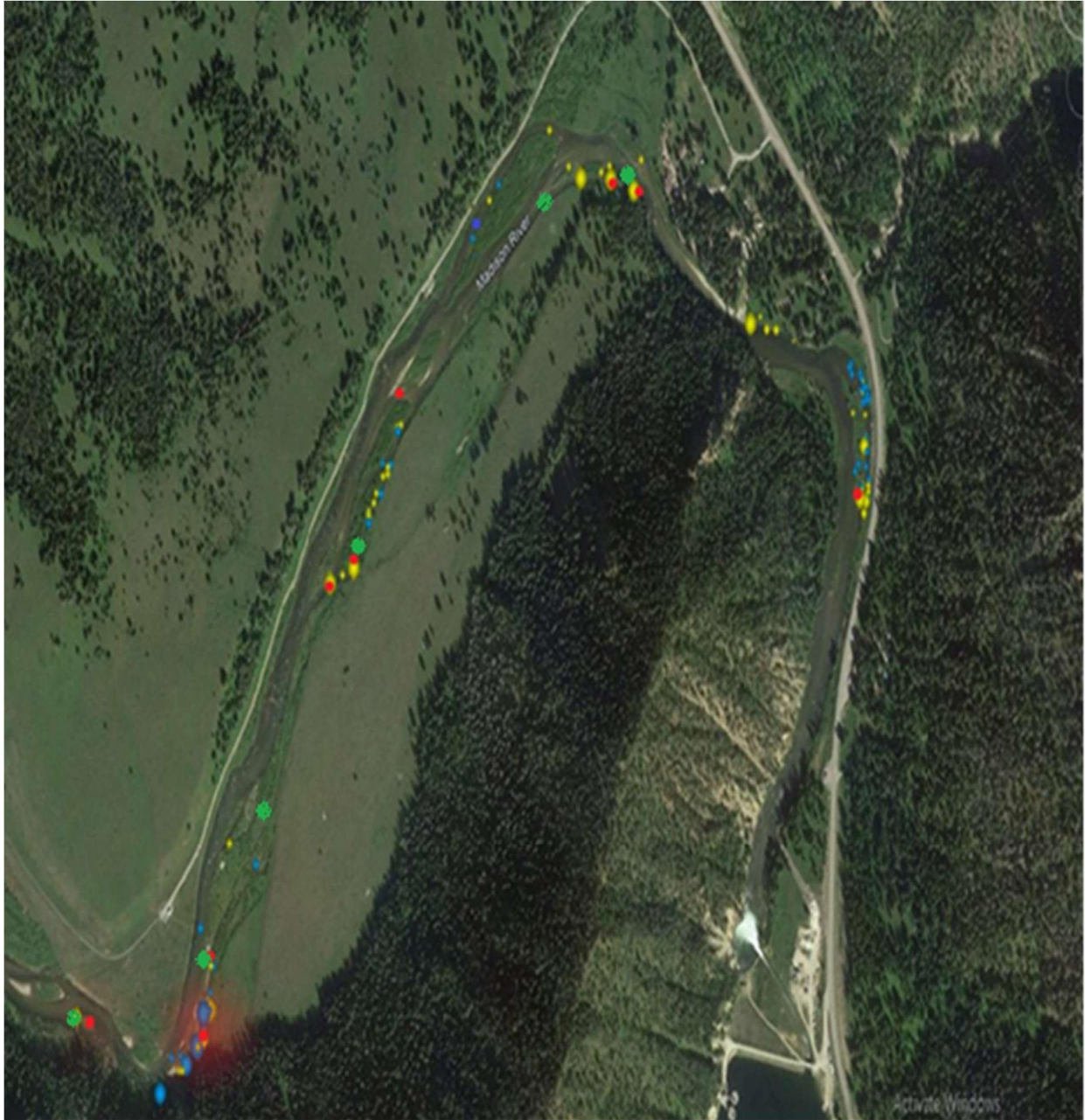


Figure 6. Locations of redds identified in the Madison River between Hebgen Dam and the Quake Lake inlet. The blue dots are redds observed in 2022, yellow dots are redds observed in 2023, red dots are redds observed in 2024, and green dots are redds observed in 2025. The size of the dot is a general representation of redd density (i.e., the larger the dot the greater the number of redds at that location).

Redd counts conducted from 2022-2025 in the Madison River between Hebgen Dam and the Quake Lake inlet showed side channel habitats were used most by Brown Trout for spawning. On average eighty eight percent of all Brown Trout redds surveyed have been detected in side channels (Table 4). The high concentration of redds within side channels may be a function of higher quality habitat and more suitable water velocities . Gravels selected for redd construction typically have a median diameter $\leq 10\%$ of the female’s body size and can be easily excavated (Chambers et. al 1955; Kondolf and Wolman 1993).

While side channel habitats had the potential to be dewatered and disconnected during the 2021 gate failure, egg mortality was likely low because flows were restored within 44 hours. Literature reviewed by Dukovcic et al. (2022) suggested trout eggs early in development can withstand 1-5 weeks of complete dewatering as long as the relative humidity in the gravel remains fairly high. This is consistent with the findings of the 2022 side channel survey where numerous Brown Trout YOY were observed.

Table 4. The proportion of Brown Trout (LL) redds observed by year and habitat type. Discharge (Q) cfs at the time of counts.

Year	Q (cfs)	Proportion of LL redds in Main stem	Proportion of LL redds Side channel
2022	689	8%	92%
2023	834	18%	82%
2024	724	6%	94%
2025	665	16%	84%
Mean		12%	88%

6) Development of Mitigation Measures to Benefit the Madison Fishery

FWP and NorthWestern Energy have identified and are pursuing projects that would increase the availability of spawning habitat and improve embryo or young-of-the-year survival in the affected reach of the river from Hebgen Dam to Lyons Bridge.

Alternatives Analysis

In 2024, FWP and NorthWestern Energy representatives, met with a contractor for an initial survey of the Madison River, below Quake Lake to Three Dollar Bridge (Figure 7), to evaluate the feasibility of implementing projects to improve spawning habitat, gravel recruitment, and embryo survival in the reach. A document describing restoration alternatives to address habitat limitations was delivered to NWE in May 2025 (Appendix A.1). After reviewing the alternatives analysis document, partners reconvened in early August 2025 to evaluate the best alternatives for advancement. Project partners identified direct gravel augmentation and side channel reconnection as the most practicable options.

FWP and NWE are currently vetting these alternatives with the community and landowners in the area. FWP and NWE anticipate that a decision on project implementation will be made in 2026.

Oliffe Creek

In 2022-2024 FWP and NWE pursued a habitat improvement project on Oliffe Creek, a Madison River tributary (Figure 7), to improve Brown Trout spawning and rearing habitat. However, due to changes in landownership of the project area implementation of the Oliffe project will not occur at this time.

Literature Cited

- Bjornn, T.C. (1991). Habitat requirements of salmonids in streams.
- Boyer, J.K. 2017. Spawning and early life history of Mountain Whitefish in the Madison River, Montana. Transactions of the American Fisheries Society. Volume 146, 5:939-954.
- Chambers, J. S., G. H. Alien, and R. T. Pressey. 1955. Research relating to the study of spawning grounds in natural areas. Annual report to U.S. Army Corps of Engineers, Contract DA-35026-Eng-20572. Washington State Department of Fisheries, Olympia.
- Downing, D.C., T.E. McMahon, and B.L. Kerans. 2002. Relation of spawning and rearing life history of Rainbow Trout and susceptibility to *Myxobolus cerebralis* infection in the Madison River, Montana. Journal of Aquatic Animal Health 14:191-203.
- Dukovcic, J.R. 2022. Hebgen dam gate failure literature review: effects of dewatering on salmonid species Madison River, Montana. Montana Fish, Wildlife and Parks. 1600 South 19th Street. Bozeman, Montana.
- Gallagher, S.P., Hahn P.K.J., and Johnson D.H. 2007. Redd Counts. Pages 197-233 in D.H. Johnson, B.M. Shrier, J.S. O'Neil, J.A. Knutzen, X. Augerot, T.A. O'Neil, and T.N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.
- Kondolf, G.M. and M. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research. 29: 2275-2285.
- Montana Fish Wildlife and Parks. 1989. Reservation requests for waters above Canyon Ferry Dam. 2: 396-398. Montana Department of Fish, Wildlife and Parks, Helena, Montana.
- Weisel, G.F. 1966. Young salmonid fishes of western Montana. Proceedings of the Montana Academy of Sciences 26: 1-21.
- Vincent, E.R. 1973. Evaluation of river fish populations. Job Completion Report, Federal Aid in Fish and Wildlife Restoration Acts. Montana Project No. F-9-R-20, Job No. III-a.

Appendix A.1



Introduction

SWCA Environmental Consultants, Inc. (SWCA) and Geum Environmental Consulting, Inc. (Geum) were retained by NorthWestern Energy to provide assessment and restoration design services for a 3.5-mile reach of the Upper Madison River extending from the outlet of Quake Lake downstream to Raynold's Pass Bridge (Figure 1). Quake Lake formed in response to the magnitude 7.5 Hebgen Lake Earthquake and resulting Madison Slide on August 17, 1959. The Project Reach of the Madison River is characterized as incised and disconnected from historical floodplain surfaces and lacks hydraulic and geomorphic complexity, compromising habitat quality and riverscape function. The following project goals were developed for the Upper Madison River by project and agency partners to guide the assessment and restoration approach, listed in order of priority:

1. Increase spawning habitat quantity and quality for rainbow and brown trout ;
2. Increase rearing habitat quantity and quality for rainbow and brown trout; and
3. Improve river, floodplain, and ecosystem function to support diverse, complex wildlife habitat.

This memorandum describes the restoration alternatives and concepts that were developed to address limiting factors to habitat and riverscape function and support the achievement of project goals.

Existing Conditions Overview

Three project sub-reaches were delineated based on channel and valley morphology and dominant geomorphic processes (Figure 1). Sub-Reach 1 extends 3,300 feet downstream from the Quake Lake outlet to the approximate downstream extent of deposition from the Madison Slide. Sub-Reach 1 is characterized by incision through the landslide debris deposit, resulting in a steep, highly entrenched channel. Sub-Reach 2 extends 7,100 feet from the toe of the Madison Slide to the approximate downstream extent of widespread aggraded slide debris. The channel through Sub-Reach 2 has historically been laterally active and subjected to multiple periods of relative stability followed by channel incision, as evidenced by a sequence of fluvial terraces (i.e. abandoned floodplain surfaces) and disconnected side channels. Sub-Reach 3 extends 7,900 feet to Raynold's Pass Bridge and has been less impacted by the Madison Slide than Sub-Reaches 1 and 2. Sub-Reach 3 exhibits a wandering channel

morphology characterized by numerous hydrologically-connected bars and islands set within well-vegetated high terraces.

Identified limiting factors to fish spawning and rearing habitat and river and floodplain function in the

Project Reach include:

- Poor hydraulic and geomorphic complexity;
- Limited spawning gravel retention;
- Impaired lateral migration processes;
- Reduced floodplain connectivity and habitat diversity; • Impaired vegetation community succession;
and
- Limited large woody debris recruitment.

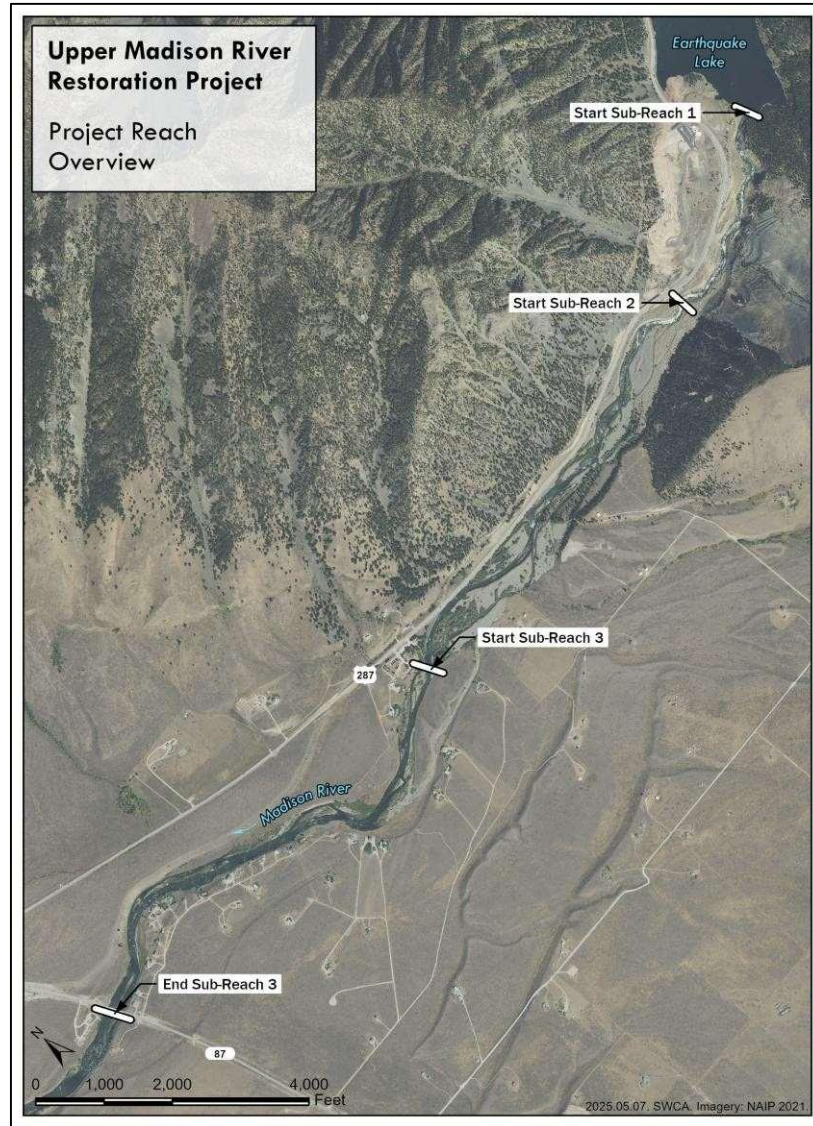


Figure 1. Upper Madison River Restoration Project overview map.

Alternatives Evaluation

The conceptual restoration alternatives described in this section aim to address identified limiting factors and support the achievement of project goals. The restoration alternatives for SubReaches 1-3 (Project Reach) include:

- No Action;
- Gravel Augmentation;
- Selective Bed Profile Adjustment; • Full Bed Profile Adjustment; and
- Floodplain Grading.

The alternatives evaluation is intended to provide a high-level summary of the benefits, risks, and feasibility considerations associated with each alternative and guide next steps in alternatives development and selection. Alternatives were ranked as low, moderate, or high in the following categories. Results of the alternatives evaluation are summarized in Table 1. Detailed descriptions, concept maps, and ranking justifications for each alternative are provided in the following sections.

Potential to Improve Spawning Habitat

This category describes the likelihood that the restoration alternative will achieve the first project goal of increasing spawning habitat quantity and quality.

- **Low** – least potential to improve spawning habitat.
- **Moderate** – moderate potential to improve spawning habitat.
- **High** – greatest potential to improve spawning habitat.

Potential to Improve Rearing Habitat

This category describes the likelihood that the restoration alternative will achieve the second project goal of increasing rearing habitat quantity and quality.

- **Low** – least potential to improve rearing habitat.
- **Moderate** – moderate potential to improve rearing habitat.
- **High** – greatest potential to improve rearing habitat.

Potential to Improve Riverscape Function

This category describes the likelihood that the restoration alternative will achieve the third project goal of improving river, floodplain, and ecosystem function.

- **Low** – least potential to improve riverscape function.
- **Moderate** – moderate potential to improve riverscape function.
- **High** – greatest potential to improve riverscape function.

Technical Feasibility

Technical feasibility describes whether the alternative can be successfully implemented from a technical standpoint within existing constraints.

- **Low** – lowest level of technical feasibility, most difficult to implement.
- **Moderate** – moderate level of technical feasibility.
- **High** – highest level of technical feasibility, easiest to implement.

Geomorphic Suitability

Geomorphic suitability considers the geomorphic setting and the effects of anticipated channel evolution trends on the long-term success of the restoration alternative.

- **Low** – least suitable given geomorphic setting and channel evolution trends.
- **Moderate** – moderately suitable given geomorphic setting and channel evolution trends.
- **High** – highly suitable given geomorphic setting and channel evolution trends.

Risk to Infrastructure

Risk to infrastructure describes the potential for existing infrastructure to be impacted by changes in water level or river and floodplain processes associated with the alternative.

- **Low** – least risk to infrastructure.
- **Moderate** – moderate risk to infrastructure.
- **High** – greatest risk to infrastructure.

Permitting Requirements

Permitting requirements describes the anticipated level of effort required to permit alternative implementation.

- **Low** – least permitting requirements.
- **Moderate** – moderate permitting requirements.
- **High** – greatest permitting requirements.

Data and Analysis Requirements

This category describes the amount of further data acquisition and analysis that would be required to implement the alternative.

- **Low** – least amount of data and analysis requirements.
- **Moderate** – moderate amount of data and analysis requirements.
- **High** – greatest amount of data and analysis requirements.

Cost

Cost describes the anticipated relative cost to implement the alternative.

- **Low** – lowest cost.
- **Moderate** – moderate cost.
- **High** – highest cost.

Table 1. Results of the restoration alternatives evaluation. Alternatives were ranked as low, moderate (mod.), or high for each category.

Restoration Alternative	Spawning Habitat Benefits	Rearing Habitat Benefits	Benefits to Riverscape Function	Technical Feasibility	Geomorphic Suitability	Risk to Infrastructure	Permitting Requirements	Data and Analysis Requirements	Cost
No Action	Low	Low	Low	High	High	Low	Low	Low	Low
Gravel Augmentation	Mod.	Mod.	Mod.	Mod.	Mod.	Low	Mod.	Mod.	Mod.
Selective Bed Profile Adjustment	High	High	High	Mod.	Low	Mod.	High	High	Mod.
Full Bed Profile Adjustment	High	High	High	Low	Low	High	High	High	High
Floodplain Grading	Mod.	Mod.	Mod.	Mod.	High	Low	Mod.	Mod.	Mod.

No Action Alternative

This alternative involves taking no restoration actions and leaving the Project Reach in its current condition. Without restoration intervention or changes to the hydrologic regime, it is unlikely that the Project Reach will evolve to conditions providing improved habitat quality and ecosystem diversity and complexity. In fact, habitat quality could be further compromised in the event of further channel incision and floodplain disconnection. Risks to infrastructure and public safety may become a concern if river use and development continue to increase.

- SPAWNING HABITAT: **Low**. Spawning habitat quantity and quality is limited in the Project Reach and may continue to decrease over time if the floodplain becomes further disconnected.
- REARING HABITAT: **Low**. Rearing habitat quantity and quality is limited in the Project Reach and may continue to decrease over time if the floodplain becomes further disconnected.
- RIVERSCAPE FUNCTION: **Low**. No benefits to riverine function and processes, including hydraulic and geomorphic complexity, floodplain connectivity, or lateral migration. Minimal scour and depositional surfaces will lead to maturation of the riparian vegetation community with limited new recruitment.
- TECHNICAL FEASIBILITY: **High**. No action required.
- GEOMORPHIC SUITABILITY: **High**. Within the constraints imposed by Hebgen Dam operations, this alternative allows natural processes of channel incision and aggradation to play out as the river adjusts to a new equilibrium slope following the Madison Slide.
- INFRASTRUCTURE: **Low**. There is currently a low risk to infrastructure barring a large flood. However, risks could increase if additional development occurs and/or encroaches in the contemporary floodplain.
- PERMITTING: **Low**. No permitting required due to no specific immediate action, but continued degradation may result in significant projects necessary to mitigate risk to public and private infrastructure.
- DATA: **Low**. No additional data or analysis is needed, although continued monitoring of geomorphic change is recommended.
- COST: **Low**. No immediate cost.

Gravel Augmentation Alternative

This alternative involves placing gravel in the Madison River channel to provide a sediment supply, increase geomorphic complexity, and provide substrates suitable for spawning. Potential gravel augmentation strategies include enhancing or creating glides and riffles, enhancing point and lateral bars to drive channel migration, and enhancing or creating mid-channel bars and islands. An additional strategy is to add gravel to the river in recruitment piles in locations of high velocity and shear stress during high

flows (e.g., outside meander bends) such that gravel is transported and deposited downstream. This alternative would utilize gravel sourced from hydrologically disconnected and unvegetated floodplain terraces. Gravel augmentation would be implemented in areas of the Project Reach in the vicinity of gravel sources, primarily in Sub-Reach 2. This alternative could be incorporated into other alternatives involving excavation of material from the floodplain.

The lack of spawning-sized substrate in the Project Reach (particularly in Sub-Reaches 1 and 2) is primarily due to limited gravel retention rather than insufficient recruitment, as evidenced by the dynamic equilibrium of gravel and cobble-based bars and islands in Sub-Reach 3. Gravel augmentation should increase gravel retention simply as a function of the increased supply relative to transport capacity. However, it is recommended that gravel augmentation be complemented by the addition of discrete roughness elements in the channel that would create new low-energy environments that could retain gravels, such as large woody debris structures or boulder clusters. The gravel augmentation alternative is illustrated conceptually in Figure 2.

- SPAWNING HABITAT: **Moderate**. The addition of gravel to the channel and the creation or enhancement of geomorphic features would increase the quantity and quality of spawning habitat.
- REARING HABITAT: **Moderate**. Using gravel augmentation strategies that promote lateral migration and formation of low-energy environments would improve rearing habitat quantity and quality.
- RIVERSCAPE FUNCTION: **Moderate**. This alternative would add geomorphic complexity in substrate size, bedforms, and bars and potentially drive channel evolution processes, thereby increasing aquatic habitat complexity and supporting riparian vegetation establishment.
- TECHNICAL FEASIBILITY: **Moderate**. Gravel augmentation could be done with heavy equipment similar to other river restoration projects. Consideration of in-water work windows and dam operations would need to be evaluated.
- GEOMORPHIC SUITABILITY: **Moderate**. This alternative could be employed to drive lateral migration and accelerate channel evolution processes. However, the likely timescales of gravel retention in the Project Reach would need to be evaluated. Given current hydraulic conditions, long-term gravel retention appears unlikely, potentially requiring multiple augmentation treatments over time.
- INFRASTRUCTURE: **Low**. There could be a long-term risk to infrastructure if gravel augmentation accelerates lateral migration in the Project Reach. Monitoring of geomorphic response is recommended.
- PERMITTING: **Moderate**. This alternative involves placing fill in the river channel and would subject to the Joint Application for Proposed Work in Montana's Streams, Wetlands, Floodplains, and Other Waterbodies (JPA) permitting process (404, 401, 310, 318) along with a floodplain permit.
- DATA: **Moderate**. Analysis would be needed to determine gravel augmentation quantities, estimate how long gravel would remain in the reach, and determine if scour/depositional surfaces and

geomorphic features could be maintained. A sediment transport analysis and hydraulic model would be needed as well as data to characterize the source gravels.

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- COST: **Moderate**. Cost would depend on the quantity of gravel added and the augmentation strategies implemented. However, this could be a fairly low-cost alternative as material would be sourced onsite and heavy equipment could be limited to one or two machines.

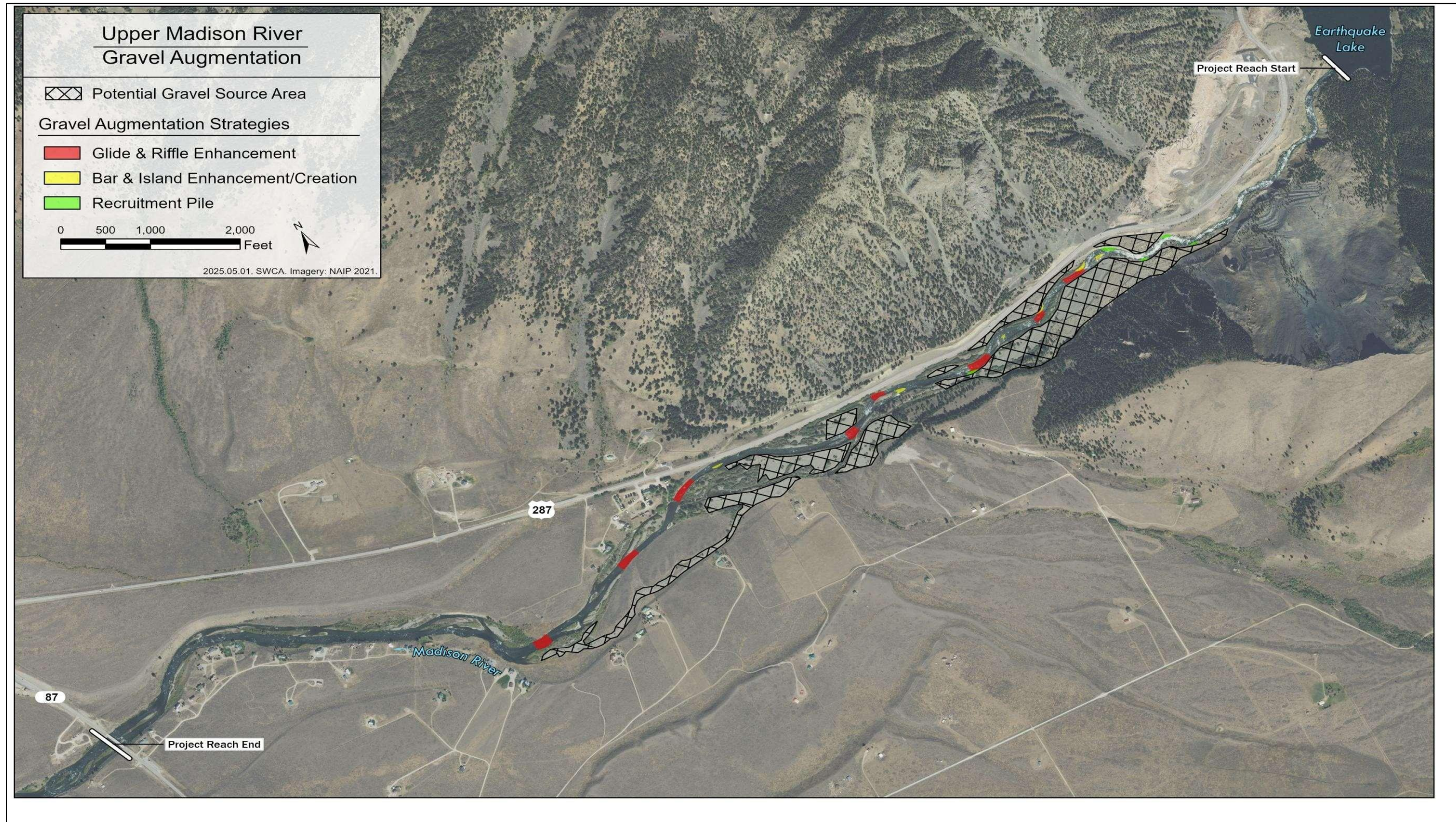


Figure 2. Gravel augmentation alternative concept map

Selective Bed Profile Adjustment Alternative

This alternative involves creating a series of channel-spanning grade control structures designed to raise the water surface elevation to connect to historical flow paths within the floodplain, thereby increasing hydraulic complexity and floodplain habitat diversity. These flow paths were historically connected to the main channel as evidenced by aerial imagery and have subsequently been disconnected due to channel incision. The structures could be designed to perennially or seasonally connect flow paths. A series of structures would be utilized to raise the water surface, and they may be designed such that they are immobile during high flows. They may also be designed to trap sediment from upstream to support channel forming processes and increase floodplain connectivity. This alternative would be implemented in Sub-Reach 2 where it is feasible to reconnect abandoned flow paths. Flow paths associated with the structures may need to be excavated at the upstream end to ensure connection at the desired hydroperiod. The selective bed profile adjustment alternative is illustrated conceptually in Figures 3 and 4.

- SPAWNING HABITAT: **High**. Reconnecting historical floodplain flow paths would provide lowenergy areas that can retain gravels and provide quality spawning habitat. Side channel reconnection would be prioritized where spawning-sized substrate exists in the floodplain and had historically been utilized.
- REARING HABITAT: **High**. Increased floodplain connectivity would promote the formation and maintenance of features that provide quality rearing habitat, including backwaters, alcoves, and wetlands.
- RIVERSCAPE FUNCTION: **High**. This alternative would increase hydraulic and geomorphic complexity and floodplain connectivity, thereby providing aquatic habitat diversity and improving floodplain water and sediment storage, nutrient processing, and recharging of groundwater and hyporheic flow pathways. This alternative would support the creation of surfaces where natural recruitment can occur to establish a variety of age classes of willows and cottonwoods. This alternative also supports scour and deposition as the side channels transport and re-distribute gravels within the floodplain.
- TECHNICAL FEASIBILITY: **Moderate**. Constructing bed profile adjustment structures and excavating side channels would require heavy equipment; however, this could be done similar to other river restoration projects designed by this team where the bed profile has been raised. Depending on the design of structures material may need to be imported. Ability to sustain grade control structures would need to be evaluated. Consideration of in-water work windows and dam operations would also need to be evaluated.
- GEOMORPHIC SUITABILITY: **Low**. Channel evolution trends are towards further incision, creating uncertainty in the long-term success of this restoration approach. A large enough flood could trigger widespread incision and lateral migration in Sub-Reaches 1 and 2, potentially undermining project success.

- **INFRASTRUCTURE: Moderate.** Connecting historical flow paths and raising the water surface elevation would increase the active width of the floodplain. Depending on the extent of flow path activation and the rise in water surface elevation there may be an increased risk to infrastructure and the highway. Additionally, this may affect landowners in cases where the public accesses currently dry side channel areas by way of the Stream Access Law.
- **PERMITTING: High.** This would require completing the JPA (404, 401, 310, 318) and a floodplain permit and flood map revision would be necessary.
- **DATA: High.** Data on the existing gravels within the floodplain would need to be gathered. A hydraulic model would need to be evaluated, and a sediment transport analysis performed to size the material for the structures. Multiple flood scenarios would need to be modeled to evaluate sustainability of structures.
- **COST: Moderate.** This would require a number of machines, and the cost would depend on the size of treatment areas and techniques used to establish bed profile adjustments.

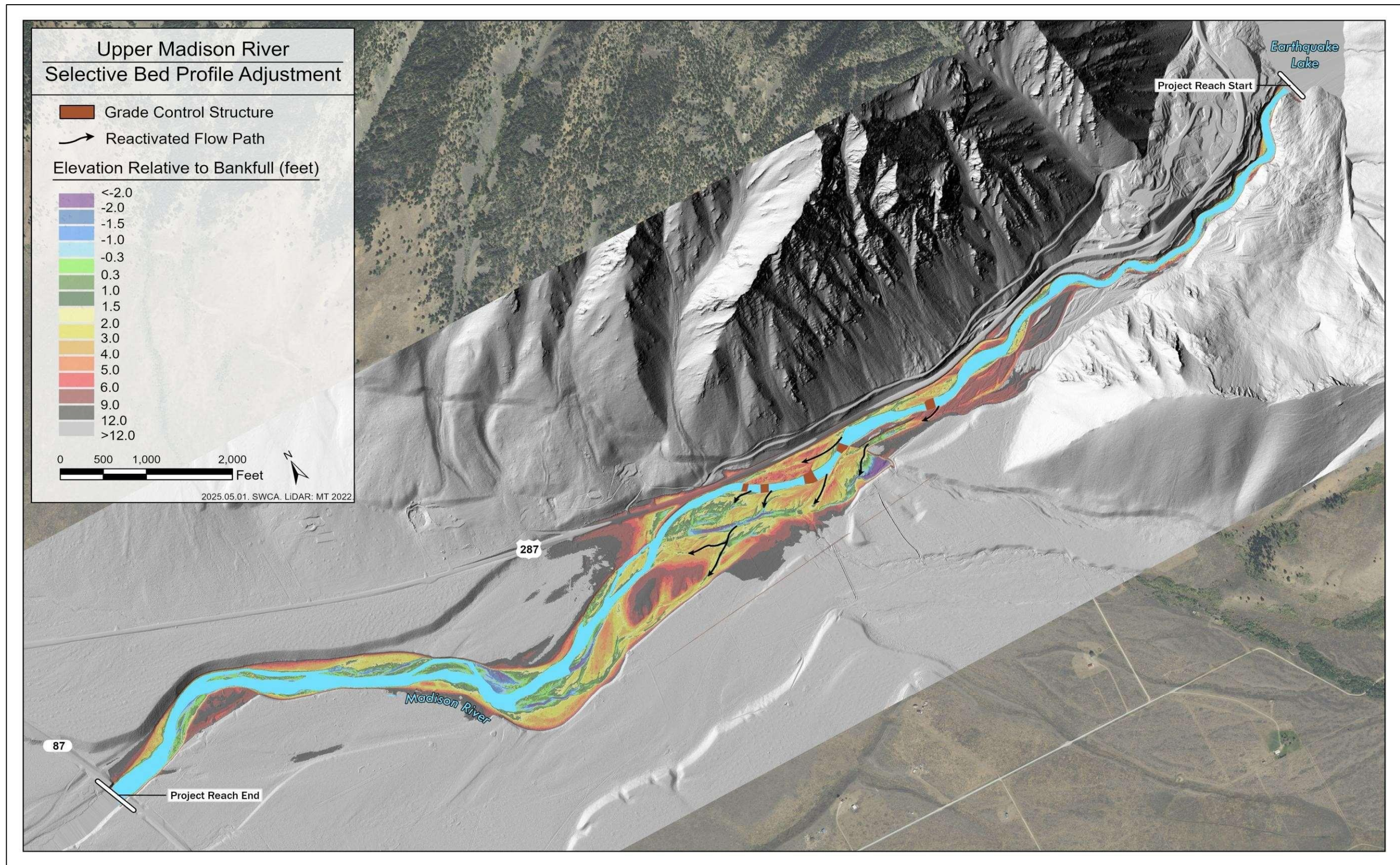


Figure 3. Selective bed profile adjustment alternative concept map with background relative elevation model



Figure 4. Selective bed profile adjustment alternative concept map with background imagery.

II Bed Profile Adjustment Alternative

This alternative involves filling the Madison River channel to permanently raise the bed elevation and fully reconnect the floodplain to the extent feasible. A greater increase in the elevation of the bed profile would result in a greater extent of floodplain connection. This alternative would increase hydraulic and geomorphic complexity and floodplain habitat diversity by reactivating disconnected flow paths and creating low-energy backwaters and wetlands. Channel fill material would be sourced from abandoned floodplain terraces if appropriately sized clasts are available. This alternative would be applied through a sub-reach of the project area. Due to the steep gradient and extreme entrenchment, bed profile adjustment is not recommended in Sub-Reach 1. Figure 5 illustrates the potential active floodplain area during the bankfull discharge given a uniform bed profile rise of 2 feet, 3 feet, 4 feet, and 5 feet.

- SPAWNING HABITAT: **High**. This alternative would create numerous flow paths and side channels that would retain gravels and support the goal of increasing spawning habitat quantity and quality.
- REARING HABITAT: **High**. Increased floodplain connectivity would promote the formation and maintenance of features that provide quality rearing habitat, including backwaters, alcoves, and wetlands.
- RIVERSCAPE FUNCTION: **High**. This alternative would increase hydraulic and geomorphic complexity and floodplain connectivity, thereby providing aquatic habitat diversity and improving floodplain water and sediment storage, nutrient processing, scour and deposition processes, and recharging of groundwater and hyporheic flow pathways. This alternative would support the creation of a variety of vegetation communities at all age classes as more surfaces would be hydrologically connected at varying durations throughout the year.
- TECHNICAL FEASIBILITY: **Low**. This option would likely require a considerable amount of large rock material and construction would require numerous machines able to work in the wet. Consideration of in-water work windows and dam operations would need to be evaluated. Significant analysis would need to be completed to confirm feasibility and sustainability of a full bed profile adjustment.
- GEOMORPHIC SUITABILITY: **Low**. Channel evolution trends are towards further incision, creating uncertainty in the long-term success of this restoration approach. A large enough flood could trigger widespread incision and lateral migration in Sub-Reaches 1 and 2, potentially undermining project success.
- INFRASTRUCTURE: **High**. This alternative would have the highest risk to infrastructure as the bed profile is raised increasing the active floodplain width and water surface elevation. Most infrastructure in the project area is located on higher terraces, but lower elevation properties exist and may be affected. The highway road grade would also likely receive higher water surface elevations and possibly varying erosional forces.

This alternative would affect landowners in cases where the public accesses currently dry side channel areas by way of the Stream Access Law.

- PERMITTING: **High**. This would require completing the JPA (404, 401, 310, 318) and a floodplain permit and flood map revision would likely be necessary.
- DATA: **High**. A hydraulic model would need to be evaluated, and a sediment transport analysis performed to size the material for the channel. Various flood scenarios would need to be modeled to evaluate sustainability of a full bed profile adjustment.
- COST: **High**. This would require a number of machines, technical design analysis, and possibly the import of material. Cost would depend on the degree of bed profile rise.

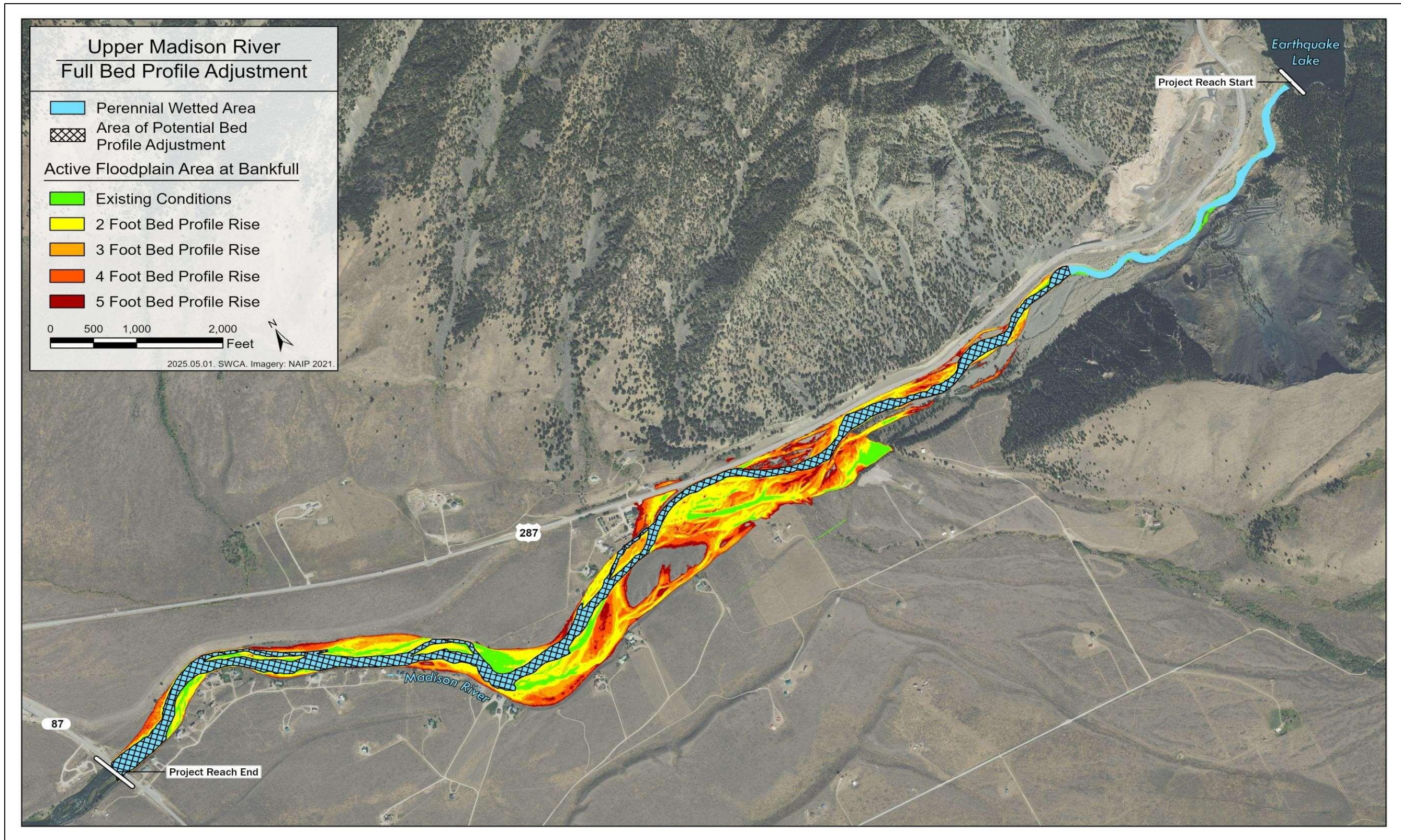


Figure 5. Full bed profile adjustment alternative concept map.

Floodplain Grading Alternative

This alternative involves selectively grading the floodplain to increase the area and frequency of hydrologically connected floodplain and enhance habitat diversity. Floodplain grading could include lowering disconnected floodplain surfaces to create an inset floodplain, expanding point bars, creating overflow paths activated at high flows, enhancing side channels, and expanding connected wetland areas. Alcove features or seasonally inundated locations could be expanded to enhance hydraulic complexity and aquatic habitat. Graded floodplain areas would interact with Madison River hydrology such that woody vegetation recruitment and establishment would be increased. Floodplain grading would primarily be implemented in Sub-Reach 2 on hydrologically disconnected and unvegetated floodplain surfaces. Floodplain grading could complement and provide a source of material for the other alternatives. The floodplain grading alternative is illustrated conceptually in Figures 6 and 7.

- SPAWNING HABITAT: **Moderate**. Expanding locations seasonally inundated at specific timeframes correlated with spawning would increase spawning habitat. Reactivating side channels would provide low-energy areas that can retain gravels.
- REARING HABITAT: **Moderate**. Increased floodplain connectivity would promote the formation and maintenance of features that provide quality rearing habitat, including backwaters, alcoves, and wetlands.
- RIVERSCAPE FUNCTION: **Moderate**. Floodplain grading would increase hydraulic and geomorphic complexity and floodplain connectivity, thereby providing aquatic habitat diversity and improving floodplain water and sediment storage, nutrient processing, scour and deposition processes, and recharging of groundwater and hyporheic flow pathways. This alternative would promote natural recruitment surfaces where willows and cottonwoods can establish.
- TECHNICAL FEASIBILITY: **Moderate**. Floodplain grading could be done with heavy equipment only and could be fairly easy to implement. If incorporated with the Gravel Augmentation alternative a cut/fill balance could be achieved resulting in no net export of material out of the project area.
- GEOMORPHIC SUITABILITY: **High**. This alternative enhances riverine processes while accommodating the long-term trend of channel incision in the Project Reach. Further channel incision could eventually disconnect lowered floodplain surfaces and potentially undermine the long-term success of the project.
- INFRASTRUCTURE: **Low**. Lowering the floodplain may increase the flood prone width in select areas; however, this alternative can be designed and implemented to avoid increasing flood risk to existing infrastructure.
- PERMITTING: **Moderate**. This alternative would likely impact some wetlands/waters and streambanks. A JPA (404, 401, 310, 318) including floodplain development permit may be necessary.

- DATA: **Moderate**. A hydraulic model would likely be necessary to evaluate pre- and post-project water surface elevations and ensure activation of graded floodplain surfaces at the desired hydroperiod.
- COST: **Moderate**. Cost would depend on the extent of grading locations and if material would need to be hauled offsite. However, this could be a fairly low-cost alternative if material did not need to be hauled offsite and a minimal number of machines is used.

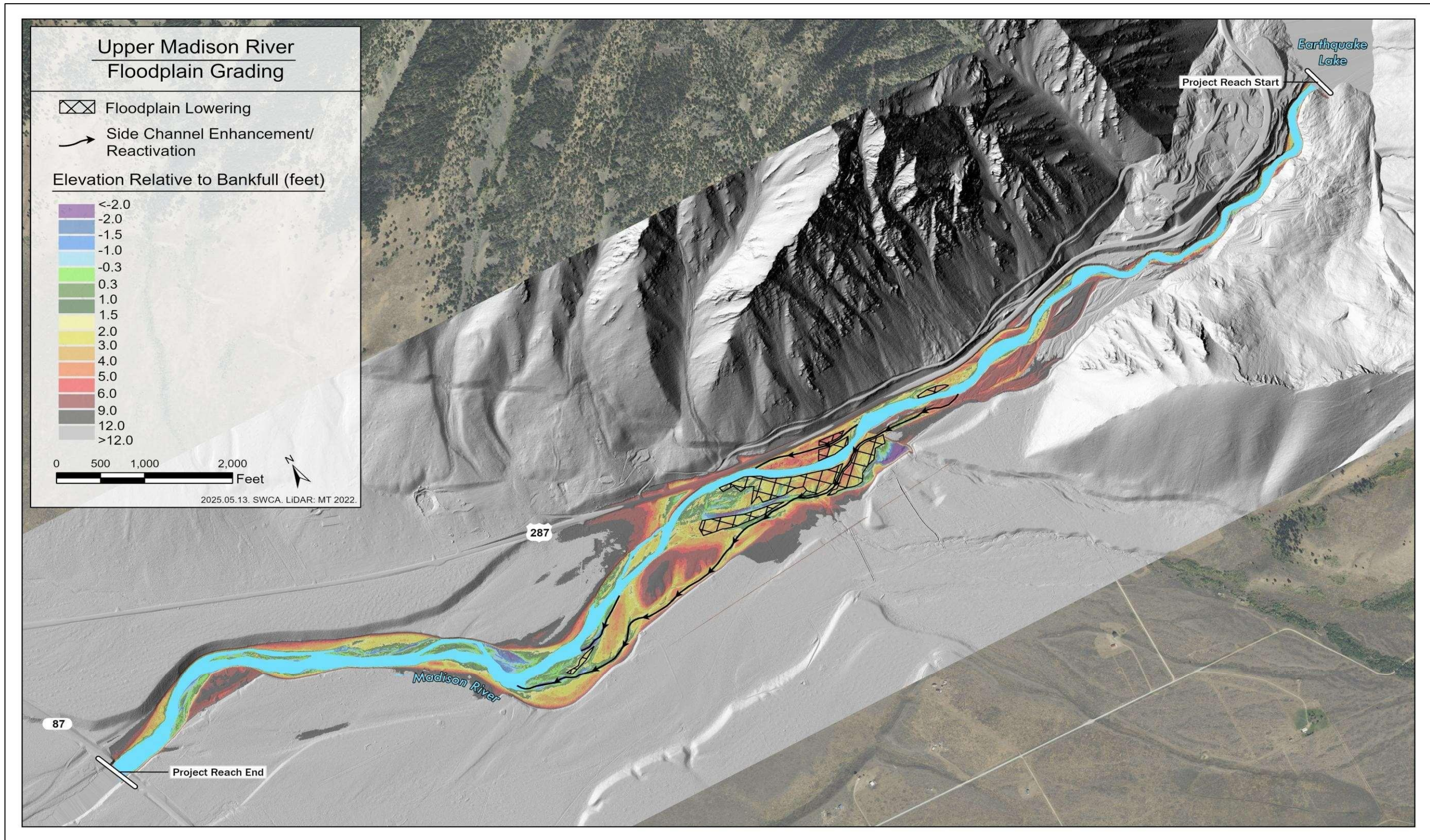


Figure 6. Floodplain grading alternative concept map with background relative elevation model.



Figure 7. Floodplain grading alternative concept map with background imagery.

Recommended Next Steps

Once Northwestern Energy and Montana Fish, Wildlife and Parks have reviewed these alternatives, the next step will be to meet and select which alternative or alternatives to carry forward to the feasibility analysis stage (alternative selection meeting). Depending on which alternative(s) are selected, further analysis may include detailed hydrologic analysis, hydraulic modeling, sediment transport modeling, evaluation of the alternatives' effects on riparian vegetation and aquatic habitat condition, and evaluation of potential risks to infrastructure, nearby landowners, and river access/recreation. In addition, a construction cost estimate will be developed for each alternative.

At the alternative selection meeting, objectives could include but not be limited to:

- Review the alternatives evaluation matrix (Table 1) and incorporate any input about whether low/mod./high assignments should be modified;
- Select which alternatives are appropriate for a more detailed feasibility analysis;
- Identify a practicable time frame for completion of the feasibility analyses and reporting.
- Coordinate on timing and approach for soliciting landowner/stakeholder feedback if needed as part of feasibility analyses.
- Discuss any other questions that should be addressed as part of the feasibility analysis step.

Appendix B

Arctic Grayling- Remote Site Incubator vs Broadcast Spawning Study

Introduction

In Montana, RSIs (Remote Site Incubators) have been used to introduce salmonid embryos into waters in remote locations (Kaeding and Boltz 2004; Anderson 2019; Shepard et al. 2021). They provide developing embryos with shelter and increase survival rates (Shepard et al. 2021). However, RSI deployment is labor intensive, and their success has varied widely among species (Haugen et al. 2000; Magee et al. 2006; Anderson 2016; Anderson 2019). Arctic Grayling embryos are placed in RSIs at a relatively high density but are highly susceptible to fungus, which can spread rapidly causing mortality. This can be mitigated by removing infected embryos, adjusting flow, and repositioning the egg basket but the labor requirements are extensive and additional handling of embryos could be detrimental to their survival. Unlike other salmonids that dig a nest in the stream bed for embryos to develop, Arctic Grayling are broadcast spawners and their embryos are dispersed in the water column where they eventually settle into the interstices of the stream bed. The dispersal of embryos likely reduces the probability of fungal infection compared to when they are concentrated in RSIs. Given the time constraints and varied success of stocking Arctic Grayling with RSIs, an alternative method may be appropriate. One method to reduce the labor required and increase survival rates for Arctic Grayling embryo introduction is to simulate egg dispersal as it occurs during spawning.

Our study compared the survival rates of stocked Arctic Grayling embryos using RSIs and a simulated broadcast spawning method. Our goal was to determine whether broadcast spawning is a viable alternative to RSIs for stocking Arctic Grayling embryos.

Study Area

Black Sand Springs located in Custer Gallatin National Forest at an elevation of roughly 9000 ft and flows through approximately 1 mile of lodgepole pine (*Pinus contorta*) forest and riparian plant assemblages before joining the South Fork Madison, which flows into Hebgen Reservoir near West Yellowstone (Figure 1). Black Sand Springs is a low-gradient stream with a year-round flow of 18.7 cfs (Montana Fish, Wildlife & Parks 1989) and was selected for grayling restoration because of the low densities of resident non-native trout and overall habitat characteristics that were identified as important to fluvial Arctic Grayling by Hubert et al. (1985) and Kaya (1992), such as constant water temperature, low-velocities, and the presence of gravel substrate for spawning.

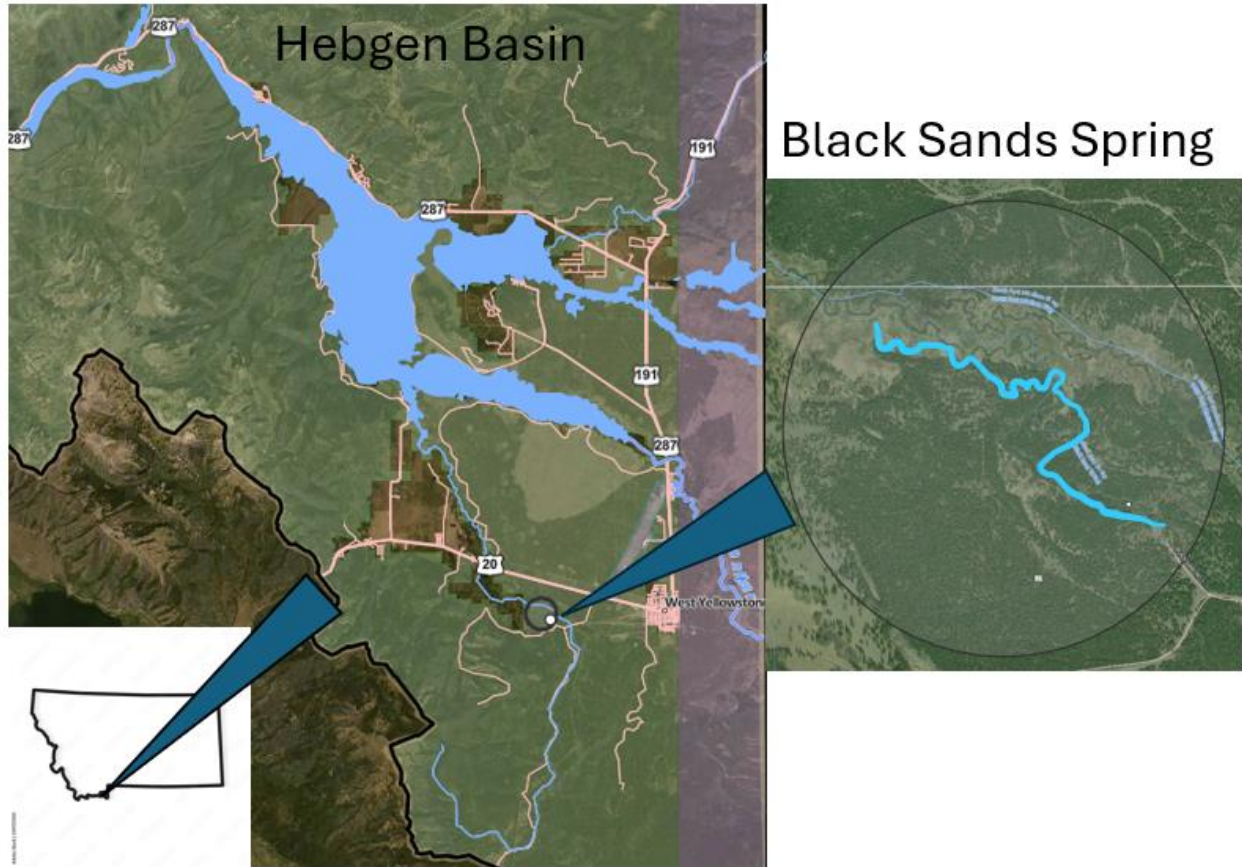


Figure 1. Map of Black Sand Spring.

Methods

To evaluate Arctic Grayling embryo survival to emergence rates, 5 RSIs and 5 simulated broadcast spawning net pens were used in Black Sand Springs in 2023, 2024, and 2025. RSIs were installed following Rupert et al. (2007) with additional fry trap boxes attached (Figure 2). The simulated broadcast spawning method used 4 ft x 2 ft x 3 ft rectangular net pens constructed with T-posts anchored to the stream bottom, 1/32" mesh, and a fry trap attached to the downstream end (Figure 2). Arctic Grayling spawning has been observed in areas with spawning gravels ranging from 2-64 mm, stream velocities of 0.75-3 ft/s, stream depths of 0.5-3 ft, areas with 25% fines (< 3mm) or less, and stream temperatures ranging from 40-55 °F (Hubert et al. 1985; Anderson 2019). Site selection for the broadcast spawning net pens was determined based on Arctic Grayling spawning suitability criteria described by Hubert et al. (1985) for velocity, depth, temperature, and substrate size. Location of RSIs within Black Sand Springs was limited to the headwaters of Black Sand Springs due to design constraints (i.e., elevation drop needed for adequate flow). Water temperature was recorded hourly using HOBO TidBit MX Temp 400 recording device.

Arctic Grayling eggs were obtained from Rogers Lake in 2023, Park Lake in 2024, and Rogers Lake in 2025. Eggs were held approximately one week by Creston Fish Hatchery for eye up. Arctic Grayling egg numbers

were estimated by volume (800 eggs per fluid ounce) using hatchery methods (Piper et al. 1983; personnel communication hatchery managers). Approximately 13,000 Arctic Grayling embryos were placed in each RSI and simulated broadcast net pen in 2024 and 2025. In 2023, a year with low egg yield and quality, few embryos were available; therefore, only 2400 embryos were placed in each RSI and broadcast pen. Fry trap boxes were checked daily, and emergent fry were enumerated and released. Survival rates were estimated by totaling the number of Arctic Grayling fry observed from each RSI and broadcast pen during the hatching period (end of May until the second week of June) and dividing by the initial number of viable embryos for each year (Table 1). Survival rates were adjusted for detection probability where RSIs were assumed to be 1.0 and broadcast net pens were estimated as 0.05 by placing 100 fry in a 6th broadcast pen and returning to count fry two days later. All data analysis was conducted in R version 4.4.3 (2025-02-28 ucrt) -- "Trophy Case".

Table 1. RSI vs Broadcast data collected by Year, Type (RSI or Broadcast (BC)), ID, Start (total eyed eggs), Count (total swim up counted), DP (detection probability), Count Scaled (Count/DP), and Survival Adjusted (Count scaled/Start).

Year	Type	ID	Start	Count	DP	Count Scaled	Survival Adj
2023	RSI	1	2400	2	1	2	0.00
2023	RSI	2	2400	3	1	3	0.00
2023	RSI	3	2400	2	1	2	0.00
2023	RSI	4	2400	2	1	2	0.00
2023	RSI	5	2400	3	1	3	0.00
2023	BC	1	2400	0	0.05	0	0.00
2023	BC	2	2400	2	0.05	40	0.02
2023	BC	3	2400	36	0.05	720	0.30
2023	BC	4	2400	16	0.05	320	0.13
2023	BC	5	2400	7	0.05	140	0.06
2024	RSI	1	13167	2094	1	2094	0.16
2024	RSI	2	13167	3667	1	3667	0.28
2024	RSI	3	13167	5836	1	5836	0.44
2024	RSI	4	13167	3673	1	3673	0.28
2024	RSI	5	13167	3749	1	3749	0.28
2024	BC	1	13167	562	0.05	11240	0.85
2024	BC	2	13167	99	0.05	1980	0.15
2024	BC	3	13167	3	0.05	60	0.00

2024	BC	4	13167	136	0.05	2720	0.21
2024	BC	5	13167	337	0.05	6740	0.51
2025	RSI	1	12800	151	1	151	0.01
2025	RSI	2	12800	2279	1	2279	0.18
2025	RSI	3	12800	950	1	950	0.07
2025	RSI	4	12800	1601	1	1601	0.13
2025	RSI	5	12800	1044	1	1044	0.08
2025	BC	1	12800	181	0.05	3620	0.28
2025	BC	2	12800	3	0.05	60	0.00
2025	BC	3	12800	7	0.05	140	0.01
2025	BC	4	12800	3	0.05	60	0.00
2025	BC	5	12800	46	0.05	920	0.07

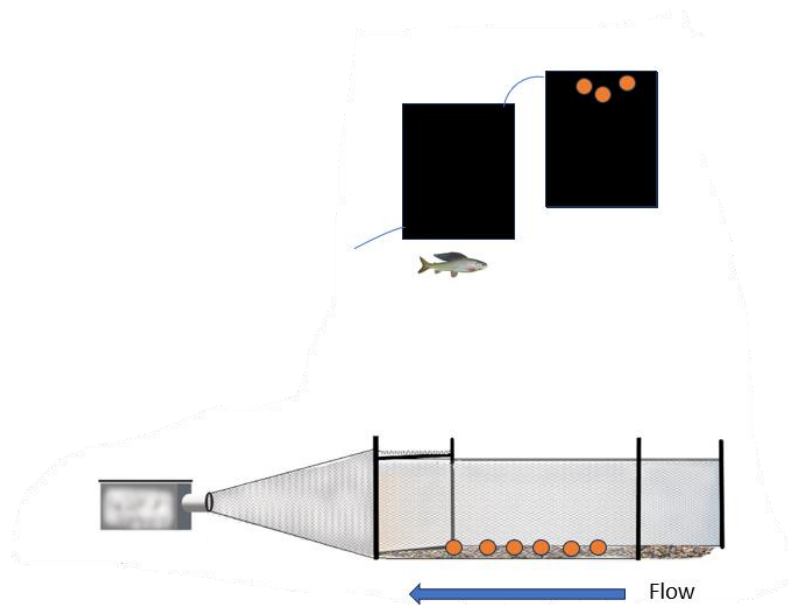




Figure 2. Diagram of experimental design (top). Diagram depicts RSIs (black squares) and broadcast net pens. Actual experiment setup (bottom) with RSIs (left) and broadcast spawning method (right).

Table 2. Summary of ARG stocking in Black Sand Spring from 2021-2025. Source is location of ARG used for spawning, eggs is number of eggs collected from spawning, Average-survival to emergence rates are calculated including both spawning methods with 95 CI in (), Fry stocked = (Eggs * Average Survival-to emergence rate).

Year	Source	Eggs	Average survival-to-emergence	Fry stocked
2021	Axolotl/Green Hollow	150000		
2022	Axolotl/Green Hollow	500000		
2023	Rogers/Green Hollow	794000	0.05 (0.0,0.12)	39700
2024	Park	218000	0.32 (0.15,0.49)	69760
2025	Rogers	1200000	0.08 (0.02,0.15)	96000

Results

Survival to emergence rates for Arctic Grayling in Black Sand Spring ranged from 0.0-85.0% with a mean of 5.0% in 2023, 32% in 2024, and 8.0% in 2025. (Table 1 and 2; Figure 3). Overall, survival rates in 2025 were not significantly different than survival rates in 2023, but slightly significantly different from 2024 (Dunn Test, 2023-2024 $p = 0.00$, 2023-2025 $p = 0.31$, 2024-2025 $p = 0.05$). Survival rates in 2024 were significantly higher than in 2023 and 2025, with a median of 0.28 (Figure 3). In 2023, the median survival was 0.0 and in 2025 the median was 0.07. There was no significant difference in survival to emergence between incubating methods within or among years (Wilcoxon Signed-Rank Test, $p = 0.8$, Figure 4). The median survival rates for RSI and Broadcast methods from 2023-2025 were 0.08 and 0.07, respectively.

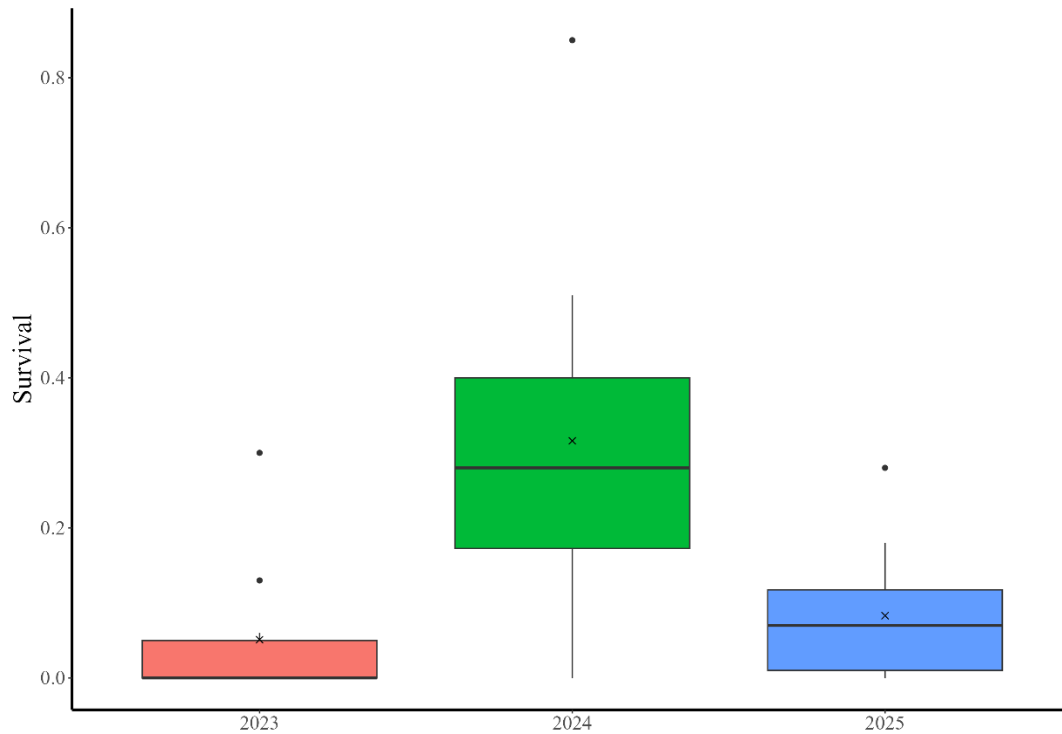


Figure 3. Boxplots representing Arctic Grayling egg to emergent fry survival (both incubation methods combined) for the years 2023, 2024 and 2025. Box shows 25th, 50th (solid line median), and 75th percentiles and whiskers show maximum and minimum values. X's represent mean values and dots are outliers.

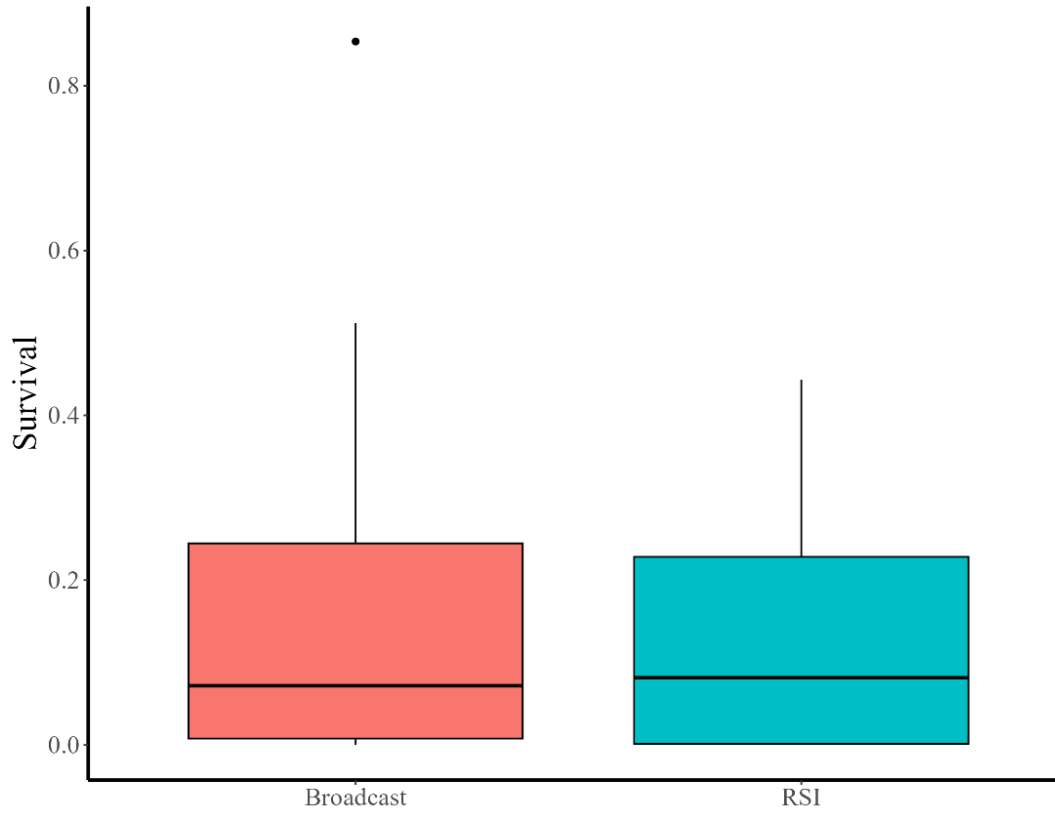


Figure 4. Boxplot depicts survival to emergence (eye-up to swim-up) for Arctic Grayling from 2023-2025 between two incubation methods 'Broadcast' and 'RSI' in Black Sand Spring. Box represents 25th, 50th, and 75th percentiles and solid black line is the median. Whiskers show maximum and minimum values of the distribution and dots are outliers.

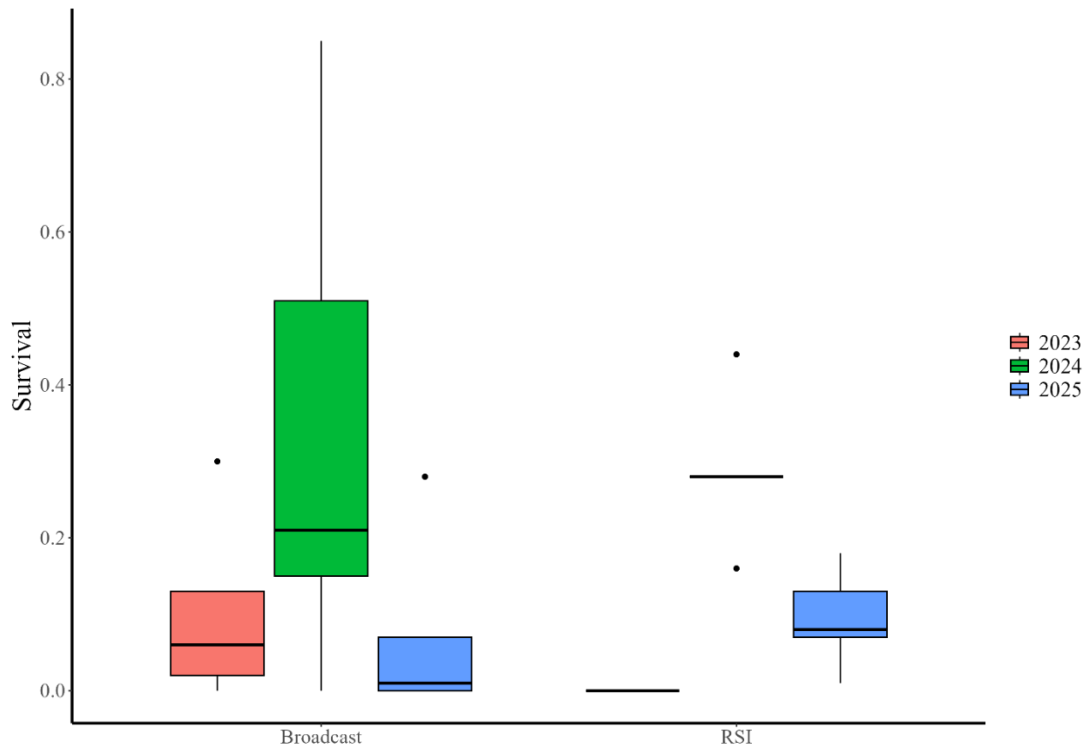


Figure 5. Boxplots depicting survival rates of Broadcast and RSI incubation methods in 2023, 2024, and 2025. Box represents 25th, 50th, and 75th percentiles and solid black line is the median. Whiskers show maximum and minimum values of the distribution and dots are outliers.

Discussion

Arctic Grayling survival to emergence rates varied widely in this study and mean survival rates were considerably lower than survival rates observed in similar studies (Kaeding and Boltz 2004; Haugen 2000; Anderson 2019). Low mean survival rates could be a product of underestimating fry by only counting live fry and overestimating detection probability in both RSIs and broadcast pens.

Low survival in 2023 can be attributed to poor egg quality during spawning and hatchery conditions at Roger's Lake (FWP hatchery personnel communication 2023). Interestingly, Arctic grayling eggs from Park Lake were used in 2024 and recorded the highest survival to emergence rates of any year in the study. In 2025, Roger's Lake eggs were used and hatchery personnel estimated 80% eye-up, indicating high quality eggs and high yield (FWP hatchery personnel communication 2025). Differences noted by hatchery and field staff further illustrate natural variation in spawning conditions and egg quality among years.

There was not a significant difference in survival to emergence rates between incubation methods (broadcast or RSI) in this study. Given limitations on equipment setup, field staff, and stream access, broadcast incubation may be an appropriate option for Arctic grayling reintroduction efforts in Black Sand Creek. Likely the most important factors in reintroduction efforts are egg quality during spawning/eye-up and quantity of eggs based on low survival rates. FWP recommends continuing to stock Black Sand Spring with Arctic Grayling eggs using the broadcast method.

Literature Cited

- Anderson, I. 2016. Influence of fine sediment on Arctic grayling (*Thymallus arcticus*) egg survival and spawning habitat suitability. Wildlife Biology Undergraduate Thesis. University of Montana, Missoula.
- Anderson, M. 2019. Sediment effects on Arctic grayling (*Thymallus arcticus*) early life history in Montana— a field experiment and literature review. FINAL REPORT. University of Montana Western, Dillon MT.
- Haugen, T.O. 2000. Early survival and growth in populations of grayling with recent common ancestors— field experiments. *Journal of Fish Biology*. 56:1173-1191.
- Hubert, W.A., Helzner, R.S., Lee, L.A., and Nelson, P.C. 1985. Habitat Suitability Index Models and Instream Flow Suitability Curves: Arctic Grayling Riverine Populations. Western Energy and Land Use Team. Division of Biological Sciences. Research and Development. Fish and Wildlife Service. U.S. Department of the Interior, Washington DC 20240.
- Kaeding, L.R. and G.D. Boltz. 2004. Use of Remote-Site Incubators to produce Arctic Grayling fry of wild parentage. *North American Journal of Fisheries Management*. 24:1031-1037.
- Kaya, C. 1992. Restoration of Fluvial Arctic Grayling to Montana Streams: Assessment of Reintroduction Potential of Streams in Native Range, the Upper Missouri River Drainage above Great Falls.
- Magee, J., Rens, E., and Lamothe, P. 2006. Arctic Grayling Recovery Program Fluvial Arctic Grayling Monitoring Report 2005. Montana Fish, Wildlife and Parks. Dillon, MT.
- Montana Arctic Grayling Workgroup. 2022. Upper Missouri River Arctic Grayling Conservation Strategy. Montana Fish, Wildlife and Parks. Dillon, MT.
- Piper, R.G., McElwain, I.B., Orem, L.E., McCraren, J.P., Fowler, L.G., and Leonard, J.R. 1983. Broodstock, Spawning, and Egg Handling. Pages 182-184. *Fish Hatchery Management*. United States Department of the Interior, Fish and Wildlife Service. Washington, D.C.
- Rupert, D., L. Nelson, M. Ruhl, and T. Koel. 2007. A guide for construction and installation of remote site incubators to introduce native fish gametes to streams. Center for Resources, Native Fish Conservation Program, Yellowstone National Park, WY, USA. <http://doi.org/10.5281/zenodo>.
- Shepard, B., Clancey, P., Nelson, L., Kruse, C., Al-Chokhachy, R., Drinan, D., Taper, M., and Zale, A. 2021. Evaluation of Remote Site Incubators to Incubate Wild and Hatchery-Origin Westslope Cutthroat Trout Embryos. *North American Journal of Fisheries Management*. 41:844-855.

