Refurbishing and Evaluating the Effects of Beaver Dams in Colorado Against Climate-Mediated Fires

Honors Thesis

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Abstract

Beaver dam analogs (BDAs) are increasingly used to restore riparian systems by mimicking the hydrologic and geomorphic effects of natural beaver dams. This study evaluated the influence of a recently installed BDA on channel form and sediment dynamics in Little Beaver Creek, a post-fire watershed in the Cache la Poudre basin. Historical beaver activity and habitat suitability were assessed using the Colorado Beaver Activity Mapper (COBAM) and the Beaver Restoration Assessment Tool (BRAT). Field measurements collected after installation revealed increased sediment deposition and reduced depths upstream, formation of a downstream plunge pool reaching bedrock, and development of gravel patches associated with sediment sorting. These early-stage responses indicate that the BDA performed as planned by slowed flow, retained sediment, and enhanced habitat complexity. In addition, the historic high-flow channel was rewetted as intended with subsequent willow growth. Despite installation delays due to winter freezing, the refurbished dam design aligns with Colorado Parks and Wildlife's draft Beaver Conservation and Management Strategy, providing a foundation for continued restoration and monitoring.

I. Introduction

1.1 Background

The role of beavers in shaping stream and wetland ecosystems has long been a subject of debate among ecologists and land managers. While some view beavers as ecological engineers that restore hydrologic function and enhance wetland biodiversity, others see them as nuisances that flood infrastructure, alter water quality, and disrupt human land use. Understanding whether beavers are ultimately beneficial or detrimental requires examining both their positive ecological contributions and the challenges they pose to human management of natural resources.

Beavers are known as a root cause of changes in river ecosystems, also known as ecosystem engineers: species that modify their environment, creating new habitats or modifying their current ones in order to inhabit the region in the fittest way (Brazier et al., 2020). They alter aquatic ecosystems behind their stable and reliable dams by decreasing water flow, raising water levels, and creating entirely new freshwater ecosystems (Gascon et al., 2015). In addition, they are also considered a keystone species for riparian ecosystems, as they also aid in the preservation of biodiversity due to the recruitment of aquatic plants and animals by raising the water levels and extending wetlands (Brazier et al., 2020). Beavers use their skills to utilize the natural resources around them, such as tree trunks, branches, stones, and mud, to transform the hydrology of rivers and streams. Without beavers and the ponds they make by building dams, the flow of water deteriorates the riverbanks. Banks grow steeper, beds are eaten away, and stream bank erosion increases (Gurnell, 1998). Without beavers, areas of stored surface water are lost, there is more carbon in the water, and marine environments are reduced (Gurnell, 1998).

Beaver dam analogues (BDAs) are man-made structures constructed using woody debris and fill material to form a pond and mimic natural beaver dams and span the channel (Wheaton et al., 2019). Using on-site woody material and sediment plugs to weave through posts to provide stability, BDAs have been found to mimic the form and function of natural beaver dams. By creating a large backwater area behind the structure, habitat and floodplain activity that was diminished and altered due to wildfires will benefit. A BDA is typically placed in the regions that were once riparian ecosystems, while also serving as an agent for mediating the effects of mega fires on water quality (Wheaton et al., 2019). For example, it prevents ash from continuing down the watershed, improving the water quality for the water users downstream. Studies have found that by reintroducing beavers into a stream to create a dam in a degraded stream, the stream in return increases aquatic plant biomass and alters macroinvertebrate community composition (Law et al., 2016). These findings provide support for implementing beaver dam analogs to help restore physical and biological diversity in degraded riparian ecosystems. Understanding how beaver-mediated ecosystem engineering improves riparian ecosystems aids in further research on developing innovative restoration strategies to rehabilitate fire-impacted watersheds.

Regarding beaver ponds becoming stores for sediments, the activity of beavers in relation to wildfires can influence burn severity. The ponds transition to large sediment and nutrient stores through increased water storage, allowing for diverse plant life and nutrient-rich waters, which benefits the species that live in the aquatic habitat created by beavers (Brazier et al., 2020). Introducing beavers into suitable streams for dam building can reestablish natural hydrologic and geomorphic processes, including floodplain connectivity and long-term stream recovery, creating a buffer against disturbances such as drought and fire (Fairfax et al., 2024). Through repeated dam building and vegetation modification, the riparian systems build up resilience to become self-sustaining over time. Knowledge of the ecological, hydrological, and social benefits of beaver reintroduction into degraded riparian ecosystems is essential to understanding how beaver activity and dam construction can restore riparian habitats, especially in post-fire landscapes.

1.2 Purpose of Study and Goals

The goal of this project is to evaluate how beaver dam analogs (BDAs) contribute to restoring riparian habitats and improving water quality in fire-impacted watersheds. Once data is collected to compare the habitat of the recently restored riparian habitat against mega fires, it will offer a very valuable resource to researchers across the country, enabling the development of informed management plans to conserve beaver dams. In addition, a service element will be completed: creating a design to reburish an existing BDA following the damage of post-fire floods to help continue the stream movement/pattern, keeping back sediment to improve the water quality downstream. Following the Cameron Peak Fire, around 330,000 water users in the Cache la Poudre watershed were affected by poor water quality as post-fire floods polluted the water with sediment, ash, and debris.

This project addresses the ongoing debate on whether beavers and the dams they create benefit or harm ecosystems by preventing ash and other pollutants in the Little Beaver Creek watershed from flowing downstream into the Cache la Poudre watershed. In doing so, it aims to enhance water quality for aquatic life, the surrounding plant growth, and the citizens who depend on this essential resource. Studies have found that the abandonment of beaver habitats in the Colorado Rockies has resulted in ecological consequences, including the drainage of ponds and altered habitat quality for vegetation and aquatic species (Neff, 1957). Therefore, promoting the roles of beavers in the proper maintenance of riparian ecosystems will serve as a persuasive argument for the species' reintroduction to aid in restoring degraded riparian habitats.

Methods

Using the GIS Colorado Beaver Activity Mapper (COBAM), both recent and historical beaver activity can be visualized to identify potential areas for conservation, riverscape restoration, and habitat suitability assessment. This will provide insights into potential past beaver dams that were once occupied, allowing for comparison of the difference in stream flow and the size of the wetland/riparian habitat. In addition, in streams, if there are no beaver pond clusters recently documented (2019-2021), the COBAM includes the Colorado Beaver Restoration Assessment Tool (BRAT) layer that includes variables such as potential dam building capacity (dams/km), existing dam building capacity (dams/km), and potential capacity dam count. This layer assesses the potential capacity for streams to support beaver dam building activity and associated habitat. Recent studies show that using BRAT to compare historical and current beaver dams in Colorado reveals that human land use changes and vegetation loss diminish the ecosystem services provided by beaver-modified streams (Scamardo et al., 2022). Therefore, creating a BDA will restore the hydrologic function and enhance water quality in fire-impacted landscapes by highlighting the potential benefits of reintroducing beaver-mediated processes.

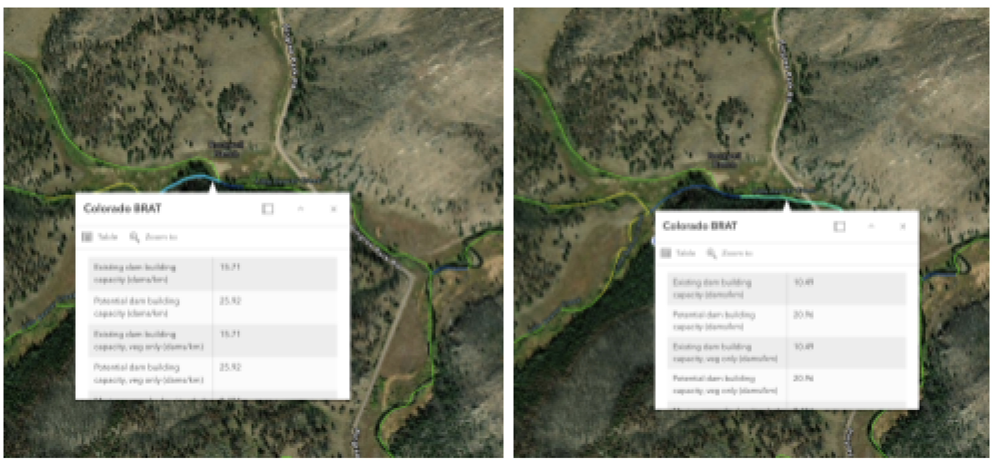

Figure 1. Historical Colorado BRAT modeled capacity for beaver dam building at the coordinates 40.62505° N, 105.52751° W for the Little Beaver Creek, where a BDA was recently implemented following the Cameron Peak Fire.

Within the area of interest in the Little Beaver Creek portion of the Cache la Poudre watershed, the Colorado Beaver Restoration Assessment Tool (BRAT) maps stream segments with different colors representing existing (green) and potential (blue) beaver dam-building capacities and habitat suitability (Figure 1). Based on the location of the stream near 40.62505° N, 105.52751° W, these historical data provide a baseline for comparing how the newly installed beaver dam analog (BDA) has influenced stream morphology and surrounding vegetation. By aligning BRAT model predictions with observed BDA performance, this project evaluates how accurately human-implemented analogs replicate natural beaver activity and contribute to riparian restoration and water quality improvement.

During the field visit to the BDA site, an assessment was conducted to document the current condition of the structure, measure stream depths, and determine how the system has been altered since installation, particularly in its ability to retain sediment and prevent downstream transport (Figure 2). Using the original depth and width measurements collected before the first dam was built, new measurements were taken before reconstruction to evaluate how the stream's geometry has changed over time. Historically, the site exhibited no plunge pool downstream, and the upstream channel had a wetted width (W) of 20.5 feet. Shallow depths (SD) measured 7 and 9.5 inches, while the deepest points (DD) were recorded at 15 and 16 inches. These baseline measurements serve as a reference for interpreting the impact of the BDA on channel morphology and hydrologic function since its implementation.

Figure 2. Pictures of the visitation of the stream, where width and depth measurements of the BDA were taken.

As part of the project’s applied service component, a dam-repair strategy was designed that sustains riparian ecosystem benefits while preventing excess sediment from moving downstream. Making sure the BDA is built with natural material surrounding the stream, along with a stable, uniform crest shape, it is expected that the BDA will continue to enhance stream morphology and sinuosity to allow the growth of plants along the sides, hold the bank together, and capture ash running off the burned area during high flow season (Wheaton et al., 2019). Through permission from the City of Greeley's Water Resource Planning and Watershed Program Manager, Matt Sparacino, we were able to visit the stream and plan out a future rough design for the reparation of the dam in the spring season, when snow melts, and flow is low. In addition, permission has already been acquired to do this service when conditions are most ideal. According to them, the Coalition for the Poudre River Watershed (CPRW) completed some instream work on Little Beaver Creek last year on the Forest Service land upstream from the BDA, and repairing it would only help the system more.

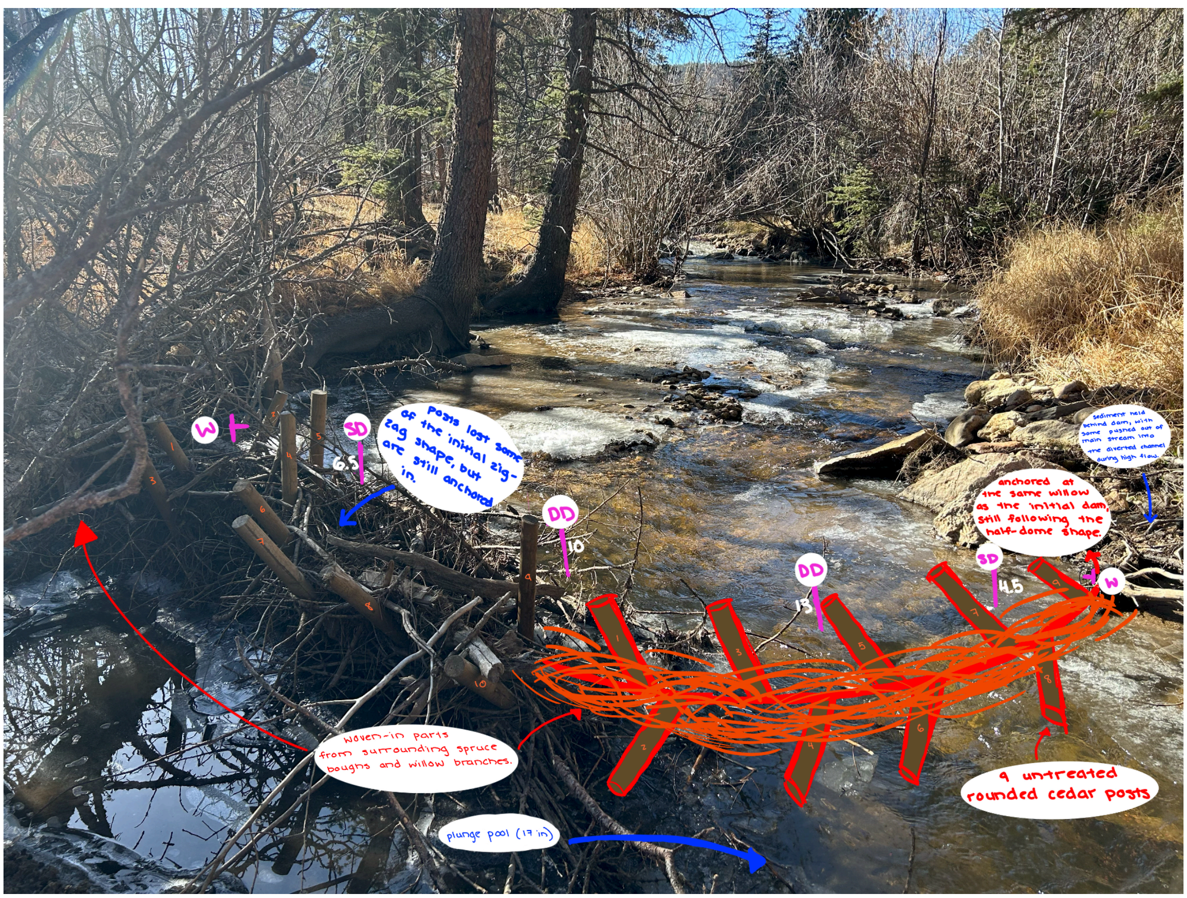

Figure 3. Design of the future reparations of the beaver dam analog (BDA); the shape follows the curvature and original shape of the first one built and measured out following the visitation of the stream.

Red is notes of the design, blue is observations of the effects of the past high flow seasons on the dam, and pink is the locations where new depth and width measurements took place.

The existing structure includes ten anchored posts and one loose post, and only the loose post will be removed and replaced during reconstruction. The rebuilt dam will follow a zigzag pattern, with posts spaced approximately 10–12 inches apart and staggered slightly forward and backward depending on where they can be securely driven into the streambed. This configuration enhances structural stability by distributing hydraulic force across multiple angles, rather than a single straight line. Based on these anchored points, the design will be re-arched to guide high flows toward the side high-flow channel, requiring an estimated nine additional posts (Figure 3). Untreated, rounded cedar posts will be used because they are stable yet biodegradable within 1–10 years, free of harmful chemical treatments, and can be easily pointed and driven into the substrate (Wheaton et al., 2019). Spruce-fir boughs and willow branches woven between the posts will create a natural, porous barrier that stabilizes the structure, reduces the risk of failure during high-flow events, and protects downstream property. Furthermore, fixing the dam to a half-dome shape will be stable for high-flow season, aiding in the diversion of some of the flow into the higher flow channel, which will act as a service for replenishing the willows, removing sediment and ash from the stream, and overall benefiting the system of the Little Beaver Creek.

Results

Using the Colorado COBAM/BRAT model, an upstream reach of Little Beaver Creek was identified as an area of previous beaver activity, supported by field observations of chewed wood and marsh-like conditions (Figure 4). These indicators suggest that the site historically supported an active beaver presence, which contributed to localized wetland formation and the development of marsh habitat. The model outputs and on-site evidence together established this reach as a location where beavers had previously altered stream morphology before relocating farther upstream.

Figure 4. BRAT-identified upstream reach in Little Beaver Creek, indicating areas of previous beaver activity prior to BDA installation.

	Hard Bank Width (W)	Wetted Channel Width	Shallow Depth (SD)	Deep Depth (DD)	Plunge Pool Depth
Historical Values	0-20.5 ft	0-20.5 ft	7 in, 9.5 in	15 in, 16 in	N/A
Observed Values	2-18 ft	2-16 ft	4.5 in, 6.5 in	10 in, 13 in	17 in (to bedrock)

Table 1. Historical and observed BDA width and depth measurements recorded.

Field measurements collected at the BDA site show clear geomorphic changes in channel form following installation (Figure 5). From Table 1, the hard bank width (W) now ranges from

2 to 18 feet, with water occupying 2 to 16 feet, depending on local topography. Upstream of the structure, shallow depths (SD) measured 4.5 and 6.5 inches, with deeper pockets (DD) of 10 and 13 inches, indicating sediment deposition behind the dam. Downstream, a 17-inch plunge pool has developed and extends to bedrock. Additional observations include a narrowing and shallowing of the channel immediately behind the dam, the presence of sandy deposits downstream of the structure, and reduced surface water directly behind the dam. In the adjacent high-flow channel, filling only during peak runoff, additional ash and sediment from the wildfire were observed, suggesting that high-flow events mobilized material and routed it out of the main channel (Figure 5).

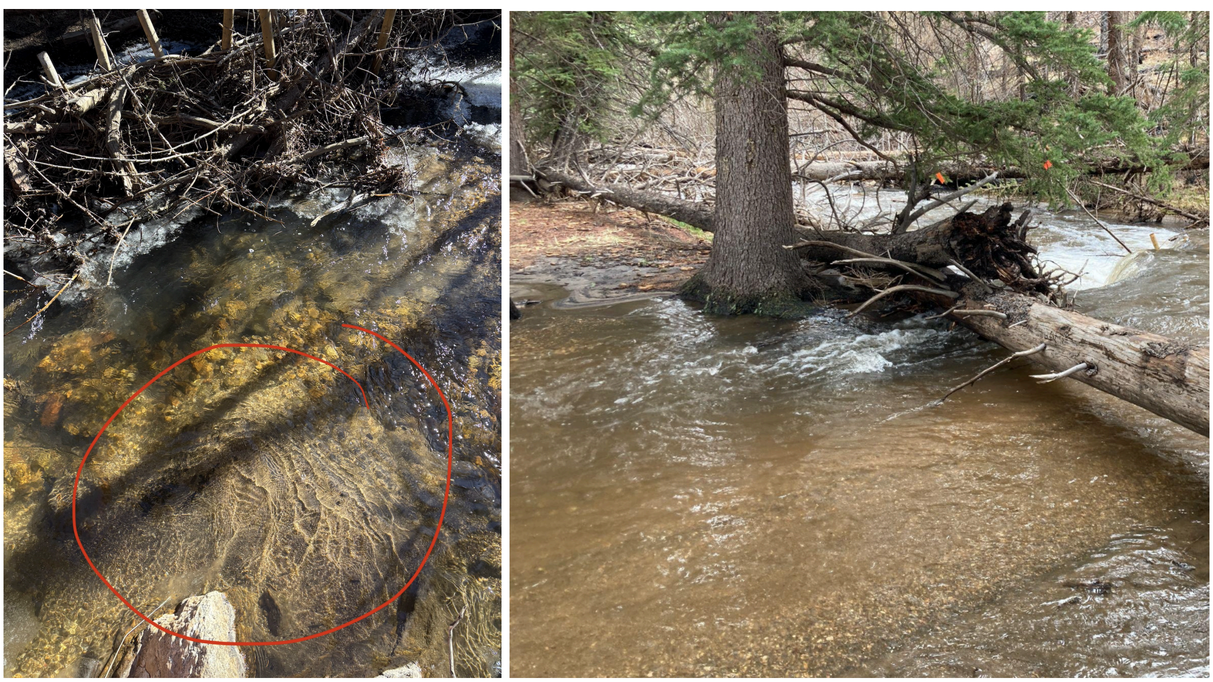

Figure 5. Sediment accumulation upstream of the BDA and into the higher flow channel.

Upstream of the BDA, several new gravel deposits were observed, indicating localized sediment sorting following installation. These gravel areas represent physical changes in substrate composition created by the altered hydraulics of the structure (Figure 6).

Figure 6. Gravel areas were created upstream of the BDA following its implementation.

Discussion

The identification of former beaver activity upstream suggests that habitat conditions in this reach likely changed over time, becoming less suitable and prompting beavers to move farther up the system (Figure 4). Although this historical presence originally informed early decisions about where to install a BDA, subsequent evaluation indicated that placing the structure slightly downstream would yield greater restoration benefits. The downstream location where the BDA is currently situated exerts a stronger hydraulic influence on the channel and is better positioned to intercept and retain sediment before it travels farther downstream. This placement enhances the BDA's capacity to support riparian recovery and aligns more effectively with the project's sediment retention and habitat improvement goals.

Following installation, clear geomorphic changes were observed in channel depth and substrate composition. Upstream of the dam, depths decreased due to the accumulation of trapped sediment behind the structure. The reduction in flow velocity caused fine materials to settle out, reshaping the channel and producing a shallower upstream profile. Figure 5 illustrates how the BDA slows streamflow and encourages this sediment deposition. In contrast, below the dam, a pronounced plunge pool formed where water dropping over the structure created concentrated hydraulic energy capable of carving into the streambed. This deeper pool, which extends to bedrock, not only stabilizes the structure by dissipating flow energy but also contributes to downstream habitat complexity. By creating greater depth, varied flow conditions, and a more heterogeneous substrate, the plunge pool provides thermal refuge, supports a broader range of aquatic species, and enhances overall ecological diversity in the reach. Additionally, new gravel patches appeared upstream, indicating localized sediment sorting (Figure 6). These patches represent early environmental benefits of the BDA, as they create potential trout spawning habitat.

Colorado Parks and Wildlife's *Draft Beaver Conservation and Management Strategy* emphasizes a statewide shift toward restoring beaver populations and expanding beaver-influenced wetlands, reflecting growing recognition of the species' ecological importance ("CPW Seeks Public Input on Its Draft Beaver Conservation and Management Strategy Through December 17," 2025). The Strategy outlines a coordinated framework to increase and sustain beaver and wetland habitat across suitable landscapes, highlighting priorities such as habitat monitoring, nonlethal conflict management, restoration planning, and improved translocation protocols. These goals align closely with the motivations behind the Little Beaver Creek BDA project, which aims to rebuild the hydrologic functions historically provided by beavers. As CPW notes, beavers occupy a broad range statewide, and conservation efforts now prioritize increasing their presence where ecological conditions are appropriate, given their role as a keystone species that supports stream resilience, water storage, and biodiversity ("CPW Seeks Public Input on Its Draft Beaver Conservation and Management Strategy Through December

17," 2025). By placing BDAs in areas identified as suitable through BRAT modeling, this project helps restore sediment retention, floodplain reconnection, water storage, and riparian habitat conditions that align with CPW's long-term vision for beaver-supported watershed resilience.

A key limitation of this project was the late assembly of the machinery required to secure the posts in the streambed. This equipment is essential for ensuring BDAs remain resilient during high-flow seasons. By the time it became operational, a hard freeze had set in, and extensive ice made it impossible for the equipment to penetrate the ground. Although this prevented full installation during the current season, the design and planning completed for this project still provide a meaningful service to the stream by guiding future restoration efforts. The results collected from the first BDA installed earlier in the season also offer valuable insight into how the structure functions under current conditions and where improvements or reinforcements may be needed. Moving forward, additional collaboration with partners will support effective construction and repair in early spring when flows are low, ensuring that the project continues toward its long-term ecological goals.

Although beavers are sometimes viewed negatively because of concerns about tree damage or flooding of infrastructure, extensive research demonstrates that their hydraulic and ecological influences generate significant long-term benefits for riparian ecosystems. Numerous experiments with BDAs and observations of stream alteration following beaver activity have established beavers as a keystone species whose population size and behavior exert a disproportionate influence on surrounding habitats (Roberts, 2019). Through their ability to raise water tables, trap sediment, create wetlands, and diversify habitat structure, beavers function as natural engineers of ecosystem resilience. The results of this study support previous research demonstrating that human-built beaver dam analogs can effectively mimic natural ecological processes, making them valuable tools for watershed restoration, sediment management, and post-fire recovery in Colorado streams.

Conclusion

This study demonstrates that the installation of a beaver dam analog (BDA) in Little Beaver Creek is beginning to replicate key geomorphic and ecological functions associated with natural beaver dams. Using COBAM and BRAT to evaluate historical beaver activity and habitat suitability provided valuable context for interpreting field results and guiding restoration decisions. The observed sediment deposition upstream, reduced channel depths, formation of a downstream plunge pool, and development of gravel patches all indicate that the BDA is altering stream hydraulics in ways that promote sediment retention, habitat diversification, and riparian recovery within this post-fire watershed. Although winter conditions limited full installation during the current season, the structural design, initial measurements, and alignment with Colorado Parks and Wildlife's draft Beaver Conservation and Management Strategy underscore the long-term potential of BDAs to support watershed resilience. Continued monitoring and planned reconstruction in spring will further refine the structure's effectiveness and contribute important insights for future beaver-based restoration efforts across Colorado.

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