Adobe Creek Avulsion Planning Project

Preliminary Engineering Report

October 2022

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SUN RIVER WATERSHED GROUP

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1 PROJECT BACKGROUND

In the vicinity of Fort Shaw, Montana, the Sun River is highly migratory and prone to avulsions, a process by which a river channel rapidly abandons an alignment and forms a new channel or recaptures a formerly active channel. Avulsions typically occur when rivers develop an overly flat gradient and can no longer efficiently convey their incoming sediment load. The river then reroutes to a steeper alignment that can more efficiently transport its sediment. Sun River channel avulsions appear to occur relatively frequently, as evidenced by the many historic channel scars and flow paths that exist throughout the river's floodplain in the vicinity of Fort Shaw. A channel migration study of the Sun River (AGI 2021) noted the slope of the river decreases from 0.30% in the reach between Highway 287 and Lowry Bridge to 0.15% between Rocky Reef and Sun River, MT. The minimally confined nature of the river as it crosses the valley from the south to the north valley wall downstream of North Fort Shaw Road, combined with the decrease in channel slope may be naturally contributing to the frequency of channel avulsions in this area.

Avulsion paths are often undesirable due to agricultural operations and developments that are affected by the new channel's alignment. New channel alignments may disrupt property access, increase erosion and flooding risk in undesirable areas, or jeopardize infrastructure such as roads, buildings, fences, and utilities. In the spring of 2021, the Sun River avulsed into the lower end of Adobe Creek just downstream of Fort Shaw Bridge and captured a former channel of the river that had been abandoned for many decades. This recaptured alignment caused significant flood damage and threatened residences and other structures. In January 2022, an ice jam caused the river to avulse into lower Adobe Creek again, causing similar issues and damages to private lands as in 2021. The Adobe Creek avulsion is referred to in this report as Avulsion Site #1 (Figure 1 and Figure 2).

In 2019, another avulsion began developing near the mouth of Adobe Creek, which threatened to overtake an irrigation channel adjacent to Parker Farms. Landowners attempted to block this avulsion path with a tall gravel berm, which forced the river back to its more northern alignment. This avulsion is referred to in this report as Avulsion Site #2 (Figure 1 and Figure 3).

During spring flows in 2020, the Sun River completely avulsed into the irrigation channel adjacent to Parker Farms just downstream of Avulsion Site #2. The river cut through an island near the mouth of Adobe Creek, captured an irrigation pump, and formed a new, straighter 2,800-foot route while abandoning its more sinuous, 6,560-foot alignment to the northwest. The river currently remains in this alignment and is actively widening as it establishes a stable gradient. This widening is resulting in erosion of the river's banks eastward into agricultural fields. This avulsion is referred to in this report as Avulsion Site #3 (Figure 1 and Figure 4).

In response to these rapid channel adjustments and subsequent damages, the Cascade Conservation District and Sun River Watershed Group secured funding from the Montana Department of Natural Resources and Conservation to perform a preliminary engineering study that would identify alternatives to achieve the following outcomes:

1. Reducing the risk of the Sun River permanently establishing an undesirable flow path;
2. Restoring connectivity between Rocky Reef Spring Creek and the Sun River;
3. Establishing a channel alignment that is technically and economically feasible while being acceptable to landowners, regulators, and other stakeholders.

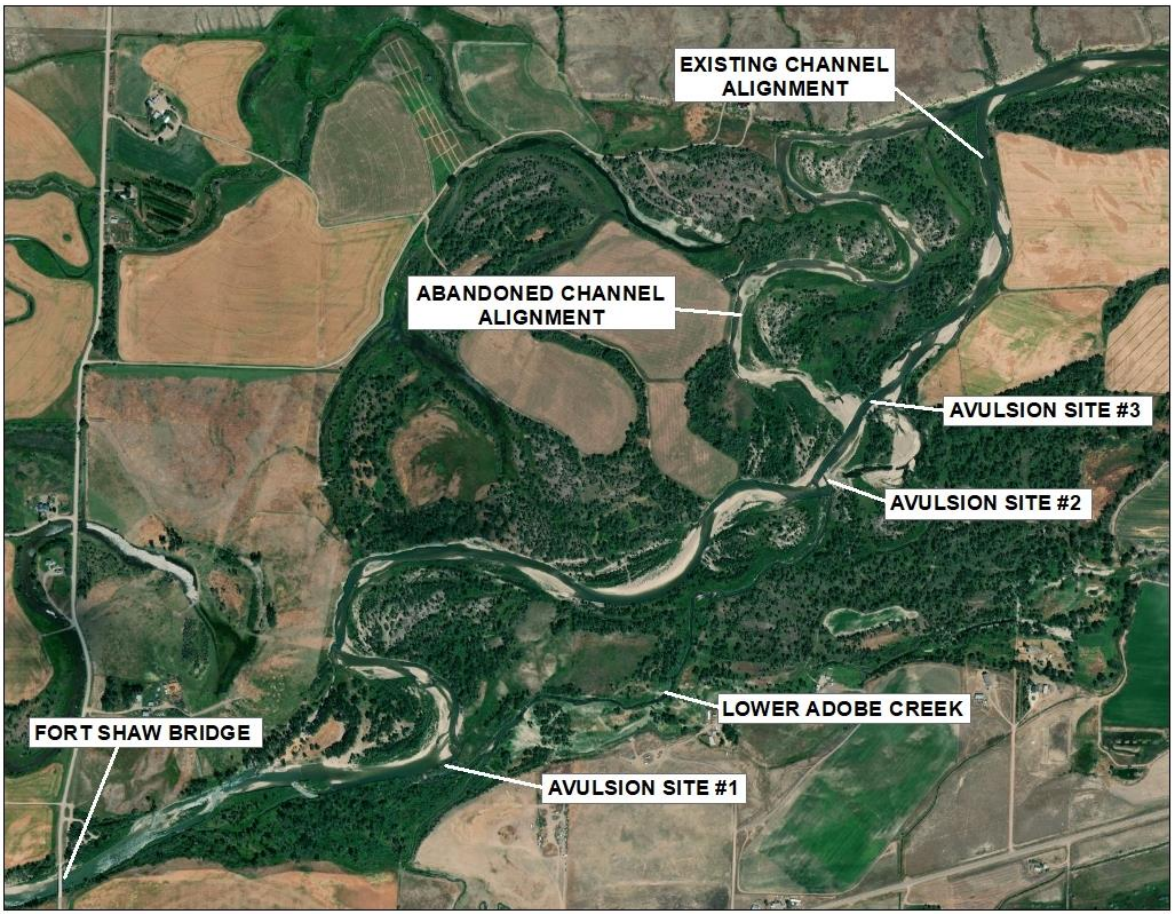


Figure 1. Adobe Creek Avulsion Planning project area.

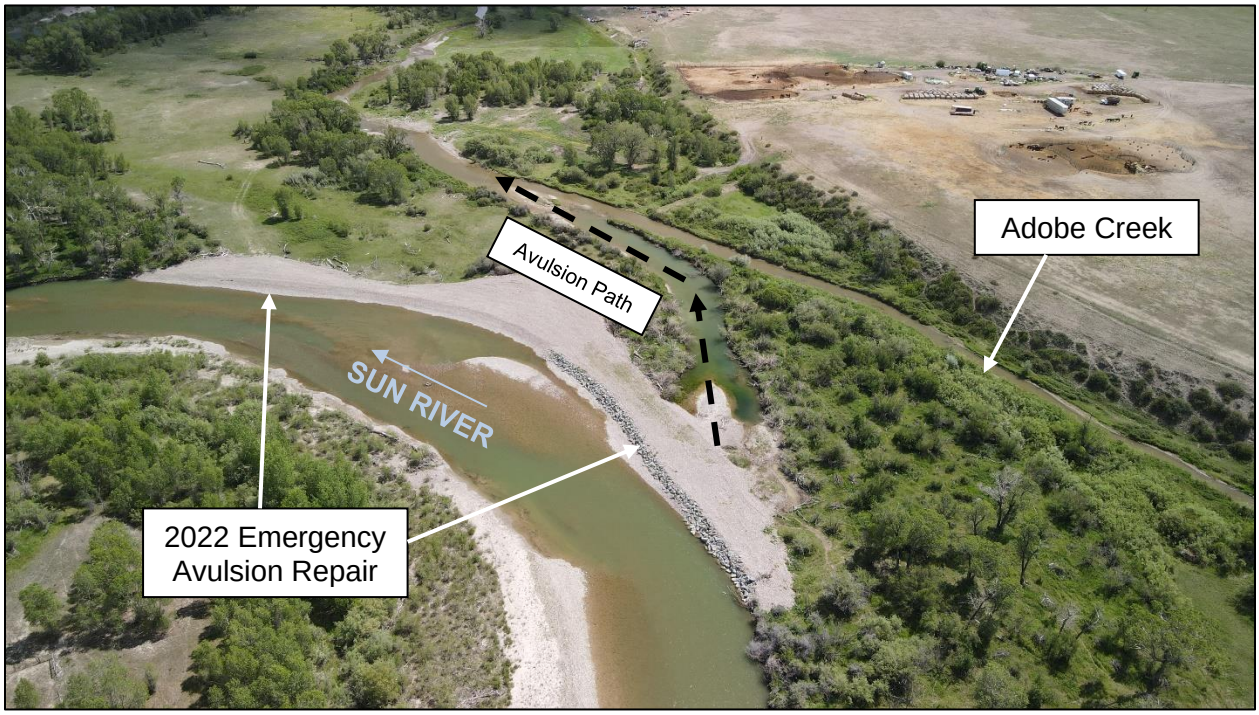


Figure 2. Aerial view of Avulsion Site #1 looking downstream.

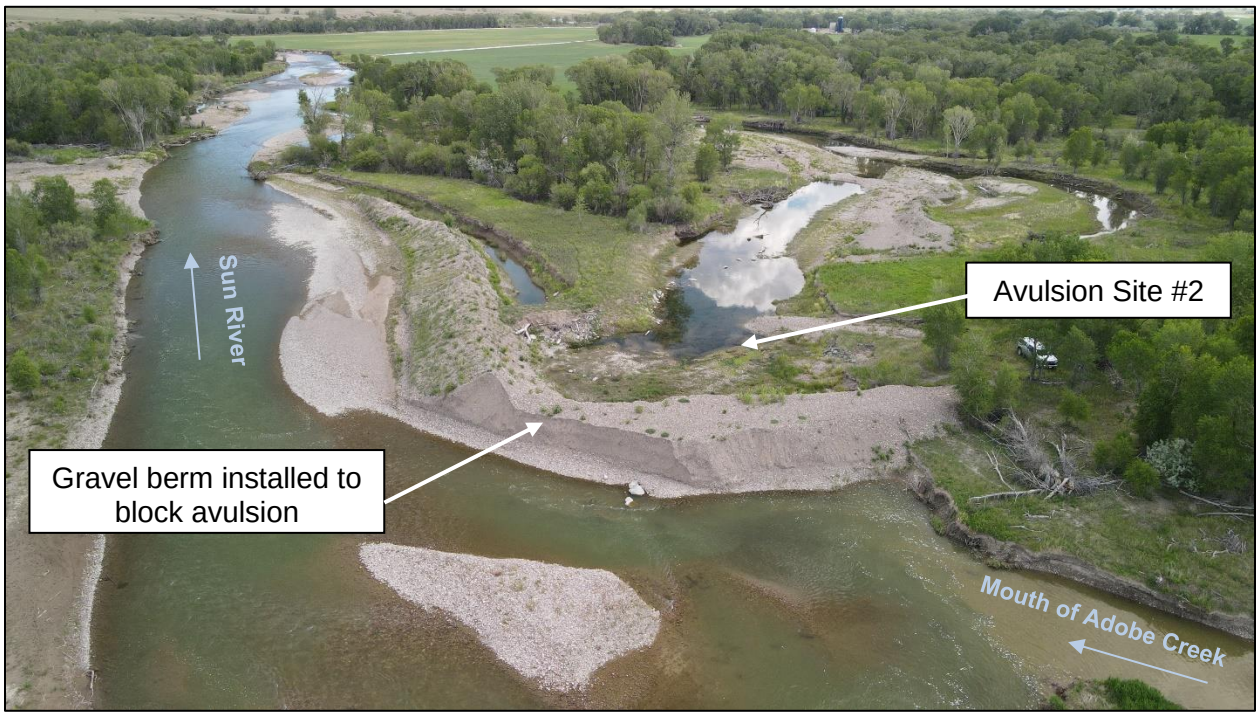


Figure 3. Aerial view of Avulsion Site #2 looking downstream (Avulsion Site #3 is in upper right corner of photo).

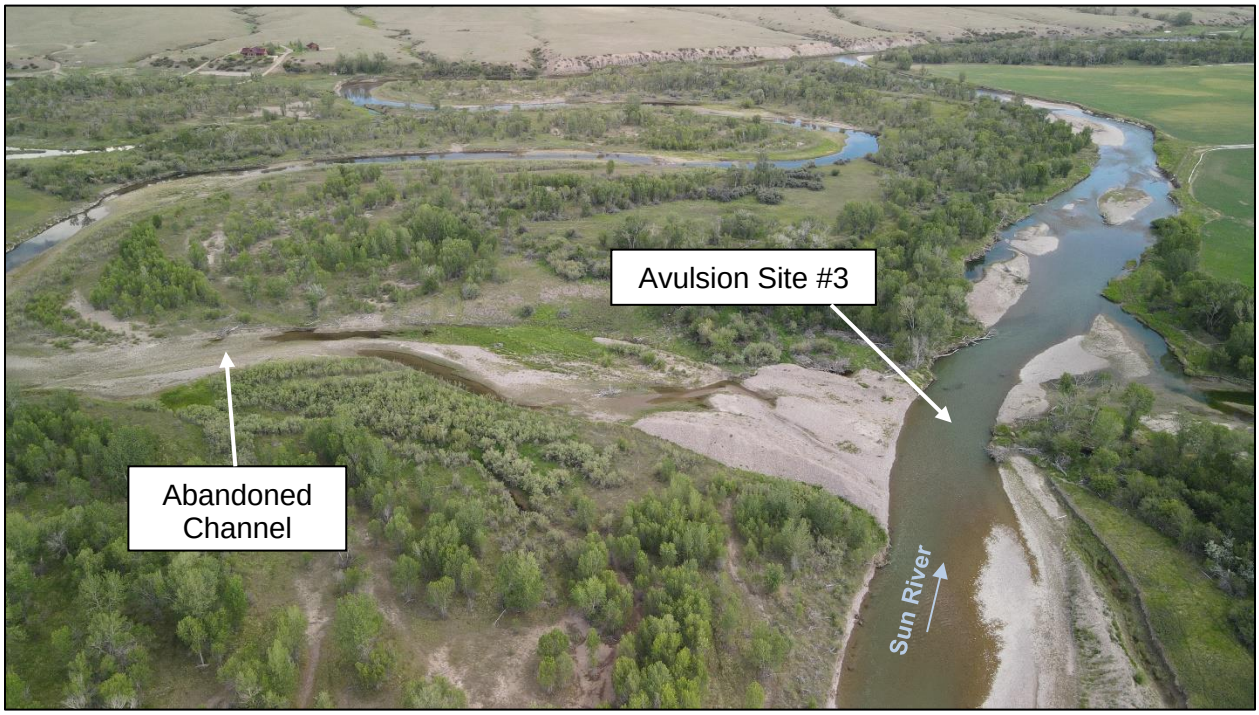


Figure 4. Aerial photo of Avulsion Site #3 looking downstream. Note: abandoned channel shown on left side of photo.

The following Preliminary Engineering Report (PER) outlines alternatives that are likely to achieve the desired outcomes. The report includes narrative descriptions, conceptual design figures, engineer's cost estimates, permitting considerations, and a cost versus risk assessment. The "No Action" alternative is also discussed for stakeholder consideration.

This PER is intended for project stakeholders to better understand the implications and relative costs of each alternative, and to assist in making informed decisions on the course of action. The drawings included with the PER are intended for planning purposes only and are not construction-ready designs. Once a preferred alternative is selected, a more comprehensive and detailed design plan will be necessary prior to commencement of the permitting and construction phases of any channel or bank alteration project.

2 AVULSION PLANNING ASSESSMENT METHODS

2.1 PUBLIC MEETING

On July 5th, 2022, the Sun River Watershed Committee and Cascade Conservation District hosted a public meeting to discuss the status of the project and entertain ideas and feedback from local landowners. Landowners were requested to complete and return feedback forms to the Conservation District within a week of this meeting. Feedback was incorporated into the alternatives presented in this report.

2.2 LIDAR AND TOPOGRAPHIC SURVEYS

In April 2020, the State of Montana funded an aerial LiDAR flight along the length of the Sun River. This LiDAR data provided detailed topographic data of the floodplain and channel alignment at that time. Confluence engineers and stream restoration specialists visited the project area on July 6th and 7th, 2022, and collected additional topographic survey data in areas that had changed since the 2020 LiDAR flight. Survey data was collected using an RTK GPS survey instrument with base station and rover units, allowing for updated surveys to tie in with previously collected LiDAR data. Survey data collected during the July 2022 site visits included:

- As-built topography of emergency repair at Avulsion Site #1,
- Topography of gravel plug installed at Avulsion Site #2
- Topography of gravel pile at the head of the abandoned river alignment
- Location and length of eroding banks on east side of Sun River downstream of Avulsion Site #3
- Existing riverbed, top of bank, and bottom of bank elevations to determine channel adjustments since 2020.
- Cross sections and riverbed elevations of abandoned channel alignment

2.3 PROJECT AREA INSPECTIONS

Confluence's lead engineer and stream restoration specialist performed a thorough inspection of the project reach, including each avulsion site, the new channel alignment, the abandoned channel alignment, Rocky Reef Spring Creek, and a historic channel alignment of the Sun River to the north of the existing channel.

2.4 DRONE PHOTOGRAPHY

Aerial drone photography was collected on July 6th to document existing conditions throughout the project area. Over 2,000 photos were taken from an elevation of 390 feet and stitched together to provide a geo-referenced orthophoto mosaic of the project area. Additional, oblique photos were also taken to document the project reach.

3 AVULSION SITE #1

The effort to stabilize an eroded bank and re-route the Sun River to its former alignment at Avulsion Site #1 was performed under emergency conditions to prevent the river from continuing down the undesired path, which caused substantial flood damages, jeopardized public safety, and threatened to abandon the main channel thread supplying water to the Sun River Ditch Company. The proposed work authorized by the Cascade Conservation District in its emergency permit included the stabilization of 300 feet of the east bank of the Sun River, including excavation of river sediments, reconstruction of the east riverbank at the avulsion site, and installation of filter fabric and riprap along the front face of the bank to protect from erosion.

A component of this PER included inspecting the emergency repair work and performing an analysis to determine whether modifications to the work are warranted. The combination of LiDAR, ground surveys, and hydraulic modelling at Avulsion Site #1 generated a map depicting shear stress during an estimated bankfull event on the Sun River (Figure 5).

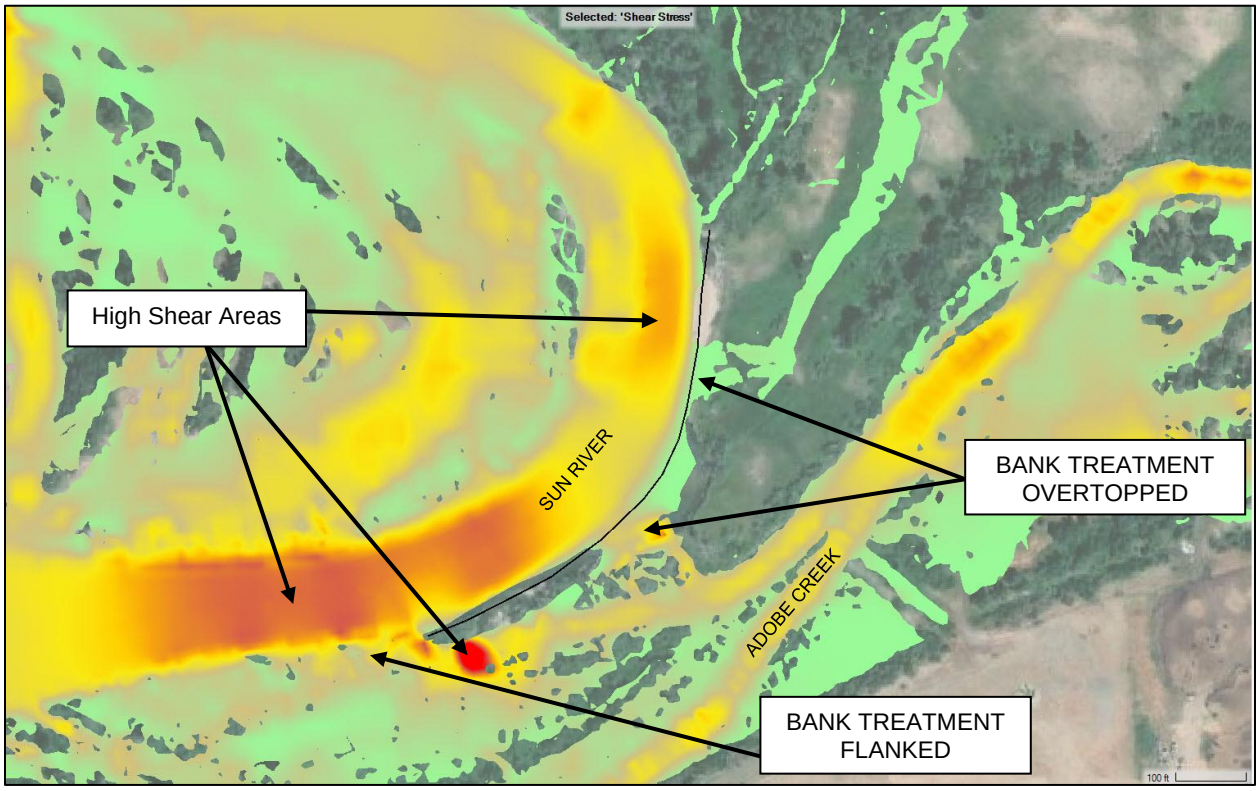


Figure 5. Shear stress map of Sun River at Avulsion Site #1 during flood event. Areas of low stress are shown in green, moderate stress are yellow, and high stress are orange/red.

Based on survey and hydraulic modeling results at Avulsion #1, the following modifications to the existing bank treatment are recommended, which are illustrated on Sheet 0 in Appendix A:

3.1 INCREASE ELEVATION OF BANK TREATMENT

The hydraulic analysis performed at Avulsion Site #1 indicated the upper end of the bank treatment remains dry; however, the middle and lower end of the treatment may get overtopped during relatively frequent flood events. Increasing the longevity of the bank treatment could be accomplished by adding a minimal amount of material and increasing the elevation of the bank to contain a 10-year discharge. Although water will still route around the bank treatment during a 10-year discharge, raising the elevation of the reinforced bank will protect it from damage by overtopping flows.

3.2 INCREASE DEPTH OF ROCK RIPRAP TREATMENT

The emergency repair included installing rock riprap along the upper 300 feet of the bank treatment face. The bank repair design called for rock be installed to the depth of scour, which is approximately 6 feet below the bed elevation of the river (WWC Engineering 2022). It could not be confirmed during the site visit for this PER whether rock was indeed installed to this depth. If emergency conditions precluded placement of rock to the depth of scour, we recommend installing rock to this depth as a precaution against undermining of the bank treatment.

3.3 INCREASE LENGTH OF BANK TREATMENT

The emergency repair included installing rock riprap along the upper 300 feet of the bank treatment face. A hydraulic analysis of the project reach indicated the gravel materials used to construct the remainder of the bank treatment will mobilize at frequent flood events. To protect the downstream end of the bank treatment from eroding during normal spring discharges, we recommend a reinforced bank treatment be placed along an additional 260 feet of the bank. To reduce the costs necessary for mitigating the impacts of riprap placement, a bank treatment using toe wood and fabric encapsulated soil lifts as shown on Sheet 6 of Appendix A is recommended.

3.4 ADD ROUGHNESS / LOG JAMS BEHIND BANK TREATMENT

The hydraulic analysis performed at Avulsion Site #1 revealed a potential for the channel that formed behind the bank treatment to headcut and re-connect with the mainstem river. Installation of log jams or other roughness elements along this channel would reduce the potential for headcutting to occur and flanking of the bank treatment.

3.5 EXTEND BANK TREATMENT UPSTREAM

Hydraulic modeling results indicate the upstream end of the emergency bank treatment is flanked during relatively frequent flows, which could be addressed by extending the treatment another 200 feet upstream. The extended bank treatment would include gravel placement to contain flood flows but would not necessitate placement of additional rock armor.

3.6 MITIGATION

The emergency bank treatment installed at Avulsion Site #1 in early 2022 was warranted to prevent additional flood damages and to address a public safety issue. The Army Corps of Engineers typically requires mitigation to offset the ecological impacts that result from installation of bank treatments that are designed to permanently prevent natural riverine processes of erosion and channel migration. Mitigation requirements can be minimized or avoided by utilizing soft, bio-engineered bank treatments; however, these treatments are not intended to be permanent solutions. If the Army Corps indeed requires mitigation to offset impacts resulting from the bank treatment at Avulsion Site #1, several options are available.

Option 1: Purchase mitigation credits from ILF Program

Mitigation "credits" may be purchased from an In-Lieu Fee Mitigation (ILF) Program, which is then responsible for identifying, executing, and monitoring a mitigation project that offsets the "debits" resulting from the stabilization project. The statewide ILF Program is Montana Freshwater Partners, a non-profit organization capable of selling stream and wetland mitigation credits. Currently, Montana Freshwater Partners has released credits available for approximately $50/credit, which converts to approximately $165 per linear foot of permanent bank stabilization treatment. Mitigation for a 300-foot armored bank treatment would cost roughly $49,500 through Montana's In-Lieu-Fee program. If the ILF program sells all of its released credits and an advance credit purchase becomes necessary, the cost to mitigate using this program will increase to approximately $550 per linear foot, or $165,000 for permanent stabilization of a 300-foot reach of the Sun River.

Option 2: Permittee-Responsible Mitigation

Permittees may provide their own mitigation to offset a project's impacts to streams, rivers, and wetlands. During the site investigation, opportunities for permittee-responsible mitigation were identified, including removal of non-functional floodplain dikes and riprap (Figure 6 and Figure 7). If needed, removal of these features could potentially qualify for mitigation under Army Corps 404 permitting, although a more in-depth investigation of feasibility would be necessary to determine if they provide enough credits to offset the armored bank's impacts. Based on the likely costs to purchase mitigation credits through the State's ILF program, versus those likely to design, implement, and monitor a permittee-responsible mitigation project, it is likely more cost effective to purchase ILF program credits.

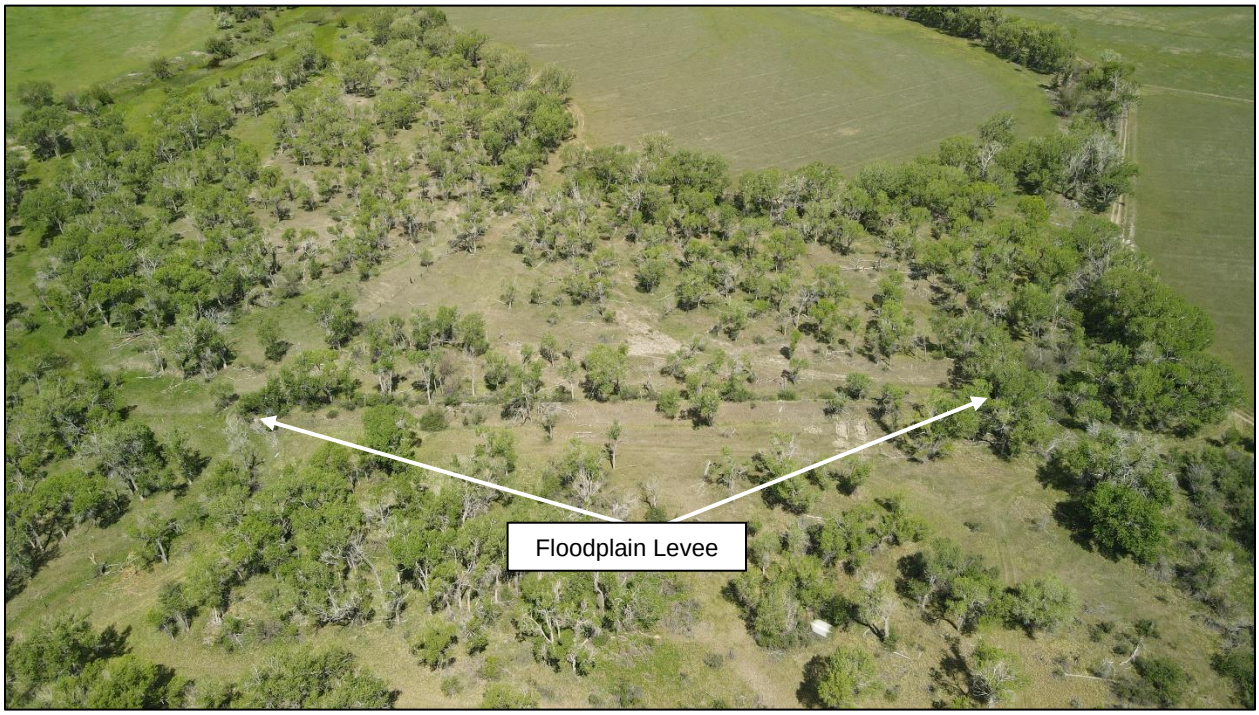


Figure 6. Levee installed approximately 600 feet north of Sun River between Avulsion Sites #1 and #2.

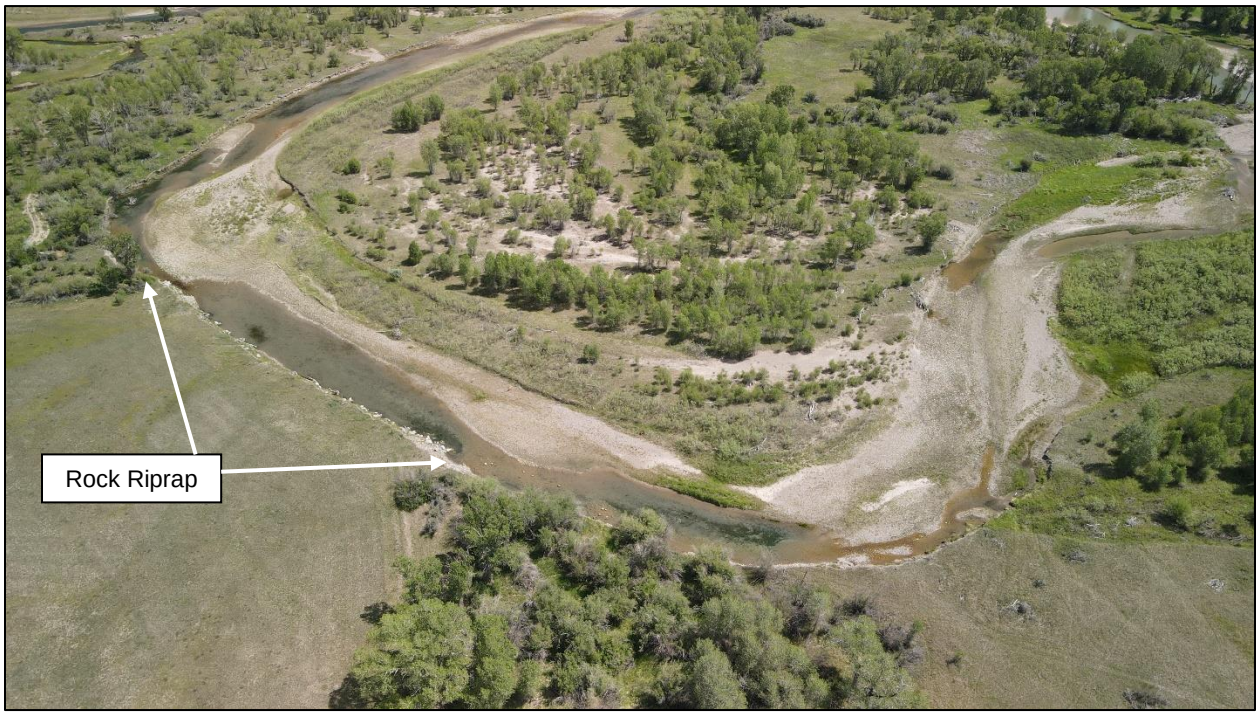


Figure 7. Rock riprap on left bank of abandoned Sun River channel.

3.7 COST ESTIMATE

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Add gravel to increase height of bank treatment	210	CY	$ 13	$ 2,730
Install bio-engineered bank treatment on downstream end of bank	260	FT	$ 430	$ 111,800
Install log/brush jams downstream of bank treatment	3	EA	$ 2,000	$ 6,000
Extend bank treatment upstream	200	FT	$ 100	$ 20,000
Mitigation - released credits from ILF Program*	300	FT	$ 165	$ 49,500
			Subtotal	**$ 190,030**
PROFESSIONAL COSTS				
Design and Permitting (15% of construction)				$ 28,500
Construction Management and Oversight (10% of construction)				$ 19,000
			Subtotal	**$ 47,500**
			Project Total	$ 237,500
			20% Contingency	$ 47,500
			Total Cost Estimate	**$ 285,000**

* Cost assumes only 300 feet of bank is permanently armored

4 AVULSION SITES #2 AND #3

Avulsion sites #2 and #3 are in close proximity and both result in routing of the Sun River away from its recently abandoned alignment to the north. As such, alternatives to address both avulsions are presented in the following section.

Prior to initiating this assessment, one of the primary goals outlined for the project was to restore connectivity between the Sun River and Rocky Reef Spring Creek. The most recent migration of the river eastward at Avulsion Site #3 was widely believed to result in the severing of fish passage between the Sun River and Rocky Reef Spring Creek, a highly productive spawning tributary that has undergone substantial restoration in the past 10 years. Following the public meeting and subsequent field investigations, it is unclear whether fish passage into Rocky Reef Spring Creek is indeed an issue, as anecdotal evidence exists that migratory fish have begun to successfully navigate between the two waterbodies. As a result, some of the alternatives presented below do not include restoring the former confluence with Rocky Reef Spring Creek and rely on fish "finding" their way to Rocky Reef through a segment of the abandoned channel. The connection between the Sun River and Rocky Reef Spring Creek should be further investigated to determine whether restoring this confluence should remain a primary project goal.

Each alternative includes a cost versus risk factor to consider during selection of a preferred alternative. Cost and risk factors are assigned based on the following:

COST

Low:	Project cost is between $0 and $750,000
Moderate:	Project cost is between $750,000 and $1,000,000
High:	Project cost is >$1,000,000

RISK

Low:	Project goal is achievable; longevity is likely
Moderate:	Project goal is achievable; longevity is questionable
High:	Project goal not achievable or longevity is unlikely

4.1 ALTERNATIVE 1: NO ACTION

Under the no action alternative, the Sun River would remain in its existing alignment. The gravel berm installed to plug Avulsion Site #2 would remain in place, as would the gravel pile at the head of the abandoned channel alignment. This alternative is depicted on Sheet 1 in Appendix A.

Benefits of Alternative 1

- No costs to implement a project
- No permitting considerations or mitigation required to offset impacts

Concerns of Alternative 1

- New channel alignment downstream of Avulsion #3 will likely continue to erode laterally and capture agriculturally productive land as it lengthens to restore a stable gradient.

Cost Estimate

No capital costs are required to implement the No Action Alternative.

Cost versus Risk

While the No Action alternative at Avulsion Sites #2 and #3 presents no cost considerations, the primary risk lies in loss of agriculturally productive lands to the east of the new channel alignment. The Channel Migration Mapping study performed for the Sun River in this reach predicts an erosion buffer width of 500 feet over the next 100 years based on measured lateral migration of the river in this reach over the past 70 years (AGI and DTM Consulting 2021). If a 500-foot erosion buffer is applied to the 2,500-foot length of bank on the east side of the channel downstream of Avulsion #3, this results in a potential loss of 28.7 acres of farmland over the next 100 years. The landowner has begun to utilize an alternative source of irrigation water from the Fort Shaw Irrigation Company; therefore, additional losses of irrigation infrastructure are not included in the risk assessment for the No Action alternative.

ALTERNATIVE	COST	RISK
Alternative 1: No Action	Low	High

4.2 ALTERNATIVE 2A: MAINTAIN EXISTING CHANNEL ALIGNMENT AND STABILIZE ERODING BANKS

Under Alternative 2A, the Sun River would remain in its existing alignment and eroding bank segments would be stabilized downstream of Avulsion Site #3 to reduce further loss of agriculturally productive land (Figure 8). This alternative is depicted in planview on Sheet 2 of Appendix A with typical bank stabilization for bio-engineered and hard armor treatments shown on Sheet 7.

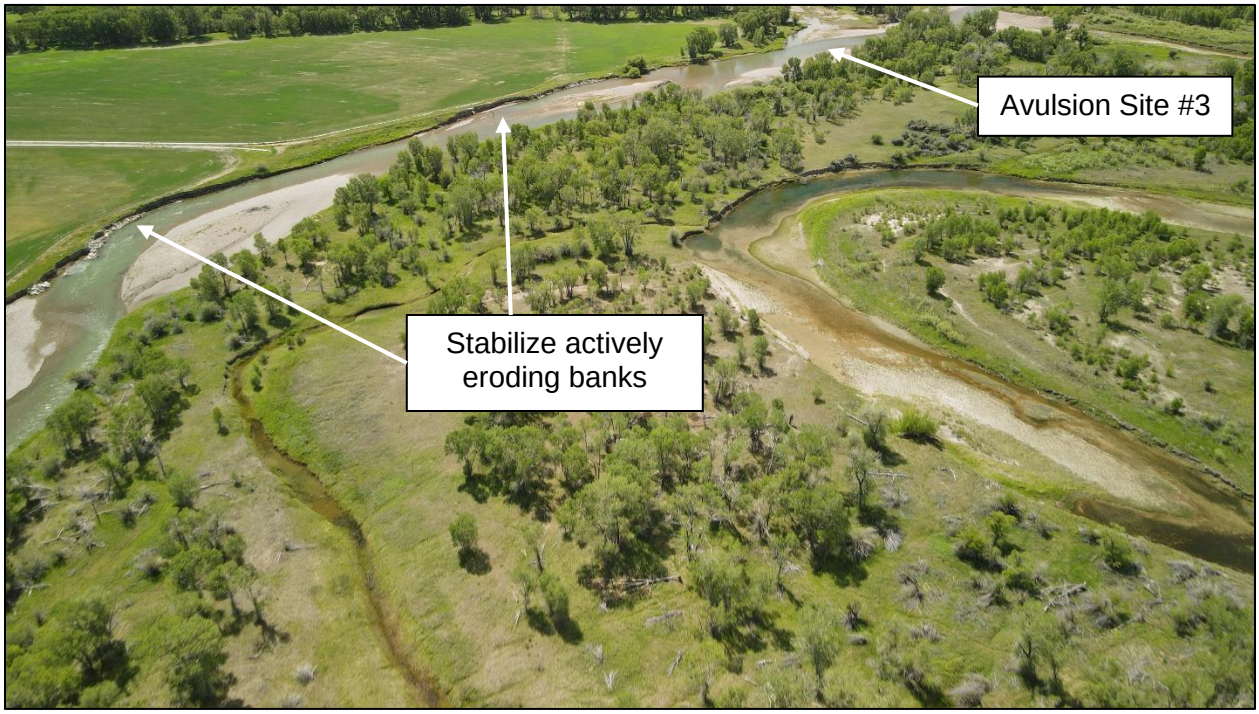


Figure 8. Aerial view of eroding bank segments downstream of Avulsion #3.

Benefits of Alternative 2A

- Loss of agricultural lands due to channel widening is reduced.
- Permitting for bank stabilization is relatively straightforward.

Concerns of Alternative 2A

- Stabilizing eroding segments of the new channel may result in accelerated erosion along other, un-stabilized banks.
- Permanently stabilizing banks is likely to require costly mitigation by the Army Corps of Engineers.
- Alternative does not restore confluence of Rocky Reef Spring Creek.

Cost Estimate

Cost estimates for two bank stabilization treatments are provided below, including 1) bio-engineered bank treatment using a wood toe and vegetated soil lifts, and 2) an armored treatment using a rock toe with vegetated soil lifts. The bio-engineered treatment is presented to provide estimated bank treatment costs using an approach that would not require mitigation by the Army Corps of Engineers; whereas the armored treatment costs include the estimated mitigation fees to purchase credits from Montana Freshwater Partners, which is Montana's only In-Lieu Fee wetland and stream mitigation program. The costs to purchase stream mitigation credits from Montana Freshwater Partners assumes released credits are available for purchase at a cost of $50/credit versus advance credits at a cost of $166/credit.

Cost #1: Bioengineered Bank Stabilization Treatment with Wood Toe

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Stabilize eroding banks - bioengineered option	1135	FT	$ 375	$ 425,625
			Subtotal	**$ 425,625**
PROFESSIONAL COSTS				
Design and Permitting (15% of construction)				$ 63,844
Construction Management and Oversight (20% of construction)				$ 85,125
			Subtotal	**$ 148,969**
			Project Total	$ 574,600
			20% Contingency	$ 114,920
			Total Cost Estimate	**$ 689,500**
			Cost/Foot	$ 607

Cost #2: Armor Bank Stabilization Treatment with Rock Toe

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Stabilize eroding banks - armored bank option	1135	FT	$ 365	$ 414,275
Mitigation - ILF Option*	1135	FT	$ 165	$ 187,275
			Subtotal	**$ 601,550**
PROFESSIONAL FEES				
Design and Permitting (10% of construction)				$ 60,155
Construction Management and Oversight (15% of construction)				$ 90,233
			Subtotal	**$ 150,388**
			Project Total	$ 751,900
			20% Contingency	$ 150,400
			Total Cost Estimate	**$ 902,300**
			Cost/foot	$ 795

* Mitigation credit purchase from Montana's In-Lieu-Fee Program

* Cost assumes released credits are available from ILF program

Cost versus Risk

The costs presented above for this alternative are based on stabilizing the existing eroding bank segments that are capturing agricultural lands. As the channel evolves over time and establishes a stable planform and gradient along its new alignment, it is likely to erode laterally against any unprotected banks. As a result, while stabilizing the existing, unstable banks will arrest erosion in those locations, erosion is prone to occur elsewhere in the future. The only means of ensuring no agricultural lands will be lost is to stabilize all 2,500 feet of the east bank of the river downstream of Avulsion Site #3, which may be difficult to successfully permit due to potential geomorphic consequences of a bank treatment that runs perpendicular to the meander belt axis and pinches the channel against the north valley wall. At an estimated cost of $600 per linear foot for a bio-engineered treatment, stabilizing the entire 2,500-foot bank length downstream of Avulsion #3 would cost approximately $1,500,000. Stabilizing the entire bank is included as Option 3 in the table below.

ALTERNATIVE	COST	RISK
Alternative 2A, Option 1:	Low	Moderate
Alternative 2A, Option 2:	Moderate	Moderate
Alternative 2A, Option 3:	High	Low

4.3 ALTERNATIVE 2B: MAINTAIN EXISTING CHANNEL ALIGNMENT, STABILIZE ERODING BANKS, AND REMOVE GRAVEL PLUG AT AVULSION SITE #2

Alternative 2B builds on Alternative 2A by removing the gravel plug at Avulsion Site #2 and re-naturalizing the river between Avulsion Site #2 and #3. Removing the gravel plug at Avulsion #2 would eliminate the artificially straightened reach of the river between Avulsion Site #2 and #3, and would reduce channel velocity, gradient, and erosive energy of the river as it enters the newly established reach. This alternative is shown in planview on Sheet 3 of Appendix A.

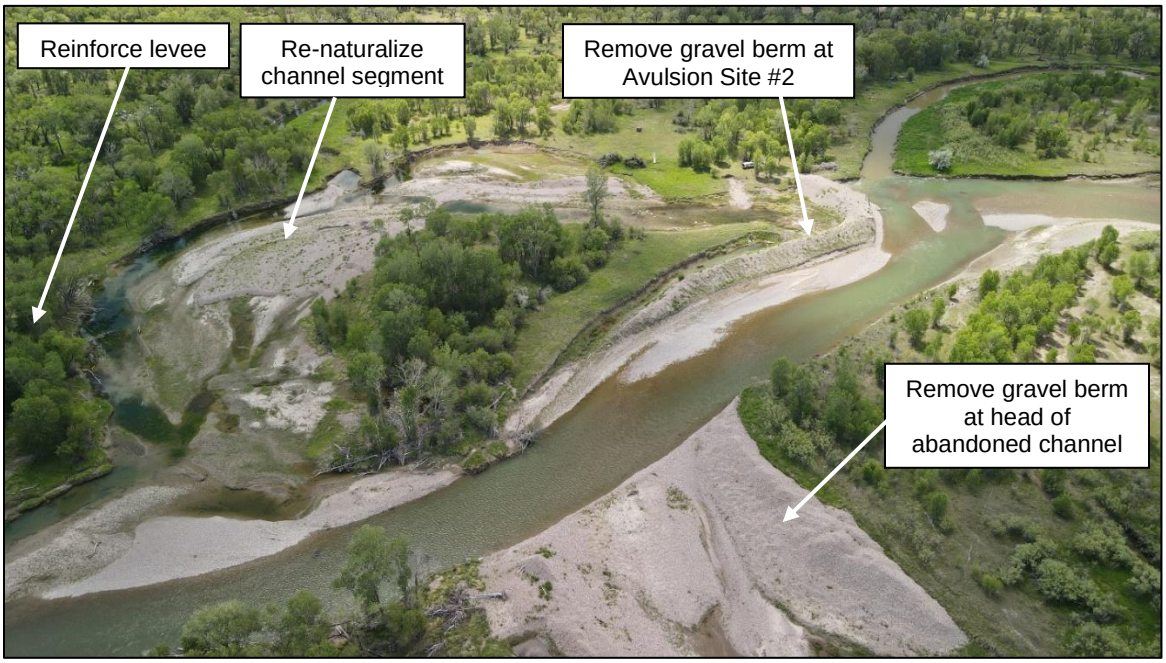


Figure 9. Aerial view of channel between Avulsion Site #2 and Avulsion Site #3

Benefits of Alternative 2B

- Loss of agricultural lands due to channel widening is reduced by stabilizing banks.
- Permitting for bank stabilization and plug removal is relatively straightforward.
- Erosive energy of channel entering newly established reach is reduced.
- Elimination of unnatural channel obstruction at Avulsion Site #2.

Concerns of Alternative 2B

- Stabilizing eroding segments of the new channel may result in accelerated erosion along other, un-stabilized banks.
- Permanently stabilizing banks is likely to require costly mitigation by the Army Corps of Engineers.
- Re-naturalizing the channel between Avulsion Sites #2 and #3 may increase potential of another avulsion route through Parker Farms.
- Alternative does not restore confluence of Rocky Reef Spring Creek.

Cost Estimate

Cost #1: Bioengineered Bank Stabilization Treatment with Wood Toe

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Stabilize eroding banks - bioengineered option	1135	FT	$ 375	$ 425,625
Remove gravel berm from Avulsion Site #2*	5100	CY	$ 15	$ 76,500
Remove gravel pile from head of abandoned alignment*	2600	CY	$ 15	$ 39,000
Reinforce levee adjacent to renaturalized reach	210	CY	$ 10	$ 2,100
			Subtotal	**$ 543,225**
PROFESSIONAL COSTS				
Design and Permitting (15% of construction)				$ 81,484
Construction Management and Oversight (20% of construction)				$ 108,645
			Subtotal	**$ 190,129**

* cost assumes material will be stockpiled in repository within 1 mile

Project Total	$ 733,400
20% Contingency	$ 146,700
Total Cost Estimate	**$ 880,100**

Cost #2: Armor Bank Stabilization Treatment with Rock Toe

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Stabilize eroding banks - armored bank option	1135	FT	$ 365	$ 414,275
Mitigation**	1135	FT	$ 165	$ 187,275
Remove gravel berm from Avulsion Site #2	5100	CY	$ 15	$ 76,500
Remove gravel pile from head of abandoned alignment	2600	CY	$ 15	$ 39,000
Reinforce levee adjacent to renaturalized reach	210	CY	$ 10	$ 2,100
			Subtotal	**$ 719,150**
PROFESSIONAL FEES				
Design and Permitting (10% of construction)				$ 71,915
Construction Management and Oversight (15% of construction)				$ 107,873
			Subtotal	**$ 179,788**

* cost assumes material will be stockpiled in repository within 1 mile

** Mitigation credit purchase from Montana's In-Lieu-Fee Program

** Cost assumes released credits are available from ILF program

Project Total	$ 898,900
20% Contingency	$ 179,800
Total Cost Estimate	**$ 1,078,700**

Cost versus Risk

As indicated in Alternative 2A, the costs presented for Alternative 2B are based on stabilizing the existing eroding bank segments that are capturing agricultural lands. As the channel evolves over time and establishes a stable planform and gradient along its new alignment, it is likely to erode laterally against any unprotected banks. As a result, while stabilizing the existing, unstable banks will arrest erosion in those locations, erosion is prone to occur elsewhere in the future. The only means of ensuring no agricultural lands will be lost is to stabilize all 2,500 feet of the east bank of the river downstream of Avulsion Site #3 which may be difficult to successfully permit due to potential geomorphic consequences of a bank treatment that runs perpendicular to the meander belt axis and pinches the channel against the north valley wall. At an estimated cost of $600 per linear foot, stabilizing the entire bank length downstream of Avulsion #3 would cost approximately $1,500,000. Stabilizing the entire bank is included as Option 3 in the table below.

Removing the gravel berm at Avulsion Site #2 poses additional risk of an avulsion path through Parker Farms. To mitigate this risk, the cost estimate for this alternative includes reinforcement of an existing levee to the east of the re-naturalized channel segment between Avulsion Site #2 and #3.

ALTERNATIVE	COST	RISK
Alternative 2B, Option 1:	Moderate	Moderate
Alternative 2B, Option 2:	High	Moderate
Alternative 2B, Option 3:	High	Low

4.4 ALTERNATIVE 3: REACTIVATE FORMER CHANNEL ALIGNMENT

Alternative 3 involves plugging the new channel alignment at Avulsion Site #3 and directing the channel back through its former alignment to the north (Figure 10). The gravel plug at Avulsion Site #2 and the gravel berm at the head of the restored channel would be modified to mimic a natural bank configuration. Two additional plugs would be constructed in the deactivated channel to reduce the potential of the river recapturing this alignment. This alternative is shown in planview on Sheet 4 in Appendix A.

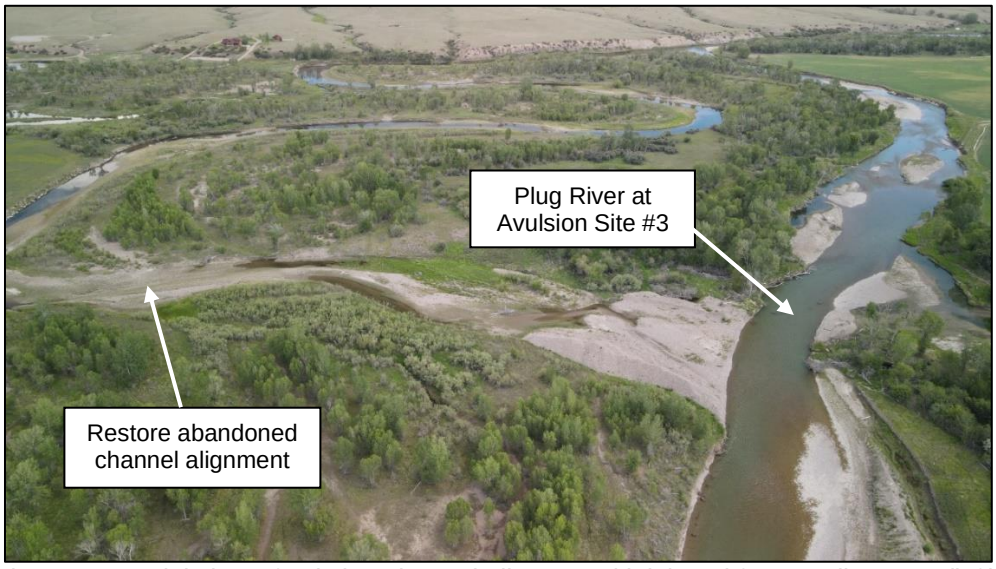


Figure 10. Aerial view of existing channel alignment (right) and former alignment (left).

Benefits of Alternative 3

- Loss of agricultural lands due to bank erosion is largely or entirely eliminated.
- Confluence of Sun River and Rocky Reef Spring Creek is restored, maximizing the potential for fish passage and productivity.

Concerns of Alternative 3

- Gradient of former channel alignment is flatter than the broader reach of Sun River, indicating questionable longevity of treatment before avulsion reoccurs.

Cost Estimate

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Construct channel plug at Avulsion Site #3	9300	CY	$ 15	$ 139,500
Construct channel plug at Avulsion Site #2	4300	CY	$ 15	$ 64,500
Install wood toe bank treatment on upstream face of plugs	540	FT	$ 375	$ 202,500
Install floodplain plugs along deactiaved channel alignment	11100	CY	$ 14	$ 155,400
Vegetate floodplain plugs	4.0	AC	$ 10,000	$ 40,000
			Subtotal	**$ 601,900**
PROFESSIONAL COSTS				
Design and Permitting (15% of construction)				$ 90,285
Construction Management and Oversight (20% of construction)				$ 120,380
			Subtotal	**$ 210,665**
			Project Total	$ 812,565
			20% Contingency	$ 162,500
			Total Cost Estimate	**$ 975,065**

Cost versus Risk

The greatest risk faced by Alternative 3 is the potential for a restored channel alignment to avulse again due to the overly flat gradient of the former channel (0.09%) as compared to the gradient of the Sun River in the vicinity of the project (0.15% - 0.17%) and the recently captured channel alignment (0.30%). Other, nearby avulsion paths (i.e., that captured at Avulsion Site #1) also result in steeper, straighter channel gradients than the former alignment, and offer evidence that restoring the channel to its previous configuration may not be a sustainable solution. To minimize risk, this alternative includes constructing gravel plugs across the deactivated channel, which will reduce the potential for the river to reclaim this channel.

ALTERNATIVE	COST	RISK
Alternative 3:	Moderate	Moderate

4.5 ALTERNATIVE 4A: REROUTE SUN RIVER TO ALTERNATE ALIGNMENT

This option involves rerouting the lower end of the newly captured channel further west to prevent it from continuing to erode against agriculturally productive lands (Figure 11). The new channel route would begin just downstream of Avulsion Site #3 and tie in with a former channel alignment just west of the existing channel. The deactivated channel alignment would be completely backfilled to the adjacent floodplain elevation and vegetated to prevent recapture by the river. A plan view of this alternative is shown on Sheet 5 of Appendix A.

Benefits of Alternative 4A

- Loss of agricultural lands due to bank erosion is largely or entirely eliminated.

Concerns of Alternative 4A

- Gradient of modified channel is similar to that of the recently captured channel and may result in near-term vertical and lateral adjustments.
- Alternative does not restore confluence of Rocky Reef Spring Creek.

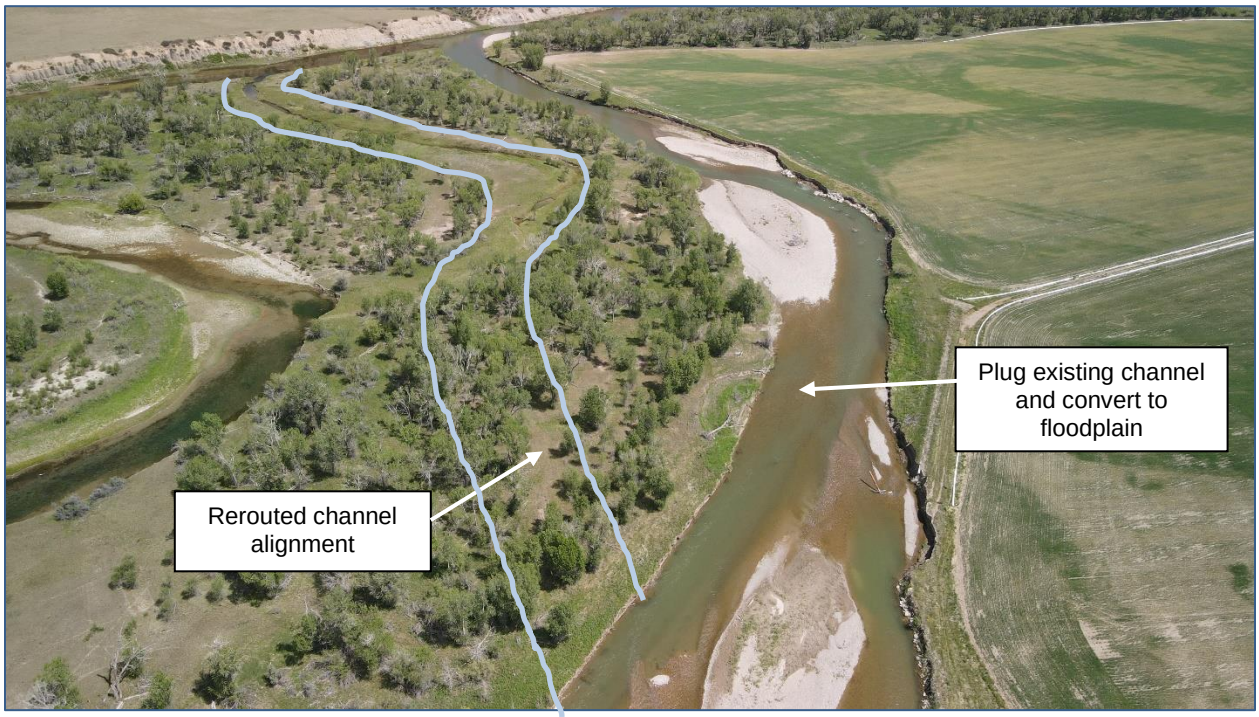


Figure 11. Potential relocation route of Sun River channel away from agricultural fields.

Cost Estimate

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Grubbing and tree removal from new channel alignment	2.5	AC	$ 8,000	$ 20,000
Excavate new channel alignment	44200	CY	$ 5	$ 221,000
Haul, place, and grade material in new channel alignment	44200	CY	$ 10	$ 442,000
Vegetate backfilled floodplain	5	AC	$ 10,000	$ 50,000
Install wood toe bank treatment on upstream face of plugs	200	FT	$ 375	$ 75,000
			Subtotal	**$ 808,000**
PROFESSIONAL COSTS				
Design and Permitting (15% of construction)				$ 121,200
Construction Management and Oversight (20% of construction)				$ 161,600
			Subtotal	**$ 282,800**
			Project Total	$ 1,090,800
			20% Contingency	$ 218,160
			Total Cost Estimate	**$ 1,308,960**

Cost versus Risk

The existing alignment of the Sun River below Avulsion Site #3 is adjusting laterally and vertically as it evolves to a stable gradient and planform. This channel lengthening process is resulting in

lateral erosion against the east and west banks as gravel bars deposit and the channel builds new floodplain. The modified channel alignment proposed in Alternative #4 will have a similar gradient to the existing alignment and is also likely to laterally adjust over time. Fortunately, these adjustments will occur across the existing floodplain and away from agriculturally productive lands. Lateral erosion eastward could result in the channel recapturing the former channel just upstream of Rocky Reef Spring Creek, which may prove to be an acceptable route.

ALTERNATIVE	COST	RISK
Alternative 4A:	Low	Low

4.6 ALTERNATIVE 4B: REROUTE SUN RIVER THROUGH LOWER END OF ABANDONED CHANNEL

This alternative is a hybrid of Alternatives #3 and #4A, where the channel would be relocated just downstream of Avulsion #3 and tie into the lower end of the abandoned channel (Figure 12). The intent of this alternative would be to establish a channel alignment that is not over-steepened is closer to an equilibrium slope with the Sun River upstream and downstream. The upstream end of this alignment above the relocated channel would be 0.16%, while the downstream end of this alignment through the reactivated channel would be 0.10%. The flatter slope through the lower end of this alignment could potentially result in another avulsion in this area; however, stakeholders have indicated a shifting channel alignment in this area would be more acceptable due to the lack of residential and irrigation infrastructure. A plan view of this alternative is shown on Sheet 6 of Appendix A.

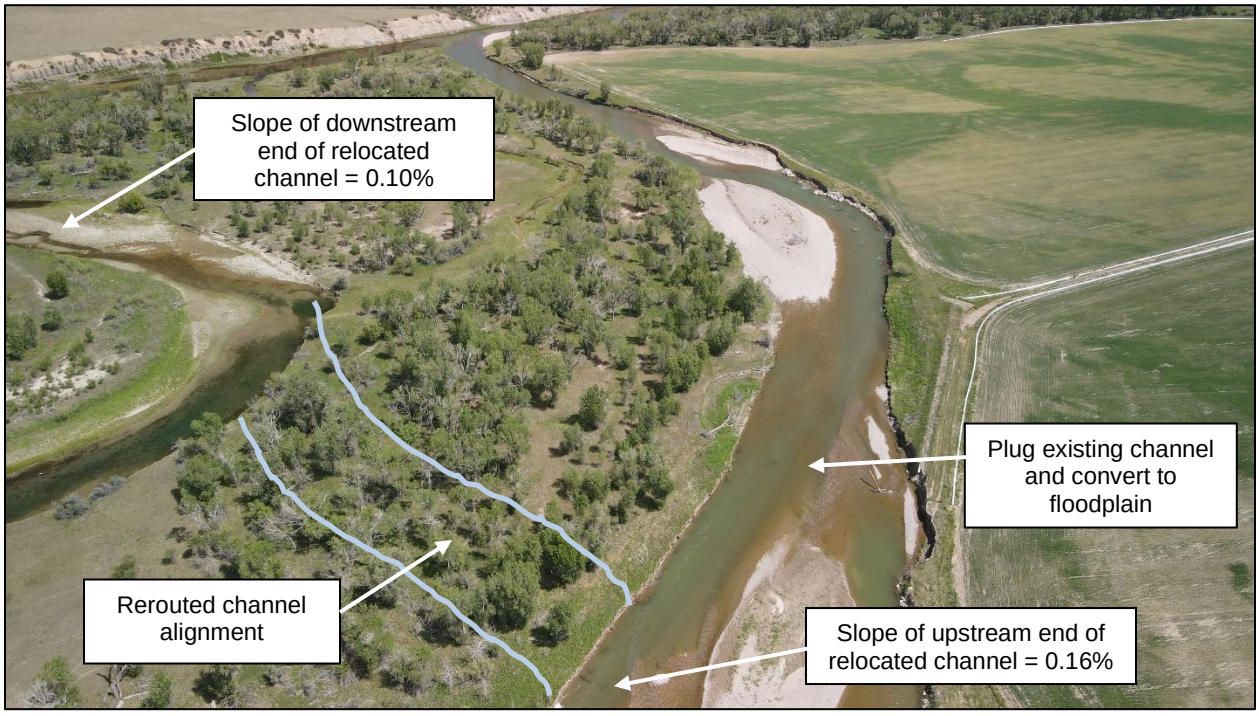


Figure 12. Potential channel alignment.

Benefits of Alternative 4B

- Loss of agricultural lands due to bank erosion is largely or entirely eliminated.
- Slope of relocated channel is closer to equilibrium as compared to Alternative 4A.
- Excavation volumes and project costs are lower than relocated channel in Alternative 4A.
- Alternative restores confluence of Rocky Reef Spring Creek.

Concerns of Alternative 4B

- Gradient of channel through the reactivated segment is very flat and may result in the channel avulsing again to create a steeper alignment.

Cost Estimate

ITEM	QTY	UNIT	UNIT COST	COST
CONSTRUCTION COSTS				
Grubbing and tree removal from new channel alignment	1.3	AC	$ 8,000	$ 10,400
Excavate new channel alignment	15500	CY	$ 5	$ 77,500
Haul, place, and grade material in new channel alignment	15500	CY	$ 10	$ 155,000
Remove gravel berm from Avulsion Site #2	5100	CY	$ 15	$ 76,500
Remove gravel pile from head of abandoned alignment	2600	CY	$ 15	$ 39,000
Vegetate backfilled floodplain	2	AC	$ 10,000	$ 20,000
Install wood toe bank treatment on upstream face of plugs	250	FT	$ 375	$ 93,750
			Subtotal	**$ 472,150**
PROFESSIONAL COSTS				
Design and Permitting (15% of construction)				$ 70,800
Construction Management and Oversight (20% of construction)				$ 94,430
			Subtotal	**$ 165,230**
			Project Total	$ 637,380
			20% Contingency	$ 127,500
			Total Cost Estimate	**$ 764,880**

Cost versus Risk

The greatest risk in Alternative 4B revolves around the flat gradient of the reactivated channel segment downstream of Avulsion Site #3. The gradient of this channel segment is 0.10%, which is flatter than the overall slope of the Sun River in the vicinity of the project reach (0.15 – 0.17%), and therefore may still be prone to sediment deposition and channel avulsion processes. If the channel were to avulse along the reactivated channel, it would do so in an area that has little consequence (no agricultural operations or diversion structures) and may therefore be an acceptable level of risk to project stakeholders. Project costs are nearly half that of Alternative 4A, potentially making this a more palatable alternative to funding entities.

ALTERNATIVE	COST	RISK
Alternative 4B:	Moderate	Low

4.7 ALTERNATIVE 5: CONSERVE CHANNEL MIGRATION ZONE OF SUN RIVER THROUGH UNSTABLE REACH

This alternative centers on the concept of compensating landowners for future loss of lands in exchange for allowing natural riverine process including scour, deposition, erosion, and channel migration to occur. Under this arrangement, the Sun River would remain in its existing alignment, and will continue to adjust vertically and laterally as it evolves into a stable planform and gradient with adjacent floodplain. The landowner would be compensated for allowing land losses to occur as a result of this process but would not be able to install bank treatments that prevent natural riverine processes to occur. This concept may be viable under the following two scenarios:

Scenario 1: Channel Migration Easement

In this scenario, the landowner would enter into agreement with an easement holder, with the agreement that areas within the easement boundary could not be modified to restrict natural river processes. Agricultural practices could still occur unimpeded within the easement boundary; however, restrictions would apply to installing bank armor, flow deflectors, or floodplain barriers such as levees and dikes that alter the river's ability to access its floodplain. Easements such as these have been successfully negotiated by Montana Freshwater Partners and private landowners on the Yellowstone River.

Scenario 2: Conservation Buyer Purchases Area Prone to Erosion

In this scenario, the landowner would sell the portion of their property that is at highest risk of loss to erosion to a buyer interested in conserving the property and allowing the river to flow unimpeded. Such an agreement could be negotiated to provide the seller an opportunity to enter into a long-term lease of the parcel allowing for continued agricultural production. As described in Alternative 1, the area identified that is most at risk of loss to erosion is within 500 feet of the active river channel, based on a recent study of nearby river migration rates on the Sun River (AGI and DTM 2021). Extending a channel migration corridor 500 feet eastward from the Sun River downstream of Avulsion Site #3 would result in 28-acre parcel (see Sheet 1 for approximate parcel size).

Cost Estimate

Costs to execute either a channel migration easement or outright purchase of a parcel will vary based on current market value of land in the area. The following cost estimates should be verified by a real estate professional or experienced appraiser:

ITEM	QTY	UNIT
Scenario 1 - Channel Migration Easement		
Easement Area	28	AC
Approximate land value*	4000	AC
Parcel Value	$112,000	
Easement Purchase % of value **	30%	
Easement Value	$33,600	
Due diligence (parcel survey, title work, appraisal)	$50,000	
Total Cost (Easement value + due diligence)	**$83,600**	
Scenario 2 - Conservation Purchase		
Easement Area	28	AC
Approximate land value*	4000	AC
Parcel Value	$112,000	
Title and Closing*	$5,000	
Total Cost (Parcel value + title and closing costs	**$117,000**	

* Should be verified by professional realtor

** Should be verified by easement holding entity

Cost versus Risk

Alternative #5 involves leaving the existing channel alignment in place and allowing lateral erosion to occur unchecked. If the landowners are willing to accept erosion and loss of agricultural land in exchange for financial compensation, the risk of project failure is low.

ALTERNATIVE	COST	RISK
Alternative 4:	Low	Low

Additional Channel Migration Easement Information

Channel migration easements are a relatively new approach to conserving river function and processes while compensating landowners for land losses. As such, funding such an approach is less straightforward than river restoration or water infrastructure projects. A successful easement project will require buy-in by one or more funding entities and a willing easement holder. Potential easement holders may include Montana Land Reliance, The Nature Conservancy, or local land trusts.

The relatively small land area protected by a channel migration easement may not attract the interest of a conservation entity that would hold the easement in trust. Most land conservation organizations prioritize easements that provide the greatest amount of conservation value; (i.e., larger tracts of lands that contain diverse habitat). As such, it may be challenging to identify a suitable easement holder for only 28 acres of Sun River floodplain. Increasing the size of the property in easement beyond 28 acres may result in added interest by land conservation organizations and the overall feasibility of a successful easement negotiation.

Mechanisms for Landowner Compensation

A channel migration easement provides a one-time, lump-sum payment to the landowner for giving up their right to armor the channel or otherwise impede the river from naturally flowing or flooding (i.e., levees, impoundments, berms, etc.) within the migration easement boundary. As stated above, this payment would rely on identifying a viable funding source to provide this compensation.

If a landowner selects to donate a conservation easement to a land trust or other conservation organization, they are entitled to a reduction in property taxes based on the reduced value of the property following execution of the easement. The reduction in value and property taxes owed remains intact throughout the duration of the easement terms. Easement terms may be negotiated – some are written to remain in perpetuity while others are limited to ~30 years or another specified timeframe.

The use of a deed restriction is another strategy to limit actions that would prevent natural riverine processes. Deed restrictions do not provide landowner compensation and do not reduce the taxable value of a property. They act like covenants and are typically intended to limit certain types of activities within parcels by filing a modification to the property's title with the County Clerk and Recorder. Deed restrictions transfer with property ownership and are difficult to remove unless undue hardship on the landowner can be proven. Due to the lack of landowner compensation, the use of a deed restriction may not be the most feasible means of limiting bank protection under this particular scenario. A deed restriction may be more suitable if a conservation buyer were to purchase the property or area within the channel migration zone outright, execute the deed restriction, then sell the property to another interested buyer.

Potential Easement Holders

The following entities may be interested in holding a channel migration or conservation easement along the Sun River:

- The Nature Conservancy
- Montana Land Reliance
- Prickly Pear Land Trust
- NRCS

Benefits of Channel Migration Easements

- Landowner receives financial compensation for future land loss
- River and floodplain processes are allowed to function naturally without anthropogenic alterations
- No permitting or agency review required unless funding is through public agency
- Landowner retains right to maintain agricultural production
- Landowner retains property ownership

Concerns of Channel Migration Easements

- Ability to restrict erosion and flooding within channel migration zone is unallowed
- Easements may require occasional monitoring and access by easement holding entity
- Easement may remain in perpetuity and transfers with property
- Funding may be questionable
- Identifying easement holder may be questionable

5 PERMITTING CONSIDERATIONS

Regulatory permits issued by local, state, and federal agencies are required to stabilize eroding banks, place fill in an active river channel, and re-route river channel alignments. The following list of regulatory permits will apply to Alternatives 2A, 2B, 3, 4A. and 4B:

Permit	Fee	Typical Timeframe for Review	Permit Application Survey and Design Requirements
Cascade Conservation District 310 Permit	No Fee	1-2 months	Project plan view and cross section views depicting all proposed stabilization treatments.
Cascade County Floodplain Development	$250	2-3 months	Survey requires channel cross sections and longitudinal profile through stabilized reach. Permit requires hydraulic analysis of river at flood stage to determine project's effect on flood elevations. Project cannot increase 100-year flood elevations by more than 0.5 feet. Permit must be certified by professional engineer licensed in the State of Montana.
U.S. Army Corps of Engineers 404 Permit	No Fee	2-3 months	Formal delineation of wetland and open waters required to identify presence of and quantify impacts to these features. Stream mitigation will be required for projects that have an impact of >0.03 acres below the existing ordinary high water mark. Wetland mitigation will be required for projects that impact >0.1 acres of jurisdictional wetlands.
DEQ 318 Water Quality Certification	No Fee	2-3 months	Project plan set illustrating project components and potential impacts to water quality.

6 FUNDING STRATEGIES

The alternatives presented above have been grouped into the following categories, which may be helpful in determining the best potential funding sources once a preferred alternative is selected. The following section provides funding opportunities for each of these alternative categories.

6.1 CATEGORY 1: MAINTAINING EMERGENCY WORK AT AVULSION SITE #1 TO PREVENT FUTURE DAMAGE TO INFRASTRUCTURE AND ABANDONMENT OF SUN RIVER CANAL COMPANY DIVERSION

Potential funding sources to address the emergency work at Avulsion Site #1 include:

- DNRC Irrigation Development Grant
- DNRC Renewable Resource Grant and Loan Program
- DNRC ARPA Grant Program (pending available funding)
- Bureau of Reclamation WaterSMART Grant

- FEMA Flood Mitigation Assistance Grants
    - Hazard Mitigation Assistance Program (HMGP): rebuilding after disaster
    - Building Resilient Infrastructure and Communities (BRIC): prevents future disasters

6.2 CATEGORY 2: BANK STABILIZATION BELOW AVULSION #3 TO PREVENT LOSS OF AGRICULTURAL LANDS

Obtaining grant funding to construct a bank stabilization project that protects private lands from naturally occurring bank erosion is unlikely. Bank stabilization projects are typically privately funded unless they serve to protect critical public lands, historic features, or other infrastructure that serves the public interest. Agency representatives on the Adobe Creek Avulsion Planning Project Technical Advisory Committee including DEQ and DNRC indicated bank stabilization projects that protect private lands would not quality or would rank poorly against competing applicants for their grant programs. Private funding is the most feasible strategy to implement any bank stabilization measures in this project reach.

6.3 CATEGORY 3: CHANNEL RELOCATION BELOW AVULSION #3 TO PREVENT LOSS OF AGRICULTURAL LANDS AND RESTORE CONFLUENCE OF SUN RIVER AND ROCKY REEF SPRING CREEK

Potential funding sources to perform a channel relocation / spring creek confluence restoration project include:

- DNRC Renewable Resource Grant and Loan Program
- DNRC Irrigation Development Grant
- DNRC ARPA Grant Program (pending available funding)
- Bureau of Reclamation WaterSMART Grant
- DNRC House Bill 223 Grant
- Montana FWP Future Fisheries Program
- Northwestern Energy Habitat Restoration / Mitigation Funds

6.4 CATEGORY 4: CHANNEL MIGRATION EASEMENT TO COMPENSATE LANDOWNER FOR LAND LOSS

As mentioned in Section 4.7, Channel Migration Easements are relatively new in Montana, and funding these easements may be challenging. Potential funding sources include the following:

- FEMA Pre-Disaster Mitigation Grants: measures are designed to reduce the risk to individuals and property from future natural hazards.
- NRCS Conservation Easement Program / WRP Program
- Vital Ground Foundation (vitalground.org)
- The Conservation Fund (conservationfund.org)
- DNRC RRGL Program

7 REFERENCES

Applied Geomorphology, Inc. and DTM Consulting, 2021. Channel Migration Mapping Sun River (Phase 1), Elk Creek (Phase 2). Prepared for Cascade Conservation District, Lewis and Clark Conservation District, and Sun River Watershed Group.

WWC Engineering, 2022. Sun River Avulsion Repair Flood Study. Prepared for Sun River Ditch Company.

Appendix A

Conceptual Design Alternatives

Adobe Creek Avulsion Planning
Preliminary Engineering Report

LEGEND

- EXISTING CONTOUR MAJOR (5')
- EXISTING CONTOUR MINOR (1')
- EXISTING RIPRAP
- RECOMMENDED RIPRAP
- TOP OF BERM ALIGNMENT
- RECOMMENDED LOG JAM/BRUSH PILE
- RECOMMENDED ADDITIONAL FILL

N

50 0 50 100
SCALE IN FEET

RECOMMENDED BANK REINFORCEMENT

RECOMMENDED ADDITIONAL FILL ON TOP OF EXISTING BERM

EXISTING RIPRAP

RECOMMENDED LOG JAMS/ BRUSH PILES

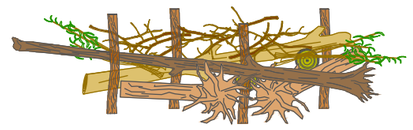
RECOMMENDED EXTENSION OF EXISTING BERM

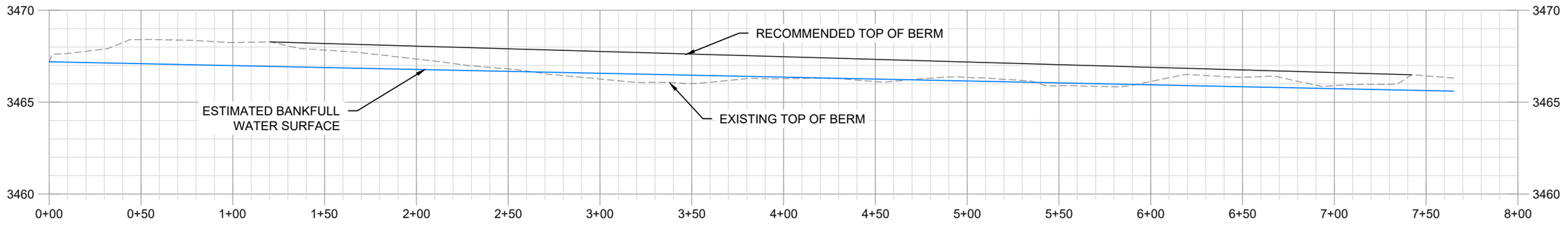
SUN RIVER

ADOBE CREEK

7+65
7+00
6+00
5+00
4+00
3+00
2+00
1+00
0+00

INSTALL CUT TREES AND SHRUBS TO CREATE A LOG JAM/BRUSH PILE





1/0 TOP OF BERM PROFILE
HORIZONTAL SCALE: 1" = 60'
VERTICAL SCALE: 1" = 6'

PROFILE LEGEND

- EXISTING GROUND ELEVATION
- PROPOSED GROUND ELEVATION
- WATER SURFACE ELEVATION

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CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

AVULSION 1
SITE PLAN
AND PROFILE

SHEET: 0

ALTERNATIVE 1:

NO ACTION

STATE OF MONTANA

SANDS HUGH D AND RITA D

TYLINSKI STEPHEN AND RHONDA

PARKER GARY A AND MARILYN B

PREDICTED 100-YEAR BANK EROSION EXTENT

SITE OVERVIEW MAP

SCALE: 1" = 300'

N

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CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

CONCEPT ALTERNATIVE 1

SHEET: 1

ALTERNATIVE 2A:

MAINTAIN EXISTING CHANNEL ALIGNMENT
STABILIZE ERODING BANKS ON PARKER PROPERTY

STATE OF MONTANA

SANDS HUGH D AND RITA D

TYLINSKI STEPHEN AND RHONDA

PARKER GARY A AND MARILYN B

STABILIZE ERODING BANKS TO REDUCE LOSS OF AGRICULTURAL PRODUCTION

SITE OVERVIEW MAP

SCALE: 1" = 300'

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SCALE IN FEET

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CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

CONCEPT ALTERNATIVE 2

SHEET: 2

ALTERNATIVE 2B:

MAINTAIN EXISTING CHANNEL ALIGNMENT
STABILIZE ERODING BANKS ON PARKER PROPERTY
REMOVE CHANNEL PLUG AT AVULSION #2
REMOVE CHANNEL PLUG AT HEAD OF ABANDONED CHANNEL
REINFORCE LEVEE TO REDUCE FLOOD HAZARDS

STATE OF MONTANA

SANDS HUGH D AND RITA D

TYLINSKI STEPHEN AND RHONDA

PARKER GARY A AND MARILYN B

REMOVE GRAVEL PLUG AT HEAD OF ABANDONED CHANNEL

STABILIZE ERODING BANKS TO REDUCE LOSS OF AGRICULTURAL PRODUCTION

REINFORCE LEVEE TO REDUCE DOWNSTREAM FLOOD HAZARD

SITE OVERVIEW MAP

SCALE: 1" = 300'

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CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

CONCEPT ALTERNATIVE 3

SHEET: 3

ALTERNATIVE 3:

REACTIVATE FORMER CHANNEL ALIGNMENT
PLUG EXISTING CHANNEL AT AVULSION #3
MODIFY PLUG AT AVULSION #2

STATE OF MONTANA

CONSTRUCT PLUG ACROSS DEACTIVATED CHANNEL TO PREVENT RECAPTURE

SANDS HUGH D AND RITA D

EXCAVATE GRAVEL DEPOSIT AT HEAD OF FORMER ALIGNMENT

TYLINSKI STEPHEN AND RHONDA

PARKER GARY A AND MARILYN B

DEACTIVATE EXISTING CHANNEL ALIGNMENT DOWNSTREAM OF AVULSION #3

CONSTRUCT PLUG AT AVULSION #3 TO DIVERT FLOW TO FORMER CHANNEL

CONSTRUCTED BANK TREATMENT

MODIFY PLUG AT AVULSION #2 TO ACCOMMODATE HIGH FLOWS

SITE OVERVIEW MAP

SCALE: 1" = 300'

LEGEND

PROPOSED PLUG

N

150 0 150 300

SCALE IN FEET

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CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

CONCEPT ALTERNATIVE 3

SHEET: 4

ALTERNATIVE 4:

CONSTRUCT NEW CHANNEL ALIGNMENT AWAY FROM AGRICULTURAL OPERATIONS
CONSTRUCT FLOODPLAIN PLUGS ACROSS EXISTING ALIGNMENT
REMOVE PLUG AT AVULSION #2
REINFORCE LEVEE TO REDUCE FLOOD HAZARDS

STATE OF MONTANA

CONSTRUCT NEW CHANNEL ALIGNMENT

FORMER CHANNEL ALIGNMENT REMAINS ACTIVE ONLY DURING HIGH FLOWS

SANDS HUGH D AND RITA D

TYLINSKI STEPHEN AND RHONDA

PARKER GARY A AND MARILYN B

CONSTRUCTED BANK TREATMENT

BACKFILL DEACTIVATED CHANNEL AND CONVERT TO VEGETATED FLOODPLAIN

REINFORCE LEVEE TO REDUCE DOWNSTREAM FLOOD HAZARD

REMOVE GRAVEL PLUG AT AVULSION #2

SITE OVERVIEW MAP
SCALE: 1" = 300'

LEGEND

- PROPOSED CHANNEL ALIGNMENT
- PROPOSED VEGETATED PLUG

N

150 0 150 300
SCALE IN FEET

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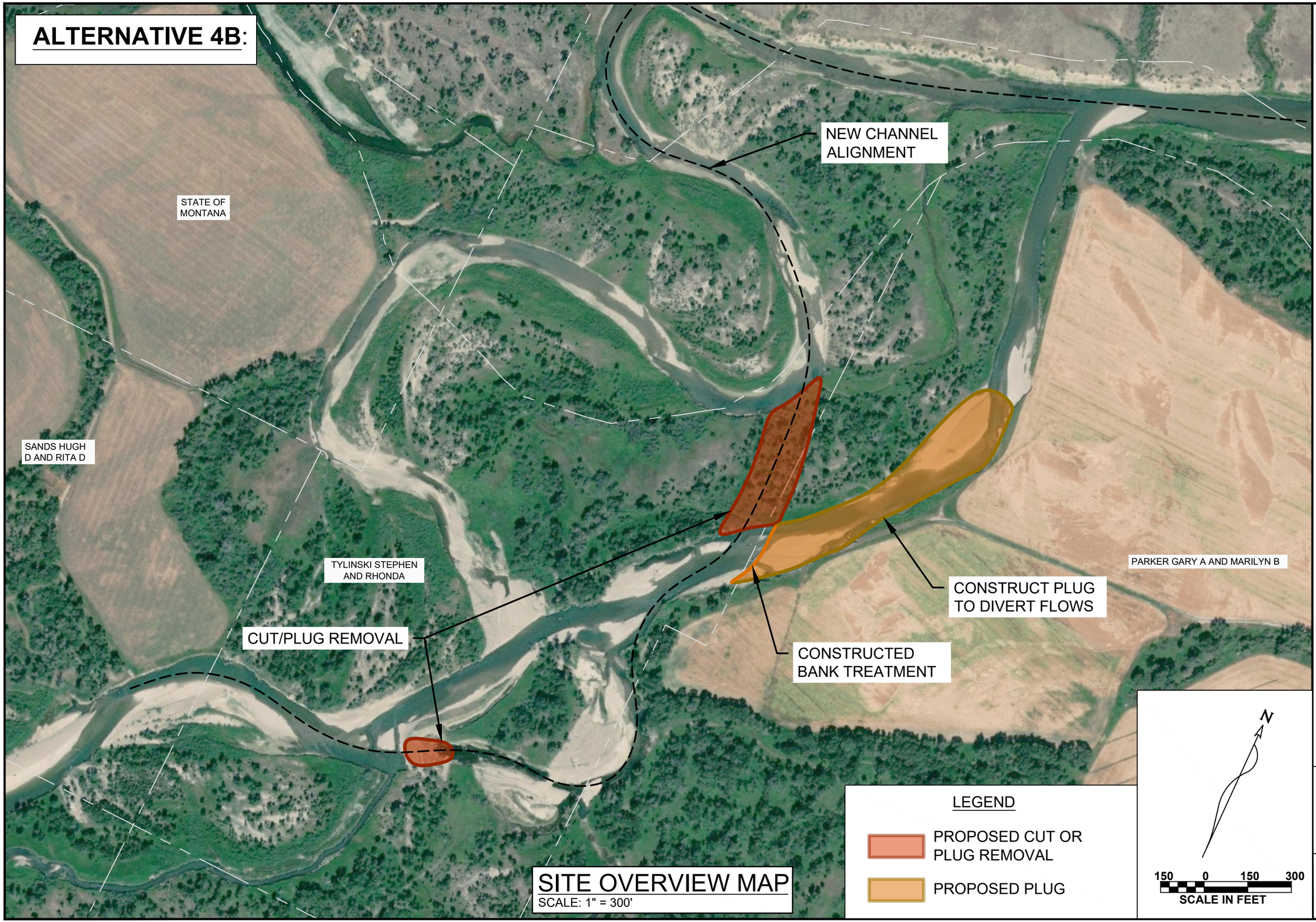
CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

CONCEPT ALTERNATIVE 4A

SHEET: 5

ALTERNATIVE 4B:



SITE OVERVIEW MAP

SCALE: 1" = 300'

LEGEND

- PROPOSED CUT OR PLUG REMOVAL
- PROPOSED PLUG

N

150 0 150 300

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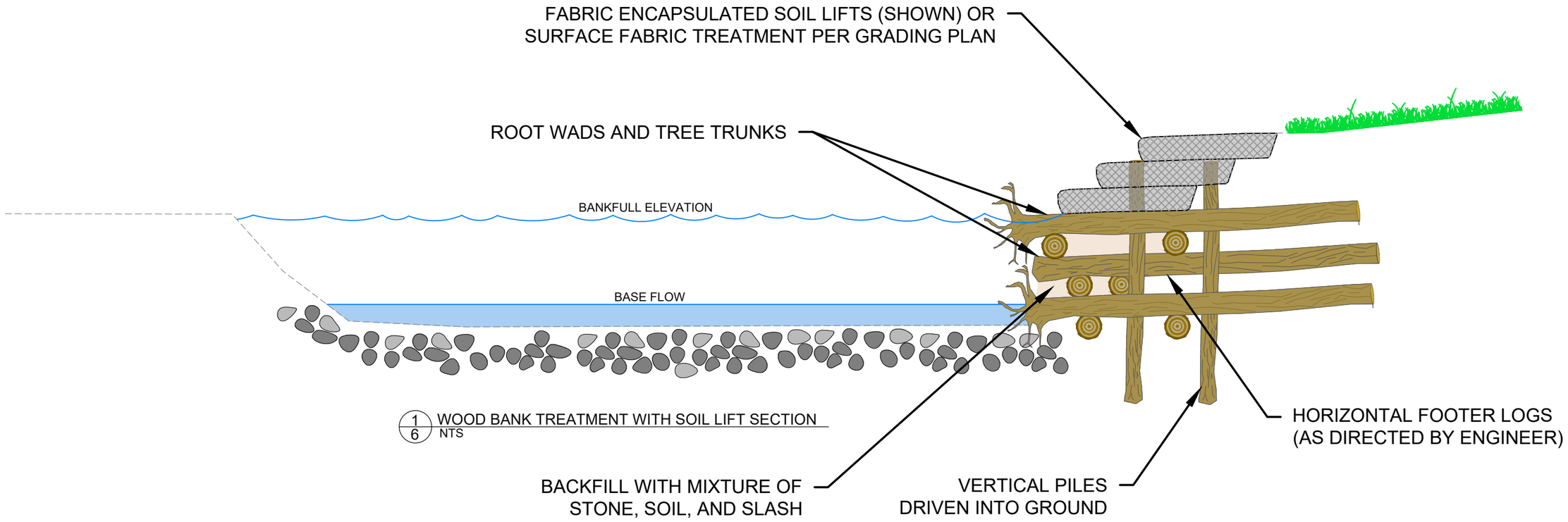
CONFLUENCE
consulting incorporated

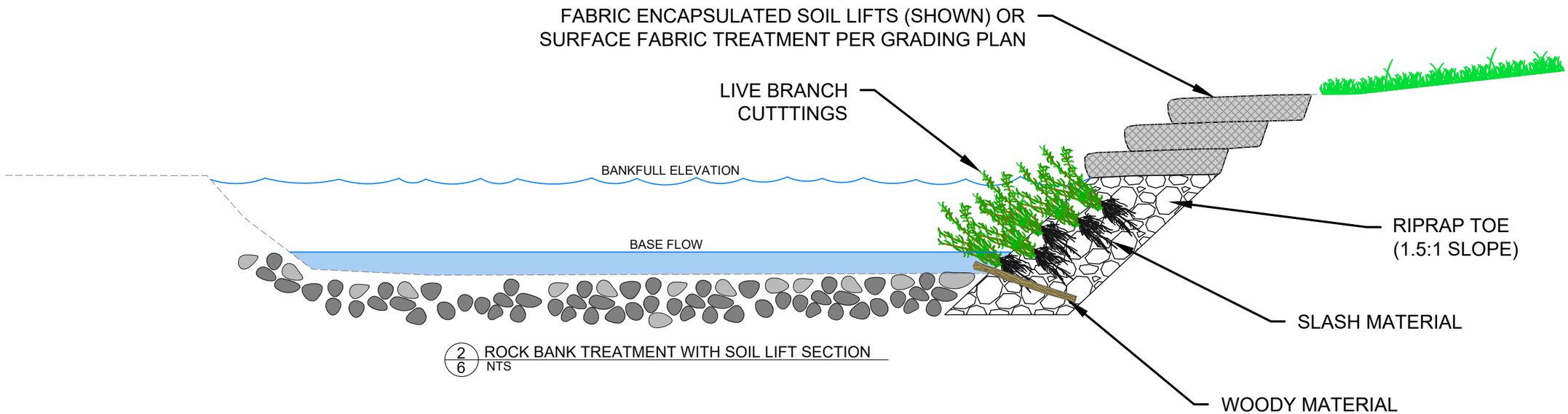
ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

CONCEPT ALTERNATIVE 4B

SHEET: 6



1/6 WOOD BANK TREATMENT WITH SOIL LIFT SECTION
NTS



2/6 ROCK BANK TREATMENT WITH SOIL LIFT SECTION
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CONFLUENCE
consulting incorporated

ADOBE CREEK AVULSION PLANNING
PRELIMINARY ENGINEERING REPORT
CASCADE COUNTY, MT

DETAILS

SHEET: 6