Select Bank Protection Alternatives

Supplement to 2018 RATT Site Reports

Introduction

This Bank Stabilization Report Supplement describes a series of bank stabilization strategies that we feel are applicable to the Musselshell River. They include the following:

I. **Full Bank Rock Riprap**: The most aggressive option, most appropriate where you want to protect key infrastructure; in most cases this approach is not necessary. Finer material can be added to this treatment to create "dirty riprap".
II. **Toe Rock with Vegetated Soil Lifts**: A common approach consisting of toe rock overlain by fabric-wrapped soils with willow cuttings, which promotes willow establishment on the upper bank.
III. **Planting Bench with a Riprap Toe/Soil Lifts**: Useful where you would like to build out from a high, steep eroding bank to create a low bench that will support riparian vegetation, or excavate a low bench against the bank.
IV. **Flow Deflectors**: Flow deflectors can be useful but should be used where you feel confident that the angle of approach by the river won't change much.
V. **Alluvial Brush Matrix**: this treatment is gaining popularity in parts of the state, and can be used in areas of moderate energy, especially where you would like to build a new bench off of a bank to and re-establish vegetation.

Numerous other types of treatments have shown success in controlling bank erosion across the state, such as using coarse woody material in bank toes, simple bank grading/planting, etc. The alternatives presented here are intended to give landowners some ideas for different treatment types in different settings, and we encourage further exploration and pilot trials.

The selection of a treatment type is dependent on the site and project objectives. Figure 1 shows an example decision tree to help identify the types of treatments that may be most applicable in a given setting. This is based on a general desire to provide the level of protection needed while minimizing unnecessary cost and impacts to stream function. Table 1 summarizes estimated costs and design considerations for the suite of approaches described in this document.

Disclaimer: The example schematic drawings that are this document have not been specifically catered to any given site on the Musselshell River. As such, their application at any given site requires site specific assessment and design. We highly recommend that landowners consult with a streambank erosion control specialist to accommodate their goals and resources; furthermore, factors such impacts on upstream/downstream landowners, ability to permit, anticipated maintenance, and availability of materials must be addressed prior to treatment selection and implementation. In summary, we make no claim that any of the treatment concepts provided here are generically appropriate without further assessment.
For additional information regarding bank armor on the Musselshell River, please refer to the RATT BMP.

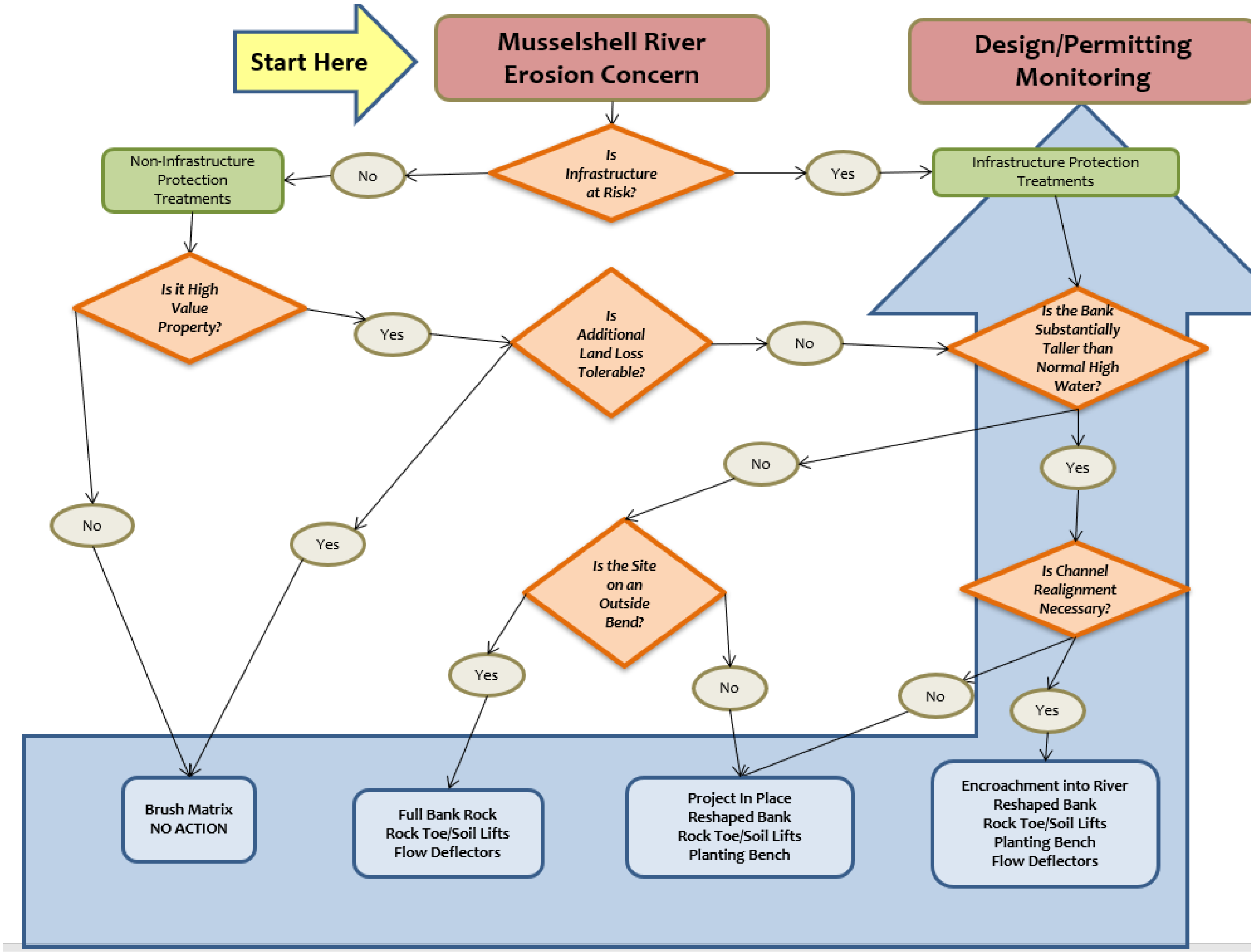

Figure 1. Decision matrix for a range of Musselshell River Bank Protection Alternatives.

Table 1. Summary of treatment cost, performance, and considerations.

Treatment	Estimated Cost*	Level of Erosion Control	Ecological Value	Key Design Considerations
Full Bank Riprap	$150/ft	High—Long Term	Low: Accelerates velocities, can cause downcutting	• Upstream and downstream extents • Toe Sizing
Toe Rock with Fabric Lifts and Planting Bench	$70/ft	High- Long Term	Moderate: Provides some shade and bank habitat	• Upstream and downstream extents • Toe Sizing • Elevation of lifts • Viabillity of willow cuttings • Timing of construction
Flow Deflectors	~7,000/ deflector	Moderate—function may degrade with time	May create scour holes off of barb, but will narrow channel and cause eddy erosion. Can affect adjacent properties	• Applicability at site • Length • Spacing • Orientation • Rock Sizing
Brush Matrix	$40/ft	Moderate- deformabillity can be designed at toe	High- Creates good cover, and enhances bankline vegetation	• Applicability at Site • Viability of willow cuttings • Alluvial source material

Costs have been estimated from other Montana projects and may vary.

I. Infrastructure Protection—No Tolerance for Bank Movement

Where there is no tolerance for additional bank movement, such as where infrastructure is at risk or where a landowner is determined to stop erosion into a field, and where the threat can't be removed by other means (such as moving a road), rock-based bank armor is likely appropriate. These treatments are based on a rock toe that extends to scour depth, with varying options for grading and upper bank treatments.

Full Bank Rock Riprap

Full bank rock riprap is a commonly expensive, susceptible to damage requiring maintenance, and prone to issues on the upstream and/or downstream end of the treatment that require project extensions. Full bank rock riprap is also commonly over-applied, as it extends to very high bank elevations where erosive energy is relatively low (Figure 2). As a result, the treatments commonly support little to no vegetation. The NRCS discourages practices that provided limited or minimally functional vegetation, or no re-vegetation (NRCS, 2011).

Figure 3 shows two examples of full-bank armor on the Musselshell. Both of these projects appear functional, with the photo on the left showing a relatively low riprapped bank, and the photo on the right showing a very high bank. With both of these projects, the most important part of the treatment is in the lowermost part of the bank, from a couple of feet above the water surface to the depth of scour below the streambed. This toe essentially provides the foundation over which the upper bank treatment is built. On the upper banks of both sites shown in Figure 3, there are means of bank shaping and incorporating or encouraging willow growth to improve aesthetics, add roughness to reduce erosive energy, and contribute some bank habitat (Figure 4). The NRCS (2011) indicates that the rock only needs to extend as high as the "stream forming flow", which is typically an average runoff event or about a 2-year flood (Figure 5).

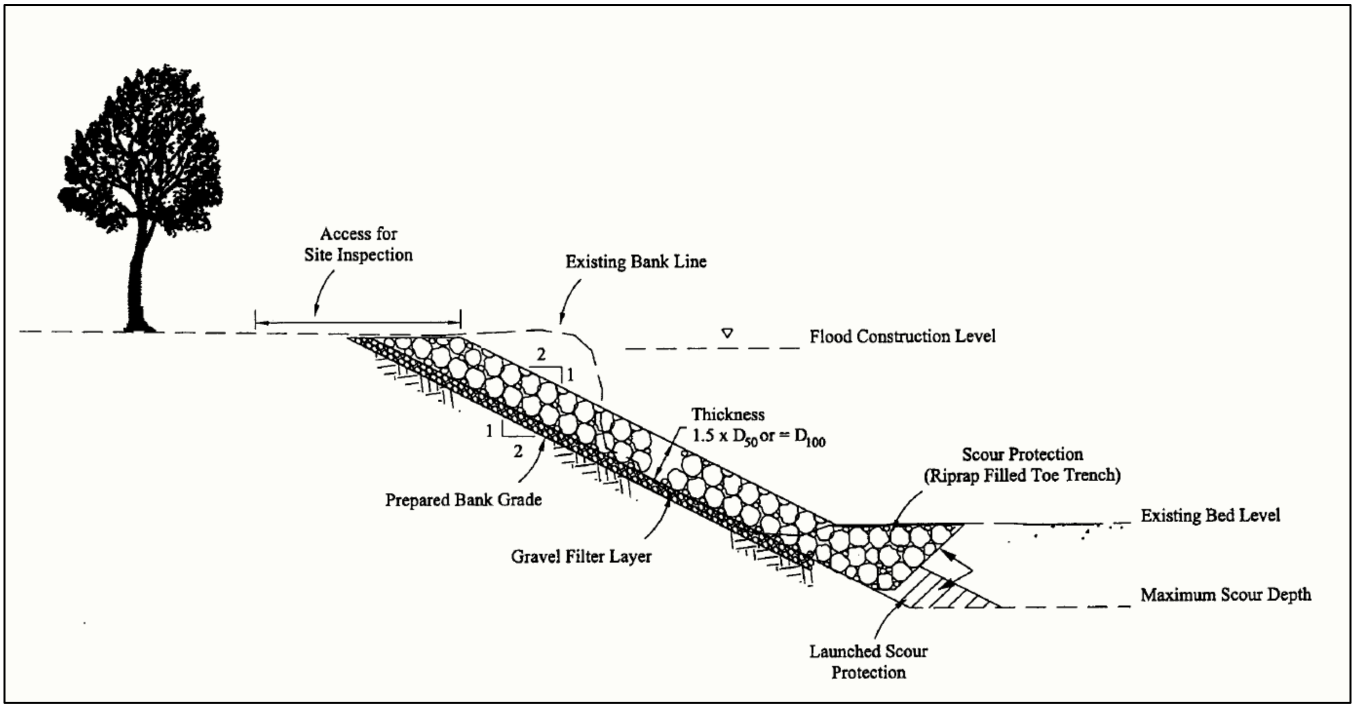

Figure 2. Cross Section of typical full-bank rock revetment.

Figure 3. Full bank rock riprap against floodplain surface (left) and higher terrace (right), Musselshell River.

Figure 4. Example of rock riprap that covers most of the bank but will allow for some vegetation growth on upper most bank -Yellowstone River, Riverside Park at Laurel (billingsgazette.com).

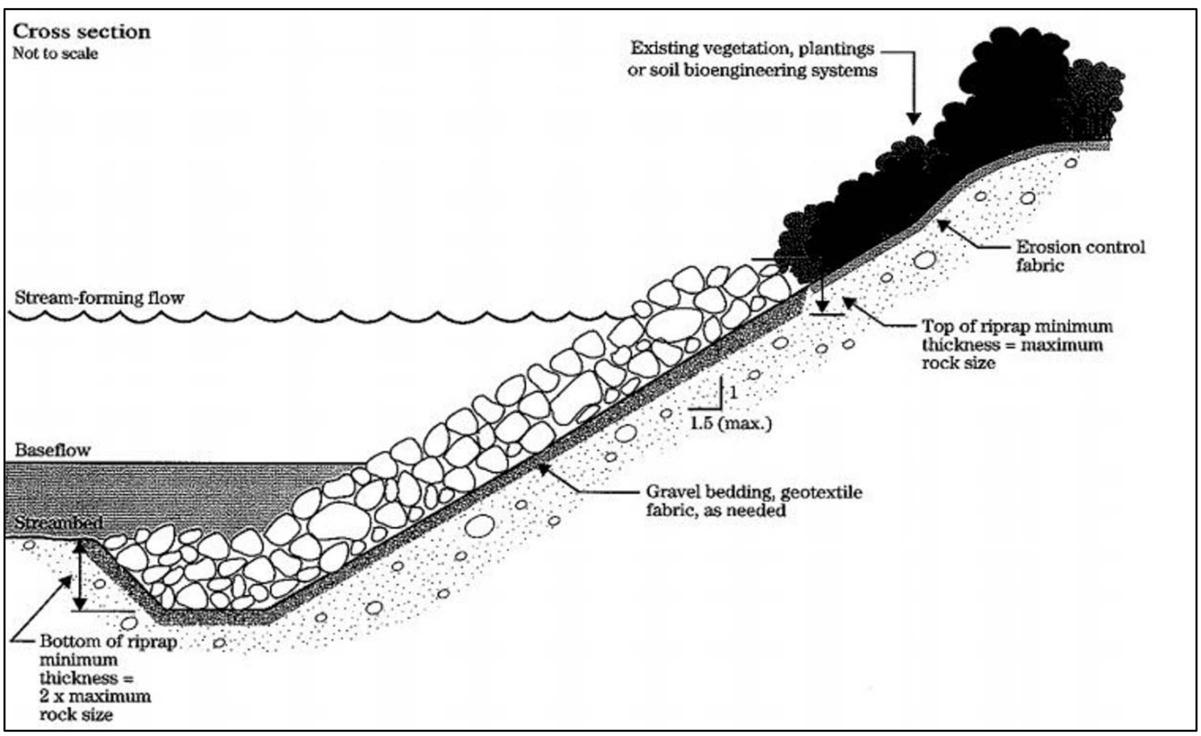

Figure 5. NRCS Cross Section of rock riprap that stops at the elevation of the "stream forming flow" transitioning to planting systems above.

Stakeholders who select full bank rock riprap as a treatment should consider the following:

- Excavate and 'key in' the base or 'toe' of the rock blanket below the elevation of anticipated bed scour as this is the zone of highest erosive stress from water, ice, and the weight of the rock above.
- Carefully consider the upstream and downstream limits of the armor to avoid project flanking or local scour failure (Figure 6).
- Utilize a gravel filter blanket beneath the rock in sites with sandy soil to retain soil fines.
- Use angular rock properly sized for the energy setting. Concrete and round rock are unsuitable as riprap.
- Avoid placing rock on slopes that are steeper than 2H:1V—although the slope in Figure 5 says a 1.5H:1V is acceptable, they note that a slope that steep should only be used if absolutely necessary and that 2H:1V is much more appropriate. If possible, a slope of 3H:1V is even better.
- Riprap projects should incorporate native vegetation into the design whenever possible and use 'dirty' rock or rock that has some soil incorporated into the rock matrix to encourage vegetation.
- Always have a qualified professional engineer and/or hydrologist evaluate, design, and oversee installation of rock riprap projects. This may help to avoid failure and treatments that simply 'band aid' a larger stream stability issue. Bank armor is notorious for being flanked, which can drive extremely fast erosion and result in costly reconstruction/repair (Figure 6).

In general, the use of full bank rock riprap without added incorporation of vegetation on the upper bank should be reserved for local infrastructure protection such as bridge crossings where floodplain restrictions create high velocities high on the channel banks (Figure 7).

Figure 6. View upstream of flanked bank armor, Musselshell River.

Figure 7. Limited application of full bank rock riprap at bridge crossing, Prickly Pear Creek at East Helena.

Toe Rock with Fabric Lifts and Planting Bench

As an alternative to full bank rock, biodegradable fabric lifts (commonly called "vegetated soil lifts") are commonly used to provide upper bank structure that supports the growth of woody vegetation. The intent of the lifts is to provide bank structure, contribute soil material for growth, and hold moisture to allow the establishment of woody vegetation that eventually takes over the bank stabilization role as the fabric decays, typically over about five years. The lifts are built above a constructed toe, above the base flow elevation (Figure 8).

In many designs such as that shown below, the lifts are angled back into the bank to keep the willow cuttings between the lifts wet at their base. Soil lifts that incorporate a low planting bench behind have been successfully used on the Musselshell (Figure 9). Figure 10 shows other soil lift examples on the Clark Fork River and Prickly Pear Creek near Helena. Both of these projects used toe material that was rounded cobble rather than quarried rock. The cobble was sorted from local alluvium. The Clark Fork River examples show how a "sacrificial toe" extending into the river below the bottom lift can become colonized by woody vegetation (Figure 10). Also, the toe material can be sized to move if that is desirable. On the Clark Fork River, for example, the toe is designed to mobilize at a 10-year flood so the river won't be perpetually locked in place, only until vegetation is reestablished.

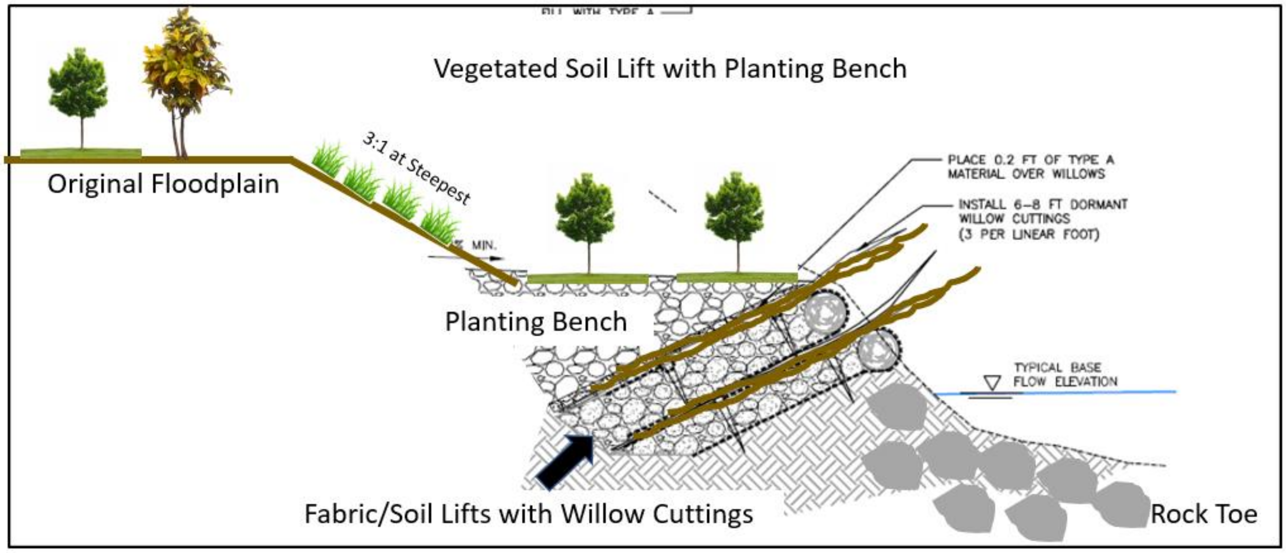

Figure 8. Example schematic drawing for vegetated soil lift design.

Figure 9. Soil lift project with planting bench behind on Musselshell River above Roundup.

Figure 10. Willow growth in soil lifts on Clark Fork River (top) and Prickly Pear Creek (bottom).

With regard to the “planting bench”, this surface can either be left for natural colonization of willows and other woody species (Figure 11), or actively planted (Figure 12). This bench is also commonly called an “inset floodplain bench” or “bankfull bench”. Many designs set this bench elevation at “Q2”, which is the 2-year flood or the water surface elevation during common snowmelt runoff events. The goal is to have a surface that is in contact with groundwater and river processes so riparian vegetation can establish at the toe of the steeper bank. The width of the bench can vary, so it can be used to rebuild floodplain to reconfigure channel alignment, such as at diversion dams. On the Musselshell, this technique could be used to rebuild floodplain area lost in the 2018 flood for example.

Figure 11. Bankfull bench construction on Clark River just after construction (left) and ~4 years later (right).

Figure 12. Bankfull bench construction on Boulder River near Drummond (George Austiguy).

Flow Deflectors

Flow deflectors is s general term of techniques that include groins, spur dikes, barbs, vanes, bendway weirs, or any other low elevation structures that project into the channel from a bank to redirect flow away from the bank. They are often combined with other types of bank protection techniques, such as bank shaping and planting between the deflectors. The long-term function of these treatments is best on long, uniform bends where the upstream approach remains relatively constant through time. They are inappropriate in channels that are actively downcutting, aggrading, or notably steep (over 2%). If an avulsion is likely in an area, flow deflectors should be avoided. And in some cases, bendways can become too compressed for flow deflectors to function. The spacing of flow deflectors depends on the length, angle, and shape of the channel and requires careful design for optimal performance. They should be properly keyed into the bank.

Barbs Vanes, or Jetties are the most common type of deflector used on the Musselshell River to date. They are designed deflect water, ice, and debris away from the bank on gentle outside bends or straight reaches. They are usually constructed of a series of evenly spaced, large diameter stone or log structures (or a combination of both). They are typically aligned perpendicular to flow, but can also be pointed at an angle upstream or downstream. Upstream alignments are becoming more common to reduce erosion between the structures at high flow. Their length should not exceed about one-fourth of the channel width. Barbs that are pointed downstream often increase erosion on the opposite bank. If the river changes its approach direction, or if the barbs are poorly design or constructed, severe erosion between the structures can occur which can result in complete flanking (Figure 13 and Figure 14). When compared to traditional rock riprap, barbs have a lower impact on natural streambank and fisheries. To improve fish habitat, wood is sometimes used in barbs. The use of concrete rubble, concrete slabs, or metal debris is highly discouraged. When building them, they can be positioned to minimize their impacts on existing vegetation. They typically require less material and cost less than rock riprap, but they are riskier.

On the Yellowstone River, barbs are generally discouraged because most projects end up being converted to full bank riprap because of erosion problems between the structures (Figure 15).

For a summary of other types of flow deflectors, see the Musselshell River Bank Armor BMP.

Figure 13. Erosion control barbs on Musselshell River (left) and Yellowstone River (right) showing orientation to flow, and erosion between structures.

Figure 14. View downstream showing recently constructed (left) and older (right) barbs showing erosion between structures in older projects.

Figure 15. Barb treatment converted to full bank riprap.

II. Non-Rock Treatments—Allowance for Some Bank Movement

In some cases there are opportunities to use “softer” bank treatments that are intended to provide shorter-term protection while a channel adjusts to a more stable planform. These are referred to as bioengineering treatments or “engineered deformability”. These treatments can be extremely cost effective where risk is low and the potential for recovering vegetation is high. The Musselshell River Bank Protection BMP document describes numerous types of bioengineered bank treatments. The soil lifts described above are a type of bioengineered bank, however the rock toe under the lifts makes them non-deformable. The treatments below are intended for use where some additional bank movement is tolerable.

Brush Matrix

One low cost, deformable treatment that is showing great promise on different rivers of Montana is referred to as a “brush matrix” which is a bank constructed of a mixture of alluvium (gravel and cobbles) mixed with wood fragments. The wood extends into the channel at all different angles, creating a rough edge that provides excellent fish habitat while reducing erosive energy. These treatments can also be built to form an inset bench that promotes woody vegetation growth (Figure 16 through Figure 19). This treatment can also be built on a larger rock toe if that is of interest; this approach was taken on the Ruby River to support fish habitat, however the toe was not riprap so some deformability is expected and desired (Figure 18).

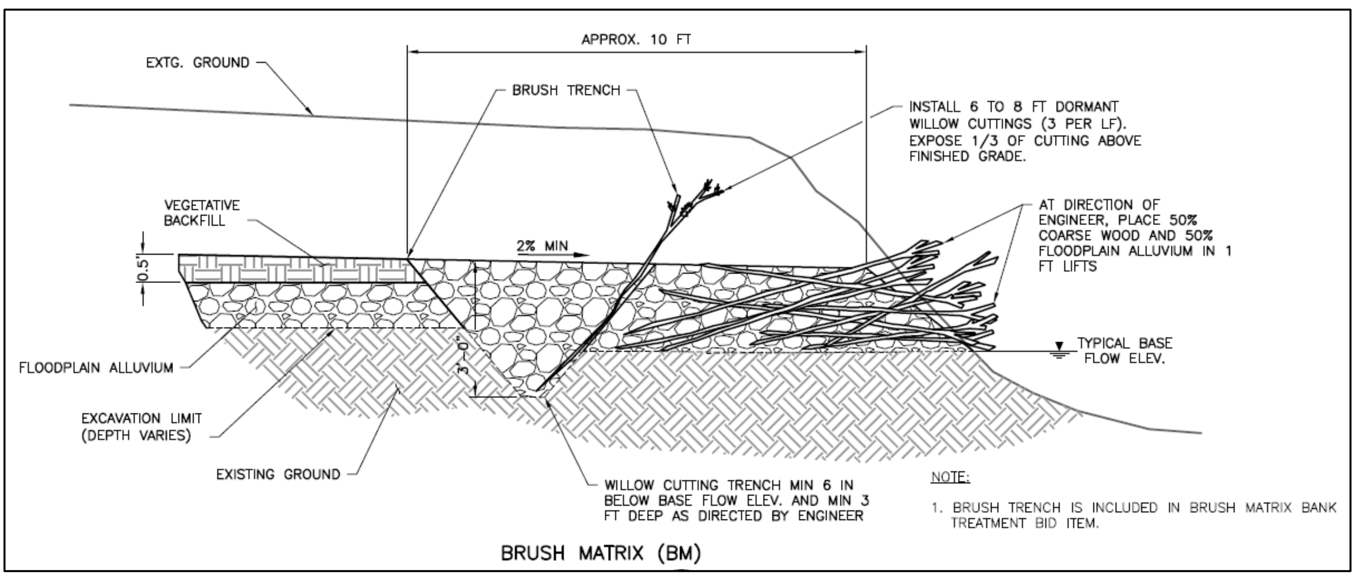

Figure 16. Example design drawing for a brush matrix treatment; this can be constructed over a rock toe in areas of higher energy (CDM Smith, 2016).

Figure 17. Recently constructed brush matrix treatments, Clark Fork River near Deer Lodge.

Figure 18. Brush matrix construction creating low bench (left), willow growth four months after installation- Ruby River near Sheridan MT (note—steep scarp on photo on left will be graded back to 3H:1V..

Figure 19. Robust willow growth ~3 years after installation, Clark Fork River near Deer Lodge.

Sources of Additional Information.

Montana Department of Natural Resources and Conservation – Guide to Permits.
http://dnrc.mt.gov/Permits/StreamPermitting/Guide.asp

Montana Department of Natural Resources and Conservation – Montana Stream Permitting Handbook.
http://dnrc.mt.gov/Permits/StreamPermitting/PermittingBook.asp

USDA Natural Resources Conservation Service Stream Corridor Restoration Handbook:
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?cid=stelprdb1043244

Integrated Streambank Protection Guidelines:
https://wdfw.wa.gov/publications/00046/