# GRAVE CREEK RIPARIAN REVEGETATION AND MONITORING PLAN

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PREPARED FOR:

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# Table of Contents

# Section 1 Introduction

## 1.1 Project Identification

This document describes a riparian revegetation and monitoring plan for a mile-long reach of Grave Creek, located in Lincoln County, near Eureka, Montana (Township 35 North, Range 26 West, Section 12; Latitude 48.81331 Longitude -114.89867). Grave Creek is a tributary to the Tobacco River, which flows into the Kootenai River (at Lake Koocanusa) west of Eureka. Figure 1 shows the location of the project reach within the Grave Creek watershed, and the project location relative to major towns and other watercourses.

This plan includes implementing various riparian and floodplain restoration and enhancement strategies in the project reach. This plan also describes how implementing these strategies should be done in conjunction with continued project monitoring using an adaptive decision making framework to track effectiveness of implemented treatments. This project continues the restoration efforts begun on this reach of Grave Creek in 2001.

The primary problem this plan addresses is the need for rapid riparian and floodplain vegetation recovery to increase stability of this restored reach of Grave Creek. The project history and value of this natural resource is detailed in the following section. In general, past restoration efforts within the project reach included re-alignment of 8,200 feet of channel in three separate phases, Demonstration Phase (1,000 feet), Phase One (4,200 feet) and Phase Two (3,000 feet). While some revegetation work has been implemented as part of these phases, this riparian and floodplain restoration plan describes additional revegetation treatments for Phase One and Phase Two of the project (Figure 2).

This project will contribute to meeting Use Support Objectives, Allocation Strategies and Restoration Objectives described in the final Grave Creek TMDL (DEQ 2005), including:

- 63% reduction in bank erosion rates in lower Grave Creek; and
- Improve large woody debris recruitment potential through protection of riparian areas on all lands.

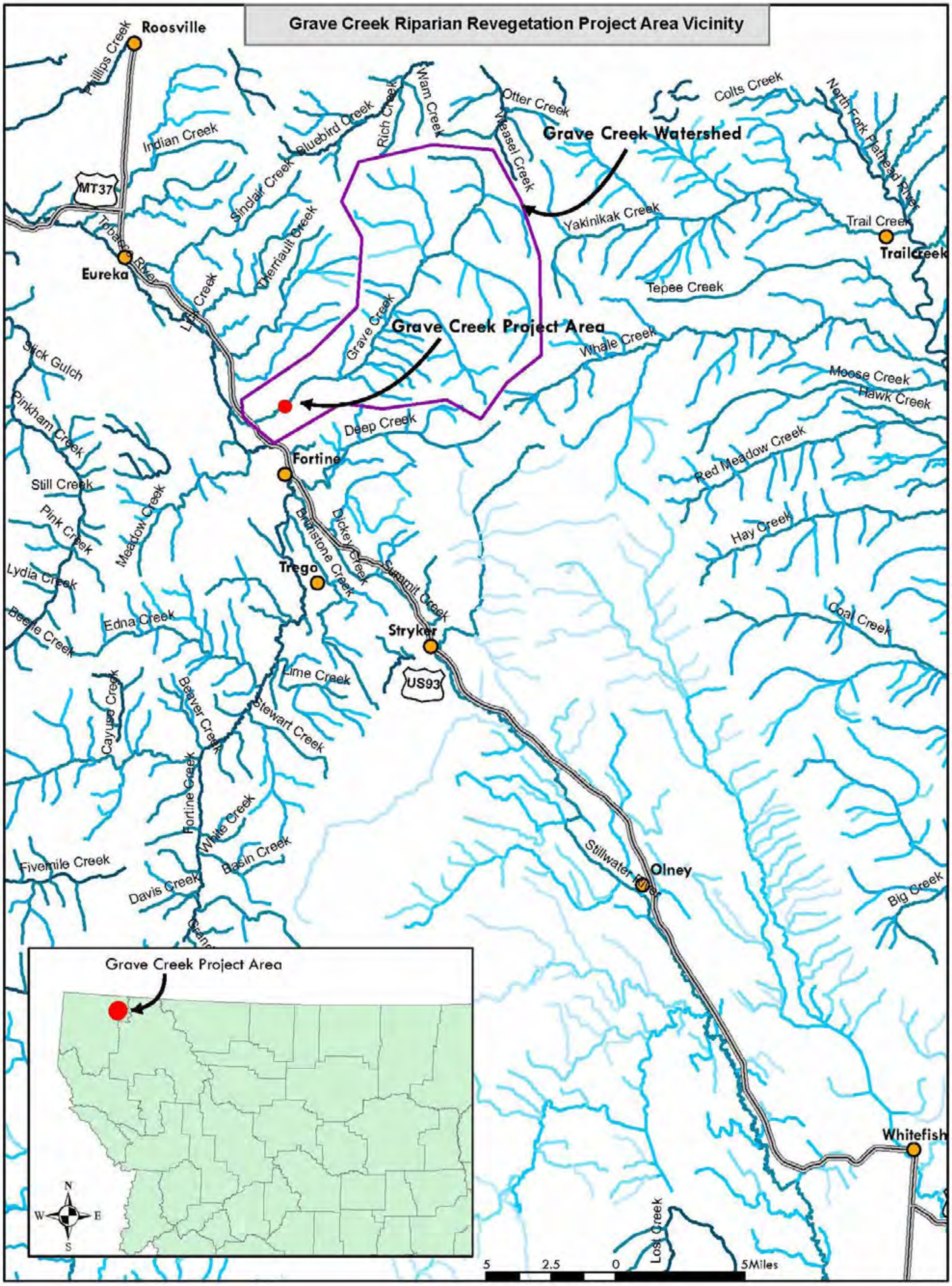


**Figure 1.** Location of the project reach in relation to the Grave Creek watershed, the larger Kootenai River Basin watershed and western Montana (inset)**.**

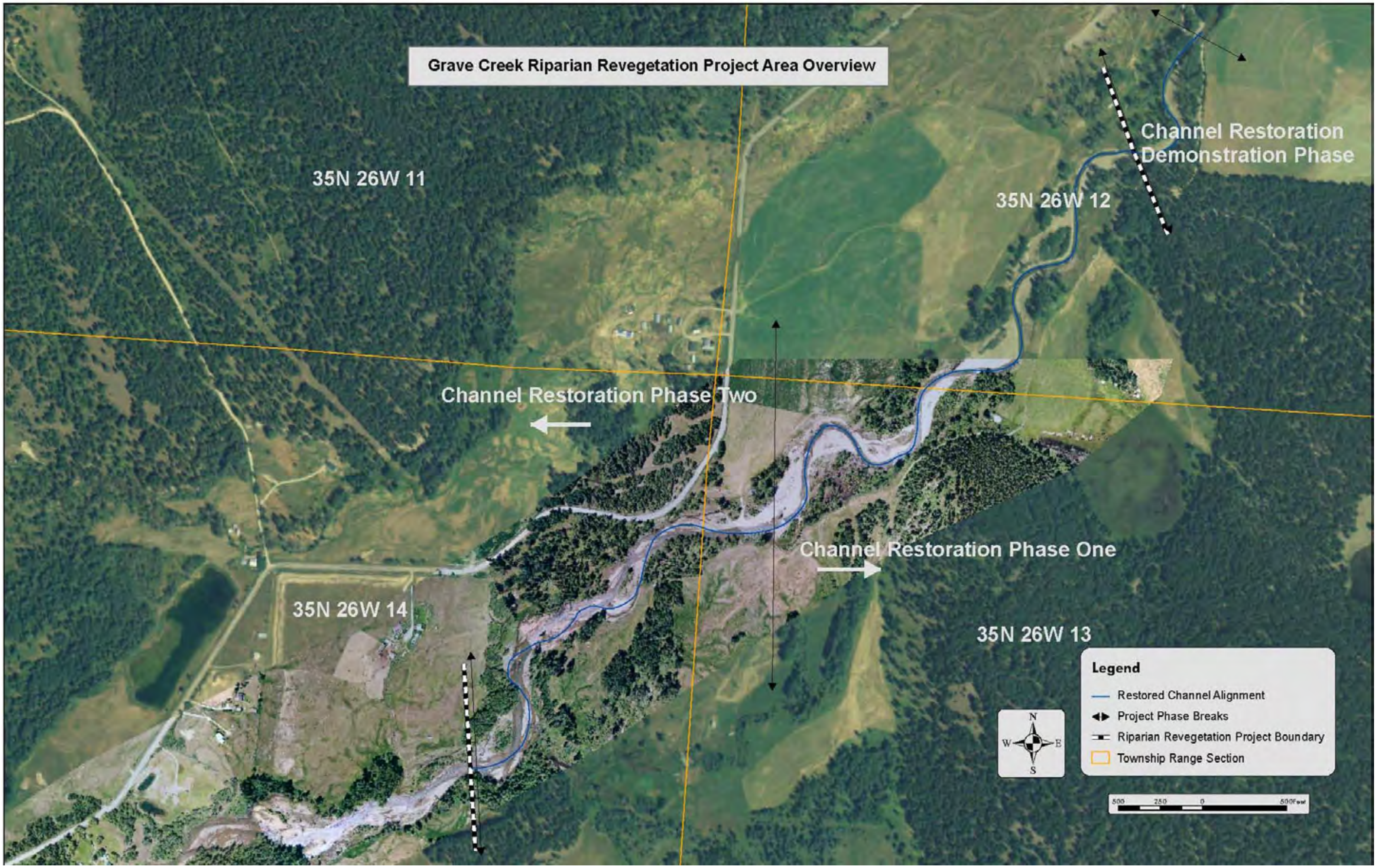


**Figure 2.** Overview of Grave Creek riparian revegetation project reach. This riparian revegetation plan includes channel restoration phases One and Two.

## 1.2 Project History

This project is the continuation of restoration efforts begun in this reach of Grave Creek in 2001. In 1996, a watershed analysis was completed to support development of a Total Maximum Daily Load (TMDL) for the watershed. This analysis identified Grave Creek as having fish habitat limitations linked to excess sediment loading (DEQ 2005). Habitat limitations in the lower reaches of Grave Creek were linked to a lack of pools and low levels of large woody debris. Additional problems in lower reaches of the watershed included: an overly widened channel; eroding banks linked to past channelization and past and recent land management practices; and a reduction in function of the riparian corridor due to historical management practices (DEQ 2005).

Grave Creek supports an important bull trout fishery and provides habitat for several other native fish, including westslope cutthroat trout. Grave Creek and its associated tributaries have been identified as the most important bull trout spawning tributary for the portion of the Upper Kootenai River watershed located in the United States (as reported in the RFP for this work prepared by Kootenai River Network (KRN)). Historical data suggest that runs of mountain whitefish, bull trout, and westslope cutthroat trout from the Kootenai River have declined since the mid 1940s due to past management practices in the watershed (DEQ 2005).

Since completion of the watershed assessment, a number of agencies and other organizations including: Montana Fish, Wildlife and Parks; U.S. Fish Wildlife Service through the Partners for Fish and Wildlife Program; the Lincoln Conservation District; and the Natural Resources Conservation Service and private landowners, have been working together to implement restoration and land management changes within the watershed.

The project reach was identified by partners as a high priority for reducing sediment sources and restoring habitat for fish. Restoration activities focused on restoring proper form and function of the river channel through reconstruction of a large gravel to small cobble, meandering, riffle-pool stream type. A variety of design methods were used including an analog or referenced based approach, hydraulic modeling, and application of regional curves and regime equations. Specific restoration actions included: channel reconstruction, installation of fish habitat features, grade control and bank stabilization structures, and improving hydrologic connectivity with the adjacent floodplain, historical wetland side channels and meander oxbows. Converting the channel from an unstable, braided system to a single thread channel resulted in large areas of bare, alluvial surfaces which require rapid development of riparian vegetation to promote floodplain and channel stability. Grade control and bank structures typically limit short-term channel movement and provide time for riparian vegetation communities to develop.

Initial revegetation of the reach was accomplished using: whole sod and shrub transplants, containerized root stock, sprigs and dormant pole plantings, broadcast seeding, and organic compost application. Initial efforts to promote revegetation of the reach resulted in limited success due to several site constraints. These constraints included: browse pressure from livestock and wild ungulates; erodible outer banks being subject to annual scour; limited moisture holding capacity of exposed cobble substrates; and lack of microsites to support plant establishment on smooth, flat constructed floodplain surfaces. These constraints are described further in Section 3. To address these constraints, supplemental riparian revegetation activities were implemented along the project reach in 2005 and 2006. Revegetation in 2005 and 2006 included: stream bank bioengineering techniques, such as vegetated soil lifts; planting a small number of containerized shrubs; and enhancement of constructed floodplain areas to promote natural floodplain processes such as sediment storage, erosion control, and plant community succession. Floodplain enhancement techniques included construction of floodplain swales, planting of containerized shrubs in select swale features, and placement of large woody debris on floodplain surfaces.

While these efforts have contributed to restoring stream and floodplain function, additional constraints and revegetation needs have been identified. This document describes those additional revegetation strategies that will more completely address site constraints. Implementing these strategies will promote recovery of desired riparian plant communities, and will protect the significant investment in channel and floodplain restoration to date.

## *1.3 Project Purpose and Objectives*

The purpose of this project is to restore the riparian and floodplain environment along Grave Creek within the project reach. The project will result in conditions that will support the establishment of diverse plant communities capable of sustaining floodplain ecological processes. These ecological processes include: plant community succession, sediment storage, flood water retention, and long-term channel stability. Implementing this project will assist project partners in preserving valuable natural resources in Grave Creek including threatened and sensitive fish species, wildlife, and water quality.

To achieve the project purpose and the desired future condition, the following specific objectives were developed:

1. Reduce deer and elk browse to allow naturally recruited and planted shrubs and trees to establish along the reach.
2. Implement long-term grazing management, including cattle exclusion and off-channel water sources, until plant communities are established.
3. Stabilize stream banks where accelerated erosion is occurring using bioengineering treatments that will provide short-term stability while vegetation establishes.
4. Promote floodplain point bar stability and revegetation through point bar grading and use of bioengineering treatments that incorporate moisture retaining coir materials with live plant materials, seeding and planting.
5. Implement an integrated floodplain and riparian monitoring program to provide the necessary data to determine how vegetation communities are developing in order to make appropriate management and restoration decisions for the project reach.

The remaining sections of this document include the following information:

- **Section 2** describes the existing conditions, desired future conditions and limiting factors to achieving the desired future condition.
- **Section 3** describes the preferred alternative for achieving project objectives and other alternatives considered, including a No Action alternative.
- **Section 4** describes how the preferred alternative to achieving project objectives will be implemented.
- **Section 5** provides a timeline for implementing the preferred alternative.
- **Section 6** provides supplemental technical documentation on the project.
- **Section 7** describes a monitoring plan for the project reach, including results of monitoring completed in December 2007 to determine effectiveness of revegetation treatments and how that data was used to develop the preferred alternative described in this plan.

# Section 2 Existing and Desired Future Condition

## 2.1 Existing Condition

The project reach was assessed during December 2007 and previously during the growing season in 2005 and 2006. Assessments focused on: characterizing existing plant communities and the natural processes contributing to the development of those plant communities; observing how the reach is responding to past restoration and revegetation efforts; and determining the existing limiting factors to achieving the desired future condition for the project reach. This section describes the current conditions of the riparian and floodplain environment within the project reach including: the reach's potential natural community; observations of riparian and floodplain revegetation processes; and the primary constraints and limitations to achieving revegetation objectives.

The concept of a potential natural community (adapted from Daubenmire 1968) refers to the plant community that will develop on a site over time as a result of (1) natural disturbance processes that occur over relatively long periods; (2) the particular combination of climate, landform, substrate, latitude, and hydrogeomorphic conditions; and (3) biological processes such as seed dispersal, soil biology, and influence from animals and birds. The potential natural community represents a range of plant communities that occur as a spatial mosaic and represent a variety of successional states corresponding with random disturbance events and complex microtopographic and moisture gradients on a site. Developing revegetation strategies based on the potential natural community of a site increases success of establishing dynamic plant communities that can be sustained long-term.

At the largest scale, Grave Creek's potential natural community within the project reach is the *Picea*/*Cornus stolonifera (*spruce/red-osier dogwood) habitat type (Hansen et al. 1995). It appears that this habitat type is capable of occupying all areas of the floodplain up to the stream bank. Because Grave Creek is a dynamic system with significant sediment transport and deposition, this habitat type will usually result from the following progression:

1. *Populus trichocarpa*/recent alluvial bar (Black cottonwood/recent alluvial bar) community will develop first, colonizing depositional areas resulting from flood events.
2. Over time, the black cottonwood/recent alluvial bar community will trap sediment, allowing first willows and then other later successional shrubs to develop, ultimately resulting in the black cottonwood/red-osier dogwood community type.
3. Once either overhead or lateral shade has developed due to cottonwoods rapidly growing, spruce seedlings will become established and longer-lived spruce will ultimately replace the cottonwood communities.

In addition to the above succession scenario, spruce appears directly to colonize alluvial bars along Grave Creek.

The speed at which this progression occurs is highly dependent on annual run-off timing and magnitude and the scour and deposition that occur as a result.

Within the spruce/red-osier dogwood habitat type, patches of minor, transitional community types may become established, such as:

- The *Salix exigua* (sandbar willow) community type (Hansen et al. 1995), which can form dense stands that may include other shrub species like *Salix drummondiana* (Drummond's willow), *Alnus incana* (mountain alder) and dogwood. These communities are likely to occur on new depositional areas along the channel or in open, low depression areas with coarse substrate within the forested overstory; or
- The mountain alder community type (Hansen et al. 1995), which may form in swales where groundwater is close to the soil surface.

Examples of vegetation community types and successional stages occurring within the project reach at Grave Creek are shown in Figures 3-8 below.

**Figure 3.** Example of Spruce/red-osier dogwood habitat type encroaching on point bar.

**Figure 4.** Example of black cottonwood/recent alluvial bar community type colonizing a point bar.

**Figure 5.** Black cottonwood/red-osier dogwood community type to the left, with black cottonwood/recent alluvial bar community type developing on recent deposition (photo center).

**Figure 6.** Mountain alder community type developing in swale (photo background).

**Figure 7.** Sandbar willow community colonizing a point bar.

In general, existing riparian plant communities throughout the project reach lack young age classes. Young stands of both cottonwoods and willows are rare within the channel migration zone. One reason for this is likely due to the pre-restoration channel conditions of the reach, which consisted of a braided channel. Cottonwoods and willows likely germinated on exposed floodplain gravels, but gravels were likely re-distributed before seedlings could establish. Another reason for this is the long history of grazing and current levels of browse occurring in the reach.

Intense levels of browse are also limiting understory shrub development in forested areas. Black cottonwood stands are common along outer meander bends, but consist almost entirely of even-aged mature stands with little to no woody understory vegetation (Figure

8). On outer meander bends, where these stands are present, the understory should consist of species such as red-osier dogwood, alder, snowberry, and rose; but consists primarily of grasses and forbs.

Browse is limiting plant community development throughout the project reach. During the December site visit, browse was observed on all unprotected shrubs and trees, with the exception of spruce, along the entire length of the reach (Figure 9). Evidence of recent cattle use was apparent, but deer and elk probably also contribute to browse. Browse pressure is likely affecting the survival of both naturally recruited and planted seedlings and saplings and may also limit the amount of available seed.

The level of browsing intensity at the site is intense, with intense defined as browse resulting in a complete annual stem segment being killed (Keigley and Frisina 1998). Most shrubs within the project reach exhibit an arrested-type architecture indicative of intense browsing. Herbivory is uniform throughout the project reach, with all individuals within the young age class exhibiting this arrested-type architecture. The existing stands of cottonwoods and willows are likely relic of an early period of light-to-moderate browsing and are often the parents of the short, heavily browsed plants.

**Figure 8.** Black cottonwood plant community illustrating the dominance of even-aged cottonwoods and a lack of understory woody vegetation.

Some portions of the project reach lack mature woody vegetation along the banks (Figure 10). This is primarily due to past land uses that resulted in the removal of riparian vegetation communities. This is also due to the short time since channel restoration was completed. Restoring the channel from braided to single thread resulted in large areas of newly constructed surfaces, which require a long period for desired, mature vegetation to develop.

**Figure 9.** Suppressed willow growth due to browse showing arrested growth structure.

**Figure 10.** Photograph of existing conditions along the project reach, where banks lack mature riparian vegetation. Past land uses resulting in removal or riparian vegetation led to an increase in lateral bank erosion, often into secondary terraces (photo left). Channel reconstruction moved the channel away from these eroding terraces through the creation of bankfull benches. Some of these benches were planted with containerized shrubs in 2005.

Within the project reach, some accelerated bank erosion is occurring in areas where mature woody vegetation is lacking. Some outer banks have migrated approximately four feet or more since 2005 (Figure 11). Most of this erosion probably occurred during one large run-off event in the late winter of 2005, but stream bank and point bar stability are also being affected by scour from anchor ice formation and break up (Figure 12).

The one exception is bioengineered stream banks, where woody vegetation is still developing but lateral erosion rates appear to be lower. This is apparent at sites where soil lifts were constructed in 2005. The channel at the toe of these structures scoured, but little to no lateral migration occur. This may indicate that if soil lifts had not been constructed at these sites, bank erosion rates in these areas would have been much higher during the winter 2005 flood. Data collected in December 2007 indicates willows are surviving in the vegetated soil lifts installed during 2005 and 2006 but have been heavily browsed (Figure 13). Continued browse pressure will result in poor long-term survival of willows in vegetated soil lifts, and reduce success of these structures at improving long-term stability.

**Figure 11.** Photograph of Fall 2005 planting site. Photograph shows the extent of lateral erosion that occurs on outer banks within the reach. The black plastic weed mat was placed approximately three feet from the edge of the stream bank in 2005 and in December, 2007one and a half feet of weed mat had slumped into the channel, indicating at least four feet of lateral erosion occurred along this bank.

**Figure 12.** Ice accumulation along the project reach affects channel stability. Ice formation results in diverting flows onto adjacent floodplain surfaces and ice break up may result in lateral shearing and vertical scour.

**Figure 13.** Photograph of vegetated soil lift bioengineered stream bank. Willows are surviving in these structures, but heavy browse (inset photo) is limiting growth and continued browse pressure could reduce survival.

Depositional bars within the project reach lack woody vegetation. In some cases, this is probably due to heavy browse pressure and in other cases it is due to insufficient microsites where plants can grow. Development of desired plant communities on point bars is necessary for long-term stability in the project reach. Numerous restoration techniques were implemented on constructed point bars to create microsites for desired woody vegetation to establish. For example, large and small coarse woody debris, excavated swales and microtopography were constructed to retain fine sediments and organic material, recruit fluvially transported seed and create protected microsites for that seed to germinate and grow.

The effectiveness of these treatments is variable within the project reach. In the upper portion of the project reach, constructed point bars lack woody species recruitment although it is obvious flood waters are accessing floodplain surfaces and sufficient roughness is present. On other point bars, woody species recruitment is occurring and in many locations this recruitment occurs in flood deposited material or in protected areas around woody debris placed on constructed point bars (Figure 14). During the December 2007 site visit, all recruited woody vegetation had been heavily browsed.

Results of monitoring data collected on point bars in December 2007 indicate that cottonwood recruitment occurs in very select areas of constructed point bars. Point bars with more surface area at an overall lower elevation (between one and two feet above the baseflow water elevation) and with gradual slopes may be more suitable for natural woody vegetation recruitment. This indicates that flood duration, timing, and access to depositional areas are all factors affecting the rate of woody species recruitment on constructed point bars. Point bars closer to low flow water surface elevations may retain flood waters longer and recession of flood waters from these areas may be slower and therefore a wider window of conditions needed for colonization of desired woody species is present.

**Figure 14.** Photograph of constructed point bar illustrating flood deposited fine sediments and organic matter accumulation around placed large woody debris. Colonization of woody species is occurring in the fine sediments deposited around the woody debris (inset photo).

Invasive species are present throughout the project reach. The primary weed species in the project reach are common mullein (*Verbascum thapsus*) and spotted knapweed (*Centaurea maculosa*). Although these species are widespread, the densities are high in only a few areas.

### 2.1.1 Current Limiting Factors

Based on the current conditions, the following causes are considered limiting factors to achieving the desired future condition:

- Cattle and ungulate browse is intense within the project reach; with most susceptible trees and shrubs are being browsed. Continued removal of terminal and lateral buds and foliage has stressed many planted and naturally recruited shrubs and trees. This historical and continued pressure has resulted in plant communities which are missing younger age classes and therefore cannot function to provide stream bank stability or create structurally complex and diverse plant communities. Browse levels have not been regularly monitored in the reach. However, based on observations made in December, 2007, it is estimated that greater than 90% of shrubs less than three feet in height are being browsed past the current year's growth.
- Stream bank, floodplain and channel instability are limiting establishment of desired plant communities. Outer banks at meander bends are subject to annual scour, resulting in an unstable soil/water interface. Where mature riparian vegetation with a diverse understory is present, this erosion appears to be minimal. Where multi-layered plant communities are lacking, exposed cobbles on cut banks allow rapid drying of substrate and these banks are susceptible to significant rates of lateral erosion. Lateral erosion of four feet or more was observed in December, 2007. Channel incision is occurring in some portions of the reach, which may result in loss of hydrologic connection between the channel and the floodplain. If the channel loses its hydrologic connection to the floodplain, the floodplain will not support water-loving riparian trees and shrubs.
- The formation and break up of anchor ice results in accelerated erosion of stream banks and floodplain areas. In addition, ice accumulation is damaging colonizing and planted shrubs and trees. The amount of scour and erosion resulting from ice formation and break up was not quantified during monitoring conducted in December 2007. However, observations made at this time indicated that all planting areas where browse protection was installed had greater than 75% damage to installed plantings, as determined by the presence of bent re-bar that was originally installed to support browse protectors placed around plants.
- Competition from weedy species may be limiting desired plant establishment in some areas of the reach.
- Some smooth, constructed floodplain surfaces are still present along the reach. These areas provide limited microsites where willow and cottonwood seeds can become trapped and germinate. This is limiting point bar plant community succession which is necessary for long-term stability of the reach.

## 2.2 Desired Future Condition

The desired future condition for the riparian and floodplain environment within the project reach is a dynamic, succession driven mosaic of plant communities capable of supporting a wide range of floodplain ecosystem functions. This is the type of environment present in many undisturbed riparian communities in large stream and river systems in the Kootenai River Basin and is the environment that was likely present before agricultural clearing and channelization occurred in the project reach. Historically, the lower Grave Creek valley consisted of a multiple channel system that developed within a broad, well-vegetated spruce wetland (General Land Office map dated March 16, 1896). This system likely meandered across a wide floodplain and supported diverse shrub and spruce wetlands (DEQ 2005). This is similar to the late successional stage described in Section 2.1. This desired condition is physically limited to some extent compared with historical conditions, by agricultural developments adjacent to the floodplain.

The desired future condition would contain the level of vegetative and structural diversity associated with mature and late-successional stands of willow, cottonwood, and spruce communities, which are necessary for bank stability in this type of system, which is a meandering, gravel-dominated, riffle pool channel. These plant communities would supply coarse woody debris sufficient to sustain physical complexity, and provide connectivity within the watershed. To successfully create and maintain a diverse mosaic of plant communities in the project reach requires acknowledging the role that fluvial processes play in determining plant community structure. Geomorphic and other disturbance processes will affect, and are necessary for, the development of the riparian and floodplain ecosystem, ultimately determining the spatial pattern and successional development of riparian vegetation.

Because stream systems are dynamic, with natural disturbance processes playing a large role, achieving the desired future condition will take several years and require an adaptive, phased approach. The focus of this riparian revegetation plan is to set the reach on a trajectory that can take numerous paths, but will ultimately reach the desired condition. For this reason, implementing a monitoring program that observes changes in the channel, floodplain and riparian environments will be necessary to determine if the project is on this trajectory and achieving the project purpose and objectives.

For example, prior to achieving the desired future condition of a multi-aged, structurally diverse mosaic of riparian plant communities, observations of the treatments implemented in the reach would help determine if conditions to support those desired plant communities are present. On point bars, this means microtopography is diverse and complex with large woody debris, coarse woody debris accumulations, and floodplain swales to capture sediments, seed, plant propagules, and create niches and microsites for plant community development. This would represent the as-built condition. Within one to two years of implementing such treatments, natural recruitment of pioneer woody vegetation should be present on some or all point bars. The extent to which this naturally recruited vegetation survives will depend on various natural disturbance processes, but it would be important that site conditions increase the survival chances of a portion of naturally recruited seedlings. Within five years of observing pioneer vegetation, stands of mature willows and pole cottonwoods would occupy a portion of point bars. The location of willow and pole cottonwood stands on a point bar will depend on the magnitude of flood events and channel migration that occurs in the period these stands are establishing. In other areas, young age class shrub stands should return within one to two years after excluding grazing and browse from the reach. In cottonwood stands, diverse shrub communities should develop and promote floodplain and channel stability within five years of excluding grazing and browse. On-going monitoring will ensure the necessary observations be made that will help determine if the reach is moving towards the desired future condition.

Factors contributing to the current condition that are limiting achieving the desired future condition include:

- Grazing and browse pressure;
- Stream bank, floodplain and channel instability;
- Winter ice formation and break up and large rain-on-snow events;
- Competition from weeds; and
- Limited point bar plant community succession.

To achieve the desired future condition and project objectives, this revegetation plan includes strategies to address these limiting factors. Table 1 summarizes the current and desired conditions of these limiting factors and the proposed revegetation strategies to address each. These strategies are described below.

### 2.2.1 Browse Pressure

Currently, riparian plant communities in the project reach consist of older age classes and woody species regeneration is being suppressed by livestock, deer and elk browse. To achieve the desired future condition, browse must be significantly reduced for at least five years to allow the existing seed bank and currently suppressed shrubs and trees to germinate and establish.

Browse will be reduced by installing wildlife fencing around the project reach. This treatment is described in Section 3 and Appendix A.

### 2.2.2 Stream bank, Floodplain and Channel Instability

Currently, some areas of bank, floodplain and channel instability are limiting development of desired plant communities in the project reach. Stream bank instability is resulting in accelerated lateral erosion in some areas, which makes establishing desired mature woody vegetation communities difficult. Instability of newly created point bars is primarily a result of high water events and to some extent scour from anchor ice formation and break up. Localized channel incision occurring in other areas of the reach reduces floodplain connectivity, which inhibits fluvial processes such as sediment and seed deposition on bare surfaces and reduces hydrologic floodplain recharge.

Localized stream bank instability has been addressed in the past by installing vegetated soil lifts with a reinforced cobble and log toe and built in conjunction with woody debris jams. Floodplain stability has been addressed by creating surface roughness to dissipate energy across the floodplain. The vegetated soil lifts have been successful at providing stability along outer meander bends while vegetation matures. Floodplain roughness features, including constructed swales and placed woody debris have been successful at limiting major point bar erosion, such as head cutting.

This plan includes additional stream bank bioengineering in high priority areas where accelerated lateral erosion is occurring due to a lack of deep, binding root mass from stream bank vegetation. Stream bank instability will also be addressed through construction of a set-back stream bank along one section of eroding bank. Floodplain instability will be addressed by promoting floodplain revegetation using techniques such as buried coir logs and willow fascines to establish vegetation in select areas of point bars. Localized channel instability will be addressed by lowering and re-shaping small sections of point bars to maintain floodplain connectivity. These treatments are described further in Section 3 and Appendix A.

### 2.2.3 Winter Ice Formation and Rain-on-snow Events

Winter anchor ice that regularly forms and breaks apart in this reach of Grave Creek may limit achieving the desired future condition. The main limitation resulting from the development of ice is the potential for bank, bed and floodplain scour to occur as ice breaks apart. Anchor ice can result in significant amounts of erosion and scour and has damaged planted shrubs and bioengineering structures installed along the reach. However, ice jams also function to increase water depths upstream of the jam which often results in water flowing onto adjacent floodplain surfaces during winter months. While it is not likely that viable seed is transported during winter months, the water flowing over point bars does result in deposition of organic material and fine sediments which create ideal sites for deposited seed to germinate and grow during the growing season (Figure 14).

Because the formation of ice is related to a variety of factors including extremes in air and water temperatures, it is not possible to address this factor through this plan. The affinity of the channel within the project reach to forming anchor ice was considered in past treatments and treatments included in this plan. For example, by creating surface roughness throughout the floodplain, the energy of over land flows are slowed and dissipated reducing the risk of surface erosion and protecting shrubs establishing in swales from direct damage from moving ice blocks. Ice formation is most common in Phase One of the reach and treatments susceptible to ice damage are not proposed in this area. In addition, browse protectors placed around individual shrubs in planting areas along the reach will be removed as these are being damaged by ice moving through the reach and injuring plants.

### 2.2.4 Weed Competition

While invasive species are present throughout the project reach, competition from these species is not considered a major limiting factor for achieving revegetation objectives. A few small infestations of spotted knapweed have established on point bars, and this may limit the establishment of desired vegetation in these areas. Other invasive species, such as common mullein, are widespread, but also pose limited risks.

Weed competition is addressed in this plan through monitoring of existing and future infestations and is discussed in Section 7.

### 2.2.5 Limited Point Bar Plant Community Succession

Simple, uniform topography on floodplain and point bar surfaces does not provide microsites to trap seed and plant propagules, nor does it promote scour and deposition needed to create and maintain microsites. Overbank flows rush over uniform floodplain surfaces without depositing sediments or organic materials, which are necessary in alluvial systems to build soil and promote vegetation establishment.

This factor has been addressed previously in the project reach through the construction of numerous swales on constructed point bar features and placement of large amounts of large and coarse woody debris on floodplain surfaces. These treatments have successfully trapped and retained fluvially transported sediments and seed, creating floodplain scour and providing refugia for establishing trees and shrubs (Figures 14 and 20). However, establishment of trees and shrubs on point bars is currently limited by browse, loss of floodplain connectivity in some areas and the high flows the reach is subject to, which reduces the probability of seedlings surviving by redistributing point bar sediments.

The project will address the lack of seedling establishment on point bars through minor floodplain grading, constructing floodplain swales, and placing additional large woody debris in the floodplain where possible. In addition, point bar revegetation in the form of seeding, pole cottonwood planting and large containerized shrubs and trees will be done in areas where site conditions are appropriate. These treatments are described in more detail in Section 3 and Appendix A.

**Table 1.** Summary of limiting factors identified for the Grave Creek riparian restoration project, existing and desired future conditions of those limiting factors and the strategies and techniques proposed to address them.

| Limiting Factors | Existing Condition | Desired Future Condition | Strategies and Techniques to Address Limiting Factors |
|---|---|---|---|
| **Browse pressure** | High levels of browse throughout the project reach is limiting plant reproduction, survival and plant community succession. | Mosaic of mature and young age class riparian and floodplain vegetation communities present on point bars and throughout the floodplain and riparian area. Sufficient structural diversity to protect young plants from excessive browse. | -Eliminate browse by cattle and wildlife for at least 5 years.<br>-Long-term, active management of the riparian and floodplain area to allow desired plant communities to establish and mature to stabilize the channel and floodplain to within natural levels of erosion and deposition, and allow natural processes to scour and deposit new sediments. |
| **Stream bank, floodplain and channel instability** | Currently, some bank, floodplain and channel instability is limiting development of desired plant communities in the project reach. Instability is apparent in accelerated lateral erosion and localized channel incision. | Mosaic of mature and young age class riparian and floodplain vegetation communities present on point bars and throughout the floodplain and riparian area. Vegetation communities would have structural diversity and deep binding root systems necessary to reduce lateral stream bank erosion to within natural limits, and reduce the risk of channel incision and point bar erosion. | -Eliminate browse by cattle and wildlife for at least 5 years.<br>-Install bioengineering techniques in areas requiring high stability during the vegetation establishment period (e.g. outside meander bends and constructed point bars).<br>-Incorporate diverse microtopography and roughness features into point bar grading.<br>-Create patches of diverse floodplain plant communities, through low maintenance revegetation techniques, including: seeding, pole cottonwood cuttings and small numbers of large container size plants.<br>-Construct set back vegetation treatments in anticipation of lateral channel migration.<br>-Long-term, allow natural processes, such as plant community succession, to restore a mosaic of floodplain vegetation communities. |
| **Anchor ice and rain-on-snow events** | Winter anchor ice regularly forms and breaks apart in the project reach which increases the potential for stream bank, bed and floodplain scour to occur. Ice jams have damaged planted shrubs and bioengineering structures installed along the reach. Common rain-on-snow events can lead to multiple high flows during the year. | Mosaic of riparian and floodplain plant communities that will provide stability for stream banks and floodplains to reduce the risk of erosion and scour during ice formation and break up and during multiple high flow events. | -Eliminate browse by cattle and wildlife for at least 5 years.<br>-Install bioengineering techniques in areas requiring high stability during the vegetation establishment period (e.g. outside meander bends and constructed point bars).<br>-Incorporate diverse microtopography and roughness features into point bar grading.<br>-Create patches of diverse floodplain plant communities, through low maintenance revegetation techniques, including: seeding, pole cottonwood cuttings and small numbers of large container size plants. |

| Limiting Factors | Existing Condition | Desired Future Condition | Strategies and Techniques to Address Limiting Factors |
|---|---|---|---|
| **Competition from weeds** | Weedy species are well distributed through out the project reach, but very few large infestations occur. | No large infestations of invasive species. Mosaic of mature and young age class riparian and floodplain vegetation communities present throughout the project reach that are capable of resisting competition with invasive species. | -Eliminate browse by cattle and wildlife for at least 5 years.<br>-Create patches of diverse floodplain plant communities, through low maintenance revegetation techniques, including: seeding, pole cottonwood cuttings and small numbers of large container size plants.<br>-Long-term, active management of the riparian and floodplain area to allow desired plant communities to establish and minimize weed infestations where necessary. |
| **Limited point bar plant community succession** | Very little natural recruitment of desired woody vegetation is occurring on point bars. | Mosaic of young age class riparian and floodplain vegetation communities colonizing point bars and maturing as natural channel migration occurs. | -Eliminate browse by cattle and wildlife for at least 5 years.<br>-Incorporate diverse microtopography and roughness features into point bar grading.<br>-Create patches of diverse floodplain plant communities, through low maintenance revegetation techniques, including: seeding, pole cottonwood cuttings and small numbers of large container size plants.<br>-Long-term, allow natural processes to restore a mosaic of riparian and floodplain plant communities. |

# Section 3 Alternatives Analysis

Four alternatives were considered that could achieve the project purpose and objectives and set the reach on a path towards achieving the desired future condition. Table 2 compares the four alternatives considered in terms of approximate costs, ecological benefit in terms of achieving project objectives, and approximate timeframe for achieving those objectives. Each alternative is described in more detail below.

## *3.1 Alternative 1: No action*

Alternative 1 includes taking no additional actions. If the no action alternative were chosen, natural processes such as scour and deposition, seed transport, plant colonization, and plant succession might still occur; but would not occur within a time frame that would protect the investment already made in restoration of the project reach. Under this alternative, none of the limiting factors described in Section 2 would be addressed.

This alternative would be the least expensive to implement; however, it is not certain if this alternative would achieve project objectives. Given time and intermittent relief from browse it is possible that desired plant communities will establish and function in the project reach; however, without the establishment of shrubs and trees along the channel and on point bars it is possible that sections of the reach may return to an unstable, braided channel that would not support desired project objectives and ecosystem functions.

## *3.2 Alternative 2: Cattle and wildlife exclusion*

Alternative 2 includes removing all cattle use and access to the riparian area within existing fenced boundaries for a minimum of five years and reducing deer and elk browse pressure through construction of additional fencing. The riparian area is currently fenced along the entire project reach; however, maintenance of the existing fence is necessary to exclude cattle use of the area. The existing fence will not prevent browse pressure from deer and elk. Therefore, enhancing the existing fence or installing new fencing would be necessary to reduce the current levels of browse that are limiting desired vegetation establishment.

This alternative might achieve project objectives, but over a longer time period compared with the preferred alternative. This alternative only addresses one of the limiting factors described in Section 2, browse pressure. It does not address the limiting factors of stream bank, floodplain and channel instability, competition from weeds and limited point bar plant community succession.

As described for Alternative 1, it may be possible within an uncertain time frame, for the desired future condition to be achieved by taking no further action; however, for this to occur, browse pressure would need to be reduced and occur only intermittently for a period of time.

## 3.3 Alternative 3: Large scale revegetation

Alternative 3 includes implementing a large scale revegetation effort within the project reach by planting all areas where vegetation community establishment is desired (approximately 10 acres). This alternative would include similar treatments as the preferred alternative, but also include planting a large number of containerized trees and shrubs. This alternative would likely achieve project objectives, but would be more expensive and potentially less effective than other alternatives. Planting large areas with nursery stock requires a significant initial investment. In addition to the cost of the plants, there would also be labor costs, and additional materials costs for browse protection and mulch to limit competition from herbaceous plants. While planting some areas with native nursery stock is an effective revegetation strategy, it is most effective when concentrated in targeted areas that can be realistically maintained. Out-planted nursery stock must be watered during the growing season for two or three years after installation; this and other maintenance requires financial and personnel resources that are not always available when needed.

At some restoration sites, large scale planting is necessary because seed sources and conditions for plant establishment are not present. However, in riparian areas like Grave Creek, where natural processes are relatively intact and seed sources are present, the most cost-effective revegetation strategy is to use small amounts of plant material in places where they are most likely to grow and contribute to improving floodplain function in the future. The following (preferred) alternative incorporates that approach and addresses the constraints identified in Section 2.

## 3.4 Alternative 4: Preferred alternative

Alternative 4, the preferred alternative, includes both active and passive approaches to restoring desired riparian and floodplain plant communities within the project reach. This alternative was designed specifically to meet project objectives and addresses, to some extent, all of the limiting factors described in Section 2. This alternative relies primarily on natural recruitment of desired vegetation for long-term success. How the proposed treatments under this alternative relate to project objectives and the desired future condition is summarized in Table 1. The preferred alternative includes the following treatments:

- **Temporary exclusion** of the riparian area from cattle and wildlife for a minimum of five years;
- **Bioengineering** treatments, including vegetated soil lifts and coir log fascines along outer meanders in high priority areas and buried coir log and willow fascines to promote point bar stability and revegetation of point bars.
- **Outer meander planting** in high priority areas where accelerated erosion is not occurring.
- **Point bar revegetation** using small numbers of large, containerized plant materials (16 gallon grow bags), cottonwood poles, and diverse seed mixes concentrated in constructed swale features with the most favorable growing conditions (organic matter accumulation and long hydroperiods).

- **Floodplain treatment** including construction of floodplain swales, large woody debris placement, and grading, on select point bars that lack microtopography or connectivity with the channel.
- **Set back stream bank vegetation** in anticipation of lateral channel migration in areas where accelerated lateral erosion is occurring but the channel plan form may not be stable.
- **Maintenance** of existing planting areas to support the continued growth of planted shrubs and trees.
- **Long term management** of weeds and grazing in the project reach.

Details on treatment locations and quantities are provided in Section 4.

**Table 2.** Comparison of alternatives considered for achieving project objectives.

| Alternative | Cost[1] | Ecological Benefit | Timeframe[3] |
|---|---|---|---|
| 1 | $0.00 | If grazing and browse continue, it is uncertain if the desired riparian and floodplain functions will develop over time. No identified limiting factors would be addressed under this alternative. | 25-50 years |
| 2 | $30,000-$50,000 | Similar ecological benefits to the preferred alternative if erosion and deposition stay within natural rates to allow natural plant community succession to progress. Would not address four out of five limiting factors. | 15-25 years |
| 3 | $150,000-$200,000 | Similar ecological benefits to the preferred alternative, but significantly higher up front and long-term maintenance costs without guarantee of proportionate increase in benefits. | 5-10 years |
| 4[2] | $75,000-$100,000 | This alternative addresses all limiting factors and provides the following ecological benefits:<br>-Jump starting desired plant community establishment<br>-Short-term bank stability<br>-Floodplain connectivity<br>-Erosion control<br>-Sediment storage<br>-Long-term fish and wildlife habitat | 5-15 years |

[1]Costs are approximate and depend on actual quantities and materials used
[2]Preferred alternative
[3]The timeframe for each alternative is estimated and based on a variety of natural and other variables

# Section 4 Project Implementation Plan

This section describes how the preferred alternative will be implemented. To assign treatments to the project reach, point bars were identified numerically from the top of the reach to the bottom. Each point bar is labeled in Figure 15. Figure 15 shows the locations of proposed treatments within the project reach. Detailed descriptions of each treatment are provided in Appendix A. Treatment quantities by point bar are described in Table 3.

Because floodplains are diverse, complex ecosystems characterized by highly dynamic processes and continuous change, the overall approach to project implementation is to implement treatments in phases, where each phase is dependent on how the site responds to earlier phases. For this reason, restoration of the riparian and floodplain ecosystem will require an approach that considers multiple timeframes and allows for flexible decision making that is driven by how the site responds to initial treatments. This is the approach that has been taken within the project reach to date and the treatments provided in this plan are based on what has been found to be effective, specific to the reach. Original restoration strategies considered overall watershed processes of sediment supply and transport, and in response, appropriate channel form and dimensions were constructed. Revegetation treatments were implemented in response to observing a lack of natural vegetation recruitment and survival. These treatments had variable success the first year, and adjustments to treatments were made based on observing early results.

It is the intent of this project to continue this adaptive approach, where short term objectives focus on floodplain and bank stability sufficient to allow vegetation to become established. Longer term objectives focus on dynamic stability, defined as erosion and channel movement that occurs within natural ranges observed on alluvial river systems similar to Grave Creek.

**Table 3.** Preferred alternative treatment locations, quantities, and priority.

| Point Bar | Location[1] | Treatment (See Appendix A for treatment descriptions) | Estimated Quantity | Priority |
|---|---|---|---|---|
| All | N/A | Fencing (supplemental or new) | 15,000 feet | High |
| 1 | Inside | None | N/A | N/A |
| | Outside | Outer meander planting | 25 | Moderate |
| | | Bioengineering: soil lift + woody debris jam | 1 | Moderate |
| 2 | Inside | Floodplain treatment | 0.5 acres | Low |
| | Outside | Set back revegetation | 200 feet | Moderate |
| 3 | Inside | None | N/A | N/A |
| | Outside | Existing planting area maintenance | 1 | High |
| | | Bioengineering: soil lift | 100 feet | Low |
| 4 | Inside | Point bar revegetation: Seeding<br>Pole cottonwoods<br>16-gallon grow bags | 0.25 acres<br>100<br>25 | High |
| | | Floodplain Treatment | 500 cubic yards | Moderate |
| | Outside | None | N/A | N/A |
| 5 | Inside | None | N/A | N/A |
| | Outside | Existing planting area maintenance | 1 | High |
| | | Bioengineering: coir log | 50 feet | High |
| | | Bioengineering: soil lift | 100 feet | High |
| 6 | Inside | None | N/A | N/A |
| | Outside | None | N/A | N/A |
| 7 | Inside | None | N/A | N/A |
| | Outside | Existing planting area maintenance | 1 | High |
| | | Bioengineering: soil lift | 100 | High |
| | | Cattle water gap removal + vane repair | 1 | High |
| | | Woody debris jam | 1 | High |
| 8 | Inside | Floodplain treatment | 1000 cubic yards | High |
| | Outside | None | N/A | N/A |
| 9 | Inside | Point bar revegetation: Seeding<br>Pole cottonwoods<br>16-gallon grow bag | 0.25 acres<br>100<br>25 | High<br>High<br>High |
| | Outside | Existing planting area maintenance | 1 | High |
| 10 | Inside | Point bar revegetation: Seeding<br>Pole cottonwoods<br>16-gallon grow bag | 0.25 acres<br>100<br>25 | Moderate |
| | | Floodplain treatment | 500 cubic yards | Moderate |
| | Outside | Existing planting area maintenance | 1 | High |
| | | Bioengineering: soil lift | 50 feet | Moderate |
| 11 | Inside | None | N/A | N/A |
| | Outside | Existing planting area maintenance | 1 | High |
| | | Bioengineering: coir log | 50 feet | Moderate |
| 12 | Inside | Point bar revegetation: Seeding<br>Pole cottonwoods<br>16-gallon grow bag | 0.25 acres<br>100<br>25 | Moderate |
| | | Floodplain treatment | 250 cubic yards | Moderate |
| | Outside | None | N/A | N/A |

| Point Bar | Location[1] | Treatment (See Appendix A for treatment descriptions) | Estimated Quantity | Priority |
|---|---|---|---|---|
| 13 | Inside | Bioengineering: buried coir log and willows | 200 feet | Moderate |
| | Outside | None | N/A | N/A |
| 14 | Inside | Bioengineering: buried coir log and willows | 200 feet | Moderate |
| | Outside | None | N/A | N/A |

[1] Location refers to outside portion of meander or inside, point bar portion of meander

## 4.1 Project Phasing, Responsibilities and Funding

The treatments included in this plan represent the third phase of riparian revegetation and enhancement efforts within the project reach. Treatments are based on observing the effectiveness of treatments implemented in the first two phases of revegetation. These earlier phases were described in Section 2.

As described in Section 7, additional project phases should be based on how the project reach continues to respond to treatments and natural processes, including disturbances. The intent of revegetation efforts is that additional phases will require minimal active revegetation; therefore, additional funding sources for these phases are not identified at this time. Plant community response to revegetation treatments should be monitored frequently, and later project phases should be adjusted based on monitoring results. Table 9 in Section 7 describes the monitoring recommendations for each year and how the results of that monitoring should guide additional revegetation treatments implemented through 2009. Achieving project objectives will likely require activities past 2009. A long-term commitment by the land owner and KRN to maintain the project and monitor progress within the reach will be necessary to achieve project objectives.

In general, the following tasks are necessary to implement this riparian revegetation plan:

- Develop detailed cost estimates for implementing the preferred alternative.
- Refine recommended treatments and treatment quantities included in the preferred alternative as appropriate for project partners' goals and funding limitations.
- Collect additional supporting data and prepare final designs for all stream bank bioengineering, channel and point bar shaping treatments.
- Apply for and obtain necessary permits for implementing project treatments.
- Order materials and retain contractors.
- Implement riparian and floodplain restoration strategies and techniques using a phased approach.
- Monitor effectiveness of treatments and incorporate data into refining additional phases of treatments (Section 7). By integrating monitoring into the implementation of the project and long-term management of the reach the chances of achieving the desired future condition will increase.

The treatments described in Table 3 would be implemented over a one to two year period, with priority given to those described as 'High' priority. The purpose of assigning priorities to the treatments listed in Table 3 is so that treatments can be selected based on available funding and partners' priorities. The project also includes continued monitoring of site response to restoration and revegetation treatments. This monitoring is described in more detail in Section 7. Table 4 lists the specific tasks associated with implementing the project phases.

The entire project reach is located on private land owned by a single landowner. Access to work on the property has been granted by the landowner. There are various routes available to access the proposed treatment sites. Specific access routes used during project implementation will be coordinated with the landowner based on land management activities, such as grazing or haying, occurring at the time.

**Table 4**. Project phases, tasks, responsibilities and approximate hours to complete the project.

| Task | Responsibility | Approximate Hours[1] |
|---|---|---|
| **Floodplain and Riparian Enhancement Phase 1** | | |
| Coordination and project permitting | Kootenai River Network and partners | 20 |
| 2008 Monitoring (July) | Kootenai River Network and partners or contracted service | 16-24 |
| 2008 Final design of bank stabilization treatments and refined based on 2008 summer monitoring | Contracted service | 48 |
| 2008 Project logistics | Contracted service | 40 |
| 2008 Project implementation tasks:<br>Oversight<br>Implementation (revegetation crew)<br>Implementation (equipment contractor) | Contracted services | <br>80<br>240<br>40 |
| **Floodplain and Riparian Enhancement Phase 2** | | |
| 2009 Monitoring (July) | Kootenai River Network and partners or contracted service | 16-24 |
| 2009 Treatment refinement | Kootenai River Network and partners or contracted service | 24-48 |
| 2009 Treatment implementation | Depends on results of project monitoring | 40-80 |

[1]Hours are approximate and based on final design, responsibilities and other factors.

## 4.2 Permits and Regulatory Approvals

The following permits, regulatory approvals, or easements will be necessary to complete the project:

- Section 310 permit issued by Montana Fish, Wildlife and Parks
- Section 404 permit issued by the Army Corps of Engineers
- 318 authorization issued by the Department of Environmental Quality

## 4.3 Project Monitoring

Measures to ensure long-term effectiveness of the project are included in the preferred alternative, such as implementing long-term grazing management, and described in Section 7, Monitoring Plan.

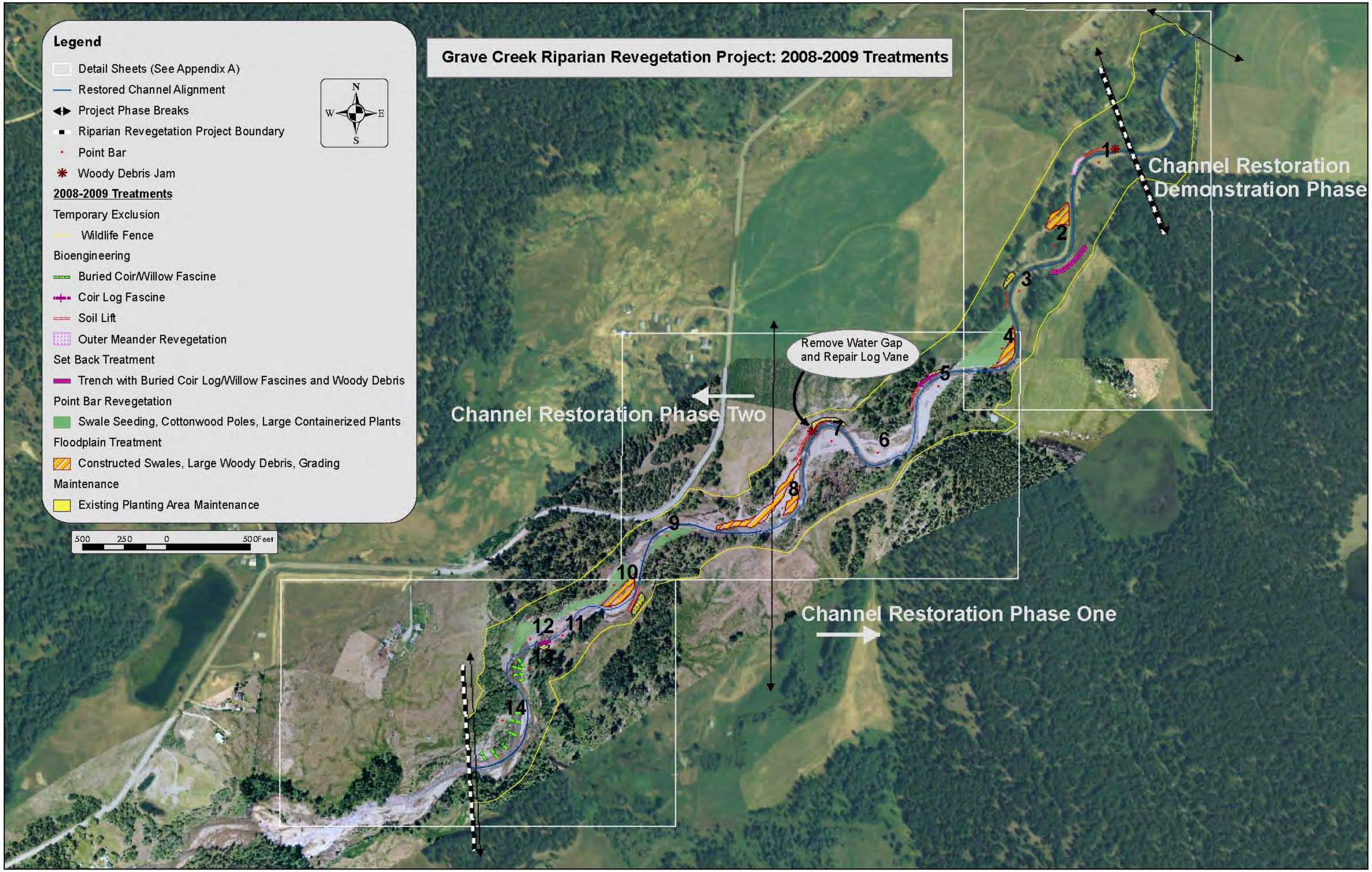


**Figure 15.** Location of riparian and floodplain revegetation treatments in the project reach. Detail sheets are provided in Appendix A.

# Section 5 Project Schedule

Table 5 provides an overview of the proposed project schedule.

**Table 5.** Grave Creek riparian revegetation implementation, monitoring and maintenance schedule.

| Grave Creek Floodplain and Riparian Enhancement Project Schedule | | | | | | |
|---|---|---|---|---|---|---|
| | **2008[2]** | | | **2009[2]** | | |
| **Project Tasks** | Sp | Su | F | Sp | Su | F |
| Permitting and other coordination | | | | | | |
| Monitor earlier phases of treatments[1] | | | | | | |
| Final design of 2008 treatments incorporating data collected in Summer 2008 | | | | | | |
| Coordination and logistics for 2008 treatments | | | | | | |
| Implement 2008 treatments | | | | | | |
| Monitor 2008 treatments and continued monitoring of earlier phases | | | | | | |
| Final design 2009 treatments incorporating data collected in Summer 2009 | | | | | | |
| Coordination and logistics for 2009 treatments | | | | | | |
| Implement 2009 treatments | | | | | | |

[1] Recommended monitoring is described in Section 7.

[2] Actual schedule will depend on project funding.

# Section 6 Supporting Technical Documentation

Supporting technical documentation for the project can be found in the following reports and assessments:

- *Grave Creek Watershed Water Quality and Habitat Restoration Plan and Sediment Total Maximum Daily Loads* (DEQ 2005).
- *Conceptual Designs for Stabilization of Grave Creek near Eureka, Montana (Water Consulting, Inc. 2000).*
- *Grave Creek Phase One Restoration Project Assessment and Final Design Report (Water Consulting, Inc. 2002).*
- *Grave Creek Phase Two Final Design Report (River Design Group, Inc. 2004).*

The TMDL document summarizes numerous data sources for the Grave Creek watershed and provides information on many of the natural features of the project area, in addition to identifying the need for riparian restoration and enhancement.

Figures 1 and 2 show overviews of the project area. Summary information on some of the natural features of the project area is provided below.

## *6.1 Natural Features*

### 6.1.1 Soils

As reported in DEQ 2005, the Kootenai National Forest has characterized soils in the Grave Creek watershed by Land Type Associations (LTAs), which are a composite classification of landform, vegetation, habitat type, geology and soils. The primary LTA in the project reach is the Andic Dystrochrepts (103) or Alluvial terraces. These soils are characterized by gravelly silt loam in the upper surface layer, and gravelly very fine sandy loam in the lower 13 inches of the soil profile. In many areas, soils are generally loamy with moderate to high quantities of boulders, cobbles, and gravels. Deeper soils are typically present in valley bottoms where alluvial sediment and nutrient accumulation and higher biomass production and moisture results in greater rates of decomposition.

### 6.1.2 Vegetation

Vegetation in the project reach is described in Section 2.1. Additional information on vegetation in the watershed can be found in the DEQ TMDL document (2005). This document reports the results of a survey of the watershed completed in 1999 by the Kootenai National Forest, which used a forest and plant type association approach. Table 6 lists the forest associations included in the DEQ 2005 document that are present in the project reach. Other plant community types and successional stages are described in section 2.1.

**Table 6.** Summary of plant associations and Major Forest Type Associations of the Grave Creek watershed that occur in the project reach.

| Forest Type (Association) | Major Trees | Major Natural Disturbance | Comments |
|---|---|---|---|
| Aspen sites | Quaking aspen | Fire | Rare, but located in small areas adjacent to the channel within the project reach |
| Agricultural land (hay, meadows, pasture) | N/A | N/A | All areas adjacent to the project reach are this cover type |
| Subalpine fir—Spruce/Menziesia | Supalpine fir, Engelmann spruce | Insect and disease, windthrow, fire | A riparian form of this community is the likely potential natural community in the project reach |

The DEQ TMDL document (2005) describes how vegetation communities in the Grave Creek watershed have changed in response to natural and human-caused disturbances; in particular those associated with a variety of land uses, including agriculture, grazing and timber harvest. This document reports that the existing lower watershed riparian community is functioning below its historical potential, mainly due to disturbances associated with past and current land uses and the colonization of invasive species on stream banks and the adjacent floodplain.

### 6.1.3 Hydrology

As described in the DEQ TMDL document (2005), the Grave Creek watershed is approximately 74.2 square miles, with elevations ranging from 2,700 feet to 7,500 feet at the watershed divide. Mean annual precipitation is estimated to be over 63 inches at the highest elevations and approximately 23 inches at the confluence. Basin average annual precipitation is estimated to be 47.9 inches with the majority of the precipitation occurring as snow, which melts between April and June on most years. The hydrology of Grave Creek is characterized by snow melt runoff with peak stream flows occurring in May and June and low flows occurring from November through March. Flows occasionally peak during mid-winter rain-on–snow events, which can produce floods of significant magnitude in the Grave Creek watershed. Significant rain-on-snow events occurred in November 2005 and November 2006 in Grave Creek.

Table 7 is reproduced from DEQ 2005, and summarizes select bankfull and flood discharges for the Grave Creek watershed.

**Table 7.** Selected bankfull and flood discharges for Grave Creek (DEQ 2005).

| Return period (years) | Discharge (cfs) |
|---|---|
| QBankfull | 640-680 |
| Q2 | 768 |
| Q10 | 1,368 |
| Q25 | 1,605 |
| Q50 | 1,862 |
| Q100 | 2,047 |

In addition to surface water, groundwater in lower Grave Creek is influenced by glacial outwash and alluvium deposits. These deposits create landforms in the lower Grave Creek watershed, which are capable of absorbing and releasing relatively large volumes of water per unit area. Groundwater exchanges in the lower reaches create gaining, losing, flow-through and parallel-flow reaches (DEQ 2005). Groundwater and surface water interaction also creates hyporheic zones, areas in which groundwater and stream water mix at the channel bed scale.

## 6.2 Applicable Statutes, Rules, Regulations and Standards

There are no applicable statutes, rules, regulations or standards associated with the project. Measures in the TMDL developed for the watershed are voluntary.

# Section 7 Monitoring Plan

This section describes a riparian and floodplain monitoring plan for the Grave Creek riparian revegetation project. This section describes the methods and results for data collected in December 2007, recommendations for additional data collection in 2008 and 2009 and an overall decision making framework for the project. The schedule for collecting monitoring data in association with this project was provided in Table 4 in Section 5.

The purpose of this monitoring plan is to determine effectiveness of revegetation activities already completed, support recommendations for additional revegetation treatments, and determine whether the project has achieved project objectives and is trending towards the desired future condition. This section describes a monitoring framework for collecting and interpreting data within the project reach to guide management and determine the need for additional treatments based on data collected.

To achieve project objectives over time, it will be necessary to observe how the strategies and techniques applied on the ground influence ecological processes in the project reach. For example, by observing and documenting natural recruitment, invasive species colonization and any shifts in species composition that reflect positive changes in hydrology and soil nutrient regimes, it will be possible to determine if the reach is progressing towards the desired future condition. Based on the results, it will be possible to identify, which revegetation actions are appropriate for future phases.

## *7.1 Monitoring Methods*

In December 2007, data were collected on the effectiveness of the following treatments implemented in earlier phases of the project: containerized plantings; vegetated soil lifts; and constructed point bars. Methods for monitoring each of these treatments are described below. Due to the time of year data were collected, it was not possible to accurately evaluate plant survival and growth in any of the treatment areas; however, observations were recorded where quantitative data could not be collected. In addition to determining treatment effectiveness in the project reach, the purpose of these data is to serve as a baseline for future effectiveness monitoring data collection.

### 7.1.1 Containerized Planting Survival Monitoring

To measure effectiveness of containerized plantings installed in 2005, monitoring plots were established in four of the planting areas (Appendix B, Figure B-1). Monitoring plots included the entire planting area at each site. Each plot was marked with rebar, survey cap and flagging on the upstream corner furthest from the channel. Within each monitoring plot, the following data were collected:

- Photograph looking from marked corner downstream across plot;
- Number of live and dead plants;
- Qualitative observations on plant height and vigor;
- Maintenance needs; and if applicable

- Qualitative observations of effectiveness of solarization fabric placed in the plot prior to planting to reduce grass competition.

### 7.1.2 Vegetated Soil Lift Monitoring

To measure effectiveness of vegetated soil lifts installed in 2005 and 2006, five soil lifts were monitored. The locations of monitored soil lifts are shown on Figure B-1 in Appendix B. One soil lift installed in 2005 and four soil lifts installed in 2006 were monitored. Data for each parameter listed below were recorded in five foot increments along the length of each monitored soil lift (Figure 16). At each monitored soil lift the following data were collected:

- Photograph of each structure taken from directly across the channel;
- Observations of rips or tears in fabric;
- Length of toe scour in feet;
- Percent cover of top lift and extending five feet behind lift by native species;
- Percent cover of top lift and extending five feet behind lift by weedy species;
- Number of dead willow stems; and
- Average length of willow-shoot growth in inches.

**Figure 16.** Photograph showing how tape is laid across top layer of soil lift to record data in five-foot increments.

### 7.1.3 Point Bar Monitoring

To measure effectiveness of treatments implemented on point bars in earlier project phases, two constructed point bars were monitored in December, 2007 (Figure B-1, Appendix B). Treatments implemented on point bars included: excavation of swales, placement of woody debris, and planting of containerized shrubs and trees. The purpose of monitoring these areas was to assess the extent and type of vegetation establishment, substrate development and effects of floods on point bar surfaces. At each monitored point bar, two transects were established that extended across the point bar, perpendicular to the channel. The start of each transect was marked with rebar, survey cap, and flagging and recorded using a GPS unit. The azimuths of each transect were also recorded. At each monitored transect, the following data were collected in ten foot by five foot wide intervals along the length of the transect:

- Number of pieces of woody debris greater than 4 inches in diameter;
- Number of pieces of woody debris less than 4 inches in diameter;
- Percent cover of woody debris if sizes are too small to distinguish, or number of pieces too large to count individually (i.e. accumulations of small sticks);
- Percent cover of invasive species;
- Percent cover of grasses and forbs;
- Number of shrubs including notes on whether shrubs were planted or naturally recruited;
- Substrate characterization by placing each interval in a substrate size class (<0.5, 0.5-2, 2-4, 4-6, 6-8 or >8 inches);
- Percent cover of fine sediment deposition;
- Percent cover of organic matter accumulation;
- Relative elevations were recorded along each transect at varying intervals; and
- Photographs at random intervals along each transect.

## *7.2 2007 Monitoring Results*

This section provides a summary of the results of 2007 monitoring data, how data was used to evaluate treatment effectiveness and inform the development of treatments included in this plan. Results are described by type of monitoring below.

### 7.2.1 Containerized Planting Survival Monitoring

The numbers and species installed at each planting site were not recorded at the time of installation; therefore, there is no baseline for the effectiveness data collected in 2007. Table 7 shows the number of live and dead plants for each of the monitoring plots, and percent survival based on these numbers.

**Table 8.** Results of 2007 containerized planting monitoring plot survival.

| Monitoring Plot | # Alive[1] | # Dead[1] | % Survival |
|---|---|---|---|
| Planting Area Monitoring Plot 1 | 46 | 14 | 77% |
| Planting Area Monitoring Plot 2[2] | 46 | 2 | 96% |
| Planting Area Monitoring Plot 3 | 12 | 2 | 86% |
| Planting Area Monitoring Plot 4 | 46 | 8 | 85% |

[1]Numbers represent numbers present at time of 2007 monitoring, not original number planted at each site.

[2]Solarization fabric was installed in this plot.

In general, surviving plants appeared vigorous; however, significant damage from ice and debris to browse protection placed around each plant is likely affecting plant growth. Planting sites were concentrated on outer meander bends, as stabilization of these areas is a high priority for long-term channel stability. Most planting sites showed significant amounts of lateral scour which resulted in the loss of up to one-third of the plants originally installed at each site. In addition, most plants have only grown as tall as the browse protectors, with all growth above this protection browsed.

One of the monitoring plots, 'Planting Area Monitoring Plot 2', was treated with solarization fabric prior to planting. Plants in this plot had a higher relative survival rate and appeared to be taller compared with plants in all other plots. Solarization fabric was very effective at killing undesirable grasses in planting sites where it was used (Figure 17).

Monitoring data and observations made of planting sites resulted in the following recommendations and treatments included in this plan:

- Implement reach wide grazing and browse protection measures for a minimum of five years.
- Remove all browse protection measures and solarization fabric, except immediately around plants, in planting sites to reduce long term damage to plants.
- Due to how effectively solarization fabric has suppressed grasses, seed treated areas at time of removal with desired forb, shrub and tree species to encourage desired plant community establishment and prevent colonization by invasive species.
- Due to level of maintenance required and significant browse pressure in the reach, limit further containerized plantings of one gallon or smaller container sizes until browse is controlled.
- Both containerized planting and solarization treatments are viable options for future project phases if determined necessary through future monitoring.

**Figure 17.** Solarization fabric treatment showing heat killed grasses under treated area.

### 7.2.2 Vegetated Soil Lift Monitoring

Results of monitoring data for the five soil lifts monitored in December 2007 are shown in Table B-2 in Appendix B. The results of this monitoring indicate that soil lifts installed in the project reach are effectively creating areas directly along the channel where woody vegetation can establish; however, monitoring also indicates that various factors are keeping the structures from functioning as effectively as they could. Results of monitoring indicate:

- Significant browse of willow cuttings and rooted plant materials is occurring at all sites (Figure 18);
- Minor rips and tears, assumed to be the result of ice formation and break up, are present on soil lifts in the upstream portion of the project reach;
- Outer coir fabric shows little sign of degradation on lifts installed in 2006 and only minimal degradation for lifts installed in 2005;
- Complete toe scour has occurred on lifts installed in 2005 (Figure 19);
- No toe scour has occurred on lifts installed in 2006;
- Percent cover by desirable forbs and grasses, assumed to be the species seeded at the time of installation, is much higher than percent cover of invasive species on lifts installed in 2005. Minimal herbaceous cover is present on lifts installed in 2006;
- The number of obvious dead willow stems was much greater on the 2005 soil lifts compared with 2006 lifts, and some lifts had numerous stems that appeared to be dead but had significant amounts of new growth (Figure 19); and
- Average shoot growth on surviving willows is between three and 24 inches and average growth was higher on lifts where woody debris was placed as a browse barrier.

**Figure 18.** Photograph of soil lift 2 illustrating log barrier placed behind the structure to prevent browse. Willows are surviving but heavily browsed down to the height of the barrier.

The most notable results of monitoring were the difference between soil lifts installed in 2005 compared with those installed in 2006. Soil lifts installed in 2006 were improved by implementing the following changes:

- Construction of a log and rock toe that extended into the active channel (Figure 16);
- Placement of soil lifts between engineered log jams;
- Off-setting the lower lift from the constructed toe approximately one to two feet to allow room for minor scour to occur (Figure 16);
- Use of containerized, rooted plants in addition to dormant willow cuttings; and
- Placement of coir wattles (four pound density logs constructed of coir fibers) to form the front face of 2006 lifts, with the intent of retaining moisture and resisting rips and tears from ice moving through the reach.

**Figure 19.** Toe scour and slumping of soil lift installed in 2005, but new willow shoot growth on decadent stems and good herbaceous cover of seeded species on top lift.

Monitoring results and observations of vegetated soil lifts resulted in the following recommendations and treatments included in this plan:

- Vegetated soil lifts, constructed with modifications made in 2006, are a preferred treatment for establishing woody vegetation in high priority outer banks in the project reach;
- The amount of browse on willows in all structures reinforces the need to implement reach wide grazing and browse protection measures for a minimum of five years;
- No maintenance of existing soil lifts is necessary; and
- The use of rooted, containerized plants should be restricted to between the bottom and top lifts and not placed in the back fill of the top lift due to risk of being exposed and desiccated.

### 7.2.3 Point Bar Monitoring

Results of monitoring data for the two point bars monitored in December 2007 are shown in Table C-3 in Appendix C. The results of this monitoring indicate that constructed point bars show evidence that the ecological processes necessary for desired pioneer plants to colonize and plant community succession to occur are present, but to varying degrees. It is unclear at this point how effective these treatments are with respect to stimulating plant community succession. Results of monitoring indicate:

- Constructed swales vary significantly in hydroperiod and ability to retain moisture during base flows. Primary factors appear to be: location on the point bar, with upstream point bars appearing to have a shorter hydroperiod; distance from the channel, with swales closer to the channel having a longer hydroperiod; and elevation relative to baseflows, with swales with bottom elevations within one foot of baseflow elevations having a longer hydroperiod.
- Point bars are accumulating variable amounts of flood and wind distributed organic matter.
- Large woody debris placed on point bars promotes floodplain scour and sediment deposition (Figure 19).
- Large woody debris placed on point bars is creating microsites where woody vegetation establishes (Figure 20) and shrub densities may be greater where woody debris (including wood greater than 4 inches in diameter and less than four inches in diameter and accumulations of small pieces) is higher.
- Cottonwood recruitment may be greater in areas where sand deposition occurs.
- At both point bars, swale bottoms were rarely at or below baseflow elevations. Shrub survival in swales appeared high up to one and a half feet above baseflow elevation.
- Evidence of scour and deposition is present more than two feet above baseflow elevation.
- Cottonwood recruitment was much higher at point bar 13, although floodplain elevations were not that different relative to baseflow levels compared with point bar 4, where no cottonwood recruitment was observed.
- Browse was observed on all naturally recruited and planted woody vegetation.

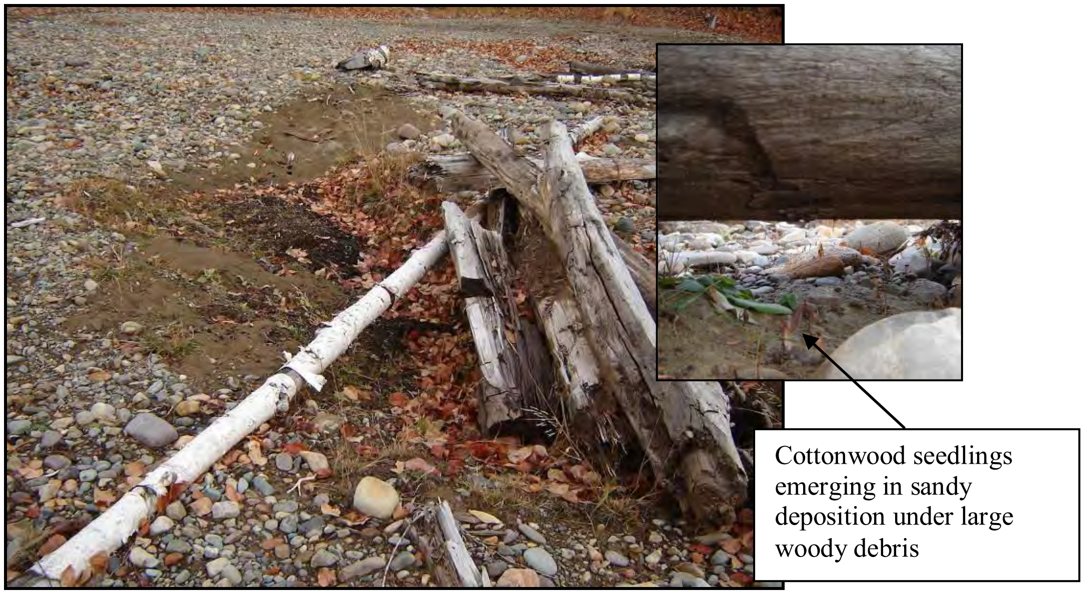


**Figure 20.** Photograph of constructed swale featuring showing substrate variation and organic matter accumulation around woody debris. Further monitoring will indicate if seedling survival in protected areas, such as around woody debris, will be higher than exposed areas.

Monitoring results and observations made of point bars resulted in the following recommendations and treatments included in this plan:

- Large woody debris and floodplain swales should be incorporated into any floodplain grading work that is implemented. Large wood appears to provide the most significant refugia for naturally recruited cottonwoods.
- Swale construction should be deep enough to intercept at least the base flow water surface elevation.
- Constructed swales should be concentrated primarily at the downstream end of point bars.
- Although signs of plant community succession are present, which is necessary for long term stability, maintaining floodplain connectivity in the interim is necessary to ensure patches of recruited shrubs and trees have conditions appropriate for growth and survival. Maintaining connectivity requires a certain degree of floodplain stability, which led to proposing many of the point bar revegetation and floodplain grading treatments in this plan.

## 7.3 2008 Monitoring Recommendations

As shown in Table 4 in Section 5, continued monitoring of the project reach is necessary to determine if the project is achieving project objectives and trending towards a desired future condition and if additional treatments are appropriate. This section provides recommendations on continuing monitoring of the project reach.

The following monitoring should be completed in summer 2008:

- Repeat containerized plant survival monitoring during the growing season to more accurately determine plant survival and condition;
- Monitor weed infestations;
- Repeat vegetated soil lift willow survival and growth monitoring; and
- Repeat point bar monitoring to determine natural recruitment and shrub survival patterns and better characterize point bar hydroperiods to refine treatment locations.

The following monitoring should be completed in fall or winter 2008:

- As-built documentation of any treatments implemented in fall 2008 to be used as baseline for future monitoring data collection efforts.

The following monitoring should be completed in summer 2009:

- Monitor weed infestations;
- Repeat vegetated soil lift willow survival and growth monitoring to determine if supplemental cuttings or plantings are warranted, including a sub-set of any soil lifts constructed in 2008;
- Repeat point bar monitoring to determine natural recruitment and shrub survival patterns; and
- Monitoring of other treatments implemented in 2008, including willow survival and scour of point bar bioengineering and release of shrubs showing arrested growth form or recruitment of young age class shrubs outside of point bar areas.

## 7.4 Decision Making Framework

This section provides an example of how monitoring data should be integrated into a decision making framework for the project reach. Table 9 describes how monitoring of each treatment described above can be used to determine effectiveness, whether project objectives have been achieved or if additional treatments are appropriate.

**Table 9.** Overview of project implementation decision framework incorporating monitoring results.

| Treatment | Monitoring and Design 2008 | 2008 Treatments (Revegetation Phase One) | Monitoring 2009 | 2009 Treatments (Revegetation Phase Two) | Monitoring 2010 |
|---|---|---|---|---|---|
| **Temporary exclusion of cattle and deer** | Potentially set up permanent monitoring plots to monitor release of existing shrubs once fencing is in place. Determine best methods for fencing and fence location. | Install wildlife fencing around entire project reach. | Monitor release of shrubs and trees within fenced area. | No additional treatments. Fence maintenance as needed. Fence should remain in place for a minimum of five years and removal should be based on monitoring of vegetation community development. | Continue to monitor growth of released shrubs and development of young age classes. |
| **Bioengineering: Soil lifts and coir logs** | Monitor existing soil lifts to refine 2008 treatments if necessary. Observe proposed treatment sites to verify site conditions. Collect additional data as necessary. | Construct soil lifts at Point Bars 1, 3, 5, 7 and 10. Construct coir logs at Point Bar 5 and 12. | Monitor bioengineering using similar methods to 2007 methods. Include a sub set of 2008 bioengineering in monitoring. | No additional treatments anticipated. Maintenance of existing bioengineering structures may be necessary. | Continue to monitor effectiveness of bioengineering treatments and implement maintenance as needed. |
| **Bioengineering: Buried coir log and willow fascines** | Observe conditions at Point Bars 13 and 14 to finalize placement of treatment within these sites. | Install buried coir logs and willow fascines at Point Bars 13 and 14. | Monitor treatment for willow growth, scour and natural recruitment. | Consider repeating treatment in other areas if monitoring shows that treatment is effective. | Monitor treatment for willow growth, scour and natural recruitment. |
| **Outer meander planting sites** | Verify site conditions in proposed planting areas to confirm species mix and other potential site prep needs such as weed control. | Implement outer meander planting at Point Bar 1. | Monitor for survival and maintenance needs. Apply supplemental irrigation if necessary. | Implement additional plantings if monitoring shows high survival and channel stability at these sties. | Continue to monitor for survival and maintenance needs. |
| **Point bar revegetation** | Repeat point bar monitoring to determine natural recruitment rates and survival of plants on point bars, which was not possible in December 2007. Select specific locations within point bars to be treated based on mid-late summer conditions in constructed swales on these sites. | Implement revegetation in select swales in Point Bars 4, 9, 10, and 12. | Conduct point bar monitoring as established in December 2007. Also monitor seed establishment, pole cottonwood survival, and natural recruitment in treated areas. | Install 16 gallon grow bags if monitoring shows poor natural recruitment at the sites. Consider repeating other treatments implemented in 2008 in swales on additional point bars if 2009 monitoring shows the treatment is effective and natural recruitment is low. | Conduct point bar monitoring as established in December 2007. |
| **Floodplain treatment** | Finalize point bar floodplain treatment locations. | Implement point bar grading at Point Bars 4, 8, and 10. Implement floodplain treatments at Point Bars 2, 8 and 10. | Conduct point bar monitoring at point bar 10 to determine if treatments resulted in increased natural recruitment. | No additional treatments anticipated. Allow natural processes to scour and create similar conditions over time. | Conduct point bar monitoring as established in December 2007 including Point Bar 10. |
| **Set back stream bank vegetation** | Complete final design of set back stream bank treatment. | Construct set back stream bank treatment at Point Bar 2. | Monitor growth of willows in treatment, supplemental irrigation may be necessary. | No additional treatments anticipated. Allow lateral erosion to continue and plants to establish in set back trench. | Continue to monitor plant growth and supplemental irrigation needs. |
| **Existing planting site maintenance** | Implement maintenance activities at all containerized planting sites in summer 2008 if possible. Repeat December 2007 monitoring for survival and plant condition, which will be more accurate during the growing season | Continue maintenance of sites as necessary. Implement seeding at solarization treated sites. | Continue to monitor sites for survival and maintenance needs. Monitor seed establishment in seeded areas. | No additional treatments anticipated. | Continue to monitor sites for survival and maintenance needs. Implement maintenance where necessary |

# Section 8 References


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## List of Appendices

## **Appendix A:** Revegetation Treatment Descriptions

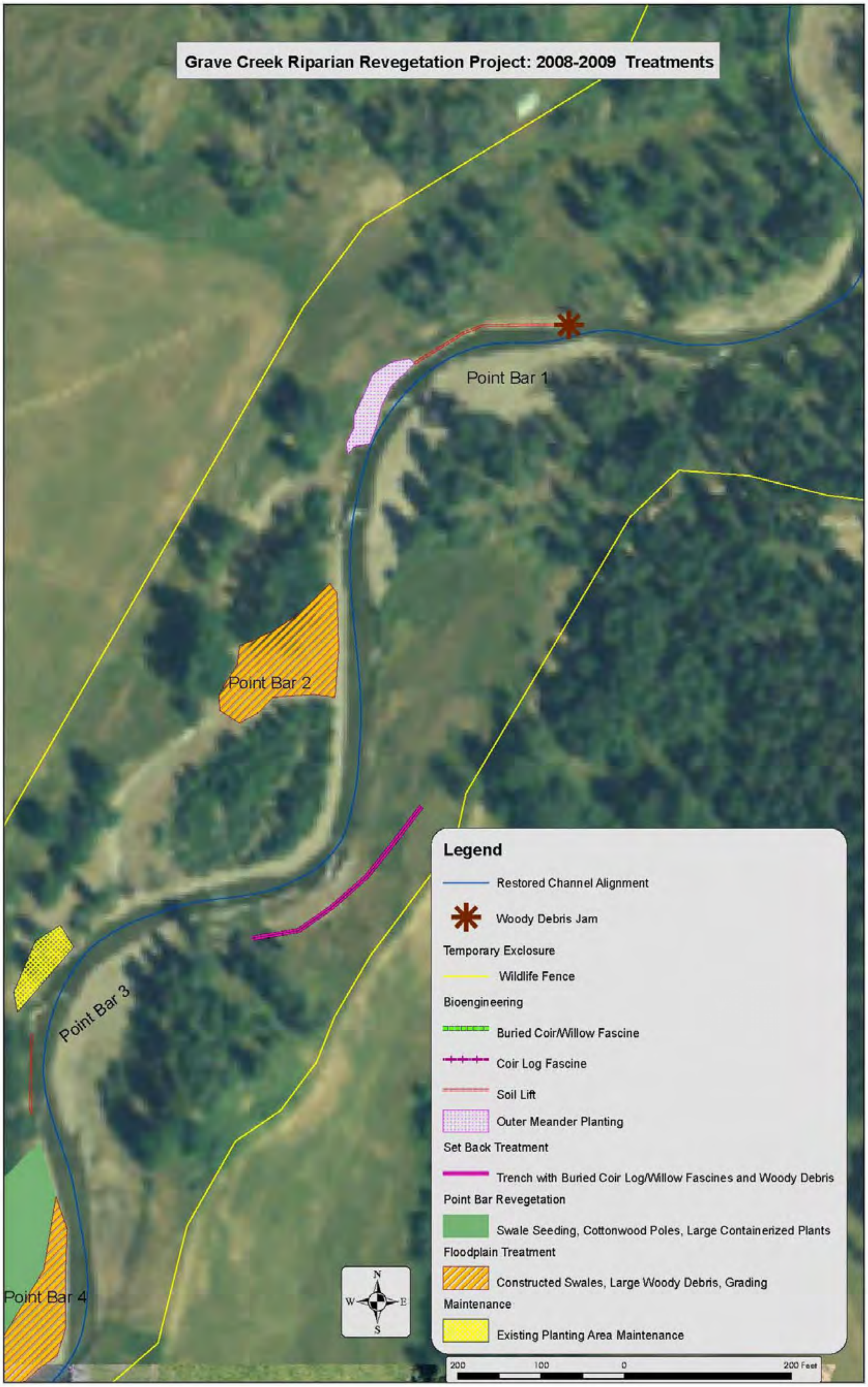


**Figure A-1.** Grave Creek riparian revegetation treatments, point bars 1-4.

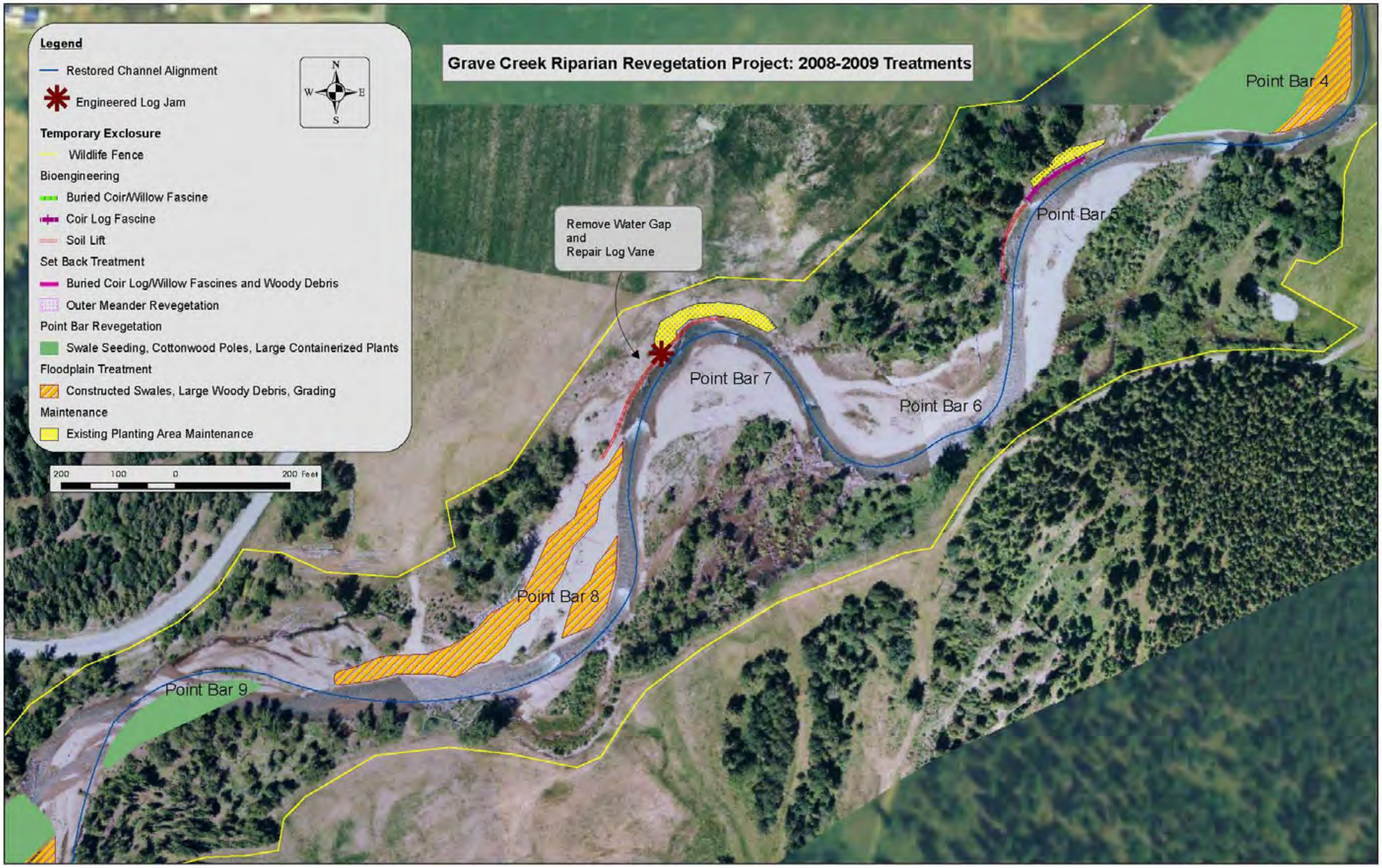


**Figure A-2.** Grave Creek riparian revegetation 2008-2009 treatments for point bars 4-9.

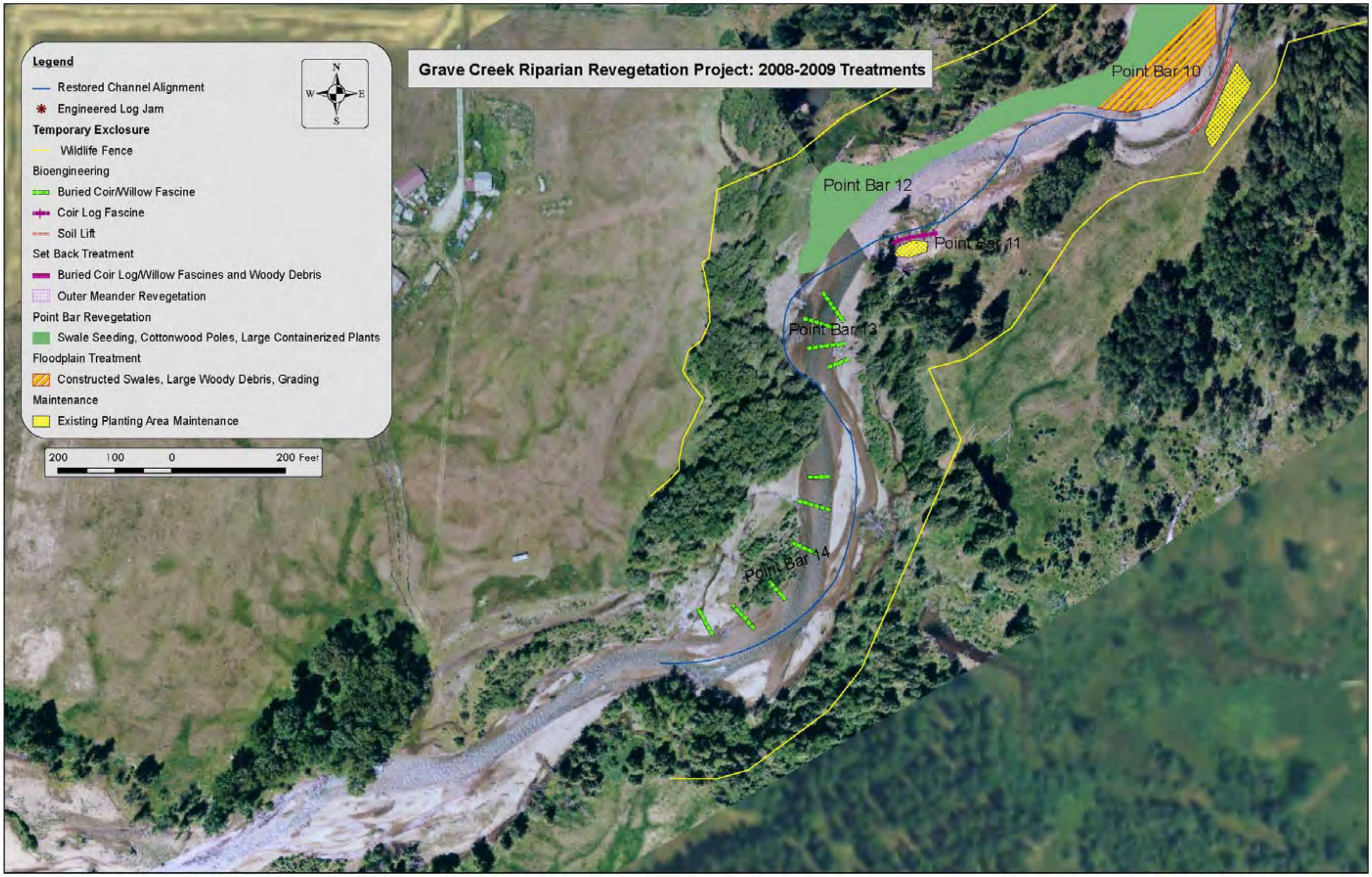


**Figure A-3.** Grave Creek riparian revegetation 2008-2009 treatments for point bars 10-14.

## Temporary Browse Exclusion

***Wildlife Fencing Option:*** This treatment consists of installing new fencing or enhancing the existing fencing to exclude the entire project reach from both livestock and wildlife browse for a minimum of five years. Electric wildlife fencing has proven successful at excluding deer, elk and other wildlife. Electric fencing may not be a viable option for excluding use of the project reach for several reasons; however, it is described in this document as a preferred option. The exact locations and methods of exclusion will need to be further addressed priori to implementing this revegetation plan.

ElectroBraid is a brand of electric fence that is durable and has been proven to be an effective deer barrier (Figure A-4). Fencing can be installed using posts, strapped to existing trees, or tied into the existing fence line. A 2002 study conducted by the USDA National Wildlife Center found ElectroBraid to be a 99% effective deer barrier (USDA 2002). This treatment will not only protect the containerized plants installed in 2005, but also allow natural regeneration of woody species to occur throughout the entire riparian area. Maintenance for this type of fence may include: checking the energizer and the fence voltage on a regular schedule; walking the fence line and visually inspecting for possible damage or shifted brace posts; cutting weeds and grass (generally once per year); and removing fallen branches.

**Figure A-4.** Photograph of ElectroBraid electric wildlife fencing.

## Bioengineering Treatments

Bioengineering treatments are used to encourage woody vegetation establishment in high priority areas, such as at the land/water interface along outer meander bends and on newly established or constructed point bars. In some areas where bioengineering treatments are proposed, minor repairs to channel habitat and grade control structures or construction of new woody debris jam habitat structures will also be done to provide stable areas for vegetation incorporated into bioengineering structures to establish.

***Vegetated soil lifts:*** Vegetated soil lifts are a revegetation and bank construction technique that combines layers of dormant willow cuttings with fabric-wrapped soil to revegetate and stabilize stream banks (Figures A-5 and A- 6). Soil is wrapped within two layers of biodegradable coconut fiber (coir) fabric to hold the soil in place while vegetation becomes established. Soil lifts, combined with a bankfull bench, will result in near bank areas where native woody vegetation can become established. To increase success, the face of the bottom soil lift should be reinforced with a coir wattle to help maintain the lift shape, keep fine soil particles from filtering out through the lift face, and maintain surface tension. The uppermost soil lift should be filled with salvaged sod or seeded with the seed mix developed for the reach. These structures should be tied into bank structures such as engineered log jams. Within the project reach, five outer meander bends have been identified for vegetated soil lift construction.

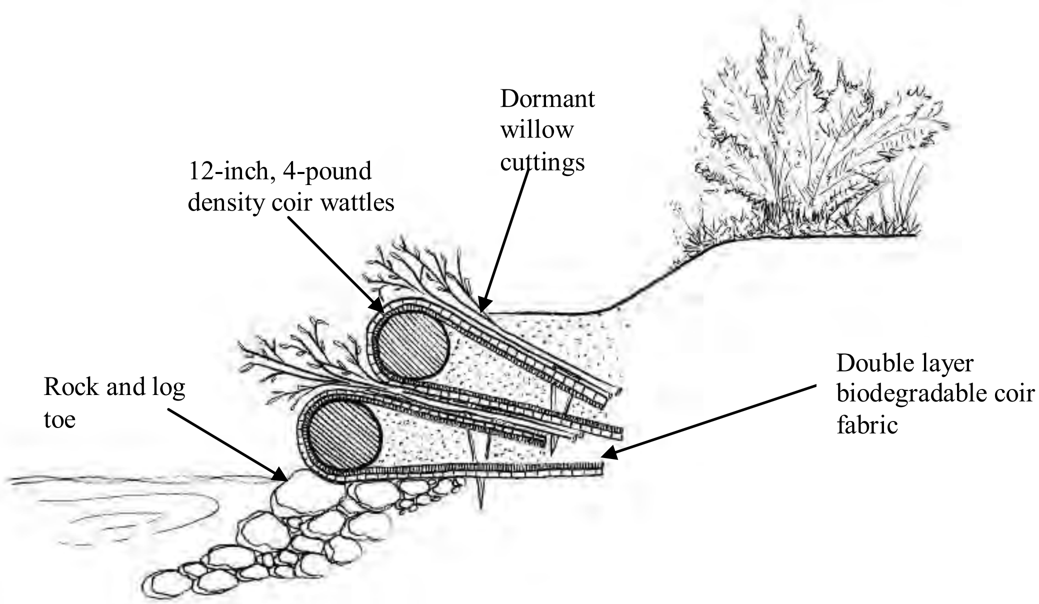


**Figure A-5.** Profile view drawing of vegetated soil lift treatment.

**Figure A-6.** Photograph showing vegetated soil lift five months after construction.

***Coir log fascines:*** This technique includes placement of coir logs, combined with dormant willow cuttings, at the toe of stream banks along selected outer meander bends. The purpose of this treatment is to establish woody vegetation along the channel in areas where scour is compromising the toe of banks, but vegetation on the bank itself is establishing; such as areas where containerized plants were installed. Coir log fascines are pre-constructed bioengineering components designed for use at the land/water interface (Figures A-7 and A-8). Coir log fascines have a natural fiber netting that contains high-density coir (coconut fiber) bales. Coir is used for bioengineering because it stores water for long periods, and its durable fibers trap sediment and mimic soil matrices formed by living roots. Coir fibers biodegrade over approximately five to seven years, thus providing a stable growing medium while native riparian plants establish. This treatment is proposed for two sites in the project reach, where the toe of the stream bank is scouring and compromising shrubs and trees planted in 2005. The coir log fascine should lessen the scouring action and allow time for woody vegetation in the planting area to establish and stabilize the bank over the long-term.

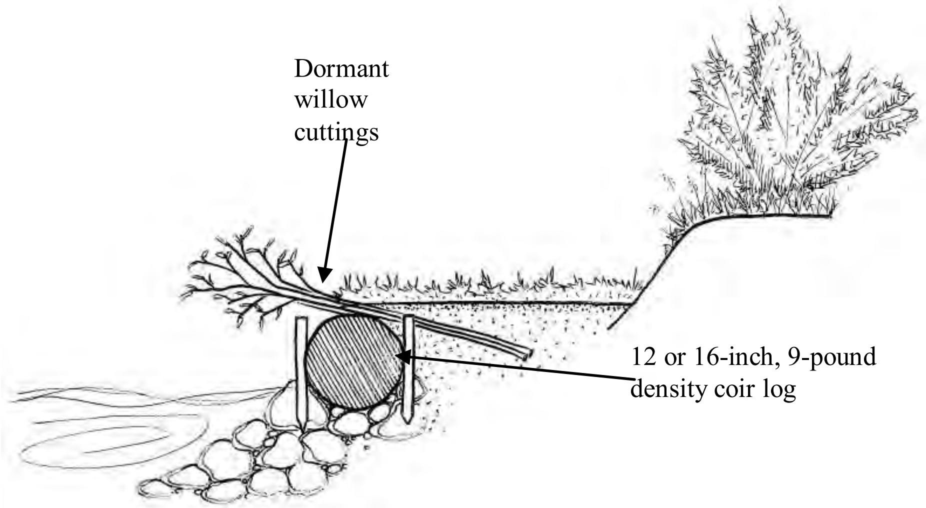


**Figure A-7.** Profile view drawing of coir log treatment.

**Figure A-8.** Photograph of coir log immediately after installation and with willow growth after three years (inset).

***Buried Coir Log Fascines:*** This treatment consists of a digging a narrow trench (approximately 12-16 inches wide and 16 inches deep) and placing coir logs and dormant willow cuttings into the trench. In lieu of individual dormant willow cuttings, willow fascines (bundles) can also be incorporated into this treatment. Willow fascines consist of willow cuttings tied together in bundles and bundles tied together end to end to form linear rows of desired lengths (Figure A-9). This treatment is proposed for use in constructed point bars to promote establishment of cottonwoods and willows. Buried coir log fascines are constructed perpendicular to the channel to encourage point bar stability. To further anchor the treatment, coir logs and willow bundles in each trench are laced together and the ends tied to rope buried three feet below the trench. Each linked length of coir logs is between 30 and 50 feet. This treatment will be used on point bars 13 and 14.


**Figure A-9.** Photograph of buried willow fascine treatment.

## Outer Meander Planting

This treatment includes planting a very small number of containerized shrubs and trees behind soil lifts installed in 2005 to create diverse riparian shrub communities and promote long term stability. These areas have a reduced risk of erosion due to the presence of bioengineering and other bank stabilization structures. Table A-1 provides a recommended species list for containerized shrub planting areas.

**Table A-1.** Recommended plant species mix for Grave Creek outer meander planting areas.

| Genus | Species | Common Name | Size | Percent of Mix |
|---|---|---|---|---|
| *Alnus* | *incana* | Mountain alder | 10x10x36 cm | 20% |
| *Cornus* | *stolonifera* | Red-osier dogwood | 10x10x36 cm | 10% |
| *Crataegus* | *douglasii* | Douglas hawthorne | 10x10x36 cm | 15% |
| *Populus* | *trichocarpa* | Black cottonwood | 10x10x36 cm | 15% |
| *Prunus* | *virginiana* | Common chokecherry | 10x10x36 cm | 15% |
| *Salix* | *bebbiana* | Bebb willow | 10x10x36 cm | 5% |
| *Salix* | *drummondiana* | Drummond's willow | 10x10x36 cm | 10% |
| *Salix* | *exigua* | Sandbar willow | 10x10x36 cm | 10% |

## Point Bar Revegetation

Vegetation establishment on point bars is necessary to create long-term stability within the reach and reduce the risk of accelerated erosion. Only small portions of the total point bar area needs to support woody plant communities to provide overall floodplain stability. This will ensure that as the channel continues to adjust and migrate in a downstream direction, there are vegetated islands within the point bar to provide stable points and colonize areas as they transition from newly deposited, pioneer bars to established floodplain areas. As this vegetation matures, it will transition to cottonwood or conifer dominated riparian areas that will provide long-term large woody debris inputs to the stream system. Three revegetation treatments are proposed for point bar revegetation: seeding, pole cottonwoods and large sized containerized shrubs. These treatments will be used in select swale areas within point bars 4, 9, 10 and 12.

***Swale Seeding:*** This treatment consists of broadcast seeding in constructed swales that have conditions favorable for seedling development (Figure A-10). This treatment will accelerate the natural process of vegetation development in swales. Table A-2 provides the recommended seed mix for the reach.

**Figure A-10.** Photograph of constructed swale with conditions, such as late season moisture retention and large woody debris creating microsites, appropriate for supporting woody vegetation establishment.

**Table A-2.** Recommended seed mix for Grave Creek point bar swale seeding.

| Genus | Species | Common Name | Percent of Mix |
|---|---|---|---|
| **Shrubs and Trees** | | | |
| *Alnus* | *incana* | Mountain alder | 25% |
| *Salix* | *drummondiana* | Drummond's willow | 25% |
| *Salix* | *exigua* | Sandbar willow | 50% |
| **Graminoids** | | | |
| *Agropyron* | *riparium* | Stream bank wheatgrass | 15% |
| *Carex* | *nebrascensis* | Nebraska sedge | 10% |
| *Carex* | *stipata* | Sawbeak sedge | 10% |
| *Deschampsia* | *cespitosa* | Tufted hairgrass | 20% |
| *Elymus* | *trachycaulus* | Slender wheatgrass | 15% |
| *Juncus* | *balticus* | Baltic rush | 10% |
| *Juncus* | *tenuis* | Poverty rush | 10% |
| *Achillea* | *millefolium* | Common yarrow | 10% |

***Cottonwood Poles**:* This treatment consists of installing small numbers of large diameter (4 to 8 inches) pole cottonwood cuttings in selected swale areas. Due to their length, pole cuttings provide an effective means to reach saturated soils and establish a high concentration of roots for that portion of the stem that does reach the water table or the capillary fringe of the water table. Cottonwood poles will be installed in select swale areas. Because of their length, poles can be installed in swales that are higher in elevation on the point bar relative to baseflows.

***Large Containerized Plant Material**:* This treatment consists of installing small numbers of shrubs grown in 16 gallon grow bags. This sized plant material will have a well developed root system and large diameter stems better able to withstand browse pressure and provide immediate root stability to the site (Figure A-11). This treatment will be concentrated in the swales connecting point bars 10 and 12. Willow, cottonwood, and alder are the desired species for use in these areas, however, exact species will depend on plant availability.

**Figure A-11.** Photograph of large containerized plant material with well developed root system and large diameter stems.

## Floodplain Treatment

The floodplain treatment consists of: constructed swales, large woody debris placement, and point bar grading. Floodplain microtopography will be created in areas where woody vegetation establishment is desired but substrate or microtopographic diversity precludes its establishment. Creating diverse microtopography on a site will provide a variety of niches for native woody vegetation by creating surfaces of varying depth and thus varying proximity to groundwater. This floodplain treatment will occur in small areas of point bars 2, 4, 8 and 10.

***Constructed Swales**:* This treatment includes constructing depressions perpendicular to the channel, which minimizes the risk of depressions capturing and transporting flood waters (Figure A-12). Swales should be excavated to a depth of one to three feet depending on the point bar elevation relative to channel features and should be approximately 10 feet wide and 20 feet long. A minimum buffer of 20 feet will be left between the edge of the channel and excavated swales. Material excavated for swale construction can be spread throughout the area to further enhance microtopography. Large woody debris will be placed along created swales, and/or partially buried adjacent to these swales to provide additional shade, create microsites, retain moisture and stimulate biological development within the soil. Adding roughness to floodplain surfaces will increase the ability of these surfaces to trap cottonwood and willow seed that naturally colonize exposed alluvial material.

**Figure A-12.** Photograph of constructed floodplain swale five months after construction.

***Large Woody Debris**:* This treatment includes placing larger diameter wood (10 inches or greater) throughout selected point bars that lack complexity. Larger pieces of wood increase surface roughness on bare floodplain surfaces which results in differential flow resistance that can cause scour during floods. This scour further increases topographic diversity and microsites where plants can become established. Like constructed swales, these scour areas will contribute to organic matter retention in the system. Larger diameter wood can be gathered and placed using an excavator, while smaller debris can be placed by hand. Smaller diameter woody debris can be placed in piles on uniform floodplain surfaces to trap sediments and entrain materials carried by flood waters. This treatment will be implemented to the extent that large woody debris is available.

***Grading:*** This treatment includes minor grading of point bars 4, 8 and 10, where channel incision has resulted in a loss of connectivity with the floodplain (Figure A- 13). Floodplain grading will consists of removal of floodplain material or re-configuring of floodplain materials with the purpose of lowering select areas of the point bar to allow overbank flows to access a larger surface area. All material removed from point bar areas will be deposited in an established waste site on the landowner's property.

**Figure A- 13.** Photograph of steep bank on point bar 10 and flat, uniform floodplain surface.

## Set Back Stream Bank Vegetation

***Set back vegetated trench:*** This treatment consists of digging a 10-foot wide trench parallel to the channel approximately 20 feet away from the existing stream bank. The trench is then filled with woody debris, coir logs, and willow bundles to create a dense hedge of vegetation set back from the existing channel. The excavated fill is then replaced, leaving only the tips of the willow bundles exposed. The coir logs and woody debris will create stability and promote establishment of the willow cuttings by retaining moisture in the rooting zone and promoting soil development. The placement of this trench is in anticipation of continued lateral channel migration at the site. Because it appears the channel is attempting to increase its radius of curvature at this site via lateral channel erosion it would not be desirable to construct vegetation treatments directly along the bank to reduce erosion rates (John Muhlfeld, personal communication, 2008). The intent of this treatment is to create a stable hedge of desired vegetation for the channel to migrate into. The trench would extend between 200 and 400 feet along the existing channel. Figure A -14 shows the area chosen for the set back treatment. The trench location is shown on Figure A-1.

**Figure A-14.** Photograph showing area selected for set back treatment. Inset photograph shows vertically eroding bank.

## Existing Planting Area Maintenance

Existing planting areas have been in place for more than two years and need maintenance to promote the continued growth and survival of planted shrubs and trees. Maintenance of these sites includes removal of existing browse protection and solarization fabric.

***Browse Protection:*** Browse protectors that have fallen over or are no longer protecting the plant should be repaired, replaced, or re-installed so that they serve their intended purpose. Browse protectors should be removed from plants that have grown too large for the protector to be effective. Browse protector maintenance should be done with care so as to not damage the plant during removal. Plants that have reached the height of the browse protector should be protected by stacking two browse protectors together so as to create taller and wider browse protection. Browse protectors should be removed from planting areas along banks affected by ice flows in the winter and spring (Figure A-15).

**Figure A-15.** Photograph showing browse protector damaged by ice. Willow has survived, but is browsed and constrained by the browse protector.

***Solarization:*** Solarization fabric has proven effective in killing undesired grass and weed species. Figure A-16 shows bare soil after two years under the fabric. Solarization fabric should be removed from the entire plot, except immediately around planted shrubs, without disturbing the containerized plantings. The bare soil can then be seeded with a native grass and forb mix to further enhance plant community structure and prevent weed species colonization. An example seed mix is shown in Table A-2.


**Figure A-16.** Bare soil under solarization fabric after three years compared with grass and weed cover just beyond the fabric.

## **Appendix B:** Monitoring Overview and Results

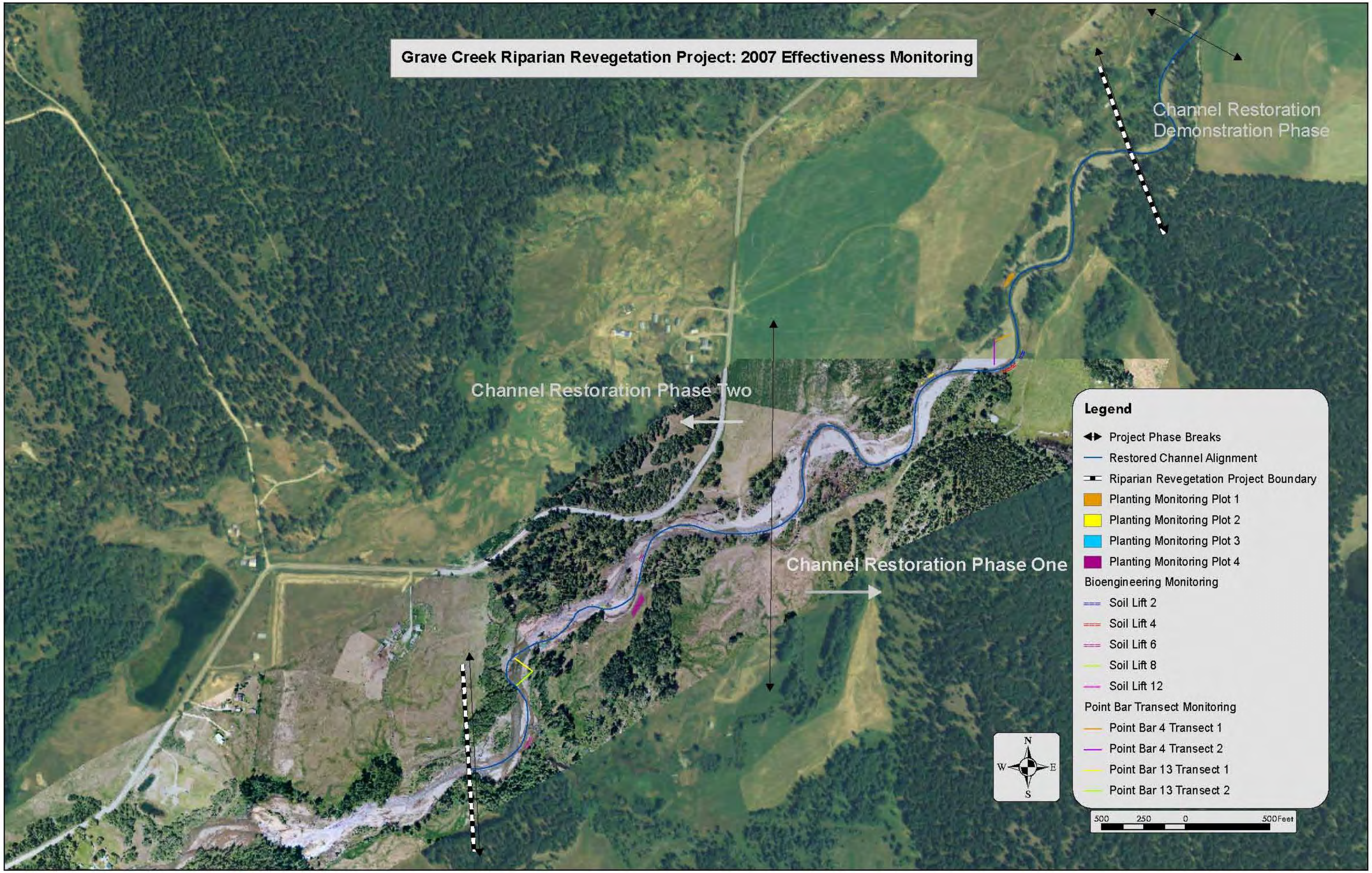


**Figure B-1.** Locations of monitoring data collected in the Grave Creek project reach in December 2007.

**Table B-1.** Containerized planting monitoring plot survival data.

| Monitoring Plot | # Alive | # Dead | % survival | Notes | Photograph |
|---|---|---|---|---|---|
| Planting Area Monitoring Plot 1 | 46 | 14 | 77% | Average plant heights are 3-4 feet. For spruce, average heights are 2 feet. Some plants in this plot may be under ice and therefore not counted during this monitoring. |  |
| Planting Area Monitoring Plot 2 | 46 | 2 | 96% | This planting plot includes solarization fabric. Average plant heights are 3-6 feet, but most are restricted to 4 feet (top of browse protection) due to browse. For spruce, average heights are 2.5 - 3 feet. This plot includes only those plants within area with fabric. There are other plants upstream of fabric. |  |
| Planting Area Monitoring Plot 3 | 12 | 2 | 86% | Average plant heights are 3 feet. For spruce, average heights are 1.5 -2 feet. |  |
| Planting Area Monitoring Plot 4 | 46 | 8 | 85% | Shrubs 2-3 feet. Spruce 1.5-2 feet. |  |

**Table B- 2.** Summary of results of December 2007 bioengineering monitoring data.

| Soil lift ID | Soil lift layer | Monitoring Parameter | Distance (ft) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | 50-55 | 55-60 | 60-65 | 65-70 | 70-75 | 75-80 |
| SL-2 2005 | 1 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| | 1 above | toe scour (ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | |
| | 1 above | % cover seeded | 60 | 40 | 30 | 30 | 20 | 15 | 20 | 10 | 5 | | | | | | | |
| | 1 above | % cover weeds | 5 | 5 | 25 | 5 | <5 | 1 | 5 | 1 | 1 | | | | | | | |
| | 1 above | dead stems | 2 | 1 | 5 | 1 | 0 | 2 | 2 | 0 | 4 | | | | | | | |
| | 1 above | avg. shoot height (in) | 3 | 12 | 10 | 8 | 12 | 6 | 8 | 8 | 6 | | | | | | | |
| SL-4 2005 | 1 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1 above | toe scour (ft) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 0 | 0 | 0 |
| | 1 above | % cover seeded | 80 | 100 | 75 | 80 | 80 | 85 | 50 | 100 | 100 | 50 | 40 | 40 | 40 | 50 | 60 | 50 |
| | 1 above | % cover weeds | 1 | 1 | 5 | 1 | 1 | 1 | 5 | 1 | 1 | 1 | 1 | 5 | 1 | 1 | 5 | 1 |
| | 1 above | dead stems | 4 | 13 | 9 | 5 | 4 | 3 | 4 | 1 | 1 | 3 | 5 | 5 | 7 | 7 | 0 | 0 |
| | 1 above | avg. shoot height (in) | 2 | 12 | 18 | 12 | 18 | 24 | 18 | 12 | 12 | 24 | 24 | 12 | 18 | 12 | 24 | 24 |
| SL-6 2006 | 1 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 1 above | toe scour (ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 1 above | % cover seeded | 20 | 15 | 10 | 40 | 20 | 20 | 10 | | | | | | | | | |
| | 1 above | % cover weeds | 5 | 10 | 5 | 5 | 5 | 5 | 0 | | | | | | | | | |
| | 1 above | dead stems | 1 | 2 | 0 | 1 | 5 | 6 | 12 | | | | | | | | | |
| | 1 above | avg. shoot height (in) | 6 | 2 | 6 | 2 | 6 | 3 | 6 | | | | | | | | | |
| SL-8 2006 | 1 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 1 above | toe scour (ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 1 above | % cover seeded | 1 | <1 | <1 | 1 | 5 | 5 | 10 | | | | | | | | | |
| | 1 above | % cover weeds | 0 | 0 | 0 | <1 | 0 | <1 | 1 | | | | | | | | | |
| | 1 above | dead stems | 2 | 2 | 1 | 5 | 0 | <1 | 3 | | | | | | | | | |
| | 1 above | avg. shoot height (in) | 10 | 4 | 10 | 8 | 10 | 8 | 10 | | | | | | | | | |

| Soil lift ID | Soil lift layer | Monitoring Parameter | Distance (ft) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0-5 | 5-10 | 10-15 | 15-20 | 20-25 | 25-30 | 30-35 | 35-40 | 40-45 | 45-50 | 50-55 | 55-60 | 60-65 | 65-70 | 70-75 | 75-80 |
| SL-8 2006 | 1 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 1 above | toe scour (ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 1 above | % cover seeded | 1 | <1 | <1 | 1 | 5 | 5 | 10 | | | | | | | | | |
| | 1 above | % cover weeds | 0 | 0 | 0 | <1 | 0 | <1 | 1 | | | | | | | | | |
| | 1 above | Dead stems | 2 | 2 | 1 | 5 | 0 | <1 | 3 | | | | | | | | | |
| | 1 above | Avg. shoot height (in) | 10 | 4 | 10 | 8 | 10 | 8 | 10 | | | | | | | | | |
| SL-8 2006 Cont. | 2 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 2 above | toe scour (ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | | | | |
| | 2 above | % cover seeded | 1 | <1 | <1 | 1 | 5 | 10 | 40 | | | | | | | | | |
| | 2 above | % cover weeds | <1 | <1 | <1 | <1 | <1 | <1 | 1 | | | | | | | | | |
| | 2 above | Dead stems | 1 | 1 | 0 | 6 | <1 | 0 | 0 | | | | | | | | | |
| | 2 above | Avg. shoot height (in) | 3 | 6 | 5 | 5 | 3 | 10 | 0 | | | | | | | | | |
| SL-12 2006 | 1 above | rips/tears | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | 1 above | toe scour (ft) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | 1 above | % cover seeded | <1 | 1 | 5 | 5 | <1 | 1 | 5 | 1 | 1 | 5 | 1 | | | | | |
| | 1 above | % cover weeds | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | 1 above | Dead stems | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 3 | 3 | 2 | 3 | | | | | |
| | 1 above | Avg. shoot height (in) | 6 | 4 | 3 | 5 | 3 | 5 | 5 | 3 | 3 | 4 | 3 | | | | | |

**Table B-3.** Results of 2007 point bar monitoring for Point Bar #4, Transect 1.

| Point Bar ID | Monitoring Parameter | LWD # <4 | LWD # >4 | LWD % | % weeds | % grasses and forbs | # Shrubs | Substrate[1] | Deposition Type & % Cover | Other notes[1] |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Distance (ft)** | | | | | | | | | |
| PB 4 | 0-10 | 1 | 6 | 40 | 10 | 40 | 0 | OM, some 6-10 | leaves: 10, OM: 2 | |
| | 10-20 | 0 | 1 | 15 | 20 | 5 | 0 | sand, OM | leaves: 20 | |
| | 20-30 | 0 | 4 | 15 | 1 | 5 | 2 | <2, 2-4, silt loam | leaves: 30 | |
| | 30-40 | 0 | 1 | 20 | 1 | 1 | 0 | <2, 2-4, 4-6, sand | leaves: 10 | |
| | 40-50 | 0 | 6 | 40 | 1 | <1 | 0 | <1, 2-4, 4-6, few >8, sand | leaves: 5 | |
| | 50-60 | 3 | 0 | 30 | 1 | <1 | 0 | <2, 2-4, 4-6, sand | leaves: 20 | |
| | 60-70 | 0 | 5 | 50 | 1 | <1 | 0 | <2, 2-4, 4-6, some >8 | leaves: 10, OM: 1 | |
| | 70-80 | 0 | 0 | 0 | 1 | 0 | 0 | <2, 2-4, 4-6, some >8, sand | leaves: 1 | swale located between 73' – 91', fine sediment and OM deposited at streamside edge of swale |
| | 80-90 | 0 | 5 | 75 | 0 | <1 | 0 | <2, 2-4, 4-6, sand | leaves:70, OM: 30 | |
| Transect 1 | 90-100 | 0 | 0 | 20 | <1 | <1 | 0 | <.5, .5-2, some 4-6 | OM: 5 | beyond 100' under ice |

[1]Numbers represent substrate size ranges in inches, OM = organic matter, soil = bare mineral soil

**Table B-4.** Results of 2007 Point bar monitoring for Point Bar #4, Transect 2.

| Point Bar ID | Monitoring Parameter | LWD # <4 | LWD # >4 | LWD % | % weeds | % grasses and forbs | # Shrubs | Substrate[1] | Deposition Type & % Cover | Other notes |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Distance (ft)** | | | | | | | | | |
| PB 4 | 0-10 | 0 | 0 | 40 | 10 | 20 | 3 | 2-4, OM, soil | leaves: 10 | |
| | 10-20 | 0 | 3 | 30 | 5 | <1 | 0 | <2, sand, silt loam | leaves: 5 | |
| | 20-30 | 0 | 2 | 15 | <1 | <1 | 0 | 4-6, some >10 | leaves: 5 | |
| | 30-40 | 0 | 1 | 5 | 1 | <1 | 0 | <.5-4, sand | N/A | |
| | 40-50 | 0 | 1 | 1 | 10 | 0 | 0 | <.5-2, some 4-6 | leaves: 1 | |
| | 50-60 | 0 | 0 | <1 | 20 | <1 | 0 | <.5-2, some 4-6 | leaves: <1 | |
| | 60-70 | 0 | 1 | 1 | 10 | <1 | 1 | 2-4, some <2, some 4-6, sand at edges of swale | leaves: 1 | swale located between 60' and 65', recorded shrub in swale |
| | 70-80 | 0 | 3 | 25 | 5 | 0 | 0 | 4-6, some >8 | N/A | |
| | 80-90 | 0 | 0 | 0 | <1 | 0 | 0 | 4-6 some 2-4 | OM: <1 | |
| | 90-100 | 0 | 0 | <1 | <1 | 1 | 1 | 4-6 top of swale, 2-4 edge of swale, OM in swale | OM: 75 | swale |
| | 100-110 | 0 | 0 | <1 | <1 | <1 | 0 | 2-4, some 4-6 | sand: 40 | |
| | 110-120 | 0 | 1 | 5 | 0 | <1 | 0 | sand, some 2-4, few 4-6 | sand: 75 | |
| | 120-130 | 0 | 0 | <1 | 0 | 0 | 0 | sand, some 2-4 | sand: 90 | |
| Transect 2 | 130-140 | 0 | 0 | 1 | 0 | 5 | 3 | sand, some 4-6 | sand: 40 | 136' – 140' under ice |

**Table B-5.** Results of 2007 Point bar monitoring for Point Bar #13, Transect 1.

| Point Bar ID | Monitoring Parameter | LWD # <4 | LWD # >4 | LWD % | % weeds | % grasses and forbs | # Shrubs | Substrate[1] | Deposition Type & % Cover | Other notes |
|---|---|---|---|---|---|---|---|---|---|---|
| | Distance (ft) | | | | | | | | | |
| PB 13 | 0-10 | 0 | 0 | <1 | 0 | 0 | 0 | <.5 some 0.5-2 | leaves: 75 | leaf deposition from mature cottonwoods directly overhead |
| | 10-20 | 0 | 0 | <1 | <1 | 0 | 0 | <0.5 some 0.5-2, silt loam, OM | leaves:1 | |
| | 20-30 | 0 | 0 | <1 | <1 | <1 | 0 | <2 some 2-4, silt loam, OM | leaves: <1 | |
| | 30-40 | 0 | 0 | 0 | 0 | 1 | 0 | 2-6, FD sand | leaves: 15, OM: <1 | |
| | 40-50 | 0 | 6 | 30 | 0 | <1 | >10 | 4-6 some >8, sand | sand: 10, OM: 1, leaves: 5 | shrubs are cottonwood seedlings unless otherwise noted |
| | 50-60 | 0 | 1 | 5 | <1 | <1 | >50 | 4-6 some >2, FD sand | leaves: 5, sand:5 | |
| | 60-70 | 0 | 3 | 20 | 1 | <1 | >20 | 4-6 some 6-8 | leaves: 20, sand:5 | |
| | 70-80 | 0 | 4 | 40 | 10 | 5 | >5 | OM, sand | sand: 30, OM: 5, leaves: 15 | swale |
| | 80-90 | 1 | 0 | 5 | 5 | 1 | >50 | 2-4 some <2, sand | sand: 10, OM: 1, leaves: 1 | |
| | 90-100 | 0 | 0 | 0 | <1 | 0 | >50 | 2-4, sand | sand: 1, leaves: <1 | |
| | 100-110 | 0 | 0 | 0 | <1 | <1 | >50 | 4-6, sand | sand: 5, leaves: 1 | |
| Transect 1 | 110-120 | 0 | 0 | 0 | 0 | 0 | >5 | 2-4, some 4-6, sand | OM: <1, sand: <1 | |
| | 120-130 | 0 | 0 | <1 | 0 | 0 | 0 | 2-4 some 4-6, sand | OM: <1, sand: <1 | |

[1]Numbers represent substrate size ranges in inches, OM = organic matter, soil = bare mineral soil

**Table B-6.** Results of 2007 Point bar monitoring for Point Bar #13, Transect 2.

| Point Bar ID | Monitoring Parameter | LWD # <4 | LWD # >4 | LWD % | % weeds | % grasses and forbs | # Shrubs | Substrate[1] | Deposition Type & % Cover | Other notes |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Distance (ft)** | | | | | | | | | |
| PB 13 | 0-10 | 0 | 1 | 5 | 0 | <1 | 5 | < 2, OM, silt loam | leaves: 95, OM: <1 | shrubs are cottonwood seedlings unless otherwise noted |
| | 10-20 | 0 | 1 | 10 | <1 | <1 | 0 | <.5, sand, silt loam | leaves: 20, OM:1 | |
| | 20-30 | 0 | 0 | <1 | 1 | 1 | >5 | <2, sand, silt loam | leaves: <1, OM:<1 | |
| | 30-40 | 0 | 0 | <1 | 1 | 3 | >10 | <2, soil, sand | leaves: 1 | |
| | 40-50 | 0 | 0 | 30 | 10 | 40 | 1 | soil, OM | leaves: 10 | shrub is willow sp. |
| | 50-60 | 0 | 3 | 40 | 1 | 10 | 1, >10 | silt loam, sand | sand: 25, leaves: 5 | 1 willow located in swale feature |
| | 60-70 | 0 | 1 | 20 | 0 | <1 | >5 | sand, OM | sand: 80, OM: 20 | swale, sand deposition ~ 12" deep |
| | 70-80 | 0 | 10 | 70 | <1 | <1 | 0 | water, sand, OM | sand: 20, OM: <1 | swale |
| | 80-90 | 0 | 1 | 10 | 5 | 1 | >10 | sand, OM | sand: 75, OM: 5, leaves: <1 | swale |
| | 90-100 | 0 | 0 | 1 | <1 | <1 | >50 | 2-4 some 4-6, sand | sand: 5, OM: 1 | |
| | 100-110 | 0 | 0 | 0 | 0 | 0 | 0 | <2 some 2-4 | leaves: 1 | |
| | 110-120 | 0 | 0 | 0 | <1 | <1 | >10 | <2 some 2-4, sand | sand: 5, leaves: <1 | |
| Transect 2 | 120-130 | 0 | 0 | <1 | 0 | <1 | >10 | 2-4 some 4-6, sand | sand: 10 | |

[1]Numbers represent substrate size ranges in inches, OM = organic matter, soil = bare mineral soil

## **Appendix C:** Past Revegetation Treatments

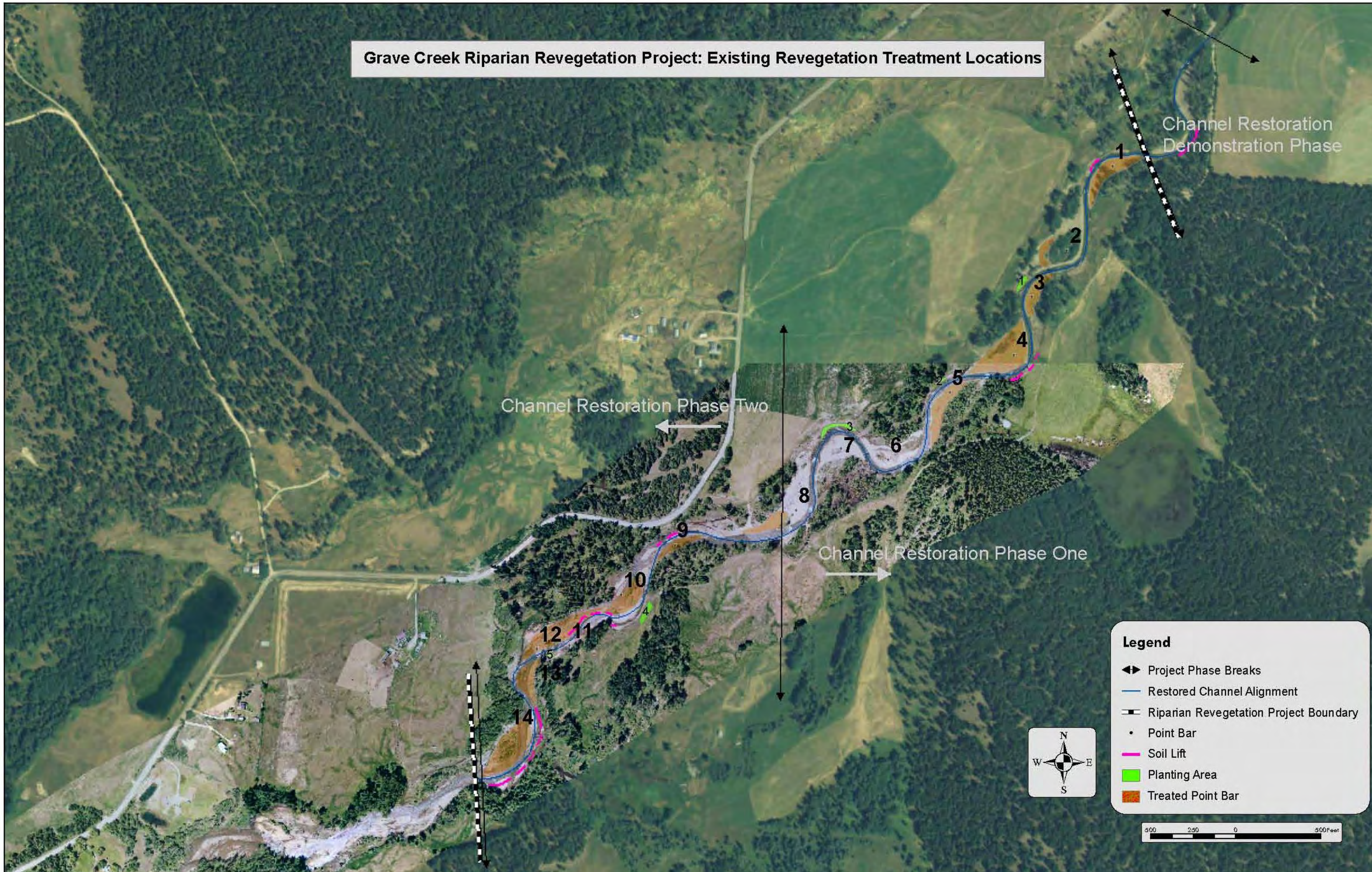


**Figure C-1.** Locations of revegetation treatments in the Grave Creek project reach implemented between Fall 2005 and Winter 2006.