Conceptual Restoration Design
Lower Blacktail Creek

FINAL REPORT

Lower Blacktail Creek Project Area

Prepared For

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1 Project Overview

Blacktail Creek is located in the headwaters of the Upper Clark Fork River Basin (UCFRB) southeast of Butte, Montana. Blacktail Creek originates at the continental divide in the Highland Mountains and flows approximately 17 miles northward before entering Silver Bow Creek in Butte, Montana. Blacktail Creek has a history of disturbance resulting in altered stream processes, impaired vegetation conditions and poor aquatic habitat for native fish species, namely westslope cutthroat trout (*Oncorhynchus clarki lewisi*). In addition, lower Blacktail Creek flows through an urban area with extensive infrastructure including interstate highways, city streets, utilities, commercial developments and residential neighborhoods. Stormwater runoff events occasionally result in elevated metals concentrations in lower Blacktail Creek (DEQ 2014).

River Design Group, Inc. (RDG) and Geum Environmental Consulting, Inc. were contracted by the State of Montana Natural Resource Damage Program (NRDP) to develop a conceptual restoration design for the lower 3.0 miles of Blacktail Creek. Blacktail Creek is identified as a Priority 2 tributary in the *Final Upper Clark Fork River Basin Aquatic and Terrestrial Resources Restoration Plans* (NRDP 2012). The 2012 Restoration Plans identified restoration actions for Blacktail Creek including:

- Riparian Habitat Protection and Enhancement Implementation
- Instream Habitat Improvement
- Fish Passage
- Water Quantity

In addition, Blacktail Creek is an important resource to Butte residents. A recreational trail system has been developed on public lands along Blacktail Creek north of Interstate 90.

The purpose of the lower Blacktail Creek restoration work is to improve stream function for native fish populations and improve riparian habitat for wildlife in the lower 3.0 miles of the Blacktail Creek watershed. The Lower Blacktail Creek Conceptual Restoration Design is being funded with natural resource damage settlement funds that are administered by the State of Montana. Project partners include NRDP, Watershed Restoration Coalition (WRC), Mile High Conservation District, Montana Fish, Wildlife and Parks (FWP), Trout Unlimited, Butte Country Club, Butte Natural Resource Council, City of Butte and Silver Bow County.

1.1 Site Conditions

Lower Blacktail Creek flows north through the Butte Country Club Golf Course before crossing under Interstate 90 and turning west toward its confluence with Silver Bow Creek. A project vicinity map is provided in Figure 1-1.

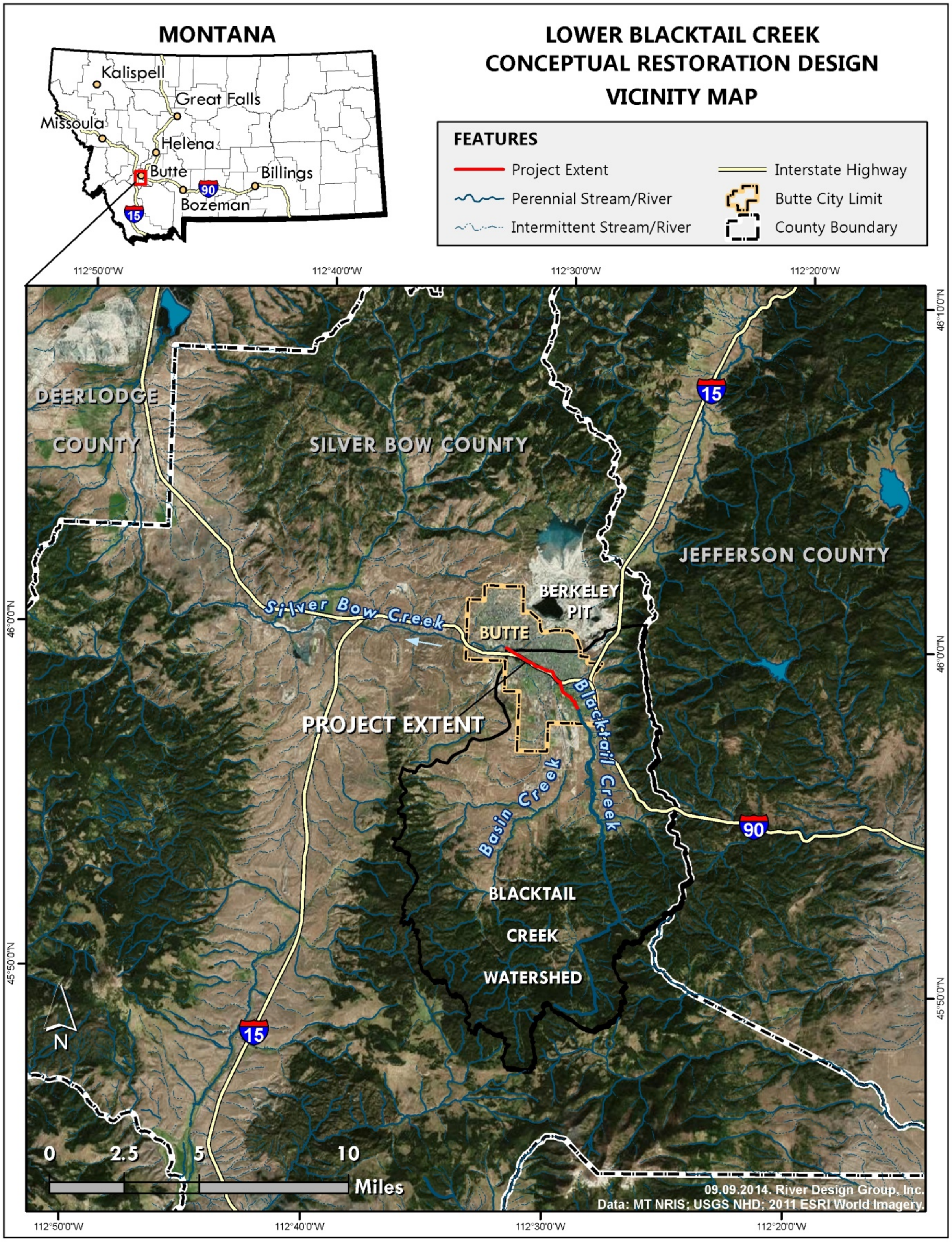

Figure 1-1. Project vicinity map for the lower Blacktail Creek Restoration Design.

Contemporary site conditions on lower Blacktail Creek reflect a long history of disturbance, pre-dating detailed maps depicting pre-disturbance conditions. Contemporary conditions are characterized by a straightened, entrenched channel and narrow floodplain corridor resulting from encroachment by development. Due to these altered conditions, Blacktail Creek lacks suitable complex aquatic habitat for native fish, and lacks connected floodplain areas for development of diverse riparian vegetation communities. Historically, it is likely that Blacktail Creek was characterized by beaver-influenced wetland complexes with highly sinuous channels and a broad floodplain as seen in similar, nearby undisturbed systems and as evidenced in Figure 1-2.

Figure 1-2. 1904 USGS map depicting the Butte area and lower Blacktail Creek in the early 1900s.

1.2 Previous Studies

This document builds upon information developed by others in support of restoration planning on Blacktail Creek. Previous studies completed on Blacktail Creek include:

- Silver Bow Creek Watershed Restoration Plan (Montana Natural Resource Damage Program 2005)
- Restoration Study of Blacktail Creek (Mile High Conservation District 2009)
- An Assessment of Fish Populations and Riparian Habitat in Tributaries of the Upper Clark Fork River Basin: Phase II (Montana Fish, Wildlife and Parks 2009)

- Final Upper Clark Fork River Basin Aquatic and Terrestrial Resources Restoration Plans (NRDP 2012)
- Blacktail Creek Assessment for NRDP (Montana Tech 2013)

In general, previous studies thoroughly document the existing condition of Blacktail Creek and describe the limiting factors responsible for the observed impairments. In addition, previous studies identify restoration opportunities on lower Blacktail Creek including potential locations for restoration as well as recommendations for restoration strategies.

1.3 Desired Conditions and Project Goals

As part of on-going partnerships in the UCFRB, it is proposed to address the primary limiting habitat factors in Blacktail Creek in order to improve stream function and aquatic resources. The desired future condition for the project area is a more natural landscape that maximizes ecological site potential by restoring native plant communities, by providing preferred habitat for native aquatic and terrestrial species, and by establishing sustainable river and floodplain morphology in the context of existing constraints. Lower Blacktail Creek flows through an urban environment and restoring the stream and floodplain to pre-urban conditions is not feasible, therefore the desired condition is to improve channel and ecological functions to the extent feasible. The following goals were developed collaboratively with the project partners:

1. Consider existing constraints in the project area including Butte Country Club Golf Course infrastructure, City utilities, streets and private land use.
2. Improve aquatic habitat conditions (i.e., woody debris availability, spawning gravels, pool quality and quantity, cover and off-channel habitat) for native fish.
3. Improve floodplain and riparian function by establishing a dynamic, succession driven mosaic of plant communities capable of supporting a wide range of ecological functions.
4. Establish sustainable river and floodplain morphology that acknowledges constraints and supports aquatic habitat and vegetation goals.

1.4 Document Organization and Purpose

The purpose of this Conceptual Restoration Design Report is to provide information that will guide the design and implementation process toward a plan that will achieve project goals.

This document is organized into the following sections and appendices.

- ***Section 1 Project Overview*** provides project background information, describes site conditions and identifies project goals.
- ***Section 2 Project Site Assessment*** describes existing site conditions, summarizes previous studies and provides supplemental analyses undertaken in support of documenting limiting factors.
- ***Section 3 Restoration Objectives and Conceptual Design Criteria*** builds upon Section 2 by providing detailed project objectives linked to limiting factors, and by summarizing design criteria for aquatic habitat, vegetation and morphology.

- ***Section 4 Restoration Strategies and Treatments*** describes a range of conceptual restoration actions developed with guidance from restoration objectives that will address limiting factors.
- ***Section 5 Restoration Alternatives*** identifies potential locations for specific restoration actions by sub reach, summarizes the process for evaluating restoration actions, and provides a recommended layout for a preferred restoration action.
- ***Section 6 Design and Implementation Considerations*** describes an approach for addressing project feasibility including performance expectations, data needs, permitting requirements, phasing options, construction materials, risk, uncertainty, and future monitoring/adaptive management recommendations.
- ***Section 7 References*** includes citations for literature and studies referenced in the document***.***
- ***Appendix A*** includes supplemental data maps for the project area.
- ***Appendix B*** includes a hydrologic summary for Blacktail Creek***.***
- ***Appendix C*** includes LiDAR exhibits.
- ***Appendix D*** includes 11x17 maps of the Conceptual Restoration Plans.

2 Project Site Assessment

This section provides a summary of existing site conditions. Existing information used to evaluate site conditions included:

- Restoration Study of Blacktail Creek (Mile High Conservation District 2009)
- An Assessment of Fish Populations and Riparian Habitat in Tributaries of the Upper Clark Fork River Basin: Phase II (FWP 2009)
- Final Aquatic and Terrestrial Resources Restoration Plans (NRDP 2012)
- Blacktail Creek Assessment for NRDP (Montana Tech 2013)
- Silver Bow Creek Watershed Restoration Plan (NRDP 2005)
- Butte-Silver Bow Flood Insurance Study (FEMA 2010)
- Butte Country Club Master Plan and Infrastructure Map
- Historical maps and aerial images of Blacktail Creek

In addition to existing documents, spatial data were acquired from publicly available GIS data sources (MT NRIS, USDA, NRCS, USGS, and FEMA) and from geodatabases provided by the project partners including:

- 2011 Bing aerial imagery
- 2011 Terrestrial LiDAR topography
- Cadastral land ownership, roadway/stormwater infrastructure and utilities
- FEMA Flood Insurance Rate Maps
- NRCS soils data
- Hydrology for USGS Gage 12323240 Blacktail Creek at Butte, MT (1988 – present)
- Monitoring sites (FWP fish habitat sites, DEQ water quality sites, NRDP riparian assessment reaches, etc.)

A field assessment was completed on September 22 and 23, 2014 to confirm and supplement existing information. Objectives for the field assessment were:

- Investigate morphological characteristics and channel evolution trends
- Assess streambank stability and document fine sediment sources
- Evaluate riparian and floodplain vegetation conditions
- Evaluate aquatic habitat conditions including cover, substrate, pool availability, hydraulic complexity, flow availability, fish passage, and entrainment risks
- Identify stormwater discharge and nutrient source points
- Identify infrastructure, land uses, and other factors that limit or constrain aquatic and riparian habitat restoration potential
- Identify conservation and restoration opportunities
- Refine the sub reach delineation

2.1 Watershed Overview

Blacktail Creek is a 91 square mile watershed located in the headwaters of the Upper Clark Fork River Basin (UCFRB) southeast of Butte, Montana. Blacktail Creek originates on the west slope of the continental divide in the Highland Mountains at elevations exceeding 7,000 feet and flows 17 miles northward before entering Silver Bow Creek in Butte, Montana at an elevation of approximately 5,400 feet. A map of the Blacktail Creek watershed is provided in Figure 2-1.

2.1.1 Geology

The mountainous upper watershed is mostly bedrock-controlled and composed predominately of easily weathered granite classified as Butte Quartz Monzonite and aplite of the Boulder Batholith (MBMG 2004). The lower watershed is situated on alluvial deposition consisting of well-drained sediments derived from the upper watershed. Figure A-3 in Appendix A includes an NRCS soils map for the project area.

2.1.2 Vegetation Cover

The Blacktail Creek watershed is approximately 12% developed with remaining areas consisting of forests, shrublands and grasslands. The upper basin is on U.S. Forest Service Land and is forested with mostly conifer species. The lower basin is on mostly private land and consists primarily of shrublands and grasslands. Figure A-2 in Appendix A includes a land cover map for the Blacktail Creek watershed.

2.1.3 Climate and Hydrology

Climate in the watershed is influenced by Pacific and continental weather patterns. Mean annual watershed precipitation is 18 inches per year compared with a relatively dry 13 inches per year in Butte, representing conditions in the lower Blacktail Creek project area. Much of the annual precipitation comes in the form of snow, which is responsible for the snowmelt driven hydrograph of Blacktail Creek (Figure 2-2). Additional hydrologic exhibits are provided in Appendix B.

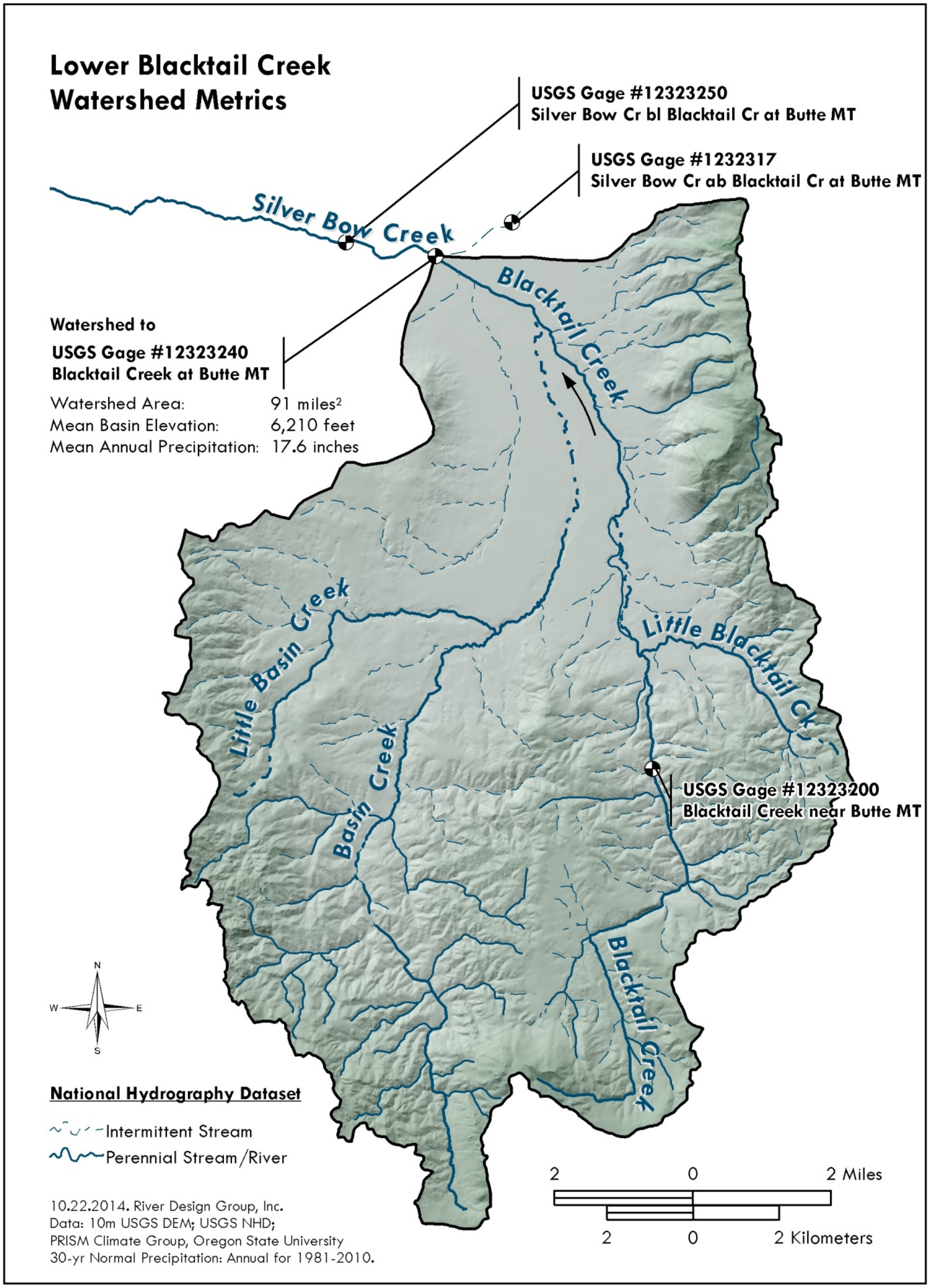

Figure 2-1. Blacktail Creek watershed.

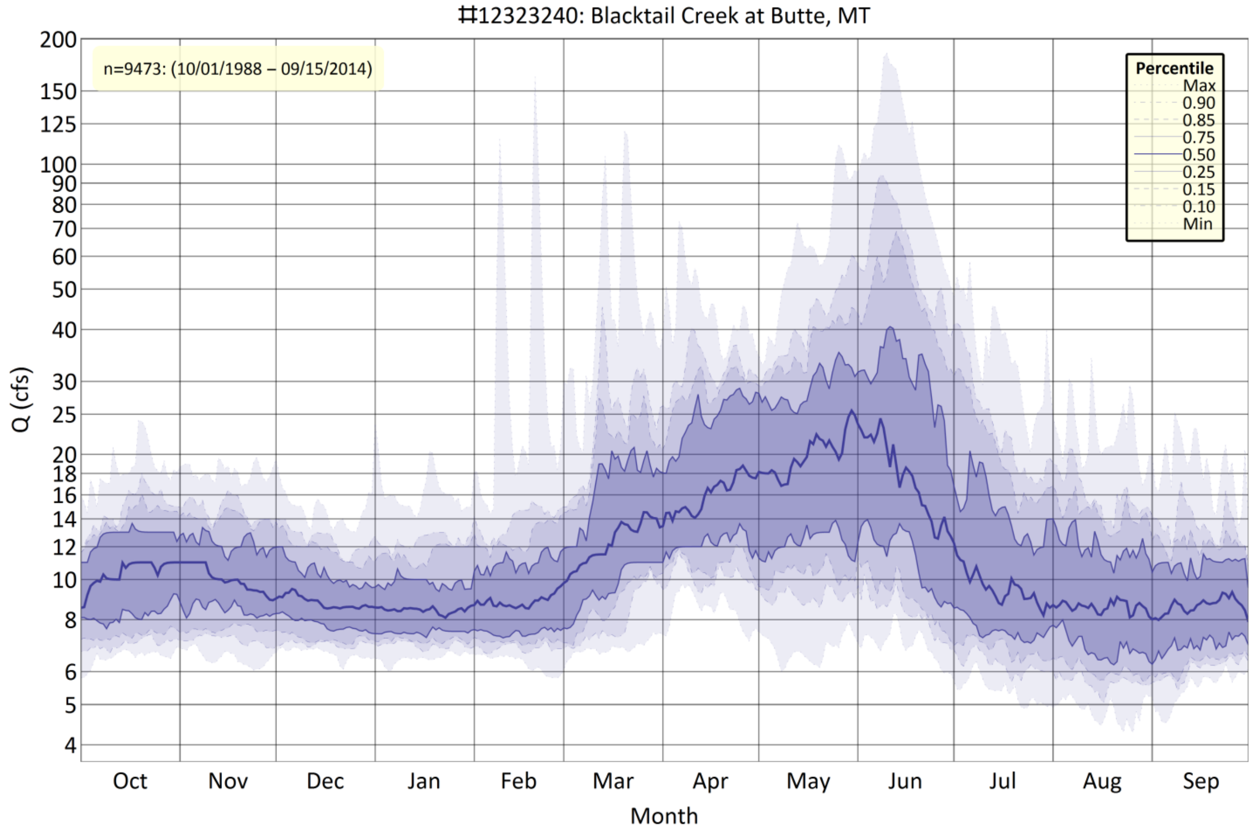

Figure 2-2. Blacktail Creek hydrograph created from mean daily flow quartiles from USGS gage 12323240 Blacktail Creek at Butte, MT.

2.2 Project Reach Delineation

As part of previous studies, Blacktail Creek was separated into 13 reaches numbered sequentially from upstream to downstream. The reach delineation was based primarily on land ownership. Sub reach delineations based on observed site conditions were added during later studies (Montana Tech 2013). The lower Blacktail Creek project area includes Reaches BTC_11 and BTC_12. For continuity, this document uses the same reach names, but provides refinement of sub reaches based on restoration potential and likelihood for contiguous restoration projects. The project reach delineation is shown in Figure 2-3. Detailed sub reach descriptions are provided in Section 5.

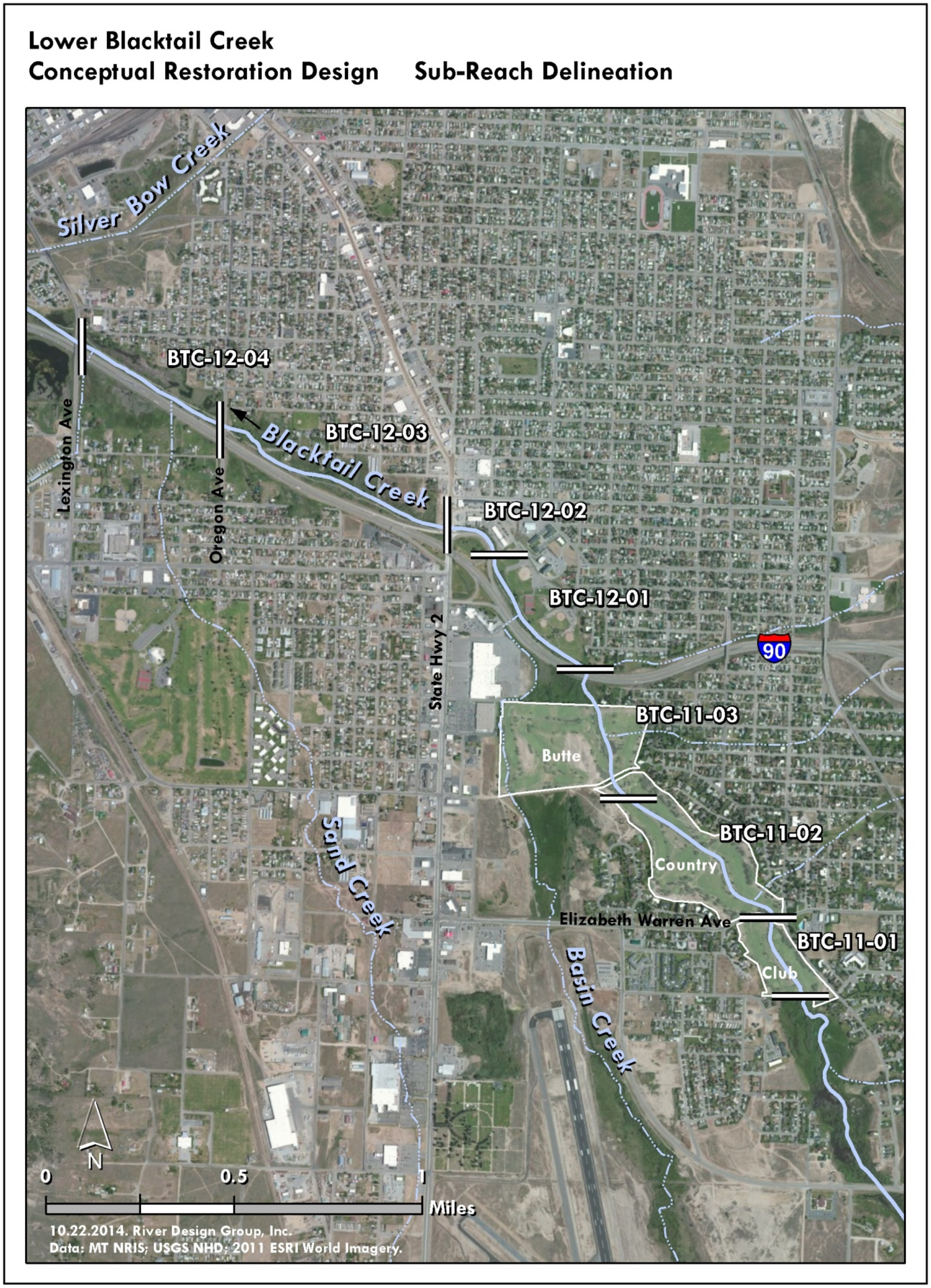

Figure 2-3. Reach delineation for the lower Blacktail Creek project area.

2.3 Aquatic Habitat Conditions and Limiting Factors

Aquatic habitat conditions in Blacktail Creek are described in previous studies (FWP 2009, Mile High Conservation District 2009, and Montana Tech 2013). In general, fish habitat conditions in lower Blacktail Creek are rated as fair and aquatic habitat conditions are rated as at risk or not stainable.

FWP completed fish sampling at five locations in July 2008. No fish sampling was conducted in the lower Blacktail Creek project area; however, the nearest sampling site located approximately two miles upstream consisted entirely of brook trout (*Salvelinus fontinalis*). Westslope cutthroat trout were found in low densities at a sampling site approximately five miles upstream (36% cutthroat trout and 64% brook trout). In general, fish populations in Blacktail Creek are dominated by non-native brook trout. Westslope cutthroat trout become the dominant species further upstream on U.S. Forest Service lands (approximately 8 miles upstream of the project area). Limited genetic sampling indicate that these fish are a pure strain of westslope cutthroat trout.

Based on previous studies and field observations, the following limiting factors are identified for aquatic habitat:

Fine sediment accumulation: A gravel channel bottom with clean interstitial spaces is the substrate condition preferred by native fish and macroinvertebrate species. Clean gravel substrates provide spawning surfaces and egg incubation habitat for larvae as well as hiding cover for juveniles. Channel entrenchment and bank erosion are contributing to altered substrate conditions in the project area. High, non-vegetated banks are delivering fine sediment loads to the project area. Channel entrenchment reduces the ability of floodplain surfaces to trap and store fine sediment, thus causing fine sediment to accumulate on the channel bottom and fill the interstitial spaces of preferred gravel substrates.

Shallow, infrequent pools: Pools offer important overwintering habitat for resident adult fish and juvenile fish, and pools may offer holding habitat during periods of high water temperature or low flow. Although pools exist in the project area, they lack the depth, cover and complexity preferred by native species. Poor pool quality is a result of altered pool forming processes such as woody debris recruitment and lateral scour caused by channel sinuosity. Consequently, the straightened channel planform and lack of woody vegetation are contributing to shallow, infrequent pools in the project area.

Lack of habitat diversity: Disturbed riparian conditions and altered stream morphology are influencing the availability of woody debris and function of pool-riffle sequences, which offer cover and complexity in the form of variable depth, velocity and substrate. Processes responsible for development of cover and complexity include floodplain interaction, channel migration and woody debris recruitment. In addition, the project area lacks off-channel habitat for juvenile rearing. Suitable juvenile rearing habitat consists of refuge from the main channel in areas of lower velocity, alternate food sources, variable substrate and warmer temperature. Side channels, alcoves and connected wetlands can provide suitable off-channel juvenile rearing habitat. Development of off channel habitat is depended on floodplain connection and riparian forest establishment.

Warm water temperatures: High stream temperatures affect salmonid growth and development, alter life history patterns, induce disease, or exacerbate competitive predator-prey interactions (Spence et al. 1996). High stream temperature can also be lethal to both adult and juvenile trout. In 2008 FWP monitored temperature at two locations in Blacktail Creek. Temperature data near the mouth of Blacktail Creek show that temperatures exceeded 15 degrees Celsius on 47 days and reached a peak temperature of 19 degrees Celsius in July. Data indicate that summer and early fall peak temperatures are not suitable for westslope cutthroat trout. Disturbed riparian conditions including reduced canopy cover and woody debris contribute to elevated water temperatures by creating less shade. In addition, water temperature is influenced by altered stream morphology which has caused increased surface area (wider channels), longer exposure to solar radiation (lower velocity), and less exchange between streamflow and cold groundwater.

Poor water quality: Nutrient loading may be causing increases in algae and aquatic vegetation growth on the streambed. Also, septic systems from nearby residential areas may be delivering nitrates to the project area. In addition, numerous stormwater drains discharge to the project raising additional water quality concerns. Although many mine waste sites on lower Blacktail Creek have been addressed through remediation, additional sites remain that may be introducing metals, including copper, to lower Blacktail Creek (USEPA 2008). The Mile High Conservation District is developing a sampling and analysis plan to identify sources of pollutants or contamination in Blacktail Creek.

Figure 2-4. Typical aquatic habitat conditions in lower Blacktail Creek displaying poor substrate conditions and simplified aquatic habitat.

2.4 Vegetation Conditions and Limiting Factors

Vegetation conditions along Blacktail Creek are described in previous studies (FWP 2009, Mile High Conservation District 2009, and Montana Tech 2013). In summary, riparian habitat conditions in lower Blacktail Creek vary widely from sustainable to unsustainable. Riparian vegetation is limited to narrow bands along the channel. Riparian vegetation is characterized by a mix of native and non-native willow species, alder, drier shrubs such as rose and honeysuckle; and wetland graminoids such as sedges, rushes and grasses. Disturbance-induced or non-native grasses such as redtop, Kentucky bluegrass, smooth brome and timothy are common. Pre-disturbance conditions were likely characterized by expansive floodplains heavily influenced by beaver activity. Pre-disturbance conditions would have included a mosaic of different vegetation communities including shrub-dominated, open water and emergent wetland areas.

Based on previous studies and field observations, the following limiting factors are identified for vegetation:

Insufficient riparian buffers: The current land uses adjacent to Blacktail Creek (golf course, parks, pedestrian paths, roads, and residential areas) require active management and result in the frequent clearing of woody riparian vegetation. Frequent clearing reduces the amount of area available for diverse riparian and floodplain vegetation to develop. Vegetation clearing combined with channel straightening has also resulted in bank erosion in some areas which further limits the establishment of riparian vegetation. In many areas, streambank vegetation has been converted from woody vegetation to grasses which provide limited soil stabilization along the channel. Land uses also result in localized impacts to existing vegetation through trampling and compaction of frequently accessed areas. A wide, densely vegetated riparian buffer is needed to promote stable geomorphology and maximize aquatic habitat potential (stability, reduce fine sediment inputs, filter nutrients and other potential contaminants, species diversity, cover and shade and input of woody material).

Lack of floodplain connection: Due to channel straightening and entrenchment through much of the project area, surfaces adjacent to the creek are relatively high compared to the channel and water table. This lack of floodplain connection limits the area suitable for supporting desired riparian vegetation. The lack of floodplain connection also reduces the extent of overbank flooding which supports a range of natural processes necessary to create and maintain diverse riparian vegetation, such as: deposition of new substrates for natural recruitment of woody species; stability of surfaces to allow vegetation to grow and establish; input of seed and plant propagules; and recharge and maintenance of groundwater tables.

Invasive species: Weeds are common throughout the project area, but densities are generally low. Noxious weeds observed in the project area include: Canada thistle (*Cirsium arvense*), spotted knapweed (*Centaurea maculosa*), common toadflax (*Linaria vulgaris*), and leafy spurge (*Euphorbia esula*). Non-native willows and reed canarygrass (*Phalaris arundinacea*) are also present in the project area and can be highly invasive in riparian areas. Competition from weeds can greatly reduce species diversity and habitats for desired species. These species will be an important consideration during revegetation of constructed floodplain surfaces.

Figure 2-5. Typical conditions along lower Blacktail Creek displaying the narrow band of riparian vegetation.

2.5 Geomorphic Conditions and Limiting Factors

Geomorphic conditions along Blacktail Creek are described in previous studies (FWP 2009, Mile High Conservation District 2009, and Montana Tech 2013). In general, the geomorphology of lower Blacktail Creek is disturbed, and contemporary geomorphology contributes to the impaired aquatic habitat and vegetation conditions noted in previous sections. Pre disturbance geomorphic conditions were likely characterized as beaver-influenced wetland complexes with highly sinuous channels currently displayed in the less disturbed reaches of Blacktail Creek.

Based on previous studies, LiDAR topography and field observations, the following limiting factors are identified for geomorphology:

Channel entrenchment: Channel cross section geometry is affecting floodplain connection and sediment transport characteristics. There are few areas along the channel margins where the water table is accessible from the surface by riparian vegetation. Although a narrow inset floodplain has developed in some areas, it is not providing enough floodplain area to establish sustainable riparian buffers capable of supporting habitat development. In addition, the existing floodplain is not providing enough area or energy dissipation to trap and store fine sediments, which are being stored within the interstitial spaces of the gravel on the channel bed. The existing channel entrenchment ratio (ratio floodplain width to channel width) is below the expected range for historical stream channel conditions.

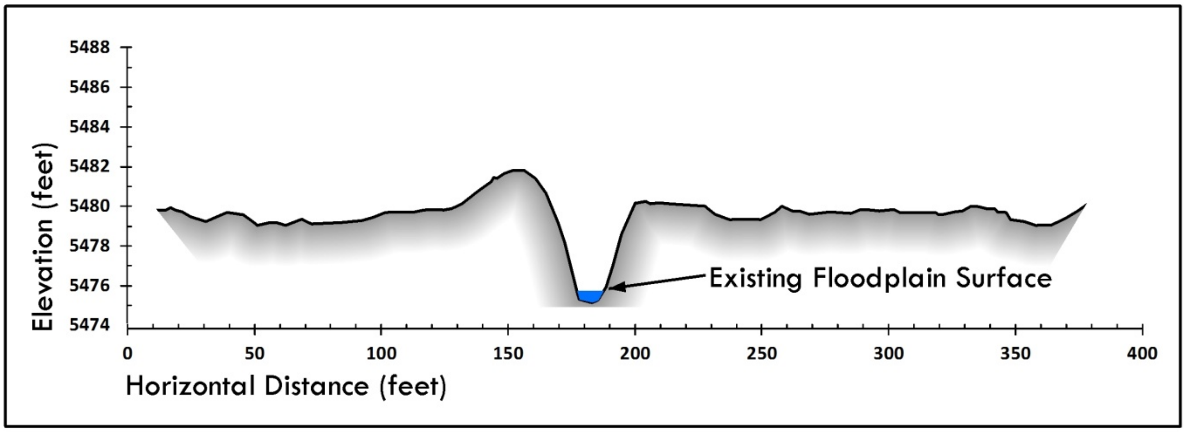

Figure 2-6. Typical channel cross section illustrating channel entrenchment in lower Blacktail Creek.

Straightened channel planform: Channel planform geometry is affecting bedform development and creating simplified habitat conditions. Sinuous planform geometry supports pool development at meander beds and creates hydraulically complex habitat in the form of variable depth, velocity and substrate. Moreover, channelization of Blacktail Creek means there is less available habitat due to decreased channel sinuosity and loss of overall channel length.

Increased channel gradient: Due to the straightened channel planform, the channel profile has a steeper slope than historical conditions. Steeper slope equates to higher velocity, increased bed mobility, and increased risk of channel response (incision and bank erosion) to altered hydraulics.

Altered pool development processes: Processes responsible for pool development in Blacktail Creek include lateral scour caused by meandering planform and contraction scour caused by flow acceleration or a constriction, and vertical scour caused by bedrock, boulders, wood or beaver dams. Historical pool development processes were likely influenced by channel complexity such as pool-riffle morphology and woody derived from floodplain vegetation. Lateral migration and beaver dams may also have influenced pool development to a degree. Despite moderate pool availability in the project areas, pool-forming processes such as lateral migration, flow acceleration and woody debris recruitment are affected by altered conditions.

Bank erosion: Blacktail Creek is responding to altered channel morphology and vegetation conditions. Steep, sparsely vegetated banks composed of fine grained soils are susceptible to bank erosion as Blacktail Creek attempts to establish equilibrium in its altered landscape. Bank erosion delivers fine sediment to the channel bed and causes damage to private property along the creek.

Additional supporting information for geomorphic limiting factors is provided in Appendix C, which contains a longitudinal profile and cross sections developed from LiDAR data.

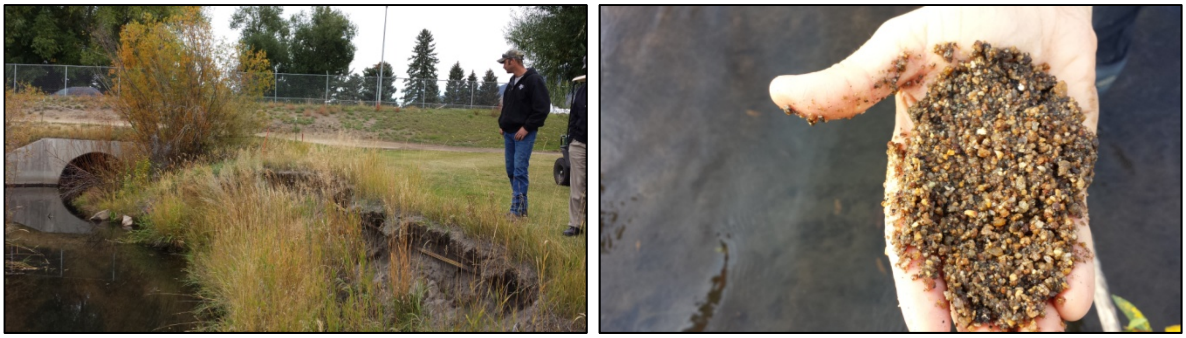

Figure 2-7. Bank erosion in lower Blacktail Creek is causing damage to infrastructure and embedding gravel substrate with sand.

2.6 Restoration Constraints

Project constraints are existing features, infrastructure, or land uses that influence project extents and ability to achieve restoration potential. The restoration potential for lower Blacktail Creek is significantly influenced by the urban setting the stream flows through. The following constraints have been identified in the project area:

Land use: Private and public lands are adjacent to the project area. Restoration actions must be compatible with adjacent land uses, and actions must be evaluated for potential effects to adjacent property. Restoration actions must take into consideration potential future land uses as well.

Infrastructure: Major roads and utilities are present throughout the project area. Extents of restoration actions must consider the locations of infrastructure. Moreover, risk to infrastructure must be evaluated during the design process and coordinated with infrastructure owners. Figure A-4 in Appendix A provides a map of utilities and infrastructure in the project area.

Regulatory Floodplain: Flood risk on Blacktail Creek is managed through the National Flood Insurance Program administered by FEMA. Development within the Blacktail Creek floodplain is regulated by federal, state and county floodplain regulations. Restoration actions that affect flood elevations must be evaluated using a hydraulic model to demonstrate compliance with applicable regulations. Actions that cause an increase in base flood elevations in Blacktail Creek could be subject to costly flood insurance rate map revisions. Figure A-5 in Appendix A provides a map of infrastructure in the project area.

Non-native fish species: Although restoration actions will improve habitat conditions for native fish species, restoration actions will not eradicate non-native fish species such as brook trout that directly compete with native species for food and habitat. Other measures beyond the scope of this project may be required to address species composition.

Water quality and upstream watershed effects: Ability to achieve restoration potential in the project area could be influenced by upstream watershed effects including sediment loading, water temperature, point source discharges, nutrient loading, mine waste sites and tributary inputs.

Effects of beaver activity: Beaver are active throughout lower Blacktail Creek and would have historically been one of the greatest influences on channel form, aquatic habitat and riparian vegetation community structure and distribution. Proposed restoration actions may be influenced by continued beaver activity in lower Blacktail Creek. It is likely that beaver will build dams in newly constructed channel reaches and browse on planted vegetation. The effect of continued beaver activity should be considered in selecting and managing restoration actions.

3 Restoration Objectives and Conceptual Design Criteria

This section provides specific restoration objectives to guide development of conceptual restoration design criteria. Limiting factors identified in Section 2 were used to link existing site conditions to objectives and conceptual design criteria aimed at achieving desired conditions. Objectives and conceptual design criteria are provided for categories of geomorphology, vegetation and aquatic habitat.

3.1 Geomorphic Objectives and Conceptual Design Criteria

Geomorphic objectives provide guidance for addressing stream channel geometry and river processes. In addition, geomorphic objectives support aquatic habitat objectives and integrate with the vegetation objectives described in subsequent sections. Table 3-1 provides a summary of geomorphic objectives, limiting factors and conceptual design criteria. Addition detail is provided in the following sections.

Table 3-1. Summary of geomorphic objectives, limiting factors and conceptual design criteria.

Geomorphic Objective	**Limiting Factor Addressed**	**Geomorphic Design Criteria**
Reduce channel entrenchment	Channel entrenchment	Floodplain inundated by flows greater than bankfull discharge. Width to depth ratio less than 12. Entrenchment ratio greater than 2.2.
Increase sinuosity	Straightened channel planform Increased channel gradient	Sinuosity greater than 1.5. Meander width ratio greater than 20.
Improve pool development processes	Altered pool development processes	Low meander radii Woody debris and vegetation incorporated into bank structures
Reduce fine sediment supply	Bank erosion	Bank erosion on less than 10 percent of banks. Floodplain roughness equates to deposition/storage of sand

<u>Geomorphic Objective 1: Reduce Channel Entrenchment</u>. Channel entrenchment will be addressed by increasing the floodplain width where practical. Channel entrenchment will also be addressed to a lesser extent by decreasing channel width.

Design Criteria for Geomorphic Objective 1: Design criteria for reducing entrenchment are derived from typical cross section geometry for the likely historical stream type for Blacktail

Creek. Cross section criteria for E stream types include width to depth ratio greater than 12 and entrenchment ratio greater than 2.2 (Rosgen and Silvey 1996). Design criteria are based incipient floodplain flooding at bankfull discharge corresponding to approximately the 1.5-year recurrence interval discharge.

Geomorphic Objective 2: Increase Sinuosity. The straightened channel planform and increased channel gradient will be addressed by reconstructing a meandering channel where feasible.

Design Criteria for Geomorphic Objective 2: Design criteria for increasing sinuosity are derived from typical planform geometry for the likely historical stream type for Blacktail Creek. Criteria for E stream types include sinuosity greater than 1.5 and meander width ratio greater than 20 (Rosgen and Silvey 1996).

Geomorphic Objective 3: Improve Pool Development Processes. Pool development processes will be addressed by modifying channel morphology and adding woody debris to the channel.

Design Criteria for Geomorphic Objective 3: Channel morphology will be modified to be an E stream type (Rosgen and Silvey 1996). Streambank treatments will include woody debris to promote scour and pool development.

Geomorphic Objective 4: Reduce Fine Sediment Supply. Fine sediment supply will be reduced by reducing bank erosion rates and increasing sediment storage potential on the floodplain.

Design Criteria for Geomorphic Objective 4: Design criteria for reducing fine sediment supply include addressing bank erosion mechanisms such as altered morphological conditions, sparse vegetation bank cover and land use such that bank erosion is limited to less than 10 percent of the total bank length (USFWS 1995). In addition, floodplain roughness will be increased in order to provide hydraulic conditions that deposit and store sand on floodplain surfaces.

3.2 Vegetation Objectives and Conceptual Design Criteria

Vegetation objectives provide guidance for addressing riparian conditions and ecological function. In addition, vegetation objectives support aquatic habitat objectives and integrate with the geomorphic objectives described in previous sections. Table 3-2 provides a summary of vegetation objectives, limiting factors and conceptual design criteria. Addition detail is provided in the following sections.

Table 3-2. Summary of vegetation objectives, limiting factors and conceptual design criteria.

Vegetation Objective	Limiting Factor Addressed	Vegetation Design Criteria
Expand width of floodplain	Insufficient riparian buffer	Connected floodplain area is expanded to width capable of supporting desired range of riparian ecological functions (min. 50 feet total width).
Increase woody vegetation on streambanks	Insufficient riparian buffer	Streambanks are reconstructed at elevations that support conditions for desired vegetation communities. Streambanks are reconstructed using native, living plant material and biodegradable materials such as woody debris and coir.
Conserve existing high quality riparian vegetation	Insufficient riparian buffer	Preserve existing areas with high quality, native riparian vegetation.
Restore floodplain connectivity and topographic diversity	Lack of floodplain connection	Floodplain is constructed to connect with the channel at flows greater than bankfull discharge. Floodplain includes diverse topographic features including swales and wetlands.
Restore diverse riparian vegetation communities	Insufficient riparian buffer Lack of floodplain connection	Floodplain includes woody debris and other roughness features. Floodplain includes diverse topographic features including swales and wetlands. Floodplain is actively revegetated with diverse mix of native species and planted stock is protected from browse and herbivory and maintained in the short-term.
Reduce invasive species	Invasive species	Site specific weed management is integrated with on-going city weed management programs

<u>Vegetation Objective 1: Expand Width of Floodplain</u>. Floodplain width will be expanded wherever feasible by excavating increased floodplain area.

Design Criteria for Vegetation Objective 1: Design criteria for expanding floodplain width focuses on creating sufficient area for desired riparian vegetation communities to develop and support a wide range of ecological functions. A generally accepted width for riparian buffers to provide many functions such as filtering runoff, providing a habitat corridor and providing flood water retention is 50 feet (25 feet on each side of the stream) (Lee et al. 2004); therefore, this is the minimum desired width for floodplain expansion in terms of riparian function.

<u>Vegetation Objective 2: Increase Woody Vegetation on Streambanks.</u> Woody vegetation will be increased on streambanks by installing streambank structures that integrate living woody vegetation.

Design Criteria for Vegetation Objective 2. Design criteria for increasing woody vegetation on streambanks include integration of living woody vegetation in all streambank structures. Design criteria also call for the use of biodegradable materials in streambank structures such as woody material including brush, logs and rootwads or fabrics made from biodegradable fibers such as coir. To maximize desired ecological functions, streambank treatments should be designed to provide a stable growing environment for desired woody vegetation to establish along and within the channel margin.

<u>Vegetation Objective 3: Conserve Existing High Quality Riparian Vegetation.</u> Where present, existing high quality riparian vegetation will be conserved.

Design Criteria for Vegetation Objective 3. Design criteria for conserving existing high quality vegetation focus on identifying areas that currently support native, self-sustaining riparian vegetation communities. These areas are supported by existing site conditions and provide a range of desired ecological functions including streambank stability, overhanging vegetation, woody debris recruitment potential, runoff filtration, and habitat corridors.

<u>Vegetation Objectives 4: Restore Floodplain Connectivity and Topographic Diversity</u>. Floodplain connectivity will be restored by constructing floodplain areas connected to the Blacktail Creek channel (located at our near bankfull elevation).

Design Criteria for Vegetation Objective 4. Where feasible, the floodplain will be expanded and lowered to an elevation that connects hydrologically to the floodplain. To accomplish this, the floodplain will lowered to connect with the existing Blacktail Creek channel. The new floodplain will incorporated features such as depressions (swales) and wetlands to further increase hydrologic connectivity between the channel and the floodplain.

<u>Vegetation Objective 5: Restore Diverse Riparian Vegetation Communities</u>. Diverse riparian vegetation communities will be restored by creating the conditions necessary for development and maintenance of a diverse mosaic of native riparian vegetation communities.

Design Criteria for Vegetation Objective 5. Riparian vegetation communities require a relatively high ground water table, connectivity with the channel and a moderate degree of soil stability to establish. Many of these conditions will be met by implementing design criteria for Vegetation Objective 4. However, additional design criteria are required to achieve this objective. Woody debris and microtopography should be incorporated into constructed floodplain surfaces to provide short-term soil stability and microsites for establishing vegetation. Diverse topography should be integrated into constructed floodplain surfaces to ensure diverse conditions are created across the floodplain to support a wide range of vegetation communities. The primary topographic features will include small depressions or swales and larger depressions or wetlands. Swales are of varying sizes but generally with a shallow depth no greater than 1 foot below the floodplain surface. Wetlands are also of varying size, but are typically larger than swales and deeper in depth. The size, location and depths of wetland features will depend on their desired function. For lower Blacktail Creek, wetlands will serve a number of functions including: habitat, water storage, and some will serve as treatment areas for point source returns to Blacktail Creek. The location and design of treatment wetlands will need to be refined as additional data become available on the nature and sources of potential pollutants. Active revegetation will be required to rapidly establish desired vegetation. Design criteria applicable to active revegetation include: planting of a diverse mix of native riparian species; seeding with a diverse mix of native riparian and upland species; protection of planted woody vegetation from browse and herbivory, primarily deer and beaver; and short-term maintenance of planted and seeded vegetation is conducted including weed control and supplemental irrigation as needed.

Vegetation Objective 6: Reduce Invasive Species. Invasive species, including noxious weeds, will be reduced or prevented by implementing weed control strategies specific to each project reach.

Design Criteria for Vegetation Objective 6. Actions implemented to achieve Vegetation Objective 5 will help prevent weed infestations and control weed densities long-term. The City and County of Butte-Silver Bow currently implement weed control along Lower Blacktail Creek targeting noxious weeds. Control of weeds in restored areas should be closely integrated with the City and County. Design criteria to reduce invasive species also consider control or eradication of non-noxious weeds that may become invasive in restored riparian areas such as reed canarygrass and non-native willows and conifers.

3.3 Aquatic Habitat Objectives and Conceptual Design Criteria

Aquatic habitat objectives provide guidance for addressing biological function and aquatic species life history needs. In addition, aquatic habitat objectives integrate with the vegetation and geomorphic objectives described in previous sections. Table 3-3 provides a summary of aquatic habitat objectives, limiting factors and conceptual design criteria. Addition detail is provided in the following sections.

Table 3-3. Summary of aquatic habitat objectives, limiting factors and conceptual design criteria.

Aquatic Habitat Objective	Limiting Factor Addressed	Aquatic Habitat Design Criteria
Maintain clean gravel substrate	Fine sediment accumulation	Bankfull channel shear stress capable of mobilizing medium gravel up to 0.5 inches. Gravel embedded with less than 20 percent fines.
Increase pool frequency and enhance pool quality	Shallow, infrequent pools	70 to 100 pools per mile. Residual pool depths greater than 3 feet deep with good cover.
Improve habitat complexity	Lack of habitat diversity	Create riffle-pool sequences with at least 40 percent pools Greater than 20 pieces of wood per mile Connect off-channel habitats
Improve streambank cover	Warm water temperatures	Streambanks treatments include vegetation component
Improve water quality	Poor water quality	Sources are removed or treated before entering the channel

Aquatic Habitat Objective 1: Maintain Clean Gravel Substrate. Medium gravel is present in Blacktail Creek and can provide preferred substrate for native aquatic species. Preferred substrate conditions will be provided by maintaining medium gravel mobility and flushing embedded fines from the interstitial spaces within the gravel.

Design Criteria for Aquatic Habitat Objective 1: Design criteria for maintaining clean gravel substrate is derived from hydraulic conditions required to mobilize medium gravels of approximately 0.5 inches during bank discharge.

Aquatic Habitat Objective 2: Increase Pool Frequency and Enhance Pool Quality. Pool frequency will be increased to be consistent with standards for properly functioning habitat for sustainable fish populations. Deep pools will provide suitable holding habitat and will provide woody debris for cover.

Design Criteria for Aquatic Habitat Objective 2: Proposed pool frequency is 70 to 100 pools per mile as derived from measured pool frequencies in properly functioning watersheds (USFS 1994). Design criteria for pool quality are residual pool depth greater than 3 feet with good cover (WDNR 1993).

Aquatic Habitat Objective 3: Improve Habitat Complexity. Habitat complexity will be improved by establishing riffle-pool sequences, increasing woody debris availability and connecting off-channel habitats.

Design Criteria for Aquatic Habitat Objective 3: The riffle-pool ratio will be appropriate for an E-stream type with pools representing at least 40 percent of the habitat features. Woody debris will be at least 20 pieces per mile (USFWS 1995). Off channel habitats including wetlands, alcoves and side channels will be connected to the main channel.

Aquatic Habitat Objective 4: Improve Streambank Cover. The channel margins will offer streambank cover including woody vegetation and woody debris. Streambank treatments will address temperature requirements for native aquatic species by providing shade and reducing solar exposure to the water surface.

Design Criteria for Aquatic Habitat Objective 4: Streambank treatments will include a woody vegetation component in order to develop streambank cover and increase shade.

Aquatic Habitat Objective 5: Improve Water Quality. Contamination sources will be identified and quantified.

Design Criteria for Aquatic Habitat Objective 5: Sources of contamination will be treated before entering the channel or will be isolated from the channel. Design criteria applicable to treatment of potential contaminants prior to entering the channel are described under Vegetation Objective 5.

4 Restoration Strategies and Treatments

This section describes a range of conceptual restoration actions developed with guidance from restoration objectives described in Section 3 that will address limiting factors identified in Section 2. Restoration actions are described conceptually whereby emphasis is placed on developing specific strategies and treatments that address geomorphic, vegetation and aquatic habitat impairments described in the limiting factors. Example applications of proposed restoration treatments are provided. Potential layouts for restoration actions based on actual site conditions are provided in Section 5.

4.1 Conservation

Conservation is a restoration strategy applied to protect existing areas that exhibit, or have potential to exhibit, high quality ecological function. Areas proposed for conservation typically display few limiting factors, and those factors that exist usually can be addressed with passive treatments such as changes in land use or weed control. Conservation can be compatible with recreational uses.

4.2 Revegetation

Revegetation is a restoration strategy applied to moderately stable areas with few geomorphic limiting factors or in conjunction with other restoration strategies such as wetland construction, streambank reconstruction or floodplain construction. Revegetation is a viable strategy for improving aquatic and terrestrial habitat in the longer term through gradual development of a riparian buffer. Revegetation encompasses a range of treatments including:

- Planting
- Seeding
- Plant protection
- Irrigation
- Weed management

Revegetation is not suitable for areas prone to high disturbance or areas with incompatible land uses such as grazing or agriculture. Revegetation strategies should only be implemented in areas where adequate site preparation is completed. Site preparation includes a wide range of treatments including weed control, grading to appropriate elevations, incorporating surface roughness, and soil placement or amendments. Most of these treatments are included as part of other restoration strategies such as floodplain construction.

4.2.1 Planting

Planting of nursery grown plant material is a strategy used to promote rapid vegetation establishment along the channel and within newly constructed floodplains. Planting can consist of installation of a wide range of container size plants and for floodplains typically includes both native tree and shrub species and herbaceous wetland species. A diverse mix of trees and shrubs are planted in select areas of the new floodplain, typically along streambanks and within floodplain swales, to develop a range of riparian vegetation communities based on expected floodplain hydrology. Wetland vegetation such as sedges and rushes are also planted in depression features within the floodplain (swales and wetlands) and occasionally along streambanks. The species planted at the site should be determined during the design phase and consist of native riparian species that represent an early successional stage of the desired vegetation communities. Planting should be done in the spring of fall when temperatures are moderate and soil moisture is relatively high.

Planting helps address a range of geomorphic, aquatic and vegetation limiting factors. Planting helps achieve geomorphic objectives by providing bank and floodplain stability via the extensive root system produced by riparian plants and by providing roughness to slow waters during higher flows and minimize erosion along the banks. Planting woody vegetation will also help improve streambank cover. The shade provided by streambank vegetation also addresses aquatic habitat objectives by keeping waters cooler and contributing detritus and nutrient sources to the channel. Planting will also help restore diverse native vegetation communities. Selecting native species for planting provides more self-sustaining and diverse vegetation communities and also prevents weed establishment by colonizing the available space.

4.2.2 Seeding

Seeding is a strategy used to promote rapid vegetation establishment on newly constructed surfaces or disturbed areas. Seeding can provide species diversity to a site for relatively low cost. Multiples seed mixes may be required and should be determined during the design phase. The species included in each seed mix should take into account: desired vegetation community, germination timing and growth period, growth form, rooting depth. In general, seed mixes should include species that have varying rooting depths and will occupy a wide range of habitats. To ensure quick, long-lasting vegetation establishment a two-stage seed mix should be used. The two-stage seed mix includes two components: a mix of quick germinating species (nurse crop or cover crop) that will provide immediate cover to limit colonization by invasive species and a mix of long-term, desired species that may not germinate immediately because they may require a stratification period.

Seeding helps address a range of geomorphic, aquatic and vegetation limiting factors. Establishing native vegetative cover on newly created streambank and floodplain surfaces is essential for maintaining soil stability and preventing weed infestations. Planting will establish native vegetation in portions of the floodplain, but seeding is the primary mechanism for stabilizing soil. Seeding helps achieve geomorphic objectives by providing streambank and floodplain stability through root system development and surface cover. Vegetation established from seed can help prevent weed infestations. The vertical (soil depth) and temporal diversity of the seeded species can prevent weeds from establishing by occupying available habitats that weeds may otherwise occupy.

4.2.3 Plant Protection

Most riparian woody plants are highly palatable and are targeted by a number of wildlife species. Protecting planted vegetation for a minimum of five years after implementation is necessary to allow vegetation to establish without stresses from browse and animal damage. In an urbanized area such as lower Blacktail Creek plant protection measures will also offer some protection from vandalism and other human disturbances. The two primary plant protection treatments for the project area include fencing and individual plant protectors. Individual plant protectors are installed around plants that are most desirable to beavers and wildlife or around plants where fencing is not feasible, such as those located on streambanks. Fencing entire areas for protection is often more affordable, requires less maintenance and is less aesthetically intrusive than individual protectors. Fencing can also protect large seeded areas during the establishment period. The material used to construct plant protection measures should take into consideration the expected degree and type of animal damage expected. . For protection against deer and elk, rigid plastic mesh may be sufficient. For protection against beaver, metal fencing is typically more effective.

4.2.4 Irrigation

Successful revegetation typically requires supplemental irrigation for two to three years following planting while the root systems of the plants establish. Supplemental irrigation may only be required in select areas, such as higher surfaces in the floodplain, but in droughty years it is likely that all plantings will require at least one round of irrigation. When required, irrigation should consist of a minimum of 5 gallons of water applied slowly to each plant.

4.2.5 Weed Management

Weed management is an important strategy to implement in all areas where construction activities are proposed. Weed management strategies can be implemented prior to construction, during construction and after construction. Prior to construction treating existing weed infestations will reduce the amount of weed seed spread during construction. During construction best management practices (BMPs) should be implemented that prevent the spread of weeds such as cleaning of equipment prior to arriving on site; ensuring equipment avoids tracking through weedy areas outside of construction limits during construction; and ensuring any imported material is weed and weed seed free. After construction, a specific weed management plan should be developed and implemented in coordination with the City and County to monitor and treat target weed species.

4.3 Streambank Structures

Installation of streambank structures is a strategy applied to the channel margins in order to establish vegetation, enhance aquatic habitat and/or improve bank stability. Depending on the application, streambank structures may be localized installations or contiguous reach-scale treatments. Streambank structures used for restoration may be deformable whereby the structures serve a temporary purpose to establish vegetation. Streambank structures used for bank stability may be more permanent in order to manage risk by protecting infrastructure or preventing channel migration. Potential streambank treatments for lower Blacktail Creek include:

- Bioengineering
- Fascines
- Woody debris jams
- Aquatic habitat enhancement

4.3.1 Bioengineering

Bioengineering is a category of streambank treatments consisting of live plant material and biodegradable coconut fiber fabrics (coir). Bioengineering treatments create bank conditions that support the establishment of woody vegetation. Figure 4-1 shows a conceptual cross section view of a typical bioengineering streambank treatment called a vegetated soil lift. Figure 4-2 shows example photos of bioengineering streambank structures.

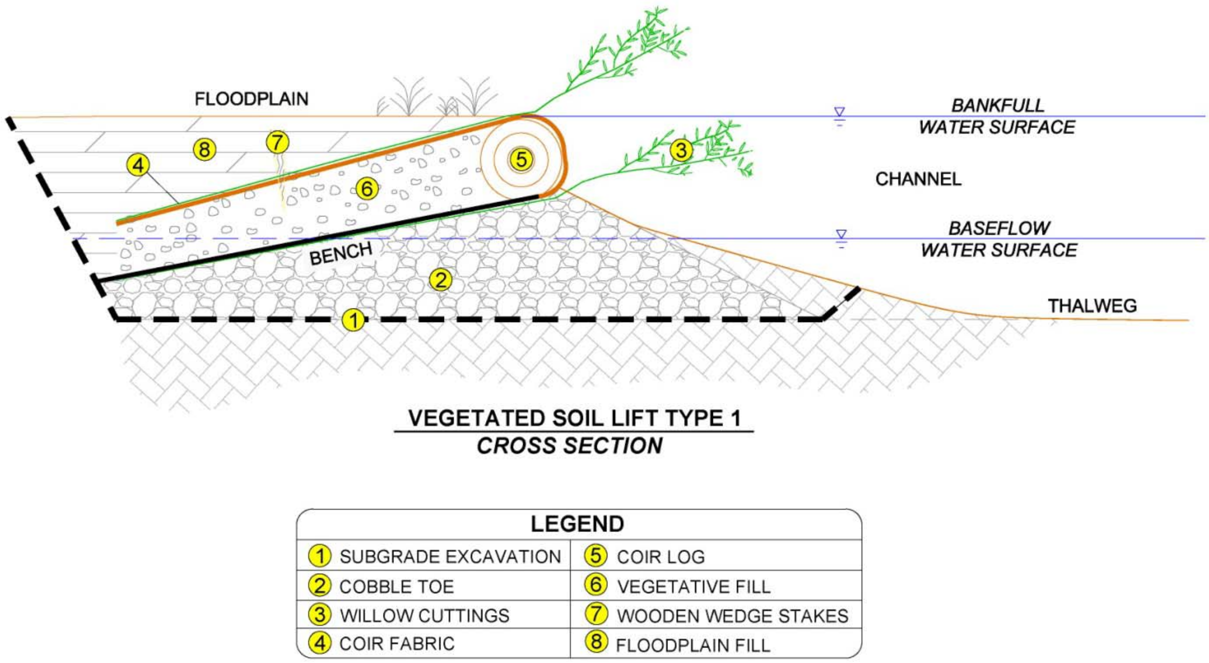

Figure 4-1. Conceptual cross section of a vegetated soil lift bioengineering treatment.

Purpose: The purpose of bioengineering is to provide temporary bank protection in order to allow bank vegetation to become established.

Placement Criteria: Bioengineering is suitable for low to moderate stress banks with low curvature.

Aquatic Habitat Objectives Addressed: Bioengineering promotes the rapid development of woody vegetation on streambanks. Woody vegetation on the streambank provides instream cover, shade for temperature reduction, woody debris recruitment over time, refuge during high flows, organic matter inputs, and supports emerging aquatic insects.

Vegetation Objectives Addressed: Bioengineering promotes rapid development of desired woody vegetation. The development of woody vegetation along the streambank provides floodplain stability, and provides a source of seeds and vegetative material to promote the establishment of desired vegetation communities in the floodplain.

Geomorphic Objectives Addressed: Bioengineering structures are composed of biodegradable fabrics and native materials. Short-term streambank stability provided by fabric and long-term stability provided by rooted woody vegetation supports desired disturbance regimes and relatively low erosion rates.

Supplemental Information: Bioengineering provides conditions along the channel banks that are suitable for growing woody riparian vegetation. Bioengineering is built on a gravel or cobble toe. Short term structure performance is dependent on toe stability as well as smooth transitions to stable upstream and downstream tie-in points. Placement of healthy woody vegetative cuttings that are placed to a depth to ensure contact with the water table throughout the growing season is critical, and long term structure performance is dependent on development of dense rootmass.

Figure 4-2. Example photographs of bioengineering streambank structures.

4.3.2 Fascines

Fascines are a category of streambank structures consisting of brush bundles and live plant material. Depending on the application and availability of materials, fascines may also include woody debris and/or wetland sod mats. Figure 4-3 shows a conceptual cross section view of a typical fascine streambank treatment called a sod and brush fascine.

Figure 4-4 shows example photos of a fascine streambank structures.

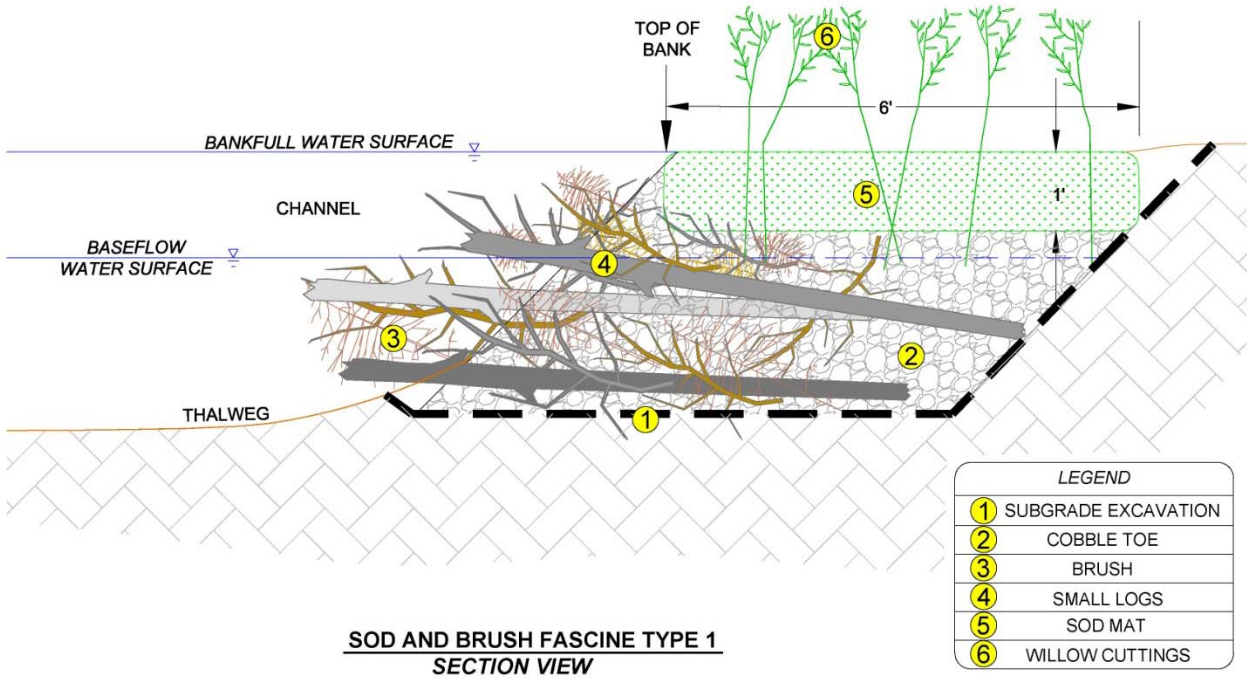

Figure 4-3. Conceptual cross section of a sod and brush fascine.

Purpose: The purpose of fascine treatments is to create a rough, complex and vegetated bank margin.

Placement Criteria: Fascines are designed to function on moderate stress banks with low to moderate curvature.

Aquatic Habitat Objectives Addressed: Brush and vegetation provide cover and hydraulic complexity. Fascines promote the rapid development of woody vegetation on streambanks. Woody vegetation on the streambank provides instream cover, shade for temperature reduction, woody debris recruitment over time, refuge during high flows, organic matter inputs, and supports emerging aquatic insects.

Vegetation Objectives Addressed: Fascines promote rapid development of desired vegetation communities. The structure surface provides microsites to support natural recruitment of early successional species of desired vegetation community types. The elevation of the structure allows floodplain connection.

Geomorphic Objectives Addressed: Fascines are composed of native materials. Fascines provide bank margin roughness similar to natural bank conditions. Structure stability supports desired disturbance regimes and relatively low erosion rates.

Supplemental Information: Fascines employ native materials to provide preferred habitat conditions along streambanks. The structure is built on a cobble and wood toe. Structure performance is dependent on toe stability as well as smooth transitions to stable upstream and downstream tie-in points. Maintaining adequate backfill ballast is critical to counteract buoyancy of wood. Placement of wood at or below bankfull and placement of healthy woody vegetation in contact with the water table throughout the growing season is critical for rapid vegetation establishment.

Figure 4-4. Examples of fascine streambank structures.

4.3.3 Woody Debris Jams

Woody debris jams are a category of streambank structures consisting of logs and brush buried into the streambank and projecting out into the channel. Woody debris jams are intended to emulate natural accumulations of woody debris along the bank margins. Figure 4-5 shows a conceptual cross section view of a woody debris jam structure. Figure 4-6 shows example photos of small woody debris jams.

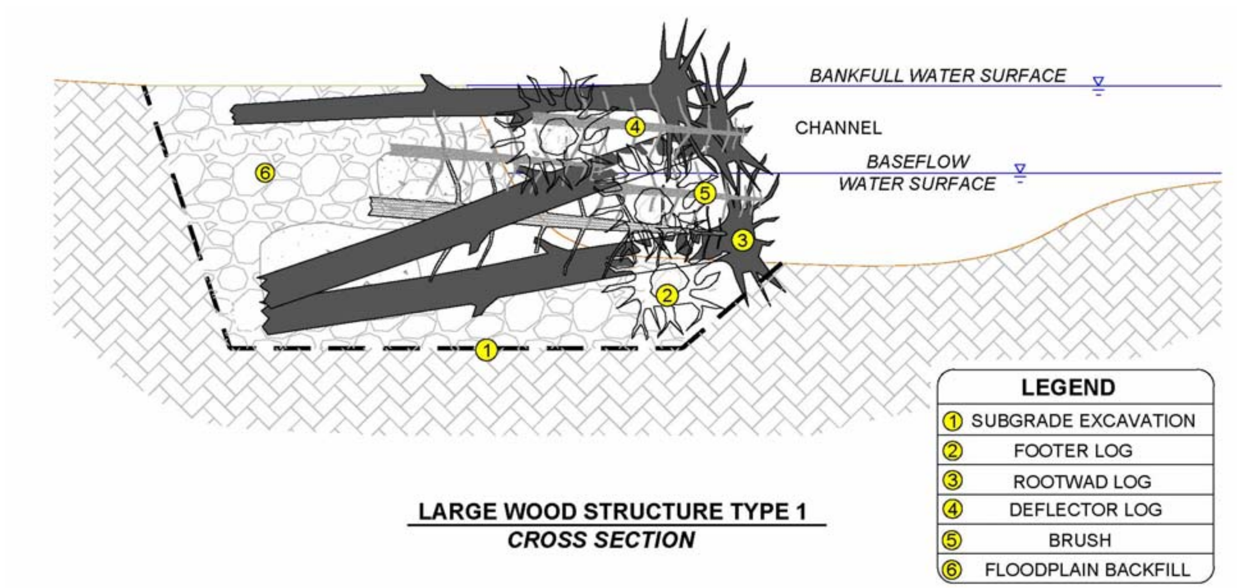

Figure 4-5. Conceptual cross section of a woody debris jam.

Purpose: The purpose of this structure is to create hydraulic conditions that maintain a deep pool.

Placement Criteria: This structure is designed to function on a high stress bank with moderate to high curvature.

Aquatic Habitat Objectives Addressed: This structure creates complex hydraulics such as eddies and secondary flow circulation. Wood provides in-stream cover and shade for temperature reduction. Deep pools improve hyporheic flow for temperature management. Residual pools provide low-velocity holding habitat and over-wintering habitat.

Vegetation Objectives Addressed: Creates stable conditions to support development of desired vegetation community types.

Geomorphic Objectives Addressed: This structure supports pool development processes. Pools provide planform variability and foster point bar development. The structure is composed of native materials.

Supplemental Information: Woody debris jams provide temporary bank protection by re-directing flow away from the bank and dissipating flow energy into the riverbed. The structure creates complex hydraulics and turbulence, which require attention to how the structure is tied in to existing features or other bank structures. Maintaining adequate backfill ballast is critical to counteract buoyancy of wood. Structure performance is dependent on structure size and use of adequately-sized wood with intact rootwads. Excavation of the pool in conjunction with the structure is recommended. The structure will tend to recruit additional woody debris. Over time, the structure will decompose or become abandoned. Integrating mature shrub transplants or plantings on the floodplain surface behind this structure creates rooting structure for long term bank stability.

Figure 4-6. Examples of woody debris jams.

4.3.4 Aquatic Habitat Enhancement Structures

Aquatic habitat enhancement structures are a category of streambank and channel structures used to address aquatic habitat limiting factors. Aquatic habitat enhancement treatments can be used to create hydraulic complexity, establish cover, alter substrate conditions or promote pool development. Structures are typically constructed from native materials including logs, brush, clump transplants and boulders. Types of aquatic habitat enhancement structures include log weirs, log vanes, boulder clusters and various other configurations using native materials. Figure 4-7 contains example photographs of habitat enhancement structures.

Figure 4-7. Examples of aquatic habitat enhancement structures including boulder clusters and log weirs.

4.4 Wetlands

Wetlands are depressional or low-lying features with standing water or saturated soils for a portion of the growing season sufficient to support wetland vegetation such as willows, sedges and rushes. Wetlands provide a wide range of ecological functions such as water quality improvement, flood attenuation and habitat for both terrestrial and aquatic organisms. Including wetlands in the restoration design will help address a number of limiting factors including poor water quality, insufficient riparian buffer and lack of habitat diversity. Two types of wetlands are proposed for the project area – floodplain wetlands and treatment wetlands. Floodplain wetlands include existing wetlands to be conserved through restoration actions or wetlands to be constructed in the new, lower floodplain that will provide ecological benefits such as habitat, species diversity and flood attenuation. Treatment wetlands will provide similar ecological benefits but will be located and oriented during the design phase to intercept specific point and non-point sources of pollutants.

In wetlands, water quality improvement is achieved by nutrient uptake via plant tissue and also through microbial nutrient cycling including processes like nitrification and denitrification. The dense, rhizomatous root network of wetland plants provides ideal habitat for soil microbes. In wetlands with various water depths both anaerobic and aerobic environments can be present. These various environments support different nutrient cycling processes. In addition to nutrient uptake, plants also provide surface area for particles of sediment to adhere to and the ponded or slow moving waters allows fines to settle out of the water column. The off-channel depressional characteristics of wetlands allow these areas to store excess water during high flows and large rain events. Water is then slowly released into the ground, filtering additional pollutants in the process and recharging groundwater well after the rains or high flows have ceased.

Visually, floodplain wetlands and treatment wetlands will be similar, both supporting wetland vegetation. However, a wetland designed specifically to enhance water quality improvement may have design elements that maximize functions such as water retention or specific nutrient cycling pathways. These design elements might include the ability to control water levels, specific layers of soil or substrate, or an under layer of pea gravel providing an anaerobic environment. Both wetland types treat water quality and store excess water during high flow or rain events. Exact design criteria for treatment wetlands should be developed during the design process and determined by the specific pollutants to be treated.

Figure 4-8. Examples of constructed wetlands in floodplains (photo left) and constructed for treatment of high levels of nutrients (photo right).

4.5 Floodplain Excavation

Floodplain excavation is a strategy applied to areas with altered channel morphology in order to improve floodplain connection. Floodplain excavation increases width of the stream corridor thus allowing increased channel sinuosity and riparian vegetation establishment. Floodplain excavation results in a lower floodplain surface relative to the stream channel, allowing flood flows to leave the channel during smaller, more frequent flow events. A lower, more hydrologically connected floodplain can improve channel stability by lowering high banks susceptible to erosion and by dissipating energy from flood flows.

Floodplain reconstruction is a viable strategy for improving aquatic and terrestrial habitat in the longer term through gradual development of mature riparian vegetation. Floodplain reconstruction encompasses a range of treatments including:

- Revegetation (including associated treatments described above)
- Construction of floodplain features such as wetlands and floodplain swales
- Woody debris placement and microtopography grading for short term floodplain surface roughness in the absence of vegetation
- Vegetation salvage and transplant to re-graded surfaces
- Soil amendments for improving growth media

4.5.1 Vegetation Salvage and Transplant

Plant salvage and transplant is a technique where healthy plants are harvested from areas inside the construction limits (or from nearby donor locations) and then transplanted back into the re-graded floodplain or along streambanks. This provides rapid establishment of mature vegetation on streambanks and constructed floodplain surfaces. Vegetation salvage and transplant helps address a number of limiting factors including insufficient riparian buffer, altered pool development processes, bank erosion, lack of habitat diversity and poor water quality. Salvaging native plants and sod can be a relatively inexpensive method for obtaining large, site-adapted plan stock for rapid vegetative reestablishment. Because this vegetation is typically mature it can quickly add natural vegetation function to streambanks and floodplains. Mature plants and high quality sod located within construction and grading areas should be salvaged and relocated to streambanks. Specific opportunities for vegetation salvage and transplant should be identified during the design phase.

4.5.2 Floodplain Features

Incorporating floodplain features into newly constructed floodplains is a restoration strategy that promotes floodplain diversity. Floodplain features will help address the limiting factor of having an insufficient riparian buffer. There are two main types of floodplain features proposed for new floodplain surfaces in the project area – wetlands and floodplain swales. Wetlands are described above in Section 4.4. Floodplain swales are small depression features incorporated into the floodplain that provide microsites where floodplain vegetation can establish at slightly lower elevations (closer to the water table) than adjacent floodplain surfaces. Floodplain swales also provide storage for flood water and sediment at variable flows, in addition to broadening the range of ecological niches available on the floodplain surface to support different life stages (and behaviors) of plant, bird, amphibian, and terrestrial wildlife species. To maximize diversity, floodplain swales should vary in size and depth but should not extend below the anticipated baseflow elevation.

4.5.3 Floodplain Roughness

Floodplain roughness is a strategy applied to areas within the floodplain where frequent interaction with the channel is anticipated. This treatment creates complexity and microsites on newly constructed floodplain surfaces to trap and protect seed and other plant propagules, and to provide resistance to erosion by limiting rill formation. Floodplain roughness is created using equipment to roughen the floodplain surface with microtopography and partially bury woody debris in the soil. Microtopography creates variation in the constructed floodplain surface ranging from 0.5 feet above to 0.5 feet below the design floodplain surface. The woody debris increases soil moisture retention, creates protective microsites for establishing seed and plants, and promotes soil development by introducing organic material.

4.5.4 Steep Slope Treatments

Steep slope treatments are applied to upland areas that are susceptible to surface erosion from drainage. Steep slope treatments are recommended for non-vegetated or disturbed slopes that are steeper than 3:1. Steep slope treatments include:

- Mesh netting or coir fabric placed on the face of the slope and anchored with stakes
- Terracing and placement of wattles
- Riprap and retaining walls for slopes greater than 1.5:1

4.5.5 Soil Amendments

Soils are one of the most important factors that can influence plant survival and establishment of desired vegetation communities. Some of the more important characteristics of soils that can affect plant health and survival include: soil texture, pH, organic matter, salinity, compaction and the presence of contaminants such as metals or residual herbicides or pesticides. Typically, native soils with no known or suspected contaminants that currently support native riparian vegetation are adequate to support planted, seeded and naturally recruited vegetation on the floodplain over time. Because the soils in most of the project area currently support native riparian vegetation it is assumed that soil texture, pH, and organic matter are sufficient and compaction is not present to a degree that precludes the establishment of desired vegetation and import of suitable growth media will not be required. It is possible that contaminants are present in the soil in some of the project reaches and a soil investigation should be completed during the design phase to verify existing soils are suitable as growth media or whether soil amendments will be required. The type of soil amendment needed will depend on this investigation.

4.6 Channel Reconstruction

Channel reconstruction is a strategy applied to areas with altered stream function through modification of channel geometry. Modification of channel geometry changes stream hydraulics, which can have an effect on depth, velocity and substrate components of aquatic habitat. Channel reconstruction is also a viable strategy for improving stream stability and establishing riparian vegetation. Channel reconstruction encompasses a range of treatments including:

- Channel shaping (modifying cross section geometry and width-depth ratio)
- Channel realignment (modifying planform geometry and channel location)
- Pool-riffle sequences (modifying profile geometry and longitudinal bedforms)
- Revegetation (including treatments described previously)
- Streambank structures (including treatments described previously)
- Floodplain excavation (including treatments described previously)

Channel reconstruction may also include reconstruction of the stream bed, whereby riffles are built from imported streambed material. Riffle construction can provide vertical streambed stability in new channel segments. In addition, riffle construction can introduce appropriate spawning substrate for focal aquatic species.

Figure 4-9. Examples of channel reconstruction (photo left) and pool-riffle sequences (photo right).

4.7 Summary of Restoration Strategies and Treatments

Table 4-1 provides a summary of potential restoration strategies for addressing limiting factors on lower Blacktail Creek. Ability to address site specific geomorphic, vegetation and aquatic habitat limiting factors is described for each restoration strategy.

Table 4-1. Summary of restoration strategies for addressing limiting factors on lower Blacktail Creek.

Restoration Strategy	Limiting Factors Addressed	Limitations
Conservation	Land use	Conservation does not directly address most limiting factors; however, conservation may improve riparian conditions in the long term. Success is dependent on selection of sites with high natural recovery potential. May provide opportunities for future restoration.
Revegetation	Altered pool development Bank erosion Insufficient riparian buffer Invasive species Fine sediment accumulation Lack of habitat diversity Warm water temperatures Poor water quality	Revegetation does not directly address limiting factors related to channel geometry such as channel entrenchment, straightened planform, or floodplain connection. Success is dependent upon routine maintenance and adaptively managing site conditions. Revegetation may improve aquatic habitat conditions in the long term.
Streambank	Altered pool	Streambank structures do not directly address limiting factors

Table 4-1. Summary of restoration strategies for addressing limiting factors on lower Blacktail Creek.

Structures	development Bank erosion Shallow, infrequent pools Lack of habitat diversity Warm water temperatures	related to channel geometry such as channel entrenchment, straightened channel planform, or floodplain connection. Success is dependent upon reach-scale stability and inclusion of vegetation components.
Wetlands	Fine sediment accumulation Insufficient riparian buffer Lack of habitat diversity Poor water quality	Wetlands do not directly address stream channel function or in-stream aquatic habitat.
Floodplain Excavation	Floodplain connection Insufficient riparian buffer Fine sediment accumulation Lack of habitat diversity Poor water quality	Success is dependent upon use in conjunction with other treatments including conservation and revegetation.
Channel Reconstruction	Channel geometry Altered pool development Bank erosion Fine sediment accumulation Shallow, infrequent pools Warm water temperatures Lack of habitat diversity	Success is dependent upon use in conjunction with other treatments including conservation, revegetation and streambank structures.

5 Restoration Alternatives

This section identifies potential locations for specific restoration actions by sub reach, summarizes the process for evaluating restoration actions, and provides a recommended layout for a preferred restoration action.

5.1 Evaluation of Alternatives

5.1.1 Alternatives for Reach BTC-11-01

Reach BTC-11-01 is located at the upstream end of the project area. The reach begins at the southern boundary of the golf course and extends 1,300 feet north to Elizabeth Warren Avenue. The landowner is the Butte County Club. This reach exhibits most, if not all, of the limiting factors described in Section 2. Restoration constraints include golf course irrigation mains, golf course fairways, infrastructure including roads and utilities, and on-going beaver activity. Opportunities exist to apply all of the recommended restoration strategies and address most of the project objectives. Feasibility considerations include channel stability and potential effects to infrastructure. Relative costs would be higher for more comprehensive restoration strategies such as floodplain excavation and channel reconstruction. Table 5-1 provides a summary of restoration alternatives for Reach BTC-11-01.

Table 5-1. Summary of restoration alternatives for Reach BTC-11-01.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve existing high quality riparian vegetation	Land use Ability to achieve goals and objectives	Low
Revegetation	Beaver Golf course fairways Land use	Increase streambank vegetation Restore diverse riparian vegetation Reduce invasive species	Floodplain connection	Low
Streambank structures	Beaver	Pools Cover Bank erosion Complexity	Steep banks Disturbance	Moderate
Wetlands	Water line and gas line	Improve water quality Reduce fine sediment supply	Type and source of pollutants	Moderate
Floodplain excavation	Golf course irrigation mains and fairways Water line and gas line	Floodplain connection	Excavation disposal Effects to infrastructure	High
Channel reconstruction	Water line and gas line Beaver	Entrenchment Sinuosity Substrate Pools Complexity	Channel stability Water management	High

5.1.2 Alternatives for Reach BTC-11-02

Reach BTC-11-02 begins at Elizabeth Warren Avenue and extends 2,800 feet downstream through the golf course. The landowner is the Butte County Club. This reach exhibits several limiting factors similar to the adjacent upstream reach. Restoration constraints include golf course irrigation mains, golf course fairways, infrastructure including roads and utilities, and on-going beaver activity. Opportunities exist to apply all of the recommended restoration strategies and address most of the project objectives. Feasibility considerations include channel stability and potential effects to infrastructure. Relative costs would be higher for more comprehensive restoration strategies such as floodplain excavation and channel reconstruction. Table 5-2 provides a summary of restoration alternatives for Reach BTC-11-01.

Table 5-2. Summary of restoration alternatives for Reach BTC-11-02.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve existing high quality vegetation	Land use Ability to achieve goals	Low
Revegetation	Beaver Golf course fairways Land use	Weeds Shade	Floodplain connection	Low
Streambank structures	Beaver	Pools Cover Bank erosion Complexity	Steep banks Disturbance	Moderate
Wetlands	Water line and gas line	Water quality Sediment	Water chemistry	Moderate
Floodplain excavation	Golf course irrigation mains and fairways Water line and gas line	Floodplain connection	Excavation disposal Effects to infrastructure	High
Channel reconstruction	Water line and gas line Beaver	Entrenchment Sinuosity Substrate Pools Complexity	Channel stability Water management	High

5.1.3 Alternatives for Reach BTC-11-03

Reach BTC-11-03 is located at the upstream end of the project area. The reach begins near the northern end of the golf course and extends 2,300 feet north to Interstate 90. The land owners are the Butte County Club and one other undeveloped private parcel located between the Butte Country Club and Interstate 90. This reach displays moderate floodplain connectivity and moderate channel sinuosity, but stream function is affected by land use and vegetation conditions. Restoration constraints include golf course irrigation mains, golf cart paths, golf course fairways, infrastructure including utilities and on-going beaver activity. Near the middle of this reach there is a constructed pond which serves as the source of irrigation water to the golf course. The outlet of this pond is connected to Blacktail Creek. The pond outlet control structure does not appear to be a fish passage barrier; however, there is an opportunity to isolate the pond from Blacktail Creek by relocating the diversion point into the pond and installing fish screens at the diversion point and pond outlet structure.

Because stream morphology is less impaired in this reach, opportunities exist to conserve existing high quality riparian vegetation and apply passive treatments for addressing vegetation and aquatic habitat conditions. There are also opportunities to address stormwater runoff and expand the riparian buffer near the irrigation pond by removing the excavated pond spoils from the floodplain. Use of streambank structures could address poor streambank conditions on the right bank within the private parcel upstream of Interstate 90. Feasibility considerations include land use and ability to achieve goals using passive measures. Relative costs for passive restoration strategies would be low to moderate. Table 5-3 provides a summary of restoration alternatives for Reach BTC-11-03.

Table 5-3. Summary of restoration alternatives for Reach BTC-11-03.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve existing high quality vegetation	Land use Ability to achieve goals	Low
Revegetation	Beaver Golf course fairways	Weeds Shade	Floodplain connection	Low
Streambank structures	Beaver	Pools Cover Bank erosion Complexity	Disturbance to existing vegetation and habitat	Moderate
Wetlands	Golf course irrigation mains and fairways Water line and gas line	Improve water quality Sediment	Effects to irrigation pond operations	Moderate
Floodplain excavation	Golf course irrigation mains and fairways Water line and gas line	Floodplain connection	Disturbance to existing vegetation and habitat	High
Channel reconstruction	Water line and gas line	Entrenchment Sinuosity Substrate Pools Complexity	Disturbance to existing vegetation and habitat	High

5.1.4 Alternatives for Reach BTC-12-01

Reach BTC-12-01 is located in the middle of the project area. The reach begins just north of Interstate 90 and extends 2,300 feet west. Landownership is Butte Silver Bow County. This reach is highly altered but supports dense riparian vegetation immediately along the channel. Basin Creek enters the reach from the south and appears to contribute a significant supply of sand to Blacktail Creek. Through this reach Blacktail Creek is straightened and entrenched, and the narrow floodplain is confined between the Interstate and Father Sheehan Park, a recreational area with paved walkways, ball fields and tennis courts. As such, restoration constraints in this reach preclude opportunities to improve conditions without causing significant disturbance to park lands and existing vegetation along the stream corridor. Table 5-4 provides a summary of restoration alternatives for Reach BTC-12-01.

Table 5-4. Summary of restoration alternatives for Reach BTC-12-01.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve existing high quality riparian vegetation	Ability to achieve goals	Low
Revegetation	Land use Beaver	Weeds Shade	Floodplain connection	Low
Streambank structures	Beaver	Pools Cover Bank erosion Complexity	Disturbance to existing vegetation and habitat	Moderate
Wetlands	Land use	Contamination Sediment	Hydrology	Moderate
Floodplain excavation	Land use Interstate 90	Floodplain connection	Disturbance to existing vegetation and habitat	High
Channel reconstruction	Land use Interstate 90 Beaver	Entrenchment Sinuosity Substrate Pools Complexity	Disturbance to existing vegetation and habitat	High

5.1.5 Alternatives for Reach BTC-12-02

Reach BTC-12-02 is located in the middle of the project area. The reach begins at the west boundary of Father Sheehan Park and extends 900 feet west to Harrison Avenue. Landownership is private commercial. This reach is highly altered but supports dense riparian vegetation. A paved trail parallels the creek. Numerous outfall drains were identified in this reach. The channel is straightened and entrenched, and the narrow floodplain is confined between the Interstate and commercial establishments. As such, restoration constraints in this reach preclude opportunities to improve conditions without causing significant disturbance to existing vegetation along the stream corridor. Table 5-5 provides a summary of restoration alternatives for Reach BTC-12-02.

Table 5-5. Summary of restoration alternatives for Reach BTC-12-02.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve existing high quality vegetation	Ability to achieve goals	Low
Revegetation	Land use Beaver	Weeds Shade	Floodplain connection	Low
Streambank structures	Beaver	Pools Cover Bank erosion Complexity	Access to the streambanks Disturbance to existing vegetation and habitat	Moderate
Wetlands	Land use	Contamination Sediment	Hydrology Access	Moderate
Floodplain excavation	Land use Interstate 90	Floodplain connection	Access Disturbance to existing vegetation and habitat	High
Channel reconstruction	Access to the streambanks Beaver	Entrenchment Sinuosity Substrate Pools Complexity	Access Disturbance to existing vegetation and habitat	High

5.1.6 Alternatives for Reach BTC-12-03

Reach BTC-12-03 is located between Harrison Avenue and Oregon Avenue. This reach is well vegetated and Blacktail Creek is bordered by paved trails and private land. The floodplain is moderately connected except for a few areas of fill at abandoned road crossings on Pinon Avenue and Johns Avenue. In general, the channel is wide and shallow through this reach, and lacks high quality pools and clean substrate. Potential alternatives include channel shaping, floodplain excavation (road reclamation) and conservation. Conservation measures could provide an opportunity to explore future restoration opportunities in collaboration with adjacent landowners. Table 5-6 provides a summary of restoration alternatives for Reach BTC-12-03.

Table 5-6. Summary of restoration alternatives for Reach 12-03.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve high quality vegetation	Ability to achieve goals Private land	Low
Revegetation	Land use Beaver	Weeds Shade	Floodplain connection	Low
Streambank structures	Land use Beaver	Pools Cover Bank erosion Complexity	Access to the streambanks Disturbance to existing vegetation and habitat	Moderate
Wetlands	Land use	Contamination Sediment	Access Hydrology	Moderate
Floodplain excavation	Land use Interstate 90	Floodplain connection	Access Disturbance to existing vegetation and habitat	High
Channel reconstruction	Access to the streambanks Beaver	Entrenchment Sinuosity Substrate Pools Complexity	Access Disturbance to existing vegetation and habitat	High

5.1.7 Alternatives for Reach BTC-12-04

Reach BTC-12-04 is located between Oregon Avenue and Lexington Avenue at the downstream terminus of the project area. This reach is the site of previous stream and wetland restoration work. This reach is bisected by a paved trail that is elevated slightly above the adjacent floodplain. Blacktail Creek is confined between the paved trails and the Interstate. Several constructed wetlands exist on the north side of the paved trail and are connected to Blacktail Creek through multiple small culverts located under the trail. Similar to adjacent reaches, the channel is wide and shallow through this reach, and lacks high quality pools and clean substrate. Two ephemeral urban drainages, Sand Creek and Grove Gulch, enter this reach from the south. Delivery of metals, including copper, from stormwater runoff is a concern in this reach of Blacktail Creek as described in the Silver Bow Creek and Clark Fork River Metals TMDLs (DEQ 2014).

Opportunities exist for addressing aquatic habitat in this reach by moving the stream channel to the wider floodplain area occupied by the wetland complex on the north side of the trail. This reach could function as an alluvial reach consisting of a stream channel and off-channel wetlands, or as a wetland reach whereby Blacktail Creek would flow through a series of wetlands interconnected with short channel segments. Water quality could be addressed by enhancing existing wetlands and converting the existing channel to a series of treatment wetlands that would intercept and process runoff from the south. Table 5-7 provides a summary of restoration alternatives for Reach BTC-12-03.

Table 5-7. Summary of restoration alternatives for Reach BTC-12-04.

Applicable Restoration Strategies	Constraints	Objectives Addressed	Feasibility Considerations	Relative Cost
Conservation	None	Conserve existing high quality vegetation	Ability to achieve goals	Low
Revegetation	Land use Beaver	Weeds Shade		Low
Streambank structures	Land use Beaver	Pools Cover Bank erosion Complexity	Disturbance to existing vegetation and habitat	Moderate
Wetlands	Land use Existing infrastructure	Contamination Sediment	Hydrology Water Chemistry	Moderate
Floodplain excavation	Land use Existing infrastructure	Floodplain connection	Repository for fill	High
Channel reconstruction	Land use Beaver	Entrenchment Sinuosity Substrate Pools Complexity	Disturbance to existing wetlands Water management	High

5.2 Preferred Alternative

Layouts illustrating preferred restoration actions by sub reach were developed collaboratively with the project partners. Preferred actions were based on the following selection criteria:

- Ability to address limiting factors and achieve project objectives
- Technical feasibility and constraints
- Land use and land ownership
- Relative implementation cost
- Social and community considerations identified by NRDP and the project partners

Preferred restoration actions are summarized in Table 5-8. The following sections provide conceptual restoration layouts and descriptions of the actions by sub reach.

Table 5-8. Summary of selected conceptual restoration actions by sub reach for lower Blacktail Creek.

Restoration Strategy	BTC-11-01	BTC-11-02	BTC-11-03	BTC-12-01	BTC-12-02	BTC-12-03	BTC-12-04
Conservation	X	X	X	X	X	X	X
Revegetation	X	X	X				X
Streambank structures	X	X					X
Wetlands	X	X					X
Floodplain excavation	X	X					X
Channel reconstruction	X	X					X

5.2.1 Concept for Reach BTC-11-01

The restoration concept for Reach BTC-11-01 is a comprehensive action encompassing all of the restoration strategies identified in Section 4. Floodplain excavation would establish an inset floodplain thereby reducing channel entrenchment and improving floodplain connection. Transition slopes from the top of bank down to the channel would be 3:1 or flatter. Channel reconstruction into an E-stream type would increase sinuosity, improve pool development processes and promote pockets of clean gravel substrate. Streambank structures composed of woody vegetation and native materials would provide bank stability and improve streambank cover. Revegetation treatments would expand the riparian buffer and reduce invasive plant species. Constructed wetlands in the new floodplain would address water quality by filtering contaminants from stormwater runoff. Constructed wetlands and floodplain swales would be located in areas where they intercept identified sources of pollutants, surface and groundwater drains or existing fairway surface water drainage. The reach would be placed in a conservation easement to provide long term protection of restoration efforts. This concept would result in the loss of approximately 3 out of 16 mature conifers in the reach. The restoration concept for Reach BTC-11-01 is presented in Figure 5-7.

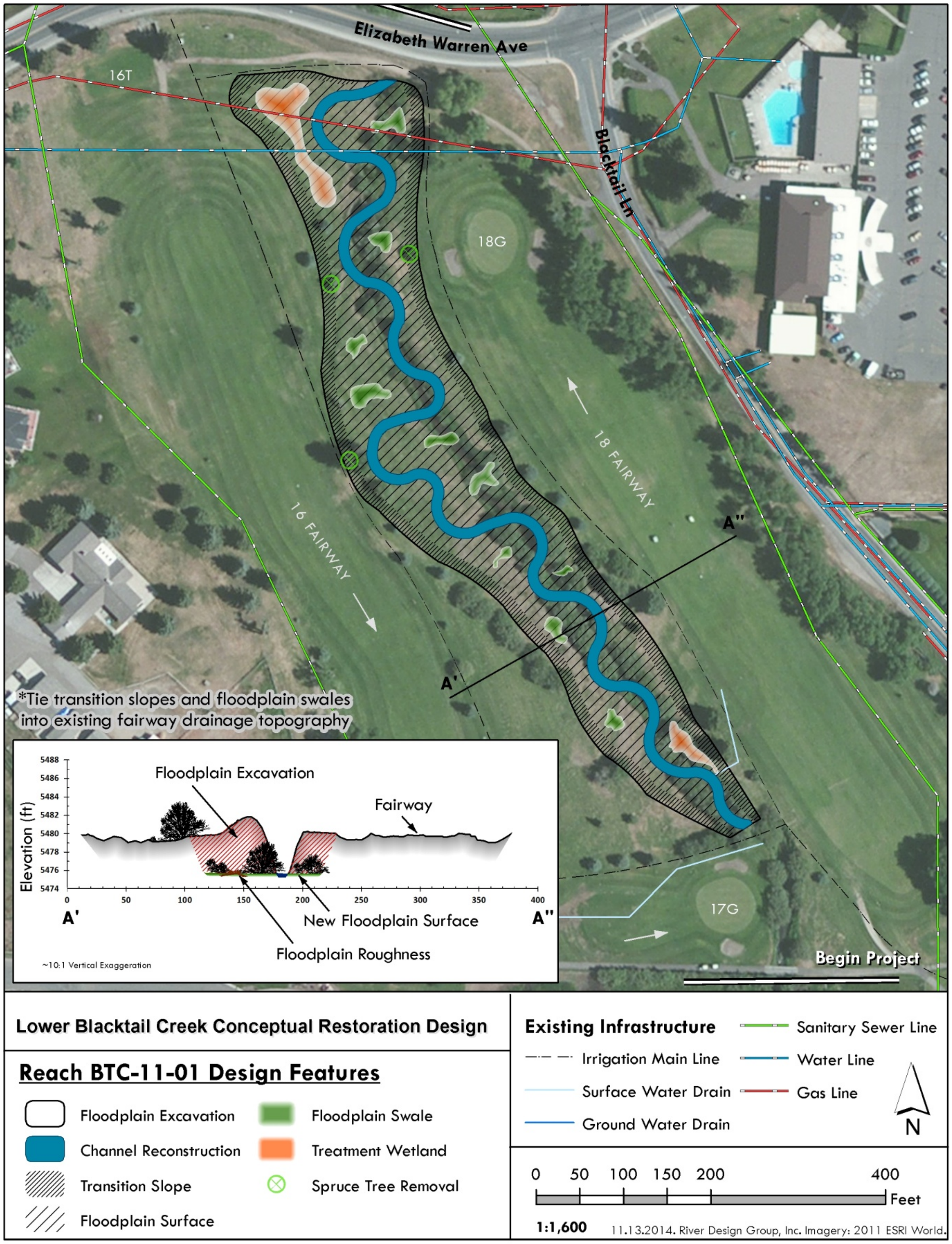

Figure 5-1. Restoration concept for Reach BTC-11-01.

This concept would have minimal effect on golf course fairways and irrigation infrastructure and would aim at improving fairway drainage. Approximately 3 out of 16 mature spruce trees would be removed by this action. Concept feasibility and effects on buried water and gas lines would have to be evaluated during subsequent design phases.

5.2.2 Concept for Reach BTC-11-02

The restoration concept for Reach BTC-11-02 is a comprehensive action similar to the adjacent upstream reach, but with a few added elements to mitigate for constraints. Downstream of Elizabeth Warren Avenue, lateral constraints preclude floodplain expansion, and therefore, actions are limited to streambank structures for approximately 500 feet. Streambank structures would be used to protect the banks and establish step pool morphology through this artificially steep reach. Step pools would support fish migration and provide a transition between the roadway culvert and the lower gradient E-stream type downstream. Transition slopes from the top of bank down to the channel would be steeper than 3:1 and would require steep slope treatments following construction disturbance.

To avoid abrupt expansions and contractions in floodplain width, existing golf cart bridge crossings at three locations would be replaced with structures that span the new floodplain. Similarly, achieving adequate floodplain width throughout this reach will require encroachment on the fairways for the 2nd, 3rd, and 4th holes and modification of irrigation mains and sprinklers. Approximately 16 out of 29 mature conifers would be removed by this action.

Similar to adjacent reaches this reach would be placed in a conservation easement to provide long term protection of restoration efforts. The restoration concept for Reach BTC-11-02 is presented in Figure 5-2 and Figure 5-3.

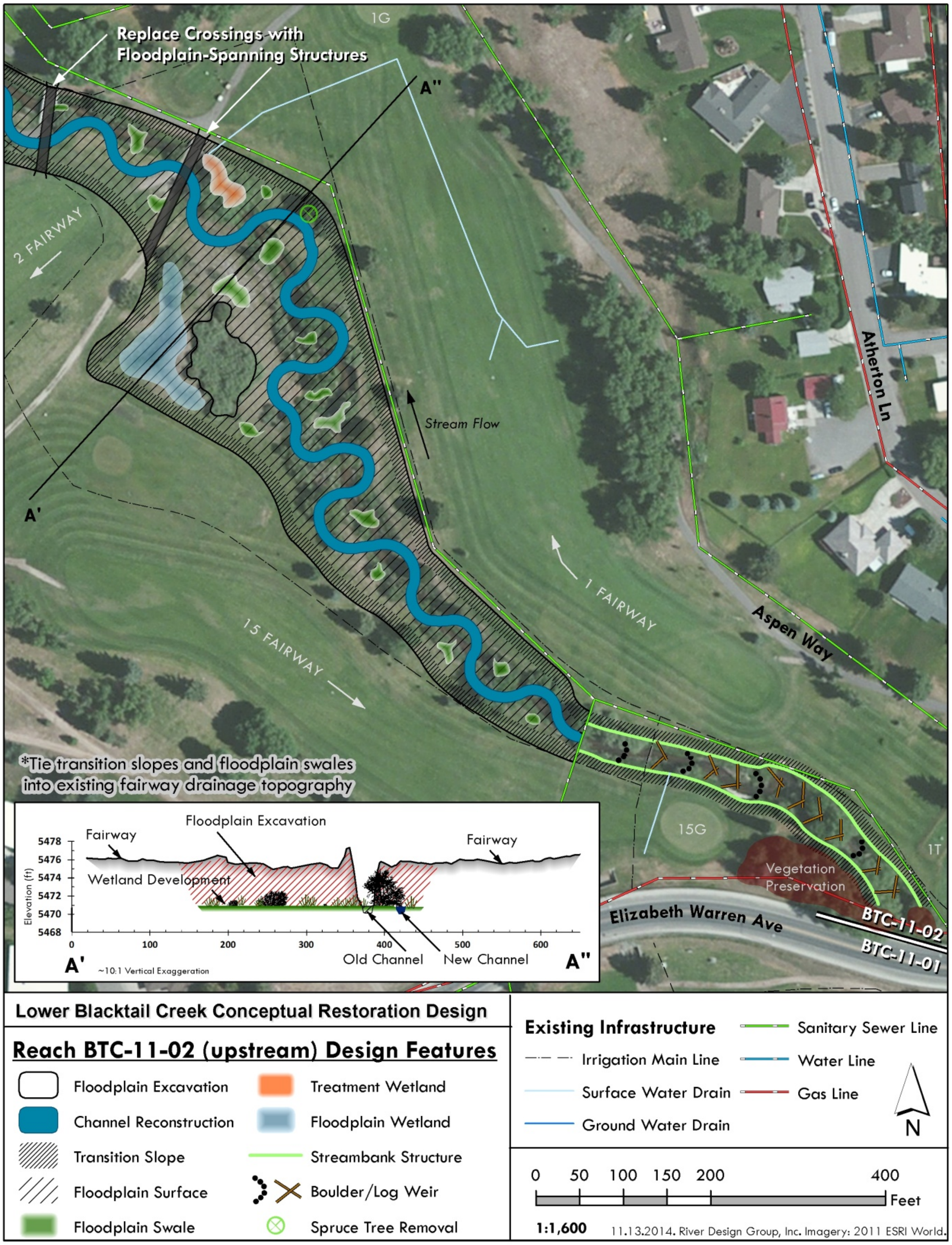

Figure 5-2. Restoration concept for the upstream end of Reach BTC-11-02.

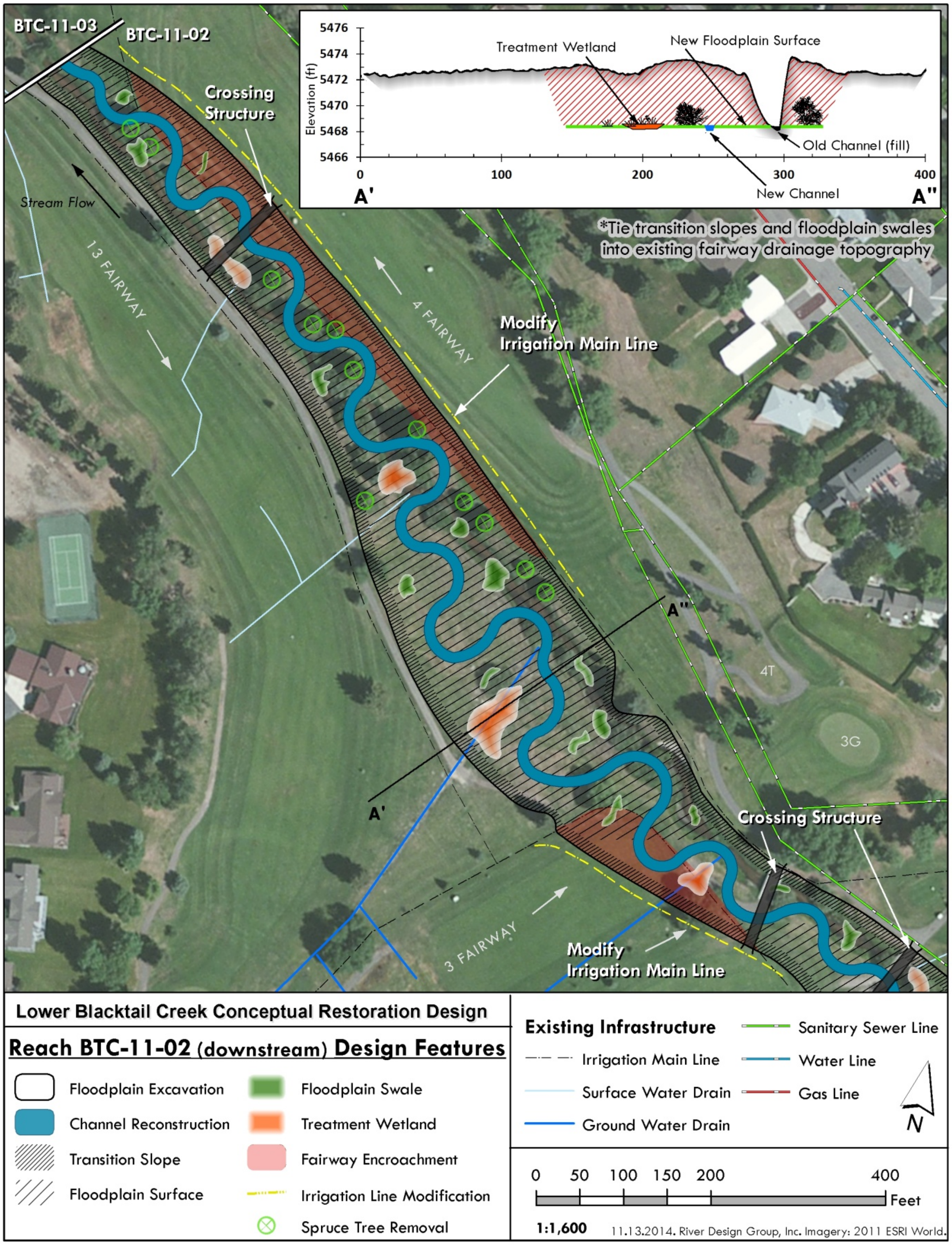

Figure 5-3. Restoration concept for the downstream end of Reach BTC-11-02.

5.2.3 Concept for Reach BTC-11-03

The restoration concept for Reach BTC-11-03 is a passive action encompassing revegetation and conservation strategies. Revegetation treatments would expand the riparian buffer and reduce invasive plant species. Conservation would protect existing riparian communities and provide long term protection of restoration efforts. Streambank structures could be installed where the 12^{th} fairway crosses the Creek.

In addition to revegetation and conservation strategies, the concept for this reach addresses the area around the golf course pond with site specific improvements. A diversion structure and screened intake would be installed upstream of the pond to divert 600 gallons per minute from Blacktail Creek into the pond for irrigation use per water right 76G-W-090656-00 for 374.1 acre-feet per year. Also, the pond outlet would be reconstructed to exclude fish from the pond. In addition, the excavation spoils remaining from pond excavation could be removed to expand the riparian buffer between the creek and the pond. Lastly, stormwater could be addressed by stabilizing an eroding ditch from the east and routing the flow directly into the pond for use as irrigation water. The restoration concept for Reach BTC-11-03 is presented in Figure 5-4 and Figure 5-5.

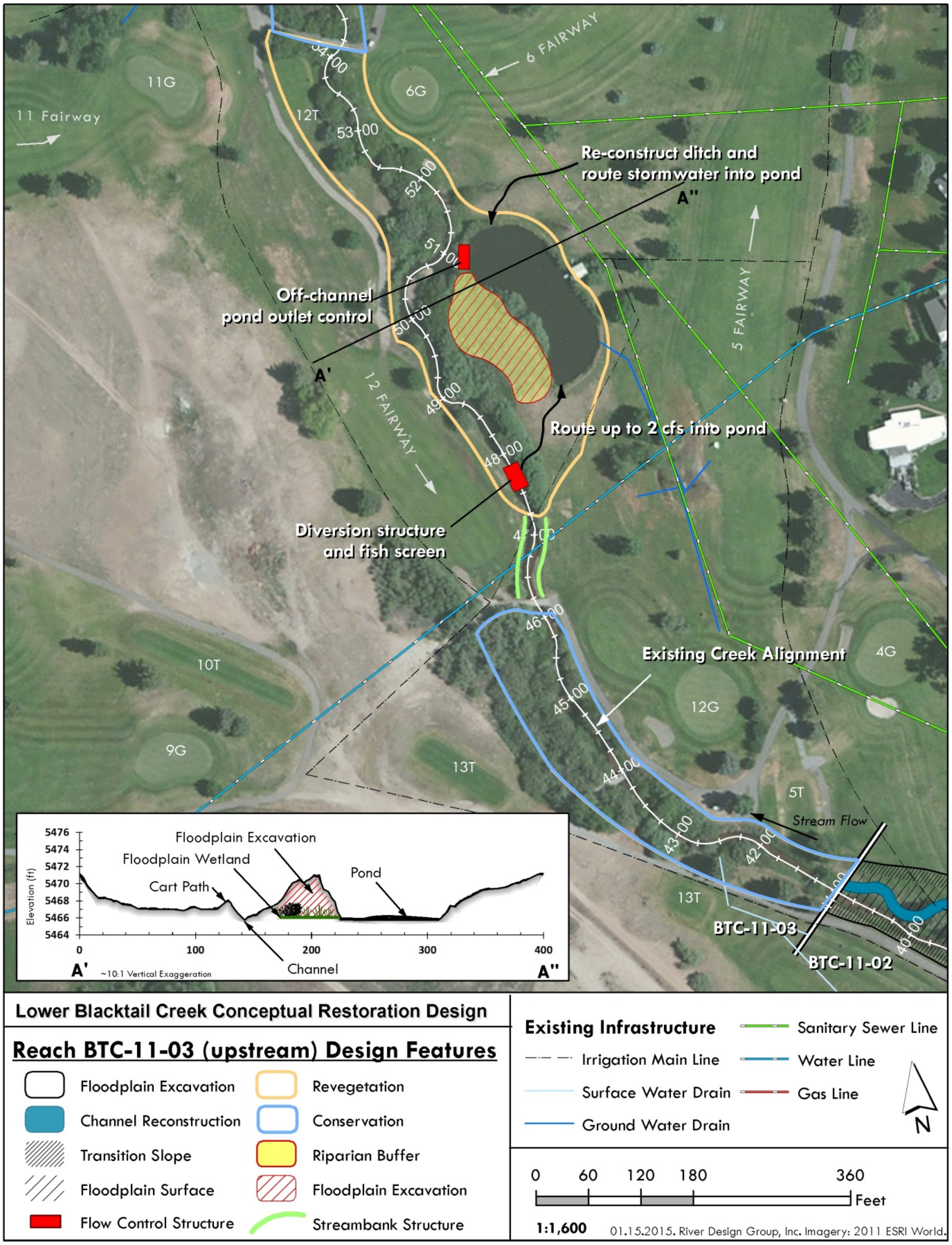

Figure 5-4. Restoration concept for the upstream end of Reach BTC-11-03.

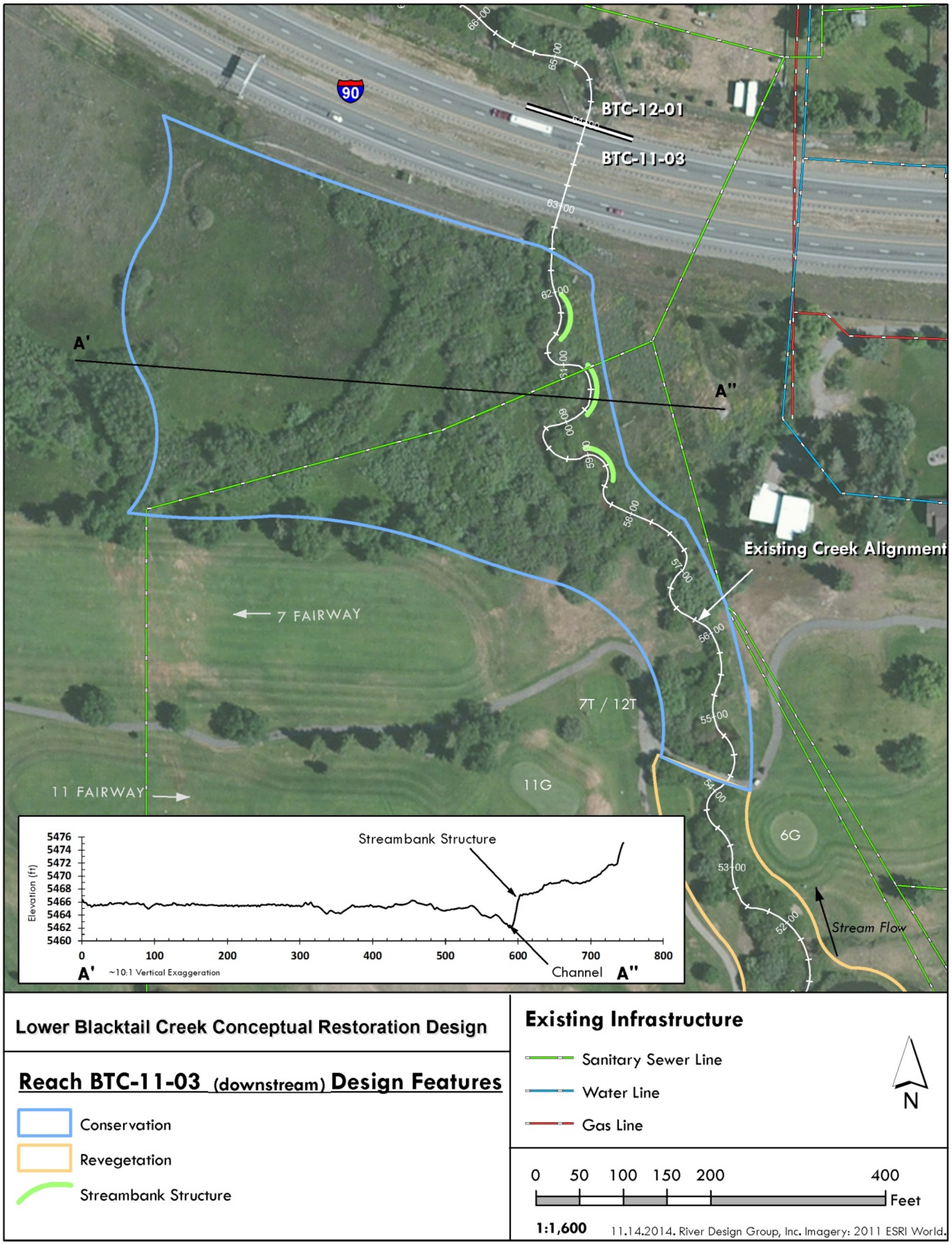

Figure 5-5. Restoration concept for the downstream end of Reach BTC-11-03.

5.2.4 Concept for Reach BTC-12-01

Due to extensive constraints and limited opportunities in Reach BTC-12-01, no restoration actions are recommended. Conservation efforts could be expanded, but already appear to be in place with the trail system. Reach BTC-12-01 is shown in Figure 5-6.

5.2.5 Concept for Reach BTC-12-02

Due to extensive constraints and limited opportunities in Reach BTC-12-02, no restoration actions are recommended. Conservation efforts could be expanded, but already appear to be in place with the trail system. Reach BTC-12-02 is shown in Figure 5-7.

5.2.6 Concept for Reach BTC-12-03

Due to private land ownership in Reach BTC-12-03, no active restoration actions are recommended. Landowner outreach could raise conservation awareness and lead to future restoration opportunities in this reach, such as floodplain or riparian buffer expansion. Continued monitoring of measures to deter beaver activity at culverts could provide useful information for expanded use of beaver deterrents in Blacktail Creek or nearby drainages. The fill from abandoned Johns Avenue is a floodplain constriction, and could be removed from the floodplain. The restoration concept for Reach BTC-12-03 is presented in Figure 5-8.

5.2.7 Concept for Reach BTC-12-04

The restoration concept for Reach BTC-12-04 is a comprehensive action encompassing all of the restoration strategies identified in Section 4. Floodplain excavation would remove elevated fills in the floodplain and expand the floodplain width. Channel reconstruction would reduce the channel width-depth ratio, increase pool frequency and improve habitat complexity. Streambank structures composed of woody vegetation and native materials would provide bank stability and improve streambank cover. Revegetation treatments would expand the riparian buffer and reduce invasive plant species. Wetlands would address water quality by intercepting stormwater runoff and capturing fine sediment. The reach would be placed in a conservation easement to provide long term protection of restoration efforts. The restoration concept for Reach BTC-12-04 is presented in Figure 5-9.

Figure 5-6. Reach BTC-12-01.

Figure 5-7. Reach BTC-12-02.

Figure 5-8. Restoration concept for Reach BTC-12-03.

Figure 5-9. Restoration concept for Reach BTC-12-04.

6 Design and Implementation Considerations

This section provides guidance for project design and implementation phases.

6.1 Design Considerations

This section describes an approach for addressing design feasibility including performance expectations, risk management, data needs and permitting requirements.

6.1.1 Performance Expectations

Performance expectations address risk, uncertainty, failure modes and timeframes for project success. Performance expectations and industry standards for the design of restoration projects vary depending on project goals and site specific situations. Because rivers are naturally dynamic systems, expectations for project stability can be expressed in the context of dynamic equilibrium, whereby project elements and restoration treatments are expected to remain quasi-stable, but change in an ecologically beneficial manner as a result of desired disturbances from natural river processes.

Newly constructed restoration projects are vulnerable whereby they do not possess the resiliency to recover from large disturbances. Over time, project resiliency improves and ability to recover or *benefit* from disturbances increases. Selection of stability criteria for design of restoration projects must balance stability and dynamic equilibrium. When in-stream structures are installed primarily for habitat, stability of the structure is usually evaluated at a 20-year flow (5 percent exceedance) event. When structures are installed for bank stability or around infrastructure, the stability of the structure is usually evaluated at a 100-year flow (1 percent exceedance) event. For this project, stability criteria may vary by location, desired ecological effect and proximity to infrastructure. Figure 6-1 provides guidance for selection of stability criteria based on desired project life and risk tolerances.

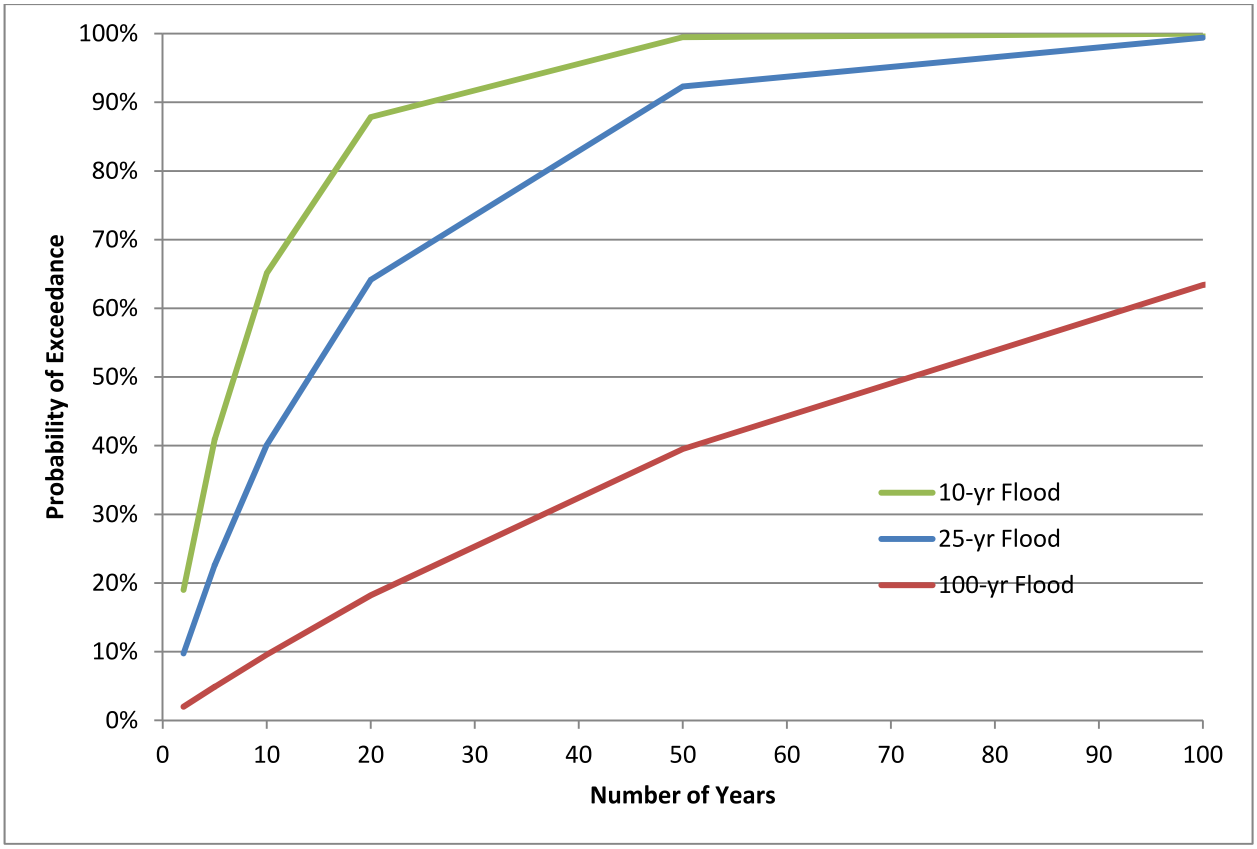

Figure 6-1. Chart illustrating probability of exceedance for selected design stability criteria.

6.1.2 Risk Management

Risk for this project can be broadly categorized as social risk (public perception) and technical risk (project failure or damage to property). Because Blacktail Creek is a naturally dynamic system flowing through an urban setting, there are technical risks associated with geomorphic and biological responses to modified stream processes from restoration. Table 1 provides a summary of potential risk elements and a suggested approach for addressing risk associated with lower Blacktail Creek restoration.

Table 6-1. Suggested risk management approach for lower Blacktail Creek restoration.

Risk Element	Potential Consequence	Risk Mitigation Strategy	Risk Assessment Method
Infrastructure	Project causes damage to bridges, utilities or infrastructure	Coordinate with owners to review risks and mitigation strategies	Evaluate localized project effects using a hydraulic model
Bank Erosion	Project increases bank erosion or causes damage to private property	Design bank treatments per selected stability criteria Coordinate with landowners to review risks and mitigation strategies	Evaluate project effects along bank margins using a hydraulic model
Flooding	Project increases flood elevations causing damage to structures	Coordinate with County floodplain coordinator to determine no rise tolerances	Evaluate project effects on published base flood elevations using a hydraulic model
Morphologic Change	Project causes deposition or scour resulting in channel instability	Design projects to process anticipated sediment loads Design projects for dynamic equilibrium	Evaluate sediment transport characteristics and thresholds for morphologic changes.
Subsurface Conditions	Unexpected subsurface conditions affect implementation	Evaluate subsurface conditions at proposed excavation locations	Subsurface borings and geotechnical characterization of subsurface materials to be used for excavation and/or fill.
Vegetation Establishment	Vegetation does not develop	Evaluate suitability of project conditions for vegetation establishment	Evaluate hydrologic conditions in planting areas relative to suitability criteria for vegetation
Habitat Suitability	Habitat is not suitable for native species, or habitat is more suitable for non-native species	Coordinate restoration designs with FWP and develop habitat suitability criteria	Evaluate habitat conditions using agreed upon biological criteria
Public Perception	Project is unpopular or has negative public image	Public outreach	Hold public meetings and distribute project information

6.1.3 Data Collection Needs

The conceptual restoration design was based on limited data. Additional data collection will be required to address project feasibility. Recommended data collection needs include:

- **Channel bathymetry** – supplement terrestrial LiDAR topography data with channel topography below the water surface.

- **Bankfull profile** – identify inset floodplain tie-in elevations by surveying existing bankfull indicators.
- **Channel geometry** – measure cross sections at reference riffle and pool units to support development of dimensions for new channel construction.
- **Channel substrate** – collect pebble count data and coring samples to characterize bed conditions and support sediment transport investigations.
- **Stage-discharge relationships** – measure stage and discharge at select locations for use in calibrating the hydraulic model. Data may be available from the FEMA study.
- **Vegetation mapping** – survey elevations of vegetation communities relative to bankfull indicators for development of vegetation design criteria. Identify potential areas for vegetation preservation and salvage.
- **Wetland delineation** – identify jurisdictional wetlands in the project area.
- **Subsurface investigations** – excavate representative soil pits at proposed excavation locations in order to characterize soils and sample for contamination.
- **Identification of pollutant point and non-point sources** – identify types and sources of pollutants or contaminants with potential to affect water quality in lower Blacktail Creek.
- **Determine bridge needs** – coordinate with the stakeholders to establish criteria for bridge width, span, load capacity and style that meet budget expectations.

6.1.4 Permitting

Lower Blacktail Creek restoration work will require preparation of a joint permit application in compliance with the following environmental regulations:

- Federal Clean Water Act Section 404 and 401
- State of Montana Stream Protection Act 124
- State of Montana Natural Streambed and Land Preservation Act 310
- Endangered Species Act Section 7 Consultation

Additional permit applications that will be required include:

- Montana State Historic Preservation Office (SHPO) to demonstrate regulatory compliance with the National Historic Preservation Act Section 106 (cultural resources investigations)
- Butte Silver Bow County to demonstrate compliance with the National Flood Insurance Program (floodplain development permit/no rise certification)
- EPA/Montana DEQ to demonstrate compliance with the Clean Water Act National Pollution Discharge Elimination System (NPDES) permit program (stormwater pollution prevention plan).

Other permit applications may be required depending on final project scope and local regulations.

6.2 Implementation Considerations

This section describes a conceptual approach for implementing the project design.

6.2.1 Construction Phasing

Lower Blacktail Creek restoration could be accomplished in three phases over three years per the following suggested timeline:

Year 1 – Reach BTC-11-01 (Phase 1)

Year 2 – Reach BTC 11-02 and Reach BTC 11-03 (Phase 2)

Year 3 – Reach BTC 12-04 (Phase 3)

Phase 1 work in Reach BTC -11-01 would be the shortest in duration and could be considered a pilot or demonstration project in order to gain knowledge for future projects by learning from initial work undertaken on a smaller scale. The construction window in Reach BTC-11 will be affected by golf course operations. It is likely that floodplain excavation in the golf course will have to occur between October and March in order to keep the course open and minimize construction hazards. As such, separate construction phases may need to be established for floodplain excavation work. All other work would take place during low flow conditions between August and November. Phase 2 work in Reach BTC-11-02 and BTC-11-03 would be the longest in duration. Golf course operations could be disrupted temporarily during bridge replacement.

Phase 3 work in Reach BTC-12-04 would occur during low flow conditions between August and November. Work in Reach BTC-12-04 will require temporary closure of the paved trail.

6.2.2 Construction Access and Staging

Few suitable areas exist in the project area for construction access and staging; and therefore, construction of site improvements will be necessary to accomplish the work.

In Reach BTC-11-01, a potential staging area could be located south of Elizabeth Warren Avenue, east of the 16th tee in the area proposed for wetland development. Temporary access roads would likely be within excavated floodplain corridor or along the top of the bank adjacent to the 16th fairway. Access and staging would affect the cart path access to the 16th tee.

Reach BTC-11-02 and BTC-11-03 could share a potential staging area located west of the 12th fairway in the existing undeveloped area adjacent to the 10th and 11th holes. Access to this area would be via White Boulevard located east of Harrison Avenue. Temporary access roads would need to cross the 12th fairway to access the irrigation pond, and cross the 13th fairway to access Reach BTC-11-02. In addition, temporary access roads would likely be within the floodplain corridor or along the top of the bank adjacent to the 4th fairway and 1st fairway.

In Reach BTC-12-04, a potential staging area would need to be located within the project area at one of the locations proposed for floodplain grading. Temporary access roads would likely follow the north side of the paved trail.

6.2.3 Water Management

Due to channel entrenchment and adjacent land uses, few opportunities exist to route Blacktail Creek around work areas during construction. As such, it will be necessary to dewater work areas, construct temporary bypass channels and work in flowing conditions. Water management will also require fish salvage operations to remove fish and other aquatic species from the construction areas. Fish salvage operations will need to be coordinated with FWP and completed by qualified biologists.

6.2.4 Construction Materials

Sourcing and staging of construction materials may need to occur in advance of implementation. Such materials may include woody debris, brush and containerized plants. Containerized plant sources may need to be identified and procured up to a year or more before expected planting to ensure appropriate species and quantities are available. Due to timing considerations, it may be necessary to designate these materials as owner-supplied items provided to the construction contractor.

6.2.5 Contracting

Restoration is a specialized construction practice requiring knowledge of water management, fish salvage operations, streambank structure installation, precision grading, planting and use of native materials. Submittal of contractor qualifications demonstrating knowledge and experience with restoration projects should be an important consideration in the bid process. Moreover, it may be necessary to procure multiple contractors responsible for various portions of the work based on qualifications such as bulk earthwork for floodplain excavation, channel reconstruction and planting.

6.3 Maintenance, Monitoring and Adaptive Management

All restoration projects should integrate maintenance, monitoring and adaptive management to determine if the project is meeting objectives, determine maintenance needs and ensure long-term project success. Monitoring can be informal and include visual observations of maintenance needs and project performance. During the design phase, project partners should determine how and when monitoring will occur and how monitoring observations will be used to determine maintenance needs and project success. Routine maintenance of restoration projects typically includes: weed management, supplemental irrigation, supplemental seeding, and minor structure repair.

6.4 Cost Estimate

Conceptual implementation cost estimates were prepared for each sub reach and provided to the project partners. Estimates include costs for design, permitting, construction implementation, revegetation, construction oversight, monitoring and maintenance. Estimates are not included in this report.

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Appendix A – Supplemental Data Maps

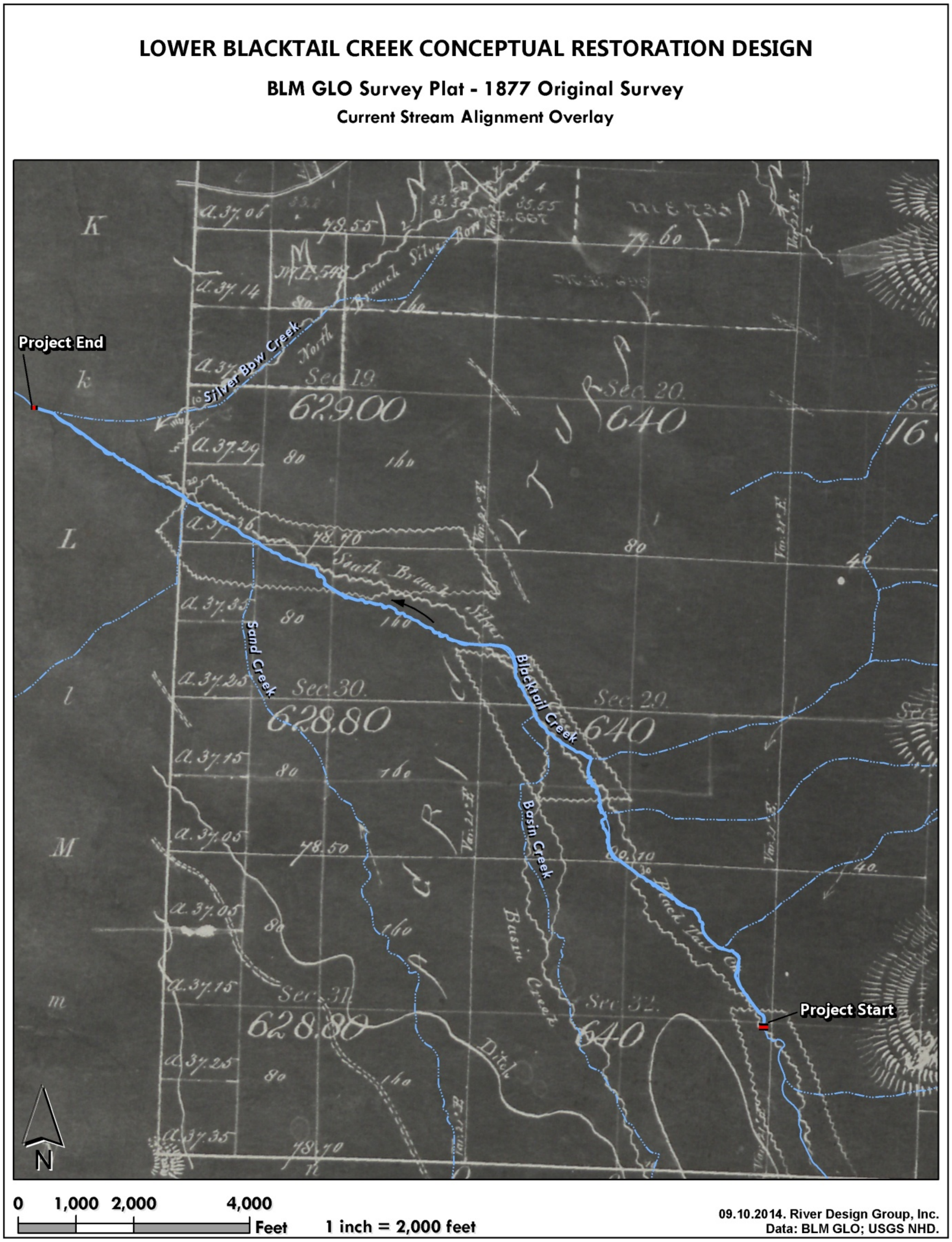


Figure A-1. GLO map for the lower Blacktail Creek Project area.

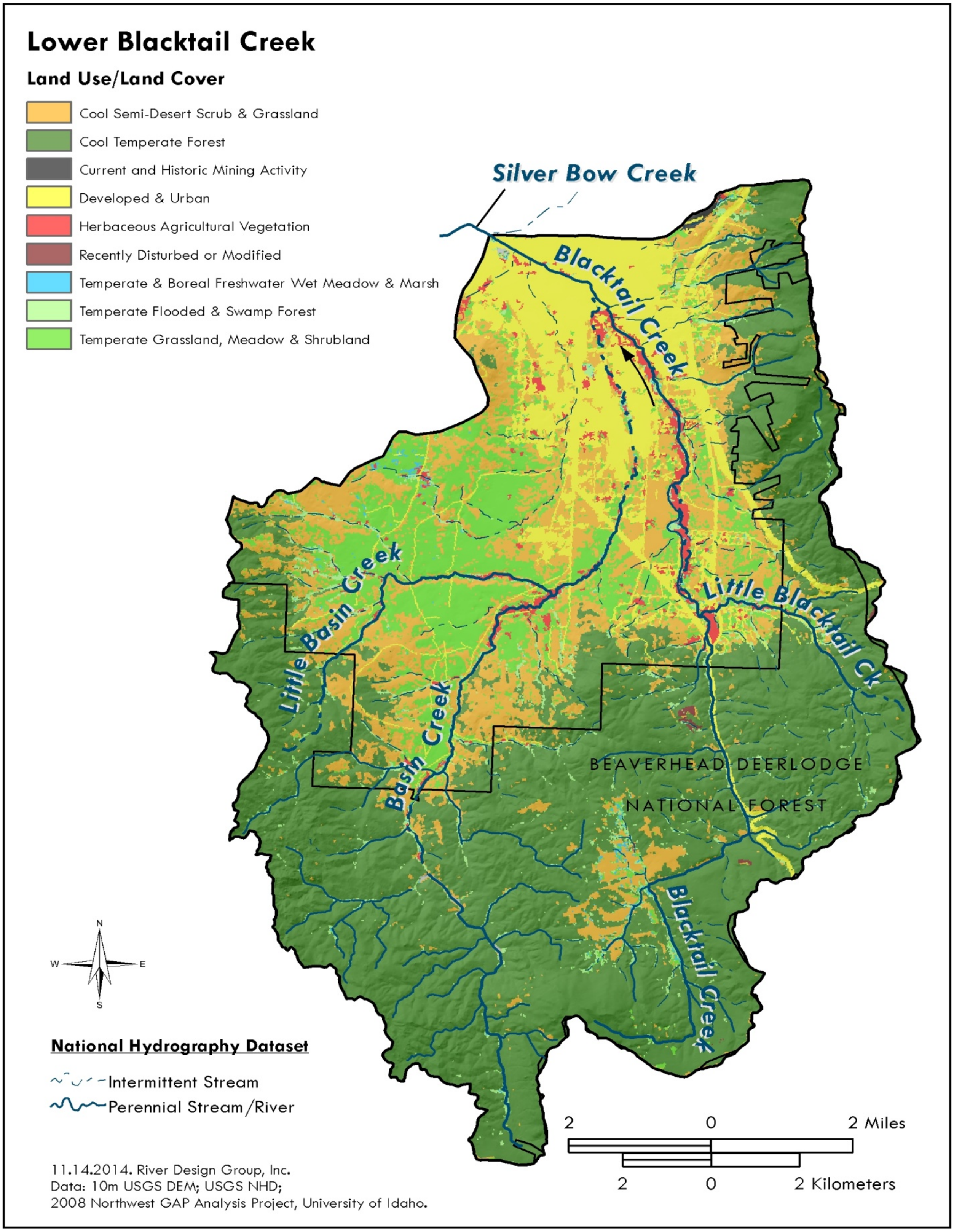


Figure A-2. Land cover map for the Blacktail Creek watershed.

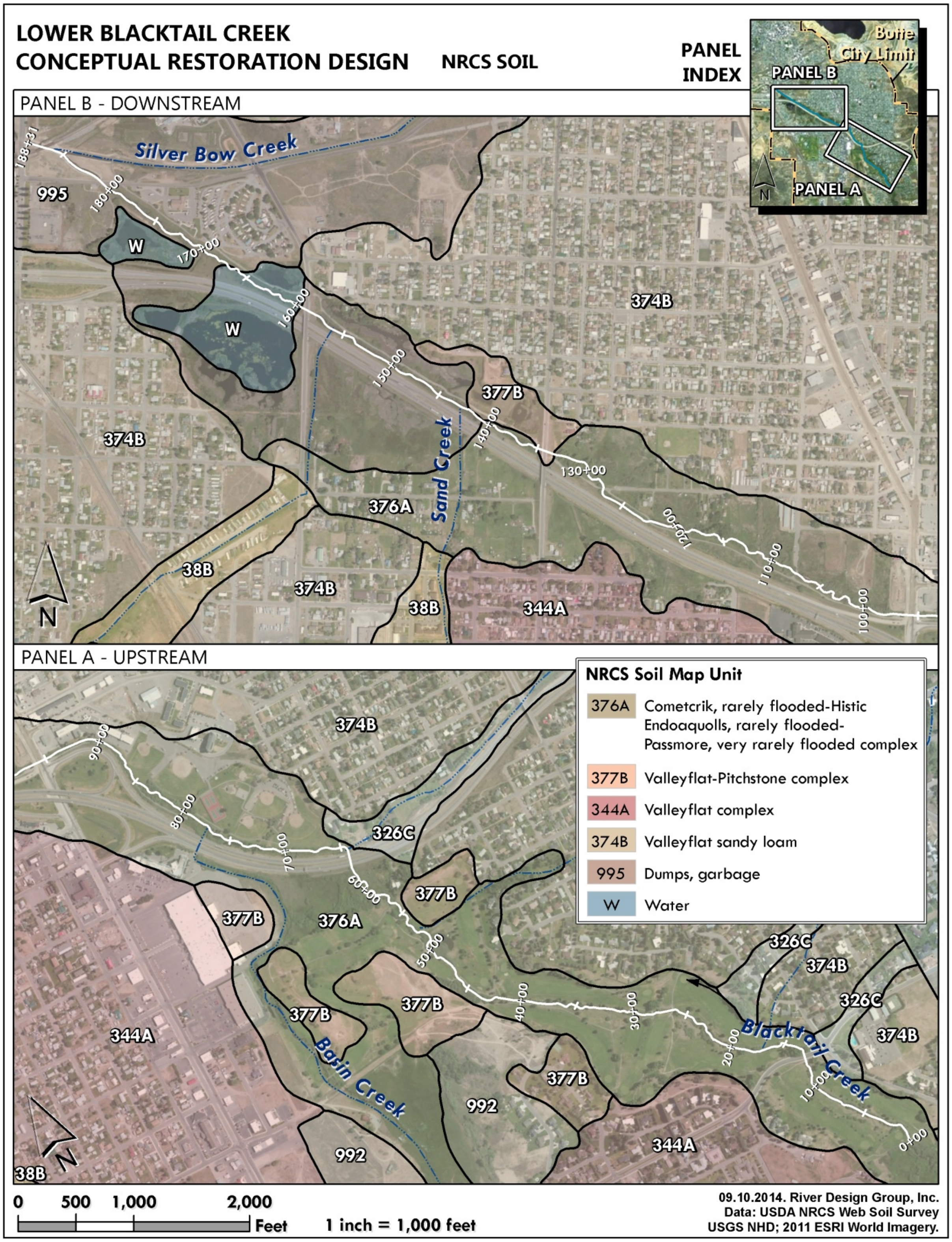


Figure A-3. NRCS soils map for the lower Blacktail Creek Project area.

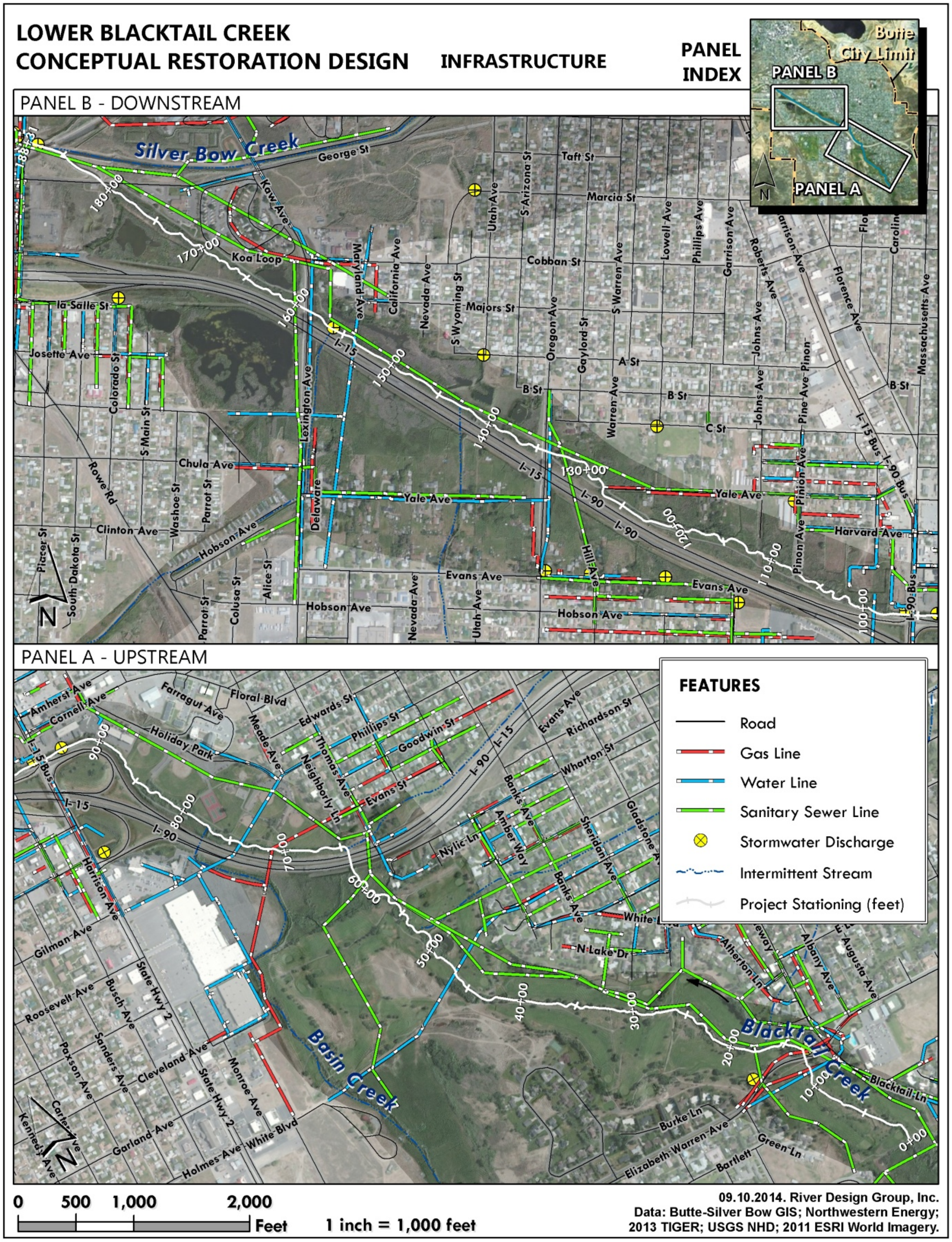


Figure A-4. Utilities and infrastructure map for the lower Blacktail Creek Project area.

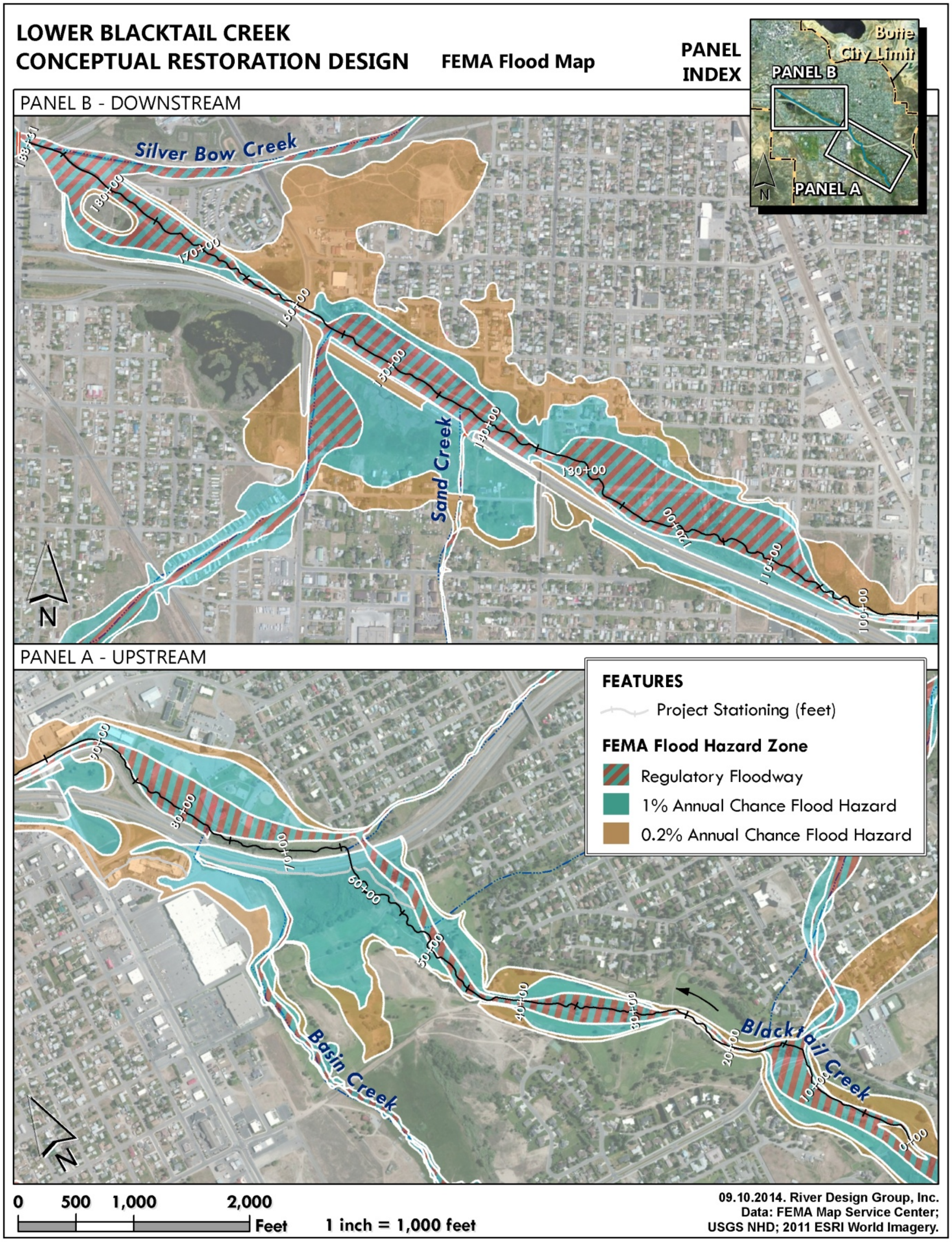


Figure A-5. FEMA Flood Map for the lower Blacktail Creek Project area.

Appendix B – Blacktail Creek Hydrology

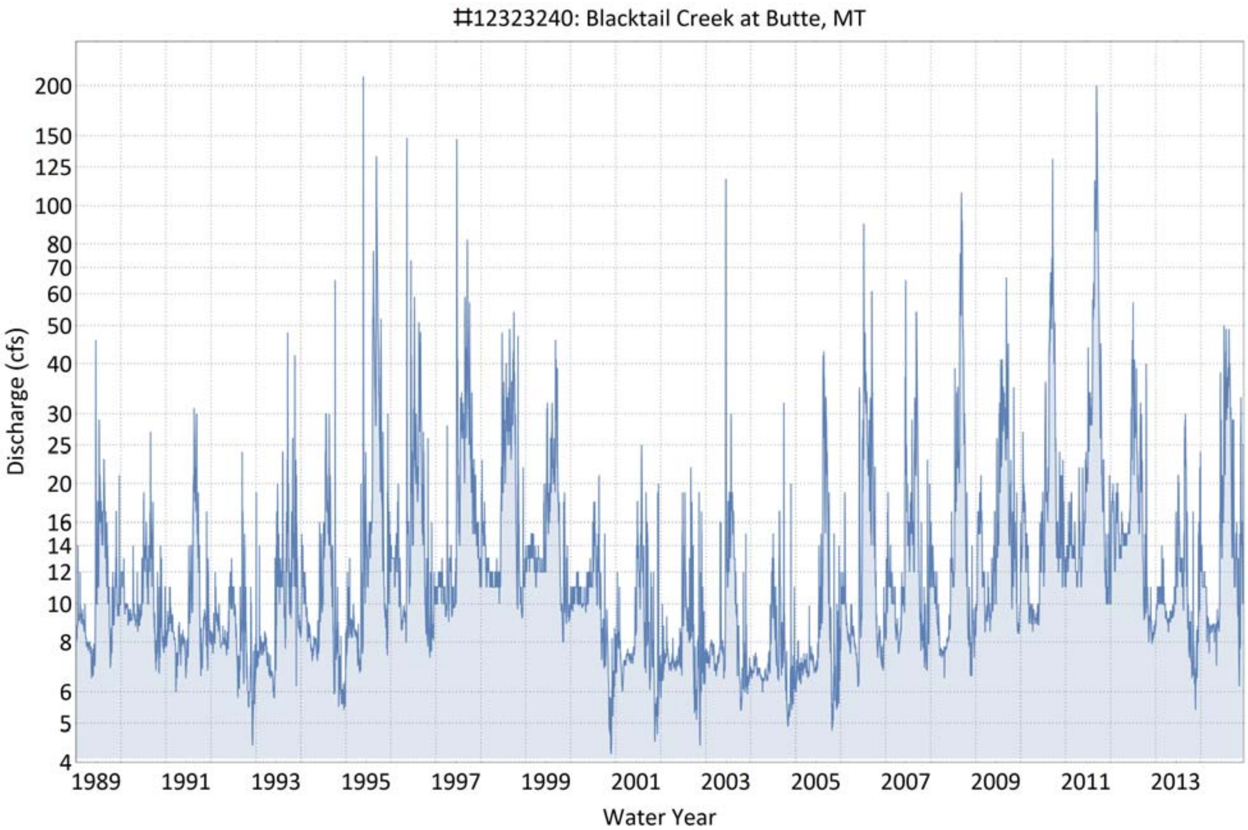
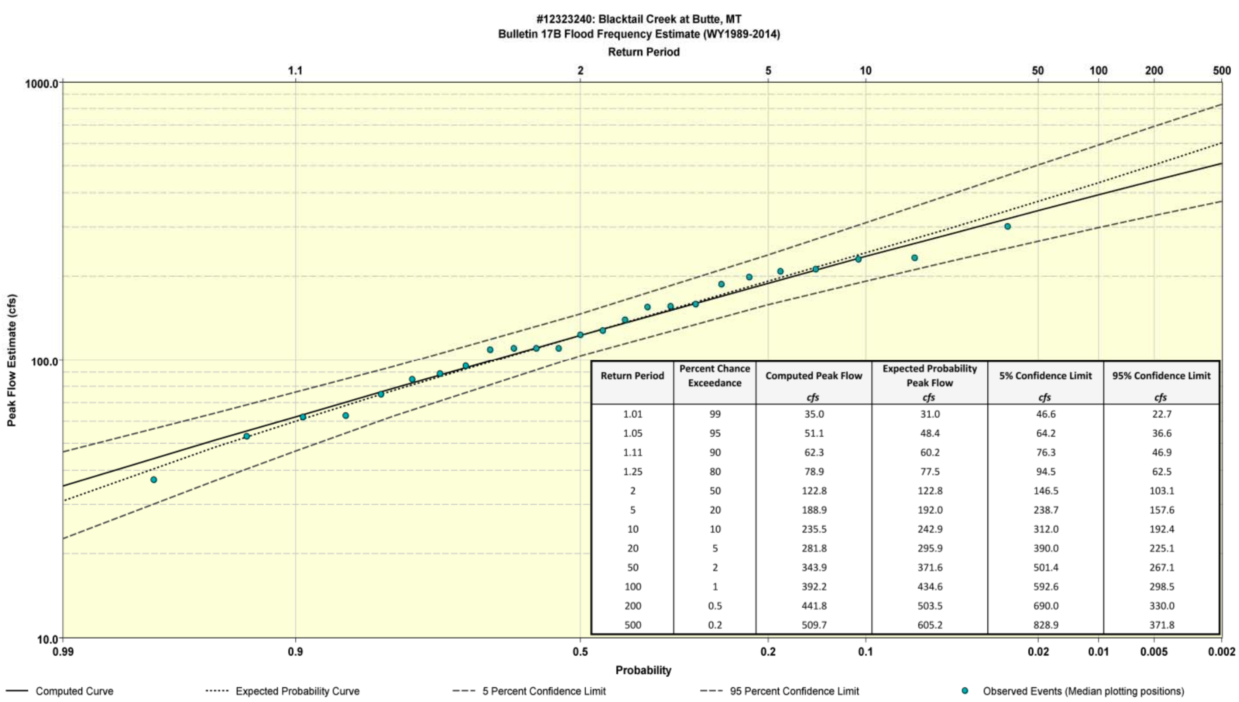


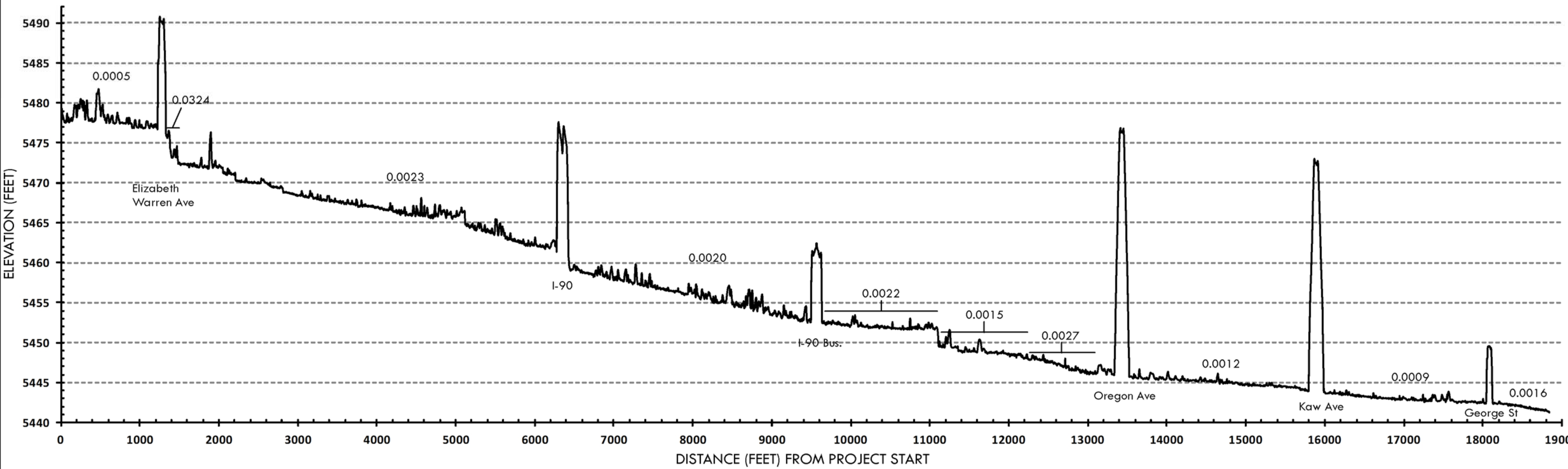
Figure B-1. Hydrologic record at USGS gage 12323240 Blacktail Creek at Butte, MT.

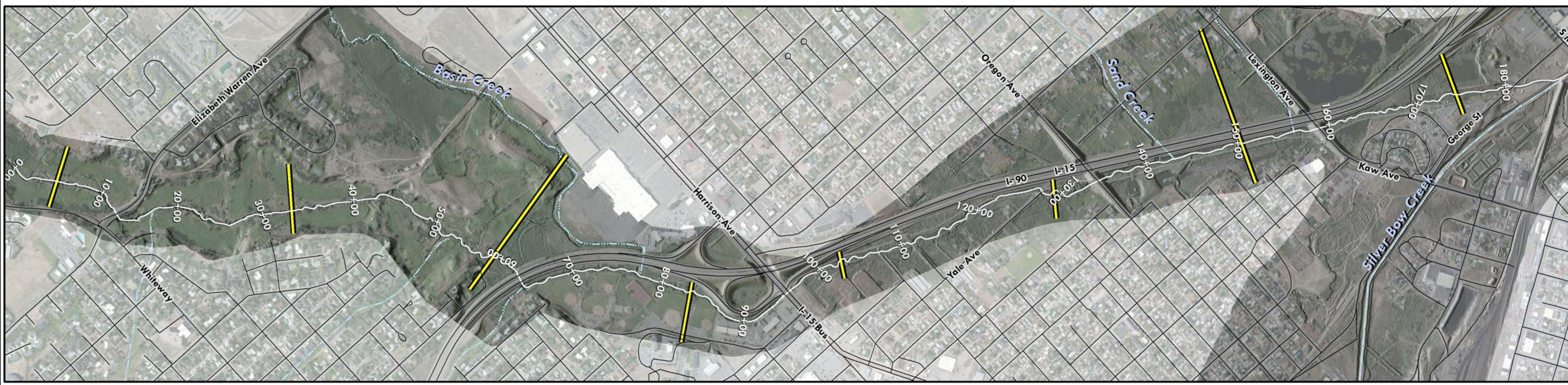


Return Period	Percent Chance Exceedance	Computed Peak Flow *cfs*	Expected Probability Peak Flow *cfs*	5% Confidence Limit *cfs*	95% Confidence Limit *cfs*
1.01	99	35.0	31.0	46.6	22.7
1.05	95	51.1	48.4	64.2	36.6
1.11	90	62.3	60.2	76.3	46.9
1.25	80	78.9	77.5	94.5	62.5
2	50	122.8	122.8	146.5	103.1
5	20	188.9	192.0	238.7	157.6
10	10	235.5	242.9	312.0	192.4
20	5	281.8	295.9	390.0	225.1
50	2	343.9	371.6	501.4	267.1
100	1	392.2	434.6	592.6	298.5
200	0.5	441.8	503.5	690.0	330.0
500	0.2	509.7	605.2	828.9	371.8

Figure B-2. Flood frequency analysis for USGS gage 12323240 Blacktail Creek at Butte, MT.

Appendix C – LiDAR Exhibits





Lower Blacktail Creek Conceptual Restoration Design

Longitudinal Profile

FEATURES

- Project Stationing (feet)
- Intermittent Stream
- Road

0 500 1,000 1,500 2,000 4,000 Feet

N

1 inch = 1,000 feet

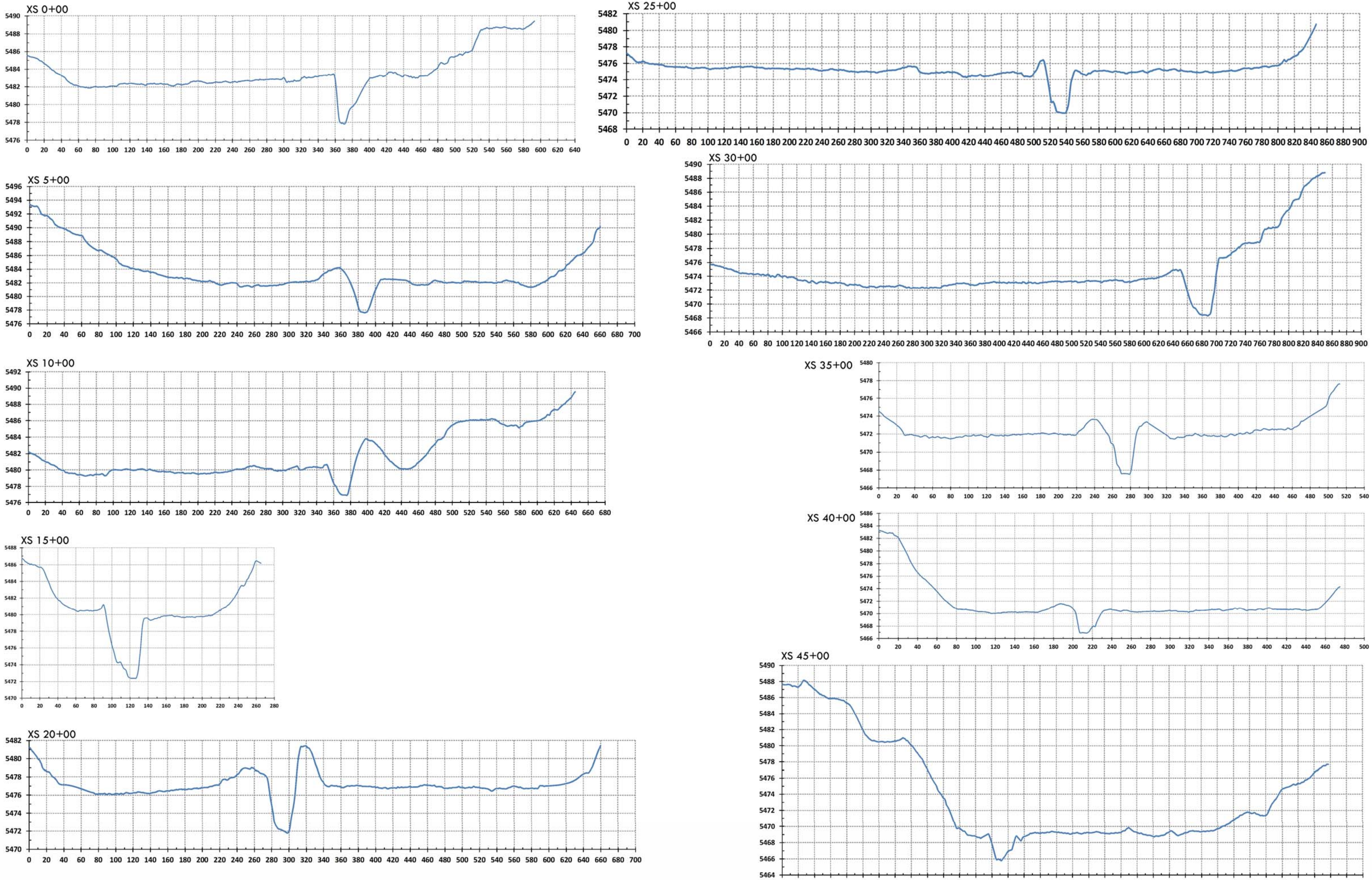
09.10.2014. River Design Group, Inc.

Data:
USGS NHD; 2013 TIGER.
Imagery:
07.12.2011 ESRI World.

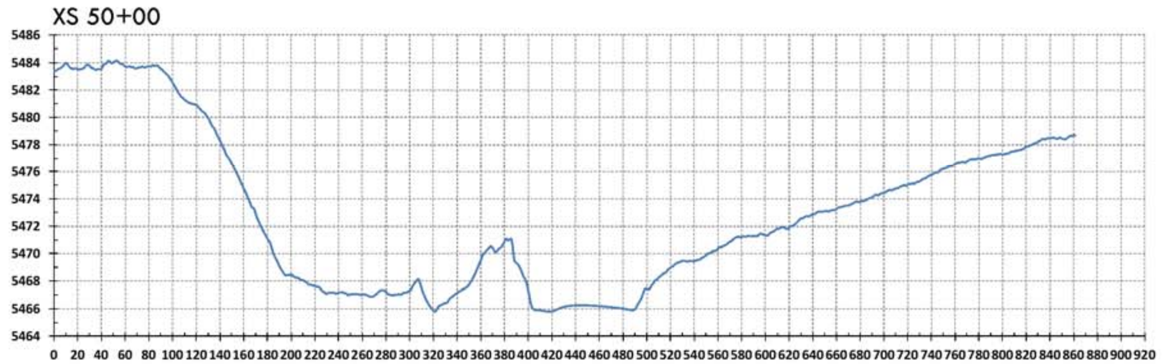
LP

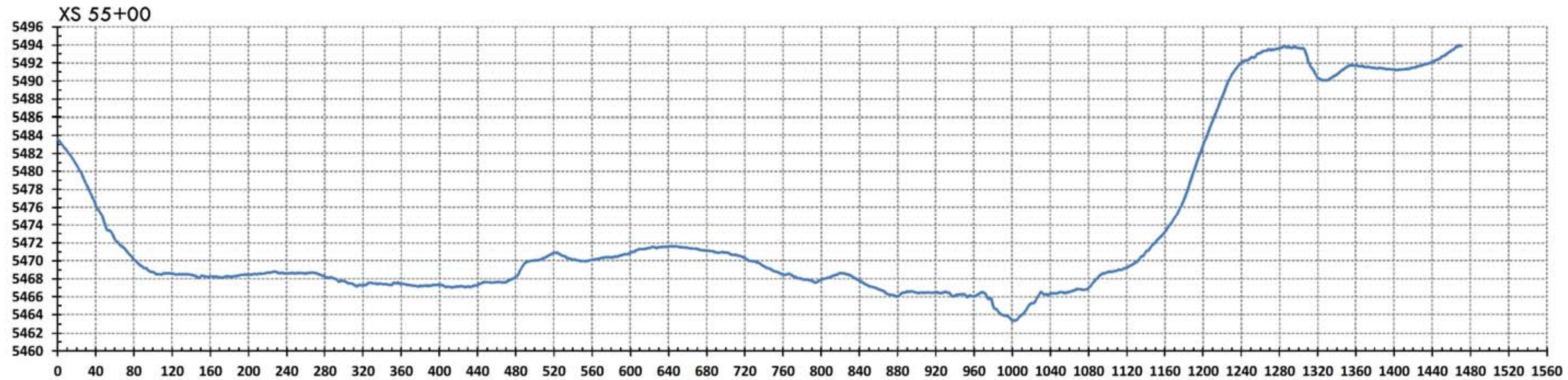
160+00
150+00
140+00
130+00
120+00
110+00
100+00
90+00
80+00
70+00
60+00
50+00
40+00
30+00
20+00
10+00
0+00
Sand Creek
Basin Creek
N
LOWER BLACKTAIL CREEK RESTORATION - CROSS SECTION LOCATIONS
0 500 1,000 1,500 2,000 4,000
Feet

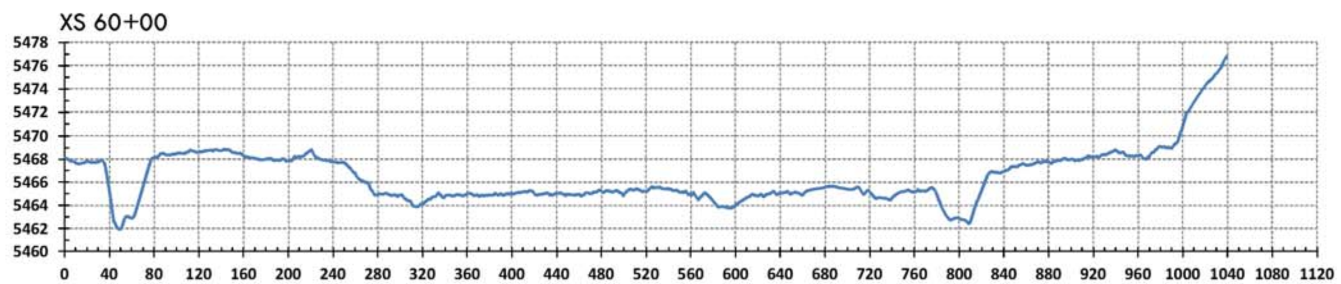
LOWER BLACKTAIL CREEK RESTORATION - CROSS SECTIONS 50+00 TO 95+00
ELEVATION IN FEET, DISTANCE FROM RIVER LEFT IN FEET

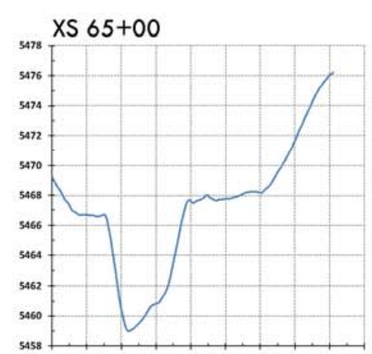


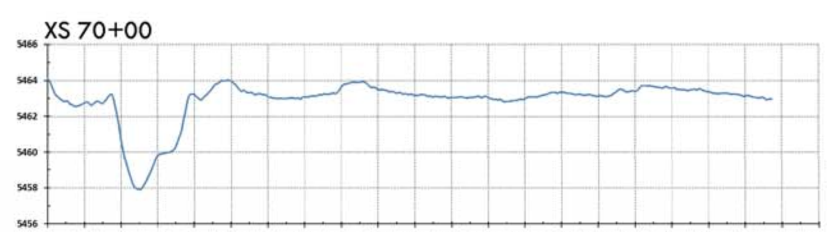
LOWER BLACKTAIL CREEK RESTORATION - CROSS SECTIONS 50+00 TO 95+00
ELEVATION IN FEET, DISTANCE FROM RIVER LEFT IN FEET

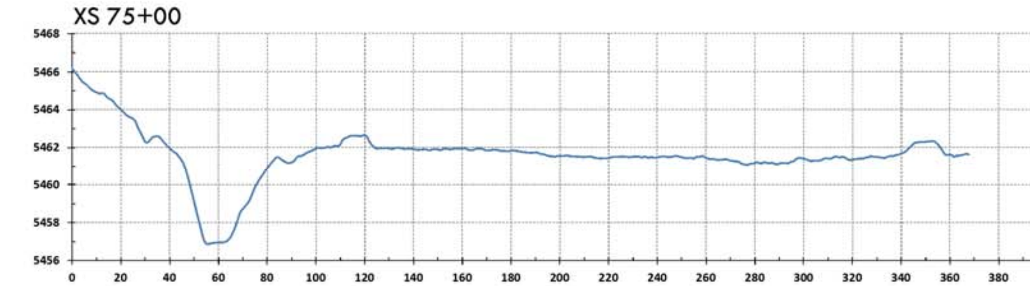


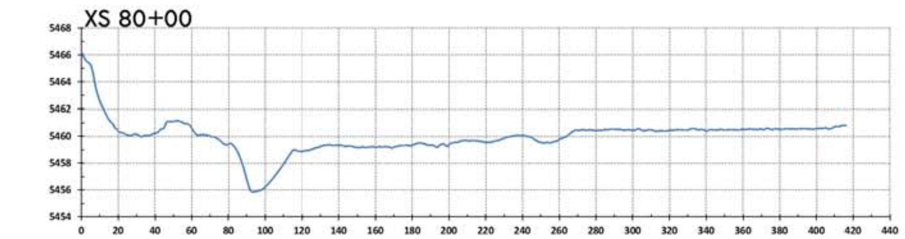


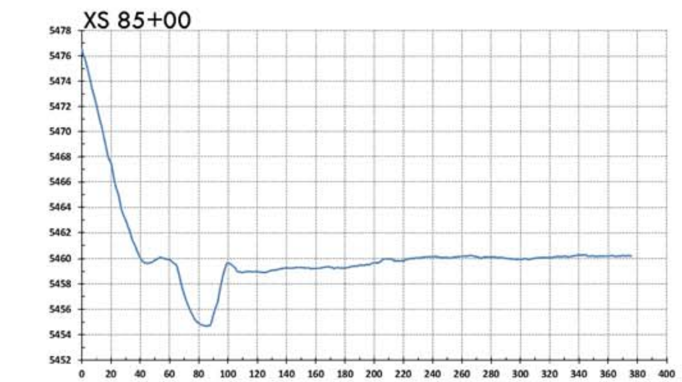


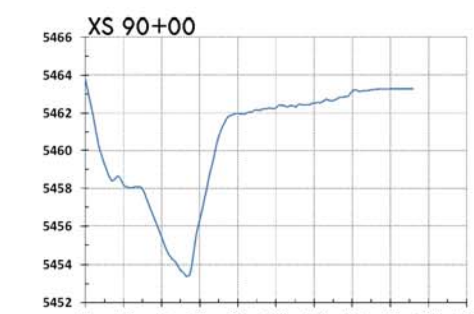


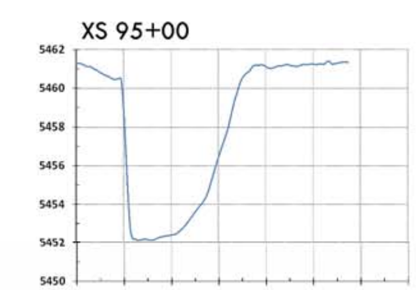






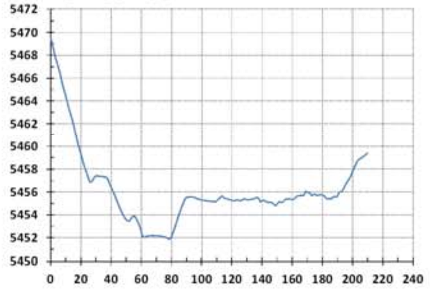




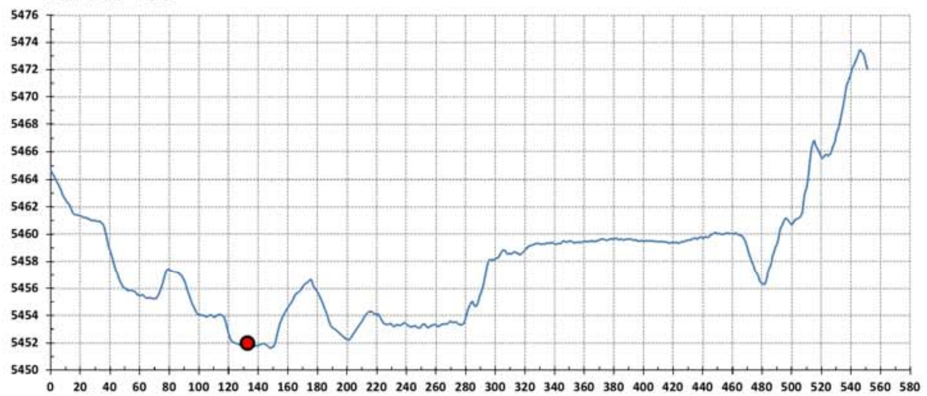


LOWER BLACKTAIL CREEK RESTORATION - CROSS SECTIONS 100+00 TO 158+00
ELEVATION IN FEET, DISTANCE FROM RIVER LEFT IN FEET

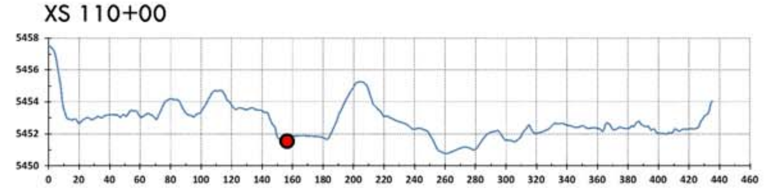
XS 100+00



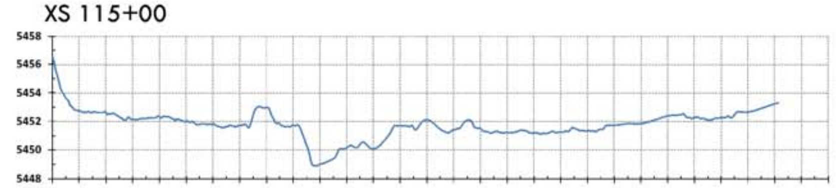
XS 105+00



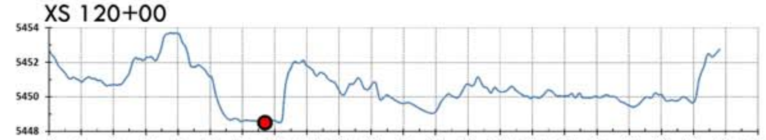
XS 110+00



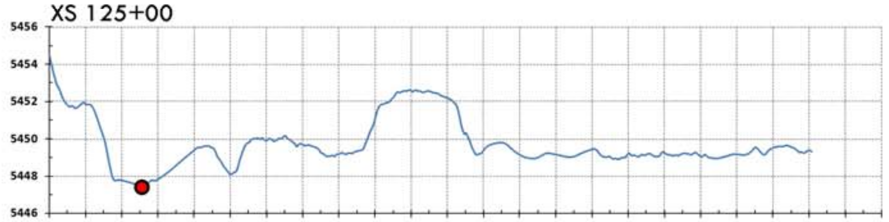
XS 115+00



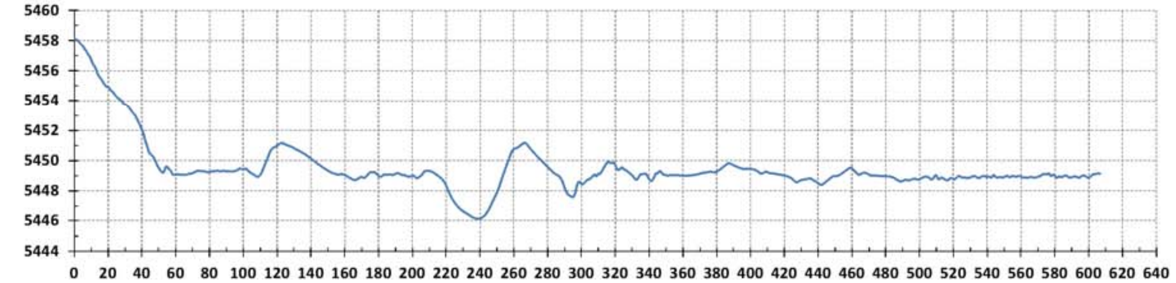
XS 120+00



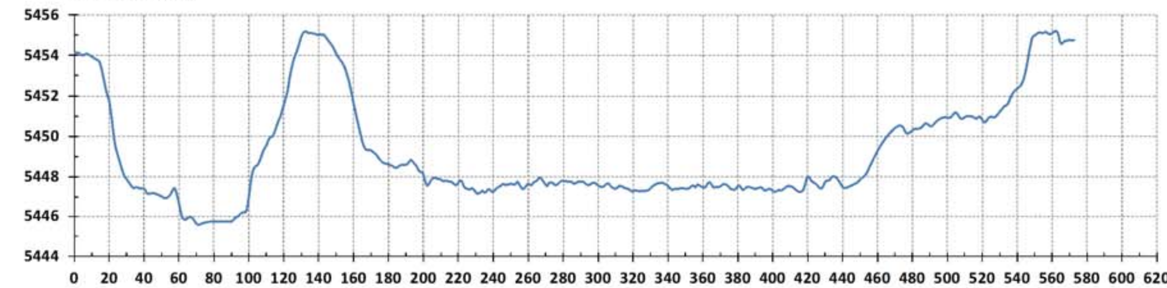
XS 125+00



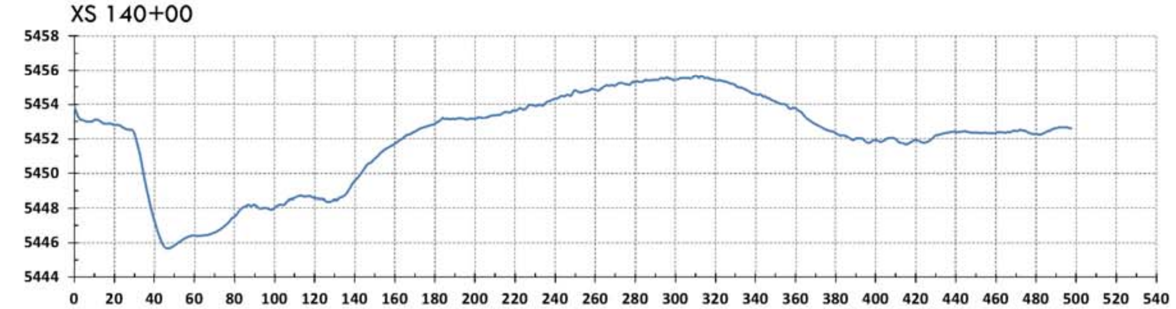
XS 130+00



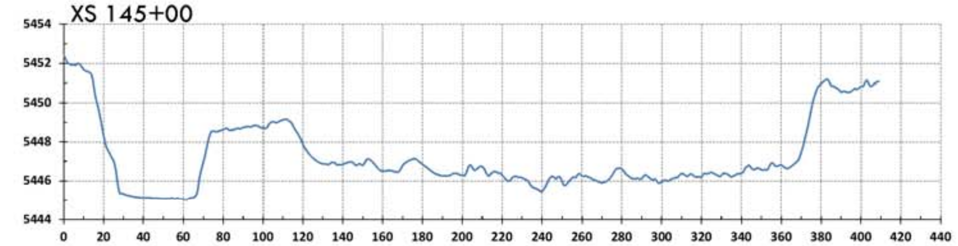
XS 135+00



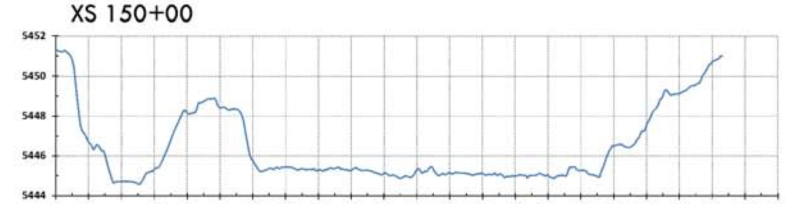
XS 140+00



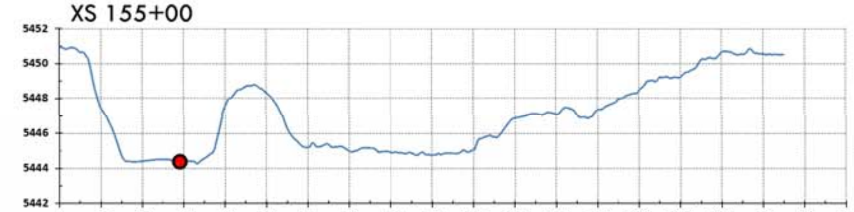
XS 145+00



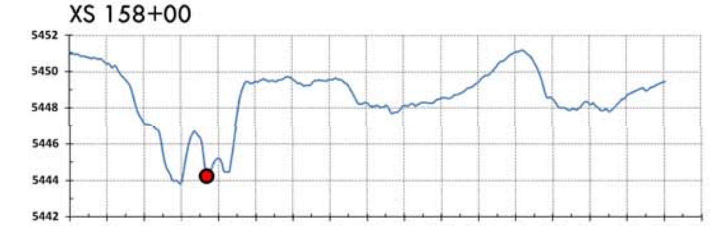
XS 150+00

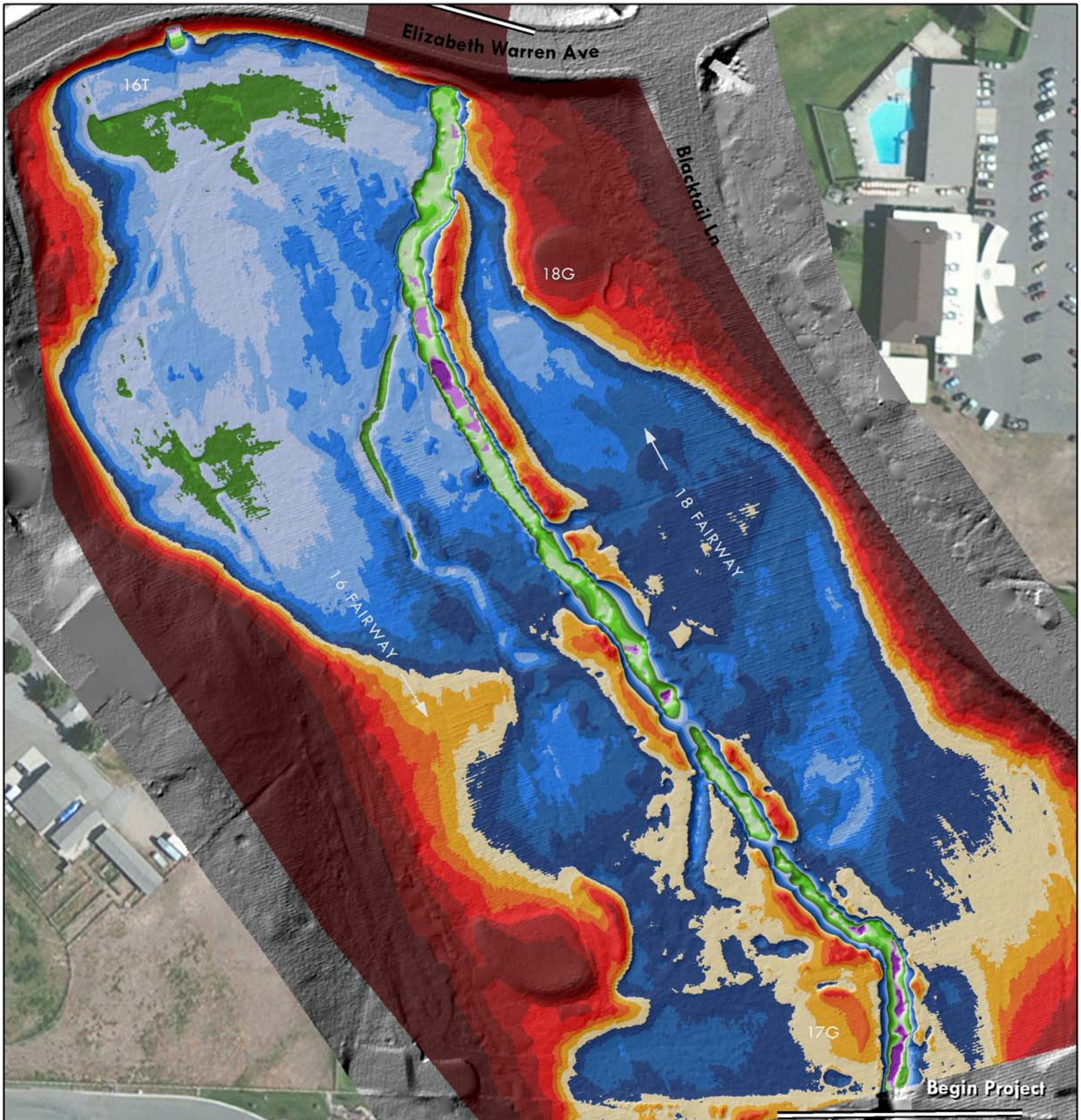


XS 155+00



XS 158+00





Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-11-01 Existing Conditions

0 50 100 150 200 400 Feet

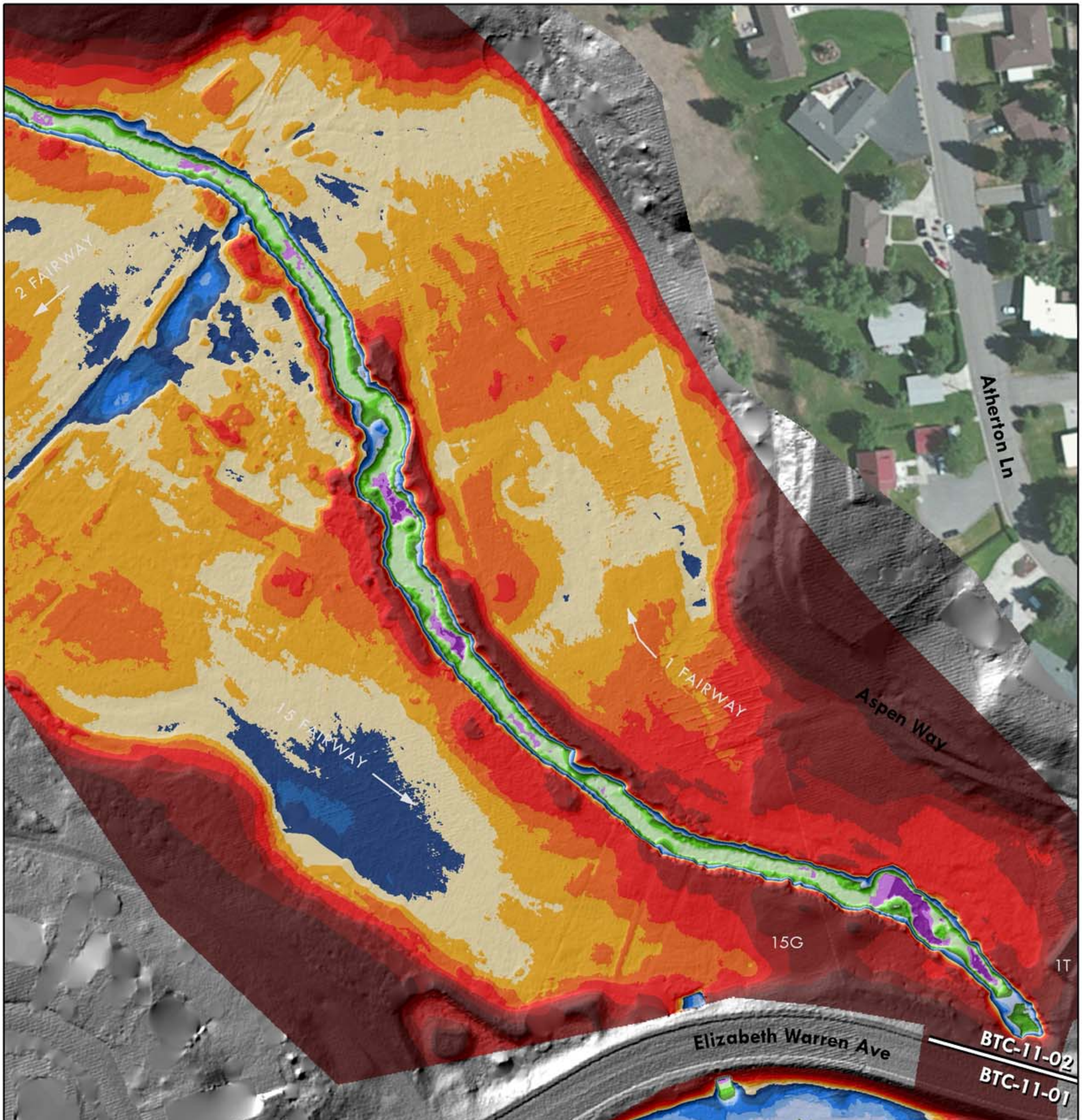
1:1,600

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 35

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-11-02 (upstream) Existing Conditions

0 50 100 150 200 400 Feet

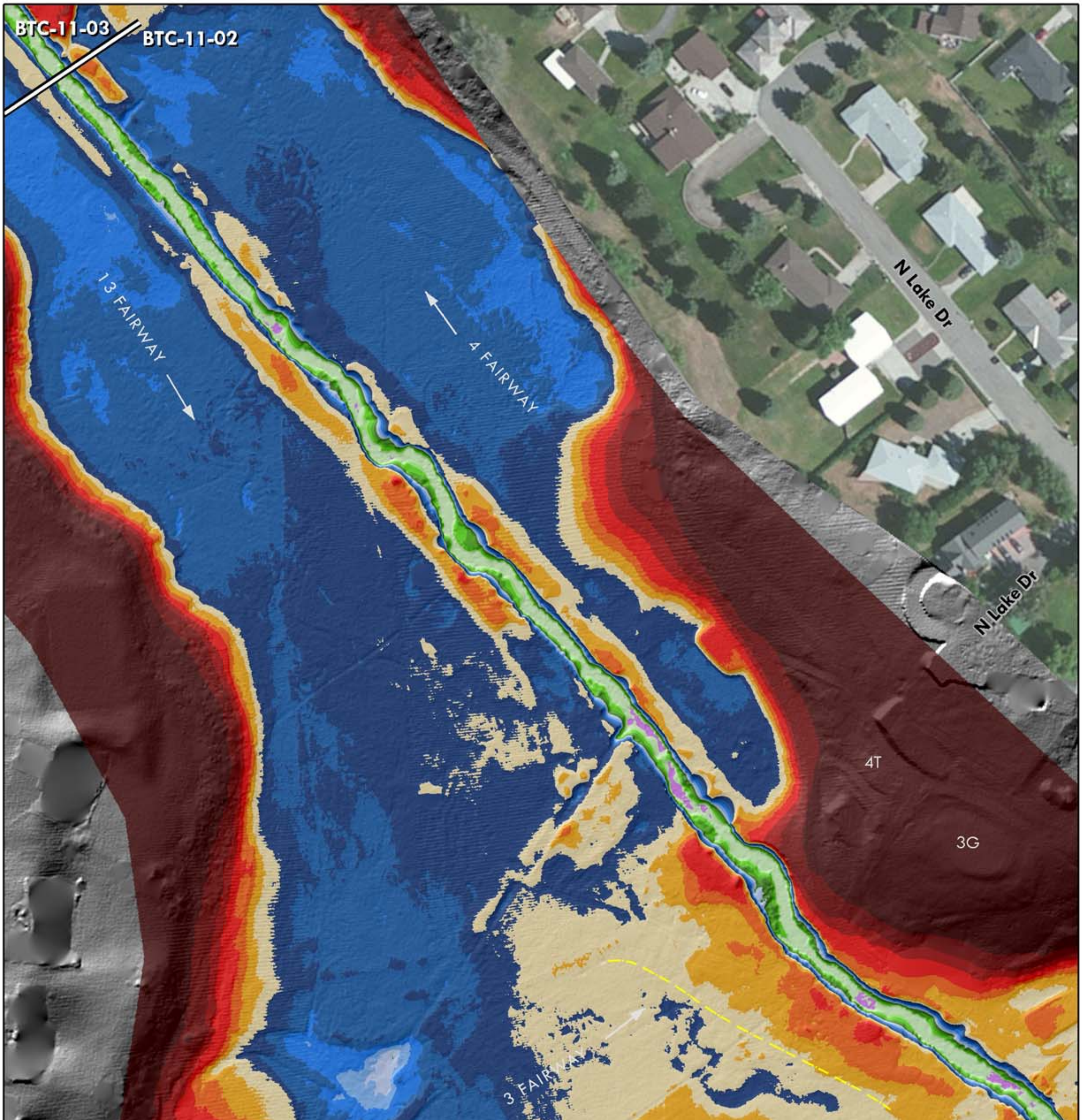
1:1,600

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design
Reach BTC-11-02 (downstream) Existing Conditions

0 50 100 150 200 400 Feet

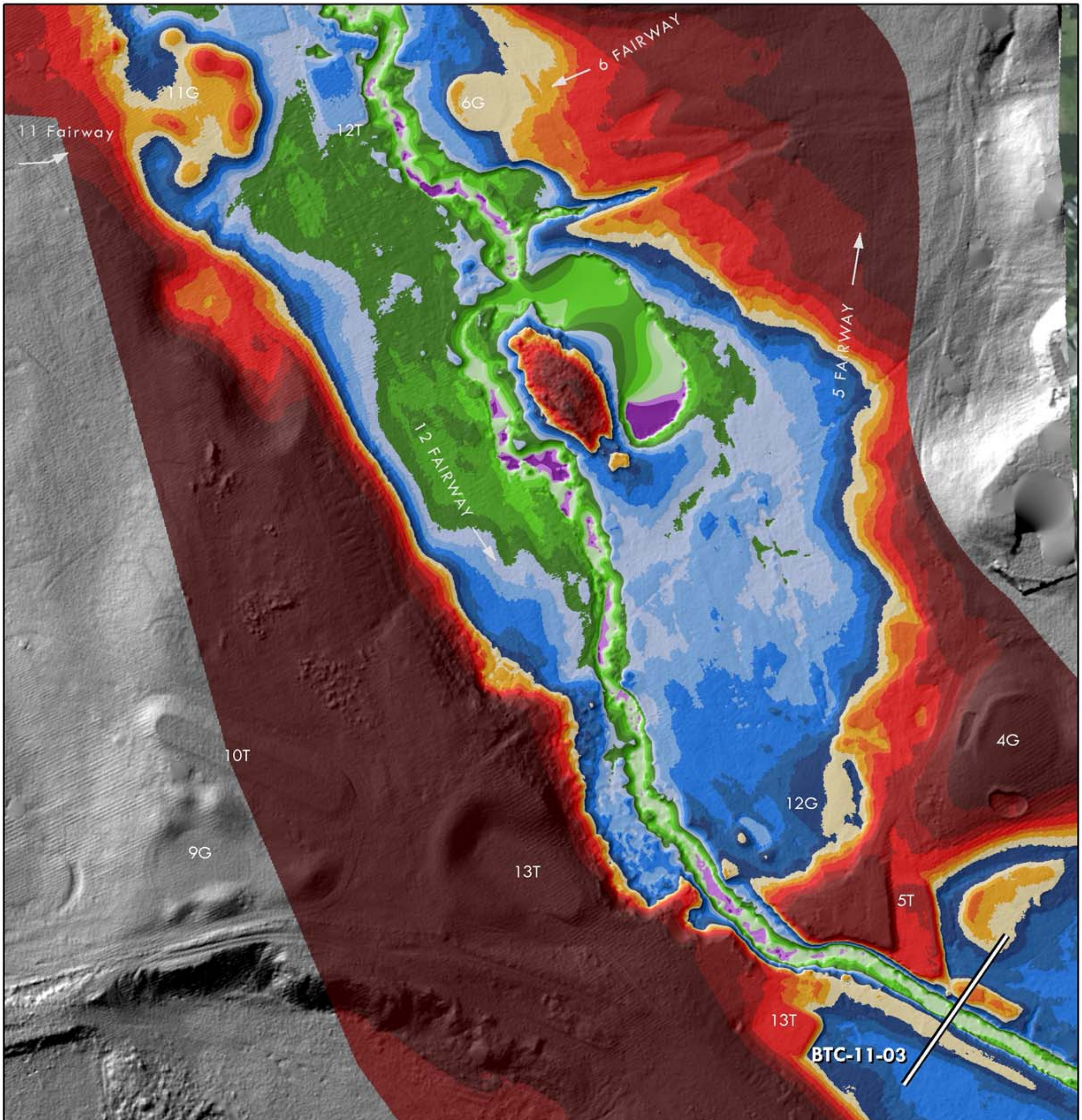
1:1,600

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-11-03 (upstream) Existing Conditions

0 50 100 150 200 400 Feet

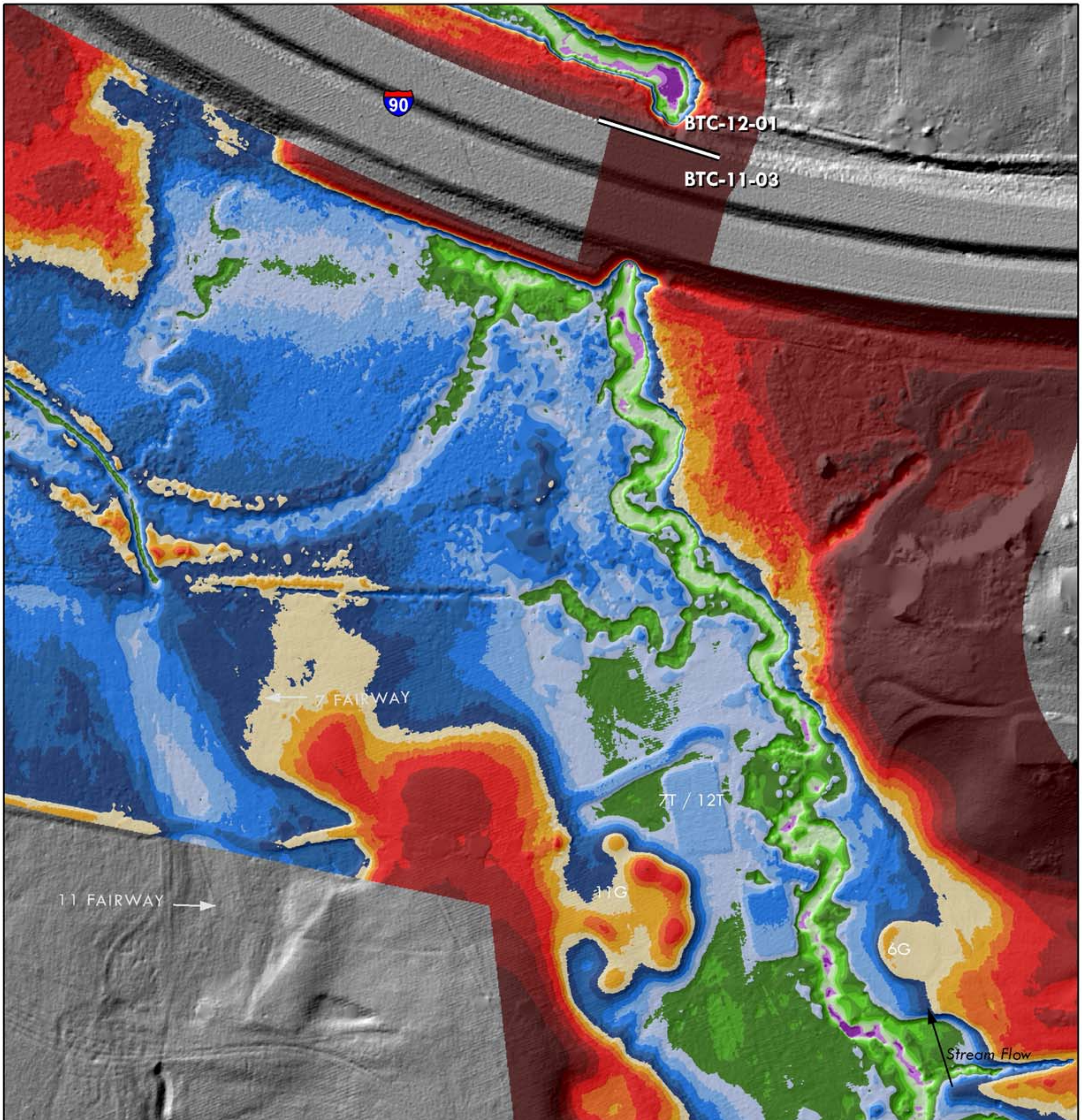
1:1,600

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-11-03 (downstream) Existing Conditions

0 50 100 150 200 400 Feet

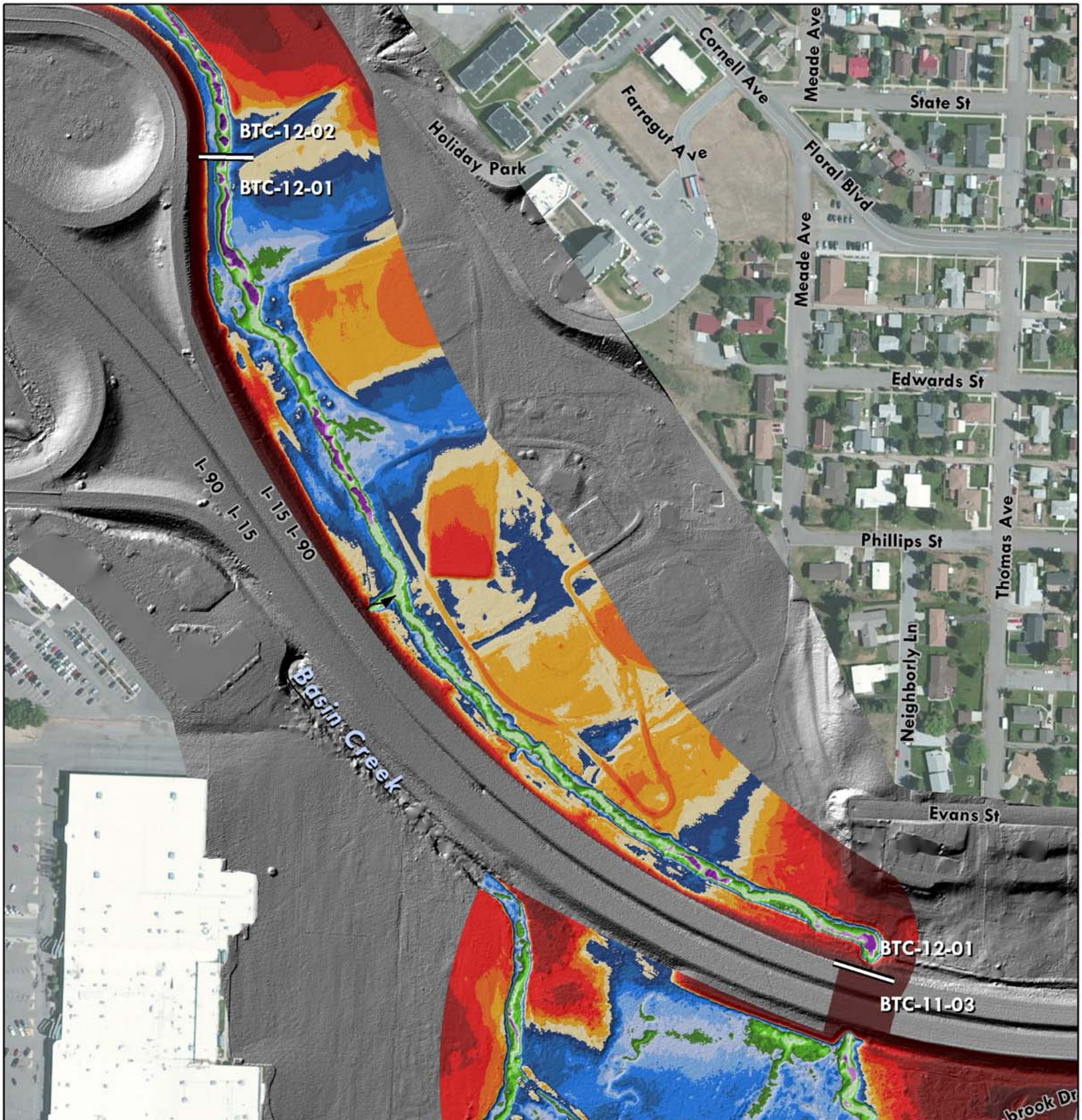
1:1,600

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-12-01 Existing Conditions

0 100 200 300 400 800 Feet

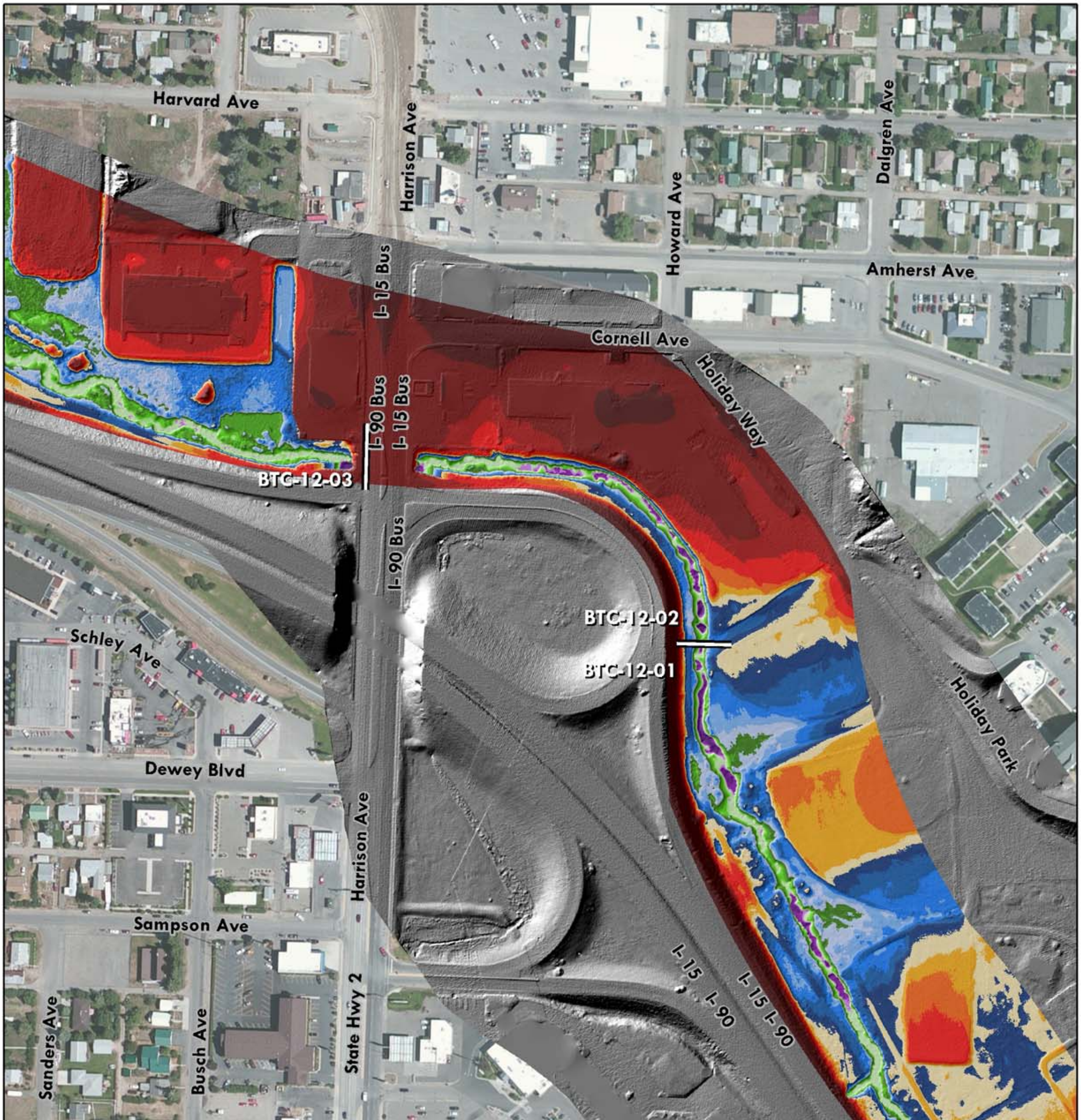
1:3,200

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-12-02 Existing Conditions

0 100 200 300 400 800 Feet

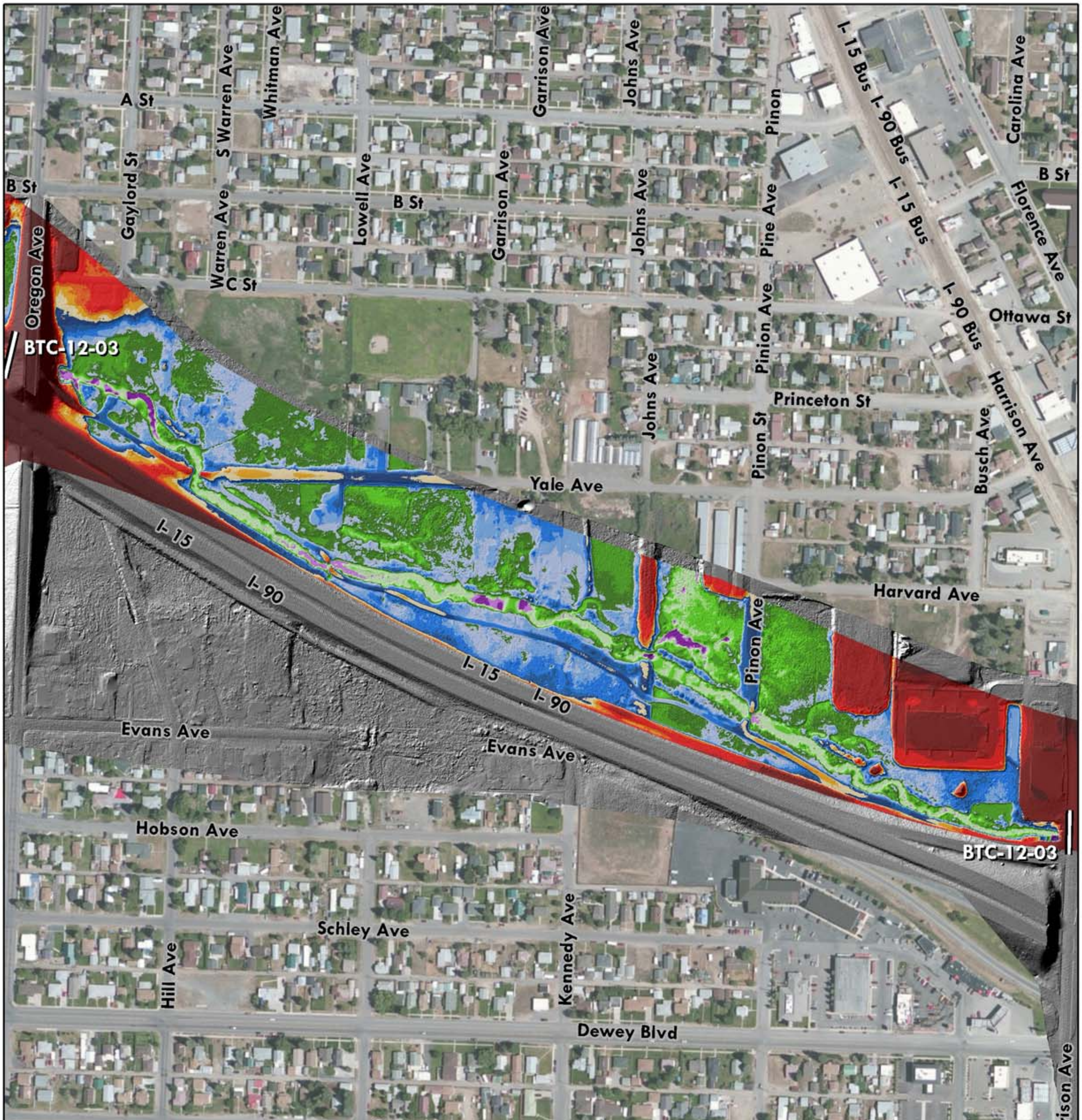
1:3,200

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-12-03 Existing Conditions

0 200 400 600 800 1,000 Feet

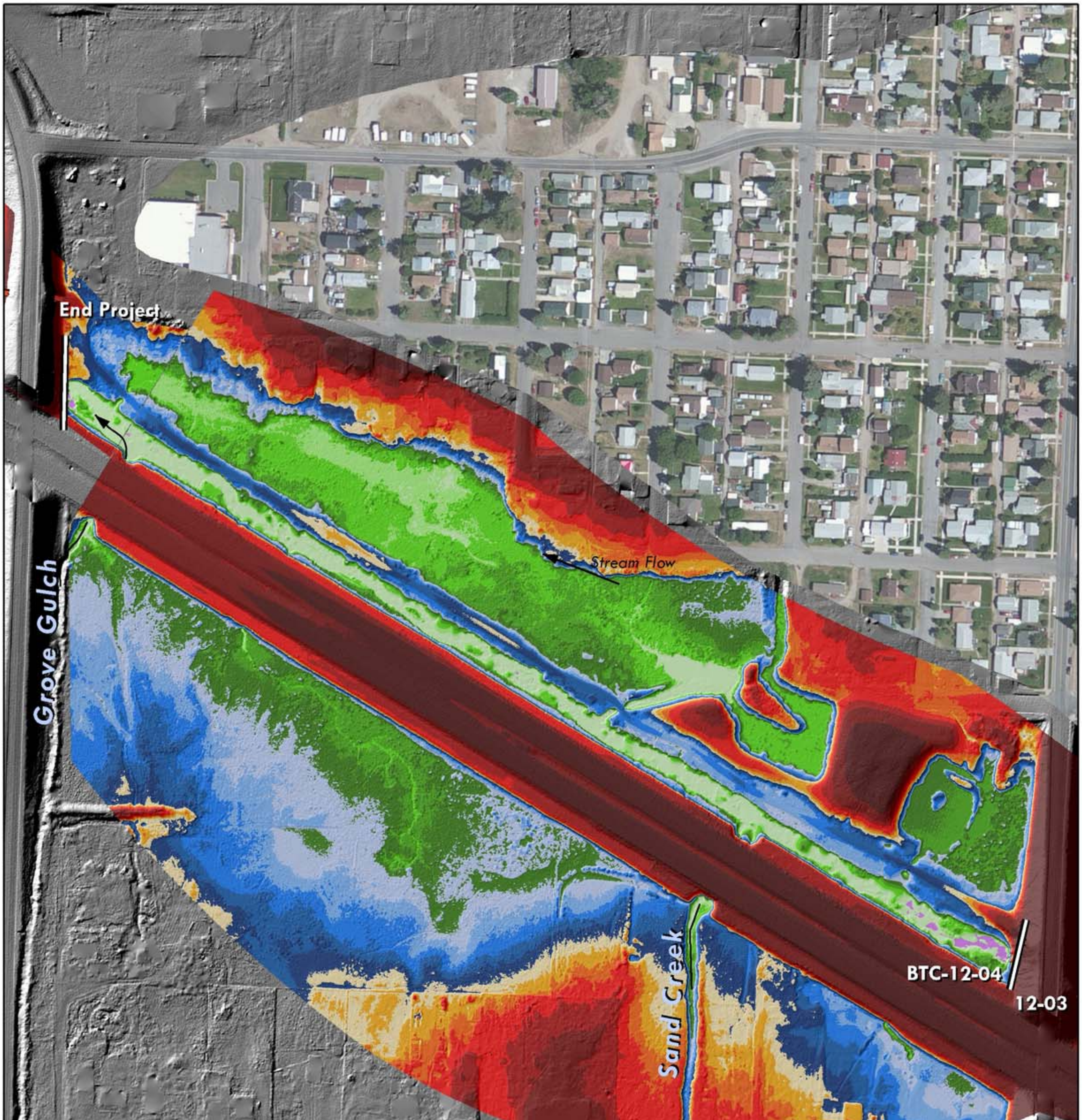
1:4,800

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.



Lower Blacktail Creek Conceptual Restoration Design

Reach BTC-12-04 Existing Conditions

0 100 200 300 400 800 Feet

1:3,200

N

Elevations Relative to Water Surface (feet)

-10 -1 -0.5 -0.25 0.25 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 7 8 10 15

11.21.2014. River Design Group, Inc. Imagery: 2011 ESRI World. LiDAR data flown 07.09.2013: City of Butte.

Appendix D – 11x17 Conceptual Restoration Plans

Lower Blacktail Creek
Conceptual Restoration Design

Reach 11 Design

Features

- Floodplain Excavation
- Channel Reconstruction
- Transition Slope
- Floodplain Surface
- Streambank Structure
- Floodplain Swale
- Treatment Wetland
- Floodplain Wetland
- Revegetation Area
- Conservation Area
- Boulder/Log Weir
- Diversion and Fish Screen
- Pond Outlet Control
- Intermittent Stream

1 inch = 200 feet

11.13.2014. River Design Group, Inc.
Data:
USGS NHD; 2013 TIGER Line Data;
Imagery: 07.12.2011 ESRI World.

Lower Blacktail Creek Conceptual Restoration Design

Reach 12 Design

Features

- Conservation Area
- Road Removal
- Intermittent Stream
- Sub-Reach Break

N

1 inch = 200 feet

11.14.2014. River Design Group, Inc.

Data: USGS NHD; 2013 TIGER Line Data; Imagery: 07.12.2011 ESRI World.

12A

Lower Blacktail Creek Conceptual Restoration Design

Reach 12 Design

Features

- Floodplain Excavation
- Channel Reconstruction
- Bridge
- Treatment Wetland
- Open Water Wetland
- Emergent Wetland (Fill)
- Conservation Area
- Intermittent Stream
- Sub-Reach Break

1:2,400

11.14.2014. River Design Group, Inc.

Data: USGS NHD; 2013 TIGER Line Data; Imagery: 07.12.2011 ESRI World.

12B