Grimes Creek Riparian Restoration Monitoring 2010 - 2012

Grimes Creek riparian, before restoration and mine tailing removal, 2011 (left); Grimes Creek riparian, 1 year after restoration and tailing removal (right)

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ABSTRACT

This report details results of before and after monitoring during the implementation phase (2010 - 2012) of a riparian restoration project on Grimes Creek in southwest Idaho. Approximately 4,200 m^2 of floodplain was restored by removing mine tailing piles left after dredge placer mining during the early to mid-1900's. Over 700 riparian trees and shrubs were planted on the site after mine tailing removal. Quantitative, reference-based effectiveness monitoring at the Grimes Creek restoration site was conducted in 2010 (pre-implementation) and in fall 2011 (post-implementation) and spring 2012. Planted species survival, woody species cover and height, herbaceous species cover and height, and ground cover features were monitored along 11 permanently marked transects. In addition, soil and floodplain characteristics were described. Results were compared to two groups of reference sites. Long-term natural recovery reference sites (> 50 years old) were located in lightly to minimally disturbed stream reaches in watersheds ecologically similar to the watershed being restored. Sections of floodplain on Mores Creek that had also been restored by removal of mine tailings 6 years ago served as other reference sites. Removal of mine tailings and restoration of floodplain at Grimes Creek met overall project objectives. The width of the floodprone area was widened, exceeding that of reference sites. The substrate became moister and finer in texture, suitable for establishment of riparian vegetation as indicated by an increase in the presence of wetland indicator species. Initial survival of planted species was acceptable and similar to other riparian restoration projects in the Pacific Northwest. The diversity of native riparian vegetation increased, but it is too early to observe any increases in riparian cover or development of multiple layers of vegetation. In general, the trajectory of succession on restored floodplain was towards that of reference sites.

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KEY WORDS

effectiveness monitoring, restoration, riparian habitat, vegetation, soil, floodplain, reference condition, watershed, stream reach, ecological group, placer mine tailings, Grimes Creek, Idaho

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INTRODUCTION

Riparian vegetation forms a critical link between terrestrial and aquatic ecosystems (Hansen et al. 1995). Intact riparian habitats are vitally important for maintaining properly functioning stream systems within natural disturbance regimes (USDI BLM 1998, Boise-Payette-Sawtooth National Forest 2003, Kershner et al. 2004). Riparian ecosystems with appropriate vegetative composition and structure (Adamus et al. 1991, Brinson 1993, Hansen et al. 1995, Smith 1995, Novitzki et al. 1996) function to:

- stabilize streambanks
- reduce sediment inputs
- maintain proper water chemistry and nutrient cycling for aquatic ecosystems
- shade water and maintain proper temperatures for aquatic organisms
- supply large woody debris for diverse channel characteristics and aquatic habitat
- retain floodwaters
- recharge groundwater
- support stream baseflows
- promote floodplain development and terrestrial habitat
- provide primary habitats for biota, including numerous at-risk species

Although riparian habitats with high ecological integrity and function still exist, many riparian areas in Idaho have been degraded by hydrologic alteration, pollution, land uses, and other impacts (Quigley et al. 1999). During the last 40 years, hundreds of riparian restoration projects have been completed throughout Idaho. Cumulatively, tens of millions of dollars have been spent and a variety of partners and communities are vested in outcomes, especially on private and state-managed land. Many public-private partnerships currently function to restore riparian habitat in Idaho.

In the Grimes Creek watershed of southwest Idaho, as well as surrounding watersheds (e.g., Mores Creek), extensive dredge placer mining for gold occurred from the 1860's to the 1950's. As a result, Grimes Creek currently flows through hundreds of acres of tall cobble and gravel mine tailing piles (Figure 1). In many areas where tailing piles abut the stream, a floodplain is lacking and riparian vegetation is minimal. Streambanks are unstable, sediment inputs are elevated, stream temperatures are excessive for trout, aquatic habitat is poor, and the stream channel is shallow and over-widened. Some riparian areas along upper Grimes and Mores Creek that were mined over 50 years ago, where tailing piles were not as high or extensive, have recovered naturally and are mostly functioning.

Figure 1. Low altitude aerial photo of dredge mine tailings along Grimes Creek, showing narrow bands of floodplain and discontinuous, degraded riparian habitat. Photo courtesy of Trout Unlimited.

To address these issues, the landowner, Trout Unlimited, and Idaho Department of Fish and Game, with assistance from various state and federal agencies, formed a partnership to restore riparian habitat in Grimes Creek. In winter 2010 - 2011, mine tailing piles covering approximately 4,200 m^2 adjacent to Grimes Creek were removed to the flood-prone elevation to restore floodplain and alluvial terrace habitat (Figure 2). From spring through fall 2011, volunteers planted over 700 native riparian shrubs and trees at the site.

Figure 2. Restored stream reach (yellow arc), approximately 300 m long, at Grimes Creek.

Objectives for most restoration projects, including the Grimes Creek project, are to restore the ecological condition, integrity, processes and/or functions of riparian ecosystems so that habitat features necessary for fish, wildlife, and waterfowl are optimized and water quality and other beneficial services to communities improved. However, across Idaho, relatively few resources have been expended to evaluate how well restoration objectives have been met. Monitoring is often lacking or limited to short periods (e.g., < 5 years) and sometimes includes only qualitative or limited quantitative observations (Wall 2011). Some programs do not, or only minimally fund monitoring and evaluation. Few programs require projects to monitor progress toward meeting quantifiable biological objectives. Data from pre-implementation and/or control reference sites is often lacking. The National River Restoration Science Synthesis found that less than 20% of Idaho's riparian management and restoration projects were monitored. When re-evaluated, many projects are found to be functioning below success standards. Because of this need for more riparian restoration monitoring and the scale of the project, we felt that it was vitally important to initiate quantitative, reference-based effectiveness monitoring at Grimes Creek. This report details results of before and after monitoring during the implementation phase of the project (2010 - 2012).

STUDY AREA

Grimes Creek is a high-order tributary stream in the Boise-Mores subbasin (Figure 3). This subbasin occurs within the Idaho Batholith Section (Bailey 1980).

Geology

The Idaho Batholith is the dominant geological formation within the Boise-Mores subbasin. The region is faulted and uplifted, characterized by highly weathered intrusive rocks and localized sedimentary and basalt outcrops (Bond and Wood 1978, Bailey 1980). The batholith formed about 63-135 million years before present. It is characterized by a mix of granite and other intrusive rocks, including quartz monzonite, monzonite, granodiorite, quartz diorite, and diorite (Bond and Wood 1978). These rocks form coarse sand and gravel soil upon erosion and weathering. Only the highest elevations of the subbasin were influenced by Quaternary glaciations, producing small cirques and u-shaped glacial trough valleys. However, lower elevation basins and wide valleys are often filled with glacial drift, outwash, and alluvium. In the Boise Basin these deposits were placer mined for gold.

Climate

Several climatic regimes exist in the Boise-Mores subbasin. Lower elevation drainages (below about 5,500 ft) have warm, dry summers, and relatively mild, moist winters. Although shrub-steppe vegetation characterizes the hottest, southerly facing foothill slopes, the majority of this zone is dominated by ponderosa pine woodland and forest. Mid-elevation mountain slopes (e.g., about 5,500-6,500 ft, depending on aspect) are significantly cooler and moister, but not necessarily extremely so. Douglas-fir forests characterize the vegetation in this zone. This is in contrast to the deep snow, high annual precipitation, and cool average temperatures found at high elevations. Lodgepole pine, subalpine fir and Engelmann spruce form forests in these cool and moist settings (both high elevations and in montane valley bottoms with cold air drainage).

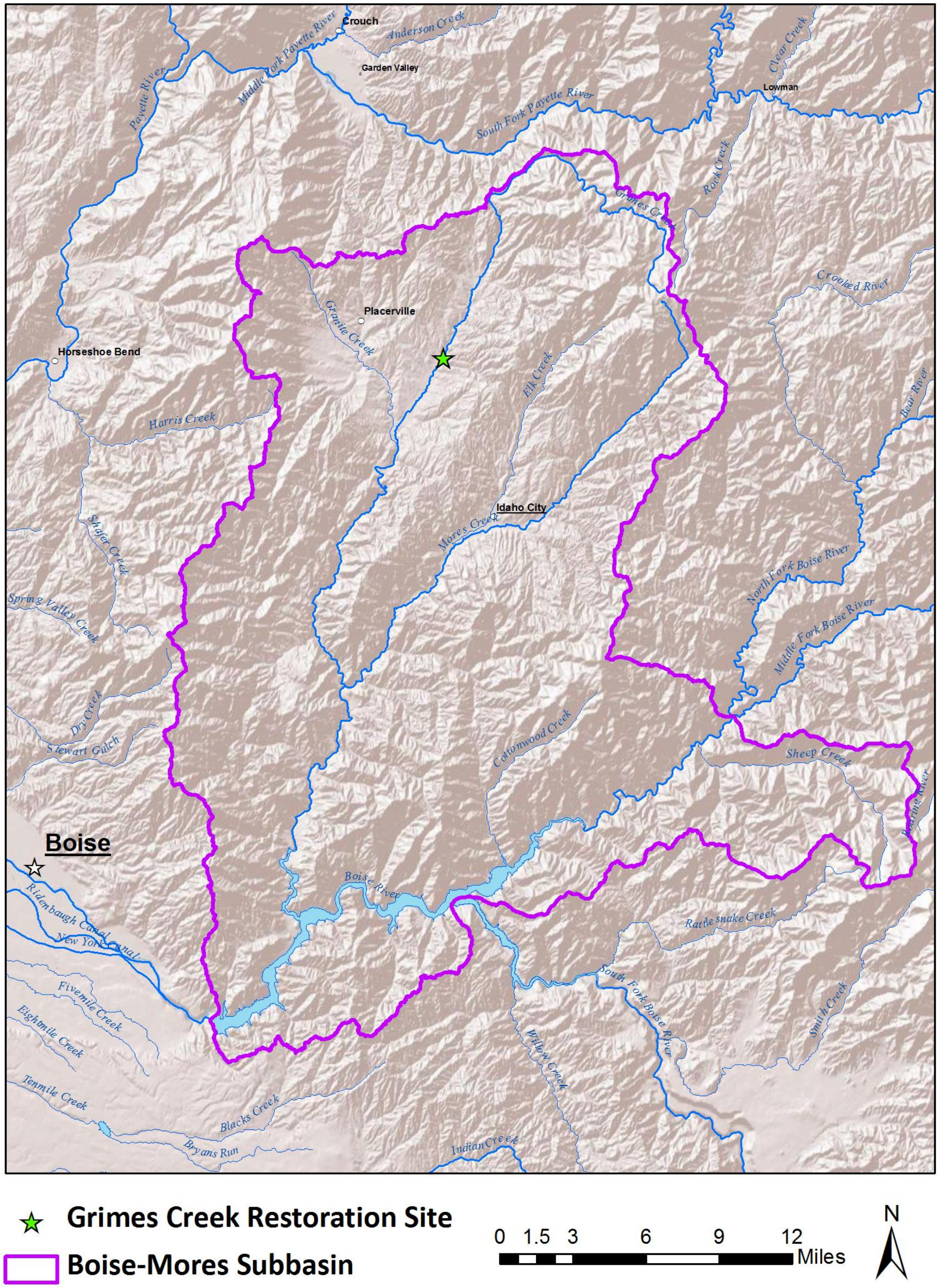

Figure 3. Location of Grimes Creek riparian restoration site.

Based on data from nearby foothill and lower montane weather stations (Lucky Peak Dam, Arrowrock Dam, Idaho City) total annual precipitation averages 36 - 61 cm (14 - 24 inches) (Idaho State Climate Services 2011). The wettest months are November through March, when 3.1 - 9.4 cm (1.2 - 3.7 inches) of precipitation falls each month (mostly as snow). Shallow snowpacks, 15 - 48 cm (6 - 19 inches) in depth, are characteristic at these low elevations. Winter minimum temperatures average about -10.6 to -6.1 C (13 to 21 F) and maximum temperatures about 0.6 to 1.7 C (33 to 35 F). During cold air inversion periods, large blocks of ice accumulate on streambanks. The growing season is from late April through September, although areas with localized cold air drainage differ. Summer high temperatures average 31.1 to 33.3 C (88 to 92 F). April through June is moderately moist, with 2.5 - 5.1 cm (1 - 2 inches) of rain falling each month. Except for occasional thunderstorms, the period from late June to late September is dry. The restoration site in Grimes Creek near Centerville has a lower montane climate, similar to the slightly cooler and moister regime occurring at Idaho City. In contrast to the low elevation climate, high elevation precipitation ranges from 74 - 117 cm (29 - 46 inches) per year. Based on snowfall data from Bogus Basin and Mores Creek Summit, snowpack depths range from 191 - 267 cm (75 - 105 inches) deep at their peak in late April (NRCS 2011).

Hydrology

High elevation headwater streams traveling through mountainous terrain have moderate to high gradients and mostly narrow floodplains. Most headwater streams originate from melting snowpack or springs on mountain slopes and flow through narrow, high gradient v-shaped valleys. Eventually, these streams enter either broad, low gradient basins filled with glacial outwash and alluvium (e.g., Mores and Grimes Creeks) or river canyons with relatively broad floodplains (e.g., Middle Fork Boise River). Other streams in the subbasin originate from either mid-slope or toeslope springs. Although low elevation snowpacks melt by March or early April, high elevation snowpacks do not melt until late May or early June. This situation creates an early spring peak flow and a larger late-spring flood peak along most streams and rivers. Groundwater discharge sustains stream flows throughout the drought-prone summer and frozen winter months. The breakup of ice on streams and rivers during mild winter periods can be an important floodplain disturbance.

Ecology

Riparian habitats in the Boise-Mores subbasin primarily occur in riverine settings (Brinson 1993). The main habitat on Grimes Creek is “Foothill and Lower Montane Floodplain and Alluvial Terrace Woodland and Shrubland.” The depth and frequency of flooding is a major factor in development of vegetation communities in this habitat (Hansen et al. 1995). Where unconstrained by mine tailing piles, riverine riparian vegetation reflects dynamic floodplain processes. Floodplain width is a function of valley width, gradient, and condition (Weixelman et al. 1996). Frequently flooded gravel bars, sites for early seral plant communities (including black cottonwood) eventually become overlain by fine sediments as channels laterally migrate. Different tree and shrub vegetation types occur on less frequently flooded terraces, the relics of floodplains later incised by stream channels. Multiple terrace complexes result in valleys that receive large deposition events (common in the Idaho batholith). Floodplain soils are often variable, ranging from fine-textured loams in gently sloped lower montane valleys to coarse sand and gravel in steeper streams (Hansen et al. 1995, Weixelman et al. 1996, Walford et al. 2001) (e.g., mid elevation, montane zone). Soils derived from recent deposits are sandy. Soil texture determines drainage, aeration, nutrient availability, chemistry, and element cycling. Soil formation is also influenced by cold air drainage, growing season length, and saturation. Prior to European settlement, beaver created most ponds in the subbasin and increased wetland and riparian habitat in broader valleys. Since settlement, dredge placer mining has created numerous ponds in valley bottoms, many of which support fringing marsh vegetation.

METHODS

The goal of monitoring was to collect information to answer the following questions related to project objectives:

- Did removal of mine tailing piles increase the width of the floodprone area and create a substrate suitable for establishment of riparian vegetation?
- What was the rate of planted species survival?
- Did restoration increase the cover and diversity of native riparian vegetation?
- Is the successional trajectory on the restored floodplain toward vegetation composition and structure that is similar to reference sites?

Vegetation composition and structure, native plant species diversity by habitat, ground cover attributes, soil characteristics, and floodplain configuration were monitored. In 2010, monitoring occurred on October 11 and October 13. In 2011, monitoring was on September 27 and September 29. In 2012, monitoring took place on June 22, June 25, and June 26.

Transect Layout

Five 50 m-long baseline transects were established parallel to the streambank through the restoration site (Winward 2000, Kershner et al. 2004, Burton et al. 2007). The baselines were contiguous end-to-end but varied in their direction due to meandering of the stream. The end-points of each transect were permanently marked with a lightweight fencepost and their locations recorded using a GPS unit. Eleven 15 m-long transects (labeled 1A, 1B, 1C, 2A, 2B, 3A, 3B, etc.) were then established perpendicular to the baselines across the restored floodplain (Harris et al. 2005). They were located at the start, mid-point (25 m point), and end of each baseline transect (Figure 4). Sampling was conducted along each 15 m transect.

Figure 4. Layout of 50 m baseline transects and perpendicular 15 m sampling transects.

Planted Species Survival Assessment

The survival of all planted species was monitored using methods similar to Harris et al. (2005). Every planted individual that could be located within the restored floodplain was tallied by species and status (live high vigor, live low vigor, or dead). The height and width dimensions (2 measurements) were recorded for the first 8 individuals of each species encountered.

Woody Species Density

Density of woody species was monitored by counting each species of tree or shrub rooted within eight 1-m² quadrats (Elzinga et al. 1998, Winward 2000, Burton et al. 2007). Species were recorded by height class (< 0.5 m, 0.5 - 2 m, > 2 m). Quadrats were regularly spaced on the left side of each 15 m-long transect at the 1 m, 3 m, 5 m, 7 m, 9 m, 11 m, 13 m, and 15 m marks. This quadrat spacing assured independence (Elzinga et al. 1998).

Woody Species Cover and Structure

The line intercept method (Canfield 1941, Elzinga et al. 1998, Winward 2000, Kershner et al. 2004, Burton et al. 2007) was used to determine the percent canopy cover of all live and dead tree or shrub species along each 15 m transect. Overhanging and rooted shrubs and trees were included, and we assumed a closed canopy until the gap exceeded 20 cm. To better describe vegetation structure, line intercept for each species was read in 3 height classes (< 0.5 m, 0.5 - 2 m, > 2 m).

Herbaceous Cover

Herbaceous cover was monitored using the same 1-m² quadrats used for recording woody species density. The canopy cover of each herbaceous species within or overhanging the 1-m² quadrat was recorded (Elzinga et al. 1998, Burton et al. 2007). The average height of all herbaceous vegetation in each quadrat was also estimated.

Ground Cover

Characteristics of the ground surface were monitored using a point intercept method (Elzinga et al. 1998). At each meter along the 15 m transect (starting at the 1 m mark) the type of substrate was recorded (water; plant litter on ground; wood (> 3 cm diameter) on ground; moss, lichen, or liverwort on soil; sand or soil (< 1 cm diameter particles); gravel (1 - 2.5 cm diameter particles); cobble (2.6 - 25 cm diameter rocks); boulder (> 25 cm diameter rocks).

Reference Sites

Reference watersheds are widely used in monitoring riparian condition and restoration progress (Harris 1999; Brooks et al. 2002; Grafe 2002*a, b*; Johnson 2005). The first step in describing reference characteristics is to analyze ecological integrity and place watersheds in condition classes (Tiner 2002; Grafe 2002*a, b*; Brooks et al. 2004; Johnson 2005). The next step is to identify which watersheds are in similar ecological groupings based on soils, hydrology, geomorphology, and climate (Spivey and Ainslie 2004, Johnson 2005, Idaho Conservation Data Center 2007). Twelve-digit (6th level) hydrologic units (HUC 12s) were used to represent watersheds for classification of ecological groups and assessment of reference condition (Grafe 2002*a, b*, Oechsli and Frissell 2003, Johnson 2005).

As part of a recently completed landscape-scale assessment project (Murphy and Schmidt 2010), spatial analysis was used to estimate the relative condition of watersheds throughout Idaho based on a variety of mapped land uses and threats. All HUC 12s statewide were ranked and placed in 6 condition classes, the breakpoints between which were similar to Troelstrup and Stueven (2007). Results from that project were applied to HUC 12s in the Boise-Mores subbasin. Multivariate analysis techniques were used to classify and ordinate the 229 HUC 12s in the Boise River, Payette River, and immediately adjacent drainages (primarily within the Idaho Batholith section) into ecologically similar groups (Johnson 2005). Complete classification methods are found in Murphy (2011).

Of the 24 HUC 12s in the Boise-Mores subbasin, 5 were minimally disturbed, 16 lightly disturbed, and 3 moderately disturbed (Figure 5). Most HUC 12s had areas of locally intensive development (e.g., residential subdivision) or disturbance (e.g., logging, mine tailings, etc.). Across nearly all HUC 12s in the subbasin, roads were the main cause of watershed degradation and impairment of hydrologic processes. Dredge and hydraulic mining tailings were poorly accounted for because a map of historic mining impacts was lacking. Existing land use and cover maps did not map, or inadequately mapped tailings, partly because they have sometimes become revegetated since disturbance. Logging and associated construction of temporary roads were also not adequately mapped throughout the subbasin. Minimally disturbed HUC 12s, such as Wild Goat Creek-Grimes Creek and Macks Creek-Grimes Creek, had relatively low road densities and only a few residential or other developments (e.g., mining, recent timber harvest). The Granite Creek-Mores Creek HUC 12 had moderate road density, but had relatively few rural residences or other developments. Lightly disturbed HUC 12s had moderate road densities and variable amounts of rural residential development, livestock grazing, and logging. Moderately disturbed HUC 12s (e.g., Bannock Creek-Mores Creek and Lower Elk Creek) were associated with Idaho City and adjacent residential development and Lucky Peak Reservoir.

The 24 HUC 12s in the Boise-Mores subbasin belonged to 4 ecological groups (Figure 6). The Grimes Creek restoration site occurred in the Henrys Creek-Grimes Creek HUC 12 which belonged to the “lower montane ridges, mountains, and alluvial valleys, batholith, low relief, temperate” ecological group. The Henrys Creek-Grimes Creek HUC 12 and similar HUC 12s (e.g., those feeding Mores Creek around Idaho City) are distinctively low montane and mostly lower in relief, underlain primarily by granitic bedrock of the Idaho Batholith.

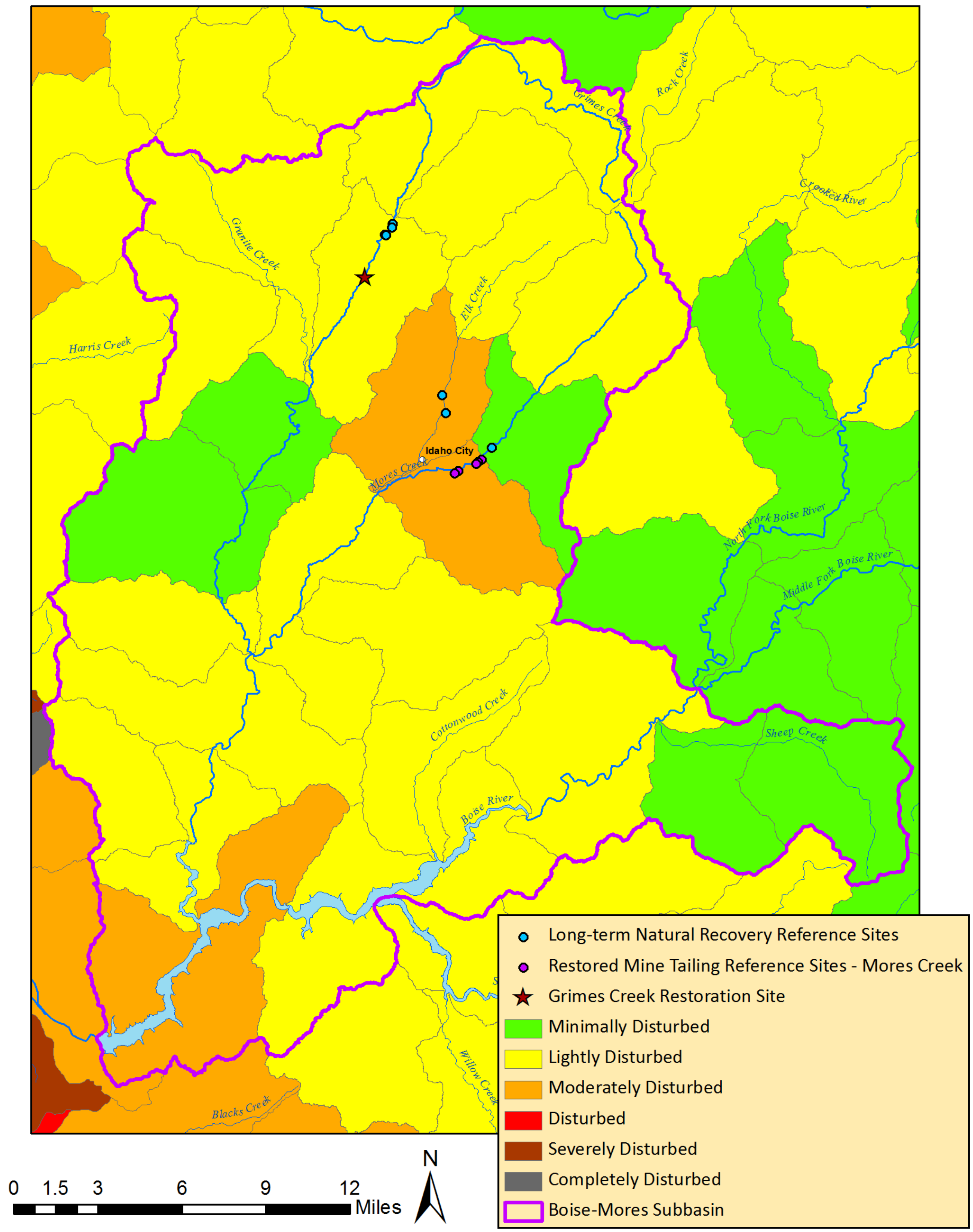

Figure 5. HUC 12 condition classes in the Boise-Mores subbasin.

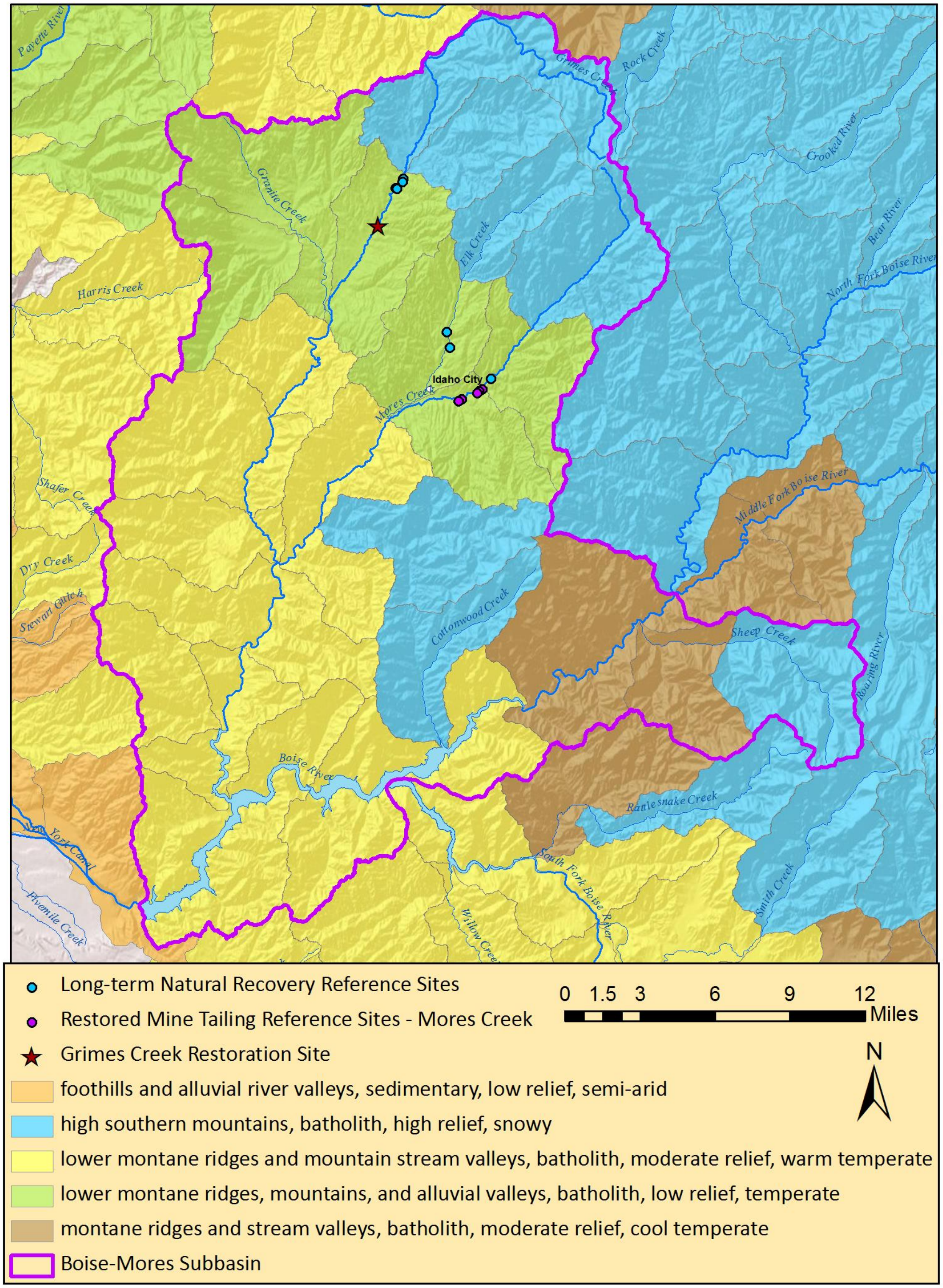

Figure 6. Distribution of HUC12 ecological groups across the Boise-Mores subbasin.

There are numerous shrub-lined, low-order perennial and intermittent streams draining ridges that feed the broad, alluvium filled valleys of large-order streams such as Granite, Grimes, and Mores Creeks. Several different willows can be abundant in these valleys on recent floodplain deposits. Black cottonwood and other shrubs occur in lesser amounts. Beaver are locally common. Winters are cool, summers warm, and precipitation moderate.

The objective for this monitoring project was to find unrestored, minimally disturbed, naturally occurring riparian reference vegetation stands and restored riparian vegetation reference stands. The HUC 12 condition map was overlaid on the HUC 12 ecological group map. This helped guide selection of minimally or lightly disturbed reference stands in the "Foothill and Lower Montane Floodplain and Alluvial Terrace Woodland and Shrubland" habitat occurring in the "lower montane ridges, mountains, and alluvial valleys, batholith, low relief, temperate" HUC 12 ecological group . A reference stand was identified in a lightly disturbed HUC 12 on upper Mores Creek (Granite Creek-Mores Creek HUC 12) and several occurred along Grimes Creek (Henry Creek-Grimes Creek HUC 12). Reference stands were also identified along a minimally disturbed stream reach of the Lower Elk Creek HUC 12 (in a moderately disturbed HUC 12) (Figures 5 and 6).

Reference Vegetation Sampling

The composition and structure of vegetation was sampled at representative reference stands. Plots were placed in the middle of relatively homogeneous stands of riparian vegetation at least twice the plot size, so as to avoid ecotones. Stands were located without preconceived bias and prior placement within an existing classification scheme. Vegetation was sampled in 20 x 5 m plots in stands with trees and in 10 x 5 m plots in shrubby stands with standard methods similar to Bourgeron et al. (1992) and Jankovsky-Jones et al. (2001). At each plot, vegetation data were recorded, including:

- canopy cover of each species
- cover of ground surface features, including water, plant litter, wood (> 3 cm diameter), non-vascular plants, sand/soil (< 1 cm diameter particles), gravel (1 - 2.5 cm diameter particles), and rocks (e.g., cobbles and boulders > 2.5 cm diameter)
- cover of trees, shrubs, graminoids, forbs, and ferns by height class of strata (e.g., tall height class > 5 m; medium 0.5 - 4.9 m; low 0.05 - 0.49 m; ground < 0.05 m).
- diameters at breast height of all trees and snags rooted in plot

Soil Characteristics

Soil samples were collected in 2012 at the Grimes Creek restoration site and all reference site vegetation plots except the two in Elk Creek (due to difficult accessibility) (5 long-term natural recovery plots in Mores and Grimes Creek and 5 restored floodplain plots in Mores Creek).

Twenty-two samples were collected at the Grimes Creek restoration site. Samples were collected in the mid-point of each 15 m transect and at the approximate center point between each 15 m transect. A sharp-shooter shovel was used to dig pits where soil samples were collected. The litter layer was first removed. Approximately 16 oz of soil was collected from each pit from the entire first 30 cm in depth. Only sand, gravel, or cobble alluvium was encountered below 30 cm. Soil samples were sent to Western Laboratories, Inc., Parma, Idaho, and analyzed for textural class, pH, salts, cation-exchange capacity, organic matter, nitrate, phosphorus, potassium, and carbon using standard methods (detailed at http://www.westernlaboratories.com/methods.htm).

Floodplain Characteristics

Characteristics of the floodplain were measured at the Grimes Creek restoration site and nearly all reference site vegetation plots. At the restoration site floodplain characteristics were measured at 3 randomly selected transects (2A, 3A, and 4B). Hydrologic, geomorphic, and other environmental data were recorded at each plot or transect, including:

- valley landform variables (e.g., slope, aspect, valley shape, width, gradient, etc.), geomorphic substrate, and adjacent vegetation
- fluvial surfaces (height above bankfull) and microtopography
- information for determining Rosgen stream type (e.g., bankfull width, bankfull depth, floodprone width, sinuosity, stream gradient, etc.) (Rosgen 1996)
- percentage of pools, glides, runs, and riffles; channel and bank materials
- presence of aggradation or downcutting
- presence/absence of woody debris
- streambank stability
- floodplain connectivity; beaver activity
- disturbances observed within sample site area (e.g., natural processes, roads, recreation sites, recent livestock use, logging, mining, hydrologic alteration, etc.)

RESULTS AND DISCUSSION

Planted Species Survival

Sixteen species of trees and shrubs were planted at the restoration site in 2011. At the end of September 2011, 578 plants were counted compared to 733 in June 2012. This included at least 75 ponderosa pines (*Pinus ponderosa*) planted on mine tailing piles adjacent to the restored floodplain. Only one ponderosa pine planted on untreated mine tailing piles survived. The reason for the difference between 2011 and 2012 was that several new clusters of trees and shrubs were planted at the restoration site in October 2011, after the initial count at the end of September. Considering just the trees and shrubs planted on the restored floodplain, there were 503 individuals counted in 2011 and 684 in 2012 (Table 1). Of these, 86% were live at the end of September 2011, compared to 84% live at the end of June 2012. These survival rates for are comparable to the average survival rate of containerized stock (82%) in a survey of 19 riparian restoration projects from the inland Northwest (Wall 2011). After planting in 2011, 59% of all plants had high vigor. By 2012, only 46% of the plants had high vigor. Plants with lower vigor tended to be clustered in higher areas of the restored floodplain that did not flood in spring 2012. These plants may be most vulnerable to mortality during summer 2012 unless supplemental irrigation is provided.

Ponderosa pine and water birch (*Betula occidentalis*) had the lowest survival rates in 2012 (both 69%) (Table 1). Ponderosa pines planted on the floodplain in October 2012 appeared to have higher survival rates than those planted during summer 2012 (e.g., survival rate was only 32% during fall 2011 monitoring). Water birch survival decreased from 90% in 2011. Peachleaf willow (*Salix amygdaloides*) had the next lowest survival rate (86%), a 10% decrease from 2011.

Decreases in vigor of $\geq$ 10% between fall 2011 and spring 2012 were recorded for Saskatoon serviceberry (*Amelanchier alnifolia*), water birch, redosier dogwood (*Cornus sericea* ssp. *sericea*), black hawthorn (*Crataegus douglasii*), black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), chokecherry (*Prunus virginiana*), and Wood's rose (*Rosa woodsii*) (Table 1). Of these species, Saskatoon serviceberry, black hawthorn, chokecherry, and Wood's rose are well-adapted to drought prone alluvial terrace habitats above the floodprone zone and not expected to have excessive mortality. Only 26% of redosier dogwood plants in 2012 were classified as high vigor. Many leaves had apparent insect damage. Whether or not these plants will recover is unknown. Plants in moister floodplain sites are most likely to survive. In general, decreased vigor resulted in decreased mean height and dimension (Table 2). In contrast, quaking aspen (*Populus tremuloides*) and golden currant (*Ribes aureum* var. *villosum*) had greater number of high vigor plants in 2012 than 2011. These species also thrive on drought prone riparian sites. Quaking aspen had the largest increase in mean height of any planted species (Table 2).

Browsing by herbivores, including beaver, was noted on only two redosier dogwood plants in 2011 and one black cottonwood in 2012. There may have been additional twigs or buds browsed during the winter, but these were not noticeable and spring growth had already masked any impacts by June 2012 monitoring.

Woody Species Density

Restoration of the floodplain and subsequent shrub planting increased tree and shrub density compared to pre-restoration levels. Thirteen of the 23 species of trees and shrubs known to occur at the restoration site were detected in the 1 m x 1 m quadrats (Table 3). Prior to restoration in 2010 woody species density was only 0.38 plants per square m. By fall 2011 after restoration, woody species density had increased to 1.35 plants per square m. Density increased mostly in the < 0.5 m height class, although gains were also recorded in the 0.5 - 2 m class. Although planted riparian trees and shrubs, such as thinleaf alder (*Alnus incana*), redosier dogwood, golden currant, peachleaf willow, and ponderosa pine, contributed to the increase, most of the increase was due to chance establishment of willow seedlings and newly sprouted off-shoots from nearby plants. For example, after spring flooding of the newly restored site in 2011 there was a flush of seedling germination of Booth's willow (*Salix boothii*), Drummond's willow (*Salix drummondiana*), and yellow willow (*Salix lutea*). Similarly, new shoots suckering from nearby narrowleaf willow (*Salix exigua*) and dusky willow (*Salix melanopsis*) were also recorded. Not all of these willow seedlings survived between fall 2011 and spring 2012. No Drummond's willow seedlings were detected in quadrats in June 2012, and yellow willow seedlings decreased from 39 to 4 in 2012. Some new seedlings of Booth's willow did germinate in spring 2012. Overall, due to some mortality between 2011 and 2012, woody species density decreased to 0.84 plants per square m by June (still over twice the density prior to restoration). Mortality occurred in both the < 0.5 m height class and 0.5 - 2 m height class (e.g., planted thinleaf alder and peachleaf willow). Increased density of redosier dogwood and ponderosa pine between September 2011 and June 2012 was likely due to supplemental plantings that occurred in October 2011.

Woody Species Cover

In the year after restoration of the floodplain and planting the cover of tree and shrub species was virtually unchanged (18.9% in 2010, 19.5% in 2012) (Table 4). By fall of 2011 post-restoration cover of woody species decreased slightly. This was because several willows present along transects prior to restoration were damaged by heavy equipment during removal of mine tailings. By 2012 these had largely recovered and many of these mature willows (primarily Booth's willow and yellow willow) had grown into the tallest height class (> 2 m). Narrowleaf willow cover increased due to sucker shoots taking advantage of the newly created, moist and sunny floodplain habitat. Thirteen of the 23 species of trees and shrubs known to occur at the restoration site were detected along the transects. Of these, most of the planted species recorded along the transects (e.g., thinleaf alder, water birch, ponderosa pine, and common snowberry [*Symphoricarpos albus*]) increased in cover only slightly or were unchanged between fall 2011 and 2012. The total cover of each planted species was minimal. Planted species increased total cover in the < 0.5 m height class from zero in 2010 to approximately 2% in 2011 and 1% in 2012. The cover of peachleaf willow and a few other planted species decreased slightly. These results were generally consistent with data on plant size collected during the survival monitoring which showed some planted species increasing slightly and others decreasing (due to dieback of branches, possibly due to early spring freeze damage). Supplemental plantings in October 2011 contributed minimally to the cover recorded along the transects. A survey of riparian restoration in the inland Northwest found that cover of woody species stays level for the first year but is expected to at least double in about 3 years post-implementation (Wall 2011).

Herbaceous Cover

Restoration by removing mine tailing piles created a floodplain substrate suitable for establishment of riparian herbaceous vegetation. With the exception of several small patches (1 - 4 m^2) of transplanted riparian sod salvaged from haul roads created during mine tailing removal, all herbaceous vegetation established from seeds brought in by spring floods in 2011 and 2012, aerial seed deposition, or shoots from rhizomatous spread of adjacent intact vegetation. The combined cover of herbaceous vegetation was very low (Table 5). It was only 4.1% prior to implementation in 2010, but increased to 5.9% in September 2011 and 7.5% in June 2012. Total plant diversity increased from 35 species prior to restoration in fall 2010 to 48 species in 2011 after restoration and 74 in June 2012. The percent of the herbaceous flora comprised of native species was unchanged from fall 2010, before restoration, and June 2012, after restoration (77%). Based on the 2012 National Wetland Plant List, the percent of the herbaceous flora that was indicative of wetland habitat (e.g., Obligate, Facultative Wet, or Facultative indicator status) ranged from 46% prior to restoration in 2010, to 75% in 2011 and 64% in 2012. This metric indicates that removal of mine tailings changed the site from mostly a dry, non-riparian habitat to a moister riparian terrace and floodplain site.

In 2010, the herbaceous species with the highest cover and constancy in the quadrats were riparian species, but these were restricted to habitat under existing mature willows. The most important species (in terms of cover and constancy), in descending order, were Kentucky bluegrass (*Poa pratensis*), woolly sedge (*Carex pellita*), Canada goldenrod (*Solidago canadensis*), and field horsetail (*Equisetum arvense*) (Table 5). The mine tailing piles were often devoid of vegetation or supported only a few upland species. Tall annual willowherb (*Epilobium brachycarpum*) was the most important species on mine tailing piles, but with only trace cover.

After restoration, in September 2011, common mullein (*Verbascum thapsus*), a non-native forb, had colonized recently constructed floodplain and become the most important species at the site (Table 5). Native herbs, notably bluejoint (*Calamagrostis canadensis*), giant mountain aster (*Canadanthus modestus*), Baltic rush (*Juncus balticus*), field horsetail, Canada goldenrod, and alpine leafybract aster (*Symphyotrichum foliaceum*) expanded their populations, primarily via rhizomatous sprouts from existing plants taking advantage of newly created sunny and moist habitat. Western marsh cudweed (*Gnaphalium palustre*), an annual native forb of floodplains, was widespread, but with trace cover. Numerous Canada goldenrod seedlings had also germinated on the floodplain. Although decreased from levels prior to restoration, Kentucky bluegrass and woolly sedge remained important at the site.

After two spring flooding episodes (2011 and 2012), the diversity and abundance of both native and non-native herbaceous species increased (Table 5). Species important in fall 2011 continued to expand their populations in spring 2012, especially woolly sedge, field horsetail, Kentucky bluegrass, western marsh cudweed, Canada goldenrod, and common mullein. In addition to those, seedlings of common, early-seral riparian species, including creeping bentgrass (*Agrostis stolonifera*), fringed willowherb (*Epilobium ciliatum*), Canada bluegrass (*Poa compressa*), willow dock (*Rumex salicifolius*), and unidentifiable grass seedlings, were abundant (although with trace cover). Rhizomatous native species, including white sagebrush (*Artemisia ludoviciana*) and Mexican bedstraw (*Galium mexicanum*), also grew more prolifically.

No noxious weeds were detected along monitoring transects in 2011 or 2012. Of the non-native species present in the restored floodplain habitat, creeping bentgrass, oxeye daisy (*Leucanthemum vulgare*), and Kentucky bluegrass are potentially aggressive invaders that could crowd out native species. Creeping bentgrass and Kentucky bluegrass are nearly ubiquitous in disturbed lower montane riparian habitats and control is difficult. Control of oxeye daisy is recommended. Other non-native species, such as common plantain (*Plantago major*), spotted ladysthumb (*Polygonum persicaria*), bluegrasses (*Poa compressa* and *P. palustris*), and curly dock (*Rumex crispus*) are common, less aggressive species expected to occur in even minimally disturbed lower montane riparian habitats. Other non-native species, including cheatgrass (*Bromus tectorum*), bull thistle (*Cirsium vulgare*), prickly lettuce (*Lactuca serriola*), black bindweed (*Polygonum convolvulus*), spiny sowthistle (*Sonchus asper*), and common mullein are opportunistic colonizers of sunny, disturbed soils and likely to decrease over time as riparian vegetation shades them out.

Ground Cover

In general, removal of mine tailings created a finer-textured substrate more suitable for the establishment of riparian vegetation. In fall 2010, prior to restoration, sand / soil comprised approximately 2% of the ground cover (Table 6). After tailing removal and spring flooding, sand / soil increased to 14% by fall 2011. After deposition of alluvium after flooding in spring 2012, sand / soil increased to 16%. In contrast, cobble and gravel combined to comprise 72% of ground cover prior to restoration. After tailing removal, approximately 64% of the ground surface was comprised of cobble and gravel. Although we did not quantify the mean substrate size, we also observed that cobble decreased from clearly large-sized (e.g., > 10 cm) to nearly the size break for gravel (2.5 cm). This created difficulty for observers and accounted for the high variability in gravel and cobble percentages between 2011 and 2012.

COMPARISON TO REFERENCE CONDITIONS

Reference-based performance standards, or quantitative success criteria, are important for determining if restoration objectives are met. Only about 10% of riparian restoration projects in the Pacific Northwest have defined quantitative performance standards (Wall 2011). While not the only measure of project success, they can be used as "targets." The trajectory of vegetation succession toward targets can be tracked to see if initial project planning was sufficient and if adaptive management is needed. Vegetation cover, vegetation height, ground cover, and floodplain performance standards for 5 years post-implementation and 10 years post-implementation were defined for the Grimes Creek riparian restoration project (Tables 7 - 10). These were determined by examining data from reference stands (especially 6 year-old restored mine tailing riparian sites on Mores Creek) and then estimating realistic, attainable goals for the Grimes Creek site.

Vegetative Cover

As expected after only 1 year since project implementation, the Grimes Creek restoration site had very low cover of trees (Table 7) and herbs (graminoids, forbs, and ferns; Table 8). Shrub cover (Table 7) was noticeably higher (19%) but over 95% of the cover was from shrubs existing on the margins of the mine tailings prior to restoration. Long-term natural recovery reference sites had very high cover of both woody and herbaceous layers. Cover was especially high in the tall and medium height classes for trees and shrubs, but also included tree reproduction and shorter shrubs in the low height layers (Table 7). Black cottonwood trees dominated only one reference stand sampled. Restored mine tailing reference sites on Mores Creek (6 year-old) had already developed high shrub cover in the medium height category, but not as high as long-term natural recovery stands. Although mean tree cover was only 2 %, due to the success of planted black cottonwood species, tree cover was progressing. Interestingly, the cover of graminoids exceeded that of the long-term natural recovery sites and forb cover equaled the long-term natural recovery sites after only 6 years (Table 8). It is expected that as tree and shrub canopies expand their shading extent over decades, herbaceous cover may decrease.

Vegetation Structure

Because large containerized trees and shrubs were planted at the Grimes Creek restoration site and existing mature shrubs were tall, after 1 year the mean tree and shrub heights were meeting 5 year performance standards (Table 9). At the long-term natural recovery reference sites both tree and shrub canopy heights averaged one meter taller than the restored mine tailing reference sites. Mean heights of trees and shrubs were somewhat low at the restored mine tailing reference sites because there was a large number of immature willows that have colonized the restored floodplain and have not yet reached heights over 2 m. It is expected that the mean height of shrubs at the Grimes Creek restoration site could decrease in the next few years as seedlings of willows proliferate on the new floodplain. Graminoid and forb layer heights at the Grimes Creek restoration site were only half the minimum heights of these layers at the restored mine tailings reference sites on Mores Creek (Table 9). This reflects that the majority of herbs at Grimes Creek were recently sprouted seedlings.

Ground Cover

Removal of mine tailings at Grimes Creek restoration site shifted the dominant ground surface from co-dominance of cobble and gravel to gravel, while increasing the amount of sand present. Deposition of alluvium in spring floods of 2011 and 2012 also added to the sand component. However, when compared to the restored mine tailing reference sites (Table 10), the amount of sand was only about one-third of the 5 year performance standard. The restored mine tailing reference sites had large amounts of recently deposited sandy alluvium, indicating that they were functioning to trap sediment in the riverine system and build riparian soils. It is hoped that deposition of sandy alluvium will continue in the near term on the floodplain of the Grimes Creek restoration site. Because of their age and high vegetative cover, long-term natural recovery reference sites have nearly twice as much plant litter and downed woody debris than the 6 year-old restored mine tailing reference sites.

Soil Characteristics

Except for in small patches of existing riparian habitat at the ends of several transects, no developed soil existed at the Grimes Creek restoration site prior to removal of mine tailings. Twenty-two soil samples were collected from the restored floodplain site in June 2012. Five soil samples were also collected from each of the two reference sites (long-term natural recovery sites and restored mine tailing riparian sites) (Table 11). Due to the high variability in riparian soil evolution (Craft and Casey 2000, Lewis et al. 2003, Ballantine and Schneider 2009), performance standards were not defined. Forty percent of soil samples at the long-term natural recovery sites had loamy sand texture with the remainder being sand. With the exception of one sample with sandy loam texture at the Grimes Creek restoration site, all other soil samples had sand texture. The oldest, most developed soils at the long-term natural recovery sites were the most fertile, having the highest percent organic matter, phosphorus, and potassium (Table 11). As expected with better developed soils having slightly loamy textures and higher organic matter, these soils also had the lowest pH, higher cation-exchange capacity, lowest nitrate amounts, and most salts (Craft and Casey 2000, Lewis et al. 2003, Ballantine and Schneider 2009). Soils at restored mine tailing sites (6 years old) had begun to develop properties of older soils, but were intermediate between long-term natural recovery sites and the 1-year-old Grimes Creek restoration site for most properties. In 6 years, the restored mine tailing sites had twice the percent organic matter and noticeably greater phosphorus, potassium, and salts as the 1-year-old Grimes Creek site. Soil pH and nitrate was also lower. Percent carbon was similar across all sites.

The patterns in soil characteristics observed at the Grimes Creek restoration site, restored sites, and long-term natural recovery sites generally mimic those reported for natural and restored floodplains in other parts of the North America (Craft and Casey 2000, Ballantine and Schneider 2009). However, the soils sampled had notably lower percent organic matter than reported by other researchers. For example, Craft and Casey (2000) found that floodplain soils > 15 years -old in Georgia had 10.4% organic matter compared to 2.6% for long-term natural recovery sites sampled in the Grimes and Mores Creek watersheds. Whether this is due to the sandy texture of soils or other environmental factors (e.g., climate, hydrology, etc.) is unknown. It can be concluded that riparian soils damaged by historic mining in the Boise Basin develop slowly.

Floodplain Characteristics

Streams at all reference sites and the Grimes Creek restoration site were classified as Rosgen C3 streams (Rosgen 1996). The bankfull width at the Grimes Creek restoration site averaged approximately 1.5 m wider than at the reference sites, but the bankfull depth was also higher (Table 12). This allowed the restoration site to meet the performance standard for width/depth ratio as determined from the reference sites. Removal of mine tailings at the restoration site increased the floodprone width by an estimated 15 m, creating a potential floodplain averaging about twice as wide as the long-term natural recovery sites on upper Grimes Creek (where tailing piles were never removed) (Table 12). The Grimes Creek restoration site also met the performance standard for entrenchment ratio. The high entrenchment ratio means that the stream has a better ability to reach the restored floodplain. Because Mores Creek is somewhat more incised into its valley floor than is Grimes Creek, the widths of floodplains at restored mine tailing reference sites were less than 25 m.

Although bank stability was not estimated at the reference sites, based on knowledge of functioning C3 streams, it is estimated that approximately 80% of streambanks should be stable and covered with anchoring, deeply rooted vegetation and woody debris. Functioning C3 streams are expected to laterally migrate across the valley bottom and have some naturally occurring bank erosion. The stream at the Grimes Creek restoration site was not yet meeting the performance standard for bank stability, but is expected to as riparian vegetation develops (Table 12).

Another objective of restoration at Grimes Creek was to reduce the amount of sand in the stream channel by increasing entrapment of sediment on the restored floodplain and reducing steambank erosion. The channel bottoms at long-term natural recovery reference sites had less sand and were dominated by cobble (Table 12). Sixty percent of restored mine tailing reference sites measured on Mores Creek had cobble-dominated channel bottoms. At the Grimes Creek restoration site one of three channel bottom samples was cobble-dominated.

Trajectory of Vegetation Succession

By comparing the entire vegetation composition at reference sites with the Grimes Creek restoration site the trajectory of succession can be determined (Table 13). Although performance standards were not defined for this metric, this analysis can inform adaptive management, such as noxious weed control or supplemental planting needs, at restored sites. Important plant species, as determined primarily by constancy and secondarily by cover, were defined for each reference site (green = high importance, present in over 75% of samples; blue = moderate importance, 50 - 75% constancy; yellow = lesser importance, 25 - 50% constancy and > 2% cover; red species are those that are expected to be important but which are poorly represented at restored sites). Because constancy data was lacking for the Grimes Creek restoration site, important species were identified by a combination of frequency of occurrence in quadrats and cover.

Vegetation succession at the 6 year-old restored mine tailing sites on Mores Creek was progressing relatively rapidly toward vegetation composition and structure of long-term natural recovery sites. Long-term natural recovery sites had a total of 107 plant species (89% native), 39 of which were important. Restored mine tailing sites had 95 species (76% native species) and included 23 of the 39 important species at long-term natural recovery sites. Drummond's willow, yellow willow, Booth's willow, thinleaf (or gray) alder, Canada goldenrod, giant mountain aster, non-native bluegrass species, and field horsetail were all prominent members of the community at both reference sites. Rose spiraea was the most notable underrepresented species on restored mine tailing sites. Overall, 51 species were shared between the two reference sites. A suite of early seral, floodplain native grasses, rushes (*Juncus* spp.), and lakeshore sedge (*Carex lenticularis*) were important at the restored mine tailing sites but not at the long-term recovery sites.

The Grimes Creek restoration site had 99 species present after only one year (80% native), 53 of which were shared with the long-term natural recovery site. Fourteen of the 39 important species at the long-term natural recovery site were present. Drummond's willow, yellow willow, Booth's willow, Canada goldenrod, Kentucky bluegrass, and field horsetail were important. Various species typical of disturbed habitats, including common mullein, were also important. Alder and rose spiraea were noticeably underrepresented at the Grimes Creek restoration site. Fifty-eight species were shared between the restored mine tailing sites and Grimes Creek. Fortunately, reed canarygrass (*Phalaris arundinacea*), an aggressively invasive non-native species important at the restored mine tailing sites was not detected at the Grimes Creek restoration site. In summary, it appears that the trajectory of succession at the Grimes Creek restoration site is trending toward that of the restored mine tailing sites on Mores Creek.

MONITORING RECOMMENDATIONS

Removal of mine tailings and creation of new floodplain at the Grimes Creek restoration site met overall project objectives. The width of the floodprone area was widened, exceeding that of comparable reference sites. The substrate became moister and finer in texture, suitable for establishment of riparian vegetation as indicated by an increase in the presence of wetland indicator species. Initial survival of planted species was acceptable and similar to other riparian restoration projects in the Pacific Northwest. The diversity of native riparian vegetation increased, but it is too early to observe any increases in riparian cover or development of multiple layers of vegetation. In general, the trajectory of succession on restored floodplain is towards that of reference sites.

Repeated long-term monitoring is recommended at the Grimes Creek restoration site. Monitoring of riparian restoration sites across the Pacific Northwest has shown that numerous changes occur 3 - 4 years after project implementation, including significant drops in survival of planted containerized trees and shrubs, but also large increases in vegetative cover (Wall 2011). Results of our vegetation sampling at mine tailing sites restored 6 years ago confirms that changes in plant cover occur rapidly after the initial establishment period (1 - 2 years). Although 1 to 2-year monitoring provides an important initial assessment of the survival of planted species (Harris 2005), quantitative long-term monitoring is required to truly know the effectiveness of any riparian ecosystem restoration effort. Moreover, monitoring provides key information for stewardship in an adaptive management context, such as mapping of noxious weed populations for control or areas of tree or shrub mortality in need of re-planting.

The challenge is that no funding has been dedicated for long-term monitoring. Monitoring at Grimes Creek could be done at years 3, 5, and 10 after restoration (Wall 2011). It is estimated that 3 eight-hour field days would be required for a biologist and a volunteer assistant to complete monitoring at the Grimes Creek restoration site. Soil monitoring would require additional time and expense, if required. It would take 1 - 2 days of staff time to enter data into spreadsheets, check for accuracy, and analyze results. Reporting would require additional time. Although a significant investment of resources by partners involved, this monitoring would yield valuable information that could be also be used to inform planning of future riparian restoration in other areas impacted by dredge mining.

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Table 1. Planted species survival by vigor class and year.

Scientific Name	Common Name	2011 total plants counted	2012 total plants counted	2011 total live plants counted	2012 total live plants counted	2011 % live	2012 % live	2011 % high vigor	2012 % high vigor	2011 % low vigor	2012 % low vigor	2011 % dead	2012 % dead
Alnus incana	thinleaf alder	68	73	61	67	90	92	51	51	38	41	10	8
Amelanchier alnifolia	Saskatoon serviceberry	10	12	10	12	100	100	70	58	30	42	0	0
Betula occidentalis	water birch	79	96	71	66	90	69	54	36	35	32	10	31
Cornus sericea ssp. *sericea*	redosier dogwood	50	58	48	56	96	97	78	26	18	71	4	3
Crataegus douglasii	black hawthorn	39	40	39	40	100	100	82	65	18	35	0	0
Pinus ponderosa (riparian only)	ponderosa pine	56	135	18	93	32	69	30	33	2	36	68	31
Populus balsamifera ssp. *trichocarpa*	black cottonwood	37	48	37	45	100	94	73	63	27	31	0	6
Populus tremuloides	quaking aspen	33	36	33	36	100	100	61	67	39	33	0	0
Prunus virginiana	chokecherry	14	15	14	13	100	87	64	47	36	40	0	13
Ribes aureum var. *villosum*	golden currant	27	45	23	43	85	96	48	69	37	27	15	4
Rosa woodsii	Wood's rose	8	33	8	33	100	100	100	70	0	30	0	0
Salix amygdaloides	peachleaf willow	54	56	52	48	96	86	65	41	31	45	4	14
Salix bebbiana	Bebb's willow	1	2	1	2	100	100	100	100	0	0	0	0
Salix boothii	Booth's willow	2	0	2	0	100	0	100	0	0	0	0	0
Sambucus nigra ssp. *cerulea*	blue elderberry	4	3	3	3	75	100	25	0	50	100	25	0
Symphoricarpos albus	common snowberry	15	15	13	15	87	100	60	53	27	47	13	0
unknown		6	17	0	0	0	0	0	0	0	0	100	100
	Totals	503	684	433	572	86	84	59	46	27	38	14	16
Pinus ponderosa (riparian and upland)	ponderosa pine	131	184	18	94	14	51	13	25	1	26	86	49

Table 2. Mean heights and widths of planted species by year.

Scientific Name	Common Name	2011 mean height (cm)	2012 mean height (cm)	2011 mean width (cm)	2012 mean width (cm)
Alnus incana	thinleaf alder	58	65	28	33
Amelanchier alnifolia	Saskatoon serviceberry	70	62	47	33
Betula occidentalis	water birch	113	80	51	38
Cornus sericea ssp. *sericea*	redosier dogwood	53	47	21	16
Crataegus douglasii	black hawthorn	146	120	62	49
Pinus ponderosa	ponderosa pine	20	19	19	20
Populus balsamifera ssp. *trichocarpa*	black cottonwood	82	58	47	30
Populus tremuloides	quaking aspen	62	77	38	34
Prunus virginiana	chokecherry	71	77	35	31
Ribes aureum var. *villosum*	golden currant	71	75	40	45
Rosa woodsii	Wood's rose	88	75	70	53
Salix amygdaloides	peachleaf willow	170	120	67	38
Salix bebbiana	Bebb's willow	101	73	79	70
Salix boothii	Booth's willow	27		33	
Sambucus nigra ssp. *cerulea*	blue elderberry	23	10	13	7
Symphoricarpos albus	common snowberry	53	54	29	32

Table 3. Density of trees and shrubs by height class and year.

Scientific Name	Common Name	2010						2011						2012					
		Total Count			Density (#/m²)			Total Count			Density (#/m²)			Total Count			Density (#/m²)		
		<0.5	0.5-2	2+	<0.5	0.5-2	2+	<0.5	0.5-2	2+	<0.5	0.5-2	2+	<0.5	0.5-2	2+	<0.5	0.5-2	2+
Alnus incana	thinleaf alder	0	0	0	0.00	0.00	0.00	0	1	0	0.00	0.01	0.00	0	0	0	0.00	0.00	0.00
Amelanchier alnifolia	Saskatoon serviceberry	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Betula occidentalis	water birch	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Cornus sericea ssp. *sericea*	redosier dogwood	0	0	0	0.00	0.00	0.00	1	1	0	0.01	0.01	0.00	0	3	0	0.00	0.03	0.00
Crataegus douglasii	black hawthorn	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Lonicera involucrata	twinberry honeysuckle	0	1	0	0.00	0.01	0.00	0	0	0	0.00	0.00	0.00	0	0	0	0.00	0.00	0.00
Pinus ponderosa	ponderosa pine	0	0	0	0.00	0.00	0.00	2	0	0	0.02	0.00	0.00	5	0	0	0.06	0.00	0.00
Populus balsamifera ssp. *trichocarpa*	black cottonwood	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Populus tremuloides	quaking aspen	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Prunus virginiana	chokecherry	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Purshia tridentata	antelope bitterbrush	1	0	0	0.01	0.00	0.00	0	1	0	0.00	0.01	0.00	0	0	0	0.00	0.00	0.00
Ribes aureum var. *villosum*	golden currant	0	0	0	0.00	0.00	0.00	0	1	0	0.00	0.01	0.00	0	1	0	0.00	0.01	0.00
Rosa woodsii	Wood's rose	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Salix amygdaloides	peachleaf willow	0	0	0	0.00	0.00	0.00	0	3	0	0.00	0.03	0.00	0	0	0	0.00	0.00	0.00
Salix bebbiana	Bebb's willow	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Salix boothii	Booth's willow	0	2	5	0.00	0.02	0.06	6	6	3	0.07	0.07	0.03	12	2	3	0.14	0.02	0.03
Salix drummondiana	Drummond's willow	0	1	1	0.00	0.01	0.01	5	0	1	0.06	0.00	0.01	0	0	2	0.00	0.00	0.02
Salix exigua	narrowleaf willow	1	1	0	0.01	0.01	0.00	11	5	1	0.13	0.06	0.01	5	4	1	0.06	0.05	0.01
Salix lutea	yellow willow	0	4	6	0.00	0.05	0.07	39	2	3	0.44	0.02	0.03	4	1	4	0.05	0.01	0.05
Salix melanopsis	dusky willow	1	6	0	0.01	0.07	0.00	12	12	0	0.14	0.14	0.00	14	6	0	0.16	0.07	0.00
Sambucus nigra ssp. *cerulea*	blue elderberry	not detected in quadrats						not detected in quadrats						not detected in quadrats					
Spiraea douglasii	rose spiraea	0	3	0	0.00	0.03	0.00	1	2	0	0.01	0.02	0.00	5	1	0	0.06	0.01	0.00
Symphoricarpos albus	common snowberry	not detected in quadrats						not detected in quadrats						not detected in quadrats					
	Totals	3	18	12	0.03	0.20	0.14	77	34	8	0.88	0.39	0.09	45	18	10	0.51	0.20	0.11
		2010 Density of All Spp. = 0.38						**2011 Density of All Spp. = 1.35**						**2012 Density of All Spp. = 0.84**					

Table 4. Cover of trees and shrubs by height class and year.

Scientific Name	Common Name	2010				2011				2012			
		<0.5 m Cover	0.5-2 m Cover	2+ m Cover	Total Cover	<0.5 m Cover	0.5-2 m Cover	2+ m Cover	Total Cover	<0.5 m Cover	0.5-2 m Cover	2+ m Cover	Total Cover
Alnus incana	thinleaf alder	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2
Amelanchier alnifolia	Saskatoon serviceberry	not detected on transects				not detected on transects				not detected on transects			
Betula occidentalis	water birch	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2
Cornus sericea ssp. *sericea*	redosier dogwood	not detected on transects				not detected on transects				not detected on transects			
Crataegus douglasii	black hawthorn	not detected on transects				not detected on transects				not detected on transects			
Lonicera involucrata	twinberry honeysuckle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5
Pinus ponderosa	ponderosa pine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2
Populus balsamifera ssp. trichocarpa	black cottonwood	not detected on transects				not detected on transects				not detected on transects			
Populus tremuloides	quaking aspen	not detected on transects				not detected on transects				not detected on transects			
Prunus virginiana	chokecherry	not detected on transects				not detected on transects				not detected on transects			
Purshia tridentata	antelope bitterbrush	not detected on transects				not detected on transects				not detected on transects			
Ribes aureum var. *villosum*	golden currant	not detected on transects				not detected on transects				not detected on transects			
Rosa woodsii	Wood's rose	not detected on transects				not detected on transects				not detected on transects			
Salix amygdaloides	peachleaf willow	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	0.0
Salix bebbiana	Bebb's willow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Salix boothii	Booth's willow	0.0	0.6	4.6	5.2	0.4	2.0	5.1	7.5	0.1	0.5	6.3	6.9
Salix drummondiana	Drummond's willow	0.0	1.2	0.5	1.6	0.0	1.0	0.4	1.3	0.0	0.6	1.6	2.2
Salix exigua	narrowleaf willow	0.0	0.0	1.2	1.2	0.5	1.6	1.0	3.1	0.1	1.4	1.5	2.9
Salix lutea	yellow willow	0.0	8.2	0.7	8.9	0.6	3.3	5.2	9.1	0.0	2.1	6.9	9.0
Salix melanopsis	dusky willow	0.0	2.6	0.2	2.8	0.0	1.9	0.5	2.5	0.2	1.7	0.0	1.9
Sambucus nigra ssp. *cerulea*	blue elderberry	not detected on transects				not detected on transects				not detected on transects			
Spiraea douglasii	rose spiraea	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4
Symphoricarpos albus	common snowberry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
unknown dead shrub		0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.1	0.3	0.5
	Combined Cover	0.0	12.8	7.1		1.6	10.9	12.3		0.6	7.7	16.6	
		2010 Cover of All Spp. = 18.9				**2011 Cover of All Spp. = 18.5**				**2012 Cover of All Spp. = 19.5**			

Table 5. Frequency and mean cover of graminoid and forb species by year.

ScientificName	Common Name	Wetland Indicator Status	2010 Frequency (%)	2010 Mean Cover (%)	2011 Frequency (%)	2011 Mean Cover (%)	2012 Frequency (%)	2012 Mean Cover (%)
Graminoids								
Agrostis exarata	spike bentgrass	FACW	0	0.000	5	0.015	1	0.011
Agrostis scabra	rough bentgrass	FAC	1	0.001	3	0.003	6	0.026
Agrostis stolonifera	**creeping bentgrass**	FAC	2	0.002	2	0.002	14	0.142
Alopecurus aequalis	shortawn foxtail	OBL	0	0.000	0	0.000	1	0.001
Bromus tectorum	**cheatgrass**	UPL	5	0.005	0	0.000	1	0.001
Calamagrostis canadensis	bluejoint	FACW	6	0.026	10	0.131	13	0.033
Carex	sedge	FACW	0	0.000	9	0.009	22	0.022
Carex athrostachya	slenderbeak sedge	FACW	0	0.000	0	0.000	5	0.005
Carex pachystachya	chamisso sedge	FAC	3	0.014	2	0.002	5	0.036
Carex pellita	woolly sedge	OBL	22	0.918	19	0.631	22	0.849
Carex stipata	awlfruit sedge	OBL	0	0.000	1	0.001	1	0.001
Deschampsia elongata	slender hairgrass	FACW	1	0.001	0	0.000	0	0.000
Elymus trachycaulus ssp. *trachycaulus*	slender wheatgrass	FAC	7	0.050	6	0.016	2	0.013
Juncus balticus	Baltic rush	FACW	2	0.091	7	0.920	5	0.376
Juncus bufonius	toad rush	FACW	0	0.000	1	0.001	1	0.001
Juncus ensifolius	swordleaf rush	FACW	0	0.000	0	0.000	1	0.001
Juncus tenuis	poverty rush	FAC	0	0.000	1	0.001	1	0.001
Poa compressa	**Canada bluegrass**	FACU	1	0.034	6	0.039	11	0.055
Poa palustris	**fowl bluegrass**	FAC	3	0.003	7	0.027	1	0.001
Poa pratensis	**Kentucky bluegrass**	FAC	15	1.643	18	0.416	16	0.710
Phleum pratense	**timothy**	FAC	0	0.000	1	0.001	1	0.001
Scirpus microcarpus	panicled bulrush	OBL	1	0.011	3	0.014	3	0.048
unknown grass seedlings	grass seedling		0	0.000	14	0.024	41	0.041
Forbs								
Achillea millefolium	common yarrow	FACU	5	0.025	6	0.070	13	0.033
Arabis holboellii	Holboell's rockcress	UPL	2	0.002	0	0.000	1	0.001
Arabis glabra	tower rockcress	UPL	0	0.000	0	0.000	6	0.006
Arnica chamissonis	chamisso arnica	FACW	1	0.001	3	0.035	2	0.035
Artemisia ludoviciana	white sagebrush	FACU	3	0.136	3	0.173	5	0.480
Canadanthus modestus	giant mountain aster	FACW	7	0.081	6	0.297	11	0.122
Cardamine oligosperma	little western bittercress	FAC	0	0.000	0	0.000	20	0.020
Cerastium	chickweed	UPL	0	0.000	0	0.000	1	0.001
Chaenactis douglasii	Douglas' dustymaiden	UPL	2	0.013	0	0.000	0	0.000
Chrysanthemum leucanthemum	**oxeye daisy**	UPL	0	0.000	1	0.001	9	0.019
Cicuta douglasii	western water hemlock	OBL	0	0.000	2	0.002	0	0.000
Cirsium vulgare	**bull thistle**	FACU	1	0.001	0	0.000	2	0.002

Forbs continued								
ScientificName	**Common Name**	**Wetland Indicator Status**	**2010**		**2011**		**2012**	
			Frequency (%)	**Mean Cover (%)**	**Frequency (%)**	**Mean Cover (%)**	**Frequency (%)**	**Mean Cover (%)**
Collomia linearis	tiny trumpet	FACU	11	0.011	6	0.006	15	0.025
Cryptantha	cryptantha	UPL	1	0.001	0	0.000	1	0.001
Epilobium brachycarpum	tall annual willowherb	UPL	8	0.084	3	0.014	11	0.075
Epilobium ciliatum ssp. *glandulosum*	fringed willowherb	FACW	0	0.000	7	0.017	36	0.118
Equisetum arvense	field horsetail	FAC	10	0.075	15	0.245	17	0.407
Eriogonum umbellatum	sulphur-flower buckwheat	UPL	1	0.001	0	0.000	0	0.000
Galium aparine	stickywilly	FACU	3	0.014	0	0.000	1	0.011
Galium mexicanum	Mexican bedstraw	FAC	3	0.125	8	0.051	6	0.219
Galium trifidum	threepetal bedstraw	FACW	0	0.000	0	0.000	3	0.003
Gayophytum diffusum	spreading groundsmoke	UPL	0	0.000	0	0.000	6	0.006
Geum macrophyllum	largeleaf avens	FAC	0	0.000	0	0.000	1	0.001
Gnaphalium palustre	western marsh cudweed	FACW	0	0.000	18	0.049	36	0.167
Heterocodon rariflorum	rareflower heterocodon	FAC	0	0.000	0	0.000	1	0.001
Lactuca serriola	**prickly lettuce**	FACU	2	0.013	0	0.000	10	0.010
Lotus unifoliolatus var. *unifoliolatus*	American bird's-foot trefoil	UPL	0	0.000	0	0.000	5	0.005
Mentha arvensis	wild mint	FACW	0	0.000	6	0.006	7	0.028
Mimulus moschatus	muskflower	OBL	0	0.000	0	0.000	2	0.002
Myosotis stricta	**strict forget-me-not**	UPL	0	0.000	1	0.001	0	0.000
Oenothera	evening-primrose	FACW	0	0.000	0	0.000	2	0.002
Plantago major	**common plantain**	FAC	0	0.000	0	0.000	1	0.001
Polygonum convolvulus	**black bindweed**	UPL	0	0.000	0	0.000	1	0.001
Polygonum douglasii	Douglas' knotweed	FACU	2	0.024	0	0.000	7	0.027
Polygonum persicaria	**spotted ladysthumb**	FACW	0	0.000	1	0.001	6	0.006
Potentilla biennis	biennial cinquefoil	FACW	0	0.000	3	0.003	6	0.049
Rorippa curvisiliqua	curvepod yellowcress	OBL	0	0.000	6	0.027	3	0.014
Rorippa islandica	northern marsh yellowcress	OBL	0	0.000	5	0.005	8	0.008
Ranunculus	buttercup	FAC	0	0.000	0	0.000	1	0.001
Rumex crispus	**curly dock**	FAC	0	0.000	3	0.003	2	0.024
Rumex salicifolius	willow dock	FACW	0	0.000	5	0.092	13	0.384
Scutellaria angustifolia	narrowleaf skullcap	UPL	0	0.000	1	0.001	1	0.023
Sedum lanceolatum	spearleaf stonecrop	UPL	1	0.001	0	0.000	1	0.001
Senecio serra	tall ragwort	FACU	1	0.011	0	0.000	1	0.227
Solidago canadensis	Canada goldenrod	FACU	15	0.559	24	1.133	38	1.275
Sonchus asper	**spiny sowthistle**	FACU	0	0.000	0	0.000	8	0.008
Spergularia rubra	red sandspurry	FAC	0	0.000	1	0.001	2	0.002
Stellaria longipes	longstalk starwort	FACW	0	0.000	1	0.001	0	0.000

Forbs continued								
ScientificName	Common Name	Wetland Indicator Status	2010		2011		2012	
			Frequency (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)
Symphyotrichum eatonii	Eaton's aster	FAC	3	0.159	6	0.140	3	0.069
Symphyotrichum foliaceum	alpine leafybract aster	FACU	2	0.002	9	0.117	7	0.160
Taraxacum officinale	**common dandelion**	FACU	0	0.000	0	0.000	1	0.001
Trifolium	**clover**	FAC	0	0.000	0	0.000	9	0.019
unknown forb seedlings	forb seedling		0	0.000	0	0.000	20	0.020
Urtica dioica	stinging nettle	FAC	0	0.000	2	0.045	6	0.016
Verbascum thapsus	**common mullein**	FACU	1	0.001	32	1.051	41	0.953
Veronica americana	American speedwell	OBL	0	0.000	2	0.002	6	0.016
Veronica peregrina	neckweed	OBL	0	0.000	3	0.003	9	0.009
		Total # of Spp.	24		32		54	
		Combined Cover	4.141		5.848		7.489	
		% Native Herbaceous Spp.	77		79		77	
		% Wetland Indicator Spp.	46		75		64	
		Mean Height (cm)	15		17		17	

Bold = non-native species

Table 6. Mean cover (%) of ground surface features by year.

Monitoring Year	Water	Litter on ground	Wood on ground (>3 cm diameter)	Moss, Lichen, or Liverwort on soil	Sand or Soil (<1 cm diameter)	Gravel (1 - 2.5 cm diameter)	Cobble (2.5 - 25 cm diameter)	Boulder (>25 cm diameter)	Basal Vegetation
2010	0.6	15.8	5.5	1.2	1.8	37.0	35.2	1.8	1.2
2011	0.0	13.9	2.4	0.0	13.9	32.7	32.7	1.8	2.4
2012	0.6	16.4	1.2	1.2	15.8	44.2	19.4	1.2	0.0

Table 7. Comparison of tree and shrub cover by height class between reference sites and restoration site.

Site	History	Value	Total Tree Cover (%)	Tall Height Tree Cover	Medium Height Tree Cover	Low Height Tree Cover	Ground Height Tree Cover	Total Shrub Cover (%)	Tall Height Shrub Cover	Medium Height Shrub Cover	Low Height Shrub Cover	Ground Height Shrub Cover
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	min	0.0	0.0	0.0	0.0	0.0	70.0	0.0	30.0	2.0	0.0
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	max	50.0	40.0	50.0	5.0	0.0	98.0	60.0	98.0	20.0	0.1
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	mean	7.2	5.7	7.1	0.7	0.0	84.7	8.6	74.7	11.0	0.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	min	0.1	0.0	0.0	0.0	0.0	30.0	0.0	30.0	1.0	0.1
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	max	6.0	0.0	5.0	2.0	0.1	70.0	0.0	70.0	10.0	1.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	mean	2.2	0.0	1.4	0.8	0.0	54.0	0.0	52.0	4.8	0.3
Grimes Creek Restoration Site	Restored Mine Tailings - 1 year	mean	0.3	0.0	0.1	0.2	0.0	19.3	0.0	19.3	0.5	0.1
Performance Standard - 5 year target			2.0					30.0				
Performance Standard - 10 year target			6.0					50.0				
Does Grimes Creek Restoration Site meet Performance Standard?			too low					too low				

Tall Height Class =	> 5 m
Medium Ht. Class =	0.5 - 4.9 m
Low Height Class =	0.05 - 0.49 m
Ground Ht. Class =	< 0.05 m

Table 8. Comparison of graminoid, forb, and fern cover by height class between reference sites and restoration site.

Site	History	Value	Total Graminoid Cover (%)	Medium Height Graminoid Cover	Low Height Graminoid Cover	Ground Height Graminoid Cover	Total Forb Cover (%)	Medium Height Forb Cover	Low Height Forb Cover	Ground Height Forb Cover	Total Fern Cover (%)	Medium Height Fern Cover	Low Height Fern Cover	Ground Height Fern Cover
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	min	2.0	0.1	2.0	0.0	15.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	max	70.0	50.0	40.0	0.1	30.0	30.0	20.0	10.0	1.0	0.0	0.1	0.0
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	mean	36.7	27.2	14.6	0.1	23.6	15.4	8.0	2.5	0.1	0.0	0.0	0.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	min	60.0	3.0	40.0	0.1	10.0	3.0	5.0	1.0	0.0	0.0	0.0	0.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	max	90.0	40.0	70.0	7.0	40.0	20.0	30.0	3.0	0.0	0.0	0.0	0.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	mean	74.0	22.2	54.0	3.2	22.0	9.8	15.0	1.6	0.0	0.0	0.0	0.0
Grimes Creek Restoration Site	Restored Mine Tailings - 1 year	mean	2.4	0.1	2.1	0.2	5.0	0.5	4.2	0.3	0.0	0.0	0.0	0.0
Performance Standard - 5 year target			60.0				10.0				0.0			
Performance Standard - 10 year target			70.0				20.0				0.1			
Does Grimes Creek Restoration Site meet Performance Standard?			too low				too low				too low			

Tall Height Class =	> 5 m
Medium Ht. Class =	0.5 - 4.9 m
Low Height Class =	0.05 - 0.49 m
Ground Ht. Class =	< 0.05 m

Table 9. Comparison of vegetation strata heights between reference sites and restoration site.

Site	History	Value	Mean Tree Canopy Height (m)	Mean Tree Sub-Canopy Height (m)	Mean Shrub Canopy Height (m)	Mean Shrub Sub-Canopy Height (m)	Mean Graminoid Layer Height (cm)	Mean Graminoid Sub-Layer Height (cm)	Mean Forb Layer Height (cm)
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	min	0.2	2.0	1.6	0.7	25	0	50
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	max	7.0	2.0	6.0	2.0	77	90	110
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	mean	2.5	2.0	3.3	1.2	59	45	77
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	min	0.1	0.7	1.2	0.8	35	5	30
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	max	1.1	0.7	2.7	1.0	88	39	85
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	mean	0.6	0.7	1.9	0.8	61	23	52
Grimes Creek Restoration Site	Restored Mine Tailings - 1 year	mean	1.2	0.2	2.7	1.3	17	n/a	17
Performance Standard - 5 year target			1.0		1.0		35		30
Performance Standard - 10 year target			2.5		2.0		60		50
Does Grimes Creek Restoration Site meet Performance Standard?			meets		meets		too low		too low

Table 10. Comparison of ground surface feature cover between reference sites and restoration site.

Site	History	Value	Water	Litter on ground	Wood on ground (>3 cm diameter)	Moss, Lichen, Liverwort on soil	Sand or Soil (<1 cm diameter)	Gravel (1 - 2.5 cm diameter)	Cobble and Boulder (>2.5 diameter)	Basal Vegetation
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	min	0.0	10.0	0.1	0.0	0.1	0.0	0.0	10.0
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	max	10.0	62.0	30.0	5.0	70.0	1.0	3.0	25.0
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	mean	2.3	43.1	12.3	1.0	20.9	0.3	1.0	19.3
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	min	0.0	8.0	0.1	0.1	30.0	0.1	0.1	10.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	max	0.1	30.0	15.0	10.0	50.0	15.0	15.0	15.0
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	mean	0.0	23.6	5.8	2.4	44.0	5.0	6.2	12.0
Grimes Creek Restoration Site	Restored Mine Tailings - 1 year	mean	0.6	16.4	1.2	1.2	15.8	44.2	20.6	0.1
Performance Standard - 5 year target			0.1	25.0	5.0	2.0	45	5	5	15
Performance Standard - 10 year target			2.0	45.0	10.0	1.0	20	1	1	20
Does Grimes Creek Restoration Site meet Performance Standard?			meets	too low	too low	meets	too low	too high	too high	too low

Table 11. Comparison of soil characteristics between reference sites and restoration site.

Site	History	pH	Salts (mmhos)	Cation-Exchange Capacity (%)	Organic Matter (%)	NO^3 (ppm)	P (ppm)	K (ppm)	Carbon (%)
Grimes and Mores Creeks (n = 5)	Long-Term Natural Recovery	5.90	0.106	4.80	2.57	3.20	7.20	74.00	18.27
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	6.14	0.054	3.60	1.25	3.60	5.00	52.00	17.88
Grimes Creek Restoration Site (n = 22)	Restored Mine Tailings - 1 year	6.83	0.028	4.05	0.64	3.95	3.68	34.18	18.11

Table 12. Comparison of floodplain characteristics between reference sites and restoration site.

Site	History	Value	Bankfull Width (m)	Bankfull Depth (m)	Bankfull Width / Bankfull Depth	Floodprone Width (m)	Entrenchment (Floodprone Width / Bankfull Width)	Channel Sinuosity	Stream Gradient	Bank Stability (Covered Unstable)	Bank Stability (Uncovered Unstable)	Bank Stability (Covered Stable)	Bank Stability (Uncovered Stable)	Dominant Channel Bottom Material
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	min	5.50	0.25	9.02	10.20	1.15	1.22	0.013	n/a	n/a	n/a	n/a	cobble (100% of samples)
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	max	10.50	0.67	35.60	40.00	3.81	1.43	0.028	n/a	n/a	n/a	n/a	
Grimes and Mores Creeks (n = 7)	Long-Term Natural Recovery	mean	7.80	0.43	20.83	17.72	2.19	1.33	0.019	n/a	n/a	n/a	n/a	
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	min	6.30	0.40	9.71	15.50	2.16	1.32	0.020	n/a	n/a	n/a	n/a	cobble (60% of samples)
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	max	9.20	0.68	20.00	23.50	2.67	1.32	0.020	n/a	n/a	n/a	n/a	sand (40% of samples)
Mores Creek (n = 5)	Restored Mine Tailings - 6 years	mean	7.36	0.57	13.59	17.74	2.41	1.32	0.020	n/a	n/a	n/a	n/a	
Grimes Creek Restoration Site (n = 3)	Restored Mine Tailings - 1 year	min	7.90	0.51	12.35	26.70	2.81	1.32	0.007	3	8	55	0	cobble (33% of samples)
Grimes Creek Restoration Site (n = 3)	Restored Mine Tailings - 1 year	max	10.00	0.81	18.63	43.00	5.00	1.32	0.007	35	20	75	2	gravel (33% of samples)
Grimes Creek Restoration Site (n = 3)	Restored Mine Tailings - 1 year	mean	9.13	0.62	15.20	36.40	4.04	1.32	0.007	16	16	67	1	sand (33% of samples)
Performance Standard - 5 year target					14 to 21		2.2 to 2.4					80		cobble (60% of samples)
Performance Standard - 10 year target					14 to 21		2.2 to 2.4					80		cobble (100% of samples)
Does Grimes Creek Restoration Site meet Performance Standard?					meets		meets					too low		too low

Table 13. Comparison of species cover between reference sites and restoration site.

ScientificName	Common Name	Long-term Natural Recovery (>50 years)				Restored Mine Tailing Sites (6 years)				Grimes Creek	
		Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)
Salix drummondiana	Drummond's willow	100	1.0	60.0	15.3	100	0.1	6.0	2.6		2.212
Solidago canadensis	Canada goldenrod	100	1.0	10.0	5.0	60	1.0	7.0	3.0	38	1.275
Canadanthus modestus	giant mountain aster	100	1.0	10.0	4.1	80	0.1	4.0	2.0	11	0.122
Alnus incana	gray alder	86	1.0	70.0	21.3	60	4.0	40.0	28.0		0.200
Salix lutea	yellow willow	86	0.1	30.0	17.5	100	8.0	40.0	21.6		8.952
Salix boothii	Booth's willow	86	5.0	40.0	15.8	100	3.0	7.0	4.6		6.933
Poa palustris	**fowl bluegrass**	86	0.1	40.0	10.9	80	5.0	20.0	13.0	1	0.001
Poa pratensis	**Kentucky bluegrass**	86	0.1	15.0	3.5	60	0.1	3.0	1.7	16	0.710
Equisetum arvense	field horsetail	86	0.1	4.0	1.7	80	5.0	9.0	6.5	17	0.407
Lonicera involucrata	twinberry honeysuckle	71	0.1	3.0	1.2	20	0.1	0.1	0.1		0.515
Geum macrophyllum	largeleaf avens	71	0.1	2.0	0.5	20	0.1	0.1	0.1	1	0.001
Carex pachystachya	chamisso sedge	71	0.1	1.0	0.3	80	0.1	2.0	0.6	5	0.036
Spiraea douglasii	rose spirea	57	6.0	60.0	31.5	20	0.1	0.1	0.1		0.364
Salix lucida ssp. *caudata*	greenleaf willow	57	1.0	30.0	11.8	100	1.0	30.0	7.4		
Glyceria striata	fowl mannagrass	57	0.1	20.0	7.8	60	0.1	2.0	0.7		
Cornus sericea ssp. *sericea*	redosier dogwood	57	4.0	7.0	5.5	100	0.1	4.0	0.9		*
Calamagrostis canadensis	bluejoint	57	0.1	15.0	4.1	60	0.1	2.0	1.0	13	0.033
Pyrola asarifolia	liverleaf wintergreen	57	0.1	7.0	4.0						
Scirpus microcarpus	panicled bulrush	57	0.1	3.0	1.8	100	1.0	30.0	8.2	3	0.048
Elymus glaucus	blue wildrye	57	0.1	2.0	0.8	20	0.1	0.1	0.1		
Mentha arvensis	wild mint	57	0.1	2.0	0.6	80	0.1	15.0	6.3	7	0.028
Rosa woodsii	Woods' rose	43	0.1	40.0	18.4	20	1.0	1.0	1.0		*
Agrostis stolonifera	**creeping bentgrass**	43	0.1	20.0	7.0	100	0.1	10.0	6.2	14	0.142
Juncus balticus	Baltic rush	43	0.1	20.0	6.7	20	0.1	0.1	0.1	5	0.376
Galium aparine	stickywilly	43	1.0	10.0	4.3					1	0.011
Symphyotrichum	aster	43	1.0	10.0	4.3						
Carex amplifolia	bigleaf sedge	43	1.0	3.0	2.0	20	1.0	1.0	1.0		
Leucanthemum vulgare	**oxeye daisy**	43	0.1	3.0	1.7					9	0.019
Epilobium ciliatum ssp. *glandulosum*	fringed willowherb	43	0.1	2.0	0.7	80	2.0	4.0	3.0	36	0.118
Mimulus moschatus	muskflower	43	0.1	2.0	0.7					2	0.002
Veronica americana	American speedwell	43	0.1	0.1	0.1	40	0.1	3.0	1.6	6	0.016
Achillea millefolium	common yarrow	43	0.1	0.1	0.1	20	0.1	0.1	0.1	13	0.033
Carex	sedge	43	0.1	0.1	0.1					22	0.022
Fragaria virginiana	Virginia strawberry	43	0.1	0.1	0.1						
Galium mexicanum	Mexican bedstraw	29	10.0	15.0	12.5	40	0.1	2.0	1.1	6	0.219
Salix lemmonii	Lemmon's willow	29	4.0	10.0	7.0	40	0.1	1.0	0.6		
Ribes inerme	whitestem gooseberry	29	4.0	7.0	5.5						
Carex pellita	woolly sedge	29	0.1	10.0	5.1	60	0.1	0.1	0.1	22	0.849
Symphyotrichum foliaceum	alpine leafybract aster	29	0.1	3.0	1.6	80	0.1	2.0	0.8	7	0.160
Equisetum hyemale	scouringrush horsetail	29	0.1	2.0	1.1	20	0.1	0.1	0.1		
Amelanchier alnifolia	Saskatoon serviceberry	29	0.1	2.0	1.1						*
Galium trifidum	threepetal bedstraw	29	0.1	2.0	1.1					3	0.003

ScientificName	Common Name	Long-term Natural Recovery (>50 years)				Restored Mine Tailing Sites (6 years)				Grimes Creek	
		Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)
Equisetum laevigatum	smooth horsetail	29	0.1	2.0	1.1						
Heracleum maximum	common cowparsnip	29	0.1	2.0	1.1						
Viola	violet	29	0.1	2.0	1.1						
Trifolium pratense	**red clover**	29	1.0	1.0	1.0	40	0.1	6.0	3.1		
Cicuta douglasii	western water hemlock	29	0.1	1.0	0.6					2	0.002
Thalictrum occidentale	western meadow-rue	29	0.1	1.0	0.6						
Salix exigua	narrowleaf willow	29	0.1	0.1	0.1	80	0.1	6.0	2.8		2.915
Ranunculus	buttercup	29	0.1	0.1	0.1					1	0.001
Bromus marginatus	mountain brome	29	0.1	0.1	0.1						
Claytonia	springbeauty	29	0.1	0.1	0.1						
Pinus contorta seedling		29	0.1	0.1	0.1						
Populus balsamifera ssp. *trichocarpa*	black cottonwood	14	50.0	50.0	50.0						*
Populus balsamifera ssp. *trichocarpa* sapling		14	40.0	40.0	40.0	20	3.0	3.0	3.0		*
Symphoricarpos albus	common snowberry	14	40.0	40.0	40.0						0.085
Populus balsamifera ssp. *trichocarpa* pole tree		14	30.0	30.0	30.0						
Phalaris arundinacea	**reed canarygrass**	14	15.0	15.0	15.0	100	2.0	30.0	12.0		
Populus balsamifera ssp. *trichocarpa* seedling		14	10.0	10.0	10.0	100	0.1	4.0	1.7		
Populus balsamifera ssp. *trichocarpa* medium tree		14	10.0	10.0	10.0						
Crataegus douglasii	black hawthorn	14	4.0	4.0	4.0						*
Rhamnus alnifolia	alderleaf buckthorn	14	4.0	4.0	4.0						
Salix geyeriana	Geyer's willow	14	4.0	4.0	4.0						
Phleum pratense	**timothy**	14	3.0	3.0	3.0	20	1.0	1.0	1.0	1	0.001
Juncus ensifolius	swordleaf rush	14	2.0	2.0	2.0	100	0.1	10.0	3.2	1	0.001
Rudbeckia occidentalis	western coneflower	14	2.0	2.0	2.0	20	0.1	0.1	0.1		
Potentilla gracilis	slender cinquefoil	14	2.0	2.0	2.0						
Carex stipata	awlfruit sedge	14	1.0	1.0	1.0	100	0.1	2.0	0.7	1	0.001
Torreyochloa pallida var. *pauciflora*	pale false mannagrass	14	1.0	1.0	1.0	40	2.0	8.0	5.0		
Prunus virginiana	chokecherry	14	1.0	1.0	1.0						*
Arnica chamissonis	chamisso arnica	14	1.0	1.0	1.0					2	0.035
Athyrium filix-femina	common ladyfern	14	1.0	1.0	1.0						
Frangula purshiana	Pursh's buckthorn	14	1.0	1.0	1.0						
Maianthemum stellatum	starry false lily of the vally	14	1.0	1.0	1.0						
Verbascum thapsus	**common mullein**	14	0.1	0.1	0.1	60	0.1	0.1	0.1	41	0.953
Centaurea biebersteinii	**spotted knapweed**	14	0.1	0.1	0.1	60	0.1	0.1	0.1		
Prunella vulgaris	common selfheal	14	0.1	0.1	0.1	60	0.1	0.1	0.1		
Rumex obtusifolius	**bitter dock**	14	0.1	0.1	0.1	60	0.1	0.1	0.1		
Stellaria longipes	longstalk starwort	14	0.1	0.1	0.1	20	1.0	1.0	1.0	1	0.001

ScientificName	Common Name	Long-term Natural Recovery (>50 years)				Restored Mine Tailing Sites (6 years)				Grimes Creek	
		Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)
Silene dioica	red catchfly	14	0.1	0.1	0.1	20	1.0	1.0	1.0		
Pinus ponderosa seedling		14	0.1	0.1	0.1	20	0.1	0.1	0.1		0.158
Elymus trachycaulus ssp. *trachycaulus*	slender wheatgrass	14	0.1	0.1	0.1	20	0.1	0.1	0.1	2	0.013
Bromus ciliatus	fringed brome	14	0.1	0.1	0.1	20	0.1	0.1	0.1		
Senecio serra	tall ragwort	14	0.1	0.1	0.1					1	0.227
Pinus ponderosa	ponderosa pine	14	0.1	0.1	0.1						0.158
Urtica dioica	stinging nettle	14	0.1	0.1	0.1					6	0.016
Arabis glabra	tower rockcress	14	0.1	0.1	0.1					6	0.006
Heterocodon rariflorum	rareflower heterocodon	14	0.1	0.1	0.1					1	0.001
Antennaria microphylla	littleleaf pussytoes	14	0.1	0.1	0.1						
Arctostaphylos uva-ursi	kinnikinnick	14	0.1	0.1	0.1						
Calamagrostis	reedgrass	14	0.1	0.1	0.1						
Carex geyeri	Geyer's sedge	14	0.1	0.1	0.1						
Chamerion angustifolium	fireweed	14	0.1	0.1	0.1						
Cirsium	thistle	14	0.1	0.1	0.1						
Cirsium scariosum	meadow thistle	14	0.1	0.1	0.1						
Erigeron speciosus	aspen fleabane	14	0.1	0.1	0.1						
Festuca subulata	bearded fescue	14	0.1	0.1	0.1						
Fragaria vesca	woodland strawberry	14	0.1	0.1	0.1						
Galium triflorum	fragrant bedstraw	14	0.1	0.1	0.1						
Hieracium albiflorum	white hawkweed	14	0.1	0.1	0.1						
Ipomopsis aggregata	scarlet gilia	14	0.1	0.1	0.1						
Juncus howellii	Howell's rush	14	0.1	0.1	0.1						
Lactuca biennis	tall blue lettuce	14	0.1	0.1	0.1						
Lupinus argenteus	silvery lupine	14	0.1	0.1	0.1						
Penstemon payettensis	Payette beardtongue	14	0.1	0.1	0.1						
Phacelia hastata	silverleaf phacelia	14	0.1	0.1	0.1						
Pinus contorta	lodgepole pine	14	0.1	0.1	0.1						
Ribes cereum	wax currant	14	0.1	0.1	0.1						
Ribes hudsonianum	northern black currant	14	0.1	0.1	0.1						
Rubus parviflorus	thimbleberry	14	0.1	0.1	0.1						
Scrophularia lanceolata	lanceleaf figwort	14	0.1	0.1	0.1						
Senecio	ragwort	14	0.1	0.1	0.1						
Senecio triangularis	arrowleaf ragwort	14	0.1	0.1	0.1						
Agrostis scabra	rough bentgrass					100	0.1	15.0	4.2	6	0.026
Juncus covillei	Coville's rush					100	0.1	10.0	4.0		
Agrostis exarata	spike bentgrass					100	0.1	9.0	3.0	1	0.011
Juncus saximontanus	Rocky Mountain rush					100	0.1	8.0	3.0		
Juncus articulatus	jointleaf rush					100	0.1	8.0	2.4		
Carex lenticularis	lakeshore sedge					80	4.0	30.0	13.5		
Juncus effusus	common rush					80	0.1	15.0	4.8		
Poa compressa	**Canada bluegrass**					80	0.1	7.0	2.3	11	0.055

ScientificName	Common Name	Long-term Natural Recovery (>50 years)				Restored Mine Tailing Sites (6 years)				Grimes Creek	
		Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)
Juncus bufonius	toad rush					80	0.1	0.1	0.1	1	0.001
Symphyotrichum eatonii	Eaton's aster					60	2.0	10.0	6.3	3	0.069
Rumex crispus	**curly dock**					60	0.1	1.0	0.4	2	0.024
Plantago major	**common plantain**					60	0.1	1.0	0.4	1	0.001
Carex subfusca	brown sedge					60	0.1	1.0	0.4		
Gnaphalium palustre	western marsh cudweed					60	0.1	1.0	0.4	36	0.167
Juncus tenuis	poverty rush					60	0.1	0.1	0.1	1	0.001
Carex nebrascensis	Nebraska sedge					40	0.1	8.0	4.1		
Deschampsia caespitosa	tufted hairgrass					40	0.1	4.0	2.1		
Lotus unifoliolatus var. *unifoliolatus*	American bird's-foot trefoil					40	1.0	2.0	1.5	5	0.005
Schoenoplectus acutus	hardstem bulrush					40	1.0	1.0	1.0		
Carex athrostachya	slenderbeak sedge					40	0.1	0.1	0.1	5	0.005
Oenothera	evening-primrose					40	0.1	0.1	0.1	2	0.002
Carex microptera	smallwing sedge					40	0.1	0.1	0.1		
Salix lasiolepis	arroyo willow					40	0.1	0.1	0.1		
Carex utriculata	Northwest Territory sedge					20	2.0	2.0	2.0		
Eleocharis palustris	common spikerush					20	2.0	2.0	2.0		
Melilotus officinalis	**sweetclover**					20	2.0	2.0	2.0		
Salix melanopsis	dusky willow					20	1.0	1.0	1.0		1.921
Salix scouleriana	Scouler's willow					20	1.0	1.0	1.0		
Purshia tridentata	antelope bitterbrush					20	0.1	0.1	0.1		*
Potentilla biennis	biennial cinquefoil					20	0.1	0.1	0.1	6	0.049
Rorippa palustris	bog yellowcress					20	0.1	0.1	0.1	8	0.008
Polygonum persicaria	**spotted ladysthumb**					20	0.1	0.1	0.1	6	0.006
Cirsium vulgare	**bull thistle**					20	0.1	0.1	0.1	2	0.002
Spergularia rubra	**red sandspurry**					20	0.1	0.1	0.1	2	0.002
Alopecurus aequalis	shortawn foxtail					20	0.1	0.1	0.1	1	0.001
Cirsium arvense	**Canada thistle**					20	0.1	0.1	0.1		
Dactylis glomerata	**orchardgrass**					20	0.1	0.1	0.1		
Erigeron annuus	eastern daisy fleabane					20	0.1	0.1	0.1		
Mimulus	monkeyflower					20	0.1	0.1	0.1		
Mimulus lewisii	purple monkeyflower					20	0.1	0.1	0.1		
Panicum capillare	witchgrass					20	0.1	0.1	0.1		
Polygonum aviculare	**prostrate knotweed**					20	0.1	0.1	0.1		
Rorippa	yellowcress					20	0.1	0.1	0.1		
Rumex acetosa	**garden sorrel**					20	0.1	0.1	0.1		
Rumex acetosella	**common sheep sorrel**					20	0.1	0.1	0.1		
Trifolium repens	**white clover**					20	0.1	0.1	0.1		
Typha latifolia	broadleaf cattail					20	0.1	0.1	0.1		
Populus tremuloides	quaking aspen										*
Ribes aureum var. *villosum*	golden currant										*
Sambucus nigra ssp. *cerulea*	blue elderberry										*

ScientificName	Common Name	Long-term Natural Recovery (>50 years)				Restored Mine Tailing Sites (6 years)				Grimes Creek	
		Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Constancy (%)	Min Cover (%)	Max Cover (%)	Mean Cover (%)	Frequency (%)	Mean Cover (%)
Artemisia ludoviciana	white sagebrush									5	0.480
Rumex salicifolius	willow dock									13	0.384
Betula occidentalis	water birch										0.182
Salix amygdaloides	peachleaf willow										0.100
Salix bebbiana	Bebb's willow										0.085
Epilobium brachycarpum	tall annual willowherb									11	0.075
unknown grass seedlings	grass seedling									41	0.041
Polygonum douglasii	Douglas' knotweed									7	0.027
Collomia linearis	tiny trumpet									15	0.025
Scutellaria angustifolia	narrowleaf skullcap									1	0.023
Cardamine oligosperma	little western bittercress									20	0.020
unknown forb seedlings	forb seedling									20	0.020
Trifolium	**clover**									9	0.019
Rorippa curvisiliqua	curvepod yellowcress									3	0.014
Lactuca serriola	**prickly lettuce**									10	0.010
Veronica peregrina	neckweed									9	0.009
Sonchus asper	**spiny sowthistle**									8	0.008
Gayophytum diffusum	spreading groundsmoke									6	0.006
Arabis holboellii	Holboell's rockcress									1	0.001
Bromus tectorum	**cheatgrass**									1	0.001
Cerastium	**chickweed**									1	0.001
Cryptantha	cryptantha									1	0.001
Myosotis stricta	**strict forget-me-not**									1	0.001
Polygonum convolvulus	**black bindweed**									1	0.001
Sedum lanceolatum	spearleaf stonecrop									1	0.001
Taraxacum officinale	**common dandelion**									1	0.001
Deschampsia elongata	slender hairgrass									1	0.001

* = present at the site but not recorded along transects

bold = non-native species

green = species of high importance at site

blue = species of moderate importance at site

yellow = species of lesser importance at site

red = important species underrepresented or lacking

APPENDIX 1

Monitoring Photos 2010 - 2012

Baseline transect 1 – start to end


10/11/2010


9/29/2011


6/22/2012

Baseline transect 1 – end to start


10/11/2010


9/29/2011


6/25/2012

Baseline transect 3 – start to end


10/13/2010

9/29/2011 – photo not available


6/26/2012

Baseline transect 3 – end to start


10/13/2010


9/29/2011


6/26/2012

Baseline transect 4 – start to end


10/13/2010


9/29/2011


6/26/2012

Baseline transect 4 – end to start


10/13/2010


9/29/2011


6/26/2012

Baseline transect 5 – start to end


10/13/2010


9/29/2011


6/27/2012

Baseline transect 5 – end to start


10/13/2010


9/29/2011


6/27/2012

Sampling transect 1A – start to end


10/11/2010


9/29/2011


6/22/2012

Sampling transect 1A – end to start


10/11/2010


9/29/2011


6/22/2012

Sampling transect 1B – start to end


10/11/2010


9/29/2011


6/25/2012

Sampling transect 1B – end to start


10/11/2010


9/29/2011


6/25/2012

Sampling transect 1C – start to end


10/11/2010


9/29/2011


6/25/2012

Sampling transect 1C – end to start


10/11/2010


9/29/2011


6/25/2012

Sampling transect 2A – start to end


10/11/2010


9/29/2011


6/25/2012

Sampling transect 2A – end to start


10/11/2010

9/29/2011 — photo not available


6/25/2012

Sampling transect 2B – start to end


10/11/2010


9/29/2011


6/25/2012

Sampling transect 2B – end to start


10/11/2010


9/29/2011


6/25/2012

Sampling transect 3A – start to end


10/13/2010


9/29/2011


6/26/2012

Sampling transect 3A – end to start


10/13/2010


9/29/2011


6/26/2012

Sampling transect 3B – start to end

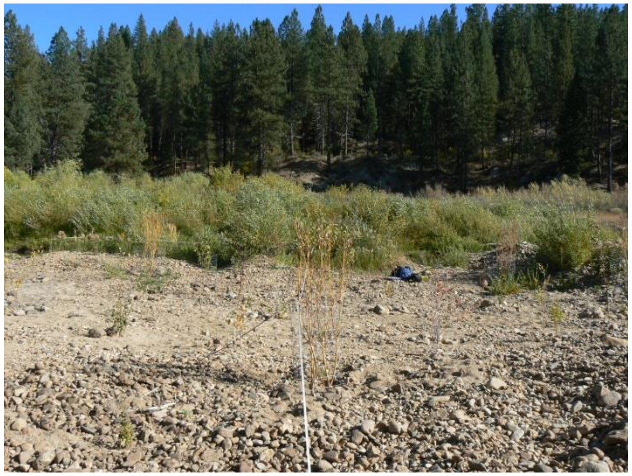

10/13/2010


9/29/2011


6/26/2012

Sampling transect 3B – end to start


10/13/2010


9/29/2011


6/26/2012

Sampling transect 4A – start to end


10/13/2010


9/29/2011


6/27/2012

Sampling transect 4A – end to start


10/13/2010


9/29/2011


6/27/2012

Sampling transect 4B – start to end


10/13/2010


9/29/2011

6/27/2012 — photo not available

Sampling transect 4B – end to start


10/13/2010


9/29/2011


6/27/2012

Sampling transect 5A – start to end


10/13/2010


9/29/2011


6/27/2012

Sampling transect 5A – end to start


10/13/2010


9/29/2011


6/27/2012

Sampling transect 5B – start to end


10/13/2010


9/29/2011


6/27/2012

Sampling transect 5B – end to start


10/13/2010


9/29/2011


6/27/2012