IDAHO TRANSPORTATION DEPARTMENT

RESEARCH REPORT

RP 217

Native Plants for Roadside Revegetation: Field Evaluations and Best Practices Identification

By

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Establishing native vegetation communities on roadsides can be a proactive approach to sustainable roadways. Revegetation with native species is the preferred management practice on Idaho roadways. The environmental and economic benefits of increasing desirable vegetation along Idaho roadways include: improving slope stabilization, soil conservation, roadway safety while reducing erosion, roadside maintenance costs and noxious weeds in right-of-ways. Selecting appropriate plant species for revegetation is the foundation for successful roadside revegetation. This report provides practical information for improving roadway revegetation in Idaho. The overall objective was to monitor vegetation and soil attributes to determine effective means for establishing perennial native vegetation, reducing surface erosion, and preventing weed encroachment. The results provide guidance and recommendations on species selection, seeding methods and site preparation techniques. Bluebunch wheatgrass and Idaho fescue were the best performing grasses. Grass species that consistently establish where seeded but have a low canopy cover include sheep fescue, western wheatgrass, and basin wildrye. Forbs and shrub species had low establishment success rates and low percent canopy cover on roadside revegetation projects. If forbs are desired, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.</td></tr>
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		LENGTH					LENGTH		
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ft	feet	0.3048		m	m	meters	3.28	feet	ft
yd	yards	0.914		m	m	meters	1.09	yards	yd
mi	Miles (statute)	1.61		km	km	kilometers	0.621	Miles (statute)	mi
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yd^2	square yards	0.836	meters squared	m^2	km^2	kilometers squared	0.39	square miles	mi^2
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ac	acres	0.4046	hectares	ha					
		MASS (weight)					MASS (weight)		
oz	Ounces (avdp)	28.35	grams	g	g	grams	0.0353	Ounces (avdp)	oz
lb	Pounds (avdp)	0.454	kilograms	kg	kg	kilograms	2.205	Pounds (avdp)	lb
T	Short tons (2000 lb)	0.907	megagrams	mg	mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME					VOLUME		
fl oz	fluid ounces (US)	29.57	milliliters	mL	mL	milliliters	0.034	fluid ounces (US)	fl oz
gal	Gallons (liq)	3.785	liters	liters	liters	liters	0.264	Gallons (liq)	gal
ft^3	cubic feet	0.0283	meters cubed	m^3	m^3	meters cubed	35.315	cubic feet	ft^3
yd^3	cubic yards	0.765	meters cubed	m^3	m^3	meters cubed	1.308	cubic yards	yd^3
Note: Volumes greater than 1000 L shall be shown in m^3									
		TEMPERATURE (exact)					TEMPERATURE (exact)		
^oF	Fahrenheit temperature	5/9 (^oF-32)	Celsius temperature	^oC	^oC	Celsius temperature	9/5 ^oC+32	Fahrenheit temperature	^oF
		ILLUMINATION					ILLUMINATION		
fc	Foot-candles	10.76	lux	lx	lx	lux	0.0929	foot-candles	fc
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2	cd/cm^2	candela/m^2	0.2919	foot-lamberts	fl
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	pound-force	4.45	newtons	N	N	newtons	0.225	pound-force	lbf
psi	pound-force per square inch	6.89	kilopascals	kPa	kPa	kilopascals	0.145	pound-force per square inch	psi

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Credits are provided for those that shared their photos for this report. For all photos with no credit, those were provided by the Western Transportation Institute at Montana State University, KC Harvey Environmental, LLC, or ITD.

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Executive Summary

Establishing native vegetation communities on roadsides can be a proactive approach to sustainable roadways and healthy ecosystems. Revegetation with native species is the preferred management practice on Idaho roadways. The environmental and economic benefits of increasing desirable vegetation along Idaho roadways include improving slope stabilization, soil conservation, and roadway safety while reducing erosion, roadside maintenance costs and noxious weeds in right-of-ways. Selecting appropriate plant species for revegetation is the foundation for successful soil conservation, plant community stability, invasive plant resistance, wildlife habitat, and water quality protection. This report provides practical information for improving roadway revegetation in Idaho.

The overall project objective was to monitor and record the vegetation and soil attributes from select sites to determine the most effective means for establishing desirable perennial native vegetation, reducing surface erosion, and preventing weed encroachment. Additionally, the data collected at each site was synthesized to provide guidance and recommendations on species selection, seeding methods and site preparation techniques that ITD staff and contractors can use to help ensure the success of revegetation projects.

This study evaluated the success of roadside revegetation on 16 sites in Idaho and one site near the Idaho border in southwest Montana. Three previously "established sites" and 14 new "opportunistic sites" were selected and monitored five years after revegetation. The study sites were selected to represent a diversity of climatic, topographic, and soil conditions in Idaho in order to provide a variety of examples of roadside revegetation projects in 6 different ecoregions of Idaho. Ecoregions are useful for structuring and implementing revegetation and management strategies because they account for climate, topography, environmental conditions and soil type variability throughout Idaho.

Once the sampling site was selected, a linear systematic-random approach was used to sample vegetation species richness, percent canopy cover of each species, and soil stability in 2012 and 2013. Due to unique site preparation and seed mixes used at each location, data were compiled, analyzed and discussed for each revegetation project by site. Each site varied in species present; therefore, for canopy cover and species richness data presentation, we combine species into functional groups.

Results derived from the 17 sites give ITD managers a wide variety of examples of the successes and failures of roadside revegetation across the state. The results provide specific information regarding species that are successful or unsuccessful at establishing, seed mix performance, invasive species of concern, and useful revegetation techniques. The "recommendations" section of each study site provide specialists at ITD with lessons learned from each sites to develop post-construction revegetation plans for future projects along the same roadways, in similar environments, or in other areas of the Level III ecosystems where these projects were located.

The "discussion and conclusions" section provides in-depth tables of seeded species establishment success, average canopy cover on sites where they established, and ecoregions where they established.

Of the seeded grass species, 21 of 27 established. On sites where they established, 11 grass species had a canopy cover >1 percent 5 years after seeding. Grass species with the highest canopy covers were streambank wheatgrass, bluebunch wheatgrass, crested wheatgrass, Idaho fescue, and Canada bluegrass. Bluebunch wheatgrass was the best performing grass because it had a high success rate and high canopy cover. Idaho fescue was also a top performer. Grass species that consistently establish on all sites where they are seeded but have a low canopy cover include sheep fescue, western wheatgrass, and basin wildrye.

Established in the sites were 10 of 23 seeded forb species and 4 of 11 seeded shrubs species. Only 4 of the established forb species had canopy covers over 1 percent. These were alfalfa, silky lupine, western yarrow, and sulfur flower buckwheat. Forb species had a low establishment success rate. No forb species had over 1 percent cover and greater than 50 percent success rate. Mountain big sagebrush was the only seeded shrub species with canopy cover greater than 1 percent. Forbs and shrub species have low establishment success rates and low percent canopy cover on roadside revegetation projects.
Do not include forbs and shrubs in seed mixes where herbicides are to be used to control weeds. Many of the seeded sites were also sprayed with broadleaf herbicides which may have caused limited success of forb and shrub establishment. If forbs are desired, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.

The seed mixes developed by ITD and the Univeristy of Idaho had a range of 4 to 15 species per mix. Monitoring of revegetation sites found mixes with fewer species seeded generally had a higher proportion of species establish. The proportion of species established was variable but the trend was seed mixes of 10 or less species resulted in ≥ 50 percent of species establishing.

As part of this project we evaluated many of the latest techniques, strategies, and management practices that help prepare roadside areas for successful revegetation. These best practices include techniques and materials that stabilize slopes, reduce soil erosion and promote seedling establishment and growth. Such techniques and materials include topsoil replacement, soil fertilization and amendments, erosion control blankets, hydroseeding and container planting. We examined peer-reviewed literature, vegetation manuals, other transportation agency reports, and general reclamation papers that inform on roadside efforts. We incorporated information gathered from the 17 revegetation sites to arrive at conclusions and recommendations for practical application along Idaho roadsides. Detailed results and recommendations by best management practices are provided in Chapter 3.

Key findings and recommendations from the study are as follows with additional details in Chapter 5.

- Soil re-application is beneficial to roadside re-vegetation projects. Limit the length of time topsoils are stockpiled to minimize loss of fertility and micro-organisms.
- Compost should be applied at 0.5 to 1.0 inch depths.
- When good quality topsoil is re-applied, no supplemental fertilizer is needed.
- Since most erosion control blankets are all highly effective in reducing soil erosion, seek the most cost-effective product for use on slope ratios greater than 3:1 and use biodegradable products over synthetics when possible.

- Roughening the soil surface is preferable to smooth slopes so that a variety of microsites are provided for seedling establishment.
- Plant materials should be selected to meet both revegetation objectives and site specific conditions.
- Revegetation with native species is the preferred management practice on Idaho roadways.
- Some exotic species are recommended for seeding in special situations if they support site objectives or provide similar ecological functions as native species.
- When seeding aggressive exotic species, eliminate or limit native species in the seed mix because they will generally have low establishment.
- Drill seeding is the most effective means of seeding. Hydroseeding results are variable and broadcast seeding alone was not an effective method of establishing vegetation in the study.
- Increased seeding rates does not necessarily equate to increased species establishment and cover.
- Incorporate short-lived perennials as part of the seed mix (e.g., slender wheatgrass) for quick establishment and immediate slope stabilization. These will eventually be replaced by the slower establishing seeded species.
- Small seeds are generally seeded at higher rates than large seeds.
- Drill seed at a rate of 20 to 50 pure live seed (PLS) per ft^2 of area, double this rate for areas broadcast or hydroseeded.
- Control weeds prior to construction. Use weed seed-free materials.
- Avoid frequent mowing or mowing to very low vegetation heights because this will reduce health and vigor of desired perennial vegetation.
- Mow when weeds are at an early flowering stage to prevent seed production and weaken perennial weeds over time. Time mowing to occur when desired vegetation is dormant.
- Do not mow if weeds have already produced seeds because mower blades can scatter seeds beyond the existing infestation.
- Continue to foster establishment of desired vegetation at sites with a low total canopy cover of weeds (<5 percent). Continue to monitor sites for increasing weediness. For sites with medium cover of weeds (5 - 20 percent), foster continued establishment of desired vegetation. Treat existing weeds appropriately. Continue to monitor sites. For sites with high cover of weeds (>20 percent), treat weeds and apply desired species seed mix again. Continue to monitor sites.

Chapter 1
Introduction

Integrating goals for establishing sustainable roadside vegetation with goals for safe transportation corridors is essential for improving efficient and cost-effective road systems. As roads are constructed or modified, an opportunity exists for improving previous conditions, mitigating impacts of roadways on the environment and improving the road ecology. Establishing native vegetation communities on roadsides can be a proactive approach to sustainable roadways and healthy ecosystems. Revegetation with native species is the preferred management practice on Idaho roadways.[1] However, establishing desired exotic vegetation species that provide similar ecological functions as native species (e.g. sheep fescue; *Festuca ovina*) can provide benefits to roadside revegetation sites (e.g. weed resistance). Throughout this report, native and desired exotic plant species will be referred to collectively as 'desirable or desired' vegetation.

The environmental and economic benefits of increasing desirable vegetation along Idaho roadways include:

- Improving slope stabilization, and reducing surface soil failures, mass wasting, and erosion.
- Improving soil conservation, reducing sedimentation of surface waters, and water quality protection.
- Reducing erosion, controlling costs, and reducing the need to repair failed best management practices.
- Reducing roadside maintenance costs for mowing and herbicide applications.
- Reducing need for active management of noxious weeds in right-of-ways.
- Improving roadway safety and aesthetics.
- Improving wildlife habitat and connectivity where appropriate.
- Minimizing the ecological footprint of the roadway.

Selecting appropriate plant species for revegetation is the foundation for affecting soil conservation, plant community stability, invasive plant resistance, wildlife habitat, and water quality. This report provides practical information for improving roadway revegetation in Idaho.

A self-sustaining plant community on a roadside stabilizes slopes, reduces erosion, and protects water quality. Ineffective revegetation efforts can lead to environmental degradation through water sedimentation, soil slumping, and debris (e.g. rocks) reaching the roadside. Soil loss from slopes decreases the quality of the site and the ability of plants to establish, increases maintenance efforts, and adversely impacts the quality of surface water. For example, removing soil or rock debris from a roadway can be a costly, repeated maintenance need. Proactive revegetation management is necessary including the use of commercially available products (e.g. mulches, erosion control blankets) and techniques (e.g. topsoil tracking) that can facilitate site stability and rapid vegetation establishment. Stabilized soils promote species establishment which further reduces soil loss by holding soil particles, filtering run-off, reducing water flow velocity, and increasing infiltration. For efficiency and cost savings, well designed and integrated revegetation can protect the function, structural integrity, and longevity of road infrastructure.

Unvegetated roadway right-of-ways with exposed soil can facilitate invasive plant establishment. Once established, invasive plants are difficult to control, can spread to adjacent lands, and decrease site diversity, which is important for many of the benefits named above such as roadway aesthetics and improving wildlife habitat and connectivity near wildlife crossings. Because invasive plants have different rooting structures than native plants, especially native bunch grasses, infestations can lead to additional soil erosion and increased bare ground and revegetation failure. Once invasive plants are established, repeated and costly mowing and herbicide management is needed. The establishment of a diverse, desired plant community is often the best long-term defense against invasive plant invasion. Establishing desired roadside vegetation can reduce maintenance costs for invasive plants and eliminate concerns of weed spread onto neighboring lands.

The establishment of desirable vegetation can support transportation safety goals. Appropriate vegetation can enhance visibility, reduce headlight glare, control snow drifts, and reduce wind speeds. Incorporating an understanding of wildlife movements and forage preferences can lead to a revegetation design that guides animals to safe crossings while minimizing wildlife-vehicle collisions (WVC). One of the most important aspects of incorporating revegetation into roadside safety considerations is to improve the function of roadside engineering. Plant materials can improve long-term slope stability and facilitate capture and drainage of roadway runoff. For instance, seeding and planting a mix of grasses, forbs, shrubs and small trees species provides vegetation that grows at various seasons and rooting depths. Diversifying the growing season increases water use over time and reduces the amount of run-off. Increasing root structure diversity improves soil binding, leads to more stable slopes, prevents slumps, and inhibits debris flow onto the road. Well planned vegetation can also create natural beauty and diversity along the roadside that improves the experience of the motorist.

Careful revegetation planning as part of the roadway construction process can minimize and mitigate the ecological footprint of roads. Roadways can cause disturbance of ecosystems and can lead to invasive plant spread, fragmentation of wildlife habitat and movement corridors, and altered ecological processes (e.g. fire cycles). Revegetation with herbaceous perennial grasses, forbs, and low-growing shrubs is integral to mitigating impacts to Idaho’s ecosystems. The use of native species in revegetation is optimal because these species are evolutionarily adapted to local climatic and edaphic conditions, contribute to habitat biodiversity, provide long-term soil stabilization, reduce the spread of invasive plants, and provide wildlife habitat where appropriate. The establishment of desired plant communities along roadways can initiate or accelerate natural successional processes essential for site repair. When planned correctly, revegetation efforts can improve the functioning of the ecosystem (nutrient, water and energy cycling), species composition and community structure, and resilience to future disturbance. The presence of birds, animals, and pollinators can be enhanced when appropriate plant species are established.

Implementing effective revegetation along roadways is critical to the Idaho Transportation Department (ITD) in delivering safe, durable transportation services to the public. Previous research projects funded by ITD have resulted in publications identifying native plant species with desirable characteristics and the best potential for long-term establishment in Idaho's roadside revegetation projects. The *Idaho Roadside Revegetation Handbook* and *Native Plants for Idaho Roadside Restoration and Revegetation Programs* are useful for plant selection.[2,3] In addition, federally funded roadway revegetation projects outline a process of initiating, planning, implementing, and monitoring roadside revegetation projects with native plants.[4,5] However, previous work was not specific to unique site characteristics and the climatically diverse ecoregions of Idaho. To determine the suitability of current practices for achieving ITD roadside revegetation objectives, this study was initiated to evaluate the establishment of seeded and planted species throughout Idaho.

Objectives

The overall project objective was to monitor and record the vegetation and soil attributes from select number of sites to determine the most effective means for establishing desirable perennial native vegetation, reducing surface erosion, and preventing weed encroachment.

The specific project objectives were to evaluate established and opportunistic ITD roadside revegetation projects for:

- Amount of weedy or introduced species establishment and encroachment at the revegetation sites.
- Plant canopy cover and species richness by species and functional groups at each sites.
- Differential establishment of native and other desirable species versus invasive species.
- Survival and growth of native seedlings planted from containers at the McCammon site in southeastern Idaho.
- Site characteristics that may influence native species' effect on weed encroachment.
- Establishment success of native plant species that were in ITD seed mixes and the survival success of the various native species planted.

Additionally, the data collected at each site was synthesized to:

- Provide guidance and recommendations on species selection, seeding methods and site preparation techniques that ITD staff and contractors can use to help ensure the success of revegetation projects.

Methodology

This study evaluated the success of roadside revegetation on 16 sites in Idaho and one site near the Idaho border in southwest Montana. The study sites were selected to represent a diversity of climatic, topographic, and soil conditions in Idaho in order to provide a variety of examples of roadside revegetation projects (Figure 1 and Figure 2). We stratified the selection of Idaho roadside study sites by the Environmental Protection Agency's Level III Ecoregions.[6] Ecoregions are useful for structuring and implementing revegetation and management strategies because they account for climate, topography and soil type variability throughout Idaho.[7] This study was structured using the Ecoregions approach to capture similar ecosystem components and response to disturbance.[8] The 17 study site locations represent 6 unique Level III Ecoregions of Idaho and are distributed across all 6 ITD Districts (Table 1).

Three sites were selected and monitored by ITD and the University of Idaho (UI) in 2009 and 2010.[9] These 3 sites, referred to as the “established study sites” were monitored again in both 2012 and 2013 for this report. These sites were initially established as research sites by ITD and monitoring was initiated the year following revegetation at each site. In 2012, 14 “opportunistic study sites” were added to the study and evaluated once in either 2012 or 2013 (Table 2). The opportunistic sites were not initially established as research sites. However, these are areas throughout Idaho that have undergone highway construction and roadside revegetation within the last three to nine years. These sites provided an opportunity to evaluate vegetation establishment in a variety of different environments. Chapter 2 discusses the unique reclamation strategies and revegetation results for each site.

While each site was unique, the sampling method for the sites was constant. Sampling methods were designed by the UI researchers during Phase I of the study. These methods were adopted and standardized for Phase II. Roadside revegetation projects are generally long narrow strips of land with variable slope lengths and aspects. A representative area of the roadside project was selected for sampling. In cases where the roadside revegetation work spanned several miles of highway, the entire revegetation project was reviewed before selecting an area of representative aspect, slope, and canopy cover of vegetation.

Once the sampling area was selected, a linear systematic-random approach was used to locate transects and plot locations. The length of the study site was measured and divided into 10 equally spaced transects spanning the length of the sampling area. The first transect was located randomly with subsequent transects equally spaced perpendicular to the road’s edge. Each transect contained five 2 x 2 foot sample frames for collecting data. A total of 50 sample frames from 10 transects were used to collect data at each site. A random number table was used to select the sample frame location along each transect. Frames alternated from the right to the left side of the transect tape (Figure 3).

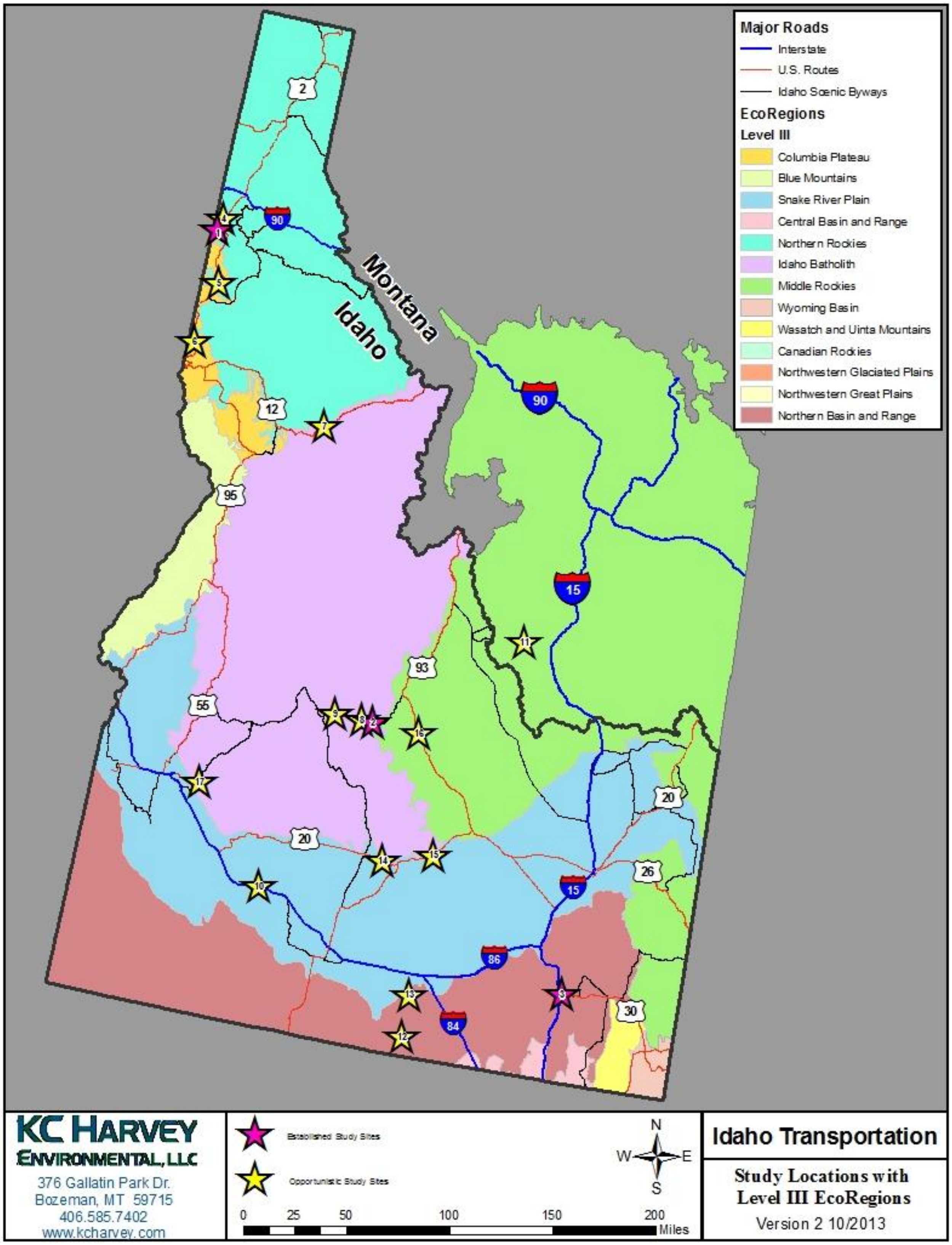

Figure 1. Location of Study Sites by Ecoregion

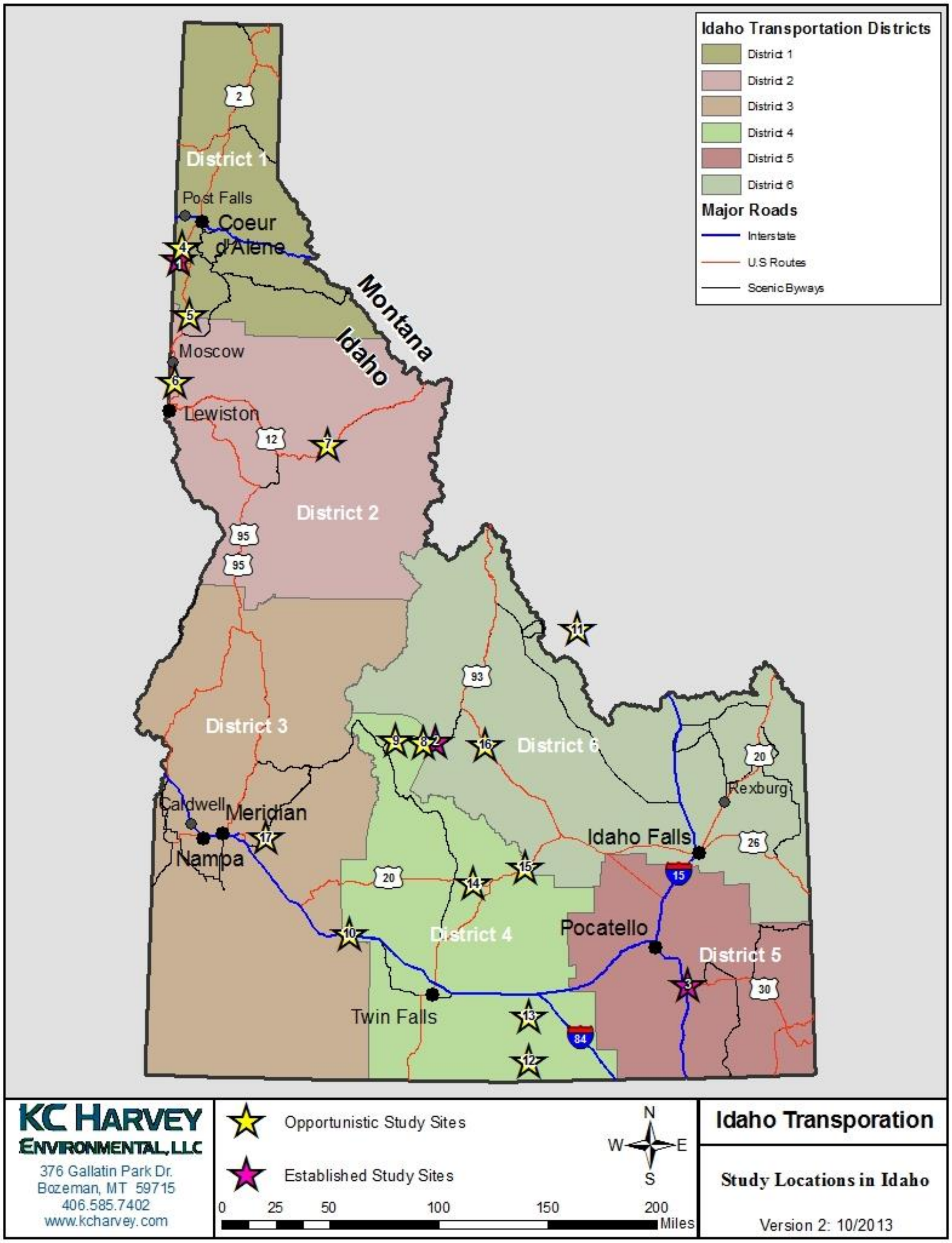

Figure 2. Location of Study Sites by Idaho Transportation Department Districts

Table 1. Monitoring Site Locations Throughout Idaho and One Montana Site

Site Number	Site Name	Highway	Level III Ecoregion	Idaho Transportation Department District
1	Worley	SH-58	Columbia Plateau	District 1
2	Clayton	SH-75	Idaho Batholith	District 6
3	McCammon	US-30	Northern Basin and Range	District 5
4	Setters	US-95	Northern Rockies	District 1
5	Electrical Substation	US-95	Northern Rockies	District 1
6	Genesee	US-95	Columbia Plateau	District 2
7	Syringa Creek	US-12	Idaho Batholith	District 2
8	Basin Creek Bridge	SH-75	Idaho Batholith	District 4
9	Slate Creek Bridge	SH-75	Idaho Batholith	District 4
10	Glenns Ferry	I-84	Snake River Plain	District 4
11	Clark Canyon Road	MT SH-324	Middle Rockies	Missoula District, MT
12	City of Rocks	STC-2841	Northern Basin and Range	District 4
13	Albion	SH-77	Northern Basin and Range	District 4
14	Silver Creek Bridge	US-20	Snake River Plain	District 4
15	Tom Cat Hill	US-93	Snake River Plain	District 6
16	Willow Creek Summit	US-93	Middle Rockies	District 6
17	Wildlife Crossing	SH-21	Idaho Batholith	District 3

Table 2. Monitoring Sites and Years Sampled by Western Transportation Institute (WTI) and KC Harvey Environmental, LLC (KCH) Field Crew

Site Number	Site Name	Date(s) Sampled	
		2012	2013
1	Worley	X	X
2	Clayton	X	X
3	McCammon	X	X
4	Setters	X	
5	Electrical Substation	X	
6	Genesee	X	
7	Syringa Creek	X	
8	Basin Creek Bridge	X	
9	Slate Creek Bridge		X
10	Glenns Ferry	X	
11	Clark Canyon Rd	X	
12	City of Rocks		X
13	Albion		X
14	Silver Creek Bridge		X
15	Tom Cat Hill		X
16	Willow Creek Summit		X
17	Wildlife Crossing		X

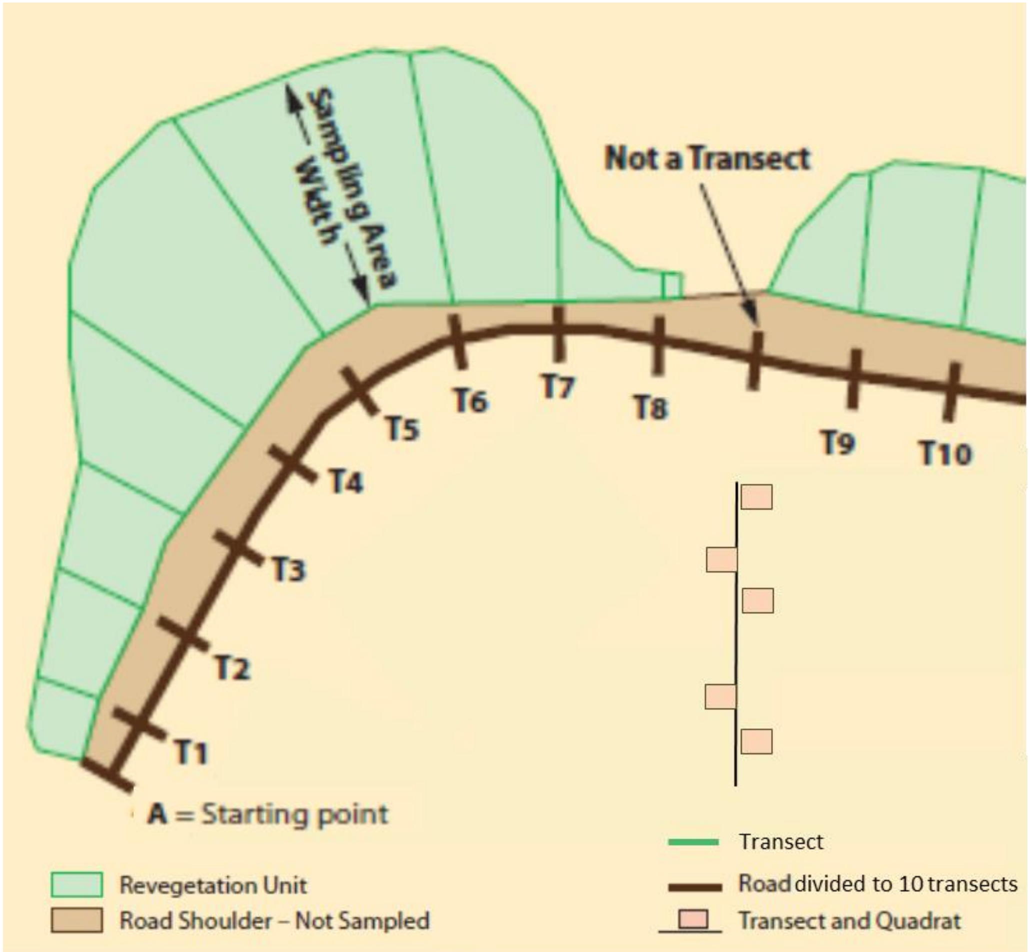

Figure 3. Sampling Design Used to Evaluate Revegetation Study Sites

The first monitoring season occurred during July 23-28, 2012, and the second season was completed during June 10-14, 2013.Percent canopy cover, defined as the vertical projection covering the ground area, was recorded for each plant species per sample frame. Canopy cover was also recorded for abiotic factors of rock, litter and bare ground because they contribute to the erosion potential of each site. At each site, the aspect, slope, and global positioning system (GPS) latitude-longitudinal position were recorded. Sites were also photographed. Indicators of erosion were measured using the erosion condition classification method of Clark to assess site stability (Appendix A).[10]

Due to unique site preparation and seed mixes used at each location, data were compiled, analyzed and discussed for each revegetation project by site, but not compared between sites. Each site varied in species present; therefore, for canopy cover and species richness data presentation, we combine species into functional groups. We also highlight individual species that performed well at each site. Note that one species can belong to more than one functional group. For example, crested wheatgrass (*Agropyron cristatum*) is a "Seeded Species" at the Willow Creek Summit site but is a "Non-Seeded Exotic Species" at other sites. The functional groups are defined below and are also listed for each species identified by the project in Appendix B.

The following definitions are provided for further clarification for the functional groups and terms used in this report.

- **Native Species:** Originated in a given geographic area without human manipulation.
- **Exotic Species**: Non-native species that owe their presence in a given geographic area to intentional or unintentional human mediated dispersal.
- **Desired Species:** Are native or exotic plant species that provide a benefit to a revegetation site.
- **Roadside:** Includes the sides of the road corridor beyond the paved road shoulders and verges including impacted or maintained roadside areas within the right-of-way (ROW).

Functional Groups

- **Seeded Grass:** Includes desired native and exotic grass species intentionally seeded.
- **Seeded Forb:** Includes desired native and exotic forb species intentionally seeded.
- **Seeded Shrub:** Includes desired native and exotic shrub species intentionally seeded.
- **Non-Seeded Native Grass:** Native grasses that have naturally colonized the site.
- **Non-Seeded Exotic Grass:** Exotic grasses that have naturally colonized the site, or are remnants from previous seeding efforts (e.g. crested wheatgrass, orchardgrass (*Dactylis glomerata*). These are not considered invasive plants because they provide benefits such as site stability or may be seeded on adjacent lands.
- **Non-Seeded Native Forb:** Native forbs that have naturally colonized the site.
- **Non-Seeded Exotic Forb:** Exotic forbs that have naturally colonized the site, or are remnants from previous seeding efforts (e.g. alfalfa, *Medicago sativa* and yellow sweetclover, *Melilotus officinalis*). These are not considered invasive plants because they provide benefits such as site stability or may be seeded on adjacent lands.
- **Non-Seeded Shrub:** Native shrubs that have naturally colonized the site.
- **Non-Seeded Tree:** Native trees that have naturally colonized the site.
- **Invasive:** Plant species on the Idaho Noxious Weed List (Appendix C), annual exotic grasses, and forbs known to be aggressive with a tendency to form monocultures and crowd out desired species.
- **Rock:** Mineral matter larger than one square inch in size.
- **Bare Ground:** Soil and mineral matter smaller than one square inch in size.
- **Litter:** Organic matter (not decomposed) in contact with the soil surface, commonly plant matter from previous growing seasons.

Chapter 2 summarizes monitoring results by site and synthesizes by ecoregion to provide revegetation recommendations for sites with similar characteristics. The results also aid in determining species adaptability and long term establishment of native plants for roadside slope stability, erosion and sediment control and weed encroachment.

Chapter 2
Idaho Roadside Revegetation Site Evaluations

The following sections describe the locations and ecological setting of each of the 3 established sites and the 14 opportunistic sites. All known revegetation site preparation techniques, seed mixes, and vegetation establishment methods are described. The results from each site include the canopy cover, species richness, erosion condition class, and individual species that performed well. Revegetation recommendations derived from each site are then summarized.

For interpretation of results, we considered a species established if it was present in the randomized sampling frames used to estimate vegetation canopy cover at each site. Species richness refers to the number of plant species represented at each site within the sampling frames. Percent canopy cover is the percentage of ground covered by a vertical projection of plant foliage. Where plants are absent the canopy cover is the amount of rock, litter, or bare ground on the soil surface.

Established Research Sites

Worley SH-58

The Worley site is located on a decommissioned section of SH-58 approximately 0.5 miles west of the intersection of US-95 and SH-58. A two acre area of the reconstruction zone was chosen for the research site. The site is located on the north side of the highway, has elevation of 2,560 ft, an aspect of 130° (southeast) and an average 10° slope (17 percent). Mean annual precipitation in the area is 21 to 28 inches.

The Worley site is within the Columbia Plateau Ecoregion (Figure 1) in Kootenai County, ID. It is an arid grassland and sagebrush steppe containing deep loess soils that are high in organic matter and easily eroded. The ecoregion has been extensively cultivated for wheat production.[11] The site is within a native plant dominated island surrounded by agricultural crop fields. The mature vegetation adjacent to the site consists of Oregon grape (*Mahonia repens*), ponderosa pine (*Pinus ponderosa*), chokecherry (*Prunus virginiana*), snowberry (*Symphoricarpos albus*), lupine (*Lupinus* sp.), Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), Sandberg bluegrass (*Poa secunda*), and smooth brome (*Bromus inermis*). Present in the area are the noxious weeds: spotted knapweed (*Centaurea stoebe*), Dalmatian toadflax (*Linaria dalmatica*), and oxeye daisy (*Leucanthemum vulgare*).

The site preparation and seeding was completed in October 2008. Site preparation included stripping and stockpiling topsoil prior to construction. After construction, topsoil was re-applied evenly over the affected area to a depth of six inches and anchored using a bulldozer to track the slopes. The site was fertilized with 40 pounds (lbs) per acre (ac) of Biosol® (6-1-3: N-P-K) and nitrogen (unknown rate) prior to hydroseeding. The site-specific “native” seed mix of 14 species was jointly developed by UI, Washington State Department of Transportation (WSDOT), and ITD (Table 3). The seed mix was hydroseeded at a rate of 79 lbs/acre. The site was then covered with wood fiber mulch and bonded fiber matrix (tackifier).

Table 3. Seed Mix Applied to Worley Research Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Seed Viability (%)	Mean Canopy Cover (%)
Grasses					
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Whitmar	15.0	27	2
Idaho Fescue	*Festuca idahoensis*	Nezpurs	5.0	40	8
Mountain Brome	*Bromus marginatus*	-	8.0	2	<1
Prairie Junegrass	*Koeleria macrantha*	-	1.5	90	<1
Forbs					
Arrowleaf Balsamroot	*Balsamorhiza sagittata*	-	1.0	69	<1
Silky Lupine	*Lupinus sericeus*	-	3.0	79	13
Western Yarrow	*Achillea millefolium*	-	1.0	89	21
Fernleaf Biscuitroot	*Lomatium dissectum*	-	12.0	90	0
Lewis flax	*Linum lewisii*	-	2.5	82	0
Pearly Everlasting	*Anaphalis margaritacea*	-	5.0	0	0
Rocky Mtn Penstemon	*Penstemon strictus*	-	5.0	67	0
Shrubs					
Oregon Grape	*Mahonia repens*	-	5.0	0	0
Snowberry	*Symphoricarpos albus*	-	5.0	20	0
Green Rabbitbrush	*Chrysothamnus viscidiflorus*	-	10.0	-	0

At the Worley site, 7 of the 14 (50 percent) species seeded established. Overall site richness was 18 species which accounted for 49 percent cover. Idaho fescue was the seeded grass species with the greatest cover (Table 3). Seeded forbs dominated the site with a combined total of 34 percent canopy cover (Figure 4). Western yarrow and silky lupine were robust and ubiquitous. Arrowleaf balsamroot was in the one-leaf stage five years after seeding. This species will likely increase in cover as existing plants grow to maturity. One non-seeded exotic grass and 2 non-seeded native forbs were present at <1percent cover each. Serviceberry (*Amelanchier alnifolia*), a non-seeded native shrub, occurred in the vicinity and was naturally colonizing the site. Present for a total of 5 percent cover were 7 invasive species (Figure 4). These included, cheatgrass (*Bromus tectorum*, <1 percent cover), bulbous bluegrass (*Poa bulbosa*, <1 cover), and the noxious weed, rush skeletonweed (*Chondrilla juncea*, <1 percent), were present. The invasive species with the highest percent cover was hairy vetch (*Vicia villosa*, 4 percent).

The erosion condition class scored “slight” at the Worley site due to several identified factors. Soil and litter movement was present with recent deposits around obstacles. Rills and gullies were also present.

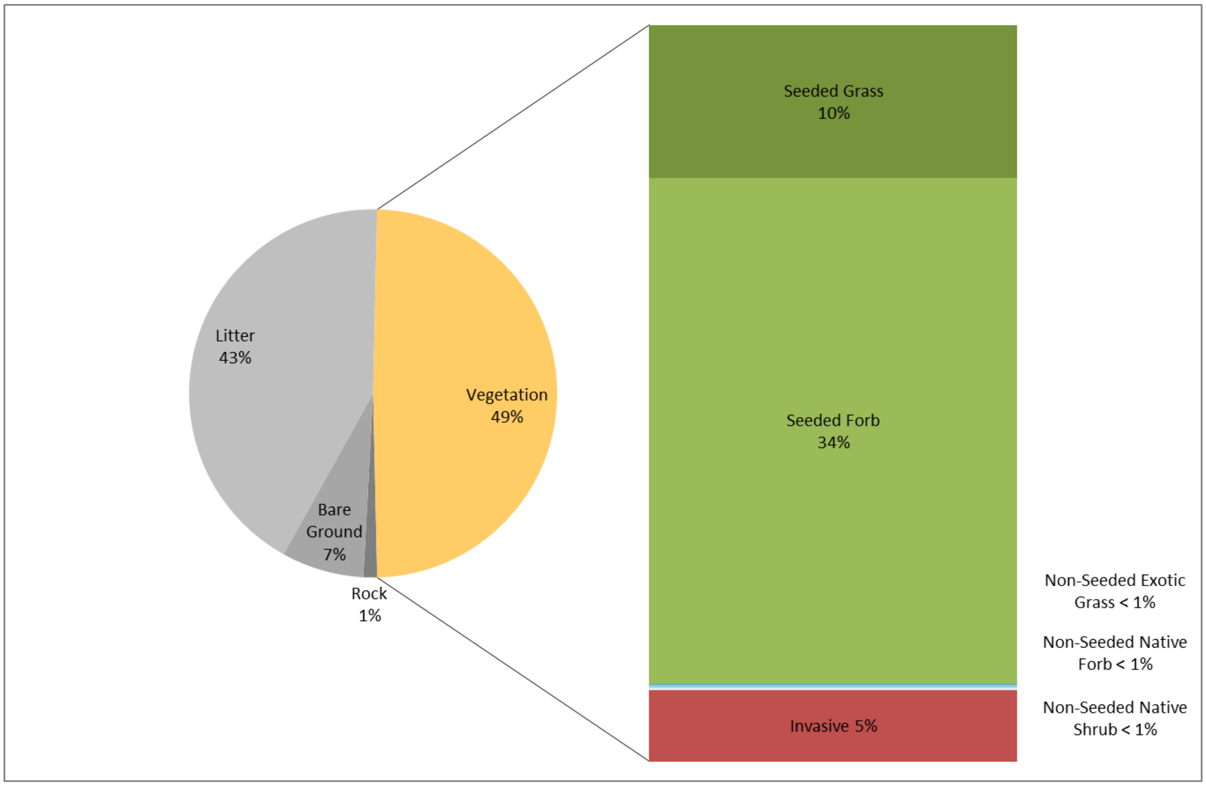

Figure 4. Mean Percent Cover by Functional Group at Worley Site

The rills were <0.5 inch deep and spaced 10 or more feet apart. Deep gullies and slumping soil were present with gullies having 5 – 10 percent active erosion in the channel bed and walls. The site was well vegetated and covered with litter (Figure 5). The deep loess soils at this site are highly erosive. Stabilizing the site may require the establishment of deep-rooted, binding vegetation such as shrubs and rhizomatous grasses.

Figure 5. Worley Research Site, June 2013[1]

Worley Site Summary and Recommendations

- Half of the seeded species established on site.
- Idaho fescue, silky lupine and western yarrow established well on the site.
- Canopy cover was dominated by seeded forb species.
- Apply lower rates of forbs and higher rates of grasses to increase cover of grass species.
- Consider planting shrubs to increase soil stabilization.
- Check the results of seed viability tests conducted at the state seed lab before purchasing seed. Seed viability will vary by species and year the seed is grown. Do not purchase seed with less than 50 percent viability – particularly expensive forbs and shrubs – if the goal is to quickly establish vegetation to stabilize the site and prevent erosion.

Clayton SH-75

The Clayton site was selected for the revegetation research project due to difficulties encountered following initial revegetation attempts in April 2008. The Clayton research site is located on both sides of SH-75 at milepoint (MP) 220.55 in Custer County, Idaho. The need for revegetation resulted from the Salmon River Bridge re-construction project and slope reshaping of SH-75. The slope on the north side of the highway averages 14° (25 percent) with a 146° (southeast) aspect. The south side slope of the highway is 27° (50 percent) with a 320° (northwest) aspect. The area receives 7 to 16 inches of annual precipitation and has an elevation of 5,560 ft. The two soil types within the Clayton site are Cryolis-Rubble land-rock and Nurkey-Dacont. The Cryolis-Rubble soil type, occurring on the northwest and

[1] All photo credits in the report are WTI, KCH, MSU, or ITD authors and staff unless otherwise noted.

southeast portion of the site, is a gravely loam to gravely sandy loam. The Nurkey-Dacont soil type on the northwest steep rocky-gravely site slopes is a very gravely loam to gravely clay loam.

The Clayton site is in the Idaho Batholith Ecoregion (Figure 1). The ecoregion is mountainous with deeply dissected canyons. Canyon vegetation is dominated by grasses and shrubs which supports grazing and recreation as the predominant land uses. Soils are derived from granitics, droughty with limited nutrients, and are highly erodible when vegetation is removed.[(11)] Pre-existing and adjacent vegetation on the site includes western yarrow, rubber rabbitbrush (*Ericameria nauseosa*), Wyoming big sagebrush (*Artemisia tridentata* ssp. *Wyomingensis*), Sandberg bluegrass, Idaho fescue, Great Basin wildrye (*Leymus cinereus*), bluebunch wheatgrass, and Indian ricegrass (*Achnatherum hymenoides*). Exotic species in the area included Russian thistle (*Salsola kali*), kochia (*Kochia scoparia*), common mullein (*Verbascum thapsus*), yellow sweet-clover, crested wheatgrass, and cheatgrass.

Initial revegetation occurred in April and May of 2008 under excessively arid and windy conditions. A combined native seed and compost mixture was applied with a blower truck. The compost was blended with the tackifier binding agent (Microblend™) and applied at approximately 550 lbs/acre. The compost was added to provide a source of nutrients and mulch. No fertilizer was added. Compost material was not applied evenly and did not receive adequate water to activate the binding material. As a result, seed and compost blew off site during spring winds and spring 2008 revegetation efforts failed.

Following the initial revegetation failure in spring 2008, ITD decided to use this project as a revegetation research site. A site-specific native seed mix composed of 5 grasses, 5 forbs, and 3 shrubs was developed (Table 4). The site was hydroseeded at 66 lbs/acre in October 2008 and May 2009. The contractor also applied two inches of wood chip compost and added water to the compost as it was applied. The water activated the tackifier allowing it to adhere to the soil and stay in place after application through the first growing season. An additional tackifier (Dirt Glue™) was applied over the top off the wood chip compost immediately after it was applied to provide additional soil/slope stability. Maintenance crews maintained the roadside vegetation for weed growth. Evidence of broadleaf herbicide use including yellowing and curling of forb leaves and stems was observed in 2012 within 30 ft of the highway.

Table 4. Seed Mix Applied to the Clayton Research Site and the Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Basin Wildrye	*Leymus cinereus*	-	7.5	5 / 3
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Jim Creek	10.0	3 / 6
Idaho Fescue	*Festuca idahoensis*	Nezpurs	6.0	<1 / <1
Indian Ricegrass	*Achnatherum hymenoides*	-	7.5	<1 / <1
Sandberg Bluegrass	*Poa secunda*	McIntyre	4.0	<1 / <1
Forbs				
Venus Penstemon	*Penstemon venustus*	-	5.0	0 / <1
Fernleaf Biscuitroot	*Lomatium dissectum*	-	8.5	0
Lewis Flax	*Linum lewisii*	-	3.5	0
Silky Lupine	*Lupinus sericeus*	-	2.5	0
Western Yarrow	*Achillea millefolium*	-	1.0	0
Shrubs				
Antelope Bitterbrush	*Purshia tridentata*	-	5.0	0
Basin Big Sagebrush	*Artemisia tridentata* ssp. *tridentata*	-	2.5	0
Rubber Rabbitbrush	*Ericameria nauseosa*	-	2.5	0

[1]The 2013 mean percent cover is presented for the north and south sides of the highway.

At the Clayton site following reseeding, 6 of the 13 (46 percent) seeded species established. All seeded species were present on both sides of the highway except for Venus penstemon, which was only on the south side (Table 4). The overall richness at Clayton was 11 species. Five species of seeded grass established; however, cover of most was <1 percent. The two seeded grasses with the highest percent of cover were basin wildrye and bluebunch wheatgrass. Two species of non-seeded native grasses, slender wheatgrass (*Elymus trachycaulus*) and foxtail barley (*Hordeum jubatum*), colonized both the North and South sample areas in trace amounts (≤1 percent). Venus penstemon was the only desired (seeded or non-seeded) forb on the site. It was particularly surprising that Lewis flax or western yarrow did not establish given their high seed rates and usual ease of establishment at other sites. The Clayton site was treated with herbicides for broadleaf weeds which may have impacted the amount of cover of desired forbs in the sample area. The Clayton site had three invasive species, which were present mostly on the North side of the highway. Spotted knapweed had trace amounts of cover on both sides on the highway. Cheatgrass had 3 percent cover and alyssum <1 percent cover only on the North side of the highway.

The erosion condition classification on both the North and South sides of the highway scored “stable”. Only minimal signs of soil and litter movement were evident. Compost was counted as litter cover and ranged from 73 – 80 percent on both sides (Figures 6 through 9). There was a slight decrease in compost cover from 2012 to 2013 which could indicate decomposition or wind loss is occurring. Compost was important in stabilizing the site. However, compost depth may have inhibited establishment of vegetation, especially for species adapted to growing on rocky substrates (e.g. sagebrush, rabbitbrush). Overall 2013 vegetation cover was 10 percent on the South side and 13 percent on the North side. As the compost decomposes, it will be critical to increase vegetation cover to maintain site stability.

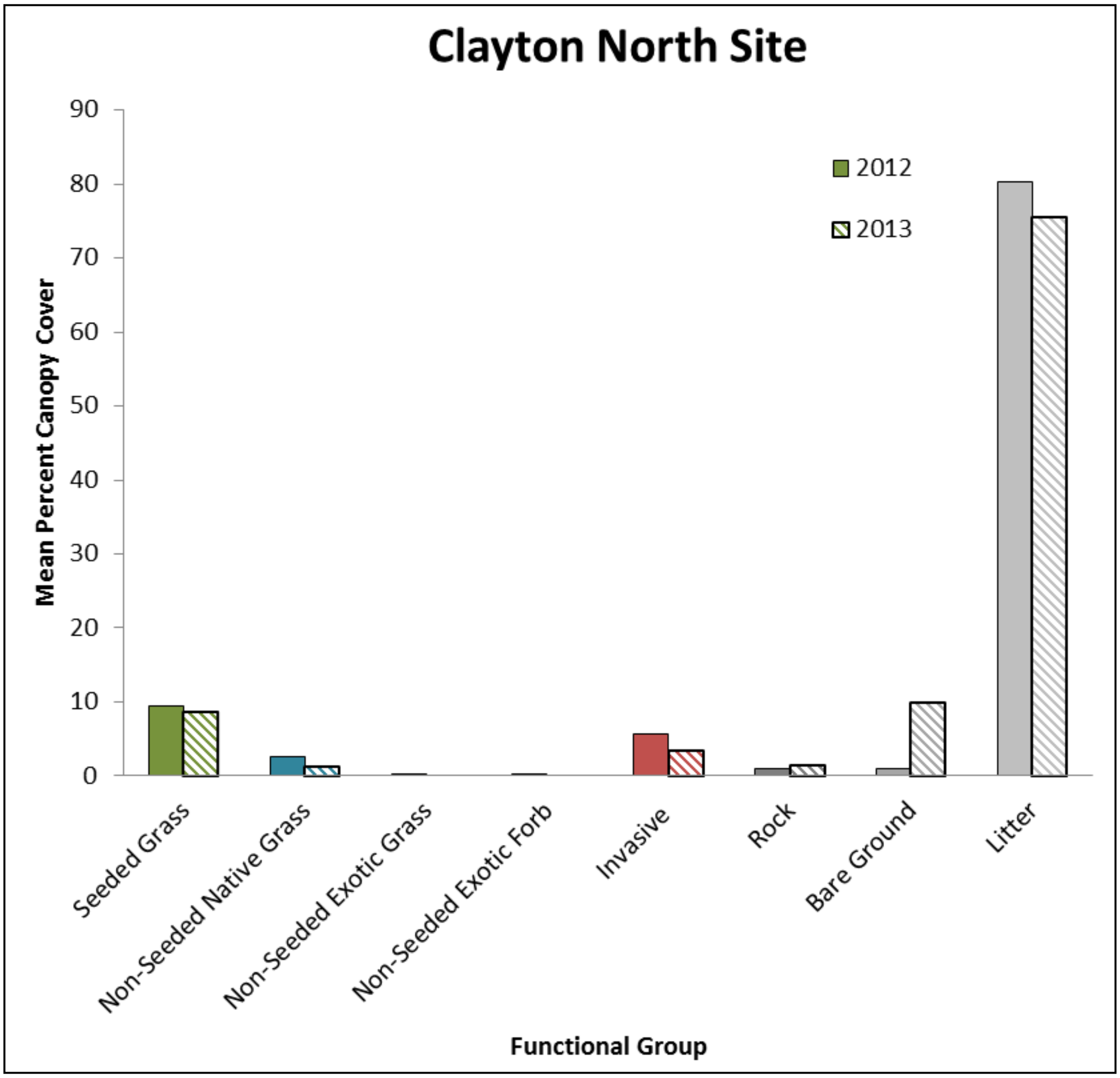

Figure 6. Mean Percent Cover by Functional Group and Year at Clayton North Site

Figure 7. Clayton Research Site North Side of SH-75, June 2013

Figure 8. Clayton Research Site South Side of SH-75, June 2013

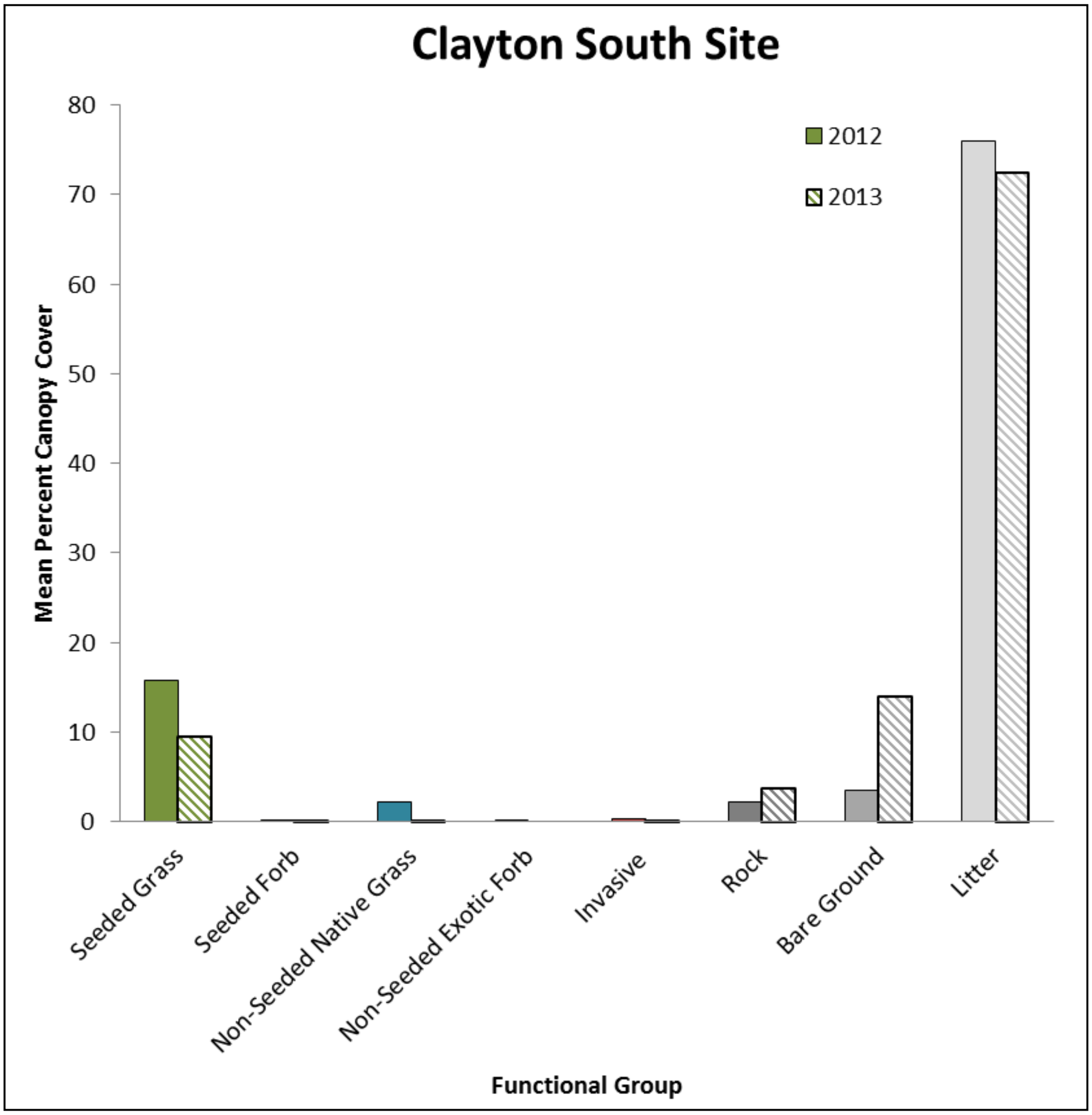

Figure 9. Mean Percent Cover by Functional Group and Year at Clayton South

Clayton Site Summary and Recommendations

- Initial site seeding failed. Seeded species did not establish (approximately 10 percent cover 5 years after seeding) well in the second seeding with supplemental compost.
- Total vegetation cover was poor since the seeded grasses combined accounted for only 5 percent cover at the site.
- Two inch depth of compost may have unfavorably impacted vegetation establishment. Many of the species seeded are small seeds that are usually applied on the soil surface. Covering with 2 inches of compost many have inhibited their light availability or growth. A general rule of thumb is to plant seed approximately five times the width of the seed at its narrowest point. For every ½ inch small seeds are placed below their optimal depths, 30 - 50 percent mortality can occur.

- Wood chip compost may negatively impact soil carbon to nitrogen ratio (C:N) making it unsuitable for plant growth. The wood chip compost adds a large source of C to the site. The N will be used to break down the C, and no N will be left available for plant growth. Additional N could be added to the site to improve the C:N ratio.
- Do not seed forbs where broadleaf herbicides are to be applied, or use forbs that are tolerant to the herbicide being applied.
- Broadcast seeding with a compost blanket and tackifier could potentially increase seeded species establishment but the results may be short-lived.
- At similar sites in Montana where vegetation cover was necessary to stabilize slopes, a revegetation program that supplements compost on a 3 to 5 year basis has improved water holding capacity and nutrients for improved plant establishment and canopy cover.

McCammon US-30

The McCammon research site is located between McCammon and Lava Hot Springs, Idaho, at MP 362.75 on US-30 in Bannock County, Idaho. The 5 acre site is accessed from Price Road and is positioned between US-30 and the Portneuf River. In 2007, US-30 was re-constructed and a wetland was constructed as part of disturbance mitigation measures. Therefore, the site required revegetation of wetland and upland vegetation. Site soils are characterized as the Inkom soil series which is comprised of silt loam mixed with alluvium. The area receives 12 to 20 inches of annual precipitation, has 3° slope (5 percent), a 169° (south) aspect, and an elevation of 4,840 ft.

The site is within the Northern Basin and Range Ecoregion and consists of dissected lava plains, rolling hills, alluvial fans, valleys, and scattered mountains (Figure 1).[11] The basins support sagebrush, cool-season grasslands, and saltbush-greasewood vegetation. Both rangeland and cropland are present in the valleys. Dominant range vegetation includes mountain sagebrush, Idaho fescue, and juniper woodlands.

The pre-existing and adjacent vegetation consists of water birch (*Betula occidentalis*), golden currant (*Ribes aureum*), aster species, softstem bulrush (*Schoenoplectus tabernaemontani*), cattail (*Typha* spp.), western yarrow, goldenrod (*Solidago canadensis*), redosier dogwood (*Cornus solinifera*), willow species (*Salix* spp.), rubber rabbitbrush, big sagebrush, sedge species (*Carex* spp.), Sandberg bluegrass, Idaho fescue, and bluebunch wheatgrass. Exotic aggressive and weedy vegetation was also found throughout the site including Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), musk thistle (*Carduus nutans*), common mullein, kochia, orchardgrass, Timothy (*Phleum pratense*) and meadow foxtail (*Alopecurus pratensis*).

Fall 2007 construction resulted in areas suitable for wetland, upland, and transitional plant communities. In summer 2008, wetland and transitional plant species were planted on site using a combination of seeding and direct planting with bare-root and one gallon container seedlings. The contractor provided the seed, live plants, mulch, tackifier and fertilizer for the first year of plant establishment. The majority of seedlings initially planted were water birch and willow. Following planting, total percent vegetative cover on site ranged from 50 to 85 percent desirable species. The location was selected as a revegetation research site due to the proximity to water and relatively low initial plant establishment in 2008.

Supplemental planting and revegetation was initiated due to relatively poor plant establishment following initial 2007-2008 revegetation efforts and the spread of exotic grasses on to the site. The University of Idaho and ITD's District 5 personnel identified revegetation techniques and target plant species optimal for revegetation of the site. The species mix, composed of seeded and live plantings, was designed to compete with established exotic vegetation.

Seeding

A 2 acre upland area was drill seeded with a nine species native seed mix at a rate of 85 lbs/acre in May 2010 (Table 5 and Figure 10). This is a higher rate than usually used at ITD sites. The site was prepared for seeding by mowing or hand-pulling previous year's undesirable vegetation using assistance from area prison crew. The revegetation strategy focused on rapidly establishing a grass cover that would reduce resources available for weedy species and subsequently reduce weed populations. In addition, the herbicide Milestone™ (unknown rate) was applied 10 days following seeding to control musk thistle, Canada thistle, houndstongue (*Cynoglossum officinale*) and other noxious weeds. Some weed species remained on site following the herbicide treatment, but their cover was reduced. A second herbicide application of Escort™ (0.5 oz/acre) with Telar™ (0.5 oz/acre) was applied in July 2011 to treat thistles, houndstongue, poison hemlock (*Conium maculatum*), and Dyer's woad (*Isatis tinctoria*).

Table 5. Seed Mix Applied to McCammon Research Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Viability (%)	Mean Canopy Cover (%)[1]
Grasses					
Basin Wildrye	*Leymus cinereus*	-	14.0	84	<1 / <1
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Anatone	12.0	90	1 / <1
Mountain Brome	*Bromus marginatus*	-	7.0	90	<1 / <1
Sandberg Bluegrass	*Poa secunda*	Mtn. Home	7.0	76	<1 / <1
Slender Wheatgrass	*Elymus trachycaulus*	-	12.0	93	3 / 2
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	Sodar	10.0	93	25 / 13
Western Wheatgrass	*Pascopyrum smithii*	-	18.0	80	<1 / 0
Forbs					
Western Yarrow	*Achillea millefolium*	-	2.0	97	0 / <1
Fernleaf Biscuitroot	*Lomatium dissectum*	-	2.5	92	0

[1]Mean percent cover for species in 2012 / 2013.

Figure 10. Planting and Seeding Zone at McCammon Research Site

The McCammon site had high species richness with 33 species present in 2012 and 27 in 2013. All of the seeded grasses established and were present at least for one year (Table 5). However, all the seeded grasses except for streambank wheatgrass had low canopy cover (<3 percent). Canopy cover of the seeded grasses may have been low due to adverse impacts from spraying Milestone™ 10 days after the spring seeding.

Milestone™ can be applied in the spring through fall to control broadleaf weeds prior to grass planting. Grasses can be seeded as a dormant planting (in the late fall or early winter) in the year of application or in the spring following the herbicide application. The herbicide and seeding applications should be timed to ensure that seeds do not germinate and emerge for at least 60 days after application to allow for some herbicide degradation, thus minimizing stunting impacts to seeded grass species. The establishment of seeded forbs may have also been negatively impacted by the herbicide treatment which will kill most broadleaf forbs. Western yarrow usually establishes well from seeding; however, the species had <1 percent cover on the site.

One species of non-seeded native grass and six species of non-seeded exotic grass were present at the McCammon site. All these species occurred in trace amounts except for Idaho fescue and orchardgrass. Idaho fescue established in dry upland areas. Orchardgrass (29 percent in 2012; 11 percent in 2013) and seeded streambank wheatgrass had the highest canopy cover in both years (Table 5 and Figure). Both of these species are adapted to the area's sub-irrigated lands. Conditions adjacent to the wetland provided good growing conditions for these species. The goal for the site was establishment of native species. Establishing native species within a well-established stand of orchardgrass will be expensive and difficult. However, orchardgrass should not be viewed as undesired if it stabilizes the site and prevents weed encroachment.

Of the non-seeded native forbs 3 species (sunflower (*Helianthus* spp.), penstemon, blanket flower (*Gaillardia* spp.) and 1 non-seeded exotic forb (white sweetclover; *Melilotus alba*) were present in 2013 with <1 percent cover each. In 2012 the white sweetclover had 8 percent cover but declined to <1 percent cover in 2013. No native shrubs had colonized the site (Figure 11).

The functional group with the highest richness in both years was the invasive group with 12 species in 2012 and eleven species in 2013. Invasive species with over 1 percent cover in 2013 included cheatgrass (8 percent cover), tumble mustard (*Sisymbrium altissimum*, 3 percent cover), and goosefoot (*Chenopodium* spp., 2 percent cover). Occurring in trace amounts were 4 species of noxious weeds including Canada thistle, field bindweed (*Convolvulus arvensis*), houndstongue, and musk thistle. In 2013 the invasive functional group doubled in cover while grass and forb functional groups decreased in cover (Figure). It will be critical to keep invasive cover low to enable desired species to continue establishing and expanding on the site. This may be especially true for invasives that have proven to be persistent in other settings such as cheatgrass, Canada thistle, field bindweed, and houndstongue.

The erosion condition classification scored "stable" for the McCammon site. Only minor evidence of surface litter movement was present. The site had a high proportion of litter and vegetation cover in both 2012 and 2013. In 2013 there was a decrease in live vegetation and an increase in vegetative litter (Figure 12). This could be the result of different weather conditions or water elevations in the wetland for those years. The site should be monitored in the future to see if vegetative cover continues to decline. Water in the wetland may need to be maintained at elevations where sub-irrigation can sustain vegetative growth.

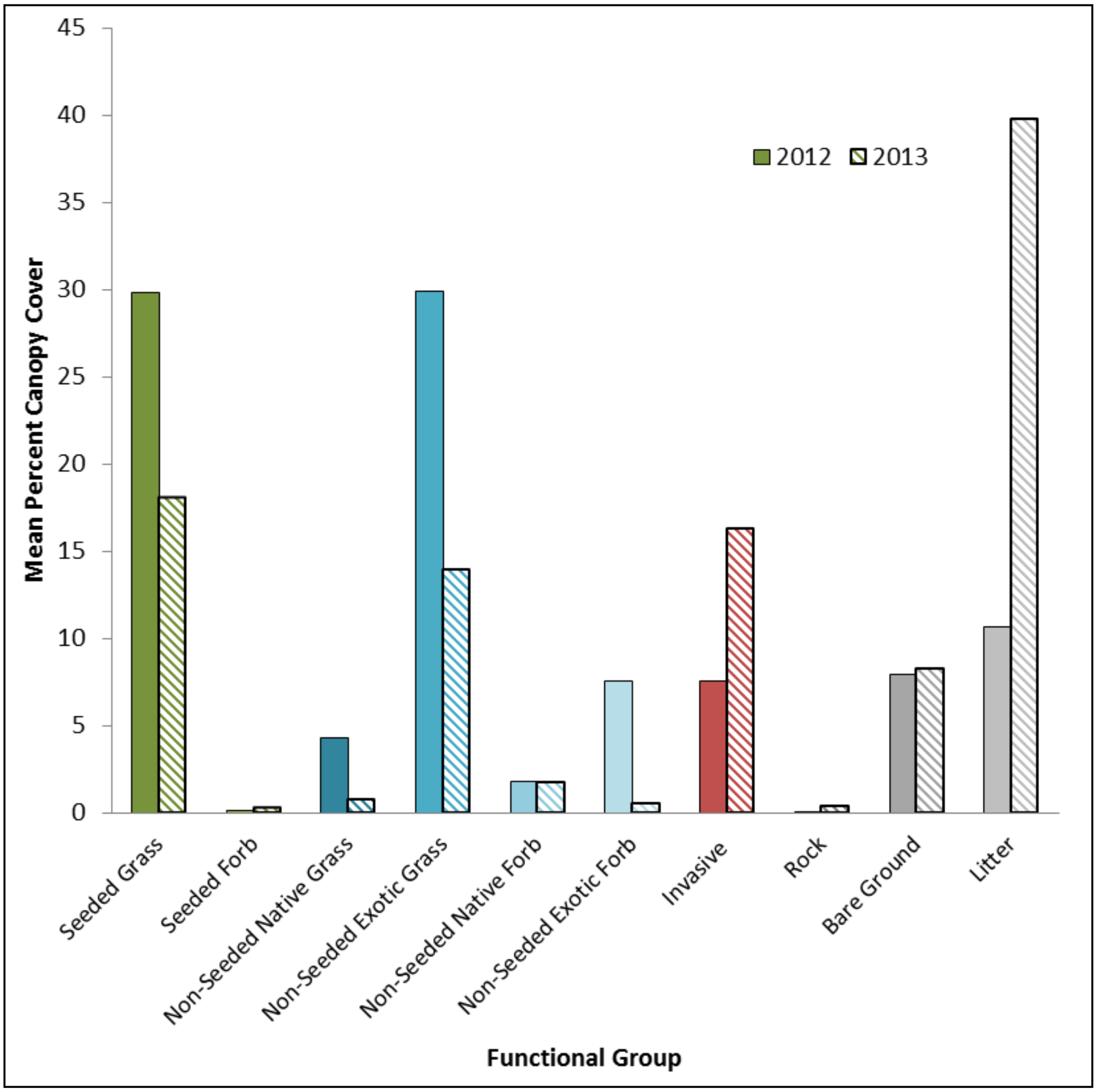

Figure 11. Mean Percent Cover by Functional Group and Year at McCammon Site

Figure 12. Upland Seeding Area at McCammon, June 2013

Live Plantings

Three microsites were selected for live plantings: upland, sloping bank and wetland edge areas (Figure 10). Microsites differed in soil moisture, compaction, aspect and proximity to standing water. The upland microsite is the most arid, disturbed and compacted. The sloping bank ranges from 3 to 5 percent slope, exhibits intermediate soil moisture and compaction, and are located 10 to 20 feet from the water edge. The wetland edge is mesic, has low soil compaction, and is directly adjacent to the water edge. Plant species were selected based on species tolerance of specific microsite conditions. In 2009, 20 in^3 seedlings were planted in grid patterns within the microsites using shovels. A total of 20 plants were installed in the upland site, 60 plants in the sloping bank site, and 80 plants on the wetland edge (Table 6). Seedlines were planted at five foot spacings. Containerized plants were monitored for survival and growth (height).

Table 6. Container Species Directly Planted in the McCammon Research Site

Common Name	Scientific Name	Number of Plants per Area		
		Upland	Sloping Bank	Wetland Edge
Antelope Bitterbrush	*Purshia tridentata*	20	-	-
Quaking Aspen	*Populus tremuloides*	-	20	-
Rocky Mtn. Juniper	*Juniperus scopulorum*	-	20	-
Mountain Ash	*Sorbus scopulina*	-	20	-
Coyote Willow	*Salix exigua*	-	-	20
Mackenzie Willow	*Salix prolixa*	-	-	20
Thinleaf Alder	*Alnus incana var. tenuifolia*	-	-	20
Water Birch	*Betula occidentalis*	-	-	20

Four years after planting, percent survival and growth of container seedlings shrubs was specific to microsite and species (Table 6). Percent survival of antelope bitterbrush in the upland was low but the shrubs that did survive were robust. Distance to water may have contributed to survival of this species.

However, since antelope bitterbrush is adapted to arid conditions, plants that survived the initial years after planting are thriving. This species could be planted at higher initial numbers to account for low percent survival in the first years after planting.

On the sloping bank, juniper, which is most adapted to arid conditions, had the highest survival (Table 7). While quacking aspen and mountain ash survived in this area, plants were small and had many dead stems. These two species appear to have died back to the ground but were re-sprouting from their roots. Based on observations in 2012 and 2013, distance to the water edge fluctuates over time in the constructed wetland. Quacking aspen and mountain ash may survive better in a location with more consistent water availability. The adaption of the juniper to more arid conditions benefited survival.

Table 7. Survival of Planted Seedlings at McCammon Site

Common Name	Survival (%)	Survival (#)	Average Height (inches)	Average Width (inches)
Upland				
Antelope Bitterbrush	15%	3	32	24
Sloping Bank				
Quaking Aspen	65%	13	20	8
Rocky Mtn. Juniper	85%	17	31	12
Mtn. Ash	15%	3	12	6
Wetland Edge				
Coyote Willow	95%	19	75	18
Mackenzie Willow	75%	15	67	20
Thinleaf Alder	0	0	0	0
Water Birch	0	0	0	0

The wetland edge site had excellent survival of coyote willow and MacKenzie's willow. The two willows were robust and tall. Coyote willow was spreading by root suckers and may be a good option for stabilizing banks for wetland construction projects (Figure 13). However, the spreading nature of coyote willow can lead to lower species diversity on a site because it can create monocultures along the water edge. MacKenzie willow was tall and not suckering which is more consistent with the species growth form. The MacKenzie willow is an excellent deep-rooted bank stabilizer and allows space for other species to occupy the site, thus adding to site diversity. Unfortunately, none of the water birch or thinleaf alder survived to year four. These species may not have been adapted to the site soils or may have lacked adequate water for growth (Table 7).

Figure 13. Coyote Willow Growth and Suckering on the Wetland Edge Microsite

Tree protectors were installed on 50 percent of the seedlings for protecting and evaluate protector effectiveness in preventing browse during the first several growing seasons. Two types of protectors were used including: yellow "Rigid Seedling Protector Tubes" and blue "Protex® Pro/Gro Solid Tube Tree Protectors". The Rigid tubes are composed of a flexible UV inhibiting polyethelene and polypropylene materials. Protex® Pro/Gro protectors are solid and are presumed to speed up photosynthesis rates by trapping moisture and raising relative humidity inside the tube. The Rigid tubes were installed on the majority of plants to allow for the multi-stemmed character of the seedlings. Approximately 10 to 12 inches of tubing was left to extend above seedlings to compensate for future growth.

During Phase I of the project, protectors were assessed for their ability to prevent browsing and persist through the winter or impact seedling growth.[9] All tree protectors were removed in spring 2012 because they became restrictive to plant growth. Therefore, protector success was not assessed during Phase 2 of the project.

Phase 1 results found ungulate browse not to be an issue in the first year of growth, thus the assessment of which tree shelter type was more successful at preventing browse was not possible. No signs of browsing were observed in the 2012 or 2013 sampling.

The yellow "Rigid Seedling Protector Tubes" were better adapted to weather conditions on the site and did not interfere with seedling growth within the first two years following planting. However, as seedlings grew in the third year, the protectors became restrictive and needed to be removed. The blue Protex® Pro/Gro Solid Tube Tree Protectors were fully or partially removed by wind and snow, causing potential damage to seedlings by bending, breaking, or reducing light availability. These Protex tubes needed to be removed due to potential seedling injury.

McCammon Site Summary and Recommendations

- Streambank wheatgrass established well on the site.
- Seeded and colonizing species that are adapted to sub-irrigated conditions thrived adjacent to the wetland.
- Herbicide labels should be read closely to determine the appropriate rate and amount of time recommended between seeding and herbicide application in order to avoid negative impacts to seeded species. Choosing a less persistent herbicide (e.g. 2,4-D, dicamba, clopyralid) may reduce the amount of time recommended between herbicide application and seeding, however the choice of a specific herbicide needs to match the weeds of concern and the site characteristics (e.g. distance to water).
- Juniper survived in arid conditions at the site and has been found to be a good revegetation species along Montana highways.
- Coyote and Mackenzie willow species had high survival along the water edge.
- Coyote willow readily sprouts from roots and spreads along the wetland edge.
- The yellow “Rigid Seedling Protector Tubes” can withstand weather conditions but should be removed after 2 years.

Opportunistic Sites

There was a desire to collect additional data on roadside revegetation throughout Idaho in Phase 2 of the roadside revegetation project. Since no other roadside revegetation sites were intentionally established as research sites, locations were chosen where roadside revegetation had occurred within 5 to 8 years prior to sampling. These are referred to as the “opportunistic” research sites because they provide an opportunity to expand the data set. The results from these sites may expand the knowledge of revegetation success and be used to improve revegetation in the various ecoregions of Idaho. The revegetation techniques and results for each site are summarized by site below and all sites are summarized in Chapter 3.

Setters US-95

The US-95 Setters Road to Bellgrove Road construction project consisted of alignment improvements including widening to divided 4 lanes, intersection improvements, and various roadside improvements. The project occurred from 2005 to 2007 in Kootenai County, ID. The construction area extends through low-relief, rolling to mountainous terrain for approximately five miles. A representative area of roadside revegetation was located at MP 414 at Alder Road. The site has a 278° (west) aspect, a 28° slope (53 percent), and a 2,630 ft elevation. The site is within the Northern Rockies Ecoregion of Idaho (Figure 1). The ecoregion is covered with volcanic ash and loess that creates rich, forest habitats.[11] The climate and vegetative species are maritime-influenced.

Slope reseeding occurred from April to October 2007. Slopes and seedbed were constructed and anchored by using a bulldozer to track the slopes. Tracking created microsites for seeds to develop. Hydroseeding was applied to all areas of the ROW with native and exotic species seed mix applied at 64 lbs/acre (Table **8**). In addition, an organic fertilizer (Biosol) and nitrogen was applied at 40 lbs/acre. A temporary bonded fiber matrix (with a pre-blended tackifier) was applied to slopes to stabilize the soil surface and prevent erosion. Native shrubs are present in the sample site; however, it is unknown if they were directly planted or had colonized the site.

Table 8. Seed Mix Applied to Setters Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Hard Fescue	*Festuca brevipila*	Durar	10	<1
Idaho Fescue	*Festuca idahoensis*	-	2	4
Sheep Fescue	*Festuca ovina*	Covar	8	<1
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	Sodar	5	<1
Upland Bluegrass	*Poa glaucantha*	Draylar	2	<1
Canada Bluegrass	*Poa compressa*	-	2	0
Intermediate Wheatgrass	*Thinopyrum intermedium*	Oahe	5	0
Mountain Brome	*Bromus marginatus*	-	5	0
Perennial Ryegrass	*Lolium perenne*	Tetraploid	5	0
Red Fescue	*Festuca rubra*	-	6	0
Smooth Brome	*Bromus inermis*	Manchar	5	0
Common Wheat	*Triticum aestivum*	Pioneer	5	0
Forbs				
White Dutch Clover	*Trifolium repens*	-	2	<1
Bird's Foot Trefoil	*Lotus corniculatus*	-	2	0

Of the 14 species seeded, 6 (43 percent) established and persisted on the site 5 years after seeding (Table 8). Monitoring results found 5 seeded grass and 1 seeded forb species accounted for 6 percent and 1percent of cover, respectively (Figure 14). Of the seeded species, hard, sheep and Idaho fescues were the most common and provided the greatest canopy cover. Present on site were five species of non-seeded native shrubs. The most predominant shrub species were snowberry, serviceberry, and snowbrush ceanothus (*Ceanothus velutinus*). Overall site richness was 21 species with 9 (43 percent) of the species belonging to the invasive plant functional group. Invasive species included North African grass (*Ventenata dubia*), prickly lettuce (*Lactuca serriola*), and St. Johnswort (*Hypericum perforatum*). None of the invasive species accounted for over 1 percent of canopy cover.

While seeded species established on site, overall vegetation cover on the site was low (Figure 15). Cover was dominated by rock and bare ground. Rock of ≥3 inches in diameter was evenly distributed over the site. This rock-armoring may have been part of the construction design. The rock contributed to a low erosion potential, but lack of soil may have prohibited vegetation establishment. Erosion condition class was "stable" with no signs of erosion and no soil collecting at the toe slope.

Setters Site Summary and Recommendations

- All seeded species that established had a low canopy cover.
- In areas of rock-armoring, mulch and tackifier are not necessary.
- Use fescue / bunchgrass species (including bluebunch wheatgrass) on rocky sites and increase the seed rate of these species to increase the overall canopy cover.

- Consider seeding or planting native shrubs on similar rocky sites in this ecoregion where there are abundant interstitial spaces.

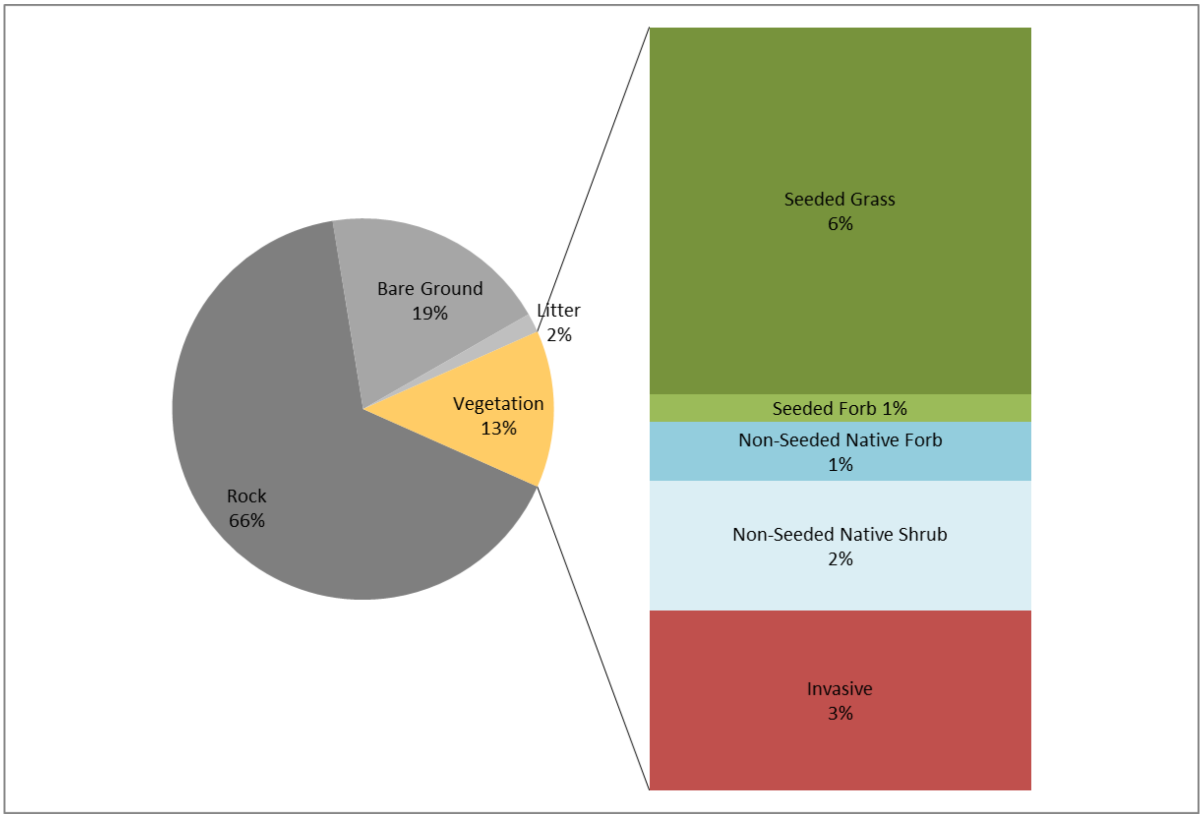

Figure 14. Mean Percent Cover by Functional Group at Setters Site

Figure 15. Setters Revegetation Site, July 2012

Electrical Substation US-95

The Electrical Substation to Smith Creek highway project was an alignment improvement on 6.6 miles of US-95 in Benewah and Latah Counties, ID. Project features included adding shoulders, incorporating turn lanes, and constructing passing lanes. A representative sample site on a fill slope was located near MP 371 north of Skyline Drive turnoff. The sample site between the holding ponds and the highway cutslope has a 25° slope (47 percent), a 340° (north) aspect, and an elevation of 2,930 ft.

The site is within the Northern Rockies Ecoregion of Idaho (Figure 1). This ecoregion is mountainous and rugged.[11] The climate and vegetative species are maritime-influenced. A mixed Douglas fir (*Pseudotsuga menziesii*), Englemann spruce (*Picea engelmannii*), western larch (*Larix occidentalis*), and western red cedar (*Thuja plicata*) forest occurs in the vicinity of the site.

Revegetation site preparation consisted of stripping and stockpiling topsoil during construction and re-spreading soil post-construction. The soil was anchored by using a bulldozer to track the slopes. Mulch was also applied and tracked prior to seed application. Hydroseeding was applied to all areas of the ROW from September 2007 to May 2008 using a 15 species native and exotic seed mix applied at 44 lbs/acre (Table 9). Although no records were provided, evidence of broadleaf herbicide use was observed within 30 ft of the highway.

Table 9. Seed Mix Applied to Electrical Substation Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bottlebrush Squirreltail	*Elymus elymoides*	-	4.0	<1
Canada Bluegrass	*Poa compressa*	-	2.0	6
Idaho Fescue	*Festuca idahoensis*	-	4.0	34
Slender Wheatgrass	*Elymus trachycaulus*	-	6.0	<1
Mountain Brome	*Bromus marginatus*	-	7.0	0
Red Fescue	*Festuca rubra*	-	2.0	0
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	-	5.0	0
Forbs				
Fernleaf Biscuitroot	*Lomatium dissectum*	-	1.0	<1
Bird's Foot Trefoil	*Lotus corniculatus*	-	1.5	0
Rocky Mtn. Penstemon	*Penstemon strictus*	-	1.0	0
Sweetvetch	*Hedysarum boreale*	-	2.0	0
Silky Lupine	*Lupinus sericeus*	-	2.0	0
Shrubs				
Bearberry	*Arctostaphylos uva-ursi*	-	2.0	<1
Snowberry	*Symphoricarpos albus*	-	2.0	<1
Oregon Grape	*Mahonia repens*	-	2.0	0

Four years after seeding, 6 of the 15 species seeded (40 percent) were established on site including 4 grasses, 1 forb, and 2 shrubs (Table 9). Seeded grasses accounted for 40 percent of total vegetative cover (Figure 16). Of these seeded grasses, Idaho fescue and Canada bluegrass contributed 34 percent and 6 percent of the canopy cover, respectively. Other seeded grasses were present at trace amounts. Fernleaf biscuitroot was the only seeded forb to establish and it had a trace (<1 percent) amount of cover. Together, snowberry and bearberry contributed 1 percent vegetative cover.

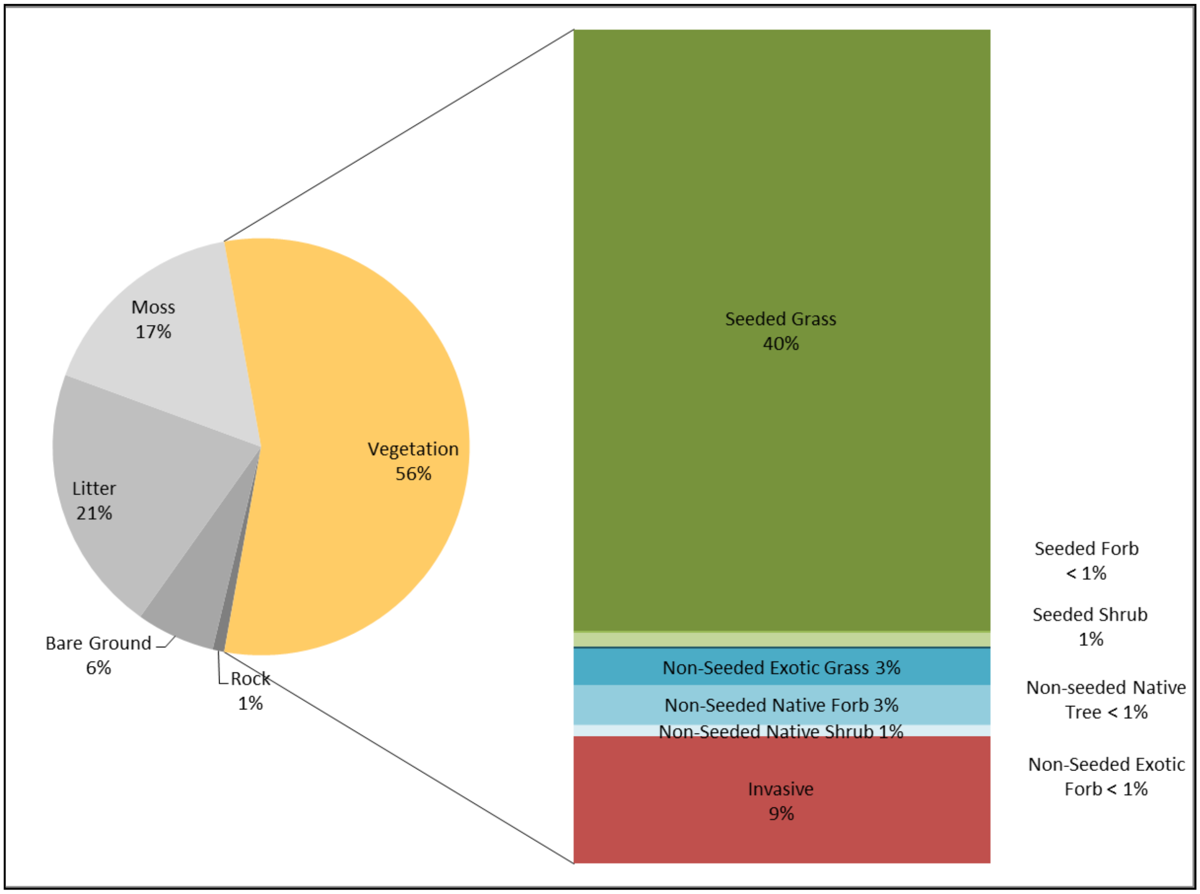

Figure 16. Mean Percent Cover by Functional Group at Electrical Substation Site

Total richness on the Electrical Substation site was 29 species. Of these, 12 species were non-seeded native species that are colonizing the site. Douglas fir, a non-seeded native tree, was present at <1 percent cover and snowbrush ceanothus, a non-seeded native shrub, was present at <1 percent cover. Of the non-seeded native forbs10 species were present each at a trace (≤1 percent) amount of cover. At this site, 8 species of invasive plants occurred. All had ≤1 percent canopy cover except for oxeye daisy which had 6 percent cover. Oxeye daisy occurred throughout the study site and is an Idaho noxious weed.

Soil condition class was stable; however, signs of soil movement were present. Soil was deposited around obstacles (e.g. straw wattles). Figure 17 demonstrates the stability of the site can be partially attributed to the proportion of ground covered by live vegetation (56 percent), moss (17 percent), and litter (21 percent). Only a relatively small amount of bare soil (6 percent) was exposed and vulnerable to erosion.

Figure 17. Electrical Substation Revegetation Site, July 2012

Electrical Substation Site Summary and Recommendations

- Two seeded grasses (Idaho fescue and Canada bluegrass) had good establishment on the site.
- All other seeded species had poor or no establishment.
- Mulch and hydroseeding were a good technique for establishing desired species on the site.
- Do not seed forbs in areas where natural forb recruitment is possible and where broadleaf herbicides are applied for weed control. If forbs are desired, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.

Genesee US-95

The Genesee highway construction project on US-95 extends from MP 330.9 to 337.76 in Latah County, ID. The project consisted of improving the road alignment, construction of a center lane, and widening from a two-lane to a four-lane highway. The project began in 2005 and revegetation was completed in 2007. A representative site at MP 325.32 was chosen for revegetation monitoring. This site has a 16° slope (29 percent), a north aspect (4°), and a 2,710 ft elevation.

The site is representative of the rolling hillsides of the Columbia Plateau Ecoregion of Idaho (Figure 1). The deep loess soils of this ecoregion are extensively cultivated for annual crops such as wheat and beans.[11] Surrounding vegetation of the site is annual agricultural cropland with scattered small remnants of native vegetation.

Prior to revegetation, slope surfaces were constructed to a rough, corrugated condition to assist in creating microsites conducive for plant establishment. Slopes were tracked with a bulldozer prior to revegetation to anchor soils and roughen surfaces prior to seeding. Fertilizer was applied at a rate of 40 lbs/acre slow-release nitrogen and 1 lb/acre phosphorous. The site was drill seeded to a depth of 2 inches with 6 grasses and 2 forbs at a rate of 33 lbs/acre (Table 10). Species were a mix of native and exotic desired species.

Table 10. Seed Mix Applied to the Genesee Site and the Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Crested Wheatgrass	*Agropyron cristatum*	Fairway	7.1	21
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	-	2.7	1
Canada Bluegrass	*Poa compressa*	-	1.8	<1
Sandberg Bluegrass	*Poa secunda*	-	3.6	0
Slender Wheatgrass	*Elymus trachycaulus*	Revenue	7.1	0
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	-	7.1	0
Forbs				
Silky Lupine	*Lupinus sericeus*	-	1.8	0
White Dutch Clover	*Trifolium repens*	-	1.8	0

Of the 8 species seeded species, 3 established on site (38 percent) including crested wheatgrass, thickspike wheatgrass, and Canada bluegrass. Of these, crested wheatgrass was the most dominant accounting for 21 percent of canopy cover (Table 10 and Figure 18). Species richness was low with a total of 10 species. Species richness included 3 seeded grasses, 1 non-seeded exotic grass (Canada bluegrass), 2 non-seeded native forbs (willowherb (*Epilobium brachycarpum*), sandwort (*Arenaria*), and 4 invasive species. The invasive functional group included the most species but lowest percent cover (Figure 18). Invasive species included prickly lettuce, North African grass, catchweed bedstraw (*Galium aparine*) and soft brome (*Bromus hordeaceus*).

Erosion condition class was “stable” for the Genesee site. Minor signs of erosion presence were soil movement and deposits around obstacles (rocks). The site was well covered with live vegetation and litter which added to site stability (Figure 19).

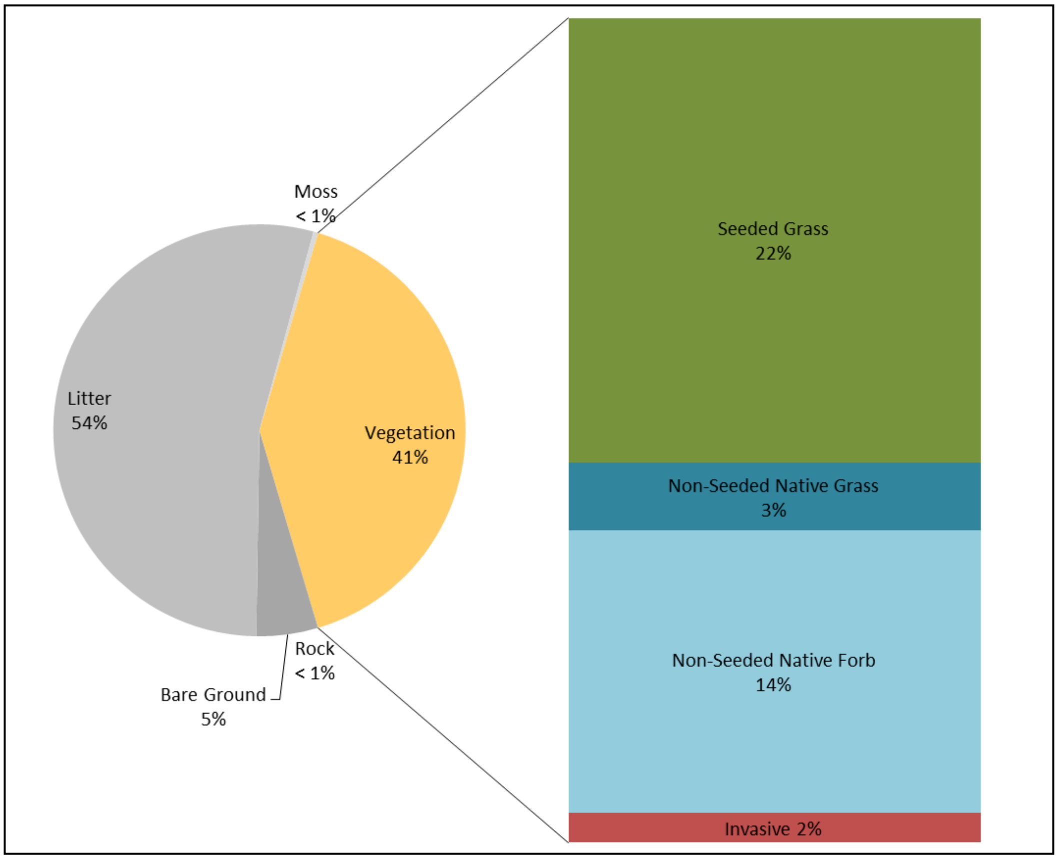

Figure 18. Mean Percent Cover by Functional Group at Genesee Site

Figure 19. Genesee Revegetation Site, July 2012

Genesee Site Summary and Recommendations

- Crested wheatgrass established well while other seeded species did not.
- Crested wheatgrass is known to establish quickly and uniformly on reclaimed disturbed sites. When seeding crested wheatgrass, eliminate or limit native species in the seed mix because they will generally have low establishment.
- Sandberg bluegrass, slender wheatgrass and streambank wheatgrass did not establish.
- Crested wheatgrass is a potential species to seed on slopes surrounded by cropland with little to no native species in the vicinity. It will reduce weed encroachment and stabilize slopes. Crested wheatgrass should not be used at sites surrounded by native species, or where a diverse assemblage of grass species is desired.
- Roughening slopes and adding fertilizer aided in seeded species establishment.
- The 2 inch seeding depth may have been too deep for the establishment of small seeds (bluegrass species). A general rule of thumb is to plant seed approximately 5 times the width of the seed at its narrowest point (¼ to ½ inch depth). For every ½ inch small seeds are placed below their optimal depths, 30 - 50 percent mortality can occur.

Syringa Creek US-12

The Syringa Creek construction project is located on US-12 between MP 90.70 and 113.80 in Idaho County, ID. The project consisted of road widening and slope work. A representative revegetation site was located at MP 106.8. The site was at an elevation of 1,610, on a curve and aspects range from 125° to 154° (southeast). The area had a consistent 36° slope (76 percent) that precluded topsoil replacement due to its steepness.

The site is part of the Idaho Batholith Ecoregion of Idaho (Figure 1).[11] The deeply dissected Lochsa–Selway–Clearwater Canyons of the ecoregion contains cold, fast-flowing rivers. Local relief is greater than in nearby mountains. Conifers of higher elevations in the ecoregion are dominated by Douglas fir, grand fir, western red cedar, western larch, and western white pine (*Pinus monticola*). Vegetation adjacent to the roadside included western red cedar, Douglas fir, and hemlock trees with a shrub understory of thimbleberry (*Rubus parviflorus*), mountain maple (*Acer spicatum*), ferns, and herbaceous vegetation.

Road construction was completed and the site was seeded in 2009. The desired species seed mix was hydroseeded at a rate of 86 lbs/acre with blown-on compost. An organic SP15-05C compost/mulch erosion blanket was then placed on top of the seed and compost to provide additional slope protection and hold the compost on the slopes (Table 11). Although no spray records were provided, evidence of broadleaf herbicide use was observed within 30 ft of the highway.

At the Syringa Creek site, 7 of the 15 seeded species (47 percent) established (Table 11).The site had relatively low species richness with only 12 species present. Of these, 5 species were seeded grasses. Seeded grasses accounted for 64 percent of total vegetative cover with Canada bluegrass, mountain brome, and hard fescue contributing a combined 62 percent of seeded grass cover. The Montana Department of Transportation (MDT) has had similar good establishment results for Canada bluegrass and mountain brome in western Montana.[12] Other seeded grass species were present in trace amounts. In addition, 1 species, crested wheatgrass, a non-seeded exotic grass was present at <1 percent cover. Other species MDT has observed to establish well in western Montana are Sherman big bluegrass (*Poa secunda ssp. ampla*), Newby hybrid wheatgrass (*Elymus hoffmannii*) and Canada wildrye (*Elymus canadensis*).[12]

Only 2 seeded forbs and no seeded shrubs established (Table 11). The invasive functional group contributed 3 percent of total vegetation cover (Figure 20). Invasive species included prickly lettuce and cheatgrass. Other invasive forbs such as spotted knapweed were present in the vicinity but the yellowing and twisting of forb leaves and stems made it visually obvious the site had been sprayed for broadleaf herbaceous weeds.

Table 11. Seed Mix Applied to Syringa Creek Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	-	12	1
Canada Bluegrass	*Poa compressa*	-	3	39
Hard Fescue	*Festuca brevipila*	Durar	4	7
Mountain Brome	*Bromus marginatus*	-	3	16
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	-	8	<1
Idaho Fescue	*Festuca idahoensis*	-	8	0
Forb				
Goldenrod	*Solidago canadensis*	-	6	<1
Western Yarrow	*Achillea millefolium*	-	4	<1
Montana Golden Pea	*Thermopsis montana*	-	4	0
Rocky Mtn. Penstemon	*Penstemon strictus*	-	8	0
Silky Lupine	*Lupinus sericeus*	-	5	0
Shrubs				
Birchleaf Spiraea	*Spiraea betulifolia*	-	8	0
Oregon Grape	*Mahonia repens*	-	4	0
Snowberry	*Symphoricarpos albus*	-	5	0
Woods' Rose	*Rosa woodsii*	-	4	0

Erosion condition class was "slight". Signs of erosion included recent deposits of soil around obstacles, surface litter movement, and flow patterns. The site had 73 percent vegetation cover and 23 percent litter cover which are both beneficial for holding soils in place (Figure 21). Steep slopes (36°) and the precipitation levels in the area may contribute to the soil and litter movement.

Syringa Creek Site Summary and Recommendations

- Seeded grasses had good establishment while forbs and shrubs did not.
- Herbicide treatments were beneficial for keeping invasive plant cover low, but it probably impacted establishment of desired seeded forbs.
- Where broadleaf herbicides will be applied, do not seed forbs. If forbs are desired, use species that are known to establish well, are relatively inexpensive, and/or are tolerant of the herbicides being applied.
- Establishing and maintaining high vegetation cover on steep slopes will be critical to maintaining stable soils and slopes at the site.

- A high seed rate does not necessarily equate to a high establishment rate.

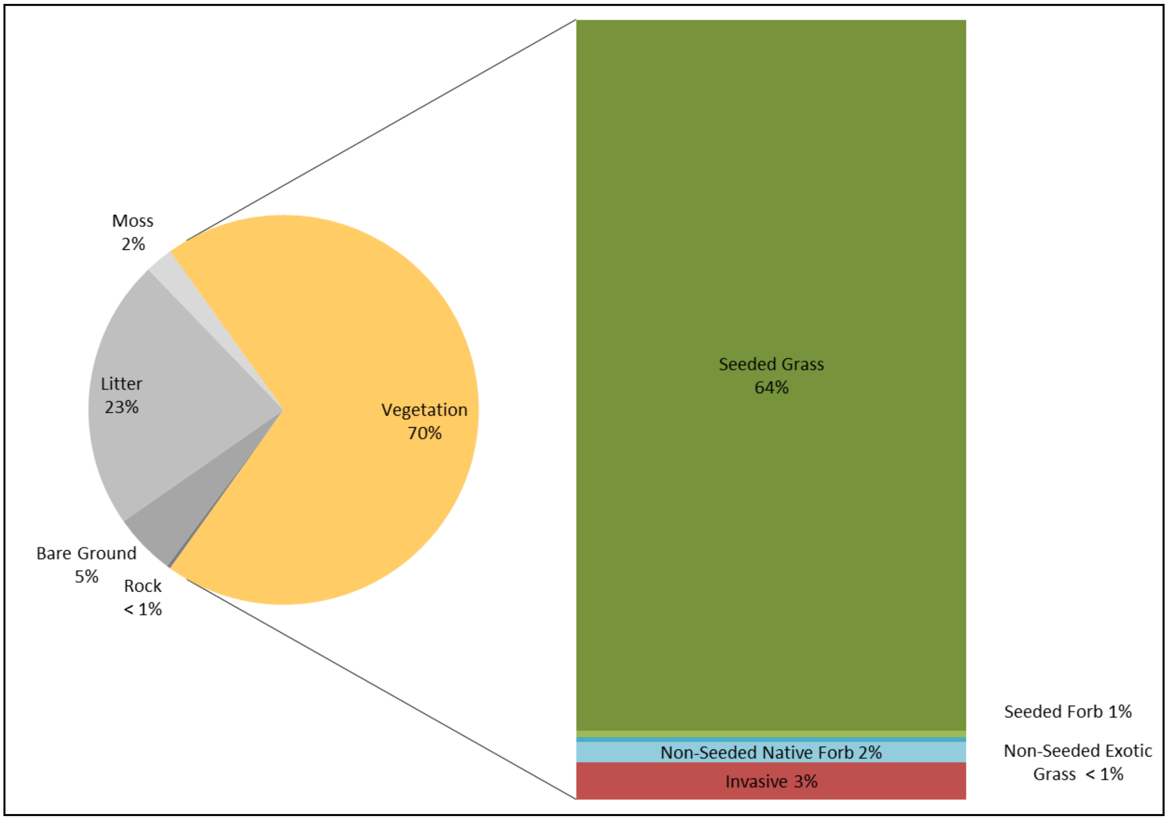

Figure 8. Mean Percent Cover by Functional Group at Syringa Site

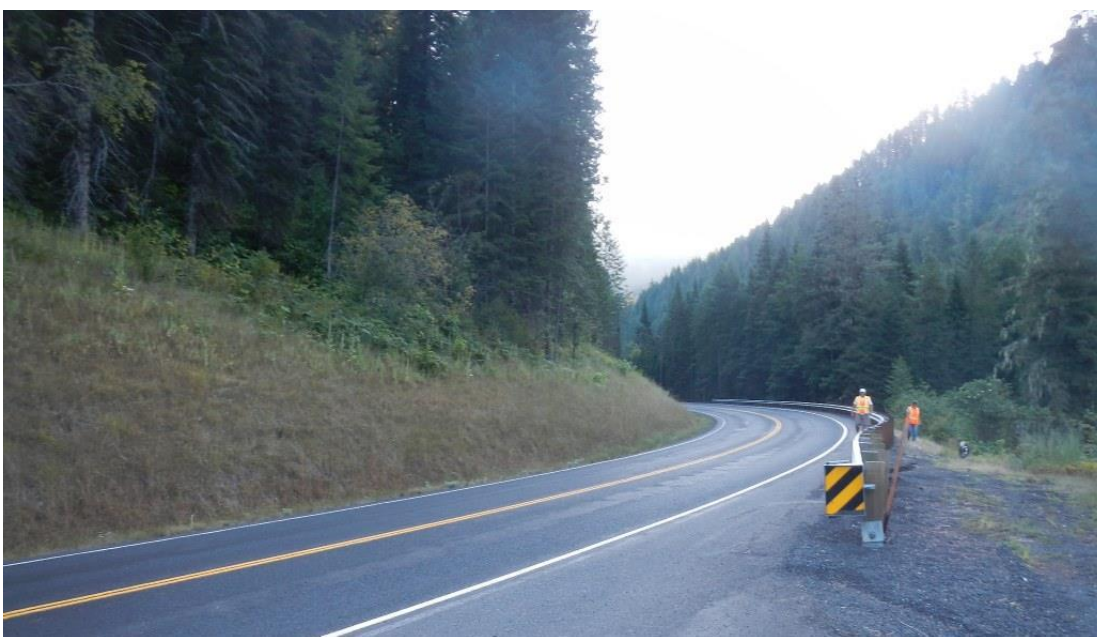

Figure 9. Syringa Creek Revegetation Site, July 2012

Basin Creek Bridge SH-75

This road project consisted of replacing the existing bridge structure over Basin Creek with base and surfacing work associated with the bridge approaches for 0.19 miles (MP 197.387 - 197.574) of SH-75 in Custer County, ID. Construction and seeding occurred in 2007. Approximately 3.5 acres of seeding occurred within the ROW limits including foreslopes, back slopes, embankments, and obliterated roadway. Both sides of the road were sampled for the revegetation study. The sample site aspect was 300° (northwest) on the north side of the road and 120° (southeast) on the south side of the road. Revegetated slopes were approximately 30 ft in length or less and ranged from 2° – 25° (4 – 48 percent) slopes and had an elevation of 6,070 ft.

The Basin Creek Bridge site is within the Idaho Batholith Ecoregion where it transitions from hot dry canyons to the southern forested mountains (Figure 1).[11] The ecoregion is surrounded by droughty soils derived from granitic rocks and is only marginally affected by maritime moisture. Mountain big sagebrush (*Artemisia tridentate ssp. vaseyana*) and forest habitats are common. Douglas fir is found locally growing on mountain sides while ponderosa pine (*Pinus ponderosa*) is present in canyon habitats.

Seeding occurred in September 2007 using 2 seed mix specifications, 1 for wetland and 1 for dryland seeding. All sampling was located in the dryland seeded areas. Prior to broadcast seeding, topsoil was re-applied to the slopes and the seedbed was raked to increase texture. The seed mix consisted of 4 native grasses, 2 exotic grasses, 2 native forbs and 1 native shrub applied at a total of 124 lbs/acre (Table 12). No fertilizer, mulch or compost was applied at the time of seeding.

Table 12. Seed Mix Applied to Basin Creek Bridge Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Canada Bluegrass	*Poa compressa*	-	21	3
Sheep Fescue	*Festuca ovina*	-	21	7
Blue Wildrye	*Elymus glaucus*	-	15	0
Idaho Fescue	*Festuca idahoensis*	-	14	0
Indian Ricegrass	*Achnatherum hymenoides*	-	21	0
Letterman's Needlegrass	*Achnatherum lettermanii*	-	12	0
Forbs				
Arrowleaf Balsamroot	*Balsamorhiza sagittata*	-	6	0
Silky Lupine	*Lupinus sericeus*	-	7	0
Shrubs				
Antelope Bitterbrush	*Purshia tridentata*	-	7	0

Overall richness at Basin Creek Bridge site was 25 species. Of the seeded species, 2 of the 9 species established (22 percent; Table 12). Both established seeded species were grasses (sheep fescue, Canada bluegrass) which accounted for 10 percent of vegetation cover (Table 12 and Figure 22). The grass species with the smallest seeds were the only seeded grasses to establish. This suggests larger seed species may not have adequate soil to seed contact to germinate and establish. The MDT has seen similar results on rocky sites. MDT has improved soil to seed contact and germination of large seed species by covering seed with mulch or compost, or by roughening soil to increase texture prior to broadcast seeding. (12)

Of non-seeded grasses 7 species accounted for another 13 percent of vegetation cover. These species included smooth brome, slender wheatgrass, and quackgrass *(Elymus repens)* with 6 percent, 4 percent, and 1 percent canopy cover, respectively. These grasses were most likely present prior to site construction and revegetation. No seeded forbs or shrubs established on site. However, 4 species of non-seeded native forbs, 2 exotic forbs, and 1 native shrub colonized the site. Of the colonizing forbs, yellow sweetclover, willowherb, and white sweetclover had the highest percent cover. Other forbs were present in trace amounts. Rubber rabbitbrush had a trace amount cover (<1 percent). The invasive functional group had the highest richness with 9 species present. The only noxious weed present was spotted knapweed with <1 percent cover.

Erosion condition class was “slight”. Signs of erosion included recent deposits of soil around rock fragments. Given that the site had over 50 percent combined cover of rock and bare ground (Figure 22), it was surprising the erosion values were low. Proportion of vegetation and litter cover are usually good indicators of site stability. However, at this site rock adjacent to the river and relatively low slope angle are armoring the site. Increasing vegetation cover will be important in the future to withstand flood events and surface flows from the road pavement.

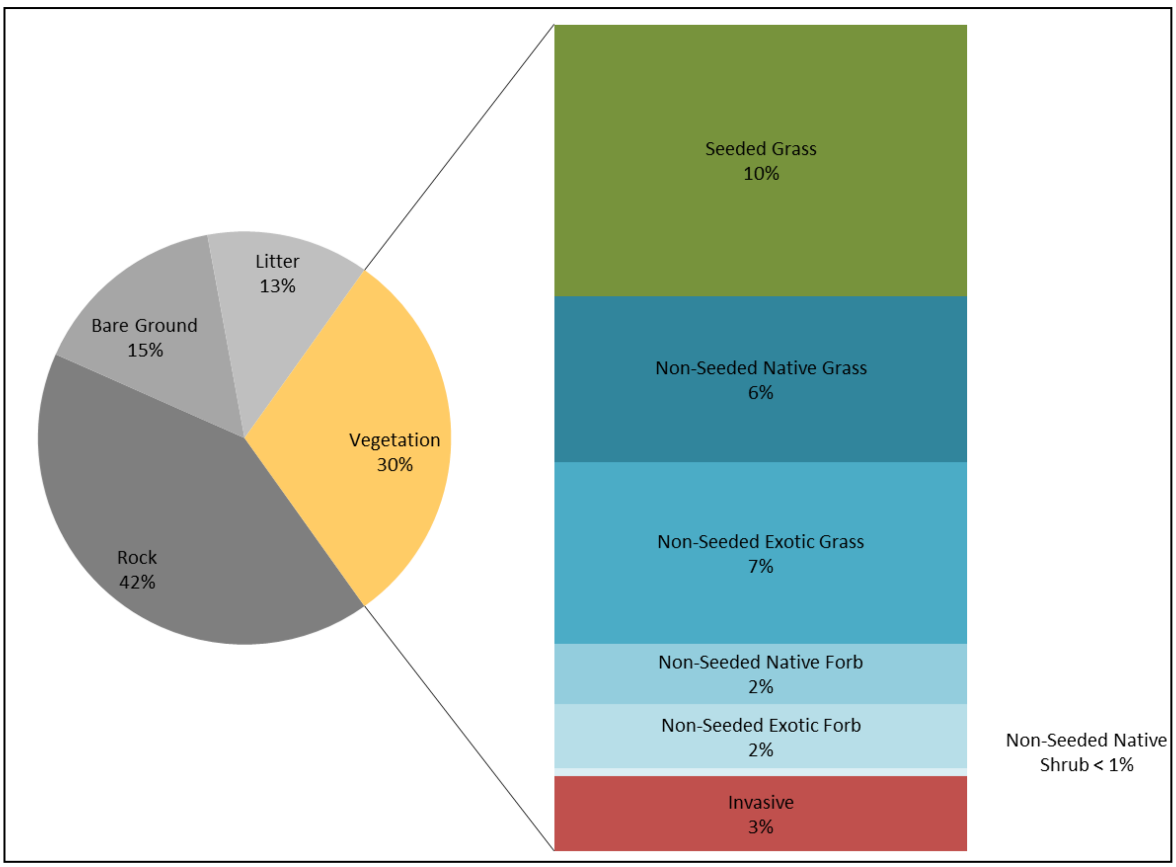

Figure 22. Mean Percent Cover by Functional Group at Basin Creek Bridge Site

Figure 23. Basin Creek Bridge Revegetation Site, July 2012

Basin Creek Bridge Site Summary and Recommendations

- Seeded grasses did not establish well on the rocky substrate except for the small seeded sheep fescue.
- Increase amount of sheep fescue on rocky sites such as river rock bottom.
- Increasing vegetation cover in rocky soil will be important to prevent noxious weeds from becoming more widespread and dominant.
- Seeded forb and shrub cover had poor establishment.
- Seeded forbs may not have been adapted to the river bottom. Consider seeding goldenrod and tufted hairgrass (*Deschampsia cespitosa*), and planting willow species on sites with a high water table.
- High seed rate did not necessarily equate to high species establishment rate on the rocky alluvial soils.

Slate Creek Bridge SH-75

The construction project consisted of replacing the bridge structure and implementing road improvements for 0.44 miles (MP 213.29 - 213.73) of SH-75 in Custer County, ID. The project area crosses the Salmon River and is adjacent to the Whiskey Flats Campground. Safety improvements were made primarily by improving sight distance, adding road width, eliminating substandard horizontal curves, and improving existing vertical profile. Approximately 3.5 acres of seeding was implemented for this project on both sides of the highway within the ROW limits including foreslopes, back slopes, embankments, and obliterated roadway. Project slopes were 3:1 or steeper and at an elevation of 5,660 ft.

The Slate Creek Bridge site is within the Idaho Batholith Ecoregion (Figure 1). Existing adjacent vegetation consists of mixed pine and Douglas fir forests on the north-facing slopes, desert shrubs on the south-facing slopes, and cottonwood (*Populus* spp.) forests along the river.

The ROW was hydroseeded from fall 2010 to fall 2011. First, topsoil was re-applied and compost added to slopes after construction activities ended. Second, a seedbed was constructed and anchored by bulldozer tracking up and down the slopes to increase soil texture and create safe sites for seed establishment. Next, the site was hydroseeded from September to November 2010 with a native seed mix applied at 25 lbs/acre which was lower than typical ITD hydroseed rates (Table 13). Erosion blankets (jute mat and straw blanket with nylon netting) were then installed on steep slopes. The second season, additional seed was broadcast applied on the top of the erosion control blanket in an effort to increase species diversity.

Table 13. Seed Mix Applied to Slate Creek Bridge Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Established
Grasses				
Idaho Fescue	*Festuca idahoensis*	-	3.0	Common
Basin Wildrye	*Leymus cinereus*	-	4.0	Rare
Letterman's Needlegrass	*Achnatherum lettermanii*	-	4.0	Rare
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	-	4.0	No
Forbs				
Silky Lupine	*Lupinus sericeus*	-	5.5	No
Shrubs				
Mountain Big Sagebrush	*Artemisia tridentata ssp. vaseyana*	-	0.5	Common
Antelope Bitterbrush	*Purshia tridentata*	-	4.0	No

The Slate Creek Bridge site was seeded two years prior to the sampling event. Established plants were seedlings with a low canopy cover. Therefore, transect and erosion condition class sampling was not implemented at this site. Instead, the entire seeded upland area was walked and species present were noted as rare (<1 percent cover), common (1 - 25 percent cover), and dominant (>25 percent cover). Of the seeded species, mountain big sagebrush and Idaho fescue were common (Table 13). The two most dominant species on site were unseeded: streambank wheatgrass and Kentucky bluegrass (*Poa pratensis*). Basin wildrye was present but rare; however, it is notoriously slow to establish and may increase over time. These dominant species were likely present prior to site construction. Only 1 invasive species was present (cheatgrass) at <1 percent cover.

Two erosion control blankets were used on site, a heavy woven jute mat and a lighter straw fabric reinforced with nylon netting. The jute mesh erosion control mat has coarse, open mesh fabric that is durable on site for two years. The straw blanket has woven nylon netting on the top and bottom of the straw to provide site stability for two or more years. More plants established in the straw blanket with nylon netting than where the jute mat was applied (Figure 24). In Figure 24, the jute mat is in the foreground and the crew is standing on the straw blanket with nylon netting. It appeared that the hydroseed applied to the top of the jute mat did not establish or increase the site revegetation success. Seed should only be applied prior to applying the erosion control matting so seed is in contact with soil surface.

Figure 24. Slate Creek Bridge Revegetation Site, June 2013

Slate Creek Bridge Site Summary and Recommendations

- Mountain big sagebrush and Idaho fescue were common on the site.
- Other seeded species were slow to establish but are present.
- Apply seed on soil surface prior to placing erosion control matting. Seeding on top of the erosion blanket did not add to site establishment success.

Glenns Ferry I-84

The Glenns Ferry to King Hill project consisted of concrete pavement reconstruction and road improvements on 12 miles of the eastbound and westbound lanes of I-84 in Elmore County, ID. The representative sample area is located in the northeast section of Exit 125 westbound off-ramp. The site has a 9° slope (16 percent), a 162° (south) aspect, and an elevation of 2,650 ft. Seeding occurred within ROW limits including roadway foreslopes, back slopes, and embankments.

The Glenns Ferry site is within the Snake River Plain Ecoregion of Idaho (Figure 1). This low hill and plains area is arid with little surface water available during most of the year. Where irrigation water and soil depth are sufficient, crops are grown. Potential natural vegetation is sagebrush steppe but barren lava fields also occur.[11] Preexisting vegetation in the area consisted of crested wheatgrass, sheep fescue, Siberian wheatgrass (*Agropyron fragile*), kochia, Russian thistle, cheatgrass, tumble mustard, and prickly lettuce.

Slopes and seedbed were constructed and anchored by using a bulldozer to track the slopes. Compost was applied and tracked prior to application of seed. Hydroseeding was applied to all areas of the ROW from September to November 2003 using a 13 desired species seed mix applied at 42 lbs/acre (Table 14). Although no records were provided, evidence of broadleaf herbicide use was observed within 30 ft of the highway in 2012.

Table 14. Seed Mix Applied to the Glenns Ferry Site and the Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Secar	10.5	13
Sand Dropseed	*Sporobolus cryptandrus*	-	6.0	<1
Indian Ricegrass	*Achnatherum hymenoides*	Nezpar	5.0	0
Sandberg Bluegrass	*Poa secunda*	-	14.0	0
Common Wheat	*Triticum aestivum*	Pioneer	2.5	0
Forbs				
Alfalfa	*Medicago sativa*	Ranger	0.9	0
Scarlet Globemallow	*Sphaeralcea coccinea*	-	0.4	0
Showy Phlox	*Phlox speciosa*	-	0.4	0
Sulfur Flower Buckwheat	*Eriogonum umbellatum*	-	0.4	0
Western Yarrow	*Achillea millefolium*	-	0.4	0
Wild Lupine	*Lupinus perennis*	-	0.4	0
Shrubs				
Big Sagebrush	*Artemisia tridentata*	-	0.4	0
Rubber Rabbitbrush	*Ericameria nauseosa*	-	0.4	0

The Glenns Ferry site is species poor with only seven species present. Only 2 of 13 species (15 percent) planted established (Table 14). Bluebunch wheatgrass established and had nearly 13 percent cover. Bluebunch wheatgrass was present in rows from the bulldozer tracking but was not expanding from the rows. Sand dropseed was found only immediately adjacent to the road surface. Sand dropseed was seeded at a high rate (i.e. suggested seed rate of 1 – 3 lbs/acre when seeded alone) but still had poor establishment. In comparison, MDT uses sand dropseed regularly along roadsides with high degree of success. [12] Often it is the only species that establishes in the exposed coarse gravel base next to the edge of pavement. The poor establishment at the Glenns Ferry site may have been from competition with invasive plants.

Four-wing saltbush (*Atriplex canescens*), a non-seeded native shrub, was present at 3 percent cover (Figure 25). No other grasses, forbs, or shrubs were present on site except invasive species. Four species of invasive plants were present at a total of 57 percent cover including cheatgrass (50 percent), tumble mustard (4 percent), filaree (*Erodium cicutarium*; 3 percent), and a trace of Russian thistle. It is probably the dominance of invasive plants at the site that limited establishment of seeded species. Cheatgrass in particular is an aggressive plant that interferes with establishment of desired plants.

Glenns Ferry erosion condition class was “stable”. The site had indicators of erosion present such as soil movement, surface litter movement, flow patterns and slight pedestalling of plants. However, each of these factors was minor. Cover on the site was primarily vegetation or litter (Figure 26), both which contribute to stability. In addition, soils in the area are volcanic and well drained which limits erosion potential.

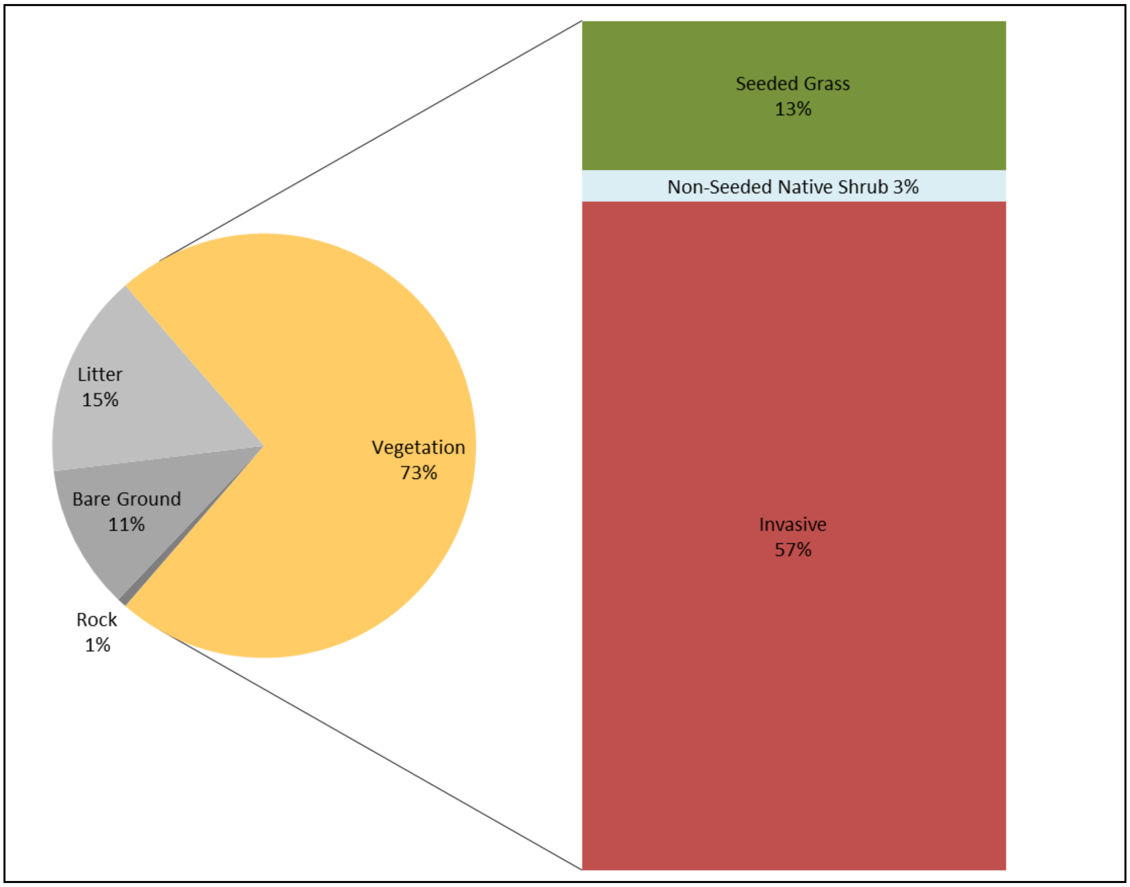

Figure 25. Mean Percent Cover by Functional Group at Glenns Ferry Site

Figure 26. Glenns Ferry Revegetation Site, July 2012

Glenns Ferry Site Summary and Recommendations

- Seeded bluebunch wheatgrass had good establishment on the coarse textured soils and south aspect.
- Other seeded grasses, forbs and shrubs had poor establishment.
- Cheatgrass had 50 percent canopy cover on the site and accounted for the majority of vegetation.
- Where cheatgrass is present, seed more aggressive desired species that have a similar phenology as cheatgrass such as sheep fescue, hard fescue, big bluegrass, and crested wheatgrass.
- Do not add a diverse forb mix to an area infested with aggressive invasive plants as herbicide treatments may be necessary to control invasives.
- While monitoring, it was observed that cheatgrass was prolific in mowed areas of the clear zone. Where mowing had not occurred, bluebunch wheatgrass and Indian ricegrass were well established.

Clark Canyon, MT - SH-324

Construction on Montana SH-324 near Clark Canyon Reservoir began in 2004 and was completed in 2007. The project area extends for 8.7 miles. A representative revegetation sampling area was located at MP 15.5 on a fill-slope with a slope of 17° (28 percent), 322° (northwest) aspect, and at an elevation of 5,780 ft.

The Clark Canyon site is in Beaverhead County, MT, within the Middle Rockies Ecoregion of Montana and Idaho (Figure 1). The ecoregion is characterized as having mountains with Douglas fir, subalpine fir

(*Abies lasiocarpa*), and Engelmann spruce forests. Foothills are partly wooded or shrub- and grass-covered, and inter-montane valleys are grass or shrub dominated. Vegetation surrounding the site is comprised of sagebrush grassland and irrigated agricultural fields.[11]

All drill seeded areas were conditioned immediately prior to seeding. The site was drill seeded to a depth of 0.25 to 0.5 inches between October 2006 and May 2007. The seed mix consisted of 6 native grasses and 1 native forb applied at 19 lbs/acre (Table 15). The site has a less than 3:1 slope and, following MDT guidelines, did not require compost or top-dressing to control erosion. The site did not appear to be treated for invasive plants with herbicides.

Table 15. Seed Mix Applied to Clark Canyon Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Secar	6	48
Green Needlegrass	*Nessella viridula*	Lodorm	2	<1
Prairie Junegrass	*Koeleria macrantha*	-	2	1
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	Sodar	3	<1
Western Wheatgrass	*Pascopyrum smithii*	Rosana	4	3
Slender Wheatgrass	*Elymus trachycaulus*	Pryor	1	0
Forbs				
Prairie Coneflower	*Ratibida columnifera*	-	1	<1

Of the seeded species 6 of the 7 species (86 percent) established at the Clark Canyon site (Table 16), and drilled seed rows were still evident. The seventh seeded species, slender wheatgrass, may have established as well but did not appear in the 50 random sample plots. Slender wheatgrass is a short-lived, early seral species that establishes quickly but only persists for approximately five years. Of seeded species, bluebunch wheatgrass was most dominant with 48 percent cover. This north-facing slope received well-timed spring rainfall following the previous fall dormant seeding which may have contributed to the establishment success. In addition to seeded species, 2 non-seeded exotic grasses (crested wheatgrass and smooth brome) were present (Figure 27). Crested wheatgrass cover was 3 percent. It may have been a legacy of previous roadside seeding or a contaminant in the seed mix used in 2004. Three species of invasive plants were present at <1 percent cover: cheatgrass, alyssum (*Alyssum* sp.), and tumble mustard.

The Clark Canyon site scored a slight erosion condition class. Signs of erosion included soil movement with deposits around obstacles and surface litter movement. While the site was well vegetated and had 23 percent litter cover, erosion was still present where there was bare ground (Figure 28).

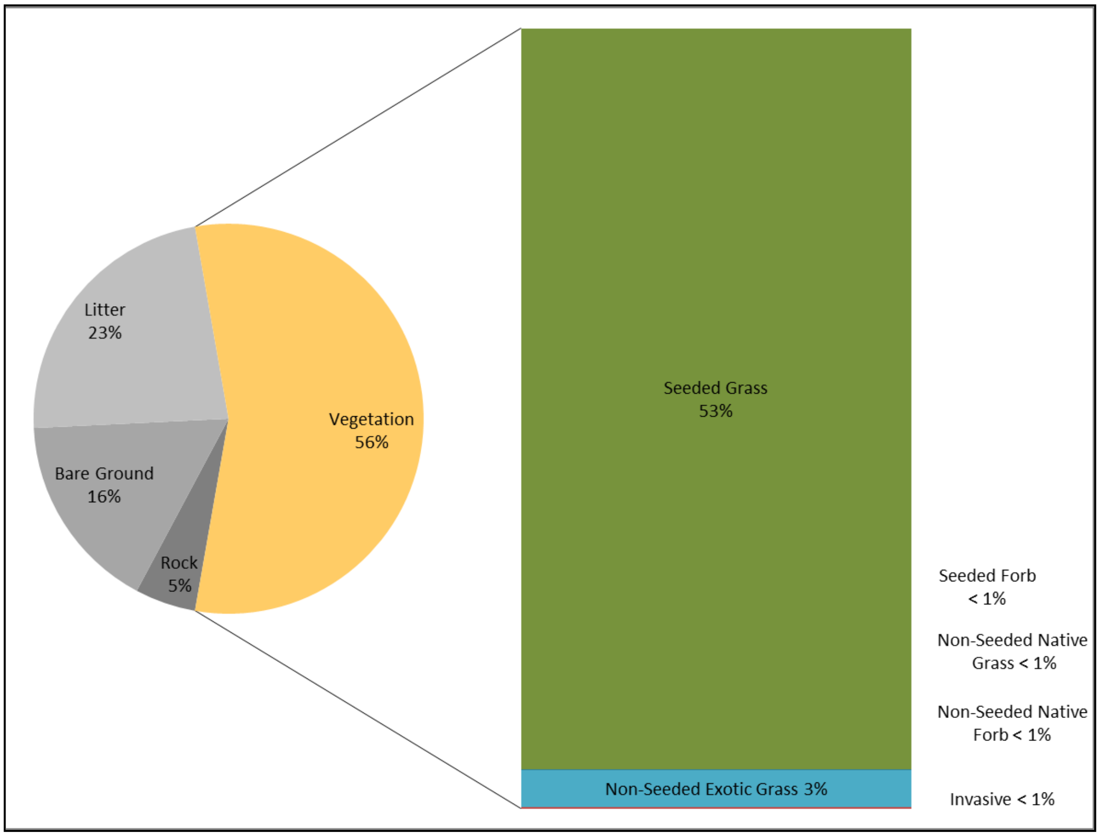

Figure 27. Mean Percent Cover by Functional Group at Clark Canyon Site

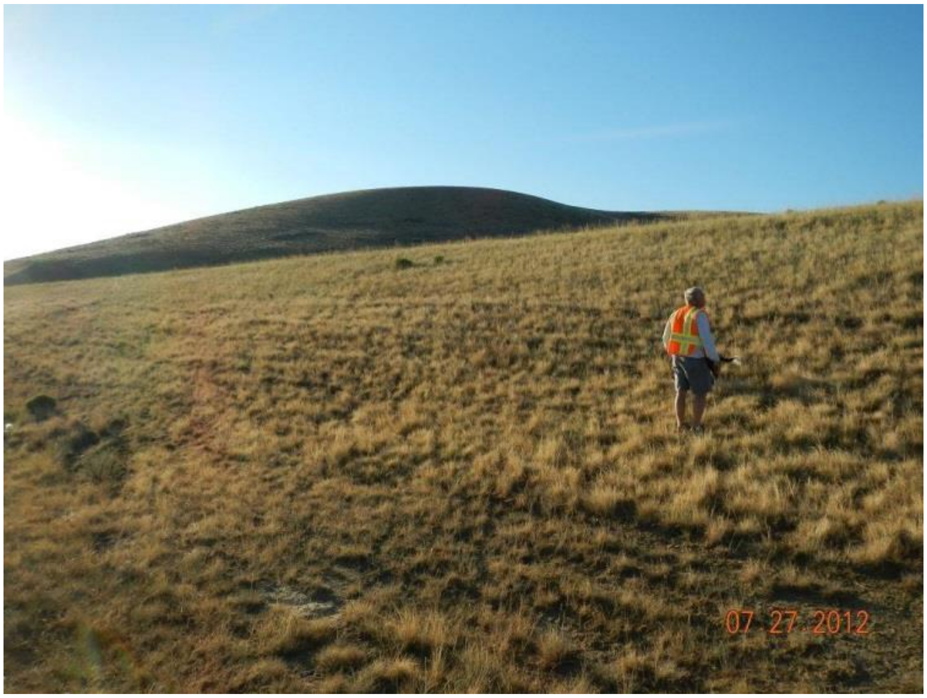

Figure 28. Clark Canyon Revegetation Site, July 2012

Clark Canyon Site Summary and Recommendations

- Bluebunch wheatgrass had excellent establishment while other seeded grasses were present in small amounts and contributed a low amount of cover.
- The seed mix with few species had a higher proportion of species establish.
- Drill seeding resulted in good plant establishment without the need for soil amendments.

City of Rocks, STC-2841

The project involves approximately 16.7 miles of reconstruction and realignment for the Elba-Almo Highway (STC-2841) in Cassia County, ID. The project constructed a 30 ft wide road and a roadside ditch on an old county road alignment. Project features included adding shoulders, improving sight distance, adding width, eliminating substandard horizontal curves, and improving existing vertical profile. Average annual temperature is 50° F and annual precipitation is 14 inches. The representative sample location is located 4 miles north of the intersection of STC-2841 with City of Rocks Road. This area is within Stage 1 of the construction which was completed in fall 2005. The sample site has an aspect of 318° (northwest), an 18° slope (33 percent), and a 5,390 ft elevation.

The City of Rocks site is within the Northern Basin and Range Ecoregion of Idaho (Figure 1). This ecoregion consists of dissected lava plains, rolling hills, valleys, and scattered mountains. Adjacent hill slopes support sagebrush fescue grasslands and juniper woodlands.[11] Crested wheatgrass has been planted on adjacent lands.

Seeding took place in fall 2005 following completion of construction. There was limited topsoil available; therefore, borrow soil was used on the slopes and areas to be revegetated. The seedbed was drill and broadcast seeded in the ROW. The 7 desired species seed mix was applied at 20 lbs/acre (Table 16).

Table 16. Seed Mix Applied to City of Rocks Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	-	8.8	7
Sandberg Bluegrass	*Poa secunda*	-	2.2	2
Streambank Wheatgrass	*Elymus lanceolatus ssp. psammophilus*	-	6.6	19
Forbs				
Alfalfa	*Medicago sativa*	Ladak	1.1	0
Purple Prairie Clover	*Dalea purpurea*	-	0.5	0
Western Yarrow	*Achillea millefolium*	-	0.5	0
Shrubs				
Basin Big Sagebrush	*Artemisia tridentata* ssp. *tridentata*	-	0.5	1

The City of Rocks site had a total richness of 12 species. All three of the seeded grasses and the seeded shrub established. None of the seeded forbs established (Table 16). Streambank wheatgrass and bluebunch wheatgrass had the greatest canopy cover. Together seeded grasses accounted for 28 percent cover (Figure 29).While Basin big sagebrush established; the slow growing species represented only 1 percent cover 8 years after seeding. Three non-seeded exotic grasses contributed a total of 9 percent of vegetative cover with crested wheatgrass being the primary non-seeded exotic grass with 8 percent cover. Crested wheatgrass was present within the ROW and on surrounding lands. It appears to have been extensively planted in the past and is persisting in the area. Four species of invasive plants were present with cheatgrass having 3 percent cover and the remaining species present in trace amounts.

Erosion condition classification scored “slight” due to soil and litter movement. The site had a combined cover of 49 percent for vegetation and litter which adds to site stability (Figure 30). The area naturally has low bare ground cover due to high cover of rock. While rock can provide armor for stabilizing slopes and reducing erosion, it can impede vegetation establishment.

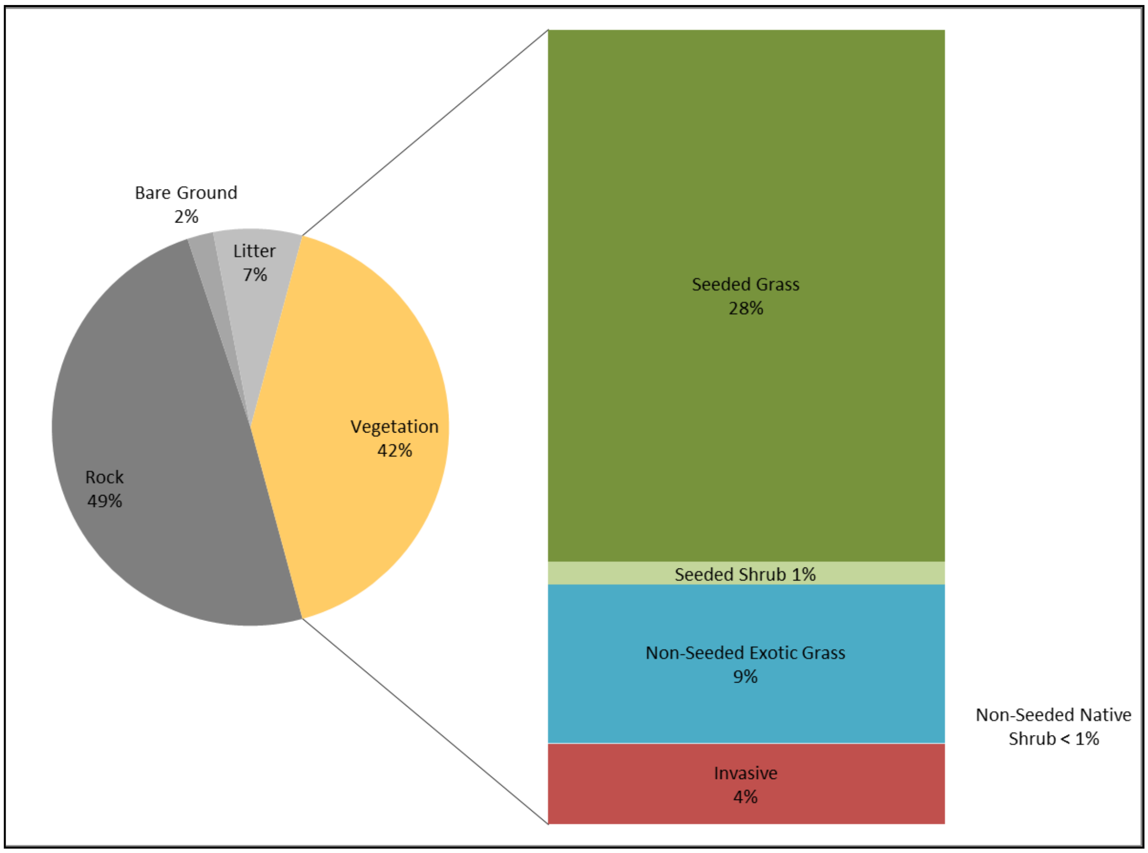

Figure 29. Mean Percent Cover by Functional Group at City of Rocks Site

Figure 30. City of Rocks Revegetation Site, June 2013

City of Rocks Site Summary and Recommendations

- Seeded grasses established well probably due to the drill seeding while forbs and shrubs did not establish.
- Seed mixes with fewer species tend to have a higher proportion of species establish.
- Rock can be beneficial at preventing erosion but may limit vegetation establishment.
- Adding mulch or another topical growth medium may have provided better microsites for plant establishment and growth to ameliorate rocky areas.

Albion SH-77

This project reconstructed approximately 4.13 miles of SH-77 from MP 18.88 to MP 23.01 in Cassia County, ID. The new 36 ft roadway consists of 2 twelve-foot lanes and 2 six-foot shoulders and an additional passing lane between MP 21.00 and MP 22.70. A representative revegetation area was sampled at MP 20.25. The site has a 228° (southwest) aspect, an elevation of 4,910 ft, and a 6° slope (10 percent).

The entire Albion reconstructed stretch is within the Northern Basin and Range Ecoregion (Figure 1). Local vegetation includes mountain big sagebrush, Indian ricegrass, snowberry, juniper, cheatgrass, and alfalfa.[11] The sample site is surrounded by irrigated farmlands, dry pasture, and sagebrush steppe habitat. Adjacent land uses are livestock grazing and farming practices.

This Albion site was seeded in spring 2006. ITD staff found the revegetation effort was not successful; however, no details were provided. The site was reseeded in fall 2006. Seed was applied using a drill seeder with rows spaced less than six inches apart. An 8 species seed mix containing native and exotic species was applied at 30 lbs/acre (Table 17). Composted and certified noxious weed free manure was applied prior to seedbed preparation at a rate of 3,290 - 3,861 ft^3/acre (0.5 to 1 in. deep if evenly applied). Livestock manure was homogeneous in color (dark loam), earthy smelling (not odiferous), and contained no visible straw, or trash. These specifications indicate the material was completely decomposed as evidenced by total breakdown of raw ingredients and lack of odor or heat generation. No commercial fertilizer was required on the project.

Table 17. Seed Mix Applied to Albion Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Secar	7.1	14
Sandberg Bluegrass	*Poa secunda*	-	8.9	<1
Sheep Fescue	*Festuca ovina*	-	6.2	10
Siberian Wheatgrass	*Agropyron fragile*	-	5.4	<1
Forbs				
Alfalfa	*Medicago sativa*	Ranger	0.9	0
Silky Lupine	*Lupinus sericeus*	-	0.4	0
Western Yarrow	*Achillea millefolium*	-	0.4	0
Shrubs				
Basin Big Sagebrush	*Artemisia tridentata* ssp. *tridentata*	-	0.4	0

Only 4 of the 8 species seeded established (50 percent). The Albion site had a total richness of 14 species. Of these, all 4 seeded grasses combined for 25 percent vegetative cover (Figure 31). The 2 species of seeded grass with the greatest amount of cover were bluebunch wheatgrass and sheep fescue (Table 17). Drill rows were still obvious and many plants had not expanded from the rows (Figure 32). One species of non-seeded native grass, Idaho fescue, and the non-seeded exotic grass, crested wheatgrass, were present. Crested wheatgrass had 19 percent cover and was present in drill seed rows. It was possibly a substituted species in the mix or a seed contaminant since it does not appear adjacent to the road in the project area. No seeded forbs were present and 2 species of non-seeded forbs had a combined cover of <1 percent. Present at the site were 6 species of invasive plants with only 1 species with a cover greater than 1 percent (cheatgrass, 3 percent cover). Field bindweed, an Idaho noxious weed, had <1 percent cover.

Erosion condition classification scored “stable”. Only minor signs of soil and litter movement were present. Ground stability can be attributed to litter and vegetation cover on the site (Figure 32). In addition, the site has a relatively low slope angle.

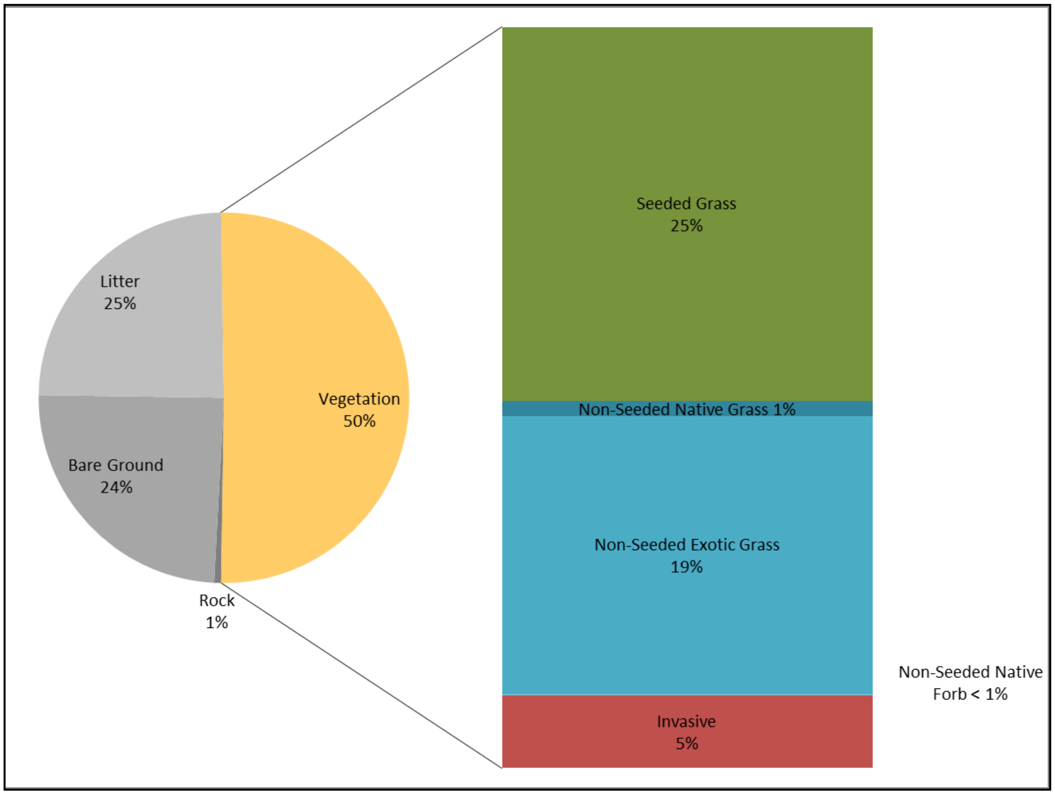

Figure 31. Mean Percent Cover by Functional Group at Albion Site

Figure 32. Albion Revegetation Site, June 2013

Albion Site Summary and Recommendations

- Seeded grasses established well while forbs and shrubs did not.
- Vegetation and litter cover contributed to soil stability.
- Drill seeding resulted in relatively high desired species cover.
- Consider seeding rhizomatous species or species that can be broadcast seeded simultaneously with grasses that are drilled to eliminate persistent drill row appearance of seeding projects.

Silver Creek Bridge US-20

The Silver Creek Bridge at MP 187.15 underwent maintenance to both east and west approaches in 2009. Approaches were replaced in their entirety, shoulders widened, and culverts replaced. Construction to widen the roadway was accomplished by removing existing shoulder material from the pavement's edge to a depth of 1.6 ft. This material was used with imported granular fill material to build the embankment and slopes (max 3:1) along both sides of the roadway. A representative revegetation area was sampled at MP 187.6 on US-20 to the east of Silver Creek Bridge. The site was primarily a toe slope along the reconstructed road prism (Figure 34). The site has a 166° (south) aspect, 14° slope (25 percent), and at elevation of 4,850 ft.

The Silver Creek site is within the Snake River Plain Ecoregion in Blaine County, ID (Figure 1). The area is characterized as unglaciated, irregular plains where rangeland is widespread. Natural vegetation is sagebrush steppe and bunchgrass grasslands.[11] The revegetation site is adjacent to Silver Creek and has areas of mesic or riparian influence. Streams in this ecoregion are relatively low gradient. The site was drill seeded with 4 desired grass species at a rate of 22 lbs/acre (Table 18). Composted manure was used for mulch. It is unknown if it was certified weed free compost.

Table 18. Seed Mixture Applied to Silver Creek Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	-	8	19
Canada Bluegrass	*Poa compressa*	-	3	<1
Hard Fescue	*Festuca brevipila*	Durar	7	5
Sandberg Bluegrass	*Poa secunda*	-	4	0

Established were 3 of the 4 species seeded (75 percent). The Silver Creek site had low species richness with a total of 8 species, 4 of which were invasive plants. Seeded grasses made up of 3 species and 1 was a non-seeded exotic grass (Table 18). There were no desired forbs or shrubs in the sample area (Figure 35). The dominant seeded grasses that established were bluebunch wheatgrass and hard fescue. The bluegrass species had low percent cover. An alternative bluegrass species to consider seeding is Canby bluegrass (*Poa canbyi*) which MDT has had consistent good results establishing.[12] Crested wheatgrass was the exotic grass at the site with 3 percent cover. This species may be present from past roadside revegetation or it may have been a seed contaminant. Of the invasive species 2 species had a canopy cover over 1 percent including cheatgrass (4 percent cover) and kochia (2 percent cover). No noxious weeds were present.

Erosion condition classification scored “stable”. Only minor evidence was found of soil and litter movement. The site is stable due to cover of vegetation and litter, and rock armoring (Figure 33).

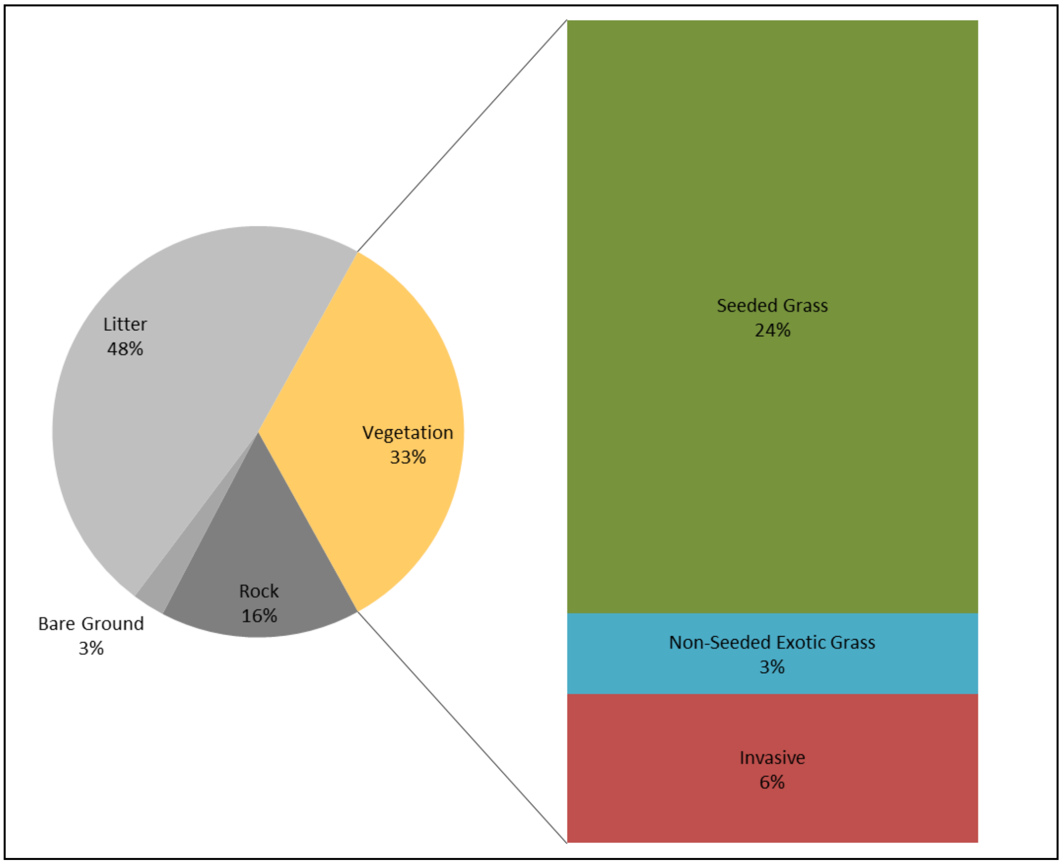

Figure 33. Mean Percent Cover by Functional Group at Silver Creek Site

Figure 34. Silver Creek Revegetation Site, June 2013

Silver Creek Site Summary and Recommendations

- Two of the four seeded grasses established with >1 percent cover.
- Seeding at 22 lbs/acre appears to be an adequate rate for establishing grasses for this ecoregion.
- Simple seed mixes have a higher proportion of species establish.

Tom Cat Hill US-93

The project involved reconstructing or realigning 8.8 miles of US-93 between MP 224.16 and MP 233.00. Construction was intended to improve smoothness of the riding surface while prolonging pavement life, smoothing joints, and eliminating segregation, roller marks, and screed indentation. In rock cuts, the final grading within 80 ft from the permanent fog line was to have a finished slope nominally equal to the typical sections. All areas disturbed were seeded in 2006. A representative revegetation area was sampled at MP 225.0 on US-93. Elevation at the site is 5,940 feet and average precipitation is 15 – 20 inches per year. The site has a 292° (northwest) aspect and a 1° slope (3 percent).

The Tom Cat Hill site is within rolling terrain and lava flows of the Snake River Plain ecoregion in Butte County, ID (Figure 1). The site is approximately 16 miles southwest of Arco, ID, and adjacent to Craters of the Moon National Monument. The area consists of exposed basalt or very shallow loessial soils over volcanics.(11) Rugged terrain is generally either barren or sparsely covered by xeric shrubs and grasses. Surrounding vegetation includes basin sagebrush, rubber rabbitbrush, bottlebrush squirreltail, and Indian ricegrass. Surface water availability is limited.

The revegetation sample area was located within seed mix Zone 2. This included areas greater than 20 ft from the pavement edge. Topsoil was available and used on slopes and areas to be seeded. In preparation for seeding, rocks larger than 1 ft in diameter were removed or fully embedded at least 0.25 ft or more below the soil surface. A native seed mix with 5 grasses, 3 forbs, and 2 shrubs was applied at 24 lbs/acre (Table 19). Grasses were seeded during the "normal" seeding season but it is unknown if they were broadcast or drill applied on the relatively flat areas. Forb and shrub seed was broadcast during winter.

Table 19. Seed Mixture Applied to Tom Cat Hill Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	Anatone	4.9	21
Bottlebrush Squirreltail	*Elymus elymoides*	Fish Creek	3.1	<1
Sandberg Bluegrass	*Poa secunda*	-	0.9	6
Indian Ricegrass	*Achnatherum hymenoides*	Nezpar	4.9	0
Needle and Thread	*Hesperostipa comata*	-	4.0	0
Forbs				
Sulfur Flower Buckwheat	*Eriogonum umbellatum*	-	2.2	5
Dusty-maiden	*Chaenactis douglasii*	-	0.4	0
Scorpionweed	*Phacelia hastata*	-	0.4	0
Shrubs				
Antelope Bitterbrush	*Purshia tridentata*	-	3.1	0
Rubber Rabbitbrush	*Ericameria nauseosa*	-	0.4	0

Only 4 of 10 seeded species (40 percent) established on the site (Table 19). The most dominant seeded grasses were bluebunch wheatgrass and Sandberg bluegrass, which together accounted for nearly the entire cover of seeded grasses (Table 19 and Figure 35). While no seeded shrubs established, the non-seeded native shrub mountain big sagebrush was present at <1 percent cover. Sulfur flower buckwheat established from seed and had 5 percent of overall vegetation cover (Figure 35). Two other seeded forbs did not establish, however, they were present in the vicinity. This indicates that they are suited to site conditions but may not have had high seed viability. Cheatgrass and kochia, 2 invasive species had a combined cover of 1 percent.

Erosion condition classification scored "stable". The site is mostly rock with little soil cover. In addition, the site had 42 percent combined cover of litter and vegetation. These cover conditions combined with low slope angle create a condition of low erosion potential (Figure 36).

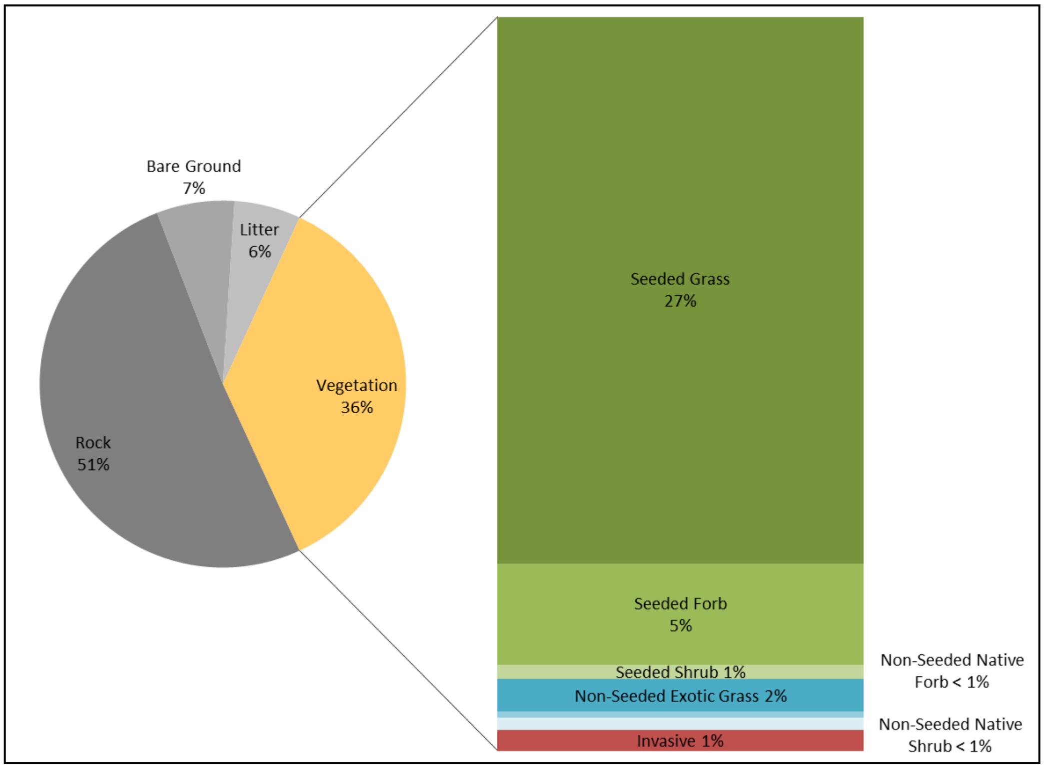

Figure 35. Mean Percent Cover by Functional Group at Tom Cat Hill Site

Figure 36. Tom Cat Hill Revegetation Site, June 2013

Tom Cat Hill Site Summary and Recommendations

- Bluebunch wheatgrass, Sandberg bluegrass, and sulfur flower buckwheat established well.
- Other seeded species had poor establishment.
- Natural recruitment on site was low. Most of the species present were seeded indicating establishing species from seed in the Snake River Plain where there are lava flows and basalt is possible.

Willow Creek Summit US-93

The Willow Creek Summit roadside revegetation project's monitoring area is located on US-93 at MP 139.3. The site had a 224° (southwest) aspect, a 17° slope (31 percent), and a 6,870 ft elevation. It is located within the Middle Rockies Ecoregion in Custer County, ID (Figure 1). The surrounding area is partly wooded at higher elevations while shrub and grass dominate the foothills and valleys. This mountainous area is arid and rugged.

In preparation for seeding, the site was bulldozer tracked to improve soil texture for improved seed and water holding capacity in microsites. The Willow Creek Summit site was drill and hydroseeded in spring 2006. The Challis Bureau of Land Management provided a recommended seed mix which contained native and exotic grasses. The following seed mix and rates were applied at the respective rates (Table 20). Crews then hand broadcast seeded Wyoming big sagebrush on the slopes in October 2006. Other forbs and shrubs may have been broadcast seeded at this time; however, the species and rates are unknown. Following seeding, a hydostraw mulch, tackifier, and liquid fertilizer were applied in fall 2006.

Table 20. Seed Mixture Applied to Willow Creek Summit Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	-	8.0	15
Canada Bluegrass	*Poa compressa*	-	unknown	<1
Sandberg Bluegrass	*Poa secunda*	-	unknown	<1
Wyoming Big Sagebrush	*Artemisia tridentate ssp. Wyomingensis*	-	0.1	2
Basin Wildrye	*Leymus cinereus*	Tailhead	1	0
Crested Wheatgrass	*Agropyron cristatum*	-	1.0	0
Hard Fescue	*Festuca brevipila*	-	unknown	0
Mountain Brome	*Bromus marginatus*	-	unknown	0
Sand Dropseed	*Spoirobolus cryptandrus*	-	0.1	0

The Willow Creek Summit site had relatively high richness with a total of 17 species. Given that 8 grasses were seeded and 3 seeded grasses established, the high richness indicates non-seeded plants are also colonizing the site. Richness of non-seeded functional groups included 1 non-seeded native grass, 1 exotic grass, 6 native forbs, 2 native shrubs, and 3 invasive species. The seeded grass, bluebunch wheatgrass, contributed the majority of seeded grass cover (Table 20) and approximately 50 percent of vegetative cover (Figure 37). Of the 6 non-seeded native forbs, only showy phlox and milkvetch

(*Astragalus* sp.) had a canopy cover over 1 percent. These two species accounted for the majority of the cover in that functional group (Figure 37). Other native forbs were present at trace amounts. Green rabbitbrush and big sagebrush had 1 percent and 2 percent cover, respectively. Cheatgrass was an invasive species present with 8 percent cover. The other two invasive species had trace cover (Figure 37). No noxious weeds were present.

Erosion condition classification indicated a "slight" degree of erosion at the Willow Creek Summit site. Indicators of erosion included soil movement with recent deposits around obstacles, litter that has been translocated, and formation of one inch deep rills. One third of the site was bare ground (Figure 38). It was also observed that vegetation established in cleated bulldozer tracks on the slope but had not spread from the rows (Figure 38). It is possible that these sites provided an area for seed and water to collect and supported plant growth. The lack of vegetation establishment outside the tracks adds to erosion potential.

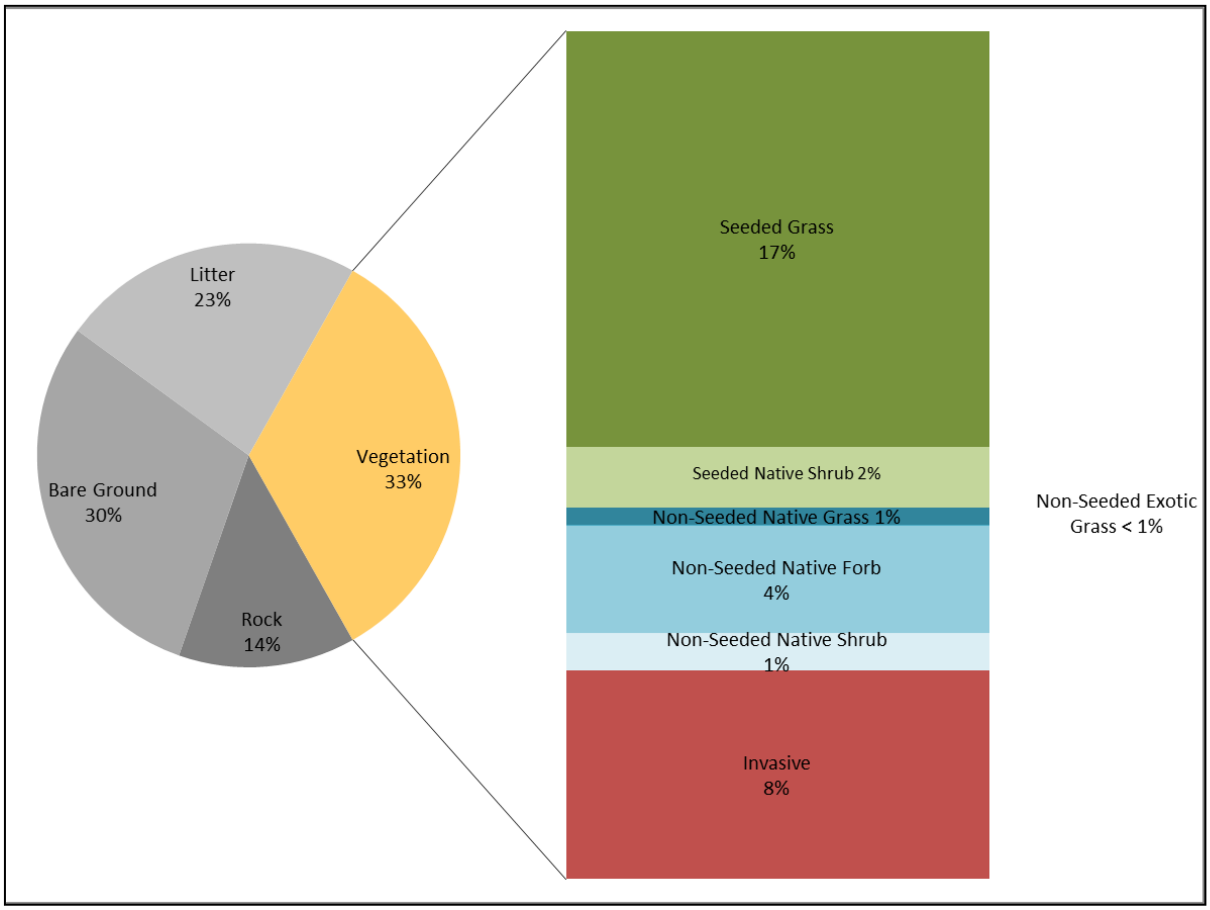

Figure 37. Mean Percent Cover by Functional Group at Willow Creek Summit Site

Figure 38. Willow Creek Summit Revegetation Site, June 2013

Willow Creek Summit Site Summary and Recommendations

- Bluebunch wheatgrass established well while other seeded species did not.
- Retaining records of final revegetation implementation techniques is important for determining success and improvement. Create a simple form that project managers can complete after revegetation to capture any changes to initial protocols.
- Cleated bulldozer tracks create soil surface complexity to assist in establishment of vegetation by providing a place for seed and water to collect.
- To increase vegetation cover and site stability, consider hydroseeding grasses on the slope between bulldozer tracks. The use of a tackifier may help seeds adhere to soil to establish in the spaces.

Wildlife Crossing SH-21

This project consisted of constructing a wildlife underpass and 6,600 linear feet of wildlife exclusion fence to guide wildlife to the crossing structure at MP 18.22 on SH-21 in Ada County, Idaho. On site evaluation of wildlife monitoring data with areas of above average WVCs allowed engineers, biologists, and planners to identify an important wildlife linkage area. The underpass location lies at the confluence of two major drainages: Mores Creek and the Boise River at Lucky Peak Reservoir. The location also lies at the base of a long mountain ridge line utilized by deer and elk as a migration corridor between summer and winter ranges. Project features included constructing a new bridge suitable for a wildlife underpass, adding shoulders, decommissioning the old roadway and bridge, and maintaining migration corridor and overall habitat integrity. Safety improvements included increasing public safety by reducing WVCs and reducing wildlife mortality.

The soils at the Wildlife Crossing SH-21 site are well drained to excessively drained with high and rapid permeability. Erosion is a concern in areas of sparse vegetation. Annual precipitation averages 12 – 16 inches in the valleys and 14 - 26 inches on north and east facing slopes. Average annual temperature is 45 - 52° F. Approximately 3.5 acres was seeded on foreslopes, back slopes, embankments, and obliterated roadway. The revegetation slope sampled as part of the study was a 350° (north) aspect, 23° slope (37 percent), and 3,240 ft elevation.

The Wildlife Crossing site is in the Idaho Batholith Ecoregion of Idaho (Figure 1). The sample area is near the valley bottom in the semi-arid sagebrush-steppe and grassland plant communities. The sage-conifer interface occurs on higher elevation slopes above the sample site. Native adjacent vegetation consists of the big, Wyoming, and silver (*Artemisia cana*) sagebrush subspecies, bitterbrush, bluebunch wheatgrass, Idaho fescue, and arrowleaf balsamroot. Exotic or invasive species in the area include cheatgrass, mustard species, and medusahead (*Taeniatherum canput-medusae*)*.* Major land use is winter range habitat of the Boise River Wildlife Management Area and Lucky Peak State Recreation Area.

The site was seeded to stabilize disturbed soils on cut and fill slopes, shoulders, swales, ditches, source sites, and staging areas. The Wildlife Crossing site was originally seeded in fall 2010 but had low initial establishment for unknown reasons. Therefore, ITD reseeded in fall 2011. Prior to seeding, topsoil was replaced on slopes and the seedbed was prepared by bulldozer tracking. The 10 species desired seed mix was either hydroseeded or drill seeded at 65 lbs/acre (Table 21). The site that was sampled was drill seeded. Seeding was used in conjunction with other temporary and permanent erosion and sediment controls including designed swales, straw wattles, ditches, terraces, and benches. A vehicle-caused wildfire burned the Wildlife Crossing site on the northeast side of the road on July 22, 2012. Some seeded areas were affected but not the area that was sampled.

Table 21. Seed Mixture Applied to Wildlife Crossing Site and Resulting Mean Canopy Cover

Common Name	Scientific Name	Cultivar	Rate (lbs/acre)	Mean Canopy Cover (%)
Grasses				
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	-	10	<1
Sandberg Bluegrass	*Poa secunda*	-	6	<1
Sheep Fescue	*Festuca ovina*	-	6	2
Siberian Wheatgrass	*Agropyron fragile*	-	5	<1
Needle and Thread	*Hesperostipa comata*	-	8	0
Forbs				
Alfalfa	*Medicago sativa*	Ranger	3	17
Arrowleaf Balsamroot	*Balsamorhiza sagittata*	-	10	<1
Palmer’s Penstemon	*Penstemon palmeri*	-	7	0
Silky Lupine	*Lupinus sericeus*	-	5	0
Shrub				
Antelope Bitterbrush	*Purshia tridentata*	-	5	0

Of the seeded species, 60 percent established (Table 21). Sheep fescue, bluebunch wheatgrass, and alfalfa were seeded species with the highest percent of cover. The Wildlife Crossing site was seeded two years prior to sampling and many of the plants were seedlings at the time of sampling. It is likely that overall vegetation cover and cover by functional group will increase over time, especially for slow growing species like arrowleaf balsamroot. Crested wheatgrass, a non-seeded exotic grass, had 14 percent cover (Figure 39). Widespread establishment of crested wheatgrass may indicate it was present on site prior to recent construction or it may have been a contaminant in the seed mix. Naturally colonizing the site are 2 species of non-seeded native shrubs (rubber rabbitbrush and big sagebrush). These species are present in adjacent lands and prefer rocky, bare soil for establishment. Their cover should increase in the future.

While the 3 species in the invasive species functional group had a low total cover (2 percent; Figure 39), the species that were present are aggressive and have the potential for spreading into recently disturbed lands. Cheatgrass (2 percent cover) and medusahead (<1 percent cover) are annual exotic grasses adapted to disturbed sites. They are opportunistic grasses able to crowd-out native plants because of prolific seed production and the ability to germinate in fall or early spring giving them a competitive advantage over native perennials. Rush skeletonweed is an Idaho noxious weed with low percent cover (<1 percent) on the site. However, mature plants are present surrounding the revegetation site and wind-carried seed have the potential of establishing on the recently disturbed site. These species should be monitored and controlled with spot applications of herbicide (for annual grasses) or hand pulling and mowing (for rush skeletonweed) to prevent negative impacts to desired seeded species.

Erosion condition classification scored “moderate”. There were multiple indicators of soil erosion including soil movement with recent deposits around obstacles, surface litter translocation, and soil removal around rock fragments. The presence of rills and gullies were of most concern. Rills were present in the revegetation area occurring in intervals >10 ft apart. One main gully was present which had active signs of erosion in its bed and walls. This site had over 50 percent bare ground 2 years after seeding (Figure 40). Actions to decrease percent bare ground taken during initial or follow-up revegetation activities could help stabilize the site. For example, including an early establishing, high density species such as slender wheatgrass in the seed mix can provide vegetative cover and soil stability for approximately five years.

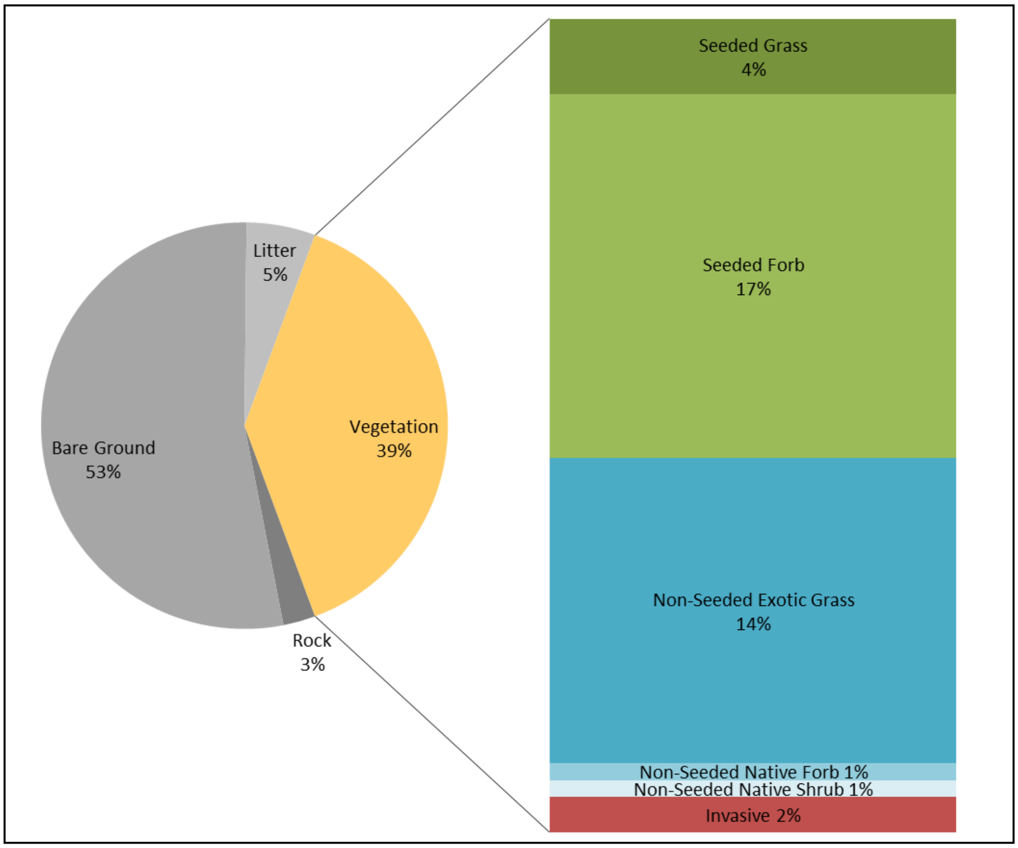

Figure 39. Mean Percent Cover by Functional Group at Wildlife Crossing Site

Figure 40. Wildlife Crossing Revegetation Site with Straw Wattles, June 2013

Wildlife Crossing Site Summary and Recommendations

- Two years after seeding, 60 percent of species seeded were present on site and have the potential to grow and increase in cover.
- Consider including a fast colonizing species such as slender wheatgrass in the seed mix to provide site stability immediately following revegetation.
- Monitor and manage invasive species in order to increase cover of desired plants.

Discussion and Conclusions

This section of the report reviewed the 16 ITD revegetation sites throughout Idaho and 1 in southwestern Montana. In Idaho 3 of the locations were established as research sites by ITD and UI and all were evaluated in the third to fifth growing seasons after construction for this study.[9] The other 13 sites were opportunistically monitored and all were evaluated within 3 to 9 years after construction. The Montana site was measured 6 years after construction and is in a Level III ecoregion that extends in to Idaho. Average time for monitoring revegetation success post-construction for all 17 sites is 5.25 years. We assume that after 3 to 5 years the species that are going to establish as a result of the revegetation effort should be present.

Results derived from the 17 sites give ITD managers a wide variety of examples of the successes and failures of roadside revegetation across the state. Revegetation sites in the 6 main ecoregions of Idaho were included in this study. The results provide specific information regarding species that are successful or unsuccessful at establishing, seed mix performance, invasive species of concern, and useful revegetation techniques. Environmental specialists at ITD can use lessons learned from these sites to develop post-construction revegetation plans for future projects along the same roadways, in similar environments, or in other areas of the Level III ecosystems where these projects were located.

Seeding

A total of 61 species were seeded to the sites including 27 grasses, 23 forbs, and 11 shrub species (Table 22). It is important to synthesize what species established and in what ecoregions so they can be strategically selected and applied to future revegetation projects in the ecoregions. Table 22 summarizes species that were seeded, number of sites where they were seeded, number of sites where they established, average canopy cover on sites where they established, and aspects they established. It is important to consider not only average canopy cover of each species, but also the proportion of sites where it successfully established. For example, silky lupine only established on 1 of the 10 sites (10 percent) where it was seeded, and had an average canopy cover of 13 percent at that one site. Therefore, this species has a low likelihood of establishing but, when it does establish, has a relatively high percent cover. Similarly, a species can have a high success rate but a low percent cover. For example, western wheatgrass had a 100 percent success rate for establishing on both sites where it was seeded but has a low average of canopy cover of 2 percent on these sites. Another consideration when reviewing the data is that some short lived perennials species (e.g. slender wheatgrass) establish quickly to stabilize a site but disappear from a site within several years. These species may be present five years after seeding but they are not expected to have a high canopy cover.

Species Success by Physiognomy

Of the seeded grass species, 21 of 27 established on the sites, (78 percent success rate; Table 22). On sites where they established, 11 grass species had a canopy cover >1 percent 5 years after seeding. Grass species with the highest canopy covers were streambank wheatgrass (13 percent), bluebunch wheatgrass (12 percent), crested wheatgrass (11 percent), Idaho fescue (10 percent), and Canada bluegrass (8 percent; Table 22). Bluebunch wheatgrass was the best performing grass because it had a high success rate and high canopy cover. Bluebunch wheatgrass established on 92 percent of sites where it was seeded and had an average cover of 12 percent per site. Idaho fescue was also a top performer and established on 71 percent of sites where it was seeded with a resulting average canopy cover of 10 percent. Grass species that consistently establish on all sites where they are seeded but have a low canopy cover include sheep fescue (5 percent), western wheatgrass (2 percent), and basin wildrye (2 percent; Table 22).

Established in the sites were 10 of 23 seeded forb species (43 percent) and 4 of 11 seeded shrubs species (36 percent; Table 22). Only 4 of the established forb species had canopy covers over 1 percent. These were alfalfa (17 percent), silky lupine (13 percent), western yarrow (7 percent), and sulfur flower buckwheat (5 percent). Forb species had a low establishment success rate. While alfalfa and silky lupine had high percent covers, they only established at 25 percent and 10 percent of sites where they were seeded, respectively (Table 22). No forb species had over 1 percent cover and greater than 50 percent success rate. Mountain big sagebrush was the only seeded shrub species with canopy cover greater than 1 percent. Many of the revegetation sites were sprayed with broadleaf herbicides to control weed species. The application of herbicides may have impacted seeded forb and shrub species establishment and persistence. Overall, forb and shrub species had limited success of establishing.

The aspect that seeded species established is included in Table 22. Some species establish better on a north aspect than a south aspect, and vice versa. However, this data should be interpreted with caution because the same species may be planted in ecoregions with different climatic conditions. In these cases, it would be unknown if it is a suitable climate or suitable aspect, or both, that lead to the species success rate.

Species Success by Level III Ecoregion

Ecoregions are useful for structuring revegetation strategies because they account for climate, topography and soil variability throughout Idaho.[6] Some species were seeded and established in more than one ecoregion (Table 23). Only 17 of 21 grass species (85 percent) established in each of the ecoregions where they were seeded. This indicates the species selected for seed mixes were well matched to soil and climatic conditions of the sites. Half of the 10 forb species (50 percent) and 2 of the 4 shrub species (50 percent) established in each of the ecoregions where they were seeded. Species that established in at least 4 ecoregions included bluebunch wheatgrass, Canada bluegrass, Sandberg bluegrass, and slender wheatgrass (Table 23). These species are able to tolerate a variety of climatic and growing conditions which may increase their overall survival and success. Additional species worth noting for their establishment success and diversity of ecoregions where they grew include hard, Idaho, and sheep fescues, mountain brome, thickspike wheatgrass, and western yarrow.

Seed Mix Success

The seed mixes developed by ITD and UI had a range of 4 to 15 species per mix (Table 24). Monitoring of revegetation sites found mixes with fewer species seeded generally had a higher proportion of species establish. Seed mixes with the highest proportion of species establish had 9, 7, or 4 species seeded (Table 24). The proportions that establish are related to a variety of issues including selecting appropriate species for the site, species that will not compete with each other, and tolerance of invasive species at the site. The proportion of species established was variable but the trend was seed mixes of 10 or less species resulted in ≥50 percent of species establishing while seeding 10 or more species resulted in ≤50 percent of species establishing.

Erosion Condition

Indicators of erosion were assessed at each site to determine site stability resulting from revegetation practices. Erosion condition classification scores were “stable” for 10 sites, “slight” for 6 sites, and “moderate” for 1 site. Erosion is a natural process that cannot be stopped completely. Sites that scored “stable”or “slight” had minor indicators of erosion including litter and soil movement. The ability of the revegetation practices to control erosion following site construction is a testament to the practicality and effectiveness of seeding and slope stabilization techniques (e.g. compost, erosion blankets, soil texturing) applied at the sites. Only the Wildlife Crossing site had a “moderate” rating for erosion. This site has highly erosive soils and was revegetated only 3 years before monitoring. The Wildlife Crossing site should continue to be annually monitored for indicators of erosion. If erosion conditions do not improve, then additional slope stabilization techniques should be implemented to hold soils while vegetation establishes.

Table 22. Species Seeded on Research Sites and Resulting Mean Canopy Cover

Common Name	Scientific Name	Number of Sites Seeded	Number of Sites Established	Establishment Success Rate (%)	Average % Canopy Cover[1]		
					All Sites	North Aspect	South Aspect
Grass							
Basin Wildrye	*Leymus cinereus*	3	3	100	2	3	2
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	13	12	92	12	14	9
Blue Wildrye	*Elymus glaucus*	1	0	0	0	<1	-
Bottlebrush Squirreltail	*Elymus elymoides*	2	2	100	<1	<1	-
Canada Bluegrass	*Poa compressa*	7	6	86	8	2	13
Crested Wheatgrass	*Agropyron cristatum*	2	1	50	11	21	0
Green Needlegrass	*Nessella viridula*	1	1	100	<1	<1	-
Hard Fescue	*Festuca brevipila*	4	3	75	4	<1	4
Idaho Fescue	*Festuca idahoensis*	7	5	71	10	10	<1
Indian Ricegrass	*Achnatherum hymenoides*	4	1	25	<1	<1	<1
Intermediate Wheatgrass	*Thinopyrum intermedium*	1	0	0	0	-	0
Letterman's Needlegrass	*Achnatherum lettermanii*	2	1	50	<1	<1	-
Mountain Brome	*Bromus marginatus*	6	3	50	2	<1	5
Needle and Thread	*Hesperostipa comata*	2	0	0	0	0	-
Perennial Ryegrass	*Lolium perenne*	1	0	0	0	-	0
Prairie Junegrass	*Koeleria macrantha*	2	2	100	<1	1	<1
Red Fescue	*Festuca rubra*	2	0	0	0	0	0
Sandberg Bluegrass	*Poa secunda*	10	7	70	2	2	<1
Sand Dropseed	*Sporobolus cryptandrus*	1	1	100	<1	-	<1
Sheep Fescue	*Festuca ovina*	4	4	100	5	5	5
Siberian Wheatgrass	*Agropyron fragile*	2	2	100	<1	<1	<1
Slender Wheatgrass	*Elymus trachycaulus*	4	2	50	1	<1	2
Smooth Brome	*Bromus inermis*	1	0	0	0	-	0
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	4	3	75	13	<1	13
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	3	3	100	<1	1	<1
Upland Bluegrass	*Poa glaucantha*	1	1	100	<1	-	<1
Western Wheatgrass	*Pascopyrum smithii*	2	2	100	2	2	-
Forb							
Alfalfa	*Medicago sativa*	4	1	25	17	17	0
Arrowleaf Balsamroot	*Balsamorhiza sagittata*	3	2	66	<1	<1	-
Bird's Foot Trefoil	*Lotus corniculatus*	2	0	0	0	0	0
Dusty Maiden	*Chaenactis douglasii*	1	0	0	0	0	-
Fernleaf Biscuitroot	*Lomatium dissectum*	4	1	25	<1	<1	0
Goldenrod	*Solidago canadensis*	1	1	100	<1	-	<1

Common Name	Scientific Name	Number of Sites Seeded	Number of Sites Established	Establishment Success Rate (%)	Average % Canopy Cover[1]		
					All Sites	North Aspect	South Aspect
Lewis Flax	*Linum lewisii*	2	0	0	0	0	0
Montana Golden Pea	*Thermopsis montana*	1	0	0	0	-	0
Palmer's Penstemon	*Penstemon palmeri*	1	0	0	0	0	-
Pearly Everlasting	*Anaphalis margaritacea*	1	0	0	0	0	-
Prairie Coneflower	*Ratabida columnifera*	1	1	100	<1	<1	0
Purple Prairie Clover	*Dalea purpurea*	1	0	0	0	0	-
Rocky Mtn Penstemon	*Penstemon strictus*	3	0	0	0	0	0
Scarlet Globemallow	*Sphaeralcea coccinea*	1	0	0	0	-	0
Scorpionweed	*Phacelia hastata*	1	0	0	0	0	-
Showy Phlox	*Phlox speciosa*	1	0	0	0	-	0
Silky Lupine	*Lupinus sericeus*	10	1	10	13	13	0
Sulfur Flower Buckwheat	*Eriogonum umbellatum*	2	1	50	5	5	0
Sweetvetch	*Hedysarum boreale*	1	0	0	0	0	-
Venus Penstemon	*Penstemon venustus*	1	1	100	<1	0	<1
Western Yarrow	*Achillea millefolium*	7	3	43	7	21	<1
White Dutch Clover	*Trifolium repens*	2	1	50	<1	0	<1
Wild Lupine	*Lupinus perennis*	1	0	0	0	-	0
Shrub							
Antelope Bitterbrush	*Purshia tridentata*	5	0	0	0	0	0
Basin Big Sagebrush	*Artemisia tridentata* ssp. *tridentata*	2	1	50	<1	<1	0
Big Sagebrush	*Artemisia tridentata*	1	0	0	0	-	0
Bearberry	*Arctostaphylos uva-ursi*	1	1	100	<1	<1	0
Birchleaf Spiraea	*Spiraea betulifolia*	1	0	0	0	-	0
Mountain Big Sagebrush	*Artemisia tridentata ssp. vaseyana*	1	1	100	2	2	-
Oregon Grape	*Mahonia repens*	3	0	0	0	0	0
Rubber Rabbitbrush	*Ericameria nauseosa*	3	0	0	0	0	0
Snowberry	*Symphoricarpos albus*	3	2	33	<1	<1	0
Woods' Rose	*Rosa woodsii*	1	0	0	0	-	0
Green Rabbitbrush	*Chrysothamnus viscidiflorus*	1	0	0	0	0	-

[1]Average canopy cover on sites where the species established. For example, if the species established on 2 of 10 sites where it was seeded, it is the average canopy cover for both sites.

[2]Research Sites with a north aspect included sites with compass azimuths of 315 – 135 degrees: Worley, Clayton, Electrical Substation, Genesee, Basin Creek Bridge, Clark Canyon Rd, City of Rocks, Tom Cat Hill and Wildlife Crossing.

[3]Research Sites with a south aspect included sites with compass azimuths of 136 - 314: Clayton, McCammom, Setters, Syringa Creek, Glenns Ferry, Albion, Silver Creek Bridge, and Willow Creek Summit.

Table 23. Level III Ecoregions Where Seeded Species Established

Common Name[1]	Scientific Name	Ecoregions (#) Seeded	Ecoregions (#) Established	Ecoregions Where Established
Grass				
Basin Wildrye	*Leymus cinereus*	2	2	Idaho Batholith, Northern Basin and Range
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	5	5	Columbia Plateau, Idaho Batholith, Northern Basin and Range, Middle Rockies, Snake River Plain
Bottlebrush Squirreltail	*Elymus elymoides*	2	2	Northern Rockies, Snake River Plain
Canada Bluegrass	*Poa compressa*	5	5	Columbia Plateau, Idaho Batholith, Middle Rockies, Northern Rockies, Snake River Plain
Crested Wheatgrass	*Agropyron cristatum*	2	1	Columbia Plateau
Green Needlegrass	*Nessella viridula*	1	1	Middle Rockies
Hard Fescue	*Festuca brevipila*	4	3	Idaho Batholith, Northern Rockies, Snake River Plain
Idaho Fescue	*Festuca idahoensis*	3	3	Columbia Plateau, Idaho Batholith, Northern Rockies
Indian Ricegrass	*Achnatherum hymenoides*	2	1	Idaho Batholith
Letterman's Needlegrass	*Achnatherum lettermanii*	1	1	Idaho Batholith
Mountain Brome	*Bromus marginatus*	5	3	Columbia Plateau, Idaho Batholith, Northern Basin and Range
Prairie Junegrass	*Koeleria macrantha*	2	2	Columbia Plateau, Middle Rockies
Sandberg Bluegrass	*Poa secunda*	6	4	Idaho Batholith, Middle Rockies, Northern Basin and Range, Snake River Plain
Sand Dropseed	*Sporobolus airoides*	1	1	Snake River Plain
Sheep Fescue	*Festuca ovina*	3	3	Idaho Batholith, Northern Basin and Range, Northern Rockies
Siberian Wheatgrass	*Agropyron fragile*	2	2	Idaho Batholith, Northern Basin and Range
Slender Wheatgrass	*Elymus trachycaulus*	4	4	Middle Rockies, Northern Basin and Range, Northern Rockies
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	5	2	Middle Rockies, Northern Basin and Range
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	3	3	Columbia Plateau, Idaho Batholith, Northern Rockies
Upland Bluegrass	*Poa glaucantha*	1	1	Northern Rockies
Western Wheatgrass	*Pascopyrum smithii*	2	2	Middle Rockies, Northern Basin and Range
Forbs				
Alfalfa	*Medicago sativa*	3	1	Idaho Batholith
Arrowleaf Balsamroot	*Balsamorhiza sagittata*	2	2	Columbia Plateau, Idaho Batholith
Fernleaf Biscuitroot	*Lomatium dissectum*	4	1	Northern Rockies
Goldenrod	*Solidago canadensis*	1	1	Idaho Batholith
Prairie Coneflower	*Ratabida columnifera*	1	1	Middle Rockies
Silky Lupine	*Lupinus sericeus*	5	1	Columbia Plateau
Sulfur Flower Buckwheat	*Eriogonum umbellatum*	1	1	Snake River Plain
Venus Penstemon	*Penstemon venustus*	1	1	Idaho Batholith
Western Yarrow	*Achillea millefolium*	4	3	Columbia Plateau, Idaho Batholith, Northern Basin and Range
White Dutch Clover	*Trifolium repens*	2	1	Northern Rockies

Common Name[1]	Scientific Name	Ecoregions (#) Seeded	Ecoregions (#) Established	Ecoregions Where Established
Shrubs				
Basin Big Sagebrush	*Artemisia tridentata* ssp. *tridentata*	2	1	Northern Basin and Range
Bearberry	*Arctostaphylos uva-ursi*	1	1	Northern Rockies
Mountain Big Sagebrush	*Artemisia tridentata ssp. vaseyana*	1	1	Idaho Batholith
Snowberry	*Symphoricarpos albus*	3	1	Northern Rockies

[1]Species seeded that did not establish are not included in this table regardless of ecoregion. Cross reference Table 22 to see species that did not establish.

Table 24. Proportion of Seed Mix that Established

Site Name	Number of Species in Seed Mix	Number of Species Established	Proportion (%) Established
Worley	14	7	50
Clayton	13	6	46
McCammon	9	8	89
Setters	14	6	43
Electrical Substation	15	6	40
Genesee	8	3	38
Syringa Creek	15	7	47
Basin Creek Bridge	9	2	22
Slate Creek Bridge	7	4	57
Glenns Ferry	13	2	15
Clark Canyon Road, MT	7	6	86
City of Rocks	7	4	57
Albion	8	4	50
Silver Creek Bridge	4	3	75
Tom Cat Hill	10	4	40
Willow Creek Summit	6	3	50
Wildlife Crossing	10	6	60

Conclusions

- Bluebunch wheatgrass, streambank wheatgrass, crested wheatgrass, Idaho fescue, and Canada bluegrass had the highest percent cover of seeded grasses where they established.
- Grass species that consistently establish on sites where they are seeded but have a low canopy cover (2 to 5 percent) include: sheep fescue, western wheatgrass, and basin wildrye. When using these species in a seed mix increase their seed rate to increase canopy cover. In addition, reduce the seed rate or eliminate species that do not establish well from the mix.
- Forbs and shrub species have low establishment success rates and low percent canopy cover on roadside revegetation projects.
- Do not include forbs and shrubs in seed mixes where herbicides are to be used. Many of the seeded sites were also sprayed with broadleaf herbicides which may have caused limited success of forb and shrub establishment.
- If forbs are desired on the site, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.
- Species that established in a diversity of ecoregions included bluebunch wheatgrass, Canada bluegrass, Sandberg bluegrass, slender wheatgrass, mountain brome, thickspike wheatgrass, western yarrow, and hard, Idaho, and sheep fescues.
- Seed mixes with 10 species or less have a greater proportion of species establish.
- When seeding crested wheatgrass or other aggressive exotic species, eliminate or limit native species in the seed mix because they will generally have low establishment.
- All sites had an erosion condition classification of “stable” or “slight”, except for the Wildlife Crossing on SH-21 which scored “moderate” for erosion. This site should continue to be monitored for signs of erosion and additional slope stabilization techniques applied as needed.

Chapter 3
Best Management Practices for Roadside Revegetation

Establishing native roadside vegetation after construction or modification of the roadside environment is an important practice to improve safety and effectiveness of roads and their adjacent environment. It allows transportation agencies, such as ITD, to not only address regulatory requirements for mitigation but also to promote ecosystem health.(5) Well-designed revegetation plans for post-construction should be appropriate for the local site's environment, serve to stabilize slopes, fight noxious and exotic weed invasions and aid in reducing water and wind erosion of soil. These plans can also help to increase native diversity, such as for plants, pollinators, butterflies, and other taxa.(13,14) The appropriate mix of grasses, forbs, shrubs and/or small trees in roadside revegetation projects should be native species and their cultivars that are best adapted for local edaphic and environmental site conditions. This helps to ensure the least amount of post-project management, such as watering, is needed for the establishment and growth of seedlings and plantings. If successful, revegetation of disturbed roadsides may not only meet management objectives but can also improve the aesthetic experience of motorists.

As part of this project we evaluated many of the latest techniques, strategies, and management practices that help prepare roadside areas for successful revegetation. These best practices include techniques and materials that stabilize slopes, reduce soil erosion and promote seedling establishment and growth. Such techniques and materials include topsoil replacement, soil fertilization and amendments, erosion control blankets, hydroseeding and container planting. We examined peer-reviewed literature, vegetation manuals, other transportation agency reports, and general reclamation papers that inform on roadside efforts. We incorporated information gathered from the 17 revegetation sites to arrive at conclusions and recommendations for practical application along Idaho roadsides.

As a result of this research and synthesis, there arose several areas of practice where it was difficult to achieve clear cut conclusions and recommendations for ITD's revegetation efforts in the future. These areas are where further research may be needed to more clearly define and describe best practices or applications for Idaho roadsides. Thus, the last section of this chapter includes recommendations for future research.

Site and Soil Preparation

Success of re-establishing vegetation after the completion of road construction is dependent on creating the best possible soil media to receive seeds or seedlings. Often post construction sites have compacted soils that are nutrient poor, have lower levels of biological activity, and have reduced porosity for water penetration and holding capacity. A variety of techniques, such as tilling, fertilizing or adding soil amendments, can help restore soil structure and function from the impacts of heavy machinery compaction, topsoil removal, and other road construction activities.(4)

An ideal soil preparation will result in:[15]

- Enough fine-grained (silt and clay) material to maintain adequate moisture content, usually 15 - 20 percent.
- Sufficient depth of soil, up to 4 to 6 inches, to provide an adequate root zone.
- A favorable, slightly acidic pH range for plant growth, 5.5 - 6.0.
- Soil compaction levels that are similar to adjacent natural conditions.
- Sufficient pore space to permit root penetration, with particular attention to the top 4 to 6 inches of the soil profile.
- Roughened surface condition that facilitates water infiltration, rather than runoff.

Re-Application of Top Soil

The re-application of topsoil for revegetation and erosion control purposes is an effective technique.[16] However, after road construction an adequate supply of topsoil is often not available and steep cut slopes make spreading topsoil impractical or economically infeasible. When on-site topsoil is available, it usually consists of the “A horizon” of the soil profile (Figure 41). The “A horizon” is characterized by high levels of carbon (C) (> 15 percent), organic matter (OM) (>3 percent), and soil microbes. Topsoil replacement has been shown to improve organic carbon on reclamation sites, and topsoil replacement was an important factor in influencing soil organic carbon (OC) and nitrogen (N) availability many years after initial treatment, but not as important as soil amendments for the availability of phosphorus.[17,18]

The re-application of topsoil to roadside reclamation projects is the most effective means to ensure long-term success of desirable plant establishment. No other cultural practice can produce such favorable, cost-effective results.

Topsoil re-application is a recommended practice to re-establish soil microorganisms (i.e., earthworms, nematodes, bacteria, fungi) that provide essential nutrients and nutrient cycling processes needed for vegetative establishment.[2] Reapplying topsoil provides nutrients to mixed subsoil profiles that are nutrient poor. While improving soil texture, structural stability, water-holding capacity, permeability and fertility.[19]

The replacement of topsoil includes replacing its seed bank. Many species native to the area will be represented in the seed bank, can reestablish and add to the diversity of vegetative reestablishment. Seed banks can contain both transient and persistent components. The transient component is composed of short-lived, non-dormant seeds such as annual forb species, often not viable after one year, and persistent seeds, such as legumes (i.e., *Lupinus* spp.) may remain viable for two or more seasons.[20] The length of time topsoil is stockpiled may affect the ability of species to re-establish from seed. Also, fertility, micro-organism numbers, and mycorrhizal inoculum (fungi) all decrease over time in stockpiled topsoils.[2]

Figure 41. Topsoil Storage on Area Adjacent to Roadway Construction

It has been found to be perfectly acceptable to re-apply topsoils on the inslopes of highways within approximately 0.5 yard of the pavement and that doing so provides a long-term benefit. A value engineering study that was unpublished by MDT engineers found that by placing topsoil on the gravel inslope it allowed native plants to establish (preferably native rhizomatous grasses), helped reduce weedy species, improved aesthetics, water quality, and reduced erosion while having no adverse effect on safety, water drainage or maintenance.[14]

The re-application of topsoil can be a source of weed seed and plants. Seeds of many weedy plants can persist in soil for decades. Some weeds common to Idaho roadsides, such as Shepard's Purse (*Capsella bursa-pastoris*), field chickweed (*Cerastium arvense*) or prostrate knotweed (*Polygonum aviculare*), have been found to be viable after more than 24 years of burial.[21] Thus, care should be taken to identify any weed populations along roadside construction sites that may contribute to the weed seed bank and be prepared to treat after construction..

Recommendations

- It is preferable for roadside revegetation plans to take advantage of the storage and re-application of construction site top soils. Re-applied topsoil can be cost effective and increase native plant diversity.
- Minimize the length of time topsoils are stockpiled to reduce loss of fertility and micro-organism numbers and activity.
- Calculate how much topsoil needs to be salvaged and stockpiled to provide sufficient quantities to cover all disturbed areas with a final depth of 4 inches. During salvage operations, monitor and measure stockpiles to assure the target salvage quantity is achieved.

Soil Conditioning and Soil Surface Roughening

There are three functions of implementing topographical enhancements to prepare roadside slopes for revegetation: reduce water flow, reduce soil erosion, and create microhabitats for plant establishment. Soil stability is an important factor in successful vegetation establishment. Soil surface conditions play an important role in controlling erosion; therefore, preparing a roadside slope should take in to consideration such factors as soil type, surface roughness and the consideration of adding non-vegetative cover (such as stones or coarse woody debris), where appropriate (Figure 42).

Figure 42. A Disc or Harrow Can Texture Soil and Alleviate Compaction for Seedbed Preparation

To reduce soil movement, it is important to treat and prepare barren slopes to address 2 hydraulic factors:

1. Water transport or flow resistance.
2. Soil transport or erosion resistance.[22]

After the soil is equitably distributed on the site, roughening of the surface such as running a bulldozer perpendicular to the slope contours is appropriate to create microsites for vegetative establishment. Microsites can be the one variable that distinguishes success from failure on a seeding site. Tracking with heavy equipment during re-contouring can create microsites, but tracking can compact soils and some areas may need to be scarified. Scarification is typically accomplished just prior to seeding operations with disks, harrows and/or chisel plows. In severe cases of soil compaction, the site may need to be scarified with heavy equipment outfitted with ripping teeth. Some revegetation techniques such as mechanical seeding address this in one step. However, MDT compared results of tracking before and after seeding and found best results were to track the slope with heavy equipment after applying seed.[12]

Another relatively inexpensive technique to roughen smooth slopes is to spread rocks or coarse woody debris across the site. In a Utah roadside study, seeded native grasses established better near stones and woody debris than on adjacent open microsites.[(23)] Poesen and others found rock fragments at the macroplot scale (i.e. upland areas with rill and interill erosion) can be soil surface stabilizers that reduce erosion.[(24)] The Setters US-95 site used rocks as a topical treatment that stabilized the slope and created microsites for plants to establish (Figure 43).

Figure 43. A Rock Armor is Used to Stabilize Roadside Reclamation Slope and Create Microsites for Successful Plant Establishment at Setters US-95 Site in Northern Idaho

Fertilizers

If topsoil replacement is insufficient or the post-construction roadside slopes to be revegetated have nutrient poor soils, then adding fertilizers may improve and speed the establishment of plantings and seedings. When fertilizing, it is an important consideration to strike a balance between speed of vegetation recovery, invasive species colonization, and erosion control. For example, use of nitrogen-rich amendments or fertilizers may rapidly reestablish vegetation cover, yet make the site more susceptible to colonization by invasives. Conversely, absence of soil nitrogen may lead to sparse vegetation cover and accelerate erosion.

Plants require both macro- and micronutrients to sustain their growth. Topsoil generally provides adequate levels of both macro- and micronutrients for native plants, yet on disturbed sites topsoil quality may be inadequate to support reasonable plant establishment and growth. Plant macronutrients include: N, P, and K. Plant micronutrients include: copper (Cu), zinc (Zn), manganese (Mn), molybdenum (Mo), Boron (B), Chloride (Cl), Iron (Fe), Calcium (Ca), magnesium (Mg), sodium (Na), and sulfur (S).

Micronutrients are generally available at adequate concentrations in the soil and are not replaced by fertilization.

Most fertilizer prescriptions emphasize replacement of soil nitrogen. Grass species have a high N requirement compared to forbs, so adequate levels of N are required for successful establishment of seed mixes dominated by native grasses. Low levels of available N are commonly observed in sparse plant communities with little ground cover. Most native plant communities thrive in low to moderate levels of soil N, while moderate to high levels of soil N favor invasive species.[25,26] Thus, both deficient and excessive levels of soil N are associated with undesirable plant community conditions and the ideal levels of available N for roadside revegetation lies somewhere between the extremes.

The Texas Department of Transportation's standard fertilizer applications seek to apply 100 lbs of N per acre and also contain both P and K for roadside revegetation projects.[27] While early plant establishment can be facilitated by fertilizer, Petersen and others found that four years after fertilizing, little difference could be observed in a Utah roadside revegetation project.[23] Experience has shown that target levels of available nitrogen are approximately 25 - 50 lbs N per acre for the establishment and growth of native plants. By comparison, agricultural application rates with their higher demands for annual crops are typically designed to achieve 60 - 90 lbs soil nitrate-nitrogen per acre.[28]

Nitrogen fertilizer can be surface applied with the expectation that it will be immediately available for plant growth. Both types of fertilizer, organic and inorganic, are appropriate for roadside revegetation application. A typical inorganic fertilizer, such as ammonium sulfate (21-0-0), is applied as pellets or granules. This and other inorganic fertilizers have relatively high concentrations of nitrogen that are rapidly available to plants but rather short-lived. Organic fertilizers slowly make nutrients available to plants and are relatively long lived in their release of N. The organic fertilizer Biosol® (6-1-1) was used by ITD on the Worley SH-58 site.

Most soils have adequate amounts of P and K from soil minerals; however, some roadside post-construction slopes may have atypical soil conditions that are nutrient poor. For example, the Genesee US-95 site applied 1 lb of elemental P per acre. Phosphorous and K are comparatively immobile in soil compared to nitrogen. As a result, the agricultural sector typically applies P and K fertilizers when they can be tilled into the soil. Surface application of P and K fertilizer will eventually benefit the plant community, but dissolution and leaching downward into the soil may require decades. Similarly, for roadside revegetation projects that require P and K fertilizer, it should be incorporated via tillage into the soil during slope preparation in advance of seeding. In addition to elemental applications of P or K fertilizers, there are many fertilizers with balanced amounts of N-P-K such as 16-16-16 or 20-20-20 that add adequate levels of all 3 macronutrients. Soil analysis is the only definitive way to assess the fertility of soils for the preparation of a fertilization strategy prior to seeding.

As shown in Table 25, of the 17 revegetation sites evaluated for this study, the following sites were known to apply fertilizers or add soil amendments. Worley SH-58 used Biosol® (6-1-3) and N at 40 lbs/acre, Clayton SH-75 used compost, and McCammon US-30 was seeded using a non-specified fertilizer (Table 25). The 14 opportunistic sites employed a variety of different fertilizers or soil amendments that aided tilth. At Setters US-95 Biosol® (6-1-3) and nitrogen were applied at 40 lbs/acre, Genesee US-95 spread slow release nitrogen at 40 lbs/acre and elemental phosphorous at 1 lb/acre. Two sites used composted livestock manure instead of fertilizer, Silver Creek Bridge US 20 and Albion SH-77. Hydro-seeded sites such as Setters US-95, Slate Creek Bridge SH-75, Glenns Ferry I-84, Willow Creek Summit US-93, and Wildlife Crossing SH-21 most likely had fertilizer in the slurry but it is undescribed for this report. The Electrical Substation US-95 and Syringa Creek US-12 sites utilized compost so the hydroseed slurry may not have had fertilizer. Reports from the other 5 sites did not describe the use, amount, or formulation of fertilizers.

The ITD revegetation sites have their own unique revegetation plans, post-construction slope preparation, and site specific soil type and fertility, it is difficult to compare effectiveness and efficiency of the various fertilizer and soil amendment practices of the 17 sites. Also, standard information on fertilizer use and application was not available for all 17 sites. Therefore fertilizer recommendations are based on general best practices. In the future, it may be beneficial to test a variety of these fertilizer and soil amendment treatments in side-by-side experiments along Idaho roadsides in various Level III Ecoregions.

If topsoil is unavailable and seed is applied to subsoil, poor plant establishment will commonly occur. Subsoil or geologic materials lacking organic matter are good candidates for compost amendment or organic fertilizers such as Biosol®. Organic fertilizers slowly make nutrients available and are long lived in the soil; conversely, inorganic fertilizers rapidly make nutrients available and are short-lived. Both organic and inorganic fertilizers are appropriate to roadside revegetation applications, yet should be tailored to soil quality. Good quality topsoil generally does not require any fertilization. Low quality topsoil or thin topsoil may benefit from supplemental fertilization. Slopes composed of exposed subsoils and geologic parent materials should be fertilized with organic fertilizers or amended with compost to support plant growth.

Table 25. Fertilizer or Other Soil Amendment Treatments of the Study Sites

Site Number	Site Name	Highway	Fertilizer Treatment[1]
1	Worley	SH-58	Biosol® and nitrogen at 40 lbs/acre
2	Clayton	SH-75	wood fiber compost
3	McCammon	US-30	undescribed fertilizer
4	Setters	US-95	Biosol® and nitrogen at 40 lbs/acre
5	Electrical Substation	US-95	mulch, so may not have fertilized via hydroseed slurry
6	Genesee	US-95	nitrogen at 40 lbs/acre, elemental phosphorous at 1 lb/acre
7	Syringa Creek	US-12	mulch, so may not have fertilized via hydroseed slurry
8	Basin Creek Bridge	SH-75	N/A[2]
9	Slate Creek Bridge	SH-75	unreported use of fertilizer in hydroseed slurry
10	Glenns Ferry	I-84	unreported use of fertilizer in hydroseed slurry
11	Clark Canyon Road	MT SH-324	N/A
12	City of Rocks	STC-2841	N/A
13	Albion	SH-77	composted manure
14	Silver Creek Bridge	US-20	composted manure
15	Tom Cat Hill	US-93	N/A
16	Willow Creek Summit	US-93	liquid fertilizer in hydroseed slurry
17	Wildlife Crossing	SH-21	unreported use of fertilizer in hydroseed slurry

[1]Fertilizer information provided by ITD. [2]N/A: information not available

Recommendations

- For good quality topsoil, supplemental fertilizer is not necessary.
- For moderate quality and/or thin topsoil, apply sufficient fertilizer, either inorganic or organic, to achieve 25 - 50 lbs/acre of available nitrate-nitrogen.
- For moderate quality and/or thin topsoil areas surrounded or infested by invasive species, do not add nitrogen fertilizer.
- When seeding on low quality soil, subsoil and geologic parent material, add enough organic nitrogen fertilizer to achieve 25 - 50 lbs/acre of nitrate-nitrogen or add compost blankets to increase both site nutrition and water retention for seedlings.

Compost and Mulches

Applying compost or mulch on roadside revegetation sites is a common practice by departments of transportation across the nation (Figure 44). There are multiple benefits of the practice such as fertilization, moisture retention, erosion control and weed control. Surface applied organic amendments, compost, or mulch can also enhance vegetation growth and soil quality characteristics. Compost is decomposed organic matter full of nutrients immediately available for plant growth. Some compost erosion control blankets have the ability to increase soil quality characteristics relative to hydroseed.[29] On construction sites, compost applications will promote quick vegetation cover with less weed growth than hydroseeding. Organic mulch, such as shredded bark or straw, placed on soil can protect young seeded plants from temperature extremes, maintain moisture availability, reduce erosion, and suppress weeds and soil-borne diseases. Mulch will eventually decompose and provide nutrients to the site.

Typical bulk compost used for intermountain roadside revegetation is a mix of mixed bio-solids or aged livestock manure and wood fiber screened so that pieces are <⅜ inches diameter. It is slightly basic (pH of 7.9) and comprised of 46 percent organic matter with total C over 31 percent and OC over 26 percent.[30] Additions of macronutrients like nitrogen (N), phosphorous (P) and potassium (K) can increase plant establishment and growth, particularly in nutrient poor post-construction soils. Compost adds macronutrients, and compared to inorganic fertilizer addition, is a long-duration, slow-release fertilizer. For example, in a roadside application tested in Montana, total N level in bulk compost had 8,570 parts per million (ppm), suggesting the compost would provide a long-term source for soil N. Phosphorous was 209 ppm and K was 8,700 ppm, suggesting compost provides healthy amounts of all 3 macronutrients.[30]

Figure 44. Example of a Blower Truck Application of Compost on a Roadside Cut Slope

Applying adequate amounts of compost to revegetation sites for enhanced vegetative establishment and erosion control is important. However, care should be taken to avoid applying excessive amounts of compost that can be costly and impede vegetation growth. Research suggests that application depths of 0.5 to 1 inches compost are adequate for establishing vegetation, suppressing weeds, and reducing soil erosion. In a study comparing three different composts, there were no significant differences between the depths. All depths found compost to be as effective as topsoil and subsoil for seedling growth while significantly reducing growth of weed species. This research indicated that shallower depths would be adequate for establishing vegetation while suppressing weeds and minimizing costs.[31] Similarly, the

MDT supported studies evaluating the effectiveness of compost depths of 0.125, 0.25, 0.5, 1, and 2 inches. The vegetative response of seeded native perennial grasses and cost-benefit analyses found that the ideal compost depth was between 0.5 - 1.0 inches.[29,32] Another study found adequate compost depth related to slope angle. As slopes increase in steepness, the thicker compost blankets performed better. For slopes greater than 4:1, compost applied 1 inch or thicker performed better particularly if rainfall totals reach 2 inches or more.[33] Adding a lightweight erosion control blanket can also aid in retaining compost on a roadside slope.[30] Similarly, applying a plant-based tackifier or hydromulch with a pre-blended tackifier immediately following the compost application helps retention.

Another practice studied the incorporation of compost into soil compared to surface applied compost blankets. The research evaluated sites with dissimilar parent material and climate where surface application rates (0, 1, and 2 inches) were compared with incorporated compost tilled to a 4 inch depth. Both techniques yielded good vegetation response.[32] While the tillage methods aided in compost retention against wind erosion, the substantial additional cost and effort required to incorporate compost into soil led to a preference for surface compost blanket methods.

Of the ITD sites evaluated, 7 of the 17 included mulch or compost in their revegetation plan to help seedling establishment, combat soil erosion, and reduce weed establishment. Worley SH-58 used wood fiber mulch and Clayton SH-75 applied 2 inches of compost. On the wetland and transitional sites at the McCammon US-30 project, compost was also applied. The Electrical Substation US-95 project added mulch that was tracked over by bulldozers before hydroseeding, while Syringa Creek US-12 used compost/mulch SP15-OTC blankets on steep cut slopes. Albion SH-77 and Silver Creek Bridge US-20 projects both used decomposed livestock manure. The mix of various applications, materials and treatments in many different Level III Ecoregions makes it difficult to draw strong conclusions on best practices for mulch and compost for this project. It does demonstrate that although these practices are common, not enough is known to summarize the effectiveness of their use and treatment to guide future use and deployment. However, the application rate of compost at the Clayton site was relatively deep at 2 inches, and may have detrimentally affected establishment of relatively small seeds of big sagebrush, rubber rabbitbrush and 5 seeded forbs. None of these seeded species established at the site. The compost may have been deeper than what was needed to ameliorate the site’s environmental conditions.

Recommendations

- Compost should be applied at depths of 0.5 to 1.0 inch, unless special circumstances (e.g., steep slopes) require lighter or heavier applications.
- It is best to apply a lightweight erosion control blanket or tackifier or hydromulch over the compost immediately following application to improve it retention.
- If compost is applied in spring immediately prior to the growing season, less emphasis on compost retention is required. Conversely, if compost is surface applied in the fall in conjunction with dormant seeding, retention of compost is a higher priority.

Incorporating Woody Debris for Erosion Control

Woody material is a relatively inexpensive soil additive. This amendment may be particularly useful if the construction project removed or chipped trees and large shrubs in the highway right-of way and the materials can be stored for reapplication via soil incorporation. Eldridge and others found that wood chips as a soil amendment increased organic matter content and reduced exotic species in non-saline soils in arid western Colorado.(34) Tahboub et al. also found that incorporation of wood chips into soil improved both soil organic matter content and aggregate stability.(35) Application rates of shredded on-site materials are most typically “field fit” rather than a specific application rate. While wooden materials are comprised partly of N they will release N to the soil over extended periods of time. Wood chip amended soils are typically associated with low nutrient availability to plants and sparse cover of grasses, and the rate of wood degradation and N release is species specific. In a study of woody root degradation in the Pacific Northwest, Chen et al. showed that the rate of degradation was slowest for Douglas fir and fastest for ponderosa pine.(36) Lodgepole pine was intermediate in decay rate.

Yellowstone National Park has developed unique approaches to roadside revegetation using native plants and woody materials to create low N roadside environments resistant to invasive colonization. On the poor-nutrient soils, the Park tries to discourage robust vegetation growth immediately adjacent to the road to avoid attracting wildlife to road corridors. The general prescription for roadside revegetation is to remove the topsoil layer and move it up slope where it is windrowed in a linear fashion. Woody material 3 inches and smaller in diameter is incorporated into the topsoil mix. Topsoil may not be piled, mixed or stored over winter. After road construction each area is lightly mulched with a partially decomposed, inert, shredded bark mulch; a combination of Douglas fir and cedar which holds moisture and catches windblown seed. Compost and fertilizer are not used to avoid excessive nutrient levels favorable to invasive species. Hydromulching is not used because of the tackifier chemistry nor are commercial mulches and erosion control fabrics used due their potential for release of nutrients, importation of invasive seed and negative interactions with wildlife.(37)

Woody materials can be used alone as a soil amendment or can be used in conjunction with fertilizer. Additional N fertilizer is commonly applied with woody material to offset consumption of N by microbes involved in decomposition of the woody material. Soil amendments using woody material should consider that wood typically has a C:N ratio greater than 500:1 (nitrogen-poor) compared with compost (nitrogen-rich) which has a C:N ratio ideally in the 10:1 to 30:1 range. Soil amendments with abundant plant available N, such as compost, are associated with rapid vegetation establishment and erosion control but have an increased risk weed invasive. Soil amendments dominated by wood are likely to yield less vegetation growth, providing better erosion control and have less risk of favoring invasive species.

Recommendations

- Use wood chips/shreds for roadside revegetation in forested and or shrubby habitats with abundant adjacent woody vegetation.
- Seed should be applied prior to wood chip/shred installation.

- Large woody debris (e.g. dead trees) can be placed on-slope outside the clear zone, and should be placed parallel to the slope and in contact with the ground to break up erosion flow paths.
- Large root wads should not be used on slope as part of the revegetation prescription.
- Rates of site-salvaged woody amendment application are best determined in the field based on slope condition, wood product characteristics and material supply.
- Nitrogen fertilizer should be applied in addition to woody material on sites requiring rapid stabilization, and abundant grass cover and where invasive species concerns are low.

Slope Stabilization and Erosion Control

Soil erosion is the largest contributor to non-point pollution in the U.S. and sediment comprises approximately two thirds of the pollutants moving in to the nation's waterways.(33,38) Sediment runoff from highway construction sites ranges from 153 - 214 tons/acre compared to 76 - 102 tons/acre for other types of construction.(39)

The ITD Best Management Practices Manual's goal for erosion control management has three categories: perimeter controls, controls within the project and final product. They also separate temporary (1-6 months) and permanent best management practices.(1) Information in this report can be used to address all three categories and both time frames. The following section will add information to support practitioners as they seek to conform to ITD's best management practices for slope and soil stabilization and erosion control.

Erosion Control Blankets

The function of erosion control blankets (ECBs) is to not only reduce soil erosion, but also to shelter seeds, promote germination and hasten re-vegetation. More broadly, ECBs are part of several erosion control products available for roadside applications, which also include erosion control nettings, erosion control meshes, and geosynthetic mattings.(38) All of these products are manufactured as rolled material and are staked or stapled to stabilize and adhere the product to the slope after they are rolled out (Figure 45 and Figure 46. ECBs have high labor inputs for installation compared to other BMPs which adds to the application expense.

In a rainfall simulation study on 8 percent and 21 percent slopes testing 4 different ECBs (wood excelsior, jute fabric, coconut fiber blanket, and coconut strand mat) all erosion control materials reduced bare soil erosion by 80 to 99 percent.(40) Thus, deployment of ECBs is proven an effective BMP. In a roadside study in Minnesota comparing bare soil, disc-anchored straw mulch, wood-fiber blanket, straw-coconut blanket and a bonded-fiber hydromulch treatments, there was no statistical difference between blankets and bonded-fiber, but they all had significantly less erosion than straw or bare soil treatments.(41) Erosion control blankets are typically used on cut and fill slopes that are steeper than 3:1 (33.5 percent) or for areas where heavy rains or winds could adversely affect revegetation success at the site. They are also very effective in preventing erosion of drainage channels and ditches, as well as cut/fill transitions.

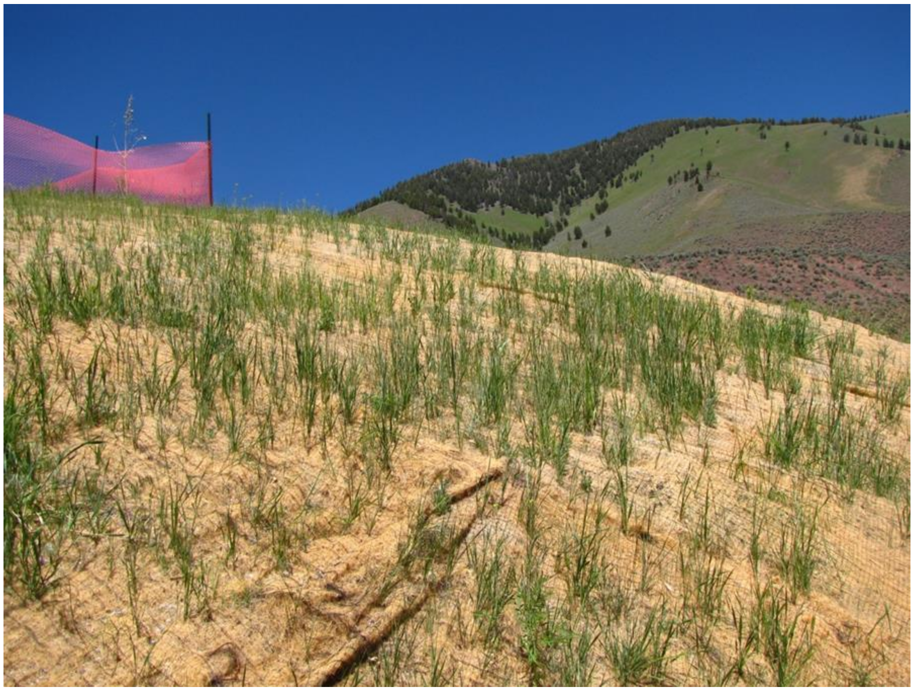

Figure 45. Coir-Straw Matrix Erosion Control Blanket at Slate Creek Bridge SH-75 Site

Figure 46. Jute Woven Matrix Erosion Control Blanket at Slate Creek Bridge SH-75 Site East of Stanley

Recommendations

- Since most ECBs are highly effective in reducing soil erosion on slopes with ratios greater than 3:1, seeking the most cost-effective product for deployment on a project is an excellent use of these relatively expensive materials.
- Selecting biodegradable products over synthetics will help protect other environmental values, which may justify higher costs.
- As a general rule, an ECB composed of straw material promotes quicker plant establishment, while an ECB composed of excelsior (woody) material is better for the protection of soils from erosion.

Wattles or Fiber Rolls on Slopes

The use of fiber rolls with woven mesh netting or wattles is a proven BMP to reduce water runoff and control soil erosion. In a post-fire western Montana study using rainfall simulation on a steep slope, straw wattles significantly reduced total runoff and sediment yield compared to the control plots.[42] Using simulated rainfall on a tilting soil, wattles were found to reduce total sediment export by 96 percent.[43] An initial experiment by the North Carolina Department of Transportation found that straw wattles with granulated polyacrylamide (PAM 75) significantly outperformed standard straw wattles in preventing erosion (Figure 47).[44] Straw wattles used for erosion control were suspected to have been complicit in slope failures on US-20 in Oregon. A study demonstrated their ability to absorb and hold water, but indicated that they had no significant effect on surficial slope stability, demonstrating that the benefits outweighed the risks of their use.[45] ITD's Clayton SH-75 site east of Stanley and the wildlife crossing SH-21 site north of Boise both used wattles that effectively controlled surface water flow and soil erosion (Figure 48).

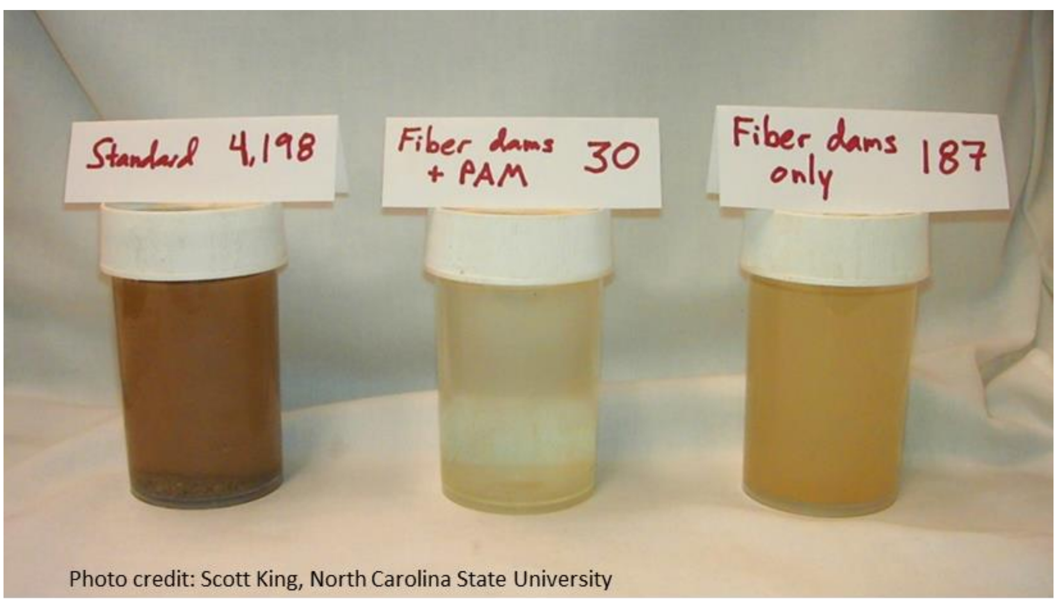

Figure 47. Photo Comparison of Average Runoff Turbidity Results for Three Treatment Types Showing Effectiveness of Polyacrylamide Additive[44]

Figure 48. Wattles Used to Control Water Runoff and Soil Erosion on Wildlife Crossing SH-21 Site

Recommendations

- Soil surface roughening is preferable to smooth slopes so that a variety of microsites are provided for seedling establishment.
- Using heavy equipment to create tracks parallel to the slopes to be seeded is an excellent practice for surface roughening. It is preferable to track slopes after seeding to maximize seed contact with the soil.
- Surface roughening can also be achieved by discing or harrowing the area to be seeded.
- Roughening can be enhanced by adding rocks, stones and/or woody debris on the surface.
- Wattles or woven fiber rolls are a proven BMP to deploy on slopes susceptible to erosive forces, especially on slopes greater than 3:1 or 33.5 percent.

Erosion Control for Ditches

Controlling sediment movement and discharge from roadside ditches during and after construction reduces sedimentation that can flow into nearby waterbodies. Check dams are one method to reduce sedimentation from such overland flows (Figure 49). Kang and others tested three types of check dams that were placed in ditches (5 – 7 percent slope) to control sediment; rock check dams, excelsior wattles, and a rock check dam wrapped with an excelsior ECB.[(46)] They found that the standard practice, excelsior wattles performed best. Next in performance was the rock dam wrapped with ECB and last was the rock check dam.[(46)] At the same time, Kang and others also tested the application of granular polyacrylamide (PAM) on the check dams and found it reduced turbidity by >75 percent compared to non-treatment for all three check dam types. The work of Kang and others comported with earlier research by McLaughlin and others.[44] They compared the standard BMP of sediment traps in the ditch, with rock check dams, fiber check dams (FCDs) of straw wattles and coir logs, and fiber check dams with granulated PAM added to each. Results of this study found significant control of sediment with FCDs and even more with PAM used on the FCDs. Current common best management practices using FCDs to line roadside ditches are adequate and PAM only improves their effectiveness.

Figure 49. Rock and Straw Check Dams in a Ditch to Control Erosion

Recommendations

- Fiber wattles and sediment traps a common best management practices and research confirms they control sediment discharge from ditches in highway construction projects, particularly before vegetation is established.
- Granular polyacrylamide (PAM) as an additive, approximately 100 grams per check dam, to fiber wattles or logs lining ditches can significantly decrease sediment discharge, and should be considered for deployment at sites with highly erosive soils or where ditches are steeper.

Soil Tackifiers

Tackifiers are synthetic or naturally derived binders that help to create a soil crust that is resistant to wind and water erosion; yet, is penetrable by emerging seedlings. They are applied separately or pre-blended in hydromulch products in order to bind compost and/or mulch materials to soil surfaces following seeding operations.

For the California Department of Transportation acceptable tackifiers include both plant based products – guar, psyllium and starch based products, as well as polymeric emulsion blends – copolymers/

polymers of acrylic, methacrylate and acrylates, sodium acrylates and acrylamides and polyacrylamides. The most common of the plant-based glues is guar, but this material is relatively expensive.[47]

Field research along a Montana highway indicated that of the three tackifiers studied which were guar-, plantago- and polymer-based, respectively, the plantago-based tackifier applied to buffer compost blankets from the effects of water and wind erosion performed the best. However; the study indicated that the tackifiers didn't retain compost as well as erosion control blankets.[30]

Another type of tackifier is polyacrylamide (PAM). A recent study using rainrall simulation compared the erosion control effectiveness of straw and hydromulch with and without polyacrylamide. Hydromulch with PAM outperformed the other three treatments, and straw with PAM outperformed hydromulch without PAM, which could be much more cost effective.[48]

Recommendations

- Soil tackifiers are useful to stabilize surface soils on steep slopes or other areas that cannot be treated with ECBs or reached by machinery. These areas are often broadcast or hydroseeded, in conjunction with hydromulch application
- Another use for tackifiers consists of large open areas vulnerable to prevailing winds that deposit unacceptable amounts of dust on adjacent residential areas, businesses or other dust sensitive areas.
- Similarly, topsoil, sand and other aggregate stockpiles can be treated with tackifiers to prevent wind erosion of material.

Wood Chips and Fibers for Erosion Control

Wood chips or fibers are another method of using native materials or importing biodegradeable products to control erosion. On-site shredding or chipping of trees can be accomplished using large wood grinders. Wood chips were found to reduce erosion by up to 86 percent compared to bare soils.[49] Small wood chips (<¼ inch), which is mostly sawdust, reduced erosion by only 22 percent while large wood chips (> 1 inch) reduced erosion by 78 percent. A mixture of chip sizes reduced erosion by 86 percent. Similarly, the U.S. Forest Service investigated the use of both shredded wood fibers and wood strands for roadside revegetation.[50] Compared to wood chips, shredded wood fiber was longer, narrower and had greater interlocking. A related commercial product WoodStraw® employs "all-wood long-strand soil erosion control mulch that is a blend of geometrically regular wood elements that have a straw-like form and function." WoodStraw® is a commercial product purchased as bales and imported to the project. Application rates of WoodStraw® range from 2 tons/acre for 40 percent soil coverage to 5 to 7 tons/acre for 70 percent soil coverage. A 3.75 ton/acre rate is recommended for 50 percent coverage on slopes angles of 5 to 33 percent.

Recommendations

- When wood chips are available from construction activities, or shredded wood are readily available from commercial sources, they may be used as a cost-effective erosion control application.

- In general, wood chips or shreds should not exceed 100 percent ground cover and should not exceed 1 inch in depth. Accumulation of wood chips several inches deep should be avoided.
- Commercial wood products for erosion control can be applied following manufacturer specifications, typically 2 to 5 tons/acre.

Selection of Plant Materials

Plant materials should be selected to meet both revegetation objectives and site specific conditions. The objectives of roadside revegetation projects may include one or more of the following:

- Establishing vegetative canopy cover.
- Controlling erosion.
- Stabilizing slopes.
- Inhibiting weed establishment.
- Enhancing beautification.
- Improving highway safety.
- Improving wildlife habitat and connectivity where appropriate.
- Minimizing site maintenance.

Species can be selected to fulfill more than one revegetation goal. For example, the native grasses Idaho fescue and Sandberg bluegrass are short stature species that provide a clear line of sight and minimize the need for mowing maintenance. Incorporating rhizomatous species with extensive root systems in a seed mix can minimize soil erosion and increase site stability. Thickspike, slender or streambank wheatgrass are rhizomatous, establish quickly, and are often used for roadside erosion control. MDT uses the short lived perennial slender wheatgrass in every seed mix at a drill seeding rate of 2 lbs per acre because of its high success rate initial soil stabilization.(12) Incorporating forb or shrub species may provide beautification, improve habitat, and increase weed resistance.

Site specific conditions to consider while selecting plant materials include:

- Soil type and texture.
- Slope angle and aspect.
- Climatic conditions (temperature, precipitation, wind).
- Elevation.
- Surrounding land uses and vegetative plant communities.
- Invasive plants present in the vicinity.

Adequate species diversity in a revegetation seed mix is important for contributing to site stability, invasive species resistance, ecological function, and wildlife habitat. However, revegetation experts advise to keep the mix simple with no more than 6 to 9 species.(51,52,53) Consider species compatibility, rate of development, and season of growth of each species to ensure compatibility and avoid competition between seeded plants. A reference area in the vicinity of the revegetation site can be used to select species that are suited to the site characteristics, species present and their proportion of the plant community, and vegetation densities that can be expected.

Recommended Seed Mix Species for Idaho Tier 3 Ecoregions

Table 26 recommends species to include in seed mixes for Idaho's Tier III Ecoregions. The creation of the table considered multiple factors. First, we populated the table with species used in seed mixes on the 17 study sites, additional species suitable for seeding in Idaho, and species recommended in scientific literature.[2,3]

Once the list was populated, a rating of recommended (R), not recommended (NR), special situations (S), and wetland areas (W) was given to each species by ecoregion. Only the Level III Ecoregions of Idaho where this study evaluated the success of planted species were included. A plant species was recommended if it had a high success rate for establishing and had a relatively high canopy cover where it established on the 17 sites monitored as part of this research (Table 22 and Table 26). For example, bluebunch wheatgrass established on 92 percent of the sites where it was seeded, had an average canopy cover of 12 percent, and grew in each of the ecoregions. Species were also recommended if the literature supports their success or ability to self-perpetuate in revegetation projects. Conversely, plant species were not recommended if they had poor establishment on the study sites. For example, fernleaf biscuitroot established on 25 percent of the sites and ecoregions where it was seeded but had a trace average canopy cover of <1 percent where it did establish even when seeded at extremely high rates (1 to 12 lbs/acre; Table 22).

Precipitation requirements and species' ranges were also used to provide recommendations for good revegetation candidates. For example, red fescue has a minimum precipitation requirement of 18 to 30 inches a year which limits the areas where it could establish successfully in Idaho. For most ecoregions it is not recommended (Table 26). Similarly, purple prairie clover has a species range limited to the extreme southeast corner of the state in the Wyoming Basin ecoregion.[54] A native species that is geographically limited is not a good revegetation species for the entire state of Idaho. We aimed to find species that could be recommended for broad use across each of Idaho's ecoregions.

The ability of a species to meet roadside revegetation goals was also considered in making recommendations for seed mix species. In most roadside sites, quickly establishing vegetation is critical for providing slope stability and increasing competition with invasive species. Including long-lived perennials in the same mix is important for long-term site stability. Utilizing short lived perennials such as slender wheatgrass or Canada wildrye for quick establishment of native grasses can meet site stabilization goals.[54] These species are often used following wildfire.[51] In fact, MDT uses slender wheatgrass in every seed mix at 2 lbs per acre because of its high success rate and initial soil stabilization. If a species is slow to develop on the study sites, it was not recommended, or is recommended if grown with other quick establishing species. For example, arrowleaf balsamroot established on 66 percent of sites where it was seeded but had a canopy cover of <1 percent 5 years after seeding (Table 22). Western wheatgrass established on 100 percent of the site where it was seeded with a canopy cover of 2 percent (Table 22). Although western wheatgrass is slow to establish, this rhizomatous native grass is known to increase in cover over time where it is planted and could provide long-term erosion control on a site.[55]

The average cost and availability of a species was used to provide species recommendations. Most of the dominant native grass species in Idaho are readily available because they are commercially grown for revegetation. Costs of bluebunch wheatgrass, Idaho fescue, or slender wheatgrass are regulated by annual seed demand. Many forb species are not commercially grown but are wildland collected.[(56)] This increases costs and limits availability. For example, goldenrod has limited seed available and is sold by the ounce which increases the cost.[(57)] This species has limited wetland areas in only two ecoregions where it is recommended for use (Table 26).

Selecting appropriate species is important when roadside revegetation projects have competing goals of increasing diverse forb species and chemically treating invasive forbs. The money spent for increasing diversity can be eliminated by one herbicide application. Therefore, we recommend forbs such as Lewis flax, blanketflower, and yarrow that are known to establish well, are readily available, and are cost effective. In addition, some forb species are known to be tolerant of specific herbicides. For example, blanketflower, silky lupine, and prairie sage (*Artemesia ludoviciana*) are tolerant of Milestone® herbicide and could be used even if the site is going to be sprayed with this herbicide. If additional forbs are desired to increase diversity along roadways, consider using “seed islands” to establish these species. Seed islands are small (3 x 10 ft) areas where soil is prepared and an individual species planted. Seed islands can be used for incorporating expensive or difficult to establish species on site.[(58)] The seed islands can be strategically placed outside of the spray zone to protect the investment in these plants. Once established, these species will spread throughout the site. Good candidates for seed islands may include species not recommended at large scale like Venus penstemon, arrowleaf balsamroot, Palmer penstemon, or prairie coneflower.

Revegetation with native species is the preferred management practice on Idaho roadways.[(1)] However, some exotic species are recommended for seeding in special situations if they support site objectives or provide similar ecological functions as native species (Table 26). For example, the exotic desired species of fescue (sheep and hard fescue) establish well on rocky sites and provide similar ecological functions as Idaho fescue. Additionally, the Genesee site is an island of vegetation surrounded by agricultural fields. Crested wheatgrass is present and stabilizing the slope. At the Kings Ferry site, the density of cheatgrass makes it difficult for a native species to establish. However crested wheatgrass is competitive with cheatgrass and can act as a bridge community to a more desired diverse plant community.[(59)] When revegetating a roadside, it is difficult to recreate a native community in its entirety. In Idaho there is a legacy of seeding exotic plants along roadways. For example, crested wheatgrass was planted along roadways for decades and it continues to persist. It was seeded on 2 and present at another 7 of the study sites. The presence of exotic species should not be categorically considered a negative, particularly if the species is contributing to the site goals of providing vegetative cover, slope and soil stability, and it is not spreading to adjacent lands.[(55)].

Recommendations

- Plant materials should be selected to meet both revegetation objectives and site specific conditions.

- Revegetation with native species is the preferred management practice on Idaho roadways.
- Table 26 provides complete recommendations for species selection by ecoregion.
- Species can be selected to fulfill more than one goal for roadside revegetation (e.g. diversity, stability, weed prevention).
- Incorporate short-lived perennials for quick establishment if slope stabilization is a concern.
- If forbs are desired, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.
- For expensive and difficult to establish native perennial forbs and shrubs, consider creating seeded “islands” rather than broadcasting across the entire site.
- Seed mixes should be limited to 6 to 9 species.
- Some exotic species are recommended for seeding in special situations if they support site objectives or provide similar ecological functions as native species

Table 26. Level III Ecoregions Where Species are Recommended for Seeding

Common Name	Scientific Name	Level III Ecoregions					
		Columbia Plateau	Idaho Batholith	Middle Rockies	Northern Basin and Range	Northern Rockies	Snake River Plain
Grasses							
Basin Wildrye	*Leymus cinereus*	NR	R	R	R	NR	R
Big Bluegrass	*Poa secunda ssp. ampla*	R	R	R	R	R	R
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	R	R	R	R	R	R
Blue Wildrye	*Elymus glaucus*	NR	NR	NR	NR	NR	NR
Bottlebrush Squirreltail	*Elymus elymoides*	R	R	R	R	R	R
Canada Bluegrass	*Poa compressa*	R	R	R	R	R	R
Canada Wildrye	*Elymus canadensis*	R	NR	NR	NR	R	NR
Canby Bluegrass	*Poa secunda ssp canbyi*	R	R	R	R	R	R
Crested Wheatgrass	*Agropyron cristatum*	S	S	S	S	S	S
Green Needlegrass	*Nessella viridula*	R	NR	R	NR	R	NR
Hard Fescue	*Festuca brevipila*	R	R	R	R	R	R
Hybrid wheatgrass	*Elymus hoffmannii*	R	NR	R	NR	R	NR
Idaho Fescue	*Festuca idahoensis*	R	R	R	R	R	R
Indian Ricegrass	*Achnatherum hymenoides*	NR	R	NR	R	NR	R
Intermediate Wheatgrass	*Thinopyrum intermedium*	R	NR	R	NR	R	NR
Letterman's Needlegrass	*Achnatherum lettermanii*	NR	NR	NR	NR	NR	NR
Meadow foxtail	*Alopecurus pratensis*	NR	NR	NR	NR	NR	NR
Mountain Brome	*Bromus marginatus*	R	NR	R	NR	R	NR
Nebraska Sedge	*Carex nebrascensis*	W	W	W	W	W	W
Needle and Thread	*Hesperostipa comata*	NR	NR	NR	NR	NR	NR
Perennial Ryegrass	*Lolium perenne*	NR	NR	NR	NR	NR	NR
Orchardgrass	*Dactylis glomerata*	S	S	S	S	S	S
Prairie Junegrass	*Koeleria macrantha*	R	NR	R	NR	R	NR
Red Fescue	*Festuca rubra*	NR	NR	NR	NR	R	NR
Sandberg Bluegrass	*Poa secunda*	R	R	R	R	R	R
Sand Dropseed	*Sporobolus cryptandrus*	NR	R	NR	R	NR	R
Sheep Fescue	*Festuca ovina*	R	R	R	R	R	R
Siberian Wheatgrass	*Agropyron fragile*	NR	R	NR	R	NR	R
Slender Wheatgrass	*Elymus trachycaulus*	R	R	R	R	R	R
Smooth Brome	*Bromis inermis*	S	NR	S	NR	S	NR
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	R	NR	R	NR	R	NR
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	R	R	R	R	R	R
Tufted Hairgrass	*Deschampsia caespitosa*	W	W	W	W	W	W

Common Name	Scientific Name	Level III Ecoregions					
		Columbia Plateau	Idaho Batholith	Middle Rockies	Northern Basin and Range	Northern Rockies	Snake River Plain
Upland Bluegrass	*Poa glaucantha*	NR	NR	NR	NR	NR	NR
Western Wheatgrass	*Pascopyrum smithii*	R	R	R	R	NR	R
Forb							
Alfalfa	*Medicago sativa*	S	S	S	S	S	S
Arrowleaf Balsamroot	*Balsamorhiza sagittata*	NR	NR	NR	NR	NR	NR
Bird's Foot Trefoil	*Lotus corniculatus*	S	NR	S	NR	S	NR
Blanketflower	*Gallardia aristata*	R	R	R	R	R	R
Dusty Maiden	*Chaenactis douglasii*	NR	NR	NR	NR	NR	NR
Fernleaf Biscuitroot	*Lomatium dissectum*	NR	NR	NR	NR	NR	NR
Scarlet Globemallow	*Sphaeralcea coccinea*	NR	NR	NR	NR	NR	NR
Goldenrod	*Solidago canadensis*	W	NR	NR	NR	W	NR
Lewis Flax	*Linum lewisii*	R	R	R	R	R	R
Montana Golden Pea	*Thermopsis montana*	R	NR	R	NR	R	NR
Palmer Penstemon	*Penstemon palmeri*	NR	NR	NR	NR	NR	NR
Pearly Everlasting	*Anaphalis margaritacea*	NR	NR	NR	NR	NR	NR
Prairie Coneflower	*Ratabida columnifera*	NR	NR	NR	NR	NR	NR
Purple Prairie Clover	*Dalea purpurea*	NR	NR	NR	NR	NR	NR
Prairie Sage	*Artemesia ludoviciana*	R	R	R	R	R	R
Rocky Mtn Penstemon	*Penstemon strictus*	NR	NR	NR	NR	NR	NR
Scarlet Gilia	*Ipomopsis aggregata*	NR	R	NR	R	NR	R
Scorpion Weed	*Phacelia hastata*	NR	R	NR	R	NR	R
Showy Phlox	*Phlox speciosa*	NR	NR	NR	NR	NR	NR
Silky Lupine	*Lupinus sericeus*	R	NR	R	NR	R	NR
Sticky Purple Geranium	*Geranium viscosissimum*	NR	NR	NR	NR	NR	NR
Sulfur Flower Buckwheat	*Eriogonum umbellatum*	NR	R	NR	R	NR	R
Sweetvetch	*Hedysarum boreale*	NR	NR	NR	NR	NR	NR
Venus Penstemon	*Penstemon venustus*	NR	NR	NR	NR	NR	NR
Western Yarrow	*Achillea millefolium*	R	R	R	R	R	R
White Dutch Clover	*Trifolium repens*	S	S	S	S	S	S
Wild Lupine	*Lupinus perennis*	NR	NR	NR	NR	NR	NR
Shrubs							
Antelope Bitterbrush	*Purshia tridentata*	NR	NR	NR	NR	NR	NR
Basin Big Sagebrush	*Artemisia tridentate* ssp. *tridentata*	NR	R	NR	R	NR	R
Big Sagebrush	*Artemisia tridentata*	R	R	R	R	NR	R
Bearberry	*Arctostaphylos uva-ursi*	NR	NR	NR	NR	NR	NR
Birchleaf Spiraea	*Spiraea betulifolia*	NR	NR	NR	NR	NR	NR

Common Name	Scientific Name	Level III Ecoregions					
		Columbia Plateau	Idaho Batholith	Middle Rockies	Northern Basin and Range	Northern Rockies	Snake River Plain
Four Wing Saltbrush	*Atriplex canescens*	NR	R	NR	R	NR	R
Mountain Big Sagebrush	*Artemisia tridentata*	R	R	R	R	NR	R
Oregon Grape	*Mahonia repens*	NR	NR	NR	NR	NR	NR
Rubber Rabbitbrush	*Ericameria nauseosa*	NR	NR	NR	NR	NR	NR
Serviceberry	*Amelanchier alnifolia*	NR	NR	NR	NR	R	NR
Silver Sagebrush	*Artemisia cana*	NR	R	R	R	NR	R
Snowberry	*Symphoricarpos albus*	R	NR	R	NR	R	NR
Woods Rose	*Rosa woodsii*	R	NR	R	NR	R	NR
Green Rabbitbrush	*Chrysothamnus viscidiflorus*	NR	NR	NR	NR	NR	NR

R = Recommended NR = Not Recommended W = Wetland Areas S = Special situations where the species is recommended

Recommended Seed Rates

Once a species mix is selected then the seeding (sowing) rate must be determined. The seeding rate is the amount of seeds applied to a given area. Rates must be calculated for each species in the mix. Additional considerations for seeding rate are seed purity, germination rate, pure live seed (PLS), proportion of each species, number of seeds per pound for each species, and seed size.

Seed purity is the proportion of seed free of chaff, stems, contaminant seed, and inert matter. *Germination* is the proportion of seed that is alive and able to grow. Both the germination and purity are listed on the label when purchasing seed. Certified seed testing laboratory results for purity and germination should be on the label. High quality seed should be 80 percent or greater purity.

The percent of pure live seed (PLS) is calculated by multiplying purity and germination then dividing by 100. The PLS is the percentage of gross seed weight composed of viable seeds. The amount of PLS per pound (PLS/lb) is the number of seeds that will germinate in a pound of gross seeds under ideal conditions. The PLS/lb is used for determining seeding rates and is calculated by multiplying the PLS by the number of seeds per pound. To calculate seeding rate from PLS/ft^2 to lb/acre, multiply the square footage of an acre (43,560 ft^2) by the product of the target PLS/ft^2 divided by the PLS/lb.

$$\text{PLS} = (\text{Purity \%} \times \text{Germination \%}) \div 100$$

$$\text{PLS / lb} = \text{PLS} \times \text{number of seeds per pound}$$

$$\text{lb PLS/acre} = 43{,}560 * (\text{target PLS/ft}^2 \div \text{PLS/lb})$$

Calculate seed rates based on the number of seeds per ft^2 or PLS per acre. Unlike calculating pounds per acre, calculating rate as seeds per square foot takes into account seed size. Seeding rates are usually 20 to 50 PLS per ft^2 of area. Rates will vary depending on species, size of seed, type of seeding equipment, presence of weeds, site conditions, and components of a seed mix. Target seeding rates are provided in Table 27 and Table 28.

Table 27. Target Number of Seeds per Square Foot Based on Seed Size

Seed Size[1]	Number of PLS per Pound	Target Number of PLS per ft^2	Rate (lbs PLS/acre)[2]
Small	> 800,000	30 to 50	2.0
Medium	80,000 to 800,000	20 to 25	2.2
Large	< 80,000	15 to 20	9.0

[1] Table adapted from Majerus.[60]
[2] Calculations based on the mid-point of the target number of PLS per foot^2 (e.g., 40 for small seeds).

Recommendations

- Table 28 provides a complete list of drill seeding rates for species recommended for Idaho roadside revegetation. These rates are for drill seeding when a single species is used. When using a species in a mix, adjust the rate based on the desired proportion of each species in the mix and the desired seeds per square foot.

- Seed at a rate of 20 to 50 PLS per ft^2 of area.
- For accurate seeding rates for each species in the seed mix, it is important to use percent pure live seed (PLS) from the labels to calculate the appropriate amount (lbs/acre) required.
- Species with small seeds are generally seeded at higher rates of seeds/ft^2 than those with larger seeds. More seeds per ft^2 does not equate to higher pounds per acre.

Table 28. Seeding Rates for Recommended Grasses, Forbs, and Shrubs

Name[1]	Cultivars[2]	Growth Form	Height (inches)	Native Status	Minimum Precipitation (inches)	Seeds per Pound	Rate: PLS lbs/acre[3]	Notes
Grasses								
Basin Wildrye (*Leymus cinereus*)	Continental, Magnar, Trailhead, Washoe	Bunchgrass	25 +	Native	8	130,000	6 - 11	Robust grass to 6 ft tall. Drought tolerant.
Big Bluegrass (*Poa secunda ssp. ampla*)	Sherman	Bunchgrass	13 – 24+	Native	10	882,000	2 - 4	Matures early in spring.
Bluebunch Wheatgrass (*Pseudoroegneria spicata*)	Anatone, P7, Goldar, Secar	Bunchgrass	13 - 25+	Native	8 - 10	140,000	6 -14	Drought tolerant and long-lived. Widely distributed and adapted.
Bottlebrush Squirreltail (*Elymus elymoides*)	Sand Hollow, Toe Jam Ck	Bunchgrass	13 - 24	Native	8	192,000	5 - 12	Drought tolerant and short-lived. Useful for heavily disturbed sites.
Canada Bluegrass (*Poa compressa*)	Foothills, Reubens, Talon	Sod-forming	13 - 24	Introduced	16	2,500,000	1 - 2	Useful for poor sites where more productive species cannot establish.
Canada Wildrye (*Elymus canadensis*)	NA[4]	Bunchgrass	25 +	Native	12	115,000	7 - 15	Tall, short-lived. Establishes quickly for initial cover.
Canby Bluegrass (*Poa secunda ssp canbyi*)	Canbar	Bunchgrass	1 - 12	Native	10	926,000	2 - 4	Extensive shallow fiborous roots. Adapted to shallow & deep soils of all textures.
Crested Wheatgrass (*Agropyron cristatum*)	Douglas, Ephraim, Roadcrest	Bunchgrass	13 - 24	Introduced	6 - 10	265,250	3 - 7	Long-lived, drought tolerant. Widely introduced species.
Green Needlegrass (*Nessella viridula*)	Cucharas, Lodorm	Bunchgrass	13 – 24	Native	12	181,000	5 - 10	Drought tolerant, long-lived. Adaptable to variety of sites.
Hard Fescue (*Festuca brevipila*)	Durar, Serra	Bunchgrass	13 – 24	Introduced	12	585,000	3 - 6	Widely adapted and long-lived. Used as turfgrass. Slow establishment.
Hybrid wheatgrass (*Elymus hoffmannii*)	Newby	Sod-forming	13 – 24	Introduced	10	122,000	12-14	Adapted to most soils including saline sites.
Idaho Fescue (*Festuca idahoensis*)	Joseph, Nezpurs, Winchester	Bunchgrass	25+	Native	12	450,000	3 - 6	Drought tolerant. Best on fertile soils. Competitive once established.
Indian Ricegrass (*Achnatherum hymenoides)*	Nezpar, Paloma, Rimrock	Bunchgrass	13 – 24	Native	8	141,000	6 – 12	Very drought tolerant. Best on deep, well-drained soils. Good reclamation species.
Intermediate Wheatgrass (*Thinopyrum intermedium*)	Chief, Greenar, Oahe, Reliant, Rush, Tegmar	Sod-forming	13 – 24+	Introduced	12 – 14	88,000	10 - 15	Robust, moderately drought tolerant.
Mountain Brome (*Bromus marginatus*)	Bromar, Garnet	Bunchgrass	25+	Native	10	64,000	10 - 19	Short-lived. Moderately moist soils. Quick establishment & good at high elevations.
Nebraska Sedge (*Carex nebrascensis)*	NA	Sod-forming	13 – 25+	Native	14	534,100	5	Wet or xeric and alkaline sites. Good for riparian restoration.

Name[1]	Cultivars[2]	Growth Form	Height (inches)	Native Status	Minimum Precipitation (inches)	Seeds per Pound	Rate: PLS lbs/acre[3]	Notes
Orchardgrass (*Dactylis glomerata*)	Chinook, Latar, Paiute, Potomac	Sod-forming	13 – 25+	Introduced	12 – 18	427,000	2 - 4	Long-lived. Adapted to a variety of t sites, not including saline.
Prairie Junegrass (*Koeleria macrantha*)	NA	Bunchgrass	13 – 24	Native	14	2,315,400	1 - 2	Drought tolerant and short-lived. Easy establishment, good for disturbed areas.
Red Fescue (*Festuca rubra*)	NA	Sod-forming	13 – 24	Introduced	18 – 30	500,000	2 – 4	Long-lived. Used for erosion control and turf.
Sandberg Bluegrass (*Poa secunda*)	High Plains	Bunchgrass	1 - 12	Native	8	1,046,000	2 – 4	Short stature, drought tolerant. Matures early in the season.
Sand Dropseed (*Sporobolus cryptandrus*)	Salado, Vegas	Bunchgrass	13 – 24	Native	5	1,758,000	1 – 3	Useful in saline and sodic soils. Large fibrous root system. Can be used for riparian restoration.
Sheep Fescue (*Festuca ovina*)	Azay, Big Horn, Black Sheep, Covar, Durar	Bunchgrass	13 – 24	Introduced	10 – 12	680,000	2 – 4	Long-lived and drought tolerant, with large root system.
Siberian Wheatgrass (*Agropyron fragile*)	P27, Vavilov	Bunchgrass	13 - 24	Introduced	6 – 10	170,000	5 – 11	Drought tolerant and very cold tolerant. Adapted to saline soils.
Slender Wheatgrass (*Elymus trachycaulus*)	Pryor, Revenue, San Luis	Bunchgrass	13 – 24	Native	10	159,000	6 - 10	Short-lived. Moderately drought tolerant. Establishes easily for quick cover.
Smooth Brome (*Bromus inermis*)	Carlton, Lincoln, Magna, Manchar, Rebound	Sod-forming	25+	Introduced	12 – 18	125,000	5 – 12	Vigorous and long-lived. Can be aggressive. Moderately drought-tolerant.
Streambank Wheatgrass (*Elymus lanceolatus ssp psammophilus*)	Sodar	Sod-forming	13 – 24	Native	6 – 8	156,000	5 - 11	Drought tolerant and strongly rhizomatous.Can be used for erosion control.
Thickspike Wheatgrass (*Elymus lanceolatus ssp lanceolatus*)	Bannock, Critana, Schwendimar	Sod-forming	13 – 24	Native	6 – 8	154,000	6 - 11	Drought tolerant and strongly rhizomatous. Well-drained soils are best.
Tufted Hairgrass (*Deschampsia caespitosa*)	Nortran, Peru Creek	Bunchgrass	13 – 24	Native	14	1,500,000	1 – 2	Leafy and dense. Moist sites between 5,000 - 13,000 ft.
Western Wheatgrass (*Pascopyrum smithii*)	Arriba, Barton, Rodan, Rosana, Walsh	Sod-forming	13 – 24	Native	10	110,000	8 - 16	Strongly rhizomatous, moderately drought tolerant. Saline tolerant.
Forbs								
Alfalfa (*Medicago sativa*)	NA	Tap rooted Legume	13 – 25+	Introduced	15- 18	210,000	5 - 15	Easy establishment, widely used for pasture. Fair drought tolerance.
Bird’s Foot Trefoil (*Lotus corniculatus*)	Empire, Leo, Norcean, Viking	Rhizomatous Legume	13 – 24	Introduced	24	370,000	3 - 6	Rhizomatous, long-lived species. Used for erosion control, and in wet, poorly drained, or acid sites.

Name[1]	Cultivars[2]	Growth Form	Height (inches)	Native Status	Minimum Precipitation (inches)	Seeds per Pound	Rate: PLS lbs/acre[3]	Notes
Blanketflower (*Gallardia aristata*)	NA	Perennial Forb	18 – 24	Native	Low	132,000	7 - 10	Fair drought tolerance, blooms June-Sept. Occurs along roads, used for erosion control.
Goldenrod (*Solidago canadensis*)	NA	Perennial Forb	12+	Native	16	4,600,000	< 0.25	Grows in moist soil of medium texture with moderate levels of organic matter.
Lewis Flax (*Linum lewisii*)	Maple Grove	Perennial Forb	12 – 36	Native	Low	170,000	3 – 6	Drought tolerant and semi-evergreen. Blooms May – July.
Montana Golden Pea (*Thermopsis montana*)	NA	Perennial Legume	12 – 48	Native	Moderate	15,000	20 – 40	Moderately drought tolerant. Blooms May – Aug. Moist sites best.
Prairie Sage (*Artemisia ludoviciana*)	Summit	Rhizomatous Sub-shrub	12 – 24	Native	10	4,500,000	< 0.25	Quick to establish pioneer species. 1 – 2 ft tall.
Scarlet Gilia (*Ipomopsis aggregata*)	NA	Biennial or Perennial	12 – 36	Native	Low	357,000	6 - 8	1 – 3 ft tall, sandy or rocky soil. Low to moderate moisture.
Scorpion Weed (*Phacelia hastata*)	NA	Perennial Forb	6+	Native	10 - 24	153,000	1	Coarse to medium texture soils.
Silky Lupine (*Lupinus sericeus*)	NA	Perennial Legume	12 - 24	Native	Low - Moderate	12,900	20 - 30	Fair drought tolerance. Blooms May – Aug.
Sulfur Flower Buckwheat (*Eriogonum umbellatum*)	NA	Perennial Forb	6 – 12	Native	Low	209,000	4 - 7	Drought tolerant, best on well-drained soils.
Western Yarrow (*Achillea millefolium)*	Great Northern	Perennial Forb	12 - 18	Native	Low	2,770,000	0.5 - 1	Aggressive, drought tolerant. Used for erosion control.
White Dutch Clover (*Trifolium repens*)	NA	Creeping Perennial	1 – 12	Introduced	35	850,000	2 - 6	Shallow-rooted, good for cool, moist sites. Easy establishment.
Shrubs								
Basin Big Sagebrush (*Artemisia tridentata ssp. tridentata*)	NA	Shrub	36+	Native	10	2,500,000	1	Height to 12 ft. Valleys and foothills up to 7,000 ft. Well-drained soils.
Big Sagebrush (Artemisia tridentata)	NA	Shrub	12+	Native	8	1,500,000	0.5 - 1	Adapted to well-drained soils.
Four Wing Saltbrush (*Atriplex canescens*)	NA	Shrub	24+	Native	5	52,000	0.25 – 0.5	Drought resistant, medium to tall. Occurs in wide range of ecotypes.
Mountain Big Sagebrush (*Artemisia tridentata spp. vaseyana*)	NA	Shrub	24+	Native	11	2,500,000	1	Height to 5 ft. Well-drained soils.
Serviceberry (*Amelanchier alnifolia*)	NA	Shrub	36+	Native	12	25,800	0.5 - 1	3 – 15 ft tall. Common in uplands and along streams.
Silver Sagebrush (*Artemisia cana*)	NA	Shrub	24+	Native	8	850,000	0.5 - 1	2 – 5 ft tall. Moist sites, tolerant of flooding.

Name[1]	Cultivars[2]	Growth Form	Height (inches)	Native Status	Minimum Precipitation (inches)	Seeds per Pound	Rate: PLS lbs/acre[3]	Notes
Snowberry (*Symphoricarpos albus*)	Trapper	Shrub	24+	Native	12	76,000	1 - 3	Rhizomatous, 2 – 5 ft tall. Well-moderately drained sites.
Woods Rose (*Rosa woodsii*)	NA	Shrub	24+	Native	12	45,300	0.5 - 1	Rhizomatous, 2 – 6 ft tall. Quick establishment.

[1] The information in the table is from a compilation of information.(551,52,53,60,61)

[2] Cultivars are bred subsets of a species selected for desirable and predicable characteristics when grown in an environment to which it is adapted. Choose the most appropriate cultivar for the revegetation goals and environmental conditions of the site.

[3] Rate is for drill seeding a single species. If broadcast or hydroseeding, double the rate. If mixing the species with other species, adjust the rate based on the desired proportion of each species in the mix.

[4] Not applicable

Seed Application Methods

Newly disturbed roadsides require some form of seed application to quickly establish vegetation. There are three basic seed application methods: broadcast seeding, drill seeding, and hydroseeding. Typically, roadside revegetation is focused on grasses and occasionally includes forbs and shrubs in order to increase diversity and provide for additional ecologic function. Seeding techniques can vary with climate and precipitation, slope, aspect, ease of access and desired species requirements. Regardless of these factors, direct seeding to a recently disturbed roadside is relatively cost-effective means for achieving vegetation establishment and soil stability.

Consideration should be made for timing of seed application. In Idaho, seeding too late in the spring can result in missing spring precipitation and related high relative humidities and elevated soil moisture availability. Seeding too early in the fall may allow for germination but seedlings may freeze and die before they can establish and overwinter. Ideally, a late fall seeding should occur in northern climates to preclude immediate germination, yet allow for winter chilling of seeds (vernalization) that then can take advantage of winter snow accumulations and a full growing season during the subsequent year. Spring seeding can be effective as well, but it may be difficult to access the site with equipment before or during the wet season.

Broadcast Seeding

Broadcast seed applications can be completed with hand spreaders or mechanical implements (Figure 50 and Figure 51). This method is typically used on steep slopes, rocky areas or sites inaccessible by machinery. Some of the benefits of broadcast seeding are that it can be used to adapt to changing site conditions, weather constraints, and allow for the application of a variety of species including fluffy forb seeds. Motorized spreaders are effective at distributing seed at large scales in a small amount of time. Broadcast seeders can be mounted to four-wheeled ATVs, tractors, trucks, or bulldozers.

Seedbed preparation is recommended prior to broadcast seeding. A scarified or roughened seedbed will increase germination by retaining seed on the site and increasing seed-soil contact. Windblown organic materials and precipitation can be captured in the textured seedbed to increase germination success. Using a rake or harrow following seed broadcasting to cover seeds with soil, compost or mulch is critical for increasing seed germination. A harrow or rake can be pulled behind a tractor or four-wheeled ATV (Figure 50 and Figure 51). If seedbed preparation is not possible due to steep slopes, then increasing seed rates may be necessary to overcome low germination and seedling survival rates.

Figure 50. Broadcast Seeder Mounted on an ATV

Figure 51. Broadcast Spreaders with Imprinters for Texture and Working Seed into Soil

Drill Seeding

A no-till drill seeder can be used for seeding on non-rocky sites accessible to equipment. Drill seeding is accomplished with a tractor pulled machine that cuts a furrow in the soil, drops the seed into the furrow, and rolls the furrow closed. Drill seeding is the preferred method of seed application because it controls the seed rate, seed depth, row width, provides even distribution, and provides immediate seed-soil contact which increases seedling establishment. It is important that packer wheels be installed and functioning properly on the drill seeder to firm the soil and close the furrow. In addition, a drag or harrow can be pulled behind the seeder to further incorporate seed in the soil (Figure 52). Drill seeding should be done perpendicular to the slope and prevailing winds to prevent drill furrows from becoming erosive waterways. The benefits of drill seeding typically lead to better seed establishment than broadcast applications.(62) In addition, seed mixes are usually applied at half the rate broadcast seed applications are applied; therefore making it less expensive.

Figure 52. A Tractor Pulling a Seeding Drill with a Harrow to Incorporate Seed into the Soil

Typical drawbacks for drill seeding include machinery access limitations, particularly on uneven or rocky terrain, and steep slopes. In addition, the persistent drill rows can take years to in-fill depending on species, soils and climate (Figure 53). These unvegetated areas between rows can be ideal places for invasive species to invade or erosion problems to begin. To alleviate persistent drill rows and allow vegetation to grow between the rows, broadcast seed additional species over the drill seeding or make two passes with the drill seeder in perpendicular directions. When the various species in the mix need to be seeded at 2 different depths, 2 separate seeding operations may be needed. Alternatively, when the drill seeder has more than 1 seed box, the shallow planted seeds can be added to 1 seed box and the drop tubes disconnected so the seed broadcasts directly on the soil.

Figure 53. Persistent Drill Rows Leaves Space for Potential Weed Invasion or Erosion

Hydroseeding

Hydroseeding is a common roadside revegetation practice that helps stabilize bare soil surfaces to prevent erosion while applying the seed mix. Hydroseeding is a form of broadcast seeding in which seeds are applied in a liquid slurry often with other organic nutrients and additives. Depending on the equipment, ingredients are mixed mechanically or hydraulically agitated, then sprayed on the slope under hydraulic pressure. Subsequent precipitation events can re-hydrate the seed bed, retain moisture, and reduce evaporation of the sub-soils. This is not to be confused with hydromulching which is simply applying mulch to prevent erosion. For stabilizing steep slopes, hydroseeding can be more effective than broadcast or drill seeding.[15] It is also a preferred technique for steep slopes and difficult roadside areas that cannot be accessed by heavy equipment (Figure 54).

On Montana's roadside that cannot be drill seeded, MDT dry broadcast seeds then covers the seed with 0.5 inches of compost and 1 ton/acre of hydromulch with tackifier.[12] Dry broadcast seeding allows seed to fall into safe sites such as soil cracks and between dirt clods and rocks. The compost and mulch then covers the seed increasing the potential for germination. The moisture retention and nutrients of the compost also increases the percent survival of the emerged seedlings.

Typical hydroseeding applications include seed and one or more of the following:

- Mulch material to assist in moisture retention and reduce invasive plant development.
- Tackifier for binding the mulch to the slope for preventing soil erosion.
- Fertilizer may be added to improve growth rates and available soil nutrients.

- Soil amendments for modifying soil pH or improving soil tilth.
- Dye colorant assists the applicator in determining coverage.

Hydroseeding can result in lower seed establishment rates than drill or broadcast seeding because seed does not always make contact with the soil surface.[56] Seed-soil contact can be improved if site preparation occurs prior to seeding (See Site and Soil Preparation section above). Other limitations for hydroseeding include seedling inability to grow through mulch material, seed damaged from the equipment, and irregular germination patterns.[56] In addition, hydroseeding requires a large amount of water for application and should be used only where adequate water supplies exist. Many of these issues can be easily managed, resulting in successful revegetation.

Figure 54. Hydroseeding Application with Dyed Mulch Tackifier, Wildlife Crossing SH-21

The 17 revegetation study sites used a mix of broadcast, drill and hydroseeding as their seed application methods. It is not possible to make comparisons of one site to the other because each site had different seed mixes, site preparations, and seed rates. However, some generalizations can be made based on the resulting canopy cover of the seeded species on the ITD study sites. The resulting canopy cover of seeded species was variable and site dependent when hydroseeding. Hydroseeding sites had both the highest (65 percent at Syringia Creek Site) and the lowest (7 percent at Setters Site) canopy cover of seeded species (Table 29). When broadcast seeding alone was used on the Basin Creek Bridge site, only 10 percent canopy cover was achieved even though it had the highest seeding rate of all 17 study sites. Drill seeding, even when the lowest seeding rates of the study were used, resulted in consistently high canopy covers ranging from 18 to 53 percent.

Table 29. Vegetation Establishment Methods of the Revegetation Study Sites

Site Name	Highway	Seeding Method	Rate (lbs/acre)	Seeded Species Canopy Cover (%)
Worley	SH-58	Hydroseed	89	44
Clayton	SH-75	Hydroseed	66	9
McCammon	US-30	Drill Seed	85	18
Setters	US-95	Hydroseed	64	7
Electrical Substation	US-95	Hydroseed	44	42
Genesee	US-95	Drill Seed	33	22
Syringa Creek	US-12	Hydroseed	86	65
Basin Creek Bridge	SH-75	Broadcast Seed	124	10
Slate Creek Bridge	SH-75	Hydroseed	25	Not Assessed
Glenns Ferry	I-84	Hydroseed	42	13
Clark Canyon Rd	MT SH-324	Drill Seed	19	53
City of Rocks	STC-2841	Drill and Broadcast Seed	20	29
Albion	SH-77	Drill Seed	30	25
Silver Creek Bridge	US-20	Drill Seed	22	24
Tom Cat Hill	US-93	Drill and Broadcast Seed	24	33
Willow Creek Summit	US-93	Hydroseed	Unknown	16
Wildlife Crossing	SH-21	Drill and Hydroseed	65	21

Recommendations

- Drill seeding can be applied effectively at lower seeding rates. It is the most effective means of seeding if the terrain is capable of safe equipment operation.
- Drill seeding resulted in consistently higher canopy cover of seeded species at the sites in comparison to other seeding methods.
- Hydroseeding can be effective but the results are variable and site dependent.
- Broadcast seeding alone was not an effective method of establishing vegetation in the study.
- Increased seeding rates does not necessarily equate to increased species establishment and cover

Planting and Care of Containerized Plant Materials

Establishing certain species from seed is difficult, particularly for trees and shrubs. For some species, direct planting is the only feasible method of establishment. Directly planting containerized seedlings avoids the susceptible seed germination and establishment stages for these species. Adding live planting to a revegetation site can complement seeding efforts, increase site diversity, and provide rapid plant establishment. In addition, adding deep-rooted shrubs to a site can increase soil and slope stability and prevent erosion. Also, adding hard-to-establish shrub or tree species to a site increases a plant's ability to naturally spread through rhizomes, suckers, and seed. Additionally, live planting can be used along roadsides for immediate beautification near urban areas, campgrounds, or scenic sites.

Seedling plantings require specific care during and following installation in order to maximize survival and establishment. While planting of containerized plant material can be beneficial for establishing species quickly, it also adds to the immediate expense of a revegetation project. Live plants can be expensive to purchase and may require additional cost for plant protectors or mulching to improve the establishment success.

Planting

To increase seedling survival, care should be taken to select the appropriate species for a site and use proper planting techniques. Selecting species adapted to the soil type, aspect, slope and climate will improve survival. Seedlings should be planted into holes approximately three times the diameter of the container will ensure plant roots can easily grow through disturbed and loosened soil. The enlarged planting hole is important because a tight hole can act as a barrier to root growth and moisture movement. Soil excavated from the planting hole is normally satisfactory for backfill. In sandy or gravelly soils, amending with compost or topsoil will help retain water, add nutrients and eliminate air pockets. Break up soil clumps, discard large rock from the backfill, and gently compact soil to eliminate air pockets. Creating a water well around plants can help retain water and prevent erosion.

Selecting an appropriate microsite for the plant seedling can aid in long-term survival. Small variations in surface topography or other natural debris such as logs and dead brush can be used to increase survival rates. These micro- topography sites are useful for moisture retention, shade and prevention of wind burn.[3,4]

Retaining moisture and decreasing competition can also improve survival of plants. Mulching around the tree or seedling with weed fabric, wood chips, bark, coarse gravel or small rock can prevent grasses and weeds from competing for water, light and nutrients. Woven or non-woven geotextile 2 ft x 2 ft squares pinned around the plant can discourage competing plants from growing (Figure 55). Larger areas of woven geo-textile fabric can also be used to prevent weed and grass growth from competing with plantings (Figure 56). These fabrics allow water to infiltrate so that it is available for container stock but prevent vegetation growth around the stem to reduce competition for resources. Another product used by MDT to decrease competition and improve survival of plants is 3 ft wide strips of 10 oz/yd^2 burlap.[12]

Holes are cut in the burlap where containerized trees and shrubs are planted. The burlap is short-lived providing approximately a year of performance; however, it can be less labor intensive because it is biodegradable and does not need to be removed from a site.

Figure 55. Geotextile Weed Squares and Plant Protectors around Plantings

Figure 56. Row Planting Using Strips of Weed Barrier as well as Planting Tubes to Establish Plants

Plant Protection

Herbivory can be a major problem for newly planted species on a revegetation site. Plant protector tubes can be an effective means for limiting browsing on small plants. For larger plants, netting, perimeter fencing, and enclosures can be effective for preventing browse on new plantings by ungulates like deer. In addition, there are a variety of browse repellent products on the market that can provide some measure of protection while plants are establishing. The most effective repellants are products that emit a sulfurous odor.[3,4] Since seedlings are mostly palatable after winter dormancy, timing of repellent application should be considered to achieve maximum success.

Figure 57. Mesh and Solid Plant Protectors on Seedling Plantings on McCammon US-30 Site

Plant protectors can be used not only to protect from herbivory but shelter from wind desiccation or sun scald. Tube shelters are often used to not only protect plant tissue from browse but act as a mini-greenhouse to protect newly planted materials (Figure 57). Solid translucent tubes (e.g. Protex® pro/gro solid tube tree protectors) encourage plants to grow upward away from competing plants and branch out after emerging from the top. A potential drawback to tubes is that increased temperatures inside the tube can overheat the seedling and limit survival and growth. Plastic mesh tree guards (e.g., rigid seedling protector tubes) can also help deter small rodents and deer from eating stems and leaves but do not significantly increase soil temperatures or enhance moisture for the plant. Depending on species and site conditions, a combination of these treatments can be used (Figure 55). In addition, shade cards can be placed on the south side of the newly planted stock to reduce sun burn and heat buildup.

In a study using plant protectors for browse control, plants had greater stem height, diameter and volume when both tree shelters and weed barriers were used (Figure 57).[63] These combined techniques, while more expensive to implement, can reduce both re-planting labor and materials costs over the course of a revegetation project.[63] Purchase the biodegradable plant protectors made from corn starch to avoid having to remove the protectors which can potentially cause damage to plants.

If large containerized plant material is desired for a site, biodegradable plant protectors can be ordered from the manufacturer at custom heights and diameters (e.g. 5 ft tall, 2 ft diameter). Alternatively, temporary fencing can be installed such as t-post with woven wire. Containerized stock can be cluster planted to minimize fencing efforts and fence height can be adjusted for browsing species in the area.

Maintenance and Irrigation

Each planting site has environmental variation that will ultimately affect planting success. Monitoring can be implemented to improve future planting success. When installed properly plant protectors and mulches require little maintenance. Nevertheless, planting should be inspected annually to assess planting survival. Once plants have established, plant protectors should be removed if they are not biodegradable so they do not restrict growth or impede proper development to a mature plant.

Irrigation or periodic watering is a challenge on roadways. Focus should be placed on proper planting locations and microsite development for shade protection and water capture. Using plants adapted to specific aspects, ecoregions and micro-topography of the planting area can eliminate the need for supplemental irrigation. Mulching around plantings to retain soil moisture is an inexpensive means to improving planting conditions. Additional technologies for improving or maintaining soil moisture are DRiWATER® and tree watering bags. DRiWATER is potable water held in a solid gel form. It is placed in the soil with the containerized plant and water is slowly-released (40 – 90 days) to the plant as enzymes break-down the gel. It has been found to increase the survival of trees in arid environments.[64] Tree watering bags are polyethylene bags placed around a tree truck after planting and filled with water. The tree bag drips up to 20 gallons of water to the tree over 5 to 10 hours. Unfortunately, the bags need to be re-filled with water regularly.

Tree and shrub plantings integrated into roadside slopes should be planted outside of the clear zone to eliminate potential for accidentally mowing newly planted seedlings. In addition, seedlings should be clearly marked where herbicide applications occur for weed control. Broadleaf herbicide applications should carefully target invasive species while avoiding seedlings to prevent any adverse effects of the herbicide on the young plants.

Results of McCammon Planting

Survival and growth of container seedlings was monitored only at the McCammon revegetation site. Eight species were planted in three different microsites. Not all species were planted in each microsite. The microsites (upland, sloping bank, wetland) differed in soil moisture, compaction, aspect and proximity to standing water and distance to the water table. Four years after planting, percent survival and growth of container seedlings shrubs was specific to microsite and species (Table 7).

The percent survival of antelope bitterbrush in the upland was low, but shrubs that did survive were robust. Juniper had the highest survival rate of the woody species planted on the sloping bank (Table 7). While aspen and mountain ash survived there, the plants appear to have died back to the ground and were re-sprouting from their roots. The aspen and mountain ash may have better survival rates in a location with more consistent water availability. The adaptation of juniper to more arid conditions, or to areas with a fluctuating water table benefited its survival rate.

The wetland edge site had excellent survival rates for both coyote and MacKenzie's willow. Conversely, water birch or thinleaf alder did not survive to year four and may not be adapted to soils at this site or their roots could not reach the water table (Table 7). The established coyote willow was spreading by root suckers. The established MacKenzie willows were tall but non-suckering, which is consistent with this species' growth form.

Tree protectors were installed on 50 percent of the seedlings for protecting and to evaluate effectiveness in preventing browse during the first several growing seasons. Two types of protectors were used: rigid seedling protector tubes and the blue Protex® Pro/Gro solid tube tree protectors (Figure 57). During Phase I of the project, protectors were assessed for their ability to prevent browsing and persist through the winter or impact seedling growth.[9] All tree protectors were removed in the spring of 2012; therefore, protector success was not assessed in 2013. Phase 1 results found ungulate browse not to be an issue. Since no browsing was occurring, the ability of the tree shelter to protect against browse could not be assessed. The yellow rigid seedling protector tubes were better adapted to weather conditions on the site and did not interfere with seedling growth within the first two years following planting. However, as seedlings grew in the third year the protectors became restricting and needed to be removed. The blue Protex® Pro/Gro solid tube tree protectors were fully or partially removed by wind and snow, causing potential damage to the seedling by bending, breaking, or reducing light availability. These Protex tubes needed to be removed due to potential seedling injury.

Recommendations

- Selecting species for site conditions will increase survival. For example, juniper was able to survive in areas with a fluctuating water table, and coyote and Mackenzie willows had high survival along the water's edge.
- Once established, some planted shrub species can spread through rhizomes. Selection of rhizomatous woody shrubs may be desirable over non-rhizomatous species for achieving higher canopy cover.
- Rigid seedling protector tubes are useful to protect woody seedling from severe weather but should be removed after two years.

Chapter 4
Post Construction Roadside Vegetation Management

Post construction roadside vegetation management is important for maintaining health and vigor of established species and minimizing invasion by weedy species. This section first covers how mowing can influence health and vigor of desired vegetation and be used as a weed control tool. Then the discussion turns to roadside weed management with a focus on results from research sites, minimizing establishment of weedy species, managing existing infestations, and managing annual grasses.

Mowing

Mowing is most often considered as a method to improve sight distance, especially in the clear zone, and minimize buildup of vegetation that can become a fire hazard (Figure 58). However, mowing can influence vegetation health and vigor and be used as a method for controlling seed production of weedy species. Understanding a few basic principles can help in designing effective mowing strategies.

Figure 58. Mowing is Used in Clear Zone to Improve Sight Distance and Minimize Vegetation Buildup

While mowing is important for roadside maintenance, mowing too frequently may reduce vigor of vegetation. Mowing too frequently may be especially detrimental to species with elevated growing points or meristematic regions. For example, some native grass species like bluebunch wheatgrass have growing points several inches above the ground, making them prone to mowing damage if mower height is too low.[65] When growing points are removed through mowing, perennial vegetation relies on carbohydrates stored in the roots to regrow. The time required for adequate regrowth depends on the species, climate, soil moisture, and time of year but can range from 15 to 90 days.[66] Repeated mowing or mowing too low can eventually weaken roots and overall plant vigor; as plants loose vigor, they may dry out earlier in the summer, posing a fire hazard (Figure 59). Mowing during early stages of species establishment can also limit seed production by desired vegetation thus reducing recruitment potential for new seedlings.[51]

Figure 59. Perennial Grass Mowed too Frequently and Low Results in Loss of Plant Vigor

Mowing can be used as a weed management tool. For species that rely on seed production to reproduce (as opposed to weeds that spread vegetatively), mowing applied at the appropriate time can reduce seed production.[67,68] In this case, the best time to mow is based primarily on growth stage of the weed targeted for control and secondarily on growth stage of desired vegetation. If possible, apply mowing when desired plants are dormant and weeds have reached full flowering stage.[67] When weeds are at flowering stage, they have invested a large amount of their energy to bolt and produce reproductive structures. Depending on environmental conditions (e.g. soil moisture, number of days remaining in the growing season), weeds mowed at this stage of growth will be less likely to regrow, flower, and produce seed by the end of the growing season. Mowing at early flowering stage can also deplete root reserves and weaken plants over time. Using mowing to control weeds that reproduce through seeds and vegetatively, for example Canada thistle, is a long-term commitment because such species have large carbohydrate reserves in their roots.

If improperly timed, mowing may increase weed spread. Once weeds have flowered and produced seeds, flailing action of mower blades will spread seeds beyond the existing infestation perimeter. Weed seeds can also become lodged in vehicles and mowing implements and carried off site where they may drop off and start new infestations.[69] If mowing occurs after weed seed set, equipment should be washed prior to moving to another site.[4,5]

Mowing will not eliminate weeds, but it can reduce weed seed production and overall plant vigor. If used as a weed management tool, mowing should be integrated with other tools and managed so that desired vegetation gains a competitive edge.[67] The benefit of repeated mowing to manage weeds needs to be weighed against the risk of stressing desired vegetation.

Recommendations

- Avoid frequent mowing or mowing to very low vegetation heights because this will reduce health and vigor of perennial vegetation and may increase risk of fire.
- Mow when weeds are at an early flowering stage to prevent seed production and weaken perennial weeds over time. Time mowing, if possible, to occur when desired vegetation is dormant.
- Do not mow if weeds have already produced seeds because mower blades can scatter seeds beyond the existing infestation.

Roadside Weed Management

Summary of Noxious Weeds and Nonnative Species at the Sites

Invasive plant species (Idaho noxious weeds, annual exotic grasses, and forbs known to be aggressive) occurred at all the sites (Table 30). Noxious weeds occurred at nearly half the sites (47 percent), and the most common noxious weed was spotted knapweed, occurring at 4 of 17 sites (24 percent). Field bindweed, oxeye daisy, and rush skeletonweed were the next most common noxious weeds, each occurring at 2 of 17 sites (12 percent). The Northern Rockies ecoregion was the only ecoregion to have noxious weeds present at 100 percent of sites, in contrast to the larger category of invasive plants which occurred at all sites across all ecoregions. This was primarily driven by the presence of oxeye daisy, which prefers areas of higher moisture, typical of that in the Northern Rockies ecoregion. In general, noxious weeds were a small component of the vegetative communities across sites (<5 percent cover). This may be due in part to active management of such species with broadleaf herbicides at many sites. In spite of low occurrence of noxious weeds, it is important to continue to monitor sites for noxious weeds and treat them to prevent small populations from spreading.[4,5] If broadleaf noxious weeds are managed primarily with herbicides, seeding native forbs during the initial stages of post construction revegetation should be applied with careful consideration of cost, feasibility of non-chemical alternatives for weed management, and long-term goals.

Invasive plants other than noxious weeds were ubiquitous, occurring at 100 percent of the sites across all ecoregions (Table 30). Cheatgrass occurred more frequently than any other single invasive plant species, being present at 14 of 17 sites (Figure 60). It was found at all sites within the Idaho Batholith, Middle Rockies, Northern Basin and Range, and Snake River Plain ecoregions. Cheatgrass did not occur in the Northern Rockies ecoregion, probably because of higher moisture typically found in that ecoregion. Other annual grasses were found at all sites within the Columbia Plateau and Northern Rockies ecoregions. Therefore, collectively, annual grasses were present across all ecoregions. After annual grasses, invasive annual forbs were the most prevalent occurring at 14 of 17 sites and all sites within the Columbia Plateau, Northern Basin and Range, Northern Rockies, and Snake River Plain ecoregions. Salsify (*Tragopogon dubius*), St. Johnswort, and bull thistle (*Cirsium vulgare*) were invasive forbs that were relatively frequent across sites.

Table 30. Frequency of Occurrence of Invasive Plants at Sites by Ecoregion

	Total (17 sites)	Columbia Plateau	Idaho Batholith	Middle Rockies	Northern Basin and Range	Northern Rockies	Snake River Plain
Invasive Plants	100%	100%	100%	100%	100%	100%	100%
-Idaho Noxious Weeds	47%	50%	60%	0%	67%	100%	0%
Spotted Knapweed	24%	0%	50%	0%	0%	50%	0%
Field Bindweed	12%	0%	0%	0%	67%	0%	0%
Oxeye Daisy	12%	0%	0%	0%	0%	100%	0%
Rush skeletonweed	12%	50%	17%	0%	0%	0%	0%
-Other Invasive Plants	100%	100%	100%	100%	100%	100%	100%
Cheatgrass	82%	50%	100%	100%	100%	0%	100%
Other annual grasses	41%	100%	20%	0%	67%	100%	0%
Annual forbs	82%	100%	60%	50%	100%	100%	100%
Salsify	29%	0%	17%	0%	67%	100%	0%
St. Johnswort	24%	0%	17%	50%	33%	50%	0%
Bull Thistle	18%	50%	0%	0%	0%	100%	0%

Figure 60. Glenn's Ferry I-84 Site Dominated by Cheatgrass (Invasive Annual Grass) Interspersed Between Bluebunch Wheatgrass (Native Perennial Bunchgrass)

Although frequency of invasive plants was high, cover was generally low. Cover ranged from <1 percent to nearly 60 percent, but averaged less than 10 percent for all but 2 sites, McCammon in 2013 and Glenns Ferry. For sites with relatively low cover of invasive plants, careful management of desired vegetation is critical to prevent weedy plants from increasing. At the McCammon site, both noxious weeds and annual grasses and forbs were present comprising about 16 percent cover (Figure 9). This site should be carefully monitored and if invasive plants increase, more aggressive weed management may be necessary. At Glenns Ferry, cheatgrass and annual forbs comprised about 57 percent cover (Figure 60). At sites like Glenns Ferry in the Snake River Valley, where invasive plants comprise such a large component of vegetative cover (e.g. >20 percent) 5 years after seeding, aggressive weed control followed by additional revegetation may be necessary. Such measures should be weighed against site factors like proximity to crop fields, composition of adjacent non-crop plant communities, risk of wildfire (especially in the case of invasive annual grasses), and probability of successful revegetation based on soils and precipitation patterns.

Recommendations

- For sites with “low” cover of weeds (<5 percent), foster continued establishment of desired vegetation. Continue to monitor sites for increasing weediness.
- For sites with “medium” cover of weeds (5-20 percent), foster continued establishment of desired vegetation. Treat existing weeds appropriately. Continue to monitor sites.
- For sites with “high” cover of weeds (>20 percent), treat weeds judiciously, monitor response of vegetation (both weedy and desired), and consider seeding again as necessary. Continue to monitor sites.
- For future projects in any ecoregion, anticipate that annual grasses will be problematic and plan accordingly.

Minimizing Establishment of Weed and Exotic Species

Weedy and exotic species can be problematic in post construction roadside vegetation management due to their propensity to thrive in disturbed environments. Road construction usually results in marginal growing conditions for plants because topsoil is lacking and soil that is present may be compacted and lack organic matter. Topsoil may be minimal or non-existent depending on the site and construction methods. Annual plants like cheatgrass, kochia, and tumble mustard often do well in compacted soils because their roots tend to stay in the upper soil surface, thus requiring shallower soils than perennial plants.[70,71] In addition to marginal soil properties, bare soil surfaces are common following road construction, creating an attractive seed bed for weedy species. To mitigate these effects, road construction projects should minimize the area that is disturbed to the greatest degree possible. Careful application of topsoil or soil amendments can provide conditions more conducive to establishment of native perennial vegetation. High seeding rates can flood bare soil surfaces with desired vegetation instead of weeds, and mulches can limit weed seed contact with germination sites provided by bare soil.[72]

In addition to thriving in disturbed areas, weedy species are also very competitive, especially in the seedling stage, due to rapid growth rates. When seedlings of weedy species compete with seedlings of native species, weedy seedlings usually win simply by growing faster.[73] However, once established, healthy and vigorous native vegetation can be much more competitive with weeds.[74] To mitigate the effects of competition at the seedling stage, post construction weed management should begin early in the planning process and focus on reducing weed seed availability. Knowledge and control of weedy species in areas adjacent to construction prior to disturbance will help to reduce the amount of ambient weed seed. Use of weed seed free materials like topsoil, gravel, compost, mulch, and seed mixes is critical for minimizing the risk of post-construction weedy and exotic species establishment. Such materials may cost more, but the return on investment may be realized through higher native plant establishment rates and decreased costs associated with weed management.

During or immediately following construction (e.g. first one to two years), the application of broadleaf herbicides to control weedy annual forbs should be used with caution in order to protect seedlings of seeded forbs and shrubs; even young grass seedlings can be injured by broadleaf herbicides. Instead, mowing in mid-summer at a height of six to eight inches will prevent or minimize seed production by weedy species like kochia and cheatgrass, provide protective surface mulch for grasses, and allow seedlings of seeded species a chance to mature before being stressed by a broadleaf herbicide application. Personnel from ITD should work closely with contractors to ensure special provisions associated with weed control immediately following construction are carried out appropriately and with the long-term success of roadside revegetation in mind.

If weedy invasive forbs (i.e. noxious weeds) are identified as being problematic in the area during the planning process, risk of their establishment post construction is high (Figure 61). Therefore, inclusion of native forbs should be carefully considered against their cost and likelihood of broadleaf herbicide applications during post construction weed management. Native forb seed can be very expensive, and native forbs are generally very slow to establish.[75,76] Revegetation may therefore need to be a multi-step process in which desired grasses are first established followed by interseeding with native forbs at a later point in time. For example, Williams et al., successfully established native forbs in established grass stands by seeding forbs into patches that had been mowed repeatedly.[77] Establishing grasses first will allow invasive forb management with herbicides with minimal injury to non-target vegetation.

Figure 61. Where Invasive Forbs are Present (left side fence line), Including Native Forbs in the Seed Mix Should be Carefully Considered Against their Cost and Likelihood of Broadleaf Herbicide Applications during Post Construction Weed Management

Research shows that exotic perennial grasses typically establish faster and resist weed invasion to a higher degree than native perennial grasses, therefore seeding exotic species with desirable traits may be warranted in some cases.[78,5] Examples include sites where the surrounding area is dominated by introduced grasses, the risk of annual grass invasion is high, or other site conditions suggest establishment of natives is not feasible.

Recommendations

- Minimize disturbance to the greatest degree possible during construction. Control weeds prior to construction. Use weed seed-free materials.
- If broadleaf weeds are predicted to be problematic at a site, consider a two-phased seeding plan. First seed desired grasses to vegetate and stabilize site. Next, treat post-construction seeded area with herbicides until weeds are controlled. Lastly, seed or plant forbs and shrubs.
- For areas where introduced grasses are prevalent and site conditions suggest that establishment of natives is not feasible, consider benefits of using exotic grasses that establish quickly and do not limit species selection to natives only.

Reducing Existing Weed and Exotics Species

Even after post construction vegetation is established, roadsides remain highly disturbed environments. Vegetation is routinely mowed, sprayed, scraped, etc., and run-off from highway residues may increase salt and nutrient concentrations in roadside soils. In addition, roads can serve as conduits for weed seed movement.[79,80] Management of weedy and exotic plants will remain an on-going endeavor.

The most sustainable, long-term method of managing weeds and exotic species is to maintain healthy vegetation that is competitive and can resist invasion. Healthy, vigorously growing vegetation will ideally capture and utilize essential plant resources like water, light, and nutrients, thereby limiting resources for weedy species to use. Grass and forb species that have different growth characteristics (e.g. bunch grass versus rhizomatous grass; early season forb and late season forb) and rooting depths will occupy multiple niches, again leaving few opportunities for weeds to invade.(81) When designing seed mixes, consider how species complement each other in regards to growth characteristics and seral stage, and aim for a simple, yet complete mix that includes grasses with varying rooting depths and forbs and shrubs that differ in morphology and phenology (e.g. early season vs. late season flowering).(82,83)

As indicated above, weeds prosper in disturbed environments, and even if weeds currently aren't present at a site, disturbance may open up space in the plant community for weeds to get established. Therefore, limit disturbance to the greatest degree possible. Avoid road maintenance activities that create bare soil surfaces and avoid mowing too frequently or at very low heights. For areas where sight distance is important for safety considerations, focus on establishing low statured native vegetation that does not need to be mowed very frequently, if ever.

The association between roads and weeds is fairly well documented, therefore preventing weeds and exotic species from establishing and moving along roads should be an overarching goal of roadside vegetation management.(84,79,80) Implementing early detection and rapid response (EDRR) measures will ensure infestations are managed when they are small and eradication or containment can be feasibly accomplished. One way to increase EDRR is to provide weed identification training, especially for high priority species, for all road maintenance personnel. Washing equipment and vehicles, especially after they have been used in weedy areas, will help to prevent weed seeds from being moved to non-infested areas.(85) Finally, as noted above, managing for health and vigor of desired vegetation will help roadsides to remain weed-free.

Where weed control measures are necessary to reduce existing weeds and exotic species, integrated methods should be used to the greatest degree possible. Weed control treatments can fall into four general categories: manual, mechanical, biological, and chemical.(5) Manual control (i.e. hand-pulling) is often the easiest and quickest method for small infestations; manual control will have minimal if any non-target impacts. Mechanical control (i.e. mowing and cutting) is best used for preventing seed production and can reduce overall vigor of weeds if timed appropriately and implemented for multiple years. Biological control, or the use of insects that selectively feed on specific noxious weeds, is ideally used on well-established, large infestations of weeds that are especially difficult to control with other methods. Grazing with livestock is considered biological control in some circles; grazing invasive forbs can be very effective, however its use along roads should be considered with caution due to the potential for livestock-vehicle collisions. Chemical control (i.e. herbicides) should be used judiciously so as to minimize injury to non-target species like forbs, shrubs, and trees. Choose an herbicide with high selectivity that will provide good to excellent control of the target weed; apply at the recommended rate and at a time during the year when the weed is actively growing and desired vegetation is dormant or semi-dormant. For example, spotted knapweed can be treated with relatively selective herbicides, at low application rates, and in fall to minimize impact on non-target vegetation.

Recommendations

- Maintain healthy, vigorous vegetation that will resist invasion.
- Minimize disturbance to the greatest degree possible.
- Take preventative actions such as early detection and rapid response and washing vehicles and equipment when they leave weed-infested areas.
- Where weed control is necessary, implement integrated weed management strategies.

Annual Grass Management

Annual grasses such as cheatgrass, North African grass, medusahead, and soft brome are especially challenging to successful revegetation with native plants (Figure 62). In particular, cheatgrass is common across much of Idaho and the Intermountain West, and its ecologic and economic impacts have been well documented.[(86)] Cheatgrass and the other annual grasses named above typically behave as winter annuals. A winter annual germinates and emerges in fall, overwinters as a seedling, and completes its life cycle the following spring and early summer. This growth habit is very successful in semi-arid regions where the majority of precipitation falls between autumn and early summer. Invasive winter annual grasses resume growth in spring prior to native grasses, thus usurping soil moisture and nutrients. By the time summer droughty conditions develop (e.g. mid-June through August), winter annual grasses have already produced the next generation of seed.

The growth habit of annual grass is ideal for semi-arid climates, but also presents opportunities for selective management. Because annual grass seedlings appear in fall and resume growth in spring earlier than native grasses, control measures are best applied in fall or spring while annual grasses are actively growing and native grasses are dormant or semi-dormant. In many cases, controlling annual grasses with herbicides will be the most practical and cost effective method. Fall applications of imazapic, rimsulfuron, or sulfometuron methyl + chlorsulfuron or an early spring application of glyphosate are viable options. Because annual grass phenology can be highly variable and closely associated with precipitation patterns, timing of fall application should coincide with annual grass growth stage and less so with calendar date. An analysis of 24 trials in Montana that tested efficacy of Imazapic for controlling cheatgrass suggested that applying in fall when cheatgrass seedlings had 1 to 2 leaves was best.[(87)] If applying glyphosate in spring, control may be best if annual grasses are tillering, suggesting that they are actively growing and more likely to be affected by herbicide. For example, Kyser et al. achieved 95 percent control of medusahead when glyphosate was applied at the tillering stage (late April to early May).[(88)] This level of control was achieved using lower application rates than was necessary if applying during early seedling stage (mid-March) or boot to flowering stage (late May to early June).

Figure 62. Cheatgrass Growing Along I-15 in Montana

Annual grasses can accumulate a sizeable seed bank.[89,90] When attempting to revegetate a disturbed area that was previously infested with cheatgrass, seedlings of perennial grasses must compete with seedlings of annual grasses which often germinate more quickly and have higher relative growth rates (Figure 63). Most annual grass seed does not remain viable for more than 2 or 3 years, so repeated efforts to control seedlings and prevent seed production will reduce potential competition between seedlings of annual grasses and native grasses.[91] If delaying revegetation is not an option, carefully planning annual grass control in conjunction with seeding is necessary. Research has shown that giving native grasses even a small size advantage can shift competitive relationships in favor of native grasses.[73] Since many annual grasses associated with roads in Idaho emerge in fall, treating them with an herbicide in fall or spring following by a spring seeding of native grasses may be effective. Native grasses that emerge the first growing season will have a small size advantage over annual grasses that emerge in fall. If spring seeding is implemented, care should be taken to seed as early in the spring as possible. Seeding too late in the spring can result in missing spring precipitation.

Figure 63. Cheatgrass (Lower Left) and Bluebunch Wheatgrass (Below Pen Tip) Seedlings Resulting from Seeds Sown at the Same Time during an Experiment

Another strategy for mitigating the challenge of competitive annual grass seedlings is through selection of species for seeding. Consider seeding native grasses that are known to establish quickly such as slender wheatgrass, or introduced grasses that are more aggressive and competitive such as crested wheatgrass or intermediate wheatgrass.[59] This strategy could be reserved for sites where the surrounding area is dominated by introduced grasses, risk of annual grass invasion is high, or other site conditions suggest establishment of natives is not feasible.

Even though annual grasses are ubiquitous across Idaho and will remain a challenge to roadside revegetation, the use high quality, clean materials for construction sites will help to reduce introduction of annual grasses. Many invasive annual grasses are not listed as noxious in western states, therefore they are not on the list of restricted species for “noxious weed seed-free” materials. Consult with suppliers of construction materials such as gravel, soil, compost, and mulch to gain knowledge of potential weedy contaminants. Do not buy seed with an undesirable or untested seed component.[5]

Recommendations

- Target annual grasses with herbicide in fall and spring for best control and minimal impacts to non-target desired grasses.
- Apply annual grass control for multiple seasons or years prior to seeding native grasses in an effort to deplete the annual grass seed bank and reduce competition between seedlings of annual grasses and desired native grasses. If delaying revegetation is not an option, carefully plan annual grass control and seeding.
- For areas where introduced grasses are prevalent and site conditions suggest that establishment of natives is not feasible, consider benefits of using exotic grasses that establish quickly.
- Use construction materials that are as free of annual grass seed as possible.

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Chapter 5
Conclusions and Recommendations

There are many conclusions and recommendations for plant materials and seed mix performance, revegetation best practices, post-construction vegetation management and future research throughout this report.

For plant materials please refer to the following tables that describe the best performing species:

- Best performing species planted at the 17 study sites (Table 22)
- Best performing species for roadside revegetation across 6 Level III ecoregions in Idaho based on 17 study sites (Table 23)
- Proportion of seed mixes that established (Table 24)
- Recommended species for seeding in each of 6 Level III ecoregions in Idaho (Table 26).
- Recommended seeding rates of desirable species for seed mix prescriptions (Table 28).
- Various noxious weeds and invasive plants of concern by Level III ecoregion (Table 30).

Conclusions from monitoring the 17 study sites include:

- Bluebunch wheatgrass, streambank wheatgrass, crested wheatgrass, Idaho fescue, and Canada bluegrass had the highest percent cover of seeded grasses where they established.
- Grass species that consistently established on sites where they were seeded but had a low canopy cover (2 to 5 percent) included: sheep fescue, western wheatgrass, and basin wildrye. When using these species in a seed mix increase their seed rate to increase canopy cover. In addition, reduce the seed rate or eliminate species that do not establish well from the mix.
- Forbs and shrub species have low establishment success rates and low percent canopy cover on roadside revegetation projects.
- Do not include forbs and shrubs in seed mixes where herbicides are to be used. Many of the seeded sites were also sprayed with broadleaf herbicides which may have caused limited success of forb and shrub establishment.
- If forbs are desired, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.
- Species that established in a diversity of ecoregions included: bluebunch wheatgrass, Canada bluegrass, Sandberg bluegrass, slender wheatgrass, mountain brome, thickspike wheatgrass, western yarrow, and hard, Idaho, and sheep fescues.
- Seed mixes with 10 species or less had a greater proportion of species establish.
- All sites had an erosion condition classification of “stable” or “slight” 3 to 9 years after revegetation, except for the Wildlife Crossing which scored “moderate” for erosion.

Conclusions and recommendations for best management practices for roadside revegetation include:

Site and Soil Preparation

- Prepare soils so enough fine-grained (silt and clay) material is present to maintain adequate moisture content, usually 15 to 20 percent. Provide sufficient soil depth for an adequate root zone. Encourage a favorable, slightly acidic pH for plant growth near 5.5 - 6.0. Ensure soil compaction levels are similar to adjacent natural conditions.
- Soil re-application is beneficial to roadside re-vegetation projects. Limit the length of time topsoils are stockpiled to minimize loss of fertility and micro-organisms. Avoid storing and reapplying topsoil if weed populations are observed or are known to have been recently treated in the project area.
- Compost should be applied at 0.5 to 1.0 inch depths, unless special circumstances require lighter or heavier applications. If the revegetation site is vulnerable to heavy winds or rains, then covering the compost blanket with biodegradable matting is recommended for compost retention, as well as applying a tackifier either alone or as part of a hydromulch.
- When good quality topsoil is re-applied, no supplemental fertilizer is needed. For moderate quality and/or thin topsoils, apply sufficient fertilizer to achieve 25 - 50 lbs/acre of available nitrate-nitrogen. For areas surrounded or infested by invasive species, do not add nitrogen fertilizer. When seeding on low quality soil, subsoil and geologic parent material add enough organic nitrogen fertilizer to achieve 25 - 50 lbs/acre of nitrate-nitrogen or add compost blankets to increase both site nutrition and water retention for seedlings.
- Use wood chips/shreds for roadside revegetation to increase soil stability and soil organic carbon. Commercial wood products for erosion control can be applied following manufacturer specifications, typically 2 to 5 tons/acre. Nitrogen fertilizer should be applied in addition to woody material on sites requiring rapid stabilization, abundant grass cover, and where invasive species concerns are absent.
- Since most erosion control blankets are all highly effective in reducing soil erosion, seek the most cost-effective product for use on slope ratios greater than 3:1 and use biodegradable products over synthetics when possible.
- Roughening the soil surface is preferable to smooth slopes so that a variety of microsites are provided for seedling establishment. This can be achieved using mechanical implements or by adding rocks, stones and/or woody debris on the surface.
- Wattles or woven fiber rolls are a proven practice for use on slopes susceptible to erosive forces, usually for areas with greater then 3:1 or 34 percent grades.

Selection of Plant Material and Seed Application Methods

- Plant materials should be selected to meet both revegetation objectives and site specific conditions.
- Revegetation with native species is the preferred management practice on Idaho roadways.
- Species can be selected to fulfill more than one goal for the roadside revegetation (e.g. diversity, stability, weed prevention).

- If forbs are desired, it is recommended to use species that are known to establish well, relatively inexpensive, and tolerant of the herbicides being applied to control weeds.
- For expensive and difficult to establish native perennial forbs and shrubs, consider creating seeded “islands” rather than broadcasting across the entire site.
- Some exotic species are recommended for seeding in special situations if they support site objectives or provide similar ecological functions as native species.
- When seeding crested wheatgrass or other aggressive exotic species, eliminate or limit native species in the seed mix because they will generally have low establishment.
- Drill seeding can be applied effectively at lower seeding rates. It is the most effective means of seeding if the terrain is capable of safe equipment operation.
- Drill seeding resulted in consistently higher canopy cover of seeded species at the sites in comparison to other seeding methods.
- Hydroseeding can be effective but the results are variable and site dependent in this study.
- Broadcast seeding alone was not an effective method of establishing vegetation in the study.
- Increased seeding rates does not necessarily equate to increased species establishment and cover.
- Based on the 17 sites it was found that increased seeding rates did not necessarily equate to increased species establishment and total desired species cover.
- Rigid seedling protector tubes are useful for protecting woody seedlings from severe weather but should be removed after two years.
- Once established, some planted shrub species can spread through rhizomes. Selection of rhizomatous woody shrubs may be desirable over non-rhizomatous species for achieving higher canopy cover.
- For areas where introduced grasses are prevalent and site conditions suggest that establishment of natives is not feasible, consider benefits of using desired exotic grasses that establish quickly.
- Incorporate short-lived perennials for quick establishment and immediate slope stabilization.
- Seed mixes should be limited to 6 to 9 species.
- To calculate seeding rate, seed purity, germination, and number of seeds per pounds is required.
- Small seeds are generally seeded at higher rates than large seeds.
- Drill seed at a rate of 20 to 50 PLS per ft^2 of area, double this rate for areas broadcast or hydroseeded.

Conclusions and recommendations for post-construction roadside vegetation management are to:

- Minimize disturbance to the greatest degree possible during the construction phase. Control weeds prior to construction. Use weed seed-free materials.
- If broadleaf weeds are predicted to be problematic at a site, consider a two-phased seeding plan. First seed desired grasses to vegetate and stabilize site. Next, treat post-construction seeded area with herbicides until weeds are controlled. Lastly, seed or plant forbs and shrubs.
- Avoid frequent mowing or mowing to very low vegetation heights because this will reduce health and vigor of desired perennial vegetation.

- Mow when weeds are at an early flowering stage to prevent seed production and weaken perennial weeds over time. Time mowing, if possible, to occur when desired vegetation is dormant.
- Do not mow if weeds have already produced seeds because mower blades can scatter seeds beyond the existing infestation.
- Continue to foster establishment of desired vegetation at sites with a low total canopy cover of weeds (<5 percent). Continue to monitor sites for increasing weediness. For sites with medium cover of weeds (5 - 20 percent), foster continued establishment of desired vegetation. Treat existing weeds appropriately. Continue to monitor sites. For sites with high cover of weeds (>20 percent), treat weeds and apply desired species seed mix again. Continue to monitor sites.
- For future projects in any Idaho Level III ecoregion, anticipate that annual grasses will be problematic and plan accordingly.

Recommendations for future ITD revegetation management, practices and research include:

- Develop a revegetation manual with prescriptions for plant mixes by ecoregion, fertilizer applications, soil amendments, erosion control methods and materials and other practical "how to" descriptions and recommendations based on commercially available products and some testing for particular prescriptions.
- Develop and test standard prescriptions for seed mixes for each of Idaho's ecoregions.
- Develop a detailed record keeping form for use by ITD contractors and employees when preparing and revegetating a roadside reclamation site.
- Test various commercially available fertilizers to develop a standard fertilizer for deploying in each of Idaho's ecoregions and common soil types. Evaluate effect of nitrogen fertilizer on invasive species establishment.
- Experiment with the efficacy of seeded or planted "islands" of forbs and woody species to increase the establishment of diverse species and deep-rooted forbs and shrubs. This may be studied at existing revegetation sites where no forbs or shrubs have established 5 years after planting.
- Evaluate revegetation using a staged approach, where perennial grasses are seeded first followed by the seeding of forbs and the seeding or planting of shrubs 2 to 3 years after grass seeding. This should be tested in areas where noxious weeds are problematic (e.g. Northern Rockies ecoregion) and the use of broadleaf herbicides is anticipated shortly after revegetation.
- At sites (or ecoregions) where invasive annual grasses are problematic and anticipated to interfere with revegetation success, evaluate different grass mixes for their speed of establishment and ability to resist invasion by invasive annual grasses.
- Given Idaho's strong forest products sector, test various wood chip and fiber products to recommend for use in erosion control on steep slopes or as a soil amendment along ITD roads.

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Appendix A
Soil Erosion Condition Classification Scoring Method

Procedure:

1. Observe the total sample area and determine the average condition.
2. Determine if each item is potentially present. Only the potentially present items are considered in the total calculation.
3. For items potentially present, review the Erosion Condition Class sheet and assign a numerical value to each erosion feature.
4. Total both the weighted values and the possible values.
5. Calculate the Total percent SSF: (identified factors / possible factors) x 100.
6. Write the total percent and corresponding condition class in the box below.

Score	Soil Condition Class
1 - 20%	Stable
21 - 40%	Slight
41 - 60%	Moderate
61 - 80%	Critical
81 - 100%	Severe

Soil Movement	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is 0 - 0.1 in. (0 - 2.5 mm) **0 or 3**	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is 0.1 - 0.2 in. (2 – 5 mm) **5**	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is 0.2 - 0.4 in. (5 - 10 mm) **8**	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is 0.4 - 0.8 in. (10 – 20 mm) **11**	Depth of recent deposits around obstacles, or in microterraces; and/or depth of truncated areas, is >0.8 in. (20 cm) **14**
Surface Litter	No movement, or if present, <2% of the litter has been translocated and redeposited. **0 or 3**	2 – 10% of the litter has been translocated and redeposited against obstacles **6**	10 - 25% of the litter has been translocated and redeposited against obstacles **8**	25 – 50% of the litter has been translocated and redeposited or removed from that area **11**	>50% of the litter has been translocated and redeposited against obstacles or removed from that area **14**
Surface Rock Fragments	Depth of soil removal around fragments, and/or depth of recent deposits around the fragments is <0.1 in. **0 or 2**	Depth of soil removal around fragments, and/or depth of recent deposits around the fragments is 0.1 – 0.2 in. **5**	Depth of soil removal around fragments, and/or depth of recent deposits around the fragments is 0.2 – 0.4 in. **8**	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments is 0.4 – 0.8 in. **11**	Depth of soil removal around the fragments, and/or depth of recent deposits around the fragments > 0.8 in. **14**
Pedestals	Pedestals are mostly <0.1 in. (2.5 mm) high and/or less frequent than 2 pedestals/100 ft^2 **0 or 3**	Pedestals are mostly 0.1 – 0.3 in. (2.5 - 8 mm) high and/or have a frequency of 2 - 5 pedestals/100 ft^2 **6**	Pedestals are mostly 0.3 – 0.6 in. (8 - 15 mm) high and/or have a frequency of 5 - 7 pedestals/100 ft^2 **9**	Pedestals are mostly 0.6 – 1 in. (15 -25 mm) high and/or have a frequency of 7 - 10 pedestals/100 ft^2 **11**	Pedestals are mostly > 1 in. (25 mm) high and/or have a frequency of >10 pedestals/100 ft^2 **14**
Flow Patterns	If present, <2% surface area shows evidence of recent translocation and deposition of soil & litter **0 or 3**	2 – 10% surface area shows evidence of recent translocation and deposition of soil & litter **6**	10 - 25% surface area shows evidence of recent translocation and deposition of soil &litter **9**	25 – 50% surface area shows evidence of recent translocation and deposition of soil &litter **12**	> 50% surface area shows evidence of recent translocation and deposition of soil & litter **15**
Rills	If present, are <0.5 in (13 mm) deep, and at intervals >10 ft. **0 or 3**	Rills are mostly 0.5 – 1 in. (13-25 mm) deep, and generally at interval >10ft. **6**	Rills are mostly 1 – 1.5 in. (25-38 mm) deep, and generally at 10 ft interval **9**	Rills are mostly 1.5 – 3 in. (38 - 76 mm) deep, and at intervals of 5 - 10 ft. **12**	Rills are mostly 3 - 6 in (76-152 mm) deep, and at intervals of <5 ft. **14**
Gullies	If present, <2% of the channel bed and walls show active erosion (no vegetation), gullies make up <2% total area **0 or 3**	2 - 5% of the channel bed and walls show active erosion (no vegetation), gullies make up 2 - 5% total area **6**	5 - 10% of the channel bed and walls show active erosion (no vegetation), gullies make up 5 - 10% total area **9**	10 - 50% of the channel bed and walls show active erosion (no vegetation), gullies make up 10 - 50% total area **12**	Over 50% of the channel bed and walls show active erosion (no vegetation), gullies make up >50% total area **15**

Appendix B
Plant Species Present at the Monitoring Sites and their Functional Group Assignments

Common Name	Scientific Name	Functional Group									
		Seeded Grass	Seeded Forb	Seeded Shrub	Non-Seeded Native Grass	Non-Seeded Exotic Grass	Non-Seeded Native Forb	Non-Seeded Exotic Forb	Non-Seeded Native Shrub	Non-Seeded Native Tree	Invasive
Alfalfa	*Medicago sativa*		X					X			
Alyssum	*Alyssum species*										X
Annual Sunflower	*Helianthus annuus*						X				
Annual Mustard	*Draba sp.*						X				
Antelope Bitterbrush	*Purshia tridentata*			X							
Arrowleaf Balsamroot	*Balsamorhiza sagittata*		X								
Aster	*Aster sp.*						X				
Basin Wildrye	*Leymus cinereus*	X									
Bearberry	*Arctostaphylos uva-ursi*			X							
Bergamot	*Monarda fistulosa*						X				
Basin Big Sagebrush	*Artemisia tridentate ssp. tridentata*			X							
Birchleaf Spiraea	*Spiraea betulifolia*			X							
Bird’s Foot Trefoil	*Lotus corniculatus*		X								
Biscuitroot	*Lomatium sp.*						X				
Blanketflower	*Gaillardia aristata*		X								
Blue Wildrye	*Elymus glaucus*	X									
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	X									
Bluegrass sp.	*Poa sp.*					X					
Bottlebrush Squirreltail	*Elymus elymoides*	X									
Buckwheat	*Eriogonum ovulatum*						X				
Bulbous Bluegrass	*Poa bulbosa*										X
Bull Thistle	*Cirsium vulgare*										X
Bur Buttercup	*Ranunculus testiculatus*										X
Canada Bluegrass	*Poa compressa*	X									
Canada Thistle	*Cirsium arvense*										X
Catchweed Bedstraw	*Galium aparine*										X

Common Name	Scientific Name	Functional Group									
		Seeded Grass	Seeded Forb	Seeded Shrub	Non-Seeded Native Grass	Non-Seeded Exotic Grass	Non-Seeded Native Forb	Non-Seeded Exotic Forb	Non-Seeded Native Shrub	Non-Seeded Native Tree	Invasive
Cheatgrass	*Bromus tectorum*										X
Chokecherry	*Prunus virginiana*								X		
Clasping Pepperweed	*Lepidium perfoliatum*										X
Collomia	*Collomia sp.*						X				
Common Mullein	*Verbascum thapsus*										X
Common Wheat	*Triticum aestivum*	X									
Cornflower	*Centaurea cyanus*							X			
Crested Wheatgrass	*Agropyron cristatum*	X				X					
Dandelion	*Taraxacum officinale*										X
Douglas Fir	*Pseudotsuga menziesii*									X	
Dusty Maiden	*Chaenactis douglasii*		X								
Equisetum	*Equisetum sp.*						X				
Fernleaf Biscuitroot	*Lomatium dissectum*		X								
Fescue	*Fectuca sp.*	X					X				
Field Bindweed	*Convolvulus arvensis*										X
Field Chickweed	*Cerastium arvense*						X				
Filaree	*Erodium cicutarium*										X
Flixweed	*Descurainia sophia*										X
Four Wing Saltbush	*Atriplex canescens*								X		
Foxtail Barley	*Hordeum jubatum*				X						
Fringed Sage	*Artemisia frigida*						X				
Geranium	*Geranium sp.*						X				
Scarlet Globemallow	*Sphaeralcea coccinea*		X				X				
Goldenrod	*Solidago canadensis*		X				X				
Goosefoot	*Chenopodium* sp.										X
Green Rabbitbrush	*Chrysothamnus viscidiflorus*			X							
Green Needlegrass	*Nessella viridula*	X									
Hairy vetch	*Vicia villosa*										X
Hard Fescue	*Festuca brevipila*	X									
Hawksbeard	*Crepis sp.*						X				

Common Name	Scientific Name	Functional Group									
		Seeded Grass	Seeded Forb	Seeded Shrub	Non-Seeded Native Grass	Non-Seeded Exotic Grass	Non-Seeded Native Forb	Non-Seeded Exotic Forb	Non-Seeded Native Shrub	Non-Seeded Native Tree	Invasive
Hawkweed	*Hieracium sp.*						X				
Houndstongue	*Cynoglossum officinale*										X
Huckleberry sp.	*Vaccinium sp.*								X		
Idaho Fescue	*Festuca idahoensis*	X									
Indian Ricegrass	*Achnatherum hymenoides*	X									
Intermediate Wheatgrass	*Thinopyrum intermedium*	X									
Kentucky Bluegrass	*Poa pratensis*					X					
Kochia	*Kochia scoparia*										X
Letterman's Needlegrass	*Achnatherum lettermanii*	X									
Lewis Flax	*Linum lewisii*		X								
Mallow	*Malva neglecta*										X
Meadow Foxtail	*Alopecurus pratensis*					X					
Medusahead	*Taeniatherum caput-medusae*										X
Milk-vetch	*Astragalus sp.*						X				
Montana Golden Pea	*Thermopsis montana*		X				X				
Mountain Big Sagebrush	*Artemisia tridentata ssp. vaseyana*			X							
Mountain Brome	*Bromus marginatus*	X									
Musk Thistle	*Carduus nutans*										X
Needle and Thread	*Hesperostipa comata*	X									
North Africa Grass	*Ventenata dubia*										X
Orchardgrass	*Dactylis glomerata*					X					
Oregon Grape	*Mahonia repens*			X							
Oxeye Daisy	*Leucanthemum vulgare*										X
Palmer Penstemon	*Penstemon palmeri*		X								
Panicgrass	*Panicum sp.*				X						
Pearly Everlasting	*Anaphalis margaritacea*		X								
Penstemon	*Penstemon sp.*						X				
Perennial Ryegrass	*Lolium perenne*	X									
Prairie Coneflower	*Ratibida columnifera*		X								
Prairie Junegrass	*Koeleria macrantha*	X									

Common Name	Scientific Name	Functional Group									
		Seeded Grass	Seeded Forb	Seeded Shrub	Non-Seeded Native Grass	Non-Seeded Exotic Grass	Non-Seeded Native Forb	Non-Seeded Exotic Forb	Non-Seeded Native Shrub	Non-Seeded Native Tree	Invasive
Prickly Lettuce	*Lactuca serriola*										X
Prostrate Knotweed	*Polygonum aviculare*										X
Purple Prairie Clover	*Dalea purpurea*		X								
Quackgrass	*Elymus repens*					X					
Red Fescue	*Festuca rubra*	X									
Red Osier Dogwood	*Cornus solinifera*								X		
Redtop	*Agrostis alba*					X					
Reed Canarygrass	*Phalaris arundinacea*										X
Rocky Mtn Penstemon	*Penstemon strictus*		X								
Rose	*Rosa sp.*								X		
Rubber Rabbitbrush	*Ericameria nauseosa*			X							
Rush	*Juncus sp.*				X						
Rush Skeletonweed	*Chondrilla juncea*										X
Russian Thistle	*Salsola kali*										X
St. Johnswort	*Hypericum perforatum*										X
Salsify	*Tragopogon dubius*										X
Sand Dropseed	*Sporobolus cryptandrus*	X									
Sandberg Bluegrass	*Poa secunda*	X									
Sandwort	*Arenaria spp.*						X				
Scorpionweed	*Phacelia hastata*		X				X				
Sedge	*Carex sp.*				X						
Serviceberry	*Amelanchier alnifolia*								X		
Sheep Fescue	*Festuca ovina*	X									
Showy Phlox	*Phlox speciosa*		X								
Siberian Wheatgrass	*Agropyron fragile*	X									
Silky Lupine	*Lupinus sericeus*		X								
Slender Wheatgrass	*Elymus trachycaulus*	X									
Snakeweed	*Gutierrezia sarothrae*								X		
Smooth Brome	*Bromus inermis*	X				X					
Snowberry	*Symphoricarpos albus*			X							

Common Name	Scientific Name	Functional Group									
		Seeded Grass	Seeded Forb	Seeded Shrub	Non-Seeded Native Grass	Non-Seeded Exotic Grass	Non-Seeded Native Forb	Non-Seeded Exotic Forb	Non-Seeded Native Shrub	Non-Seeded Native Tree	Invasive
Snowbrush Ceanothus	*Ceanothus velutinus*								X		
Soft Brome	*Bromus hordeaceaus*										X
Sorrel	*Rumex acetosella*						X				
Speedwell	*Veronica sp.*						X				
Spotted Knapweed	*Centaurea stoebe*										X
Spanish Clover	*Lotus purshiana*										X
Stoneseed	*Lithospermum arvense*						X				
Streambank Wheatgrass	*Elymus lanceolatus ssp psammophilus*	X									
Sulfur Flower Buckwheat	*Eriogonum umbellatum*		X				X				
Sulfur Cinquefoil	*Potentilla recta*										X
Sweetvetch	*Hedysarum boreale*		X								
Tarweed	*Madia sativa*										X
Thickspike Wheatgrass	*Elymus lanceolatus ssp lanceolatus*	X									
Timothy	*Phleum pratense*					X					
Toano Milkvetch	*Astragalus toanus*						X				
Tumble Mustard	*Sisymbrium altissimum*										X
Upland Bluegrass	*Poa glaucantha*	X									
Venus Penstemon	*Penstemon venustus*		X								
Vetch	*Vicia sp.*						X				X
Western Wheatgrass	*Pascopyrum smithii*	X									
Western Yarrow	*Achillea millefolium*		X								
White Dutch Clover	*Trifolium repens*		X								
White Fringed Orchid	*Platanthera dilatata*						X				
White Sweetclover	*Melilotus alba*							X			
Wild Lupine	*Lupinus perennis*		X								
Willowherb	*Epilobium brachycarpum*							X			
Woods Rose	*Rosa woodsii*			X							
Yellow Pea	*Astragalus sp.*						X				
Yellow Sweetclover	*Melilotus officinalis*							X			

Appendix C
Idaho Noxious Weed List

The Idaho State Department of Agriculture noxious weed list is divided into three categories for management including species targeted for early detection rapid response (EDRR), control, or containment.

Common Name	Scientific Name	EDRR List	Control List	Containment List
Black Henbane	*Hyoscyamus niger*		X	
Bohemian Knotweed	*Polygonum bohemicum*		X	
Brazilian Elodea	*Egeria densa*	X		
Buffalobur	*Solanum rostratum*		X	
Canada Thistle	*Cirsium arvense*			X
Common Crupina	*Crupina vulgaris*		X	
Common/European Frogbit	*Hydrcharis morsus-ranae*	X		
Common Reed (Phragmites)	*Phragmites australis*		X	
Curlyleaf Pondweed	*Potamogeton crispus*			X
Dalmatian Toadflax	*Linaria dalmatica*			X
Diffuse Knapweed	*Centaurea diffusa*			X
Dyer's Woad	*Isatis Tinctoria*		X	
Eurasian Watermilfoil	*Myriophyllum spicatum*		X	
Fanwort	*Cobomba caroliniana*	X		
Feathered Mosquito Fern	*Azolla pinnata*	X		
Field Bindweed	*Convolvulus arvensis*			X
Flowering Rush	*Butomus umbelltus*			X
Giant Hogweed	*Heracleum mantegazzianum*	X		
Giant Knotweed	*Polygonum sachalinense*		X	
Giant Salvinia	*Salvinia molesta*	X		
Hoary Alyssum	*Berteroa incana*			X
Houndstongue	*Cynoglossum officinale*			X
Hydrilla	*Hydrilla verticillata*	X		
Japanese Knotweed	*Polygonum cuspidatum*		X	
Johnsongrass	*Sorghum halepense*		X	
Jointed Goatgrass	*Aegilpos cylindrica*			X
Leafy Spurge	*Euphorbia esula*			X
Matgrass	*Nardus stricta*		X	
Meadow Knapweed	*Centaurea debeauxii*		X	
Mediterranean Sage	*Salvia aethiopis*		X	
Milium	*Milium vernale*			X
Musk Thistle	*Carduus nutans*		X	

Common Name	Scientific Name	EDRR List	Control List	Containment List
Orange Hawkweed	*Hieracium aurantiacum*		X	
Oxeye Daisy	*Leucanthemum vulgare*			X
Parrotfeather Milfoil	*Myriophyllum aquaticum*		X	
Perennial Pepperweed	*Lepidium latifolium*			X
Perennial Sowthistle	*Sonchus arvensis*		X	
Plumeless Thistle	*Carduus acanthoides*			X
Poison Hemlock	*Conium maculatum*			X
Policeman's Helmet	*Impatiens glandulifera*	X		
Puncturevine	*Tribulus terrestris*			X
Purple Loosestrife	*Lythrum salicaria*			X
Rush Skeletonweed	*Chondrilla juncea*			X
Russian Knapweed	*Acroptilon repens*		X	
Saltcedar	*Tamarix sp.*			X
Scotch Broom	*Cytisus scoparius*		X	
Scotch Thistle	*Onopordum acanthium*			X
Small Bugloss	*Anchusa arvensis*		X	
Spotted Knapweed	*Centaurea stoebe*			X
Squarrose Knapweed	*Centaurea triumfetti*	X		
Syrian Beancaper	*Zygophyllum fabago*	X		
Tall Hawkweed	*Hieracium piloselloides*	X		
Tansy Ragwort	*Senecio jacobaea*			X
Variable-Leaf-Milfoil	*Myriophyllum heterophyllum*	X		
Vipers Bugloss	*Echium vulgare*		X	
Water Chestnut	*Trapa natans*	X		
White Bryony	*Bryonia alba*			X
Whitetop	*Cardaria draba*			X
Yellow Devil Hawkweed	*Hieracium glomeratum*	X		
Yellow Flag Iris	*Iris psudocorus*			X
Yellow Floating Heart	*Nymphoides pelata*	X		
Yellow Hawkweed	*Hieracium caespitosum*		X	
Yellow Starthistle	*Centaurea solstitialis*			X
Yellow Toadflax	*Linaria vulgaris*			X